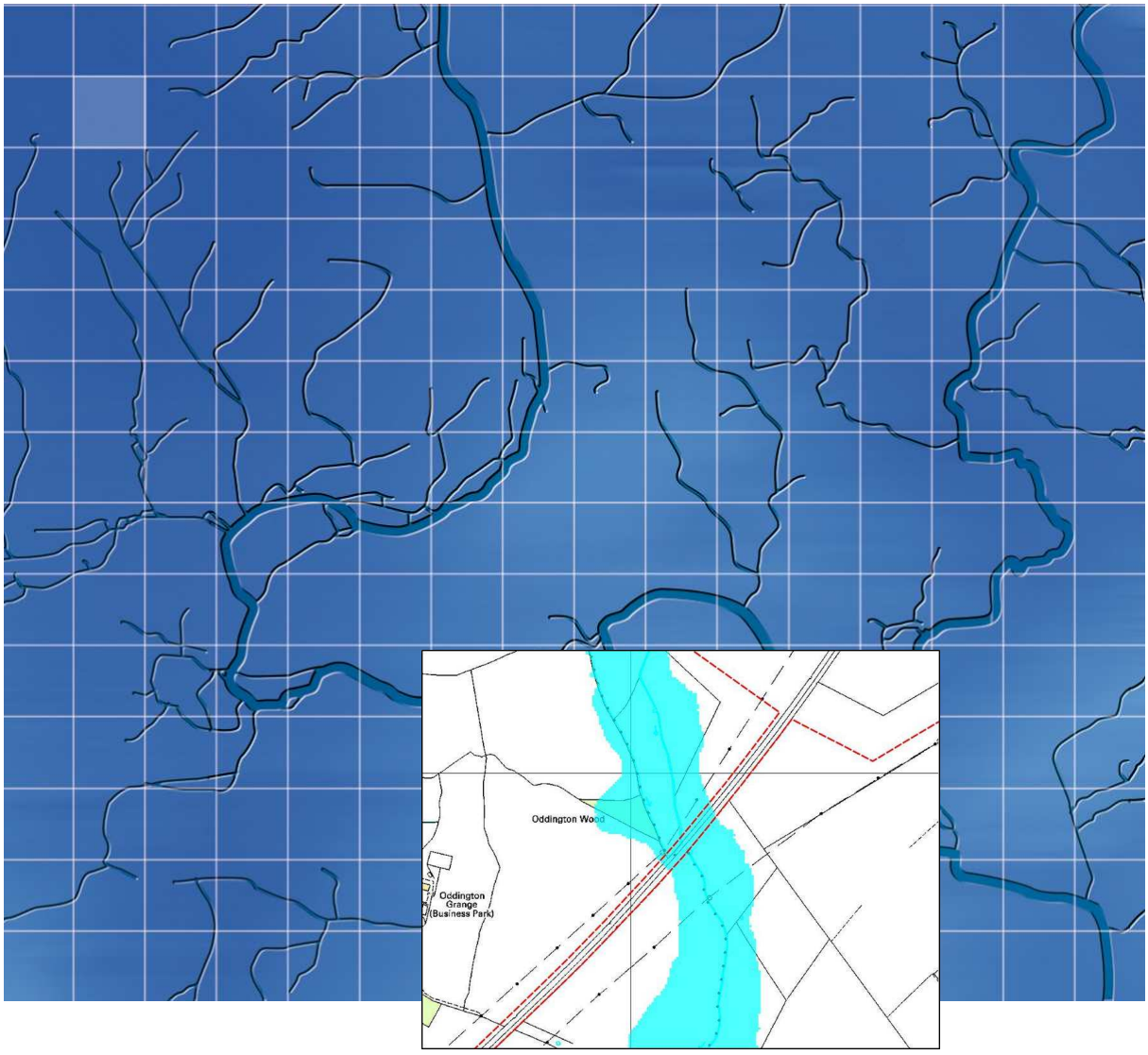
Network Rail and Chiltern Railways

July 2014

EWR-P1-Level 3 FRA: Islip to M40 Embankment Works



Wallingford HydroSolutions Limited

Network Rail and Chiltern Railways

EWR P1 - Level 3 FRA: Islip to M40 Embankment Works

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For and on behalf of Wallingford HydroSolutions Ltd.

Prepared by T. Hughes

Approved by P. Blackman
Position *Technical Director*

Date **4th July 2014**

This report has been produced in accordance with the WHS Quality Management system which is certified as meeting the requirements of ISO 9001:2008.

WHS

Registered Office Maclean Building, Benson Lane, Wallingford OX10 8BB
www.hydrosolutions.co.uk

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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 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. However, the proposed works to the embankments along the route was not included within this original Level 2 FRA study as the extent of embankment widening and cutting works was not clearly identified at the time. Subsequently, Atkins has provided details on the locations of embankment widening works and where these coincide with active flood zone areas an additional Level 3 FRA is required.

1.2 Scope of Level 3 FRA

This document constitutes a Level 3 FRA for the proposed embankment widening works between Islip and the M40, as required by Planning Condition 12 of deemed planning permission granted alongside the Order under the Transport and Works Act 1992.

This document also provides the information required by the National Planning Policy Framework (NPPF) and the associated requirements of PPS25.

As part of the improvement works, the existing railway embankment is to be strengthened to allow for a dual mainline track between Oxford and Bicester. This FRA document has been commissioned to address the flood risk issues that result from the proposed embankment widening work within active flood zone areas. The location of these works considered within this FRA is between Islip and the M40 and is shown in Figure 1. The purpose of this FRA is to quantify any adverse impacts on flood risk and provide sustainable and effective mitigation where required.

The scope and method of analysis for this FRA have been agreed in discussions with the Environment Agency (EA).

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

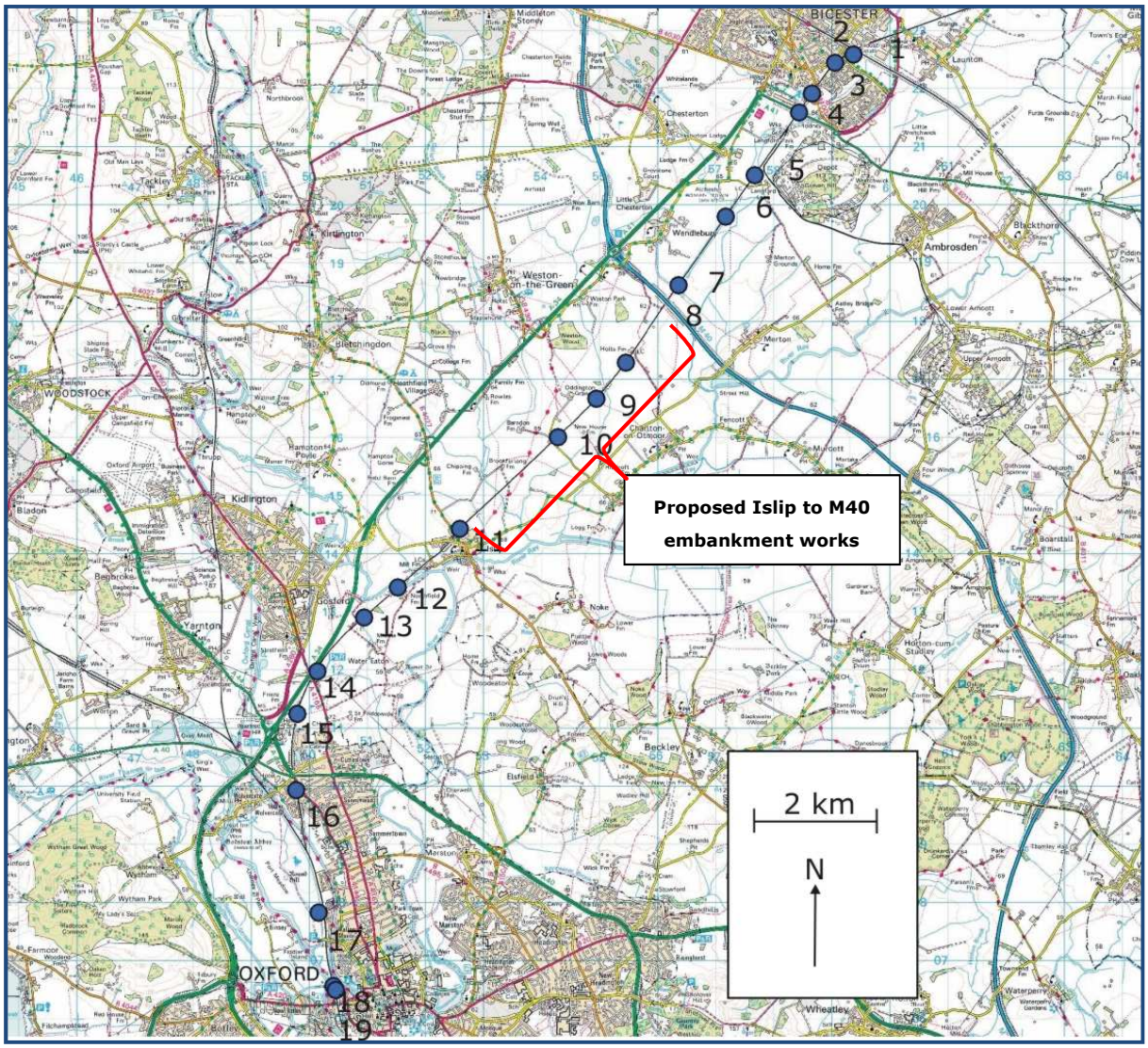

Figure 1 – Scheme Overview Showing Assessment Points.

2 Site Description

2.1 Overview

The proposed development area is located between Islip to the south and the M40 to the north. This area has been split into two geographically distinct hydraulic sub units, Islip and Oddington where embankment widening works are proposed on two watercourses with separate floodplains. A summary of the location of these sub units is provided by Figure 2.

This site specific Level 3 FRA considers works proposed within each of these hydraulic sub units whereby embankment widening work undertaken within each of the sub units will need to be mitigated within the same unit to ensure flood risk is effectively managed.

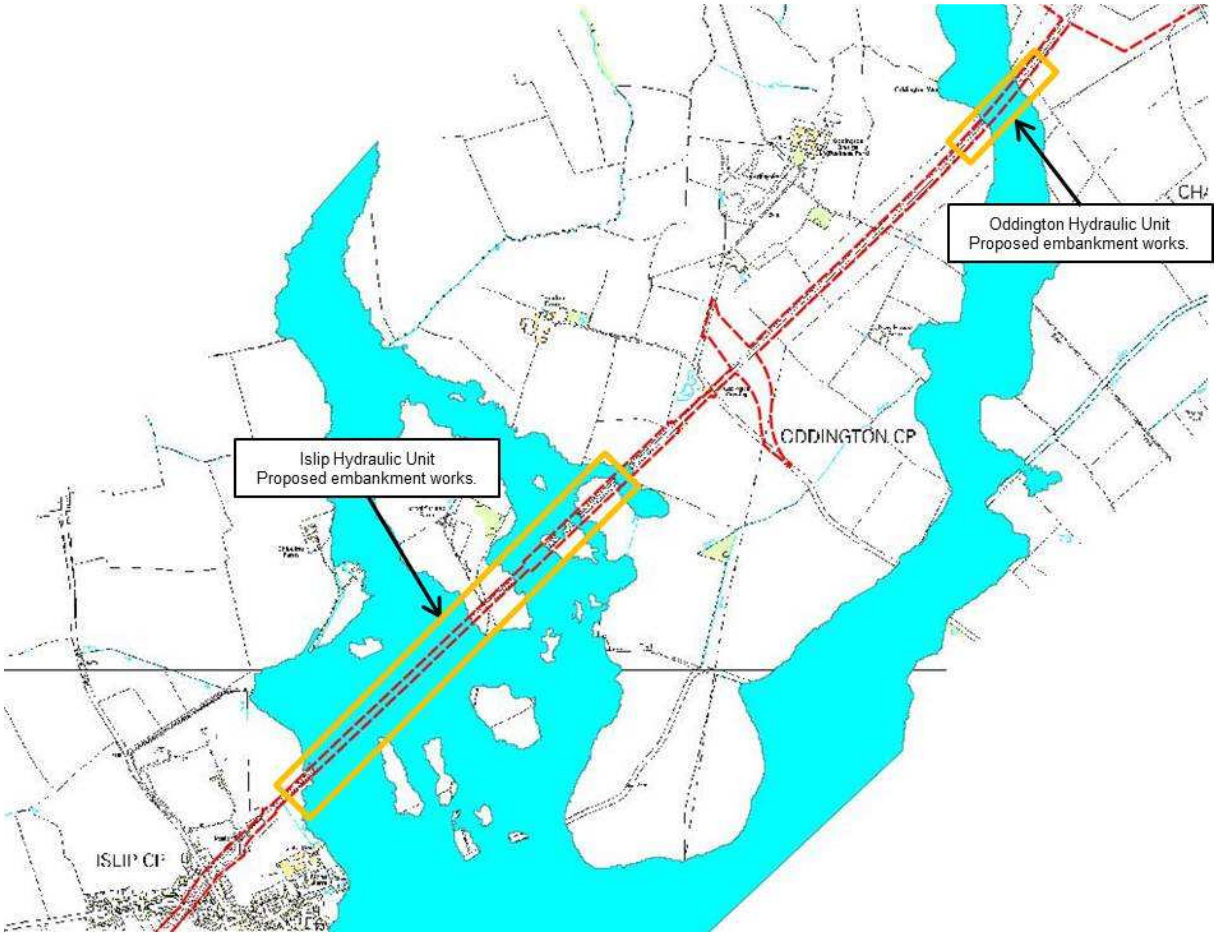

Figure 2 –Islip to M40 Development Area.

2.2 Description of the Proposed Works

In order to allow the dual tracking of the line between Oxford and Bicester, embankment widening/ strengthening works are required. This will be achieved through a number of construction methods. For the section between the Islip and the M40 the proposed earthwork solutions include regrading of the existing embankments as the preferred option with regrading with a gabion toe wall for those sections where land available within the LOD boundary is constrained.

The majority of the required embankment widening in this section will be achieved using conventional earthworks regrading. This approach will involve adding engineered fill to the outer margins of the embankment to form a wider section at cess level. Granular fill material will be used and, following soft strip, benches will be cut into the existing embankment to allow this additional fill to compacted into layers to create widened form. The maximum slope gradient will be 1:2.5 with shallow slopes being used where stability assessment indicate this is required. This regrading solution will be adopted on one or both sides of the existing embankment depending on the permanent way alignment requirements and the availability of space within the TWA boundary. A typical section within this section is shown in Figure 3.

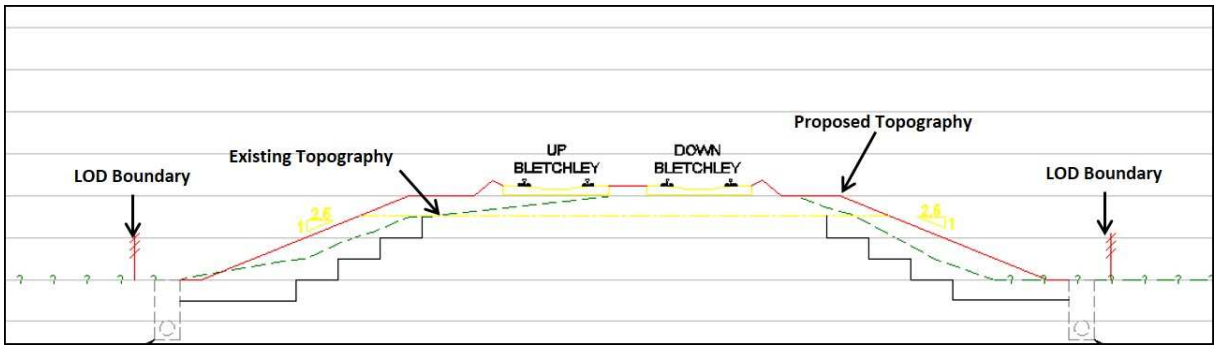

Figure 3 – Typical Cross Section Representing the Regrade Earthwork Stabilisation Solution.

In some instances where there is limited space within the LOD boundary a regrade solution with a gabion toe solution will be implemented. A typical section showing a typical regrade solution on the left side with a regrade and gabion toe wall on the right side is shown in Figure 4.

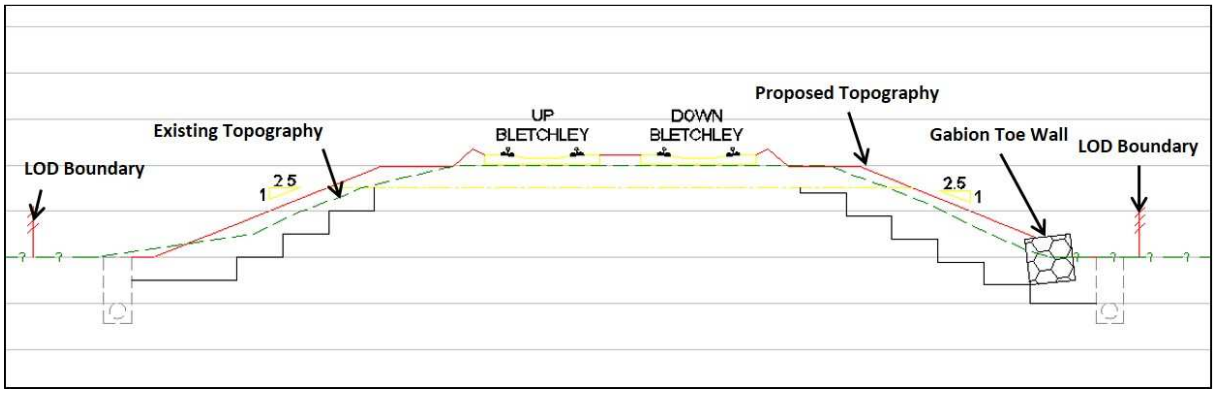

Figure 4 – Typical Cross Section Representing a Regrade Solution of the Left and Regrade and Gabion Toe Wall on the Right.

3 Flood Risk Impacts

3.1 Data Sources Used and Proposed Methodology

This section outlines the methodology used in undertaking the flood impact assessment for the proposed work between Islip and the M40. 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 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 embankment widening using the best available data which is JFlow modelling provided by the Environment Agency.
- Calculation of the subsequent flood storage volumes lost as a result of the embankment widening works. This uses detailed earthworks design sections provided by Atkins[2] to assess volumes of floodplain lost.
- Assessment of the potential for level for level storage within the current Limits of Deviation boundary (LOD).

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

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

- Detailed earthworks cross sections[2] of the proposed works within the 1 in 1000 year flood zone at 20m intervals.
- LiDAR data have been purchased through Geomatics Group. This has a 2m resolution, with a vertical accuracy of +/- 0.15 m;
- The Scheme 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.
- Hydraulic modelling outputs from JFlow flood depth grids provided by the Environment Agency are used to delineate the inundation area and obtain design flood levels for the 1:1000 year event.

3.2 Predicted Flood Level

The EA has provided JFlow flood depth grids in GIS format to inform this FRA. It has been confirmed that there has not been any more detailed modelling undertaken in the area between Islip to M40 and the JFlow modelling represents the most accurate flood modelling information. It has been agreed with the EA that the more conservative 1 in 1000 year JFlow flood levels should be used in the assessment of storage volumes lost due to uncertainties in the predicted flood levels.

[2] Atkins. 2014. Provided detailed earthworks sections between Islip and the M40 in AutoCAD format.

To obtain a design flood level along the proposed embankment widening works sited within a flood zone the JFlow depth grid and the underlying JFlow DTM has been interrogated at strategic points adjacent to the embankments. The flood depth and ground level are then added together to give a predicted flood level for the 1 in 1000 year extreme flood event.

However, because of the coarse resolution of the grids that are used in the JFlow modelling a correction factor has been applied to the flood level to account for the difference between the JFlow DTM and the more accurate LiDAR data (vertical accuracy of +/- 0.15m). This correction factor provides a more accurate prediction of actual flood levels. Please see Figure 5 below for a graph of the two grids. Differences of up to 200mm exist between the two model grids.

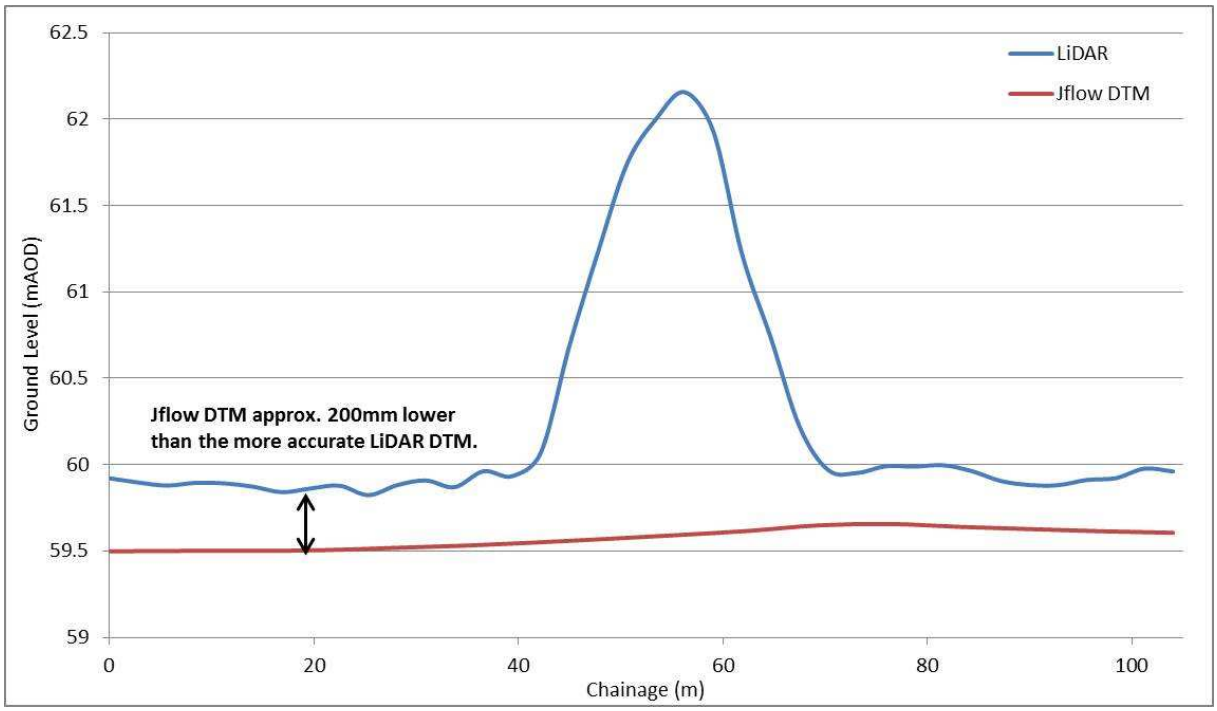

Figure 5 – Flood Level Correction Factor.

3.2.1 Oddington Hydraulic Unit

Within the Oddington hydraulic unit the maximum predicted 1 in 1000 year flood level on the western side of the main railway embankment is 61.03mAOD whilst on the eastern side this is lower at 60.86mAOD as shown in Figure 6. A correction factor has been applied to account for differences in ground profiles. These flood levels have been compared against the corresponding earthworks cross sections provided by Atkins to undertake the storage analysis provided in section 3.3.

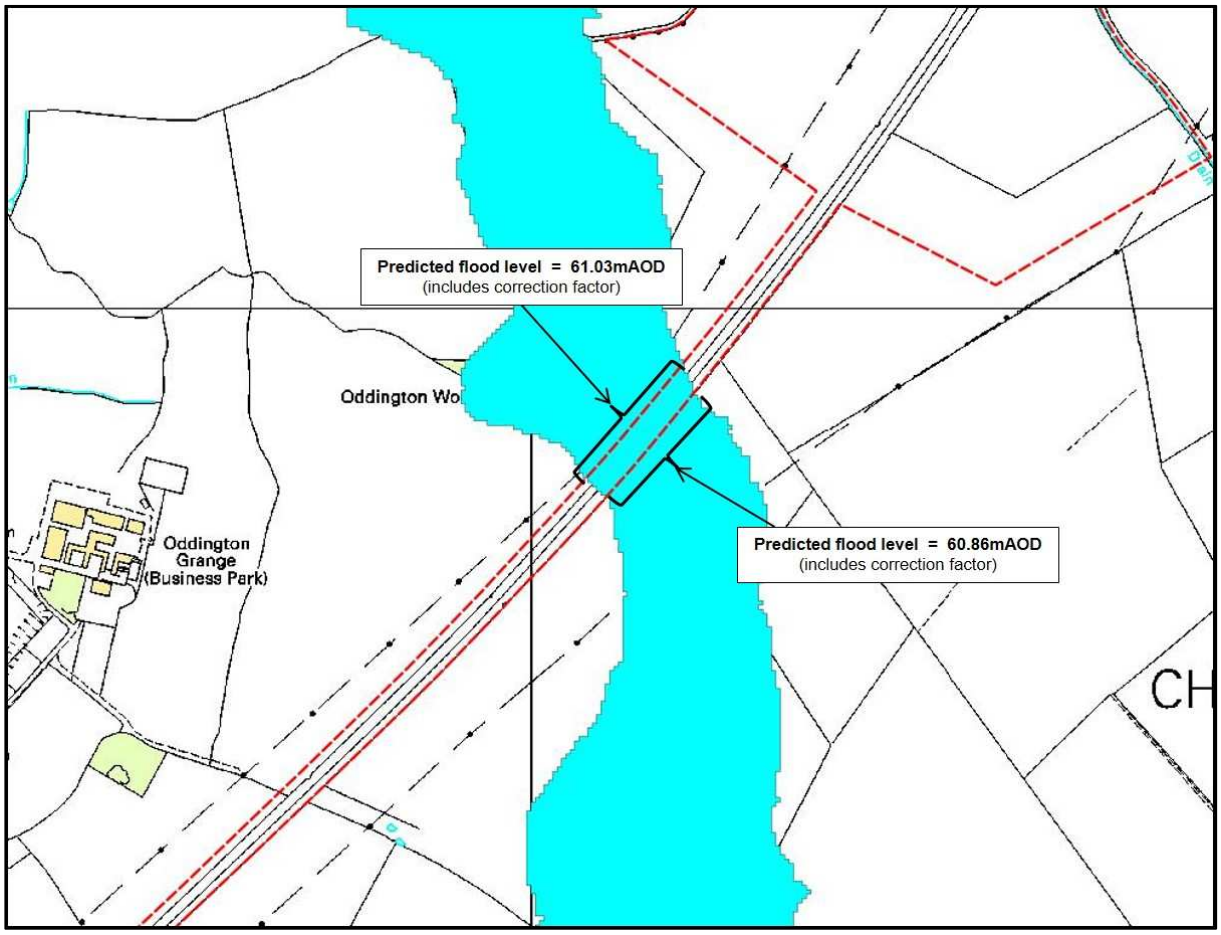

Figure 6 - 1 in 1000 Year Predicted Flood Levels Within the Oddington Hydraulic Unit.

3.2.2 Islip Hydraulic Unit

The Islip hydraulic unit covers a much larger area of floodplain extending some 1.4km from Islip in the south west to Brookfurlong Farm in the north east. Therefore predicted flood levels for this hydraulic unit will fluctuate along the railway corridor. To account for this flood levels have been extracted in three distinct regions that share a similar level as per Figure 7. A correction factor has been applied to account for differences in ground profiles. These flood levels have been compared against the corresponding earthworks cross sections provided by Atkins to undertake the storage analysis details provided in section 3.3.

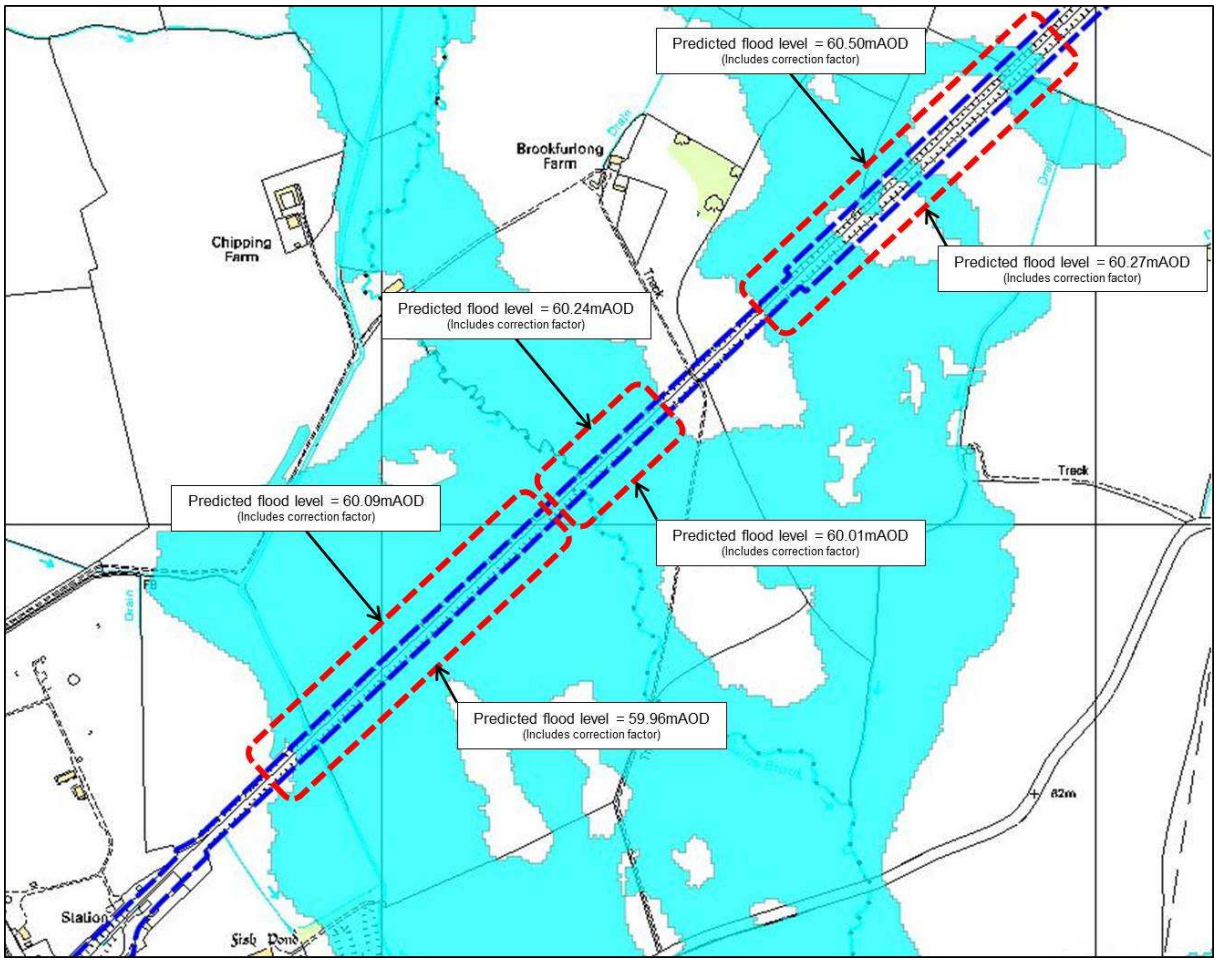

Figure 7 – 1 in 1000 Year Predicted Flood Levels Within the Islip Hydraulic Unit.

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 floodplain 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 intervals along the proposed works area. 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. The area lost has been calculated at 0.2m bandings. See Figure 8 for a typical earthworks cross section of the embankment widening work and Figure 9 for details of how the cross-sectional area lost under the 1 in 1000 year flood event has been calculated.

- This process is repeated for all earthworks sections that lie within the 1 in 1000 year flood inundation area along the length of the proposed works.

- The final stage is to calculate the total volume lost. 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 to give the total storage volume lost at each banding level as well as overall volume.

Table 1 and Table 2 provide a summary of the volumes of floodplain storage predicted to be lost as a result of the proposed works at 200mm level bandings at each cross section within the Oddington and Islip hydraulic units respectively. The total storage volume lost is 343m^3 for the Oddington and Islip hydraulic units combined.

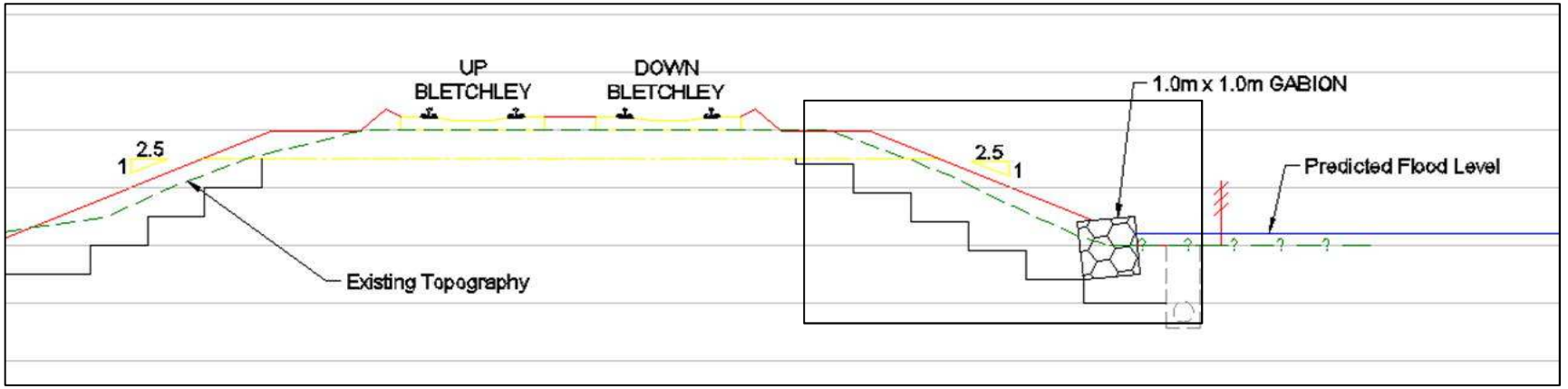

Figure 8 – Typical Design Cross Section Between Islip and the M40 Showing the Proposed Earthworks Solutions of Simple Regrade on the East and Regrade and Gabion Wall on the West.

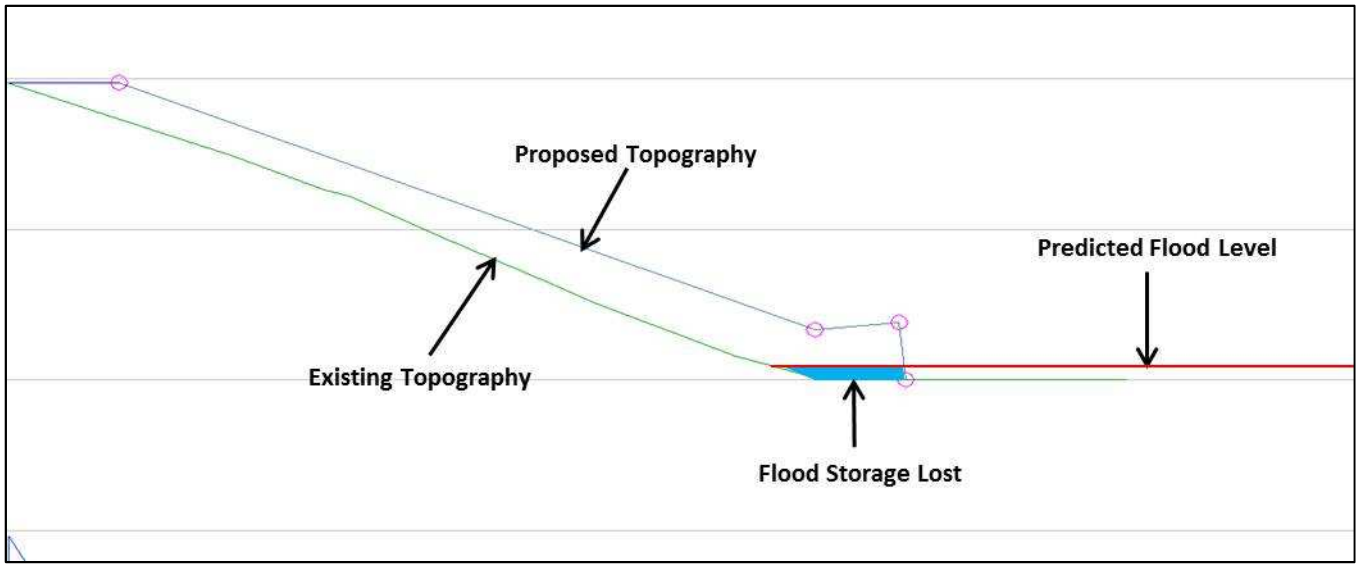

Figure 9 – Example of Calculation Method for Flood Storage Loss at each Cross-section along the Embankment.

Table 1 – Floodplain Storage Volume Lost at each Design Cross-Section at 200mm Level Bands for the Oddington Hydraulic Unit.

		Volume loss by level band (m^3)				
		Level Band (mAOD)				
Section	Embankment Face	60.0 to 60.2	60.2 to 60.4	60.4 to 60.6	60.6 to 60.8	60.8 to 61.03
116900	W	-	-	0.4	3.2	8.2
	E	-	-	-	-	-
116920	W	-	-	2.8	6.8	7
	E	-	-	-	-	-
116940	W	-	-	4	8.8	9
	E	-	-	-	-	-
116960	W	2.6	5.4	9	10	10.8
	E	-	-	-	1.6	1.2
116980	W	3.4	6	8.6	8.4	9
	E	-	-	0.2	2.2	1.2
117000	W	-	3.4	6.8	7.2	6.4
	E	0.8	0.6	-0.2	-0.4	-0.2
117020	W	2.4	5.8	6.8	5.6	4.8
	E	-	-0.2	-1	-	0.4
117040	W	-	-	0.4	7.2	8.4
	E	-	-	-	0.6	0.8
117060	W	-	-	-	-	1
	E	-	-	-	-	-
Totals		**9.2**	**21**	**37.8**	**61.2**	**68**
					Sum of Totals	**197.2**

Table 2 – Floodplain Storage Volume Lost at each Design Cross-Section at 200mm Level Bands for the Islip Hydraulic Unit.

		Volume loss by level band (m^3)				
		Level Band (mAOD)				
Section	Embankment Face	59.4 to 59.6	59.6 to 59.8	59.8 to 60.0	60.0 to 60.2	60.2 to 60.4
119380	W	-	-	-	0.8	0.4
	E	-	-	-	-	-
119400	W	-	-	-	0.2	0.4
	E	-	-	-	-	-
119420	W	-	-	-	0.2	0.4
	E	-	-	-	-	-
119440	W	-	-	-	4	1

		Volume loss by level band (m^3)				
		Level Band (mAOD)				
Section	Embankment Face	59.4 to 59.6	59.6 to 59.8	59.8 to 60.0	60.0 to 60.2	60.2 to 60.4
	E	-	-	-	-	-
119460	W	-	-	-	0.4	0.4
	E	-	-	-	-	-
119480	W	-	-	-	4	1
	E	-	-	-	-	-
119500	W	-	-	-	4.2	1
	E	-	-	-	-	-
119520	W	-	-	-	0.2	0.2
	E	-	-	-	-	-
119540	W	-	-	-	6	1.2
	E	-	-	-	-	-
119560	W	-	3.6	6	7	1.4
	E	-	-	-	-	-
119580	W	0.4	1.8	2.6	2	0.4
	E	-	-	-	-	-
119600	W	-	-	-	1.8	-
	E	-	-	-	-	-
119620	W	-	-	-	2.2	-
	E	-	-	-	-	-
119640	W	-	-	-	2.2	-
	E	-	-	-	-	-
119680	W	-	-	-	2.8	-
	E	-	-	-	-	-
119700	W	-	-	-	1.8	-
	E	-	-	-	-	-
119720	W	-	-	-	1.2	-
	E	-	-	-	-	-
119740	W	-	-	-	1	-
	E	-	-	-	-	-
119760	W	-	-	-	0.6	-
	E	-	-	-	-	-
119780	W	-	-	-	-	-
	E	-	-	-	-	-
119800	W	-	-	-	-	-

		Volume loss by level band (m^3)				
		Level Band (mAOD)				
Section	Embankment Face	59.4 to 59.6	59.6 to 59.8	59.8 to 60.0	60.0 to 60.2	60.2 to 60.4
	E	-	-	-	-	-
119820	W	-	-	-	1	-
	E	-	-	-	-	-
119840	W	-	-	-	1.8	-
	E	-	-	-	-	-
119860	W	-	-	-	-	-
	E	-	-	-	-	-
119880	W	-	-	-	-	-
	E	-	-	-	-	-
119900	W	-	-	-	1.2	-
	E	-	-	-	-	-
119920	W	-	-	-	0.8	-
	E	-	-	-	-	-
119940	W	-	-	-	0.2	-
	E	-	-	-	-	-
119960	W	-	-	-	0.8	-
	E	-	-	-	-	-
119980	W	-	-	-	2	-
	E	-	-	-	-	-
120000	W	-	-	-	1	-
	E	-	0.6	3.8	-	-
120020	W	-	-	0.2	1.4	-
	E	-	-	0.2	-	-
120040	W	-	-	2.8	2.2	-
	E	-	2.6	4.2	-	-
120060	W	-	0.4	4.6	3.4	-
	E	-	2.8	4.2	-	-
120080	W	0.2	2	7.6	5.2	-
	E	2	5.4	5.6	-	-
120100	W	-	-	0.8	2	-
	E	1.2	2.8	2.4	-	-
120120	W	-	-	-	0.2	-
	E	-	-	-	-	-
120140	W	-	-	-	1.2	-

		Volume loss by level band (m^3)				
		Level Band (mAOD)				
Section	Embankment Face	59.4 to 59.6	59.6 to 59.8	59.8 to 60.0	60.0 to 60.2	60.2 to 60.4
	E	-	-	-	-	-
120160	W	-	-	-	-	-
	E	-	-	-	-	-
Totals		**3.8**	**22**	**45**	**67**	**7.8**
					Sum of Totals	**145.6**

3.4 Viability of Level for Level Storage

3.4.1 Initial Assessment of Viability

The EA has confirmed that level for level storage is required when providing compensatory storage. The total volume of floodplain storage lost is 343m^3 as summarised in section 3.3 between 59.40mAOD (lowest ground level) and 61.03mAOD (maximum predicted flood level). However, there are two distinct hydraulic units where floodplain storage is lost and it is imperative that the correct volume of compensatory storage is provided within each hydraulic unit to account for the volume lost to ensure that flood risk at each location is not increased. The total volume of flood compensation required at each location is;

- 197m^3 at Oddington between 60.0mAOD (lowest ground level) and 61.03mAOD (maximum predicted flood level). Please see Table 1 for detailed breakdown of volume lost at 200mm intervals.

- 146m^3 at Islip hydraulic unit between 59.4mAOD (lowest ground level) and 60.24mAOD (maximum predicted flood level). Please see Table 2 for detailed breakdown of volume lost at 200mm intervals.

An assessment of the availability of suitable land to provide the compensatory storage has been undertaken within each hydraulic unit. Throughout the process of identifying suitable locations for storage there are a number of key factors that have been considered that include:

- 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.

3.4.2 Oddington Hydraulic Unit

Review of the levels and areas available locally within the Oddington hydraulic unit indicate that there is sufficient space available within the LOD (Permanent) with a slight ingress into the LOD (Temporary) boundary to provide level for level storage. The areas identified within Figure 10 provide adequate ground levels and space to accommodate the required level for level storage. This was confirmed through the checking of ground levels based on LiDAR data as summarised in Figure 11. Cross sections taken along and across the area also confirm the mitigation potential as highlighted in Figure 12.

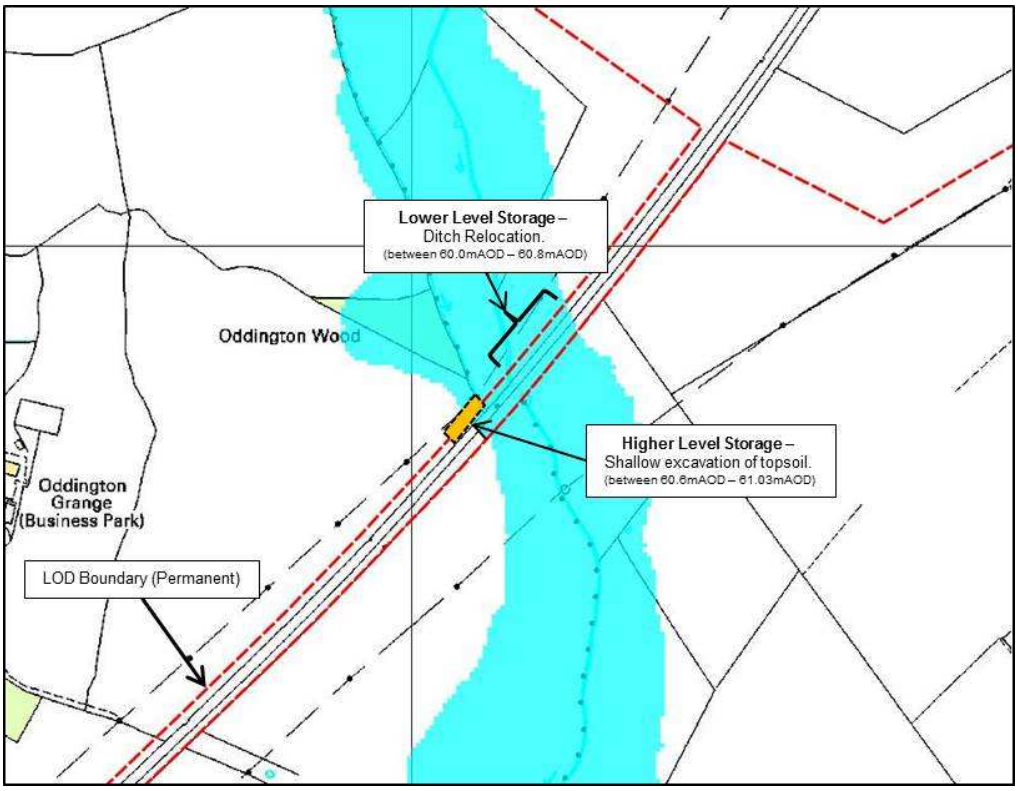

Figure 10 – Location Considered for Provision of Level for Level Storage.

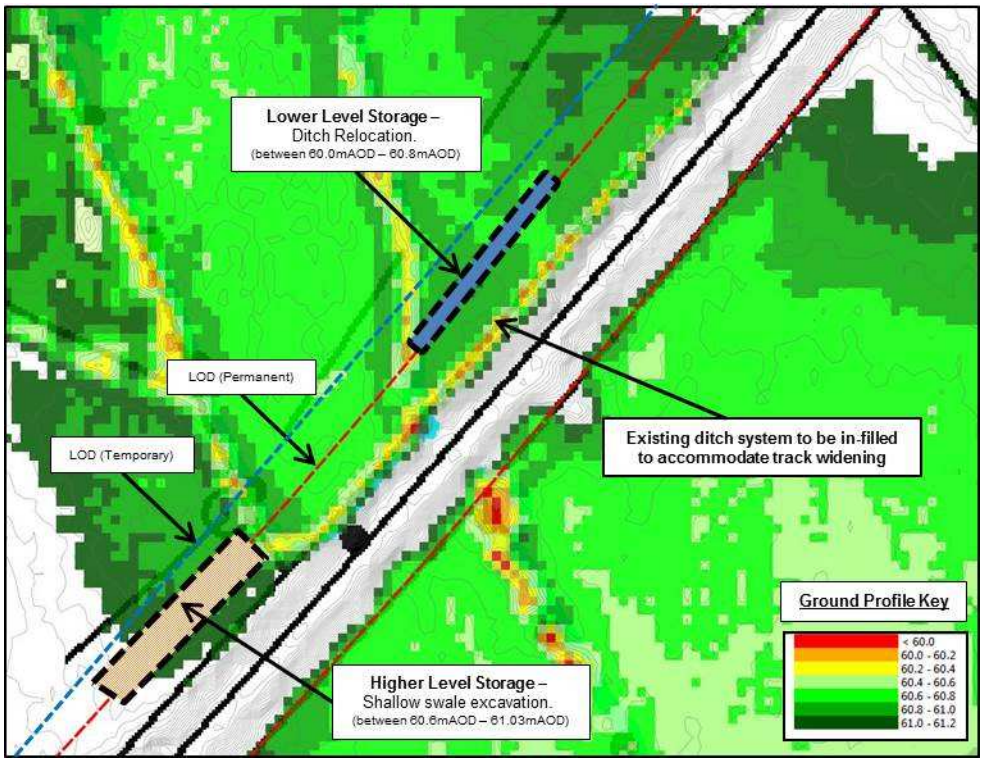

Figure 11 – Topographic Assessment using LiDAR.

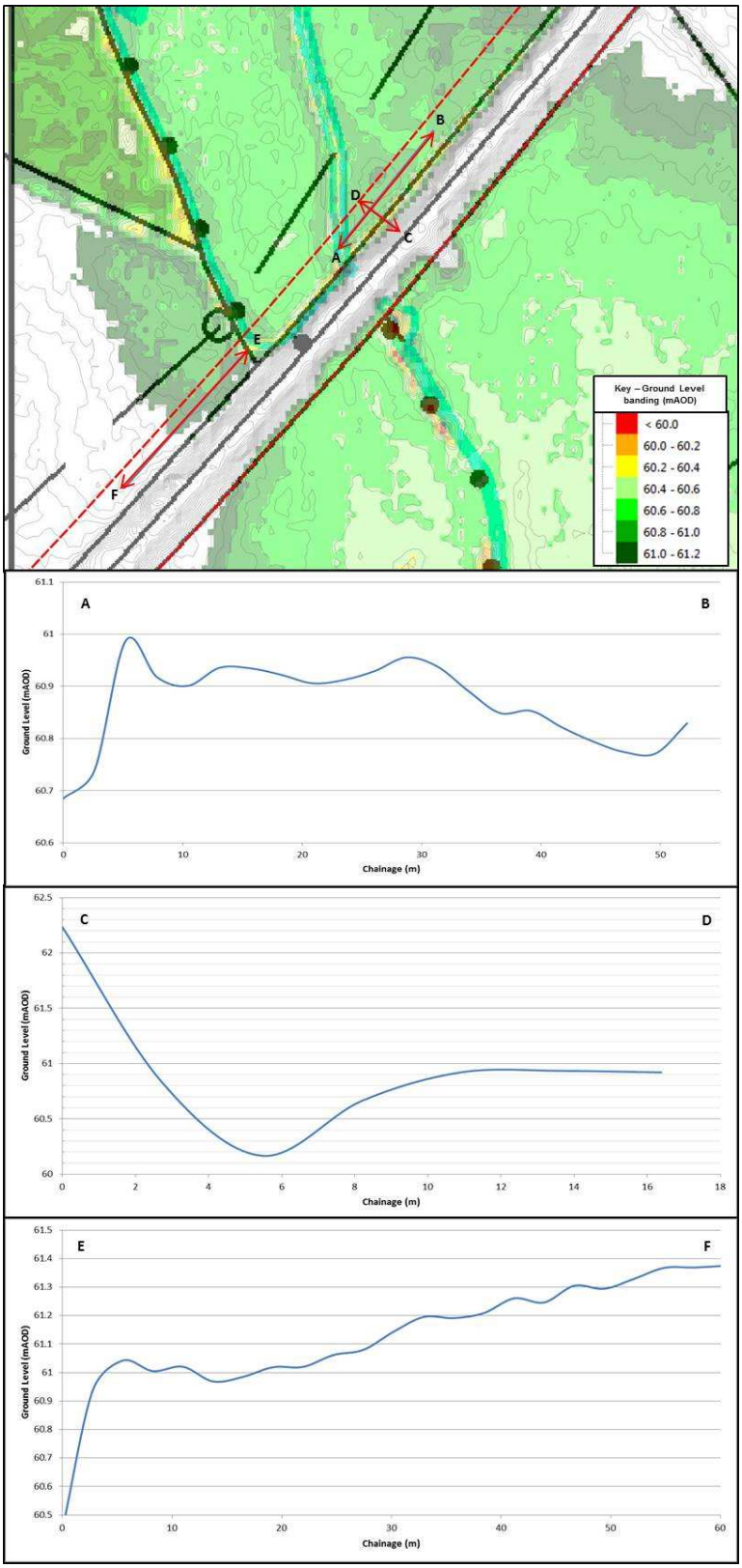

Figure 12 – Topography Upstream of the Railway Embankment at Oddington – Based on LiDAR (2m resolution).

To provide the lower level storage (i.e between 60.0mAOD to 60.8mAOD) a new ditch excavation similar to the existing ditch being in-filled is proposed as per Figure 13. This ditch excavation will ensure that the new ditch system is hydraulically connected to the existing watercourse so that this storage volume at the lower levels are utilised during a flood event.

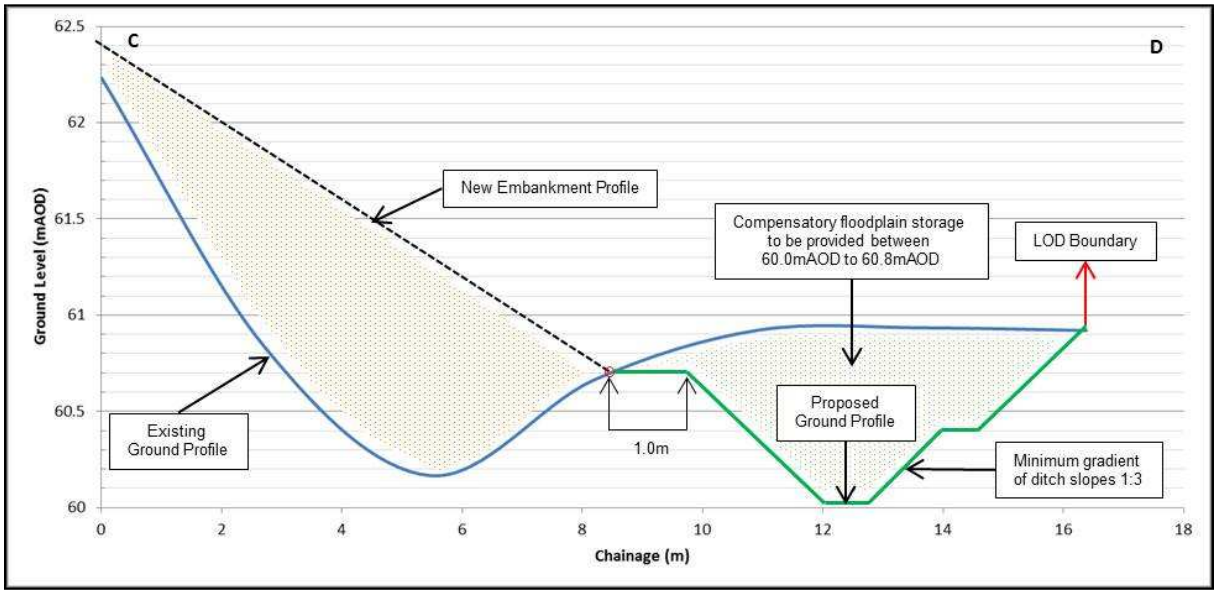

Figure 13 – Lower Level Storage Indicative Cross Section (Set to Cross Sections Locations shown in Figure 12).

To provide the higher level storage (i.e between 60.8mAOD to 61.03mAOD) a shallow swale excavation down to 60.8mAOD as per Figure 14 will be provided. This swale will need to be approximately 60m long by 6 - 7m wide to ensure that the 68m^3 of storage volume can be accommodated.

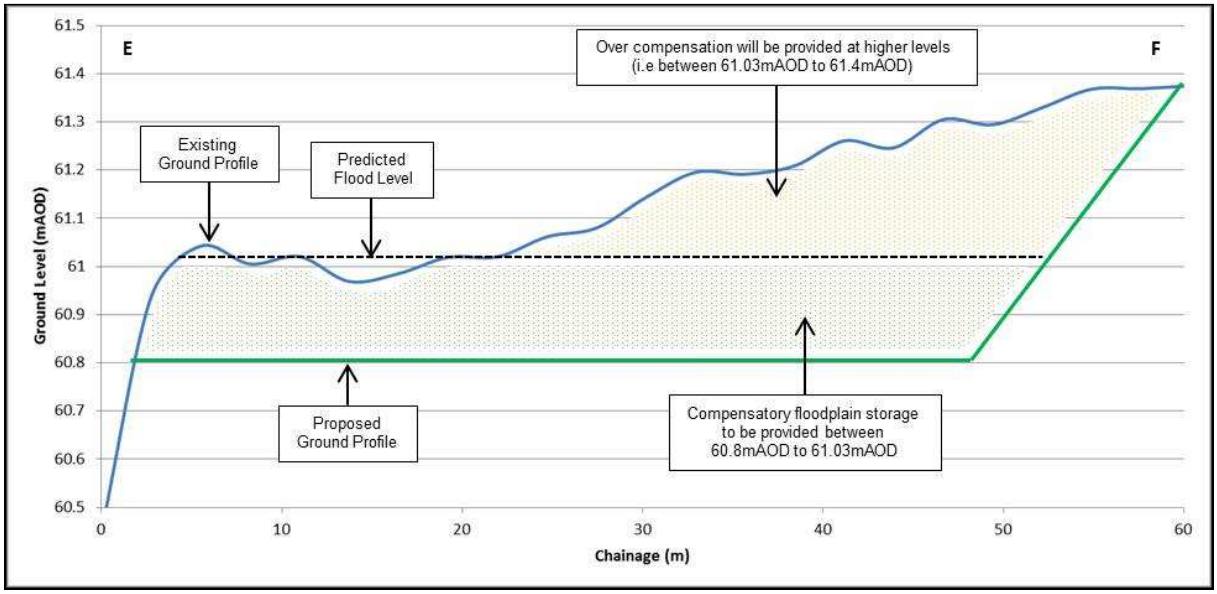

Figure 14 – Higher Level Storage Indicative Cross Section (Set to Cross Sections Locations shown in Figure 12).

3.4.3 Islip Hydraulic Unit

Review of the levels and areas available locally within the Islip hydraulic unit indicate that there is sufficient space available within the LOD (Temporary) to provide level for level storage.

The areas identified within Figure 15 provide the potential for level for level storage. This was confirmed through the checking of ground levels based on LiDAR data. Cross sections taken along the areas confirm the mitigation potential as highlighted in Figure 16 and Figure 17.

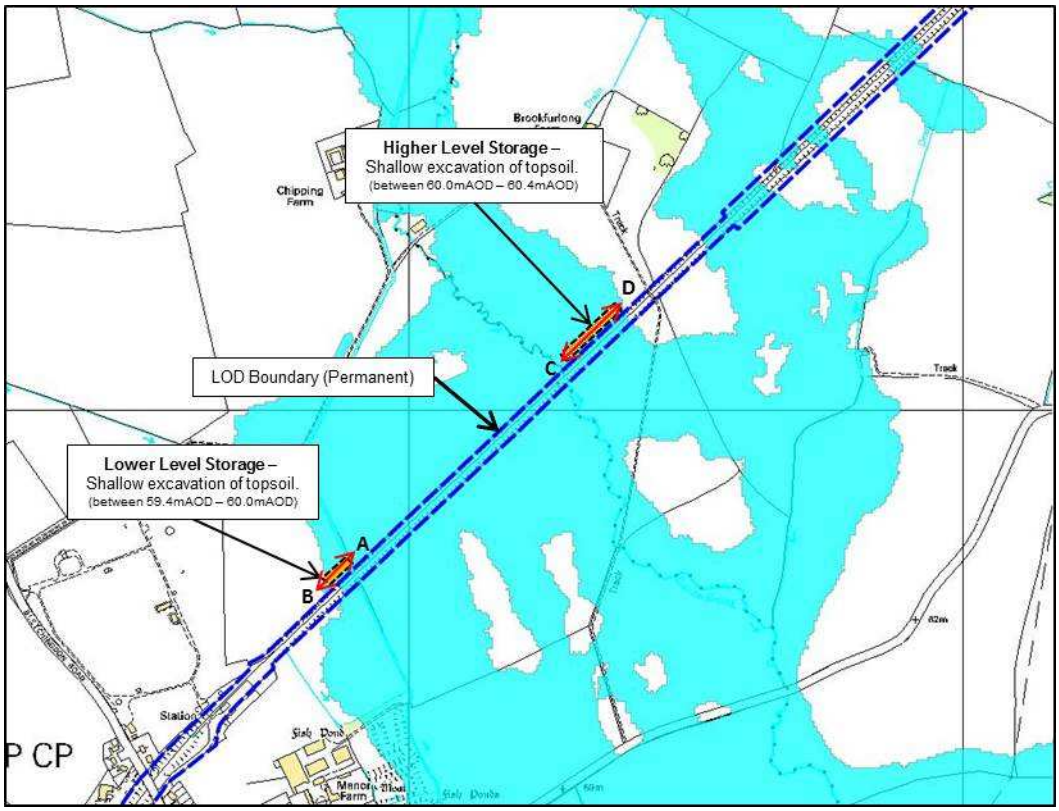

Figure 15 - Location Considered for Provision of Level for Level Storage Within the Islip Hydraulic Unit.

To provide the lower level storage (i.e between 59.4mAOD to 59.8mAOD) a shallow staged swale type excavation down to 59.4mAOD as per Figure 16 will be provided. This swale will need to be approximately 20m long by 6m wide to ensure that the 22m^3 of storage volume can be accommodated in the critical depth band between 59.6mAOD to 59.8mAOD.

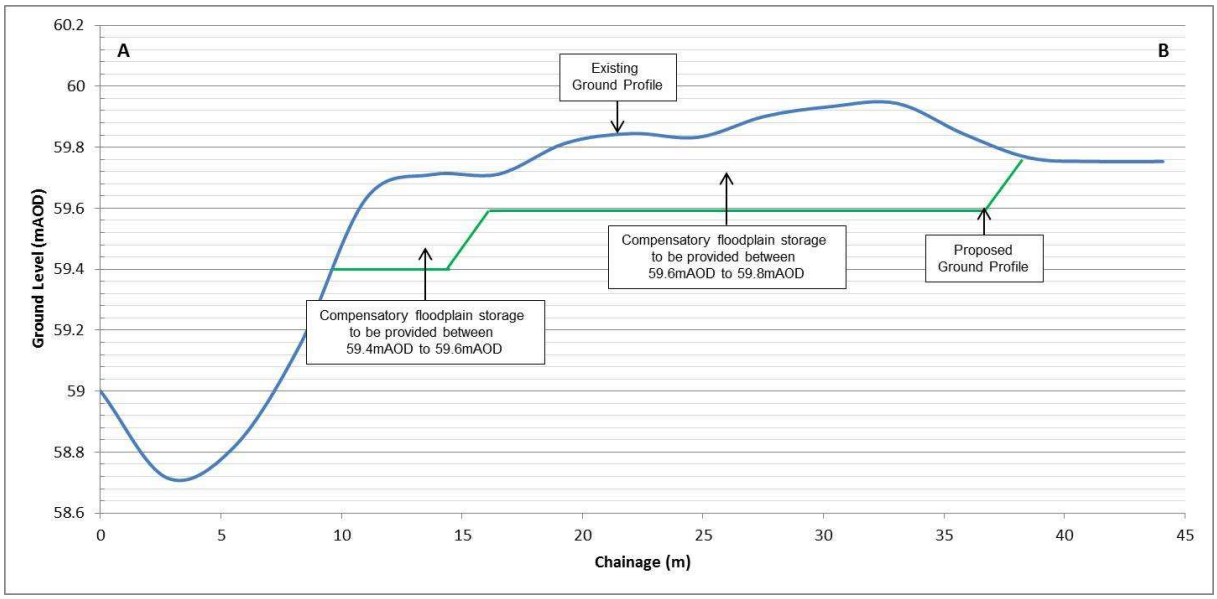

Figure 16 - Lower Level Storage Indicative Cross Section (Set to Cross Sections Locations shown in Figure 15).

To provide the higher level storage (i.e between 59.8mAOD to 60.4mAOD) a shallow swale excavation down to 59.8mAOD as per Figure 17 will be provided. This swale will need to be approximately 60m long by 6m wide to ensure that the 68m^3 of storage volume can be accommodated in the critical depth band between 60.0mAOD to 60.2mAOD.

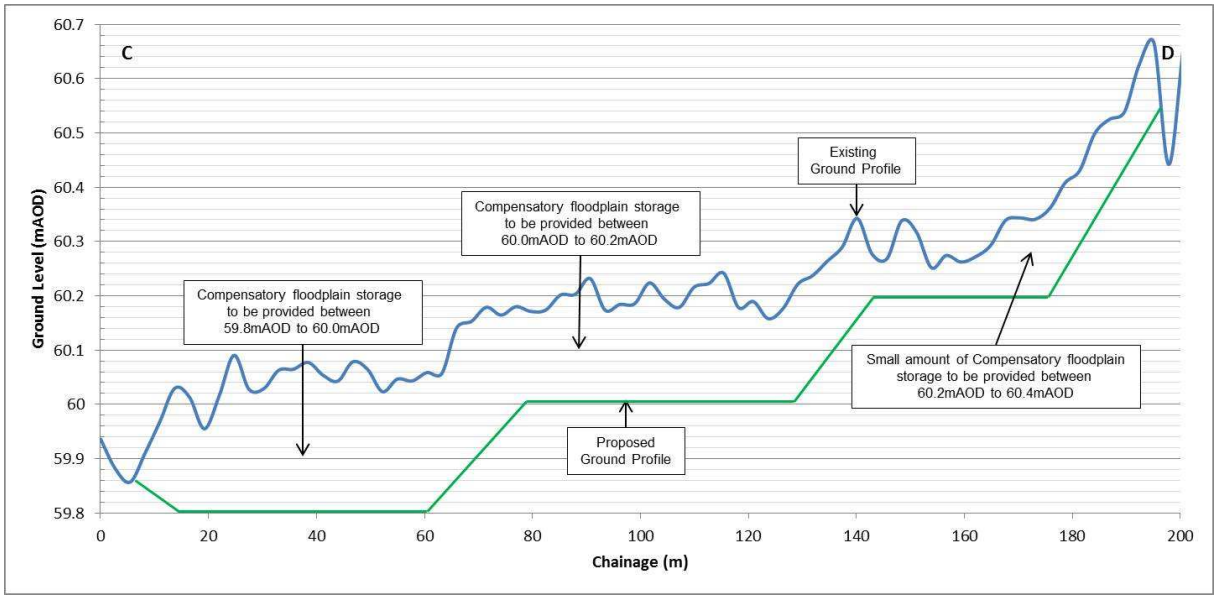

Figure 17 - Higher Level Storage Indicative Cross Section (Set to Cross Sections Locations shown in Figure 15).

This initial assessment has conducted a review of ground levels and areas within the LOD boundary that are suitable to be used for compensatory floodplain storage. Detailed design of the storage areas will be undertaken by Atkins through a detailed ground modelling exercise to accurately

design storage areas based on the volumes and levels provided in Table 1 for the Oddington hydraulic unit and Table 2 for the Islip Hydraulic unit.

4 Conclusions

The key conclusions of this FRA are as follows:

- The proposed embankment widening works between Islip and the M40 would lead to a reduction in floodplain storage volume of 343m^3. This total volume is split between two distinct hydraulic units that include;
  - 197m^3 required at Oddington Hydraulic Unit.
  - 146m^3 required at Islip Hydraulic Unit
- **Oddington Hydraulic Unit** – Flood compensation for this hydraulic unit will be provided through the provision of two separate solutions that include;
  - The lower level storage (i.e between 60.0mAOD to 60.8mAOD) is provided via a ditch re-profiling type excavation.
  - The higher level storage (i.e between 60.8mAOD to 61.03mAOD) is provided via a shallow swale excavation.

Please see 3.4.2 for full details of storage area locations and solutions.

- **Islip Hydraulic Unit** - Flood compensation for this hydraulic unit will be provided through the provision of two separate solutions that include;
  - The lower level storage (i.e between 59.4mAOD to 59.8mAOD) is provided via a shallow staged swale type excavation.
  - Higher Level Storage (i.e between 59.8mAOD to 60.4mAOD) is provided via a shallow swale excavation.

Please see 3.4.3 for full details of storage area locations and solutions.

- Detailed design of the storage areas will be undertaken by Atkins through a detailed ground modelling exercise to accurately design storage areas based on the volumes and levels provided in Table 1 for the Oddington hydraulic unit and Table 2 for the Islip Hydraulic unit.

4.1 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 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 Islip to M40 embankment widening. 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.

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