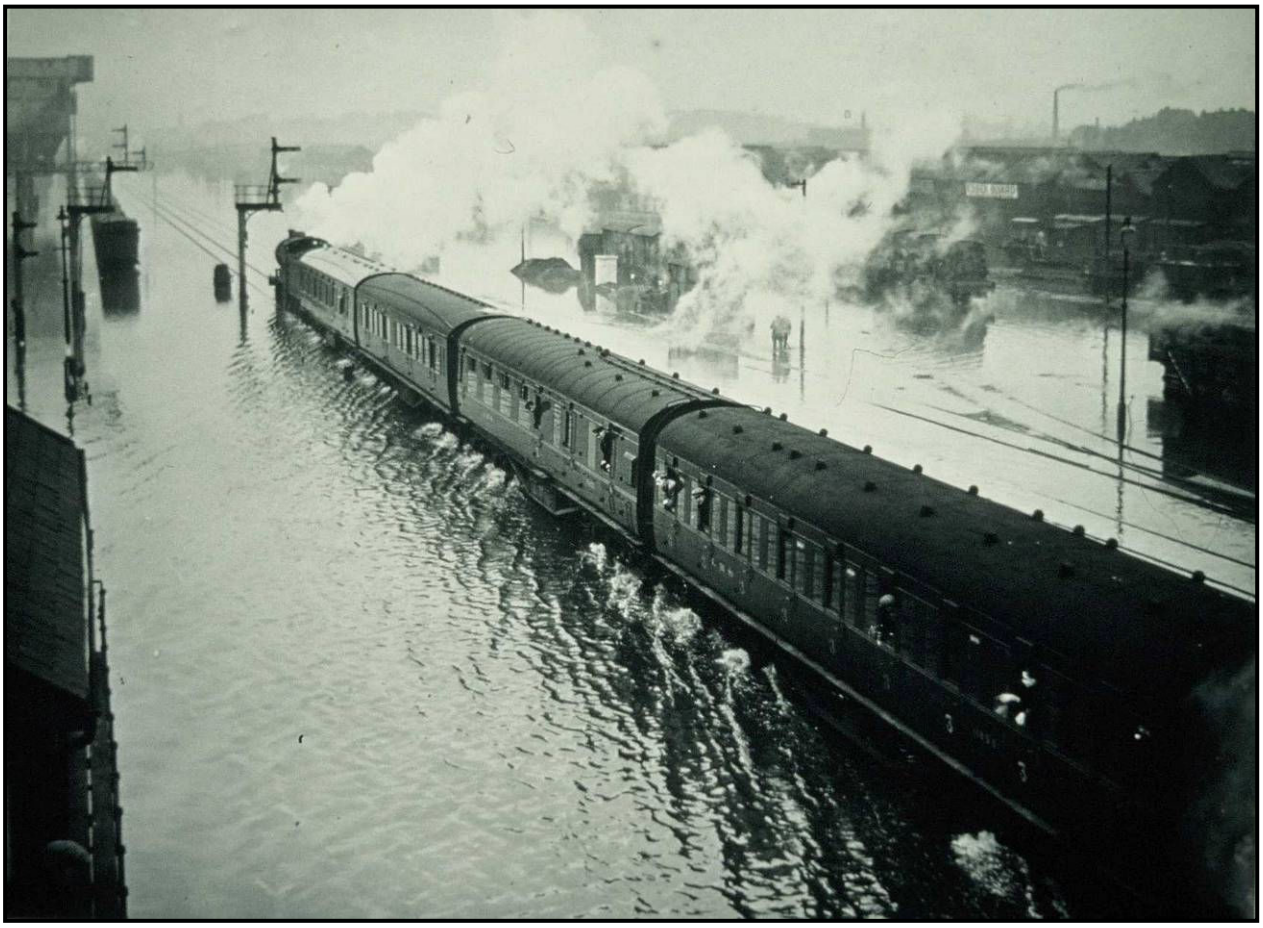
NOTTINGHAM (LEFT BANK)
FLOOD ALLEVIATION SCHEME

FLOOD RISK ASSESSMENT
Incorporating The Attenborough Village Peripheral Route

March 2010



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NOTTINGHAM TRENT LEFT BANK FLOOD ALLEVIATION SCHEME FLOOD RISK ASESSMENT INCORPORATING THE ATTENBOROUGH VILLAGE PERIPHERAL ROUTE

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Cover Photograph: Midland Station in Nottingham during the 1947 Floods

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1	10/01/07	Internal review	-
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Whilst all reasonable care has been taken in this assessment we cannot guarantee that during the lifetime of the flood risk assessment water levels may not exceed those stated. The report has addressed the risk of flooding from the River Trent only, and the conclusions stated in it are based on our best estimate using available data with a precautionary approach taken where possible. We have not assessed flood risks from other sources. We must make it clear that the assessment of weather generated flooding is inexact and that analysis is limited by the accuracy and availability of recorded data. Higher water levels may occur in the future due to the actions or omissions of third parties, or to poor maintenance, blockage, storm events in excess of the design standard quoted, inaccuracy or unavailability of data. Flooding beyond that estimated in this report may also occur due to climate change.

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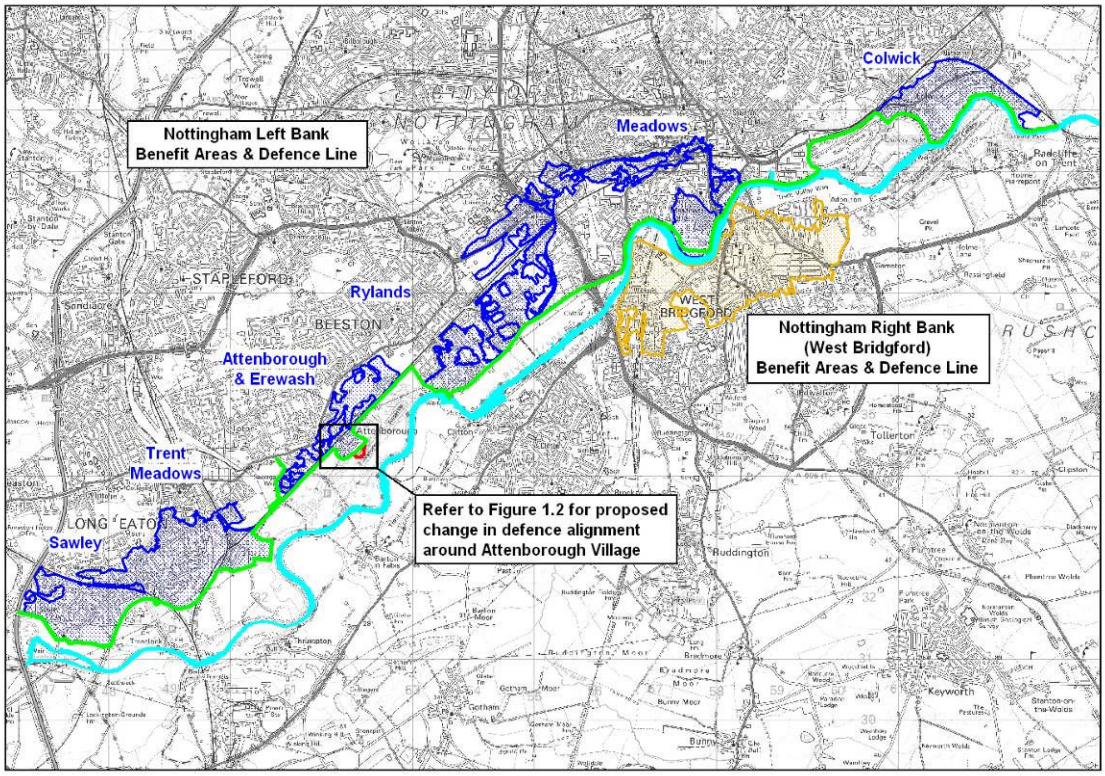
1 INTRODUCTION

1.1 Background

1.1.1 The flood risk along the fluvial Trent through Nottingham was originally studied as part of the Fluvial Trent FRMS and subsequently in greater detail, by the Nottingham Strategy. The Nottingham Strategy demonstrated that the Trent through Nottingham comprises two flood cells, namely the right (south) and left (north) banks. The Nottingham Strategy recommended providing flood defences that would protect against a flood with a 1% (1 in 100) annual probability of occurring for both cells. Figure 1.1 shows the areas to benefit from the flood defence schemes along the left and right banks of the Trent through Nottingham.

Figure 1.1 – Nottingham Trent Left and Right Bank Benefit Areas

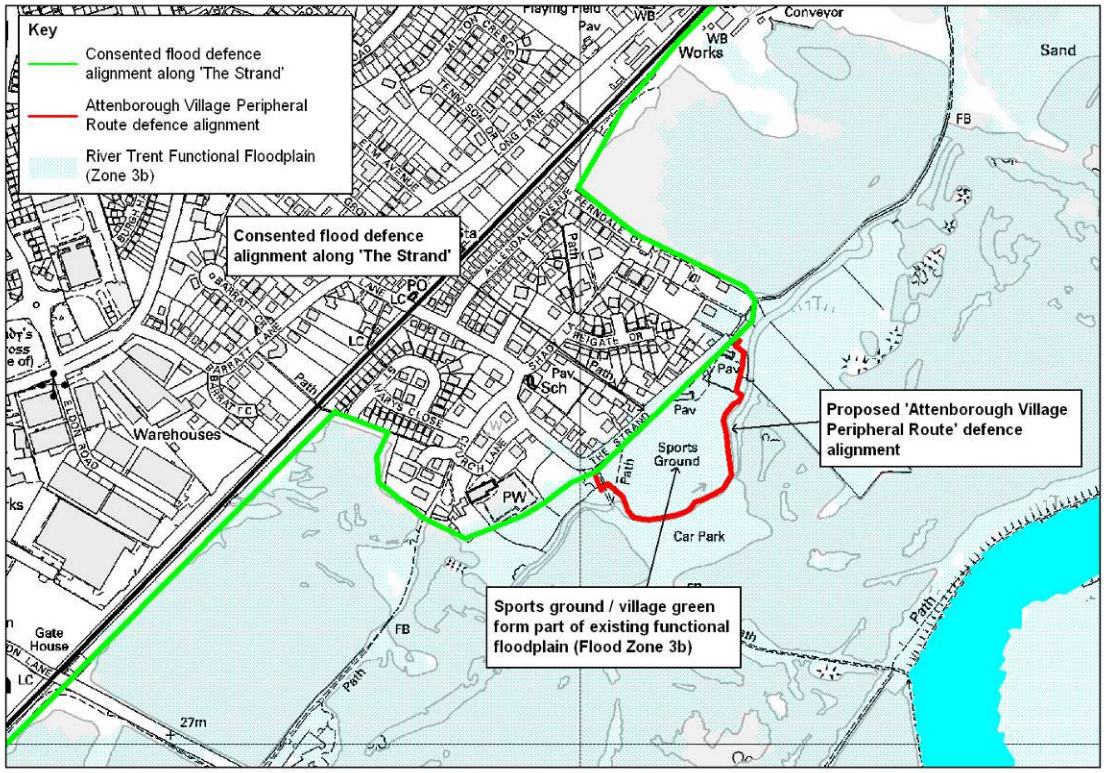


1.1.2 Works to the defences on the right bank flood cell (referred to as the 'West Bridgford Flood Alleviation Scheme') were undertaken using the Environment Agency's permissive development powers and were completed during April 2008.

1.1.3 Planning permission for works to the defences on the left bank (referred to as the 'Nottingham Trent Left Bank FAS') was granted during March 2009. Construction works commenced during Summer 2009, and are now substantially complete around Sawley and Trent Meadows.

1.1.4 Further to the start of construction works, the Environment Agency are now seeking planning permission for an alternative flood defence alignment around Attenborough Village. The new alignment is known as the 'Attenborough Village Peripheral Route'; refer to Figure 1.2 and 'Figure AVA1' (Drg. 108806-3900-0220-A).

Figure 1.2 – Attenborogh Village Peripheral Route Flood Defence Alignment



1.1.5 Figure 1.2 shows that the Attenborough Village Peripheral Route alignment will result in a loss in functional floodplain storage compared to the previously consented flood defence alignment along 'The Strand'. Consequently, in accordance with the Town and Country Planning (Environmental Impact Assessment) Regulations (1999), this Flood Risk Assessment has been prepared accompany the proposed route's Environmental Statement.

1.1.6 This report investigates the flood risk associated with the **Nottingham Trent Left Bank FAS** with the proposed **Attenborough Village Peripheral Route** alignment**.** Whilst planning permission is only being sought for the flood defences associated with the Attenborough Village Peripheral Route, flood risk associated with the proposed route should be assessed both locally and in the context of the whole left bank scheme**.** The report has been produced in accordance with Planning Policy Statement 25: 'Development and Flood Risk' (referred to subsequently as PPS25)[1] and its associated practice guide[2]. For completeness, the existing *Nottingham Left Bank FAS Flood Risk Assessment* (Black & Veatch, October 2008) is attached to this report as Annexe A.

1.2 Location

1.2.1 The city of Nottingham is located in Nottinghamshire, close to the county boundaries of Derbyshire and Leicestershire. The city has a population of 270,000 and is reported as being the fastest growing city in England. Situated on the banks of the River Trent, Nottingham contains over 16,000 properties at risk from a flood with a 1% (1 in 100) annual probability of occurring.

[1] *Planning Policy Statement 25: Development and Flood Risk*, Communities and Local Government, December 2006.
[2] *Planning Policy Statement 25: Development and Flood Risk Practice Guide*, Communities and Local Government, June 2008.

1.2.2 Nottingham is located along the lower reaches of the Trent (refer to Figure 1), just downstream of its confluences with the Rivers Soar and Derwent, two major watercourses in their own right. Owing to the size and rural nature of the upstream catchment, the Trent at Nottingham responds slowly to rainfall and the flood hydrograph peak may last several days. The natural width of the floodplain at Nottingham is some 1.5km, but this has historically been reduced to just 100m through the centre of the city.

1.2.3 Two other notable tributaries discharge to the Trent along its left bank through Nottingham namely, the Rivers Erewash and Leen. Whilst both can result in flooding of property through the city, neither exerts a significant influence upon flood levels along the Trent when the Trent is in flood.

1.3 Proposed Nottingham Left Bank Flood Alleviation Scheme (FAS) Incorporating Attenborough Village Peripheral Route

1.3.1 The proposed Nottingham Left Bank FAS is to raise the existing defences and to construct new defences (where required) along the left bank of the Trent between the M1 at Sawley and Radcliffe Railway Viaduct; a length of some 27km. The scheme is to be designed to prevent flooding against an event with a 1% (1 in 100) annual probability of occurrence. Owing to the extent of the scheme, the left bank was split into seven scheme areas. The scheme areas and associated works are summarised in Figure 1.1 and Table 1.1.

1.3.2 Construction works on the scheme commenced during Summer 2009; the flood defences are now substantially complete in the Sawley and Trent Meadows scheme areas. Works are ongoing or are due to commence shortly in Attenborough, Rylands and Meadows.

1.3.3 The Attenborough Village Peripheral Route comprises a change in the previously consented flood defence alignment around Attenborough Village. An assessment of the Attenborough Village Peripheral Route by Black & Veatch found that the alignment has a localised impact on floodplain hydraulics between Barton Lane and Attenborough Village. The Attenborough Village Peripheral Route will also result in the volumetric loss of 53,000m^3 of functional floodplain. This constitutes 0.01% of the 1% (1 in 100) annual probability flood volume on the Trent at Nottingham.

1.3.4 Referring to Table D.2 of the Planning Policy Statement, the planned/completed works, including the Attenborough Village Peripheral Route alignment, are a ‘water-compatible development’ as they form part of the Environment Agency’s ‘flood control infrastructure.’ PPS25 Tables D1 and D3 show that these works are permitted within flood zones 3a and 3b.

Table 1.1 – Nottingham Left Bank FAS Proposed Works

Area	Description of Proposed Works
Sawley	Flood defence works are now substantially complete for both these reaches
Trent Meadows	
Erewash	570m of new embankment to a maximum height of 1.4m.
Attenborough	3600m of new flood walls between 0.8m and 2.8m in height. Wall to run parallel to the existing railway embankment and around the edge of Attenborough Village Green (Attenborough Village Peripheral Route). 240m of new embankments. Raise road levels by up to 1m on Barton Lane and Allendale Avenue. A new pumping station and drainage improvements to Attenborough village.
Rylands	Raise 930m of existing embankments. Raise 970m of existing flood walls. Raise road levels on Riverside Road. 500m of new flood wall to between 0.4m and 2.3m in height. Replace flood gates at Beeston Lock (Beeston Canal). 2100m of defence to be provided by high ground.
Meadows	Replace and raise 220m of existing flood walls. 715m of new flood embankment to a maximum height of 2.5m set-back through playing fields. 560m of new wall to a maximum height of 1.5m set-back along garden boundaries on Victoria Embankment Raise 150m of existing flood wall by up to 0.3m 85m of existing floodwall to be replaced around Meadow lane Lock Area 160m of new wall to a maximum height of 1.0m A new pumping station at the outfall of Tinkers Leen. An automated flood gate to replace existing at Meadow Lane Lock (Nottingham Canal).
Colwick	Raising 1225m of existing flood embankments. 480m of existing flood wall to be replaced. 280m of new embankment to maximum height of 0.4m. 295m of new floodwall (including 165m replacing an existing embankment) to a maximum height of 2.3m. Construction of a new pumping station on Holme Dyke Raise road levels along River Road and Private Road No.5. Creation of a continuous riverside footpath.
General	Local measures to address issues such as access, landscaping, & drainage

Notes

1. The railway embankments at Sawley and Trent Meadows already form part of the existing flood defence line, and performed satisfactorily as a defence during the November 2000 flood event. Use of these embankments as part of the Nottingham Left Bank FAS is to be agreed with Network Rail through the completion of 'Form A' and 'Form B' approval documents. Form A approval has already been granted for the works.
2. Flood defence works at Sawley and Trent Meadows are now substantially complete
3. Following completion of the previous flood risk assessment, the flood defences within Meadows have been re-aligned around Victoria Embankment to increase floodplain storage in the centre of Nottingham

1.4 Forms of Flooding

1.4.1 Flooding can occur from a number of sources. The following paragraphs detail the possible causes of flooding in Nottingham and the implications for the proposed Nottingham Trent Left Bank FAS.

Flooding from Rivers

1.4.2 The Nottingham Left Bank FAS is designed to protect against flooding of the city solely from the River Trent (report sections 3 & 4). The scheme will not reduce flood risk from other rivers draining through the city e.g. the River Leen. As part of this assessment however, the impact of the proposed scheme upon rivers flowing through the proposed defence line was considered (report section 4).

Flooding from the Sea

1.4.3 There is no risk of tidal flooding through Nottingham; the altitude along the river is typically 20 to 30mAOD.

Flooding from Land

1.4.4 Flooding of land located immediately behind the existing flood defences from surface water runoff occurred during the November 2000 flood event. The implications of the proposed scheme on surface water flooding are considered in section 4.5 of this report.

Flooding from Groundwater

1.4.5 Flooding of land behind the proposed defence line from groundwater during previous flood events has been observed. For much of the scheme, seepage through or under the existing defences is not a concern due to the thickness of less permeable surface strata and land use. The exception is Attenborough, Erewash and Rylands, where granular alluvium has a high permeability and hydraulic connection to the Rivers Trent and Erewash. Analysis completed to date indicates that a cut-off is required for the defences in this area to prevent seepage under the proposed defences.

1.4.6 For the Meadows scheme area, the granular alluvium may have a hydraulic connection with the River Trent. Initial findings from groundwater monitoring have shown that although seepage may occur, no properties are likely to be flooded from water ponding in the low lying areas. Further appraisal will be carried out during the detailed design phase.

Flooding from Sewers

1.4.7 Flooding of land from sewers and minor storm drains crossing the existing flood defences occurred during the November 2000 flood event. The implications of proposed scheme on flooding from minor watercourses and sewers are considered in section 4.5 of this report.

Flooding from Reservoirs, Canals and Other Artificial Sources

1.4.8 The Beeston, Erewash and Nottingham Canals all cross the proposed defence line. In major flood events, the three canals have conveyed flood water through the city and resulted in flooding of land and property. Existing flood gates are located across all three canals, which are to be replaced or improved as part of the left bank scheme; refer to Table 1.1

2 DATA COLLECTION

2.1 Available Data

2.1.1 Table 2.1 is a summary of available reports on the River Trent at Nottingham, which have been reviewed and referenced in the production of this Flood Risk Assessment (FRA).

Table 2.1 – Existing Reports Available on the River Trent at Nottingham

Title	Author	Date
Fluvial Trent Strategy Final Strategic Appraisal Report Appendix F – Final Modelling Report Volume 1: Final Hydrological Report	B&V	April 2005
Fluvial Trent Strategy Final Strategic Appraisal Report Appendix F – Final Modelling Report Volume 5: Model 4 Report	B&V	April 2005
Fluvial Trent Hydraulic and Economic Study Nottingham – Hydraulic Modelling Report	B&V	July 2005
Strategy for the River Trent in Nottingham	B&V	July 2005
Nottingham Trent Left Bank Flood Alleviation Scheme – Scoping Report	B&V	November 2005
River Trent Review and Recommendations on Flood Warning	B&V	April 2006
Project Appraisal Report – Nottingham Trent Left Bank Flood Alleviation Scheme	B&V	May 2006
Nottingham (Left Bank) FAS: Assessment of Mitigation Options for Villages Downstream of Nottingham	B&V	February 2006
Nottingham Left Bank FAS Drainage Assessment	B&V	June 2006
Nottingham Hydraulic Model Review	Jacobs	October 2007
Nottingham ISIS/Tuflow Hydraulic Model Review [see note 1]	Jacobs	March 2008
Greater Nottingham Strategic Flood Risk Assessment (GNSFRA)	B&V	June 2008
Nottingham ISIS/Tuflow Hydraulic Modelling Review – Issue of Interim Results	B&V	August 2008
Nottingham ISIS/Tuflow Model – B&V Response to Jacobs Review	B&V	September 2008
Nottingham Trent Left Bank FAS Environmental Statement	B&V	November 2008
Nottingham Trent left Bank Flood Alleviation Scheme – Hydraulic Modelling Review Stage 3	Jacobs	February 2009
Nottingham ISIS/Tuflow Model – B&V Response to Jacobs Stage 3 Hydraulic Modelling Review	B&V	April 2009
Nottingham Left Bank FAS – River Erewash ISIS/Tuflow Modelling Study	B&V	August 2009
The River Erewash at Nottingham Road (Project Note)	B&V	October 2009
Nottingham Left Bank FAS – Attenborough Village Peripheral Route (Technical Note)	B&V	February 2010
Greater Nottingham Strategic Flood Risk Assessment Update (GNSFRA)	B&V	*In press*

Notes
1. Black & Veatch did not receive a full version of Jacobs March 2008 review

2.1.2 The documents listed above have been subject to extensive reviews previously. This FRA has extracted the necessary data, drawings, flood outlines, hydrological flows and river model results from these reports.

3 EXISTING FLOOD RISK

3.1 Flood History

3.1.1 Nottingham has a long and well recorded history of flooding. The November 2000 event was the most recent flood event to result in significant property flooding, with approximately 60 properties flooded along the left bank. The largest recorded flood events through the city occurred during 1795, 1875 and 1947. Around 3000 properties were flooded during the latter event which prompted construction of the existing defences through the city during the 1950s. The existing defences prevented widespread flooding of the city during November 2000.

3.1.2 A summary of the key historical flood events on the Trent at Nottingham since 1700 is presented in Table 3.1

Table 3.1 – River Trent at Nottingham Flood History

Event Date	Rank (since 1795)	Level at Trent Bridge (m OD)	Peak Flow (m^3/s)	Annual Probability (%)
February 1795	1	24.55[see note 1]	1416	<0.05%
October 1875	2	24.38	1274	0.05 – 1%
March 1947	3	24.30	1107	1.3 – 2%
November 1852	4	24.26	1082	2 – 3%
November 2000	5	23.80	1019	3%

Notes
1. The 1795 flood level is approximate
2. The flow estimates ascribed to the 1795 and 1875 events were first reported in '*Flood prevention schemes in the vicinity of the city of Nottingham, with special reference to the hydraulic model constructed at Delft University, Holland*', Haile, W.H. & Cheetham, H., Journal of the Institution of Civil Engineers, Vol. 35, 1950.
3. The flow estimate for the 1852 event was calculated by Black & Veatch as part of the *Fluvial Trent Strategy Final Strategic Appraisal Report Appendix F – Final Modelling Report Volume 1: Final Hydrological Report* (2005)

3.2 Hydrological Analysis

3.2.1 The derivation of design flows for the River Trent at Nottingham is detailed within the *Fluvial Trent Strategy Final Strategic Appraisal Report Appendix F – Final Modelling Report Volume 1: Final Hydrological Report*, issued April 2005. The results of the strategy's hydrological analysis were reviewed previously as part of [the] *Fluvial Trent Hydraulic and Economic Study Nottingham (July 2005)* and *Nottingham ISIS/Tuflow Model Review (September 2008),* and are suitable for use in this Flood Risk Assessment.

3.2.2 The hydrological assessment for Nottingham comprised the following key activities:

- Derivation of a continuous Annual Maxima (AMAX) series for the River Trent at Nottingham dating back to 1852, using the records from the Trent Bridge (1852 to 1968) and Colwick (1968 to date) Gauging Stations.
- An FEH single site flood frequency analysis using the Trent Bridge/Colwick AMAX series to determine design flows for the Trent through Nottingham.
- Derivation of a continuous AMAX series for Shardlow Gauging Station dating back to 1954.
- An FEH single site flood frequency analysis using the AMAX series for Shardlow Gauging Station to determine design flows on the Trent just upstream of Nottingham.

- Adjustment of the flood growth curve and design flows for Shardlow Gauging Station to ensure consistency with those derived for the upstream (Drakelow) and downstream (Colwick/Trent Bridge) gauging stations on the Trent
- Derivation of design flows for the River Derwent at St Mary's Gauging Station using the FEH single site method. Design flows were also calculated as part of the Fluvial Trent Strategy for the River Soar at Kegworth Gauging Station, but these were amended by B&V as part of the Nottingham ISIS/Tuflow model review.
- Derivation of design flows for the Rivers Leen and Erewash using the FEH index flood pooling group method.

3.2.3 Design flows for the River Trent and its tributaries through Nottingham are summarised in Table 3.2.

Table 3.2 – River Trent at Nottingham: Adopted Design Flows

Return Period		Adopted Design Flows (m^3/s)					
%	Years	Trent at Colwick	Trent at Shardlow	Derwent at St Mary's	Soar at Kegworth	Erewash at Sandiacre	Leen at Triumph Road
50	2	476	254	140	100	19.2	10.8
20	5	670	343	190	135	27.4	14.5
10	10	800	417	232	158	33.3	16.6
4	25	975	195	298	188	41.9	19.3
2	50	1090	584	361	212	49.4	21.3
1	100	1200	648	438	238	57.9	23.3

3.2.4 It should be noted that owing to concerns regarding the accuracy of gauged flows at Kegworth Gauging Station, the design flows calculated for the Soar should be treated with caution. This is not critical to the study as the key flow calibration point is at Colwick where there is a long and reliable flow record.

3.3 River Modelling

3.3.1 The following hydraulic river models are available to assess the existing flood risk from the River Trent through Nottingham. Further details of all four models are given below in Table 3.3 and Figure 3.1.

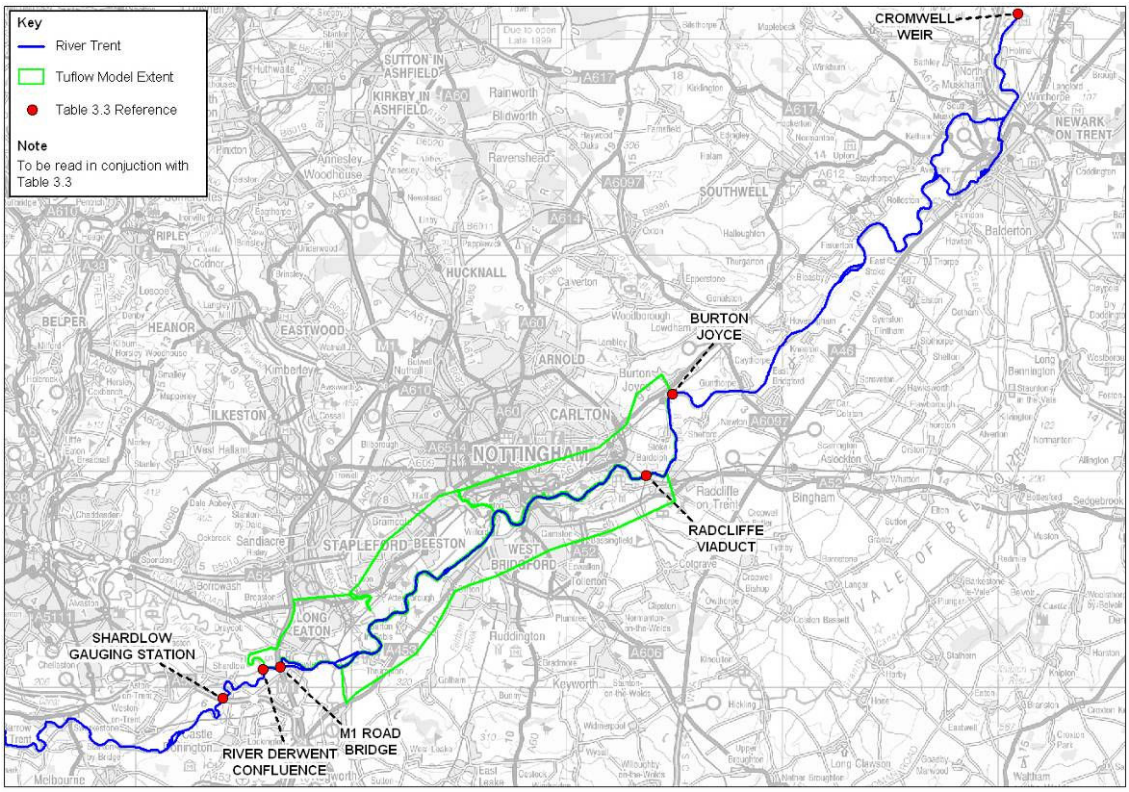
- Fluvial Trent Strategy Model 4 (April 2005);
- the Nottingham Trent Model (July 2005);
- Greater Nottingham SFRA ISIS/Tuflow Model (June 2008);
- July 2008 Nottingham ISIS/Tuflow Model (September 2008); and
- Greater Nottingham SFRA ISIS/Tuflow Model (January 2010)

Table 3.3 – Existing Hydraulic Models through Nottingham

Model Name	Date	Type	Extents[1]				Length (km)
			Upstream		Downstream		
Fluvial Trent Model 4	April 2005	1D ISIS	Shardlow	SK 4480 3006	Cromwell Weir[2]	SK 8092 6114	80
Nottingham Trent Model	July 2005	1D ISIS	M1 Road Bridge	SK 4659 3089	Radcliffe Railway Viaduct	SK 6364 3972	27
GNSFRA Nottingham ISIS/Tuflow[1]	June 2008	1D/2D Linked ISIS/Tuflow	M1 Road Bridge	SK 4659 3089	Burton Joyce	SK 6508 3620	31
July 2008 Nottingham ISIS/Tuflow[1]	September 2008	1D/2D Linked ISIS/Tuflow	River Derwent Confluence	SK 4592 3079	Burton Joyce	SK 6508 3620	32
January 2010 Nottingham ISIS/Tuflow[1]	January 2010	1D/2D Linked ISIS/Tuflow	River Derwent Confluence	SK 4592 3079	Burton Joyce	SK 6508 3620	32

Notes: 1. For the 1D/2D linked models, the extents given are for the 2D (Tuflow) domain.
2. Cromwell Weir is downstream of Newark.

Figure 3.1 – Details of Existing Model Extents



3.3.2 Fluvial Trent Strategy Model 4 was built as part of the Fluvial Trent Strategy for the purpose of a strategic level assessment of flood risk along the Trent between Stoke-on-Trent and Cromwell Weir.

3.3.3 The Nottingham Trent Model was built from Fluvial Trent Model 4 for the purpose of project appraisal study through Nottingham. Work to the Nottingham Trent Model comprised a comprehensive review of Fluvial Trent Strategy Model 4, resulting in re-schematisation and significant improvement to the calibration of the model through Nottingham. The Nottingham Trent Model was reported in *Fluvial Trent Hydraulic and Economic Study*

Nottingham, and was recommended for use in the derivation of flood defence levels along both the West Bridgford and Nottingham Left Bank FAS reaches.

3.3.4 Following the issue of the Nottingham Trent Model, the Greater Nottingham Strategic Flood Risk Assessment (GNSFRA) was undertaken. The GNSFRA study comprised construction of a linked 1D/2D ISIS/Tuflow model for Nottingham. The purpose of the study was to provide a more accurate representation of floodplain flows through Nottingham than could be provided by the previous 1D ISIS model. The model produced by the study is known as the GNSFRA ISIS/Tuflow Model.

3.3.5 Whilst the results of the GNSFRA ISIS/Tuflow model were broadly consistent with those of the Nottingham Trent Model, the two models differed around the key area of Attenborough Village, with the GNSFRA 1% annual probability level up to 0.8m higher than the Nottingham Trent Model 1% level. Detailed reviews[3] of both models around the Attenborough area were undertaken, and the GNSFRA model was recommended for use in the derivation of flood defence levels, subject to additional calibration and changes to the model schematisation.

3.3.6 A full review of the GNSFRA model was undertaken by Jacobs during March 2008, with a number of recommendations made for changes to the model. Following the second Jacobs review, Black & Veatch (B&V) amended and re-calibrated the model; the resulting model was known as the 'July 2008 Nottingham ISIS/Tuflow Model'. For full details of the model, the reader is referred to *Nottingham ISIS/Tuflow Model B&V Response to Jacobs Review*, Black & Veatch, September 2008.

3.3.7 The July 2008 Nottingham ISIS/Tuflow Model was recommended for use by B&V in the derivation of design levels for the Nottingham Left Bank FAS. Flood levels from the July 2008 Nottingham ISIS/Tuflow Model were also used in the *Nottingham Left Bank FAS Flood Risk Assessment* (Black & Veatch, October 2008).

3.3.8 The January 2010 Nottingham ISIS/Tuflow Model (Black & Veatch, January 2010) was developed for additional work on the Greater Nottingham SFRA. The model is very similar and produces nearly identical results to the July 2008 Nottingham ISIS/Tuflow Model. Unless stated, all flood levels quoted in this FRA are taken from the January 2010 Nottingham ISIS/Tuflow Model.

[3] *Nottingham Hydraulic Model Review*, Jacobs UK, October 2007.

3.4 Results

Flood Levels

3.4.1 The January 2010 Nottingham ISIS/Tuflow model was used to derive design water levels for the existing situation through Nottingham for the 1% (1 in 100) annual probability event. Table 3.4 is a summary of the 1% annual probability peak water levels at key locations along the Nottingham Left Bank FAS.

Table 3.4 – January 2010 Nottingham ISIS/Tuflow 'Existing Conditions' Design Water Levels

Location[1]	OS Grid Reference	ISIS Node	1 % Annual Probability Water Level (m AOD) [2]
M1 Road Bridge	SK 4659 3089	4050111460D	31.90
Harrington Bridge	SK 4711 3396	4050110600	31.83
Sawley Viaduct	SK 4784 3080	405019821	30.97
Thrumpton Weir	SK 4963 3095	405017960	29.93
Cranfleet Lock	SK 5025 3152	405017210	29.44
Pasture Lane	SK 5030 3249	405014720	28.48
Attenborough Village	SK 5207 3441	405011950	27.55
Beeston Weir	SK 5343 3531	405010030	27.28
Clifton Bridge	SK 5616 3670	4040110760	26.21
Wilford Bridge	SK 5688 3811	404018960	25.50
Welbeck Road Footbridge	SK 5794 3766	404017510	24.76
Trent Bridge	SK 5813 3829	404016890	24.39
Lady Bay Bridge	SK 5847 3872	404016300	23.73
Holme Sluices	SK 6132 3932	Col_13010	22.26
Colwick Gauging Station	SK 6206 3988	404012070	21.81
Radcliffe Viaduct	SK 6366 3972	403568850u	21.11

Notes
1. Locations are shown in Figure 2
2. Peak water levels are mean channel peak water levels extracted from the ISIS part of the model.

3.4.2 To validate the ISIS/Tuflow 1% (1 in 100) annual probability peak water levels, the modelled peak water level at Trent Bridge are compared against the historic flood mark series at the bridge; refer to Figures 3.2 and 3.3.

Figure 3.2 – Historic Flood Levels at Trent Bridge

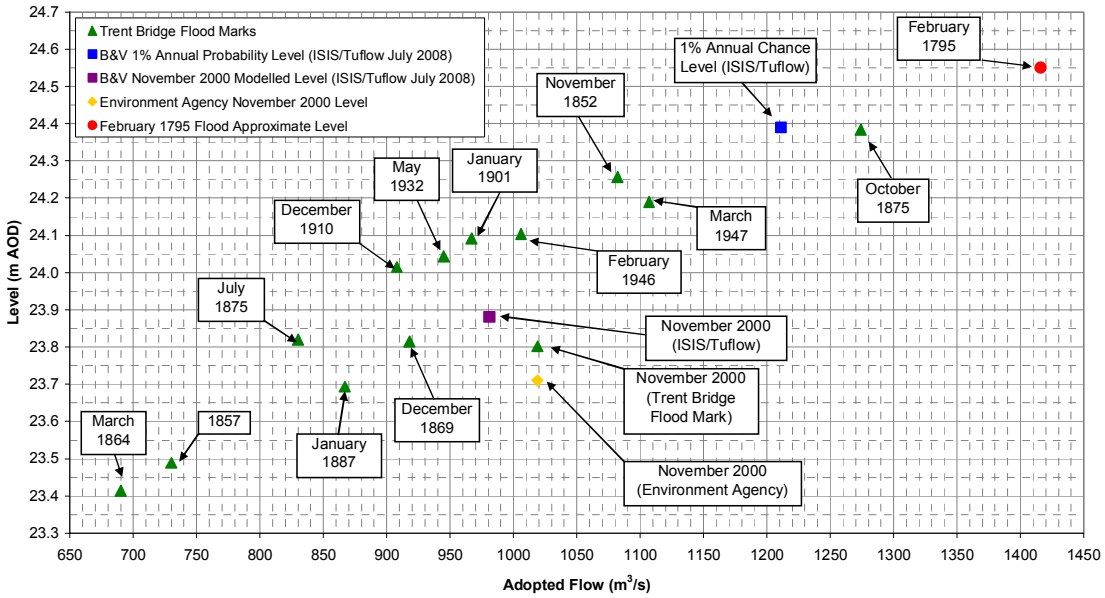


Figure 3.3 – Trent Bridge Wrack Marks

Trent Bridge	Trent Bridge Wrack Marks
	

3.4.3 The 1% (1 in 100) annual probability level from the July 2008 Nottingham ISIS/Tuflow Model is similar to the recorded level for the October 1875 flood event.

3.4.4 The October 1875 event is estimated to be a 0.6% (1 in 175) annual probability event and is commonly reported as being the second most severe flood event to occur along the lower Fluvial Trent. This lends confidence to the 1% annual probability level derived using the July 2008 ISIS/Tuflow model as, given the likely decrease in 'natural floodplain' since 1875 due to urban development, it would be expected that the present day 1% annual probability level should be equivalent to historic events of a slightly larger magnitude.

3.4.5 The 1% annual probability level is 0.15m lower than the approximate peak level for the February 1795 flood event. The 1795 event is commonly described as the most severe event to occur along the lower Fluvial Trent, and is almost certainly the largest flood event to occur at Nottingham in the past 300 years. The 1795 event is estimated to be a 0.2% (1 in 500) annual probability event with a reported peak flow of 1416m^3/s, 18% larger than the adopted 1% annual probability design flow. Again, historic changes in the extent of available floodplain would alter the peak level.

Flood Defence Standard of Protection

3.4.6 Presently, the flood defences along the left bank are typically built to around the 2% (1 in 50) annual probability level. The main exceptions are at Sawley and Trent Meadows, where the new defences provide a 1% (1 in 100) annual probability standard of protection and at Attenborough, where properties are at risk from flooding during the 4% (1 in 25) annual probability event. Based upon Defra's Flood and Coastal Defence Project Appraisal Guidance 3 (FCDPAG3), a 1% (1 in 100) annual probability standard of protection is recommended for Nottingham.

3.4.7 In addition, the *Strategy for the River Trent in Nottingham*, highlighted that the majority of the existing defences along the left bank are nearing the end of their design life and are in poor condition, with sections in Rylands and Colwick due for replacement in the next 5 to 10 years.

3.4.8 The flood risk area for the Nottingham Left Bank flood cell is presented in Figure 1. The extent was developed as part of the ongoing Greater Nottingham SFRA study and accounts for possible failures or breaches in the existing defences at key locations on the defence line. As shown, large areas of Nottingham on the left bank of the Trent are at risk from flooding notably, Long Eaton, Attenborough, Beeston, Meadows and Colwick.

4 IMPACT OF THE SCHEME

4.1 Appraisal Methodology

4.1.1 As detailed in Section 1.3 of this report, the Nottingham Left Bank FAS comprises raising the existing defences and constructing new defences (where required) between the M1 Road Bridge and Radcliffe Railway Viaduct. The railway viaduct therefore provides a convenient hydraulic reference point for assessing the impact of the scheme on the areas that benefit from the flood defence works and those that do not.

4.2 Upstream of Radcliffe Viaduct

Modelling Methodology & Derivation of Flood Defence Levels

4.2.1 In order to determine the 'with scheme' water levels for the Nottingham Left Bank FAS with the Attenborough Village Peripheral Route, the proposed flood defences were added to the Tufow part of the January 2010 Nottingham ISIS/Tuflow model as '3-D lines.'

4.2.2 The flood defence levels included in the model (including the Attenborough Village Peripheral Route alignment) were based on those calculated previously using the July 2008 Nottingham ISIS/Tuflow Model, which were derived as follows:

Flood Defence Level (m AOD) = Design Water Level (m AOD) + Freeboard Allowance (m)

4.2.3 The adopted freeboard allowances for the Nottingham Left Bank FAS are given below in Table 4.1. The freeboard allowances were calculated using the methods detailed in the *Fluvial Freeboard Guidance Note* (Environment Agency, 2000) and are reported fully in *Nottingham Left Bank FAS – Assessment of Freeboard Version 2* (Black & Veatch, 2008), to which the reader is referred for further details.

Table 4.1 – Nottingham Left Bank FAS Adopted Freeboard Allowances

Scheme Area	Recommended Freeboard Allowance (mm)	
	Hard Defences	Soft Defences
Sawley	300	400
Trent Meadows	300	400
Attenborough	300	400
Rylands (Upstream Beeston Weir)	300	400
Rylands (Downstream Beeston Weir)	450	550
Meadows (Upstream Trent Bridge)	550	550
Meadows (Downstream Trent Bridge)	450	450
Colwick (Upstream Crosslands Meadow)	350	450
Colwick (Downstream Crosslands Meadow)	450	450

4.2.4 Freeboard allowances vary along the length of the scheme due to the changing sensitivity of the model to variations in key hydraulic parameters, e.g. flow, roughness, which are integral to the freeboard calculations. An additional 100mm allowance has also been assumed for all 'soft' defences to account for possible degradation of these types of defences. It should be

noted that the adopted freeboard allowances **do not** include an allowance for future climate change.

4.2.5 1% annual probability with scheme water levels for key reference points along the January 2010 Nottingham ISIS/Tuflow Model are detailed in Table 4.2. Selected flood defence levels for the Nottingham Left Bank FAS are presented in Table 4.4.

Change in Flood Depths & Floodplain Extent

4.2.6 Raising the defences along the left bank to provide a 1% annual probability standard results in an increase in peak water levels and flows though Nottingham. The 1% annual probability 'with scheme' levels at key locations along the entire length of the Nottingham Left Bank FAS are compared to those for the exiting situation in Table 4.2. A more detailed assessment of pre and post scheme levels around Attenborough Village is given in Table 4.3 and Figure 4.1.

Table 4.2 – 1% (1 in 100) Annual Probability 'Existing Conditions' and 'With Scheme' Peak Water Levels

Location	OS Grid Reference	ISIS Node	1 % Annual Probability Water Level (m OD)		Difference (m)
			Existing Conditions	With Scheme	
M1 Road Bridge	SK 4659 3089	4050111460D	31.90	31.91	0.00
Harrington Bridge	SK 4711 3396	4050110600	31.83	31.83	0.00
Sawley Viaduct	SK 4784 3080	405019821	30.97	30.97	0.00
Thrumpton Weir	SK 4963 3095	405017960	29.93	29.93	0.00
Cranfleet Lock	SK 5025 3152	405017210	29.44	29.44	0.00
Pasture Lane	SK 5030 3249	405014720	28.48	28.49	0.01
Beeston Weir	SK 5343 3531	405010030	27.28	27.29	0.01
Clifton Bridge	SK 5616 3670	4040110760	26.21	26.22	0.01
Wilford Bridge	SK 5688 3811	404018960	25.50	25.52	0.02
Welbeck Road Footbridge	SK 5794 3766	404017510	24.76	24.78	0.02
Trent Bridge	SK 5813 3829	404016890	24.39	24.41	0.02
Lady Bay Bridge	SK 5847 3872	404016300	23.73	23.75	0.02
Holme Sluices	SK 6132 3932	Col_13010	22.26	22.28	0.02
Colwick Gauging Station	SK 6206 3988	404012070	21.81	21.83	0.02
Radcliffe Viaduct	SK 6366 3972	403568850u	21.11	21.13	0.02

Notes
1 Locations are shown in Figure 2
2 Peak water levels are extracted from the ISIS part of the January 2010 Nottingham ISIS/Tuflow model

4.2.7 The largest increases in water levels are between Wilford Bridge and Radcliffe Viaduct. This encompasses the centre of Nottingham where land use constraints confine the river to a narrow channel. Through Sawley and Trent Meadows, the defences are either set back from the river's edge or there is significant floodplain storage available on the right bank to reduce the impact of the loss in storage from behind the left bank flood defences.

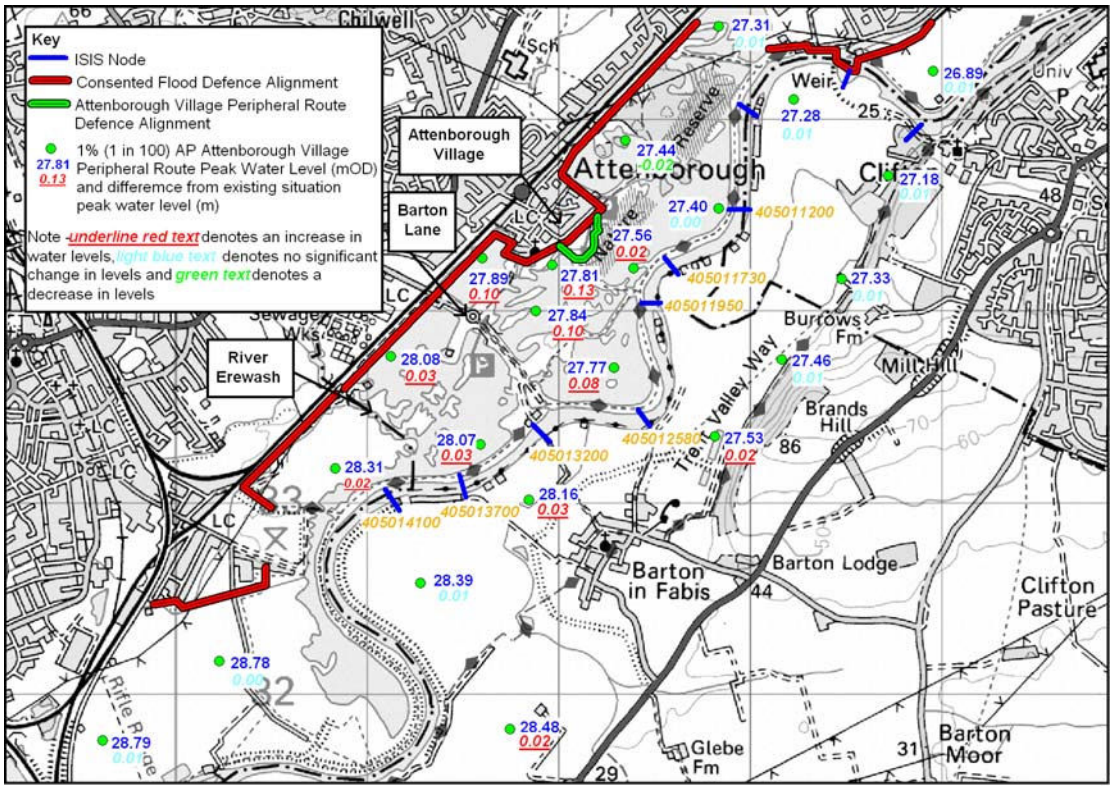
Table 4.3 – 1% (1 in 100) Annual Probability 'Existing Conditions' and 'With Scheme' Peak Water Levels at Attenborough Village

ISIS Node	ISIS 1% AEP Channel Water Level (m OD)		Difference (m)
	Existing Conditions	With Scheme	
405014100	28.32	28.34	0.02
405013700	28.19	28.21	0.02
405013200	28.02	28.05	0.03
405012580	27.67	27.69	0.02
405011950	27.55	27.57	0.02
405011730	27.47	27.47	0.00
405011200	27.36	27.37	0.01

Notes
1. Section locations are shown in Figure 4.1 below

4.2.8 Table 4.3 compares the 1% (1 in 100) annual probability 'existing situation' and 'with scheme' peak water levels for the main river channel around Attenborough Village. As shown, the Nottingham Left Bank FAS results in a 0.02m increase in peak channel water levels upstream of Attenborough Village. Downstream of Attenborough Village towards Beeston Weir, the Nottingham Left Bank FAS has little impact on peak channel water levels.

Figure 4.1 – Impact of Nottingham Left Bank FAS incorporating Attenborough Village Peripheral Route on 1% (1 in 100) AEP Existing Conditions Peak Water Levels



4.2.9 Figure 4.1 shows that the impact of the Nottingham Left Bank FAS with the Attenborough Peripheral Route on peak water levels, differs on both banks of the river. As shown, on the left bank floodplain immediately upstream of the village, peak water levels are increased by up to 0.13m. By contrast, in the main channel (Table 4.3) and on the right bank floodplain upstream of the village, peak water levels are increased by just 0.02m. Downstream of

Attenborough Village, peak water levels are increased by around 0.01m in the main channel and on both sides of the river.

4.2.10 Black & Veatch undertook a detailed assessment of the proposed Attenborough Village Peripheral Route, which is reported in the Technical Note *Nottingham Left Bank FAS – Attenborough Village Peripheral Route*, Black & Veatch, February 2010. The technical note is presented in Appendix A and its key findings are given below.

4.2.11 The study showed that construction of the proposed flood defences along the Attenborough Village Peripheral Route alignment had a localised impact on floodplain hydraulics between Barton Lane and Attenborough Village. Between Barton Lane and Attenborough Village, a section of the left bank channel bank is above the 1% (1 in 100) annual probability peak water level, which constrains the flood water on the left bank. Consequently, construction of the flood defences along the Attenborough Village Peripheral Route creates a 'pinch point' in the left bank floodplain, which raises peak water levels on the left bank floodplain between Barton Lane and Attenborough Village. It should be noted however, that the small increase in flood level as a result of the Attenborough Village Peripheral Route Alignment is contained by the proposed flood defences in this reach.

4.2.12 The Attenborough Village Peripheral Route does not affect the onset of flooding within the wider nature reserve. Flooding of the nature reserve occurs during a 10% (1 in 10) annual probability event and the proposed alignment has no impact on flood levels for events of this magnitude.

4.2.13 The Attenborough Village Peripheral Route alignment does not raise peak water levels significantly downstream of Attenborough Village, because the overall loss in floodplain associated with the alignment is small compared to flood volumes on the Trent at Nottingham. This can be demonstrated as follows:

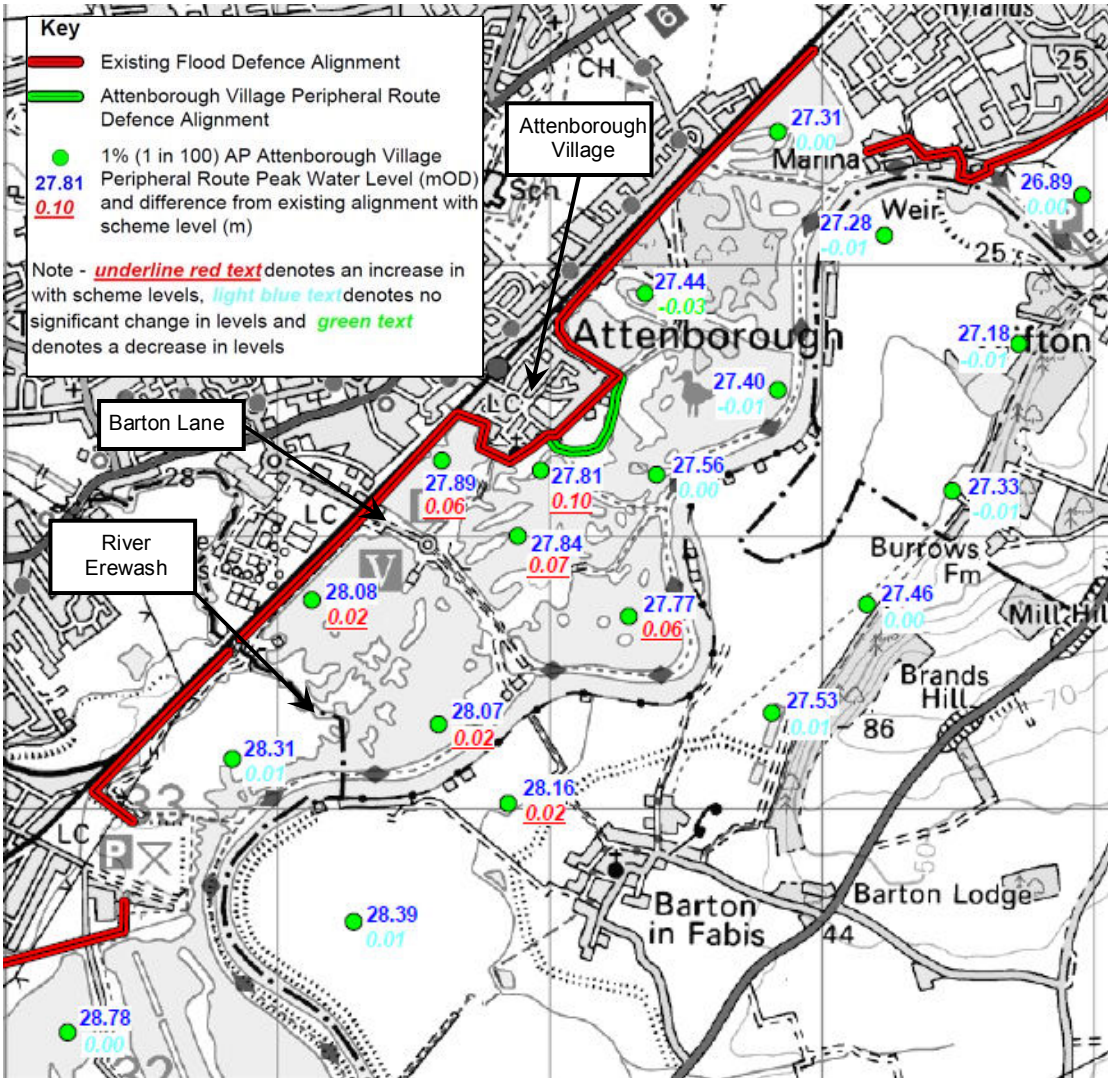
- The Attenborough Village Peripheral Route results in a 53,000m^3 loss in functional floodplain storage compared to the consented alignment. This constitutes 0.013% of the Trent 1% (1 in 100) annual probability flood volume, which is in excess of 400,000,000m^3.
- A volume of functional floodplain equivalent to that lost by the Attenborough Village Peripheral Route could be filled as follows, by the flows listed below:
    - River Trent Q_{95} exceedance flow (low flow) of 27.6m^3/s = 32-minutes
    - River Trent mean flow of 85m^3/s = 10-minutes
    - 1% (1 in 100) Annual Probability Peak Flow of 1200m^3/s = 45-seconds

4.2.14 The 'with scheme' 1% annual probability flood extent through Nottingham is presented in Figure 3. Comparison to Figure 2 shows that raising the defences along the left bank results in narrowing of the natural floodplain, particularly through the centre of the city.

Comparison with Nottingham Left Bank FAS Consented Alignment

4.2.15 For completeness, the impact of Attenborough Village Peripheral Route alignment on flood risk has been compared against the consented flood defence alignment along 'The Strand'. The results of this assessment are described fully in the Technical Note *Nottingham Left Bank FAS – Attenborough Village Peripheral Route*, Black & Veatch, February 2010, which is presented in Appendix A and summarised below.

Figure 4.2 – Impact of Attenborough Village Peripheral Route on 1% (1 in 100) Annual Probability 'With Scheme' Peak Water Levels
(Adapted from Figure 1 in Attenborough Village Peripheral Route Technical Note, Black & Veatch, February 2010)



4.2.16 Between Barton Lane and Attenborough Village, with scheme peak water levels are raised by up to 0.10m compared to the consented alignment along 'The Strand'. These water level increases on the left bank floodplain will be contained by the Nottingham Left Bank FAS defences, therefore, flood risk to people and property following the construction of the proposed peripheral route will not increase. Downstream of Attenborough Village, the Attenborough Village Peripheral Route and consented flood defences alignments result in similar with scheme peak water levels. This is because the volumetric loss in floodplain as a result of the Attenborough Village Peripheral Route is small compared to flood volumes on the Trent.

Flows & Flow Volume

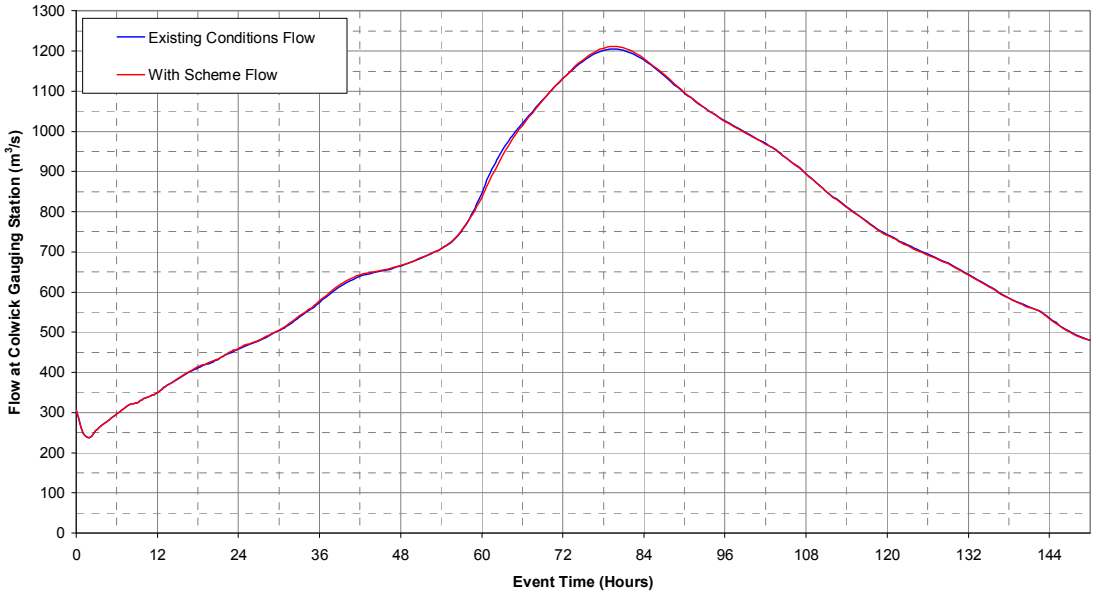
4.2.17 The loss in floodplain storage as a result of raising the left bank flood defences will result in a small increase in peak flows through Nottingham during the 1% (1 in 100) annual probability event. There will also be a small associated increase in 1- and 2-day runoff volumes around the peak of the event, however the total volume of the event will be unchanged over longer durations.

4.2.18 The impact of the scheme upon peak flows and flow volumes at Colwick Gauging Station was assessed using the January 2010 Nottingham ISIS/Tuflow 'Model; the results are presented in Table 4.4 and Figure 4.3.

Table 4.4 – Impact of the Nottingham Left Bank FAS on Flows through Nottingham

Event Peak Flow (m^3/s)			Duration	Flood Runoff Volume (cumec-day)		
Existing Conditions	With Scheme	Difference (m^3/s & %)		Existing Conditions	With Scheme	Difference (%)
1205	1212	+7m^3/s +2%	1 – Day	1144	1147	<1
			2 – Day	2040	2042	<1
			3 – Day	2896	2896	-
			5 – Day	4117	4117	-

Figure 4.3 – 1% (1 in 100) Annual Probability Flow Hydrographs at Colwick



4.2.19 The effects of Nottingham Left Bank FAS with the Attenborough Village Peripheral Route alignment upon flows through Nottingham are small. As shown, the scheme results in a 1% increase in peak flows and a nominal increase in the 1- and 2-Day runoff volumes at Colwick for the 1% annual probability event. The scheme has no impact on 3-day (and longer duration) runoff volumes at Colwick for the 1% annual probability event.

Properties Protected

4.2.20 The Nottingham Left Bank FAS will protect some 15,100 residential properties and 1,300 industrial/commercial properties to the 1% (1 in 100) annual probability standard. Presently, flooding of properties along the left bank occurs during the 4% (1 in 25) annual probability event.

4.2.21 The Nottingham Left Bank FAS will however result in an increased risk of flooding to the villages of Barton-in-Fabis, Holme Pierrepont and eight other villages located downstream of Nottingham; refer to Section 4.3 for further details.

Standard of Protection

4.2.22 Presently, the flood defences along the left bank are typically built to around the 2% (1 in 50) annual probability level, however, a number of properties particularly through Attenborough, are at risk from flooding during the 4% (1 in 25) annual probability event. The Nottingham Left Bank FAS PAR identified that this was below the optimal 1% (1 in 100) annual probability standard of flood protection for Nottingham[4].

4.2.23 The Nottingham Left Bank FAS will protect the whole of the Nottingham Left Bank flood cell to the 1% (1 in 100) annual probability standard.

Climate Change

4.2.24 PPS25 states that any development within the floodplain should consider the effects of future climate change. The recommended sensitivity ranges for peak river flows are given in Table B.2 of PPS 25 (Annex B) and are restated in Table 4.5 below.

Table 4.5 – Recommended National Precautionary Sensitivity Ranges for Peak River Flows (*extracted from Table B.2, PPS25, Annex B*)

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak River Flow	+10%	+20%		

4.2.25 The effect of future climate change upon flood levels was assessed by increasing the flows through the January 2010 Nottingham ISIS/Tuflow with scheme model by 10% and 20%. Flood levels at key reference points along the length of the left bank scheme for 10% and 20% increases in flow are given in Table 4.6, alongside indicative flood defence levels.

[4] *Nottingham Left Bank Flood Alleviation Project Appraisal Report (PAR)*, Black & Veatch, May 2006. This report confirms the business case and recommended standard of protection for the Nottingham Left Bank FAS. The Nottingham Left Bank FAS PAR was based upon the FCDPAG3 guidelines, which were superseded in March 2010 by *Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG)*, Environment Agency, March 2010

Table 4.6 – Impact of Climate Change on Design Water Levels

Location & (ISIS Node Label)	Indicative 1% Annual Probability Water Level (m OD)	Minimum Freeboard Allowance (m)	Indicative Flood Defence Level (m OD)[2]	Indicative Peak Water Level (m AOD)		Increase in Peak Water Level (m)	
				10% increase in flows	20% increase in flows	10% increase in flows	20% increase in flows
M1 Road Bridge (4050111460D)	31.91	0.30	32.21	32.02	32.12	0.11	0.21
Harrington Bridge (4050110600)	31.83	0.30	32.13	31.97	32.09	0.14	0.26
Sawley Viaduct (405019821)	30.97	0.30	31.27	31.11	31.25	0.14	0.28
Thrumpton Weir (405017960)	29.93	0.30	30.23	30.04	30.13	0.11	0.20
Cranfleet Lock (405017210)	29.44	0.30	29.74	29.53	29.60	0.09	0.16
Pasture Lane (405014720)	28.49	0.30	28.79	28.61	28.72	0.12	0.23
Attenborough Village (405012580) [1]	27.89	0.30	28.19	28.08	*28.25*	0.19	0.36
Attenborough Village (405011950) [1]	27.81	0.30	28.11	27.99	*28.16*	0.18	0.35
Attenborough Village (405011730) [1]	27.56	0.30	27.86	27.75	*27.92*	0.19	0.36
Beeston Weir (405010030)	27.29	0.30	27.59	27.51	*27.71*	0.22	0.42
Clifton Bridge (4040110760)	26.22	0.45	26.67	26.53	*26.76*	0.31	0.54
Wilford Bridge (404018960)	25.52	0.55	26.07	25.80	25.99	0.28	0.47
Welbeck Road Footbridge (404017510)	24.78	0.55	25.33	25.03	25.23	0.25	0.45
Trent Bridge (404016890)	24.41	0.55	24.96	24.65	24.84	0.24	0.43
Lady Bay Bridge (404016300)	23.74	0.45	24.19	23.88	23.99	0.14	0.25
Holme Sluices (Col_13010)	22.28	0.35	22.63	22.48	22.62	0.20	0.33
Colwick Gauging Station (404012070)	21.84	0.45	22.29	22.01	22.14	0.17	0.30
Radcliffe Viaduct (403568850u)	21.13	0.45	21.58	21.29	21.40	0.16	0.27

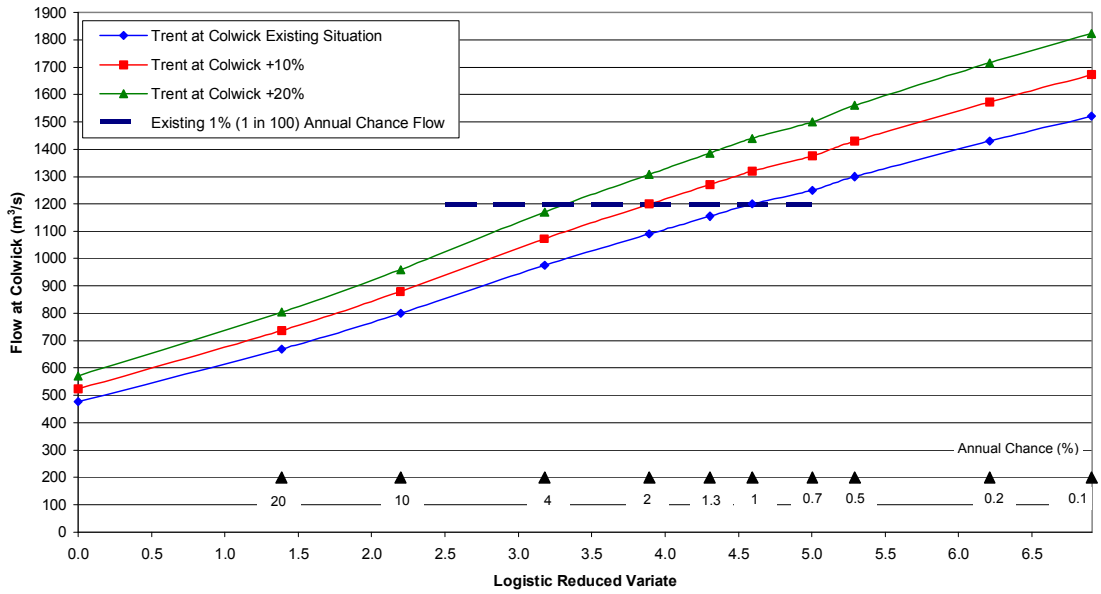
Notes
1. Water Levels are extracted from the Tuflow domain for these locations
2. Indicative flood defence level calculated as 1% flood level + lowest recommended location freeboard allowance.
3. Water levels shown in *red italics* exceed the proposed flood defence level

4.2.26 For a 10% increase in flows, peak water levels are increased by up to 0.31m; for a 20% increase, peak water levels are increased by up to 0.54m. In both cases the largest increase in levels is for the reach between Beeston Weir and Trent Bridge, where the floodplain is at its narrowest. The impact of the future climate change scenarios is significantly less for the reach between Sawley and Pasture Lane, where the floodplain is relatively wide.

4.2.27 The proposed defences will be sufficient to contain a 10% increase in flows on the 1% annual probability event, but with a significantly reduced freeboard. Figure 4 shows the predicted 1% (1 in 100) annual probability with scheme flood extent with a 20% increase in flows. Overtopping of the defences at Attenborough Village and Beeston Weir is predicted, which results in flooding of Attenborough, Rylands, Beeston and Nottingham City Centre. The proposed defences at Sawley and Trent Meadows will be sufficient to contain a 20% increase in flows on the 1% annual probability event, although there would only be a small freeboard allowance on these defences.

4.2.28 It should be noted that the recommended increases for future climate change within PPS25 have a significant impact upon the probabilities assigned to present day flood events. The present day flood frequency curve for the River Trent at Nottingham has been re-calculated in Figure 4.4 to represent the effects of future climate change.

Figure 4.4 – River Trent at Colwick Flood Frequency Curves



4.2.29 As shown, the present day 1% annual probability flow equates to a 2% (1 in 50) annual probability event for a 10% increase in flows and a 4% (1 in 25) annual probability event for a 20% increase in flows. Conversely, a 10% increase in fluvial flows at Colwick results in a flow of 1320m^3/s which is approximately equivalent to the present day 0.5% (1 in 200) annual probability event. A 20% increase in flow results in a flow of 1440m^3/s, approximately equivalent to a present day 0.2% (1 in 500) annual probability event.

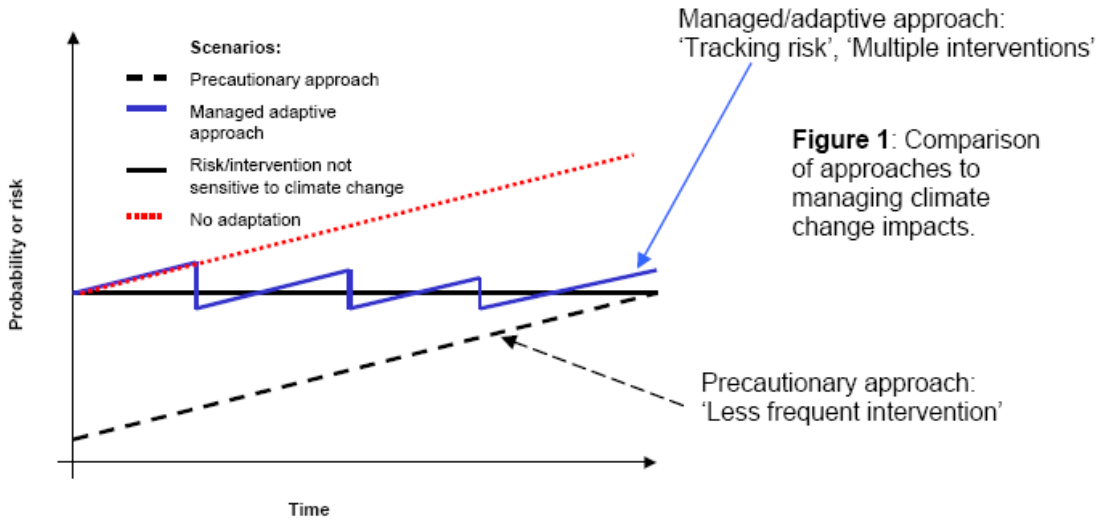
4.2.30 The *PPS25 Practice Guide* cites the guidance given in *FCDPAG3 Economic Appraisal Supplementary Note* (October 2006) for considering the effects of future climate change. *FCDPAG3 Economic Appraisal Supplementary Note* recommends the following two approaches for taking climate change into consideration in the design of flood defence measures:

- **the Managed Adaptive Approach:** this involves identifying the sensitivity of results to potential changes that could occur as a result of climate change and then making specific allowances to allow for adaptation in the future. The method is appropriate in the majority of cases where ongoing responsibility can be assigned to tracking and managing the change in flood risk through multiple interventions;

- **the Precautionary Approach:** this is applied in circumstances where future adaptation may not be technically feasible or too complex to implement over the long term (up to 100 years). In such circumstances multiple interventions to manage the change in flood risk is unlikely to be practicable and a one-off intervention at the outset of the scheme is the only feasible option.

The two approaches are shown graphically in Figure 4.5.

Figure 4.5 – Managing Climate Change Impacts
(Taken from *Figure 1* of
FCDPAG3 Economic Appraisal Supplementary Note, October 2006)



4.2.31 The *PPS25 Practice Guide* adds that when using the indicative sensitivity ranges (as detailed in PPS25, Table B.2), consideration should be given to adopting the managed adaptive approach. The guide notes that the managed adaptive approach will be appropriate in cases where:

- the design takes specific account of the potential need to adapt the flood risk measures at a future date; and
- ongoing responsibility can be assigned to ensuring the change in risk can be tracked and managed, with the appropriate adaptations made over the lifetime of the development.

If neither of the above criteria are met, then the precautionary approach to managing future climate change may be more appropriate.

4.2.32 Given the uncertainties regarding the magnitude of future flow increases due to climate change, particularly for a large, lowland watercourse such as the Trent, a managed adaptive approach is to be adopted for the left bank scheme. This complies with the criteria set out in the PPS25 Practice Guide. The Environment Agency will be responsible for maintaining the flood defences and monitoring change in flood risk, and the works will include measures such as over-sizing the foundations to defences allowing them to be raised (rather than replaced) within the design life of the scheme. In accordance with the recommendations of *FCDPAG3 Supplementary Note* (October 2006), a precautionary approach will be employed for the following locations / works on the scheme, where future raising would be particularly costly or impractical:

- Replacement of Sheetstores Floodgates;
- Improvements to Beeston Lock gates;
- All tie-ins to the existing railway embankments at Sawley and Trent Meadows;
- The flow control structure on the Siemens Stream;
- Tinkers Leen Pumping Station; and
- Holme Sluice Pumping Station

4.2.33 Full application of the 'precautionary approach' is not economically viable for the Nottingham Left Bank FAS. This was proven in the scheme's *Project Appraisal Report*

(March 2006), which demonstrated the managed adaptive approach provided the more appropriate use of public funds.

Impact on West Bridgford FAS Defences

4.2.34 The impact of the Nottingham Left Bank FAS with the Attenborough Peripheral Route on the West Bridgford FAS, has been assessed using the January 2010 Nottingham ISIS/Tuflow Model. Representative flood defence levels along the length of the West Bridgford scheme are presented in Table 4.7 and are compared to the results of the January 2010 ISIS/Tuflow Model.

Table 4.7 – Impact of the Nottingham Left Bank FAS upon the West Bridgford FAS Defences

Section	Indicative As-Built Level (m AOD)	Design Freeboard[2] (m)	January 2010 With Scheme Level (m AOD)	Revised Freeboard (m)
Wilford Lane Embankment (Embankment)	26.20	0.30	25.37	0.83
Wilford Lane Embankment (Wall)	25.95	0.30	25.15	0.80
Wilford Lane Wall	25.72	0.30	24.97	0.75
Trentside	25.43	0.20	24.73	0.70
County Hall	25.37	0.30	24.67	0.70
Holme Road Wall[1]	24.35	0.20	23.73	0.62
Holme Road Embankment	24.35	0.30	23.67	0.68
Holme Grove Wall	23.94	0.20	23.36	0.58
Adbolton West Embankment	23.79	0.30	23.19	0.60
Adbolton Wall	23.70	0.20	23.00	0.70
Adbolton East Embankment	23.68	0.30	22.90	0.78

Notes
1. Holme Road Wall is an existing floodwall, for which refurbishment works were carried out as part of the West Bridgford Scheme. The wall was not raised as part of the flood defence works.
2. The freeboard allowances adopted for the West Bridgford FAS are reported in '*Assessment of Freeboard for the Nottingham Flood Alleviation Scheme*, Black & Veatch, October 2005.

4.2.35 The West Bridgford FAS was designed to provide a 1% (1 in 100) annual probability standard of protection, which included up to a 0.3m freeboard allowance. Comparison of the as-built flood defences levels for the scheme against the July 2008 1% annual probability 'with scheme' levels, shows the revised freeboard allowances for the scheme to be between 0.58m and 0.83m. The Nottingham Left Bank FAS will therefore **not** adversely affect the existing design standard of the West Bridgford flood defences.

Tributary Flood Risk

4.2.36 In accordance with the guidelines given in PPS25, the impact of the Nottingham Left Bank FAS upon flood risk along each of the major tributaries discharging to the Trent through

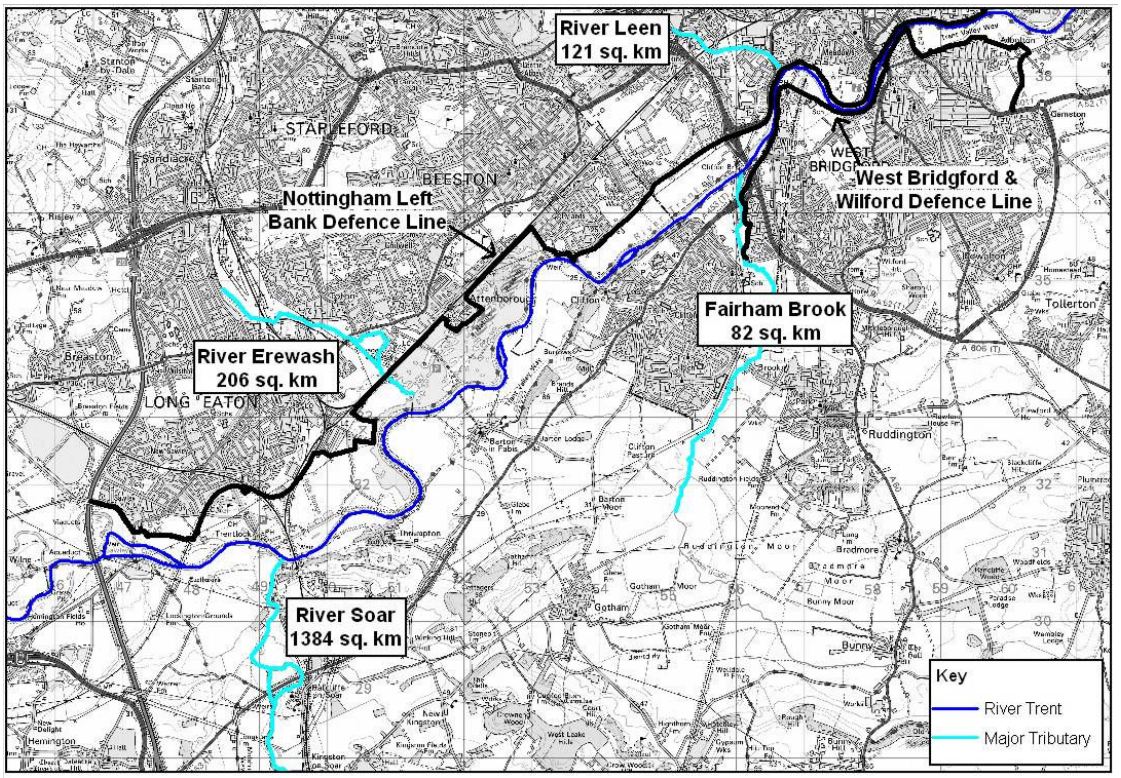
Nottingham has been considered[5] and is discussed in the following paragraphs. These are shown in Figure 4.6 and summarised in Table 4.8.

Table 4.8 - Major Tributaries of Trent at Nottingham

Tributary	Left or Right Bank	Catchment Area (km^2)	Confluence OS Reference	Trent Confluence Location	Outlet Control
River Soar	Right	1384	SK 49339 30924	u/s of Thrumpton Weir	None
River Erewash	Left	206	SK 51245 33343	Attenborough Nature Reserve	Flapped Outfall[1]
Fairham Brook	Right	82	SK 56059 36595	u/s of Clifton Bridge	None
River Leen	Left	121	SK 56671 38119	u/s of Wilford Bridge	Flapped Outfall

Notes
1. The River Erewash discharges into the Attenborough Nature Reserve Lakes. Water levels in the lakes are controlled by a flap valve which allows the lakes to overspill into the River Trent
2. For comparison, the River Trent's catchment area to Colwick Gauging Station is $7486km^2$.

Figure 4.6 – River Trent at Nottingham Major Tributaries



River Soar

4.2.37 The River Soar is a major right bank tributary of the River Trent, draining an area of $1384km^2$. Owing to the size and rural nature of the catchment, the Soar exhibits a slow response to runoff, thus, there is a high probability of coincident peaks on the Rivers Soar and

[5] *For details of the measures considered to manage runoff from the minor drains and sewers draining the defended area, the reader is referred to Section 4.5.*

Trent. Consequently, an increase in flood levels along the Trent could result in an increase in flooding along the Soar, should the hydrograph peaks on the two rivers coincide.

4.2.38 The January 2010 Nottingham ISIS/Tuflow model indicates that the Nottingham Left Bank FAS will have no impact upon flood levels at the Trent/Soar confluence. This is due to the broad floodplain at the location which is able to accommodate the loss in flood storage associated with the left bank scheme.

River Erewash

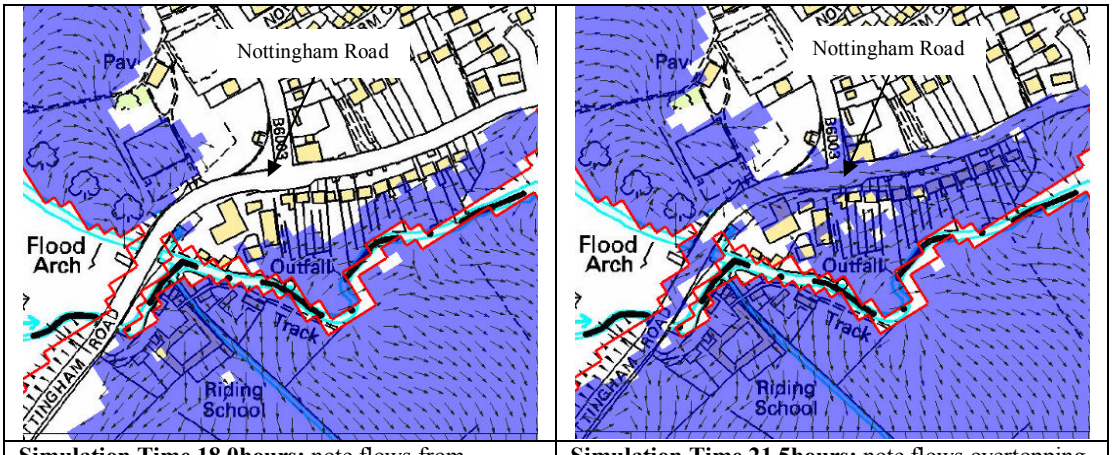
4.2.39 The River Erewash is a large left bank tributary of the Trent draining an area of 206km^2. Peak water levels along the lower reaches of the Erewash are known to be influenced by water levels on the Trent. During November 2000 the River Trent backed up along the River Erewash beneath the railway embankment to the A6005.

4.2.40 The 'with scheme' peak water levels from the July 2008 Nottingham ISIS/Tuflow Model showed that during the 1% annual probability event, the Trent could back up along the Erewash and flood properties between the railway embankment and the A6005. Similar results are produced by the January 2010 model.

4.2.41 Following completion of the July 2008 Nottingham ISIS/Tuflow study, Black & Veatch were commissioned to undertake a detailed study of the River Erewash at its confluence with the Trent. The study is reported fully in *Nottingham Left Bank FAS – River Erewash ISIS/Tuflow Modelling Study*, Black & Veatch, August 2009; the key findings can be summarised as follows:

- Construction of new flood defences to protect the properties on Nottingham Road from flooding from the Trent could result in increased flood depths to these properties from the Erewash. This is because flood flows from the Erewash overtop Nottingham Road upstream and would be stored behind the new flood defences; refer to Figure 4.7.
- Flood defence works are required around Toton Sewage Treatment Works to prevent flooding of properties from Trent flows backing-up along the Erewash. These defences would also provide a 1% (1 in 100) annual probability standard of protection from the Erewash.

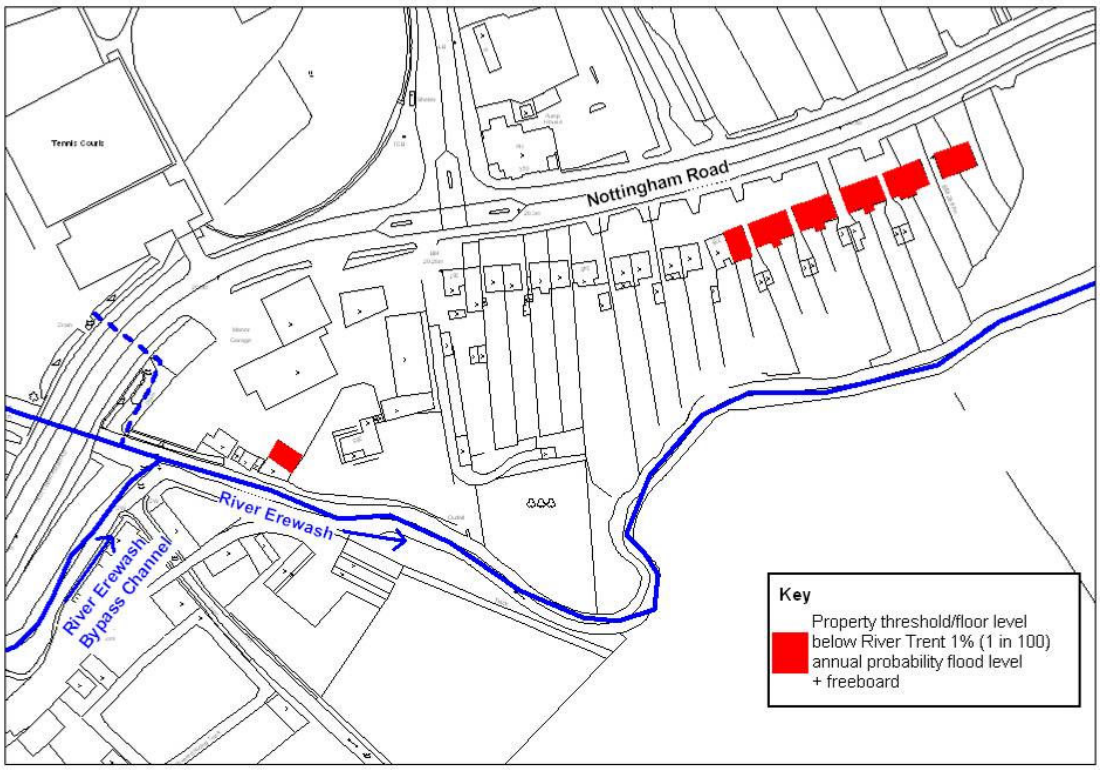
Figure 4.7 – Flood Risk at Nottingham Road
(Taken from Figure 6.2 in River Erewash ISIS/Tuflow Modelling Study)



Simulation Time 18.0hours: note flows from Erewash only inundate property gardens downstream of Nottingham Road	**Simulation Time 21.5hours:** note flows overtopping Nottingham Road from recreation ground and flooding properties

4.2.42 Following completion of the River Erewash ISIS/Tuflow study, Black & Veatch commissioned a survey of property threshold levels along Nottingham Road. The survey confirmed that the property threshold levels were above the Trent 1% (1 in 100) annual probability flood level but some threshold levels were below the 1% flood defence level i.e. with freeboard; refer to Figure 4.8.

Figure 4.8 – Nottingham Road Property Threshold/Floor Levels below River Trent 1% Annual Probability Design Water Level
(Taken from Figure 2 in River Erewash at Nottingham Road Project Note)



4.2.43 The River Erewash study concluded that construction of the proposed flood defences to protect the properties along Nottingham Road from the Trent was not appropriate, without considerable flood defence works upstream of Nottingham Road to protect the properties from the Erewash. These works could not be justified within the Nottingham Left Bank FAS's business case. Individual property flood protection measures are to be offered to reduce the risk of flooding to these properties from both the Trent and Erewash. Works remain necessary however to construct defences to 'close' the Nottingham Left Bank FAS flood cell at Golden Brook and Toton Sewage Works/Chilwell Retail Park.

Fairham Brook

4.2.44 Fairham Brook is a medium sized right bank tributary, draining 82km^2, which discharges to the Trent just upstream of Clifton Bridge. The January 2010 Nottingham ISIS/Tuflow Model predicts that the Nottingham Left Bank FAS will result in a 0.02m increase in water levels at the Trent/Fairham Brook confluence.

4.2.45 Owing to the relatively steep gradient of this watercourse, this small increase in Trent water levels has no significant impact on flood risk or extent along this tributary. Furthermore, Fairham Brook is a relatively urbanised catchment which will respond rapidly to runoff, thus, the likelihood of coincident events on the brook and Trent is very low.

River Leen

4.2.46 The River Leen is a large left bank tributary of the Trent draining an area of 121km^2. The Leen discharges to the Trent via a flapped outfall, which closes when the Trent is in flood.

4.2.47 Although completion of the left bank scheme will result in a 0.02m increase in peak water levels at the Leen's confluence with the Trent, this will not increase flood risk along the Leen. This is because the Leen is a highly urbanised catchment with a very flashy runoff response. Consequently, the probability of coincident flood events occurring on the Rivers Leen and Trent is very low. There is also significant in-channel storage in the lower reach of the Leen, designed to contain its flow when the Trent is high.

4.3 Downstream of Radcliffe Viaduct

Methodology

4.3.1 Previous work to assess the impact of the Nottingham Left Bank Scheme upon flood levels downstream of Nottingham used the following methodology:

- The model extents were from the M1 at Sawley to Cromwell Weir (located downstream of Newark)
- The model hydraulics were taken from two sources, to provide the best available data for each reach:
  - between the M1 and Radcliffe Viaduct the Nottingham Trent 'With Scheme' model was used.
  - from Radcliffe Viaduct to Cromwell Weir the Fluvial Trent Strategy Model 4 was used.
- The tributary flows were as derived for the Fluvial Trent Strategy; refer to Table 3.2.

4.3.2 As neither the January 2010 nor July 2008 ISIS/Tuflow Models extend sufficiently far downstream of Nottingham to allow the impact of the scheme to be fully assessed, the combined Nottingham Trent Model/Fluvial Trent Model 4 was used to assess the impact of the scheme upon flood levels for all locations. A comparison between the modelled water levels from the July 2008 Nottingham ISIS/Tuflow Model and Nottingham Trent Model for the reach between Radcliffe Railway Viaduct and Burton Joyce showed that the levels from the ISIS/Tuflow model are generally slightly lower than the Nottingham Trent Model; refer to Table 4.8. This ensures a conservative approach is adopted in assessing the adverse impacts of the scheme upon flood risk for the downstream communities.

Extent of Impact

4.3.3 The natural floodplain width just upstream of Nottingham is approximately 1.5km. Raising the defences through Nottingham reduces this width and, through the centre of Nottingham, the resulting channel width is around 100m. Inevitably, the loss in floodplain storage through Nottingham results in an increase in peak water levels and flows downstream of Nottingham.

4.3.4 Figure 4.9 shows the villages adversely affected by the Nottingham Left Bank FAS. The impact of the scheme upon water levels for each of the affected villages for the 1% annual probability event is shown in Table 4.9.

Figure 4.9 – Communities Adversely Affected by the Left Bank Scheme

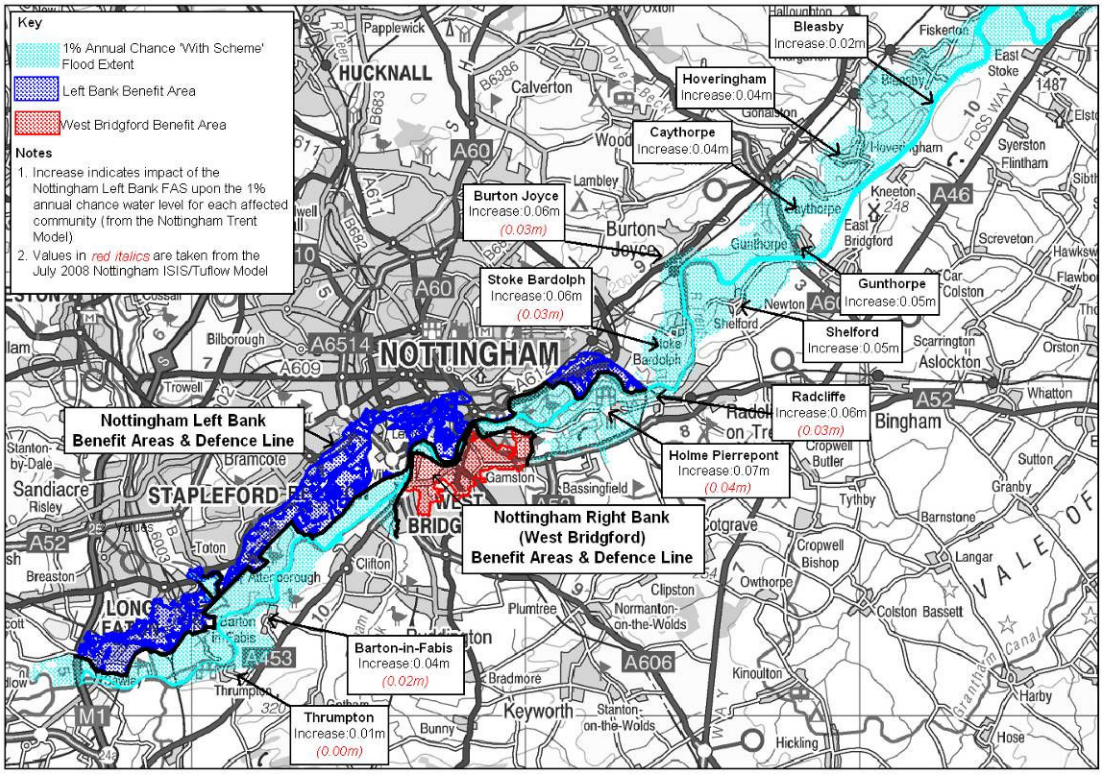


Table 4.9 – Pre and Post Scheme Water Levels for Affected Communities

Location	1% (1 in 100) Annual probability Water Level (m AOD) see note 1		Increase in Water Levels (m)
	Existing Conditions	Post Scheme	
Thrumpton	29.03 *(28.95)*	29.04 *(28.95)*	0.01 *(0.00)*
Barton-in-Fabis	28.31 *(28.25)*	28.35 *(28.27)*	0.04 *(0.02)*
Holme Pierrepont	21.52 *(21.47)*	21.59 *(21.51)*	0.07 *(0.04)*
Radcliffe	21.10 *(21.13)*	21.16 *(21.16)*	0.06 *(0.03)*
Stoke Bardolph	20.08 *(20.03)*	20.14 *(20.06)*	0.06 *(0.03)*
Burton Joyce	19.49 *(19.52)*	19.55 *(19.55)*	0.06 *(0.03)*
Shelford	19.07	19.12	0.05
Gunthorpe	18.48	18.53	0.05
Caythorpe	17.44	17.48	0.04
Hoveringham	17.06	17.10	0.04
Bleasby	15.72	15.74	0.02
Fiskerton	14.84	14.84	No impact

Note

1. Values shown in *red italics* are extracted from the July 2008 Nottingham ISIS/Tuflow Model. As this model does not extend sufficiently far downstream to fully assess the impact of the scheme, these levels have not been used to assess the downstream scheme impacts or to determine mitigation measures. As shown, the increase in water levels predicted by the ISIS/Tuflow model is less than from the Nottingham Trent Model suggesting the adopted approach is conservative.

4.3.5 For the 1% annual probability event, the Nottingham Left Bank Scheme results in an increase in water levels downstream to Bleasby, some 16km beyond the Radcliffe Viaduct. Downstream of Bleasby the impact of the scheme diminishes and by Fiskerton, the scheme has no impact on levels or flows. As shown in Table 4.8, the largest increase in peak water levels as a result of the scheme is 0.07m at Holme Pierrepont. For the other villages, the increase in peak water levels is between 0.02m and 0.06m

4.3.6 The water levels given in Table 4.9 were compared against surveyed property thresholds through the affected villages to determine if the increased water levels would result in any additional properties being brought into the 1% (1 in 100) annual probability floodplain The results of this assessment are given in Table 4.10.

Table 4.10 – Number of Properties Flooded in Affected Communities

Location	Number of Properties at Risk During the 1% (1 in 100) Annual probability Event		Increase in Properties Flooded Due to the Left Bank Scheme
	Existing Conditions	Post Scheme	
Thrumpton	14	14	0
Barton-in-Fabis	97	97	0
Holme Pierrepont	6	6	0
Radcliffe	0	0	0
Stoke Bardolph	9	11	2
Burton Joyce	352	400	48
Shelford	0	0	0
Gunthorpe	137	142	5
Caythorpe	0	0	0
Hoveringham	104	111	7
Bleasby	53	60	7
Total	**758**	**827**	**69**

4.3.7 As shown in Table 4.10, there are 69 additional properties at risk during the 1% annual probability event as a result of the scheme. Over two thirds of these properties are located in Burton Joyce with remainder split between Stoke Bardolph, Gunthorpe, Hoveringham and Bleasby. For the remaining villages, the Nottingham Left Bank FAS results in no change to the existing number of properties at risk from flooding during the 1% annual probability event.

4.3.8 Mitigation measures to manage the increased risk of flooding for each of the affected communities are given in Section 4.4.

4.4 Mitigation Measures

4.4.1 The Nottingham Left Bank FAS increases the risk of flooding to 10 villages located within the Trent valley. In accordance with the guidelines given in PPS25, the following mitigation measures were considered to alleviate the increased risk of flooding to these communities:

- floodplain compensation works;
- optimisation and improvement of existing floodplain storage through Nottingham; and
- local flood defence works for each affected village.

The suitability of each of these measures to alleviate the increased risk of flooding to the 10 villages is detailed in the following paragraphs.

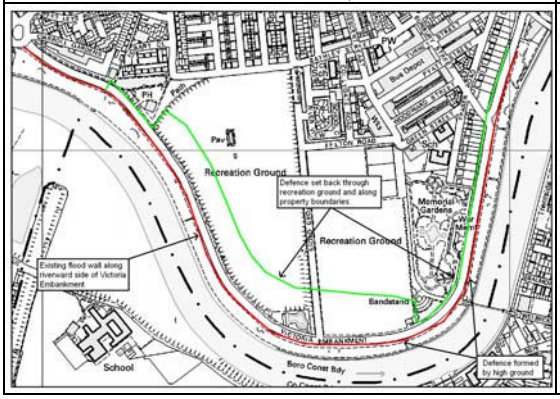
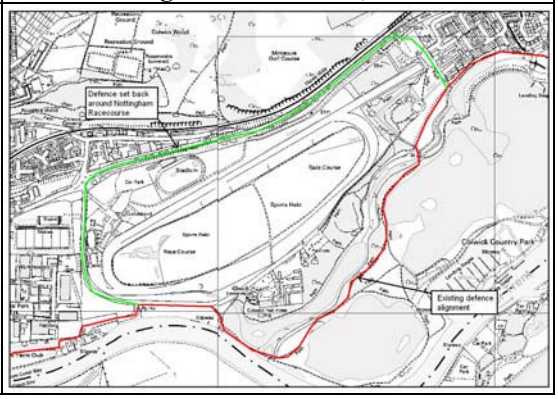
Floodplain Compensation Works

4.4.2 Floodplain compensation works comprise removing an equivalent volume of land outside the existing floodplain to that which is lost to any development within the floodplain. Floodplain compensation works should be made on a level for level basis and as close to the area of lost floodplain as practicable so that it remains effective.

4.4.3 Due to the extent of the left bank scheme and the amount of floodplain lost, full floodplain compensation works are not practicable. Along the length of the scheme, and particularly through the centre of Nottingham, the floodplain is extensively developed meaning that there are no suitable sites available for floodplain compensation works. Furthermore, the costs associated with full floodplain compensation works would mean that the Nottingham Left Bank Scheme would not be economically viable.

4.4.4 It should be noted that where possible, the alignment of the left bank flood defences have been chosen to minimise the loss in 'functional floodplain' (PPS25 flood zone 3b) as a result of the scheme. Examples of this practice are shown in Figure 4.10.

Figure 4.10 - Nottingham Left Bank FAS Examples of Set-back Defences

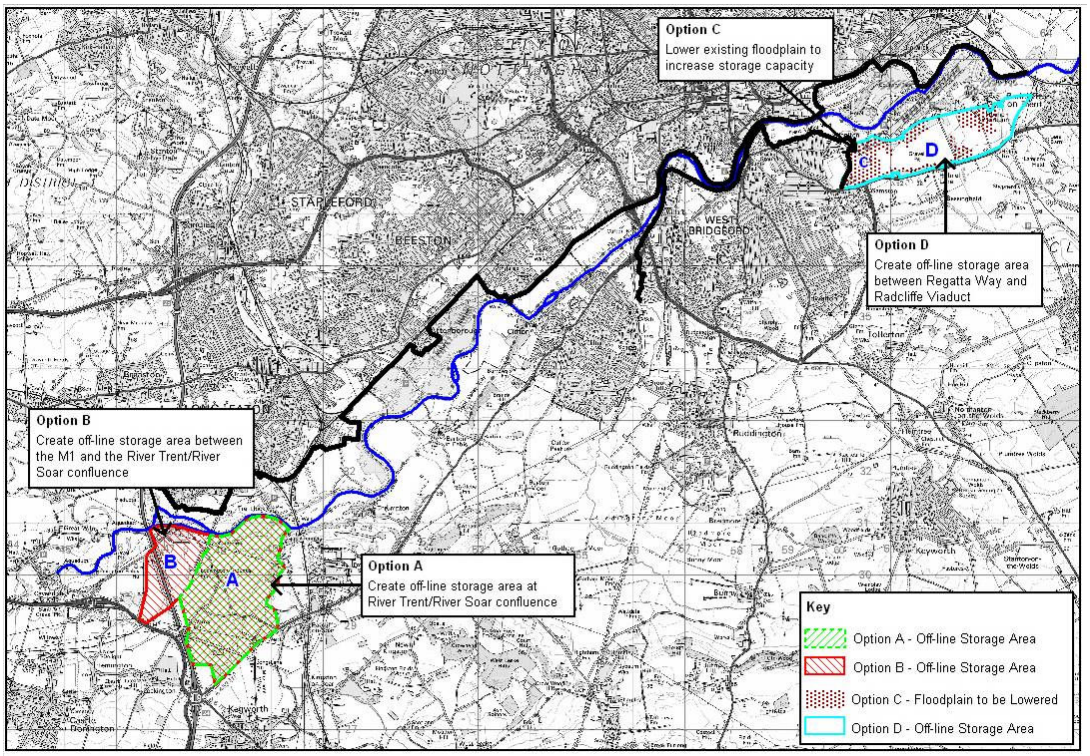
Victoria Embankment, Meadows	Nottingham Racecourse, Colwick
	

Optimisation of Existing Floodplain Storage

4.4.5 Optimisation of existing floodplain storage comprises constructing new or raising existing low level banks to increase the capacity of existing off-line storage areas through Nottingham. These storage areas would be designed to attenuate the peak of large flood events at the expense of a small loss in floodplain storage for smaller flood events.

4.4.6 Further optimisation of the existing floodplain storage was reviewed as part of the *Nottingham (Left Bank) FAS: Assessment of Mitigation Options for Villages Downstream of Nottingham*, (Black & Veatch, 2006). The study identified four options to improve floodplain storage through the city which are shown Figure 4.11.

Figure 4.11 – Nottingham Left Bank FAS Mitigation Options



4.4.7 The impact of each of the mitigation option upon water levels downstream of Nottingham was assessed as part of the study using the Nottingham Trent Model. The results are detailed fully in the *Nottingham (Left Bank) FAS Assessment of Mitigation Options for Villages Downstream of Nottingham*, and can be summarised as follows:

Option A reduced (but did not fully offset) the impact of the Nottingham Left Bank Scheme upon downstream water levels for the 1% annual probability event. Option A resulted in an increase in water levels upstream of Harrington Bridge (Sawley).

Option B fully offset the impact of the Nottingham Left Bank Scheme upon downstream water levels for the 1% annual probability event, but resulted in a large increase in water levels upstream of Harrington Bridge.

Option C had no impact on peak water levels downstream of Nottingham for the 1% annual probability event.

Option D offset the increase in water levels downstream of Nottingham for the 1% annual probability event, but resulted in increased risk of flooding for Holme Pierrepont and Radcliffe. Regatta Way would also need to be raised to prevent flooding of properties behind the recently completed West Bridgford flood defences.

4.4.8 The study concluded that due to the adverse impact upon local water levels, the offline storage works proposed (Options A, B and D) were unsuitable to offset the impact of the Nottingham Left Bank Scheme upon water levels downstream of Nottingham. Furthermore, expensive capital works of this nature were not considered to be an efficient use of public funds, with local flood mitigation works for each affected community preferred.

4.4.9 These options have not been reviewed using either the January 2010 or July 2008 Nottingham ISIS/Tuflow models.

Local Flood Defence Works

4.4.10 As neither full floodplain compensation works nor the optimisation of existing storage areas are considered to be suitable to offset the impact of the left bank scheme upon downstream water levels, a separate commission has been set up to investigate and implement methods to reduce the long term flood risk to the affected communities.

4.4.11 The following paragraphs describe the progress made to date and the further investigations planned for each affected village. For many of these villages, works are already in hand, or even completed, to reduce flood risk. These works also protect many properties which are not affected by the Nottingham Left Bank FAS. The works' progress are also summarised in Table 4.11.

Thrumpton

4.4.12 Thrumpton is located on the right bank of the Trent, just downstream of the Trent's confluence with the Soar. The village is undefended, and a threshold survey has shown that 14 properties through the village are at risk from flooding during the 1% annual probability event. The Environment Agency are carrying out individual property flood protection measures for those at risk properties that have requested it

4.4.13 The Nottingham left bank scheme results in a 0.01m increase in water levels for Thrumpton. This does not result in any additional properties being brought into the 1% annual probability floodplain so no additional mitigation measures are proposed.

Barton in Fabis

4.4.14 Barton in Fabis is located on the right bank of the Trent, opposite the town of Beeston. The village was protected by an existing ring-bank, which is below the existing the 1% annual probability flood level. Completion of the left bank scheme will result in a 0.04m increase in water levels through the village for the 1% annual probability event, however, no additional properties will be flooded as a result of the left bank scheme.

4.4.15 To mitigate the impact of the left bank scheme upon the village, the existing flood defences have been raised to the 1% annual probability flood level. This has improved the standard of flood protection to all 97 properties currently at risk from flooding within the village.

Holme Pierrepont

4.4.16 Holme Pierrepont is located on the right bank of the River Trent, opposite Colwick Industrial Estate. The village is predominantly located on an island of high ground within the Trent floodplain. A threshold survey however has shown that 6 properties through the village are at risk from flooding during the 1% annual probability event.

4.4.17 The Nottingham left bank scheme results in a 0.07m increase in water levels for Holme Pierrepont but this does not result in any additional properties being brought into the 1% annual probability floodplain.

4.4.18 Given the isolated nature and small number of properties at risk from flooding, it is unlikely that a single solution will be suitable for all. Given the relatively low flood depths, individual property protection measures such as flash boards may be appropriate in the future.

Radcliffe-on-Trent

4.4.19 Radcliffe is located on the right bank of the Trent, immediately downstream of Radcliffe Viaduct. The residential area is located outside the existing 1% annual probability floodplain, with only Radcliffe Mobile Home Park at risk from flooding.

4.4.20 The left bank scheme will result in a 0.06m increase in water levels for Radcliffe, but will not result in flooding of the residential area. Increased flood depths will be experienced through the mobile home park. To mitigate this impact, a scheme funded through the local levy programme was approved by the Environment Agency to improve defences around the mobile home park. These proposals were however were rejected by the local residents and the scheme has been withdrawn.

Stoke Bardolph

4.4.21 Stoke Bardolph is located approximately 3km downstream of Radcliffe Viaduct on the left bank of the Trent. The old part of the village is located on high ground, above the 1% annual probability level, but there are a small number properties located below this level. The left bank scheme will result in a 0.06m increase in water levels for Stoke Bardolph for the 1% annual probability event.

4.4.22 Nine properties in the village are currently at risk from flooding, and the increase in water levels will cause an additional two properties to be at risk from flooding during the 1% annual probability event. These properties have been identified as part of the threshold survey and individual property protection measures have been offered to the residents. Due to the small number and position of the properties in the floodplain, it is unlikely that any other form of protection would be cost effective.

Burton Joyce

4.4.23 Burton Joyce is located on the left bank of the River Trent approximately 5km downstream of Radcliffe Viaduct. The village is located on the landward side of a low railway embankment which prevented widespread flooding of the village during November 2000, but is below the 1% annual probability flood level.

4.4.24 Presently, 352 properties are at risk from flooding during the 1% annual probability event. The Nottingham Left Bank FAS results in a 0.06m increase in peak water levels through Burton Joyce for the 1% annual probability event, resulting in an additional 48 properties to be at risk from flooding.

4.4.25 To address the adverse impact of the left bank scheme upon flood risk through the village, improvements to the flood defences in the village have been proposed. The works are being undertaken in two phases:

- Phase 1 consists of construction of a new pumping station on the 'Crock Dumble', which is a small watercourse that flows through the village, and is prone to backing up from the Trent. The pumping station was completed in August 2008; a permanent electricity supply is still to be added, however in the interim period a generator supply will be used.
- Phase 2 of the flood defence works consists of construction of a new flood bank on the riverward side of the railway embankment. These works are programmed for 2010.

Once complete, the flood defences around Burton Joyce will provide protection from the 1% annual probability flood event and all 48 properties adversely affected by the left bank scheme can be removed from the affected list. Furthermore, 352 properties presently at risk

from flooding through the village during the 1% annual probability event will benefit from an improved standard of flood protection.

Shelford

4.4.26 Shelford is located on the right bank of the River Trent, approximately 6km downstream of Radcliffe Viaduct. The village is protected by an existing flood embankment which ties into high ground to the east and west of the village, and provides 1% annual probability standard of protection.

4.4.27 The Nottingham Left Bank FAS results in a 0.05m increase in peak water levels for Shelford during the 1% annual probability event. The available crest level survey shows the flood embankment is above the post-scheme 1% annual probability flood level. Consequently, no further works are proposed for Shelford.

Gunthorpe

4.4.28 Gunthorpe is located on the left bank of the River Trent, approximately 9km downstream of Radcliffe Viaduct. The older parts of the village are located on higher ground outside the 1% annual probability floodplain, but more recent developments within the village have been located on lower ground at a higher risk from flooding. During November 2000, a number of properties were flooded and the village was also cut off due to flooding of the A6097, the only access road into the village.

4.4.29 Currently, 137 properties through Gunthorpe are at risk from flooding during the 1% annual probability event. The Nottingham Left Bank FAS will result in a 0.05m increase in water levels through Gunthorpe meaning an additional 5 properties will be at risk from flooding during the 1% annual probability event.

4.4.30 A combination of individual flood protection measures and new flood banks has been planned for Gunthorpe to address the impacts of the Nottingham Left Bank FAS, and improve the standard of flood protection through the village. The works undertaken to date comprise:

- Installation of individual property protection measures. This was completed for 34 houses in March 2008 with work consisting of an individual flood risk assessment followed by a tailored package of measures for each property e.g. flood guards to the doors and air bricks, non return valves on the main sewer, sealing around entry points, rendering, waterproofing brickwork and under floor sump pumps.
- On-going works for a new flood bank around Pasture Lane, Gunthorpe; this is programmed to be completed during 2010. These works will provide an improved standard of protection (4% annual probability) to 18 properties in the village.

Further options to reduce flood risk around Gunthorpe are currently being considered. Property protection measures to the 5 properties which would be adversely affected by the scheme are still to be completed.

Caythorpe

4.4.31 Caythorpe is located on the left bank of the River Trent, approximately 12km downstream of Radcliffe Viaduct. The threshold survey showed that none of the 22 properties within the village are below either the pre or post scheme 1% annual probability level. No further works are therefore required for Caythorpe.

Hoveringham

4.4.32 Hoveringham is located on the left bank of the Trent, approximately 13km downstream of Radcliffe Viaduct. Currently, 104 properties through the village are at risk from flooding during the 1% annual probability event. The Nottingham Left Bank FAS results in a 0.04m increase in peak water levels meaning a further 7 properties are at risk from flooding during the 1% annual probability event.

4.4.33 Individual property protection measures have been offered to residents and to date, 16 properties have been fitted with products and more are planned in future years.

Bleasby & Gibsmere

4.4.34 Bleasby and the nearby hamlet of Gibsmere are located on the left bank of the River Trent, approximately 16km downstream of Radcliffe Viaduct. The majority of properties are located on high ground outside the 1% annual probability floodplain, however, some 53 properties are at risk from flooding during this event.

4.4.35 The Nottingham Left Bank FAS results in a 0.02m increase in water levels for Bleasby during the 1% annual probability event, meaning an additional 7 properties are at risk from flooding. In March 2008, individual property protection measures were applied to 17 of the most vulnerable properties in the area as part of a Defra pilot project.

Mitigation Measures: Conclusions

4.4.36 Neither floodplain compensation works nor improvements to existing floodplain storage through Nottingham are practicable to mitigate the impact of the Nottingham Left Bank FAS upon the increased flood risk through the 10 villages. Consequently, a separate commission has been established by the Environment Agency to investigate and implement methods for reducing the long term flood risks to these communities.

4.4.37 The measures currently being considered and completed to date for the affected communities are summarised in Table 4.11.

4.4.38 In many cases, the mitigation measures being considered or recently completed will provide protection from the 1% annual probability flood event not only to ‘new’ properties adversely affected by the left bank scheme, but also those already at risk from flooding. For example, the mitigation works at Barton in Fabis and Burton Joyce will provide protection from flooding against the 1% annual probability event to 449 properties currently at risk from flooding.

Table 4.11 – Nottingham Left Bank FAS Mitigation Measures

Location	Mitigation Works Already Completed	Mitigation Works Planned or On-going	Comments & Additional Information
Barton in Fabis	Existing flood defence raised to 1% annual probability level.	Road crossings on existing defence line to be raised to 1% level	Mitigation works will result in a significant improvement in the existing standard of flood protection for Barton in Fabis
Holme Pierrepont	-		-
Radcliffe	-	Flood defence scheme to improve standard of protection around the caravan park was approved by Regional Flood Defence Comitee	Scheme not progressed as residents not in favour of proposals
Stoke Bardolph	-	Individual property protection offered	-
Burton Joyce	New pumping station on the 'Crock Dumble'	New flood defence works around the village, due to be complete during 2010/11	Mitigation works will result in an improved standard of protection for 352 properties in the village in addition to off-setting the adverse impact of the left bank scheme
Shelford	-	-	No mitigation works are required for Shelford
Gunthorpe	Installation of a variety of individual property protection measures completed to 34 houses	Construction of a new flood bank at Pasture Lane is scheduled for completion during 2010.	Further options to reduce flood risk through the village are being considered.
Caythorpe	-	-	No mitigation works are required for Caythorpe
Hoveringham	Individual property protection offered-		
Bleasby & Gibsmere	Individual property protection measures applied the 17 most vulnerable properties as part of a defra pilot study.	-	

4.4.39 In addition to these, all properties affected will be offered a flood warning service, if they are not already signed up to receive it. Improvements to the flood warning service to villages along the lower Fluvial Trent have been made as part of a number of recent commissions established by the Environment Agency[6].

4.4.40 Extensive discussions have also been held with representatives from each of the affected villages to advise of how they will be impacted by the scheme and the measures currently being considered to address any increase in the risk of flooding.

4.5 Managing Storm Runoff

4.5.1 In accordance with the guidelines given in PPS25, Black & Veatch has investigated the impact of the Nottingham Left Bank FAS upon surface water runoff from the landward side of the proposed flood defences. During November 2000, flooding was observed behind the existing defences at a number of locations due to backing-up of minor watercourses and storm drains when the Trent was in flood.

4.5.2 The assessment of the left bank scheme upon minor watercourses and storm drains was completed during June 2006, and comprised the following work:

[6] *River Trent Review and Recommendations on Flood Warning*, Black & Veatch, April 2006;
River Trent Review and Recommendations on Flood Warning Addendum, Black & Veatch, September 2006;
River Trent Flood Warning Review (Lower Fluvial Trent Valley), Black & Veatch, February 2008.

- Minor watercourses, storm drains and drainage paths crossing the defence line were identified from sewer network data, the FEH CD-ROM, OS Landline Tiles and site visits. Catchment areas for each drain were estimated from the available data which are detailed in Appendix B;
- The risk of flooding of properties as a result of backing up of the 37 drains identified was assessed using information from the November 2000 flood event and from discussions with Severn Trent Water and the local drainage boards. Each of the 37 drains was then designated as either, low, medium or high risk, depending on the likelihood of property flooding as a result of the drain backing up whilst the Trent is in flood. The results of this assessment are shown in Appendix B.

4.5.3 Of the 37 areas, 5 are classed as high risk, 13 as medium, and the remaining 19 are low risk. Works have been proposed to reduce the risk of flooding along the drains which were deemed to be high risk, and are summarised in Table 4.12. Watercourses deemed to be medium risk will be reviewed further during detailed design to confirm if any further works are required to reduce flood risk along these watercourses. No further work is proposed under this scheme in low risk areas. It should be noted ponding of surface water behind the flood defences may occur when the Trent is in flood within these risk areas, however this will not result in property flooding.

Table 4.12 – Drainage Mitigation Works

Catchment No.	Catchment Area (ha)	Notes	Works Proposed [see note 1]
14	13.8	**Attenborough Village** - Two surface water gravity sewers (225 and 375mm ø) which outfall into the stream that flows around the perimeter of the cricket ground. Local residents reported that during November 2000 flooding of Attenborough occurred initially from water backing up through road drains.	300l/s submersible pumping station to be constructed along The Strand to over-pump surface water runoff when the Trent is in flood
15	248.5	**Chilwell Brook** – heavily urbanised catchment draining the Chilwell area of Nottingham. Extensive flooding occurred along the tributary across Chilwell Golf Course during November 2000, nearly flooding properties along Long Lane	300mm high embankment to be constructed along the southern edge of Chilwell Golf Course to prevent flooding of properties along Long Lane
26	~280	**Tinkers Leen** – heavily urbanised tributary which is fed by runoff from central Nottingham and overflows from the Nottingham Canal. Backing-up of this tributary during November 2000 resulted in flooding along Meadow Lane.	Pumping station to be constructed near the Tinkers Leen outfall to over-pump the watercourse when the Trent is in flood.
34	~23	**Crosslands Meadow** – heavily urbanised watercourse draining the Candle Meadow estate via a pumped outfall. Failure of the pumping station could result in extensive property flooding.	Flapped outfalls are to be raised above the flood defence level to improve performance.
36	~23	**Holme Dyke** – heavily urbanised watercourse draining the Colwick Industrial Estate. Flooding was reported along the watercourse during November 2000 as the tributary is unable to drain when the Trent is in spate.	A pumping station is to be constructed near the tributary's outfall

Notes
1. Design standards for the proposed mitigation works will be confirmed during detailed design. Due consideration will be given to the impact of future climate change in the design of the works.

4.5.4 In addition to the works outlined in Table 4.9, all new walls and embankments will have filter drains and catch pits included in the design on the landward side of the defence. This will collect and discharge surface water trapped locally by the new defence line during normal flow conditions on the Trent.

4.5.5 An assessment of surface water flooding through Nottingham was also undertaken as part of the Greater Nottingham SFRA. This comprised compilation of the reported incidents of surface water flooding identified by Severn Trent Water, the borough council drainage engineers and local parish councils. The reported incidents relevant to the Nottingham Left Bank FAS are detailed in Table 4.13, along with the predicted impact of the scheme upon flood risk at these locations.

Table 4.13 – Summary of Greater Nottingham SFRA Surface Water Flood Risk Locations along the Nottingham Left Bank FAS

GNSFRA Reference	OS Reference	Location	GNSFRA Details	Impact of Nottingham Left Bank FAS & Proposed Mitigation Measures
3	SK 5928 3889	Storm tanks off Daleside Road	Sewer backs up from storm tanks and flood subway at Lenton Lane and Queens Drive	Not affected by proposed works, no mitigation measures required.
53	SK 6160 3975	Land to West of Mile End Road	Land to west of land drain if pumping station fails	Catchment no. 33 (2006 study), proposed works will not affect operation of pumping station
54	SK 6186 3969	Junction of Trent, Ouse Dyke and land drain	Pumping Station	Catchment no. 34 (2006 study), flapped outfalls are to be raised above the flood defence level to improve performance.
55	SK 6219 4020	Industrial properties on Road No. 2	Properties at risk from flooding if water level in Trent prevents watercourse draining. Hired pumps employed previously to over-pump watercourse to Trent	Catchment no. 36 (2006 study), a pumping station is to be constructed near tributary outfall. This will significantly reduce flood risk at this location.
138	SK 4882 3219	Erewash Canal Overflow to New Sawley Brook	Joins New Sawley Brook at Fields Farm Road	New Sawley Brook is pumped over the proposed defences. The scheme will not affect the operation of this pumping station.
139	SK4868 3201	Erewash Canal Overflow, Sheetstores	Canal Overflow	Canal floodgates are to be raised, flood risk from the canal when the flood gates are closed to be investigated in further detail.
183	SK 5670 3815	Victoria Embankment	Failure of pumping station would result in severe property flooding	Pumping station noted by 2006 study, scheme will not affect its operation
204	SK 5906 3877	Beck Valley Culverts	Public surface water sewers, CSOs on system which discharges by Trent.	Works in this area are being undertaken by private developers and do not form part of the scheme
205	SK 5744 3770	Embankment recreation ground	Flooded during November 2000 from rising groundwater	Groundwater interaction with the Trent will be addressed during detailed design. Flooding of this nature is unlikely to be affected by the scheme.

Notes
1. The 2006 Study referred to in the table is *Nottingham Left Bank FAS Drainage Assessment,*,2006, Black & Veatch. The catchment numbers quoted for that study are not the same as those used elsewhere in this FRA report.

4.5.6 The GNSFRA study identified many of the catchments noted as part of the previous (June 2006) investigation. In the majority of cases, the locations identified will not be affected by the Nottingham Left Bank FAS. The key exceptions are as follows:

- Flood risk for GNSFRA ref.54 will be **reduced** by the scheme as the existing flap valves are to be raised to improve the performance of this outfall;
- Flood risk for GNSFRA ref.55 will be **reduced** by the scheme as a new pumping station is proposed;

- Further works are required to assess the impact of raising the canal floodgates upon flood risk along the canal overflow at Sheetstores.

4.6 Other Risks Associated with Extreme Events

Overtopping

4.6.1 The defences are to be designed to withstand floods in excess of the design event without significant damage. If the defences are overtopped, the Major Incident Plan, owned by Nottingham City Council will be implemented. Upon completion of the Nottingham Left Bank FAS, the flood warning trigger levels within the Major Incident Plan will need to be revised.

Flood Defence Breach

4.6.2 The impact of a breach in the left bank defence line upon flood risk through Nottingham was assessed as part of the Greater Nottingham SFRA study. The effect of breaches in the left bank defence line at the following locations were assessed:

- Sawley
- Trent Meadows
- Attenborough
- Rylands
- Meadows
- Colwick

4.6.3 For each location, a 50m long breach was added to the model 'breakline' representing the flood defences. The model was then run for the 1% annual probability event to determine the extent of flooding behind the breached defence.

4.6.4 Map 1-FDP-32, Map 1-FDP-33 and Map 1-FDP-34, which are taken from the Greater Nottingham SFRA study and are presented in Appendix C, show the extent of flooding behind the defences for the breach scenarios.

4.6.5 In the event of a breach in flood defences, the Major Incident Plan would be implemented. Breaches typically occur due to either overtopping-induced damage of the flood defences, or from weaknesses which arise from deficiencies in their design, construction, and/or maintenance. Occurrence of a breach in the flood defences is considered to be unlikely as:

- the defences will be designed to withstand overtopping; and
- weaknesses in the defences are unlikely, as they will be constructed and maintained by the Environment Agency, who are national experts in this field.

5 CONCLUSIONS

5.1.1 Nottingham has a long and well recorded history of flooding. The largest recorded flood events through the city occurred during 1795, 1875 and 1947. The latter event prompted the construction of the existing defences through the city during the 1950s. These defences prevented widespread flooding of Nottingham during the recent November 2000 flood event.

5.1.2 The existing flood defences along the left bank of the Trent through Nottingham are typically built to the 2% (1 in 50) annual probability level, however, key sections of the defence line only protect against the 4% (1 in 25) annual probability event. This is well below Defra's recommended indicative standard of protection for Nottingham. Furthermore, many of the existing defences are nearing the end of their design life and are in poor condition.

5.1.3 The Nottingham Left Bank FAS comprises raising the existing defences and constructing new defences (where required) along the left bank of the Trent between the M1 at Sawley and Radcliffe Viaduct, to protect against the 1% (1 in 100) annual probability event. Planning permission for works was granted during March 2009 and are now substantially complete around Sawley and Trent Meadows.

5.1.4 Further to the start of construction works, the Environment Agency are seeking planning permission for an alternative flood defence alignment around Attenborough Village known as the 'Attenborough Village Peripheral Route'. The Attenborough Village Peripheral Route has a localised impact on floodplain hydraulics between Barton Lane and Attenborough Village. The consequence of this is an increase of water levels on the left bank floodplain of the Trent of up to 0.1m, for a distance of 1.2km upstream of Attenborough Village. These water level increases on the left bank floodplain will be contained by the Nottingham Left Bank FAS defences, therefore, flood risk to people and property following the construction of the proposed peripheral route will not increase. The Attenborough Village Peripheral Route will result in the volumetric loss of 53,000m^3 of functional floodplain. This constitutes 0.01% of the 1% (1 in 100) annual probability flood event volume on the Trent at Nottingham.

5.1.5 Due to the loss in floodplain storage through Nottingham, the scheme will result in an increase in water levels of up to 0.06m downstream of Nottingham. This increase in downstream levels would increase flood risk at 69 additional properties downstream of Nottingham during the 1% annual probability event. These impacts are unchanged as a result of adopting the Attenborough Village Peripheral Route in preference to the consented flood defence alignment along 'The Strand'.

5.1.6 To alleviate the increased risk of flooding to the communities which will not benefit from the scheme itself, a number of separate measures have been proposed including local flood defence works and individual property protection. When complete, communities such as Barton-in-Fabis and Burton Joyce will benefit from a significant reduction in flood risk as a result of the mitigation measures. Furthermore, extensive discussions have also been held with representatives from each of the affected villages to advise of the scheme's impact and the measures currently being considered to address any increase in the risk of flooding.

5.1.7 Other works are proposed as part of the scheme to address local issues within the benefit area, such as improvements to the urban drainage system to mitigate backing up of drains.

5.1.8 The Nottingham Left Bank FAS therefore defends over 16,000 properties in the main conurbation from the River Trent during a 1% (1 in 100) annual probability event. Separate measures are in hand to mitigate the impacts and improve the existing standard of protection to nearby villages

FIGURES

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APPENDIX A –
Attenborough Village Peripheral Route
Black & Veatch Technical Note

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APPENDIX B–
Drainage Area Plans

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APPENDIX C–
GNSFRA Flood Defence Brach Outlines

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