

SECTION 7

COASTAL DEFENCES AND STRUCTURES

7 COASTAL DEFENCES AND STRUCTURES

7.1 Objectives of Coast Defence for the Isles of Scilly

The primary objectives of coast defence have been stated quite simply⁽¹⁾ by the government to be the reduction of risks to people and the developed and natural environments from flooding and coastal erosion. The government states furthermore that the safeguarding of lives must clearly be of the highest priority.

In meeting the primary objectives, and in order to qualify for grant funding, the defences must fulfil three standard criteria defined by the principal UK funding agency for coast protection (i.e. the protection of the land from erosion and encroachment by the sea) which is the Ministry of Agriculture, Fisheries and Food (MAFF). The criteria are:

- technical feasibility;
- economic viability;
- environmental sensitivity.

The first two criteria are stringent and clear-cut and relatively easily understood and managed by engineers and lay people alike. The last may be open to some interpretation (for example, aesthetics) and may best be resolved in discussion and collaboration with the local population and other main statutory consultees. It should be noted that the notional environmental sensitivity of schemes might also be considered against wider criteria established by the UK government following the Rio Convention on Biological Diversity in 1992.

A variety of secondary criteria may also be stated:

- the conservation of internationally important environmental sites;
- the preservation of archaeological and historical remains;
- the enhancement of amenity for all coast users and, generally,
- the improvement of the environment.

The satisfaction of these criteria is important but only as supplementary conditions to the principal objectives of individual schemes. Grant aid made available under the relevant Coast Protection and Sea Defence legislation is directed expressly at satisfying the primary objectives of individual schemes.

(1)

Strategy for Flood and Coastal Defence in England and Wales, PB1471, Ministry of Agriculture, Fisheries and Food, London, 1993

7.2 Existing Defences and Structures

The existing defences of the Isles of Scilly were surveyed by MAFF Flood and Coastal Defence Division in 1993 as part of the Coast Protection Survey of England (CPSE)⁽²⁾. The relevant extracts of the CPSE are reproduced in Appendix 4. The plans show the extent of the defences on the main island of St Mary's and the so-called "off-islands" of St Agnes, Bryher and Tresco; there are apparently no coastal defences on St Martin's. There is a high level defence against erosion by splashing to the garden of the **Turk's Head** on St Agnes which is not mentioned in the CPSE. This defence is understood to be suffering minor damage as is the neighbouring (albeit abandoned) slip.

The existing defences have been constructed over the years on an *ad hoc* basis as erosion and overtopping problems have become evident. They are comprised of a variety of structural types varying from rubble mounds to stone walls, timber **cribwork** and mass and reinforced concrete structures. The protection afforded by the individual schemes usually has a low return period owing to the relatively great expense, to a formerly subsistence level community, of building anything more substantial. The structures have, to a greater or lesser extent, served their purpose over the years although many have now reached the ends of their lifetimes. The structures do not generally meet accepted design criteria.

Following the severe storms of 1989/1990, all five inhabited islands reported damage. Appendix 1 reproduces the original damage assessments made by the Council⁽³⁾. DHV were subsequently appointed Consultants to the Council of the Isles of Scilly for the appraisal of coast protection and sea defences on all the inhabited islands of the archipelago.

Existing defences and problem sites were inspected in September 1991 following which preliminary designs were made for the construction of new works and for remedial works to existing coastal defences. Benefit/cost assessments of the proposed works were undertaken and priorities for future work defined. The appraisal report⁽⁴⁾ was presented to the Council and the Ministry of Agriculture, Fisheries and Food (MAFF) in April 1992.

(2) *Coast Protection Survey of England, Summary Survey Report, PB1667, Ministry of Agriculture, Fisheries, and Food, London, 1994*

(3) *Storm Damage Reports, Council of the Isles of Scilly. December 1989*

(4) *Report on Existing Sea Defences and Proposals for Remedial and Additional Works, DHV Burrow-Crocker Consulting, Bristol, April 1992*

Subsequent to the publication of the CPSE, new coast defence structures have been constructed at three locations on Bryher and at Porth Cressa, Porth Minick and Old Town on St Mary's, and three locations around Big Pool on St Agnes.

7.2.1 1995 Coast Protection on Bryher

Bryher was separated into two project areas forming the Popplestones/Great Pool cell to the north-west and the Great Porth South/Stony Porth cell in the south-west of the island.

The Popplestones/Great Pool cell was partially protected by an old and dilapidated seawall as described in the CPSE" (Drawing 69018918). This structure had marginal stability and was threatened by an increasingly severe wave climate as Popplestone Brow to its north continued to be dramatically eroded (it reportedly lost 3.5 m in height during the storms of 1989/90 and a further 0.5 m in the storms of Easter 1994). The old seawall at Great Popplestones cracked in Easter 1994 during the design of its replacement and 10 m of its eastern end was lost during storms in early 1995. The wall was protected by a new rock revetment ($W_{50} = 1.5$ Tonnes) of imported Cornish Armorican granite which was overlain at its flanks by existing boulder beaches.

Erosion at the north edge of the dune system near Little Popplestones threatened to breach during severe conditions with potential flooding and contamination of the island's fresh water supply as a consequence. The transition zone between the boulder tombola, in the lee of Little Popplestone, and the sand dune system itself was reinforced with a short rock revetment buried beneath the sand. This would only be exposed under severe wave conditions and natural processes would be expected to re-bury it during subsequent calmer conditions.

The old seawall (CPSE Drawing 69018917) at the north of Great Porth protected the garden of *Old* School House. The wall was built in the early 1960's using local labour and materials provided by the Duchy of Cornwall and had a rather ugly appearance having been constructed using corrugated iron sheeting as formwork. Timber piles into the beach lending stability to the mass concrete wall were rather dilapidated. The existing wall was supplemented in 1995 by a rock armour revetment ($W_{50} = 1.35$ Tonnes) which was constructed to extend east and south of the existing seawall to protect the low-lying and vulnerable part of the beach.

The length of new revetment that it was possible to build at Great Porth was restricted by the low benefit of the area but it was possible to

supplement it by repositioning existing large boulders to form an extended revetment. The existing seawall was retained to stop water penetration into the garden of the *Old School House* but the action of excavating for the new revetment has enabled water to percolate under the old wall. This has since been alleviated by the construction of a diaphragm wall. The inhabitants of *Old School House* report that the effect of the new revetment is the replacement of the previous shingle beach by a higher beach of sand.

7.2.2 1995 Coast Protection at Porth Cressa, St Mary's

Hugh Town, the main settlement of the Isles of Scilly, is situated on the sand isthmus between Buzza and Garrison Hills. On the southern side of the isthmus is Porth Cressa beach which is a sandy beach and one of the more important tourist beaches on the isles. It was formerly protected at its crest by a timber bulkhead (CPSE Drawing 69018906) surmounted by a two metre wide footpath at +6.0 mAOD which was concreted for a limited length at the west. The timber cribwork defence was constructed in 1963 following storm damage in 1962 which threatened to break through the sand dunes, then the only defence, and engulf the town.

A stone-faced reinforced concrete wall was constructed during early 1995 approximately two metres south of the timber cribwork which was partially removed (the sub-structure remaining) on completion of the replacement seawall. The concrete seawall is 1.6 m high with its crest at +6.0 mAOD (the same as the previous promenade) and has its toe protected against undermining by an *Armorflex* cable-tied concrete block revetment. The apron revetment is buried under the beach and will only be exposed under storm conditions. The concrete wall is piled with pile caps at six metre centres. The total length of seawall is approximately 225 m and a new slipway orientated at an angle to the wall (i.e. roughly south-south-west) was constructed at the eastern end to replace the previous timber Buzza Street slip. South of the slip, for a distance of approximately 90 m, a rock revetment ($W_{50} = 3.5$ Tonnes) was built to protect the exposed ram cliff from further fretting. The new slip has been designed to allow a 22 Tonne 360 degree excavator, purchased by the Council for coast protection purposes, access to the beach for maintenance of the rock revetment.

7.2.3 1996 Coast Protection at Big Pool SSSI, St Agnes

The island of St Agnes is sparsely populated and is partly dependent for its fresh water supplies on an aquifer with boreholes abstracting supplies from the Big Pool Site of Special Scientific Interest (SSSI). The Big Pool area is protected by low, small volume dunes which are slowly eroding. Breaches

in the existing dune defence system would cause the Big Pool to become saline which would not only affect a substantial portion of the island's fresh water supplies but also the flora and fauna. Migrating birds currently using the site on passage would no longer visit if the Big Pool were to become saline which would severely affect the island tourist industry with further effects on tourism on St Mary's.

A low-lying headland containing the Big Pool SSSI juts out of the main body of the island with its centreline orientated in a north-north-westerly direction. To its east is the embayment of Porth Killier, to its north-west is the embayment of Porth Coose and to its west is the embayment of Periglis. Periglis and Porth Coose are separated by an eroding spit of land (reinforced around the early 1960's by a cribwork of old railway lines containing boulders sourced from the beach) connecting westwards to the rocky promontory of Ginamoney Carn, itself attached further west by a drying bank to the Burnt Island rocks.

The dune backing Porth Coose has proven particularly vulnerable to erosion in the past and is considered by the islanders to be the weakest link in the natural defences to the Big Pool. In the "do nothing" scenario, it is considered that it could breach at any time. Erosion there has been estimated to range from virtually nothing to 40 m³/yr. Porth Killier is similarly vulnerable and its volumetric rate of erosion has been estimated in the order of 10-35 m³/yr. The patterns of erosion and accretion determinable in Periglis from maps have apparently changed in response to the state of repair of the old lifeboat slipway. Since no severe problems are reported from Periglis, this embayment may well be exhibiting medium term stability.

The St Agnes scheme was finished in July 1996 and was principally an (*Armorflex* or similar) cable-tied concrete block revetment system buried into the existing dune and beaches at Porth Killier and Porth Coose, such that its visual impact was minimised, with (*Enkammat* or similar) erosion control matting reinforcing a graded and "bulked-out" shallower back face. A small (85 m long) granite-faced mass concrete seawall protects the east end of Porth Killier where the cliff is vertical and there are internationally important archaeological remains which need protecting.

Transition zones between different structural types and at the ends of the concrete block revetments is protected with imported Cornish Armorican granite armour rock ($W_{50} = 500$ kg). The rock armour stone which reinforces the existing stone and rail groyne between the Porth Coose and Periglis beach and Ginamoney Carn was also sourced from the same quarry.

The Periglis Bank has been raised slightly where there was a local depression and erosion control matting was used on the rear face.

7.2.4 1997 Coast Protection at Porth Minick, St Mary's

Porth **Minick** is an embayment situated to the south-east of Old Town which is the second largest settlement on St Mary's. Low lying land behind the small embankment at the back of the sand and boulder beach has been flooded by past breaches which are considered to have reduced the return period at which they may be affected in the future. Council and Duchy of **Cornwall** owned housing estates are located at the limit of the area flooded by the last breach.

The preferred scheme is that of a cable-tied concrete block revetment (**Armorflex** or similar) fixed at a crest elevation of **+6.0 mAOD** and extending down the beach for approximately six metres at the centre of the bay and somewhat longer at the flanks to where, in normal circumstances, it will be overlain by one or more metres of sand. It will be necessary over a short length to build up the crest of the beach to attain the minimum desirable crest level. Material was won from the volume displaced by the concrete block mattress throughout the length of the protection.

There is already well established vegetation around much of the beach crest and one objective of the works was the re-establishment of this cover over the new revetment. Vegetation cover serves two purposes in that it hides the artificial revetment and also, in storm conditions, resists erosion and therefore delays the onset of removal of beach cover. The concrete block revetment serves to provide the in-depth defence once erosion of the beach has started to occur. The block revetment will be protected at its flanks by rock **armour** shoulders. These rock structures have the necessary flexibility to adjust to minor erosion around them and may be simply adjusted during maintenance operations by the labour force and equipment available on the island.

7.2.5 1997 Coast Protection at Old Town, St Mary's

During late 1996, the original seawall at the north-east corner of Old Town Bay (date unknown, but probably built at the same time as the seawall at St Mary's which was constructed in 1930) began to fail significantly. Large cracks began to develop and the lower stones dropped; arching action temporarily prevented the upper courses from dropping. The cause of the failure was undermining as the wall had no foundations as such and the

structure was built directly on the beach. Sea level rise and beach loss have jointly reached a point such that the wall would get increasingly unstable.

The opening up of cracks in the seawall enabled the loss of fines from the road behind it occasionally resulting in damage to the road and presenting a real threat to traffic and pedestrians. The risk would increase in time. A breach of the seawall which would enable the low-lying hinterland to the north to be flooded was threatened and the Council instructed a replacement of this sea defence as a matter of urgency before this scenario developed.

The existing seawall was replaced by a masonry-faced mass concrete vertical seawall of generally similar appearance to its predecessor with foundations allowing erosion of one metre of beach levels. Although the degree of protection offered is no more than previously, it is more resistant to breaching. It can be expected to overtop in extreme conditions.

7.3 Current Proposals for New Coast Defences

The Council has a rolling programme for the provision of coast protection to areas which have been identified as being at particular risk. Projects under consideration for construction from the financial year 1997/98 onwards are for the Island Hotel (Tresco), and Porth Loo and Town Beach (St Mary's). Some of the more definite proposals are discussed below.

7.3.1 Island Hotel, Tresco

Tresco has been developed over the last twenty years or so to cater to the all-important tourist industry. Part of that development has been brought about by the construction of the heliport in the grounds of the Abbey which has enabled easier and faster access to the island. Improved accessibility has increased tourist demand to which the island has responded with an expansion in tourist accommodation including the five star Island Hotel.

An extension to the hotel has been built within the last ten years which has brought the dining room within a few paces of a ram cliff which is rapidly eroding. Owing to the proximity of the dining room to the cliff, the options for coast protection are limited and the likely solution will be a mass concrete seawall faced with masonry and with a rock armour toe protection. Surveys and studies have been commissioned by the Council for this work to proceed in the spring of 1998.

7.3.2 South Beach (Crab's Ledge), Tresco

Tresco is eroding at several locations around the island and has lost stretches of footpaths and roads in very recent times. The present crisis point is the road south of Great Rock between Sea Carn and Skirt Island which, for reasons of safety, has had to be closed to traffic and pedestrians owing to erosion. Cornwall Archaeological Unit (CAU) have been involved in monitoring archaeological remains at the site and have noted in a letter to the Council's Chief Planning Officer dated 25 September 1995 that "... it is clear that the rate of erosion on the beach varies from year to year and ... the peat appears to have become more exposed as a result of the extraction previously of building sand from the adjacent sand dune."

It is interesting to note that South Beach was not identified by the 1992 DHV Burrow-Crocker report⁽³⁾ as being a problem area and the firm's engineers had at that time inspected "those areas where damage had been suffered in the 1989/90 storms or where potential damage had already been identified by the Council." It is clear therefore that South Beach was not recognised as being a problem or potential problem three years ago. The excavation of sand for building purposes is reported to have ceased within the last couple of years.

Planning permission for a 200 m length of new coast protection ranging from 100 m east to 300 m east of Sea Carn was granted by the Council to the Tresco Estate in October 1995. The proposed protection consisted of cleft log fencing dug into the beach and strapped together at the top. Marram would be encouraged to re-establish. CAU expressed reservations about the scheme as there had been no consideration within it of changes to patterns of erosion and accretion and because no Environmental Statement had been produced. They further noted in their letter of 25 September 1995 their understanding "... that the scheme presently proposed is intended as a temporary measure ..."

CAU were presumably referring to a potential permanent structure to be funded by the Council as the coastal authority. However, the Council had at October 1995 expressed no commitments or plans for coast defences at this location. It is understood, furthermore, that following the 1995/96 storms the proposal for temporary coast protection by Tresco Estate was abandoned.

7.3.3 Town Beach, St Mary's

The seawall at Town Beach was the subject of an investigation in March 1997⁽⁵⁾. The seawall is in a serviceable condition north of the steps at the extreme east end of Town Beach (chainages 0 m to -63.1 m) but requires remedial work, including pressure pointing and possibly some grouting, within the next five years to reinstate it. The toe needs further protection in places by extension of the apron seawards and downwards and the posts and railing are in need of immediate replacement or removal.

The CPSE in 1989 (i.e. some eight years ago) considered that the Town Beach seawall had a residual life in excess of ten years. The evidence seen from the seawall west of the Rechabite Slipway is that that part of the wall is fast approaching the end of its life and is in need of extensive repair and upgrading or, indeed, total replacement in the next few years.

Since the wall east of the slip is in a better condition than that west of the slip, it may be reasoned that this section of wall has a somewhat longer residual life. It must be considered, however, that the seawall at this location is probably of identical construction to that at the west. In similar weather, it would probably suffer a similar fate to the western stretch of wall if the extent of beach lowering during storms were the same. Considering that this stretch of seawall is less sheltered, its exposure would consequently be worse and damage incurred during storms would be expected to be greater notwithstanding its better present condition.

The Council is planning to undertake remedial work probably following completion of the *island Hotel* coast protection project.

7.4 Areas of Risk

The Council's damage assessment following the December 1989 storms highlighted areas which had suffered damage at that time and also raised concerns about other areas which had appeared vulnerable. Subsequent to the storms of 1989/1990 the Council commissioned DHV to investigate "... areas of potential damage identified by the Council ..." in addition to those that had suffered actual damage in the 1989/90 storms. Areas of risk identified in that report may be summarised as being the following:

(5)

Town Beach Seawall, St Mary's - Report of Visual Inspection, Report Nr F4116, Aspen Burrow Crocker. Bristol, April 1997

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- St Mary's
 - Porth Cressa
 - Old Town Bay
 - Porth Minick
 - Porth Hellick
 - Porth Loo
 - Town Beach
- St Martin's
 - Higher Town Bay
 - Lawrence's Bay
 - Neck of the Pool
- Bryher
 - Great Popplestones
 - Great Porth
 - Stony Porth
 - Green Bay
- Tresco
 - Appletree Beach
 - Timothy's Corner
 - Island Hotel, Old Grimsby
 - Old Grimsby
- St Agnes and Gugh
 - Porth Killier
 - Porth Coose
 - Periglis
 - Blanket Bay
 - The Bite
 - Cove Vean
 - St Warna's Cove
 - Bergecooth

Findings of DHV Burrow-Crocker's 1992 Report⁽³⁾ are summarised below.

7.4.1 St Mary's

- **Porth Cressa Beach**

During the December 1989 storm, the timber cribwork wall, footpath and mound suffered considerable damage which was repaired by replacing timbers and filling behind the wall with sand and stones wrapped in geotextile and **Tensar** geogrid.

This defence has been replaced in 1995 by a new stone-faced reinforced concrete wall and extended to the south east by a rock revetment.

- **Old Town Bay**

The 1964/65 seawall was reportedly eroded at its eastern end but this was rapidly reinstated by the sea itself. A stonework revetment failed over 9 m² at the western end of the bay where it may have been weakened by a tree. A road and estate of houses lie beyond the reinforced concrete seawall.

The masonry eastern end of the seawall, between the 1964/65 reinforced concrete seawall and the slip, began to fail in late 1996 and was replaced as a matter of urgency outside the planned works (see Table 7.1) and extended slightly south eastwards in early 1997. The new structure is a stone-faced mass concrete seawall.

- **Porth Minick**

The dune at the crest of the beach was breached permitting flooding of the bulb fields behind. Flooding reached the houses of the housing estate behind but did not flood them. Some repairs have been carried out to the bank but the defence is now weaker than previously.

A cable-tied *Aarmorflex* concrete block revetment with flanking rock shoulders was constructed concurrently with the Old Town seawall in early 1997.

- **Porth Hellick**

The main source (70% by volume) of St Mary's fresh water. Its defences were intact after the storms of 1989/1990 having suffered little or no damage but the Council is concerned about its long-term security.

- **Porth Loo**

A road and a terrace of six houses was threatened during the 1989/1990 storms by overtopping and extensive flooding and erosion of the ram cliff. Royal Marines effected repairs using boulders from the beach. A monitoring programme was instituted in March 1997.

- **Town Beach**

Town Beach formerly flooded on spring high tides from the slip by the *Atlantic Hotel*. This was cured by the fitting of stoplogs. However, occasional flooding of the road still occurs via the road gulleys and the stormwater drainage system.

Only the eastern half of Town Beach (from Holgate's Green to Carn Thomas) has a formal seawall. General dilapidation including incipient collapse near Holgate's Green was noted in March 1997 and a report prepared for the consideration of the Council⁽⁵⁾.

7.4.2 Tresco

- **Appletree Beach**

The beach accreted by some 2 m during the storms but the roadway, supported on beams off the top of the reinforced concrete seawall, was destroyed. The seawall has moved down the beach and rotated during storm activity. Builder's rubble is being dumped near the wall. The roadway has now been abandoned and the road diverted further inland. The High Water mark at this point has reportedly retreated by some 6-9 m over the period 1987-1992.

- **Timothy's Corner, New Grimsby**
The extension of the dry stone wall protecting New Grimsby at Timothy's Corner is rather less substantial than the main wall and has been partially demolished by sea action over time with erosion removing the reserve between the road and the cliff (**4 m** in **40 years**). Four two-bedroomed cottages and a road containing the main sewer and water main are threatened by continued erosion.
- **Island Hotel, Old Grimsby**
There are signs of an old seawall some 7 m seaward of the existing ram cliff. Erosion of the ram cliff seriously threatens a recent extension to the hotel. The present rate of erosion has been estimated at 0.6 m in four years.
- **Quay, Old Grimsby**
There is a low point at the root of the quay in Raven's Porth which was flooded.

7.4.3 St Martin's

- **Higher Town Bay**
A dune system some 700 m long protects disused (in **7991**) bulb fields, a well and a popular cricket field. The dune system is reportedly dynamically stable.
- **Lawrence's Bay**
The bay is 600 m long and is composed of dune for one half and ram cliff for the other. The cliff has eroded but is backed only by disused (in **1991**) bulb fields.
- **Neck of the Pool**
The dune system here is 600 m long and there are indications of possible erosion (6 m is mentioned but no timescale is indicated). The dunes protect a well and a campsite.

7.4.4 St Agnes and Gugh

- **Porth Killier**
A ram cliff contains internationally important prehistoric remains and was partially protected by a **1931** cobble and concrete wall. Additional protection was provided by boulders deposited nearby by the farmer who owns the nearby **Lower Town Farm**. There was evidence of the steepening

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of the beach and fretting of the dune. A new defence was constructed in **1996**.

- **Porth Coose**

A low dune separates the beach from the Big Pool SSSI and was vulnerable to erosion and breaching. Royal Marines and islanders placed **20** Tonnes of boulders retrieved from Periglis in the weakest sections of the dune following the storms of **1989/190**. A new defence was constructed in **1996**.

A rail and boulder groyne connects Porth Coose and Ginamoney Carn together. This is in poor condition and has lost about **60%** of its filling. This defence was strengthened in **1996**.

- **Periglis**

The defences consist of a shallow dune which occasionally overtops. The beach is apparently stable although the shape of the high and low water marks had changes over time in response to structures being built and demolished around the bay.

- **Big Pool SSSI**

The Big Pool has no man-made features which are immediately at risk but the threat of any breach to the natural defences is to the water supply to the Lower Town area and to so-called eco-tourism dependent on migrating birds flocking to the existing fresh water supply.

Coastal protection works at bays around the SSSI comprising mass concrete sea wall, concrete block revetment, rock armour and erosion control matting are now in place. Construction finished in July **1996**.

- **The Bite**

The sand dune vegetation comprises marram grass and mesembryanthemum. Some erosion was reported after the December **1989** storms but nothing of any value was apparently threatened.

- **Cove Vean**

This is a sheltered cove facing south east with a sandy beach at its upper end. Some cliff damage was reported after the storms.

- **St Warna's Cove**

St Warna's Cove is rocky with rock outcrops onto the beach. Some cliff falls were evident after the storms.

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- **Bergecooth**

The ram cliff backs a beach consisting of boulders varying in size from 2-3 Tonnes at the low water mark to 300 mm diameter at the foot of the cliff. Troy Town well and a camp site lie behind the well.

7.4.5 Bryher

- **Popplestones Bay**

The December 1989 storm eroded some 1,000 Tonnes of rock from Popplestones Brow which has been sheltering a 70 year old wall at Great Popplestones within the bay. The old structure needed emergency repairs and there was concern that it would fail in the future due to its now increased exposure to storms from the north-north-west. Overtopping at Little Popplestones threatened the island's water supply.

- **Great Porth**

The neck between Great Porth and the Great Pool has been inundated and there were concerns that this would breach leading to a medium-term threat particularly to the Hell **Bay** Hotel but also to two cottages which would be cut off from the remainder of the island.

- **Stony Porth**

The beach has reportedly recently receded 9 m - mostly in the December 1989 storm. More recent investigation⁽⁶⁾ has shown this claim to be exaggerated but there is no doubt that the beach continues to erode. The land behind is a Site of Special Scientific Interest, designated, amongst others, for a rare dwarf pansy.

- **Green Bay**

Although in a sheltered location, a stone wall which had previously kept out high waters was damaged by the storms. The banks are covered with exotic plants (mesembryanthemum and agapanthus) which form good ground cover and resistance to erosion. Several low-lying cottages are around the bay although not immediately threatened.

Subsequent to the 1992 DHV Burrow-Crocker report being published, works were undertaken to the island. These were composed of rock revetments at Great and Little Popplestones and at the north end of Great Porth with sand fences at the south of the island.

(6)

Bryher Coast Protection, Engineer's Report, DHV Burrow-Crocker, Bristol, May 1994

7.4.6 Crab's Ledge, Tresco

Planned coast defence works at Crab's Ledge on Tresco (see Section 7.3.2) have come about as a response to an erosion problem which was not identified in 1992. The problem appears, at least in part, to be a response by Nature to over-exploitation of the beach for building sand. The Works at Crab's Ledge are said to be temporary in nature and it is possible that other works may need to be designed for this location in the longer term.

7.4.7 Pentle Bay, Tresco

Pentle Bay was mentioned by Tresco Estates as being a particular cause for concern owing to evidence of continuing steady erosion along the margins of the bay. A preponderance of south-easterly winds throughout the early winter 1995/1996 was said to be the reason for this. In early January 1996 a series of marker pegs were placed along South Beach and Pentle Bay. The most dramatic erosion occurred on spring tides in late January 1996 when the navigation cable marker in the middle of Pentle Bay, which was formerly some 4.5 m away from the dune cliff, was washed away together with a further 3 m of land behind it.

Further to the erosion at Pentle Bay, it is believed that much of the eroded material is being taken a short distance offshore to form a bank at the north of the bay between the Great Pentle Rock and Lizard Point.

The 1995/1996 Capital Expenditure Profile submitted by the Council of the Isles of Scilly to MAFF has set their short-term priorities for the financial years 1996/1997 to 1998/1999. These are shown in Table 7.1. No longer term objectives have, at the time of writing (September 1996), specifically been defined.

7.5 Strategic Coastal Defence Options

Prior to any consideration being given to the types of coastal defences that could be provided, there are four generic strategic options which should be considered for each management unit (MU) which are⁽⁷⁾:

- do nothing;
- hold the existing defence line by maintaining or changing the standard of protection;

(7)

Shoreline Management Plans - A Guide for Coastal Defence Authorities, PB2197, Ministry of Agriculture, Fisheries and Food, London, 1995

- advance the existing defence line;
- retreat the existing defence line.

Each strategic option should be considered in relation to its likely effect on adjacent **MUs** and the sediment cell as a whole. Furthermore, any strategic option must be sustainable and compatible with the objectives set for adjacent **MUs** and the processes at work within the sediment cell.

The strategic options are considered in tabular form in Section 6. Having been identified, the preferred strategic coastal defence option is to be referred to all interested organisations. In the present Shoreline Management Plan consultation has been undertaken by the circulation of the draft document from September **1996** to March **1997** to the parties shown in Table **7.2**. Their comments and observations have been incorporated into the text of this final version of the SMP.

7.6 Design Considerations

7.6.1 Standards of Protection

The Ministry of Agriculture, Fisheries and Food has published indicative standards of protection (stated as return periods) for various land uses in tidal and non-tidal situations (see Table 7.3 for a synopsis).

Owing to the low density of population and the relatively poor quality and low productivity of farmland on the Isles of **Scilly**, there are few locations where an indicative standard of protection with a high return period would be justified (see Table 7.31. Hugh Town on St Mary's is probably the only location in the **Scillies** where a return period of the order of 50-150 years could be justified based on indicative standards. Old Town, also on St Mary's, could probably justify an indicative standard of 50 years but all other locations would probably vary between 5 and 20 years.

Scillonian coast defence projects incur large overheads compared to equivalent schemes on the mainland owing to two problems: the logistical difficulties in bringing plant and material across the sea and the necessity, owing to the heavy dependence of the islands' economy on tourism, of having to undertake the works at times of the year when the weather is least benign - incurring downtime particularly in marine transport.

The high costs of constructing projects in the islands coupled with the generally low level of tangible benefits combine to yield low benefit/cost ratios. This criterion is one of three on which projects are considered by MAFF to be eligible for grant aid. With the exception of Porth Cressa, it has

been necessary on the schemes for Bryher, St Agnes and Porth Minick (St Mary's) to design for low return periods. The schemes considered by the Council of the Isles of Scilly to be most urgent have been completed and were designed for return periods of 5-10 years. Remaining schemes will probably have similarly low benefit/cost ratios and it is recommended therefore that the design sea level and wave height are to the once in five year return period. One or two individual schemes with high benefits may warrant the consideration of a longer return period where appropriate.

MAFF emphasise that the indicative standards quoted above do not represent either an entitlement to protection or a minimum level at which protection should be aimed - they are the starting point from which benefit/cost assessments may be commenced. MAFF's decision rule as to which coast defence project should be selected from a range of options considered states that it is that scheme with the greatest average benefit/cost ratio in excess of unity meeting or exceeding the indicative standard.

The consequence of designing for low return periods is that there would be more damage incurred to coast defences when events with higher return periods occur. The burden of maintenance would, therefore, be expected to be higher than for coast defence works designed to a higher standard.

An additional consideration on the Isles of Scilly is the fact that the islands are remote from ready sources of heavy plant (although a 22 Tonne excavator is owned by the Council, having been purchased specifically for coast defence works, and is kept on St Mary's). Should emergency repairs be needed which require the use of heavy plant on one of the off-islands, it would be necessary to move it by means of floating plant.

Since emergencies requiring repairs to the defences almost inevitably arise during storms, the easy movement of small floating plant, such as landing craft (the Mojo based at Penzance is used frequently for transport of occasional items of heavy plant to and from the islands and requires winds to be less than Beaufort Force 4/5), which are suitable for access to the small bays and coves on the islands would be precluded until such time as the sealweather abates. As this process can take some time, the Council ideally wishes that the maintenance requirement for future defences is minimised as far as is possible.

7.6.2 Design Still Water Level

Because of the length of time for which coastal defence structures are designed (50 and 60 years being common periods), they must be capable

of maintaining the design level of protection throughout their lifetimes. Over a fifty year period, for example, the still water level will increase by 250 mm. Table 7.4 gives a summary of design still water levels for typical structure lifetimes.

Notwithstanding the recommendation above that the design still water level (SWL) be the once in five year return period, any structures designed will be in place for design lives of 50-60 years. The design SWL, taking account of the increase in sea levels due to global warming expected in this time period will be as shown in Table 7.4. A design SWL of **+3.6 mAOD** is therefore recommended.

7.6.3 Design Significant Wave Height

Much of the interior of the archipelago is inward facing which generally restricts the wave climate to that which can be generated by waves across the limited fetches (generally less than 5,000 m) available. Wave development is further restricted by the shallow water depths prevailing within the sheltered confines where average bed levels are of the order of Chart Datum owing to the presence of extensive drying banks. Water depths are therefore restricted to around 6.5 m on the peak spring tides.

Taking the wind condition as that of a Force 10 blowing directly across the fetch onto the shore of concern, the fully developed significant wave height determined from the modified depth-limited Sverdrup-Munk-Bretschneider (SMB) curves⁽⁸⁾ is generated in around 30 minutes and is slightly less than one metre in height with a period of the order of 3 s. Cross-checking against the deep water SMB predictions produces very little difference.

The above design wave condition for the interior of the archipelago needs to be treated with some caution as there are certainly more vulnerable areas where the deep water channels permit more damaging longer period ocean waves to penetrate within the archipelago. There are four main channels into the centre of the island group which are described further below.

New Grimsby and Old Grimsby Channels both run approximately north-south to the west and east of Tresco respectively (see Drawing 1) and permit the penetration of what are locally termed ground seas to travel along them into the flats between the islands. Since the directions of the two Grimsby

(8)

Shore Protection Manual, US Army Coastal Engineering Research Center, US Government Publishers, Washington DC, 1984

Channels do not point directly towards land, the waves penetrating along them generally dissipate their energy in refraction and diffraction in the large open spaces of the Tresco and St Martin's Flats into which they then move.

The channel between Bryher and Samson points from the open sea south-west of Bryher more-or-less directly towards Appletree Point on Tresco. Wave orthogonals north and south of the channel are refracted to north and south respectively while those centred on the channel continue with a combined refraction and shoaling index at chart datum just offshore Appletree Point of the order of 0.5 for 9 s period waves. Inshore wave heights derived from the combined refraction and shoaling index probably slightly overstate the wave size that can be expected as diffraction (lateral transfer of wave energy) and friction effects (normally assumed to be zero) have been conservatively assumed to be zero.

Crow Sound is orientated approximately north-west to south-east and permits the penetration of long period waves into Pentle Bay. Combined refraction and shoaling effects at this location are slightly lower (i.e. not so effective in wave height reduction) than at Appletree Point. Although the offshore significant wave heights generated from the south-east are lower than those generated from the south-west, the higher combined refraction and shoaling index allows an inshore wave height of approximately the same height as at Appletree Point in the same water depth.

Although other inward facing parts of the islands can be attacked by waves generated offshore, they are in general protected by rocky outcrops and shoals and refraction and shoaling attenuates the magnitude of offshore wave attack.

Outward facing shores are obviously the most exposed and have suffered from damage in the past. Even relatively sheltered and deep bays such as Porth Cressa are affected. Where shorelines of concern are affected by wave attack they fall broadly into two categories:

- those with high level beaches fronting them (Figure 7.1) such that erodible land is landward of the still water level and attack is in the form of bore of water generated by wave uprush;
- those with lower level beaches where erodible land is seaward of the still water level (Figure 7.2). Depending on water depths, this type of shore is vulnerable to the higher waves that can be supported in larger water depths.

It is recommended in Section 7.5.2 that the five year return period is used as the starting point for design and the offshore significant wave heights at this level are given in Table 2.5.

7.6.4 Overtopping

Overtopping is always a consideration in design, particularly where the terrain behind the defences is liable to flooding such as Old Town and Porth Minick on St Mary's. In many locations on the islands, however, overtopping of natural or man-made defences in itself is not a problem and causes little difficulty (e.g. overtopping into the Big Pool area of St Agnes). Indeed, overtopping onto Rushy Bay Green on Bryher was considered by English Nature to have been generally beneficial in the spread of the nationally rare dwarf pansy (*Viola kitaebeliana*).

The problem for these locations is the erosion of forward defences (e.g. beaches and dunes) and the consequences of resultant flooding or increased overtopping that that would have for the hinterland including in many instances the security of water supplies (e.g. Bryher and St Agnes). The prevention of overtopping, although an inconvenience, is therefore not always essential. Loss of fresh water supplies is a significant risk since Samson was abandoned in recent history (about 100 years ago) owing to the loss of its fresh water supply.

Apart from technical feasibility, the other two of the three criteria on which any potential scheme will be assessed will be the environmental suitability of what is proposed and the result of its benefit/cost assessment. In order to achieve schemes that dramatically reduce the amount of overtopping experienced, it will be essential to increase the height or magnitude of such defences so that they interfere with their perceived visual and general environmental acceptability.

The Scillies are essentially a rural/semi-rural environment set within a Heritage Coast and the large defences that would be needed to greatly diminish overtopping are probably inappropriate in terms of aesthetics and general environmental sensitivity. It is sensible to examine the return periods for which coast defence designs are made and this has been done. However, reducing the return periods for which defences are designed makes little significant difference to the defence height (certainly in terms of cost) that would be needed to reduce overtopping volumes below a defined level.

Owing to the significant logistical overhead that any scheme on the Scillies bears compared to an equivalent project on the mainland, the benefit/cost analyses, certainly in terms of tangible assets, are usually marginal on the lower end of the sensitivity range tested. It is therefore necessary to design schemes for a lower return period than might be possible for an equivalent scheme on the mainland.

7.7 Potential Structural Types

The Scillies are an extremely sensitive environmental area as recognized in the definition of Heritage Coast and designation as an Area of Outstanding Natural Beauty (AONB). Care must be taken when selecting coast protection types such that they are not only appropriate on technical and economic grounds but that they will harmonise insofar as possible with the surrounding townscapes and natural landscapes. The above consideration swiftly discounts such alternatives as plain concrete walls (although textured concrete utilising exposed granite aggregates or facings of stone may be acceptable) and exposed revetments of linked concrete armour blocks or asphalt. Potential alternatives are discussed below with outline sketches included in Appendix 11.

7.7.1 Offshore Breakwaters

The use of offshore breakwaters is appropriate in certain circumstances in dissipating wave forces before waves reach vulnerable shorelines. The energy shadow created in their lees can result in the reduction of the longshore transport current and the accretion of a protective beach from material which would otherwise continue to be carried in suspension.

Natural offshore breakwaters are in evidence throughout the archipelago, such as in Porth Cressa (Porth Cressa Brow) on St Mary's and in Pentle Bay (Great Pentle Rock) on Tresco, although these have limited value as protection owing to their restricted heights. Some of the islets close to the main islands are taller and more extensive than the rocks mentioned above and provide good protection to the adjacent shorelines; Toll's Island on St Mary's, which has accumulated a substantial tombola in its lee, is a good example albeit much bigger than an offshore breakwater would be.

During the early stages of design of the coast protection scheme for Bryher there were objections voiced by English Nature to the potential use of offshore breakwaters. These structures would be very noticeable as they would be high (rising of the order of 4 m above the seabed) and, in the early years following construction before they have weathered and accumulated

coatings of seaweed and lichens, they would be more visible than in later years owing to the harsh appearance of freshly quarried rock.

English Nature have stipulated that any rock proposed for use in coast protection schemes on the Scillies should be *Armorican/Hercynian* granite quarried from Cornwall. A suitable quarry was named by English Nature as being Carnsew, near Falmouth. The beds at Carnsew used to produce *armour* rock and facing stone for the schemes on Bryher and St Mary's have furnished high quality *armour* stone but it is from a rock which is light grey in appearance compared to the light brown of the native rock. The imported stone will mellow in time when colonised by lichens and intertidal seaweeds and when natural marine debris (seaweed, etc.) begins to accumulate. The appearance of the pre-cast concrete panels of the reconstructed quay head on St Mary's are a perfect example since they were originally light grey and have mellowed appreciably in the two years since their construction and installation.

7.7.2 Beach Replenishment

Beach replenishment is a way to increase the volume of the beach and to raise its height such that wave energy is dissipated on the beach before reaching the defences proper. It would have the advantage, at locations such as Porth Cressa, of increasing the amenity value of the existing beach while providing structural benefit to the shoreline defence in terms of reduced wave forces.

The Scillies have been declared a voluntary nature reserve and it is therefore not possible to obtain a supply of material for beach replenishment locally. Dredged material would have to be obtained from further afield and problems are presented by changes in marine legislation which now require that an existing licensed dredging site would have to be closed before another could be opened. This action therefore places a premium on the supply of dredged fill.

English Nature have indicated previously that English China Clays (ECC) in Cornwall produce sand as a by-product from their operations which they (English Nature) consider would be suitable for use in beach replenishment in the Isles of Scilly. While the ECC sand is quartz, with high mica and clay fractions, rather than the naturally occurring silica sand found in the Scillies, English Nature consider it to be acceptable in terms of its mineral composition. The ECC sand, once all clay traces had been washed out would be whiter than the native sand but neither English Nature nor the Countryside Commission would object to this colour difference.

Discussions with ECC reveal that their sand cannot be cleaned sufficiently to remove all traces of the clay fraction. Grading curves of "tip sand" presented by ECC show that only 65% of the material is sand coarser than 600 microns with fully 25% of the total grading being clay. ECC estimate that it would take of the order of two to five years before natural washing by the sea removed the silts and clays. During this time there would be some staining present in the sea. Moreover, calculations indicate that the cost of having to import sand from Cornwall make it uncompetitive compared to other alternatives. Recent (but unexceptional) gales which eroded large parts of the coastline on Tresco show the vulnerability of this type of material to loss which would create an unacceptably costly maintenance commitment on Scilly for reasons stated above.

In most instances on the Isles of Scilly, beach recharge in itself would not be sufficient. The use of beach recharge, while reducing the degree of run-up and magnitude of wave attack, does not address the problem of elderly and insufficient structures higher up the beach and supplementary shore works would still be required. This requirement in most, if not all, instances places a high financial penalty on beach replenishment as an option owing to the high mobilisation charges for all construction forms.

7.7.3 Armoured Revetments

Armoured revetments are a suitable construction type for use at many locations throughout the islands and have been used most recently at Bryher and St Mary's. They can be constructed from many materials, typically concrete blocks (often cable tied), open stone asphalt and the more traditional rock or concrete armour units. Thomas and Hall⁽⁹⁾ give a suitable review of sloping porous walls which form revetments; pertinent findings of which are summarised below.

- Open Stone **Asphalt**

Open stone asphalt is a system of loose rock continuously or pattern-grouted using asphalt. It is suitable for use in mild to moderate wave climates (i.e. wave heights less than 4 m) and, as such, would be suitable throughout the Isles of Scilly. Its main drawback in a sensitive environment is the visual impact of the black asphalt in the joints (although this may become less severe with weathering). It may, however, be suitable for use in certain applications such as within the working harbour of St Mary's.

(9)

Seawall Design, R.S. Thomas & B. Hall, CIRIA, Butterworth Heinemann, Oxford, 1992

Open stone asphalt is stated to have only fair durability and maintenance would therefore be a considerable problem owing to the total lack of material, specialist equipment and trained personnel on the islands for dealing with not only with the material itself but with its specialist application in the marine environment. Notwithstanding the above, the potential use of open stone asphalt in the Scillies would most likely be on the upper beach and therefore somewhat easier to deal with.

- **Concrete Blocks**

Concrete blocks are available in a variety of shapes and sizes and often are part of patent systems. Wave run-up and hence overtopping would be greater with the smoother concrete block system than with an equivalent rock revetment but in most locations within the islands, the occasional overtopping may not be a problem.

The visual appearance of a concrete block system is obviously that of a fabricated man-made structure and so the locations at which their use is proposed would have to be selected carefully. A patent system (Armorflex) has been used (1995) at Porth Cressa to protect the toe of the new stone-faced reinforced concrete seawall from undermining and, at the time of writing, a similar system has been constructed on St Agnes at Porth Coose and Porth Killier to reinforce the natural dune system (1996). As with the system at Porth Cressa, it is the intention that the beach and dune is the main protection but that the concrete block system forms a longstop during extreme conditions. During the winter 1995/96, a prolonged and relatively unusual run of persistent south-east gales drove much sand from the eastern end of south-facing beaches to the west. At Porth Cressa, the new toe protection became exposed for a length of 20-30 m but gradually accreted sand over itself as expected.

Flexible armoured revetment systems are only suitable in mild wave climates (that is, wave heights less than about 1.5 m). They would therefore be useful defence elements within the Isles of Scilly in many inward facing shores where water depths are shallow and fetch lengths restricted to the order of 3,000 m. Experience of the recent construction in Porth Cressa, which employed the Armorflex cable-tied concrete block revetment system, and which required adjacent mats to be meshed together and the cables to be rethreaded and crimped showed that maintenance issues are not a problem and can be dealt with locally.

- **Concrete/Rock Armour**

Where the exposure of stretches of coastline is greater than the more sheltered inward-facing shores, it will be necessary to look to more

substantial structures to provide the necessary protection. Rock or concrete armour units can do this. For a given wave climate, smaller concrete armour units would provide the requisite protection compared to the equivalent rock armour unit but they are generally economical only where the unit size, depending on the quarry yield curve for the rock alternative, is above about ten tonnes.

Apart from technical and economic considerations, the aesthetics of a concrete armour protected slope are not as sympathetic to the needs of a Heritage Coast as is the alternative of rock. The visual impact of rock would be more acceptable given the visually broadly similar collections of rock around the margins of the islands bay.

Where defences formed of rock or concrete armour units would present problems would be in restricting access to the beach for pedestrians, boats, etc. although slips/access ramps, for example, set back into the structure could relatively easily be accommodated.

Rock revetments have now been provided at Bryher and Porth Cressa and it is likely that rock will further provide, if not the entire protection system, then elements of coast protection schemes elsewhere within the islands. It is within the nature of rock armour that individual elements are susceptible to being moved by the elements and that maintenance of some degree will be required from time to time.

Since the islands form a small community operating an agricultural/tourist economy supported by some light industry, they have a major drawback compared with mainland communities in that suitable items of heavy plant are not readily available. One of the major concerns of the Council therefore has been in providing for maintenance of their coastal structures. To this end, they have acquired a 22-tonne 360' tracked backactor equipped with a rock grab through the rolling programme of coastal schemes. This machine is adequate for most maintenance purposes utilising rock armour up to a mean weight of 3.5 tonnes (i.e. individual stones of 5 tonnes). There will always remain the problem of moving the machine between islands as needed to repair storm damage.

7.7.4 Seawalls

Seawalls can be constructed using concrete, stone, timber or steel and examples of the use of all materials are seen throughout the islands. Concrete, for example, has been used on Tresco (Appletree Point) and dressed stone is in evidence on Tresco (New Grimsby) and St Mary's (Town

Beach). Timber was used for the construction of the bulkhead on Porth Cressa beach (St Mary's) in 1963 but was replaced in 1995 after earlier storm damage; some timber uprights are in evidence on Tresco although they have been ineffective. Steel has not been used widely on the Scillies owing to the need for and high cost of specialist plant (piling hammers and cranes) for its installation but it has been used for the strengthening of the Quay on St Mary's where the sheet steel piles have been faced with precast concrete panels to give the appearance of large dressed stones.

As has been emphasised time and again throughout this document, aesthetics are an important consideration for the design and construction of new coastal structures. The example quoted above for the facing to the strengthened Quay is important since it has been followed by the design of the new seawall at Porth Cressa. This wall incorporated stone blocks to create the appearance of random stone walling to harmonise with the background of stone buildings in the nearby Hugh Town.

Nowadays, the use of vertical seawalls is avoided wherever possible owing to their propensity to become undermined because of their generally high wave reflection characteristics. This property is readily evident at many locations within the archipelago but probably most prominently at Appletree Point at Tresco where the erosion has reached such a degree that the seawall has failed and is in urgent need of replacement. The use of vertical, or near vertical, seawalls is still justifiable such as at locations where ram cliffs have been created with roads close by and where there is really no feasible alternative. Seawalls form a useful secondary purpose in providing platforms for promenades - witness the popularity of the previous (1963) and present (1995) seawalls at Porth Cressa.

Some form of toe protection would, however, have to be provided to protect against the eventuality of undermining. Toe structures are frequently of steel sheet piling but alternatives such as the flexible *Armorflex* type apron provided at Porth Cressa could be provided in appropriate applications. This type has the benefit of allowing free movement of tidal and ground water and dissipation of excess pore pressures under the superstructure while having the flexibility to accommodate some differential movement. The use of any type of toe protection, and indeed superstructure, will be governed by the prevailing ground conditions.