West Oxfordshire District Council

March 2015

Witney Level 2 Strategic Flood Risk Assessment

Wallingford HydroSolutions Limited

West Oxfordshire District Council

Witney Level 2 Strategic Flood Risk Assessment

Document issue details

WHS1277

Version number	Issue date	Issue status	Issuing Office
V1.0	6th February 2015	Draft	Cardiff
V2.0	12th February 2015	Final	Cardiff
V3.0	9th March 2015	Draft (with modelling)	Cardiff
V4.0	20th March 2015	Final (with modelling)	Cardiff

For and on behalf of Wallingford HydroSolutions Ltd.

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Date **20th March 2015**

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Executive Summary

Scope of Level 2 SFRA

Wallingford HydroSolutions (WHS) Ltd has been commissioned by West Oxfordshire District Council (WODC) to undertake a Level 2 Strategic Flood Risk Assessment (SFRA) in accordance with the National Planning Policy Framework (NPPF) and associated Environment Agency Flood Risk Standing Advice (FRSA) in support of the pre-submission draft West Oxfordshire Local Plan.

WODC published a Local Plan Housing Consultation Paper[1] which identifies the land north of Witney as a Strategic Development Area (SDA). A pre-requisite of this draft allocation is the provision of a new river crossing over the River Windrush, known as the West End Link (WEL).

A Level 1 SFRA[2] was undertaken in 2009, which identified that a Level 2 SFRA could be provided to present more detailed information regarding flood risk and development within Witney, to include both surface water and fluvial flooding.

This Level 2 SFRA builds upon the Level 1 SFRA and should be read in conjunction with it regarding strategic policy level information and requirements. This report gathers together available site-specific data and evidence, the primary objectives of which are to provide information on the flood risks and impacts associated with the SDA and WEL, along with recommendations for future site-specific FRAs.

Key Findings for the North Witney Strategic Development Area

1. The North Witney development is sited largely in Flood Zone 1 and housing development is not to be located in the relatively localised areas of Flood Zones 2 and 3 where the site is affected by flooding from the Hailey Road drain. Hence, it can be concluded that development of the site can be designed such that it complies with the Sequential Approach requirements of the National Planning Policy Framework (NPPF). It must be noted that this SFRA does not negate the requirement for the Sequential Test to be undertaken in accordance to the NPPF.
2. To inform a future site-specific FRA and the development layout, the existing EA hydraulic model of the Hailey Road drain should be extended through the site to confirm the extents of flooding. This modelling should assess the impact of a culvert or trash screen blockage scenario, in agreement with the Environment Agency.
3. Finished floor levels of properties within the SDA should be set at a minimum of 300mm above the modelled 1 in 100 year plus an allowance for climate change levels.
4. Our review of available desk top data suggests that there are no other sources of flooding that might significantly affect the development (ie pluvial, groundwater and sewer).
5. Localised areas of the SDA outside of the Hailey Road drain flood zones are at moderate risk of surface water flooding. A future FRA should demonstrate that these local risks can be managed through suitable design of drainage and development levels.
6. Due to the relatively complex geology of the site, ground investigation should be undertaken to confirm the groundwater regime and seasonal variation of groundwater to inform the development design and in particular the design of sustainable drainage systems. Infiltration testing should also be undertaken to confirm the viability of infiltration drainage techniques, which is likely to be variable across the site.

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[1] West Oxfordshire District Council (2014). *West Oxfordshire Local Plan: Housing Consultation Paper*.
[2] Scott Wilson (2009). *Cherwell and West Oxfordshire: Level 1 Strategic Flood Risk Assessment.*

7. Currently, the inadequate capacity of the 750mm diameter culvert that conveys the Hailey Road drain from the development site causes flood water to overtop the existing headwall and has historically caused flooding to properties downstream of the SDA. The culvert trash screen arrangements do not comply with the current recommendations of the Environment Agency Trash and Security Screen Guide 2009, meaning that the screen is too small and easily blocked by debris, which is difficult to remove during flood conditions. Water has also historically escaped from manholes on the culvert, due to surcharging of the culvert. This represents an off-site flood risk, rather than a flood risk that would directly affect the housing development per se. Local flood protection measures have been carried out by Oxfordshire County Council (OCC), WODC, Environment Agency (EA) and Thames Water (TW) to manage flood routing and improve flood resilience of the adjacent properties.
8. There is scope to attenuate flows from the Hailey Road drain by the provision of a storage pond or ponds that would reduce the frequency of flooding on Eastfield Road and Hailey Road.
9. The development should include sustainable drainage (SUDS) measures to reduce run-off rates below existing greenfield rates. Such SUDS measures should use a suitable combination of at source solutions, such as permeable paving in parking areas, as well as 'end-of-pipe' measures, such as attenuation or infiltration ponds. SUDs measures should also be located outside of the 1 in 100 year plus an allowance for climate change flood extent.
10. A future site-specific FRA for the SDA should demonstrate that the scope for improvement of downstream flood risk due to the Hailey Road drain culvert has been fully considered. A key objective of the FRA should be to demonstrate as a minimum that the capacity of the Hailey Road drain culvert system is not exceeded during a 1 in 30 year event and that no flooding of properties occurs during a 1 in 100 year event as a consequence of floodwater escaping from the Hailey Road drain culvert. Review of the available evidence suggests that there is significant scope through appropriate design of the housing development to improve the existing downstream flooding problems through a combination of:
    a. River attenuation to reduce peak flows from the Hailey Road drain catchment
    b. Appropriate SUDS design to reduce run-off rates from the development site
    c. Improvements to the existing culvert headwall structure and trash screen.
11. The future site-specific FRA should demonstrate that safe access and egress routes are provided to the development that remain free from flooding, or that the hazard due to any flooding is sufficiently low.
12. Thames Water has indicated that infrastructure upgrades are likely to be required in order to maintain and/or reduce the current risk of sewer water flooding within Witney.

Key Findings for the West End Link Road Bridge

1. The North Witney development also includes the development of the West End Link Road, which includes a river crossing of the River Windrush. By definition, the bridge crossing passes through Flood Zone 3 and hence the impact of this development on flood risk will be required within a future site-specific FRA to ensure that flood risk is not increased elsewhere.
2. As the bridge crossing is located in Flood Zone 3, it will marginally reduce the volume of storage in the floodplain. A future site-specific FRA should demonstrate that compensatory storage can be provided locally to the bridge structure or within the same hydraulic unit. This should normally be provided on a 'level for level' basis. If suitable sites are not available, then the storage may be provided on a 'volume for volume' basis subject to agreement with the Environment Agency. In the latter case, a degree of overcompensation is likely to be required and hydraulic modelling would be required to demonstrate that there is no unacceptable increase in flood risk.
3. Measures should also be taken to ensure that surface water run-off from the increased impermeable area of the highway is maintained below existing greenfield run-off rates.
4. Initial hydraulic modelling undertaken to inform this FRA indicates that the proposed WEL bridge crossing does not lead to an unacceptable increase in flood risk elsewhere, satisfying this element of the exception test.

5. The modelling of options to restrict flows through the WEL bridge indicated that there was no significant benefit to the downstream urbanised area of Witney. However, in order to further investigate the benefit of utilising the WEL bridge crossing as part of a wider flood alleviation scheme, there would be merit in investigating the viability of other more engineered flood alleviation solutions upstream of the bridge crossing as described in Section 4.3.

Contents

1 Introduction

1.1 Background

Wallingford HydroSolutions (WHS) Ltd has been commissioned by West Oxfordshire District Council (WODC) to undertake a Level 2 Strategic Flood Risk Assessment (SFRA) in accordance with the National Planning Policy Framework (NPPF) and associated Environment Agency Flood Risk Standing Advice (FRSA) in support of the pre-submission draft West Oxfordshire Local Plan.

WODC published a Local Plan Housing Consultation Paper[1] which identifies the land north of Witney as a Strategic Development Area (SDA). A pre-requisite of this draft allocation is the provision of a new river crossing over the River Windrush, known as the West End Link (WEL).

A Level 1 SFRA[2] was undertaken in 2009, which identified that a Level 2 SFRA could be provided to present more detailed information regarding flood risk and development within Witney, to include both surface water and fluvial flooding.

1.2 Scope

This Level 2 SFRA builds upon the Level 1 SFRA and should be read in conjunction with it regarding strategic policy level information and requirements. This report gathers together available site-specific data and evidence, the primary objectives of which are to provide information on the flood risks and impacts associated with the SDA and WEL, along with recommendations for future site-specific FRAs.

The majority of the SDA is situated within Flood Zone 1, with a small section located within Flood Zones 2 and 3a. The WEL has sections located within Flood Zones 2,3a and 3b, where the flood zones are defined in Table 1.

Table 1 – Definition of Flood Zones

Flood Zone	Description
Flood Zone 1	• Considered at low risk of fluvial flooding (less than 1 in 1000 year or 0.1% Annual Exceedance Probability (AEP)) • Consists of all areas outside of flood zones 2, 3a and 3b • Risk of flooding from other sources may still be an issue
Flood Zone 2	• Extreme flood event outline • Defined as the 1 in 1,000 year or 0.1% AEP
Flood Zone 3a	• Severe flood event outline • Defined as the 1 in 100 year or 1.0% AEP
Flood Zone 3b	• Functional Floodplain (FFP) • Defined as the 1 in 20 year or 5.0% AEP

To provide support in the decision making process, this SFRA covers a number of issues outlined below:

- Provide a more detailed qualitative flood risk assessment of the SDA and WEL
- Collate and analyse environmental and flood risk information obtained from a desk based review, building on the information contained within the West Oxfordshire Level 1 SFRA
- Provide a preliminary estimate of greenfield runoff rates and make an assessment of any potential attenuation volume required to ensure that the greenfield run-off rates are not exceeded post-development
- Identify the principles for surface water management for the development.
- Provide advice regarding any foul drainage constraints for the site
- Provide recommendations for further work and site investigations to inform future detailed site specific Flood Risk Assessments (FRA)
- Identify where opportunities exists to reduce the impact of flooding within Witney
- Provide an initial assessment of the application of the sequential and exception tests, as required by the NPPF and FRSA.
- Initial hydraulic modelling of the flood risk impacts of the West End Link Bridge.

2 Site Details and Development Proposals

2.1 Site Details

The land to the north of Witney in west Oxfordshire has been identified as a Strategic Development Area (SDA) and is located at National Grid Reference 436270 211770. The SDA is split into two sections, see Figure 1. The larger section of the site sits between Hailey Road and New Yatt Road, whilst the smaller section is located to the north west of Woodstock Road.

The total site area is approximately 55.5ha, where the land at Hailey Road is approximately 48.8ha and the land at Woodstock Road is approximately 6.7ha. The Hailey Road drain runs through the centre of the land at Hailey Road and becomes culverted as it runs through the urbanised area of Witney before discharging into the River Windrush.

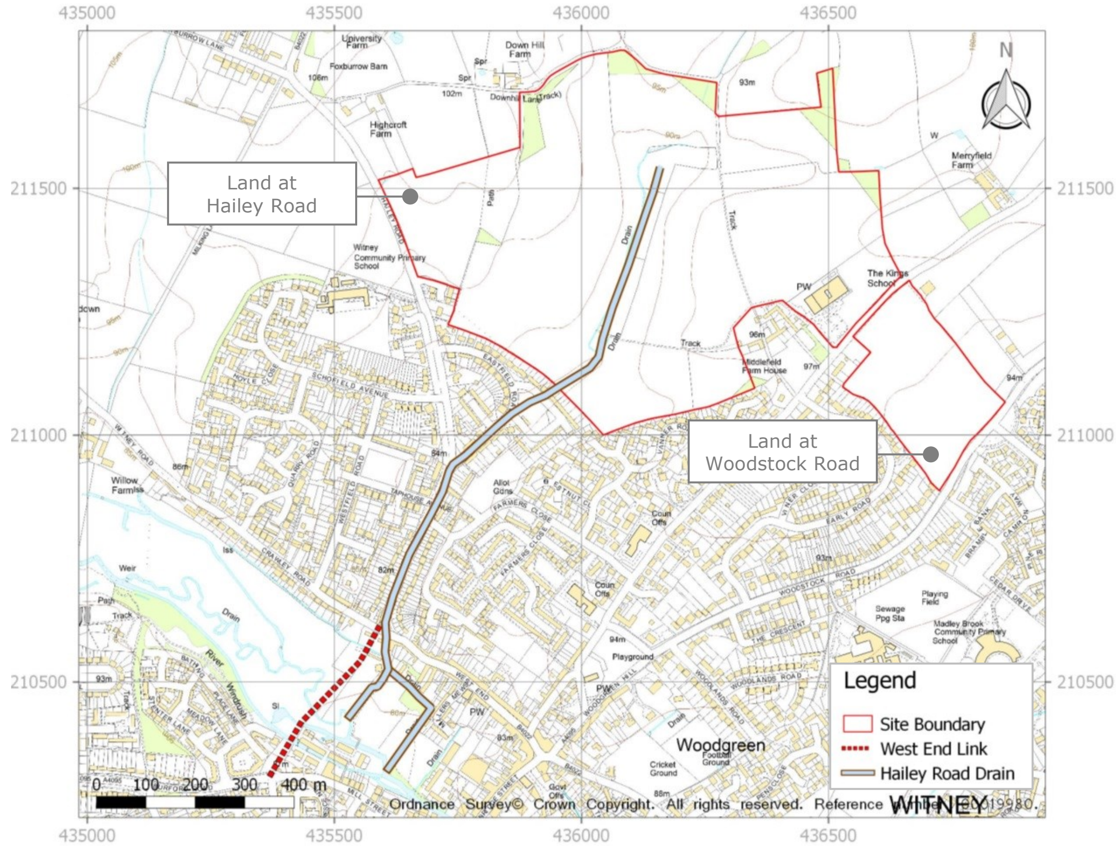


Figure 1 – Site Location

2.2 Topography

The topography of the site has been analysed using LiDAR data, which is a relatively accurate form of aerial survey data, see Figure 2. For the land at Hailey Road, the site topography generally slopes towards the centre where the Hailey Road drain is located. For the land at Woodstock Road, the site generally slopes towards the southernmost corner. The anticipated surface water flow direction is shown in Figure 2, based on the average flow direction over a 50m grid.

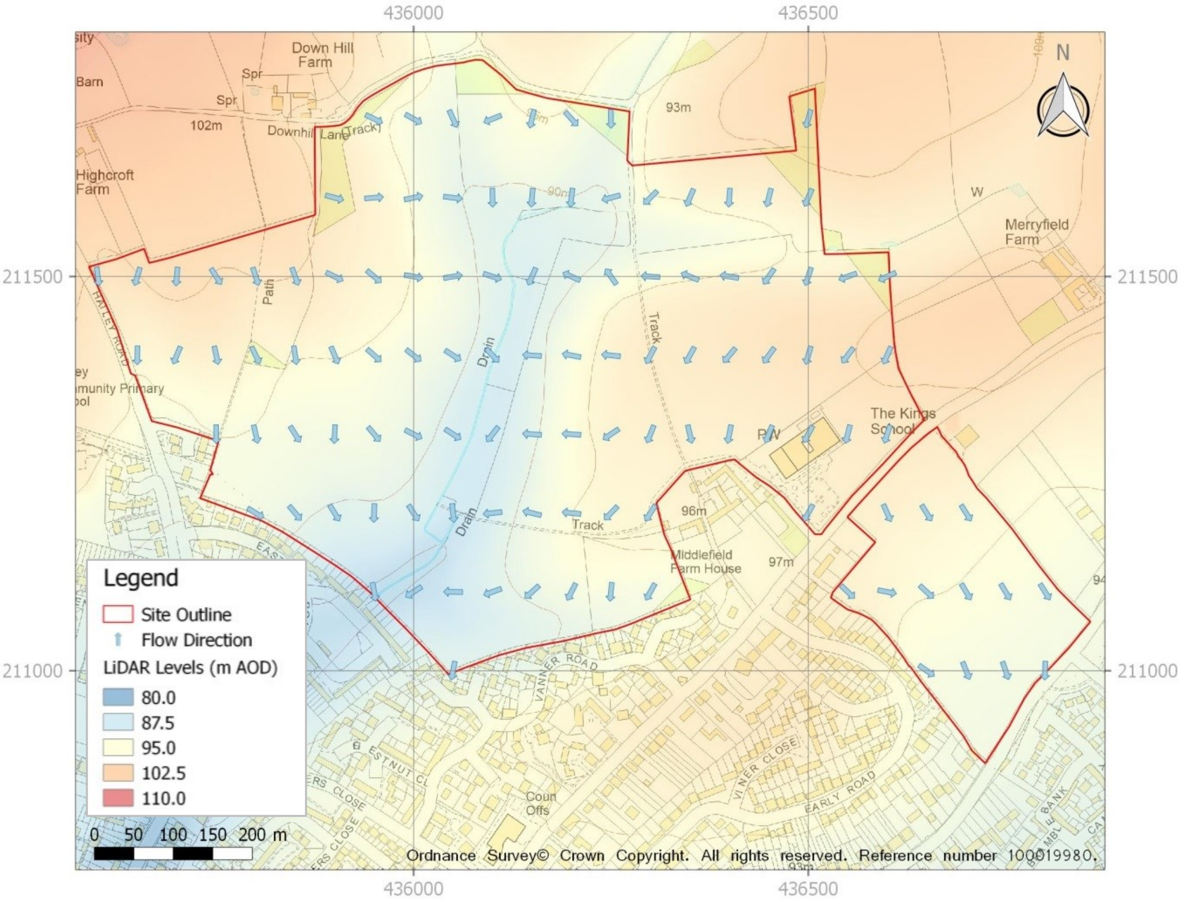


Figure 2 – Topography based on LiDAR aerial survey data

2.3 Proposed Development

2.3.1 Housing

The SDA has the potential to accommodate 1,000 homes constructed across the two sections[1] shown in Figure 1. A planning application for the land at Woodstock Road has already been submitted[3] to West Oxford District Council (WODC) by Taylor Wimpey for up to 200 new homes.

It is anticipated that the land at Hailey Road may be suitable for the construction of approximately 800 new homes.

2.3.2 Road Infrastructure

WODC has made the pre-requisite that any development of the land at Hailey Road would also require a new river crossing across over the River Windrush. This river crossing is known as the West End Link (WEL) and it is located to the south of the SDA as shown in Figure 1.

[3] Boyer Planning for Taylor Wimpey (2014). *Land at Woodstock Road: Planning Statement.* 14.127

3 Existing Flood Risk

3.1 Main Sources of Data Used

The existing flood risk to the proposed development has been established from review of relevant data sources and previous reports. The following datasets and reports have been reviewed in order to get a broad understanding of all sources of flood risk;

- EA Flood Mapping (Rivers and Seas, Reservoirs and Surface Water)[4]
- Flood depth and flood extent modelling results of the River Windrush[5] and Hailey Road drain[6]
- Environment Agency Initial Assessment: Witney Flood Alleviation[7]
- Level 1 Strategic Flood Risk Assessment for Cherwell and West Oxfordshire[2]
- West Oxfordshire District Council Parish Flood Report: Witney[8]
- Environment Agency Witney Flood Review[9]
- Atkins Hailey Road Drain Upstream Storage Options Pre-Feasibility Study [10]
- Peter Brett Associates, Drainage Study Hailey Road and Eastfield Road, Witney[11]
- The British Geological Survey (BGS) Infiltration SuDS Geo Report[12]

3.2 Fluvial Flood Risk

There are two key watercourses that affect the development. The Hailey Road drain runs through the centre of the Hailey Road development area and is the key source of fluvial flood risk affecting the SDA housing development. The River Windrush runs through the centre of Witney and is the key fluvial flood risk relevant to the construction of the WEL bridge. Sections 3.2.1 and 3.2.2 below consider these two key sources of flood risk as they relate to the SDA and WEL bridge crossing respectively.

The Hailey Road drain runs through the centre of the land at Hailey Road, as such it is the primary source of flooding to the SDA. Hydraulic modelling of the Hailey Road drain has been undertaken by the EA in 2014. The upstream boundary of this model is situated to the south of the proposed development. As such only a small section of the Hailey Road drain that runs through the proposed site has been modelled; hence a large section of the flood extent throughout the site has not been established through modelling, see Figure 3. In order to establish the flood extent and level

[4] Environment Agency Flood Maps. *http://maps.environment-agency.gov.uk*. Accessed 19th Jan 2015.
[5] CH2MHill (2014). *Post 2007 ABD – Windrush: Worsham to Witney (A40) Modelling Report.*
[6] CH2MHill (2014). *Post 2007 ABD – Hailey Road Drain Modelling Report.*
[7] Environment Agency (2014). Initial Assessment: Witney Flood Alleviation. IMSE500111.
[8] West Oxfordshire District Council (2008). *Parish Flood Report: Witney.*
[9] Environment Agency (2008). *Witney Flood Review July 2007.*
[10] Atkins (2008). *Hailey Road Drain Storage Options Options Pre-Feasibility Study*. 72DG013.
[11] Peter Brett Associates (2003). *Drainage Study, Hailey Road and Eastfield Road, Witney.* 13673.
[12] British Geological Society (BGS) (2014). Infiltration SuDS GeoReport. GR_210452/1.

throughout the proposed site, it is recommended for a future site-specific FRA that the Hailey Road drain model is extended to cover the proposed site in its entirety.

The Hailey Road drain is classified as main river to a point just upstream of the existing culvert inlet, indicated as the model extent in Figure 3 below. As such Flood Defence Consents for this section of the watercourse will be approved by the EA, whilst consents upstream of this point will be approved by the Lead Local Flood Authority, Oxfordshire County Council. The River Windrush is classified as main river and hence consents will be approved by the EA.

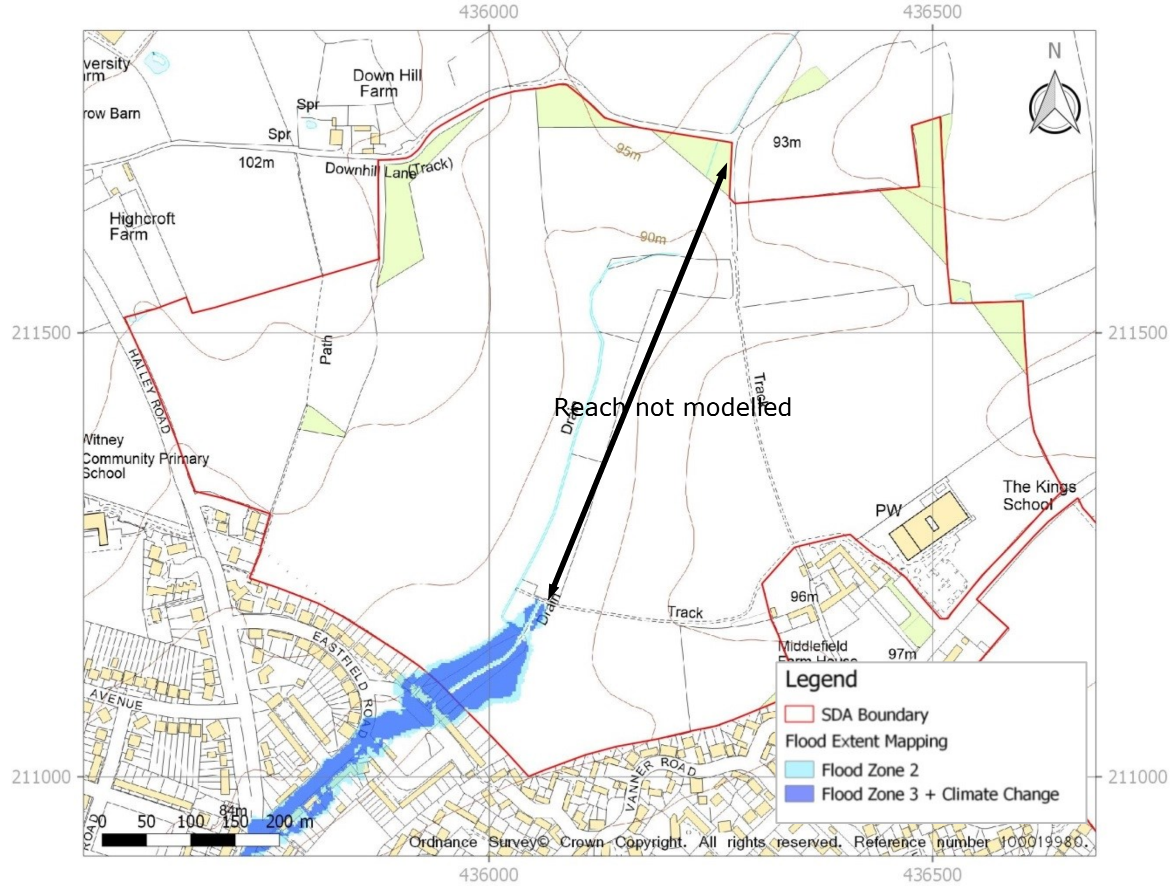


Figure 3 – Existing model extents of Hailey Road drain

3.2.1 Housing

The Hailey Road drain runs through the centre of the land at Hailey Road. The catchment for the Hailey Road drain is approximately 4.1km^2 and is predominantly rural consisting of mostly agricultural land[6]. Due to the size of the catchment, the response time for flood events is relatively short.

Detailed modelling of Hailey Road drain has been carried out by CH2MHill on behalf of the EA in April 2014. This model provides detailed flood mapping of the urbanised area between the location where Hailey Road drain becomes culverted and its confluence with the river Windrush.

The modelled flood extent for the 1 in 100 year including an allowance for climate change event is shown in Figure 4. It can be seen that a number of properties along Eastfield Road, Hailey Road and at the junction of Hailey Road and Crawley Road are predicted to flood during this flood event.

During the 1 in 100 year including an allowance for climate change flood event for Hailey Road drain, a total of 17 properties are predicted to flood. The flooding mechanisms for this event are described in Figure 4. The model also shows that there is localised flooding within the proposed development area.

In July 2007, the Hailey Road drain experienced an extreme flood event. There are no gauging stations installed on the Hailey Road Drain and as such the return period for the flows during this event cannot be established. There is a tipping bucket gauge installed in the Severn Trent sewage treatment works to the south of Witney. The rainfall recorded at this gauge during the July 2007 flood event was suggests a 1 in 150 year rainfall event[7] locally at Witney. During this event 35 properties were flooded due to the Hailey Road Drain.

It is noted that the model in its current form does not include any of the flood protection measures that have already been carried out by OCC, WODC, EA and TW to control surface water flows and improve property resilience to flooding.

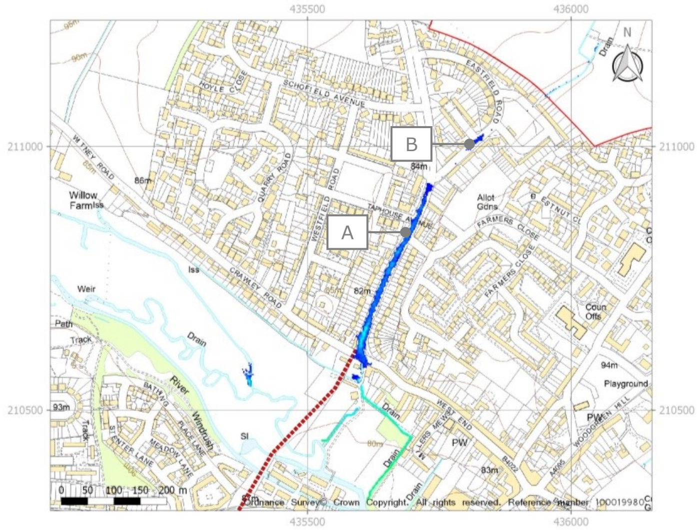
It is likely that the Hailey Road drain culvert was constructed after World War II when the Eastfield Road housing estate was constructed. The minimum size of the culvert is 750mm diameter and the modelling results clearly demonstrate that the culvert is of insufficient capacity.

The land at Woodstock Road lies within Flood Zone 1. There are no nearby water bodies and it is concluded that there is no fluvial flood risk affecting the proposed development site.

1 in 100 year + Climate Change
at **3.5** hrs

[A] Flooding of Hailey Road initiated by surcharging of manholes

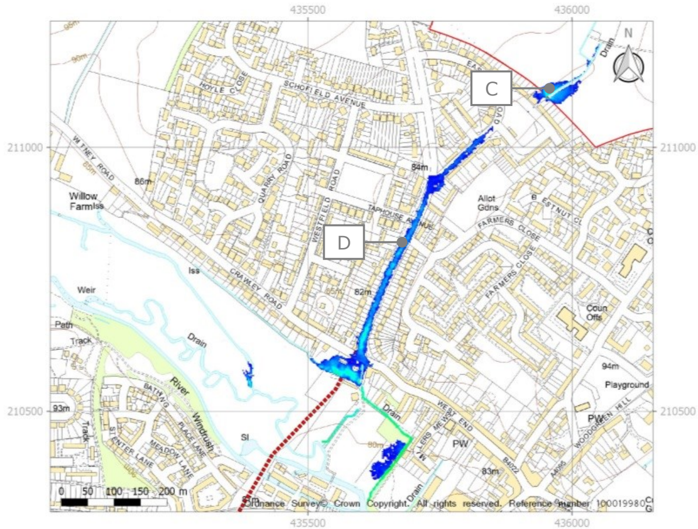
[B] Followed by flooding of Eastfield Road, again initiated by surcharging of man holes



1 in 100 year + Climate Change
at **4.0** hrs

[C] Hailey Road drain culvert inlet reaches capacity and water begins to back up

[D] Flood water is conveyed down Eastfield Road and Hailey Road



1 in 100 year + Climate Change
at **Max Flood Depth**

[E] 7 properties predicted to flood at the inlet to the Hailey Road drain culvert

[F] 8 properties predicted to flood along Eastfield Road

[G] 2 properties predicted to flood at the junction of Hailey Road and Crawley Road

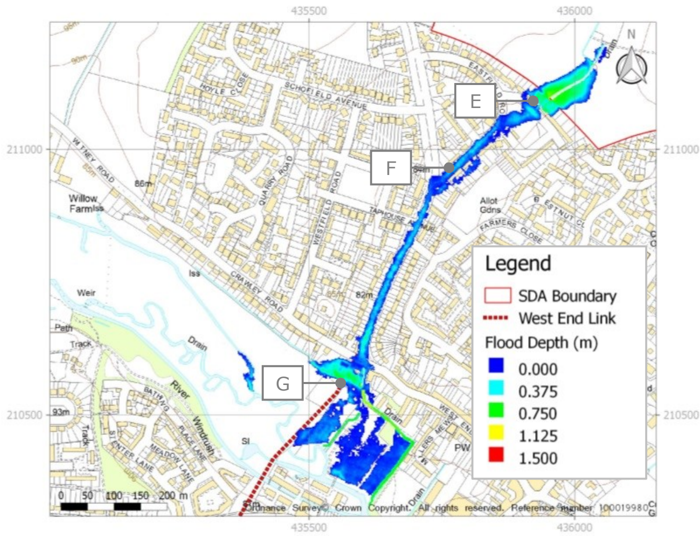


Figure 4 – Hailey Road drain flood extents

3.2.2 Road Infrastructure

Upstream of Witney the River Windrush is a single channel that runs through a predominantly rural catchment consisting of grass fields and agricultural land. At the location of the WEL, the River Windrush consists of several channels that meander through a grass field floodplain. Downstream of the WEL the river Windrush runs through Witney then continues to run through rural land as a multi-channel river before reaching its confluence with the River Thames.

There is a gauging station located upstream of Witney (Station 39076 – Windrush at Worsham). The catchment area for this gauging station is 296km^2 and consists largely of arable land and grassland. The geology of the catchment is primarily high permeability fissured bedrock[13]. These characteristics lead to a relatively long flood duration heavily influenced by groundwater levels.

There is significant fluvial flood risk associated with the River Windrush, although the River Windrush has no impact on the North Witney SDA directly, it does affect the downstream boundary of the Hailey Road drain. The proposed West End Link crosses the river Windrush, which could result in localised changes to the flood risk in the area due to its construction. For these two reasons, the risk of fluvial flooding from the River Windrush is considered within this report.

Modelling of the River Windrush was initially undertaken in 2010 by Halcrow, it was then updated in April 2014 by CH2MHill. Figure 5 shows the flooding extents during the 1 in 100 year plus an allowance for climate change event. During the 1 in 100 year plus an allowance for climate change flood event the model indicates that 100 properties will be flooded in Witney[7]. The July 2007 flood event (estimated to be a 1 in 300 year fluvial flood event[7] for the wider River Windrush catchment) resulted in 120 properties being flooded, with additional properties that also flooded as result of the Madley Brook and pluvial flooding due to the high rainfall intensity.

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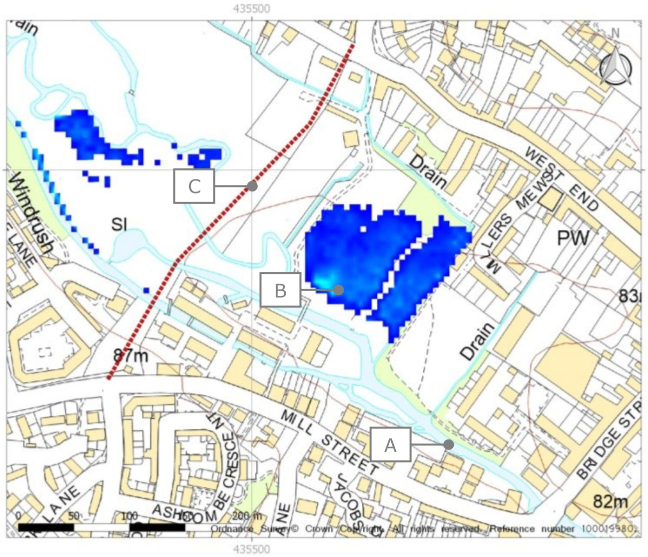
[13] Centre for Ecology & Hydrology. National Flow River Archive. *http://www.ceh.ac.uk/data/nrfa/data/spatialdata.html?39076* . Accessed 27th Jan 2015.

1 in 100 year + Climate Change
at **10** hrs

[A] Bridge Street Bridge controls flood levels in this area. The bridge has a 400mm head loss and causes water to back up in the relatively narrow channel, resulting in raised flood levels which eventually spill into the flood plain.

[B] Flooding of grass fields is initiated by overtopping of the river as a result of [A].

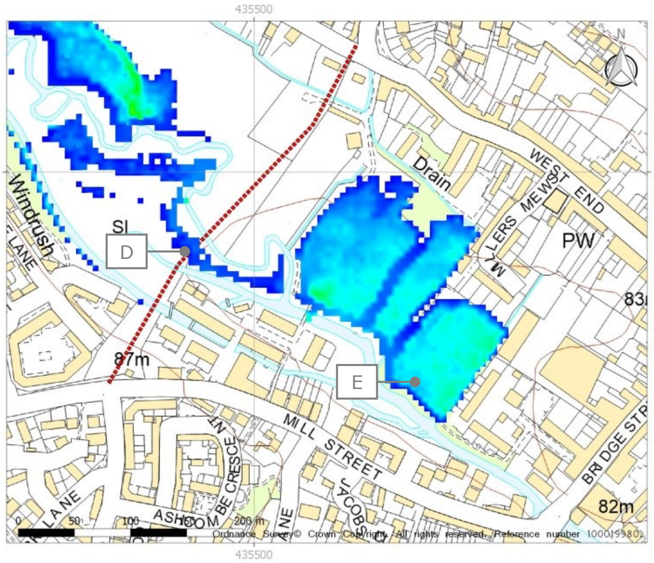
[C] At the location of the WEL, overtopping of the river has not begun



1 in 100 year + Climate Change
at **14** hrs

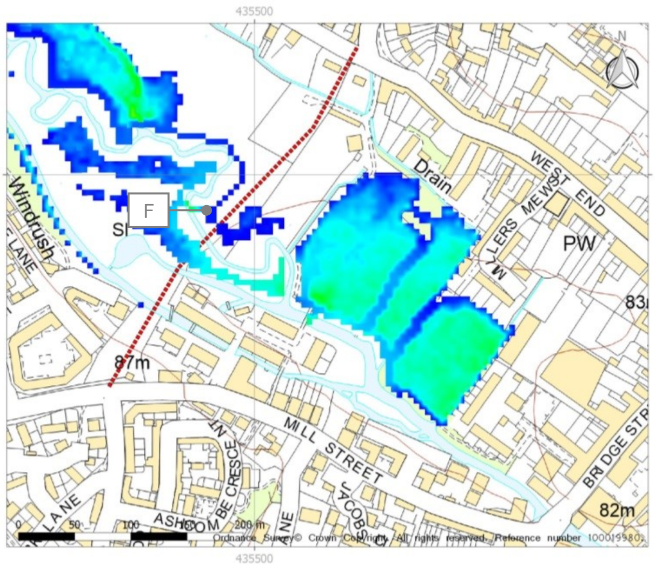
[D] Overtopping of the river in-between two of the channels that run under the WEL

[E] Flood extent extended into the next field



1 in 100 year + Climate Change
at **27** hrs

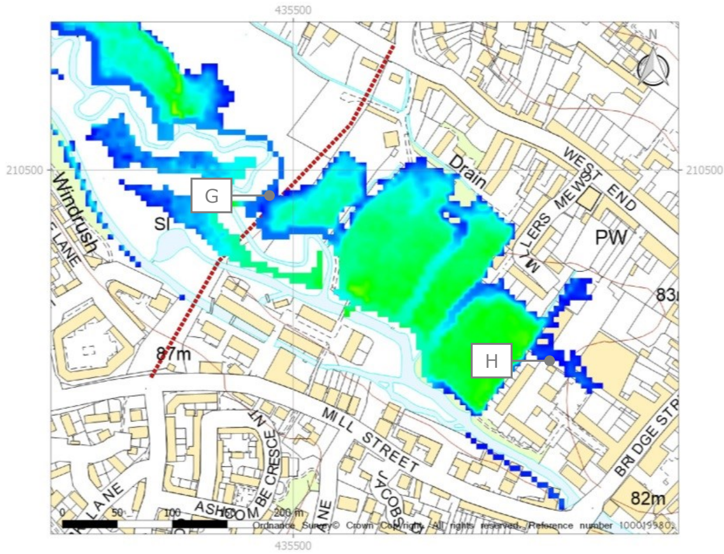
[F] Additional overtopping at the location of the WEL, however it is still localised flooding and the floodplain is not conveying flood waters downstream



1 in 100 year + Climate Change at **42** hrs

[G] Flood extent at the WEL is increased, flood waters begin to convey into the downstream flood extent

[H] Flooding of the urbanised area begins



1 in 100 year + Climate Change at **Max Flood Depth**

[I] Maximum flood extent observed with significant flooding observed to the urbanised area

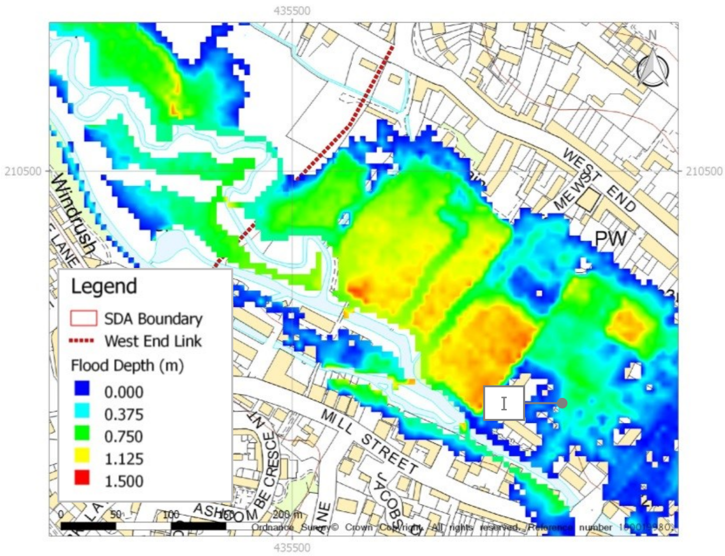


Figure 5 - Windrush flood extents, focused on proposed West End Link

3.3 Pluvial Flood Risk

Pluvial flooding is defined as flooding caused by rainfall-generated overland flow before the runoff enters a watercourse or sewer. In such events, drainage systems and watercourses may be entirely overwhelmed. Pluvial flooding will usually be a result of intense rainfall, often of short duration, that is unable to soak into the ground or enter a watercourse or drainage system. In such cases overland flow and 'ponding' in topographical depressions may occur resulting in localised flooding. Environment Agency (EA) surface water flood mapping (Figure 6) identifies areas that are likely to flood following extreme rainfall events. The majority of the SDA has been identified as being at Very Low risk to surface water flooding.

The area adjacent to the Hailey Road drain is however identified to be at a High Risk of flooding. There are also localised areas which are identified to be at a Medium Risk of flooding. The location of these areas coincides with low sections of the topography of the SDA.

There is a small portion of the land at Woodstock Road that is identified as being at low to medium risk of surface water flooding, localised at the southern extent of the site.

All development is to be sited outside of the areas identified as being at High Risk of pluvial flooding, to be confirmed through more detailed hydraulic modelling of the section of the Hailey Road drain that runs through the site. The other localised low to medium risk areas of the site should be managed by appropriate design of the site levels and appropriate drainage design at the site boundaries to control potential pluvial run-off.

The Environment Agency has confirmed that that they do not have a policy on surface water protection in Witney, other than the guidance contained within the Level 1 SFRA.

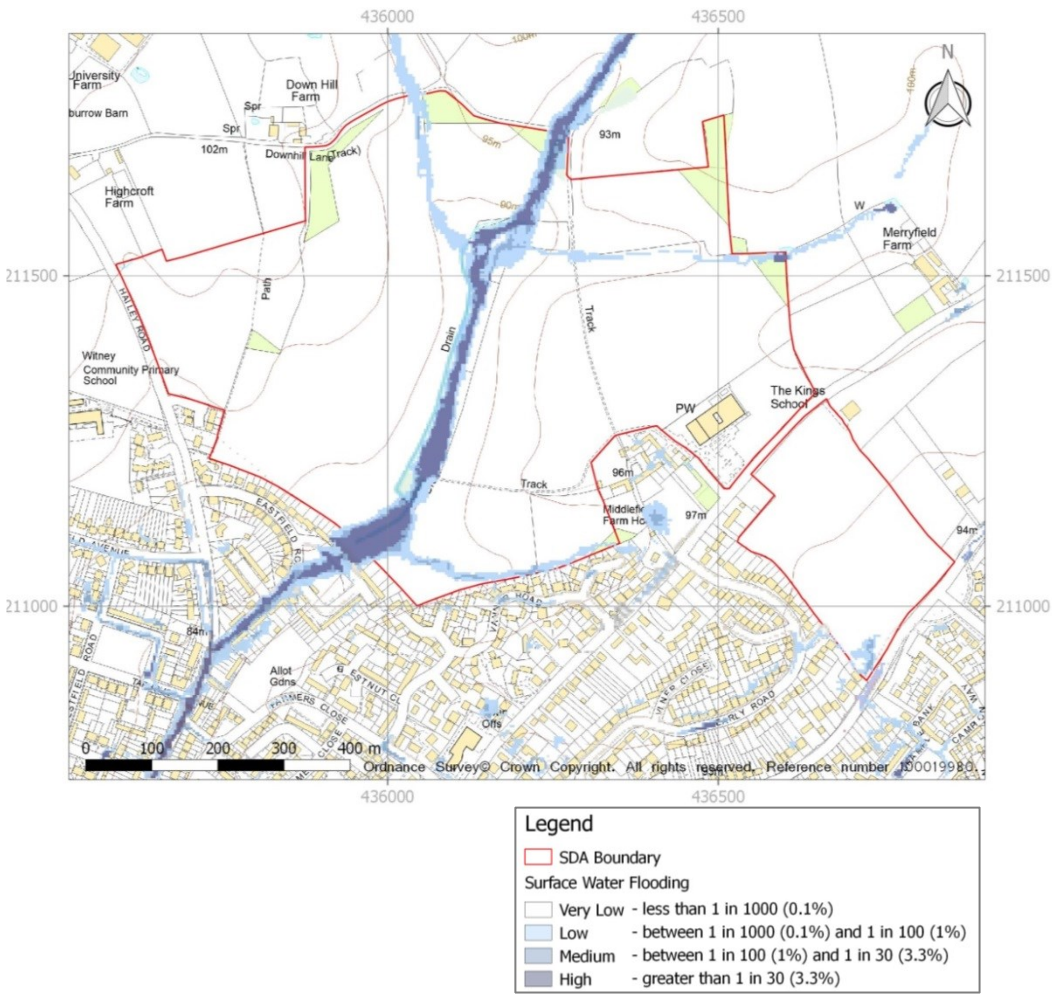


Figure 6 – Pluvial Flood Map

3.4 Groundwater Flood Risk

Groundwater flooding is defined as the emergence of groundwater at ground level, or the rising of groundwater into man-made locations that exceed the normal range of groundwater. The British Geological Survey has prepared susceptibility to groundwater flooding datasets that identify areas where geological conditions could potentially enable groundwater flooding to occur. The susceptibility data is suitable for use for regional and national planning purposes to inform groundwater flood risk.

Review of the relevant BGS reports indicates that the SDA could have a relatively high water table, at a depth likely to be less than 3m[12] below ground level. Mapping data indicate the presence of springs on the north west periphery of the land at Hailey Road, adjacent to Downhill Farm. Anecdotal observations of Oxfordshire County Council indicate that surface water flooding has occurred on Hailey Road upslope of the Witney Primary School and that this flooding may have been the result of groundwater seepage from the site. However, there are no records available to verify this.

The land at Hailey Road is underlain by a combination of permeable limestone and impermeable mudstone. The Forest Marble Formation (FMB) is prominent within this site alternating between seams of mudstone (FMB-MDST) and limestone (FMB-LMST). Through the centre of the site are deposits of permeable White Limestone Formation (WHL-LMST). The far east of the site is underlain by relatively impermeable Kellaways Clay Member Mudstone (KLC-MDST). A fault line runs from the northeast to the southwest through the mudstone and sandstone, turning 90 degrees (northeast/southwest) in the southeast extent of the site.

The land at Woodstock Road is underlain by relatively impermeable mudstone (KLC-MDST) in the western extents and relatively permeable Cornbrash Formation Limestone (CB-LMST) in the east.

The majority of the development area does not contain any superficial deposits, however a small area of alluvium is present in the central extents of the Hailey Road site in the valley of the Hailey Road drain.

The limestone deposits underlying this site are likely to harbour groundwater due to their high porosity, whereas the mudstone remains fairly impermeable. Therefore emerging groundwater (spring lines) may occur at the geological contact between the limestone and mudstone. The fault line is also likely to harbour small volumes of groundwater which may emerge when present over the impermeable mudstone. The small area of superficial deposits in the centre of the Hailey Road site is likely to harbour groundwater which will increase the groundwater flooding risk in this area.

The majority of the development area can be described as being at relatively low risk of groundwater flooding, but which may rise to a moderate risk at geological interfaces and at the fault line. The small area of higher risk associated with the superficial deposits coincides with the lower lying areas of the land at Hailey Road, which would not be developed as these areas are also at risk of flooding from the Hailey Road drain.

It is considered that the risk of groundwater flooding can be managed by appropriate design of the developed site levels. The nature of the groundwater regime in the area is of more significance to the design of the drainage for the development.

Given the relatively complex geology and in order to inform a future site-specific FRA and appropriate drainage design and development levels it is recommended that ground water monitoring is undertaken to establish likely maximum groundwater levels, seasonal variation and the presence of ephemeral springs.

3.5 Sewer Flood Risk

The public sewer network is managed by Thames Water and their records show that only 1 property in Witney has been flooded with foul water in the past 10 years[2]. Given the location of the SDA upslope of the main conurbation of Witney it is unlikely that sewer flooding is a significant risk for the site.

Thames Water has indicated that the current sewer capacity is likely to be insufficient to accommodate the proposed development's foul flows and would likely require the development of significant drainage infrastructure[14]. With appropriate drainage design and necessary infrastructure upgrades, it is anticipated that there would be no increase in the risk of sewer flooding.

3.6 Reservoirs and Other Artificial Sources of Flooding

Review of the EA flood maps shows that there are no reservoirs or other artificial waterbodies in the vicinity of Witney or at any upstream location. Based on this there is no risk of flooding due to reservoir failure.

3.7 Existing Flood Defences

Currently Witney does not benefit from any formal flood defences. A maintenance regime is in place on the Windrush, Hailey Road drain, Madley Brook, Colwell Brook and Queen Emma's Dyke. The River Windrush has biannual clearance of aquatic weeds and obstacles, whilst Hailey Road drain has annual clearance of aquatic vegetation[7]. This maintenance regime is likely to reduce the flood risk in lower order flood events.

Minor works have been carried out at a number of locations in the vicinity of Hailey Road drain, these include[7];

- A trash screen has been installed at the inlet to the Hailey Road drain culvert to prevent internal blockage of the culvert, see Figure 7.
- Remote monitoring has been installed to monitor the build-up of debris on the trash screen protecting Hailey Road drain culvert.
- Part of the culvert headwall has been lowered, to reduce the level of water backing up and flooding adjacent properties.
- Kerbs have been lowered and a cycleway has been installed on Crawley Road, this allows overland flow to more efficiently discharge into the downstream watercourse.
- Double height kerbs have been installed along Eastfield Road to increase the capacity of conveyance within the road and reduce the frequency of flooding of properties.
- Sealed manhole covers have been installed on Hailey Road to reduce discharge of surface water, along with a vented manhole cover to remove the possibility of the covers lifting.

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[14] Thames Water response to *West Oxfordshire – Local Plan: Housing Consultation Plan* (24th Sep 2014). Consultation Question 6.

- Property level protection in the form of flood barriers has been installed to 10 properties along Eastfield Road and at the junction of Hailey Road and Crawley Road.

- A swale has been constructed on the public space adjacent to Eastfield Road to direct overland flow.

Figure 7 - Photo of Hailey Road drain culvert inlet showing installed trash screen and removed section of headwall

4 Flood Risk Management Measures

This section deals with the flood risk management measures that could be implemented through development of the SDA and WEL bridge crossing. The likely flood risk impacts of the proposed development are assessed along with the potential to improve existing flood risk in Witney. The key impacts assessed are:

- Surface water run-off from the SDA development
- Foul water discharge from the SDA development
- Impacts on flooding from the River Windrush due to the proposed WEL bridge crossing

4.1 Management of Surface Water Run-Off

4.1.1 Planning Requirements

Based on guidance set out in NPPF, FRSA and through discussions with the EA any development greater than 1ha in size should include measures for the management of surface water run-off to greenfield run-off rates using suitable sustainable drainage techniques (SuDS). The drainage systems should be designed for a range of storms up to and including the 1 in 100 year (plus an allowance for climate change) event, thereby ensuring no detrimental impacts of flooding at the site or to adjacent areas.

The following sections describe how surface water should be sustainably managed on site and provide an initial assessment of greenfield run-off rates, along with recommendations for the most suitable SuDS techniques and an initial assessment of attenuation volumes required for this development. It should be noted that this SFRA presents a preliminary assessment which will be refined for a future site-specific FRA.

4.1.2 Greenfield Runoff Rates

The following surface water run-off calculations have been assessed;

- Peak runoff rates for the 1 in 1 year, 1 in 30 year, 1 in 100 year and 1 in 100 year plus an allowance for climate change rainfall events

- Attenuation storage volume estimation for the 1 in 100 year (plus climate change) rainfall event to ensure that the greenfield runoff rates can be achieved post development

In line with the DEFRA guidance on rainfall runoff management[15] a preliminary assessment using the calculation procedure set out in the Institute of Hydrology Report No. 124 (IH124), 'Flood Estimation for Small Catchments' has been used to estimate greenfield run-off rates from the site. The IH124 method has been developed for catchments in excess of 50ha. Existing run-off rates have therefore been estimated using an area of 50ha before being linearly scaled based on the proposed development site area of 48.8ha for the land at Hailey Road and 6.7ha for the land at Woodstock Road. Table 2 presents the greenfield runoff rates for this development site. Supporting calculation sheets are provided within Appendix A of this report.

Table 2 – Peak Greenfield Runoff Rates from the site.

Return Period	Peak Flow (l/S/ha)
1:1	1.26
1:30	3.32
1:100	4.73
1:100+CC	6.15

It should be noted that the greenfield runoff rates calculated above are based on the calculation procedure set out in IH124. The soil type using this procedure was established to be SOIL type 1, for which the standard percentage run-off (SPR) is defined as 0.1. A more accurate estimate of SPR was established by reviewing 1km^2 Hydrology of Soil Types (HOST) classification tiles over the target site. A weighted average of each HOST category was used to establish the average SPR for the site, which was found to be 0.28. Any future ground investigation, undertaken to inform a future site-specific FRA, would inform a more accurate assessment of SPR value for use in detailed design at a later stage.

[15] Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme. Preliminary rainfall runoff management for developments. R&D Technical Report W5-074/A/TR/1 (Rev E). January 2012.

A SOIL type of 1 suggests that this site is relatively permeable and therefore infiltration drainage could be a viable SuDS option. This relative permeability is also reflected in the HOST classification. However, as noted in Section 3.4, it is recommended that a detailed ground investigation is undertaken to inform a future site-specific FRA and to ascertain groundwater levels and infiltration rates to support the use of infiltration SuDS techniques to manage surface water.

4.1.3 Proposed Land Use

For the purposes of this SFRA it is assumed that 40% of the site will contain impermeable surfaces. This assumption is a conservative estimate based on typical development layouts, where the impermeable surface areas for housing developments is generally in the range of 30% to 40%. It is anticipated that any proposed layout will be able to achieve lower impermeable areas.

The development area will include housing and highway infrastructure. Assuming that 40% of the development area will be impermeable, the total impermeable area is 22.2ha. For the purposes of this SFRA, this impermeable area has been used to undertake a preliminary assessment of likely attenuation requirements for this development.

4.1.4 Surface Water Drainage

The management of surface water run-off should be considered using the following sequential hierarchy in order of preference;

- Infiltration system - Surface water drainage should discharge into a soakaway or other infiltration device where ground conditions are favourable

- Discharge to a watercourse – The EA, OCC and WODC will require the rate of discharge to be attenuated to the greenfield runoff rates for the site as a minimum, this will prevent any increase in runoff and minimise the risk of increased flooding downstream

- Discharge to a storm, foul or combined sewer – where other forms of outlet are not achievable discharge should be made to a sewer. However it should be noted that this is unlikely to be compatible with the current limitations on foul and combined sewer capacity and the requirement for significant upgrade works, as discussed in section 4.44.

The potential for the use of infiltration techniques should be confirmed through site investigation to inform a future site-specific FRA. Our review of available data suggests that the site is a mix of permeable and impermeable geology and parts of the site should in theory be suitable for infiltration systems, subject to further investigation of groundwater levels. In line with the Level 1 SFRA[2] and the CIRIA SUDS Manual[16], infiltration systems are the preferred option for managing surface water runoff when the soil permeability is moderate to high.

To assess the viability of the site for infiltration the Infiltration SuDS GeoReport[12] has been purchased to make a preliminary assessment of the ground conditions at the site. This report provides information on the potential suitability of infiltration systems such as soakaways, infiltration basins or permeable pavements. In summary this report suggests that parts of the site

[16] CIRIA. 2007. *The SUDS Manual.* CIRIA C697.

are likely to be compatible for infiltration systems. It states that the subsurface is probably suitable although the design may be influenced by local ground conditions. The key points raised in this report include;

- Alluvium superficial deposits are located in the approximate location of the watercourse running through the site
- Bedrock geology is a combination of impermeable mudstone and permeable limestone[17], which may dictate the locations at which infiltration systems can be used.
- Groundwater is likely to be less than 3m below ground level. This may prevent infiltration if the groundwater level is less than 1m below the invert level of any infiltration system.

See section 3.4 for a more detailed description of the site geology.

It is recommended that a geotechnical site investigation is undertaken at this site to inform a future site-specific FRA and the drainage strategy for the site. This site investigation should obtain information relating to soil permeability, infiltration rates and groundwater level.

If site investigation does prove infiltration to be a viable option, the preferred solution will be to provide infiltration and above ground SuDS at source, i.e. multiple features located upstream of the drainage systems, rather than a single feature at the lowest section of the site. It should be noted that if infiltration is viable then the sizing of any attenuation structures would be reduced as surface water run-off would be controlled at source. Provided that infiltration is a viable option, there are a number of SuDS that would be appropriate for the North Witney SDA. Potential SuDS features are outlined in Table 3, identifying the benefits that they provide. Further details are provided in Appendix B.

[17] British Geological Society (BGS).2006. *Guide to Permeability Indicies.* CR/06/160N

Table 3 – Potential SuDS Features

SuDS Feature	Benefit to Flooding	Reduction in Pollution Runoff	Improvement to Wildlife and Landscaping
Retention ponds	YES	YES	YES
Detention basins	YES	YES	YES
Balancing ponds	YES	YES	YES
Constructed wetlands	YES	YES	YES
Basins and ponds	YES	YES	YES
Living roofs	YES	YES	YES
Filter strips and swales	YES	YES	YES
Soakaways	YES	YES	YES
Infiltration trenches and basins	YES	YES	YES
Infiltration devices	YES	YES	YES
Permeable surfaces	YES	YES	
Gravelled areas	YES	YES	
Solid paving blocks	YES	YES	
Porous pavements	YES	YES	
Over-sized pipes/tanks	YES		
Tanked systems	YES		
Storm cells	YES		

As the viability of infiltration cannot be verified at this stage, as a worst case we have assessed the viability of discharging the surface water run-off into the watercourse that runs down the centre of the site.

An initial assessment of the greenfield runoff rate has been carried out as part of this SFRA, see Appendix A. The mean annual greenfield peak flow ($Qbar_{rural}$) has been calculated in line with the Institute of Hydrology Report No. 124[18], this provides a relatively simple method of calculating $Qbar_{rural}$. The peak flows associated with the SDA for different return periods have also been estimated and are available in Appendix A. The objective of the drainage strategy for the site should be to achieve betterment over current greenfield rates.

An initial conservative estimate of the storage volumes that would be required to maintain current greenfield runoff rates is provided in Appendix A. Attenuation storage volumes have been calculated on the basis that an average current greenfield runoff rate is maintained for all rainfall events up to and including the 1 in 100 year plus an allowance for climate change. Due to their close proximity, the land at Hailey Road and the land at Woodstock Road are assumed to have the same site characteristics. A conservative estimate of storage requirement per unit area has been calculated as 334m^3/ha. Usually storage features are designed to be between 0.5m and 1.5m deep, however this depends on the site topography and location of the storage feature, which can only be established during detailed design. An indication of land take for storage features, based on a storage requirement of 334m^3/ha and a storage depth of between 1.5m and 0.5m is 222m^2/ha to

[18] Institute of Hydrology (1994). *Flood Estimation for Small Catchments.* Report No. 124.

668m^2/ha. This equates to an indicative land take of between 2.2% and 6.7%. A detailed ground investigation undertaken to inform a future site-specific FRA would establish more accurate soil permeability rates and hence a more accurate storage requirement, which is likely to reduce if infiltration is confirmed to be viable in some parts of the site.

4.1.5 Drainage Design Criteria

With respect to other design criteria for the surface water drainage system, the following guidance shall be complied with during the detailed design of the drainage systems:

- Site layout and surface water drainage systems should cope with events that exceed the design capacity of the system, so that excess water can be safely stored on or conveyed from the site without adverse impacts.
- The surface water drainage arrangements for any development site should be such that the volumes and peak flow rates of surface water leaving a developed site are no greater than the rates prior to the proposed development, unless specific off-site arrangements are made and result in the same net effect. In the case of the North Witney SDA, the drainage strategy should seek to achieve betterment on greenfield run-off rates.
- All sewers that will subsequently be adopted by the sewerage undertaker must be designed and built in accordance with the requirements of Sewers for Adoption, Edition 7 (WRc 2012). This document provides guidance on suitable return periods for use in the design of sewerage systems for various development types. In general terms, sewers should be designed to ensure that no flooding occurs above ground level for events with a return period of 30 years.
- For events with a return-period in excess of 30 years, surface flooding of open spaces such as landscaped areas or car parks is acceptable for short periods, but the layout and landscaping of the site should aim to route water away from any vulnerable property, and avoid creating hazards to access and egress routes. No flooding of property should occur as a result of a one in 100 year storm event (including an appropriate allowance for climate change).
- Drainage of rainwater from the roofs of buildings and paved areas around buildings should additionally comply with the 2002 amendment to Approved Document H – Drainage and waste disposal, of the Building Regulations (BR part H).

More specifically for soakaways and infiltration SuDS the following criteria should be used in detailed design;

- Any individual infiltration SuDS infrastructure should be designed for the 1 in 10 year rainfall event or the 1 in 30 year rainfall event, depending on the type of SuDS feature. The overall drainage system should be designed to achieve no flooding of properties during the 1 in 100 year plus an allowance for climate change rainfall event and that flows are managed on site.
- Infiltration testing of the soils should be carried out in accordance with BRE Digest 365.
- The base of any infiltration structure should be at least 1m from the groundwater table and 5m from any building foundations.

- SuDS features should be placed outside of the Hailey Road drain 1 in 100 year plus an allowance for climate change flood extent.

4.2 Potential to Alleviate Flooding from Hailey Road Drain

As described in Section 3, the culverted section of the Hailey Road drain does not have the capacity to convey extreme flood events[8]. Increasing the capacity of the culvert would reduce the risk of flooding on Hailey Road; however this would be costly and disruptive to implement and it would marginally increase the peak flows entering the River Windrush.

The Environment Agency commissioned a pre-feasibility report to assess the options to provide upstream storage on the Hailey Road drain in order to attenuate or reduce peak flows entering the culvert, which was undertaken by Atkins in November 2008. This report concluded that the provision of storage to reduce peak flows was feasible but likely to be too costly to justify construction for the number of properties that would be protected[7]. This conclusion was based on the use of grant funding, which requires the scheme benefits to be greater than the scheme costs.

Development of the SDA provides the opportunity to reduce the flood risk currently associated with Hailey Road Drain by reducing surface water run-off from the development area and/or by attenuating flows in the drain upstream of the existing culvert. There are a number of options available to alleviate the flood risk, outlined below;

- Design of an appropriate mix of infiltration and attenuation SuDS features to achieve betterment over the existing greenfield runoff rate, ie to reduce existing surface water flows from the development area.

- Incorporate on site flood storage within the Hailey Road drain to attenuate peak flows from the drain's catchment.

- Incorporate off site flood storage within the Hailey Road drain upstream of the site to attenuate peak flows before they enter the site

With careful planning and design, the options to reduce flood risk could be incorporated with the need to provide public open space. The land take for flow control measures could then serve a dual function.

It should be noted that any flood storage feature constructed with an embankment capable of holding more than 25,000m^3 of water, would be subject to the Reservoirs Act 1975. The criteria for this may reduce to 10,000m^3, subject to the phased implementation of the requirements of the Flood and Water Management Act 2010.

Hence there is scope to reduce the peak flows entering the Hailey Road drain culvert through a combination of appropriate SuDS design and provision of in-river attenuation storage and any future FRA should propose measures that achieve a significant reduction in peak flow through the culvert.

A key objective of the FRA should be to demonstrate as a minimum that the capacity of the Hailey Road drain culvert system is not exceeded during a 1 in 30 year event and that no flooding of properties occurs during a 1 in 100 year event as a consequence of floodwater escaping from the Hailey Road drain culvert.

4.3 Potential to Alleviate Flooding from River Windrush

The EA has developed an Initial Assessment of the available flood risk management options available in Witney[7]. The assessment outlines a number of options that would reduce the risk of flooding to Witney. The report concluded that the cost/benefit ratio was too low to justify their construction, which is related to the cost of the schemes to implement and the limited number of properties that would benefit. The only option that was found to be viable was property level protection (PLP) and this is currently being investigated further by the EA and WODC.

Option 5 of the EA's Initial Assessment identifies a flood dam in the approximate location of the WEL bridge crossing. This dam could restrict peak flows passing through to the Bridge Street bridge and would utilise the undeveloped land upstream as a flood storage area. The principle outlined in the EA's Initial Assessment report is that the dam would reduce peak flows and hence reduce downstream flooding in the centre of Witney.

Discussions between the EA, WODC and Oxfordshire County Council have identified that the WEL bridge crossing could potentially be engineered to attenuate river flows if designed to significantly restrict flows passing downstream. This could assist with the economic implementation of this flood risk management option.

Consequently the scope of this SFRA was extended to include preliminary hydraulic modelling of the proposed WEL bridge crossing to assess the potential benefits that the WEL may provide to the downstream flood levels, the impact of flooding to the existing Bridge Street Bridge and any consequential upstream impacts. The details and results of the modelling are provided in Appendix C, which contains details of the hydraulic modelling and analysis of the impacts of the proposed WEL bridge.

The following bridge options were modelled:

- Option 1 – Viaduct with 9 Piers within the flood plain and clear span bridges over the existing river channels to minimise impact on flood levels (least restricted option, see Appendix CD).
- Option 2 – Raised embankment through the floodplain and clear span bridges over the three existing water courses.
- Option 3 – Raised embankment through the floodplain and restricted bridge openings for the watercourses, to match the restricted conveyance area of the existing Bridge Street bridge in the centre of Witney.

This initial modelling exercise has confirmed that Option 1 leads to insignificant changes in flood depth, hence satisfying the requirement to cause no detrimental impact on flood risk (Figure 8).

For Options 2 and 3, the initial modelling indicated that restricting flow through the WEL bridge crossing does not lead to a significant benefit to flooding in Witney, although as anticipated there are significant increases in flood level upstream of the proposed bridge for these options. The results and analysis of modelling all three options are provided in in Appendix C.

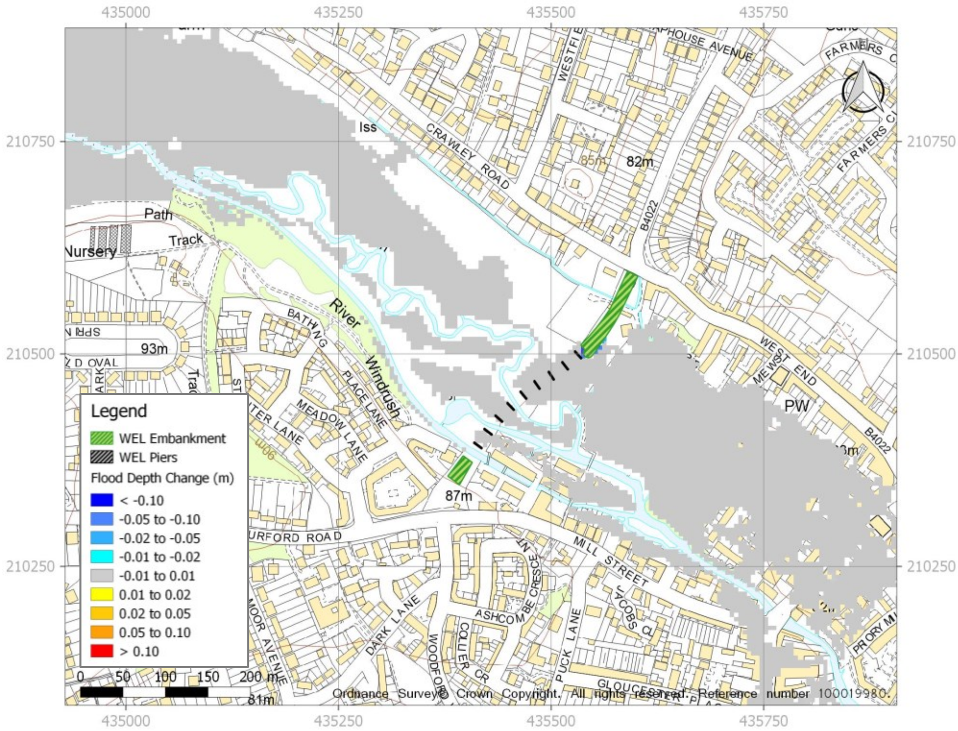


Figure 8 – Flood Depth Change as a result of the WEL Option 1 (viaduct on piers)

The hydrology of the River Windrush is such that flood events last for several days, with the peak flow being maintained for several hours. This means that the volume of storage that would be required to significantly attenuate or reduce downstream peak flows would be significant. In order to further investigate the benefit of utilising the WEL bridge crossing as part of a wider flood alleviation scheme, there would be merit in investigating the viability of other more engineered flood alleviation solutions, for example:

- Re-routing of the two watercourses in the floodplain to a single, more restricted outfall point through the WEL bridge.
- Excavation within the floodplain upstream of the WEL bridge to create additional storage and wetland features.
- Provision of additional storage areas upstream of Witney. For example, WODC has previously considered storage areas in the Crawley area.

In terms of other residual flood risk impacts, as the bridge crossing is located in Flood Zone 3, it will marginally reduce the volume of storage in the floodplain. Compensatory storage should be provided locally to the bridge structure or within the same hydraulic unit. This should normally be provided on a 'level for level' basis. If suitable sites are not available, then the storage may be provided on a 'volume for volume' basis subject to agreement with the Environment Agency. In the latter case, a degree of overcompensation is likely to be required and hydraulic modelling would be required to demonstrate that there is no unacceptable increase in flood risk.

Measures should also be taken to ensure that surface water run-off from the increased impermeable area of the highway is maintained below existing greenfield run-off rates.

4.4 Management of Foul Water

The Level 1 SFRA for Oxford City Council[19] identifies that 1 property has been flooded by foul water in Witney over the past 10 years (Postcode OX28). This suggests that the current foul water management system in place is sufficient to cope with the current demand.

The existing sewage treatment works is located to the south of Witney, approximately 3km away from the SDA. Thames Water has expressed concern that the current foul water capacity of the sewerage system is insufficient to support the proposed development[20]. Thames Water would require a detailed drainage strategy to establish infrastructure requirements and to ascertain for certain if any upgrade is actually required. The lead time to deliver upgraded infrastructure (if required) would be approximately 3 years, or alternatively the developer may wish to requisition the infrastructure in order to deliver the upgrades sooner.

4.5 Sequential and Exception Test

In order to identify the suitability of the SDA and WEL for development, the sequential test and where applicable the exception test must be applied. Review of the outlined development options has led to three scenarios where the sequential test must be applied, Table 4. It must be noted that the SDA can be split into development of residential homes within Flood Zone 1 and development of flood control infrastructure within Flood Zone 3. Determining whether development is appropriate is based on the compatibility criteria set out within the sequential test which is defined in the NPPF, Table 5.

Table 4 – Sequential Test parameters

Location	Development Type	Flood Zone	Vulnerability Classification	Is Development Appropriate
SDA	Residential homes	1	More Vulnerable	Yes
SDA	Flood attenuation features	3	Water Compatible	Yes
WEL	Bridge piers/abutments	3	Essential Infrastructure	Exception Test required

[19] Atkins. 2011. Level 1 Strategic Flood Risk Assessment for Oxford City. 5093353_DG_062_002_F2.
[20] Thames Water response to LP Housing Consultation Plan. 25th September 2014.

Table 5 - Flood risk vulnerability and flood zone 'compatibility'[21]

Flood risk vulnerability classification		Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood zone	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	Exception Test required	✓
	Zone 3b functional floodplain	Exception Test required	✓	×	×	×

Key: ✓ Development is appropriate.
× Development should not be permitted.

Applying the sequential test to the development of the SDA has shown that development is appropriate as the majority of the site is defined as being at the lowest risk to fluvial flooding and all housing development will take place in Flood Zone 1. A site specific FRA would be required to support this decision. As discussed previously, the full extent of Flood Zone 2 and 3 has not been fully established within the site through detailed modelling. Extension of the current Hailey Road drain model would inform the full flood zone extents and hence identify the area suitable for residential development. As with all developments greater than 1ha, a detailed site specific FRA would be required to provide a quantitative assessment.

Application of the sequential test to the WEL bridge crossing has identified that the exception test is required. In order to pass the exception test[21];

- The development must demonstrate that it provides wider sustainable benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared.

- A site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

[21] Communities and Local Government (2012). *National Planning Policy Framework (NPPF).*

For the WEL bridge crossing to pass the exception test the above points have been considered and assessed to establish if the criteria have been met as shown in Table 6 below. A detailed site specific FRA would be required to demonstrate that all of the exception test requirements have been met. If the site specific FRA is able to demonstrate that all of the requirements have been met, then it is possible that the exception test can be passed.

Table 6 – Requirements to pass the exception test

Exception Test Requirement	Points to support the Exception Test
The development must demonstrate that it provides wider sustainable benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared	● Wider sustainable benefits through improved transportation links - WODC to confirm that the improved transport links will benefit the wider community; initial transport modelling suggests a number of wider benefits. ● Initial hydraulic modelling of the WEL in its current form suggests that there is no unacceptable increase or decrease in flood risk. Alternative options should be modelled to determine if reduced flood risk can be achieved.
A site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall	● A detailed site specific FRA must be produced to assess the impact any final design of the WEL or any alternative options aimed at reducing the overall flood risk, assessing the impact over a range of flood events, generally between the 1 in 2 year (50% AEP) and 1 in 1,000 year (0.1% AEP) flood event. ● Initial modelling of the bridge in its current form has confirmed that the road itself is not at risk of flooding and that the bridge does not cause any significant increase to flood risk elsewhere.

5 Conclusions & Recommendations for Site Specific FRAs

The conclusions and recommendations as a result of this Level 2 SFRA are outlined below;

5.1 North Witney Strategic Development Area

1. The North Witney development is sited largely in Flood Zone 1 and housing development is not to be located in the relatively localised areas of Flood Zones 2 and 3 where the site is affected by flooding from the Hailey Road drain. Hence, it can be concluded that development of the site can be designed such that it complies with the Sequential Approach requirements of the National Planning Policy Framework (NPPF).
2. To inform a future site-specific FRA and the development layout, the existing EA hydraulic model of the Hailey Road drain should be extended through the site to confirm the extents of flooding. This modelling should assess the impact of a culvert or trash screen blockage scenario, in agreement with the Environment Agency.
3. Finished floor levels of properties within the SDA should be set at a minimum of 300mm above the modelled 1 in 100 year plus an allowance for climate change levels.
4. Our review of available desk top data suggests that there are no other sources of flooding that might significantly affect the development (ie pluvial, groundwater and foul water).
5. Localised areas of the SDA outside of the Hailey Road drain flood zones are at moderate risk of surface water flooding. A future FRA should demonstrate that these local risks can be managed through suitable design of drainage and development levels.
6. Due to the relatively complex geology of the site, ground investigation should be undertaken to confirm the groundwater regime and seasonal variation of groundwater to inform the development design and in particular the design of sustainable drainage systems. Infiltration testing should also be undertaken to confirm the viability of infiltration drainage techniques, which is likely to be variable across the site.
7. Currently, the inadequate capacity of the 750mm diameter culvert that conveys the Hailey Road drain from the development site causes flood water to overtop the existing headwall and has historically caused flooding to properties downstream of the SDA. The culvert trash screen arrangements do not comply with the current recommendations of the Environment Agency Trash and Security Screen Guide 2009, meaning that the screen is too small and easily blocked by debris, which is difficult to remove during flood conditions. Water has also historically escaped from manholes on the culvert, due to surcharging of the culvert. This represents an off-site flood risk, rather than a flood risk that would directly affect the housing development per se. Local flood protection measures have been carried out by Oxfordshire County Council (OCC), WODC, Environment Agency (EA) and Thames Water (TW) to manage flood routing and improve flood resilience of the adjacent properties.
8. There is scope to attenuate flows from the Hailey Road drain by the provision of a storage pond or ponds that would reduce the frequency of flooding on Eastfield Road and Hailey Road.
9. The development should include sustainable drainage (SUDS) measures to reduce run-off rates below existing greenfield rates. Such SUDS measures should use a suitable combination of at source solutions, such as permeable paving in parking areas, as well as 'end-of-pipe' measures, such as attenuation or infiltration ponds. SUDs measures should also be located outside of the 1 in 100 year plus an allowance for climate change flood extent.
10. A future site-specific FRA for the SDA should demonstrate that the scope for improvement of downstream flood risk due to the Hailey Road drain culvert has been fully considered. A key objective of the FRA should be to demonstrate as a minimum that the capacity of the Hailey Road drain culvert system is not exceeded during a 1 in 30 year event and that no flooding of properties occurs during a 1 in 100 year event as a consequence of floodwater escaping from the Hailey Road drain culvert. Review of the available evidence suggests that there is significant scope through appropriate design of the housing development to improve the existing downstream flooding problems through a combination of:
    a. River attenuation to reduce peak flows from the Hailey Road drain catchment

   b. Appropriate SUDS design to reduce run-off rates from the development site
   c. Improvements to the existing culvert headwall structure and trash screen.
11. The future site-specific FRA should demonstrate that safe access and egress routes are provided to the development that remain free from flooding, or that the hazard due to any flooding is sufficiently low.
12. Thames Water has indicated that infrastructure upgrades are likely to be required in order to maintain and/or reduce the current risk of sewer water flooding within Witney.

5.2 West End Link Bridge Crossing

1. The North Witney development also includes the development of the West End Link Road, which includes a river crossing of the River Windrush. By definition, the bridge crossing passes through Flood Zone 3 and hence the impact of this development on flood risk will be required within a future site-specific FRA to ensure that flood risk is not increased elsewhere.
2. As the bridge crossing is located in Flood Zone 3, it will marginally reduce the volume of storage in the floodplain. A future site-specific FRA should demonstrate that compensatory storage can be provided locally to the bridge structure or within the same hydraulic unit. This should normally be provided on a ‘level for level’ basis. If suitable sites are not available, then the storage may be provided on a ‘volume for volume’ basis subject to agreement with the Environment Agency. In the latter case, a degree of overcompensation is likely to be required and hydraulic modelling would be required to demonstrate that there is no unacceptable increase in flood risk.
3. Measures should also be taken to ensure that surface water run-off from the increased impermeable area of the highway is maintained below existing greenfield run-off rates.
4. Initial hydraulic modelling undertaken to inform this FRA indicates that the proposed WEL bridge crossing does not lead to an unacceptable increase in flood risk elsewhere, satisfying this element of the exception test.
5. The modelling of options to restrict flows through the WEL bridge indicated that there was no significant benefit to the downstream urbanised area of Witney. However, in order to further investigate the benefit of utilising the WEL bridge crossing as part of a wider flood alleviation scheme, there would be merit in investigating the viability of other more engineered flood alleviation solutions upstream of the bridge crossing as described in Section 4.3.

Appendix A. - Surface Water Run-off Calculations

Greenfield Runoff Estimate
Calculation Sheet

Site Name	Witney SFRA
Site Location	Witney
X (Eastings)	436270
Y (Nothings)	211770
Engineer	Brett Park
Checked by	Tom Hughes
Reference	WHS1277
Revision	1
Date	07-Jan-15

Site Description

Total Area (ha)	55.5
SAAR (mm)	667
Soil Type	1
SPR - Revised value taken from HOST data set	0.28

Estimating Qbar

Institute of Hydrology Report No. 124

Estimating Qbar for small rural catchments (<50ha)
Area = 50ha

$$Qbar_{Rual} = 1.08 \times Area^{0.89} \times SAAR^{1.17} \times SPRHOST^{2.17}$$

Qbar = **74.1** *l/s*

Prorata to for Qbar/ha (÷50)

Qbar = **1.5** *l/s/ha*

Apply Growth Curves

Hydrological Region: 6

Event	Q/Qbar	Q (l/s/ha)
Q1	0.9	**1.26**
Q30	2.2	**3.32**
Q100	3.2	**4.73**
Q100+CC		**6.15**

Determine Discharge for target site

Multiply Unit discharge rate by area of target site

Event	Q (l/s/ha)	Q (l/s)
Q1*	*2.0*	**111.00**
Q30	*3.3*	**184.02**
Q100	*4.7*	**262.53**
Q100+CC	*6.1*	**341.29**

Q1	**111**	*l/s*
Q30	**184**	*l/s*
Q100	**263**	*l/s*
Q100+cc	**341**	*l/s*

*Note: *Minimum Q is recommended to be 2 l/s/ha*

Storage Estimate
Calculation Sheet

Site Name	Land at Hailey Road
Site Location	Witney
X (Eastings)	436133
Y (Nothings)	211398
Engineer	Brett Park
Checked by	Tom Hughes
Reference	WHS1277
Revision	1
Date	07-Jan-15

Interception Storage

Total Area (m^2)	[A]	486,700	
Impermeable Area (m^2), 40% assumed	[B] = [A] x 40%	194,680	

Interception storage prevents runoff up to a depth of 5mm

Volume required for Inception Storage	[C] = [B] x 0.005	973	V_{Incp} = **973** m^3

Attenuation Storage

Outflow rates from Greenfield Runoff estimate
Average Outflow used to provide a conservative estimate (Min: 2 l/s/ha)

Event	Q (l/s/ha)
Q1	1.3
Q100	4.7
Avg. Outflow	3.0

Rainfall Duration (mins/hrs)	Rainfall Depth (mm)	Rainfall + CC (30%) (mm)	Inflow vol (less Incp.) (m3/m2)	Outflow (m3/s) x (m3/m2)	Volume = In - Out (m3/m2)
15 min	30.3	39.4	0.034	0.0003	0.034
30 min	35.5	46.2	0.041	0.0005	0.041
1 hr	41.7	54.2	0.049	0.0011	0.048
2 hr	48.9	63.6	0.059	0.0022	0.056
4 hr	57.3	74.5	0.069	0.0043	0.065
6 hr	63.0	81.9	0.077	0.0065	0.070
12 hr	73.8	95.9	0.091	0.0129	0.078
24 hr	84.3	109.6	0.105	0.0259	0.079
48 hr	96.2	125.1	0.120	0.0518	0.068

MAX Storage Required (m^3/m^2)	[D]	0.079	
Est. Attenuation Storage (m^3)	[E] = [B] x [D]	15,323	V_{Attn} = **15,323** m^3

Total Storage Required

Total Storage = Inception Storage + Attenuation Storage

[F] = [C] + [E]	16,297	V_{Tot} = **16,297** m^3

WHS

Site Name	Land at Woodstock Road
Site Location	Witney
X (Eastings)	436693
Y (Nothings)	211099
Engineer	Brett Park
Checked by	Tom Hughes
Reference	WHS1277
Revision	1
Date	07-Jan-15

Storage Estimate
Calculation Sheet

Interception Storage

Total Area (m^2) [A] 66,800

Impermeable Area (m^2), 40% assumed [B] = [A] x 40% 26,720

Interception storage prevents runoff up to a depth of 5mm

Volume required for Inception Storage [C] = [B] x 0.005 134

V_{Incp} = **134** m^3

Attenuation Storage

Outflow rates from Greenfield Runoff estimate
Average Outflow used to provide a conservative estimate (Min: 2 l/s/ha)

Event	*Q (l/s/ha)*
Q1	*1.3*
Q100	*4.7*
Avg. Outflow	*3.0*

Rainfall Duration (mins/hrs)	Rainfall Depth (mm)	Rainfall + CC (30%) (mm)	Inflow vol (less Incp.) (m3/m2)	Outflow (m3/s) x (m3/m2)	Volume = In - Out (m3/m2)
15 min	30.3	39.4	0.034	0.0003	0.034
30 min	35.5	46.2	0.041	0.0005	0.041
1 hr	41.7	54.2	0.049	0.0011	0.048
2 hr	48.9	63.6	0.059	0.0022	0.056
4 hr	57.3	74.5	0.069	0.0043	0.065
6 hr	63.0	81.9	0.077	0.0065	0.070
12 hr	73.8	95.9	0.091	0.0129	0.078
24 hr	84.3	109.6	0.105	0.0259	0.079
48 hr	96.2	125.1	0.120	0.0518	0.068

MAX Storage Required (m^3/m^2) [D] 0.079

Est. Attenuation Storage (m^3) [E] = [B] x [D] 2,103

V_{Attn} = **2,103** m^3

Total Storage Required

Total Storage = Inception Storage + Attenuation Storage

[F] = [C] + [E] 2,237

V_{Tot} = **2,237** m^3

Appendix B. - Sustainable Drainage Systems (SuDS)

SuDS Background

Sustainable Drainage Systems (SuDS) is a design approach which aims to replicate natural drainage patterns from a site prior to development and to reduce pollution from runoff. A holistic SuDS scheme gives equal consideration to improving water quality, controlling water quantity and providing opportunities for amenity and biodiversity.

Just as in a natural catchment, a combination of drainage techniques are linked together to both control flows and volumes as well as treat surface water runoff in stages. This principle is referred to as the management or treatment train. The use of such a system ensures that runoff has to pass through various treatment stages before infiltrating into the ground or being released into a watercourse. Runoff volumes and flow rates are controlled by attenuating, storing and infiltrating surface water locally within each SuDS component, reducing the need for large storage facilities at the end point of the system. Runoff from the development is managed on site equal to the runoff prior to development (or Greenfield runoff rate) ensuing rain water is returned to the natural water environment as close to source as possible. In summary, the benefits of SuDS are;

- Reducing flood risk from development (Water Quantity Control)
- Minimising Pollution from surface water run-off, both dispersed and to groundwater (i.e water quality control)
- Minimising Environment Damage, e.g bank erosion
- Maintaining groundwater levels
- Often producing cost savings as compared to more traditional drainage systems
- Enhancing the nature conservation and amenity (and therefore economic) value of developments

SuDS drainage should be the first option for all developments requiring surface water drainage infrastructure to deal with additional surface runoff. It can only be excluded for implementation where sufficient justification is demonstrated on the grounds of implacability or otherwise.

SuDS Approaches

SuDS systems are extremely versatile and can be designed to fit most urban settings. The options available should be considered at the early stages of development, and should take full account of the surface water management train (Please see Figure 1), with the objective of exhausting all measures at the top of the management train before considering other control options. The management train starts with prevention, or good housekeeping measures, for individual premises; and progresses through local source controls to larger downstream site and regional controls. Runoff need not pass through all the stages in the management train. It could potentially flow straight to a site control, but as a general principle it is better to deal with runoff locally, returning water to the natural drainage system as or near source as possible.

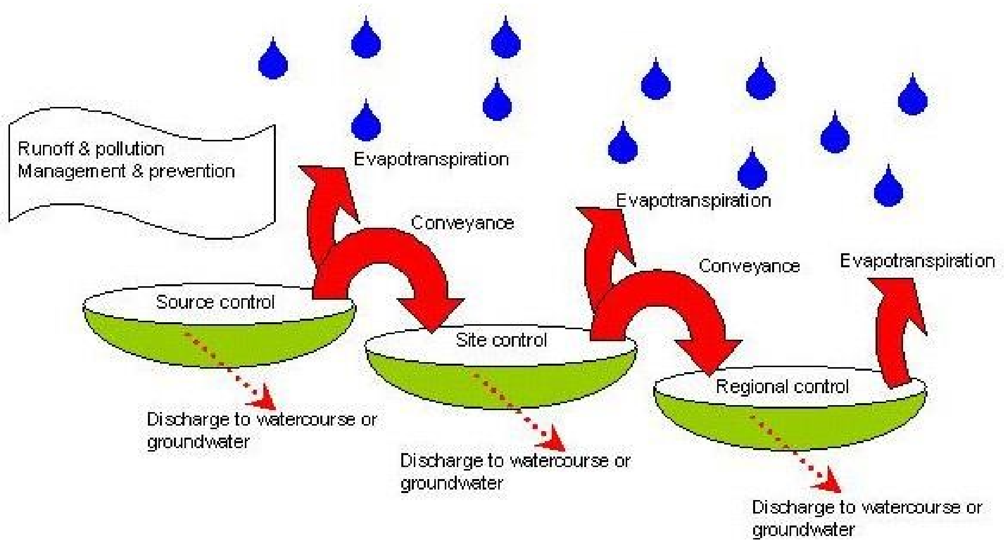


Figure 1 – SuDS Management Train Diagram. (Source, CIRIA. 'The SuDS Manual)

It is well documented that there should be a SuDS approach adopted for every situation to deal with excess surface water from new developments, although the suitability of each will depend on the type of scheme, catchment area, local hydrological conditions and geology of the area. There are numerous different ways SuDS can be included into a development and the most commonly found components of a SuDS system are outlined in Table 1. For a full list and description of applicable SuDS techniques please refer to the CIRIA publication 'The SuDS Manual (C697)' available online from their website: www.ciria.org.

Table 1 – SuDS Components

SuDS Component	Description
Pervious Surfaces	Surfaces that allow inflow of rainwater into the underlying construction or soil.
Green Roofs	Vegetated roofs that reduce the volume and rate of runoff and remove pollution
Filter Drains	Linear drains consisting of trenches filled with a permeable material, often with a perforated pipe in the base of the trench to assist drainage, to store and conduct water; they may also permit infiltration
Swales	Shallow vegetated channels that conduct and retain water, and may also permit infiltration; the vegetation filters particulate matter.
Basins, Ponds and Wetlands	Areas that may be utilised for surface runoff storage.
Infiltration Devices	Sub-surface structures to promote the infiltration of surface water to the ground. They can be trenches, basins or soakaways.
Bio-retention Areas	Vegetated areas designed to collect and treat water before discharge via a piped system or infiltration to the ground.

Appendix C. - Hydraulic Modelling

1 Existing Hydraulic Model

1.1 Model History

The baseline model is a 1D-2D linked ISIS/TuFLOW hydraulic model. The model was developed in 2010 by Halcrow[22]; it incorporated previous cross sections that were originally used in a 2001 ISIS model for the area.

The model was recently updated by CH2MHILL[23] in 2014, these updates included;

- Incorporating Woodford Mill Fish bypass
- Updating a number of cross sections with new survey data
- Updating the parameters for the 1D unit representing Bridge Street Bridge
- Addition of new 1D bridge units

1.2 Baseline Model

The baseline model was re run in order to validate that the flood levels being produced were consistent to the results obtained during the 2014 update. Re-running the model produced minor differences in flood levels, however it was concluded that the model was running correctly.

The assessment of the impact that the WEL has on flood levels was determined using the following versions of ISIS and TuFLOW.

- ISIS Version 3.6.0.156
- TuFLOW Version 2012-09-AE-iDP-w64

[22] Thames: St Johns to Evenlode Confluence Flood Risk Mapping Study (TH001).
[23] Post 2007 ABD – Windrush: Worsham to Witney (A40)

2 Hydraulic Modelling Updates

2.1 Proposed Development Scenarios

Three potential bridge crossing options were considered when assessing the impact of the proposed WEL. Each option was chosen to provide a different level of flow constriction to the River Windrush, in order to assess whether this could lead to reduced downstream flood levels in the centre of Witney.

Option 1 consisted of a viaduct crossing the floodplain and clear span bridges crossing the three river channels of the River Windrush. This option was considered to provide the lowest impact on flood levels, see Figure 1 and Appendix D.

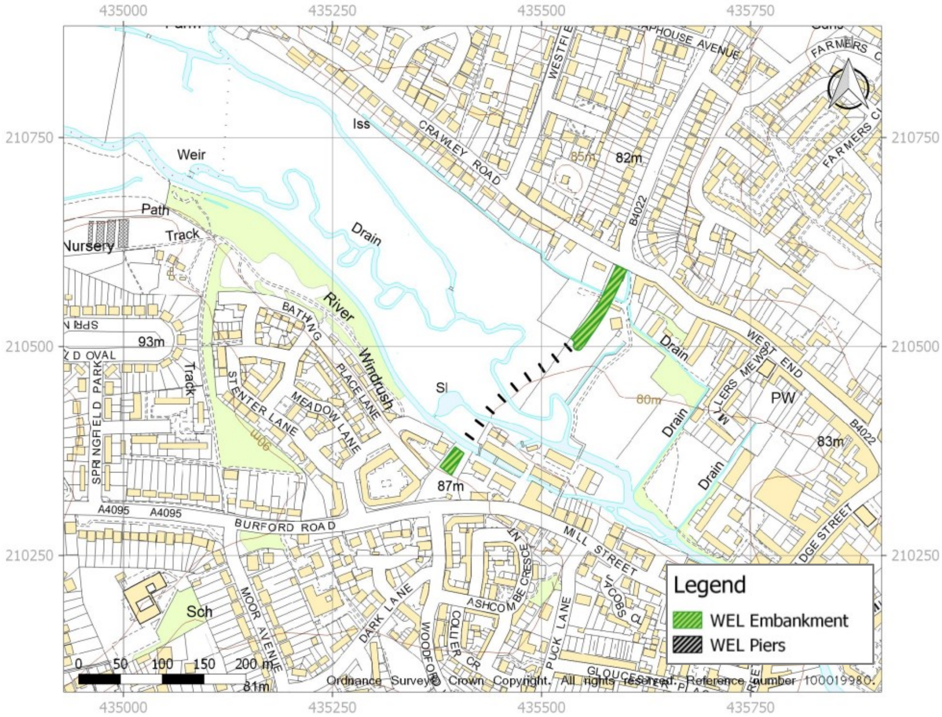


Figure 1 – Plan view of Option 1

Option 2 consisted of a raised embankment along the floodplain and clear span bridges across the three river channels of the River Windrush. This option prevents flow along the flood plain an keeps it all within the existing three channels.

Option 3 provided the most constrained option, which was similar to option 2, however with the flow area of the three channels reduced to match the existing flow area of Bridge Street bridge. This option is a theoretical assessment to determine an extreme flow constriction option.

2.1.1 Option 1

Option 1 was modelled by incorporating the proposed abutments of the WEL as a topographic feature in the 2D domain. Additionally the 9 piers were modelled by adding a flow constriction shape file to the 2D domain.

The proposed soffit level of the viaduct is set above the 1 in 100 year plus an allowance for climate change flood event. This simplified the modelling process as only the impact of the piers needed to be modelled.

Modelling the Abutments

The WEL abutments were modelled by raising the topography at their deign locations, see Figure 2. The location of the abutments was extracted from the relevant detailed design drawing[24], see Appendix D. The topography was raised to a level above the 1 in 100 year plus an allowance for climate change flood event at the connection to the viaduct, sloping down with a constant gradient to ground level at the proposed tie in location.

Modelling the Piers

From the detailed design drawings[24], the piers are 4.00m wide perpendicular to flow and 13.47m long in the direction of flow. Modelling the impact that they have on flow was done by incorporating a flow constriction layer into the 2D domain. The attributes of the flow constriction layer used in the model are given below;

- Percentage blockage (pBlockage) = 26%
- Form Loss Coefficient (FLC) = 0.225

Where the percentage blockage is the fraction of the pier widths (4.00m) in relation to the width of the flow in the 2D domain and the FLC is derived in accordance to the method set out in Hydraulics of Bridge and Waterways[25].

---

[24] Richard Jackson Design Drawing for Information. 43163-S-11. 28th Sep 2011.
[25] Bradley, J, N (1978). *Hydraulics of Bridge Waterways [Online]*. Available at: http://www.ciccp.es/ImgWeb/Castilla%20y%20Leon/Documentaci%C3%B3n%20T%C3%A9cnica/Hydraulics%20of%20Bridge%20Waterways%20%281978%29.pdf (Accessed: 11th Feb 2015)

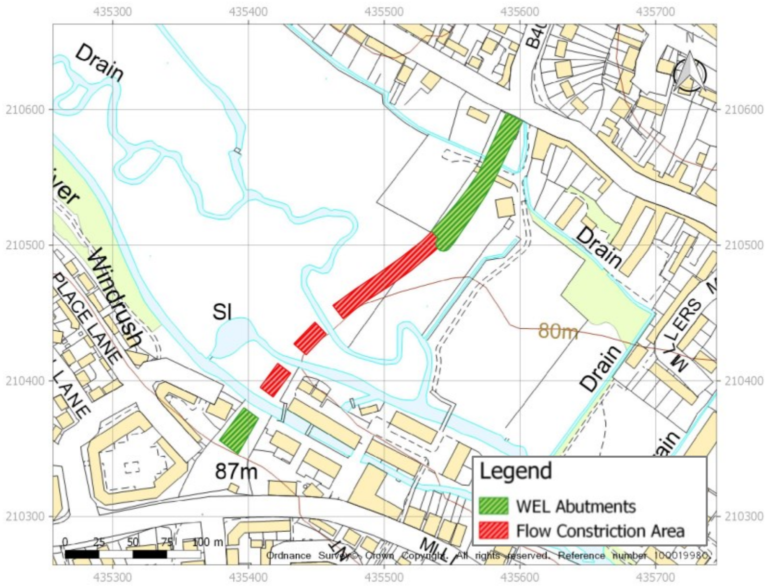


Figure 2 – Model Modifications for Option 1

A summary of the files used in Option 1 are outlined in Table 1.

Table 1 – Files used to model Option 1

Model File Names	Description
2d_zsh_Abutment_R_001.shp	WEL Abutment location
2d_zsh_Abutment_P_001.shp	WEL Abutment levels
2d_fcsh_Option1_R_001.shp	Flow constriction to model impact of WEL piers

2.1.2 Option 2

To model a raised embankment along the flood plain for the WEL, flows across the 2D floodplain were completely restricted. To completely restrict flows in the 2D domain, both the topography of the flood plain and the 1D/2D linkage were modified.

The embankment was modelled using the same method that was used to incorporate the abutments used in Option 1; again the level of the embankment was set above the 1 in 100 year plus an allowance for climate change flood event, see Figure 3.

Figure 3 - Model Modifications for Option 2

The 1D/2D linkage was modified at the location of the three channels for the River Windrush. This was done by adding dummy 1D node sections on the upstream and downstream side of the embankment, removing the sections of the HX line which crosses the embankment and then connecting the modified HX lines to the dummy node sections. A summary of the files used in Option 2 are outlined in Table 2.

Table 2 - Files used to model Option 2

Model File Names	Description
2d_zsh_Option2_R_001.shp	Embankment location
2d_zsh_Option2_P_001.shp	Embankment levels
1d_isis_nodes_witney_WEL_001.MIF	Modified 1D node locations, with dummy sections added
2d_bc_witney_WEL_001.MIF	Modified 1D/2D linkage

2.1.3 Option 3

Option 3 builds on the modifications made in Option 2, with the addition of two bridge units and a culvert incorporated into the 1D Isis model to model the increased constrictions to flow. The flow area of the two bridge units was set to the same flow area of Bridge Street bridge. This was achieved by placing the bridge abutments at reasonable locations at the top of bank for both channels and calculating the required soffit level to achieve the required flow area. A culvert was added to the third channel (Woodford Mill leat) to provide a nominal level of flow constriction. Figure 4 shows the location of the restricted flow areas and the culvert used in Option 3.

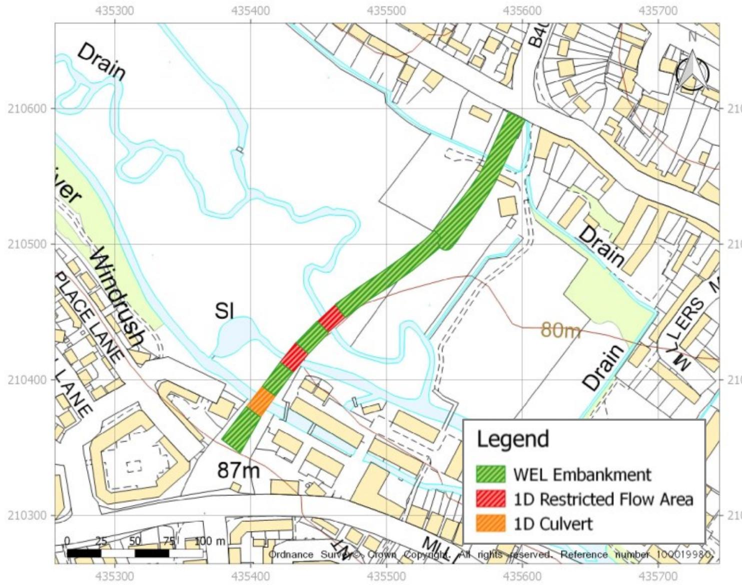


Figure 4 - Model Modifications for Option 3

A summary of the files used in Option 3 are outlined in Table 3.

Table 3 - Files used to model Option 3

Model File Names	Description
2d_zsh_Option2_R_001.shp	Embankment location
2d_zsh_Option2_P_001.shp	Embankment levels
1d_isis_nodes_witney_WEL_002.MIF	Modified 1D node locations
2d_bc_witney_WEL_002.MIF	Modified 1D/2D linkage

2.2 Proposed Development Hydraulic Modelling Results

Each of the proposed options were modelled for the 1 in 100 year plus an allowance for climate change flood event and compared against the baseline modelling results. The difference between the flood levels as a result of each option is used to assess the impact that the proposed WEL development has on the upstream and downstream flood levels within Witney. These results are illustrated in Figure 5, Figure 6 and Figure 7.

2.2.1 Option 1

The impact of Option 1 is illustrated in Figure 5. The modelling results show that the predicted change in flood depth is insignificant; all flood depth changes are less than 10mm. A summary of the impact of the proposed WEL Option 1 is provided in Table 4.

Table 4 – Summary of Flood Impact due to Option 1

Location	Impact Assessment
Upstream of WEL	• No significant change in flood depths, all impacts are less than 10mm.
At WEL	• No significant change in flood depths, all impacts are less than 10mm.
Downstream of WEL	• No significant change in flood depths, all impacts are less than 10mm.

2.2.2 Option 2

The impact of Option 2 is illustrated in Figure 6. There are some localised minor impacts as a result of the raised embankment. A summary of the impact of the proposed WEL Option 2 is provided in Table 5.

Table 5 - Summary of Flood Impact due to Option 2

Location	Impact Assessment
Upstream of WEL	• No significant change in flood depths, all impacts are less than 10mm.
At WEL	• Upstream face of WEL ◦ Some back water affect causing an increased flood depth on the upstream face of the embankment for the WEL. ◦ Increased flood depths extend approximately 75m upstream. ◦ Increases in flood depth in the range of 10mm to 25mm. • Downstream face of WEL ◦ Some decreases in flood depth on the downstream face of the embankment for the WEL. ◦ Decreased flood depths extend up to 25m downstream. ◦ Decreases in flood depth in the range of -10mm to -15mm.
Downstream of WEL	• No significant change in flood depths, all impacts are less than 10mm.

2.2.3 Option 3

The impact of Option 3 is illustrated in Figure 7. There are significant impacts as a result of the raised embankment and restricted flow area within the main channels. A summary of the impact of the proposed WEL Option 3 is provided in Table 6.

Table 6 - Summary of Flood Impact due to Option 3

Location	Impact Assessment
Upstream of WEL	• Significant increases in flood depths. • Impact on flood depths extend approximately 550m upstream of WEL. • Flood depths increased in the range of 100mm to 300mm.

At WEL	• Upstream face of WEL
	  ◦ Significant increases in flood depths.
	  ◦ Flood depths increased in the range of 300mm to 325mm.
	• Downstream face of WEL
	  ◦ Some decreases in flood depth on the downstream face of the embankment for the WEL.
	  ◦ Decreased flood depths extend up to 90m downstream.
	  ◦ Decreases in flood depth in the range of -25mm to -65mm.
	  ◦ Immediately after the restricted flow area, increased turbulence within the channel causes increased flood depths in the range of 20mm to 50mm

Downstream of WEL	• No significant change in flood depths, all impacts are less than 10mm.

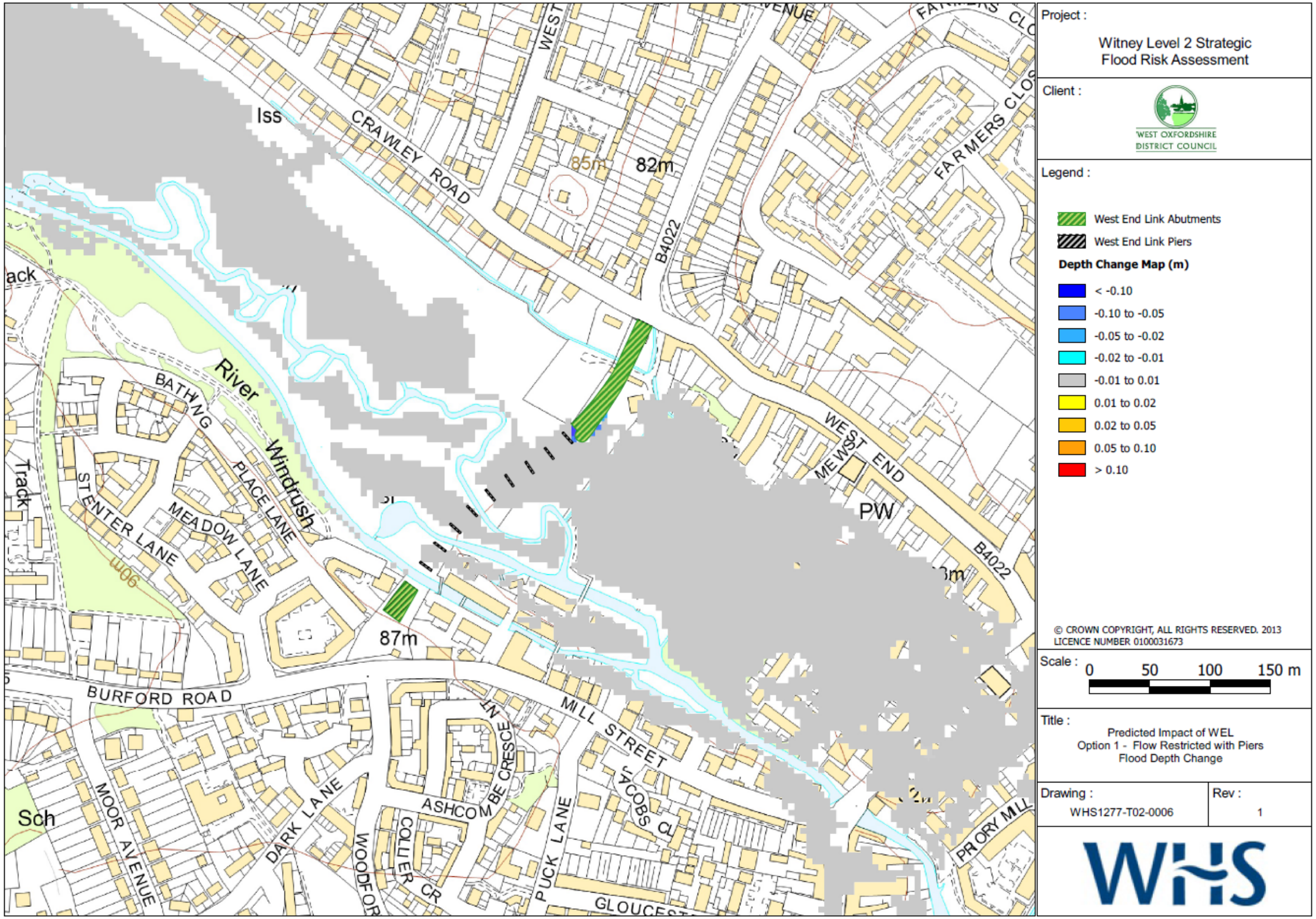


Figure 5 – Impact of Option 1 on Flood Depths

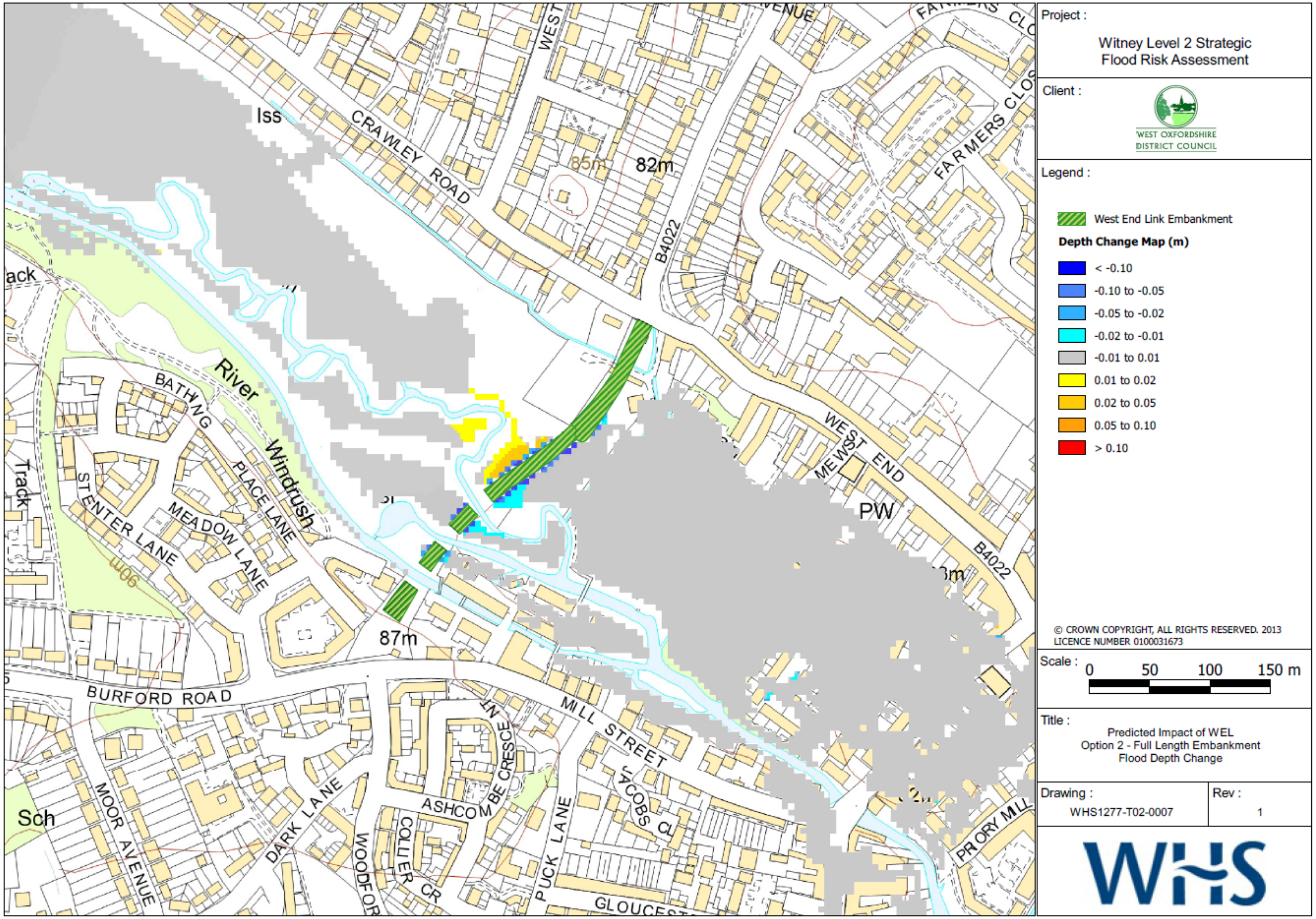


Figure 6 – Impact of Option 2 on Flood Depths

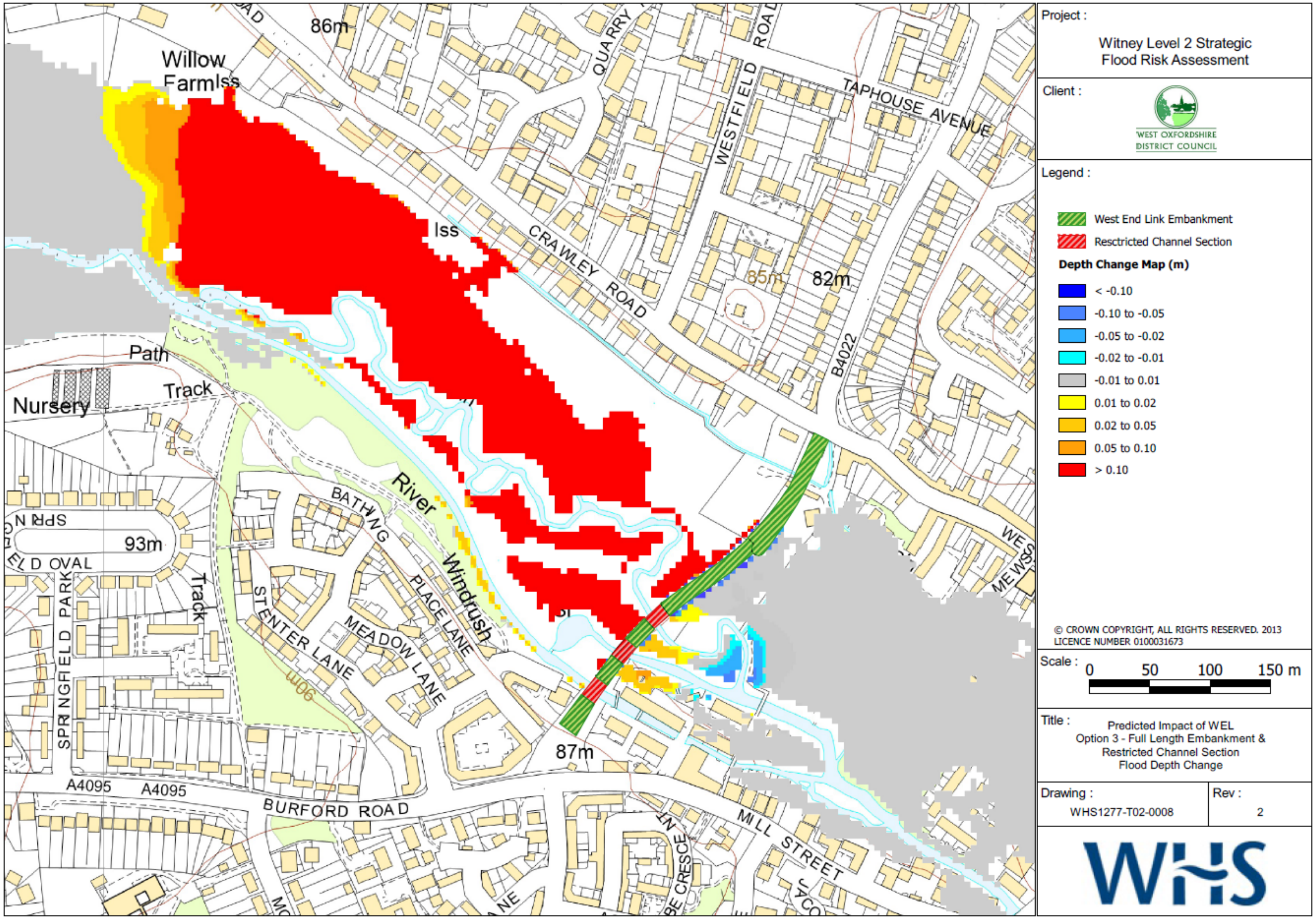


Figure 7 – Impact of Option 3 on Flood Depths

2.3 Sensitivity Analysis

Sensitivity Analysis was carried out on the Form Loss Coefficient (FLC) used in the modelling of the bridge piers in Option 1. The FLC is influenced by a number of factors, these include;

- Width of pier normal to predominant flow direction
- Shape of pier
- Width of flow area

The FLC was increased by 100% to assess the impact of a relatively high FLC pier arrangement. The results of the sensitivity analysis show that there are minor differences in flood depths (Figure 8 and Table 7), which do not affect the overall assessment made in Appendix C Section 2.2.1. This reflects the fact that, whilst flows spill into the floodplain the flows spread laterally though the floodplain, rather than the floodplain conveying any significant flow.

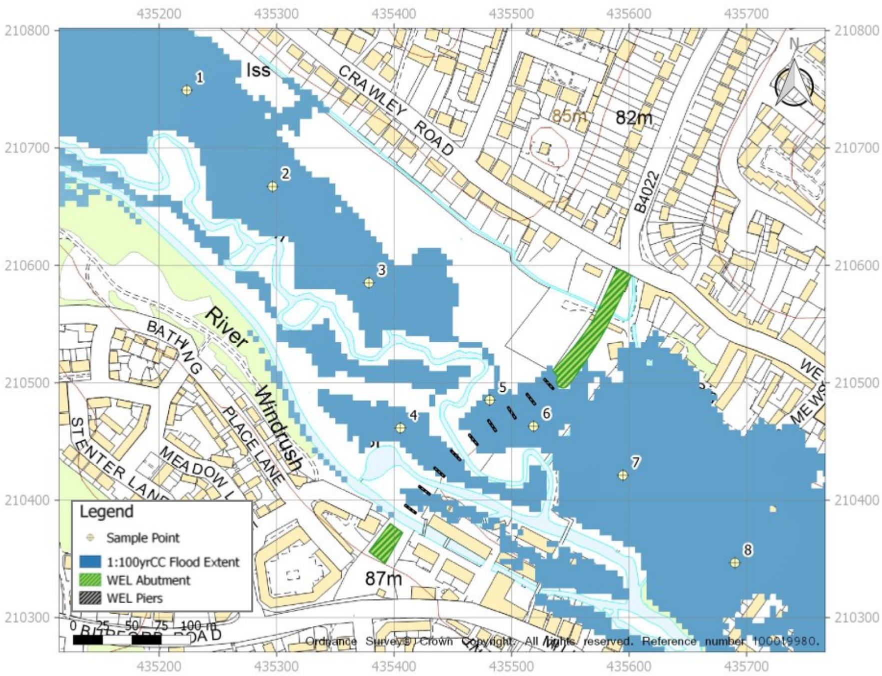


Figure 8 – Sample Points for Sensitivity Analysis

Table 7 – Flood Level Comparison for Sensitivity Analysis

Sample Point	Flood Level Option 1 (m AOD)	Flood Level Sensitivity Analysis (m AOD)	Difference (m)
1	81.716	81.715	-0.001
2	81.672	81.671	-0.001
3	81.622	81.621	-0.001
4	81.551	81.550	-0.001
5	81.543	81.542	-0.001
6	81.527	81.527	-
7	81.518	81.518	-
8	81.522	81.522	-

2.4 Model Stability

Review of the model convergence and total flow plots shows that the model was stable for all scenarios, see Figure 9. Some reduced stability is seen during the peak flows within option 3, this is due to the restricted flow area within the main channels however it is still within the allowable tolerance and is considered acceptable.

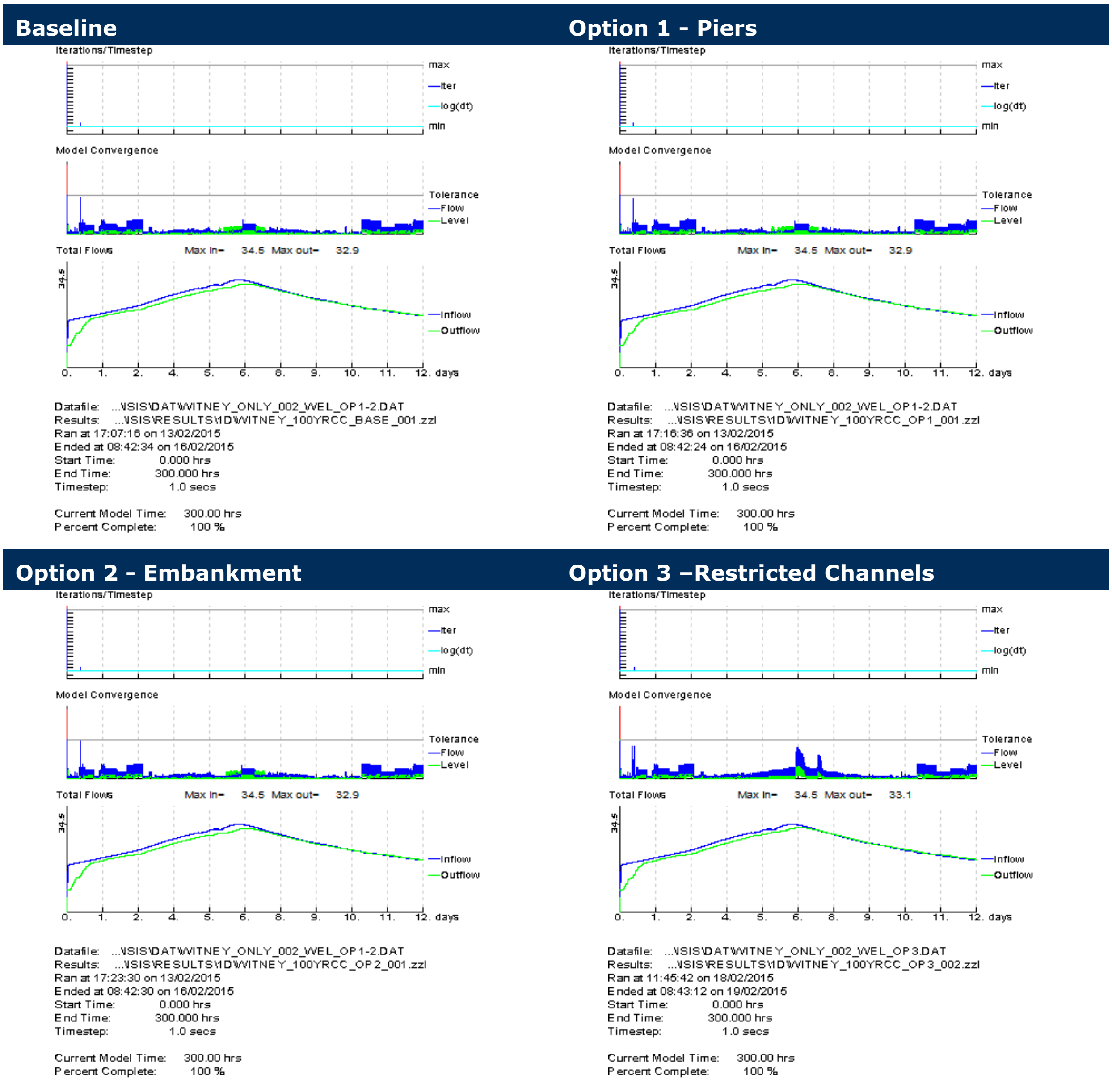
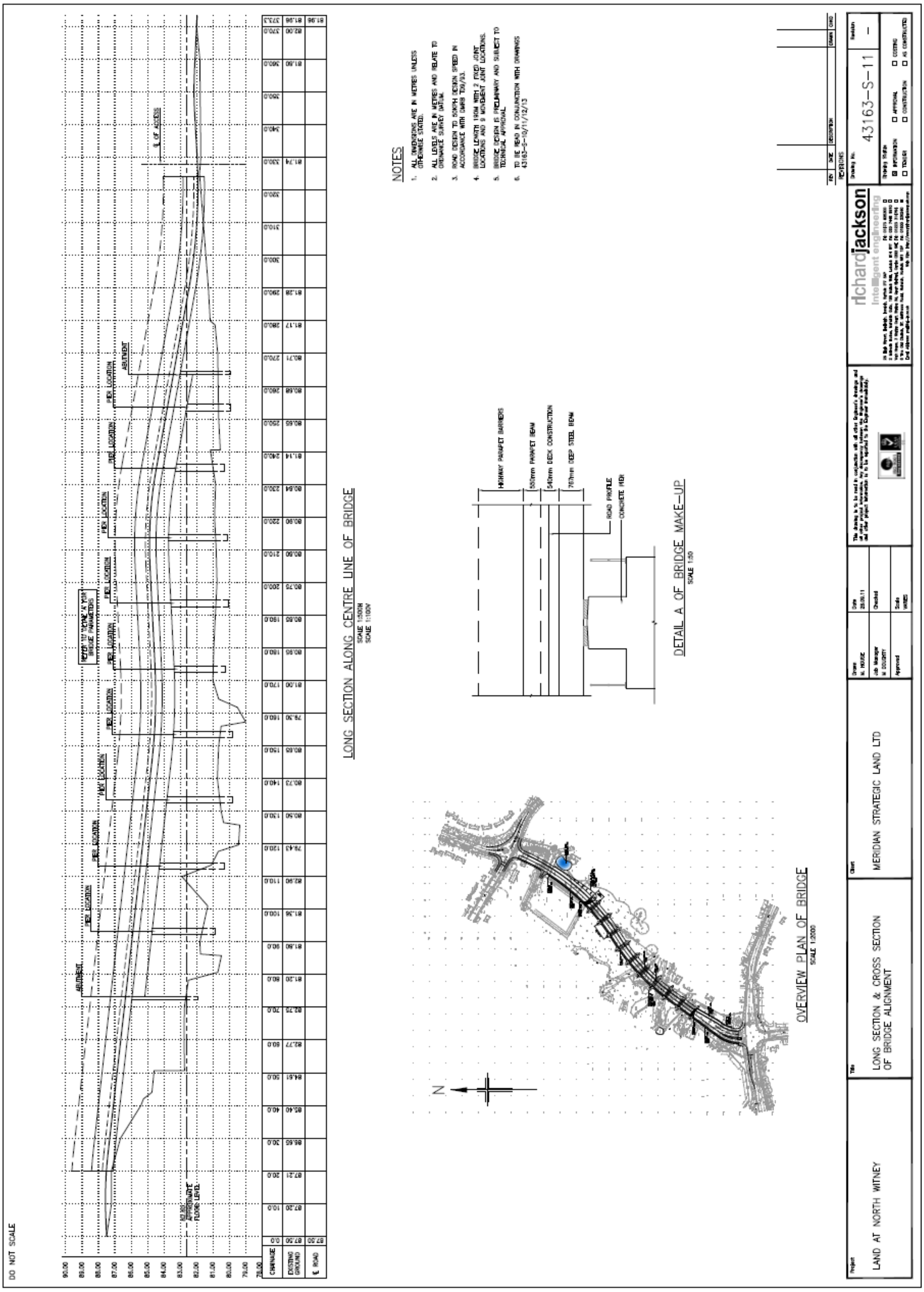


Figure 9 – ISIS Summary Plots

Appendix D. - Design Drawings


DO NOT SCALE
LONG SECTION ALONG CENTRE LINE OF BRIDGE
SCALE 1:500H
SCALE 1:100V
DETAIL A OF BRIDGE MAKE-UP
SCALE 1:50
OVERVIEW PLAN OF BRIDGE
SCALE 1:2000
HIGHWAY PARAPET BARRIERS
ROAD PROFILE
CONCRETE PIER
ABUTMENT
PIER LOCATION
CHAINAGE
EXISTING GROUND
℄ ROAD
NOTES
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE STATED.
2. ALL LEVELS ARE IN METRES AND RELATE TO ORDNANCE SURVEY DATUM.
3. ROAD DESIGN TO 50KPH DESIGN SPEED IN ACCORDANCE WITH DMRB TD9/93.
4. BRIDGE LENGTH 190M WITH 2 FIXED JOINT LOCATIONS AND 9 MOVEMENT JOINT LOCATIONS.
5. BRIDGE DESIGN IS PRELIMINARY AND SUBJECT TO TECHNICAL APPROVAL.
6. TO BE READ IN CONJUNCTION WITH DRAWINGS 43163-S-10/11/12/13
richardjackson
intelligent engineering
LAND AT NORTH WITNEY
LONG SECTION & CROSS SECTION OF BRIDGE ALIGNMENT
MERIDIAN STRATEGIC LAND LTD
43163-S-11