Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Developing the evidence base to describe the flood risk to agricultural land in England and Wales

R&D Technical Report FD2634/TR

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Statement of use
This report was commissioned by Defra Flood Management and forms part of the joint Defra / Environment Agency research programme. The report was prepared by HR Wallingford as a lead contractor, with the collaboration of Cranfield University, Royal Haskoning and RYE Consultancy, and is an assessment of the flood risk to agricultural land, reporting at national (England and Wales) and regional level. The assumptions noted throughout the report, together with the restrictions listed in Chapter 4, should be considered when using these datasets to inform policy decisions.

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Executive summary

The aim of this project is to identify, assemble, verify and utilise a numerical evidence base together with an agreed and repeatable methodology to describe the flood and coastal erosion risk to agricultural land in England and Wales. The project report does not debate the policy issues surrounding the protection of agricultural land but provides the evidence base to assist any future debate. The project has been commissioned by Defra within the joint Environment Agency and Defra R&D programme.

The study results provide information on the interactions between flood risk and agricultural land at a national scale, and hence are of interest to Defra, WAG, the Environment Agency and a wide range of stakeholders.

The project made use of existing datasets to investigate the relationships between agricultural land (both grade and land use) and flood hazard (with and without defences, today and in the future), including:

- Agricultural Land Classification[1] (ALC, 1974)
- Land Cover Map (LCM, 2000)[2];
- Flood Zones (Flood Map v3.15)
- The Environment Agency's National Flood Risk Assessment (NaFRA08, 2008)
- Foresight Future Flooding (2004)
- The Environment Agency's Long Term Investment Strategy (LTIS, 2008).

The project used GIS to create a one hectare resolution (100m by 100m) Reference Grid covering all of England and Wales, and the source data were transferred to this grid for purposes of comparison and integration.

The results are presented for England and Wales as well as for the Environment Agency Regions in England. The results are presented together with an explanation of the methodology, some supporting information considered necessary, and the identification of the datasets used to obtain the results.

The project has reported that:

- The floodplain area represents approximately 12% of the total land area in England and 10% of the total land area in Wales
- The proportion of floodplain land within each Region varies, Anglian Region has the highest proportion at 22%
- In England 39% of land in agricultural use (LCM2000) in the floodplain is at flood risk from the sea or tidal rivers. Southern Region has the highest percentage at risk (62%) from this source

[1] Both the English and Welsh ALC datasets
[2] The source data from the LCM 2007 map was not available to this project

- The Environment Agency Anglian Region has by far the largest area of Grade 1 to Grade 3 agricultural land in the floodplain and the largest overall total of agricultural land
- The North-East Region has the highest percentage of its Grade 1 land in the floodplain – 86%
- The national percentage of best and most versatile land (ALC Grades 1, 2 and 3) located in the floodplain is 13% in England and 10% in Wales
- More than half (58%) of the total resource of Grade 1 agricultural land in England is within the floodplain. The equivalent figure for Wales is 13%
- Of this Grade 1 land in England only 5% of that land in the floodplain is at very significant[3] flood risk
- In England 78% of Grade 1 land in the floodplain is at low[4] flood risk, and 48% of the best and most versatile land in the floodplain is at low flow risk
- In Wales 33% of the Grade 1 land in the floodplain is estimated to be at low flood risk, and 27% of the best and most versatile land
- Internal Drainage Boards (IDBs) cover around 1.2m ha of agricultural grade land in England, about 50% of this area relies on pumped drainage
- More than 85% of the total Grade 1 agricultural land in the North-East and Anglian regions is in IDB districts
- Fluvial defences provide protection to agricultural land and reduce flood related agricultural losses by around £5.2m annually (£0.2m in Wales and £ 5m in England)
- Coastal defences provide protection to agricultural land and reduce flood related agricultural losses by around are £118m annually (£7m in Wales and £111m in England)
- 1,180ha of land in England has been converted to intertidal habitat through managed realignment schemes (in the period1991 to 2009)
- The total area of agricultural grade land within flood storage areas in England is 12,270ha
- The area of built up land in England increased by 29,000ha between 1998 and 2007. The equivalent figure in Wales is 15,000ha.
- The area of land in agricultural use in England has remained broadly the same between 1998 (8.393m ha) and 2007 (8.311m ha)

In reviewing the findings from this project it should be noted that although every attempt has been made to gather the latest nationally available information, all of the datasets reflect to some extent a dynamic environment and hence may not reflect current day conditions. However the flood risk component of the analysis uses the NaFRA08 dataset which at the time the data analysis was undertaken was the latest available national assessment of flood risk. Although agricultural land use may change year by year at a local level, aggregated at a national level these changes are minor[5]. Updates to NaFRA and the availability of the latest land cover map (LCM2007) data will allow these results to be re-run to update the baseline established by this report.

[3] Very significant flood risk defined as a flood return period equal to, or more frequent than, 1 in 20 years
[4] Low flood risk defined as a flood return period of 1 in 200 years or less
[5] See the supporting information against Question 8

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1. Introduction

Flood and coastal erosion risk management (FCERM) activities have shaped much of today's agricultural production having reclaimed and improved the floodplains of the rivers and coast in England and Wales for agricultural purposes over hundreds of years.

The aim of this project is to identify, assemble, verify and utilise a numerical evidence base together with an agreed and repeatable methodology to describe the flood and coastal erosion risk to agricultural land in England and Wales.

In meeting this aim the project provides:

- Evidence on the area and grade of agricultural land at risk of flooding in England and Wales.
- A methodology to describe how current FCERM national policies and their implementation may impact on future agricultural land at risk of flood.
- Evidence to inform any future FCERM outcome measures.

It is not the purpose of this project to debate the policy issues surrounding the protection of agricultural land, nor to provide detailed economic review of the results, but rather to provide the evidence base to support any future debate.

1.1 Objectives

The project has six specific objectives as follows:

1. To identify the most suitable datasets to inform the debate on flood risk management for agricultural land, together with their limitations, accuracy, ownership, maintenance, availability and relevance.

2. To undertake analysis using these datasets to provide best estimates, at a national (England and Wales) and regional level, to answer a series of specific questions posed in the project brief.

3. To make recommendations for improvements to the availability, accuracy, deployment, usability or relevance of these or, where required, new datasets.

4. To identify the most appropriate way of providing access to these data for all operating authorities to ensure a consistent input into project appraisal reports.

5. To identify the most cost-effective way of maintaining the integrity, relevance and availability of these data into the future so as to effectively monitor and report on the changing exposure of agricultural land in England & Wales to flood and coastal erosion risk.

6. To briefly compare the results from this research with that from other recent similar initiatives (for example Countryside Survey 2007 and the Environment Agency draft report “Developing the evidence base on flood risk management and food security”) and account for any discrepancies.

1.2 Target audience

The results of this project provide data about the interactions between agriculture and flood risk on a national scale to a number of organisations and authorities such as Defra, the Environment Agency and any stakeholders with an interest in the subject.

1.3 Outline of the report

Following this brief introduction the report is structured as follows:

Chapter 2 identifies the most suitable datasets to identify the area and grade of agricultural land at flood and coastal erosion risk. A brief description of the datasets is provided in this chapter and more detailed information can be found in Appendix 4.

General aspects of the method used to undertake the analysis of these datasets are explained in **Chapter 3**. Question-specific aspects related to the methodology applied are described when answering each question in Chapter 4. More detail about the methodology can be found in the appendices.

Chapter 4 provides the answers to the questions posed in the project brief. The results are presented for England and Wales as well as for the Environment Agency Regions in England. The answers to the questions follow the same pattern: the results are provided first, then the particular methodology used to obtain the results is described and some supporting information is added if considered necessary. The datasets used to obtain the results are identified at the end.

Chapter 5 Provides information about the availability, accuracy, usability and relevance of the datasets used in this project.

Chapter 6 Provides information about data accessibility and how to maintain its relevance in the future.

Finally, **Chapter 7** summarizes the main results of the project in relation to the datasets, the answers to the questions posed in the project brief and proposals for future updates of those results.

Note: The convention used in this report is that important assumptions or advisory comments are preceded by “*Note:”;* significant assumptions or comments by “***Note:***”.

2. Identification of most suitable datasets

A summary of the data used in this project is given below. More detailed information relating to each dataset is provided in Appendix 4.

Note: Not all relevant and suitable datasets identified during the early stages of the project were available during the timeframe of this project and hence alternative data sources have been sought. In some instances it has not been possible to identify reliable alternatives and hence it has not been possible to answer all questions poised in the project brief.

2.1 Datasets used within the study

The main datasets used are discussed below:

- **Agricultural Land Classification (ALC, 1974) –** describes the potential of land for agricultural use. Within the ALC five primary grades are used to categorise this potential, defined as:

  - Grade 1 land (excellent quality) has no or very minor limitations to agricultural use.
  - Grade 2 land (good quality) has minor limitations which affect crop yield. Yields are generally high but may be lower or more variable than Grade 1.
  - Grade 3 land (good to moderate quality) has minor to moderate limitations which affect crop yield.
  - Grade 4 land (poor quality) presents a significant limitation to agricultural use. It is mostly suited to grass and occasional arable crops.
  - Grade 5 land (very poor quality) provides limited support to crops and agriculture is generally restricted to permanent pasture or rough grazing.

  For more details about these categories, and the additional information held in the ALC relating to areas not classified as agricultural in 1974, the reader is referred to MAFF (1988).

  The best and most versatile land is defined as Grades 1, 2 and 3 by policy guidance (see Planning Policy Statement 7, PPS7, Sustainable Development in Rural Areas, published in August 2004).

  The ALC for England is owned by Natural England and is fundamental to define the quality of the land that could potentially be used for agricultural purposes. It was created in 1974 however and may not therefore always represent the present-day land use. Furthermore, the information was digitised from published 1:250,000 maps which were in turn compiled from the published 1 inch to 1 mile maps, without reference to detailed underlying Ordnance Survey (OS) data. This is further complicated by the embedded (but not explicit) consideration of the proneness to flooding in determining the ALC grade, so in some part, the ALC is not a pure reflection of the soil conditions but also the hydrological conditions.

An ALC dataset covering **Wales** was separately obtained with permission from the National Assembly Wales. As with the ALC England this is based on survey work carried out in the 1960's and 1970's and was digitised in 1999.

See Section 3.7 for work done in this project to update the ALC dataset.

- **Land Cover Map 2000 (LCM2000) –** describes the surface cover of the land (i.e. the actual land use at the time the survey was taken). The dataset is owned by the Centre for Ecology & Hydrology (CEH) and is the primary land cover dataset for the UK. It is available on a 25m resolution grid and provides attributes such as land cover class (urban, sub-urban etc), parcel area, length of boundary, processing history, knowledge-based correction and identification of the original satellite scene.

  Note: The different classifications of the LCM were derived from satellite images taken during summer and winter season in 1998 with some follow-up site visits to confirm identification.

- **National Flood Risk Assessment (NaFRA08) –** Describes the present-day (as of 2008) probability of flooding in England & Wales within the extreme flood outline. Relates to flooding from the sea and rivers only. The Environment Agency owns this dataset. It is based on the Risk Assessment for System Planning (RASP) probabilistic modelling approach (developed by HR Wallingford for the Environment Agency) which considers the existence and performance of flood defences as well as a range of storm loading conditions. The NaFRA08 data contains information relating to depths and probabilities of flooding provided on a 50m grid of so-called *Impact Cells*.

  Note: Within this study, the depth against inundation probability data provided by NaFRA08 are used together with a calculated depth - agricultural damage relationship to determine the risk (probability and consequence) of flooding to agricultural land.

- **Flood Zones –**Created by the Environment Agency this defines the current floodplain extent in the 1:100 (fluvial), 1:200 (coasts) and 1:1000 (fluvial and coasts) year storms (i.e. taking no account of existing defences).

  Note: Within this study this dataset is used to define the limits of the fluvial and coastal floodplain and hence the limits of the study area (surface water flooding is not considered in this report).

These are the primary datasets used. In addition to these a number of supporting datasets have been utilised including:

- **Internal Drainage Board Boundaries** – Contains the spatial delineation of the Internal Drainage Boards. Information was provided by Natural England.

- **System Asset Management Plans (SAMPS) NaFRA analysis** – Created by the Environment Agency using the RASP analysis (as in NaFRA08) but based on the assumption of "no defences". The estimated depth versus probability is provided in the same form as NaFRA08 (i.e. a 50m grid).

- **Environmental Stewardship -** Owned by Natural England, provides spatial information about the location of Environmental Stewardship schemes.

- **OS MasterMap –** Created by Ordnance Survey the OS MasterMap records every fixed feature of Great Britain larger than a few metres.

- **LCM 1990 –** Created by CEH the LCM1990 provides the previous version of the LCM 2000 and is used to explore change in land use with time.

- **Flood Storage Areas** – Created by the Environment Agency this dataset forms part of the Flood Map and defines those areas of the floodplain set by to act as flood storage areas in times of flood (implying that there is a management of these areas; therefore it does not include the natural floodplain other than those areas of the natural floodplain used to store floodwater).

- **Foresight Future Flooding** – A study commissioned by the Government and reporting in 2004, the Foresight Future Flooding utilised an early version of the RASP models to explore the change in future flood risk under different climate and management futures. It also included a project of future coastal erosion. HR Wallingford hold the base data on future flooding from this study and this has been used to support the assessment of future losses reporting here (in the absence of the data from the Long Term Investment Strategy studies – see below).

- **Catchment Flood Management Plans (CFMPs) Policy Unit data** – Created by the Environment Agency the CFMP Policy Unit data provides a spatial dataset which defines the boundaries where the different CFMP policies have been assigned to the management of fluvial flood risk.

  Note: CFMPs were not complete for England during the data processing stage of this project so complete CFMP policy information has not been available to answer some questions (for example question F3).

2.2 Useful Datasets not available for use by this project

The datasets identified as potentially suitable to describe the area of agricultural land at flood or erosion risk but which it has not been possible to obtain during the duration of the project are listed below for future reference:

- **National Flood and Coastal Defences Dataset (NFCDD) -** held by the Environment Agency; in the context of this project it was envisaged that the NFCDD would be used to identify the area benefiting from pumped drainage and the organizations operating these systems. It is believed that the data contained within NFCDD for pumps relates to the assets themselves and there is little or no data relating to the area drained by each pump. For this reason, even with the NFCDD pump information, it is likely that the question would be more reliably answered using the alternative approach described below.

  Alternative approach adopted – In the absence of this data the IDB dataset has been used to identify areas of agricultural land with special drainage needs. Approximately 50% of land within IDB Districts (c. 636,000 ha) is pumped drained. (*Note:* the Environment Agency also operates some pumps outside of IDB districts that are predominately for land drainage so the total area benefiting from pumped drainage will be greater than the figures given in this report).

- **Medium Term Plan** – Created by the Environment Agency this is a list of potential FCERM projects submitted for possible funding. *Note:* A GIS layer of the Medium Term Plan was only available for the Environment Agency Anglian Region. This layer however did not provide sufficient standard of protection data for use within this project.

  ***Alternative approach adopted*:** None. The question was answered using reasonable best endeavours with the data available for Anglian Region only.

- **Long Term Investment Strategy (LTIS):** Created by the Environment Agency, it was proposed to use the LTIS dataset to provide the probability of inundation versus depth data for various future time horizons and management options, i.e. 25, 50 and 100 years, include climate change and the policy options P1 (“do nothing”) and P3 (“maintain crest level”).

  Alternative approach adopted: Datasets from the Foresight Future Flooding Study have been used to provide a view of the future. However the Foresight studies are not as extensive or up to date as the LTIS analysis and therefore offer only a limited alternative (and hence the ability in this project to explore future agricultural impacts has been restricted) See supporting information for question F1 in appendix 5).

- **National Coastal Erosion Risk Map (NCERM)** – Being developed by the Environment Agency and held by its contractor. This dataset will provide estimates of future erosion rates and could be used to estimate the area of agricultural land potentially at risk to coastal erosion in the future.

Alternative approach adopted: None.

- **Surface Water Flooding Map -** Licensed by the Environment Agency from a third party contractor the map shows areas susceptible to surface water flooding from local rainfall. Could be used to obtain information on sources of flooding other than rivers and sea.

  Alternative approach adopted: None.

- **Reservoirs dataset -** Created by the Environment Agency this dataset contains reservoir data (location and area). It was planned to use this data to identify the agricultural land take in each Environment Agency region associated with past reservoir construction.

  Alternative approach adopted: None.

- **Land Cover Map (LCM2007) –** Unfortunately the LCM2007 source data were not available in time for use in this study. Once available (from CEH) this dataset could be used to update the results presented in this report.

  Alternative approach adopted: The LCM2000 has been used as the base land cover input.

3. Data analysis method

The project develops a methodology that is repeatable and generates evidence on the flood and coastal erosion risk to agricultural land in England and Wales, which, in turn, will support informed FCERM policy decisions.

This chapter provides an overview of the methods used to analyse the datasets to provide the answers to specific questions posed by Defra, with more detailed information provided in Chapter 4 alongside the results.

Note: Throughout the analysis, the quality and relevance of the input data (as described in the previous chapter) should be borne in mind. It should also be remembered that the methods used are focused on providing a credible national view not local accuracy.

3.1 Software framework used

For future reference the software used to undertake the analysis was:

- Geographical Information Systems (namely ArcMap) where the Reference Grid was created and a script developed to map the source data onto the Reference Grid system.
- Microsoft SQL Server, where the NaFRA08 and SAMPS data were extracted and mapped to the Reference Grid
- Microsoft Access where the cross-referencing queries (written in Structured Query Language(SQL)) were produced and run in order to obtain the relationships between each of the different source datasets for each Reference Grid location.

3.2 Establishing a common spatial reference between datasets

The project makes use of existing datasets to investigate the relationships between agricultural land (grade and land use) and flood hazard (with and without defences, today and in the future). The datasets used are held using a variety of spatial constructs. A Reference Grid of one hectare resolution (100m by 100m) covering all of England and Wales has been created and all the source data transferred to this Grid.

The Environment Agency map of regions has been used to create the Reference Grid and the total area of land in England and Wales presented in the report is obtained from this Reference Grid database.

Once established, the Reference Grid supports an efficient analysis of the data and can easily be updated to accommodate new or updated datasets as they become available without the need to integrate their geospatial information with all of the previous datasets used in the study on a dataset by dataset basis.

Once mapped to the Reference Grid, the relationships between the data can be explored efficiently via Structured Query Language (SQL) queries to obtain, for each Reference Grid location, information from all input datasets.

The Reference Grid provides a common platform to compare the information from datasets with different origin and accuracy. It facilitates the use of new information as it becomes available since this only requires mapping to the Reference Grid in order to be compatible with all of the other datasets. The Reference Grid is at 100m x 100m resolution; thus each Reference Grid location represents a hectare. This gives accurate representation of the source data since these are all national datasets and therefore tend to be based at similar scales and it is appropriate for the level of detail required from this analysis.

Using the Reference Grid approach, for continuous data such as the probability of flooding to a 0.5m depth, the Reference Grid locations were assigned the mean value of all coincident NaFRA Impact Cells while for nominal data, such as ALC or LCM, the predominant class for a given hectare was assigned to the Reference Grid location. This process does have a tendency to slightly underestimate the area associated with classes that are present in very small quantities. For example, as shown in Figure 1, the central grid cell has two different Grades (using the Agricultural Land Classification). In this project, Grade 2 is considered the one representative of the cell as it covers more area than that of Grade 3.

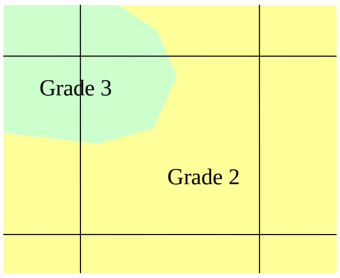

Figure 1 The native datasets are transferred onto a 1ha square Reference Grid for ease of analysis and update (The example shows the transfer of ALC Grade polygons to the Reference Grid)

Given the high resolution of the Reference Grid (1ha) the impact of this integration process on data accuracy is considered small in the context of this study. For example, Table 1 shows the degree of data loss using this process with the ALC data, where the total area of each grade in the source vector data is compared with the total area in the Reference Grid representation of the data. The table shows that the largest impact of this data loss was in ALC Grade 2, where 0.2% of the Grade 2 Area has been lost. Given the small degree of data loss associated with this approach, using the Reference Grid at 100m x 100m scale is considered to be a very good representation of the source data – giving all of the benefits mentioned above regarding ease of data integration and flexibility for future work with very minor loss of data accuracy.

Table 1 Degree of data loss using the methodology explained applied to the ALC datasets for England and Wales

NAME	Source ALC Area (ha)	RefGrid ALC Area (ha)	Difference (ha)	Difference (%)
GRADE 1	358,641	358,253	-388	0.1%
GRADE 2	1,890,655	1,887,763	-2,892	0.2%
GRADE 3	6,629,444	6,628,108	-1,336	0.0%
GRADE 4	2,667,097	2,668,503	1,406	-0.1%
GRADE 5	1,741,165	1,741,116	-49	0.0%
NON-AGRICULTURAL	827,289	828,107	818	-0.1%
URBAN	1,010,527	1,011,667	1,140	-0.1%
TOTAL	15,124,820	15,123,517	-1,303	0.0%

Note: The source data totals in Table 1 relate to the original unmodified ALC datasets (see Section 3.7)

3.3 Defining the probability of flooding

The Environment Agency's National Flood Risk Assessment 2008 (NaFRA08) is used to define the probability of flooding (from fluvial and coastal sources) within the floodplain.

The geographic building block of NaFRA08 is a grid of 50m x 50m so-called Impact Cells. For this project the probability of flooding within each Impact Cell (50m x 50 m) has been transferred to the Reference Grid (100m x 100m) by calculating the mean from up to four NaFRA08 Impact Cells contained in the Reference Grid (1 ha).

***Note*:** Calculations in NaFRA08 consider that damages occur once the depth of inundation exceeds 0.5m and a flood with a depth <0.5m is assumed to cause no damage. This reflects the role flood duration has in causing damage[6]. Unfortunately, at present the NaFRA data provides no indication of flood duration. Therefore, it is assumed that a shallow depth flood is unlikely to persist (and therefore causes limited damage) and, it is not until the depth exceeds 0.5m that duration of flooding is sufficient to cause damage. A similar assumption was adopted within the Foresight Future Flooding studies and, although not ideal and a significant assumption, it is considered reasonable in the context of this study and the limitations associated with modelling.

3.4 Estimating the benefit provided to agricultural land

This section summarises the estimation of the monetary benefit provided to agricultural land (in the form of damages avoided) by flood and coastal erosion risk management assets. For a detailed explanation refer to Appendix 1 and 2.

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[6] Property damage in NaFRA is based on the depth damage curves in the Multi-Coloured Manual– these give damage commencing at 0.3m below threshold. However, previous NaFRA reports, Foresight and MDSF2 use the 0.5m depth assumption for assessing agricultural damage.

The methods given in FCDPAG1 (Ministry of Agriculture Fisheries and Food, 2001) for the “valuation of agricultural output and land” and the subsequent supplementary note (Defra, 2008) present three scenarios:

- Scenario 1: land is abandoned or lost for agricultural purposes for the foreseeable future
- Scenario 2: occasional losses of output as a result of flooding
- Scenario 3: agricultural output per hectare falls.

This study does not estimate a risk free market value of the agricultural land and hence seek to “cap” the economic losses in the case of frequent flooding that may lead to abandonment (hence Scenario 1 is not considered)[7]. The methodology considers the impacts of occasional floods which may (or may not) cause a reduction of yield in the year of the flood, but not necessarily a “complete loss”.

A permanent change in land use or land management practice can occur as a result of increased flooding incidence or a rise in the soil-water level. This is not considered in this project (i.e. it has been assumed that any changes in the flood frequency will not result in a change of land grade or use) Therefore, in order to estimate the current benefits of flood and coastal erosion defence assets it is assumed that land use/grade remains constant.

The recent Flood and Coastal Erosion Risk appraisal guidance (Environment Agency, 2010) proposed that the Multi-Coloured Manual (Penning-Rowsell, et al., 2005) should be used for quick approaches to estimating impacts on agricultural land. We have therefore based our methods on that approach (see Appendix 1).

The following changes have been made to the method as presented in the Multi-Coloured Manual (Penning-Rowsell, et al., 2005):

- Land use classes have been redefined to reflect those available from the Land Cover Map (LCM2000) and to provide a finer resolution of analysis. The likely losses for each land use class have been estimated on the basis of Dunderdale and Morris (1997) as recommended in FCDPAG1 (Ministry of Agriculture Fisheries and Food, 2001).
- Prices and costs have been updated to 2009 levels using the Farm Management Pocketbook (Nix, 2009) as recommended in FCDPAG1 (Ministry of Agriculture Fisheries and Food, 2001).
- The assumed seasonality of flooding has been changed. The flood damages were weighted damage costs based on assumptions about the seasonality of flooding from unpublished data from catchments in the Midlands of England (Hess & Morris, 1988). This is deficient in three respects:
  a) it is based on data from the Midlands Region only,

[7] Such an approach would, for example, be considered in a cost benefit appraisal of a project to change the standard of defence. This report considers expected annual damages avoided as a result of the current flood defence system.

b) it was based on a few years of data, and
c) it relates to fluvial flooding only.
In this study the seasonality of fluvial flooding has been determined from more recent data covering all of England and Wales and the seasonality of coastal flooding has been based on an analysis of tide data. See Appendix 1 and 2 for more details.

- The flood damage costs for agricultural land presented in the Multi-Coloured Manual (Penning-Rowsell, et al., 2005) refer to fluvial flood events. Estimates have been made for coastal flooding impacts as described in Appendix 1. These include costs resulting from changes in production in subsequent years as proposed in FCDPAG1 (Ministry of Agriculture Fisheries and Food, 2001).

  The damages expected to occur in any one year to agricultural land due to flooding, expressed as £/ha/year, are calculated by multiplying the annual probability of flooding of the area (obtained from the NaFRA and SAMPS models and then seasonally adjusted) by the associated loss of production.

For example:

Determining the event damage **-** In the event of a flood the damage will vary according to season. In a particular situation, the damage may be high in the growing season (say, £100 per hectare) but outside of this there may be no damage (£0 per hectare). This event is seasonally weighted, so, if the damage during the growing season is £100/ha and there is a 0.25 chance that a flood in any year will occur in the growing season then the weighted event damage is £25/ha.

Assigning the probability of flooding – From NaFRA08 there is, say, a 0.4 chance that a flood exceeding 0.5m depth will occur in any given year. Therefore the probability of flooding is 0.4.

Calculating the damages (or risk) – The damage is then calculated as:

Annual probability of flood depth exceeding 0.5m (0.4) * consequence per hectare (£25) = Risk, £10 /ha/yr

3.5 Determining the category of agricultural land

Land Cover Map 2000 defines 72 different variants of land use (Appendix 3). Those relating to agricultural land are listed in Table 2. The Groups and Land-use categories have been defined by this project.

Table 2 Categories of agricultural land considered in the Land Cover Map 2000

Class no.	Group	Land use	Variant
9	Grass	Rough grazing	Saltmarsh (grazed)
30	Arable	Cereals	Barley
31	Arable	Cereals	Maize

Class no.	Group	Land use	Variant
32	Arable	Cereals	Oats
33	Arable	Cereals	Wheat
34	Arable	Cereals	Cereal (spring)
35	Arable	Cereals	Cereal (winter)
36	Arable	Other arable	Arable bare ground
37	Horticulture	Horticulture	Carrots
38	Arable	Other arable	Field beans
39	Horticulture	Horticulture	Horticulture
40	Arable	Other arable	Linseed
41	Arable	Roots	Potatoes
42	Arable	Other arable	Peas
43	Arable	Oilseed rape	Oilseed rape
44	Arable	Roots	Sugar beet
45	Arable	Other arable	Arable unknown
46	Arable	Other arable	Mustard
47	Arable	Other arable	non-cereal (spring)
48	Horticulture	Orchard	Orchard
49	Grass	Improved grass	Arable grass (ley)
50	Setaside	Setaside	Setaside (bare)
51	Setaside	Setaside	Setaside (undifferentiated)
52	Grass	Improved grass	Intensive grass
53	Grass	Improved grass	grass (hay / silage cut)
54	Grass	Rough grazing	Grazing marsh
56	Grass	Rough grazing	Rough grass
57	Grass	Unimproved grass	grass (neutral / unimproved)
58	Grass	Unimproved grass	Grass (calcareous managed)
59	Grass	Rough grazing	Grass (calcareous rough)
60	Grass	Unimproved grass	Grass acid
61	Grass	Rough grazing	Grass acid (rough)
62	Grass	Unimproved grass	Grass acid
63	Grass	Unimproved grass	Grass acid

3.6 Defining regional reporting scales

In addition to national figures for England and Wales the Environment Agency Regions (Figure 2) have been used to provide a regional breakdown of the analysis.

EA Region	Total area (all land) (ha)
Thames Region	1,291,700
South West Region	2,038,254
Southern Region	1,093,436
North West Region	1,441,953
North East Region	2,269,713
Midlands Region	2,189,319
Anglian Region	2,680,080
(EA) Wales	2,110,994
Total	15,115,449

Data source: "EA Regions" GIS layer

Figure 2 Definition of reporting regions (based on the regional management structure of the Environment Agency)

Note: In this report the former boundaries of the Environment Agency region Wales have been used in all the calculations referred to as "Wales". (Note, however, that from 1st April 2010 the EA Wales boundary has changed to match the national boundary)

3.7 Update of ALC

To take account of permanent changes in land use since the Agricultural Land Classification (ALC) map was created, the dataset has been updated to remove the areas that are clearly identified in the Land Cover Map 2000 (LCM2000) as out of agricultural use, such as suburban/rural developed (68), urban residential/commercial (69) and urban industrial (70). Nevertheless, other possible areas that may be out of agricultural use have not been considered when updating the ALC dataset[8].

As explained in chapter 2 the ALC describes the potential of the land for agricultural use although this may not be its current use. Therefore, the amount

[8] For example land classified as ALC grade land may contain on farm areas of broad-leaved woodland (LCM2000 subclass 23), conifers, coniferous woodland (subclass 27), despoiled, Inland rock (subclass 71) and bog (subclass 17). These areas are included as agricultural grade land in the ALC but not included as land in agricultural use in the LCM2000. Note that large woodland areas – such as Forestry Commission land – are typically not recorded as agricultural land in the ALC.

of agricultural land calculated using the ALC dataset will be higher than the amount calculated with the Land Cover Map 2000 where agricultural land is defined by its current use.

When using this dataset to answer the questions in the next chapter, the ALC dataset used is the updated version unless indicated otherwise.

4. Data analysis: answers to the questions in the project brief

This chapter presents the answers to a series of specific questions posed in the project brief using the datasets described in the previous chapter. This relationship is summarised in Table 3.

As identified in Section 2.2 it has not been possible to answer all of the questions in the project brief. In particular, this report contains no analysis of possible future losses to agricultural land from coastal erosion nor does it contain data on the potential impact of changes in flood risk management practice to reflect CFMP policies. In both cases (coastal erosion policies and implementation of CFMP policies) this is due to the policy development not being fully complete at the time the report was compiled. The intended questions are included in Appendix 5 - together with partial answers where available – for future reference.

Note: Please bear in mind the following when considering these results:

- Where appropriate the figures are rounded to the nearest hundred hectares, which will result in slight differences between summary tables and detail tables.

- All results are reported by England and Environment Agency Wales (see note in Section 3.6) and by Environment Agency regions.

- Groundwater and surface water (pluvial) flooding can be important in the context of agricultural impacts (as high water tables and water standing after heavy rain are major limitations on agricultural production) but these sources of flood risk are not included in this project.

- The agricultural land classification dataset (ALC) identifies, at broad brush national scale, the potential of land for agricultural use. The land cover map (LCM2000) dataset reports on actual agricultural land use at the time of the survey.

- The study area for this project is the extreme flood outline (referred to as the floodplain in this project) used in the Flood Map. This is defined as the current modelled extent of a 1 in 1000 year flood from the sea or rivers[9] taking no account of the presence or condition of defences. This is equivalent to Flood Zone 2.

[9]NaFRA analysis includes main rivers and many ordinary watercourses

Table 3 Datasets used to answer each question

Databases	Questions																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	F1	F2	F3	F5
Reference Grid	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•		•	•				•
EA regions dataset	•	•	•	•	•	•	•		•		•		•	•	•	•	•		•	•				•
ALC		•	•		•									•	•	•			•					
LCM 2000		•								•	•		•	•	•				•	•				
NaFRA08		•		•		•	•		•								•							
Flood Zones	•	•	•	•																•				
SAMPS				•		•	•																	
MTP							•																	
IDB's boundaries					•																			
Environmental Stewardship									•															
OS MasterMap											•													
LCM 1990												•	•	•	•									
Flood Storage Areas																•	•							
Foresight Future Flooding																					•			
CFMPs																								•

4.1 Question 1

Question 1: *What is the total area of land at risk of flooding from (i) rivers and watercourses (ii) the sea (iii) any other source, within the extreme flood outline for England and Wales?*

The total area at risk of flooding in England and Wales is detailed in the table below specifying the source of flooding. The area at risk of flooding plus the area outside the floodplain gives the total area of England and Wales in the Flood Zone 2 dataset.

Table 4 Total Flood Zone 2 (FZ2) area - England and Wales

Country	Source of flooding	Area (ha)
England	Rivers	987,800
	Sea	441,300
	Rivers and sea	226,300
	Total area at risk	**1,655,400**
	Outside FZ2	11,623,200
	TOTAL area	**13,278,600**
Wales	Rivers	106,400
	Sea	79,300
	Rivers and sea	28,900
	Total area at risk	**214,600**
	Outside FZ2	1,985,300
	TOTAL area	**2,199,900**

Method:

The Flood Zones 2 dataset (from Environment Agency) was mapped on to the reference grid (1 ha resolution) representing England and Wales. Statistical analyses followed differentiating the Flood Zones 2 attributes as “Rivers”, “Sea” and “Rivers or sea” sources. Additionally the dataset of 7 EA regions covering England was mapped to the reference grid and the previously obtained results related to the Flood Zones 2 dataset were analysed with reference to these regions (see Figure 5).

Note: The Flood Zone 2 area includes open water within estuaries. Hence the “source of flooding – sea” totals are greater than the totals shown in Tables 16 and 17.
Similarly, the totals shown here are slightly different from those in Table 1 and Figure 2 because different datasets are used.

Supporting information:

The graphics below represent the data shown in Table 4.

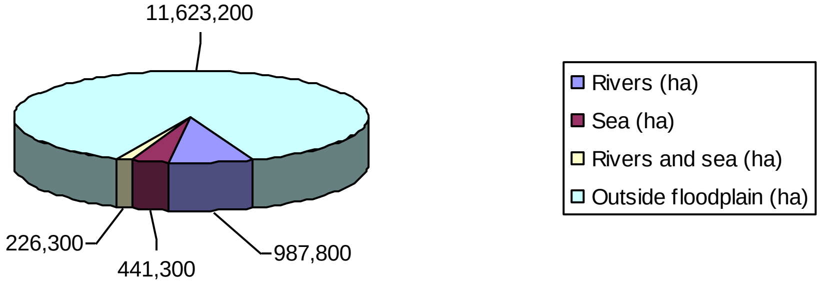

Figure 3 Flood Zone 2 as a proportion of total area - England (ha)

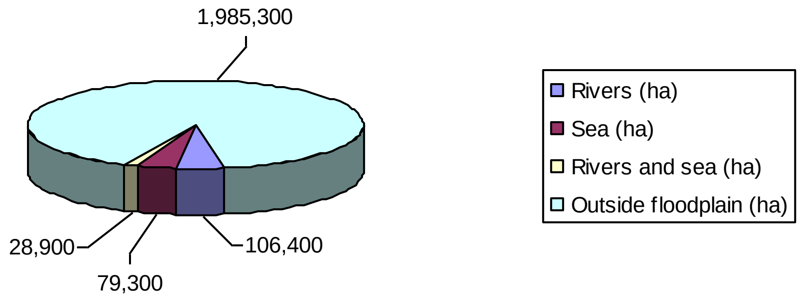

Figure 4 Flood Zone 2 as a proportion of total area - Wales (ha)

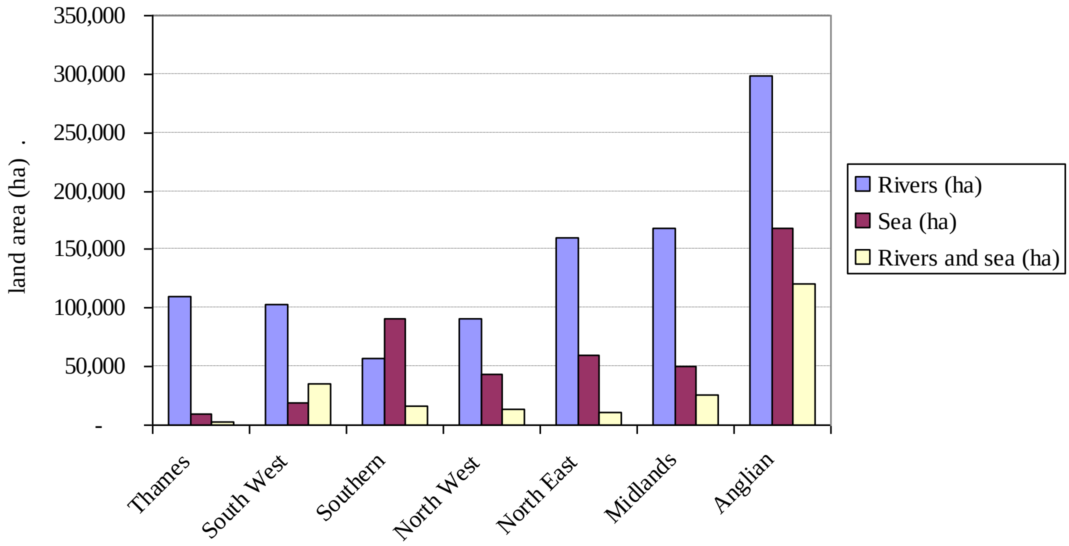

Figure 5 Flood zone 2 totals by source of flood risk - English EA region

Note: The values in Figure 5 and the data table at Figure 2 can be used to approximate the proportion of the regional area that is floodplain.

Datasets used:

Reference grid, Flood Zone 2 (from Flood Map), EA Regions

4.2 Question 2

Question 2: *How much of this area is agricultural land by land use type and agricultural land grade?*

The total area of land in agricultural use at flood risk from rivers or the sea or from both sources in England and Wales is 1,336,000 ha.

In England there are 1,224,900 ha of land in agricultural use (LCM 2000) in the floodplain. This covers 74% of the total area of the floodplain.

In Wales there are 111,100 ha of land in agricultural use in the floodplain, covering 52% of the total floodplain area.

Tables 5 and 6 below show the area at risk of flooding for the different agricultural land use categories for England and Wales by source of flooding. They have been determined using the information in the LCM2000 dataset.

Table 5 Agricultural land use in the floodplain - England (ha)

		Source of flooding		
	Area in the floodplain	Rivers	Sea	Rivers and sea
Grass	480,200	325,200	93,800	61,200
Arable	693,000	384,700	183,600	124,700
Horticulture	16,600	8,800	3,800	4,000
Set aside	35,100	23,900	7,100	4,100
TOTAL	**1,224,900**	**742,600**	**288,300**	**194,000**

Table 6 Agricultural land use in the floodplain - Wales (ha)

		Source of flooding		
	Area in the flood plain	Rivers	Sea	Rivers and sea
Grass	91,000	62,800	14,000	14,300
Arable	19,400	14,700	2,600	2,100
Horticulture	100	100	0	0
Set aside	600	500	100	100
TOTAL	**111,100**	**78,000**	**16,700**	**16,400**

Note: The value “0” in this Table may indicate a total less than 50ha

Table 7 below shows the agricultural land area (ALC grade) at risk of flooding, using the ALC dataset.

Table 7 Agricultural grade land in the floodplain categorised by ALC grade (ha)

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
England	187,000	302,000	549,100	264,500	27,900	1,330,500
Wales	1,500	8,900	41,900	54,000	21,700	127,900

Note: The totals above are greater than the totals in Tables 5 & 6 because this Table uses the ALC dataset. (See Section 3.7 and comments at the start of this chapter for more information).

Method:

After mapping the LCM2000 on to the reference grid, its attributes were categorised into "Grass", "Arable", "Horticulture" and "Set aside" according to the table in Appendix 3. The resulting database was then cross-referenced with the Flood Zones 2 data to obtain area values for each source of flooding.

The same methodology was used to generate Table 7, in this case using the ALC dataset instead of the LCM2000.

Supporting information:

Tables below show the area at risk by agricultural land use and EA region in England. When summing the area at risk of flooding by rivers, sea, and rivers and sea, slight differences can appear with the total area in the floodplain due to rounding.

Table 8 Agricultural land use in the floodplain - Thames Region

Thames Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	37,800	36,600	700	600
Arable	28,900	28,600	200	100
Horticulture	500	500	0	0
Set aside	5,000	4,800	100	100
Total	72,200	70,800	1,100	800

Table 9 Agricultural land use in the floodplain - South West Region

South West Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	84,800	54,700	8,000	22,100
Arable	31,700	21,800	3,200	6,700
Horticulture	300	300	0	0
Set aside	1,300	800	200	300
Total	118,100	77,600	11,400	29,100

Table 10 Agricultural land use in the floodplain - Southern Region

Southern Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	47,700	20,200	19,000	8,500
Arable	44,900	15,100	25,300	4,500
Horticulture	1,600	500	900	200
Set aside	3,500	1,400	1,700	300
Total	97,700	37,200	46,900	13,500

Table 11 Agricultural land use in the floodplain - North West Region

North West Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	63,600	47,400	9,100	7,000
Arable	22,000	15,300	4,400	2,300
Horticulture	0	0	0	0
Set aside	600	500	100	< 100
Total	86,200	63,200	13,600	9,300

Table 12 Agricultural land use in the floodplain - North East Region

North East Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	63,300	50,300	10,800	2,200
Arable	98,400	61,800	30,700	5,800
Horticulture	0	0	0	0
Set aside	1,100	1,000	100	0
Total	162,800	113,100	41,600	8,000

Table 13 Agricultural land use in the floodplain - Midlands Region

Midlands Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	91,600	71,000	14,300	6,300
Arable	92,700	51,700	25,800	15,200
Horticulture	0	0	0	0
Set aside	3,100	2,500	700	0
Total	187,400	125,200	40,800	21,500

Table 14 Agricultural land use in the floodplain - Anglian Region

Anglian Region	Area in the floodplain (ha)	Rivers (ha)	Sea (ha)	Rivers and sea (ha)
Grass	91,500	45,100	32,000	14,400
Arable	374,500	190,300	94,000	90,100
Horticulture	14,200	7,500	2,800	3,900
Set aside	20,500	12,900	4,300	3,300
Total	500,700	255,800	133,100	111,700

Note: The value “0” in these Tables may indicate a total less than 50ha

The Table below shows the areas in the floodplain categorised by ALC Grade.

Table 15 Total area (ha) agricultural grade land in the floodplain categorised by ALC grade – EA regions England

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Thames	1,300	10,400	29,500	34,600	1,300	77,100
South-West	1,400	13,000	63,200	54,000	3,800	135,500
Southern	9,900	21,000	40,000	31,600	1,700	104,200
North-West	6,600	12,700	48,700	26,800	8,000	102,800
North-East	8,700	44,000	90,900	26,100	8,900	178,600
Midlands	8,500	35,000	105,300	53,100	3,200	205,100
Anglian	150,600	165,900	171,500	38,300	1,000	527,300

Note: The equivalent figure for EA Wales is shown in Table 7.

This information is graphed in the figure below:

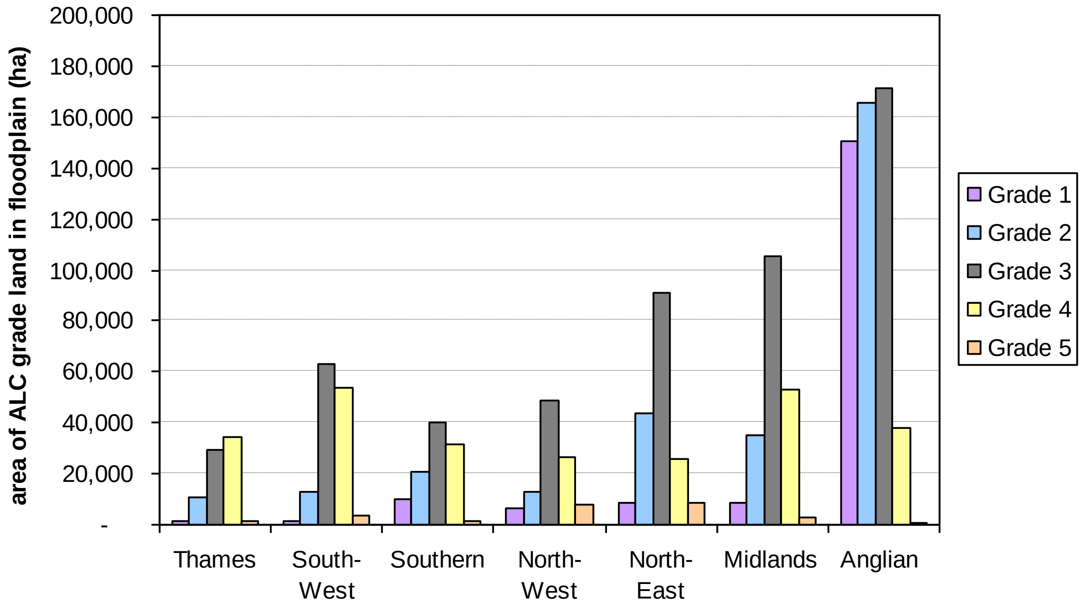

Figure 6 Total agricultural grade land in the flood plain by ALC grades (ha)

There are slight differences between the figures obtained with the LCM and ALC datasets. As explained in Section 3.7, the ALC describes the potential of the land for agricultural use not necessarily its current use.

The tables below show the flood risk to land in agricultural use by use category, for England and Wales.

Table 16 Area of land (ha) in agricultural use within the floodplain by flood return period (years) - England

		<3	3-5	5-10	10-20	20-75	75-200	>200	Totals
Grass	Rivers	13,900	6,100	36,000	34,900	94,000	37,100	103,200	325,200
	Sea	1,700	900	4,900	12,300	25,400	15,000	33,500	93,800
	Rivers & sea	1,300	1,200	6,700	10,000	19,000	6,200	16,800	61,200
	Outside floodplain								4,151,300
Arable	Rivers	8,100	3,800	21,900	25,300	66,800	34,400	224,400	384,700
	Sea	3,000	900	5,200	15,400	47,700	43,200	68,200	183,600
	Rivers &sea	700	500	3,100	6,500	23,600	13,200	77,100	124,700
	Outside floodplain								3,934,500
Horticulture	Rivers	100	100	300	400	600	400	7,100	8,800
	Sea	-	-	100	300	800	400	2,100	3,800
	Rivers &sea	-	-	-	100	400	300	3,300	4,000
	Outside floodplain								56,500
Set aside	Rivers	400	200	2,100	2,000	3,000	1,800	14,400	23,900
	Sea	200	100	500	700	1,100	700	3,800	7,100
	Rivers & sea	-	-	100	200	400	200	3,100	4,100
	Outside floodplain								190,500
Non-agricultural	Rivers	6,800	3,400	21,400	19,400	64,000	30,800	97,700	243,500
	Sea	3,100	1,300	4,000	7,800	21,500	15,000	77,700	130,400
	Rivers & sea	800	400	1,900	3,700	7,700	3,400	14,500	32,200
	Outside floodplain								3,176,600
Total	Rivers	29,300	13,500	81,600	81,900	228,500	104,500	446,800	986,200
	Sea	8,000	3,200	14,700	36,500	96,600	74,300	185,400	418,600
	Rivers & sea	2,800	2,100	11,900	20,400	50,900	23,300	114,700	226,100
	Outside floodplain								11,509,400
Total area at risk of flooding		40,100	18,800	108,200	138,800	376,000	202,100	746,900	1,630,900

Note: The "total area at risk of flooding" figure includes land not in agricultural use.
The figures in the return period categories are not cumulative; they represent the area of land (ha) at risk within each frequency band.
"-" may indicate a value less than 50ha

Table 17 Area of land (ha) in agricultural use within the floodplain by flood return period (years) - Wales

		<3	3-5	5-10	10-20	20-75	75-200	>200	Totals
Grass	Rivers	7,600	3,900	12,800	8,100	9,100	3,500	17,900	62,800
	Sea	2,100	800	3,000	2,300	2,500	600	2,700	14,000
	Rivers & sea	2,300	1,000	2,900	1,700	2,700	900	2,800	14,300
	Outside floodplain								1,261,100
Arable	Rivers	3,425	908	1,939	1,646	1,843	714	4,200	14,700
	Sea	343	207	649	420	448	107	400	2,600
	Rivers & sea	200	100	200	100	400	100	1,000	2,100
	Outside floodplain								149,600
Horticulture	Rivers	33	0	0	0	0	0	-	100
	Sea	0	0	0	0	0	0	0	0
	Rivers & sea	0	0	0	0	0	0	0	0
	Outside floodplain								400
Set aside	Rivers	100	0	0	0	100	0	100	500
	Sea	0	0	0	0	0	0	-	100
	Rivers & sea	0	0	0	0	0	0	0	0
	Outside floodplain								4,700
Non-agricultural	Rivers	2,900	1,600	5,100	3,300	5,000	2,300	8,300	28,400
	Sea	3,600	800	1,900	1,600	2,400	900	24,800	36,100
	Rivers & sea	1,200	500	1,400	800	1,500	600	6,300	12,300
	Outside floodplain	-	-	-	-	-	-	-	543,800
Total	Rivers	14,100	6,400	19,800	13,100	16,000	6,500	30,500	106,400
	Sea	6,100	1,800	5,600	4,300	5,300	1,600	28,000	52,800
	Rivers & sea	3,700	1,600	4,600	2,600	4,600	1,600	10,100	28,700
	Outside floodplain								1,959,700
	Total area at risk of flooding	23,900	9,800	30,000	20,000	25,900	9,700	68,500	187,800

Note: The "total area at risk of flooding" figure includes land not in agricultural use.
The figures in the return period categories are not cumulative; they represent the area of land (ha) at risk within each frequency band.
"-" may indicate a value less than 50ha

Datasets used:
Reference grid, Flood Zones 2 (from Flood Map), LCM2000, EA Regions, ALC reviewed, NaFRA08

4.2 Question 3

Question 3: *What do these areas represent as a percentage of the national resource? Are there high-value, specialist, or regionally constrained farming outputs that are disproportionately at flood risk?*

The area of ALC grade land in the floodplain compared with the total area of that resource at a national scale for England and Wales is presented in the tables below.

Table 18 Total area of agricultural grade land and proportion in the floodplain - England

ALC Grade	Total area (ha)	Area in the floodplain (ha)	% of ALC grade land in the floodplain
1	323,000	187,000	58%
2	1,680,700	302,000	18%
3	5,837,300	549,100	9%
4	1,832,600	264,500	14%
5	1,147,000	27,900	2%
TOTAL	**10,820,600**	**1,330,500**	**12%**

See also Table 30 for the area of land at flood risk within each ALC grade.

Table 19 Total area of agricultural land and proportion in the floodplain - Wales

ALC Grade	Total area (ha)	Area in the floodplain (ha)	% of ALC grade land in the floodplain
1	11,700	1,500	13%
2	109,600	8,900	8%
3	409,000	41,900	10%
4	724,100	54,000	7%
5	575,500	21,700	4%
TOTAL	**1,829,900**	**128,000**	**7%**

See also Table 31 for the area of land at flood risk within each ALC grade.

The best and most versatile agricultural land is land grades 1, 2 and 3. The table below shows the amount of this type of land in the floodplain compared with the total amount of this resource at a national level.

Table 20 Total area of best and most versatile (BMV) agricultural land and proportion in the floodplain in England and Wales

	Total area of BMV land (ha)	Total area of BMV land in the floodplain (ha)	%
England	7,841,000	1,038,100	13%
Wales	530,300	52,300	10%

Note: The dataset used does not distinguish grade 3a and grade 3b land areas. It is not known whether these have been mapped nationally or whether this is available on a GIS layer.

Method:

The ALC dataset was mapped to the reference grid and then cross-referenced with the dataset representing the EA regions. This combination resulted in total area of agricultural land by ALC grade in England and Wales. Furthermore, this dataset combination was again cross-referenced with the Flood Zones 2 dataset to get the proportion of agricultural land in the floodplain.

Supporting information:

The tables below show the total area of agricultural grade land by Environment Agency region.

Table 21 Total ALC grade land - England

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Thames Region	6,800	154,600	594,500	131,200	2,700	**889,800**
South West Region	30,500	143,400	1,102,400	387,900	132,300	**1,796,500**
Southern Region	39,700	96,900	551,200	150,600	16,400	**854,800**
North West Region	25,800	64,000	440,100	289,100	366,200	**1,185,200**
North East Region	10,100	250,800	813,300	343,000	505,400	**1,922,600**
Midlands Region	15,600	254,900	1,038,000	389,400	121,300	**1,819,200**
Anglian Region	194,500	716,100	1,297,800	141,400	2,700	**2,352,500**
TOTAL	**323,000**	**1,680,700**	**5,837,300**	**1,832,600**	**1,147,000**	**10,820,600**

Table 22 Total ALC grade land - Wales

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Wales	11,700	109,600	409,000	724,100	575,500	1,829,900

The information in Tables 15 and 21 has been used to calculate the percentages shown in the figure below. This shows, for example, that 86% of the Grade 1 land in the North-East region is in the floodplain.

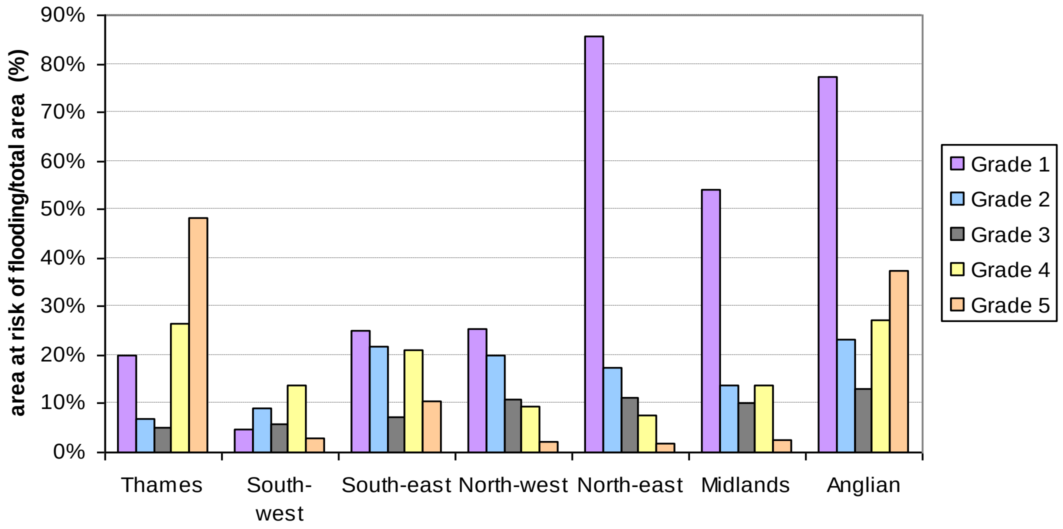

Figure 7 Percentage of regional ALC grade land in the floodplain - England

(*Note:* Southern Region is incorrectly labelled “South-east” in the Figure above)

Datasets used:

Reference grid, Flood Zones 2 (from Flood Map), ALC reviewed, EA Regions

4.3 Question 4

Question 4: *What is the area of agricultural land that is presently protected by defences, reporting by standard of protection, agricultural land classification grade, and agricultural land use type? What proportion (by length) of these defences is maintained by parties other than operating authorities? (identify these 3rd parties where possible)*

Agricultural land (and properties) may be situated in the floodplain but not benefit from defences either because defences are not present or because the land (or property) sits beyond the protection of the defence.

The area of agricultural land benefiting from defences is calculated as the difference between the area at risk of flooding if no defences were present and the actual area at risk of flooding taking account of the presence of defences and the defence condition (established through a programme of defence inspection). The tables below show the results of this calculation.

Table 23 Area (ha) of ALC grade land benefiting from defences - England

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Fluvial defences	22,300	58,800	189,600	130,300	11,700	412,700
Coastal defences	25,200	52,700	117,700	28,500	4,600	228,700
Fluvial and coastal defences	13,000	45,500	46,500	14,600	1,600	121,200
TOTAL	60,500	157,000	353,800	173,400	17,900	762,600

Note: This tables uses the SAMPs and NaFRA datasets

Table 24 Area (ha) of ALC grade land benefiting from defences - Wales

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Fluvial defences	300	1,400	9,100	15,900	3,300	30,000
Coastal defences	0	300	7,900	6,200	2,900	17,300
Fluvial and coastal defences	0	1,400	3,200	6,600	5,200	16,400
TOTAL	300	3,100	20,200	28,700	11,400	63.700

Note: This tables uses the SAMPs and NaFRA datasets

See Tables 18 and 19 for the total area of agricultural grade land in the floodplain and Tables 21 and 22 for the total agricultural grade land in England and Wales.

The operating authorities with maintenance responsibilities are identified in the table below showing the length of defence assets maintained by each authority.

Note: It has not been possible to identify the boundaries of those defence systems that only protect agricultural land, therefore these figures (Tables 25, 26, 27) refer to all land use.

Table 25 Maintenance responsibility (km of raised defence assets) for river and coastal defences

	Environment Agency	Local authority	Internal Drainage Board	others	Total length (km)
England	7,208	1,101	20	3,027	11,356
Wales	529	120	-	1,151	1,800

Note: The data in this table are taken from the Environment Agency's NFCDD database. This is incomplete for defence systems not maintained by the Environment Agency so, for example, the IDB value is underestimated.

Note: This Table refers to maintained raised defences. It does not included natural defence systems such as beaches and dune systems. The figures here, and in Tables 26 and 27, include culvert lengths where these are part of a river system. The category "others" relates to privately maintained defences (included MoD and Port Authorities, and culverts in riparian ownership). "Maintenance responsibility" does not necessarily imply ownership. Table 30 presents the figures for English EA regions.

The length of the defences (in km) classified by their Standard of Protection (based on the crest level of the defence only) is summarised in Table 26 for the English regions and in Table 27 for Wales.

Table 26 Length (km) of raised defence asset by standard of protection – England

	Nominal standard of protection (return period, years) provided by the defence asset								
Region	**No stnd**	**1-3**	**4-5**	**6-10**	**11-25**	**26-50**	**51-100**	**>100**	**total length (km)**
Anglian Region	243	52	165	662	756	252	904	497	3,532
Midlands Region	223	92	29	203	138	122	345	21	1,171
North East Region	48	826	2	70	112	301	377	113	1,849
North West Region	43	3	11	27	217	623	401	58	1,381
South West Region	302	95	181	55	81	89	366	78	1,247

Southern Region	93	222	166	31	71	291	436	138	1,447
Thames Region	5	8	404	1	36	28	66	183	730
Total	955	1,299	957	1,047	1,410	1,706	2,894	1,088	11,356

Note: "No stnd" means that no standard of protection was recorded in NFCDD. This typically refers to culverts.

Table 27 Length (km) of raised defence asset by standard of protection – Wales

	Nominal standard of protection (return period, years) provided by the defence asset								
	No stnd	**1-3**	**4-5**	**6-10**	**11-25**	**26-50**	**51-100**	**>100**	**total length (km)**
Wales	134	83	137	206	91	159	257	733	1,800

Note: "No stnd" means that no standard of protection was recorded in NFCDD. This typically refers to culverts.

Supporting information:

The area of agricultural grade land benefiting from fluvial and coastal defences in the different regions is shown in the table below:

Table 28 ALC grade land (ha) benefiting from defences by region

	Type of defence	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Thames Region	Fluvial	600	4,600	10,800	13,200	600	29,800
	Coastal	100	0	0	0	0	100
	Fluvial& Coastal	0	0	200	0	0	200
South West Region	Fluvial	300	2,300	18,500	26,100	1,600	48,800
	Coastal	200	800	7,200	1,800	800	10,800
	Fluvial& Coastal	100	6,600	15,000	5,000	200	26.900
Southern Region	Fluvial	400	2,200	8,800	10,100	200	21,700
	Coastal	5,900	14,100	8,600	9,300	900	38,800
	Fluvial& Coastal	400	600	8,300	4,200	200	13,700
North West Region	Fluvial	3,300	8,200	29,400	14,300	3,300	58,500
	Coastal	600	3,000	6,400	3,200	1,700	14,900
	Fluvial& Coastal	0	900	6,900	1,800	200	9,800
North	Fluvial	3,900	16,600	49,500	19,400	5,100	94,500

East Region	Coastal	2,300	14,400	19,400	1,800	500	38,400
	Fluvial& Coastal	1,900	3,800	1,400	500	300	7,900
Midlands Region	Fluvial	500	7,400	43,900	36,000	900	88,700
	Coastal	7,100	10,200	16,700	3,400	300	37,700
	Fluvial& Coastal	300	8,400	6,200	800	700	16,400
Anglian Region	Fluvial	13,300	17,500	28,700	11,200	0	70,700
	Coastal	9,000	10,200	59,400	9,000	400	88,000
	Fluvial& Coastal	10,300	25,200	8,500	2,300	0	46,300
TOTAL	Fluvial	22,300	58,800	189,600	130,300	11,700	412,700
	Coastal	25,200	52,700	117,700	28,500	4,600	228,700
	Fluvial& Coastal	13,000	45,500	46,500	14,600	1,600	121,200

Note: Refer to Table 15 for the area of ALC grade land in the floodplain for each region and to Table 21 for the total area of ALC grade land in each region.

The operating authorities with maintenance responsibilities in the different regions are identified in table below.

Table 29 Maintenance responsibility (km of raised defence assets) for river and coastal defences – by English Region

	Environment Agency	Local authority	Internal Drainage Board	Others	Total length
Thames Region	75	113	-	542	730
South West Region	663	232	-	351	1246
Southern Region	724	249	16	458	1447
North West Region	568	130	-	683	1381
North East Region	1,244	142	4	458	1848
Midlands Region	977	20	0	174	1171
Anglian Region	2,956	215	1	361	3533
total	7207	1101	21	3027	11356

Note: Table 25 gives the figures for Wales. Refer also to Notes below Table 25.

The area of floodplain ALC grade land in the different flood risk categories is shown in the following tables for England and Wales.

Table 30 Area (ha) of land at risk of flooding; Flood return period and grade of agricultural land - England

		<3	3-5	5-10	10-20	20-75	75-200	>200	Totals
Grade 1	Rivers	700	200	1,200	1,400	4,000	5,000	89,700	102,100
	Sea	100	100	700	3,400	9,200	6,800	25,100	45,400
	Rivers & sea	-	-	100	800	3,700	2,800	32,000	39,400
	Outside floodplain								136,100
Grade 2	Rivers	2,500	900	7,000	8,800	24,700	12,800	96,100	152,700
	Sea	600	100	1,300	6,800	15,700	19,300	20,400	64,300
	Rivers & sea	200	300	3,500	5,200	16,900	9,500	49,500	85,200
	Outside floodplain								1,378,500
Grade 3	Rivers	13,000	6,200	30,800	34,100	94,200	40,100	123,100	341,300
	Sea	3,300	1,100	5,900	14,200	43,500	30,500	48,100	146,600
	Rivers & sea	1,100	800	5,000	9,600	19,500	6,400	18,700	61,100
	Outside floodplain								5,288,200
Grade 4	Rivers	10,100	4,900	30,200	26,800	58,800	20,800	58,500	210,100
	Sea	1,300	600	3,000	4,600	8,200	3,400	16,400	37,500
	Rivers & sea	900	700	2,200	2,500	5,600	1,700	2,900	16,400
	Outside floodplain								1,568,200
Grade 5	Rivers	200	200	1,000	1,700	7,100	2,500	5,600	18,200
	Sea	200	100	300	600	1,500	800	3,700	7,300
	Rivers & sea	-	-	100	400	600	200	1,200	2,500
	Outside floodplain								1,118,900
non agricultural	Rivers	2,500	1,100	11,400	9,200	39,300	23,100	67,600	154,200
	Sea	1,400	800	2,500	5,300	14,800	12,400	40,100	77,300
	Rivers & sea	500	200	800	1,800	4,400	2,600	8,600	18,900
	Outside floodplain								1,940,700
Total	Rivers	29,000	13,500	81,600	81,900	228,100	104,200	440,500	978,700
	Sea	6,900	2,800	13,700	35,000	93,000	73,200	153,900	378,400
	Rivers & sea	2,700	2,100	11,800	20,300	50,600	23,200	112,900	223,600
	Outside floodplain								11,430,600
Total area at risk of flooding		38,500	18,400	107,000	137,100	371,600	200,700	707,300	1,580,600

Note: The difference between the total area of agricultural grade land in the floodplain shown here and the total shown in Tables 7 and 18 is due to rounding.
The "outside floodplain" figures have been derived from Table 18, the total area (including non-agricultural and urban land) outside of the floodplain in England is estimated at 11,856,900 ha.
"-" may indicate a value less than 50ha.

Table 31 Area (ha) of land at risk of flooding; Flood return period and grade of agricultural land - Wales

		<3	3-5	5-10	10-20	20-75	75-200	>200	Totals
Grade 1	Rivers	200	100	100	100	200	100	700	1,500
	Sea	-	-	-	-	-	-	-	-
	Rivers & sea	-	-	-	-	-	-	-	-
	Outside floodplain								10,300
Grade 2	Rivers	1,000	400	500	600	800	400	3,000	6,800
	Sea	100	-	-	-	100	-	100	300
	Rivers & sea	-	-	100	-	200	100	1,300	1,700
	Outside floodplain								100,800
Grade 3	Rivers	6,900	2,200	4,700	3,600	4,200	1,500	7,800	31,000
	Sea	1,200	600	2,200	1,600	1,200	100	900	8,000
	Rivers & sea	400	200	800	500	500	-	500	3,000
	Outside floodplain								367,000
Grade 4	Rivers	4,400	2,600	10,300	5,600	6,000	2,200	9,600	40,600
	Sea	1,200	500	1,400	900	1,100	300	900	6,400
	Rivers & sea	1,100	500	1,400	700	1,500	500	1,200	7,000
	Outside floodplain								670,100
Grade 5	Rivers	400	500	1,800	1,400	1,700	800	3,700	10,300
	Sea	700	200	500	400	600	200	2,900	5,400
	Rivers & sea	1,300	500	1,100	700	1,100	300	1,000	6,000
	Outside floodplain								553,800
non agricultural	Rivers	1,200	500	2,300	1,800	3,000	1,500	5,600	16,000
	Sea	1,300	400	1,100	1,100	1,800	800	3,000	9,500
	Rivers & sea	400	200	600	500	1,200	500	1,800	5,200
	Outside floodplain								255,000
Total	Rivers	14,100	6,400	19,800	13,100	15,900	6,500	30,300	106,200
	Sea	4,500	1,700	5,200	4,100	4,800	1,500	7,800	29,600
	Rivers & sea	3,200	1,500	4,000	2,500	4,400	1,500	5,700	22,800
	Outside floodplain								1,957,000
Total area at risk of flooding		21,800	9,600	29,000	19,600	25,200	9,500	43,800	158,600

Note: The difference between the total area of agricultural grade land in the floodplain shown here and the total shown in Tables 7 and 19 is due to rounding.
The “outside floodplain” figures for Grades 1 to 5 have been derived from Table 19.
“-“ may indicate a value less than 50ha.

Datasets used:

Reference grid, Flood Zones 2 (from Flood Map), SAMPS, NAFRA08, EA Regions, ALC reviewed.

4.5 Question 5

Question 5: *What is the area and grade of agricultural land benefiting from pumped drainage? (Identify where possible which organisation operates these systems).*

It has not been possible to identify the total area of agricultural land benefiting from pumped drainage as the benefit area for each pumping system is not routinely identified. However the Internal Drainage Board (IDB) dataset has been used to identify the area of agricultural grade land falling within IDB districts.

IDBs are the drainage bodies that undertake work to secure drainage and water level management of their districts. Much of their work involves the maintenance of non-main rivers, drainage channels and pumping stations, facilitating drainage of new developments and advising on planning applications, they operate and maintain over 500 pumping stations.

IDB districts do not cover all areas of special drainage need, in some places (such as on Dengie Marsh in Essex or the Lyth Valley in Cumbria) this function is undertaken by the Environment Agency. The data provided in this report relates to IDBs only and thus does not represent the full area benefiting from pumped drainage or land drainage measures.

The 2006 report[10] by JBA calculated that 635,722 ha of land within IDB districts rely on pumped drainage, about 50% of the total IDB area.

The dataset identifies an area of 1,352,000 ha covered by IDB districts. The amount of agricultural grade land, by grade, within IDB districts is shown in the table below.

Table 32 Area (ha) of agricultural land by ALC grade within IDB districts

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
England	191,700	331,300	537,300	103,700	5,200	1,169,200
Wales	1,000	8,000	12,700	9,900	4,100	35,700

Note: IDB districts may slightly extend beyond the area covered by the Environment Agency's flood map, therefore the data in Table 32 does not represent the area of IDB district agricultural grade land within the floodplain. (Compare with Table 7). The regional breakdown of these figures is given in Table 33.

The information in the table above is shown as percentages of the total agricultural grade land within IDB districts in the figures below. These show, for example, that 46% of agricultural grade land within IDB districts in England is grade 3 land.

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[10] Internal Drainage Board Review. Final Report. February 2006. Available at http://www.defra.gov.uk/environment/flooding/documents/who/idb/jbareport.pdf

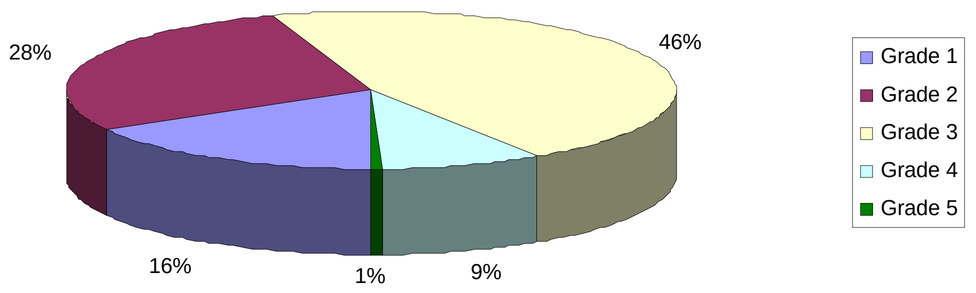

Figure 8 Composition of agricultural grade land in IDB districts - England

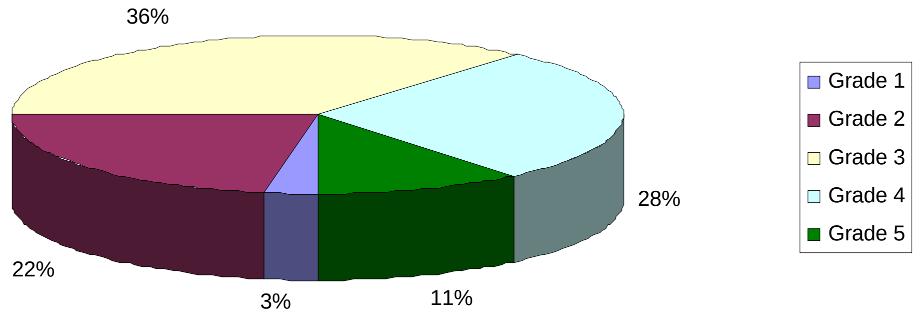

Figure 9 Composition of agricultural grade land in IDB districts - Wales

Method:

The ALC dataset was mapped to the reference grid and then cross-referenced with the dataset representing the EA regions. This combination produced the area of agricultural land by ALC grade in England and Wales.

Supporting information:

IDBs are geographically concentrated in the Norfolk and Suffolk Broads, the Fens in East Anglia and Lincolnshire, Somerset Levels, Kent, Nottinghamshire and Yorkshire covering parts of growth areas such as the Thames Gateway and Milton Keynes & South Midlands, and existing developed areas of the Thames gateway, East Midlands and the Humber Estuary.

The regional distribution of agricultural grade land within IDB districts is shown in the table below.

Table 33 Area (ha) of agricultural grade land within IDB Districts by Environment Agency region - England

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	total
Thames Region	0	0	0	0	0	0
South West Region	2,000	12,000	43,700	13,300	100	71,100
Southern Region	14,700	22,000	55,700	22,300	700	115,400
North West Region	0	0	0	0	0	0
North East Region	8,800	69,000	136,300	19,300	2,400	235,800
Midlands Region	1,500	34,000	82,000	16,400	2,000	135,900
Anglian Region	164,700	194,300	219,600	32,400	0	611,000
TOTAL	191,700	331,300	537,300	103,700	5,200	1,169,200

Note: Compare with Table 21 showing the regional and national totals for ALC grade land in England. This shows, for example, that in Anglian Region 85% of grade 1 land is in an IDB district (164,700 ha / 194,500 ha). See Figure 11 (below). Note also that some land within IDB districts is outside of the floodplain as defined by this project.

The data presented in the tables above are summarized in graphical format in figures below. Wales is added for comparison in the graphs showing the results for the different regions in England

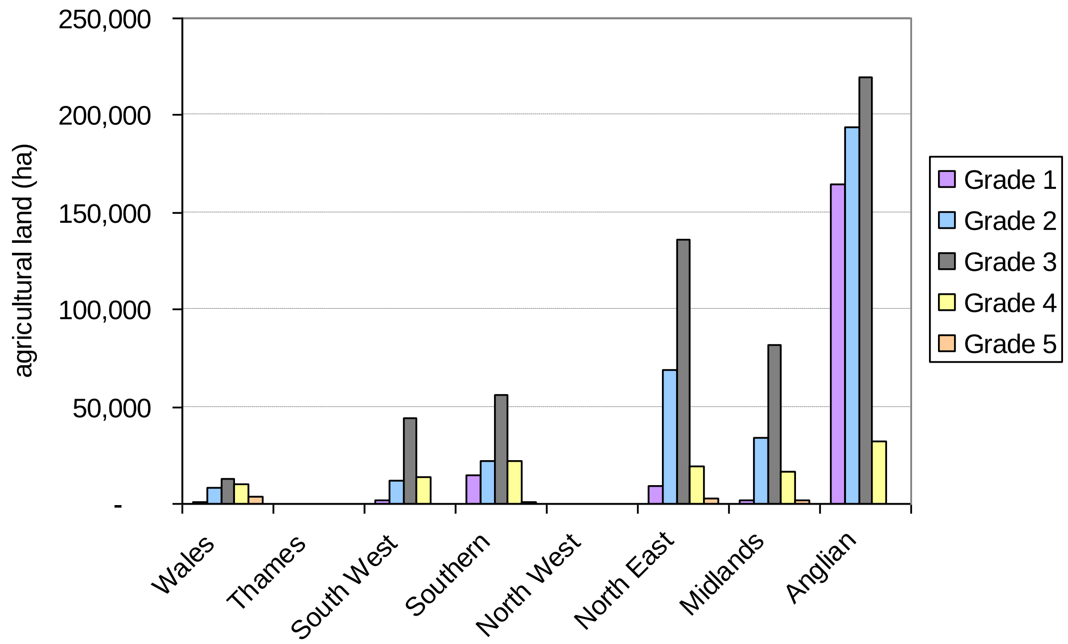

Figure 10 Area (ha) of agricultural grade land in IDB districts in Wales and regions in England

The percentage of the regional total of agricultural grade land (Table 21) within IDB districts is shown in the Figure below showing, for example, the high incidence of grade 1 land within IDB districts in Anglian, North-East, and Midlands regions. (A similar result for the distribution of agricultural grade land within the floodplain is given in Figure 7).

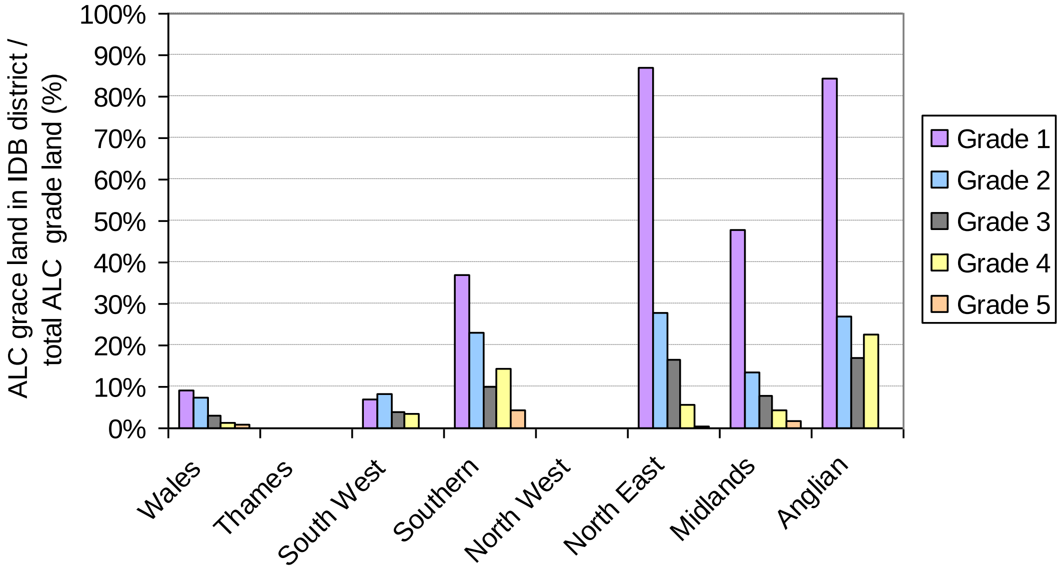

Figure 11 Proportion of total agricultural grade land (by grade and Region) located within IDB districts

Datasets used:
Reference grid, ALC, EA Regions, IDB dataset

4.6 Question 6

Question 6: *What is the expected annual damage avoided to agricultural land by FCERM defences? Clearly identify the assumptions made (for example with regard to tolerance to inundation and crop values and write-off points) in generating this answer.*

The expected annual damage avoided is calculated using the methodology described in Section 3.4 of this report. The results presented are calculated considering separately fluvial and coastal defences. However it is possible for an area of land to benefit both from fluvial and coastal defences. In this case the benefit is shown in both categories. For the purpose of this analysis coastal defences are considered to extend up to the tidal limit. They protect from saline flooding, this has a different scale of impact to fluvial flooding as described in Appendix 1. The reader is advised to check Chapter 3 (and Appendixes 1 and 2) for a complete understanding of the method used to calculate the results presented in the tables below.

Table 34 Expected annual damages avoided (expressed as £m) by fluvial and coastal defences in England and Wales

	Expected annual damages avoided (£m)		
	Fluvial defences	**Coastal defences**	**total**
England	5.0	110.8	115.8
Wales	0.2	6.9	7.1

Method:

The methodology used to calculate this result is explained in detail in Section 3.4.

Supporting information:

The graphs below present the damages avoided by the presence of fluvial and coastal defences to land in agricultural use in English EA regions and Wales.

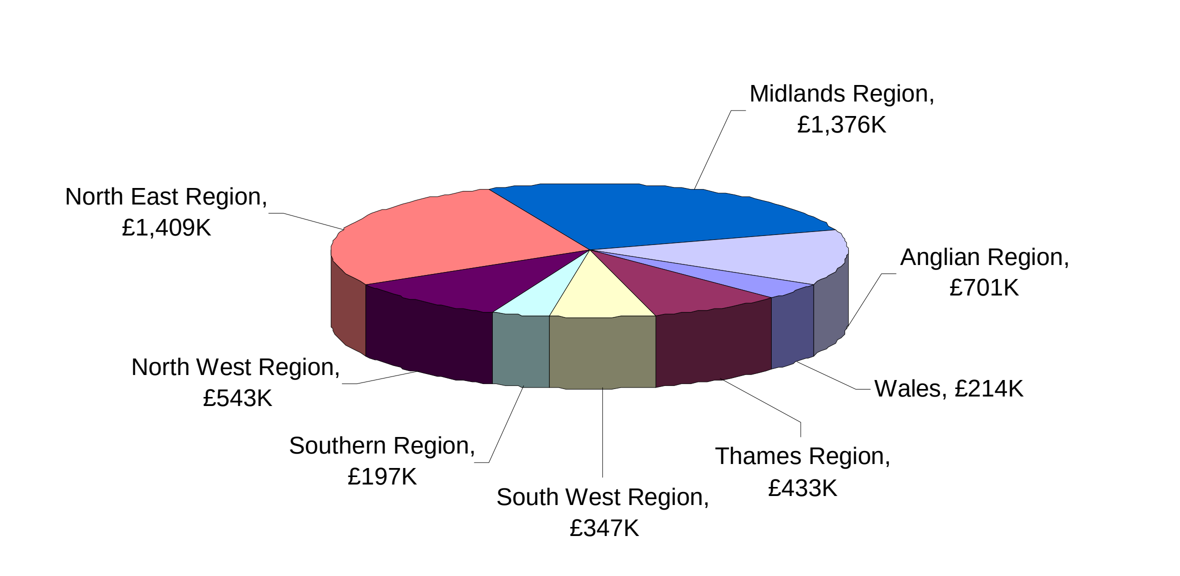

Figure 12 Expected annual damages avoided to agricultural land by <u>fluvial</u> defences in England and Wales

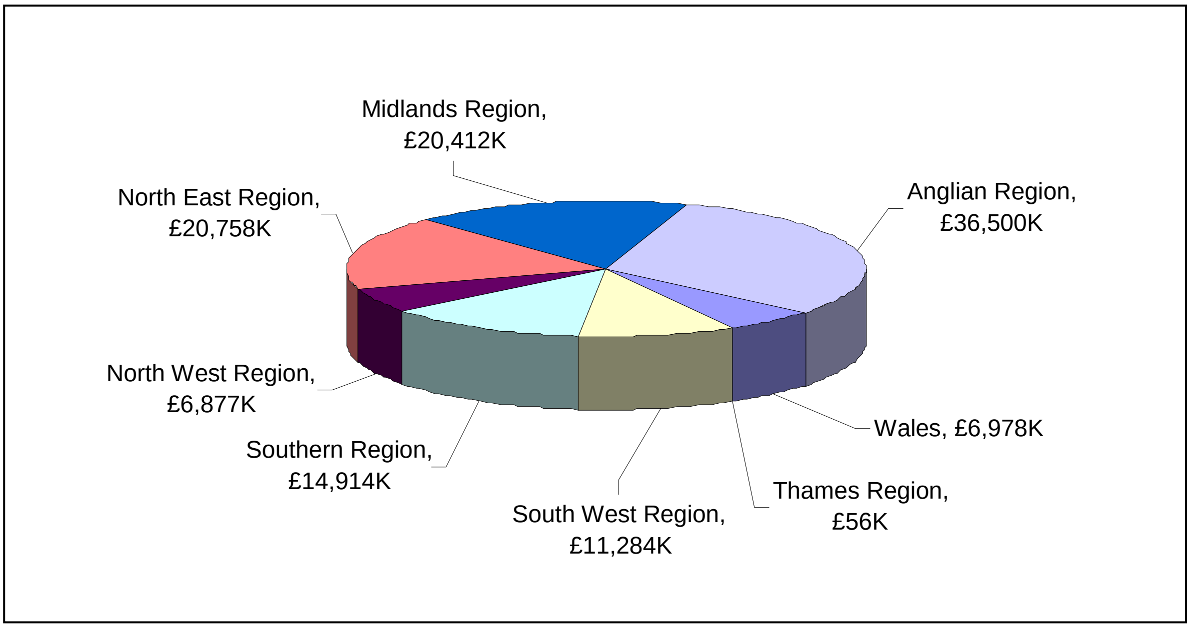

Figure 13 Expected annual damages avoided to agricultural land by <u>coastal</u> defences in England and Wales

The estimated value of the expected annual damages to agricultural land from fluvial and coastal flooding in the defended and non defended scenarios is provided in the tables below. The damages avoided figures (shown above) have been calculated as the difference between these values.

Table 35 Expected annual damages (£) to agricultural land from fluvial and coastal flooding in England and Wales

	Expected annual damages (£) - with defences		Expected annual damages (£) – without defences	
	fluvial	coastal	fluvial	coastal
England	4,249,000	6,468,000	9,256,000	117,268,000
Wales	866,000	1,270,000	1,080,000	8,248,000

The same results are presented below by English region.

Table 36 Expected annual damages (£) to agricultural land from fluvial and coastal flooding by region

	Expected annual damages (£) – with defences		Expected annual damages (£) – without defences	
	fluvial	coastal	fluvial	coastal
Thames	630,000	3,000	1,063,000	58,000
South West	747,000	1,431,000	1,094,000	12,715,000
Southern	237,000	1,048,000	434,000	15,962,000
North West	88,000	346,000	631,000	7,223,000
North East	433,000	384,000	1,842,000	21,142,000
Midlands	1,014,000	653,000	2,390,000	21,065,000
Anglian	1,101,000	2,603,000	1,802,000	39,102,000

Note: "with defences" refers to the current defence situation (as reflected in NaFRA08), "without defences" is a hypothetical situation assuming no defences are in place.

Datasets used:

Reference grid, SAMPS, NaFRA08, EA Regions

4.7 Question 8

Question 8: *The Countryside Survey 2007 identifies that the UK area of arable and horticultural land declined by 467,000 ha between 1998 and 2007. Referring to the proportion of this total that falls in England & Wales identify the flood risk status and agricultural grade classification of this land if the LCM 2007 dataset is available. Compare this to the total figure for these agricultural grade classifications within the extreme flood area (answer to question 2) to assess whether flood risk might be a factor in this change. [ie. whether the land taken out of arable production is significantly correlated with flood risk] Suggest why this change may have occurred.*
It has not been possible to respond to this question directly as the necessary GIS source data for the LCM2007 was not available. A more general discussion is however provided under 'Supporting information'.
Method: N/A
Supporting information: The Countryside Survey 2007 identifies that the area of arable and horticultural land in the UK declined by 467,000 ha between 1998 and 2007. 81% of that area is in England (378,300 ha). Wales does not show the same tendency but a slight increase in the amount of arable and horticultural land in that period (12,000 ha). That survey reports the following changes in England: "The Arable and Horticulture Broad Habitat covered about 4.0 million ha of England in 2007 compared to about 4.4 million ha in 1998, an 8.8% decrease, marking a shift away from the relatively constant area that had been observed in Countryside Survey between 1990 and 1998. A significant decrease was observed in the Easterly and Westerly Lowlands Environmental Zones. The Improved Grassland Broad Habitat in England covered an area of approximately 2.9 million ha in 2007, with the largest area in the Westerly Lowlands. The area of Improved Grassland in England increased by 5.2% (142,000ha) between 1998 and 2007, although this was not statistically significant. This increase followed decreases from 1984 to 1998. A significant increase of 14% (approx 130,000ha) was observed in the extent of Improved Grassland in the Easterly Lowlands, where the Arable and Horticulture Broad Habitat was the predominant agricultural habitat type".[11] The conclusions presented in Morris et al (2009) suggest that flooding is not a major determinant on land use. Their work compares land use in 1980s and in 2007 across 8 sites that have received defence schemes (totalling around 5,000 ha) within the floodplains of England showing that land use has changed very little (see below) since the 1980s.

[11] The Countryside Survey 2007: England Results. Available at http://www.countrysidesurvey.org.uk/eng_reports2007.html

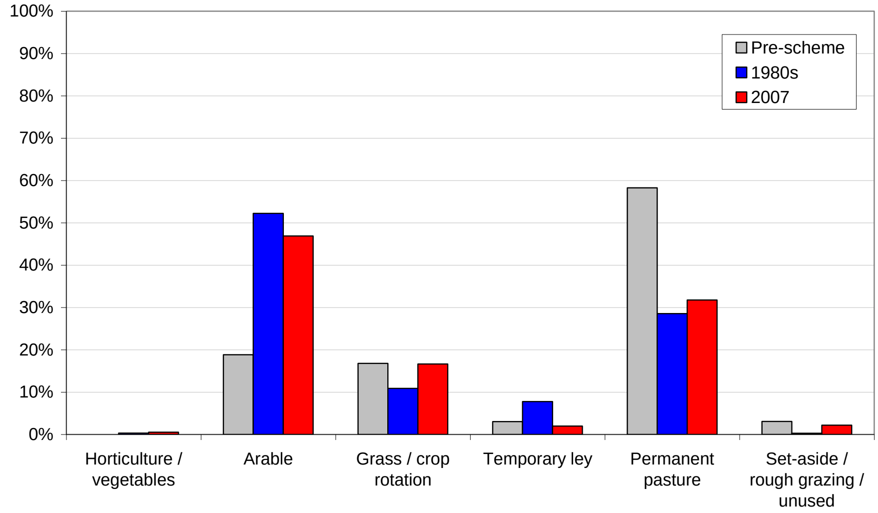

Figure 14 Comparison of land use between 1980s and 2007 (extracted from Morris et al. 2009)

The study showed that there has been a significant shift from dairy following a national trend that is not related with flooding. There is some suggestion of a shift to less intensive land use – e.g. dairy to beef, root crops to cereals - but very little land had gone out of production. Where it had, this was due to "local" circumstances, e.g. mining subsidence that had caused a deterioration of land drainage or land purchased by a conservation organisation.

Datasets used:

N/A

4.8 Question 9

Question 9: *Describe the spatial distribution of agricultural land within agri-environment schemes in England and Wales and hence the flood risk category (expressed in area by scheme type and as a percentage of the national resource) of these sites. Identify any link between agri-environment scheme designation and flood risk.*

The total area of agricultural grade land (identified in the ALC dataset) and the amount of land in agri-environment schemes (identified in the Environmental Stewardship dataset) is shown in the table below.

Table 37 Percentage of land within agri-environment schemes compared to total agricultural land (England and Wales)

	Total area of ALC grade land (ha)	Total land in agri-environment schemes (ha)	% of total
England	10,820,600	5,024,200	46%
Wales	1,829,900	97,400	5%

The current (2009) area of agricultural land within agri-environment schemes in England and Wales is 5,121,600 ha (i.e. 40% of the total ALC grade land). This result is consistent with the Defra statistics published in May 2009 (http://www.defra.gov.uk/evidence/statistics/foodfarm/index.htm) which show a significant increase in Entry Level Stewardship since 2004 reaching, over 5 million hectares in England in 2008.

The distribution of land between the different agri-environment schemes in England and Wales is presented in the figure below (as a % of the total 5,121,600 ha). The Entry Level Stewardship is the most prevalent, with 4,080,200 ha (see Table 40).

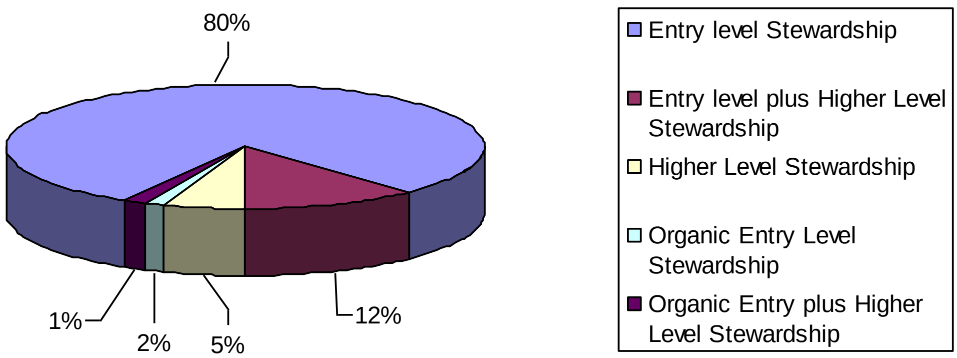

Figure 15 Percentage composition of agricultural land in agri-environment schemes (England & Wales)

The amount of agri-environment scheme land at risk of flooding and the frequency of flooding are identified in the tables below with the risk of fluvial, coastal, and combined fluvial and coastal flooding shown separately. These values are not cumulative and should be considered as the area at risk of flooding within each frequency band (expressed as a return period).

Table 38 Area (ha) of agri-environment scheme land at flood risk by probability of inundation - England

Flood source	Flood return period (years)							
	<3	3-5	5-10	10-20	20-75	75-200	>200	Totals
rivers	11,100	4,900	25,800	28,400	74,500	33,500	175,800	353,900
sea	2,000	600	4,200	13,100	37,300	31,600	50,300	139,100
rivers & sea	800	600	3,700	6,300	21,200	10,100	53,400	96,100
Total agri-environment scheme land at flood risk	13,900	6,100	33,600	47,800	133,000	75,300	279,500	589,100
Total ALC grade land at flood risk	34,000	16,200	92,400	120,900	313,100	162,500	591,000	1,330,200

Table 39 Area (ha) of agri-environment scheme land at flood risk by probability of inundation - Wales

Flood source	Flood return period (years)							
	<3	3-5	5-10	10-20	20-75	75-200	>200	Totals
rivers	2,800	800	1,000	1,000	900	400	3,300	10,100
sea	-	-	-	-	-	-	1,000	1,100
rivers & sea	-	-	-	-	100	-	200	300
Total agri-environment scheme land at flood risk	2,800	800	1,000	1,000	900	400	4,500	11,400
Total ALC grade land at flood risk	19,000	8,400	25,100	16,200	19,200	6,700	33,400	127,900

These figures suggest that agricultural grade land in the floodplain within an agri-environment scheme is more likely to be land at a higher flood risk. Thus in England 18% (19,600 ha / 111,300 ha) of land in agri-environment schemes within the floodplain is at very significant flood risk (up to 1 in 20 year return period) compared with 4% (54,300ha / 1,338,600ha) of all ALC grade land in the floodplain (Table 30).

The following table presents the area of land within the floodplain by agri-environment scheme type.

Table 40 Area of land within agri-environment schemes within the floodplain by scheme type

	Total area (ha) (England & Wales)	Within the floodplain (ha)
Entry Level Stewardship	4,080,200	491,426
Entry Level plus Higher Level Stewardship	615,200	66,772
Higher Level Stewardship	279,300	24,935
Organic Entry Level Stewardship	82,600	8,115
Organic Entry Level plus Higher Level Stewardship	64,400	9,284

Method:

Data of agri-environment schemes were mapped on to the reference grid and then cross-referenced with the EA region dataset. Results from Q3 were used to determine the percentage of land in agri-environment schemes in relation to the total amount of agricultural land for each area of interest. Furthermore, both fluvial as well as coastal NaFRA data was then cross-referenced with the agri-environment scheme dataset to obtain the area at risk of flooding in relation to its probability of flooding.

Supporting information:

The table below shows the proportion of agricultural grade land (ALC dataset) in agri-environment schemes (using the Environmental Stewardship dataset) in 2009.

Table 41 Area of land (ha) within agri-environment schemes – England

	agricultural grade land (ha)	land in agri-environment schemes (ha)	% of total
Thames Region	889,800	407,700	46%
South West Region	1,796,500	803,400	45%
Southern Region	854,800	339,000	40%
North West Region	1,185,200	424,700	36%
North East Region	1,922,600	955,700	50%
Midlands Region	1,819,200	752,600	41%
Anglian Region	2,352,500	1,341,100	57%

The value for Wales is shown in Table 39. Refer to Table 21 for the regional breakdown of agricultural grade land in England.

The data in Table 41 is shown in the Figure below. The area of land within agri-environment schemes is compared with the total agricultural land in Wales and the different regions of England.

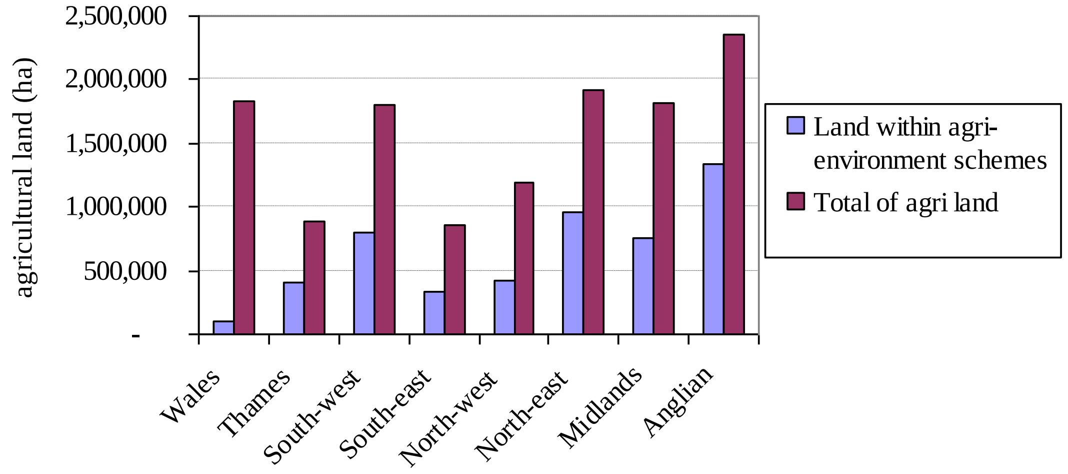

Figure 16 Land within agri-environment schemes compared to total ALC grade land – English regions and Wales

(Note: Reference to “South-east” region should read “Southern”)

Datasets used:

Reference grid, NaFRA08, Environmental Stewardship, EA Regions

4.9 Question 10

Question 10: *What is the total area of land in England & Wales in set-aside now (latest figures) and since the start of this scheme??*
The set aside scheme was introduced in the UK and the rest of the European Union in 1992 as part of a programme to tackle the over production of cereals within the EU. The Land Cover Map 2000 identifies 225,500 ha within three different sub-classes of set-aside land in England and 5,400 ha in Wales. 15% of that area is in the floodplain (see Table 16 (England) and Table 17 (Wales)). This figure is supported by previous analysis for Defra by the University of Cambridge (Hodge et al, 2006) that identified 264,000 ha of set-aside land in 1997 and 371,300 ha in 2005. *Note:* The set-aside scheme percentage is now set to 0%.
Method: The reference grid with Land Cover Map 2000 data mapped on to it was analysed to identify all grid reference points within the LCM2000 sub-classes. Those were then counted up and compared to the total agricultural land. The three LCM2000 sub-classes identifying set aside land are: 50 - setaside (base) 51 - setaside (undifferentiated) 55 - grass setaside
Datasets used: Reference grid, LCM2000

4.10 Question 11

Question 11: *What is the area of land that has been converted to inter-tidal habitat through managed realignment (or other similar techniques such as RTE) in England and Wales to date?*

The managed realignment of tidal and coastal defences and subsequent creation of inter-tidal habitats is one of several options that could reduce the costs of maintaining embankments and at the same time deliver environmental benefits. Managed realignment schemes generally aim to realign defences in a manner that will not only reduce the length of defence required, but will also increase the overall area of inter-tidal habitat. This is partly to create inter-tidal habitat as a means to compensate losses through coastal squeeze and also because it has long been recognised that the inter-tidal zone acts to reduce erosion pressure on built defences.

No managed realignment locations were identified in Wales.

In England, the total area of land converted to inter-tidal habitat in the period 1991 to 2009 through managed realignment is around 1180 ha. Its distribution through the different regions is shown in the table below. It has to be noted that not all land at managed realignment sites is of intertidal character as schemes may include other habitats such as transitional habitats or coastal grasslands.

Table 42 Area of land (ha) within managed realignment sites (created 1991 to 2009) - England

Region	Managed realignment area (ha)
Thames Region	0
South West Region	70
Southern Region	20
North West Region	120
North East Region	150
Midlands Region	350
Anglian Region	470

Note: The managed realignment area total in the Midlands region is high because one of the biggest schemes, Alkborough, with 350 ha in the Humber estuary is located in the Environment Agency Midlands Region.

Method:

Managed realignment site information taken (March 2010) from the ABPmer website at:
http://www.abpmer.net/omreg/index.php?option=com_wrapper&Itemid=8.

This information has been used to create a GIS footprint of each scheme which was then combined with the LCM 2000 and OS Master Map to provide an estimate of the area of land converted to inter-tidal habitat, represented as reference grid points.

These grid points were assigned the managed realignment attributes and the dataset was cross-referenced with the EA region data.
Datasets used: Reference grid, EA Regions, LCM2000, OS Master Map

4.11 Question 12

Question 12: *In relation to question 11: What is the percentage of this area of managed realignment that was previously agricultural? (within 10 years prior to conversion)*
An area of 700 ha was identified as being in arable use in LCM 1990 and now within a managed realignment scheme (59% of the total area). The rest of the area of managed realignment (the remaining 500 ha) is classified in the LCM 1990 as grass heath, mown and grazed turf, meadow, verge, or semi-natural and rough/marsh grass.
Method: The Land Cover Map 1990 has been used to define the percentage of managed realignment areas that were agricultural land in the late 1980's (when LCM 1990 was produced). It was mapped on to the reference grid and the grid points falling into the managed realignment category were summed up.
Datasets used: Reference grid, LCM1990

4.12 Question 14

Question 14: *What is the agricultural land quality (by grade) of the land that has been converted to intertidal habitat through both managed and un-managed realignment?*

It has not been possibly to generate a reliable answer for the area of agricultural land converted to intertidal habitat through unmanaged realignment (see Question 13, Appendix 5).

The agricultural land classification grade of the area converted to intertidal habitat through managed realignment during the period 1991 to 2009 is shown in the table below for England. No schemes were identified in Wales:

Table 43 ALC grade of land converted to intertidal habitat through managed realignment (1991 to 2009) - England and Wales

	Converted land (ha) by ALC grade					total
	1	2	3	4	5	
England	0	424	348	285	28	1085
Wales	0	0	0	0	0	0

Note: Land cover map results (see Q12) identify 700ha of this realigned area was previously in use for arable crops. The remainder of the realigned area (95 ha (1180 – 1085)) in England would include land not classified in the ALC database as agricultural land such as open water, or land not surveyed. For more detail about this classification system refer to MAFF (1988).

Method:

Database tables representing mapped data to the reference grid such as managed realignment, LCM1990, LCM2000, ALC and the EA Region were cross-referenced and summarised to the table shown above.

Supporting information:

The table below shows the regional distribution of ALC grade land converted to managed realignment (1991 to 2009) in England.

Table 44 ALC grade land converted to intertidal habitat through managed realignment by English region

	Converted land by ALC Grades (ha)					TOTAL
	1	2	3	4	5	
Thames Region	0	0	0	0	0	0
South West Region	0	0	24	35	0	59
Southern Region	0	9	0	7	0	16
North West Region	0	0	7	116	0	123

North East Region	0	96	32	7	9	144
Midlands Region	0	280	37	31	1	349
Anglian Region	0	39	248	89	18	394
TOTAL	0	424	348	285	28	1,085

Datasets used:

Reference grid, ALC, EA Regions

4.13 Question 15

Question 15: *In relation to question 14: what is the equivalent amount of crop, (e.g. Tonnes of wheat) that could have been produced on the agricultural land (using an average productivity value) that was converted to inter-tidal habitat through managed and un-managed realignment?*

It has not been possibly to generate a reliable answer for the area of agricultural land converted to intertidal habitat through unmanaged realignment (see Question 13, Appendix 5).

An average yield of winter wheat across the country has been assumed to calculate an answer for potential cereal production foregone as a consequence of managed realignment. Different values are used depending on the land grade as shown in the table below.

Table 45 Assumed average yield of winter wheat (tonnes per hectare) by land grade

ALC Class	t/ha
Grade 1	9
Grade 2	7.55
Grade 3, 4 and 5	6.15

Using this transformation the potential annual amount of tonnes of wheat that could have been produced on the agricultural grade land (using an average productivity value) that was converted to inter-tidal habitat in England is 7,266 tonnes. (*Note*: This assumes that all of the ALC grade land is used for wheat production).

The average production of wheat in England is about 13.8 million tonnes per year (Defra website http://www.defra.gov.uk/evidence/statistics/foodfarm/food/cereals/cerealsoilseed.htm) so the amount above represents about 0.05% of English production.

Method:

The results of Q14 were multiplied by the yields of winter wheat shown in Table 47

Datasets used:

Reference grid, LCM1990, LCM2000, ALC, EA Regions

4.14 Question 16

Question 16: *What is the extent and grade of agricultural land currently classified as within an inland flood storage area in England and Wales?*

The total area defined as being within a Flood Storage Area in England is 14,300 ha and 500 ha in Wales.

The distribution of this by ALC grade is shown in the table below.

Table 46 Land in Flood Storage Area by ALC Grade - England

ALC Grade	Land in flood storage area (ha)	% of the total flood storage area
1	80	0.6%
2	1,580	11.0%
3	5,780	40.3%
4	4,830	33.7%
5	0	0.0%
Non agricultural	2,070	14.4%
Total	**14,340**	**100%**

Table 47 Land in Flood Storage Area by ALC Grade - Wales

ALC Grade	Land in flood storage area (ha)	% of the total flood storage area
1	0	0.0%
2	40	8.4%
3	30	5.5%
4	50	10.6%
5	0	0.0%
Non agricultural	390	75.5%
TOTAL	**510**	**100%**

Method:

The Flood Storage Area dataset was mapped on to the reference grid and cross-referenced with the ALC dataset to identify the area by ALC grade. Further cross-referencing was done with the EA Regions dataset to obtain a spatial overview of the current Flood Storage Areas.

Supporting information:

Flood Storage Areas (FSA) are man-made areas that temporarily fill with water during periods of high river levels, retaining a volume of water which is released back in to the watercourse after the peak river flow has passed.

In the Environment Agency report “Achieving more: operational flood storage areas and biodiversity” (October 2009) 1,000 FSA were identified in England ranging in size from a fraction of a hectare through to 2,300 ha but almost 95% of them less than 75 ha. The data provided in that report is extracted from two sources: the NFCDD and the Reservoirs database. The report points out some inconsistencies that were encountered between the amount of information provided for different sites in NFCDD and the Reservoirs Database.

The slight difference between the Environment Agency report “Achieving more: operational flood storage areas and biodiversity” (October 2009), where it is estimated that 13,800 ha agricultural land are within an FSA in England and this study is most likely explained by the use of different datasets and the inconsistencies detected in the datasets used in the previous report.

The distribution of the flood storage areas in the different regions is concentrated overwhelmingly in Anglian and North East regions (see Figure below).

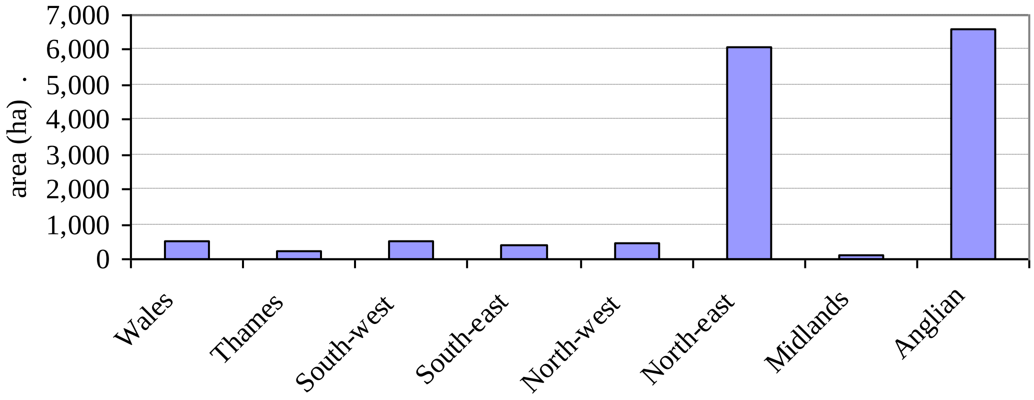

Figure 17 Distribution of Flood Storage Areas - England and Wales

Note: The label “South-east” should read “Southern”.

Datasets used:

Reference grid, FSA, ALC, EA Regions

4.15 Question 17

Question 17: *What is the typical frequency and seasonality of flooding in flood storage areas (by region)?*

No existing national dataset provides detailed information on the depth and duration of flooding for different seasons. Therefore the frequency of a flood event has been used as a proxy to help define both duration and water depth (both important parameters for this study). Events with a low frequency (high return periods) usually will be characterised by long durations and high water depths. Many land uses are tolerant of short-duration flooding, considered as less than one week.

The NaFRA 08 dataset has been used to identify the frequency of flooding within an FSA (based only on the probability output from NaFRA08 and not taking account of any management activities to flood the FSA). The results are presented in the table below. They show that for example just over 10% of the total flood storage area in England will begin to flood in a 1 in 75 year return period flood. The maximum flood risk management benefit is obtained leaving the FSA empty and filling it only when the maximum downstream attenuation can be provided. The evacuation of flood water should ideally be quick in order to provide storage for subsequent events. Therefore, the seasonality of flooding in flood storage areas is dependent on the hydrological processes but also on the FSA management approach. This has implications for the consideration of any additional use of flood storage areas (for food production, natural habitats, or amenity areas for example).

Table 48 Frequency of flooding and extent of FSA inundation - England

Frequency of flooding (by return period, years)	Area of FSA flooded (ha)	As total of all FSA (%) (cumulative)
<5	53	0.4%
5-10	447	3.1%
10-20	541	3.8%
20-75	5,533	38.6%
75-200	2856	19.9%
>200	4,348	30.3%
Outside flood zone	571	4.0%

Table 49 Frequency of flooding and area of FSA inundation – Wales

Frequency of flooding (by return period, years)	Area of FSA flooded (ha)	As total of all FSA (%) (cumulative)
<5	80	15.7%
5-10	6	1.2%
10-20	6	1.2%
20-75	12	2.3%
75-200	3	0.6%
>200	398	77.9%
Outside flood zone	6	1.2%

Note: Data are indicative only and assume flood conditions occur equally across all regions. Flood storage areas are not restricted to main river and include surface water attenuation ponds identified in the Environment Agency FSA database which may be located outside of the floodplain.
Method: The FSA dataset mapped to the reference grid was cross-referenced with the NaFRA08 dataset to identify the areas flooded at different return periods.
Supporting information: The expected frequency of flooding defines the viability of the land use within FSAs. For example, horticultural and intensive arable land requires protection against summer flooding as a single event can result in the complete loss of yield. Cereals are more tolerant and freshwater floods with a probability of 20% (5 years return period) can be acceptable. Improved grassland may tolerate flooding up to once every other year (50%). (Refer to Appendices 1 and 2 for further information on flood seasonality).
Datasets used: Reference grid, NaFRA08, FSA

4.18 Question 18

Question 18: *In comparison estimate the extent (and former grade where known) of agricultural land converted since 1945 to use as permanent reservoirs (eg. for public water supply or farm irrigation).*

A GIS layer representing reservoir extent was not available for use by this project.

Method:

n/a

Supporting information:

The total number of reservoirs and their areas (obtained from the Environment Agency's reservoir database) is presented in the table below. These data probably exaggerate the total number of reservoirs as some of these will be local authority or IDB operated flood storage areas rather than permanent water reservoirs. The majority however are assumed to be permanent water reservoirs.

Table 50 Number and area of reservoirs (excluding EA reservoirs but including those under construction) - England and Wales

	No. of reservoirs	Area (ha)
England	1,670	28,705
Wales	194	7,698

The breakdown by Environment Agency region is shown in the table below.

Table 51 Number and area of reservoirs (excluding EA reservoirs but including those under construction) – English regions

	No. of reservoirs	Area (ha)
Thames Region	208	3,068
South West Region	118	2,936
Southern Region	116	1,225
North West Region	285	4,800
North East Region	296	5,754
Midlands Region	334	4,987
Anglian Region	313	5,935
Total	1,670	28,705

It was not possible to obtain a GIS layer for these data and so they could not cross referenced with the ALC dataset to determine the area of agricultural grade land converted to use as permanent reservoirs. Furthermore, it was not possible to obtain a construction date for these reservoirs, so it has not been

possible to report on the change in reservoir surface area since 1945.
Datasets used: Extract of Environment Agency’s reservoir database (2010)

4.19 Question 19

Question 19: *What is the total area of agricultural land (and grade) that has been converted from agricultural use to a non-agricultural use in the last 10 and 25 years.*

Over 10 years
The Countryside Survey is not optimised for an assessment of built-up areas but at a national scale it reports for England an increase in the extent of built-up areas and gardens and un-surveyed urban land from 1.427m ha in 1990, to 1.437m ha in 1998, and 1.466m ha in 2007[12]. For Wales the equivalent figures are 132K ha in 1998 and 147K ha in 2007[13]. The previous use of this land has not been identified and it may not have been in agricultural use.

The area of land in agricultural use (note that this is different from agricultural grade land) has remained broadly the same in England between 1998 (8.393m ha) and 2007 (8.311m ha). There was however a change in the type of agricultural use (from arable to grassland) over this period – see Question 8. In Wales the area of land in agricultural use was 1.054m ha in 1998 and 1.066m ha in 2007.

Due to the unavailability of the LCM2007 GIS data it was not possible to compare this dataset with LCM2000 to provide more detail (such as spatial distribution) on the numbers stated by the Countryside Survey.

Over 25 years
It has not been possibly to reliably answer this question. An analysis was undertaken of the area of land converted to non agricultural use by comparing the difference between the extent of the original ALC dataset (from 1974) and the same dataset updated with the urban areas shown in the Land Cover Map 2000. The difference identified is 578,700 ha in England and 54,600 ha in Wales. However this approach is limited and misleading because the 1974 ALC dataset did not include small settlements within its “urban” category but included them within ALC grades 1 to 5. The LCM2000 dataset however includes these settlements in the urban or suburban land use class (see appendix 3 for a list of classifications). Therefore the result presented above significantly exaggerates the scale of change over this period.

For information the table showing this analysis is included in Appendix 5.

[12] The Countryside Survey 2007: Results for England. Available at http://www.countrysidesurvey.org.uk/eng_reports2007.html
[13] The Countryside Survey 2007: Results for Wales. Available at http://www.countrysidesurvey.org.uk/welsh_reports2007.html

5. Possible dataset improvements

This chapter identifies possible improvements to the availability, accuracy, usability and relevance of the datasets used. The datasets used to answer each question in the report are identified in Chapter 4, the datasets used are described in Chapter 2, and a detailed description is provided in Appendix 4.

5.1 Data availability

The easiest and quickest way to access datasets is to download them over the internet. For example, datasets from Natural England are available on its website after registration together with detailed information about the dataset.

Some datasets originally identified as suitable to answer the questions in the project brief were not available to the project team and alternatives were sought wherever possible.

Suggestions for future data acquisition requests are:

- where data requirements are known then ensure key datasets are available for use before projects are scoped and awarded. If there are access difficulties with certain key datasets these should be resolved before project commencement
- provide as much detail as possible about data requirements to the licensing team ahead of the acquisition request
- identify and make contact with the data owner within the organisation before project commencement
- understand the resources required by third parties to provide information and encourage their engagement.

5.2 Data accuracy

The methodology used in this project, making use of a high resolution Reference Grid (1ha) to integrate all the information from the source datasets, has a small impact on data accuracy, explained in chapter 3.2.

The improvement in accuracy of datasets, for example the ALC, depends on collation of new data at a national scale, requiring a huge amount of resources and specific programmes to be set up by the data owners.

The method adopted in this project to populate the information from different datasets onto a common reference grid aims to reduce the impact of differences of accuracy between datasets. The scale adopted, 1 hectare, is considered detailed enough to provide detailed figures at a national scale. The results are generally rounded to the nearest 100 ha which in some cases produces rounding differences between summary and detail tables.

It would be possible to study in more detail the information related to probabilities of flooding, for example considering other return periods than the ones used in this project. This information is already available in the datasets but the extraction of this information is particularly time consuming due to the massive volume of data to be interrogated and the nature in which the data are held (eg. in excess of 140 different databases which are held offline). It is also possible to explore different depth versus inundation duration assumptions, however this is also particularly time consuming (for the same reasons).

5.3 Data use

Much of the information contained in the identified datasets can be analysed using the described methods without any difficulty, making repeat analysis against new versions of these datasets reasonably straight forward. Repeating the analysis would be a matter of cross-referencing the new data against the Reference Grid and repeating the SQL queries to report the relationships between the data themes.

Exceptions to this statement however are the data contained in the NaFRA08, SAMPS and LTIS datasets. The use and manipulation of the NaFRA dataset is key for this analysis. The extraction of information for probability of flooding at a particular depth provided by these datasets requires a lot of pre-processing work and previous knowledge of the data that can be difficult for a non-familiar user. The data are held in catchment specific databases (which often exceed 200mb in size) for fluvial and tidal models. Approximately 140 databases make up the complete coverage for England and Wales. Within each database, a number of tables are required, hence to analyse the data, a significant amount of effort is required to acquire the archive, reinstate the databases, extract the appropriate tables, compile them into national tables and allocate them to the Reference Grid.

The method developed in this project to answer the questions using the different datasets also requires previous knowledge of GIS and SQL.

5.4 Data relevance

The most relevant datasets have been identified in Chapter 3. They are:

- Agricultural Land Classification: as it is the only national dataset that provides information about the quality of agricultural land
- Land Cover Map (more recent version available): as it identifies the actual use of agricultural land at the point in time of the survey
- Flood Zones: to define the areas flooded by main rivers and sea
- National Flood Risk Assessment (NaFRA): as it provides information on probabilities of flooding, therefore on return periods, giving an idea of frequency of flooding.

Another dataset that is considered relevant to inform the debate on flood risk management for agricultural land is LTIS as it provides probabilities of inundation for future scenarios.

6. Data access and relevance

Access to data

Although this project has identified the most relevant datasets together with their ownership and associated licensing issues it has not been possible to provide a common framework to access all the different datasets because they are owned by different institutions and have different restrictions (some are freely accessible, others require licenses).

The results provided in this report will be made available as part of the Defra / Environment Agency science programme.

Further work

The results presented in this report should be updated with information from those datasets unavailable at the time this project was undertaken. In particular this will help to provide a clearer view of the likely extent of coastal erosion impacts.

The most important update of the results relates to the use of the Land Cover Map 2007 that is expected to be released in 2010.

Questions related to future scenarios should be updated using information from the LTIS.

Any updates should use similar or updated datasets to the ones used in this project. Datasets from National England are easily downloadable from its website; datasets from Defra and Environment Agency requires a license. Other datasets used in this project, such as the Land Cover Map, requires the licence and payment of some fees.

An updated ALC dataset should provide more accurate information about the distribution of agricultural grade land although the project team is not aware of any immediate future update (and according to the explanations for creating the existing one, this may not be an easy task). As stated in the report it is considered important to update the results with the new LCM2007.

Groundwater and surface water flooding can be important in the context of agricultural impacts (as high water tables and water standing after heavy rain are major limitations on agricultural production). For future updates of the results provided by this project it would be useful to include these other sources of flood risk.

Future NaFRA reports should identify the current flood risk to agricultural land (effectively updating Tables 30 and 31 to reflect the current risk of inundation).

Amending project appraisal report templates to capture the agricultural benefits of proposed flood and coastal erosion risk management projects will allow investment outcomes to be routinely tracked (see question 7).

7. Conclusion

This project represents an attempt to comprehensively quantify for the first time the extent of flood and coastal erosion risk to agricultural land in England and Wales.

This chapter summarises the main findings of the project:

Datasets used and limitations

- The main datasets required for this purpose are Agricultural Land Classification (ALC), Land Cover Map (LCM), Flood Zones, National Flood Risk Assessment (NaFRA) and Long Term Investment Strategy (LTIS)
- Datasets have a wide range of sources, formats, scales and resolution
- Access by this project to some cross government datasets has been slow. A more streamline process of data retrieval from consultants, storage and cross-government licensing should be developed
- Although the best available datasets have been used, some of the agricultural and land use datasets are dated. For example, the ALC was produced in 1974 and the Land Cover Map used relates to1997. It should be noted that the results describe the situation with respect to the snapshot that these datasets represent. The method allows for the results to be recalculated as more recent data become available (eg LCM 2007)
- The project takes account of permanent changes in land use since the ALC was created by excluding areas now shown as developed in the LCM 2000
- The project used the best available dataset (NaFRA08) to identify flood risk.

In relation to the methodology

- The project makes use of existing datasets to investigate the relationship between agricultural land (grade and land use) and flood hazard (with and without defences, today and in the future). The datasets are held using a variety of spatial constructs. A Reference Grid of one hectare resolution (100m by 100m) covering all of England and Wales was created and all the source data transferred to this Grid. The Reference Grid provides a common platform to compare the information from datasets with different origin and accuracy. It facilitates the use of new information as it becomes available since this only requires mapping to the Reference Grid in order to be compatible with all of the other datasets.
- The damages expected to occur in any one year (expected annual damage, EAD) to agricultural land due to flooding, expressed as £/ha/year, are calculated by multiplying the annual probability of flooding of the area (obtained from the NaFRA and SAMPS models and then seasonally adjusted) by the associated loss of production. The damages avoided by the presence of flood defences is calculated as the difference between the damages occurring with defences and the damages occurring if no defences existed (and the current land use continued)
- Results are presented at a national (England and Wales) scale and by Environment Agency region.

In relation to the answers to the questions posed in the project brief
The main results obtained are summarised below. The results have been grouped where possible by related themes. The relevant dataset reference (Table or Figure) is given in square brackets (for example, [T22, F5]):

The area at risk of flooding and the flood risk to agricultural land

- Flood risk from rivers and the sea has been assessed up to a 1 in 1000 year event taking no account of the presence of defences. (This area is equivalent to the extent of Flood Zone 2 and is referred to as the floodplain and includes the area covered by Flood Zone 3).
- This floodplain area represents approximately 12% of the total land area in England and 10% of the total land area in Wales [T4].
- The proportion of floodplain land within each Region varies, Anglian Region has the highest proportion at 22% [F2, F5]
- 74% of the floodplain land area in England (1,224,900 ha) and 52% in Wales (111,100 ha) is in agricultural use [T4, T5, T6] (LCM 2000 figures).
- In England 39% of land in agricultural use (LCM2000) in the floodplain is at flood risk from the sea or tidal rivers [T5]. Southern Region has the highest percentage at risk (62%) [T10].
- The Environment Agency Anglian Region has by far the largest area of grade 1 to grade 3 agricultural land in the floodplain [T15] and the largest overall total of agricultural land [T21].
- The North-East Region has the highest % of its grade 1 land in the floodplain – 86% [T15, T21].
- The percentage of best and most versatile land (ALC grades 1, 2 and 3) in the floodplain in England is 13% [T7, T21] and 10% in Wales [T7, T22].
- More than half (58%) of the total resource of grade 1 agricultural land in England is within the floodplain [T7, T21]. The equivalent figure for Wales is 13% [T7, T22].
- Of this grade 1 land in England only 5% of the land in the floodplain is at very significant[14] flood risk [T30]
- In England 78% of grade 1 land in the floodplain is at low[15] flood risk [T30, T18], and 48% of the best and most versatile[16] land in the floodplain is at low flow risk [T30, T18]
- In Wales 33% of the grade 1 land in the floodplain is estimated to be at low flood risk [T31, T19], and 27% of the best and most versatile land.

Internal Drainage Boards

- Internal Drainage Boards cover around 1.2m ha of agricultural grade land in England, about 50% of this area relies on pumped drainage [Q5, T32]
- More than 85% of the total grade 1 agricultural land in the North-East and Anglian regions is in IDB districts [T33, T21]

[14] Very significant flood risk defined as a flood return period equal to, or more frequent than, 1 in 20 years
[15] Low flood risk defined as a flood return period of 1 in 200 years or less
[16] Best and most versatile land defined as grades 1, 2, and 3

Damages avoided (benefits) due to flood defences

- Fluvial defences provide protection to agricultural land and reduce flood related agricultural losses by around £5.2m annually (£0.2m in Wales and £ 5m in England) [T34]
- Coastal defences provide protection to agricultural land and reduce flood related agricultural losses by around are £118m annually (£7m in Wales and £111m in England) [T34]
- In England just over ¾ million ha (57% of the floodplain total) of agricultural grade land in the floodplain benefits from the presence of defences [T23, T7]
- In Wales 50% of agricultural grade land in the floodplain benefits from defences [T24, T7]

Changes to agricultural land

- 1180ha of land in England has been converted to intertidal habitat through managed realignment schemes (1991 to 2009) [T42]
- About 700ha of this was previously in arable use (in 1990)
- The total area of agricultural grade land within flood storage areas in England is 12,270ha [T46]
- Reservoirs in England cover 28,700ha and 7,700ha in Wales [Environment Agency reservoirs database, T50, T51]
- The area of built up land in England increased by 29,000ha between 1998 and 2007 [Countryside Survey 2007, Q19]. The equivalent figure in Wales is 15,000ha.
- The area of land in agricultural use in England has remained broadly the same between 1998 (8.393m ha) and 2007 (8.311m ha)

Suggestions for the on-going maintenance of relevant data

- The ALC dataset has been updated to consider new urbanised areas using the information in the Land Cover Map 2000. This analysis could be updated using the data from Land Cover Map 2007
- Groundwater and pluvial flooding can be important in the context of agricultural impacts. For future updates of the results provided by this project it would be useful to include these other sources.
- Questions related to future scenarios should be updated using information from the LTIS dataset.

8. References

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Appendix 1 Methodology for the assessment of benefits provided to agricultural land

Following Environment Agency guidance, the benefits of flood and coastal erosion risk management are defined as the positive impacts and damages avoided as a result of an action (Environment Agency 2010). Benefits can accrue from reducing the probability of flooding or reducing the consequence of an event. In the context of this study, we only consider the benefits accruing from a change in flood probability.

The value of the benefits provided to agricultural land by FCERM defences can be identified by using the results from the so-called "undefended" NaFRA run versus those from the NaFRA 08 (defended situation). NaFRA uses a depth-probability relationship in combination with a depth-damage relationship to derive the damage-probability function and hence average annual flood damage with (w) and without (o) defences (Figure A1). The benefit of the defences is;

$B = \bar{F}_o - \bar{F}_w$ [*Equation 1]*

B = Benefit, £ ha^{-1} y^{-1}

$\overline{F_i}$ = annual average flood damage under scenario i, £ ha^{-1} y^{-1}

And

$\bar{F}_i = FP_i$ [*Equation 2]*

F = flood damage resulting from a single event, £ ha^{-1}

P_i = annual probability of inundation under scenario I, y^{-1}

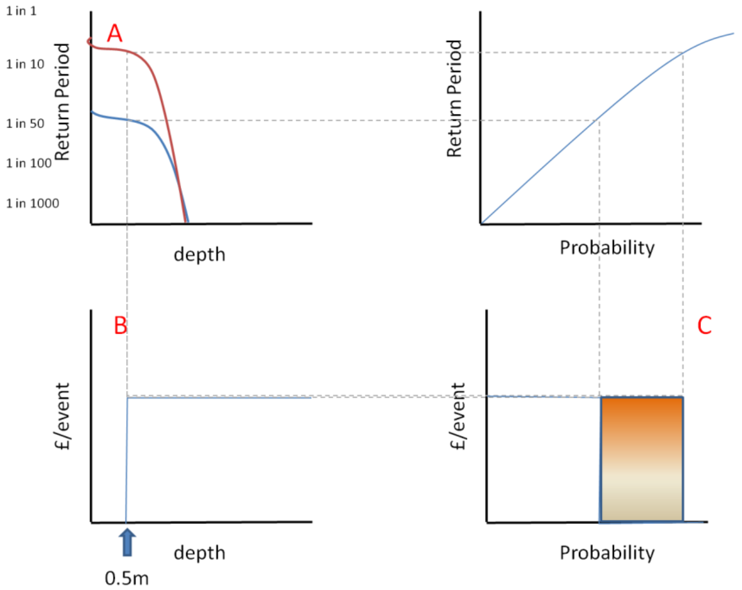

Figure A1-1 Estimation of average annual flood damage used in NaFRA.

The depth-probability curve (A) is output from NaFRA. The flood damages curve (B) is considered for existing receptors only based on the land use and Agricultural Land Classification (ALC) class.

For agriculture, the duration of inundation is important in determining the magnitude of the damage, however, NaFRA contains no information on flood duration. As a proxy, it has been assumed that damages occur once the depth of inundation exceeds 0.5m and floods with a depth <0.5m are assumed to cause no damage. This is of course, not true, but the suggestion is that shallow floods (<0.5m) may be of short duration and therefore cause less damage.

Methods

The method used to estimate damages to agricultural land are based on the "Multi-coloured Handbook" methods for the assessment of the benefits of flood and coastal risk management (E. J. Penning-Rowsell 2005) for agriculture[17] and Defra guidance (Defra 2008) as recommended in the EA project appraisal guidance ((Environment Agency 2010).

Selection of land use classes

The Land Cover Map (LCM2000) identifies 72 land cover variants, but many of these can be considered to be non-agricultural. The following classes were categorised as non-agricultural;

- Broad-leaved woodland; Coniferous woodland; Bracken; Dwarf shrub heath; Open dwarf shrub, heath; Fen, marsh, swamp; Bog; Water (inland); Montane habitats; Inland bare ground; Suburban/rural developed; Continuous Urban; Supra-littoral rock; Supra-littoral sediment; Littoral rock; Littoral sediment; Saltmarsh; Sea/Estuary. Land classified as Setaside (bare), setaside (undifferentiated) was treated as land use class 3 (Extensive Arable).

Area and land cover

The following LCM2000 variants are considered agricultural;

LCMvec	LCM variant	Area in floodplain, ha	%
9	Saltmarsh (grazed)	527	0.04%
30	Barley	60,332	5.08%
31	Maize	4,306	0.36%
32	Oats	966	0.08%
33	Wheat	171,629	14.44%
34	Cereal (spring)	7,277	0.61%
35	Cereal (winter)	12,714	1.07%
36	Arable bare ground	14,362	1.21%
37	Carrots	8	0.00%
38	Field beans	22,443	1.89%
39	Horticulture	15,999	1.35%
40	Linseed	37,282	3.14%
41	Potatoes	34,351	2.89%
42	Peas	30,581	2.57%
43	Oilseed rape	32,585	2.74%

[17] Chapter 9.

44	Sugar beet	22,919	1.93%
45	Arable unknown	233,509	19.65%
46	Mustard	2,368	0.20%
47	Non-cereal (spring)	5,290	0.45%
48	Orchard	595	0.05%
49	Arable grass (ley)	1,742	0.15%
52	Intensive grass	250,660	21.09%
53	grass (hay / silage cut)	61,387	5.16%
54	Grazing marsh	4,686	0.39%
56	Rough grass	23,759	2.00%
57	grass (neutral / unimproved)	18,810	1.58%
58	Grass (calcareous managed)	26,679	2.24%
59	Grass (calcareous rough)	73,768	6.21%
60	Grass acid	6,585	0.55%
61	Grass acid (rough)	10,148	0.85%
62	Grass acid	330	0.03%
	TOTAL	1,188,600	100%

For the purposes of assessing damages, the agricultural land cover variants were grouped into 18 land use classes;

- Arable bare ground
- Other arable
- Barley
- Cereal spring
- Cereal winter
- Field beans
- Linseed
- Maize
- Oats
- Oilseed rape
- Peas
- Potatoes
- Sugar beet
- Wheat
- Horticulture
- Rough grass
- Extensive grass
- Intensive grass

Flood frequency and land use
For agriculture it is important to consider the change in productivity as well as changes in flood damages (Morris, et al. 1984). Therefore the benefit of the flood and coastal risk management assets is the sum of the damage avoided

and the productivity enhancement. The “Multi-Coloured Handbook” (Penning-Rowsell, et al. 2005) has assumed critical flood probabilities for land use classes, however, these were based on expert judgement in the 1980s and there is no evidence to support these assumptions.

The LCM2000 land covers were classified into four major land use classes and compared with modelled flood frequency (Table A1) in order to identify the extent to which flood probability influences land use. Some observations are;

- 33% of land that floods more frequently than 1 in 5 years (from fluvial or coastal flooding) is under arable crops.
- For flooding more frequent than 1 in 5 years, there is no difference between fluvial and coastal flooding.
- The distribution of land use for land with a flood return period between 1 in 10 and 1 in 5 is similar to land that is outside the floodplain. i.e. flooding is not a significant constraint on land use.
- Floodplain land that floods less frequently than 1 in 10 has a higher proportion of arable and horticulture than land that is outside the floodplain, especially on land within the coastal (as opposed to fluvial) flood zone. It suggest that defended floodplain makes a major contribution to national arable and horticultural production

Table A1-1 Land use distribution according to fluvial and coastal flood return period[18]

		<3	5	10	25	50	>50	dnf*	Outside
Horticulture	Coastal	0%	0%	1%	1%	1%	1%	3%	1%
	Fluvial			0%	0%	1%	1%	2%	
Arable	Coastal	33%	32%	45%	49%	57%	62%	74%	41%
	Fluvial			36%	38%	40%	48%	58%	
Grass	Coastal	65%	66%	53%	49%	41%	35%	17%	56%
	Fluvial			60%	59%	57%	49%	38%	
Setaside	Coastal	2%	1%	3%	2%	2%	2%	5%	2%
	Fluvial							2%	

* dnf = Does not flood

The model for coastal flood frequency has separated return periods <1.1 years from 1.1 – 3 years return period (Table A2).

Table A1-2 Distribution of land use according to coastal flood frequency, ha.

Row Labels	**<1.1**	**3**	**5**	**10**
Horticulture	11	117	57	296
Cereals	621	4,171	1,741	9,286
Oilseed rape	58	299	125	2,103
Other arable	601	5,329	2,322	13,100
Roots	61	526	256	862
Rough grazing	597	4,536	1,495	6,069
Unimproved grass	191	2,152	1,017	3,805
Improved grass	696	14,137	6,334	20,049
Grand Total	**2,836**	**31,267**	**13,347**	**55,570**

Although the area subject to flooding more frequently than 1 year in 1.1 is very small, it has a larger proportion that is arable (47%) than the land subject to flood between 1.1 and 1 in 5 years (33%). This would suggest that either the land use is insensitive to flood probability or that the model is insufficiently sensitive at frequent events.

Figure A2 shows that flood probability does have an impact on high value land uses. Where land has a probability of flooding less frequently than 1 in 10 years, there is a higher proportion of land under horticulture, potatoes and sugar beet than outside the floodplain. However, the total area under horticulture with a flood return period <10 years is only 1,621 ha throughout England and Wales. This is probably too small an area to comment on reliably.

[18] No information is available from the modelling of fluvial flood frequency to sub-divide events more frequent than 1 in 3 years.

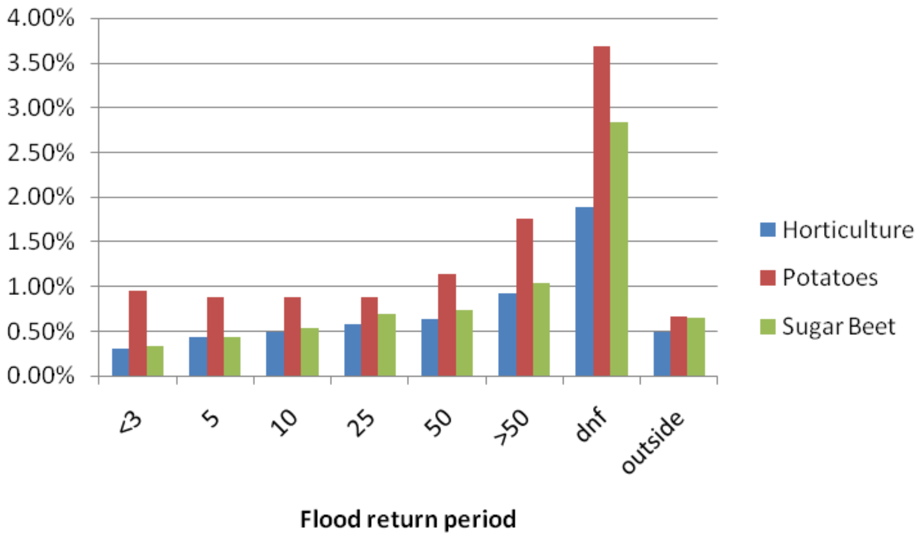

Figure A1-2 Proportion of area under horticulture, potatoes and sugar beet according to flood return period

On the basis of the above, there is little evidence to suggest that land use is significantly affected by flood frequency (it cannot be assumed that if flood frequency increases to 1 in 3 years or more the land use will change), therefore, in order to estimate the benefits of flood and coastal erosion defence assets we are assuming that land use will remain constant.

Flood damages

The estimates for the damage resulting from a single flood event are based on the methods used to derive the tables in the "Multi-Coloured Handbook" (E. J. Penning-Rowsell 2005) and compatible with the Environment Agency guidance (Environment Agency 2008) for valuing occasional losses of agricultural output.

Arable and horticultural land uses

Most flooding of arable land (independent on the source of flooding) will not result in complete write-off of crops (depending on the time of year). Based on the "Multi-Coloured Handbook" (E. J. Penning-Rowsell 2005) and experience of the Summer 2007 flood (Posthumus, et al. 2009) the flood damage resulting from a single event (F, £ ha^{-1}) (including cleanup costs) can be estimated from;

$$F_i = YL_iP(1 + Q) + E - H$$

Where

Y = expected (unflooded) yield, t/ha

L_i = average yield loss from a flood in month i, fraction

P = market price, £/t

Q = yield quality penalty, fraction

R = reseeding costs, £/ha

E = extra non-production costs, £/ha

H = Post-harvest saving, £/ha

2009 prices and yield estimates were based on the Farm Management Pocketbook (Nix 2009).

Fluvial flooding
Yield loss factors for fluvial flooding were based on earlier work Table A3.

TableA1-3 Yield loss due to flooding >1 week duration at various times of year as % of unflooded yield (after Dunderdale and Morris, 1997)

Month	Yield loss as % of unflooded control				
	Winter cereals	Spring cereals	Roots	Oilseed rape	Spring peas
October	100*	0	50	100*	0
November	10	0	0	10	0
December	10	0	0	10	0
January	10	0	0	15	0
February	10	20	5	15	0
March	10	60	10	15	50
April	28	30	50	30	55
May	50	55	100	50	73
June	80	80	100	80	100
July	100	100	100	100	100
August	100	100	100	100	50
September	0	50	100	60	0

* possibly reseed with spring crop

Coastal flooding
Yield loss estimates in the Multi-Coloured Handbook ((E. J. Penning-Rowsell 2005) relate to fluvial (freshwater) flooding however coastal (saline) flooding will lead to greater damages for a number of reasons;

1. The impact on plant growth and yield. High salt concentrations at germination and establishment cause crop failure, whilst high salt concentrations in the soil during the growing season cause plant stress and restricted growth, limiting yields. Extreme salinity is toxic and kills the plant.

Crops vary in their tolerance to salinity (Table A4).

Table A1-4 Relative salt tolerance of agricultural crops (after, Ayers & Westcot, 1985, p34)

Tolerant	Barley, oilseed rape, sugar beet
Moderately tolerant	Wheat, oats, triticale, red beet
Moderately sensitive	Beans, maize, most vegetable crops (incl. potato)
Sensitive	Carrots, onions, parsnips

2. Coastal flooding (due to a breach or overtopping of defences) is likely to be longer duration due to the lack of gravity outfall.

As a result the yield penalties assumed in Table A5 have been adjusted according to the values in Table A4

Table A1-5 Yield penalties for coastal flooding, relative to fluvial flooding

Crop group	Sensitivity	Yield penalty
Barley & Oilseed rape	Tolerant	As for fluvial, but increased by 10%
Sugar beet	Tolerant	10% pre-planting. As for fluvial, but increased by 10%
Potatoes & hort	Moderately sensitive / sensitive	30% reduction in yield for flooding before planting. 100% after.
Spring cereals	Moderately tolerant	10% reduction in yield for flooding before planting. 20% increase over fluvial after.
Spring peas	Moderately sensitive	15% reduction in yield for flooding before planting. 20% increase over fluvial after.
Winter cereals	Moderately tolerant	15% increase over fluvial.

3. Longer lasting impacts on plant growth and soil structure due to saline flooding. It may take some time for the excess salt to be leached out depending on the permeability of the soils, ranging from 1 year on sandy soils to several years on heavier soils. Buxton (1939) recorded the effects of the February 1938 floods on a yearly basis from 1939 – 1944. It took 5 years after the sea flooding of 1938 for the worst affected grazing marshes to get back to the condition they were prior to flooding. Similarly, 65,000 ha (160,000 acres) of agricultural land were inundated in the 1953 East Coast floods. Two-thirds of the flooded area was under water for only a short period, but about one-third of the total area flooded was seriously affected by the salt water (Hansard 1953) and not usable for several years. Almost 200,000 hectares of land was flooded in the Netherlands (and 44,000 ha in Belgium) and the contamination by the salty water meant that the once fertile soil was unusable for many years[19].

Reclamation can be speeded up with the application of gypsum to the soil however; it is likely that in the first year following a saline inundation, a salt tolerant crop (e.g. winter barley) would be grown in place of salt sensitive crops. Therefore we have assumed an addition of gypsum to speed up reclamation and a reduction of gross margin (if applicable) in the subsequent year.

Grass land uses

Fluvial flooding

Losses to grassland are based on estimated loss of utilized metabolisable energy (UME) valued at a cost of replacement feed (Hess and Morris 1988) taking account of seasonality of grass growth, nitrogen application rate and grass conservation method. In addition to direct losses of grass production at the field scale, livestock farms suffer farm level production losses. These vary by farm, but include; decreased livestock production (e.g. reduced live weight gain rates for beef); additional labour costs; cost of moving livestock; extra

[19] http://www.deltawerken.com/Rescue-and-consequences/309.html

purchased feed; slurry disposal costs; alternative drinking water supply; treatment costs for animal diseases; lost livestock; forced sales; and lost milk production. The costs are only incurred during the grazing season, taken as April to September. Thus, the flood damage resulting from a single event (F, £ ha^{-1}) (including farm level costs) can be estimated from;

$$F = \sum_{1=12}^{i=1} (UME_i V) + \sum_{1=9}^{i=4} (O_i + N)$$

Where
$\bar{L}$ = average financial loss from a flood in any month, £ ha^{-1}
UME_i = weighted UME loss from a flood in month i, MJ ha^{-1}
V = value of UME, £ MJ^{-1}
O = other production loss, £ ha^{-1}
N = non-production losses, £ ha^{-1}

Coastal flooding
Coastal flooding will have a greater impact on grassland systems. Although perennial ryegrass is moderately tolerant to salinity, a saline flood at any time of year will cause more of a reduction in grass yield than a fluvial flood. UME losses have been increased by 10% over the fluvial case. In addition there will be a greater impact on livestock grazing due to contamination of drinking water supplies and grass palatability. Significantly, the lack of local high ground would mean that more livestock would be lost. For example, in the 1953 East Coast floods, 46,000 head of livestock were lost. We have estimated stocking rates from UME yields and assumed a 20% loss of livestock valued at £2,500/Livestock unit.

Seasonality of flooding
Agricultural damages (unlike urban damages) are very sensitive to the time of year in which a flood occurs. For example, a flood in winter on land prepared for potatoes may cause minimal damage, whereas a flood in July could result in completer write-off of the crop.

Fluvial flooding
The figures in the “Multi-Coloured Handbook” (E. J. Penning-Rowsell 2005) are weighted damage costs based on assumptions about the seasonality of flooding from unpublished data from catchments in the Midlands of England (Hess and Morris 1988).

In order to update and extend the information on flood seasonality, 428 catchments were selected from the in HiFlowsUK POT database which met the following criteria;

- Located in England or Wales
- Suitable for pooling
- >9 events

For each, the mean data of occurrence of the annual maximum flood (θ) and spread of flood peaks (r) was calculated (after FEH (Robson and Reed 1999)). It was shown that EA region had a very significant (P<0.0001) effect on θ and r. However, Midlands, Southern and North East could be grouped, as could South West, North West and Wales (Figure A3). The mean seasonal distributions were derived for each group of regions.

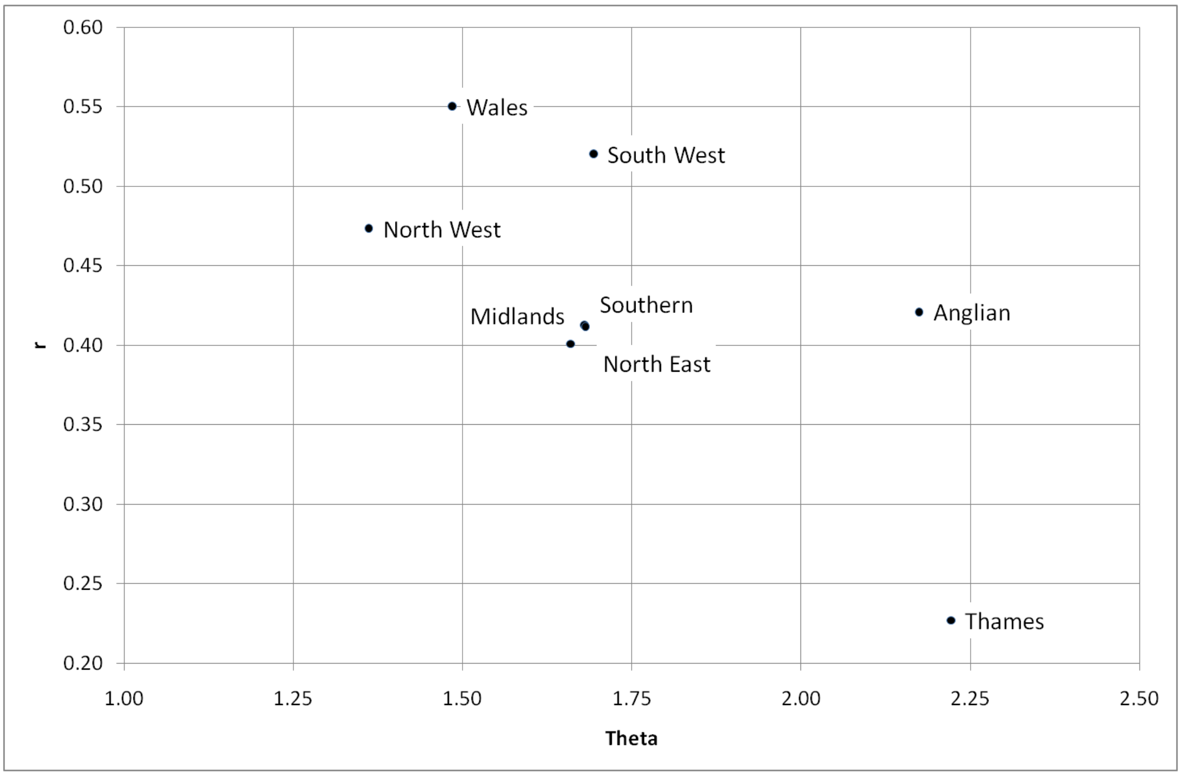

Figure A1-3 Regional variation in the mean data of occurrence of the annual maximum flood (theta) and spread of flood peaks (r)

The proportion of floods in each catchment in each of 12 months of the year was calculated and averaged by region (Figure A4).

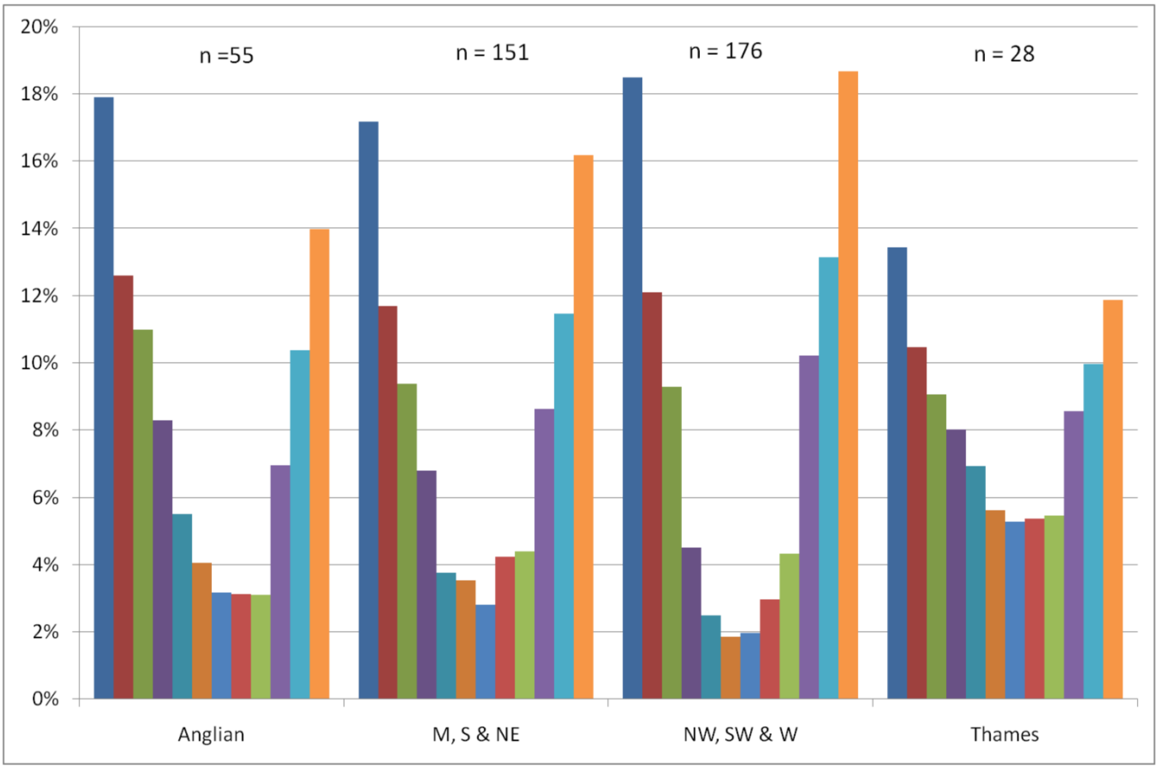

Figure A1-4 Average seasonal (January – December) distribution of peak flows by region

Coastal flooding

In the UK, coastal flooding will generally occur on a spring tide, and the level of flooding can therefore be considered strongly correlated to the peak of the spring tidal cycle. Although the spring-neap tidal cycle repeats itself every two weeks, there are also patterns within the spring-neap tidal pattern throughout the year (and on longer timescales). The largest peaks of the spring tide occur around the equinoxes. Therefore it would be expected that the most significant flooding would occur during the periods September-October and March. The more severe weather of the winter months also means that significant flood events may also occur during the months of November, and particularly February, where the general stronger winds of the winter months would result in larger surges than at other times of the year. This is particularly the case for the east coast of England, where in relative terms, surges are a more significant component of the sea level than they are on the west coast. Conversely to this, little flooding would be expected during the period May-August which is away from the two equinoxes and coincides with the time of year when wind speeds and therefore surges would be expected to be at their smallest (Hames, D., 2010, Pers. Com.).

Table A1-6   Assumed seasonal distribution of coastal flood probability in UK.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9%	14%	19%	7%	0%	0%	1%	7%	15%	13%	9%	6%

Seasonally weighted flood damage
The seasonal flood distributions (above) are used to calculate average loss from a single flood at any time of year. We assume that arable / horticultural crops will not be grown in areas subject to very frequent flooding where the risk of more than one flood per year is significant.

$$\bar{F} = \sum_{1=12}^{i=1} P_i F_i$$

Where
$\bar{F}$ = average damage from a flood in any month, fraction
F_i = damage from a flood in month i, fraction
P_i =relative probability of a flood in month i

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Appendix 2 Coastal flood seasonality

Internal communication from Dominic Hames (HR Wallingford).

Reference: Hames, D. (2010) Coastal flood seasonality. Internal communication

Coastal flood seasonality

Flooding at the coast is generally a combination of high sea levels combined with significant wave activity, with the relative importance of each dependent on exposure of the site to wave action, and the distribution of sea levels.

As wave heights at the coastline are dependent on the nearshore water depths, the dominant component in relation to flooding is the sea level, as generally without a high sea level there cannot be significant wave activity and therefore flooding. This is particularly the case around the coastlines of the UK where large tidal ranges mean that flooding will not occur unless there is a comparatively high sea level.

Sea levels are composed of an astronomical tide and a surge which is a result of weather patterns (e.g. local pressure and wind speeds and direction). By far the dominant component of this combination is the astronomic tide, which follows a two weekly cycle of low neap tides followed by high spring tides.

Considering the UK only, flooding will only occur on a spring tide, and the level of flooding can therefore be considered strongly correlated to the peak of the spring tidal cycle. Although the spring-neap tidal cycle repeats itself every two weeks, there are also patterns within the spring-neap tidal pattern throughout the year (and on longer timescales). The largest peaks of the spring tide occur around the equinoxes. Therefore it would be expected that the most significant flooding would occur during the periods September-October and March. The more severe weather of the winter months also means that significant flood events may also occur during the months of November, and particularly February, where the general stronger winds of the winter months would result in larger surges than at other times of the year. This is particularly the case for the east coast of England, where in relative terms, surges are a more significant component of the sea level than they are on the west coast. Conversely to this, little flooding would be expected during the period May-August which is away from the two equinoxes and coincides with the time of year when wind speeds and therefore surges would be expected to be at their smallest.

Two further points to consider in relation to flooding, is the 18.6 tidal modulation and the time of day that flooding occurs. Tides modulate over a period of 18.6 years. This results in a significant variation in high tides over this period. For example, in the Severn Estuary, high tides are typically 0.2m lower at the low point of this tidal modulation relative to the high point. The last high point of this modulation was in 1997, resulting in extreme astronomic tides in early March

1997. The next high point of this modulation is due in 2015. Time of day is also an effect to consider in flooding, with the high point of the highest astronomic tides occurring at the same time at the same location. For example, around Liverpool the highest high tides always occur around midday or midnight. At Newport this is at about 8 in the morning or afternoon, and in central London about 3 or 4 in the morning or afternoon. These times correlate closely with historic flood events, and it would be expected that given a location, the time (although not the date) of a future flood could be predicted within a short period with some certainty.

The following distribution of coastal flood is suggested:

Month	Probability of flooding
Jan	9%
Feb	14%
Mar	19%
Apr	7%
May	0%
Jun	0%
Jul	1%
Aug	7%
Sep	15%
Oct	13%
Nov	9%
Dec	6%

For the period May-July, the flooding occurrences are 0%. This is nor surprising, as it corresponds to the time of year when the highest tides are at there lowest and weather is at its most stable.

Incidentally, the large percentages in Jan and Dec, between the equinoxes is as a result of the weather during these months, which produce higher surges, although not enough to result in more of a risk of flooding during the higher tidal events around the equinoxes.

Appendix 3 Land Cover Map 2000 classification

Land cover map classification and definition of agricultural and non-agricultural land. The groups and land-uses have been defined by this project.

Class number in the LCM2000	Variant in the Land Cover Map 2000	Group	Land use
0	Not covered	Not covered	Not covered
1	sea	Non-agricultural	Non-agricultural
2	water (inland)	Non-agricultural	Non-agricultural
3	rock	Non-agricultural	Non-agricultural
4	rock with algae	Non-agricultural	Non-agricultural
5	mud	Non-agricultural	Non-agricultural
6	sand	Non-agricultural	Non-agricultural
8	saltmarsh	Non-agricultural	Non-agricultural
9	saltmarsh (grazed)	Grass	Rough grazing
10	rock	Non-agricultural	Non-agricultural
11	shingle (vegetated)	Non-agricultural	Non-agricultural
12	Shingle	Non-agricultural	Non-agricultural
13	Dune	Non-agricultural	Non-agricultural
14	Dune shrubs	Non-agricultural	Non-agricultural
15	Bog	Non-agricultural	Non-agricultural
16	Bog	Non-agricultural	Non-agricultural
17	Bog	Non-agricultural	Non-agricultural
18	Bog	Non-agricultural	Non-agricultural
19	Dwarf shrub heath	Non-agricultural	Non-agricultural
20	Dwarf shrub heath	Non-agricultural	Non-agricultural
21	Dwarf shrub heath	Non-agricultural	Non-agricultural
23	Broad leaved woodland	Non-agricultural	Non-agricultural
24	Broad leaved woodland	Non-agricultural	Non-agricultural
26	Broad leaved woodland	Non-agricultural	Non-agricultural
27	Coniferous woodland	Non-agricultural	Non-agricultural
28	Coniferous woodland	Non-agricultural	Non-agricultural
29	Coniferous woodland	Non-agricultural	Non-agricultural
30	Barley	Arable	Cereals
31	Maize	Arable	Cereals
32	Oats	Arable	Cereals
33	Wheat	Arable	Cereals
34	Cereal (spring)	Arable	Cereals
35	Cereal (winter)	Arable	Cereals
36	Arable bare ground	Arable	Other arable
37	Carrots	Horticulture	Horticulture
38	Field beans	Arable	Other arable
39	Horticulture	Horticulture	Horticulture
40	Linseed	Arable	Other arable
41	Potatoes	Arable	Roots
42	Peas	Arable	Other arable
43	Oilseed rape	Arable	Oilseed rape
44	Sugar beet	Arable	Roots

Class number in the LCM2000	Variant in the Land Cover Map 2000	Group	Land use
45	Arable unknown	Arable	Other arable
46	Mustard	Arable	Other arable
47	non-cereal (spring)	Arable	Other arable
48	Orchard	Horticulture	Orchard
49	Arable grass (ley)	Grass	Improved grass
50	Setaside (bare)	Setaside	Setaside
51	Setaside (undifferentiated)	Setaside	Setaside
52	Intensive grass	Grass	Improved grass
53	grass (hay / silage cut)	Grass	Improved grass
54	Grazing marsh	Grass	Rough grazing
55	grass setaside	Setaside	Setaside
56	Rough grass	Grass	Rough grazing
57	grass (neutral / unimproved)	Grass	Unimproved grass
58	Grass (calcareous managed)	Grass	Unimproved grass
59	Grass (calcareous rough)	Grass	Rough grazing
60	Grass acid	Grass	Unimproved grass
61	Grass acid (rough)	Grass	Rough grazing
62	Grass acid	Grass	Unimproved grass
63	Grass acid	Grass	Unimproved grass
64	Bracken	Non-agricultural	Non-agricultural
66	Fen/marsh	Non-agricultural	Non-agricultural
67	Fen/willow	Non-agricultural	Non-agricultural
68	Suburban/rural developed	Non-agricultural	Urban / suburban
69	Urban	Non-agricultural	Urban / suburban
70	Urban	Non-agricultural	Urban / suburban
71	Inland rock	Non-agricultural	Non-agricultural
72	Inland rock	Non-agricultural	Non-agricultural

Appendix 4 Details of datasets used in the analysis

Name
Flood zones (contained in the Flood Map)

Description
The flood zones are areas, which could be affected in the event of flooding from rivers and the sea. They do not consider the presence or performance of flood defences. There are three ‘Zones’
• The Flood Zones 1 is the area which is not inundated in a 1 in 1000year event. ie, the areas have less than 0.1 per cent chance of being inundated in any year. These areas are not explicitly produced as a deataset since they cover all areas of England and Wales outside of Flood Zones 2 and 3.
• The Flood Zones 2 indicate the extent of an extreme flood from rivers or the sea with a 0.1 per cent (1in 1000) chance of happening in any year.
• In the case of river flooding the Flood Zones 3 indicates the extent of a flood with a 1 per cent (1 in 100) chance of happening in any year.
• In the case of flooding from the sea the Flood Zones 3 indicates the extent of a flood with a 0.5 per cent (1 in 200) chance of happening in any year.
The Flood Map is made up of several different layers of data, and contains the Flood Zones dataset, which gives a national picture of flood risk for England and Wales.

Ownership
Environment Agency

Maintenance
The Flood Map is kept up-to date by producing updates every three months. The Environment Agency also has an ongoing programme to improve Flood Map as more detailed models are developed. Other information added from ongoing studies is related to new flood defences as they are built, and information on areas that benefit from flood defences.

Availability
Licensed through Environment Agency

Accuracy
Flood zones are defined in the government’s planning policy for England and are produced ignoring the presence of existing flood defences, since defences can be ‘overtopped’ if a flood occurs which is higher than the defences are designed to withstand or they can fail in extreme events. The Welsh Assembly Government publishes Development Advice Maps to support planning policy in Wales.

Version used in the project
V3.15

Name
Flood Storage Areas (contained in the Flood Map)

Description
The flood storage areas are defined in the Flood Map that gives a national picture of flood risk for England and Wales. Flood storage reservoirs are one of many methods of reducing overall flood risk and can be used alone or to complement other measures such as flood
defence walls. They are designed to allow flows up to a certain rate to flow unimpeded, with this flow determined by the amount that can flow onwards without causing significant flooding. This amount is specific to each reservoir and depends on the local circumstances.

Ownership
Environment Agency

Availability
Licensed through the Environment Agency

Accuracy
Dependent on the update cycle

Name
Agricultural Land Classification - England
Agricultural Land Classification - Wales

Description
Agricultural land is classified into five grades: grade one is best quality and grade five is poorest quality. A number of consistent criteria are used for the assessment which include climate (temperature, rainfall, aspect, exposure, frost risk), site (gradient, micro-relief, flood risk) and soil (depth, structure, texture, chemicals, stoniness).
The dataset defines polygons showing the 5 classes of agricultural land plus classifications for urban and non-agricultural land. It spatially covers England and Wales

Ownership
Natural England

Maintenance
Existing version from 2002. There is no clear plan of maintenance

Availability
This dataset can be downloaded from
http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp

Accuracy
The dataset is a raster digital mapping with a scale of 1:250,000.
It is digitised from the published 1:250,000 maps which was in turn compiled from the published 1 inch to 1 mile maps. It is digitised without reference to underlying O.S. detail.

Limitations
The data were created in 1974 and therefore there are significant areas which are no longer available to agriculture due to urbanisation for example

Name
Land Cover Map 2000

Description

LCM2000 exists in different levels and therefore details. While Level 2 is a raster dataset with a resolution of 25 m divided into 26 subclasses, Level 3 is a vector dataset and is made up of 72 variants. Both datasets represent the land use within England and Wales and are used for analyses with Geographic Information Systems. The data is made up of areas of land as cell clusters or polygons. The attribute table cover such topics as land cover class, parcel area, length of boundary, processing history, knowledge-based correction and identification of the original satellite scene.

Ownership
Centre for Ecology & Hydrology

Maintenance
A new dataset called LCM2007 is currently under creation and is expected to be published early 2010.

Availability
The dataset is supplied under licence and costs are calculated according the type of use (commercial, non-commercial or academic)

Accuracy

CEH has carried out a calibration with the CS2000 field survey which provides information to assess the quality of LCM2000. It was found that structural patterns are usually similar. Some exceptions occur where the lower spatial resolution of LCM2000 affects the detail. Where classes differ, they usually show confusion between similar types: bracken and acid grass, rough and semi-natural grass, conifers and broadleaved trees

Limitations
Most current land cover map available but dating back to land use state of 1998

Version used in the project
LCM2000 Level3

Name
Land Cover Map 1990

Description
LCM1990 is the first land use dataset created for the UK. The coverage is not complete and a certain number of raster cells contain “No Data”. The grid has a resolution of 25 x 25 metres and covers 25 different land use classes

Ownership
Centre for Ecology & Hydrology

Maintenance
Dataset was updated by creating LCM2000

Availability
The dataset is supplied under licence and costs are calculated according the type of use (commercial, non-commercial or academic)

Limitations
The data are not directly comparable to LCM2000 since the classes and methods used to assign them to the geographies are not consistent

Version used in the project

LCM1990

Name Environmental Stewardship

Description
Environmental Stewardship is a new agri-environment scheme which provides funding to farmers and other land managers in England who deliver effective environmental management on their land. Environmental Stewardship has three elements: Entry Level Stewardship (ELS), Organic Entry Level Stewardship (OELS) & Higher Level Stewardship (HLS)
Ownership
Natural England
Availability
This dataset can be downloaded from
http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp
Accuracy
Data captured with co-ordinate precision of sub 1 metre.
Quality control by comparison to Aerial Photography, RPA's IACS database and digital copies of legacy scheme agreement maps. Final version signed off by land owner and copies returned to RPA.
Version used in the project
Areas under Environmental Stewardship agreement in 2009

Name Managed Realignment

Description
The term Managed Realignment (also called ‘De-Embankment’ in mainland Europe) is most commonly understood to involve a deliberate breaching, or removal, of existing seawalls, embankments or dikes in order to allow the waters of adjacent coasts, estuaries or rivers to inundate the land behind. Dataset created for use in GIS was derived from the Online Managed Realignment Guide created by ABPmer in comparison with the OS Map.
Ownership
ABP mer
Availability
ABPmer website
http://www.abpmer.net/omreg/index.php?option=com_wrapper&Itemid=8
Accuracy
Punctual data with attributes covering: name, location, type, area, breach date
Limitations
No data available for Wales
Relevancy
Dataset was used to identify managed realignment as well as un-managed realignment sites.

Name Internal Drainage Boards (IDB).

Description
This is a Publication Scheme for Internal Drainage Boards (IDB). There are over 200 IDBs in England and Wales and their duties and powers are specifically

provided for by the Land Drainage Acts 1991 and 1994. Duties include general supervision over all aspects of land drainage within their district, duties to conservation and raising income to support land drainage works.

Ownership

IDBs are responsible to the Department of Environment Food and Rural Affairs (DEFRA) from whom all legislation/regulations affecting them is issued.

Availability

Data can be licensed through Defra

Name

NaFRA08/ SAMPS fluvial and coastal probability of flooding dataset

Description

Flood probability and risk data for impact cells on a 50m vector grid by Hydrometric Area for England and Wales. The data are derived via a probabilistic systems based modelling approach that considers the presence and performance of flood and coastal erosion defences. The data include depth versus exceedance probabilities for a range of water depths. These data were matched to the Reference Grid used for the analysis.

Ownership

Environment Agency

Availability

Licensed through Environment Agency

Name

Catchment Flood Management Plans (CFMP) Policy Unit data

Description

The Catchment Flood Management Plan Boundaries (CFMP) Policy Units are a spatial dataset that defines the boundaries where policies (e.g. reduce flood risk) are assigned in Catchment Flood Management Plans. These are long-term policies for inland flood risk management and do not necessarily relate to standards of protection or defences (flooding from the sea is dealt with in the Shoreline Management Plan). These policies should be used in conjunction with the CFMP Action Plan.

Ownership

Environment Agency

Availability

Licensed through Environment Agency

Limitations

National dataset currently lacks information in areas related to the following regions: North-East, Midlands and Anglia

Relevancy

Dataset has been useful in assessing the future change in risk to agricultural land.

Name

Anglian Pilot for Medium Term Plan

Description

The data holds details of the flood and coastal risk management schemes to be considered for Grant in Aid funding.. The schemes listed are intended to reduce the risk of flooding from rivers and the sea and to reduce the risk from coastal erosion. It does not include work to reduce the risks of other types of flooding, such as flooding from drains, sewers, groundwater or from surface water.

Ownership

Environment Agency

Availability

Licensed through Environment Agency

Limitations

Dataset is under construction.

Relevancy

Dataset has been helpful to determine the damages avoided to agricultural land.

Appendix 5 Questions not addressed in this report

The project brief included a number of questions designed to investigate the potential impact on agricultural land of FCERM policies into the future. As mentioned in Section 2.2 it has not been possible for this project to address these questions. In some cases the policy development was at the time ongoing and subject to change (for example Shoreline Management Plans and Catchment Flood Management Plans) and it was decided that the use of partial or incomplete information might be misleading.

For reference the questions are listed here:

F1. How might the flood risk to agricultural land (see answer to Q2) change in the future given predicted (UKCIP) changes in sea level and river flows?

F2. Coastal erosion. How much agricultural land (area and grade) is potentially lost to future (unconstrained) coastal erosion?

F3. Withdrawal of maintenance. Using the preferred policy options selected in CFMPs (such as CFMP policy option 1) [noting that 60 out of 68 CFMPs are complete] or SMPs (NAI), [recognising that most SMP2 will not be finalised during this project lifetime, so may need to refer back to original SMP] what is the potential area [worst case estimate – with assumptions] of agricultural land where flood risk is likely to increase (and by what extent) - assuming land owners or other 3rd parties do not maintain their own defence following withdrawal of maintenance by the EA or other operating authority? What does this represent as a percentage of the total area of agricultural land at flood risk (by grade) presently? Distinguish between land at risk of tidal flooding and fluvial flooding.

F4. Coastal erosion - No active intervention. Where "no active intervention" has been proposed as the preferred policy option in existing or reviewed SMPs, what is the potential area of agricultural land where erosion risk is likely to increase (and to what extent)? What does this represent as a percentage of the total agricultural land at erosion risk in that grade?

F5. How much area and grade of agricultural land is likely to be used in the future for flood storage (for example CFMP policy option 6)? What does this represent as a percentage of the total agricultural land in that category (region and grade)? What impact might this have on national or regional agricultural productivity?

In addition there are a number of questions where the input data are incomplete or the project team do not have sufficient confidence in the answers generated to include these in this final report. These questions and partial answers have also been removed from the main body of the report but are recorded here.

Question 7

Question 7: *Using the same methodology (as in Question 6), what is the value of agricultural land use benefits provided by the Operating Authorities current 5 year capital plan (Environment Agency published medium term plan)?*
It has not been possible to respond to this question for all projects in the Medium Term Plan as the data was not available to create a GIS layer showing the benefit area for each project.
Method: The Environment Agency's flood and coastal erosion risk management Medium Term Plan (MTP) data was only available in a GIS format for the Anglian Region. A subset of Q6 was used to attempt to answer this question. Capital projects on the Medium Term Plan are either maintenance or improvement projects. Maintenance projects with a benefit area including agricultural land can use the approach described in Q6. Where a project involves a change of standard of protection, the new probability of flooding has to be recalculated dependent on the new standard of protection values and then multiplied with the given damage/costs value. The method suggested for further analysis when data becomes available is as follows: • The Standard of Protection of the new schemes is identified in the Medium Term Plan. • The probability of flooding in the impact cells in the benefit area of the new schemes is determined with the NaFRA08 results. • if the probability of flooding in those impact cells is higher than the standard of protection provided by the new scheme, the value of probability is changed to the value of the standard of protection. • if the Medium Term Plan identifies no active intervention, the probabilities of the impact cells in the areas are compared with those provided by SAMPs rather than NaFRA08 (as SAMPS provides probabilities of flooding with no defences in place) Once the probabilities have been changed to reflect the project details in the MTP the estimation of the benefits follows the same methodology as Question 6.

Question 13

Question 13: *What is the best estimate of the total area of agricultural land that has been converted to inter-tidal habitat through un-managed realignment (including coastal erosion) in England and Wales over 10 years?*
It has not been possible to reliably answer this question. An analysis was attempted on agricultural land identified in the LCM1990 database and subsequently shown in LCM2000 as sea, saltmarsh, shingle or rock. However the database providers (CEH) warn that direct comparisons between the 1990 and 2000 datasets are not valid (see notice at http://www.ceh.ac.uk/sci_programmes/BioGeoChem/Dataproductdescription.html) so the values obtained are more likely to be an artefact of the approach taken rather than a real world result. A similar comparison between LCM2000 and LCM2007 may be valid and will give an indication of the area of land in agricultural use lost to coastal erosion or other unmanaged realignment.
Method: N/A
Datasets used: N/A

Question 19

Question 19: *What is the total area of agricultural land (and grade) that has been converted from agricultural use to a non-agricultural use in the last 10 and 25 years.*

Additional information:

Over 25 years
It has not been possibly to reliably answer this question. An analysis was undertaken of the area of land converted to non agricultural use by comparing the difference between the extent of the original ALC dataset (from 1974) and the same dataset updated with the urban areas shown in the Land Cover Map 2000. The difference identified is 578,700 ha in England and 54,600 ha in Wales. However this approach is limited and misleading because the 1974 ALC dataset did not include small settlements within its "urban" category but included them within ALC grades 1 to 5. The LCM2000 dataset however includes these settlements in the urban or suburban land use class (see appendix 3 for a list of classifications). Therefore these results significantly exaggerate the scale of change over this period.

The table below shows the difference in the area classified as agricultural grade land in the ALC dataset (nominally from 1974) and that shown in that dataset updated to remove those areas shown in the LCM2000 as being in urban or suburban use (see also Section 3.7 of the main report).

Table A52 Reduction in area (ha) classified as ALC grade land 1974 to 1998 – England and Wales

	Area converted to a non-agricultural use (ha)	
ALC grade	**England**	**Wales**
1	22,800	600
2	91,400	6,100
3	363,200	18,600
4	90,700	21,100
5	10,500	8,200
TOTAL (between 1974 and 1998)	**578,700**	**54,600**

Note: For the reasons given above these figures significantly exaggerate the loss of agricultural grade land during this period

Method:

To identify the area of land recognised as urban or suburban in 1998 but recorded as ALC grade land in the ALC dataset use has been made of the Agricultural Land Classification dataset ALC (from 1974), and the Land Cover Map 2000. The first dataset, from 1974, has been modified to include the areas identified in the LCM 2000 as suburban, rural developed, urban residential and commercial (and not already recorded as such in the ALC). The method assumes there has been no measurable change in the opposite direction, ie. land in non-agricultural or urban use at the time of the ALC survey now changed to agricultural use.

Supporting information:

The table below shows the area and grade of land reclassified as non-agricultural by this project in the period between 1974 and 1998 in the different regions in England.

Table A5-2 Area of land (ha) reclassified as non-agricultural in England for the period 1974 to 1998

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL	% of original ALC
Thames Region	1,100	9,000	43,500	9,900	100	63,500	6.7%
South West Region	2,500	9,100	53,800	12,700	2,800	81,000	4.3%
Southern Region	4,300	9,100	35,500	11,700	900	61,500	6.7%
North West Region	3,300	7,100	34,500	13,600	2,500	61,100	4.9%
North East Region	700	12,800	53,100	14,300	3,100	84,000	4.2%
Midlands Region	1,100	19,300	81,000	20,000	1,000	122,500	6.3%
Anglian Region	9,900	25,200	61,700	8,400	100	105,300	4.3%
TOTAL	22,800	91,400	363,200	90,700	10,500	578,700	

The table below shows the area and grade of land reclassified by this project as non-agricultural for the period between 1974 and 1998 in Wales.

Table A5-3 Land reclassified as non-agricultural in Wales for the period 1974 to 1998 (ha)

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL	% of original ALC
Wales	600	6,100	18,600	21,100	8,200	54,600	2.9%

Datasets used:

Reference grid, ALC, LCM2000, EA Regions

Question 20

Question 20: *Repeat this calculation for land identified as being at flood risk.*

Note: Refer to Question 19. These values significantly exaggerate the area of agricultural land converted to a permanent non-agricultural use over this period.

The area of agricultural land in the floodplain reclassified as non-agricultural is 71,620 ha, this is 11.3% of the total area reclassified and is in line with the national proportion of ALC grade land in the floodplain (Tables 18 and 19).

The area identified in England is 65,350 ha and 6,270 ha in Wales. Tables below show the area for each land grade.

Table A5-4 Land (ha) in the floodplain reclassified as non-agricultural in England for the period 1974 to 1998

ALC grade	Area reclassified to a non-agricultural use (ha)
1	8,560
2	12,130
3	31,680
4	12,160
5	820
TOTAL	65,350

Table A5-5 Land (ha) in the floodplain reclassified as non-agricultural in Wales for the period 1974 to 1998

Agricultural Land Class	Area reclassified to a non-agricultural use (ha)
1	50
2	540
3	2,320
4	2,600
5	770
TOTAL	**6,270**

Method:

The same method has been used as for Q19 and the resulting dataset cross-referenced with the flood zone dataset to identify land in the floodplain.

Supporting information:

The area of land in the floodplain reclassified as being in non-agricultural use in each of the regions of England is shown in the table below.

Table A5-6 Land area (ha) in the floodplain reclassified as non-agricultural use in the different English regions within the period 1974 to 1998

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	TOTAL
Thames Region	220	950	2,470	1,870	30	5,530
South West Region	80	370	3,500	1,760	120	5,820
Southern Region	540	790	2,410	1,610	90	5,440
North West Region	550	820	2,560	980	150	5,060
North East Region	600	2,850	6,190	1,420	330	11,390
Midlands Region	520	2,210	7,570	3,050	90	13,440
Anglian Region	6,060	4,150	6,980	1,470	10	18,670
TOTAL	8,560	12,130	31,680	12,160	820	65,350

Datasets used:

Reference grid, ALC, LCM2000, Flood Zones 2 (from Flood Map), EA Regions

Question F1: *How might flood risk to agricultural land (answer to question 2 above) change in the future given predicted (UKCIP) changes in sea level and river flows?*

It is not possible to respond to this question directly as the required dataset (LTIS – see Section 2.2) was not available for use by this project.

A large modelling exercise beyond the scope of this project would have been necessary to achieve alternative results about the additional agricultural land that will fall within the flood plain given expected sea level rise or changes in river flows.

Method:
n/a

Supporting information:

The data provided to answer this question in the absence of the LTIS dataset, have been extracted from the Foresight Future Flooding Study (Evans et al 2004).

Four scenarios are considered within this Foresight study. The scenarios and their assumptions are summarized below as information. More details can be found in the original report:

1. World Markets/High emissions (WM):
   - Highest national and global growth.
   - No action to limit emissions.
   - Price of fossil fuels may drive development of alternatives in the long term.
2. National Enterprise/Medium High emissions (NE):
   - Medium-low growth, but with no action to limit emissions.
   - Increasing and unregulated emissions from newly industrialised countries.
3. Local Stewardship/Medium Low emissions (LS):
   - Low growth
   - Low consumption.
   - Less effective international action.
   - Low innovation.
4. Global Sustainability/Low emissions (GS):
   - Medium-high growth,
   - Low primary energy consumption.
   - High emphasis on international action for environmental goals (e.g. greenhouse gas emissions control).
   - Innovation of new and renewable energy sources.

For each of these scenarios a qualitative assessment of flood risk in the 2080s is made. In addition, to investigate the evolution of risks over time, the World Markets/High emissions scenario for the 2050s is also analysed.

The agricultural damages for the scenarios above have been analysed based on typical losses associated with the different grades of Agricultural Land Classification. These losses are noted as being incurred during any flood event occurring in summer or an event lasting more than 1 week in winter. The duration and timing of the inundation event are not, however, represented within the analysis methodology. Therefore, to provide a proxy to the length of time of the inundation, flooding to a depth of 0.5m has been assumed to be sufficiently severe to last 1 week in duration. To calculate the agricultural losses, the annual probability of inundation to a depth of 0.5m or greater has therefore been multiplied by the potential losses per grade of agricultural land to derive Expected Annual Damage net of agricultural subsidies. The results in millions are presented in the table below:

Table A5-7 All Foresight Futures: Expected Annual Damage (£ millions) – agricultural production for England (Foresight Volume 1, Chart 4.6)

	Foresight Future					
	Present day	**WM 2050s**	**WM 2080s**	**NE 2080s**	**LS 2080s**	**GS 2080s**
Thames Region	0.2	0.7	0.5	0.6	1.5	0.9
South West Region	0.3	0.8	1.2	0.9	2.4	1.3
Southern Region	0.4	12	9.1	13.4	18.8	14.3
North West Region	0.8	2.4	1.4	2.8	5	3.4
North East Region	0.7	11.8	5.3	6.7	10	6.7
Midlands Region	0.5	2.2	2.9	2	5	2.8
Anglian Region	2.6	10	13.2	12.7	16.8	11.8
TOTAL	5.5	39.9	33.6	39.1	59.5	41.2

Table A5-8 All Foresight Futures: Expected Annual Damage (£ millions) – agricultural production for Wales (Foresight Volume 1, Chart 4.6)

	Foresight Future					
	Present day	**WM 2050s**	**WM 2080s**	**NE 2080s**	**LS 2080s**	**GR 2080s**
Wales	0.4	1.7	0.8	2	4	2.7

The difference between the scenarios WM, NE, LS and GS, and the Present day scenario show the increase in damages due to the increase in flood risk.

The values corresponding to the present day scenario in the table above cannot be compared directly with the results obtained in question 6, as that question presents the damages avoided due to the presence of flood defences (the difference between the scenarios with and without defences, therefore the difference between NaFRA08 and SAMPS datasets). The present day values are also dissimilar to the results presented in question 6 (which are more

accurate) since Table A5-7 is based on the NaFRA 2002 method while the present day risk results presented in this report are based on NaFRA 2008. There were substantial improvements in the RASP method and NaFRA base data during this time, resulting in significantly improved outputs.
Datasets used: Foresight Future Flooding, Volume 1

Question F5

Question F5: *How much area and grade of agricultural land is likely to be used in the future for flood storage (for example CFMP policy option 6)? What does this represent as a percentage of the total agricultural land in that category (region and grade)? What impact might this have on national or regional agricultural productivity?*

CFMPs are high level plans developed by the Environment Agency in consultation with local authorities, land owner organisations, Natural England, and other stakeholders. The plans set out the preferred flood risk management policy option for a catchment. Policy Option 6 refers to areas of low to moderate flood risk where the Environment Agency will take action with others to store water or manage run-off in locations that provide overall flood risk reduction or environmental benefits. This policy will tend to be applied where there may be opportunities in some locations to reduce flood risk locally or more widely in a catchment by storing water or managing run-off. The policy has been applied to an area (where the potential to apply the policy exists) but would only be implemented in specific locations within the area – not to the entire area - after more detailed appraisal and consultation[20].

The information obtained from the CFMP dataset is not complete for all of England as there are large areas where plans were not complete when the project results were generated. The results provided in Table A5-9 below are therefore only partial as they do not cover all of England (Figure A5-1shows in red the areas with no information). The regions affected are the North East, Midlands and Anglian region.

Table A5-9 Agricultural grade land (ha) in CFMP policy option 6 areas - Wales

	Grade 1	Grade2	Grade 3	Grade 4	Grade 5	TOTAL
Wales	7,800	64,800	89,400	142,600	101,400	406,000

Note: refer to Table 22 for the total area of ALC grade land in Wales

The total area assigned to catchment flood management plan policy 6 is shown in the table below by Environment Agency Region. (*Note*: Data for Anglian, North-East, and Midlands regions are incomplete). Refer to Table 21 for the total area of ALC grade land in each Region.

Table A5-10 Area (ha) identified as CFMP Policy Option 6 by ALC grade - England

	Grade 1	Grade2	Grade 3	Grade 4	Grade 5	TOTAL
Thames Region	1,600	99,900	380,800	85,400	2,200	569,900
South West Region	10,500	47,500	347,900	165,000	81,200	652,100
Southern Region	2,200	20,100	201,400	72,600	12,300	308,600
North West Region	8,600	37,700	183,600	73,500	133,800	437,200
North East Region	0	3,400	55,200	15,700	27,800	102,100

[20] For more information about catchment flood management plans see the Environment Agency website - http://www.environment-agency.gov.uk/research/planning/33586.aspx

Midlands Region	0	7,300	92,000	112,600	56,100	268,000
Anglian Region	300	3,600	34,600	2,600	0	41,100
TOTAL	23,200	219,500	1,295,500	527,400	313,400	2,379,000

Note: When the report data were generated the following plans had not been published and hence the policy 6 areas had not been agreed: North-East – rivers Aire, Calder, Derwent, Don and Rother, Esk, Yorkshire Ouse, Hull and coastal streams; Midlands – river Trent; Anglian – river Great Ouse. These unpublished CFMPs are estimated to cover the following proportions of the total land area in each Region: North-East – 57%, Midlands – 48%, Anglian 32%.

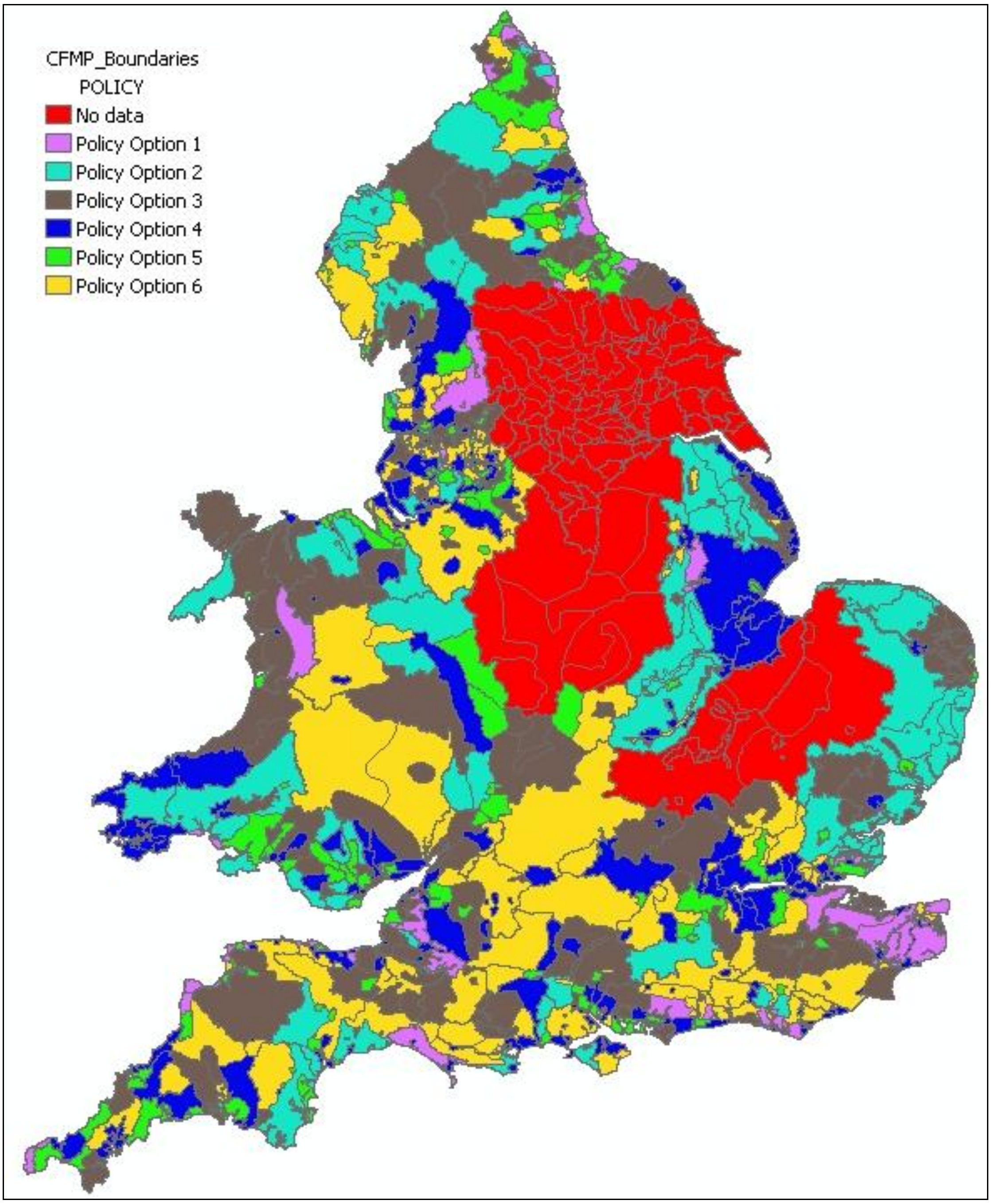

Figure A5-1 CFMP – assigned policy areas (data for England incomplete)

Method: The CFMP policy 6 data was mapped to the reference grid and cross-referenced with the ALC dataset and then again with the EA Regions data to obtain results for all regions.
Datasets used: Reference grid, CFMP Policy Option 6, ALC, EA Regions

[Report Ends]