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Barton-on-Sea: Development of an Alternative Approach to Coast Protection.

Paper presented to the Geological Society Engineering Group regional meeting at Southampton University, September 1978.

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BARTON-ON-SEA

DEVELOPMENT OF AN ALTERNATIVE APPROACH TO COAST PROTECTION

Introduction

Barton-on-Sea, Hampshire, is situated on Christchurch Bay, approximately midway between Hengistbury Head and the outer end of the shingle spit on which Hurst Castle stands. Although interspersed with periods of beach accretion the trend on this coastline has been one of erosion by the sea for many centuries. The rate of recession had increased over the past 50 years until coast protection works around the bay were undertaken in the 1960s. In common with many other cliff locations in which sedimentary materials are either underlain or intercollated with impervious strata, the combination of ground failure through groundwater pressure and constant erosion at beach level had caused the cliffs at Barton to recede steadily.

As the Barton clays are rich in paleantological material, the continual recession of the cliffs was of great interest to the geologist who has the opportunity of inspecting a fresh exposure of the Barton Beds at each visit. However, for residents with properties on the cliff top and for the Local Authority with powers and duties to be exercised for the benefit of all residents and visitors in relation to an area of high environmental potential, the surface mud flows down such cliffs and their continual recession is a constant problem and cause of expense.

Stabilising such cliffs and foreshores is a difficult coastal engineering problem and at Barton the work has been evolutionary in form. In addition to the limited knowledge of response of coastlines to the marine climate which existed 15 to 20 years ago the work has been conditioned by a range of factors, including those engendered by social forces, economic constraints, and Governmental response. This paper describes some of the problems encountered at Barton and the methods, still developing, to overcome them.

The Natural Situation

The landward topography at Barton consists of a fairly level plateau at an average height of about 35 m above Ordnance Datum (approximately Mean Sea Level), fronted by a steep cliff below which lies an undercliff area of broken ground extending for about 70 m out to the foreshore. The toe of the natural undercliff is formed of a clay bank, exposed to wave action in storms and at high tides, then several flat terraces which tend to pond water, with intermediate clay banks and, beyond, a water-logged broken silty-sandy stretch of ground rising at a slope of about 1 in 3 to the foot of a steep cliff of terrace gravels. Figure 1 shows a plan of Christchurch Bay and Figure 2 (a) is a typical cross-section of the cliff and foreshore as it was in 1960.

The geological structure of the ground, shown in Figure 3, is one in which a capping of open plateau gravel rests uncomformably on semi-permeable silty sands of the Upper Barton Beds which in turn overlie the impermeable silty clays of the Middle Barton Beds. The beds dip towards the east at a variable slope, but averaging 1 in 80. Thus the top of the undisturbed Middle Barton clay stands at about 30 m above Ordnance Datum near the western Barton boundary on the line of the Walkford Brook in Chewton Bunny and drops to about 15 m below Ordnance Datum 3.5 km to the east, at the point where the stream in Beckton Bunny flows into the sea.

Groundwater in the Barton sands is perched above the clay and although it generally drains inland following the strata dip, it does also emerge as springs on the undercliff. The waterlogged material resulting from this flow causes clay slumps and mud flows towards the sea. This reduces support for the gravel cliff face and results in periodic massive cliff falls which gradually subside to become mixed with the flows. This material on reaching the foreshore is easily distributed by waves, the finest particals being carried offshore, the sand and fine gravels oscillating in and out of the tidal range as littoral drift, and only the very course material remains on the beach throughout the winter.

Cliff top land usage was originally arable, with a village centre surrounded by farms. During the 19th Century a number of substantial houses were built overlooking Christchurch Bay and the western end of the Isle of Wight. The village centre was gradually forced into a concentrated area owing to progressive failure of the cliff edge, but the Barton area in general became increasingly favoured for residential development. The road system gradually extended inland and is now established to 700 m on either side of the central road leading to Old Milton and the A337 road between Christchurch and Lymington. The system of residential roads is aligned east and west parallel to the cliff edge, those nearest the sea having been developed largely before 1914 and the housing infill between Old Milton and Barton being mainly post - 1945.

Considering now the seaward topography in Christchurch Bay, this is contained between the apparently stable features of Hengistbury Head at the west end and Hurst Spit at the east end, both of which extend well out below low water in the form of elongated banks, as shown in Figure 1. To the west Christchurch Ledge extends some 5 km SE from the Head to a depth of some 6 m below Datum and to the east the Shingles Bank extends some 6 km SSW from Hurst Bank at a shallower depth along the NW side of the Needles Channel. These underwater features act as submerged offshore breakwaters, protecting the Barton frontage from the larger storm waves generated from SSW to W and from SE.

Between the ends of these features, a distance of some 5 km, the bed depths reach 15 to 20 m below datum and this gap allows full storm waves, of 6 to 8 m height, to approach the Barton frontage directly over an arc of some 45°, from the SSW to SSE. Waves of 4 m or greater crossing either bank become unstable and tend to break, while smaller waves are shortened and steepened on passing over the banks. The tidal range of mean spring tides is about 2.2 m, and that of the highest and lowest astronomical tides is about 3.3 m, being the range resulting from average meteorological conditions coupled with the greatest conjunction of astronomical conditions. The raising of the still water level, or set-up, as a result of the influx of storm winds and waves on the Barton coast may add 0.5 m to the height of the wave crest.

Need for Stabilisation

Comparison of previous editions of the Ordance Survey maps showed that erosion of the foreshore, followed by consequent cliff falls, although irregular and at times reversed by accumulation of beach material, had averaged approximately 1 m per annum since 1871. At the western end of the Borough the clay cliff on the foreshore was under intermittent attack by storm waves unimpeded by the narrow shingle beach. Towards Beckton Bunny in the east pressure of groundwater was causing the semi-permeable silts to flow seaward followed by a series of repeated collapses of the upper gravel cliff. Between these two extremities lay the central green of the township, with cliff failures having already claimed a number of buildings and others being put at steadily increasing risk of having to be abandoned as dangerous.

Had the land for a substantial distance from the cliff top remained undeveloped for residential purposes it is probable that there would have been no call for remedial action to be taken. However, a high proportion of the population are in Barton to enjoy their years of retirement and, particularly those having properties on the seaward side of the town, expressed their agitation concerning the threat to which they were exposed. The Local Authority engineers too, realised that even if the toe of the cliff were protected the slumping slope would encroash much further inland before reaching stability and the Authority decided to present the problem to consulting engineers for advice and recommendations.

Stabilisation Works

The mechanics of the cliff instability were first described in a report dated 1960 and alternative stabilisation schemes were recommended. One of these incorporated filter wells some distance landward of the cliff top, and another a steel sheet piled diaphragm backed by a filter drain on the undercliff. It was appreciated that there was unlikely to be a once and for all solution but the second scheme was considered to provide the best chances of bringing the mud flows under control. However, before proceeding with a full scheme, it was decided to construct an experimental length of works (Stage 1) in 1964 consisting of 300 m of filter drain, half with and half without a steel sheet piled diaphragm, three drainage outfalls together with four groynes without intermediate revetment. This experimental length was from west of Hoskins Gap (Manhole 14) to east of Fisherman's Walk (mid way between Manholes 17 and 18), as shown in Figure 4.

A report in August 1965 on the effectiveness of this experimental length noted the adverse effect of having to site the filter drain further forward from the gravel cliff than had been recommended due to the extent of boundaries of private properties on the undercliff. This resulted in the seaward slope of the cliff being at the limit of stability, even when drained, and shallow slips occurred which ruptured the outlet pipes. However, within parameters that could then be fairly well defined, the scheme was shown to be successful.

The main works were eventually constructed in 1967/68 including 16 timber groynes and a rock fill and timber revetment along 1.8 km of coast. By this time the toe of the undercliff had receded yet further along the experimental length and dry rock walls were provided landward of the revetment maintenance berm, as shown in Figure 2b, in an effort to reduce the undercliff slope and so achieve better stability. Despite these efforts, however, the undercliff remained sensitive to persistent rainfall.

A series of tests initiated in 1970 to monitor the performance of the works confirmed that between Hoskins Gap and Fisherman's Walk the filter drain was maintaining the water table at a level some 3 m below ground level behind the steel sheet pile cut-off, but a well established, almost horizontal, bench plane of sliding existed some 5 m below the top of the piling. In this area the very sensitive Chama silts and fine sands have their maximum depth in the cliffs immediately beneath the terrace gravels and consequently the steel sheet piled diaphragm is subjected to the maximum pressure from saturated soils. Even if a slope of well drained soil can be maintained seaward of the diaphragm at a maximum slope of 1 in 3, the factor of safety of the large volume of material above the plane of sliding is not much greater than unity. If this soil becomes damp with prolonged rainfall consequential surface slides can lower the factor of safety to slightly below unity. Further, if this situation is allowed to persist the diaphragm gradually loses support and moves forward at an increasing rate.

Maintenance works, therefore, were concentrated upon improving the surface drainage of the undercliff to prevent such superficial slips. In addition the slope providing passive resistance in front of the diaphragm was extended, by placing 0.75 tonne rock blocks seaward of the timber revetment, down to sea bed level as illustrated in Figure 2b. A substantial rock splash wall was also provided landward of the revetment maintenance road to enable the slope in the Chama silts to be flattened off to 1 in 4. Additional rock fill counterfort drains were installed to increase the rate of surface drainage. It was later found to be necessary to place a row of concrete. Tripod armour units at the toe of the rock slope to prevent breaking storm waves drawing the rock seaward.

In 1974, after successfully withstanding several winters of severe storms and heavy rains, an exceptional storm caused run-up over-topping the rock wall and penetrating the silts above. This caused an extensive mud run to develop which materially changed the approach to remedial works. Additional measures were needed to reduce the slope of the undercliff and to renourish the beach in order to control erosion of the inshore sea bed.

Behaviour of the Timber Revetment

The timber revetment was designed to encourage the build up and retention of a natural shingle beach by absorbing wave energy. Timber groynes were provided to assist in limiting, but not stopping the drift of material retained on the beach. It was found, however, that the rock fill revetment did not absorb as much of the wave energy as expected and winter storms drew down the natural beach to such an extent that there was insufficient cover to prevent the underlying clay from being eroded. This led to the situation in which the lower the sea bed levels went, the more difficult it was to retain material on the beach and lengths of timber piling became unstable and were forced forwards. Attempts were made to extract and redrive the piles between groynes 16 and 20 and to support the reformed revetment by a rock and Tripod slope as described above. This had the desired effect, providing the rock slope was not greater than 1 in 3 in order to achieve sufficient reduction in wave reflection. However, this was costly and could only be used on the most threatened length of the works.

Strong Points

The decision to construct an experimental flexible, rockfill strong point in place of the updrift terminal groyne, No. 10, was taken to prevent loss of material from the groyne system during periodic severe reverse drift. At the same time it was intended to accumulate on the updrift side the smaller natural beach material, as, being in greater shelter from Hengistbury Head, it could be retained on the beach. The strong point, illustrated in Figure 5, was very successful and one year later, in 1973, a considerable beach had been built up and retained on the western, updrift side and this beach was gradually extending westward providing increasing protection to the clay undercliff and foreshore. In extending it was adopting the plan form of the down drift end of a crenelated bay. A larger strong point proposed at Chewton Bunny intended to form the updrift headland to this artificial bay has not been constructed to date due to private property and Authority boundary complications.

However, the indications of success in this simple approach to coast protection led to the construction of two more strong points in 1975. These were built as short armoured rock-rubble breakwaters, using the existing timber groynes 18 and 22 as protection against short term erosion on the down drift side. Figure 4 shows the position of these strong points and Figure 5 indicates their construction, following typical breakwater practice. Again toe protection, against the rock fill spreading under wave action, is provided by concrete Tripods of 2.2 tonnes each. These are a simple form of interlocking armour unit, developed by the Author's Firm, which are ideal for stabilising the toe of shallow water rock embankments.

The strong points are, in effect, artificial headlands and their position at Barton is chosen to take advantage of indents in the coast line; which is virtually straight. Their spacing was chosen to encourage the formation of crenelated bays, related to the beach material between them. The height of rock fill was adopted to prevent waves breaking over them and by a process of refraction and defraction of waves to encourage the retention of beach material on a profile orientated to the waves.

As indicated earlier, the coastline fronting Barton is exposed to storm waves and as a consequence the beach tends to change its shape rapidly. To counteract this it is intended to construct similar artificial headlands and at present plans are well advanced to construct one at the eastern terminal groyne, No. 25. This will be a downdrift strong point to the one at groyne 22 and an updrift headland to the strong point formed by the sea outfall at Beckton Bunny.

Beach Nourishment

In 1975/76 a massive renourishment of Bournemouth beach was undertaken and a Research Project was set up by Bournemouth Borough Council with grant aid from the Department of the Environment. The area lies in Poole Bay and, as the beaches are very sheltered by Portland, sand was used to feed the beaches. In Christchurch Bay the strong point at Groyne 10 had demonstrated that naturally occuring beach material derived from the eroding cliffs could be retained on the beach in the more sheltered, western end. However, this was obviously not so further east, where the coast is exposed to storm waves, and it was decided to provide beach nourishment between the strong points at groynes 18 and 22 using a much larger material. A supply of gravel pit rejects was available, ranging from 75 to 200 mm in size, and 30,000 tonnes of this was placed on the 400 m of beach. The result was very successful in providing material that will remain on the exposed beach and attract the smaller natural beach material to lodge in the interstices. Once the material has been distributed by waves and drift it can respond to winter and summer conditions by adopting appropriate shallow and steep profiles respectively, at the same time maintaining a high water mark seaward of the easily erodible silts and clays. However, the precise conditions required for this to form a stable bay beach are still not known and it was decided to extend the Poole Bay Research to cover studies on the behaviour of this beach, with particular concern to the response of the inshore sea bed. The results of this study will be the subject of a report to be prepared in 1979. Meanwhile the results are encouraging in the economic use of materials to provide natural coast protection.

The Residents on the Cliff

Mention has earlier been made of the housing developments at Barton, some of the houses and hotels being more than 70 years old. In fine weather the cliff top frontagers enjoy a superb southerly view over Christchurch Bay and the Needles; even in stormy weather the view is impressive from such a vantage point. It is therefore not surprising that the properties on the south side of Marine Drive have been very much in demand and that the infilling of vacant plots by private development has followed the break-up of fields previously forming parts of individual farms around Barton.

As a result of expenditure on coast protection works since 1959 by the Local Authority, acting upon the recommendations of the consulting engineers, the residents had become accustomed to a stable cliff line. However, the winters of 1973-74 and 1974-75 were accompanied by unusually heavy rainfall and high seas, and a rise in ground water on the sensitive length of undercliff, where the original experimental works were installed, resulted in ground movement and eventually a severe mud flow. This overwhelmed a length of the revetment and the resulting cliff movement penetrated to the cliff top. This unexpected threat led to the frontagers in Marine Drive becoming alarmed for the security of their properties and they threatened to sue the Local Authority for failure to provide adequate and meaningful protection.

It is worth recording that prior to 1949, statutory powers and duties to maintain coastlines had been confined to harbour authorities within the area under their own jurisdiction; a local authority having no responsibility for the maintenance of harbour works was legally unable to carry out coast protection works as these were outside the powers of the local authority. Each frontager was responsible for his own protection. With the passing of the Coast Protection Act in 1949, the limitations were removed. Consequently, in order to be certain of their position the local authority sought legal opinion. The advise they received was that powers to carry out such works was legally exercisable only if the responsible authority considered the works to be either necessary or expedient. Should the authority conclude that the execution or maintenance of coast protection works was neither necessary nor expedient then that authority would not only have no duty to undertake such works, but not have even the power to do so. Excessive cost could be a decisive factor in expediency.

The Local Authority appreciated that it was important to explain to the local resident the various options open to them in maintaining and improving the protection works. The types of construction and possible benefits derived from each were explained; the extent of maintenance each type would involve; the cost of works and of maintenance; and the probable rate of cliff top attrition in each case, both in the short term and in the long term. As it was to be expected a conflict of priorities arises between the owners of properties situated immediately landward of a crumbling cliff face and those living further away and, even more so, remote from such a risk. Major repair works assume a very high cost, in times of high inflation, when compared to the cost of the whole works built some 10 years previously and tend to enhance a feeling of failure among residents remote from the scene. Those who feel threatened on the other hand can appreciate the rapid deterioration that will take place if the limited amount of repair required to be carried out exceeds the capacity of the Local Authorities resources. Despite the probability of substantial grants being made by the Department of the Environment and the County Council towards the cost of agreed additional works to contain a serious cliff slide and restablise it, the effect on the local rates-demand, of further contract costs and a greater annual charge for maintenance of beach protection and an undercliff drainage system, could not be denied. After the subject having been exhaustively explained, discussed and argued, at a meeting on 30th June 1975, the New Milton Barton and District Ratepayers and Residents Association, unanimously agreed to support this Council fully in its efforts to reinstate the sea defences, and improve them if possible, even though this meant a small increase in the rates demand.

Justification for Expenditure

The development of the right balance of coast protection works at Barton has been an ongoing and evolutionary process since 1959. The Engineer by his training and experience endeavours to advance the state of the art and to achieve a best solution satisfactory to all the interested parties at the least overall financial cost. He attempts to quantify other costs related to environmental and social values, which are not in themselves directly related to financial terms and submit these to the same rigorous examination leading to alternative solutions.

In a difficult coastal project, such as that at Barton, there is usually no absolute technical solution that can be justified economically. Complete protection involving works to prevent further erosion of the inshore bed; to provide full toe protection; to achieve a stable undercliff and to prevent absolutely any further movement and recession of the cliffs would involve considerable and environmentally unacceptable works. At the same time the fresh exposures of the Barton beds which geologists require for a unique opportunity of study and the holiday visitor for observation of a wild natural habitat would be impossible to retain. The initial scheme provided, over the most threatened section, basic essential drainage and a system of toe protection. Subsequent works extended this, while endeavouring to keep rates of expenditure under control, the unstable undercliff dried out and settled within acceptable limits to approach a stable condition. To achieve this the scope of the protection has had to be revised from time to time as the foreshore regime changed, especially in areas where the rate of erosion of the inshore bed was not reduced sufficiently by the works in relation to the rate at which the undercliff approached stability.

The ability to deal effectively with the limited areas in which problems arose was an essential part of an economic engineering solution. Stated in present day financial terms the solution, including maintenance, has cost approximately £ 2 million for bringing stability to 2 km of frontage in which water bearing silts and impervious clay produce one of the most difficult combinations in which to achieve stability in coastline cliffs.

Response to Emergencies

It is normal on coast protection works to provide a maintenance gang, with some funds allocated for plant and the supply of materials. Such a gang is employed by the New Forest District Council for protection works on a very extended coastline which includes Barton. Throughout the life of the works they have kept a close watch over the drainage system, the groynes and strong points, and the beach feeding.

Nevertheless, unexpected sudden deteriorations in a previously stabilised ground condition requires the ability to respond quickly and effectively. This was demonstrated at Barton by the mud slides in the winter 1974/75 to be difficult to achieve and calls into question the present time-consuming procedure required by the democratic processes of local government and the grant-aiding organisations of regional and central government. Particularly at a sensitive coastline there is an urgent need for the Local Authority or its Engineer to take effective measures to arrest deterioration with the least delay. In the case of the severe slip at Barton in 1975 the cost of emergency measures necessary were rapidly outstripping the Local Council's funds. Although arrangements for emergency repair works were agreed quite rapidly, the time required for all the procedures to letting a contract took several months. Consequently, the instability which at first affected only some 50 m of revetment and was only just beginning to affect the steel sheet pile disphragm, had spread to 500 m of revetment and caused falls along some 100 m of cliff top before it was brought under control.

It is evident that for such circumstances some procedure is needed in which a Contractor, after competitive tendering, on an agreed schedule of rates covering most items of labour, plant and materials, can be engaged by the Local Authority on an annual stand-by basis to undertake emergency works. It is generally the winter season in which rapid deterioration occurs, when daylight hours are short, conditions for working in exposed situations are at their worst and most hazardous. On the other hand this is precisely when speed in undertaking restorative measures are most urgent and will control damage to a fraction of that occuring if not tackled. The Author's Firm provides advise and support to several successful schemes where stand-by Contractors organised to respond to "fire brigade" calls.

Conclusion

An effective maintenance organisation backed up with observations and trials at Barton on Sea will continue to form essential features in ensuring that the groundwater drainage system and the beach protection continue to function satisfactorily. The extension of the system of flexible strong points to east and west will assist in linking together the protective works around Christchurch Bay, and the introduction of intermediate strong points in place of normal groynes in suitable locations is expected to extend attraction and retention of greater quantities of littoral drift material.

The achievement of ground stability in a cliff and foreshore of sedimentary materials consisting of clays silts, sand and gravel, one of the most difficult combinations which the coastal engineer has to face, has only come as a result of a combined effort, of mutual trust, clear explanation of the probable outcome of alternative options, and purposeful discussions between all the people, both resident and advisory, concerned in halting the retreat of the cliffs.

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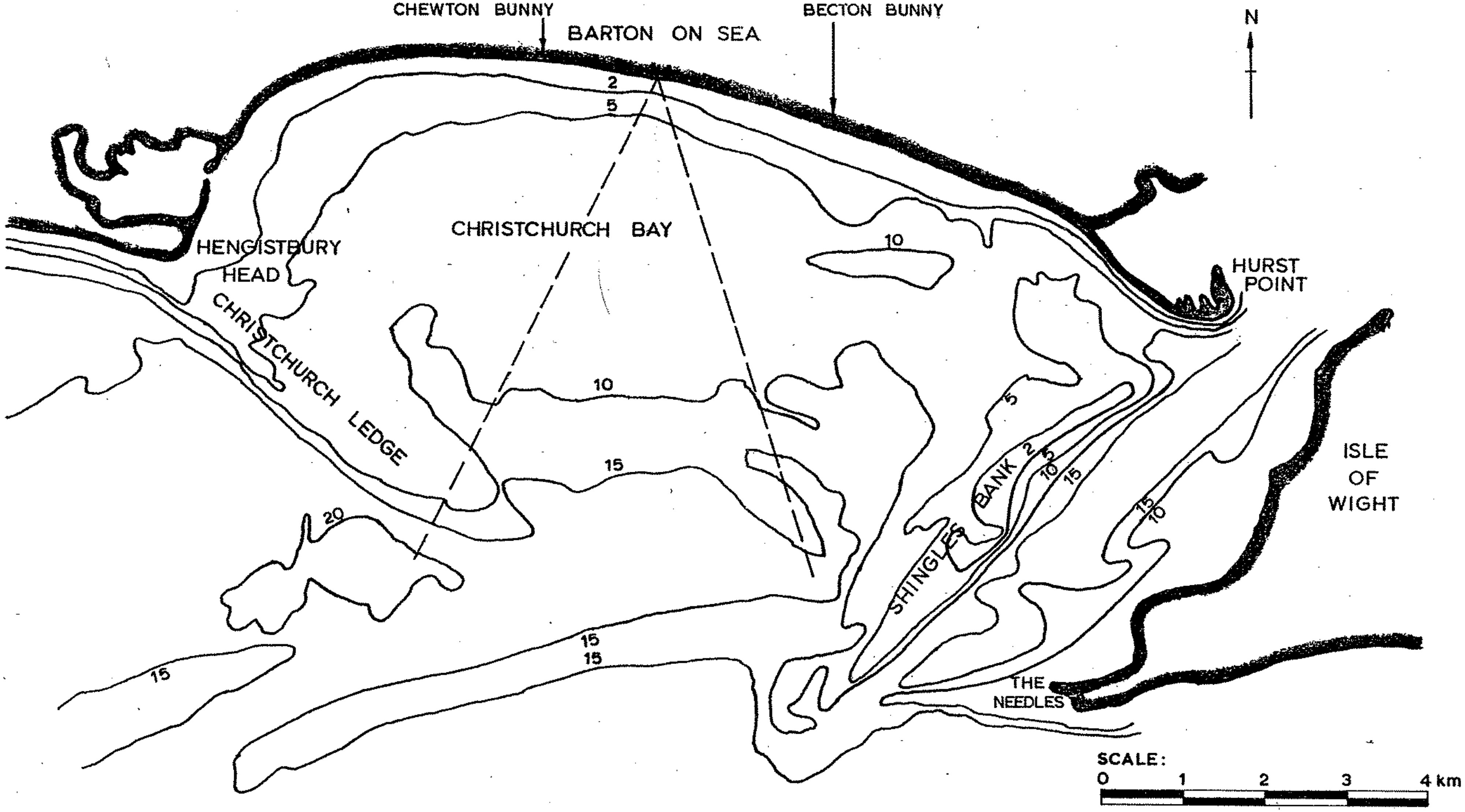


ALL DEPTHS IN METRES BELOW CHART DATUM

FIGURE 1. CHRISTCHURCH BAY

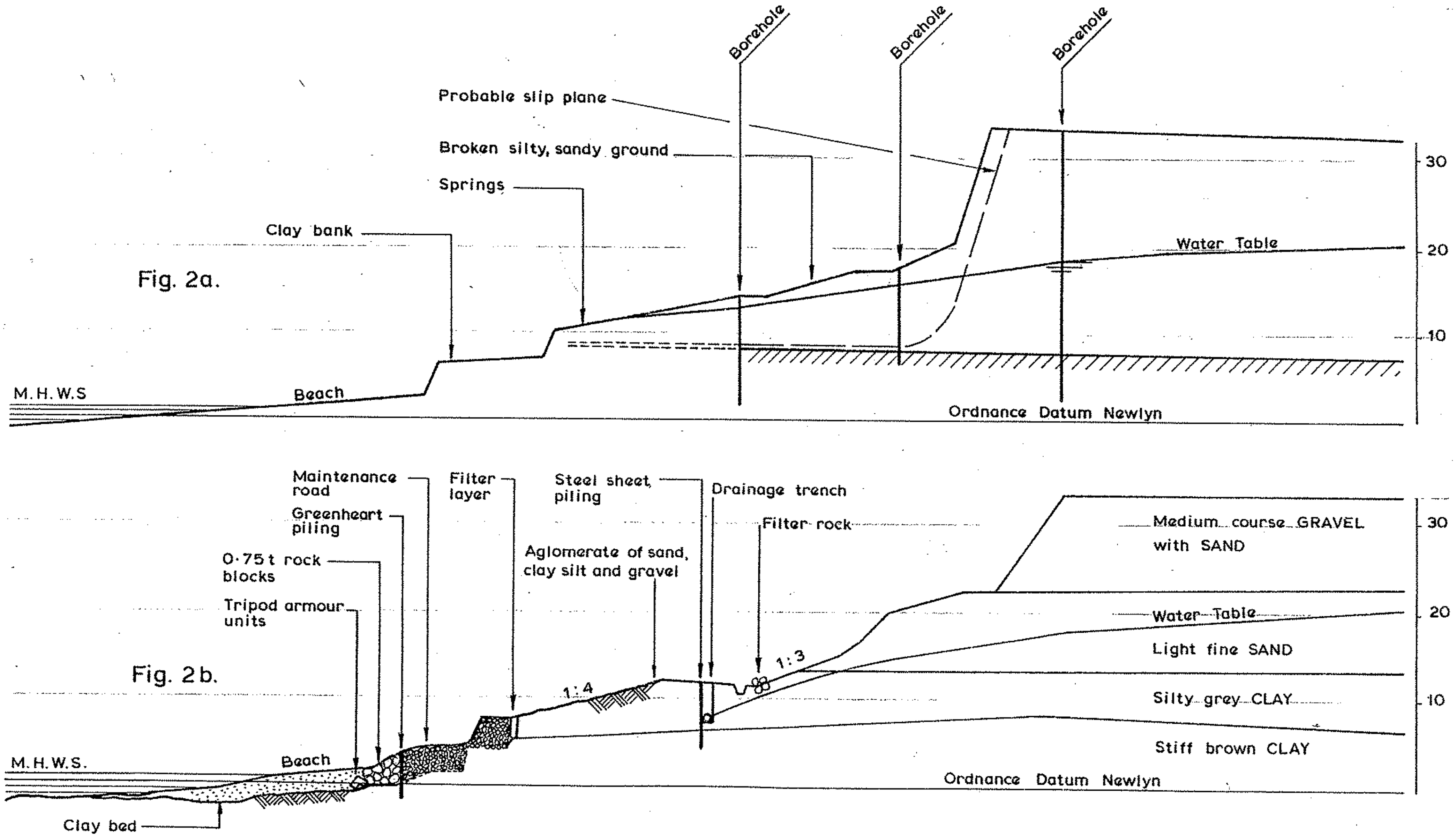


FIGURE 2. CROSS SECTIONS OF FORESHORE AT BARTON-ON-SEA a) 1960 b) 1978

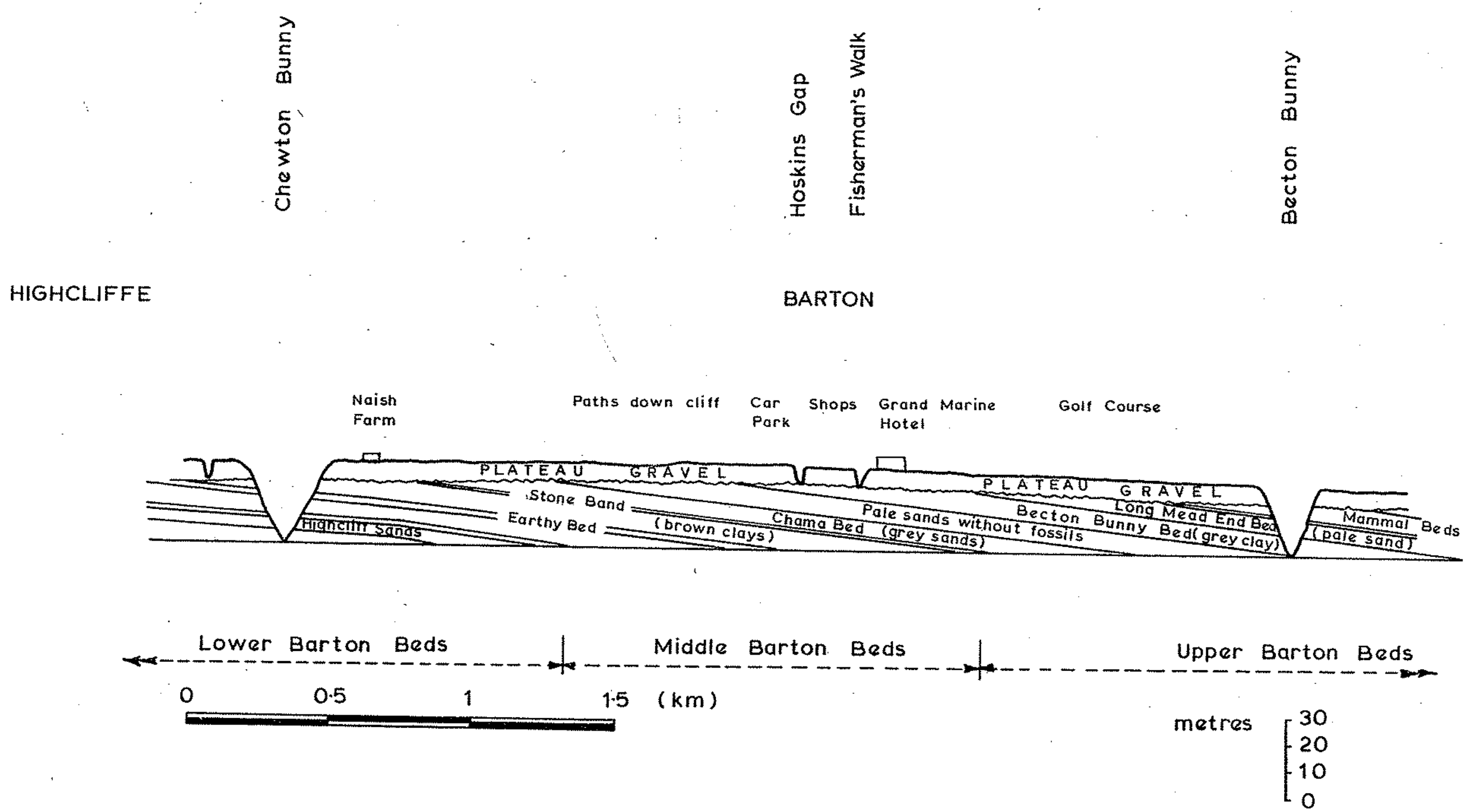


FIGURE 3. GEOLOGICAL ELEVATION THROUGH CLIFF AT BARTON

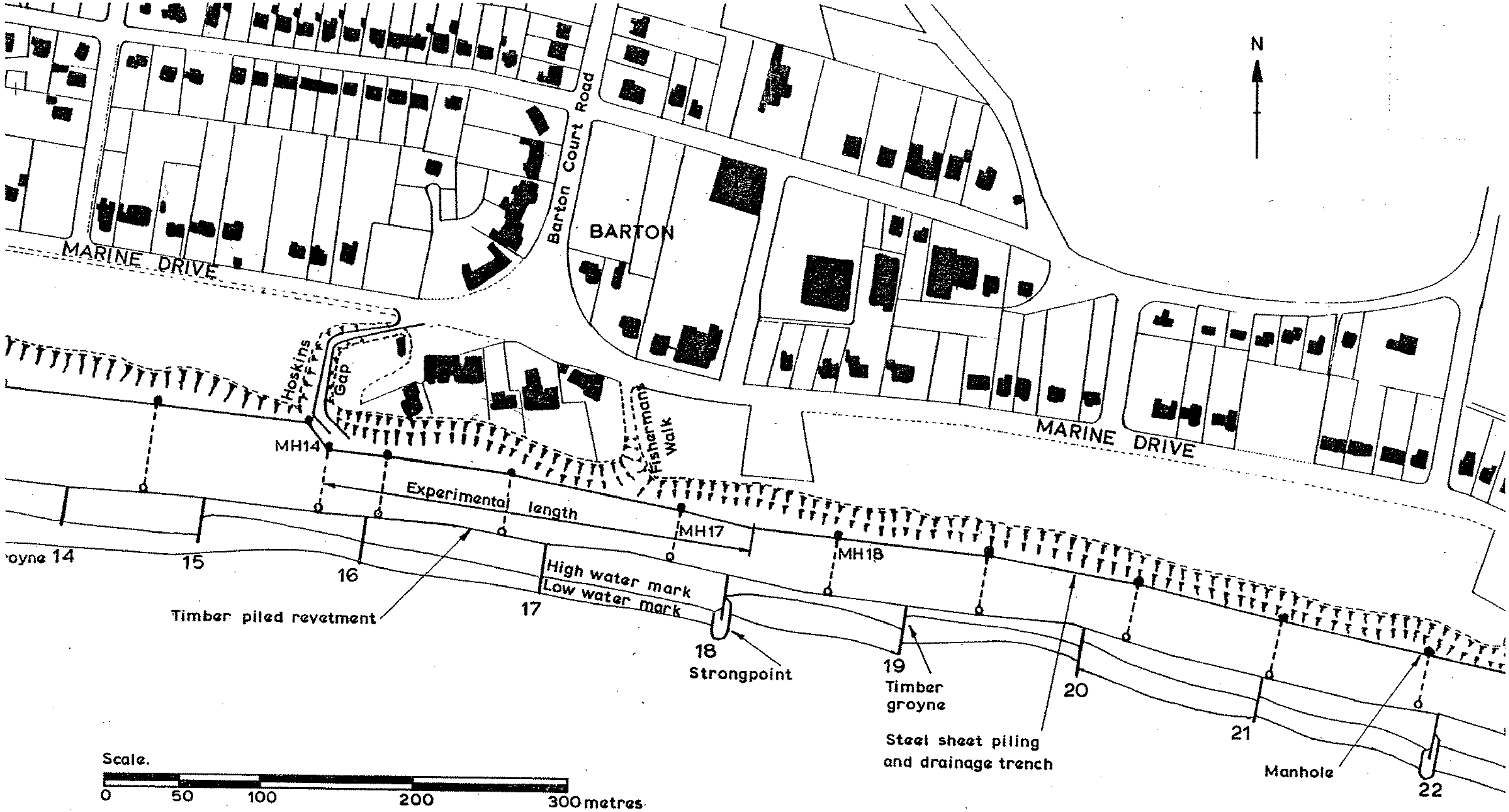
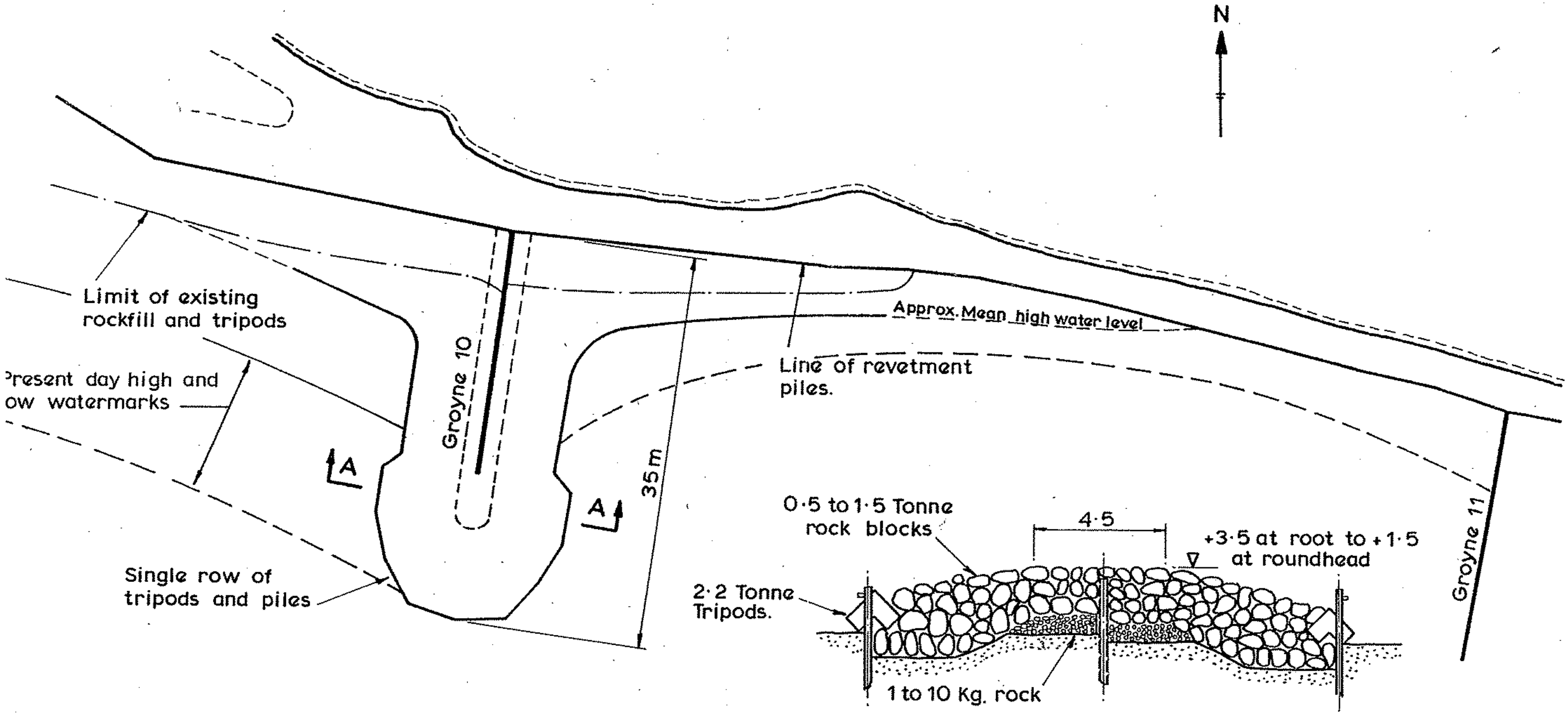


FIGURE 4. CENTRAL BARTON - REMEDIAL WORKS.



SECTION A-A

FIGURE 5. STRONGPOINT AT GROYNE 10