Department for Environment, Food and Rural Affairs

National Appraisal of Assets at Risk from Flooding and Coastal Erosion, including the potential impact of climate change

Final Report

July 2001

A report produced for the Department by:

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Foreword

The Department of Environment, Food and Rural Affairs has commissioned this report to update the findings of the initial National Assets at Risk from Flooding and Coastal Erosion report produced in June 2000. This report replaces and updates the earlier version.

This report extends the original to include:

- Damage estimates for Wales.
- The incorporation of additional data on Flood Defences.
- Assessment of agricultural losses.
- Consideration of the impact of road transportation disruption.
- Provision of preliminary estimates of the impacts of future climate change.

The report therefore brings together and updates the best available data at the country scale on flood and coastal erosion risks in England and Wales for policy development purposes. Whilst the Department commends the report for use by others as a broad overview of the current situation, any such use should take full account of the qualifications in the text and limitations of data available. In particular, readers should be aware that there is a current initiative sponsored by the Department and lead by the Environment Agency to consolidate all data on flood and coastal defences and risk areas in England and Wales. This National Flood and Coastal Defence Database (NFCDD) is intended to provide the basis for improved risk assessments from 2002 onwards.

Any views or opinions expressed do not necessarily represent the policy of the Department of Environment, Food and Rural Affairs or any other Government Department.

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1 Introduction

In June 2000 MAFF (now DEFRA) Flood and Coastal Defence with Emergencies Division (FCDE) published the previous report “National Appraisal of Assets at Risk from Flooding and Coastal Erosion”. That report examined the following issues within the English Regions of the Environment Agency:

- Evaluation of the potential national economic impact of flooding and coastal erosion;
- Identification and estimation of the degree of risk reduction from current national investment in flood defence activities;
- Examination of alternative investment scenarios;
- Identification of methods for prioritising a national investment strategy;
- Identification of methods for measurement and monitoring of the effectiveness of investment in achieving policy aims;
- Identification of areas of uncertainty in the analysis and recommendations for further work to reduce or quantify the uncertainties.

The findings of that report have been used by Government to help inform decisions made regarding the future need for funding and provision of flood and coastal defences.

Following the publication of that report further research was commissioned by DEFRA. This had the following objectives:

- To extend the work of the preceding study for England through into Wales in consultation with the National Assembly for Wales.
- To re-evaluate the available information on standards of service for flood defence.

- To map areas at a sub-regional level according to flood damage characteristics.

- To incorporate climate change scenarios into the estimation of economic impacts.

- To implement the developed methodologies for assessing the impacts of flooding to road traffic and agriculture.

This work has been taken forward by a research team comprising Halcrow, HR Wallingford and John Chatterton & Associates. This report incorporates the findings of this research, and is intended to supersede the report of June 2000. To this end, it follows the same general format as that report and incorporates many of the same tables, though the results published within it are amended to reflect updated or new information.

2 Approach

This section outlines the approach taken in making the assessment of risk and economic impacts of coastal erosion and flooding. The same basic approach has been adopted for current and future climate change scenarios. The refinements in methodology adopted for analysing the impacts of climate change are explained in Section 2.5.

2.1 General Approach for Current Climate Scenario

To achieve the aims of the project, the following approach was adopted:

- Establish the extent of area affected (floodplain or erosion limits);
- Establish what assets lie within those areas (number of properties/other facilities/land use);
- Establish the economic value attached to those assets (damage and loss values);
- Examine the standard of services required of, and provided by, existing defences;
- Estimate the costs of providing and maintaining those standards of service.

As described in the following sub-sections, there are considerable differences between the information needed for the ideal level of analysis and the information that exists. Therefore the approach adopted at this stage has been to make best use of existing information within the constraints of time, budget and the need to have an approach which can be applied on a nation-wide basis.

Full details of the analytical methods, summarised below, have been provided in separate technical reports to DEFRA.

2.2 Defining the Risks

2.2.1 Factors to be considered

Definition of the area at risk can be determined through consideration of three main factors:

- The characteristics of the land at risk, e.g. the floodplain, and the manner in which this may become affected by an event, such as flood extent or rate of erosion;

- The hydraulic condition which might instigate the flooding or erosion, and its frequency of occurrence;

- The likelihood that flooding or erosion will occur, depending upon the degree of protection and adequacy of any defence.

In the ideal situation, for any given hydraulic event the likelihood of occurrence will be accurately known, the performance of the defence in response to that event can be accurately calculated, and the area affected will be precisely determined.

The preferred approach to analysing flood risks would then be one of analysing the discharge of water over or through a defence and into the floodplain for different hydraulic events, and identifying the extent of flooding and depth/duration of flooding for all points within the affected area.

2.2.2 Limitations

There are some general limitations regarding existing information that mitigate against adopting the preferred approach. These are as follows:

- High resolution topographic mapping of flood areas is not consistently available;

- Potentially influential features such as secondary structures and other obstacles are not easily identified from existing mapping;

- There is no existing mapping of erosion extent around the UK coast;

- The probability and magnitude of hydraulic events is not well established on a national basis – detailed studies are site specific and all results are based upon limited data sets;

- Defence details are variable, in some cases non existent and information on standards of protection is even more sparse;

- Defence response/breach failure mechanisms are not sufficiently understood to enable accurate calculation of probability.

2.2.3 *Analytical Approach*

(a) Extent of Flooding

The Environment Agency's existing flood mapping has been used to define flood areas. These maps represent the total extent of the floodplain based upon Section 105 modelling[1], historical flood mapping and the IoH 130 line[2] (in that order of precedence). In adopting this approach the following points should be noted:

- There is no spatial differentiation between floods of different intensity or probability, i.e. not all events will flood the same area;

- There is uncertainty regarding the extreme limits of the defined flood areas, particularly because of the coarseness of definition within the IoH data, and their basis which in some cases include for defences being in place, whilst in others they do not;

- Broad assessments of the limits of fluvial flooding within the floodplain have been necessary;

- Secondary structures, which could restrict flows, may or may not be included in the mapping;

- The information used will not facilitate calculation of depth of flooding.

[1] Modelling and mapping of flood risk areas carried out by the Environment Agency under section 105 of the Water Resources Act 1991

[2] A national assessment of river flood risk areas carried out by the then Institute of Hydrology (now the Centre for Ecology and Hydrology, Wallingford) in 1995 and published as IoH report 130.

(b) Extent of Erosion

Areas at risk from coastal erosion have been defined by thorough review of latest information, obtained primarily from the Shoreline Management Plans. These provide rates of retreat which can be broadly applied to different areas but the erosion risk areas produced are limited in their accuracy because:

- The rates of erosion have been derived from a variety of sources, the reliability of which are unknown;

- Mapping of erosion extent behind defended areas assumes that rates of erosion will be similar to that on adjacent lengths of coastline;

- Differential erosion rates are not considered.

(c) Hydraulic Conditions

With the exception of coastal flood risks (where previous work undertaken for the Association of British Insurers (ABI) has been used), hydraulic conditions have not been considered independently for this present analysis. Account has been made as far as possible through other information (mapped flooding extent and present defence standards) and through some of the analytical methods developed and applied (flood damage algorithms and defence standards algorithm). In adopting this approach the following points need to be considered:

- Differential flood extents cannot be determined;

- The actual standards of defences cannot be determined, nor can the actual potential for exceedence and thus flooding/erosion be accurately assessed;

(d) Standards of Defence

Information about current flood defence standards is not universally available. Previous work undertaken for the ABI has been used to estimate coastal flood defence standards. Advice, and review of data sets, provided through the Environment Agency Regional Offices has been used where available to update this information and build up an assessment of current fluvial flood defence standards.

Probable/likely indicative standards have been estimated for fluvial and estuarine defences through examination of the nature of built property and agricultural land within the floodplain (consistent with FCDPAG3[3]). Where available, information from FDMS[4] has been used to identify whether the indicative standards are met or not. Where this is not possible, a probabilistic algorithm has been developed and applied to determine the likelihood of indicative standards being met.

Note: Throughout this report where values for Standards of Service (SOS) for flood defences are discussed they are considered in terms of the preferred terminology of a probability value that flooding may occur in any given year. Where appropriate the equivalent 'return periods', which are the expected average interval between such events, are quoted.

It has been assumed that coastal protection defences will operate at the necessary "no erosion" standard of service until they reach the end of their residual life, details of which are obtained from the CPSE[5].

The approach adopted has the following limitations:

- The actual standards of protection and thus likelihood of flooding/erosion remain uncertain;

- The timing and frequency of flooding/erosion in periods less than the residual life of the defence are not considered.

(e) Management Scenarios

Throughout the study analyses of damages have been calculated under three defence management scenarios:

- "Do Nothing" i.e. expenditure and work on the maintenance of existing defences and on the consecution of new defences ceases, and the effective standard of existing defence declines through time.

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[3] DEFRA Flood and Coastal Defence Project Appraisal Guidance Volume 3, Economic Appraisal, Published in 1999, available from DEFRA Publications, ref. PB4650

[4] The Environment Agency's Flood Defence Management System, a database of flood defence assets

[5] The Coast Protection Survey of England covering all coast protection structures (i.e. those providing protections against coastal erosion), initially carried out on behalf of MAFF in 1993 and subsequently updated with returns from Maritime District Councils

- "Maintain Current Standard" i.e. maintenance and new work is funded to the extent that current existing standards of protection continue to be provided, but no improvement in those standards are made.

- "Meeting Indicative Standards" i.e. maintenance and new work is funded to the extent that, where necessary, current standards of service are improved to a level to provide appropriate protection to the people and property at risk. These indicative standards are based on DEFRA guidelines.

2.3 Asset Valuation

2.3.1 Factors to be considered

There are three main factors that require consideration:

- The location of assets which lie within the areas at risk from flooding or erosion;

- The economic value attached to the loss or damage of those assets;

- The probability that those assets may be lost or damaged.

The major economic consequences of flooding or erosion can be attributed to built property and contents therein. Second to this is loss or damage to land, e.g. loss of productivity from agricultural land. Other factors include disruption to other economic activity, transport and utilities, and less tangible factors such as impact upon peoples' lives (stress and ill health).

To accurately establish economic impacts, the precise location of individual properties would need to be known. The individual property value plus the contents value would also need to be known, or alternatively (and perhaps more reasonably) the type and size of the property. In addition all other tangible losses/damages would be quantified, for example all other land, and methods would be available to appraise the impacts of less tangible factors.

The favoured approach to analysing economic loss/damages is then one of using the likely frequency, depth and duration of flooding already determined (as described in section 2.2.1) to calculate the values associated with different events.

2.3.2 *Limitations*

There are some general limitations regarding existing information, which are as follows:

- The Ordnance Survey (OS) Addresspoint database provides locations for individual postal delivery points, and has been used as a surrogate to locate and count properties within the floodplain. It does not identify all buildings and provides no differentiation regarding house type;

- Use of Addresspoint for narrow bands such as coastal erosion could prove very inaccurate;

- The CPSE provides only broad band figures for properties affected;

- Size and use of commercial properties is not known for individual properties. These can be extremely variable within a single property type(e.g. retail outlets);

- The data has no allowance for high rise buildings where double-counting of losses could be incurred;

- Individual property values would be difficult to obtain and it would be impractical to attempt to do so;

- Accuracy of information regarding agricultural land use values and productivity is limited to regional pricing and broad based;

- Whilst road traffic disruption has been assessed in terms of increased travel costs any consequential economic impacts on business (for example, due to loss of trade) have not been addressed. Currently there is a lack of information regarding these broader effects due to disruption of services such as road, rail and utilities;

- The wider impacts of flooding are not well established, for example, impacts on productivity both locally and as a national impact;

- Readily useable quantified data on other consequences of flooding or erosion, for example human suffering/health or the natural environment, does not currently exist.

2.3.3 *Analytical Approach*

(a) Built Property

OS Addresspoint has been used as a surrogate to identify individual property locations within flood areas. The capital values of residential properties have been determined using regional house price values (no differentiation has been made by house type, the only split made being between residential and non-residential properties). Rateable values have been used for commercial property, with an average size adopted for nine non-residential property types.

Damages have been assessed using updated FLAIR database values and algorithms developed to estimate average depth/duration of flooding, regardless of location within the floodplain.

(b) Agricultural Land

Agricultural land losses have been determined from Agricultural Land Classification maps and farmland survey data (1999), which provides land values at a county level. Additionally, foregone production through declining gross margin of production has been assessed for a "Do Nothing" management case, using agricultural census statistics as the basis for assessing current yields within floodplain farmlands.

(c) Disruption and Other Impacts

An assessment has been made of the costs incurred through disruption to road traffic travelling on A-roads and motorways within flood risk areas. This is calculated by assessing the costs of diverting traffic on to longer routes, and those associated with longer travel times.

(d) Calculation of Economic Damages and Losses

The project has involved establishing pragmatic methodologies for quantifying the following components:

- Capitalised values of built property (residential and non-residential);
- Damage and damage avoided (benefits) to built property;
- Capitalised values of agricultural land
- Damage to, and foregone, agricultural production

- Increased travel costs due to road traffic disruption.

The method used emulates the approach in FCDPAG3 to calculate Annual Average Damages (AAD's) for any floodplain, from property data counts within these pre-defined areas. It is felt that FDCalc[6] is based on reasonable assumptions considering the scale of this evaluation and employs a methodology that may be seamlessly repeated. **It should be noted that all damages/losses have been calculated as Annual Average Damages (AAD's), not Present Value Damages (PVd's)**. This is appropriate because the damages and investment needs are being considered as part of a rolling programme of schemes that would be implemented on an annual basis over a 50 year period. This obviates the need to address timing of defence breaches and losses, and also expenditure, all of which cannot be reliably ascertained within the scope of this present project.

Whilst repeat fluvial and coastal flood scenarios use updated Middlesex University Flood Hazard Research Centre depth damage data as the basis for estimating damages, damages avoided and therefore the benefits of alternative flood defence strategies, the coastal walk-away scenario uses the capital value of assets to determine the Do Nothing losses.

The FDCalc method is heavily dependent on the availability or deduction of SOS data for discrete flood areas. 'As Indicative', 'Above Indicative' and 'Below Indicative' standards are calculated against the mid range of DEFRA indicative standards set out in FCDPAG3 for land classes A to E. The Indicative SOS is categorised according to the land use in table 2.1.

Where information on current SOS has been available it has been used within the AAD calculation. Where this information does not exist a probabilistic model for the assignment of a current SOS to a reach has been used.

To overcome the difficulty of differential flood risks within a floodplain, weighted event damages have been calculated for selected flood frequencies. These are based upon the percentage distribution of flood depths across the

[6] *The FDCalc methodology is fully described in the Environment Agency publication "Maintenance Operations – Urban Benefits, R&D Technical Report W126". Conceptually FDCalc uses weighted average damages of typical flood depth distributions to calculate AAD's, based on a knowledge of the probability of flooding, and the number and type of properties at risk within a defined area.*

floodplain from data analysed from previous research. For each property, for each return period, event weighted damage per property is accumulated.

Land use band	Housing units (or equivalent) per km	Description of land use	Indicative standard assumed (annual probability of failure)	
			Fluvial	Coastal/Tidal
A	> 50	Intensively developed urban areas	1%	0.5%
B	25-50	Less intensive urban areas	1.3%	0.67%
C	5-25	High grade agricultural or areas with some properties	4%	2%
D	1.25-5	Mixed agricultural with few agriculture related properties	10%	5%
E	< 1.25	Low grade agriculture isolated agricultural or seasonally occupied properties	100%	20%

Table 2.1 Indicative Standards of Service applied

In undertaking this analysis the following assumptions and defaults have been included:

- Tidal and coastal defended areas are assumed to be protected by structures e.g. sea walls or embankments that are susceptible to breaching;

- The design standard is assumed to be that of the current Standard of Service, with the probability of failure in year 0 equal to the SOS, the asset life defaulted to 50 years, if not otherwise stated, and the annual breach probability at the end of the asset life defaulted to 20%;

- Once breached, flooding will occupy all of the floodplain;

- Repeat flooding AAD is calculated for all events greater than SOS. The ‘Walk-away’ scenario is invoked for all events more frequent than and including the event with 20% annual probability;

- In fluvial situations, property affected is only that which lies within the currently defined floodplain, although it is acknowledged that blockages and other factors could change the extent of area affected;

If regional damage values exceeded capital values (their PVd equivalent), damages were capped at this level, assuming a regular distribution of losses, i.e. 1/16.65 of the regional total per year. Losses due to coastal erosion have been determined as annual average values using capital values for properties. When considering coastal erosion damages property counts using OS Addresspoint were decided to be inappropriate. Therefore CPSE property bands were used, although these are broad (e.g. 100-1000). Average values for each band were adopted. Losses were again assumed to be regular, with failure of $1/50^{th}$ of a regions defences in any one year, and linear erosion thereafter. This however differs from flooding in that the annual losses are only 1% per year (to account for deferred losses until such time as a defence fails).

2.4 Defence Needs and Costs

2.4.1 Factors to be considered

The key factors in considering either existing defence against flooding or erosion, or future defence and investment needs, are as follows:

- Location and type of individual defences;
- Standard of protection and residual life of the defence;
- Replacement (i.e. rebuild/refurbishment) and maintenance costs for individual defences/defence types;

Best results are obtained where each defence can be linked to a discrete flood or erosion risk area, the timing and extent of works required for that defence are known, as are the costs. Preferably, sufficient detail will exist to analyse the relative merits of different build/maintenance regimes.

2.4.2 Limitations

There are some general limitations regarding existing information, which are as follows:

- Not all defence locations are identified or recorded in FDMS, particularly fluvial and tidal defences where large gaps in the database currently exist (although this is in the process of being updated);
- Defence type/condition details etc are not available for all defences;

- Defence lengths do not necessarily correspond with discrete risk areas;

- Defence works vary considerably from defence to defence, for example the extent of work required to refurbish/rebuild;

- Costs for defence works vary considerably and may be site specific;

- The relationship between different levels of spend on maintenance and the extended life is not well established.

2.4.3 *Analytical Approach*

(a) Defence Standards

Defence locations have been obtained as far as possible from various regional Environment Agency data sets, the NAW and the CPSE. Some of these databases also contain information on defence standard and residual life. Where this has not been available, a probabilistic approach to estimate standard, and default assumptions regarding residual life, have been adopted.

(b) Defence Costs

Replacement costs for defence structures have been obtained through consultation with the regions of the Environment Agency and a selection of local authorities. These are based upon different types of defence, from which average values for different generic location types have been generated as follows:

Fluvial flood defence:	£ 8,400/km/yr
Tidal flood defence:	£10,300/km/yr
Coastal flood defence:	£32,300/km/yr
Coast protection:	£53,700/km/yr

Through this approach issues such as lack of information on defence type are overcome.

Future costs have been calculated on the basis that all defences will need to be replaced once every 60 years. This is on the basis of them being constructed for a nominal 50 year design life but with the expectation that they may continue to provide residual protection to a similar standard for a further 10 years. Given the differences in the age of defences, and variability in residual life, it has been assumed that the total costs for all defence works will be evenly spread over the next 60 years.

Whilst maintenance costs were provided, these have been queried in some instances, there being uncertainty over future investment needs. Based upon the information provided from some sources, a value of 38% of the annual capital costs has been determined to provide a reasonable estimate of actual costs required (i.e. average annual expenditure for each defence equivalent to 38% of 1/50th of the capital cost of providing a defence with a 50 year life). This value has been adopted for all defences in assessing future investment needs

(c) Changing Standards

The replacement costs associated with altering the defence standard to meet indicative standards have been based upon broad assumptions, but rationalised to derive typical average values for each generic location type. These are as follows:

Fluvial flood defence – change in standard = replacement cost +/-10%

Tidal flood defence – change in standard = replacement cost +/-9%

Coastal flood defence – change in standard = replacement cost +/-11%

Coast Protection – change in standard = replacement cost +/-13%

No data or guidance was available to assess changes in maintenance needs, although these may reasonably be regarded as minimal given the assumed changes in construction are required to provide different standards of defence.

(d) Caveats

This approach adopted for assessing defence needs and costs has the limitations that:

- Many fluvial flood defences are not currently defined in the databases. Consequently the probability of defence works being required could be over or under-estimated, and any analyses seeking to target where expenditure should be directed cannot be accurately performed. Thus, the analyses at this stage must necessarily be focussed at national and regional levels only;

- The actual extent and timing of defence works are uncertain and there will be peaks and troughs in expenditure needs;

- The analysis assumes that all defences will need to be completely replaced within a lifecycle of 60 years, which may be a conservative assumption;

- Costs are based upon estimated values from previous work at other sites, they are not site specific. They also assume any replacement defence will be of the same nature as that which exists at present;

- Maintenance costs are based upon current levels of expenditure rather than an assessment of actual need;

- The costs of providing different standards of defence are broad estimates and could be much higher or lower for individual sites or defence types;

- Account has been taken of the present costs for other structures such as culverts, sluices and pumping stations, but no allowance has been made in the analysis for tidal barrages.

2.5 Climate Change

2.5.1 Factors to be considered

The economic consequence of climate change upon flooding or coastal erosion can be considered through the resultant impact upon standard of service relating to a change in the hydrodynamic regime. There are three main areas to consider, each having different hydrodynamic circumstances:

- Tidal flooding, sensitive to changes in sea level and wave conditions increasing breach potential and frequency of flooding;

- Fluvial flooding, sensitive to changes in river flows increasing breach potential and flooding;

- Coastal erosion, also sensitive to changes in water levels and wave conditions increasing exposure and thus potential for defence failure.

The preferred approach would be to analyse changes in these conditions at all defences, together with associated morphological changes, and reappraise individual defence standards.

2.5.2 Limitations

There are some general limitations which constrain the approach and accuracy of any predictions made:

- There are a range of predicted climate change scenarios associated with the consequences of global warming;
- For any scenario, different existing climate change models predict different values, i.e. there is no commonly agreed single set of results that can be applied;
- Output from models are generated at a large scale thus no detail exists on local variability;
- The interactions between different climate change effects are not understood sufficiently to readily combine information with any degree of certainty (e.g. waves and surges and sea level rise);
- Most analysis is restricted to changes in the hydrodynamics and does not include morphological changes and consequent influences (e.g. river section changes, coastal realignment).

2.5.3 Analytical Approach

(a) Economic impact

In examining the impacts of climate change on the levels of economic loss due to flooding it has been possible to adapt the calculations made to assess AAD from flooding by adjusting current SOS values. Because of the lack of sufficiently detailed information relating to current coastal erosion rates and mechanisms, attempting to quantify the increased economic losses from erosion due to climate change was not considered appropriate.

The main basis for establishing the potential impacts of predicted future climate change on flood frequency and flood damage has been to assess the change in current standards of service (SOS) relative to increases in peak river flow, tidal water levels and predicted changes in wave characteristics.

Combined with these effective changes in SOS, work has also been undertaken to re-evaluate increases in typical flood damage cost estimates associated with given return period events.

(b) Establishing the future climate

An important consideration of the study has been the choice of climate change scenario and General Circulation Model (GCM) used to predict the associated changes in the fluvial and tidal environments. The use of results from both the UK Met Office Hadley Centre for Climate Predictions and Research (HADCM2) and the Max Planck Institute for Meteorology (Hamburg) (ECHAM4) models was considered within this project.

(c) The tidal scenario

For the purposes of this project the SOS has been directly related to the change in the return period of specified overtopping rates for three different 'typical' structure types. This rate has been chosen as the coastal response variable most appropriate to characterise SOS, as it is closely linked to breach probability, is relatively well understood and is influenced by both water levels and wave conditions.

Current tidal flood areas have been categorised according to the type of structure known to be defending them. Then reductions in SOS calculated due to 2075 climate change conditions have been assigned accordingly. No attempt to re-assess the extent of the future tidal floodplain (and so the potential increase in the number of assets at risk) has been made.

(d) The fluvial scenario

Rather than tying the economic assessments to specific climate simulations from a particular GCM and emission scenario, the sensitivity of the national economic assessment of flood damages was based upon scenarios of increases in regional flood discharge. These are expressed as percentage change from the "current" peak flood flow, without reference to a specific GCM or emission scenarios.

The regional information across the UK has been taken from the Flood Studies Report (FSR) (NERC, 1975) and the supplementary report series. The following assumptions were made:

- that flood peak discharge is an appropriate measure of the hazard

- that peak flood discharge increases proportionately for all return periods (that is the shape of the regional growth curve is unaffected by climate change)

- that there are no large-scale river changes which affect the stage-discharge relationship at the catchment scale, and

- that the performance of flood defence infrastructure, and hence damage, is related to the value of peak discharge.

A methodology was developed to provide a future return period for any current return period in any FSR region, for percentage changes in flood flow from –10% to + 25%.

Results for AAD to built property within the fluvial floodplain were calculated under 10% and 20% increases in flood flow. The figure of 20% is broadly in line with the scenarios of increase in winter precipitation by the 2080’s for the current UKCIP studies and appears as an illustrative assessment scenario in the new PPG 25 on development and flood risk. Running scenarios of 10% and 20% flood flow increases has allowed a comparison of the sensitivity to increases in flows to AAD in each of the Environment Agency Regions.

(e) Establishing future erosion risk

The main emphasis of this project is on changes in flood risk as a result of climate change. However, whilst it has been possible to carry out summary calculations of beach changes (as an indicator for erosion risk) for five locations around England and Wales, it has not been possible to produce a regional measure of future erosion risk. Changes in erosion risk are likely to be highly site specific with a potential for large variation over short stretches of coastline.

3 Results

3.1 *Extent of Risk*

Recent significant events, such as the autumn floods of 2000, have raised both levels of awareness of potential fluvial, tidal or coastal flooding, and coastal erosion risks and the expectation that people and properties should be protected against them.

Historically development originally took place in many of these risk affected areas as result of the various benefits to man provided by the location. Latterly, development has expanded in some of these areas as a result of human intervention to provide 'protection' from flooding and erosion. A measure of the potential risk to the nation can be readily appreciated from examination of the number of residential and commercial properties that are located within these areas, over **1.8 million residencies** and **140,000 commercial properties** (see table 3.1a). As a crude estimate, this equates to **4-5 million people** who could potentially be directly affected by flooding or erosion. In addition to this, approximately **1.4 million hectares of agricultural land** is at risk (see table 3.1b). This includes 218,000 ha of Grade 1 land, 61% of the total Grade 1 land in England and Wales (49% lying in East Anglia alone).

The total capital value of the assets potentially at risk amounts to approximately **£222 billion** (see table 3.1c). Approximately 50% of this, worth some £110 billion, lies within Thames Region, with London having a dominant impact upon the figures. For this reason (and questions regarding investment needs) some of the analyses described further on have considered Thames Region separately from the rest of the country to avoid a skewed national picture.

In terms of value, property potentially at risk from sea and tidal flooding represents the largest element (59%), followed by fluvial flooding (34%). Agricultural land represents only approximately 3% of the assets at risk, although this value does not account for potential crop losses.

Coastal erosion losses represent only just over 3% of the total risk, although this is based upon an average estimation of property numbers (value £7.7

billion). However, even taking the extreme property number estimates, for which asset values vary between £2.7 billion and £12.2 billion, this still only represents 2% to 6% of the total capital value of assets at risk.

3.1.1 Mapping of Results

A series of maps (Appendix A) have been produced which, on a broad regional level, display some components of the damage analysis. For presentational purposes, the maps show England and Wales in three regional areas (Northern, Western and Eastern) for each of which four figures have been produced. These are:

1) Estimated "do nothing" Annual Average Damages - These maps show levels of AAD per hectare (calculated by combining damages for built property, agriculture and traffic disruption) based on a "do nothing" scenario.

2) Estimated Annual Average Damages – Current Standards Maintained – These maps show levels of AAD per hectare (calculated by combining damages for built property, agriculture and traffic disruption) based on our knowledge of current standards of service.

3) Comparison of Assigned and Indicative Flood Defence Standards – Where estimates of current standards of service are available these have been mapped against indicative standards related to land use (see table 2.1). Where current standards fall below these indicative standards the maps show the land use band of the area below standard. The maps also indicate areas where no standard of service information has been identified.

4) Estimated Impacts of Climate Change on Annual Average Damage by 2075 – These figures show estimated increases in AAD to built property due to reduced standards of service associated with changes in wave and water level conditions on the coast, and peak flood flows in fluvial systems. The climate change scenarios are discussed in more detail in section 4.

When examining the maps it should be borne in mind that in some areas (defined on figures 3a-c) current SOS information is not available and in these areas damage calculations have therefore been based on probabilistically determined current standards. Also the length of reaches for which damages have been calculated are typically at Environment Agency operational reach level or above. Therefore while the maps illustrate areas that may be of potential concern (in either the level of damages calculated or through the comparison of current and indicative standards of service) it should be recognised that if individual locations were considered at a sub-reach level a different picture might emerge.

		Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	**Resid**	156	161	88	37	41	36	175	53	747
	Comm	8	17	9	3	4	4	13	4	62
Sea/ Tidal	**Resid**	127	26	156	119	30	116	402	50	1,026
	Comm	6	2	10	6	4	10	32	4	74
Total (Flood)	**Resid**	283	187	244	156	71	152	577	103	1,773
	Comm	14	19	19	9	8	14	45	8	136
Coast Erosion	**Resid**	7	0	12	6	19	25	0	44	113
	Comm	< 1	< 1	2	< 1	1	3	0	2	9
Overall Total	**Resid**	290	187	256	162	90	177	577	147	1,886
	Comm	14	19	21	10	9	17	45	10	145

Table 3.1a Number of Properties Within Areas Potentially at Risk (000's)

		Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	**Gr 1,2**	305	17	26	3	12	4	9	6	**1,024**
	Gr 3,4,5	143	120	101	31	85	33	58	71	
Sea/ Tidal	**Gr 1,2**	54	33	34	20	1	31	< 1	2	**432**
	Gr 3,4,5	56	44	40	27	12	47	< 1	28	
Total (Flood)	**All**	**559**	**214**	**201**	**81**	**110**	**115**	**69**	**107**	**1,456**
Coast Erosion	**All**	1	0	< 1	1	< 1	2	0	1*	**5**
Overall Total	**All**	**560**	**214**	**201**	**82**	**110**	**117**	**69**	**108**	**1,461**

Table 3.1b Agricultural Land Within Areas Potentially at Risk (000's hectares)

* Due to limitations on the availability of information on erosion rates within Wales an average value has been adopted.

		Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	Propert	10.7	14.1	7.8	2.9	3.9	4.6	28.6	4.1	76.6
	Agricul	2.9	0.6	0.4	0.2	0.4	0.1	0.3	0.2	5.1
	Total	13.6	14.7	8.2	3.1	4.3	4.7	28.9	4.3	81.7
Sea/Tidal	Propert	9.7	1.8	9.3	7.8	2.9	13.8	81.3	3.5	130.2
	Agricul	0.7	0.3	0.3	0.2	0.1	0.3	0.0	0.1	2.0
	Total	10.4	2.1	9.6	8.0	3.0	14.1	81.3	3.6	132.2
Total (Flood)	Propert	20.4	15.9	17.1	10.7	6.9	18.4	109.8	7.6	206.8
	Agricul	3.6	0.9	0.7	0.4	0.5	0.4	0.3	0.3	7.1
	Total	24.0	16.8	17.8	11.1	7.4	19.8	110.1	7.9	213.9
Coast Erosion	Propert	0.6	0.0	1.3	0.5	1.6	3.2	0.0	0.6	7.7
	Agricul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
	Total	0.6	0.0	1.3	0.5	1.6	3.2	0.0	0.6	7.7
Overall Total	Propert	21.0	15.9	18.4	11.2	8.5	21.6	109.8	8.2	214.5
	Agricul	3.6	0.9	0.7	0.4	0.5	0.4	0.3	0.3	7.1
	Total	24.6	16.8	19.1	11.6	9.0	22.0	110.1	8.5	221.6

Table 3.1c Capital Value of Assets at Risk (£ billion's)

3.2 *Do-Nothing*

The total capital value of assets at risk, presented in table 3.1b, assumes that no defences have been constructed. A more realistic picture of present-day risks must take into account that defences are in place and, even if they were not maintained or replaced, would continue to offer some residual protection for some years to come. These values are presented in table 3.2.

Total values of assets at risk are a combination of some walk-away losses and some damages from repeat flooding. For tidal flood areas the analysis compared both scenarios. The AAD values reported are based on the repeat flooding scenario, which consistently produced lower annualised damage figures in each region compared to walk-away losses. Coastal erosion losses are all based upon capital values. For agricultural losses, it should be noted that although scenarios of both 10 and 20 year periods for decay have been evaluated, the 20 year land management system decay has been used to provide the damage values for table 3.2. It is evident that in overall terms the losses in the 10 and 20 year scenarios are not greatly different and use of the 20 year decay scenario gives the more conservative loss estimate.

In all cases the assumption has been that of a linear distribution of defence failures and economic damages over a 50 year period

The total potential Annual Average Damages have been calculated to be approximately **£3.5 billion** per year. This is the cost to the nation if flood and coastal defences did not exist. These damages are mostly associated with properties affected by flooding, and are relatively evenly spread between fluvial and tidal/sea areas (40% and 44% respectively). Foregone agricultural production makes up 14% of the total, around half of this being within Anglian Region, whilst coastal erosion losses are 2%.

Thames Region alone constitutes approximately 27% of the total do-nothing damages, with £419 million AAD of this within the London tidal area upstream of the Thames Barrier. This represents around 12% of the national total.

However, care should be taken in seeking to draw too many definitive conclusions on these damage figures (and those in sections 3.3 and 3.4) at a regional level, because of the variability in data quality, in particular regarding defence standards of service. Whilst the national totals are considered to be of the right order, regional values should be treated as indicative of the order of magnitude of damages, not as absolute values.

		Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	**Property**	210.9	327.6	220.7	66.6	88.0	67.8	343.5	93.6	1,418.7
	Agricult	181.2	41.3	52.9	18.1	26.7	10.8	16.7	32.7	380.4
	Traffic	0.7	0.7	0.4	0.1	0.2	0.1	0.5	0.2	2.9
	Total	392.8	369.6	274.0	84.8	114.9	78.8	360.7	126.5	1,802.0
Sea/ Tidal	**Property**	153.7	40.1	263.6	128.9	64.1	221.1	571.2	85.0	1,527.7
	Agricult	34.2	17.8	19.4	8.0	1.8	16.7	< 0.1	9.8	107.7
	Traffic	0.3	0.3	0.3	0.2	0.1	0.2	0.3	0.1	1.8
	Total	188.2	58.2	283.2	137.1	65.9	238.1	571.5	94.9	1,637.2
Total (Flood)	**Property**	364.6	367.7	484.3	195.5	152.1	288.9	914.7	178.7	2,946.5
	Agricult	215.4	59.2	72.3	26.1	28.5	27.6	16.7	42.5	488.1
	Traffic	1.0	1.0	0.6	0.3	0.3	0.4	0.8	0.3	4.6
	Total	581.0	427.8	557.2	221.9	180.9	316.9	932.2	221.4	3,439.2
Coast Protect	**Property**	6.0	0.0	13.0	5.0	16.0	32.0	0.0	12.0	84.0
	Agricult	0.1	0.0	< 0.1	0.1	< 0.1	0.1	0.0	< 0.1	0.3
	Total	6.0	0.0	13.0	5.0	16.0	32.0	0.0	12.0	84.3
Overall Total	**Property**	370.6	367.7	497.3	200.5	168.1	320.9	914.7	190.7	3,030.5
	Agricult	215.5	59.2	72.3	26.2	28.5	27.7	16.7	42.5	488.4

	Traffic	1.0	1.0	0.6	0.3	0.3	0.4	0.8	0.3	4.6
	Total	587.1	427.8	570.2	227.0	196.9	349.0	932.2	233.4	3,523.5

Table 3.2 Do-Nothing Annual Average Damages (£ million's/year)

3.3 *Maintain Current Standards*

This analysis tested the resultant damages if defences are to be maintained and replaced to continue to provide their present standards of protection against flooding and erosion, and the investment needed to achieve this.

3.3.1 *Economic Damages*

Even at present levels of protection, some economic damages must be expected as a result of events that exceed the design thresholds for these defences. The resultant average damages from this scenario, totalling **£814 million** per annum, are presented in table 3.3a.

In the Maintain Current Standards (and Meeting Indicative Standards) scenario for agricultural losses AAD has been calculated in terms of one year's lost production. Of the £814 million AAD 12% of these have been calculated as being associated with agriculture. The remaining 88% of damages are largely attributed to built property, with traffic disruption costs making up less than half of one percent of total AAD's.

No data or methods were available to develop any residual damage estimates for coast protection. Therefore, for the purposes of this analysis a somewhat conservative estimate of 20% of the "do-nothing" losses has been adopted.

The damage averted by providing protection can be established from comparison with the "do-nothing" property damages, see table 3.3b. These benefits total nearly **£2.7 billion**. As may be expected from the previous results, protection of flood areas constitute the bulk of these, some 98%, with coast protection offering only 2%. Again, protection provided within Thames Region yields 24% of the benefits, with tidal areas in London upstream of the Thames barrier producing approximately 15% of the total (£397 million). (Indeed the total for London will probably be slightly higher as the barrier provides at least a 0.1% (1 in 1000 year) standard of protection whereas the default maximum for calculating damage values within this analysis has been 0.5%).

3.3.2 *Investment Needed*

Note: This consideration of Investment Needs has been based on feedback on current levels of maintenance and replacement costs drawn from work commissioned separately by the Environment Agency. This work has been reported in the Environment Agency report "Flood Defence Investment Strategy *for England". As the report excludes the Welsh Environment Agency Region no such information on investment levels within Wales has been available.*

A separate review of flood and coast defence renewal and maintenance for Wales would need to be undertaken to fully evaluate investment needs within England and Wales.

Table 3.3c presents the annual average investment required, in England only, to maintain present defence standards, based upon returns from the Environment Agency and a selection of local authorities. This indicates a required spend of approximately £260 million per year on replacement works.

Based on the assumption that the average expenditure required for maintenance is equivalent to approximately 38% of the estimated annual replacement costs, the estimated annual maintenance cost is approximately £100 million. This produces an overall investment needs total of **£361 million** per year, as shown in Table 3.3c.

A further feature of the values should also be noted, as it has a potentially significant impact upon the scale of the projected investment needs. In Thames Region, replacement costs for tidal defences are reported to be ten-times the national average. Valid reasons exist for higher costs, such as accessibility of sites and difficult working conditions. However, whether a ten-fold difference is accurate is questioned. As a guide to the sensitivity of this information, even accepting a three-fold difference would reduce the quoted figures by approximately £20 million. A further point to note relating to the Thames is that no costs have been included for any works associated with maintaining the Thames Barrier.

Some uncertainty was also identified for fluvial defence needs in South West Region. However, for the purposes of this study, these have been ignored, although some additional investment may be determined as necessary at a later date.

In producing the investments needs estimates, average defence costs have been used, with the exception of Thames tidal defences. Sensitivity tests were then performed, applying highest and lowest quoted values for different types of work across all defences in all regions. The conclusion reached from this exercise was that confidence in the accuracy of the total replacement cost estimate is +/- £40 million, i.e. 10% to 15% of the total estimated value. (This excludes any adjustments that may be appropriate as a result of the issues described in South West and Thames Regions).

Even considering all three of the above points, it can be concluded that, as a lowest possible investment scenario, **£300 - £340 million** per annum is still required to maintain current standards of defence.

3.3.3 *Return on Investment*

Averting an annual average damage of £2.72 billion for an annual investment of £360 million, produces an overall return of approximately 8:1. Excluding Thames Region, where the benefit-cost ratio is equivalent to 10:1, gives an overall return of 7:1.

As discussed previously, it is not appropriate to draw too many conclusions regarding other regional differences, but assessment can be made regarding defence against different risks, i.e. fluvial flooding, tidal/sea flooding and coastal erosion. The results of this analysis for England only are as follows:

Fluvial Flood Defence*	10:1
Tidal/Sea Flood Defence*	9:1
Coast Protection	< 1:1

(*costs of 'other structures' evenly divided)

The below unity average figure for coast protection reflects the fact that there may be many areas where defence is no longer justified but it is recognised that there are other areas where very robust economic justification for continued investments can be established. It should also be noted that should assumptions regarding continued losses be incorrect, for example 10% rather than 20% of the do-nothing value, and a higher bound asset value was used, this would modify the average benefit cost ratio to approximately 1.3:1.

Of the flood areas, fluvial defence would appear to offer a marginally better return. However, again this is a broad assumption and in fact both will contain areas with high return and both will contain areas where the benefit-cost ratio is less than unity, where replacement may not be justified on economic grounds.

	Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	81.3	62.8	48.9	25.3	37.2	17.8	207.2	40.7	521.3
Sea/Tidal	28.0	10.8	73.2	20.1	10.5	45.5	59.1	15.5	262.8
Total (Flood)	109.2	73.6	122.1	45.4	47.8	63.4	266.3	56.3	784.0
Coast Protect	1.2	0.0	2.6	1.0	3.2	6.4	0.0	2.4	16.6
Overall Total	**110.4**	**73.6**	**124.7**	**46.4**	**51.0**	**69.8**	**266.3**	**57.3**	**800.8**

Table 3.3a Annual Average Damages by Maintaining Present Levels of Protection (£ million's/year)

	Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	311.5	306.9	225.0	59.5	77.7	60.9	153.4	85.8	**1,280.8**
Sea/Tidal	160.3	47.4	210.0	117.0	55.4	192.6	512.5	79.4	**1,374.4**
Total (Flood)	471.7	354.2	435.1	176.5	133.1	253.5	665.9	165.2	**2,655.2**
Coast Protect	4.8	0.0	10.4	4.0	12.8	25.6	0.0	9.6	**67.5**
Overall Total	**476.6**	**354.2**	**445.5**	**180.6**	**145.9**	**279.2**	**665.9**	**174.8**	**2,722.7**

Table 3.3b Annual Average Damages Avoided to Property by Maintaining Present Levels of Protection (£ million's/year)

		Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	**Replace**	15.83	9.38	24.42	19.55	7.33	3.90	6.38	N/A	**86.78**
	Maint*	6.01	3.56	9.28	7.43	2.79	1.48	2.42	N/A	**32.98**
	Total	**21.84**	**12.94**	**33.70**	**26.98**	**10.12**	**5.38**	**8.80**	N/A	**119.72**
Sea	**Replace**	7.32	0.48	0.68	0.61	8.71	8.61	0	N/A	**26.40**
	Maint*	2.78	0.18	0.26	0.23	3.31	3.27	0	N/A	**10.03**
	Total	**10.10**	**0.66**	**0.94**	**0.84**	**12.02**	**11.88**	**0**	N/A	**36.43**
Tidal	**Replace**	10.97	5.48	6.15	1.23	3.58	8.95	34.45	N/A	**70.82**
	Maint*	4.17	2.08	2.34	0.47	1.36	3.40	13.09	N/A	**26.91**
	Total	**15.14**	**7.56**	**8.49**	**1.70**	**4.94**	**12.35**	**47.54**	N/A	**97.73**
Others	**Replace**	2.72	5.00	0.32	1.18	1.93	3.24	7.50	N/A	**21.89**
	Maint*	1.03	1.90	0.12	0.45	0.73	1.23	2.85	N/A	**8.32**
	Total	**3.75**	**6.90**	**0.44**	**1.63**	**2.66**	**4.47**	**10.35**	N/A	**30.21**
Total (Flood)	**Replace**	36.83	20.33	31.57	22.56	21.55	24.70	48.34	N/A	**205.88**
	Maint*	14.00	7.73	12.00	8.57	8.19	9.38	18.37	N/A	**78.21**
	Total	**50.82**	**28.06**	**43.57**	**31.13**	**29.74**	**34.08**	**66.71**	N/A	**284.09**
Coast Protect	**Replace**	7.29	0	6.67	7.65	9.22	24.98	0	N/A	**55.82**
	Maint*	2.77	0	2.53	2.91	3.50	9.49	0	N/A	**21.21**
	Total	**10.06**	**0**	**9.20**	**10.56**	**12.72**	**34.47**	**0**	N/A	**77.03**
Overall Total	**Replace**	44.12	20.33	38.25	30.21	30.77	49.68	48.34	N/A	**261.71**
	Maint*	16.77	7.73	14.53	11.48	11.69	18.90	18.37	N/A	**99.45**
	Total	**60.89**	**28.06**	**52.78**	**41.69**	**42.46**	**68.58**	**66.71**	N/A	**361.16**

Table 3.3c Investment Needs to Maintain Present Standards (£ million's per year)
(*adjusted maintenance needs, i.e. 38% of replacement costs)

3.4 *Meeting Indicative Standards*

Indicative standards of protection are given in FCDPAG3 and it is recognised that not all defences meet these standards, and indeed some exceed them. This scenario has examined the changes in investment needs and resultant damages if indicative standards are to be met.

3.4.1 *Economic Damages*

The resultant damages and hence benefits if indicative defence standards were to be achieved nationally are presented in tables 3.4a and 3.4b respectively. It is estimated that provision of defences to these standards will reduce annual average damages to £260 million, and thus provide and annual economic benefit of **over £3.2 billion**, an increase of more than £500 million compared to present day protection levels.

However, it must be recognised that these values are based upon probabilistic routines to generate likely defence standards in many areas where the data is currently lacking. Nearly 30% of the increased benefit results from Thames defences alone which appears disproportionate compared to other areas of the country. Consequently, without further data in all areas, it is not recommended that these values are adopted for any other purpose than being indicative of the fact that there is scope to further reduce damages.

3.4.2 *Investment Needed*

The changes to defences, and thus investment needed to meet indicative standards, are also difficult to ascertain given the level of information available to this study. Therefore the two extremes of investment needs have been calculated as national totals, i.e. assuming either that all defences are either currently above or below standard. The results of this analysis are presented in table 3.4c. As there is no reliable mechanism for calculating any change in maintenance costs, nor other control structure needs, analysis has been made on capital replacement costs alone and other costs have been assumed to remain the same. Indeed it is reasonable to assume that maintenance needs will vary little, as it is only the size of the defence which would change.

Of particular interest is the relatively small change in investment that might be needed, over and above that needed to maintain current standards, to meet these standards, i.e. **less than £30 million per year**, which is approximately 11% of replacement costs but only 8% of total investment needs. However caution should be applied in interpreting this result because there is significant uncertainty in the relative cost assumptions made and the methodology assumes only that, when they are replaced, new defences would adopt a higher standard. It does not, for example, take account of the work that would have to be carried out to other defences protecting the same area if the higher standard was to be effectively realised. This does, however, support the FCDPAG3 methodology that encourages the adoption of higher standards wherever they are justified by the marginal return on the additional investment.

3.4.3 *Return on Investment*

As described above there is uncertainty over the actual levels of benefits or costs associated with meeting indicative standards, therefore detailed assessment of returns is inappropriate. It may, however, be possible to broadly conclude that a similar return in overall benefit-cost terms will be obtained, offering a considerable potential reduction in annual damages for a relatively small additional investment, although again this will tend to vary significantly from location to location.

	Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	48.4	36.5	23.9	11.2	13.0	9.5	33.5	15.2	**191.3**
Sea/Tidal	11.6	0.8	30.2	3.1	1.1	3.7	9.1	1.5	**61.1**
Total (Flood)	59.9	37.3	54.1	14.3	14.0	13.2	42.6	16.8	**252.4**
Coast Protect	0.6	0.0	1.3	0.5	1.6	3.2	0.0	0.5	**7.7**
Overall Total	60.5	37.3	55.4	14.8	15.6	16.4	42.6	17.3	**260.1**

Table 3.4a Annual Average Damages to Property by meeting Indicative Standards (£ million's/year)

	Anglian	Midland	North East	North West	South West	Southern	Thames	Wales	Total
Fluvial	344.4	333.1	250.0	73.6	101.9	69.2	327.1	111.3	**1,610.8**
Tidal	176.7	57.3	253.0	133.9	64.9	234.4	562.4	93.4	**1,576.1**
Total (Flood)	521.1	390.5	503.1	207.6	166.8	303.6	889.6	204.7	**3,186.8**
Coast Protect	5.4	0.0	11.7	4.5	14.4	28.8	0.0	11.5	**76.6**
Overall Total	526.6	390.5	514.8	212.2	181.2	332.5	889.6	216.2	**3,263.4**

Table 3.4b Annual Average Damages Avoided to Property by meeting Indicative Standards (£ million's/year)

	Maintain	Meet Indicative (Lower Bound)	Meet Indicative (Upper Bound)
Fluvial	86.78	74.10	99.45
Sea	26.40	23.50	29.31
Tidal	70.82	64.45	77.19
Total (Flood)	**184.00**	**162.04**	**205.95**
Coast Protect	55.82	48.56	63.07
Total Replacement	**239.82**	**210.60**	**269.02**
Maintenance	99.45	Not Established	Not Established
Other Structures	21.88	Not Established	Not Established
Total	**361.15**	**331.93***	**390.35***

Table 3.4c Investment Needs to meet Indicative Standards (£ million's/year) (excludes Wales)
(*assumes no change to maintenance costs or other structures - see text for other assumptions made in deriving these results.)

3.5 Maintaining Present Investment Levels

3.5.1 Investment

Annual investment in flood and coastal defence is presently approximately **£240 million** per year, comprised of some £150 million spent on capital works and between £80 and £90 million per year on maintenance, with funds available for capital works investment having increased recently by 25% from the average in recent years.

It is clear from the results presented in the preceding sections that a substantially higher level of investment is required to avoid deterioration from the standards currently provided. For England this higher level of investment has been calculated as a further **£110 to 120 million per year** on capital works and approximately **£10 to 20 million per year** on maintenance. Even taking account of the major uncertainties and sensitivities (see section 3.3.2) a 50% increase in overall expenditure has been identified, although this is in the form of **at least a 70% increase** in capital investment.

3.5.2 Economic Damages

With the information currently available it has not been possible to accurately establish the extent of damages or benefits if present investment levels are not increased. However, some general observations can be made.

At the proposed level of investment of £0.36 billion, approximately £2.7 billion of damages would be averted on an annual basis. This leaves a residual damage of some £0.8 billion per year.

Present investment of about £0.24 billion/year yields an average benefit-cost ratio of approximately 7:1 (section 3.3.3). If there is a continuing shortfall of annual investment in defence renewal of about 40% of the theoretical rate required to keep up with defence deterioration then the average annual damages can be expected to increase by some 1.5% per year. This would amount to an increase of some £12m per year or £120m per decade so that even without any impact of climate change the average annual damages would exceed £1bn per annum by 2020. Clearly with each year of delay a greater backlog of improvements and replacements is created.

3.5.3 Future Policy

It is clear from the work described in section 3.4 that adopting a minimum defence scenario, i.e. providing many defences but to only low standards, is not a solution, as this still requires investment of the order of 90% of that estimated. Therefore, to maximise benefits given current levels of investment, it may be necessary to target protection of particular areas and abandon others. If present investment levels are not increased substantially, this may have to be considered as the long term defence policy.

It is not possible within this present project to specifically analyse which areas, or how many areas, should be protected or abandoned to obtain best value, nor would it be appropriate to do so, given the paucity of information in certain regions. Whilst section 3.3.3 has provided a broad assessment of the relative merits of protecting against different risks, it is most likely that some combination of fluvial, tidal and coastal defence, concentrated upon urbanised areas, will yield the greatest return on investment. It is perhaps in this area that future studies will need to be focussed.

It should also be noted that experience tends to show that in individual cases some small-scale investments, which alleviate damage from the most frequently occurring events, often produce the highest returns. Such considerations could not be taken into account in the broad methodology of this project but are available to those analysing specific problems. This again emphasises the difficulty of defining broad national policy options and the importance of looking at each situation individually within appropriate policy and strategic planning frameworks.

4 Influence of Climate Change on Flooding

The results presented in section 3 examine the economic impacts of flooding and coastal erosion under current climatic conditions. This section of the report compares the results of the climate change impacts analysis for flooding against those for the current climate 'Maintain Current SOS' defence option.

The AAD values calculated assume that defence structures remain physically unchanged e.g. where crest levels are currently sufficient to defend against a 2% (1 in 50 years) event now, that same crest height may in 2075 only represent adequate defence against a 4% (1 in 25 year) event. Tables 4.1 and 4.2 show the comparison of AAD values, and figures 4a-c in Appendix A map out calculated increases in damage. It should be emphasised that in practice it is likely to be well worthwhile to mitigate against such increases in damage through additional defence works or other flood management activities. This practice is already recommended in DEFRA guidance and these figures amply illustrate the potential benefits of adopting such a precautionary approach.

Region	**2001 AAD**	**2075 AAD**	**% of current AAD**
Anglian	£21.49	£71.41	332
Midlands	£4.54	£34.87	768
North East	£60.64	£252.23	416
North West	£18.78	£76.24	405
Lower Thames*	£36.94	£163.67	443
Southern	£43.79	£285.00	651
South West	£10.30	£59.50	577
Wales	£13.95	£62.21	446
Total	**£210.43**	**£1,005.13**	**478**

Table 4.1 Calculated increases in tidal flood damage to built property due to climate change (£ millions)

* N.B. no increase in AAD from flooding in the Tidal Thames upstream of the Barrier is assumed due to the assessed 0.1% defence standard in this reach.

	Current AAD	Predicted AAD		% of current AAD	
Region	(£ million)	10% Flood Flow Increase	20% Flood Flow Increase	10% flood flow increase	20% flood flow increase
Anglian	£55.02	£78.16	£111.70	142	203
Midlands	£54.85	£85.71	£129.06	156	235
North East	£47.29	£90.81	£111.70	192	236
North West	£19.22	£34.03	£54.45	177	283
Thames	£201.26	£245.21	£295.45	122	147
Southern	£15.51	£22.28	£32.69	144	211
South West	£28.90	£41.92	£60.86	145	211
Wales	30.15	47.06	72.46	156	240
Total	**£452.20**	**£645.18**	**£868.37**	**143**	**192**

Table 4.2 Calculated increases in fluvial flood damage to built property due to climate change (£ millions)

It should be noted that whilst these increases in damage appear exceptionally high, they are based on a 75 year time horizon, not 50 year as used in the previous section. To make a comparison with a 50 year time horizon, the %AAD increases will be closer to half to two-thirds of these values, i.e. the total in Table 4.1 may be 300-350% of current AAD (rather than 477%) and the totals in Table 4.2 closer to 120-130% (for the 10% flow increase), and 145-165% (for the 20% flow increase).

In terms of investment needed, the basis upon which the upper bound values in Table 3.4c were derived may be adopted for estimating the influence of climate change upon investment needs. This suggests a need to look at increasing investment by between **£30 to 60 million/year** to meet indicative standards in the future. Given the sizeable increase in damages however, it is clear that the limited size of investment required produces a much higher benefit cost ratio compared to the present day.

5 Conclusions and Recommendations

5.1 *Conclusions*

The conclusions from this research project are as follows:

- Approximately 10% of the population of England and Wales live within areas potentially at risk from flooding or coastal erosion, whilst approximately 12% of the agricultural land (including 61% of the country's Grade 1 agricultural land) is also located in these areas;

- Property worth over £220 billion and agricultural land worth approximately £7 billion is located within these areas potentially at risk;

- Without any flood and coastal defences, the annual average economic damage from flooding and coastal erosion in these areas would be over £3.5 billion/year;

- The capital works and maintenance investment needed to continue to provide and maintain present defence standards is in excess of £0.3 billion/year;

- Current standards of defence reduce annual average damages to approximately £0.8 billion/year;

- Continuing to invest at present levels of approximately £0.24 billion per year will result in increasing annual average damage possibly at the rate of some £10-15 million per year.

- Accommodating climate change is likely to require a further increase in investment of between 10% and 20% over and above that required to meet indicative standards under present day conditions;

- Without allowance for accommodating the predicted impacts of climate change within defence provision the economic impacts associated with flooding could increase significantly, with annual average damages increasing in fluvial areas by approximately 50% and in excess of 200% on the coast by the year 2050.

The current study has involved some broad-based assumptions and there is scope to further improve upon the accuracy of the analysis. However, there is sufficient confidence in the order of magnitude of the results to conclude that there is a need to reappraise even the recently enhanced levels of funding for flood and coastal defence.

Although definitive arguments regarding how and where to invest should not be drawn from this study, there is little doubt that there is a clear need to substantially increase expenditure on flood and coastal defence to maintain the same level of protection as that which currently exists. Failure to do so will inevitably lead to an increase in economic damages year by year, i.e. when another significant event occurs, such as in 1953 or 2000, the extent of area affected and the resulting losses/damage could potentially be significantly greater unless the rate of investment in replacement or renewal of defences is increased. It should also be noted that present defences appear, in several places, to be below the indicative standards recommended in FCDPAG3.

The earlier study (2000) indicated that present investment levels needed to be increased by between 50% and 100%, based upon an investment of approximately £0.2billion/year. This is modified to 25% to 65% based upon the current revised investment of £0.24 billion/year. The conclusions from assessing climate change impacts are that a 35% to 85% overall increase may however still be required to meet indicative standards of protection over the next 50 years. Although the most severe impacts of climate change may not be experienced for some time, it is apparent that it is likely to be well worthwhile to make advance investments to accommodate climate change. The balance between gradually providing higher standards as defences require replacement and making provision for future improvements needs to be considered on a case by case basis but where significant works are deferred then the adaptation costs will be additional to those of the normal replacement cycle.

If investment is maintained at or around present levels, the results imply that effective protection can only be provided to selected areas of the country, i.e. a conscious decision might be required to abandon defences to some less populous areas. This leads to further questions, such as where new residential properties and businesses should be located? This study cannot attempt to resolve such issues, though the mapping out of the value of assets, calculated damages and indicative and current standards of protection can at least provide a preliminary focus in the consideration of where priorities for defence provision should lie.

5.2 Recommendations

5.2.1 Existing Improvements

Since the original study, which was completed in 2000, a number of actions have been taken. These include the joint DEFRA/Environment Agency development of the R&D Themes that are targeting future needs based upon industry requirements. This should include consideration of the findings of that previous study and new research to help address some of the limitations identified therein to provide improved accuracy in future analyses.

In addition, the Environment Agency, with DEFRA support, are now developing the National Flood and Coastal Defence Database (NFCDD), which will eventually provide the basis for regular assessments such as this through routine updating of the relevant datasets and the ability to resolve some of the analyses at a range of scales (i.e. local through to national).

Funding has also been made available for increased investment in capital works since the original study was completed. The annual budget of £150 million of capital works supported by DEFRA grant represents a 25% increase over the £110-120 million average in recent years.

Notwithstanding these improvements there will continue to be room for further advances in the work presented here. Full recommendations were made in the original report of 2000. These are summarised from that report in the following final sub-sections.

5.2.2 Data and Analysis to Reduce Uncertainty

This study has established an analytical framework and combined data-sets for assessing national risks and investment needs. However, it has also drawn attention to the need for improved data to provide improved accuracy and confidence in the results and, in particular, to reduce dependence on some of the assumptions that have been required.

5.2.3 Strategic Framework for Decision Making

The collection of new data and more efficient management of both new and existing information will enable the results to be improved and provide greater confidence in the recommendations as well as providing greater flexibility in their use. Given the conclusions of this study, and the possibility that investment to maintain or improve current defence standards throughout will not be forthcoming, there is a very real need to ensure that the strategic framework of national guidance will obtain the best value from available funds. The work already undertaken for this study forms the basic building block for development of such tools.

5.2.4 Programme for Implementation

Accuracy of analysis and the ability to analyse strategic options will improve with time as more data becomes available. However, to maximise return on the present study and minimise uncertainty in future decision making, it is proposed that the recommendations made here are progressed henceforth.

The importance of good data cannot be over-stressed and future data collection needs to be integrated with the strategic assessment needs. A clear target for the Environment Agency and DEFRA is to have improvements in the data, with the appropriate tools to manage it within a reasonable timeframe. Already work through DEFRA's Broad Scale Modelling research, which ties in closely with the developing Catchment Flood Management Plans, is seeking to put such tools in place. Closely paralleling this work is the construction of the National Flood and Coast Defence Database which too should form a basis for providing consistent data and analyses at a local and strategic level.

A Mapped Results

A.1 Mapped Results

The following figures are presented within this appendix. Refer to section 3.1.1 for a description of the derivation of their contents.

1a	Estimated 'do nothing' Average Annual Damages - Northern Area
1b	Estimated 'do nothing' Average Annual Damages - Western Area
1c	Estimated 'do nothing' Average Annual Damages - Eastern Area
2a	Estimated Average Annual Damages - Current Standards Maintained - Northern Area
2b	Estimated Average Annual Damages - Current Standards Maintained - Western Area
2c	Estimated Average Annual Damages - Current Standards Maintained - Eastern Area
3a	Comparison of Assigned and Indicative flood defence standards - Northern Area
3b	Comparison of Assigned and Indicative flood defence standards - Western Area
3c	Comparison of Assigned and Indicative flood defence standards - Eastern Area
4a	Estimated impacts of Climate change on Annual Average Damage by 2075 - Northern Area
4b	Estimated impacts of Climate change on Annual Average Damage by 2075 - Eastern Area
4c	Estimated impacts of Climate change on Annual Average Damage by 2075 - Western Area

Table A.1 Appendix contents

Estimated "do nothing" Annual Average Damages
Northern Area

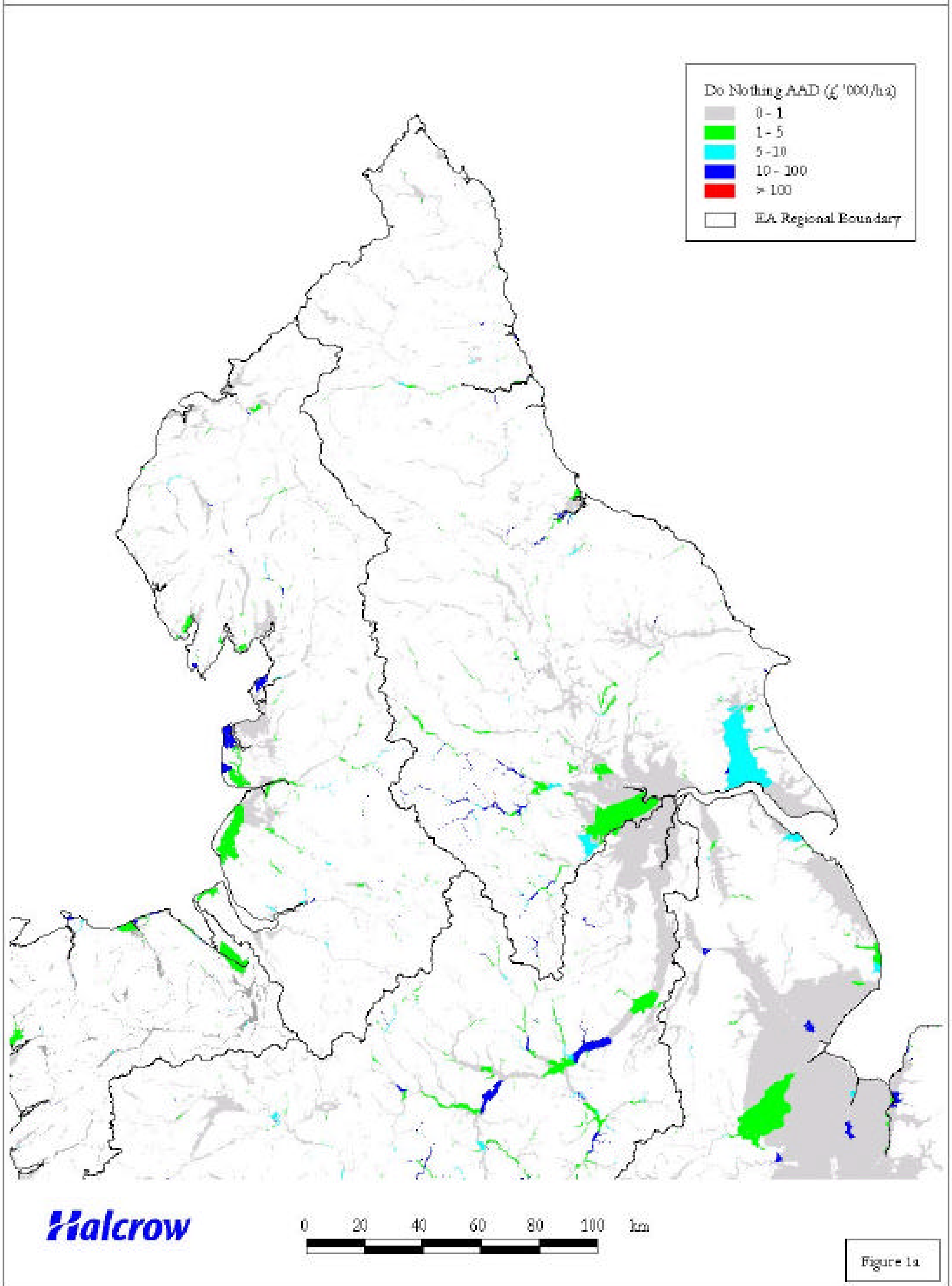

Figure 1a

Estimated "do nothing" Annual Average Damages
Western Area

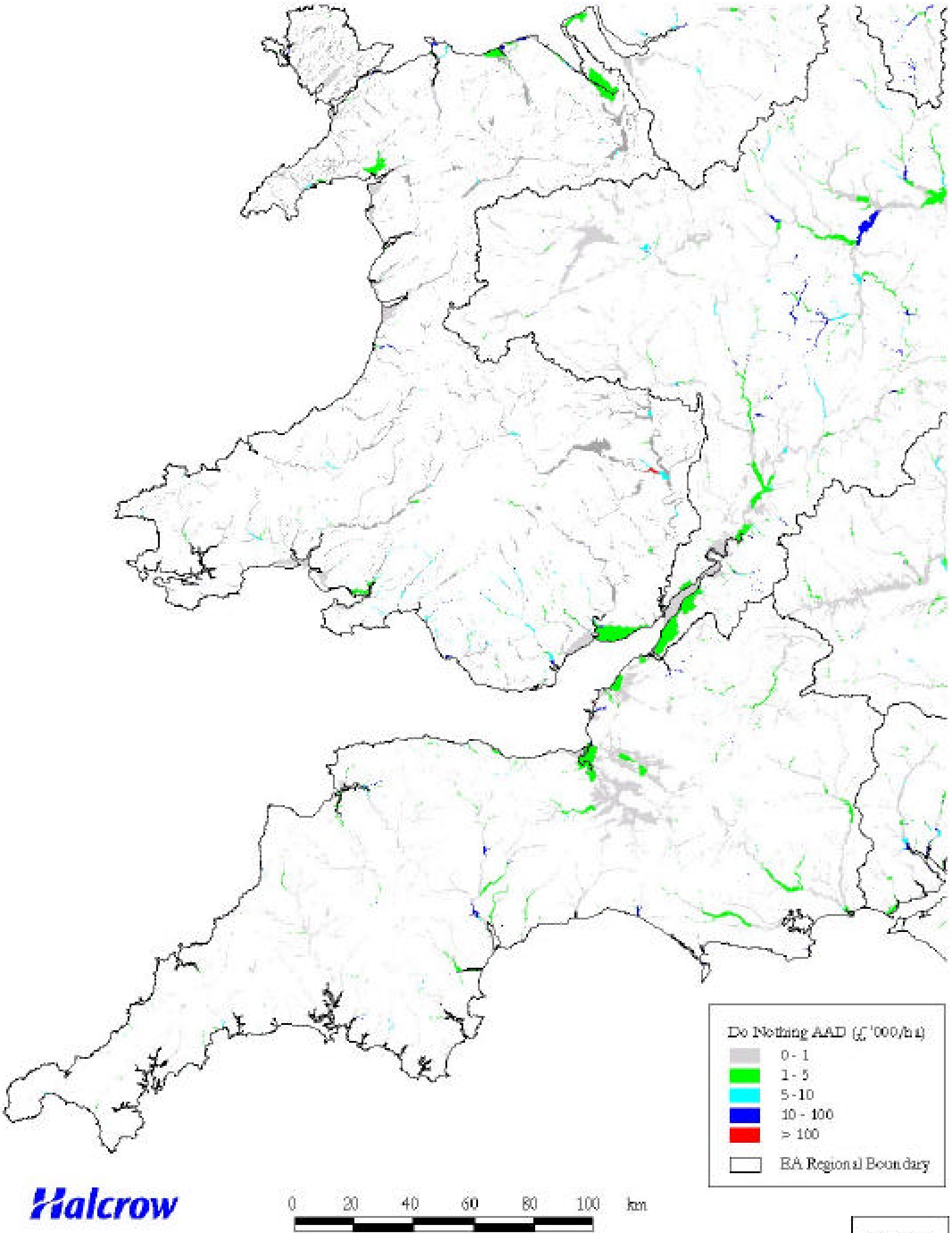

Figure 1b

Estimated "do nothing" Annual Average Damages
Eastern Area

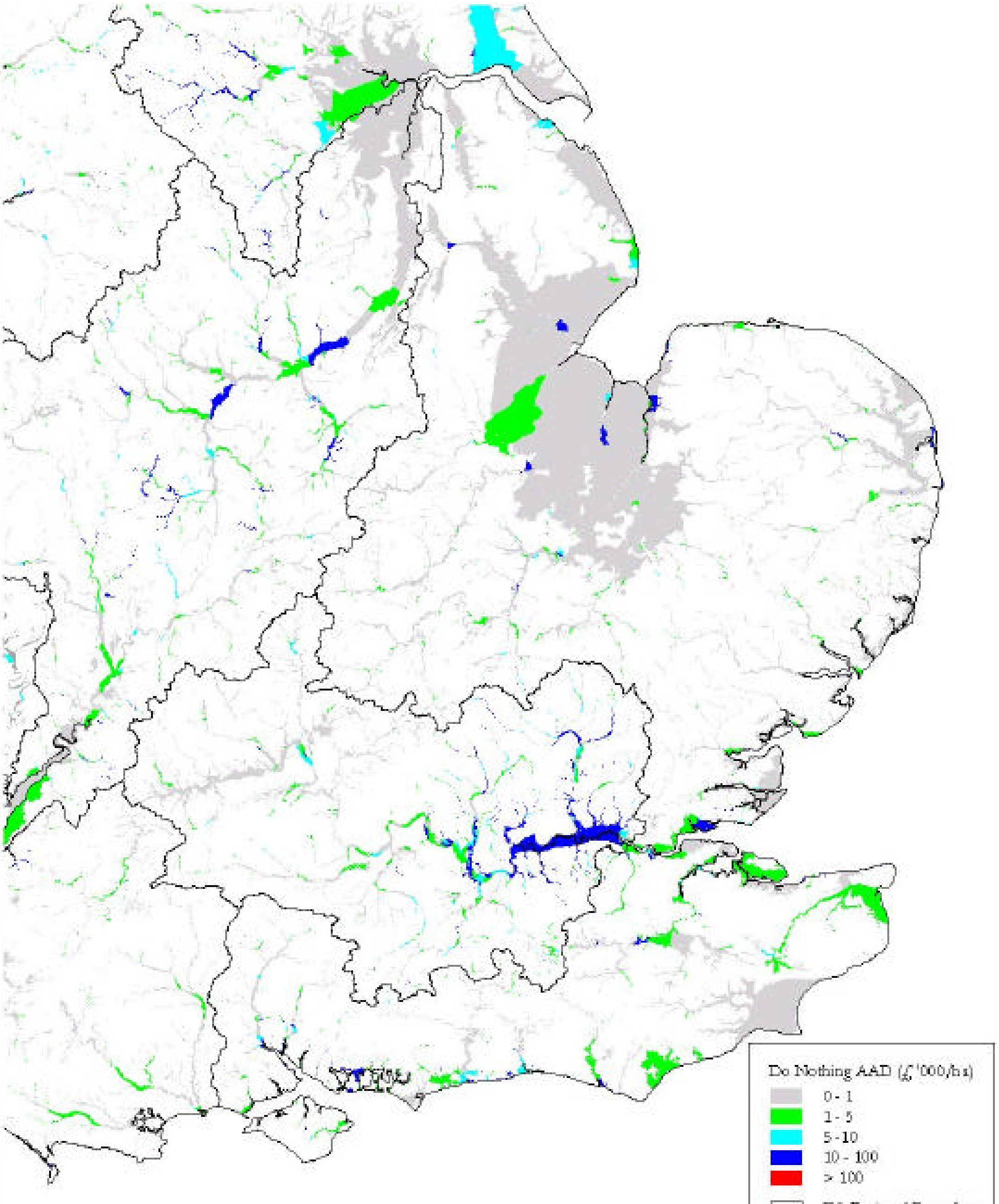

Figure 1c

Estimated Annual Average Damages - Current Standards Maintained
Northern Area

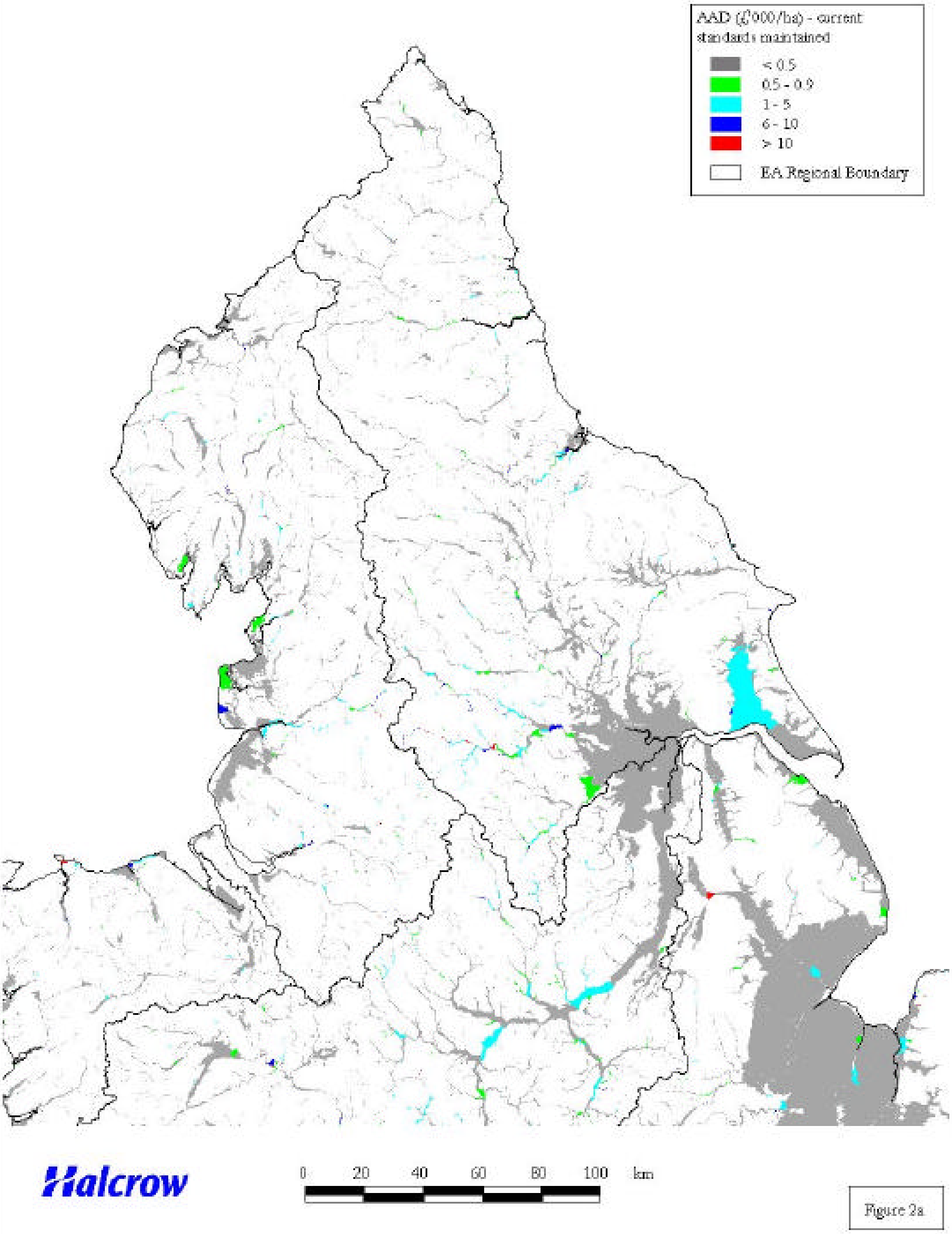

Figure 2a

Estimated Annual Average Damages - Current Standards Maintained
Western Area

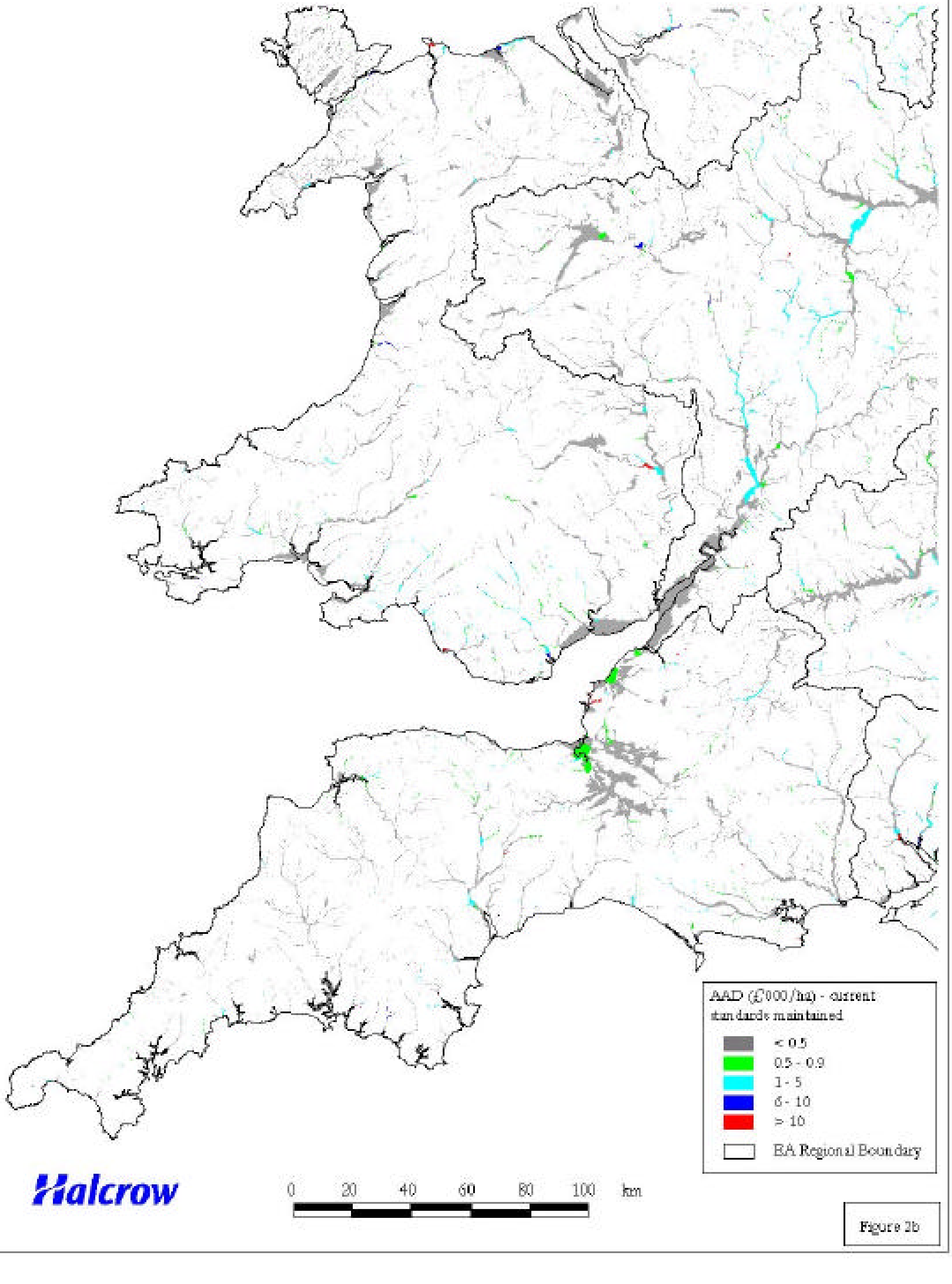

Figure 2b

Estimated Annual Average Damages - Current Standards Maintained
Eastern Area

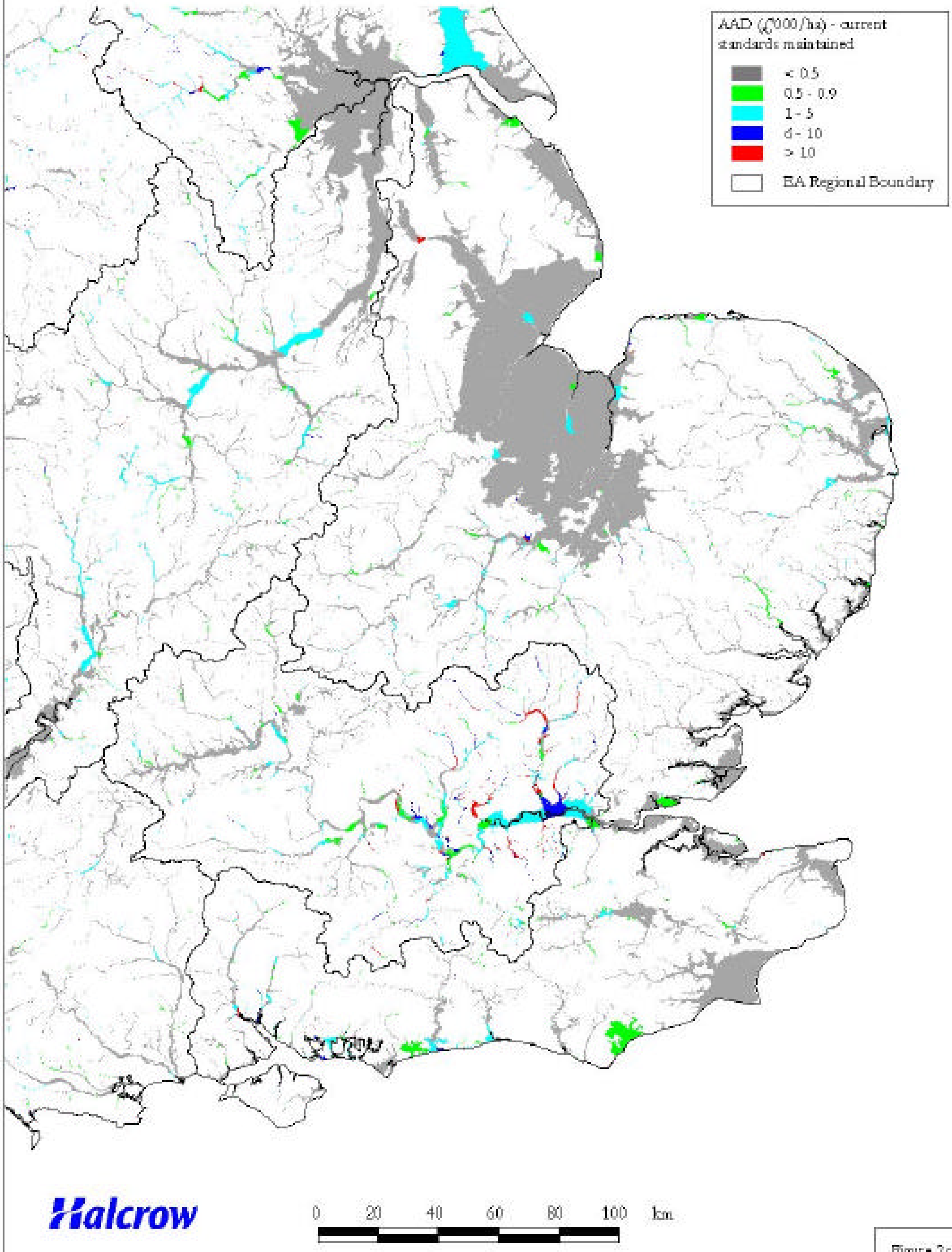

Figure 2c

Comparison of Assigned and Indicative Flood Defence Standards
Northern Area

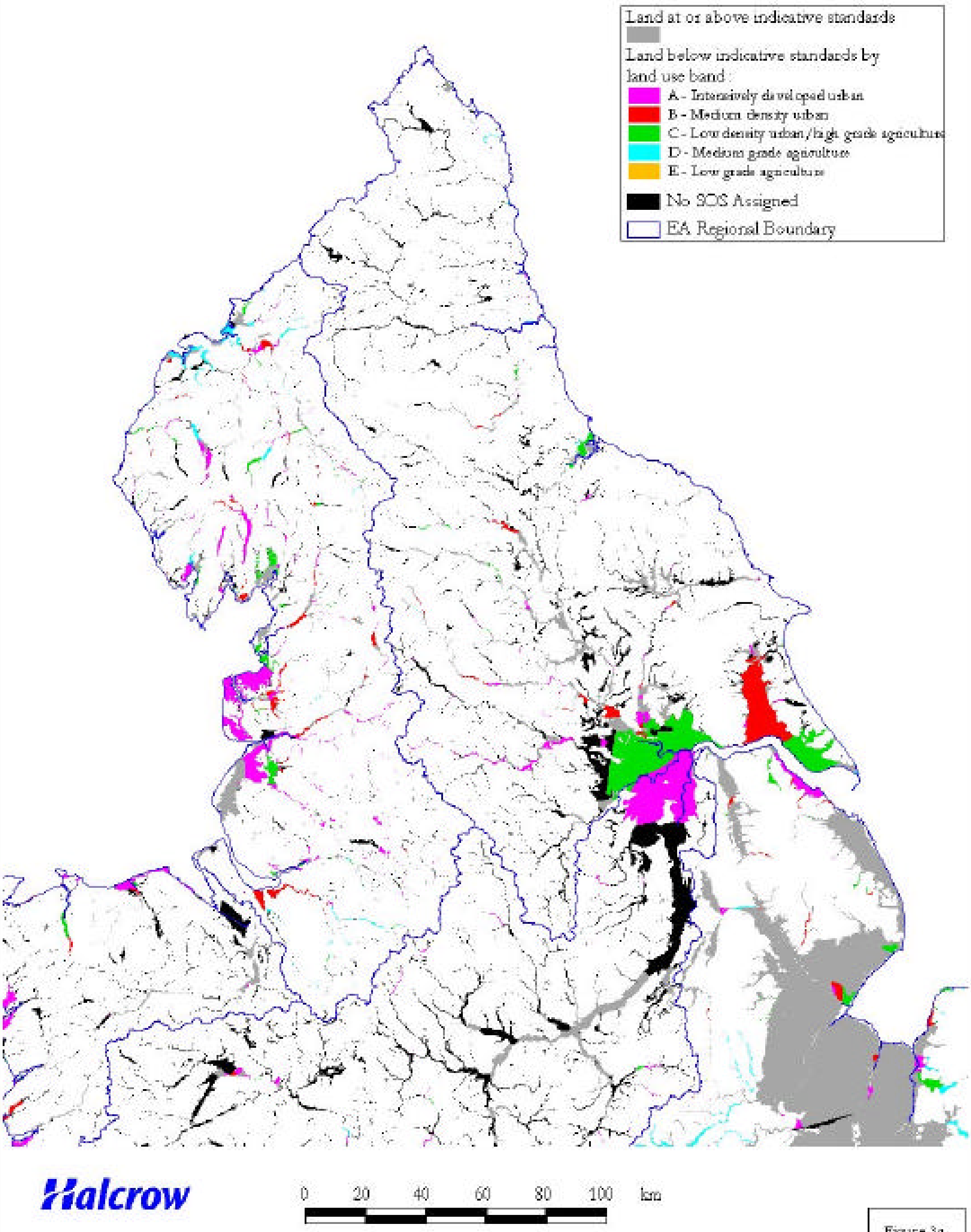

Figure 3a

Comparison of Assigned and Indicative Flood Defence Standards
Western Area

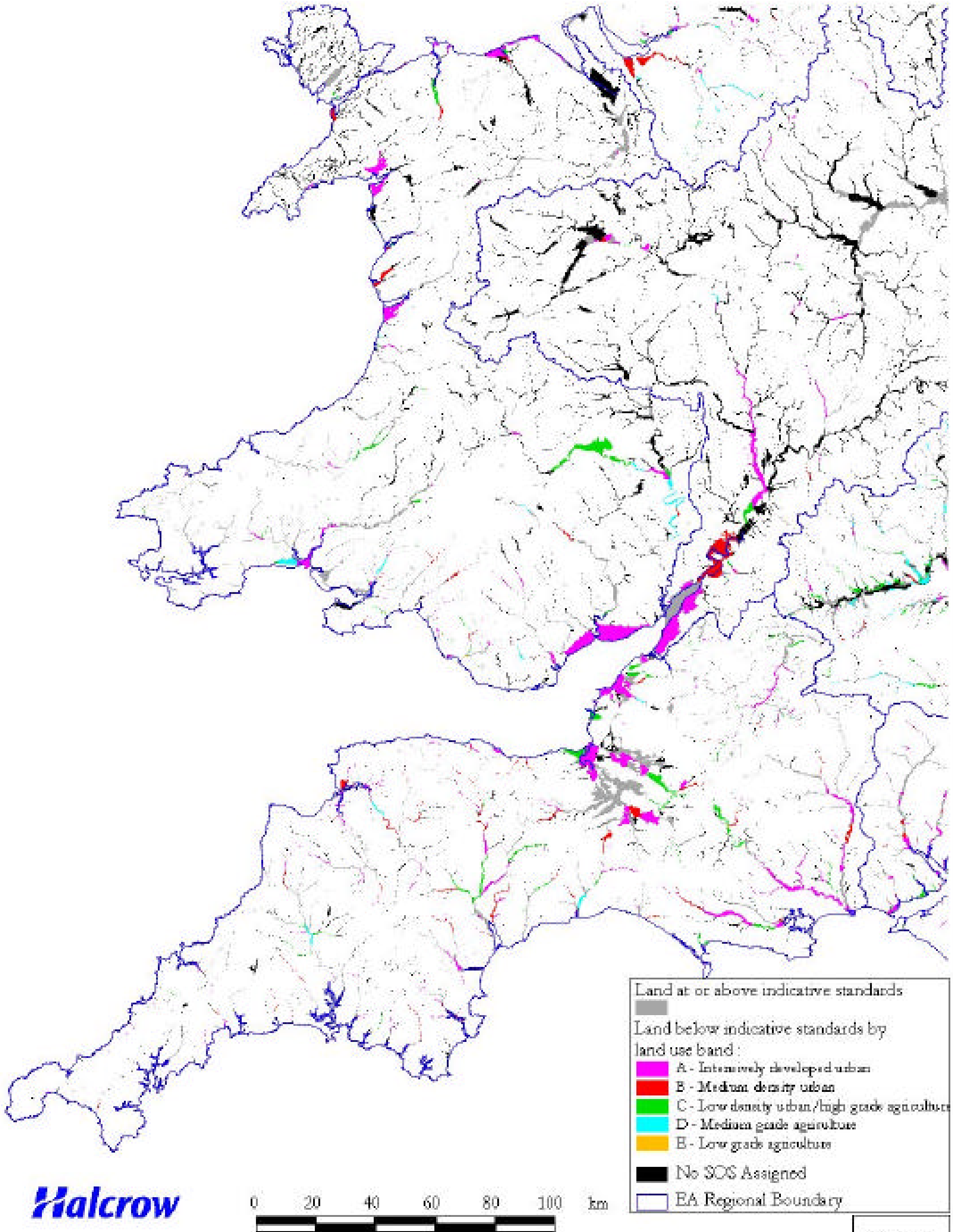

Figure 3b

Comparison of Assigned and Indicative Flood Defence Standards
Eastern Area

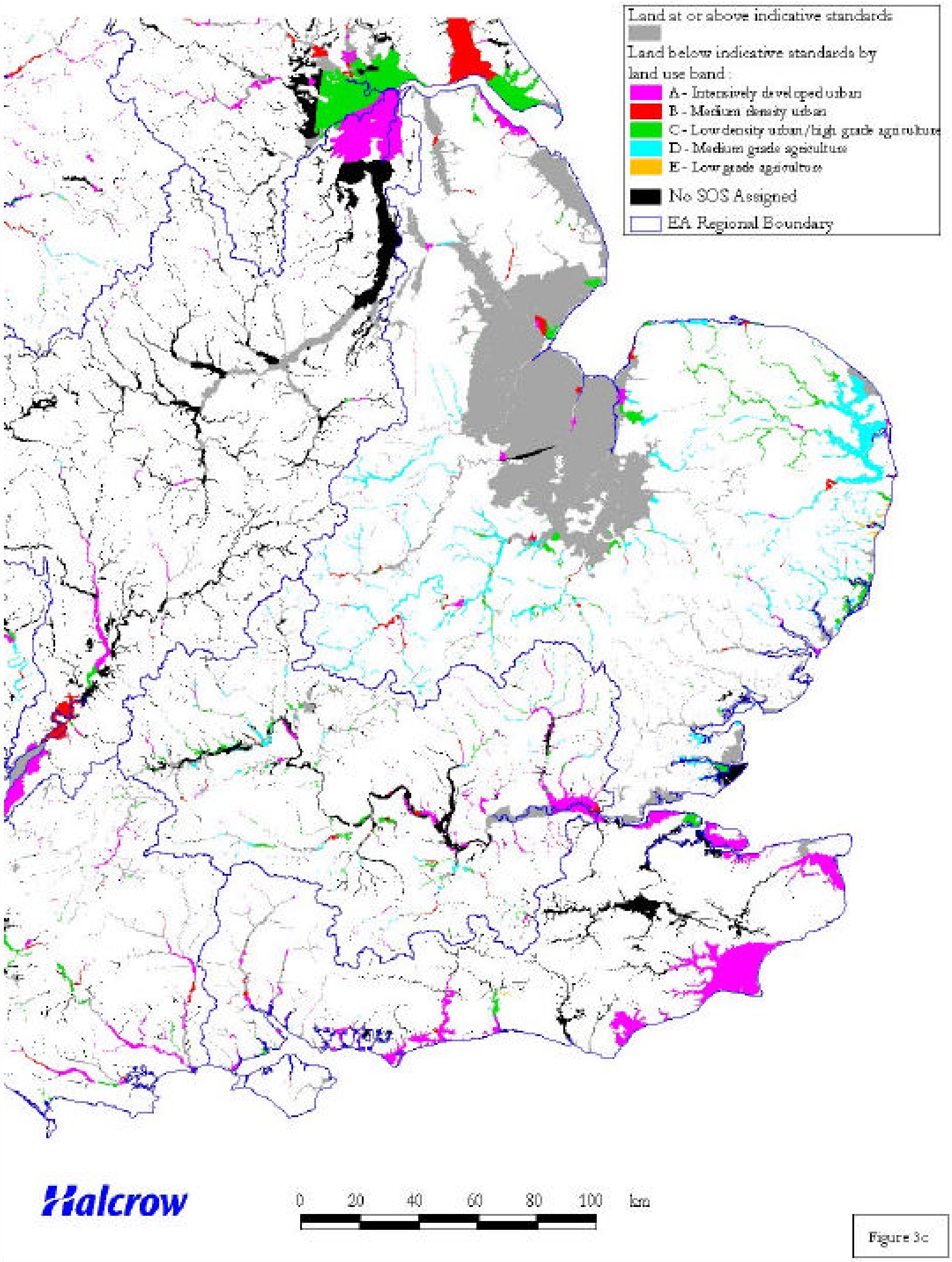

Figure 3c

Estimated Impacts of Climate Change on Annual Average Damage by 2075 (without any adaptation)
Northern Area

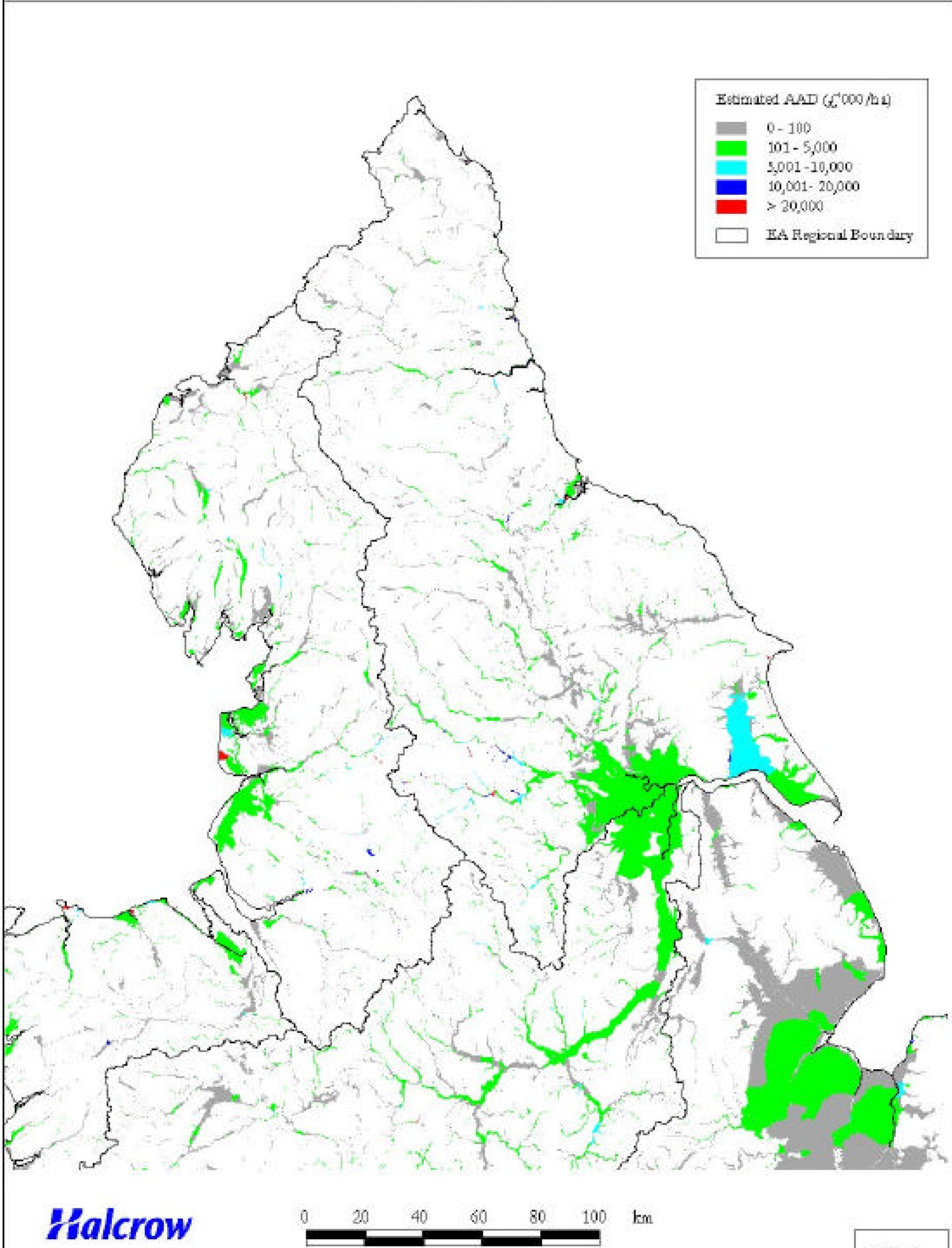

Figure 4a

Estimated Impacts of Climate Change on Annual Average Damage by 2075 (without any adaptation)

Western Area

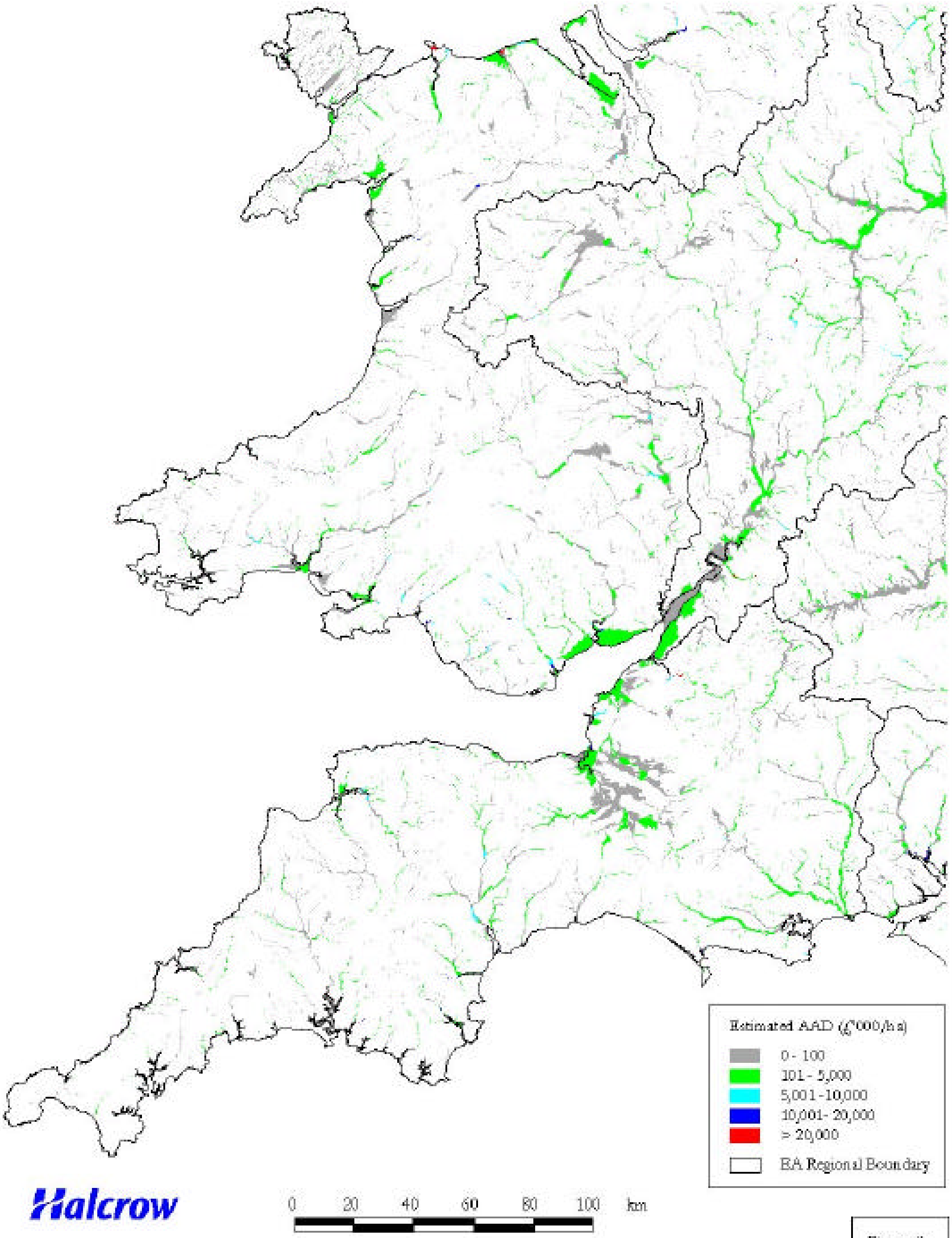

Figure 4b

Estimated Impacts of Climate Change on Annual Average Damage
by 2075 (without any adaptation)
Eastern Area

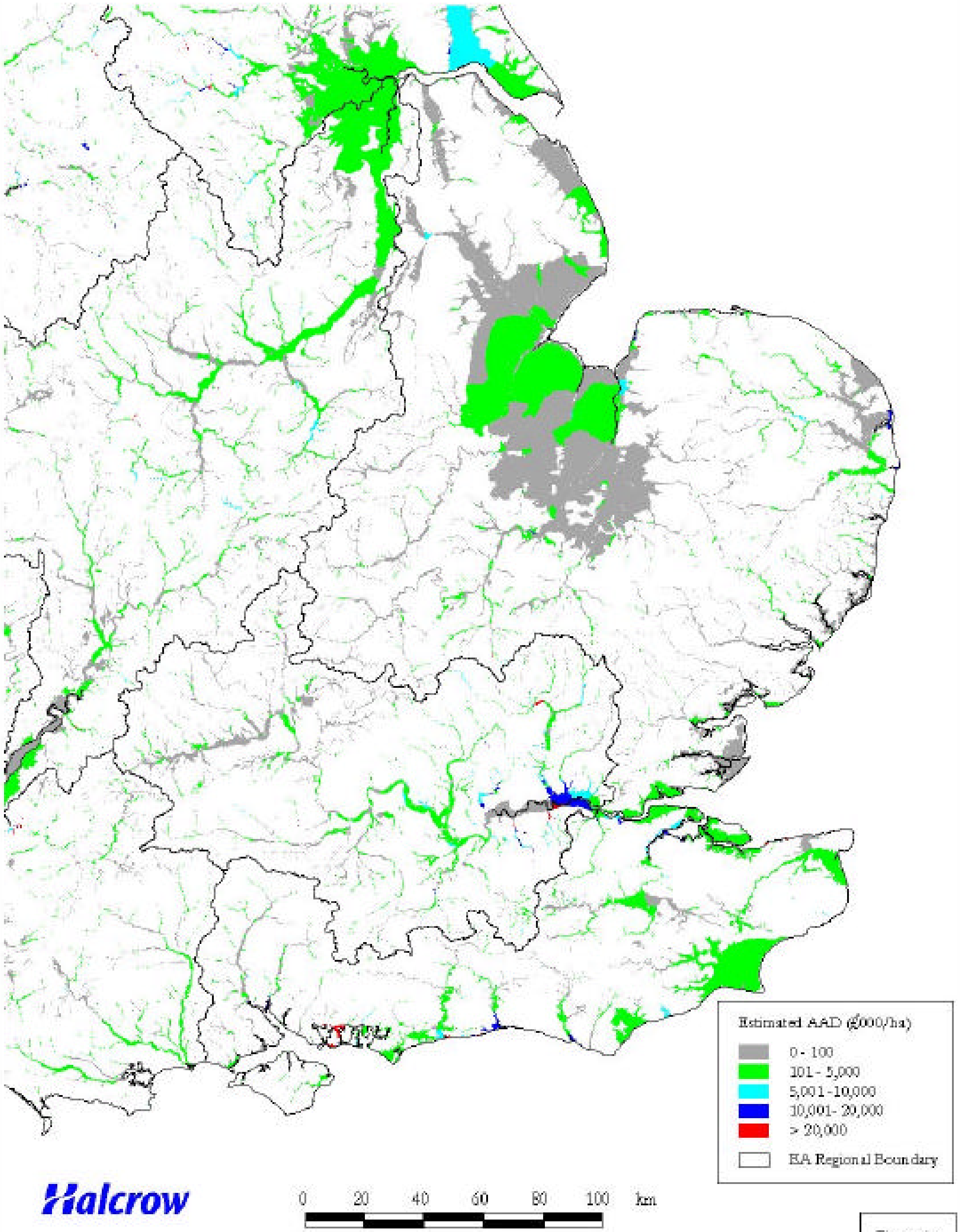

Figure 4c