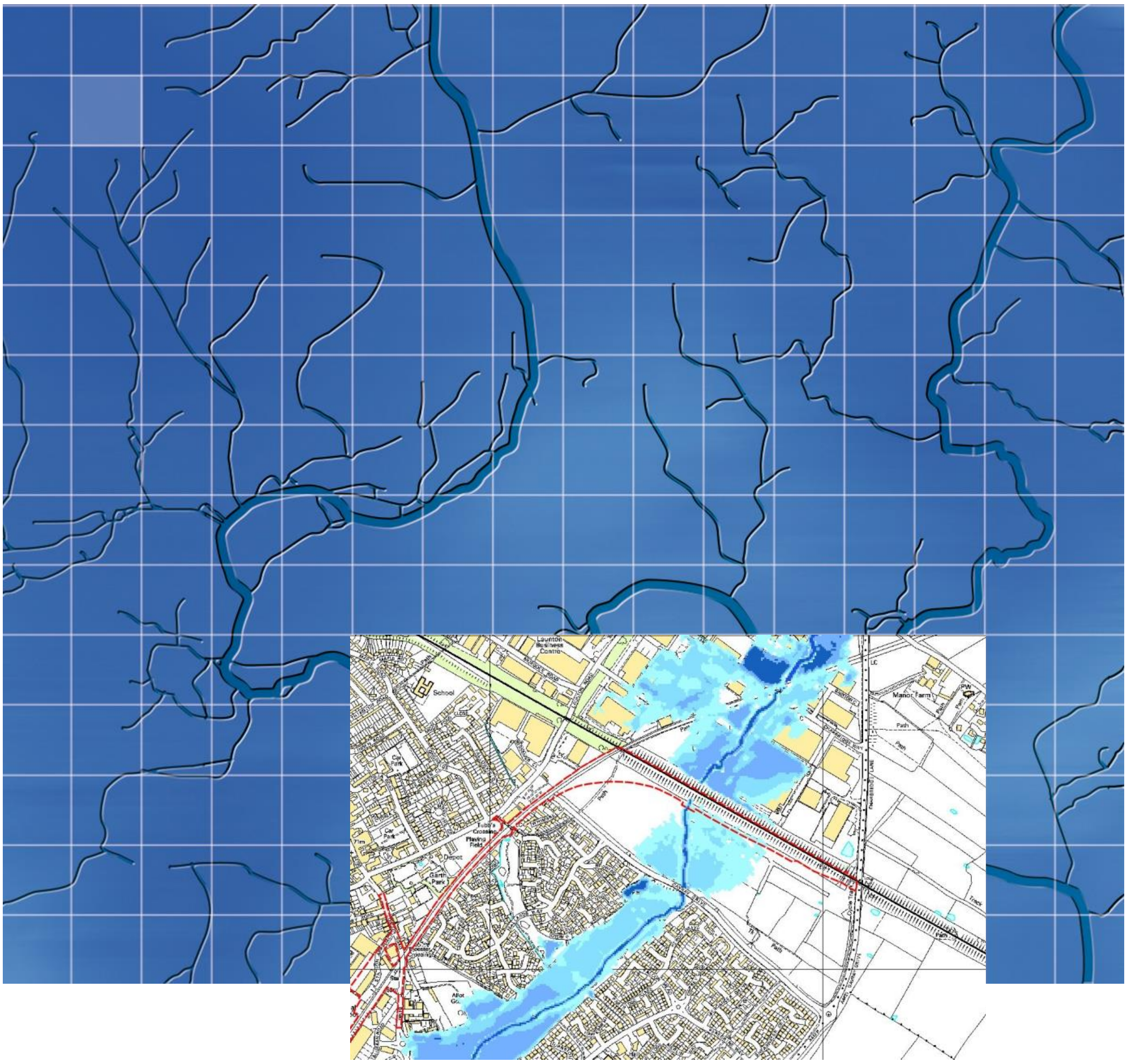
Chiltern Railways

July 2013

EWR-P1- Level 3 FRA: Bicester Chord



Wallingford HydroSolutions Limited

Chiltern Railways

EWR P1 - Level 3 FRA: Bicester Chord

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For and on behalf of Wallingford HydroSolutions Ltd.

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Position *Technical Director*

Date **02nd July 2013**

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Contents

Appendix 4 – Bicester Chord Surface Water Assessment Proposed Drainage Arrangement

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 outlining flood storage mitigation requirements (Chiltern Railways Bicester to Oxford Improvements Level 2 Flood Risk Assessment, July 2010 & Compensatory Storage Technical Paper and Level 3 FRA Specification) 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 Planning Policy Statement 25: Development and Flood Risk (PPS25), and its 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. These assessment points included AP1 – Bicester Chord.

1.2 Scope of Level 3 FRA

This document constitutes a Level 3 Flood Risk Assessment and surface water drainage assessment for AP1 – Bicester Chord, as required by Planning Conditions 12 and 13 of deemed planning permission granted alongside the Order under the Transport and Works Act 1992.

This document, together with the original Level 2 FRA, also provides the information required by the National Planning Policy Framework (NPPF) and the associated requirements of PPS25.

This FRA document has been commissioned to address the flood risk and surface water drainage issues that result from the construction of the Bicester Chord line extension. The location of the Bicester Chord works is shown in Figure 1 and 2 below. As part of the Bicester Chord, a new double track railway is to be built upon a significant embankment, up to 8m high. 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.

Although surface water drainage issues are dealt with in this FRA, an additional document titled (ERW P1 – SW Drainage Assessment (footbridges)) was also submitted in June 2013 which focuses on the surface water runoff issues resulting from the construction of a number of additional pedestrian overbridges that are to be built as part of the overall scheme and includes the proposed footbridge at the Bicester Chord.

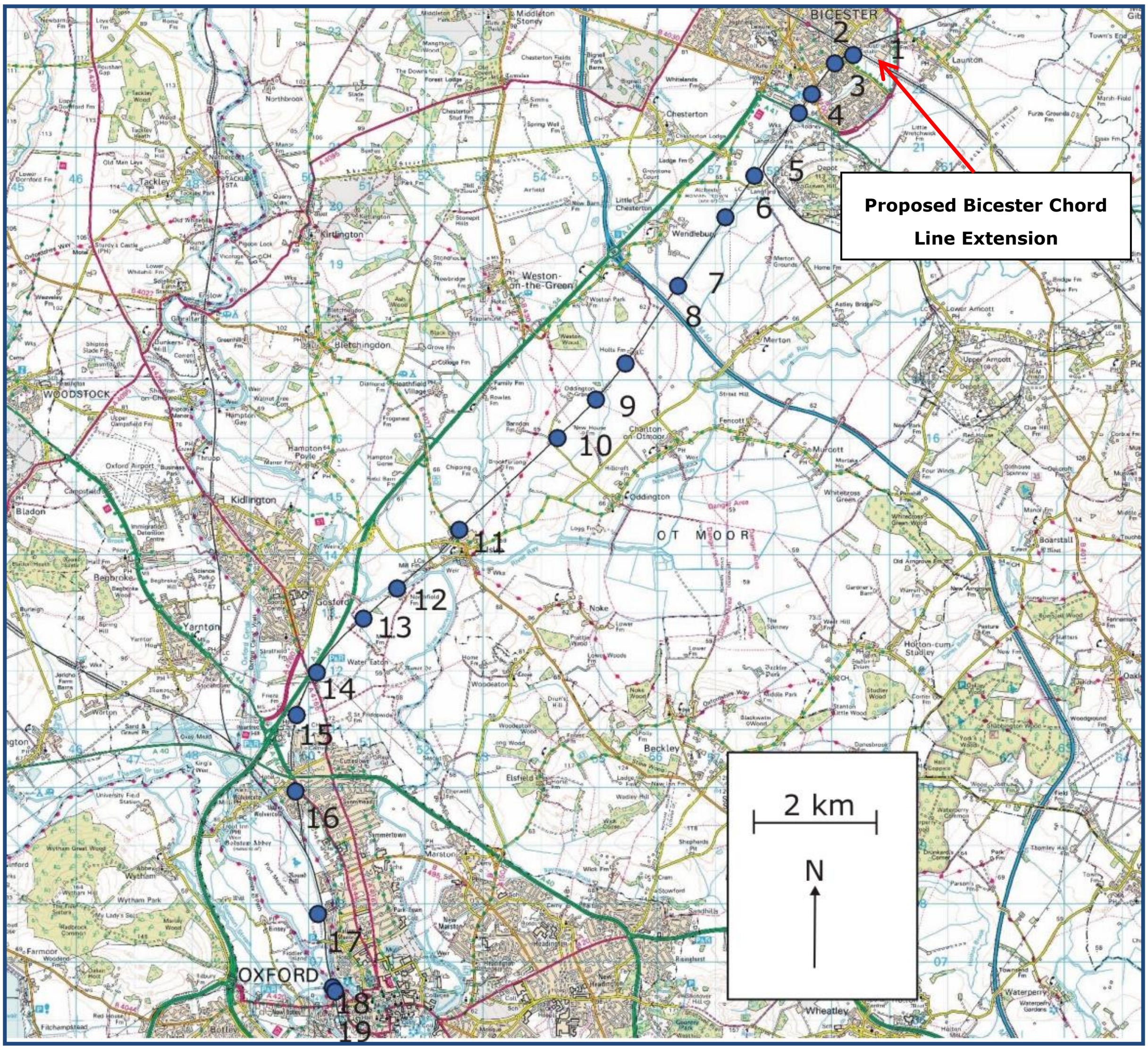

Figure 1 – Scheme Overview showing various assessment points.

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; a new independent line being built between Oxford North Junction and Oxford station, using a disused track bed parallel to the existing railway; the existing stations at Bicester Town and Islip will be rebuilt, and a new station built at Water Eaton Parkway; and at Oxford the disused parcels platforms at the north end of the station will be removed and replaced for passenger use for Chiltern Railways services.

This site specific Level 3 FRA considers Assessment Point 1 – The Bicester Chord Line Extension. The proposed Bicester Chord is a double track chord enabling trains to and from Oxford to transfer to the London to Birmingham railway. Figure 2 below shows the location of the proposed Bicester Chord extension, along with the flood inundation area defined by the 1 in 100 year (plus an allowance for climate change) Bicester Model output grid[1]

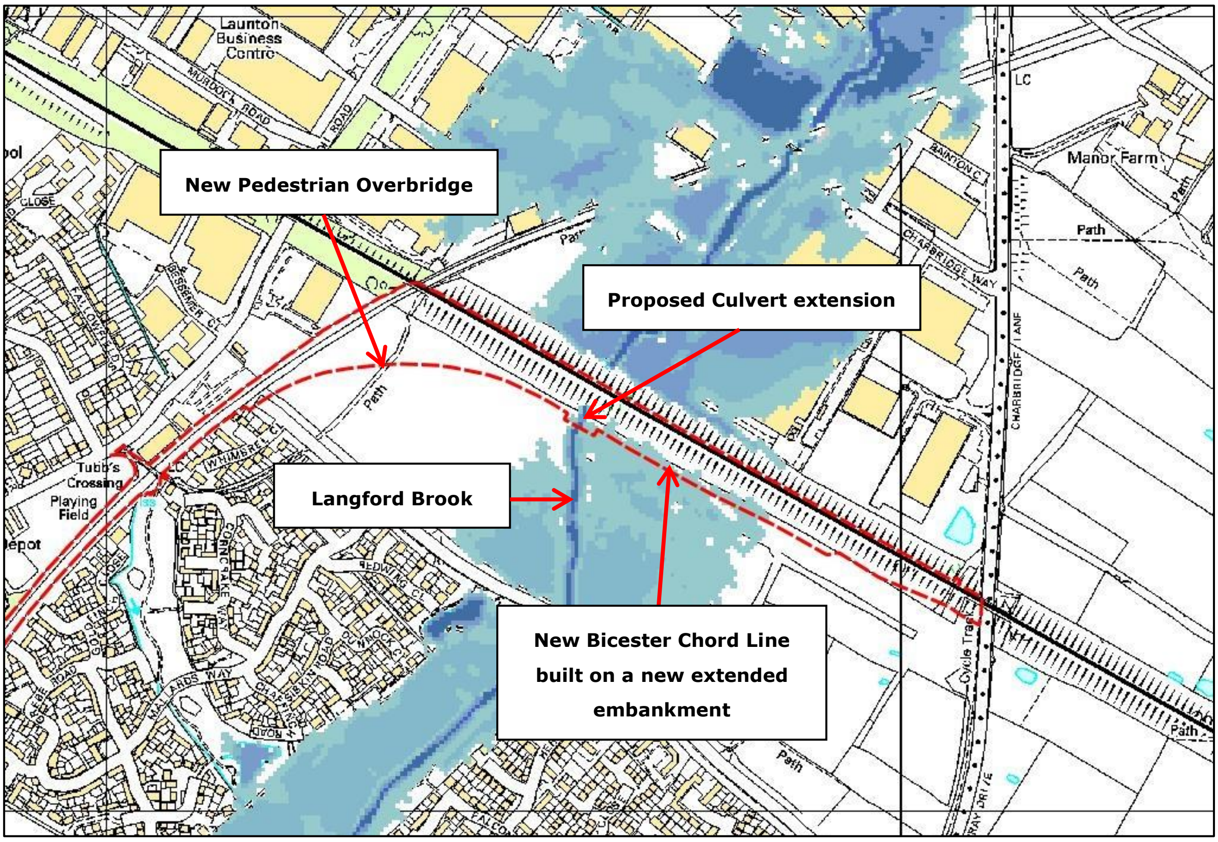

Figure 2 – Bicester Chord location plan with Q100+CC flood mapping.

[1] Peter Brett Associates (2009) *Flood Risk Mapping Study, Final Modelling Report.*

2.2 Description of the Proposed Works

2.2.1 Pedestrian Overbridge

A new pedestrian overbridge is to be built across the new chord line to maintain access through the public right of way (running essentially parallel with the Bletchley to Oxford line) as shown in Figure 3 below.

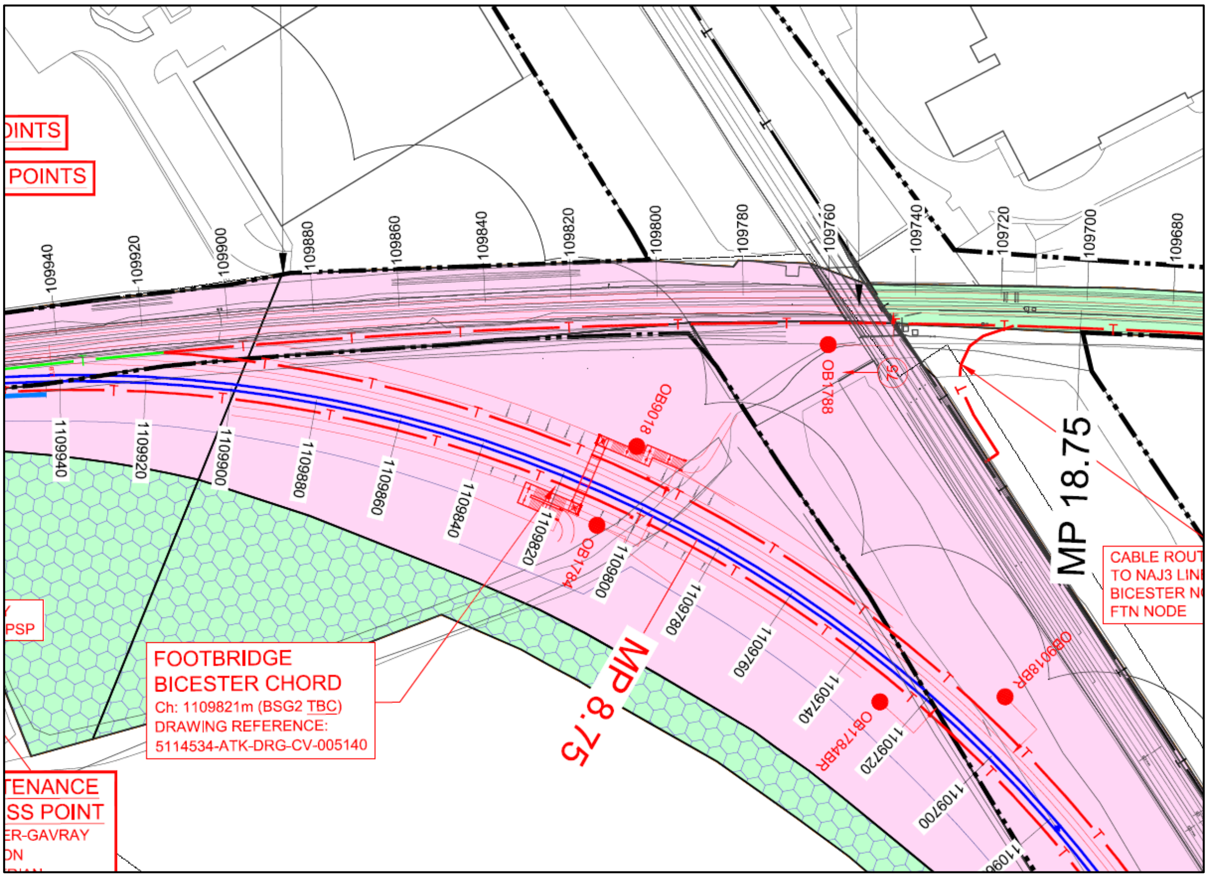

Figure 3 – Proposed pedestrian overbridge location. (Atkins 2012. Coordination Drawings)

2.2.2 Bicester Chord Embankment Works

As part of the Bicester Chord works package there is a new double track to be built upon an embankment, which rises up from existing ground level up to 8m above ground, in order for the track to gain the required height to join the Birmingham to London line, as shown in Figure 4 below. The Langford Brook flows under the existing Birmingham to London line and the proposed embankment widening work impinges on to the active floodplain of the Langford Brook as defined by the 1 in 100 year (plus an allowance for climate change) Bicester model[1] flood extents. The scale and relative impacts of this embankment widening work will be investigated in this report with appropriate mitigation measures recommended to effectively manage flood risk.

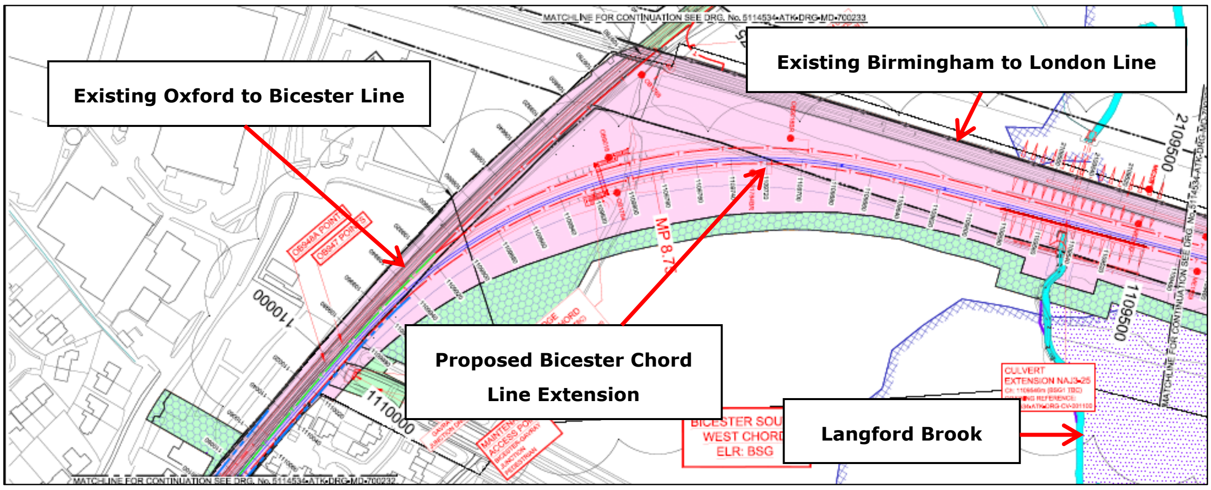

Figure 4 – Bicester Chord Line Extension Design. (Atkins 2012. Coordination Drawings)

2.2.3 Culvert Extension

The existing Langford Brook crossing (a masonry arch culvert) is to be extended by 5m to accommodate the widened embankment footprint using pre-cast reinforced concrete box culvert sections. The cross sectional area of the extension is larger than that of the existing culvert, therefore it is unlikely that the extension will act as a constriction to flow. However, hydraulic modelling of the pre and post development arrangements has been conducted to ensure impacts of this culvert extension do not increase flood risk. Figure 5 below shows the location of the proposed culvert extension.

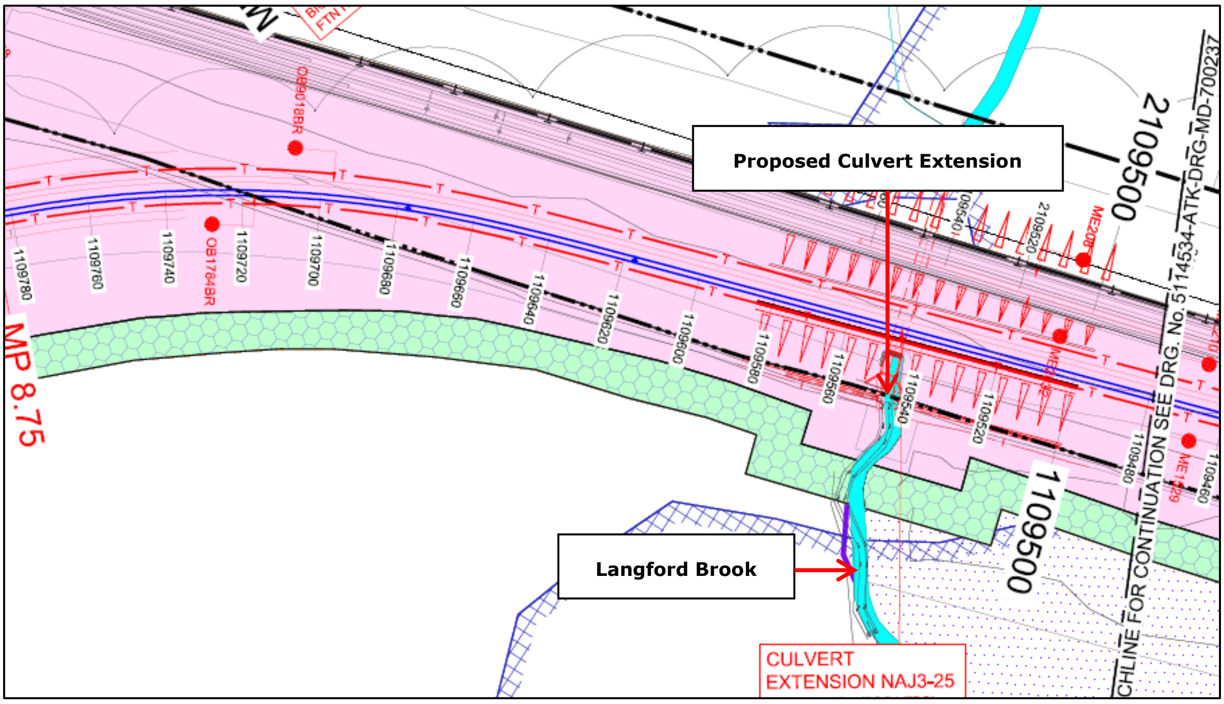

Figure 5 – Proposed Culvert Extension. (Atkins 2012. Coordination Drawings)

2.2.4 Works Approvals

A 'Works Approval' is to be submitted separately in due course for the culvert extension and any flood compensation storage pond for approval by the EA, 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 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 of the Bicester Chord line extension. 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 hardcore or stone surface to avoid increasing the impermeable footprint of the site.

Chiltern Railways will submit applications for the permanent Works Approvals and the Contractor will submit applications for temporary works approvals, where necessary.

3 Bicester Chord Embankment Works

This section outlines the methodology used in undertaking the flood impact assessment for the embankment widening work at the Bicester Chord. This involves an assessment of the floodplain storage volume lost as a result of embankment widening and includes recommendations for mitigation measures to provide compensatory floodplain storage. The Bicester hydraulic model[1] has been used to inform design, which has been approved for use for this study by the Environment Agency (EA). 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:

- Calculate the predicted flood level adjacent to the proposed Bicester Chord line extension using the Bicester model output grids provided[1].

- Calculate the subsequent flood storage volume lost at 200mm depth intervals as a result of the embankment widening works. This uses detailed earthworks design sections provided by Atkins[2] to assess volumes of floodplain lost.

- Provide compensatory floodplain storage on a level for level basis as a mitigation measure to ensure flood risk is effectively managed.

The approach used in this assessment has been discussed and agreed with the EA.

3.1 Data Sources Used

A number of data sources have been used in the current assessment which include;

- Detailed earthwork cross sections[2] of the proposed Bicester Chord embankment located within the 1 in 100 year (plus an allowance for climate change) flood zone at 20m centres.

- LiDAR data have been purchased through Geomatics Group. This has a 2m resolution, with a vertical accuracy of +/- 0.15 m;

- The Scheme Boundary, which for the purposes of the flood risk aspects of the Scheme is referred to as the 'blue line' boundary. This boundary incorporates land within the Limits of Deviation (LOD) and those areas of the Limits of Land to be Acquired and Used (LLAU) where Chiltern Railways has the legal powers to install flood mitigation, without further land acquisition.

- Aerial photography has been purchased from Centremaps to aid in the ground truthing of LiDAR data and identifying areas suitable to provide compensatory flood storage.

- Hydraulic modelling outputs from the EA Bicester Model[1] are used to delineate the inundation area and obtain design flood levels for the 1:100 year (plus climate change allowances) event. This is a model developed for SFRA purposes, and is the most detailed available for this section of the scheme.

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[2] Atkins. 2013. Provided detailed earthworks section of the Bicester Chord Line Extension in AutoCAD format.

3.2 Predicted Flood Level

The Bicester model flood level grid has been used to obtain a predicted flood level adjacent to the Bicester Chord, as shown in Figure 6. This grid has been examined within a GIS software package and an average predicted flood level of 67.04mAOD been taken between the earthwork sections on the floodplain to the east of the Langford Brook. However, flood levels around the Langford Brook are elevated locally and a flood level of 67.15mAOD has been applied to sections adjacent to the Brook.

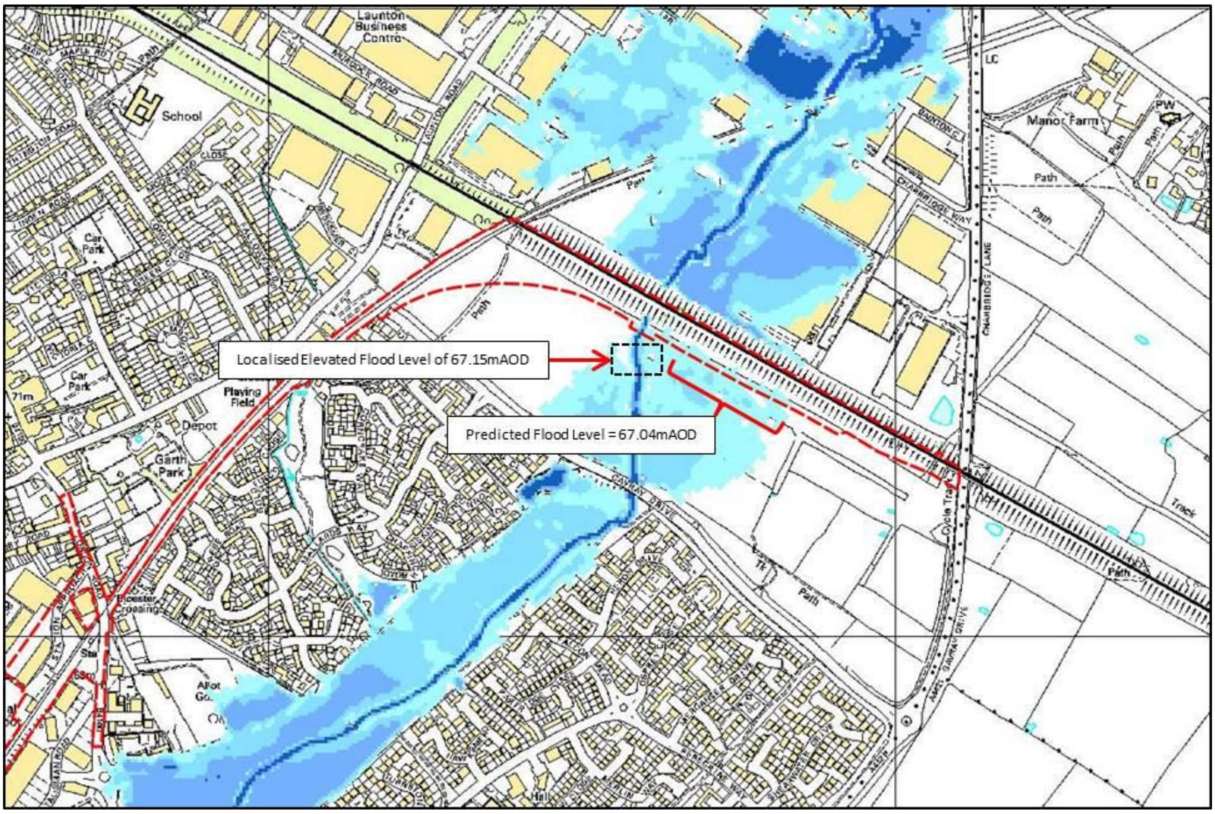


Figure 6 – Predicted flood level adjacent to the Bicester Chord.

3.3 Floodplain Storage Loss Analysis

The volume of floodplain storage lost as a result of the embankment widening work 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 AutoCAD design software. The method adopted is outlined below;

- Atkins has provided detailed earthworks sections[2] at 20 metre centres along the Bicester Chord Line extension. For each cross section, the area of floodplain lost has been determined by plotting the predicted flood level onto the embankment design sections and calculating the area of floodplain lost at set 200mm depth increments. See Figure 7 for a typical earthworks cross section of the embankment widening work and Figure 8 for details of how the cross-sectional area lost under the Q100+CC flood event has been calculated at 200mm intervals.

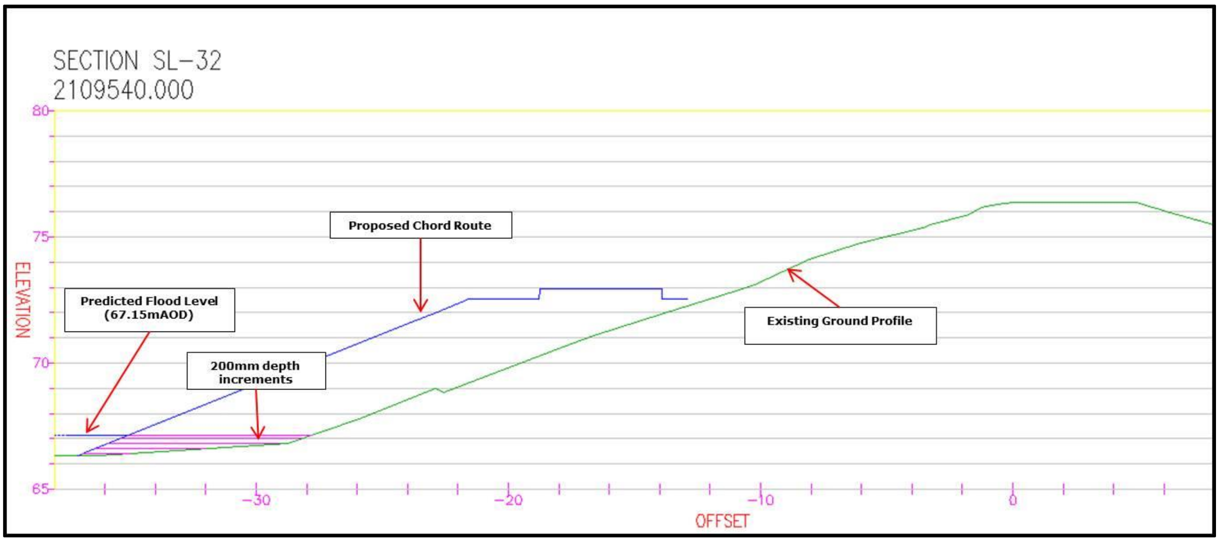


Figure 7 – Typical Earthwork section of the Bicester Chord embankment widening work. This figure shows the existing ground profile (green solid line), proposed Chord Embankment (blue solid line), predicted Flood Level (blue dashed line) and the set 200mm depth increments (pink solid line). (Earthwork Section Reference - 2109540)

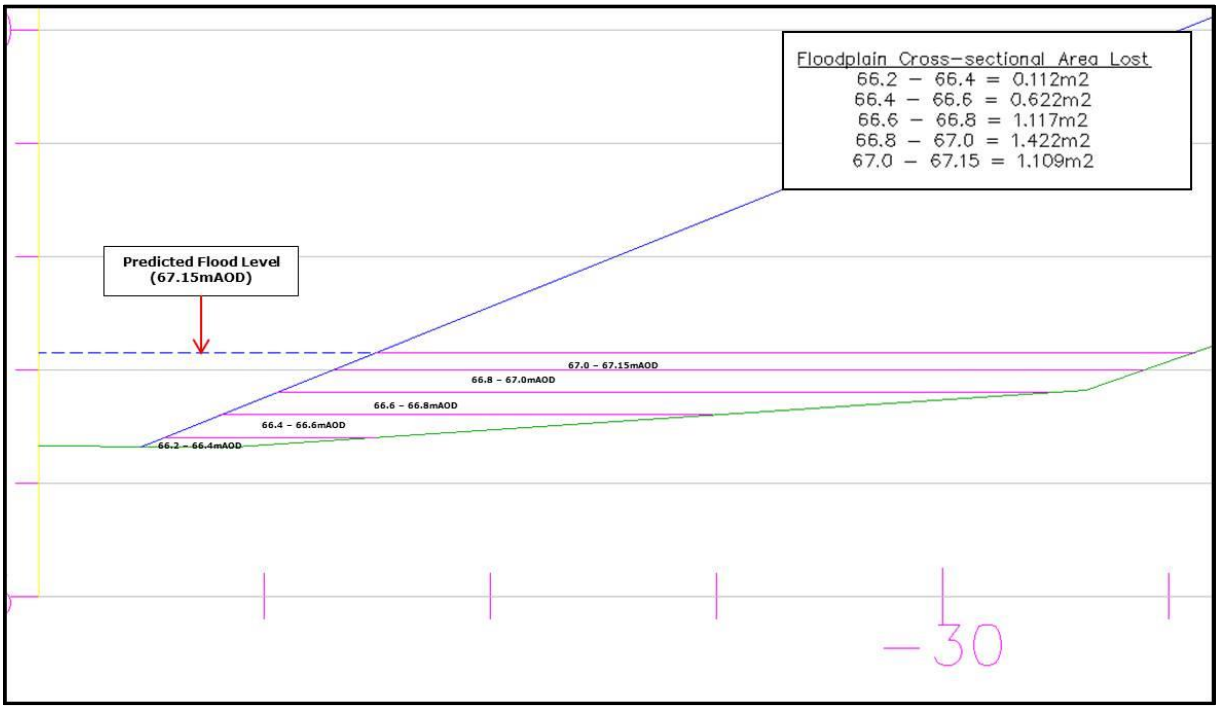


Figure 8 – Detailed breakdown of the cross-sectional area of floodplain lost to the embankment widening works at 200mm increments. (Earthwork Section Reference - 2109540)

- This process is repeated for all earthwork sections that lie within the 1 in 100 year (plus an allowance for climate change) flood inundation area along the length of the Chord.

- The final stage is to calculate the total volume lost within each depth band. This is achieved by multiplying the measured cross-sectional area within each depth band by the associated chainage (i.e 20m centres) over the total length of the Bicester Chord to give the total storage volume lost.

Table 1 below provides a summary of the level for level storage requirements at 200mm increments. The total storage volume lost to the Bicester chord line extension is 315m^3. Please refer to Appendix 1 for a breakdown of the floodplain volumes lost at each depth band across the total length of the Chord extension situated within an active flood zone.

Table 1 – Floodplain Storage volume losses at 200mm increments.

Depth Band	Loss of Storage Volume (m^3)	Land take Area Required (m^2)
66.2 - 66.4	3	15
66.4 - 66.6	14	70
66.6 - 66.8	45	230
66.8 - 67.0	143	720
67.0 - 67.15	110	730
Total Storage volume lost (m^3)	**315**	

3.4 Compensatory Storage Provision

The EA has confirmed that compensatory storage should be provided on a strict level for level basis to mitigate against the volume of floodplain lost as a result of the embankment widening works. The total volume of floodplain storage lost is 315m^3 as summarised in section 4.4 above. To achieve the level for level storage requirement, the compensatory storage volume needs to be provided between 66.2mAOD (lowest ground level at toe of new embankment) and 67.15mAOD (maximum predicted flood level).

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 that include;

- Where practicable, storage is to be provided within the 'blue line' boundary, as close as possible to the point of impact.

- Ensure compensatory storage areas can be hydraulically connected to the floodplain.

- Identify areas that can provide the required storage on a level for level basis. Volume requirements to be assessed at 200mm intervals, based on LiDAR data.

- Review of aerial photography to ensure areas are appropriate to be utilised as storage areas and to ensure LiDAR data are accurate. (i.e no tree cover that could influence levels etc.)

From the above assessment two potential mitigation options have been identified to provide compensatory floodplain storage.

The preferred solution (Option A) consists of a storage pond situated to the north west of the Bicester Chord line extension. This is the preferred flood storage option as it most closely replicates the criteria described above. However, it is outside the 'blue line' and if the required land agreements to obtain the land required for the storage are not in place by the construction start date, then Option B would be implemented. Option B consists of a culverted storage structure to the south west of the Bicester Chord line extension, within the 'blue line'.

It should be noted that EA and local authority approval for both options is required to ensure that the construction programme is not delayed. Both of the compensatory floodplain storage options are described in more detail in the following sections.

3.4.1 Storage Pond (Option A)

The preferred solution for the provision of compensatory floodplain storage is to construct a storage pond to the north west of the Bicester Chord line extension set at the correct topographic levels to provide a level for level storage provision. A location plan is provided in Figure 9 below. The scheme designer, Atkins, has used the floodplain volume losses presented in Table 1 above to undertake outline design of the storage pond and ensure it is engineered to accommodate the storage volumes at the required levels. Please refer to Appendix 2 for more detailed plans of the storage pond design including cross-sections through the storage pond structure. The storage pond is to be hydraulically connected to the Langford Brook by a short channel parallel to the rail embankment. This channel is to be a minimum 3m wide at its base and to be as far as possible from the toe of the main line rail embankment to avoid any slope stability problems.

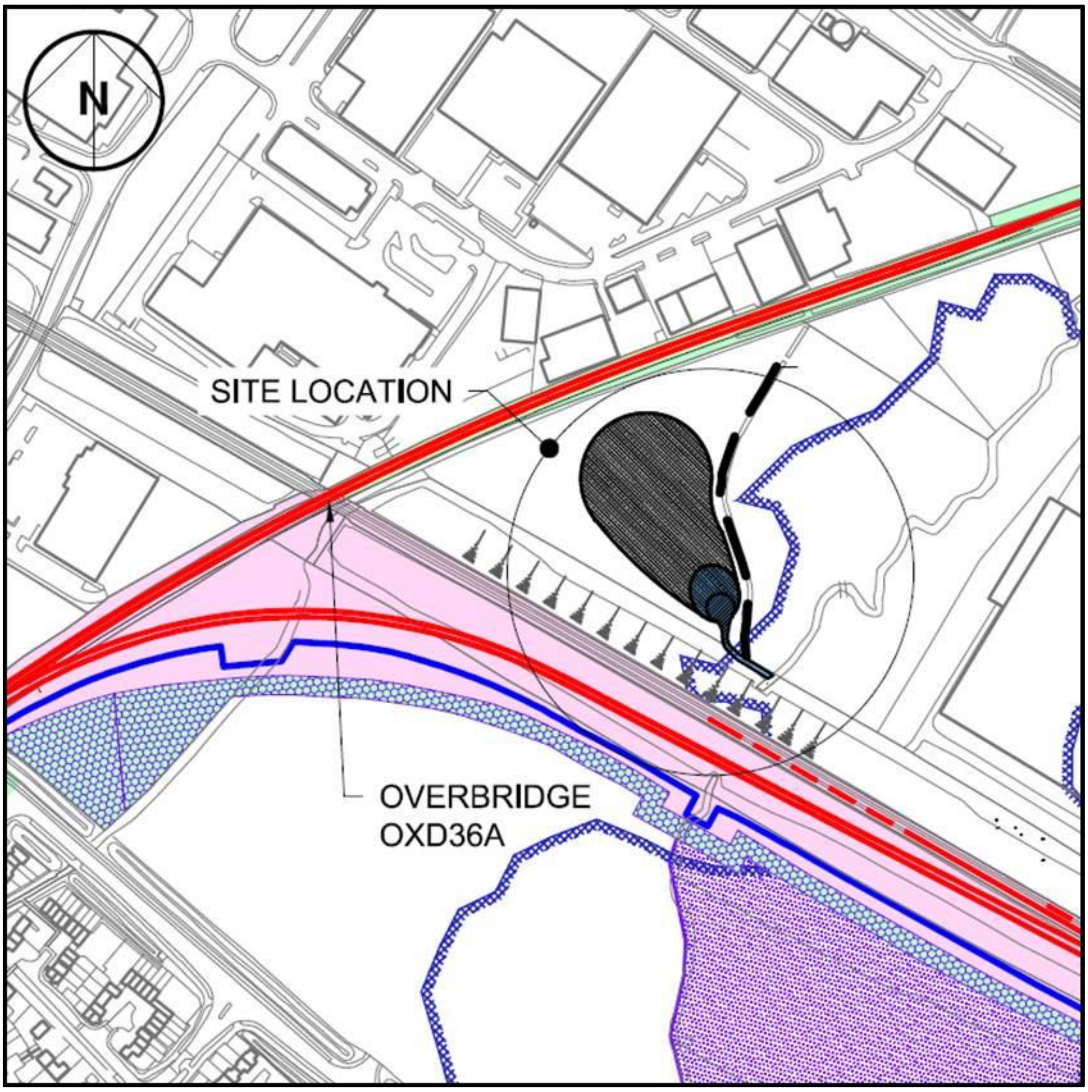


Figure 9 – Location of the proposed Bicester Chord Flood Storage Pond. (Option A)

In summary, Option A has been selected as the preferred solution to provide floodplain compensatory storage for a number of reasons, which include that it:

- Is located upstream of and relatively close proximity to the point of impact.
- Can be hydraulically connected to the Langford Brook floodplain.
- Provides appropriate topography to achieve the level for level storage requirement including a degree of over compensation at higher levels.
- Provides potential additional ecological benefits by creating a pond storage structure keeping the flood water on surface creating additional habitat and increasing biodiversity in the area.
- Provides potential benefit to the local communities in mitigating flood risk to other areas of Bicester.

- Could potentially also be utilised to mitigate against potential impacts of the EWR P1 project at development locations further downstream on the Langford Brook.

Atkins has confirmed through a detailed topographic survey that the levels of the Langford Brook adjacent to the proposed pond inlet are around 66.6mAOD. This means that the lower level storage requirements (i.e between 66.2 – 66.6mAOD) cannot be provided without significant re-profiling of the river channel. However, these lower levels only account for 15m^3 of storage requirement, which when taken into context of Bicester floodplain is a negligible volume. However, there is sufficient area available to provide a degree of over compensation in the upper levels of the proposed flood storage, should this be required.

3.4.2 Culverted Storage (Option B)

Option B has been considered as a second option, only to be implemented if land agreements are not in place with the owners of the land to the north of the Chord by the construction start date. However, this FRA seeks approval for both options A and B.

Option B consists of a twin box culvert structure to be constructed between the new embankment toe and the agreed Limits of Deviation starting at the outfall of the chord culvert and extending towards the chord footbridge. A location plan is provided in Figure 10 below. This structure has been designed in three sections set at a constant gradient which will ensure that 315m^3 of flood compensation is provided on a level for level basis. In order to facilitate maintenance a number of inspection/ access covers will be provided along the culvert length. Please refer to Appendix 3 for a more detailed plan of the culverted storage system design including cross-sections through the structure.

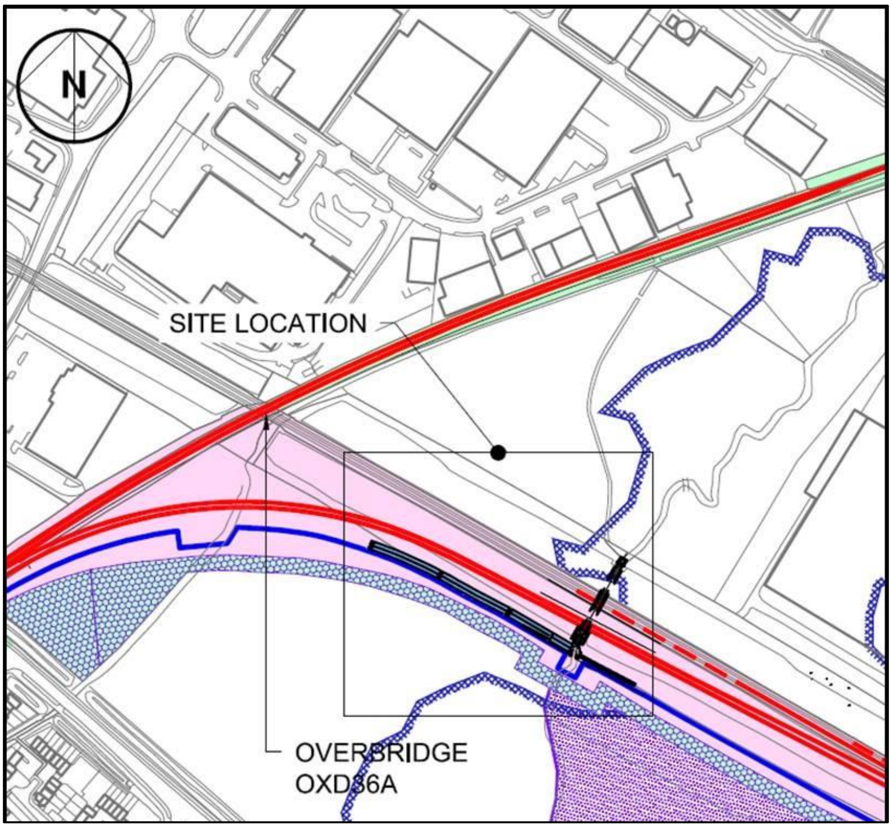


Figure 10 - Location of the proposed Culverted Storage. (Option B)

4 Langford Brook Culvert Modelling

4.1 Methodology

4.1.1 Introduction

This section outlines the methodology used in undertaking the flood impact assessment for the culvert extension works at the Bicester Chord. Modelling was undertaken based on the original Bicester hydraulic model, which has been approved for use for this study by the EA. Modifications to the model were made in order to assess the impact of the proposed culvert works.

A copy of the original model report undertaken by Peter Brett Associates[1], outlining the 1D-2D model development, is available on request from the Environment Agency.

4.1.2 Proposed culvert

WHS was provided with proposed culvert extension plans from Atkins in February 2013. The extension plans, Figure 11, show that a 5m extension of the culvert is proposed. The culvert will be tied into the existing section, with the invert levels designed to match. The slope of the culvert will match that of the existing channel.

The proposed culvert is a box culvert of pre-cast concrete. A bed substrate will be applied to the invert through the culvert. This will be built up to match the existing downstream invert of the current culvert. The box culvert will be slightly larger than the existing culvert, and as a result a constriction to flow is not expected. The dimensions of the culvert extension will be 3.4m wide, with a height of 3.1m. However, the culvert has been modelled as smaller than this to match the dimensions of the existing culvert and to take account of the bed material on the invert. The culvert has, therefore, been modelled as a box culvert, 3.4m in width and 2.66m in height.

4.1.3 Hydrology

No changes were made to the flood hydrology used in the original EA model. Details of hydrological inputs to the model can be found within the original model report. Hydrology used within the original model has been reviewed by the EA as part of the original study.

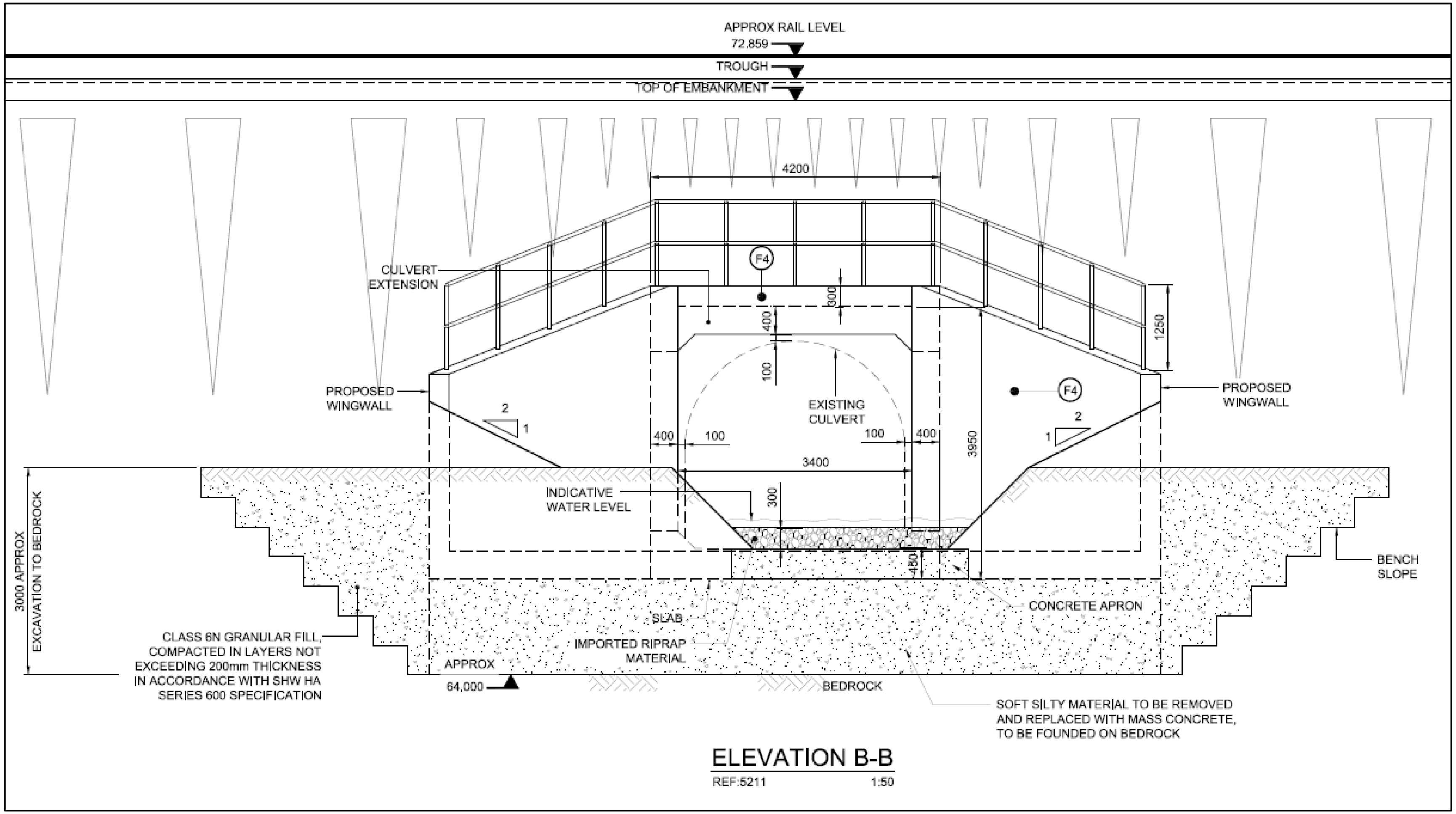


Figure 11 – Proposed culvert design as outlined by Atkins drawing 5114534-ATK-DRG-CV-001101

4.1.4 Model Upgrade assessment

The model was re-run using the latest version of ISIS (3.6.0.156) and TUFLOW (2013-03-01) as is best practice. In order to ensure that the baseline (pre-extension) results were comparable to that currently in use by the EA, a simple comparison of 1D and 2D results for the 1 in 1000 year simulation was undertaken.

1D water level

In order to compare and verify 1D water levels in the re-run baseline model, each node was considered within the model. For the 1 in 1000 year event simulation, the re-run model predicted the maximum water level at all nodes to be within +/- 0.03m of the original results. The average difference was smaller than 0.003m. Therefore this suggests that the 1D model results have not altered significantly as a result of the upgrade in model version.

2D water levels

Verification of re-run 2D depths was undertaken against the original model output provided by the Environment Agency. To compare the two sets of data, 14 sample points were placed randomly within the original maximum flood event outline for the 1 in 1000 year event. At each point, the re-run and original model level output was sampled and recorded allowing a difference between the two to be ascertained.

Based on analysis, summarised in Table 2, both models were found to provide comparable results. This analysis demonstrates that model re-run has not resulted in any significant changes to flood depths within the 2D domain.

Table 2 - Comparison of maximum flood depth results between EA model results and re-run model.

Point ID	Maximum Depth (m) (original model)	Maximum Depth (m) (re-run model)	Difference (rounded)
1	0.76	0.75	0.00
2	0.33	0.33	0.00
3	0.55	0.55	0.00
4	0.53	0.51	-0.01
5	0.84	0.83	-0.01
6	1.06	1.06	0.00
7	0.32	0.32	-0.01
8	1.04	1.04	0.00
9	0.54	0.54	0.00
10	0.47	0.47	0.00
11	0.79	0.79	0.00
12	0.91	0.90	-0.01
13	0.36	0.36	0.00
14	0.96	0.96	0.00

4.1.5 Modelling of the culvert extension

The culvert extension was modelled based on the AutoCAD drawings supplied by Atkins. The dimensions of the new culvert have already been discussed within this report. The extension was applied as a new rectangular conduit unit linked by a junction to the existing culvert model units. A schematic of how this extension was modelled is presented in Figure 12.

The downstream river cross section was unchanged except for the distance downstream value which was reduced by 5m to 15m to account for the increased length of culvert.

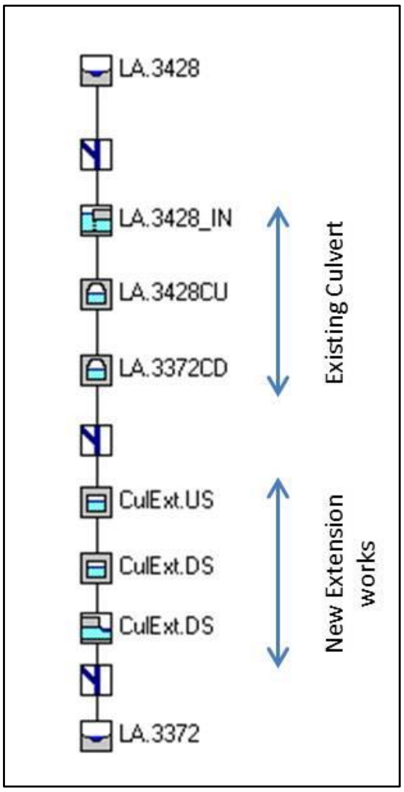


Figure 12 –Schematic plan of extension works as modelled in ISIS

4.2 Results

4.2.1 1D results

As shown by the 1D results in Table 3 there is insignificant predicted impact on maximum water levels within the 1D network as a result of the culvert extension. As highlighted in Table 2 maximum water levels are decreased. Within open channel units, the maximum change is -0.04m and -0.09m at node LA.3372 for the 1 in 100 year plus climate change and 1 in 1000 year event respectively.

There is a slight draw down in water levels both within and upstream of the culvert. This slight draw down is as a result of a reduced Manning's roughness value within the culvert compared to that modelled within the river network downstream. This reduction in Manning's is shown to marginally increase velocities through the culvert, for example, maximum velocities at node LA.3372CD (downstream section of existing culvert) increase from 2.03 to 2.18m/s during the 1 in 100 year plus climate change event. This increase is not however predicted downstream of the culvert itself.

A sample of nodes upstream and downstream of the culvert is provided in Table 3 below.

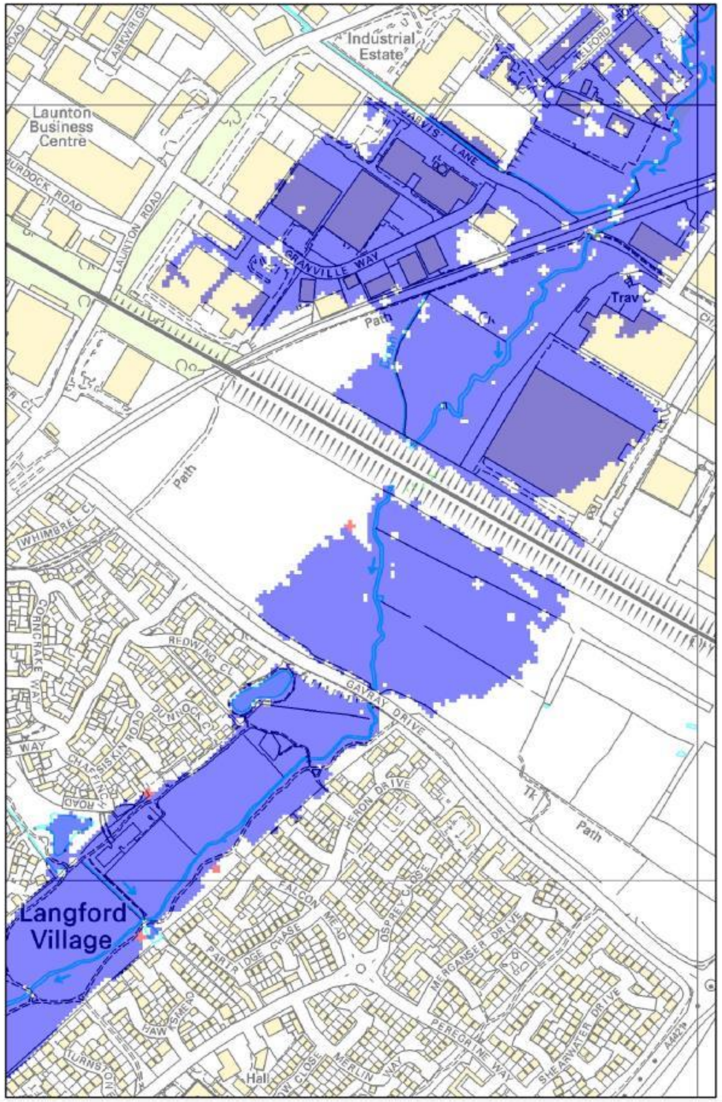
4.2.2 2D results

As shown in Figure 13 and 14, there is no significant increase in flood extent as a result of the new culvert being constructed. Single grid cell increases in extent are found downstream of the development area, however these are not significant and do not result in new property being put at risk.

2D model depths upstream are reduced marginally as a result of the slight draw down of flood waters due to the reduced manning's roughness coefficient. These decreases are marginal. No significant change is predicted in 2D flood velocities as highlighted in Figures 15 and 16.

Table 3 – Change in maximum water level as a result of culvert extension works.

1D ISIS Node	1 in 100 yr. +CC			1 in 1000 yr.		
	Maximum water level (pre-culvert ext.) mAOD	Maximum water level (post culvert ext.) mAOD	Difference (m)	Maximum water level (pre-culvert ext.) mAOD	Maximum water level (post culvert ext.) mAOD	Difference (m)
LA.3503SU	67.879	67.852	-0.03	68.279	68.257	-0.02
LA.3503BU	67.879	67.852	-0.03	68.279	68.257	-0.02
LA.3503	67.879	67.852	-0.03	68.279	68.257	-0.02
LA.3500_RSD	67.878	67.851	-0.03	68.279	68.257	-0.02
LA.3500_RBD	67.878	67.851	-0.03	68.279	68.257	-0.02
LA.3500_R	67.878	67.851	-0.03	68.279	68.257	-0.02
LA.3439	67.873	67.845	-0.03	68.277	68.255	-0.02
LA.3428	67.69	67.649	-0.04	68.061	68.028	-0.03
LA.3428_IN	67.69	67.649	-0.04	68.061	68.028	-0.03
LA.3428CU	67.612	67.566	-0.05	67.953	67.914	-0.04
LA.3372CD	67.333	67.229	-0.10	67.563	67.458	-0.11
LA.3372_OUT	67.123	67.081	-0.04	67.248	67.161	-0.09
LA.3372	67.123	67.081	-0.04	67.248	67.161	-0.09
LA.3352	67.178	67.18	0.00	67.259	67.261	0.00
LA.3272	67.037	67.039	0.00	67.141	67.144	0.00
LA.3178	66.974	66.977	0.00	67.115	67.119	0.00
LA.3109	66.925	66.928	0.00	67.075	67.079	0.00



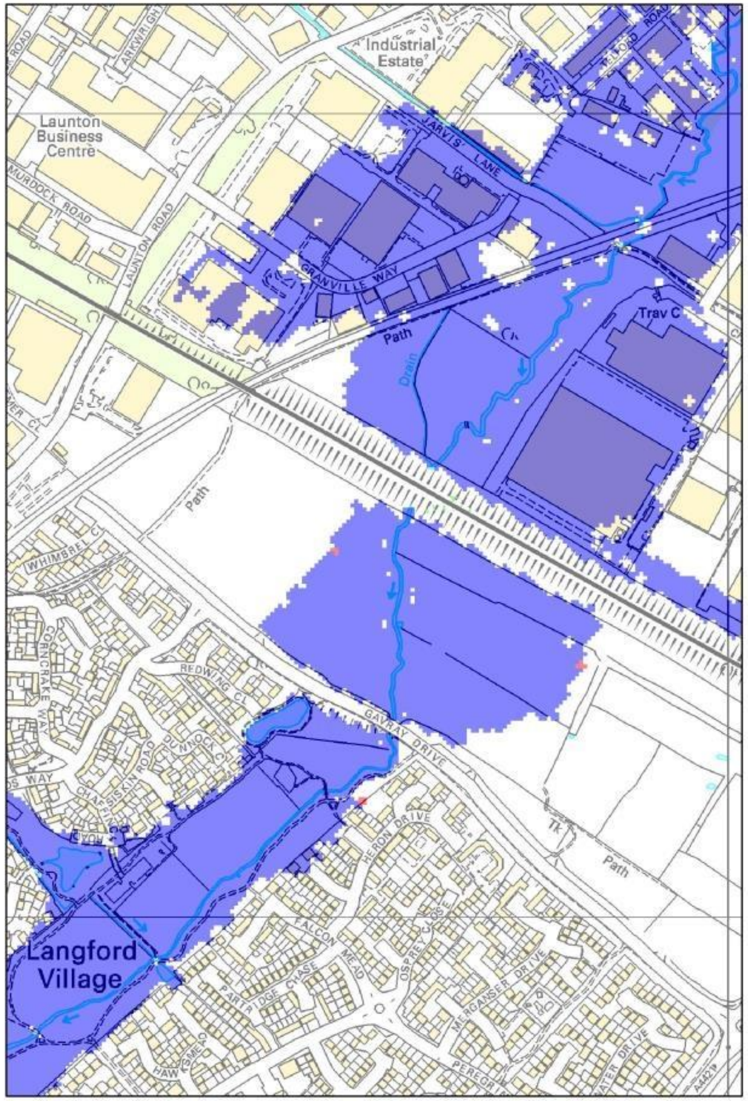


Figure 13 –Maximum Flood Extent 1 in 100 yr. + CC (post culvert = red) **Figure 14 – Maximum Flood Extent 1 in 1000 yr. (post culvert = red)**

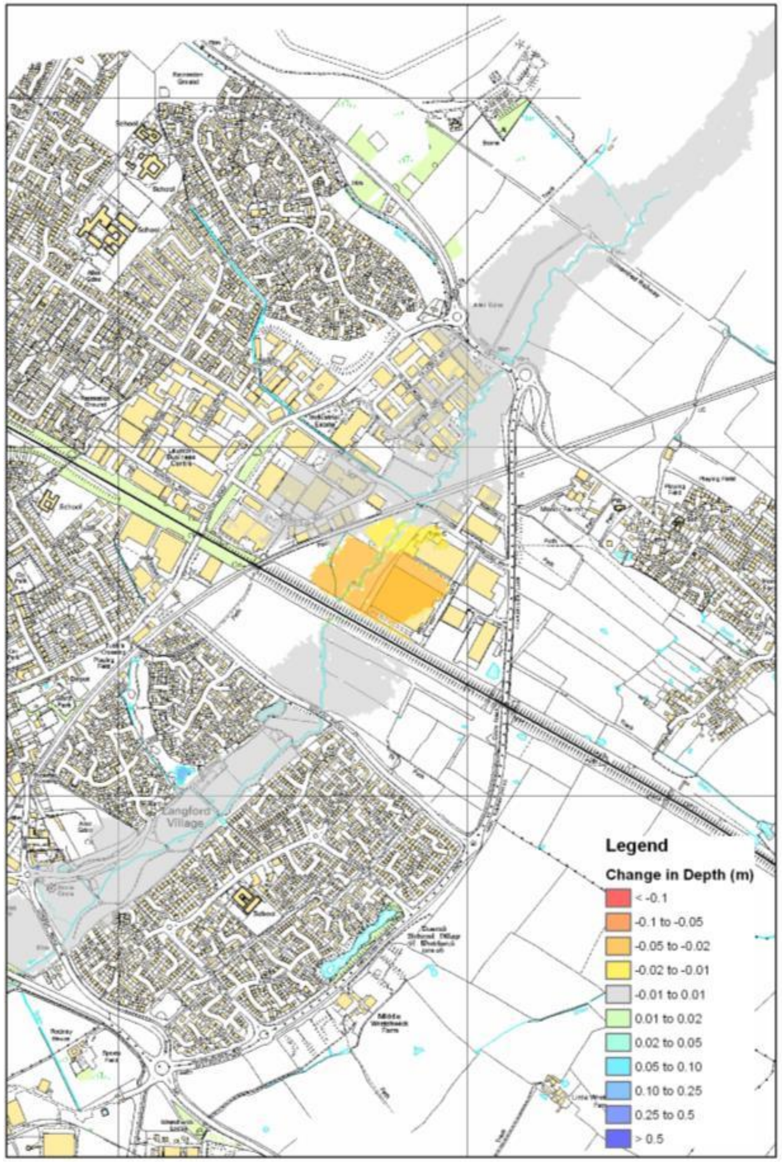


Figure 15 –Change in flood depth, 1 in 100yr. + CC

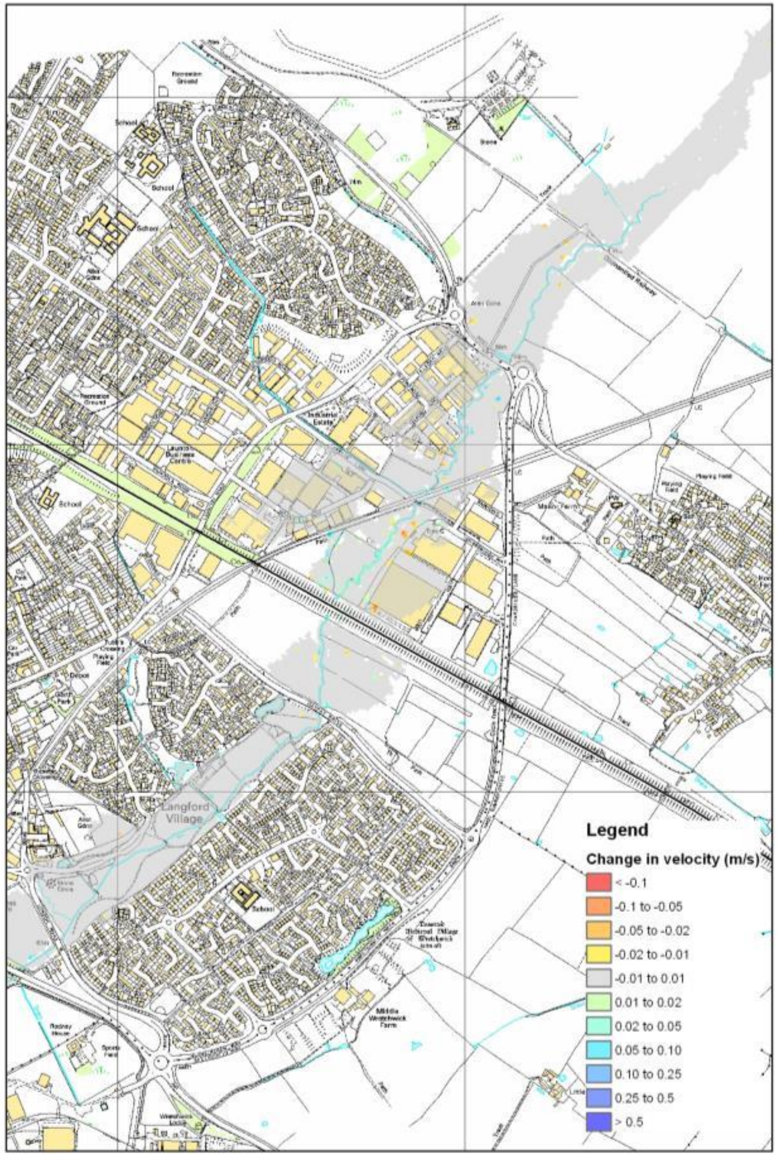


Figure 16 – Change in flood velocity, 1 in 100yr. + CC

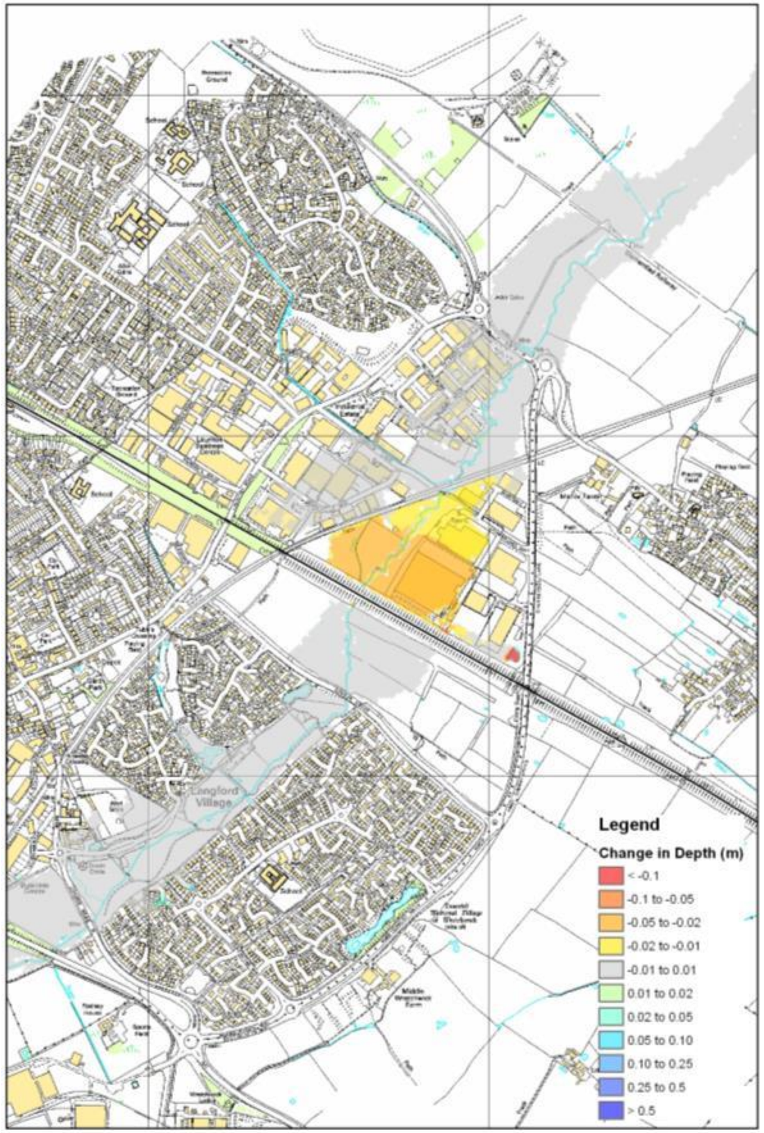


Figure 17 –Change in flood depth, 1 in 1000yr

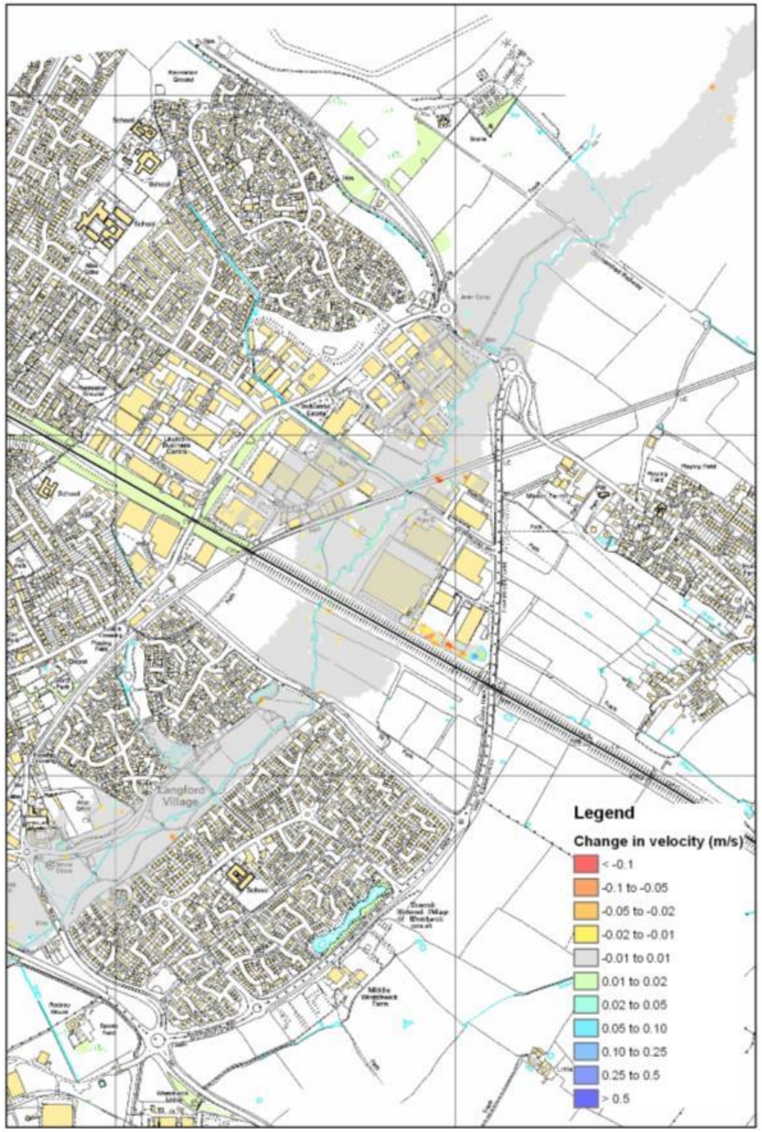


Figure 18 – Change in flood velocity, 1 in 1000yr

5 Surface Water Drainage Assessment

A new pedestrian overbridge is to be built across the new chord line as shown in Figure 3. Our previous surface water drainage submission[3] deals with the surface water impacts of this structure. The initial Level 2 FRA document produced in July 2010 assumed that the footbridge would be provided with a formal drainage system to collect surface waters. However, during detailed design the design team have confirmed that no formal drainage is to be provided to these structures and Network Rail are satisfied that surface water will drip from the footbridges onto the railway line and associated embankment.

The construction of the Chord itself will comprise recycled railway ballast as the principal earthworks, with permeable ballasted track laid on this formation. No formal drainage system is provided under the ballast and rainwater (including that from the footbridges) will permeate through the ballast and the embankment. A toe drain at the toe of the railway embankment will collect any greenfield surface water run-off from the embankment.

Hence, with there being no formal surface water drainage provision for the footbridge or railway line, there is no effective increase in impermeable area as all rainwater will fall onto the railway ballast and embankment. Under this scenario there is no predicted increase in surface water discharge rate or volume.

The Proposed Drainage Arrangement Plan is provided in Appendix 4 and outlines the arrangement for the toe drain and associated discharge points for the Bicester Chord railway embankment.

[3] ERW P1 – SW Drainage Assessment (footbridges).

6 Conclusions

The key conclusions of this FRA are as follows:

- The total floodplain storage volume lost to the Bicester chord line extension is 315m^3.

- The EA has confirmed that compensatory storage will need to be provided on a strict level for level basis to mitigate against the volume of floodplain lost as a result of the embankment widening works.

- An assessment of land available to provide compensatory floodplain storage has demonstrated that there is restricted land available within the permanent or temporary land available to the EWR P1 project that could be used to provide the required floodplain storage on a level for level basis.

- Therefore, two separate options have been designed in collaboration with Atkins to provide the compensatory floodplain storage on a level for level basis. These options include;

  - Option A – This is the preferred approach and involves the construction of a storage pond to the north west of the Bicester chord line.

  - Option B – This is a contingency option that involves a culverted storage system. This option will only be implemented if land agreements are not in place with the owners of the land to the north of the Chord by the construction start date.

- It is proposed that Atkins use the storage volume losses presented in Table 1 of this FRA to inform the detailed design of the final compensatory flood storage option and ensure that level for level storage provision is achieved.

- The proposed 5 metre extension of the Langford Brook culvert has been modelled and is demonstrated to have no significant impact on flood risk to the surrounding area.

- There is no effective increase in impermeable area as a result of the Bicester chord development as all rainwater will fall onto the railway ballast and embankment and infiltrate to ground. Additionally, the principal earthworks material for the embankment is recycled railway ballast. Any greenfield run-off from the rail embankment will be collected by a toe drain at the toe of the embankment. Under this scenario there is no predicted increase in surface water discharge rate or volume. Please refer to the EWR P1 – SW Drainage Assessment (footbridges) report for details of the full surface water drainage assessment conducted for the footbridges.

Appendix 1 – Storage Volume Tables

1.1 Depth Band = 66.2 - 66.4

Section	Area of Proposed Embankment within flood zone (m^2)	Length Between Sections (m)	Volume of Floodplain Lost (m^3)
2109280	0	20	0
2109300	0	20	0
2109320	0	20	0
2109340	0	20	0
2109360	0	20	0
2109380	0	20	0
2109400	0	20	0
2109420	0	20	0
2109440	0	20	0
2109460	0	20	0
2109480	0	20	0
2109500	0	20	0
2109520	0	20	0
2109540	0.122	20	2.44
2109560	0	20	0
		Total Volume (m^3)	**2.44**

1.2 Depth Band = 66.4 - 66.6

Section	Area of Proposed Embankment within flood zone (m^2)	Length Between Sections (m)	Volume of Floodplain Lost (m^3)
2109280	0	20	0
2109300	0	20	0
2109320	0	20	0
2109340	0	20	0
2109360	0	20	0
2109380	0	20	0
2109400	0	20	0
2109420	0	20	0
2109440	0	20	0
2109460	0	20	0
2109480	0	20	0
2109500	0	20	0
2109520	0	20	0
2109540	0.622	20	12.44
2109560	0.067	20	1.34
		Total Volume (m^3)	**13.78**

1.3 Depth Band = 66.6 - 66.8

Section	Area of Proposed Embankment within flood zone (m^2)	Length Between Sections (m)	Volume of Floodplain Lost (m^3)
2109280	0	20	0
2109300	0.095	20	1.9
2109320	0.55	20	11
2109340	0.009	20	0.18
2109360	0	20	0
2109380	0	20	0
2109400	0	20	0
2109420	0	20	0
2109440	0	20	0
2109460	0.158	20	3.16
2109480	0	20	0
2109500	0	20	0
2109520	0	20	0
2109540	1.117	20	22.34
2109560	0.336	20	6.72
		Total Volume (m^3)	**45.3**

1.4 Depth Band = 66.8 – 67.0

Section	Area of Proposed Embankment within flood zone (m^2)	Length Between Sections (m)	Volume of Floodplain Lost (m^3)
2109280	0.064	20	1.28
2109300	1.297	20	25.94
2109320	0.907	20	18.14
2109340	0.091	20	1.82
2109360	0	20	0
2109380	0	20	0
2109400	0	20	0
2109420	0	20	0
2109440	0.02	20	0.4
2109460	1.534	20	30.68
2109480	0	20	0
2109500	0.653	20	13.06
2109520	0.802	20	16.04
2109540	1.422	20	28.44
2109560	0.382	20	7.64
		Total Volume (m^3)	**143.44**

1.5 Depth Band = 67.0 – Flood Level (either 67.04 or 67.15)

Section	Area of Proposed Embankment within flood zone (m^2)	Length Between Sections (m)	Volume of Floodplain Lost (m^3)
2109280	0.207	20	4.14
2109300	0.355	20	7.1
2109320	0.188	20	3.76
2109340	0.03	20	0.6
2109360	0	20	0
2109380	0	20	0
2109400	0	20	0
2109420	0	20	0
2109440	0.016	20	0.32
2109460	1.163	20	23.26
2109480	0	20	0
2109500	1.088	20	21.76
2109520	1.054	20	21.08
2109540	1.109	20	22.18
2109560	0.279	20	5.58
		Total Volume (m^3)	**109.78**

Appendix 2 – Option A - Storage Pond Design

Appendix 3 – Option B – Culverted Storage Design

Appendix 4 – Bicester Chord Surface Water Assessment Proposed Drainage Arrangement