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EX 5516

Climate change, Jersey:
Effects on coastal defences

Report EX 5516
Release 2.0
April 2007

Document Information

Project	Climate change, Jersey:
Report title	Effects on coastal defences
Client	Transport and Technical Services Department, States of Jersey
Client Representative	Mr Chris Sampson
Project No.	CBM5720
Report No.	EX 5516
Project Manager	Dr A H Brampton
Project Sponsor	Dr K A Powell

Document History

Date	Release	Prepared	Approved	Authorised	Notes
13/04/07	1.0	AHB	KAP	KAP	Draft final report for Client review
30/04/07	2.0	AHB	KAP	KAP	After Client review

Prepared ....

Approved ....

Authorised ....

Summary

Climate change, Jersey:

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This report summarises a brief study into the potential consequences for coastal defences in Jersey of climate change caused by global warming. It looks forward to the 2080s and provides recommended allowances for increased high tide levels and altered wave conditions by that time, based on recent modelling of changes in the Earth's atmosphere. It then goes on to describe how climate change might affect various types of coastline, both natural and defended, to provide a background explanation to the future challenges that will need to be met to protect Jersey from coastal erosion and flooding.

To provide a context for the remainder of the study, a brief history of the past management of seawalls and other defences around Jersey is provided, including the current Island Sea Defence Strategy, and a table summarising present-day coastal flooding problems, produced by the Transport and Technical Services Department, is presented.

While great progress has been made in recent years in maintaining and strengthening Jersey's coastal defences, in future there will be a need for their "adaptive improvement", so that they will continue to maintain or improve their present standard of protection against coastal flooding despite higher tidal levels and possibly larger waves. This report suggests a number of long, medium and short-term objectives that need to be started soon, before the expected acceleration of climate change effects, to prepare for and plan such improvements. It is likely that maintaining the existing high standards of coastal defence enjoyed by Jersey will require an increasing budget, and it will be important to allocate the available funds in a transparent manner, that reflects the urgency and extent of the risks of flooding or erosion at different locations. The report concludes that, as part of this planning, it would be sensible to review and revise the monitoring of the beaches and coastal defences around the Island, to update and build upon the existing Coastal Defence Asset Management Database.

Contents

Contents continued

Figures

Table

Appendix

1. Introduction

1.1 BACKGROUND TO THIS STUDY

The coastline and climate of Jersey are two of its greatest natural assets; both will change as a result of global warming. Its present beaches and seaside facilities are, for holidaymakers and residents alike, a vitally important aspect of Jersey's character and economy. Much of the coastal zone is also important because of the essential infrastructure it contains, for example coastal roads, harbours, outfalls, cables and pipelines. The nearshore waters, inter-tidal areas and the immediate coastal hinterland are also important because of the natural habitats, plants and animals that these areas contain. Finally, many of these areas have considerable importance from the viewpoints of archaeology and "built heritage", i.e. historic buildings and monuments.

Understanding as early as possible how the coastline might change under the effects of a changing climate will help in both in the management and long-term planning of the coastal zone and in the assessment of how best to respond to problems being experienced along particular stretches of coastline. This study was commissioned by the Transport and Technical Services Department of the States of Jersey in December 2006, to provide an initial assessment of the coastal defence management implications of global warming.

1.2 TERMS OF REFERENCE

The aims of this project, as set out in the original study proposal and modified by subsequent discussions with the Clients, are as follows:

- To provide a general introduction explaining the likely impacts of climate change on coastal erosion and flooding risks. In this report, "risk" is interpreted as a combination of the chance of a particular event occurring, with the impact that the event would cause if it occurred. Risk therefore has two components – the chance (or *probability*) of an event and the impact (or *consequence*) associated with it;

- To review the knowledge of present-day wave and tidal conditions around Jersey and provide advice on how the possible effects of climate change might alter these;

- To discuss the overall impacts of climate change on coastal defences in Jersey, providing a number of examples of these from various parts of the island, and discuss how they may be affected in the future;

- To discuss how such decisions about intervention might be taken, both at the level of an overall "coastal defence policy" for Jersey and for particular frontages; and

- To make recommendations for further work and monitoring to improve knowledge of how Jersey's coastline will evolve, what the erosion and flood risks will be and quantify the consequences.

The remainder of this report describes the work undertaken on these topics in the order of the objectives set out above.

2. Global warming and its effects

Concerns at both national and international levels about the consequences of global warming are increasing almost on a daily basis. As this report was being produced, the United Nations published a new report by the IPCC (Intergovernmental Panel on Climate Change) that predicted a 3°C increase in global temperatures by 2100 (mean estimate), and more firmly than previously attributed such global warming to the activities of man, particularly the increased emissions of "greenhouse gases" such as Carbon Dioxide (CO_2) (IPCC, 2007).

To place this prediction into context, global temperatures have increased by ~0.6°C during the last 100 years (UKCIP, 2002; Lowe and Gregory, 2005). The evidence for an increase in this rate of temperature rise, especially since 1975, is strong. Figures 1 and 2 are two presentations of global temperature changes over the last 150 years, obtained from the UK Meteorological Office (2007). The values plotted are the difference in temperature from its average value between 1961 and 1990. Figure 1 shows a "smoothed" line, in which a running 5-year average has been presented, while Figure 2 shows each annual temperature with an associated estimate of the error in that value. The temperature in the UK has increased similarly, by almost 1°C in Central England over the last century (UKCIP, 2002).

To eventually stabilise concentrations of carbon dioxide in the atmosphere would require a decrease by 60-70% of global emissions (UKCIP, 2002). Once this had happened, even then the long life of CO_2 in our atmosphere would result in temperatures continuing to rise for several decades thereafter. In practice, such emissions are continuing to increase around the world, further accelerating the rate of temperature increase.

From the viewpoint of managing coastlines, and the risks of flooding and erosion by the sea, many low-lying coastal areas (including the majority of Jersey's major settlements) are at potential risk from various manifestations of climate change including sea level rise, changes in wind patterns and thus wave climates, and changes in storm frequency/severity. Other climate change effects, for example increased winter rainfall, may also have significant effects in some parts of the world, for example affecting river flows and their capacity to transport sediment, but are unlikely to be significant in Jersey from a coastal defence viewpoint. These various consequences of climate change are returned to, and discussed in more detail, in Chapter 3 of this report.

2.1 PREDICTIONS OF CLIMATE CHANGE EFFECTS ON JERSEY

Quantitative predictions of climate change, and its effects, have to be made using computer simulations of the global atmosphere and weather patterns, and a variety of these models have been produced and used by numerous, often national, meteorological institutes. The differences in the results from these different simulations are often substantial, especially in terms of predicting future storm frequency and intensity.

As an example, much of the present thinking and guidance on climate change effects in the UK is based on a model developed and run at the Hadley Centre, part of the UK Meteorological Office. This was used as the basis for an important report by the UK Climate Impacts Change Programme (UKCIP) published in 2002. This model was run for four possible scenarios for future global greenhouse gas emissions – from Low Emissions through to High Emissions, and results were presented for each of these.

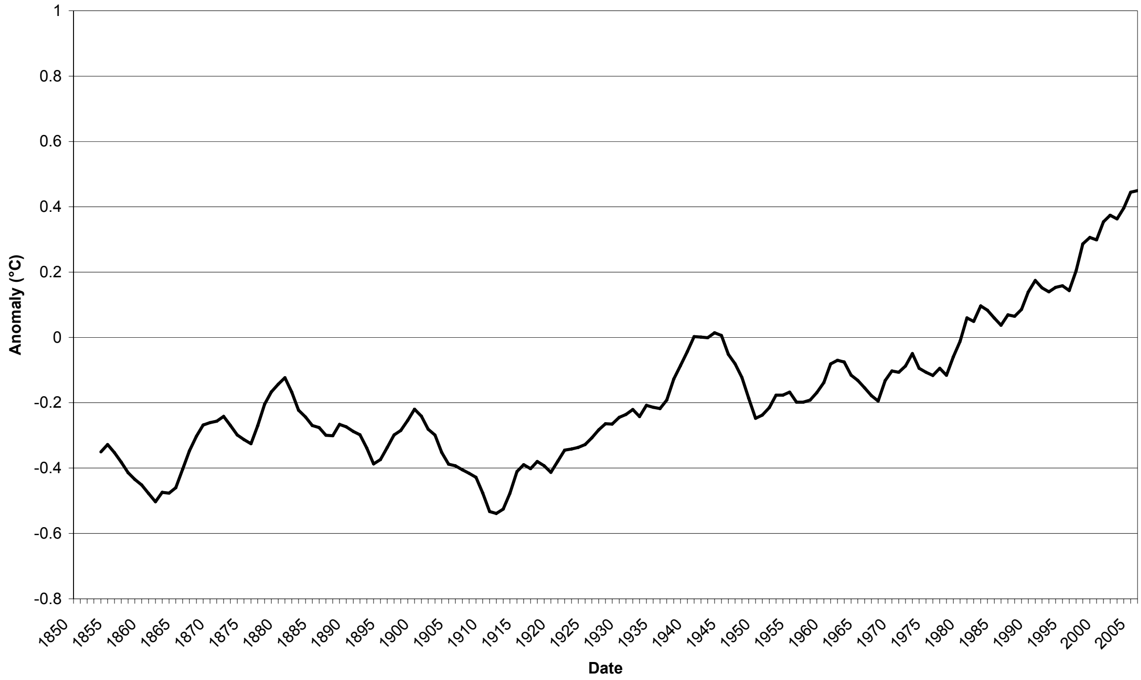

Figure 1 Global temperature increase (zero = average from 1961- 1990): five-year running means

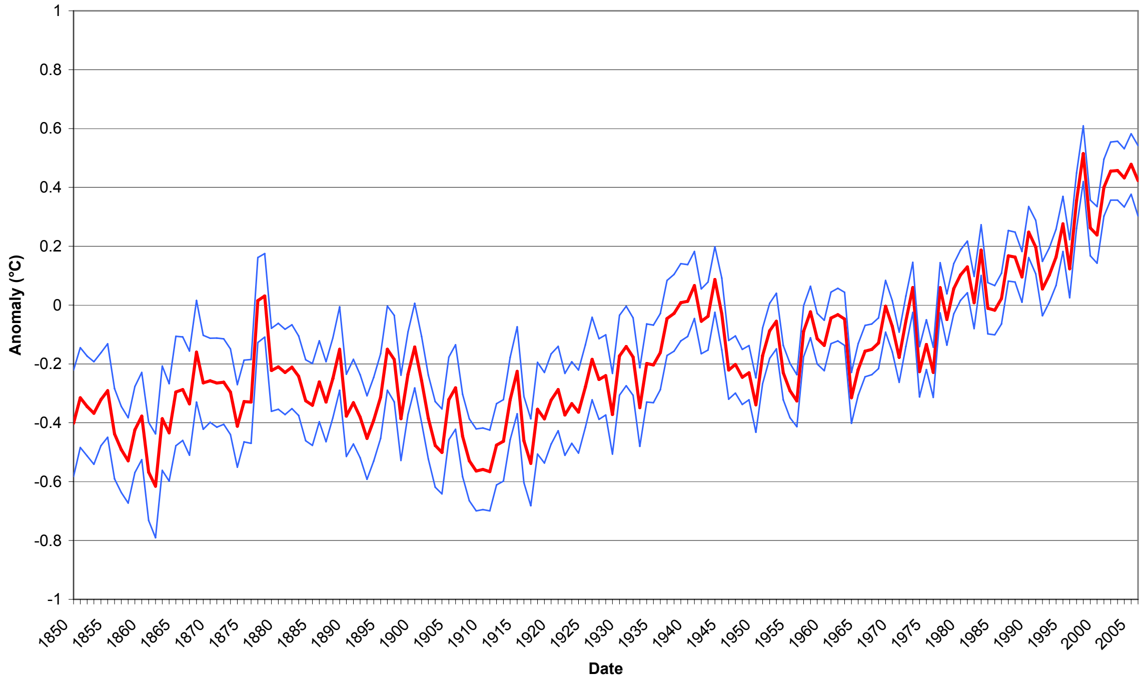

Figure 2 Global temperature increase (zero = average in 1961 – 1990): best estimate for each year (red line) and 95% confidence limits (blue lines)

The highlights of this modelling were that global mean sea levels were predicted to increase by 25-35 cm by the 2080s, resulting from thermal ocean expansion, melting of smaller glaciers and changes in the mass balance of the Greenland and Antarctica ice sheets. Annual temperatures UK-wide were predicted to increase by 2-3.5°C, with water temperatures also expected to rise. Generally, winters will become wetter and milder, and summers drier and hotter, with corresponding decreases in snowfall, and increases in severe events (UKCIP, 2002).

The Gulf Stream, and other features of the North Atlantic Ocean circulation system, was predicted to decrease in strength by approximately 20% during the 21st Century, although not completely "switch off" as has previously been feared. Changes in wind speed were not predicted to be significant.

The resolution of this model, however, was too coarse to represent the Channel Islands or to provide accurate predictions of the generation of storm surges. Since 2002, therefore a Hadley Centre regional climate model has been modified with a resolution of 25km enabling resolution of Britain's small islands, including the Channel Islands (British-Irish Council (BIC), 2003). This was the first time that specific predictions for the BIC islands have been made. However, even with this increase in resolution, the Channel Islands have not themselves been gridded (variations in climate over such a small scale is unlikely) and thus a single result is returned for each island. Improvements in the resolution of this model are currently underway, although this is unlikely to significantly affect the predictions of the main factors affecting coastal evolution, i.e. increased sea levels and change in offshore wave conditions.

As with models run at a global scale, the same four emissions scenarios used for the UKCIP (2002) study have been considered. The Medium-High scenario has been used as a basis for assessing the impacts of climate change on Jersey. The BIC have considered climate change as a difference between a "recent climate" (i.e. 1961-1990) and future (2080s). Basic impacts for Jersey are a warming in summer of up to 3.8°C, with frequency of hot summer days increasing by 4 or 5. There is a corresponding 70-85% reduction in frost occurrence, and an average winter increase of 2.4°C. Days experiencing heavy precipitation are predicted to decrease in summer by up to 50% and increase by 30-50% in winter, with Jersey experiencing on average 45% less rainfall in summer.

Therefore mean annual rates of temperature and precipitation change from the current to the future scenarios equate to +3°C and -4% respectively. Much of the winter precipitation initially falls as snow, but melts as it falls through the warming air. By the 2080s therefore, the warmer temperatures may result in a reduction in snowfall, by 70-90%, and a corresponding increase in rain is predicted. This model also indicated that the warmer winters might cause an increase in extreme events, particularly storm frequency and in extreme wave heights in coastal areas.

At present, the Hadley Centre model used to inform the UKCIP report of 2002 is being refined, to consider a wider range of possible emission scenarios and to provide results at a finer spatial resolution; this modelling is due to be reported in 2008.

Such improvements in computer simulations of global and regional atmospheric conditions will continue, and these will provide further predictions of sea level rise and of changes in winds, waves and tidal surges for Jersey's coastline. While advances in knowledge and the sophistication of such computer simulations will both increase in time, so that the accuracy of the predictions made can be expected to increase, there will always be uncertainty regarding the many assumptions made on which those predictions are based, and hence a range of possible outcomes that need to be considered. Chapter 6 of this report discusses how this uncertainty might be addressed within the context of decision-making about coastal defence. This follows a more detailed assessment of the expected effects of climate change on sea conditions around Jersey and discussion of the vulnerability of different parts of its coastline.

3. Climate change effects on tides and waves

3.1 MEAN SEA LEVEL CHANGE

From a coastal management viewpoint, the most confidently predicted relevant consequence of global warming is an increase in sea levels. This will be caused by the thermal expansion of the upper layers of the world's oceans and by an increase in the total volume of water in the oceans due to the melting of glaciers and inland ice sheets. (Note that the melting of floating ice sheets will not increase sea levels directly). Changes in sea temperatures are not likely to be uniform, however. For example, the melting of ice in the Artic has been cited as a reason for an observed decrease in sea temperatures in Scotland and a reduction in the rate of sea level rise in recent years. However, these regional variations will diminish with time.

The predicted increase in sea levels varies considerably depending on the assumptions made about the emission of greenhouse gases. Rather than making a firm prediction, therefore, organisations like the Hadley Centre make a range of predictions, based on assumptions about these emissions. The UKCIP report published in 2002 presented results for four such emissions scenarios, but provided no opinion on which of these was the most probable. The predicted range in global increases in sea level by the 2080s was between 90mm and 690mm higher than the mean value in the period 1961 to 1990. A revised estimate of this increase was published by the IPCC during the course of this study that suggested an increase of between 180mm and 590mm relative to average levels between 1980 and 1999 (or about 140mm to 550mm relative to levels in 1961-1990 if converted to make the comparisons easier to make). This very recent research therefore produces a somewhat narrower range of estimates of sea level rise than that published by UKCIP in 2002, with the highest predictions of increased sea level being rather lower.

From a coastal management viewpoint, any predictions of increases in sea level need to be adjusted by taking into account the extra effects of changing land levels. In some northern parts of Europe, land levels are still rising following the melting of glaciers at the end of the last Ice Age. This effect can reduce the predicted sea level rise relative to the land, or even outstrip it, leading to a continuing lowering of sea levels at the coast relative to the land.

More commonly, however, land levels are stable or falling, the latter therefore adding to the relative rate of sea level rise at the coast. This is the situation in Jersey according to a report by the British-Irish Council (BIC, 2003), which indicates a future very small lowering of land levels amounting to only 50mm over 100 years. This assumed low rate of future land lowering indicates the present stability of Jersey's landmass, which is further supported by very low rates of measured sea level rise on the French coast. At Cherbourg (Paskoff, 2004), sea levels have only increased relative to the land by between 0.4 to 1.2mm per annum (1860-1981) depending on the period used for analysis. At Brest they have increased by about 1.2mm per annum (1890 to 1981). Given a (deduced) increase in regional sea levels of between 1.2 to 1.5mm per annum over these periods, this indicates, if anything, a possible small increase in land levels at Cherbourg and a virtually stable situation at Brest. In a review of the possible effects of climate change, including sea level change, on the coast of France (Paskoff, 2004), the only mention of the Brittany coast is in connection with the observed increase in the extent and levels of the saltmarshes in Baie du Mont St. Michel, which would be unexpected in a situation where sea levels were increasing rapidly relative to the land.

In summary, therefore, the net increase in sea levels around Jersey's coastline by the 2080s can be expected to be higher than in the period 1961-1990 by about 140mm to 740mm (using UKCIP 2002) or by 190mm to 600mm (using IPCC, 2007). Some of this increase has already taken place, however, and according to IPCC (2007) global sea levels will have risen by about 1.8mm per annum between 1961 and 1993, and by about 3.1mm per annum between 1993 and 2003. On this basis, it can be expected that relative sea level rise in Jersey has been, very roughly, about 85mm – 90mm since the mid-point of the period 1961-1990.

Summary

The likely further increase in Mean Sea Level relative to the land in Jersey between now and the 2080s can therefore be predicted to be in the range 100mm to 500mm.

3.2 CHANGES IN TIDAL LEVELS

In the description of sea level rise presented in section 3.1, the estimates of future relative sea level increases should all be interpreted as meaning increases in Mean Sea Level. For coastal management, however, this particular tidal level is of less importance than the changes in the levels at low tide and at high tide, and particularly during exceptionally high tides.

It is not necessarily the case that low tide and high tide levels will change in the future by the same amount as Mean Sea Level, because two further possible changes have to be taken into account. Firstly, the rise and fall of the "astronomic" tide, i.e. that which would be observed in the absence of any meteorological effects such as changes in atmospheric pressure or wind stresses, may change as a result of the increased overall water depths. The speed of propagation of the tide, and hence the time it takes to travel, for example, the length of the English Channel, will increase in deeper water, and the effects of the funnelling of the tide into estuaries and bays will change. Where, for example, the period of (one component of) the tide is close to that of the time the tide takes to travel into and out from an estuary or inlet, then there will be a "resonance" of the tide in that area leading to increased tidal amplitudes and ranges. (The tidal range is the vertical difference in level between high and low water). By increasing the water depths and hence the tidal propagation speed, then such an estuary or inlet may towards or away from this resonance with a corresponding increase or decrease in the tidal range. This possibility is clearly of relevance to Jersey which has a very large tidal range at present, as a result of both funnelling and resonance effects.

This possible mechanism for a change in tidal range, however, is greatly complicated by the numerous tidal components of different periods and amplitudes and by the effect of distortions to the tidal propagation caused by shallow water effects. Attempts have been made, using numerical models, to predict how an increased sea level would affect tidal ranges around the UK coastline, for example by Flather and Williams (2000) but these results have not been widely used so far.
The second reason why high (or low) tidal levels might change in the future by a different amount than Mean Sea Level is that meteorological effects on the tides may alter. Increased wind speeds and / or more frequent and rapidly moving depressions would create larger tidal "residuals", i.e. the differences between forecast and measured tidal levels. Of particular interest is the possibility of larger storm surges, which can produce very significant increases in exceptionally high tide levels and hence in flooding risks. It is worth noting in passing that large "negative" surges can also occur,

producing exceptionally low tidal levels at low tide; this can cause a problem for navigation but is generally not a great concern for coastal defences or management.

The concern about larger and more frequent storm surges has led to considerable publicity about their occurrence in the future. Computer simulations of future atmospheric conditions in north-west Europe, undertaken by different organisations, have produced very different predictions of how winds and storms might change, even for identical assumptions about future emissions. Overall, there is little agreement regarding the future frequency or magnitude of storm surges, some simulations indicating a decrease near Jersey, others an increase.

In view of the uncertainties involved in the predictions of future changes in tidal ranges and in meteorological effects on tidal propagation, it was concluded by Flather and Williams (2000) that future high (or low) tidal levels are likely to increase more or less in line with Mean Sea Level, but with a possible difference of ±20%. In Jersey, therefore, the likely increase in high tide levels by the 2080s, with or without a significant surge, can be expected to lie between 80mm and 600mm, depending on the future emissions of greenhouse gases.

Summary

For the purposes of simplifying the rather complicated discussions and calculations presented above, and providing a single figure for sea level rise that will probably err on the side of caution, we suggest that further consideration of coastal defences and flooding and erosion risks assumes that:

There is likely to be an increase in High Tide Levels around Jersey of 500mm by the 2080s.

This should be regarded as applying equally to low and high tide levels, both those predicted as arising from the "astronomical" tides or as modified by meteorological effects, i.e. tidal levels affected by winds or atmospheric pressures and including storm surges.

This increase would have a significant effect on the performance of the existing coastal defences in Jersey, especially where overtopping already occurs, if these are not improved to cope with the higher tide levels. One way of emphasising such consequences is to compare the frequency of a given high tide level being experienced now and in about 80 years time.

On this basis, a very high tide level in St Brelade's Bay or St Ouen's Bay that presently has only a 20% chance of being reached (or exceeded) in any year will be likely to occur 5 times a year by the 2080s (based on the results presented in HR Wallingford 1995a and 1995b respectively). Similarly, a tidal level that presently has only a 2% chance of being reached (or exceeded) in any year in these bays would be expected to be reached or exceeded perhaps twice a year in that decade.

3.3 CHANGES IN WAVE CONDITIONS

The offshore wave climate around Jersey varies considerably as a result of the different "fetch" lengths measured out from its shores, i.e. the uninterrupted distances over which winds can generate waves travelling towards that coastline. The largest waves occur off the west coast, where waves generated by the dominant westerly and south-westerly winds are augmented by swell waves arriving from the central or western parts of the

North Atlantic, and even from the South Atlantic. Wave conditions generally become less severe the further east along the southern and northern coasts of Jersey one travels. The eastern coast has the least severe wave climate because of the short fetches across to the French coast and the relatively scarcity of winds from the east. The following table, originally presented in HR Wallingford report EX2490 (1991), summarises the extreme wave heights that can be expected to occur just offshore at three contrasting locations, namely St Ouen's Bay, St Aubin's Bay and Anne Port. The direction from which the largest waves are likely to arrive is also shown for the first two of these sites.

Return period	**Extreme offshore wave heights**		
	St Ouen's Bay (Centre) 270°	St Aubin's Bay (Centre/East) 230°	Anne Port
1 year	4.23	3.1	1.13
5 years	4.80	3.5	1.39
10 years	5.16	3.8	1.54
20 years	5.40	4.0	1.65
50 years	5.72	4.2	1.79

In addition to the spatial variations in wave climate, variations in wave conditions also occur over a variety of time scales. Changes occur in response to changing wind strengths and directions over periods from a few hours to several days, in response to the movement of weather systems.

There is also a marked seasonal variation in wave conditions, with heights typically peaking in late December or early January, although large storms might occur at almost any time from October to March.

These variations, while unpredictable in detail more than perhaps two days in advance, are not unexpected. However, there are also longer-term variations, stretching over periods of decades, that have a significant effect on wave heights but whose causes have only recently been clarified. Measurements made at the Seven Stones Light Vessel, between Scilly and Lands End, over a prolonged period (1962 – 1986) were analysed by Bacon & Carter (1991), who concluded, using this and other data, that wave heights had increased by 2.5% per annum "over the whole of the North Atlantic in recent years, possibly since 1950". Since this increase would inevitably have lead to a corresponding increase in wave activity along coastlines that are affected by swell waves from the North Atlantic, including most of Jersey's, then this conclusion gave rise to considerable concern to coastal managers. Recent and more detailed analysis of wave data has confirmed the increase in wave heights over the period from 1950 to 2000, and shown that there have been significantly more severe storms over the UK in the same period.

However, it has also been realised that both of these trends formed a part of a pattern of variability in the weather patterns that change over a number of decades. These changes are caused by long-term variations in the atmospheric pressure field, now known as the North Atlantic Oscillation (NAO) and defined by the difference in pressure between the "Azores High" and the "Iceland Low". (Bacon and Carter, 1993) There has been considerable analysis of the relationship between gale occurrence (and hence severe wave conditions) and the NAO that shows a clear correlation, especially along the north-western coastline of Scotland. While the long period of increase in the NAO in the last half of the 20th Century may have been unprecedented, it is not necessarily linked to the increase in global temperature over the same period (Osborn, 2004).

Indeed there appears to be some evidence of a flattening out of this trend in recent years.

For the purposes of this report, however, the main issue is whether continued global warming might lead to an increase in the NAO, and hence an inevitable increase in both gales and swell waves, both of which would increase wave heights at least along the coastlines of the western part of Jersey. This is presently a subject of considerable debate, with different computer simulations producing conflicting predictions. For example, the UKCIP results published in 2002 suggested slightly weaker winds and a reduction in storminess, while other models have indicated the opposite.

In view of this uncertainty, it is unwise to make any firm predictions of how wave climate will change in the future. Nevertheless, it is prudent to take account of those forecasts that do suggest greater storminess and checking that any coastal defence scheme could cope with an increase in wave heights or periods. This issue was examined in a research project (Environment Agency, 2003), which concluded that the designs of such schemes should be subjected to sensitivity testing, assuming an increase in general wave heights of 5% and in extreme wave heights of 10% by the 2080s. Similar testing assuming the same increases in wave period was also recommended. In addition to these possible changes, observations and wave measurements have shown that mean wave directions have varied substantially over the last 20 -30 years, reflecting the changes in weather conditions associated with the variations in the NAO. Since no consensus has been reached on the linkage between global warming and NAO, it is not possible to predict how wave directions may alter in the future. Such change, however, would be important in altering beaches, for example reversing the present-day longshore transport of beach sediments and causing unexpected changes in beach widths and levels.

Where beach levels dwindle in front of coastal defences in response to changes in wave direction, then there are risks of greater wave impacts and overtopping as well as of undermining of the structures themselves. Because of wave refraction, even substantial changes in wave direction offshore will result in much smaller changes in shallow water. There has been no guidance published, as far as we can determine, on making allowances for possible future changes in wave directions but we recommend testing proposed coastal defence or management schemes assuming a ±2º shift in wave directions in shallow water as a sensible precaution. The effects of such changes on beach widths and levels would need to be assessed by predictive modelling to then ascertain the effects on beach levels in front of coastal defences.

Summary

There is no consensus regarding the likely changes in wave conditions, i.e. in their heights, periods or directions, over the next few decades. However, some modelling of future climate change does indicate the possibility of more frequent and severe storms. In cognisance of this, it is suggested that a precautionary approach is taken when designing new or improved coastal defence schemes. This approach involves sensitivity testing of proposed schemes assuming alterations in nearshore wave conditions, as indicated below, to ensure that the preferred option remains the appropriate choice despite such possible changes:

General wave heights: 5% increase Extreme wave heights: 10% increase
General wave periods: 5% increase Extreme wave periods: 10% increase
Inshore wave direction:Change of ±2º

3.4 OTHER EFFECTS OF CLIMATE CHANGE

3.4.1 Changes in tidal currents

As long as the range of the tides is not altered by sea level rise (see section 3.2), then there are unlikely to be significant changes in tidal currents in general. The potential exceptions to this are in very shallow water areas, particularly inter-tidal areas, where the increased water depths due to the increase in mean sea level will tend to decrease the frictional resistance of the seabed and hence increase the tidal currents speeds at any given location.

Thus if tidal flows are strong, for example around a breakwater or against the toe of coastal defences or past the tips of groynes, then the increase in depth may strengthen these currents, perhaps adding to their potential for scouring the seabed. There may also be subtle changes in the flows in and out of tidal inlets, for example reflecting slightly different tidal propagation speeds, but these are not thought likely to be a major concern for coastal defence in Jersey.

3.4.2 Changes in precipitation

Although there is a predicted mean annual change of precipitation rates of –4%, the frequency and intensity of severe rainfall events during the winter months is expected to increase. With severe rainfall, there are a number of possible associated effects on the coastline. Of these, the most important in most parts of the world is the anticipated increase in river flows, and the associated impacts on the rate of sediment transport to the coast, especially during severe flood events. In the UK, guidance on the potential effects on peak river discharges is to assume an increase of 20% by the 2080s. Where rivers presently supply large volumes of sediment to beaches, this increase may be beneficial. However, in Jersey as in much of England, rivers do not carry significant amounts of sand to the coast, and increases in their discharges will not change this situation.

The remaining effects of changes in precipitation, described below, are likely to be of lesser importance in Jersey, but are included for completeness:

- **De-stabilisation of coastal cliffs**
  Cliff falls are usually caused by a combination of marine erosion, e.g. undercutting their front face, and geotechnical problems, e.g. rotational slips. The latter effect is always increased by greater rainfall, and hence run-off, higher water table levels etc. In the long-term, this will tend to result in beaches receiving fresh supplies of sediment. This benefit, however, may not be so apparent to those living near the cliff edge. In Jersey, there are only very few locations where there are coastal cliffs in "soft rock" where groundwater flows are a significant factor in land-sliding.

- **Impacts on sand transport**
  In locations where a beach is affected by surface water run-off from the land, there are often localised erosion problems, e.g. around outfalls. The frictional resistance of sand is reduced by out-flowing water, making it easier to mobilise by waves and currents, and increased rainfall will tend to exacerbate such problems.

- **Impacts on dune building**
  Sand on the foreshore will be much less easily transported by winds if it is wet than if it is dry, potentially reducing the rate at which it is blown inland onto dunes. However, many dune-binding grasses suffer in drought conditions, and are

generally healthier in wetter climates. This would help to increase their efficiency in trapping and binding sand, and encourage them to colonise new areas more quickly. It is not clear, therefore, whether decreased rainfall, especially in the summer, will assist dune growth or be detrimental to it.

3.4.3 Changes in wind speeds and directions

Changes in wind conditions, as well as affecting the growth of both waves and storm surges discussed earlier, may also affect coastlines and their evolution directly.

Strong winds are capable of transporting large quantities of sand, both along the coastline and perpendicular to it. The former effect can add to, or counteract wave induced longshore drift, but tends to take place at higher levels on the beach profile. Onshore transport by wind action typically exceeds offshore movement. This is partly because winds blowing over the sea towards the shore are stronger (less affected by friction) than those blowing offshore. Also, onshore winds, created as a result of differential heating of land and sea, tend to occur during the warmest part of the day, and therefore when the sand is driest and most easily moved.

A change in wind strengths or directions may alter existing patterns of sand transport. It is likely this will be most noticeable in changes in dunes, rather than on beaches themselves, which are dominated by wave action.

3.4.4 Changes in water temperature

The viscosity of seawater decreases as the water temperature increases. The fall velocity, i.e. the speed that particles of sediment fall through the water column, after being placed into suspension, will then increase. This is an equivalent effect to the particles having a larger diameter, and will thus tend to increase the stability of beaches.

Summary

These other changes likely to occur as a result of climate change may affect Jersey's coasts, but their effects cannot be predicted with any certainty. These may slightly add to the problems that climate change will cause but do not require any specific intervention to offset their effects.

4. Overview of effects of climate change on coastlines

As previously discussed, the increase in sea level in Jersey relative to the land is predicted to be approximately 500mm by the 2080's. In addition there may be increases in wave heights and periods and changes in wave directions. These changes will not only affect the risks of coastal flooding and erosion directly, but also indirectly by altering the morphology of the coastline e.g. of the beaches and nearshore seabed. This chapter discusses the impacts of climate change on various types of coastline in Jersey, covering:

- Natural beaches (both pocket bays and longer embayments);
- Nearshore seabed features, e.g. shore-platforms and sandbanks;
- Coastal cliffs; and
- Seawalls, revetments and flood embankments.

The present study concentrates on just the last of these types of coastline, but this chapter also briefly considers natural shorelines for completeness.

4.1 EFFECTS ON BEACHES

Changes in sea level and/ or wave conditions will alter both the profiles and plan shapes of beaches.

A number of methods for predicting beach profile response to rising sea levels have been proposed (e.g. Bruun 1962, Leatherman 1990), and widely applied. Such methods, broadly, rely on the concept of the upper part of a beach profile remaining in the same position relative to mean sea level. As a consequence, it will tend to retreat as sea level rises, by a horizontal distance proportional to the increase in level divided by the "average" beach slope. Hence a steep shingle beach will tend to retreat less far than a flat sandy coastline. The following table provides an approximate indication of the landward retreat of natural beaches in response to an increase in sea level of 500mm:

Shingle	5m – 10m
Coarse sand	10m – 20m
Fine sand	20m – 40m
Muddy	250m – 500m

Along most of the coastline of Jersey, beaches are prevented from retreating to this extent by the presence of seawalls at their crest. In these situations, however, it is likely that the effect of sea level rise, or an increase in wave heights, would be to lower beach levels in front of the seawall. Such beach lowering will affect the performance of coastal defences, and this issue is referred to again in section 4.3 below. Note that the lowering of beaches as a result of increasing sea levels has already been occurring for many decades, requiring the extensive underpinning of seawalls in Jersey over the last five years or so by the Transport and Technical Services Department (see Chapter 5).

An overall change in wave heights is also likely to affect beach profiles. In general, an increase in the occurrence of very large waves is likely to have a noticeable effect on sedimentary coastlines, for example by altering beach profiles. A large barrier beaches will be moved landwards in (only) such events, with material being washed over its crest onto its landward side. The largest waves are also likely to cause dune erosion that may take many months, even years, to repair naturally. Recovery is assisted by the "binding and trapping" effects of vegetation, which itself may be affected by climate change (see section 3.4). An increased frequency of such erosive events is therefore likely to result in dune erosion and retreat that may take decades to restore.

The effects of a general increase in wave heights, i.e. not just in those occurring in very severe storms, could be expected to result in flatter beach gradients, by drawing the analogy with larger waves over the winter months tending to result in a flatter slope than in the calmer summer weather. However, it is also possible that an increase in the general level of wave energy may increase the occurrence of more modest waves that tend to transport sand onshore, and his could lead to a general steepening of the beach profile (and a reduction in dune erosion where these occur).

Since the present guidance on future wave conditions, following climate change, is to assume for the purposes of coastal defence planning, that the largest waves will increase to a greater extent than more commonly occurring conditions (see section 3.3), and then it is logical to also allow for an increase in the rate of beach lowering in front of defences. If the present rate of beach lowering in front of a coastal defence is a consequence of sea level rise, then it can reasonably be assumed that the rate of beach lowering will increase proportionately with the future increase in the rate of sea level rise. Thus if beach lowering presently averages about 2mm per annum in a situation where sea level is increasing by 1mm/year, then an increased rate of sea level rise to, say, 6mm/year in line with the increase by the 2080's in tidal levels by 500mm (see section 3.2) , would theoretically increase beach lowering to about 12mm/annum. The present and future rates of beach lowering in Jersey, particularly in front of seawalls, will need to be monitored and the results used as an important input to the consideration of the type and timing of improvements to defences as part of a long-term process of adapting to the effects of climate change (see Chapter 6)

The second potential effect of climate change on beaches, and one that is much less well publicised, is that of a change in their plan-shape caused by a change in wave directions. Along most coastlines around the world, the major cause of change in beach morphology is the longshore transport of beach material, or more precisely the changes in that transport from point to point along the coast. Longshore transport depends on wave height, but more crucially on wave direction. The former influence, in the long-term, can increase or decrease the rate at which a coastline is presently eroding or accreting. On many pocket beaches (such as Greve de Lecq) that have adjusted to reach a position of no nett drift, a change in the wave heights will have no effect on the longshore transport, although beach profiles may alter as mentioned above.

However, a change in the "average" wave direction will first alter the longshore drift of beach sediments and then the orientation of the beach contours. Where beaches are long and straight, for example in St Ouen's and St Aubin's Bays, even a small change in the beach orientation could result in substantial movement of sand from one end of the bay to the other, resulting in higher wider beaches at one end of the bay, but lower narrower beaches at the other. The latter consequence may be a significant concern in front of coastal defences, as in the case of beach levels being lowered by large waves. This issue is returned to in section 4.4.

Summary
Increasing sea levels will tend to cause beaches to retreat landwards or, where they are prevented from doing so by defences, will cause beach levels to become lower.

Changes in wave conditions, particularly in mean wave direction, will redistribute beach sediments along the coastline in some places raising beach levels but in other places lowering them. Lower beach levels together with higher tidal levels will lead to greater potential for overtopping of seawalls and associated flooding. Monitoring and analysis of changing beach levels will be required as an important input into the long-term adaptive improvement of coastal defences in Jersey.

4.2 EFFECTS ON THE SEABED AND INTER-TIDAL ZONE

An increase in sea level will have an effect on the morphology of the seabed, particularly in shallower water where the proportional increase is greatest. Along much of the western and south-eastern coastline of Jersey, there is a wide, rocky and shallowly-sloping shore-platform. One obvious consequence of sea level rise is that the low water contour will move landwards across this platform; in most cases, since the high water mark is prevented from moving landwards by the presence of a coastal defence, typically a seawall, this will inevitably result in a narrowing of the inter-tidal zone, a phenomenon now widely referred to as “coastal squeeze”. This in turn reduces the amount of inter-tidal habitat for plants and animals, and thus will have an adverse effect on the natural environment.

An increased water depth over these shore platforms, and indeed over the nearshore seabed in general, will also reduce the dissipation of wave energy by bottom friction, i.e. by creation of turbulence adjacent to the seabed, and by breaking, particularly over rugged reefs and rock outcrops. This in turn will allow greater amounts of wave energy closer inshore, with potential adverse effects on (upper) beach levels and on coastal defences. Along much of the coastline of England, there would also be an increase in the erosion, and vertical lowering, of the rocky shore-platform itself. This process, known as “down-cutting”, can proceed rapidly if the platform is of “soft” rock, e.g. clay or chalk; it seems likely that the much harder rocks of Jersey, however, will be much less strongly affected by such lowering.

Changes in the seabed further offshore are less likely to be noticeable. As the water depth increases, so the sediments on the seabed become less regularly or strongly transported by waves or tidal currents. As a result, if there is presently an onshore movement of such sediments, for example by long-period swell waves, then this will diminish as a result of climate change. As a very broad guide, coastlines where sea level is falling experience an onshore movement of sand, while those where it is rising do not.

There may also be changes in sandbanks’ heights and positions in response to changes in tidal currents and water depths. This is an area where little research has been carried out, or guidance on the effects of climate change provided. Given an ample supply of sediment, there is evidence to suggest that sandbanks in shallow water will adjust their morphology to maintain their crest heights relative to, for example, mean tidal level, as sea levels increase. Where sediment supply is limited, however, then sandbanks may dwindle and become “relict” features, i.e. responding first less and then not at all to the changes in tides and waves. Specific consideration would need to be given to any sandbanks of particular interest around Jersey to determine whether, first, there was likely to be any appreciable change in the patterns and rates of tidal currents (as mentioned in section 3.4). If this was not the case, then significant changes in such sandbanks are unlikely, although periodic surveying of them would be prudent.

Summary
Climate change has the potential to alter the nearshore seabed around Jersey, for example affecting sandbanks and submerging rocky shore-platforms and reefs to a greater depth as sea levels rise. Where sandbanks in shallow water, in particular, provide natural offshore breakwaters for the coastline, periodic monitoring of their levels is suggested as part of the long-term monitoring and management of Jersey's coastal defences.

4.3 EFFECTS ON COASTAL CLIFFS

The collapse and recession of coastal cliffs is a complicated process, and varies considerably depending on the geology of the cliffs. Where the cliffs are of "soft" and permeable rock, for example glacial till, then the main cause of landsliding is excess groundwater pressure. One predicted consequence of climate change in Jersey is of greater winter rainfall, and summer droughts, and should this occur, the risks and rates of landslides will be greater. In addition, wave action at the toe of these types of cliff reduces the stability of their seaward face, thus "triggering" rather than directly causing landslides. In parts of East Anglia, for example, where longshore drift accelerates the erosion of beaches and shore –platforms in front of such cliffs, the rate of cliff top recession can reach 10-15m per annum and persist at this rate for decades. As discussed for beach lowering, the available guidance on rates of cliff top recession along a natural coastline as a consequence of climate change indicates that such rates are proportional to that of sea level rise. There are locations along undefended stretches of the coastline of Jersey, for example at Portelet Bay and in Bonne Nuit Bay, where the coastal cliffs are of "soft" rock and these are areas where landsliding is likely to become a greater problem in future, as sea levels rise.

On harder rock cliffs, wave action gradually erodes and undercuts the cliff face, which eventually will suffer a "block" collapse. In this case, however, average erosion rates may be of the order of 0.01m – 0.001m per annum, and collapses at any particular location may only occur every century or so, or even less frequently. In general and particularly along significant stretches of the north coast, the coastal cliffs of Jersey are of very hard rock, and these will be little affected by the predicted changes in marine conditions discussed in Chapter 2.

It seems therefore that at present and for most of the coastline of Jersey, the effects of climate change on coastal cliff retreat will be localised and modest. However, should coastal defences fail revealing softer rock (or even unconsolidated "head" or loess deposits as found in some parts of the Island), then this assessment could rapidly change.

As with the discussion of changes in beaches and the nearshore seabed presented above, the recommended course of action is to monitor coastal cliffs, particularly those of soft rock, to gain information on present and future recession rates. While the focus of this report is on Jersey's coastal defences, it is nevertheless suggested that "soft" cliffs along undefended stretches of coastline, especially those adjacent to defences, are also monitored with a view to anticipating problems that may arise in the future.

Summary
The anticipated effects of climate change over the next few decades on Jersey's coastal cliffs are only likely to be noticeable where they are of "soft rock" and are not protected by coastal defences such as seawalls. Monitoring of such cliffs is

recommended, both along defended and undefended stretches of the coast, with particular attention being paid to cliffs at the end of lengths of coastal defence.

4.4 EFFECTS ON COASTAL DEFENCES

In many cases the natural evolution of Jersey's coastline has long been forestalled by the construction of coastal defences, typically concrete seawalls that are regularly reached by the tide and affected by wave action. Since these defences protect the assets of greatest value to Jersey against the joint effects of coastal flooding and erosion, it is the effects of climate change on them that are of the principal focus of the present study. In particular, it is the performance of defences under exceptionally severe conditions that is of paramount importance.

However, in considering how these defences will perform in the future, given the predicted changes in tides and waves as a result of global warming, a precautionary approach is recommended. Bearing in mind the discussion in sections 3.2 and 3.3 of this report, this will mean assuming that, by the 2080s, extreme tidal levels will be 500mm higher, and extreme wave heights (offshore) will be 10% larger. In addition, at least for structures situated in the upper part of the inter-tidal zone, some allowance probably needs to be made for future beach levels being lower than at present. Figure 3 shows these potential changes in a sketch form.

Both the increase in sea levels and the beach lowering will cause an increase in the water depth (h) at the face of a coastal defence, while the former will also cause a decrease in the "freeboard" (R_c), i.e. the vertical distance between the (extreme) tidal level and the crest of the defence. Wave heights approaching the defence will perhaps be less affected by dissipation in shallow water areas, but ultimately will be limited in height by the depth of water in front of the defence. The likelihood and rate of overtopping of the defence depends crucially on the freeboard, R_c, which will decrease over time, and the wave height (and period) just in front of the structure, which are both expected to increase over time. It is thus very likely that the frequency and rates of overtopping of seawalls in Jersey will increase as a consequence of climate change.

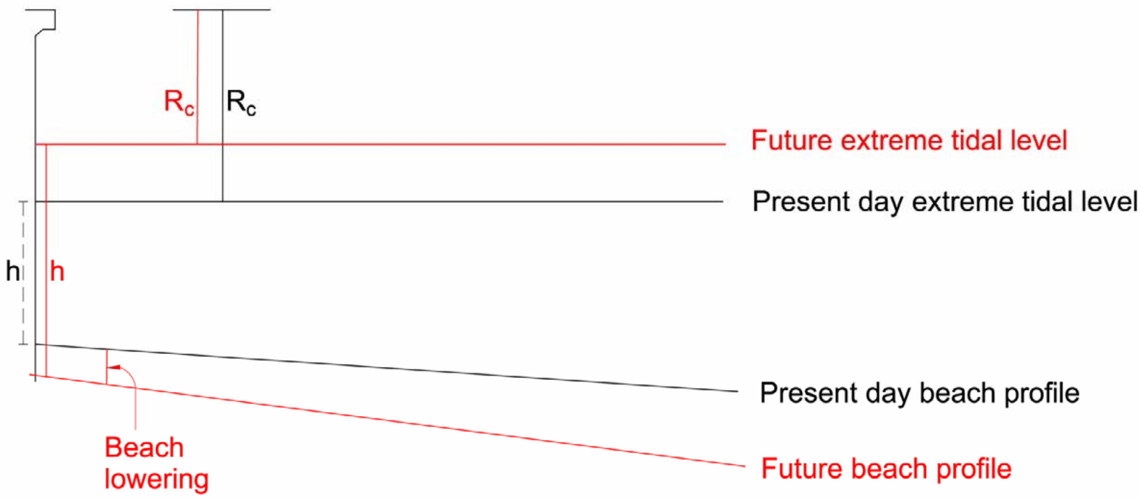

Figure 3 Sketch of effects of sea level rise on seawall freeboard (R_c) and water depth (h)

In general terms, the coastal defences in Jersey have been constructed to a high standard, with some masonry walls over a hundred years old still adequately fulfilling their function of protecting against flooding and erosion. In general, the greatest risk to coastal communities defended by such seawalls is that of undermining of the front face of the defences as a result of beach lowering, which is likely to accelerate in response to climate change. If this was to occur, and it has been the most common cause of failure of seawalls in the UK in the past, then it is likely that it would occur suddenly during a severe storm. Past experience, for example at Towyn in North Wales in 1990, shows that such collapses can be very dangerous for those living or working behind the seawall. Problems experienced in Jersey during that same winter led to a review of some of the seawalls, and over the following years various studies of the defences were commissioned that led to the drawing up and adoption of the “Island Sea Defence Strategy” in 2002. A review of recent works undertaken to improve the structure of these defences is presented in the following chapter of this report.

In future, there will be an extra need, however, namely to improve the performance of the defences, rather than just their structure, so that the same (or better) standard of protection against flooding will be enjoyed despite the changing climate. Because the increase in sea levels in the immediate future (10-20 years) are likely to be slow, there is time to assess the existing standards of protection offered by Jersey’s seawalls, to evaluate how that standard would decline if nothing was done, and to then introduce a programme of adaptive improvement, tackling first those defences with the greatest overtopping risks (i.e. the combination of this probability with the consequences of the overtopping).

Since the studies carried out in 1991 to 2002 investigating the likely performance of Jersey’s coastal defences in extreme events, there has been considerable development of both the methods used to calculate overtopping rates and in how to interpret them in terms of “acceptability”, i.e. the effects of the overtopping on people and properties behind the seawalls. Further, the estimates of the effects of climate change on waves and tidal levels have altered, and it is entirely possible that beach levels in front of some of the coastal defences considered at that time have altered. Because of this, it is suggested that a similar exercise will be needed in the near future as one of the first steps in assessing the risks of coastal flooding in Jersey as a result of climate change.

It is much more difficult, in general, to assess the potential risks to coastal defences themselves as a result of the changes sketched in Figure 3. The increases in tidal levels and wave heights against the front face of the defences will increase the loadings on the structures themselves; increased overtopping may also lead to erosion of the soil behind the defences, and to greater water seepage through and under them, thus increasing the risks of voids forming behind their front faces. However, this is an issue that has been addressed by the recent Island Sea Defence Strategy, and the subsequent improvements to the seawalls around the Island, and is therefore not pursued further in this study.

The implications of climate change for structures in deep water, such as breakwaters may also need to be considered, where these provide some degree of defence against flooding or erosion. As for coastal structures, there will be a decrease in the “freeboard” to the crest of offshore breakwaters, for example, with a corresponding increase in the frequency and magnitude of overtopping. This in turn may affect the stability of the crest and landward slope of these structures, as well as potentially significant increases in wave disturbance in the sheltered areas in their lee. In addition, any armouring on the front face of such structures may also be affected by greater wave heights. For example, an increase in extreme wave heights of 10% would require armour unit weights to be some 33% greater to achieve the same degree of safety.

Summary

In general, the coastal defences in Jersey have been constructed to a high standard, with some masonry walls over a hundred years old still fulfilling their function of protecting against flooding and erosion. Since the adoption of the Island Sea Defence Strategy, the structure of the coastal defences around the island has been addressed and necessary improvements carried out, or identified for attention in the coming few years. The main challenge posed by climate change will be to adaptively improve the standards of defence offered by these defences, in order to cope with increased high tidal levels, lower beach levels and possibly larger extreme wave heights.

5. Review of coastal defence management, Jersey

The preceding chapters of this report have concentrated on those predicted consequences of climate change that may affect Jersey's coastline, and how such effects may occur. Before going on to discuss, in Chapter 6, how to cope with these changes it is first important to review the present coastal defences in Jersey and how they are being managed. As previously mentioned, while many are old, the seawalls around Jersey's coastline have provided a good standard of protection against flooding for many decades. These defences were only subject to minor repairs and maintenance until the late 1980s. However, since the beginning of 1990, more attention has been paid to the structural condition and performance of these structures as briefly discussed below, to form a historical context for consideration of dealing with future challenges that will be set by the changing climate.

The following section of this report briefly summarises the work undertaken between 1999 and 2001 to study and improve Jersey's coastal defences, and is followed by a discussion in Section 5.2 of the current "Island Sea Defence Strategy", instigated in 2002, and the works undertaken under that programme.

5.1 COASTAL DEFENCE MANAGEMENT IN JERSEY (1990-2001)

Concerns about coastal flooding and the condition of some of the seawalls arose following the severe winter of 1989/1990, the Transport and Technical Services Department commissioned a report into the problems experienced at that time (HR Wallingford, 1991). This study reviewed the standard of protection offered by the defences and made recommendations for a number of short-term and long-term actions for their improvement. The need to continue repairs and improve the foundations of the seawalls was emphasised at that time, not least because of a concern regarding long-term lowering of beach levels in front of many of the seawalls. In addition, a number of "problem areas" were identified and ranked in priority for improvement and recommendations were made for monitoring the coastline and defences to assist in the long-term management of the Island's defences. Following this report, work was put in hand to improve the defences in some of the areas identified as of high priority (e.g. at Fauvic and Anne Port).

Subsequently, in 1994/1995, more detailed studies were undertaken for two areas, St Ouen's and St Brelade's Bays, where concerns remained about the threats to the elderly seawalls, and the risks of coastal flooding. For these extensive frontages, the required financial outlay for some of the defence improvement options put forward was very high, and there were associated concerns about their environmental acceptability. Two reports were produced on these areas (HR Wallingford, 1995 a, b), and these provided options for the improvements of the seawalls, bearing in mind the constraints of affecting the amenity values of these Bays and the financial implications of any major reconstruction or improvements to the existing structures.

During the intervening period, repairs on these and other seawalls were being continued, and a programme of beach monitoring had been initiated around Jersey, providing valuable data for assessing the long-term lowering of beach levels.

Following the production of these reports in 1995 by HR Wallingford, a detailed Feasibility Report was produced by the Transport and Technical Service Department for States consideration in April 1996 which summarised those reports, the decisions made by the Public Services Committee up to the date of the Report and the funding that had been received to carry out planning and Capital Works.

Four major areas of concern were noted in the Feasibility Report as requiring urgent attention. These were Fauvic Bay, Anne Port Bay, St Brelade's Bay and St Ouen's Bay. Successful Capital Works had been undertaken at Fauvic and Anne Port Bay at the time, with minor works also completed at St Brelade's Bay. The Committee of the day concluded that it was unable to make a firm recommendation regarding the future of St Ouen's Bay Sea Defences based on the information presented to them at the time. It was decided that further studies were required such that the available options could be considered and in addition it was considered that a Working Party should be set up to oversee and manage these studies. It was further noted in the Report that other areas around the Island would need urgent consideration in the near future due to their continuing deterioration.

Following this report an extensive data gathering process was carried out during 1997, 1998 & 1999, which aimed to establish the coastal processes around the Island, which affected its coastal defences. As part of this Island wide study, specific information was captured at St Ouen's Bay in order that the problems being encountered in that Bay could be considered in greater detail.

On completion of these field studies the data was used to produce and support a full geomorphological and hydraulic modelling study of the Island. The information from the computer model and the gathered field data allow informed decisions to be made with regard to the natural processes occurring and the future management of Jersey's coastal defences.

As St Ouen's Bay was the only priority area listed in the 1991 report that had not been improved by 1999, HR Wallingford were instructed to produce a Feasibility Study for all the available management options for St Ouen's Bay. It should be noted that following the 1996 Feasibility Report, no major works had been initiated in St Ouen's Bay with the concern that the need for substantial expenditure required to prevent major collapse of these seawalls had gradually increased in the intervening period.

This study was summarised in a report produced in April 1999 (HR Wallingford, 1999), which included a list of possible options with indicative prices. The only option not priced in that report was that for the radical option of a "managed retreat", i.e. removing the existing seawalls and allowing the sea to flood the backshore, eventually producing a new shoreline in a position and at an alignment more in equilibrium with the waves and tides within that Bay. Following a joint Committee meeting of the Public Services and Planning and Environment Committees, it was subsequently decided that the costs and implications of partial and full managed retreat should be investigated.

Consultation was carried out with relevant States Departments who were able to supply information relating to the potential costs and effects of implementing a managed retreat scheme. HR Wallingford then submitted their Report on Managed Retreat of St Ouen's Bay in May 2001 and the key points were subsequently incorporated into an amended report received in August of that year (HR Wallingford, 2001). This report provided a feasibility study of the available options for St Ouen's Bay Sea Defences, with the costs of the options ranging in price from £7.5m to £110m, and addressed the key issues highlighted by the Sea Defence Working Party in 1996 with regard to St Ouen's Bay. Subsequently, the Public Services Committee selected the "Continued Maintenance" option for the future management of St Ouen's sea defences. At the same time, the

Committee noted that St Ouen's Bay would not be considered in isolation and that it would form part of an overall Sea Defence Strategy, which would address all the issues set out in the 1996 Feasibility report.

Soon after this, it was decided to carry out a full review/inspection of all the Sea Defences owned or administered by the States of Jersey. It was intended that results of this new study could then be compared with the results of the 1991 study to determine levels of change and to determine the effectiveness of the major and minor capital works carried out during the period.

In November 2001, HR Wallingford was commissioned to carry out an updated study of the Island's Sea Defences. Their brief was to conduct a visual appraisal of the condition and performance of the coastal defences around Jersey, to identify known and potential failure and/or performance risks to the defences or protected backshore areas and to provide recommendations and budget costs for future Capital Works. As well as the visual inspection, officers from Public Services, responsible for maintenance of the sea defences, assisted in the initial assessment and gave their "local" views and knowledge with regard to proposals and solutions for future capital works.

The initial purpose of the study was to identify defence sections that would potentially require capital expenditure over the next 10 years either in addition to, or to help reduce, the ongoing coastal defence maintenance programme. Based on this information a prioritised list of potential capital works was developed. No detailed scheme appraisal for each site was conducted within this study; rather capital work recommendations were developed from discussions regarding the issues, requirements and constraints for each section of defence.

5.2 COASTAL DEFENCE MANAGEMENT IN JERSEY (2002 ONWARDS)

In 2002, a substantial change in the management of the coastal defences of Jersey took place. The Island-wide review of the defences undertaken by HR Wallingford was published in April of that year (HR Wallingford, 2002a) and this identified the substantial requirements for improvements needed, together with the estimated costs and priorities for undertaking such works. This in turn was followed by the production of a paper summarising the study and its findings to Jersey's Public Services Committee in the same month.

In May 2002, a report was produced recommending the initiation of the Island Sea Defence Strategy, which essentially was a 10-year plan for the improvement of Jersey's coastal defences. This strategy estimated a need for expenditure of £13M (at 2002 rates) over that period, and set out an expenditure profile for each of the ten subsequent years, with the expenditure in the first three years (2003 – 2005) accounting for some 57% of the overall expenditure.

This Strategy was approved later that year and since that time has provided the framework for strengthening of the seawalls that started in 2003 and continues today. In total, 55 improvement schemes are included in this strategy, with these ranging from "High" to "Low" priority and considerable progress has been made since the beginning of 2003, with the situation at the end of 2006 being as follows.

Priority	Number of schemes identified (2002)	Schemes completed by (31/12/06)
High	7	5 (71%)
High - Moderate	1	1 (100%)
Moderate	10	6 (60%)
Moderate - Low	3	2 (67%)
Low	33	9 (27%)

For the most part, these schemes have involved adding a sheet steel pile and concrete "toe" to the existing seawalls, to avoid them being undermined and, where necessary, re-facing or repair of the face of the walls themselves. In a few cases, concrete aprons have been built to prevent undermining rather than using piling. In addition, there have been other works carried out at some locations to cope with the effects of overtopping, for example at one site improving promenade drainage. However, in general these works only strengthened the existing defences rather than aiming to improve their capacity to resist overtopping. As climate change occurs, these defences will also need adaptive improvement, so that despite sea level rise they will maintain or improve the present standard of protection against overtopping. There are various ways in which this might be achieved, of which the simplest is to raise the crest height of the seawall, hence increasing its "freeboard", shown as R_c in Figure 3, and discussed in section 4.1.

A summary of the remaining Capital Works projects, as at 31 March 2007, is included in the Appendix to this report for interest.

Following the inception of the Island Sea Defence Strategy, and as part of its implementation, HR Wallingford was commissioned in May 2002 to develop an asset management database for the use of the Public Services Department (PSD) on Jersey to aid the planned management and maintenance of coastal structures under the responsibility of that Department. This database was produced later that year, and essentially comprises a computer-based system for storing information about the coastal defences around Jersey, in particular technical drawings and photographs of the defences taken in May 1991, November 2001 and in January and February 2002 (HR Wallingford, 2002b).

This database forms a valuable depository for information on the defence structures that can be used to assess how these will perform in severe wave and tidal conditions in the future, i.e. how the standard of protection they currently provide will alter in a changing climate and, potentially, with lowered beach levels in front of them. Since its creation in 2002, Transport and Technical Services have updated the database with condition survey data and changes to individual asset structures following substantial maintenance projects. This subject is returned to in the following chapter, in which a forward look at managing Jersey's coastal defences is presented.

6. A decision making framework for coastal defence improvements in Jersey

6.1 INTRODUCTION

The objective of this chapter is to discuss how decisions about expenditure on the adaptive improvement of coastal defences in Jersey might be taken, both at the level of an overall policy and for particular frontages, given the likely impacts of climate change. The main objective of the improvements envisaged here is to maintain or improve the standard of protection that the existing defences provide against overtopping and associated coastal flooding.

The overall context of coastal defence management in Jersey, as in many parts of the developed world, is influenced by a number of factors that constrain the options available. These can be summarised briefly as:

- Coastal developments and usage contribute enormously to the overall social, cultural and economic character of Jersey;
- There is a desire to preserve or improve the character of the coastline, in terms of its amenity, landscape, aesthetics and ecological attributes;
- There is a pressure for further development of the coastline and immediate hinterland, for example in connection with recreation, tourism, commerce or housing; and
- The expectations of the community at large are generally for continued access to and use of the coast, and for protection, from flooding and erosion even in extreme storm events.

It is impossible to entirely eliminate the risks of coastal flooding and erosion however much is spent on defences. The issue therefore becomes one of managing such risks so that they are acceptably low, while ensuring that the expenditure on defences is sustainable, committed only when necessary and avoiding adverse effects on the environment as far as possible. The present emphasis in the media regarding climate change and its effects means that it is timely to open a debate about these issues.

As explained in Chapter 2 of this report, there will always be uncertainty about the effects of climate change on future sea levels, winds, waves and tidal levels. This stems in part from the uncertainty about future greenhouse gas emissions and partly from the huge complexity of the Earth's atmosphere and its weather patterns. Because the predictions of future effects of climate change are constantly changing, and the subsequent increases in risks of flooding and erosion are difficult to evaluate, it can be difficult to prove to the public that early precautionary intervention is wise and eventually cost-effective. Such changes will also be gradual and it may take many years to separate out the underlying trends for increased tidal levels, for example, from the inevitable variability of occurrence of severe storm events.

However, even taking the most optimistic, i.e. the lowest, predictions of future temperature increases, there is a clear conclusion that the potential risks to Jersey and its people of coastal flooding, and perhaps of coastal erosion, are going to increase in the coming years. To manage these risks, decisions have to be taken continuously both about the wisdom of allowing new developments close to the coastline and about the need for, and costs of, protecting assets already threatened by flooding and erosion.

In many ways, the first of these types of decision is the easier to deal with, through the planning system, since the discussion is about assets, as yet only envisaged, that may be at risk at some future date rather than already being under threat. Nevertheless, a decision has to be made about whether it is preferable to take an optimistic view of future risks, and hence allow more development close to a coast or to take a precautionary one and constrain it. At present, however, there appears to be no planning policy in the 2002 Island Plan to prevent development close to the coastline of Jersey in areas that are presently, or in the foreseeable future may be at risk from coastal hazards such as erosion or flooding. Policy M2 does anticipate the adoption of a Coastal Zone Management Strategy for Jersey, and such a Strategy is at the consultation draft stage, according to the States of Jersey website (see web-page http://www.gov.je/PlanningEnvironment/Environment/Marine+Management/Coastal+Zone+Management.htm posted on 7 July 2006). This strategy, once adopted, taken together with the commitment to support sustainable development, should allow for an appropriate degree of caution in using areas threatened by such hazards.

It is generally more difficult to decide how to deal with the ever increasing risks to existing assets (e.g. property, infrastructure, land use and habitats), and to people, from coastal flooding and erosion. In the UK, for example, the existing standard of protection against these threats offered by coastal defences such as seawalls is often very much lower than specified for new coastal developments under planning guidance.

However, improving coastal defences is expensive, is often criticized as being unsustainable and such works will often have adverse effects on the natural and human environment. Further, the need for improvements in coastal defences is likely to be greatest where there is already considerable development at risk, but this is usually the same type of coastline where the acceptable options for intervention are fewest. Some of these difficulties may be experienced in Jersey in the coming decades.

There will be a need for coastal defence improvements in response to climate change, producing an overall framework for such schemes that is accepted by the public as well-reasoned and fair is not an easy task. While the effects of climate change on coastlines and the corresponding increases in risks of flooding and erosion are well-accepted in the scientific and civil engineering community, these will only become evident very slowly. The gradual acceleration in sea level rise over the next 10-20 years may occur without being noticed by most people. Indeed it is more likely that the public will only be concerned about such increased risks following particular severe storm events that cause damage, or even loss of life, and before these occur may regard expenditure on precautionary improvements to coastal defences within the next 20 years as a low priority.

It is therefore suggested that it is sensible to begin a number of initiatives that will both assess and reduce coastal flooding and erosion risks, both in the short-term and in many years time. The expenditure on managing coastal defences can initially be modest but it must be expected to increase in future to provide protection to people and their property. As these initiatives are progressed, there will need to be a corresponding increase in the involvement and hopefully the understanding of the public. At present, there is no need to consider abandoning any of Jersey’s coastal defences, and this is a very different situation to that faced in the UK where such decisions are now being taken. Despite this, there are still potential difficulties ahead as the disadvantages (including cost) as well as the advantages of improving the defences to adapt to climate change become apparent.

In the following sections we discuss a number of initiatives to overcome these difficulties; it is recommended that, for the most part, these initiatives should be started now or very soon, although their benefits will become important at different times in the future.

6.1.1 Initiatives providing long-term benefits

There are many areas in Jersey close to the coastline where at present the probability and/ or consequences of coastal flooding or erosion are very low, but where these may increase in the future, either as a result of climate change or as a result of development in those areas. There are two initiatives that aim to reduce the burden of installing and maintaining coastal defences for future generations, namely:

L1 Land-use planning controls to restrict new developments that may be affected by coastal flooding or erosion many decades hence; and

L2 Development controls, ensuring that any new developments permitted within areas that may eventually be at such risk are designed to cope with coastal flooding.

There will be a need to decide whether a precautionary attitude is taken in setting restrictions on new developments in Jersey, for example in a manner similar to that adopted elsewhere. Predictions of climate change, defence performance and consequent risks of flooding or erosion are only part of the input to such restrictions. The socio-economic consequences of unduly restricting future investment and the expected lifetime of such developments, which may 50-100 years or more, also need to be taken into account. It would be optimistic to believe that a private developer, for example, would accept responsibility for the costs of coastal defences for his/ her scheme indefinitely, or to agree to pay for the removal of the assets as the risk of flooding or erosion become unacceptable. These burdens may therefore eventually fall on the public purse.

In this respect, the recent changes in planning guidance in England and Wales may be of interest. Following the UCKIP 2002 report, guidance on future coastal flood risk was based upon predictions of climate change effects based on the Medium-High emissions scenario, as predicted by the Hadley Centre model. Following the Stern report, the UK's Department of Environment, Food and Rural Affairs (Defra) issued new guidance in late October 2006 for assessing publicly funded coastal defence projects, indicating the concerns about predicted future sea level rise and potential increases in extreme wave conditions (see www.defra.gov.uk/news/2006/061107a.htm). This guidance required coastal authorities to allow for greater climate change effects, such as sea level rise and wave height increases, over the next 100 years than previously assumed when assessing plans for future development near the sea, based on the predictions assuming a High Emissions scenario. This advice has now been reflected in the new Planning Policy Statement 25 (DCLG, 2006), which principally sets out guidance for development control in areas at risk from flooding (by the sea, rivers or rainfall).

A further initiative that may only yield benefits some time in the future is:

L3 Planning for relocation or removal of assets that will not be adequately protected by coastal defences.

In England, improving existing coastal defences that protect assets at risk from flooding or erosion has or will soon become so expensive that such schemes will no longer be cost effective, i.e. the benefits to the public of such improvements would be much less than the cost of such works. This is particularly the case where the assets at risk, e.g. properties, are privately owned and the public derives little direct benefit from protecting them. Allowing existing defences to fall into disrepair, or even announcing that this is the policy that will be adopted for a particular frontage in the future, are nevertheless difficult steps to take. Recent experience of cliff coastlines in East Anglia has shown the difficulties involved in such circumstances, not least because there is a very stark transition from being protected (at least to some degree) to receiving no protection or compensation.

At present, there is no intention in Jersey for similar decisions to be taken; rather the stated intention is to "Hold the Line" and hence, implicitly, to improve defences so that the level of protection they provide is maintained or improved despite the effects of climate change. Nevertheless, there may still be a few locations where, in the fullness of time, there would be a better economic case for relocating or removing some of the (publicly owned) assets than commit to great expense in protecting them, for example where a replacement seawall was needed. Some guidance on when and how such a decision might be taken may therefore be needed, although such decisions may not be faced for more than 20 years into the future.

6.1.2 Initiatives providing medium-term benefits

The following set of initiatives is suggested as a framework for deciding on future defence improvement schemes in Jersey with a view to establishing and applying this within the next 5-10 years:

M1 **Monitoring changes to the coastline (cliffs, beaches and nearshore seabed);**

M2 **Reviewing defences (condition and performance), the predictions of climate change and the resulting changes in present/ future flooding and erosion risks;**

M3 **Establishing the social, economic and environmental consequences of coastal changes;**

M4 **Establishing guidelines that allow for available funding for maintaining or improving defences to be appropriately allocated to the most deserving frontages, bearing in mind the economic, social, and environmental consequences of such schemes and the urgency for intervening;**

M5 **Mitigating the impacts of flooding events. Where possible, it may be more beneficial to introduce planning controls for assets at possible risk, for example aimed at increasing the flood resilience of buildings, rather than trying to reduce the occurrence or severity of flooding; and**

M6 **Deriving generic options for improving defences well before they need to be installed so that full discussion of the options, advantages and disadvantages can be held and mitigation for unavoidable impacts agreed.**

These medium-term initiatives are designed to establish, in advance, the methods by which a possible coastal defence improvement scheme is assessed, in the light of changing circumstances as time passes. As pointed out in Chapter 4, a lowering of beach levels may have at least as severe an effect on coastal flood risks as a corresponding increase in sea levels; the former, however, may occur much more quickly than the latter.

Along frontages where previous (short-term) assessments have shown there to be a significant flood risk at present, or following climate change, there will be a need for periodic review of the coastline (M1) and of its defences and the standard of protection they provide. This would need to include a review the predictions of the timing and scale of changes to tidal levels and waves in line with latest predictions of the effects of climate change, and of beach levels (M2).

Similarly, it is possible that the assets at risk behind (or in the vicinity of) coastal defences, or the usage of that part of the coastline, will change over time. As a consequence, it will be necessary to establish both a baseline evaluation of the assets at risk, and to periodically review that evaluation, for example reflecting increased property values, the possible addition or removal of assets at risk from coastal flooding or erosion, or changes in the environmental and social importance of that particular stretch of coastline (M3). This initiative is also intended to gather information on the "indirect" benefits of managing coastlines, particularly beaches, in terms of establishing the numbers of people using a particular frontage and the economic benefits of this usage. It will be easier, in most cases, to find an acceptable way of improving coastal defence standards on coastline that have little usage than for those that regularly attract large numbers of people.

Perhaps the most difficult decisions lie in directing the available funds to coastal defence schemes in a fair and transparent manner (M4). In England and Wales there has been continuing discussion and change in the way in which such decisions are made, and the present system for allocating central Government funding to such schemes considers:

- Benefits (in losses avoided over the whole life of a proposed defence scheme);
- Scheme costs (initial and recurring, over the whole life of a proposed defence scheme);
- Social status of the area (greater investment in deprived areas);
- Numbers of residences affected;
- Environmental gains or losses, i.e. to natural habitats;
- Urgency of works; and
- Losses of features of archaeological or historic importance (e.g. Listed Buildings).

In addition, other factors can be taken into account, in a marginal costs/ benefits manner, to allow extra funding for increased "indirect" benefits from a scheme, e.g. to amenity and recreational uses of the coastline. This complex evaluation process in England and Wales reflects the very large demands for coastal defence and the limited funds available to fulfil those desires. Because of its complexity, it can also be a time-consuming and expensive process to undertake. In contrast, although subject to very similar legislation, the situation in Scotland is very different, with little coastal defence traditionally being centrally funded and the assessment procedures less complicated, mainly reflecting the economic aspects of a proposed scheme. Here, however, there is generally a tendency to protect publicly-owned assets or communities rather than privately owned properties.

Developing such an evaluation scheme for Jersey is likely to be simpler, but still will need to direct funding for coastal defence to produce the greatest benefit. Determining the amounts and timing of public expenditure on individual coastal defence schemes is a matter for local consideration and debate to reflect the relative priorities that the Island wishes to give to the assets at risk. The development of such a scheme is beyond the remit of this study, however, and it is recommended that it is one of the "future studies" as returned to in Chapter 7 of this report.

The final two medium-term initiatives relate to methods of reducing the consequences of (M5), or the occurrence / severity of (M6) coastal flooding or erosion events. In many cases, relatively simple and inexpensive works can be undertaken to reduce the damage caused by flooding events.

Examples include:

- Improving storage and drainage routes for marine floodwater, for example improving the design of seawall/ promenade "scuppers", or diverting overtopped water into emergency drainage channels;
- Improving the flood resilience of buildings, perhaps by amending building regulations for developments in areas at risk. Elsewhere consideration has been give to providing guidance (perhaps assistance) to property owners regarding the waterproofing of permeable walls, and/or installing demountable flood barriers across doors, airbricks and other ingress points, shutters for windows etc;
- Issuing and acting on storm/ flooding warnings, for example closing promenades and roads at risk from wave overtopping. One advantage of the very large tidal range in Jersey is that the periods of such overtopping will be short, around the time of high water. Since overtopping is most likely on a high spring tide, and these tend to occur at about 08:00 and 20:00 (GMT) in Jersey, these are the times of day when flooding is most likely to occur, thus for example affecting journeys to work and school in the morning but being less of a hazard in the evening. Modern weather forecasting systems allow early prediction of both waves and tidal surges, so initial warnings of events occurring can be made 36 hours in advance, and refined several times, as necessary before the onset of overtopping. Such a system is already in place, and the areas at risk have been summarised in Table 1, which also indicates the actions taken before and after such events at particularly vulnerable locations.

Finally, early consideration of alternative defence improvement options can avoid unnecessary delay and effort in design and consultation. Coastal defences vary in type around the world in response to the availability of construction materials and the equipment to deliver and place it. Some possible defence improvement options, and constraints on their use, are briefly discussed below:

- Options such as beach recharge using dredged sand may be impractical in parts of Jersey, despite the clear benefits that might be gained from an amenity viewpoint, because of the difficulties and cost of obtaining suitable sand and delivering it to the beaches;
- Simple raising the crest level of seawalls may be acceptable in some areas, but elsewhere may prevent a clear view of the sea, not only affecting the aesthetics and enjoyment of a promenade or coastal road but also potentially increasing the

risks to people or vehicles from sudden overtopping by waves that cannot be seen approaching;

- Recreational uses of some sections of the coastline, as well as costs, may mean that rock revetment, offshore rock breakwaters or reefs are likely to be unpopular;
- Rebuilding or altering historic seawalls may be unacceptable from the viewpoint of maintaining the "built heritage" of Jersey.

By identifying these and other potential constraints on intervention early on, and establishing whether there are insurmountable obstacles to some options, will reduce the time spent on the detailed consideration of them.

6.1.3 Initiatives providing short-term benefits

Commissioning the present study is perhaps in itself an initiative that will encourage debate about and consideration of the threats to Jersey's coastline, and its coastal defences, from future changes in the climate. A number of other short-term initiatives are suggested that will hopefully carry this important debate forwards, namely:

S1 Educating and engaging with the public about coastal flooding and erosion risks in Jersey;

S2 Assessing present and likely future risks to people and property at the coast;

S3 Sub-dividing and characterising the coastline of Jersey according to the risks along different frontages of erosion or flooding and establishing a priority ranking for coastal defence management;

S4 Monitoring beach levels and coastal flooding / erosion events; and

S5 Planning and management of emergency responses to flooding / erosion events.

As previously mentioned, the effects of climate change on coastal flooding and erosion in Jersey will be gradual, and for the next ten to twenty years or so probably difficult to discern given the variability in frequency and intensity of storm events. Nevertheless, the opportunity should be taken, whenever possible, to explain that the risks of flooding and erosion are both serious and likely to worsen in the future. Preparing the public for at least an increase in investment in managing these risks is an important early target (S1).

The quantification of the magnitude of these risks (S2), however, is complicated task. Methods for calculating the performance of coastal defences under specified wave and tidal conditions exist, and can be used as inputs to further predictive modelling to predict the consequences of, for example, a flood event. To carry out such modelling, it will be necessary to update the information on beach levels held in the Coastal Defence Asset Management Database, and to analyse beach monitoring data, where available, to anticipate future changes in levels in front of the defences. The evaluation of the frequency, and predicted rates of overtopping provide one element in assessing flooding risks.

In addition, however, there needs to be a consideration of the effects of such overtopping. There are methods for evaluating the consequences, in financial terms, of such flooding (or erosion) although these need information on the assets, e.g. properties that are likely to be affected. Compiling all of this information to estimate the probability of damage is a substantial task, and will need to be undertaken gradually, concentrating on the areas that are judged, on the basis of experience and simpler calculations, to have the greatest risks.

The assessment of present-day risks will be most conveniently undertaken piecemeal, concentrating first on the frontages most obviously of concern (i.e. those with existing coastal defences that suffer overtopping) and leaving other frontages until later. Eventually, it might be decided, as in the UK, to assess hazards and coastal defence policy for the whole of Jersey's coastline, whether or not it presently has coastal defences. While this project only considers the effects of climate change on Jersey's coastal defences, it is noted above that a Coastal Zone Management Strategy is in draft form and open for consultation. This Strategy will also require consideration of the whole of Jersey's coastline.

Taken together, these future initiatives suggest that a suitable sub-division of the coastline of Jersey (S3) needs to reflect both the physical characteristics and the distribution of assets at risk. A convenient way to do this therefore is an initial coarse division into "Coastal Process Units" reflecting the main geomorphological units, followed by a further division into "Coastal Management Units" which would have broadly the same risks and assets along the whole unit.

For example, the Coastal Process Units might (provisionally) be chosen as:

St Ouen's	(Le Grand Etacquerel to Corbiere)
St Brelade's	(Corbiere to Noirmont)
St Aubin's	(Noirmont to St Helier Harbour)
St Clement	(St Helier Harbour to La Rocque)
Grouville	(La Rocque to Le Petit Portelet)
St Catherine's	(Le Petit Portelet to La Coupe)
North Coast	(La Coupe to Le Grand Etacquerel)

Within each of these Coastal Process Units would then be a number of Coastal Management Units, reflecting the assets at risk. So for example, the "St Brelade's" CPU would be subdivided into perhaps the following smaller units:

1. Corbiere to La Grosse Tete
2. Beauport to La Saline
3. La Rocquaise to Le Grouin
4. Le Grouin to Ouaisne slipway
5. Ouaisne slipway to Portelet
6. Portelet
7. Portelet to Noirmont

In practice it would be simpler to define the boundaries between such units on a map, and number them, rather than trying to name each boundary using geographical features, not least because there may be no named and convenient feature present. Of these seven proposed units in the suggested St Brelade's CPU, only two have existing defences and would therefore require consideration for improvements to cope with climate change, and for very different reasons, namely the risk of flooding of properties in Unit 3 and of important habitats in Unit 4.

This study only considers the effects of climate change on coastal defences which fall under the responsibility of the States of Jersey, and thus does not consider the risks of erosion or flooding along parts of the coastline that are presently protected by privately owned defences or are undefended, for example at Portelet Bay (Unit 6). The study of such "natural" frontages is therefore not addressed in this report, although in other parts of the world these investigations might be carried out, for example to support spatial planning policy.

Establishing the priority order for detailed assessments of flood risk for critical defence lengths will need to be undertaken using experience and judgment, supported by simple calculations. Clearly the sites where overtopping already occurs and causes inconvenience (see Table 1) are likely to be the first to be considered, followed by those where works have been done recently to strengthen the defence structures, particularly in response to low beach levels.

These updated assessments will require information not only on future tidal levels and wave conditions, incorporating estimates of the effects of climate change but also information on present-day beach levels. A programme of routine beach level measurements was carried out between 1992 and 2003. It is therefore suggested that a review of the data available, together with new measurements in front of defences judged of highest priority for improvement, is undertaken as part of this initiative.

In order to collate and retain the outputs from this initiative, it would be sensible to update and improve the existing Coastal Defence Asset Management Database, for example re-organising it to reflect whatever sub-division of the coastline is decided upon in S3, and storing the results of the risk assessments carried out under initiative S2.

Consideration of continuing such surveys, at an appropriate frequency, is suggested as a part of S4. In addition, considerably more weight will be given to the assessments of flood or erosion risks along any stretch of coastline if they are supported by information on actual flooding or erosion events, i.e. their timing and extent. Having data on exactly when and to what extent overtopping of any defence occurred, and the consequences of it, is extremely helpful in verifying computational models of the future risks of such events, for example including the effect of an increased sea levels as a result of climate change.

Clearly if such events are happening much more often, or much less frequently, than predicted by computer modelling, then the reason for this mismatch could be investigated, and predictions of the consequences of much more severe events, either now or after expected changes in the climate, revised. This may increase or decrease the initial estimate of flooding or erosion risks, but would always add confidence in the robustness of the assessment of those risks.

It is a relatively simple matter to record such events (S4), even if they are minor and cause no significant damage, and a task that might be usefully shared with interested members of the public in due course. There is already a considerable body of experience available on such events, and formalising this within the Coastal Defence Asset Management Database would be very worthwhile.

In general, knowledge of the problems that presently occur along any stretch of coastline as a result of coastal flooding, and of the responses to these, is a valuable as a guide to what may be needed in the future before, during or after potentially much more severe events. The compilation by the Transport and Technical Services Department during the current project of the information presented in Table 1 indicates that there has already been a gathering together of such knowledge, and this should be extended and formalised to assist in initiative S5. Again this information should be collated and stored in the Coastal Defence Asset Management Database, and will be useful in deciding upon issues such as implementing storm warning and evacuation systems, particularly where coastal defences in Jersey are already failing to provide complete protection against overtopping.

6.1.4 The overall decision-making framework

The above series of initiatives are suggested as part of an overall framework for reviewing coastal defences, and deciding whether or not to intervene to alter these. For every coastal defence Management Unit, it will be necessary to carry out an initial and probably a very simple assessment of the present coastal flooding and erosion risks, and then for those frontages where such risks are significant, embark upon a cycle of periodic assessment and review of the risks, possible intervention schemes and monitoring of the situation.

This overall framework is summarised in a simple flowchart presented as Figure 4. The top row of this flow-chart, i.e. boxes 1, 3 and 6 will need to be periodically revised, perhaps every 5 years, in light of changing circumstances, for example new predictions of sea level rise, after there has been development or removal of assets close to the coastline or as the available budget for coastal defence in Jersey alters respectively. This suggested periodic review reflects the past practice adopted by the Transport and Technical Services Department; Chapter 5 describes the reviews of coastal defences that were undertaken in 1991, 1995 and again in 2002 (this leading to the Island Sea Defence Strategy) , and the present study can be regarded as the beginning of a further review five years later.

The left hand part of the flow chart summarises the periodic review of the condition and likely performance of coastal defences, which will both change if, for example beach levels become lower or the structure of a defence deteriorates. In many parts of the coastline of Jersey, this review of beach levels and defence structures may only be required infrequently. Where the flooding and erosion risks are highest, however, it is recommended that such reviews need to be annual. The information gathered then leads into the calculation of flood and erosion risk. A decision then needs to be made about whether it is necessary to consider intervening to reduce those risks. This decision (central decision “diamond”) will need to be taken based on the “Decision Making Criteria”, and might, for example, be related to the potential loss of assets along the particular Management Unit in the next 5 years. For example, if a storm with a 50-year return period is estimated to cause flooding that results in damage valued at £50M, then the risk over the next 5 years would be £5M. The costs of reducing such risks would be related to the length of the coastal defences, and assuming that in this example a 500m length of seawall might need to be improved, then the risk per metre run would be £10,000. Since it would be possible to substantially improve a seawall for less than this amount, then intervention would be worthwhile considering. Should similar calculations elsewhere result in a much lower “risk / metre run”, then intervening would be a much lower priority.

If intervention does seems worthwhile, i.e. the “yes” answer to the central decision, then a range of possible options need to be considered (Box 7), compared with one another and evaluated on the basis of the various considerations described in section 6.1.2 (initiative M4). Note that even the preferred intervention option might not, in the end, be considered either sufficiently urgent or worthwhile to fund when all the decision-making criteria are taken into account. Whether a scheme is or is not implemented, however, the decision made will itself be reviewed in the future by the continuation of the monitoring and review cycle shown.

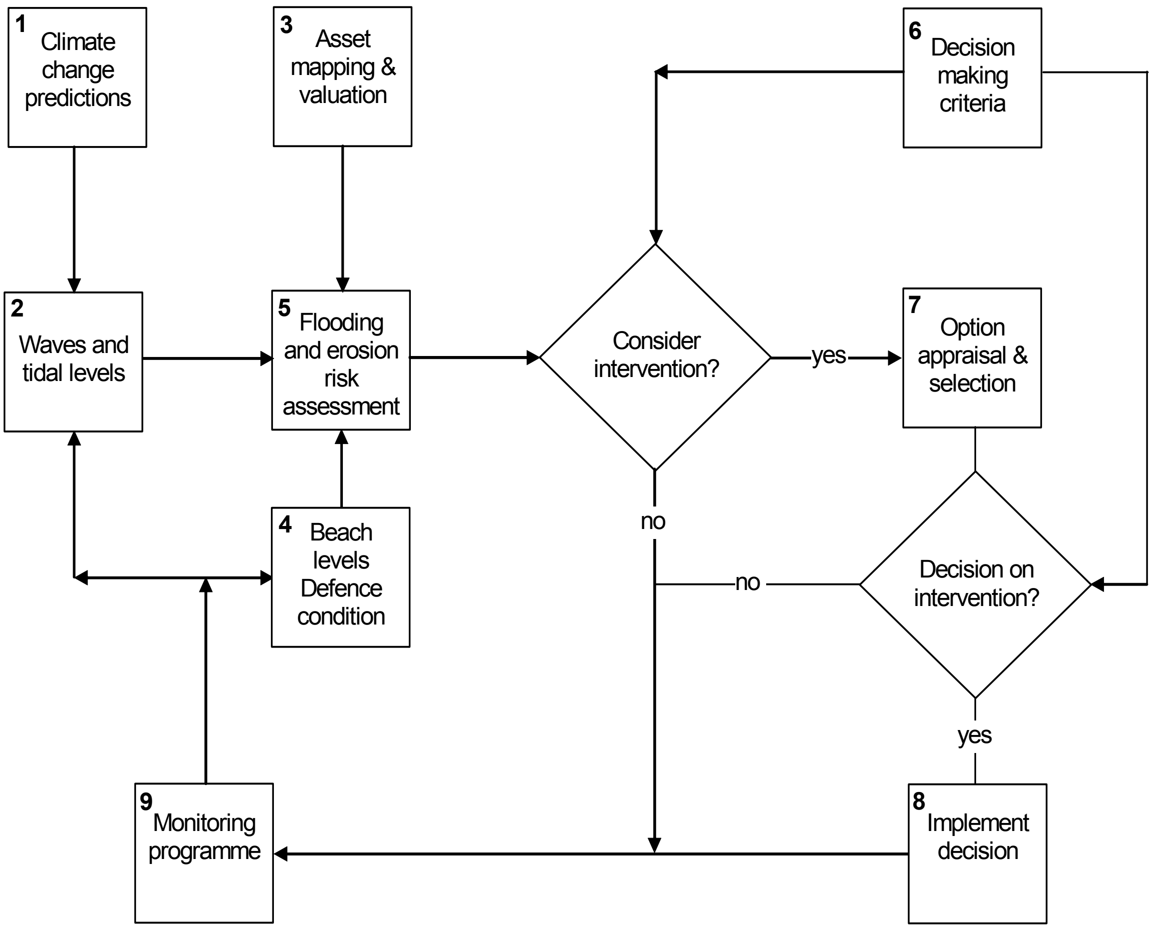

Figure 4 Flowchart of decision making framework

7. Suggestions for the way forward

The discussion in the previous chapter identified a number of long, medium and short-term initiatives needed to develop a coastal defence policy for Jersey in response to the threats of climate change. Such a policy is needed to ensure that the risks of coastal flooding and erosion, both now and in the future will be managed in a sustainable, fair and transparent manner.

The effects of climate changes on these risks will be gradual, and predictions of sea level rise and storm frequency and intensity will alter in the coming years. In general, the seawalls around Jersey provide an acceptable standard of defence against the sea, and the predicted acceleration in sea level rise is small over the next 10-20 years. There is therefore no need for precipitate action to improve the ability of Jersey's coastal defences to reduce flooding risks.

However it is important to start planning for such changes without delay. Many of the seawalls are old, and were previously in danger of being undermined as beach levels fall. These problems have been recognised and the Island Sea Defence Strategy introduced in 2002 has resulted in the underpinning of the seawalls most at risk; this programme of strengthening the seawalls around Jersey's coastline continues.

A few of the seawalls have been overtopped in recent years, resulting for example in the flooding of roads and promenades with obvious dangers to drivers and pedestrians, and requiring clean-up operations afterwards.. A summary of these problems has been provided by the Transport and Technical Services Department for this study and is presented as Table 1 in this report.

Climate change has the clear potential to worsen these existing problems. While improving the capacity of coastal defences to resist wave overtopping is often technically challenging and expensive, it is certainly prudent to anticipate and avoid severe flooding or erosion events than reacting to them after the event. As well as continuing the existing programme of securing and strengthening these and other seawalls, there will therefore also be a need to adapt to sea level rise and to increased heights of waves and surges should these occur, to retain or improve the present standard of protection. This can be termed "adaptive improvement" of the defences in response to climate change.

In the near future, therefore, it is recommended that, at least, the short-term initiatives, labelled S1 to S5, identified in Chapter 6 should be pursued. These are all envisaged as needing to be continued indefinitely, or at least periodically re-visited, but the initial stage of each of these should be completed within 2-5 years from now. In brief, these have the objective of improving knowledge and awareness of the existing risks of flooding and erosion around the island, and of the likely consequences.

Much of the information and effort needed to achieve these objectives relies on the involvement of people living or working close to the coast, and this involvement is crucial to the eventual formation of a coastal defence planning and management framework for Jersey.

In general, the gathering information about past flooding or erosion and its consequences along any stretch of coastline provides very valuable information to verify the methods used to predict what might happen in future, more severe, events.

Such information may be held by a wide range of organisations and individuals. In Jersey, this process is already underway and should be encouraged and expanded when and where necessary to supplement the information already being held in the Coastal Defence Asset Management Database maintained and operated by the Transport and Technical Services Department of the States of Jersey. Ideally this process should also involve the community, for example residents and local schools, to strengthen the awareness of the potential risks of climate change.

In the same vein, organising the recording, in a "diary", of information on future events will serve the same valuable purpose (e.g. when and where overtopping started and finished and the effects in terms of flood extent and severity). A review of past events, whether based on detailed records or anecdotal information, will also help in the task of identifying the sections of coastline where the concerns regarding coastal flooding or erosion are greatest and provide useful information to calibrate predictive models of future, more damaging events

To focus attention, at least initially, on the areas where the risks are greatest, it will be important to produce a sub-division of the varied coastline of Jersey into Coastal Process Units and Coastal Defence Management Units as a priority (even if this is subsequently revised in the light of later investigations). Part of the necessary information for this task is already available in the Coastal Defence Asset Management Database, and it would be appropriate to then re-organise that database so that information on defences in the same Coastal Processes Unit are grouped together.

It is suggested that the mapping of the Coastal Process Units and Coastal Defence Management Units would be best undertaken within a GIS system, so that further information, for example on property values, land levels etc, could also be added later. Such an approach would also allow an easy interface with any modelling of the volumes and spreading of water that overtops a defence (or perhaps passes through a breach in a seawall), or of erosion if defences are removed or fail. The spatial extent of such flooding and erosion could then be more easily converted into approximate financial consequences, allowing the direct benefits of defence improvements to be assessed. Such modelling will require, however, updated information on beach levels in front of defences at least in those areas where evaluating flooding and erosion risks, both now and in the future following climate change, is a priority.

Further studies and information will be needed, in time, to refine estimates of the flooding and erosion risks, in order to make progress with the medium and longer-term initiatives described in Chapter 6. Such extra work will take some time, quite probably a period of several years, extending the frontages considered and collecting further data and taking into account revisions in the effects of climate change or changes in the assets at risk from flooding or erosion. The context of such further studies is to improve the information available, and hence the standards and accuracy of the defence assessment and review process shown in Figure 4 above.

8. Conclusions and recommendations

8.1 CONCLUSIONS

1 This brief study has reviewed the evidence for changes in tidal levels, wave conditions and other consequences of climate change that might have an effect on coastal flooding and erosion risks in Jersey. It is concluded that in order to assess the future performance of such defences, it is prudent to assume that by the 2080s:

- All tidal levels, including exceptionally high tides, will increase by 500mm;
- Extreme wave heights (offshore) may increase by 10%;
- Extreme wave periods (offshore) may increase by 10%;
- Normal wave heights (offshore) may increase by 5%;
- Normal wave periods (offshore) may increase by 5%;
- Wave directions (nearshore) may vary by ±2°; and
- Present rates of beach lowering will increase proportionately with sea level rise.

2 The major potential risks to people and property around Jersey's coastline predominantly arise from flooding where the existing seawalls, while presently providing a high standard of defence, could suffer from more frequent and intense wave overtopping in the future. Existing defences will need to be improved in an adaptive manner over the coming decades to cope with this threat.

3 The predicted acceleration in sea level rise is small over the next 10-20 years, and there is therefore no need for hurried action to improve the ability of Jersey's coastal defences to reduce flooding risks. Planning for and prioritising such improvements, however, should be started very soon, to ensure that the best, i.e. most cost-effective, environmentally acceptable and sustainable measures can be taken to manage such risks.

4 As well as assessing the ever-increasing risks of flooding by overtopping, there is a need to regularly review the structural condition of the coastal defences. Many of these are over 60 years old, some even older. Along coastlines where beach levels have already become lower over the years, there is a danger of these structures being undermined, leading to voids forming behind them and the danger of a sudden and unexpected collapse. The recently adopted "Island Sea Defence Strategy" (2002) has already greatly increased the security of seawalls around Jersey from this threat and work continues to underpin the remaining defences.

5 In Jersey, cliff top recession as a result of wave and tidal action at the base of coastal cliffs is a much lesser concern than coastal flooding, not least because most cliffs are of a very resilient igneous geology. There are a few locations where cliffs are of softer rock, i.e. glacial till, where problems do occur. Further, if defences were to collapse, there are other areas where erosion of the soft, loose and sandy deposits behind seawalls would be very rapid.

6 Establishing a decision-making framework to consider how to manage coastal defences in the future, that is transparent, fair and considers all of the aspects of concern is a difficult task. Involving the public by both educating them of the risks that climate change will bring, and gaining their support for often difficult decisions about whether or not to protect against the twin threats of coastal flooding and erosion is likely to be valuable.

7 Central to the overall framework will be the criteria used to decide how best to invest available public funding to reduce the threats to the community of flooding and erosion. The relative weighting to be given to protecting "public" and "privately owned" assets, to preserving or enhancing the natural environment, to preserving assets of historical or cultural importance and to the wider socio-economic character of Jersey, which is strongly influenced by its beaches and coastline, needs to be discussed and agreed to help make decisions about coastal defences in future.

8.2 RECOMMENDATIONS

1. An overall flow-chart suggesting a decision-making process, adapted from a more general concept recommended previously for dealing with the impacts of climate change (UKCIP, 2002) has been proposed (Figure 4 of this report). It is recommended that this, or an equivalent framework, is discussed, revised and agreed as a necessary first step in managing coastal defences in Jersey over the coming few decades.

2. In order to implement such a system, a number of long-term, medium-term and short-term initiatives have been developed and described. Each of these aims to make assessing coastal flooding and erosion risks, and deciding whether or not to intervene, a more effective and consistent process that includes a wide range of people and organisations with interests in Jersey's coastline.

3. While the predictions of climate change will themselves alter in the coming years, there is a need to start on the process of risk assessment and review without delay. The present interest in climate change and its effects forms a helpful context for discussion with and involvement of the public. Ideally they should be involved in forming the decision-making criteria necessary to decide whether or not to alter coastal defences, as well as providing information on flooding or erosion events.

4 This planning of the adaptive improvements in Jersey's coastal defences that will be necessary to cope with climate change should include enhancing and improving the existing Coastal Defence Asset Management Database maintained and operated by the Transport and Technical Services Department of the States of Jersey.

5 A number of further technical studies have been recommended in Chapter 7 to advance with the short-term initiatives identified by this study. These should be reviewed, prioritised and set in train during the coming few years to define and prepare for the necessary improvements to the Island's defences.

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Table

Table 1 Summary of wave overtopping problems, Jersey (March 2007)

Location	Assets	Event Frequency			Planned temporary protection	Other
		Road closed	**Damage to private property**	**Attendance required for clear up**		
ANNE PORT	Slipway & road	Never	Never	Minor - 24 per year	None	
WELCOME	Slipway & road	Never	Every 10 years	Minor - 12 per year	None	
LA HUREL	Slipway & road	Unknown	Never	Minor - 24 per year	None	Shingle on the road can be dangerous to motorists
LA ROCQUE	Road immediately prior to slip when heading West.	Unknown	Never	Minor - 12 per year	None	
LE DICQ to ROSE SLIP	Road, footpath & promenade.	Every 10 years	Every 10 years	Minor - 12 per year on promenade	None	5 tonnes of seaweed reported to have been found on roof of 3-storey property bordering the promenade.
HAVRE DES PAS	Road & footpath.	Every 2 years	Unknown	Minor - 12 per year	Tidal barrier on slipway for tides exceeding 37ft	
GREEN STREET	Promenade	Never	Unknown	Minor - 6 per year	None	
VICTORIA AVENUE West Park to First Tower	Promenade, car parks & road	3 per year	Unknown	Minor - 24 per year	None	
LA PERQUAGE	Car park, promenade, footpath & road.	Every 5 years	Unknown	Minor - 12 per year	Tidal barrier on slipway & steps for tides exceeding 37ft	Severity increases with heavy rain.
GUNSITE to ST AUBINS VILLAG:	Slipways, promenade approach roads, car parks, footpath & road.	Every 5 years	Unknown	Minor - 6 per year	None	
OUAISNE	Slipway & approach road.	Never	Never	Minor - 6 per year	None	
ST BRELADE'S	Promenade.	Never	Unknown	Minor - 6 per year	None	
ST OUEN'S	Promenade.	Every year	1 every 5 years	Minor - 24 per year More extensive - 6 per year	None	

N.B. Most debris left on the roads, car parks, promenade and footpaths is cleared the next normal working morning.

Appendix

Appendix 1 Summary of remaining coastal defence maintenance capital works priorities – 31 March 2007

REMAINING COASTAL DEFENCE MAINTENANCE CAPITAL WORKS PRIORITIES

Summary - 31 March 2007

HIGH PRIORITY

Number	Area	Location	Defence Code	Description	Status
01	St Aubin's Bay	First Tower to West Park Slip	07-16D	Sheet pile & concrete toe. Rock Armour. Flood wall. Prom Drainage.	Complete
02	Havres des Pas	Fort D'Auverngne Hotel to Havres des Pas Slip	09-01D	Concrete Toe & Piling	Detailed Design
03	Le Dicq	Le Dicq Slip to steps	10-02D	Detailed design required	Detailed Design
04	St Ouen's Bay	Bunker to Cutty Sark	35-11D	Sheet pile & concrete toe. Re-facing concrete wall.	Complete
05	St Ouen's Bay	Cutty Sark to L'Ouziere Slip	35-12D	Sheet pile & concrete toe. Rock Armour.	Complete
06	St Ouen's Bay	L'Ouziere Slip to El Tico Cafe	35-14D	Sheet pile & concrete toe. Re-alignment of L'Ouziere slip.	Complete
07	St Ouen's Bay	El Tico Café to Le Braye	35-15D	Sheet pile & concrete toe. Re-facing concrete wall.	Complete

MODERATE - HIGH PRIORITY

Number	Area	Location	Defence Code	Description	Status
08	La Rocque	La Rocque Slip to start of private housing	19-05D	Rock Armour.	Planned work

MODERATE PRIORITY

Number	Area	Location	Defence Code	Description	Status
09	La Collette	East of Green St. Slip	08-03D	Wave return wall. Concrete Aprons	Complete
10	Havres des Pas	Chateau Le Mer Hotel to Eastern end	09-04D	Rock Armour.	Planned work
11	Bay of Fountaines	Western and Central Section	14-01D	Concrete promenade. Sheet pile & concrete toe	Planned work
12	Le Hocq (East)	Le Hocq Inn to the headland	15-03D	Rock Armour.	Do nothing
13	Grouville Bay	Le Hurel Slipway	20-05S	Masonry wall.	Do nothing
14	Grouville Bay	Le Hurel Slipway to Fort Henry Steps	20-06D	Replace Concrete Aprons.	Complete
15	Archirondel	Slip to Headland	24-02D	Pile & Concrete toe. Masonry crest and upstand wall.	Planned work
16	St. Catherines Bay	Slip	25-04D	Extend outfall along slip.	Planned work
17	Flicquet	South of Flicquet Slip	27-03D	Sheet pile, toe and apron	Planned work
18	Bouley Bay	Slip to Waters Edge Steps	31-03S & 04D	Sheet pile & concrete toe.	Complete

Summary - 31 March 2007 – *continued*

LOW - MODERATE PRIORITY

Number	Area	Location	Defence Code	Description	Status
19	L'Ouaisne	Mid Bay to Slip	04-02D	Sheet pile & concrete toe.	Complete
21	St Catherines Bay	Headland to Lifeboat Station	25-01D	Concrete Apron and repair of concrete toe.	Complete
22	La Greve de Lecq	Slipway to Harbour	33-03D	Move steps. Recurve parapet wall.	Planned work

LOW PRIORITY

Number	Area	Location	Defence Code	Description	Status
23	St Brelade's Bay	Mid-bay to La Grouin	03-07D	Sheet pile & concrete toe.	Planned work
24	L'Ouaisne	East of Slip	04-04D	Rock Armour and Beach Drainage	Complete
25	St Aubin's Bay	Harbour to La Haule slip	07-01D	Sheet pile & concrete toe. Consolidate masonry wall.	Planned work
26	St Aubin's Bay	La Haule slip to German wall	07-03D	Sheet pile & concrete toe.	Planned work
27	St Aubin's Bay	Toilets to carpark	07-05D	Sheet pile & concrete toe.	Do nothing
28	St Aubin's Bay	Car Park to Sugar Basin Slip	07-06D	Sheet pile & concrete toe.	Do nothing
29	St Aubin's Bay	Sugar Basin slip to Gunsite Cafe	07-08D	Sheet pile & concrete toe.	Do nothing
30	St Aubin's Bay	Gunsite slip to weatern end of German Section	07-11D	Sheet pile & concrete toe.	Complete
31	Green Island	Green Island slip to Le Nez Point	13-04D	Sheet pile & concrete toe.	Planned work
32	Le Hocq	Le Hocq Tower	14-04D	Rock Armour.	Do nothing
33	Pontac	West of La Greve de Pontac slip	16-01D	Sheet pile & concrete toe.	Planned work
34	Pontac	East of La Greve de Pontac slip	16-03D	Sheet pile & concrete toe. Rock Armour.	Planned work
35	Grouville Bay	Tower 1 to Seymour slip	20-01D	Rock Armour.	Planned work
36	Grouville Bay	Seymour slip to Tower 3	20-03D	Rock Armour.	Planned work
37	Grouville Bay	Le Hurel slip to Bunker (Fort Henry) – North	20-06D	Rock Armour.	Planned work
38	Grouville Bay	Margaret Terrace	20-11D	Sheet pile & concrete toe.	Planned work
39	Le Petit Portelet	Le Petit Portelet	21-01D	Rock Armour.	Planned work
40	Archirondel (south)	Car park frontage	23-02D	Sheet pile & concrete toe.	Planned work
41	Bouley Bay	Revetment / wall east of Waters Edge Hotel	31-02D	Sheet pile & concrete toe.	Planned work
42	Bouley Bay	Toilets to main slip (wall section at main slip	31-06D	Rock Armour.	Planned work
43	Bonne Nuit	Unprotected frontage between slip and sea wall	32-01D & 02D	Rock Armour.	Do nothing
44	Pebble Beach	Ad hoc defences west of slip	06-01D	Sheet pile & concrete toe.	Planned work
45	St Ouen's Bay	Cutty Sark to L'Ouziere Slip	35-12D	Replace concrete promenade (approx 2660m²)	Complete

LOW PRIORITY - *continued*

46	St Ouen's Bay	L'Ouziere Slip to El Tico	35-14D	Replace concrete promenade (approx 150m)	Planned work
47	St Aubin's Bay	First Tower to Bel Royal	07-16D	Replace concrete promenade (approx 150m)	Ongoing
49	Grouville Bay	Bunker to Fort William	20-07D	Concrete overlay / repair wall in front of golf course	Planned work
50	St Aubin's Fort	Causeway		Replace /Repair	Planned work
51	Elizabeth Castle	L'Hermitage breakwater		Condition survey & repair	Ongoing
52	Various	St. Brelades Bay and others		Showers for beach users	Ongoing
53	Various	To be confirmed		Concrete overlay	Extent to be agreed
54	Various	To be confirmed		Promenade replacement	Ongoing
55	Various	To be confirmed		Railing replacement	Extent to be agreed
56	St Ouen's Bay	Cutty Sark to Watersplash		Dwarf Wall Replacement	Ongoing
57	Various	To be confirmed		Emergency Work	Unplanned