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SWANSEA BAY (SKER) PROJECT

by

A. P. Carr and M.W.L. Blackley

TOPIC REPORT : 1

(a) INTRODUCTION
(b) LONG–TERM CHANGES IN THE COASTLINE

Report No 42

1977

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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(a) INTRODUCTION

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A P Carr and M W L Blackley

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the Department of the Environment

Institute of Oceanographic Sciences
Crossway
Taunton
Somerset

July 1977

SWANSEA BAY

'The Bay is universally allowed to be singularly beautiful and the shore very commodious for bathing ....." (Morris, 1802).

(It) 'has been compared to the Bay of Naples, and the comparison to those who have seen both, must be striking' (Anon., pub. David Jenkins, 1813).

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SUMMARY

This Report is the first in a series concerning Swansea Bay. The Introduction outlines the role of the Institute of Oceanographic Sciences in the work, together with the objectives of the research programme. Thereafter the geological and topographical background is briefly described.

The main part of the Report is devoted to a review of the documentary evidence which sheds light on the evolution of Swansea Bay and especially its eastern shore. Much of the supporting evidence is given in the form of Tables, Appendices and Figures. (Figure 1 shows the location of the places mentioned in the text). Section 3 of the text discusses the hydrographic charts, land surveys and written records, while Section 4 summarises the evidence of consultants prior to and during the 1973 Public Inquiry together with the Inspector's conclusions to the latter. Section 5 provides figures for both sea landings of sand at South Wales ports and for sand-winning from the beach along the E side of Swansea Bay. It then goes on to discuss capital and maintenance dredging at Swansea and Port Talbot.

Section 6 lists Conclusions to the Report. While these are less positive than might have been hoped they are, nevertheless, of interest and significance. Later Reports should help to clarify certain of the aspects raised.

The dune systems along the E side of the Bay do not exceed 6000 years in age. At their maximum extent, before extraction by man, they probably contained about 1.2×10^8 tonnes of sand, most likely derived from earlier dunes located further seaward rather than directly from the sea bed.

The documentary evidence provided by hydrographic charts suggests that the offshore banks have progressively changed their relative position between 1859 and 1974 but that the apparent differences in their volume are not significant. Maps, dating between the 1840's and early 1960's cover the E coastline of the Bay. They indicate that since the mid-nineteenth century there have been two main areas of change, that around the R Neath and that close to Port Talbot. Each site has been associated with civil engineering works; the Neath with a training wall built in the 1870's and the Port Talbot docks with a series of breakwaters begun in 1865 and extended several times thereafter. Recession of low water mark is particularly noteworthy, but there have been local areas of accretion of which Crymlyn Burrows is the most important.

From Witford as far S as Morfa Mawr the beach gradient has become progressively steeper but S of that again the position is indeterminate.

The historical evidence from about 1100AD onwards emphasises the long-term variability of this area of coast both in the context of the flooding and reclamation of the marshes and in the instability of the sand dune systems.

There was disagreement amongst the various consultants prior to, and during, the 1973 Public Inquiry as to the cause of erosion of the beach between Port Talbot and Sker Point. However, its existence was generally accepted. Increasing concern about the problem was shown over time.

Between 1970 and 1976 an average of just over 4×10^5 tonnes of marine dredged sand and gravel was unloaded at Swansea and Briton Ferry each year, mostly derived from Nash Bank. This compares with an annual average of 1.15×10^5 tonnes from the E foreshore of Swansea Bay over the period 1970-73. Calculations, based on figures for the whole foreshore extraction period (approximately 1934-73) suggest a lowering of the beach by up to 0.25m, assuming uninterrupted longshore drift between Port Talbot and Sker Point, uniform distribution across the beach, and no gain or loss offshore.

Sand-winning from the dunes is of longer standing and still continues. It has been of a similar order of magnitude to that of the foreshore.

Capital dredging for the Port Talbot tidal harbour was 11.2×10^6 tonnes. Estimated maintenance dredging for Port Talbot and Swansea between 1960 and 1976 has been comparable in volume of sediment involved.

Swansea Bay (Sker) : First Topic Report

Preface

Because this is the first Topic (as distinct from Progress) Report it is necessary to provide a general Introduction to the project as a whole prior to discussing the long-term changes along the eastern shore of Swansea Bay and the banks offshore. This Introduction is divided into two parts. The former states the Terms of Reference and the objects of the research programme. The second part describes the topography, geology, etc., both onshore and offshore, but only in sufficient detail as to enable the subsequent studies to be understood. Relevant details will be filled in in later reports.

(a) INTRODUCTION

1.1 Terms of Reference

Early in 1973 Glamorgan County Council, as it then was, approached the former Unit of Coastal Sedimentation regarding erosion along the foreshore of the E part of Swansea Bay (Figure 1, which shows the principal places referred to in the text). This was formalised in a letter dated 12 June 1973, part of which is reproduced as Appendix 1. Subsequently it was agreed that the Institute of Oceanographic Sciences' Taunton Laboratory (into which the UCS had by then been incorporated) would write a preliminary report for the Council suggesting work which needed to be undertaken to assess the reality and extent of the erosion and its possible cause(s), the report being without a guarantee that IOS could undertake the work. The Summary and Conclusions of the Report are attached as Appendix 2.

IOS subsequently decided that many of the aspects of the problem were of widespread interest and applicability and that the subject would be very suitable for a type study. Furthermore this study could be fitted into the organisation's overall research programme. Because of its broad relevance the Department of the Environment agreed that the project should be included in their programme of commissioned work initially covered by Memorandum of Agreement Contract No 481/50, covering the period April 1974 - March 1977 and extended thereafter.

There are thus two levels at which the study may be viewed, that of the immediate area and its specific problems, and in the wider context of the inter-relation between coastline and offshore, in general. It is in this latter context that a contrasting site for a second study was later selected on the East Anglian coast.

In December 1973 a Public Inquiry was held by the Welsh Office into the Borough of Port Talbot Coast Protection Order 1973 and the same authority's Interim Coast Protection Order. These orders had had the effect of prohibiting the extraction of beach material from the foreshore, at least in the short term. While upholding the Orders the Inspector wrote that: "A detailed study of the foreshore and the sea-bed conditions is necessary .... before long-term conclusions can be reached". Therefore: "The Coast Protection Authority shall undertake or cause to be undertaken a detailed study of the evolving beach conditions, the offshore sea-bed conditions and the potential sediment budget available for beach replenishment". A more extended record of the Inspector's conclusions and recommendations forms Appendix 3. (See also Section 4.2).

1.2 Objects of research

The objectives of the research project in Swansea Bay can therefore be outlined as follows: Locally,

1.2.1.1 To try and assess the causes of erosion along the foreshore and the proportionate responsibility of the potential factors (land reclamation near Swansea, construction of training walls along the Neath estuary; the building of the Port Talbot tidal harbour; extraction of sand and gravel from the foreshore and offshore banks; and the inhibiting effect on coarse sediment bed-load transport by silt spoil deposited in the bay).

1.2.1.2 To calculate the amount of sediment reaching the beach from offshore; its particle size range; and the variability in volume dependent upon prevailing physical conditions. In the specific context of Swansea Bay this particular problem is probably only solvable qualitatively because of the environmental variability and conflicting evidence.

These two questions have wider spatial relevance but the Institute's main concern, reflected in the financial support provided by central government (DOE) can be outlined as follows:

1.2.2.1 To identify, and where possible isolate, the processes responsible for erosion, accretion and transport of sediment; to assess their relative importance with a view to concentrating upon the most critical aspects. To determine the nature of sediment circulation cells; the extent to which they are self-contained, and the effect of particle size upon this.

1.2.2.2 To develop and evaluate methods and techniques for the study of the coastline and the offshore zone and determine the most useful (ie least ambiguous) forms of analysis.

1.2.2.3 To attempt quantification of the various processes with the aim of producing a realistic sediment budget.

1.2.2.4 To understand the overall system sufficiently well so as to allow prediction of the effects of altering various conditions and parameters.

1.2.2.5 Where these goals prove impossible, to identify the precise difficulties in order that research may be directed towards their solution.

These broad objectives are both ambitious and long-term. The Swansea Bay project can only be used as a preliminary step towards their solution.

1.3 Programme of research

The Swansea Bay study has incorporated three different but complementary approaches. These are the examination of historical and other records; the acquisition of data from field equipment and experimentation

and, finally, the interpretation and synthesis of the information so acquired in order to try and establish causes. There is thus a systematic progression from description to interpretation, the latter in as quantifiable a way as possible but largely using existing methods. (It is the task of another team in the Sedimentation Group of the Institute of Oceanographic Sciences to look at basic research into transport mechanisms and to develop new analytical methods).

In the specific Swansea Bay context there was a prime need to confirm the reality of the problem of coastal erosion and to see, if it existed on a significant scale, to what extent it was of recent origin. Hence the initial desk study concentrated on the documentary records and it is this subject which forms the main part of the present Report. Having established that the problem was a genuine one the research programme then developed a two-pronged attack. One approach was to describe the area using geological, geophysical and other surveying techniques. Because the coastline and offshore are intimately related any such investigation must include both. The examination of the physical background provides a basis on which the second aspect, process data and experimental work, can be developed. The main emphasis of the latter has been the collection of wave data, both from a Waverider buoy and seabed pressure units, and the deployment of recording current meters at a number of sites and depths during representative summer and winter periods. Experimental studies, using sand labelled with fluorescent dyes on the beach, and with radioactive tracer offshore, have helped to clarify and complement these hydraulic data. Both approaches have been closely linked and, indeed, for the beach experiments especially, synoptic studies of the physical processes and sediment movement have been made.

The data and analysis of the various aspects will be the subject of a series of Topic Reports of which this is the first. It is envisaged that future Reports will deal with the evidence for the geology and sediment distribution both offshore and onshore; beach stability; wave data; tidal currents; and the relation of offshore sediment movement in relation to observed tidal data and the wave climate. Finally, there will be a Report which is essentially to be a synthesis of the remainder of the series and will attempt to assess the significance of the various sources of information as part of a composite whole. It is intended that this should be an analysis of the cause or causes of the erosion problem in quantitative form.

The various aspects of the research programmes are all necessary and inter-dependent.

The Institute of Oceanographic Sciences commenced work on research in Swansea Bay in mid-1974. It is anticipated that the analysis of the study, under its present terms of reference, will be completed towards the end of 1978.

2. Description of the Research Area

2.1 Geology and Geomorphology

The research area is shown in Figure 1. It is bounded by the coastline on W, N and E sides. The southern limit has been drawn immediately S of Scarweather Bank and thence, from the western end of the Bank, to the Mumbles headland. Work has been concentrated in the eastern half of this area.

2.1.1 Structure, bedrock and glacial deposition

Much of the geological information contained in this Section of the Report is based on the appropriate regional memoir by the Institute of Geological Sciences.

The land area bounding Swansea Bay can be divided into three geographical units, the Gower Peninsula in the west, the plateau of the South Wales coalfield in the north and the Vale of Glamorgan in the east. The dominant rocks of the region are those of the Carboniferous system, the embayment itself being cut in the less resistant Lower and Middle Coal Series and Millstone Grit Shales.

At the beginning of the Carboniferous period the rocks of the area underwent intense Hercynian folding forming a large synclinal structure in the Coal Measures of the South Wales Plateau region. The massive micaceous sandstones and grits of the Pennant Measures form a southern escarpment of this plateau region and back the coastal lowlands of the Vale of Glamorgan. This scarp slope can be traced from Port Talbot through Swansea and across the neck of the Gower peninsula. Further south, in the Gower itself, the folding was more intense with the main anticlines trending ESE-WNW. The Devonian conglomerates and sandstones were brought to the surface in the cores of the anticlines as a result of these earth movements.

In the Vale of Glamorgan the rocks are mainly limestones and shales of Lower Lias and Carboniferous age with the folding trending more E-W. Isolated outcrops of Triassic conglomerates and breccia are found in the Sker Point area. Intense folding also occurred in certain narrow belts. These included the Neath and Swansea Valley disturbances which, while they are of Caledonoid origin, reached maximum development in late Carboniferous times.

Earth movements in Miocene times downwarped and down faulted the Bristol Channel area. Later, probably during the Pliocene, periodic marine inundations of the land led to the formation of a series of erosion platforms at varying heights. These platforms are particularly well developed in the Gower and Vale of Glamorgan areas where they cut across the underlying geological structures.

Little remains of any of the deposits that were laid down between the end of the Carboniferous period and the onset of the glaciations in the Pleistocene. The morphology of Swansea Bay has been greatly modified by this glacial action and the deposition of Pleistocene sediments. At least two periods of glaciation can be detected in South Wales (Bowen, 1970), where the Older Drift is separated from the Newer Drift by a warmer interglacial period. During the first glaciation Irish Sea ice extended eastwards along the depression of the Bristol Channel. Meanwhile ice from the local Welsh ice cap was flowing southwards across the low coastal region and out into the Bristol Channel area where the two met.

During the Eemian interglacial that followed it is thought that relative sea level may have reached as much as 10m above that of present day (Bowen, 1971). This was succeeded by the Devensian glaciation (Newer Drift) which was restricted to a local ice sheet. The maximum extent of the latter has been dated at between 20,000 and 17,000 years BP (Bowen 1970). The valleys of the Neath and Tawe were overdeepened by the passage of the ice (Charlesworth 1929).

More recently Al-Saadi and Brooks (1973) found a large buried valley in the north of Swansea Bay running in a southwestwards direction. This they have interpreted as being an extension of the Neath Disturbance, crossing the Bay and passing seaward of Mumbles Head. As the ice finally began to retreat, the gently south-sloping bedrock, which floors Swansea Bay was left covered by a thickness of stiff pebbly clay drift. Only an isolated outcrop just NE of Kenfig Patches proves an exception to this. Near Port Talbot the drift is about 15m thick. From Scarweather Sands northwards there is an elaborate system of infilled channels cut in the drift surface. Various existing borehole records were consulted to help clarify the land geology along the eastern area of the Bay. Furthermore, 6 new boreholes were undertaken in order to fill in the gap in the data under Kenfig Dunes (referred to as BH 1 - 6 below and shown on Fig 1). It was anticipated that these would help in determining bedrock level; in the calculation of the amount of sand present in the dune system; and that any peat found could be used for radiocarbon dating and thence to help provide a time scale over which accretion had taken place.

It has already been mentioned that, along the coastal strip between Sker Point and Port Talbot, bedrock only outcrops at the southern margin. Elsewhere it is mantled by a thickness of recent deposits. A borehole (BH_3) in the dunes near Sker Point reached pieces of Triassic conglomerate at -8.5m OD. Further north in the Margam area drilling on the British Steel Corporation land revealed bedrock lying between -13 and -22m OD and comprised an irregular surface of hard dark grey carbonaceous mudstone. Further to the north east, just offshore of Port Talbot, laminated grey siltstones with thin coal seams were found at depths of -25 to -30m OD during the construction of the tidal harbour. This suggests

a rock surface rising gradually landward with an eastward limit in the Sker region.

2.1.1 Post-glacial changes in sea level:

The Flandrian rise in sea level reflected the final melting of the ice. In Swansea Bay it had the effect of causing either erosion or accretion in response to the nature of the irregular drift surface at any particular point. Where deposition of muds, sands or gravels took place this was liable to be very variable spatially and was further complicated by the inter-relation of marine and estuarine clays inter-bedded with terrestrial peats, possibly as a response to the existence of transitory barriers and lagoons.

Although the precise relationship of particular peat beds to mean sea level has not always been clearly established the evidence nevertheless helps to give some indication of the relative rise of sea level during the post-Glacial period. Evans (1973) recorded a freshwater organic mud at a depth of -35.5m OD just south of the Scarweather lightship and pollen analysis showed it to be of pollen Zone IV age ($\sim$ 10,000 years BP). Peats have also been found in the Port Talbot tidal harbour area. The deepest recorded lay at -27m OD. A second peat band had a base at -20m OD and rested on the local drift surface. Its upper surface lay at -18m and was overlain by silts and clays. Radiocarbon dates showed that it accumulated between 11,900 and 8,900 years BP (Godwin and Willis, 1964) and indicated that the Flandrian transgression reached the position of the present coastline at a date of 8,900 BP but at a depth of -18m.

The rise in mean sea level continued until about 6,000- 5,500 years BP when it reached about -3m OD. Godwin and Willis (1961) obtained a date for a basal peat in the Margam area of 6184 $\pm$ 143 BP. This has been supported by a radiocarbon date of 5686 $\pm$ 45 (SRR - 967) obtained on a thin peat band occurring at -3.10m OD in BH_4 in the Kenfig Dunes.

As the sand dunes had not yet formed in their present position the sea was able to penetrate further inland than now. The Flandrian sedimentation came to a halt about 2500 years BP as is indicated by a peat at Llanwern, near Newport (Godwin and Willis, 1964). Its level was at +3m OD which equates to peat found at Blackpill, Swansea Bay. The latter, a submerged forest bed exposed on the foreshore was allocated to Zone VIII on pollen analysis (von Post 1933). Salt marsh peat frequently develops up to about mean high water mark which is of the order of +3 to 4m OD.

2.1.3 Sand dunes

After about 2500 years BP the low energy conditions typical of the silts, clays and peats of the Flandrian deposits were replaced by the higher energy

conditions of the present day beach. This change, towards the end of the Flandrian transgression, may have been brought about by the breaching or removal of sand barriers further offshore (Culver, 1976). The result was the formation of sand dunes along the northeastern and eastern margins of Swansea Bay. These often overlie the Flandrian peats as evidenced by BH_4 at Kenfig (Fig 1).

At the present time Kenfig Burrows is the only remaining large expanse of near natural sand dunes fringing the research area. The four most coastal boreholes carried out as part of the current study were situated in low-lying areas, the thickness of the sand increasing to a maximum of 12m towards the north east . In BH's 3, 4 and 6, the junction between the base of the sand and the underlying grey silty clay was quite sharp. There are occasional organic bands within the sand. BH_5 did not reach the clay but alternations of sand and sand and gravels were encountered. As this borehole was further seaward than the others the cobbles may represent former beach deposits. Alternatively, it may reflect changes due to its closeness to the present day Kenfig River.

Two further boreholes, 1 and 2, were put down in the vicinity of Kenfig Pool. A brown peat was recovered from a depth of 4m (+ 6.1m OD) and gave a radiocarbon date of 793 $\pm$ 40 BP (SRR - 968). This indicates that as late as the 12th century this part of Kenfig was free of sand and that in the intervening years a net build-up of 4m of wind-blown sand has accumulated here. Further landward the sand continues to thin and in the Mawdlam area forms a thin veneer over hummocky boulder clay.

It is difficult to calculate a volume of sand for the various dune systems along the eastern side of the Bay. However, using the borehole and other geological data, supplemented by some geophysical information; knowledge gained from photogrammetry; and by topographic survey, a rough order of magnitude estimate is possible. This suggests that for Kenfig Burrows there is some 4×10^7 tonnes of sand. If the entire sand dune area once stretching from the R Neath to Sker Point were to be included a figure of about three times this amount is probable. This volume must have accumulated over a period not exceeding 6000 years probably from a pre-existing dune coastline further seawards

2.1.4 Offshore sediment distribution:

This topic will be referred to very briefly here because of its relevance to Report No 5 where it will be discussed in some detail. The only large bodies of sand that lie within the offshore research area are the three sandbanks Scarweather Sands, Hugo Bank and South Kenfig Patches. Scarweather Sands is 9.6 km long and 1.6 km wide, the central and eastern portions drying

out on low spring tides. Hugo Bank, 5 km long and 1 km wide, lies to the north, separated from the Scarweather Sands by the Shord Channel. Further north still lie the South Kenfig Patches, a more diffuse sand body with limbs of sand tailing off the main body in a south easterly direction.

North west of the sand banks is an area of largely muddy sediment. The sediments become more variable in nature between this area and that west of the Scarweather Sands. Surrounding much of the Scarweather Sands the sea bed is covered by a veneer of sandy shelly gravels, while patches of boulder clay can still be found exposed in the shallow area of the North Kenfig Patches.

2.2 Bathymetry and Topography

2.2.1 Bathymetry. While some of the features described above are reflected in the bathymetry this is not always so. Thus, apart from N and S Kenfig Patches, Hugo Bank and Scarweather Sands, only the Outer Green Grounds, a Carboniferous outcrop with boulder clay cover, has any obvious topographic expression. Elsewhere the contours are broadly in sympathy with the surrounding coastline and depths progressively increase to about 10m below Chart Datum (approximately -15m OD) by 4 km offshore.

2.2.2 Topography. The coastal area along the eastern side of the bay is bounded by the shoreline on one side and, for much of its length, by the massive Pennant grits on the other. Throughout this zone there is a fringing dune system inland of which are areas of reclaimed marsh. The latter taper towards the south and are finally wedged out by the broader Kenfig sand dunes on the one hand and the glacial deposits on the other. The marsh areas are typically flat and at, or somewhat below, high tide level. Although the sand dunes reach to as much as 15 - 20 m OD on occasion they are generally much less than this and, usually, areas of grey dune and slacks predominate over vigorous marram (Ammophila arenaria) dunes which are largely restricted to a very thin coastal belt. Like the marshes, the slacks are close to high tide level.

Thus the overall picture is one of a flat marsh strip with an accidented but small scale pattern of relief to seaward.

The beach is almost universally broad and flat, gradients of the order of 1 : 50 being typical everywhere other than near high water mark where the slope locally becomes appreciably steeper.

This broad pattern of marsh and dune has been modified by the activities of man, mainly by removing extensive volumes of material from the sand dunes or by the construction of industrial plant over both dune and marshland.

The picture elsewhere around the edge of the bay is more complicated and, in general, expresses a greater element of relief. It is, however, less germane to the present research study and will not be discussed further.

(b) LONG-TERM CHANGES IN THE COASTLINE

3.1 Evidence from Hydrographic Charts

3.1.1 Data sources

Appendix 4 lists the various charts available for the whole or parts of the Swansea Bay area. Only those for 1859 (C dr Alldridge) and 1974 (C dr Pugh) effectively cover the whole area of interest although the combination of those by C drs Tizard (1881) and Archdeacon (1884), and the 1938 revision of the Scarweather area (C dr Hardy) provide useful corroborative evidence of the trends indicated over the whole period.

Figs 2 to 5 show the 5 charts contoured at 2m intervals in relation to the chart datum employed in the 1974 survey. This is 5.20m below Ordnance Datum (Newlyn). This chart datum corresponds closely to the water level for lowest astronomical tides while OD is approximately mean sea level. Figs 6-8 compare the changes in terms of erosion and accretion between 1859 and 1974; 1881/4 and 1974; and 1938 and 1974, respectively. 1974 was chosen as the comparison in each instance because of the partial nature of the intervening surveys and because of the likelihood of greater positional accuracy over time.

Fig 9 is a diagrammatic map showing the relative position of the crest lines of the offshore banks (to 10m below chart datum where practicable) at the times of successive surveys.

For comparative purposes all the charts were adjusted photographically onto a common scale (1 : 25,000) and datum. While the slight reduction to 1 : 25,000 of the 1859 and 1884 surveys from 1 : 22,600 and slight increase to 1 : 25,000 of the 1881 and 1938 surveys presented little problem, the need to obtain a common datum proved rather more difficult. The basis on which this was done is explained in Appendix 5. All values were metricated to conform with the 1974 survey.

3.1.2 Change:

The main changes shown by the hydrographic surveys are:

3.1.2.1 Scarweather Sands: Some growth towards the west has occurred during the timespan of a century and a quarter. This is not well shown by the crest line limits for 10m (Fig 9) but the fact that the 1859 survey did not extend as far west - it did not need to - as later ones is indicative of the situation. More conspicuous is the elimination of the swatchway (at Lat 51°28'30"N, Long 3°49'30"W) over the intervening period. As a consequence the Scarweather Bank has become progressively less sinuous over time.

3.1.2.2 Hugo Bank and Kenfig Patches: Unlike the relative stability of Scarweather, both the position of Hugo Bank and the relationship between it and S Kenfig Patches has shown appreciable change between 1859 and 1974. Hugo Bank appears to be variable in length on its western extremity but the S Kenfig Patches indicate little change in relative position. Their eastern end (ie

that nearest the coastline towards Sker Point) appears particularly constant. The most marked change is the elimination of a link between Kenfig Patches and Hugo Bank. This was prominent in 1859, tenuous in 1938 and non-existent in 1974. As a result the two banks are now clearly separated, with the Kenfig in the form of a flood-orientated parabola and the Hugo an ebb-orientated parabola.

The figures (6 - 8) which depict erosion and accretion demonstrate the scale at which long-term net change has operated. A maximum of some 13m of both erosion and accretion is shown while values of up to 10m occur at a number of places on and around the banks. Apart from the realignment there is a tendency for the mass of the banks to be located further southward over time although the crests are more constant in position. This displacement can be confirmed by examining the references to leading marks in the early editions of the relevant Admiralty Coastal Pilot (eg 1891).

3.1.2.3 Further north in the Bay there are only relatively minor bathymetric changes. This probably reflects the greater resistance of glacial sediments and the existence of local rock outcrops together with more subdued bed topography and lower velocity tidal currents. The 1859, 1884 and 1974 surveys cover the area together with a further one by Comm Lowry dated 1949.

3.1.3 Volume of material: Calculations have been made to assess the difference in the volume of material covering the eastern half of the Bay and extending as far south as Lat 51°25'30"N (ie the deep water immediately S of Scarweather Sands) between 1859 and 1974. This suggests a loss of 12.3 x $10^6 m^3$ over the period. Unfortunately the whole of this amount, and more, could be eliminated by a change in the relative datum between the surveys of only 0.1m and there are also other considerations that have a bearing on the calculations. These, and the computation itself, are discussed in Appendix 6. No firm conclusion can be drawn.

3.2 Evidence from land cartography

3.2.1 Introduction

In common with most other areas the early (ie pre-19th century) maps of the Swansea region are either small scale or inaccurate and not infrequently both. The fact that much of the eastern side of the Bay was in single ownership reduced the need for any accurate plans for litigational purposes, indeed there is not even a Tithe Map for the parish of Margam. Thus useful cartographic evidence is concentrated within the 19th and 20th centuries and effectively falls into 2 categories, the series of Tithe Maps dating from around 1840 and the medium and

large scale Ordnance Survey maps. These are listed as Appendix 7. Figures 11 and 12 give an indication of the change in high and low water marks between around 1840 and 1949-65. It must be borne in mind in this context that there is always an element of uncertainty in this form of comparison (especially as far as low water is concerned); that the Ordnance Survey changed their water mark criteria in 1868 so surveys prior to and post that date are on a somewhat different basis; that date of publication is not necessarily closely related to date of survey and that revisions are only selective; that maximum development may occur between surveys, while the Tithe Maps are neither explicit nor consistent. In spite of all these reservations there is a reasonably coherent picture and this is summarised in Table 1. The location of the section lines used in the comparison is shown in Fig 10.

3.2.2 Erosion and accretion

The land surveys show 2 major areas of change over the period 1842 - 1965. These are the Crymlyn-Witford area bisected by the R Neath, and the coastline both immediately north and south of Port Talbot harbour. Elsewhere net changes are relatively minor.

3.2.2.1 River Neath area

While most of the coastline along the eastern shore of Swansea Bay has been revised by the Ordnance Survey over the period 1949-65 , this is not true of the Crymlyn section (Section 1) shown on Table 1. However, the series of surveys from the 1840's tithe maps to that of the OS in 1914 indicates consistent accretion on a modest scale. The picture for low water is confused, partly as a result of the varying degree of generalisation between surveys, but primarily because of the construction of the training wall for the R Neath during the 1870's. This had the effect of reducing the maze of tidal creeks evident previously and in causing marked scour of the coastline south of the embankment within the intertidal zone. Sections 2 and 3 for Witford reflect this phenomenon and suggest recession of the low water mark of the order of 1.2 km overall. The trend for the high water mark for the corresponding sections is again complicated but this time by the effect of the bar/spit which is recorded at its apparent maximum during the 1914 survey.

3.2.2.2 Afan/Port Talbot harbour area

Sections 4 and 5 are located N of the harbour, 6 to the S of it. All these show a progressive steepening of the beach over time. In the case of sections 4 and 5 high water mark has shown very little change between 1859 and 1955-63; both lines are now artificially stabilised by sea defences to landward. Section 6 shows net accretion (124m between 1859 and 1955-63) at high water mark. This is almost certainly attributable to the silting up and final reclamation of the old entrance of the R Afan, together with tipping of slag and other material by the British Steel Corporation at the edge of the dune system (There is some suggestion of local erosion previous to this).

The picture for low water mark in Section 4 is somewhat inconsistent until 1876 but shows progressive erosion thereafterwards. Sections 5 and 6 show constant erosion from 1876 onwards. This is of the order of 342m and 214m respectively. Allowing for the accretion at the top of the beach on Section 6 (124m) the steepening of the beach gradient is almost identical; high and low water lines are 342 and 338m closer together for Sections 5 and 6 over the period 1876 to 1963. The initial southern breakwater of the 'old' Port Talbot harbour was built in 1865 and extended twice during the 1890's and again about 1912 (Cleaver, 1913). Low water mark receded landward by 370m in this area between 1843 and 1963, ie marginally more than on the sections immediately to N and S.

3.2.2.3 Morfa Mawr

Section 7 is essentially transitional. Negligible recession is shown for high water mark; a rather moderate degree of erosion is reflected in the landward displacement of low water mark by some 77m between 1859 and 1963.

3.2.2.4 River Kenfig to Sker Point

Sections 8 to 11 cover the area from immediately north of the R Kenfig to Sker. The changes indicated by the surveys from 1859 onwards up until the early 1960's are small, variable and inconsistent.

3.2.3 Beach Gradient

The steepening of the beach slope over the period 1876 - 1965 is a striking feature of the overall pattern of change. Although there are topographic and hydrographic complications at various locations between Crymlyn and Sker there is a remarkably consistent picture taking the area as a whole. Thus for Sections 2 to 7 the reduction in distance between high and low water marks are 1417, 1160, 687, 331, 338 and 77m, respectively. Corresponding beach gradients would be from 1 : 300 to 1 : 140, 1 : 200 to 1 : 65, 1 : 130 to 1 : 50, 1 : 85 to 1 : 45 for both Sections 5 and 6, and 1 : 60 to 1 : 50 for Section 7.

This steepening of beach gradient is both a symptom and a cause: an indication of the incidence of erosion in the area and, by permitting wave energy to be more effective thereafter, a cause of further erosion.

3.2.4 Clay and peat Outcrops

The geological survey of 1952, which was produced on a scale of 1 : 10560, included the peat and clay exposures on the beach south of the old Port Talbot harbour as far south as Sker Point. The photogrammetric surveys compiled by IOS from aerial photographs taken in 1968, 1970 and 1975 give updated information on this aspect. Since the photogrammetry is discussed in Topic Report 2 it seems more logical to review the 1952 data as part of that study.

3.3 The documentary record

Documentary sources are almost exclusively land-orientated. Information in this field falls into two categories. These are the historical sources, either in the form of original documents and papers or derived from them, and the various topographies written to describe the local or regional scene at different periods of time. One of the difficulties incurred in using the latter is the extent to which the compilers have resorted to earlier rather than contemporary sources of information without acknowledgement. A further problem often lies in accurately identifying the area to which reference is made either because it is not specific enough or because the place-names are no longer extant. This applies especially in the context of land charters and leases.

Nevertheless three themes stand out above all others. They are the mobility of sand in the coastal zone; the maintenance of the dune system, either in the context of warrening or artificial planting and stabilisation; and the struggle to build and maintain sea walls to protect the low-lying marsh areas from flooding. Each of these will be dealt with in turn in a chronological, rather than a geographical, sequence. (Place-names are shown on Figure 1; documentary references are collated in Appendix 9; bibliographic references immediately after the text of this Report).

3.3.1 Sand mobility: As early as the 12th century there are records referring to sand accumulation at Kenfig dunes as well as other locations outside the immediate area of concern, such as Merthyr Mawr and on the Gower peninsula (O'Brien, 1927). Richards (1927) describes storms in 1188 and again in 1222 AD which resulted in both sand blowing and flooding. By about 1300 AD the sand problem was becoming more acute - sufficient to warrant the word 'drowning' (Grey, 1909) while in 1326/1336 AD the Abbot of Margam complained of sand drift (O'Brien,1927). The hermitage of Theodoric (now under Margam steelworks) was probably already buried by then. Evans (1960) notes encroachment of sand in 1316 AD also. Rhys (1911) put the first serious invasion of the Glamorgan coastline by sand at 1384. The old town of Kenfig, some 1.7 km from the coastline, was subject to progressive inundation while the navigation value of the R Kenfig also deteriorated. One reference suggests a specific date for Kenfig's demise, 1470 AD (Evans, 1960 quoting Leland 1538). There is strong circumstantial evidence for this period as being of particular instability because round about 1400 AD the old coast road was abandoned and a new inland route chosen for communication between Cardiff and Swansea while in 1485 Pyle church superseded that at Kenfig (Richards, 1927). Even so, Kenfig's demise was a protracted affair.

The coastline between the R Neath and Sker Point appears to have been affected relatively early as compared with that elsewhere. Thus by 1538/9 Leland described Kenfig village and castle as 'almost shokid and devourid with the sandes that the Severn Se ther castith up'. By 1526 AD, too, Kenfig parish was recorded as being

half drift sand (Grey, 1909), yet Candleston Heights, to landward of Merthyr Mawr (Randall, 1928) were still clear of sand as late at 1600 AD. The parliamentary Act of 1554 AD was in many respects too late to be of benefit to Kenfig but it demonstrates the degree of concern. Part of the preamble reads:

> 'to refourme the greate hurte nuysaunce and losses that comethe and chaunceth to the Quenes Highnes and her Subjectes, by reason of Sande rising out of the Sea and dryven to Lande by Stormes and Windes, whereby muche good Grounde lyeing on the Seacoastes in sundrye places of this Realme and especially in the Countye of Glamorgan, bee covered with suche Sande rising out of the Sea that ther comethe no Profitte of the same, to the greate loss of the Quenes Highnes and her loving Subjectes, and more ys lyke to ensue yf spedye Remedie be not therein provided....' (Quoted in full in Appendix 8).

In 1572 there was an ordinance in respect of sand blowing at Kenfig (Evans, 1960) and a further reference in 1607, this time to the Margam area. Between the surveys of 1582 and 1633 fields near the R Afan had become overwhelmed with sand. Both the Survey of Kenfig dating from 1660/61 and Lhwyd's description of Kenfig in 1696-1700 show that there was still, possibly a considerable amount of, mobile sand. Lhwyd also refers to Newton Nottage being afflicted in the same way, while Baglan had 'great drifts of sand wch may well be called mountaines'. Wyndham in his lurid description of 1774 refers to Kenfig Castle as being 'surrounded by naked sands, blown up in irregular heaps and subject to alteration by every storm'; and the 1832 report undertaken for the Home Department (prior to the legislation which deprived Kenfig of its borough status) recorded the continuing inroad of sand.

The picture, then, is of long-term instability of sand throughout the recorded history of over 700 years, probably reaching a maximum in the 15th century. Archaeological sections at Kenfig suggest gradual accumulation with considerable periods between violent storms (Richards, 1927).

3.3.2 The maintenance of the dunes: The coastal sand dune systems had an economic value as rabbit warrening and the destruction of the vegetation by rabbits may, in part, account for the instability of the dunes themselves. However attempts to maintain the stability of the dunes by marram (Ammophila arenaria) planting were practised from a very early date and careful management appears to have been practised. Thus there is a reference to rabbit warrening around 1316 (Evans, 1960) while in 1330 there is an ordinance prohibiting 'sedge' (ie marram grass) cutting (Rhys, 1911; Evans, 1960).

> 'Noe manner of person or persons whatsoever shall reap any sedges neither draw nor pull any rootes nor cut any furzes in any place whatsoever, nor do any other thing that may be to the ruin, destruction and overthrow of the said burrough'.

A similar injunction applied to Newton Clovis around 1400 (Rhys, 1911). While in 1344 Hugh le Despenser granted the right of free warrening in Afan and Kenfig, the Kenfig burgesses exerted strong pressure in trying to ensure dune stability.

Warrening and dune reclamation became more to the fore again from the end of the 17th century coinciding with the active encouragement of the then government's Board of Agriculture. Lhwyd refers to reclamation in Newton Nottage and the stabilisation of sand dunes with sedges. He relates that while near both the rivers Neath and 'Avan' the 'best of the parish is now swallowed up by the sea and over run by sand' between these two areas the mobility is almost stopped by the use of a certain matting in Welsh called 'Myrydd'. Thus the technique of dune 'thatching' appears to have had a long history.

Estate records dating from 1732 refer to expenditure on sedge planting at Margam Burrows while those from 1744, 1745 and 1747 all relate to warrening at Kenfig and Afan. That for 1745 links one with the other. The 1832 Home Department survey (mentioned above) refers to planting, as follows:

> 'The inroad of sand still continues, and if it were not for the precautions taken in planting "bent", a grass or sand rush, which has been found to be the best means of checking it, large quantities of valuable land would soon be covered'. (Llewellyn, 1898).

Both Lewis (1849) and Rhys (1911) describe tenancy agreements which include a clause on marram planting whereby the tenant covenanted to give a day (or more depending upon the size of his holding) to help with planting and enhance stability.

3.3.3 Sea walls and flooding:

In the same way that there is an inter-relation between warrening and dune planting there is a close link between reclamation of the marshlands and their flooding by the sea. This struggle refers to Baglan, Afan and Margam in particular. Flooding in 1188 AD caused considerable loss of cattle and some of men also (Richards, 1927). Early in the following century there are definite records of sea walls being built at Margam. Further storms ensued in 1222 AD, while by 1316 AD rents had fallen to as low as 2s.6d. (Richard, 1927) owing to inundation by the sea and burial by sand. The rent of a piece of land known as the Rabbits Pasture was reduced 'because the greater party is drowned by the sea' (Rhys, 1911). It is very much chance as to what events are recorded and what documents survive. As a result it is not clear whether the next 2 to 3 centuries were less critical or not. However, in the well-known storm of 1607 in which over 500 people died along the Welsh coast, there is a reference to flooding and the subsequent financial assistance of Swansea to Afan (O'Brien, 1927); in 1657 the use of stones to repair a sea wall at Afan is recorded in Estate records, while Lhwyd (1696 - 1700) refers to Baglan and Aberafan marshes now being below high water spring tides and to the flooding which occurred a decade before. He writes:

'..... for at this day, were it not for banks rais'd, all our and Aberavan's marsh would be at high springs overflowed by the sea, as some ten years agoe ..... it did ..... and, indeed it has not to this day recovered its fertility .....' (Lhwyd, 1911).

Further flooding at Aberafan occurred in 1768 when the town "was covered with mud and slime" (O'Brien, 1927). Another reference to the relative height of the marshes and spring tides, this time at Port Talbot harbour, occurs in a letter dated 1840, as '..... an ancient sea wall ..... which could not keep out the present high water by several feet'. The same letter describes various artefacts, together with the remains of old fences and building foundations, found during harbour construction at between 5 and 25 feet below the then ground level. These remains included Bronze Age and Roman relics as well as more recent material. Along with the earlier references it provides historical support to the physical evidence for relative changes in sea level (Section 2.1.2 above).

3.3.4 The documentary evidence focuses attention towards the long-term struggle of man versus natural forces on the coastline; the problems of sand stabilisation, reclamation, and the susceptibility of marshland areas to marine incursion through flooding. Rhys (1911) was conscious of the tendency towards erosion when he wrote: 'The sea had been there before; just as certainly the sea is gaining upon this coast again'.

4.1 Evidence of consultants to the local authority

There are a number of reports and expressions of view which are of interest both for the evidence they appear to provide and for the way in which they focus attention to some of the doubts and possibilities as to the cause of coastal change.

In 1964, W S Atkins and Partners were commissioned to write a Report to supersede that of Professor H Cox, dated 1950. Cox had endorsed continuing extraction of both dunes and beach S of the R Kenfig although with specific longshore limits. (However, the appropriate local authority, the Penybont Rural District Council, decided to prohibit working above high water mark. A Coast Protection Order was issued limiting extraction to 27,000 tons per annum). Atkins' Report of February 1966 included an analysis of meteorological records, geological maps and hydrographic charts, together with the surveying of beach sections over a ten-month period and the acquisition of oblique aerial photographs of the site.

In this consultants' view, Skarweather Sands and Kenfig Patches "shoals .... act as a reservoir of material for the replenishment of the beaches and there is no doubt that a considerable transference of material in both

directions takes place under different conditions .....". They believed that the effects of "..... (littoral) ..... currents may be discounted ..... And..... "there is evidence along this coast that a considerable volume of sand is still blown inshore by the prevailing South-westerly winds".

Several profiles across that part of the beach exposed at low water had originally been surveyed by the Penybont Rural District Council surveyor seven times between May 1958 and the end of 1959, and twice in 1962. They were repeated ten times in 1965 by Atkins and Partners (and more recently by Ogwr Borough Council). Local variations in 1965 showed changes of up to 2 feet vertically. Changes of up to 6 feet had occurred between January and March 1962; such changes represented a volume of 300,000 tons. Atkins and Partners calculated that between 1962 and the date of their Report some 170,000 tons had returned to the beach in spite of commercial extraction during the period, but that exposure of boulders in the contractor's area during 1965 suggested "at least a marginal effect". They therefore proposed that, for amenity reasons, a sand cover should be left over the boulders and that this should be accomplished by retaining the existing extraction total but extending the longshore limits of removal. They believed that, at the time when they wrote, the extraction was "having no significant effect compared with the changes brought about by the natural action of wind and tide". Excavated material would otherwise have merely augmented the supply in the dunes to landward.

During 1972 and 1973 there were three further sources of comment and data. These are the letter by Dr B Bluck, a sedimentologist who carried out his early research in the area, and reports by Dr P Davies, a geomorphologist, and Dr G Kelling, another sedimentary geologist. Dr Bluck (1972) stated that evidence for the loss of sand at Sker over the previous 10 years took three forms: exposure of underlying clay, increase in the gravel lag, and changes in the beach profile. He believed that there were also three possible causes: excessive sand taken by man from the beach; sand removal from offshore shoals, and/or longshore "flow of sand" broken by an obstruction "such as a pier". He considered that: "Whatever the cause ..... removal by a Sand and Gravel Company can only help the beach to deteriorate".

Dr Davies (1973) wrote: "The only change in the recent past which could have had repercussions ..... has been the construction of the Port Talbot jetty" but that this could only be proved by experimentation and observation. He believed "the lack of sand cover on the beach and the construction of the jetty would seem to suggest a casual relationship" and advocated both a restriction of, or prevention of, commercial sand removal until the "true facts about the beach behaviour are established". He believed that the use of groynes would reduce erosion at Kenfig, and observed that under contemporary conditions the foredunes were not being replenished.

Dr G Kelling was principally concerned with the Morfa Mawr area, north of the R Kenfig, in his Report to the (then) Port Talbot Borough Council. He adopted an empirical approach in his report but stated: "Only when the rate, amount and direction of natural transfer of sediment through the system has ..... been established can the long-term effects of commercial abstraction be properly assessed and predictions made of the ensuing results". "Establishment of the sediment-budget in these terms is a complex, costly and time-consuming operation .....".

In examining the beach and dune features he concluded that there was sedimentary evidence for both onshore and longshore movement of material. This mainly took the form of progressive changes in mean size of beach sand and in the existence of small scale sedimentary structures. He thought that while extraction of sand from the Morfa Mawr dunes could continue, subject to satisfactory safeguards, this did not apply to the beach. He examined the evidence for diminution of sand supply and said that it was not clear whether it was the result of natural or man-made erosion. "However it can scarcely be coincidental that the part of the beach which is most denuded of sediment is that region from which, according to Council records, sand and gravel has been extracted for the longest period". "..... Council would be well advised to adopt a precautionary stance....". "Restoration of sediment cover..... is only possible (but cannot be guaranteed) by an immediate cessation of sand and gravel extraction from all parts of the beach". Even for the beach to be maintained Dr Kelling thought that extraction should be restricted to the area at the mouth of the River Kenfig, the effects being monitored and extraction licences issued on a 6-monthly or yearly basis.

Consultants' reports prior to the 1973 Public Inquiry demonstrate:

(a) the varying views as to the cause of beach erosion and the extent to which such erosion is man-induced;

(b) the different emphasis on the severity of the problem, although the more recent observations indicated increasing concern;

(c) the recognition of the high cost in terms of money and resources which would be incurred if a study was initiated to cover both onshore and offshore aspects.

4.2 Technical evidence at the 1973 Public Inquiry

Statements and documents submitted to the Public Inquiry include:

(a) Consultants' reports, notably those by Dr G Kelling, to which reference has been made in 4.1 above.

(b) Information on sand and gravel extraction provided by the operators. This forms much of the basis for Section 5.3, Table 3 and Figure 13 below.

(c) A selection of other documents and statements. Most of these are not greatly relevant to the present situation and are inevitably somewhat subjective in nature. However, the present Section of this report briefly considers salient points of this evidence insofar as it has a bearing on the physical situation.

4.2.1 Extent of clay and peat areas exposed

One witness, H A Beynon, Manager of the Margam Sand and Gravel Co., estimated that when his firm began working the beach in 1940 about 1 acre ($4000m^2$) of clay was exposed and that this amount varied very little up till the time they ceased foreshore extraction in 1957. He measured the clay exposure when his company began beach working again in March 1973; it was then $9\frac{1}{4}$ acres ($37,600m^2$). (This figure corresponds very well with the area calculated by photogrammetry - see Report 2). In December 1973 it had fallen to only $4\frac{1}{4}$ acres ($17,300m^2$) in spite of sand working. Beynon linked the increasing clay exposures with the construction of the tidal harbour. Several other witnesses testified that some clay had been exposed in 1937 or even earlier although one thought it much more recent with an accelerated deterioration 'in recent years'. J A Lewis argued that, because the beach showed no significant changes over the period 1900 - 63, and that the clay was known to have been present then, it must therefore have been exposed for a long time. Both Beynon and Kelling commented on the existence of small clay exposures between the access ramp and the R Kenfig, ie S of the main exposures. During 1973 Robinson undertook 6 surveys of 2 beach sections in the area between the Access Ramp and the R Kenfig. These showed little change.

4.2.2 Evidence for sediment transport and supply.

The three main expert witnesses, Dr (now Prof) Kelling; Dr A Robinson, Reader at the University of Leicester; and Mr J A Lewis of Lewis and Duvivier, Consulting Engineers, approached this problem in different ways and reached rather different conclusions.

Robinson carried out two short-term fluorescent tracer experiments near low tide level on the Morfa Mawr Beach. The results were variable both in respect of distance and direction. However, he believed that, overall, sediment was transported in relation to the dominant waves and hence, in this case, towards the SSE. Around the R Kenfig the reverse might be true. Robinson argued that the long term map evidence also supported this overall view. Kelling explained the interpretation that he had earlier submitted to the local authority in his Report. Lewis concurred with Kelling that sediment transport was broadly to the NE but believed it to be locally N at the R Kenfig and along the lower foreshore of Kenfig Sands. However, north of the tidal harbour

he considered that transport was probably southwards. The Port Talbot borough engineer believed there was no littoral drift.

Robinson's limited hydrographic survey suggested that there were suitable grades of sediment available to supply the beach from offshore in the area S of the Access Ramp but only mud further N. Both he and Lewis thought that the stability of the beach was governed primarily by what happened below low water mark but disagreed as to whether the beach needed to be considered as a whole.

The evidence submitted by Beynon had included a comment as to the increasing quantity of pebbles and cobbles at the top of the beach between 1957 and 1973. Kelling accepted the view that these were probably derived from offshore and did not necessarily result from the removal of the finer fraction of the inter-tidal beach material.

4.2.3 Conclusions from Inspector's Report

The tone of the Inspector's Report is often highly critical. He was concerned, for example, that all the expert witnesses had concentrated on visual interpretations of beach characteristics accompanied by causal explanations. He held that virtually the only quantified evidence related to the tonnages of sand removed. It was not clear whether the steepening gradient along much of the beach in the previous decade reflected a cyclic process or net erosion but sand extraction had increased by $3\frac{1}{2}$ - 4 times between 1968/9 and 1973 to a total of about 225 x 10^3tonnes p.a. None of the objectors sought to justify the then current rates although it was said that 60 x 10^3tonnes was regarded as an economic minimum for Margam Beach. (This figure was not reached prior to 1967).

The Inspector wrote:

(a) "There are changes taking place along the foreshore.....

(b) The mechanism of these changes is not properly understood.

(c) The beach is accretionary in parts. The rate of accretion is not known.

(d) A detailed study of the foreshore and sea bed conditions is necessary over a period of at least 3 years and before long-term conclusions can be reached. Morfa Mawr and Kenfig Sands should be considered jointly". (A more extensive outline of his conclusions and recommendations is included as Appendix 3).

5 Records of sand and gravel extraction, including port landings. Dredging.

Extraction of sand from the dunes and foreshore has been carried out for a long period of time and had clearly reached a sizeable scale as early as 1911 when Rhys wrote:

> 'The sand is now extensively worked, and transported by rail for building and other purposes ..... . But every autumn and spring the winds more than make good the exported sand' (Rhys, 1911).

The first part is a statement of fact, the second one of supposition which will be discussed further elsewhere.

Local offshore sand and gravel working appears to date from about 1926 when Nash Bank began to be exploited. Port landing figures date from an earlier period than this but suffer from 2 defects. Firstly, there is no indication of source although the N Devon coast is known to be included. Secondly, the classification which included building sand was initially drawn much wider than this and only subsequently restricted; marine dredged sand was classified specifically by BTDB from 1965.

Sometimes it is difficult to identify dune sand extraction as distinct from foreshore extraction. A further problem which applies in general, but especially to the land extraction, is the degree of confidentiality of the operator's data. Nevertheless, it is thought that the sand and gravel-winning estimates are firmly based.

According to the DOE total land production in and around Swansea and South Pembroke was 392 x 10^3 tonnes in 1970 and 602 x 10^3 tonnes in 1971. This is between $\frac{1}{3}$ and $\frac{1}{2}$ of the total, the remainder being of marine origin.

5.1 Sea landings: This section of the Report is divided into 2; the first briefly discusses extraction sites off the S Wales coast while the second gives an indication of requirements as reflected in port landing figures.

5.1.1 Offshore sites: According to Hess (1971) offshore extraction was concentrated on Nash Bank and, further up estuary at several sites such as One Fathom Bank, Barry; New Patch, Mackensie Shoal and Cardiff Grounds, all between Barry and Cardiff; and West Middle Ground to the south of Newport. The Crown Estates Commissioners (in correspondence) state that extraction on Nash Bank - the most siginficant site in the context of Swansea Bay - was mainly from the centre and western end. Figures for 1971 - 73 were 235; 264 and 242 x 10^3 tonnes respectively. These rates were typical at least for the previous decade.

5.1.2 Port Landing figures: The principal ports are Newport, Swansea and

Cardiff, followed by Barry and Briton Ferry/Neath. Port Talbot was important until the closing of the old harbour and the construction of the new tidal harbour which has concentrated on bulk iron ore cargoes. Newport has 2 port authorities; only the Commissioners have landed sand and gravel since 1964. Small amounts of material were also landed at Llanelly, Lydney, Barry Port and Penarth up to 1930, 1940, 1941 and 1943 respectively.

The landing figures for each decade from 1930 onwards are summarised below. More detailed figures, together with explanatory notes are given in Table 2.

	Swansea	Briton Ferry	Port Talbot	Barry	Cardiff	Newport
1970 - 76	2,620,419	282,779	-	432,644	2,426,342	*
1960 - 69	2,867,616	207,965◊	109,751ø	468,457	3,719,712	
1950 - 59	2,927,111	215,285◊	203,078	314,467	2,252,019	
1940 - 49	793,955	222,522	10,278	224,020	727,963	
1930 - 39	476,349	8,661	26,085	126,404	512,753	
1930 - 76	9,685,450	937,212	349,192	1,565,992	9,638,789	tonnes

Notes:

◊ No figures for 1955-62 inclusive

ø Ceased early 1967

* Data unobtainable. Total production 1974 - 76 = 1,726,663 tonnes.

In sum, it would appear that approximately 22.2 x 10^6 tonnes of material has been landed at the South Wales ports≠ since 1930, of which 19.0 x 10^6 tonnes is since 1950. Over 5.0 x 10^6 tonnes was landed at Swansea and Cardiff during the 7-year period 1970-76 inclusive, this sum being almost equally divided between the two sites.

5.2.1 Land sand and gravel extraction:* Apart from the removal of dune sand, there were 3 main operational areas, that between Sker Point and the R Kenfig; that from the Kenfig to the 'Access Ramp' (see Figure 1) and the area immediately to the north of the ramp. The operators changed over time but basically Sker Sand and Gravel Ltd and later Evan John Ltd operated the southern tract while M John, then Avon Sand and Gravel, and finally British Dredging Ltd, operated the middle area. Throughout most of the period Margam Sand and Gravel Ltd had the rights to work the northern zone although initially (1937 - 39) and, again in 1973 under licence, Evan John Ltd also extracted sand from there. Sand-winning is known to have begun by 1934 in the Kenfig dunes and foreshore, by 1937 north of the

≠ Excluding Newport

*Swansea Bay area: until 1973 aggregate was also worked at Merthyr Mawr, near Porthcawl.

access ramp and by 1947 between these areas. In all cases foreshore extraction ceased within 6 months either side of December 1973 in part as a consequence of the Public Inquiry of that month. Morfa Beach was the last one to be worked in S Wales.

Dune sand-winning had terminated earlier S of the R Kenfig but still continues north of the river.

5.2.2 Rate of extraction showed a progressive increase between 1934 and 1973. Table 3 and Fig 13 give some indication of the trend for beach extraction. Between 1934 and 1945 it is estimated that sand (and gravel) winning did not exceed 10×10^3 tonnes per year while over the next 12 years (1946 - 1957) it was of the order of 22×10^3 tonnes p.a. Between 1958 and 1966 extraction averaged 35×10^3 tonnes while for the ensuing years 1967 - 1973/4 almost exactly 10×10^4 tonnes was removed per year. Known beach extraction figures, calculated largely on the 1973 Public Inquiry evidence, would give a total yield of 1.11×10^6 tonnes between 1934 and 1973; calculations suggest that the estimated extraction totals would be about 1.58×10^6 tonnes for the same period. The figure for the beach south of the R Kenfig would be 390 and 455×10^3 tonnes respectively, the balance relating to the northern area.

5.2.3 Effect on beach levels: Using these figures and those in Table 3 it is possible to estimate the maximum change in beach volume. For this purpose the following assumptions were made:

(a) Length of beach = 8.5 km (Distance from Port Talbot tidal harbour southern breakwater to Sker Point). Sediment transport was assumed to be unimpeded throughout this length.

Width of beach = 350m (typical 'medium' low tide width)

$\therefore$ area of beach = $2975 \times 10^3 m^2$

(b) Unit weight lbs/ft^3 (from Terzacki & Peck & US Coastal Engineering Research Center Shore Protection Manual, Vol 1) =

130 for dense saturated uniform sand

(109 " " unsaturated " ")

$\therefore m^3 = 35.32 \times 130$ lbs = 4592 lbs = 2.05 UK tons = 2.08 tonnes

(c) No material was added to, or taken away from the beach by natural causes.

(d) The fall in beach level was spread evenly throughout the exposed length and low-tide breadth of the beach; eg recession of the dune face was not considered. The historical evidence, and the Public Inquiry Inspector's conclusions (see Section 4.2.3) make this a tenable hypothesis.

On the basis of the beach being saturated the following results were obtained:

(i) Prior to 1964 the beach would have been lowered by 0.05m on the basis of known extraction, or 0.09m at the estimated rate.

(ii) The corresponding figures for the decade 1964-73 are 0.13 and 0.16m respectively.

Thus the overall totals would be 0.18 and 0.25m. If longshore transport was, in fact, localised these values would be greater for certain areas. For example, if the R Kenfig acted as an effective barrier than the estimated fall in beach levels to the N in relation to the extraction having taken place there would be 0.065 and 0.12m for pre-1964; 0.19 and 0.24m for 1964-73, and the totals 0.255 and 0.36m for known and estimated extraction respectively.

5.2.4 Dune extraction: It is more difficult to estimate the quantity of sand removed from various dune sites ranging between Baglan in the north and Kenfig in the south. This is because extraction began earlier (at approx 10×10^3 tonnes p.a. from 1900 onwards near Pyle). In any event most of the sand-winning since 1945 has been a necessary pre-requisite to the construction of major industrial plant for the steel and, to a lesser extent, the chemical industries. Extraction is still continuing. The total quantity removed by 1973 was of the same, or fractionally greater, order of magnitude as that calculated for the foreshore. Since dune extraction is not specifically relevant to IOS's remit it will not be considered further in this Report.

5.3 Dredging: Table 4 gives a record of spoil removed from Swansea Docks and Port Talbot Docks/tidal harbour between 1960 and 1976. These values include the port approaches. The original figures were recorded in hopper yards and have been converted to an estimate of saturated sediment in tonnes. (For the basis on which this has been done see the notes to the Table). Figures for Swansea Docks have varied only slightly during the overall period and, indeed, were of the same order between 1925 and 1960 although Port Talbot is more complex. Before 1969 the dredging quantities refer to the old docks; between 1969 and 1971 they refer to both the former docks and the new tidal harbour. The old docks were closed in 1972 and thereafter the quantities refer to the tidal harbour alone. In addition, capital dredging took place between 1967 and 1969. This totalled approximately 11.2×10^6 tonnes, all deposited at the 'new' spoil ground off Mumbles Head. Proposed deepening of the channel to permit larger vessels at Port Talbot would involve further capital dredging of about 5×10^6

tonnes. Maintenance dredging - mainly silt - is now dumped at the same Mumbles spoil ground; earlier it was deposited immediately E of Outer Green Grounds, at a site within the Bay, virtually midway between Mumbles and Port Talbot. At one time (not within the period covered by Table 4) spoil from Port Talbot docks was dumped only about 1 km SW of the tidal harbour's southern breakwater.

The dredging figures suggest that a total of about 11.5×10^6 tonnes of saturated bed material has been removed over the 17-year period 1960-76, making an average of about $\frac{2}{3}$ of a million tonnes per year. Of this total rather over a half has been extracted from around Swansea Docks and its approach channel, the balance from Port Talbot. Since the opening of the Port Talbot tidal harbour, however, the proportions have changed somewhat with the result that between 1970 and 1976 almost 3/5 of the total came from that site. At least some of the dredged material is likely to have found its way back into the dock approach areas over time.

6. Long-term changes in the coastline: Conclusions

Cartographic and Documentary Records:

Offshore: 3.1.2 There are changes in the position of the banks over time

3.1.3 The differences in total volume are not significant

Onshore: 3.2.2 The maps and plans covering the E side of Swansea Bay during the period 1840's - 1960 show 2 major areas of change: Crymlyn-Witford and Port Talbot harbour. Both have been subject to major civil engineering works.

3.2.3 Almost as far S as Morfa Mawr (ie on Sections 2 to 7) the beach gradient has become steeper, principally by the displacement of low water mark towards the land. South of Morfa Mawr the situation is indeterminate. (Field surveys by the OS are nowhere later than 1965; they therefore do not cover the period of maximum sand-winning).

3.3.4 The documentary evidence focuses attention towards the long-term struggle of man versus the natural forces on the Swansea Bay coastline; the problems of reclamation, stabilisation and the susceptibility of marshland areas to marine incursion through flooding. (In this context it provides support for the geological data on the post-glacial rise of relative sea level). Mobility of the sand-dunes, while reaching its maximum at Kenfig during the 15th century, appears to have been a long-

term problem over a widespread area.

4.1 Reports and observations by consultants, prior to the 1973 Public Inquiry, provide varying explanations as to the mechanism by which foreshore erosion might be taking place. However, there is increasing concern at the situation over time.

4.2 The Inspector's Report, following the Public Inquiry, was highly critical at the lack of quantification in the evidence provided by the technical witnesses. He proposed a scientific study of both the foreshore and offshore over a period of at least 3 years before long-term conclusions could be reached.

Sand and Gravel

Offshore extraction:

5.1.2 Between 1970 and 1976 an average of just over 4×10^5 tonnes of marine dredged aggregate was unloaded at Swansea and Briton Ferry each year. Nearly 90 per cent of this was at Swansea. Known extraction from Nash Banks accounted for some 60 per cent of the total. By 1970-71 marine sources provided between $\frac{1}{2}$ and $\frac{2}{3}$ of all the aggregate used in the Swansea and S Pembroke administrative area.

Land extraction:

5.3.1-2 Morfa Beach was the last foreshore site in S Wales from which sand-winning took place. Extraction increased rapidly after 1967, reaching a maximum of about 2×10^5 tonnes in 1973.

The known total figure for the area between Port Talbot tidal harbour and Sker Point is 1.11×10^6 tonnes over the period 1934 to 1973; the quantity estimated by IOS is 1.58×10^6 tonnes. Rather more than $\frac{2}{3}$ came from the area N of the R Kenfig.

5.3.3 Assuming uninterrupted littoral drift between Port Talbot and Sker Point, uniform distribution across the beach, and no gain or loss onshore, these quantities would cause a fall in beach level of 0.18 and 0.25m respectively.

5.3.4 Dune extraction is likely to have been of a similar order to that from the beach but began earlier and still continues.

Dredging:

5.4 Capital dredging for Port Talbot tidal harbour was 11.2 x 10^6 tonnes. Maintenance dredging for Swansea Docks and Port Talbot appears to have come to a similar amount (11.5 x 10^6 tonnes) over the period 1960 - 76. Recently some 60 per cent of spoil came from the Port Talbot tidal harbour and its approaches.

Some of the dredging material is likely to have been re-circulated, particularly during the earlier years, when the spoil grounds were nearer the docks.

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TABLE 2

	Barry	Burry Port	Briton Ferry	Cardiff	Llanelly	Lydney	Newport	Penarth	Port Talbot	Swansea
1976	87		49	378			600			336
75	75		49	360			599			417
74	49		39	322			527			401
73	65		40	383						405
72	51		37	371						376
71	63		28	324						346
1970	43		42	288						338
69	58		35	316						283
68	46		22	330						259
67	45		31	310					< 1	247
66	51		29	425					9	237
65	83		30	496					14	255
64	52		23	515					15	297
63	35		37	350					17	309
62	26		)	350					17	330
61	33		)	340					18	353
1960	40		) No	287					18	298
59	53		) Data	320					17	294
58	38		)	266					18	340
57	34		)	281					20	311
56	36		)	290					21	311
55	22		)	249					25	329
54	24		27	174					19	300
53	33		42	195					30	274
52	25		34	178					21	261
51	31		47	168					13	281
1950	18		65	130					17	225
49	20		66	104					4	196
48	18		62	85					2	138
47	17		25	72					1	86
46	12		16	54					1	64
45	8		9	66					< 1	58
44	21		6	75					< 1	61
43	31		6	53				< 1	-	47
42	23		9	51					< 1	50
41	41	< 1	12	88					< 1	53
1940	34		11	78		< 1			< 1	42
39	41		3	73		< 1			3	43
38	29	< 1	1	77		< 1			1	51
37	17	< 1	< 1	57		< 1			4	45
36	5	< 1	4	31		< 1			4	44
35	4	< 1		73		< 1			2	45
34	7	< 1		62		< 1			6	68
33	7	< 1		39		< 1			3	61
32	6	< 1		38		< 1			1	43
31	7	< 1		34		< 1			1	42
1930	5	< 1		30	< 1	< 1		< 1	< 1	34
29	4	< 1		37		< 1		< 1	2	28
28	6	3	< 1	27				< 1	3	28
27	6		< 1	46				< 1	3	31
26	8		< 1	53	< 1			1	6	24
25	16		2	73				-	-	27
24	10		2	72				-	< 1	10
23	16			46				< 1	< 1	12
22	18			46				< 1	2	-
21	18			51				< 1	< 1	-
1920	10								-	-
13	32		1	49	1			< 1		-

See note on page 35

Notes: In tonnes x 10^3

Barry: Comments as Swansea. Figures 1889 - 1920 = 530 x 10^3 tonnes

Cardiff: Coastwise only listed. Comments as Swansea except explicit statement that landings for 1951-54 include rock etc.

Newport: No comprehensive data available prior to 1974. Newport has been the main landing site for marine aggregate at least through the 1970's.

Port Talbot: Small workings listed from 1915 to 1919. Comments as Swansea.

Swansea: 1965-76 listed as dredged sand and gravel; 1950 - 64 as building and road making materials; pre-1949 as building sand.

TABLE 3

Beach extraction	Known		Estimated total	
	S of River	N of River Kenfig	S of River	N of River Kenfig
1934 - 39			30[x]	15
1940 - 45		61		61
1946 - 49		126	20	162
1950 - 59	48		63	94
1960 - 69	245	202	245	427
1970 - 73	97	363	97	363
1934 - 73 (Total)	390	752	455	1122
	1142		1577	

Sand and gravel winning 1934 - 1973 : Port Talbot to Sker Point : In x 10^3 tonnes

Notes:

All dates inclusive. Where there is a known figure which spans a period overlapping the decade (or sub-decade) unit used in the table the value has been adjusted proportionately. Data largely based on information provided to the 1973 Public Inquiry. (x = includes some dune sand also; dunes otherwise excluded).

See also Figure 13

TABLE 4 Dredging figures for Port Talbot and Swansea Docks 1960-76

Year	Port Talbot				Swansea	
	Docks		Tidal harbour			
	Hopper yds	tonnes (estimated)	Hopper yds	tonnes (estimated)	Hopper yds	tonnes (estimated)
1976			1500	500	890	297
1975			1200	400	1000	333
1974			1400	467	1100	367
1973			1600	533	1100	367
1972			1390	463	1100	367
1971	319	106	1400	467	1000	333
1970	257	86	1500	500	811	270
1969	350	117	* 295	98	1600	533
1968	608	203	*		1342	447
1967	556	185	*		1260	420
1966	533	178			1311	437
1965	524	175			954	318
1964	401	134			1100	367
1963	390	130			1200	400
1962	378	126			1321	440
1961	288	96			1205	402
1960	281	94			920	307
Total 1960-76	4885	1628	10285	3428	19214	6405

Notes: Values in (hopper yds/tonnes) x 10^3

To obtain a value for the weight of solid material dredged the hopper yards figure is divided by a hopper factor. This varies both as to the area dredged and as to whether an estimate of saturated bed material or dry weight is required. Typically this factor can vary between 2.5 and 5 (2.5 and 4 for saturated bed values); 3 has been taken as the conversion factor in the table above.

*Plus capital dredging to a total of approx 11.2 x 10^6 tonnes

APPENDIX 1

Terms of reference for the initial report as specified by Glamorgan County Council in their letter of 12 June 1973:

"1. On the basis of the evidence already available from the existing reports by other Consultants, and any other readily available sources, to recommend the type and scope, and cost of further investigations required:

(a) To determine the causes of the changes (if any) in the position, levels and nature of Kenfig and Morfa Mawr foreshores from the Port Talbot Tidal Harbour (SS.758 873) to Sker Point (SS.783 798). In particular to determine the effects of:

(i) sand extraction from the foreshore

(ii) the construction of Port Talbot Tidal Harbour

(iii) sand extraction offshore

(b) To determine whether the changes are affecting the supply of sand (if any) from the beach to the dunes or vice-versa.

(c) To determine whether these changes pose a threat of inundation or erosion (temporary or permanent) to the land above high water mark.

(d) To enable recommendations to be made for remedying the situation.

2. As the reliability of the results from the studies may be affected by their scope (including geographical extent) and as this will affect the cost, you should feel free to recommend several projects of varying scope. All such options must be costed and the advantages of the more thorough options clearly stated.

3. To give outline consideration to the additional cost involved in extending the scope of the same surveys (for the same purposes) to include the foreshore from Sker Point to Trwyn-y-Witch (SS.885 726)."

APPENDIX 2

The Summary and Conclusions of the Report to Glamorgan County Council in November 1973 included the following points:

(i) Existing reports on the coastal erosion problem are largely subjective in character, being based on expert opinion but supported by little quantitative data, and lacking even elementary calculations. For example, it is not recognised that the scale on which aggregate removal has been carried out by man over the past four decades is of an entirely different order of magnitude to the rate of long-term natural accretion which has taken place over the nearby dune systems. Nor do the reports adequately consider offshore implications.

(ii) Any study undertaken must include the offshore banks in its remit as the County Planning Officer's Report of 12 January 1973 recognised.

(iii) There already exist, or will soon exist, invaluable data and facilities which could provide a useful input to a research project at minimal cost. In particular, these include BTDB (British Transport Docks Board) aerial photography of the coastline and a new Hydrographic Office offshore survey. The former should be used for photogrammetry while the latter would serve as a base for tracer studies and as a source of comparative data with charts spanning over 100 years.

(iv) Research should not only maximise the use of existing data, but gain information in a wider field. In particular, studies should be directed to:

(a) Acquisition and analysis of wave data, tidal currents, etc.

(b) Computations of wave energy and refraction in the light of (a) above.

(c) Tracer experiments both alongshore and offshore using fluorescent and radioactive labelling as appropriate.

These aspects should not exclude other techniques such as those listed in Table I (not included in the present Report).

APPENDIX 3

Extracts from the Conclusions and Recommendations of the Inspector's Report relating to the Public Inquiry held in December 1973.

Conclusions:

5. There are changes taking place along the foreshore including the erosion of an exposed clay stratum which underlies the beach.
6. The mechanism of these changes is not properly understood.
7. The changes may be due wholly or in part to sand extraction the rate of which has increased substantially in the last two years.
8. Alternatively, the changes may be due to storms or to alterations in local tidal currents and other offshore conditions brought about by the construction of the Port Talbot tidal harbour.
9. The beach is accreting in parts. The rate of accretion is not known.
10. A detailed study of the foreshore and sea-bed conditions is necessary over a period of at least three years and before long-term conclusions can be reached.
11. The Morfa Mawr foreshore should be regarded as an extension of the industrial hinterland site. As such, the working of sand should not be curtailed for amenity reasons. Nevertheless in the absence of proper records of beach changes including cyclic variations and offshore sea-bed conditions, there is a serious danger of over-exploitation of the present beach regime.
12. Long term management of the beach and its potential yield can best be secured in the interests of the parties and the community at large through a licensing system provided that such a licensing system is conducted upon a scientifically conceived and properly monitored basis. This conclusion has been reached because all parties have shown an inadequate knowledge of the long term effects of sand extraction for prudent management of the foreshore, both as a resource and as a bulwark against the sea ---------- .
14. The physical processes of sediment transportation on to Morfa Mawr beach and Kenfig Sands appear to be related ---------- .
15. In considering the problems of sediment transportation, it is desirable that the beach is considered as a whole and indeed the conditions at Morfa Mawr may be so intimately related with those appertaining on Kenfig Sands that I am of the opinion that the two beaches should be studied jointly ---------- .

Recommendations:

I recommend that for the prudent exercise of their statutory duties the Port

Talbot BC (or their successors) is requested to comply with the following recommendations:

1. That the Coast Protection Authority shall undertake or cause to be undertaken a detailed study of the evolving beach conditions, the offshore sea-bed conditions and the potential sediment budget available for beach replenishment extending over a period of three years and thereafter to be monitored at appropriate intervals.
3. That sand extraction shall be controlled by licence, six monthly during the first five years and thereafter as may be appropriate. The licences shall be explicit in duration and may set down the amount of sand which may be removed and from whence.
4. That the burden of justifying the quantities of sand to be extracted or the cessation of those operations shall relate to a quantitative evaluation and forecast of the Coast Protection Authority which shall be up-dated from time to time.

H M G COCKBAIN
Engineering Inspector

(February 1974 : Welsh Office)

APPENDIX 4

Swansea Bay: List of Hydrographic Surveys (Hydrographic Office except where stated)

Survey	Date	Title	Scale	Comments
D4585 /8	1858/60	Swansea and Neath	1 : 22,600	
D4583	1859	Neath to Porthcawl	1 : 10,000	Covers most of area of interest
D3891	1859	Swansea Bay, Bristol Channel	1 : 7,000	
D4314	1859	Additions to D3891	1 : 31,500	
D5191	1860	Porthcawl to Breaksea Pt	1 : 10,500	
A7520	1881	Nash & Scarweather Shoals	1 : 29,000	Revision of parts of 1859 & 1860 surveys
A8771	1884	Sker Pt to Pwlldu Hd	1 : 22,800	Covers area N of 51°30N
E5503	1938/9	Scarweather Sands & Kenfig Patches		1 : 29,250
E6851	1943	Porthcawl entrance	1 : 6,000	
E6852	1943	Shord Channel	1 : 29,250	
E8675	1949	Worms Hd to Watchet	1 : 75,000	
E8676	1949	Sker Pt to Nash Pt	1 : 25,000	
E8677	1949	Swansea Bay	1 : 25,000	Covers area N of 51°32'45"N
E9019	1951	Port Talbot	1 : 2,500	
K1785	1957	Port Talbot	1 : 5,000	Kelvin Hughes
K1786	"	" "	1 : 1,250	" "
K3660 (1-2)	1962	Port Talbot Docks and Channel	1 : 1,250	BTDB
K4994	1966	Approach to Neath	1 : 25,000	
K6097	1969	Port Talbot approach channel	1 : 2,500	Rendel, Palmer and Tritton
K6161	1971	" " " "	"	Rendel, Palmer and Tritton
MOD(N)	1974	Approaches to Swansea	1 : 25,000	Full cover

Surveys prior to 1858/9 have been omitted as having insufficient detail and/or accuracy.

APPENDIX 5

Swansea Bay hydrographic surveys - Chart Datums

Date of survey	Surveyor	Tide data (m)			Title of survey/area
		Mumbles	Port Talbot	Porthcawl	
1827	White	Equi. Spring range = 12.0m Ord.neap range = 6.1m		12.0m 6.1m	(Part of) Survey of the Severn
1831	Denham	Location of tidal data not clear Equi.spring range = 10.2m Ord. " " = 9.0m Neap " " = 4.4m			Mumbles to Nash Point
1859	Alldridge	Equi.spring rise = 9.5m Ord. " " = 8.6m			Neath to Porthcawl
1858/60	"	Neap " " = 6.3m Neap range = 3.8m MWL = 4.4m Soundings in fathoms from LW (ie 4.4m below MWL or 26.8m below BM on Mumbles L/house)			Swansea and Neath
1860(a)	"			HWS=8.7m HWN=6.5 Neap range=4.3m	Kenfig R to Nash Point including Scarweather and Nash Sands
1860(b)	"			4.6m below MWL	Porthcawl to Breaksea Point
1881	Tizard	Presumably as Alldridge, 1860(a)			(Revision of Scarweather and Nash Sands)
1884	Archdeacon	Covers whole bay using Alldridge Mumbles data			Sker Point to Pwlldu Head Scarweather Sands and Kenfig Patches Swansea Bay
1938	Hardy			Reduced to 4.5m below ODN	
1947	Lowry	4.4m below ODN at Mumbles			
1974	Pugh	5.0m below ODN at Swansea	5.20 below ODN at Port Talbot	5.30 below ODN at Porthcawl	
1974	IOS(T)		5.20 below ODN at Port Talbot		

APPENDIX 6

Calculation of change in volume of material between 1859 and 1974 surveys

Problems stem from:

(a) the limits of the surveys do not cover the entire area subject to change, especially at the W end of Scarweather for 1859.

(b) there may be limitations in the accuracy of the isopleths of change in respect of actual position, interpolation, and generalisation caused by using a 1m interval.

(c) there is a paucity of survey data immediately adjacent to the coastline.

(d) discrepancies result from the use of different instrumental methods during the actual field survey, eg echo-sounding v. lead line; electronic methods v sextant angles for position-fixing.

(e) use of least depth values on Hydrographic Department charts tends to exaggerate volumes of sediment.

(f) the adjustment of chart datum between the surveys is not ideal.

Calculation:

The changes in the areas of erosion and accretion between the two surveys were measured in terms of 1m layers for each $\frac{1}{4}$ cm^2 on the 1:25,000 charts (equivalent to a value for every $62.5m^2$ in the field). These gave values for:

Accretion: $599.75cm^2$ (x 1m thick)

$\therefore$ volume = 37.4844 km^2 (x 1m)

= $37.48 \times 10^6 m^3$

Erosion; $796.5cm^2$ (x 1m thick)

$\therefore$ volume = $49.78 \times 10^6 m^3$

Difference in erosion/accretion = $12.30 \times 10^6 m^3$

If error in chart datum $\leqslant$ 0.1m (the attainable limit of accuracy) the whole difference can be accounted for (ie the 1859 chart datum would be 0.1m higher and depths therefore 0.1m greater). The other possibilities mentioned above may have a bearing on the results. Alternatively the change in volume may be real and a physical explanation is called for.

APPENDIX 7

Principal cartographic data sources: Land surveys 19 - 20th century

(a) Tithe maps: E side of Swansea Bay

Parish	Scale	Surveyor	Date Survey	Date Approved by Commissioners	Notes
Aberavon	1:3168 (4 ch = 1")	L J Griffiths	-	1843	
Baglan	" "	-	-	-	Very fragmented parish
Cadoxton-juxta-Neath	1:6336 (8 ch = 1")	-	-	1844	Survey in 2 parts
Coedffranc	" "	-	1842	1843	Part 1 of survey only relevant
Llansamlet	1:3168 & 1:6336 (4 & 8 ch = 1")	-	1846/48	1848	
Neath	1:6336 (8 ch = 1")	-	-	1845	
Pyle and Kenfig	" "	L J Griffiths	1847	1847	
Swansea	" "	-	-	-	Part 1 of survey only relevant

(b) Ordnance Survey maps and plans of Swansea Bay

1:2500	1st ed. Surveyed 1867-78	Published 1868-85		County sheet lines
	2nd ed. Revised 1896-99	"	1898-1901	
	Another ed. " 1913-16	"	1914-20	
	Revised ed. 1936-48	Incomplete		Excludes Margam, Morfa Mawr and R Kenfig.
	1st ed. Surveyed 1955-65	-		National Grid lines sheets SS78NE SE. Some 1:1250 for sheet SS79SW.
1:10560	1st ed. Surveyed 1868-82	Published 1883-87		County sheet lines
	2nd ed. Revised 1896-99	"	1899-1901	" " "
	Another ed. " 1913-16	"	1921-32 Incomplete	" " " ; sheet 39 is not included
1:10560	Glamorgan Air Photo Mosaics	"	1947-53 Incomplete	5x5km format. Sheet 21/78NE & NW covers Port Talbot

APPENDIX 8

Act: 1 Mariae, St 3. Chapter 9. AD 1554

'An Acte touching the Sea Sandes in Glamorganshire'.

'Where in the xxiij yere of the Reigne of the Excellent Prince of famouse memorie King Henry theight, It was enacted and established, That Commissions of Sewers from tyme to time when nede should require, should bee directed to suche substancyall and indifferent persones as should bee named by the Lorde Chauncellor of Englande, the Lorde Treasurer, the Lorde Pryvie Seale, and the twoo Cheife Justices or thre of them, whereof the Lorde Chauncellour to be one, aucthorising them or syxe of them to surveye Walles Streames Dyches Bankes Gutters Sewers Buttes Caweies Bridges Trenches Milles Mylledames Fludgates Powndes Cockes Ebbing Weires and other Lettes and Nuysaunces, by reason of the outrageous course and rage of the Sea in and uppon Marshes and other lowe Places; which good Lawe dothe not extende nor is not taken to give aucthoritee and power unto the sayd Cõmissioners of Sewers to refourme the greate hurte nuysance and losses that cõmethe and chaunceth to the Quenes Highnes and her Subjectes, by reason of Sande rising out of the Sea and dryven to Lande by Stormes and Windes, wherby muche good Grounde lyeing on the Seacoastes in sundrye Places of this Realme and especially in the Countye of Glamorgan, bee covered with suche Sande rising out of the Sea that ther comethe no Profitte of the same, to the greate loss of the Quenes Highnes and her loving Subjectes, and more ys lyke to ensue yf spedye Remedie be not therin provided: Maie it therefore please the Quenes Highnes with the assent of the Lordes Spirituall and Temporall and the Cõmons in this p̃nte Parliament assembled, and by thaucthoritee of the same, Be It Enacted, That aswell the said Acte of Sewers made in the sayd xxiij yere, as all Comissions of Sewers hereafter to bee directed according to the tenour of the said Acte, maye extende and gyve aucthorite that the Cõmissioners therein named for the Countie of Glamorgan, or syxe of them, whereof three to bee of the Quorum, shall by this Acte and the sayd former Acte and Comission to them directed, have full power and aucthoritee from time to tyme to make suche Lawes Provisions Ordinaunces Judgements and Decrees within the said Countye of Glamorgan, for the redresse and saving the sayd Groundes from hurt or destruction by reason of the said Landes, as they might or may doo by the said former Acte and Cõmission, for the withstanding and avoiding of the outragious course and rage of the Sea, or other Waters; Any Usage or Custome to the contrary notwithstanding.'

(Act of Henry VIII is in considerable detail; 1531-2 to run (initially) for 20 years. Concentration on evaluation of weirs, etc., walls, 'fludgates'; whether harmful or not. Regulations for repair of sea walls and other defences. No victimisation).

APPENDIX 9

References to Documentary Sources

1. Act : 1 Mariae, St. 3, Chapter 9. AD 1554. 'An Acte touching the Sea Sandes in Glamorganishire.'

2. Havod y Porth and Margam : Survey 1633. Penrice & Margam Estate (PME) record Ref. 1282. Re sand burial.

3. Repairs to sea walls with stones, 1657. PME Ref 3756.

4. Severall persons for works done in planting sedges. dated 8 May 1732. PME Ref 6709.

5. Warren draft lease : Kenfig. Re Robert Turpin, 1744. PME 5128.

6. Warren and part of the demesne lands in Kenfigg Burrough leased to William John, 1745. PME Ref 4753

7. Indenture : right of Evan John to warrening between R Avan and R Kenfig, 1747. PME Ref 8353

8. Reports of Commissioners on proposed division of Counties and boundaries of boroughs, Part 8, Home Department, 1832

9. Letter by C R M Talbot to L W Dillwyn dated 12 March 1840. Quoted in O'Brien (1927).

10. Cox, J., 1950. Unpublished report. Referred to by Atkins and Partners and County Planning Officer.

11. Atkins, W.S. and Partners. February 1966. The extraction of sand and gravel from Kenfig Beach. Report to the Glamorgan County Council. 7 pp. 6 figures, and plates.

12. Bluck, B J Sept,1972. Deterioration of Sker Beach. 1 pp.

13. Davies, P. 1973. Beach changes and the behaviour of the Kenfig dune system. 4 pp, 1 figure.

14. Kelling, G. March 1973. Morfa Mawr Beach - a preliminary evaluation of the effects of sand and gravel extraction. With addendum on: The Morfa Mawr dune complex. Report to the Port Talbot Borough Council. 19 pp, 4 figures and 16 plates.

15. Sker Beach and the adjacent areas, Swansea Bay. Report by the Institute of Oceanographic Sciences (Taunton) for the Glamorgan County Council, November 1973. 13 pp and Appendices.

16. Submissions to the Public Inquiry into the Borough of Port Talbot Interim Coast Protection Order and Coast Protection Order 1973 together with the Inspector's (H M G Cockbain) Report, dated February 1974.

17. Submissions to the Appeal in the High Court of Justice, Queen's Bench Division, 1974.

APPENDIX 10

Acknowledgements

The Institute of Oceanographic Sciences wishes to express its thanks to the many organisations and individuals who have assisted in providing data and facilities for this Report.

Figures 4 and 5 are mainly based on surveys produced by the Hydrographic Office, Ministry of Defence, and are reproduced by permission of the Hydrographer of the Navy and the Controller of HMSO.

The radiocarbon determinations for IOS boreholes 2 and 4 were carried out by the Scottish Research Reactor Centre.

APPENDIX 11

Note on the spelling of Place-names

Place names are spelled in accordance with the preferred form on current Ordnance Survey 1 : 10,000 or 1 : 10,560 sheets except that Afon Cynffig is shown as River Kenfig. It thus conforms to the name of the former town and present village, together with the spelling of Kenfig Sands, Burrows and Pool.

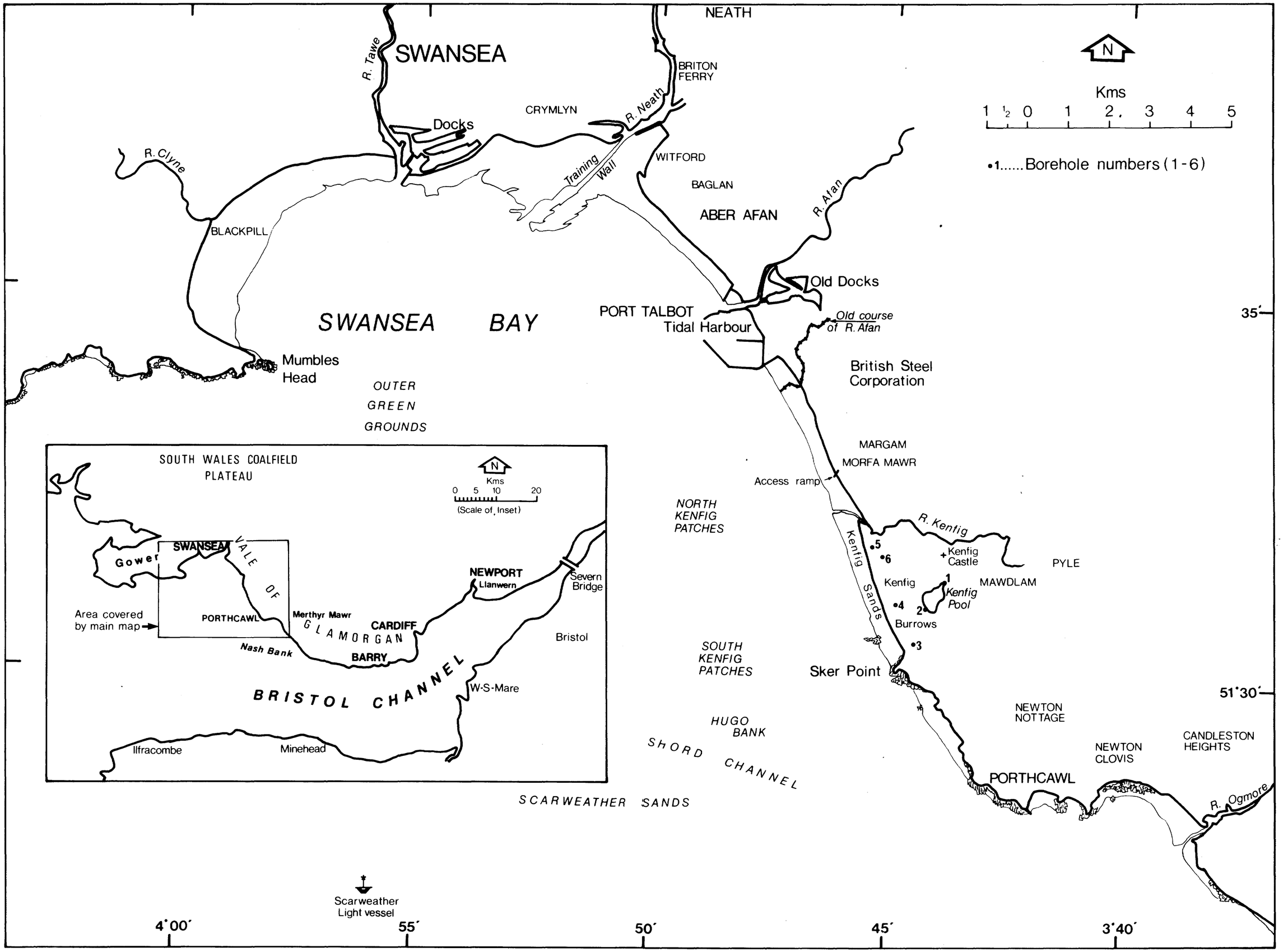
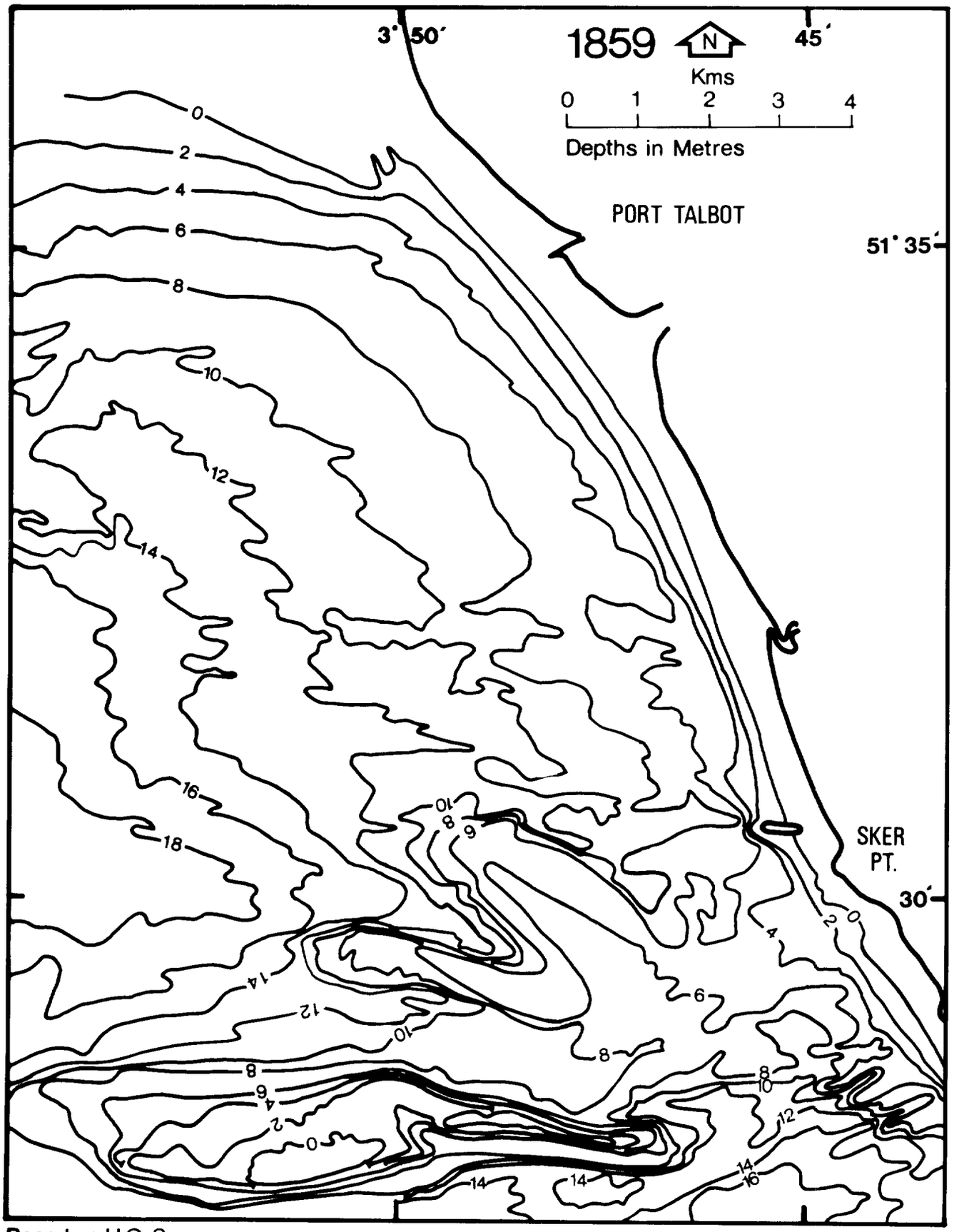

NEATH
SWANSEA
R. Tawe
BRITON FERRY
R. Neath
CRYMLYN
Docks
R. Clyne
Training Wall
WITFORD
BAGLAN
ABER AFAN
R. Afan
BLACKPILL
Old Docks
SWANSEA BAY
PORT TALBOT
Tidal Harbour
Old course of R. Afan
Mumbles Head
British Steel Corporation
OUTER GREEN GROUNDS
MARGAM
MORFA MAWR
Access ramp
NORTH KENFIG PATCHES
R. Kentig
Kentig Sands
Kentig Castle
PYLE
Kenfig
MAWDLAM
Kentig Pool
Burrows
SOUTH KENFIG PATCHES
Sker Point
NEWTON NOTTAGE
CANDLESTON HEIGHTS
NEWTON CLOVIS
PORTHCAWL
R. Ogmore
HUGO BANK
SHORD CHANNEL
SCARWEATHER SANDS
Scarweather Light vessel
N
Kms
1 ½ 0 1 2 3 4 5
•1.....Borehole numbers (1-6)
35'
51°30'
4°00'
55'
50'
45'
3°40'
SOUTH WALES COALFIELD PLATEAU
N
Kms
0 5 10 20
(Scale of Inset)
Gower
SWANSEA
VALE OF
Area covered by main map
PORTHCAWL
Merthyr Mawr
GLAMORGAN
CARDIFF
NEWPORT
Llanwern
Severn Bridge
Nash Bank
BARRY
Bristol
BRISTOL CHANNEL
W-S-Mare
Ilfracombe
Minehead

Fig.1 (51)



Based on H.O. Survey

Fig. 2

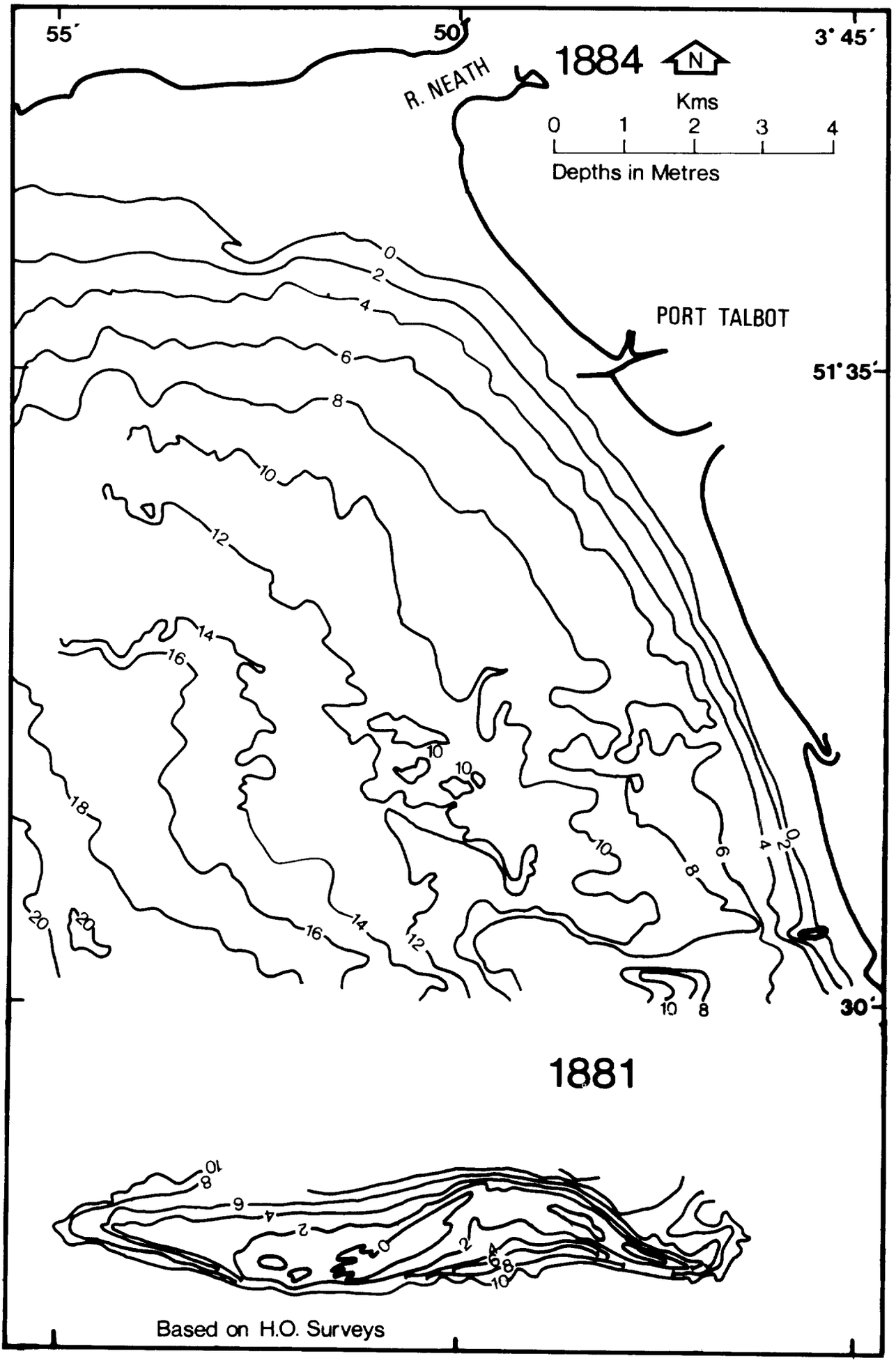

55′
50′
3° 45′
1884
N
Kms
0 1 2 3 4
Depths in Metres
R. NEATH
PORT TALBOT
51° 35′
30′
1881
Based on H.O. Surveys

Fig. 3

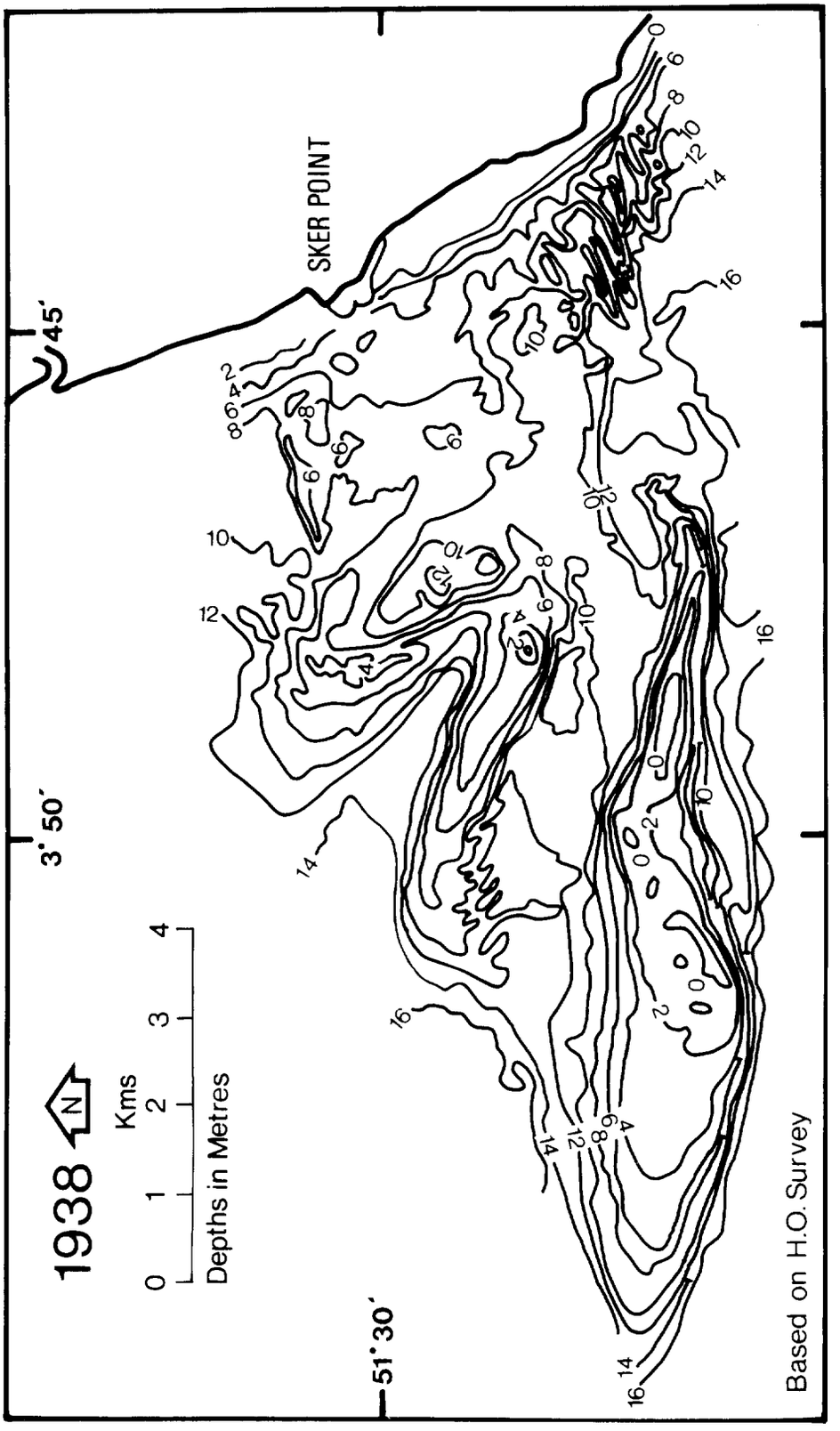

SKER POINT
45'
3° 50'
51° 30'
1938
N
Kms
0 1 2 3 4
Depths in Metres
Based on H.O. Survey

Fig.4

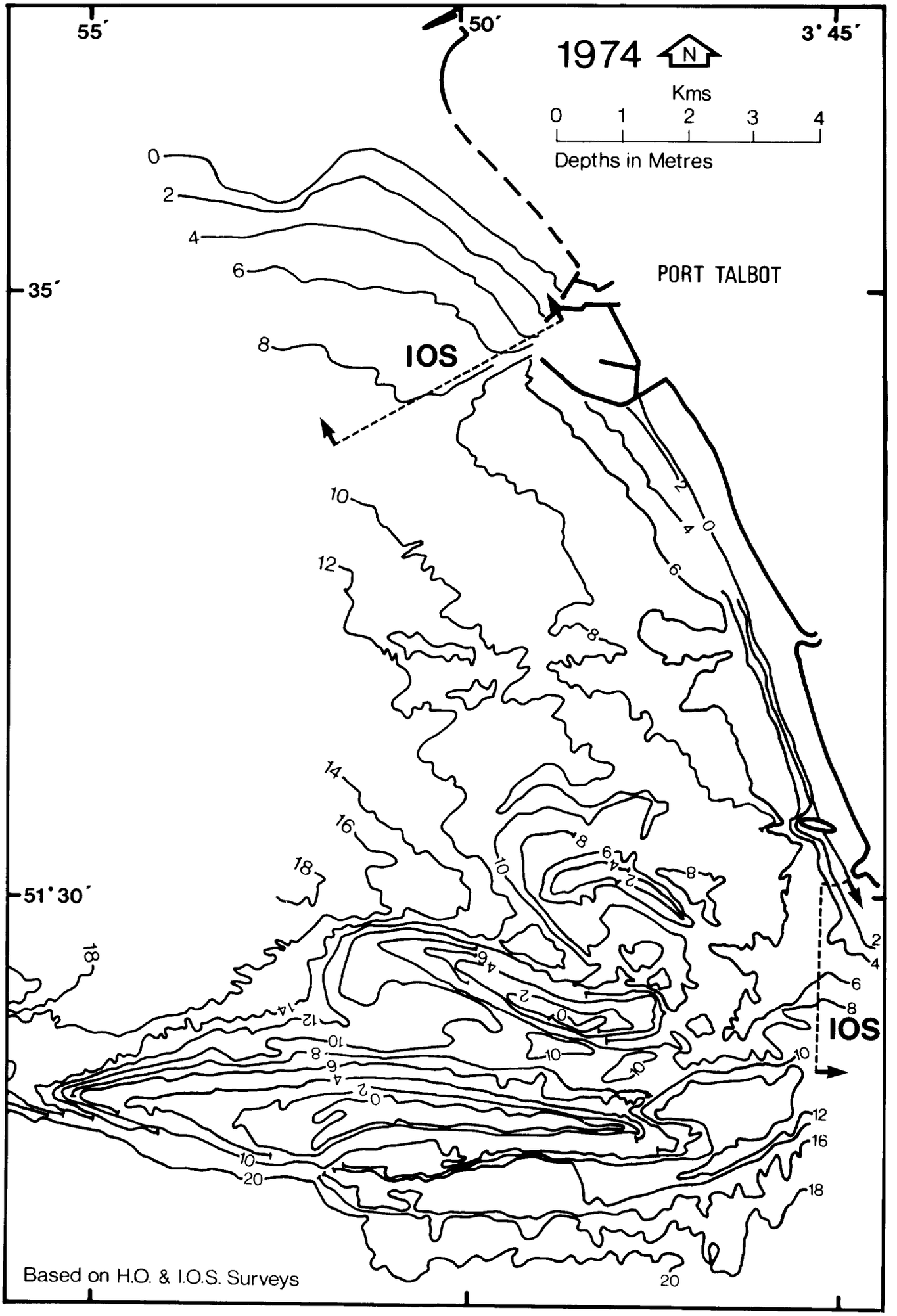

55′
50′
3° 45′
1974
N
Kms
0 1 2 3 4
Depths in Metres
PORT TALBOT
35′
IOS
51° 30′
IOS
Based on H.O. & I.O.S. Surveys

Fig. 5

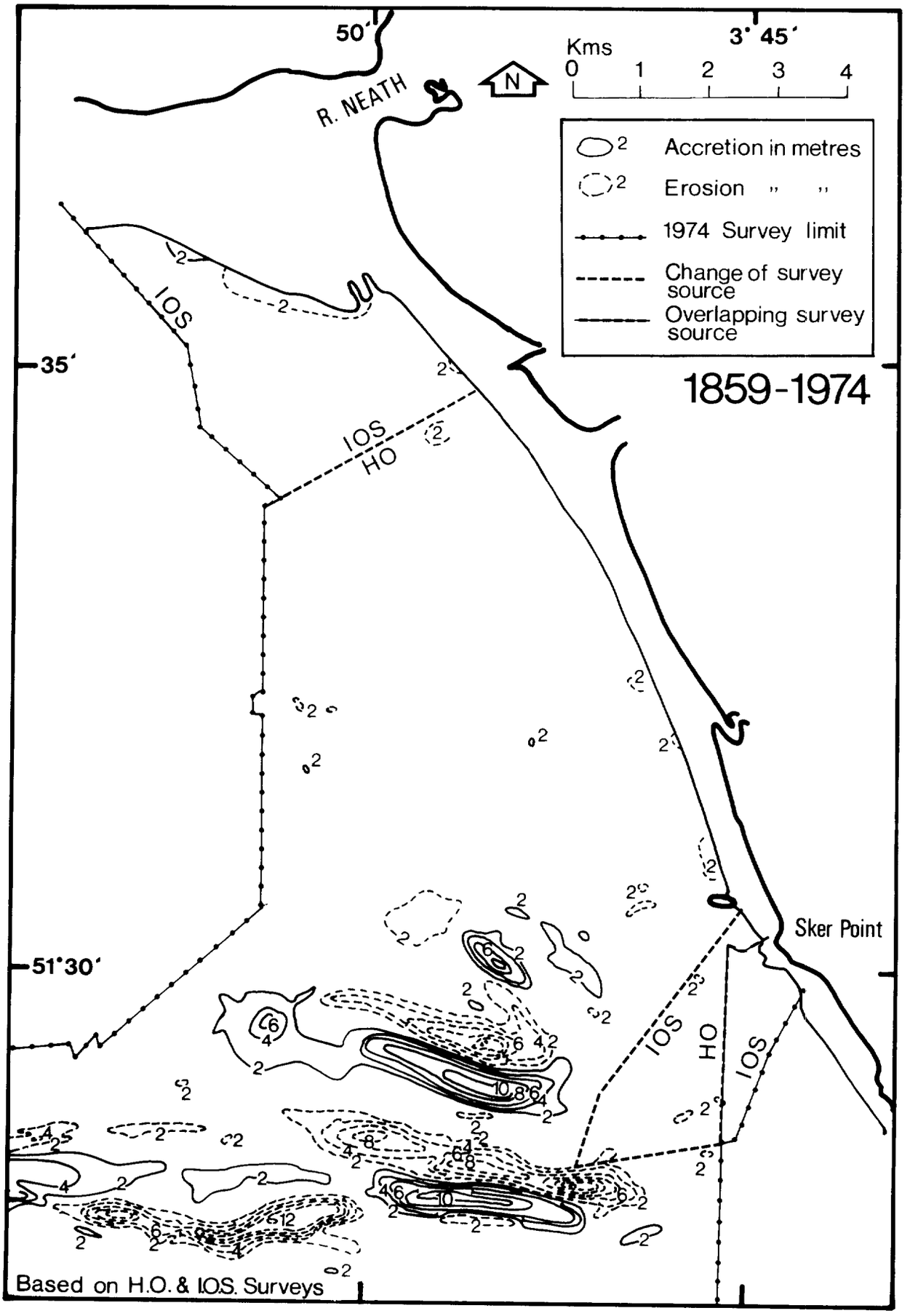

50'
3° 45'
Kms
0 1 2 3 4
N
R. NEATH
Accretion in metres
Erosion " "
1974 Survey limit
Change of survey source
Overlapping survey source
1859-1974
35'
IOS
IOS
HO
51°30'
Sker Point
IOS
HO
IOS
Based on H.O. & I.O.S. Surveys

Fig. 6

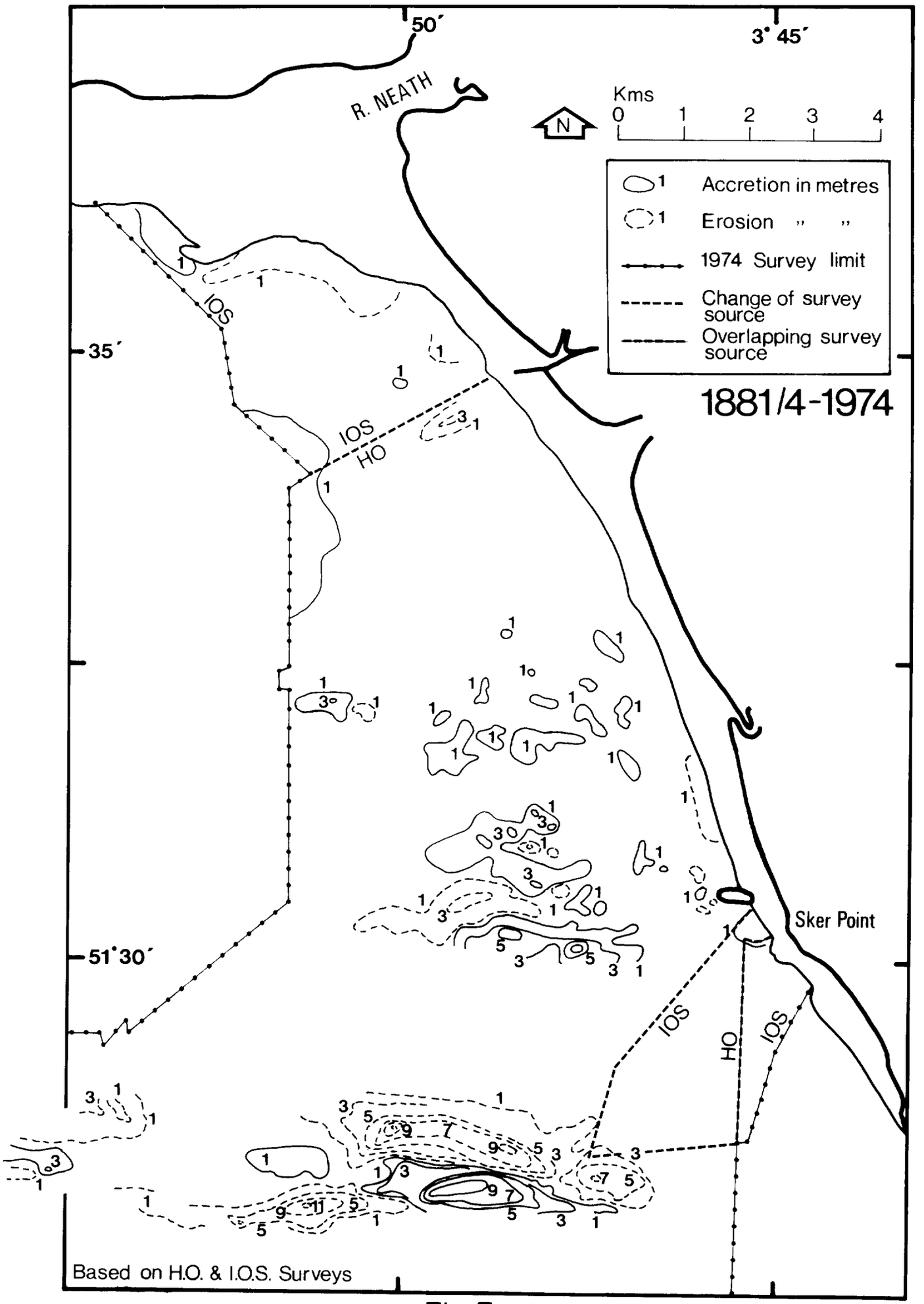

50′
3° 45′
R. NEATH
Kms
0 1 2 3 4
N
Accretion in metres
Erosion " "
1974 Survey limit
Change of survey source
Overlapping survey source
1881/4-1974
IOS
35′
IOS
HO
51°30′
Sker Point
IOS
HO
IOS
Based on H.O. & I.O.S. Surveys

Fig. 7

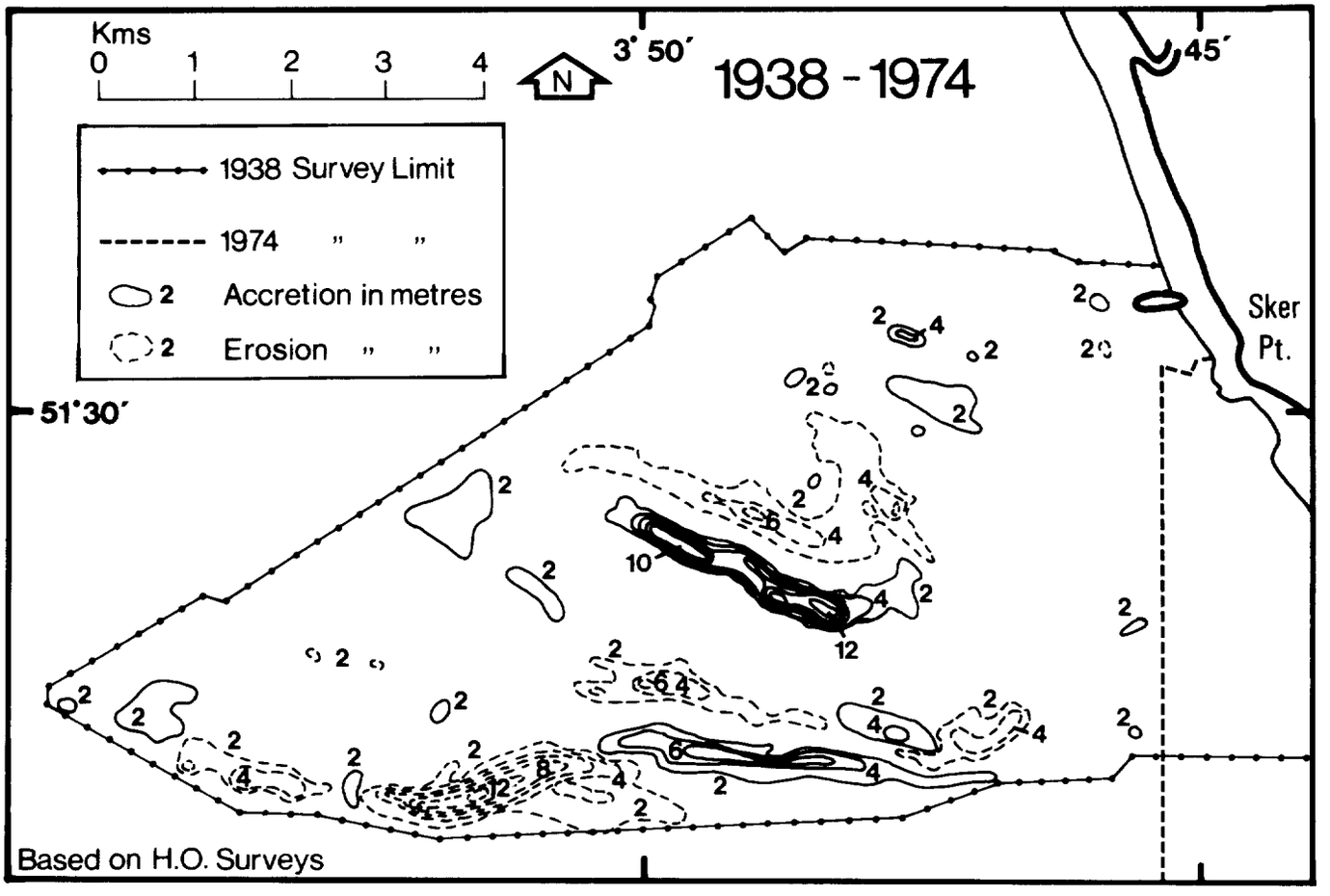

Kms
0 1 2 3 4
N
3° 50′
1938 - 1974
45′
1938 Survey Limit
1974 " "
2 Accretion in metres
2 Erosion " "
Sker Pt.
51°30′
Based on H.O. Surveys

Fig. 8

Position of Crestlines 1859 - 1974

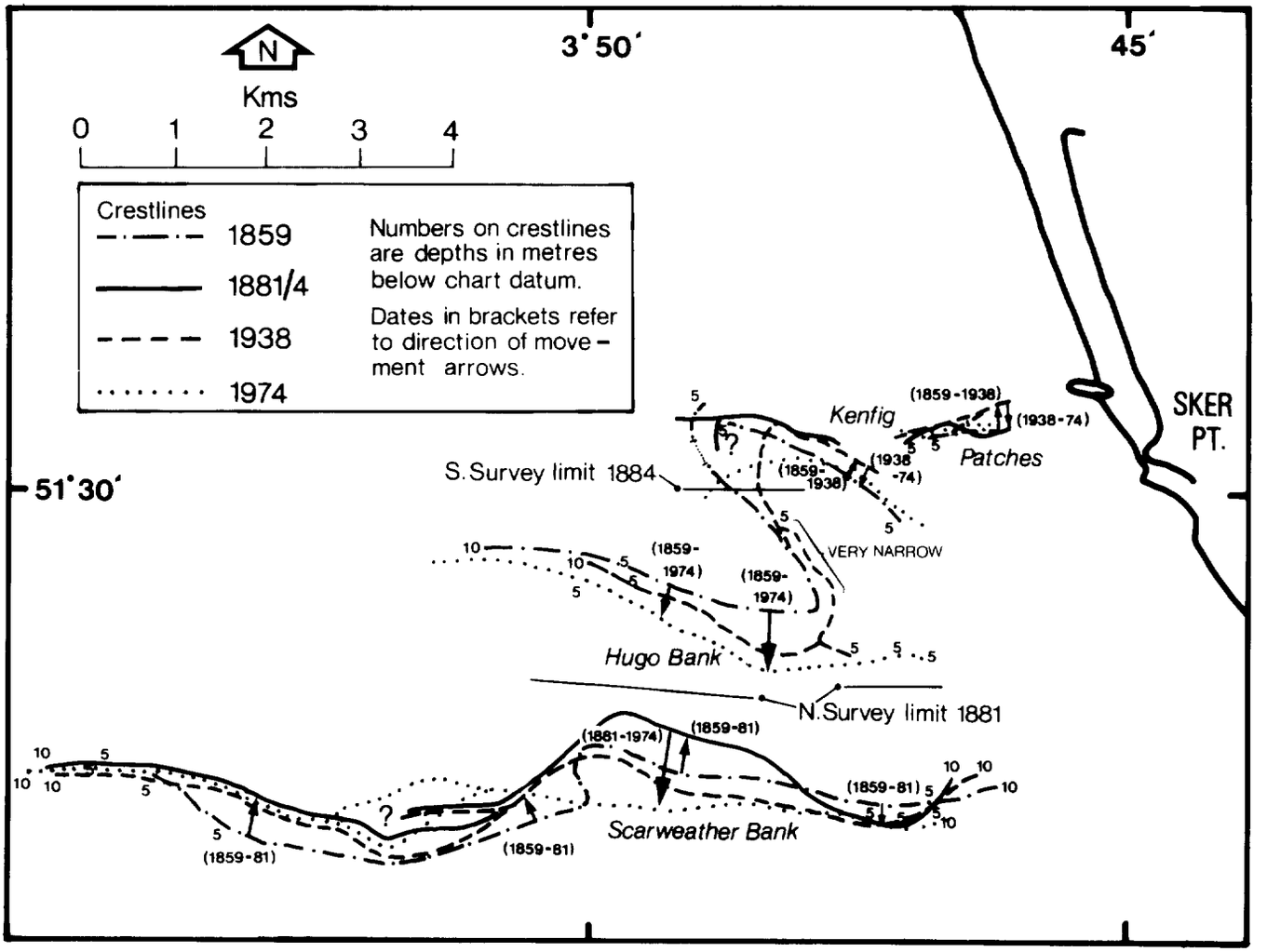


Fig. 9

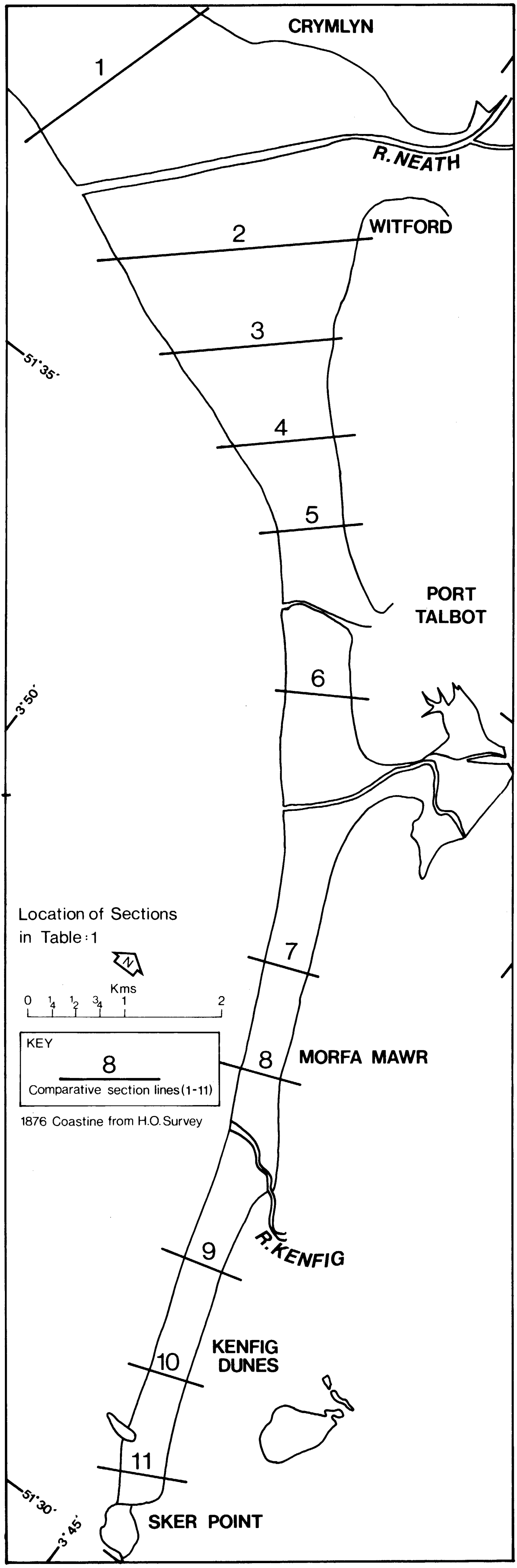

CRYMLYN
1
R. NEATH
WITFORD
2
3
51°35'
4
5
PORT
TALBOT
6
3°50'
Location of Sections
in Table : 1
N
Kms
0 1/4 1/2 3/4 1 2
KEY
8
Comparative section lines (1-11)
1876 Coastine from H.O. Survey
7
8
MORFA MAWR
9
R. KENFIG
KENFIG
DUNES
10
11
51°30'
3°45'
SKER POINT

Fig.10

Position of High and Low Water Marks 1840's - 1960's

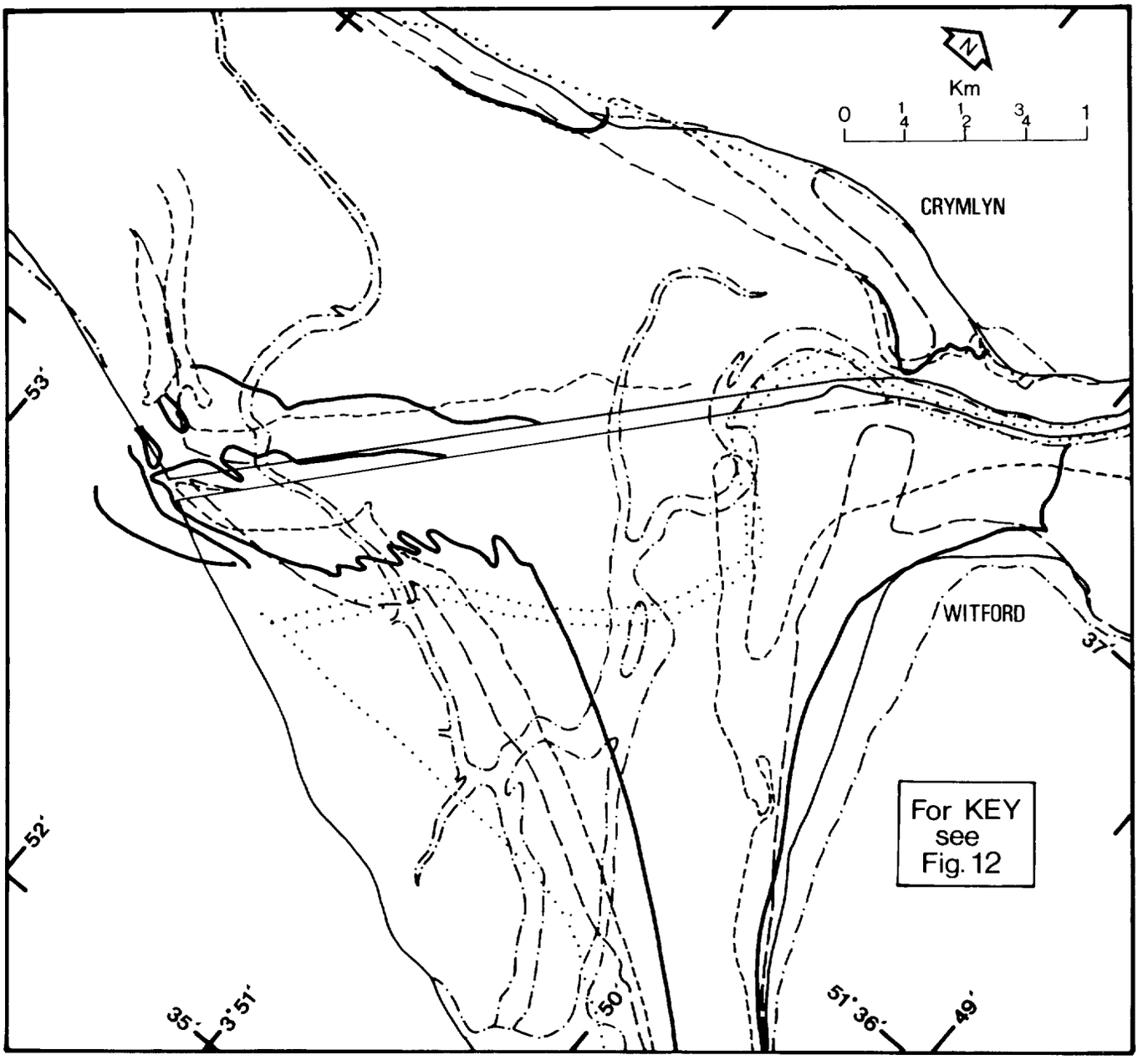


Fig.11

Position of High and Low Water Marks 1840's - 1960's

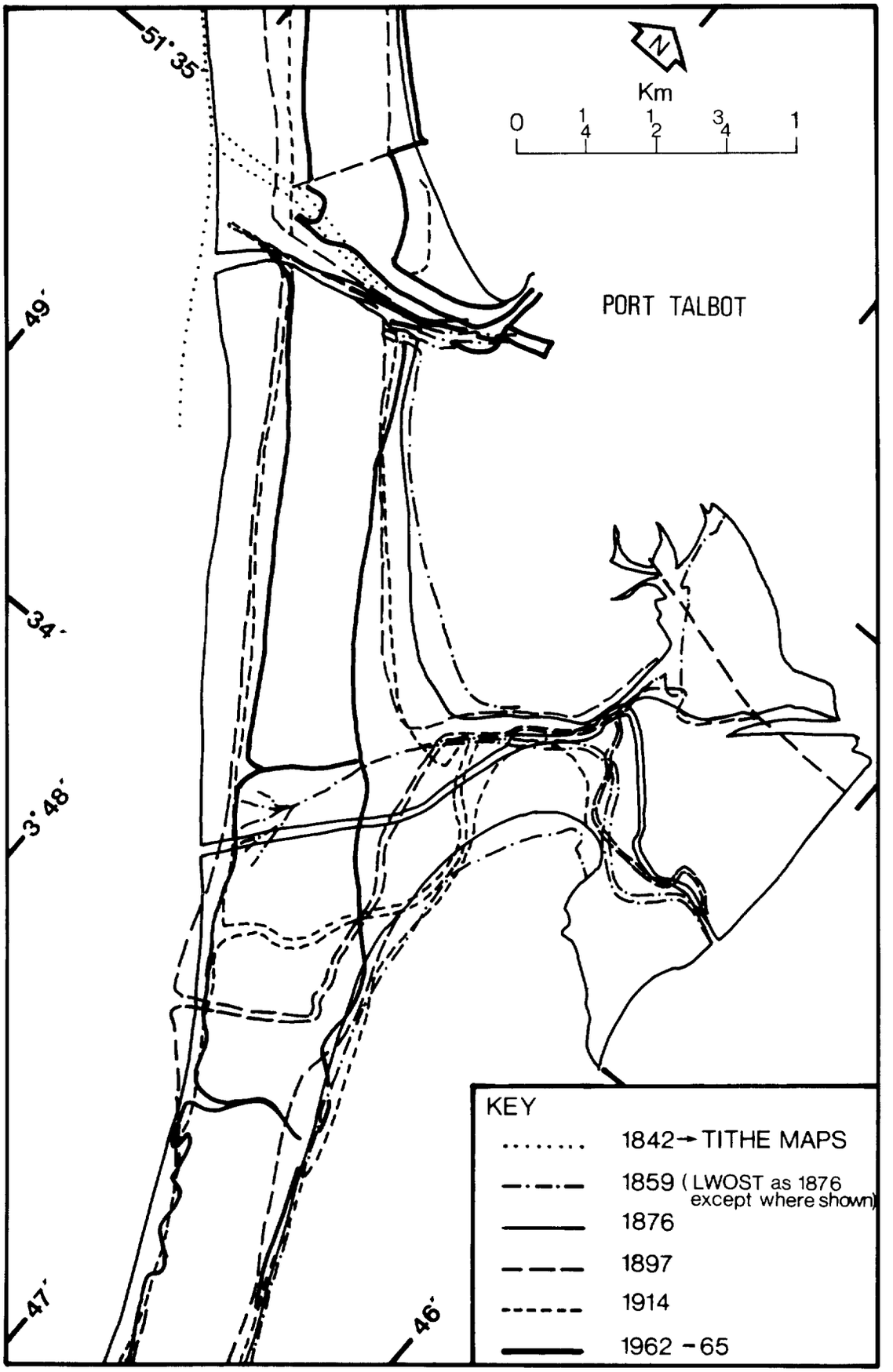


Fig. 12

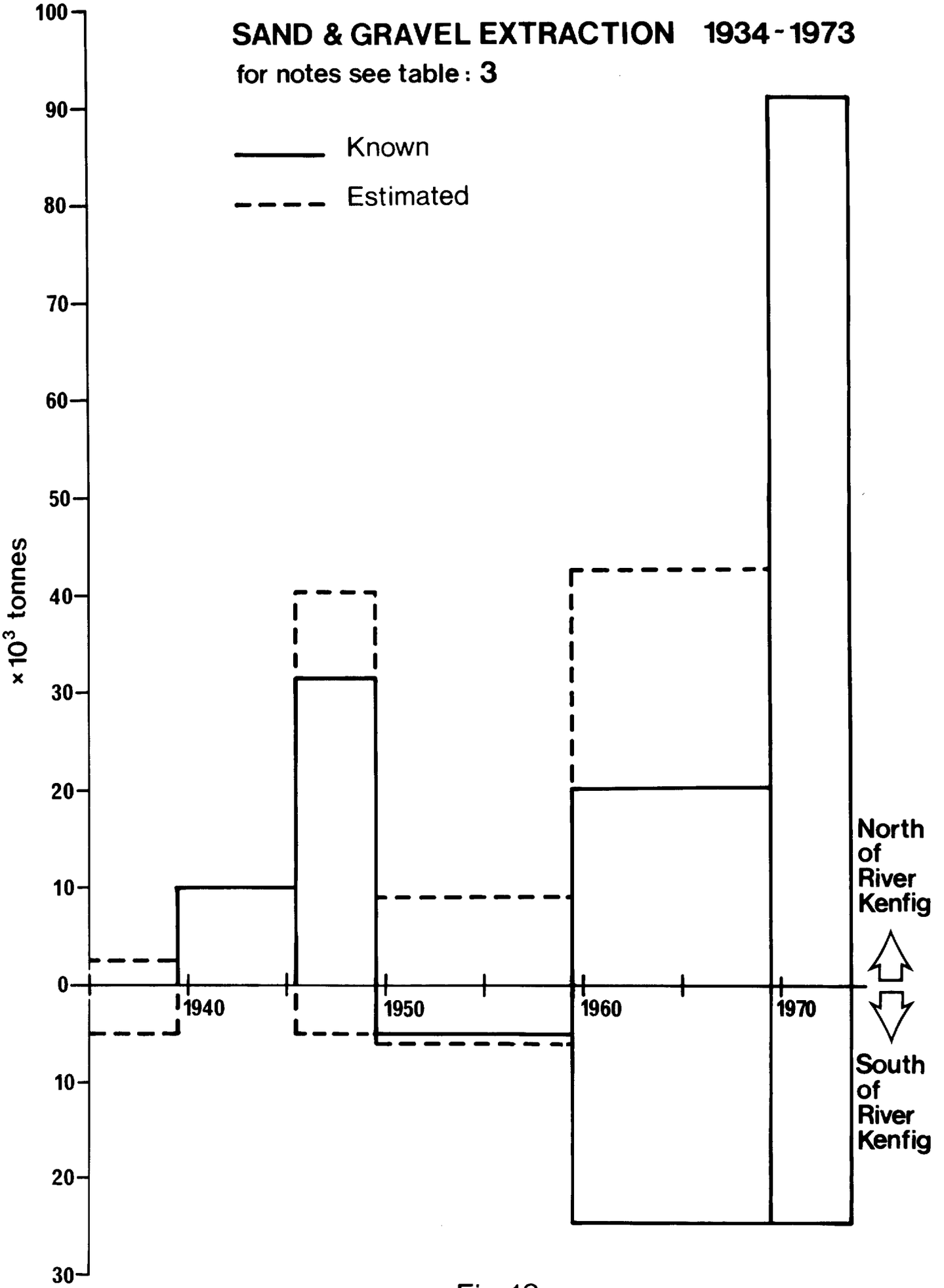

PORT TALBOT to SKER POINT
SAND & GRAVEL EXTRACTION 1934-1973
for notes see table: 3
Known
Estimated
100
90
80
70
60
50
40
30
20
10
0
10
20
30
× 10³ tonnes
1940
1950
1960
1970
North of River Kenfig
South of River Kenfig

Fig. 13