## SECTION 3 TECHNICAL VIABILITY

### 3.1 The Decision-Making Process in Respect of the Retreat Option

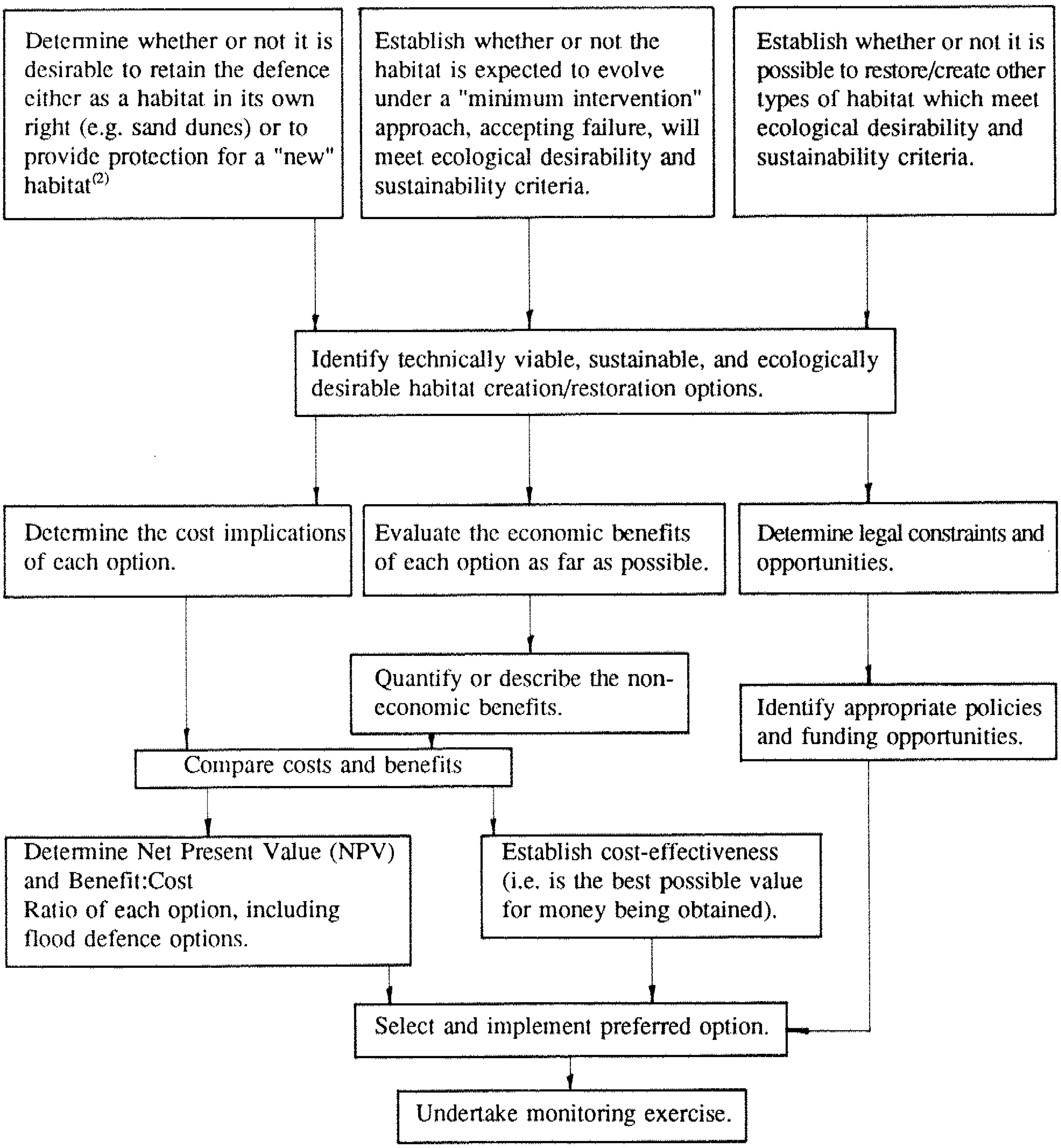
3.1.1 Section 2 sets out the combination of issues, concerns, and threats to coastal habitats which have combined to place the concept of retreat to benefit nature conservation and landscape quality onto the decision making agenda.

The creation or restoration of coastal habitats in association with a retreat from the existing line of flood defence is fine in principle. If the idea is to become reality, however, the technical, economic and legal viability of such initiatives must be demonstrated, and the question of ecological desirability must be resolved.

On a site-specific basis, the decision-making process is likely to start with an assessment of the technical viability and the management implications of a range of alternatives. These alternatives will include both maintaining the flood defence and restoring or creating coastal habitats under a retreat scenario. In some cases it may be necessary to maintain the flood defence in order to protect a site of existing nature conservation interest which is considered to be "too valuable" to lose even if the creation of an alternative habitat appears to be technically viable. This possibility is examined in Section 4.1.6. Elsewhere however, having determined the type of habitat(s) which it might be possible to create or restore and sustain at the site, it is necessary to determine their relative benefits in terms of ecological desirability and to assess the economic implications of each option. The mechanisms by which a preferred option might be implemented in practice, will then also depend on legal constraints and opportunities; the policies of the various interested parties involved; and the availability of funding. This decision making process is summarised in Figure 3.1.1 and it **should be stressed that <u>all</u> routes through this figure will need to be investigated for any specific project.**

3.1.2 Figure 3.1.1 demonstrates that the identification of sustainable, technically viable options and the determination of their ecological desirability will be very closely linked for a particular site. There is little point in devoting time and money to the economic evaluation of a resource which is not considered to be desirable and/or valuable in terms of potential nature conservation interest. The purpose of this report, however, is to investigate the general issues associated with the retreat option and to put forward a framework for future use in assessing issues on a site specific basis. Section 3 therefore deals with the technical viability and sustainability of habitat creation and restoration under a scenario of managed retreat, independently of ecological desirability which is considered alongside other evaluation requirements in Section 4. In both sections, the issues which need to be addressed as part of the overall decision making process are identified and reviewed. In neither case, however, is the report intended to provide detailed technical guidance on "how-to-do" managed retreat. Although the United States in particular has a great deal of practical experience in both habitat creation/restoration and the economic evaluation of environmental goods and services, many of the various techniques discussed in the following sections will require careful examination and experimentation before they can be applied with confidence in Great Britain.

**Figure 3.1.1 The Decision-Making Process in Respect of the Retreat Option**[1]




(1) Figure 3.1.1 assumes that retreat will not be considered as an option if the environmental assessment process demonstrates that an existing nature conservation resource protected by the defences is considered to be too valuable to lose (see Section 4.1.6).

(2) Such protection could involve e.g. a breakwater protecting a new saltmarsh against erosion or a defence for a new grazing marsh against unacceptably frequent flooding.

### 3.1.3 The Nature Conservation Value of the Defence

One of the first issues which should be investigated when evaluating the technical viability of the retreat option is whether or not the defence itself is of nature conservation or landscape value. If the defence consists of a natural feature such as a shingle ridge, saltings or sand dunes, a careful assessment will be required to investigate both the desirability and technical viability of restoring that feature. Restoration options might include shingle or sand replenishment, the placing of dredged material, or vegetation planting. The various techniques associated with these options are discussed in Sections 3.3 to 3.5 inclusive. Additional considerations, however, relate to the land behind the defence and to the upstream and/or downstream implications of abandonment. In many cases if a defence is being maintained simply for its habitat value, a general reduction in the standard of flood defence provided might be anticipated. Flooding might be expected more frequently, saline intrusion through or under any bank might increase or a lagoon habitat might develop. Depending on the existing nature of the hinterland area, any such implications could potentially be of significant environmental importance, particularly if the land in question is currently intensively farmed. An increasing risk of inundation might dictate a less intensive agricultural regime and the overall total benefits of this type of option (i.e. maintaining a defence as a habitat in its own right and accepting a reducing standard of protection) could therefore be quite high. Another possible benefit of this strategy would be that the maintenance of the defence in some form should ensure that possible significant (adverse) effects elsewhere on the coastline are minimised.

In many situations, however, it is envisaged that an option involving a retreat from the existing line of flood defence will offer significant environmental benefits, enabling or encouraging the migration inland of coastal habitats. If this is the case, the degree of management or intervention which might be required to achieve different environmental objectives must be very carefully considered because of:-

- the possible cost implications of a long-term management policy based on intervention
- the general desirability of creating or restoring a habitat which will become self-sustaining
- the need to avoid undesirable consequences (e.g. increased erosion or deposition) elsewhere in the estuary or along the coast.

### 3.1.4 Sustainability Criterion

Some of the criteria discussed in Sections 3.3 and 3.4 will define the short term viability of an option according to present conditions (ie. proximity of adjacent habitats, wave climate, etc.). Due consideration must, however, also be given to the longer term situation, particularly in respect of the implications of an increase in the rate of sea level rise discussed in Section 2.2. Habitat creation using dredged material, for example, has a better chance of long term sustainability if there is a natural source of sediment available for subsequent accretion. Similarly, consideration might be given to the removal of a groyne structure to help restore the littoral movement of material, rather than creating or restoring a habitat which will subsequently require continual artificial replenishment over the longer term. **It is not an objective of this study to promote the creation of habitats which subsequently require as much maintenance as the flood defence structures which preceded them.**

### 3.1.5 Project Planning Requirements

Finally, whichever option is selected, one important additional factor must be considered throughout the decision making process. **Experience in the United States has demonstrated that a key factor in successful habitat creation/restoration initiatives is a careful prior appraisal of the situation and, if appropriate, well researched design undertaken by suitably qualified personnel.** The San Francisco Bay Conservation and Development Commission (BCDC, 1988) highlight this issue in a review of fourteen marsh creation and/or restoration projects undertaken in the San Francisco Bay area. Their report cites general poor planning, or the unauthorised modification or inadequate execution of the plan submitted and approved under Section 404 procedures (see Section 5.5.3), as being among the primary reasons for the failure or partial failure of eight of these fourteen projects. In Great Britain Hollis et al (1990), reporting on work carried out by Sills and Becker (1988), similarly conclude that **sea level rise is likely to lead to the creation of new habitats which, with sufficient skill and funding, can be turned into nationally or even internationally important sites.**

## 3.2 Ecological Development Following Bank Failure

### 3.2.1 Review of Available Information

Areas where sea defences or tidal embankments have failed in the past provide case studies of the ecological processes which might be anticipated if sea level rise leads to increased saline flooding and a retreat from the existing line of sea defence. These areas present an opportunity to study the natural biological and physical implications of the retreat option. In order to understand fully the ecological changes likely to occur under a planned retreat scenario, however, a complete knowledge of the processes and characteristics affecting the site are required. This enables the most appropriate habitat restoration and creation initiatives to be identified and implemented at any particular site.

As demonstrated in Table 3.2.1 which presents the results of one element of the "regional round-up" exercise discussed in Section 1.3.4, the Essex and Suffolk coastlines offer many examples of where bank failure has led to the inundation of low coastal lands - often lands which were previously "reclaimed" from the sea. Mudflats, low level Aster, and high level Halimione saltmarsh are the main habitats which have developed in these areas, the differences being a result of the particular land levels at the time of flooding and the physical and biological processes subsequently operating at the site. Following bank failure, sites such as Bridgemarsh Island and Brandy Hole reverted to saltmarsh, but these are presently rapidly eroding to mudflat, possibly because the level of protection afforded by the deteriorating defence has declined (see Section 3.1.3). At other sites (e.g. in the Blyth Estuary), areas of mudflats have developed, fringed by accreting saltmarsh and at North Fambridge, high level saltmarsh has formed in the area which breached in 1902, while low level saltmarsh has developed in the area breached before 1902.

These differences in habitat development may be due to erosion or a lack of accretion affecting the habitat since bank failure, or they may be a result of different land levels prior to bank failure. A general lack of monitoring at most of the sites described on Table 3.2.1, however, means that no precise data are available to enable the habitat development process at specific sites to be assessed.

The present ecological importance of these sites depends on the location, the type of habitat lost and the value of the "new" habitat. In addition to assessing the past and present botanical importance of a site, however, ornithological and entomological characteristics should also be reviewed. In the Suffolk estuaries of the Blyth and the Alde large areas of mudflat have developed, but on observation the "new" mudflats have been found to support a lower density of feeding birds than other Suffolk estuaries. The Suffolk Wildlife Trust is currently surveying invertebrate densities to try to account for the low numbers of feeding birds. In areas of Hamford Water in Essex meanwhile, the breached sea banks have led to the formation of isolated islands which form excellent undisturbed habitats for nesting gulls and shelduck.

Finally, any gain to conservation following retreat will also depend on the wildlife value of the habitat present before bank failure. Shotley Marshes in the Orwell Estuary, for example, is already an ecologically important area of grazing marsh. Bank failure and a reversion to mudflat at this site may therefore lead to a net loss in conservation terms.

**Table 3.2.1 Examples of Ecological Development Following Bank Failure (By Region)**

**Region: Anglian**

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Holbrook, Stour Estuary *Grazing Marsh* | | Muddy lagoon due to low land levels prior to failure. | Limited habitat or ecological benefit, but within the Stour Estuary SSSI. | Personal Communication (1)(2) |
| Bridgemarsh Island, Crouch Estuary *Grazing Marsh* | 1930/40's | High and low level saltmarsh depending on land levels prior to breaching; some areas rapidly eroding to mudflats. | In area of estuary designated as a SSSI. | Personal Communication (1)(2) |
| North Fambridge, Crouch Estuary *Grazing Marsh* | Southern side 1902 Northern side pre-1902 | Southern part: high level saltmarsh - Halimione. Northern part: low level saltmarsh - Aster. | In area of estuary designated as SSSI. | Personal Communication (1)(2) |
| Brandy Hole, Crouch Estuary *Grazing Marsh* | 1902 | Low level Aster saltmarsh. | In area of estuary designated as a SSSI. | Personal Communication (1)(2) |
| Northey Island, Blackwater Estuary *Grazing Marsh* | | Saltmarsh | National Trust; SSSI | Personal Communication (1)(2) |
| Wivenhoe area, Colne Estuary *Grazing Marsh* | 1953 and subsequent failures | High level saltmarsh | | Personal Communication (1)(2) |

| **Area and Habitat at Time of Failure** | **Failure Date (If Known)** | **Resulting Habitat** | **Desirability** | **Reference** |
|---|---|---|---|---|
| Horsey and Hedge-End Island, Hamford Water *Grazing Marsh* | | Saltmarsh | Estuary designated as a SSSI. | Personal Communication (1)(2) |
| Pewit and New Island, Hamford Water *Grazing Marsh* | | Saltmarsh | Estuary designated as a SSSI. | Personal Communication (1)(2) |
| Garnham's Island, Hamford Water *Grazing Marsh* | | Low level saltmarsh | High level saltmarsh/old seawall support a gull colony. SSSI. | Personal Communication (1)(2) |
| Skipper's Island, Hamford Water *Grazing Marsh* | 1953 | Saltmarsh developed and the island has been subsequently separated into three. Diverse habitat, supporting breeding birds and unusual plants. | Site now an Essex Naturalists Trust Reserve; SSSI. | Personal Communication (1)(2) |
| Northern edge of Hamford Water *Grazing Marsh* | | High level saltmarsh protected by relatively new low dune system. | Estuary designated as a SSSI. | Personal Communication (1)(2) |

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Titchwell Marsh *Root crops and grazing marsh used by cattle and horses* | 1949-1953 | Gradual reversion to low diversity saltmarsh behind dunes and shingle; formation of a large tidal reedbed in the area influenced by freshwater. | In 1970's the RSPB created a reserve by using sluices to create brackish and freshwater marsh and freshwater reedbed. The reserve is designated as a SSSI, Ramsar site and SPA. | Hollis et al (1990) Sills (1988) Personal Communication (3) |
| Blyth Estuary *Grazing Marsh* | 1903-1950 | Intertidal mudflats fringed by saltmarsh in zones of accretion and reedbeds in areas of freshwater influence. | Designated a SSSI and proposed Ramsar Site because of habitat diversity. | Beardall et al (1988) Personal Communication (2)(4) Anglian Regional Meeting |
| Deben Estuary *Grazing Marsh* | 1940 and subsequent failures. | The Deben Estuary's area above MHW increased from 182 to 251 hectares (since the 1840s) following breaches at a number of sites. North and South Waldringfield - formation of saltmarsh with some mudflats. Martlesham Creek - mudflats Sutton Hoo - mudflats and saltmarsh. | | Beardall et al (1988) Anglian Regional Meeting |

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Alde Estuary *Grazing Marsh* | | Snape Warren - mudflats and saltings formed Iken Marsh - mudflat and reedbed formation due to freshwater input. | | Beardall et al (1988) Anglian Regional Meeting |
| Read's Island *Mudbank* | 1970 and subsequent failures | Following the seawall failure, erosion and flooding caused a loss of half the island to mudflat. | | Yorkshire Regional Meeting |

**Region: Severn Trent**

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Arlingham | 1980s | | Retreat from defence line to ease flood flow. Produced conservation benefits. | Severn Trent Regional Meeting |

Region: Southern

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Bunnymeads, River Hamble *Low-lying pasture, below river level* | 1930s and subsequent failures. | Three breaches have occurred with the subsequent formation of tidal mudflats, fringing saltmarsh and reedbeds. In 1980-81 the bank was repaired to reinstate the public footpath but the tidal character was maintained by culverts. This has caused some channelling and scour. | Significant amenity and conservation gains. | Personal Communication (6) Southern Regional Meeting |
| Pagham Harbour *Reclaimed agricultural land* | 1890 | Reverted to a tidal inlet following failure. Over the past 20-30 years the narrow entrance formed by a shingle spit has moved. | The site is very important having been designated a Ramsar site and SPA. Managed as a Local Nature Reserve by West Sussex County Council. | Personal Communication (5) Southern Regional Meeting |
| Newtown Harbour, Isle of Wight | 1953 | Mudflat grading into saltmarsh. | Very good site ecologically, managed by the Isle of Wight County Council as a Local Nature Reserve. | Southern Regional Meeting |

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Exbury | | Estate land flooded following failure. Spartina marsh has developed. | | Southern Regional Meeting |
| Brading Harbour, Bembridge, Isle of Wight *Former Reservoirs* | | Tidal mill failed and the area reverted to intertidal mudflat. | | Southern Regional Meeting |
| Pennington *Coastal Grazing Marsh* | 1953 | Seawall failed and was reconstructed further inland. Mudflat formed in abandoned area. | The area still existing as grazing marsh is a nature reserve managed by Hampshire County Council. | Southern Regional Meeting |
| Sowley, East Lymington *Medieval saltings* | 1950's | Medieval saltings were protected by a small shingle bank which failed in 1910. The area has reverted to an intertidal area since further failures in the 1950s. | | Southern Regional Meeting |
| Elmley Marshes *Grazing Marsh* | 1953 | Various breaches killed reedbeds, etc. No documentation is available. | RSPB Reserve, SSSI, Ramsar Site and SPA. | Personal Communication (7) |

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitats | Desirability | Reference |
|---|---|---|---|---|
| Barksore, Medway Estuary *Grazing Marsh/ Agricultural land* | | History of breaches and subsequent repair of the privately owned defence. The peninsula is presently impounded and maintained, though the tidal creek system is still evident. | | Personal Communication (7) |
| Nor Marsh, Medway Estuary *Grazing Marsh* | | Protected in the past, now reverting to intertidal habitat - both accretion and erosion are occurring. | RSPB Reserve and SSSI. | Personal Communication (7) |

N.B. There are a number of further examples in the Southern Region where bank failures have led to the development of natural/semi-natural habitats.

**Region: South West**

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| River Dart<br>*Low grade agricultural land* | 1980's | Slowly reverting to mudflat. | | South West Regional Meeting |
| North of Millbrook | 1940's | Area formerly impounded for fish ponds has now reverted to marsh. | | South West Regional Meeting |
| Erme and Yealm Estuaries | | Some failures; little documentation. | | South West Regional Meeting |

**Region: Yorkshire and Northumbria**

| Area and Habitat at Time of Failure | Failure Date (If Known) | Resulting Habitat | Desirability | Reference |
|---|---|---|---|---|
| Holy Island<br>*Agricultural* | 19th Century | Failure of some defences led to general changes in vegetation type over parts of the island. | | |

Personal Communication
(1) Dr. R. Hamilton; Dr. C. Gibson (Colchester, NCC)
(2) Dr. M. George
(3) Mr. N. Sills
(4) Dr. C. Beardall
(5) Nature Conservancy Council, Lewes Office
(6) Mr. C. Cuthbert (County Recreation Department)
(7) Dr. M. Clarke (South East Region, RSPB)

### 3.2.2 Titchwell Marsh

Titchwell Marsh was originally claimed from the sea in 1786. It was converted to grazing land and arable land for root crops, while the reedbed was grazed by horses (N. Sills, personal communication, 1991). At the end of the 1940's the sea walls were weakened and in the tidal surge of 1953 the wall breached. Following bank failure, the agricultural marsh gradually reverted to a low diversity Aster saltmarsh and a large tidal reedbed developed (Hollis et at, 1990). The marsh was protected from the sea by sand dunes and shingle, but tides regularly flooded the saltmarsh and most of the reedbed during the summer (Sills, 1988), limiting the viability of the site for breeding birds. In the 1970's the RSPB purchased the marsh and, using seawalls, dams and sluices, regulated salinity and water levels to create 10 ha of freshwater reedbed, 11 ha of freshwater marsh and 17 ha of brackish marsh. 58 ha of the original saltmarsh and 14 ha of tidal reedbed (Sills, 1988) were retained. The higher level saltmarsh which is now only flooded by 10 per cent of tides supports a diversity of flora and provides a suitable area for ground nesting birds; the lower Aster marsh is flooded by approximately half the tides and, while not suitable for nesting, provides a valuable winter food source for birds. As a SSSI, Ramsar and SPA, and as part of the North Norfolk Heritage Coast and Area of Outstanding Natural Beauty, Titchwell Marsh therefore provides a superb example of the type of resource which can be created with careful management following the failure of sea defences.

### 3.2.3 Blyth Estuary

In the Blyth estuary, over 1100 hectares of intertidal habitat had been subject to land claim and converted to arable by 1842. In 1991, approximately 1,278 hectares of agricultural land in the locality are estimated to have been "claimed" from former saltmarsh and mudflat. Since the turn of the century, however, 250 hectares have reverted back to intertidal areas following bank failures with the 1953 tidal surge causing the most damage. The Blyth presently has 10km of tidal channel containing 55 ha of saltmarsh and 276 ha of mudflats (Beardall et al, 1988). Where breaches have occurred, the majority of the area has reverted to intertidal mudflats due to the low level of land behind the embankments, but accretion has allowed saltmarsh to develop round the periphery of the new estuary. In areas where a freshwater flow is predominant, reedbeds are also present. Areas of tidal mudflats and associated habitats of the Blyth are part of the Walberswick National Nature Reserve adding to its diversity of habitat. The area is also classified as a proposed Ramsar site, an internationally important wetland site under the terms of the Ramsar Convention.

### 3.2.4 Monitoring Requirements

In France, the monitoring of an area at L'aber de Crozon where a flood defence barrier was deliberately breached by the Conservatoire du Littoral ensured that biological changes were documented and habitat development processes were recorded. Unfortunately, none of the British sites recorded in Table 3.2.1 have been monitored in any detail following bank failure and flooding. Such monitoring would have provided valuable information on the rate of habitat development and ecological desirability in terms of colonising species and sustainability. Some information about when the failure occurred and what subsequently developed is, however, available from maps and aerial photographs of differing dates, and this would enable a more detailed investigation to be made of ecological development in certain cases. This type of research would then enable more accurate predictions to be made in terms of the type of habitat likely to develop at a specific site.

**Any information which can be gained about habitat development through studies of past failure sites would be of immense value to future decision-making. It is therefore recommended that a study be undertaken, firstly to identify sites at which photographic evidence, unpublished data etc. is likely to be available, and subsequently to document changes over time and compare development at different sites.** In this way it is hoped that a picture could be built up, explaining the physical, biological and temporal processes of significance in the past development of different coastal habitats, improving our understanding and providing important lessons for the future.

## 3.3 Physical Considerations

### 3.3.1 General discussion

The coastal environment is dynamic and the mechanisms at work are powerful. Particularly on exposed coasts, the coastal process regime will need to be understood if habitat restoration/creation opportunities are to succeed and are not to cause problems elsewhere. The various physical considerations in respect of the retreat option are summarised on Table 3.3.1 and discussed in more detail in the following sections. The specific relevance of these considerations to different coastal habitats is then considered in Section 3.5. The relatively brief discussion in Section 3.3 is not meant to reflect the level of analysis that will be necessary when considering retreat at a particular site: coastal processes are complex and frequently require detailed analysis, numerical modelling, measurements and monitoring. The discussion in the report does, however, serve to highlight those areas where such detailed information will be required.

**Table 3.3.1 Physical Characteristics Controlling the Development of Sustainable Habitats**

| | |
|---|---|
| Waves | Coastal habitats in exposed, high wave energy environments may require protection (e.g. a breakwater, peninsula or similar). |
| Tidal Currents | Knowledge of tidal currents is essential in determining sediment transport regime. Tidal prism at a site is important because it enables the exchange of waters and hence sediments, fauna, seeds, etc. |
| Sediment | Sediment type and availability, and the site specific transport regime will be key factors in determining both the technical viability of types of habitat, and their likely long-term sustainability. |
| Surges | Important in determining extreme high water levels. |
| Elevation | Elevation controls the type of coastal habitat which can be sustainably developed at a site, as different habitats depend on different periods of inundation. |
| Grade | Grade controls drainage which is essential in maintaining a healthy habitat. |
| Size | Site stability and ecological diversity will both benefit from the largest possible size, particularly if the site is isolated from other similar habitats. |

### 3.3.2 Waves

At any individual location, exposure to wave action is a function of wind climate, fetch (the distance over which the wind can blow before reaching the site), water depth and, in the case of protected waters, exposure to the open sea. The importance of these characteristics cannot be overstated: the US Army Corps of Engineers (USACE), for example, suggest the wetland habitat creation in an unprotected area where the fetch is greater than 10 miles will have less than a 20% chance of success (USACE, personal communication, 1990). Similarly, the chance of success reduces as offshore depth increases.

To assess the wave climate at a given location there are published techniques (USACE, 1984) for calculating wave heights if water depth, wind speed and fetch are known. On an exposed coast, waves are often generated elsewhere (swell waves) and there is no substitute for records. Full account should also be taken of shallow water wave processes (wave breaking, friction loss, wave refraction) which, depending on the site, can require numerical modelling.

Exposure to wave action plays a large part in determining whether a particular coastal site should be considered a low energy or high energy environment. To a large extent this in turn governs the type of habitat that will survive. That is not to say that a saltmarsh, for example, cannot survive on an open coast. What it does mean is that for saltmarsh to survive it may require protection. In the US, at Shooter's Island New York for example, protection has been achieved using breakwaters (USACE, personal communication, 1990). A suitably shaped site will, however, afford its own protection.

In areas less exposed to wind and waves, boat-generated waves have been found to be significant. In estuaries and on tidal rivers, due note should therefore be taken of the type of navigational uses.

### 3.3.3 Tidal Currents

Assuming tidal levels are known, a knowledge of land levels will indicate the extent of land which would be regularly inundated under a retreat scenario. For an enclosed tidal water body (such as a harbour or an area of low lying land into which the tide will flow if a wall is breached) a knowledge of tidal levels will also enable ebb and flood flow discharges to be calculated. However, tidal currents around the site may require specific measurement campaigns using current meters, floats or other techniques. A good knowledge of tidal currents will be essential in determining the sediment transport regime at a defined location but the required extent of measurements, and possible subsequent modelling (which can greatly enhance measured data at modest cost) can only be judged on a site specific basis.

The tidal prism at a site is equally important not only because of its role in stabilising the channel inlet to a site, but also in ensuring water circulation exchange and flushing, and hence the supply of sediment, fauna, seeds, etc. Finally, the impact of abandoning the flood defences at a site should be viewed not only in the light of any consequent increase in the tidal prism (the volume of water entering and leaving the site) and thus in tidal streams at the retreat site, but also the possible implications in terms of erosion or sedimentation elsewhere in the estuary or along the coast.

### 3.3.4 Sediment

The subject of sediments and sedimentation is broad, covering wave and current induced sediment transport, the type and quantity of sediment, local conditions within the site under consideration, and the overall coastal regime within the area. An awareness of sediment size, type, availability and transport will be of critical importance to the decision-making process for the managed retreat option becuase these factors will determine:-

- whether or not, in the short-term, material will need to be imported (e.g. to raise the elevation of the land)
- whether or not the created or restored habitat is likely to be sustainable over the longer term (e.g. will the habitat be able to accrete sufficiently quickly to keep up with sea level rise?)
- which species of fauna and flora will thrive in the created/restored habitat (vegetation developed on an area of uniform sediment size/type will be less diverse than that on an area of mixed sediments).

- **Sediment type**

The physical nature (organic content, pH, salinity, particle characteristics, and chemical composition) of sediment will need to be determined both at the site and in the general vicinity. This is particularly important in areas, such as in the channel inlet to a proposed intertidal area, where sediment may be eroded. Away from the site, the foreshore/seabed/riverbed/beach sediment properties should also be investigated in terms of their potential for being transported. The biological and chemical considerations in respect of sediment requirements for habitat creation or restoration are considered in detail in Section 3.4.

- **Sediment in suspension**

The ability of coastal and estuarine habitats to adapt to sea level rise is often dependent on the amount of sediment available for deposition. An assessment of the likely ability of a particular area to provide sufficient sediment must be based on measurements of the amount of sediment in suspension. At minimum, measurements should be taken at all depths in the water column, throughout a full 12.5 hour spring tide. The need to take additional measurements during, for example, times of high rainfall when suspended solids may be temporarily increased, should also be carefully assessed.

- **Transport regime**

A knowledge of wave climate, tidal currents and sediment availability provides the basic data for an analytical treatment of sediment transport. However, sediment transport (particularly by waves) is not well understood, and as much factual data as possible will be required on the physical evidence of transport in the vicinity of the site. Such data might include old maps, soundings, surveys, and any details on the effect of port works such as dredging or construction. Taking these data together, and supplementing them with modelling as necessary, an attempt should be made to define some or all of the following as appropriate:-

i. the amount of material that will be brought into or onto a new tidal area on each tide, and will thus be available for deposition

ii. the annual and storm-related rates of longshore drift along a stretch of coastline: this is particularly important if habitat creation involves the artificial breaching of a defence because, unless the habitat area has a large enough tidal volume, there is a substantial likelihood of rapid closure of that breach by longshore transport. Although such a closure could possibly be re-opened in times of high fresh water flow, there may be a significant decrease in the salinity and/or quality of the retained water in the meantime.

iii. the variation in beach profiles, including on/offshore transport, through the year

iv. past trends of erosion or deposition

v. the likely impact of the proposed scheme on other areas. This assessment should include the possibility of a blockage or interruption in longshore transport and also the likelihood of an increase in the tidal volume of an estuary leading to increased scour and deposition, problems with navigation, or a general disturbance to the tidal regime.

### 3.3.5 Surges

Data on surges will be required where it is necessary to know extreme high tide levels, the maximum area likely to be flooded, or where prolonged surges occur (i.e. over low water). This can cause long periods without an effective low water, such as frequently occurs in the Norfolk Broads. The Proudman Oceanographical Laboratory are the main British centre in this field and might, therefore, be contacted as part of a site specific assessment. The likely increase or change in surge patterns as a result of increased rates of sea level rise has already been discussed in Section 2.3.3.

### 3.3.6 Elevation

Elevation relative to typical tide levels and the tidal range is of prime importance in determining the viability of different coastal habitat types. The design of habitat creation/restoration projects should also make allowance for sea level rise and the predicted changes in tide levels. Values such as mean high water of spring and neap tides (MHWS and MHWN), mean sea level, and mean low water of spring and neap tides (MLWS and MLWN), which are obtainable for many locations from the Admiralty Tide Tables (published annually) are of particular significance. The elevation of the site relative to a standard datum should thus be established, and tidal levels can be used to assess the site's suitability for the development of a particular habitat type. Where the site elevation is too low for the desired habitats, experience elsewhere has demonstrated that it is possible to raise the elevation either by encouraging natural deposition or by artificially filling the site.

The first case (natural deposition) requires that adequate sediment be brought in to raise the site over an acceptable period of time. Data required to determine this will include suspended solids measurements (see Section 3.3.4), tidal range and the tidal volume of the site. The shape of the site should be such that good tidal flushing is achieved (ie. as much exchange of water on each tide as possible). Warping (deliberatly retaining water to enable sediments to settle out) may also be a practical option at some sites.

In the second case (artificial raising with imported materials) the proposed fill will need to be acceptable in terms of its chemical composition and drainage characteristics. In fine materials, clays and silts, settlement or consolidation should be expected. The use of dredged material as an option for raising land levels is discussed in detail in Section 3.4.7.