

Report Title

FLOOD RISK ASSESSMENT

Property Address

Proposed Barn Conversion
Burnfoot Grange,
Wigton,
Cumbria
CA7 9HL

Client

Clare Donohue

Our Reference

24-309r001

Date

September 2024

Prepared by

Colin Aimers
BEng Hons CEng MICE CEnv
Director
Kingmoor Consulting Ltd

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INTRODUCTION

BACKGROUND

Kingmoor Consulting were commissioned in August 2024 to prepare a Flood Risk Assessment (FRA) for the proposed barn conversion at Burnfoot Grange, Wigton, CA7 9HL.

This flood risk assessment is to inform further design phases associated with the developments on the site and support the application for the proposed change of use..

SITE DETAILS

SITE DETAILS AND LOCATION

The application site comprises an existing barn located adjacent to Burnfoot Cottage, Wigton. A former school is located immediately adjacent to the site with planning permission for conversion to dwellings, with the Lidl Supermarket located to the south of the site and Burnfoot Cottage to the east. The Speet Gill is immediately adjacent north of the site.

The national grid reference for the site is 325737E, 548551N.



Site Location Plan - Source Bing Maps



Site Block Plan - Source Bing Maps

PROPOSED DEVELOPMENT

The site is an existing barn to be converted to a dwelling.

INITIAL FLOOD RISK

An initial flood risk assessment was undertaken looking at the Environment Agency flood mapping. The site appears to be covered by low resolution flood mapping at <https://flood-map-for-planning.service.gov.uk/> and this identified the area of the site to be within a Flood Zones 3. An extract of the flood data is presented below.



Figure 1 - Extract from River Flood Maps for Planning Dataset



Figure 2 - Surface Water Flood Extent

DETAILED FLOOD RISK ASSESSMENT

FLOOD RISK ASSESSMENT CRITERIA

Flood Data was requested from the Environment Agency and they have confirmed that they have previously modelled the site and provided information relating to this site. It is noted that the current flood model held by the Environment Agency is being updated and shall be issued early 2025 for review. A copy of the issued documents are appended to this report.

The zoning associated with the initial flood appraisal considered earlier in this report is based on a generalised flood model and the EA states the following .:

The Flood Zones for this requested location are based upon the original 2004 Jflow Data (national generalised modelling). This is available through Data.gov.uk as "Modelled fluvial flood depth data created 2004". This data is not suitable for identifying whether an individual property will flood, for detailed decision making or for use in site specific Flood Risk or Strategic Flood Risk Assessments. Where this data is used for anything other than broad catchment or Shoreline Management Plan scale further evidence, verification and studies should be undertaken.

The Flood Zone classifications are as follows :

- Flood Zone 1 - land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding (<0.1%).
- Flood Zone 2 - land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% - 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% - 0.1%) in any year.
- Flood Zone 3 - land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

HISTORIC FLOODING

Wigton has a history of flooding and the most documented flood was that of Storm Desmond in December 2015. A detailed flood report was produced by Cumbria County Council [Lead Flood Authority] at the time detailing the flood routes and affected properties. The area around the proposed development was flooded but the property was not engulfed in flood waters.

Extensive modelling has been undertaken by JBA on behalf of the Environment Agency to determine options associated with flood alleviation within the town. This includes improvements at Speet Gill, including removal of silt from the river channel immediately adjacent to the site.

SOURCES OF FLOODING

As part of the risk assessment, consideration shall be given to the following sources of flooding and what effect these could have on the development:

Flooding from Rivers / Watercourses

The Speet Gill is located adjacent to the site and would be the primary source of river flooding on the site.

The Environment Agency have deemed the risk to this site as **High**. Further analysis, however, shall be carried out as the risk associated with flooding on the site is not property specific and the flood levels on the site have not been determined.

Flooding from Reservoirs / Lakes

Flooding from reservoirs and lakes is unlikely as indicated from the flood risk authority. We consider the risk associated with floods from reservoirs lakes to be **Low**.

Flooding from the Sea

Not applicable.

Flooding from the Land

The extract from the surface water flood risk map in Figure 2 shows the flood extent from surface

water runoff which indicates very little impact on the site and therefore we consider the risk associated with flooding from the land to be **Low**.

Flooding from Groundwater

Data from the flood risk management authority and Natural England Groundwater vulnerability maps indicate low groundwater vulnerability on the site and therefore we consider that flooding from Groundwater to be **Low**.

Flooding from Sewers

We consider the risk of flooding from sewers to be **Low**.

Summary

The following table indicates a summary of the risks and control measures required:

Source of Flooding	Risk	Control Measures
Rivers / Watercourses	High	Further analysis required.
Reservoirs/Lakes	Low	-
Sea	n/a	-
Land	Low	-
Groundwater	Low	-
Sewers	n/a	-

DETAILED FLOOD MODELLING

From the information provided by the Environment Agency, a detailed flood modelling assessment shall be undertaken on the site and from topographic survey information obtained on site.

ENVIRONMENT AGENCY DATA

Flood data was obtained from the Environment Agency to inform this report. The following flood levels were provided and are summarised below. It is noted that Node ref EA01102WAMPPOOL_SPET1_557.* was adopted for use in this analysis, this is located immediately opposite the site on Speet Gill.

Note	Scenario	1 : 25 Y flood level [<i>flow</i>]	1 in 100 Y flood level [<i>flow</i>]	1 in 1000Y flood level [<i>flow</i>]
SPET1_557.*	Defended	21.04 [5.64]	21.16 [7.55]	21.29 [12.54]

Levels are noted as metres AOD, flow levels are presented as cumecs].

Climate Change

In accordance with the EA guidelines, an allowance for climate change needs to be applied in order to consider the impact of climate change on proposed development. In accordance with Table 1 of the EA's climate change allowances, the 'central' and 'higher central' allowances are to be applied as the lifetime of the proposed 'More Vulnerable' development is likely to extend into the 2050s.

The EA flood data provided did not include an allowance for climate change, therefore it is proposed that the above figures are to be adjusted in accordance with the river flow allowances for the catchment. The following table indicates these allowances.

Waver and Wampool Management Catchment peak river flow allowances

Scenario	2020-2035	2035-2065	2066-2095
Central	11%	18%	34%

We have considered the use of the Central scenario for the site as the guidance states for flood zone 3 and More Vulnerable sites these values are to be adopted. Although these do not directly relate to

flood levels, the following table indicates the revised flows at the site.

Revised Flows for Climate Change [Central allowance considered]

Flood Event	2020-2035		2035-2065		2066-2095	
	Flow	Flow + CC	Flow	Flow + CC	Flow	Flow + CC
1:25 Y	5.64	6.26	5.64	6.65	5.64	7.55
1: 100 Y	7.55	8.38	7.55	8.91	7.55	10.17
1: 1000 Y	12.54	13.91	12.54	14.79	12.54	16.80

All flows are indicated in cumecs.

In considering the above flows, we consider that the flow presented for the 1 : 100 Y [2066-2095] of 10.17 cumecs shall be adopted and from linear interpretation of the flows in the river channel between the published levels and flows, a flood level of 21.240m AOD should be assumed for this flood event.

Topographic Data

Topographical data was obtained for the site and flood levels mapped based on the flood level of 21.240m [1 : 100 Y + CC]. This was modelled in Autodesk Civil 3D to provide a three dimensional model of the site and to allow prediction of flood depths.

Drawing 24-309 DWG001 indicates levels across the site, and 24-309 DWG002 indicates flood depths and flow directions.

Flood Depths

From the topographic survey, the property has an existing floor level of approx 20.820m AOD indicating that flood depths within the property would be in the region of 420mm based on the 21.240m flood depth.

FLOOD MITIGATION MEASURES

In respect to the proposed development, this is classified as 'More Vulnerable' and as such flood mitigation measures are required to address :

- Floor levels and Flood compatibility
- Access and evacuation

FLOOR LEVELS AND FLOOD COMPATIBILITY

It is proposed that floor levels will reflect the requirements of the development as the existing property cannot be adequately adopted to facilitate an increase in floor levels. It is therefore proposed that the following mitigation measures would be adopted for the property conversion :

- Flood gates at entrances and door openings
- One way valves for drains into the building
- Concrete floors and masonry construction associated with the sub structure
- Overhead electrical supplies to the building
- Locating electrical equipment and other plant at raised levels
- Adoption of water resisting materials where appropriate.

More detailed considerations to these aspects can be identified as part of the Building Control process and adopted as required during construction.

ACCESS AND EVACUATION

An emergency access plan should be adopted for the site and include the following procedures for the property.

- Early Warning Alert system for the Local Catchment (EA Notifications etc)
- Safe isolation of electrical feeds to the property.
- Safe evacuation of occupants of the site.
- Process for site attendance post flood waters

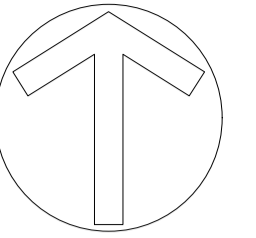
SUMMARY

It is proposed that there is a change of use associated with the conversion of a barn to residential development within a Flood Zone 3 area. The property has had no flood history within the property however areas around the site have been subject to historic flooding principally associated with the Speet Gill adjacent to the site. Flooding has occurred at this area of Wigton due to a number of factors including the limited capacity of the adjacent Burnfoot Bridge and debris screens on the Speet Gill.

These areas have been studied in detail by the Environment Agency and wider catchment mitigation measures are to be implemented to further reduce the flood risk in the immediate area of the site.

APPENDICES

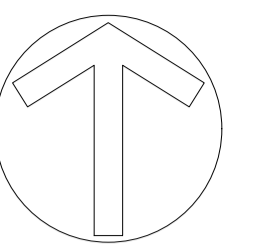
APPENDIX A - DRAWINGS



PLAN
SCALE 1:150

- GENERAL NOTES**
1. ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED AND NOT TO BE SCALED FROM DRAWINGS. USE WRITTEN DIMENSIONS ONLY AND CHECK ON SITE BEFORE ORDERING MATERIALS OR STEELWORK.
 2. ALL DRAWINGS TO BE READ IN CONJUNCTION WITH DRAWINGS PRODUCED BY OTHERS AND ANY ERRORS TO BE BROUGHT TO THE ATTENTION OF THE ENGINEER PRIOR TO COMMENCEMENT OR INSTALLATION OF THE WORKS.
 3. ALL MATERIALS AND WORKMANSHIP TO BE UNDERTAKEN IN ACCORDANCE WITH BEST PRACTICE AND THE RELEVANT CODES INCLUDING BRITISH STANDARDS AND BUILDING REGULATIONS.
 4. THIS WORK MAY BE REQUIRED TO COMPLY WITH THE BUILDING SAFETY ACT 2023. IF WORK REQUIRES MORE THAN ONE CONTRACTOR TO UNDERTAKE THE WORKS, THE CLIENT IS REQUIRED TO APPOINT A PRINCIPAL DESIGNER TO COORDINATE DESIGN WORKS, AND ENSURE THAT ALL DESIGN AND WORKS ARE CONSTRUCTED IN ACCORDANCE WITH THE BUILDING REGULATIONS. IT CANNOT BE ASSUMED THAT KINGMOOR CONSULTING LTD ARE BY DEFAULT THE PRINCIPAL DESIGNER UNLESS APPOINTED SPECIFICALLY FOR THIS ROLE.

ENGINEER		CLIENT	
SUITE 4 ATLANTIC HOUSE, PARKHOUSE BUSINESS PARK, CARLISLE, CA3 0LJ T: 01228 915900 E: hello@kingmoorconsulting.co.uk			
PROJECT BARN CONVERSION, BURNFOOT GRANGE KING STREET, WIGTON, CA7 9HL			
TITLE EXISTING SITE LAYOUT			
SCALE AS NOTED	STATUS FOR PLANNING APPLICATION		
PAPER SIZE A1	DRAWN BY C AIMERS	CHECKED AND APPROVED C AIMERS	
PROJECT PHASE PLANNING	DATE AUGUST 2024	DATE MARCH 2024	
DRAWING NUMBER 23-309-DWG001			REVISION A



KING STREET

ALDI CAR PARK

BURNFOOT COTTAGE

FORMER SCHOOL
 CONSENTED FOR RESIDENTIAL
 UNDER REF FUL/2020/0067

PLAN
 SCALE 1:150

SURFACE LEVEL DATA			
NUMBER	MINIMUM LEVEL	MAXIMUM LEVEL	COLOUR
1	-0.750	-0.300	Blue
2	-0.300	0.000	Cyan

<p>KINGMOOR CONSULTING</p> <p>SUITE 4 ATLANTIC HOUSE, PARKHOUSE BUSINESS PARK, CARLISLE, CA3 0LJ T: 01228 915900 E: hello@kingmoorconsulting.co.uk</p>		CLIENT
PROJECT BARN CONVERSION, BURNFOOT GRANGE KING STREET, WIGTON, CA7 9HL		
TITLE FLOOD DEPTHS AND FLOWS		
SCALE AS NOTED	STATUS FOR PLANNING APPLICATION	
PAPER SIZE A1	DRAWN BY C AIMERS	CHECKED AND APPROVED C AIMERS
PROJECT PHASE PLANNING	DATE AUGUST 2024	DATE MARCH 2024
DRAWING NUMBER 23-309-DWG002		REVISION A

APPENDIX B - ENVIRONMENT AGENCY MAPS

**Fluvial Model Outline Map:
St Ursulas School,
Burnfoot, Wigton,
CA7 9HL**

Produced: 15 July 2019
Our Ref: CL134049
NGR: 325,642 548,460

Key

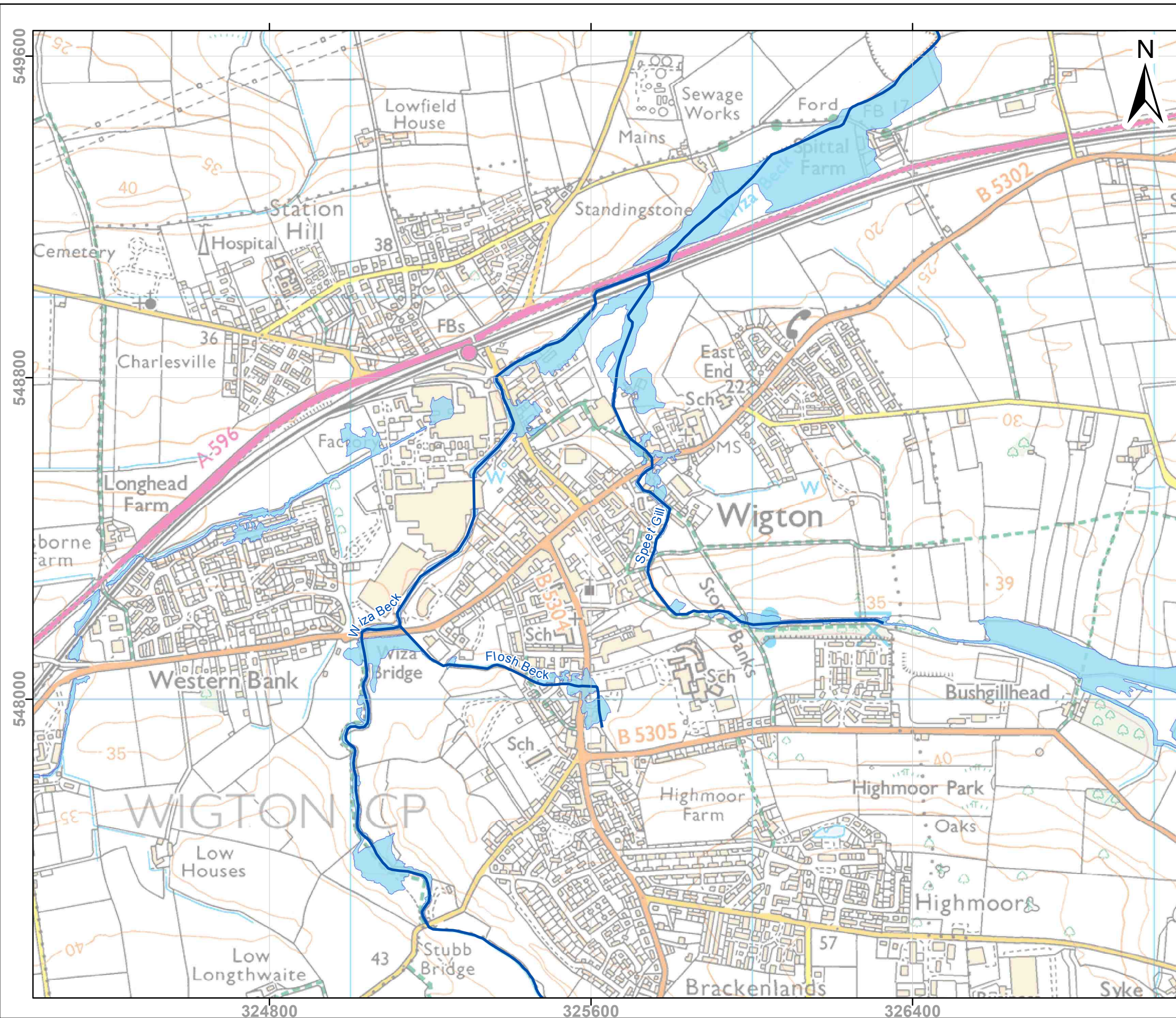
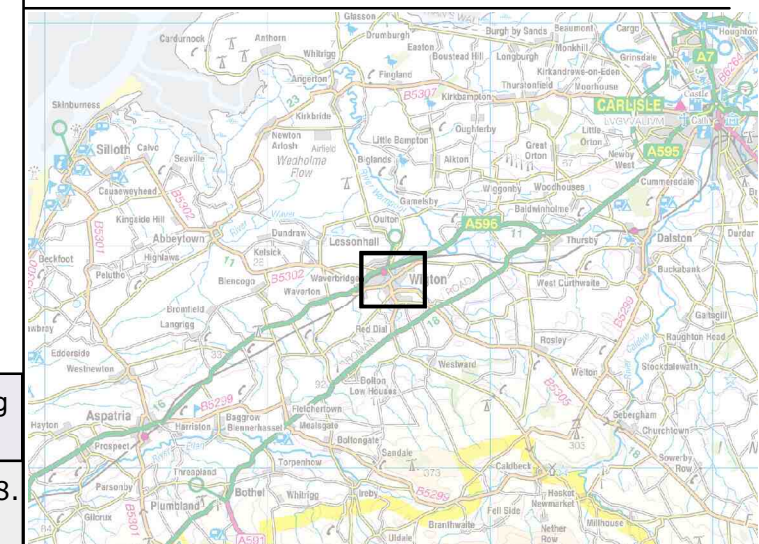
-  Main River
-  1 in 10 Defended Outline

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website; www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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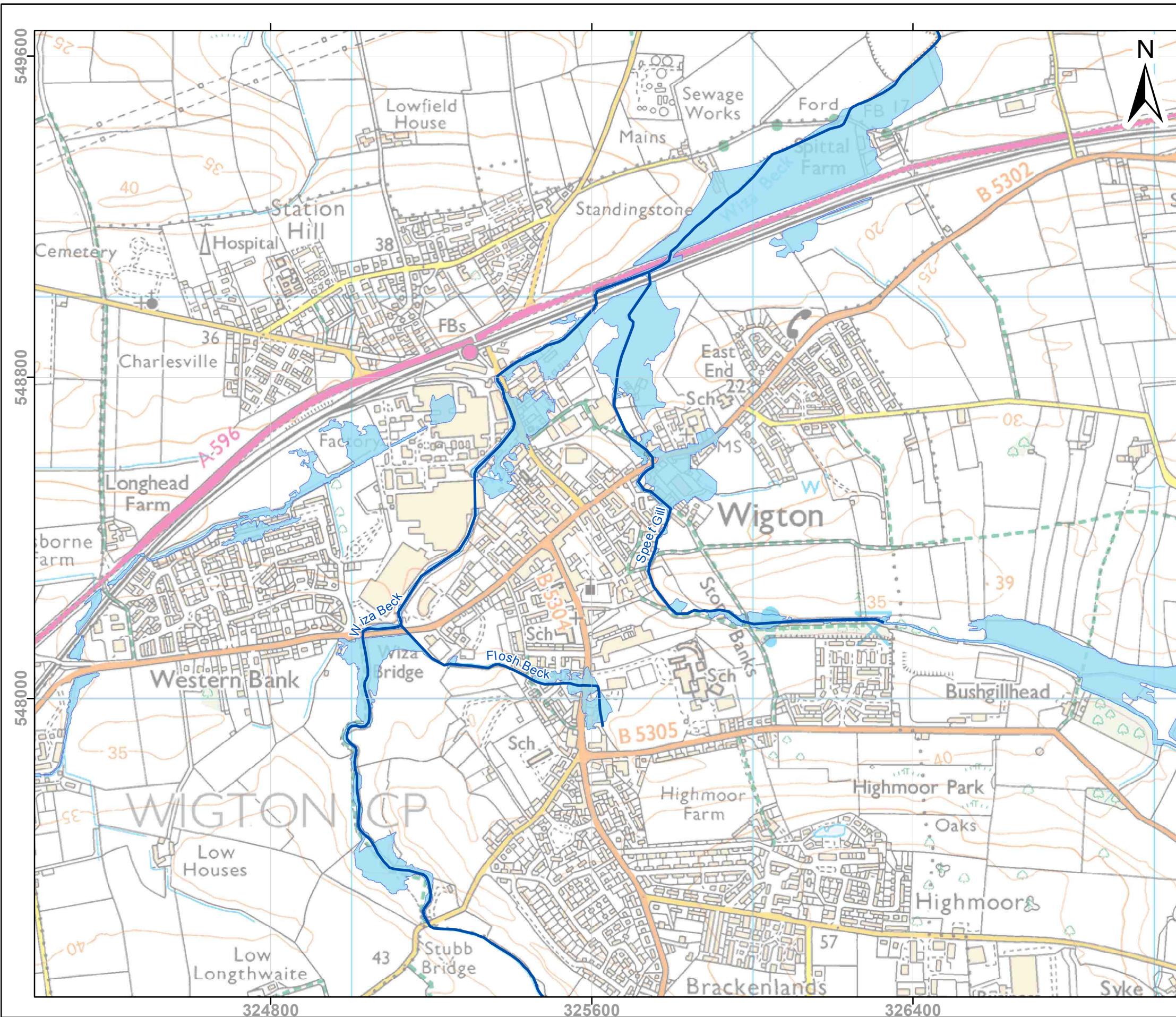
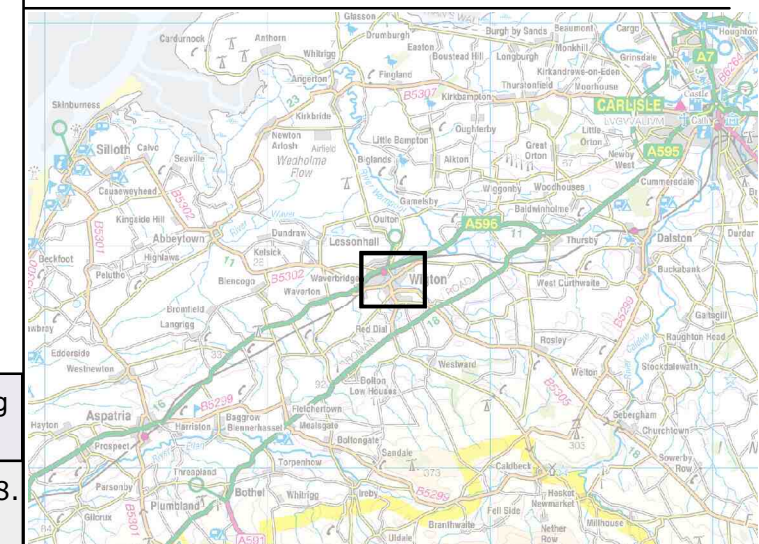
-  Main River
-  1 in 25 Model Outline

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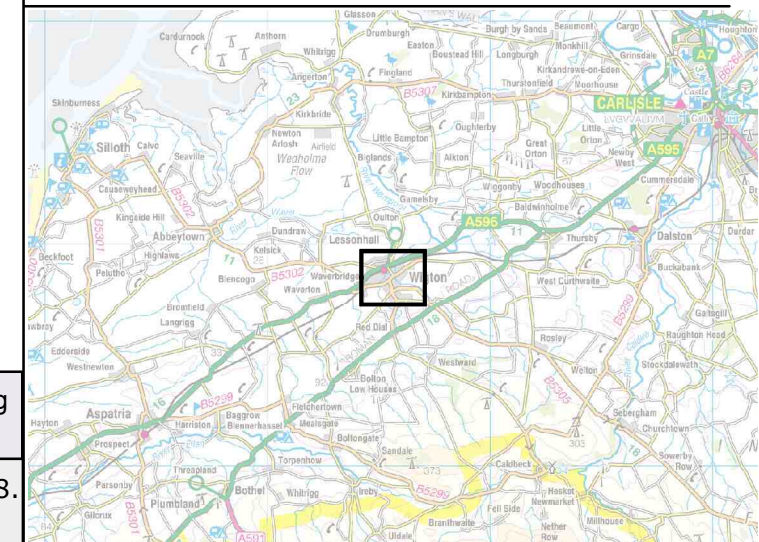
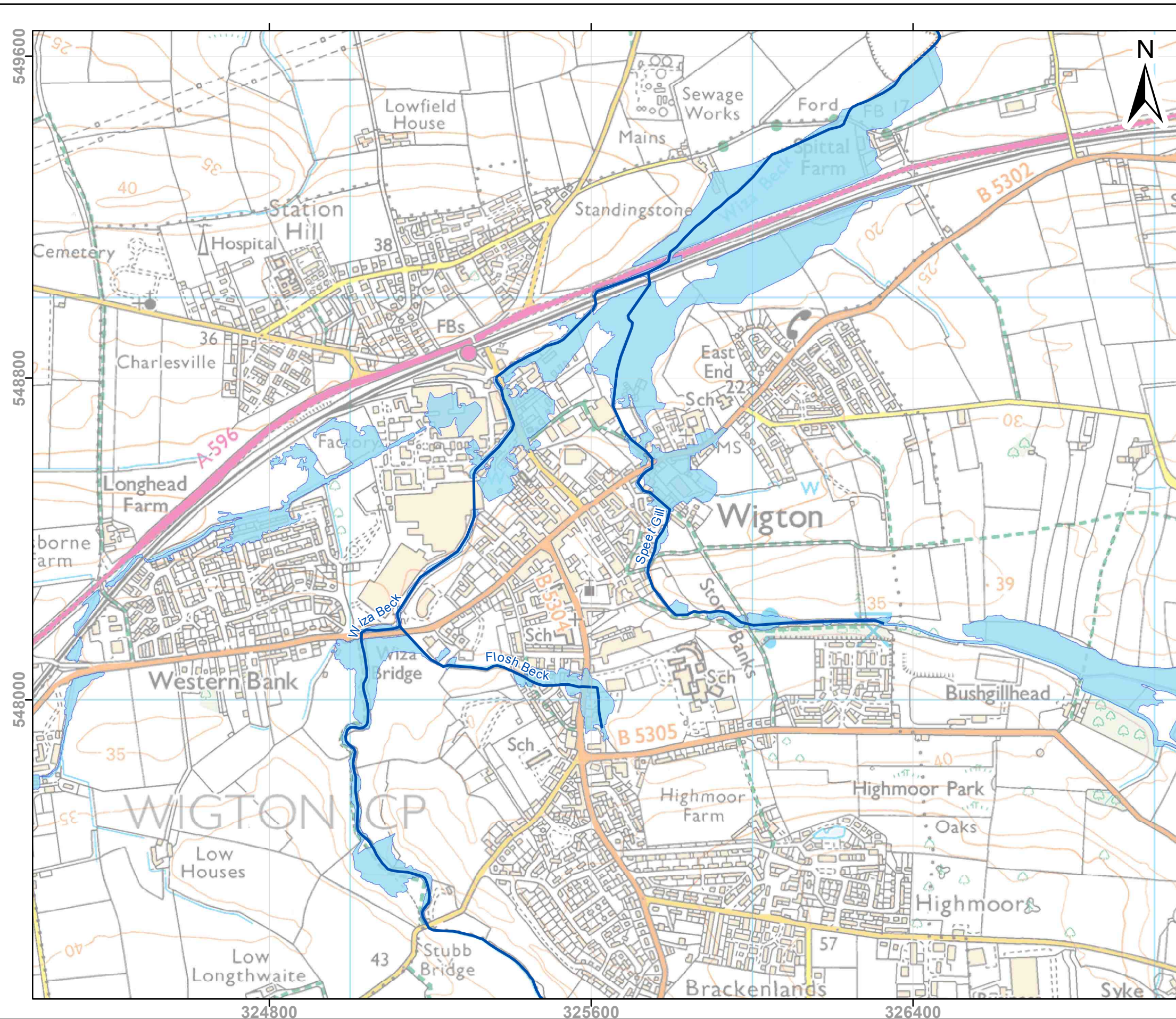
-  Main River
-  1 in 50 Defended Outline

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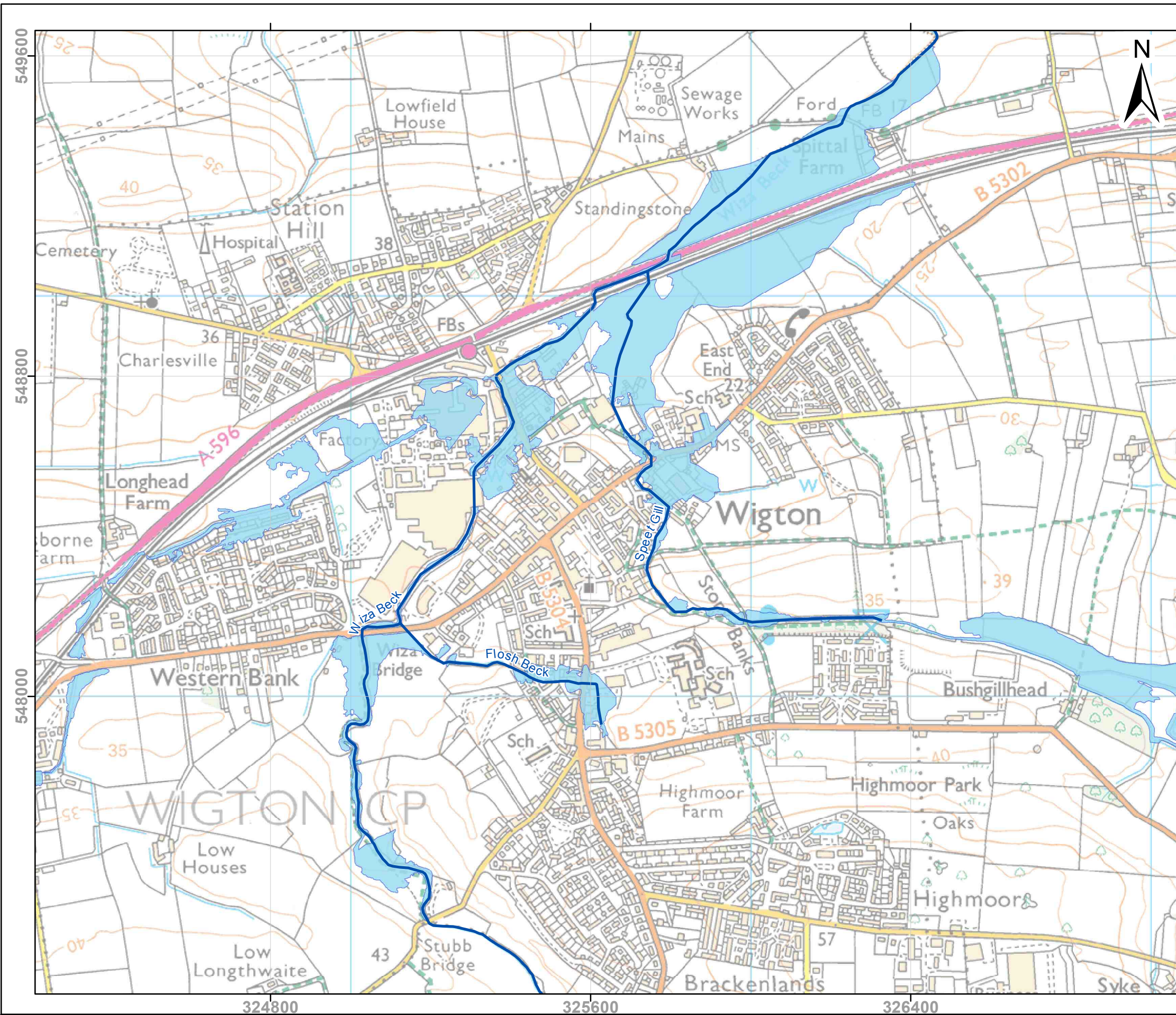
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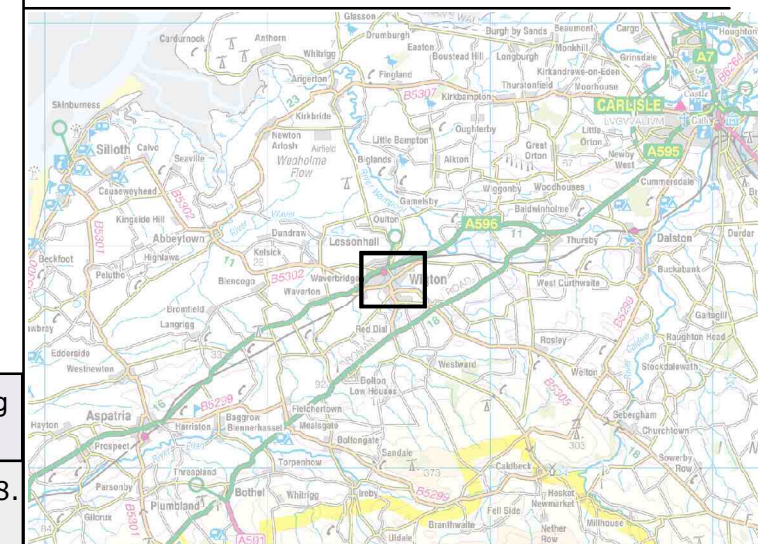
-  Main River
-  1 in 75 Defended Outline

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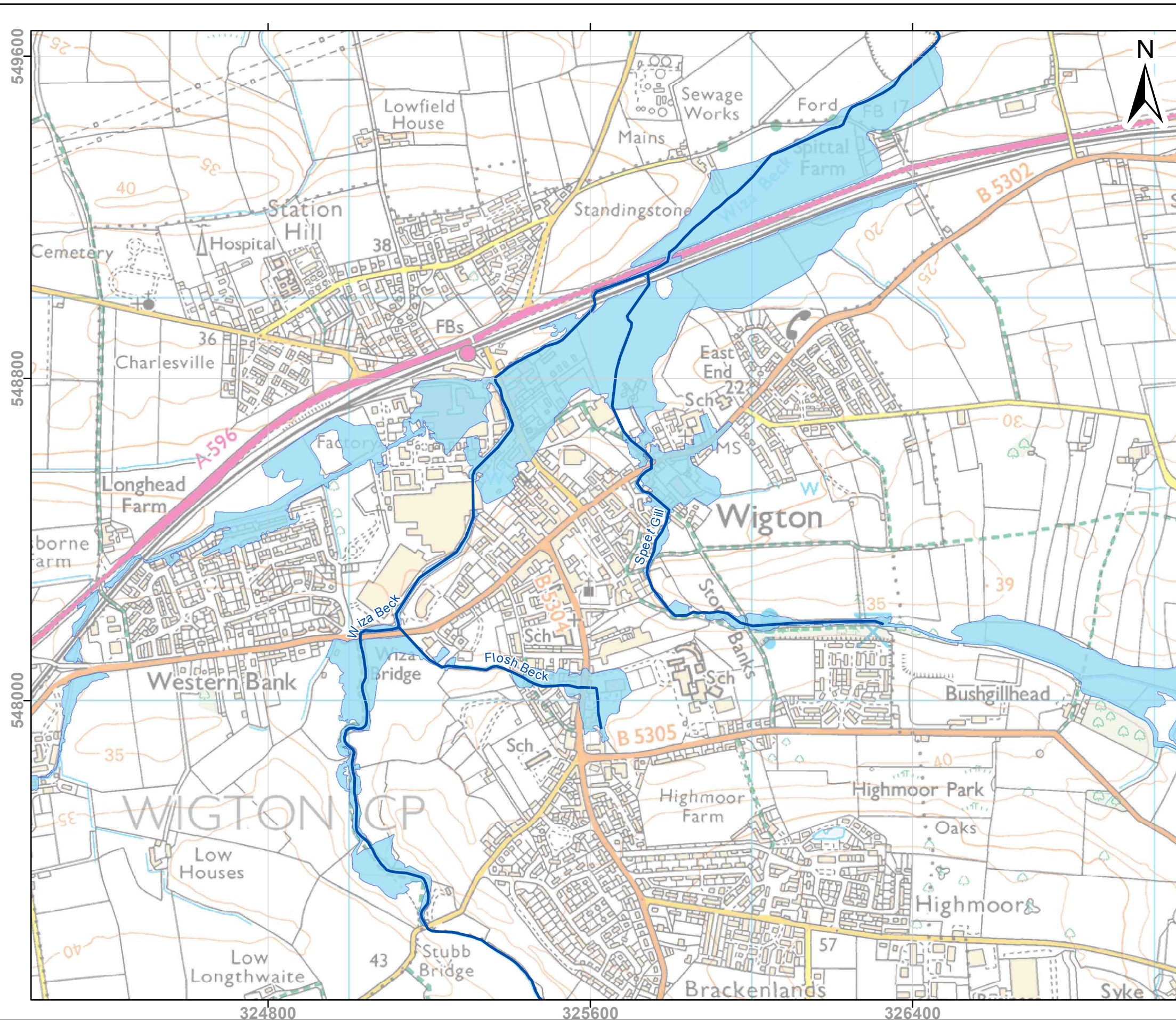
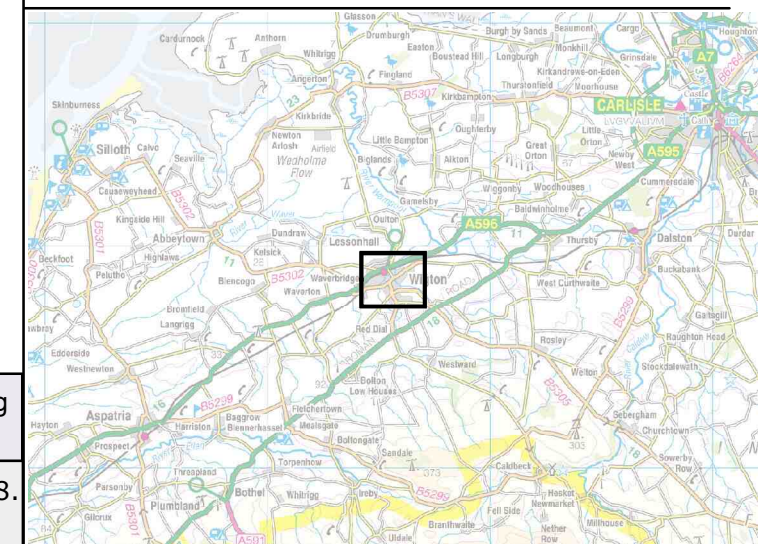
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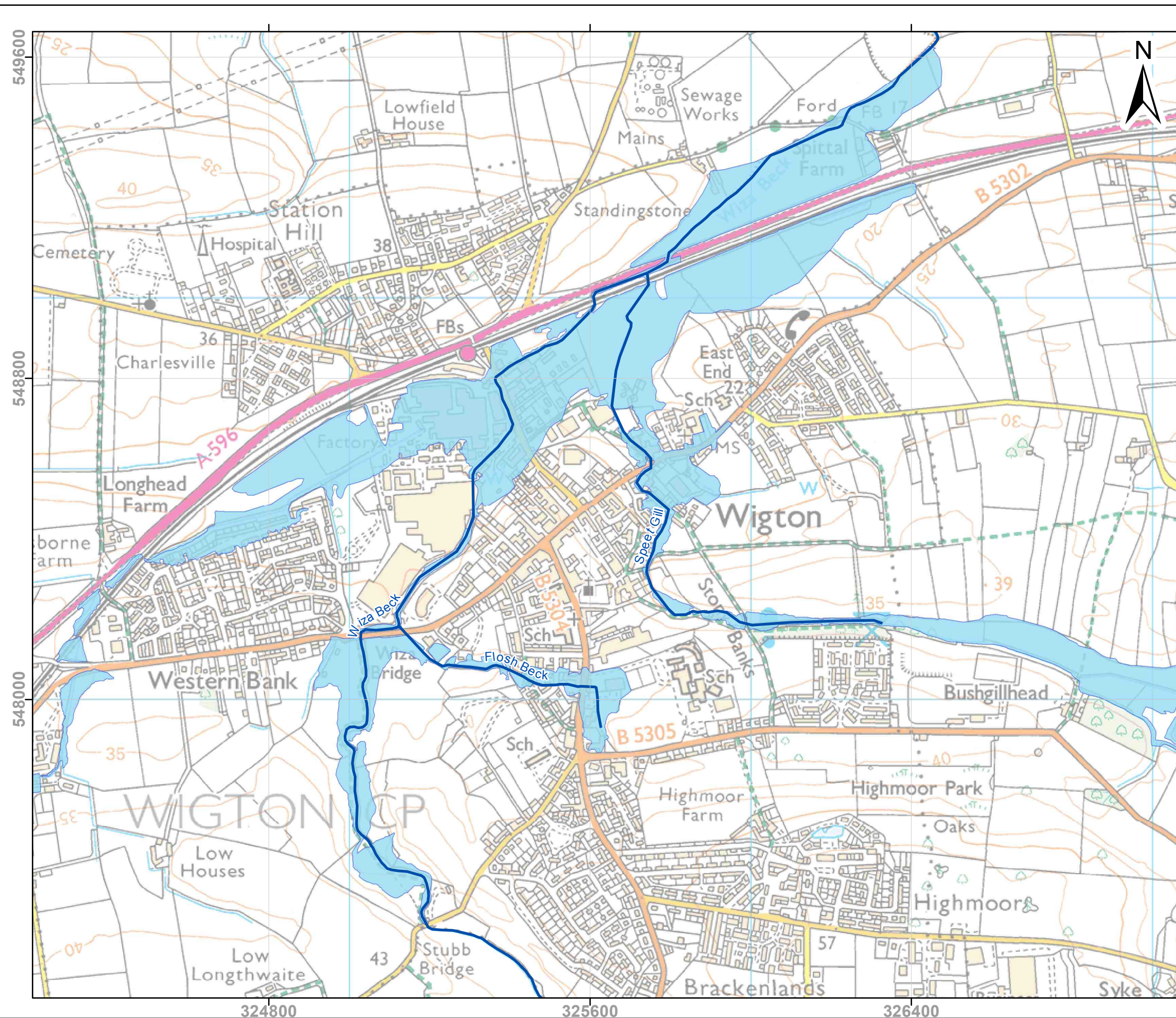
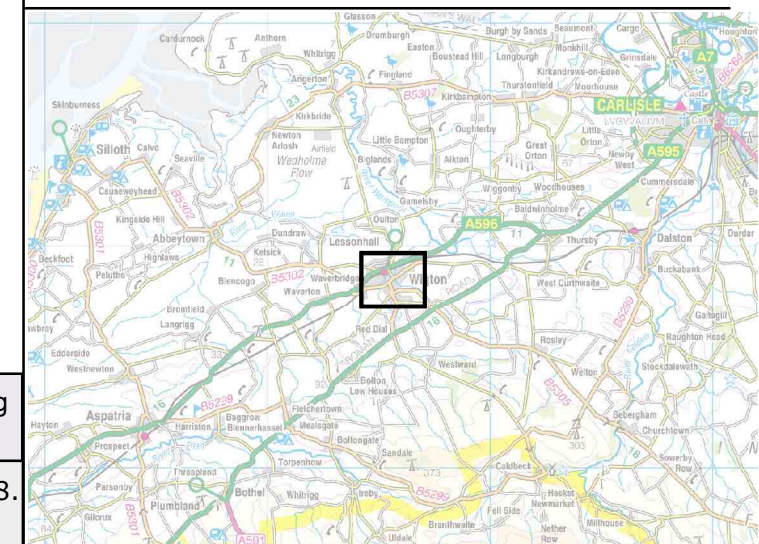
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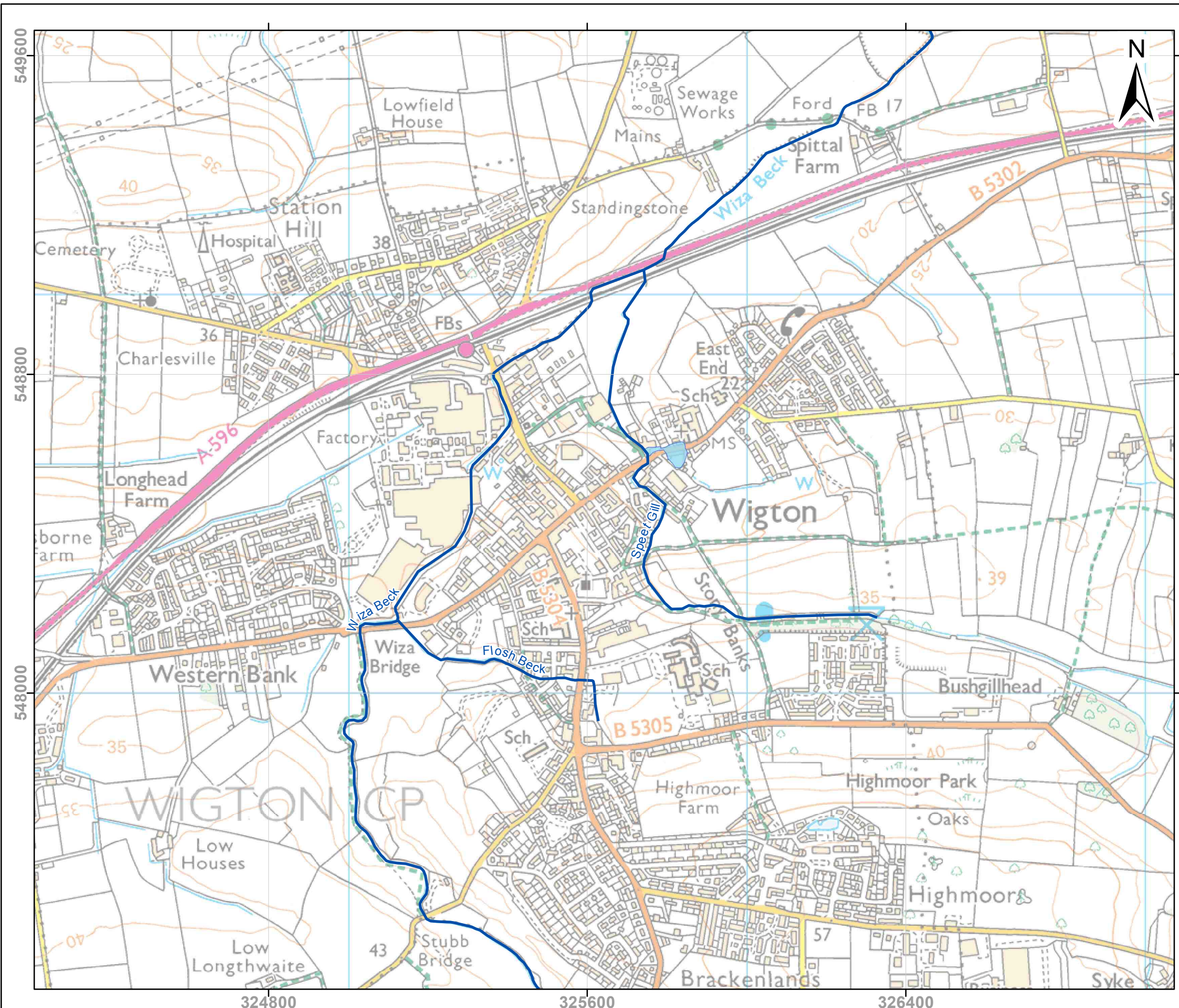
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Historic Flooding Map: St Ursulas School, Burnfoot, Wigton, CA7 9HL

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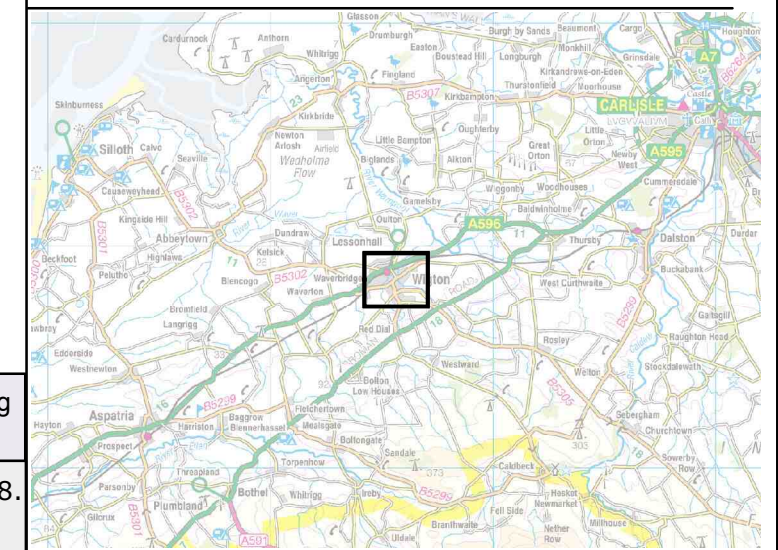
-  Main River
-  January 2000

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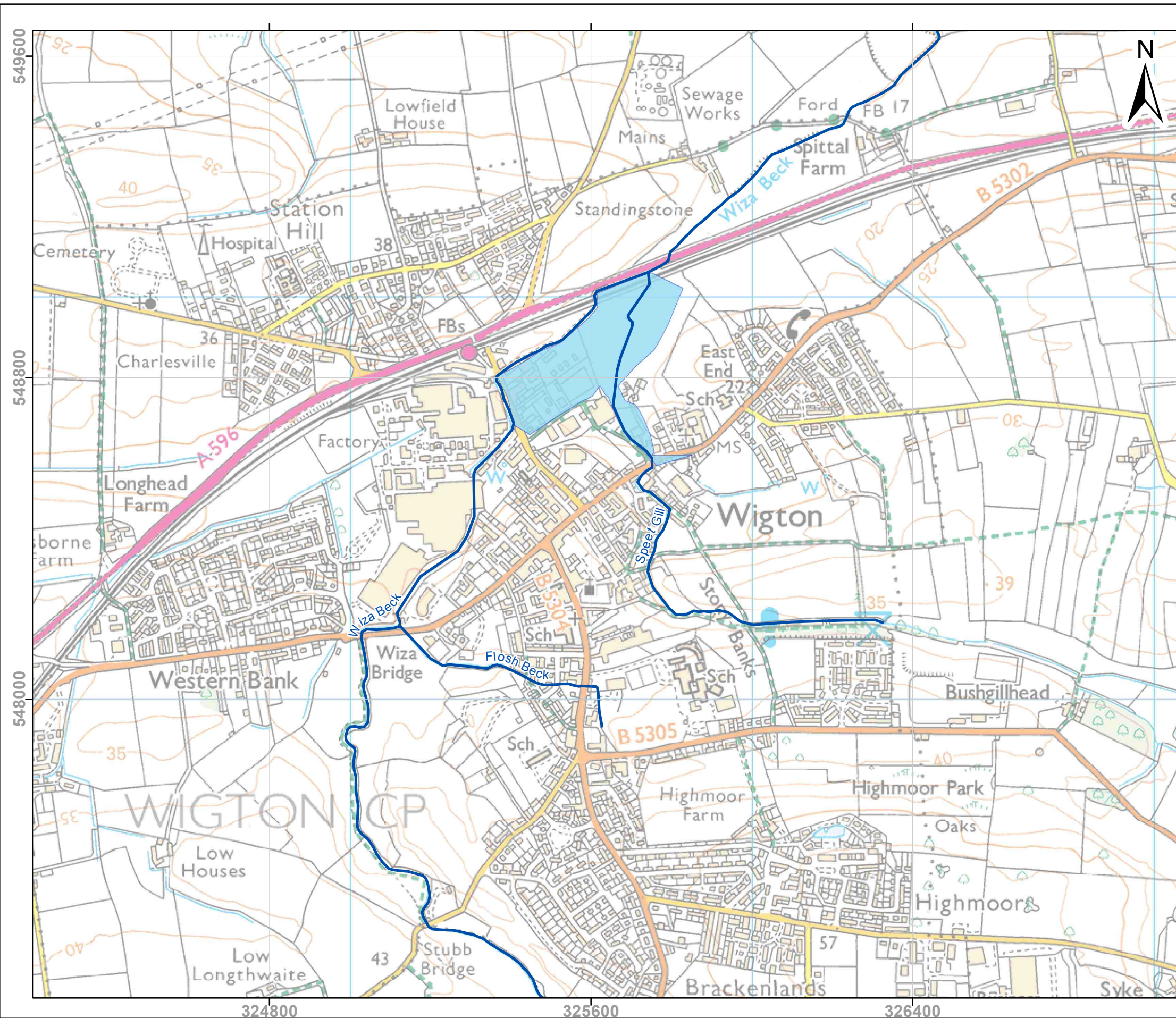
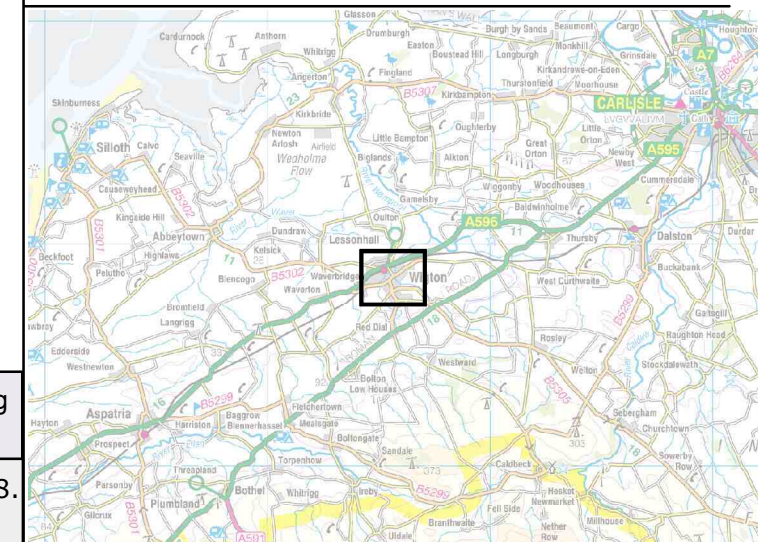
-  Main River
-  January 2004

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NGR: 325,642 548,460

Key

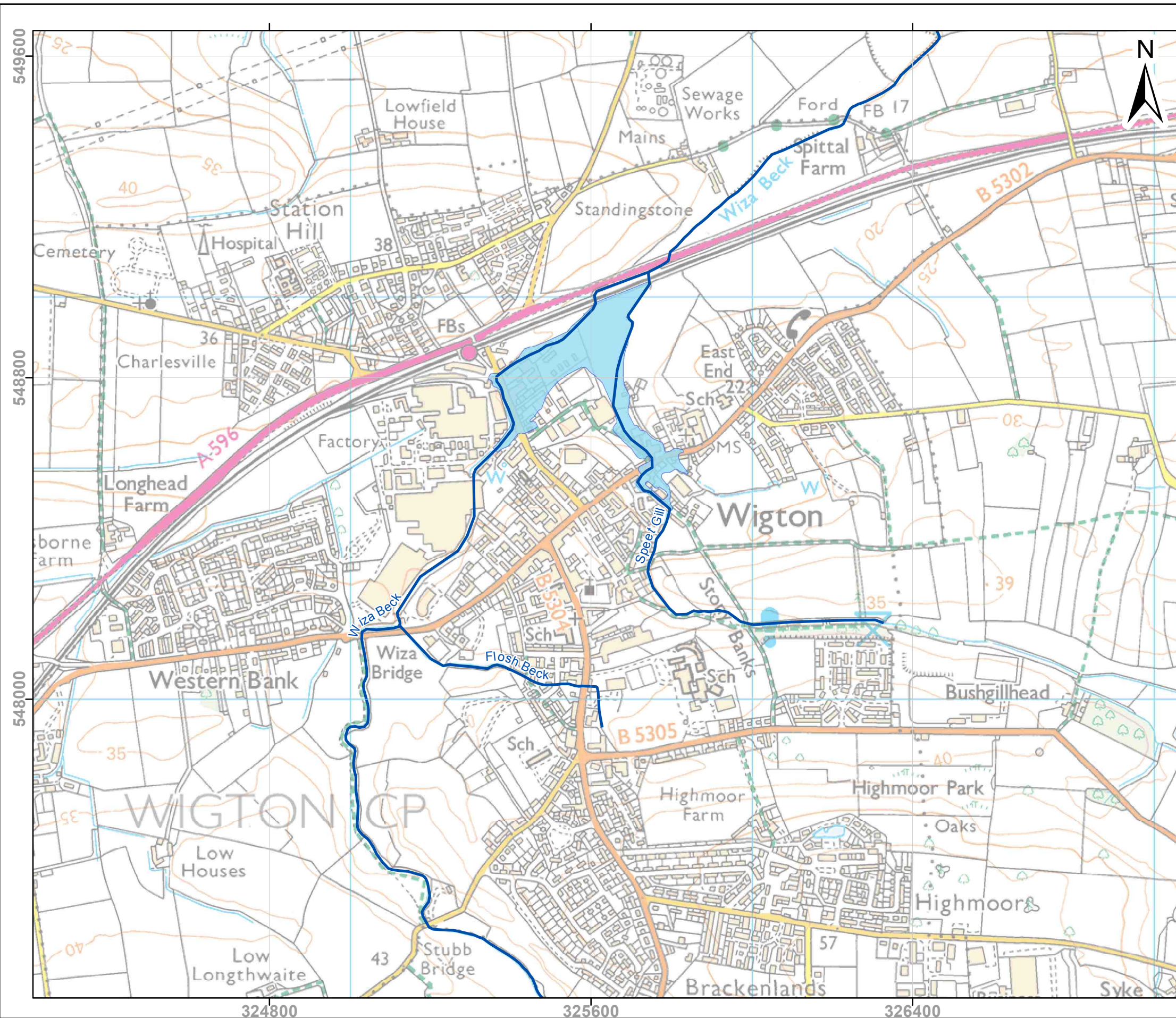
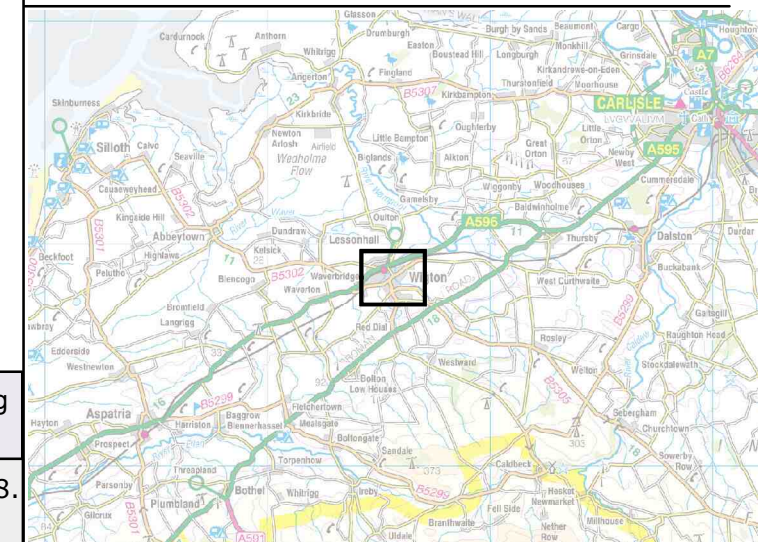
-  Main River
-  January 2005

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website; www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Historic Flooding Map: St Ursulas School, Burnfoot, Wigton, CA7 9HL

Produced: 15 July 2019
Our Ref: CL134049
NGR: 325,642 548,460

Key

 Main River

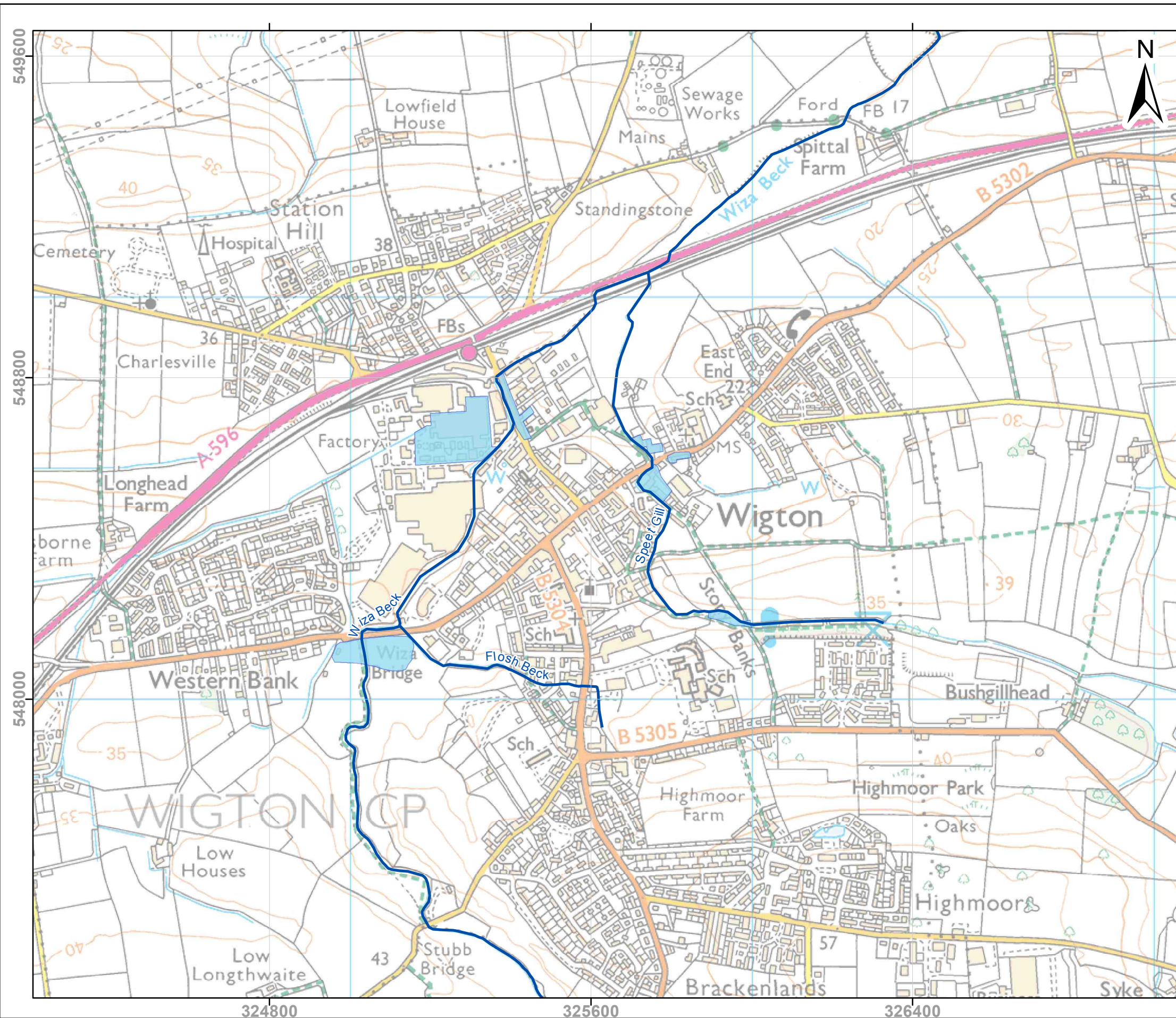
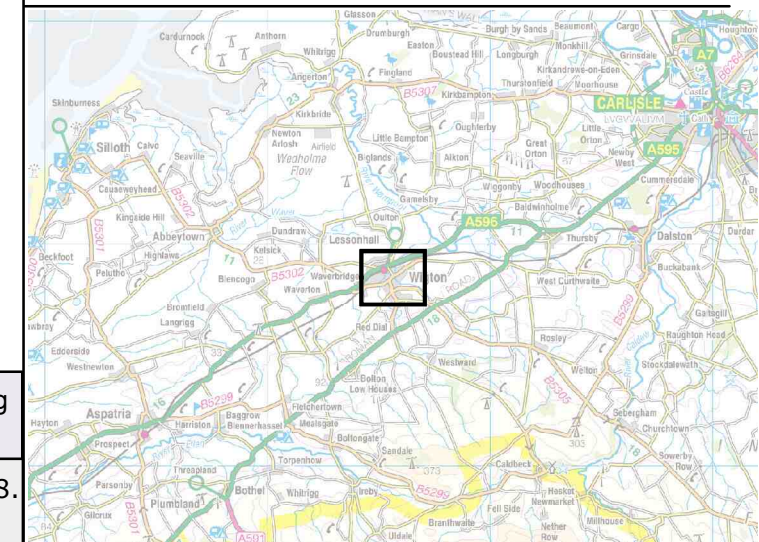
 December 2015

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**Flood Map for Planning:
St Ursulas School,
Burnfoot, Wigton,
CA7 9HL**

Produced: 15 July 2019
Our Ref: CL134049
NGR: 325,642 548,460

Key

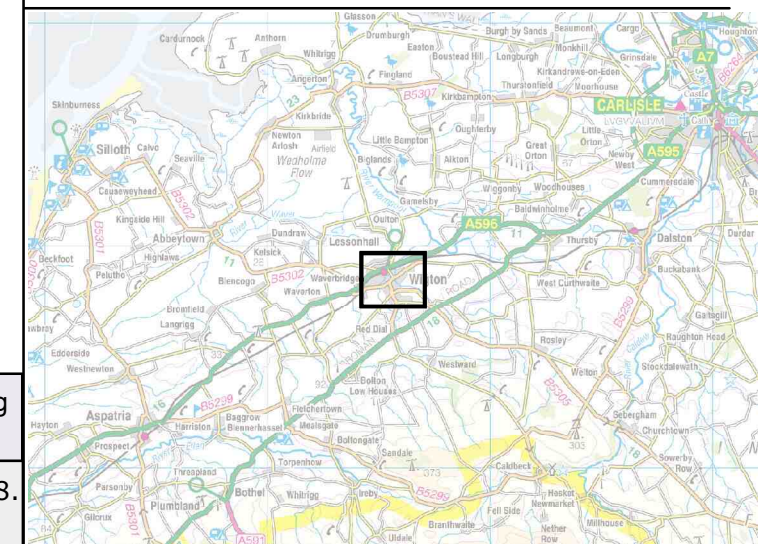
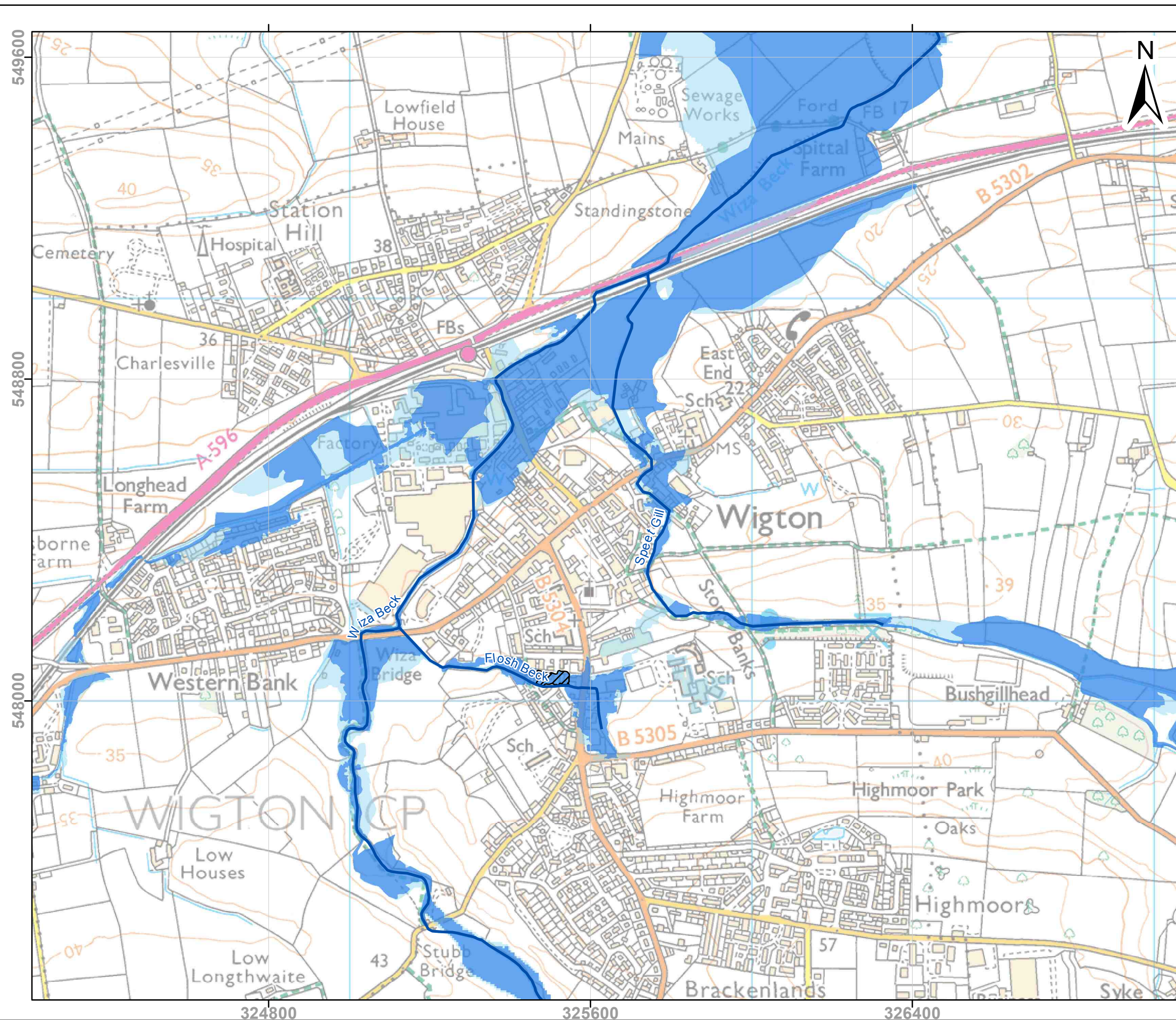
-  Main River
-  Areas Benefiting from Defences
-  Flood Zone 3
-  Flood Zone 2

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Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Node Point Location Map: St Ursulas School, Burnfoot, Wigton, CA7 9HL

Produced: 15 July 2019
Our Ref: CL134049
NGR: 325,642 548,460

Key

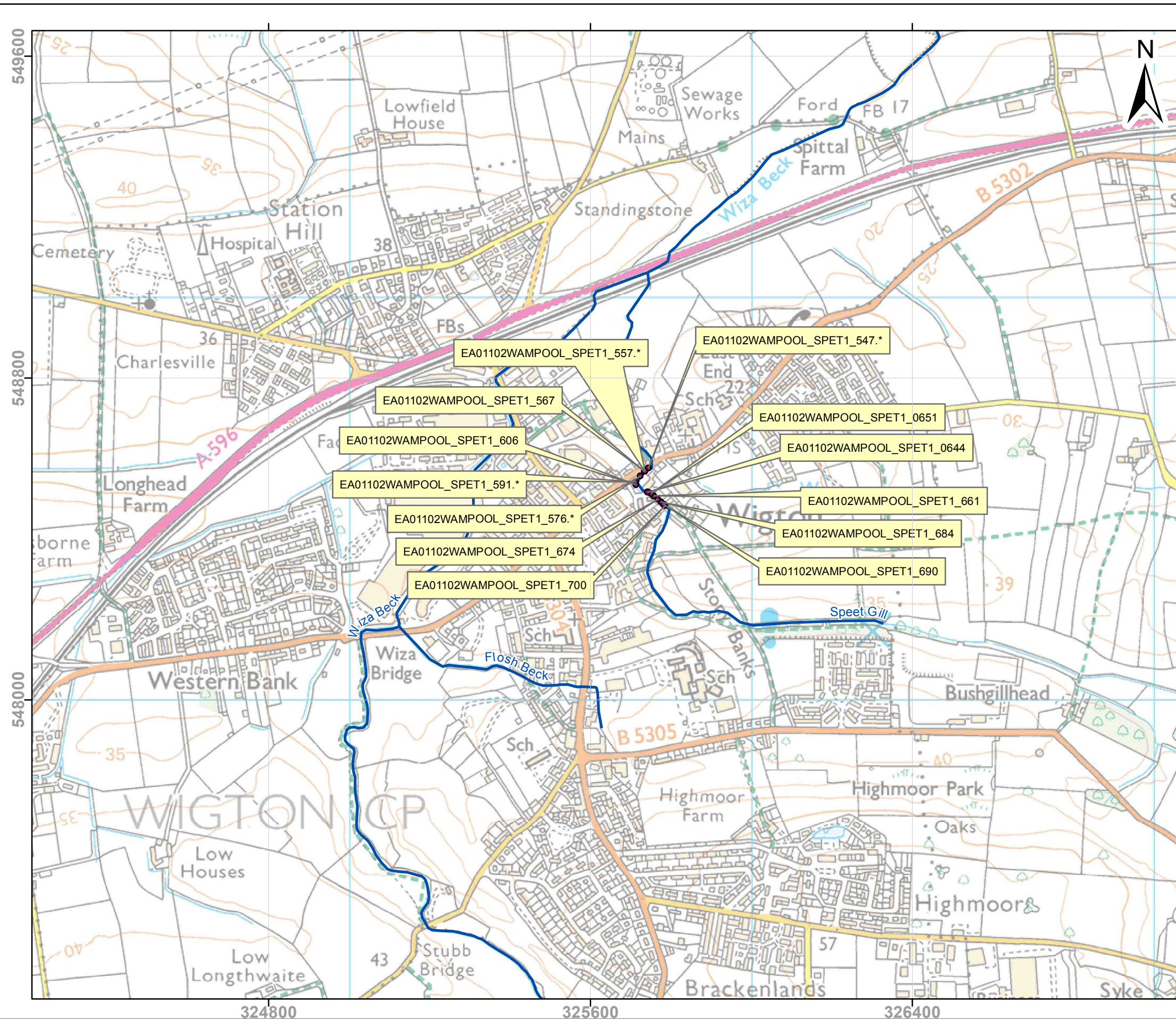
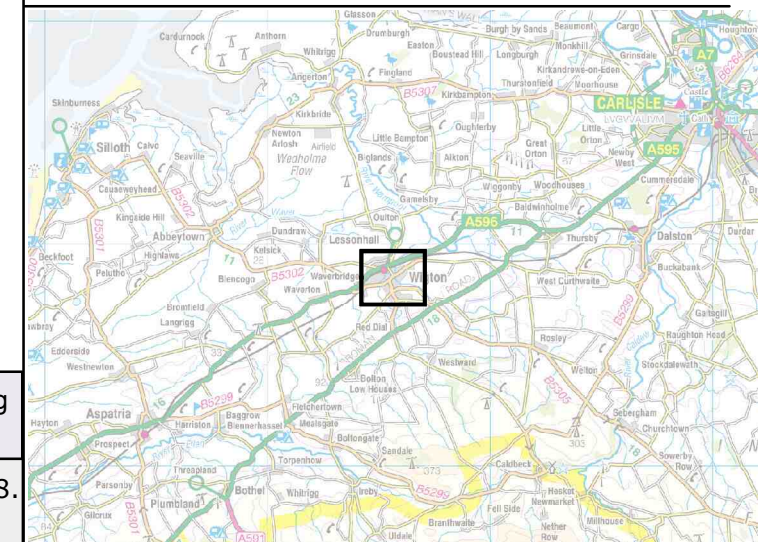
- Modelled Node Point
-  Main River

Flood Zone 3 shows the area that could be affected by flooding:

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Node point name	ModelledFloodGroupCode	ReturnPeriod (Yrs)	LevelValue (Maod)	FlowValue(cumecs)
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	2	20.61	2.81
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	5	20.77	3.82
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	10	20.87	4.53
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	25	21.03	5.64
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	50	21.08	6.52
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	100	21.15	7.55
EA01102WAMPOOL_SPET1_547.*	EA01102WAMPOOL	1000	21.29	12.54

EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	2	20.61	2.81
EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	5	20.77	3.82
EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	10	20.87	4.53
EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	25	21.04	5.64
EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	50	21.08	6.52
EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	100	21.16	7.55
EA01102WAMPOOL_SPET1_557.*	EA01102WAMPOOL	1000	21.29	12.54

EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	2	20.61	2.81
EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	5	20.78	3.82
EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	10	20.89	4.53
EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	25	21.04	5.44
EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	50	21.09	5.93
EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	100	21.16	6.52
EA01102WAMPOOL_SPET1_567	EA01102WAMPOOL	1000	21.3	9.37

EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	2	20.95	2.71
EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	5	21.05	3.72
EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	10	21.09	4.44
EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	25	21.15	5.34
EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	50	21.18	5.83
EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	100	21.23	6.42
EA01102WAMPOOL_SPET1_606	EA01102WAMPOOL	1000	21.35	9.27

EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	2	20.73	2.81
EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	5	20.9	3.82
EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	10	21	4.54
EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	25	21.1	5.44
EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	50	21.14	5.93
EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	100	21.19	6.52

EA01102WAMPOOL_SPET1_591.*	EA01102WAMPOOL	1000	21.32	9.37
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EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	2	20.63	2.81
EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	5	20.79	3.82
EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	10	20.9	4.53
EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	25	21.06	5.44
EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	50	21.11	5.93
EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	100	21.18	6.52
EA01102WAMPOOL_SPET1_576.*	EA01102WAMPOOL	1000	21.31	9.37

EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	2	21.43	2.71
EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	5	21.74	3.72
EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	10	21.89	4.44
EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	25	22.02	5.34
EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	50	22.08	5.83
EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	100	22.14	6.43
EA01102WAMPOOL_SPET1_651	EA01102WAMPOOL	1000	22.33	9.27

EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	2	21.2	2.71
EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	5	21.28	3.72
EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	10	21.32	4.44
EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	25	21.38	5.34
EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	50	21.41	5.83
EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	100	21.46	6.43
EA01102WAMPOOL_SPET1_644	EA01102WAMPOOL	1000	21.6	9.27

EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	2	21.5	2.71
EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	5	21.79	3.72
EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	10	21.96	4.44
EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	25	22.09	5.37
EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	50	22.14	5.93
EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	100	22.19	6.64
EA01102WAMPOOL_SPET1_661	EA01102WAMPOOL	1000	22.37	9.98

EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	2	21.7	2.71
EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	5	21.91	3.72
EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	10	22.07	4.44
EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	25	22.19	5.44
EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	50	22.24	6.09

EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	100	22.29	6.92
EA01102WAMPOOL_SPET1_684	EA01102WAMPOOL	1000	22.48	10.8

EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	2	21.74	2.71
EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	5	21.96	3.72
EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	10	22.11	4.44
EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	25	22.27	5.44
EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	50	22.35	6.09
EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	100	22.39	6.92
EA01102WAMPOOL_SPET1_690	EA01102WAMPOOL	1000	22.57	10.8

EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	2	21.59	2.71
EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	5	21.86	3.72
EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	10	22.03	4.44
EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	25	22.15	5.44
EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	50	22.2	6.09
EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	100	22.26	6.92
EA01102WAMPOOL_SPET1_674	EA01102WAMPOOL	1000	22.45	10.8

EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	2	21.79	2.71
EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	5	21.99	3.72
EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	10	22.12	4.44
EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	25	22.28	5.44
EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	50	22.35	6.09
EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	100	22.39	6.92
EA01102WAMPOOL_SPET1_700	EA01102WAMPOOL	1000	22.57	10.8

Site Location	St Ursulas Convent School, Burnfoot, Wigton	CL134049
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Fluvial Defences

Asset Ref.	National Grid Reference	Asset Type	Protection Type	Location	Maintained By	Design Standard (Return Period)	Overall Condition Grade (Excellent 1- 5 Very Poor)	Effective Crest Level (m)		E.C.L Data Quality (Reliable 1-4 Unreliable)	Length (m)	Height (m)
								UCL (mAOD)	DCL (mAOD)			
01102SPET0101R08	NY 25796 48473	High Ground	Fluvial	Adjacent Tenders to Road Bridge next to School	Private	20	3	-	-	-	68.2	-
01102SPET0101R09	NY 25744 48518	High Ground	Fluvial	Road Bridge next to School to Footbridge off West Street	Private	20	3	-	-	-	74.3	-
01102SPET0101R03	NY 25734 48566	Wall	Fluvial	Footbridge off West Street to West Street (Burnfoot Bridge)	Environment Agency	100	3	21.12	21.14	1	31.6	-
01102SPET0101R10	NY 25751 48590	Wall	Fluvial	West Street (Burnfoot Bridge) to Downstream of West Street (Burnfoot Bridge)	Environment Agency	25	3	20.83	20.86	1	25.6	-
01102SPET0101R04	NY 25741 48612	Wall	Fluvial	Downstream of West Street (Burnfoot Bridge)	Environment Agency	10	3	20.86	20.86	2	23.2	-

The Environmental Permitting (England and Wales) Regulations 2016 require a permit to be obtained for any activities which will take place:

- **on or within 8 metres of a flood defence structure or culvert (16 metres if tidal)**
 - **on or within 16 metres of a sea defence**

Site Location	St Ursulas Convent School, Burnfoot, Wigton	CL134049
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Fluvial Structures

Asset Ref.	National Grid Reference	Asset Type	Protection Type	Location	Maintained By	Design Standard (Return Period)	Overall Condition Grade (Excellent 1- 5 Very Poor)	Length (m)	Height (m)
01102SPET0101R03003	NY 25743 48573	Outfall	Fluvial	Upstream of West Street (Burnfoot Bridge)	Private	-	2	-	-
01102SPET0101R03002	NY 25745 48575	Outfall	Fluvial	Upstream of West Street (Burnfoot Bridge)	Private	-	3	-	-
01102SPET0101R03004	NY 25747 48577	Outfall	Fluvial	Upstream of West Street (Burnfoot Bridge)	Unknown	-	3	-	-
01102SPET0101R03001	NY 25749 48579	Outfall	Fluvial	Upstream of West Street (Burnfoot Bridge)	Private	-	3	-	-
01102SPET0101R10001	NY 25749 48603	Outfall	Fluvial	Downstream of West Street (Burnfoot Bridge)	Private	-	3	-	-

APPENDIX C - REPORTS

Wigton

Flood Investigation Report



Burnfoot, Wigton, Cumbria

Flood Event 3rd – 5th December 2015

This flood investigation report has been produced by the Environment Agency as a key Risk Management Authority under Section 19 of the Flood and Water Management Act 2010 in partnership with Cumbria County Council as Lead Local Flood Authority.

Version	Prepared by	Reviewed by	Approved by	Date
Draft for client comment	Evi Papadopoulou Richard James	Jaime Ball	Ruth Goodall	May 2016
Final draft for client comment	Richard James	Jaime Ball	Ruth Goodall	June 2016
Final version				

DRAFT

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Executive Summary

Wigton experienced severe flooding on the 3rd December 2015 with further flooding on the 5th of December 2015 as a result of Storm Desmond. As a precursor of Storm Desmond, a period of intense rainfall fell across north-west Cumbria. This was prior to the prolonged rainfall that impacted the whole of the county. These rainfall events, falling on an already saturated catchment, led to record high river levels and surface water flooding throughout Cumbria and beyond.

In response to the flood event, this Section 19 Flood Investigation Report has been completed by the Environment Agency as a key Risk Management Authority (RMA) working in partnership with Cumbria County Council as the Lead Local Flood Authority (LLFA), under the duties as set out in Section 19 of the Flood and Water Management Act 2010. This report provides details on the flooding that occurred in Wigton on the 3rd and 5th of December 2015, and has used a range of data collected from affected residents, site visits, surveys of the area, data collected by observers and river & rainfall telemetry during the flood event.

There are no formal Environment Agency flood defences within Wigton. There are, however, a number of informal structures which may act as a defence during times of flood. In 2013 a Flood Storage Basin was constructed upstream of Wigton on the Wiza Beck designed to hold just less than 10,000 cubic metres of flood storage. A number of residents within Wigton also employ property resilience measures and as a result it is estimated that 9 residential properties and a number of commercial businesses (including the large Innovia Films Factory) were impacted by the December 2015 flood event.

This report details the flooding that occurred from the Wiza Beck, Floss Beck, Speet Gill and the Black Beck, plus flooding from other watercourses and from surface water. It identifies the flow routes and the causes of the flooding including where river banks were overtopped in a number of locations in Wigton.

Eleven actions have been recommended in this report to manage future flood risk in Wigton, which will require the involvement of a number of organisations and local communities. In response to the flooding, community meetings have taken place, and these will continue in order to ensure that all those affected are given the opportunity to be involved in reducing the flood risk in their area of the town.

Any additional information that residents and others can provide to the Environment Agency and Cumbria County Council to help develop our understanding of the flooding is welcomed. A lot of information has already been provided, much of which has been used to inform this report. The scale of this report means that not every piece of information can be incorporated into the document. Any additional information should be provided to:

<http://www.cumbria.gov.uk/planning-environment/flooding/floodriskassessment.asp>

Introduction

Under Section 19 of the Flood and Water Management Act (2010) Cumbria County Council, as Lead Local Flood Authority (LLFA), has a statutory duty to produce Flood Investigation Reports for areas affected by flooding. Section 19 of the Flood and Water Management Act states:

- (1) *On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate:*
 - (a) *which risk management authorities have relevant flood risk management functions, and*
 - (b) *whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in response to the flood.*
- (2) *Where an authority carries out an investigation under subsection (1) it must —*
 - (a) *publish the results of its investigation, and*
 - (b) *notify any relevant risk management authorities.*

This section of the Act leaves the determination of the extent of flood investigation to the LLFA. It is not practical or realistic for Cumbria County Council to carry out a detailed investigation into every flood incident that occurs in the County, but every incident, together with basic details will be recorded by the LLFA.

Only those with 5 or more properties/businesses involved will have investigations published. An investigation will be carried out, and a report prepared and published by the LLFA when the flooding impacts meet the following criteria:

- where there is ambiguity surrounding the source or responsibility of flood incident,
- internal flooding of one property that has been experienced on more than one occasion,
- internal flooding of five properties has been experienced during one single flood incident and
- there is a risk to life as a result of flooding.

As a flood Risk Management Authority (RMA), the Environment Agency have partnered with Cumbria County Council (CCC) to produce the 53 flood investigation reports across Cumbria.

Scope of this Report

This Flood Investigation Report **is**:

- an investigation on the what, when, why, and how the flooding took place resulting from the 5th-6th December 2015 flooding event and
- a means of identifying potential recommendations for actions to minimise the risk or impact of future flooding.

This Flood Investigation Report **does not**:

- interpret observations and measurements resulting from this flooding event. Interpretation will be undertaken as part of the subsequent reports,
- provide a complete description of what happens next.

The Flood Investigation Reports outline recommendations and actions that various organisations and authorities can do to minimise flood risk in affected areas. Once agreed, the reports can be used by communities and agencies as the basis for developing future plans to help make areas more resilient to flooding in the future.

For further information on the S19 process, including a timetable of Flood Forum events and associated documentation, please visit the County Council website at:

<http://www.cumbria.gov.uk/floods2015/floodforums.asp>

To provide feedback on the report please email LFRM@cumbria.gov.uk.

Flooding History

Wigton is a market town in Cumbria, located approximately 15 miles south west of Carlisle. The town is located at Ordnance Survey National Grid Reference NY 255 481 and lies at the confluence of Wiza Beck, Speet Gill, Black Beck and the Flish Beck on the relatively low lying North Cumbrian Plain. This area is part of the River Wampool river catchment and drains to the Solway Firth. The upland catchment is flashy, responding rapidly to rainfall events, although the town itself is located on flatter land, where river channels merge and have been constrained by buildings and other development on the adjacent flood plains.

The River Derwent Catchment Flood Management Plan (CFMP)¹ identifies that within Wigton there are approximately 155 properties at risk of flooding in a 1% annual exceedance probability (AEP) event and 72 properties in a 10% AEP.

The AEP describes the likelihood of a specified flow rate (or volume of water with specified duration) being exceeded in a given year. There are several ways to express AEP as shown in Table 1. Throughout this report AEP is expressed as a percentage. As such an event having a 1 in 100 chance of occurring in any single year will be described as a 1% AEP event.

AEP (as percent)	AEP (as probability)
50%	0.5
20%	0.2
10%	0.1
4%	0.04
2%	0.02
1%	0.01
0.1%	0.001

Table 1-Probabilities of Exceedance

The main sources of the flooding are the Wiza Beck, Speet Gill and Black Beck. The Environment Agency currently manages flood risk by maintaining the river channels and there are no formal flood defences in Wigton. The Environment Agency operates a Flood Warning service in Wigton for one Flood Warning Area.

A site location map of Wigton, the main rivers and the surrounding area is shown in **Figure 1**.

The Allerdale Strategic Flood Risk Assessment (SFRA) indicates that Wigton has a long history of flooding, with newspaper reports that can be traced back through the past 300 years². The SFRA identifies that there have been 5 significant flood events within recent years, with the largest occurring in January 2005 where 22 residential properties were affected from the Wiza Beck and the Speet Gill. This event also impacted on critical infrastructure, a school, fire station and an electricity substation.

¹ River Derwent Catchment Flood Management Plan. December 2009: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289419/Derwent_Catchment_Flood_Management_Plan.pdf

² Allerdale Strategic Flood Risk Assessment 2010: http://www.allerdale.gov.uk/downloads/EB20c_SRFA_2011_Vol_2_of_2.pdf



Figure 1 Wigton location map

Event Background: December 2015

This section describes the location of the flood incident and identifies the areas that are known to have flooded as a result of the December 2015 Storm Desmond event.

Flooding Incident

Between the 3rd and 5th December 2015 multiple areas and properties across Wigton experienced flooding. For the purpose of this report Wigton has been divided into 5 flood cells for further investigation. The division of the flood cells is outlined below.

1. **Flood Cell A.1:** Covering land around the upper reach of the Wiza Beck, Wigton Bowling Green, Sports Pitch and the southern entrance to the Innovia Films Factory.
2. **Flood Cell A.2:** Covering land around the Innovia Films Factory, Station Road, Royal Mail Post Office and the Station Road Business Park.
3. **Flood Cell B:** Covering land around Lowmoor Road, Wigton Swimming Baths and the Nelson Thomlinson School.
4. **Flood Cell C:** Covering land around the ATS Garage and Burnfoot Bridge.
5. **Flood Cell D:** Covering the land around Spittal Farm and the Wiza Beck.

Please note references to left and right bank are taken looking downstream with the flow of water. The location of the flood cells are shown relative to the Environment Agency’s Flood Map for Planning in **Error! Reference source not found.**

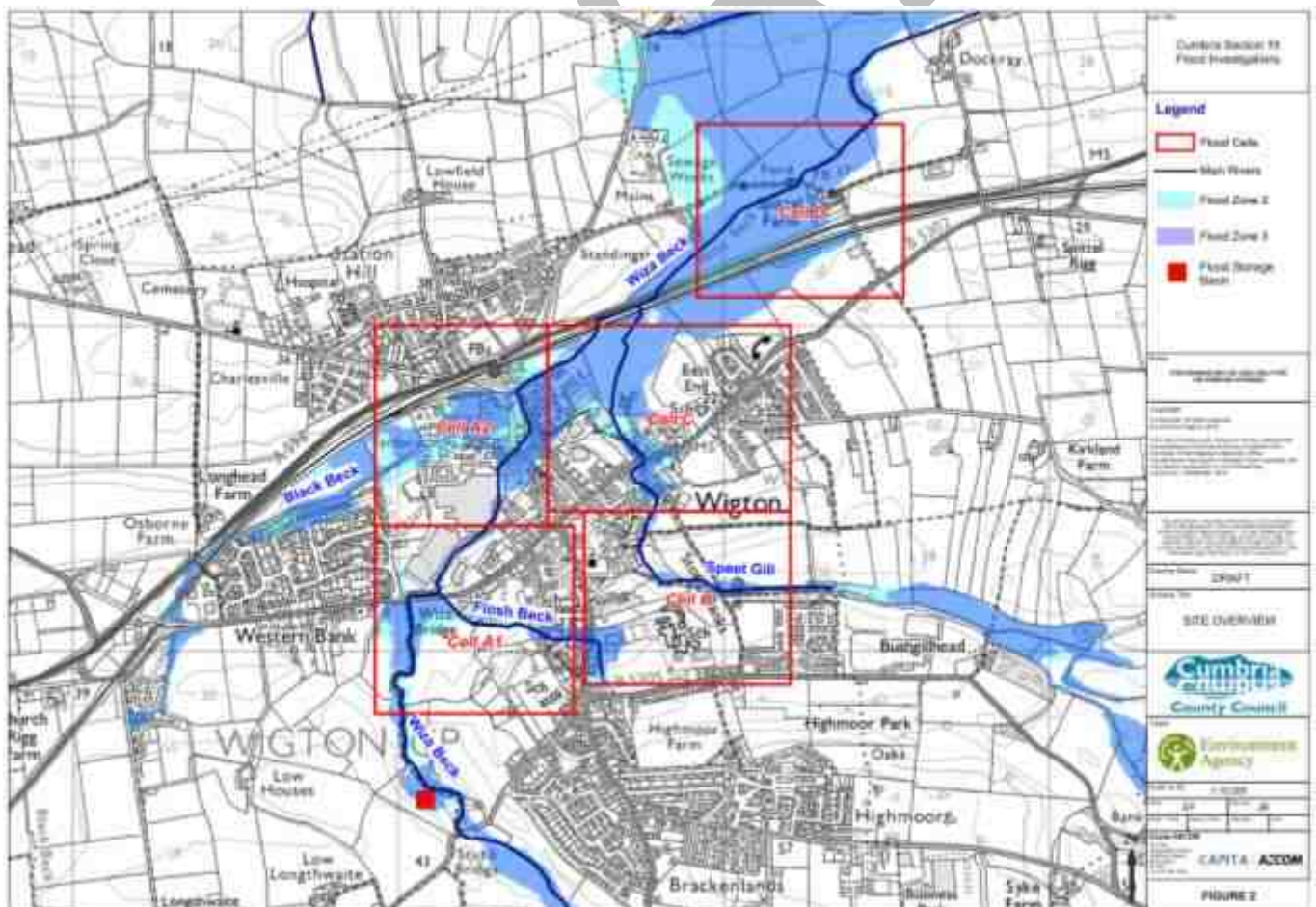


Figure 2 Wigton Flood Cells

Existing Flood Defences

There are no formal Environment Agency flood defences within Wigton. There are, however, a number of informal structures which may act as a defence during times of flood. A number of residents within Wigton also employ property resilience measures.

In 2013 a Flood Storage Basin was constructed upstream of Wigton on the Wiza Beck, north of Stubb Bridge off Longhwaite Road (as shown in **Figure 2**). This basin is designed to hold just less than 10,000 cubic metres of flood storage and is throttled by a short-length of culvert. Whilst the basin does not directly defend adjacent properties, it serves to provide additional time for residents on Station Road to install their property resilience measures. Once the capacity of the basin is exceeded, it overtops into Wiza Beck. Flood warning telemetry is also present at this location and is used to provide the Environment Agency's flood warning service in Wigton.

DRAFT

Flood Investigation

This section provides details of the rainfall event and any previous flood history in the area.

Rainfall Event

December 2015 was the wettest calendar month on record for the UK, with much of northern England receiving double the average December rainfall. This also followed a particularly wet November and as such, much of the ground within the Cumbria catchments was already saturated.

From the 4th to the 7th of December there was a period of prolonged, intense rainfall caused by Storm Desmond. Over this period, new 24 hour and 48 hour rainfall records were set for the UK. Both of these were within Cumbria and broke the previous records, also within Cumbria, set during the November 2009 floods.

Location	3 December 2015 00:00 – 23:59
	mm
Honister Pass – Highest recorded rainfall (5 December)	341.4
Thursby WWTW	31.8
Skelton	27.6
Abbeytown	40.6
Quarry Hill	35.6
Sunderland	39.8

Table 2: Cumbria 24 Hour Rainfall Totals/Records in December 2015

The Environment Agency operate two river level gauges on the Wiza Beck near Wigton. These are level only (and do not provide an estimate of river flows). These gauges are as follows:

- Station Road, Wigton (NGR NY 25392 48735)
- Wiza Beck Storage Basin, Wigton (NGR NY 25185 47524)

These level gauges are used to deliver flood warning services to the community at Wigton. Both river gauges recorded levels that were more than 2m above gauge datum on the 3rd and 5th of December 2015, as shown in **Figure 3** and **Figure 4**.

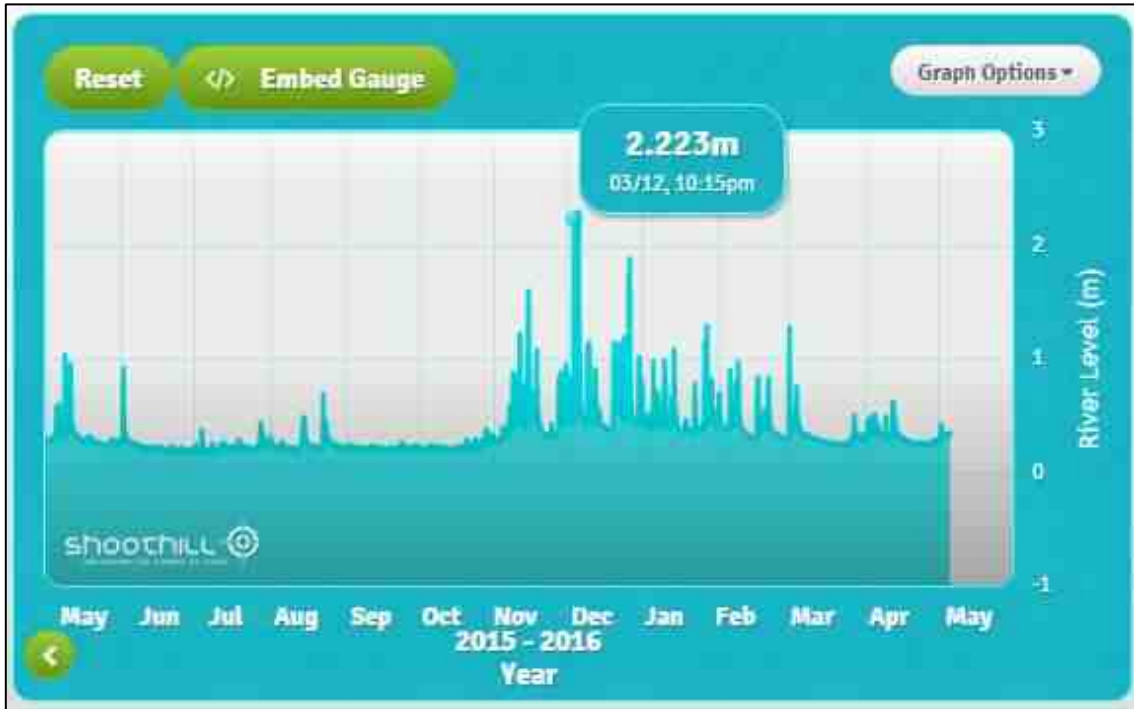


Figure 3: Recorded Levels at the Wiza Beck Storage Basin



Figure 4: Recorded Levels at the Station Road Level Gauge

Map of Flow Routes

The flow paths taken by floodwater can be seen in **Figure 5** below.

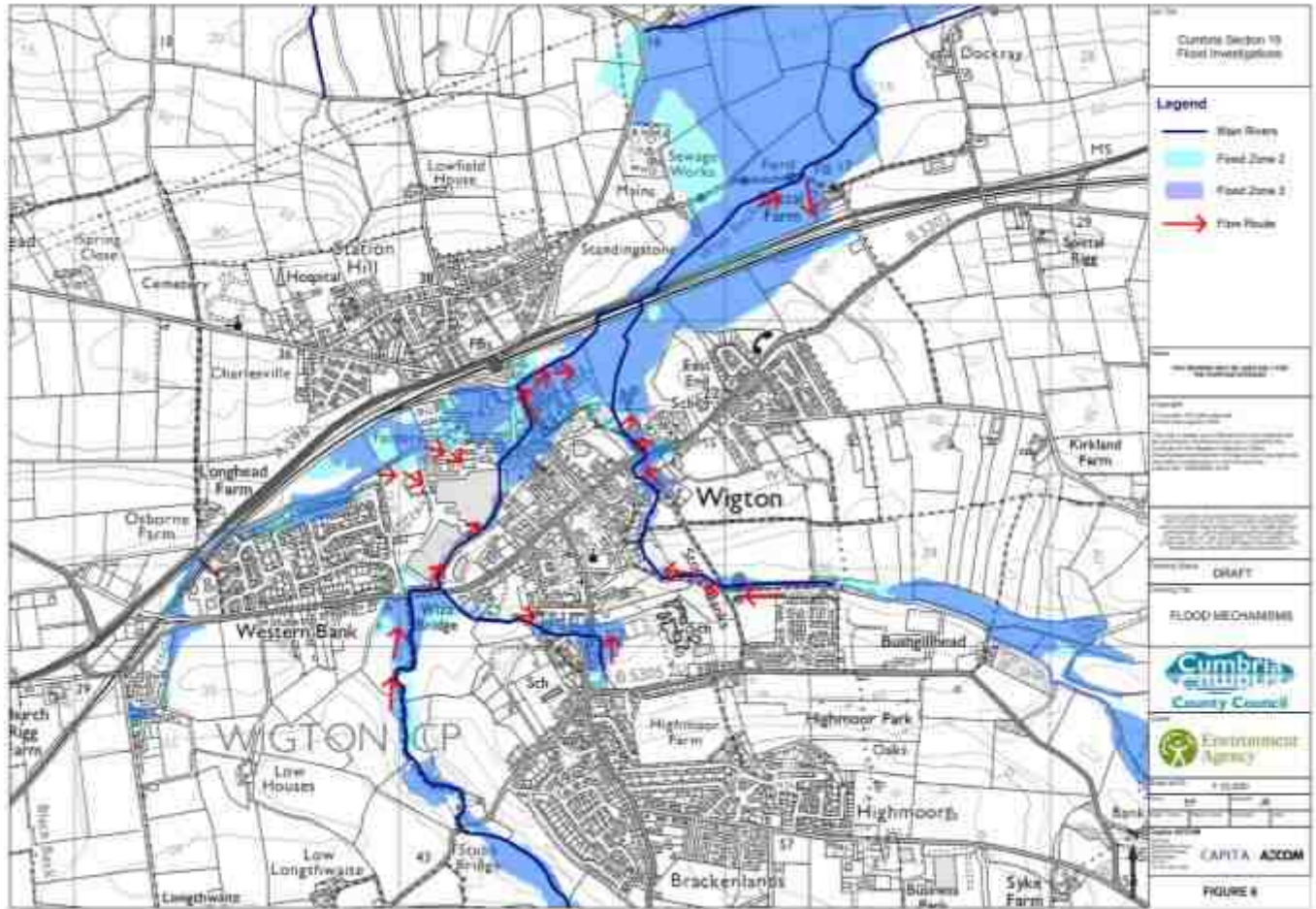


Figure 5 Flooding Mechanisms

Impacts and Likely Causes of Flooding

A site visit was undertaken on Tuesday 26/4/16 by the Capita AECOM survey team. The survey team undertook a walkover of the 5 flooding cells within Wigton.

Key features, observations and photographs from the site visit are presented in **Figure 6**.

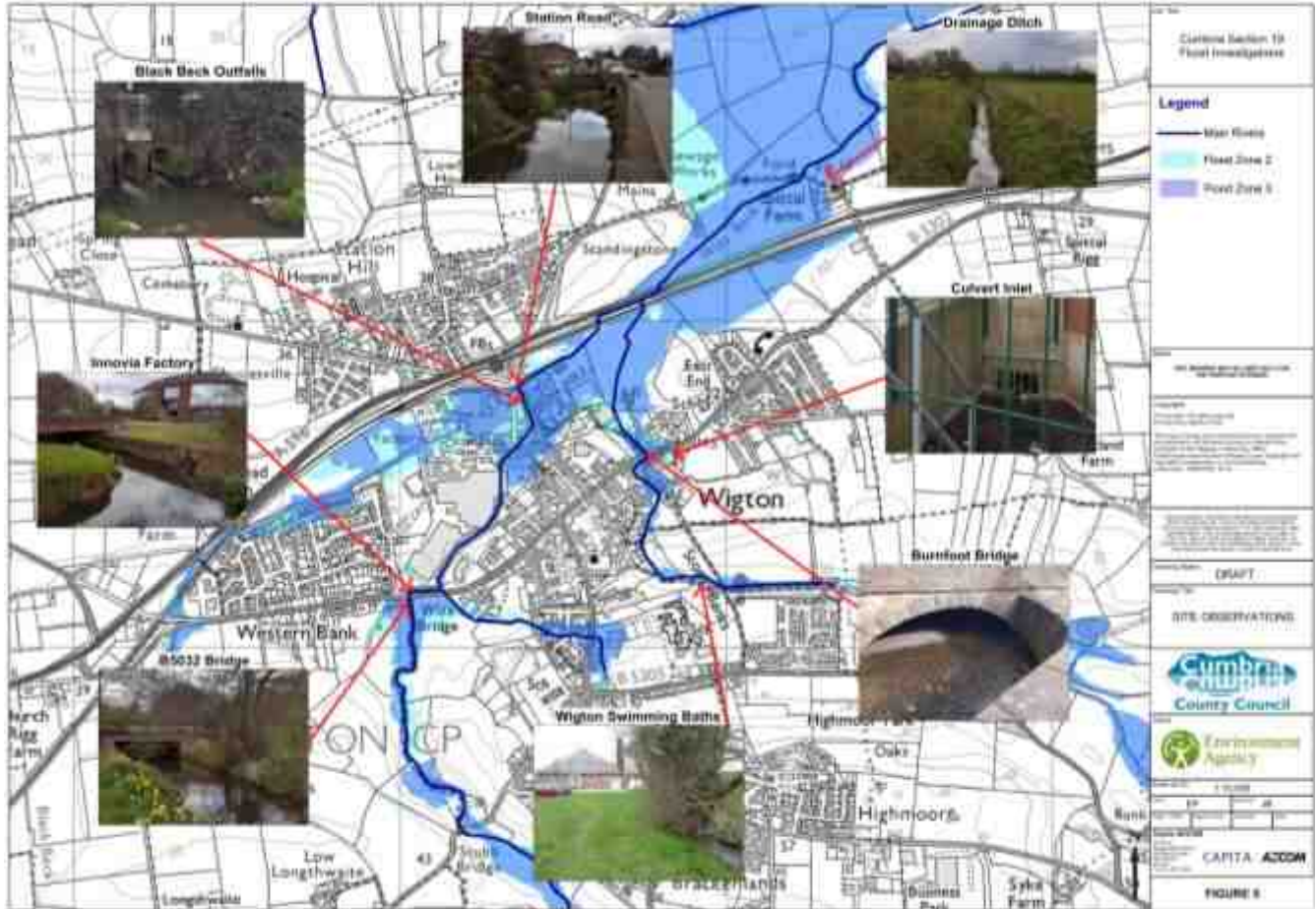


Figure 6 Key Observations

Flood Cell A1: Upper reach of the Wiza Beck, Wigton Bowling Green, Sports Pitches and the southern entrance to the Innovia Films Factory

A number of the fields near the Flosch Beck and Wiza Beck were flooded during the December 2015 flooding (**Photograph 1**). This did not impact on residential property, although the playing fields and changing room facilities were affected by the flooding. The flood flows also resulted in bank erosion, scour and damage to a kissing gate near the sports pitches (**Photograph 2**).



Photograph 1: Flooding from the Flosch Beck (15th December 2015)



Photograph 2: Bank damage near the Sports Pitches (15th December 2015)

Key Site Observations

The Wiza Beck is a main river that flows south to north along the sports pitches south of the B5032. Significant gravel deposition was observed in the watercourse upstream of the B5032. Bank erosion on the Wiza Beck near the sports field had resulted in a kissing gate collapsing into the watercourse.

North of the B5032 the Wiza Beck flows north-east, following the alignment of the main road and is flanked on either side by raised banks before a 90 degree turn at the entrance to the Innovia Films Factory.

The Flosh Beck is a main river that flows east to west alongside the Wigton Bowling Club (**Photograph 4**). This watercourse forms a tributary of the Wiza Beck (**Photograph 3**) via a large box culvert beneath the B5032. The confluence is throttled at the downstream end by a circular conduit that discharges into the Wiza Beck at the 90 degree bend at the entrance to the Innovia Films Factory.

The Black Beck is an ordinary watercourse that flows from the south to the north-east through residential properties between the B5032 and the A596. This Innovia Films Factory is therefore situated between the Black Beck and the Wiza Beck. The Black Beck later discharges into the Wiza Beck and is discussed further within Flood Cell B2.

The survey team could not access the full length of the Black Beck or the Wiza Beck due to restricted access and private land ownership.



Photograph 3: Wiza Beck, Looking Upstream

Photograph 4: Flosh Beck, Looking Upstream

Summary of observations

It is concluded that the flooding in this cell was a result of:

- Flood flows in the Wiza Beck exceeding the capacity of the channel in the area upstream of the B5032, resulting in lateral flooding of the sports pitch. This also resulted in bank erosion and collapse of a kissing gate and footpath.
- Flood flows on the Flosh Beck being throttled by the capacity of the culvert which outfalls into the Wiza Beck downstream of the B5302. This issue may have also been compounded by elevated water levels within the Wiza Beck causing a backwater effect on the Flosh Beck. This resulted in the flooding of the fields adjacent to the Wigton Bowling Green.
- Flood flows on the Black Beck exceeding the capacity of the culverted reach beneath the Innovia Films Factory. This resulted in widespread internal flooding within the factory as flows continued in a north-easterly direction towards Station Road.

Flood Cell A2: Innovia Films Factory, Station Road, Royal Mail Post Office, and Station Road Business Park

The Station Road area is occupied by one of the main roads through Wigton, local businesses and homes including a residential static caravan park. Station Road was flooded from Wiza Beck on the 3rd December 2015 (**Photograph 5**).

A number of residents on Station Road use flood gates and other resilience measures to defend their properties from flooding. On the 3rd and 5th December 2015 floodwater is reported to have reached approximately half a metre up the streetside floodgates, although this did not result in residential property flooding as resilience measures had been put in place.

The Station Road Business Park was protected by sandbags and bags of salt (stock) provided by a local business which diverted the water (**Photograph 6**). The area was also helped by the Fire & Rescue Service pumping water away from property. The Post Office was flooded during the December 2015 event and also on two other previous occasions.



Photograph 5: Flooding on Station Road (3rd Dec 2015)



Photograph 6: Temporary Sandbags and bags of salt on Station Road (7th Dec 2015)

The Innovia Films Factory experienced severe internal flooding, with various locations within the factory being inundated from the Black Beck.

Key Site Observations

The main entrance to the Innovia Films Factory is located on Station Road. As detailed in Flood Cell A1, upstream of this point, the Wiza Beck flows south to north through the Innovia Films Factory and subsequently follows the alignment of Station Road towards the junction with the A596.

The Wiza Beck passes west to east beneath Station Road via a brick arch conduit (**Photograph 7**). The watercourse continues in an easterly direction before later passing beneath the A596. The Black Beck discharges into the Wiza Beck via a pair of large concrete conduits immediately upstream of the Station Road Bridge. An Environment Agency level gauge is located on the Wiza Beck and there is Environment Agency telemetry at this location.

Property-level resilience measures (i.e. flood gates and doors) were observed at multiple properties on Station Road and evidence of post-flood refurbishment works was observed. Sandbags were present at the entrance to the small business trading estate on Station Road.



Photograph 7: Wiza Beck and Station Road



Photograph 8: Flood Gates on Station Road

Summary of observations

It is concluded that the flooding in this cell was a result of:

- The Wiza Beck overtopping the right bank of the watercourse next to Station Road. This consequently led to widespread flooding on Station Road and impacted on residential property, the small business estate and the Royal Mail Post Office.
- The flooding on Station Road may have also been compounded by surface water runoff and flows from the Black Beck.
- The Innovia Films Factory grounds were impacted by flooding from the Wiza Beck and the Black Beck.

Flood Cell B: Lowmoor Road, Wigton Swimming Baths and the Nelson Thomlinson School

The Wigton Swimming Baths was flooded twice during December 2015. On the 3rd of December the floodwater reached chest height within the building. The water flooded the boiler room and caused damage to pool plant motors, starter motor and electrical circuitry.

The Nelson Thomlinson Secondary School was also affected during the event. The boiler room and the sports hall were flooded resulting in extensive damages (**Photograph 9**). Consequently the school was closed for the day and the sports hall was closed until further repairs and refurbishment could be undertaken. Flooding is likely to have resulted from surface water sources rather than floodwater from Speet Gill or the Floss Beck.



Photograph 9: Nelson Thomlinson School – Sports Hall Flood Damage

Key Site Observations

The Speet Gill flows east to west through the agricultural land north of the Nelson Thomlinson School at this location. The Speet Gill is constrained by relatively steep valley topography, although Wigton Swimming Baths is located at the bottom of the hillslope adjacent to the watercourse.

The Wigton Swimming Baths (**Photograph 10**) were observed to be closed and a number of sandbags were observed as partially covering the airbricks and access points to the basement.

The Nelson Thomlinson School is, for the most part, located at the crest of a hill between Lowmoor Road and the Speet Gill. The gradient of the site slopes away from the main facility towards its south-west corner where the Sports Hall is located (**Photograph 11**).



Photograph 10: Wigton Swimming Baths



Photograph 11: Nelson Thomlinson School

Summary of observations

It is concluded that the flooding in this cell was a result of:

- The Speet Gill flooding the basin of the valley that contains the Wigton Swimming Baths
- The Sports Hall at the Nelson Thomlinson School is located next to the Floss Beck that is culverted beneath the B5304. Flooding is likely to have resulted from surface water sources rather than

floodwater from Speet Gill or the Flosch Beck. Flood flows on the Flosch Beck watercourse exceeded the capacity of the channel.

- The Sports Hall is also located at the bottom of a hill in a topographic hollow. Given the wet antecedent conditions rainfall would have been unable to effectively infiltrate into the ground and would have resulted in the generation of surface water. This would have consequently been routed across the playing fields, along the topographic gradient, and would have compounded the ponding around the Sports Hall.

Flood Cell C: ATS Garage and Burnfoot Bridge

On the east side of Wigton, the ATS Garage and 9 residential properties were affected by flooding from the Speet Gill and an unnamed ordinary watercourse due to a blocked trash screen on a non-main river and severe volumes of flow (**Photograph 12**). This resulted in flooding of the public highway (**Photograph 13**) and ingress to residential properties via air-bricks and other similar openings to property basements. Although water reached Lidl, no ingress occurred.



Photograph 12: Trash Screen on the Tributary Next to Lidl



Photograph 13: Wreck Marks on Burnfoot (7th Dec 2015)

Key Site Observations

An unnamed watercourse flows east to west alongside the Lidl car park. This watercourse is a tributary of the Speet Gill, a main river that flows south to north along Tenters, beneath Burnfoot (B5032) and continues north alongside the ATS Garage.

The unnamed ordinary watercourse is culverted beneath Burnfoot and discharges into the Speet Gill via a circular culvert that is covered by a basic trash screen (of a non-standard Environment Agency design as shown in **Photograph 14**). This design results in difficulty removing debris build up and consequently may lead to a backwater effect from the culvert inlet.

The Speet Gill is bounded on the right bank by a small dwarf wall that may act as a defence but is not considered a formal Environment Agency asset. The Speet Gill passes beneath Burnfoot via a brick arch conduit with a low invert level. This capacity issue may constrain flow conveyance during times of flood and result in a local backwater effect from the structure.

Evidence of historic flooding was observed around the residential properties on the right bank of the Speet Gill (i.e. silt wrack marks and mortar loss). It was observed that residents had previously attempted to prevent water from entering into basements by covering airbricks and other access points into the property.

North of Burnfoot, the Speet Gill passes between the ATS Garage and a series of community-owned allotments on the left bank of the watercourse. The main river later passes by a WCF Pet and Equestrian warehouse that is effectively protected by a local informal embankment comprised of made ground.



Photograph 14: Lidl Trash Screen



Photograph 15: Burnfoot Bridge

Summary of observations

It is concluded that the flooding in this area a result of:

- High water levels in the Speet Gill overtopping the de facto defences on the right bank of the watercourse due to capacity issues beneath the Burnfoot road bridge (**Photograph 15**). This would have subsequently resulted in residential property flooding and inundation of basements via unprotected airbrick covers and other openings.
- The trash screen on the unnamed watercourse at the Lidl car park becoming blocked with debris and resulting in a localised backwater effect and potential overtopping of the culvert into the Lidl car park.

- Floodwater would have been routed over Burnfoot as a result of the throttled capacity on both watercourses. This issue would have been compounded by surface water runoff following the gradient of the topography west of Lidl and adjacent to the residential properties.
- The public highway sits in a topographic hollow at this location and is likely to have resulted in localised ponding that consequently impacted on flooding at the ATS Garage.

Flood Cell D: Spittal Farm

Spittal Farm is a development of approximately 10 houses next to the A596. There is a drainage channel below the Spittal Farm development that discharges into the Wiza Beck. During the December flood event high water levels within this drainage channel caused flooding to two residential properties at Spittal Farm.

Key Site Observations

Spittal Farm is located immediately north of the A596. Spittal Farm has been developed into private accommodation, providing approximately 10 homes. The Farm is bounded on its western side by a drainage ditch from the A596 that subsequently discharges into the Wiza Beck (**Photograph 16 and 17**).

The drainage ditch adjacent to Spittal Farm discharges into the Wiza Beck via a short culverted section. An Environment Agency level gauge with data logger is located immediately upstream of the confluence of the Wiza Beck with the drainage ditch.



Photograph 16: Wiza Beck near Spittal Farm



Photograph 17: Spittal Farm Drainage Channel

Summary of observations

It is concluded that the flooding in this cell was a result of:

- Elevated water levels in the Wiza Beck preventing the drainage ditch from freely discharging into the receiving watercourse. This resulted in a localised backwater effect and consequently flooded properties at Spittal Farm.

Recommendations

Table 3 details recommended actions for various organisations and members of the public to consider.

Table 1: Recommended Actions for Wigton

Cumbria Flood Partnership Theme	Action By	Recommended Action	Timescale
Community Resilience	Cumbria Local Resilience Forum*, Environment Agency	Review and update plans to enable homes & business to be better prepared for flooding & reduce the impacts of flooding.	2016
	Environment Agency, Cumbria County Council Highways, and Electricity North West.	To review the flood risk and resilience of critical transport, communication, and power supply infrastructure.	Autumn 2016
	Cumbria Planning Group, Allerdale District Council	Review Local Development Plans and Strategic Flood Risk Assessment to reflect current understanding of flooding.	2016
	Environment Agency	Ensure all properties at risk can register to receive flood warnings and details are up-to-date.	Summer 2016
	Cumbria Local Resilience Forum*, Environment Agency	Communication: Continue to encourage residents to report issues of flooding. Outline who this should be reported to and what mechanisms are available to report flooding (phone, email, mobile app etc.).	2016
	Cumbria Local Resilience Forum	Records: Ensure systems are set up to efficiently record details of flooding.	2016

Upstream Management	Cumbria Floods Partnership (CFP)	The CFP action plan will consider natural flood management options to reduce flood risk across the catchment. This may also include land use changes and or flood storage.	Summer 2016
Maintenance	Environment Agency	Complete on-going inspections and repairs to assets, which may have been damaged during the flood event.	2016
	Environment Agency	Review maintenance programme in response to the flooding events of 2015.	2016
Strengthening Defences	Environment Agency	Scoping/design of a flood defence scheme in Wigton. Funding has been secured.	TBC
	Environment Agency	The Environment Agency is carrying out a series of repairs to flood defence assets that were damaged during the floods as part of the c.£10m Asset Recovery Programme which covers Cumbria & Lancashire. This programme of repairs is scheduled to be complete before winter 2016/17.	Winter 2016/17

* The Cumbria Local Resilience Forum includes emergency services, Local Authorities, Cumbria County Council, Environment Agency, Maritime Coastguard Agency and health agencies along with voluntary and private agencies. Under the Civil Contingencies Act (2004) every part of the United Kingdom is required to establish a resilience forum.

Next Steps for Flood Risk Management in Cumbria

The Cumbria Floods Partnership has brought together a wide range of community representatives and stakeholders from a variety of sectors to plan and take action to reduce flood risk. The Cumbria Floods Partnership, led by the Environment Agency, is producing a 25 year flood action plan for the Cumbrian catchments worst affected by the December 2015 flooding.

The plan will consider options to reduce flood risk across the whole length of a river catchment including upstream land management, strengthening flood defences, reviewing maintenance of banks and channels, considering water level management boards, and increasing property resilience. The Cumbria Floods Partnership structure below details how these 5 themes are being delivered in the Flood Action Plans which will be completed in July 2016.

The 'Cumbria Floods Partnership' was set up by Flood Minister Rory Stewart MP following December's floods, and includes all of Cumbria's Flood Risk Management Authorities. They are working alongside the existing 'Cumbria Strategic Partnership', which was formed as part of the Flood and Water Management Act 2010 and comprises of the County's Flood Risk Management Authorities (RMAs) including the Environment Agency, Cumbria County Council, Local Authorities, and United Utilities. Both partnerships are working with communities, businesses, and relevant stakeholders to understand and reduce flood risk across Cumbria.

Figure 7 below helps demonstrate how the two partnerships are working together:

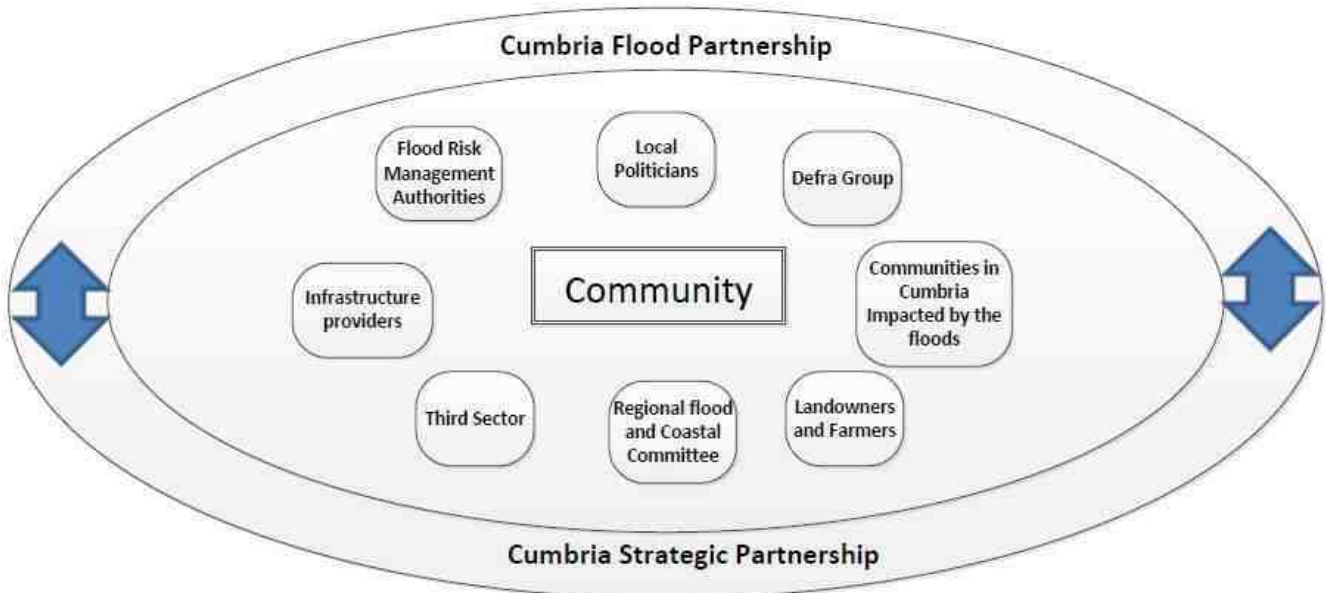


Figure 7 Cumbria Flood Partnership and Cumbria Strategic Partnership

Appendices

Appendix 1: Acronyms and Glossary

Acronym Definition

EA	Environment Agency
CCC	Cumbria County Council
UU	United Utilities
ABC	Allerdale Borough Council
LLFA	Lead Local Flood Authority
FAG	Flood Action Group
LFRMT	Local Flood Risk Management Team
FWMA	Flood and Water Management Act 2010
LDA	Land Drainage Act 1991
WRA	Water Resources Act 1991

Term Definition

Aquifer	A source of groundwater comprising water-bearing rock, sand or gravel capable of yielding significant quantities of water.
Attenuation	In the context of this report - the storing of water to reduce peak discharge of water.
Catchment Flood Management Plan	A high-level planning strategy through which the EA works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
Culvert	A channel or pipe that carries water below the level of the ground.
De Facto Flood Defence	A feature or structure that may provide an informal flood defence benefit but is not otherwise designed or maintained by the Environment Agency
Flood Defence	Infrastructure used to protect an area against floods as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Floodplain	Area adjacent to river, coast or estuary that is naturally susceptible to flooding.
Flood Resilience	Measures that minimise water ingress and promotes fast drying and easy cleaning, to prevent any permanent damage.
Flood Risk	The level of flood risk is the product of the frequency or likelihood of the flood events and their consequences (such as loss, damage, harm, distress and disruption)
Flood Risk Regulations	Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically

Term	Definition
	address flood risk by prescribing a common framework for its measurement and management.
Flood and Water Management Act	Part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England.
Flood Storage	A temporary area that stores excess runoff or river flow often ponds or reservoirs.
Flood Zone	Flood Zones are defined in the NPPF Technical Guidance based on the probability of river and sea flooding, ignoring the presence of existing defences.
Flood Zone 1	Low probability of fluvial flooding. Probability of fluvial flooding is < 0.1%
Flood Zone 2	Medium probability of fluvial flooding. Probability of fluvial flooding is 0.1 – 1%. Probability of tidal flooding is 0.1 – 0.5 %
Flood Zone 3a	High probability of fluvial flooding. Probability of fluvial flooding is 1% (1 in 100 years) or greater. Probability of tidal flooding is 0.5%(1 in 200 years)
Flood Zone 3b	Functional floodplain. High probability of fluvial flooding. Probability of fluvial flooding is >5%
Fluvial	Relating to the actions, processes and behaviour of a water course (river or stream)
Fluvial flooding	Flooding by a river or a watercourse.
Freeboard	Height of flood defence crest level (or building level) above designed water level
Functional Floodplain	Land where water has to flow or be stored in times of flood.
Groundwater	Water that is in the ground, this is usually referring to water in the saturated zone below the water table.
Inundation	Flooding.
Lead Local Flood Authority	As defined by the FWMA, in relation to an area in England, this means the unitary authority or where there is no unitary authority, the county council for the area, in this case Lancashire County Council.
Main River	Watercourse defined on a 'Main River Map' designated by DEFRA. The EA has permissive powers to carry out flood defence works, maintenance and operational activities for Main Rivers only.
Mitigation measure	An element of development design which may be used to manage flood risk or avoid an increase in flood risk elsewhere.
Overland Flow	Flooding caused when intense rainfall exceeds the capacity of the drainage systems or when, during prolonged periods of wet weather, the soil is so saturated such that it cannot accept any more water.
Residual Flood Risk	The remaining flood risk after risk reduction measures have been taken into account.
Return Period	The average time period between rainfall or flood events with the same intensity and effect.

Term	Definition
River Catchment	The areas drained by a river.
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
Sustainability	To preserve /maintain a state or process for future generations
Sustainable drainage system	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques.
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations meeting their own needs.
Sustainable Flood Risk Management	Sustainable Flood Risk Management promotes a catchment wide approach to flooding that uses natural processes and systems (such as floodplains and wetlands) to slow down and store water.
Topographic survey	A survey of ground levels.
Tributary	A body of water, flowing into a larger body of water, such as a smaller stream joining a larger stream.
Watercourse	All rivers, streams, drainage ditches (i.e. ditches with outfalls and capacity to convey flow), drains, cuts, culverts and dykes that carry water.
Wreck Marks	An accumulation of debris usually marking the high water line.
1 in 100 year event	Event that on average will occur once every 100 years. Also expressed as an event, which has a 1% probability of occurring in any one year.
1 in 100 year design standard	Flood defence that is designed for an event, which has an annual probability of 1%. In events more severe than this the defence would be expected to fail or to allow flooding.

Appendix 2: Summary of Relevant Legislation and Flood Risk Management Authorities

The table below summarises the relevant Risk Management Authority and details the various local source of flooding that they will take a lead on.

Flood Source	Environment Agency	Lead Local Flood Authority	District Council	Water Company	Highway Authority
RIVERS					
Main river					
Ordinary watercourse					
SURFACE RUNOFF					
Surface water					
Surface water on the highway					
OTHER					
Sewer flooding					
The sea					
Groundwater					
Reservoirs					

The following information provides a summary of each Risk Management Authority's roles and responsibilities in relation to flood reporting and investigation.

Government – DEFRA develop national policies to form the basis of the Environment Agency's and the LLFA's work relating to flood risk.

Environment Agency has a strategic overview of all sources of flooding and coastal erosion as defined in the Act. As part of its role concerning flood investigations this requires providing evidence and advice to support other Risk Management Authorities (RMA's). The EA also collates and reviews assessments, maps, and plans for local flood risk management (normally undertaken by LLFA).

Lead Local Flood Authorities (LLFAs) – Cumbria County Council are the LLFA for Cumbria. Part of their role requires them to investigate significant local flooding incidents and publish the results of such investigations. LLFAs have a duty to determine which RMA has relevant powers to investigate flood incidents to help understand how they happened, and whether those authorities have, or intend to, exercise their powers. LLFAs work in partnership with communities and flood RMA's to maximise knowledge of flood risk to all involved. This function is carried out at CCC by the Local Flood Risk Management Team.

District and Borough Councils – These organisations perform a significant amount of work relating to flood risk management including providing advice to communities and gathering information on flooding. These organisations are classed as RMA's.

Water and Sewerage Companies manage the risk of flooding to water supply and sewerage facilities and the risk to others from the failure of their infrastructure. They make sure their systems have the appropriate

level of resilience to flooding and where frequent and severe flooding occurs they are required to address this through their capital investment plans. It should also be noted that following the Transfer of Private Sewers Regulations 2011 water and sewerage companies are responsible for a larger number of sewers than prior to the regulation. These organisations are classed as RMA's

Highway Authorities have the lead responsibility for providing and managing highway drainage and certain roadside ditches that they have created under the Highways Act 1980. The owners of land adjoining a highway also have a common-law duty to maintain ditches to prevent them causing a nuisance to road users. These organisations are classed as RMA's

Flood risk in Cumbria is managed through the Making Space for Water process, which involves the cooperation and regular meeting of the Environment Agency, United Utilities, District/Borough Councils and CCC's Highway and LFRM Teams to develop processes and schemes to minimise flood risk. The MSfWGs meet approximately 4 times per year to cooperate and work together to improve the flood risk in the vulnerable areas identified in this report by completing the recommended actions. CCC as LLFA has a responsibility to oversee the delivery of these actions.

Where minor works or quick win schemes can be identified, these will be prioritised and subject to available funding and resources will be carried out as soon as possible. Any major works requiring capital investment will be considered through the Environment Agency's Medium Term Plan process or a partners own capital investment process.

Flood Action Groups are usually formed by local residents who wish to work together to resolve flooding in their area. The FAGs are often supported by either CCC or the EA and provide a useful mechanism for residents to forward information to the MSfWG.

Appendix 3: Useful contacts and links

Sign up for Flood Warnings

<https://www.gov.uk/sign-up-for-flood-warnings>

Environment Agency – Prepare your property for flooding; a guide for householders and small businesses to prepare for floods

<https://www.gov.uk/government/publications/prepare-your-property-for-flooding>

Environment Agency – What to do before, during and after a flood: Practical advice on what to do to protect you and your property

<https://www.gov.uk/government/publications/flooding-what-to-do-before-during-and-after-a-flood>

Environment Agency – Living on the Edge: A guide to the rights and responsibilities of riverside occupiers

<https://www.gov.uk/government/publications/riverside-ownership-rights-and-responsibilities>

Flood and Water Management Act 2010:

<http://www.legislation.gov.uk/ukpga/2010/29/contents>

Water Resources Act 1991:

<http://www.legislation.gov.uk/all?title=water%20resources%20act>

Land Drainage Act:

<http://www.legislation.gov.uk/all?title=land%20drainage%20act>

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Appendix 4: Flood Warnings and Alerts

DRAFT

Land at former St Ursula's School, Wigton.

Appendix 2

Wigton Hydraulic Modelling Study – JBA Consulting 2013

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Wigton - Hydraulic Modelling Study

Final Report

July 2013

Environment Agency - North East Region



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Revision History

Revision Ref / Date Issued	Amendments	Issued to
Final Report (July 2013)	Final amendments	Rachel Gerrard (1 digital copy)
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Draft Final Report		Rachel Gerrard (1 digital copy)

Contract

This report describes work commissioned by the Environment Agency under Purchase Order number 30356366 dated 18 September 2012. The Agency's representative for the contract was Rachel Gerrard. Mark Tywang and Matthew Scott of JBA Consulting carried out this work.

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Purpose

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Acknowledgements

We would like to thank Rachel Gerrard of the Environment Agency for her help with the study.

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Executive Summary

In October 2012, JBA Consulting was commissioned to undertake a comprehensive model update of the Speet Gill / Wiza Beck system. The principle aims of the study were to:

1. extend the Speet Gill and Wiza Beck model reaches and update other re-surveyed areas,
2. assess the impact of the recently constructed Wiza Beck throttle structure, and
3. assess the effectiveness of the introducing an additional flood retention basin in the upper reaches of Speet Gill.

The brief also required that a review of the model was undertaken and where possible, model updates undertaken to reflect new information and current best practice. This has required the integration of new topographic survey data and update of hydrological inputs to the model.

Model Updates

Hydrological Analysis

It is usual practice to employ the FEH Statistical Method to estimate design flood peaks, unless there is good reason to utilise an alternative approach (such as the Revitalised Flood Hydrograph (ReFH) for example). This involves using a regression equation to predict the median annual flood (QMED) from catchment descriptors, determination of an appropriate QMED adjustment factor using one or more local donors (where available) and derivation of flood growth curves using a pooling approach.

As the King Street record provides only seven years' data, a Peaks over Threshold (PoT) analysis has been undertaken to determine QMED according to the methodology outlined in Volume 3 of the FEH. A total of 18 PoT events were identified based on a flow threshold of $0.83\text{m}^3/\text{s}$, and these gave rise to a QMED estimate of $2.53\text{m}^3/\text{s}$. This estimate tallies extremely well with the value of QMED produced from catchment descriptors using the new regression model published by Kjeldsen in 2008, which is $2.60\text{m}^3/\text{s}$. On the basis of this agreement it was deemed acceptable to apply the FEH QMED equation without any donor adjustment.

Hydraulic Modelling

Model Updates - (i) Extension of model reaches

In order to be able to assess the Wiza Beck retention basin and that proposed for Speet Gill, it was necessary to extend the model to include the upstream reaches of both Wiza Beck and Speet Gill. Therefore the model has been extended up to the A595 to include an additional 2km of Speet Gill, as well as a right bank drain (referred to as Speet Gill Reach 3). The Wiza Beck reach has been extended by approximately 600m up to and including Longthwaite Road. The reach now includes the Wiza Beck retention basin.

Model Updates - (ii) Modelling of Wiza Beck retention basin

The retention basin on Wiza Beck acts as a hydraulic throttle as opposed to a formal flood storage area. The structure is designed to restrict conveyance by preventing/restricting the movement of water into the downstream reaches. The structure comprises three main elements;

- 1) Hydraulic Throttle.
- 2) Retaining Embankment
- 3) Increase in floodplain

Model Updates - (iii) Innovia culverts - removal of silt

One of the key hydraulic constrictions in the Wiza Beck system is the group of culverts adjacent to the Innovia complex on Union Street (model node WIZA01c_2010). These allow Wiza Beck to be routed below the main buildings and comprise three 3.57m wide rectangular barrels, 66m in length.

The structures have been identified as a major factor during previous flood events, which is due in part to the reduction in capacity as a result of significant siltation. This siltation has previously led to one of the barrels becoming completely blocked and therefore in the previous modelling a depth of blockage was applied to each of the barrels. As all barrels have recently been de-silted

in order to restore the capacity of the structure, all the 2012 model simulations have been run assuming no blockage of this structure.

Model Updates - (vi) Update of cross sections u/s of Wiza Bridge

Since the last study modifications have been carried out to the section of channel upstream of Wiza Bridge (model node WIZA01_2012_2631 to 2468) in order to improve conveyance. These measures have included widening the channel by up to 2m in places. To reflect these changes, all cross sections between 2631 and 2468 have been replaced with the surveyed cross sections taken as part of the 2012 survey.

Model Updates - (v) ATS garage walls and channel

Further capital works had been carried out on the flood walls adjacent to the ATS garage. The main changes included the replacement / improvement of the wall directly adjacent to the ATS site. The mid section highlighted during the site visit has been replaced since the original modelling study. The 2012 survey captured the new wall heights and these data have been incorporated into the updated model.

Impact on Flood Risk - Comparison with previous mapping

The Wigton area was originally mapped for flood risk as part of the River Wampool Flood Risk Mapping Study in 2006. Overall the 2012 flood extents are consistent with the outlines derived in 2006. The key areas of change are on Flosch, Beck, Wiza Beck upstream of the Innovia site and Speet Gill upstream of Burnfoot Bridge.

The results have shown that the Wiza Beck retention basin shows no benefit in terms of removing properties from flood risk.

Effectiveness of Wiza Beck flood retention scheme

The model analysis has indicated that, under its current configuration, the scheme will only provide a limited benefit in terms of flood risk alleviation. While the structure will be able to store or 'hold' approximately 8,500m³ of water in the upstream reaches this not be sufficient to significantly reduce flood risk.

When considered as a means to reduce the speed at which a flood wave would reach the vulnerable areas of Wigton following a large rainfall event the analysis has indicated that the basin will add between 20-35 additional minutes (depending on the size of the event) to the time taken for the flood wave to reach the populated areas of the catchment.

From a flood warning perspective this is unlikely to prove significant particularly if the event occurs during the day when many residents will be at work and will be unable to implement and property level flood defence procedures. To put this in context, the time of travel for the 5-year event peak between the upstream limit of Wiza Beck (WIZA01_3379) to the Innovia site (WIZA01c_2011) prior to the scheme being built was approximately 10 minutes. With the scheme in place the time of travel is increased to 20 minutes. The modelling has also shown that this impact is less for the larger flood events. Table 1 summarises the analysis

Table 1: Analysis of impact of Wiza Beck Flood Retention Basin - Impact on Progression of flood wave

Model Node	Location	Flood Event Return Periods (years) - Timing of Flood Peak (hours)					
		2-year (time of peak flow)		5-year (time of peak flow)		10-year (time of peak flow)	
		Pre-Scheme	Post-Scheme	Pre-Scheme	Post-Scheme	Pre-Scheme	Post-Scheme
2482	Wiza Bridge (u/s face)	09:10 hrs	08:55 hrs (-15 mins)	8:55 hrs	09:00 hrs (-5mins)	8:55 hrs	09:00 hrs (-5mins)
2011	Innovia Main Culvert (u/s face)	09:10 hrs	08:55 hrs (-15 mins)	8:55 hrs	09:01 hrs (-6mins)	09:00 hrs	09:00 hrs (-0mins)
1826	Station Road - u/s of Black Beck confluence	09:10 hrs	08:55 hrs (-15 mins)	9:00 hrs	09:05 hrs (-5mins)	09:00 hrs	09:00 hrs (-0mins)
1631	Station Road Bridge	08:45 hrs	08:50 hrs (-5mins)	8:40 hrs	08:45 hrs (-5mins)	08:45 hrs	08:50 hrs (-5mins)

Time (hours) is from the start of the design simulation

Developing a flood warning system on this basis would be problematic as the speed with which the flood develops will make the issuing of flood warnings with sufficient time for residents and agencies to respond difficult.

Effectiveness of Speet Gill Options

Throttle Structure

The feasibility of introducing a throttle and embankment structure similar to that on Wiza Beck has also been investigated.

The practical considerations of the scheme and specifically the desire to store or 'hold' a maximum volume 10,000m³ in order to ensure that the structure is not within the remit of the Reservoirs Act of 1991 have meant that the maximum embankment height would be in region of 1.1-1.2m above existing ground levels. A retention structure based on these criteria has been shown to have a limited effect in terms of reducing flood levels and overall flood risk in the lower reaches of the catchment.

The main benefit of the scheme would be in terms of impeding the speed at which the flood wave reaches the vulnerable areas of the catchment, notably at Tenters Lane. An assessment of the model results for the existing site conditions has indicated that the time of travel of the flood wave between the proposed site of the Speet Gill throttle (SPEE02_2651) and Tenters Bridge (SPEE01_0650) is 1.5 hours for a 10-year event. The construction of the retention basin in the upper reaches of Speet Gill has been shown to add an additional 15 minutes to the time of travel.

The characteristics of the catchment mean that a flood warning system based on a level recorder located in the upper reaches of Speet Gill may prove effective as a tool for issuing warnings for the Tenters Lane area. Furthermore the introduction of a retention basin would further improve the effectiveness of any flood warning system.

De-siltation of Burnfoot Bridge

The analysis of the removal of silt at Burnfoot Bridge has indicated that while this would offer an improvement in channel conveyance, the benefits in terms of flood risk would be fairly minimal given the impact of other hydraulic factors such as the narrow channel and the misalignment of the structure and channel.

In summary, while the removal of the silt would reduce the blockage risk at the structure, there would be no significant impact on overall flood risk.

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Abbreviations

AEP	Annual Exceedance Probability
CFMP.....	Catchment Flood Management Plan
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EA	Environment Agency
FEH.....	Flood Estimation Handbook
ISIS	Hydrology & Hydraulic Modelling Software
JBA	JBA Consulting - Engineers & Scientists
mAOD	metres Above Ordnance Datum
OS.....	Ordnance Survey
QMED	Median Annual Flood (with return period 2 years)
ReFH.....	Revitalised Flood Hydrograph
FEH R-R	Flood Estimation Handbook Rainfall-Runoff method
REFHBDY.....	Hydraulic boundary unit I ISIS using an inflow from the ReFH model
SoR.....	Statement of Requirements
SoP.....	Standard of Protection

1 Introduction

1.1 Client brief

In October 2012, JBA Consulting was commissioned to undertake a comprehensive model update of the Speet Gill / Wiza Beck system. The principle aims of the study were to:

- (1) extend the Speet Gill and Wiza Beck model reaches and update other re-surveyed areas,
- (2) assess the impact of the recently constructed Wiza Beck throttle structure, and
- (3) assess the effectiveness of the introducing an additional flood retention area in the upper reaches of Speet Gill.

The brief also required that a review of the model was undertaken and where possible, model updates undertaken to reflect new information and current best practice. This has necessitated the integration of new topographic survey data and update of hydrological inputs to the model.

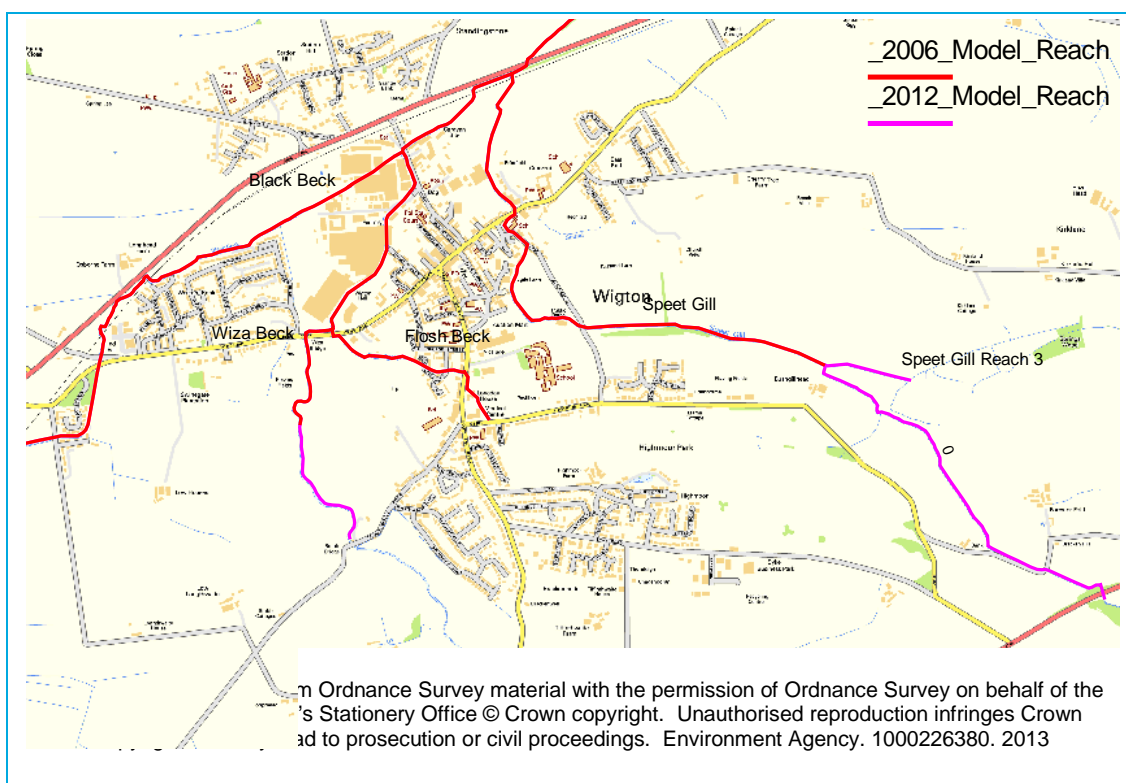
1.2 Study approach

In order to achieve the objectives of the study the following phases of work have been undertaken.

1.2.1 Phase 1 - Extension of model reaches

In order to gain a more detailed understanding of the active flooding mechanisms within the catchment it was necessary to extend the model reaches further to the South and South East of Wigton. Therefore additional topographic surveys were commissioned to include cross sections in the upper reaches of Speet Gill between Kirkland Lane and upstream of Stony Banks, and the upper reaches of Wiza Beck between Low Houses and Longthwaite Road (Figure 1-1). Crucially the Wiza Beck survey included the Wiza Beck throttle structure, while the Speet Gill survey included sections of the field drain between Spring Woods and Bushgillhead.

Figure 1-1: Newly surveyed reaches



1.2.2 Phase 2 - Updates to existing reaches

The 2006 River Derwent Catchment Flood Management Plan (CFMP) study identified the existing Speet Gill and Wiza Beck flood risk areas. Since then, a number of flood mitigation strategies have been implemented to help improve conveyance and reduce flood risk. The most significant changes have been the introduction of the Wiza Beck throttle structure and realignment of a section of channel upstream of Wiza Bridge. The hydraulic model has been updated to account for these recent changes to the channel and floodplain geometry.

The design event hydrographs applied at the model boundaries and other inflow points have also been updated to ensure that they take account of guidance presented in the Environment Agency's (EA) Operational Instruction on Flood Estimation as well as making use of the hydrometric data that have become available thanks to installation of temporary level gauge on Speet Gill.

Wiza Beck throttle structure and retention basin:

The throttle structure and associated retention basin (Figure 1-2) were constructed near Stubb Bridge in 2012, with the aim of relieving flood risk at a number of vulnerable areas downstream including Wiza Bridge, Innovia and Station Road. The culvert and adjacent raised embankment have been designed to reduce the amount of water able to be conveyed downstream both in the channel and floodplain.

Updates to Speet Gill:

A section of raised walls on the right bank of Speet Gill adjacent to the ATS Garage have also been replaced and improved.

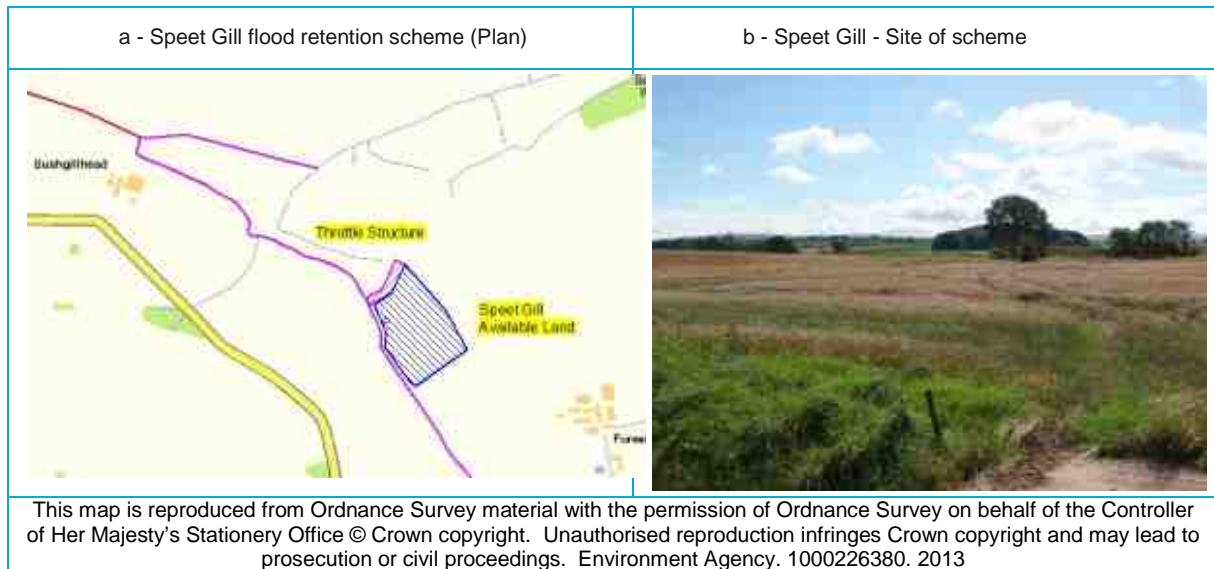
Figure 1-2: Wiza Beck throttle structure



1.2.3 Phase 3 - Evaluation of the proposed Speet Gill flood retention scheme

The EA is considering implementing a throttle structure in the upstream reaches of Speet Gill in order to reduce the downstream flood risk at Burnfoot Bridge (on the south-western side of Wigton). This is likely to be of similar design to that employed at Wiza Beck. The EA are currently negotiating with landowners in order to secure the use of an area of low lying farmland located on the right bank of Speet Gill, upstream of Bushgillhead, as shown in Figure 1-3.

Figure 1-3: Proposed Speet Gill flood retention scheme



1.3 Report structure

Chapter 2 - Data collection - This section describes the data requirements of the investigation.

Chapter 3 - Modelling updates - This section describes the updates to the hydrological and hydraulic modelling that have been implemented. As well as detailing the decision making processes that have been used.

Chapter 4 - Flood risk areas - Detailed description of the flooding mechanisms that operate in the catchment.

Chapter 5 - Flood mitigation: Options Testing - Analysis of a range of flood mitigation options.

Chapter 6 - Analysis and conclusions

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2 Data collection

The following sections will describe the datasets that have been utilised in the study.

2.1 Previous studies

Two previous studies have investigated flood risk in the Wigton, the outputs of which have been used as the basis for the model development work undertaken in this study:

- The River Wampool Flood Risk Mapping study¹, undertaken in 2005/6 by JBA Consulting, led to the development of the model being used as the basis of this project.
- In 2007 the area was assessed again as part of the River Derwent CFMP - Areas Benefitting from Defence (ABD) study². This study was also undertaken by JBA and used the modelling results produced in the original flood mapping study.

2.2 Topographic survey

The Statement of Requirements (SoR) for this project required that a detailed topographic survey should be undertaken to facilitate the extension of the Speet Gill and Wiza Beck model reaches. The survey took the form of detailed cross sections at specified open channel locations and captured key channel features (including bed level and shape); bank tops heights and the profile of adjacent floodplain areas. Cross sections were also collected at relevant hydraulic structures including bridges, culverts and weirs. A detailed spot level survey of the Wiza Beck flood retention basin and embankment was also undertaken.

The survey was collected by JBA's in-house survey team in accordance with the EA Survey Specification. A detailed survey report is supplied as part of Appendix A. A summary is provided in Table 2-1.

Table 2-1: Summary of the 2012 survey

Watercourse	Open Channel Cross Sections	Number of Surveyed Bridges / Culverts	Number of Surveyed Weirs	Spot level survey	Other
Wiza Beck	8	1	-	-	Spot level survey of retention basin and embankment
Speet Gill	17	12	1	-	
Flosh Beck	-	-	-	Footpath Levels	-

2.2.1 Hydrometric data

Temporary loggers installed on Wiza Beck and Speet Gill have provided stage data back to 2005 for a number of locations across the catchment. However a review of the data by the EA's Hydrometry and Telemetry (H&T) team highlighted various data quality issues including incomplete records and, crucially, poor reliability during high flow periods. As a result only the data collected from the logger near King Street on Speet Gill (gauge ref 755820) are considered suitable flow estimation. The record for King Street runs from January 2006 to the present day. The nearest model node is SPET01_0650. In terms of its application to this study this data will be used in conjunction with the rating derived from the hydraulic model to produce a flow record for the system which will in turn be used to refine the hydrological inputs described in section 3.1.

¹ JBA Consulting (2006): River Wampool Flood Risk Mapping Study - Final Report

² JBA Consulting (2007): River Derwent CFMP Catchment - Areas Benefitting from Defences - Main Study Report

2.3 Historical flooding

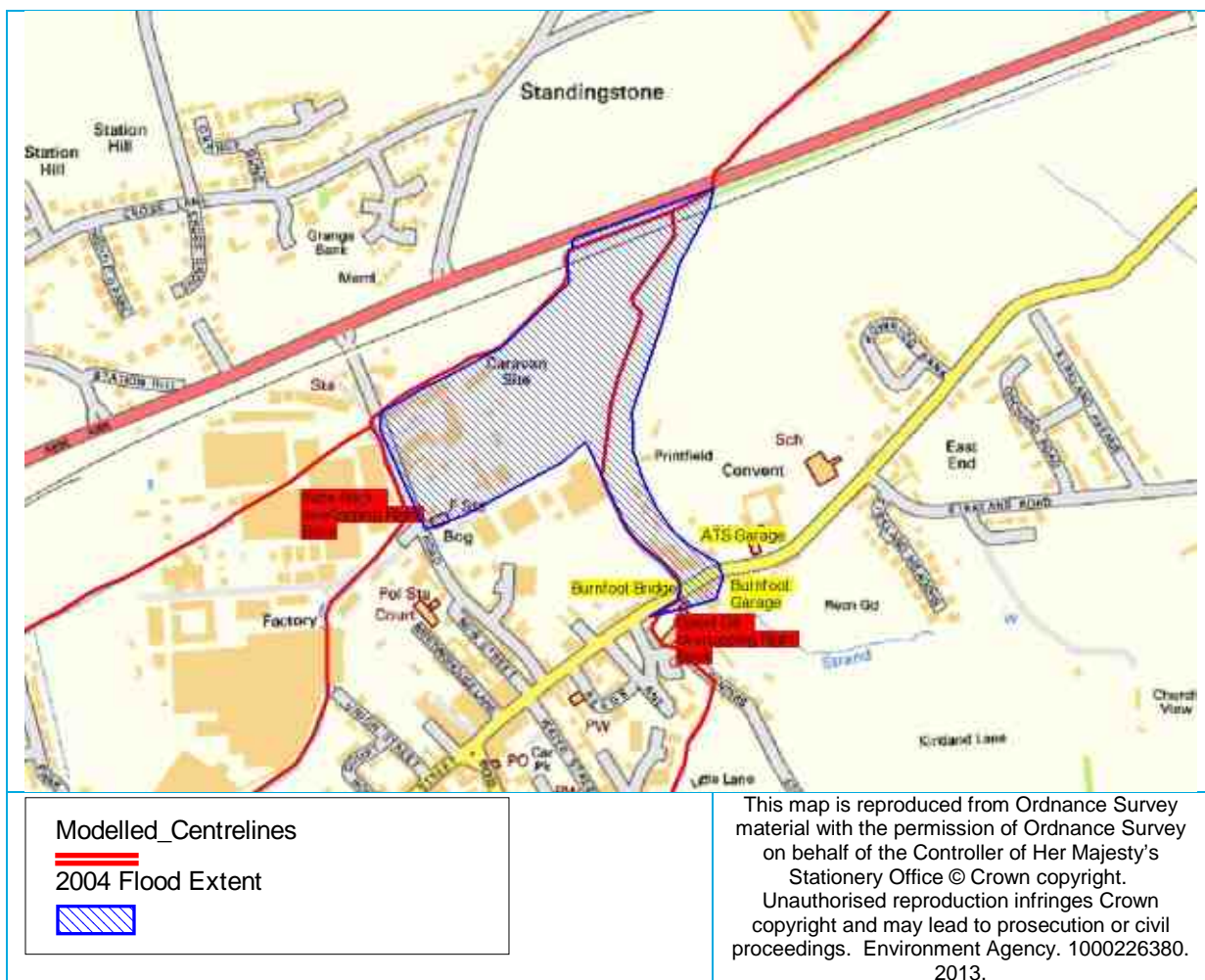
Wigton has been flooded at least four times in the last decade. Although no formal calibration has been undertaken anecdotal evidence regarding past extents and mechanisms of flooding has been used to guide the configuration of the hydraulic model and verification of the model outputs. The following sections detail the main flood events that have occurred in the catchment.

2.3.1 Flood event (1) 31 January 2004

During this event there was flooding from both the River Wiza and Speet Gill. As shown in Figure 2-1, Wiza Beck became out of bank in the vicinity of Station Road where the channel bends sharply downstream of the Innovia site. There was inundation on right hand floodplain which caused flooding to one property on Station Road as well as affecting a large part of the caravan park and the Fire Station.

Speet Gill also overtopped. This is known to have occurred both upstream and downstream of Burnfoot Bridge causing floodplain inundation on West Street in the vicinity of Burnfoot Garage (now an Aldi store), the ATS garage and adjacent buildings. A number of cottages were also surrounded but not flooded.

Figure 2-1: Extent of flooding at Wigton during the January 2004 event

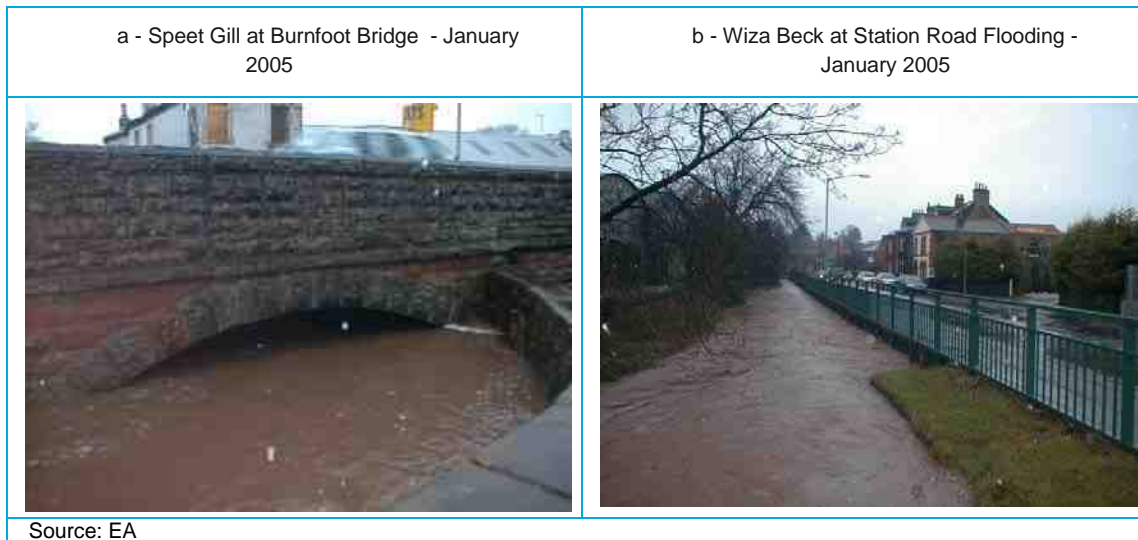


2.3.2 Flood event (2) - 7-8 January 2005

Flooding occurred following over thirty hours of intense rainfall. Significant overtopping occurred on both Wiza Beck, where flooding on Station Road resulted in the flooding of thirteen businesses and properties. Speet Gill also flooded from Tenters Lane flooding the St. Ursula's School and a number of other businesses in the area.

Figure 2-2 illustrates the key pinch points on Wiza Beck and Speet Gill.

Figure 2-2: Photographs of flooding in 2005



2.3.3 Flood event (3) - 10 April 2008

Station Road was also severely flooded in April 2008 when up to nine properties, including the Royal Mail sorting office, were inundated. The mechanisms of flooding were similar to those experienced during the 2004 event, in which the overtopping occurred at the "dog leg" bend of Wiza Beck downstream of the Innovia site. The photographs shown in Figure 2-3 have been supplied by the local media and illustrate the extent of flooding.

Figure 2-3: Photographs of flooding in 2008



2.3.4 Flood event (4) June 2012

More recently, the sports fields located upstream of Wiza Bridge were inundated by flash flooding from the River Wiza. Although no properties were flooded the Wigton carnival, which was due to take place on the day of the flood, had to be postponed.

In addition the fire station on Station Road was also flooded. During the event the Wiza Beck retention basin was overtopped.

The photographs shown in Figure 2-4 have been supplied by the Environment Agency and illustrate the extent of flooding.

Figure 2-4: Photographs of flooding in June 2012



2.3.5 Flood Event (5) 18th May 2013

The most recent event occurred in May 2013 following 24 hours of heavy rainfall. Flooding affected large sections of the Wiza Beck system, most notably the fields upstream of Wiza Bridge. The flooding was also shown to overtop the raised footpath which separates Wiza Beck and Flosch Beck upstream of the B5302.

In addition significant sections of Station Road including the entrance to the Innovia site were also flooded.

Similarly to the June 2012 event the Wiza Beck retention basin was overtopped.

Figure 2.5 illustrates the main flooded areas.

Figure 2-5: Photographs of flooding in June 2012



3 Modelling updates

3.1 Hydrological analysis

3.1.1 Existing analysis

Flood estimates for the Wigton study reach were originally calculated as part of the River Wampool FRM study in 2006. The modelling was carried out in unsteady state in order to account for both the in-channel and out of bank attenuation which characterise the Wiza Beck and Speet Gill catchments, thus requiring design flood hydrographs to be determined.

The methodology and results are described in detail in the 2006 report. In line with contemporary best practice a range of flood estimation methodologies were investigated, with the final design flows being based on the Flood Estimation Handbook (FEH) Rainfall-Runoff method.

3.1.2 Justification for updating design flood hydrographs

The current EA guidelines reflect a number of recent improvements to FEH techniques, and are reasonably different to those which were followed during the 2006 study. For instance the FEH Rainfall-Runoff method is now recommended for use only in specific circumstances. A further six years' flood peak data are also now available and, critically, local data from the King Street loggers provide an opportunity to further improve the robustness of design flood estimates for the study area.

3.1.3 Use of gauged data from King Street

Following the recommendations of the 2006 study water level loggers were installed on Speet Gill at Kings Street and Low Mill. An assessment of the data has suggested that only the Kings Mill gauge provides data that are sufficiently reliable in terms of record length and performance at high flows.

No formal stage-discharge (rating) has been derived for the Kings Street gauge meaning that there is no official flow record for the site. It is however possible to utilise the stage-discharge relationship calculated by the hydraulic model (for model node SPET01_0650) to derive a formal rating equation from which flows can be determined for a given stage.

Using JRacuda (JBA's in house rating development tool) a stage-discharge relationship has been derived for Kings Street and applied to the entire level record. This relationship is of the form $Q = C(h-a)^b$ and consists of five limbs.

3.1.4 Revised approach

It is usual practice to employ the FEH Statistical Method to estimate design flood peaks, unless there is good reason to utilise an alternative approach (such as the Revitalise Flood Hydrograph (ReFH) for example). This involves using a regression equation to predict the median annual flood (QMED) from catchment descriptors, determination of an appropriate QMED adjustment factor using one or more local donors (where available) and derivation of flood growth curves using a pooling approach. A detailed description of the hydrological analysis is included in the FEH calculation record in Appendix A.

As the King Street record provides only seven years' data, a Peaks over Threshold (PoT) analysis has been undertaken to determine QMED according to the methodology outlined in Volume 3 of the FEH. A total of 18 PoT events were identified based on a flow threshold of $0.83\text{m}^3/\text{s}$, and these gave rise to a QMED estimate of $2.53\text{m}^3/\text{s}$. This estimate tallies extremely well with the value of QMED produced from catchment descriptors using the new regression model published by Kjeldsen in 2008, which is $2.60\text{m}^3/\text{s}$. On the basis of this agreement it was deemed acceptable to apply the FEH QMED equation without any donor adjustment.

3.1.5 Peak flow estimates

The peak flow estimates calculated for the main model inflows are detailed in Table 3-1.

Table 3-1: Flood peak estimates

Flood Estimation Point	Location	Flood Events - Peak Flows (m ³ /s) - Return Period (years)							
		2-yr	5-yr	10-yr	25-yr	50-yr	75-yr	100-yr	1,000-yr
Black 10	U/s limit of Black Beck	2.11	3.02	3.68	4.63	5.45	5.97	6.37	10.49
WIZA50	U/s limit of Wiza Beck (WIZA01_20 12_3379)	8.02	10.67	12.52	15.11	17.26	18.63	19.64	32.46
WIZAint ¹	Intermediate Flow Wiza Beck	4.81	6.88	8.29	10.21	11.77	12.75	13.47	21.61
SPEE30 ⁴	U/s limit of Speet Gill - (SPET02_34 46)	1.59	2.21	2.68	3.38	4.01	4.43	4.75	8.09
SPEEint ²	Intermediate Flow Speet Gill	1.23	1.65	1.92	2.27	2.55	2.71	2.84	4.58
FLOS10_2 012	U/s limit of Flosh Beck (FLOS01_68 2)	0.42	0.58	0.70	0.87	1.02	1.12	1.20	2.18
FLOSint ³	Intermediate Flow Flosh Beck	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29

1 WIZAint - flow distributed between four model nodes - (1) WIZA01_2012_2757, (2) WIZA01c_2379, (3) WIZA01b_1646 and (4) WIZA01a_1086
2 SPEEint - flow enters system at SPET02_2957
3 FLOSint - Constant sweetner flow added to aid stability
4 SPEE30 - Flow split between the upstream reach of Speet Gill reach 2 (SPET02_3446 - 90% of inflow) and the upstream reach Speet Gill Reach 3 (SPET03_0602 - 10% of inflow)

3.2 Hydraulic modelling

3.2.1 Existing model

The existing hydraulic model covers four watercourses:

- The Wiza Beck is modelled between a point downstream of Spittal Farm and upstream of Wiza Bridge on West Road, Wigton.
- Speet Gill is a tributary of Wiza Beck, modelled upstream to a point north of the Scholars Green housing estate.
- Black Beck, another tributary of Wiza Beck, is modelled up to Cuddy Lonning, a small area of houses just outside Wigton to the southwest.
- Flosh Beck is modelled upstream to Lowmoor Road in Wigton.

A detailed description of the model is provided in the 2nd volume of JBA's 2006 report on the River Wampool Flood Risk Mapping study. The topographic survey on which the model is based was collected by Atlantic Geomatics in 2005 whilst the floodplain topography is based on information extracted from Light Detection and Ranging (LIDAR) data provided by the EA.

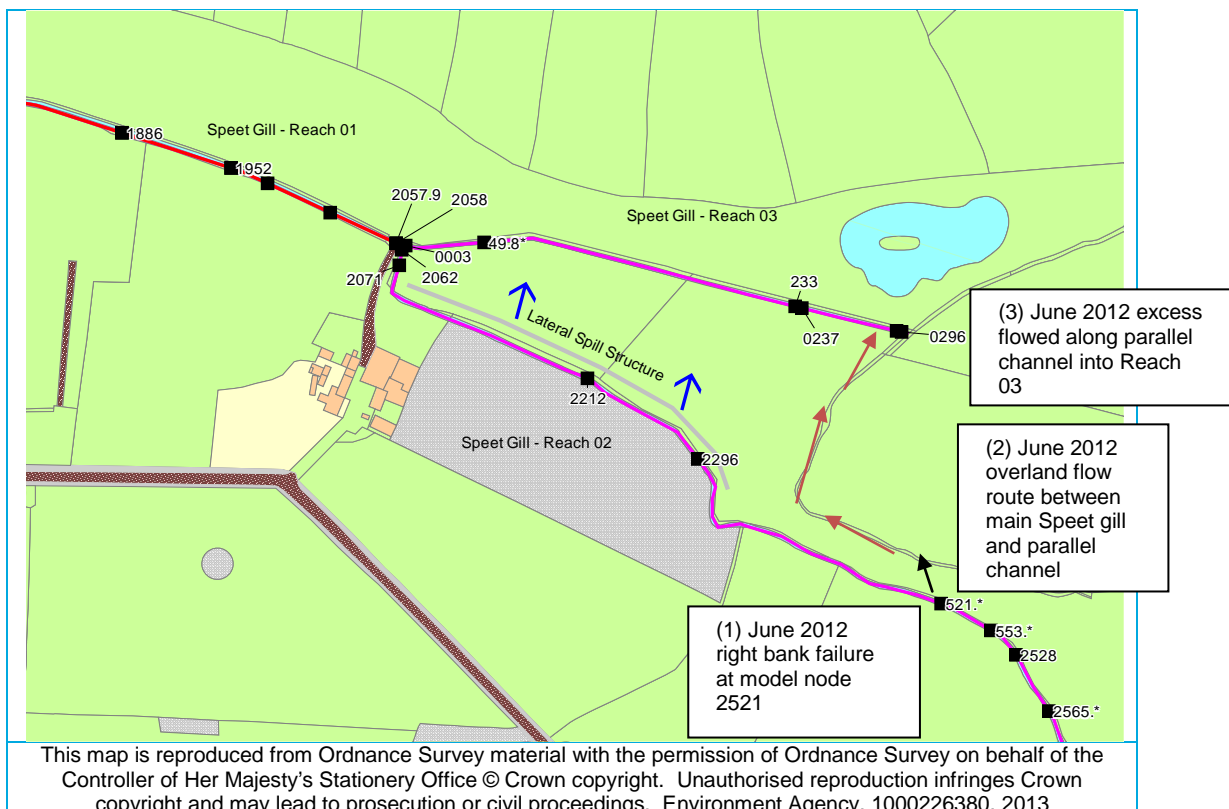
A schematic of the model is provided in Table 3-1. The modelling software was HEC-RAS. In the model, floodplain areas were represented using a combination of extended cross sections (for reaches where the floodplain conveys) and reservoir units (for areas of static floodplain storage).

Inclusion of Speet Gill lateral structure

In the vicinity of Bushgillhead (Figure 3-2) Speet Gill is characterised by a wide open floodplain. The main Speet Gill channel flows along the side of this area whilst a tributary stream (labelled here as reach SPET03) flows at a lower level in the valley apex. The tributary stream joins the main channel at model node SPET02_2062.

As the channels flow in parallel for a time it is possible that they may interact. Any water overtopping the right bank of the main channel would potentially merge with any left bank floodwater from SPET03 and jointly convey downstream. This is allowed for in the model by a lateral spill structure along reach SPET02.

Figure 3-2: Representation of Speet Gill lateral spill structure



During the summer 2012 event flooding a partial bank failure caused by scour at lead to the development of an overland flow route between cross section 521 on Speet Gill reach 2 (see Figure 3-2). The use of the lateral structure along this section has allowed this mechanism to be represented in the hydraulic model.

3.2.4 Modelling of Wiza Beck retention basin

The attenuation pond at Wiza Beck acts as a hydraulic throttle designed to restrict the conveyance of flow to the downstream reaches of the catchment and increase the time taken for the flood wave to reach the populated areas of the town. The structure shown in Figure 3-3 and Figure 3-4, comprises three main elements;

- 1) Hydraulic Throttle - in the form of a box culvert which has been designed to cause sufficient headloss in order that water is displaced onto the floodplain upstream of the structure. The size of the structure in effect controls the maximum flow that can be 'passed forward' to the lower, more vulnerable reaches of Wiza Beck.
- 2) Retaining Embankment - A large raised embankment adjoining the throttle structure which prevents displaced water from bypassing the throttle structure and controls the amount of water that is held upstream of the structure.
- 3) Increase in floodplain capacity - The area upstream of the embankment has also been engineered in order to increase the volume of water that can be retained behind the

embankment. This has included a lowering of bank levels and an excavation of the floodplain to increase the available capacity.

Figure 3-3: Wiza Beck Flood Retention Basin

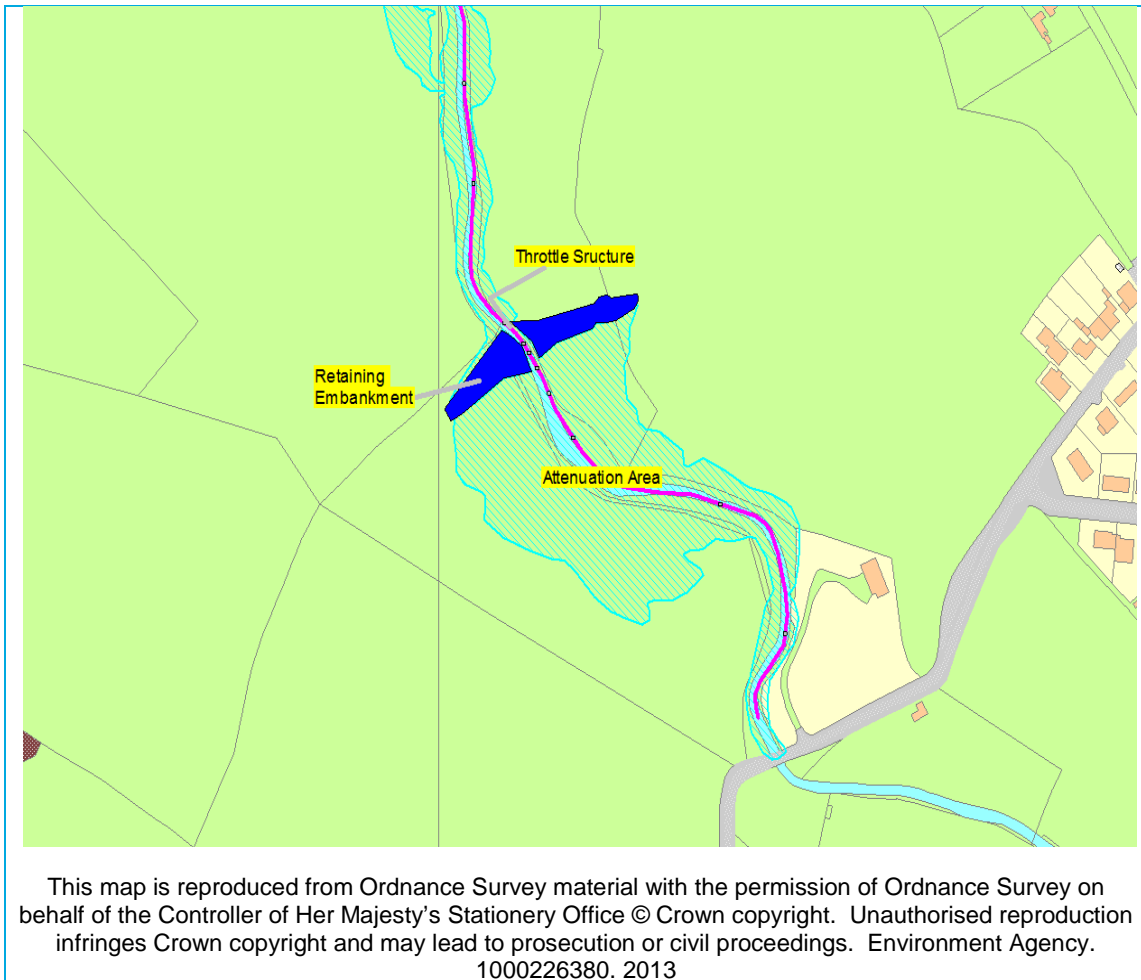


Figure 3-4: Wiza Beck Flood Retention Basin: structures



Modelling Approach - HEC-RAS

Following a site inspection of the scheme and discussions regarding how the structure operates during a flood the structure has been modelled using two main components in order to represent the throttling effect and also the impact upon floodplain conveyance.

Firstly, the throttle structure has been modelled as an 8m long box culvert with adjoining raised embankments on the left and right banks. The culvert and embankment dimensions have been based on a combination of the design and as built surveys.

In reality any out of bank flow upstream of the embankment will still be acting as conveyance albeit with a reduced velocity due to the restrictions caused by the throttle and embankment. In order to represent this in the hydraulic model the floodplain areas have been represented as extended cross sections, rather than using flood storage units which would not allow for any conveyance in the floodplain areas to occur.

3.2.5 Innovia culverts

One of the key hydraulic constrictions in the Wiza Beck system is the group of culverts adjacent to the Innovia complex on Union Street (model node WIZA01c_2010). These allow Wiza Beck to be routed below the main buildings and comprise three 3.57m wide rectangular barrels, 66m in length.

The structures have been identified as a major factor during previous flood events, which is due in part to the reduction in capacity as a result of significant siltation (Figure 3-5). This siltation has previously led to one of the barrels becoming completely blocked and therefore in the previous modelling a depth of blockage was applied to each of the barrels. As all barrels have recently been de-silted in order to restore the capacity of the structure, all the 2012 model simulations have been run assuming no blockage of this structure.

Figure 3-5: Photos illustrating the Innovia culverts



In order to quantify the impact of silt build up on flood risk a sensitivity test was undertaken where a 50% blockage was applied to each barrel. This would represent the potential barrel capacity after significant siltation had occurred.

In terms of the impact on flood risk the analysis has shown that a substantial silt build up in the structure will result in increased risk at the Innovia site as the culvert will be bypassed on the right bank causing flooding in the car park area between Union Street and Meetinghouse Lane. This flooding will then merge with the existing flooding in the area downstream of the culvert, creating a larger flood risk area.

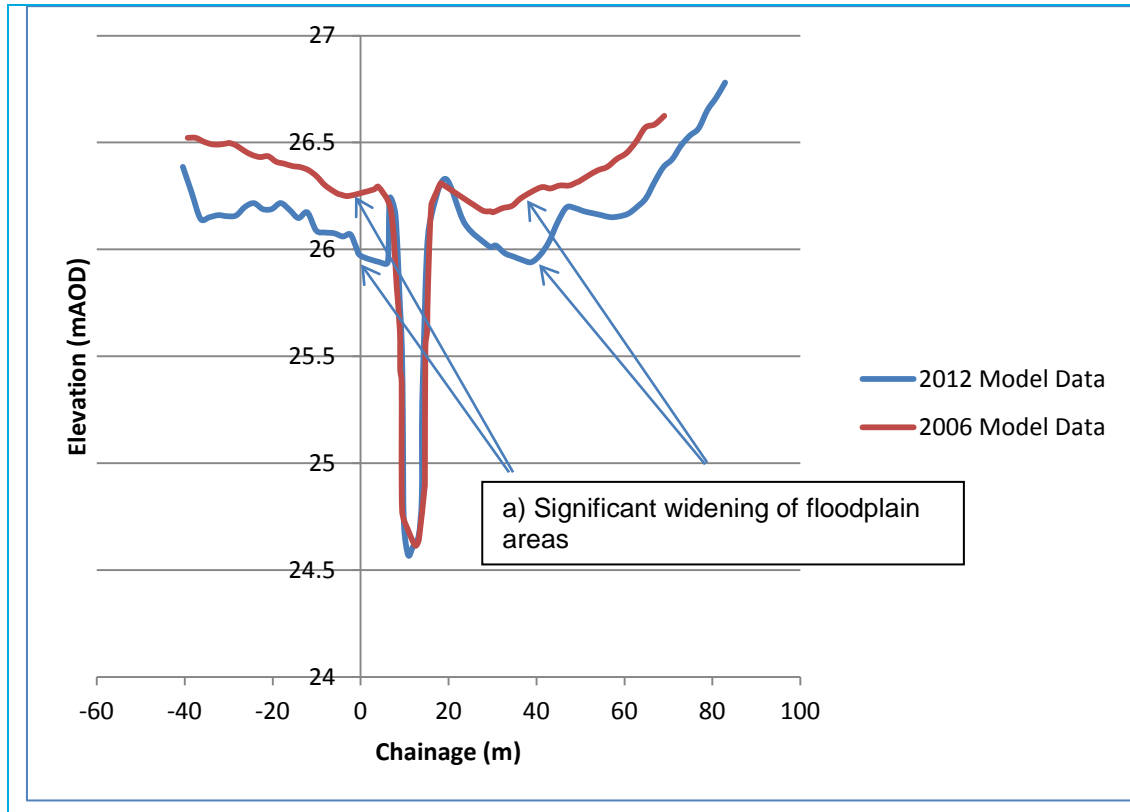
When clear of silt the structure has a capacity in excess of a 100-year event. Conversely, with a significant silt build up (50% reduction in capacity) the capacity is greatly reduced with flooding occurring during a 50-year event.

3.2.6 Update of cross sections u/s of Wiza Bridge

Since the last study modifications have been carried out to the section of channel upstream of Wiza Bridge (model node WIZA01_2012_2631 to 2468) in order to improve conveyance. These measures have included widening the channel by up to 2m in places. To reflect these changes, all cross sections between 2631 and 2468 have been replaced with the surveyed cross sections taken as part of the 2012 survey.

Figure 3-6 illustrates the update to the cross section dimensions at cross section WIZA01c_2531.

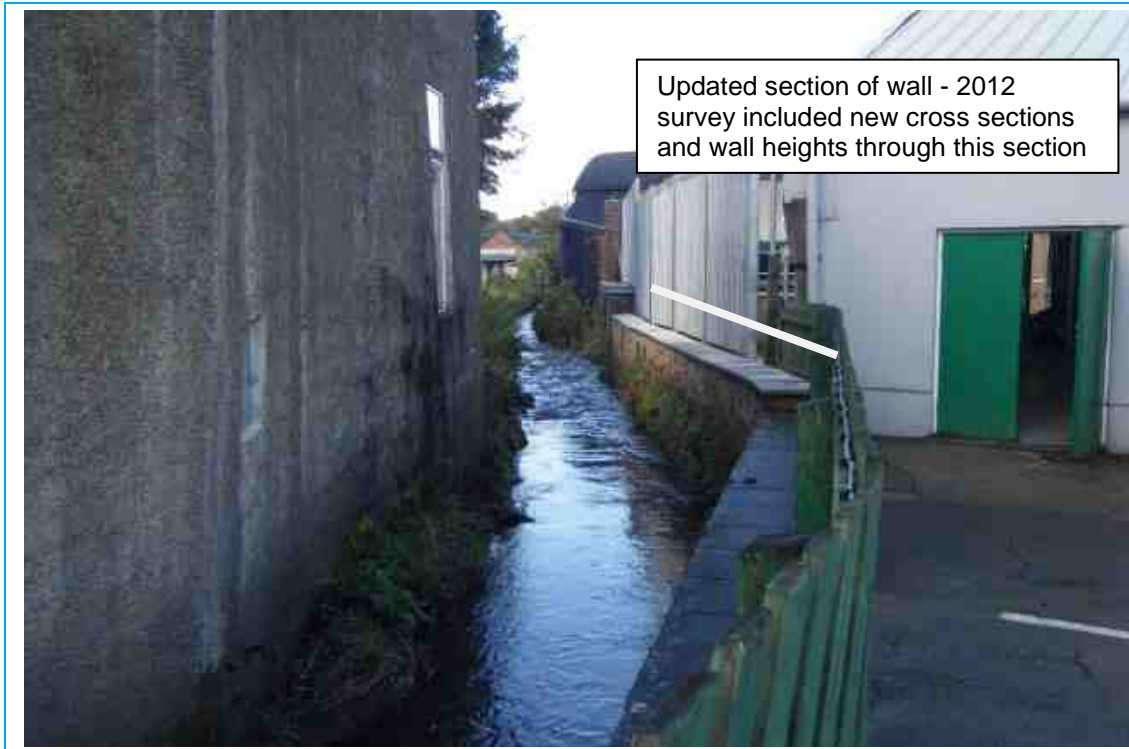
Figure 3-6: Cross Section Update 2012 (WIZA01c_2531)



3.2.7 ATS garage walls and channel

Further capital works had been carried out on the flood walls adjacent to the ATS garage. The main changes included the replacement / improvement of the wall directly adjacent to the ATS site as illustrated in the photograph below (Figure 3-7). The mid section highlighted in the photograph has been replaced since the original modelling study. The 2012 survey captured the new wall heights and these data have been incorporated into the updated model.

Figure 3-7: ATS garage - Flood wall update 2012



4 Flood risk areas

4.1 Introduction

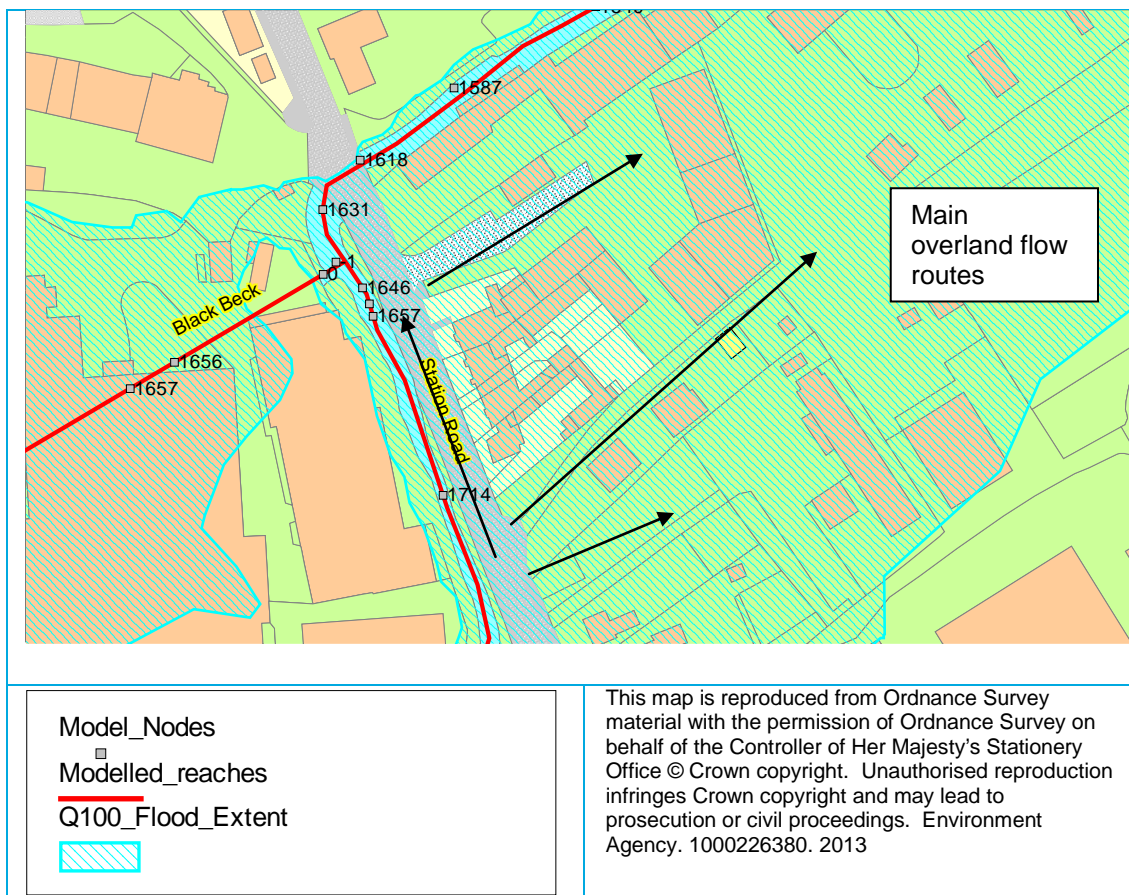
The following sections discuss the main flood risk areas and mechanisms that have been identified in the system using the updated model. The modelling approaches used are also summarised.

4.1.1 Bypass of Station Road Bridge on Wiza Beck

In the January 2005 event, water left the Wiza Beck channel at Station Road and flowed through the industrial estate and caravan site. This area is represented in the model using extended cross sections, under the assumption that the whole valley (river plus floodplain) will act as a single wide channel in a major flood, i.e. the water levels on the floodplain and channel will be equal. The footprint of some of the larger buildings on the industrial estate have been added to the cross sections as they will obstruct the flow.

In reality, flood flow routes in this area will be more complex; as shown in Figure 4-1 one possible flow route is parallel to Station Road another is perpendicular to it. The extended cross sections have been oriented as best as possible to represent the varying flow routes in the area.

Figure 4-1: Mechanisms of flooding from Wiza Beck at Station Road



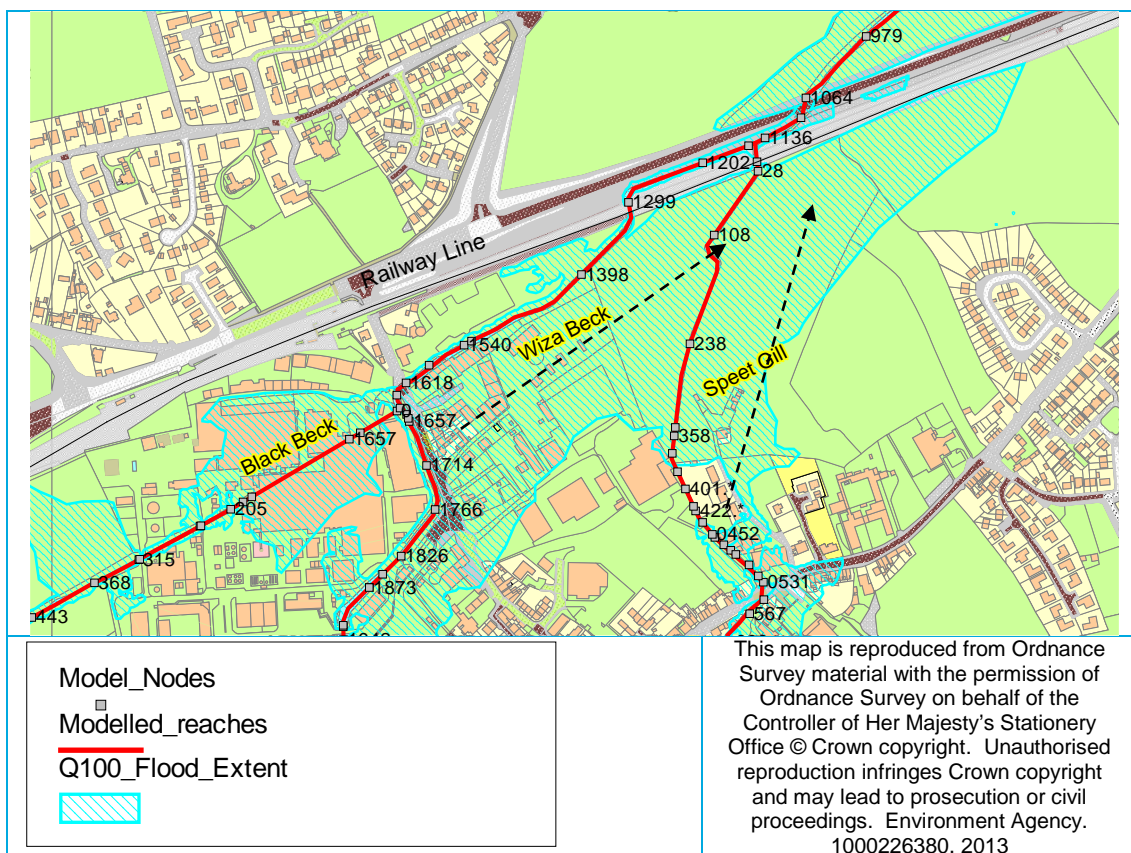
The analysis has shown that, as a result of insufficient channel capacity, Wiza Beck will overtop onto the right bank floodplain along the 100m section upstream of the confluence with Black Beck. Once overtopping occurs the flooding will initially inundate Station Road before flowing east through the adjacent caravan park. The out of bank flows will eventually combine with those arising from Speet Gill (located to the east of the River Wiza).

4.1.2 Interaction between Wiza Beck and Speet Gill upstream of railway line

Wiza Beck and Speet Gill flow close together (within 80m) before passing under the railway line north of Wigton through separate bridge structures. Their confluence is downstream of the railway. In a flood, as can be seen from the January 2005 and January 2004 outlines, floodwater from the two rivers combine in the wide area of open land upstream of the railway crossing (Figure 4-2).

This interaction has been modelled using lateral spills that allow exchange of water between the two rivers. There is a net flow from the Wiza Beck into the Speet Gill because levels on the Wiza Beck are higher as there is a greater distance downstream to the confluence on the Wiza Beck.

Figure 4-2: Mechanisms of flooding from Wiza Beck at its confluence with Speet Gill



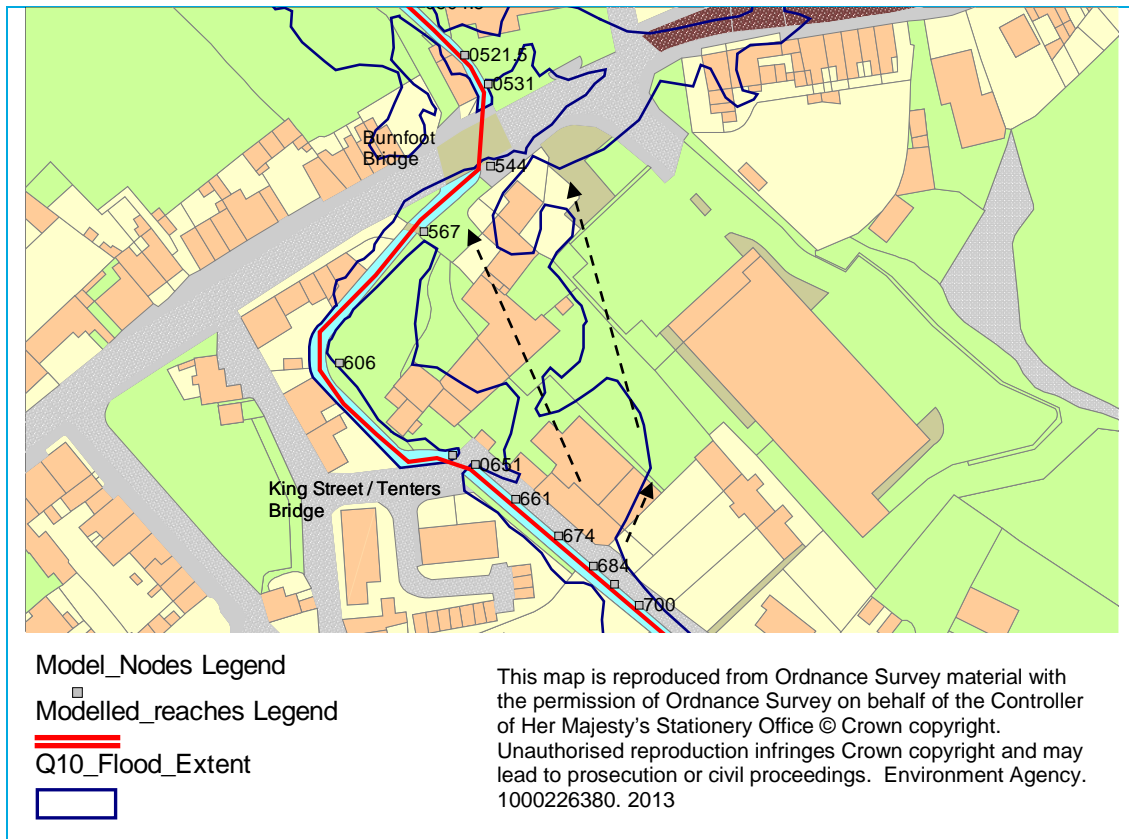
4.1.3 Bypass of Tenter Bridge (Speet Gill) by flow through St Ursula's School

Bypassing of Tenter Bridge has also been observed in events such as January 2005. Water discharges out of Speet Gill at Eastley Terrace and Tenter Bridge and flows generally north through St Ursula's School. It can then combine with floodwater from the Strand and re-enters Speet Gill in the vicinity of Burnfoot Bridge.

In the model this has been represented using two lateral spills which allow water to leave the channel at Eastley Terrace (ignoring the garden wall that could act as a flood defence) and through the gate in the school wall upstream of Tenter Bridge. Water that passes over these spills re-enters the channel upstream of Burnfoot Bridge.

The analysis has shown that the bypass mechanism will only become active during the 10-year event. The model predicts that Tenter's Lane will be inundated during an event with a return period of 5-years, however St. Ursula's will be inundated first during an event with a return period of between 5 and 10-years.

Figure 4-3: Mechanisms of flooding from Speet Gill - St. Ursula's Bypass

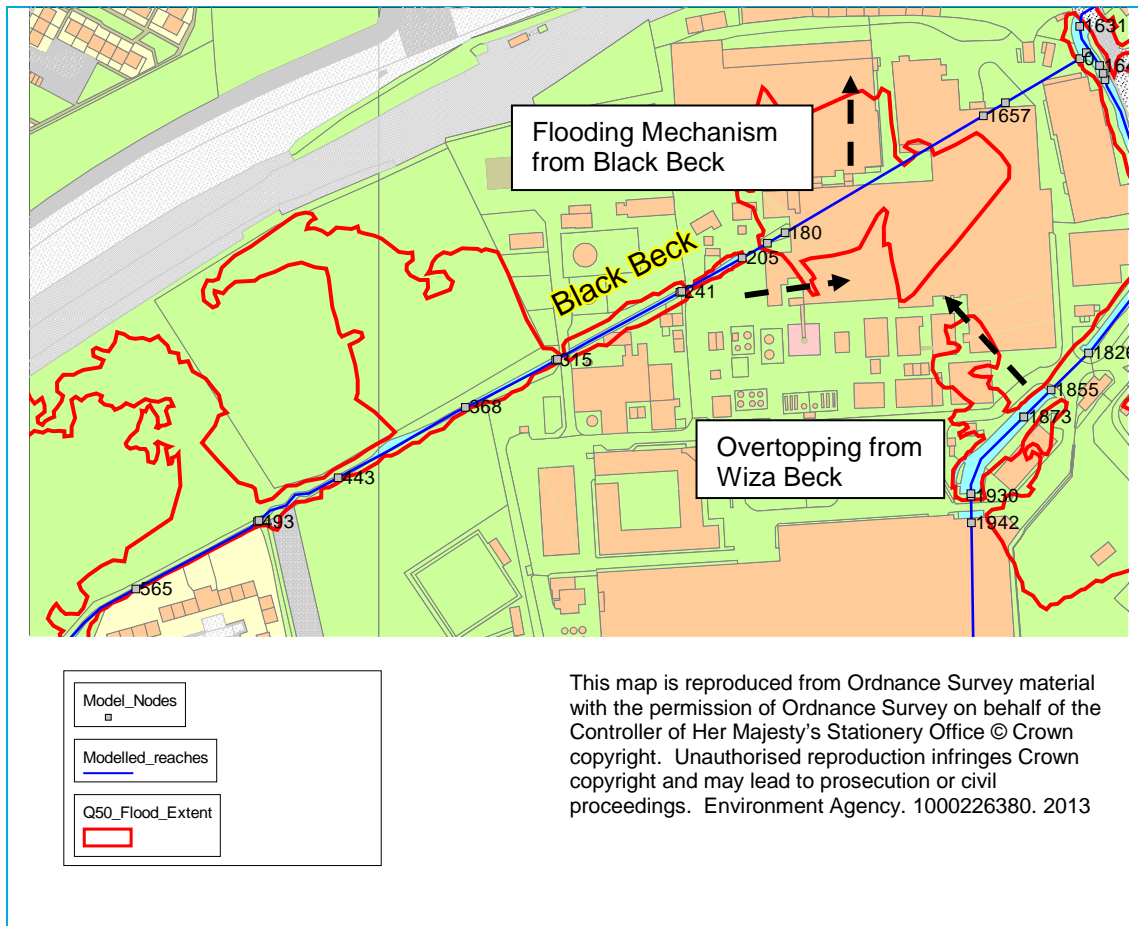


4.1.4 Bypass of Black Beck culvert at Innovia factory

The Black Beck culvert flows under a large factory building and as such there is no straightforward bypass route should the culvert capacity be exceeded. Flow routes within the factory were investigated on site by a walkover survey and discussions with Innovia staff who witnessed the January 2005 flood. This was reported to be the only flood of the factory in at least the last 29 years. Flood water in January 2005 ponded upstream of the culvert and flowed straight through the main plant building above the culvert. Cellars in the workshop and offices building to the north flooded from drains backing up. Flood water also entered the site from a gate leading into the field to the west.

Rather than attempting to model flow routes through buildings and the site drainage system, an assessment was made of the most likely overland flow route. This was found to be a corridor between the two buildings mentioned above, north of the culvert inlet. Flow can pass along this corridor, round the north of the large building and hence into the Wiza Beck at Station Road Bridge. This was modelled using a storage area connected by lateral spills to the Black Beck and the Wiza Beck as shown in Figure 4-4.

Figure 4-4: Mechanisms of flooding from Black Beck at the Innovia Site



4.1.5 Interaction between Wiza Beck and Flosch Beck upstream of Wiza Bridge

In major floods, it seems likely that Wiza Beck and Flosch Beck will combine as they pond upstream of the West Road embankment. This has been modelled by adding a lateral spill to allow flow from Wiza Beck into Flosch Beck. The geometry is very similar to that described above for Wiza Beck and Speet Gill.

4.1.6 2D Modelling

The mapping undertaken in 2006 incorporated a 2D modelling element in the flood mapping phase in order to capture the out of bank flooding mechanisms at the upstream end of Flosch Beck and also the area adjacent to Tenters Lane on Speet Gill.

The assessment of the flooding mechanisms in 2012 which utilised the HEC-RAS in-built mapping tool (RAS-Mapper) has been shown to be sufficient to capture the impact of the flooding mechanisms identified using the 2D model. Consequently the mapping undertaken in 2012 has not utilised the 2D models.

4.2 Effectiveness of Wiza Beck flood retention basin

The study has also looked at measuring the effectiveness of the Wiza Beck flood retention basin. The current configuration of the retention basin is able to 'hold' in the region of 8,500m³ of water in the reaches upstream of the structure without overtopping. This has been assessed by modelling both the pre- and post-scheme channel conditions and then comparing the flood risk characteristics.

As anticipated the scheme has little impact on overall flood levels and the analysis has therefore focused more on the effect on the time taken for the for the flood wave to reach the populated sections of the Wiza catchment.

In summary, the retention basin will apply a short delay in the flood peak reaching the key flood risk areas in the town centre. The analysis has focused primarily on the flow conditions at Wiza Bridge (WIZA01_2012_2482), the main Innovia culvert (WIZA01c_2011), Station Road (WIZA01c_1714) and Station Road Bridge (WIZA01b_1630).

The analysis detailed in Table 4-1 shows that the basin is more effective during low flow events (<~5 years) beyond which the scale of overtopping at the retaining embankment means that the peak of the event is largely unaffected.

In terms of the speed at which the peak of the event reaches the populated areas of the catchment the analysis has shown that for the 2-year event the arrival of flood peak at Wiza Bridge and the Innovia culvert has been delayed by approximately 20 minutes following the introduction of the flood retention basin.

The impact in the Station Road area is less significant which may be the fact that Black Beck is confluent with Wiza Beck in this area and the additional flow entering the system here negates the impact of the retention basin.

For the 5-year event the arrival of the peak of the event is delayed by between 5 and 10 minutes only. The impact is even less prominent during the 10-year event.

Table 4-1: Analysis of impact of Wiza Beck Flood Retention Basin - Impact on Progression of flood wave

Model Node	Location	Flood Event Return Periods (years) - Timing of Flood Peak (hours)					
		2-year (time of peak flow)		5-year (time of peak flow)		10-year (time of peak flow)	
		Pre-Scheme	Post-Scheme	Pre-Scheme	Post-Scheme	Pre-Scheme	Post-Scheme
2482	Wiza Bridge (u/s face)	09:10 hrs	08:55 hrs (-15 mins)	8:55 hrs	09:00 hrs (-5mins)	8:55 hrs	09:00 hrs (-5mins)
2011	Innovia Main Culvert (u/s face)	09:10 hrs	08:55 hrs (-15 mins)	8:55 hrs	09:01 hrs (-6mins)	09:00 hrs	09:00 hrs (-0mins)
1826	Station Road - u/s of Black Beck confluence	09:10 hrs	08:55 hrs (-15 mins)	9:00 hrs	09:05 hrs (-5mins)	09:00 hrs	09:00 hrs (-0mins)
1631	Station Road Bridge	08:45 hrs	08:50 hrs (-5mins)	8:40 hrs	08:45 hrs (-5mins)	08:45 hrs	08:50 hrs (-5mins)

Time (hours) is from the start of the design simulation

4.2.1 Wiza Beck Improvements - Option 1 - Raised Embankment

Following consultation with the EA the option testing has involved identifying what modifications to the existing structure would be required to raise the Standard of Protection (SoP) to a 10-year level.

A number of iterations of the model have been simulated which has looked at optimising the embankment height in relation to preventing overtopping of retaining embankment during a 10-year event.

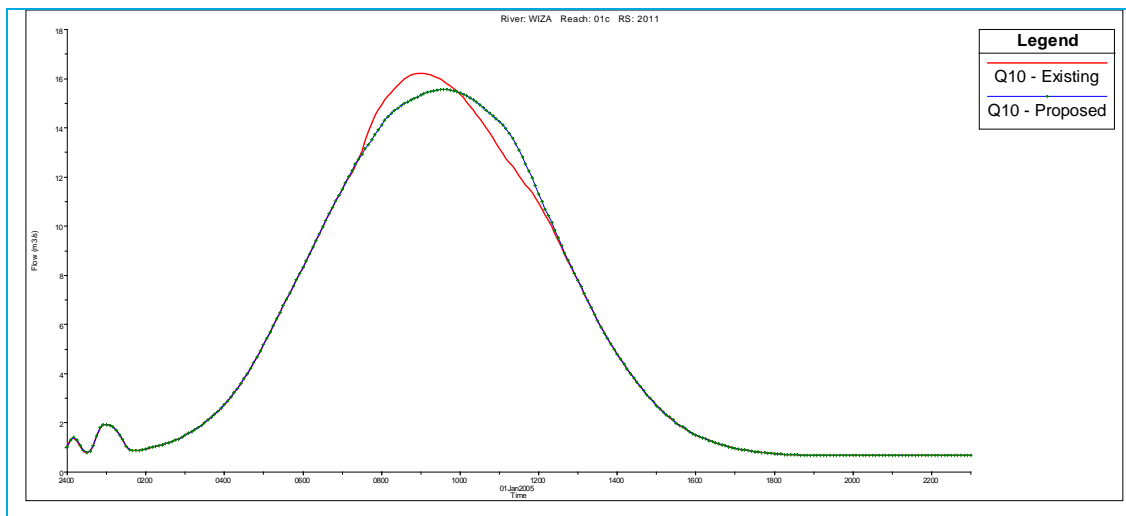
The analysis has shown that order to prevent overtopping during a 10-year event the embankment crest would need to be raised to a minimum of 31.1mAOD along the full length of the crest (+0.5-0.6m). An analysis of the amount of water that would be held upstream of the structure before overtopping has estimated the total volume to be in the region of 13,500m³.

The impact on flood levels would be minimal with peak water levels at the Innovia culvert (WIZA01c_2010) being lowered by approximately 0.02m for the 10-year event.

The effect on the speed at which the flood wave reaches the lower reaches of Wiza Beck would be more pronounced with the flood peak reaching the Innovia site (WIZA01c_2010) 35 minutes later than would be case with the current embankment dimensions.

Figure 4-5 illustrates the impact of the proposed refinements to the structure.

Figure 4-5: Option 1 - Wiza Beck Improvement s - Raised Embankment - Impact on hydrograph timings at Innovia Culvert (WIZA01c_2010)



The benefits from a flood warning perspective have not been thoroughly tested as part of the study however, an additional lead time (time from flood warning) of 30-35 minutes is unlikely to be significant in terms of flood warning, particularly if the flood occurs during the day when many residents will be at work and will be unable to implement and property level flood defence procedures.

The impact has also been assessed for the 25-year flood event where the embankment will be overtopped during the event. In this case the impact on the progression of the flood wave is minor and therefore highlights how the structure is largely ineffective once overtopped.

4.2.2 Wiza Beck Improvements - Option 2 - Raised Embankment and Adjusted Throttle

A further option (Option 2) which focused on coupling a raised embankment with a reduced size of the throttle structure was also evaluated. The analysis has shown that an increase in the embankment crest and a significant reduction in the size of the throttle structure (soffit lowered by 0.5m) would make the scheme more effective across a range of return periods. For a 5-year event this may restrict the progression of the flood wave to the vulnerable areas of the catchment by between 30 and 60 minutes.

Conversely for the larger the return periods Option 2 is much less effective as the increased overtopping of the embankment resulting from the lowered capacity of the throttle structure means that the structure would not significantly disrupt a flood wave of this magnitude (>10-years) to improve the flood warning conditions at the site. Consequently, Option 2 offers no significant benefits for events in of a magnitude in excess of a 5-10-year event.

Table 4.2 summarises the findings of the analysis.

Table 4-2: Wiza Beck Improvements - Wiza Beck Flood Retention Basin - Impact of proposed structure refinements

Model Node	Location	Flood Event Return Periods (years) - Timing of Flood Peak (hours)							
		5-year (time of peak flow)				25-year (time of peak flow)			
		Pre-Scheme	Existing	Option 1 - Raised embankment	Option 2 - updated throttle	Pre-Scheme	Existing	Option 1 - Raised embankment	Option 2 - and updated throttle
2482	Wiza Bridge (u/s face)	08:55 hrs	09:00 hrs (-5mins)	09:20 hrs (-25 mins)	09:55 hrs (-60 mins)	09:00 hrs	09:00 hrs (-)	09:30 hrs (-30 mins)	09:00 hrs (-)
2011	Innovia Main Culvert (u/s face)	08:55 hrs	09:01 hrs (-6mins)	09:20 hrs (-25 mins)	09:50 hrs (-55 mins)	09:00 hrs	09:00 hrs (-)	09:30 hrs (-30 mins)	09:00 hrs (-)
1826	Station Road - u/s of Black Beck confluence	09:00 hrs	09:05 hrs (-5mins)	09:20 hrs (-20 mins)	09:45 hrs (-45 mins)	09:00 hrs	09:00 hrs (-)	09:35 hrs (-35 mins)	09:00 hrs (-)
1631	Station Road Bridge	08:40 hrs	08:45 hrs (-5mins)	08:45 hrs (-5mins)	09:10 hrs (-30mins)	08:45 hrs	08:45 hrs (-)	09:35 hrs (-35 mins)	08:45 hrs (-)
Existing - Embankment crest and throttle dimensions as per survey Option 1 - Embankment crest raised to 31.5mAOD (0.75-1m increase in crest height) Option 2 - Existing embankment dimensions, throttle dimensions - 2.3m x 1m (existing 2.3m x 1.5m)									

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5 Flood mitigation - options testing

5.1 Options testing - Speet Gill

A range of flood mitigation measures have been investigated and evaluated against the degree to which they might alleviate flood risk or improve the feasibility for implementing an effective flood warning system in the most vulnerable areas in the catchment.

The most vulnerable areas are in the lower reaches of Speet Gill between Tenters Lane and the reach downstream of Burnfoot Bridge, which are at risk of flooding during events with a return period of 5-10-years. The concentration of property and infrastructure in this area means that reducing flood risk has become a key area of consideration for the EA.

Following discussions and a site visit with the EA and two potential options were identified:

1. Attenuation in upper reaches of Speet Gill
2. Desiltation of the Burnfoot Bridge to increase capacity of structure.

5.2 Option 2: Speet Gill flood retention basin

Utilising a similar approach to that adopted on Wiza Beck the first option focuses on attenuating water in the upper reaches of the catchment, the primary aim being to reduce the speed at which flood waves reach the lower reaches of Speet Gill as well as reducing flood risk. Similarly with the Wiza Beck structure the intention would be to utilise the benefits of the structure in order to develop a flood warning system for the high risk areas of Speet Gill.

As discussed in section 1.2.3 the EA have started negotiations for landowner agreement to utilise land in the upper reaches of Speet Gill for controlled flood attenuation. It is intended to construct a hydraulic throttle and retaining embankment that will limit the amount of flow being able to the pass downstream reaches. A number of potential embankment dimensions have been evaluated using the model. The option has been tested using a 0.75m diameter pipe to allow low flows to pass down through the system.

The following sections detail the findings of the option testing that have been undertaken. The analysis has focused on assessing the timing of the flood peaks in the reach between Tenters Lane (SPET01_0748) and the ATS Garage (SPET01_0504).

Option 1a: Embankment Crest - 1m high embankment (37.07m AOD)

The analysis has shown that the return period at which the embankment is overtopped is crucial to its effectiveness. An embankment with these dimensions would be expected to hold a volume of water in the region of 10,000m³, however the structure has been shown to be readily overtopped.

Once the embankment is overtopped, or bypassed, water levels in the lower reaches of the catchment are able to return to levels similar to those modelled for the existing (undefended) system.

In terms of the impact on the speed at which a flood wave would reach the lower sections of the Speet Gill the analysis has shown that for the 10-year event the structure would ensure only a 10-12 minute delay in the flood peak reaching Tenters Lane (SPET01_0650). This increases to approximately 20 minutes for events of a magnitude less than a 5-year event as the embankment provides more a physical barrier to the flood wave.

In terms of its effectiveness as a flood defence, Option 1a shows no significant benefit for all return periods covered by the analysis. Furthermore, using the structure as a means to improve the effectiveness of a flood warning system this option is unlikely to provide a significant additional lead time (20 minutes maximum) during an event.

Option 1b: Embankment Crest - 2.97m high embankment (39.00m AOD)

Option 1b focuses on using a significantly higher embankment (3m) in order to increase the return period at which the structure overtops. The analysis has shown that the embankment would not be overtopped unless the event return period exceeded 100-years. Due to the greater level of protection offered, there is a significant decrease in flood risk within the vulnerable areas adjacent to Burnfoot Bridge. In particular the in-channel flow rates are sufficiently reduced to

prevent overtopping between the upstream end of Tenters Lane (SPET01_0748) and the low lying sections downstream of Burnfoot Bridge (SPET01_0456) during the 100-year event.

Despite the obvious benefits of the proposed structure there are a number of practical considerations which may make this option difficult to justify from a planning and health and safety perspective. The main issue would be the volume and depth of water that would need to be retained upstream of the embankment. Initial estimates from the modelling indicate that water would accumulate to a depth of 3m in places, with a volume of up to 80,000m³ needing to be attenuated. This would potentially bring the structure within the remit of the Reservoirs Act (1991).

Similarly to option 1a, the introduction of the throttle structure will increase the time taken for the flood wave to reach to the lower sections of Speet Gill. The model analysis has indicated that for flood events where the retaining embankment is not overtopped (<100-year event) the presence of the structure will increase the time of travel between the basin and Tenters Lane by between 1.5 and 2 hours.

5.2.1 Feasibility of Speet Gill options

When assessing the Speet Gill options it was important to make a compromise between the flood defence benefits associated with Option 1b and the practical considerations in terms of constructing a retention basin of sufficient size and also the desire on behalf of the EA to ensure that the volume of water held by the structure did not exceed the 10,000m³ which would bring the structure within the remit of the Reservoirs Act.

The investigation has estimated that the maximum height of the proposed Speet Gill embankment should be between 1.1-1.2m (~37.15mAOD) as this would ensure that volume held by the structure does not exceed the Reservoirs Act threshold. These calculations have been based on ground level data extracted from LIDAR. A more robust estimate of volume based a detailed spot level survey would be required should the study proceed to a design phase.

5.2.2 Flood Warning

As discussed in the previous sections the construction of the Speet Gill embankment will be able to disrupt the natural conveyance of the system sufficiently to extend the time of travel between the flood wave passing the embankment and then reaching Tenters Lane (SPET01_0650).

The current time of travel between the upper reaches of Speet Gill (model node SPEE02_2998) and Tenters Lane (SPEE01_0650) is 1.5-2 hours based on an analysis of the progression of the design flood wave using the hydraulic model. This means that once the flood peak reaches the SPEE02_2998 it will take between 1.5-2 hours to reach Tenters Lane. The modelling has shown that the introduction of the retaining embankment may extend the travel time of the flood peak by up to 20 minutes.

On this basis the creation of a flood warning system based on water level monitoring in the upper reaches of Speet Gill may be feasible.

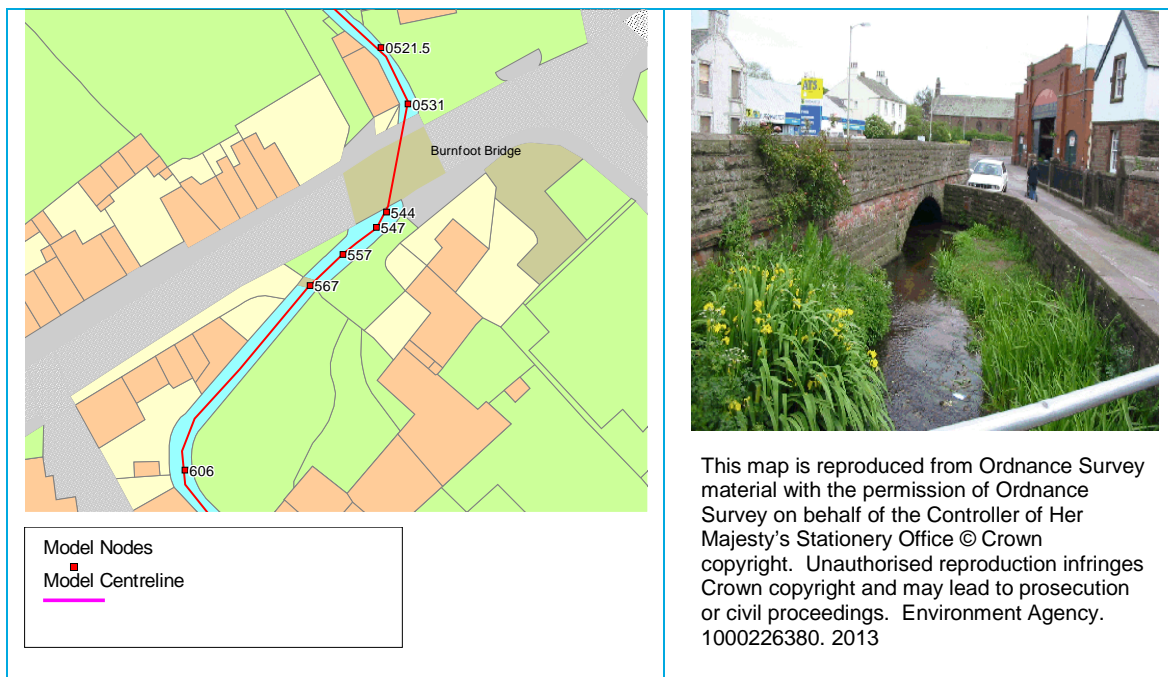
In practical terms it would be necessary to install a hydrometric monitoring station either within or upstream of the proposed storage area. Additional testing using the hydraulic model would then be undertaken to develop an understanding of the relationship between the upstream monitoring gauge and the existing gauge at Kings Street / Tenters Lane. This would allow the system to relate the threshold of flooding at Tenters Lane to a corresponding level at upstream gauge.

Flood warning thresholds would then be calculated at levels lower than the flood peak to allow for a sufficient lead time between a flood warning being issued and the subsequent onset of flooding in the populated areas.

5.3 Option 2: De-siltation of Burnfoot Bridge (SPET01_0544)

There is a strong misalignment between Burnfoot Bridge and the channel, as shown in Figure 5-1. This means that the structure generates a significant headloss leading to a noticeable drop in velocities in the upstream channel reach. As a result the channel is subjected to significant siltation which, over the years, has led to a noticeable reduction in the structure's capacity. All design model simulations have been undertaken assuming a degree of siltation similar to that recorded during the channel survey of 2005.

Figure 5-1: Option 2 - De-Siltation - Burnfoot Bridge (SPET01_0544) plan



The introduction of a regular channel clearance regime in order to remove/control the silt build up could be implemented as a means to maintain the maximum capacity of the structure and alleviate some of flood risk associated with the structure. However, owing to the compaction of the silt that has occurred at the structure the survey was not able to determine the depth of silt that has accumulated. Consequently it is not possible to accurately determine how much of the structure has become blocked.

In order to illustrate the potential benefit of de-silting the channel the analysis has therefore assumed 0.3m depth of silt in both the structure and the reach immediately upstream. The assessment of the impact of de-siltation has therefore involved lowering the bed levels of the bridge and open channel sections to the estimated 'hard bed' level by the assumed silt depth. The following adjustments to cross sections have been undertaken:

- Open channel cross section - SPET01_0567 - Existing bed level - 19.74mAOD - **De-silted bed level - 19.44mAOD**
- Open channel cross section - SPET01_0557 - Existing bed level - 19.64mAOD - **De-silted bed level - 19.34mAOD**
- Open channel cross section - SPET01_0547 - Existing bed level - 19.51mAOD - **De-silted bed level - 19.21mAOD**
- Open channel cross section - SPET01_0544 (upstream face of bridge) - Existing bed level - 19.47mAOD - **De-silted bed level - 19.17mAOD**

The impact of the increased channel capacity was tested for a range of flood events (2-year, 25-year and 100-year). The analysis is summarised in Table 5-2.

Table 5-1: Option 2 - Impact of desiltation on modelled water levels

Model Node	Water Surface Elevation (mAOD)					
	2-year		25-year		100-year	
	Existing	Option 2	Existing	Option 2	Existing	Option 2
SPET01_0544 (u/s face of bridge)	20.61	20.58	21.03	20.98	21.15	21.04
SPET01_0557	20.61	20.58	21.03	20.98	21.16	21.05
SPET01_0567	20.61	20.59	21.04	20.99	21.16	21.06
SPET01_0644 (D/s face of King Street bridge)	21.20	21.20	21.38	21.38	21.46	21.44

The analysis shows that while the removal of silt will improve conveyance and lead to a small reduction in flood levels, the overall flood risk will not be significantly reduced. It is possible to conclude that while the siltation is contributing factor to flood risk, the other mechanisms discussed in Chapter 4 are more critical to the overall flood risk.

6 Analysis and conclusions

6.1 Impact of flood risk

As part of the flood mapping phase of the study a property count of flood risk properties has been undertaken. Table 6-1 summarises the numbers properties affected.

A full set of updated flood maps are included as part of the digital deliverables package.

Table 6-1: Properties at Flood Risk in Different Scenarios

Scenario	Return Period (years)						
	2	5	10	25	50	75	100
Existing - Pre / Post Wiza Beck basin	11	38	56	87	127	146	176
Post Speet Gill Scheme (Option 1b) - 3m high embankment		29	43	62	95	114	143

The analysis highlights the fact that the introduction of the proposed Speet Gill scheme will lead to an approximate 30% reduction in the numbers of properties affected by flood risk across the full range of return periods.

In summary the results have shown that the Wiza Beck retention basin shows no benefit in terms of removing properties from flood risk.

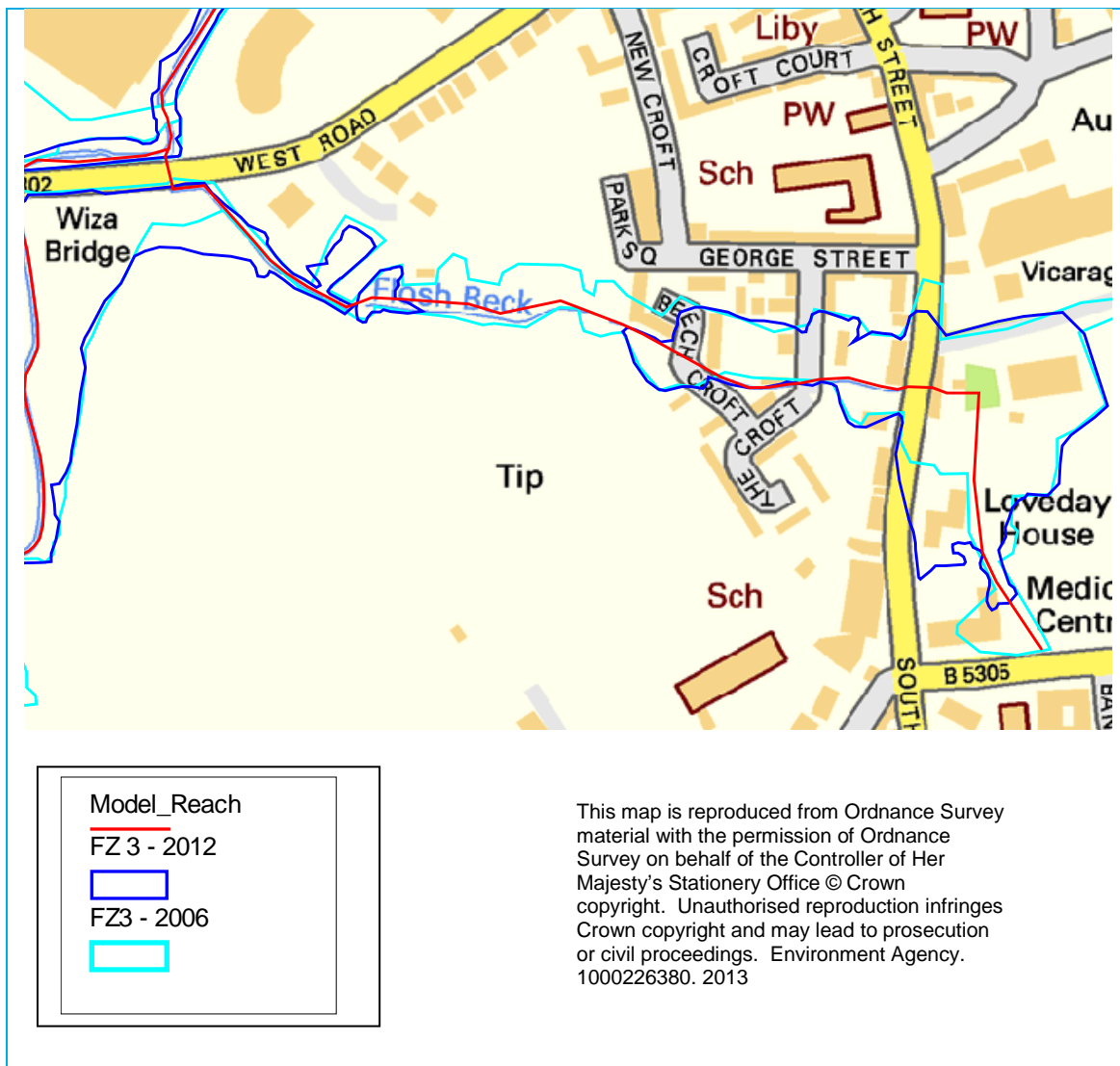
6.1.1 Comparison with previous mapping

The Wigton area was originally mapped for flood risk as part of the River Wampool Flood Risk Mapping Study in 2006. Overall the 2012 flood extents are consistent with the outlines derived in 2006. The key areas of change are on Flosch, Beck, Wiza Beck upstream of the Innovia site and Speet Gill upstream of Burnfoot Bridge.

(1) Flosch Beck

The main areas of difference are the mid sections of Flosch Beck downstream Beech Croft, where the 2012 flood extent covers a smaller area (see Figure 6.1a). This change is largely down to the use of higher resolution LIDAR data when defining the flood extents.

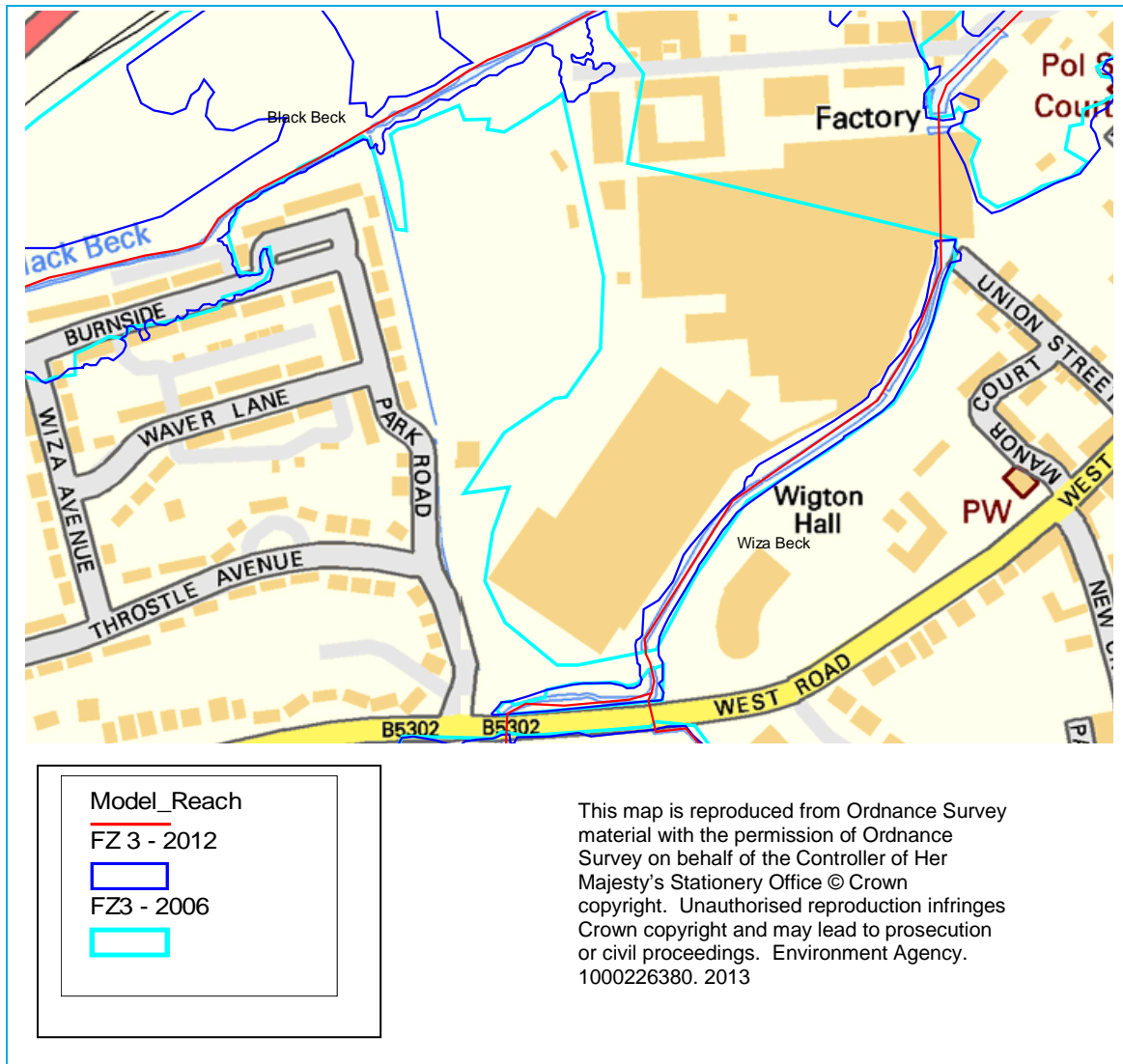
Figure 6-1a: Updated Flood Zone 3 - Flosch Beck



(2) Wiza Beck

The second area is on Wiza Beck where the 2012 flood extents are a much less extensive on the left bank downstream of Wiza Bridge. The difference in flood extents is due to a reduction in the peak flows used in the modelling, the modelling of blockage at the Innovia culverts (refer to section 3.2.5) and also the impact of the Wiza Beck flood retention basin which was not included in the 2006 study. In addition Innovia have carried out some work in the form of introducing block walls in order to prevent or disrupt flow routes developing throughout the site. The revised flood risk area is illustrated by Figure 6.1b.

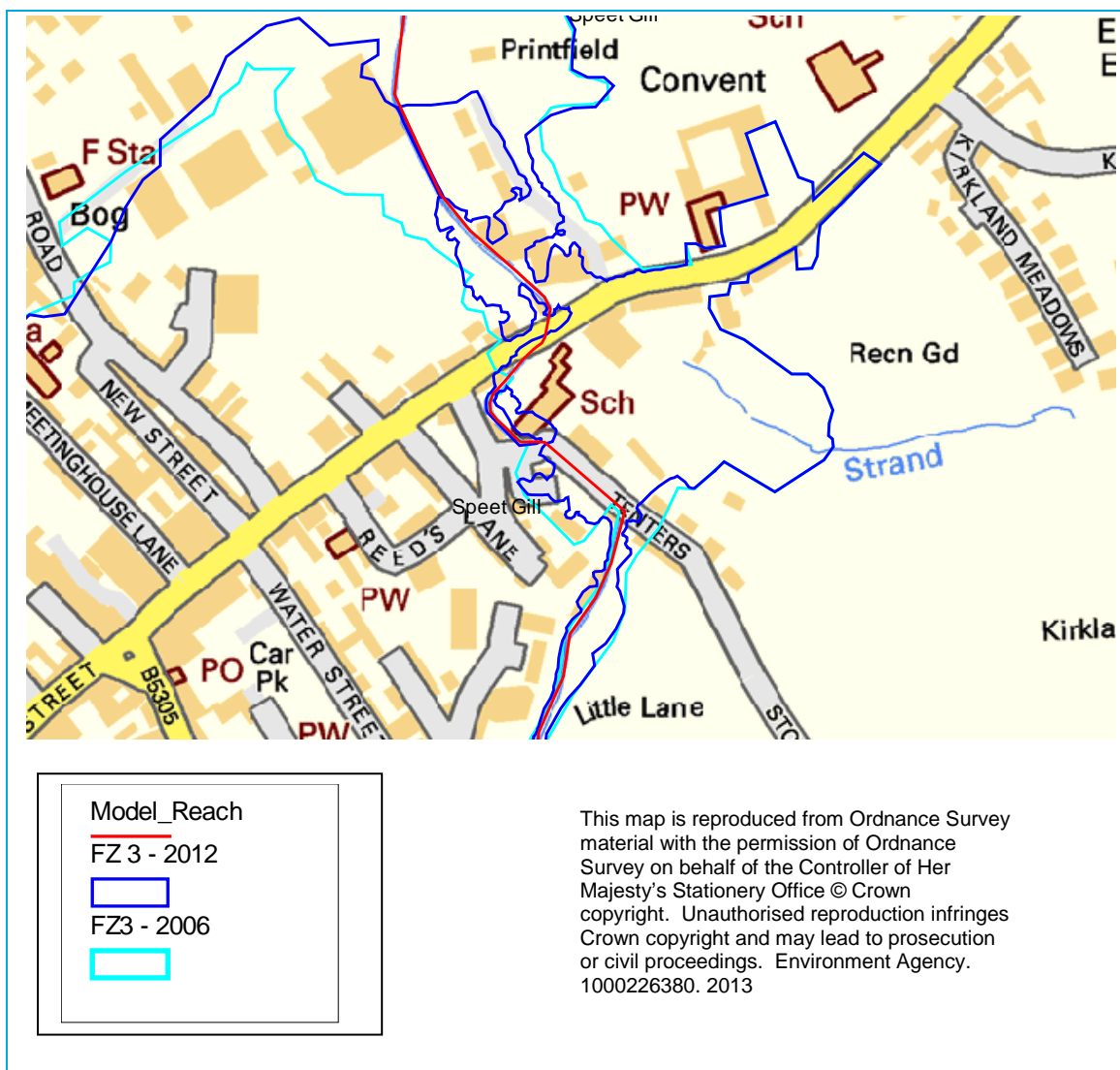
Figure 6-1b: Updated Flood Zone 3 - Wiza Beck



(3) Speet Gill

The Speet Gill flood extents are largely similar throughout much of the study reach. The main area of difference relates to the modelling of flood risk from the un-modelled Strand watercourse (located to the north east of Tenters Lane). The 2012 flood maps have not taken account of flood risk from the Strand, the flood extents for this watercourse have therefore been refined using the flood risk information identified during the 2006 flood zone update. Figure 6.1c illustrates the flood risk areas on Speet Gill.

Figure 6-1c: Updated Flood Zone 3 - Speet Gill



6.2 Effectiveness of Wiza Beck flood retention basin

As discussed in section 4.2 the model analysis has indicated that, under its current configuration, the scheme will only provide a limited benefit in terms of flood risk alleviation.

When considered as a means to reduce the speed at which a flood wave would reach the vulnerable areas of Wigton following a large rainfall event the analysis has indicated that the basin will add between 20-35 additional minutes (depending on the size of the event) to the time taken for the flood wave to reach the populated areas of the catchment.

From a flood warning perspective this is unlikely to prove significant particularly if the event occurs during the day when many residents will be at work and will be unable to implement and property level flood defence procedures. To put this in context, the time of travel for the 5-year event peak between the upstream limit of Wiza Beck (WIZA01_3379) to the Innovia site (WIZA01c_2011) prior to the scheme being built was approximately 10 minutes. With the

scheme in place the time of travel is increased to 20 minutes. The modelling has also shown that this impact is less for the larger flood events.

Developing a flood warning system on this basis would be problematic as the speed with which the flood develops will make the issuing of flood warnings with sufficient time for residents and agencies to respond difficult.

6.3 Effectiveness of Speet Gill Options

6.3.1 Throttle Structure

As discussed in section 5.2, the effectiveness of a similar throttle and embankment structure in the upper reaches of Speet Gill has also been investigated.

The practical considerations of the scheme and specifically the desire to store or 'hold' a maximum volume 10,000m³ in order to ensure that the structure is not within the remit of the Reservoirs Act of 1991 have meant that the maximum embankment height would be in region of 1.1-1.2m above existing ground levels. A retention structure based on these criteria has been shown to have a limited effect in terms of reducing flood levels and overall flood risk.

The main benefit of the scheme would be in terms of impeding the speed at which the flood wave reaches the vulnerable areas of the catchment, notably at Tenters Lane. An assessment of the model results for the existing site conditions has indicated that the time of travel of the flow peak between the proposed site of the Speet Gill throttle (SPEE02_2651) and Tenters Bridge (SPEE01_0650) is 1.5 hours for a 10-year event. The construction of the retention basin in the upper reaches of Speet Gill has been shown to add an additional 15 minutes to the time of travel.

The characteristics of the catchment mean that a flood warning system based on a level recorder located in the upper reaches of Speet Gill may prove effective as a tool for issuing warnings for the Tenters Lane area. Furthermore the introduction of a retention basin would further improve the effectiveness of any flood warning system.

6.3.2 De-siltation of Burnfoot Bridge

The analysis of the removal of silt at Burnfoot Bridge has indicated that while this would offer an improvement in channel conveyance, the benefits in terms of flood risk would be fairly minimal given the impact of other hydraulic factors such as the narrow channel and the misalignment of the structure and channel.

In summary, while the removal of the silt would reduce the blockage risk at the structure, there would be no significant impact on overall flood risk.

Appendices

A Appendix A - 2012 Survey Report

Environment Agency
NW Region



REPORT OF SURVEY

**Wiza Beck and Speet Gill
Channel Survey**

Date of Survey: October 2012

Location: Wigton, Cumbria NY 2548

JBA Consulting
Port Neuk
1 Longcraig Road
South Queensferry
EDINBURGH
EH30 9TD

Company Ref: 2012s6525

Report of Survey

Job No: 2012s6525

Date of Survey: Oct 2012

1.0 Introduction

1.1 This survey has been carried out according to the Environment Agency National Contract and Survey Specifications v3.1. It involved the survey of additional channel cross sections, structures and bank levels, to complement survey / modelling that had been carried out in 2005.

2.0 Survey Requirements

The technical requirements of the survey brief are to survey additional channel and structure cross sections on both the Wiza Beck and Speet Gill, to undertake a level survey within the Wiza Beck Flood Storage Area and to survey a number of wall heights within the town reach of the Speet Gill.

Existing survey control existed within the area from the 2005 survey, therefore no new EACS were established.

3.0 Survey Control

3.1 No new EACS's were established for the survey. It was deemed more appropriate to use existing EACS established for the original survey, and carry out a number of independent checks.

3.2 A number of checks were undertaken of hard detail to ensure the new survey data tied in with the various existing survey data sets. These included

Description	Existing Level	JBA Survey Level	Difference in Level (m)
E30110041	27.149	27.114	-0.035
Wiza Beck Bridge Soffit	26.66	26.60	-0.06
Wiza FSA Survey - US Sof	29.81	29.81	0.00
Wiza FSA Survey - DS Sof	29.78	29.78	0.00
Speet Gill Bridge US Soffit	20.92	20.89	-0.03

3.3 To ensure consistency within the survey data, the JBA survey levels were adjusted appropriately for each set of data.

3.5 The review of existing hard detail levels were checked by Robbie Cowan, Survey Manager at JBA Consulting.

4.0 Channel Survey

4.1 All cross sections and topographical detail were surveyed using Leica GPS 1200 equipment and/or Leica TS06 Total Stations. Observations were generally taken with the GPS on RTK mode. In areas where GPS proved to be an impractical or inefficient approach, Total Station observations were undertaken based on the temporary E4 control.

4.2 The following checks were made:

- Various quality checks were made with existing survey data, across the site.
- Total Station set up orientation's was set using 2 independent E4 control stations, with the misclosure reviewed.
- 2 water level reading were taken at either bank and compared for consistency.

4.3 The detail survey has been quality checked by Robbie Cowan, Survey Manager at JBA Consulting.

5.0 Presentation

5.1 Files relating to survey deliverables are submitted in files 2012s6525 Survey Data.zip.

6.0 Equipment Calibration / verification certificates



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Certificate of Calibration

901/H/CAL/S131

Certificate of Calibration Number: **C 46726** Date: **13/9/12**
 Depot Number: **901** Depot Name: **RAINBUNSH**
 Make: **LAICA** Model: **T506**
 Description: **FLAKING TOTAL STATION**
 Asset Number: **MA00 45746** Serial Number: **132318**
 Re-calibration Due: **13/9/13**

The instrument detailed above has been calibrated to the manufactures specification, detailed below, using test equipment serial no: **030126** traceable to collimator serial no: 71374
 Which is calibrated to national and international standards by a UKAS
 Accredited laboratory, registration no:0026, certificate of calibration serial no: **49276**

Manufactures deviation mm	Distance
+ - 5"	1 Km Double Run
Actual deviation mm	Distance
Within	Spec

Rod eye has been visually inspected and function tested. N/A

Remote control has been visually inspected and function tested. N/A

Signed:  Print: **Daniel Grandison**

Speedy Asset Services Limited, Chase House, 16 The Parks, Newton-le-Willows, Merseyside WA12 0JQ
 Tel. 0845 601 5129 Fax. 01942 402 870 Email. customerservices@speedyservices.com
 Co No: 06847930 VAT No: 151 6295 70

1SPH10667 (10/09) Issue 1

7.0 Comments

- 7.1 Breaching of the channel on the Speet Gill was witnessed at the time of survey, about 20m down stream from cross section SPET01_2528. The survey had to be abandoned at this time due to the high water levels, with it progressing the following week. The surveyed water levels along the Speet Gill therefore do show a marked drop between SPET01_2528 and SPET01_2625.



Survey Report Prepared by: Robbie Cowan Date: 2 November 2012

Job Title: Survey Manager

Appendix A – Existing EA Survey Control Used

E30110041

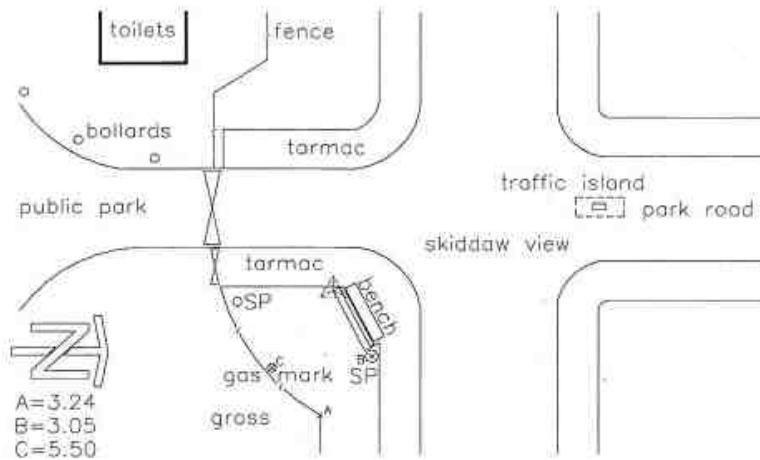


**ENVIRONMENT
AGENCY**

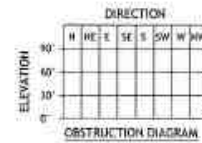
E3 GPS STATION DESCRIPTION

STN: E30110041

WITNESS DIAGRAM



A=3.24
B=3.05
C=5.50



O.S. GRID REFERENCE:
(8 FIGURES)

NY 2500 4815

LOCATION:

Skiddaw View, Wigton

DESCRIPTION:

Brass stud in concrete surround of bench

SURVEYED BY:

atlantic geomatics (uk) ltd

DATE SURVEYED: 19/08/2005

JOB NUMBER: 2031

SESSION TIME 2x 30min



NETWORK BASED ON GPS STATIONS

1. E20110009 3. 5.
2. E20110111 4. 6.

ALTITUDE COMPARISON BASED ON EXISTING BENCHMARKS

1. type:
ALTITUDE FROM OLD BM SYSTEM(m) ODN:

ETRS89 CO-ORDINATES

LATITUDE: 54°49'21.27277"N
LONGITUDE: 3°10'07.66387"W
ELLIPSOIDAL HEIGHT (m): 79.999

OSGB36 CO-ORDINATES:

(CONVERTED BY OSTN02/OSGM02)

EASTING: 325001.990

NORTHING: 548151.329

ALTITUDE (m) ODN: 27.149

(GPS ORTHOMETRIC HEIGHT)

EVERY USER HAS BEEN TAKEN INTO ACCOUNT THE INFORMATION IN THIS RESPONSIBILITY FOR ANY OCCASIONED BY ANY PERSON ACTING UNDER INFORMATION HAS BEEN ACCEPTED BY THE ROYAL CANADIAN AGENCY

VALIDATED:-

K.M. Square: NY 2548

Appendix B – New EA Survey Control Established

None

B Appendix B - Hydrological Analysis

Flood estimation calculation record

Introduction

This calculation record is based on a supporting document to the Environment Agency’s flood estimation guidelines (Version 4, 2012). It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

Contents

1	Method statement	1
2	Locations where flood estimates required	5
3	Statistical method	9
4	Revitalised flood hydrograph (ReFH) method	14
6	Discussion and summary of results	16
7	Annex – supporting information	19

Approval

	Name and qualifications
Calculations prepared by:	Mark Tywang BSc
Calculations checked by:	Duncan Faulkner MSc DIC MA FCIWEM C.WEM CSci

Abbreviations

AM.....	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE.....	Council for the Protection of Rural England
FARL.....	FEH index of flood attenuation due to reservoirs and lakes
FEH.....	Flood Estimation Handbook
FSR.....	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT.....	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR.....	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: <ul style="list-style-type: none"> Purpose of study Approx. no. of flood estimates required Peak flows or hydrographs? Range of return periods and locations 	<p>A flood mapping study of the catchment area of Wigton was previously carried out in 2005. Updates to the hydraulic model and the design flood estimates used in the 2005 study are now being undertaken in order to make better use of recent data.</p> <p>Flood hydrographs are required for the 2, 5, 10, 25, 50, 75, 100, 100 (plus climate change) and 1,000 year return periods.</p> <p>Estimates are required at a number of locations along Wiza Beck and its tributaries.</p>

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	<p>Wigton is a largely rural catchment (except Wigton town itself URBEXT=0.28) situated at the transition from steeper upland watercourses of the northern outliers of the Lake District hills to much flatter lowland rivers of the flat Cumbrian coastal plain.</p> <p>The geology of the catchment is predominantly Permo-Triassic sandstones and the principal soil is Clifton, slowly permeable seasonally waterlogged fine and coarse loamy soils derived from reddish till.</p>

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Yes – Version 3.1.2, December 2011
---	------------------------------------

1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catchment area (km ²)	Type (rated / ultrasonic / level...)	Start and end of flow record
Speet Gill	King Street	755820	n/a	NY 25750 48509	6.52	Level	01/2006 - 02/2013
Speet Gill	Low Mill	755815	n/a	NY 26270 48200	6.07	Level	01/2006 - 02/2013

Notes: These gauges are formally level-only however a stage-discharge rating was recently developed for the King Street gauge.

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality e.g. information from HiFlows-UK, trends in flood peaks, outliers.
N/A						
Give link/reference to any further data quality checks carried out						
Note – include plots of flood peak and flood hydrograph data at relevant gauging stations along with interpretation, e.g. in the Annex.						

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons e.g. availability of recent flow gaugings, amount of scatter in the rating.
Speet Gill	Modelled high flow rating	No	The rating has been derived from the 2013 Wigton SFRM model, with some minor modifications. The stage-discharge relationship is that for model node SPET 01 650. The high flow control is Tenters Bridge, which is approximately 2m downstream of the gauged section. No check gaugings are available for the site.
Give link/reference to any rating reviews carried out		N/A	
Source of rating		JBA Consulting	
Datum		20.54mAOD - estimated from analysis of gauge record and levels measured during survey.	
Limb	Min Stage (m)	Max Stage (m)	Form of rating (e.g. $Q=K * (h + a) ^p$)
1	0.55	0.67	$Q = 2.894 * (h+0.00) ^ 1.907$
2	0.665	0.748	$Q = 5.301 * (h+0.00) ^ 3.394$
3	0.748	1.020	$Q = 3.422 * (h+0.00) ^ 1.868$
4	1.020	1.189	$Q = 3.528 * (h+0.00) ^ 0.323$
5	1.189	1.320	$Q = 2.972 * (h+0.00) ^ 1.302$

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data and licence reference if from EA	Date obtained	Details
Check flow gaugings (if planned to review ratings)	Yes	No			
Historic flood data – give link to historic review if carried out.	Yes	Yes	CBHE – British Chronologist (2 nd Edition)	2005	Details of 8 flood events – see table below.
Flow data for events	Yes	Yes- Level only	Environment Agency	2013	2006 – 2013 - Level data from King Street logger

Rainfall data for events	Yes	No			
Potential evaporation data	Yes	No			
Results from previous studies	Yes	Yes	JBA Consulting	2005	2005s1218 – Wampool Flood Mapping Study – Wigton HEC-RAS model and included in report.
Other data or information (e.g. groundwater, tides)	No	No			

1.8 Flood history

Source	Date Sourced	Details of flood event
CBHE – British Chronologist (2 nd Edition)	2005	02/08/1758 – Great flooding of Wigton – bridges swept away and 6ft high in houses
http://www.stevebulman.f9.co.uk/cumbria/dalston.html	2005	1803 – Flooding in headwaters of Wampool.
Old Wigton by Trevor Grahamslaw (2003)	2005	19 th century - Station Road in Wigton was known as Bog Road and it flooded regularly in the 19th century.
Old Wigton by Trevor Grahamslaw (2003) & Cumberland News for 25 September 1926.	2005	19-Sep-1926 - Notable flood at Wigton. Roads flooded at Western Bank [Black Beck], Burnfoot [Speet Gill] and Station Road [Wiza Beck]. Flow estimated at 28m ³ /s.
18-Nov-1991	2005	Flood level of 17.15mAOD on Wiza Beck downstream of railway bridge, Wigton.
11-Jan-2000	2005	11-Jan-2000 - Flood outline for Wigton: Strand Terrace and church to east of Burnfoot Bridge. Possibly due to minor watercourse, the Strand?
EA digital data, photographs and notes from site visit	2005	31-Jan-2004 - Flooding at Wigton: Station Road and Burnfoot Bridge. 6 commercial and 1 residential properties flooded around Station Road. 4 commercial properties affected at Burnfoot Bridge. Water came out of bank both upstream and downstream of the bridge on the right bank.
EA digital data, photographs and notes from site visit	2005	07-Jan-2005 - Flooding in Wigton: Station Road (8 businesses, fire station, TA centre, caravan site, 3 houses) and Burnfoot Bridge (3 businesses, 1 school, 4 houses).

1.9 Initial choice of approach

<p>Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.</p>	<p>FEH Statistical and ReFH rainfall runoff methods are appropriate for this catchment. However, the FEH rainfall runoff method was used for the previous study with similar results to the updated ReFH rainfall runoff methods.</p> <p>The Floss Beck catchment is small, urbanised and not available on the FEH CD-ROM. Previous guidelines would suggest the FEH statistical method is not suitable for a catchment this small but this is now outdated and the original catchment descriptors used for the previous study have been processed with the latest FEH methods to estimate flood flow.</p>
<p>Outline the conceptual model, addressing questions such as:</p> <ul style="list-style-type: none"> • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides...) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse? 	<p>Update hydrology to produce flood estimation points for the Wigton catchment (Wiza Beck, Speet Gill and their associated tributaries) and to run in an existing HEC-RAS model (2005s1218 – Wampool Flood Mapping Study).</p> <p>The main sites of interest are the built up residential areas of Wigton and the key pinch points of West Street bridge on Speet Gill and Station Road at the Wiza Beck and Black Beck confluence.</p>
<p>Any unusual catchment features to take into account?</p> <p>e.g.</p> <ul style="list-style-type: none"> • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully 	<p>None.</p>
<p>Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?</p>	<p>To keep in line with the previous 2005 study the ReFH rainfall runoff method has been chosen due to its similar resulting flood estimation points. Also, data from the level gauge on Speet Gill was used to extract a POT rating to compare with the estimated flows.</p>
<p>Software to be used (with version numbers)</p>	<p>FEH CD-ROM v3.0¹ WINFAP-FEH v3.0.002² / ReFH spreadsheet / HEC-RAS</p>

¹ FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

² WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

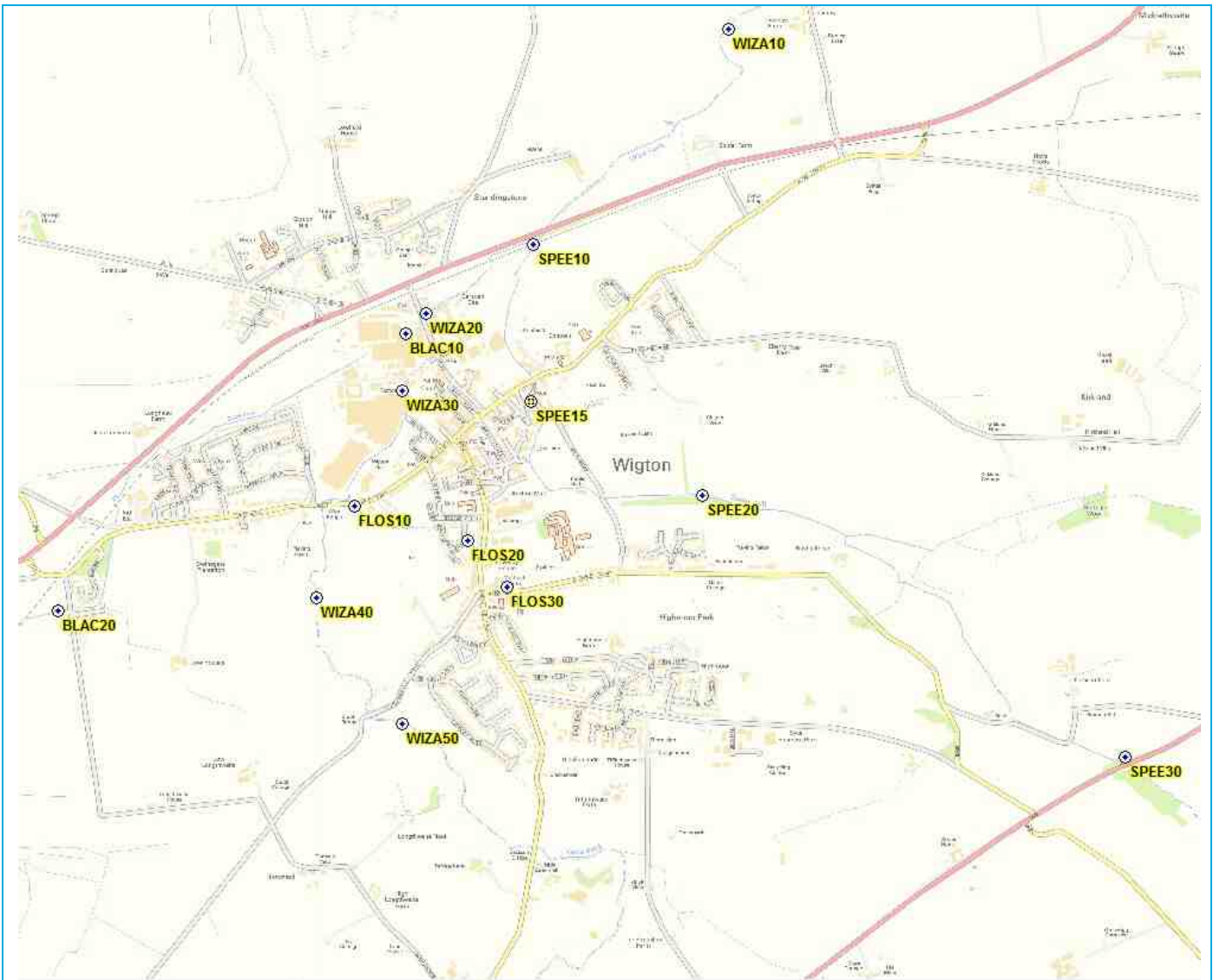
Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km ²)	Revised AREA if altered
BLAC10	Black Beck	Confluence with Wiza Beck	325300	548750	7.21	N/A
BLAC20	Black Beck	Upstream model limit	324150	547800	5.74	N/A
FLOS10_2012	Flosh Beck	Confluence with Wiza Beck	326100	547000	0.86	N/A
SPEE10	Speet Gill	Confluence with Wiza Beck	325750	549050	6.96	N/A
SPEE15 – King Street gauge	Speet Gill	Upstream of Tenters Bridge	325750	548500	6.52	N/A
SPEE20	Speet Gill	Old model upstream limit	326400	548200	6.04	N/A
SPEE30	Speet Gill	Upstream model limit	327850	547200	3.71	N/A
WIZA10	Wiza Beck	Downstream of Spital Farm	326450	549800	36.87	N/A
WIZA15	Wiza Beck	Downstream of Speet Gill	325800	549100	34.48	N/A
WIZA20	Wiza Beck	Station Rd, Wigton	325350	548800	27.36	N/A
WIZA30	Wiza Beck	Weir at Innovia factory	325300	548500	20.05	N/A
WIZA40	Wiza Beck	Old model upstream limit	325000	547800	19.27	N/A
WIZA50	Wiza Beck	Upstream model limit	325300	547400	19.05	N/A
Reasons for choosing above locations		Subject sites chosen at key locations throughout the model catchment; upstream model limit, confluences (upstream and downstream) and downstream limits of tributaries to Wiza Beck.				

2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT	FPEXT
BLAC10	0.992	0.62	0.505	3.88	28.8	902	35.15	0.017	0.1715
BLAC20	0.990	0.62	0.537	2.74	31.1	911	34.01	0.000	0.1638
FLOS10_2012	1.000	0.62	0.479	0.74	31.4	887	36.2	0.290	0.1289
SPEE10	1.000	0.62	0.403	4.28	41.2	892	38.93	0.019	0.0934
SPEE15 – King Street gauge	1.000	0.62	0.404	3.88	42.7	894	38.88	0.011	0.0834
SPEE20	1.000	0.62	0.406	3.13	43.5	897	38.82	0.001	0.0775
SPEE30	1.000	0.62	0.399	2.09	45.4	914	39.16	0.000	0.0377
WIZA10	0.999	0.62	0.424	8.00	49.0	933	37.85	0.016	0.1005
WIZA15	0.998	0.62	0.423	7.39	51.2	938	37.84	0.016	0.0877
WIZA20	0.998	0.62	0.429	7.50	53.8	951	37.56	0.015	0.0844
WIZA30	1.000	0.62	0.401	8.46	63.0	969	38.43	0.011	0.0522
WIZA40	1.000	0.62	0.402	7.86	64.3	973	38.38	0.004	0.0504
WIZA50	1.000	0.62	0.403	7.39	64.6	974	38.36	0.003	0.0489

The map below shows the distribution of flood estimation point throughout the Wiza Beck catchment.

Figure 1: Flood estimation point locations



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2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	Catchment boundaries have been checked against OS OpenData and MasterMap mapping, LIDAR and a site visit to confirm.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	Soils checked on the Cranfield University - National Soil Resources Institute website maps; "Main soil type is slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils". Therefore, the SPRHOST values appear to be reasonable.
Source of URBEXT	URBEXT1990
Method for updating of URBEXT	CPRE formula from FEH Volume 4

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

<p>Comment on potential donor sites</p> <p>Mention:</p> <ul style="list-style-type: none"> Number of potential donor sites available Distances from subject site Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors Quality of flood peak data <p>Include a map if necessary. Note that donor catchments should usually be rural.</p>	<p>There are no good quality local donor records from catchments with similar characteristics in terms of size, urbanisation and geology.</p> <p>A check on the estimated QMED has been achieved by estimating LMED from the historic stage record at King Street and applying the JBA rating curve.</p>
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3.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)
King Street	Gauge covering flows from the study catchment (Speet Gill)	PoT	N/A	2.53	2.60	0.97

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m ³ /s)	Data transfer						Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d _{ij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B) ^a	If more than one donor		
							Weight	Weighted ave. adjustment	
BLAC 10	CD	2.11	N/A	N/A	N/A	N/A	N/A	N/A	2.11
BLAC 20	CD	1.49	N/A	N/A	N/A	N/A	N/A	N/A	1.49
FLOS 10_2012	CD	0.42	N/A	N/A	N/A	N/A	N/A	N/A	0.42
SPEE 10	CD	2.83	N/A	N/A	N/A	N/A	N/A	N/A	2.83
SPEE 15 - King Street gauge	CD	2.6	N/A	N/A	N/A	N/A	N/A	N/A	2.6
SPEE 15 - King Street gauge	POT	2.53	N/A	N/A	N/A	N/A	N/A	N/A	2.53
SPEE 20	CD	2.40	N/A	N/A	N/A	N/A	N/A	N/A	2.40

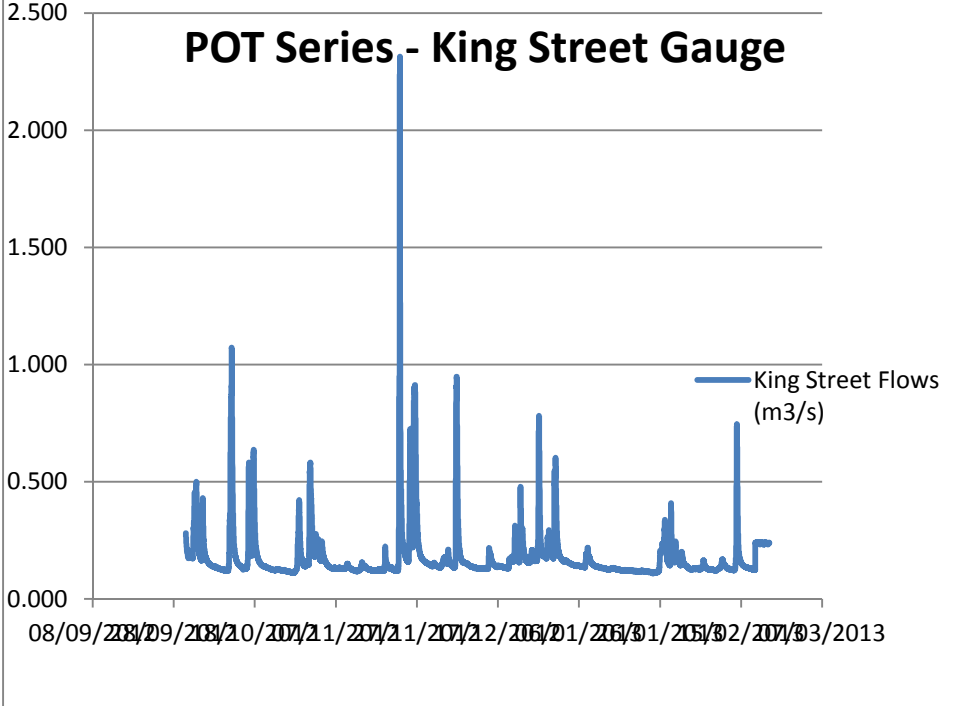
SPEE 30	CD	1.59	N/A	N/A	N/A	N/A	N/A	N/A	1.59
WIZA 10	CD	12.83	N/A	N/A	N/A	N/A	N/A	N/A	12.83
WIZA 15	CD	12.21	N/A	N/A	N/A	N/A	N/A	N/A	12.21
WIZA 20	CD	9.94	N/A	N/A	N/A	N/A	N/A	N/A	9.94
WIZA 30	CD	8.48	N/A	N/A	N/A	N/A	N/A	N/A	8.48
WIZA 40	CD	8.13	N/A	N/A	N/A	N/A	N/A	N/A	8.13
WIZA 50	CD	8.02	N/A	N/A	N/A	N/A	N/A	N/A	8.02
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?						Yes			
<p>Important note on urban adjustment</p> <p>The method used to adjust QMED for urbanisation, for both subject sites and donor sites, is that published in Kjeldsen (2010)³ in which PRUAF is calculated from BFIHOST. The result will differ from that of WINFAP-FEH v3.0.003 which does not correctly implement the urban adjustment of Kjeldsen (2010). Significant differences will occur only on urban catchments that are highly permeable.</p>									
<p>Notes</p> <p>Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.</p> <p>When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below.</p> <p>The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is (A/B)^a times the initial estimate from catchment descriptors.</p> <p>If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.</p>									

The similarity between the estimates of QMED calculated from data at King Street and from catchment descriptors (0.97 multiplier) suggests that the catchment descriptor approach will provides a robust estimate of QMED in the Wigton catchment.

Given the verification of the QMED estimates provided by the analysis of the gauged data, it was therefore decided that the use of catchment descriptors to estimate QMED was the most appropriate method by which to estimate QMED for the entire study reach.

³ Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. *Hydrol. Res.* **41**. 391-405.

3.3.1 Note on POT data

Source of POT DATA	Level data up to the end of the 2012 hydrometric year were provided by the Environment Agency. The relevant POT values were extracted from these by applying a threshold of 0.281m. These levels were subsequently used to calculate POT flows for Speet Gill, using the JBA Rating Curve.
Total number of POT	18
Rejected years	2005 and 2012 (incomplete records)
Chart	 <p>The chart displays the POT series for King Street Gauge. The x-axis represents the hydrometric year from 08/09 to 12/13. The y-axis represents flow in m³/s, ranging from 0.000 to 2.500. The data shows several peaks, with the highest peak occurring in the 2011/12 year, reaching approximately 2.3 m³/s. Other notable peaks are seen in 2009/10, 2010/11, 2011/12, 2012/13, and 2013/14.</p>
Comments and characteristics	Length of POT record should be sufficient to estimate QMED, record contains a number of large flood peaks above 2.5 m ³ /s.
LMED from POT data	The value of LMED (the 2-year return period level) from the POT series is 0.85m.
QMED from POT data	The value of QMED based on applying the Rating Curve to LMED is 2.53m ³ s ⁻¹ . This is around 3% lower than the catchment-descriptor based estimate of QMED.

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
BLAC10	BLAC10	No	Site "Flore" removed <8year of data	0.261 + 0.197
BLAC20	BLAC20	No	Site "Flore" removed <8year of data	0.248 + 0.195
FLOS10_2012	FLOS10_2012	No	Site "Flore" removed <8year of data	0.225 + 0.229
SPEE10	SPEE10	No	None	0.254 + 0.220
SPEE15 - King Street gauge	SPEE15 - King Street gauge	No	Site "Flore" removed <8year of data	0.248 + 0.229
SPEE20	SPEE20	No	Site "Flore" removed <8year of data	0.250 + 0.232
SPEE30	SPEE30	No	None	0.230 + 0.246
WIZA10	WIZA10	No	"Keer@ High Keer Weir" removed discordant	0.234 + 0.150
WIZA15	WIZA15	No	"Keer@ High Keer Weir" removed discordant	0.234 + 0.185
WIZA20	WIZA20	No	None	0.231 + 0.135
WIZA30	WIZA30	No	"Piddle@ Little Puddle" removed discordant	0.228 + 0.179
WIZA40	WIZA40	No	"Piddle@ Little Puddle" removed discordant	0.229 + 0.179
WIZA50	WIZA50	No	"Piddle@ Little Puddle" removed discordant	0.229 + 0.179

Notes

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape) after adjustments)	Growth factor for 100-year return period
BLAC10	P	BLAC10	Generalised logistic	Not adjusted	Not adjusted	4.05
BLAC20	P	BLAC20	Generalised logistic	Not adjusted	Not adjusted	2.87
FLOS10_2012	P	FLOS10_2012	Generalised logistic	Not adjusted	Not adjusted	2.83
SPEE10	P	SPEE10	Generalised logistic	Not adjusted	Not adjusted	3.02

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape) after adjustments)	Growth factor for 100-year return period
SPEE 15 – King Street gauge	P	SPEE15 – King Street gauge	Generalised logistic	Not adjusted	Not adjusted	3.03
SPEE 20	P	SPEE20	Generalised logistic	Not adjusted	Not adjusted	3.07
SPEE 30	P	SPEE30	Generalised logistic	Not adjusted	Not adjusted	3.55
WIZA 10	P	WIZA10	Generalised logistic	Not adjusted	Not adjusted	2.58
WIZA 15	P	WIZA15	Generalised logistic	Not adjusted	Not adjusted	2.72
WIZA 20	P	WIZA20	Generalised logistic	Not adjusted	Not adjusted	2.50
WIZA 30	P	WIZA30	Generalised logistic	Not adjusted	Not adjusted	2.65
WIZA 40	P	WIZA40	Generalised logistic	Not adjusted	Not adjusted	2.65
WIZA 50	P	WIZA50	Generalised logistic	Not adjusted	Not adjusted	3.29

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the v3 method: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008).

3.6 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	5	10	25	50	75	100	100 CC	1000
BLAC10	2.11	3.11	3.97	5.39	6.78	7.76	8.54	10.25	18.62
BLAC20	1.49	2.08	2.51	3.14	3.67	4.01	4.27	5.13	6.95
FLOS10_2012	0.42	0.57	0.69	0.86	1.01	1.11	1.19	1.43	2.01
SPEE10	2.83	3.98	4.84	6.12	7.24	7.97	8.53	10.23	14.53
SPEE15 King St	2.62	3.68	4.48	5.67	6.72	7.41	7.93	9.52	13.63
SPEE20	2.40	3.39	4.14	5.25	6.23	6.88	7.37	8.84	12.75
SPEE30	1.59	2.38	2.98	3.88	4.69	5.23	5.65	6.77	10.23
WIZA10	12.83	17.55	20.81	25.31	29.03	31.37	33.11	39.73	49.99
WIZA15	12.21	16.78	20.05	24.72	28.70	31.24	33.16	39.79	52.69
WIZA20	9.94	13.52	15.95	19.26	21.96	23.64	24.89	29.87	36.73
WIZA30	8.48	11.57	13.77	16.90	19.54	21.23	22.50	27.00	35.32
WIZA40	8.13	11.10	13.21	16.21	18.74	20.36	21.58	25.90	33.87
WIZA50	8.02	11.23	13.82	17.92	21.75	24.36	26.41	31.69	50.86

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

Site code	Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	T _p (hours) Time to peak	C _{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
BLAC10	CD	2.19	350	30.1	1.51
BLAC20	CD	1.84	371	30.3	1.61
FLOS10_2012	CD	0.36	333	10.1	1.43
SPEE10	CD	2.08	282	27.4	1.18
SPEE20	CD	1.81	284	27.2	1.19
SPEE30	CD	1.14	280	24.9	1.17
WIZA10	CD	2.93	296	32.4	1.25
WIZA15	CD	2.75	296	31.8	1.25
WIZA20	CD	2.75	300	32.2	1.27
WIZA30	CD	2.87	281	32.4	1.18
WIZA40	CD	2.79	282	32.6	1.18
WIZA50	CD	2.7	282	32.3	1.18
Brief description of any flood event analysis carried out (further details should be given below or in a project report)					

4.2 Design events for ReFH method

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
BLAC10	Rural	Winter	4.2	0.95
BLAC20	Rural	Winter	3.4	0.95
FLOS10_2012	Urban	Winter	0.6	0.95
SPEE10	Rural	Winter	3.8	0.95
SPEE20	Rural	Winter	3.4	0.95
SPEE30	Rural	Winter	2.6	0.96
WIZA10	Rural	Winter	5.8	0.93
WIZA15	Rural	Winter	5.4	0.93
WIZA20	Rural	Winter	5.4	0.93
WIZA30	Rural	Winter	5.4	0.94
WIZA40	Rural	Winter	5.4	0.94
WIZA50	Rural	Winter	5.4	0.94
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			No	

4.3 Flood estimates from the ReFH method

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	5	10	25	50	75	100	100 CC	1000
BLAC10	3.44	4.45	5.23	6.20	7.07	7.65	8.10	9.72	13.34
BLAC20	2.79	3.62	4.27	5.09	5.82	6.31	6.68	8.02	11.10
FLOS10_2012	0.92	1.28	1.56	1.95	2.29	2.53	2.71	3.25	4.92
SPEE10	3.89	5.07	5.99	7.15	8.19	8.88	9.42	11.31	15.73
SPEE20	3.62	4.74	5.62	6.72	7.71	8.37	8.88	10.66	14.88
SPEE30	2.55	3.36	4.01	4.83	5.57	6.06	6.44	7.73	10.96
WIZA10	17.92	23.03	26.99	31.88	36.27	39.18	41.44	49.72	67.67
WIZA15	14.26	22.22	26.07	40.18	35.13	37.98	40.18	48.22	65.85
WIZA20	13.81	17.77	20.85	24.67	28.09	30.37	32.13	38.56	52.70
WIZA30	10.49	13.53	15.88	18.81	21.44	23.19	24.55	29.46	40.48
WIZA40	10.29	13.27	15.59	18.47	21.06	22.79	24.12	28.95	39.78
WIZA50	10.40	13.42	15.76	18.68	21.29	23.04	24.39	29.26	40.29

6 Discussion and summary of results

6.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 2 years			Return period 100 years		
	ReFH	Statistical	POT	ReFH	Statistical	POT
BLAC10	3.44	2.11		8.10	8.54	
BLAC20	2.79	1.49		6.68	4.27	
FLOS10_2012	0.92	0.42		2.71	1.19	
SPEE10	3.89	2.83		9.42	8.53	
SPEE15 King St gauge	n/a	2.62	2.53		7.93	
SPEE20	3.62	2.40		8.88	7.37	
SPEE30	2.55	1.59		6.44	5.65	
WIZA10	17.92	12.83		41.44	33.11	
WIZA15	14.26	12.21		40.18	33.16	
WIZA20	13.81	9.94		32.13	24.89	
WIZA30	10.49	8.48		24.55	22.50	
WIZA40	10.29	8.13		24.12	21.58	
WIZA50	10.40	8.02		24.39	26.41	

6.2 Final choice of method

<p>Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.</p>	<p>The preference, for this watercourse, is to use those estimates derived using the Statistical Method. The estimates from ReFH are somewhat similar, giving values that are higher than the estimates from the Statistical Method. The agreement of ReFH and Statistical Method estimates is not a reason in itself to accept either set of estimates, however it does lend confidence in the results. In both cases the flow magnitudes seem commensurate with the catchment size and characteristics.</p> <p>An estimate of LMED has been derived by extracting the POT series from the level gauge at King Street. The LMED estimate is considered robust. The uncertainty arises from the application of the rating curve, which is derived from a model that has not been calibrated to a sufficiently wide range of check gaugings, to determine a gauged value of QMED. This yields a value that is remarkably similar to the catchment-descriptor based estimate, suggesting good confidence in the statistical method estimates.</p> <p>The previous flows estimates (2005) used the Rainfall-Runoff method for all catchments except Flosch Beck which, due to its small catchment area used the IH124 method, which was recommended at the time for the estimation of flows in small catchments. This method is no longer recommended for use for flow estimation on small catchments in the latest EA FEH Guidelines (page 90) and has therefore not been used for the 2012 update.</p> <p>The analysis of the hydrometric data at Kings Street and the subsequent strengthening of the outputs from the FEH Statistical method has meant that this approach is considered the most robust for all of the study reaches, including Flosch Beck.</p>
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6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	It has been assumed that the pooling group catchments accurately represent the hydrological attributes of the catchments requiring estimates. It is assumed that flow data is recorded accurately at gauging stations used in the pooling groups.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	The LMED estimate derived from the 2013 HECRAS model is not calibrated with a wide range of flow gaugings. Therefore the resulting flow estimates may not truly represent flows through the catchment.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008).	There is uncertainty in the accuracy of the catchment descriptors and the methods used to determine flow from the catchment descriptors.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The lack of flow data for the study catchments means that the flood estimates must be treated with care, and as such are probably not transferable. This study was undertaken solely to define flood risk maps and floodplains with return periods of 2 to 1000 years. Before the results are used for any other purposes a review of hydrology is recommended.
Give any other comments on the study, for example suggestions for additional work.	More level or in particular flow data would be very useful to validate these estimates. Check gaugings would be useful to allow the uncertainty associated with the rating curve to be estimated.

6.4 Checks

Are the results consistent, for example at confluences?	The sum of the upstream estimates is slightly greater than the downstream estimate at one of the confluences. This is to be expected. BLAC10 plus WIZA30 equals 10.59 and the downstream estimate at WIZA20 is 9.94
What do the results imply regarding the return periods of floods during the period of record?	There were no flow records available for the study sites.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	The 100 year growth factor ranges from 2.50 to 4.05. This is within the expected range. The catchment is partially rural so a moderate to steep growth curve is expected.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The ratio between the 100 year and 1000 year ranges from 1.48 to 2.18. The normal expected range for the ratios from the 2009 EA Flood estimation Guidelines is a range of 1.6 to 2.0, but up to 3.3 on highly permeable catchments. The ratio for this study falls inside the normal expected range.
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	The specific runoff ranges from 7.44 to 15.22l/s/ha. These are within the expected range for a catchment with no unusual characteristics.
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	A full set of design flows were calculated for the 2005 River Wampool Flood mapping study. The peak flows were calculated using the Rainfall-Runoff method. The analysis has shown that typically the 2005 flows are higher by

	<p>anything from 10-30% than the 2012 estimates. Despite being less conservative the 2012 estimates are considered more appropriate as they make use of the most up to date techniques as well making use of the gauged record from Kings Street on Speet Gill.</p>
Are the results compatible with the longer-term flood history?	Preliminary model simulations have shown that the design flows used in the modelling produce patterns of flooding similar to that from previous flood events.
Describe any other checks on the results	<p>Soil types and catchment areas checked with mapping and adjusted where necessary. Checked that flows increase from upstream to downstream. Checked consistency at confluences.</p>

6.5 Final results

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	5	10	25	50	75	100	100CC	1000
BLAC10	2.11	3.11	3.97	5.39	6.78	7.76	8.54	10.25	18.62
BLAC20	1.49	2.08	2.51	3.14	3.67	4.01	4.27	5.13	6.95
FLOS10_2012	0.42	0.57	0.69	0.86	1.01	1.11	1.19	1.43	2.01
SPEE10	2.83	3.98	4.84	6.12	7.24	7.97	8.53	10.23	14.53
SPEE20	2.40	3.39	4.14	5.25	6.23	6.88	7.37	8.84	12.75
SPEE30	1.59	2.38	2.98	3.88	4.69	5.23	5.65	6.77	10.23
WIZA10	12.83	17.55	20.81	25.31	29.03	31.37	33.11	39.73	49.99
WIZA15	12.21	16.78	20.05	24.72	28.70	31.24	33.16	39.79	52.69
WIZA20	9.94	13.52	15.95	19.26	21.96	23.64	24.89	29.87	36.73
WIZA30	8.48	11.57	13.77	16.90	19.54	21.23	22.50	27.00	35.32
WIZA40	8.13	11.10	13.21	16.21	18.74	20.36	21.58	25.90	33.87
WIZA50	8.02	11.23	13.82	17.92	21.75	24.36	26.41	31.69	50.86

<p>If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)</p>	<p>N:\2012\Projects\2012s6525 - Environment Agency - North West Region - Wigton - HEC-RAS Model\Calculations\Hydrology\Flood hydrographs</p>
---	--

7 Annex – supporting information

7.1 Pooling group composition

Pool 1 (BLAC10) – Default pooling group

27073	Brompton Beck	Snainton Ings	1980 to 2008
44009	Wey	Broadwey	1975 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
45816	Haddeo	Upton	1992 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
28033	Dove	Hollinsclough	1965 to 2008
25019	Leven	Easby	1970 to 2008
20002	West Peffer Burn	Luffness	1965 to 2005
33045	Wittle	Quidenham	1967 to 2008
36009	Brett	Cockfield	1967 to 2008
29009	Ancholme	Toft Newton	1974 to 2008
25003	Trout Beck	Moor House	1962 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
72014	Conder	Galgate	1965 to 2008

Pool 2 (BLAC20) - Default pooling group

27073	Brompton Beck	Snainton Ings	1980 to 2008
44009	Wey	Broadwey	1975 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
45816	Haddeo	Upton	1992 to 2008
28033	Dove	Hollinsclough	1965 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
76011	Coal Burn	Coalburn	1966 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
25019	Leven	Easby	1970 to 2008
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
25003	Trout Beck	Moor House	1962 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
20002	West Peffer Burn	Luffness	1965 to 2005
36009	Brett	Cockfield	1967 to 2008
206006	Annalong	Recorder 1895	1894 to 1942
33045	Wittle	Quidenham	1967 to 2008

Pool 3 (FLOS10_2012) - Default pooling group

76011	Coal Burn	Coalburn	1966 to 2008
45817	Rhb Trib to Haddeo	Upton (Trib)	1992 to 2008
54092	Severn	Hore Flume	1973 to 2008
54091	Severn	Hafren Flume	1975 to 2008
45816	Haddeo	Upton	1992 to 2008
44009	Wey	Broadwey	1975 to 2008
27073	Brompton Beck	Snainton Ings	1980 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
28033	Dove	Hollinsclough	1965 to 2008
91802	Allt Leachdach	intake	1938 to 1974
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
54022	Severn	Plynlimon flume	1951 to 2008
25003	Trout Beck	Moor House	1962 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
25019	Leven	Easby	1970 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
206006	Annalong	Recorder 1895	1894 to 1942

Pool 4 (SPEE10) - Default pooling group

44009	Wey	Broadwey	1975 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
45816	Haddeo	Upton	1992 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
28033	Dove	Hollinsclough	1965 to 2008
25019	Leven	Easby	1970 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
27073	Brompton Beck	Snainton Ings	1980 to 2008
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977
25003	Trout Beck	Moor House	1962 to 2008
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
206006	Annalong	Recorder 1895	1894 to 1942
50009	Lew	Norley Bridge	1987 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007
49003	De Lank	De Lank	1966 to 2008

Pool 4 (SPEE15 – King Street gauge) - Default pooling group

44009	Wey	Broadway	1975 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
45816	Haddeo	Upton	1992 to 2008
28033	Dove	Hollinsclough	1965 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
25019	Leven	Easby	1970 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977
25003	Trout Beck	Moor House	1962 to 2008
206006	Annalong	Recorder 1895	1894 to 1942
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
27073	Brompton Beck	Snainton Ings	1980 to 2008
50009	Lew	Norley Bridge	1987 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007
76011	Coal Burn	Coalburn	1966 to 2008

Pool 5 (SPEE20) - Default pooling group

44009	Wey	Broadway	1975 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
45816	Haddeo	Upton	1992 to 2008
28033	Dove	Hollinsclough	1965 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
25019	Leven	Easby	1970 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
25003	Trout Beck	Moor House	1962 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977
206006	Annalong	Recorder 1895	1894 to 1942
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
76011	Coal Burn	Coalburn	1966 to 2008
50009	Lew	Norley Bridge	1987 to 2008
27073	Brompton Beck	Snainton Ings	1980 to 2008
45817	Rhb Trib to Haddeo	Upton (Trib)	1992 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007

Pool 6 (SPEE30) - Default pooling group

45816	Haddeo	Upton	1992 to 2008
44009	Wey	Broadwey	1975 to 2008
27051	Crimple	Burn Bridge	1972 to 2008
45817	Rhb Trib to Haddeo	Upton (Trib)	1992 to 2008
76011	Coal Burn	Coalburn	1966 to 2008
28033	Dove	Hollinsclough	1965 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
54091	Severn	Hafren Flume	1975 to 2008
25011	Langdon Beck	Langdon	1969 to 2008
25019	Leven	Easby	1970 to 2008
54092	Severn	Hore Flume	1973 to 2008
26802	Gypsey Race	Kirby Grindalythe	1997 to 2008
25003	Trout Beck	Moor House	1962 to 2008
91802	Allt Leachdach	intake	1938 to 1974
206006	Annalong	Recorder 1895	1894 to 1942
54022	Severn	Plynlimon flume	1951 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977

Pool 7 (WIZA10) - Default pooling group

41020	Bevern Stream	Clappers Bridge	1969 to 2008
203042	Crumlin	Cidercourt Bridge	1979 to 2008
72014	Conder	Galgate	1965 to 2008
203049	Clady	Clady Bridge	1982 to 2008
53017	Boyd	Bitton	1973 to 2008
41022	Lod	Halfway Bridge	1973 to 2008
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
33054	Babingley	Castle Rising	1976 to 2008
28041	Hamps	Waterhouses	1967 to 2008
43806	Wylze	Brixton Deverill	1991 to 2008
33032	Heacham	Heacham	1965 to 2008
206004	Bessbrook	Carnbane	1983 to 2008
26003	Foston Beck	Foston Mill	1958 to 2008
42011	Hamble	Frogmill	1972 to 2008
49004	Gannel	Gwills	1969 to 2008

Pool 8 (WIZA15) - Default pooling group

41020	Bevern Stream	Clappers Bridge	1969 to 2008
203049	Clady	Clady Bridge	1982 to 2008
72014	Conder	Galgate	1965 to 2008
203042	Crumlin	Cidercourt Bridge	1979 to 2008
203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
53017	Boyd	Bitton	1973 to 2008
28041	Hamps	Waterhouses	1967 to 2008
41022	Lod	Halfway Bridge	1973 to 2008
206004	Bessbrook	Carnbane	1983 to 2008
49004	Gannel	Gwills	1969 to 2008
43806	Wylve	Brixton Deverill	1991 to 2008
72007	Brock	U/S A6	1977 to 2008
76811	Dacre Beck	Dacre Bridge	1999 to 2008
44809	Piddle	Little Puddle	1992 to 2008
42011	Hamble	Frogmill	1972 to 2008
44003	Asker	Bridport	1966 to 2008
48803	Carnon	Bissoe	1994 to 2008
24006	Rookhope Burn	Eastgate	1960 to 1979

Pool 9 (WIZA20) - Default pooling group

203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
203049	Clady	Clady Bridge	1982 to 2008
41020	Bevern Stream	Clappers Bridge	1969 to 2008
73015	Keer	High Keer Weir	1970 to 2008
72014	Conder	Galgate	1965 to 2008
28041	Hamps	Waterhouses	1967 to 2008
206004	Bessbrook	Carnbane	1983 to 2008
72007	Brock	U/S A6	1977 to 2008
44809	Piddle	Little Puddle	1992 to 2008
76811	Dacre Beck	Dacre Bridge	1999 to 2008
48803	Carnon	Bissoe	1994 to 2008
49004	Gannel	Gwills	1969 to 2008
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
24006	Rookhope Burn	Eastgate	1960 to 1979
50009	Lew	Norley Bridge	1987 to 2008
53017	Boyd	Bitton	1973 to 2008
36009	Brett	Cockfield	1967 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007
20002	West Peffer Burn	Luffness	1965 to 2005

Pool 10 (WIZA30) - Default pooling group

203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977
50009	Lew	Norley Bridge	1987 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007
203049	Clady	Clady Bridge	1982 to 2008
25019	Leven	Easby	1970 to 2008
26802	Gypsey Race	Kirby Grindalythe	1997 to 2008
73015	Keer	High Keer Weir	1970 to 2008
72014	Conder	Galgate	1965 to 2008
27032	Hebden Beck	Hebden	1965 to 2008
41020	Bevern Stream	Clappers Bridge	1969 to 2008
48004	Warleggan	Trengoffe	1969 to 2008
48803	Carnon	Bissoe	1994 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
72007	Brock	U/S A6	1977 to 2008
28041	Hamps	Waterhouses	1967 to 2008

Pool 11 (WIZA40) - Default pooling group

203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977
50009	Lew	Norley Bridge	1987 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007
25019	Leven	Easby	1970 to 2008
26802	Gypsey Race	Kirby Grindalythe	1997 to 2008
203049	Clady	Clady Bridge	1982 to 2008
73015	Keer	High Keer Weir	1970 to 2008
72014	Conder	Galgate	1965 to 2008
27032	Hebden Beck	Hebden	1965 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
48004	Warleggan	Trengoffe	1969 to 2008
48803	Carnon	Bissoe	1994 to 2008
41020	Bevern Stream	Clappers Bridge	1969 to 2008
48009	St Neot	Craigshill Wood	1970 to 1982
72007	Brock	U/S A6	1977 to 2008

Pool 12 (WIZA50) - Default pooling group

203046	Rathmore Burn	Rathmore Bridge	1981 to 2008
44008	Sth Winterbourne	W'bourne Steepleton	1974 to 2008
27010	Hodge Beck	Bransdale Weir	1935 to 1977
50009	Lew	Norley Bridge	1987 to 2008
22003	Usway Burn	Shillmoor	1965 to 2007
25019	Leven	Easby	1970 to 2008
26802	Gypsy Race	Kirby Grindalythe	1997 to 2008
203049	Clady	Clady Bridge	1982 to 2008
73015	Keer	High Keer Weir	1970 to 2008
72014	Conder	Galgate	1965 to 2008
44006	Sydling Water	Sydling St Nicholas	1969 to 2008
27032	Hebden Beck	Hebden	1965 to 2008
48004	Warleggan	Trengoffe	1969 to 2008
48803	Carnon	Bissoe	1994 to 2008
48009	St Neot	Craigshill Wood	1970 to 1982
41020	Bevern Stream	Clappers Bridge	1969 to 2008
72007	Brock	U/S A6	1977 to 2008

7.2 Additional supporting information



Offices at

Atherstone

Doncaster

Edinburgh

Haywards Heath

Limerick

Newcastle upon Tyne

Newport

Saltaire

Skipton

Tadcaster

Thirsk

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C Appendix C - Hydraulic Model Check File

Introduction

This report provides a detailed record of information on the hydraulic models constructed for the Wigton model update study. It complements the information in the main Hydraulic Modelling Report which gives more general information on the model.

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JBA Project Manager

Matthew Scott

Revision History

Revision Ref / Date Issued	Amendments	Issued to
Final Model Check File 4 th June 2013		Digital version issued to Rachel Gerrard (EA)

Modellers

Prepared by Mark Tywang BSc
Analyst

Reviewed by Matthew Scott BSc MSc
Team Leader

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1. Structures

1.1 Introduction

This section details those areas of the Wigton model that have been revised or added as part of the 2012 model update.

All existing structures are covered in the hydraulic model check file that accompanies the existing model constructed in 2005/6.

1.1.1 Topographic Data

The modelling has made use of new topographic data from two main sources:

- (1) Detailed channel survey – produced by JBA's in house survey team. This data was used to allow the modelling of the upper reaches of Speet Gill (Reaches 2 and 3) and additional sections of Wiza Beck, including the flood retention basin.
- (2) LIDAR – Updated high definition LIDAR has been produced since the completion of the original study and this data has been used to update all floodplain areas of the model (storage areas, extended cross sections and lateral structures), replacing the previous data.

1.2 Wigton Model Structures – Speet Gill

1.2.1 A595 Embankment

Included in model? (state reason if not):	Yes
Model label:	SPET02_3444
Type:	Culvert
Approx. constriction ratio:	0
How has structure been modelled?	Box culvert – span (2.41m), Rise (1.87m) Length (42.89m) Invert level (40.22)
Assumptions made?	Road level estimated from LIDAR (53m)



Photograph from site visit (JBA - October 2012)

1.2.2 Brecon Hill Road Bridge

Included in model? (state reason if not):	Yes
Model label:	SPET02_3197.9
Type:	Bridge – (1.1m from invert to soffit)
Approx. constriction ratio:	0.3
How has structure been modelled?	Modelled as a box culvert as structure represents a significant constriction to flow and consequently modelling the structure as a bridge may underestimate Friction losses through the barrel. Upstream Invert (38.73) Downstream Invert (38.67) (Span (2.13m), Rise (1.1m), Length (11.98m) Weir Coefficient (1.4)
Assumptions made?	Road level of 40.51mAOD assumed to extend along whole cross section.



Photograph from site visit (JBA – October 2012)

1.2.3 Track Bridge near Bank

Included in model? (state reason if not):	Yes
Model label:	SPET02_2999.9
Type:	Bridge – (1.44m from invert to soffit)
Approx. constriction ratio:	0.2
How has structure been modelled?	Bridge- Bed level (37.52) Soffit (38.96) Width (1.9m) Length (2m) Weir Coefficient (1.4)
Assumptions made?	N/A



Photograph from site visit (JBA – October 2012)

1.2.4 Track Bridge near Bushgill Head

Included in model? (state reason if not):	Yes
Model label:	SPET02_2074.9
Type:	Bridge (0.97m from invert to soffit)
Approx. constriction ratio:	0.6
How has structure been modelled?	Bridge- Bed Level (32.27) Soffit (33.24) Width (3m) Length (4m) Weir Coefficient (1.4)
Assumptions made?	Downstream face copied from surveyed upstream.



Photograph from site visit (JBA - October 2012)

1.2.5 Culvert near Bushgill head

Included in model? (state reason if not):	Yes
Model label:	SPET03_370.9
Type:	Culvert
Approx. constriction ratio:	0.2
How has structure been modelled?	A concrete circular pipe culvert unit has been used to model this structure. Soffit (33.14) Length (6m) Diameter (1.02m) Upstream Invert (32.129) Downstream Invert (32.2) Weir Coefficient (1.4)
Assumptions made?	N/A



Photograph from site visit (JBA - October 2012)

1.2.6 Road Bridge near Bushgill Head

Included in model? (state reason if not):	Yes
Model label:	SPET03_236.9
Type:	Culvert
Approx. constriction ratio:	0.2
How has structure been modelled?	A circular pipe culvert has been used to model this structure. Soffit (32.86) Length (4m) Diameter (1m) Upstream Invert (31.76) Downstream Invert (31.76) Weir Coefficient (1.4)
Assumptions made?	N/A



Photograph from site visit (JBA - October 2012)

1.3 Wigton Model Structures – Wiza Beck

1.3.1 Wiza Beck Throttle Structure

Included in model? (state reason if not):	Yes
Model Label:	WIZA01_2012_3082.9
Type:	Culvert
Approx. constriction ratio:	0.4
How has this structure been modelled?	Box Culvert- Culvert with raised embankment (left and right bank). Span (2.3m) Rise (1.5m) Length (8m) Upstream Invert Level (28.41) Downstream Invert Level (28.41)
Assumptions made?	Upstream cross sections represented as extended cross sections. Structure dimensions based on a spot level survey produced by JBA (2012)



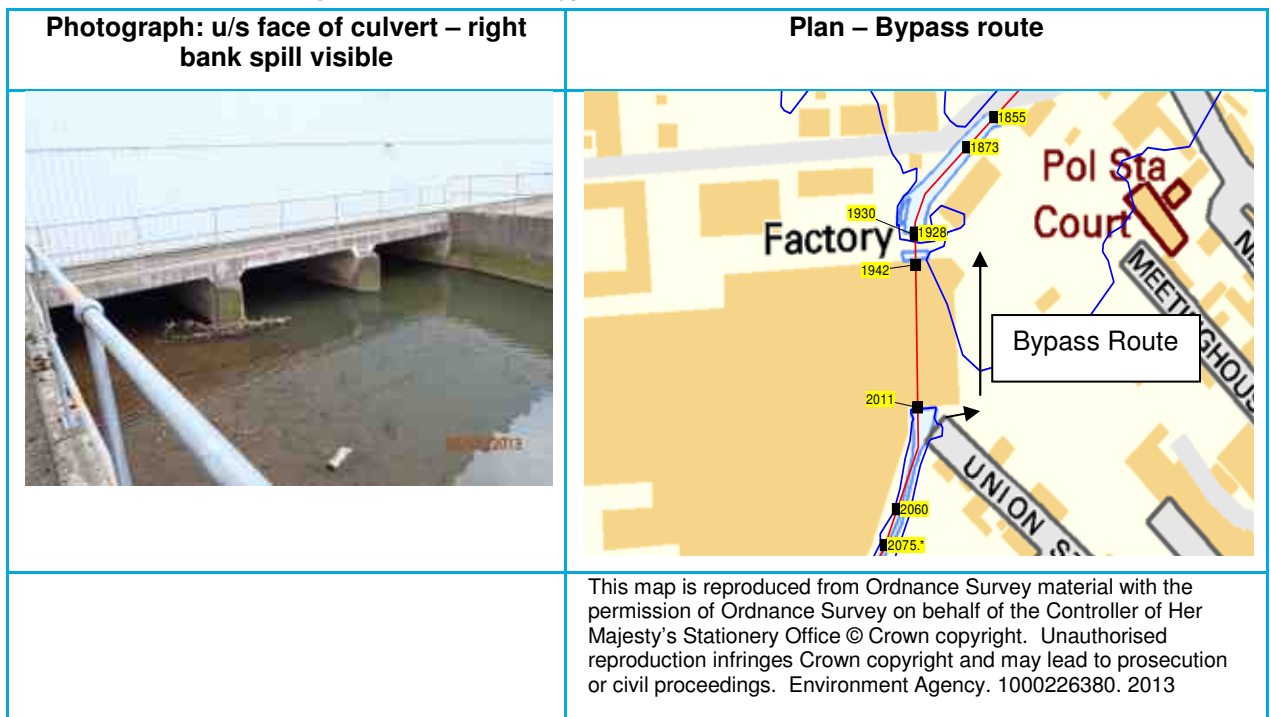
Photograph from site visit (JBA - October 2012) – Throttle Structure

1.4 Other Changes to Model

1.4.1 Wiza Beck – Innovia Culvert (WIZA01c_2010)

For events larger than the 100-year scenario bypassing of the structure has been modelled using a lateral spill unit connecting the upstream reaches of Wiza Beck (WIZA01c_2020). The dimensions of the structure are based on the right bank levels immediately upstream of the structure. Any flow overtopping the spill level will be transferred to model node WIZA01c_1942, located downstream of the culvert (see Figure 3.4.1). This structure has only been included in the ‘large flow’ model (G.03) and is not included in design geometry files.

Figure 3.4.1 – Innovia bypass structure

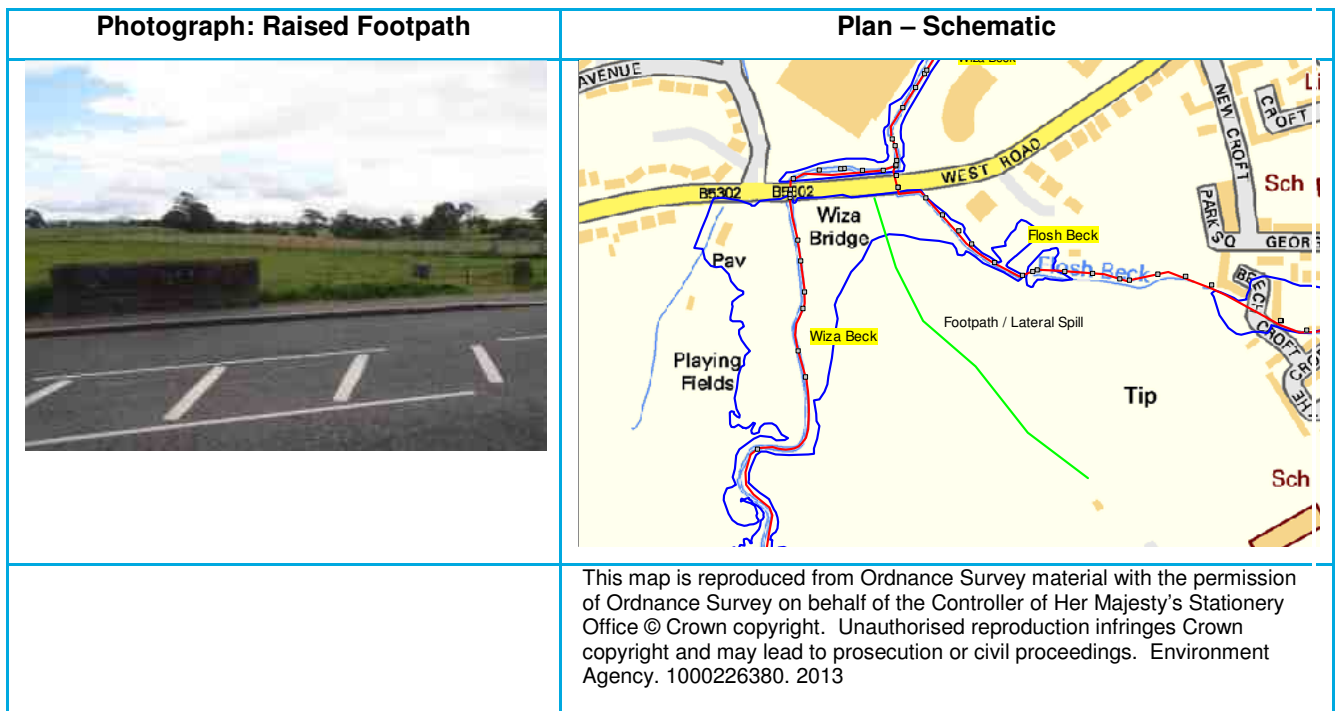


1.4.2 Update of Wiza Beck – Flosh Beck Lateral Structure

The interaction between the flood waters from Wiza Beck and Flosh Beck are represented using a lateral spill structure marking the threshold beyond which floodwater will spill between the catchments.

The topographic control between the catchments is the raised footpath running south from the B5302 (see Figure 3.4.2). The lateral structure has been updated using the spot level survey collected for the path in 2012/13).

Figure 3.4.2 – Wiza Beck / Flosh Beck Lateral Structure



2. Model runs

2.1 Model run (Unsteady HEC-RAS)

2.1.1 Existing Site Conditions

Design Runs – Existing site conditions					
Scenario / Event	Geometry File (.G)	Description	Unsteady Flow File (.u)	Initial Conditions Files (.rst)	Unsteady Plan File (.p)
2-year (Existing)	G.96 (32)		U.34 (28)	Wiza.p44.02JAN200 5 1600.rst	P.74 (33)
5-year (Existing)	G.96 (32)		U.30 (28)	Wiza.p44.02JAN200 5 1600.rst	P.70 (33)
10-year (Existing)	G.96 (32)		U.31 (28)	Wiza.p44.02JAN200 5 1600.rst	P.71 (33)
25-year (Existing)	G.96 (32)		U.32 (28)	Wiza.p44.02JAN200 5 1600.rst	P.72 (33)
50-year (Existing)	G.96 (32)		U.33 (28)	Wiza.p44.02JAN200 5 1600.rst	P.73 (33)
100-year (Existing)	G.96 (32)		U.35 (28)	Wiza.p44.02JAN200 5 1600.rst	P.05 (33)
100cc-year (Existing)	G.03 (33)	Additional lateral spill added to model additional flow routes from large event.	U.02 (28)	Wiza.p44.02JAN200 5 1600.rst	P.07 (33)
1,000-year (Existing)	G.03 (33)	Additional lateral spill added to model additional flow routes from large event.	U.28 (28)	Wiza.p44.02JAN200 5 1600.rst	P.55 (33)

2.1.2 Wiza Beck Retention Basin – Analysis

Wiza Beck Analysis					
Scenario / Event	Geometry File (.G)	Description	Unsteady Flow File (.u)	Initial Conditions Files (.rst)	Unsteady Plan File (.p)
Option 1 – Raised Embankment					
5-year (Option 1)	G.16 (41)	Wiza Embankment raised to 31.1mAOD. Throttle structure unchanged	U.30 (28)	Wiza.p44.02JAN200 5 1600.rst	P.39 (41)
10-year (Option 1)	G.16 (41)	“ “	U.31 (28)	Wiza.p44.02JAN200 5 1600.rst	P.49 (41)
25-year (Option 1)	G.16 (41)	“ “	U.32 (28)	Wiza.p44.02JAN200 5 1600.rst	P.61 (41)
Option 2 – Raised embankment & reduced throttle size					
5-year (Option 2)	G.21 (45)	Wiza Embankment raised to 31.5mAOD. Throttle height lowered to 1m (from 1.5m)	U.30 (28)	Wiza.p44.02JAN200 5 1600.rst	P.46 (41)
10-year (Option 2)	G.21 (45)	“ “	U.31 (28)	Wiza.p44.02JAN200 5 1600.rst	P.48 (41)
25-year (Option 2)	G.21 (45)	“ “	U.32 (28)	Wiza.p44.02JAN200 5 1600.rst	P.47 (41)
Pre-Scheme Analysis					

Wiza Beck Analysis					
Scenario / Event	Geometry File (.G)	Description	Unsteady Flow File (.u)	Initial Conditions Files (.rst)	Unsteady Plan File (.p)
	G.04 (36)	Wiza embankment and throttle removed	U.34 (28)	Wiza.p44.02JAN200 5 1600.rst	P.30 (36)
5-year (pre scheme)	G.04 (36)	“ “	U.31 (28)	Wiza.p44.02JAN200 5 1600.rst	P.29 (36)
10-year (pre scheme)	G.04 (36)	“ “	U.32 (28)	Wiza.p44.02JAN200 5 1600.rst	P.09 (36)
25-year (pre scheme)	G.04 (36)	“ “	U.30 (28)	Wiza.p44.02JAN200 5 1600.rst	P.08 (36)
Sensitivity Test – Blockage at Innovia Culvert (WIZA01c_2010)					
25-year (sen)	G.19	As existing with 50% blockage applied to Innovia culvert (WIZA01c_2010)	U.32 (28)	Wiza.p44.02JAN200 5 1600.rst	P.57
50-year (sen)	G.19	“ “	U.33 (28)	Wiza.p44.02JAN200 5 1600.rst	P.56

2.1.3 Speet Gill Scheme Analysis

Scheme Analysis					
Scenario / Event	Geometry File (.G)	Description	Unsteady Flow File (.u)	Initial Conditions Files (.rst)	Unsteady Plan File (.p)
Option 1f					
10-year (1f)	G.22 (37)	Throttle – 0.75m diameter Embankment crest – 37.15mAOD	U.31 (28)	Wiza.p44.02JAN200 5 1600.rst	P.54 (37)
Option 1a					
2-year (1a)	G.46 (33)	Throttle – 0.75m diameter Embankment crest – 37.00mAOD	U.34 (28)	Wiza.p44.02JAN200 5 1600.rst	P.80
10-year (1b)	G.46 (33)	“ “	U.31 (28)	Wiza.p44.02JAN200 5 1600.rst	P.81
50-year (1b)	G.46 (33)	“ “	U.33 (28)	Wiza.p44.02JAN200 5 1600.rst	P.83
Option 1b					
2-year (1b)	G.47 (34)	Throttle – 0.75m diameter Embankment crest – 39.00mAOD	U.34 (28)	Wiza.p44.02JAN200 5 1600.rst	P.82
50-year (1b)	G.47 (34)	Throttle – 0.75m diameter Embankment crest – 39.00mAOD	U.33 (28)	Wiza.p44.02JAN200 5 1600.rst	P.84

D Appendix D - Updated Flood Maps

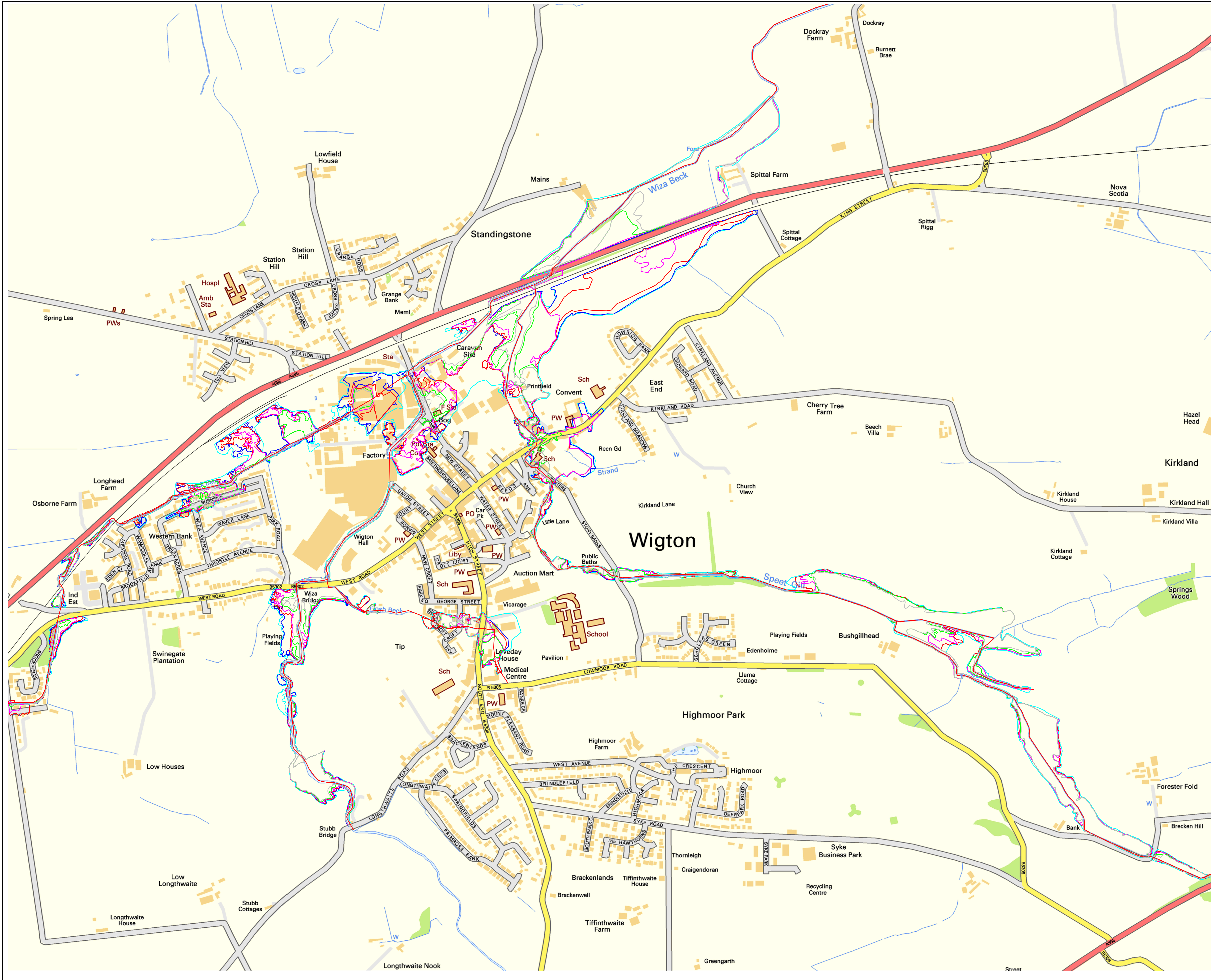
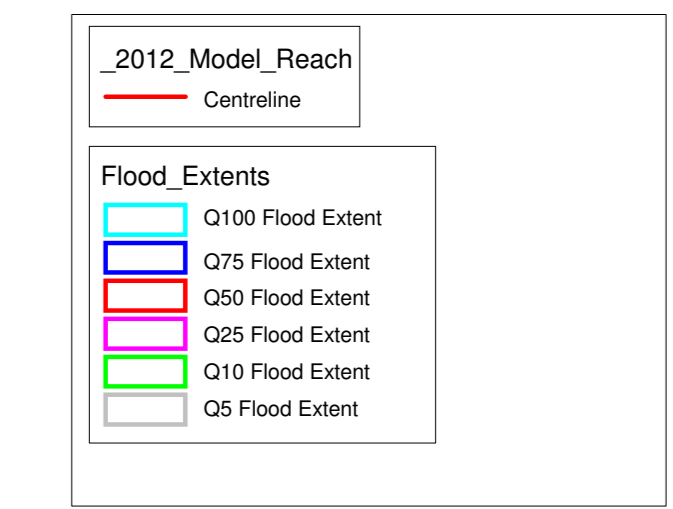


Figure Legend



Rev.	Modifications	Date	Drawn	Checked	Approved




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**WIGTON MODELLING STUDY
 FLOOD RISK AREAS (EXISTING) - BLACK BECK,
 WIZA BECK, FLOSS BECK AND SPEET GILL**

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