# Appendix A: Scenarios Framework

## The Scenarios Framework Used in the Tyndall Coastal Simulator

This appendix summarises the scenarios framework used in the Tyndall Coastal Simulator including a quantification of the scenarios used in Phase 1 (2001–2006) and Phase 2 (2006–2009) activities. It addresses climate change, socio-economic change and management responses.

### Introduction

Scenarios, or plausible futures, are a recognised technique for investigating long-term change where there are many complex and interacting variables and where the future is very uncertain (e.g. Carter et al. 2007). The extreme complexity of evolving coastal erosion and flooding systems and other uncertainties surrounding climate and socio-economic change make scenarios a valuable tool for the development of long-term shoreline management policies (Nicholls et al. 2008, 2012).

We have used pre-existing frameworks to construct a number of alternative coastal scenarios and assessed the scale and nature of the resulting erosion and flood risks. In so doing, it is possible to gain a broad appreciation of the scale of future risks that may need to be addressed and the extent to which policies can be developed to manage them.

Two different types of scenario have been combined in our analysis:

1. Climate change projections driven by global greenhouse gas emissions scenarios and their subsequent impact on environmental loadings such as sea-level rise and storm characteristics
2. Socio-economic scenarios which describe changes to population, assets and land use as well as the context in which shoreline management policy and practice might be enacted



R.J. Nicholls et al. (eds.), *Broad Scale Coastal Simulation*, Advances in Global Change Research 49, DOI 10.1007/978-94-007-5258-0

This combination of scenarios is important: climate change will tend to affect the nature of coastal hazards, whilst socio-economic factors will largely determine the severity of resulting impacts. Both are needed to provide a complete picture of future flood and erosion risks. There is no exact causal link between the climate and socio-economic scenarios considered, in part because they were developed for different purposes but also because the climate scenarios are based upon global greenhouse gas emissions, whilst the socio-economic scenarios consider local or national issues. However, some combinations of climate and socio-economic scenarios exhibit trends that are more coherent than others – for example, the highest national growth in UK population and global growth in emissions are often considered to be more plausible than a situation where the UK bucks global trends in greenhouse gas emissions. However, to understand the sensitivity and relative contribution of socio-economic and climate factors, we analysed all scenario combinations. The climate change scenarios focus on key drivers of global climate change such as energy consumption and greenhouse gas emissions, whilst the socio-economic trajectories were developed to consider UK social, political and economic trajectories. Whilst global socio-economic scenarios have been developed (e.g. Carter et al. 2007), there are so many local factors to consider that are not ideal for the scale of analysis in this book. Furthermore, a low-carbon UK does not necessarily imply a decarbonised planet, or vice versa, so testing a wide range of combinations of these scenarios provides the most representative range of possible future flood and erosion risks.

Many of the results reported do not account for socio-economic change and therefore consider the impact of a changing climate on today's development and vulnerability. This is useful to understand the relative contribution to changing erosion and flood risks of climate and socio-economic drivers.

A coastal manager has a range of options by which they can respond to these climate and socio-economic pressures. The range of alternative management policies are also considered across the range of possibilities.

## Climate Change Scenarios

The UKCIP02 (Hulme et al. 2002) and, subsequently, UKCP09 (Lowe et al. 2009) national climate simulations were used to drive the Tyndall Coastal Simulator in Phase 1 and Phase 2, respectively. These both follow the SRES (Special Report on Emissions Scenarios) scenario framework shown in Fig. A.1 (Nakicenovic et al. 2000) typically adopted in international climate change studies. The relationship between SRES, UKCIP02 and UKCP09 scenarios is shown in Table A.1. The process of downscaling from these scenarios to extract climate variables over the Coastal Simulator's model domain is explained in Chap. 2 of this book. Whilst we have focused on the SRES framework, our analysis is compatible with other scenario frameworks such as the emerging RCP/SSP (Reference Concentration Pathway/Shared Socio-economic Pathway) framework being developed for the IPCC AR5 (e.g. Moss et al. 2010; Kriegler et al. 2010).

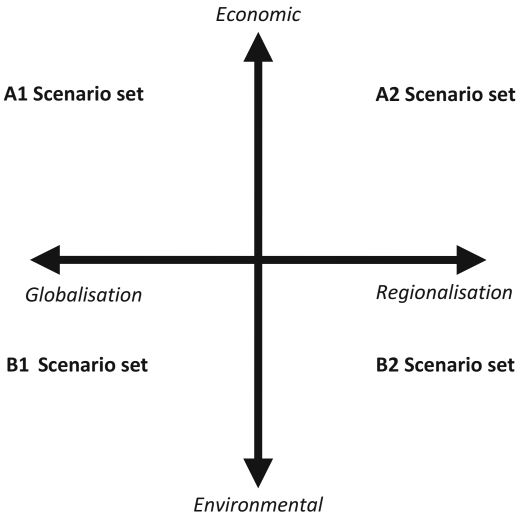


**Fig. A.1** Axes of the four SRES storylines and the resulting sets of scenarios

The four SRES scenario sets are distinguished by two global trends: one varies between strong economic values and strong environmental values, the other trend between increasing globalisation and increasing regionalisation. The scenario sets are summarised as follows (Nakicenovic et al. 2000):

- A1 scenario set – a future world of very rapid economic growth, declining global population after the middle of the century and rapid introduction of new and more efficient technologies. Variants include A1FI (FI–fuel intensive) with high emissions and A1B (B–balanced) with medium emissions.
- A2 scenario set – a heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than the other sets of scenarios.
- B1 scenario set – the same global population as the A1 storyline, but with rapid changes in economic structures towards a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies.
- B2 scenario set – a world in which the emphasis is on local solutions to sustainability issues, with continuously increasing population, although lower than A2, and intermediate economic development.

In all 40 scenarios are defined by SRES, and five of the scenarios typically used and considered as representative 'markers' form the basis of UKCIP02 and UKCP09 scenarios (Table A.2). A summary of all the climate scenarios considered over both phases of the work is shown in Table A.3. Further detail is provided in the following sections.

**Table A.1** Summary of the labels used throughout the book to refer to climate change scenarios and management strategies.

| | | Phase 1 scenarios (based on UKCIP02) | | | | | | | | | Phase 2 scenarios (based on UKCP09) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sea-level rise | Low | | | | Med | High | | | | Low | Med | High | H++ |
| | Offshore wave ($H_s$) | Low | High | High+ | High– | Med | Low | High | High+ | High– | | | | |
| Management strategy (% cliff coast protected) | M1 (100 %) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 101 | 102 | 103 | 104 |
| | M2 (71 %) | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 105 | 106 | 107 | 108 |
| | M3 (34 %) | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | – | – | – | – |
| | M4 (34 %) | – | – | – | – | – | – | – | – | – | 109 | 110 | 111 | 112 |
| | M5 (34 %, no nourishment) | – | – | – | – | – | – | – | – | – | 113 | 114 | 115 | 116 |
| | M6 (16 %) | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | – | – | – | – |
| | M7 (0 %) | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 117 | 118 | 119 | 120 |

When reporting results that also consider socio-economic change, the same numbering scheme is used but prefixed by WM, GS, LS and NE to correspond to the world markets, global sustainability, local stewardship and national enterprise socio-economic scenarios, respectively. Full descriptions of the climate, socio-economic and management scenarios are provided in this Appendix

**Table A.2** Relationship between the SRES, UKCIP02 and UKCP09 scenarios

| SRES | UKCIP02 | UKCP09 |
|---|---|---|
| A1FI | High | High |
| A2 | Medium high | – |
| A1B | – | Medium |
| B2 | Medium low | – |
| B1 | Low | Low |

**Table A.3** Climate scenarios considered during Phases 1 and 2 of the Tyndall Coastal Simulator study

| | |
|---|---|
| **Phase 1** | |
| *Relative sea-level rise* | |
| Low | +0.2 m by 2100 (no change in rate of SLR) |
| Medium | +0.45 m by 2100 |
| High | +1.2 m by 2100 |
| *Offshore wave conditions* | |
| Low | No change |
| Medium | 7 % increase in winter wave height by 2100 |
| High | 10 % increase in winter wave height by 2100 |
| High+ | High, plus clockwise rotation of wave rose 10° |
| High *surge conditions* | High, plus anticlockwise rotation of wave rose 10°<br>No change |
| **Phase 2** | |
| *Relative sea-level rise* | 5th–95th percentiles |
| Low | 0.223–0.614 |
| Medium | 0.239–0.751 |
| High | 0.264–0.913 m |
| H++ | 0.925–2.1 m |
| *Offshore wave conditions* | No change |
| *Surge conditions* | No change |

## Phase 1 Climate Scenarios

Three representative relative sea-level rise scenarios were selected to encompass the range of uncertainty in global, regional and local sea levels. The 'low' scenario of relative SLR represented little or no anthropogenic influence, i.e. a continuation of the recent historic rate of 1.5 mm year$^{-1}$ (see also Miller and Douglas 2004). The 'medium' scenario follows the UKCIP02 medium-high scenario and results in a twenty-first century increase of 0.45 m by 2100. The 'high' scenario is based on the IPCC high limit plus an additional regional (North Atlantic scale) sensitivity of 50 % (following Hulme et al. 2002) to allow for spatial variability in thermal expansion (see Gregory et al. 2001). This scenario results in an increase in sea level of 1.2 m by 2100 over the twenty-first century. All three SLR scenarios used include a regional subsidence rate based on long-term geological observations of 0.7 mm year$^{-1}$ (Shennan and Horton 2002).

Long-term predictions of changes in wind, and hence wave, speed and direction from climate models remain uncertain – although as shown in Chap. 2, our capability in this area evolved alongside the research programme. However, climate model predictions are supported by observations in the North Sea and Atlantic Ocean, which suggested that extreme wave heights may be increasing (Bouws et al. 1996; Kushnir et al. 1997). Given the concern about increasing wave heights including from coastal practitioners and the lack of credible scenarios, the *sensitivity* of erosion and flood risk to a range of possible future conditions rather than downscaling climate model outputs directly was explored. Wave heights were unchanged in the 'low' scenario, whereas in the 'medium' and 'high' scenarios, offshore winter wave heights were increased up to a maximum of 7 % and 10 %, respectively, by 2100. These increases were applied linearly over the twenty-first century. In addition, the 'high' scenarios included +10° (clockwise) and –10° (anticlockwise) rotations of the offshore wave rose. Potential changes to wave period were not considered.

In Phase 1 of the research programme, it was not feasible to test all the combinations of sea-level rise, wave height and wave direction scenarios as well as testing all the management options. Therefore, there was a deliberate focus on the low and the high scenarios of relative sea-level rise, to provide potential boundary limits on the future outcomes. Table A.1 summarises the combinations of scenarios and management options that were tested in the coupled analysis.

### Phase 2 Climate Scenarios

As described in Chap. 2, climate scenarios that were more detailed, and included probabilistic elements, became available during Phase 2 of the Tyndall programme (these were provided by UKCP09, see Lowe et al. 2009). This coincided with the availability of enhanced computing capacity, which allowed more extensive exploration of their consequences and the associated uncertainties. This included detailed analysis of the influence of climate ensemble members on marine climate. This analysis, and the Phase 1 risk analysis (see Chap. 9), showed negligible future (climate-driven) change in surge magnitude and wave height of the Norfolk coast. Consequently in the second phase of analysis, these elements of climate were assumed to be stationary (i.e. to be statistically constant and neither grow nor decay over time). For the erosion and flood impacts analysis, 250 realisations of each of four sea-level rise scenarios were explored. Figure A.2 shows the 5th and 95th percentiles of the low, medium and high scenarios (which correspond to those in Table A.2) and a high-end 'H++' scenario (Lowe et al. 2009; Nicholls et al. 2011). This H++ scenario was interpreted from the IPCC Fourth Assessment Report and subsequent literature that responded to a lack of scientific understanding on the behaviour of ice sheet failure. The lower limit of the H++ scenario was based on the

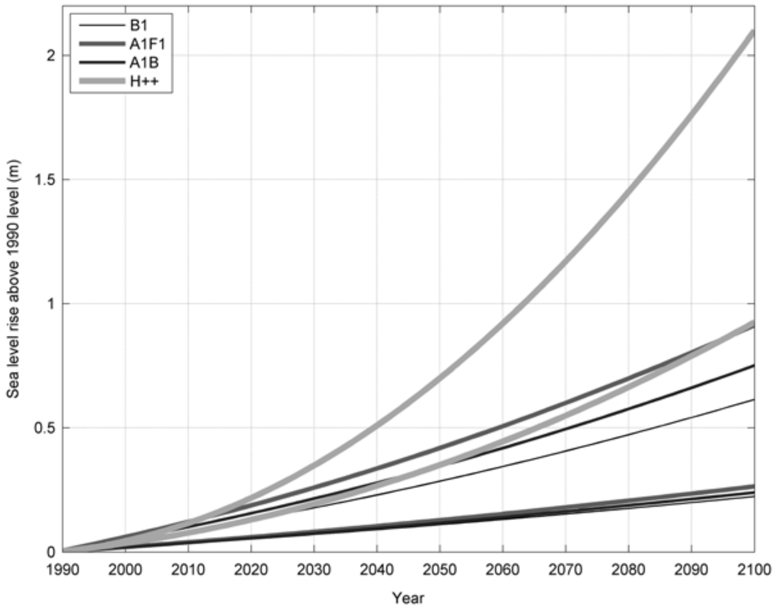


**Fig. A.2** Projected sea-level rise around North Norfolk (Lowe et al. 2009)

maximum global mean sea-level rise given by the IPCC Fourth Assessment Report, whilst the upper limit was inferred from several lines of evidence, including indirect observations of sea-level rise during the last interglacial. This upper limit is believed to be highly unlikely and is intended to inform certain types of contingency planning.

All sea-level rise scenarios are assumed to be normally distributed about the central value (which is at the midpoint of the 5th and 95th percentiles) and the H++ trend is treated similarly to the other three projections.

## Socio-economic Change

To account for potential changes in socio-economic conditions, we use the ForeSight programme[1] scenarios (DTI 2002) which have been applied in a range of future analyses such as the Foresight Future Flooding Study (Thorne et al. 2007). The ForeSight scenarios were developed to explore alternative directions in which social, political, economic and technological changes may evolve over coming

[1] The UK government launched the ForeSight programme in 1994 to prepare for the future by bringing together representatives from business, government, academia and others to identify potential future threats and opportunities. It is currently based in BIS within the UK government.

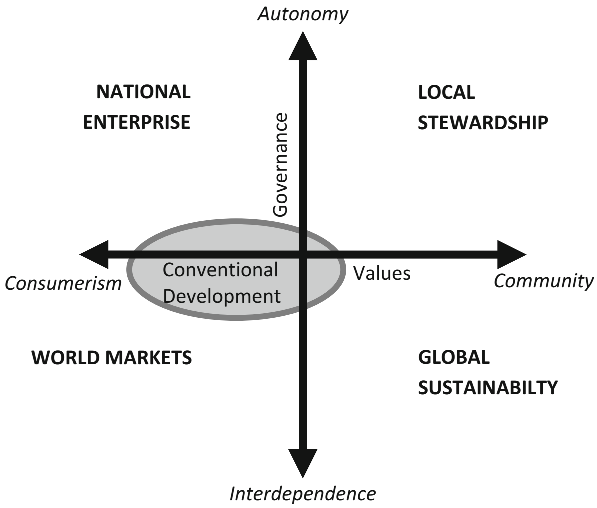


**Fig. A.3** The ForeSight scenario axis and the four scenarios used in this analysis (SPRU 1999; DTI 2002)

decades in the UK. Importantly, they describe a whole range of drivers and issues, not just those related to climate change, and these feed through the entire integrated assessment (cf. Nicholls et al. 2008, 2012).

Typically the four ForeSight scenarios are presented along two axes which define fundamental different ways in which society could evolve (Fig. A.3). Along the vertical axis is the system of governance, ranging from autonomy where power remains at the national level to interdependence where power increasingly moves to other institutions, e.g. up to the EU or down to regional government. Along the horizontal axis are social values, ranging from individualistic values to more community-oriented values.

The national scenarios are summarised in Table A.4, and their interpretation for East Anglia is summarised in Table A.5. This ‘qualitative downscaling’ to consider the local implications of the ForeSight scenarios was a precursor to enumerating key variables for use in the quantitative analysis of land use in Chap. 4. This subsequently enabled the estimation of the change in the number of properties in the floodplain (Table A.6). Contrary to the climate scenarios, the same socio-economic scenarios were used throughout both phases of the research programme. However, as described in Chap. 4, a more sophisticated agent-based modelling approach was used to simulate land use in Phase 2 of the programme, so the details of these scenarios changed from Phase 1 to Phase 2.

**Table A.4** Summary of the ForeSight socio-economic scenarios for the UK (DTI 2002)

| | World markets (WM) | Global sustainability (GS) | Local stewardship (LS) | National enterprise (NE) |
|---|---|---|---|---|
| Description | *People aspire to personal independence, material wealth and mobility to the exclusion of wider social goals. Integrated global markets are seen as the best way to deliver this. Internationally coordinated policy sets framework conditions for the efficient functioning of markets. Wherever possible, the provision of goods and services is privatised, under the principle of minimal government. Rights of individuals to personal freedoms are enshrined in law* | *People aspire to high levels of welfare within communities with shared values, more equally distributed opportunities and a sound environment. These objectives are thought to be best achieved through active public policy and international cooperation within the EU and at the global level. Social objectives are met through public provision, increasingly at an international level. Markets are regulated to encourage competition amongst national players. Personal and social behaviour is shaped by commonly held beliefs and customs* | *People aspire to sustainable levels of welfare in federal and networked communities. Markets are subject to social regulation to ensure more equally distributed opportunities and a high quality local environment. Active public policy aims to promote economic activities that are small scale and regional in scope and acts to constrain large-scale markets and technologies. Local communities are strengthened to ensure participative and transparent governance* | *People aspire to personal independence and material wealth within a nationally based cultural identity. Liberalised markets together with a commitment to build capabilities and resources to secure a high degree of national self-reliance and security are believed to best deliver these goals. Political and cultural institutions are strengthened to buttress national autonomy* |
| Social values | Internationalist, libertarian | Internationalist, communitarian | Localist, co-operative | Nationalist, individualist |
| Governance | Weak, dispersed, consultative | Strong, coordinated, consultative | Strong, local, participative | Weak, national, closed |
| Role of policy | Minimal, enabling markets | Corporatist, political, social and environmental goals | Interventionist, social and environmental | State-centred market regulation to protect key sectors |
| Economic development | High growth, high innovation, capital productivity | Medium-high growth, high innovation, resource productivity | Low growth, low innovation, modular and sustainable | Medium-low growth, low innovation, maintenance economy |
| Structural change | Rapid, towards services | Fast, towards services | Moderate, towards regional systems | More stable economic structure |
| Fast-growing sectors | Health and leisure, media and information, financial services, biotechnology, nanotechnology | Education and training, Large systems engineering, new and renewable energy, information services | Small-scale manufacturing, food and organic farming, local services | Private health and education, domestic and personal services, tourism, retailing, defence |
| Declining sectors | Manufacturing, agriculture | Fossil fuel energy, traditional manufacturing | Retailing, tourism, financial services | Public services, civil engineering |
| Income | High | Medium high | Low | Medium low |
| Equity | Strong decline | Improvement | Strong improvement | Decline |

**Table A.5** Summary of the four storylines and how they are interpreted for East Anglia, including detailed consideration of demography, household location preferences and planning strategies

| Storyline for East Anglia | Demography and migration | Location preferences | Planning strategy |
|---|---|---|---|
| *World market (WM)* | | | |
| The integrated trading systems lead to more development of the main urban centres in East Anglia, which are still shadowed by London. They attract more workforces, at the expense of more remote locations. The increasing economy and wealth boosts private consumption and materialistic personal well-being, testified by larger new houses and more second homes. There will be a continued pressure to build more houses, and these are attracted to coastal and floodplain locations. Consequently, significant developments would occur in all areas including the floodplain and cliff areas | With medical advances, life expectancy rises significantly. Today's decrease of the birth rate accelerates. Inflow migrations are happening for two distinct reasons. On the one hand, the developing urban centres are attractive to the workforce. On the other hand, an increasing number of London workers seek cheaper homes farther from the city, increasing the resident commuters group. There is also an increased individual desire for more permanent leisure location at the coast for both retirees and second-home owners as their purchasing power is increasing | Households have more interest for locations with (very) good connection to the rest of the region and the country. Therefore, it is vital for them to be close to main roads. They are also more interested in locations with a good accessibility to jobs and services in the larger cities, to the expense of remote, small and medium-sized urban areas. Therefore, the current ranking of urban areas is reinforced. Residents' desire for environmental amenities is also increasing. Also, the importance to be located close to the coast is getting critical for retirees and second-home owners | Regulations are going down as both urban and rural rule out the necessity for defining priority areas. There is a lot less planning intervention in the residential development process so restrictions are not enforced and people choose their location at their own risk |
| *Global sustainability (GS)* | | | |
| The 'think global, act local' motto encourages people to reduce their ecological footprint and to invest in their social network rather than in material and goods. The economy grows at a lower path than today. The main urban centres tend to delegate to smaller towns part of the activities so services are closer to everyone and size differences are lessened. Population and household numbers increase; new developments will be mostly confined to existing urban areas. Less new development on coasts and floodplains arises partly through more planning and also through smaller growth in the number of households. Floodplain occupancy is discouraged under this scenario | With medical advances, life expectancy rises and the number of today's average births reduce, but to a lesser extent than for WM. The 'think global, act local' motto encourages most households to not purchase second homes and to buy existing buildings within urban areas where they work and of reasonable size as it creates economies of scale for the community services and diminish commuting. Migration flows are reduced as economic activities target local workforce and sustainability over high profits | Households are aware of the risks attached to hazardous zones. They prefer locations where they have less impact on the environment. Thus, existing urban areas are favoured to the countryside | Regulations are more restrictive. Both urban and rural planners impose a strict priority hierarchy amongst development areas in order to increase urban density. Risk prevention is enforced throughout the region with safety buffers applied around hazardous locations |

| | | | |
|---|---|---|---|
| *Local stewardship (LS)* | | | |
| Political actions are put in place to boost the local economy which increases jobs provision. The concern about natural resources and the environment pushes political actions to be taken to better inform on the negative consequences of new development in general and second homes ownership in particular. Most people are receptive to these concerns and information. The local economic activities maintain a sustainable viability of every community which are as autarchic as possible and mainly maintain contacts with the surrounding communities. A conservationist ethic and lower demand for new development contributes to the continuing dominance of traditional housing. Floodplain occupancy is kept stable. The urbanisation of the countryside comes to a halt as planning controls are tightened and strong land use control avoids flood-prone areas | With medical advances, life expectancy rises. Today's birth rate trend is inverted as people are encouraged to contribute to the local age pyramid for maintaining the local community alive. Nevertheless, the increased jobs provision still attracts new migrants who settle permanently. External retirees tend to be attracted as today by the region because of its mild weather and its welcoming local community attitude | Autarchy values encourage households to go and remain in areas of origin. Also, they tend to avoid protected and hazardous areas to preserve the community safety as suggested by the politics. Thus, secondary urban areas are growing more than cities. Local economy growth focuses on active neighbourhood activities and local exchanges, which reduces the commuting loads and thus the importance to reside close to main roads | Rural planners impose development priorities to better organise and structure the local landscape around the local community, as they are freed from regional and national strategies. Restrictions are applied firmly for community safety in hazardous zones only. Urban planners' strategies remain the same as the community logic does not prevail as much in larger built areas |
| *National enterprise (NE)* | | | |
| Liberalised markets do not greatly shift the gravity centre of economy towards the region but maintain their activities to today's levels. Population, households, urban areas and second homes increase largely in East Anglia. However, the increase will not be as high as that of the world markets scenario since there are lower levels of investment in housing. As well as the issue of urban sprawl, the increase in the number of households may be exacerbated by a coastal attraction and people relocating in coastal regions from large urban areas like London. Planning controls are relaxed, allowing more buildings and more people to live in floodplains | With medical advances, life expectancy rises. The birth rate keeps at today's level. Personal independence and material wealth encourages people to invest in second homes at the coast. London keeps its influence and migrations occur similarly as today | Households devote their attention on medium-sized urban areas because they are perceived as the right balance between social needs and open-space will. Also, they need to stay close enough to the main jobs centres, represented by the cities and large towns. At the same time, residents have more desire for environmental amenities. Retirees and second-home owners' attraction to the coast is increasing | The planning control is getting weaker, particularly in the countryside, where the economical focus prevails over landscape conservation. Restrictions on hazardous zones remain as today's and less attention is given to the conservation of natural areas |

**Table A.6** Summary of the new and percentage increase of residential (RP) and non-residential (NRP) properties in the floodplain and within 400 m of the cliff top under the four socio-economic scenarios to the 2080s (Chap. 4, see also Mokrech et al. 2012)

| Scenario | Type of property | Local stewardship | | Global sustainability | | National enterprise | | World markets | |
|---|---|---|---|---|---|---|---|---|---|
| | | *N* | % | *N* | % | *N* | % | *N* | % |
| New properties in the coastal floodplain | RP | 1,343 | 8 | 10,882 | 64 | 19,550 | 114 | 19,719 | 116 |
| | NRP | 80 | 2.5 | 1,082 | 34 | 1,908 | 60 | 2,127 | 66 |
| New properties within 400 m of cliff top | RP | 330 | 7 | 511 | 11 | 654 | 14 | 787 | 17 |
| | NRP | 17 | 2 | 44 | 5 | 52 | 6 | 85 | 9 |

## Management Strategies

This coast has been shaped by human management for hundreds of years as shown in Chap. 1. These strategies comprised increasing lengths of hard defences on the cliffed coast and a mixture of toe protection, offshore reefs and beach nourishment on the flood-prone coast. Here we consider different options of protection for the cliffed coast and beach nourishment for the flood-prone coast assuming the other defences on the flood-prone coast are maintained.

A number of different scenarios of coastal management policies were represented to explore how human interventions may change future coastal evolution and flood risk and also influence the system's sensitivity to climate change. As with the exploration of climate and socio-economic scenarios, our approach has been to explore a sufficiently broad range of management policies to ensure we develop a rich understanding of the system behaviour. For example, to understand the importance of cliff erosion, and the sensitivity of flood risk to sediments from the cliffs, we tested policies with no artificial beach nourishment, which at the moment is undertaken from Sea Palling to Winterton to manage flood risk (see Figs. 1.4 (b) and 1.8 in Chap. 1).

Over the timeframe of the project, the Shoreline Management Plan (SMP) was proposed and developed through several consultation periods (see Box A.1). Several of the management strategies correspond to realisations of SMP policies. Management strategy M4+N (with nourishment) is the most closely aligned to current policy; however, shoreline management planning is a dynamic process, and consequently none of the management strategies reported here provide a precise representation of the current SMP (NNDC 2012) policies. M4-N (no nourishment) was intended to reveal the value of beach nourishment in reducing flood risk. M3 and M5 represent policies closely aligned to those considered during the first phase of modelling (M3 is very similar to M4-N), with M5 corresponding to a more radical realignment than M3.

Management policy M2 was included with the intention of informing public debate around the implications of maintaining historic defence policies. M1 and M6 were included to explore the most extreme changes in coastal management (i.e. almost a sensitivity analysis).

In those management scenarios where structures were gradually removed from the coast (M3, M4, M5), effort was made to simulate realistically managed retreat, in that structures were assumed to be removed first from areas with the lowest economic value and allowed to expire without renewal at the end of their expected lives, generally before 2030. This was implemented deterministically for management policies tested during Phase 1 (M3, M5) and probabilistically during Phase 2 (M4). In addition to representing uncertainty in structure failure years, the probabilistic treatment also provided a more progressive representation failure, rather than a sudden simultaneous collapse of extended lengths of structures as was assumed for M3 and M5.

**Box A.1 A Brief History of SMPs in North Norfolk**[2]

In 1996, North Norfolk District Council adopted the first generation Shoreline Management Plan along the Sheringham to Lowestoft SMP (Subcell 3b, now SMP6) frontage. In 2002, in advance of the preparation of new guidance from Defra, a review commenced for a modified frontage from Kelling to Lowestoft (SMP6) as one of three national case studies. That revised plan appeared in draft in 2004 to much public disquiet and concern because of the proposal not to maintain or renew large sections of cliff defence (a nonactive intervention policy), where before the policy was to 'hold the line'. Waveney District Council adopted the original plan in 2007. Subsequently an amended version (similar to North Norfolk's – see below) was approved by Great Yarmouth Borough Council. North Norfolk District Council's Cabinet agreed at its meeting of September 2007 that a revised SMP is accepted conditionally and that the government be urged to include a wider economic appraisal, implement integrated coastal zone management and undertake research into the effects of intermittent defences.

In 2009, a revised version of the SMP and a strategic environmental assessment (SEA required by legislation) was subject to consultation. Following the consultation and review, a slightly amended SMP was finally adopted by The Anglian (Eastern) Transitional Regional Flood and Coastal Committee at its meeting on 15 April 2011. As some changes were made to the SMP since the first strategic environmental assessment was undertaken on the 2005 version of the SMP, there was a statutory requirement to reassess and reconsult on an amended SEA. The consultation was completed between February and April 2012, and the consultation responses are now being considered.

North Norfolk District Council's Cabinet resolved to adopt SMP6 alongside its partner organisations at a meeting in November 2011. All partners finally adopted SMP6 at the end of 2012 (NNDC 2012).

[2]Adapted from North Norfolk District Council's webpages: http://www.northnorfolk.org/coastal/9871.asp accessed on 1st December 2012.

**Table A.7** Management strategies tested during the development and application of the coastal simulator[a]

| | Description | Percentage of cliffed coast with coastal protection (%) | Nourishment | |
|---|---|---|---|---|
| | | | No (−N) | Yes (+N) |
| M1 | Construction of seawalls along the entire coast in the year 2000 | 100 | Phase 1 | Phase 2 |
| M2 | Maintenance of all existing structures | 71 | Phase 1 | Phase 2 |
| M3 | Structures removed from less inhabited locations (similar to early draft of the SMP) | 34 | Phase 1 | – |
| M4 | Implementation of the policies recommended by the North Norfolk Shoreline Management Plan (SMP, North Norfolk District Council 2010) | 34 | | Phase 2 |
| M5 | Implementation of the policies recommended by the North Norfolk Shoreline Management Plan (SMP, North Norfolk District Council 2010) but with no beach nourishment at Sea Palling | | Phase 2 | |
| M6 | Structures removed from larger towns/industrial sites, i.e. Overstrand, Mundesley, Bacton Gas Terminal (most radical proposals from an early draft of the SMP) | 16 | Phase 1 | – |
| M7 | Removal of all coast protection structures (i.e. those intended to prevent erosion) in the year 2000 | 0 | Phase 1 | Phase 2 |

[a]In M3 to M6 in Phase 1, structures are removed in 2030, whilst in Phase 2, their failure was simulated probabilistically based on a reliability assessment (Chap. 7)

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R.J. Nicholls et al. (eds.), *Broad Scale Coastal Simulation*, Advances in Global Change Research 49, DOI 10.1007/978-94-007-5258-0