Final Strategic Appraisal Report

Main Report

Authority Scheme Reference	G1009
DEFRA CPW/LDW Number	
Promoting Authority	Environment Agency Midlands Region
Scheme Name	Fluvial Trent Strategy

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ENVIRONMENT AGENCY
MIDLANDS REGION

NATIONAL ENGINEERING & ENVIRONMENTAL CONSULTANCY AGREEMENT

FLUVIAL TRENT STRATEGY
STRATEGIC APPRAISAL REPORT – MAIN REPORT

ISSUE (No)	PRINCIPAL AUTHORS	PRINCIPAL CHECKER	PRINCIPAL REVIEWER	ISSUE DATE
Final (Version 4)	P W Smyth/ M D Redding/ E A Stevens	P W Smyth	C Wotherspoon	31/3/05
Final for Agency Review (Version 3)	P W Smyth/ M D Redding/ E A Stevens	P W Smyth	C Wotherspoon	14/3/05
Draft for Consultee Review (Version 2)	P W Smyth/ M D Redding/ E A Stevens	P W Smyth	C Wotherspoon	2/4/04
Draft for Agency Review (Version 1)	P W Smyth/ M D Redding/ E A Stevens	P W Smyth	C Wotherspoon	1/3/04

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CONTENTS PAGE

APPENDICES – See accompanying Documents

A EXISTING ENVIRONMENTAL CONDITIONS

B REPORT ON CONSULTATION PROCESS

C OPTIONS APPRAISAL

D FIGURES

E FLOODPLAIN MAPS

F MODELLING REPORTS

- **Volume 1: Hydrology Report**
- **Volume 2: Model 1 Report**
- **Volume 3: Model 2 Report**
- **Volume 4: Model 3 Report**
- **Volume 5: Model 4 Report**

ABREVIATIONS AND GLOSSARY

Abbreviations

AONB	Area of Outstanding Natural Beauty
BAP	Biodiversity Action Plan
BW	British Waterways
CAMS	Catchment Abstraction Management Strategy
CAP	Common Agricultural Policy
CESMM	Civil Engineering Standard Methods of Measurement
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
CSS	Countryside Stewardship Scheme
Defra	Department for Environment Food and Rural Affairs (formerly MAFF & DETR)
EC	European Commission
EIA	Environmental Impact Assessment
ESA	Environmentally Sensitive Area
EU	European Union
FCDPAG	Flood and Coastal Defence Project Appraisal Guidance
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
GQA	General Quality Assessment
HOST	Hydrology of Soil Type
IFM	Indicative Floodplain Map
LPA	Local Planning Authority
PFA	Pulverised Fuel Ash
PPG25	Planning Policy Guidance 25; Development and Flood Risk (DTLR)
RQO	River Quality Objective
SAC	Special Area of Conservation
SAM	Scheduled Ancient Monument
SEA	Strategic Environmental Assessment
SINC	Site of Interest for Nature Conservation
SMP	Shoreline Management Plans
SPA	Special Protection Area
SPR	Standard Percentage Runoff; an FEH parameter
SPRHOST	Standard Percentage Runoff derived using the HOST (Hydrology of Soil Type) classification; an FEH parameter
SSSI	Sites of Special Scientific Interest
SuDS	Sustainable Urban Drainage Systems
Tp	Unit hydrograph time-to-peak; an FEH parameter

Glossary

100-year return period flood	Size of flood that is statistically predicted to happen, on average, once every 100 years. It does not mean it will occur once in 100 years as it could happen in consecutive years or more than once in any year. There is a 100 to 1 probability of the flood being equalled or exceeded in any year.
Abstraction	Water abstraction is the removal of water from a source, either permanently or temporarily. It includes groundwater from wells and boreholes, or surface water from rivers, streams, lakes and coastal waters.
Agri-environmental	A series of government funding incentives to enable farmers to pursue more conservation orientated land management. The schemes of greatest relevance to natural conservation in England include Environmentally Sensitive Areas and Countryside Stewardship.
AMAX Series	A series of Annual Maximum recorded flood peaks, based on the water year convention (see: Water Year).
Attenuation	Holding back flow, which reduces the peak flow and level downstream. The same volume of water is passed downstream over a longer time period. Naturally occurs over floodplains but can be enhanced through the use of control structures, such as sluice gates/weirs or flood banks.
Base-rich flushes	Habitat type created through a localised upwelling of groundwater through base-rich geology.
Biodiversity	The existence of a wide range of different species in a given area.
Bird strike	The collision of aircraft and birds.
Brownfield	A site which has been previously developed.
Catchment Abstraction Management Strategy	CAMS are seen as a more sophisticated way of managing water resources. The main concepts are resource assessment, resource availability status and sustainability appraisal. They make more information on water resources allocation publicly available and allow the balance between the needs of abstractors and those of the aquatic environment to be determined in consultation with the local community and interested parties.
Catchment Flood Management Plan	A large-scale planning document that identifies long-term sustainable policies for the holistic management of flood risks in a defined river catchment or group of related catchments.
Conservation Areas	An area considered to be of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance. Designated under the Planning (Listed Buildings and Conservation Areas) Act 1990.
Countryside Stewardship Scheme	The Countryside Stewardship Scheme is operated by MAFF (Defra) to conserve and enhance some English landscapes, features and habitats, and where appropriate, improve access to them. The scheme offers 10 year agreements with annual management payments and a wide range of accompanying capital grants.
Cyprinid	Soft-finned mainly freshwater fish typically having toothless jaws and cycloid scale.
Environmental	When environmental issues are referred to, this term is used to encompass landscape/natural beauty, flora, fauna, geological or geo-morphological features, buildings, sites and objects of archaeological, architectural or historic interest.
Environmental Appraisal	Form of environmental assessment used in the U.K (primarily for development plans) since the early 1990's supported by the "Environmental Appraisal of Development Plans: A good Practice Guide" (DoE, 1993). Less detailed and more qualitative than other forms of environmental assessment. Superseded by sustainability appraisal.
Environmental Assessment	A tool to integrate environmental considerations into decision making by ensuring that significant environmental effects are taken into account. In the SEA Directive, an environmental assessment means "the preparation of and environmental report and the results of the consultations, the taking into account of the environmental report and the results of the consultations in decision-making and the provision of information on the decision", in accordance with the Directive's requirements
Environmental Impact Assessment (EIA)	EIA applied at the project level is a process intended to ensure that environmental impacts of schemes are identified prior to the work being carried out, so that proposals can be modified or managed in such a way that adverse impacts are avoided or minimised. It is also referred to in some of the literature as Environmental Assessment (EA).

ESTDAM	A computer software package used in the economic appraisal of flood defence schemes.
Eutrophic	Nutrient rich waters with high productivity.
Flashes (or subsidence flashes)	A pond, especially one produced as a consequence of land subsidence.
Floodplain	The low relief area of valley floor adjacent to a river that is periodically inundated by flood waters.
Flood Risk Mapping (S105 Mapping)	Flood Risk Mapping is the production of maps by/for the Environment Agency, usually using computational modelling of the watercourse. It shows the extents of areas affected by varying probabilities of flooding (see also Indicative Floodplain Maps).
Fluvial	Of, or occurring, in a non-tidal river.
Greenfield	Area of land previously undeveloped, such as agricultural or recreational land.
Grip Blocking	Blocking up of drains (grips) to encourage re-vegetation of the land surface
Head loss	The difference between upstream and downstream water level as water flows over, or through, a hydraulic structure such as a weir or bridge arch.
Historic Parks and Gardens	A register of Parks and Gardens of special historic interest in England is maintained by English Heritage
In-bye land	In-bye or intake is land that is associated with hill farming. It is usually enclosed farmland of hill and upland areas, typically used for rearing cattle and sheep. The land is generally permanent grassland farmed at lower intensity than lowland areas because of constraints imposed by climate and steepness of the slopes.
Intake (s)	Refer to In-bye land
Indicative Floodplain Map (IFM)	The current best estimate of floodplain extent; 100-year (or greatest recorded flood) for fluvial rivers and 200-year (or greatest recorded flood) in tidal areas.
Indicator	Measure of variables over time, often used to measure achievement of objectives or targets.
Indirect (or secondary) effects	Effects which are not a direct result of the plan, often produced away from, or as a result of, a complex pathway (based on European Commission, 1999), for example: a development that changes a water table and thus effects the ecology of a nearby wetland.
ISIS	A 1-dimensional mathematical hydraulic river modelling computer package.
Listed Buildings	A 'list' or register of buildings of special architectural or historic interest, compiled by the Department of Culture, Media and Sport, recording the best of British buildings.
Lower Trent	Length of River Trent downstream of the confluence with the River Dove.
Main River	This is a term defined in the Water Resources Act 1991. A Main River is a 'watercourse shown as such as a main river map'. Copies of the main river maps are available for public inspection at the Environment Agency's offices.
Mesotrophic	Applied to waters having levels of plant nutrients intermediate between those poor in nutrients with low productivity (oligotrophic) and nutrient rich waters with high productivity (eutrophic)
Mitigation Measures	Steps that may be taken to minimise, eliminate or compensate the adverse effects of a development.
Navigable Waters	Inland waters sufficiently deep and wide for navigation by all, or specified sizes of vessels
Objective	A statement of what is intended, specifying the desired direction of change in trends (See also Stage B)
Open Access Land	Land, that is uncultivated and open as defined by the Countryside Right of Way Act 2000, for recreational use by the general public.
Plan	For the purposes of this guidance, the term 'plan' covers any land use plans to which the Directive applies. These include local authority development plans, regional planning guidance, and any plans which may be introduced as a result of the reforms proposed in the Governments Planning Policy Statement "Sustainable Communities-Delivering through planning".
Pulverised Fuel Ash	Coal is pulverized prior to burning at modern power stations. Pulverised fuel ash is the residue collected directly from the flue gases created by the process of burning fuel.
Return Period	Refer to 100-year return period flood

Riffle	Where shallow waters flow swiftly over coarse gravel, stones and/or boulders.
Salmonid	Any member of the taxonomic family Salmonidae, which includes all species of salmon, trout, char, whitefish and grayling.
Scheduled Ancient Monument	Nationally important archaeological sites are scheduled under the Ancient Monuments and Archaeological Areas Act 1979.
Scoping	Process of deciding the scope and level of detail of the SEA, including environmental effects and options to be considered, assessment methods to be used, and the structure and contents on the resulting environmental report.
Screening	For EIA, the process of deciding which developments require an environmental impact assessment to be carried out and at what level of detail. For SEA, the decision on which plans, strategies or programmes require a strategic environmental assessment to be carried out.
Shoreline Management Plan	A large-scale planning document that identifies policies for coastal defence for a specified length of coast, taking account of natural processes and human and other environmental influences.
Site of Interest for Nature Conservation	Non-statutory designation for a site normally of county value for nature conservation, although some protection is provided through the planning system.
Site of Special Scientific Interest	Sites protected under the Wildlife and Countryside Act and Countryside and Rights of Way Act.
Special Area of Conservation	Sites designated under the Habitats Directive (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora. All sites are SSSIs.
Standard of Protection	The return period of flooding that a flood defence will protect against. The standard of protection quoted usually excludes a freeboard allowance, the consequence of which is that the defence has the capability of protecting against a flood greater than the theoretically derived value stated.
Strategic	The undertaking of any process in a holistic manner taking account of all associated impacts, interests of other parties and considering the widest set of possible options for a solution with respect to flooding.
Strategic Environmental Assessment (SEA)	Generic term used internationally to describe environmental assessment as applied to policies, plans and programmes. In this guidance, "SEA" is used to refer to the type of environmental assessment required under the SEA Directive.
Sustainability	The degree to which flood and coastal defence solutions avoid tying future generations into inflexible and or expensive options for defence. It will also take account of long-term demands for non-renewable materials.
Sustrans	The Sustainable Transport charity, working on practical projects to encourage people to walk, cycle and use public transport, in order to reduce motor traffic and its adverse effects.
Target	An objective that seeks a specified desired end, stated usually within a specified time scale.
Unit Cost Database	A database detailing the actual cost of recently constructed flood defence schemes. It was used in the strategy to compare estimated costs for proposed flood defence schemes.
Upper Trent	Length of River Trent upstream of the confluence with the River Dove.
Washlands	Used interchangeably with the term 'floodplain'. Sometimes are associated with flood banks which provide some protection of land behind (often a settlement) during flood events, whilst allowing the rest of the floodplain to flood. Previously referred to as 'controlled' floodplains.
Water Year	A hydrological convention, where the period 1st October to 30th September is used to encompass the whole winter flooding season in one year.
Wildlife Sites	Sites of Important Nature Conservation (SINC).

PREFACE

Consultations

The draft findings of the River Trent Fluvial Strategic Study were issued for general comment on the 2nd April 2004. Formal launches and public exhibitions were held in Nottingham and Alrewas on the 6th and 7th April, which helped raise public interest and allowed initial queries to be answered.

Due to a change in ministerial policy, coupled with the high level of interest, the consultation period was extended from 1 month to 3 months, with all comments received before the 1st July 2004 considered. In total, 60 responses were received during the period covering a wide range of issues. **Table B.3** of **Appendix B** details the comments received and provides specific responses. All comments were proven to be extremely valuable and careful consideration was given to each point raised.

A number of comments were repeatedly raised which can be summarised into the following seven themes:

1. Why is the 100-year return period used in the economic assessment of the flood management options?
2. Clarification on how priority scores are calculated for the proposed flood management options.
3. The appraisal methods, particularly priority score calculation methods and the use of the 100-year standard, appear to be biased towards providing schemes for populated urban areas.
4. Concerns were raised that most recommended options are not sustainable.
5. Several consultees consider that the gravel pits could provide valuable flood storage facilities, which is contrary to the strategy findings.
6. Could partnerships or sources of additional funding influence the findings of the Strategy?
7. What is the programme for delivery of the River Trent Catchment Flood Management Plan (CFMP) and the Tidal Trent Strategy?

Section B3 of **Appendix B** provides responses to these seven 'common themes'. A number of the issues relate to the methods currently used to appraise schemes and, as such, were passed to Defra, for consideration in any future changes to their policy or appraisal methods.

Findings of the Strategy Versus Work Done to Date

A number of options were identified in the draft report for immediate consideration. As indicated in the report, further work would be necessary to more fully assess the viability of these options. This work is ongoing and the issue of the final report was delayed from January 2005, to enable a comparison of the findings to date with those from the strategy.

Schemes for Nottingham, Burton and Newark have commenced, for which the following additional investigations were undertaken:

- A topographic survey, to obtain further accurate flood defence levels and other information
- A more detailed appraisal of the defences condition
- Further modeling work for certain reaches, to confirm design water levels
- Definition of the extent of the hydraulic flood cells
- A more rigorous assessment of the economic viability

The verification process has shown that the findings of the strategy are appropriate, given the level of study. However, it needs to be recognised that confidence and accuracy in the findings will improve from high level planning, through strategic studies to the detailed appraisal stage of a scheme. There is no guarantee that a flood management scheme identified through a high level strategic study will be ratified during a detailed appraisal.

It is considered that the findings of the strategy are appropriate, given the high level nature of study, and give a true representation of the relative merits of the options.

1 EXECUTIVE SUMMARY

1.1.1 The history of flooding on the Trent is graphically illustrated by the carved level marks on Trent Bridge. The worst recorded event is that of 1795, when flooding through the Trent Valley reached unprecedented levels. The most severe event of the last century was in March 1947, when thousands of properties in Burton upon Trent and Nottingham were flooded. Following this, major flood defences were constructed in the urban areas. These defences limited the extent of flooding during the most recent flood event of November 2000 but villages such as Attenborough and Gunthorpe were affected.

1.1.2 The flood risk has been the subject of a number of discrete studies but there is a need to take a more holistic approach. The principal aim of the Fluvial Trent Strategy is to identify the preferred high level approaches to sustainably manage flood risk along the Trent corridor over the next 50 years. The implementation of any flood protection measures will require more detailed investigations and appraisal.

1.1.3 The Trent has a number of major tributaries, including the rivers Sow, Tame, Dove, Derwent and Soar. Strategic studies are currently being undertaken for these and the tidal reach of the Trent. The relevant findings from this study will be made available to the other teams and a coordinated approach will be taken.

1.1.4 The study considers flood risk solely from the Trent between the head of main river at Stoke-on-Trent, to the tidal limit at Cromwell Weir downstream of Newark, a distance of some 200km. However, in the appraisal of options to reduce the risk of flooding, local and catchment wide solutions are investigated.

1.1.5 The fluvial Trent source is on Biddulph Moor, north of Stoke-on-Trent and the catchment drains an area of approximately 8228km^2 to Cromwell Weir. Although the catchment is primarily rural, the Trent flows through the conurbations of Stoke on Trent, Burton upon Trent, Nottingham and Newark.

1.1.6 There are approximately 75km of flood defence in the study area, which are mainly located in Burton upon Trent and Nottingham; these provide a range of standards of protection to over 31,000 properties and businesses. The defences in Nottingham are approaching the end of their design life, which is considered to be 75 years.

1.1.7 To accurately define the extent of the current flooding problem, four separate hydraulic models were constructed. These computer-based mathematical models were calibrated using observed data from recent flood events and were used to produce floodplain maps for a range of return periods between 5 and 200-years.

1.1.8 The models indicate that the Trent floods an area of approximately 160km^2 during a 1 in 100-year event; the width of the floodplain generally increases in proportion to the catchment area. There are currently 27 separate flood risk locations and some 15,000 properties in the 100-year floodplain. This takes into account the protection provided by the current defences. The majority of the properties at risk are located in Nottingham, where there are apparent -low spots in the current defences. This is in contrast to Burton upon Trent, where the current defences protect to a 100-year

standard. Outside Nottingham and Burton, other areas with significant numbers of properties at risk include Willington, Barrow upon Trent, Gunthorpe, Farndon and Newark.

1.1.9 There are currently 6 Sites of Special Scientific Interest and a significant number of non-statutory local wildlife sites within the floodplain. These local sites are a significant component of the impoverished bio-diversity resource of the Midlands and many are secondary habitats that have developed on areas of disused mineral workings.

1.1.10 Following extensive consultations during the early stages of the study, 18 generic flood management options were identified and taken forward for consideration. Initially, the generic options were subject to a high level technical and environmental review to assess their suitability. At that stage, a number were discounted and the remaining ones were taken forward for a more detailed appraisal.

1.1.11 The remaining generic options were considered for each of the 27 discrete flood risk locations. The result was that 95 options were identified and a technical and environmental assessment was undertaken for each. This involved a site visit and, where appropriate, the options were incorporated into the hydraulic models to assess their effectiveness. An economic analysis was undertaken for those options which satisfied the technical and environmental criteria.

1.1.12 A computer package was used to estimate the damages associated with flooding. Costs for each option were determined from various sources, including previously completed flood defence schemes and published cost databases. An optimism bias of 60% is included in the cost of all options. This takes into account the difficulty in estimating costs using limited data. The costs were benchmarked against those for recently completed schemes of a similar nature. For each option, the outputs of the economic analysis are: -

- A benefit/cost ratio, which is the reduction in damages divided by the cost of an option. It is an indicator of the cost effectiveness of the works and those options with a ratio less than 1 are not normally promoted.
- A priority score, which takes into account the benefit/cost ratio plus social and environmental factors. This allows the most beneficial schemes to be identified. Schemes must have a priority score of 20 to be considered for construction during the financial year 2004/05. It is likely that, in future years, the qualifying score will reduce as the more beneficial schemes are progressed.

1.1.13 **Table 1.1** highlights the options that have a benefit/cost ratio greater than 2 and a priority score greater than 12. The options are ranked according to their priority score.

1.1.14 A number of the options are located in Burton upon Trent and Nottingham, which presently provide protection to a 100-year standard. Their priority scores are high because of the large number of properties protected. As stated previously, the defences have limited residual lives although failures are not expected for at least another 10 years. The replacement of such defences should be phased, taking into account factors such as their actual condition, priority score and budgetary constraints. The condition

of the defences should continue to be routinely monitored so that any deterioration is identified.

1.1.15 The immediate focus should be on those flood risk areas that are not protected to a 100-year standard. **Table 1.2** ranks these top 10 options on priority score. An important issue which needs to be further considered is the programme for implementation. This is particularly relevant through Nottingham, where raising the defences in an area is likely to have a detrimental effect on flood risk in adjacent areas. For example, works at West Bridgford could impact on Queens Drive, which currently has a 100-year standard of protection. As stated previously, budget constraints will also influence the programme.

1.1.16 The effects of climate change were assessed using the models. Using the current recommendation, this would result in the 100-year water levels in Burton upon Trent and Nottingham increasing by approximately 350mm over the next 50 years.

1.1.17 For illustrative purposes, to maintain this 100-year standard in future years it would be necessary to: -

- Construct the works identified in this study to a higher level. The additional cost of this in Burton and Nottingham would be £10.1m and £2.8m respectively (at 2004 prices).
- Raise those defences which presently meet this standard. It should be noted that the costs of this are not quantified.

1.1.18 In addition, flooding could become more frequent at locations such as Gunthorpe, Caythorpe and Hoveringham. Villages on the periphery of the floodplain could experience flooding in locations previously considered to be at little risk.

1.1.19 A number of options could not be appraised in detail but are considered to be best practice and are recommended. These are: -

- Sustainable Urban Drainage Systems: either retrofitted or on new developments. They would have the greatest impact in the upper reaches of the Trent, particularly in the vicinity of Stoke.
- Development Control: appropriate measures to restrict inappropriate developments.
- Land Management: appropriate land management techniques that could reduce surface runoff.
- Floodplain Obstructions: the removal of such obstructions, where appropriate, to improve local conveyance.

1.1.20 The more detailed appraisal of specific options identified locations where works are not presently economically justifiable. However, the following could provide local environmental benefits and should be considered if alternative sources of funding become available: -

- High Bridge Banks: remove the flood banks upstream of High Bridge to create additional floodplain.

- Flood defences near the sailing club at Holme Pierrepont: remove flood banks on the right bank adjacent to Holme Pierrepont to create additional floodplain.

1.1.21 A further recommendation is to undertake additional investigations, as and when required. In summary, these are: -

- River Models: A more sophisticated hydraulic model is recommended to assess any future works in the floodplain downstream of Nottingham.
- Development Control: for any proposed development in, or on the periphery of, the 100-year floodplain, more detailed local models should be constructed to complement the current models.
- Topographical Surveys:
  1. Determine the levels of those existing defences where the current standard of protection is considered to be less than 100-years.
  2. Determine specifically which properties are at risk. Threshold surveys of those properties within the 100-year floodplain should be undertaken.
- Structural Surveys: the condition codes used in this study are based on visual inspections. Before any defences are replaced, ground investigations and structural analyses should be undertaken.
- Flood Warning:
  1. The Trent hydraulic models should be included in the programme for incorporation into the Agency's new forecasting procedures.
  2. The Agency should review its current Automatic Voice Messaging and flood warning procedures to reflect the 100-year floodplain produced as part of this study.
- Tributary Storage: appropriate results from this study should be passed to those undertaking the strategies for the major tributaries.
- Flood Gates: consideration should be given to the operational suitability of Sawley flood gates (Sheetstores) at the Erewash Canal.
- Flood Proofing: residents should be made aware that flood proofing measures are available. This is particularly important for properties in the floodplain where no protection scheme is likely to be promoted in the near future.

1.1.22 The contributions of the consultees to the strategy and the inputs of staff from the Agency and its Consultants are gratefully acknowledged. It is anticipated that this final report will form the basis for future flood risk management on the River Trent.

Table 1.1: Preferred Flood Management Options

Option				PS	B/C	Cost (£m)	EA	Standard of Protection	Condition Code	
No.	Location		Description						Average[A]	Worst[B]
	Town	Flood Cell								
3.2	Burton upon Trent	3.3	Defences	35	150.4	£4.00	✓✓	100+	1.5	3
4.1	Sawley	4.2	Defences	34	153.4	£1.90	✓✓	25-50	2.4	3
4.7	Wilford	4.14	Defences	34	64.7	£4.30	✓✓	100+	1.6	2
4.11	West Bridgford	4.23	Defences	34	51.9	£1.60	✓✓	100+	2.1	3
4.11	West Bridgford	4.21	Defences	34	39.8	£1.60	✓✓	50-100	2.7	3
4.11	West Bridgford	4.16	Defences	34	26.7	£3.50	✓✓	50-100	2	3
4.9	Queens Drive	4.18	Defences	33	21.6	£1.30	✓✓	100+	3.0	3
3.2	Burton upon Trent	3.4	Defences	33	13.2	£3.90	✓✓	100+	1.2	2
3.2	Burton upon Trent	3.2	Defences	32	76.9	£0.90	✓✓	100+	1.9	2
4.39	Newark	4.48	Defences	32	55.8	£1.10	✓	N/A	2.0	2
3.2	Burton upon Trent	3.1	Defences	32	54	£0.70	✓✓	100+	2.0	2
4.6	Rylands	4.9	Defences	32	43.1	£2.40	✓✓	100+	2.2	4
4.11	West Bridgford	4.24	Defences	32	34.3	£1.00	✓✓	25-50	3.2	4
4.13	Colwick	4.29	Defences	32	15.4	£6.30	✓✓	25-50	2.2	4
4.13	Colwick	4.25	Defences	30.5	25.3	£3.20	✓✓	50-100	1.9	2
4.35	Rolleston (Notts)	4.43	Remove banks	28.8	9.3	£1.00	✓✓	Low Level Banks		
3.2	Burton upon Trent	2.19	Defences	28	8.4	£1.90	✓✓	100+	2.2	4
4.7	Wilford	4.12	Defences	26.4	16.5	£1.00	✓✓	100+	2.6	3
4.4	Trent Meadows	4.4	Defences	24.9	6.8	£1.00	✓✓	100+	2.0	2
4.36	Rolleston (Notts)	4.43	Defences	24	9.2	£1.00	✓	No Existing Defences		
4.37	Farndon	4.44	Defences	20	4.2	£1.90	✓	<25	3.7	5
4.8	Meadows	4.19	Defences	19.6	3.6	£4.10	✓✓	25-50	2.8	3
4.5	Barton in Fabis	4.6	Defences	19.4	5.7	£2.80	✓✓	25-50	2.0	2
4.3	Attenborough	4.7	Defences	19.2	3.2	£3.40	✓✓	50-100	2.8	4
3.15	Shardlow	3.15	Defences	18.7	6	£1.60	✓✓	100+	2.3	3
4.9	Queens Drive	4.17	Defences	16.8	2	£1.30	✓✓	100+	3.0	3
4.39	Newark	4.50/ 4.51	Defences	15.9	2	£0.50	✓	No Existing Defences		
4.21	Gunthorpe	4.36	Lower A6097	14.5	4.4	£1.30	✓	No Existing Defences[C]		
3.2	Burton upon Trent	3.6	Defences	14	4	£2.60	✓✓	100+	1.3	2
3.1	Swarkestone	3.12	Defences	12.4	3.5	£1.20	✓✓	No Existing Defences		

Note: Table ordered by Priority Score then Benefit/Cost Ratio

B/C Benefit/Cost ratio

EA Environmental Assessment; ✓ - Acceptable; ✓✓ - Preferred; X - Unacceptable

PS Priority Score

A. Average condition code weighted on defence length

B. Worst condition code of all defences in that flood cell

C. Not a scheme considering flood defences

N/A Defence exists, but hinterland level is above 100-year water level, therefore failure is irrelevant.

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Table 1.2: Summary of Preferred Options for Immediate Consideration

Option				Objectives															
No.	Location		Description	Priority Score	Benefit/Cost Ratio	Cost (£m)	Reduce flood risk	Technically feasible	Increase quality of life	Sustainable	Protect existing uses and future needs for informal water and land based recreation	Conserve features of archaeological and historic interest	Maintain, develop and improve fisheries.	Maintain and enhance bio-diversity	Maintain and enhance water quality	Conserve and enhance landscape character	Enhance opportunities for development in accordance with existing planning policy	Maintain and enhance existing transport links in accordance with planning policy	Protect interests of the agricultural community	Minimise use of natural resources
	Town	F/Cell																		
4.1	Sawley	4.2	Defences	34.0	153	£1.9	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.11	West Bridgford	4.21	Defences	34.0	39.8	£1.6	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.11	West Bridgford	4.16	Defences	34.0	26.7	£3.5	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.39	Newark	4.48	Defences	32.0	55.8	£1.1	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.11	West Bridgford	4.24	Defences	32.0	34.3	£1.0	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.13	Colwick	4.29	Defences	32.0	15.4	£6.3	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.13	Colwick	4.25	Defences	30.5	25.3	£3.2	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.35	Rolleston (Notts)	4.43	Remove low banks	28.8	9.3	£1.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4.36	Rolleston (Notts)	4.43	Defences	24.0	9.2	£1.0	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.37	Farndon	4.44	Defences	20.0	4.2	£1.9	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X

Note: Table ordered by Priority Score then Benefit/Cost Ratio

✓ Objective is met

X Conflict with objective

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2 INTRODUCTION

2.1 The Strategic Approach

Background

2.1.1 Against a backdrop of widespread flooding throughout England and Wales in Easter 1998 and Autumn 2000, the Department for Environment Food and Rural Affairs (Defra) issued the Flood and Coastal Defence Project Appraisal Guidance (FCDPAG or PAG) series of documents in April 2001. These set down best practice in the appraisal of flood and coastal defence projects, with a view to promoting a more strategic approach to the management of flood risk.

2.1.2 This study was carried out in accordance with the guidance notes, in particular PAG 2 "Strategic Planning and Appraisal".

Benefits of the Strategic Approach

2.1.3 Taking a strategic approach to the management of flood risk results in a number of significant benefits, including: -

- It enables the flood risks to be assessed on a catchment wide scale and encourages the development of more innovative solutions.
- It affords the opportunity to achieve value for money through a planned approach to investments, particularly for major capital works.
- It brings transparency to the decision making process.
- It takes account of all the key issues, including impacts and consequences.
- It encourages co-operation and partnerships between operating authorities, other stakeholders and interested parties.
- It promotes sustainability.
- It permits assessments of risk and sensitivity at a catchment wide scale, for example, climate change.

2.1.4 It is for such reasons that the Environment Agency, in its role as the public body responsible for protecting and improving the environment, is currently undertaking a large number of strategic studies throughout England and Wales.

2.2 Aims and Objectives of the Fluvial Trent Strategy

2.2.1 The principal aim of the Fluvial Trent Strategy is to identify the preferred approach and potential solutions to sustainably manage flood risk along the Trent corridor over the next 50 years. To meet this objective, the strategy has undertaken a number of important tasks, including: -

- Extensive consultation, enabling the views of a wide range of interested organisations, authorities and persons to be taken into account.
- A catchment wide hydrological and river modelling study.
- A review of the condition, performance and level of protection provided by the existing flood defences.
- Identification of existing and possible future flooding problem areas.
- Production of floodplain maps, for a range of return periods. These will be taken into account in the planning process, as the planning authorities look to implement the requirements of PPG25[1].
- A catchment wide Strategic Environmental Assessment (SEA). This includes identification of opportunities for environmental enhancement, for example, wetland creation or urban regeneration, where these are compatible with the objectives of flood management.
- Assessment of a wide range of flood management options at a strategic level.
- Prioritisation of the options.

2.2.2 Following receipt of the consultees' views and as our understanding of the River Trent and its environment increased, the following set of objectives was compiled for use in the evaluation of options: -

- To reduce flood risk. This includes capital works and actions to reduce the consequences of flooding, such as flood warning and household protection.
- To be technically achievable.
- To be cost beneficial.
- To increase the quality of life.
- To be sustainable.
- To protect existing uses and future needs and demands for informal water and land based recreation.
- To conserve features of archaeological and historic interest.
- To maintain, develop and improve fisheries.
- To maintain and enhance bio-diversity.
- To maintain and enhance water quality.
- To conserve and enhance the landscape character.

[1] Planning Policy Guidance 25: Development and Flood Risk

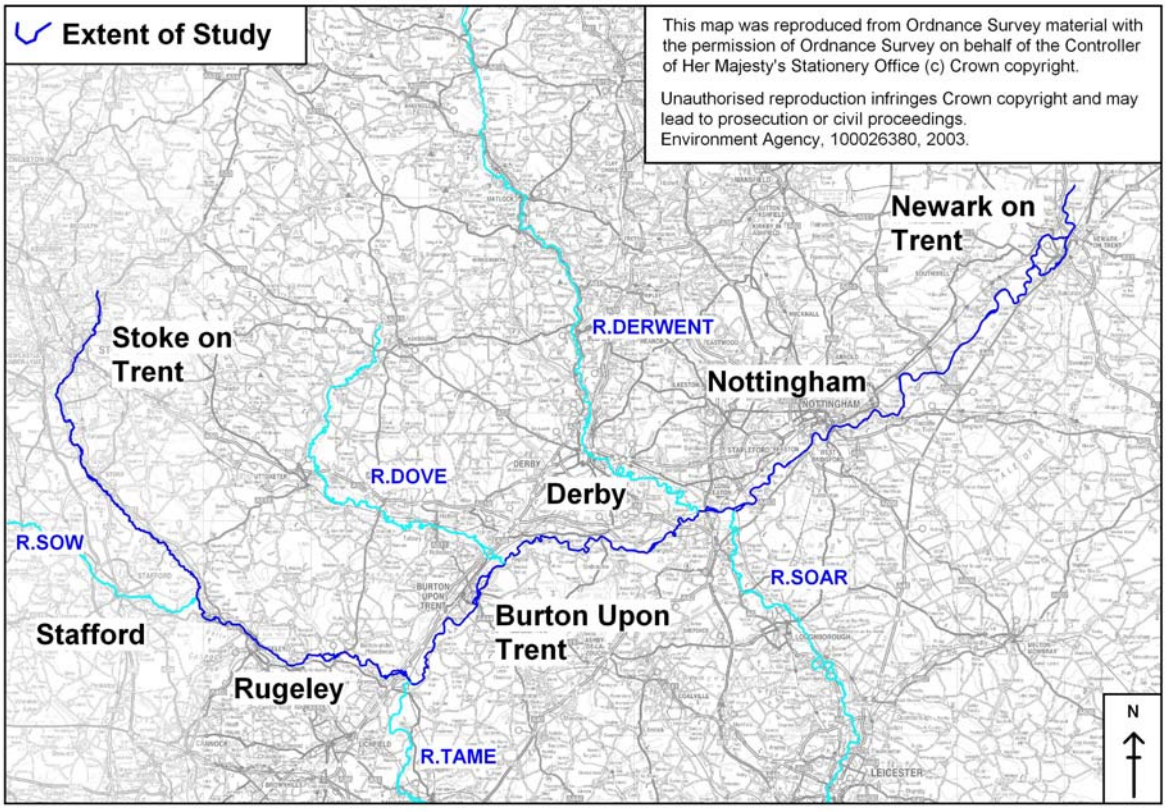
- To enhance opportunities for development and redevelopment, in accordance with existing planning policy.
- To maintain and enhance existing transport links, in accordance with planning policy, including navigation and private access.
- To protect the interests of the agricultural community.
- To minimise the use of natural resources.

2.3 The Study Area

Catchment Description

2.3.1 The fluvial Trent drains an area of approximately 8228km^2. Its source is on Biddulph Moor, north of Stoke-on-Trent, and the tidal limit is Cromwell Weir, which is approximately 10km downstream of Newark on Trent. The study is limited to any reach in this area that is at risk of flooding from the River Trent. The study area is shown in **Figure 2.1**

Figure 2.1: Extent of Study Area



2.3.2 Whilst it is only the flood risk in such areas that is considered, local and catchment wide solutions are appraised.

2.3.3 The catchment comprises parts of Staffordshire, Nottinghamshire, Derbyshire, Leicestershire, Rutland, Warwickshire, Worcestershire, Yorkshire and Shropshire. It extends to the west of Stafford and drains a significant area of Birmingham. Its southern limit is to the south of Leicester and the eastern edge runs south from Newark towards Oakham. The north of the catchment includes the upland areas of the Peak District National Park, to the west of Sheffield, which is classified as an Environmentally Sensitive Area.

2.3.4 Major tributaries include the Sow, Tame, Dove, Derwent and Soar. As the catchment area increases, flows also generally increase.

2.3.5 The upper reaches of the Trent comprise a mixture of coal measures and Triassic Marl. Further downstream, the catchment encompasses areas of boulder clay and valley gravels; the areas not overlain by drift are mainly Keuper Marl and sandstones.

2.3.6 The catchments of the northern tributaries comprise areas of sandstone and carboniferous limestone. Towards its fluvial limit, the catchment contains areas of terrace gravels and alluvium, with significant areas of clays and Mercia Mudstone.

2.3.7 Land use is hugely diverse and varies from open moorland and mixed farming through to heavily urbanised and industrialised areas. The landscape is predominately rural and ranges from rolling countryside in lowland areas to upland grazing in parts of the upper catchment. The major urban areas are Stoke on Trent, Birmingham, Derby, Nottingham and Newark.

The Trent Corridor

2.3.8 The Trent is classified as main river from just upstream of the A53 in the Baddeley Green area of Stoke on Trent. Downstream of this point, the river comes under the jurisdiction of the Agency.

2.3.9 Through Stoke, the Trent is a typical urbanised watercourse; it passes beneath numerous roads and is culverted for certain reaches. Downstream, the Trent flows through arable land in a south-easterly direction towards Stafford.

2.3.10 The Trent does not flow through Stafford but receives runoff from it via the River Sow. Thereafter, it flows in a mainly easterly direction and passes through Rugeley and King's Bromley. Downstream of King's Bromley, the Trent passes beneath the A38, which is just upstream of its confluence with the River Tame. The Tame is a major river in its own right and receives flows from large areas of Birmingham.

2.3.11 Downstream of the confluence, the Trent flows in a north-easterly direction towards Burton upon Trent. The river channel bifurcates as it passes through Burton and becomes a single watercourse just upstream of the confluence with the River Dove. The Dove is another significant tributary, which rises to the east of Stoke and flows through Uttoxeter.

2.3.12 Now a more mature river, the Trent flows to the south of Derby by Castle Donington towards the confluences with the Derwent and Soar, which are within 4km of each

other. The Derwent flows in a southerly direction through Matlock and Derby and discharges to the Trent on its left bank. The Soar flows through Leicester and Loughborough in a northerly direction and discharges to the Trent on its right bank.

2.3.13 Downstream, the Trent flows in a north-easterly direction towards Nottingham through the suburbs of Long Eaton and Beeston. Trent Bridge and Colwick Gauging Stations are situated within 5km of each other and provide a continuous dataset of recorded levels and flows through Nottingham since 1884. Sporadic historical data is available as far back as 1775.

2.3.14 Downstream of Nottingham, the river is relatively flat. Significant storage is available in the surrounding arable and pastoral floodplains, in the vicinity of the villages of Gunthorpe, Caythorpe and Hoveringham.

2.3.15 The channel bifurcates through Newark but it becomes a single river just before it passes beneath the A1. Cromwell Weir is a short distance downstream of Newark; this is the recognised limit of the fluvial Trent and the downstream extent of the study.

2.4 Interface with Previous, Existing and Neighbouring Plans

Previous Flood Risk Management Studies

2.4.1 To date, flood alleviation schemes along the Trent were promoted on a piecemeal basis and the associated studies were only undertaken when a specific need was identified. Examples of these studies include: -

- Flood Prevention Schemes in the Vicinity of Nottingham, 1950; refer to the Delft University Modelling Study, 1948.
- Hydraulic Model of the River Trent at Burton, 1991.
- Nottingham Strategic Study, 1996.
- Queens Drive Flood Defences, Project Appraisal Report, 2001.
- Attenborough Flood Alleviation Scheme, Feasibility Report, 2002.

2.4.2 The 1948 study had the greatest influence in shaping current flood management on the Trent. It was undertaken following the storms of 1946 and 1947, which caused widespread flooding throughout much of the lower Trent valley. Colwick Sluices and many of the current flood defences through Nottingham were constructed following this study.

2.4.3 The Fluvial Trent Strategy is the first catchment wide assessment of flood risk to be undertaken for the River Trent.

Environmental Action and Water Level Management Plans

2.4.4 There are a number of existing environmental plans and policies which cover sections of the Trent. These are detailed in **Appendix C** and include: -

- Catchment Abstraction Management Strategy (CAMS) for the River Trent. This outlines the Agency's approach to the management of water resources for the next 6 years. It sets out the strategy in respect of the licensed abstraction of water from the river system and identifies how it should be managed in a sustainable way.
- The UK Biodiversity Action Plan (BAP) process was launched in 1994. It provides an important framework to ensure that key habitats and species under threat in the UK are recognised. Any issues and actions that are required should be clearly identified and monitored. There are local BAPs for all regions of the Trent Valley.

Neighbouring Strategic Plans

2.4.5 This strategy is one of a number which the Agency is currently undertaking in the Midlands Region. Those which relate to, and are likely to be influenced by the findings of this strategy, are detailed in **Table 2.1.**

Table 2.1: Neighbouring Strategic Studies

River	Extent of Study		Anticipated Completion Date
	Upstream	Downstream	
Dove	Okeover Bridge	Trent confluence	Winter 2004
Tame	Oldbury and Willenhall	Trent confluence	Winter 2004
Derwent	Ladybower Reservoir	Trent confluence	Spring 2005
Soar	Sharnford	Trent confluence	Winter 2004
Tidal Trent	Cromwell Weir	Humber Estuary	Summer 2005

2.4.6 The Trent Catchment Flood Management Plan (CFMP) is currently programmed to commence in 2005. **Section 2.5** provides information on the purpose and contents of the CFMP, including its relationship to the strategies.

2.5 Hierarchy of Plans

2.5.1 The Agency adopts a tiered approach to flood management and a schematisation of this is provided in **Figure 2.2**. At the highest level are the large-scale plans, such as CFMPs and Shoreline Management Plans (SMPs).

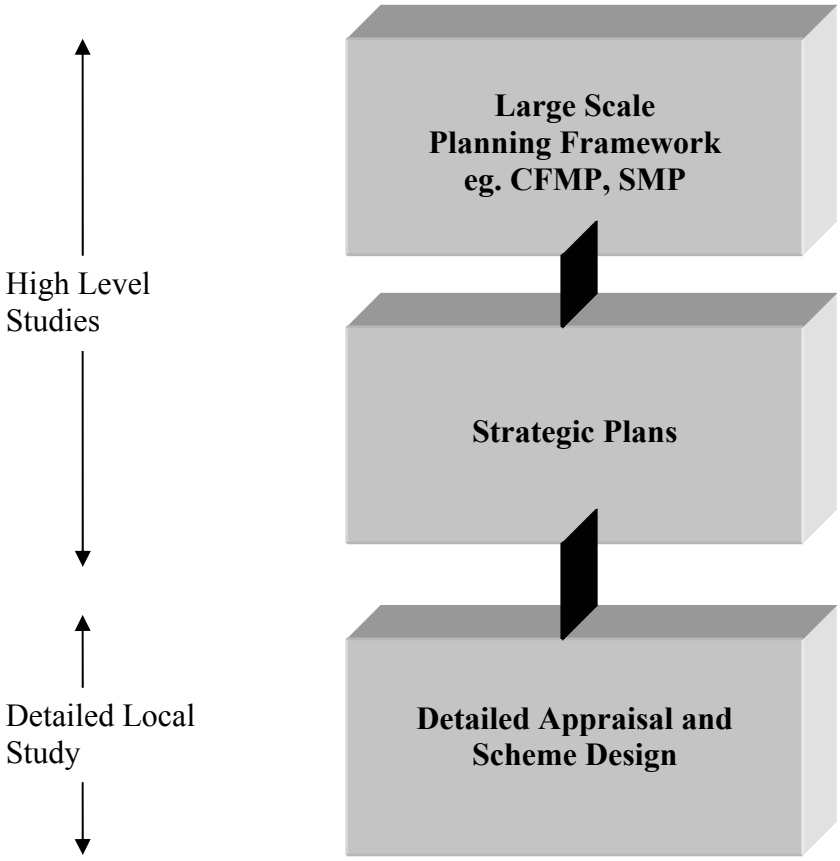
2.5.2 CFMPs will deliver a broad-brush assessment of the risks, opportunities and constraints, including areas of uncertainty, associated with flood management policy.

2.5.3 Following on from CFMPs, are the strategic studies, such as this one. Strategy Plans would normally be prepared for an entire river within the catchment. They would take forward the preferred policies identified from the CFMP and apply these for part of

the catchment. The preferred approach is, therefore, to prepare a CFMP in advance of a strategy. However, the need to assess the current flood risk within the Trent Valley was such that this strategy commenced ahead of the CFMP.

2.5.4 Following completion of the high level studies, schemes would be appraised in more detail and those which meet the current funding criteria would be promoted. This does not preclude urgent works being undertaken in advance of such studies. This can be done if the need can be demonstrated and there is an expectation that such works would be in accordance with the likely findings of the high level studies.

Figure 2.2: Hierarchy of Flood Defence Management



2.6 Consultations

2.6.1 The consultation process commenced in June 2002, with the publication of the River Trent Strategy Scoping Report; this outlines the purpose and objectives of the study. Originally, copies of the Scoping Report were issued to a number of interested groups, individuals and organisations. It was subsequently provided for general viewing at libraries, local Agency offices and via the internet.

2.6.2 Consultation and communication with the public continued beyond the scoping stage. Progress Reports, which provided updates on developments and general progress on

the strategy, were issued to all consultees in December 2002, May 2003 and December 2003.

2.6.3 The draft report was issued in advance of the official launch of the strategy. Interested organisations, the local press and the general public were invited to seminars and exhibitions held at Nottingham and Alrewas on 6th and 7th April 2004, respectively.

2.6.4 Following the launches, a 3 month consultation period was set, during which 60 responses were received. **Table B.3** of **Appendix B** lists all the comments, together with the specific response. Where appropriate, the final report was amended.

2.6.5 The comments received covered a wide variety of topics. However, a number of comments were repeatedly raised which, broadly speaking, can be summarised into the following seven themes:

1. Why is the 100-year return period used in the economic assessment of the flood management options?
2. Clarification on how priority scores are calculated for the proposed flood management options
3. The appraisal methods, particularly priority score calculation methods and the use of the 100-year standard, appear to be biased towards providing schemes for populated urban areas
4. Concerns were raised that most recommended options are not sustainable.
5. Several consultees consider that the gravel pits could provide valuable flood storage facilities, which is contrary to the strategy findings.
6. Could partnerships or sources of additional funding influence the findings of the Strategy?
7. What is the programme for delivery of the River Trent Catchment Flood Management Plan (CFMP) and the Tidal Trent Strategy?

2.6.6 **Section B3** of **Appendix B** provides details responses to these seven 'common themes'. A number of the issues relate to the methods currently used to appraise schemes and, as such, were passed to Defra, for consideration in any future changes to their policy or appraisal methods

2.7 Timescales

Appraisal

2.7.1 As stated in **Section 2.2**, the principal objective of the study is to identify the preferred approach and potential solutions for the sustainable management of flood risk along the Trent corridor over the next 50-years. The reasoning behind the 50-year time period is: -

- It is generally not feasible to make reliable physical or social predictions over a longer period.
- Policies that can be shown to be sustainable over this period are more likely to be sustainable in the longer term.

- Current research on climate change quantifies the potential increase in risk over this time period.

2.7.2 As part of the economic appraisal, Defra's procedures in Supplementary Note to Operating Authorities, March 2003, were followed. Amongst other things, this states that a 100-year appraisal period should be adopted. Therefore, a 100-year period was adopted for the economic appraisal of all options but the solutions would apply only for the next 50 years.

Strategy Review

2.7.3 The strategy report is a live document and is presently programmed to be reviewed at five yearly intervals. However, it may also be reviewed more frequently if significant changes occur, including those with respect to policy.

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3 CURRENT FLOOD RISKS AND MANAGEMENT

3.1 History of Flooding

3.1.1 The characteristics of this stretch of the river vary significantly. In its upper reaches, it is a highly urbanised river, which is susceptible to short intensive storms. In its lower reaches, it is a more mature river, which requires prolonged and continuous rainfall, or snowmelt, across much of the catchment before levels rise significantly. Consequently, it is unusual for a single storm event to cause flooding along its entire length.

3.1.2 A brief chronology of extreme events, including the areas most affected, is provided in **Table 3.1.**

Table 3.1: Chronology of Extreme Flood Events in the Trent Valley

Date	Areas most affected
February 1795	Majority of the Trent valley, Burton, Nottingham and Newark.
October 1875	Lower Trent, Burton, Nottingham and downstream villages
March 1947	Lower Trent, Burton, Nottingham and downstream villages
December 1960	Lower Trent, Burton, Nottingham and downstream villages
January 1982	Burton and surrounding villages
August 1987	Upper Trent, most notably Stoke-on-Trent
November 2000	Lower Trent, Burton, Nottingham and downstream villages

3.1.3 The most severe flood of the last century was that of March 1947. Snowmelt was a factor, but the event was notable for its prolonged duration and associated flood volume. Thousands of properties were flooded in Burton and Nottingham, and the villages along much of the Trent valley were also badly affected. This event acted as a catalyst for construction of the present flood defences along the Trent.

3.1.4 The event of August 1987 caused localised flooding in the upper reaches of the Trent valley, particularly through Stoke-on-Trent. The event was due to severe and intense rainfall from a localised thunder storm. Flooding in Stoke was worsened by a skip that was washed into the river, resulting in the complete blockage of Bucknall Road Bridge.

3.1.5 In November 2000, flooding was experienced across much of England and Wales, with approximately 9,000 properties affected nationally. The Trent valley was no exception and although the defences through Burton and Nottingham successfully protected most of these areas, flooding was experienced in surrounding villages, such as Willington and Gunthorpe. The event had a return period of between 1 in 20 and 1 in 50-years, depending on the location along the Trent.

3.1.6 The assessment of the severity of historical flood events within the Trent catchment is facilitated by the extensive recordings of water levels for Nottingham, including a

series of carved level marks on Trent Bridge. Without doubt, the event of 1795 is the worst on record, with the extent and depth of flooding notably higher than for any other recorded event.

3.1.7 This is confirmed in H. R. Potter's work[2] which states: -

> "Wherever there is a sequence of flood marks in the Trent valley, it is always found that the same order is recorded – February 1795, October 1875, March 1947."

3.1.8 **Appendix F** – Volume 1 (Hydrological Report), contains a more detailed appraisal of the historic flooding along the Trent and how this has influenced the design flows adopted for this study.

Unicorn Pub, Gunthorpe, flooding November 2000.

Attenborough, flooding November 2000.

[2] Introduction to the History of the Floods and Droughts of the Trent Basin. Trent River Authority internal report of the 1960s (exact date unknown).

3.2 Flooding along the River Trent

Floodplain Maps

3.2.1 The current Indicative Floodplain Maps (IFMs) for the fluvial Trent are a combination of historical flood data, the results from previous modelling studies and information provided by the Institute of Hydrology. Now known as the Centre for Ecology and Hydrology, the Institute of Hydrology undertook a national floodplain mapping exercise in the late 1990s. The IFMs are also an indication of the flood extent and a more detailed and appropriate flood mapping exercise for the Trent was necessary.

3.2.2 Consequently, one of the key deliverables of this study is to update the floodplain maps. To this end, a detailed catchment wide study of flood flow and frequency at various locations was undertaken. The flow data, together with topographic information for the river, floodplain and principal structures, was used to build hydraulic models of the Trent. Once calibrated against observed levels and flows for recent flood events, the models were used to generate flows and levels at selected points for a range of return periods. The levels for the 100-year return period event (1% probability of flooding) were used in conjunction with mapping to produce the flooding extents. In practice, computer software is used to assist the process and, for example, the mapping is done using a digital terrain model rather than paper maps.

3.2.3 The 1 in 100-year floodplain maps were compared and verified against known historic data, most notably the 1947 and 2000 floods. All maps were reviewed by appropriate staff from the Agency and they are considered to be a realistic representation of those areas at risk from flooding. There are a number of important factors that should be borne in mind when viewing the maps, such as: -

- The accepted tolerance band for the 1 in 100-year peak water levels, is $\pm$ 0.2m.
- The maps were generated at a scale of 1:10,000 for approximately 200km of river. Consequently, the detail of the mapping is appropriate for this scale and size of floodplain.
- The maps were generated using natural ground levels and do not take account of the threshold levels of individual properties.
- Flood outlines are dependent on the detail of the available topographic data.
- The 1 in 100-year map was used to identify those areas to be investigated as part of this study.

3.2.4 The 1 in 100-year floodplain map, which is to be taken as the new IFM, is included in **Appendix E**. Floodplain maps for other return periods, including the 1.33%, or 1 in 75-year flood, were also produced. Anyone interested in viewing these maps should contact their local Environment Agency office.

Areas at Risk from Flooding

3.2.5 The River Trent floods an area of 160km^2 during a 1 in 100-year event and the floodplain width gradually increases directly with the catchment area.

3.2.6 Generally, there are relatively few flooding problems in the upper Trent, between Stoke-on-Trent and Burton upon Trent. The current flood defences through Burton protect the majority of the town and only the outlying properties are at greater risk.

3.2.7 Through the lower Trent, a significant number of locations are at risk of flooding. These include periphery flooding of villages such as Willington, Barrow upon Trent, Caythorpe and the more widespread flooding at Gunthorpe and Hoveringham.

3.2.8 At the very downstream reaches of the fluvial Trent, significant flooding occurs through Farndon and Newark, where the low lying flat valley results in a floodplain width of approximately 3km.

3.2.9 The most significant area of interest is the Greater Nottingham Conurbation, where for a number of reaches, the defences do not protect up to a 1 in 100-year standard and a large number of properties are at risk. For such a densely populated area, the indicative standard of protection ranges from 50 to 200-years.

3.2.10 In total, there are presently some 15,000 properties and businesses at risk within the 1 in 100-year floodplain; this takes into account protection provided by the current defences. **Table 3.2** details the 'hot spots', where there are a significant number of properties at risk.

3.2.11 The potential flooding would also have a very serious impact on the transport infrastructure. **Table 3.3** details the major roads and railways which are most at risk.

Table 3.2: Hot Spots and the Number of Properties at Risk (taking into account existing defences) during a 100-year Event

Location	Area or County	No. of Properties at Risk
Stoke on Trent	Staffordshire	51
Rugeley	Staffordshire	21
Burton Upon Trent	Staffordshire	63
Willington	Derbyshire	118
Barrow Upon Trent	Derbyshire	155
Swarkestone	Derbyshire	28
Shardlow	Derbyshire	67
Sawley	Derbyshire	2721
Trent Meadows	Derbyshire	151
Long Eaton	Derbyshire	18
Barton In Fabis	Nottinghamshire	94
Attenborough	City of Nottingham	956
Meadows	City of Nottingham	1530
West Bridgford	City of Nottingham	5710
Colwick	City of Nottingham	1335
Radcliffe on Trent	City of Nottingham	114
Shelford	Nottinghamshire	76
Gunthorpe	Nottinghamshire	215
Caythorpe	Nottinghamshire	61
Hoveringham	Nottinghamshire	114
Bleasby	Nottinghamshire	57
Rolleston	Nottinghamshire	39
Farndon	Nottinghamshire	265
Newark	Nottinghamshire	339
Kelham	Nottinghamshire	42
South Muskham	Nottinghamshire	124
North Muskham	Nottinghamshire	55
Total Number of Properties at Risk		**14,519**

Note: The number of properties at risk was calculated using the 'At Risk' database, supplied by the Agency and sourced from Ordnance Survey AddressPoint database.

Note: This Table represents flood 'Hot Spots' only and is not intended to be an exhaustive list of all flood risk locations.

Table 3.3: Transport Infrastructure at Risk during a 1 in 100-year Event

Name	Type	Location
A515	Road	King's Bromley
-	Railway	Stretton, Burton Upon Trent
A5132	Road	Willington
-	Railway	Attenborough - Nottingham
A6097	Road	Gunthorpe
A46	Road	Farndon
A616	Road	Newark

Flood Cell Definition

3.2.12 For the purposes of this study, the Trent was split into 99 independent flood cells. The criteria adopted to define a flood cell are as follows: -

- To, at least, encompass those areas at risk from a 1 in 200-year event.
- To ensure that there was not a significant change in peak water level across the cell.
- Within large urban areas, the flood cells are approximately equidistant.
- Smaller towns and villages at risk, such as Rugeley, Willington and Gunthorpe are represented by a single flood cell.
- The interface between flood cells is at a definable location, such as bridge or the end of a flood defence.

3.2.12 It should be noted that these are not hydraulic flood cells, but are discrete manageable units intended to provide realistic flood management schemes.

3.2.13 It should be noted that the cells are not hydraulically independent. They are a way of breaking down such a large study area into more manageable units.

3.2.14 **Figures 3.1 to 3.3** show the location of the flood cells.

3.3 Existing Flood Defences

3.3.1 There are currently some 75km of flood defences in the study area, which provide a range of standards of protection to over 31,000 properties and businesses.

3.3.2 Other than at Burton, there are no large-scale or major urban defences in the upper reaches of the Trent. The majority of flood defences are situated in the lower reaches, particularly downstream of Sawley.

3.3.3 Flood defences generally are an effective and simple means of protection. In their simplest form, they can be a wall or earth embankment adjacent to the area. There are, however, two significant disadvantages with flood defences: -

- The associated loss of floodplain can result in increased water levels elsewhere along the river.
- They are not a truly sustainable option, as they require continued maintenance and have a definite design life, after which time they would require major refurbishment and possibly reconstruction.

3.3.4 The former issue can be managed through the use of compensatory storage areas. The option appraisal process would have compared the advantages of protecting an area against any associated detrimental impacts.

3.3.5 The latter issue is less clear cut. Many of the defences were originally built along the Trent following the 1947 flood and are nearing the end of their useful life. The Agency is aware of this problem and is committed to the ongoing refurbishment and replacement of such assets. The Agency undertook a catchment wide asset condition survey for the Trent in the 1990s, which is continually updated through a programme of planned inspections. It provides information on the type of asset and its general condition by the use of a 'condition code'. Code 1 denotes that a defence is in excellent condition and code 5 denotes one in extremely poor condition. This code is based on a visual inspection of the asset. Further site investigation and stability analyses are required before a prioritised list of asset renewals can be drawn up.

3.3.6 The worst and average condition codes were determined for each flood cell with existing defences. The average code was calculated using a weighted average relative to condition length. To initially prioritise the replacement of existing defences, a correlation was made between an asset's condition code and its residual life. A baseline date of 2004 was assumed and the results are presented in **Table 3.4**.

3.3.7 **Table 3.4** also shows the current standard of protection provided by the flood defences. This figure takes no account of freeboard and is essentially the maximum design event prior to the onset of flooding. In some instances, based on information gathered from various site visits, it was decided to ignore some unrealistically low spots in the survey data. To compensate for uncertainties, the standard of protection was split into 4 categories namely <25years, 25 to 50years, 50 to 100years and 100+years.

Table 3.4: Condition of Existing Flood Defences and Expected Replacement Date

Flood Cell	Location	Trent Bank	Standard of Protection	Average Condition Code[A]	Worst Condition Code[B]	Replacement Date[C]
2.19	Burton upon Trent	Left	100+	2.2	4	2014
3.1	Burton upon Trent	Left	100+	2.0	2	2034
3.2	Burton upon Trent	Left	100+	1.9	2	2034
3.3	Burton upon Trent	Left	100+	1.5	3	2024
3.4	Burton upon Trent	Left	100+	1.2	2	2034
3.5	Burton upon Trent	Left	100+	1.3	2	2034
3.6	Burton upon Trent	Left	100+	1.3	2	2034
3.15	Shardlow	Left	100+	2.3	3	2024
4.2	Sawley	Left	25-50	2.4	3	2024
4.4	Trent Meadows	Left	100+	2.0	2	2034
4.6	Barton In Fabis	Right	25-50	2.0	2	2034
4.7	Attenborough	Left	50-100	2.8	4	2014
4.9	Rylands	Left	100+	2.2	4	2014
4.11	Rylands	Left	100+	1.0	1	2054
4.13	Rylands	Left	N/A	2.0	2	2034
4.12	Wilford	Right	100+	2.6	3	2024
4.14	Wilford	Right	100+	1.6	2	2034
4.15	Queens Drive	Left	N/A	2.9	3	2024
4.17	Queens Drive	Left	100+	3.0	3	2024
4.18	Queens Drive	Left	100+	3.0	3	2024
4.19	Meadows	Left	25-50	2.8	3	2024
4.20	Meadows	Left	25-50*	2.7	3	2024
4.22	Meadows	Left	N/A	3.0	4	2014
4.16	West Bridgford	Right	50-100	2.0	3	2024
4.21	West Bridgford	Right	50-100	2.7	3	2024
4.23	West Bridgford	Right	100+	2.1	3	2024
4.24	West Bridgford	Right	25-50	3.2	4	2014
4.25	Colwick	Left	50-100	1.9	2	2034
4.29	Colwick	Left	25-50	2.2	4	2014
4.26	Holme Pierrepont	Right	50-100	2.7	3	2024
4.27/4.28	Holme Pierrepont	Right	L/L	2.1	4	2014
4.31	Stoke Bardolph	Left	50-100	2.3	3	2024
4.32	Shelford	Right	L/L	2.0	2	2034
4.34	Shelford	Right	25-50	2.1	3	2024
4.33	Burton Joyce	Left	N/A	1.8	2	2034
4.42	Fiskerton	Left	100+	2.0	2	2034
4.43	Farndon	Left	L/L	No code provided		-
4.44	Farndon	Right	<25	3.7	5	2009
4.47	Little Carlton	Left	25-50	1.4	3	2024
4.48	Newark	Left	N/A	2.0	2	2034
4.49	South Muskham	Left	N/A	1.8	4	2014
4.53	North Muskham	Left	L/L	3.0	3	2024
4.54	Holme	Right	100+	3.0	3	2024

A. Average condition code weighted on defence length
B. Worst condition code of all defences in that flood cell
C. Replacement date is based on a correlation between worst condition code and failure date of 5=5yrs; 4=10yrs; 3=20yrs; 2=30yrs; 1=50yrs. It is the latest date by which these defences should be replaced, but replacement could occur earlier if a specific need arises.

N/A Defence exists, but hinterland level is above 100-year water level, therefore failure is irrelevant.
L/L Denotes low level banks protecting agricultural land.

3.4 Existing and Past Flood Management

Flood Warning Procedures

3.4.1 The objective of flood warning is to give those householders and businesses at risk of flooding, sufficient time to take appropriate action to protect themselves and their property. Nationally, the Agency operates the following different levels of flood warning: -

- All Clear: No flood warnings or flood watches in place
- Flood Watch: Weather forecast and antecedent conditions suggest flooding is possible
- Flood Warning: Flooding of some properties expected; less than 100 properties
- Severe Flood Warning: Widespread flooding of properties or infrastructure

3.4.2 Currently in the study area, there are 10 Flood Warning Areas managed by the Agency.

3.4.3 The Agency faces a number of difficulties when issuing flood warnings, such as: -

- Forecasting levels for flood events.
- The issue of timely and accurate flood warnings.

Flood Forecasting

3.4.4 For the upper reaches of the Trent, flood forecasting is a particular problem because of the relatively quick response time between rainfall and the rise in river levels. For the lower reaches, particularly through and downstream of Nottingham, the river levels are dictated by the volume of water already in the upstream rivers and it is, therefore, slightly easier to predict the likely severity of an event.

3.4.5 From discussions with Agency staff, the current flood warning system could only be improved through enhanced forecasting. Flood forecasting is outside the scope of this study, but there are a number of projects currently underway that are considering improvements.

3.4.6 One such project is the procurement of a new national forecasting shell, which is planned to be delivered to the Midlands Region during early 2005. This will have the benefit of flexibility and enable forecasting models to be readily updated.

3.4.7 Over the next year, Midlands Region are planning to convert 3 existing hydrodynamic river models for real-time use and incorporate them into the new forecasting system. This will help improve the forecasting capability in areas of the region that have previously proved problematic.

Issuing of Flood Warning

3.4.8 The Agency currently aims to provide at least 2 hours warning before the onset of any flooding. Warnings are generally issued by Automatic Voice Messaging (AVM), however, only those properties that have signed up to the system will receive the warnings. Those properties which are not covered by AVM may be served by other means, such as loud hailers, sirens or the local media.

3.4.9 The study has concentrated on the likelihood of people receiving such a flood warning. The Flood Warning Area Maps show the extent of the various flood warning areas and indicate where the AVM system is currently available.

Recommendations for Improvement

3.4.10 The following recommendations are made in respect of flood warning: -

- The hydrodynamic river models of the Trent should be incorporated into the new forecasting shell, together with relevant models from the other strategies.
- The Agency should review its current AVM and flood warning procedures to reflect the revised IFM.

Development Control

3.4.11 The Agency would like to ensure that new developments are not located in areas that are at risk from flooding. Such developments can result in problems such as: -

- Flooding of the developments.
- A reduction in floodplain capacity, which could result in increased flood risk at other locations.
- Impediment of flows.

3.4.12 Development and planning control is crucial to minimise flood risk to both new and existing developments. Currently, Planning Policy Guidance 25: Development and Flood Risk (PPG25) provides guidance to Local Planning Authorities (LPAs) on the control of development in flood risk areas. Developers must undertake flood risk assessments and where development on the floodplain is permitted, mitigation measures are required. The Agency are involved in the planning process and provide advice to LPAs on all applications.

3.4.13 As part of this study, development control is considered as a flood risk management option and is discussed in greater detail in **Section 6.2**.

4 EXISTING ENVIRONMENTAL CONDITIONS

4.1 Definition and Extent of Study Area

4.1.1 As shown on **Figure 2.1,** the study covers the length of the Trent from the head of main river at Stoke-on-Trent to the tidal limit at Cromwell Weir. The overall objective of the study is to identify the preferred approach and potential flood risk management solutions in the Trent corridor. However, many of the influences on flooding and some of the potential solutions are related to the wider catchment. Full details of the existing environmental conditions for both the catchment and the Trent Valley are provided in **Appendix A**.

4.2 Description of the Catchment

Flora and Fauna

4.2.1 The catchment supports a wide range of habitats and species. At a strategic level, English Nature have reviewed each region of the UK and split them into areas of different natural character (Natural Areas). These Natural Areas highlight the importance of rivers and wetlands: they are shown on **Figure 4.1** and details are provided in **Table 4.1**.

4.2.2 It is recognised that over the last century, the Midlands suffered perhaps the worst decline in biodiversity of any English region. There are, however, a number of Sites of Special Scientific Interest SSSIs throughout the catchment; refer to **Figure 4.2.** These are sites of at least national importance for nature conservation and several are considered of international importance.

4.2.3 The UK Biodiversity Action Plan (UK BAP) and Local Biodiversity Action Plans (LBAPs) list 'Priority' habitats and species for conservation action. A number of these species and habitats are related to water and are listed in **Appendix A**.

River Trent near the confluence with the River Derwent.

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Table 4.1: English Nature Natural Areas for the Trent Catchment

Area	Summary
Potteries and Churnet Valley	Largely located within northern Staffordshire, this contrasting area includes the sprawling conurbation of the Potteries sandwiched between the wild landscape of the uplands around Biddulph to the north. The sheltered wooded valleys and pastures of the Churnet Valley to the south east, and the rural landscape of the Staffordshire/Cheshire plain to the south and west.
South West Peak	A mosaic of closely related landform and vegetation patterns. These include extensive tracts of wild, heather-dominated moorland and blanket bog with wooded cloughs.
White Peak	A distinctive area of Carboniferous limestone surrounded by gritstone moors to the north, west and east, and by the Pennine fringes to the south. The plateau of the White Peak is dissected by numerous valleys or dales, which have sites of geological and biological importance.
Dark Peak	An area of peat-covered, high hills dissected by deep, narrow valleys or 'cloughs' with fast flowing streams. Upland heathland and blanket bog cover extensive areas, woodland is largely confined to the cloughs and moorland fringes. Reservoirs are a characteristic feature.
Derbyshire Peak Fringe and Lower Derwent	This natural area comprises the lower catchments of the Rivers Derwent and Amber as well as the entire catchment of the River Ecclesbourne, these river valleys have a dominant influence on the landscape. Mixed stock rearing with rough grazing and permanent pasture is the main land cover in the area.
Meres and Mosses	These form one of the most important wetland areas in England. The landscape in which they occur is a gently undulating plain broken by sandstone ridges. The area is mainly rural and agricultural.
Needwood and South Derbyshire Claylands	The general character of the area is one of rolling countryside, broadly divided by the wide shallow valley of the River Dove, which also separates the Staffordshire and Derbyshire elements of the area.
Charnwood	The upper peaks of the Charnwood Natural Area are formed from some of the oldest Precambrian rocks in England. Charnwood forest has a variety of habitats including extensive woodlands and acid grassland and lowland heath on the hills.
Trent Valley and Rises	A large part of the area is under intensive agriculture, however, a number of important habitats remain including neutral, acidic and calcareous grasslands. Wet floodplain grasslands occur along the Soar and Trent, there are numerous standing water habitats

Table 4.1: English Nature Natural Areas for the Trent Catchment

Area	Summary
	including gravel pits. Rivers, streams and associated habitats feature. The area is poorly wooded but significant concentrations of important sites are scattered throughout.
Coal Measures	The topography is gently undulating and the network of towns and cities is characterised by a matrix of acidic ancient and secondary woodlands, valley wetlands, neutral and acid grasslands, and mixed agriculture. Canals, mill-ponds and natural rivers are also important features.
Southern Magnesian Limestone	The Magnesian Limestone forms the primary bedrock of this area, which forms a narrow band less than five miles wide. The soft rock has weathered to form rounded escarpments. Much of the area has been ploughed leaving only small remnants of the original vegetation. Base-rich flushes, rivers and streams form important wetland features.
Sherwood	Land use in the Sherwood Natural Area is dominated by agriculture and conifer plantations. Despite this, there are a number of important habitats remaining. Long-established woodland is limited to a few fragments, dominated by oak and birch, and wet woodlands line several streams. Wetlands are scarce in Sherwood.
Lincolnshire and Rutland Limestone	This natural area contains a lot of woodland. Broadleaved woodland, scrub and wood pasture can all be found. Small pockets of calcareous grassland are scattered about the natural area. Freshwater habitats in the Natural Area include rivers and streams and a few flooded gravel pits. Farming is the principle land use.

Landscape and Visual Amenity

4.2.4 The landscape character of the Trent Valley and wider catchment has changed significantly, both historically and in more recent years, through changes in land use and management. It is a mosaic of landscapes, ranging from the extensive flat agricultural land of the Lower Trent valley to the moorlands of the Peak District within the Peak District National Park; refer to **Figure 4.3**. Although a predominantly rural landscape, the catchment does contain some heavily industrialised and urban areas.

4.2.5 The Countryside Character Initiative is a programme which provides information and advice on the character of the English countryside. It includes a systematic description of the features and characteristics that make up the landscape. Each region is broken down into Landscape Character Areas. Those for the Trent catchment are shown on **Figure 4.4** and a summary of each is provided in **Table 4.2**. Historic Landscape Characterisation (HLC) projects have also been completed for Nottinghamshire and Derbyshire and one is underway for Staffordshire.

4.2.6 There is only one statutory landscape area within the catchment, which is an Area of Outstanding Natural Beauty (AONB) at Cannock Chase; refer to **Figure 4.3**.

River Trent floodplain, near King's Bromley

Water

4.2.7 Water quality in the catchment is variable, due predominantly to nutrient enrichment from sewage effluent and agricultural runoff. Other water quality impacts include discharge from industrial sites and mines.

4.2.8 Both the Upper and Lower Trent catchments are important water resources and abstractions take place from the rivers, reservoirs and major sandstone aquifers.

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Table 4.2: Countryside Agency Landscape Character Areas for the Trent Catchment

Character Area	Summary
Dark Peak	The Dark Peak is an extensive area of high moorland and adjacent in-bye land within the Pennines comprising a large part of the Peak District National Park. Much of the area is designated as open access land and the Pennine Way starts in Edale village and rises to cross the Dark Peak on its way north.
White Peak	The area comprises a limestone plateau with a number of deep limestone dales. The gently rolling plateau of the limestone is deeply dissected by the rivers Manifold, Dove, Larkhill and Wye and their associated network of dry tributary valleys. Semi-natural woodlands, grassland, with scrub and outcropping rock features, are of major ecological importance in the dales.
South West Peak	The South West Peak is an area of upland and associated foothills in the south-west part of the Pennines. Landscapes range between extensive tracts of wild, open, expansive moorland and intimate small-scale domesticated farmsteads in sheltered locations, all within a relatively compact area. Some of the area is controlled by the MOD and has restricted access. The National Park Authority manages large tracts of land.
Derbyshire Peak and Lower Derwent	The area includes small towns. The River Derwent flows through the heart of the area in a deep valley with some notably steep-sided stretches. Other significant rivers include the Amber and Ecclesbourne. The predominant landuse is agriculture with mixed stock rearing and rough grazing on improved grassland.
Potteries and Churnet Valley	The landscape is very varied. There is an underlying landform of deeply incised, steep valleys and high, much-dissected ridges rising to the Peak District. This is combined with a transition from lowland to upland vegetation and with an ancient pattern of valley-bottom villages with scattered farmsteads and hamlets on the slopes above.
Shropshire, Cheshire and Staffordshire Plain/Cheshire Sandstone Ridge	The Shropshire, Cheshire and Staffordshire Plain extends from the broad Mersey Valley, with its urban and industrial development, in the north, to the Shropshire Hills in the south. Much of the Plain is gently rolling. Throughout, the predominant landuse is the production of grass for dairy cattle; fields are put down to grass for grazing, silage or hay. The water-retention and fertility of the widespread clay soils support lush pastures and thick hedgerows.
Needwood and South Derbyshire Claylands	Needwood and the South Derbyshire Claylands make up an area bounded by the River Trent and the rising ground of Cannock Chase and Cank Wood to the south west and by the wide Trent Valley Washlands with their dense settlement to the south east. To the north and west, the area grades into the rising ground of the Pennine fringes. It consists of two main divisions separated by the wide floodplain of the River Dove.

Table 4.2: Countryside Agency Landscape Character Areas for the Trent Catchment

Character Area	Summary
Cannock Chase and Cank Wood	Cannock Chase lies on a central elevated plateau. It is an unenclosed, heavily wooded landscape with a varied, often steeply-sloping surface dominated by heathland and conifer plantations. The large area of plantations is complemented by broad tracts of heathland There is much local variety within the many valleys, known locally as slades.
Mid Severn Sandstone Plateau	This area lies around the catchment of a central section of the Severn and the lower Stour rivers. The core of the area is a predominantly rural landscape of rolling landform which was formerly dominated by heathland and woodland. These still survive in patches as one of the most characteristic features. The weak, predominantly regular, field pattern with deteriorating or closely trimmed hedges has little effect in reducing the scale of the open, intensively farmed, arable landscape. However, along the valley bottoms there is greater tree cover from the lines of alder, willow and poplar.
Arden	Arden comprises farmland and former wood-pasture lying to the south of Cannock Chase and Cank Wood. Within the overall character, there is wide variation which ranges from the enclosed river valleys, through the undulating wooded landscape and small hedged fields of the main plateau, to the remains of the coal industry in the north-east. Surviving features include sprawling settlements of urban fringe character with red-brick terraced housing, spoil heaps and small pockets of rather run-down pasture and arable farmland.
Mease/Sense Lowlands	The claylands surrounding the Mease and Sence fall southwards towards the valleys of the rivers Anker and Trent and are characterised by extensive areas of arable cultivation with low, sparse hedges and few hedgerow trees. The Lowlands are very gently rolling clay ridges and shallow valleys becoming virtually flat around the Sence and Mease. Small villages, generally on the crests of the low ridges, are the most prominent features in the landscape other than unfortunately-sited pylons.
Leicestershire and South Derbyshire Coalfields	The coalfield landform is one of gentle ridges and shallow valleys. The undulations become particularly shallow towards the south where there are locally thick deep deposits of glacial till. There is very little woodland or scrub other than that which has regenerated on abandoned mineral workings. The open character is emphasised by the hedgerows, which tend to be low, and hedgerow trees are generally infrequent. The farmland is in mixed arable and pasture use.
Charnwood	The essence of Charnwood's distinctive character is its upland qualities which contrast with the surrounding gentle midland landscapes. It is formed of Precambrian slates and volcanic rocks, which are intruded by Plutonic rocks to the south, and it has abundant heathlands, woodlands, stone buildings and stone walls. There are a few small villages and a scattering of farmsteads in contrast to the nucleated villages and open farmland of the adjacent character areas.

Table 4.2: Countryside Agency Landscape Character Areas for the Trent Catchment

Character Area	Summary
Northamptonshire and Leicestershire Vales	This large, complex and heterogeneous area comprises low-lying clay vales and river valleys extending between wold landscapes and other areas of higher ground, including the area referred to as High Cross Plateau in Warwickshire. Woodlands are small and are confined mainly to valley sides areas and to copses and spinneys on the ridges. Leicester and Northampton are large towns with extensive edges of commercial and retail buildings and out of town development. There are several smaller towns in the area. The river valleys of the Soar, Welland and Nene are much larger-scale landforms than the clay vales forming the hinterland of this area. They have wide, flat floodplains on which an older landscape of meadows, willow pollards and alders survives.
Melbourne Parklands	The Melbourne Parklands are steeply undulating and several valleys have been blocked to create large reservoirs. Historically important parklands are surrounded by substantial woodlands and there are commanding views across the Trent Valley. Settlements are more substantial along the edge of the Trent Valley than in the Lowlands. An urban fringe character is apparent where the uplands slope down to the river Trent.
Trent Valley Washlands	The Trent Washlands form a distinct, linear, landscape character where the Trent passes through its middle reaches in central England. The character area includes the valleys of two main tributaries, the Tame and the Soar, which drain in from the south. The Washlands comprise a somewhat fragmented landscape of pastoral and arable land intermixed with urban development. In these pastoral stretches, fields are small with full hedges but few hedgerow trees; it is the riparian vegetation that gives a sense of lushness and enclosure. Within the valleys, the rivers are unobtrusive, meandering between high flood banks, and often only revealed by the lines of willows and poplars. The rivers regularly flood, spreading widely over the adjacent land.
Nottinghamshire, Derbyshire and Yorkshire Coalfield	This is a large landscape area embracing the major industrial towns, cities and a substantial slice of countryside and villages of the Nottinghamshire, Derbyshire and Yorkshire Coalfields. The landscape is underpinned by generally low and undramatic but variable hills, escarpments and broad valleys, and is dominated everywhere by extensive urban influences and industry. Several major rivers cross the area, including the Aire, Calder, Dearne, Rother, Don and Erewash, but their courses tend to be obscured by the industrial development that has grown up around them. Subsidence flashes and lagoons create valuable wildlife habitats in these valleys but they are often surrounded by mines, tips and industrial works.
Southern Magnesian Limestone	This landscape is formed by the two escarpments of the Upper and Lower Magnesian Limestone which stretch from near Bedale, running southwards through South Yorkshire and into Derbyshire, where they terminate near Nottingham. Throughout the length of the limestone belt, the well-drained soils, reasonably good climate, and low altitude has created a landscape of rolling landform, fertile farmland and well wooded estates, cut by numerous dry valleys.

Table 4.2: Countryside Agency Landscape Character Areas for the Trent Catchment

Character Area	Summary
Sherwood	Sherwood contains a wide range of landscapes. It includes the historic heartlands of Sherwood Forest, the extensive parklands and estates of the Dukeries and the estate farmlands south of the hill settlement of Blyth. It extends in a broad band from the northern edge of Nottingham and lies chiefly on well-drained, infertile, sandstone-derived soils, which historically supported extensive heathlands and woodlands and are now substantially converted to arable.

Land Use

4.2.9 Land use within the Trent basin is hugely diverse and varies from open moorland and mixed farming through to heavily urbanised and industrialised areas. There has been significant development of agricultural land over recent years but pasture and arable land are still the dominant land uses.

4.2.10 The intensification of agricultural land use during the twentieth century has contributed to a faster and higher rate of surface runoff. This, combined with loss of woodlands and rough vegetation to farmland or urban development, may have contributed to changed flow regimes in the rivers. It has also impacted on water quality through raised nutrient levels. Part of the Peak District is now designated an Environmentally Sensitive Area (ESA); refer to **Figure 4.3**.

4.2.11 This change in land management has been due mainly to the Common Agricultural Policy (CAP). Significant changes are now proposed to the CAP, which should lead to the de-intensifying of land management over potentially large areas. The potential impacts of CAP reform are discussed in **Appendix C**.

4.2.12 Historically, there has also been a change from traditional floodplain meadows to the use of floodplain land for agriculture all the year round. This has, in many cases, led to attempts to lower the water table at all times of the year and even to protect the natural floodplain from flooding.

4.2.13 There are also a number of industrial sites and extensive mineral workings within the catchment, including the extraction of sand, gravel, limestone, coal and igneous rocks. Some 20% of the UK's aggregates are produced in the East Midlands.

Contrast in land use in the Trent Valley near Nottingham.

Cultural Heritage, Archaeology and Material Assets

4.2.14 The Trent catchment has a significant amount of historical interest, ranging from structures and buildings to buried archaeology. The Lower Derwent Valley is designated as a World Heritage Site. There are also a large amount of Scheduled Ancient Monuments (SAMs) throughout the catchment; refer to **Figure 4.5**. In addition, the catchment contains significant other historic resources, including Historic Parks and Gardens, Registered Battlefields, Listed Buildings and Conservation Areas.

Soil, Geology and Hydrogeology

4.2.15 The upper reaches of the Trent comprise a mixture of coal measures and Triassic Marl. Further downstream, the catchment encompasses areas of boulder clay and valley gravels; the areas not overlain by drift are mainly Keuper Marl and sandstones. The northern catchments comprise areas of sandstone and carboniferous limestone. There are areas of terrace gravels and alluvium, with significant areas of clays and Mercia Mudstone towards the fluvial limit.

4.3 The Trent Corridor

4.3.1 The Trent Valley is recognised as a strategically important feature in terms of its wildlife, landscape, archaeology and recreational potential. However, the habitats, landscape features and the archaeological resources of the River Trent and its floodplain have suffered severe losses. These were caused by flood control, drainage, agricultural improvements, mineral extraction, built development and canalisation for navigational purposes.

4.3.2 There are many strategic groups and initiatives, which are currently trying to improve the environment of the Trent Valley. These include the OnTrent and Central Rivers initiatives.

Recreation

4.3.3 There is considerable leisure and recreation interest in some parts of the valley, both on and adjacent to the river, particularly downstream of Shardlow, where it is navigable. Recreation opportunities include strategic and local footpaths and cycleways, bird watching, sailing on restored gravel pits, rowing, canoeing and kayaking,

4.3.4 Fishing is also a major water-based recreation on the river and restored mineral sites.

Flora and Fauna

4.3.5 The biodiversity of the Trent Valley has been severely impacted by river modifications, agricultural improvement, drainage, urban development and historically poor water quality. The biodiversity directly supported by the river is now considered to be generally poor. Many of the areas of high existing and potential biodiversity are no longer naturally linked hydraulically to the river as a result of flood defences. English Nature and other conservation organisations would like to see such linkages returned, where desirable and feasible. Many washlands do not, however, deliver the maximum possible biodiversity gain, because the agricultural land use within them is not sympathetic to wildlife.

4.3.6 The key natural features of each Natural Area are detailed in **Appendix A**. The Trent forms a significant feature in all the Natural Areas but, by definition, is most dominant in the 'Trent Valley and Rises'. Here,, key characteristics include wet floodplain grasslands and standing water provided by gravel pits.

4.3.7 There are only 6 SSSIs in the 100-year floodplain but there are a substantial number of non-statutory 'local' wildlife sites. These local wildlife sites are a significant component of the impoverished bio-diversity resource of the Midlands. Many of these are secondary habitats that have developed on areas of disused mineral workings.

Fisheries

4.3.8 The River Trent is now a recovering migratory fish river, including trout and salmon. With recent improvements in water quality, the greatest remaining problem to the successful re-establishment of a migratory salmonid species is the obstructions caused by the navigation and industrial weirs on both the Trent and its tributaries. Flood peaks are essential in a number of cases to allow migratory fish to cross these obstructions and travel up the river.

4.3.9 Defra has recently proposed an extension to the coarse fishery designation to include the entire Trent. The development of coarse fishery in the Trent is currently restricted due to the limited availability of suitable habitat for spawning and nursery areas for juvenile fish. This is mainly due to habitat modification for drainage and navigational purposes. However, positive measures are being undertaken to enhance the river for fisheries.

Landscape and Visual Amenity

4. 3.10 The landscape along the Trent river corridor varies along its course. Initially at Stoke, the river runs through a highly urbanised environment. The channel is often severely modified and has been relocated in areas to accommodate development. More recently, there have been a number of local initiatives to improve the environment along the course of the river in Stoke.

4. 3.11 Downstream of Stoke, the river flows through a predominantly rural setting. The floodplain gradually widens and becomes more extensive, particularly downstream of Nottingham. Except for the urban centres, the floodplain is generally agricultural although mineral workings are a significant feature. In this location, it is more typical of a slower flowing lowland river surrounded by gently rolling hills.

Water

Quality

4. 3.12 There have been significant improvements during the 1990s in both chemical and biological water quality along the Trent, mainly as a result of improvements in wastewater discharges. However, there are still problems of diffuse pollution associated with urban surface water runoff and modern agricultural practices, such as nutrient enrichment, pesticides and sedimentation.

Water Resources

4. 3.13 Most of the water abstracted from the Trent is used for power generation and public

water supply. The largest single authorised abstraction is for the hydropower scheme at Beeston in Nottingham, which is all returned to the river downstream.

4. 3.14 Water quality improvements over recent years have allowed river water to be abstracted for potable water supply. There is a licenced abstraction point for public water supply at Shardlow, south of Derby.

4. 3.15 A Catchment Abstraction Management Strategy (CAMS) for the Trent corridor has been finalised and published in November 2003. The aim of the CAMS is to manage water resources sustainably and to provide a consistent and structured approach to local water resources management, which recognises both the needs of the abstractors and the environment.

Land Use

Agriculture

4. 3.16 Agriculture is the dominant land use along the Trent corridor. Upstream of Nottingham, the agricultural use is largely cattle and sheep; arable farming is predominant in the lower reaches of the Trent valley, where the land quality is high.

Development

4. 3.17 Considerable urbanisation has occurred within the Trent catchment over the past 50 years, including the expansion of existing cities, towns and villages.

4. 3.18 The Trent, with its major tributaries, is one of the leading areas of gravel production in England. The Midlands produces 20 million tonnes of sand and gravel per year and the majority of this is from the Trent Valley. Old workings are now open water areas or have been infilled and reclaimed for agriculture.

4. 3.19 There are two sites on the Trent where hydropower is used to produce electricity for the National Grid, namely Burton upon Trent and Beeston Weir in Nottingham.

Navigation

4. 3.20 The Trent is extremely popular for recreational boating. The upper limit of the navigation starts at Shardlow and extends to Trent Falls at the Humber, although a 5km stretch through Nottingham is not navigable. Most leisure craft join the River Trent from the Trent and Mersey Canal at Sawley Lock, which is downstream of Shardlow. This is one of the busiest locks in the country.

4.3.21 Upstream of Shardlow, there is an assumed public right of navigation but there is no navigation authority. There are several marinas along the Trent that provide mooring and other facilities for boat users.

Cultural Heritage, Archaeology and Material Assets

4.3.22 There is considerable archaeological and historical interest along the Trent Valley.

Much of this is buried and preserved beneath the alluvium on the floodplain and is unrecorded.

4.3.23 The Trent was a trading route between the English Midlands and overseas ports for centuries. Training walls, weirs and locks were built and the river was dredged during the eighteenth and nineteenth centuries to maintain an adequate depth.

4.3.24 There are many designated and non-designated historic sites including Listed Buildings, Scheduled Ancient Monuments and Historic Parks and Gardens throughout the Trent corridor. Many of the settlements in the Trent Valley are of historic significance and are designated Conservation Areas.

Traffic and Transportation

4.3.25 As with many lowland rivers, the flat topography of the floodplain has resulted in the development of major roads and railways. Significant roads which cross the Trent include the M1 south of Nottingham, the A38 near Burton and several arterial roads into Nottingham. There are several proposals for new and upgraded roads across the floodplain.

Soil, Geology and Hydrogeology

Geomorphology

4.3.26 The River Trent has had a complex geomorphological history and has been shaped by the impact of ice, flooding, sea level changes and man. These have caused significant changes to its route and character.

Geology

4.3.27 The Trent rises from the Carboniferous Millstone Grit on the west flank of the Pennines in Staffordshire. The river flows across the Triassic Sherwood Sandstone and Mercia Mudstone formations, except beneath Stoke-on-Trent and Cannock Chase, where Coal Measures are exposed. The Trent itself has deposited a blanket of sand, gravel and alluvium across the valley floor which conceals the solid geology beneath it.

Soils

4.3.28 It is likely that some sites within the floodplain were used in the past for the disposal of hazardous and domestic waste, although the location of contaminated land was not investigated as part of this study. There are no known ongoing environmental impacts on habitat or water quality from contaminated land sites on the Trent itself.

4.4 Significant Opportunities and Constraints

4.4.1 The size of the Trent catchment means that the opportunities provided by flood alleviation are significant. The opportunities resulting from the generic flood management options are dealt with in **Appendix C**.

4.4.2 The quality of the environment has become degraded along much of the Trent Valley. Therefore, any physical works associated with flood management are an opportunity to enhance the local environment for biodiversity, recreation, education and landscape. In particular, there should be opportunities to target enhancement to national and local BAP habitats and species. Losses and gains of BAP habitats through any schemes should be recorded to ensure an overall strategic benefit.

4.4.3 Farmland has been identified by English Nature as a major opportunity for habitat creation and maintenance, and species protection and enhancement. Therefore, any options that may change the existing farm management practices would provide opportunities to enhance the area for biodiversity. Changes in land management or land use may occur through increased flooding, severance, or through the need to purchase land to implement an option. Changes in the CAP and the agri-environmental grant schemes will be important factors in this. Biodiversity benefits can only be maximised through positive management.

4.4.4 A number of initiatives are already in place to enhance the natural environment, for example, OnTrent, Central Rivers Initiative, the Great Riverscape, Nottingham Riverside and Rivers of Renewal. These are listed in **Appendix A** and many share similar objectives to this study. A section of the Trent also falls within the National Forest and partnership opportunities exist for woodland creation.

4.4.5 Site specific enhancement opportunities are highlighted in the detailed assessments for each flood cell in **Appendix C**. These opportunities are directly related to the flood management options under consideration but significant opportunities not directly related to flood management are also identified.

5 FACTORS AFFECTING FLOOD MANAGEMENT

5.1 Potential Influences on Flood Risk

5.1.1 The development of appropriate measures to manage flood risk requires an understanding of how the flood risk is likely to change in the future. The following factors will have a significant impact on future flood risk: -

- Urban Development
- Land Use Planning and Land Management
- Climate Change

5.1.2 These factors are considered over a time horizon of 50 years.

Urban Development

5.1.3 The Trent Catchment is predominately rural. Although there are large urban areas, such as Birmingham, Derby and Nottingham, only a small percentage of the catchment is classed as urban.

5.1.4 Using guidance from the Flood Estimation Handbook, the percentage increase in urban area for the catchment over the next 50 years is likely to be less than 1%. The impact of this on peak flows would be negligible and, therefore, in terms of assessing strategic flood risk management options, urban development is ignored.

5.1.5 It is acknowledged that, for example, through Stoke on Trent where the catchment area is small but highly urbanised, significant development could increase water levels during extreme flood events. Accordingly, it is recommended that Sustainable Urban Drainage Systems (SuDS) should be adopted on all new developments. This could help offset the effects of any increase in effective urbanisation of the catchment in the future.

5.1.6 **Section 6.2** provides more details on the assessment of SuDS as a flood risk management option.

Land Use Planning and Land Management

5.1.7 Currently, the level of understanding of the effects of land use and management on large catchments, like the Trent, is limited. Various field studies have been undertaken on small catchments in the UK, but there remains a large degree of uncertainty as to whether these findings will scale up to larger catchments.

5.1.8 Therefore, the study does not take into account any changes in land use planning and management. It may, however, be feasible to consider these in the future reviews of the strategy or as part of the Trent CFMP.

5.1.9 Locally, it is appreciated that land management could provide benefit to the immediate environment and receiving watercourse. Accordingly, it is recommended that appropriate land management practices should be adopted as 'best practice', wherever possible.

5.1.10 **Section 6.2** provides more details on the assessment of Land Management as a flood risk management option.

Climate Change

5.1.11 The UK Climate Impacts Programme (UKCIP) indicates that winters may become wetter and summers drier. Nationally, this is likely to result in a reduction of up to 50% on summer precipitation by the 2080s with winter precipitation increasing by up to 30%.

5.1.12 Of particular interest to the Trent basin, is the simulation modelling work undertaken by Crooks *et al*[3], which assessed the likely climate change effects on the Trent, Severn and Thames basins over the next 10 to 50 years. This concludes that, as a result of the enhanced rainfall, the 50-year flood flows for the Trent could increase by a maximum of some 10%.

5.1.13 Defra also recognises that some aspects of the expected climate change will have an impact on flood defence and coastal management. In April 2003, a Supplementary Note to the FCDPAG guidelines was issued, entitled 'Climate Change consideration for flood and coastal management'. This recommends testing the sensitivity of any proposals to changes in climate by increasing peak flows by 20% over a 50-year period.

5.1.14 **Section 5.3** deals with the sensitivity analyses for climate change in more detail.

5.2 Funding Constraints

5.2.1 From April 2004, most capital works schemes undertaken by the Agency will be effectively funded out of general taxation, although Flood Defence Committees can continue to raise local levies for schemes in their areas. Defra are the appropriate Government department which oversees flood risk management. Their decision on whether a scheme is to receive funding is based on an appraisal of technical, environmental and economic factors; the guidelines are detailed in the FCDPAG document series.

5.2.2 A scheme could be both technically and environmentally feasible but unless it is economically viable, it cannot be promoted by the Agency. This decision is based on the following core criteria: -

- The benefit/cost ratio
- The priority score

[3] Modelling the Flood Response of Large Catchments: Initial Estimates of the Impacts of Climate Change and Land Use Change. Maff Project FD412, 1996.

Benefit/Cost Ratio

5.2.3 For a scheme to be economically viable, its cost must be less than the damages caused by flooding of the infrastructure; it must have a benefit/cost ratio greater than 1. The calculation of benefits is undertaken using standardised guidelines and figures, provided in FCDPAG and The Flood Hazard Research Centre's 'The Benefits of Flood and Coastal Defence: Techniques for 2003'.

5.2.4 Economic appraisals have a number of goals, which can be summarised as follows: -

- Best use of public money: Demands for public funding always exceed the money available. It is, therefore, necessary to target spending.
- Accountability: It provides a formal process of project appraisal. It demonstrates that a wide range of alternatives was considered and that the advantages and disadvantages of each were properly taken into account.
- Quality Assurance: Good economic appraisals save both time and money by the early rejection of unrealistic options and increase certainty and confidence in the final outcome.

5.2.5 **Section 6.2** provides more details on the methodology adopted to appraise the various flood risk management options.

Priority Score

5.2.6 The economic analysis confirms the justification for a scheme but, in itself, it is not considered to be the best indicator of priority.

5.2.7 Defra has, therefore, introduced a logical, transparent and equitable system of prioritisation to ensure that funds are properly invested. The 'Scheme Prioritisation System' was introduced in March 2002. The priority score is based on the following criteria: -

- Economics
- People
- Environment

5.2.8 The above elements are scored separately and summed to provide a total priority score. The maximum potential score is 44. Current Defra guidelines are that schemes constructed during financial year 2003/04 should have a minimum score of 22. For 2004/05, the figure is 20. As the more worthwhile schemes are promoted, Defra anticipate that the minimum priority score will reduce year on year.

5.3 Future Flood Risk and Problem Areas

5.3.1 As discussed in **Section 5.1**, it is a requirement of the FCDPAG supplementary note of April 2003, that a sensitivity assessment of climate change is undertaken to identify potential future flood risk and problem areas.

5.3.2 A climate change option for 2054 was represented in the hydraulic models by increasing the 1 in 100-year flows across all the tributaries by 20%. **Table 5.1** provides an indication of the potential impacts of climate change for key hot spots across the study area.

Table 5.1: Potential Impacts of Climate Change

Location	Applicable Flood Cells	Average Water Level difference between 2004 and 2054 (mm)
Stoke On Trent	1.1 to 1.9	210
Rugeley	2.9	170
Burton Upon Trent	3.1 to 3.6	350
Willington	3.8	140
Barrow Upon Trent	3.11	310
Attenborough – Nottingham	4.5	350
Colwick – Nottingham	4.25 & 4.29	400
Stoke Bardolph	4.31	270
Gunthorpe	4.36	300
Hoveringham	4.38	370
Bleasby	4.40	290
Farndon	4.44	370
Newark	4.46 & 4.48	470
Cromwell Weir	4.55	240

5.3.3 These results show that the areas most sensitive to climate change are the highly urbanised ones, such as Burton, Nottingham and Newark, where the river is constrained by defences. Over time, the standard of protection provided by such defences will reduce.

6 OPTION APPRAISAL

6.1 Approach

6.1.1 Following consultations during the early stages of the study, a list of generic flood risk management options was compiled and taken forward for consideration. **Table 6.1** summarises the options.

Table 6.1: Generic Options

No.	Name	Description
1	Do Nothing	Undertake no further maintenance or construction work whatsoever on the watercourse
2	Do Minimum	Continue to undertake present day maintenance and flood warning tasks, but would not construct any new schemes.
3	Off-line and Floodplain Storage	The increase in capacity, or managed use of available floodplain storage
4	On-Line Storage	The creation of a water retaining structure(s) across the valley to create a flood storage area(s)
5	Managed Retreat	Abandon flood defences and defended property and revert back to a natural floodplain
6	Development Control	Prevent development within areas that are at risk from flooding
7	Sustainable Urban Drainage Systems	Drainage systems that mimic natural processes, such as allowing water to soak into the ground.
8	Managing the Effects of Floods	Raise awareness of flooding issues, including the use of local flood-protection measures
9	Land Management Options	Change land use to reduce the amount and rate of runoff to local watercourses
10	Weirs and Sluices	Manage water levels in the river using existing, or new control structures
11	Groundwater Recharge	Divert flood water into natural underground aquifers
12	Underground Tanks	Divert flood water into man made underground tanks
13	Dredging	Mechanically remove sediment from the river bed to increase the capacity of the river channel
14	Remove Floodplain Obstructions	Remove, or modify structures that have a detrimental effect on water levels within the floodplain
15	River Re-profiling	Re-build the river channel to aid the dispersal or storage of flood flows
16	Flow Diversion	Create artificial channels to divert flood water
17	Tributary Storage	Retain water within tributary catchments to reduce flows in the Trent
18	Defences	Raise existing, or construct new barriers to protect property from flood water

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Table 6.2: Summary of Impacts of General Strategic Options

Receptors	Human Beings			Flora & Fauna	LVA	Water			Land Use		CH	TT	Soil, Geology and Hydrogeology			UNR
Sub-Receptors **GENERIC STRATEGIC OPTIONS**	Provision of goods and services	Health and safety	Quality of life and standard of living	Habitats & Species	Landscape & Visual Amenity	Quality	Quantity	In channel hydraulics	Built Environment	Agriculture & Forestry	Archaeological Sites & monuments	Transport & Travel	Geological/ Geomorphological features / processes	Hydrogeology	Soil & Land Quality	Sustainable Use
Do nothing	🔴	🔴	🔴	⊘	⊘	🔴	=	🟢	🔴	🔴	🔴	🔴	⊘	=	🔴	🟢
Do minimum (maintain existing defence to current defence level and flood warning as current)	🔴	🔴	🔴	⊘	🔴	=	=	🟢	🔴	🔴	🔴	🔴	⊘	=	⊘	🔴
Off-line storage	🔴	🔴	🔴	🟢	🔴	=	=	⊘	🔴	🔴	⊘	🔴	⊘	🟢	⊘	🔴
Washlands and Natural floodplain	🔴	🔴	🔴	🟢	🟢	=	=	🟢	=	🔴	🟢	⊘	🟢	🟢	⊘	🟢
On-line storage	🔴	🔴	🔴	🟢	🔴	=	=	⊘	🔴	🔴	⊘	🔴	🔴	=	⊘	🔴
Managed retreat	🔴	🔴	🔴	⊘	🔴	🔴	=	🟢	🔴	🔴	🔴	🔴	⊘	=	⊘	🔴
Hard defences (new or raised)	🟢	🟢	🟢	🔴	🔴	🟢	=	🔴	🟢	⊘	⊘	🟢	🔴	=	⊘	🔴
Development Control	🟢	🟢	🟢	🟢	🟢	=	=	🟢	=	🟢	🟢	=	🟢	=	=	🟢
Sustainable Urban Drainage Systems	=	🔴	🟢	🟢	🟢	🟢	⊘	🟢	⊘	=	🔴	=	🟢	🟢	🟢	🟢
Flood warning and forecasting and flood proofing	🔴	🔴	🔴	⊘	🔴	=	=	⊘	🔴	🔴	🔴	🔴	⊘	=	⊘	🔴
Changes in Land Management/Best Farming Practice	⊘	=	⊘	🟢	⊘	🟢	⊘	⊘	=	⊘	🔴	=	⊘	⊘	🟢	🟢
Afforestation/Floodplain woodlands	🟢	=	🟢	🟢	⊘	🔴	=	🔴	=	⊘	🔴	=	🔴	=	⊘	🔴
Weirs and sluices (adding)	=	🔴	⊘	🔴	🔴	⊘	⊘	🔴	=	=	🔴	=	🔴	⊘	=	🔴
Weirs and sluices (removing)	=	🟢	⊘	🟢	⊘	⊘	⊘	🟢	=	=	🔴	=	🟢	⊘	=	🟢
Groundwater recharge	=	=	=	⊘	🔴	🔴	⊘	🔴	=	⊘	🔴	=	🔴	🔴	⊘	🟢
Underground tanks	=	=	🔴	🔴	🔴	=	⊘	⊘	=	⊘	🔴	=	🔴	🔴	=	🔴
Dredging	=	🔴	⊘	🔴	🔴	🔴	=	🔴	🔴	=	🔴	🔴	🟢	🟢	⊘	🔴
Removal of obstructions	=	🟢	⊘	⊘	⊘	=	=	🟢	🔴	🟢	🔴	🔴	⊘	⊘	⊘	🟢
River re-profiling	⊘	⊘	⊘	⊘	⊘	🔴	⊘	🔴	⊘	⊘	🔴	⊘	🔴	⊘	⊘	🔴
Flow diversion - new channel	⊘	⊘	⊘	🔴	⊘	⊘	=	🔴	⊘	🔴	🔴	⊘	🔴	=	🔴	🔴
Flow Diversion - Canal	🟢	🔴	🟢	🔴	🔴	🔴	=	🔴	🔴	⊘	🔴	🔴	🔴	=	=	🔴
Tributary Storage	⊘	⊘	⊘	⊘	⊘	⊘	⊘	🔴	⊘	⊘	⊘	⊘	🔴	⊘	⊘	🟢
River Maintenance	=	🟢	🟢	🔴	⊘	🔴	⊘	🔴	🔴	=	🔴	⊘	🔴	⊘	⊘	🟢

KEY

LVA = Landscape & Visual Amenity

CH = Cultural Heritage, Archaeology & Material Assets

TT = Traffic & Transport

UNR = Use of Natural Resources

🔴	Major negative
🔴	Moderate negative
🔴	Minor negative

🟢	Major positive
🟢	Moderate positive
🟢	Minor positive

=	No impact/neutral
⊘	Change (can be combination of positive and negative impact, or too uncertain or subjective to classify)

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Technical Appraisal

6.1.2 All the generic options presented in **Table 6.1** were initially subjected to a high level technical review to assess their suitability. The methodology for this included a review of available data and, where appropriate, the option was incorporated into the hydraulic models. **Section 6.2** provides information on the outcome of this review; it identifies those options recommended for further consideration and those discounted.

6.1.3 The development of the hydraulic models forms an important and integral part of the study. The modelling was undertaken by dividing the river into 4 separate reaches. This was done to ease data handling and manipulation. **Appendix F** describes the model build and calibration processes.

6.1.4 At the outset of the strategy, consideration was given to the most appropriate method of river modelling, taking into account the requirements of the Agency's Specification for Section 105 – Flood Risk Mapping. An ISIS 1-D mathematical model was adopted for the following reasons: -

- The length of river under consideration.
- The extent and detail of the required channel and floodplain survey information.
- The change in floodplain width and conveyance over the length of the river.
- The principal requirement to produce peak levels and flows for a range of return periods at 'hot spot' locations along the Trent.

6.1.5 The hydraulic models enabled those areas at risk from flooding to be identified. Following the high level review, the remaining options were assessed for each flood location. This identified some 95 specific flood management options.

6.1.6 Each option was subject to a detailed technical analysis which comprised: -

- A site visit and desk study to assess suitability and clarify any specific mitigation measures.
- The use of the models to assess the hydraulic effectiveness and the extent of any upstream and downstream effects.

6.1.7 Where the site visit or desk study indicated that the option was unsuitable, modelling was not necessarily undertaken. **Section 6.2** provides details of the options and the results of the individual technical appraisals.

Environmental Appraisal

Stage 1

6.1.8 A Strategic Environmental Assessment (SEA) of the generic options highlighted at the scoping stage was undertaken. No specific locations were identified and this assessment was high level, but included consideration of the following: -

- Direct, indirect, cumulative, permanent, positive, negative and secondary effects.

- Mitigation and the degree of viability.
- Environmental enhancement opportunities including partnerships.
- Responses from consultees on the Scoping Report.

6.1.9 A description of this SEA is provided in **Section 6.2** and **Appendix C**.

6.1.10 Following the SEA, and in combination with a high level technical appraisal, generic options were developed for specific locations at risk from flooding.

Stage 2

6.1.11 A pre-feasibility Environmental Impact Assessment (EIA) was undertaken for each flood cell, or group of flood cells with similar characteristics. Only the 'Do-Nothing' and 'Do Minimum' plus the specific flood management options were assessed. This EIA process is further described in **Appendix C** but it included: -

- A review of desk top data.
- A site visit to visually assess the impact of options on the existing environment.
- The production of a matrix for each location, summarising the key impacts, mitigation and enhancement or partnership opportunities.
- A decision on whether an option is environmentally acceptable.
- The identification of preferred environmental options. It is feasible to have more than one per flood cell.

6.1.12 The EIA matrices are contained in **Appendix C** and summarised in **Section 6.3**.

Economic Appraisal

6.1.13 Only those specific flood management options which satisfied both the technical and environmental assessments, were carried forward for an economic analysis.

6.1.14 The initial stage was to construct an economic model, which was divided into 4 reaches to mirror the river models. The technical software specified to undertake the economic modelling is ESTDAM version 2.1.

6.1.15 ESTDAM was developed by Middlesex University's Flood Hazard Research Centre and version 2.1 was released in 1994. It uses flood depths from the hydraulic models to derive the benefits arising from flood alleviation works. More details on the methodology are provided in **Appendix C**.

6.1.16 Costs were calculated for each option, using information from various sources including, previously completed flood defence schemes, CESMM and the draft release of the Agency Unit Cost Database. The total cost for each option includes for: -

- Construction
- Landscaping
- Project appraisal and design

- Environmental Impact Assessment
- Site supervision

6.1.17 In addition to the above elements, an optimism bias figure of 60% was adopted to take into account the difficulty in estimating scheme costs using limited data; this is in accordance with Defra guidelines.

6.1.18 **Appendix C** includes a summary of the costs of the options.

6.1.19 In addition to the benefit/cost ratio for each option, the priority score was also evaluated.

Preferred Options

6.1.20 A list of preferred options was drawn up to include those that were economically, technically and environmentally acceptable.

6.2 Generic Option Appraisal

DO NOTHING

Description

6.2.1 In flood defence terms, this means that nothing would be done with regard to flood warning and no new flood alleviation schemes would be promoted. No maintenance work to the channel or the existing flood defences would be carried out.

Technical Assessment

6.2.2 The consequences would be the gradual deterioration of the watercourse and any existing flood defences, leading to the eventual failure and breaching of the defences. As the existing defences deteriorate and blockages are not cleared, the standard of protection would reduce.

6.2.3 Do nothing is used as the benchmark to assess the economic viability of all options. The effects of undertaking river maintenance are detailed for the "Do Minimum" option and this gives guidance on how these are quantified.

Environmental Assessment

6.2.4 The main positive impact would be that the natural floodplain would gradually re-establish over time and natural hydrological processes would develop. As the defences fail, the channel could develop a more natural course. However, although much of the Trent has been modified in some way, the main sections of flood defences are in urban areas where the environmental benefits would be minor and the negative social impacts significant. In addition, there would not be the option to manage these areas pro-actively for bio-diversity or recreation, although there are likely to be bio-diversity gains.

6.2.5 The do nothing option would also mean that existing control structures, culverts and flap valves would not be maintained. This could result in the long term failure of such structures leading to blockages. This would impact on the natural river processes and could also disrupt transport networks. Areas not previously known to flood may be at risk. Structures may be of historical value and any lack of maintenance or failure could have a significant local visual impact. Where sluices and flap valves fall into disrepair, this could affect drainage into the Trent and cause localised flooding behind the defences.

6.2.6 Over time, existing defences would fail and previously defended areas would flood. Most defences protect significant urban centres and, therefore, this could have very significant negative environmental impacts on public health and safety, property, and the existing natural and cultural value of the area.

6.2.7 As the whole river regime is likely to change in the long term, areas previously at flood risk may now not be affected. Conversely, areas currently not within the 100-year floodplain may eventually be at risk of flooding.

DO MINIMUM - INCLUDING MAINTENANCE AND FLOOD WARNING

Description

6.2.8 In flood defence terms, this means that only activities such as maintenance of the existing flood defences to the present standard, flood warning and channel maintenance would be carried out. As a result of climate change, the standard of protection would reduce with time.

6.2.9 River maintenance includes the management of riverside trees and vegetation, localised dredging and the removal of actual, or potential, obstructions.

Technical Assessment

Assessment Methodology – Maintenance

6.2.10 A major effect of a lack of maintenance would be blockage of culverts and bridges by debris. This would restrict flows and raise water levels upstream. The blockage of structures was simulated using the hydraulic models. The economic damages associated with blockages are quantified for all flood risk locations.

Assessment Methodology – Flood Warning

6.2.11 The major advantage of flood warning is that it allows those households and businesses at risk to move some of their possessions out of reach of the flood waters. The effectiveness of flood warning depends on the likelihood of people being able to receive and respond to the warning in sufficient time.

6.2.12 Flood warning is an integral part of the Agency's overall flood risk management strategy and the current procedures for the Trent discussed in **Section 3.4**.

Environmental Assessment

6.2.13 There would be significant social and economic benefits in maintaining the existing flood defences as several major urban areas are defended. However, the do minimum option would mean that areas which currently flood would remain in the floodplain.

6.2.14 Under the do minimum option, defences are likely to fail in the long term. Although they would be repaired, there would be a period beforehand when the area would be at a much greater risk of flooding. This could have significant environmental impacts on both people and the natural and built environment.

6.2.15 Insurance for properties in undefended areas is likely to remain an issue. Properties in the presently defended areas may also attract higher insurance premiums as a result of the gradual deterioration in the defences and the increase in flood risk.

6.2.16 Many consultees have highlighted that much of the river is now disconnected from its floodplain. Under this option, this would still be the case, except possibly through long-term climate change. Neither would the option address areas where the existing standard of protection of a defence is not considered to be adequate.

6.2.17 Whilst flood warning has obvious benefits in reducing risks to property, life and livestock, it is not guaranteed to reach everyone and, therefore, carries an inherent risk. Areas at new or increased flood risk would not benefit from improved flood warning under these cicumstances.

6.2.18 Only targeted maintenance is currently carried out on the Trent and, therefore, the associated environmental impacts are generally minor and local. Impacts of maintenance are more fully described in **Appendix C.**

6.2.19 More details on the environmental issues of the 'do-minimum' option are provided in **Appendix C** and a summary is given in **Table 6.2.** In conclusion, it is considered to be environmentally acceptable and the preferred environmental option for areas which do not contain significant populations, regionally important transport networks or nationally important natural or cultural features. However, where the value of natural or cultural features is dependent on the current flooding regime, do-nothing may also be the preferred environmental option. Examples of this would be wetlands or areas of archaeological importance that are preserved by high water levels.

6.2.20 The do-minimum option is not considered environmentally acceptable where there would be significant environmental impacts through the short term failure of defences and reduced level of protection through long term climate change. These are likely to be mainly urban areas.

OFF-LINE AND FLOODPLAIN STORAGE

Description

6.2.21 Significant areas of natural floodplain exist within the Trent catchment. The use of these to store floodwaters could be by the following two sub-options, which are detailed in the Scoping Report: -

- Off-line storage with embanked areas of floodplain.
- Floodplain, or washland storage; the use of areas within the floodplain that are unprotected from flood events and flood naturally.

Off-line storage on the Trent, near Rolleston (Notts) during a small flood event; note the River Trent on the left and water in storage on the right.

Washland storage on the Trent near Twyford during a small flood event

6.2.22 Many of the technical and environmental issues surrounding the two options are similar and, for the purposes of this study, they are considered as a single option.

6.2.23 The use of floodplain storage is an entirely natural process within all river systems and, on average, a river will typically flow out of bank once every two years. During

large flood events, such as November 2000, vast areas of the River Trent floodplain were inundated.

6.2.24 Embanked off-line flood storage areas should be protected from flooding during the smaller events; this provides better control of the larger flood events. The areas often result in, or are a consequence of, the protection of farmland from low return period flooding.

6.2.25 During larger events, inundation of the land behind off-line storage embankments will occur at a later time. This potentially allows the available storage capacity to be used to store water from the peak of the event, leading to reduced flood levels.

6.2.26 Conversely, floodplains can be fully inundated and all available storage capacity is utilised prior to the arrival of the main flood peak. This would have minimal effect on water levels, either locally or further downstream.

6.2.27 There are extensive areas of gravel pits within the Trent valley, which appear to offer potential storage. However, in reality, a gravel pit is unlikely to significantly increase the available storage. Due to the permeable nature of the strata, groundwater is likely to flow into the pits over time unless some form of permanent dewatering or impermeable lining is provided. Such works would be extremely expensive.

6.2.28 Due to the size of the Trent catchment, peak flows are extremely high and of long duration, hence, a vast amount of additional storage areas would be required to have a significant effect on water levels.

Technical Assessment

The Current Situation

6.2.29 The 100-year floodplain maps provide the best insight into the extent of the current floodplain.

6.2.30 To assess current off-line storage areas, data for all known flood defences along the Trent corridor was reviewed. In Upper Trent, no low level banks were identified that currently form off-line storage areas. Data for Lower Trent indicates that there are a number of 'minor' flood banks, which currently offer a low standard of protection to agricultural land. These banks are particularly evident near Long Eaton and between Nottingham and Newark.

Assessment Methodology

6.2.31 Efforts were concentrated on increasing or making best use of available floodplain storage. The creation of off-line storage areas on existing undefended floodplain was assessed, together with the raising or removal of existing low-level flood banks. The following options were identified and taken forward for further consideration: -

- Option 2.4; remove flood banks upstream of High Bridge.
- Option 2.6; create an off-line storage area on the left bank between Yoxall Bridge and Wychnor, using low-level flood banks.

- Option 3.1; increase available floodplain storage upstream of Burton at Catton Park, behind Branston railway and at Drakelow Power Station.
- Option 4.16 and 4.18; assess raising or the removal of the low-level flood banks around the Shelford storage area
- Option 4.22; assess the sensitivity of river levels to the available floodplain and gravel pit storage near Hoveringham.
- Option 4.35; assess raising or the removal of the low-level flood banks between Rolleston and Staythorpe.

6.2.32 Further details on these detailed assessments are provided in **Section 6.3.**

Environmental Assessment

6.2.33 The use of washlands is favoured by many consultees as it is sustainable and uses natural river processes. It also allows opportunities to maximise biodiversity. For instance, an objective of English Nature's Natural Areas initiative is to retain and, where necessary, enhance the physical and biological diversity of rivers and streams, including bank, floodplain and channel features and their associated communities. Floodplain grazing marshes are also identified as characteristic of the Trent Valley and Rises Natural Area. The use of washlands would provide an opportunity to create and manage habitats to increase the overall biodiversity of the Trent Valley. Less intensive land management of washlands could also create opportunities for informal recreation.

6.2.34 The use of off-line storage would be less beneficial for the natural environment. Low banks would decrease connectivity between the river and its floodplain. The storage area would flood infrequently and, therefore, offer less potential opportunities to enhance biodiversity.

6.2.35 The use of off-line storage areas and washlands would affect land use. These areas are likely to be agricultural and increased flooding may affect current farming practices and productivity. This impact would be more significant for washlands where flooding would be more frequent.

6.2.36 Water levels can be crucial in preserving Scheduled Ancient Monuments or other areas of archaeological interest. Therefore, impacts of changes in the flooding regime in any such area would need to be assessed.

6.2.37 The impacts on any communities in, or adjacent to, these storage areas would need to be assessed. Potential impacts include the effects of flooding of properties or access routes within storage areas. Flood banks around off-line storage areas may also have an impact on both landscape and access.

6.2.38 More detail on the environmental issues of off-line and washland storage is included in **Appendix C** and a summary is given in **Table 6.2.** Both are considered environmentally acceptable, although the use of washlands is preferred, as it is more sustainable and allows natural river processes. All proposed locations would require an Environmental Impact Assessment.

ON-LINE STORAGE

Description

6.2.39 On-line storage involves the attenuation of flows in the river in order to raise upstream levels and increase the available flood storage volume. This could be achieved by constructing a new retaining structure with outlet controls or using an existing storage area, such as a reservoir. The only example of an on-line storage system within the catchment is at Kings Bromley, but this is only a small reservoir and it provides minimum additional storage opportunities.

6.2.40 Due to the magnitude and duration of floods on the Trent, the opportunities to adopt this option are limited. Significant areas of land would be required and water would be impounded to a significant height. This would lead to safety concerns and any such structure would probably have to comply with the Reservoirs Act; this applies to all structures which are capable of impounding in excess of 25,000m^3 of water.

An on-line storage reservoir under construction on a small watercourse; the photograph shows the upstream face of the dam and the control gates, which are used to regulate water flows.

Technical Assessment

Storage Volumes Required

6.2.41 Investigations were undertaken to estimate the storage volumes required to reduce flood peaks at various locations along the Trent. For the 7 key gauging stations between Stoke and North Muskham, the 100, 75 50, 25, 10 and 5-year flood hydrographs were considered.

6.2.42 The design hydrographs for each gauging station were capped to the maximum flow of the next lowest return period. For example, the 100-year hydrograph was capped to the maximum flow of the 75-year hydrograph. The differences in flow volume between the full and capped hydrographs are given in **Table 6.3.**

Table 6.3: Estimated Storage Volumes Required to Cap Hydrograph Flows

Station	Storage Volume Required (x1000m^3)				
	100-75yr	75-50yr	50-25yr	25-10yr	10-5yr
Stoke	64	71	162	198	62
Darlaston	79	114	230	315	181
Yoxall	455	805	1430	1942	1395
Drakelow	732	1291	4655	4570	4036
Shardlow	1021	2006	7744	6645	7399
Colwick	1598	2971	7741	16291	11380
Muskham	2253	4061	10947	22856	16774

(*Note: this table assumes no use of storage prior to the set flow)*

6.2.43 **Table 6.3** shows that considerable volumes of water would need to be stored. Realistically, on-line storage could only be considered upstream of Shardlow. As a guide, a standard football pitch flooded to a depth of 1m would store approximately 9500m^3 of water; this is equivalent to 9.5 (x1000m^3) in the above table.

Identification of Suitable Locations

6.2.44 It would be possible to create an on-line storage reservoir by restricting flow through the canal aqueduct in Rugely. This scheme (Option 2.1) was assessed further and details are given in **Section 6.3.**

6.2.45 It would also be possible to create an on-line storage reservoir upstream of Shardlow, near Weston-on-Trent, where the valley is relatively narrow. This scheme (Option 3.14) was assessed further and details are given in **Section 6.3.**

6.2.46 No other feasible locations were identified.

Environmental Assessment

6.2.47 On-line storage would still allow the natural floodplain to be used to store water. This area, however, may be greater than the current 100-year floodplain. Environmental impacts of flooding areas not previously subject to flooding would need careful assessment. The depth of stored water could also have additional impacts over the usual flooding regime, for example, on structures or habitats.

6.2.48 The construction of control structures, however, would impact on the natural river regime and potentially on any historic features. In-channel structures could have impacts on the passage of wildlife and navigation, as well as a visual impact. The release of water would also need to be carefully controlled to avoid downstream impacts of increased flows on banks, structures, boats and wildlife.

6.2.49 More detail on the environmental issues of on-line storage is provided in **Appendix C** and a summary is given in **Table 6.2.** It is considered environmentally acceptable, although it would require detailed Environmental Impact Assessment. At some locations it may be the preferred environmental option.

MANAGED RETREAT

Description

6.2.50 Managed retreat means the large scale abandonment of major flood defences and, therefore, the properties in the floodplain.

6.2.51 Where the long term defence of property or land is no longer economically viable, managed retreat, may become an option. It would offer the opportunity to increase available floodplain storage and, therefore, provide benefits similar to the off-line and floodplain storage options.

6.2.52 The managed retreat of low-level banks, which currently protect farmland, was considered as part of the off-line and floodplain storage options.

Technical Assessment

6.2.53 Other than Burton, there are very few formally defended areas in the Upper Trent. The managed retreat of such a large town is clearly impractical.

6.2.54 Interrogation of the 100-year floodplain maps for the Lower Trent shows that there are no areas where formal defences protect isolated properties. All major defences protect conurbations with significant numbers of properties and it is not possible to justify their abandonment.

Environmental Assessment

6.2.55 The environmental issues of managed retreat would be similar to those of creating washlands. The natural floodplain would be restored but there could be negative impacts of flooding land which was previously defended. The major defences currently along the Trent defend urban centres and managed retreat would, therefore, have significant impacts on communities, including physical damage to property and emotional distress.

6.2.56 If a small number of properties were to be affected, it may be possible to relocate them outside the floodplain. However, this would cause distress to the occupiers and have an economic impact on owners and businesses.

6.2.57 There would be the positive impact of reduced flood risk downstream. There would also be an assured standard of flood protection for communities behind the area of managed retreat. Good communication would be required, however, to reassure communities who may see floodwater closer to their homes than previously.

6.2.58 More details on the environmental issues of managed retreat are provided in **Appendix C** and a summary is given in **Table 6.2.** It is considered that this option is not environmentally acceptable due to the significant impacts of flooding populated areas.

DEVELOPMENT CONTROL

Description

6.2.59 The objectives of development control are to ensure that new developments are not constructed at locations at risk of flooding and to prevent an increase in flood risk to others. Mitigation measures could be undertaken, such as building defences or raising land/floor levels above anticipated flood levels. However, if not properly managed, the subsequent reduction in floodplain capacity could be detrimental to other locations.

6.2.60 Development and planning control is crucial to minimise flood risk to both new and existing developments. Currently, PPG25 provides guidance to Local Planning Authorities on the control of development in flood risk areas. Where development is permitted, mitigation measures are required to ensure new developments would not reduce flood storage areas or lead to increased surface runoff to watercourses. The Agency are consultees and provide advice to Local Planning Authorities on all proposed developments.

Technical Assessment

6.2.61 The new floodplain maps are of key importance when considering future development. Their improved overall accuracy should enable more informed decisions to be made.

6.2.62 Where developments are proposed on the fringe of 100-year floodplain, it should be borne in mind that a more detailed study could result in revisions to the extent of the floodplain locally. This applies to developments currently just inside and outside the 100-year floodplain. Accordingly, in such circumstances, it is recommended that local assessments are undertaken.

6.2.63 Development control, other than that for specific locations, is not an option that lends itself to direct quantification using the hydraulic models. Any small scale changes to runoff from developments within the Trent corridor or the catchments of the major tributaries, would not have a quantifiable effect on water levels, particularly where the Trent is more mature.

6.2.64 Around Stoke, due to the high level of urbanisation of the catchment and the number of smaller tributaries, it is possible that individual developments could have a measurable effect on flood flows. However, no major proposed developments are planned for this reach. It is possible that the generally predicted increase in urbanisation would affect flows at Stoke and this is considered in further detail under Sustainable Urban Drainage Systems (SuDS) in **Section 6.2**.

Environmental Assessment

6.2.65 Development control may only provide localised benefit for flood alleviation. However, it is often a very important issue to local residents, who see ‘inappropriate’ development near their homes. Many larger environmental and government organisations also see it as a key issue. It has the advantage of being a non-intrusive and a sustainable option, as no physical works are involved.

6.2.66 The control of development outside the floodplain also needs to be considered due to the impacts on runoff. This is closely linked to the implementation of SuDS. To be effective, development control requires Local Planning Authorities to be fully informed of flood risks and for all government agencies to have legal authority to enforce decisions.

6.2.67 The restriction of development in the floodplain could create good opportunities for sites to be developed for nature conservation and/or recreation. In urban locations, this could lead to an improved living environment.

6.2.68 Development control, however, could have a significant impact on the local community by restricting development and economic growth. Existing 'brownfield sites' may become derelict, if permission for their redevelopment is refused. Having derelict structures in the floodplain would not benefit flood defence or provide any other environmental benefit. It may also force development into more sensitive sites.

6.2.69 More detail on the environmental issues associated with development control is provided in **Appendix C** and a summary is given in **Table 6.2.** Development control is considered environmentally acceptable and is preferred as general good practice that should be implemented throughout the catchment. However, as it does not address those areas currently at risk from flooding, it should not be considered as a stand-alone option.

SUSTAINABLE URBAN DRAINAGE SYSTEMS (SuDS)

Description

6.2.70 The objective of SuDS is to reduce the rate of urban runoff from developed areas. Traditional urban drainage systems promote rapid runoff into the receiving watercourses. This increases the speed of response of the watercourse to rainfall, the percentage of rainfall entering the watercourse and the flood peaks. Methods such as storage areas, porous pavements, grass strips, soakaways, rainwater recycling and filter drains are essentially an attempt to mimic natural drainage processes and reduce the rate of runoff during storm events.

6.2.71 In addition to reducing flood peaks, SuDS could result in improvements in river water quality because of the filtering effect on pollutants from the urban areas.

A roadside soakaway; an example of the application of SuDS.

Technical Assessment

Introduction

6.2.72 It is likely that SuDS would have the most noticeable effect on flood flows in the upper reaches of the Trent, around Stoke. At this location, the catchment is small and a substantial proportion of it is urbanised. At Burton or Nottingham, for example, surface runoff from these urban areas is not a significant percentage of the peak river flow. Large flood events in these areas are dominated by flows already in the Trent.

6.2.73 Retrofitting SuDS to existing developments could be impractical and would be relatively expensive. Retrofitting on a scale that would affect flows during major flood events would be impractical. Accordingly, this has not been considered further.

6.2.74 However, whilst the effects of SuDS in the lower parts of the catchment are unlikely to be quantifiable using current modelling techniques, this should not preclude their implementation as a ‘best practice’ approach.

Further Assessment

6.2.75 Despite a lack of research to quantify the effects of SuDS on a catchment wide scale, attempts were made to do this for the upper reaches of the Trent. Further details on this can be found in **Appendix C.** It shows that, although subject to several key assumptions, SuDS could have a positive and quantifiable effect on flood flows, if applied to all new developments in Stoke.

Environmental Assessment

6.2.76 SuDS have the potential to increase local bio-diversity and improve water quality. Wetlands can often have a positive impact on the community by providing informal amenity opportunities and improved landscape. However, public health and safety must be considered in the creation of open water habitats.

6.2.77 SuDs are often not fully sustainable, as they require ongoing maintenance for effectiveness. Who is responsible for maintenance also needs to be clearly identified at the outset and maintenance costs included in the budget. There could also be impacts on existing nature conservation, archaeological and landscape interest.

6.2.78 More detail on the environmental issues associated with SuDS is provided in **Appendix C** and a summary is given in **Table 6.2.** They are considered to be environmentally acceptable and best practice for all new developments. However, the most suitable measure at each location would need to be environmentally and technically assessed. The possibility of introducing retrospective SuDS to existing developments is also environmentally preferred, although, as it is likely to be disruptive and costly, Accordingly, sites should be targeted where there would be the most benefits.

MANAGING THE EFFECTS OF FLOODS

Description

6.2.79 It may not be feasible or economically viable, to protect properties in certain flood risk areas. Under such circumstances, it may be appropriate to : -

- Raise people's awareness of flood risks and levels of protection.
- Raise their understanding of the need to take precautionary measures to minimise impacts on property and possessions.
- Improve their awareness of flood proofing measures, including portable flood barriers, door guards, air brick covers, etc.

6.2.80 Raising awareness of these issues has been a major aim for the Agency in recent years.

Flood proofing of a residential property.

Technical Assessment

6.2.81 It is recommended that flood proofing measures are considered for properties where no other cost-effective solutions can be identified. This option was taken forward and suitable locations were identified. Further details are presented in **Section 6.3.**

6.2.82 Funding for temporary flood proofing and protection measures is unlikely to be available from the Government under current legislation and, therefore, a detailed economic assessment of flood proofing was not undertaken.

6.2.83 Accurate flood warning could help to minimise impacts. Early flood warning can allow people time to implement flood proofing measures and protect some property, vehicles and livestock. It can also reduce the risk to human life. However, it is dependent on individuals receiving the warning and being able to understand it. In certain areas flood warning may not be practical due to very short warning times.

Environmental Assessment

6.2.84 Flood proofing would allow the natural floodplain to be partly maintained and, if effective, it could significantly reduce costs to the community. However, especially where flood proofing of individual properties is adopted, there would remain an impact on the quality of life with the residual anxiety caused by the risk of flooding. It also relies on accurate flood warning. Flood proofing cannot be guaranteed to be 100% successful and, therefore, some socio-economic costs would remain. Flood proofing may also damage historical features such as listed buildings.

6.2.85 More detail on the environmental issues associated with flood proofing is provided in **Appendix C** and a summary is given in **Table 6.2.** Flood proofing is considered environmentally acceptable and generally preferred except for the following locations:-

- Areas of significant populations, where flood proofing is likely to be impractical and the socio-economic costs of continued flooding would be significant.
- Areas where there are nationally important cultural or natural features which cannot be protected by flood proofing measures and that would be negatively affected by flooding.

6.2.86 Accurate flood warning is considered environmentally acceptable and preferred as best practice, but it may need to be used in conjunction with other options.

LAND MANAGEMENT OPTIONS

Description

6.2.87 Land management options would essentially rely on changing the way land is used in order to reduce the rate and quantity of runoff to the receiving watercourse. Such options were included in the Scoping Report under the following main headings but due to similarities in their approach, they are analysed as one generic group: -

- Changes in Land Management. Reduced intensity of agricultural practices, reduced grazing of upland areas and the use of gravel extraction areas.
- Best Farming Practices. The use of cover crops, reduced compaction of soils, changes in cropping practices.
- Afforestation and Floodplain Woodlands. The use of floodplain woodland to attenuate floodplain flows, use of headwater catchment forest to reduce runoff.

The compaction of soil by vehicles, leading to increased surface runoff.

Technical Assessment

6.2.88 The present understanding of the effects of land management options on rivers is extremely limited and subject to a large degree of uncertainty. However, relevant research findings were collated and used to assess the possible effects. Further details are provided in **Appendix C.** The assessment, although subject to uncertainty, shows that the correct implementation of appropriate land management options could slightly reduce surface runoff to the River Trent and its tributaries.

Environmental Assessment

Changes in land management and best practice farming techniques.

6.2.89 These options would likely require substantial areas to provide any significant flood benefit, and the environmental impacts, both positive and negative would be potentially large. Practically, sites would need to be assessed on an individual basis but general issues are discussed below and in **Appendix C.** In summary, it is

considered that changes in land management and the use of best practice farming techniques are environmentally acceptable and preferred as best practice.

6.2.90 The key to implementing these changes is the review of the Common Agricultural Policy (CAP). Changes in subsidies could have a significant effect on the rural economy and there would be a need for sufficient financial incentives for changes to be taken up on the necessary scale.

6.2.91 The impact of intensive agricultural practice has been widely documented as having negative impacts on biodiversity and water quality. Changes in management to less intensive methods should have a positive benefit on both. However, some species and habitats are dependent on agriculture. For example, cereal field margins are a key biodiversity habitat. Local BAPs should be reviewed to ensure no priority habitats or species would be negatively affected by significant changes in farming practices.

6.2.92 Current landscape within the Trent catchment is often defined by agricultural practice. Changes in land management could change the local landscape character. Historical landscapes are now being mapped and, therefore, land management changes may create an opportunity to return to an historic landscape. However, landscape quality can be a very personal view and many may value a highly managed agricultural landscape.

6.2.93 Archaeology is very sensitive to changes in land management, through either changes in water table or direct impacts through tilling or reversion to woodland.

6.2.94 Changes in upland land management would be in accordance with the objectives of many organisations, for example, English Nature's Natural Areas initiative. Changes in agricultural land management to less intensive methods and the re-instatement of upland heath is an objective of many organisations, including the Environment Agency, Defra and English Nature.

Afforestation

6.2.95 In appropriate locations, afforestation and floodplain woodlands could benefit BAP targets, landscape and water quality. It could also provide recreational and sporting opportunities and benefit the local economy by attracting visitors. The woods could be managed for traditional woodland products, new renewable energy or biomass projects. The National Forest in the Midlands will result in one third of the 200 square miles it covers being planted with trees over the next two decades. An opportunity exists, therefore, for partnership in creating floodplain woodlands or for changes in management in more upland areas.

6.2.96 Wet woodland is a characteristic habitat of the Trent Valley and Rises Natural Area. An objective of this initiative is to create new broadleaved woodlands around existing blocks and link small isolated fragments, for example, along river corridors. New floodplain woodland would, therefore, help towards this objective if carefully located.

6.2.97 The location of new woodland sites would need to be carefully considered. Sites may have existing nature conservation or archaeological value which would be negatively affected either directly by the planting of woodland or indirectly by changes in the local hydrology. They could also be inappropriate to the local landscape.

6.2.98 More detail on the environmental issues associated with afforestation is provided in **Appendix C** and a summary is given in **Table 6.2.** However, in summary, afforestation is considered to be an environmentally acceptable and preferred environmental option, subject to an assessment of impacts at an individual location.

WEIRS AND SLUICES

Description

6.2.99 The addition, removal or adjustment of weirs along the River Trent was noted in the Scoping Report as a flood management option. It is possible that, by using weirs to control water levels in the river, improvements could be made to some of the current flooding problems.

6.2.100 There are a number of problems with such use of weirs. Under flood conditions, many are drowned out. That is, they are fully submerged by water and there is little or no difference in water level upstream and downstream. Consequently, they have no hydraulic influence over water levels or flows. Also, adding or removing weirs could cause difficulties in maintaining the navigability of the river and could create problems with the stability of banks and existing riverside structures.

Cromwell Weir on the River Trent; the tidal limit of the Trent and the downstream limit of the strategy.

Colwick Sluices on the River Trent downstream of Nottingham.

Technical Assessment

Assessment Methodology

6.2.101 A key factor is to determine from the hydraulic models which existing weirs exert a hydraulic influence during peak flows. Where there is a notable head loss across a weir (i.e. the difference between upstream and downstream water levels), this could indicate the potential for upstream levels to be lowered by its removal. In cases where there are flood risk areas upstream of such weirs, the effects of their removal were assessed using the hydraulic models.

Initial Assessment

6.2.102 The model results indicate that the majority of weirs either have no effect on upstream levels or, where they do, there are no properties at risk. Details of this initial assessment are included in **Appendix C.**

Detailed Assessment

6.2.103 The following options were taken forward for more detailed assessment: -

- Option 1.2; remove Boothen Road Weir near the old football ground in Stoke.
- Option 4.14; remove Colwick Sluices.
- Option 4.24; assess the effects of Gunthorpe Weir
- Option 4.41; assess the hydraulic performance of Averham Weir and the potential benefits in Newark.
- Option 4.49; assess whether lowering or bypassing Cromwell Weir could reduce upstream flood levels.

6.2.104 Further details on these detailed assessments are provided in **Section 6.3**

Introduction of New Weirs

6.2.105 It is likely, particularly in the downstream reaches, that any such weirs would need to be extremely large to exercise any form of control. Colwick Sluices are an indication of the potential size of any new structure.

6.2.106 No locations were identified where new weirs would offer significant advantages to the current flood risk areas.

Environmental Assessment

6.2.107 The removal of weirs would increase the naturalness of the river and improve navigation and migration of wildlife. Although there would be a permanent impact on the current flow regime, in time the river would return to equilibrium. Although the location of pools and gravels used by fish and other fauna may change, they are unlikely to be lost overall. Any return to a more natural river regime is likely to be welcomed by nature conservation organisations, despite possible short term negative

impacts. Existing weirs or sluices could be of historic significance or provide a feature of local interest along the river.

6.2.108 Any new weirs or sluices would need to be designed to maintain navigation and passage for wildlife. If carefully designed, the introduction of new weirs may provide an opportunity for associated environmental enhancement of bankside habitats, the local landscape or recreational facilities.

6.2.109 The impacts on fisheries, recreation and nature conservation would need to be fully assessed through changes in flow regime as a result of any new structures. Impacts on existing landscape and archaeology would also need to be assessed.

6.2.110 More detail on the environmental issues associated with weirs and sluices is provided in **Appendix C** and a summary is given in **Table 6.2.** The removal of weirs or sluices would generally be environmentally acceptable and preferred, subject to EIA, as this would allow a more natural river regime. New structures would not generally be environmentally acceptable, although there may be locations where there would be significant environmental benefits associated with landscape or recreation.

GROUNDWATER RECHARGE

Description

6.2.111 Aquifers are naturally occurring beds of underground gravels or porous stone that contain water. The storage of river water in them could be used to recharge the aquifer and maintain underground supplies. Whilst recharge normally involves natural processes of rainfall and percolation, it is also possible to recharge aquifers artificially. This is often practiced in arid areas where rainfall is rare and intermittent, and runoff is rapid. Recharge usually requires the storage of runoff in a reservoir to allow time for the water to percolate into the aquifer. Whilst recharge is theoretically possible during times of flood, runoff is usually too rapid in temperate climates to allow significant quantities of water to enter an aquifer.

6.2.112 In the case of the River Trent, most of the major recognised aquifer units are in upland areas remote from the river. Much of the Trent corridor, particularly downstream of the Dove confluence, lies on impermeable rocks, notably the Keuper Marl, which has no direct links to major aquifers. Therefore, floodwater would need to be pumped significant distances. In flood events, where flows are in excess of $1000m^3/s$, this would be a major undertaking. There would be maintenance and operational issues concerning the infrequent use of this infrastructure.

6.2.113 Given the nature of the Trent catchment, with extensive agricultural land and significant urban areas, there is a risk of polluting the groundwater supplies. Sediment washed from farmland, pesticides and fertiliser residues from agricultural land and urban runoff would require significant treatment, with associated costs. Recent research in the USA has shown that even treated water used to recharge aquifers can have a detrimental effect on groundwater quality.

6.2.114 These factors indicate that groundwater recharge is not sustainable and would incur significant construction, operating and maintenance costs.

Technical Assessment

6.2.115 With the exception of the upper parts of the catchment, large flood events typically occur during the wetter autumn and winter months. The major events, such as November 2000, typically occur after a prolonged period of wet weather. During such events, levels in the aquifers tend to be high. Therefore, there is a high risk that the required storage volume would be not be available during a flood event.

6.2.116 In the vicinity of Stoke on Trent, where the catchment is relatively small and highly urbanised, large flood events are more likely to occur at any time of the year. For these events, groundwater recharge would be less problematical. Such schemes are, however, unlikely to be economically viable considering the relatively small number of properties at risk from flooding in Stoke during a 100-year event.

Environmental Assessment

6.2.117 In principle, the idea of recharging groundwater appears to have little environmental impact. However, there would be potential contamination of groundwater from floodwater and significant engineering works would be required.

6.2.118 In areas where aquifers are being depleted, such as Sherwood, it would provide an opportunity to supplement supplies, provided pollution issues can be addressed.

6.2.119 More detail on the environmental issues associated with groundwater recharge is provided in **Appendix C** and a summary is given in **Table 6.2.** However, due to the potential to contaminate groundwater supplies, it is not considered an environmentally acceptable option at this time. Further research, however, may provide cost-effective measures of treating the water and, therefore, it should not be ruled out environmentally as an option for future consideration.

UNDERGROUND TANKS

Description

6.2.120 Underground tanks could theoretically be used to store excess water during flood events. Water would be diverted into the tanks when necessary, but would have to be pumped out when the river levels recede.

6.2.121 Underground tanks are unlikely to be practical, with concerns over their size, cost and sustainability issues associated with emptying the tanks following a flood event. In addition, such tanks would silt up and regular de-silting operations would be required. This would be expensive and result in health and safety risks to the operatives working in confined spaces.

Technical Assessment

Storage Volumes Required

6.2.122 An analysis of storage volumes was undertaken for the on-line storage option. This was used to estimate typical storage capacities at various locations along the Trent. The methodology is detailed earlier in this section and the results are presented in **Table 6.3.** Based on these volumes**,** tank sizes were estimated and are given in **Table 6.4**. These results are based on the use of a square tank of depth 5m.

Table 6.4: Estimated Tank Sizes

Station	Depth of Tank (m)	Length/Width of Square Tank (m)				
		100-75yr	75-50yr	50-25yr	25-10yr	10-5yr
Stoke	5	113	119	180	199	111
Darlaston	5	126	151	214	251	190
Yoxall	5	302	401	535	623	528
Drakelow	5	383	508	965	956	898
Shardlow	5	452	633	1245	1153	1216
Colwick	5	565	771	1244	1805	1509
Muskham	5	671	901	1480	2138	1832

6.2.123 As anticipated**, Table 6.4** indicates that very large underground tanks would be required. Upstream of Drakelow, the tank sizes are slightly more realistic, but there are few major flood risk areas in these reaches.

Environmental Assessment

6.2.124 The main structure would be underground and there would be very little permanent effect on land-use or the landscape. Agriculture, for instance, could be resumed on the re-instated land. Some above ground control structures would be required, which would have some impact on land-use and the landscape, the significance of which would depend on size.

6.2.125 However, the construction of the tanks would result in very significant negative environmental impacts as large areas would be disturbed. Underground works would destroy any archaeological or geological interest. Groundwater regimes would be disrupted, which may have indirect effects on aquifers, existing wetlands and springs. Large amounts of material would also need to be removed which would need to be disposed of or recycled.

6.2.126 More detail on the environmental issues associated with underground tanks is provided in **Appendix C** and a summary is given in **Table 6.2.** However, due the significant negative environmental impacts, both temporary and permanent, associated with this scale of works, this option is not considered environmentally acceptable.

DREDGING

Description

6.2.127 Dredging is lowering the river bed by removing sediment and gravels, or hard bed materials. This could theoretically increase the capacity of the channel during flood events. However, other factors, such as floodplain conveyance, can be more significant. During major floods, the flow in the channel represents only a small proportion of the total. Dredging is currently carried out on a local scale by some organisations for navigation purposes, but has not been carried out on a large scale by the Agency, or its predecessors, for approximately 30 years.

6.2.128 Should dredging be adopted, there could be problems associated with the stability of riverside structures. Around Stoke in particular, dredging is likely to be impossible in certain areas due to the culverted nature of the watercourse and the existence of concrete beds.

6.2.129 Dredging remains an unsustainable option, as regular operations are necessary to maintain an artificially lowered bed.

An example of a typical dredging exercise.

Technical Assessment

Assessment Methodology

6.2.130 The effects of dredging are directly quantifiable using the hydraulic models. Dredging was carried forward for detailed assessment at the following locations: -

- Option 3.6; to assess the impacts of dredging at Willington, which is considered representative of large lengths of the rural River Trent. Bed levels in the hydraulic models were lowered by 300mm between Willington Bridge and Weston.
- Option 4.9; to assess the impacts of dredging through Nottingham, where the channel is constrained by existing defences. Bed levels in the hydraulic models were lowered by 300mm between Clifton Bridge and Holme Pierrepont.

6.2.131 Further details on this assessment are provided in **Section 6.3.**

Environmental Assessment

6.2.132 Dredging could have positive environmental impacts through decreasing flood risk and possibly improving navigation.

6.2.133 Dredging, however, is an environmentally disruptive and unsustainable option. There can be significant direct impacts on the channel and bed habitats, and their associated flora and fauna. Dredging would release silt into the river. This could have significant effects on fisheries and other riparian flora, through the decrease in water quality and smothering downstream habitats, such as fish spawning areas. Disturbed silt could also release contaminants. Dredging can have impacts on recreation by direct disturbance, decreasing water quality and possibly lowering channel water levels in periods of low flows, which could mean that moorings or fishing platforms are distanced from the water.

6.2.134 Dredging could have a negative impact on visual amenity in two main ways. Best practice for dredging is to leave the silt on the banks to allow invertebrates to return to the river. This practice, in addition to reducing floodplain storage capacity, can have temporary or permanent visual impact along the riverside depending on how long the material is left. In addition, lowered water levels may expose the un-vegetated base of river banks or mud, which may be less visually attractive than the current habitat. If dredging is undertaken from the bank, there will be additional disturbance to adjacent land and habitats.

6.2.135 Lowering water levels could destabilise any bankside structures, some of which may be of historical importance. Water can preserve archaeological features so any lowering of water levels which cause their exposure to the air result in decay. Dredging also has the potential to physically damage archaeological and historic features.

6.2.136 More detail on the environmental issues associated with dredging is provided in **Appendix C** and a summary is given in **Table 6.2.** Due to the potential significant negative impacts, it is not considered environmentally acceptable. However, small scale removal of silt bars etc under normal maintenance operations could be environmentally acceptable.

REMOVAL OF FLOODPLAIN OBSTRUCTIONS

Description

6.2.137 The removal of structures from within the floodplain could be used to create additional storage. As well as taking up storage space, floodplain obstructions may be barriers and impede the natural flow of water, resulting in artificially raised water levels upstream. Typical obstructions could be abandoned flood defences or spoil tips.

6.2.138 Bridges, roads and railway embankments in the floodplain can significantly obstruct flows. During construction, flood relief culverts are frequently built through any embankments to promote the passage of water across the floodplain. Where existing structures raise flood levels, there remains the option of widening existing or constructing new flood relief culverts, to reduce upstream levels.

Flood relief culverts under Willington Causeway allow the passage of water across the floodplain.

Technical Assessment

6.2.139 Considering the width and linear extent of the Trent floodplain during a major event, it is unlikely that the additional storage resulting from the removal of obstructions would have any appreciable effect at the flood risk locations. A review of the 100-year floodplain maps shows that there are no structures of sufficient size to influence levels. However, it is best practice to remove such structures, where possible.

6.2.140 The removal of floodplain obstructions is more likely to have an effect on water levels locally. The models were used to identify locations where water levels are raised by structures in the floodplain. The following options are taken forward for more detailed assessment: -

- Option 1.3; assess the backwater effect of the A52 bridge and possible improvements in this hydraulic control.
- Option 1.5; remove the disused railway bridge south east of Birches Head housing estate.

- Option 2.2; assess the headloss (the difference between upstream and downstream water levels) through the railway bridge at Rugeley to ensure there is no backwater effect through the town.
- Option 2.5; assess the impact of improving the flow through High Bridge.
- Option 3.3; lower Willington Causeway to improve flood flow across the floodplain.
- Option 3.4; an additional flood relief culvert to improve flow through Willington Bridge and Causeway.
- Option 3.8; lower the road or construct additional flood relief culverts to improve flow through Swarkestone Bridge and causeway.
- Option 3.11; assess the headloss through the railway bridge (Sarsons Bridge) and whether improvement to pass forward flow would benefit areas upstream.
- Option 3.12; assess the headloss across Kings Mill Lane and whether improvement would benefit areas upstream.
- Option 4.12; remove flood defences near the sailing club at Holme Pierrepont.
- Option 4.21; Lower the A6097 through Gunthorpe.
- Option 4.23; assess the headloss across Gunthorpe Bridge and investigate the possibility of diverting flood flow around the right bank, using culverts.
- Option 4.42; Assess the headloss across Kelham Bridge and whether altering the hydraulic performance of the structure would affect local flood levels.

6.2.141 Further details on the above are provided in **Section 6.3**

Environmental assessment

6.2.142 Removing structures would increase the natural function of the floodplain. It may remove obstacles that are unsightly, for example, spoil heaps, abandoned roads or buildings. Where structures are removed, the land could be returned to agricultural use or the opportunity taken to use it for nature conservation and/or recreation.

6.2.143 However, structures may have a significant historical value or have become local features of the landscape. Abandoned areas also could have significant wildlife value. Disused roads and railways often become green corridors and important wildlife and recreational routes.

6.2.144 The most significant environmental impact would be where a property or structure is still in use. Its removal would result in emotional distress to the occupants and financial impacts to businesses. It should only be considered where the owners and occupiers are supportive.

6.2.145 More detail on the environmental issues associated with the floodplain obstruction is provided in **Appendix C** and a summary is given in **Table 6.2.** In summary, it is considered environmentally acceptable and preferred if the obstacle does not have a significant local historical, recreational, nature conservation or landscape value.

RIVER RE-PROFILING

Description

6.2.146 River re-profiling is the re-alignment of a watercourse. This can be brought about by the introduction of meanders to promote flow attenuation and slow down flows, or straightening meanders to speed flows up. These would change water levels and the relative timings of flood peaks on the main river and its tributaries.

6.2.147 River re-profiling is subject to many constraints. As well as technical considerations, there could be limits on the availability of land and possible effects on existing infrastructure, navigation and maintenance. On rivers as large as the Trent, it can be difficult to implement re-profiling on a scale large enough to impact on flood levels.

A re-profiling scheme under construction on a small watercourse.

Technical Assessment

Assessment Methodology

6.2.148 The alignment of a river has the greatest influence on water levels when the flows remain in channel. When significant inundation of the floodplain occurs, any changes to channel alignment would have negligible effects. For the majority of flood risk locations along the Trent, flooding occurs during the more severe events in areas where the floodplain is significant.

6.2.149 On small river systems, river re-profiling is possible, where flood timings on tributaries follow recognisable patterns. This is frequently a consequence of a single storm covering, or moving in a predictable manner, across the whole catchment. On the River Trent, flood events can be as a consequence of large flows in the main river or large inputs from the major tributaries. The concept of one large rainfall event over the whole catchment is unrealistic and Trent flood events rarely follow recognisable patterns. Re-profiling as a means of de-synchronising flood peaks is not a feasible flood management option for the River Trent.

Stoke Pathfinder Scheme

6.2.150 Significant local channel improvement works are planned as part of the Highways Agency's Pathfinder Scheme in Stoke, where an existing road junction is to be altered and the River Trent re-structured. The scheme is to be investigated under Option 1.1 to check that it would have no detrimental effect on the aims of this study. Further details on this assessment are provided in **Section 6.3**.

Environmental Assessment

6.2.151 Re-profiling could afford good opportunities to create habitats or provide recreation. However, new channel alignments would also require land take. Potentially this could have significant negative impacts on existing land use, nature conservation, archaeology and the landscape. Re-profiling may require the disposal of large quantities of material.

6.2.152 There would be positive benefits to communities where flood relief would be provided. However, there may be floodplain features such as wetlands and archaeological sites that are dependent on flood events.

6.2.153 There would also be temporary impacts on the river and its associated flora and fauna, as the existing hydrological regime settles into equilibrium. The construction of additional new channels could also permanently lower the base flow of the original river with potential impacts on nature conservation, recreation, abstractions and bankside structures.

6.2.154 More detail on the environmental issues associated with river re-profiling is provided in **Appendix C** and a summary is given in **Table 6.2.** However, any works that would involve increased modification of a channel from a natural profile are not considered environmentally acceptable. Works where a channel would be returned to a more natural profile, with increased channel features, are considered environmentally acceptable and preferred. English Nature's Natural Areas objectives for freshwater in the West Midlands include 're-establishing of natural waterside habitats' and 'maintaining and re-creating natural channels by river engineering and flood defence works'. The use of hard revetment to stabilise the channel should be avoided.

FLOW DIVERSION

Description

6.2.155 This would involve diverting excess flows from vulnerable flood risk areas, or improving the flow around 'bottlenecks' by providing alternative flow channels. The following principal options are available: -

- new river diversion channels;
- use the canal network to divert and store flood water; or
- use existing navigation locks to divert flow around weirs.

6.2.156 For new river diversion channels to be technically feasible, the gradient of the river and the local topography would need to be suitable. It is possible to use tunnels or pumping stations in some circumstances.

6.2.157 For a river diversion channel to have an appreciable effect during a large flood event, it should ideally be outside the floodplain. Diversion channels within the floodplain would only have an effect whilst flows remain in bank. Once the floodplain comes into operation, the effect of the diversion channel would become much less pronounced as the floodplain flow becomes a greater proportion of the total flow. In extreme cases, it is possible that the only benefit offered by a diversion channel would be the small increase in floodplain storage provided by the new channel.

6.2.158 Canals and navigation locks are not designed to convey significant quantities of water. Rapid flow along them can lead to significant problems, such as structural damage to the channel, possibly resulting in instability and collapse of the banks. In addition, the overtopping of canal banks by flood water could possibly lead to failure of the banks and the sudden inundation of previously risk free areas. The issues of structural stability would also extend to canal side structures such as buildings, bridges and lock gates. Diverting floodwater through canals could also significantly endanger boats and would place additional locations at risk from flooding, requiring the significant expansion of current flood warning systems.

6.2.159 The diversion of flood water around weirs was considered in greater detail under the Weirs and Sluices option.

Technical Assessment

6.2.160 A number of locations outside the floodplain were identified, where diversion channels could potentially reduce flows through flood risk areas. These options are discussed in the following sections.

River Diversion 1 – Darlaston to the River Blithe

6.2.161 The diversion of flows from the River Trent at Darlaston into the Blithe catchment, upstream of Blithfield Reservoir, was considered. This would potentially enable the reservoir to attenuate flows from the upper Trent catchment. Whilst this option

could reduce the flood risk in the towns of Stone and Rugeley, the 100-year floodplain maps show minimal flooding in these locations.

6.2.162 The topography of the area would make such a diversion extremely difficult and expensive. For the chosen route, Darlaston lies below the level of the upstream end of Blithfield Reservoir and pumping would be required. A large ridge of hills runs between the Trent and Blithe valleys and extensive tunneling would be required for a distance of some 20km at a depth of approximately 70m. Alternatively, an above ground pipeline could be used, but this would have very significant maintenance costs associated with it.

6.2.163 For a gravity feed to be practical, the Trent would need to be diverted from upstream of Stoke Gauging Station. Significant problems would arise in constructing a diversion channel through the urban areas of Stoke.

6.2.164 Blithfield Reservoir is used for water supply purposes by South Staffordshire Water and, generally, reservoir levels are maintained as high as possible. Therefore, unless significant changes in operating procedures can be negotiated, there is likely to be limited capacity in the reservoir to store flood water. The diversion of urban runoff from Stoke into the reservoir could have significant detrimental effects on the quality of water quality and require major changes to the treatment processes.

River Diversion 2 – South of Burton

6.2.165 To reduce flood risk in Burton, the option of diverting water around the town was considered. An assessment of the most suitable routes was made, based on Ordnance Survey maps. As with the Blithe diversion, the topography of the valley sides around Burton would necessitate tunneling. To minimise the depth and avoid urban areas, a route passing to the south east of Burton would be preferable. This would require 13km of tunnel at depths of up to 80m.

River Diversion 3 – South of Nottingham

6.2.166 Possible diversion schemes were considered to reduce flood flows through Nottingham. As a result of the topography, no above ground schemes could be identified and tunneling would be the only option. A diversion to the north of Nottingham, which avoids the urban areas, would result in a prohibitively long tunnel. A scheme to divert flows from the River Soar around the south of Nottingham would be preferable; this would avoid the major developed areas and the areas of higher ground.

6.2.167 For this to result in appreciable reductions in levels through Nottingham, it would be necessary to divert a significant proportion of the flow in the Soar. This would require in excess of 20km of tunnel at depths up to 15m.

6.2.168 The major drawback of this would be the reliance on large flood events at Nottingham coinciding with large floods on the Soar. It is entirely probable that a large flood event could occur at Nottingham without a major flood event on the Soar; the Soar catchment contributes less than 20% of the flow at Nottingham. In such an

event, this proposed diversion scheme would provide no benefits to Nottingham and would not reduce the flood risk.

Use of Canal Network for Flow Diversion and Storage

6.2.169 The diversion of floodwater via the canal network is unlikely to be feasible; there are few locations where it is possible. It is unlikely that canals would be able to transport significant flows, due to their flat gradient and limited channel capacity.

6.2.170 Should canals be used for diversion purposes, they would offer a small amount of increased storage. During large rainfall events, canals are often at full capacity, and water spills from the canal to local watercourses. However, if an average canal is assumed to be 10m wide and has an available freeboard of 300mm, each metre length of canal could offer $3m^3$ of storage volume. The lengths of canal in highlighted in **Table 6.5** would be required to store the flood volumes in **Table 6.3**.

Table 6.5: Estimated Lengths of Canal Required to Store Capped Hydrograph Flows

Station	Length of Canal Required for Storage (km)				
	100-75yr	75-50yr	50-25yr	25-10yr	10-5yr
Stoke	21	24	54	66	21
Darlaston	26	38	77	105	60
Yoxall	152	268	477	647	465
Drakelow	244	430	1552	1523	1345
Shardlow	340	669	2581	2215	2466
Colwick	533	990	2580	5430	3793
Muskham	751	1354	3649	7619	5591

6.2.171 These results show that it is not feasible for canals to be used to store floodwater from the River Trent.

Environmental Assessment

6.2.172 Channel diversions can either be open channels or tunnels. Open channels can provide good opportunities to create habitats or recreational uses, depending on the degree of flow. However, new channels would also require land take and cause severance of land. This could have potentially significant negative impacts on existing land use, nature conservation, archaeology and the landscape.

6.2.173 Tunnels would have similar impacts to underground tanks, with permanent significant impacts to geology and archaeology. In addition, there would not be any associated opportunities for biodiversity or recreation. For both diversion options, there would be the need to dispose of large quantities of material.

6.2.174 There would be positive benefits to communities where flood relief would be provided. However, there may be floodplain features, such as wetlands, that are dependent on flood events. A flow diversion channel could also permanently lower

the base flow of the original river with potential impacts on nature conservation, recreation, abstractions and bankside structures.

6.2.175 Canals can have significant wildlife value but this is based around a still or very slow moving flow regime. The introduction of flood waters, therefore, could have a negative impact on biodiversity.

6.2.176 However, where the restoration of canals is proposed, there is the opportunity to incorporate flood storage into their design. Partnership opportunities could be developed between the Environment Agency, British Waterways, Inland Waterways Association and local councils.

6.2.177 The use of existing navigation locks to divert flow around weirs may affect the existing structures; these may have historical value.

6.2.178 More detail on the environmental issues associated with flow diversion is provided in **Appendix C** and a summary is given in **Table 6.2.** In summary it is considered that, subject to environmental impact assessment: -

- Open river diversion channels; environmentally acceptable and preferred
- Tunneled river diversion channels: environmentally acceptable
- Use of canals: not environmentally acceptable unless associated with a restoration scheme.
- The use of existing navigation locks to divert flow around weirs: environmentally acceptable and preferred.

TRIBUTARY STORAGE

Description

6.2.179 Although outside the scope of the study, storage of floodwaters within the catchments of the major tributaries could reduce flooding on the Trent. The effects of such schemes have not been assessed in detail as part of this study but they will be considered in the strategies for the tributaries.

6.2.180 Various measures could be used to affect flows from the tributaries. These would be aimed at reducing or slowing the passage of floodwaters to the Trent. On-line, off-line and floodplain storage could achieve this and these would have similar advantages and disadvantages to the main river ones identified earlier in this Section.

Technical Assessment

Assessment Methodology

6.2.181 Using the hydraulic models, the sensitivity of water levels in the River Trent to changes in flow in the major tributaries was assessed. 100-year return period flows in the key tributaries were changed by +5%, -5%, -10%, -20% and -30%.

6.2.182 As an example, reducing flows on the River Derwent by 20% would lower the 100-year water level in Nottingham by around 80mm and reducing flows on the River Tame by 20% would lower the 100-year water level at Burton upon Trent by 120mm.

6.2.183 Full results from this sensitivity analysis are presented in **Appendix C**.

6.2.184 The reduction of tributary inflows would lead to a reduction in flood levels on the River Trent. These findings will be made available to the teams working on the relevant studies of the tributaries and the Trent CFMP, as appropriate.

6.2.185 For the upper reaches of the rivers, where the tributaries contribute a larger proportion of flows in the main river, tributary storage would have a greater effect. The effects at Stoke-on-Trent of reducing flows in Lymme Brook are quantified in greater detail under Option 1.6. Further details on this assessment are provided in **Section 6.3.**

Environmental Assessment

6.2.186 Options to store flows in the tributaries, such as on line storage or off-line storage, would have similar generic environmental impacts to those being considered for the Trent. However, where used upstream, the volumes of water may be less and therefore, any negative environmental impacts may be reduced. However, this will be dependent on the option and the location.

6.2.187 More detail on the environmental issues associated with tributary storage is provided in Appendix C and a summary is given in **Table 6.2.** However, tributary

storage is generally an environmentally acceptable and a preferred option, although this would depend on the methodology and location.

DEFENCES

Description

6.2.188 At a number of locations, defences, such as walls and earth embankments, would provide a suitable means of flood protection. There are presently significant major defences around the urban areas of Nottingham and Burton upon Trent, and a number of smaller towns and villages.

6.2.189 Whilst one aim of the study is to consider flood management on a catchment wide scale, it is also necessary to consider existing and possible new defences as it is extremely unlikely that the principal defences in the study area could be abandoned.

6.2.190 Only the major flood defences which protect urban areas are, therefore, considered. For minor banks, which generally protect agricultural land, their effects were considered under the off-line and floodplain storage option.

Flood defence walls along the River Trent at Queens Drive, Nottingham.

Flood defence embankments along the River Trent at Burton Upon Trent.

Technical Assessment

New Defences

6.2.191 New defences were considered for the following flood risk areas: -

- Option 1.4; University and Seven Arches Way
- Option 2.3; Rugely
- Option 3.7; Willington
- Option 3.9; Barrow upon Trent
- Option 3.10; Swarkestone
- Option 3.13; Castle Donington Industrial Estate, via a flap valve on Castle Donington Drain
- Option 4.3; Attenborough
- Option 4.25; Gunthorpe
- Option 4.27; Caythorpe
- Option 4.30; Hoveringham
- Option 4.32; Bleasby
- Option 4.36; Rolleston (Notts)
- Option 4.37; Farndon
- Option 4.38; Farndon, via the construction of the proposed A46 road
- Option 4.39; Brewers Wharf , Newark
- Option 4.43; Kelham, via flow over the A617
- Option 4.44; Little Carlton and South Muskham
- Option 4.47; North Muskham

6.2.192 Further details on these assessments are provided in **Section 6.3**

Existing Defences

6.2.193 The hydraulic models were used to assess the standard of protection provided by all existing defences. The assessment considered for the following flood risk areas: -

- Option 3.2; Burton upon Trent
- Option 4.1; Sawley
- Option 4.2; Long Eaton, via flood gates on the Erewash Canal
- Option 4.4; Trent Meadows
- Option 4,5; Barton in Fabis
- Option 4.6; Rylands
- Option 4.7; Wilford

- Option 4.8; Meadows/South Bank
- Option 4.10; Queens Drive
- Option 4.11; West Bridgford
- Option 4.13; Colwick
- Option 4.15; Radcliffe on Trent
- Option 4.17; Shelford
- Option 4.19 and 4.20; Burton Joyce
- Option 4.34; Fiskerton
- Option 4.40; Newark Cattle Market area

Further details on these assessments are provided in **Section 6.3**

Environmental Assessment

6.2.194 There can be a perception from local residents that defences are the best and most reliable measure. With a sympathetic design, they can actually provide a stimulus to improve the waterfront in terms of landscape and formal recreation. With an 'assured' standard of flood defence, development and economic growth may be stimulated. Rivers in urban areas can often provide a good focus for residential, recreational and commercial development.

6.2.195 However, hard flood defences reduce the natural function of the river by separating it from the floodplain. Depending on extent, design and location, they could have significant impacts on nature conservation, archaeological and historic sites and their settings, recreation and landscape. They can be a barrier to the community and restrict access for people and transport. Where defences are set back, there is a potential for the undefended land to be left undeveloped or fall into disuse.

6.2.196 Defences can only be constructed to a particular standard, for example, 100-years. However, if a greater event were to overtop them, the impacts could be more significant. Communities in defended area would probably not be aware of the impacts of flooding and would not know the basic precautionary measures to minimise impacts. Without proper design, defences can potentially impound water behind them, thus prolonging and exacerbating the flooding.

6.2.197 Raising or lowering existing defences should have relatively minor (positive or negative) environmental impacts, although this would depend on the degree of change. Demountable barriers often have less environmental impacts but are reliant on accurate flood warning and adequate resources to install them.

6.2.198 More detail on the environmental issues associated with hard defences is provided in **Appendix C** and a summary is given in **Table 6.2.** In summary, it is considered that hard defences in urban areas are environmentally acceptable and preferred only where there are no technically and economically viable and sustainable alternative options. A detailed EIA will be undertaken for any option that is to be further

considered. At a project level, the use of sustainable construction materials will be promoted if hard defences are still shown to be the best solution.

6.2.199 Opportunities for environmental enhancement for landscape, bio-diversity or recreation should be considered as part of any scheme. Mitigation would also be needed to ensure there was no net loss of floodplain.

SUMMARY OF FLOOD MANAGEMENT OPTIONS

6.2.200 Table **6.6** summarises the flood management options that are recommended, those discounted and those taken forward for a more site specific assessment.

Table 6.6: Summary of Flood Management Options

No.	Name	Description	Adopted	Discounted	Taken Forward
1	Do Nothing	Undertake no further maintenance or construction work whatsoever on the watercourse			✓
2	Do Minimum	Continue to undertake present day maintenance and flood warning tasks			✓
3	Off-line & Floodplain Storage	The increase in capacity, or managed use of available floodplain storage			✓
4	On-Line Storage	The creation of a water retaining structure(s) across the valley to create a flood storage area(s)			✓
5	Managed Retreat	Abandon flood defences and defended property and revert back to a natural floodplain		✓	
6	Development Control	Prevent development within areas that are at risk from flooding	✓		
7	Sustainable Urban Drainage Systems	Drainage systems that mimic natural processes, such as allowing water to soak into the ground.	✓		
8	Managing the Effects of Floods	Raise awareness of flooding issues, including the use of local flood-protection measures	✓		✓
9	Land Management Options	Change land use to reduce the amount and rate of runoff to local watercourses	✓		
10	Weirs and Sluices	Manage water levels in the river using existing, or new control structures			✓
11	Groundwater Recharge	Divert flood water into natural underground aquifers		✓	
12	Underground Tanks	Divert flood water into man made underground tanks		✓	
13	Dredging	Mechanically remove sediment from the river bed to increase the capacity of the river channel			✓
14	Remove Floodplain Obstructions	Remove, or modify structures that have a detrimental effect on water levels in the floodplain	✓		✓
15	River Re-profiling	Re-build the river channel to aid the dispersal or storage of flood flows		✓	
16	Flow Diversion	Create artificial channels to divert flood water		✓	
17	Tributary Storage	Retain water within tributary catchments to reduce flows in the Trent			✓
18	Defences	Raise existing, or construct new barriers to protect property from flood water			✓

6.3 Specific Option Appraisal

6.3.1 Flood risk locations were identified using the hydraulic models and 100-year flood outline. **Table 6.7** summarises the hot spots, together with the appropriate flood cell and the number of options considered.

Table 6.7: Flood Risk Locations Considered for Further Assessment

Flood Risk Location		Flood Cells	No. of Options	Comment
No	Location			
1	Stoke On Trent	1.1;1.9	6	3 locations identified as being at risk.
2	Rugeley	2.9;2.10	3	
3	High Bridge	2.11	2	
4	Yoxall Bridge	2.13;2.14	1	
5	Burton Upon Trent	2.19;3.6	8	Defences assessed for each of the 7 flood cells.
6	Willington	3.8	4	
7	Barrow & Swarkestone	3.11;3.12	4	
8	Kings Mill Lane	3.13	1	
9	Castle Donington	3.14	1	
10	Weston On Trent	3.14	1	This option provides protection to other areas.
11	Shardlow	3.15	1	
12	Nottingham	4.1;4.29	27	Defences assessed for most of 29 flood cells.
13	Stoke Bardolph	4.31	1	
14	Shelford	4.34	2	
15	Burton Joyce	4.33	2	
16	Gunthorpe	4.36	5	
17	Caythorpe	4.37	3	
18	Hoveringham	4.38	3	
19	Bleasby	4.40	2	
20	Fiskerton	4.42	1	
21	Rolleston (Notts)	4.43	2	
22	Farndon	4.44	2	
23	Newark	4.46;.4.51	5	
24	Kelham	4.47	2	
25	Little Carlton	4.47;4.49	3	
26	North Muskham	4.53	2	
27	Cromwell Weir	4.55	1	This option provides protection to other areas.

6.3.2 The following paragraphs provide a summary of the technical, environmental and economic assessment process undertaken for each option.

6.3.3 A table was produced for each location, which presents the results for the various options. The following points should be borne in mind when viewing these tables and results: -

- Each option was subjected to a technical and environmental assessment. A ✓ or an X denotes whether the outcome of this assessment was successful or not.
- For the environmental assessment, a ✓✓ denotes that the option is environmentally acceptable and preferred, whereas a ✓ denotes the option is simply environmentally acceptable.
- The flood defences through Nottingham and Burton were analysed as a series of individual flood cells to pinpoint those reaches most in need of protection.
- There is a drawing to accompany each flood risk location. This provides details of the options.
- An economic assessment was undertaken for those options with a ✓ for both the technical and environmental assessments.
- Any scheme with a benefit/cost ratio of less than 1 is described as economically unviable.
- Only those options with a benefit/cost ratio greater than 2 are considered economically robust enough to be recommended by this study.
- The current Defra guidelines are that a minimum Priority Score of 20 is required for schemes to be constructed during the financial year 2004/05. There remains the possibility that the Priority Score will reduce over coming years.
- A ✓ in the final column 'Strategy Recommend' denotes that the option meets all Defra requirements. It passes the technical and environmental appraisals, has a benefit/cost ratio greater than 2.0 and has a minimum priority score of 12. Exceptions to this are those options which don't qualify for an economic assessment but are recommended for further consideration outside the strategy.

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Flood Risk Location 1: STOKE ON TRENT **Refer to Figure No. 6.1**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
1.1	Pathfinder Channel Improvements.	1.7	Model used to check this Highways Agency scheme. Results indicate the scheme would have no detrimental effect on flood levels through Stoke.	✓	Environmentally preferred as good potential for environmental enhancements.	✓✓	Not within remit of study to provide economic assessment for this scheme.			X
1.2	*University and Seven Arches Way area*: remove Boothen Road Weir near old football ground.	1.6	Model indicates that this would have a very pronounced effect on local peak levels. However, would not extend far enough upstream to benefit flood risk areas.	X	Environmentally preferred as increases natural river processes.	✓✓				X
1.3	*University and Seven Arches Way area*: backwater effect of A52 bridge. Possible improvement of this hydraulic control.	1.6	Model indicates that providing a second culvert would sufficiently reduce levels at the University.	✓	Environmentally acceptable but not preferred due to potential construction impacts.	✓	Cost would be significantly more than Option 1.4, which isn't cost beneficial			X
1.4	*University and Seven Arches Way area*: construction of localised defences to protect property.	1.6	Model indicates that defences would have a noticeable detrimental effect on local levels upstream and downstream (max of 300mm).	✓	Environmentally preferred option due to flood relief to University with low environmental impact.	✓✓	£0.9	0.1	5.8	X
1.5	*Birches Head Road Area:* Removal of disused railway south east of Birches Head Housing Estate.	1.3	Model indicates that this would only have a local impact on flood levels. Not sufficient to provide any benefit to properties at risk.	X	Environmentally acceptable but not preferred as would remove future potential of railway as a green corridor for wildlife and recreation, or transport network.	✓				X
1.6	*Lymme Brook*: Reduce Lymme Brook inflow	1.9	A 30% reduction in 100year flow along Lymme Brook would reduce flooding to properties at Whitmore Road.	✓	Environmentally acceptable but not the preferred option due to increased flooding of storage site.	✓	Not within remit to provide economic assessment on options along tributary catchments.			X

Flood Risk Location 2: RUGELEY **Refer to Figure No. 6.2**

Option			Detail Appraisal Results							
No	**Description**	**Flood Cell**	**Technical** ✓ Technically acceptable X Technically unacceptable	**Passed**	**Environmental** ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	**Passed**	**Economic**			**Strategy Recommend**
							Cost (£M)	**B/C**	**P.S.**	
2.1	Create on-line storage by reducing aqueduct pass through flow at northern end of Rugeley	2.8	Model indicates that pass forward flow would need to be reduced by 75%. A dam would be required to encompass flow. Insufficient area available for this scheme.	X	Environmentally acceptable but not preferred as aqueduct may have historic significance and risk of increased flood risk upstream.	✓				X
2.2	Assess headloss at railway bridge at Rugeley to ensure there is no backwater effect through the town.	2.9	Model indicates that there is negligible headloss though this bridge and it would have no effect on upstream water levels	X	Environmentally acceptable and preferred option as low environmental impacts.	✓✓				X
2.3	Construct local defences to protect property.	2.9	Model indicates that defences would have a negligible detrimental effect on local levels upstream and downstream.	✓	Environmentally acceptable and a preferred option as provides flood protection with low environmental impacts.	✓✓	£0.2	0.0	12.0	X

Flood Risk Location 3: HIGH BRIDGE **Refer to Figure No. 6.3**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
2.4	Remove flood banks upstream of High Bridge to increase storage	2.11	Model indicates that the removal of the banks would only have an effect on local peak flood levels. No improvement to flooding of properties.	X	Environmentally acceptable and a preferred environmental option as would restore natural floodplain.	✓✓				✓
2.5	Assess the impact of improving pass through flow at High Bridge.	2.11	High Bridge only has a local effect on peak flood levels. Improvement of pass through flow would not reduce any flooding to properties.	X	Environmentally acceptable but not preferred due to construction impacts.	✓				X

Flood Risk Location 4: YOXALL BRIDGE **Refer to Figure No. 6.4**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
2.6	Create off-line storage by constructing low level banks along left bank from Yoxall Bridge to Wynchor Park.	2.14	The inclusion of low level banks would only affect flood levels immediately adjacent to the banks. Negligible impact shown 1km upstream or downstream. Option would provide no improvement to flooding of properties.	X	Environmentally acceptable and a preferred environmental option.	✓✓				X

Flood Risk Location 5: BURTON UPON TRENT **Refer to Figure No. 6.5**

Option			Detail Appraisal Results							
No	**Description**	**Flood Cell**	**Technical** ✓ Technically acceptable X Technically unacceptable	**Passed**	**Environmental** ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	**Passed**	**Economic**			**Strategy Recommend**
							Cost (£M)	**B/C**	**P.S.**	
3.1	Floodplain storage upstream of Burton: locations at Catton Park, Branston and Power Station considered.	2.16 to 2.19	Model indicates that there is insufficient capacity within these areas to store the required volume of flow to have any impact on Burton flood levels.	X	Catton Park: Environmentally acceptable but not preferred due to potential for significant construction impacts. Branston: Environmentally acceptable and preferred due to potentially decreased flood risk to Burton. Power Station: Not environmentally acceptable due to potential for contaminated land.	✓ ✓✓ X				X

Flood Risk Location 5: BURTON UPON TRENT **Refer to Figure No. 6.5**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
3.2	Construct local flood defences to protect property.	2.19	Currently Burton defences provide protection to a 1 in 100+year event. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and preferred due to significant benefits of maintaining flood protection to major urban centre.	✓✓	£1.9	8.4	28.0	✓
		3.1		✓		✓✓	£0.7	54.0	32.0	✓
		3.2		✓		✓✓	£0.9	76.9	32.0	✓
		3.3		✓		✓✓	£4.1	150	35.0	✓
		3.4		✓		✓✓	£3.9	13.2	33.0	✓
		3.5		✓		✓✓	£0.6	0.0	5.0	X
		3.6		✓		✓✓	£2.6	4.0	14.0	✓

Flood Risk Location 6: WILLINGTON **Refer to Figure No. 6.6**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
3.3	Improve pass forward flow at Willington Bridge: lower Willington causeway to improve flood flow across the floodplain.	3.8	Model indicates that lowering the right bank causeway by 1m, could improve flood levels at Willington.	✓	Environmentally acceptable but not preferred due to potential impacts on archaeology.	✓	£7.9	0.7	4.6	X
3.4	Improve pass forward flow at Willington Bridge: construct additional flood relief culverts to improve flow through causeway.	3.8	Model indicates that the inclusion of large flood relief culverts (capable of conveying approximately 300 m^3/s) would improve flood levels at Willington.	✓	Environmentally acceptable but not preferred due to potential impacts on archaeology.	✓	£23.6	0.2	4.2	X
3.5	Option number not used									
3.6	Dredge the river between Willington and Weston (15km)	3.8	Model indicates that dredging by 300mm would reduce water levels slightly for more frequent flood events (<25year). However, it would have negligible impact on peak flood levels during the 1 in 100year event.	✓	Not environmentally acceptable due to potential impacts on biodiversity and riverside structures.	X	£5.3	0.1	4.8	X
3.7	Construct local flood defences to protect property.	3.8	Model indicates that embankments would have a negligible detrimental effect on local levels upstream and downstream	✓	Environmentally acceptable and preferred subject to EIA.	✓✓	£5.8	0.9	5.5	X

Flood Risk Location 7: BARROW UPON TRENT & SWARKESTONE Refer to Figure No. 6.7

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
3.8	Improve pass forward flow at Swarkestone Bridge: lower road or construct additional flood relief culverts	3.12	Model indicates that Swarkestone Bridge does have an effect on 100year levels. Lowering the road or including flood relief culverts would reduce flooding.	✓	Environmentally unacceptable due to historic value of bridge.	X				X
3.9	*Barrow Upon Trent*: construct local flood defences to protect property.	3.11	Model indicates that embankments would have a negligible detrimental effect on local levels upstream and downstream	✓	Environmentally acceptable and the preferred option.	✓✓	£5.0	0.5	6.9	X
3.10	*Swarkestone*: construct local flood defences to protect property.	3.12	Model indicates that embankments would have a negligible detrimental effect on local levels upstream and downstream	✓	Environmentally acceptable and a preferred option.	✓✓	£1.2	3.5	12.4	✓
3.11	Assess headloss of Sarsons Railway Bridge to identify whether it affects flood levels at either Swarkestone or Barrow.	3.12	Model indicates that there is minimal headloss though this bridge and it has a negligible effect on upstream water levels	X	Environmentally acceptable and a preferred option if bridge not found to have significant historic value.	✓✓				X

Flood Risk Location 8: KINGS MILL LANE **Refer to Figure No. 6.8**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
3.12	Assess headloss across Kings Mill Lane.	3.13	Site visit concluded that Kings Mill Lane is at floodplain level and will not adversely affect flood flows	X	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓				X

Flood Risk Location 9: CASTLE DONINGTON **Refer to Figure No. 6.9**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
3.13	Include a flap valve on the Castle Donington Drain as it flows under the railway	3.14	Castle Donington industrial estate is a defended area. A flap would be required to ensure there is no flow path for the Trent in flood.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	Insufficient benefits to warrant an economic assessment			X

Flood Risk Location 10: WESTON ON TRENT **Refer to Figure No. 6.10a, b and c**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
3.14	Weston-on-Trent Storage Reservoir: include a dam across the floodplain adjacent to Weston-on-Trent to store flood waters upstream and reduce pass forward flow by 50%.	Entire reach from Willington to Cromwell Weir	Model indicates that the 50% reduction in pass forward flow would reduce the current 100-year levels by approximately 0.4m through Nottingham; which is equivalent to the current 25-year levels. However, there are the following problems: - Complete inundation of Barrow and Swarkestone villages upstream (relocation of village required) - Complete protection still not achieved. Villages downstream of Nottingham still liable to flooding in extreme events. - Defences and their maintenance are still required within Nottingham - Storage area is upstream of Derwent and Soar confluence. Therefore a risk still exists from flooding from these major tributaries. Figure 6.10 provides a comparison of 100year flood outlines between the existing conditions and with the storage reservoir in place.	✓	Not environmentally acceptable due to impacts of increased flooding on communities upstream	X	£177	6.6	23.5	X

Flood Risk Location 11: SHARDLOW **Refer to Figure No. 6.11**

Option			Detail Appraisal Results							
No	**Description**	**Flood Cell**	**Technical** ✓ Technically acceptable X Technically unacceptable	**Passed**	**Environmental** ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	**Passed**	**Economic**			**Strategy Recommend**
							Cost (£M)	**B/C**	**P.S.**	
3.15	*Shardlow*: assess current standard of protection	3.15	Currently Shardlow defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.6	6.0	18.7	✓

Flood Risk Location 12: NOTTINGHAM **Refer to Figure No. 6.12**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.1	*Sawley*: assess current standard of protection	4.2	Currently Sawley defences provide protection to a 25-50 year standard. Replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and preferred option as provides increased flood protection to Sawley.	✓✓	£1.9	153	34.0	✓
4.2	Recommend the upgrade and improvement of the Sawley flood gates (Sheetstores) at the Erewash Canal	4.3	Current flood gates are manually operated. Suggest their upgrade as part of any Sawley flood defence scheme.	✓	Environmentally acceptable and preferred as provides increased flood protection to Sawley.	✓✓				✓
4.3	*Attenborough*: construct local flood defences to protect property	4.5	Model indicates that embankments would have a negligible detrimental effect on local levels, upstream and downstream	✓	Environmentally acceptable and preferred subject to rigorous EIA due to proximity of SSSI.	✓✓	£7.2	1.2	9.9	X
		4.7	Model indicates that embankments would have a negligible detrimental effect on local levels, upstream and downstream	✓	Environmentally acceptable and preferred subject to rigorous EIA due to proximity of SSSI.	✓✓	£3.4	3.2	19.2	✓
4.4	*Trent Meadows (Home Farm)*: assess current standard of protection	4.4	Current Trent Meadows defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and preferred as will provide increased flood protection to Trent Meadows.	✓✓	£1.0	6.8	24.9	✓
4.5	*Barton in Fabis*: assess current standard of protection	4.6	Current Barton defences provide protection to a 25-50year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and preferred as will provide increased flood protection to Barton in Fabis.	✓✓	£2.8	5.7	19.4	✓

Flood Risk Location 12: NOTTINGHAM **Refer to Figure No. 6.12**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.6	*Rylands*: assess current standard of protection	4.9	Current Rylands defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and preferred as will provide increased flood protection to Rylands	✓✓	£2.4	43.1	32.0	✓
		4.11	Current Rylands defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and preferred as will provide increased flood protection to Rylands	✓✓	£2.8	1.3	6.5	X
		4.13	No formal defences exist. Natural high ground protects area from inundation.	X	Environmentally acceptable and a preferred option due to increased flood protection to Rylands.	✓✓				X
4.7	*Wilford*: assess current standard of protection	4.12	Current Wilford defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and preferred as will provide increased flood protection to Wilford	✓✓	£1.0	16.5	26.4	✓
		4.14	Current Wilford defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and preferred as will provide increased flood protection to Wilford	✓✓	£4.3	64.7	34.0	✓

Flood Risk Location 12: NOTTINGHAM **Refer to Figure No. 6.12**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.8	*Meadows*: assess current standard of protection	4.19	Current defences provide protection to a 25-50year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£4.1	3.7	19.6	✓
		4.20	Current defences provide protection to a 25-50 year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.5	1.2	12.4	X
		4.22	Insufficient information on existing defence heights to provide an accurate assessment on the level of protection.	X	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓				X
4.9	*Queens Drive* assess current standard of protection	4.15	Formal flood defences exist, but hinterland area is higher than flood level, therefore no defence required for 100year event.	X	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓				X
		4.17	Current defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.3	2.0	16.8	✓
		4.18	Current defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.3	21.6	33.0	✓

Flood Risk Location 12: NOTTINGHAM **Refer to Figure No. 6.12**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.10	Dredge the river between Clifton Bridge and Holme Pierrepont.	4.14 to 4.26	Model shows that dredging 300mm from invert through Nottingham, would reduce peak flood levels for all return periods by 300mm along dredged reach.	✓	Not environmentally acceptable due to significant disturbance of river and bank side habitat.	X	£3.8	5.3	24.0	X
4.11	*West Bridgford*: assess current standard of protection	4.16	Current defences provide protection to a 1 in 50-100year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£3.5	26.8	34.0	✓
		4.21	Current defences provide protection to a 1 in 50-100year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.6	39.8	34.0	✓
		4.23	Current defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.6	51.9	34.0	✓
		4.24	Current defences provide protection to a 1 in 25-50year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option due to increased flood protection.	✓✓	£1.0	34.3	32.0	✓
4.12	Remove flood defences near the sailing club at Holme Pierrepont	4.26	Site visit confirmed removal of flood defence would improve local conveyance. A more sophisticated hydraulic model is needed to assess impact. No flood protection to properties though.	✓	Environmentally acceptable but not preferred. Owing to minimal environmental impacts of increased flooding.	✓✓	Insufficient benefits to warrant an economic assessment			✓

Flood Risk Location 12: NOTTINGHAM **Refer to Figure No. 6.12**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.13	*Colwick*: assess current standard of protection	4.25	Current defences provide protection to a 1 in 50-100year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and preferred.	✓✓	£3.2	25.3	30.5	✓
		4.29	Current defences provide protection to a 1 in 25-50year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and preferred.	✓✓	£6.3	15.4	32.0	✓
4.14	*Colwick*: abandon and remove Colwick Sluices	4.25	Model shows that during extreme floods the structure's piers will cause local headloss; but not enough to warrant their replacement with a single span sluice/radial control.	X	Environmentally acceptable but not preferred due to potentially significant impacts on river regime.	✓				X
4.15	*Radcliffe on Trent*: determine if there are flood flow routes under railway	4.30	Site visit confirmed that a ring bank prevents flood flows from passing unimpeded beneath railway. A survey is required to confirm the ring bank's standard of protection.	X	Environmentally acceptable and preferred due to reduced flood risk to Radcliffe on Trent.	✓✓				X

Flood Risk Location 13: STOKE BARDOLPH **Refer to Figure No. 6.13**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.16	Assess raising or removal of low-level flood banks around the Shelford storage area	4.31	Model indicates that the removal of banks would maximise floodplain storage and improve conveyance. Flood levels through Stoke Bardolph would be reduced.	✓	Environmentally acceptable and preferred as only minor environmental impacts.	✓✓	Insufficient benefits to warrant an economic assessment			X

Flood Risk Location 14: SHELFORD **Refer to Figure No. 6.14**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.17	*Shelford* Assess current standard of protection	4.34	Current defences provide protection to a 1 in 25-50year standard. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and preferred.	✓✓	£2.0	0.1	7.8	X
4.18	Assess raising or removal of low-level flood banks around the Shelford storage area	4.34	Assessed under Option 4.16.	✓	Not environmentally acceptable due to combined flood risk to Shelford.	X	£1.4	0.1	5.1	X

Flood Risk Location 15: BURTON JOYCE **Refer to Figure No. 6.15**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.19	Site visit to assess whether railway acts as a defence and ascertain whether Station Road acts as a possible flow path during flood events	4.33	Site visit confirmed that Burton Joyce was satisfactorily defended by the railway line.	X	Not applicable, already undertaken.					X
4.20	Assess current standard of protection provided by railway	4.33	Railway line is not an Agency asset. It is beyond the scope of the study to comment on the protection being provided by this railway line.	X	Environmentally acceptable and preferred, due to reduced flood risk at Burton.	✓✓				X

Flood Risk Location 16: GUNTHORPE **Refer to Figure No. 6.16**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.21	Lower the A6097 through Gunthorpe	4.36	Model indicates that the road influences local flood levels. Lowering the road by 300mm in isolated locations would reduce local flood levels.	✓	Environmentally acceptable but not preferred.	✓	£1.3	4.4	14.5	✓
4.22	Assess the sensitivity of modelled water levels to the available floodplain and gravel pit storage near Hoveringham	4.36	Model indicates that increasing the floodplain storage at Hoveringham would have no effect on flood levels through Gunthorpe	X	Environmentally acceptable and preferred.	✓				X
4.23	Assess headloss across Gunthorpe Bridge and investigate the possibility of diverting flood flow (via flood culverts) around the right bank	4.36	Model indicates that any culvert would have to convey approximately 450m^3/s of water to protect Gunthorpe. Insufficient room on right bank to construct this size of culvert.	X	Environmentally acceptable and preferred owing to the reduced flood risk at Gunthorpe.	✓✓				X
4.24	Assess the effects of Gunthorpe Weir	4.36	Model indicates that the weir affects flood levels through Gunthorpe. Its replacement with a sluice arrangement would improve flood levels locally.	✓	Environmentally acceptable and preferred owing to the reduced flood risk at Gunthorpe.	✓✓	£14.9	0.5	3.3	X
4.25	Construct local flood defences to protect property	4.36	Option A – Ring Banks A more sophisticated model is recommended to accurately assess the impact these defences would have on flood levels.	✓	Environmentally acceptable and preferred owing to the reduced flood risk at Gunthorpe.	✓✓	£5.1	3.0	11.9	X
		4.36	Option B – Linear Banks A more sophisticated model is recommended to accurately assess the impact these defences would have on flood levels.	✓	Environmentally acceptable and preferred owing to the reduced flood risk at Gunthorpe.	✓✓	£6.5	2.4	11.1	X

Flood Risk Location 17: CAYTHORPE **Refer to Figure No. 6.17**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.26	Assess the effects of Options 4.16, 4.21 and 4.22 on Caythorpe	4.37	Model suggests that none of these options would have significant detrimental effects on Caythorpe flood levels. However, a more sophisticated model is recommended to check this.	X	As 4.16, 4.21 and 4.22.					X
4.27	Construct local flood defences to protect property	4.37	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable but not a preferred option.	✓	£4.9	0.3	4.1	X
4.28	Flood proof properties	4.37	Owners to consider this option. However, grant aid is unlikely to be available.	✓	Environmentally acceptable and a preferred option, owing to reduced flood risk.	✓✓				X

Flood Risk Location 18: HOVERINGHAM **Refer to Figure No. 6.18**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.29	Assess the effects of Options 4.16, 4.21 and 4.22 on Hoveringham	4.38	Model suggests that none of these options would have significant detrimental effect on Caythorpe flood levels. However, a more sophisticated model is recommended to check this.	X	4.16: Environmentally acceptable and preferred. 4.21 & 4.22: Environmentally acceptable	✓ ✓✓				X
4.30	Construct local flood defences to protect property	4.38	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable but not a preferred option.	✓	£4.2	0.9	5.5	X
4.31	Flood proof properties	4.38	Owners to consider this option. However, grant aid is unlikely to be available.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓				X

Flood Risk Location 19: BLEASBY **Refer to Figure No. 6.19**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.32	Construct local flood defences to protect property	4.40	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓	£2.7	0.5	4.9	X
4.33	Flood proof properties	4.40	Owners to consider this option. However, grant aid is unlikely to be available.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓				X

Flood Risk Location 20: FISKERTON **Refer to Figure No. 6.20**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.34	Assess current standard of protection	4.42	Current Fiskerton defences provide protection to a 1 in 100+year standard. Replacement is necessary when their 'design life' has expired.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓	£3.2	0.4	6.1	X

Flood Risk Location 21: ROLLESTON (Notts) Refer to Figure No. 6.21

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.35	Assess raising or removal of low-level flood banks between Rolleston and Staythorpe	4.43	Model indicates that the removal of banks would maximise floodplain storage and improve conveyance. Local flood levels would be reduced.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓	£1.0	9.3	28.8	✓
4.36	Construct local flood defences to protect property	4.43	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable but not preferred.	✓	£1.0	9.2	24.0	✓

Flood Risk Location 22: FARNDON Refer to Figure No. 6.22

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.37	Construct local flood defences to protect property	4.44	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable but not preferred.	✓	£1.9	4.2	20.0	✓
		4.46					£1.3	0.6	12.0	X
4.38	Assess how the proposed A46 could be utilised to provide flood protection to Farndon	4.44	Model suggests that the flood flow path across the current A46 is insignificant. Any new A46 scheme to remove this flood flow path would not raise levels on the Trent.	X	Environmentally acceptable and preferred.	✓✓				X

Flood Risk Location 23: NEWARK **Refer to Figure No. 6.23**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.39	*Newark*: assess current standard of protection	4.48	Currently Newark defences only provide protection to a standard less than 50years. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓	£1.1	55.8	32.0	✓
		4.50	Currently Newark defences only provide protection to a standard less than 50years. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓	£0.5	2.0	15.9	✓
		4.51	Currently Newark defences only provide protection to a standard less than 50years. Their replacement to provide a 100year standard of protection is required.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓				
4.40	*Cattle Market*: assess current standard of protection	4.48	Current defences provide protection to a 1 in 100+year standard. Local defences provide protection to a small number of properties. Their replacement is not assessed.	X	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓				X
4.41	Assess the hydraulic performance of Averham Weir and potential benefits in Newark	4.45	Model suggests that lowering the weir by 300mm would reduce flood levels through Newark. Replacement of weir with sluice gates would provide necessary control.	✓	Environmentally acceptable but not preferred.	✓	£14.9	3.6	11.3	X

Flood Risk Location 24: KELHAM **Refer to Figure No. 6.24**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.42	Assess the headloss across Kelham Bridge and whether altering the hydraulic performance of the structure would affect local flood levels	4.47	Headloss across Kelham Bridge is negligible. No suitable means of improving the hydraulic performance of this bridge	X	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓				X
4.43	Assess the floodplain flow over the A617 and whether defences alongside the road could provide protection to property	4.47	From levels generated from the model, defences alongside A617 would provide protection to Kelham. A more sophisticated model is recommended to assess impact the flood defences would have on surrounding levels.	✓	Environmentally acceptable but not preferred.	✓	£1.0	0.7	5.1	X

Flood Risk Location 25: LITTLE CARLTON AND SOUTH MUSKHAM Refer to Figure No. 6.25

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.44	Construct local flood defences to protect property	4.47 & 4.49	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable but not preferred.	✓	£2.5	0.7	7.6	X
4.45	Flood proof properties	4.47 & 4.49	Owners to consider this option. However, grant aid is unlikely to be available.	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓✓				X
4.46	Assess the effects of Option 4.49 on Little Carlton and South Muskham	4.47 & 4.49	Assessed as Option 4.49.	✓	Environmentally acceptable but not preferred.	✓				X

Flood Risk Location 26: NORTH MUSKHAM **Refer to Figure No. 6.26**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.47	Construct local flood defences to protect property	4.53	Model suggests that loss of floodplain would have a negligible impact on surrounding flood levels. However, a more sophisticated model is required to check this	✓	Environmentally acceptable and a preferred option, due to reduced flood risk	✓	£2.1	0.4	6.0	X
4.48	Assess the effects of Option 4.49 on North Muskham	4.54	Assessed as Option 4.49	✓	Assessed as Option 4.49	✓	£14.9	3.5	11.7	X

Flood Risk Location 27: CROMWELL WEIR **Refer to Figure No. 6.27**

Option			Detail Appraisal Results							
No	Description	Flood Cell	Technical ✓ Technically acceptable X Technically unacceptable	Passed	Environmental ✓ environmentally acceptable ✓✓environmentally acceptable & preferred X environmentally unacceptable	Passed	Economic			Strategy Recommend
							Cost (£M)	B/C	P.S.	
4.49	Assess whether lowering or bypassing Cromwell Weir could reduce upstream flood levels	4.55	The model suggests that the replacement of the weir with a sluice arrangement would reduce water levels for up to 6km upstream.	✓	Environmentally acceptable but not preferred.	✓	£14.9	3.5	11.7	X

6.4 Risk and Sensitivity Analyses

Strategic Appraisal

6.4.1 In relation to stakeholder participation, the greatest risks in this process are likely to be: -

- The approach to option appraisal is poorly defined. In some instances, it may be difficult to visualise the benefits and constraints associated with the options and difficult to understand the reasons for discounting and/or progressing the chosen options.
- The staged approach is perceived as unable to deliver solutions quickly. During the early stages of the project, the benefits of the strategic assessment relate primarily to providing direction to future activities. There is a risk that the strategic appraisal may be viewed as not providing 'value for money'.
- Without careful planning, stakeholder buy-in and participation can be rapidly lost.

6.4.2 A great deal of work was undertaken to develop an agreed approach for this study. This was based on the underlying principle that involving people during the various stages is more likely to encourage acceptance of the final product. Risk mitigation has been and will continue to be practiced by: -

- Communication with public and consultees
- Team building
- Openness and impartiality

6.4.3 In the appraisal of options, it is important to identify all major risks and uncertainties which could affect the final choice. Even if they cannot be fully evaluated, they are made transparent to all parties.

Appropriate Duration of Strategy

6.4.4 It is unrealistic to consider a period greater than 50-years. It would be pragmatic to review the findings of the strategy at 5 yearly intervals.

Climate Change

6.4.5 The study made use of the current predictions on climate change and incorporated these into the hydraulic models. If the climate change predictions are correct and the effects are as indicated by the model, the 1 in 100-year peak levels within Burton and Nottingham would increase by approximately 350mm in 50 years time.

6.4.6 For illustrative purposes, to maintain this 100-year standard in future years it would be necessary to: -

- Construct the works identified in this study to a higher level. The additional cost of this in Burton and Nottingham would be £10.1m and £2.8m respectively (at 2004 prices).

- Raise those defences which presently meet this standard. It should be noted that the costs of this are not quantified.

6.4.7 If climate change was to occur, flooding would become more frequent at villages such as Gunthorpe, Caythorpe and Hoveringham. Villages such as Willington, Bleasby and Farndon, which are currently on the periphery of the 1 in 100-year floodplain, could experience flooding in locations previously considered to be a little risk.

Government and Legislation

6.4.8 If environmental legislation to protect designated sites becomes stronger, or if the number of designated sites increases, it is likely that the outcomes of the SEA and the EIAs for the options would change

6.4.9 Future political pressures both in the UK and across Europe cannot be predicted either in relation to environmental or agricultural policy. It is assumed that future flood risk management measures will largely be funded by the public purse. A major shift from this position would inevitably mean a proportionate change in local policy.

Costs

6.4.10 Due to the size of the study area and the number of options considered, it was important to adopt a consistent and appropriate methodology for costing purposes. The adopted one is pragmatic. Construction costs are based on principal quantities, and unit rates from standard sources. Percentage allowances are used to account for associated activities, such as design, and an optimism bias of 60% is included. This figure is accepted by Defra and allows for the difficulty in estimating costs from limited data. The total costs were benchmarked against the Agency's cost data for completed schemes. However, there remains the risk that once more detailed information on site conditions is available, some of the costs will alter. It is, therefore, for this reason that only those options with a benefit/cost ratio greater than 2 are considered robust enough to be recommended.

Implementation

6.4.11 The study acknowledges the major risks to implementation, including certainty of funding. To secure funding, it is suggested that detailed appraisals of the priority schemes are undertaken as soon as possible to enable them to be incorporated into the Agency's long term plan.

7 PREFERRED OPTIONS

7.1 Selection of Preferred Options

7.1.1 The appraisal of the options for specific flood risk locations is discussed in **Section 6.3**. Only those options with a benefit/cost ratio greater than 2 and a priority score above 12 are considered sufficiently robust to be taken forward for further consideration. **Table 7.1** summarises these options, which are ranked according to their Priority Score.

7.1.2 At the majority of these locations, there are presently defences which provide protection to a 1 in 100-year standard. Their priority scores are high because they protect a large number of properties. The defences are nearing the end of their design life, however, failures are not expected for at least another 10 years. Therefore, it is recommended that the immediate focus is on the flood risk areas which are not currently protected to a 1 in 100-year standard.

7.1.3 **Table 7.2** lists such locations and identifies where the stated objectives of the study would be met. Defences, as such, would not meet the objectives of 'being sustainable' and 'to minimise natural resources'. These impacts would be addressed at project level and mitigated through, for example, the use of re-cycled materials.

7.1.4 Options such as a reservoir upstream of Nottingham and dredging through Nottingham have high benefit/cost ratios and priority scores, but are not recommended. Although technically and economically viable, these would have severe environmental impacts.

7.1.5 In accordance with current Defra guidelines, the next stage for any of the options listed in **Table 7.2**, is further feasibility work and production of a Project Appraisal Report (PAR). At the latter stage, the options would be developed to outline design and any necessary investigations would be undertaken to increase confidence in the business case.

7.1.6 An important element of future studies would be to consider the programme for implementation. This is particularly relevant through Nottingham, where raising existing defences is likely to have a detrimental effect on the flood risk in adjacent flood cells.

7.2 Other Preferred Measures.

7.2.1 During the initial high level technical review of flood management options, the following 'best practice' measures were identified and are recommended: -

- Sustainable Urban Drainage Systems: either retrofitted or on new developments. They would be particularly beneficial in the upper reaches of the Trent around Stoke.

- Development Control: the adoption of appropriate measures to restrict unsuitable developments.

- Land Management: the adoption of appropriate land management options that could reduce surface runoff.

- Floodplain Obstructions: the removal of such obstructions wherever appropriate to improve conveyance locally.

7.2.2 A number of options could not be recommended on economic grounds. However, the following would provide local environmental benefits and should be considered if alternative sources of funding become available: -

- High Bridge Banks (Flood Cell 2.11): remove the flood banks upstream of High Bridge to create additional floodplain.

- Flood defences near the sailing club at Holme Pierrepont (Flood Cell 4.26): remove flood banks on right bank near to Holme Pierrepont to create additional floodplain.

Table 7.1: Preferred Flood Management Options

Option				PS	B/C	Cost (£m)	EA	Standard of Protection	Condition Code	
No.	Location		Description						Average[A]	Worst[B]
	Town	Flood Cell								
3.2	Burton upon Trent	3.3	Defences	35	150.4	£4.00	✓✓	100+	1.5	3
4.1	Sawley	4.2	Defences	34	153.4	£1.90	✓✓	25-50	2.4	3
4.7	Wilford	4.14	Defences	34	64.7	£4.30	✓✓	100+	1.6	2
4.11	West Bridgford	4.23	Defences	34	51.9	£1.60	✓✓	100+	2.1	3
4.11	West Bridgford	4.21	Defences	34	39.8	£1.60	✓✓	50-100	2.7	3
4.11	West Bridgford	4.16	Defences	34	26.7	£3.50	✓✓	50-100	2	3
4.9	Queens Drive	4.18	Defences	33	21.6	£1.30	✓✓	100+	3.0	3
3.2	Burton upon Trent	3.4	Defences	33	13.2	£3.90	✓✓	100+	1.2	2
3.2	Burton upon Trent	3.2	Defences	32	76.9	£0.90	✓✓	100+	1.9	2
4.39	Newark	4.48	Defences	32	55.8	£1.10	✓	N/A	2.0	2
3.2	Burton upon Trent	3.1	Defences	32	54	£0.70	✓✓	100+	2.0	2
4.6	Rylands	4.9	Defences	32	43.1	£2.40	✓✓	100+	2.2	4
4.11	West Bridgford	4.24	Defences	32	34.3	£1.00	✓✓	25-50	3.2	4
4.13	Colwick	4.29	Defences	32	15.4	£6.30	✓✓	25-50	2.2	4
4.13	Colwick	4.25	Defences	30.5	25.3	£3.20	✓✓	50-100	1.9	2
4.35	Rolleston (Notts)	4.43	Remove banks	28.8	9.3	£1.00	✓✓	Low Level Banks		
3.2	Burton upon Trent	2.19	Defences	28	8.4	£1.90	✓✓	100+	2.2	4
4.7	Wilford	4.12	Defences	26.4	16.5	£1.00	✓✓	100+	2.6	3
4.4	Trent Meadows	4.4	Defences	24.9	6.8	£1.00	✓✓	100+	2.0	2
4.36	Rolleston (Notts)	4.43	Defences	24	9.2	£1.00	✓	No Existing Defences		
4.37	Farndon	4.44	Defences	20	4.2	£1.90	✓	<25	3.7	5
4.8	Meadows	4.19	Defences	19.6	3.6	£4.10	✓✓	25-50	2.8	3
4.5	Barton in Fabis	4.6	Defences	19.4	5.7	£2.80	✓✓	25-50	2.0	2
4.3	Attenborough	4.7	Defences	19.2	3.2	£3.40	✓✓	50-100	2.8	4
3.15	Shardlow	3.15	Defences	18.7	6	£1.60	✓✓	100+	2.3	3
4.9	Queens Drive	4.17	Defences	16.8	2	£1.30	✓✓	100+	3.0	3
4.39	Newark	4.50/ 4.51	Defences	15.9	2	£0.50	✓	No Existing Defences		
4.21	Gunthorpe	4.36	Lower A6097	14.5	4.4	£1.30	✓	No Existing Defences[C]		
3.2	Burton upon Trent	3.6	Defences	14	4	£2.60	✓✓	100+	1.3	2
3.1	Swarkestone	3.12	Defences	12.4	3.5	£1.20	✓✓	No Existing Defences		

Note: Table ordered by Priority Score then Benefit/Cost Ratio

B/C Benefit/Cost ratio

EA Environmental Assessment; ✓ - Acceptable; ✓✓ - Preferred; X - Unacceptable

PS Priority Score

A. Average condition code weighted on defence length

B. Worst condition code of all defences in that flood cell

C. Not a scheme considering flood defences

N/A Defence exists, but hinterland level is above 100-year water level, therefore failure is irrelevant.

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Table 7.2: Flood Management Options Recommended for Immediate Consideration

Option				Objectives															
No.	Location		Description	Priority Score	Benefit/Cost Ratio	Cost (£m)	Reduce flood risk	Technically feasible	Increase quality of life	Sustainable	Protect existing uses and future needs for informal water and land based recreation	Conserve features of archaeological and historic interest	Maintain, develop and improve fisheries.	Maintain and enhance bio-diversity	Maintain and enhance water quality	Conserve and enhance landscape character	Enhance opportunities for development in accordance with existing planning policy	Maintain and enhance existing transport links in accordance with planning policy	Protect interests of the agricultural community	Minimise use of natural resources
	Town	F/Cell																		
4.1	Sawley	4.2	Defences	34.0	153	£1.9	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.11	West Bridgford	4.21	Defences	34.0	39.8	£1.6	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.11	West Bridgford	4.16	Defences	34.0	26.7	£3.5	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.39	Newark	4.48	Defences	32.0	55.8	£1.1	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.11	West Bridgford	4.24	Defences	32.0	34.3	£1.0	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.13	Colwick	4.29	Defences	32.0	15.4	£6.3	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.13	Colwick	4.25	Defences	30.5	25.3	£3.2	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.35	Rolleston (Notts)	4.43	Remove low banks	28.8	9.3	£1.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4.36	Rolleston (Notts)	4.43	Defences	24.0	9.2	£1.0	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X
4.37	Farndon	4.44	Defences	20.0	4.2	£1.9	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X

Note: Table ordered by Priority Score then Benefit/Cost Ratio

✓ Objective is met

X Conflict with objective

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8 RECOMMENDATIONS AND CONCLUSIONS

8.1 Recommendations

8.1.1 The recommendations of the study include more detailed consideration of a number of flood management options at selected locations and the adoption of several best practice techniques. The study also identified schemes which would result in environmental improvements and areas where further investigations are required. In summary, these are: -

A. Flood Management

The options listed in **Table 7.2** should be considered for implementation in the short to medium term. In the longer term, the focus should be on the replacement of those existing defences that are nearing the end of their useful lives. **Table 7.1** details those with highest priority scores.

B. The Adoption of 'best practice' Measures.

These include: -

- Sustainable Urban Drainage Systems
- Development Control
- Land Management
- Floodplain Obstructions

C. Environmental Improvements

Removal of the defences at High Bridge Farm and near the sailing club at Holme Pierrepont would have environmental benefits and should be considered if alternative sources of funding become available.

D. Further work

This includes: -

River Models: A more sophisticated hydraulic model is recommended to assess any works within the floodplain downstream of Nottingham.

Development Control: for any proposed development within, or on the periphery of, the 100-year floodplain, more local models should be constructed to complement the current models.

Topographical Surveys:

- Accurately determine the levels of those existing defences where the current standard of protection is considered to be less than 100-years.
- To determine which properties are at risk, threshold surveys of those within the 100-year floodplain should be undertaken.

Structural Surveys:

- The condition codes used in this study are based on visual inspections. Before any defences are replaced, ground investigations and structural analyses should be undertaken.

Flood Warning:

- The Trent hydraulic models should be included in the programme for incorporation into the new forecasting procedures.
- The Agency should review its current Automatic Voice Messaging and flood warning procedures to reflect the 100-year floodplain produced as part of this study.

Tributary Storage: appropriate results from this study should be passed to those undertaking the strategies for the major tributaries.

Flood Gates: consideration should be given to the operational suitability of Sawley flood gates (Sheetstores) at the Erewash Canal.

Flood Proofing: residents should be made aware that flood proofing measures are available. This is particularly important for properties in the floodplain where no protection scheme is likely to be promoted in the near future.

8.2 Conclusions and Way Forward

8.2.1 The Agency should now develop a phased programme to implement the findings of this study. The next stage for any of the options identified is further feasibility work and production of a Project Appraisal Report (PAR).

8.2.2 It needs to be recognised that confidence and accuracy in the findings will improve from high level planning, through strategic studies to the development of a PAR. There is a risk that a scheme identified in this strategic study will not be confirmed during the subsequent appraisals or that it may proceed to a different timescale.

8.2.3 Further investigations will be required prior to submission of any PARs. The recommended approach for an individual area can be summarised as follows:

- Obtain accurate topographic and level information
- Establish the hydraulic flood cells
- Confirm the existing standard of protection
- Undertake site investigations to confirm the condition of the existing assets
- Confirm the design flood levels
- Undertake a more rigorous economic appraisal, including re-costing
- Prepare PAR