NEWCASTLE CITY COUNCIL

SHIFTING SANDS AT STOCKTON BEACH

Prepared by:

Umwelt (Australia) Pty Limited
Environmental and Catchment Management Consultants

in association with

SMEC

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Prepared for:

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1.0 INTRODUCTION

The Port of Newcastle is located in the lower reaches of the Hunter Estuary. Breakwaters have been constructed at the mouth of the Hunter River, against bedrock cliffs, rocky reef and the Nobbys Head promontory on the southern side and against unconsolidated sand deposits of Stockton peninsula on the northern side. Prior to development of the harbour and construction of the breakwaters, what is now Newcastle Harbour was typified by shallow depths with an active alluvial bedload that was constantly added two by flood flows and freshes in the Hunter River. Hydrosurvey information from 1816 shows that the harbour had a central channel with a depth of approximately 6 metres with large areas of shallow sand shoals both within the harbour and off Stockton Beach. Sandy shoals adjacent to the northern side of the river mouth claimed several ships, and entry to the port was hazardous in unfavourable weather.

To provide for the development of the Newcastle Harbour, the Southern and Northern Breakwaters were constructed and between 1859 and 1989 approximately 133 million m^3 (*in-situ*) of material was dredged from Newcastle Harbour. Since construction of the breakwaters, sand has accumulated against the breakwater on southern side of the river mouth to form Nobbys Beach, but Stockton Beach to the north has suffered ongoing erosion that now threatens some of the infrastructure of Stockton township.

Other factors which may be impacting on the behaviour of sediment around the river mouth are deepening within the harbour and channel entrance to accommodate ships; maintenance dredging of these channels; increased tidal volumes entering and leaving the harbour, changes to sediment supply to the entrance channel and offshore dumping of dredge spoil.

Stockton Beach has a documented history of erosion and at times accretion. Public Works Department (1985, 1997) indicates that severe storm events have been recorded in September 1892, June 1896, August 1899, August 1908, January 1911, July 1912, December 1920, June 1928, June 1935, June 1945, July 1948, June 1952, May 1974, 1978, June 1994, March 1995, June 1995, September 1995, August 1996, May 1997, July 1999 and August 2001. Each of these storm events has resulted in erosion of the back beach escarpment. As can be noted, the majority of these storms occurred in late autumn and winter with only the storms in 1911 and 1920 being recorded in summer.

Since 1812, Stockton Beach and Newcastle Harbour have undergone some substantial infrastructural and developmental changes. In 1812 Governor Macquarie laid the first stone off Macquarie Pier with the pier finally connecting Newcastle to Nobbys Island in 1846. Construction of Macquarie Pier created shipping hazards especially adjacent to Stockton and in 1859 dredging of Newcastle Harbour commenced. In 1875 the breakwater beyond Nobbys was commenced however a significant portion of this was washed away and had to be reconstructed before the breakwater was finally completed in 1891. In 1898 construction of the Northern Breakwater commenced with the 1136 metre long wall being completed in 1912 (Newcastle Port Corporation Tide chart & Information Handbook 2001, pp 22 & 23). Following construction of the Northern Breakwater, accretion of sand at the southern end of Stockton Beach occurred.

In 1961, Newcastle Harbour was approximately 8 metres deep. Between 1962 and 1967 the harbour was deepened to 11 metres, however at this depth the bar was still reported to be unsafe and greater depth was required to facilitate the passage of larger vessels. Between 1977 and 1983 the harbour was further deepened to its present depth of 15.2 metres within the harbour entrance extending to a depth of approximately 18 metres at the eastern end of the Northern Breakwater.

In 1989 approximately a 500 metre long rock seawall was built along the central section of Stockton Beach to prevent erosion of Mitchell Street. Over recent years the toe of the seawall has begun to collapse due to continued erosion of sand from the beach system.

Previous studies of erosion of Stockton Beach have concentrated on beach sand volumes and location (i.e. the volume and location of sand above the low water mark) with some limited work being done on changes in nearshore beach profiles. The Department of Land and Water Conservation (DLWC) (1995) compiled available survey information depicting recorded changes in the High Water Mark between 1866 and 1995 (see **Figure 1.1**).

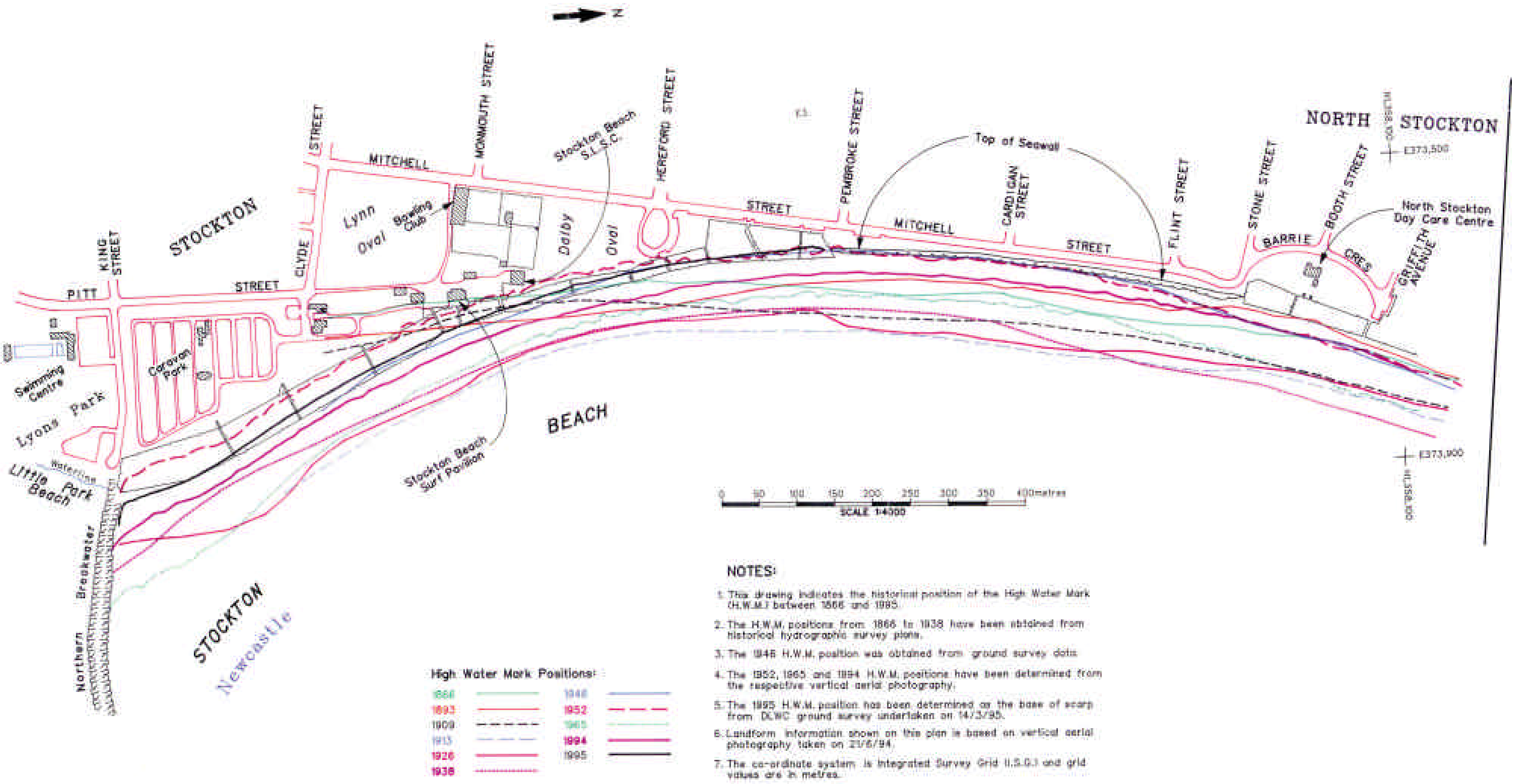
This survey information indicates that Stockton Caravan Park at the southern end of Stockton Beach is built to the east of the 1866 and 1909 High Water Mark. The survey information also indicates that Stockton Beach Surf Pavilion and Stockton Beach S.L.S.C. are located just to the landward (western) side of the 1952 High Water Mark and seaward of the 1952 erosion escarpment. The survey information also shows that the beach immediately to the north of the Northern Breakwater has accreted and in 1995, following periods of severe beach erosion, was still approximately 200 metres east of the 1866 High Water Mark. Further north along Stockton Beach the reverse has happened with the 1995 High Water Mark being located approximately 50 metres to the west of the 1866 High Water Mark in the vicinity of Pembroke Street and Cardigan Street.

Previous studies have provided a general description of the processes and hazards at Stockton Beach, however they have also highlighted a number of uncertainties in the understanding of these processes making development of appropriate mitigation works not possible without ongoing monitoring and investigations. Appropriate mitigation works may include beach nourishment, seawall construction, construction of artificial reefs.

To assist in understanding the processes occurring on Stockton Beach, hydrosurvey information for the period 1816 to 1988 was obtained in hard copy from Public Works Department archives. Hydrosurvey information for 1995 and 2000 was obtained in electronic form from DLWC's Coastal Unit in Newcastle and additional harbour channel surveys for the period 1983 to 2000 were obtained from Newcastle Port Corporation. Copies of the available hydrosurvey information are provided in **Appendix 1**.

Collated hydrosurvey information was then adjusted to a common height datum and geo-rectified using known and consistent features such as Nobbys Island, streets within Stockton and for later data the location of the Southern and Northern Breakwaters. Once corrected for height datum and location, the hydrosurvey information was used to compile a set of three-dimensional time series models of the bed profile of Stockton Beach and the channel entrance to Newcastle Harbour. This set of models has been developed to further understanding of sand movements off Stockton Beach and the changes that have occurred since commencement of construction of Macquarie Pier in 1812.

The time series display enables observed changes in sand volume and sand profiles over time, to be viewed in animated form.



0 100 200 350m

FIGURE 1.1
Stockton Beach Profiles

A4 Scale 1:7500

Ref No.:R04_V1/1411_127.dgn

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2.0 PREVIOUS STUDIES AND REPORTS

2.1 BETWEEN WIND AND WATER (COLTHEART 1997)

A history of port development is provided in Coltheart (1997). Excerpts from the chapter 'Dredging a future: 1890s – 1920s' of relevance in considering erosion off Stockton Beach are reproduced below.

> *"The Dorus (in 1892) was also at working the harbour removing a spit above Callan's Slip and pumping the sand onto Stockton Beach. The severe floods in March 1893 kept several dredges constantly working to restore shipping channels. Portus (first master of the Newcastle) summarised the endless task:*
>
> > *Year following the same story has unfortunately to be told of the unending deepening of Newcastle Harbour. No sooner is a channel completed than work is ready at the other end of it, where the dredge had, perhaps, started but a few months before. Great floods and small freshes are alike in leaving alluvial deposits to be removed.*
>
> *In spring of that year (1904) the barque Adolphe was wrecked on the north side of the entrance on top of four earlier wrecks. Conditions in the entrance were poor; the sand was 'all alive' and the channel reduced at times to eighteen feet. Construction of the southern breakwater was stopped so the northern wall could be built up as quickly as possible; according to the harbour Improvement Board, the northern breakwater had caused a very considerable current to concentrate at the outer end, with the result that sand had been scoured out from an original depth of thirteen feet at low water to the rock – a depth of some 37 feet. The sand thus scoured out has be brought into the channel and on the ebb tide, removed a distance of 1,500 feet beyond where the old bar originally existed; the consequence being, that instead of 32 feet of water at this place there now is 21 feet, and in heavy weather the break which formerly took place on the oyster bank, now occurs in the fairway.*
>
> *In order to reduce the scour which meant that double the estimated amount of stone would be required to complete the breakwater, the Board recommended sinking hulks along the line of the breakwater between the tip head and the collection of wrecks as far as the remains of the Regent Murray.*
>
> *C.W. Darley commented at a meeting of the British Institution of Engineers in 1910 that he didn't consider the 'curious expedient' of using the wrecks had either hastened or cheapened construction of the breakwater, but Joseph Davies, a member of the harbours Improvement Board at that time, pointed out the serious scour encountered meant that the northern breakwater needed to be thirty feet deeper than Darley and Moriarty had anticipated."*

Uses of the port referenced, included shipment of coal which had risen steeply from 3 million tons in 1888 to 8 million tons in 1910 and the establishment of BHP with the government guaranteeing (under the Steel Works Act of 1912) a route 25 feet deep between the sea and BHP wharf.

As stated below, Newcastle Port has played an important role in employment in the Hunter:

> *"The establishment of the BHP steelworks at Waratah, 'the greatest single event in the city's 20^{th} Century history', was a major impetus to harbour works as well as to commerce and employment in Newcastle. The decline in population as coal mines and towns developed elsewhere in the region was arrested by the decision to locate the steelworks at the port – a decision no doubt influenced by the assistance provided by the McGowen Labor government in its accelerated public works program from 1911-1914.*
>
> *Of the total expenditure of almost 3.5 million pounds on Newcastle harbour to 1921, nearly 1.5 million pounds had been spent on dredging, with 12 dredges stationed in the Hunter in 1921. At that time the cost of the long-term scheme of shaping a harbour around what had become a major national port had grown by 2 million pounds more than port revenue of 1.5 million pounds. While such calculations had rationalised decisions not to develop the northern rivers*

ports, the investment at Newcastle had passed any threshold for rethinking of Moriarty's ambitious plan to transform the Hunter entrance."

2.2 NEWCASTLE HARBOUR INVESTIGATION (PWD (1963) REPORT 104)

Concerns over siltation rates in Newcastle Harbour and ongoing associated dredging costs triggered the commissioning of number of reports into various aspects of silt movement into and out of Newcastle Harbour.

PWD Report 104 which is a series of articles and comments by different practitioners investigating silt movement in harbours, makes reference to a fixed bed model of the harbour that had been constructed at Manly Hydraulics Laboratory and the use of this model to determine bed velocities to be used in the Newcastle Wave Model that was to be a moving bed model.

On silt loads WA Price states:

"Many checks have been made on the rate at which silt load varies with the tidal range , and with reasonable confidence one can state that the silt load varies as the tidal range to the 5^{th} power, i.e. S varies R^5 and consequently S varies V^5 and obviously a small increase in velocity and tidal range causes large increases in silt load in the estuary".

Taking this into account, the converse also applies in that deepening and widening the entrance channel will reduce velocities and therefore will reduce the sediment transport capacity into and out of the channel. This is recognised on page 7 of the 1963 report that states:

"At Newcastle when the entrance is deepened under the existing rock removal contract, there could be a tendency to shoal in this deepened channel. Calculations have shown that it is a border line case and with existing knowledge no definite statement can be made on whether the channel will remain clear or shoal."

2.3 NEWCASTLE HARBOUR – HYDROGRAPHIC HISTORY (MANLEY 1963)

As part of the studies into siltation in Newcastle Harbour, Manley (1963) reviewed available hydrographic survey information for the entrance to Newcastle Harbour and the adjacent southern section of Stockton Beach for the period 1902 to 1957. In the Summary to this report, Manley states:

"The majority of the changes in surveys has been attributable to development of the breakwaters, river bank protection and development of dredging"

On the effects of breakwater construction, Manley 1963 (p22) comments that the Southern Breakwater was mostly completed between 1878 and 1891, resulting in shallowing in the vicinity of the Northern Breakwater by 5 ft (1.51 metres) over a large area. Manley subsequently attributes further sand loss from Stockton Beach area to the construction of the Northern Breakwater by commenting:

"On construction of the Northern Breakwater, the sand bank northeast of Stockton tip began to be eliminated… By the time the breakwater was completed, there was no shoal on the northern side of the breakwater... However, there appeared to be deepening close to the end of the Northern Breakwater… The deepening of the entrance channel can be mainly attributed to dredging, and natural erosion of the restricted channel after completion of the breakwater."

Manley (1963) examined bed contour information at the northern end of the Northern Breakwater between 1900 and 1960 by comparing bed contours (see **Figure 2.1**) and bed profiles (see **Figure 2.2**) along auxiliary leads of the channel. Comparison of bed contours as shown on **Figure 2.1** showed substantial deepening at the end of the Northern Breakwater following breakwater construction, whilst comparison of auxiliary lead bed profiles (**Figure 2.2**) showed substantial deepening of the channel profile since 1902, with large fluctuations being attributed to dredging.

Manley's analysis focused on the development of a 'shoal' within the entrance channel that was causing navigational problems and in this regard he states:

> *"In general terms, if the maps are compared in turn since the Northern Breakwater was constructed, it can be seen that up to 1950 little to no shallowing on the so-called "shoal" occurred, in fact the area remained particularly static whilst the area immediately off the end of the breakwater deepened considerably. The obvious remedy to having a relatively shallow area at the harbour entrance in such conditions would be the extension of both breakwaters equal amounts until they are in deep water, then the "shoal" would be in a greater depth assuming static conditions as at present. Both of the more detailed investigations tend to confirm that a shoal had not been forming, but a deepening off the end of the Northern Breakwater had been brought about. In drawing PHL254, the 1909 levels were reduced progressively to a static level in 1926-1950, although considerable siltation down the seaward slope has progressively come about. In drawing PHL 159, the last diagram shows that total movement of the bed from when the Northern Breakwater was constructed to the present day, and from this it can be seen that deposition has been occurring some distance out to sea, in fact in an area where the previous depth exceeded 40 feet (12m). There has been considerable erosion of the end of the breakwater, giving the effect of the shoal moving seawards….*
>
> *Since 1950 however, the whole of the area in the vicinity of the ends of the breakwaters has undergone considerable siltation (note the 1963 curve on drawing PHL 254) causing a reduction of depth of approx. 5 ft. From Drawing EHL 28 it appears that this reduction will continue for the next few years at least but it does not give any indication of the time cycle involved."*

It is apparent from this discussion that prior to deepening of the harbour between 1962 and 1967, there was a substantial build up of sand forming at the entrance to the harbour.

Manley's Drawing EHL 28 is reproduced as **Figure 2.3**, and shows bed level movement with time for points 400, 800, 1200 and 1600 feet from the breakwater. **Figure 2.3** shows:

- Deepening of some 15 ft (4.6 metres) at 400 ft from the Northern Breakwater between 1900 and 1940 with subsequent shallowing of approximately 1 metre between 1940 and 1960,
- Little change at 800 ft from the Northern Breakwater between 1910 and 1935 with subsequent deepening of approximately 3 ft (1 metre) between 1935 and 1950 and then shallowing of approximately 3 ft (1 metre) between 1950 and 1960
- Shallowing of approximately 12 ft (4 metres) at 1200 ft from the Northern Breakwater between 1910 and 1935 with a subsequent relatively stable period up until 1950 followed by further shallowing of approximately 5 ft (1.5 metres) between 1950 and 1960.
- Shallowing of approximately 20 ft (6 metres) at 1600 ft from the Northern Breakwater between 1910 and 1960.

Clearly Manley's analysis shows that following construction of the breakwaters and up until 1963, a shoal was developing at the end of the breakwaters at a distance of approximately 1500 feet from the end of the Northern Breakwater. At the same time a significant scour

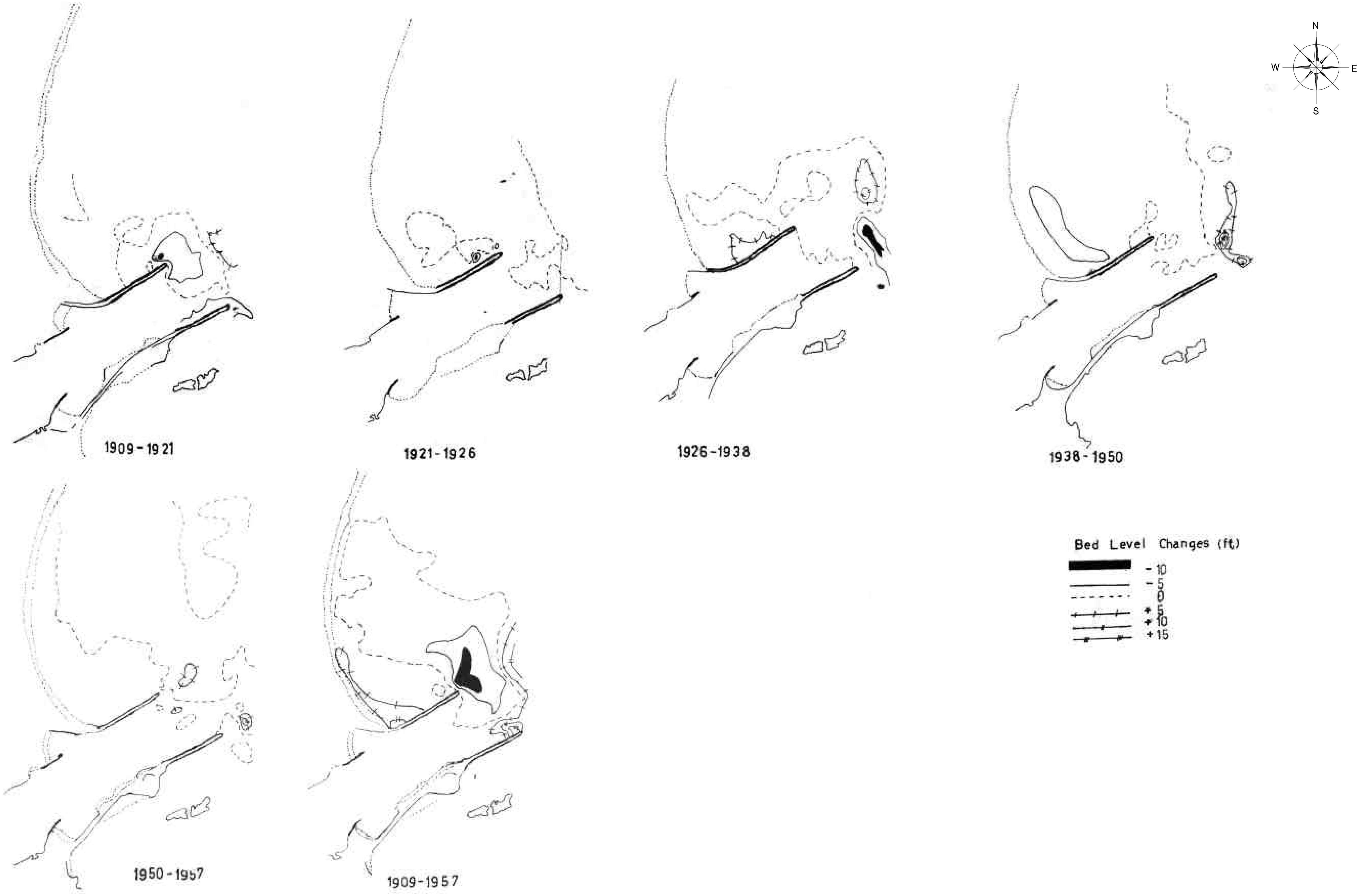


FIGURE 2.1
Changes in Bed Elevation at Newcastle Harbour Entrance between 1909 & 1957

A3 Not to Scale | Ref No.:R04_V1/1411_155.dgn

Umwelt (Australia) Pty Limited
Source: Dept of Public Works, NSW, Australia. Harbours and Rivers Branch. Hydraulic and Soils Laboratory, Manly. 'Newcastle Harbour - Hydrographical History'

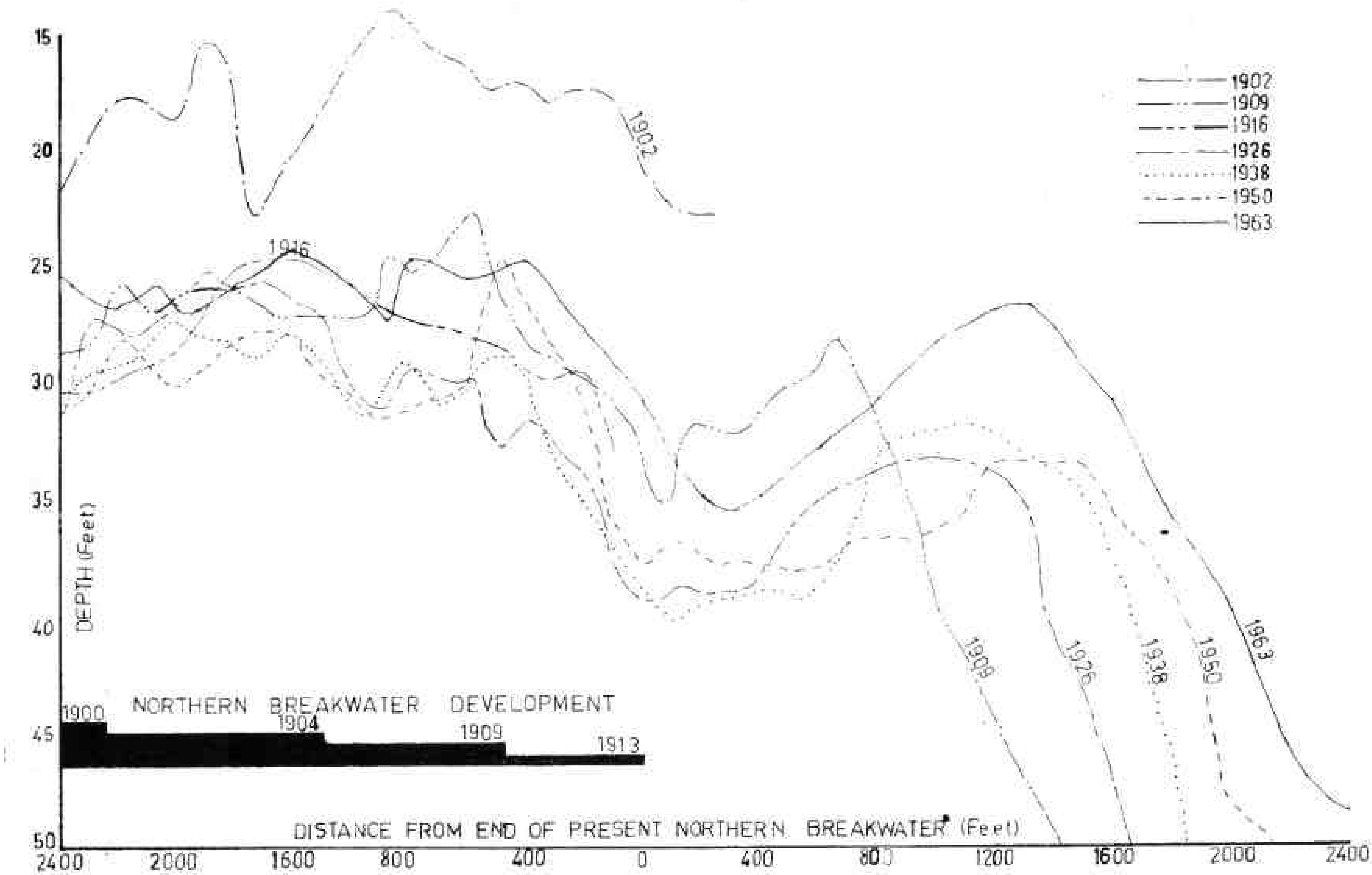
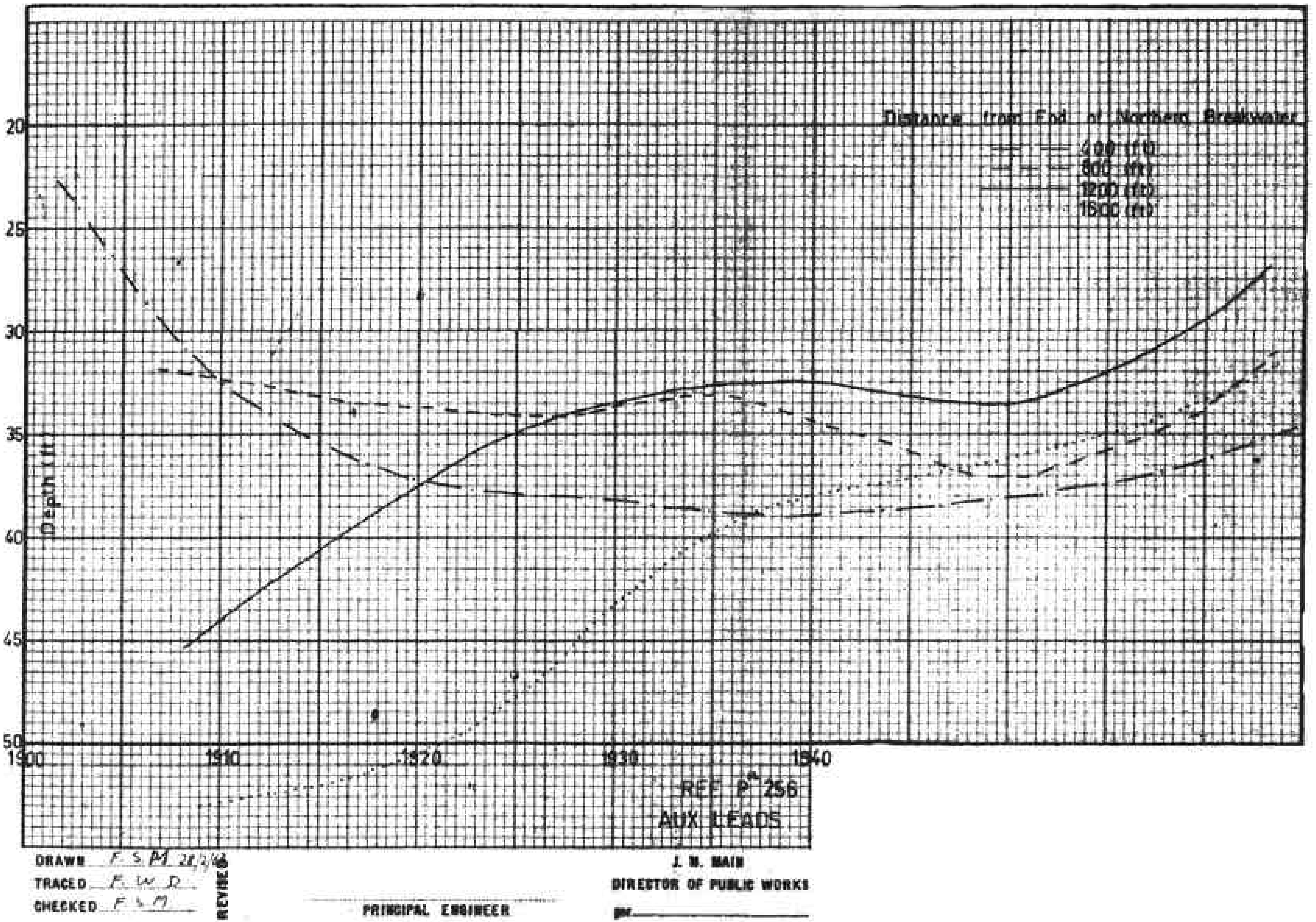


FIGURE 2.2
Auxiliary Leads Bed Profile
1902 – 1963

A4 Not to Scale | Ref No.:R04_V1/1411_156.dgn

Umwelt (Australia) Pty Limited
Source: Dept of Public Works, NSW, Australia. Harbours and Rivers Branch. Hydraulic and Soils Laboratory, Manly. 'Newcastle Harbour - Hydrographical History'



Umwelt (Australia) Pty Limited
Source: Dept of Public Works, NSW, Australia. Harbours and Rivers Branch. Hydraulic and Soils Laboratory, Manly. 'Newcastle Harbour - Hydrographical History'. Refer to figure 'EHL 28'

FIGURE 2.3
Channel Entrance
Bed Level Movement

A4 Not to Scale | Ref No.:R04_V1/1411_157.dgn hole was developing at the tip of the Northern Breakwater with the major period of development of this scour hole being between 1909 when the breakwater was completed and 1921. The analysis also indicates no real change in the size or depth of the scour hole between 1926 and 1957 with a shoal starting to form off the end of the Northern Breakwater between 1950 and 1957. Over the period 1909 to 1957, the analysis indicates a net accumulation of 5 to 10 feet of sand at the southern end of Stockton Beach with 5 to 10 feet of shallowing occurring at the entrance to the channel.

Analysis of Manley's compiled data indicates that by 1957 the rate of erosion of the scour hole at the end of the Northern Breakwater had slowed and the beach and entrance system was approaching equilibrium.

2.4 LITTORAL DRIFT IN THE VICINITY OF NEWCASTLE HARBOUR (BOLEYN AND CAMPBELL CIRCA 1966)

In regard to the shoal described by Manley (1963), Boleyn and Campbell (1966 p3) state:

> *"A shoal has been evident off the northern breakwater for more than 60 years. Its appearance dates from the time of construction of the Northern Breakwater in 1891. Extension of the breakwater has moved the shoal further out to sea.*
>
> *The size of the shoal has varied considerably since the construction of the Northern Breakwater. The volume and location of the shoal as surveyed remained much the same from 1921 until the early fifties. From this time, the volume of the shoal has rapidly increased and the depth to the uppermost point of the shoal has shown a slow but irregular decrease since the shoal was first recorded. Because of the increasing draught of vessels using the port, the problem of the growth and presence of the shoal in the main channel is accentuated.* ***Stockton Beach and beaches south of the entrance have changed little; this would indicate that changes about the harbour are quite localised.***
>
> *Recently the Department of Public Works has been engaged in an extensive programme of deepening the main channels and the entrance to Newcastle harbour to 36 ft below I.S.L.W. and in the future an additional 4 ft to 40 ft to cope with draughts of present day shipping likely to use the Port. These harbour depths ensure the continuance of Newcastle Harbour as a major port of Australia.*
>
> *The presence of a shoal in the vicinity of the harbour entrance limits the draught and restricts the approach of vessels entering the harbour. Remedial measures were deemed necessary."*

As part of investigations into silting of Newcastle Harbour and particularly development of the 'shoal', in 1966 Boleyn and Campbell undertook studies of littoral drift off Newcastle Harbour. At this time deepening of the harbour entrance from 8 metres to 11 metres, which was completed in 1967, would have been well advanced.

King, on "Sand Movement at Newcastle Entrance" was of the opinion that sand moved in a southerly direction from Newcastle Bight on the flood tide to the Newcastle Harbour Entrance. As a result of this information and similar local opinion, it was assumed that sand moved down Stockton Beach and onto the shoal area. This belief is consistent with the current movements associated with the development of a separation eddy and a large sand shoal adjacent to Stockton Beach following construction of the Southern Breakwater.

Results of Boleyn and Campbell's work using radioactive tracers showed that the direction of littoral drift was northwards from Nobbys Beach area to the entrance channel. Results of the tracer studies are shown on **Figures 2.4** to **2.8**. Based on the findings of their studies, Boleyn and Campbell stated:

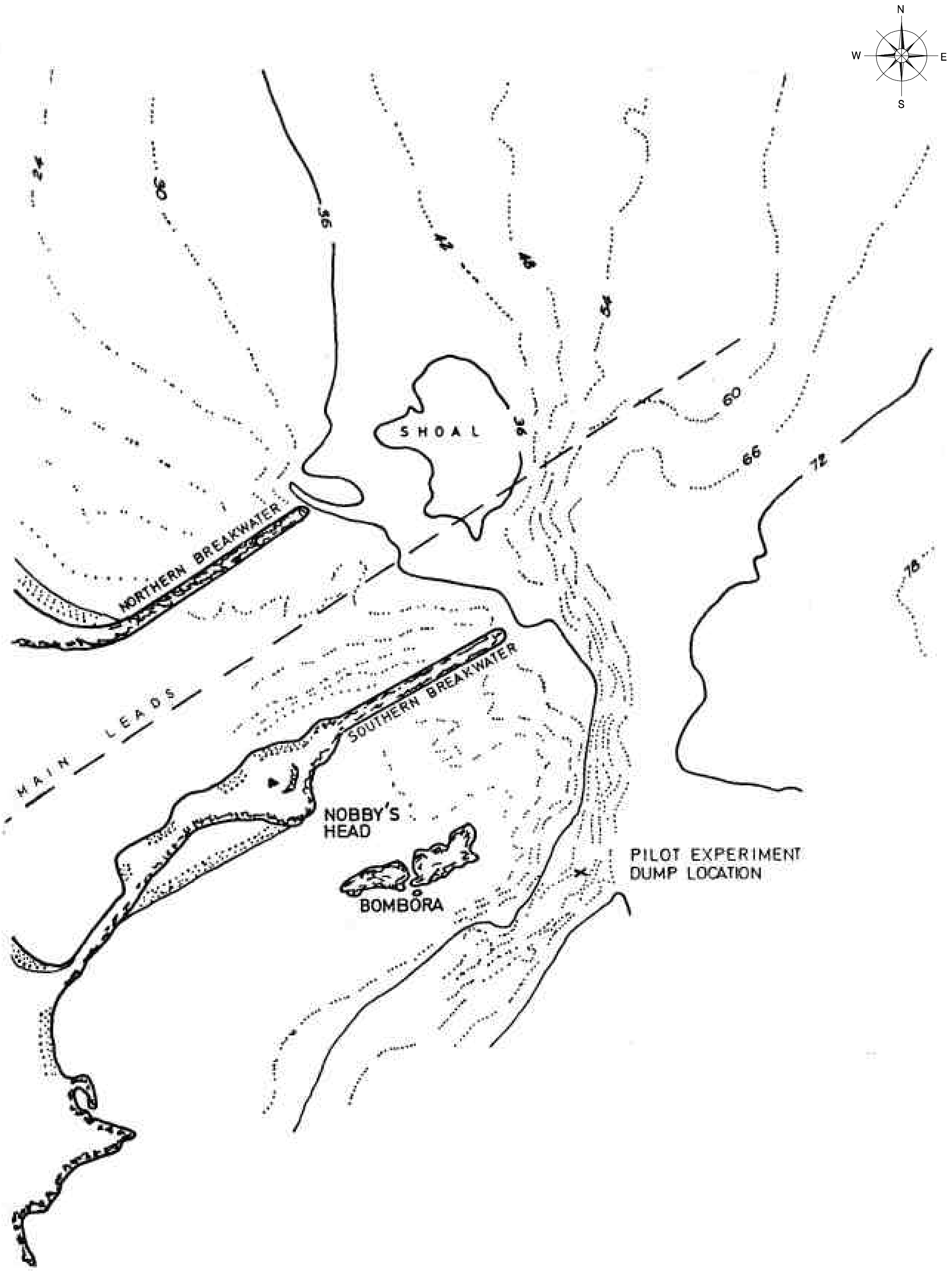


FIGURE 2.4
Newcastle Hydrographic Survey (1957)
Location of Radioactive Sand
Tracing Experiment

A4 Not to Scale | Ref No.:R04_V1/1411_150.dgn

Umwelt (Australia) Pty Limited
Source: Boleyn & Campbell

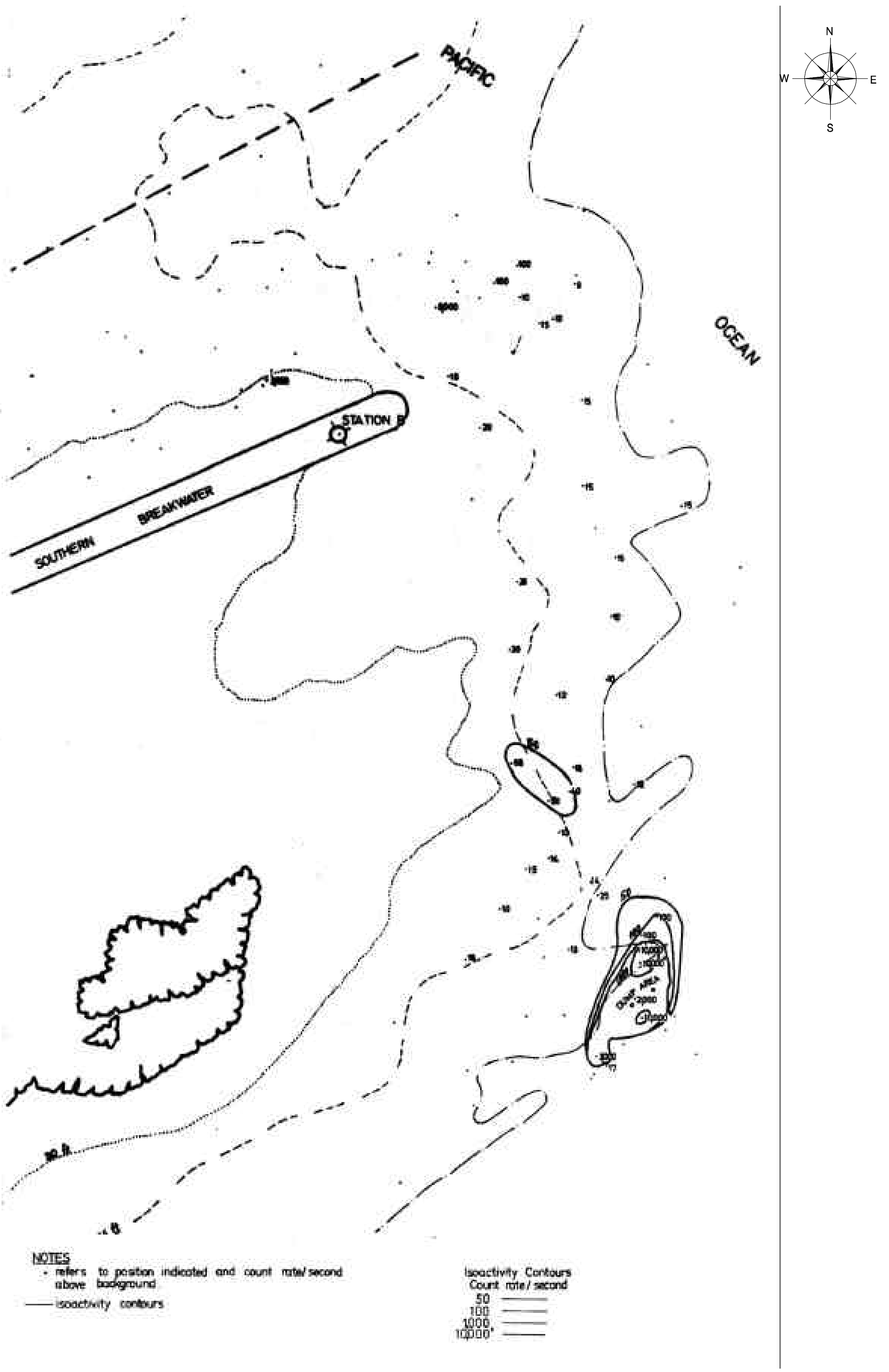


FIGURE 2.5
Newcastle Ocean Sand Tracing Experiment. Position of Radioactive Gold – 10.2.66

Umwelt (Australia) Pty Limited
Source: Boleyn & Campbell

A4 Not to Scale | Ref No.:R04_V1/1411_153.dgn

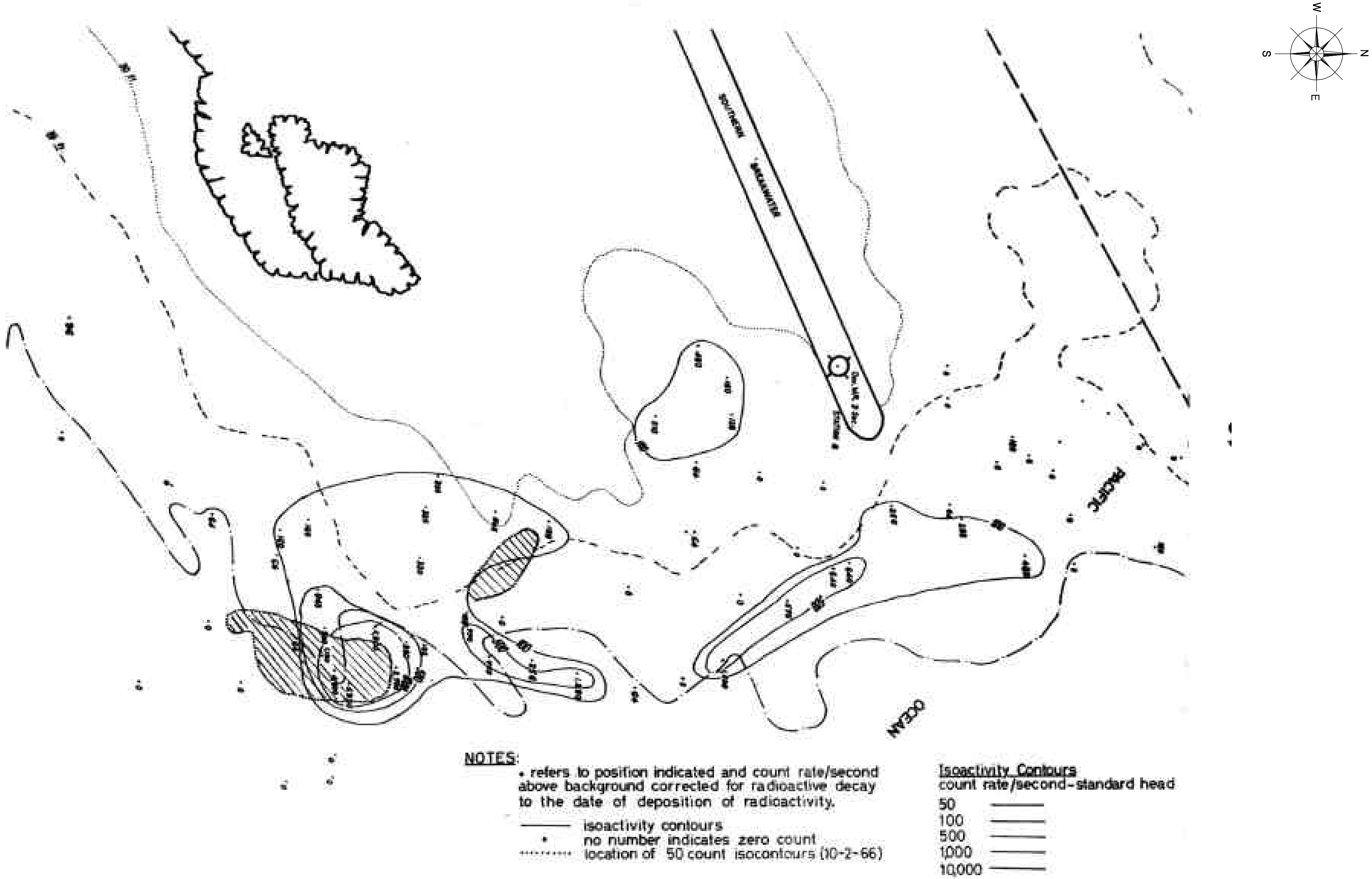


FIGURE 2.6
Newcastle Ocean Sand Tracing Experiment. Position of Radioactive Gold – 23.2.66

A4 Not to Scale | Ref No.:R04_V1/1411_154.dgn

Umwelt (Australia) Pty Limited
Source: Boleyn & Campbell

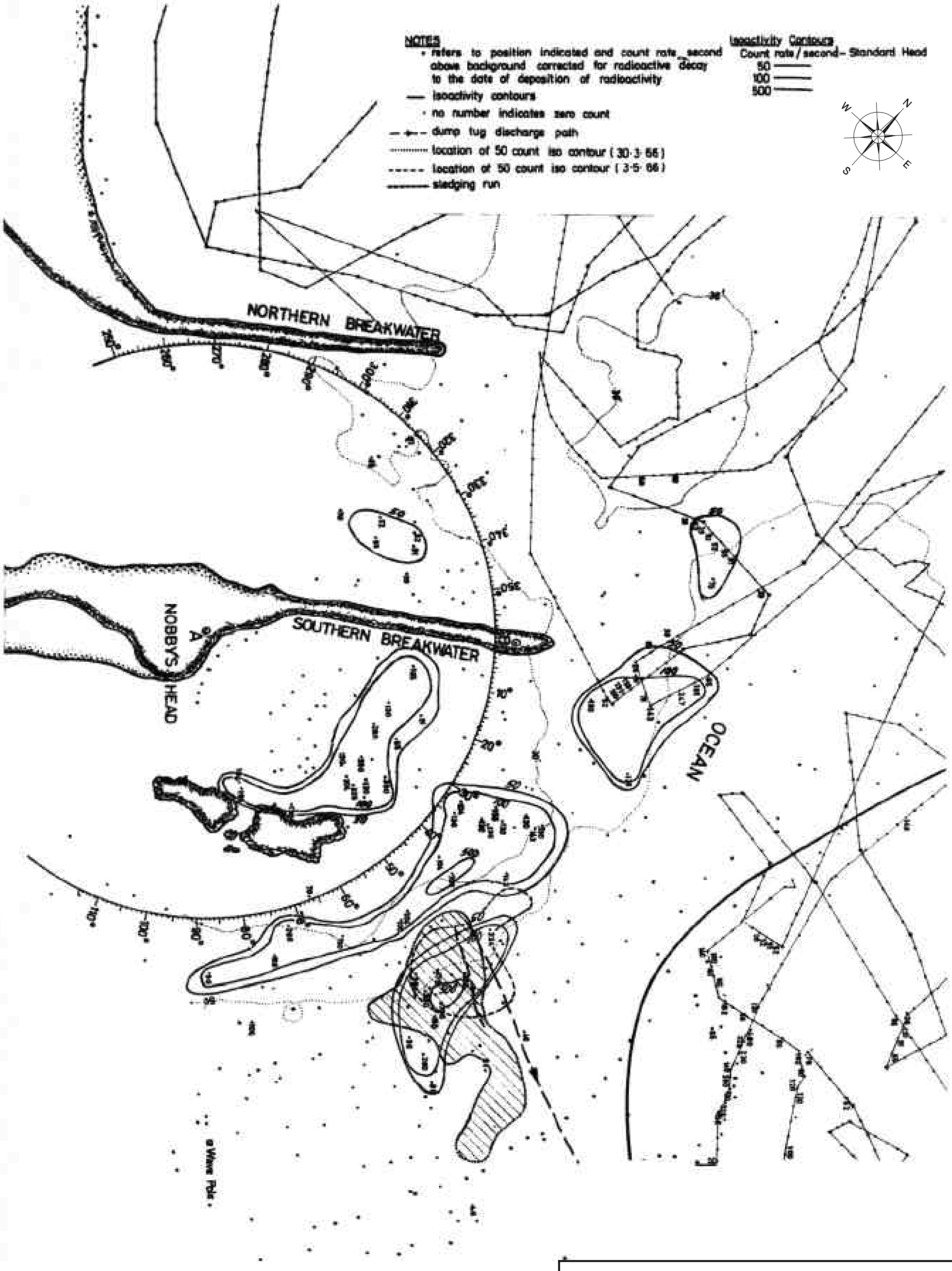


FIGURE 2.7
Newcastle Ocean Sand Tracing –Chromium. Location of Radioactive Sand Movement from 30.3.66 – 14.7.66

A4 Not to Scale | Ref No.:R04_V1/1411_151.dgn

Umwelt (Australia) Pty Limited
Source: Boleyn & Campbell

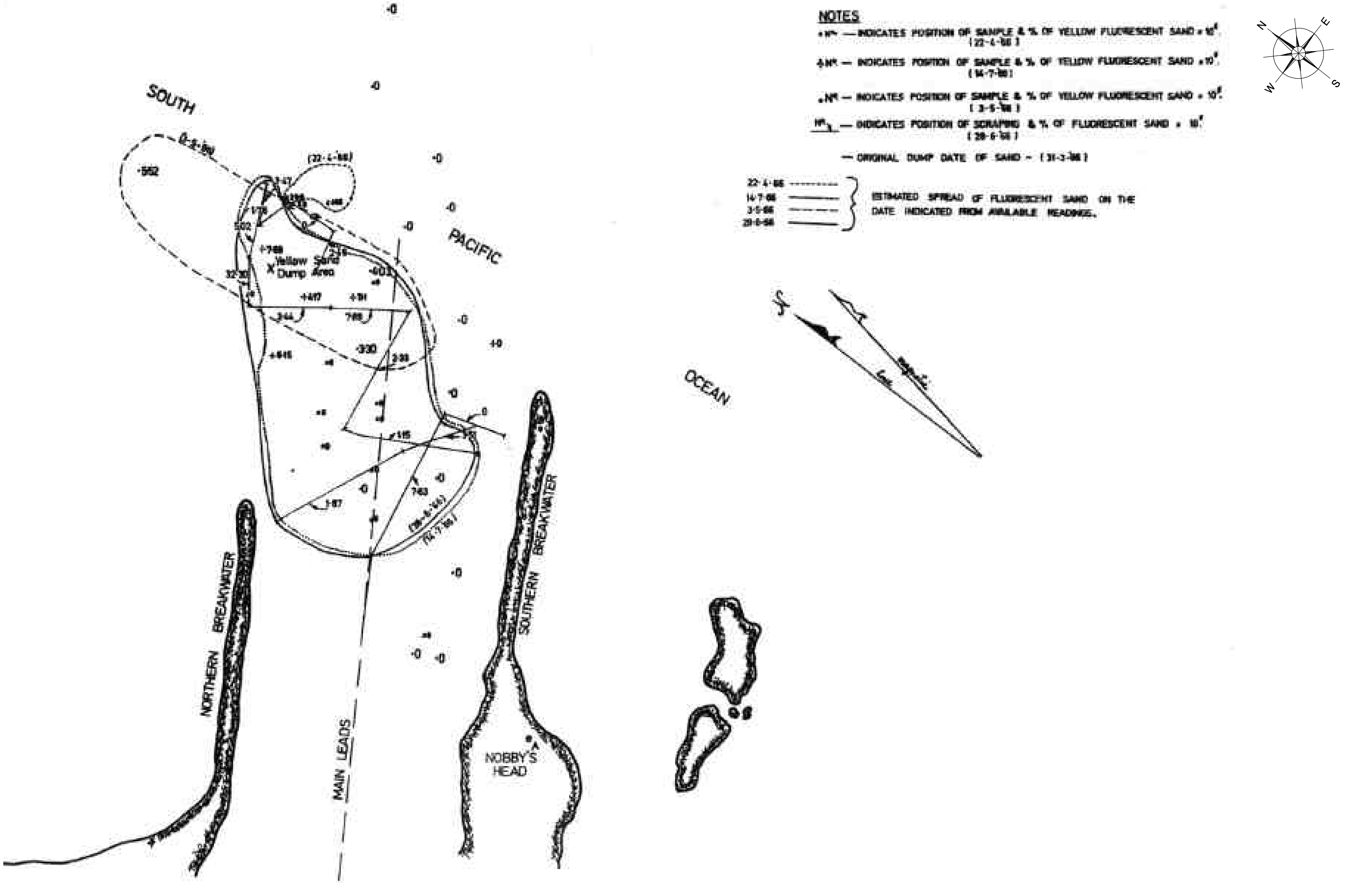


FIGURE 2.8

Newcastle Ocean Sand Tracing
Scraping & Rocket Sample Positions &
Fluorescent Sand Content – Shoal Dump

A4 Not to Scale	Ref No.:R04_V1/1411_152.dgn

Umwelt (Australia) Pty Limited
Source: Boleyn & Campbell

"The annual amount of sand passing the entrance to Newcastle Harbour based on the above assumptions is 128,000 cubic yards (98,000 m^3) moving over a front of 10,000 ft (3000 m).

In the shoal area, considering the transport rate to be equivalent to sand moving in a depth of 36 ft (12 m) of water over a front of 2,400 ft (800 m), the quantity of littoral drift is 30,000 cubic yards/annum (23,000 m^3/annum)."

The south to north movement of sand is consistent with wave energy analysis, with Boleyn and Campbell stating:

"Analysis of hindcast data and wave refraction diagrams for Newcastle shows that 80% of the annual offshore wave energy is derived from the south-eastern quadrant and 40% of this comes from within 5^o of south-east. Thus most of the rough weather comes from this direction and under these conditions it is anticipated that sand will move from south of the harbour to north of the entrance."

Boleyn and Campbell's work as shown on **Figure 2.8**, also demonstrated that at the time of their studies, that the fluorescent tracer sand over a 4 month period between the end of March 1966 and end of July 1966, moved from outside of the breakwaters into the entrance channel.

Since Boleyn & Campbell's studies, the entrance to the harbour has been further deepened from approximately 12 metres to 18 metres. As a consequence it is not known at this time whether sand still moves from outside of the channel into the channel or if the channel is too deep for this to occur nowadays.

Boleyn and Campbell state that sand at Newcastle is medium sized uniformly graded quartz sand with a medium diameter of 0.24 mm that would have threshold velocity for sand movement of 0.7 to 1.3 ft/sec (0.2 to 0.4 m/s).

In regard to tides, Boleyn and Campbell state:

"Except at the entrance to the harbour the tidal current are so small as not to warrant consideration. The flood tide comes from Newcastle Bight and enters the harbour north of the leads; on the ebb the flow is along the northern side of the harbour and south around the end of the southern breakwater. The peak tidal flood velocity, at the bed, at the entrance is 1.3 feet/sec and the mean ebb velocity is 1.6 feet/sec. for normal river flows. The mean tidal range is 4.26 feet".

It is apparent from this, that at the time of Boleyn and Campbell's work, tidal velocities had sufficient capacity to trigger sand movement into and out of the entrance. No more recent tidal velocity information has been sourced to enable it to be established as to whether tidal velocities are still sufficient to cause sediment movement at the bed of the channel.

2.5 NEWCASTLE HARBOUR SILTATION INVESTIGATION (PWD 1969)

Department of Public Works in conjunction with The Hydraulic Research Station, Wallingford England undertook extensive investigations between 1962 and 1967 into causes of siltation in Newcastle Harbour and into mechanisms and structures that could be employed to minimise the annual dredging requirement to maintain the navigability of the harbour. As part of these studies a fixed bed siltation model was developed for Newcastle Harbour and a mobile bed wave model was developed for the entrance to Newcastle Harbour.

In regard to flood flows, PWD 1969 states that the North Arm carried approximately 80% of tidal flow with the South Arm carrying the remainder. During high flood flows, approximately 45% of flood waters passed down North Arm, 35% down South Arm and approximately 20% passed over the islands which have subsequently been filled to form Kooragang Island.

The report states that approximately half the tidal compartment of 34,000 acre feet occurred within 6 miles of the entrance and that the semi-diurnal mean tidal range was 3.44 feet. Peak tidal velocities were reported as an average over a cross-section reach of 3 feet/second with observed surface velocities during floods of up to 8 feet/second. Peak velocity averaged over the entrance cross-section is 2.5 feet per second for a mean spring tidal range of 4.26 feet. Corresponding peak tidal discharge is 96,000 cusecs.

PWD (1969) on p 199 state:

> *"If heavy south or southeast swell occurs, then there will be a sand feed across the entrance of the harbour…. (From the wave model the maximum sand feed across the entrance per year is inferred as 23,000 cubic yards).*
>
> *It is considered that south and south east swells will only occur at the same time as winds above 20 knots for less than ½% of the year. When it does it would be desirable to sound the harbour entrance channel and shoal immediately to observe performance of shoal but it is not anticipated that more than 6" (six inches) of shoaling will occur"*

2.6 ENVIRONMENTAL IMPACT STATEMENT DEEPENING OF NEWCASTLE HARBOUR (MSB 1976)

The EIS sets out the extent of dredging which is shown on **Figure 2.9** and the areas of rock removal from within the channel which are shown on **Figure 2.10**. The EIS does not provide any assessment of impact of harbour deepening on Stockton Beach although it does state that deepening of the harbour would not have any impact. The EIS notes the importance of the provision of a deep water port to service the Hunter Region and discusses a number of alternative locations (Port Stephens, offshore terminal at Stockton Bight and an inshore port at Williamtown). The EIS states:

> *"The Interdepartmental Committee made its initial recommendations to the Government in September 1974. The major recommendation was that "improved port facilities to serve the Hunter Region be provided at this time by the deepening of the existing Port of Newcastle….*
>
> *The recommendations of the Interdepartmental Committee were based on cost considerations as no environmental impacts were identified of sufficient magnitude to affect the overall decision."*

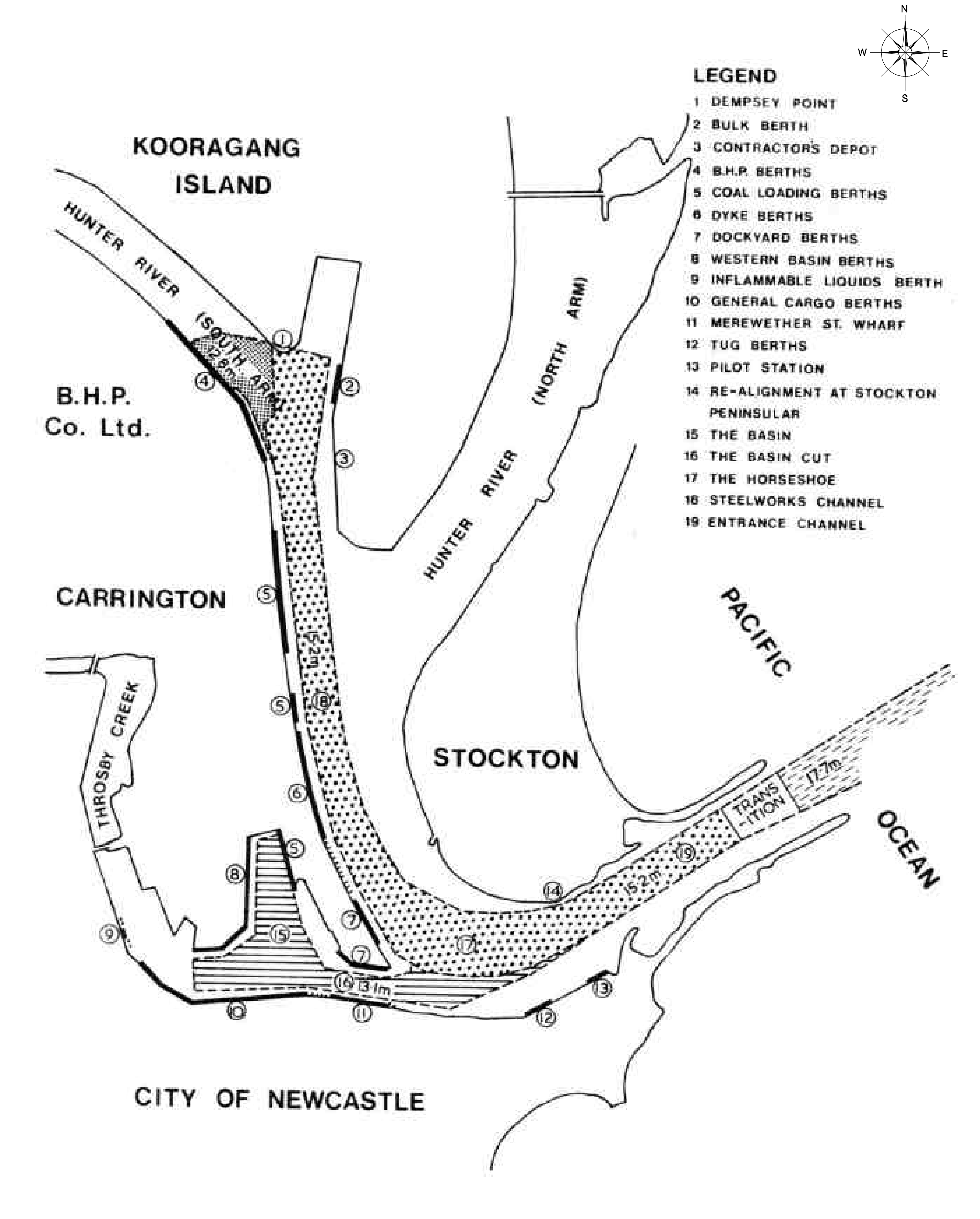
Section 4.3.3 of the EIS on channel flow states:

> *"Some hydraulic changes are likely to take place in the section of the river between the breakwaters, in particular a decrease in maximum velocities and a marginal increase in maximum wave height. None of these effects would have any significant environmental impacts."*

What was not addressed was the impact of a deepened channel on the stability of the adjoining sandy seabed or what impact increased tidal volumes entering the harbour as discussed in **Section 2.5**, would have on velocities and scour at the tips of the breakwaters, particularly the Northern Breakwater.

Section 6.2.2 of the EIS states:

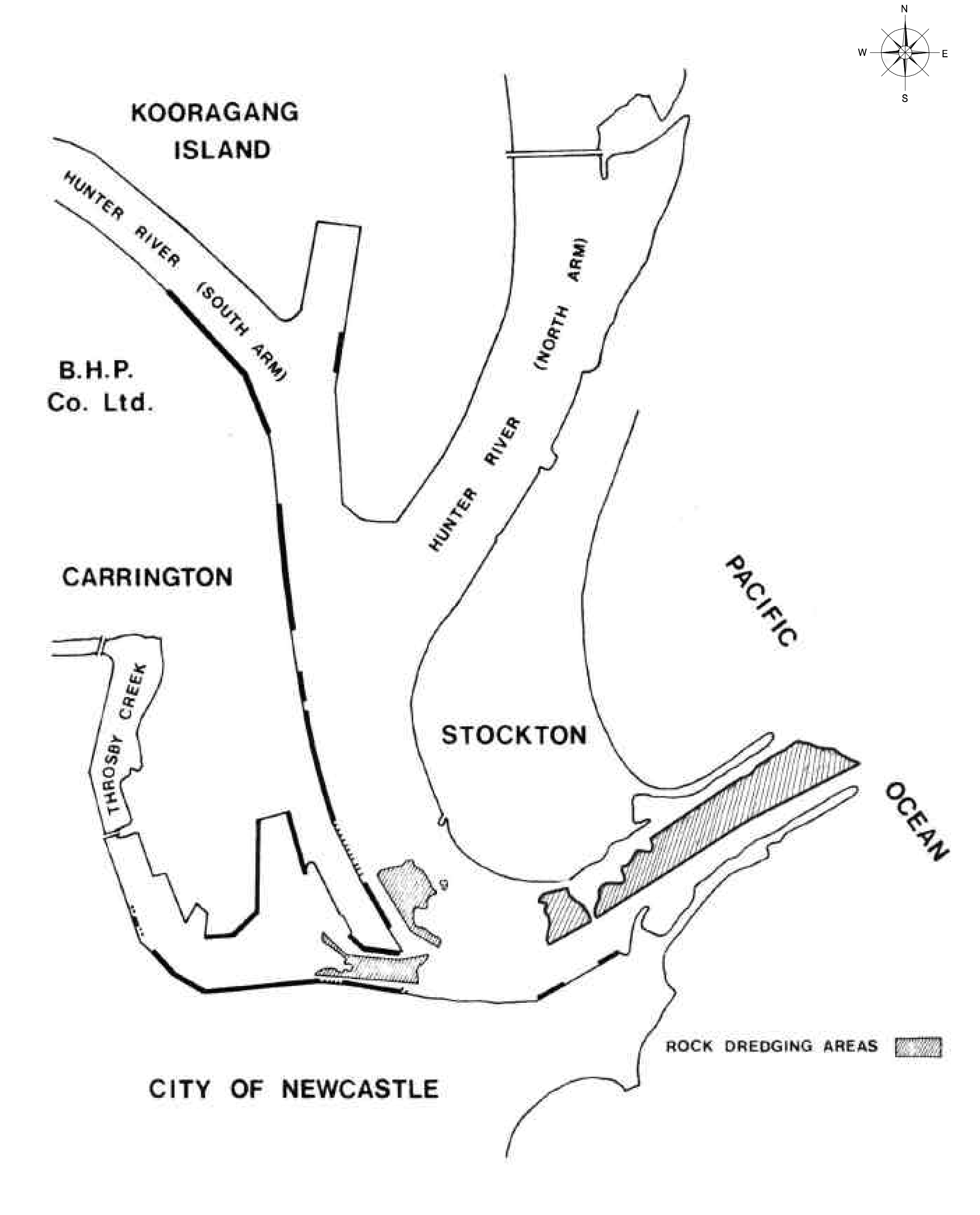
> *"Beach siltation is not a permanent environmental problem and any temporary effects will be readily controlled and there will be no change in sea conditions at any of the ocean beaches."*



Umwelt (Australia) Pty Limited
Source: The Maritime Services Board of NSW - Environmental Impact Statement, Deepening of Newcastle Harbour; Figure 1.

FIGURE 2.9
Deepening of Newcastle Harbour
Port Layout and Area to be Dredged

A4 Scale 1:30 000	Ref No.:R04_V1/1411_183.dgn



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Source: The Maritime Services Board of NSW - Environmental Impact Statement, Deepening of Newcastle Harbour; Figure 2.

FIGURE 2.10
Deepening of Newcastle Harbour
Rock Dredging Areas

A4 Scale 1:30 000 | Ref No.:R04_V1/1411_184.dgn

The potential environmental impacts considered in the EIS do not include impacts on sand movement on Stockton Beach or supply to the beach system. Given the early reports dating back to 1904 and as late as 1963 (Manley) of sand draining from Stockton Beach into the channel, it is hard to imagine that the potential for this to continue or be exacerbated by the then proposed deepening wasn't considered in preparing the EIS. Similarly, the work by Boleyn and Campbell in 1966 demonstrated that in the order of 23,000 m^3 of sand was supplied to the entrance of the channel from Nobbys Beach by longshore drift. Deepening the entrance to greater than 12 metres as proposed would impact on this littoral sand supply, however this also was not assessed in the EIS.

2.7 FEASIBILITY STUDY ON NOURISHMENT OF STOCKTON BEACH (DEPARTMENT OF PUBLIC WORKS 1978)

Following a representation from Newcastle City Alderman Mrs S Macleod, The Deputy Premier and Minister for Public Works instructed the Department of Public Works to examine the feasibility of using sand from deepening of Newcastle Harbour to nourish Stockton Beach.

The report states:

> *"Stockton Beach is adjacent to the northern breakwater of the Newcastle harbour entrance and is part of a 30 kilometre length of sandy foreshore known as Newcastle Bight. As with much of the New South Wales coastline, the entire Bight area has been subject to erosion over the past few years. The erosion is most apparent in the Stockton Beach area."*

The report explores the causes of erosion at Stockton Beach stating that the quantity of "sand budget" for the entire Newcastle Bight is depleting due to loss of sand to vegetated sand dunes. The report states:

> *"More locally at Stockton, the residential development has encroached upon the dunes. The reservoirs of sand, in the form of dunes, are not available to the same extent as with the more northern sections of Newcastle Bight. Therefore, the result of losing sand through wave attack is much more significant as there is no sand to replenish and maintain the beach profile."*

The report identifies that the deepening of Newcastle harbour work was to be undertaken by Westham Dredging Company under contract to Maritime Services Board and that there was some 3 million m^3 of sand to be dredged of which 0.5 million was to be pumped to Kooragang Island. The report also identifies that the D_{50} sand gradings along Stockton Bight varied from 0.26 mm diameter at Stockton to 0.7 mm approximately 10 kilometres north and decreasing to 0.24 mm at the northern end near Morna Point. The report then goes on to conclude that the minimum D_{50} sand size for nourishment at Stockton Beach would be between 0.3 mm to 0.5 mm however this size selection is not substantiated other than stating that:

> *"…the selection of a D_{50} sand size for nourishment in the Stockton area is a complex problem requiring a more detailed study than time permits for this report. However it can be said that the minimum size of sand required would have a D_{50} size of between 0.3 mm and 0.5 mm which corresponds with that of a coarse grained sand."*

This conclusion is not consistent with earlier references by Boleyn and Campbell (1966) which found that the medium grainsize diameter of sand was 0.24 mm. Adoption of a smaller medium sand size such 0.24 mm would have meant that a significantly larger component of the 3 million m^3 of sand to be dredged from the harbour would have been suitable for use for the nourishment of Stockton Beach.

In examining the location at which sand could be dumped and be moved onshore, PWD 1978 cites extensive offshore investigations that were undertaken as part of the Williamtown Port Study. The report states:

> *"During the investigation offshore beach profiles were carried out on a monthly basis over a two year period at six locations, some 500 metres apart. The conclusion of the investigation was that:*
>
> > *"In general, the profile data indicated that sand movements ceased in 12 to 14 metres of water."*
>
> *This cessation of sand movement has further been substantiated in more recent research. Sand samples from the inner high energy zone have been found to have completely different characteristics, under microscopic inspection, from those of the offshore sands, thus proving the lack of movement of sand from one zone to another."*

The report is dismissive of the idea of using sand dredged from to harbour to nourish Stockton Beach from the start, citing a number of problems such as:

- The wrong type of dredge is proposed to be used;
- The viable depth of water for dumping off Stockton Beach is too shallow for the proposed bottom dumping dredge;
- The volume of available material in the adopted size range (D_{50} of 0.3 to 0.5 mm diameter) is limited and doesn't warrant use;

Interestingly, there are several earlier references to sand being pumped to Stockton Beach from dredging operations including a reference to sand being initially pumped to a second barge from where it was pumped to Stockton Beach.

The report concludes:

> *"Due to the type of equipment available for use by the Dredging Contractor and the proposed method of operation of this equipment, suitable sand cannot easily be placed within the required limits of the beach profile without endangering the dredging equipment. The difficulty of operation and lack of suitable sand would make it more economical to transport sand from other area of Newcastle Bight to Stockton Beach rather than using the material from the dredging project.*
>
> *In conclusion it can be said that under different operational and geological circumstances the proposal to use dredging spoils from the deepening project to nourish Stockton Beach would be sound in both terms of engineering practicability and also from an economic point of view. However, due to the Contractor's type of equipment, dredging methods and lack of suitable material of the correct grading, the proposal is not feasible in this particular instance."*

2.8 NEWCASTLE COASTLINE HAZARD DEFINITION STUDY (WBM 1998)

WBM 1998 undertook a review of available information as part of the Hazard Definition Study. The review mainly focused on sand volumes above High Water Mark and found that since 1952, there had been periods of erosion and accretion.

> *"There is no recent survey data to assess the current extent of any nearshore bar or whether it has been influenced by longshore sand movements as discussed below. However, a detailed hydrographic survey undertaken by DLWC in July 1995 indicates a significant longshore bar about 60 metres offshore at the southern end of the beach and about 100 metres offshore near the seawall.*

The implications of those patterns are that:

- *It is probable that, over time, the beach will again recover depending on any longer term recession trends as discussed below;*
- *This rate of recovery may be quite slow; and*
- *In the interim period, the beach is vulnerable to further storm erosion, the extent of which will be dependent on the status of nearshore bar."*

To explore the size and extent of the longshore bar further, DLWC's 1995 hydrosurvey information has subsequently been incorporated into a digital terrain model and is reproduced in **Figure 2.11**. A similar model has also been produced using DLWC's detailed 2000 hydrosurvey information and is reproduced in **Figure 2.12**. As can be seen from **Figures 2.11** and **2.12**, there is a sand bar off the beach with the sand bar being more pronounced in 2000 than in 1995. It is of note that the digital terrain models shown in **Figures 2.11** and **2.12**, have significant vertical exaggeration in the scale and that the actual sand volumes contained in the sandbars is not substantial. **It is also of note that the seaward face of the sand bar appears to be much steeper in 2000 than in 1995.**

WBM (1998) estimated potential longshore transport of sand for the beaches south of the Hunter River of approximately 30,000 m^3 per year but then considered due to the presence of rock along the foreshore and slight alterations in beach alignment as a result of groyne effects of the headlands that actual transport rates would be less and in the order of 10,000 m^3 per year. WBM (1998) compared 1957 and 1995 sand volumes for the 3 kilometre section of Stockton Beach north of the breakwater and calculated that approximately 1 million m^3 had been lost from the beach and immediate nearshore system. WBM indicated that this suggested a net northward longshore sand movement of approximately 20,000 to 30,000 m^3 of sand per year which was consistent with the modelling for the southern beaches and with the earlier findings of Boleyn and Campbell's sand tracer experiments in 1966. WBM (1998) surmised:

"This implies that either:

- *This unit possibly experienced a similar net northward transport prior to the breakwater construction, depending on a natural sand supply from the river and/or from the southern beaches of about 20,000 to 30,000 m^3/yr;*

- *The breakwaters have prevented the natural sand supply from feeding the Stockton Beach system;*

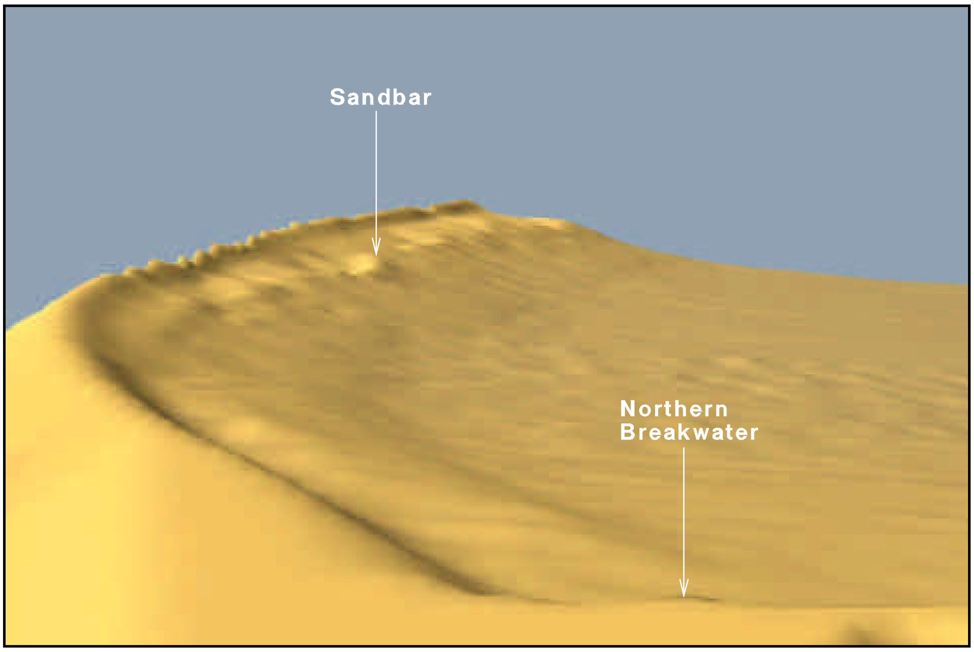
- *The former natural sand supply must be accumulating elsewhere;*

- *The beach unit is possibly responding to larger scale cycles in longshore transport within Stockton Bight which is effectively a closed system (i.e. no input or output) of sediment;*

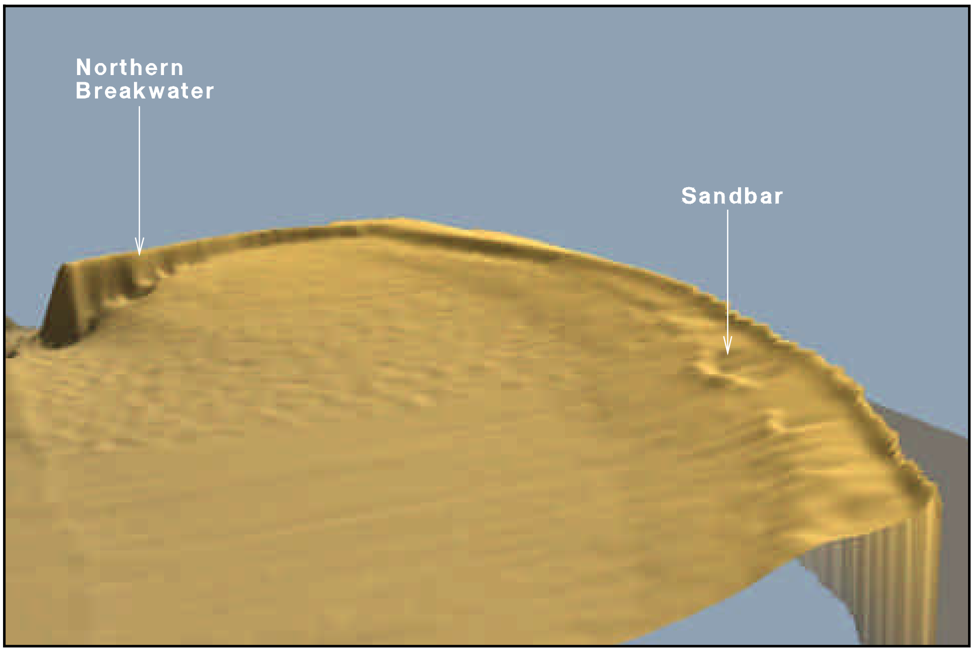
- *The sand lost from Stockton Beach is accumulating further to the north in Stockton Bight and may return during periods of more dominant southerly transport under north east and easterly wave conditions*

If the sand supply was predominantly the river, the sand would be accumulating within the river or outside (and probably north of) the entrance. If the supply was from the southern beaches, the sand would accumulate on Nobbys Beach, be diverted offshore near the entrance, or transported into the river entrance.

Further study is needed to confirm the relative contributions of these sources. Anecdotal evidence is that there may be substantial sand supply from the river. As well, the survey data suggests significant accumulation of sand immediately to the north of the river entrance in around 15 to 20 metres water depth. There is also evidence of a build up of sand around Nobby Head and inside the river entrance.



View looking Northeast from Northern Breakwater



View looking Southwest to Northern Breakwater

FIGURE 2.11
Digital Terrain Model from 1995 DLWC Hydrosurvey off Stockton Beach

A4 Not to Scale | Ref No.:R04_V1/1411_178.dgn

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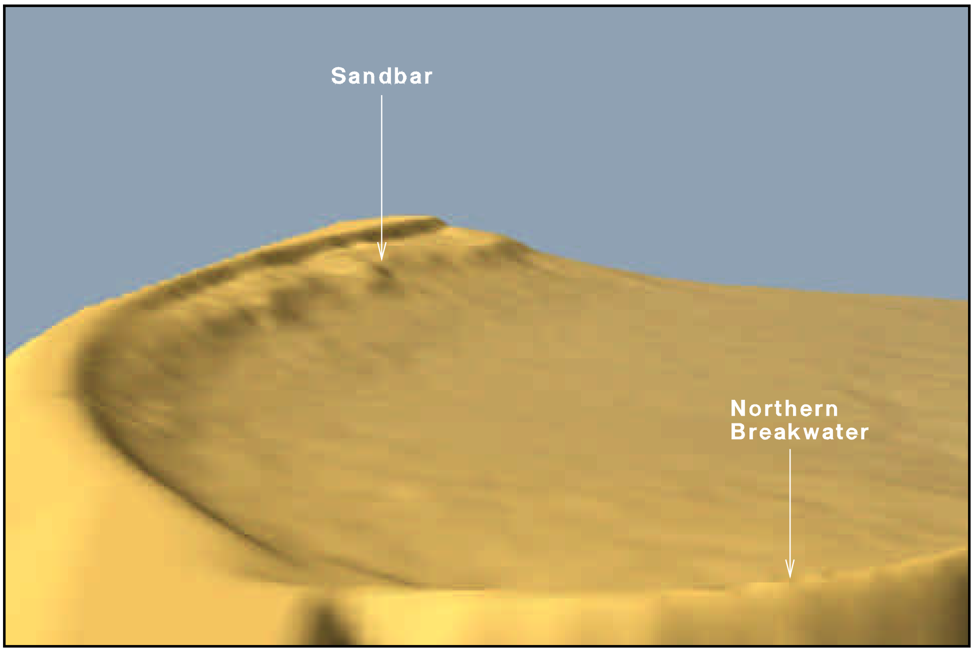
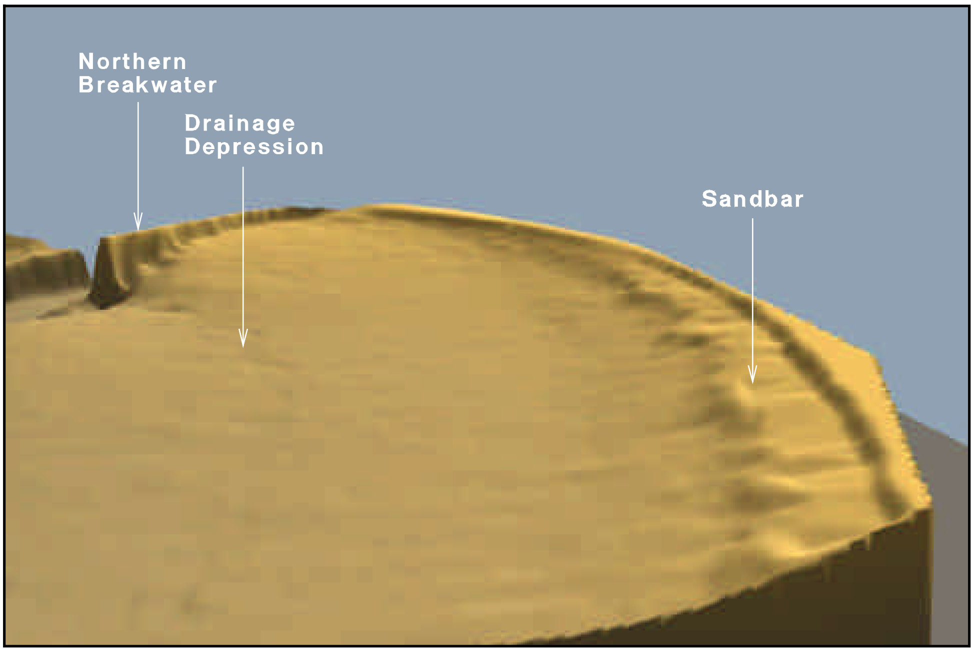


View looking Northeast from Northern Breakwater



View looking Southwest to Northern Breakwater

FIGURE 2.12
Digital Terrain Model from 2000 DLWC Hydrosurvey of Stockton Beach

A4 Not to Scale

Ref No.:R04_V1/1411_182.dgn

> *Conversely, Hunter Ports Authority has advised that there has not been a requirement to dredge marine sands from the entrance to the Hunter River between the breakwaters since the harbour was deepened in the 1980's. The recent surveys are presently too limited to quantify any accumulation. It is recommended that a more extensive hydrographic survey be undertaken to assist with this assessment."*

Using 1957 and 1995 hydrographic survey information, WBM developed digital terrain models of the subsurface section of Stockton Beach for an area extending from approximately 100 metres offshore to the end of the breakwall and extending for a distance of approximately 3 kilometres north of the breakwall. The difference in elevation of the models was compared to produce a difference plot for the period 1957 to 1995 as shown on **Figure 2.13**. The plot demonstrated that over this period, there had been a net loss of up to 3 metres of sand from a section adjacent to Stockton Beach that extended from just north of the surf club to the northern limit of the study area. The comparison showed that there had been an accumulation of up to two metres of sand immediately to the north of the Northern Breakwater and an accumulation of approximately 1 metre of sand in a shoal approximately 300 metres to 400 metres to the northeast of the tip of the breakwater.

These two areas of sand deposition appear to be separated by a deeper section of channel that starts from the scour hole at the tip of the breakwater. This indicates that outer sand deposits may be the start of the formation of a shoal in the area similar to that reported off Stockton Beach prior to the construction of the Northern Breakwater except at greater depth. WBM modelling indicates that the scour hole at the tip of the Northern Breakwater has increased in depth by 3 metres or more between 1957 and 1995. This is interesting considering that Manley's (1963) analysis as discussed in **Section 2.3**, indicates that scour hole had not substantially increased in extent or depth since approximately 1926 and that prior to 1957 the system appeared to be approaching equilibrium.

The formation of a shoal off the end of the Northern Breakwater and the existence of a related drainage feature has been further explored by detailed analysis of the DLWC 2000 hydrosurvey information around the entrance to the harbour and is reproduced as a digital terrain model in **Figure 2.14** and as a contour plot on **Figure 2.15**. As can be seen from **Figures 2.14** and **2.15**, a shoal exists approximately 350 metres north-northeast of the tip of the Northern Breakwater with a pronounced drainage depression existing between the shoal and the end of the Northern Breakwater. The bed profile adjacent to the tip of the Northern Breakwater and for some 300 to 400 metres north of the tip is significantly steeper than the adjoining area leading back to Stockton Beach indicating an erosional environment. As can be seen on **Figure 2.12** the drainage depression appears to extend back from the tip of the Northern Breakwater in an arc that is approximately parallel with Stockton Beach. Comparison of the 1995 and 2000 digital terrain models indicates that the shoal is more developed in 2000 than in 1995. As shown on **Figure 2.15**, the southern face of the shoal for a distance of some 600 metres east of the tip of the Northern Breakwater is also significantly steeper than the prevailing beach profile extending back to Stockton Beach. This also indicates an erosional environment.

The sequence of views of the end of the entrance channel shown on **Figure 2.14**, show the extent of rock removal from the bed of the channel that was removed as part of the 1979 to 1983 harbour deepening program. The views also show a build up of sand along the southern side of the channel near the entrance with the sand covering a section of the excavated rock wall off the tip of the Southern Breakwater. This indicates that sand is continuing to move from Nobbys into the channel. Similarly on the northern side of the channel the southern face of the shoal has encroached into the previously dredged channel by some 100 metres with the build up of sand from Nobbys meeting the southern face of the shoal in approximately the centre of the channel.

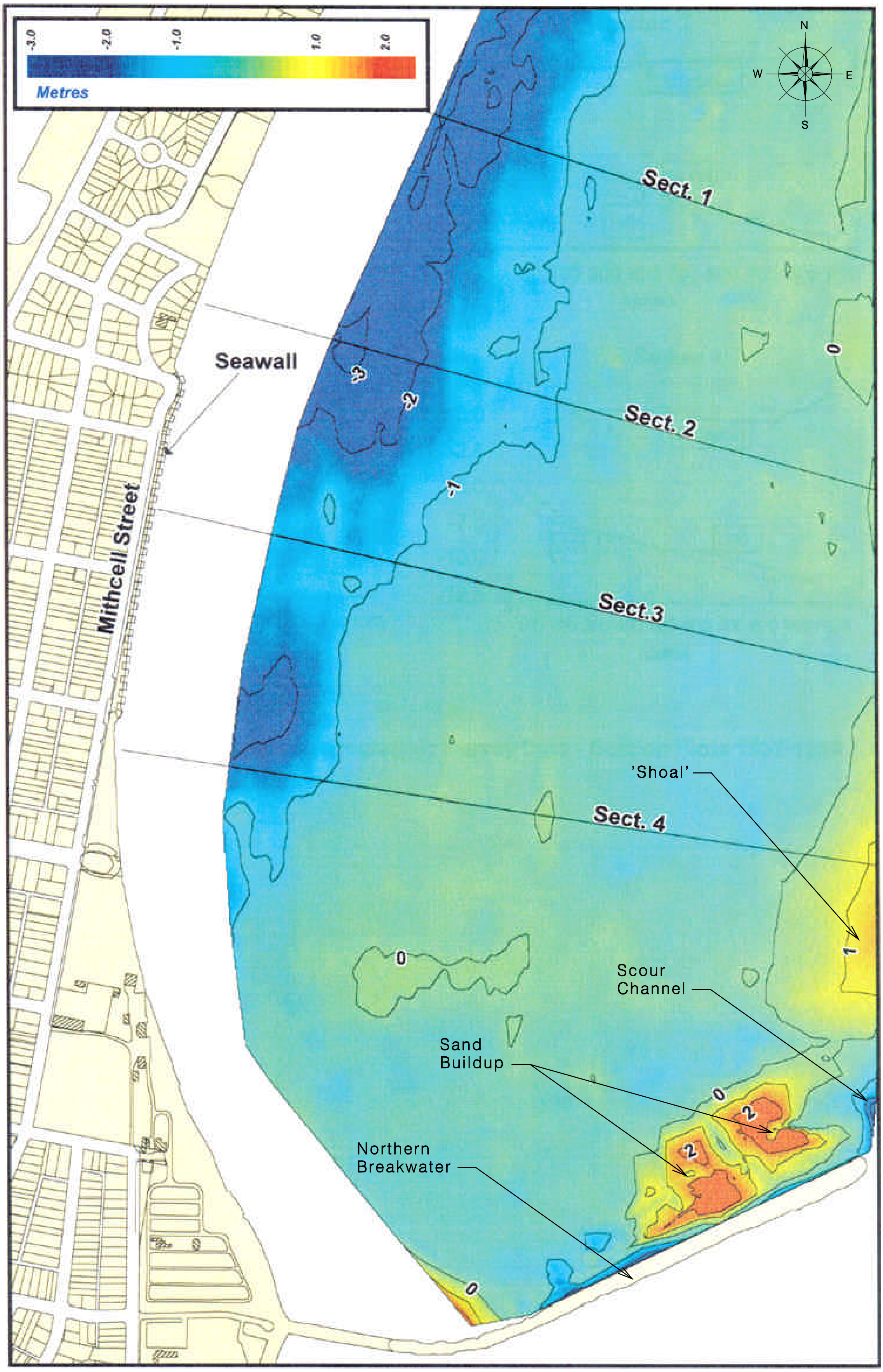


FIGURE 2.13
Stockton Beach
Hydrographic Survey Data
Difference Plot 1957–1995

A4 Not to Scale	Ref No.:R04_V1/1411_180.dgn

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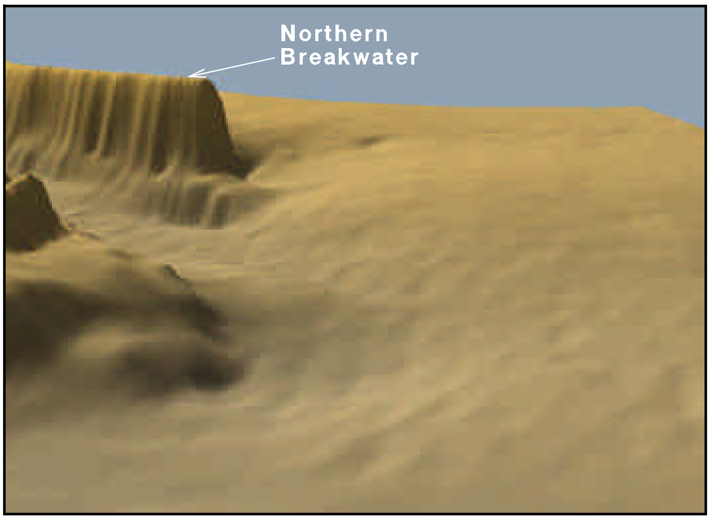
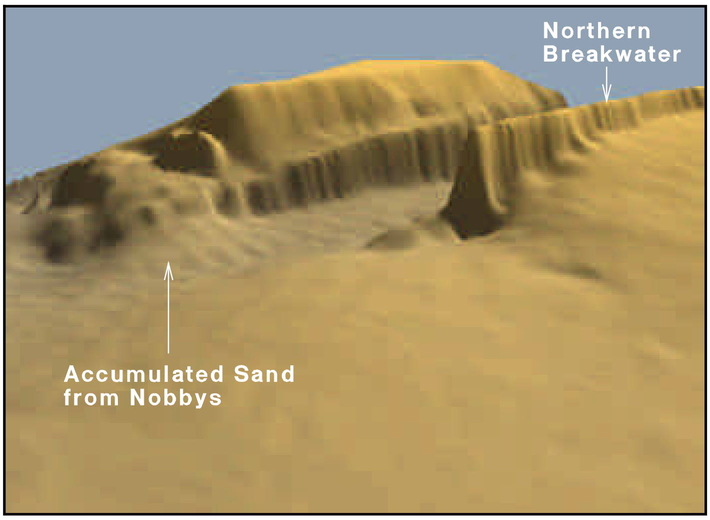
Source: WBM





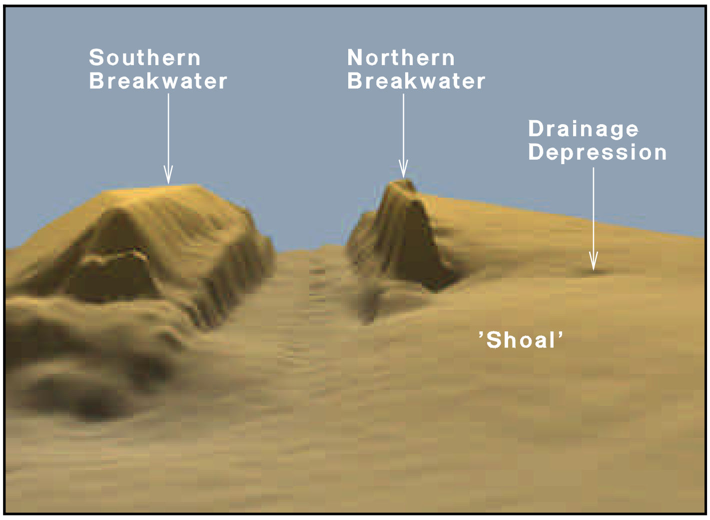


FIGURE 2.14

Digital Terrain Model of Harbour Entrance
Based on 2000 DLWC Hydrosurvey

A4 Not to Scale	Ref No.:R04_V1/1411_177.dgn

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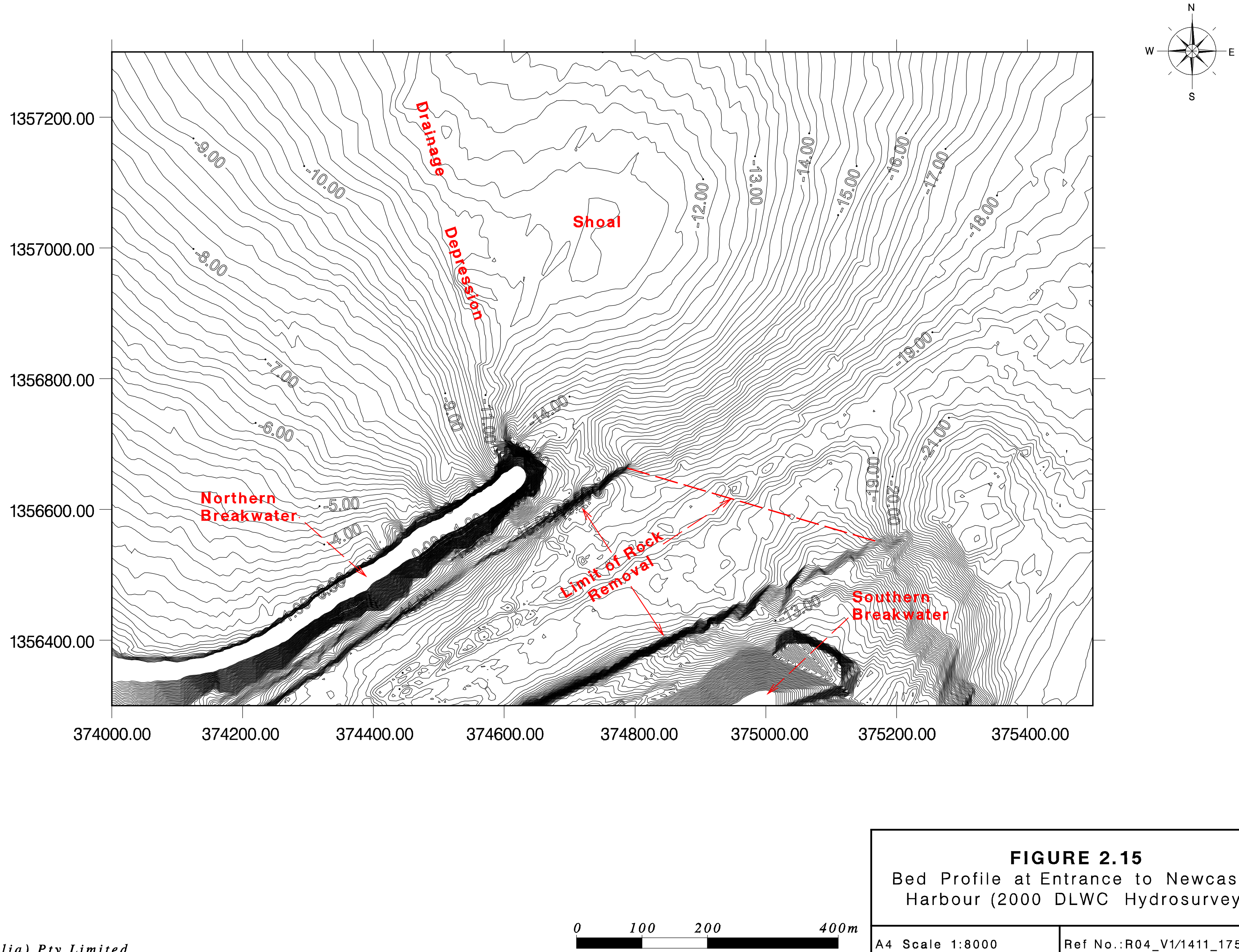

FIGURE 2.15
Bed Profile at Entrance to Newcastle Harbour (2000 DLWC Hydrosurvey)

A4 Scale 1:8000 | Ref No.:R04_V1/1411_175.dgn

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This analysis indicates that sand is in fact moving into the outer section of the channel from both Nobbys and Stockton Beach. The digital terrain models indicate that there does not appear to be any significant build up of sand in the channel westward of the tip of the Northern Breakwater. Newcastle Port Corporation personnel have stated that:

> *"Maintenance dredging has rarely occurred further than 200 metres east of Stockton Ferry terminal, and has never occurred more than 200 metres east of the eastern end of the seawall at Pirate Point."*

There was no evidence of any dredging within the channel other than for earlier capital works (i.e. 1962 to 67 and 1979 to 1983) in Newcastle Port Corporation records that were reviewed as part of this study.

2.9 TIDAL RANGE INFORMATION

To assist in understanding the changes that have occurred around the entrance to Newcastle Harbour, a review of available historic and current tidal plane and tidal range information by Newcastle Port Corporation and DLWC was undertaken.

The oldest reference to tidal gradients found was for 1895 on a chart titled "Tidal Gradients, Newcastle Harbour" which was prepared by Department of Public Works. The chart showed an approximation of the tidal planes before the extension of the Northern Breakwater and an estimation of the tidal plane after its extension. The chart was drawn to scale, however did not contain sufficient information to allow comparison with more recent tidal plane information.

Average tidal range information at the entrance to the Harbour, Stockton Bridge and Hexham Bridge has been compiled for 1950s, 1980s and 1990s and is provided in **Table 2.1**.

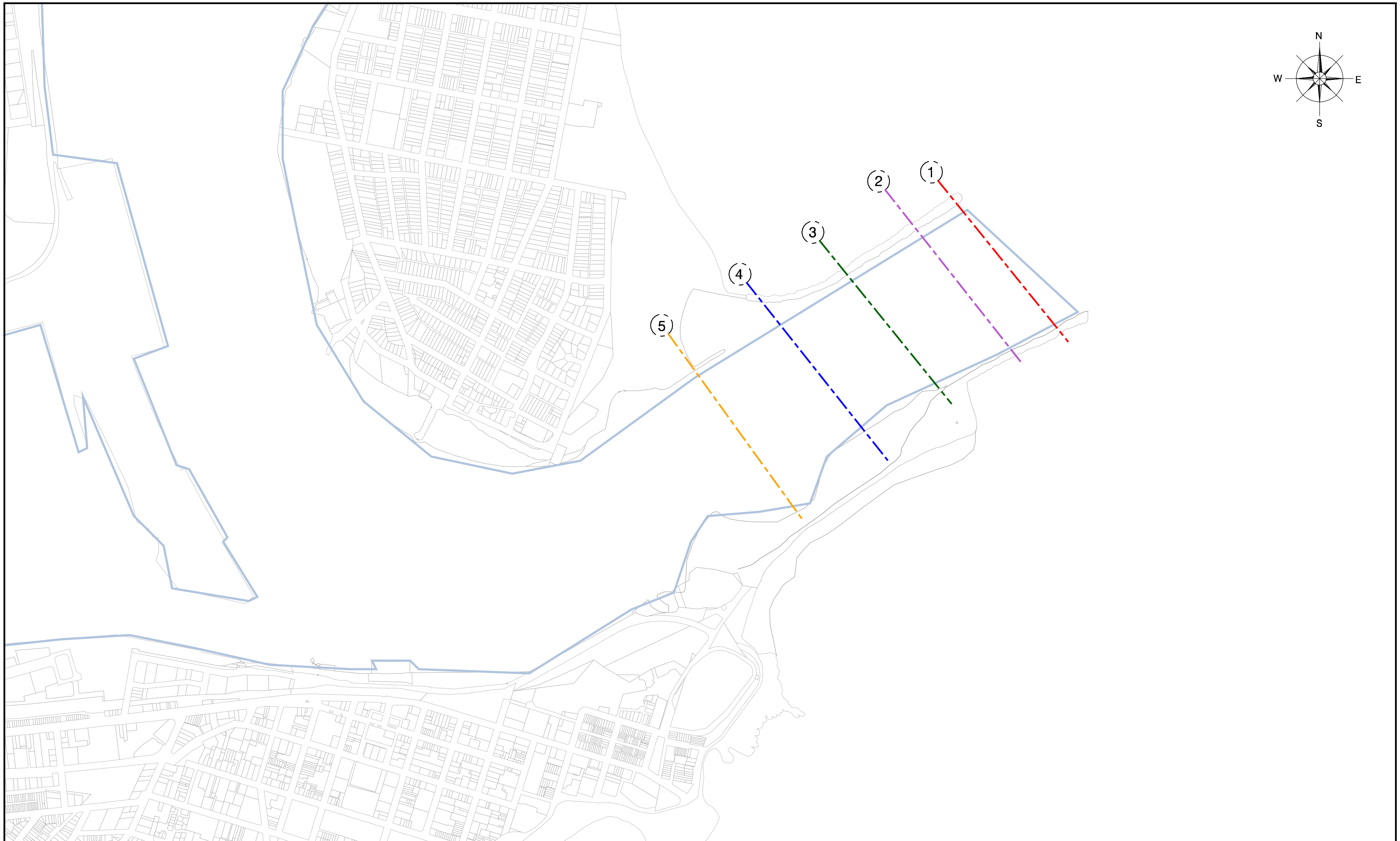
Table 2.1 – Tidal Range Information

Tide	**Tidal Range**						
	Entrance	**Stockton Bridge**			**Hexham Bridge**		
	All Years	1950s	1980s	1990s	1950s	1980s	1990s
Solstice	1.97	1.84	1.94	1.93	1.55	1.79	1.80
High/Low Water Springs	1.35	1.27	1.32	1.31	1.07	1.18	1.20
Mean High/Low Water	1.06	-	1.06	1.06	-	0.97	0.99
High/Low Water Neaps	0.81	0.81	0.80	0.81	0.81	0.75	0.78

Available tidal information indicates that for Spring and Solstice tides, since the 1950s the tidal range has increased by approximately 50 mm to 100 mm respectively at Stockton Bridge and by approximately 130 mm to 250 mm respectively at Hexham Bridge with smaller increase being observed for Mean tides and Neap tides between 1980s and 1990s.

These recorded increases in tidal range indicate that a greater volume of water now passes through the entrance channel on each tidal cycle with estimates indicating approximately a 5% increase in tidal exchange volume.

Analysis of channel cross-sectional information as shown on **Figures 2.16** and **2.17**, indicates that since 1950 the controlling cross-sectional area of the entrance channel has increased from approximately 3400 m^2 in the 1950s to approximately 5780 m^2 in 2000 with a corresponding increase in depth from approximately 10 metres to approximately 17 metres. This equates to approximately a 1.7 times increase in entrance channel cross-sectional area.



Legend

Approximate Top Water Level

(1) For Section details refer to Figure 2.17

(R04_V1/1411_149.dgn)

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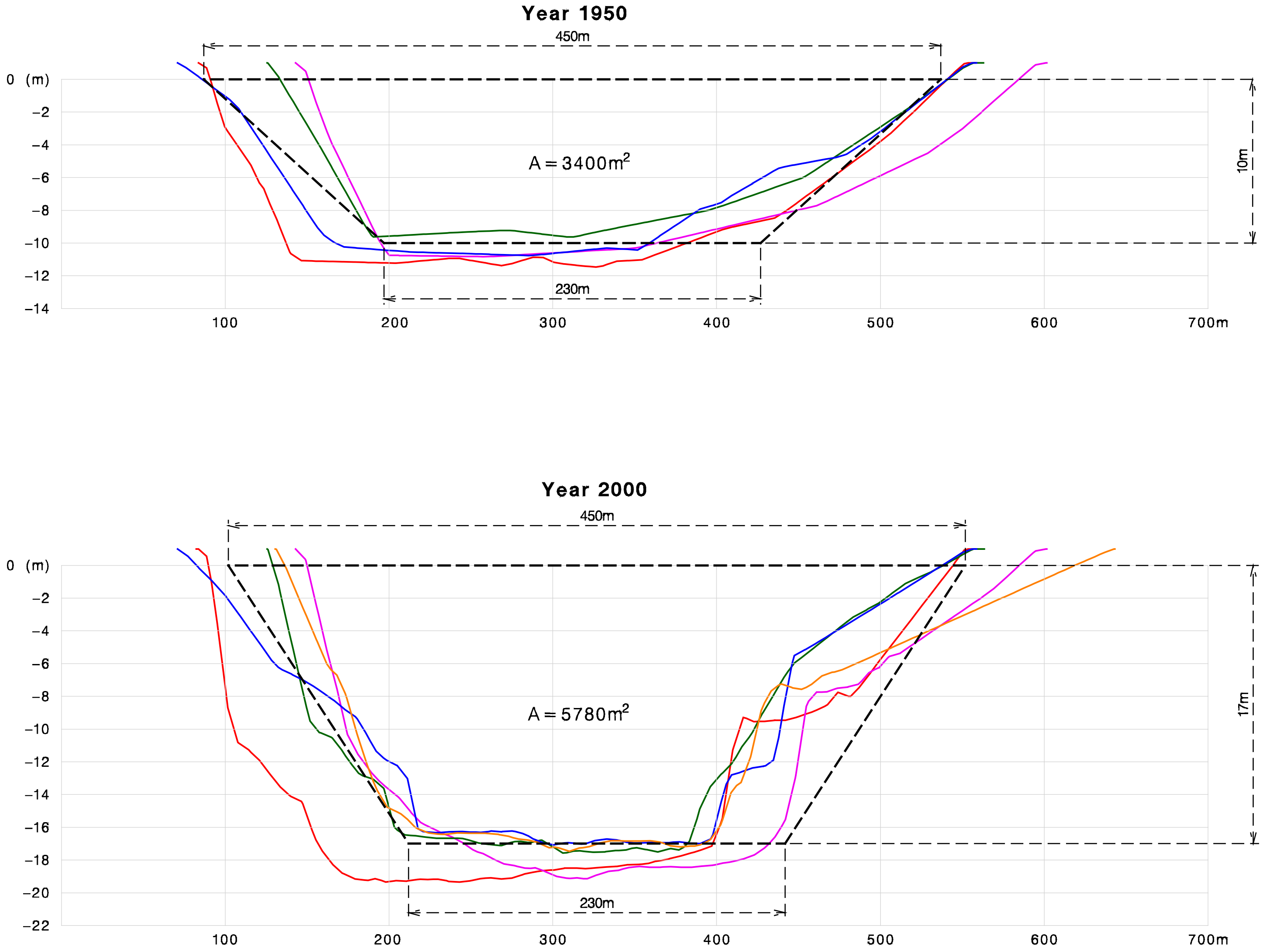
FIGURE 2.16

Location of Cross Sections used to calculate generalised Channel Area

A4 Scale 1:15 000

Ref No.:R04_V1/1411_146.dgn



Legend

Section 1
Section 2
Section 3
Section 4
Section 5

Typical Cross Section Dimensions and Area

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0 5 10 20m
Vertical Scale 1:400

0 50 100 200m
Horizontal Scale 1:4000

FIGURE 2.17
Year 1950 and Year 2000 Channel Cross Sections

A4 Scale as Shown

Ref No.:R04_V1/1411_149.dgn

As a result of the significant increase in channel cross-sectional area, present day tidal velocities within the channel are lower than in the 1950s despite the increase in tidal exchange volume.

The increase in tidal exchange volume does have the potential to increase velocities of flows immediately outside the entrance channel and the area of influence of these tidal processes. Greater flows and deepening of the channel also have the potential to impact on the magnitude and sediment transport capacity of the tidal jet which could subsequently influence tidal currents at and adjacent to the entrance. Given the fine to medium sandy nature of the sea bed, these changes are also likely to have impact on bed profiles and sediment transport in the area.

Without detailed modelling, it is not possible to determine the magnitude or potential impact of these changes.

3.0 BED PROFILES AND SAND VOLUMES

3.1 STOCKTON BEACH BED PROFILES

To understand changes that have occurred in the beach profile of Stockton Beach, a series of fifteen shore normal (east-west) cross-sections, each 100 metres apart, have been constructed north of the Northern Breakwater and covering that section of Stockton Beach as far north as Stockton Wastewater Treatment Plant. The location of each of the cross-sections is shown on **Figure 3.1** and cross-sectional profiles at each of these locations showing recorded changes over time are provided in **Appendix 2**. Cross-section 4, which is typical of the observed changes, is reproduced as **Figure 3.2**.

The information used to generate each of the cross-sections has been derived from available hydrosurvey information as discussed in **Section 1.0**. Sources of the hydrosurvey information and height datum to which the survey was referenced is provided in **Table 3.1**.

Table 3.1 – Source and Height Datum for Hydrosurvey Information

ID	Year	Name	Details	Height Datum
1	1816	Contours	Digitised contours from 1816 map.	Unknown
2	1816	Low Water Mark	Digitised from Harbour Plan	AHD-1
3	1816	High Water	Digitised from Harbour Plan	AHD-1
4	1816	Southern Edge of Harbour	Foreshore edge along south side of harbour obtained using bearing-distance from Nobbys Head	AHD-1
5	1816	Low Water in Harbour	Shallow Shoals within harbour obtained using bearing-distance from Nobbys Head	AHD-1
6	1851	Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	Unknown
7	1851	Low Water Mark	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
8	1851	High Water Mark	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
9	1866	Low Water Mark	Digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1866	AHD-1
10	1866	South Bank	South bank of Newcastle Harbour obtained from bearing-distance readings from Drawing Showing Stockton	AHD-1
11	1866	Digitised Contours	Digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1866	LWST
12	1866	Breakwall	Digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1866	AHD-1
13	1866	High Water Mark	Digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1866	AHD-1
14	1866	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	LWST
15	1878	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	LWST
16	1878	North Bank of Harbour	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
17	1878	North Breakwall	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
18	1878	South Bank	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
19	1878	Low Water Level	Stockton beach low water level digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1878	AHD-1

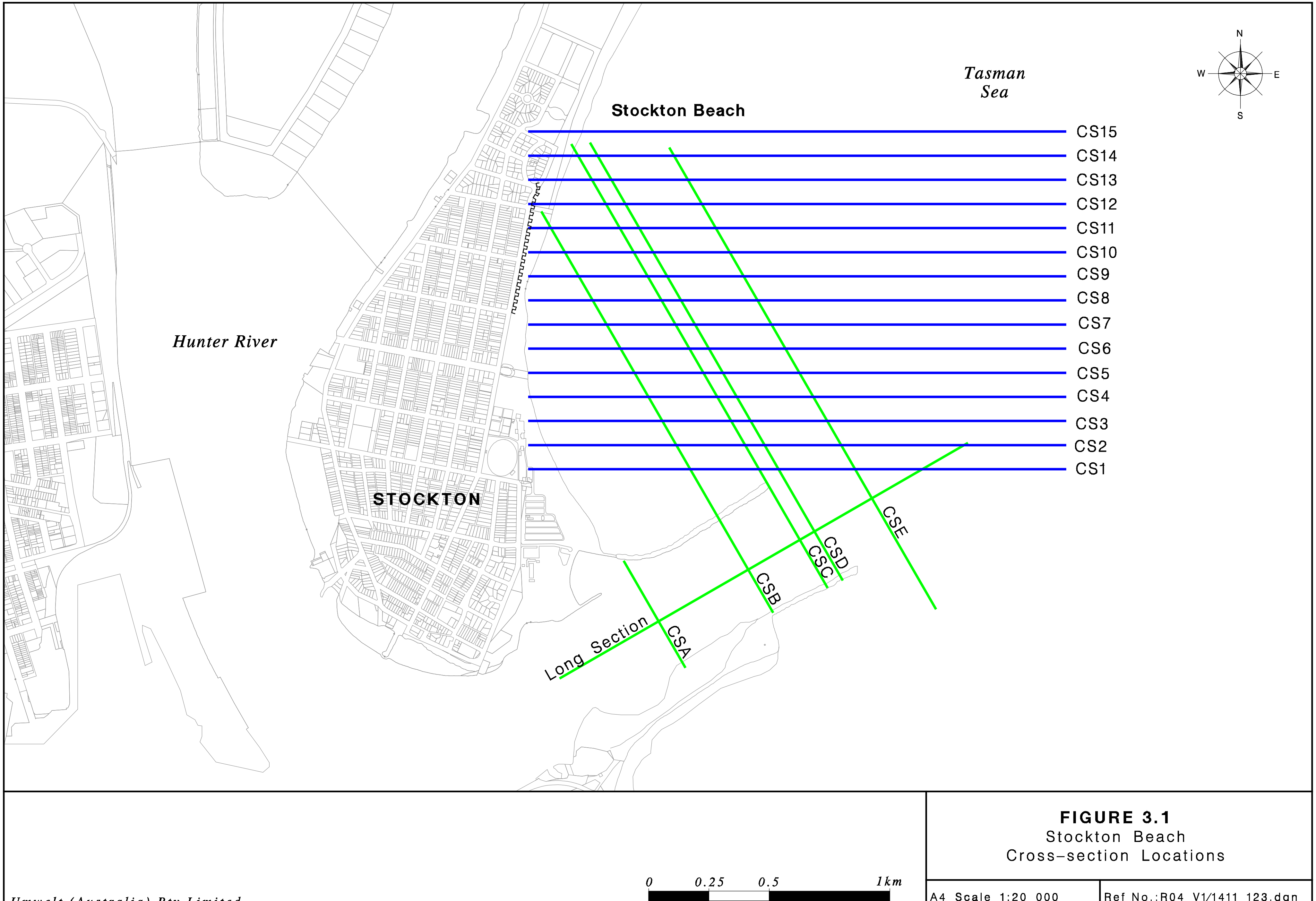

FIGURE 3.1
Stockton Beach
Cross-section Locations

A4 Scale 1:20 000

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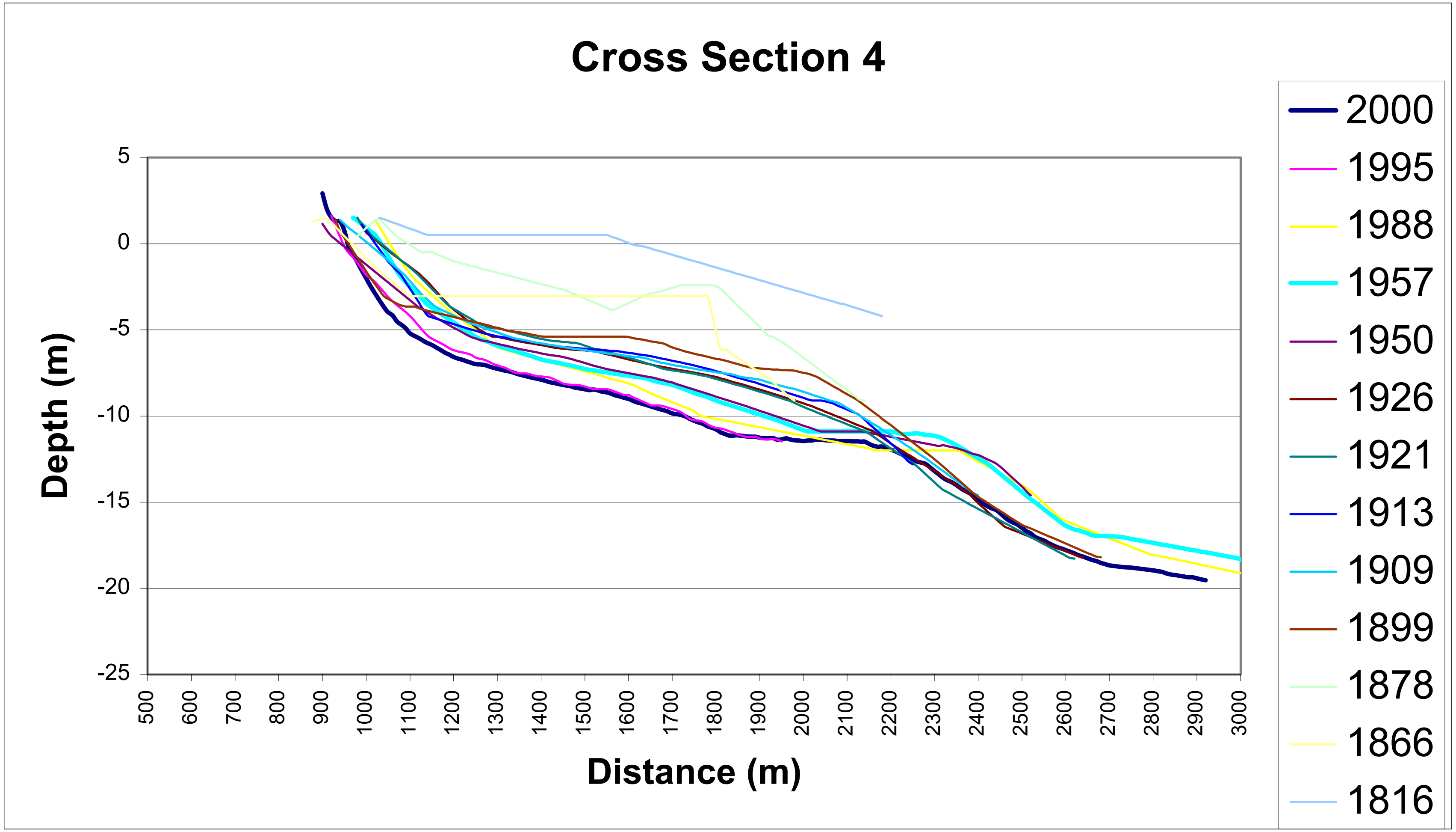


Figure 3.2

Cross Section 4

Table 3.1 – Source and Height Datum for Hydrosurvey Information (cont)

ID	Year	Name	Details	Height Datum
20	1878	Digitised Contours	Digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1866	LWST
21	1878	Breakwall	Digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1866	AHD-1
22	1878	High Water Level	Stockton beach low water level digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1878	AHD-1
23	1899	High Water Level	Stockton beach high water level digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1899	AHD-1
24	1899	Low Water Level	Stockton beach low water level digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1899	AHD-1
25	1899	Breakwall	Southern Breakwall digitised from Scan of Drawing Showing Stockton and Newcastle Harbour in 1899	AHD-1
26	1899	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	LWST
27	1899	Wave Trap	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
28	1899	North Bank	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
29	1899	South Bank	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
30	1899	Contours	Bearing Distance measurements from Nobbys Head on scale map	LWST
31	1909	Low Water	Digitised from scan of port map	AHD-1
32	1909	Contours	Digitised from scan of port map	unknown
33	1909	Breakwall	DXF plan from a later year	AHD-1
34	1909	Channel Spots	Bearing Distance measurements from Nobbys Head on scale map	unknown
35	1909	High Water	Digitised from scan of port map	AHD-1
36	1913	Low Water	Digitised from scan of port map	AHD-1
37	1913	High Water	Digitised from scan of port map	AHD-1
38	1913	Contours	Digitised from scan of port map	unknown
39	1913	North Breakwall	DXF plan from a later year	AHD-1
40	1913	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	unknown
41	1921	Low Water	Digitised from scan of port map using Microstation	AHD-1
42	1921	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	LWST
43	1921	Wave Traps	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
44	1921	Wave Traps - Low Water Mark	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
45	1921	South Shore of Newcastle Harbour	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
46	1921	North Shore of Newcastle Harbour	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
47	1921	Contours	Digitised from scan of port map using Microstation	LWST
48	1921	Breakwall	DXF plan from a later year	AHD-1
49	1921	Wave Traps	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
50	1921	High Water	Digitised from scan of port map using Microstation	AHD-1
51	1926	Low Water	Digitised from scan of port map using Microstation	AHD-1

Table 3.1 – Source and Height Datum for Hydrosurvey Information (cont)

ID	Year	Name	Details	Height Datum
52	1926	Contours	Digitised from scan of port map using Microstation	unknown
53	1926	Breakwall	DXF plan from a later year	AHD-1
54	1926	Highwater	Digitised from scan of port map using Microstation	AHD-1
55	1950	Low Water	Digitised from scan of port map using Microstation	AHD-1
56	1950	Breakwall	DXF plan from a later year	AHD-1
57	1950	High Water	Digitised from scan of port map using Microstation	AHD-1
58	1950	Contours	Digitised from scan of port map using Microstation	ISLW
59	1950	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	ISLW
60	1950	North Shore	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
61	1957	Contours	Digitised from scan of port map using Microstation	ISLW
62	1957	Low Water	Digitised from scan of port map using Microstation	AHD-1
63	1957	High Water	Digitised from scan of port map using Microstation	AHD-1
64	1957	Wave Trap	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
65	1957	North Shore	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
66	1957	Breakwall	DXF plan from a later year	AHD-1
67	1957	Channel Spot Depths	Bearing Distance measurements from Nobbys Head on scale map	AHD
68	1988	Breakwall	DXF plan	AHD-1
69	1988	High Water	Digitised from scan of port map using Microstation	AHD-1
70	1988	Contours	Digitised from scan of port map using Microstation	ISLW
71	1988	Wave Trap	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
72	1988	Harbour North Shore	Bearing Distance measurements from Nobbys Head on scale map	AHD-1
73	1988	Channel Spot Depths - set 1	Bearing Distance measurements from Nobbys Head on scale map	AHD
74	1988	Channel Spot Depths - set 2	Bearing Distance measurements from point on scale map	AHD
75	1988	Channel Spot Depths - set 3	Bearing Distance measurements from point on scale map	AHD
76	1995	Channel Spot Depths	Obtained from Ports Authority	AHD
77	1995	Breakwall	DXF plan	AHD-1
78	1995	Offshore Spot Depths	Supplied as digital XYZ file	AHD
79	2000	Offshore Spot Depths	Supplied as digital XYZ file	AHD
80	2000	Breakwall	DXF plan	AHD-1
81	2000	Channel Spot Depths	Supplied as XYZ file	AHD

As shown on the cross-sections provided in **Appendix 2**, since 1816 the depth of water off Stockton Beach and the slope of the bed profile of the beach have increased significantly with the bed elevation at approximately 900 metres offshore, typically 4 to 7 metres lower in 2000 than in 1899.

The time series data sets provided in **Appendix 2** indicate these changes in water depth and bed profile extend to approximately 1.5 to 2 kilometres offshore. At this distance offshore, the bed elevation ranges from approximately –15 mAHD to –20 mAHD.

3.2 ENTRANCE TO NEWCASTLE HARBOUR

Historic hydrosurvey information is available for the entrance to Newcastle Harbour and where available has been included in **Appendix 1**. As discussed, additional detailed bathymetry for the entrance to the channel for 1983, 1988, 1995 and 2000 has been obtained from Newcastle Port Corporation in hard copy with 1995 and 2000 information being provided also in digital format.

Using recent bathymetry and historic hydrosurvey information, changes in the entrance channel geometry since 1816 have been tracked using the 3D bathymetric models that have been developed. It is noted that the 1816 data is not extensive or detailed and has been included as an indicative reference starting point only. Changes along the entrance channel over time are shown in cross-section on **Figures 3.3** to **3.8** with the location of each of the cross-sections shown on **Figure 3.1**.

As shown on **Figure 3.3**, substantial channel deepening occurred between 1957 and 1988 with the controlling channel depth being increased from approximately 8 metres to 17 metres. As shown on **Figures 3.4** to **3.8** over the same period, the cross-sectional area of the entrance to Newcastle Harbour has increased significantly as has the depth to the bed of the channel with the 1979 to 1983 capital dredging works in the channel extending approximately 1000 metres eastward of the Northern Breakwater.

Cross-sections CSC (**Figure 3.6**) and CSD (**Figure 3.7**) demonstrate that at and adjacent to the end of the Northern Breakwater an erosion scour approximately 4 to 5 metres deep exists. **Figures 3.7** and **3.8** also exhibit an infilling of the southern edge of the channel in the vicinity of Cross-Sections CSD and CSE suggesting an ongoing supply of sand to the entrance channel from the south (i.e. Nobbys).

3.3 CHANGES IN SAND VOLUMES

It is apparent from the cross-sectional information presented in **Sections 3.1** and **3.2**, that since 1816, the volume of sand off Stockton Beach has decreased dramatically. At the same time the depth and extent of the entrance channel to Newcastle Harbour has been deepened with capital dredging extending up to approximately 1 kilometre east of the eastern extent of the Northern Breakwater.

To help understand the extent and rate of change of sand volumes off Stockton Beach, the volume of sand above –20 mAHD was calculated for an area within which bathymetric data is available for each of the years for which a 3D model was developed. The area used to calculate changes in the volume of sand is shown on **Figure 3.9** (Area 1). Area 1 was chosen as it is the common area of coverage of survey data dating back to 1816. This area does not cover the full seaward extent of observed changes in bed profile, which as previously discussed extend approximately 1500 metres to 2000 metres off the coastline. The implications of this are discussed later.

As shown in **Appendix 1**, only limited hydrosurvey information for 1816 exists, however the available data does indicate a large sand shoal adjacent to Stockton Beach. Estimated sand quantities derived using the 1816 data are considered indicative only however are included due to the considerable difference in depicted bed elevations that exist between 1816 and 1866.

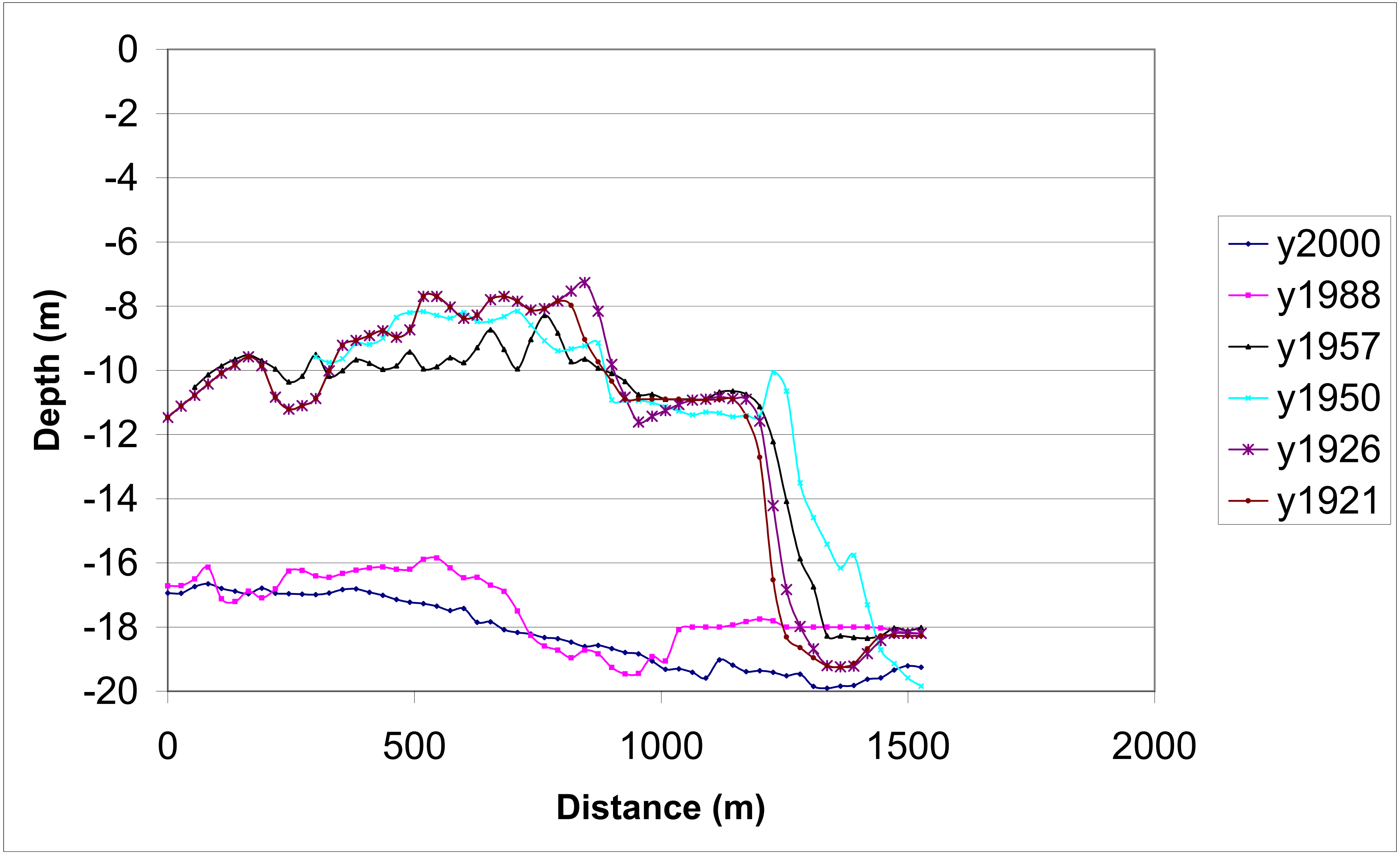


Figure 3.3
Channel Long Section

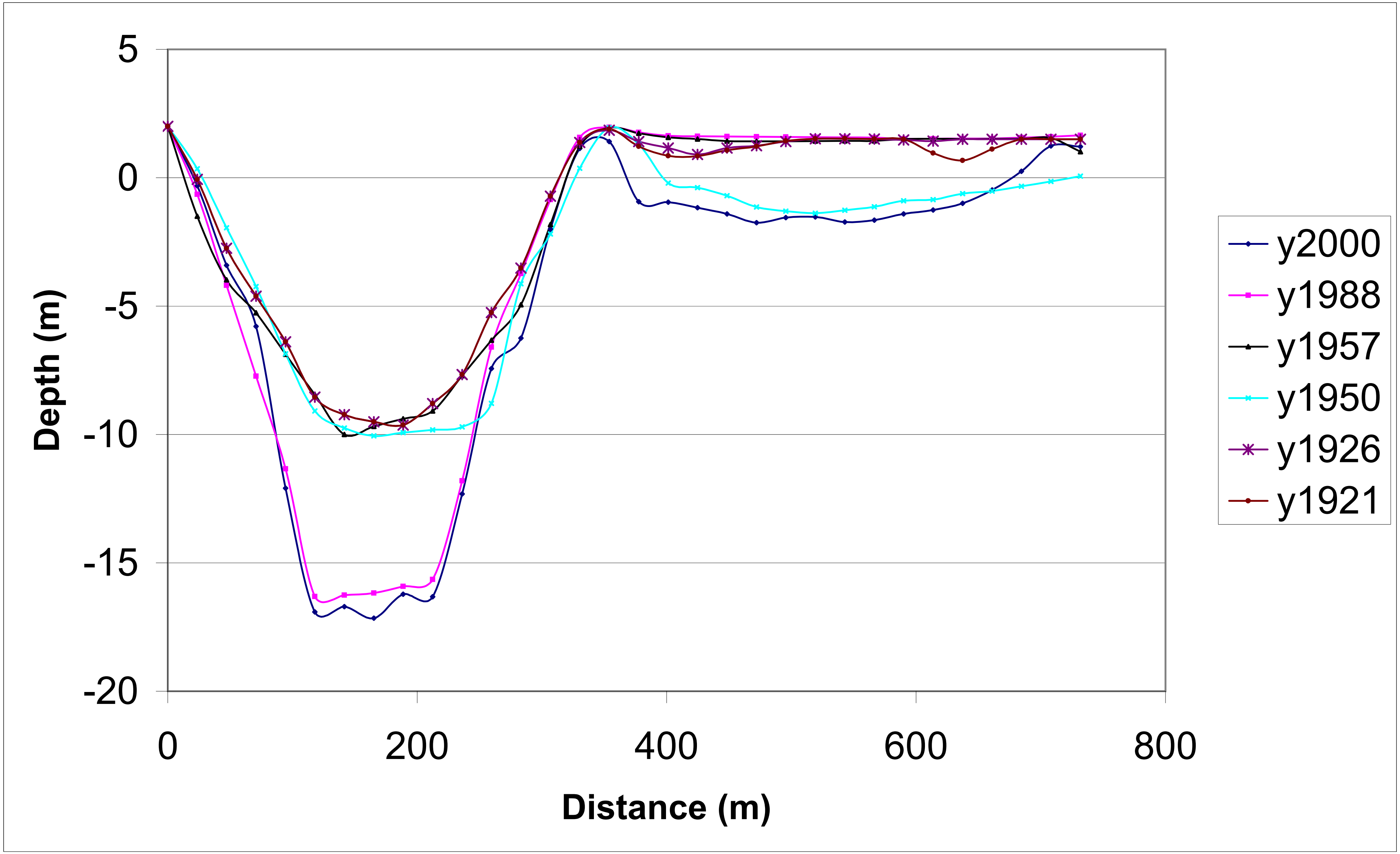


Figure 3.4
Cross Section A

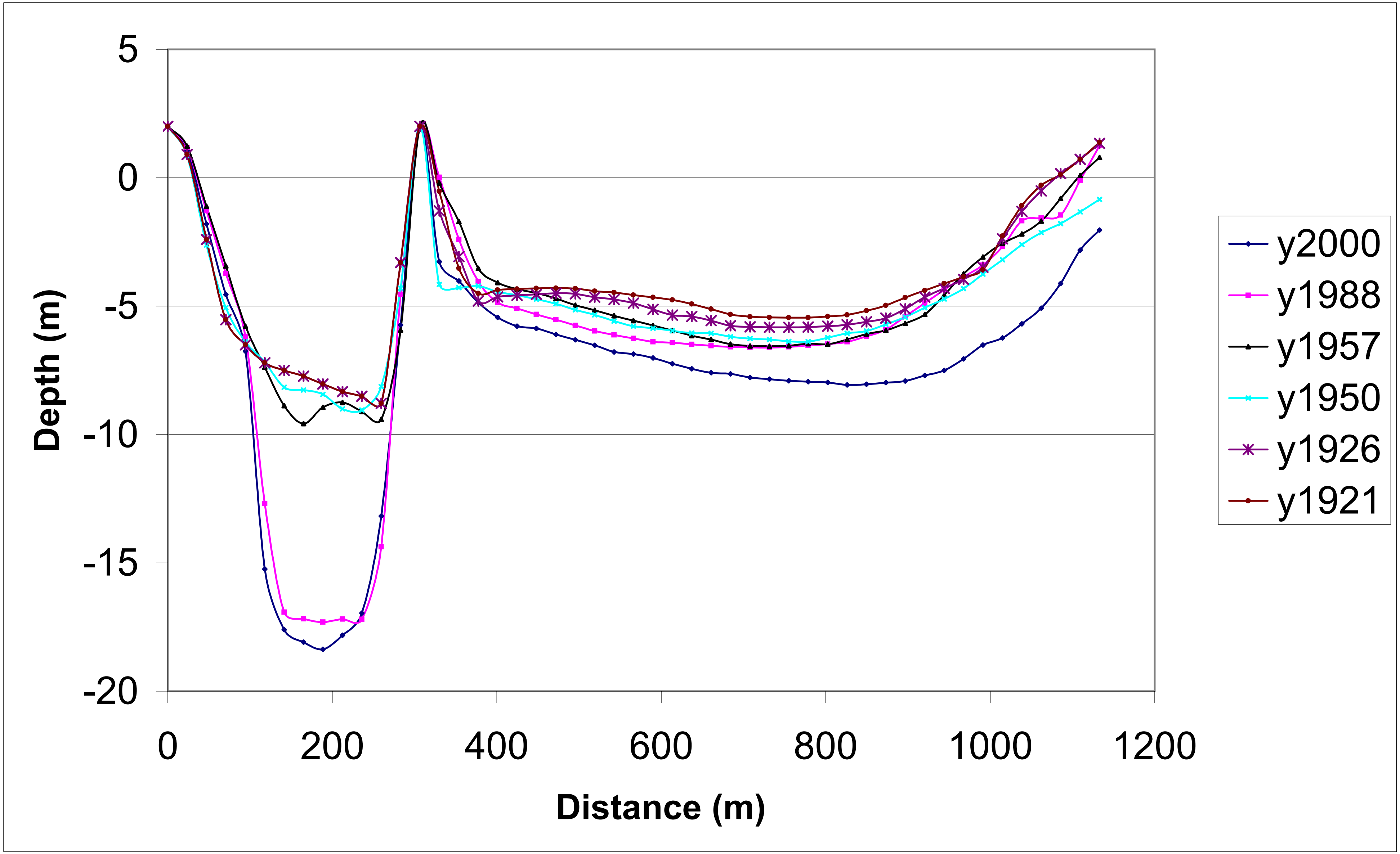


Figure 3.5
Cross Section B

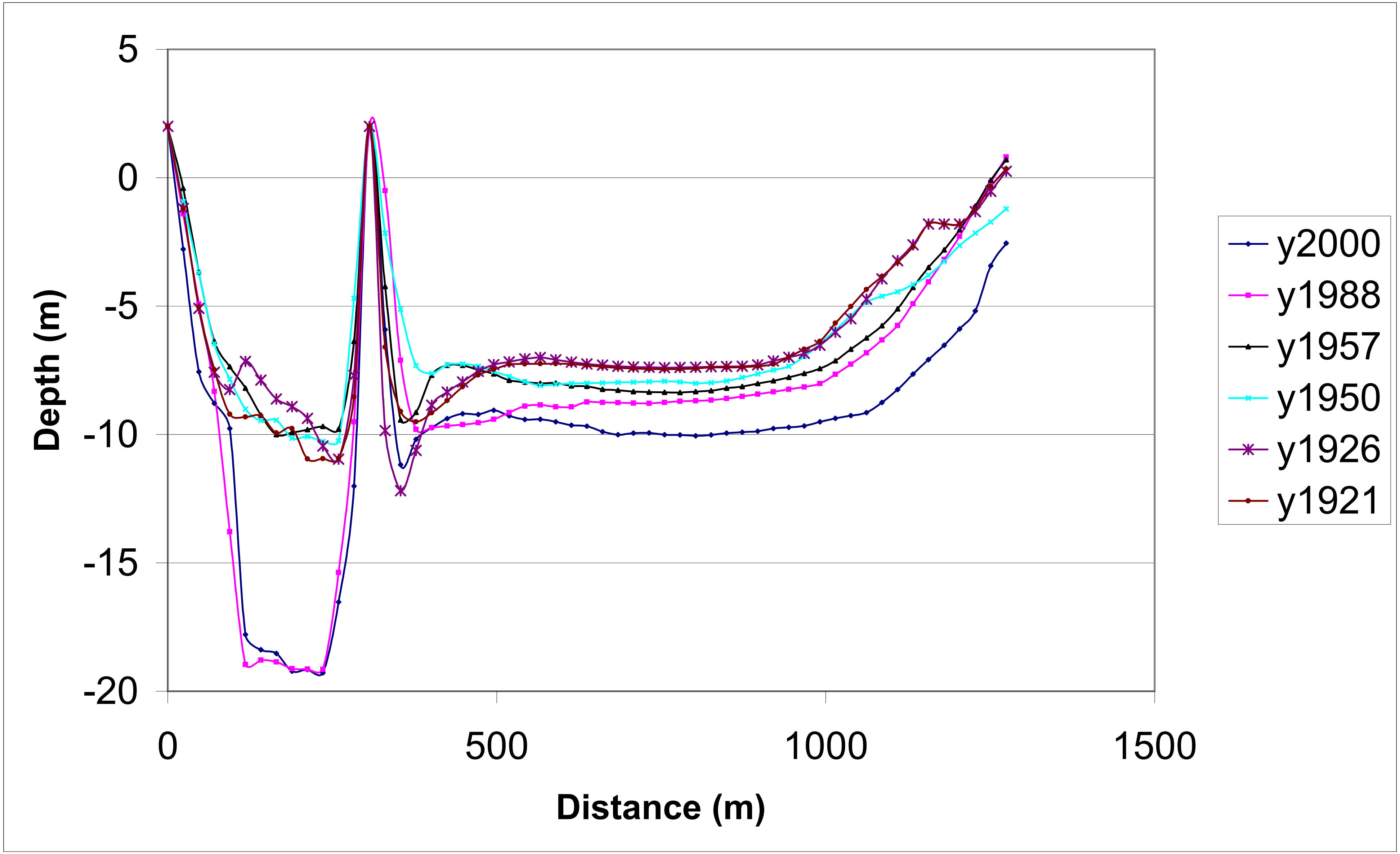


Figure 3.6
Cross Section C

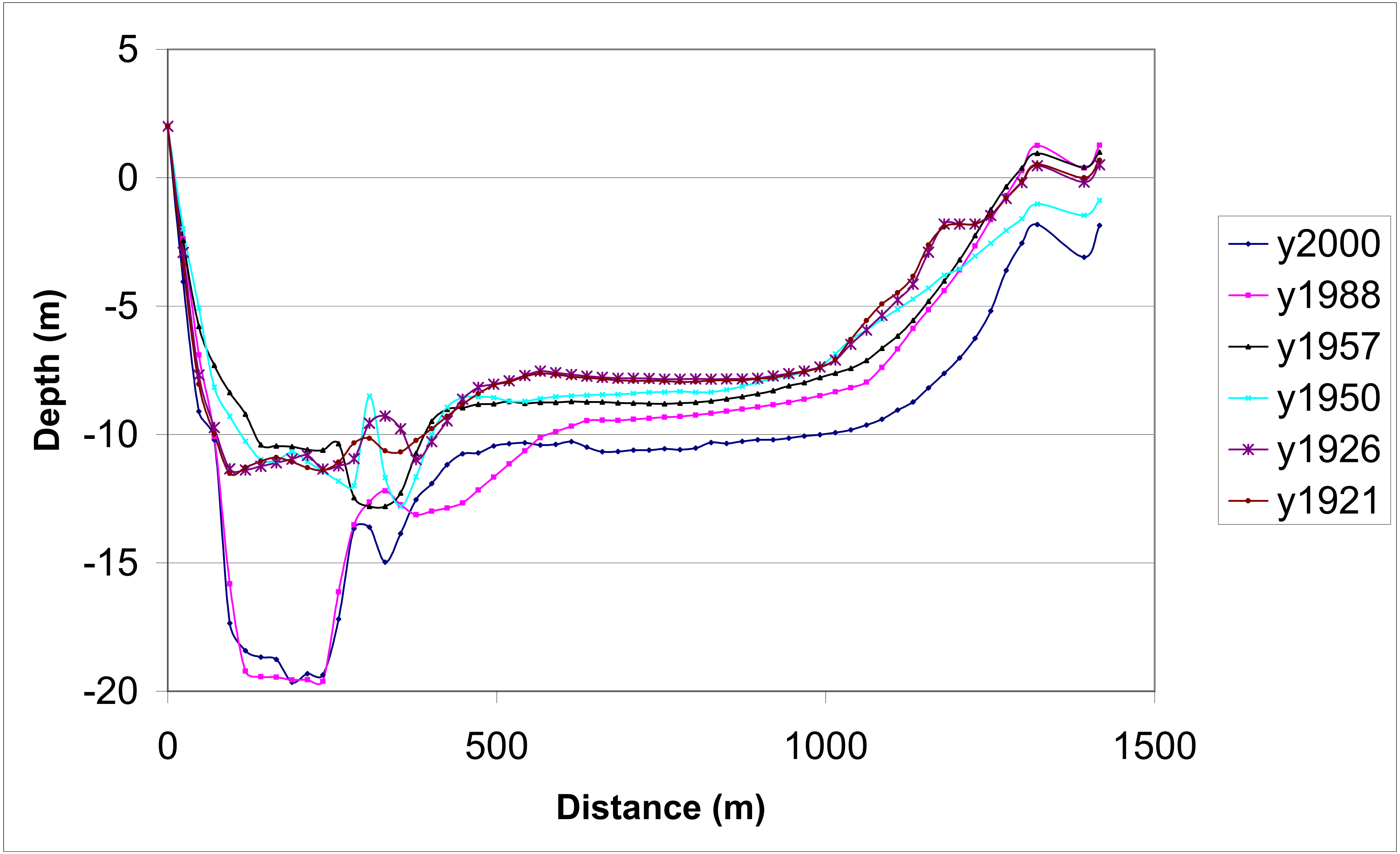


Figure 3.7
Cross Section D

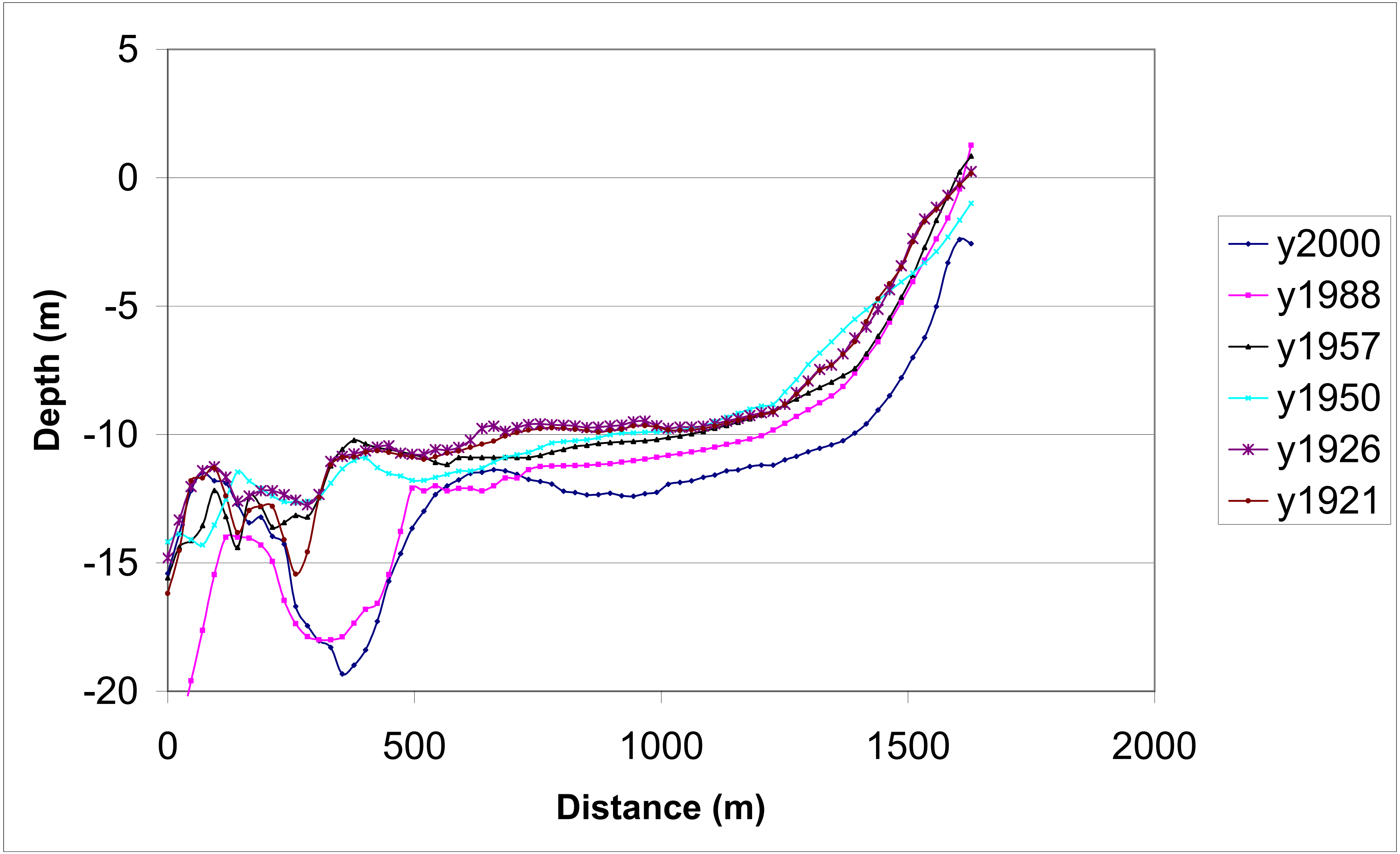
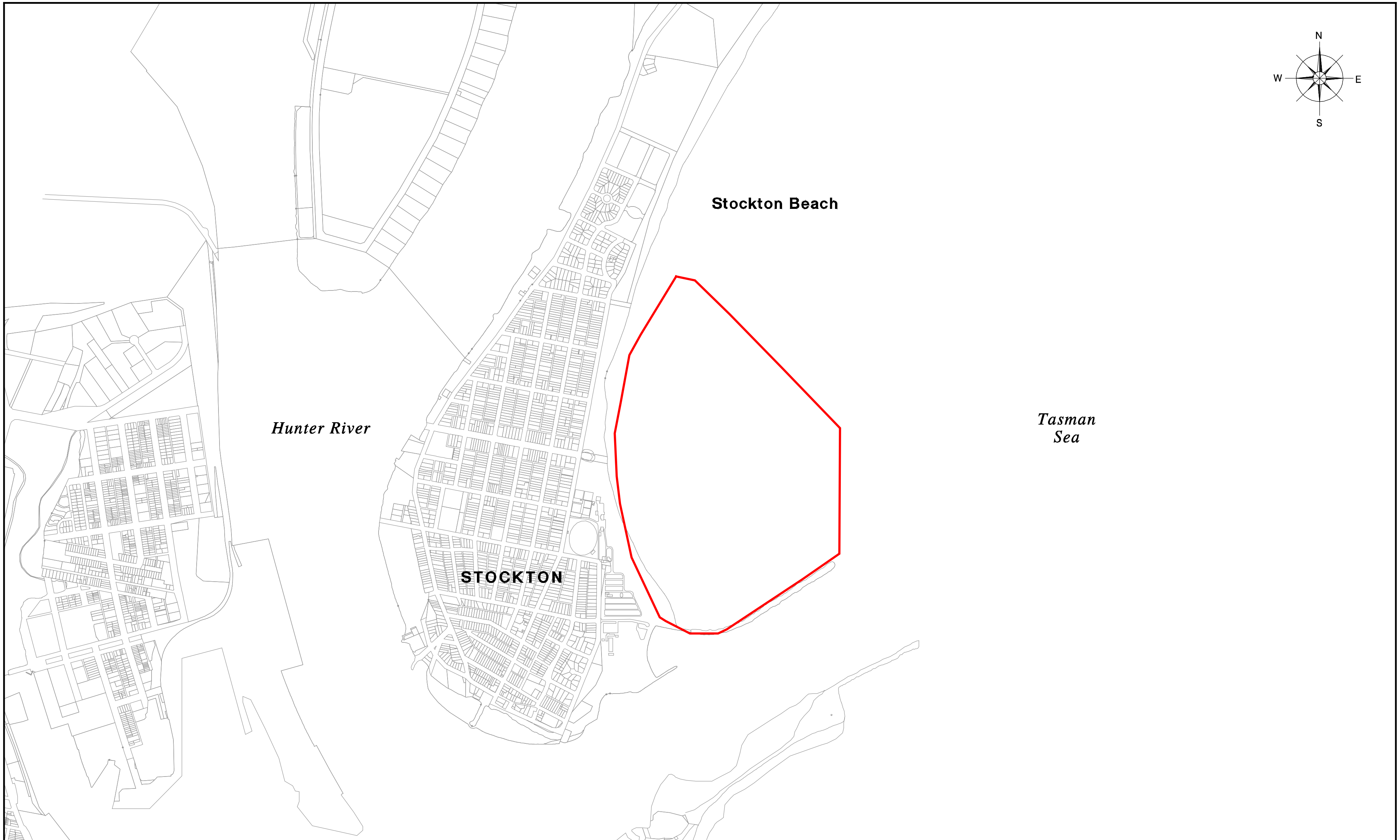


Figure 3.8
Cross Section E



Legend

Area 1

Umwelt (Australia) Pty Limited

0 0.25 0.5 1km

FIGURE 3.9

Sand Loss Analysis – Area 1

A4 Scale 1:22 500

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The calculated change in sand volume above –20 mAHD within Area 1 as shown on **Figure 3.9**, over each of the modelled time periods is listed in **Table 3.2**, as is the estimated rate of change in sand volume per year.

Table 3.2 – Estimated Changes in Sand Volume Within Area 1 Off Stockton Beach North of the Northern Breakwater (1816 to 2000)

Year	Indicated Change in Sand Volume (m^3) in Area 1	Indicated Cumulative Change in Sand Volume Since 1816 (Million m^3)	Indicated Cumulative Change in Sand Volume Since 1866 (Million m^3)	Rate of Change per Year (m^3)
1816	0	0	-	0
1816-1866	4489273	4.5	0	89785
1866-1899	654272	5.1	0.6	19826
1899-1909	258687	5.4	0.9	25869
1909-1913	-44993	5.4	0.9	-11248
1913-1921	-170898	5.2	0.7	-21362
1921-1926	54525	5.2	0.7	10905
1926-1950	693566	5.9	1.4	28899
1950-1957	-82196	5.9	1.4	-11742
1957-1988	314019	6.2	1.7	10130
1988-1995	1714037	7.9	3.4	244862
1995-2000	262827	8.1	3.6	52565
Average/Year (1816 to 2000)				**41500**
Average/Year (1866 to 2000)				**26667**
Average/Year (1921 to 2000)				**32200**

From **Table 3.2** it can be seen that since 1816 there is an indicated net loss of approximately 8 million m^3 of sand from Area 1, as shown on **Figure 3.9**. Average sand loss rate for the period 1816 to 2000 is estimated to be approximately 41,500 m^3/year. As previously discussed, limited survey data exists for 1816 with survey data from 1866 being more comprehensive and accurate. The average annual sand loss rate between 1866 and 2000 is approximately 26700 m^3/year which is consistent with Boleyn & Campbell (1966) and WBM (1998) longshore drift estimates of approximately 23,000 m^3/year to 30,000 m^3/year as discussed **Section 2.8**.

As shown in **Table 3.2**, the greatest indicated rate of change (loss) in sand volume within Area 1 was between 1816 and 1866 following construction of the Southern Breakwater which commenced in 1812. Over this 50 year period, available hydrosurvey information indicates that in the order of 4.5 million m^3 of sand was lost from Area 1. This equates to an average loss of approximately 90,000 m^3/year of sand.

Analysis indicates that between 1866 and 1899 prior to commencement of construction of the Northern Breakwater a further 650,000 m^3 of sand was lost from Area 1 (see **Figure 3.9**).

Between 1899 and 1909 during the period the Northern Breakwater was being constructed, a further 260,000 m^3 of sand was lost from the Stockton Beach system at an average rate of approximately 26,000 m^3/year. From 1909 to 1926, analysis indicates that there was no substantial change in the volume of sand off Stockton Beach with a period of accretion being observed between 1909 and 1921. Between 1926 and 1950 approximately 700,000 m^3 of sand was lost from Area 1 (see **Figure 3.9**) with sand loss occurring at an average rate of approximately 29,000 m^3/year.

Patterson Britton (1989) report that between 1859 and 1988 on average approximately 1 million m^3/year of *in-situ* material was dredged from Newcastle Harbour and by 1989 approximately 133 million m^3 of material had been dredged from Newcastle Harbour.

Records also indicate (Newcastle Port Corporation Tide Chart & Information Handbook 2001), that the entrance to Newcastle Harbour was deepened from 8 metres to 11.0 metres between 1962 to 1967. At about this time, some of this sand material was placed at the southern end of Stockton Beach. Between 1977 and 1983 the harbour was further deepened to 15.2 metres. Between 1950 and 1988 an additional approximately 720,000 m^3 of sand was lost from Area 1 with the average rate of loss over the period being approximately 19,000 m^3/year.

From 1988 to 2000, analysis indicates that approximately 2,000,000 m^3 of sand has been lost from Area 1 (see **Figure 3.9**) with the average annual rate of loss increasing to approximately 150,000 m^3/year over this period.

These observed cumulative changes in sand volume over time within Area 1 (see **Figure 3.9**) are shown graphically on **Figure 3.10**. As can be seen from **Figure 3.10**, since 1988 the rate of sand loss has increased significantly and appears to be still a long way from establishing equilibrium. Based on the observed trends, it appears that sand loss from the Stockton Beach system will continue for a number of years yet, however as shown on **Figure 3.10**, there is an observed minor decrease in the rate of sand loss from Stockton Beach between 1995 and 2000.

As discussed above, Area 1 (see **Figure 3.9**) only covers part of the area over which changes in bed level have been observed. From approximately 1921 on, with the exception of 1995, the available bathymetric data extends approximately 800 metres seaward of Area 1 (see **Figure 3.9**).

Using this extended data set, the total change in sand volumes since 1921 both within Area 2 which is the extended area of Stockton Beach and the entrance channel (Area 3) have been estimated and are provided in **Table 3.3**. The area used to determine these changes in sand volume extends to a distance of approximately 1700 metres off-shore as shown on **Figures 3.11** (Area 2-Stockton Beach) and **Figure 3.12** (Area 3-Entrance to Newcastle Harbour).

Table 3.3 - Reduction in Sand Volume in Areas 2 and 3

Year	Estimated Reduction in Sand Volume (m^3) (1921 to 2000)					
	Stockton Beach North of Breakwater (Area 2)		Stockton Beach and Entrance Channel North		Entrance Channel (Area 3)	
	Cumulative (m^3)	Average Rate (m^3/year)	Cumulative (m^3)	Average Rate (m^3/year)	Cumulative (m^3)	Average Rate (m^3/year)
1921	0	0	0	0	0	0
1926	-171740	-34348	-221016	-44203	-49276	-9855
1950	409377	24213	106302	13638	-303075	-10575
1957	514373	14999	343260	33851	-171113	18852
1988	1553529	33521	4780757	143145	3227228	109624
2000	6030899	373114	9836955	421350	3806056	48236
Ave/Year	**-**	**67010**	**-**	**109300**		**42290**

NB: 1995 hydrosurvey does not cover all of Area 2 and has not been included in estimates

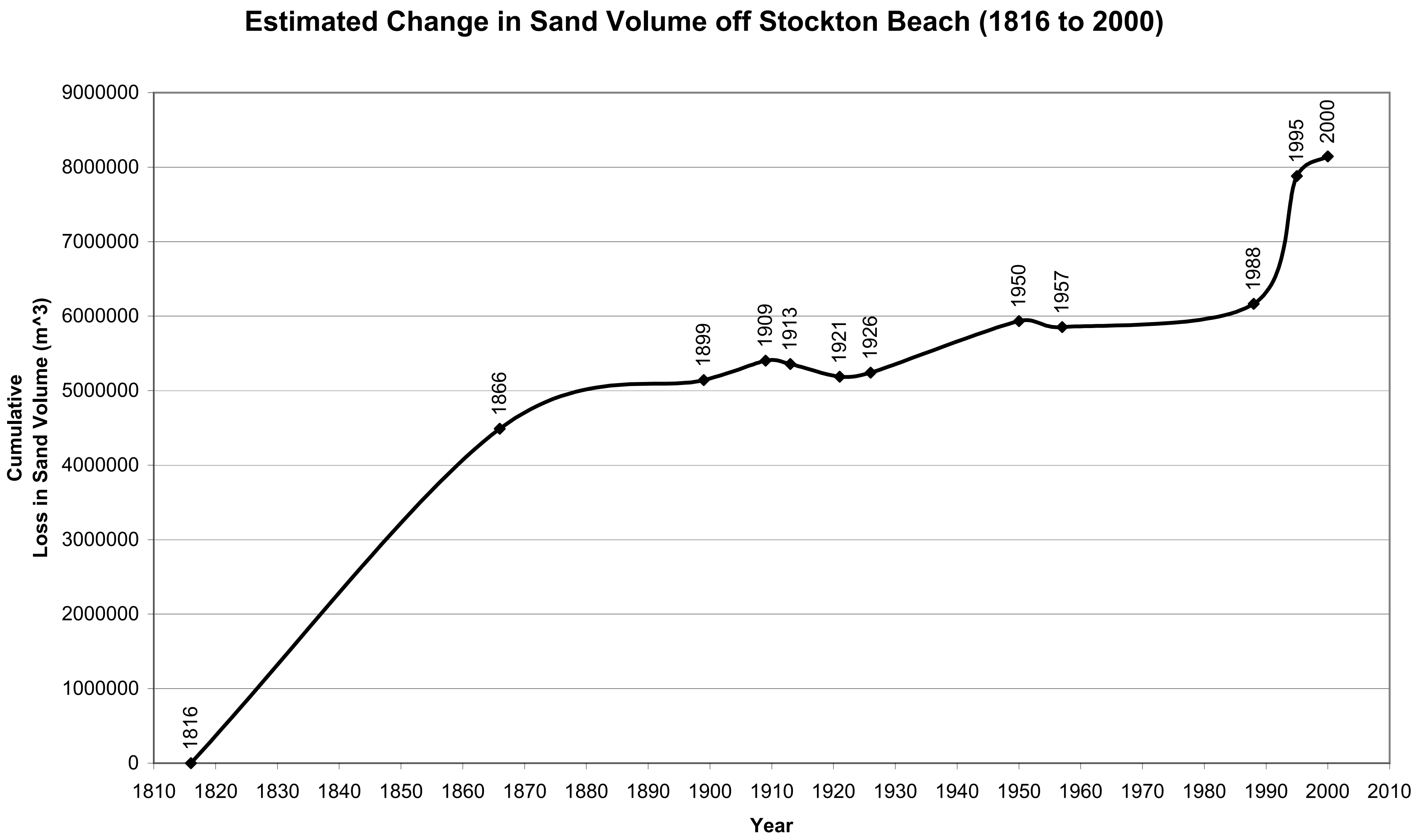
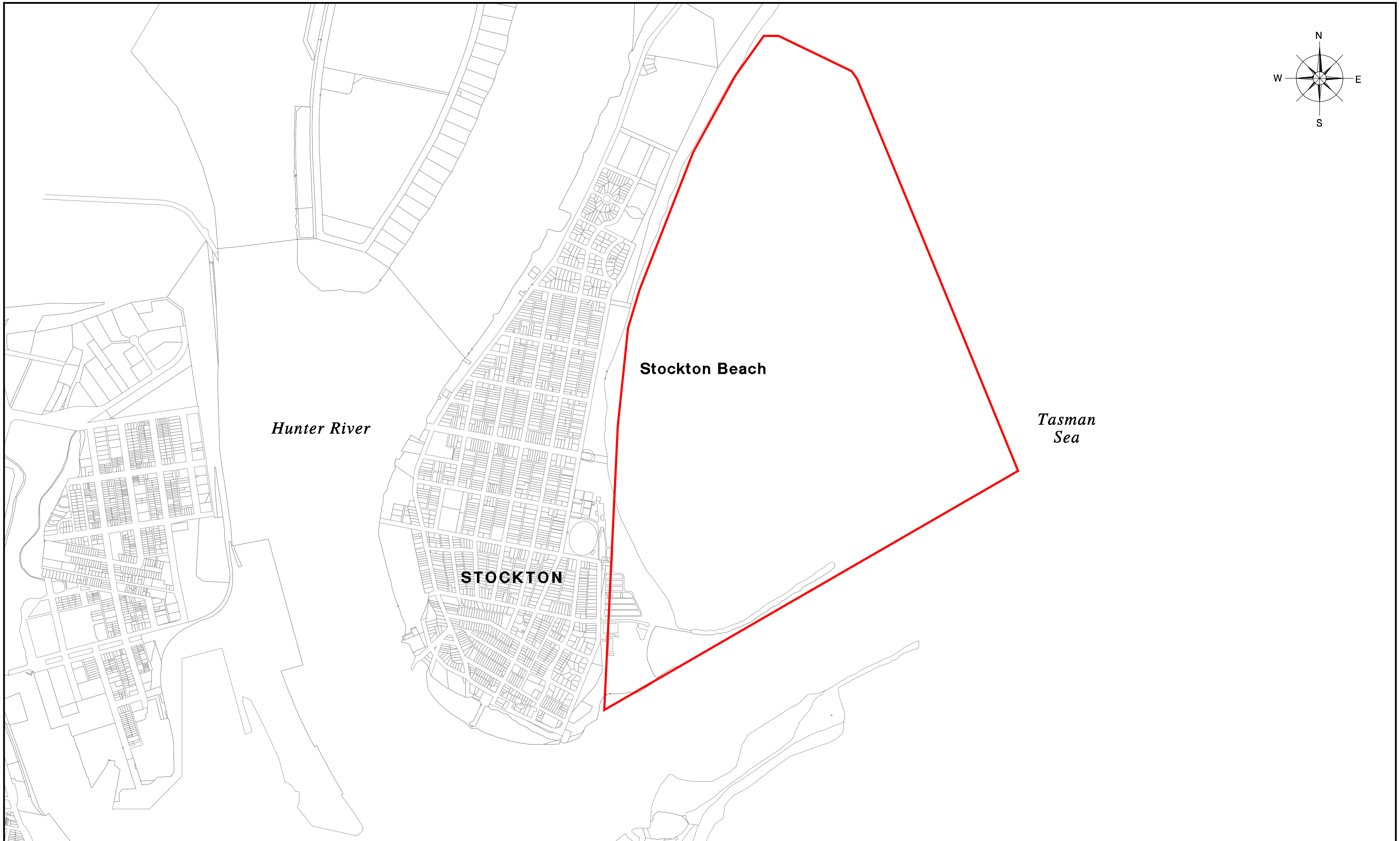


Figure 3.10
Sand Volume Changes Area 1 (1816-2000)



Legend
Area 2

0 0.25 0.5 1km

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FIGURE 3.11
Sand Loss Analysis – Area 2

A4 Scale 1:22 500

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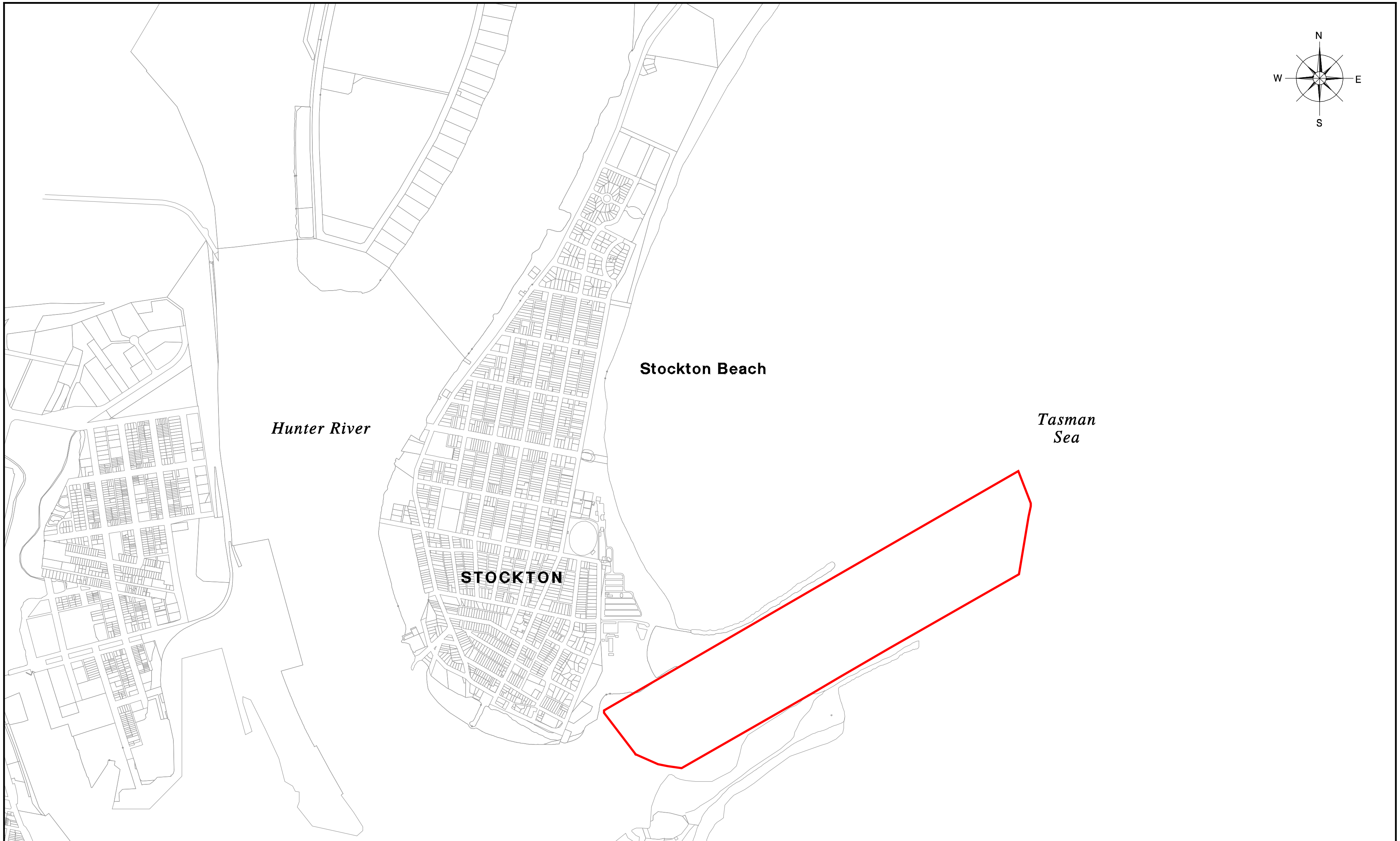

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Area 3

0 0.25 0.5 1km

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FIGURE 3.12

Sand Loss Analysis – Area 3

A4 Scale 1:22 500

Ref No.:R04_V1/1411_125.dgn

As can be seen from **Table 3.3**, the average rate of sand loss from Area 2 (see **Figure 3.11**) between 1921 and 2000 of 67,010 m^3/year is approximately double that from Area 1 (see **Figure 3.9** and **Table 3.2**). As Area 2 extends out to a depth of –20m AHD which is deeper than the area affected by littoral movement of sand, the above changes in sand volume indicates that the sand lost from Stockton Beach has either moved north of the study area by longshore drift processes and/or has moved at least 1700 metres offshore into water depths of at least 20 metres and is therefore no longer available by natural littoral processes to replenish Stockton Beach.

As detailed in **Table 3.3**, between 1988 and 2000 nearly 4.5 million m^3 of sand was lost from the Area 2 off Stockton Beach with an additional 1 million m^3 lost between 1957 and 1988 from the same area. Between 1988 and 2000 the rate of sand loss from Area 2 was approximately 370,000 m^3/year or approximately five times greater than the average rate between 1921 and 2000.

As shown on **Figure 3.12**, Area 3 includes the entrance channel to approximately the western end of Horseshoe Beach and an area the width of the channel extending approximately 1 kilometre east of the tip of the Northern Breakwater. Information in **Table 3.3** for the period 1921 to 1957 is consistent with earlier analysis of available hydrosurvey information undertaken by Manley (1963) (see **Section 2.2**) which indicated significant infilling of the channel and shoal development at the entrance to the channel. From **Table 3.3**, between 1921 and 1950 approximately 10,000 m^3 of sand material accumulated within Area 3 per year. From reports by Manley (1963), the infilling of this material and the corresponding development of a shoal near the entrance to the channel was considered a significant navigational problem as addressed in **Section 2.0**

As discussed in **Section 1.0** and **Section 2.0**, in response to this shoal development and the need for greater entrance depth to allow passage of larger vessels, significant capital dredging works were undertaken between 1962 and 1983. Theses works included deepening the main part of the channel from 8.0 metres to 15.2 metres, the removal of a sand shoal at the end of the Northern Breakwater and removal of a significant volume of rock from within the entrance channel. These works are reflected in **Table 3.3**, which indicates that between 1957 and 1988 a net volume of some 3.4 million m^3 of material was removed from Area 3.

Information in **Table 3.3** indicates that between 1988 and 2000 that the net volume of sand within Area 3 reduced by a further approximately 580,000 m^3 or was lost at a rate of approximately 48,000 m^3/year over this period. Newcastle Port Corporation records and discussions with Newcastle Port Corporation personnel indicate that there has been no capital or maintenance dredging undertaken within Area 3 since the completion of the 1983 capital dredging program.

As discussed in **Section 2.8**, DLWC's 2000 hydrosurvey information indicates that there is continued sand supply from south of the entrance (Nobbys) into the channel within Area 3 with additional sand being transported into Area 3 from the shoal that appears to be developing approximately 350 metres off the tip of the Northern Breakwater. At the same time there doesn't appear to be a build up of sand within the remainder of the entrance channel, indicating that for the sand volume in Area 3 to be 580,000 m^3 less in 2000 than in 1988, that in excess of 580,000 m^3 of sand must have been transported out of Area 3 either into deep water to the east or to the south or north. As the principal direction of longshore movement is to the north as shown by earlier studies by Boleyn and Campbell (1966) and by the build up of sand along the southern edge of the channel, it is considered that the loss of sand is likely to have been offshore from Area 3.

From the above discussion, recorded significant changes in nearshore sand volumes off Stockton Beach, appear to correlate with entrance deepening, although this cannot alone be considered proof of a relationship. Further investigation will be required to examine if there is a relationship between entrance channel deepening and sand loss off Stockton Beach.

3.4 RATE OF CHANGE OF SAND VOLUME ALONG STOCKTON BEACH

As discussed in **Section 1.0** during 1989 a seawall was constructed in the central section of Stockton Beach to protect Mitchell Street and adjacent properties. The seawall is located adjacent to Cross-Sections 8 to 13 as shown on **Figure 3.1**.

WBM (1998) states that analysis of nearshore beach profile data indicates that the rate of erosion north of the seawall is greater than to the south of the seawall. Concern has also been raised that the seawall itself may be increasing the rate of erosion of sand from the Stockton Beach system.

To better understand erosion characteristics along Stockton Beach, a comparison in changes in rate of erosion per unit area along each of the cross-sections shown on **Figure 3.1** was undertaken for the period 1926 to 2000. This was done to firstly explore changes in the rate of erosion over time and secondly to determine if greater rates of erosion were being experienced adjacent to the seawall compared to other sections of the beach. To provide a better understanding of where the erosion was occurring, the comparison was undertaken for sections of the beach profile extending 100 metres, 200 metres 500 metres and 1000 metres off Stockton Beach. The results of this analysis are shown graphically on **Figures 3.13**, **3.14**, **3.15** and **3.16** respectively.

As can be seen from **Figures 3.13** to **3.16**, during 1926 to 1950, the rate of erosion per unit area decreases from south to north for each of the beach profiles sections with an overall net loss from the Stockton Beach system. In the 1950 to 1957 period there is net accretion near the shore with an overall trend for the 1000 wide metre strip adjacent to the beach of accretion in the south and erosion in the area north of where the seawall was subsequently built. In the 1957 to 1988 period the rate of erosion along Stockton Beach was reasonably uniform with a slight trend of an increasing rate of erosion from south to north.

The 1988 to 1995 period was by far the greatest period of erosion with average erosion rates of up to 300 mm/m^2 per year being recorded over a 1 kilometre wide strip off Stockton Beach. Over this period there was marked increase in the rate of erosion from south to north with the rate of erosion in the vicinity of the seawall being consistent with or less than erosion rates of the adjacent areas for all sections of beach profile examined.

For the period 1995 to 2000, **Figure 3.13** to **3.16** indicate a substantial drop in the rate of erosion from the 1988 to 1995 period with the rate of erosion decreasing from the south to the north.

Comparison of 1926 data with that of 2000 shows that the rate of erosion along the beach over this period is reasonably consistent at approximately 30 to 40 mm/m^2 per year with no obvious increase in rate north to south, south to north or in the vicinity of the seawall. This erosion rate equates to a net average loss over the 1 kilometre wide strip off Stockton Beach between 1926 and 2000 of approximately 2.3 to 3 metres/m^2.

This analysis supports previous views that areas of erosion fluctuate along the beach with these fluctuations typically having a north-south or south-north trend. The analysis also demonstrates that since construction of the seawall in 1989, areas up to 1000 metres offshore from the seawall are not experiencing greater rates of erosion than other sections of Stockton Beach. On this basis it is considered that the seawall is not contributing to the significant erosion rates that have been recorded off Stockton Beach.

Figure 3.13
Average Erosion Rate for 100m Wide Strip off Stockton Beach

Figure 3.14
Average Erosion Rate for 200m Wide Strip of Stockton Beach

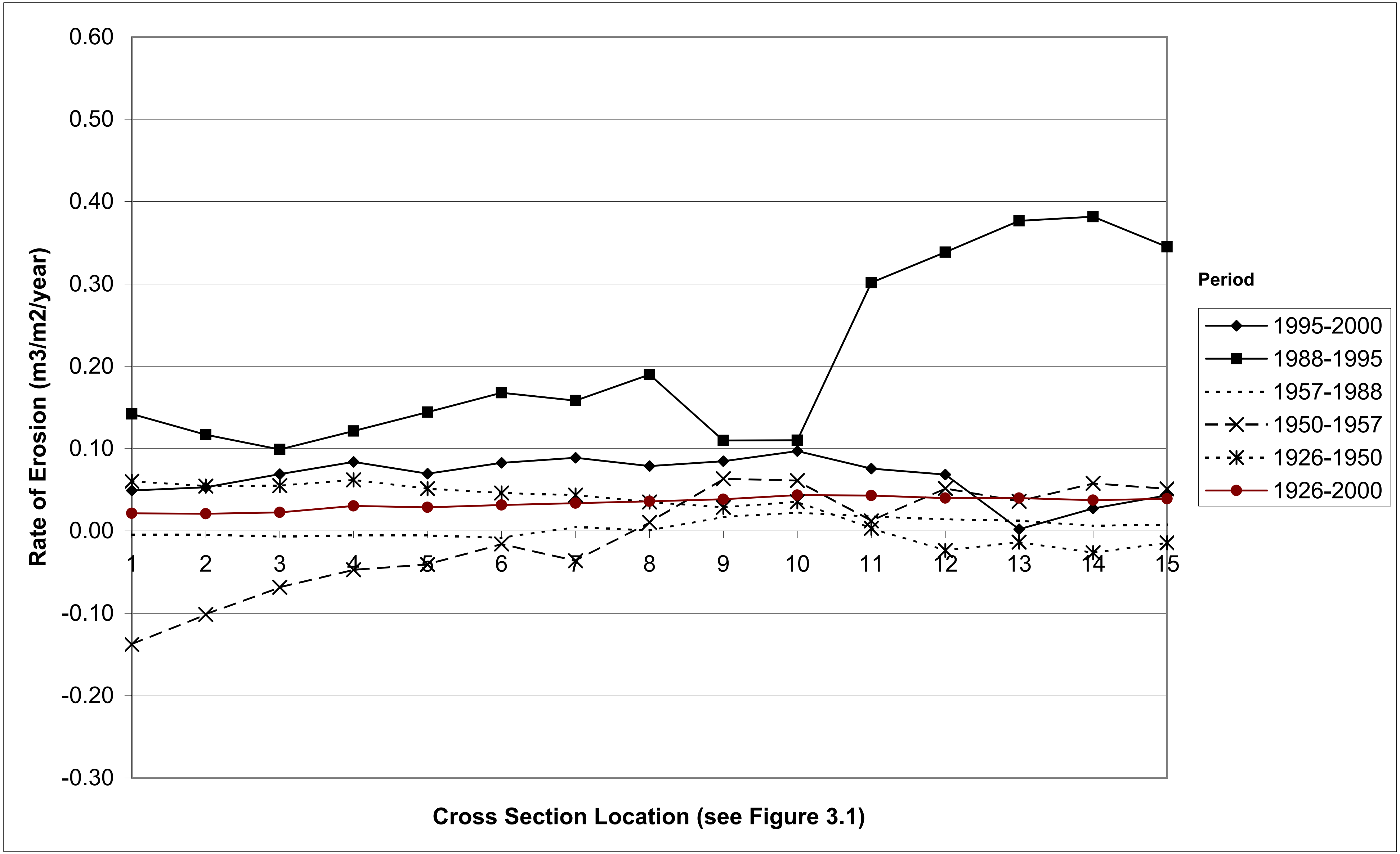

Figure 3.15
Average Erosion Rate for 500m Wide Strip off Stockton Beach

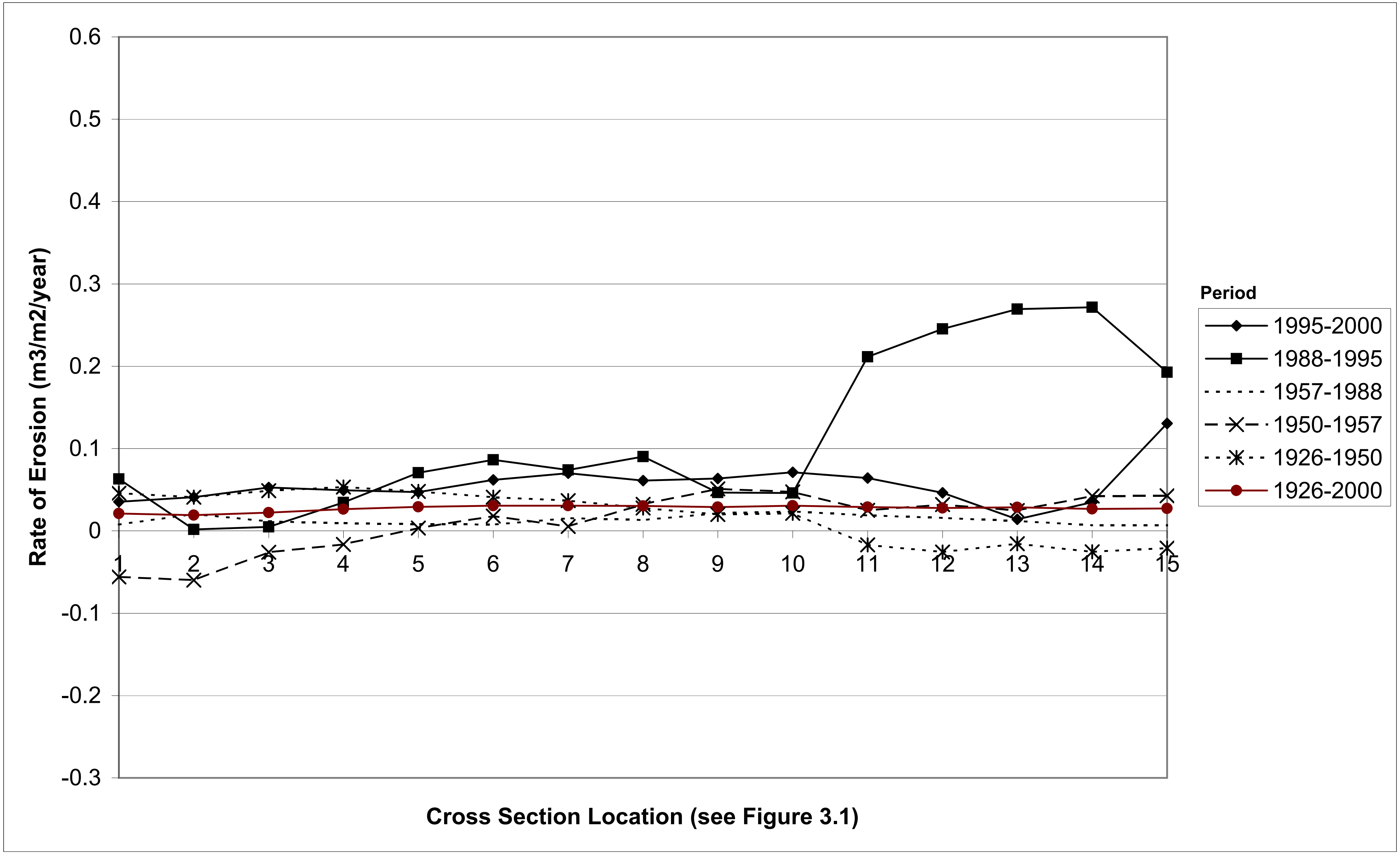

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Figure 3.16
Average Erosion Rate for 1000m Wide Strip off Stockton Beach

3.5 OVERVIEW OF CHANGES IN SAND VOLUME

Analysis of available hydrosurvey and bathymetric data dating back to 1816 demonstrates that the bed level of Stockton Beach approximately 900 metres offshore has lowered by 4 to 7 metres. In addition, available hydrosurvey information indicates that since 1816, even taking into account the limited extent of the 1816 survey information, in excess of 10 million m^3 of sand has been lost from Area 2 off Stockton Beach.

More accurate and extensive hydrosurvey exists since the early 1900s. Since 1921 over 6 million m^3 of sand has been lost from Area 2 off Stockton Beach. Approximately 4.5 million m^3 of this material has been lost since 1988 with the rate of sand loss between 1988 and 2000 being approximately 5 times that of the average rate of sand loss between 1921 and 2000.

Over the same period of time significant changes to the entrance channel and Newcastle Harbour have occurred through the construction of an extensive breakwater system and substantial deepening of the Harbour and entrance.

The recorded losses of sand are substantial and far greater than has been observed along other sections of NSW and far greater than could be considered to be consistent with natural, cyclic erosional processes. It is considered that the lost sand is likely to have either been moved into deep water to the east of Area 3 or to the north of Area 2 by longshore processes however at this time the actual pathway of sand movement is not known, only the fact that it has gone is known.

Analysis of erosion rates along the nearshore zone off Stockton Beach indicates that even though there are recorded periods where the rate of erosion increases from south to north and north to south, that overall the rate of erosion along Stockton Beach nearshore zone between 1926 and 2000 is reasonably consistent from south to north with a significant net loss from the system over this time.

4.0 CAUSES OF GEOMORPHOLOGICAL CHANGE

4.1 OVERVIEW

As discussed in **Section 2.0**, significant changes to the nearshore zone of Stockton Beach have been recorded since the 1800s. However, in respect of the current coastal zone management program being undertaken for the Newcastle City Council foreshore, there has yet to be presented a coastal process understanding delineating the mechanisms of sediment transport at Stockton Beach that can be demonstrated to be the cause of these changes.

The coastal processes in Newcastle Bight have been studied as documented in Public Works Department (1977). However, that study was concerned with broad scale processes and did not present any detail of the processes relevant to the beach changes at Stockton or of the processes related to the entrance of the Hunter River. Further, significant changes to the beach at Stockton have occurred since that study was completed.

The development of a clearer understanding of the coastal processes relevant to foreshore change at Stockton Beach would require detailed hydrodynamic and nearshore wave transformation modelling. However, much can be gleaned from a review of the hydrographic survey data, particularly when related to changes documented elsewhere from similar breakwater construction.

It is postulated here that the major cause of change to the nearshore and foreshore zone of Stockton Beach can be related to changes made to the configuration of the Hunter River estuary entrance, (i.e. breakwater construction and the deepening of the entrance channel). Other factors that may have a significant influence also could include differential longshore transport rates as has been identified by WBM in 1999 and major flooding of the Hunter River (Public Works Department, 1977) however work by Patterson Britten (1989, 1992) indicates that since the substantial and extensive deepening of the harbour and its entrance, negligible amounts of sand sized sediment are transported to the harbour entrance as a result of flooding in the Hunter River. This was not always the case as identified in the historic review by Coltheart referred to in **Section 2.1**.

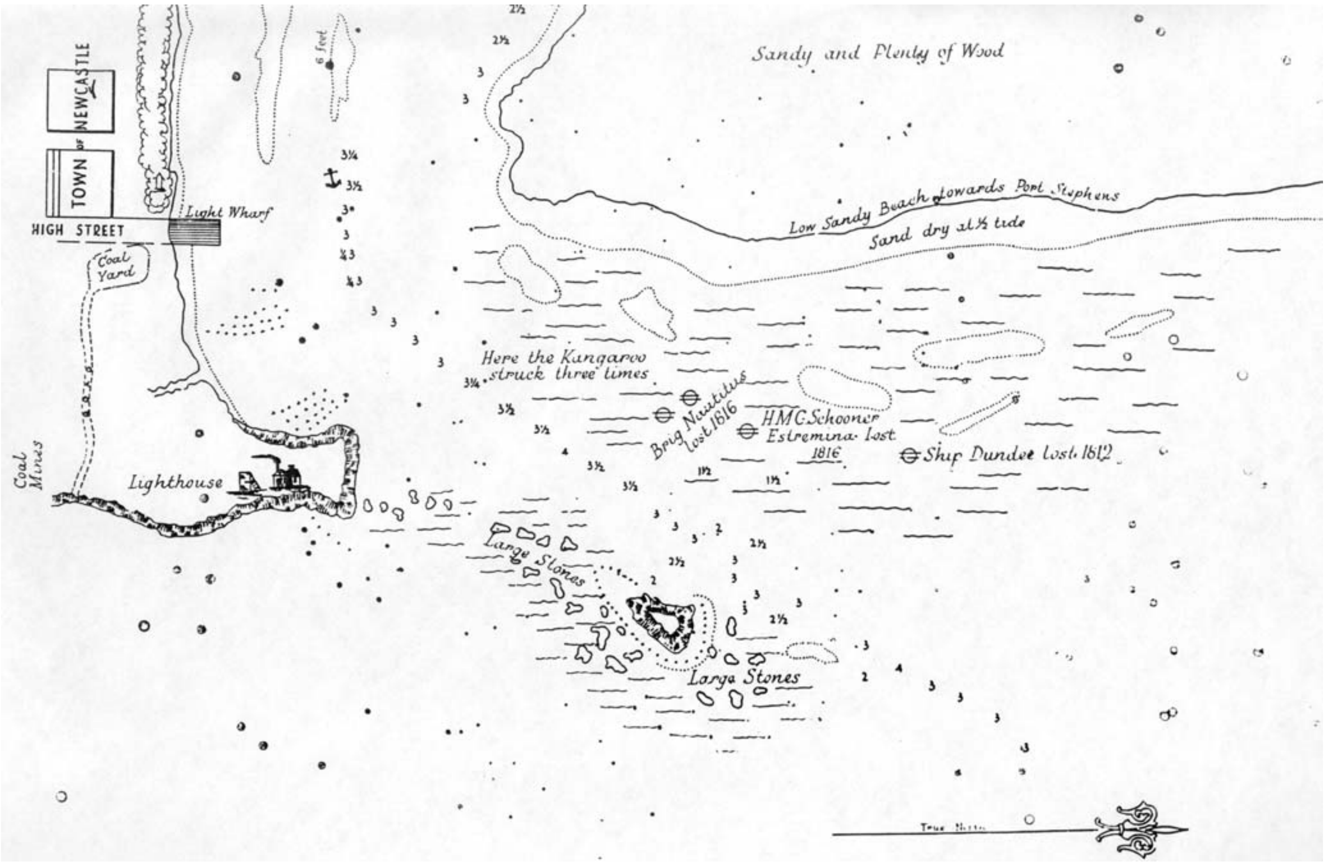
4.2 SEAWALL CONSTRUCTION

As discussed in **Section 3.4**, analysis of erosion rates along Stockton Beach and for a distance 1 kilometre offshore indicate that that construction of the seawall in 1989 has not adversely impacted on erosion rates along Stockton Beach.

4.3 BREAKWATER CONSTRUCTION

The hydrographic survey plans of the entrance to Newcastle Harbour, dating back to 1816 (see **Appendix 1**), indicate the profound effect that the construction of breakwaters at the entrance to the Hunter River, has had on the nearshore bathymetry and sediment transport processes at Stockton Beach. In the following the salient points gleaned from selected hydrographic survey plans are summarised and synthesised with our understanding of corresponding changes to inlet hydrodynamics developed from other projects.

Figure 4.1 presents parts of two hydrographic surveys of the entrance to the Hunter River undertaken in 1816 and 1851. The former presents depths in fathoms (6 feet = 1 fathom = 1.8 metres approximately), the latter presents depths in feet (0.3 metres approximately). It is important to note here that some of the older hydrographic surveys, which were prepared for purposes of safe navigation, did not present the actual depth data recorded (the fair sheets)



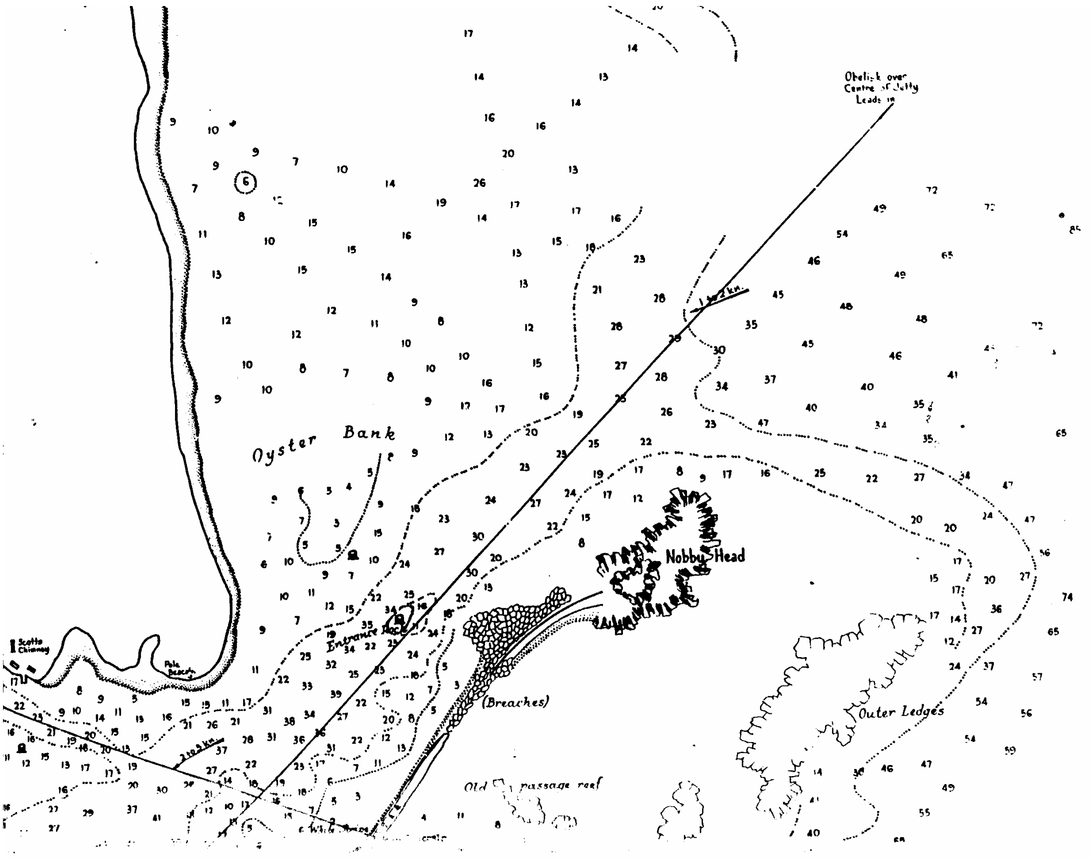


Figure 4.1: 1816 (top) and 1851 (bottom) Hydrographic Survey Plans of the Entrance to Newcastle Harbour

but, rather, they presented the *clearance depths*, being the shallowest reading chosen to represent the data over a selected area. This means that the depths shown on a hydrographic chart may be shallower than the actual depth at a particular location.

The 1816 survey portrays the entrance prior to any entrance training works having been constructed. Of particular relevance to note is that the ruling depth on the bar was 3 fathoms (18 feet or 5.5 metres). Further, however, the survey depicted a shoaled area offshore of Stockton, showing the wrecks of four ships and the note that the survey brig *Kangaroo* struck the bottom three times. The banks on the northern side of the channel, opposite Nobbys, were chartered to 1½ fathoms (9 feet or 3 metres approximately). However, the plan indicated that the tops of the banks dried at ½ tide.

The 1851 survey and plan portrays the construction of the Southern Breakwater to Nobbys Head and provides far greater detail of the depths over the entrance region. It shows that the ruling depth over the entrance bar was 23 feet (7 metres) (i.e. had increased in depth by approximately 2 metres since 1816). It shows also a deeper marginal flood tide channel running parallel to the beach inshore of the *Oyster Bank* off Stockton. It shows the tops of the *Oyster Bank* reaching 3 feet (1 metre).

Figure 4.2 presents part of the hydrographic survey and plan of the entrance to Newcastle Harbour dated January 7, 1899. On this plan, the Southern Breakwater is shown extending well past Nobbys. The survey was undertaken prior to the construction of the Stockton Breakwater, with the plan showing the northern training wall (termed *Breakwater*) and, what appears to be a short length of the Stockton Breakwater under construction. However, the short breakwater stub appears, merely, to be superimposed onto the plan, as there is no apparent effect on the surrounding bathymetric contours. Nevertheless, at this length its influence on the geomorphology of the entrance bar would have been minor. This plan shows greater bathymetric detail of the inlet as trained by a single southern breakwater. The soundings are given in feet and are presented as *fair sheets*, which gives confidence that the data are an accurate portrayal of water depths (rather than clearance depths). The plan shows the Southern Breakwater having been extended to a water depth of around 30 feet (9 metres), with a ruling depth on the bar of around 25½ feet (8 metres). The marginal flood tide channel is some 10 feet (3 metres) deep inshore of the *Oyster Bank,* which shoals to around 3 feet (1 metre) opposite Nobbys.

The bathymetric details offshore of Stockton, as shown on the 1851 and 1899 hydrographic survey plans, portray typical features of an estuary river entrance that is partially protected by breakwaters of unequal length. The distribution of the sand shoals on the northern side of the inlet, with the deeper marginal flood tide channel running parallel to the beach inshore of the *Oyster Bank*, were indicative of a large separation eddy that would have formed on that side during ebb tide as a result of the breakwater constructed to and beyond Nobbys Head. Such features were common on other similar asymmetrical entrances of the NSW coast, such as those, for example, at the ocean entrance of Wallis Lake at Foster (Nielsen & Gordon, 1980) and of the Hastings River Entrance at Port Macquarie (Druery & Nielsen, 1980).

As indicated in **Figures 4.3** and **4.4**, which depict the flood and ebb tide current patterns at these two similar asymmetrical estuary inlets, this marginal flood tide channel conveyed an inlet directed current during all tidal stages, which would have brought littoral drift into the entrance channel. This material would have been transported either into the estuary on subsequent flood tides or deposited onto the ocean bars during ebb tide. Such a circulation of sediment transport maintained the large swash shoals (*Oyster Bank*) on the northern side of the inlet. The formation of ebb tide separation eddies, as implied by the distribution of sand shoals and field current measurements depicted on hydrographic surveys, is demonstrated also by hydrodynamic modelling studies, such as that done for the asymmetrical ocean inlet to the Songkhla estuary, Thailand (**Figure 4.5**).

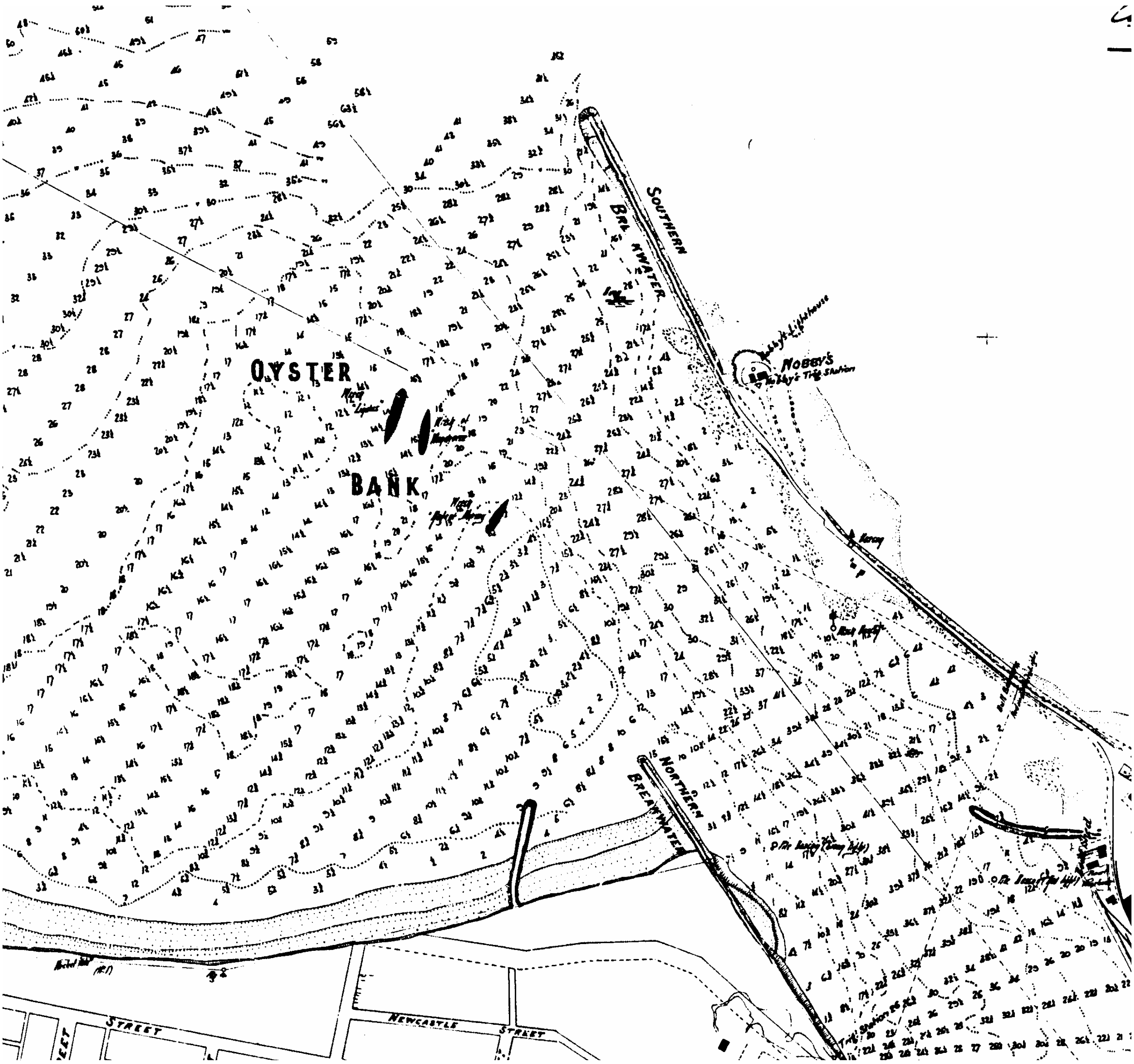


Figure 4.2: Jan 7 1899 Hydrographic Survey and Plan of the Entrance to Newcastle Harbour

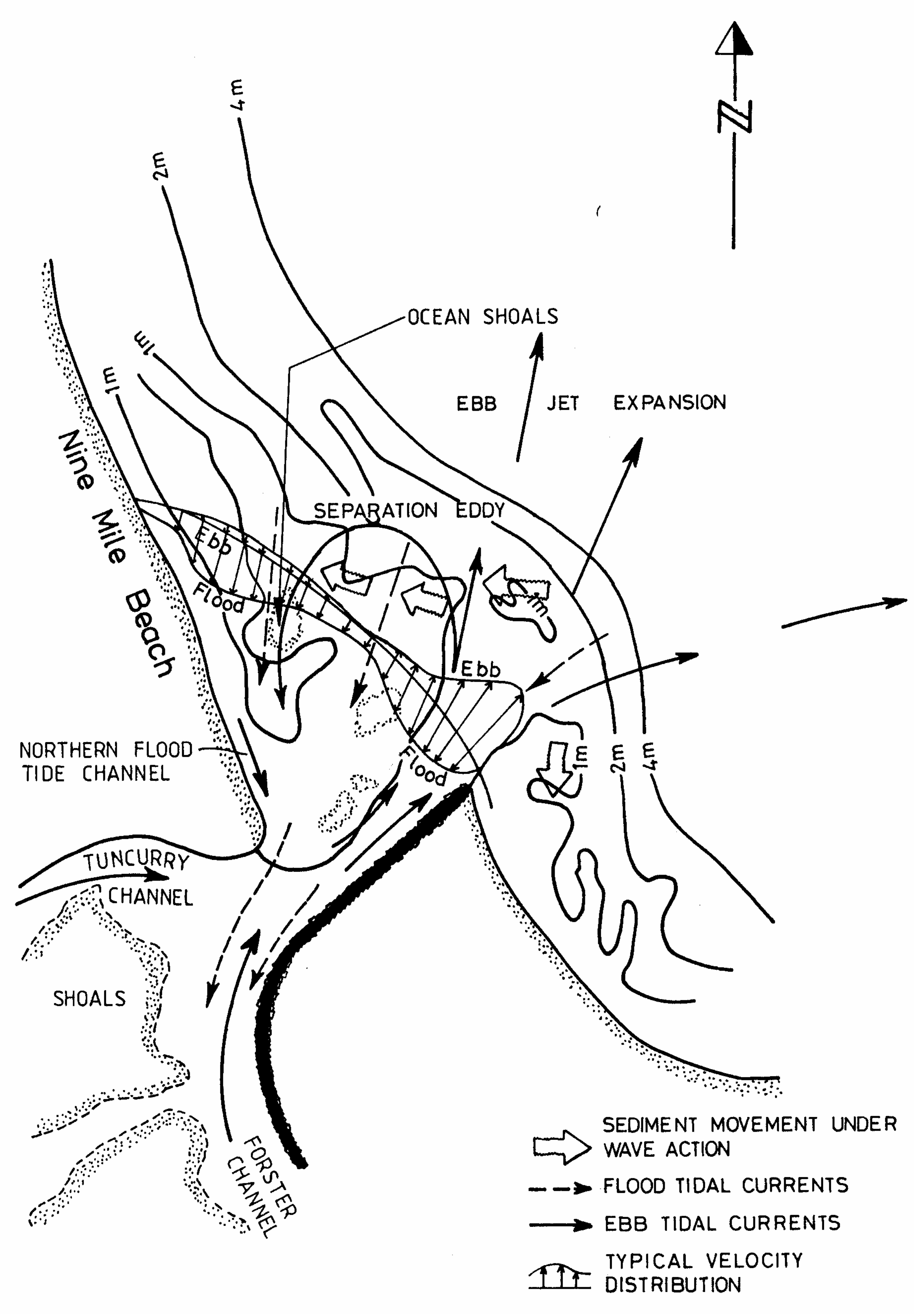


Figure 4.3: Schematic Representation of Flood and Ebb Tide Current Patterns at an Asymmetrical Inlet as Exemplified at the Wallis Lake Ocean Entrance, Foster/Tuncurry (after Nielsen & Gordon, 1980).

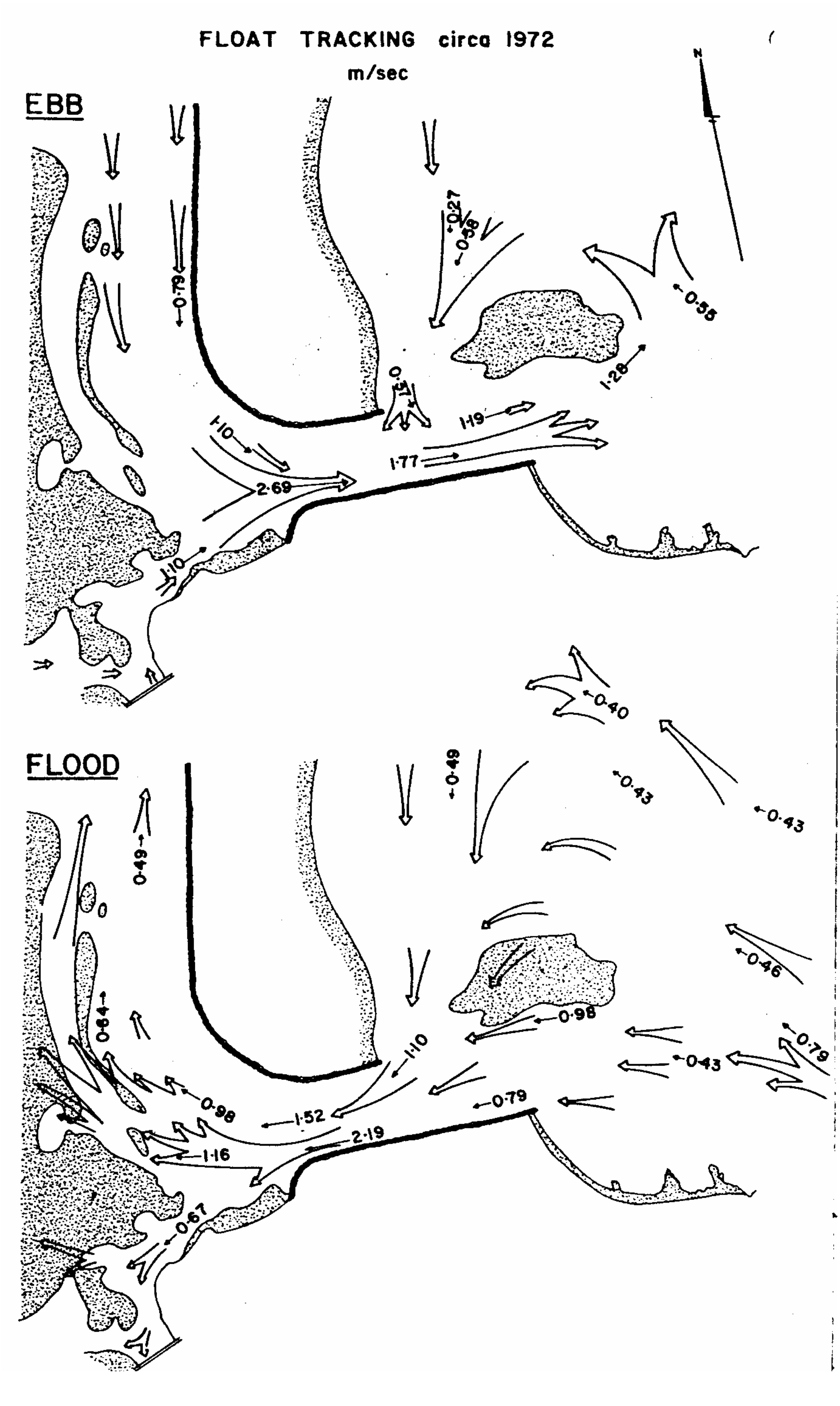
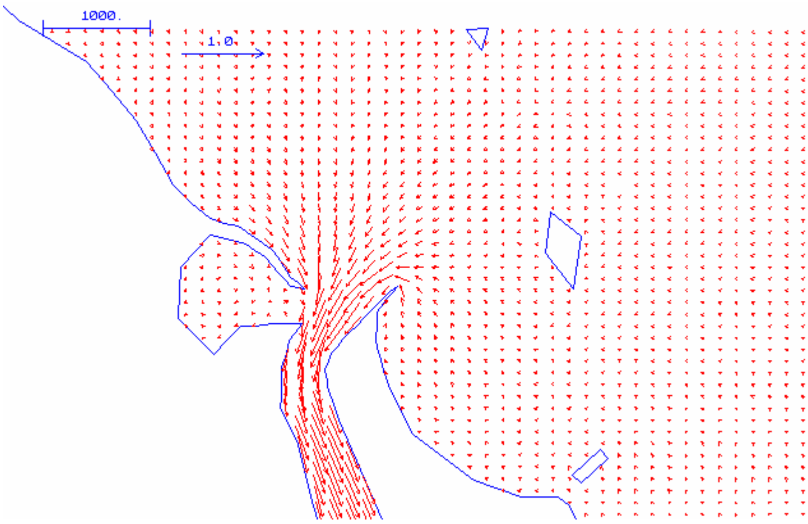
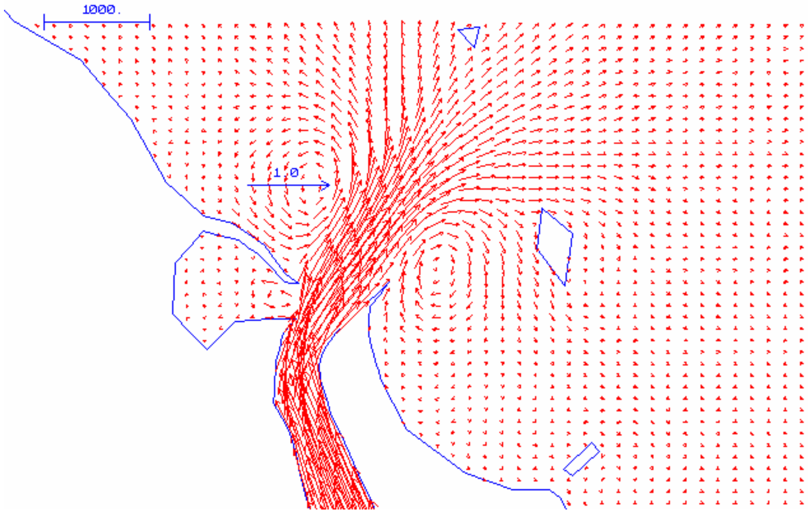


Figure 4.4: Schematic Representation of Flood and Ebb Tide Current Patterns at an Asymmetrical Inlet as Exemplified at the Hastings River Entrance, Port Macquarie (after Druery & Nielsen, 1980).

Inlet Configuration



Flood Tide



Ebb Tide

Figure 4.5. Numerical Model Results Depicting Tidal Current Velocities at an Estuary Entrance with Breakwaters of Unequal Length as Exemplified at Songkhla, Thailand (after Nielsen *et al*., 2001)

The inlet configuration that has developed following the construction of the Northern Breakwater is shown in **Figure 4.6**, which portrays part of the NSW Public Works Coast and Rivers Branch hydrographic survey dated 1988. The construction of the Northern Breakwater has caused significant alterations to the bar morphology. The interception of the marginal flood tide channel and the large swash shoals of the *Oyster Bank* has resulted in the elimination of the near shore separation eddy and inlet-directed ebb-tide current. The swash shoals have migrated onshore to form a large sand fillet against the northern side of the Northern Breakwater. This was observed in the earlier work by Manley (1963). These processes were also detailed at Port Macquarie in Druery and Nielsen (1980). The survey shows the ruling depth at the entrance to be around 18 metres, with no entrance bar feature as such across the breakwater tips.

The construction of the Northern Breakwater would have had similar impacts to those constructed at other inlets on the NSW coast. Nielsen & Gordon (1980) showed that at the Wallis Lake inlet, the northern breakwater construction resulted in significant improvement to the hydraulic conveyance of the inlet at Foster/Tuncurry. As shown in **Figure 4.7**, the entrance bar was deepened and the tidal flow became more streamlined. This led, *inter alia*, to an increase in the ability of the estuary to discharge floodwaters and also led to increased tidal discharge. This has led to the subsequent scouring of the entrance channel and other changes, which were predicted to develop for some 50 years.

Numerical modelling of the impacts of a similar construction at the Songkhla inlet, Thailand, as shown in **Figure 4.8**, shows that not only are the tidal discharge conveyance characteristics of the inlet improved, but strong flood tide velocities would be developed at the tip of the new breakwater extension. This is likely to cause channelling, seabed scour and sediment transport locally at the tip of the breakwater, with sediment transport directed towards and into the entrance channel. That this is occurring actively at Stockton is evidenced by the deep scour channel that has developed at the tip of the Northern Breakwater. **Figure 4.9** shows a detail of the 1957 Hydrographic Survey depicting relative seabed scour in excess of some 15 feet (5 metres) at the breakwater tip to a depth of 45 feet (14 metres) at the 30 foot (9 metres) isobath. This flood tide scour channel is likely to be drawing down sediment from offshore of Stockton Beach into the entrance channel.

As discussed in **Section 2.8**, and shown on **Figures 2.12**, **2.14** and **2.15**, the bed form near the channel entrance as recorded in DLWC's detailed 2000 hydrosurvey, exhibits features that indicate that sand is moving from Stockton Beach into the channel near the tip of the Northern Breakwater.

4.4 ENTRANCE DREDGING

Further to the impacts of breakwater construction, the channel has been deepened by dredging to provide for the draught of larger vessels. In 1961, Newcastle Harbour was approximately 8 metres deep. Between 1962 and 1967 the harbour was deepened to 11.0 metres. However, at this depth the bar was still unsafe. Between 1977 and 1983 the harbour was further deepened to its present day depth of 15.2 metres. The 1988 hydrographic survey shows the depth of the entrance bar at around 18 metres.

At a depth of 15 metres to 18 metres, the bar cannot transfer littoral drift material from the south side of the entrance to the Stockton Beach system. Further, as flood tidal currents carry littoral drift into the channel from the relatively shallow, 10 metres to 12 metres depth, region off the Northern Breakwater, these depths are too great for the sand to be returned to these areas offshore from Stockton during ebb tides. The deepened channel, therefore, is likely to be causing drawdown of the surrounding seabed area as is indicated on **Figures 2.12**, **2.14** and **2.15**. This, in turn, could be causing drawdown of the nearshore area of Stockton Beach.

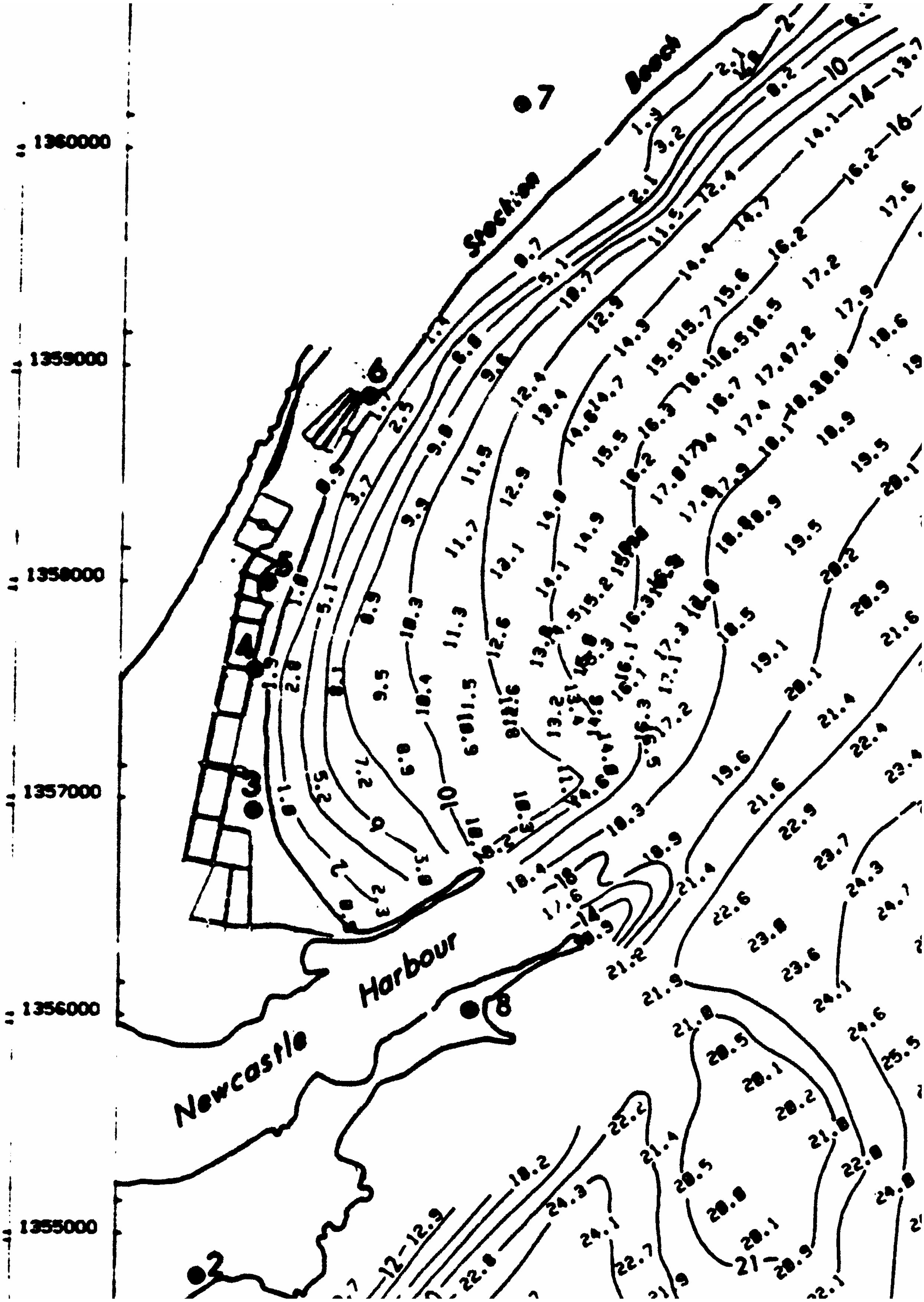


Figure 4.6 Part of the NSW Public Works 1988 Hydrographic Survey (depths shown in metres)

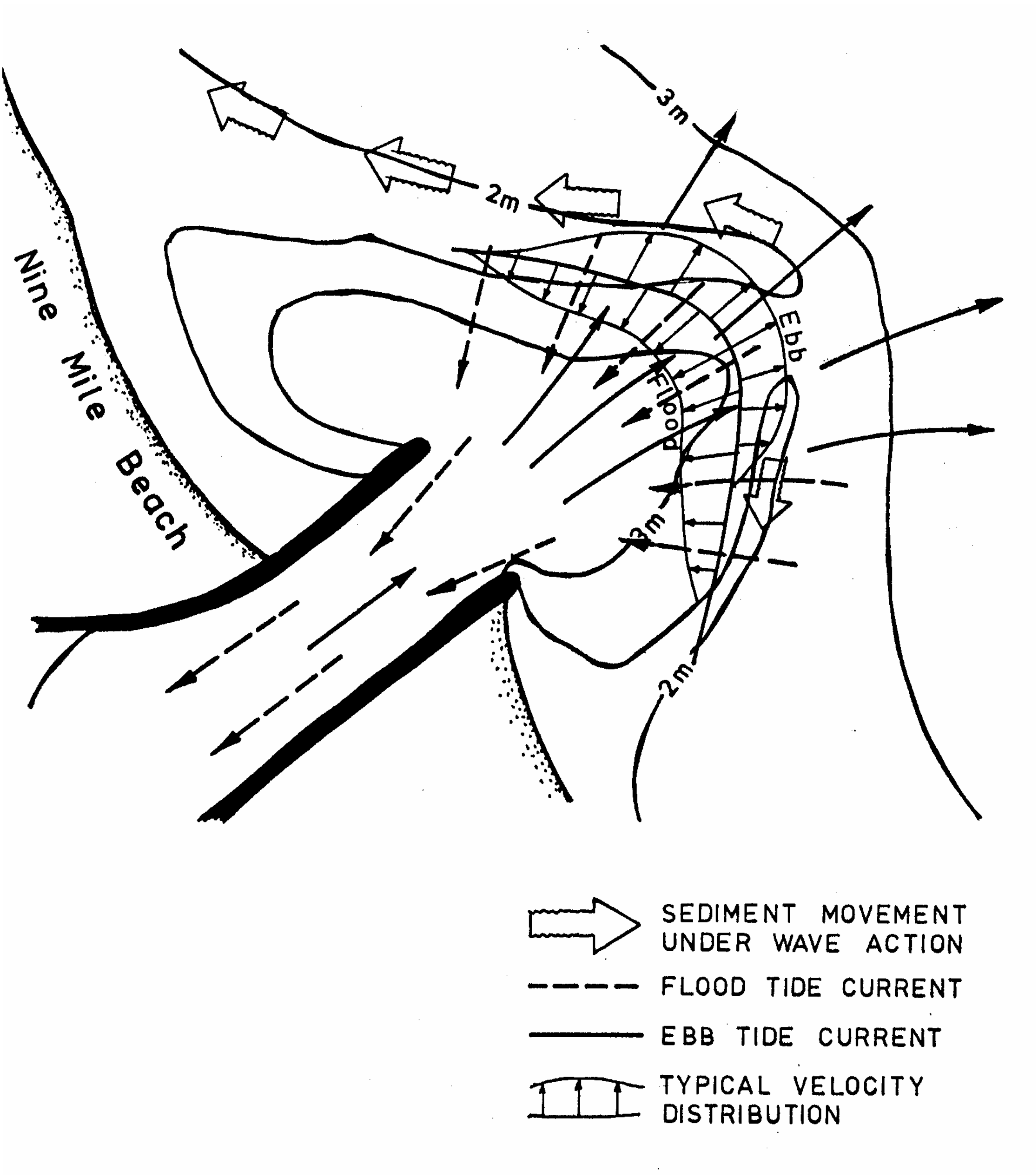
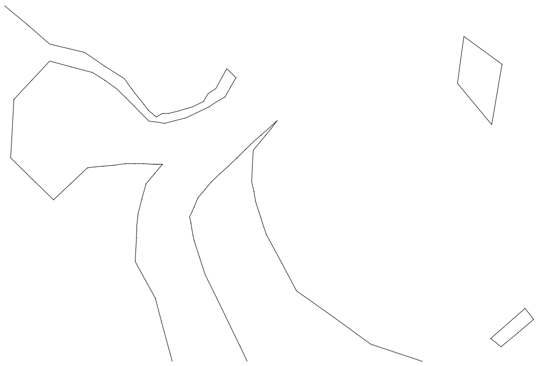
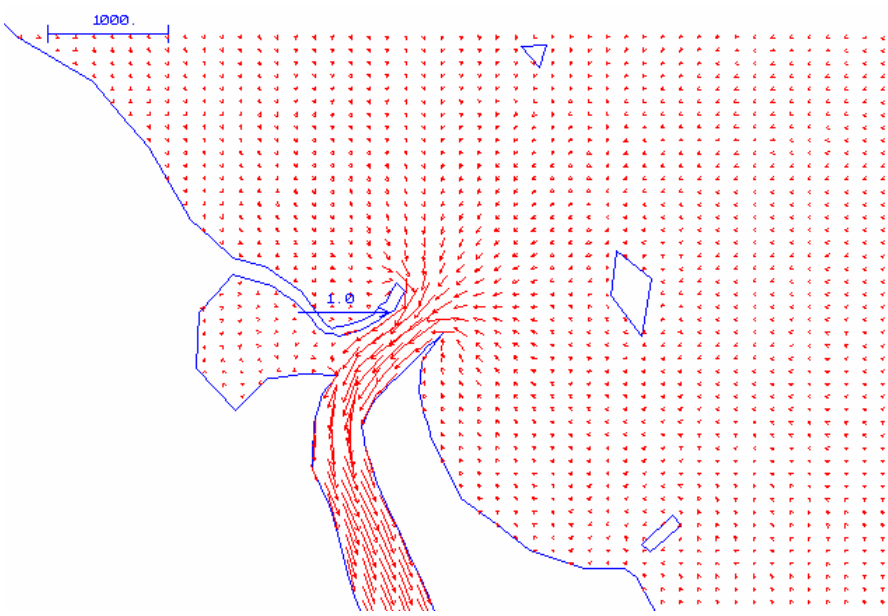


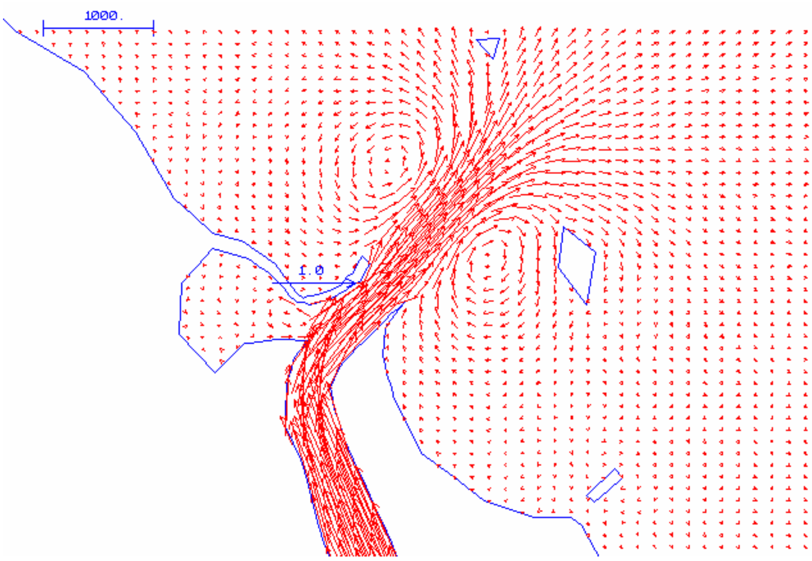
Figure 4.7: Schematic Representation of Flood and Ebb Tide Current Patterns at a Trained Inlet with Equal Length Breakwaters, Exemplified at the Wallis Lake Ocean Entrance (after Nielsen & Gordon, 1980).



Inlet Configuration



Flood Tide



Ebb Tide

Figure 4.8. Example of a Numerical Model Depicting Tidal Current Velocities at the Estuary Entrance in Figure 4.5 but with Extended Breakwaters of Equal Length

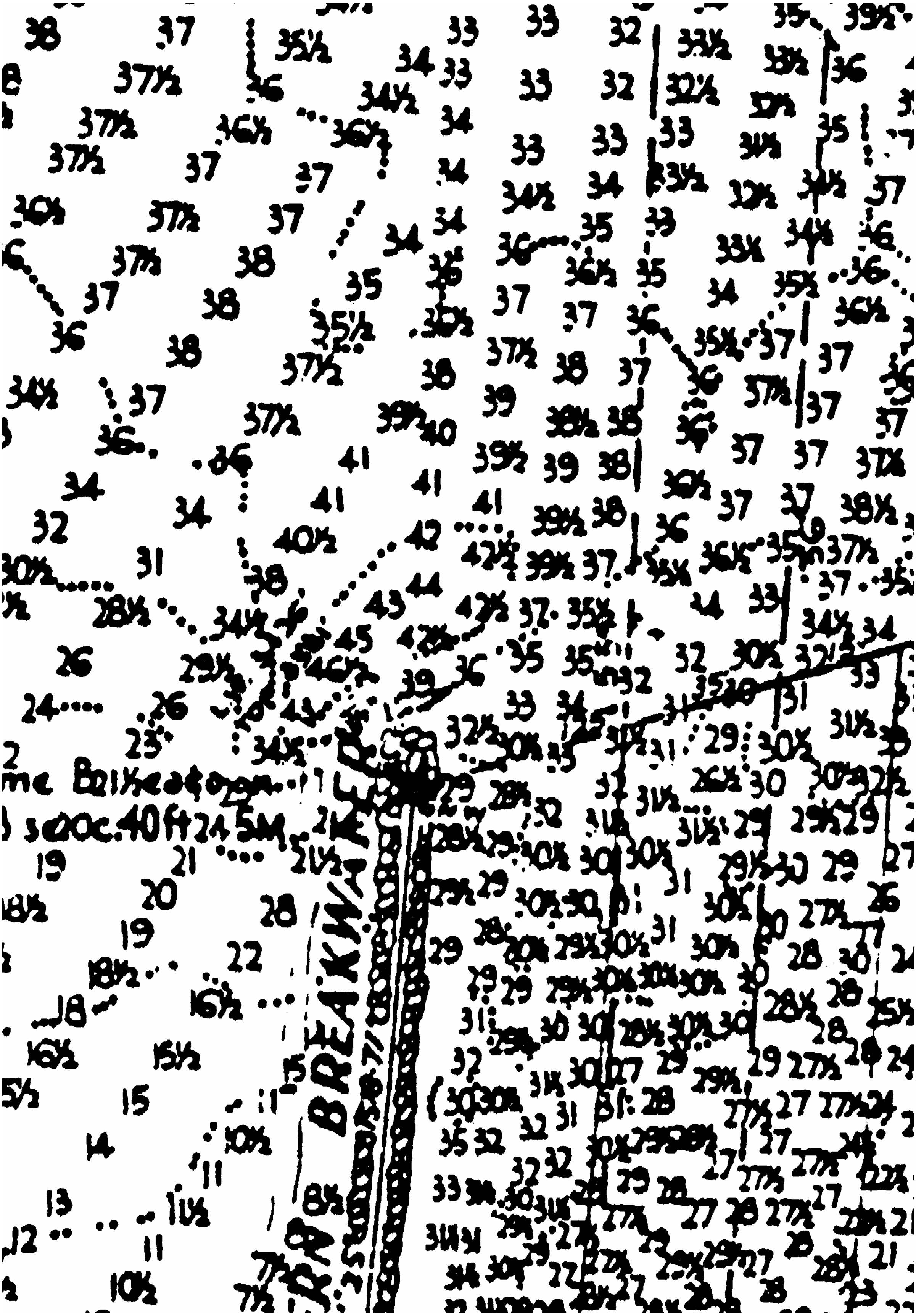


Figure 4.9 Enlargement of Bathymetry at the Tip of the Northern Breakwater from the 1957 Hydrographic Survey (depths shown in feet)

4.5 IMPACTS OF BREAKWATER CONSTRUCTION AND CHANNEL DREDGING

As with the construction of breakwaters at other estuary entrances on the NSW coast, breakwater construction at Newcastle Harbour has had considerable geomorphological and, hence, hydrodynamic impacts on the inlet and surrounding nearshore and foreshore areas of Stockton Beach, which are summarised as follows:

1) Construction of the Southern Breakwater and subsequent deepening of the entrance channel has cut off any littoral drift transport from south of the entrance to Stockton Beach. Prior to breakwater construction, the ruling depths on the entrance bar of around 5 metres to 7 metres would have been sufficient to bypass littoral drift to Stockton Beach. Work by Boleyn and Campbell (1966) and WBM (1998) indicates that this littoral drift would have supplied on average in the order of 30,000 m^3 of sand to the Stockton Beach system. Subsequent extension of the Southern Breakwater to the 10 metres isobath would restrict severely the transport of littoral drift material from south to north across the inlet as most of the littoral drift transport occurs in the nearshore littoral zone shallower than around 12 metres (Nielsen, 1994). At a rate of 30,000 m^3/year, over the 190 years since 1812, approximately 5.7 million m^3 of sand would have been supplied to the Stockton Beach system from south of the entrance if the Southern Breakwater had not been constructed and the channel had not been deepened preventing this supply of littoral drift material.

2) Construction of the Southern Breakwater has changed the tidal discharge characteristics of the inlet, affecting the morphology of the nearshore shoals and bars resulting in a progradation of the southern end of the beach. Further, however, the changes also have caused a lowering of the seabed offshore of Stockton Beach, as occurred following the northern breakwater construction at the Port Macquarie entrance (Druery & Nielsen, 1980).

3) Dredging of the entrance channel has created a potential sediment sink for the deposition of littoral drift material carried to the channel from the surrounding seabed under wave and flood tidal current action. As discussed in **Section 2.8**, DLWC's 2000 hydrosurvey indicates a build up of sand along the southern edge of the channel near the end of the Southern Breakwater and a sand build up in the channel associated with the shoal that is located approximately 350 metres northeast of the tip of the Northern Breakwater. This could also contribute to long term erosion of Stockton Beach.

4) The Northern Breakwater has accelerated the flood tide flow at its tip, resulting in scouring of a deep channel and directing sediment transport into the entrance channel from the Stockton side. Analysis of available hydrosurvey by Manley (1963) suggests that following initial establishment between 1912 and 1921, the scouring at the end of the breakwater didn't develop further until after 1957. Subsequent review by WBM (1998) indicates that following deepening of the channel in 1962-67 and again in 1979-83, the scour hole deepened further by in excess of 3 metres. This, in conjunction with increased tidal exchange volumes also has the potential to cause an acceleration of sediment drawdown from Stockton Beach.

5) Dredging to some 18 metres has removed the river entrance bar and has created water depths across the entrance that are now too deep to allow any littoral drift supply to Stockton Beach (Nielsen, 1994) from the south, thereby cutting off an historical sand supply to Stockton Beach. As discussed above, this would have equated to in the order of 5.7 million m^3 of sand supply over the last 190 years.

5.0 IMPACTS OF GEOMORPHOLOGICAL CHANGE ON FORESHORE EROSION

5.1 OVERVIEW

Changes effected on the nearshore bathymetry have the potential to alter current patterns and wave transformation characteristics. In respect of the latter, changes to wave transformation characteristics can be reflected through changes in wave refraction patterns as well as in changes to wave shoaling characteristics.

Changes to nearshore wave characteristics can result in changes to the potential for foreshore erosion. For example, if the nearshore seabed is lowered, there is the possibility of greater wave energy penetrating to the shore. For a given storm, therefore, this can result in increased erosion of the subaerial part of the beach.

The changes to the potential for storm related beach erosion at Stockton Beach have been investigated using numerical modelling techniques. Other erosion processes including longshore movement of sand, rip currents etc. have not been taken into consideration in this assessment. The approach taken was to apply a schematisation of a very severe storm, such as that occurring in 1974, to the surveyed profiles of Stockton Beach for the range of survey dates available.

5.2 METHOD

5.2.1 Numerical Model

The numerical model chosen for this assessment was SBEACH (32 Version 2.0). SBEACH (**S**torm-Induced **BEA**ch **CH**ange 32) is an empirically based, two-dimensional, morphological, numerical model for simulating storm-induced beach change. The model is founded on extensive analysis of beach profile change produced in large wave tanks and in the field (Larson *et al*., 1990). The model accepts as data:

- surveyed beach profiles;
- time-varying water levels;
- regular or irregular wave heights and periods;
- wave angles;
- wind speeds and wind directions; and
- an arbitrary grain size in the fine-to-medium sand range.

The model provides estimates of beach profile change including beach scour levels and sand bar development, wave setup and runup water levels and wave-height variation across the surf zone. Apart from varying grain size and other input parameters, tuning parameters in the model include various sand transport coefficients.

Data were not available to enable validation of the model for Stockton Beach. However, accurate tuning of the model was not deemed necessary as only the relative differences between various profiles was being assessed. Nevertheless, recommended values for the various tuning parameters were used, along with sand transport parameters used for the successful validation of the model for beaches on the Australian eastern seaboard (Carley *et al*., 1999).

5.2.2 Storm Schematisation

The model was developed on a severe storm event that was schematised from the very severe storm that occurred on the central coast of NSW in May-June 1974. As deepwater data were not available for that event, a time history of wave height, period and water level was used that was synthesised from various sources after Nielsen *et al.* (1993). The time series for the severe storm is presented in **Figure 5.1**.

5.2.3 Beach Profile Schematisation

The beach profiles used for the schematisation comprised a synthesis of:

- the hydrographic profiles developed for this study from the available hydrographic plans. Cross-sections are provided in **Section 3.0** and cross section locations are shown on **Figure 3.1**; and
- the photogrammetric profiles provided by the Department of Land and Water Conservation, as were used in DLWC (1995) and WBM Oceanics Australia (1998).

The profiles that were matched are in **Table 5.1**.

Table 5.1 - Hydrographic and Photogrammetric Profiles Synthesised for Beach Profile Schematisation

Hydrographic Survey Profile Number (Figure 3.2)	Photogrammetric Survey Profile (Block Number, Profile Number)
1	A, 14
4	B, 3
7	B, 11

Profiles 1, 4 and 7 from **Figure 3.1** were selected for closer examination and analysis because they represented the range of profiles taken and were not affected by the Stockton Beach revetment construction.

The nearshore profiles used were schematised from six of the hydrographic surveys, which were selected based on the temporal coverage that was given and the adequacy of their spatial coverage. The profiles were matched to the photogrammetric profiles as indicated in **Table 5.2**. The chainages adopted for the synthesised profiles were those used in the photogrammetry. Initially, the 1995 profiles were matched, given that they coincided temporally. Precedence was given to the photogrammetric data on the basis that it was more likely to be precise in the swash zone. Following that, the chainage adjustment determined for the 1995 hydrosurvey was applied to the other hydrosurveys to bring them all back to the same baseline. For the pre-1950 hydrosurveys, the subaerial portion of the beach profile was taken from the 1952 photogrammetry, with the profiles synthesised at the swash zone.

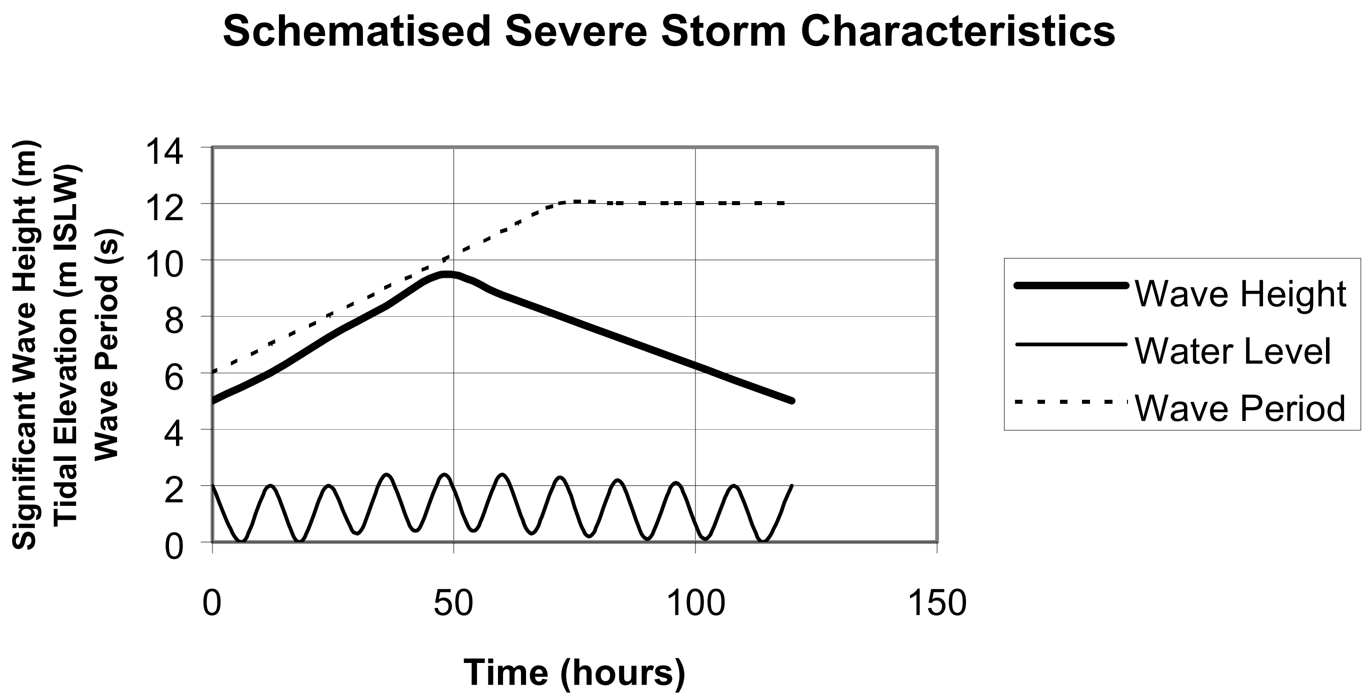


Figure 5.1: Schematisation of Severe Storm used for Comparative Beach erosion Modelling

Table 5.2 - Dates of Surveys Synthesised for Beach Profile Schematisation

Hydrographic Survey Date	Photogrammetric Survey Date
2000	1999
1995	1995
1988	1991
1950	1952
1926	1952
1899/78	1952

A comparison of the profiles is presented in **Figure 5.2**. **Figure 5.2** shows the progressive deepening that has occurred over the subaqueous domain at least since the hydrographic survey of 1899. As discussed in **Section 3.0**, over a significant portion of the domain, the bed level has lowered by around 3 metres to 5 metres.

5.3 CHANGES TO CROSS-SHORE WAVE TRANSFORMATION

All of these profiles were subjected to the *design storm* depicted in **Figure 5.1**. **Figure 5.3** presents the spatial and temporal variations in wave height transformation across the nearshore zone at Stockton Beach for the selected years of 1878/99, 1950 and 2000. These plots show that, across the entire domain, there is a progressive increase in nearshore wave height from 1878/99 to 2000, with design storm wave height 500 metres off shore increasing by approximately 2 metres or approximately 30% to 50%. This is attributed entirely to the progressive deepening of the offshore zone, as this was the only factor varied in the model.

5.4 CHANGES TO CROSS-SHORE BEACH EROSION PROCESSES

The temporal and spatial variation in the potential for subaerial beach erosion, as determined from the numerical modelling, is depicted in **Figure 5.4**. **Figure 5.4** shows that, over the entire domain, there has been an increase in subaerial beach storm erosion potential along the Stockton foreshore. Further, the strong indications are that this increase in erosion potential has accelerated over the past decade with potential storm erosion increasing from approximately $1m^3/m$ in 1990 at Profile 1 to approximately 60 m^3/m in 2000. Similarly, at Profiles 4 and 7, erosion potential has increased from approximately 40 m^3/m and 60 m^3/m respectively in 1990 to approximately 100 m^3/m and 120 m^3/m respectively in 2000. This represents a 2 to 2.5 times increase in potential subaerial beach erosion in the last decade. Modelling indicates that since 1950 there has been approximately a 5 to 6 fold increase in potential subaerial beach erosion.

This increasing risk of storm erosion is attributed to the progressive deepening of the seabed offshore of Stockton Beach.

5.5 DISCUSSION OF FINDINGS

A review of available historical hydrographic survey data has indicated significant long-term changes occurring at Stockton Beach for over a century. These changes include a progressive lowering of the seabed, which is thought to have effected foreshore erosion processes at Stockton Beach. While no detailed coastal process studies have been undertaken to examine

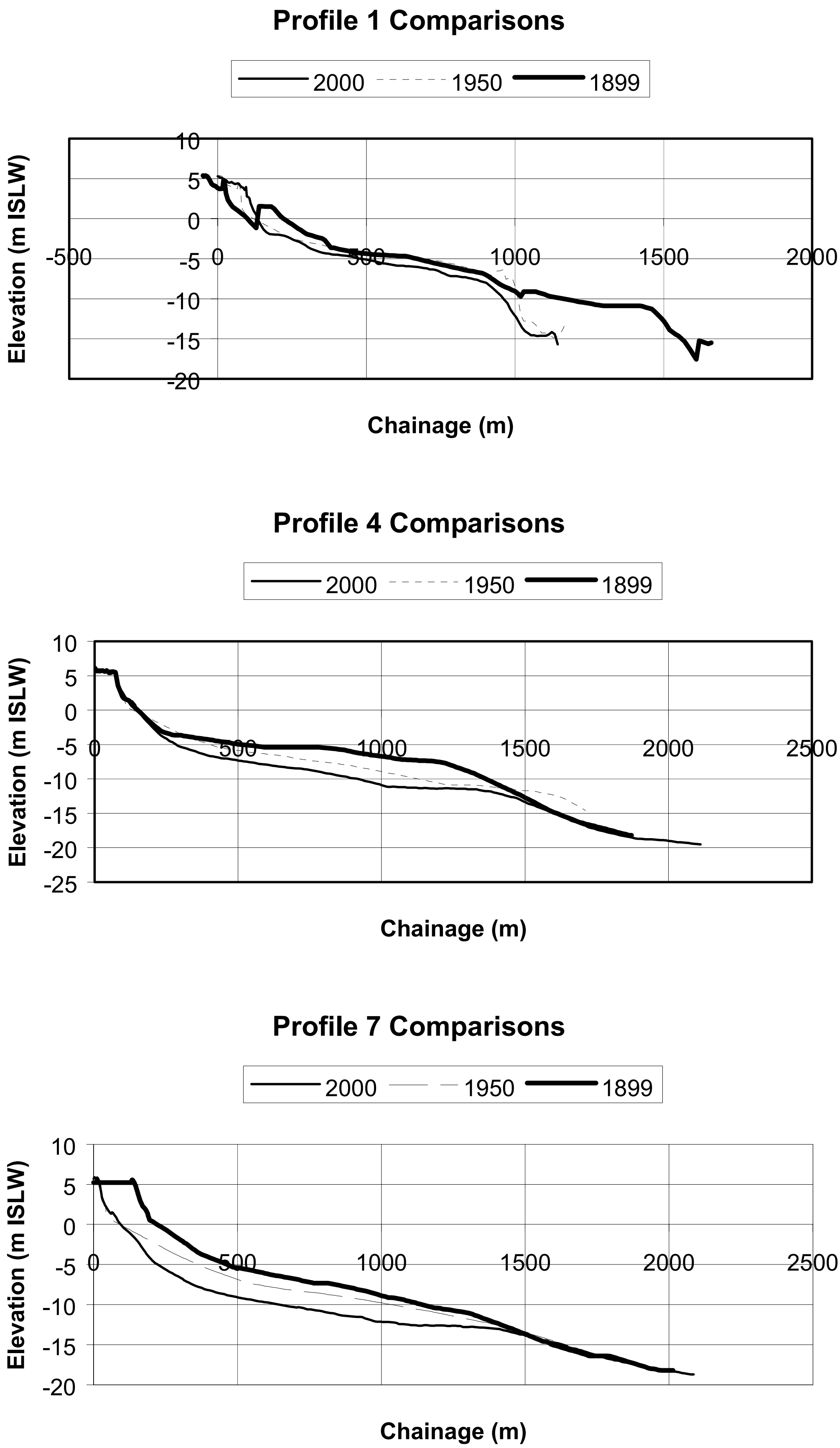
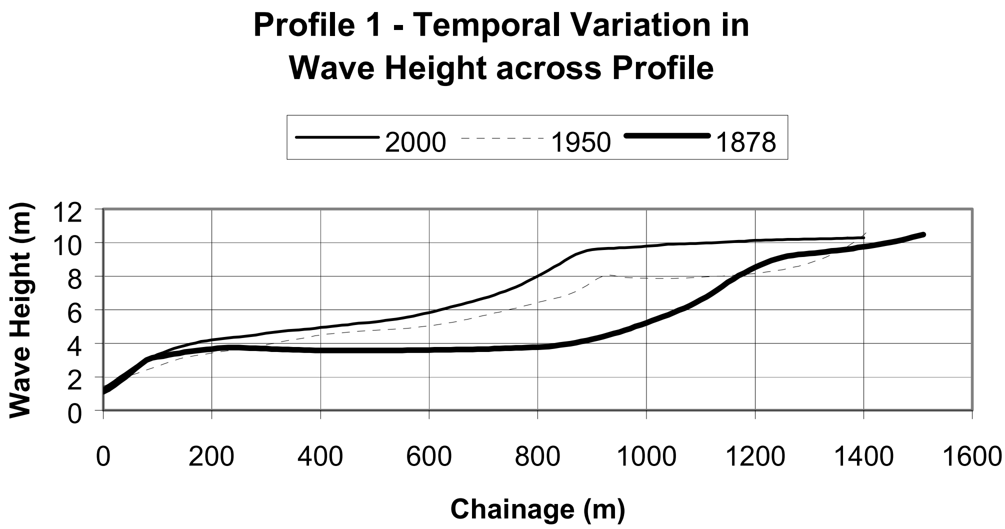
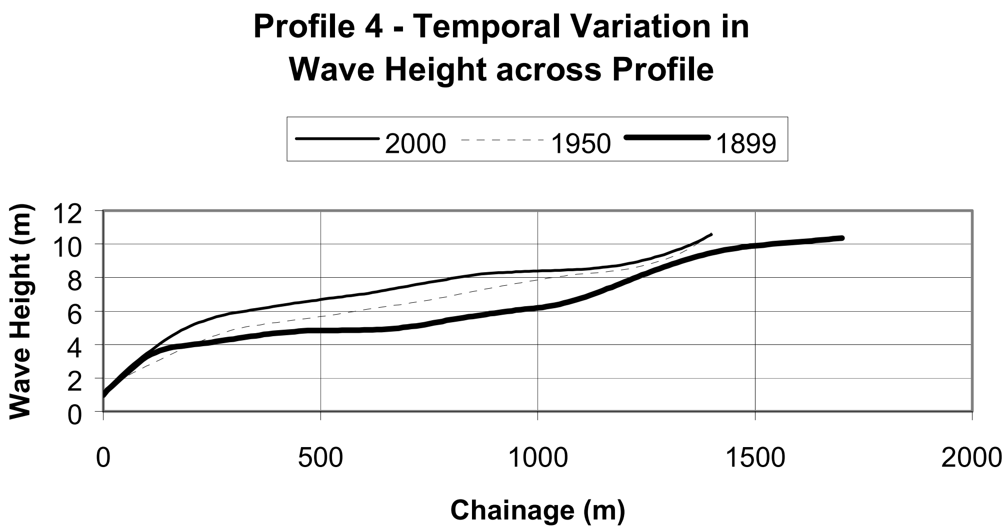


Figure 5.2: Selected Profile Comparisons





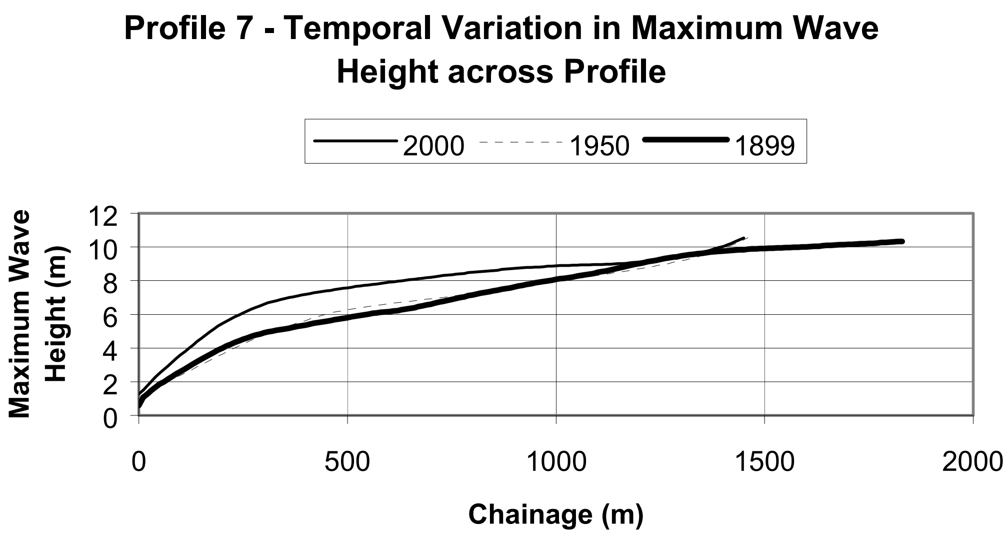


Figure 5.3: Variations in Wave Height Transformation across the Nearshore Zone

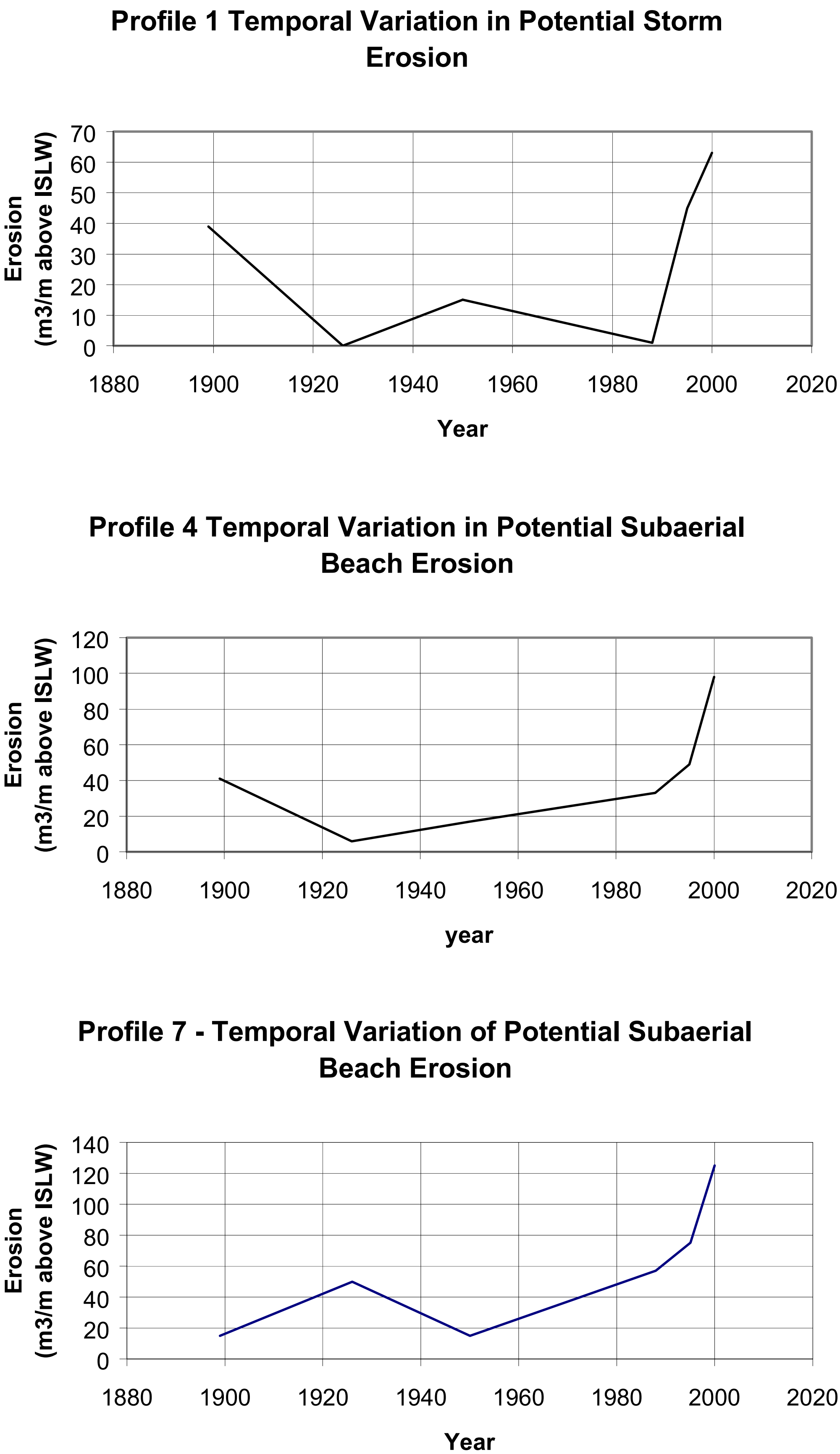


Figure 5.4: Relative Variations in Subaerial Beach Erosion Potential

these changes, the data have been interpreted based on experience gleaned from studies of other similar estuary entrances.

It has been postulated that the major cause of change to the nearshore and foreshore zone of Stockton Beach can be related to changes made to the configuration of the Hunter River estuary entrance, occasioned by breakwater construction, and the deepening of the entrance channel.

The photogrammetric study (DLWC, 1995) identified a major accretionary stage of Stockton Beach between 1950 and 1965, which has been followed since by progressive erosion. Various explanations for this trend shown in the surveys of the subaerial beach sand volumes have been proffered, including major flooding of the Hunter River (Public Works Department, 1977) and medium-term decadal oscillations in wave climate. However, the most obvious explanation may lie in the anecdotal evidence of Professor Ron Boyd (Dept. of Geology, Uni. of Newcastle). Professor Boyd, a long term resident of Stockton Beach since early childhood, has recalled massive sand nourishment of the beach occurring during the entrance dredging operations being undertaken in the 1960s.

The acceleration in the potential erosivity of the Stockton foreshore, as indicated by the SBEACH modelling, has been reflected in the historical shoreline change analysis presented in DLWC (1995). While the severity of the 1974 “Sygna” storm may yet to be repeated, DLWC (1995) has attributed what appears to be a recent acceleration in beach erosion throughout the 1990s to the occurrence of severe storms during that period. As indicated by the SBEACH modelling, should the observed trend in change to the nearshore morphology continue, progressively greater erosion of the beach can be expected with even regular storm activity.

It has been concluded that the current trend of nearshore recession experienced at Stockton Beach is progressive rather than cyclic. Further, the erosivity of the foreshore at Stockton is likely to increase with time, thereby resulting in an ever-increasing risk to development located there.

Management of this situation is likely to be best effected by mechanisms that work with the natural processes rather than conflicting with them. Given that the supply of sand to Stockton Beach from the south by longshore drift processes has been significantly reduced if not stopped by construction of the Southern Breakwater and deepening of the entrance channel, it is likely that sand nourishment is the only management process that, technically, could be sustained *ad infinitum*. The economic feasibility of this without the implementation of other measures to minimise the rate of sand loss, would however be questionable.

6.0 CONCLUSIONS AND RECOMMENDATIONS

It is apparent from the analysis of available hydrosurvey and bathymetric information that there have been substantial changes to bed profile, water depth and sand volume off Stockton Beach with the changes being observed to a distance of approximately 1700 metres offshore and to water depths of 20 metres. At approximately 800 to 900 metres offshore, bed elevation has lowered by 4 to 7 metres. Available hydrosurvey information indicates that in excess of 10 million m^3 of sand has been lost from an area (Area 2) off Stockton Beach system since construction of the Southern Breakwater commenced in 1812. This does not include the material that has been removed or lost from the entrance channel and the sea bed immediately to the east.

Contrary to previous believe, this review demonstrates that the observed changes are progressive rather than cyclic and are still occurring at a rapid rate with approximately 4.5 million m^3 of sand being lost from the Stockton Beach system (Area 2) since 1988. This equates to an average loss rate of approximately 370,000 m^3/year over the past 13 years which is nearly 5 times that of the estimated average loss rate since 1921.

Analysis of the hydrosurvey information, clearly indicates that presence of an erosion scour zone at the tip of the Northern Breakwater with this area appearing to trigger drawdown or ‘drainage’ of sand from the Stockton Beach system. The belief that sand is being transported from Stockton Beach into the entrance channel is supported strongly by close analysis of the detailed 2000 hydrosurvey undertaken by DLWC as shown on **Figure 2.14**, which clearly exhibits a drainage pathway from the nearshore area of Stockton Beach to the entrance channel. Previous studies (White 1901, PWD 1966) have also reported sand draining from Stockton Beach to the channel.

Wave transformation analysis indicates that at approximately 500 metres offshore, wave height in response to a design storm (based on the 1974 storm that sank the Sygna) has increased by approximately 2 metres or 30% to 50% since 1899 with the potential beach erosion from a design storm being approximately 5 to 6 times greater in 2000 than it was in 1950.

These observed changes have occurred over the same time period as extensive changes to the entrance to Newcastle Harbour including:

- Construction and extension of the Southern Breakwater between 1812 and 1875.
- Construction of the Northern Breakwater between 1898 and 1912.
- Dredging of approximately 133 million m^3 from Newcastle Harbour and its entrance between 1857 and 1989. Maintenance dredging in excess of this has been ongoing to present and will continue.
- Deepening of the harbour entrance from 8 metres to 11 metres between 1962 and 1967 and then further deepening to 15.2 metres between 1977 and 1983 with dredging extending eastward approximately 1 kilometre past the tip of the Northern Breakwater to provide a transition between a water depth within the channel of 15.2 metres and a depth outside the entrance of approximately 20 metres.

These changes to the entrance configuration of Newcastle Harbour have the potential to impact on the sand supply for Stockton Beach in the following ways:

1. Prior to the construction of the Southern Breakwall, sand would have been transported across the sandbar at the entrance to the Hunter River to the Stockton Beach system.

Estimates by Boleyn and Campbell (1966) and WBM (1998) indicate that this would have been in the order of approximately 30,000 m^3/year on average. Construction of the Southern Breakwater and subsequent deepening of the harbour entrance has removed this supply of sand.

2. Construction of the Southern Breakwater and deepening of the channel generated a large separation eddy adjacent to Stockton Beach which eroded the adjoining sand bars, transporting the sand into the harbour entrance.

3. Erosion at the tip of the Northern Breakwater appears to propagate back towards Stockton Beach with a drainage pathway from the nearshore zone of Stockton Beach to the entrance channel being apparent in the 2000 hydrosurvey. The presence of this drainage pathway suggests that sand continues to drain from the Stockton Beach system to the entrance channel.

4. Earlier dredging has removed the tidal delta from the entrance to Newcastle Harbour has prevented ongoing supply of sand from the south to the north via littoral processes. As a consequence there is a significantly reduced supply of sand at the entrance to the Harbour that would be available to be reworked by floods. In addition, the depth of the channel is such now that any such sand would not be deposited on Stockton Beach.

Analysis of hydrosurvey information indicates that following construction of the Northern Breakwater the beach system appeared to be approaching a new equilibrium by about the late 1950s. Between the late 1950s and late 1980s this apparent new equilibrium was subsequently disturbed with sand loss rates between 1988 and 2000 being approximately five times the average rate between 1921 and 2000. Indications are that following massive erosion rates off Stockton Beach between 1988 and 1995, the rate of erosion is starting to slow down as the beach system maybe once again starting to approach a new if not considerably deeper equilibrium.

What is not known is what brought about this change however indications are that it is strongly linked to deepening of the harbour entrance which would have impacted on tidal currents, bed stability and sand supply from the south.

Newcastle Port Corporation now proposes to further deepen Newcastle Harbour to provide for large vessels. The impact of this on rates of sand loss from Stockton Beach is not known, however any further deepening is likely to cause a change in tidal currents, current patterns and sea bed stability adjacent to the deepened channel.

To understand the impacts of further deepening of the channel and to enable appropriate mitigation measures to be developed to address the current and real erosion problems on Stockton Beach, a number of detailed studies are required. These include:

- Sand Tracer studies to determine direction of sand movement around Stockton Beach and the Harbour Entrance.

- Detailed hydrographic survey of the current bed profile off Stockton Beach, the harbour entrance and south to Nobbys Beach for subsequent use in modelling and for comparison purposes.

- Development of a detailed integrated suite of hydrodynamic, sediment transport and wave transformation models of Stockton Beach and the Harbour Entrance to determine sand movement pathways, erosion processes and erosion rates. These models will be used to explore mechanisms of mitigating erosional processes and the potential impacts of the proposed further deepening of the harbour.

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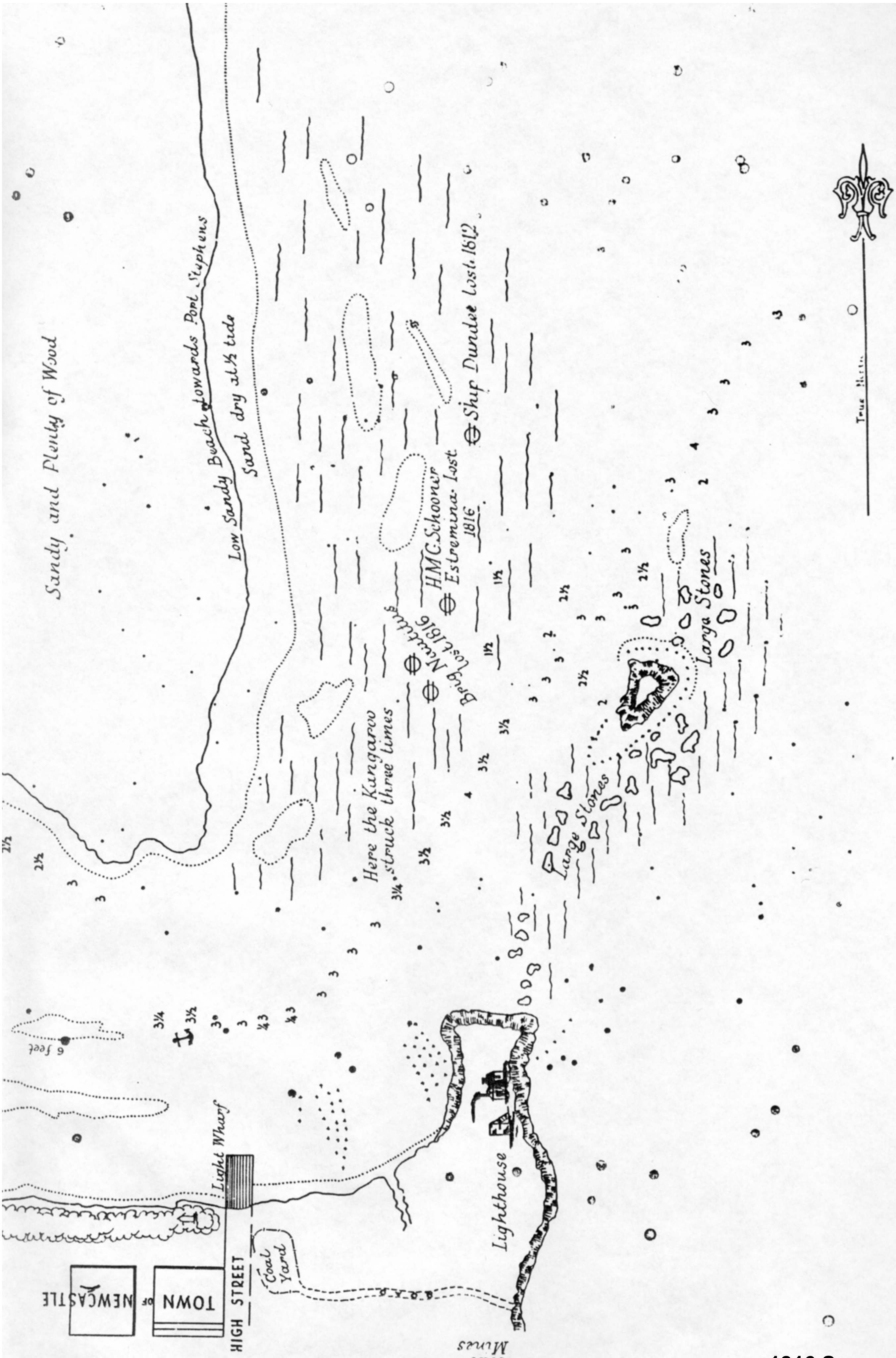
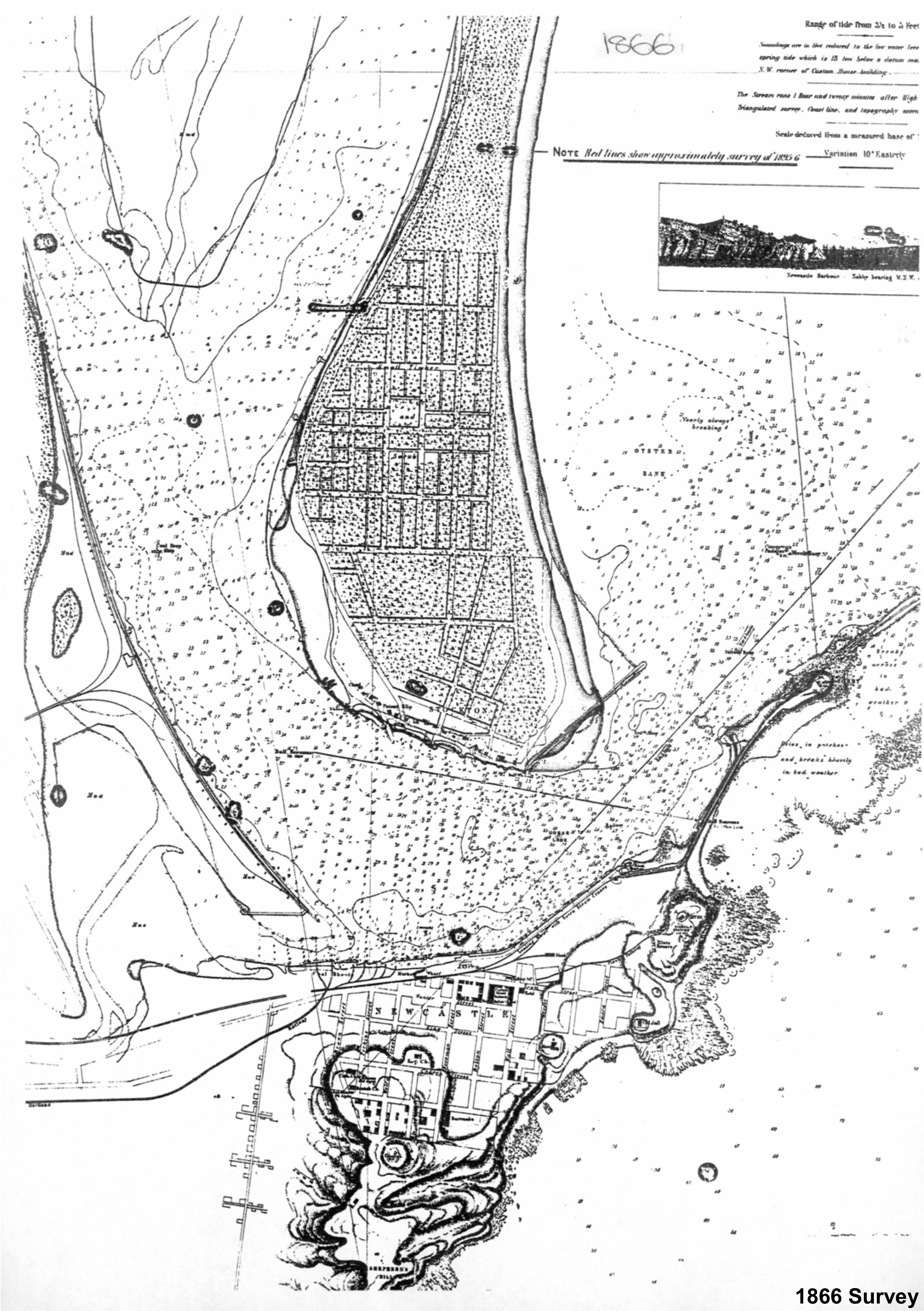
APPENDIX 1

Hydrosurvey Information

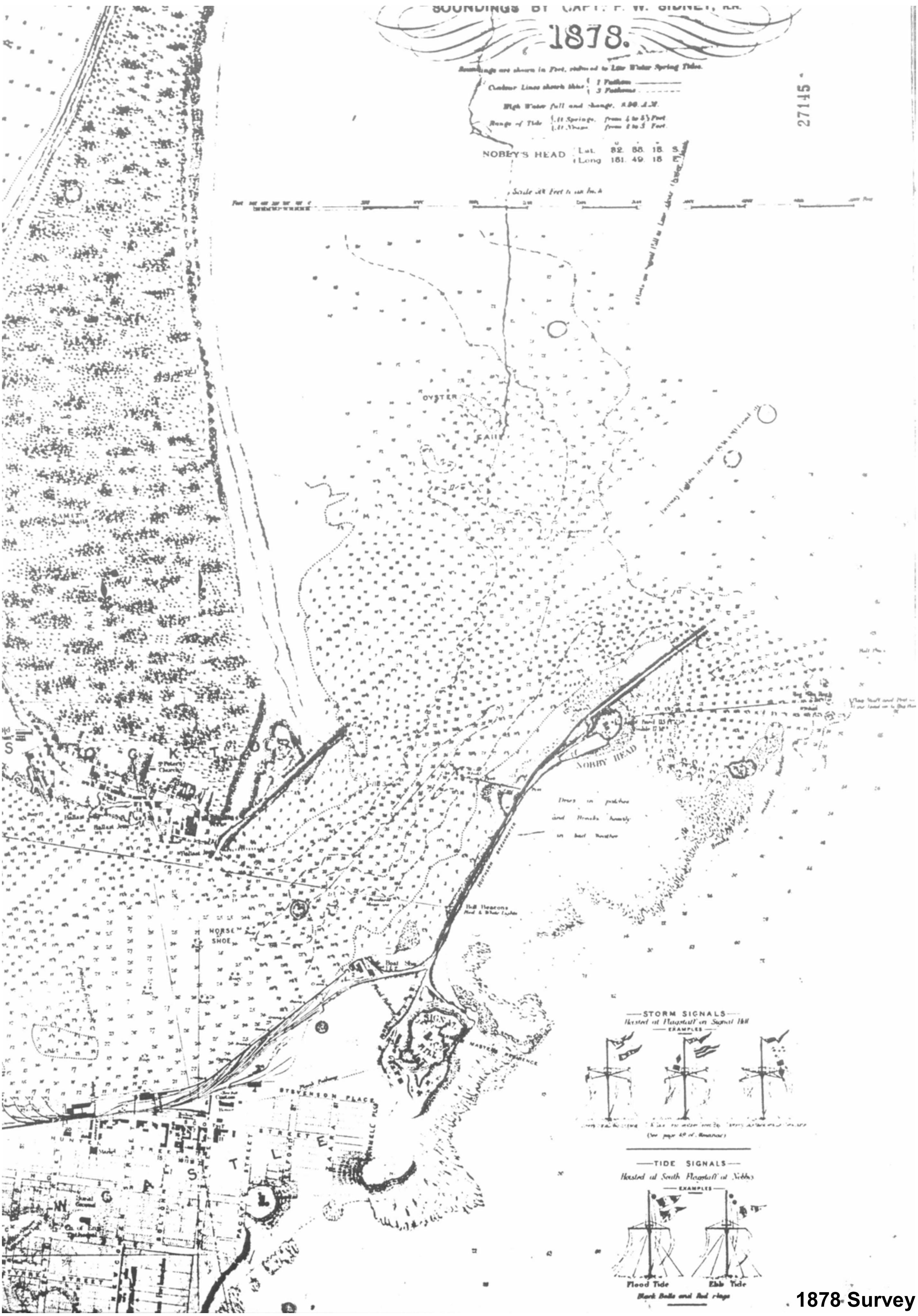

Sandy and Plenty of Wood
Low Sandy Beach towards Port Stephens
Sand dry at ½ tide
Here the Kangaroo struck three times
Brig Nautilus Lost 1816
H.M.C. Schooner Estremina Lost 1816
Ship Dundee Lost 1812
Large Stones
Large Stones
Lighthouse
Light Wharf
Coal Yard
HIGH STREET
TOWN OF NEWCASTLE
Coal Mines
6 feet

1816 Survey



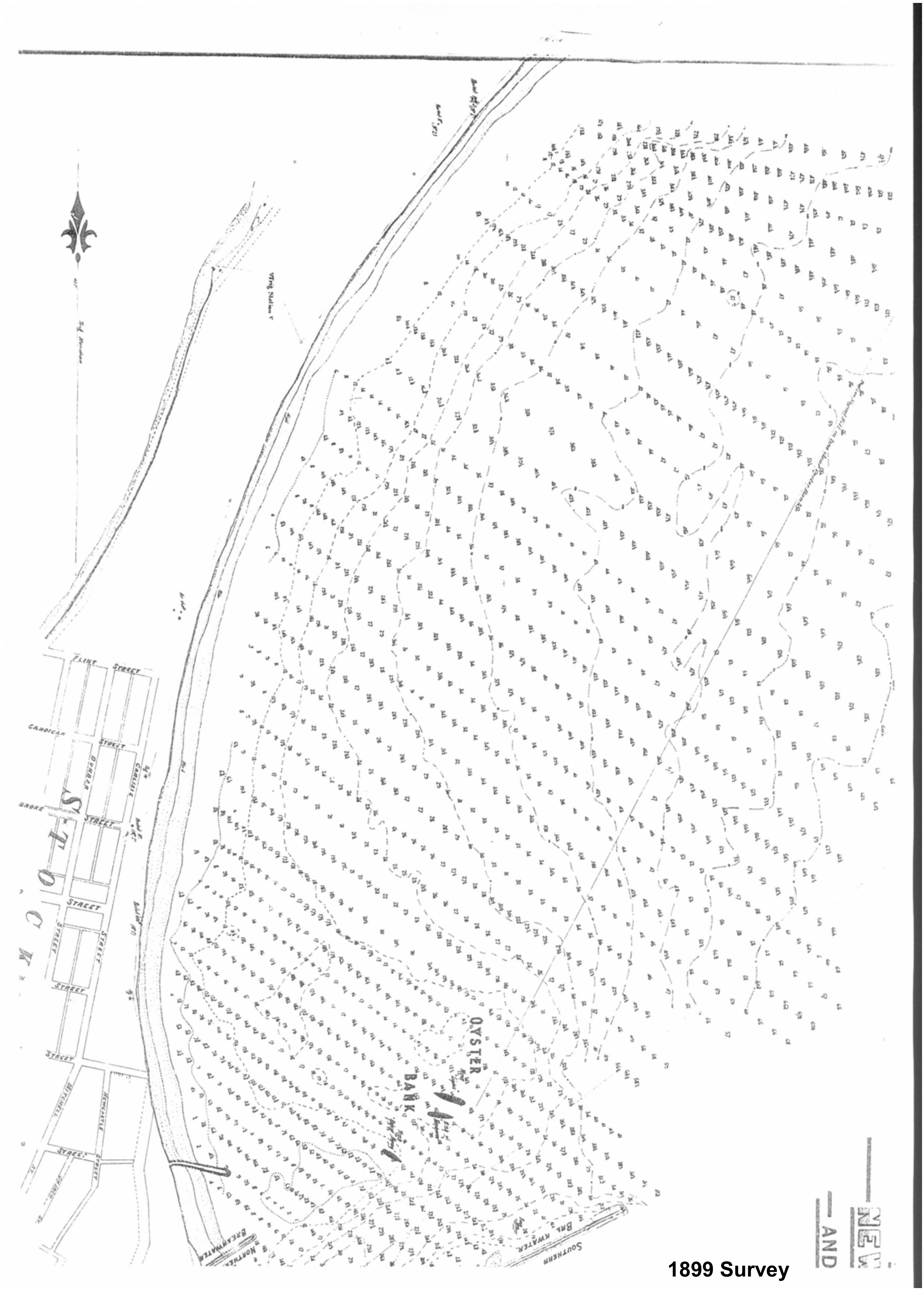
Range of tide from 3½ to 5 Feet
Soundings are in feet reduced to the low water leve
spring tide which is 13 feet below a datum ma
S. W. corner of Custom House building.
The Stream runs 1 hour and twenty minutes after High
Triangulated survey. Coast line, and topography
Scale deduced from a measured base of
Variation 10° Easterly
NOTE Red lines show approximately survey of 1895 6
1866
Newcastle Harbour
Nearly always breaking
OYSTER BANK
NEWCASTLE
SHEPHERD'S HILL

1866 Survey

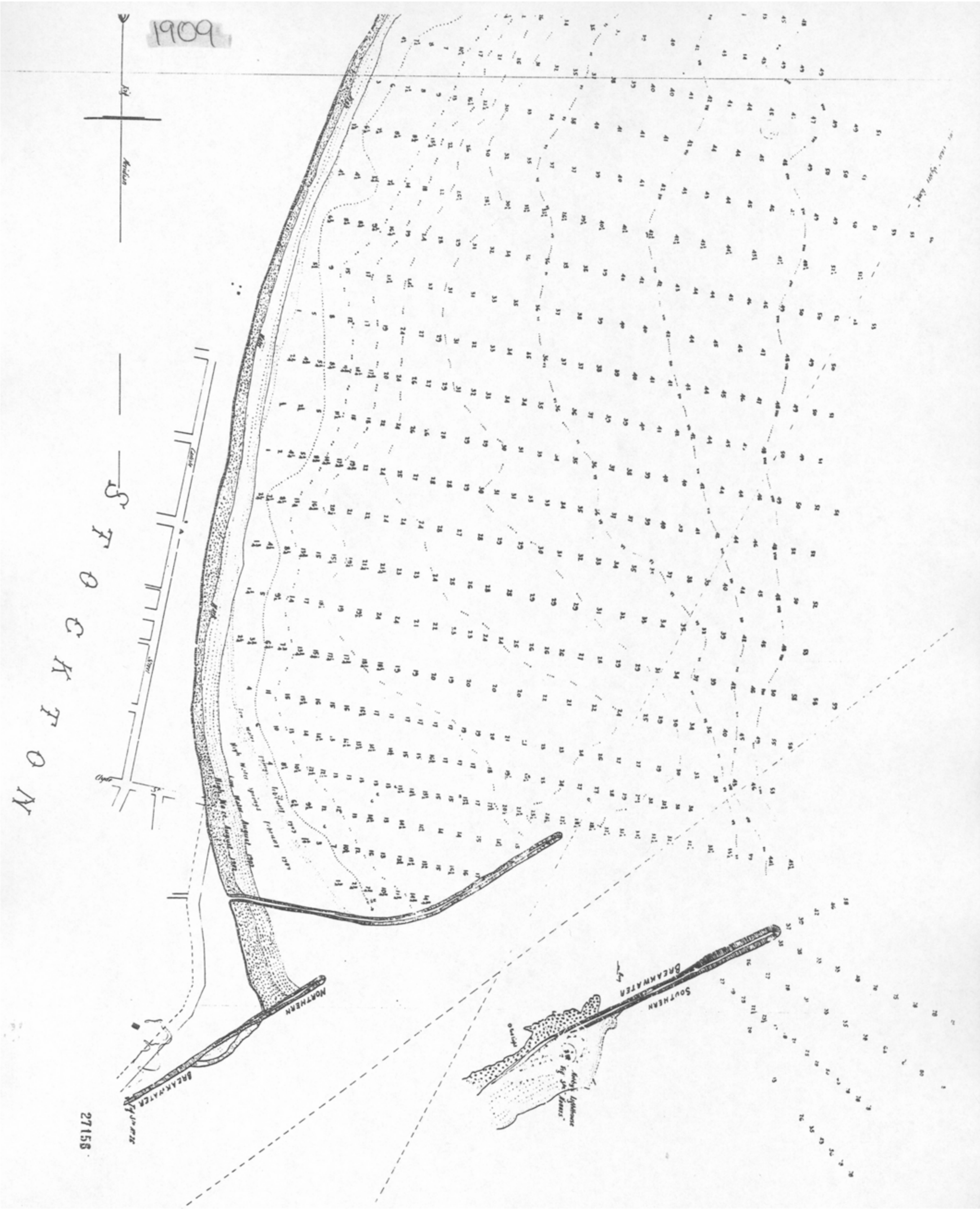


SOUNDINGS BY CAPT. F. W. SIDNEY, R.N.
1878.
NOBBY'S HEAD
27145
OYSTER
NOBBY HEAD
STOCKTON
HORSE SHOE
STEVENSON PLACE
NEWCASTLE
STORM SIGNALS
TIDE SIGNALS
Flood Tide
Ebb Tide

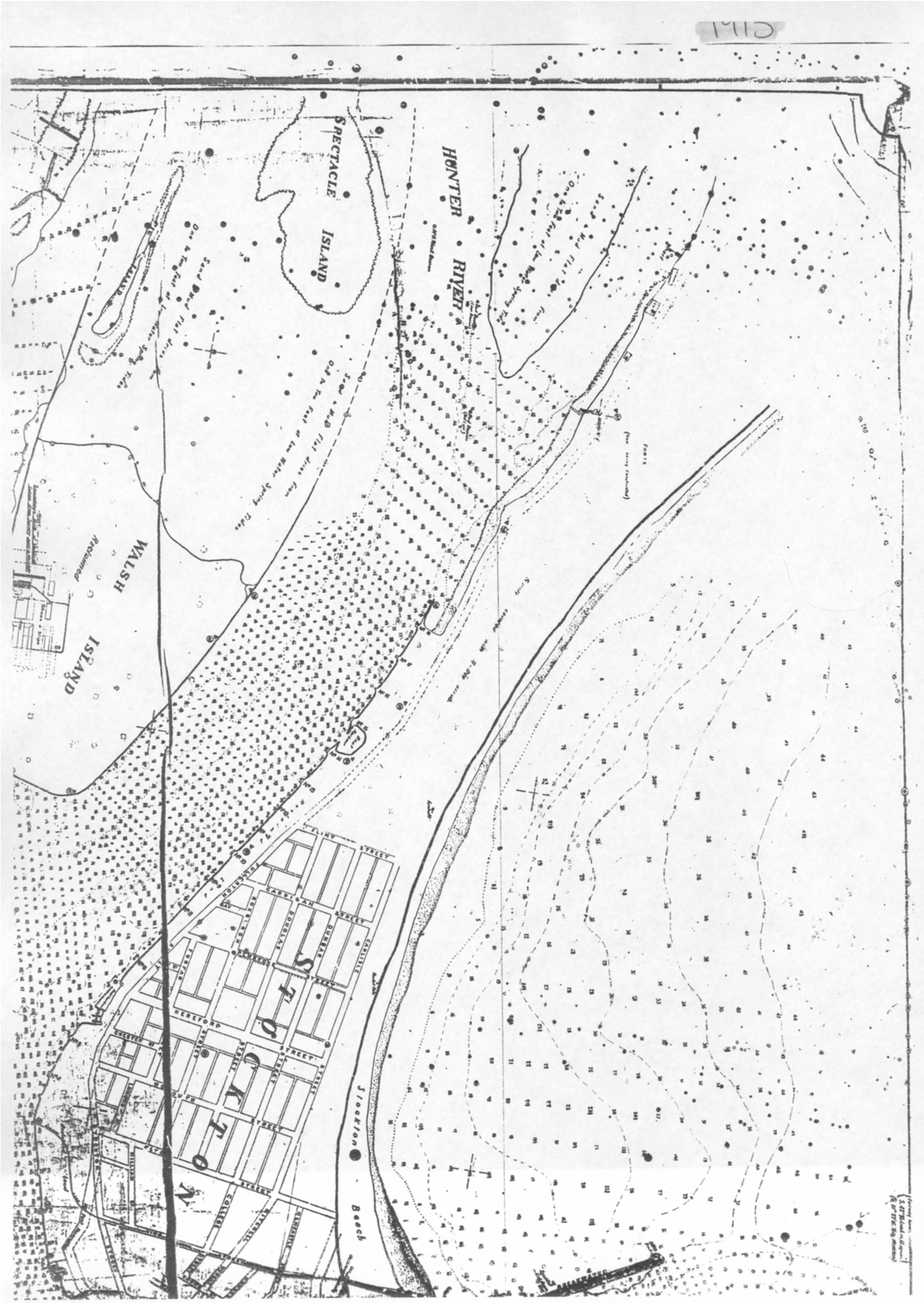
1878 Survey


OYSTER
BANK
FLINT STREET
CARDIGAN STREET
GROVE STREET
DUNBAR
CARLISLE
NORTHERN BREAKWATER
SOUTHERN BREAKWATER
AND

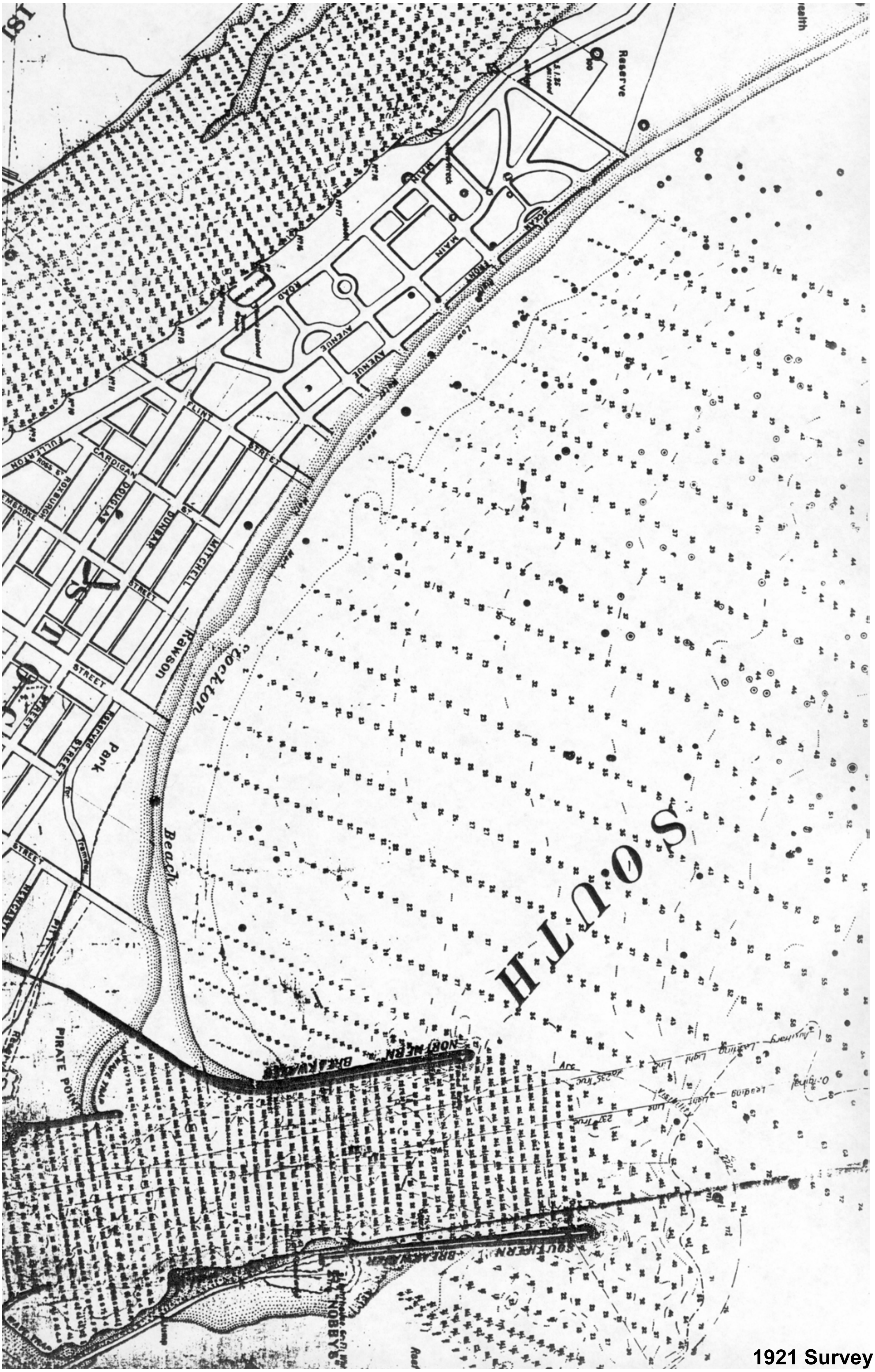
1899 Survey


1909
STOCKTON
NORTHERN BREAKWATER
SOUTHERN BREAKWATER
27155

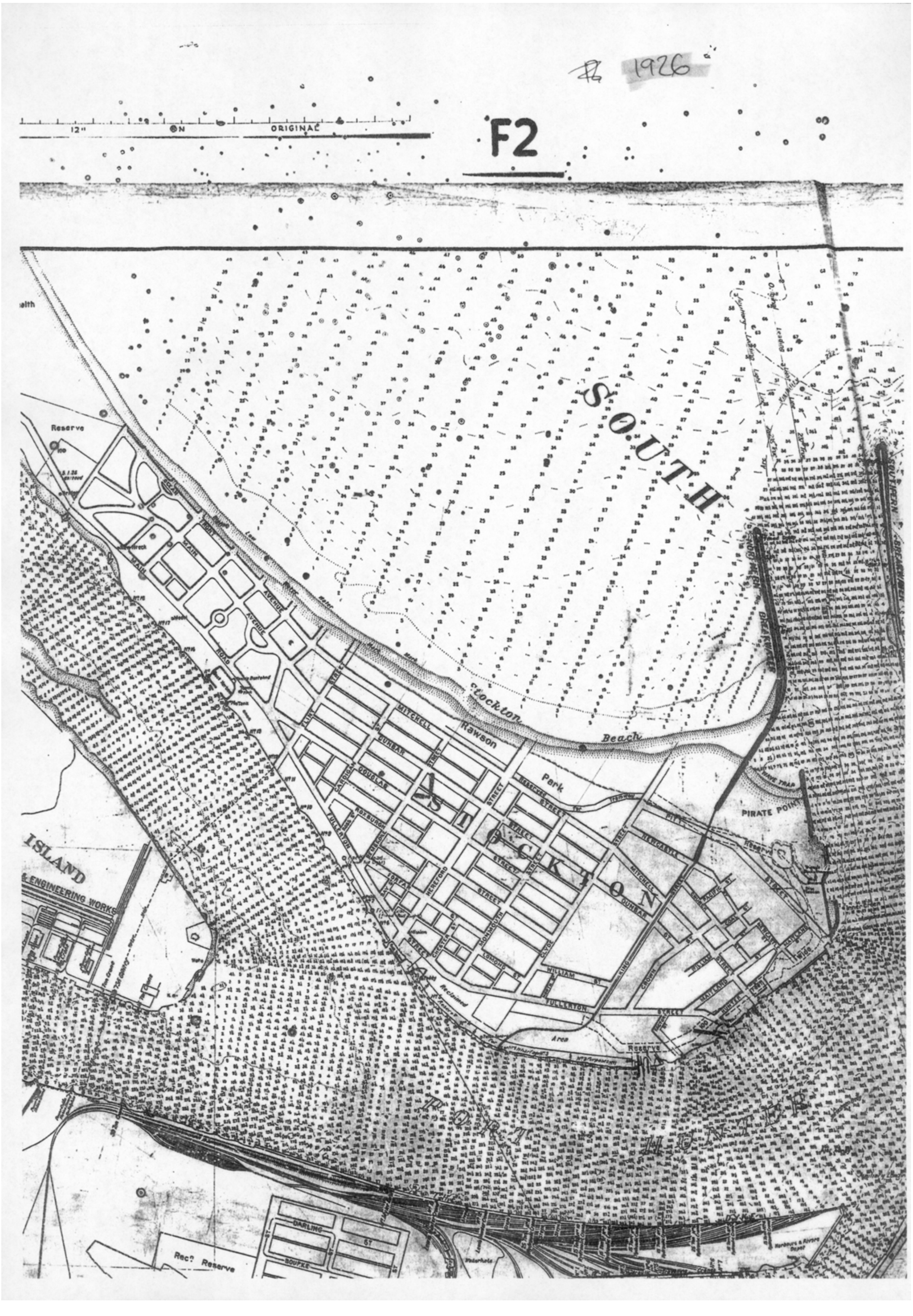
1909 Survey


1913
SPECTACLE ISLAND
HUNTER RIVER
WALSH ISLAND
Reclaimed
STOCKTON
Stockton Beach
FLINT STREET
CARDIGAN STREET
HEREFORD STREET

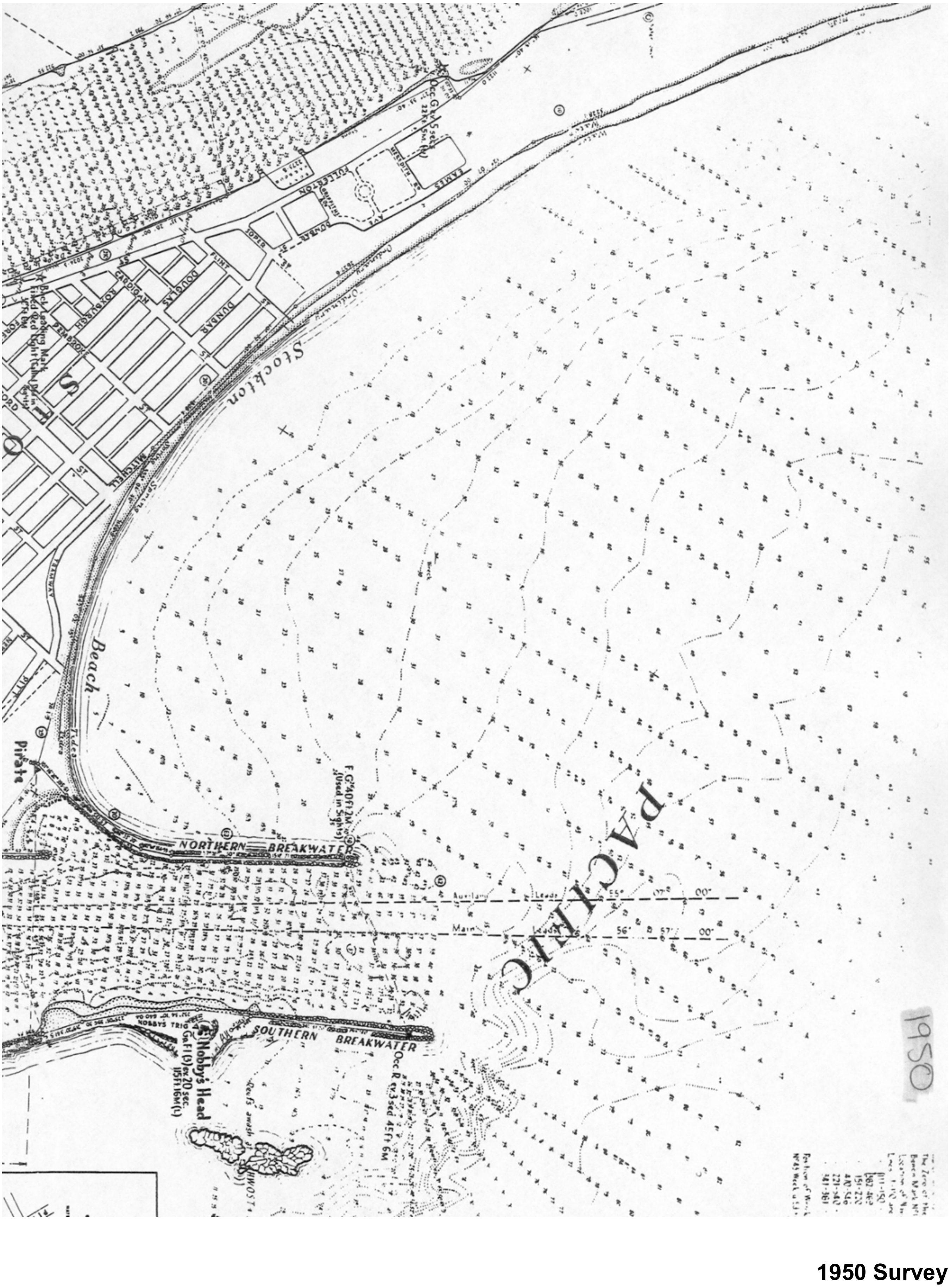
1913 Survey


SOUTH
Stockton
Rawson
Beach
Park
PIRATE POINT
NORTHERN BREAKWATER
SOUTHERN BREAKWATER
NOBBY'S
FLINT
STREET
CARDIGAN
DOUGLAS
DUNBAR
MITCHELL
FULLERTON
ROXBURGH
MAIN
AVENUE
ROAD
Reserve

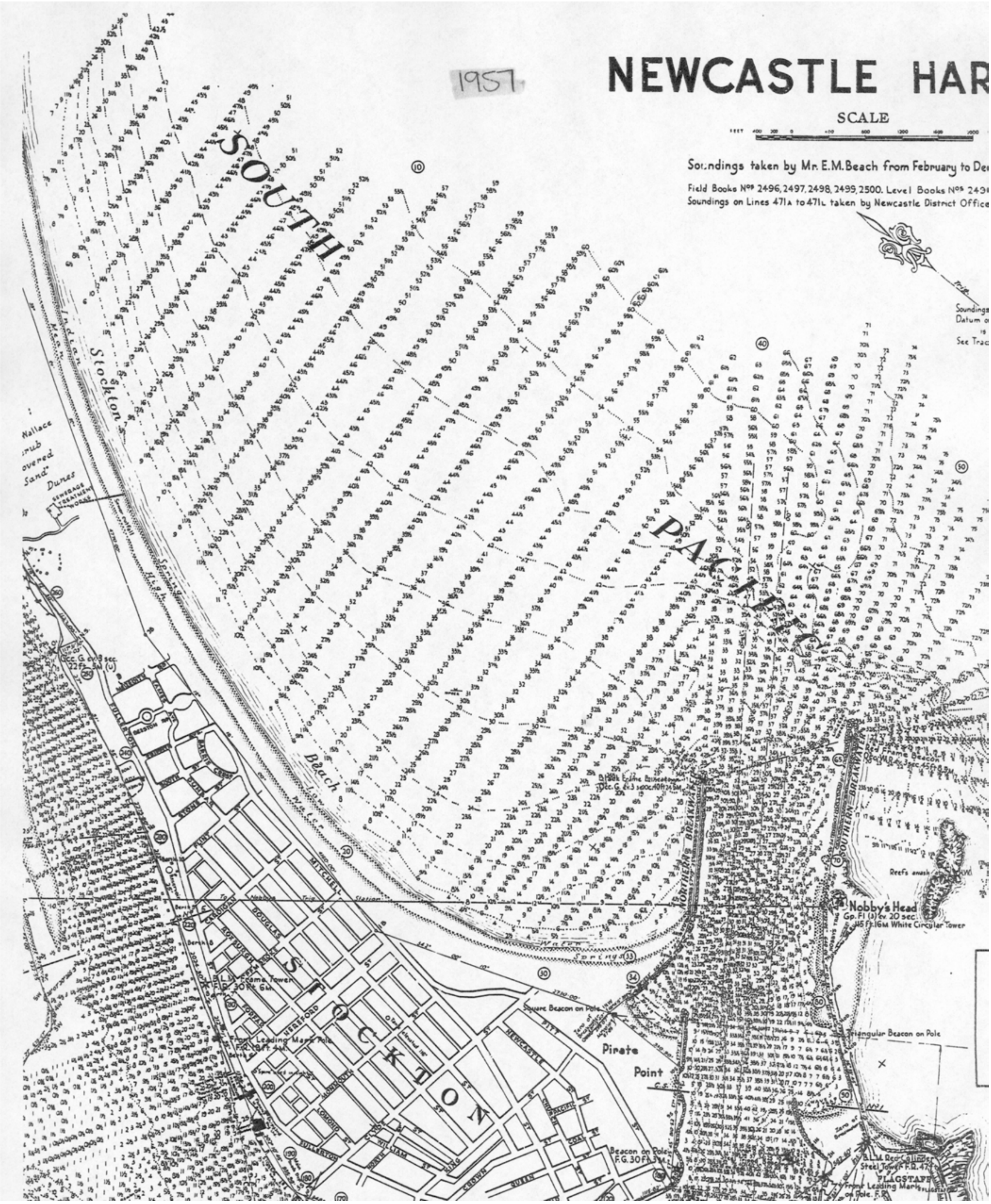
1921 Survey


1926
F2
12" ON ORIGINAL
SOUTH
STOCKTON
Stockton Beach
Rawson Park
PIRATE POINT
Reserve
ISLAND
ENGINEERING WORKS
MITCHELL
DUNBAR
DOUGLAS
FULLERTON
WILLIAM ST
PORT HUNTER
DARLING ST
BOURKE
Rec? Reserve

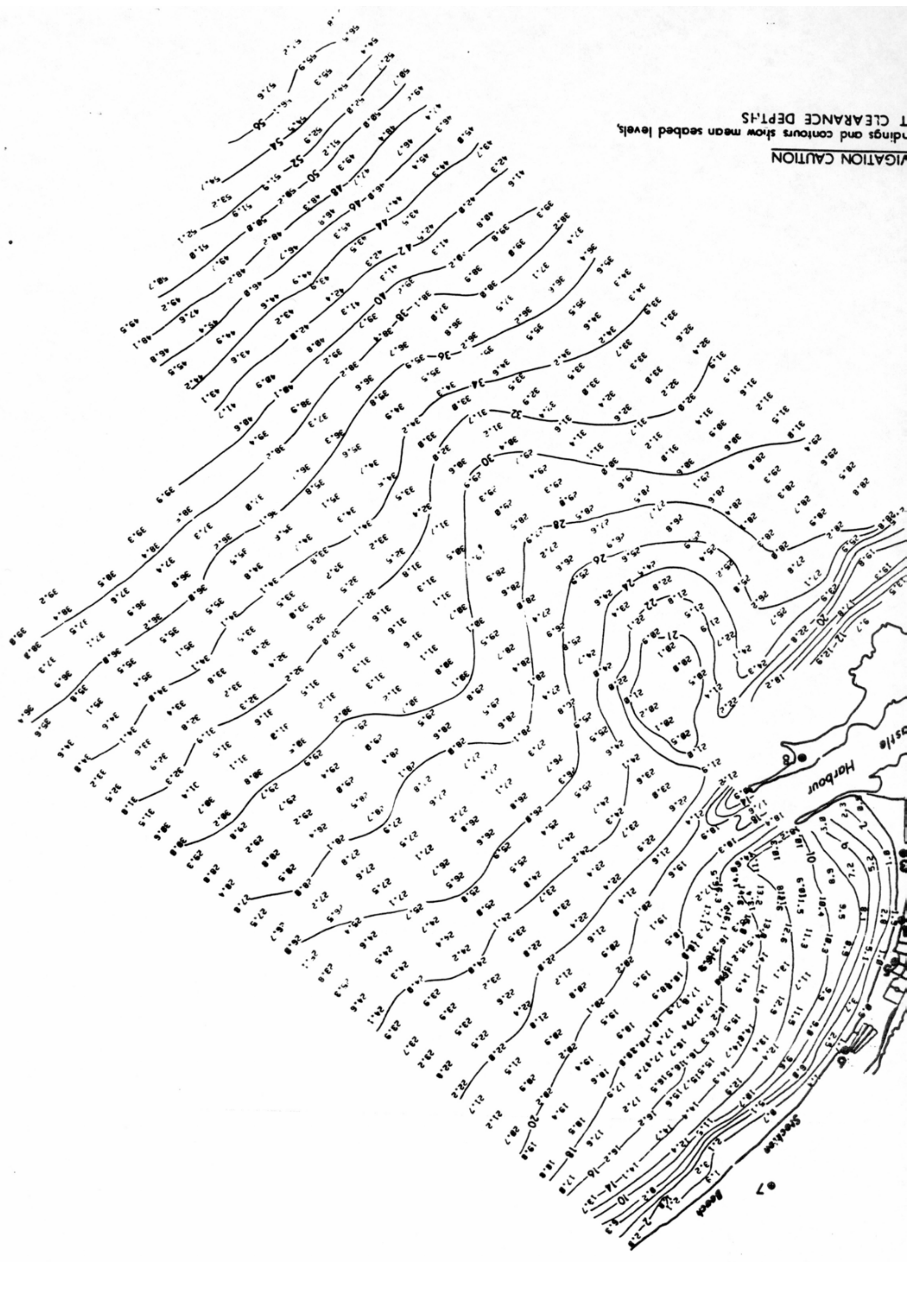
1926 Survey


Stockton
Beach
NORTHERN BREAKWATER
SOUTHERN BREAKWATER
PACIFIC
Nobby's Head
Pirate
Main Leads
Auxiliary Leads
1950

1950 Survey


1957
NEWCASTLE HAR
SCALE
Soundings taken by Mr. E.M.Beach from February to De
Field Books Nos 2496, 2497, 2498, 2499, 2500. Level Books Nos 243
Soundings on Lines 471A to 471L taken by Newcastle District Office
SOUTH
PACIFIC
Stockton
Beach
STOCKTON
Pirate Point
Nobby's Head
Gp. Fl (3) ev. 20 sec.
White Circular Tower
Square Beacon on Pole
Triangular Beacon on Pole
FLAGSTAFF
Steel Tower
NORTHERN BREAKWATER
SOUTHERN BREAKWATER
MITCHELL
NEWCASTLE
Sewerage Treatment Works

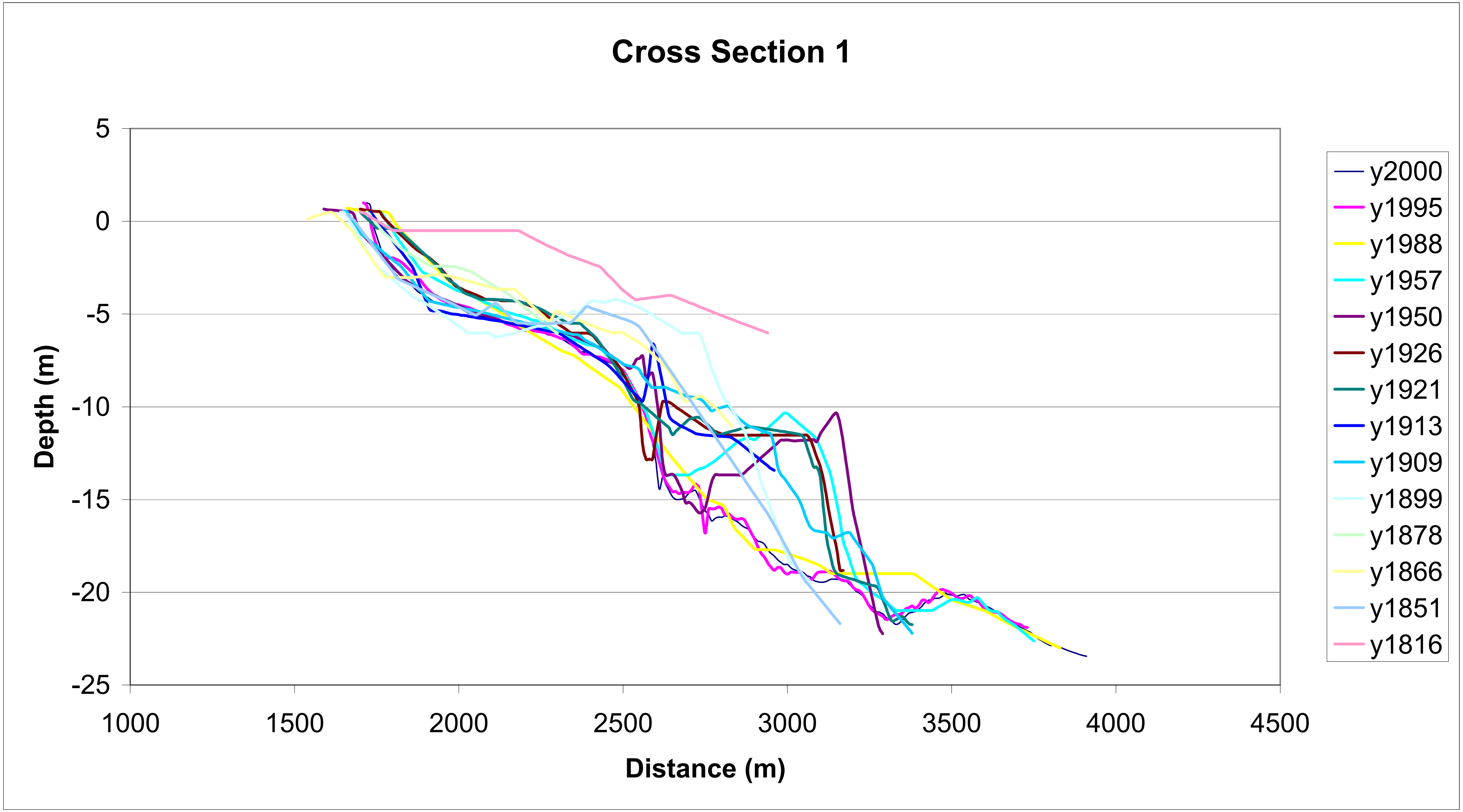
1957 Survey

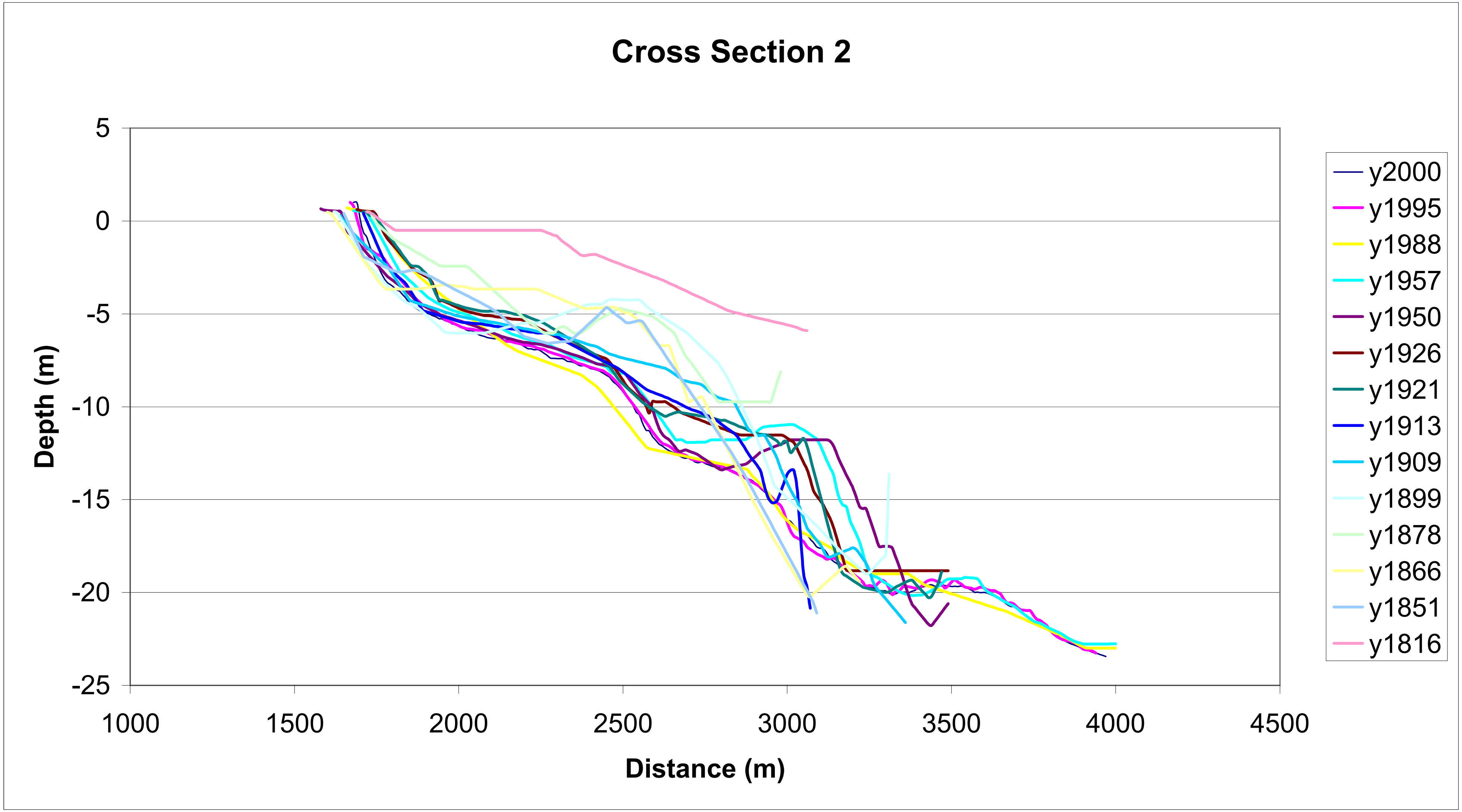

VIGATION CAUTION
ndings and contours show mean seabed levels,
T CLEARANCE DEPTHS
Harbour
Beach

1988 Survey

APPENDIX 2

Cross-sections


Cross Section 1
Depth (m)
Distance (m)
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
4000
4500
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816


Cross Section 2
Depth (m)
Distance (m)
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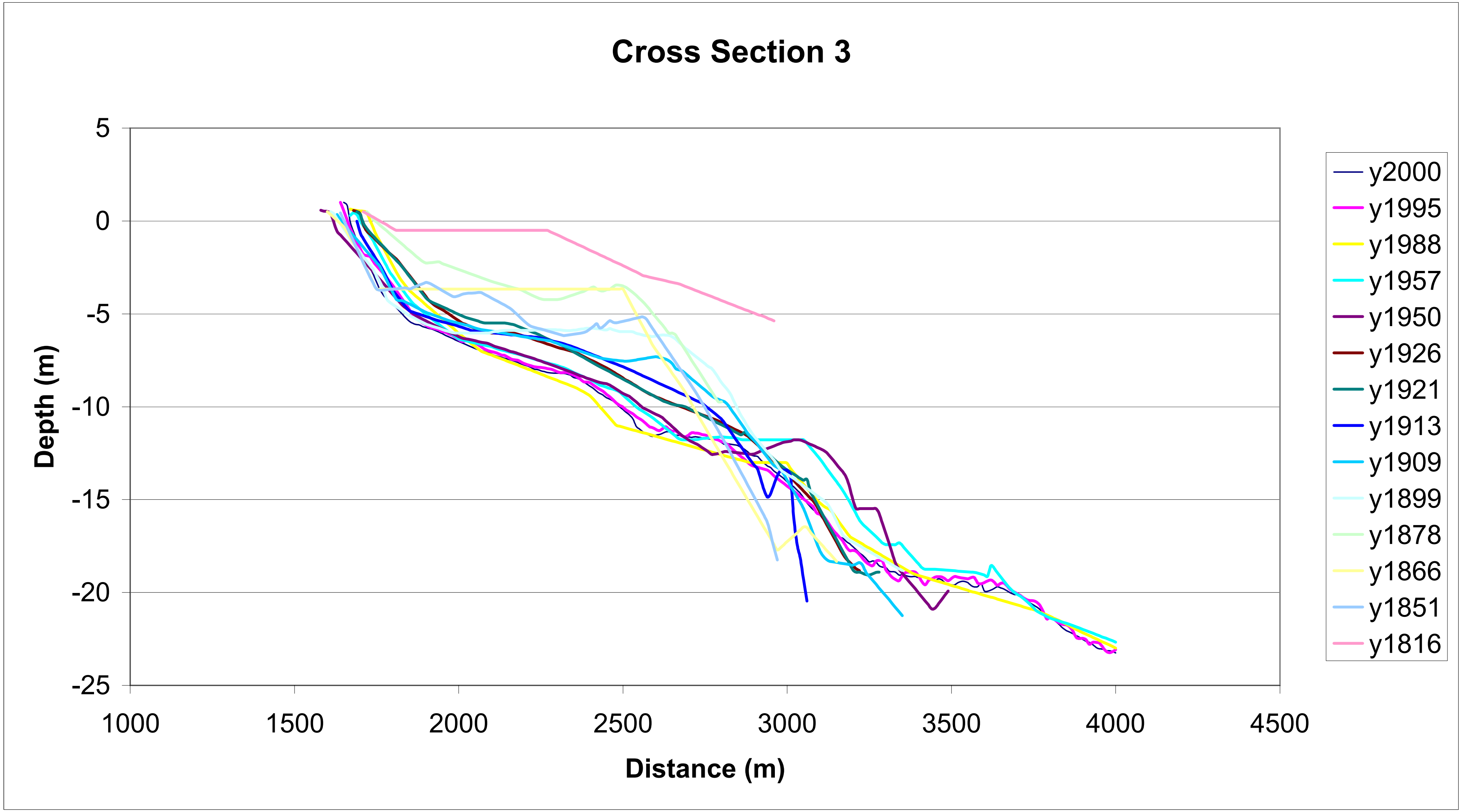
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
4000
4500
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816


Cross Section 3
Depth (m)
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0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
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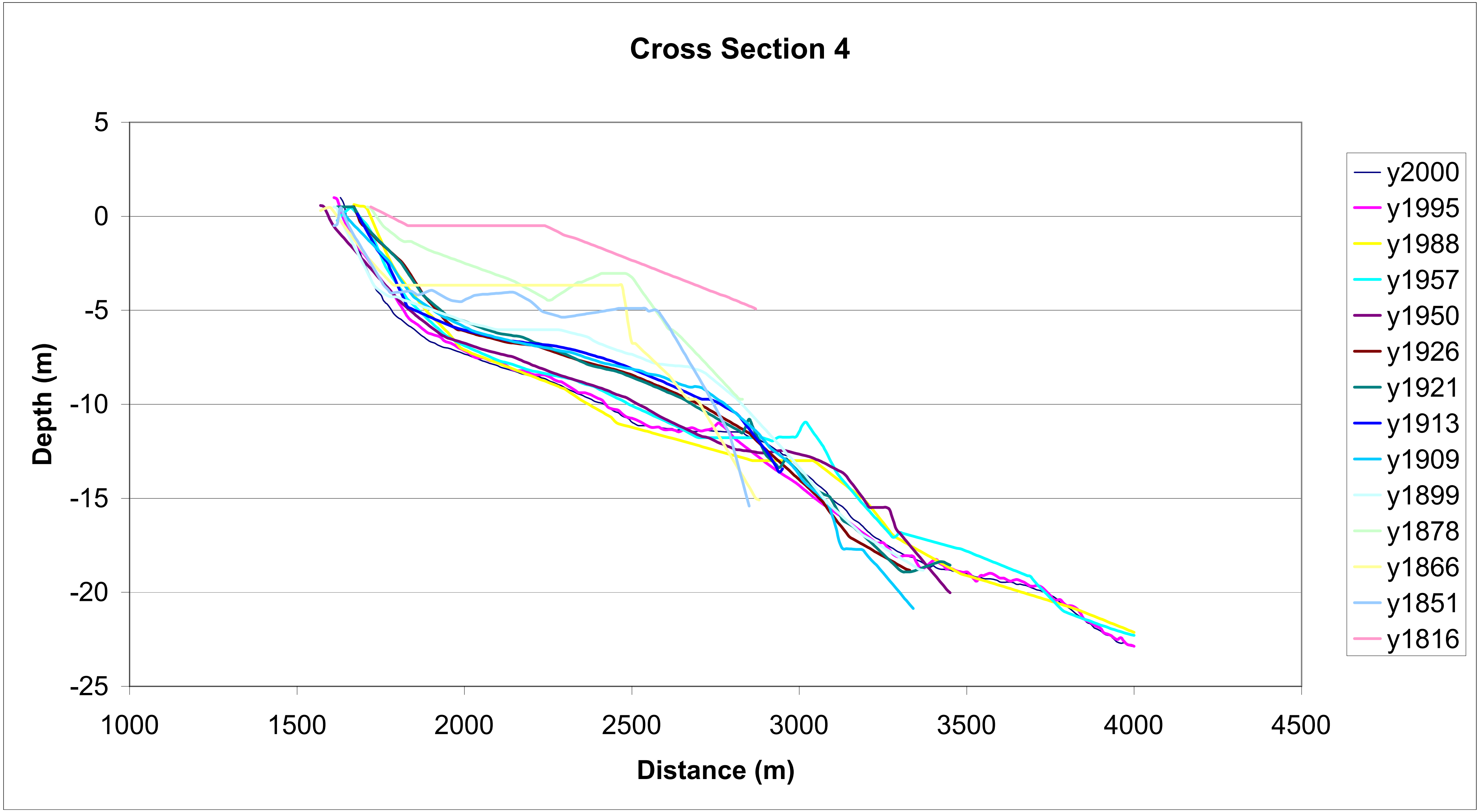
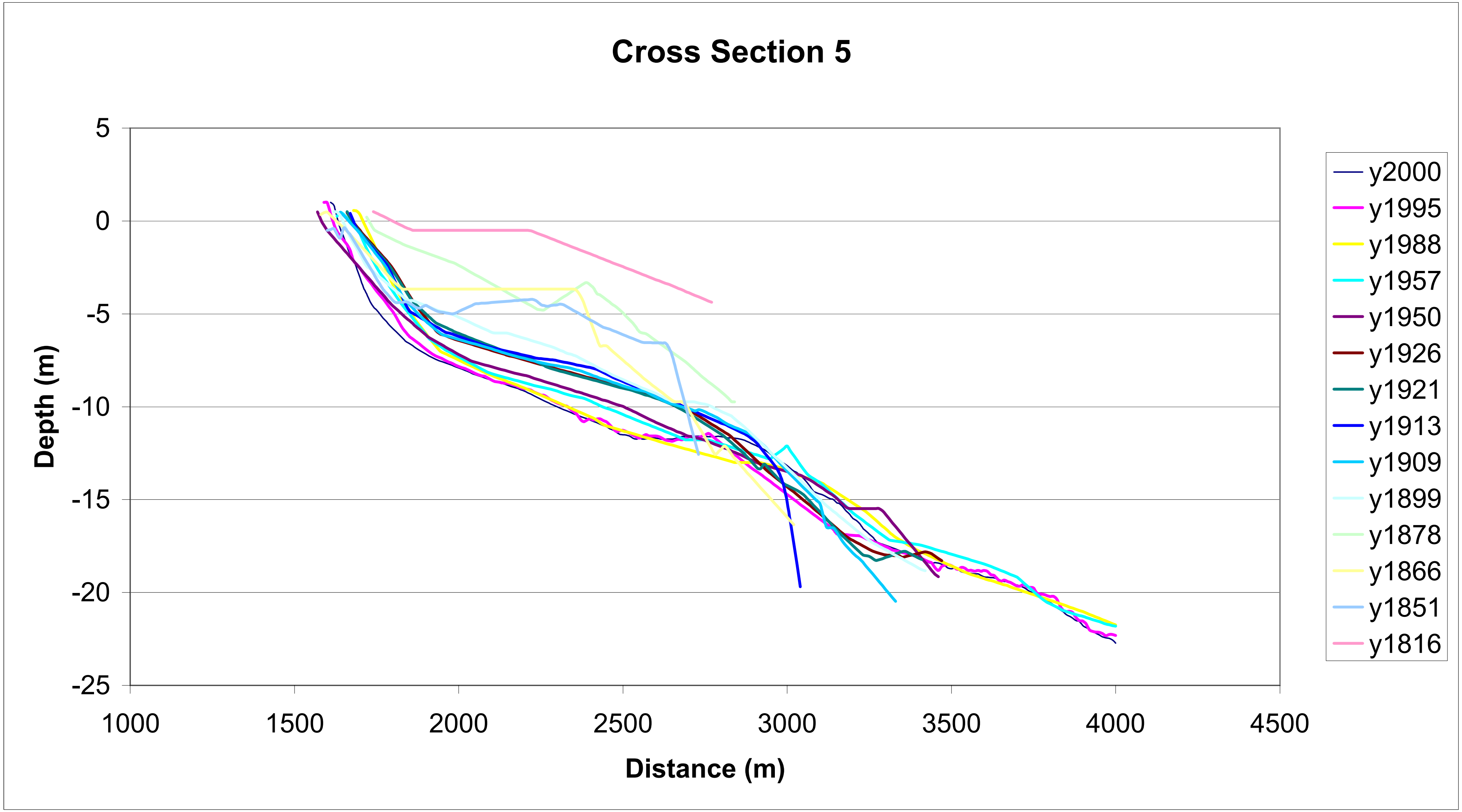
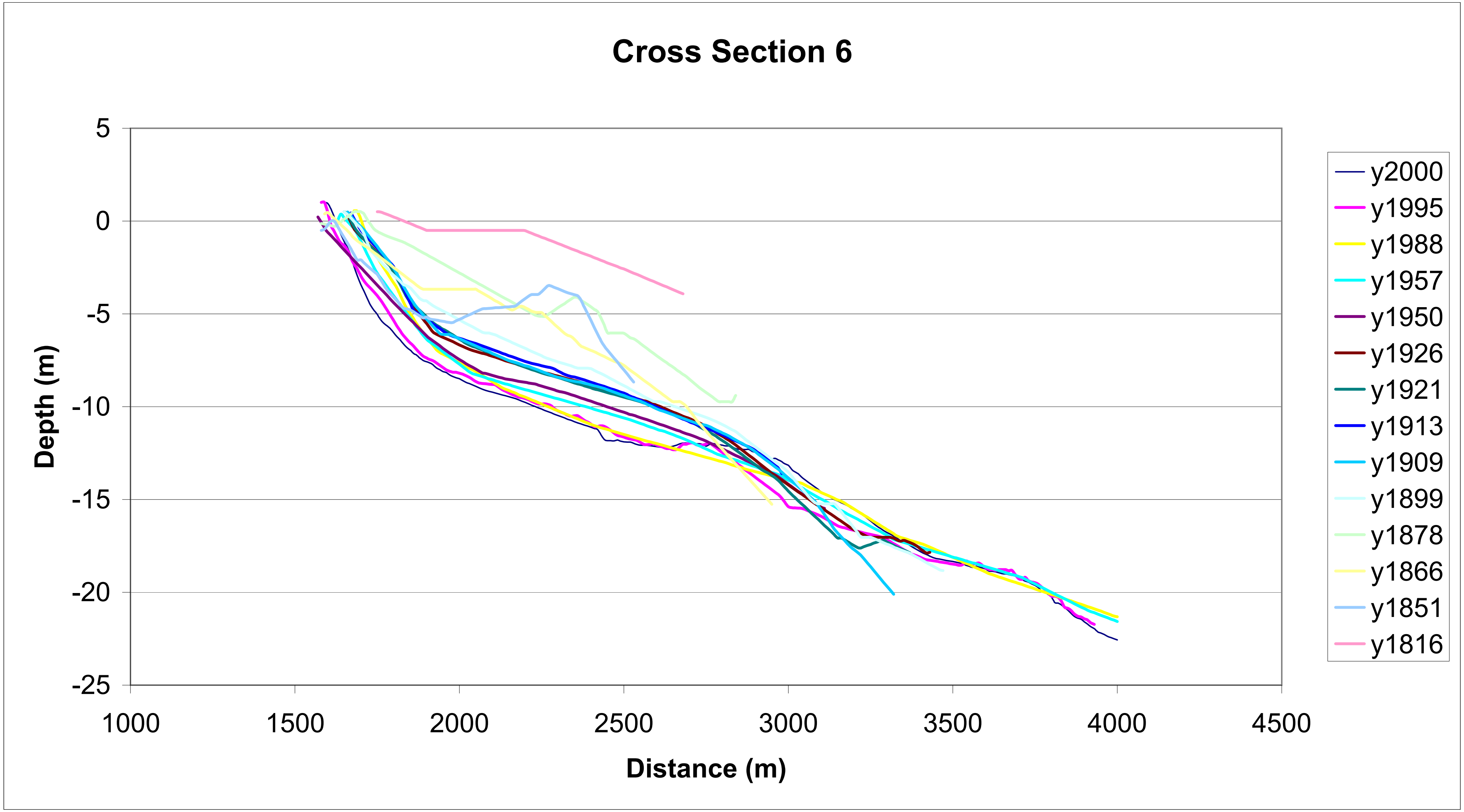
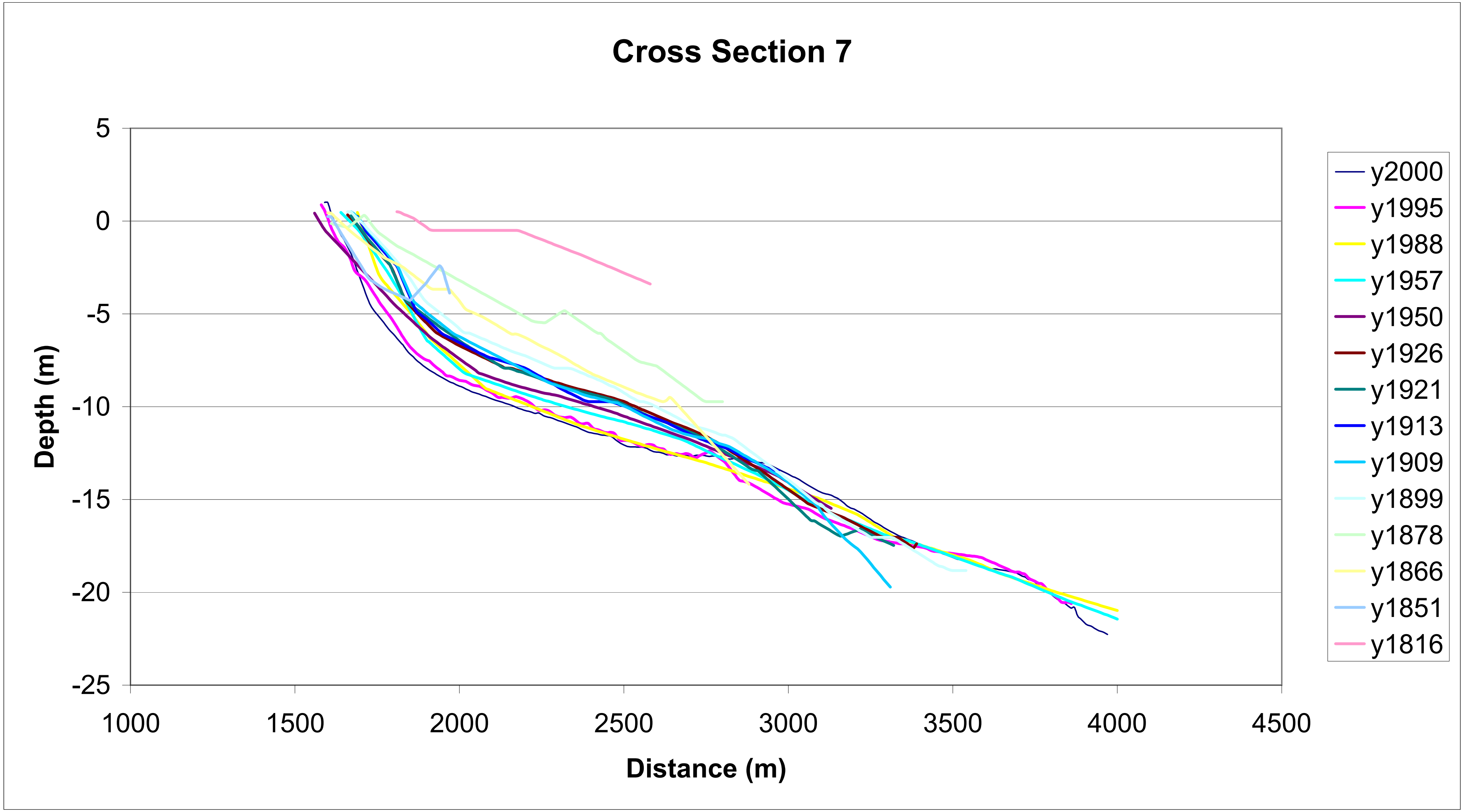
4500
Distance (m)
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816


Cross Section 4
Depth (m)
Distance (m)
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
4000
4500
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816



Cross Section 5
Depth (m)
Distance (m)
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
4000
4500
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816


Cross Section 6
Depth (m)
Distance (m)
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
4000
4500
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816


Cross Section 7
Depth (m)
Distance (m)
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
4000
4500
y2000
y1995
y1988
y1957
y1950
y1926
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y1909
y1899
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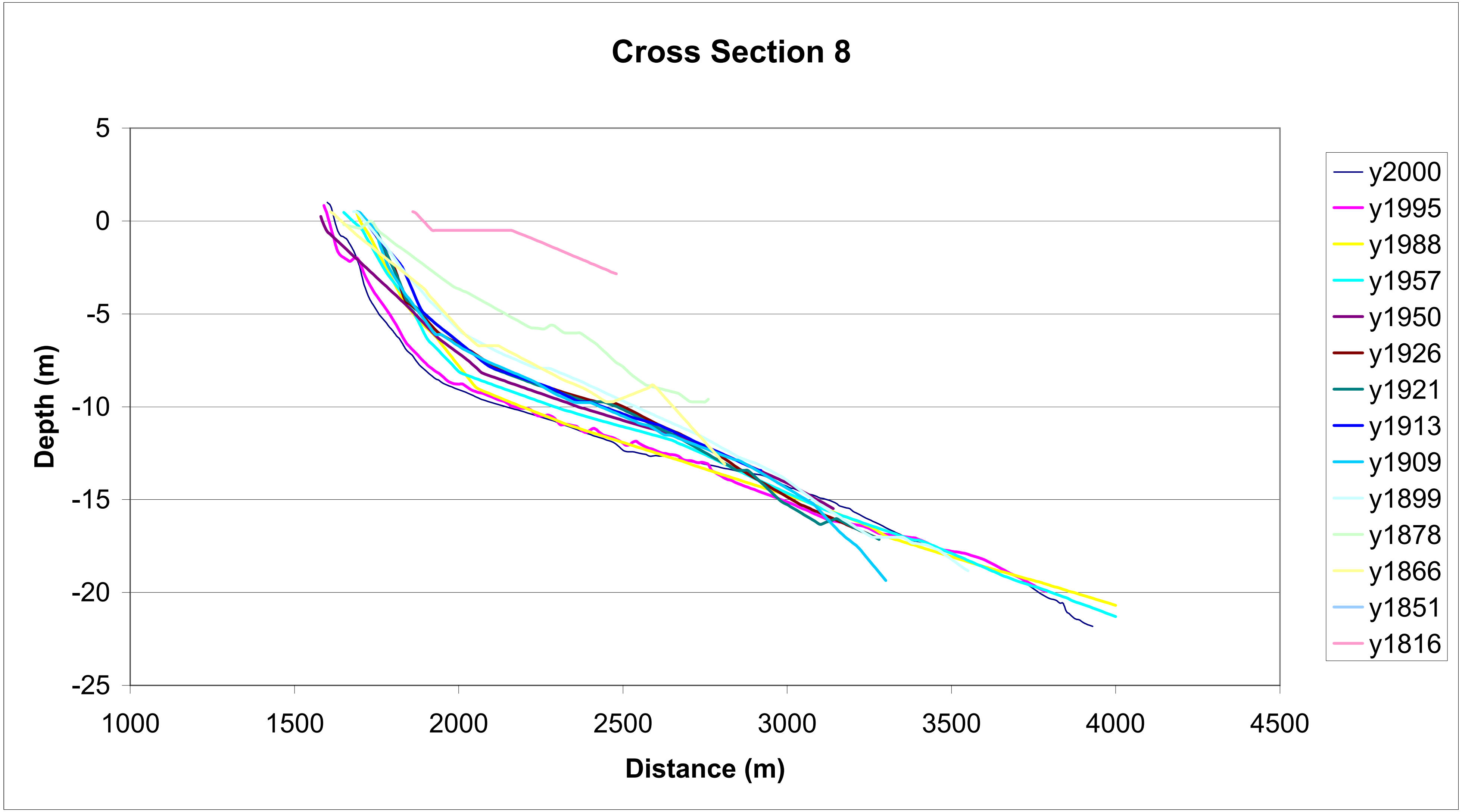
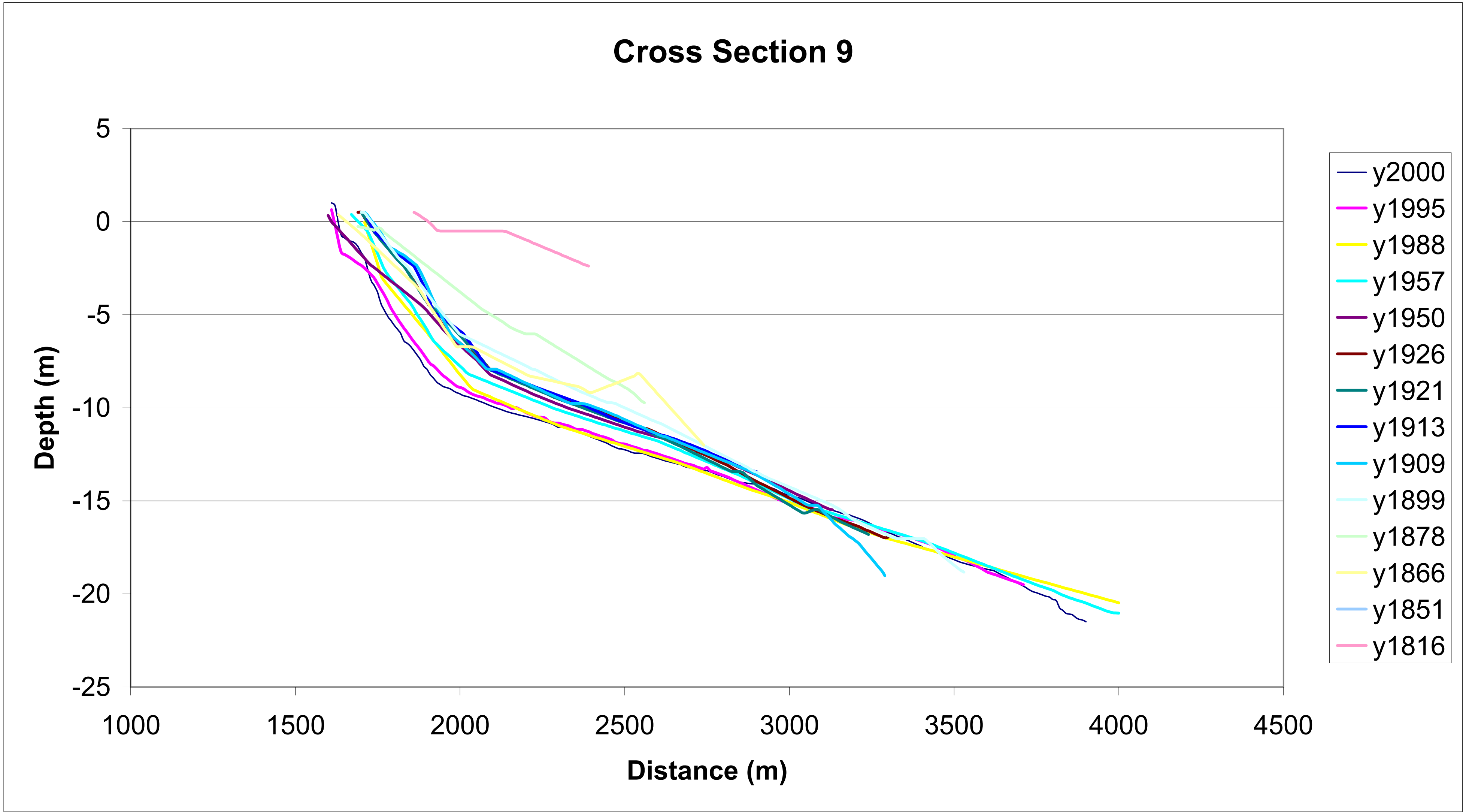
y1866
y1851
y1816



Cross Section 8
5
0
-5
-10
-15
-20
-25
Depth (m)
1000
1500
2000
2500
3000
3500
4000
4500
Distance (m)
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816



Cross Section 9
5
0
-5
-10
-15
-20
-25
Depth (m)
1000
1500
2000
2500
3000
3500
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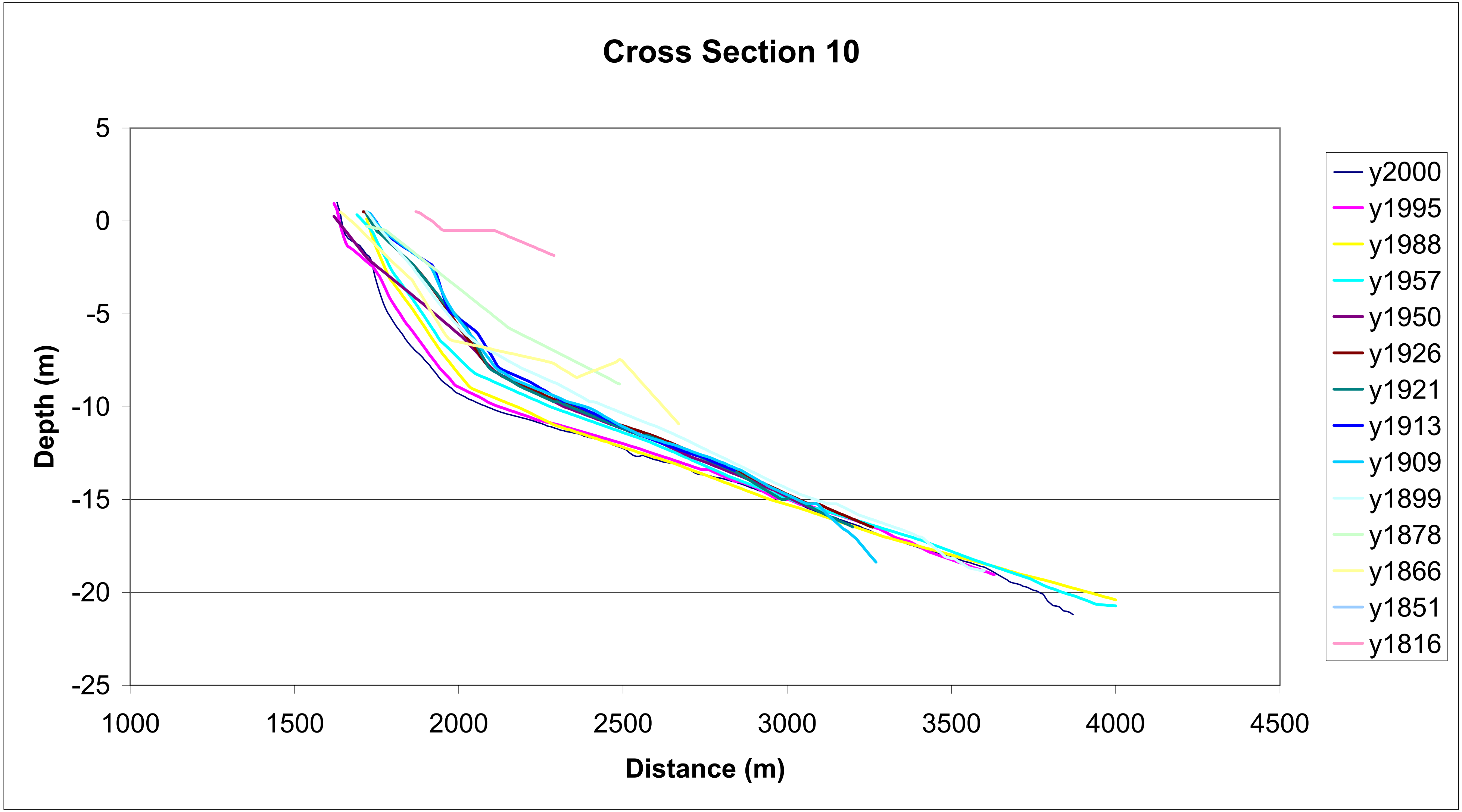
4500
Distance (m)
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816


Cross Section 10
Depth (m)
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
3000
3500
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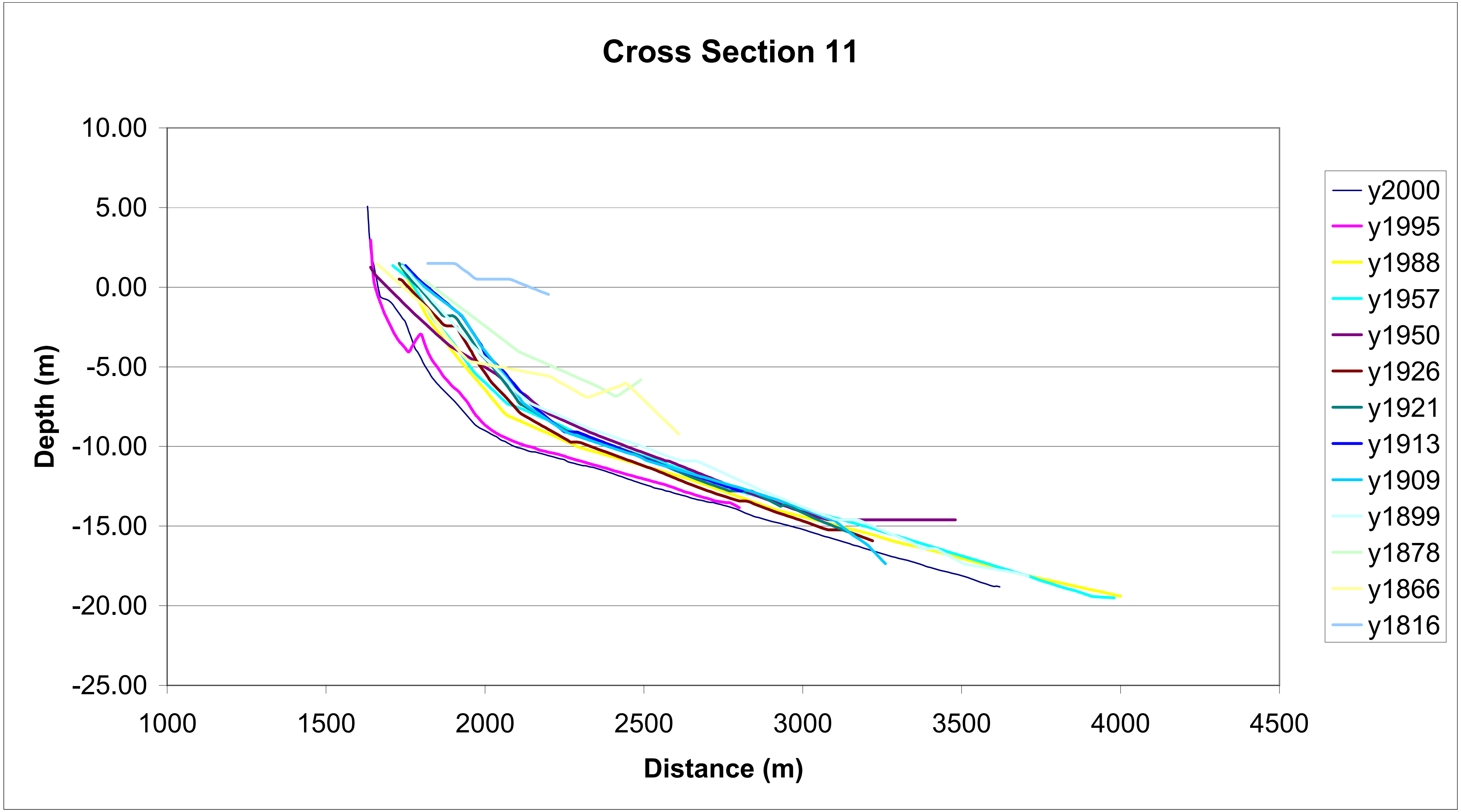
4500
Distance (m)
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1851
y1816



Cross Section 11
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
Depth (m)
1000
1500
2000
2500
3000
3500
4000
4500
Distance (m)
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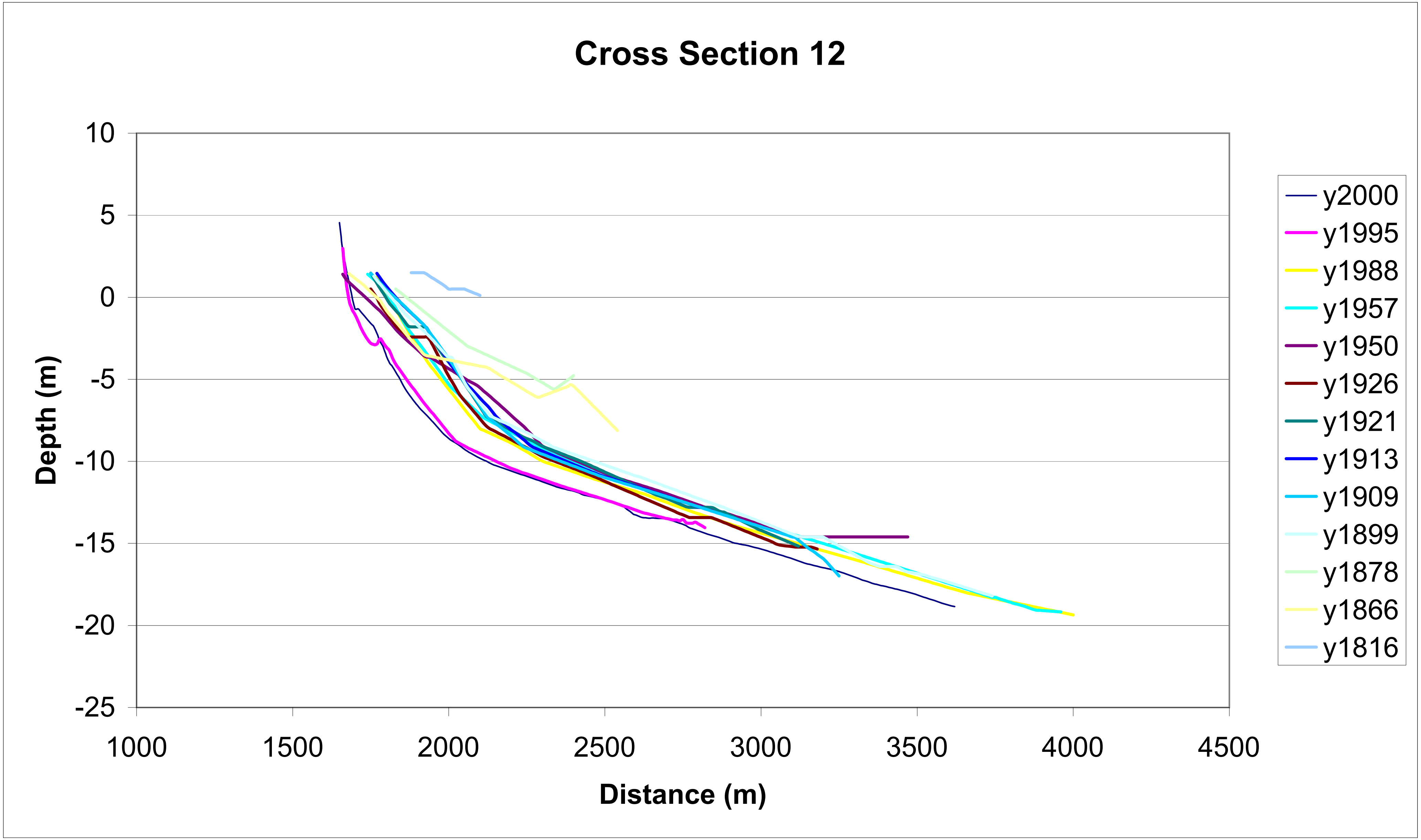
y1878
y1866
y1816



Cross Section 12
Depth (m)
10
5
0
-5
-10
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-20
-25
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1500
2000
2500
3000
3500
4000
4500
Distance (m)
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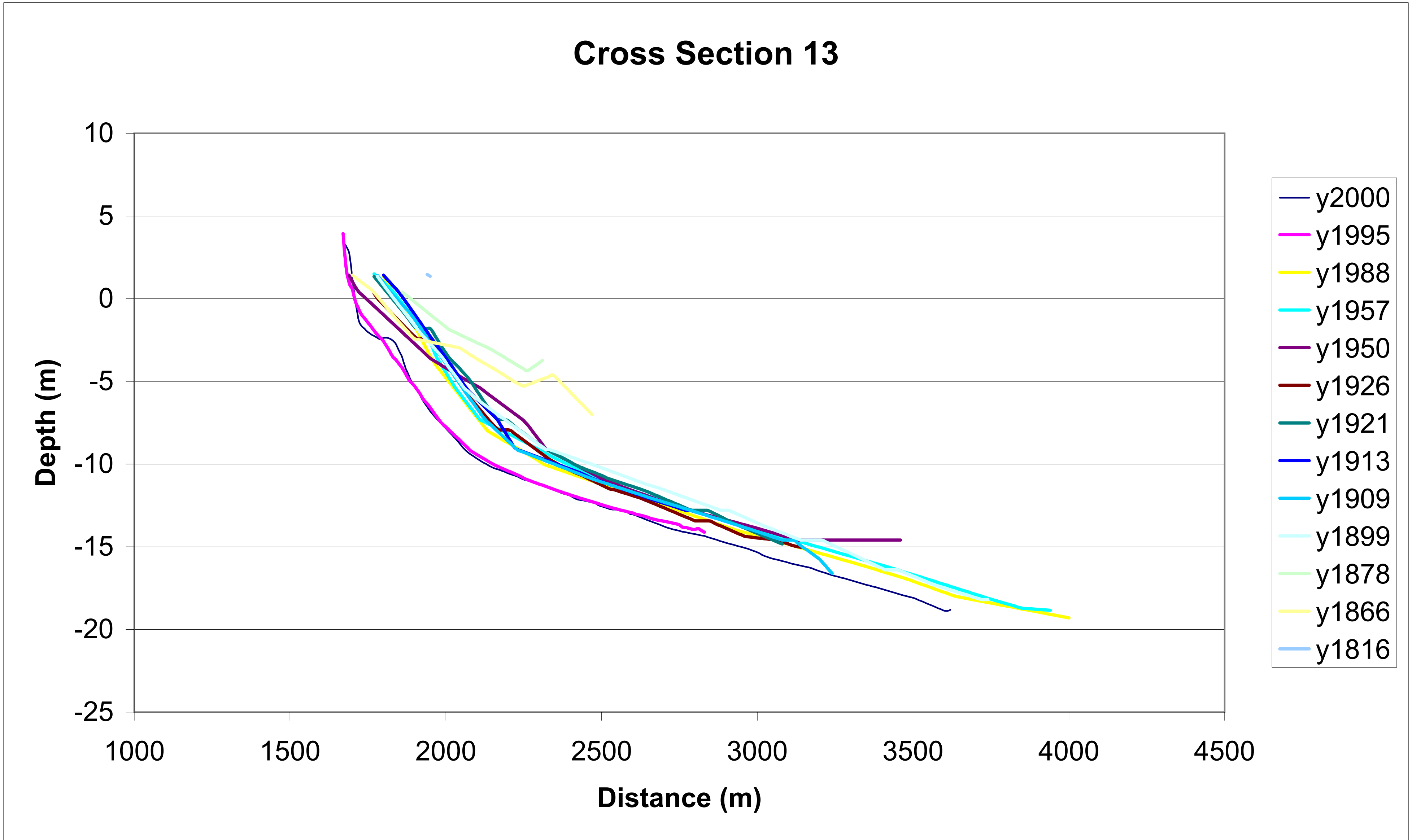

Cross Section 13
Depth (m)
Distance (m)
10
5
0
-5
-10
-15
-20
-25
1000
1500
2000
2500
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3500
4000
4500
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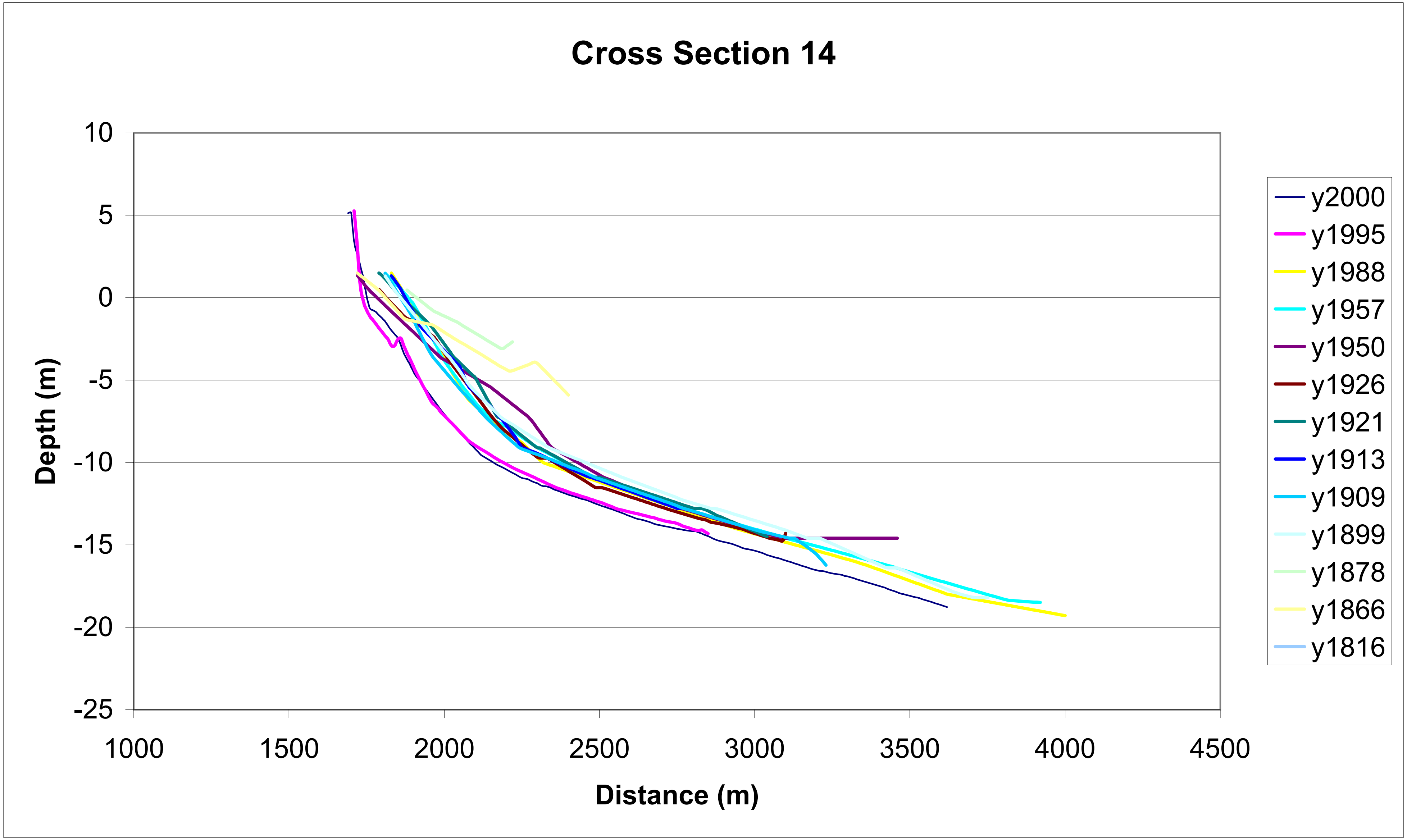

Cross Section 14
10
5
0
-5
-10
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-20
-25
Depth (m)
1000
1500
2000
2500
3000
3500
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4500
Distance (m)
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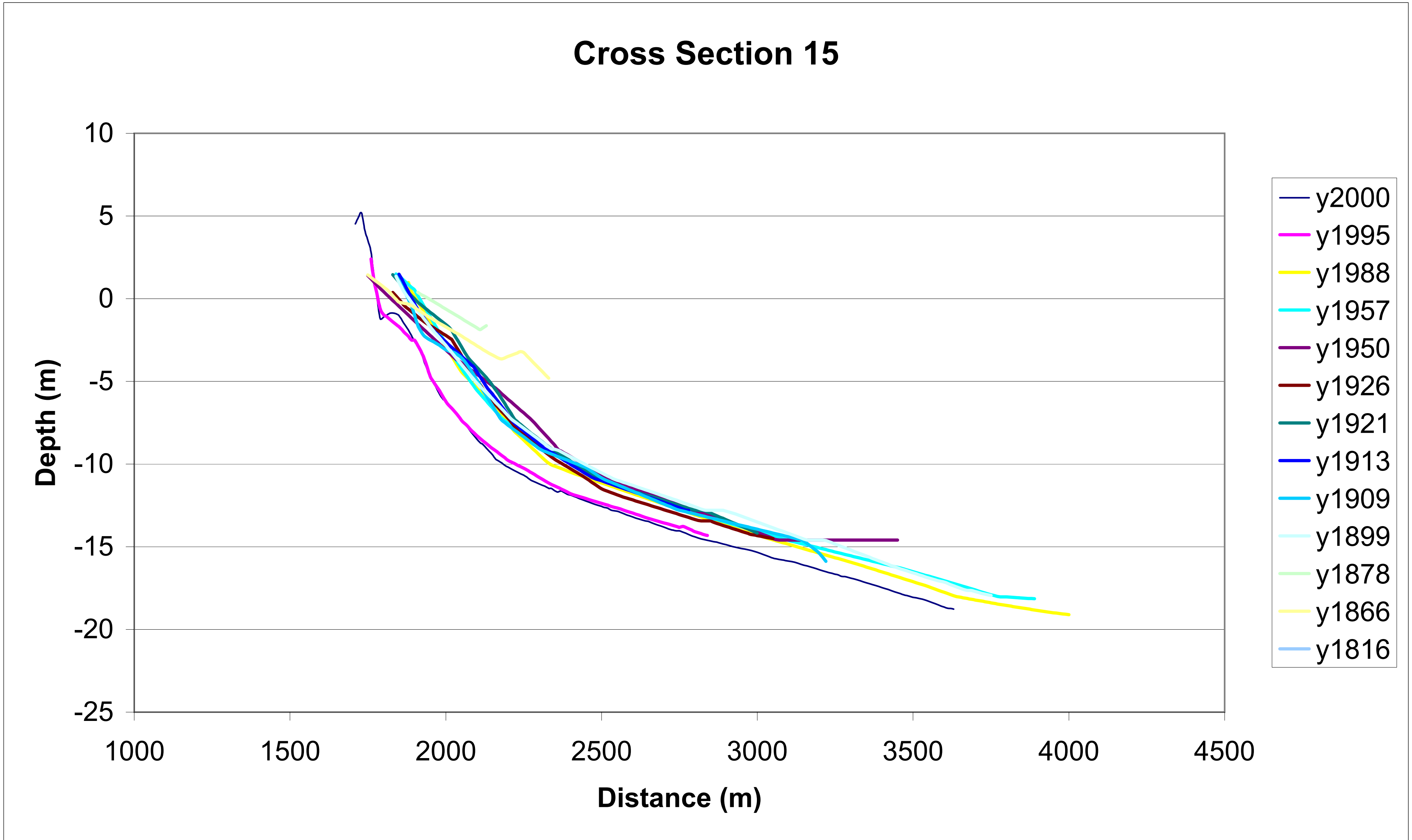
y1816


Cross Section 15
Depth (m)
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5
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-25
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2500
3000
3500
4000
4500
Distance (m)
y2000
y1995
y1988
y1957
y1950
y1926
y1921
y1913
y1909
y1899
y1878
y1866
y1816