Peterborough SFRA
Stage 2 Report

Peterborough City Council

November 2005

Final Report

9P8284

ROYAL HASKONING

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all dimensions

Peterborough Strategic Flood Risk Assessment Stage 2 Report

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ROYAL HASKONING

HASKONING UK LTD.
COASTAL & RIVERS

Rightwell House
Bretton
Peterborough PE3 8DW
United Kingdom
+44 (0)1733 334455 Telephone
01733 333538 Fax
info@peterborough.royalhaskoning.com E-mail
www.royalhaskoning.com Internet

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Drafted by	R Gunasekara	
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Study Objectives

The Strategic Flood Risk Assessment (SFRA) for the Peterborough City Council (Council) has been undertaken to provide a robust assessment of the extent and nature of the risk of flooding and its implications for land use planning. In addition, the SFRA sets the criteria for the submission of planning applications in the future and for guiding subsequent development control decisions. The key objectives of the study are to:

- Provide a reference and policy document to inform preparation of the Local Development Frameworks for the Council's District;
- Ensure that Council meets their obligations under the Department of Transport, Local Government and the Regions Planning Policy Guidance Note 25 "Development and Flood Risk". The guidance note is referred to here as PPG25; and
- Provide a reference and policy document to advise and inform private and commercial developers of their obligations under PPG25.

Outputs

The principal output from the study is a set of maps, which categorise the Council's area into flood risk categories according PPG25 but consider the presence of flood defences where they exist to assess actual risk to the land. These maps have been produced adopting a robust assessment to give the Council sufficient information so as to have an overall view of flood risk areas for strategic planning purposes.

The maps and this accompanying report will provide a sound framework enabling consistent and sustainable decisions to be made when making future planning decisions. Methods of assessment and limitations of the SFRA outputs, including further recommendations to address them, are also presented.

The SFRA evaluates the present-day (year 2005) situation and the situation after 50 years time (year 2055) with increased peak flood flows and sea level rise to allow for projected climate change.

Figure 1 shows the study area and the key sources of fluvial flooding that were considered. SFRA flood risk categories do not consider the blockage risk, storm water and overland flooding or failure of storm water retention facilities.

Data Sources

Figure 2 shows the extent of data that was made available for the study.

Co-operation

The SFRA was carried out with the co-operation and support of the Environment Agency Anglian Region, Welland and Deepings Internal Drainage Board, North Level Internal Drainage Board and the Council.

GLOSSARY

Adoption of sewers	The transfer of responsibility for the maintenance of a system of sewers to a sewerage undertaker
Afflux	Increase in upstream flood level caused by an obstruction to flow in a watercourse or on a *floodplain*.
Annual flood probability	The estimated probability of a flood of given magnitude occurring or being exceeded in any year. Expressed as, for example, 1-in-100 chance or 1 per cent.
Antecedent conditions	The condition of a *catchment* area at the start of a rainfall event.
Artificial drainage system	A constructed drainage system such as a drain, sewer or ditch.
Attenuation	To reduce the peak flow and increase the duration of a flood event.
Balancing pond	A pond designed to attenuate flows by storing runoff during the peak flow and releasing it at a controlled rate during and after the storm. Also known as wet detention pond.
Basin	A ground depression acting as a flow control or water treatment structure that normally is dry and has a proper outfall, but which is designed to detain stormwater temporarily.
Boundary condition	A specified variable, typically water level or flow, which is defined at the edge of the spatial extent of a model to allow the model to solve its governing equations.
Brownfield site	Any land or site that has been previously developed.
Catchment	The area contributing flow or *runoff* to a particular point on a watercourse.
Climate change	Long-term variations in global temperature and weather patterns both natural and as a result of human activity, primarily greenhouse gas emissions.
Coastal flooding	Flooding from the sea.
Commuted sum	A single payment made at the beginning of an agreement to cover maintenance for an agreed period of time.

Critical ordinary watercourse	An *Ordinary watercourse* which the Environment Agency and other operating authorities agree is critical because it has the potential to put at risk from flooding large numbers of people and property.
Culvert	Covered channel or pipe that forms a *watercourse* below ground level.
Design criteria	A set of standards agreed by the developer, planners and regulators that the proposed system should satisfy.
Design event	An historic or notional *flood event* of a given *annual flood probability*, against which the suitability of a proposed development is assessed and *mitigation measures*, if any, are designed.
Design flood level	The maximum estimated water level during the *design event*.
Detention basin	A vegetated depression that normally is dry except following storm events. It is constructed to store water temporarily to attenuate flows and may allow *infiltration* of water to the ground.
Development	The carrying out of building, engineering, mining or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land.
Discharge	Rate of flow of water.
Extended detention basin	A detention basin where the runoff is stored beyond the time for *attenuation*. This provides extra time for natural processes to remove some of the pollutants in the water.
Field drainage	System of drains to control the *water table* in agricultural land.
Filter drain or filter trench	A linear drain consisting of a trench filled with a permeable material, often with a perforated pipe in the base of the trench to assist drainage. Its purpose is to store and conduct water, but may also permit *infiltration*.
Filter strip	A vegetated area of gently sloping ground designed to drain water evenly off impermeable areas and filter out silt and other particulars.
Filtration	The act of removing sediment or other particles from a fluid by passing it through a filter.
First flush	The initial *runoff* from a site/*catchment* following the start of a rainfall event. As *runoff* travels over a catchment it will collect or dissolve pollutants and the “first flush” portion of the flow

	may be the most contaminated as a result. This is especially the case for intense storms and in small or more uniform catchments. In larger or more complex catchments pollution wash-off may contaminate runoff throughout a rainfall event.
Flap valve	A simple form of non-return valve, employing a hinged flap to prevent reverse flow. Used in this guide as a generic term for any device which prevents backflow of water up a *watercourse* or *artificial drainage system*.
Flood defence	Flood defence infrastructure, such as flood walls and embankments, intended to protect an area against flooding, to a specified *standard of protection*.
Flood defence crest level	The level to which flood defences are constructed, that is the level of the top of flood walls and embankments, expressed relative to Ordnance Datum.
Flood event	A flooding incident characterised by its level or *flow hydrograph.*
Flood probability	The estimated probability of a flood of given magnitude occurring or being exceeded in any specified time period. See also *annual flood probability*.
Flood risk	An expression of the combination of the *flood probability* and the magnitude of the potential consequences of the *flood event*.
Flood risk assessment	A study to assess the risk of a site or area flooding, and to assess the impact that any changes or development in the site or area will have on *flood risk*.
Flood storage	The temporary storage of excess runoff or river flow in ponds, basins, reservoirs or on the *floodplain* during a flood event.
Floodplain	Area of land that borders a watercourse, an estuary or the sea, over which water flows in time of flood, or would flow but for the presence of flood defences where they exist.
Flow control device	A device used to manage the movement of surface water into an out of an *attenuation* facility, eg weirs.
Fluvial flooding	Flooding from a river or other *watercourse*.
Freeboard	The difference between the *flood defence crest level* and the *design flood level*.
Functional flood plain	Unobstructed areas of the *floodplain* where water regularly flows in time of flood.

Greenfield runoff rate	The rate of *runoff* that would occur from the site in its undeveloped (and therefore undisturbed) state.
Greywater	Greywater is water from sinks, baths, showers and domestic appliances. Kitchen sink or dishwasher wastewater is not generally collected for use, as it has high levels of contamination from detergents, fats and food waste, making filtering and treatment difficult and costly.
Groundwater	Water in the ground, usually referring to water in the saturated zone below the *water table*.
Groundwater flooding	Flooding caused by *groundwater* escaping from the ground when the *water table* rises to or above ground level.
Highway authority	A local authority with responsibility for the maintenance and drainage of highways maintainable at public expense.
Hydrograph	A graph that shows the variation with time of the level or discharge in a *watercourse*.
Impermeable surface	An artificial non-porous surface that generates a surface water *runoff* after rainfall.
Infiltration (to the ground)	The passage of surface water through the surface of the ground.
Infiltration basin	A dry basin designed to promote *infiltration* of surface water to the ground.
Infiltration capacity	A soil characteristic determining or describing the maximum rate at which water can enter the soil.
Infiltration trench	A trench, usually filled with permeable granular material, designed to promote infiltration of surface water to the ground.
Land drain	Drain used in agriculture to control the *water table* and reduce the frequency with which land becomes waterlogged.
Local Development Documents	Documents that set out the spatial strategy for local planning authorities which comprise development plan documents.
Local Development Framework	Framework which forms part of the statutory development plan and supplementary planning documents which expand policies in a development plan document or provide additional detail.
Local planning authority	Body responsible for planning and controlling development, through the planning system.

Main River	A watercourse designated on a statutory map of Main rivers, maintained by Defra.
Material consideration	Matters which need to be taken into account by a planning authority when determining an application for planning permission.
Mitigation measure	A generic term used in this guide to refer to an element of *development* design which may be used to manage *flood risk* to the *development*, or to avoid an increase in *flood risk* elsewhere.
Model Agreement	A legal document that can be completed to form the basis of an agreement between two or more parties regarding the maintenance and operation of sustainable water management systems.
Ordinary watercourse	A watercourse which is not a private drain and is not designated a *Main river*.
Overland flow flooding	Flooding caused by surface water *runoff* when rainfall intensity exceeds the infiltration capacity of the ground, or when the soil is so saturated that it cannot accept any more water.
Passive flood plain	Areas that are within the “natural” *floodplain* but are not now subject to frequent flooding, because of the presence of flood alleviation measures.
Permeable surface	A surface that is formed of material that is itself impervious to water but, by virtue of voids formed through the surface, allows infiltration of water to the sub-base – for example, concrete block paving.
Pond	Permanently wet depression designed to retain stormwater above the permanent pool and permit settlement of suspended solids and biological removal of pollutants.
Precautionary principle	The approach, to be used in the assessment of *flood risk*, which requires that lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to avoid or manage *flood risk*.
Rainwater use systems	A system that collects rainwater from where it falls rather than allowing it to drain away, treats and stores it and then distributes it for use. This includes water that is collected within the boundaries of a property, from roofs and surrounding surfaces, including areas of hardstanding and pervious paving.
Rapid Inundation	For this project, rapid inundation zone was defined as an area

Zone	that can be expected to flood to a depth of 0.3metres within half an hour of a possible breach in a relevant raised defence.
Retention pond	A pond where runoff is detained for a sufficient time to allow settlement and possibly biological treatment of some pollutants.
Return period	A term sometimes used to express *flood probability*. It refers to the estimated average time gap between floods of a given magnitude, but as such floods are likely to occur very irregularly, an expression of the *annual flood probability* is to be preferred.
River flooding	See *fluvial flooding*.
Runoff	Water flow over the ground surface to the drainage system. This occurs if the ground is impermeable or saturated, or if rainfall is particularly intense.
Sequential test	A risk-based approach to *flood risk assessment* in accordance with Planning Policy Guidance Note 25, applied through the use of flood risk zoning, where the type of *development* that is acceptable in a given zone is dependent on the assessed *flood risk* of that zone.
Sewerage undertaker	This is a collective term relating to the statutory undertaking of water companies that are responsible for sewerage and sewage disposal, including surface water from roofs and yards draining through public sewers.
Soakaway	A subsurface structure into which surface water is conveyed to allow infiltration into the ground.
Source control	The control of runoff or pollution at or near its source.
Standard of protection	The estimated probability of a *design event* occurring, or being exceeded, in any year. Thus it is the estimated probability of an event occurring which is more severe than those against which an area is protected by *flood defences*.
Strategic flood risk assessment	A study to examine *flood risk* issues on a sub-regional scale, typically for a river *catchment* or local authority area during the preparation of a development plan.
Sustainable drainage systems (SUDS)	A sequence of management practices and control structures, often referred to as SUDS, designed to drain surface water in a more sustainable manner. Typically, these techniques are used to attenuate rates of *runoff* from *development sites*.
Swale	A shallow vegetated channel designed to conduct and retain water, but may also permit infiltration; the vegetation filters

particulate matter.

Treatment Improving the quality of water by physical, chemical and/or biological means.

Water table The level of *groundwater* in soil and rock, below which the ground is saturated.

Watercourse Any natural or artificial channel that conveys surface water.

Wetlands An area where saturation or repeated inundation of water is the determining factor in the nature of the plants and animals living there.

Whole-life costing Accounting system that considers all the costs (private and social) that accrue to the initiation, provision, operation, maintenance, servicing and decommissioning over the useful life of an asset or a service.

ABBREVIATIONS

AVM	Automatic Voice Messaging
COW	Critical Ordinary Watercourse
DTLR	Department of Transport, Local Government and the Regions (DTLR no longer exists as there is a separate Department for Transport now. The other responsibilities of former DTLR are now within the Office of the Deputy Prime Minister and the Department of Constitutional Affairs.)
DTM	Digital Terrain Model
EA	Environment Agency
EERA	East of England Regional Assembly
EFO	Extreme Flood Outline
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
FSR	Flood Studies Report
FWRFA	Flood Warning Flood Risk Area
GIS	Geographical Information System
IDB	Internal Drainage Board
LDD	Local Development Documents
LDF	Local Development Framework
LiDAR	Light Detection And Ranging
LPA	Local Planning Authority
NFCDD	National Flood and Coastal Defence Database
PPG25	Planning Policy Guidance Note 25 – Development and Flood Risk
PSR	Peterborough Sub-Region
PSRS	Peterborough Sub-Regional Study
RSS	Regional Spatial Strategy

SAR	Synthetic Aperture Radar
SFRA	Strategic Flood Risk Assessment
SoP	Standard of Protection
SUDS	Sustainable Drainage Systems
UCS	Urban Capacity Study

1 INTRODUCTION

1.1 Scope

This report concerns a Strategic Flood Risk Assessment (SFRA) covering the whole of Peterborough City Council's administrative area.

The report accompanies mapping which shows the relative risk of flooding for land within the study area, assessed at a strategic level. The report explains the background, the data used, method of assessment, development issues, limitations and recommendations for further work. Developer guidance and technical information are also given in appendices.

The key activities in preparation of the SFRA are presented in *Table 1* below.

Table 1 Key activities in the SFRA

Stage 1	• Start up project • Collect and review data • Review of recent flood events • Review of watercourses maintained by the Peterborough City Council • Liaison with key consultees • Review present and proposed land use and policy documents • Assess adequacy of data to carry out SFRA • Agree SFRA methodology for Stage 2 • Produce Stage 1 report
Stage 2	• Undertake overall Strategic assessment of the flood risk, following the Environment Agency guidance for Local Authorities Issue 4(b) • Carry out more detailed assessment in the land use and policy document of development areas • Assess Standard of Protection of watercourses at key locations • Map flood risk categories to supplement the current Environment Agency Flood Zones • Produce guidance for developers • Produce draft and final versions of Stage 2 report and associated mapping

1.2 Background

Haskoning UK Ltd (formerly Posford Haskoning Ltd) was appointed by the Peterborough City Council (Council) in December 2004 in order to undertake a SFRA for their District. Haskoning UK Ltd. is a company of Royal Haskoning. The initial Terms of Reference for the assessment were set out in Royal Haskoning's proposal dated August 2004. The proposal was accepted by the Council in their letter of 20th December 2004.

The SFRA was carried out with the co-operation and support of the Environment Agency (EA), Welland and Deepings Internal Drainage Board (IDB) and North Level IDB to help the Council fulfil their obligations under the Department of Transport, Local Government and the Regions (DTLR) Planning Policy Guidance Note

25 "Development and Flood Risk "(July 2001). The Guidance Note is referred to here as PPG25.

A key element within PPG25 is the concept of Flood Zones, whereby land is categorised as being in one of a range of zones according to the annual probability of flooding to the land. The Flood Zones are defined in Table 1 of PPG25 Clause 30; that table is reproduced as *Table 2* in this report. This clause emphasis that the Government expects Local Planning Authorities (LPAs) to apply a risk-based approach to the preparation of development plans and their decisions on development control, through a sequential test based on Table 1.

The final output of the SFRA provides sufficient information on flood risk issues for the Council to prepare the emerging strategy plans for Peterborough District under the Regional Spatial Strategy (RSS) for East of England.

1.3 Objectives

The objectives of the SFRA are to:

- Provide a reference and policy document to inform preparation of the Local Development Frameworks (LDFs) for the Peterborough District;
- Help that the Council meet their obligations under PPG25 and any other relevant guidance; and
- Provide a reference and policy document to advise and inform private and commercial developers of their obligations under PPG25.

Table 2 Planning response to sequential characterisation of flood risk (Table 1 - PPG25, DTLR 2001)

FLOOD ZONE (see Note a)	**APPROPRIATE PLANNING RESPONSE**
1. Little or no risk Annual probability of flooding: River, tidal & coastal <0.1%	No constraints due to river, tidal or coastal flooding.
2. Low to medium risk Annual probability of flooding: River 0.1-1.0% Tidal & coastal 0.1-0.5%	Suitable for most development. For this and higher-risk zones, flood risk assessment appropriate to the scale and nature of the development and the risk should be provided with applications or at time of local plan allocation. Flood-resistant construction and suitable warning/evacuation procedures may be required depending on the flood risk assessment. Subject to operational requirements in terms of response times, these and the higher-risk zones below are generally not suitable for essential civil infrastructure, such as hospitals, fire stations, emergency depots etc. Where such infrastructure has to be, or is already, located in these areas, access must be guaranteed and they must be capable of remaining operational in times of emergency due to extreme flooding.

3. High risk (see note b) Annual probability of flooding, with defences where they exist: River 1.0% or greater Tidal & coastal 0.5% or greater	**a) Developed areas.** These areas may be suitable for residential, commercial and industrial development provided the appropriate minimum standard of flood defence (including suitable warning and evacuation procedures) can be maintained for the lifetime of the development (see paragraph 31), with preference being given to those areas already defended to that standard. In allocating or permitting sites for development, authorities should seek to avoid areas that will be needed, or have significant potential, for coastal managed realignment or washland creation as part of the overall flood defence strategy for coastal cells and river catchments. **b) Undeveloped & sparsely developed areas** These areas are generally not suitable for residential, commercial and industrial development unless a particular location is essential, eg for navigation and water-based recreation uses, agriculture and essential transport and utilities infrastructure, and an alternative lower-risk location is not available. General-purpose housing or other development comprising residential or institutional accommodation should not normally be permitted. Residential uses should be limited to job-related accommodation (eg caretakers and operational staff). Caravan and camping sites should generally not be located in these areas. Where, exceptionally, development is permitted, it should be provided with the appropriate minimum standard of flood defence and should not impede flood flows or result in a net loss of flood-plain storage. **c) Functional flood plains** These areas may be suitable for some recreation, sport, amenity and conservation uses (provided adequate warning and evacuation procedures are in place). Built development should be wholly exceptional and limited to essential transport and utilities infrastructure that has to be there. Such infrastructure should be designed and constructed so as to remain operational even at times of flood, to result in no net loss of flood-plain storage, not to impede water flows and not to increase flood risk elsewhere. There should be a presumption against the provision of camping and caravan sites.

Notes :

(a) All risks relate to the time at which a land allocation decision is made or an application submitted. The Environment Agency will publish maps of these flood zones. Flood zones should be identified from Agency flood data ignoring the presence of flood defences. Local planning authorities should, with the Agency, identify those areas currently protected by defences and the standard of protection provided by those defences.

(b) Development should not be permitted where existing sea or river defences, properly maintained, would not provide an acceptable standard of safety over the lifetime of the development, as such land would be extremely vulnerable should a flood defence embankment or sea wall be breached, in particular because of the speed of flooding in such circumstances (see paragraph 69).

2 GENERAL CRITERIA

2.1 Requirements of the SFRA

PPG25 states that Government expects local planning authorities to apply a risk-based approach to the preparation of development plans and their decisions on development control through a sequential test. The EA have published Flood Zones (Environment Agency, June 2005) ignoring the presence of flood defences. In applying the sequential test, local planning authorities should consult and take the advice of the EA on the distribution of flood risk and the availability of flood defences in their areas. They should take account of the resulting level of actual risk in drawing up development plans and policies and considering proposals and applications for development. The Council intends to achieve this from this SRFA.

The EA Anglian Region has already published guidance notes on the strategic assessment of flood risk entitled Strategic Assessment of Flood Risk, Guidance for Local Planning Authorities, Issue 4 (b) – *see Appendix 2*. These notes provide general information and background to the production of the SFRA document although it was necessary to tailor the requirements to suit the needs of the Peterborough District. Further specific requirements for the SFRA were identified within the Consultants Brief supplied by the Council with their letter of 10th August 2004.

The Environment Agency's National Standing advice to LPAs in England for making decisions on low risk planning applications is also available on www.pipernetworking.com/floodrisk/.

The SFRA considers flood risk from the fluvial and tidal flooding sources shown in *Figure 1*. Anglian Water storm water or foul drainage systems have not been investigated in detail as part of this study. This aspect may be looked at as part of a further study if needed. Other non-fluvial flooding sources such as key storm water balancing ponds within the Peterborough District were identified and general recommendations for the long-term management of Sustainable Drainage Systems (SUDS) are included within the report.

The SFRA evaluates the present-day (year 2005) situation and the situation for 50 years time (year 2055) with increased peak flood flows and sea level rise to allow for projected future climate change.

2.2 Technical Criteria

Section 3.1 summarises the specific approach and methodology employed in the SFRA. *Appendix 2* also includes the EA's general guidance to Local Planning Authorities for undertaking strategic assessment of flood risk and this gives further technical information on various aspects of the SFRA. Technical data such as chainage maps, water levels, defence freeboards and breach parameters are included in *Appendix 4*.

2.3 Data Sources

Section 3.3 fully describes the data that was considered in the assessment. *Figure 2* also graphically illustrates the extent of data that was made available for the study. In summary, the key sources of data include:

- EA publications and archive reports;
- Relevant reports and studies by consultants;
- Modelling and topography survey/terrain data;
- Flood extent data;
- Flood defence and other key assets information, including condition survey reports;
- Local knowledge and historical flooding information; and
- Land usage and planning policy documents and reports on RSSs for East of England (RSS).

A project data register is compiled and included in *Appendix 5*.

3 STRATEGIC FLOOD RISK ASSESSMENT

3.1 Approach and methodology

The general approach to the SFRA took account of the issues raised in PPG25. In addition, the topics set out in Section 3.0 of the EA's guidance notes, Strategic Assessment of Flood Risk, Guidance for Local Planning Authorities Issue 4 (b) and the criteria set out in Council's Consultants Brief were taken as a general guide to the SFRA.

A key aspect of the assessment was to consider the actual flood risk to the land at a strategic level by giving consideration to the existing flood defences and other raised features within the District.

Figure 2 shows the principal sources of fluvial flooding that were considered, which included:

Main River Systems:

1) The Environment Agency Main Rivers (including former Critical Ordinary Watercourses):

- River Nene
- Tributaries of River Nene
  - Billing Brook
  - Castor Splash
  - Orton Dyke
  - Fletton Spring
  - Stanground Lode
  - Padholme Drain
  - Morton's Leam
  - Thorpe Meadows
- River Welland
- Main tributaries of River Welland
  - Maxey Cut
- Peterborough Brooks
  - Folley River
  - Car Dyke
  - Brook Drain
  - Werrington Brook
  - Paston Brook (Including St Paul's Road)
  - Marholm Brook

2) Internal Drainage Board (IDB) systems:

- North Level IDB Drains
- Welland and Deepings IDB Drains

As agreed with the Council and the EA, the actual risk was considered in further detail to selected parts of the District where sufficient data was already available for the SFRA or where land has been currently identified for future development as part of the existing land allocations or East of England growth areas. *Section 3.5* and accompanying SFRA maps indicate the rivers modelled in detail as part of the SFRA.

It should be noted that all Critical Ordinary Watercourses (COWs) within the study area were reclassified as Main Rivers under the responsibility of the EA as of 1st April 2005. This change applied to Thorpe Meadows, Marholm Brook and Saint Paul's Road (Paston Brook).

3.2 Causes of Flooding

The main causes of flooding within the District include:

- Overflow of watercourses and existing flood defences including water retention facilities such as flood storage reservoirs/ washlands and storm water balancing ponds;
- Breaching of existing flood defences;
- Mechanical, structural or operational failure (including due to blockages) of existing hydraulic structures, pumps etc.; and
- Localised surface water flooding (including overland flooding).

3.3 Data Collection and Review

3.3.1 National Flood Zones

Flood Zone data (June 2005) was obtained from the EA for the study area. National Flood Zones for fluvial flooding come from the Extreme Flood Outline (EFO) produced by JBA Consulting Ltd. They show the 1.0% annual probability exceedence (1 in 100 year return period) and 0.1% annual probability exceedence (1 in 1000 year return period) for all watercourses with a catchment area greater than 3km^2 in the UK. It uses a modelling technique called J-Flow to derive flood extents based on Flood Estimation Handbook (FEH) derived hydrology and a 2-dimensional flow spreading algorithm. The automated mapping process relies on the SAR (Synthetic Aperture Radar) Digital Terrain Model (DTM) created from the SAR survey undertaken by Intermap for the whole of Great Britain. These Flood Zones take no account of defences as all man-made features have been removed from the SAR DTM. Historical flooding, if on Main River and where known and mapped, was included in the extent of the EFO for 0.1% exceedence event.

3.3.2 Historical Flooding

Figure 2 and *Table 3* summarise the details of historic flooding within the Peterborough District.

Information about historical flooding was obtained from the EA. As indicated in *Figure 2*, the largest known flood outlines within the District were derived from the EA's digital flood extents for the events of Easter 1998 and March 1947 where records already exist.

Some additional local flooding information was also available under different formats (flood maps, reports, recorded flood levels, flood damage analysis, etc.) although the EA's historic flood extent shown in *Figure 2* excludes these additional flooding records.

Table 3 Historic Flooding Records

Location	Date	Source of flooding	Properties affected	Comments
Peterborough	1947	River Nene		Estimated return period between 1:100yrs and 1:150 yrs (Peter Bye Report)
Woodcroft Castle Village (North East of Peterborough)	1986	Tributaries of Brook Drain		Flooding due to intense rainfall and high water levels in Brook Drain backing up the tributaries
Local areas along Werrington Brook	1986	Werrington Brook	Gardens, roads and areas of hardstanding along the Werrington Brook	Return period estimated of approximately 1:5 yrs event (Peterborough Brooks Reports)
Corfe Avenue, Rockingham Grove and Cisbury Ring (South of Werrington)	1997	Surface Water Sewers		Flooding due to high water levels in Werrington Brook causing sewers to back up (Peterborough Brooks Reports)
Merlin Business Park (East of Peterborough)	1997	Unnamed tributary u/s of confluence with Marholm Brook, Marholm Brook itself and surface water sewers	Industrial units and vacant land adjacent to confluence with Brook Drain	Flooding due to Marholm Brook overtopping its banks Return Period estimated to be just over a 1:50yr event (Peterborough Brooks Reports)
Thorpe Meadows	1998	Thorpe Meadows (former COW) and River Nene	100 properties (inc offices d/s of Town Bridge)	Estimated return period of event > 1:150 yrs (Peter Bye Report)
Warley Road and adjacent to Town Bridge	1998	River Nene	9 residential and 9 commercial properties	Estimated return period of event > 1:150 yrs (Peter Bye Report)
Merlin Business Park (East of Peterborough)	1998	Unnamed tributary u/s of confluence with Marholm Brook	Lloyds Bank Computer Centre	Total of 9 commercial properties were affected. (Peterborough Brooks Reports)
Waterworks Lane Glinton Woodcroft	1998	Brook Drain and IDB Drains		Localised overtopping of banks due to high water levels in Brook Drain backing up the tributaries (according to IDB)
Stirling Way Industrial Estate	1998	Werrington Brook		Flow occurred over the sidewalls (Peterborough Brooks Reports)
Ashton Village (North East of Peterborough)		Highway drainage system and IDB drains	Highway only (no records of property flooding)	Frequent flooding of highway following heavy rainfall according to IDB.

Important

This table does not include all historic flooding events and should not be used as a confirmation that flood risk does not exist in areas not detailed in the table.

3.3.3 Topographical Data

LiDAR (Light Detection And Ranging) and SAR data within the District were obtained from the EA. However, LiDAR was only available for certain parts and *Figure 2* shows the available coverage for this SFRA.

The LiDAR spatial resolution in this area is 2m. Taken together with the generally accepted vertical accuracy of ±11cm to 25cm, this indicates that in the areas covered by the LiDAR data would provide a good representation of ground surface for the required flood risk mapping where modifications to the current Flood Zones are required.

The vertical accuracy of SAR data quoted by the suppliers, Intermap, for the Anglian Region is ± 0.5m for the Surface Model and ±0.7m for the DTM at a positional accuracy of up to ±1.25m. SAR data is provided at a spatial resolution of 5m.

3.3.4 Existing Studies, Fluvial Defences and other Key Assets

Table 4 lists, per watercourse, the relevant reports/drawings that were obtained for the SFRA from the EA, the Council and IDBs. *Figure 2* shows these watercourses. In addition, Flood Zones were available for all watercourses that have a catchment area greater than $3km^2$.

Raised defences are particularly important to address the issue of "rapid inundation" as recommended in PPG25 Clause 69. Flood defence assets from the National Flood and Coastal Defence Database (NFCDD) were supplied by the EA and these included the location and the length of any raised defences. Defence heights were partially available from the NFCDD.

The locations of the hydraulic structures operated by the EA were supplied, although no information regarding the operational standard was given. *Figure 3* shows the key hydraulic structures within the Peterborough District.

Table 4 Existing studies within Peterborough District

Watercourse	Reach covered	Data source	Type of data	Comments
1 River Nene	Whole River Nene from Daventry to the Wash	2004 The River Nene Model Volume 1 Design Model	• ISIS model results • FEH hydrology	+20% inflow sensitivity test modelled according to PPG 25
	Peterborough Study Area	Peterborough Flood Alleviation Scheme Pre-Feasibility Report	• Recorded 1998 event levels • ISIS modelling • SoP assessment • Option costing & identification	
	Whole catchment	EA's Flood Map Data	• ArcView digital shape file for 1947/1998 flood events	
	Dog-in-a-Doublet PS	North Level IDB	• History of PS and pumping capacities • New PS capacity of 5.8 cumecs with a catchment of 2,484Ha	Information limited to pumping stations.

Watercourse	Reach covered	Data source	Type of data	Comments
	Whole IDB catchment	North Level IDB	• Catchment Plan	Details of pumped catchment
1.1 Padholme Drain	Whole catchment: Padholme Drain Adderley Drain Racecourse Drain Catswater Drain Willow Hall Drain Edgerley Road Drain Parish Dyke No 36	Padholme Catchment – Flood Protection Strategy	• History of flooding • SoP • Topographic survey • Improvement options • InfoWorks CS hydraulic and hydrological modelling inc surface water sewers	No reported flooding in the catchment although development anticipated to increase flows into Padholme Drain
	Padholme catchment	Flood Risk Assessment in the Padholme Catchment	• Guidance for Developers	Report as an Initial Draft only (at the time of writing this report)
	Padholme PS and Surface Water Storage Reservoir	North Level IDB	• Surface water storage reservoir constructed to reduce flows from 5.7 cumecs to 2.0 cumecs using Padholme PS into River Nene	No information included about the other drains within the study area.
	Whole length	Peterborough Flood Alleviation Scheme, Pre Feasibility Study	• Modelled 1:200 yr water level • Estimated defence levels and existing SoPs from LiDAR data	
	Padholme Catchment	"Padholme Catchment Flood Protection Strategy - Hydraulic Modelling" report	• Locations of predicted Anglian Water sewer flooding, • Flood depths and flood volumes.	Flooding related to the Anglian Water sewer system was not mapped through the current SFRA as this aspect was not studied within the whole of Peterborough District
1.2 Stanground Lode	Whole length	Peterborough Flood Alleviation Scheme, Pre Feasibility Study	• Recorded 1998 flood event levels • ISIS modelling • Modelled return period flows	
	Whole catchment	Hampton Surface Water Strategy	• ISIS modelling • FEH hydrology • Modelled flood levels and discharge rates • Balancing ponds details (i.e. locations, volumes, design methods etc.)	
	Whole catchment (hydrology) and specific details for IKEA Development and area downstream	Flood Risk Assessment for IKEA Development	• ISIS modelling • FEH hydrology • Modelled flood levels/ flows • Flood mitigation measures (improvements to Fletton Lake, balancing lakes etc.)	

Watercourse	Reach covered	Data source	Type of data	Comments
1.3 Fletton Spring	Whole catchment	Flood Defence SoP – Fletton Spring in Peterborough	• ISIS modelling – steady state • FEH hydrology • Revised FRA Maps • Modelled flood levels/ flows for various return periods • Existing and Indicative SoPs revised	• Used survey data obtained between 1972 and 1981 in conjunction with survey done for project in 2000. • No formal raised flood defences
1.4 Thorpe Meadows (former COW)	Whole length	Survey Data (Ratcliff Land and Engineering Surveys, 1998)	• Cross-sections and details of structures	
2. River Welland	Tixover to The Wash	1992 Mott MacDonald Welland / Glen River Model Report and model results	• FSR Hydrology • LORIS/ SALMON-F model • Modelled water levels for various return period	• Water levels available only for downstream of Tallington weir (Limited river cross-sections were made available for the stretch between Uffington and Tallington and for the Crowland Wash as part of ongoing modelling by the EA) • No information on formal raised flood defences other than digital modelled cross-section data
	Tallington Gauge to d/s Marsh Road Sluice Gate	A1073 Spalding to Eye Improvement Scheme FRA	• FEH hydrology and pooling group • MIKE11 Hydraulic modelling • Peak flows for various return periods	• Model adapted from the Anglian Flow Forecasting Modelling System. Original files from EA. • +20% inflow sensitivity test modelled according to PPG 25
2.1 Maxey Cut	Whole catchment	1992 Mott MacDonald Welland/ Glen River Model Report and model results	• FSR Hydrology • LORIS/ SALMON-F model • Modelled water levels for various return period	
		Peterborough Brooks Flood Investigation Preliminary Study	• Cross-sections	
2.2 Folley River	Whole catchment	Peterborough Brooks Flood Investigation Preliminary Study	• Topographic survey data available • History of flooding • FSR hydrology • ISIS modelling • SoP assessment • Existing defences	

Watercourse	Reach covered	Data source	Type of data	Comments
			• Predicted water levels • Cross-sections	
2.3 Car Dyke	Whole length	Peterborough Brooks Flood Investigation Preliminary Study	• Topographic survey data available • History of flooding • FSR hydrology • ISIS modelling • SoP assessment • Existing defences • Predicted water levels • Cross-sections and long sections	
	Length local to scheme	A1073 Spalding to Eye Improvement Scheme FRA	• Flood map for 1:100yr event • Channel survey data • FEH Hydrology • MIKE11 hydrodynamic modelling and sensitivity testing • Modelled water levels at various culverts • Defences SoP > 1:100 yrs	
	Length local to scheme	Manor Drive, Paston Reserve, Peterborough Preliminary FRA	• Topographic survey data available • FEH rainfall runoff • Modelled flood levels • Storm water storage • No history of flooding • Site specific preliminary FRA	
2.4 Brook Drain	Whole length	Peterborough Brooks Flood Investigation Preliminary Study	• Topographic survey data available • History of flooding • FSR hydrology • ISIS modelling • SoP assessment • Existing defences • Predicted water levels • Cross-sections and long-sections	
	Whole length	Peterborough Brooks Flood Investigation – Stirling Way Industrial Estate Feasibility Study	• History of flooding inc flood levels • Refinement of hydraulic modelling from Prelim Study	Follows on from the Preliminary Study (as above)

Watercourse	Reach covered	Data source	Type of data	Comments
	Area local to Stirling Way, Bretton	Stirling Way, Peterborough Flood Risk Assessment	• Refinement of ISIS modelling from Peterborough Brooks Reports (PBR) • FEH hydrology – estimates significantly lower than FSR estimates from PBR • Appraisal of flood control options identified in PBR	Modelling included maximum flows and water levels for each of the options using the FEH hydrology estimates.
2.5 Werrington Brook	Whole length	Peterborough Brooks Flood Investigation Preliminary Study	• Topographic survey data available • History of flooding • FSR hydrology • ISIS modelling • SoP assessment • Existing defences • Predicted water levels • Cross-sections and long sections	
	Whole length	Peterborough Brooks Flood Investigation – Stirling Way Industrial Estate Feasibility Study	• History of flooding inc flood levels • Refinement of hydraulic modelling from Preliminary Study	Follows on from the Preliminary Study (as above)
	Area local to Stirling Way, Bretton	Stirling Way, Peterborough Flood Risk Assessment	• Refinement of ISIS modelling from Peterborough Brooks Reports (PBR) • FEH hydrology – estimates significantly lower than FSR estimates from PBR • Appraisal of flood control options identified in PBR	Modelling included maximum flows and water levels for each of the options using the FEH hydrology estimates.
2.6 Paston Brook	Whole length	Peterborough Brooks Flood Investigation Preliminary Study	• Topographic survey data available • History of flooding • FSR hydrology • ISIS modelling • SoP assessment • Existing defences • Predicted water levels • Typical cross-section of Paston Brook at Saint Paul's Road	
	Whole length	Peterborough Brooks Flood Investigation – Stirling Way Industrial Estate Feasibility Study	• History of flooding inc flood levels • Refinement of hydraulic modelling from Prelim Study	Follows on from the Preliminary Study (as above)

2.7 Marholm Brook (Former COW)	Area local to Stirling Way, Bretton	Peterborough Brooks Flood Investigation – Stirling Way Industrial Estate Feasibility Study	• Inclusion into the hydrological and hydraulic modelling done for PBR Prelim Study • Modelled flood water levels for each option identified for Stirling Way • Cross-sections	
	Area local to Stirling Way, Bretton	Stirling Way, Peterborough Flood Risk Assessment	• Refinement of ISIS modelling from Peterborough Brooks Reports (PBR) • FEH hydrology – estimates significantly lower than FSR estimates from PBR • Appraisal of flood control options identified in PBR	Modelling included maximum flows and water levels for each of the options using the FEH hydrology estimates.
3. Welland and Deepings IDB System	Limited coverage	Welland and Deepings IDB	• Maps showing locations of drains and pumping station • Cross-sections of main drains • Spot levels	
4. North Level IDB System	Limited coverage	North Level IDB	• Maps showing locations of drains, pumping stations • Cross-sections of main drains • Spot levels • GIS data covering main drains, pumping stations and sub-catchments	
	Dog-in-a-Doublet Catchment	Conclusions from the Dog-in-a-Doublet Catchment Hydraulic Modelling Report made available by North Level IDB	• Indications on the standards of defence in the Dog-in-a-Doublet catchment	
5. Parish Dykes/ Community Related Asset (CRA) Ditches/ Ordinary Watercourses	Parish Dykes/ CRA Ditches/ Ordinary Watercourses	Parish Dykes and CRA Ditch Plans and Ordinary Watercourse Flood Defence Condition Assessment	• Maps showing locations of Parish Dykes and CRA Ditches • Status and lengths of CRA ditches, maintenance schedule • Condition survey reports for flood defences on Ordinary Watercourses	No cross section information available within the reports
6. Sustainable Drainage Systems (SUDS)	Whole study area	Council's Ordinary Watercourse Flood Defence Condition Assessment	• Photos and conditions of structures, defences and attenuation ponds	No digital outlines of the locations of SUDS available

Not all of the collated data given in *Table 4* was suitable for the SFRA and therefore only relevant information was used in the study following appropriate quality checks. *Figure 2* maps most of the information listed above and illustrates the suitable modelled river extents.

Section 6 reports the conclusions of modelling, the limitations of the models used for the SFRA and the recommendations for future enhancements.

The EA advised Royal Haskoning during the study that new modelling for the River Welland (including Peterborough Brooks) is currently planned using MIKE 11 software. The modelling (including surveying) will be undertaken in two phases where Phase 1 and Phase 2 will include modelling of main River Welland / Glen system and the main tributaries (e.g. Peterborough Brooks) respectively. Modelling results from this study were not available for the SFRA although relevant survey information from Phase 1 was supplied by the EA through their modelling consultant Mott MacDonald.

In contrast to the watercourses listed in *Section 3.1*, *Table 4* also highlights the fact that the existing studies do not cover all watercourses. The EA's Main rivers within the study area without any previous studies other than the historic flooding envelope and the Flood Zones are listed here below:

- Orton Dyke;
- Castor Splash; and
- Billing Brook.

In addition, modelling data was not generally available for the former COWs and the IDB watercourses. According to the North Level IDB, the Dog-in-a-Doublet catchment has been recently modelled by JBA Consulting Ltd. and the IDB has confirmed that improvements to this catchment will ensure a standard of 1 in 100 year return period although this catchment may be at some risk of flooding if climate change impacts are to be considered. The works will be completed within the next six months and therefore it was agreed with the EA and the Council that the SFRA should proceed on the basis that the works were complete.

3.3.5 Non-Fluvial Drainage

Previously known storm water flooding records were obtained from Anglian Water although the storm water drainage systems were not assessed in detail as part of the SFRA. According to Anglian Water records (*see Table 5*), it can be seen that there have been only a few recorded flooding incidents within the Peterborough District. Recommendations for further consideration with regard to this aspect under RSS for East of England are included in *Section 6* of this report.

The key surface water balancing facilities within the Peterborough District were identified and presented in *Figure 2*. General long-term management of these features and other SUDS were briefly reviewed and recommendations are included in *Section 6*.

Table 5 Reported non-fluvial flooding incidents (Source: Anglian Water 2005)

Location	Details of flooding
Splash Lane, Castor	External flooding, no indication on storm sewer or foul sewer flooding
King Street, West Deeping	Internal foul sewer flooding
Park Road, Peterborough City	Internal foul sewer flooding

3.3.6 Projected Development and Identified Land

The Peterborough Local Plan (First Replacement, adopted 2005) and the planning documents available from the Council's website (1995 Local Plan and subsequent documents) were reviewed to identify the currently allocated development land within the District.

Growth areas and general policies were also reviewed from the draft Regional Spatial Strategy Report for the East of England. Attention was mainly focused on Housing and Employment Land uses as these are areas which are defined in the Development Plan. The reviewed documents include:

- Peterborough and the Fens Sub-Regional Study - Key Issues Report, East of England Regional Assembly (September 2003);
- Peterborough Sub-Regional Study - Final Report, East of England Regional Assembly (November 2003);
- Peterborough Growth Area Study - East of England Regional Assembly (August 2004);
- Draft Regional Spatial Strategy/East of England Plan - Revision to Regional Spatial Strategy for East of England (December 2004);
- Peterborough Local Plan (First Replacement) (adopted 2005);
- Cambridgeshire and Peterborough Structure Plan 2003; and
- Regional Spatial Strategy for the East Midlands (March 2005).

It is acknowledged that the Cambridge and Peterborough Joint Structure Plan (2003) states that an approximate provision of 12,800 dwellings in Peterborough and 5,200 dwellings in the Hampton area with a potential 2,000 extra should be made available between 1999 and 2016. A resolution was passed to grant planning permission for an additional 1,700 dwellings at Hampton Leys in 2003, making total permissions 6,900 in the Hampton area. Further information obtained from the RSS for the East of England Plan shows that the total capacity of dwellings for Peterborough between 2001 and 2021 is 21,200. The total number of completed dwellings in the Hampton area (as of March 2004) was 1,430. *Table* 6 gives a breakdown of how proposed levels of growth might be accommodated in the Peterborough District.

Table 6 Anticipated levels of growth within the Peterborough District (Source: Peterborough City Council, July 2005)

Capacity at 31 March 2005	
Dwellings Constructed (1st April 2001 – March 2005)	**2,832**
Identified Capacity – Permissions & Allocations	
Dwellings to be completed on sites under construction excluding Hampton	793
Dwellings on sites with full planning permission where construction had not started excluding Hampton	702
Sites with outline planning permission excluding Hampton	760
Peterborough Local Plan Fisrt Replacement allocated site without permission	5,422
Dwellings to be completed on sites under construction at Hampton	397
Land at Hampton with full permission where construction has not yet started	318
Land at Hampton with outline permission (see Note 1 overleaf)	2,675
Additional capacity at Hampton identified in Cambridgeshire and Peterborough – Structure Plan 2003	2,000
Total identified capacity	**13.067**
Non-Estate Contribution Allowance	1,296
Current Capacity, 2001-2005	**17,195**
Needs	
Current Regional Spatial Strategy (to 2021)	
Requirement	21,200
Capacity Shortfall - homes	4,005

Notes:

1 – This figure refers to the residual from the original planning consent for 5,200 dwellings at Hampton. It does not include the additional 1,700 dwellings identified which the Council resolved to grant outline planning permission in 2003.

According to the advice received from the Council, the Greater Peterborough Sub-Regional Study prepared by Llellwyn Davies (available on the East of England Regional Assembly web-site) has looked at the capacity for additional development up to 2021 as well as the broad geographical direction this could take. In addition, a number of case study areas have been explored. The potential development areas include the following and are shown in *Figure 5*.

A. The south-western area of the City between the current Hampton development and the A1(M);
B. North/ north west of Werrington, south of the village of Glinton;
C. West of Bretton around the urban edge towards the village of Marholm;
D. North east of Stanground;
E. The area between Parnwell in Peterborough and towards the villages of Eye and Eye Green; and
F. East of Padholme Eastern Industry.

Section 5 of this SFRA report discusses the development issues related to currently allocated local plan sites and future growth area sites as part of RSS for the East of England. The key issues with the proposed development in terms of flood risk management including the concept of integrated water cycle management are further discussed in *Section 6*.

3.4 SFRA Inception (Stage 1) Report

The SFRA Inception report was produced by Royal Haskoning in June 2005 to report the findings of the data collection and review, together with the methodology proposed for the stage 2 assessment. This report was issued to the Council, the EA and IDBs for their comment and agreement. The methodology developed is further described in *Section 3.5* of this report.

The key points of the Inception report are summarised below:

It was concluded that there was sufficient information in terms of quantity and quality to proceed to the Stage 2 assessment whilst meeting the Council's programme. However, it was envisaged that further studies would be needed by the Council and developers to supplement the results of this SFRA in order to facilitate future development within the Peterborough District.

With respect to the ground surface data required for mapping, it was determined that LiDAR does not cover most areas of interest for the study including significant urbanised areas and the entire River Welland floodplain. In these areas, SAR data would be used as best available information for the SFRA.

The outputs from recent modelling studies carried out for the EA and the Council would be assessed to provide the basis for flood extent mapping. The 1 in 1000 year return period flood extent for Zone 2 for watercourses would be determined mainly from the EA's currently published EFO unless suitable water levels could be found from the previous studies.

For all former COWs and the relevant reaches of unmodelled Main river tributaries, proposals were put forward for evaluating the suitability of existing Flood Zones by using currently available survey data and further limited site survey and inspections, together with simple modelling techniques.

3.5 Stage 2 Strategic Assessment of Flood Risk

3.5.1 Overview

Section 3.1 above already described the general approach and methodology employed in the SFRA. In addition, at the strategic level a number of issues were considered including:

- Records of past flood events, including depth of flooding if available;
- Identification of factors affecting flood risk, including climate change;
- Flood warning and evacuation procedures;
- Responsibilities of long term maintenance of Sustainable Drainage Systems (SUDS) features;
- Identification of areas at risk from flooding, including an assessment of the key defences and responsibilities for maintenance and ownership; and

- Impact of flood risk both within the plan areas and downstream.

Following a review of the currently available documents regarding the planned development within the District, and in agreement with the EA and the Council, it was decided to focus the efforts of the SFRA to the areas where development pressure is high, where there are defences protecting existing settlements and where there are records of previous flooding. For these areas/watercourses, the existing Flood Zones were refined if needed and specific guidelines/references were included in the following sections for the attention of developers. In addition, where surface water runoff issues were identified due to the proposed developments, recommendations for further studies are given in *Section 6*. The existing Flood Zones were used where development pressure is currently low and historic flooding is not significant, but cautions are given as needed with regard to their use as a planning tool in the long term.

The SAR terrain data was used for the assessment and mapping where there was no LiDAR coverage.

Table 7 below summarises the methodology implemented per watercourse. All Main rivers and Non-Main rivers within the study area not mentioned in this table have been directly mapped using the latest Flood Zones. As the best available information to date, the direct use of Flood Zones for the SFRA flood risk categories was considered to be acceptable at some places especially where there were no raised flood defences or where the confidence limit of the other model outputs was judged to be low.

Wherever Flood Zones are used directly for the mapping of the SFRA flood risk categories:
- the 1 in 100 year and 1000 year return period Flood Zones are taken to represent the present day flood risk for the respective return period events, and
- the 1 in 1000 year return period Flood Zone also represents the 1 in 100 year flood risk in 2055 (to account for the potential effects of climate change).

In line with the Environment Agency's Guidance Issue 4b, breach analysis was carried out on the key raised defences that protect significant flood risk areas (generally > 1km^2). It was assumed that a breach develops to its full width as soon as the water level exceeds the defence crest. For adequately defended areas, it was assumed that a breach would occur coinciding with the flood peak provided that a breach scenario is plausible after examining the available defence data. In summary, breach analysis was carried out using an in-house breach program at the following areas:
- Along the River Nene, downstream of the A1139 Bridge – left bank
- Along the River Welland (downstream of Deeping Gate) – right bank
- Along the Maxey Cut – both banks
- Along the Car Dyke and Folley River – right bank

The nomenclature 'left' and 'right' bank is taken as viewed looking downstream in the direction of river flow.

When assessing defence standard, a freeboard was calculated following the guidance given in the EA's Technical Report W187 "Fluvial Freeboard Guidance Note". In general, a minimum of 600mm freeboard was allowed for all raised defences within the Peterborough District.

Following the methodology given in *Table 7*, flood risk was assessed at a strategic level for the present day (2005) and future scenario (2055). For the 1000 year return period, only the present day scenario was assessed and this flood risk category was determined mainly from the EA's latest Flood Zones unless suitable water levels could be found from new modelling or from the previous studies.

Section 3.5.2 describes the methodology adopted in the assessment in more detail. *Appendix 4* includes further technical information (e.g. chainage map, water levels, defence freeboard and breach parameters) for the modelled Main rivers and the figures showing the flood risk for the studied IDB drains.

Table 7 Strategic approach for flood risk mapping

Watercourse name	Need for improving Flood Zones?	Methodology
1 River Nene	Yes – Full length	• Map Halcrow's River Nene model and Peterborough pre-feasibility study outputs onto LiDAR/ SAR data; use any existing watercourse survey information for verification of levels if needed; replace current Flood Zones with new outlines. • Carry out breach analysis downstream of the A1139 Bridge (left bank) and replace Flood Zones with new outlines mapped with breach water levels.
1.1 Billing Brook	No	• Retain current Flood Zones as this watercourse is not subjected to any raised defences or proposed development sites.
1.2 Castor Splash	No	• Retain current Flood Zones as this watercourse is not subjected to any raised defences or proposed development sites. A site inspection and the historic flooding records also indicated that the Flood Zones are satisfactory for this watercourse.
1.3 Orton Dyke	Yes – Full length	• Road culverts / bridge inspections. • FEH hydrology, limited surveying to supplement LiDAR and limited modelling using HEC-RAS. • Map calculated water levels onto LiDAR. • Replace current Flood Zones with new outlines.
1.4 Fletton Spring	Yes – Full length	• Map Halcrow's Fletton Spring previous study outputs onto LiDAR data; use any existing watercourse survey information for verification of levels if needed. • Replace current Flood Zones with new outlines. • Recommend reviewing the results when the final results from the EA's current modelling study are officially published.
1.5 Stanground Lode	Yes – Full length	• Review PBA's results from Hampton Drainage Strategy with Halcrow's Peterborough pre-feasibility study/ River Nene modelling outputs for Stanground Lode. • Map Halcrow's modelled water levels from the River Nene/ Stanground model onto SAR/ LiDAR data; use any existing watercourse survey information for verification of levels if needed. • Replace current Flood Zones with new flood outlines.

Watercourse name	Need for improving Flood Zones?	Methodology
1.6 Padholme Drain	Yes – Full length	• Review Atkin's Padholme Catchment Flood Protection Strategy outputs and supplement current Flood Zones with new outlines if needed; use any existing watercourse survey information for verification of levels if needed.
1.7 Thorpe Meadows (former COW)	Yes – Full length	• Road culverts / bridge inspections. • FEH hydrology, limited surveying to supplement LiDAR and limited analysis using HEC-RAS. • Produce new flood outlines.
2. River Welland	Yes – Full Length	• Upstream of Stamford – retain current Flood Zones as this stretch of the river is not subjected to any raised defences or proposed development sites. • Stamford to Tallington – limited iSIS modelling between Uffington Park and Tallington by using flood flows from Mott MacDonald's River Welland study, existing river cross-sections and SAR data; Map modelled water levels onto SAR data and compare with Flood Zones; Retain Flood Zones where modelled extents reasonably agree with the modelled extents or where no better information can be found. • Tallington to eastern study limit – Map Mott MacDonald's modelled water levels using existing river cross-sections and SAR data and compare with Flood Zones; use any existing watercourse survey information for verification of levels if needed; Retain Flood Zones where modelled extents reasonably agree with the modelled extents. Carry out breach analysis where existing defences exists (e.g. downstream of Deeping Gate – right bank) and replace Flood Zones with new outlines mapped with breach water levels. • Recommend reviewing the results for the full length when the EA's current modelling for the entire River Welland / Glen system has been completed.
2.1 Maxey Cut	Yes – Full length	• Map Mott MacDonald's modelled water levels from River Welland study using existing river cross-sections and SAR data and compare with Flood Zones; use any existing watercourse survey information for verification of levels if needed. • Carry out breach analysis (both banks) and replace Flood Zones with new outlines mapped with breach water levels. • Recommend reviewing the results when the EA's current modelling study for Maxey Cut as part of the entire River Welland / Glen system has been completed.
2.2 Folley River	Yes – Full length	• Map modelled water levels derived from Binnie Black and Veatch's Peterborough Brooks Study using further iSIS modelling, existing river cross-sections and SAR data; compare risk areas with Flood Zones and replace with new outlines as needed. • Carry out breach analysis (right bank) and replace Flood Zones with new outlines mapped with breach water levels.

Watercourse name	Need for improving Flood Zones?	Methodology
		• Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.
2.3 Car Dyke	Yes – Full length	• Map modelled water levels derived from BBV's Peterborough Brooks Study using further iSIS modelling, existing river cross-sections and SAR data; compare risk areas with Flood Zones and replace with new outlines as needed. • Carry out breach analysis (right bank) and replace Flood Zones with new outlines mapped with breach water levels. • Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.
2.4 Brook Drain	Yes – Full length	• Map modelled water levels derived from BBV's Peterborough Brooks Study using further iSIS modelling, existing river cross-sections and SAR data; compare risk areas with Flood Zones and replace with new outlines as needed. • Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.
2.5 Werrington Brook	Yes – Full length	• Map modelled water levels derived from BBV's Peterborough Brooks Study using further iSIS modelling, existing river cross-sections and SAR data; compare risk areas with Flood Zones and replace with new outlines as needed. • Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.
2.6 Paston Brook	Yes – Full length	• Map modelled water levels derived from BBV's Peterborough Brooks Study using further iSIS modelling, existing river cross-sections and SAR data; compare risk areas with Flood Zones and replace with new outlines as needed. • Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.
2.7 Marholm Brook (Former COW)	Yes – Full length	• Road culverts / bridge inspections and limited surveying as needed. • Compare modelled water levels from Peterborough Brooks Study (including Stirling Way Industrial Estate Study) and English Partnerships' FRA for Stirling Way in Bretton. • Map relevant water levels using SAR data and existing local topographical survey etc.; compare risk areas with Flood Zones and replace with new outlines as needed. • Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.

Watercourse name	Need for improving Flood Zones?	Methodology
2.8 Paston Brook- St Paul's Road (Former COW)	Yes – Full length	• Road culverts/ bridge inspections. • FEH hydrology, limited surveying to supplement SAR data and existing watercourse survey; limited analysis using iSIS and map modelled water levels onto SAR data to produce new flood outlines. • Recommend reviewing the results when the EA's planned modelling study for the Peterborough Brooks as part of the entire River Welland/ Glen system has been completed.
3. Welland and Deeping IDB Drains	Yes – main drains (within proposed development areas or locations with known flooding problems)	• For the IDB drains outside EA Main River flooding extents (i.e. not directly connected), assume 1in 100 year flood protection in accordance with the IDB policy statements and consultation carried out during the study. This standard will also be maintained when considering the effects of climate change on flood extents. • For the IDB drains that are specifically studied as part of the SFRA, assume 100 year standard (for the present day situation) without freeboard; assess flood risk for 1 in 100 year (with climate change) and 1000 year (present day situation) to the pumped and gravity fed drains within the Peterborough District. Use any available design water levels/ freeboard and watercourse survey information from the IDB and LiDAR/ SAR data for the assessment and mapping. Include supplementary figures within the SFRA report to present the estimated flood risk to the studied IDB drains.
4. North Level IDB Drains	Yes – main drains (within proposed development areas or locations with known flooding problems)	• For the IDB drains outside EA Main River flooding extents (i.e. not directly connected), assume 1in 100 year flood protection in accordance with the IDB policy statements and consultation carried out during the study. This standard will also be maintained when considering the effects of climate change on flood extents. • Dog-in- a- Doublet pumped catchment: Assume 1 in 100 year standard for the present day situation (no freeboard); assess the risk for 1 in 100 year with climate change allowance and 1 in 1000 year (present day situation) for the drains affected by the proposed development. Use any available design water levels/ freeboard and watercourse survey information from the IDB and LiDAR/ SAR data for the assessment and mapping. Include supplementary figures within the SFRA report to demonstrate the estimated flood risk to the studied IDB drains within the Dog- in - a- Doublet catchment.

The small part of the Middle Level IDB catchment south of Morton's Leam was not studied in detail as part of the SFRA and if any development is proposed in this area then flood risk from the IDB system needs to be investigated. *Figure 6* shows the IDB boundaries within the Peterborough District.

3.5.2 Detailed methodology

3.5.2.1 River Nene

The mapping process also took into account raised defences as shown in the NFCDD database and other raised structures as picked up by modelled cross-sections, LiDAR data and site inspections.

Halcrow's River Nene Model (Version 1) results were made available by the EA in GIS format. These included water levels and flows modelled for the 1 in 100 year and 1 in 1000 year return period events for present day and future scenarios with a 20% increase in the inflows and sea level rise to cater for the possible effect of climate change. The influence of sea level rise due to possible climate change is likely to have minimal impact on flood risk within the Peterborough District. The River Nene is subject to some tidal influence up to the Dog – in – a – Doublet sluice where the tide can be controlled by the operation of this sluice if needed. The entire River Nene and its main tributaries were modelled as part of the River Nene Model by taking into consideration the effect of existing defences.

In general, the SFRA flood risk categories for the 1 in 100 year and 1 in 1000 year return periods were mapped by projecting modelled water levels horizontally over the floodplain. This approach was used to map all flood risk categories upstream of the A1139 Bridge.

Using an in-house breach program, breach analysis was carried out on the raised defences that protect large areas of low lying land on the left bank of the River Nene downstream of the A1139 Bridge. Analysis was undertaken for the 100 year event (with and without climate change) and 1000 year (without climate change). It was taken that a breach failure could occur, although it would be repaired sufficiently to stop further flooding within a finite time based on the guidance given in EA's guidance note 4b for local authorities.

Details of the breach parameters and the average peak water levels are given in *Appendix 4*. The analysis demonstrated that highest peak water levels within flood compartments are resulting from breaching of the defences upstream of the Dog – in – a – Doublet sluice where the river is dominated from fluvial flooding. Breach base levels were estimated using the cross-sections extracted from LiDAR data. Compartments and boundary levels were derived from a combination of SAR and LiDAR data. Flow and level hydrographs were extracted from the River Nene iSIS model supplied by the EA at the request of Royal Haskoning. When mapping the flood risk categories using the calculated average peak water levels within the compartments flow routes were added as appropriate to give realistic flood extents.

A minimum freeboard of 600mm was generally allowed for all raised defences when assessing their effectiveness against the estimated water levels for 1 in 100 year return period (flood risk category 3). If the freeboard was less than 600mm then the risk area behind was classified as "undefended". Conversely, if the freeboard was greater than

600mm then the risk area was classified as "defended". The accompanying SFRA maps show the defended and undefended areas within the flood risk category 3 (for the present day situation without climate change).

3.5.2.2 Orton Dyke

As part of this SFRA, Orton Dyke was modelled using a steady state HEC-RAS model. The model covers 1.26km of Orton Dyke, from upstream of the A1139 culvert to the River Nene floodplain.

The hydrology was derived using the FEH rainfall-runoff method. The inflows for the 100 year return period with climate change were obtained adding a 20% increase on the 100 year return period inflows. The downstream boundary condition was taken using water levels from the River Nene iSIS model for coincident return periods. In reality, the joint probability of a 100 year event occurring at the same time for the River Nene and for Orton Dyke is lower than 1% annual probability (greater than 100 year return period) and therefore SFRA outputs represent a potential worst case scenario adopting a precautionary approach.

LiDAR data was used to extract cross-sections. A site visit was then made to take measurements of the modelled structures and to verify the LiDAR data.

Mapping of the flood risk categories for 100 year and 1000 year events has been undertaken by horizontal projection of the water levels onto the LiDAR derived ground surface.

3.5.2.3 Fletton Spring

In June 2000, Halcrow submitted to the EA the "Flood Defence Standard of Protection" for Fletton Spring. This study used a steady state iSIS model that covered the stretch from Belsize Avenue (near the Recreation Playground) to the confluence with Stanground Lode. The hydrology was derived using an approach based on the FEH. Halcrow carried out a survey that provided the model cross-sections. The study only provided results for the 100 year return period. However, following the mapping of the 100 year return period water levels, it appeared that the water levels in the upstream part of the model, near the Recreation Ground, were too high and not realistic.

The Halcrow "Fletton Spring Pre-Feasibility Draft Report" was later released during the course of this SFRA in June 2005. The draft report was made available to Royal Haskoning by the EA. A similar approach to that used in the June 2000 study has been adopted by Halcrow. The hydraulic model and hydrology have been improved and the results provided in this report were used for the mapping. The 100 year return period water levels were directly available from the report and water levels for the other return periods for SFRA mapping were estimated using logarithmic extrapolation.

Mapping of the flood risk categories for 100 year and 1000 year events has been undertaken by horizontal projection of the water levels onto the LiDAR derived ground surface.

3.5.2.4 Stanground Lode

Water levels for Stanground Lode were available from two sources:

- Results from Halcrow's River Nene Model (Version 4), that included results for Stanground Lode;
- Results from the "Hampton Peterborough Strategic Flood Risk Study (June 2002)" carried out by Peter Brett Associates. As part of this study, Peter Brett Associates modelled Stanground Lode using a hydrodynamic iSIS model.

Water levels from both sources were briefly reviewed although PBA results were only available at a few selected locations limiting this comparison and mapping. From this initial review, it appeared that the results were significantly different in places, the River Nene Model generally giving higher results than PBA's earlier model of the Stanground Lode. It was then decided to produce the SFRA maps based on Halcrow's latest model results as this forms the EA's strategic model for the River Nene giving a consistent approach to the study. It was recognised that PBA's model results come from a more site specific analysis and potentially could be more accurate than Halcrow results. However, for strategic planning purpose, using the higher water levels derived from the recent EA's River Nene model was considered to be acceptable as a precautionary approach. The main Hampton development area is not at risk of flooding from the Stanground Lode for the 1 in 100 year return period with climate change consideration.

Mapping of the flood risk categories for 100 year and 1000 year events has been undertaken by horizontal projection of the water levels onto the SAR derived ground surface except for the downstream reaches of the Stanground Lode where LiDAR data was available for mapping.

3.5.2.5 Padholme Drain

Atkins modelled the Padholme catchment as part of a study commissioned by the Council. This catchment is a mixture of urban and rural areas covering a total area of approximately $6km^2$ and is located on the eastern boundary of Peterborough. The Council and the English Partnerships have developed a strategy for mitigating flood risk that aims to provide appropriate flood defence standards to the catchment, enabling proposed development (as detailed in the Peterborough Local Plan 1st Replacement) to be undertaken.

Atkins have produced the following reports:

- Padholme Catchment Flood Protection Strategy – Hydraulic Modelling Report (Final), October 2004
- Padholme Catchment Flood Protection Strategy – Implementation Plan (Final), September 2004

Padholme Drain and the pumping station are maintained by the EA, whilst Adderley Drain is the responsibility of the North Level IDB. The adopted surface water sewer system is maintained by Anglian Water including the Catswater Drain. The remainder of the watercourses are generally under the responsibility of the Council.

The modelling was carried out using the InfoWorks CS package produced by Wallingford Software. The hydraulic model assesses the effects of proposed developments within the Padholme Catchment, on the performance of Padholme Drain and its tributaries. The model covers the piped network, inclusive of Anglian Water surface water system and the principal watercourses (e.g. Padholme Drain, Adderley Drain, Racecourse Drain, Edgerley Road Drain, Catswater Drain, Willow Hall Drain and Parish Dyke No. 36) down to Padholme Pumping Station. The modelled system can be seen from the figures included with the above reports prepared by Atkins.

Atkins model has allowed for 68.7ha of redeveloped land, made up of 9.5ha housing and 59.2ha of industrial usage. All proposed industrial areas were assumed high impermeability, with housing taken as medium impermeability to match the surrounding developments. No specific allowance had been made for infill development or extensions to the existing buildings.

The key findings of the Atkins study include:

- The urban areas of the catchment are not at risk from fluvial flooding for the 100 year event (2004);
- The current level of protection is just below 100 year return period event (2004) against fluvial flooding from open watercourses, resulting in localised flooding in rural areas;
- Future climate change is likely to reduce the current level of protection to 50 year return period by 2054;
- Proposed developments will further reduce the standard of protection due to increased amounts of surface runoff;
- Minor improvement works would provide significant benefits and remove the flood risk for the events up to and including 100 year return period; and
- The urban water collection system is not sufficient to collect and convey the flows expected in 100 year return period event, resulting in localised flooding.

Two critical storm durations had been considered in the assessment. The 60 minute storm was found to be critical for the upper reaches in the urban area and the 480 minute storm was critical for the main reaches in the rural part of the catchment. Some flooding was identified with both the urban and rural catchments; Atkins proposed certain mitigation measures to mitigate the predicted flooding. Atkins model indicated that the following key locations are currently at risk of flooding:

- Rural areas surrounding the Flag Fen site where the ground level is low; and
- Urban areas where the piped surface drainage system is not of capacity to accommodate the 100 year event.

It should be noted however that despite the area having significant rainfall events in 1998 and 2001, there are no recorded flooding incidents within the entire Padholme catchment.

The key elements of the proposed mitigation works to accommodate the planned development and the future climate change impacts include:

- Phase 1 – Reversal of the Adderly Drain to the North Level IDB's Dog – in – a Doublet pumped catchment

- Phase 2 – Creation of a high level overflow weir from the Padholme Drain into the Adderly Drain
- Phase 3 – Reprofiling of the Racecourse Drain to provide extra capacity, including the enlargement of culvert under Third Drove
- Phase 4 – Increasing online storage by widening, reprofiling and desilting of the Padholme Drain
- Phase 5 – Improving Padholme Pumping Station by installing standby diesel generators or pumps
- Phase 6 – Improving Catswater Drain

Subsequent to the publication of Padholme Catchment Flood Protection Strategy – Implementation Plan in September 2004, Atkins have agreed with the Council that reprofiling of the Racecourse Drain (i.e. Phase 3) is no longer required due to the minimal benefits compared with the cost of carrying out any meaningful work.

Phases 5 and 6 will only be implemented if desired after further studies and consultations. Once the Phases 1 to 4 are completed, then the works will ensure 1 in 100 standard within the catchment (allowing for the planned development and climate change impacts) except for the flooding at the Anglian Water sewer network which has a standard of approximately 1 in 30 years. The proposed solutions will not remove the flood risk from the Anglian Water system as provision of 1 in 100 year standard is not standard practice for any of the utility companies.

Phase 1 of the works has been completed at the time of writing this report and the remaining works will be carried out in the summer 2006. During this SFRA, Atkins have confirmed that the completion of Phase 1 works will give a standard of 1 in 100 year (allowing for climate change) within the existing catchment if the planned development stipulated in the current local plan is not considered. Therefore, the SFRA maps do not show any flooding for 1 in 100 year return period directly from the Padholme Drain. For 1000 year return period this catchment may also be subjected to the flood risk from the River Nene. Flooding related to the Anglian Water sewer system was not mapped within the SFRA maps as this aspect was not studied within the whole of Peterborough District. Atkins report "Padholme Catchment Flood Protection Strategy - Hydraulic Modelling Report, October 2004 indicates the locations of predicted Anglian Water sewer flooding and flood depths and flood volumes.

3.5.2.6 Thorpe Meadows

As part of this SFRA, Thorpe Meadows was modelled using a steady state HEC-RAS model. The model covers 1km of Thorpe Meadows, from upstream of the A1179 culvert to the confluence with the River Nene.

The hydrology was derived using the FEH rainfall-runoff method. The inflows for the 100 year return period with climate change were obtained adding a 20% increase on the 100 year return period flow. The downstream boundary condition was taken using water levels from the River Nene iSIS model for coincident return periods. In reality, the joint probably of a 100 year event occurring at the same time for the River Nene and for Thorpe Meadows is lower than 1% annual probability (greater than 100 year return period) and therefore SFRA outputs represent a worst case scenario following a precautionary approach.

Survey data (Ratcliff Land & Engineering Surveys, June 1998) was made available by the Council to derive the model cross-sections and the dimensions of the structures. A site visit was made to verify survey and LiDAR data. When modelling Thorpe Meadows, it was assumed that the water overtopping Thorpe Meadows (left bank) eventually joins the River Nene floodplain further downstream by flowing down the playing field on the left bank. The available information suggests that this scenario is likely.
Mapping of the flood risk categories for 100 year and 1000 year events has been undertaken by horizontal projection of the water levels onto LiDAR derived ground surface. The profiles were then reviewed to include the flow path between Thorpe Meadows and the River Nene.

3.5.2.7 River Welland

In July 1992, Mott MacDonald submitted to the Anglian Region of the National Rivers Authority the "Welland/Glen River Model Final Report". The study is based on a one dimensional hydrodynamic LORIS model which takes into account the existing defences. The river network was modelled using surveyed cross-sections. Certain parts of the floodplain were modelled using flood plain cells. The results from Tallington to the Crowland Wash were available for the 100 year return period for a range of downstream tidal conditions. The results demonstrate that this part of the River Welland and the Maxey Cut are not tidally affected.

The latest Flood Zones were retained for the small area upstream of Stamford that is still within the Peterborough District. This approach is judged to be satisfactory especially as there are no flood defences or planned development at this location.

For the section between Uffington Park and Tallington, Mott MacDonald provided cross-section survey data used for their current modelling work (correspondence of the 17/06, 07/07 and 14/07/05). Therefore this reach of the River Welland was modelled using a simple hydrodynamic iSIS model. Dimensions of cross-sections and structures were taken from the survey data provided. The floodplain was modelled using reservoir cells in iSIS. The area-elevation relationships characterizing the reservoirs were derived using SAR data. The 100 year inflow hydrograph was taken from the hydrological study in the "Wellland/Glen River Model Final Report". The downstream boundary conditions were taken from the coincident water levels in the River Welland from the same Mott MacDonald's 1992 study. The modelled water levels were mapped by horizontal projection of the water levels at the corresponding cross-sections and flood compartments onto SAR derived ground surface. It was observed that the mapping of the estimated 1000 year using the extrapolated flood flows from Mott MacDonald's 1992 study gives a significantly larger flood extent than the EA's Flood Zone 2 downstream of Uffington Road. It was judged that the Flood Zone 2 may be more representative at this location as the extrapolation of flood flows modelled flood conditions, only available up to 100 year return period, is likely to ignore the flow attenuation which would arise due to the significant out of bank flow upstream of Stamford and Tallington. The mapped outlines agreed reasonably well with the Flood Zone 3 and therefore, the latest Flood Zones for both 100 year and 1000 year were retained over the section downstream of Uffington Road and Tallington.

For the River Welland between Tallington and Crowland Wash, water levels for 1 in 100 year return period were taken directly from Mott MacDonald's 1992 study. The results for the 100 year return period with climate change and for the 1000 year return period were calculated where possible by using water balance calculations. Mapping of the flood extents has been undertaken by horizontal projection of the derived water levels onto the SAR derived ground surface. A shortcoming of this method was later discovered at some places (e.g. between King Street and the A15 Deeping Bypass) as the projected water levels for 100 year event at some locations on the River Welland branches were reaching as far as Maxey Cut; this was considered to be unrealistic due to the significant available flood storage and general flood plain flow. A potential solution to overcome this problem would be to model these locations as flood cells by properly accounting for the overtopped flood volume, available flood storage and flow paths using an updated ground survey. However, it was not possible to calculate the overtopped floodplain volume from the River Welland as hydrographs were not available for this stretch from the 1992 Mott MacDonald study. From a verification with LiDAR in other locations within the District, it also appears that SAR data is generally underestimating the ground levels within the Peterborough District and therefore the projected water levels may have overestimated the flood extents, as only SAR data was available for the River Welland. Further modelling of the River Welland along this stretch to provide a more realistic flood extent was beyond the scope of this current SFRA and therefore it was decided to retain the EA's latest Flood Zones for the SFRA flood risk categories between King Street and the A15 Bypass as best available information. This approach was deemed to be acceptable, given that in particular no raised defences were present and no development is currently planned along this stretch of the River Welland.

Within the Peterborough District, raised defences are located on the River Welland downstream of Deeping Gate (right bank). Breach analysis on those defences was undertaken using an in-house breach program. It was taken that a breach failure could occur although it would be repaired sufficiently to stop further flooding within a finite time based on the guidance given in EA's guidance note 4b for local authorities. Details of the breach parameters and the average water levels within the compartments are given in *Appendix 4*. Breach base levels were obtained from survey data and hydrographs at the breach location were derived from hydrographs taken from the "Welland/Glen River Model Final Report". Breach compartments and boundary levels were derived from SAR data. When mapping the flood risk categories using the average water levels within the compartments flow routes were added as needed to give realistic flood extents.

A minimum freeboard of 600mm was allowed for all raised defences when assessing their effectiveness against the estimated water levels for 1 in 100 year return period (flood risk category 3). If the freeboard was less than 600mm then the risk area behind was classified as "undefended". Conversely, if the freeboard was greater than 600mm then the risk area was classified as "defended".

From the available survey data and modelling information for the Crowland Wash it was considered that a breach is very unlikely here for the 100 year event and breach risk areas behind the South Barrier Bank were not shown on the SFRA maps. This is because the estimated breach base level for the South Barrier Bank is sufficiently higher than the predicted water level of 3.80m ODN for 100 year event from Mott MacDonald 1992 study. This approach has also been accepted by the EA for the SFRA for the neighbouring South Holland District Council.

For the 1000 year return period the latest Flood Zones were generally retained for the River Welland. Some additional areas have been added to the SFRA flood risk categories if the SFRA analysis has already shown larger areas for the 100 year flood event (with climate change impacts) than the Flood Zone 2. This was the case where raised defences can result in higher water levels in the river channel limiting overtopping to the floodplain.

3.5.2.8 Maxey Cut

In July 1992, Mott MacDonald submitted to the Anglian Region of the National Rivers Authority the “Welland/Glen River Model Final Report”. The study is based on a one dimensional hydrodynamic LORIS model which takes into account the existing defences. The river network was modelled using surveyed cross-sections. Certain parts of the floodplain were modelled using flood plain cells. The results from Tallington to the Crowland Wash including the entire length of Maxey Cut were available for the 100 year return period for a range of downstream tidal conditions. The results demonstrate that this part of the River Welland and the Maxey Cut are not tidally affected.

For the Maxey Cut, the results for the 100 year return period with climate change and for the 1000 year return period were calculated by using water balance calculations.

Raised defences are located on the whole of the Maxey Cut. Mapping of the flood extents has been undertaken by horizontal projection of the derived water levels onto the SAR derived ground surface if flood storage is negligible. Breach analysis on those defences with significant flood risk areas was undertaken using an in-house breach program. It was taken that a breach failure could occur although it would be repaired sufficiently to stop further flooding within a finite time based on the guidance given in EA’s guidance note 4b for local authorities. Details of the breach parameters and the average water levels within the compartments are given in *Appendix 4*. Breach base levels were obtained from the existing survey data and the hydrographs at the breach location were derived from the hydrographs extracted from the “Wellland/Glen River Model Final Report”. Breach compartments and boundary levels were derived from SAR data. When mapping the flood risk categories using the average water levels within the compartments flow routes were added as needed to give realistic flood extents.

A minimum freeboard of 500mm was allowed for all raised defences when assessing their effectiveness against the estimated water levels for 1 in 100 year return period (flood risk category 3). If the freeboard was less than 500mm then the risk area behind was classified as “undefended”. Conversely, if the freeboard was greater than 500mm then the risk area was classified as “defended”. A freeboard of 500mm was considered to be appropriate for the Maxey Cut as the crest width of the raised embankments were greater than 5m.

3.5.2.9 Peterborough Brooks – Folley River, Car Dyke, Brook Drain, Werrington Brook, Paston Brook and Marholm Brook

In February 1999, Binnie Black and Veatch (BBV) submitted the “Peterborough Brooks Flood Investigation Preliminary Study Report”. The work carried out comprised the development of a hydrodynamic iSIS model covering 23.5km of channels. The modelled watercourses are:

- Brook Drain
- Werrington Brook (including the balancing lake)
- Paston Brook

- Car Dyke
- Folly River
- The approach channel to Peakirk Pumping station.

Cross-section survey data used for the modelling was supplied by the EA. The final model was not calibrated as no calibration data was available.

Binnie Black and Veatch also produced the "Peterborough Brooks Flood Investigation, Stirling Way Industrial Estate Feasibility Report" in September 1999. This report completed the second phase of the preliminary investigation and includes reviewed water level results.

The iSIS model used for the investigation was provided for this SFRA. The key modifications made during the SFRA to the original model include:

- Addition of reservoir units (Car Dyke, Paston Brook, Werrington Brook). The area-elevation relationships characterizing the reservoirs were derived using SAR data.
- Extension of cross-sections along the Brook Drain using SAR data
- Addition of the control structure (tidal doors) at Peakirk Pumping Station
- Modification to the inflow hydrographs to Paston Brook at the upstream of BBV's model to account for the flow restriction due to the culvert under Soke Parkway.

The models were run using the 100 year return period inflows already in the model. The inflows were increased by 20% to obtain the 100 year return period with climate change inflows. Inflows for the 1000 year return period were obtained using a logarithmic extrapolation.

Mapping of the flood risk categories for 100 year and 1000 year events has been undertaken by horizontal projection of the water levels onto LiDAR derived ground surface except where breach analysis was undertaken on those defences with significant flood risk areas. Breach analysis was carried out on the right bank of Car Dyke and Folley River using an in-house breach program. It was taken that a breach failure could occur although it would be repaired sufficiently to stop further flooding within a finite time based on the guidance given in EA's guidance note 4b for local authorities. Details of the breach parameters and the average water levels within the compartments are given in *Appendix 4*. Breach base levels were obtained from survey data and hydrographs at the breach location were derived from the model results. Breach compartments and boundary levels were derived from SAR data. When mapping the flood risk categories flow routes were added as needed to give realistic flood extents.

A minimum freeboard of 600mm was allowed for all raised defences when assessing their effectiveness against the estimated water levels for 1 in 100 year return period (flood risk category 3). If the freeboard was less than 600mm then the risk area behind was classified as "undefended". Conversely, if the freeboard was greater than 600mm then the risk area was classified as "defended".

The former COW section at the upstream reaches of Paston Brook (Saint Paul's Road) was modelled separately with iSIS, using the limited survey data provided by the Council and the extended cross sections from SAR data. Downstream boundary conditions for this model were taken from the corresponding levels for the Paston Brook from the wider

Peterborough Brooks iSIS model. Mapping of the flood risk categories for the 100 year and 1000 year events has been undertaken by horizontal projection of the water levels onto the SAR derived ground surface. Noticeable potential flooding upstream of Soke Parkway can be seen from the SFRA mapping. This is largely attributed to the flow restriction at the culverts under Soke Parkway and potential overestimating of inflows to this model reach. The inflows to this model extension were taken directly from BBV's Peterborough Brooks model and it may be that the flood flows have been overestimated at this location. In practice the estimated flows may not reach this far due to the potential flow restrictions at upstream culverts, pipes and surface water ponding etc. and therefore the mapped flood risk categories represent a possible worst case scenario. No attempt was made to review the hydrology for this complicated urban catchment as part of the SFRA as it was considered to be beyond the scope of the current study. Modelling accuracy may further be improved if needed with the use of improved topographic survey.

3.5.2.10 Welland and Deepings IDB Drains

For the IDB drains outside EA Main River flooding, 1in 100 year flood protection was generally assumed in accordance with the IDB policy statements and consultation carried out during the study. Historical evidence also supports this assumption. Therefore, the assumption was made that the IDB drains in this area are at bankfull capacity for the 100 year return period and this standard will also be maintained when considering the effects of climate change on flood extents.

However, during Easter 1998 event overtopping occurred in the areas of Ashton and Woodcroft Castle but no property was flooded. It is believed that this flooding at Ashton village was largely due to the surface water runoff from adjacent high ground where as at Woodcroft Castle due to general backing up of water levels from the Brook Drain. Potential flood risk to these two villages for the 100 year return period with climate change and the 1000 year return period was assessed as part of the SFRA. For these return periods, the excess water compared to the 100 year return period was calculated using the FEH rainfall simulator for a storm duration of 24 hours. The volumes in excess for the corresponding return periods were then spread in the lowest areas of the identified catchments. This was carried out using projections onto the SAR derived ground surface.

The flood risk categories for the studied IDB drains are included as supplementary figures in *Appendix 4* of this report. It is important to note that the SFRA mapping excludes the flood risk from the studied drains, as the entire drainage system was not studied as part of this SFRA. Therefore the SFRA maps within the IDB district are based on the latest Flood Zones when reporting flood risk directly due to the IDB drains.

3.5.2.11 North Level IDB Drains

For the IDB drains outside EA Main River flooding, 1in 100 year flood protection was generally assumed in accordance with the IDB policy statements and consultation carried out during the study. Therefore as for the Welland and Deepings IDB, the assumption was made that the IDB drains in this area are at bankfull capacity for the 100 year return period and this standard will also be maintained when considering the effects of climate change on flood extents. The EA's Flood Zone 2 (June 2005) was retained for the 1000 year flood extent for these IDB drains.

The Dog-in-a-Doublet catchment is the principal IDB area that may be subjected by the proposed development within the Peterborough District and the IDB drains directly affected by the potential development sites in this catchment were further studied as part of this SFRA. Following consultation with the IDB, the assumption was made that the IDB drains in the Dog-in-a-Doublet Catchment are at bankfull capacity for the 100 year return period. The "Dog-in-a-Doublet Catchment Hydraulic Modelling Study Final Report", submitted in 2004 by JBA, supports this assumption.

Similar to the Welland and Deepings IDB, for the studied IDB drains within the Dog-in-a-Doublet catchment (the 100 year return period with climate change and the 1000 year return period), the excess water compared to the 100 year return period was calculated using the FEH rainfall simulator for a storm duration of 24 hours. The volumes in excess for the corresponding return periods were then spread in the lowest areas of the identified catchments. This was carried out using projections onto the SAR derived ground surface.

The flood risk categories for the studied IDB drains are included as supplementary figures in *Appendix 4* of this report. SFRA mapping excludes the flood risk from the studied drains, as the entire drainage system was not studied as part of this study.

3.5.2.12 Rapid Inundation Zones

Raised defences are particularly important when addressing the issue of rapid inundation as recommended in Clause 69 of PPG25. The SFRA mapping shows a rapid inundation zone behind all relevant raised defences for a possible breach scenario. Within this zone it may be expected that flooding to a depth of 0.3metres could occur within half an hour of a possible breach in the defence. In addition, the velocity of the corresponding floodwater could be high enough to cause damage, particularly close to the line of the defence, and to make evacuation difficult.

A rapid inundation zone is shown regardless of whether or not the corresponding raised defence is considered secure against the 1 in 100 year flood event.

An empirical calculation together with the professional judgement was used, assuming the breach flow would spread to give a square flooded area along the breached raised defence. Breach widths were taken from the EA guidance for undertaking breach calculations. Raised features located along flood defences, such as roads and railways were used as boundaries in the calculations. The breach analysis results and the compartments used for the general flood risk category mapping were also used to verify the rapid inundation zone derived from the empirical calculation.

In general, a conservative approach was adopted in the mapping of the rapid inundation zones. The widths of the rapid inundation zones were extended in places where houses fell just outside the calculated rapid inundation zone as a precautionary approach.

4 SFRA MAPPING

The key results from the SFRA are shown on the accompanying maps. Paper copies of the maps are only produced for areas where flood risk has been identified.

The maps are produced at 1:1,250 scale for urban areas and 1:2,500 scale for rural areas (as defined by data availability from the Ordnance Survey) and show land classified as flood risk categories, 1, 2 and 3 by taking into account the effect of the raised defences. A summary set of maps is produced at 1:10,000 scale. Maps show the three flood risk categories for the present day (2005), and also the flood risk category 3 with the impact of climate change on river flows and sea level rise in 50 years (2055). The maps are produced both digitally and in paper copy format with OS mapping as a backdrop. These maps show OS grid co-ordinates and include a legend and title block; additional notes are given to aid the interpretation of the mapped data. Based on the best available information to date, the maps indicate areas at risk of flooding within the study area. Special attention is needed when maps are used for the areas at the study boundary as the data has been cut to the study boundary and potential flooding outside the study boundary has not been shown.

The final maps are supplied in a GIS format compatible with the ArcView; the shape files are attributed to suit the outcome of the study. *Table 8* shows the attributes used for mapping files. A user-friendly map generator is provided in pdf format by which maps can be printed if needed. A key plan facility is provided with the map generator to speed up navigation and printing. The GIS data and the map generator are supplied in a CD - Rom.

For watercourses identified as “modelled” the flood risk categories take into account the effects of raised defences and other raised features on flooding for planning and development control purposes. In general, if the flood risk is only limited to the confines of the modelled watercourse (i.e. no out of bank flow) then flood risk categories are not shown on the maps.

Colour hatching delineates the flood risk categories, 1, 2 and 3. For flood risk category 3, the areas with an adequate standard of protection (greater than 1.0% annual probability or 100 years return period) are shown for the present day situation (2005) as “defended”. The differentiation between flood risk category 3a (developed areas) and flood risk category 3b (undeveloped and sparsely populated areas) can be seen from the underlying OS mapping. Flood risk category 3c (functional floodplain) is not shown, as sufficient modelling data is not available to show this category throughout the study area. In addition, the maps show the washlands designated by the EA which should be treated as entirely within the flood risk category 3c for land use planning purpose.

Also included on the maps are the locations of the raised defences and the watercourses studied. The locations of the raised defences were taken directly from the EA’s NFCDD data. Raised defences within the IDB catchments were also added as needed. Where the EA’s data (e.g. raised defences, Main river centre lines, historic flooding, Flood Zones, flood storage areas etc.) is used directly for mapping purpose no attempt was made to edit the data supplied.

A potential “rapid inundation zone” behind raised defences was investigated and shown, as advised by Clause 69 of PPG25. As agreed with the EA this zone is defined as meaning a minimum depth of water of 0.3m that may be achieved in 30 minutes in the event of a possible breach in the raised defence.

In addition, GIS data has been prepared showing the location of key hydraulic structures, historic flood locations and key water retention facilities/ SUDS. These have not been included in the final SFRA maps but is shown in the figures included within the *Appendix 1* of this report. Also the additional flood risk areas associated with the IDB watercourses at the areas with known flooding problems and within the planned development areas have been assessed but not included in the SFRA maps. This information is presented as supplementary figures within the *Appendix 4* of the report.

Plans are produced to the following scales. *Table 9* presents a schedule of 1:10,000 scale maps produced.

- 1:10,000 for the summary plans;
- 1:1,250 for the urban area:
- 1:2,500 for the other areas.

Figure 4 presents a key plan of all maps produced as part of the SFRA. *Table 8* shows the details of ArcView shape files given to the Council as part of the SFRA.

Table 8 ArcView File Attributes

Feature	ArcView Shape file name	Description of main attributes
1 in 100 year return period flood risk category 3 (2005) for Peterborough	100-without-cc.shp	River_name, Modelled, Defended Flood_zone, Climate, Source
1 in 100 year return period flood risk category 3 with climate change (2055) for Peterborough	100-with-cc.shp	Same as above
1 in 1000 year return period flood risk category 2 (2005) for Peterborough	1000-without-cc.shp	Same as above
SUDS/ Balancing Ponds within Peterborough	SUDS_Ponds.shp	Description Owner (if known)
Raised defences within Peterborough	defences.shp	NFCDD attributes for NFCDD items, Asset description for others
Key hydraulic structures within Peterborough	defences,.shp locks.shp Pumping Stations.shp sluices.shp weirs.shp	NFCDD id (if referenced), Asset description, Watercourse name
EA historic Flooding within Peterborough	EA Historic Floodevent.shp	River name and various details of flooding
Rapid inundation zone	rapid_flood.shp	
IDB Boundaries	idb_bound.shp	Location of IDB boundaries within Peterborough District

Table 9 Schedule of 1: 10,000 Summary Plans

OS Map Tile
TF00NW
TF00SW
TL09NW
TF00NE
TF00SE
TL09NE
TF10NW
TF10SW
TL19NW
TL19SW
TF10NE
TF10SE
TL19NE
TL19SE
TF20NW
TF20SW
TL29NW
TL29SW
TF20NE
TF20SE
TL29NE
TF31SW
TF30NW
TF30SW

5 DEVELOPMENTS ISSUES

5.1 Current Local Plan Sites

The SFRA reviewed existing land allocations in the currently adopted Local Plan for the Peterborough District and identified the key development issues, in terms of flood risk and water cycle management.

Table 10 indicates the details of the currently allocated development sites within the District.

Table 10 Allocated development sites in Peterborough District

Policy Reference	Location	Total residential (dwellings/ha) and/ or Employment (ha)	Flood Risk directly from a studied watercourse? (Yes or No)	Status (at 31st March 2005) - Developed - Under Construction - Undeveloped
H3.01	North Westgate, Peterborough	1.25 ha	No	Undeveloped
H3.02	103 Oxney Road, Peterborough	1.99 ha	Yes[2]	Developed
H3.03	Land North of 103 Oxney Road, Peterborough	1.94 ha	No	Undeveloped
H3.04	Potters Way, Peterborough	9.20 ha	Yes	Undeveloped
H3.05	Riverside Place (Formerly British Sugar), Peterborough	44.73 ha	No	Part Developed/ Part Under Construction
H3.06	South Bank Opportunity Area, Peterborough	7.00 ha	Yes[1]	Undeveloped
H3.07	Land off Oundle Road (Galvanising Works), Peterborough	1.44 ha	Yes	Undeveloped
H3.08	Land off Oundle Road (Marshalls), Peterborough	1.60 ha	No[1]	Under Construction
H3.09	Land off Oundle Road (Cherry Tree PH), Peterborough	0.37 ha	No	Undeveloped
H3.10	London Road Opportunity Area, Peterborough	17.80ha (residential)/ 10ha (employment)	No	Undeveloped
H3.11	Land North of Wesleyan Road, Peterborough	1.67 ha	Yes	Undeveloped
H3.12	Land North of Dunblane Drive, Peterborough	11.55 ha	No	Undeveloped
H3.13	Land off Oundle Road (EoE Showground), Peterborough	6.20 ha	No	Under Construction
H3.14	Dogsthorpe Road (PFS), Peterborough	0.57 ha	No	Undeveloped
H3.15	Land at Manor Drive, Paston Reserve, Peterborough	8.20 ha	No	Undeveloped
H3.16	Land South of Manor Drive, Paston Reserve, Peterborough	37.34 ha	No	Undeveloped
H3.17	Westwood Local Centre,	0.44 ha	No	Undeveloped

Policy Reference	Location	Total residential (dwellings/ha) and/ or Employment (ha)	Flood Risk directly from a studied watercourse? (Yes or No)	Status (at 31st March 2005) - Developed - Under Construction - Undeveloped
	Peterborough			
H3.18	Land West of Monarch Ave, Fletton, Peterborough	1.00 ha	No	Undeveloped
H3.19	Former Fletton Goods Yard, Peterborough	1.28 ha	No	Undeveloped
H3.20	Land west of Dearleap, Bretton, Peterborough	3.10 ha	No	Undeveloped
H3.21	Land off Itter Crescent, Peterborough	1.90 ha	No	Undeveloped
H3.22	Barbers Hill Phase 2, Peterborough	0.93 ha	No	Undeveloped
H3.23	Land R/O 467 Fulbridge Road, Werrington	1.67 ha	Yes (1000 year only)	Undeveloped
H3.24	Land at The Grange, Netherton, Peterborough	2.50 ha	No	Undeveloped
H3.25	Fellowes Road, Fletton, Peterborough	1.22 ha	No	Undeveloped
H3.26	Land South of Stanground	70.30 ha	No	Undeveloped
H4	Hampton Township	6900 Nr	Yes (1000 year only)	Under Construction
H9.01	Thorney Road, Eye	4.34 ha	No	Part Under Construction/ Part Undeveloped
H9.02	Land R/O 2-40 High Street, Eye	4.90 ha	No	Undeveloped
H9.03	Tasman Caravan Park, Eye	0.70 ha	Yes	Undeveloped
H9.04	Land South of Nature Reserve, Eye Green	1.48 ha	No	Undeveloped
H9.05	Land South and West of Crowland Road, Eye Green	0.93 ha	No	Undeveloped
H9.06	Land off London Road, Yaxley	1.67 ha	No	Developed
H10.01	Station Road, Ailsworth	1.42 ha	No	Undeveloped
H10.02	Uffington Road, Barnack	1.50 ha	No	Undeveloped
H10.03	Clay Lane, Castor	1.67 ha	No	Undeveloped
H10.04	Land Adjacent to the surgery, Glinton	0.93 ha	No	Undeveloped
H10.05	Land North of Deeping St James Road, Northborough (Deeping Gate Parish)	1.02 ha	Yes (1000 year only)	Undeveloped
H10.06	Old Manor Farm Yard, Wittering	1.65 ha	No	Undeveloped
H10.07	Land rear of Boxer Road, Wittering	0.44 ha	No	Undeveloped
H11.01	Land R/O 35 St Pegas Road, Peakirk	0.60 ha	No	Undeveloped
OIW 2.01	Stirling Way (North)	6.7 ha	Yes	Undeveloped.
OIW 2.02	Stirling Way (Extension)	5.3 ha	Yes	Undeveloped
OIW 2.03	Edgerly Drain Road	4.7 ha	No	Under Construction

Policy Reference	Location	Total residential (dwellings/ha) and/ or Employment (ha)	Flood Risk directly from a studied watercourse? (Yes or No)	Status (at 31st March 2005) - Developed - Under Construction - Undeveloped
OIW 2.04	Fengate	0.20 ha	Yes[2]	Developed
OIW 2.05	First Drove	2.2 ha	Yes[2]	Undeveloped
OIW 2.06	Flag Fen Farm	2.3 ha	No	Undeveloped
OIW 2.07	Murdens, Fengate	3.4 ha	Yes[2]	Under Construction
OIW 2.08	Newark Road	0.7 ha	No	Undeveloped
OIW 2.09	Perkins (North)	5.1 ha	Yes[2]	Undeveloped
OIW 2.10	Perkins (South)	2.4 ha	Yes[2]	Undeveloped
OIW 2.11	Perkins (West)	3.0 ha	Yes[2]	Undeveloped
OIW 2.12	Third Drove (North)	7.9 ha	Yes[2]	Undeveloped
OIW 2.13	Third Drove (South)	4.6 ha	Yes[2]	Part Under Construction/ Part Undeveloped
OIW 2.14	Mallory Road	3.4 ha	Yes[2]	Developed
OIW 2.15	Cygnet Park	26.7 ha	No	Part Developed/ Part Under Construction/ Part Undeveloped
OIW 2.16	Hampton (East)	58.3 ha	Yes	Part Developed/ Part Undeveloped
OIW 2.17	Bakewell Rd	7.4 ha	No	Part Under Construction/ Part Undeveloped
OIW 2.18	Bakewell Rd (South)	0.6 ha	No	Undeveloped
OIW 2.19	Oxney (East)	2.1 ha	No	Undeveloped
OIW 2.20	Oxney (North)	20.6 ha	No	Part Under construction/ Part Undeveloped
OIW 2.21	Oxney (South)	6.8 ha	No	Part Under Construction/ Part Undeveloped
OIW 2.22	Dukesmead	0.8 ha	Yes	Developed
OIW 2.23	Papyrus Road (North)	1.7 ha	No	Part Developed/ Part Undeveloped
OIW 2.24	Saville Road	0.9 ha	No	Part Developed/ Part Undeveloped
OIW 2.25	Shrewsbury Avenue	1.0 ha	No	Undeveloped
OIW 4.01	Oak Tree Site	1.3 ha	Yes (1000 year only)	Undeveloped
OIW 4.02	Lynch Wood 1	1.0 ha	No	Undeveloped
OIW 4.03	Lynch Wood 2	1.3 ha	No	Undeveloped
OIW 4.04	Lynch Wood 3	5.1 ha	No	Part Developed/ Part Under Construction/ Part Undeveloped
OIW 4.05	Thomas Cook	1.1 ha	No	Undeveloped
OIW 4.06	Thorpe Wood	2.7 ha	No	Undeveloped
OIW 9.01	Northam Works, Eye Green	2.2 ha	No	Undeveloped
OIW 9.02	Station Road, Thorney	1.0 ha	No	Undeveloped

Notes:

1. Site within close proximity of flood risk area associated with a studied watercourse. Further investigation based on detailed modelling and accurate topographical data is recommended.
2. Site is shown as an area that may be subjected to flooding from the Anglian Water storm sewer system in accordance with Atkins Final Hydraulic Modelling Report for Padholme Catchment Flood Protection Study (October 2004). Therefore, further investigation is recommended to assess actual flood risk to the site.
3. Shaded Cells are Residential Developments.
4. Peterborough Local Plan First Replacement (Adopted 2005) can be found on www.peterborough.gov.uk.

Site specific Flood Risk Assessments (FRAs) will be needed to determine the suitability of all proposed development inline with the guidance given in PPG25. Depending on the size of the developments and the problems associated with the receiving watercourses, a FRA may be required in accordance with the guidance presented in *Appendix 3* and the EA should be consulted prior to the submission of planning applications. The information presented in *Appendix 3* includes the EA's National Standing advice to LPAs in England for making decisions on low risk planning applications that is also available on www.pipernetworking.com/floodrisk/.

It is expected that all development sites that are shown at risk of flooding in *Table 10* above (including the sites that are very near to a studied watercourse) will need FRAs. In addition, it is recommended that all sites within the Padholme catchment be generally further investigated by referring to the outputs of this SFRA and Atkins recent modelling using InfoWorks CS software package. Atkins modelling indicates the details of flooding from the Anglian Water storm sewer system within the Padholme catchment. Atkins have also produced guidance for undertaking flood risk assessment for all sites within the Padholme catchment.

All development sites within the District need consideration of surface runoff management using SUDS which aims to control runoff from developments so that it mimics greenfield runoff and maintains the natural drainage patterns as far as possible. PPG25 recommends the promotion of these systems through the planning system. *Section 6.0* and *Appendix 3* of this report provide further recommendations and guidance on the use of SUDS together with possible strategic solutions to control runoff.

The additional runoff generated from upstream reaches of the River Nene and its tributaries and the upstream reaches of the River Welland due to any committed and proposed development by the neighbouring planning authorities will increase flood risk in the Peterborough District. Therefore proposed developments within all planning authorities upstream of the Peterborough District will need effective surface water control measures using a combination of SUDS and strategic surface water balancing ponds as advised by the EA. It is also important that these measures are adequately managed in the long-term and therefore, effective arrangements will be needed by the relevant local authorities and potential developers to ensure this. Development in the existing floodplain should also be avoided by the neighbouring planning authorities to minimise any adverse effect on river flows and water levels within the Peterborough District during severe flood events.

The other key related issues associated with the currently allocated sites and other growth areas under RSS for the East of England and the East Midlands include water supply and effluent disposal, pollution of watercourses and ground water, and the impact on wildlife, conservation and lifestyle. Although the Peterborough District is not directly within the area covered by the RSS for the East Midlands (RSS8) the impact due to the RSS8 should be looked at due to any cross boarder issues.

5.2 Regional Spatial Strategy (RSS) for the East of England

5.2.1 General

The following regional approach to development and flood risk is suggested in RSS for the East of England (Policy SS14).

Coastal and river flood risk is a significant factor in the East of the England. The priority is to defend existing properties from flooding, and where possible locate new development in locations with little or no risk of flooding.

Local Development Documents (LDDs) will:

- promote the use of SFRAs to guide development away from floodplains, areas at risk or likely to be at risk in future from flooding, or where development would increase the risk of flooding elsewhere;

- include policies to protect floodplains and land liable to tidal or coastal flooding from development, based on the EA's Flood Zone maps, supplemented where necessary by historical and modelled data (e.g. Section 105 maps) and indications as to other areas which could be at risk in future (including proposals for 'managed retreat' where appropriate);

- require that all developments and, where subject to planning control, all land uses (including agricultural activities and changes to drainage in existing settlements) should not add to the risk of flooding elsewhere and should reduce flooding pressures by using appropriate SUDS; and

- only propose development in floodplains, areas at flood risk or at risk of flooding in future, or where development would increase the risk of flooding elsewhere, where land at lower risk of flooding is not available, where there is a significant overriding need for the development, and the risk can be fully mitigated by design or engineering measures.

As part of the RSS for the East of England the following potential development areas have been identified. Approximate locations of these development areas are shown in *Figure 5*.

A. The south-western area of the City between the current Hampton development and the A1(M);
B. North/ north west of Werrington, south of the village of Glinton;
C. West of Bretton around the urban edge towards the village of Marholm;
D. North east of Stanground;
E. The area between Parnwell in Peterborough and towards the villages of Eye and Eye Green; and
F. East of Padholme Eastern Industry.

Based on the currently available information from the published RSS for the East of England, and the advice received from the Council during the SFRA, the key watercourses potentially affected by the proposed development include:

- River Nene;
- Stanground Lode;
- Orton Dyke
- Padholme Drain;
- Brook Drain;
- Car Dyke; and
- IDB watercourses.

Some of the watercourses mentioned above (e.g. River Nene, Stanground Lode and Brook Drain) have previously suffered from flooding and therefore careful attention is needed to ensure no further increase in flood risk due to any development proposals either from additional runoff, obstruction to flood flow and loss of flood storage. PPG25 seeks a reduction in flood risk from future development and therefore opportunities for possible improvements have to be investigated, where possible adopting a strategic approach.

The flood risk associated with the above watercourses is presented on the accompanying maps. The SFRA looked at the key issues arising from the proposed development at a strategic level and recommendations are given in *Section 6* to further address these issues. Flood risk implications within the District due to any proposed development by neighbouring planning authorities were also briefly assessed in general terms although specific development areas were not reviewed as part of this study.

The two key issues associated with the potential East of England growth sites within the context of this SFRA are:

- inappropriate development in the areas that may be currently at flood risk or may be at risk of flooding in the future (i.e. direct flood risk to sites); and
- possible increased flood risk within the Peterborough District and neighbouring areas due to additional runoff (i.e. flood risk elsewhere from surface runoff).

5.2.2 Direct flood risk to sites

Out of the possible development areas (A) to (F) in *Table 11*, (B) and (E) include noticeable areas that may be currently in the 1 in 100 year event undefended floodplain of the Brook Drain and Car Dyke respectively. Development area (A) will also have small areas of undefended floodplain for the 1 in 100 year event at the upstream reaches of the Stanground Lode. Therefore, further development should be avoided in these areas where an adequate flood protection is not currently available.

Development areas (D) and (F) will be within the defended flood risk area of the River Nene for the 1 in 100 year return period (even after allowing for future climate change). In addition, the area (D) will be within the rapid inundation zone and therefore development within this area should be avoided if possible. Area (F) is suitable for development.

5.2.3 Flood risk elsewhere from surface runoff

Brook Drain, Stanground Lode and Car Dyke are known to have suffered from flooding problems in the past and therefore any development within the areas (A), (B), (C) and (E) need careful consideration on surface water management in particular. The gravity fed drainage system within the Welland and Deepings IDB's catchment is known to have suffered from the high water levels of the Brook Drain which can be exacerbated due to the extra runoff from the development areas (B) and (C). Increase in peak runoff rates and additional runoff volume due to the development sites should be fully considered and appropriate mitigation measures incorporating SUDS should be provided for these development areas in consultation with the EA, the Council and the IDBs. Development area (F) is not included in the existing Padholome Catchment Strategy and therefore the additional impact of this site on all watercourses within this catchment and the neighbouring North Level IDB's Dog – in – a – Doublet catchment should be considered.

5.2.4 Summary of flood risk

Findings regarding the above development areas are summarized in *Table 11*.

Table 11 Flood risk in the potential key growth area sites

Reference	Location	Direct flood risk to sites	Flood risk elsewhere from surface runoff	Recommendation
(A)	Area between the current Hampton development and A1(M)	Small areas of undefended floodplain for 1 in 100year event at the upstream reaches of Stanground Lode	Careful surface water management required as Stanground Lode is known to have capacity problems at its downstream reaches.	Avoid development within high risk areas. Consider the use of SUDS to mitigate the increased runoff (rate and volume) caused by development. Consider flow diversion to Middle Level IDB system if possible.
(B)	North/North West of Werrington	Noticeable areas that may be currently in the 1 in 100 year event undefended flood plain of Brook Drain	Careful surface Water Management required as Brook Drain is generally known to have capacity problems.	Avoid development within high risk areas. Consider the use of SUDS to mitigate the increased runoff (rate and volume) caused by development.
(C)	West of Bretton	No direct flood risk from a modelled watercourse.	Careful surface Water Management required as Brook Drain is generally known to have capacity problems.	Consider the use of SUDS to mitigate the increased runoff (rate and volume) caused by development.
(D)	North East of Stanground	Area defended but within Rapid Inundation Zone	Surface Water Management required.	Development in this area should be avoided if possible as it is within the rapid inundation zone. Further development in this area may also restrict

				the potential for future expansion of Whittlesey Wash for strategic flood storage.
(E)	Parnwell/Eye	Noticeable areas may currently be in the 1 in 100 year event undefended flood risk area/ flood route of Car Dyke (right bank).	Careful surface Water Management required as Car Dyke is generally known to have capacity problems.	Review the results in further detail. Investigate potential flooding in Eye on the right bank of Car Dyke through further survey and modelling. Consider raising of right bank levels or avoid development within the identified flood risk area.
(F)	East of Padholme Eastern Industry	Within defended flood risk area of the River nene for the 1 in 100 year return period (with Climate Change).	Surface water management is required as this area is not currently included in the Padholme Catchment Flood Protection Strategy.	Current Flood Protection Strategy should be reviewed to mitigate additional impact on all watercourses within this catchment including North Level IDB's Dog-in-a Doublet catchment.

Before confirming the development sites In terms of flood risk and related issues, LDDs should take into account the findings and recommendations presented in *Section 5* and *Section 6* of this report.

5.3 Flood Warning and Emergency Evacuation

Within the Peterborough District, as elsewhere in England, the responsibility for flood warning rests primarily within the EA. The Environment Agency provides flood warnings for designated Flood Warning Flood Risk Areas (FWFRAs) that are based on risk categories, which take into account factors such as the likelihood and impact of flooding, and the resulting risk for each FWFRA. During the Stage 2 SFRA, the EA supplied the details of present flood warning arrangements for the District. Currently these include all Main river reaches (excluding former COWs) within the study area.

<u>Warning Dissemination</u>

Warnings are disseminated via a system known as Automatic Voice Messaging (AVM) directly to public recipients, who have registered, as a pre-recorded message to their telephone. The message details the level of warning issued, the area for which the warning is in force and advice on what action to take. As flood events develop recorded messages giving further details of the risk area are sent out automatically. This system requires residents of "at risk property" to register their telephone numbers with the EA. Concerned parties are able to obtain current flood warning information according to a particular river, reach of river, or FWFRA. The EA is currently working on a project to implement a dissemination system "Floodline Warnings Direct", which will give the capability to use other channels for issue of warnings, including e-mail and text message.

Other current methods of warning dissemination include:

- The media – warnings are issued through the media; they are broadcast on TV weather bulletins and on radio weather and travel reports. Flood warnings are also displayed on ITV Teletext regional weather pages (page 154) and on the BBC Ceefax (page 419).
- Floodline 0845 9881188 – offers callers the option to listen to recorded flood warning information 24 hours a day and speak to a trained operator for more advice.
- Internet – The EA's website **www.environment-agency.gov.uk/flood** contains live warning information.

The EA issues flood warnings using a set of four easily recognisable codes which include:

- **Flood Watch**, where flooding is possible;
- **Flood Warning**, where flooding of homes, businesses and main roads is expected;
- **Severe Flood Warning**, where severe flooding is expected. Imminent danger to life and property; and
- **All Clear**, where flood watches or warnings are no longer in force.

A **Flood Watch** would be issued when water levels along the river are forecast to overtop banks.

A **Flood Warning** is issued when the Environment Agency anticipate flooding to property. The trigger levels currently set for this are based on the levels of permanent dwellings.

The trigger for issue of a **Severe Flood Warning** is dependent on a number of factors, but is essentially used when there is thought to be imminent danger to life. This is a decision that would be made on the basis of river levels, numbers of properties affected, response required by emergency services and local authorities, likely impact on major infrastructure etc.

The EA aims to give a two-hour lead time for all of the above levels of warning. However in certain cases of severe or "flash flooding" this may not always be possible. Certain areas may be at additional risk due to their location downstream of heavily urbanised areas and urban areas that have the potential for "flash flooding", surcharging the capacity of existing sewers and watercourses. This aspect should be further considered in conjunction with the emerging flood warning arrangements for this area to ensure that adequate telemetry, flood warnings etc. are provided.

The Council have no formal responsibility or system for providing flood warning. During severe events they work within the Northamptonshire County Council Emergency Plan to liaise with the emergency services and the EA to co-ordinate such activities as the provision of sand bags to the properties at risk and, if required, the evacuation of properties.

5.4 Flood Risk Assessments

The SFRA gives, as its name implies, a strategic overview of flood risk within the District. It does not, however, remove the need for site specific Flood Risk Assessments

(FRAs) in individual cases. These would generally need better site survey information and also include consideration of issues not relevant at a strategic level such as site drainage, the use of SUDS, overland flooding, blockage risk, flood risk to individual developments, and the impact of particular proposed developments on flood risk elsewhere.

Advice for undertaking FRAs is given in Appendix F of PPG25, EA guidance notes and the Developer Guidance presented in *Appendix 3* of this report. The Environment Agency's National Standing advice to LPAs in England for making decisions on low risk planning applications is also available on www.pipernetworking.com/floodrisk/.

A site specific FRA would generally have the benefit of more detailed local data than was available for this SFRA. It may therefore amend the result of the SFRA in that particular area. Such a process should be welcomed as improving rather than invalidating the SFRA.

5.5 Responsibilities for Flood Defences and SUDS

Figure 3 shows all the identified raised flood defences and the key flood storage facilities within the study area.

Under the Water Resources Act 1991, the EA has the permissive powers for the maintenance for all Main rivers and its flood defences. As the former COWs within the District are reclassified as Main rivers since 1st April 2005, they also now come under the responsibility of the EA.

Any flood defences on ordinary watercourses are generally the responsibility of the riparian owners, although there is no formal register of such features within the District. However, under the Land Drainage Act 1991 and 1994, the Council have permissive powers within the study area for the maintenance of ordinary watercourses (including any flood defences). However, IDBs may also be responsible for flood defences on ordinary watercourses and, under the Land Drainage Act 1991, can exercise general supervision over all matters relating to the drainage of land within their District.

In consultation with the Councils, the EA have prepared Operational Plans and these detail the maintenance responsibilities of various parties for the key flood defences within the District.

CIRIA 625 (Model agreements for sustainable water management systems, CIRIA 2004) provides background and long-term framework for the operation and maintenance of SUDS. This includes model agreements for specific scenarios:

- Implementation and maintenance of SUDS through the planning process, either as a planning obligation under Section 106 of the Town and Country Planning Act 1990 or as a condition attached to planning permission; and
- Implementation and maintenance of SUDS between two or more parties (outside the requirements for planning permission), i.e. private SUDS model agreement.

The Interim Code of Practice for SUDS (National SUDS Working Group, 2004) provides a strategic approach to the allocation and maintenance of SUDS in England and Wales and refers to the CIRIA model agreements above.

The use of SUDS and their long-term management are further discussed in the developer guidance presented in *Appendix 3* (*Sections 13* and *14*) of the SFRA report.

6 CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 Conclusions

Conclusions of the modelling and resulting development issues per watercourse are summarized in *Table 12*.

Table 12 Conclusions of modelling and development issues

Watercourse	Methodology	Development Issues
River Nene	Mapping carried out using water levels from Halcrow's River Nene model version 1. Breach analysis was carried out on raised defences.	Existing development and potential new development within high flood risk areas.
Orton Dyke	Water levels extracted from HEC-RAS model built as part of this SFRA (July 2005)	No existing development or new development within high flood risk areas.
Fletton Spring	Water levels extracted from Halcrow's Fletton Spring Pre-Feasibility report (June 2005)	No new development within high flood risk areas. Some existing development within high risk areas.
Stanground Lode	Mapping carried out using water levels from Halcrow's River Nene model version 4	Existing development and potential new development within high flood risk areas.
Padholme Drain	Results taken from Atkins Padholme Catchment Flood Protection Strategy (Hydraulic Modelling report, Oct 2004; Implementation Plan Sept 2004)	Existing development and potential new development within flood risk areas (storm water flooding).
Thorpe Meadows	Water levels extracted from HEC-RAS model built as part of this SFRA (July 2005)	No new development currently planned within high flood risk areas. Existing development within high risk area.
River Welland	Results extracted from Mott MacDonald's Welland/Glen River Model Final Report (July 1992). Some iSIS hydraulic modelling carried out on the upstream reach. Flood Zones (June 2005) were retained in places where no better data could be obtained either from existing or new modelling. Breach analysis was carried out on the raised defences.	No development currently planned within high flood risk areas. Existing development within high risk areas.
Maxey Cut	Results extracted from Mott MacDonald's Welland/Glen River Model Final Report (July 1992). Flood Zones (June 2005) were retained in places where no better data could be obtained either from existing or new modelling. Breach analysis was carried out on the raised defences.	No development currently planned within high flood risk areas. . Existing development within high risk areas.
Peterborough Brooks – Folley River, Car Dyke, Brook Drain, Werrington Brook, Paston Brook and	Results were derived from Binnie Black and Veatch Peterborough Brooks Flood Investigation Preliminary Study Report (February 1999) and further iSIS modelling.	Existing development and potential development within high flood risk areas.

Marholm Brook		
Welland and Deepings IDB Drains	For the IDB drains outside EA Main River flooding, 1in 100 year flood protection was generally assumed in accordance with the IDB policy statements and consultation carried out during the study. This standard will also be maintained when considering the effects of climate change on flood extents. The EA's Flood Zone 2 (June 2005) was retained for the 1000 year flood extent for these IDB drains. Rainfall-runoff analysis was carried out in places where known to have known flooding problems.	No new development currently planned within high flood risk areas.
North Level IDB Drains	For the IDB drains outside EA Main River flooding, 1in 100 year flood protection was generally assumed in accordance with the IDB policy statements and consultation carried out during the study. This standard will also be maintained when considering the effects of climate change on flood extents. The EA's Flood Zone 2 (June 2005) was retained for the 1000 year flood extent for these IDB drains. Rainfall-runoff analysis was carried out in strategic places where development is currently planned.	No new development currently planned within high flood risk areas.

6.2 Limitations

Where SAR data is solely used in the assessment (e.g. River Welland, Maxey Cut, Brook Drain, Car Dyke, parts of Stanground Lode, parts of River Nene floodplain, IDB areas) the accuracy of Flood Risk Categories is affected to some degree due to the reduced quality of ground survey data. Many raised features such as roads or embankments are not represented by SAR data. As a result, any horizontal projection of calculated flood water levels may be flawed.

The EA's current Flood Zones were directly used for the Main rivers that are not shown as "modelled rivers" in SFRA maps. For these watercourses, flood risk was not a major concern at present and Flood Zones were used to reasonably achieve the objectives of the SFRA within the available budget and timescale. The main limitations of the EA's Flood Zones are at road crossings since they ignore such features. Road crossings and other restrictions may increase the risk of flooding upstream and reduce the risk downstream. It was also noted that EA's Flood Zones do not necessarily follow the alignment of watercourses shown on Ordnance Survey background maps.

The Binnie Black and Veatch's Peterborough Brooks iSIS model was uncalibrated. Its accuracy is therefore limited.

SFRA flood risk categories do not consider the blockage risk, surface water, overland flooding or failure of water retention facilities.

Where used for mapping, the SFRA did not attempt to amend the EA digital data sets such as "historic flood extent " , "flood defences" and "Flood Zones".

6.3 Recommendations

Flood risk maps for the River Welland, for the Maxey Cut, Stanground Lode, Brook Drain, Car Dyke and the River Nene floodplain, where SAR data have been used for mapping need further consideration to define actual flood risk. The use of LiDAR data for mapping in these areas will generally improve the quality of study outputs.

The SFRA flood risk categories for the entire River Welland and Maxey Cut (including the Peterborough Brooks) should be reviewed when the EA's ongoing modelling study is completed.

The other aspects of flooding such as flash flooding, blockage risk, surface water and overland flooding or failure of water retention facilities should be further considered.

The SFRA will generally benefit from further surveys and hydraulic modelling, as this would further enhance the accuracy of the results, increasing the confidence levels in its future use.

When preparing development plans the District should recognise that any future amendments to the key hydraulic structures may have a significant impact on the flood risk within the District and downstream areas.

The SFRA recognised the importance of developing a strategy for flood risk management incorporating the principles of whole water cycle management for the future sustainability of the District. The key aims of this strategy are to identify the constraints for the future developments within the District and to develop a concept plan to address the following key aspects in a fully integrated manner at a local level as well as strategic level by promoting several measures:

- sustainable flood risk management and surface runoff control;
- reduction of additional potable and non-potable water supply and effluent disposal;
- decreased pollution of watercourses, ground water and soil;
- advantage for wildlife, conservation and lifestyle and opportunities for new 'green infrastructure'; and
- potential for efficient use of water using rainwater use systems and greywater recycling.

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