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The geomorphology of Morrich More: management prescription review

J D Hansom & D L Black

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THE GEOMORPHOLOGY OF MORRICH MORE: MANAGEMENT PRESCRIPTION REVIEW

1.0 INTRODUCTION AND AIMS

This report forms a supplement to, and should be read in conjunction with, the report entitled "The Geomorphology of Morrich More: Development of a Scientific Database and Management Prescription", prepared for the NCC under CSD contract HF3-03-325 (362) and published in 1990 (hereafter referred to as "the main report").

1.1 The Morrich More

The Morrich More is a large coastal strandplain on the southern shore of the Dornoch Firth between Tain and Inver (Figure 1). Its development is related to a shallow offshore zone and the presence of abundant sandy material which has been deposited in a series of sequential beach ridges. A prominent Postglacial cliffline formed the basis for the development of the first beach ridges about 7000 years ago and since then successive ridges have been deposited. This has created an important and unique coastal landform extending some 7 km into the firth in a north easterly direction. Partly for this reason, the site has been designated a grade 1 SSSI.

1.2 Aims of the Report

a. To summarise the historical evidence and data from beach landform surveys prior to 1989 used in the preparation of the main report.

b. To collate and assess subsequent coastal survey data acquired by SNH since 1991, including aerial photography of the site.

c. Where possible to link these data sets in order to provide an assessment of the coastal process regime and landform response at Morrich More.

d. To identify any significant landform changes and overall process trends occurring on the Morrich More coastal edge, and to assess their impact on the geomorphological interest of the site.

e. In the light of the above to review, where necessary, the research requirements and management recommendations made in the main report.

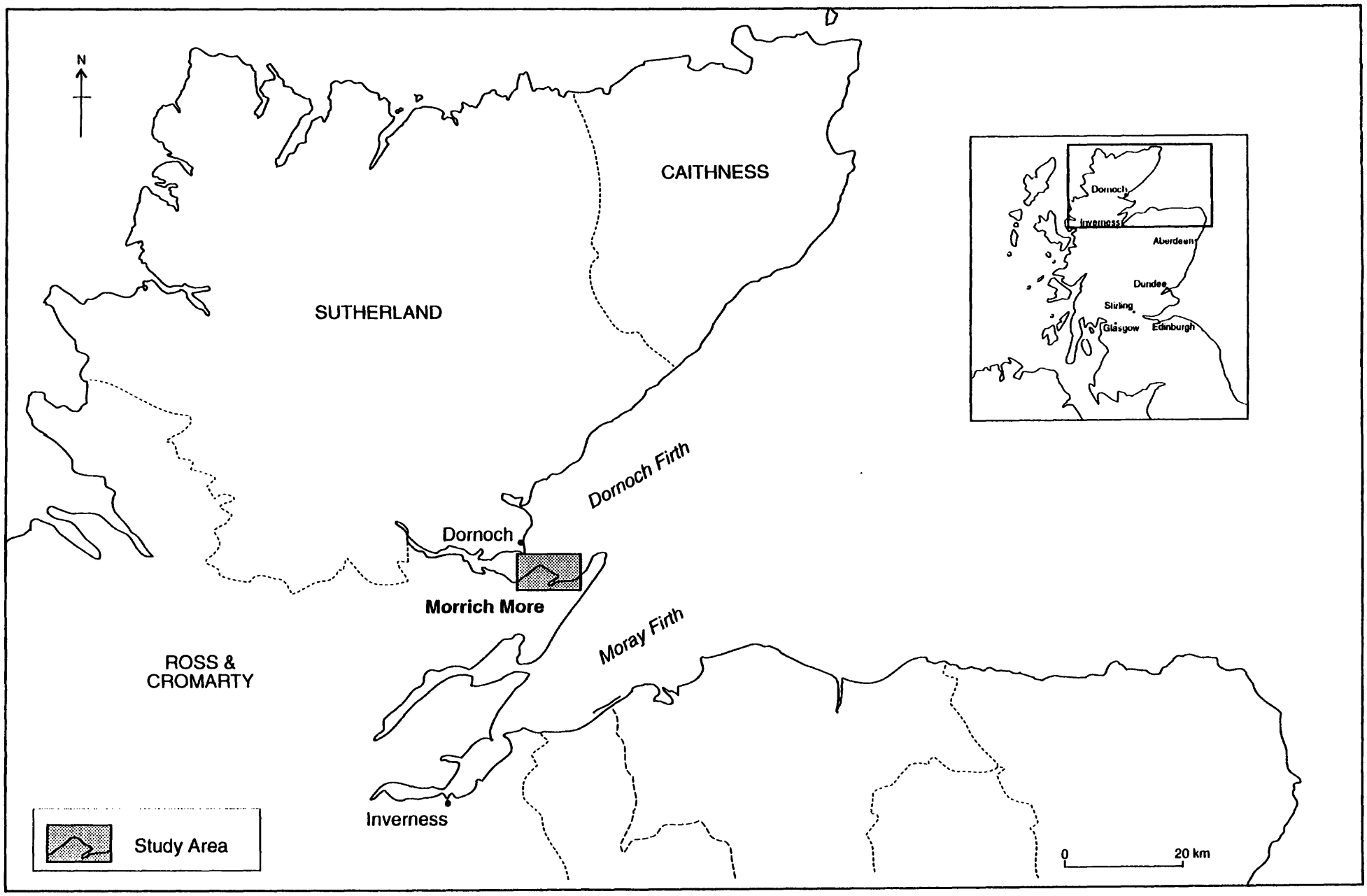


Figure 1. Location map of the Morrich More

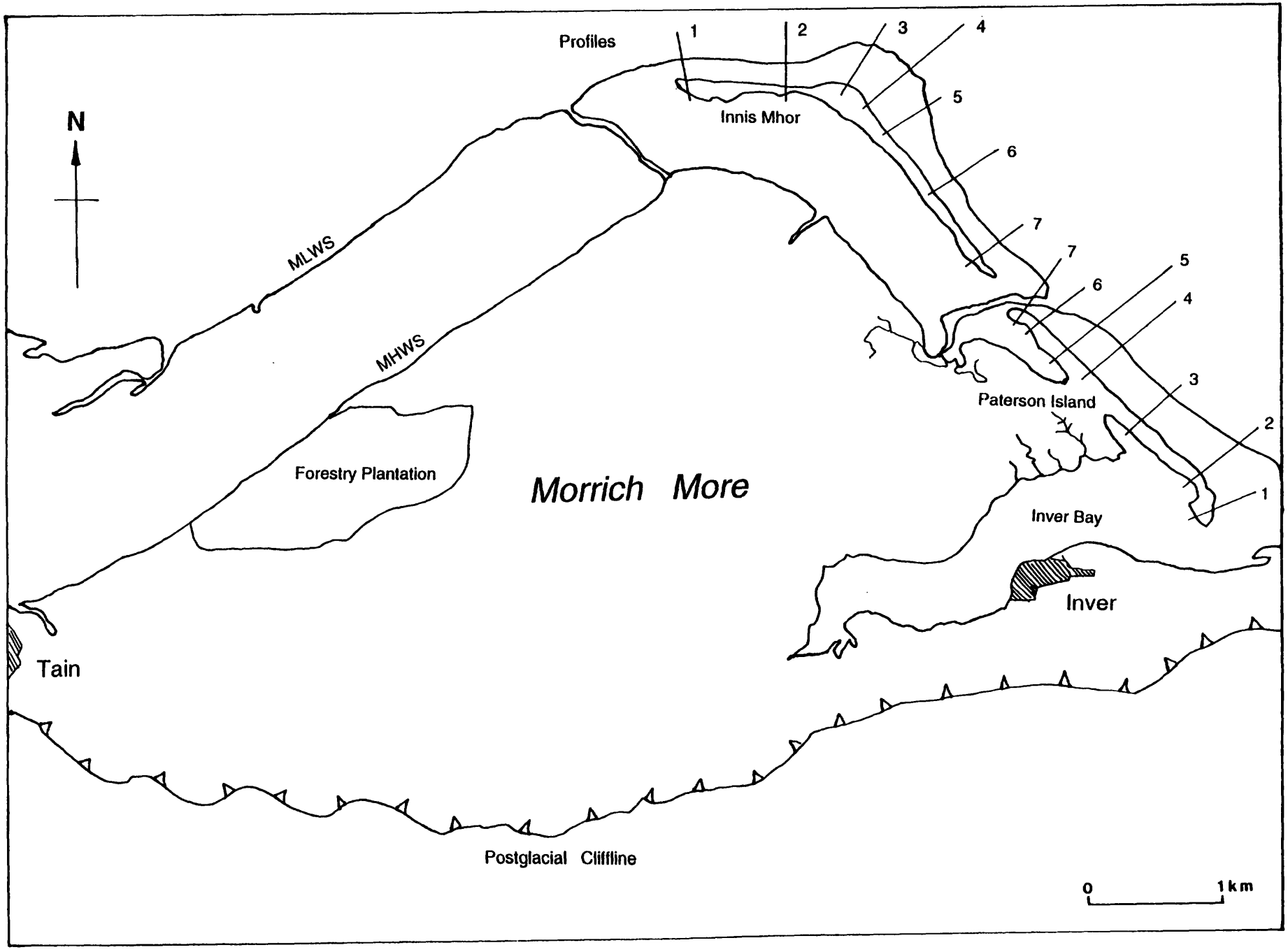


Figure 2. Plan of Morrich More showing beach profile locations

2.0 REVIEW OF COASTAL PROCESSES AND LANDFORM CHANGES

2.1 Summary of Previous Findings (Dataset 1)

In the main report, tables 4.7 (a) and 4.7 (b) list sequential gains and losses of beach material for a total of 14 cross-sections of the north east coast of Morrich More, seven covering Innis Mhor and seven covering Paterson Island (Figure 2). For comparative purposes only, these are expressed as percentages of a total beach profile area as enclosed by arbitrarily positioned x and y axis boundaries, dependant upon beach elevation and seaward extension. The timescale of the surveys in the main report (known as dataset 1) extends from winter 1987 to summer 1989 at approximately quarterly intervals.

To allow more direct comparison of results with subsequent surveys (known as dataset 2), three key profiles, common to both datasets, have been selected for each of the two areas of interest. These Profiles (1,3 and 4 on Innis Mhor and 1,3 and 6 on Paterson Island) are reviewed here before assessment of the second dataset is made.

2.1.1 Innis Mhor beach profiles (Dataset 1)

Several trends emerge in relation to sediment movement on Innis Mhor. The clearest of these is a high and persistent loss of material from the vicinity of profile 3, which is located on the elbow connecting Innis Mhor to its westward extending "flying bar". Commensurate gains occur on either side of this apex, although from 1987-1989 the bulk of the accumulation was recorded to the west of the apex, along the narrow spine of the flying bar. Further west, at the tip of the bar, profile 1 shows a cyclical pattern of moderate gains and losses, the gains tending to be in the upper beach dunes and the losses in the lower beach area. Similarly, to the east of the apex, profile 4 portrays upper beach building associated with active dune accretion. Likewise, losses occur in the lower beach platform, but these are small at this location and thus profile 4 experiences a net gain throughout the survey period. In summary, the Innis Mhor coastline is accreting steadily with the exception of the severe erosional zone around the apex at profile 3. Net gains are occurring at almost all other points on the island, although the overwash zone between Inis Mhor and Paterson Island occasionally loses material from the upper beach to the wide sand flats behind. These wide sand flats, sheltered by Innis Mhor, are accretionary and saltmarsh colonisation on the mainland of Morrich More is steadily encroaching onto this area (Figure 3). The longer term patterns at

the western end of the flying bar (profile 1) seem to indicate that the bar feature is highly active but with a general conservation of the constituent sediments.

2.1.2 Paterson Island beach profiles (Dataset 1)

The hammerhead-shaped bar of Paterson Island (now substantially connected to the mainland of Morrich More, and no longer an island) is generally accreting healthily. This can be attributed to the ready supply of material from shallow offshore banks in the Dornoch Firth to the north and also to delivery of material from the dynamic frontage of Innis Mhor to the west. Profiles 1 and 3 show persistent deposition even throughout the normally erosive conditions of the winter months, easily offsetting the intermittent minor losses at profile 6 on the western tip of the bar. It is likely that much of the material lost from this point is carried behind the distal tip of the bar during strong flood tides, where the lower energy regime then encourages deposition. The remainder is almost certainly carried east to feed the rest of the Paterson Island beach/dune system. Another area of loss, especially in the upper beach area, is between profiles 1 and 3. This is explicable in terms of its open dune-free nature and frequent storm overwash. The material lost from these areas contributes to rapid accretion on the sand flats behind Paterson Island at both its northern and southern extremities. Accretion in the lee of the southern spit contributes to ongoing saltmarsh build-up in Inver Bay. Overall, sediment gains on Paterson Island tend to occur in the central and eastern sections of the complex, with localised but limited net losses at the western end of the island where a substantial tidal inlet carries material into the sand flats behind.

2.2 Analysis of Recent Surveys (Dataset 2)

Surveys carried out on the Innis Mhor and Paterson Island beach complexes by NCC/SNH between spring 1991 and summer 1994 provide an extended record of sediment movement patterns on the Morrich More, and allow a longer term assessment to be made (Section 2.5). In addition, recent aerial photography is available for the coastline of Morrich More, greatly helping in the identification of the longer term scenario.

2.2.1 Innis Mhor beach profiles (Dataset 2)

The 1991-1994 surveys of Innis Mhor strengthen the evidence for an accretional eastern coast combined with a persistently erosional northern apex. Again the western end of the flying bar exhibits a cyclical tendency, apparently unrelated to

seasonal forcing. Profile 1 shows an overall small gain in the upper beach/dune system, but this is linked to heavy net erosion of the lower beach (up to 2.2 m loss of depth at a point some 100 m seaward of the survey peg). Commensurate with the 1987-1989 surveys of Innis Mhor apex, profile 3 displays large losses, reaching 2.0 m vertically over the winter of 1991/92. Furthermore, the ongoing erosion of the *c* 6 m OD dune ridge during the winter storms of 1992/93, with the consequent loss of the profile 3 survey peg, highlights the rate of recession at this point. At profile 4, an overall loss is displayed, mostly in the upper beach, which is probably linked to the proximity of the continually eroding zone around profile 3, but this is largely offset by a strong build-up of the lower beach area. An area of accretion is also evident in the sand flats to the rear of Innis Mhor, where ongoing saltmarsh and extensive algal colonisation visible on aerial photographs indicates enhanced stability.

2.2.2 Paterson Island beach profiles (Dataset 2)

The 1991-94 surveys of Paterson Island portray much the same scenario as that indicated by the earlier surveys. Heavy sediment gains at profile 1 are in close correspondence with the previous findings, and small upper beach losses at profile 6 are balanced, as before, by slow building of the surrounding tidal sand flats. One difference which is highlighted in the 1991-94 data, however, is the sudden, marked erosion of the whole beach at profile 3 during the winter of 1992/93. However, this reversal of the apparent trend is short-lived and by summer 1994 the beach level appears to stabilise again. In summary, Paterson Island remains heavily accretional along its eastern end and, to a lesser extent, in the central section, where seasonal losses are readily replaced within an active sediment exchange regime. The western end continues to exhibit a more confused picture of roughly equivalent gains and losses, probably attributable to its central location and complicated by the nearby tidal channel. Aerial photography shows that accretion is ongoing in the sand flats to the rear of Paterson Island, both in the centre of the beach and into Inver Bay.

2.3 Linking Datasets 1 and 2

Some problems were encountered in linking datasets 1 and 2. Only a few of the original pegs were relocated in the second survey and in an active yellow dune environment these sites are likely to have suffered accretion in the intervening years. Given the possibility of such vertical changes, the two datasets are analysed qualitatively on an independent basis to identify common trends. This information is then augmented by analysis of the aerial photography and by

combining both media it is possible to establish the longer term process picture. The trends which emerge from each dataset are consonant and so some confidence can be attached to the summaries.

2.4 Analysis of Aerial Photographs

In the course of researching the main report in 1987, an aerial survey was carried out, providing an excellent high resolution image of Morrich More complementing the existing surveys from 1944, 1967 and 1970. Construction of a pipeline launching facility across the saltmarsh skirting the Inver tidal inlet then prompted a further specially-commissioned colour aerial photographic survey. This was flown in September 1993 by Photoair Surveys Ltd. and is extremely useful in the up-to-date assessment of short-term erosion and deposition trends along the Morrich More coastline. From the photographs it is possible to accurately position the average high water mark, equated here to mean high water springs (MHWS). Figure 3 illustrates the historical sequence of beach ridges discussed in the main report, with the coastline derived from the 1993 aerial survey added. This map allows direct assessment of recent coastline changes to be made and the photographs themselves provide important additional detail.

2.4.1 Aerial Survey - 1944

Tracing the position of the coast over successive aerial surveys, a picture of dramatic change emerges. In 1944, the Morrich was surrounded by a 1.5 km wide sand flat divided into two distinct sections by a sharp apex at the northernmost point. None of the Paterson Island complex existed and the only evidence of Innis Mhor was a single islet some 300 m long and 150 m wide perched on the apex about 1 km to seaward of MHWS and tentatively colonised by sparse dune grasses.

2.4.2 Aerial Survey - 1967

By 1967 Innis Mhor had doubled in length and become much more established with the attendant growth of dune topped islets to the east and a narrow 'flying bar' extending to the west. Paterson Island had begun to appear about 600 m to seaward of MHWS as a line of four separate islands each about 150 m in length. The sand flats separating both complexes from the mainland of Morrich More were showing increasing evidence of vertical and horizontal accretion. This was particularly true behind the Paterson chain of islands where the saltmarsh on the mainland edge had already advanced some 50 m to seaward since 1944 and

substantial 'greening' of the sands indicated stability and a reduction in tidal overwash in this area.

2.4.3 Aerial Survey - 1970

By 1970, although only three years had passed, the changes since the 1967 survey were marked. The flying bar on Innis Mhor had extended notably and become fully capped by dunes and dune grasses, while to the east a broad swash bar had developed. This feature, apparently consisting largely of windblown sand had increased the length of Innis Mhor to 2.2 km. The situation was echoed on the Paterson complex, where the four islands had been joined by a fifth, much further to the east, and linked by a long and remarkably straight sand bar. This feature, now some 2.3 km in length, was also in the process of being connected to the Morrich mainland by a rapidly accreting tombolo near the centre of the complex. Small but definite areas of saltmarsh had also developed along the north east facing Morrich More mainland edge since the 1967 survey, especially behind Paterson Island.

2.4.4 Aerial Survey - 1987

As might be expected, in the years between the 1970 and 1987 surveys, further dramatic changes had taken place all along the north eastern edge of Morrich More. By 1987, the flying bar on Innis Mhor had extended to 1 km in length and was fully capped by active dunes and vegetated with dune grasses. Its proximal end had thinned to less than 20 m wide and it appeared as though it would soon become breached. Behind Innis Mhor, however, an area of rapid saltmarsh growth had developed on the northern corner of the Morrich mainland. This would appear to have been encouraged by a combination of substantial deliveries of sediment from the west flank of the Morrich and the shelter afforded by the enlarged flying bar. At the north apex of the mainland, the sandy beach of 1970 had been left some 140 m inland by 1987, illustrating the extraordinary speed of coastal development in this area. This trend is reflected in the shelter of Paterson Island where the two central dune-capped islands in the complex had merged and become connected to the mainland by a well developed salt marsh system built around the tombolo which appeared in 1970. Behind the other outlying islands of the Paterson system, sedimentation had also increased so that tidal inundation was restricted to the highest events only. Evidence of further organic colonisation could now be seen clearly over most of the low sand flats between Innis Mhor, Paterson Island and the Morrich mainland.

2.4.5 Aerial Survey - 1993

The relentless build-up of sediments along the eastern coast of the Morrich More continues to show on the 1993 aerial survey. A further 30 m of saltmarsh accretion is evident along the northern apex of the mainland and greening of the sand flats behind Innis Mhor indicates that the two areas may soon become merged. Since both the 1987 and 1993 photos were flown in September, the increase in vegetation cover is unlikely to be seasonally related. The beach along the landward edge of the Innis Mhor flying bar has become subject to burial in places by tidally delivered and wind blown sands. Two particularly interesting occurrences have taken place on Innis Mhor. Firstly, the narrowest point of the flying bar (which appeared very narrow in 1987) has widened again by some 10 m and the dune ridge has become more strongly established. Secondly, the bar has pivoted 60 m to seaward about its root and extended 300 m in length to the west. Although from the profiles, this area was seen to exhibit a cyclical movement over time, the extent of this recent migration to the north is noteworthy. Whether this relates to long term changes in wind or wave approach directions remains to be established. While substantial changes had occurred behind Paterson Island by 1987, the 1993 survey shows less change here than behind Innis Mhor. However, the saltmarsh areas have become more fully developed and a distinct high water mark is visible around much of the Paterson complex as it has become gradually more consolidated. The eastern arm of Paterson Island remains largely an overwash zone at the highest tides, although partial greening visible on the 1993 survey (which is in colour) suggests that at MHWS it remains dry. In Figure 3, therefore, this area appears as a zone of substantial horizontal development, whereas it may be a few more years before this area has accreted sufficiently to allow saltmarsh vegetation to take a firm hold.

2.4.6 Beaches on the north west coast

Although the north west of the Morrich More, between Tain and Inis Mhor, exhibits far smaller rates of movement than the heavily accretional north eastern edge, the changes are important owing to their predominantly erosional nature. Retreat rates are varied along this coastline, but in general they range from 5 mm to 300 mm per annum. An area of marked change in the past 50 years has been a 1.5 km section of coast north east of the forestry plantation which has retreated some 6.5 m since 1970. However, near Tain at the southern end of this shoreline, a 1 km stretch of coast has been stabilised with crushed rock barrier islands because of unacceptable erosional losses fronting agricultural property and a golf course.

This has halted erosion along this stretch but will inevitably reduce the supply of material delivered to beaches to the north east. The section of forestry between these two zones of erosion was planted in the 1950's on an area of dune suffering severe blowout damage. Comparing aerial photography from 1944 and 1993, the stabilising effect of this forestry on the sand dunes has been considerable. An area which shows a reduced rate of erosion is a 500 m long area immediately north of the forestry plantation. Erosion has been slowed here by the outcrop of a peat bed underlying the dunes and now exposed on the beach.

2.4.7 Inver Channel

To the extreme east of the Morrich More complex, the location of the tidally swept channel at Inver has remained remarkably stable in plan, although considerable siltation associated with the seaward growth of the Morrich has reduced its depth dramatically over the past two centuries. This, in turn, has progressively reduced the vigour of the tidal prism in the Inver channel, and a zone of accretion has become established behind the east arm of Paterson Island (Figure 3).

2.5 Identification of Longer Term Trends

From a process point of view, the coastline of Morrich More consists of two distinct but interrelated regimes; the steadily accreting north east facing beaches and the generally erosional north west beaches. Future management of the Morrich More shoreline requires not only a knowledge of this present process regime, but also an assessmentof the likely natural development of the complex.

The principal long term trends on the Morrich More are as follows;

1. Erosion of the north west coast between Tain and Innis Mhor. This is likely to increase as sediment supplies from the south west diminish in quantity as a result of artificial protection of the shore between Tain and the golf course.

2. Associated lowering of the intertidal sand banks in the Dornoch Firth on the north west coast of the Morrich More.

3. Longshore movement of material along the north west coast into the sheltered area behind Innis Mhor. This will eventually lead to reduced tidal penetration as accretion enhances elevations and promotes growth of saltmarsh vegetation.

4. Continued development of the coastal edge to the north east of the Morrich mainland, currently consisting of the Innis Mhor and Paterson Island complexes. These are nevertheless likely to remain separated from each other for several years to come by the centrally positioned tidal channel which provides a substantial drainage outlet for the Morrich mainland.

5. Continued overwash accretion of the sand flats landwards of the above central channel so that the islands and the mainland of the Morrich More continue to become progressively joined as a result of accretion and vigorous saltmarsh growth.

6. Ongoing siltation of the Inver tidal channel in parallel with further accretion of the sand flats at the western end of Paterson Island.

7. Looking further ahead, and thus more speculatively, as the Inver Channel exit becomes increasingly subject to sediment infill from the west, its viability may be under threat in the future. Since there is presently very little freshwater input into the Bay, the channel is kept open only by the tidal flux of water. Figure 3 shows this progressive narrowing over the last 250 years. Any potential natural closure of Inver Bay is most likely following a period of strong northerly waves, longshore sediment delivery from the west and associated sediment deposition at the eastern end of the Morrich. It is possible that such an occurence may happen in the next 50-100 years or so.

8. In advance of any progressive closure of Inver Bay, the saltmarsh habitat would increasingly be subject to modification due to reduced tidal penetration and duration. Ultimately it may be replaced by a brackish or freshwater habitat.

3.0 RECOMMENDATIONS FOR SHORELINE MANAGEMENT

3.1 Recommended Management Strategy

The recommendations made in the main report in connection with coastal erosion remain pertinent and are reiterated here with specific emphases as follows;

1. An understanding of the processes of coastal erosion and deposition on the Morrich More is vital to the development of a sustainable management strategy.

2. Any applications for coastal edge development, such as extension or development of the pipeline facility, should be strongly resisted. Any future efforts to locally restrict the dynamic erosional and depositional processes would adversely affect the medium and long term stability and functioning of the Morrich More.

3. The present policy of minimal disturbance by military vehicles of vegetated areas, especially where these have been recently colonised , should be maintained.

4. Any proposals for further coastal protection works should be opposed. This is especially relevant to any extension of the existing barrier system to the west of Ardross Forest. Such an extension would be likely to exacerbate frontal losses elsewhere along the north west coast of the Morrich and to reduce sediment supply to the accretionary beaches and sandflats of Innis Mhor and, ultimately, of Paterson Island.

5. Any applications for beach mining on any of the beaches of the Morrich More should be opposed.

3.2 Future Research and Monitoring

1. The six profiles reviewed here should continue to be surveyed to provide a longer record of sediment movements on the advancing shore of the Morrich.

2. It is recommended that survey sites be re-established along the north west coast of the Morrich in order to permit bi-annual or quarterly monitoring of horizontal and vertical recession rates. Careful siting of these profiles will enable particular problem areas to be closely watched. These areas include the northern end of the existing protection works at Ardross, the forest edge and the retreating section between the forest and Innis Mhor.

3. It is recommended that survey sites be re-established within Inver Bay to closely monitor the sedimentation regime within both the Bay and the exit channel.

4. It is recommended that a further aerial photographic survey of the coastline is conducted within 5-10 years of the 1993 survey and that at an intermediate time scale the position of the MHWS be surveyed using a GPS surveying system in order to establish short term fluctuations in the position of the shore.

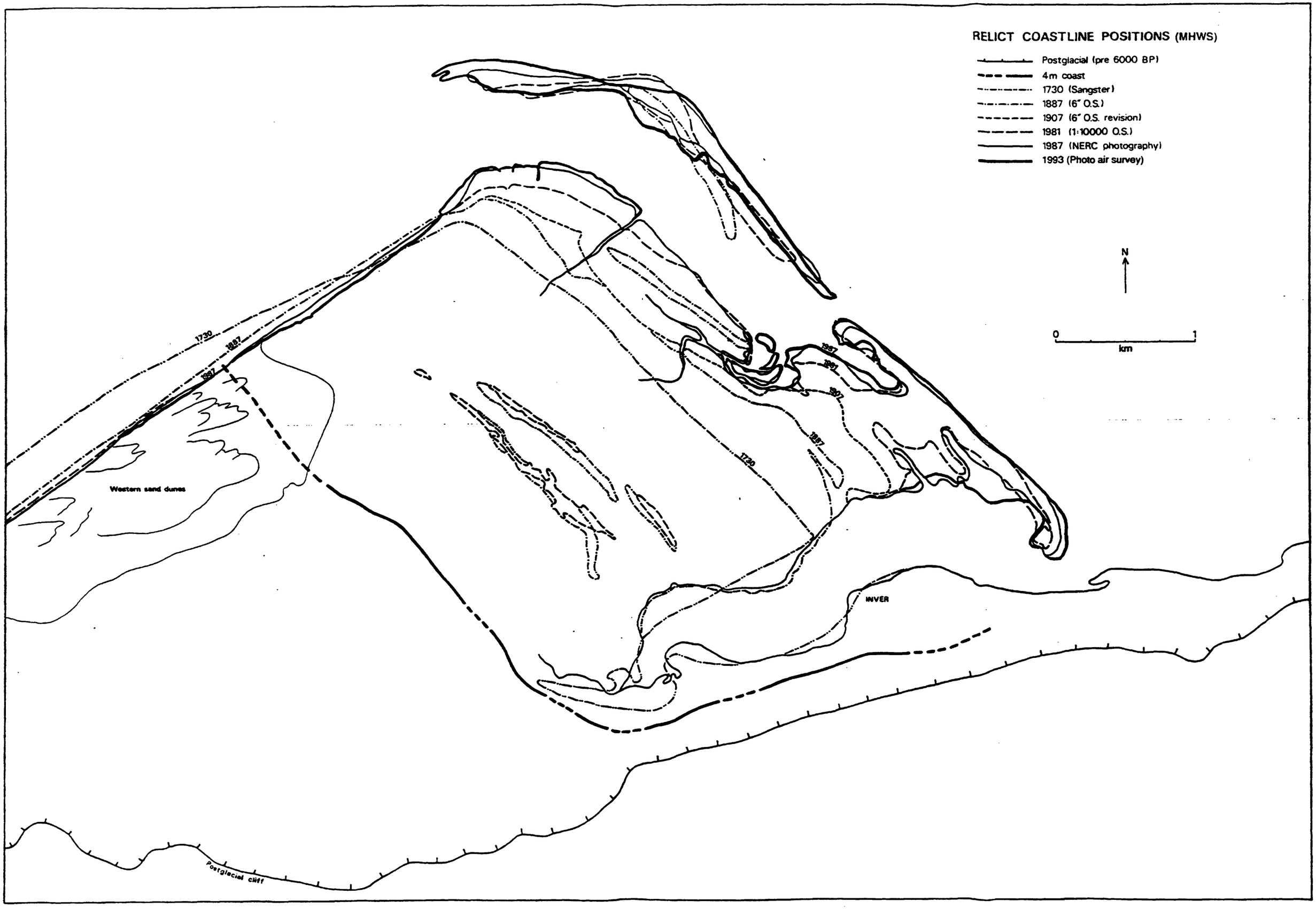
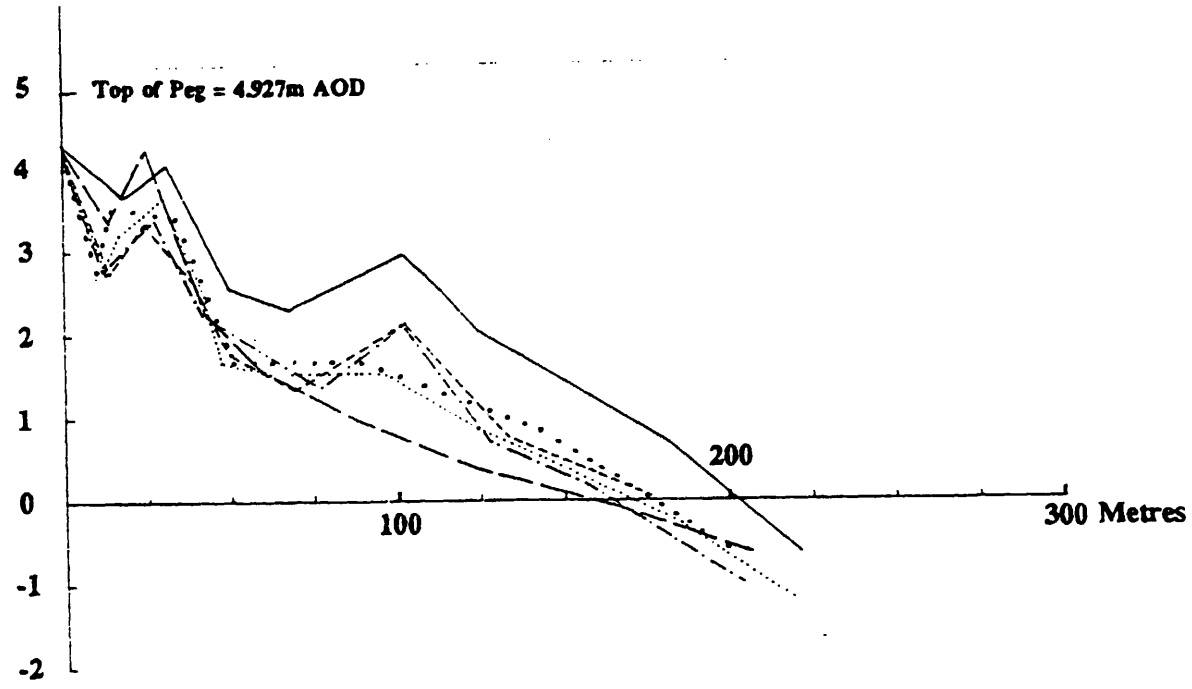


Figure 3. Relict coastline positions (MHWS)

INNIS MHOR

Survey of May 1991 ————————
Survey of March 1992 - - - - - - - - - - - - - - - -
Survey of June 1992 —·—·—·—·—·—·—·—
Survey of January 1993 . . . . . .
Survey of June 1993 .....
Survey of March 1994 — — — — — —

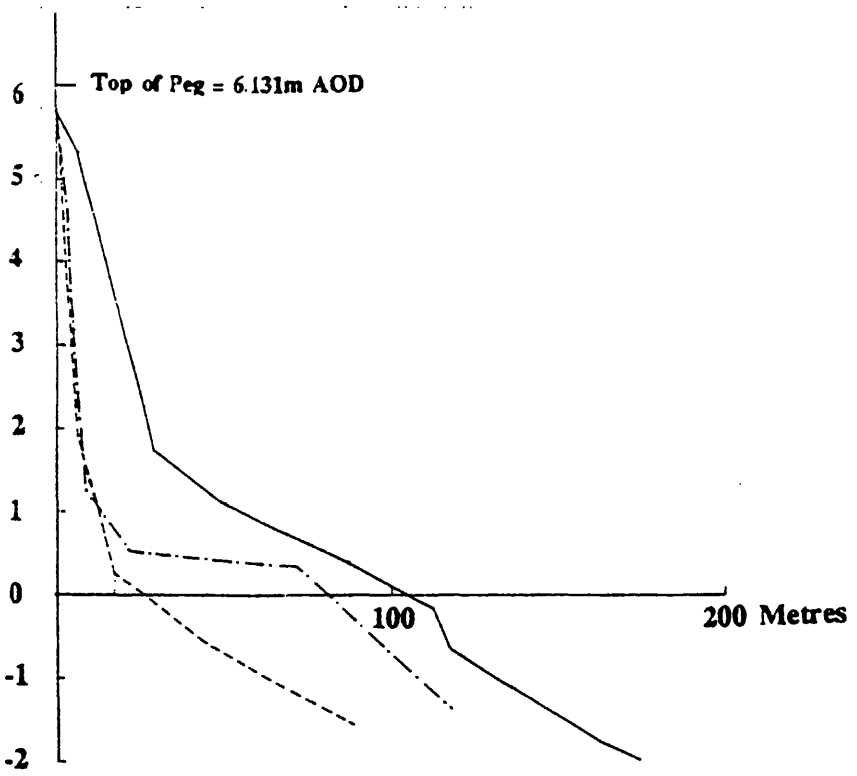
PROFILE No 1



INNIS MHOR

Survey of May 1991 ————————
Survey of March 1992 - - - - - - - - - - - - - - - -
Survey of June 1992 _ . _ . _ . _ . _ . _ . _ . _
Survey of January 1993 . . . . . .
Survey of June 1993 .....
Survey of March 1994 — — — — — —
Survey of July 1994 .. _ .. _ .. _ .. _ .. _ .. _

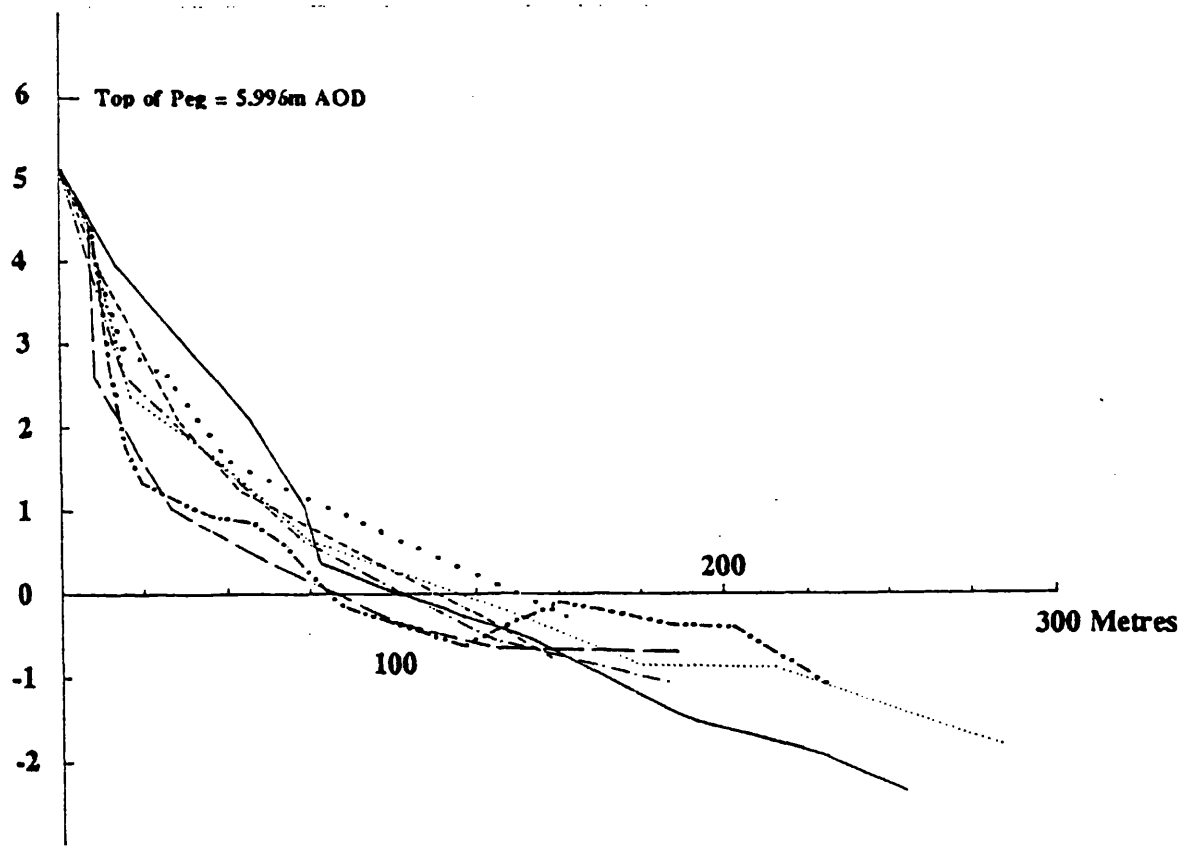
PROFILE No 3



INNIS MHOR

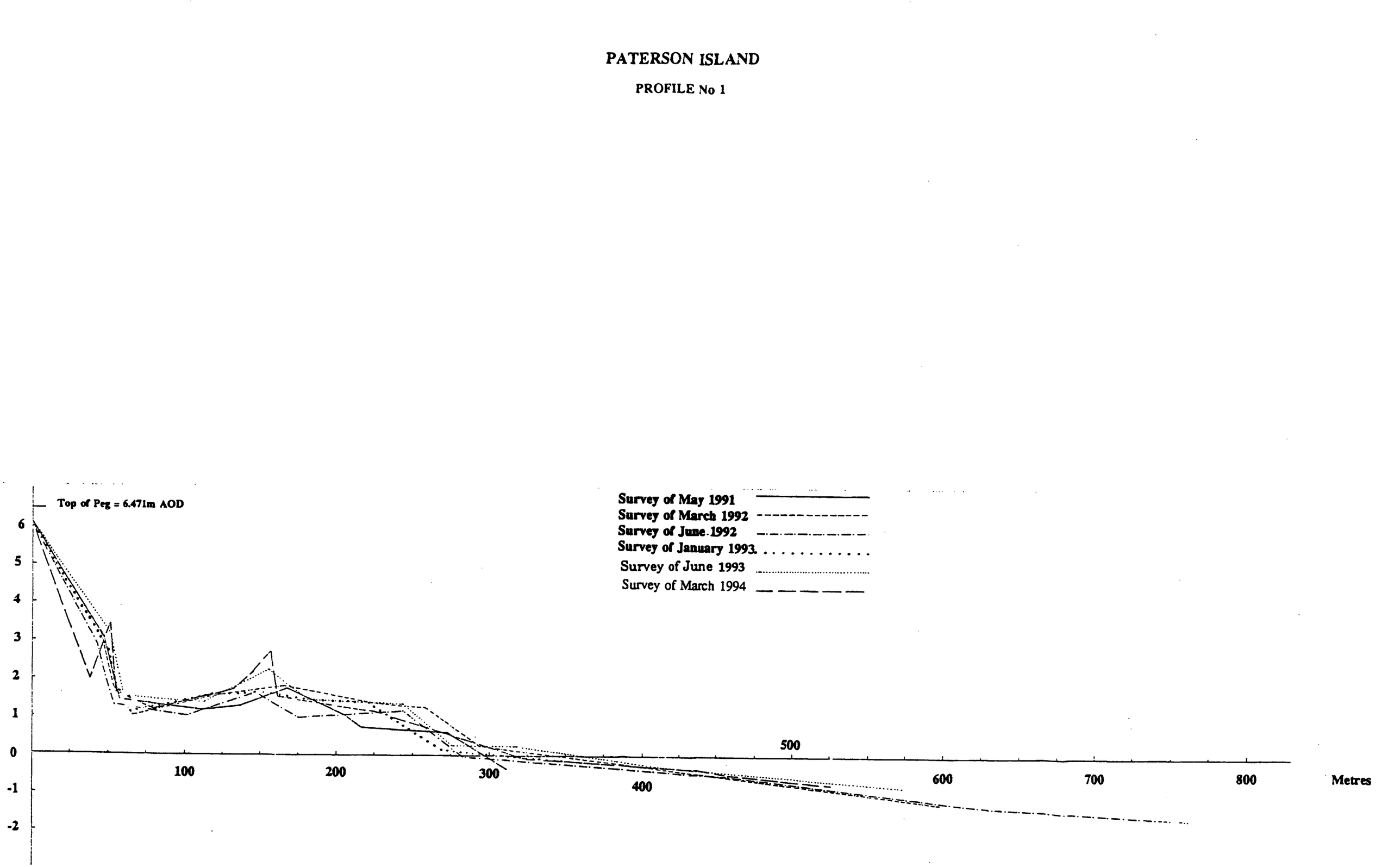
Survey of May 1991 ————————
Survey of March 1992 - - - - - - - - - - - - - - - -
Survey of June 1992 _ . _ . _ . _ . _ . _ . _ . _ .
Survey of January 1993 . . . . . .
Survey of June 1993 .....
Survey of March 1994 — — — — — —
Survey of July 1994 .. _ .. _ .. _ .. _ .. _ .. _

PROFILE No 4



PATERSON ISLAND

PROFILE No 1



PATERSON ISLAND

Survey of May 1991 ————————————
Survey of March 1992 - - - - - - - - - - - - - - -
Survey of June 1992 — . — . — . — . — . —
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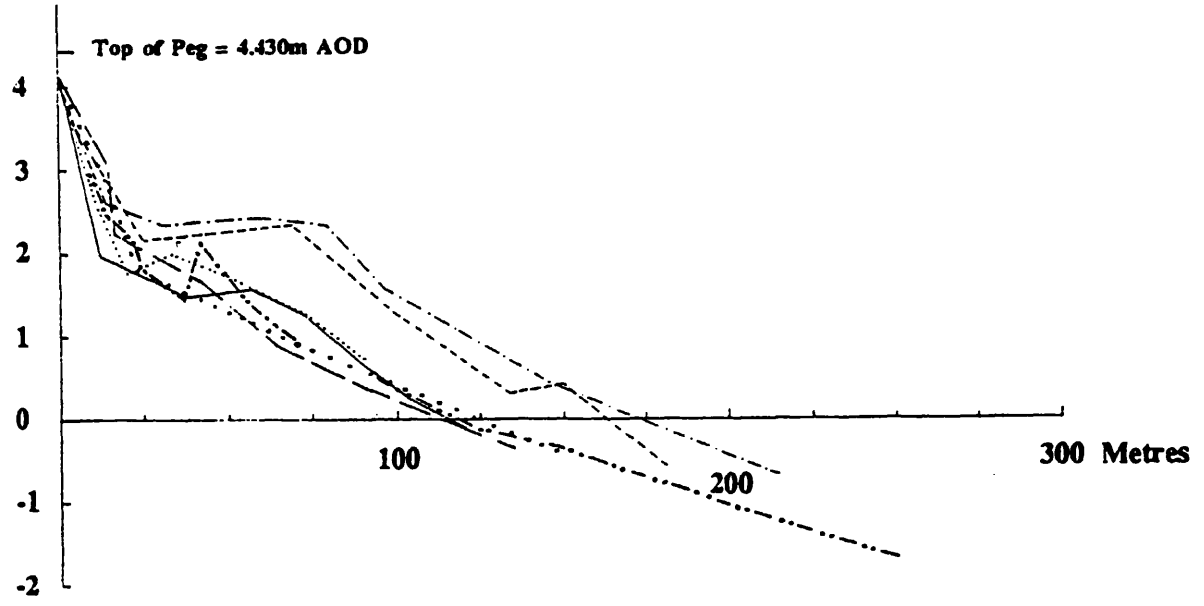
PROFILE No 3



PATERSON ISLAND

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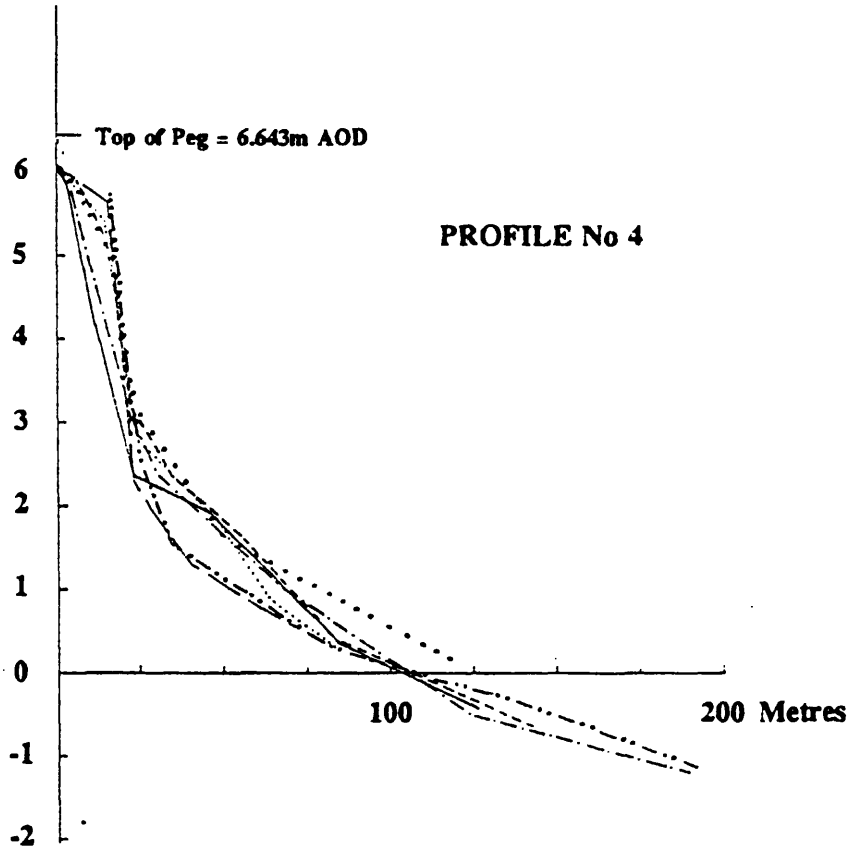

PATERSON ISLAND

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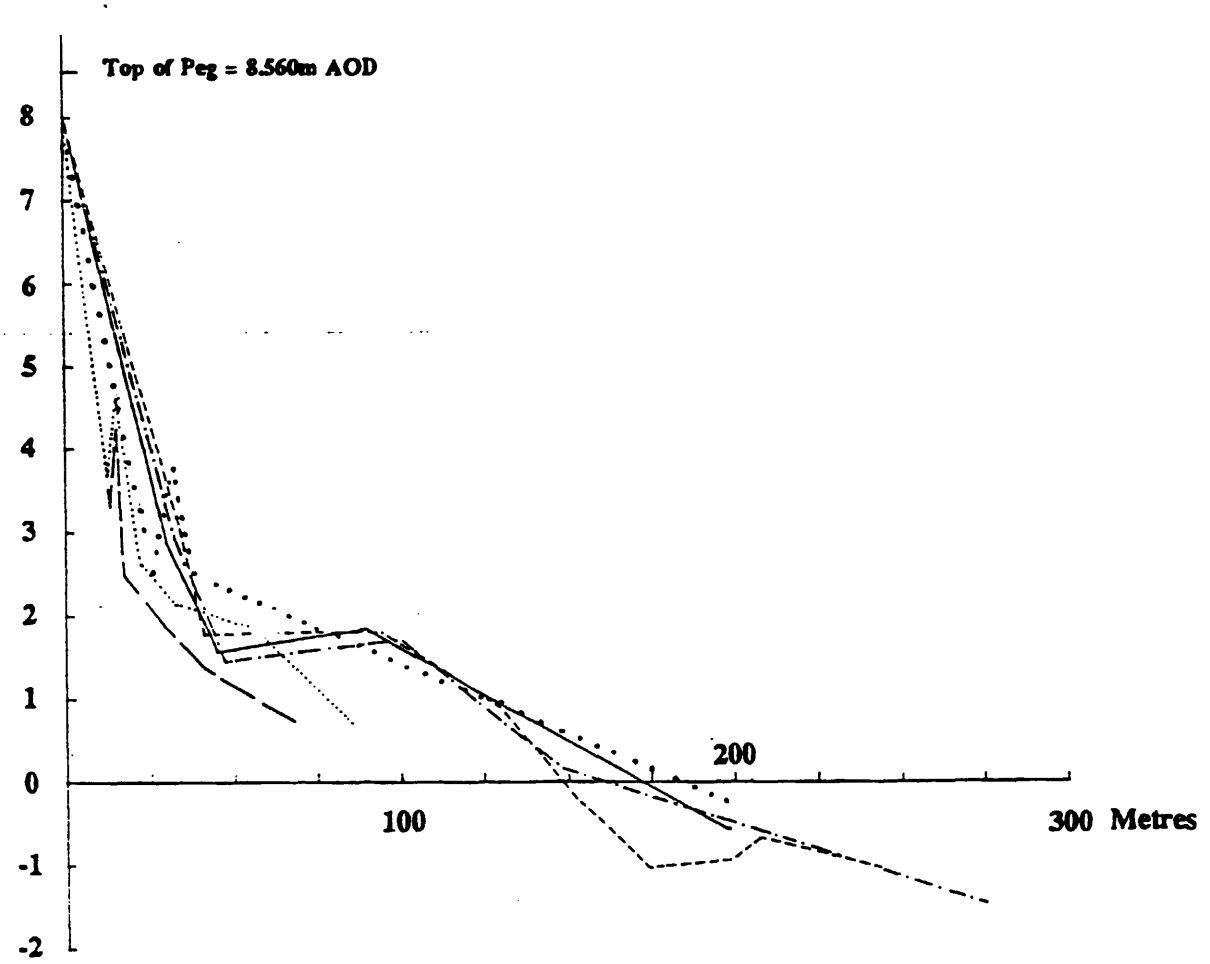

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Scottish Natural Heritage

Scottish Natural Heritage is an independent body established by Parliament in 1992, responsible to the Secretary of State for Scotland.

Our task is to secure the conservation and enhancement of Scotland's unique and precious natural heritage - the wildlife, the habitats, the landscapes and the seascapes - which has evolved through the long partnership between people and nature.

We advise on policies and promote projects that aim to improve the natural heritage and support its sustainable use.

Our aim is to help people to enjoy Scotland's natural heritage responsibly, understand it more fully and use it wisely so that it can be sustained for future generations.