

**COASTAL MANAGEMENT IN THE
21ST CENTURY: COPING STRATEGIES
FOR VULNERABILITY REDUCTION**

by

**R.K. Turner, D. Burgess, D. Hadley,
E. Coombes and N. Jackson**

CSERGE Working Paper ECM 06-04

**COASTAL MANAGEMENT IN THE 21ST CENTURY: COPING STRATEGIES FOR
VULNERABILITY REDUCTION**

by

R.K. Turner^{2*}, D. Burgess^{1,3}, D. Hadley², E. Coombes², and N. Jackson^{3,4}

¹Agri-Food and Bioscience Institute, Belfast, BT9 5PX

**²CSERGE, School of Environmental Sciences, University of East Anglia,
Norwich, NR4 7TJ**

**³Formerly at CSERGE, School of Environmental Sciences, University of East Anglia,
Norwich, NR4 7TJ**

⁴Upstream, London, WC2A 1HR

Author contact details:

Email: r.k.turner@uea.ac.uk

Phone: +44 (0)1603 592551

Fax: +44 (0)1603 593739

Acknowledgements

The support of the Economic and Social Research Council (ESRC) is gratefully acknowledged. This work was part of the interdisciplinary research programme of the ESRC Research Centre for Social and Economic Research on the Global Environment (CSERGE).

ISSN 0967-8875

Abstract

European coasts are coming under increasing threat as a result of climate change from erosion and flooding, with 20% of the coastline seriously impacted and 15 km² of land lost each year (Doody *et al.* 2004). While coastal defences such as sea walls have been constructed since Roman times to protect human settlements from the sea, it is now increasingly recognised that these defences are unsustainable. The security provided by the 'hard' engineered defences has encouraged excessive development on the coast, and the defences themselves have led to the loss of intertidal habitat and the natural protection it provides.

An alternative to maintaining 'hard' defences (hold-the-line) to protect land from increasing sea levels is managed realignment, where the engineered defences are deliberately breached. By allowing the coastline to recede to a new line of defence further inland intertidal habitat is created providing natural protection from flooding and erosion.

In the face of rising sea levels and as existing coastal management strategies are being reviewed, it is pertinent to assess the economic efficiency of all methods of coastal defence. In this study, a cost-benefit analysis is undertaken in the Humber Estuary in North-east England, comparing a strategy of holding-the-line with various managed realignment scenarios. Cost-benefit analysis is viewed as one component of a wider policy appraisal process within integrated coastal management.

Keywords: Managed realignment; Cost-benefit analysis; Coastal defence; Scenario analysis

1. INTRODUCTION

Traditional sea defence and coastal erosion strategies in England and Wales have sought to provide long-run engineered 'hold the line' fixed protection for people, property and other assets against the vagaries of dynamic coastal environments. The British coast has been heavily modified by flood and coastal defences for the last 600 years (Evans *et al.*, 2004), with intensive construction periods around the First and Second World Wars when the need for agricultural self-sufficiency was paramount. Currently, the English coastline is protected by over 2000 km of flood defences – 860 km of erosion protection and 1259 km of flood protection structures (Crooks, 2004). Many of these structures are now reaching the end of their design lives. The expenditure of public funds on the implementation of this approach has been justified by reference to a rank ordering system underpinned by standard economic cost-benefit analysis (CBA) applied on a project by project basis (Penning-Rowsell *et al.*, 2005). However, set against a contemporary and likely future context of increasing sea levels and increasing severity and frequency of storm conditions (Nicholls and Klein, 2005), both the cost and the effectiveness of traditional coastal management must be seriously questioned. As our knowledge of coastal dynamics and climate change improves it has become increasingly apparent that sole reliance on engineered 'hard' defences is unlikely to be sustainable. Instead emphasis is switching to a 'coping strategy' based on a mixed approach, with protection focused on strategic and high value areas and the rest of the coastline left to adapt to change more naturally. Measures such as 'managed realignment' which involves the deliberate breaching of engineered defences to allow coastal migration and the creation of extended intertidal marshes and mudbanks is typical of this new approach (Reed *et al.*, 1999; Andrews *et al.*, 2000; Pethick, 2001; Pethick, 2002; Winn *et al.*, 2003).

This reorientation towards a more flexible management process will not be a straight forward transition. In principle, the new know-how and arrangements should be better able to cope with changing circumstances, changing social tastes, improvements in knowledge about coastal processes, human behaviour and ecosystem 'values', as well as changing technology, factor prices and political ideology (Bower and Turner, 1998). In practice, because of the range of stakeholders and competing resource usages typical of coastal areas a number of challenges need to be urgently addressed. The politics of coastal management has become increasingly polarised and contested (Fletcher, 2003). Consultation processes seeking to take forward new shoreline management plans in England, for example, have stalled and controversy surrounding compensation, planning and development and equity and natural justice has intensified (O'Riordan *et al.*, 2005). The new coastal strategy will also serve to expose and re-ignite a long standing debate about the appropriateness of a decision support system anchored to economic CBA and related appraisal methods. It is the latter problem which is examined in this paper. The next section will look at the evolution and current standing of project and policy appraisal methodology and practice and assess its role in the new approach to coastal management. A case study of managed realignment in the Humber estuary in England will then be presented to illustrate the advantages and limitations of CBA. In the final section, some concluding comments on future ways forward will be set out.

2. COST-BENEFIT ANALYSIS VERSUS POLICY ANALYSIS: DECISION RULE OR HEURISTIC AID

Simplifying matters, CBA can be utilised as a method for identifying a "decision rule" for choosing a preferred alternative, or as a component of a comprehensive policy analysis with an heuristic purpose. In the former role, economic CBA has been directly deployed in order to

indicate which option is welfare maximising according to a utilitarian social welfare function and hence prescribing that option choice. The options assessed must have well defined outputs that are quantifiable and reducible to a single money metric, as costs or benefits. Individual flood protection and/or coastal erosion protection schemes fit this reference frame quite well. It is also possible to perceive of CBA in terms of an 'indirect deployment', with the analysis reflecting rational choice theory outcomes and offering a 'sounding board' against which other forms of appraisal and outcomes can be compared. CBA is based on a particular utilitarian (economic efficiency) social welfare function but as there are no meta ethical rules for selecting social welfare functions then a 'sounding board' comparative evaluation against alternative social welfare functions might be beneficial. The choice will then turn on criteria such as, among others, 'ethical reasonableness' and 'consensus achievement potential'.

In the latter heuristic role, the art of policy analysis is a "set of procedures for inventing, exploring and comparing the alternatives available for achieving certain social ends - and for inventing, exploring and comparing the alternative ends themselves - in a world limited in knowledge, in resources and in rationality" (Rowan, 1976 p137). The concept of integrated coastal management (ICM) seems to require this wider policy appraisal approach. There has nevertheless been a continuing debate in academic and policy making circles about the realities of environmental policy formation and implementation and the most appropriate enabling decision support system and methods and techniques. Is environmental policy better enabled via CBA which requires the aggregation of individual choices made independently in a market context; or via a multi-criteria assessment (MCA) process (which may or may not include a form of economic CBA as one component) that is adapted to real political economy in which plural and contested interests and values have somehow to be reconciled and consensus achieved? Or, can a hybrid policy appraisal method encompassing elements of CBA and MCA as separate but complementary assessment arrays do the best job? Or, is the technical - rational model of appraisal so unreliable that politicians should find alternative ways of legitimising policy decisions (Owens et al, 2004).

Formal CBA techniques have been required to support environmental regulation in the USA since the early 1970s. In the UK, together with Western Europe, environmental policy assessment through CBA was slower to develop and more piecemeal in its application (Pearce 1998; Hanley 2002). The centralised sectoral and ministerial political system in the UK probably accounts for the different characteristics of the policy appraisal approach. Individual government ministries/departments such as those concerned with transport policy and flooding and coastal protection and defence policy have a long track record in project-based CBA going back to the 1960s/70s. The then Ministry of Agriculture Fisheries and Food (MAFF) which also had responsibility for aspects of flooding and sea defence policy rank ordered projects using a CBA methodology which was continually updated and made more extensive in its impacts converge. Guidance evolved from depth-damage property calculations to human health and environmental "intangibles" valuation (Penning-Rowsell and Chatterton, 1977; Parker et al 1987; Penning-Rowsell et al 1992; Penning-Rowsell et al 2005). The first crude application, in 1986, of a prototype environmental contingent valuation study within a public sector project (a sea defence project), for example, was funded within this context (Turner, Bateman and Brooke, 1992). Critics of land drainage and flood protection appraisals conducted during the 1970s and 80s correctly highlighted the importance of the political and institutional framework and warned that this could easily lead to 'regulatory or institutional capture' of CBA (Bowers, 1988). In the last few years the Government has sought to re-orientate its coastal change strategy and to adopt both the principles and practice of integrated coastal zone management (ICZM) (Bower and Turner, 1998). Much greater stakeholder inclusion and participation is the avowed aim

(Evans *et al.* 2004; Defra, 2005; English Nature, 2005) but the implications for technical decision support systems have yet to be clarified.

Other areas of government have been more resistant to the advances of CBA and related techniques and it was not until 1990 following the publication of the Pearce Report (Pearce *et al.* 1989) and a Government white paper 'This Common Inheritance' (1990) that implementation became in principle more extensive. Best practice guidelines for the valuation of environmental goods using stated preference methods were published in 2002 under a joint initiative of two government departments DTLR and DEFRA (Bateman *et al.* 2002). But a key point to note was that under official guidance both project appraisal via CBA and wider policy appraisal were twin-tracked. This juxtaposition of approaches has been a continuing source of confusion and debate within government circles, confusion which the plurality of relevant academic argumentation has only served to magnify.

So given the at best 'patchy' take up of CBA by policy makers and the sharp divisions about its efficacy in academic and policy circles, is CBA 'fit for purpose'? If society is simply the sum of isolated individuals, and their wants/needs are, if not infinite, many and diverse, and if resources are scarce (relative or absolute) then CBA and its economic efficiency based social welfare function is relevant to and useful for public policy choice making. Further, given that all policy choices are made by humans, some conception of "preferences" and their human motivation lie behind any environmental policy. But many would contend that collective society is more than the aggregation of individuals and that other social welfare functions have validity (e.g. Sagoff, 2000). They would also dispute the economic (new welfare economics) explanation of how preferences are determined and would not agree that self-interestness is the only 'rational' motivation, rather than 'other regarding' preferences towards humans and entities in nature. These differing theoretical and applied viewpoints do not, however, necessarily mean that all forms of technical-rational models of resource allocation appraisal should be abandoned. While there is a very strong case for arguing that technical analysts need to develop a far better understanding of the pressures on and motivations of actual decision makers; and that we currently lack an adequate theory of environmental policy. It is equally true that policy practitioners need to acquire a far better understanding of technical appraisal methods. Environmental problems are often too complex to be solved/mitigated by technical analysis alone, but taking decisions without any formal decision support system would not seem sensible either.

A large body of theoretical work since the 1950s has shown that the concept of a Potential Pareto Improvement (PPI) determined by the Kaldor-Hicks compensation test, which underpins traditional CBA, is not a reliable basis for evaluating environmental policies (e.g. Scitovsky, 1941; Sen, 1970; Boardman, 1974; Bromley, 1990).. The Kaldor-Hicks approach states that a policy is to be judged socially beneficial if the gainers secure enough benefits so as to be able to compensate any losers and still have some net gain left over. Such a policy is justified (on efficiency grounds) even if no actual compensation is paid. But a number of theoretical difficulties (the Scitovsky, Boardman paradoxes etc) ensure that PPIs cannot be consistently identified by comparing individual welfare changes. Gowdy (2004) concludes that there is no theoretically justifiable way to make welfare judgements without interpersonal comparisons of utility and this is forbidden by the assumptions of neoclassical welfare economics. If compensation is not actually paid it is necessary to know if the gainers really could compensate the losers i.e. the relative size of the gains and losses must be known, which means comparing utilities across different individuals. A way out is to argue that compensation should be actual but this introduces distributional issues which the Kaldor-Hicks approach seeks to avoid. Since managed realignment policy if it is implemented on an extensive basis in the future is likely to

create winners and losers the need for a fair system of compensation is a significant requirement which cannot be avoided.

If CBA (broadly interpreted) is to continue to play a role in the policy process then the neglect of distributional or equity concerns needs to be rectified. A two stage approach needs to be adopted in which the spread of costs and benefits across different affected individuals and groups in society needs to be accounted for and then weighting could be applied. Project appraisals funded by development agencies have often included distributionally weighted costs and benefits calculations but this practice has not been commonplace in other public sector applications in the donor countries themselves. As a minimum, the way in which the CBA 'accounts' are set out and formatted needs to be changed in order to incorporate and highlight financial transfers and the distributional impact of the costs and benefits across stakeholders. Krutilla (2005) has set out a tableau format which disaggregates the benefits and costs of a project or policy among stakeholders and encompasses and records all inter-stakeholder financial transfers. It also serves to highlight key issues such as the level of aggregation adopted and the project/policy accounting boundary.

Adaptive coastal management inevitably involves winners and losers, for example, the deliberate removal of erosion protection on one stretch of coast to allow an accretion of beach material further along; or the realignment of defences to allow extended intertidal marshes at the expense of agricultural land. Compensation/reimbursement measures are not currently in place, although both monetary (e.g. agri-environmental scheme payments, developer compensation funding, environmental taxation (carbon etc.)) and non-monetary ('like-for-like' habitat creation/restoration schemes etc.) mechanisms are possibilities. Aggregation and boundary issues are also important in coastal CBA. The old scheme by scheme approach is not suitable in managed realignment contexts where the spatial scales involved are often at estuary level and encompass a series of sites. The 'whole' estuary strategy needs to be appraised.

Environmental change impacts such as climate change and biodiversity loss often carry with them long term consequences and so policy responses need to be flexible and adapted to long time horizons and future 'surprises'. The standard CBA practice of positive, fixed and short term (<25 years) discounting does not sit easily with these contexts but is critical in determining whether a project/policy passes a CBA test (Lind, 1982). What is indisputable is that discounting at a constant positive social rate of discount is problematic (increasingly so the higher the rate) over a time horizon of 100 years or more. The effect is to make even large costs/benefits incurred in the distant future seem inconsequential and this intuitively feels wrong (Weitzman, 1998). Groom et al (2005) comment that contemporary decisions taken on the basis of standard CBA appear to tyrannise future generations and in some cases impose future risk because future costs carry no weight (due to positive discounting) e.g. nuclear decommissioning, or when current inaction inhibited by cost considerations neglects low weighted future benefits e.g. climate change.

While zero discounting may be a threat to the least well-off in today's society, and a single invariant low rate of discount could allow a greater volume of projects to pass the CBA test and therefore strain resource capacities, some modification to the standard procedure is overdue. There is now a growing consensus on the adoption of a time declining discount rate (DDR) procedure over at least a 100 year time horizon. Official guidance on UK public sector project/policy appraisal now advocates such an approach (HMT, 2003) and it also fits more easily with the strategic policy goal of sustainable development.

For some the case for DDR is, however, still not proven beyond doubt (Groom et al, 2005). But given the underlying message in this paper, that whatever decision support system is eventually adopted it must be suitable for utilisation by real policymakers operating iteratively in the non-linear real world political economy, then DDR has more advantages than limitations. Along similar lines, critics of CBA have questioned the way in which standard CBA values the losses and gains connected to projects/policies. Knetch (2005) claims that individuals discount future losses at a lower rate than the value of future gains and that therefore rates reflecting observed individual preferences would give more weight to future environmental losses, justify greater current sacrifices to deal with them and support policies that reduce the risk of future losses. We adopt a 100 year time horizon for the managed realignment case study analysis and also highlight the influence of DDR.

Over the years work done by behavioural and experimental scientists have shown that individuals' preferences do not always conform with the standard assumptions of CBA theory (Gowdy 2004). The theory assumes that each individual has consistent preferences over all combinations of private and public goods, that these preferences are reasonably stable across time and that they are independent of the contexts in which, and the mechanisms through which, they are revealed. Analysts working with stated preferences techniques (contingent valuation surveys and choice experiments) in environmental and other contexts have found responses that contravene these assumptions (so-called "anomalies"). Psychologists have found explanations for these behavioural responses which to the standard economist seem 'non-rational'. Other critics of standard economics argue that it is the rational choice theory itself which is problematic because it denies the existence of 'endogenous preferences' i.e. preferences that depend on personal experiences, social context and historical/cultural background.

To navigate a route through the complex and diverse set of arguments about human preferences and motivations specifically in relation to environmental policy a few simplifying assumptions will be introduced. In the first instance, we will assume that there is a legitimate and meaningful role for market transactions and related human behaviour in the environmental domain and that therefore CBA is not ruled absolutely out of scope (Aldred, 2002). For a critique of this assumption, see O'Neill (1997) and Burgess *et al.* (2000). Second, we assume that a typology of environmental values based on 'use' and 'non-use/existence' value concepts, more or less captures human-related instrumental and intrinsic environmental values (Turner, 1999); and that comparability and monetary incommensurability problems are not totally intractable (Aldred, 2002), at least as far as 'use' and option values are concerned. Existence values do not fit into this consumer frame of reference and are better elicited through more deliberative forms of valuation in which individuals are encouraged to act as citizens in a collective process (O'Connor, 2002). For arguments in favour of including moral sentiments i.e. non use/existence values, via WTP/WTC, in CBA see Zerbe *et al.* (2006). Thirdly, that since public (environmental) goods often do not have market price tags and society requires that their provision should be decided by collective decisions, it is legitimate to take into account individual preferences, values or attitudes and guard against the dominance of special interest groups and/or special pleading (Sugden, 2005). The aggregation of individual preferences represents the collective choice outcome and the individual preferences themselves are given and context independent.

Given these assumptions a pragmatic way forward is to accept that behavioural anomalies (i.e. preferences that fail to satisfy standard economic coherence conditions) exist but that their prevalence can be reduced to such an extent that stated preference studies/data can play a useful role in the project/policy appraisal process (Hanley and Shogren, 2005; List, 2005).

Other economic valuation methods such as revealed preference methods (travel costs, hedonic pricing) are also still available and relevant for 'pricing' a wide range of environmental goods/services. So comparisons of value findings derived from similar methods across different environmental goods/services and rough 'ball park' comparisons across method outcomes can provide some meaningful indication of economic value (short of absolute money values).

As the process of environmental change across local to regional and up to the global scale has intensified and increased in pace, so the risks posed to the integrity and resilience of ecosystems, not least in coastal areas have increased in parallel. Unanticipated irreversible damage to "critical natural capital" is a risk that not only impacts on environmental systems but also on their provision of livelihood support. In the past, nature conservation and protected area policy has been justified by a combination of scientific and ethical 'intrinsic value' arguments. But in contemporary conditions where natural resources are under severe development pressures the traditional arguments in support of ecosystem conservation may not be sufficient to win political arguments. Rather, we require the additional support of what has been called the 'ecosystem services' methodology. This is based on 'instrumental' values in nature (expressed in monetary terms and fitted into the CBA format) to support the case for more protected areas or better management and sustainable use of ecosystems under threat of conversion or degradation from economic development (Costanza *et al.*, 1997; Daily, 1997; Bockstael *et al.*, 2000; Balmford *et al.*, 2002). Both the general amenity value and the value of the carbon storage function provided by coastal wetlands (Turner, *et al.* 2000) are investigated and included in the case study presented in the next section.

The individual ecosystem goods/service valuation approach which fits most easily into the CBA approach can however mislead policymakers (Turner *et al.* 2003a). The total system value is greater than the sum of its parts and threshold effects may lead to non-linear damage impacts. The hierarchical and multifunctional characteristics of ecosystems means that the double counting of benefits from individual services during any valuation aggregation produce is an ever present danger (Barbier, 1994).

This section began by highlighting the two basic rules for CBA, as a "decision rule" method or a "heuristic aid" operating as one component of policy analysis. At various points, issues have been raised which point to a mismatch between CBA (rule variant) as a process of aggregating independent individual choice in a market context and the real world policy process. In the real world it is claimed that the policy challenge is about reconciling contested value realms and achieving consensus and that policy evolves in a recursive and iterative manner (Rhodes, 1997; Sabatier, 1998).

On balance, it seems that the future for CBA as a policy relevant decision aid lies in the policy analysis frame. It is unlikely to become more relevant if it remains as a procedure for identifying which option is welfare-maximising according to a single social welfare function, and if it seeks to prescribe the option choice on claimed "rationality" grounds. As one complementary component of a wider, multi-criteria policy analysis decision support system there is still an important role for economic analysis. CBA accounts properly formatted to highlight distributional issues and incorporating DDR can provide useful information on environmental valuation and policy problems. The appropriate scope for CBA should probably be limited to use and option values in the environmental context, with existence value questions left to other forms of analysis. In the next section we present a case-study of managed realignment in the Humber Estuary to illustrate how CBA could be deployed within a wider policy analysis.

3. MANAGED REALIGNMENT POLICY APPRAISAL

The analysis presented below must be viewed as preliminary and partial but as also providing one significant component of a more comprehensive coastal policy appraisal. The managed realignment example that it is focussed on has a number of particular characteristics which may not always be typical of a more extensive managed realignment strategy. People and property assets as well as nature conservation designation sites, are not part of the trade-off in this set of realignments. The sites have been deliberately chosen to avoid such conflicts and all involve the loss of agricultural land for a compensating gain of saltmarsh and mudflat habitats. In the longer term future, the mixed approach to coastal management may well have to face up to more 'politically sensitive' and highly 'contested' trade offs, especially if the more severe climate change modelling predictions are accurate. But this only serves to emphasise the argument in favour of economic CBA as a complementary component within a policy analysis-based decision support system which will have to grapple with compensation, planning law and regulations, public trust and social norms of fairness and accountability dimensions of decision making. With these caveats in mind we turn to the application of the CBA model to managed realignment policy.

The construction of coastal defences effectively immobilises a naturally dynamic and adaptive ecosystem at the land-sea interface. In response to rising sea levels, a modified coast is unable to adapt by migrating landwards with the result that valuable intertidal habitats are eventually lost ("coastal squeeze"). There are two main consequences of this "squeeze" effect. It can be argued that the ability of the intertidal zone to absorb energy and water and thereby contribute to sea defence will be diminished. The loss of a 'first line' of defence against waves and tides, especially during storm conditions, can result in increased capital and maintenance costs for engineered defences (Reed *et al.*, 1999; Dixon *et al.*, 1998). Secondly, "squeeze" results in degraded or destroyed mudflats, sandflat and saltmarsh habitats. These habitats are significant reservoirs of biodiversity (Boorman, 2003), and have attracted a range of conservation designations. Under the EU Water Framework Directive loss of conservation area must be compensated for on a 'like for like' basis. But the situation is further complicated because many freshwater coastal sites are also protected on nature conservation grounds. Pethick (2002) has claimed that a stalemate might develop between the requirements of freshwater and intertidal habitats conservation. If sea defences are removed the freshwater habitat is compromised, if the defences are maintained then the intertidal habitat is reduced. Managed retreat seems to offer a way of mitigating this problem by deliberately breaking defences, allowing the coastline to recede and the intertidal zone to expand.

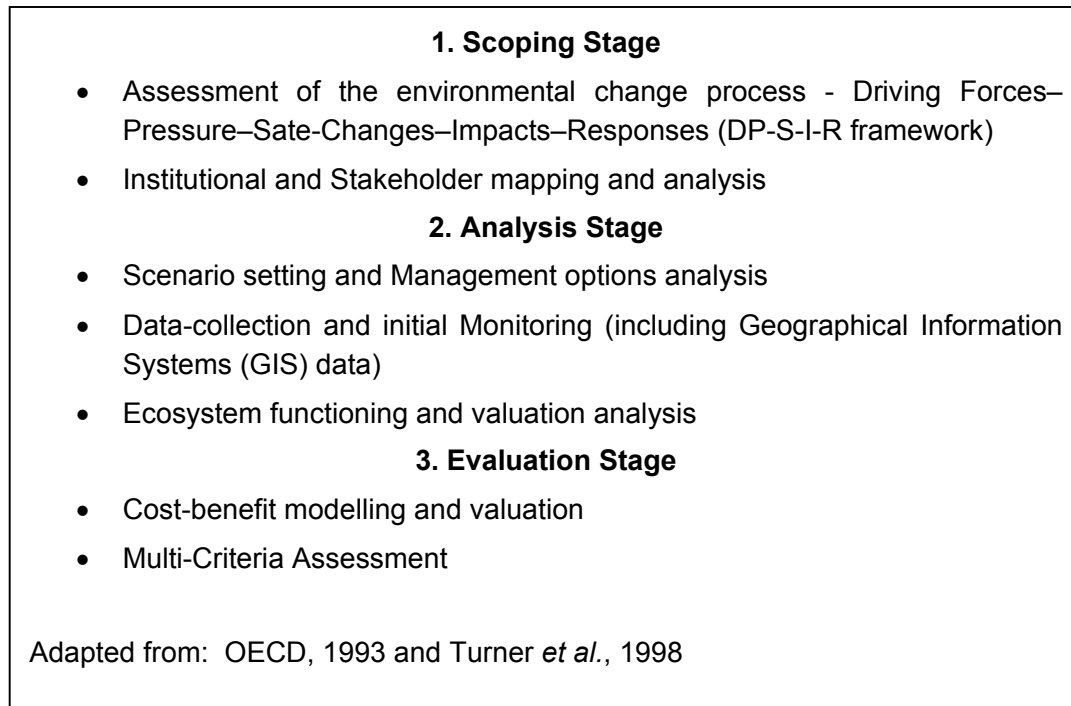
While managed realignment seems to provide a number of benefits the realignment process also incurs engineering costs and other opportunity costs (e.g. the unsubsidised value of any land lost which was previously protected). Government guidance on CBA now emphasises, where appropriate, the need to use a declining discount rate over a long run time horizon and to include as many benefits and costs (market and non-market) as is feasible with a money metric and existing knowledge (HMT, 2003). The CBA then becomes one component of an overall policy analysis which itself is a three-stage process (Turner *et al.*, 2003b). Figure 1 sets out the scoping, analysis and evaluation stages of the decision support system.

4. MANAGED REALIGNMENT IN THE HUMBER ESTUARY, ENGLAND

Cave *et al.* (2003) have used the framework in Figure 1 to examine the complex interplay of factors in the Humber estuary and catchment. Ledoux *et al.* (2005) have applied futures scenario analysis to help scope possible management strategies for the Humber estuary. The

case study presented here builds on this existing body of work and adopts the five scenarios (a “hold the line” approach versus four other possible states of the world with increasing reliance on managed realignment measures) of possible futures set out by Ledoux *et al.* (2005).

Figure 1: Decision support system for the Socio-Economic Analysis of coastal and flood defences



The five scenarios are based on the following assumptions:

1. *Hold-the-line (HTL)*: the existing defences are maintained to a satisfactory standard, but intertidal habitat will be lost due to continued development and coastal squeeze.
2. *Business-as-usual (BAU)*: this option takes into account existing realignments; however compliance to the Habitats Directive is also lax, with continued economic development leading to an overall net loss of habitat due to coastal squeeze.
3. *Policy Targets (PT)*: Economic growth is combined with environmental protection, with realignment undertaken to reduce flood defence expenditure and compensate for past and future intertidal habitat loss in compliance with the Habitats Directive.
4. *Deep Green (DG)*: Environmental protection takes priority over economic growth, while development continues; the maximum feasible area of intertidal habitat is created.
5. *Extended Deep Green (EDG)*: A greater emphasis is placed on habitat creation, with less restrictive criteria being used to identify suitable areas for realignment.

The macro-tidal Humber estuary is one of the largest in the UK, fed by two principal river systems, the Ouse and the Trent. With a maximum tidal length of 147 km from Cromwell Weir on the Trent to the Humber's mouth, and maximum width of 15 km, it is comparable with the Thames and Severn Estuaries (Andrews *et al.* 2000). Draining over a fifth of the land area of England (24,000Km²), the Humber estuary is the largest source of freshwater (approximately 250 m³sec⁻¹) into the North Sea from all the British rivers (Jarvie *et al.* 1997). Much of the land surrounding the Estuary is the result of historical land reclamation, created from the enclosure of salt marshes and mudflats. For example, Davidson *et al.* (1991) estimated that 4,600 hectares of intertidal habitat was reclaimed in the Humber between 1600 and 1850. Consequently, approximately 90,000 hectares of land surrounding the Humber Estuary is below high spring tide level and is currently protected by 235 km of flood and coastal defences (405 km including those defences along the tidal reaches of the Rivers Trent and Ouse) (Winn *et al.* 2003). This area is comprised of mainly agricultural land (85%), limited housing (8%) and commercial or industrial activities (3%).

The Humber Estuary is of international importance for wildlife, particularly birds, with a large area of intertidal habitat of between 10-11,000 hectares (Environment Agency 1998; Andrews *et al.* 2000), of which around 90% consists of mudflats and sandflats with the remainder being mainly saltmarsh (Winn *et al.*, 2003). This intertidal habitat plays an important role within the estuary, through the recycling of nutrients within the estuary, and their role as soft sea defences, dissipating wave energy. They are highly productive biologically in terms of bird species - the Humber is recognised internationally for its breeding, passage and wintering birds. The entire estuary has been proposed as a marine 'Special Area of Conservation' (SAC) while the Humber Flats are designated a 'Special Protection Area' (SPA), 'Site of Special Scientific Interest' and Ramsar site.

However, through land-claim, the Humber estuary has an uncharacteristically low extent of saltmarsh for an English Estuary (Davidson and Buck, 1997). Jickells *et al.* (2000) have estimated that more than 90% of the intertidal area and sediment accumulation capacity of the Humber estuary has been lost over the last 300 years with protected areas becoming threatened. In areas with extensive seawalls and commercial development, such as around Grimsby and Hull, tidal flats are narrow (<100m wide) or absent. The natural succession of marine to terrestrial environments has been truncated by the construction of seawalls. Before extensive human involvement the vegetation succession probably incorporated much wider tracts of saltmarsh, progressing to less saline fen and carr environments, it now ends at mature saltmarsh. These types of marginal marine-terrestrial environments are no longer present in the Humber system (Andrews *et al.*, 2000).

In addition to the loss of intertidal habitats through reclamation and coastal squeeze, there is also concern regarding the state of traditional sea defences within the Humber Estuary (Ledoux *et al.*, 2005). As many of the defences in the estuary were built following the 1953 flooding disaster on the East Coast, they are now reaching the end of their design life and are currently unsatisfactory and in need of repair or replacing (Environment Agency, 2000). Both of these problems are likely to be exacerbated by climate change related sea level rise and increased storm conditions (Evans, *et al.* 2004). With the reduction of intertidal habitats and increasing costs of maintaining defences, the flood defence strategies for the Humber estuary are being reassessed and a limited amount of realignment work has begun. In 2003, the EA undertook the first realignment of the flood and coastal defences in the Humber, by breaching the defences at Thorngumbald, on the north bank of the Humber, east of Hull creating 80 hectares of intertidal habitat, having identified a further 11 potential sites (Environment Agency, 2000; Pilcher *et al.*, 2002).

To identify areas suitable for future possible realignment in the Humber for each of the scenarios outlined in previous section, five key criteria were considered – see Figure 2

Figure 2: GIS – based realignment site location criteria

Criterion 1 – The Area below the High Spring Tide Level

The high spring tide level is the highest point at the coastline that is reached by the sea during a spring tide. The area below the high spring tide level illustrates the maximum area of intertidal habitat that could be created, before other factors are considered.

Criterion 2 – The Present Land Use of the Area

In all the managed realignment scenarios, i.e. BAU, PT, DG and EDG, it was not considered appropriate to carry out realignment where protected flora or fauna or historical/cultural assets would be put at risk. Therefore Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC) and other similarly protected areas together with historically significant buildings were excluded from the realignment areas.

Criterion 3 – The Infrastructure of the Area

For all of the scenarios, the transport network – including roads, railway lines and canals – were taken into account.

Criterion 4 – The Historical Context of the Area

The BAU, PT and DG scenarios considered the historical context of the potential areas for realignment. This constraint dropped for the EDG scenario.

Criterion 5 – The Spatial Context of the Areas

SIZE: The BAU, PT and DG scenarios considered that it would only be cost effective to realign areas that are greater than 5 ha in size (Pilcher *et al.*, 2002), while EDG scenario did not comply with this restriction, considering the creation of any intertidal habitat to be beneficial.

SHAPE: The BAU, PT and DG scenarios considered that the optimum shape for realignment areas can be considered as a trade-off between creating a wide intertidal area to maximise benefits, while ensuring that the length of realigned defences to protect the surrounding land is no greater than those which already exist (Pilcher *et al.*, 2002). This limitation was relaxed in the EDG scenario.

ELEVATION: All of the scenarios favoured retreat to an elevation above the high spring tide level where possible.

PROXIMITY TO EXISTING INTERTIDAL HABITATS: All of the scenarios considered that it is preferable to create intertidal habitats where they will fit in with the overall vegetation succession to facilitate the movement of species between habitats (Bergstrom *et al.*, 1996).

Details of the areas that were identified as suitable for realignment, for each of the scenarios, are illustrated in Table 1. The table shows the implications of realignment on defence length, the amount of habitat that could be created and the subsequent impacts on carbon sequestration. Figure 3 illustrates the extent of the area of habitat that could be created under each of the scenarios.

Table 1: Details of areas suitable for realignment

	<i>Scenarios</i>				
	<i>HTL</i>	<i>BAU</i>	<i>PT</i>	<i>DG</i>	<i>EDG</i>
Length of defences before realignment (km)	405.3	405.3	405.3	405.3	405.3
Length of defences after realignment (km)^a	405.3	396.8	361.6	318.2	284.5
Length of realigned defences (km)	0.0	7.0	30.8	69.0	102.7
Length of unsatisfactory defences after realignment (km)	64.6	61.9	42.2	38.2	34.0
Amount of intertidal habitat created by realignment (ha)^b	0.0	300.2	1320.9	2332.4	7493.6
Estimated tonnes of Carbon stored each year^c	0	660.6	2908.8	5135.1	16501.8

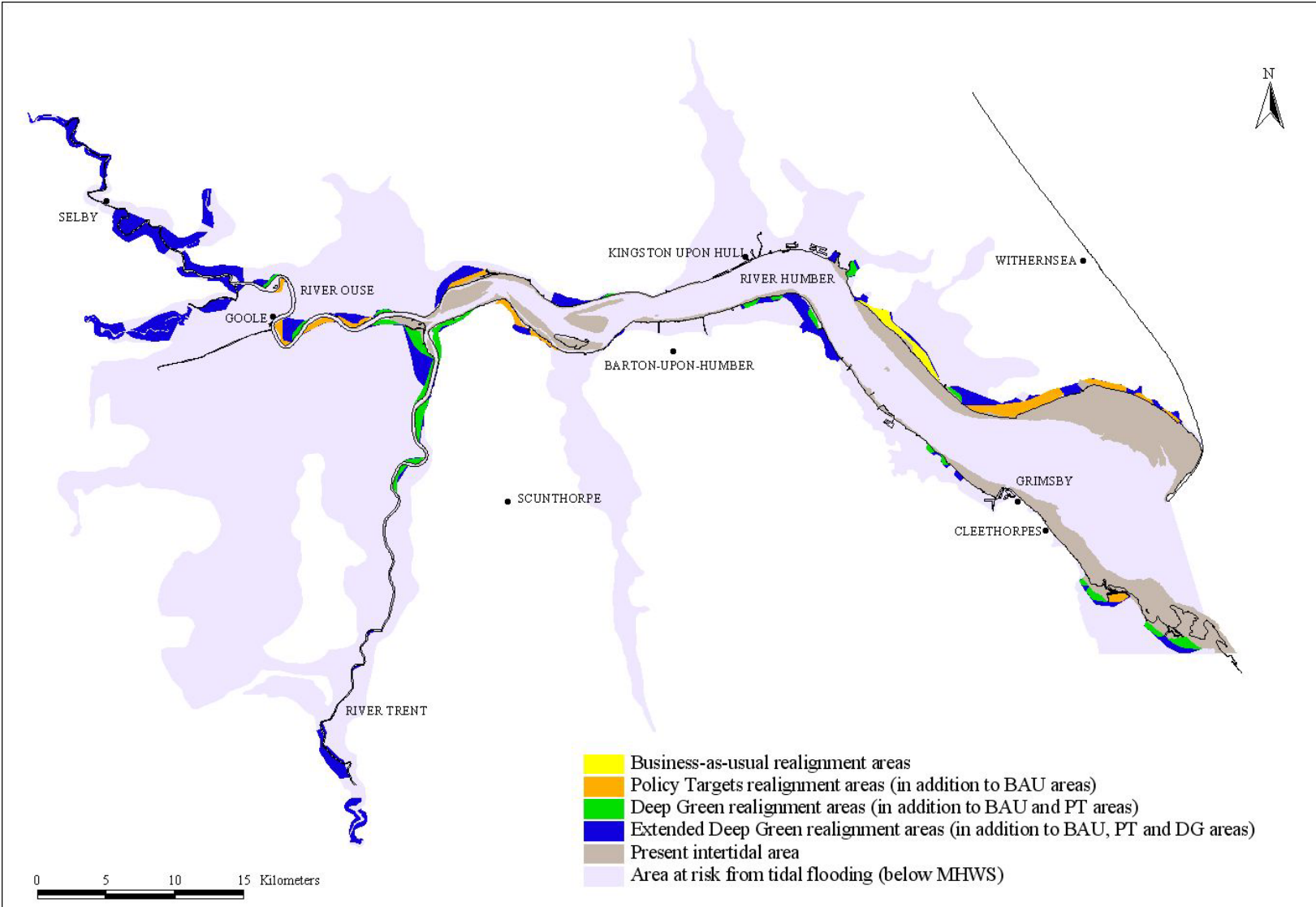
Notes:

^a The process of realigning defences can involve the maintaining of existing defences and potentially the creation of new sea walls therefore the length of defences after realignment is greater than the length before minus the length to be realigned.

^b Due to uncertainty over the loss of intertidal habitat due to coastal squeeze over the next 50 years, it is assumed that no further coastal squeeze takes place. Therefore, the Hold-the-line scenario as the baseline scenario assumes no loss of intertidal habitat and no carbon sequestration, and the habitat creation and sequestration in the other scenarios are relative to base.

^c Estimates of the carbon storage capacity of newly created inter-tidal habitat are derived from Andrews et al, 2000.

Figure 3: Areas suitable for managed realignment in the Humber Estuary under the various scenarios



5. REALIGNMENT COST- BENEFIT MODEL

The elements of the analysis are summarised in the three equations and Table 2 below and follow the standard ‘with and without’ procedure which in this case sets the net discounted benefits of realignment against the net discounted benefits of the hold-the-line traditional sea defence strategy.

Hold-the-line ‘Status Quo’ Defences

$$\text{Where: } C_t^{sq} = \sum_{t=0}^T \frac{1}{(1+r)^t} \left[l^{sq} (C_{r,t}^{sq} + C_{m,t}^{sq}) + C_{br,t}^{sq} \right]$$

C_t^{sq} = Present value of total cost of status quo defences at time t (£million).

r = Discount rate.

l^{sq} = Length of the status quo defences (km).

$C_{r,t}^{sq}$ = Replacement cost of the status quo defences at time t (£/k).

$C_{m,t}^{sq}$ = Maintenance cost of the status quo defences at time t (£/km/yr).

$C_{br,t}^{sq}$ = Cost of repairing breaches in the status quo defences at time t (£/km).

Managed Realignment

$$\text{Where: } C_t^{mr} = \sum_{t=0}^T \frac{1}{(1+r)^t} \left[l^{mr} (C_{k,t}^{mr} + C_{m,t}^{mr}) + a^{mr} (L_{agr,t}^{agr} - B_{e,t}) \right]$$

C_t^{mr} = Present value of total cost of managed realignment at time t (£million).

r = Discount rate.

l^{mr} = Length of the managed realigned defences (km).

$C_{k,t}^{mr}$ = Capital cost of realignment at time t (£/km).

$C_{m,t}^{mr}$ = Maintenance cost of realignment at time t (£/km/yr).

a^{mr} = Area of intertidal habitat created by realignment (ha).

$L_{agr,t}^{agr}$ = Forgone agricultural land value if realignment takes place (£/ha).

$B_{e,t}$ = Environmental value gain associated with realignment e.g. habitat services, functions and products (£/ha).

Net Present Value

$$NPV_t^{mr} = \sum_{t=0}^t (C_t^{mr} - C_t^{sq})$$

Where:

NPV_t^{mr} = Net present value of managed realignment in comparison to hold-the-line for a given stretch of coastline (£ million).

Table 2 : Values used to estimate the costs and benefits of realignment

Costs/Benefits	Value
Capital costs of realignment ^a	£878,159/km
Opportunity costs:	
Grade 1 and 2 agricultural land ^b	£4,790/ha
Grade 3 agricultural land ^b	£5,458/ha
Maintenance costs of defences ^c	£3,560/km/yr
Replacement costs ^d	£668,441/km
General habitat creation benefits ^e	£621/ha/yr
Carbon sequestration benefits	£7.77/tonne CO ₂ equivalent

Notes:

All values are converted to 2005 prices using the GDP deflators published by HM Treasury (<http://www.hm-treasury.gov.uk/>).

^aCosts based on contemporary realignment schemes (Halcrow, 2000)

^bBased on sale prices (DEFRA, 2004) and adjusted downwards for the effects of the single farm payment following Penning-Rowsell *et al.* (2005).

^cMaintenance costs are taken from Black & Veatch/Halcrow (2005). These are assumed to increase in the future due to the effects of climate change. Following current government guidance (Penning-Rowsell *et al.* 2005) maintenance costs are increased by a factor of 1.5 for the period between 20 and 50 years into the future and by a factor of 2 for years further into the future.

^dOnly the costs of replacing unsatisfactory defences (DEFRA, 2001) not affected by realignment are included.

^eAssumed to be gained immediately, although in practice habitat establishment may take some time before 'maturity' is achieved.

Edwards and Winn (2006) state that the intertidal habitat created by managed realignment can produce benefits by dissipating wave energy and hence reducing the estuary's erosive impact on flood defences. Maintenance cost savings will vary from site to site according to wave climate, coastal topography and consequent defence works. It therefore seems reasonable to assume that across an estuary or extensive stretches of coast, realignment strategies will yield significant maintenance cost savings. We take this possible effect into account within the CBA

by comparing the situation where the costs of maintaining defences are equal across non-realigned and realigned defences with one where the costs of maintaining realigned defences are 50% lower. These results are presented in Table 4 where changes in the 'switching points' (the year in which the NPV of managed realignment scenarios becomes positive) are apparent. Sensitivity analysis indicated that decreases in maintenance costs of less than 50% had little effect on the NPV of schemes.

In order to avoid double counting problems the environmental benefits derived from realignment schemes, as intertidal habitats are created, were treated as one composite value. An estimate of £574/ha/yr (£621/ha/yr when adjusted to 2005 prices) was used based on the results of a meta analysis of wetland values (Woodward and Wui, 2001; Brander *et al.* 2006). But it is also the case that ecosystems such as saltmarshes act as sinks for organic carbon (C) and nitrogen (N) and particle reactive phosphorus (P) (Andrews *et al.* 2000; Jickells *et al.* 2000). The nutrients (N and P) storage function has not been separately valued because its human welfare impact is felt via better water quality and consequent amenity/recreational quality enhancement. This impact we have assumed is already encompassed by our composite wetland value. The same is not the case for carbon burial which we have included as an independent and separately valued benefit of realignment.

Various approaches exist for estimating the monetary value of carbon storage. In this study we made a modest monetary estimate (£7/tc, based on Pearce, 2003; Tol *et al.* 2000) of the environmental damage done per tonne of carbon equivalent emitted into the atmosphere – the "damage cost avoided" by storing rather than releasing a given quantity of carbon equivalent units. Some damage cost avoidance estimates are high as £70/tc, but corroborative evidence from the carbon credit trading market (related to the Kyoto Protocol and greenhouse gas emissions taxation regimes) and from emissions abatement cost estimates, suggests that a value per tc between £7 and £15 is realistic.

To estimate the net present value of providing defence for each of the scenarios, the present value of all the costs were subtracted from the present value of all the benefits. The present value for the Hole-the-line scenario was subtracted from the present values for the BAU, PT,DG and the EDG scenarios respectively, to calculate the net present value of realignment for each scenario (on the basis of a declining discount rate, HMT, 2003). The results are presented in Table 3 and indicate that managed realignment is more cost-effective the longer the time horizon over which the appraisal is undertaken. This effect is particularly marked in the DG scenario. If a constant discount rate or a gamma discount rate are used then the CBA results are significantly different for the DG scenario and to a lesser extent for the EDG and the BAU scenarios. The 'switching points' beyond which NPV becomes positive are summarised in Table 4.

Table 3: Net present Values at 25, 50 and 100 years of Providing Flood Defence for the BAU, PT, DG and EDG scenarios as compared to the Hold-the-Line scenario using a declining discount rate.

Scenario	25 Years	50 Years	100 Years
<i>Business as usual</i>			
BAU	-72,748,196	-88,545,279	-106,964,304
HTL	-70,404,389	-87,805,060	-107,611,098
NPV	-2,343,807	-740,219	646,794
<i>Policy Targets</i>			
PT	-73,335,164	-83,405,325	-96,795,875
HTL	-70,404,389	-87,805,060	-107,611,098
NPV	-2,930,775	4,399,735	10,815,223
<i>Deep Green</i>			
DG	-97,509,518	-102,165,512	-110,870,115
HTL	-70,404,389	-87,805,060	-107,611,098
NPV	-27,105,129	-14,360,452	-3,259,017
<i>Extended Deep Green</i>			
EDG	-94,906,735	-73,084,078	-59,184,503
HTL	-70,404,389	-87,805,060	-107,611,098
NPV	-24,502,346	14,720,981	48,426,595

Notes:

A declining discount rate is used following current HM treasury guidance for project appraisal (HMT, 2003); 3.5% for years 1 to 30, 3% for years 31 to 75 and 2.5% for years 76 to 100.

Table 4: Year in which NPV (scenario costs - HTL costs) becomes positive under alternative discount rates.

Scenario	Discount Rate Type		
	Constant ^a	Declining ^b	Gamma ^c
<i>Assuming equal maintenance costs non-realigned and realigned defences</i>			
Business as usual	125	73	49
Policy Targets	34	34	30
Deep Green	Never	137	63
Extended Deep Green	41	39	34
<i>Assuming maintenance costs of realigned defences are 50% lower</i>			
Business as usual	71	58	44
Policy Targets	30	30	27
Deep Green	Never	88	55
Extended Deep Green	37	36	32

Notes:

^aDiscount rate constant for years 1 to 100 at 3.5%.

^bSee note for Table 3.

^cThe hyperbolic gamma discounting method described by Weitzman (2001) is used here.

Concluding comments

Using for the most part conservative assumptions and estimates, the CBA shows that managed realignment assessed over an extensive spatial and temporal scale and with nm-constant discounting provides efficiency gain. This positive finding needs to be evaluated alongside other considerations in a comprehensive coastal policy appraisal, underpinned by integrated coastal management (ICM) principles and practice. Current coastal policy and institutions fall well short of ICM and issues of distributional equity, compensation and remuneration, and inclusion, trust and accountability all remain to be satisfactorily resolved. Setting out the CBA in a format which highlights the financial flows between stakeholders will be a necessary future requirement if the more flexible/adaptive coastal management strategy is to become the norm. Greater stakeholder inclusion and more transparent technical aids to decision making are also needed.

References

- Aldred, J., 2002. Cost-Benefit Analysis, Incommensurability and Rough Equality. *Environmental Values* 11, 27-46.
- Andrews, J. E., Samways, G., Dennis, P. F. and Maher, B. A., 2000. Origin, abundance and storage of organic carbon and sulphur in the Holocene Humber Estuary: emphasising human impact on storage changes. In Shennan, I. and J. Andrews, J. (Eds), *Holocene Land-Ocean Interaction and Environmental Change around the North Sea*. Geological Society Publishing House, Bath, UK. **Geol. Soc. Spec. Publ. 166**: 145-170.
- Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., and Turner, R.K., 2002. Economic reasons for conserving wild nature. *Science* 297, 950-953.
- Barbier, E. B., 1994. National capital and the economics of environment and development. In Jansson, A.M., Hammer, M., Folke, C. and Constanza, R. A. (Eds), *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*. Island Press, New York.
- Bateman, I., Carson, R., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D., Sugden, R. and Swanson, J., 2002. *Economic Valuation with Stated Preferences*. Edward Elgar, Cheltenham.
- Bergstrom, J. C., Boyle, K. J., Job, C. A. and Kealy, M. J., 1996. Assessing the Economic Benefits of Groundwater for Environmental Policy Decisions. *Water Resources Bulletin* 32(2), 279-291.
- Black & Veatch/Halcrow, 2005. *Humber Estuary Flood Defence Strategy: Strategy Development Study Technical Report*, Report to the Environment Agency, Leeds.
- Boardway, R.W., 1974. The welfare foundations of cost-benefit analysis. *Economic Journal* 84, 926-939.
- Bockstael, N., Freeman, A.M., Kopp, R., Portney, P., and Smith, V.K., 2000. On valuing nature. *Environmental science and technology* 34, 1384-1389.
- Boorman, L. A., 2003. *Saltmarsh Review. An overview of coastal saltmarshes, their dynamic and sensitivity characteristics for conservation and management*. JNCC Report, No. 334, Peterborough.
- Bower, B. and Turner, R.K., 1998. Characterising and analysing benefits from integrated coastal zone management. *Ocean and Coastal Management* 38, 41-66.
- Bowers, J., 1988. Cost-benefit analysis in theory and practice: agricultural land drainage projects in Turner, R.K. (Ed.) *Sustainable environmental management: principles and practice*. Belhaven, London.
- Brander, L.M., Raymond, J.G., Florax, M. and Vermaat, J., 2006. The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature. *Environmental and Resource Economics* 33, 223-250.
- Bromley, D.W., 1990. The ideology of efficiency: searching for a theory of policy analysis. *Journal of Environmental Economics and Management* 19, 86-107.
- Burgess, J., Clark, J. and Harrison, C.M. 2000. Knowledge in action: An actor network analysis of a wetland agri-environment scheme. *Ecological Economics* 35, 119-132.
- Cave, R.R., Ledoux, L., Turner, R.K., Jickells, T., Andrews, J.E. and Davies, H., 2003. The Humber catchment and its coastal area: from UK to European perspectives. *The Science of the Total Environment* 314-316, 31-52.
- Costanza, R., d'Arge, R., deGroot, R., Farber, S., Crasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. and Vander Belt, M., 1997. The value of the world's ecosystem services and natural capital. *Nature* 387, 253-260.

- Crooks, S., 2004. The effect of sea-level rise on coastal geomorphology. *Ibis* 146(Suppl.1), S18–S20.
- Daily, G.C., 1997. *Nature's Services*. Island Press, Covelo, California.
- Davidson, N.C. & Buck, A.L., 1997. *An Inventory of UK Estuaries. I. Introduction and Methodology*. Joint Nature Conservation Committee, Peterborough, UK.
- Davidson, N. C., Laffoley, D. D. A., Doody, J. P., Way, L. S., Gordon, J., Key, R., Drake, C. M., Pienkowski, M. W., Mitchell, R., and Duff, K. L., 1991. Nature Conservation and Estuaries in Great Britain. Nature Conservancy Council, Peterborough, UK.
- Defra, 2001. FCDPAG3 Flood and Coastal Defence Project Appraisal Guidance: Economic Appraisal. <http://www.defra.gov.uk/enviro/fcd/pubs/pagn/fcdpag3/default.htm>.
- Defra, 2004. Agricultural Land Sales and Prices in England Quarterly. On-line edition (16/06/04), <http://statistics.defra.gov.uk/esg/statnot/alp.xls>.
- Defra, 2005. Taking forward a new Government strategy for flood and coastal erosion risk management in England. <http://www.defra.gov.uk/enviro/fcd/policy/strategy.htm>.
- Dixon, A. M., Leggett, D. J. and Weight, R. C. 1998. Habitat creation opportunities for landward coastal re-alignment: Essex case study. *Journal of the Chartered Institution of Water and Environmental Management* 12, 107-112.
- Doody, P., Ferreira, M. Lombardo, S., Lucius, I., Misdorp, R., Niesing, H., Salman, A. and Smallegange, M., 2004. Living with Coastal erosion in Europe: sedimentation and space for sustainability: Results from the EUROSION study. European Commission.
- Edwards, A. M. C., and Winn, P. S. J., 2006. The Humber Estuary, Eastern England: Strategic planning of flood defences and habitats. *Marine Pollution Bulletin* 53, 165-174.
- English Nature, 2005. *Our coasts and seas - making space for people, industry and wildlife*. English Nature, Peterborough.
- Environment Agency, 1998. *Humber Estuary: State of the Environment Report*. Environment Agency.
- Environment Agency, 2000). *Planning for Rising Tides: The Humber Estuary Shoreline Management Plan*. Environment Agency.
- Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A., 2004. *Foresight. Future Flooding. Scientific Summary: Volume I - Future risks and their drivers*. Office of Science and Technology, London.
- Fletcher, S., 2003. Stakeholder representation and the democratic basis of coastal partnerships in the UK. *Marine Policy* 27, 229-240.
- Gowdy, J.M., 2004. The revolution in welfare economics and its implications for environmental valuation and policy. *Land Economics* 80, 239-257.
- Groom, B., Hepburn, C., Kondouri, P. and Pearce, D., 2005. Declining discount rates: the long and short of it. *Environmental and Resource Economics* 32, 445-493.
- Halcrow UK, 2000. *Humber Estuary Tidal Defences, Urgent Works 1 - Little Humber to Thorngumbald Clough*. Engineer's Report prepared for the Environment Agency.
- Hanley, N., 2002. Cost-benefit analysis, In Folmer, H., and Landis Gabel, H., (Eds.) *Principles of Environmental and Resource Economics*, Edward Elgar, Cheltenham.
- Hanley, N. and Shogren, J.F., 2005. Is cost-benefit analysis anomaly proof?. *Environmental and Resource Economics* 32, 13-34.
- HMT, 2003. *Green Book: Appraisal and Evaluation in Central Government*. HMSO, London.
- Jarvie, H., Neal, C. and Robson, A., 1997. The geography of the Humber catchment. *Science of the Total Environment*, 194-195, 87-99.
- Jickells, T., Andrews, J., Samways, G., Sanders, R., Malcolm, S., Sivyer, D., Parker, R., Nedwell, D., Trimmer, M. and Ridgway, J., 2000. Nutrient Fluxes through the Humber Estuary - Past, Present and Future. *Ambio* 29(3), 130-135.
- Knetch, J., 2005. Gains, Losses and the US-EPA Economic analyses Guidelines: A Hazardous Product?. *Environmental and Resource Economics* 32, 91-112.

- Krutilla, K., 2005. Using the Kaldor-Hicks Tableau Format for Cost-Benefit analysis. *Public Policy Analysis and Management, Curriculum and Case Notes*, 864-875.
- Ledoux, L., Beaumont, N., Cave, R., and Turner, R. K., 2005. Scenarios for integrated river catchment and coastal zone management. *Regional Environmental Change* 5, 82-96.
- Lind, R., 1982. A primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options, In Lind, R. (Ed.) *Discounting for time and Risk in Energy Policy*, Resources for the Future, Washington.
- List, J.A., 2005. Scientific Numerology, Preference Anomalies, and Environmental Policymaking. *Environmental and Resource Economics* 32, 35-53.
- Nicholls, R.J. and Klein, R.J.T., 2005. Climate change and coastal management of Europe's coast, In Vermaat, J.E., Bouwer, L., Turner, K. and Salomons, W. (Eds.) *Managing European Coasts, Past, Present and Future*, Springer, Berlin.
- O'Connor, M., 2002. Social Costs and sustainability, in Bromley, D. and Paavola, J. (Eds.) *Economics, Ethics and Environmental Policy*. Blackwell, Oxford.
- OECD, 1993. OECD Core Set of Indicators for Environmental Performance Reviews. A Synthesis Report by the Group on the State of the Environment. OECD, Paris.
- O'Neill, J., 1979. Managing Without Prices: The Monetary Valuation of Biodiversity. *Ambio* 26, 546-550.
- O'Riordan, T., Watkinson, A. and Milligan, J., 2005. Living with a changing coastline: exploring new forms of governance for sustainable coastal futures, Tyndall Centre Technical Report, School of Environmental Sciences, University of East Anglia, Norwich.
- Owens, S., Rayner, T. and Binna, O., 2004. New Agendas for Appraisal: Reflections on Theory Practice and Research. *Environment and Planning A* 36, 1943-1959.
- Parker, D.J., Green, C.H. and Thompson, P.M., 1987. *Urban Flood Protection Benefits: A Project Appraisal Guide*. Gower, Aldershot.
- Pearce, D.W., Markandya, A. and Barbier, E., 1989. *Blueprint for a Green Economy*. Earthscan, London.
- Pearce, D.W., 1998. Environmental Appraisal and Environmental Policy in the European Union. *Environmental and Resource Economics* 11, 489-501.
- Pearce, D.W., 2003. The Social cost of carbon and its policy implications. *Oxford Review of Economic Policy* 19, 362-384.
- Penning-Rowsell, E.C. and Chatterton, J.B., 1977. *The Benefits of Flood Alleviation: A Manual of Assessment Techniques*. Gower, Aldershot.
- Penning-Rowsell, E.C., Green, C.H., Thompson, P., Coker, A., Tunstall, S., Richards, C. and Parker, D.J., 1992. *The Economics of Coastal Management: A Manual of Benefit Assessment Techniques*. Gower, Aldershot.
- Penning-Rowsell, E.C., Johnson, C., Tunstall, S., Tapsell, S., Morris, J., Chatterton, J. and Green, C., 2005. *The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques*. Middlesex University Press, London.
- Pethick, J., 2001. Coastal management and sea-level rise. *Catena* 42, 307-322.
- Pethick, J., 2002. Estuarine and Tidal Wetland Restoration in the United Kingdom: Policy Versus Practice. *Restoration Ecology* 10(3), 431-437.
- Pilcher, R., Burston, P. and Davis, R., 2002. *Seas of Change*. Royal Society for the Protection of Birds, Sandy, Bedfordshire.
- Reed, D. J., Spencer, T., Murray, A. L., French, J. R. and Leonard, L. 1999. Marsh surface sediment deposition and the role of tidal creeks: implications for created and managed coastal marshes. *Journal of Coastal Conservation* 5, 81-90.
- Rowan, H., 1976. Policy analysis as Heuristic Aid: The Design of Means, Ends and Institutions, In Tribe, L. (Ed.) *When Values Conflict*. Ballinger, Cambridge, Mass.
- Sabatier, P.A., 1998. The Advocacy Coalition Framework: Revisions and Relevance for Europe. *Journal of Public Policy* 83, 201-220.

- Sagoff, M., 2000. Environmental economics and the conflation of value and benefit. *Environmental Science & Technology* 34, 1426-1432.
- Sen, A.K., 1970. *Collective Choice and Social Welfare*. Holden-Day, San Francisco.
- Scitovsky, T., 1941. Note on welfare propositions in economics. *Review of Economic Studies* 9, 77-88.
- Sugden, R., 2005. Anomalies and stated preference techniques: A framework for a discussion of coping strategies. *Environmental and Resource Economics* 32, 1-12.
- Tol, R.S.J., Fankhauser, F., Richels, R.G., and Smith, J.B., 2000. How much damage will climate change do? Recent estimates. *World Economics* 1, 179-206.
- Turner, R. K., Lorenzoni, I., Beaumont, N., Bateman, I. J., Langford, I. H. and McDonald, A. L., 1998. Coastal management for sustainable development: analysing environmental and socio-economic changes on the UK coast. *The Geographical Journal* 164, 269-281.
- Turner, R.K., 1999. The Place of Economic Values in Environmental Valuation, In Bateman, I.J. and Willis, K.G. (Eds.) *Valuing Environmental Preferences*. Oxford University Press, Oxford.
- Turner, R.K., Bateman, I.J. and Brooke, J.S., 1992. Valuing the Benefits of Coastal Defence: A Case Study of the Aldeburgh Sea Defence Scheme', In Coker, A. and Richard, C. (Eds.) *Valuing the Environment: Economic Approaches to Environmental Evaluation*. Belhaven Press, London.
- Turner, R. K., van den Bergh, J. C. J. M., Soderqvist, T., Barendregt, A., van der Straaten, J., Maltby, E. and van Ierland, E. C., 2000. Ecological-economic analysis of wetlands: scientific integration for management and policy. *Ecological Economics* 35(1), 7-23.
- Turner, R.K., Paavola, J., Cooper, P., Farber, S., Jessamy, V. and Georgiou, S., 2003a. Valuing Nature: Lessons Learned and Future Research Directions. *Ecological Economics* 46, 493-510.
- Turner, R.K., Georgiou, S., Brouwer, R., Bateman, I.J. and Langford, I.J., 2003b. Towards an integrated environmental assessment for wetland and catchment management. *Geographical Journal* 169, 99-116.
- Weitzman, M., 1998. Why the Far Distant Future Should be discounted at its Lowest Possible Rate. *Journal of Environmental Economics and Management* 26, 200-209.
- Weitzman, M. L., 2001. Gamma discounting. *American Economic Review* 91, 260-271.
- Winn, P. J. S., Young, R. M. and Edwards, A. M. C., 2003. Planning for the rising tides: the Humber Estuary Shoreline Management Plan. *The Science of The Total Environment* 314-316, 13-30.
- Woodward R.T. and Wui Y-S., 2001. The economic value of wetland services: a meta analysis. *Ecological Economics* 37, 257-270.
- Zerbe, R.O., Bauman, A. and Finkle, A., 2006. An aggregate measure for benefit-cost analysis. *Ecological Economics* 58, 449-461.