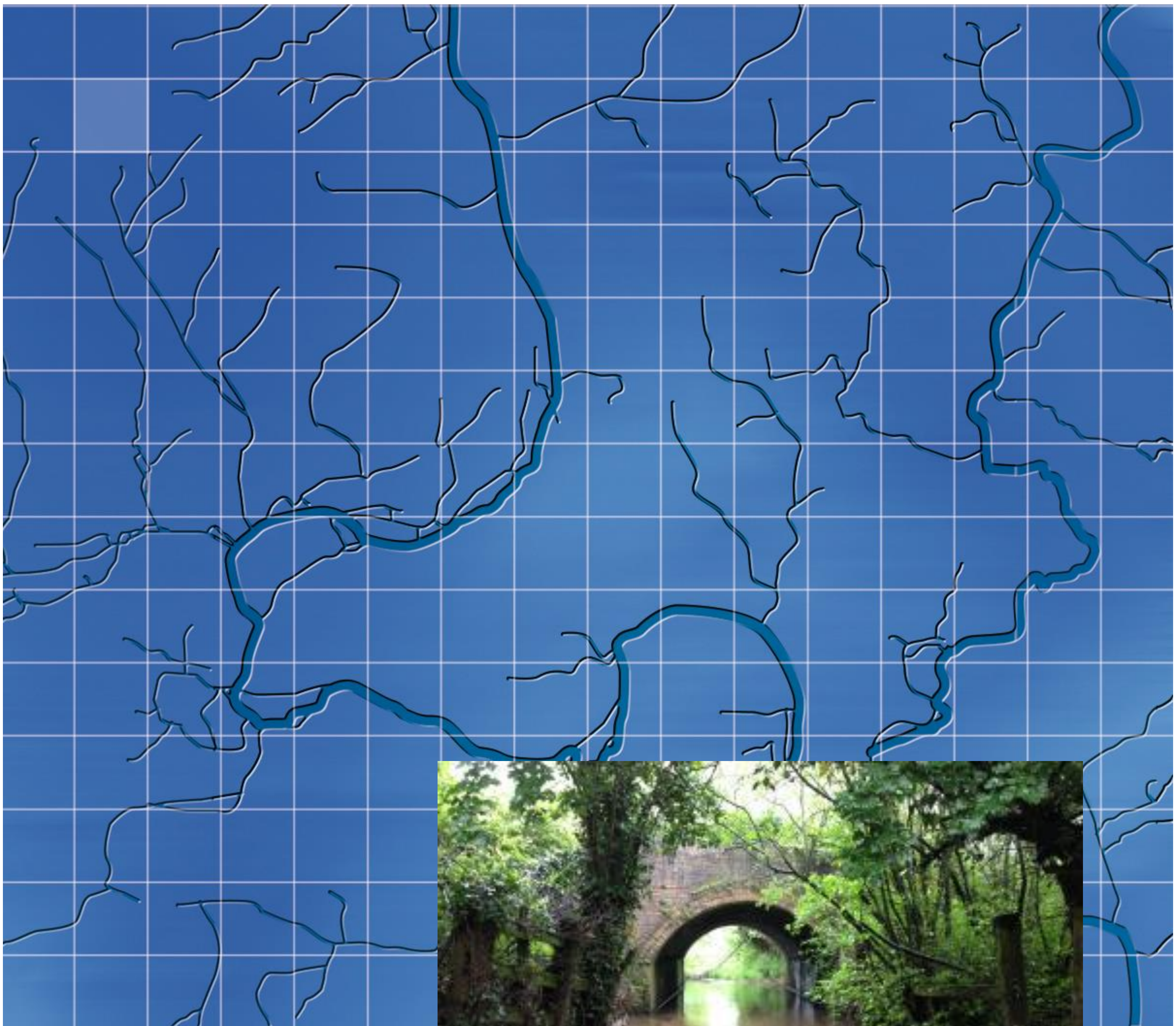
Network Rail & Chiltern Railways

October 2016

EWR-P1- Level 3 FRA:

Brookfurlong Farm



Wallingford HydroSolutions Limited

Network Rail & Chiltern Railways

EWR-P1- Level 3 FRA: Brookfurlong Farm

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For and on behalf of Wallingford HydroSolutions Ltd.

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Contents

1 Introduction

1.1 Background

Environmental Resources Management (ERM) and Wallingford HydroSolutions Ltd. (WHS) completed a Level 2 Flood Risk Assessment (FRA) in 2009 (including a revision in July 2010), together with a Technical Paper[1] outlining potential flood storage mitigation requirements for the proposed Chiltern Railways Bicester to Oxford improvement scheme in support of an application for an Order under the Transport and Works Act 1992 (TWA) by Chiltern Railways (CRCL). The TWA Order was granted by the Secretary of State for Transport in October 2012. This gives statutory powers to authorise the East West Rail Phase 1 (EWR P1) project, comprising the redevelopment and operation of the railway between Oxford and Bicester. The project seeks to introduce a new, fast service between London and Oxford.

The Level 2 FRA was conducted in accordance with National Planning Policy Framework (NPPF), and its Planning Practice Guide companion. The Level 2 FRA document highlighted a number of locations along the railway corridor where proposed developments lie within Flood Zones 2 or 3 and could potentially have impacts upon the incidence of local flooding. The report identified a number of assessment points (AP's) along the route of the EWR P1 that require further consideration in a Level 3 FRA.

Since this initial Level 2 assessment, additional assessment requirements have been identified relating to the required upgrade works to an access road for Brookfurlong Farm, required due to the need to close the current access via a level crossing. This access road crosses two watercourses and the existing structures will be upgraded to provide improved access.

1.2 Scope of Level 3 FRA

This document constitutes a Level 3 FRA for the proposed works for Brookfurlong Farm access road, this document also provides the information required by the NPPF.

This FRA document has been commissioned to address the flood risk issues that result from the access road upgrade works, which will cross two watercourses. The proposed works involve the upgrade of an existing farm access road to maintain access to Brookfurlong Farm as a result of a proposed level crossing closure. The purpose of this FRA is to quantify any adverse impacts on flood risk and provide sustainable and effective mitigation where required to mitigate any impacts.

[1] WHS. 2010. Chiltern Railways Bicester to Oxford Improvements Level 2 Flood Risk Assessment

2 Site Description

2.1 Overview

EWR P1 is a major package of infrastructure investments including: the doubling of the line between Bicester town and Oxford North Junction; the existing stations at Bicester Town and Islip being rebuilt and a new station built at Water Eaton Parkway (now referred to as Oxford Parkway).

In order to allow for increased train speeds, a number of level crossings will also be closed along the rail line.

This site specific Level 3 FRA considers access road upgrade works at Brookfurlong Farm, located to the north of AP11, see Figure 1.

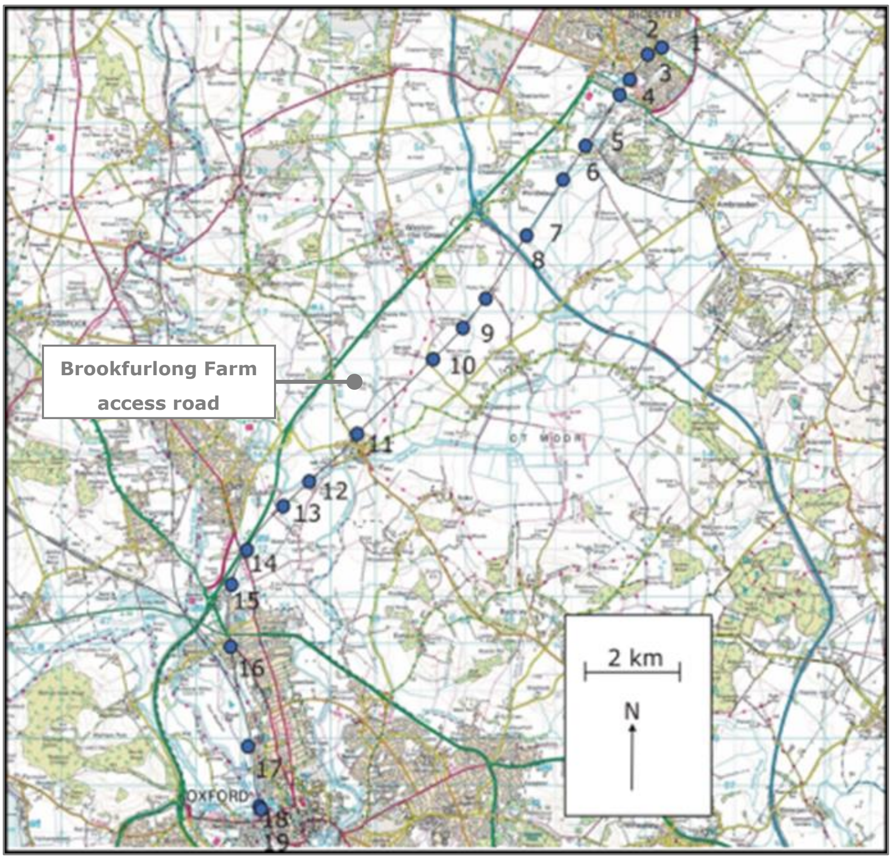

Figure 1 - Scheme Overview showing various assessment points.

2.2 Description of proposed works

The proposed works centre around Brookfurlong Farm, to the north east of the small town of Islip. The surrounding area is predominantly farmland, being a mix of pasture and agriculture. Figure 2 provides an overview of the land use in the surrounding area.

A number of watercourses are found within the study area. The proposed access road upgrade works cross the Gallos Brook at two locations. As shown on Figure 2, the brook splits into two channels just upstream of the road. The western channel appears to be an old mill pass and as such will be referred to as Mill Run; the eastern natural channel will be referred to as Gallos Brook.

The two arms of the Gallos Brook (Gallos Brook & Mill Run) join the River Ray approximately 1.5km downstream. The River Ray flows west towards Islip prior to joining the River Cherwell. A sketch of the watercourses in the area of interest is provided in Figure 2.

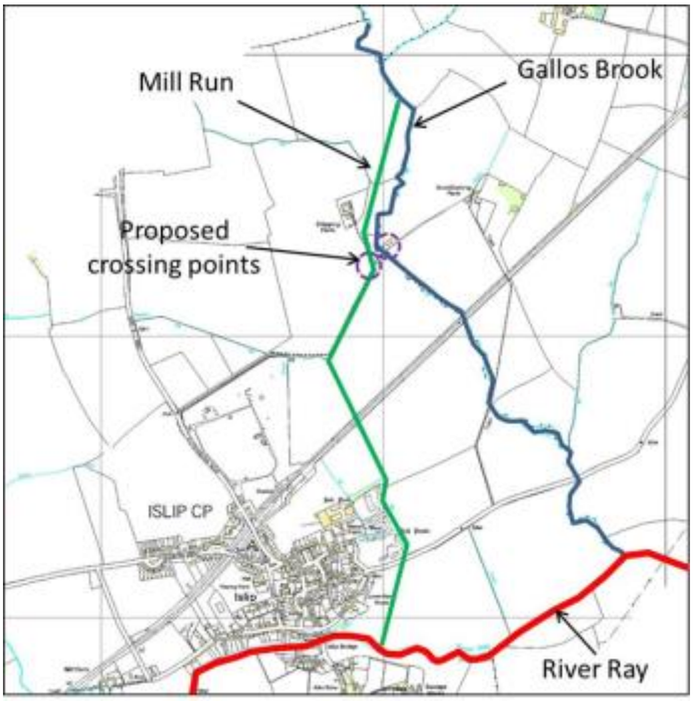

Figure 2 – Overview of land use and watercourses in the study area

Current Environment Agency Flood Maps suggest that part of the proposed access road is at risk of flooding during both the 1 in 100 year and 1 in 1,000 year events. It has been confirmed by the Environment Agency (EA) that this flood mapping is based on JFLOW modelling. Figure 3 shows an extract from the EA Flood Maps available online.

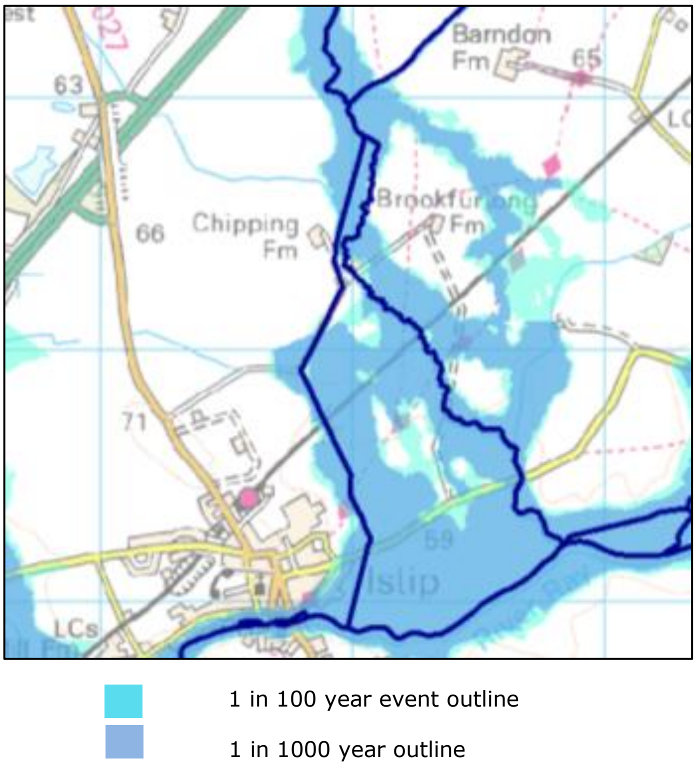

Figure 3 – Extract from the Environment Agency flood map (available online) showing extensive flood extent in the area.

As part of the proposed railway upgrade between Bicester and Oxford, there is a requirement to close the level crossing which currently provides access to Brookfurlong Farm. As a result, upgrades to the existing access road are required. The road will be re-surfaced and existing structures will be strengthened. The road will cross the watercourses in two locations. Currently the crossings comprise of a railway sleeper bridge and a culvert. The locations of the two existing structures are highlighted in Figure 4 below. Figure 4 also outlines the proposed road alignment.

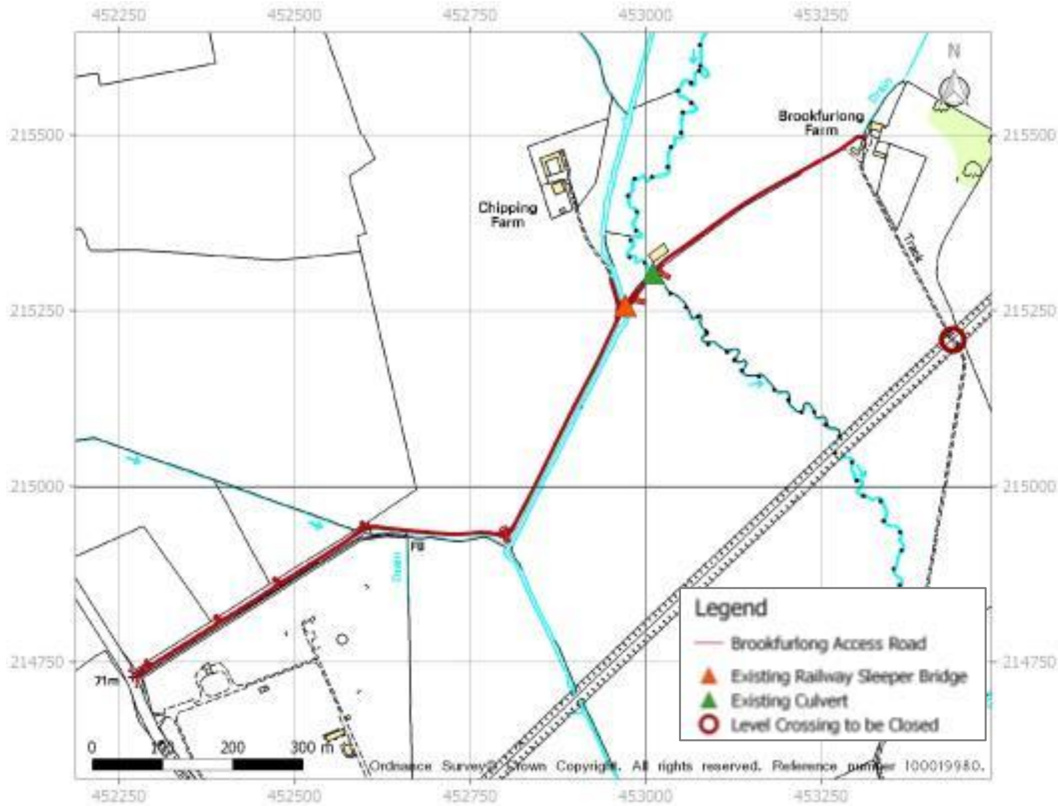

Figure 4 – Proposed alignment of Brookfurlong Farm access road, following closure of existing level crossing

In order to minimise the impact on flooding the vertical alignment of the upgraded access road has been kept as close as possible to the existing alignment. The existing Brookfurlong bridge consists of railway sleepers on timber beams[2], there is no parapet, raised kerbs or any other form edge protection, see Figure 5. The span is approximately 3.13m and the soffit level is 60.49m AOD.

Figure 5[2] – Existing Brookfurlong Bridge

The proposed bridge[3] provides betterment to the existing bridge in a number of ways;

- Increased clear span from approximately 3.13m to 5.00m.
- Raised soffit level from 60.49m AOD to 60.59m AOD.
- Improved edge protection with 1.00m high post and rail parapets.

By raising the bridge soffit level, the risk of blockage is reduced from that currently. The 1 in 100 year plus an allowance for climate change flood level at the upstream side of the proposed bridge is 60.65m AOD. This is 60mm above the proposed soffit level.

The option to raise the soffit level above the predicted flood level and to provide a freeboard was considered, however it would require raising the ground level on the approach roads, which could potentially restrict flows in the floodplain.

Following discussion with Lewis Purbrick of the Environment Agency, it is concluded that increasing the vertical alignment of the access road immediately before and after the bridge in order to achieve a higher soffit level is not desirable, given that the current proposed soffit level already provides betterment over the existing bridge arrangement. Sensitivity analysis in section 4.1 of Appendix B shows that raising the soffit level above the flood level decreases the flood level by 6mm, which is considered insignificant. The decrease in flood level is due to removing the back water effect that is caused when the bridge deck is surcharged by 60mm.

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[2] Atkins Drawing 5114534-ATK-DRG-CV-002703. 29th Oct 2014
[3] Atkins Drawing 5114534-ATK-DRG-CV-002702. 28th Oct 2014

3 Flood Risk

3.1 Overview

The proposed development runs through Flood Zone 3 of the EA flood risk maps, at the location where the access road crosses Gallos Brook and Mill Run. This location is also where the upgrading works to the existing structures is to be carried out.

A hydrological assessment has been undertaken by WHS for use within this hydraulic model. The hydrological assessment is provided in Appendix A. Development of the hydraulic model used to assess the flood risk impact of the proposed development is described in Appendix B.

3.2 Data Sources used and proposed methodology

LiDAR data were used to build up a ground profile representing the 2D model ground levels. The LiDAR data were provided by the Environment Agency, through the Geomatics Team. LiDAR data at 2m horizontal resolution were adopted for this hydraulic model. The vertical accuracy of the LiDAR provided is ±0.15m.

The vertical alignment of the proposed road was obtained from detailed design drawings[4], available in Appendix C.

3.3 Flood Risk Sources

The primary flood risk source is due to fluvial flooding of Gallos Brook and Mill Run, where overtopping of the river banks is expected during extreme flood events. The current culvert and bridge that crosses Gallos Brook and Mill Run throttle the flow and cause increased flooding upstream due to the back water effect. The railway culverts downstream of Brookfurlong Farm access road will cause a similar impact to flood levels.

3.4 Baseline Model Simulation

The baseline model was run with the current ground levels and hydrology derived in Appendix A. The results of this baseline simulation for the 1 in 100 year plus an allowance for climate change flood event can be seen in Figure 6.

The baseline model confirms that there is flooding at the location where the access road crosses Gallos Brook and Mill Run. It is predicted that a 200m stretch of the access becomes inundated during the 1 in 100 year plus an allowance for climate change flood event. The flood depth at this location during this flood event is generally in the range of 10mm to 20mm; see Figure 7 and Table 1.

To assess the impact that the proposed road upgrade has on the flood levels, a number of sample points have been selected to compare the baseline flood depth to the flood depth as a result of the proposed development. The location of these sample points can be seen in Figure 7.

[4] Atkins Drawing 5114534-ATK-DRG-HW-140104 to 140106. 18th Nov 2014.

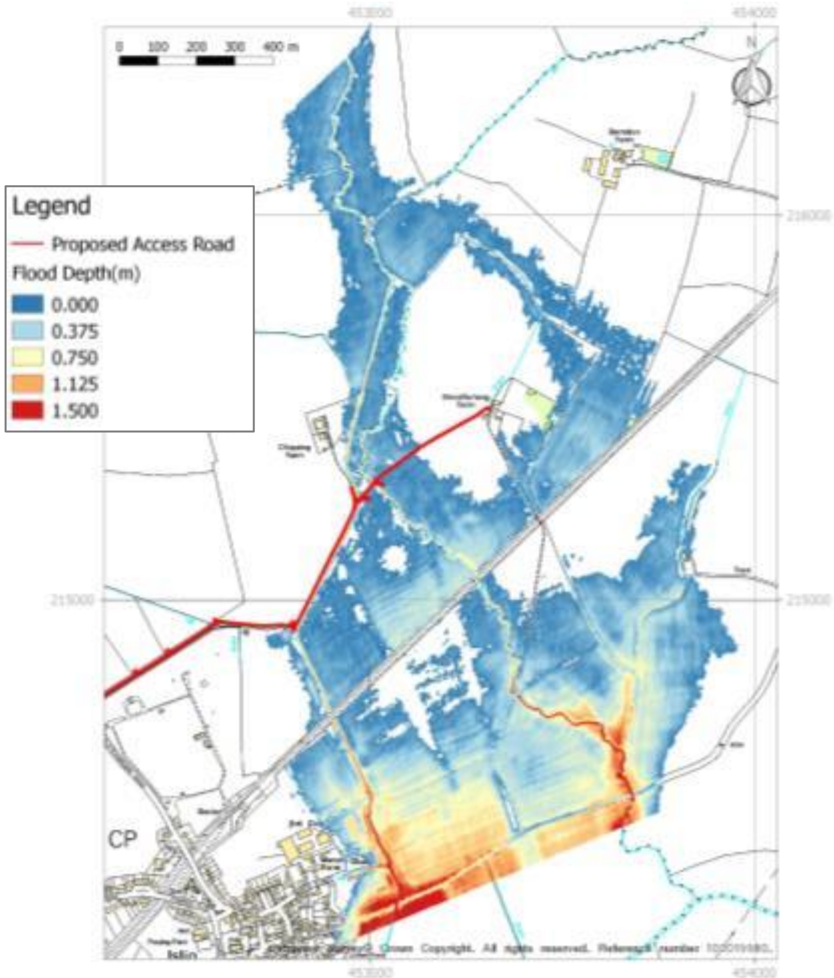


Figure 6 – Baseline model, 1 in 100yr + CC Flood Depth

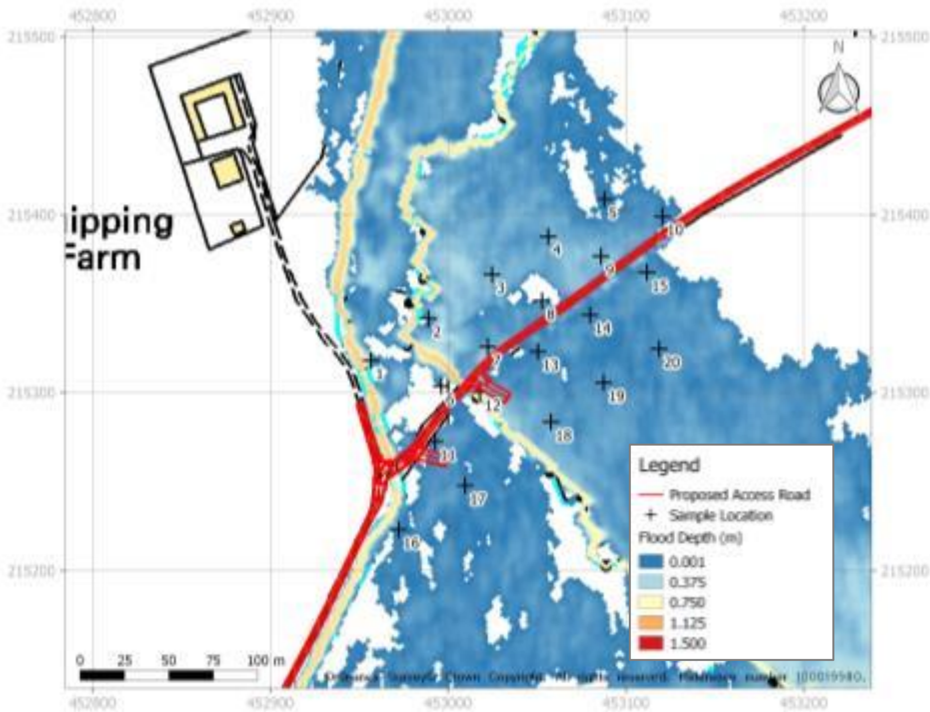


Figure 7 – Location of Sample Points

3.5 Post Development Model Simulation

The proposed profile for the re-surfaced access road for Brookfurlong Farm has been incorporated into the 2D hydraulic model. The result of running the model with the updated topography has produced a revised flood extent and flood depths. The revised flood extent and flood depths can be compared to the base line in order to establish the impact that the upgraded access road has on flood levels.

The change in flood depth at the sample points identified in Figure 7 is shown in Table 1. The sample points located upstream of the proposed access road see an average increase in flood depth of 60mm, whereas the sample points located downstream of the proposed access road have generally decreased by 10mm. This is due to the slightly raised profile of the access road, which causes a back water effect resulting in flood waters being partially retained upstream.

Table 1 – Flood Depths at Sample Points

Sample Point	Position Relative to Access Road	Baseline Flood Depth (m)	Post Development Flood Depth (m)	Change in Depth (m)
1	Upstream	0.20	0.23	0.03
2	Upstream	0.08	0.14	0.06
3	Upstream	0.25	0.30	0.05
4	Upstream	0.18	0.24	0.06
5	Upstream	0.04	0.10	0.06
6	Upstream	-	0.04	0.04
7	Upstream	0.25	0.32	0.07
8	Upstream	-	0.07	0.07
9	Upstream	0.25	0.32	0.07
10	Upstream	0.06	0.13	0.07
11	Downstream	0.09	0.10	0.01
12	Downstream	0.13	0.14	0.01
13	Downstream	0.09	0.08	-0.01
14	Downstream	0.10	0.06	-0.04
15	Downstream	0.12	0.11	-0.01
16	Downstream	0.09	0.10	0.01
17	Downstream	0.07	0.08	0.01
18	Downstream	0.17	0.17	-
19	Downstream	0.12	0.11	-0.01
20	Downstream	0.11	0.10	-0.01

3.5.1 Impact on Flood Extents

It is shown in Figure 8 that there are only localised changes to the flood extent as a result of the proposed access road. The key impacts are;

- The raised road causes backing up of the water level on the upstream side of the road, resulting in a localised increase to the flood extent.
- The backing up also causes a greater volume of water to flow along the Mill Run leg of Gallos Brook, causing minor localised increases to the flood extent to the south of the road adjacent to the Mill Run leg of Gallos Brook.

3.5.2 Impact on Flood Levels

Flood depth changes occur as a result of the proposed road, it can be seen in Figure 9 that there are both localised increases and decreases in the flood depths. The key points from the analysis of the results are;

- Greatest increases in the flood depth is seen just upstream of the proposed road, where flood depth has increased in the region of 10mm to 100mm.
- An approximate 300m reach of Mill Run has increased depth of 10mm to 20mm.
- To the south east of the proposed road, flood depths have been reduced in the region of 10mm to 50mm, this is as a result of the raised road profile holding back the flood water.

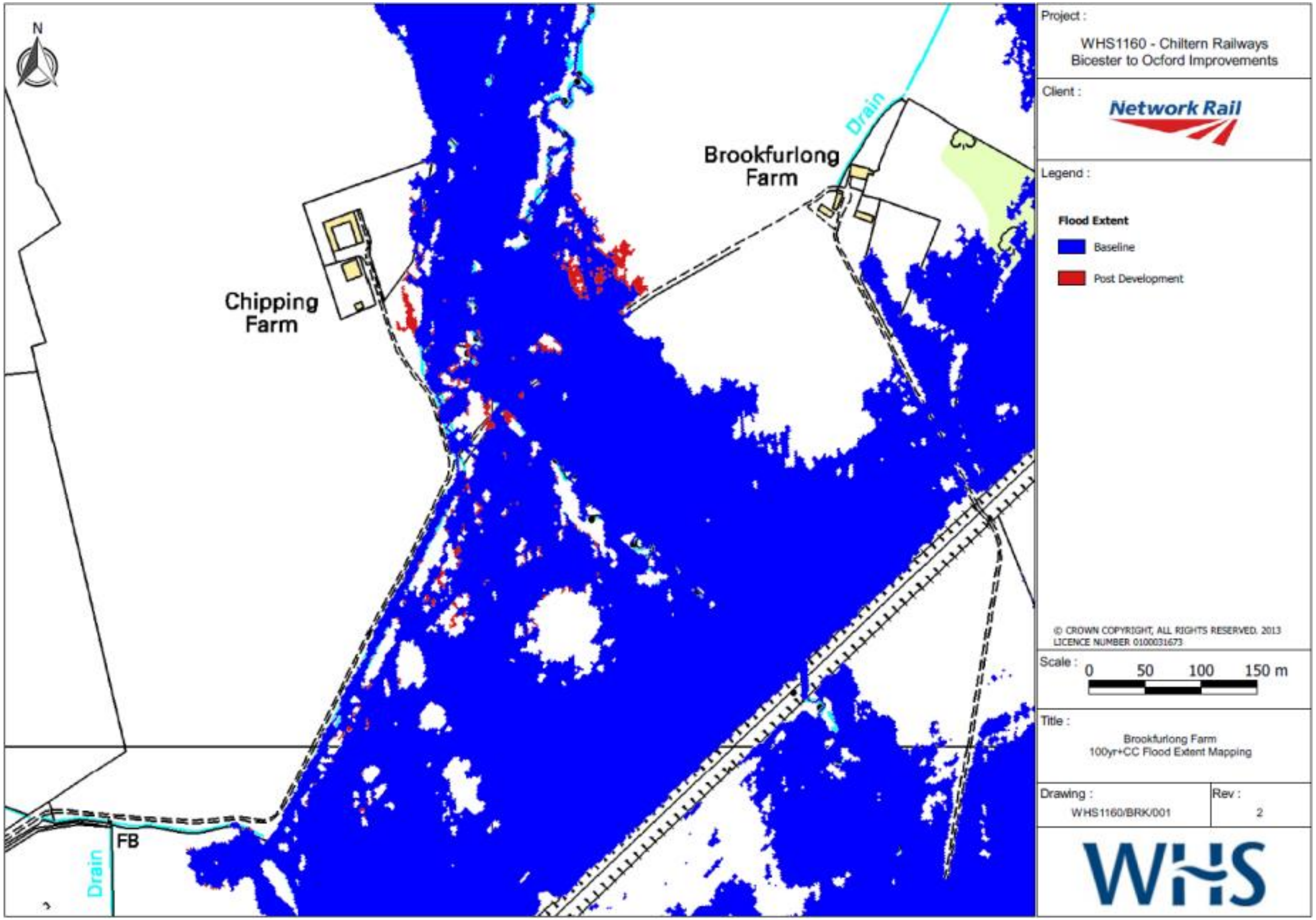


Figure 8 - Flood Extent Comparison Map

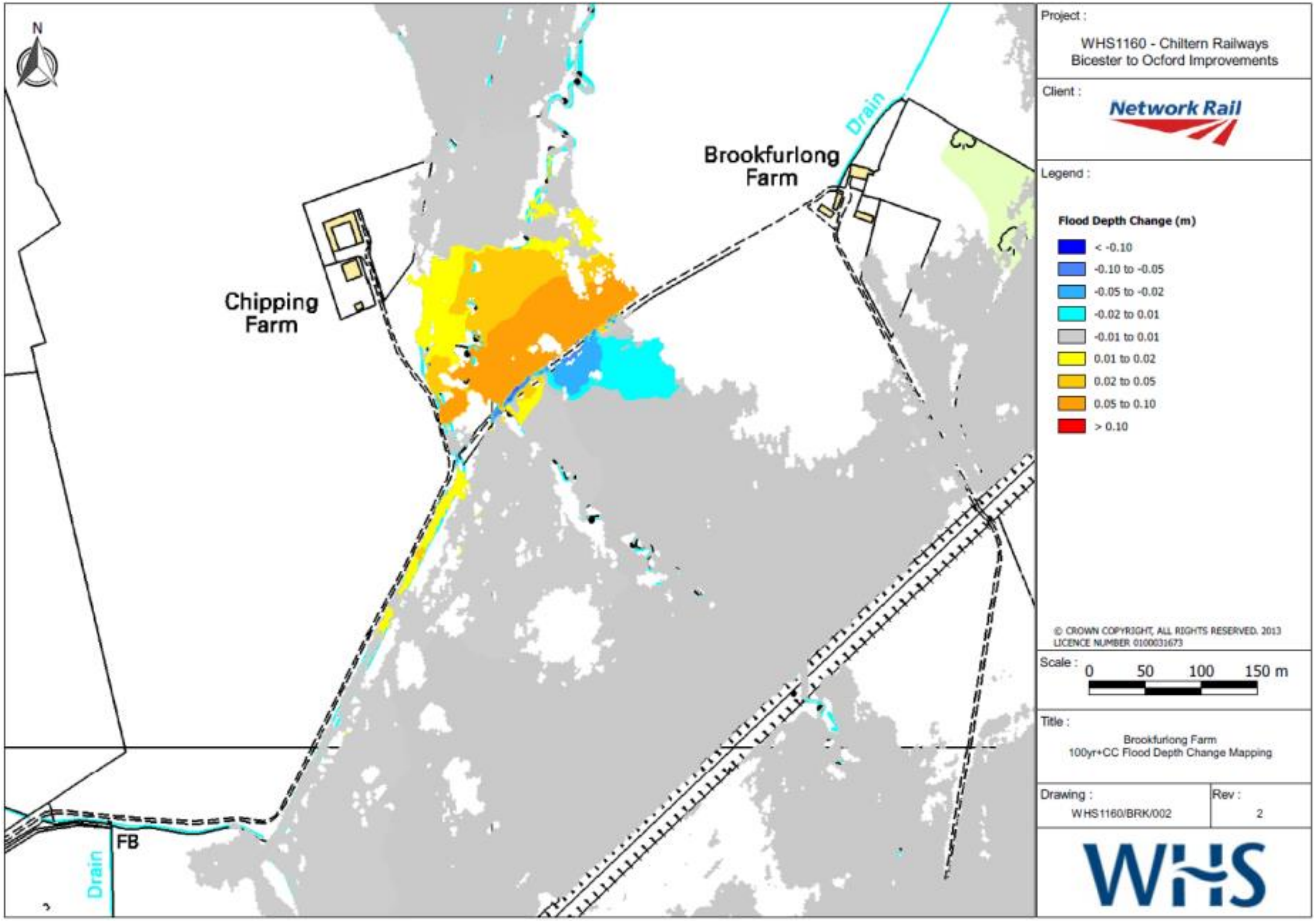


Figure 9 - Flood Depth Change Map

4 Floodplain Storage Loss Analysis

4.1 Methodology

This section outlines the methodology used in undertaking the flood impact assessment for the revised road alignment of Brookfurlong Farm access road. This involves an assessment of the floodplain storage volume lost as a result of new road construction and includes recommendations for mitigation measures to provide compensatory floodplain storage. The updated WHS hydraulic model has been used to inform design. The methodology, parameters and working assumptions, together with the results and recommendations for mitigation are all described in the following sections. An outline of the procedure used to calculate floodplain storage loss is presented below;

- Calculation of the predicted flood level adjacent to the proposed access road using the WHS modelling data
- Calculation of the subsequent flood storage volume lost at 200mm depth intervals as a result of the proposed works
- Provision of compensatory floodplain storage as a mitigation measure to ensure flood risk is effectively managed

4.2 Analysis

The volume of floodplain storage lost as a result of the proposed access road has been calculated to inform the design of any compensatory storage provision that is required to ensure flood risk is effectively managed. The loss of floodplain storage volume has been calculated with the aid of GIS design software. The method adopted is outlined below;

- Atkins has provided design layout drawings of the proposed access road which has been used in conjunction with the updated WHS model to define the flooded area of the development
- To define the ground profile a GIS point layer has been created with an individual point being generated for each LiDAR cell within the flooded area. Each point was then interrogated to obtain a ground elevation for each cell
- Predicted flood depths at each cell were calculated by subtracting the associated ground level from the predicted flood level
- Flood volumes were then calculated by multiplying the predicted flood depth by the plan area of each cell
- The total volume was then segregated into 200mm banding levels

Table 2 provides a summary of the level for level storage requirements at 200mm banding levels. The total storage volume lost due to the access road is 25.5m^3.

Table 2 – Storage Lost

Banding Level (m)	Volume (m^3)
59.80 - 60.00	*0.02*
60.00 - 60.20	*0.06*
60.20 - 60.40	*0.15*
60.40 - 60.60	*0.61*
60.60 - 60.80	*20.67*
60.80 - 61.00	*4.02*
Total	***25.53***

4.3 Compensatory Storage Provision

Compensatory storage should be provided, where possible, on a level for level basis to mitigate against the volume of floodplain lost as a result of the proposed road alignment. The volume of storage lost between banding levels 59.8m to 60.4m AOD is considered to be negligible due to the small volumes involved. Provision of compensatory storage will focus on the banding levels between 60.4m and 61.0m AOD.

To achieve the level for level storage requirement, 25.5m^3 of compensatory storage volume needs to be provided. An assessment of suitable land has been undertaken in order to confirm that there are suitable areas in the vicinity of the site to provide the compensatory storage. Throughout the process of identifying suitable locations for storage, there are a number of key factors that have been considered;

- Where practicable, storage is to be provided within the LOD boundary, as close as possible to the point of impact.
- Ensuring compensatory storage areas can be hydraulically connected to the floodplain.
- Identifying areas that can provide the required storage on a level for level basis. Assessing volumes at 200mm banding intervals, based on LiDAR data.
- Reviewing aerial photography to ensure areas are appropriate to be utilised as storage areas and to ensure LiDAR data is accurate (i.e. no tree cover that could influence levels etc.).

From the above assessment it is proposed to provide compensatory floodplain storage to the south west of Brookfurlong Farm adjacent to where the access road joins the route to Chipping Farm. The storage area will be located between Mill Run and Gallos Brook as shown in Figure 10. Based on the calculations shown in Table 2, a total of 25.5m^3 of storage is required to compensate for the access road construction. The critical bands are 60.6-60.8m AOD and 60.8-61.0m AOD where 20.67m^3 and 4.02m^3 respectively are required for level for level storage. Based on flood levels and surveyed topography, the following level for level storage is achievable at the key bands (Table 3). Although the small amount (1.7m^3) of storage necessary to meet the required storage volume in the 60.6 – 60.8m AOD band is not met, overall, the compensation has been achieved. The total achievable volume is 18% (5.4m^3) greater than the required volume.

Table 3 – Flood Compensation Volume Calculations

Brookfurlong Farm Flood Compensation		
Level Band (m AOD)	Required Volume (m^3)	Achievable Volume (m^3)
60.6 - 60.8	20.7	19.0
60.8 – 61.0	4.0	11.1
TOTAL	24.7	30.1

The primary constraint influencing the design is the availability of land. Providing compensatory storage to the north of the road in the form of a swale has been considered, however, this would result in further loss of arable farm land and prohibited access to the adjacent field. Construction of culverts or structures over the flood compensation feature would be required to maintain this access which would be prone to blocking.

The proposed solution is essentially a relatively shallow excavation over a larger surface area, which provides a more robust storage provision.

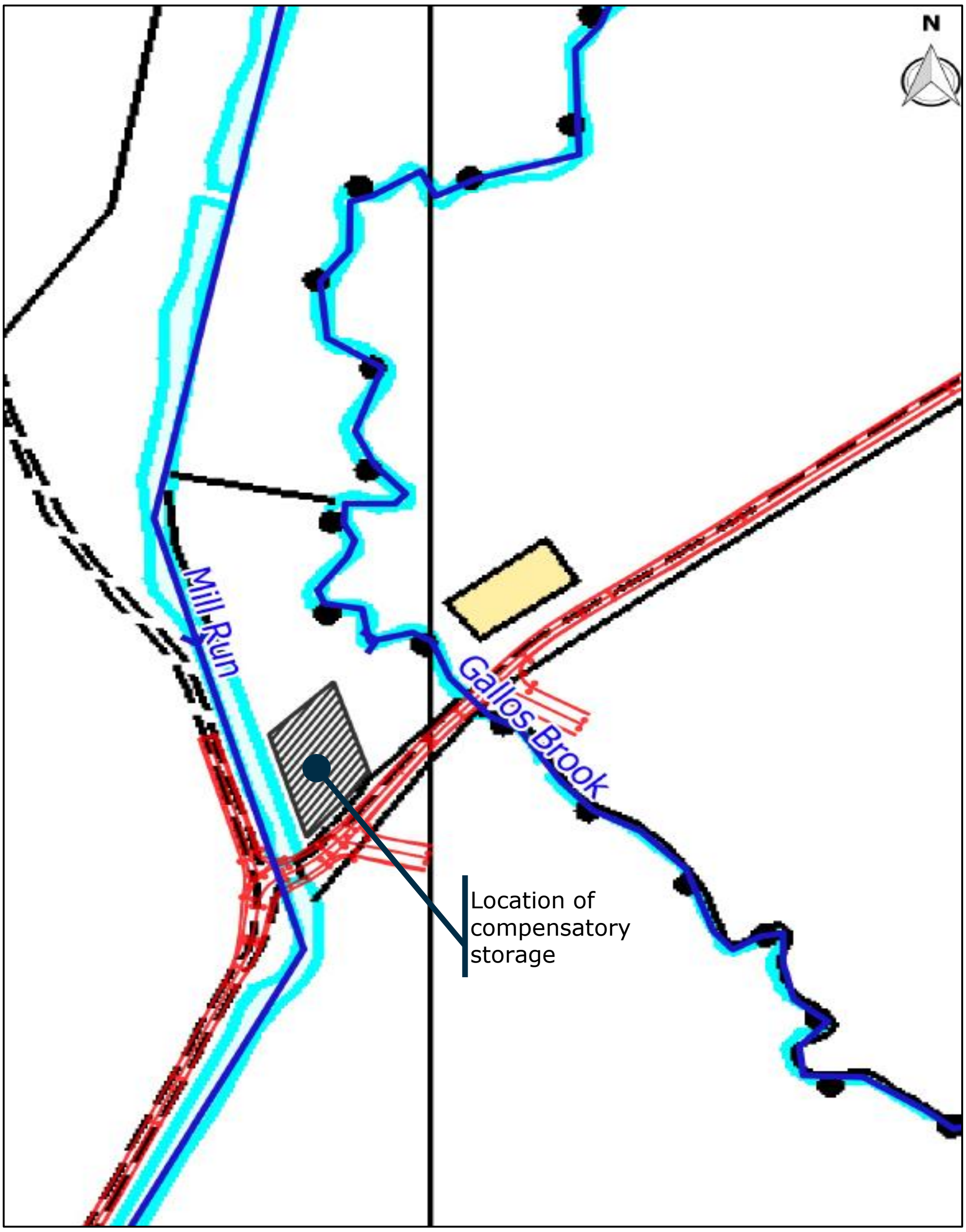


Figure 10 – Proposed compensatory storage location

5 Conclusion

The key conclusions to this report are outlined below;

- Modelling of Gallos Brook has been successfully carried out and a base line flood level has been established.
- The proposed upgrade to the Brookfurlong Farm access road has been incorporated into the model and compared to the base line flood level.
- The road upgrade works have been designed to minimise the vertical alignment of the road, whilst raising the bridge soffit level form 60.49m AOD to 60.59m AOD. The improvement in the bridge arrangements will reduce the risk of blockage affecting upstream flooding.
- The flood extent as a result of the proposed road upgrade works has localised very minor increases, this is predominantly caused by water backing up as a result of the slightly raised road profile, but which also leads to a raised soffit level and reduced risk of blockage at the bridge location.
- Similarly there are also localised minor increases in flood depths upstream of the access road. Again this is caused by the raised profile of the road causing water to back up.
- Maximum flood depth increases are typically in the range of 60mm to 80mm.
- Downstream of the access road there are localised decreases in the flood depth, typically in the range of 20mm to 50mm.
- A solution to provide the minor compensatory storage required has been identified. Detailed design of the proposed solution will be undertaken by others.

5.1 Future Considerations

A 'Works Approval' is to be submitted separately in due course for the proposed works in this area, under the provisions of Schedule 15 of the TWA Order. Works Approvals will also be required for any temporary works within 16 metres of the main watercourses such as Langford Brook or within flood zones 2 and 3. There are some points that need to be considered by the contractor in relation to the temporary works required during the construction phase. These include:

- All compounds, stockpiles and other works will need to be kept outside Flood Zones 2 & 3 and be sited within Flood Zone 1.
- All temporary haul roads within Flood Zones 2 and 3 will need to be kept at grade to avoid any requirement for compensatory flood storage.
- All roads should be constructed with a permeable hard-core or stone surface to avoid increasing the impermeable footprint of the site.
- Network Rail will submit applications for the permanent Works Approvals and the Contractor will submit applications for temporary works approvals, where necessary.

Appendix A. Hydrology

Appendix A – Contents

1 Introduction

Wallingford HydroSolutions Ltd. (WHS) are completing a Level 3 Flood Risk Assessment (FRA) to comply with the requirements of an Order under the Transport and Works Act 1992 (TWA). The TWA Application was made to the Secretary of State for Transport, for statutory powers to authorise the Evergreen3 (EG3) project, comprising the redevelopment and operation of the railway between Oxford and Bicester.

WHS have completed the Level 2 FRA, including a revision in July 2010. The Level 3 FRA work will build upon this work to assess flood risk impacts at the proposed Brookfurlong Farm access road. The current document outlines the hydrological input to the hydraulic model which will be used to complete the Level 3 FRA work.

Flood hydrographs are required for the Gallos Brook, which the proposed new access road crosses in two locations.

Flood levels on the Gallos Brook may also be influenced by the River Ray – approximately 1.4km downstream of the proposed development. Flood modelling and hydrology has already been undertaken for the River Ray as part of the Islip hydraulic modelling study (REF).

Flood design hydrographs are required for the 1 in 100 year event. A 20% increase in peak flow is used to allow for climate change as per current EA guidance[5].

2 Flood Hydrology

2.1 Catchment Description

The proposed development crosses the Gallos Brook in two locations. Upstream of the site, the river splits into two; it is though that the western course is a historic mill run, which now forms the dominant flow route. Within this report, the natural course of the river is referred to as Gallos Brook, with the western branch referred to as the Mill Run. Figure 1 below summarise the location of the development and the two watercourses. A combined hydrological assessment has been undertaken as the Mill Run chute is not identified within the FEH-CDROM data set.

The Gallos Brook catchment is approximately 35km^2 in size, and is rural in nature. The average annual rainfall for the combined catchment is calculated to be 664mm.

Urban extent (URBEXT) value of 0.02 highlights this catchment has only a minor urban element. As the value is <0.03 an urban adjustment consideration is not required.

[5] Environment Agency (2013). *Climate Change Allowance for Planners: Guidance to support the National Planning Policy.*

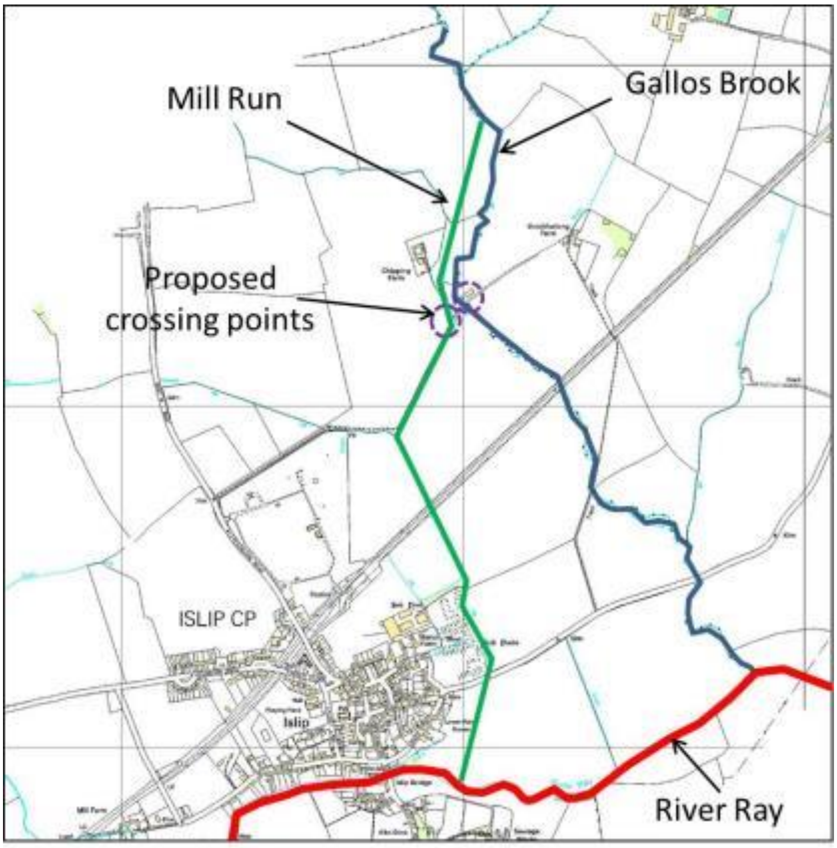


Figure 1 – Hydrology overview map, showing the location of the three watercourses and proposed crossing points for upgrade.

2.2 Available Data

No flow gauging stations are located on the Gallos Brook. As such the hydrology to be used within the hydraulic model will be calculated using the most up to date techniques, outlined within the methodology section below.

2.3 Methodology

2.3.1 Overview

Flood hydrographs were required for the catchment to support the unsteady flow analysis required for the hydraulic model simulation.

The applicability of the Statistical Methods and Rainfall Runoff techniques to the current study is detailed on Table 1.

Based on the initial review of available data and methods, it was considered appropriate to adopt the hybrid method for the estimation of flow and creation of hydrographs for this catchment. This combines the hydrograph of ReFH with the peak flows from the statistical methodology. Environment Agency guidance indicates that the peak flows from ReFH should not be used in highly permeable catchments.

Table 1 - Summary of applicability of FEH approaches for this study.

Method	Relevance to the study catchment
Statistical approach Single Site analysis	Not applicable.
Statistical approach Pooled analysis	Applicable. Catchment descriptors available. Donors available for data transfer. Pooling group available.
Statistical approach Enhanced single site analysis	Not applicable.
Rainfall Runoff Approach (ReFH)	The catchment is highly permeable (BFIHOST 0.728) hence methodology should be used with caution. EA guidance indicates that QMED can be underestimated on highly permeable catchments.
Hybrid Method	Applicable. Hydrographs required. Statistical Method used to define peak flow. ReFH used to define hydrograph shape for all events.

2.4 Estimate of Index Flood (QMED)

- **QMED from catchment descriptors:** Estimates of the index flood were derived from catchment characteristics using WINFAP FEH 3. No adjustment for urbanisation was required due to the catchment being considered predominantly rural (URBEXT=0.02). The estimates of QMED from catchment descriptors were calculated to be;

  $QMED_{CDS\_raw} = 1.67 m^3 s^{-1}$

2.5 Pooling Group and Growth Curve

A pooling group was created for the catchment using WINFAP FEH 3. The initial pooling group of 12 stations was reviewed and in total 13 were used, giving a station year count of 519 (>500 years considered desirable). The final group is classified as heterogeneous (H_2 = 2.86).

The pooled data were calculated to best fit the General Logistic (GL) distribution, and this was adopted to estimate the flood growth curves for the catchment as shown in Figure 2.

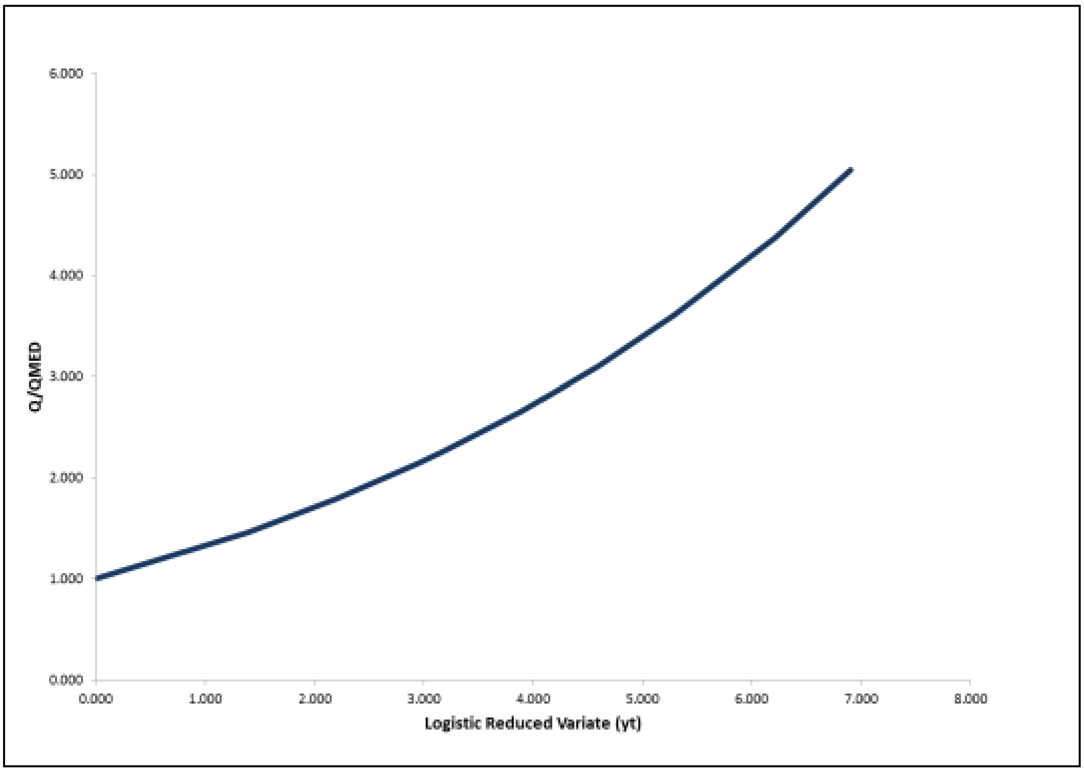


Figure 2 – Final growth curve for the Gallos Brook watercourse

Table 2 - Pooling group selection and reasons for retaining or removing from the final pooling group.

Station	Distance SDM	Years of Rec.	AREA	SAAR	FARL	URBEXT 2000	Suitable for pooling	Suitable for QMED	Decision	Reasoning
29009 (Ancholme @ Toft Newton)	0.316	35	29.52	616	0.997	0.004	Y	Y	Retain	
33045 (Wittle @ Quidenham)	0.391	41	27.55	608	0.974	0.01	Y	Y	Retain	
20002 (West Peffer Burn @ Luffness)	0.844	41	26.31	616	0.996	0.002	Y	Y	Retain	
33054 (Babingley @ Castle Rising)	0.988	33	48.51	686	0.944	0.005	Y	Y	Retain	Permeable adjustment applied
34005 (Tud @ Costessey Park)	1.091	48	72.12	649	0.973	0.029	Y	Y	Retain	
33032 (Heacham @ Heacham)	1.099	41	56.18	688	0.983	0.006	Y	Y	Retain	Permeable adjustment applied
36003 (Box @ Polstead)	1.33	46	56.46	566	0.993	0.012	Y	Y	Retain	
41020 (Bevern Stream @ Clappers Bridge)	1.453	40	35.42	886	0.993	0.013	Y	Y	Retain	
36007 (Belchamp Brook @ Bardfield Bridge)	1.495	45	58.16	560	0.996	0.004	Y	Y	Retain	
43014 (East Avon @ Upavon)	1.526	38	84.63	744	1	0.011	Y	Y	Retain	Permeable adjustment applied
43017 (West Avon @ Upavon)	1.527	39	84.62	744	1	0.011	Y	Y	Retain	Permeable adjustment applied
36004 (Chad Brook @ Long Melford)	1.54	42	50.32	589	1	0.006	Y	Y	Retain	
203042 (Crumlin @ Cidercourt Bridge)	1.546	30	54.47	991	1	0.005	Y	Y	Retain	
36009 (Brett @ Cockfield)	1.018	39	25.62	598	1	0.005	Y	Y	Remove	Bounded distribution
26003 (Foston Beck @ Foston Mill)	1.242	49	59.4	698	0.987	0.004	Y	Y	Remove	Bounded distribution
37003 (Ter @ Crabbs Bridge)	1.444	45	77.76	570	0.994	0.012	Y	y	Remove	Bounded distribution
33029 (Stringside @ Whitebridge)	1.46	44	95.53	628	0.991	0.007	Y	Y	Remove	Bounded distribution

2.6 Flood Frequency Curve

A flood frequency curve was derived using the $QMED_{CDS}$ estimate of 1.67m^3s^{-1} and the pooling group growth curve. The resulting design flood peak flow estimates are shown on Table 3 below.

Table 3 - Statistical Method estimated flood flows for a range of design return period events.

Return Period	Peak Flow (m^3s^{-1})
2	1.67
100	5.20

2.7 Adjustment for Climate Change

As outlined within the current National Planning Policy Framework[6] in making an assessment of the impacts of climate change on flooding from rivers as part of a flood study peak flows should be increased by 20% over the 1 in 100 year event flow. As such Table 4 outlines the final 1 in 100 year plus climate change flows to be used within the hydraulic modelling.

Table 4 Statistical Method estimated flood flows for a range of design return period events.

Watercourse	Return Period	Peak Flow (m^3s^{-1})
Gallos Brook	100	5.20
Gallos Brook	100 + CC	6.24

2.8 Flood estimation using ReFH rainfall runoff method

The Gallos Brook catchment is considered to be rural, as such the standard ReFH rainfall runoff method is considered appropriate for use as outlined by Environment Agency guidance[7].

The ReFH spreadsheet[8] applies the method by creating a 'design storm' from the FEH CD-ROM 3 rainfall statistics and routs it through a simple catchment model to produce a design flood hydrograph. All parameters were derived from catchment characteristics. The ReFH spreadsheet was used to estimate key flows, which are shown on Table 5. The duration of the event was taken to be 46 hours. This duration was used to be consistent with the Islip hydraulic model previously developed the outputs of which are used in the subsequently hydraulic analysis.

[6] Department for Communities and Local Government (2012) Technical Guidance to the National Planning Policy Framework

[7] Environment Agency: Flood estimation guidelines. [Flood Estimation Guidelines EA OI_197_08 Jun12.pdf]

[8] NERC (CEH). 2005.Revitalised FSR/FEH rainfall runoff method. Spreadsheet application version 1.4.http://www.ceh.ac.uk/feh2/SpreadsheetimplementationofReFH.html

Table 5 ReFH estimated flood flows for a range of design return period events

Return Period	Peak Flow (m^3s^{-1})
2	1.67
100	5.10
100 + CC	6.12

2.9 Summary of Results

The final flood hydrographs were estimated by rescaling the ReFH hydrographs by the statistical methodology peak flow estimates, see Figure 3. Tables 4 and 5 indicate that the RefH peak flows are generally lower than the WINFAP peak flow estimates thus this is a conservative estimate of the hydrographs. These results are consistent with Environment Agency guidance which states that QMED (and other peak flows) can be underestimated when using ReFH within highly permeable catchments.

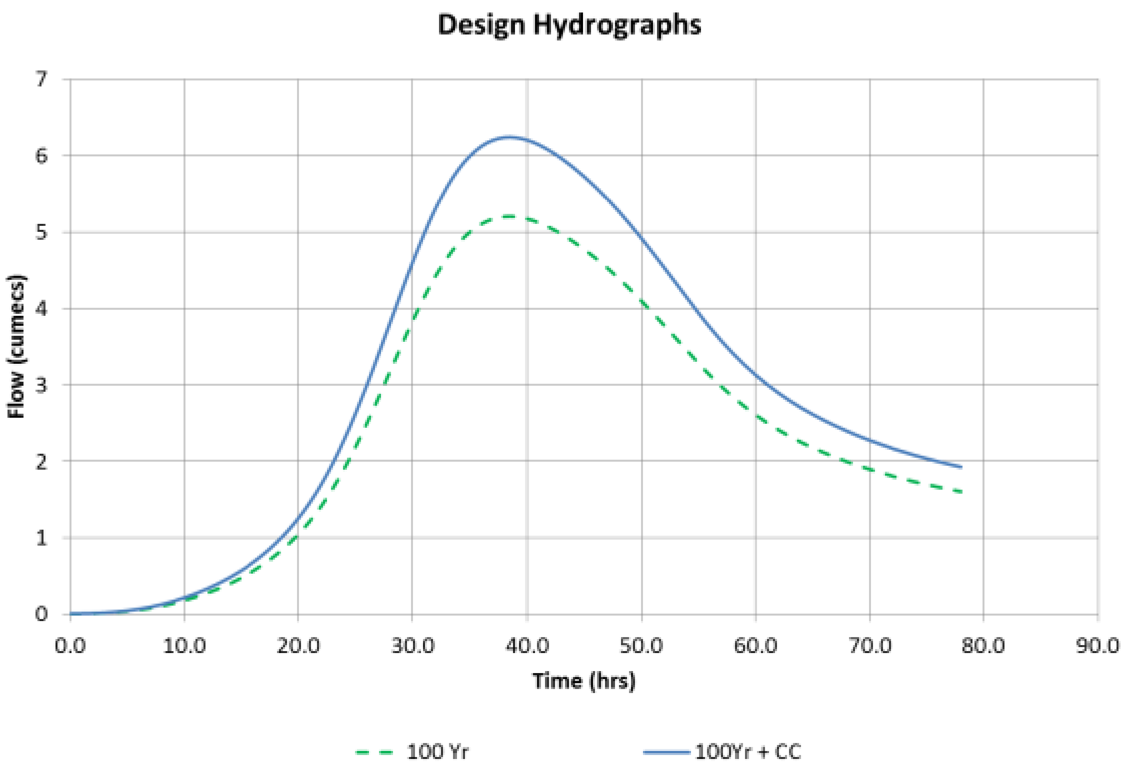


Figure 3 Final design hydrographs adopted

Appendix B. Hydraulic Model

Appendix B – Contents

1 Introduction

1.1 Methodology

The scope of modelling work was set out in a number of discussions and email communications with the Environment Agency. Given the nature of the surrounding catchment, the rural setting and relatively low flows indicated by the hydrological assessment, a 2D modelling exercise was considered appropriate. 1D ESTRY elements were used to define small culverts within the model area.

It was concluded that given the relatively small width of watercourse, it was appropriate for this study to use a relatively fine 2D topographic grid, set to 2m horizontal resolution.

The 2m grid resolution, will allow the development features (i.e. roads etc.) to be mapped and modelled more accurately, and therefore allow for a more accurate assessment of their true impacts on flood risk and levels across the wider area.

The methodology was agreed in principal with Lewis Purbrick of the Environment Agency in a phone call conversation dated June 2014.

1.2 Previous Model Study

As part of a separate flood modelling study, WHS undertook detailed hydraulic modelling of the River Ray through Islip on behalf of Network Rail in early 2014. The northern boundary of this model was located to the south of the railway embankment (south of Brookfurlong Farm). The hydraulic model was a fully integrated 1D/2D model using ISIS-TUFLOW modelling software.

Although this model will not be used in its current form, this model will be used to inform the downstream boundary conditions for the modelling carried out as part of this study.

2 2D Modelling

2D modelling allows the flow of flood waters across the floodplain to be considered as well as those within smaller watercourses. Using 2D modelling, features such as buildings or a change in topography can be incorporated into a DTM (digital terrain model) of the floodplain. This allows for consideration of impacts caused as a result of development works (which alter the ground levels across an area). This study used 2D modelling in order to assess the change in flood depths, velocities, water levels upstream and downstream of the proposed Brookfurlong Farm works.

A number of files were used in order to build up a digital representation of the floodplain and the potential flood routes that exist. Additional topographical layers were added to alter the digital terrain model with proposed post-development levels. The construction of the 2D domain is considered in the following sections.

TUFLOW was used as the 2D model package. The 2D model component was run using a 2m grid cell size, which is small enough to allow for 2D flood plain features such as the proposed road works to be represented accurately. A 1 second time step was used during the simulations to aid in any stability issues.

2.1 Channel and Floodplain Topography

Prior to commencement of this project, LiDAR data were collated for the model study area. It was noted that the channel banks and widths were relatively well defined within the 2m horizontal data set. It was also observed that the water surface level within both channels was also clear at a number of locations along each channel. The level within the LiDAR datum is considered to represent a conservative estimation of bed level, given a) the horizontal accuracy and the likelihood of obtaining the exact bed level, and b) the inability of LiDAR to penetrate deep water (although less of an issue is expected in these sized watercourses). As such using the LiDAR would give a conservative estimation of depth of channel.

As such, in order to aid in the speed of model delivery it was concluded that "bed level" could be identified from LiDAR but checking of the accuracy would first be required. During June 2014, site survey was undertaken by WHS. This involved obtaining the depth of channel from left bank at a number of sections through each reach. This could then be checked against the LiDAR.

At a number of comparable points, the LiDAR was shown to represent the channel width and shape well. The depth of channel was somewhat conservative however this is considered to allow for a conservative method of modelling.

Given the assumed bed level was not picked up by LiDAR throughout the channel, interpolation between points was undertaken along a Zline feature. This interpolated levels between LiDAR bed levels along the channel allowing a clear channel for flows to pass through. This is the same concept used within 1D model when a downstream distance to a next section is used. The width of the bed was set to 2m, meaning only the in-stream bed levels were changed, whilst ensuring additional channel storage wasn't created. The alignment of the zline used in order to model the watercourse is highlighted within Figure 1.

Lidar data were used as the underlying topographic data, for representation of the floodplain. A 2m resolution data set was used, and converted to a 2m model grid. Flood plain extent was considered to be relatively large in this area, as the topography is very flat. As a result, a large 2D code polygon (defining the active area for modeling to occur) was used. This reduces the risk of glass walling occurring. Figure 1 highlights the area of 2D model extent.

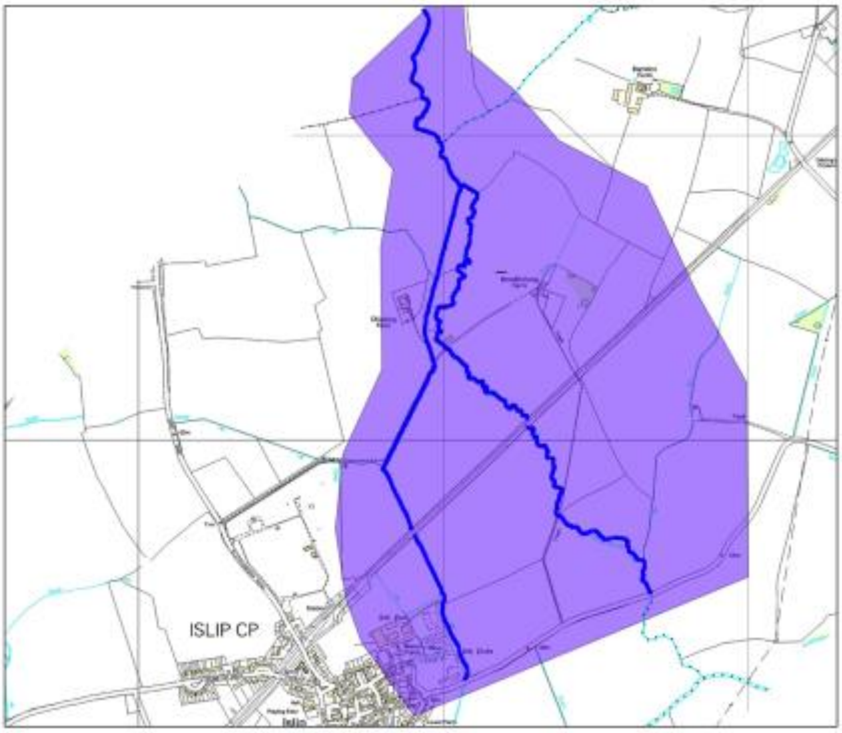


Figure 1- 2D model extent with alignment of watercourse network Zline

2.2 Roughness Co-efficient

A baseline Mannings 'n' roughness coefficient was applied across the 2D domain. The floodplain is essentially rural pastureland / agricultural land. The baseline Mannings value equates to 0.045 (farmland – long crops). The 2d_mat_Brook_R_001.shp provided within the model files allows analysis of other values used across the floodplain, this mainly relate to the urban area around Islip adopted from the previous model.

Given the channel is being represented within the 2D model; there was a need for this to be assigned a suitable Mannings value. Given the relatively dense vegetation along the channel a relatively high Mannings of 0.045 was used. This also matches the baseline Manning's adopted across the floodplain.

2.3 Structures

A number of in channel structures exist on both the Gallos Brook and Mill Run, as such these need to be taken into account within the baseline and post development modelling. Figure 2 below highlights the location of the structures, a description of structures and method of representation is provided within the following sections.

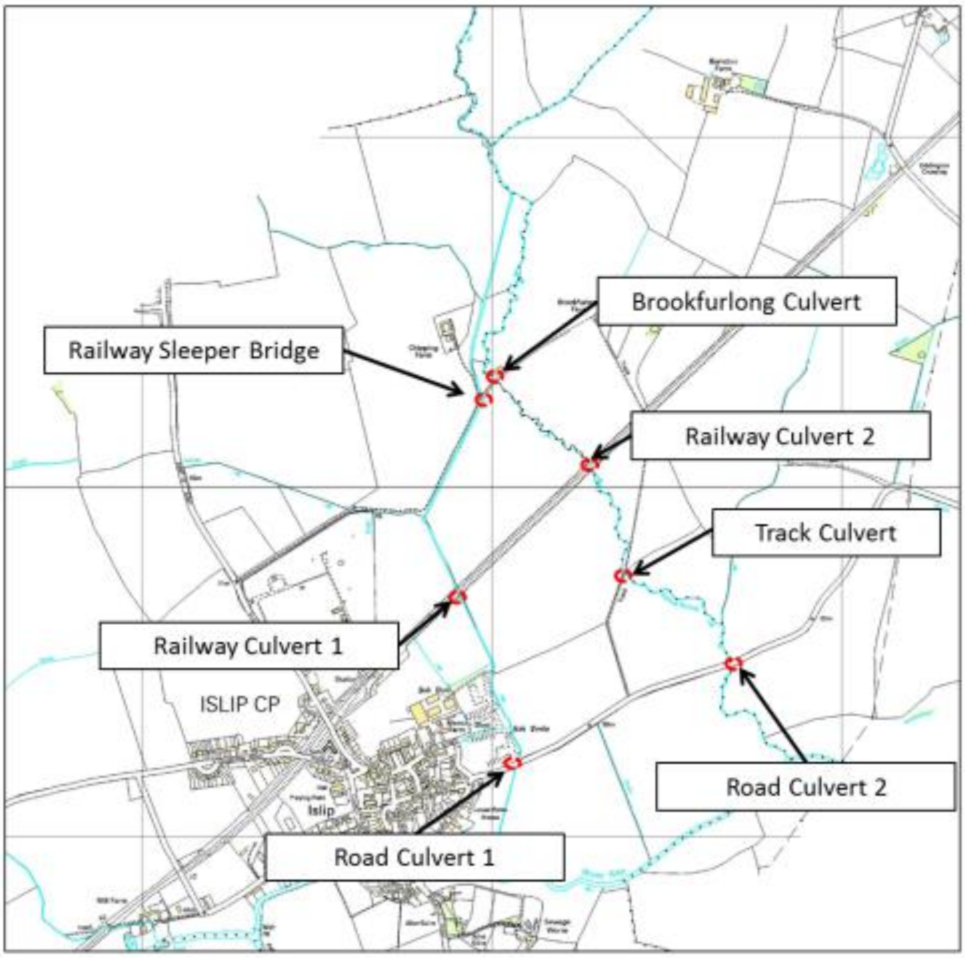


Figure 2 - Location of instream structures within the model domain

Brookfurlong Culvert

Based on site survey, this culvert is approximately 0.3m in diameter. As such this structure has been represented within the model as an ESTRY culvert unit. The upstream and downstream bed levels are based on those levels identified as the bed from LiDAR.

Railway Sleeper Bridge

The structure is approximately 3.13m in width. During the baseline modelling this structure has not been modelled in ESTRY. Rather, the 2D floodplain levels representing the bridge were removed by 1 cell in width. This is considered a conservative representation of the structure. A flow constriction layer was added to model the depth of beams and railway sleepers when flood levels are above 60.49m AOD, i.e the soffit level of the existing bridge.

Railway Culvert 1 and Railway Culvert 2

Based on our survey section at these structures the width of these crossings are 4m, with a soffit 3.5m above the bed level. Access to culvert 2 was greatly restricted and so based on what could be observed this has been modelled to assume a similar structure. The structures have been modelled in the same method as the Railways Sleeper Bridge upstream. The width has been modelled as 2 model cells in width (4m).

Due to the minor uncertainty in the width of Railway Culvert 2, sensitivity analysis was carried out. The model was adjusted so that the width of Railway Culvert 2 was 2m, this forces the model to be more conservative as flow is further restricted. The results of this sensitivity analysis are given in Appendix B section 4 of this report.

Road Culvert

A small culvert was observed at this location as the road crosses the watercourse. As such an ESTRY culvert unit was used to model the 0.9m diameter pipe.

Road Culvert 1 and 2

These structures given their size have been modelled as with the Railway Culverts. Given the location of these structures and the fact the road is overtopped this will have no impact on the final levels at Brookfurlong Farm. These have been inserted to allow for sensitivity assessment on the downstream boundary to allow the simulation of a receding River Ray in combination with an event on the Gallos Brook.

2.4 Upstream Boundary

The upstream boundary of the model has been set as a QT boundary. This reads in the 1 in 100 year plus climate change flood hydrology as calculated within the 0. This has been set as a boundary line to aid in stability rather than a point.

2.5 Downstream Boundary

A downstream boundary has been set up as a 2D HT boundary. The HT boundary represents the maximum flood level predicted during previous modelling of the River Ray for the model at Islip. To be conservative in our assessment the HT boundary is set to the maximum level during the 1 in 100 year CC event on the Ray in combination with a 1 in 100 year CC on the Cherwell for the entire model duration.

To aid in stability an initial water level has been set across the lower portion of the model domain; this is set to the maximum flood level as outlined above.

2.6 Development – 2D Alterations

A number of alterations were made to the 2D domain in order to simulate the predicted impacts as a result of the proposed works. The proposed vertical alignment of Brookfurlong Farm access road was provided by Atkins and input into the model as a zshape set to raise the associated zpoints to the required design level. The location of the zshape and zpt level are highlighted in Figure 3.

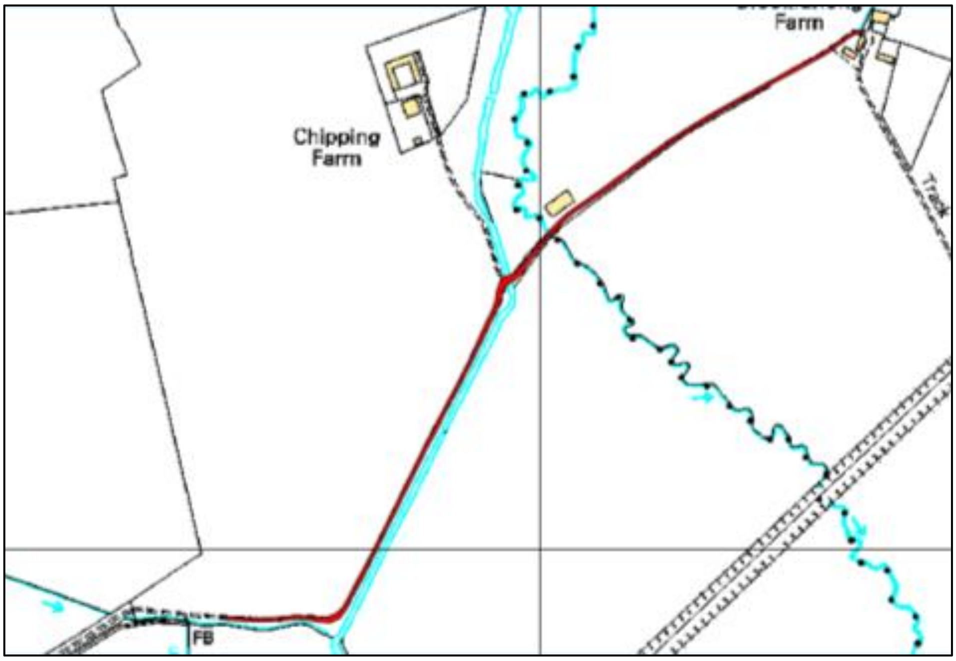


Figure 3 - Location of zshape representing the proposed development road

3 Model Runs

A number of simulations were undertaken in order to assess the impacts of the proposed works. The following flow events were simulated;

Baseline Simulation

- 1 in 100 year plus climate change on Gallos Brook combined with downstream boundary set to the maximum level for the 1 in 100 year plus climate change event on the River Ray

Sensitivity Analysis on Proposed Bridge Soffit Level

- Post development simulation with no flow constriction associated with the railway sleeper bridge

Sensitivity Analysis on Railway Culvert 2

- Baseline simulation plus reduced dimensions of Railway Culvert 2

Post Development Simulation

- 1 in 100 year plus climate change on Gallos Brook combined with downstream boundary set to the maximum level for the 1 in 100 year plus climate change event on the River Ray

4 Sensitivity Analysis

4.1 Soffit levels of proposed Bridge

The soffit level for the proposed bridge crossing over Gallos Brook is 60.59m AOD. This is 60mm below the predicted 1 in 100 year plus an allowance for climate change flood level of 60.65m AOD.

To determine the impact that the 60mm inundation of the bridge soffit level has on the predicted flood levels, sensitivity analysis was carried out by modelling a scenario where the soffit level of the bridge is raised completely above the predicted flood level.

The results of this sensitivity analysis show that raising the soffit level of the bridge so that it is above the predicted 1 in 100 year plus an allowance for climate change flood level, leads to no significant increases in flood depths. The maximum flood depth increase at the location of the bridge is 6mm, Figure 4.

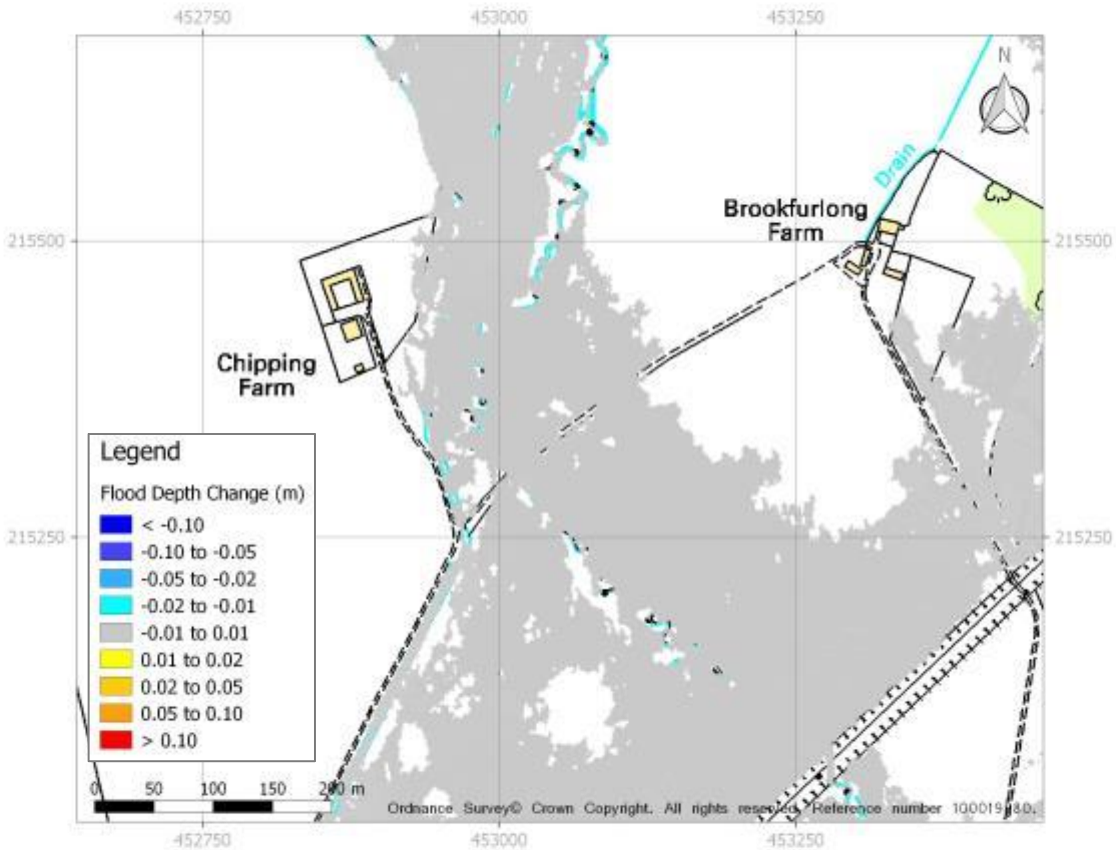


Figure 4 – Sensitivity Analysis, Raising proposed bridge soffit level above the predicted 1 in 100 year plus an allowance for climate change flood level

4.2 Railway Culvert 002

The sensitivity of Railway Culvert 002 was tested due to uncertainties in its dimensions. To determine how much of an impact that the culvert has on the model, the model width of the culvert was reduced by 50%. The results from the 1 in 100 year+cc baseline model was compared to the results of running the model with the reduced culvert dimensions.

Analysis of the change in flood depth is shown in Figure 5. It can be seen that there are no significant changes in flood depth either upstream or downstream of the culvert. Within the culvert itself, the water level has dropped by approximately 30mm.

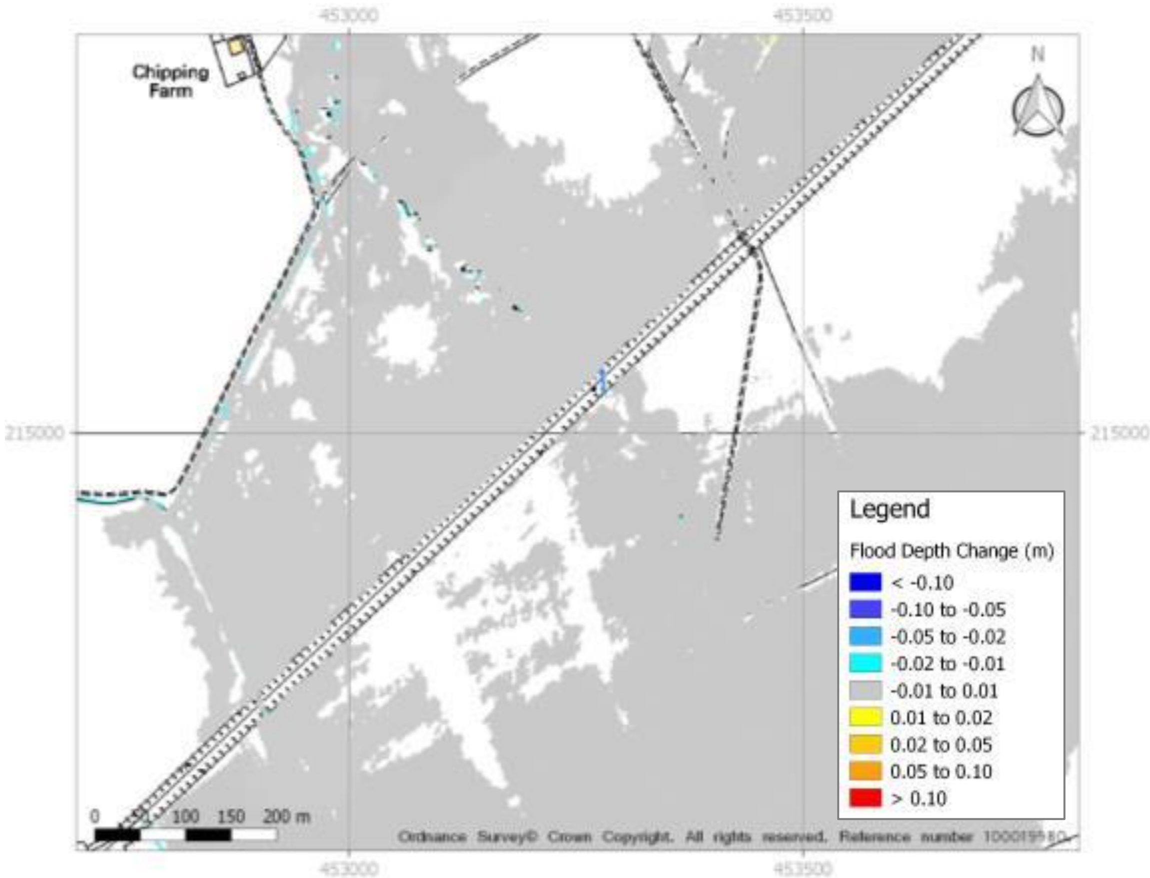


Figure 5 – Sensitivity Analysis, Change in Flood Depth due to Reduced Railway Culvert Dimensions

To confirm the cause of the reduced water level within the culvert, the velocity was also analysed. It can be seen in Figure 6 that there are increases in the water velocity within the culvert.

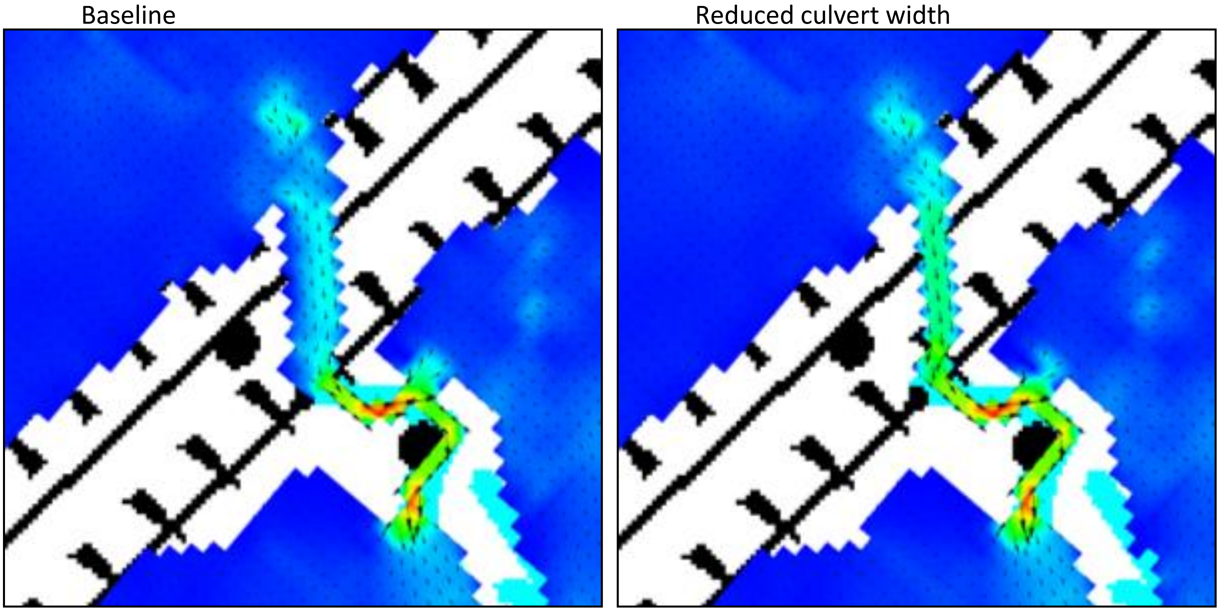


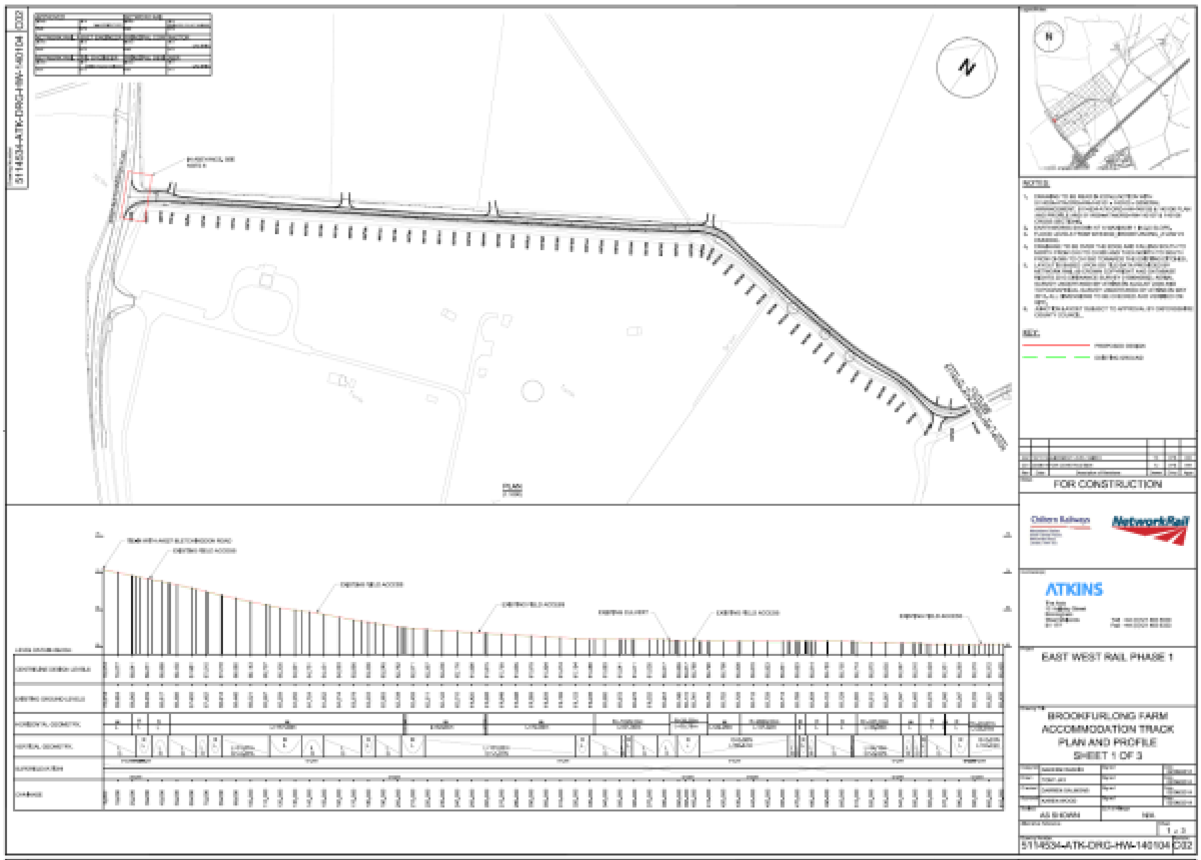
Figure 6 – Velocity Grid throughout Railway Culver 002

It is concluded that the reduction in the culvert width has caused higher flow velocities and reduced flood depths within the culvert. This is supported by the increased velocity and decreased flood depth that is seen during the sensitivity analysis.

Reducing the culvert width has negligible impacts on the flood depth; as such the uncertainty in the culvert dimensions does not impact the model, particularly at the points of interest around the Brookfurlong Farm access road.

As the model is focused on establishing the relative impact of revised level for the Brookfurlong Farm access road, additional sensitivity analysis is not required.

Appendix C. Design Drawings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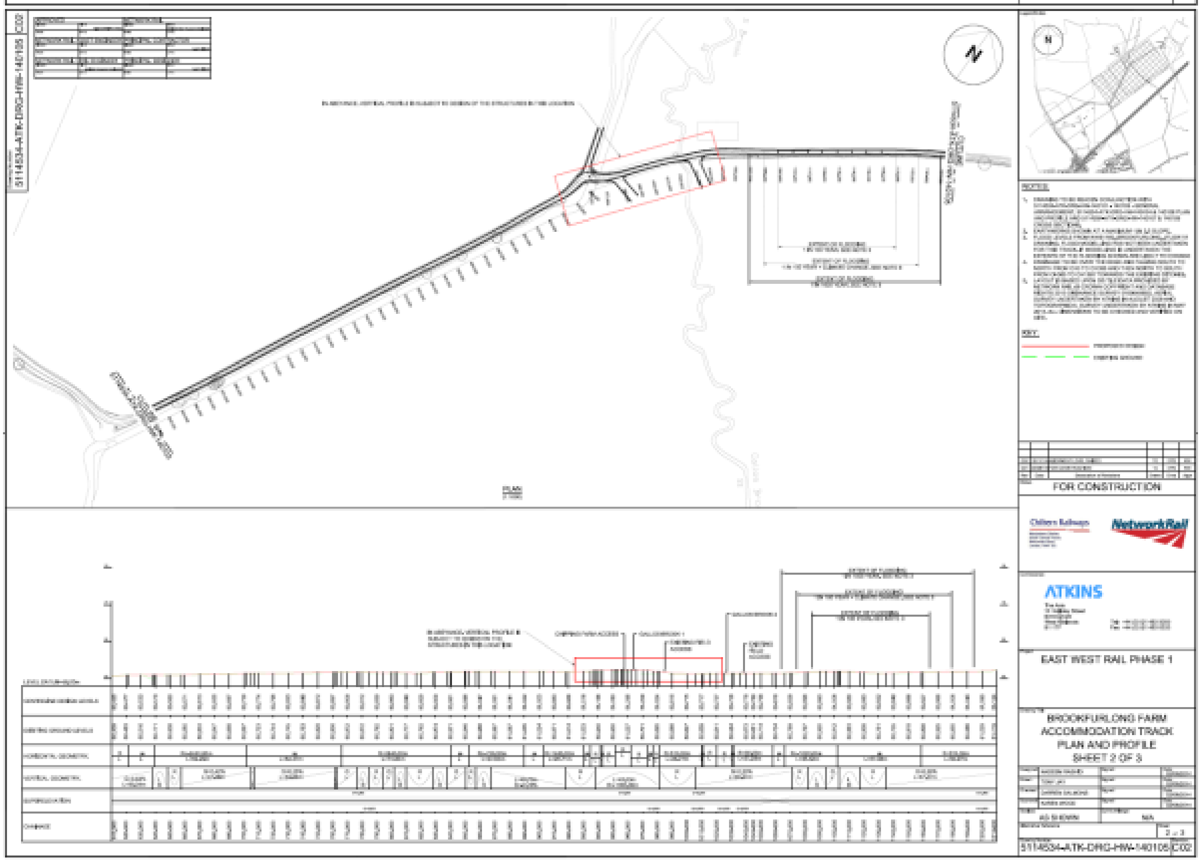
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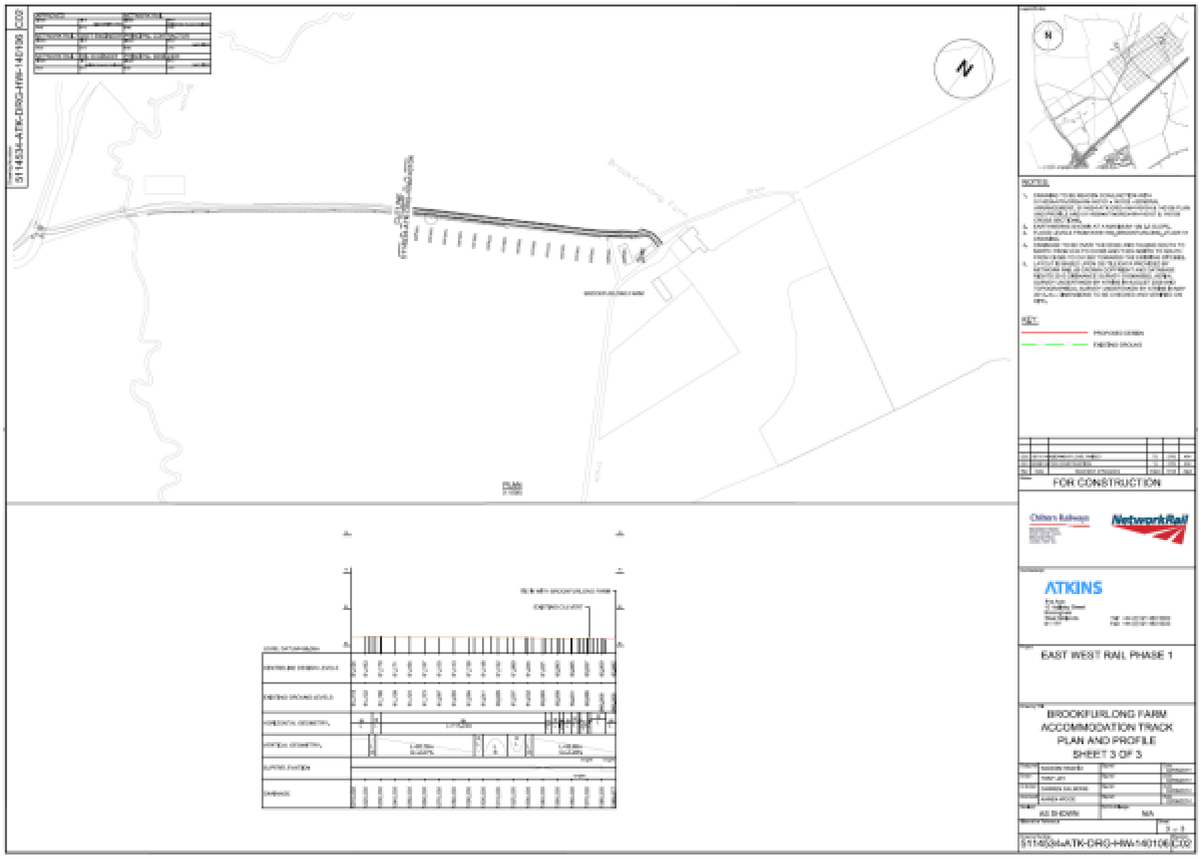
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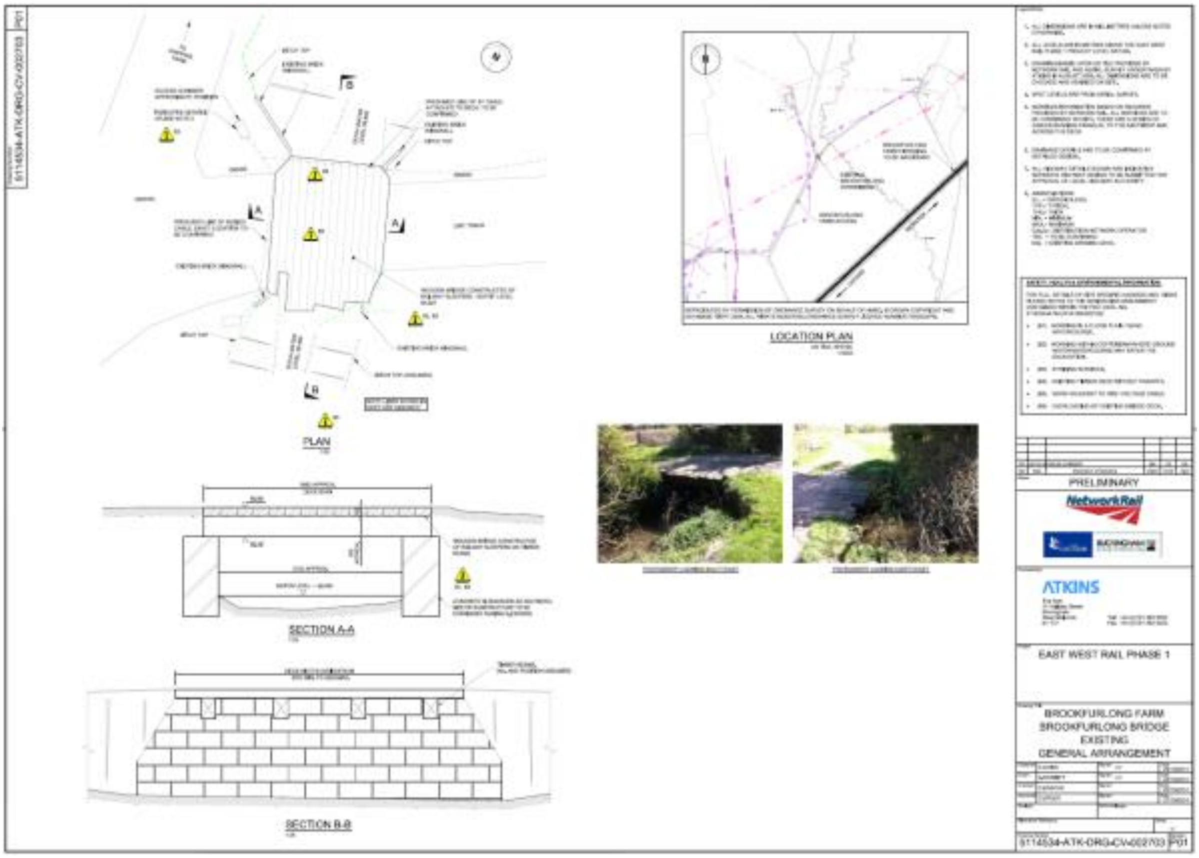
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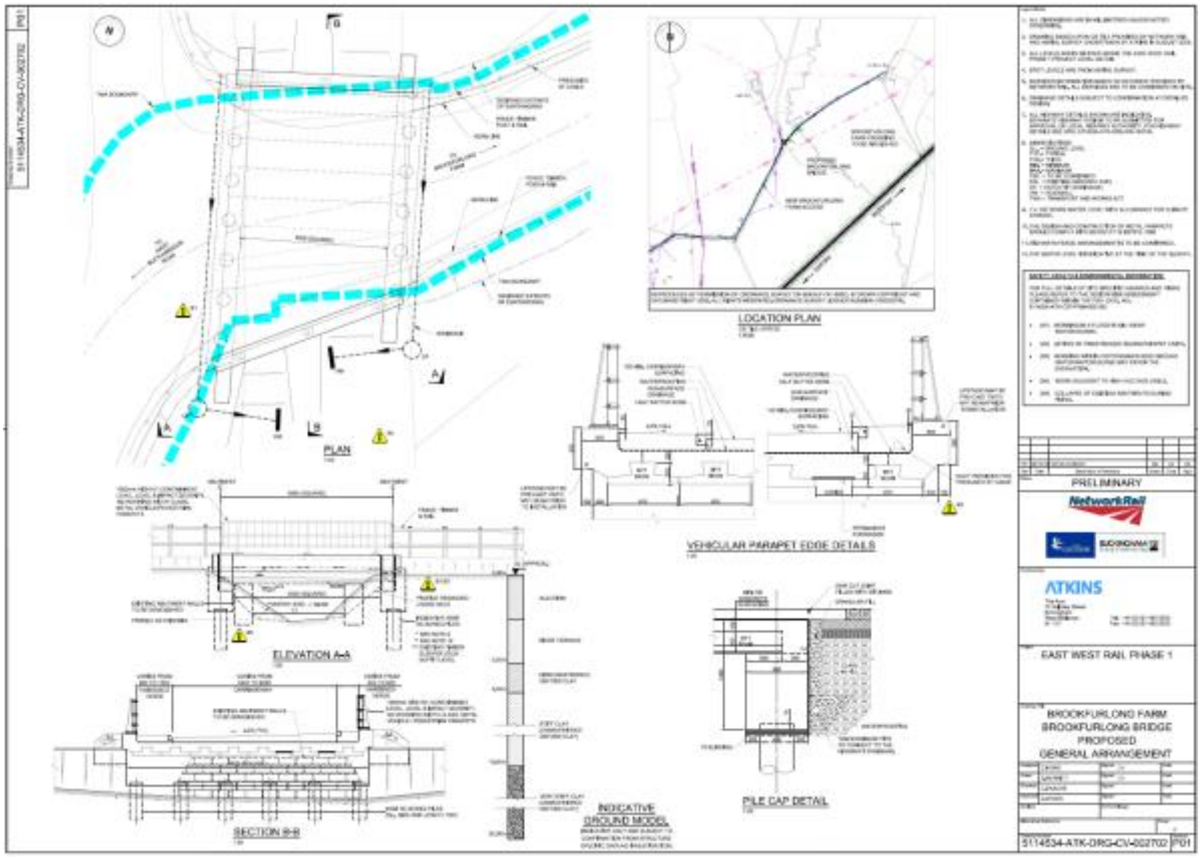
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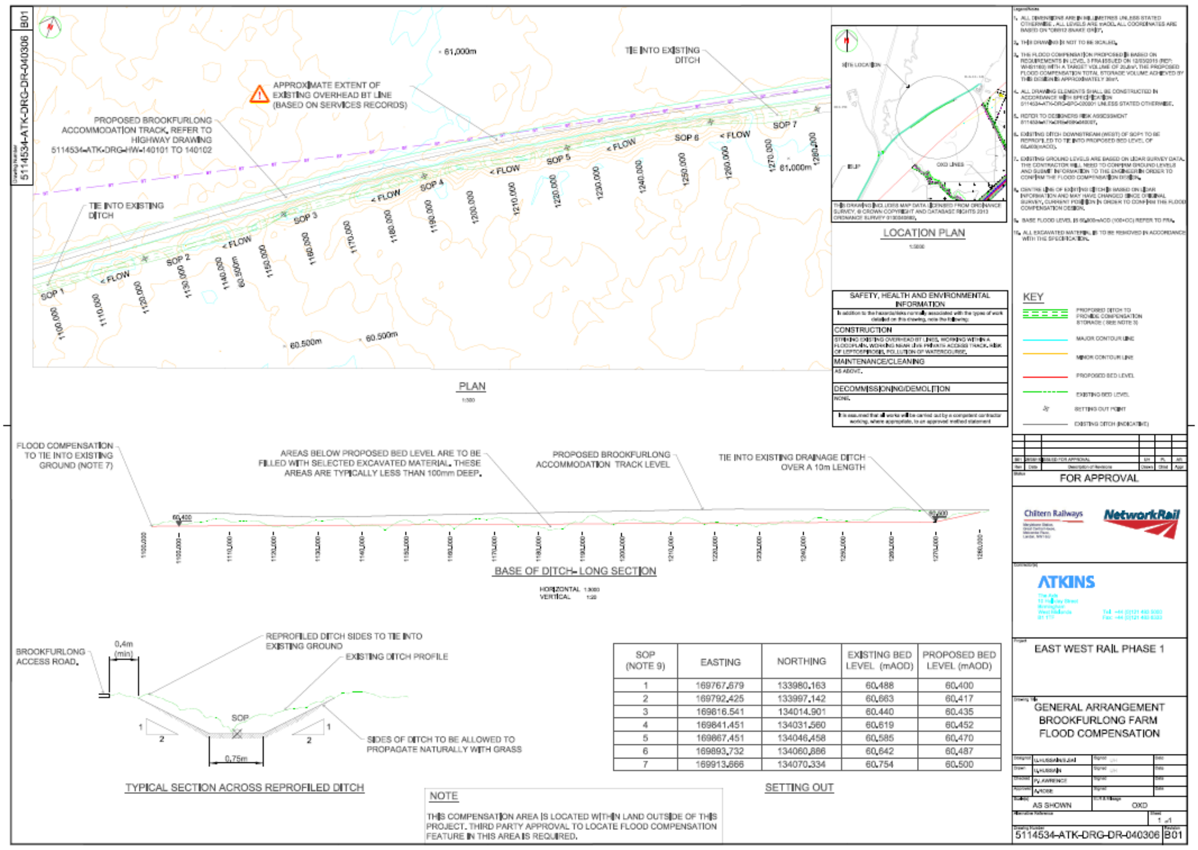

SOP (NOTE 9)	EASTING	NORTHING	EXISTING BED LEVEL (mAOD)	PROPOSED BED LEVEL (mAOD)
1	169767.679	133980.163	60.488	60.400
2	169792.425	133997.142	60.683	60.417
3	169816.541	134014.901	60.440	60.435
4	169841.451	134031.560	60.619	60.452
5	169867.451	134046.458	60.585	60.470
6	169893.732	134060.886	60.642	60.487
7	169913.666	134070.334	60.754	60.500

SETTING OUT