Melton Mowbray Distributor Road

Flood Risk Assessment

Leicestershire County Council

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Quality information

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1. Introduction

AECOM Infrastructure & Environment UK Limited (AECOM) has been commissioned by Leicestershire County Council (LCC) to undertake a Flood Risk Assessment (FRA) in support of the planning application for the proposed North & East Melton Mowbray Distributor Road in Melton Mowbray, Leicestershire. This FRA has been prepared in accordance with the National Planning Policy Framework (NPPF)[1] and the accompanying Planning Practice Guidance (PPG)[2].

This report provides an assessment of the present flood risk along the proposed route as well as the effect of the proposed scheme on flood risk to adjacent areas.

1.1 Location of Project

Leicestershire County Council (LCC) have assessed highway alignment options to accommodate future growth and to address congestion issues within and through Melton Mowbray town centre to divert traffic away from the town centre onto more suitable local distributor roads. Following an Options Assessment exercise, the proposed North & East Melton Mowbray Distributor Road, herein referred to as the proposed scheme, was determined as the preferred option to facilitate development included in the Melton Borough Council Draft Local Plan.

The proposed road is located to the north and east of Melton Mowbray. It runs from the A606 Nottingham Road at its junction with St Bartholomew's Way to the A606 Burton Road at its junction with Sawgate Road. The scheme includes six at-grade roundabouts, one at each end at the tie-ins to the existing network and four where it intersects existing roads; Scalford Road, Melton Spinney Road, A607 Melton Road, B676 Saxby Road. The proposed scheme alignment is shown in Appendix A.

The land use in the area consists of predominantly mixed arable and livestock (dairy cattle and sheep rearing) which surrounds the urban fringe of Melton Mowbray to the north and east.

The proposed scheme intersects one Main River - the River Eye, and five Ordinary Watercourses which are tributaries of the River Eye, a railway line, and the former now disused Melton Mowbray Navigation and Oakham Canal. The five Ordinary Watercourses are two unnamed minor watercourses located near Sysonby Lodge Farm, Scalford Brook, Thorpe Brook and the unnamed watercourse located adjacent to Lag Lane which will be referred to as the Lag Lane watercourse hereon. In addition, Burton Brook (an Ordinary Watercourse), which is not crossed or culverted, is located within 800 m of the proposed scheme to the southeast.

To the northeast of Melton Mowbray just beyond the route alignment is the Twinlakes Theme Park. There are a number of offline ponds within the Twinlakes Theme Park.

To the north of Melton Mowbray just south of the route alignment is the Melton Mowbray Country Park. Various ponds and stillwaters are present within the area, including a series of small lakes within the Melton Mowbray Country Park that are online with Scalford Brook which form the Scalford Brook Flood Storage Area. The Scalford Brook Dam flood retention facility was completed in 1990 to control the rate of discharge into Melton Town centre and offer a 1% AEP standard of protection.

In addition, there is the Brentingby Flood Storage Area contained within a large flat area within a meander of the River Eye to the south of the Brentingby Railway Junction.

Detailed information on topography, rainfall, land use, surface water features, geology and ecology are included in Chapter 16: Road Drainage and the Water Environment of the Environmental Statement (AECOM, 2018).

[1] Department for Communities and Local Government. 2018. National Planning Policy Framework. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733637/National_Planning_Policy_Framework_web_accessible_version.pdf

[2] Department for Communities and Local Government. 2014. Planning Practice Guidance: Flood Risk and Coastal Change. Available at: http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/

1.2 Background

LCC has assessed highway options to accommodate future growth and to address congestion issues within and through Melton Mowbray town centre to divert through traffic away from the town centre onto more suitable local distributor roads. Chapter 3: Assessment of Alternatives of the Environmental Statement describes the various options that have been developed and considered; ultimately resulting in the definition of the proposed scheme. A brief overview of the options appraisal process is included below.

The selection of the proposed scheme has been an iterative process that began with a study in 2014 to examine how future development within Melton Mowbray will affect traffic congestion in the town centre. The study showed that the road network in Melton Mowbray's town centre is close to its capacity and any future development will require significant improvement to the current road network. Workshops were held by Melton Borough Council (MBC) with stakeholders and residents to discuss potential solutions, resulting in development of 60 different options to address the issues. This 'long list' was then assessed in terms of deliverability, affordability and acceptability to narrow the options down to a 'short list' of 24 options. In February 2015 workshops were held with representatives from MBC to further assess the options. The results showed that the highest performing options were all different types of distributor road. Using this information a traffic modelling assessment was carried out to compare the performance of an inner distributor road and an outer distributor road.

- Inner distributor road: linking the A606/ Mucky Lane junction to the A606 at the Cattle Market junction via the A607/ Dalby Road junction and onwards to the A6006/ Park Avenue junction.
- Outer distributor road: linking the A606 Burton Road in the south to Scalford Road in the north via a westerly route which passes the B6047 Dalby Road, A607 Leicester Road and the A6006, before heading in a north westerly direction along Welby Road and Welby Lane to the A606 Nottingham Road.

The results indicated that both an inner and outer distributor road would reduce the levels of traffic in the town centre, however the outer distributor road would provide a greater reduction in congestion and also provide the additional road capacity to support Melton Mowbray's growth aspirations. In September 2016 Leicestershire County Council's Cabinet approved the development of a Transport Strategy for Melton Mowbray to examine options for an outer distributor road.

Four options were explored for the route of an outer distributor road as shown in Figure 1-1 below.

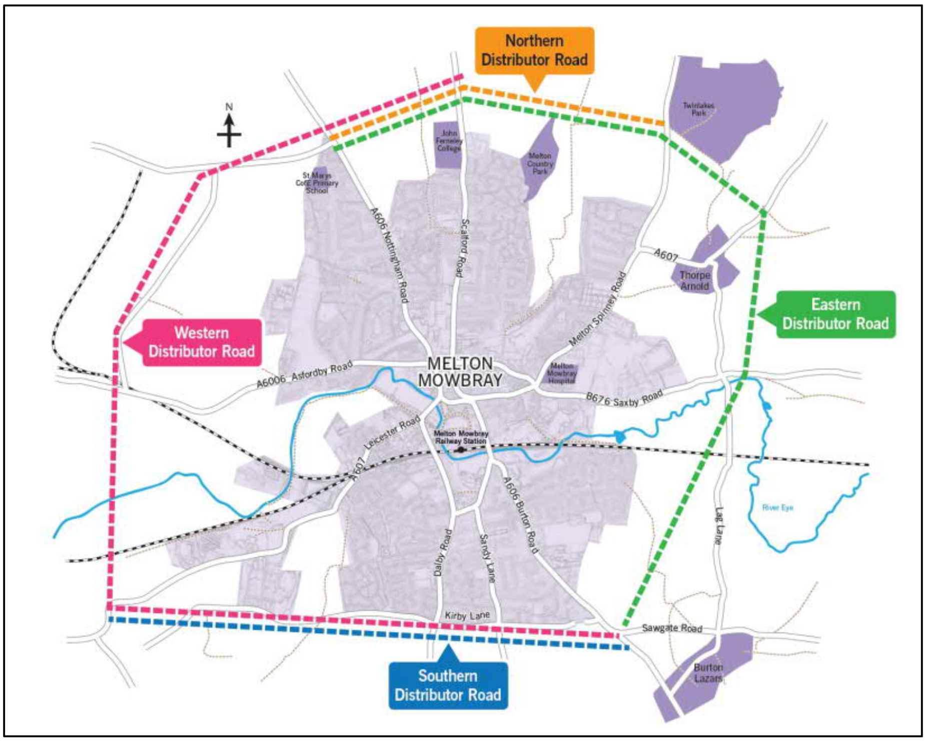


Figure 1-1 Options considered for an Outer Distributor Road

The four options were then appraised, with the results showing that the eastern and western distributor roads were the best options to improve congestion in Melton Mowbray. These two routes were then presented to a workshop group and the decision taken that the eastern option would provide the best cost/ benefit ratio for Melton Mowbray.

Both the western and eastern distributor roads would involve crossing of the River Eye and its associated flood plain.

In July 2016 two potential routes were developed for the eastern outer distributor road. Figure 1-2 shows the two options.

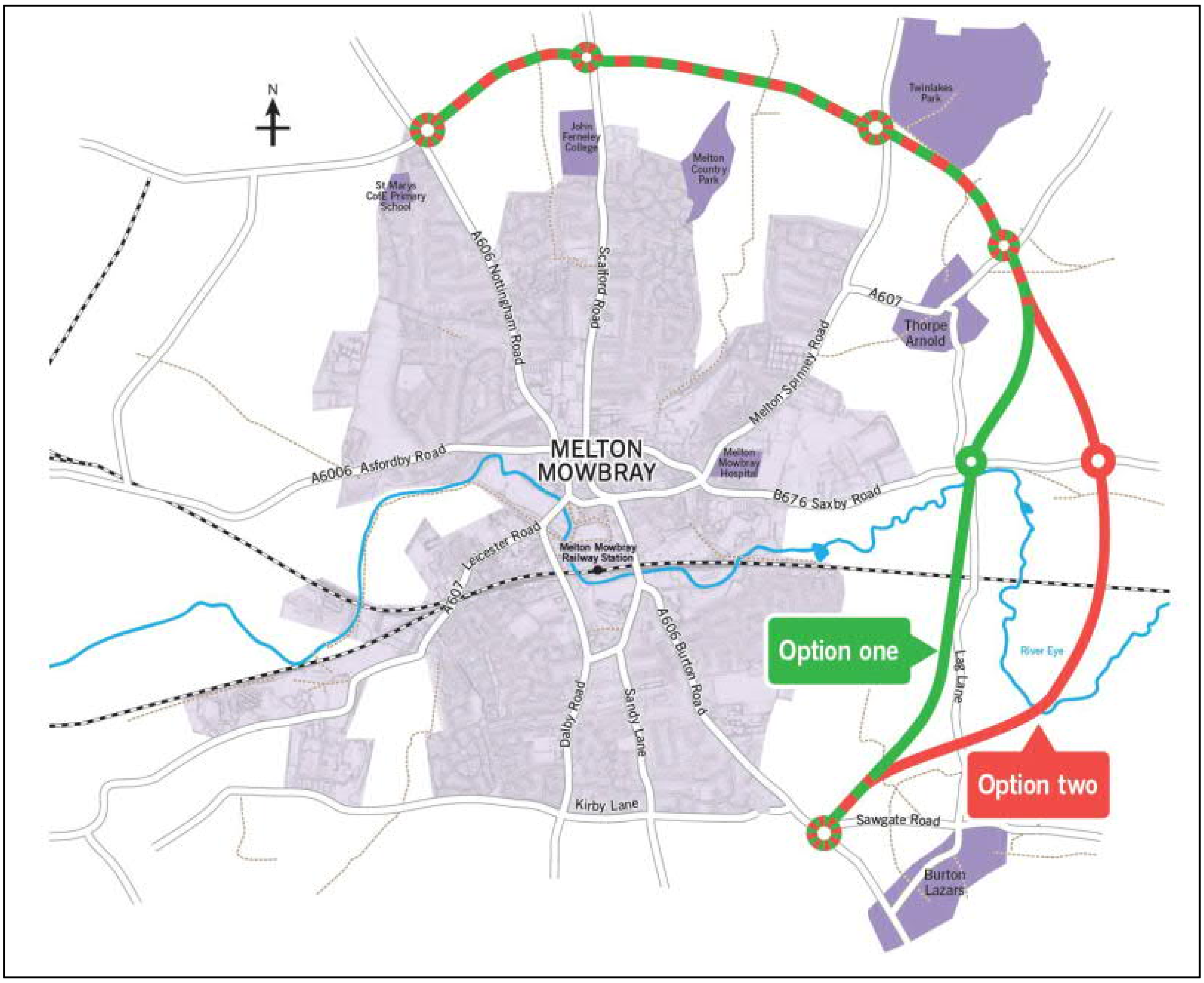


Figure 1-2 Options for Eastern Distributor Road

The assessment process suggested that Option 1 would more effectively deliver the aims of the distributor road and would do so with a lesser environmental impact than Option 2. Some of the key environmental aspects where Option 1 fares better than Option 2 are as follows:

- Option 2 is approximately 0.5km longer than Option 1, would have a greater journey time for users of the route and would require a larger amount of land. The increased length of the road would have additional environmental impacts.
- Option 2 would take the road further from Melton Mowbray, extending the urban fringe of the town further into the surrounding rural area, although in doing so would take the road further from properties on the outskirts of the market town. Option 2 also passes through the Brentingby Flood Storage Area, with significant impacts on the flood storage capacity and environmental impacts on the area that may not be acceptable to the Environment Agency in the context of other options. Where the route of Option 2 crosses the Brentingby Flood Storage Area, a viaduct or multi-span structure would be required of approximately 700m in length. The scheme would pass through a larger amount of land in Flood Zones 2 and 3 than Option 1.

- Option 2 would still require a crossing over the River Eye, although the crossing location would not be in close proximity to high voltage powerlines. The two routes diverge to the south east of Thorpe Arnold so the impact of the scheme on the village would be similar for the two options.

1.3 Development Proposals

This section provides a brief overview of the proposed structures across the five Ordinary Watercourses and the River Eye (See Table 1-1 below). In addition, this section provides a summary of the development proposals in the vicinity of the proposed River Eye crossing. General arrangement drawings of these proposed structures are provided in Appendix A.

Table 1-1 Details of proposed structures across the six watercourses being intersected by MMDR

Structure Name	Location	Watercourse	Description of structure
C01	Chainage 220	Unnamed Ordinary Watercourse located adjacent to Sysonby Lodge Farm	Reinforced concrete 1.5 x 1.5m (internal) box culvert passing through highway embankment with invert set-down 0.3m beneath bed of watercourse. Length approximately 60m due to high skew.
C02	Chainage 730	Unnamed Ordinary Watercourse located near Sysonby Lodge	Reinforced concrete 1.5 x 1.5m (internal) box culvert passing through highway embankment with invert set-down 0.3m beneath bed of watercourse. Length approximately 30m.
B01	Chainage 1980	Scalford Brook (Tributary of the River Eye)	A single 9m clear span bridge, open span structure across the Scalford Brook watercourse. Fully integral bridge with precast beam deck supported on either: • piled reinforced concrete abutments, or • steel sheet-pile abutments
B02	Chainage 3260	Thorpe Brook (Tributary of the River Eye)	A single 15.5m clear span bridge, open span structure across Thorpe Brook watercourse and combined farm track / NMU route. Thorpe Brook bridge enables the farm track and NMU route to pass north-south beneath the MMDR on the east side of the watercourse. Fully integral bridge with precast beam deck supported on either: • piled reinforced concrete abutments, or • steel sheet-pile abutments
C03	Chainage 3950	Lag Lane Ordinary Watercourse (tributary of the River Eye) is crossed by the proposed MMDR at chainage 3950	Reinforced concrete 2.0 x 2.3m high (internal) box culvert passing through highway embankment with invert set-down 0.3m beneath bed of watercourse. Length approximately 55m.
C04	Under realigned Lag Lane	Lag Lane Ordinary Watercourse by realigned Lag Lane in the vicinity of the proposed roundabout 5	3.0 x 1.3m box culvert carrying the Lag Lane watercourse beneath the B676 Saxby Road and proposed bridleway west of

	in the vicinity of Saxby Road c. 4850		Roundabout 5, with invert set-down 0.3m beneath bed of watercourse. Length approximately 10m (TBC).
C05	Under Saxby Road c. 4950	Lag Lane Ordinary Watercourse: By the realigned Saxby Road in the vicinity of the proposed roundabout 5 immediately upstream of its confluence with River Eye	3.0 x 1.3m box culvert carrying the Lag Lane watercourse beneath the B676 Saxby Road and proposed bridleway west of Roundabout 5, with invert set-down 0.3m beneath bed of watercourse. Length approximately 40m.
B04	Chainage 5100	River Eye	A 55m, 4-span structure to accommodate flood flows and an accommodation works track access. Listed north to south the proposed bridge spans are as follows: • Span A: 11m flood relief span • Span B: 14m flood relief span / livestock underpass • Span C: 14m River Eye span (25m further south than original proposal) • Span D: 11m flood relief span / accommodation works track access In addition to the MMDR carriageway and shared footway/cycleway, the River Eye bridge incorporates a separate farm access track / NMU route north to south over the River Eye.

Proposed River Eye Crossing

The proposed scheme crosses the River Eye just to the south of the junction of Saxby Road and Lag Lane. The development proposals in the vicinity of this crossing are shown on Figure 1-3 and listed below:

- A new culvert (C03), located on the Lag Lane tributary, approximately 1km upstream of its confluence with the River Eye, where the proposed highway crosses the tributary;
- The removal of the existing Lag Lane bridge crossing the River Eye;
- A proposed new junction (Roundabout 5) replacing the existing junction of Saxby Road and Lag Lane;
- Realignment of the existing northern branch of Lag Lane to join the proposed new junction, and replacement of the existing southern branch of Lag Lane with the proposed southbound highway;
- Saxby Road realigned to join the proposed junction/ highway;
- Realignment of Lag Lane tributary to the west of the proposed junction, including a new culvert (C04) under the realigned Lag Lane and a new culvert (C05) under the realigned Saxby Road. In addition, the portion of the Lag Lane watercourse to the south of Saxby Road will be day-lighted;
- New bridge (B04) for the proposed highway to cross the River Eye;
- Realignment of the River Eye channel upstream of the proposed highway; and
- Existing River Eye channel to be retained as a backwater.

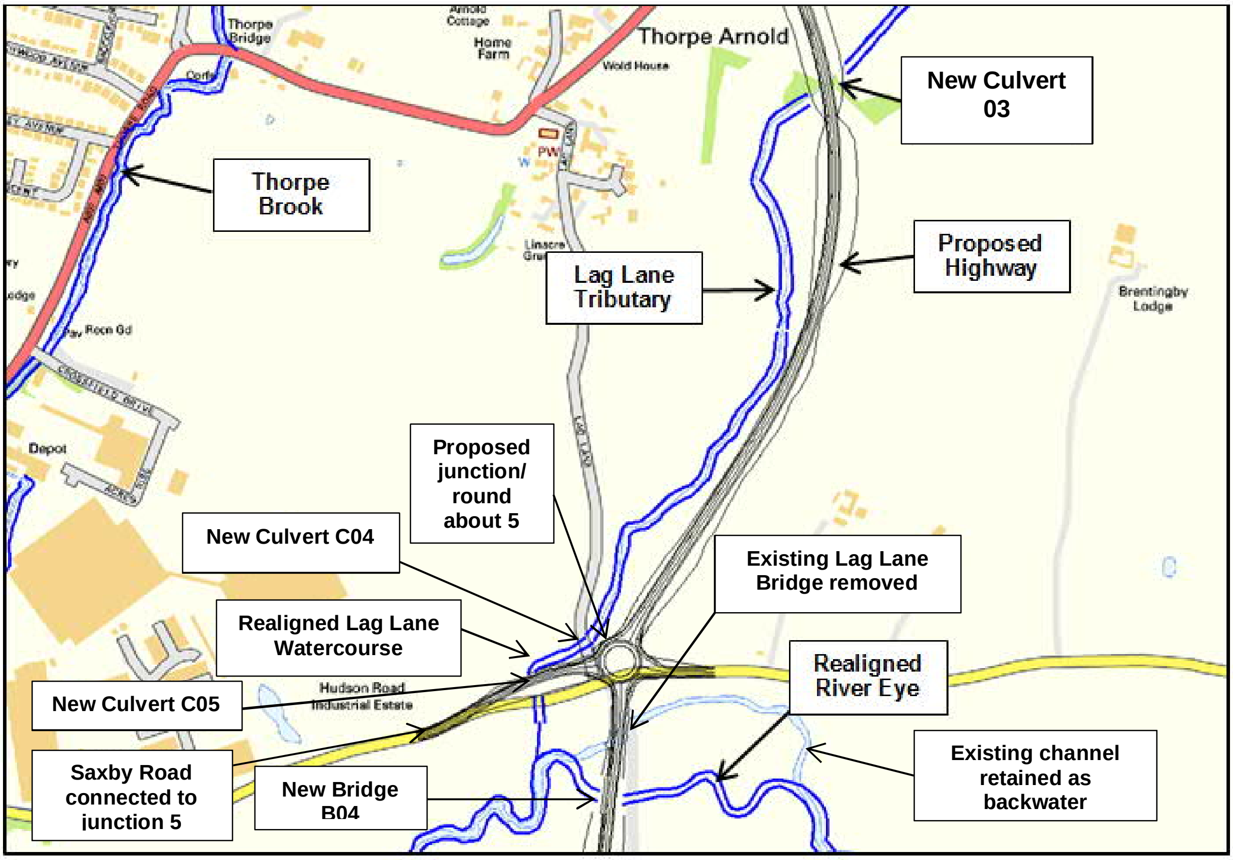


Figure 1-3 Development proposals in the vicinity of the River Eye Crossing

1.4 Methodology

A FRA is required to assess the risks from all sources of flooding to and from a proposed development. Section 10 of the NPPF provides national policy in relation to development and flood risk. This is supported by the PPG which accompanies the NPPF. The NPPF emphasises the need for a risk-based approach to be adopted through the application of the 'Source-Pathway-Receptor' model. In accordance, AECOM's approach to this FRA is based on the Source-Pathway-Receptor model.

The Source-Pathway-Receptor model firstly identifies the causes or 'sources' of flooding to and from a development based on a review of local conditions and consideration of the effects of climate change. The nature and likely extent of flooding arising from any one source is considered, e.g. whether such flooding is likely to be localised or widespread. The presence of a flood source does not always infer a risk. It is the exposure 'pathway' or the flooding mechanism that determines the risk to the receptor and the effective consequence of exposure. For example, sewer flooding does not necessarily increase the risk of flooding unless the sewer is local to the site and ground levels encourage surcharged water to accumulate. The varying effect of flooding on the 'receptors' depends largely on the sensitivity of the target. Receptors include any people or property within the range of the flood source, which are connected to the source of flooding by a pathway. In order for there to be a flood risk, all the elements of the model (i.e. a flood source, pathway and receptor) must be present. Furthermore, effective mitigation can be provided by removing one element of the model.

AECOM's approach involves a desk-based review of available information in combination with hydraulic modelling to establish the levels of flood risk. Once the flood risks had been established, mitigation measures are proposed (where necessary) and residual risks are addressed.

1.5 Aims and Objectives

The aim of this report is to provide LCC with a FRA to inform of the risks to flooding posed to and by the proposed scheme in support of a planning application for the proposed scheme. The FRA has been prepared in accordance with the NPPF, its associated PPG and other relevant local policy.

To achieve the above aim the following objectives were met:

- review of existing site data including Environment Agency (EA) flood risk data, ground conditions (if available), scheme proposals and reference to relevant Leicestershire County Council policy including Strategic Flood Risk Assessments, Preliminary Flood Risk Assessments, Surface Water Management Plans and Local Flood Risk Management Strategies;
- liaison with the EA to outline and agree requirements regarding various flood related issues around the proposed River Eye crossing and River Eye hydraulic modelling;
- liaison with LCC Flood team (Lead Local Flood Authority) to outline and agree requirements for the site-specific FRA;
- liaison with the AECOM Highways and Infrastructure Teams to obtain scheme drawings, proposed drainage scheme drawings, topographical data etc.;
- assessment and interpretation of available information to identify potential sources of flood risk. These include fluvial (River Eye and its tributaries), pluvial (surface water), groundwater, combined, foul or surface water sewers, and infrastructure failure (e.g. canals, reservoirs, pumped catchments) including any history of burst water mains, blocked sewers, canal breach events etc.);
- hydraulic modelling to confirm baseline conditions and assess the fluvial flood risk impact of the proposed development in the vicinity of the proposed River Eye crossing. This included modelling of the existing baseline conditions and of the proposed scenario with the new bridge for a series of magnitude fluvial events;
- identification of potential measures to mitigate the fluvial flood risk impacts of the proposed development;
- a review of the surface water drainage design that has been prepared for the proposed development, and incorporation of the design calculations into the FRA; and
- discussion and provision of recommendations for flood mitigation measures including fluvial volume compensatory storage and residual risk mitigation measures in line with the conclusions of the drainage strategy, where applicable.

1.6 Data Sources

The baseline conditions for the proposed route have been established through a desk study and via consultation with the Environment Agency and been utilised to inform the assessment made within this report. Data collected during the course of this assessment is described in Table 1-2.

Table 1-2: Sources of Data Reviewed

Purpose	*Data Source*	*Comments*
Identification of Hydrological Features	1: 25,000 Ordnance Survey (OS) mapping.	Identifies the position of the routes and local hydrological features.
Identification of Existing Flood Risk	EA Indicative Flood Zone Map[3] (online).	Identifies fluvial/ tidal inundation extents and historical flooding.
	EA Long Term Flood Risk Map[4] (online).	Provides information on the risk of flooding from fluvial, surface water and reservoirs (artificial sources).
	Leicestershire County Council Preliminary Flood Risk Assessment[5] (PFRA), Leicestershire County Council Local Flood Risk Management Strategy[6] (LFRMS), and	Assesses flood risk across the county and borough boundary areas. Includes flood risk from fluvial/tidal, sewers, overland flow and

[3] Environment Agency Flood Map for Planning [Online] Accessed: 02.09.18
[4] Environment Agency Flood Risk from Reservoirs [Online] Accessed: 02.09.18
[5] URS Scott Wilson (2011) Leicestershire County Council Preliminary Flood Risk Assessment.
[6] Leicestershire County Council (2015) Local Flood Risk Management Strategy

Purpose	Data Source	Comments
	Melton Mowbray Strategic Flood Risk Assessment[7] (SFRA);	groundwater.
	British Geological Survey records.	Provides details of geology and hydrogeology in the vicinity of the Site.
Identification of Historical Flooding	SFRA and PFRA.	Provides locations of historical flooding.
Details of the Scheme	Proposed alignment drawings General arrangement drawings of proposed watercourse crossing structures Proposed River Eye re-aligned channel design	Provides layout of the proposed MMDR route and the various structures crossing the River Eye and other ordinary watercourses Provides the alignment of the proposed River Eye diversion
Surface Water Drainage	PFRA, SFRA, EA Flood Risk from Surface Water Map[8] (online), and DEFRA SuDS – Non-statutory technical standards[9]	Identifies existing surface water flood risk from the route options. Provides information regarding drainage requirements for the route.
Planning Policy	Melton Borough Council Draft Local Plan[10] National Planning Policy Framework (NPPF)[11] and Planning Practice Guidance (PPG)[12]	Provides information regarding national and local policy requirements.
Baseline fluvial flood model	Environment Agency River Wreake Hydraulic Model	The existing River Wreake model was updated using new LiDAR data and new channel survey data in the vicinity of the proposed River Eye crossing and re-run to provide baseline flood extents and design flood levels
Climate Change Guidelines	Environment Agency Guidance for Flood Risk Assessments: climate change allowances[13]	Provides guidance on when and how to use climate change allowances in flood risk assessments

[7] JBA Consulting (2015) Melton Borough Council Level 1 and Level 2 Strategic Flood Risk Assessment
[8] Environment Agency Flood Risk from Surface Water Map [Online] Accessed: 02.09.18
[9] Department for Environment, Food and Rural Affairs (2015) Sustainable Drainage Systems: Non-statutory technical standards for sustainable drainage systems
[10] Melton Borough Council (2016) Draft Local Plan (Pre-Submission)
[11] Department for Communities and Local Government (March 2012) National Planning Policy Framework. Chapter 10: Meeting the challenge of climate change, flooding and coastal change. Paragraphs 93 to 108.
[12] Department for Communities and Local Government (March 2014) National Planning Practice Guidance. Flood risk and coastal change.
[13] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#what-climate-change-allowances-are

2. Planning Policy and Guidance

The following planning policies and guidance are relevant to the proposed scheme with regards to flood risk and surface water management.

2.1 National Planning Policy Context

The National Planning Policy Framework (NPPF) is supported by the Planning Practice Guidance (PPG), an online resource published in March 2014. The PPG supersedes the PPS25 Practice Guide[14] and the Technical Guidance to the National Planning Policy[15], as detailed in the Ministerial Statement 'Making the planning system work more efficiently and effectively'[16].

The NPPF and PPG must be taken into account in the preparation of local and neighbourhood plans, and are a material consideration in planning decisions. It constitutes guidance for local planning authorities (LPAs) and decision-takers, both in drawing up plans and as a material consideration in determining applications.

The NPPF and PPG recommend that Local Plans should be supported by a SFRA and develop policies to manage flood risk from all sources, taking account of advice from the EA and other relevant flood risk management bodies, such as LLFAs and Internal Drainage Boards (IDBs). Local Plans should apply a sequential, risk-based approach to the location of development to avoid, where possible, flood risk to people and property and manage any residual risk, taking account of the impacts of climate change, by:

- Applying the Sequential Test;
- Applying the Exception Test, if necessary;
- Safeguarding land from development that is required for current and future flood management;
- Using opportunities offered by new development to reduce the causes and impacts of flooding; and
- Seeking opportunities to facilitate the relocation of existing development, including housing, to more sustainable locations where climate change is expected to increase flood risk.

2.1.1 NPPF Flood Zones

The Flood Zones referred to in the NPPF and PPG are classified as shown in Table 2.1 (based on Table 1 of the PPG).

Table 2-1 Flood Zone Definition

Flood Zone	Definition
Zone 1 **Low Probability**	Land having a less than 1 in 1,000 annual probability of river or sea flooding (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3).
Zone 2 **Medium Probability**	Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding or land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (Land shown in light blue on the Flood Map)
Zone 3a **High Probability**	Land having a 1 in 100 or greater annual probability of river flooding or land having a 1 in 200 or greater annual probability of sea flooding (Land shown in dark blue on the Flood Map).
Zone 3b **The Functional Floodplain**	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

[14] Communities and Local Government, (2012); 'Planning Policy Statement 25: Development and Flood Risk, Practice Guidance'
[15] Communities and Local Government, (2012); 'Technical Guidance to the National Planning Policy Framework'
[16] Communities and Local Government (2014); 'Making the planning system work more efficiently and effectively'

2.1.2 The Sequential and Exception Tests

The overall aim of the Sequential Test is to steer new development to areas designated as Flood Zone 1. Where there are no reasonably available sites in Flood Zone 1 areas, LPAs allocating land in Local Plans or determining planning applications for development at any particular location should take into account the flood risk vulnerability of land uses and consider reasonably available sites in Flood Zone 2 areas, applying the Exception Test if required. Only where there are no reasonably available sites in Flood Zone 1 or 2 areas should the suitability of sites in Flood Zone 3 be considered, taking into account the flood risk vulnerability of land uses and applying the Exception Test if required.

For the Exception Test to be passed:

- It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where one has been prepared; and,
- A site-specific FRA 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.

Both elements of the test will have to be passed for development to be allocated or permitted.

2.1.3 Development and Flood Risk Vulnerability

The NPPF considers the vulnerability of different forms of development to flooding and classifies proposed uses accordingly. Section 7, Paragraph 066 of the PPG illustrates a matrix which identifies which vulnerability classifications are appropriate within each flood zone. This can be seen below in Table 2.2.

Table 2-2 Flood Risk Vulnerability and Flood Zone Compatibility

Flood risk Vulnerability classification	*Essential Infrastructure*	*Water Compatible*	*Highly Vulnerable*	*More Vulnerable*	*Less Vulnerable*
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	Exception test required	✓	✓
Zone 3a	Exception test required	✓	×	Exception test required	✓
Zone 3b 'Functional Flood plain'	Exception test required	✓	×	×	×

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

The proposed scheme is considered 'Essential Infrastructure' under the heading "Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk". The proposed scheme route crosses Flood Zone 3 at three locations in the vicinity of the proposed crossings of the River Eye, Scalford Brook and Thorpe Brook. As Table 2.2 above indicates, the Exception Test is required for the development.

However, the proposed North & East MMDR alignment has been included in MBC's latest Local Plan following a rigorous options appraisal process, which considered various factors including environmental impacts and long–term sustainability. The Local Plan has demonstrated that the proposed scheme alignment would have the greatest positive long term effects on traffic congestion within the town centre and offer best value for money. Therefore, the proposals will pass the Exception Test as long as flood risk is not increased.

2.2 Regional Planning Policy

2.2.1 Leicestershire County Council Preliminary Flood Risk Assessment

The LCC PFRA (published in June 2011) provides a high level screening assessment of local flood risk across the County, including information on historic and potential flooding and the consequences.

Leicestershire has been identified as being within an Environment Agency Indicative Flood Risk Area; however this does not extend as far as Melton Mowbray (PFRA Figure 5-4). Figure 5-3 in the PFRA does however indicate that Melton Mowbray is located above the Flood Risk Threshold. While the area above the threshold is centred on the urban centre of Melton Mowbray parts of the proposed alignment, particularly where the proposed highway ties in with existing infrastructure, are likely to be located within this area.

2.2.2 Leicestershire Local Flood Risk Management Strategy

The LCC LFRMS outlines the sources of flooding in Leicestershire focussing on flooding from heavy rainfall, groundwater and from Ordinary Watercourses (i.e. small ditches and streams that are not Main Rivers). The LFRMS gives an overview of how flood risk will be managed and sets out which organisations are responsible for different types of flooding. The LFRMS includes Melton Mowbray within the list of 40 priority settlements that are at highest risk of flooding within Leicestershire.

2.3 Local Planning Policy

2.3.1 Melton Mowbray Borough Council Core Strategy Development Document

The Melton Local Plan is currently under preparation with the Plan due for adoption by the Council in 2018. The Local Plan will form the basis of how planning decisions are made in Melton by guiding decisions on planning applications for development and setting out the strategic direction of the area on social, economic and environmental matters.

One of the key environmental strategic objectives of the Draft Local Plan is to "*reduce the risk of flooding and avoid development in flood prone areas."* The relevant borough wide policies with regards to flood risk and surface water management include:

Policy EN11 – Minimising the Risk of Flooding

- Melton Borough Council will ensure that development proposals do not increase flood risk and will seek to reduce flood risk to others;
- The council will follow a sequential approach to flood risk management with the aim of locating development on land with the lowest risk of flooding (Flood zone 1);
- All planning applications for development in Flood Zones 2 and 3, or which exceed one hectare should be accompanied by a flood risk assessment; and
- Where appropriate the Council will require developers to restore watercourses to a much more natural state through the removal of hard engineering, such as culverts and bank reinforcement, in order to reduce flood risk and provide local amenity and biodiversity benefits.

Policy EN12 – Sustainable Drainage Systems

- For major development, proposals should demonstrate through a surface water drainage strategy that properties will not be at risk from surface water flooding allowing for climate change effects;
- Surface water management should be undertaken, wherever practicable through the utilisation of appropriate SuDS techniques which mimic natural drainage patterns, and where appropriate achieve net gains for nature through the creation of ponds and wetlands near watercourses; and
- All developments will be expected to be designed to achieve, where appropriate, a net decrease in surface water runoff rates, including through green infrastructure provision such as the planting of native trees and bushes and the consideration of using 'green roofs'. All developments on greenfield sites will be expected to achieve greenfield runoff rates.

2.3.2 Melton Borough Council Level 1 and 2 Strategic Flood Risk Assessment

The SFRA for Melton Mowbray (published in October 2015) is used to inform decisions on the location of future development and the preparation of sustainable policies for the long-term management of flood risk. The SFRA contains a Level 1 and Level 2 assessment. The Level 1 assessment provides an appraisal of all potential sources of flooding including Main River, Ordinary Watercourse, surface water and groundwater across the Borough. The Level 2 assessment includes detailed site-specific assessments for the Strategic Site Options as identified by Melton Borough Council. There is no specific mention of the proposed development within the SFRA.

2.3.3 Melton Mowbray Surface Water Management Plan

Surface Water Management Plans (SWMPs) outline the preferred surface water management strategy in a given location. SWMPs are undertaken, when required, by LLFAs in consultation with key local partners who are responsible for surface water management and drainage in their area. SWMPs establish a long-term action plan to manage surface water in a particular area and are intended to influence future capital investment, drainage maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

There is currently no published SWMP for Melton Mowbray.

2.4 Other Relevant Policy and Guidance

2.4.1 Sustainable Drainage Systems: Non-statutory technical standard for sustainable drainage systems

A Non-statutory Technical Standard for Sustainable Drainage Systems guide was published by Defra in March 2015. To be used in conjunction with NPPF and PPG, it sets out non-statutory technical standards for sustainable drainage systems that cover the following areas:

- Flood risk outside the development;
- Peak flow control;
- Volume control;
- Flood risk within the development;
- Structural integrity;
- Designing for maintenance considerations; and
- Construction.

2.4.2 Building Standards Regulations 2000 Part H

The Building Standards Regulations 2000 Part H[17] requires that surface water runoff be preferentially discharged first to soakaway, then to surface watercourse and finally to sewer.

2.5 Consultation with Environment Agency & Lead Local Flood Authority

2.5.1 Environment Agency

Initial consultation was undertaken with the Environment Agency Partnership and Strategic Overview Team. This preliminary consultation was to get guidance on the two Eastern Distributor Road route options and to discuss requirements / restrictions on development in Flood Storage Areas (FSA) and compensatory floodplain storage. Based on the outcome of this consultation Option 1, which did not cross the Brentingby Dam's Flood Storage Area was chosen as the preferred option.

Following the scoping phase of the project, regular correspondence has been maintained with the Environment Agency to:

- agree the River Eye hydraulic modelling approach (Refer to meeting minutes provided as Appendix B1) ;

[17] Office of the Deputy Prime Minister (2002) The Building Regulations 2000, Drainage and Water Disposal (Approved Document H)

- to discuss the various River Eye crossing options (Refer to Volume III: Appendix 3.1 of Environmental Statement - River Eye Options Appraisal);
- discuss the proposed River Eye realignment in the vicinity of the proposed crossing (Details provided in Volume III, Appendix 16.5: Water Framework Directive Report of the Environmental Statement);
- obtain the Environment Agency's requirements related to freeboard to be maintained between the design flood level and the proposed River Eye bridge soffit, afflux that may result due to the proposed scheme and flood compensatory storage (Refer to Appendix B2);
- agree the Brentingby Dam Breach modelling approach (Refer to Appendix B3); and
- obtain Environment Agency's Modelling & Forecasting team's comments regarding the River Eye hydraulic modelling (Refer to Appendix B4).

The key guidance provided by the Environment Agency is summarised below:

- When developing the flood risk assessment the vulnerability of the development and the impact of climate change on peak river flows should be considered. In this instance it may be appropriate to consider the impact of the upper end climate change allowance (e.g. 1 in 100yr event plus 50% climate change allowance);
- The Flood Risk Assessment will need to show that the development is safe for its lifetime, taking the upper end climate change scenario into account, and doesn't increase risk of flooding elsewhere;
- The proposed bridge soffit level should be set 600mm above the 100yr+50% CC level modelled in the proposed scheme option i.e. 600mm freeboard should be maintained post scheme. The freeboard should be measured from the highest level;
- The proposed scheme should result in no increase in water levels between the baseline scenario and the post scheme scenario;
- Floodplain compensation may not be required for the development passing through the area benefitting from flood defences, depending on the flood risk mitigation required to ensure there is no increase in flood risk to third parties. However, if flood plain compensation is required, calculation of flood storage volumes should be based on the design event and include an allowance for climate change. As a minimum the EA would expect floodplain compensation providing up to the higher central allowance; and
- Consider the scenario of a breach of the Brentingby Dam. This is considered a low probability/ high impact event. The EA's advice was consider the Brentingby Dam breach scenario modelling to decide on whether to ensure any road and road bridge is designed in such a way as to remain operational during such an event or to accept that such an event would lead to road closures.

2.5.2 Leicestershire County Council (Lead Local Flood Authority)

Leicestershire County Council was consulted in their role as the Lead Local Flood Authority (LLFA). Responses to consultation queries regarding the proposed crossing of the five ordinary watercourses and surface water flood risk issues, provided by the LCC are presented in Appendix C.

2.6 Climate Change

The EA published updated climate change guidance in February 2016[18]. The guidance indicates that climate change is likely to increase river flows, sea levels, rainfall intensity, and wave height and wind speed.

2.6.1 Peak River Flow Allowances by River Basin District

The peak river flow allowances show the anticipated changes to peak flow by river basin district. The range of climate change allowances is based on percentiles. A percentile is a measure used in statistics to describe the proportion of possible scenarios that fall below an allowance level. The 50th

[18] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

percentile is the point at which half of the possible scenarios for peak flows fall below it and half fall above it.

- central allowance is based on the 50th percentile;
- higher central is based on the 70th percentile;
- upper end is based on the 90th percentile.

If the central allowance is 30%, scientific evidence suggests that it is just as likely that the increase in peak river flow will be more than 30% as less than 30%.

At the higher central allowance, 70% of the possible scenarios fall below this value. So, if the higher allowance is 40%, then current scientific evidence suggests that there is a 70% chance that peak flows will increase by less than this value, but there remains a 30% chance that peak flows will increase by more.

Both possible routes are located within the Humber River Basin District. Table 2-3 shows the climate change allowances for the Humber River Basin District.

Table 2-3: Climate Change Allowance for the Humber River Basin District

Allowance category	*Total potential change anticipated for '2020s' (2015 to 2039)*	*Total potential change anticipated for '2050s' (2040 to 2069)*	*Total potential change anticipated for '2080s' (2070 to 2115)*
Upper end	20%	30%	50%
Higher central	15%	20%	30%
Central	10%	15%	20%

2.6.2 Peak River Flow Allowances for Different Assessments

For FRAs, the "flood risk vulnerability classification" (Table 2 in NPPG) for the type of development and the "flood zone" (Table 1 in NPPG) should be used to decide which peak river flow allowances (allowance category) to use based on the lifetime of the proposed route options (Table 2-4).

Table 2-4. Peak River Flow Allowances Based on Flood Risk Vulnerability Classification and Flood Zone

Flood Zone 2
Essential infrastructure – use the higher central and upper end to assess a range of allowances
Highly vulnerable – use the higher central and upper end to assess a range of allowances
More vulnerable – use the central and higher central to assess a range of allowances
Less vulnerable – use the central allowance
Water compatible – use none of the allowances
Flood Zone 3a
Essential infrastructure – use the upper end allowance
Highly vulnerable – development should not be permitted
More vulnerable – use the higher central and upper end to assess a range of allowances
Less vulnerable – use the central and higher central to assess a range of allowances
Water compatible – use the central allowance
Flood Zone 3b
Essential infrastructure – use the upper end allowance
Highly vulnerable – development should not be permitted

More vulnerable – development should not be permitted

Less vulnerable – development should not be permitted

Water compatible – use the central allowance

If (exceptionally) development is considered appropriate when not in accordance with flood zone vulnerability categories, then it would be appropriate to use the upper end allowance.

2.6.3 Peak River Flow Allowances for the Proposed Development

It is assumed that the lifetime of the proposed scheme is 100 years therefore the peak river flow climate change allowances for the lifetime of the proposed route should be assessed as shown in Table 2-5.

Table 2-5:. Peak River Flow Allowances for the Proposed Development

Proposed Development	
River Basin District	Humber
Flood Zone	1, 2 & 3 (including 3b functional floodplain)
Flood risk vulnerability classification	Essential Infrastructure (transport link)
Lifetime of development	100 years
Climate change allowance to be assessed	Higher Central & Upper End Allowances (30% & 50% respectively)

2.6.4 Peak Rainfall Intensity Allowance

Increased rainfall affects river levels and land and urban drainage systems. Table 2-6 shows anticipated changes in extreme rainfall intensity in small and urban catchments. For FRAs and SFRAs, both the central and upper end allowances need to be assessed to understand the range of impact.

Table 2-6: Peak Rainfall Intensity Allowance

Applies across all of England	*Total potential change anticipated for 2010 to 2039*	*Total potential change anticipated for 2040 to 2059*	*Total potential change anticipated for 2060 to 2115*
Upper End	10%	20%	40%
Central	5%	10%	20%

3. Flood Risk to the Development

The NPPF requires site specific FRAs accompanying planning applications to assess the risk of all sources of flooding to and from the development and to demonstrate how these flood risks will be managed so that the development remains safe throughout its lifetime, taking climate change into account.

The following flood risk baseline is based on publically available information including the SFRA, PFRA and Environment Agency Interactive Flood Maps (online). More detailed flood information has been requested from, and provided by, the Environment Agency, including the River Wreake hydraulic model that informs the baseline fluvial flood levels for the River Eye (Main River).

3.1 Fluvial Flood Risk

The proposed route alignment cross a total of six watercourses as identified in Figure 16.2 provided in Appendix A. The River Eye is an Environment Agency Main River at the crossing point, whilst the remaining is classed as Ordinary Watercourses (note that Thorpe Brook becomes a Main River upstream of the A607 and Scalford Brook downstream of the disused railway embankment).

The majority of the proposed route is located within Flood Zone 1 (Environment Agency Flood Map for Planning, 2017) and are therefore considered to have a low risk of flooding. Flood Zone 1 comprises land assessed as having a less than 1 in 1000 year, or <0.1% Annual Exceedance Probability (AEP) of fluvial or tidal flooding in any given year. Given the proposed use of the development (highway), development within these areas is considered acceptable from a flood risk perspective.

Areas of higher risk are associated with the watercourses identified above and the crossing locations are discussed in further detail below.

3.1.1 River Eye (Main River)

The proposed route alignment takes the highway through an area shown to benefit from flood defences which is afforded a 1% AEP standard of protection as a result of the Melton Mowbray Flood Alleviation Scheme (FAS) at Brentingby located approximately 250m upstream (to the south). The FAS was completed in 2003, providing alleviation for over 650 residential and commercial properties in the town. The structure across the River Eye enables storage of approximately 3.7 million cubic metres of water across an area of 2.4km^2.

The proposed crossing location is such that the highway would intersect Flood Zones 2 and 3, including Flood Zone 3b (Functional Floodplain).

To achieve comprehensive understanding of flood risk posed by River Eye to its immediate surroundings in the vicinity of the proposed MMDR, AECOM has undertaken an update to the existing hydraulic modelling of the current channel conditions to provide a baseline for comparison of the potential impacts and/ or benefits of the proposed replacement bridge design.

Hydraulic Modelling

The Environment Agency supplied AECOM with the latest model of the River Wreake (Eye) and its tributaries, last updated by Halcrow in 2011. Upon review of the supplied model, it was concluded that modifications would be required in order to include the Lag Lane tributary within the baseline scenario model. The baseline scenario model was further updated to include newly available channel survey data in the vicinity of the proposed crossing.

The proposed scenario model was developed to include the proposed bridge design, realigned River Eye channel upstream of the proposed bridge, diverted Lag Lane Watercourse and associated culverts under Lag Lane and Saxby Road.

Detailed reporting of the work carried out, including the modelling methodology, is provided in the Hydraulic Modelling Report in Appendix D.

The results of the modelling and the implications for flood risk at the River Eye crossing for the proposed route are summarised below.

Existing Baseline Model Results

In the 1% AEP event (1 in 100 Year Return Period), the baseline model results indicate that River Eye does not overtop its banks, which can be attributed to the presence of the Brentingby Dam upstream., however localised flooding of the Lag Lane and Saxby Road junction is shown to occur from the existing culvert that joins the Lag Lane watercourse to the River Eye.

In the 1% AEP + 50% climate change event (1 in 100 Year + 50% CC), the floodplain along the River Eye is inundated; the modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 73.8mAOD (this flood level was taken from the 2D modelled flood elevation in the vicinity of the proposed River Eye bridge).

Figures 3-1 and 3-2 below provide the modelled flood depths in the baseline scenario for the 1% AEP (1 in 100 Year Return Period) and in the 1% AEP + 50% climate change (1 in 100 Year + 50% CC) events respectively.

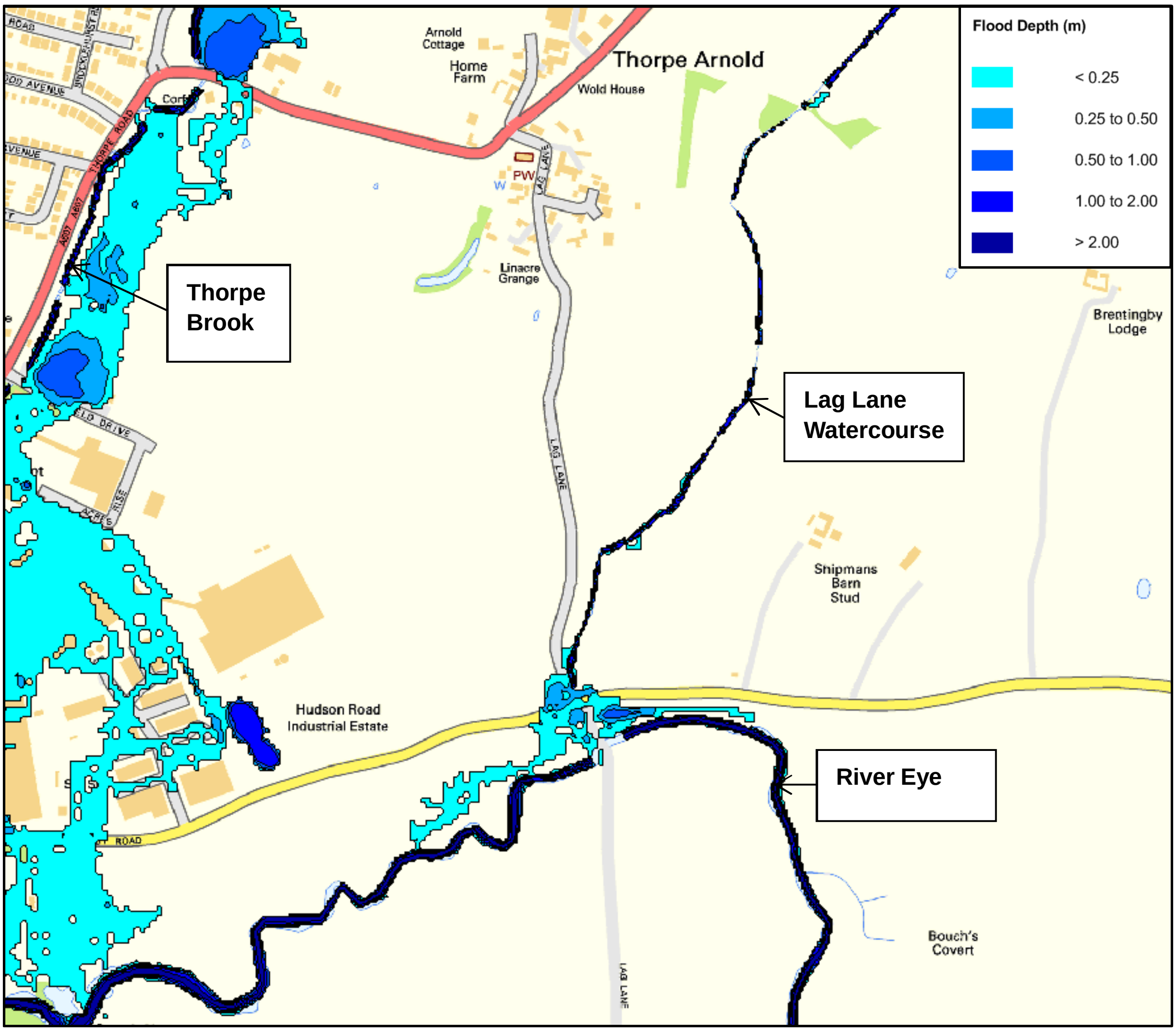


Figure 3-1 Baseline Scenario Modelled Flood Depths in the 1% AEP event

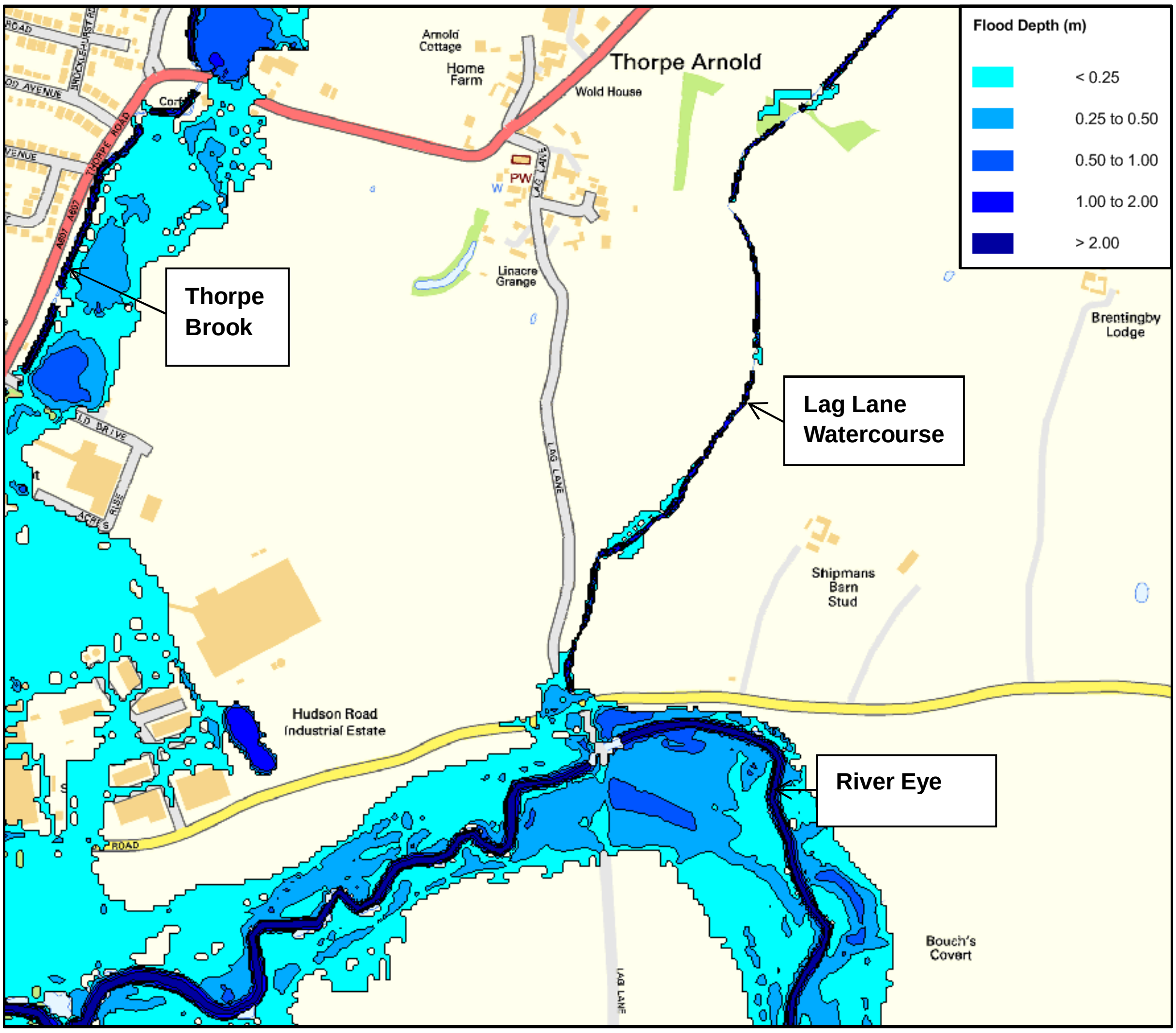


Figure 3-2 Baseline Scenario Modelled Flood Depths in the 1% AEP+ 50% Climate Change event

Proposed Model Results

In the proposed scenario, hydraulic modelling has shown that there is no flooding of the proposed scheme up to the design standard of 1% AEP + 50% climate change (1 in 100 Year + 50% CC) event. In addition, hydraulic modelling has shown that the proposed diversion of the Lag Lane watercourse, realignment of existing Saxby Road, Lag Lane and the proposed culverts (C04 & C05) has eliminated flooding of Saxby Road.

The modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 74.05m AOD, for a 1% AEP plus 50% climate change event (this flood level was taken from the 2D modelled flood elevation in the vicinity of the proposed River Eye bridge). The minimum level of the road in this area is 74.19m AOD (approximately where Lag Lane Bridge was located); hence the freeboard to the proposed highway is at least 140mm.

The soffit level of the proposed River Eye bridge is 76.18m AOD, and therefore has a freeboard of 2130mm. The freeboard of the main bridge successfully meets the standard design standards outlined by the EA, which requires a minimum of 600mm freeboard above the 1% AEP + 50% climate change event flood level.

The minimum soffit level of any of the bridge spans is 74.97m AOD (located to the north of the main bridge), and therefore has a minimum freeboard of 920mm which again exceeds the EA minimum design standards.

Figures 3-3 and 3-4 below provide the modelled flood depths in the proposed scenario for the 1% AEP (1 in 100 Year Return Period) and in the 1% AEP + 50% climate change (1 in 100 Year + 50% CC) events respectively.

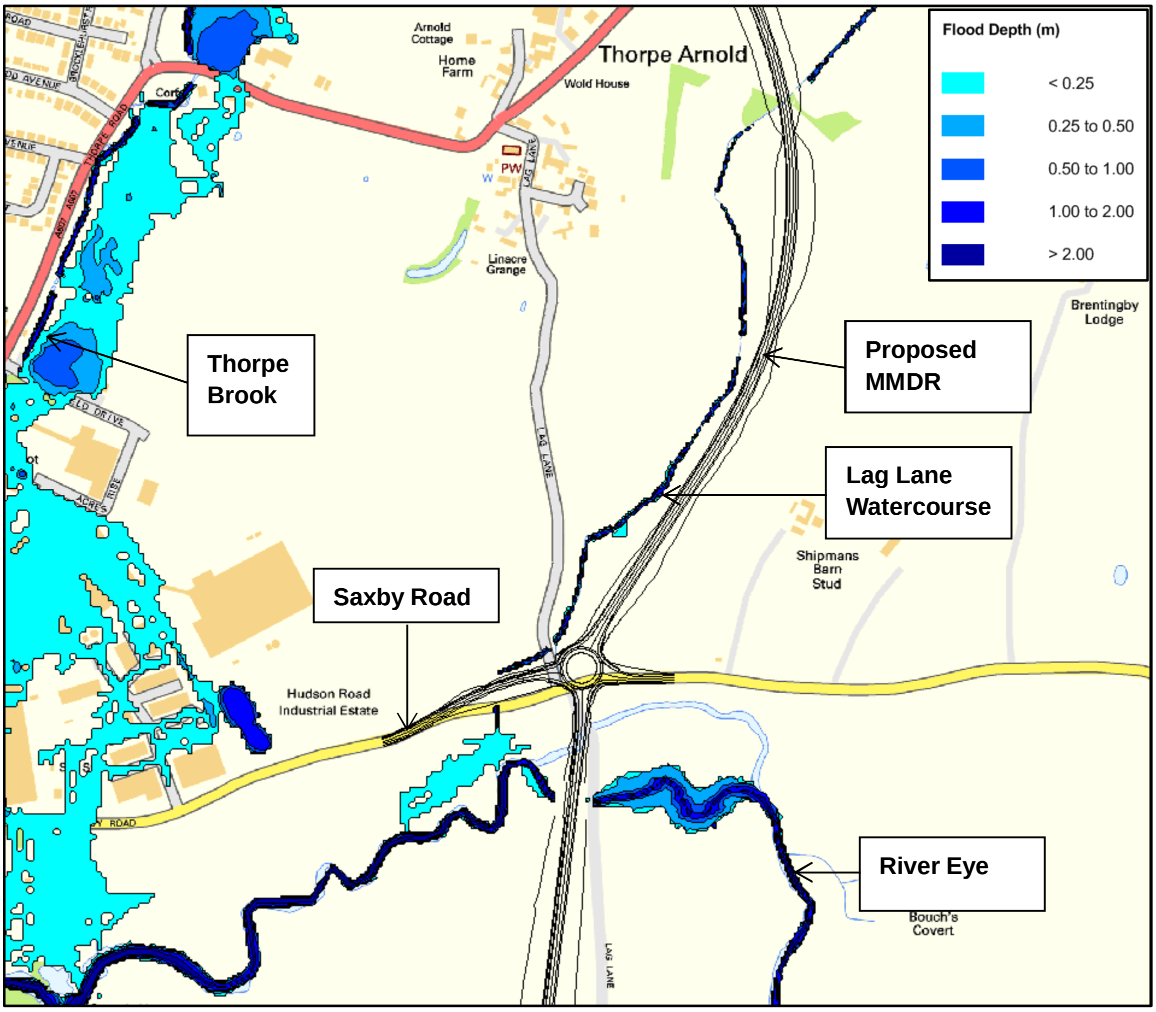


Figure 3-3 Proposed Scenario Modelled Flood Depths in the 1% AEP event

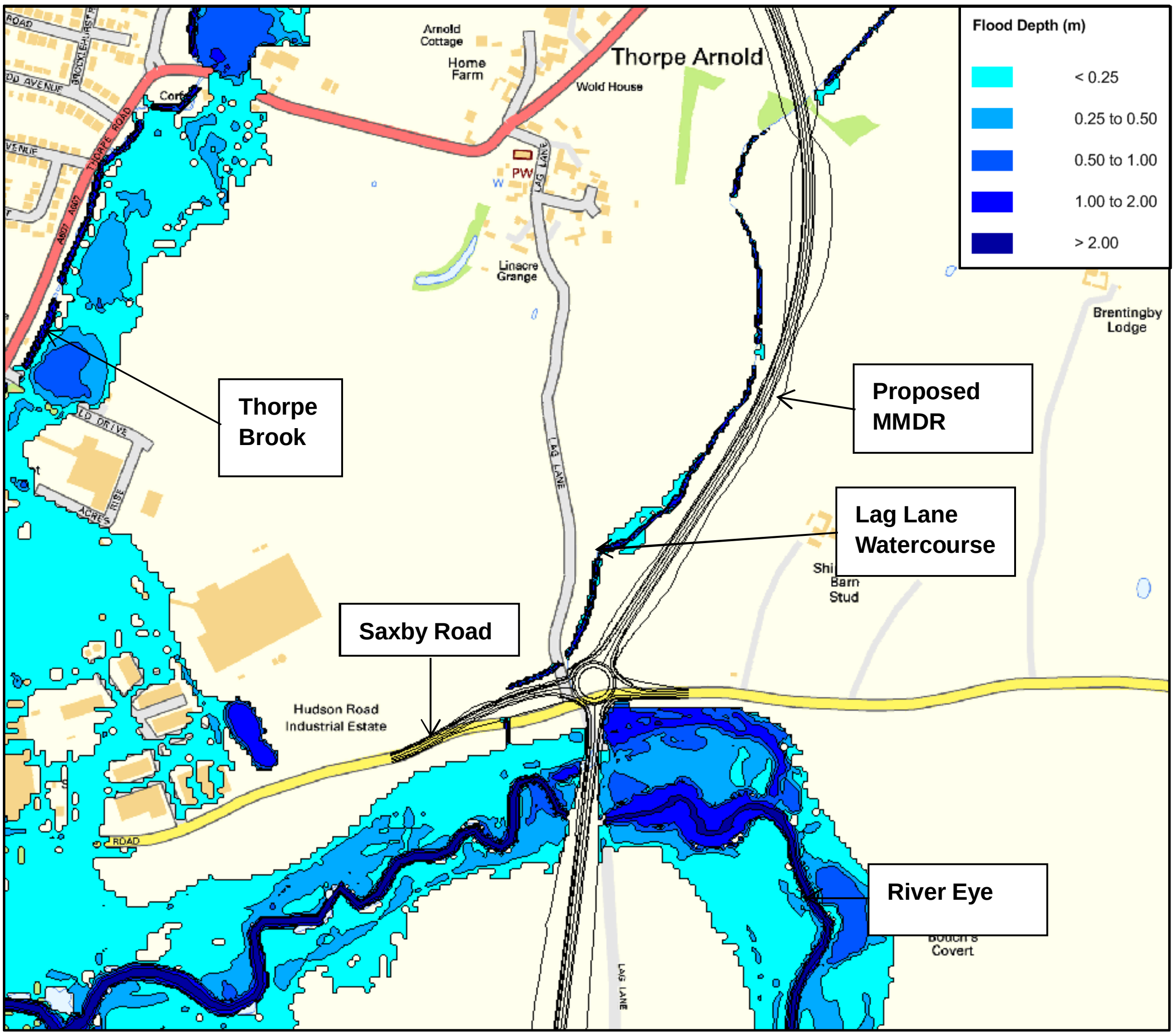


Figure 3-4 Proposed Scenario Modelled Flood Depths in the 1% AEP + 50% Climate Change event

Thus, the flood risk from the River Eye to the proposed scheme is considered low since hydraulic modelling has demonstrated that there is no flooding of the proposed highway even in the 1% AEP + 50% CC event.

3.1.2 Ordinary Watercourses

3.1.2.1 Methodology used to size structures

As previously stated in Section 1, the proposed scheme crosses five ordinary watercourses. At this stage, hydraulic modelling has been undertaken only for the Lag Lane watercourse in compliance with LCC's requirements (refer to consultation response in Appendix C) since flooding in the area of its confluence with the River Eye has been reported in the past. The Lag Lane tributary was incorporated into the River Eye model. However, it was agreed with LCC (LLFA) to use simple (non-hydraulic modelling) techniques to estimate culvert sizing on the other Ordinary Watercourse/ tributary crossings.

Early on in the course of this project, a technical note was produced that provided a starting point for the structural team to size culvert crossings and bridge structures for all Ordinary Watercourses not being modelled at this stage. This technical note has been included in Appendix E1.

A summary of the methods used for sizing of the structures from the technical note is provided below:

1. Hydrological Analysis: In order to estimate peak flows, the FEH statistical, ReFH and ReFH2 methods were applied to derive flows for each catchment.

2. Culvert Size Analysis: Three methods were then used to make a rough assessment of the culvert size for the 1% AEP design event:

   a) A simple "pipe flow" program, which involved a trial and error approach, was used to determine the range of diameters which could effectively convey the target flows. This method required a number of assumptions to be made, such as the slope of the culvert, and the finish of the pipe. This method also does not account for inlet losses or backwater effect, and is based on full bore flow. An increase in the diameters may be required to account for these.
   b) The small orifice equation (standard hydraulic theory) method involves determining the pipe diameter which will achieve the required peak flow. ReFH2 was used as it provided the highest flows. This option also requires assumptions on the slope and pipe finish, and does not account for inlet losses or backwater effect, but is based on full bore flow. An increase in the diameters may be required to account for these.
   c) The Manning's equation method involves using standard hydraulic theory. The span culvert width was pre-determined based on assessment of existing watercourse top width. The box culvert rise was then determined in order to achieve a peak flow. ReFH2 based peak flows have been considered here, as they provide the highest flows. The same assumptions and allowances should be made as with methods 1 & 2.

   Ultimately, the Small Orifice equation and Manning's equation were used to determine the required circular pipe size and/or box culvert sizing, as they provided the largest estimations for sizing and therefore a conservative approach.

3. Sensitivity Analysis for climate change: To make allowances for climate change, the diameter sizes were increased by 20%, 30% and 50%, and tests were carried out to reveal sensitivities to different Manning's equations.

Thus, the sizing of the proposed structures on the remaining four Ordinary Watercourses were based on the above methodology, to convey the 1% AEP + 50% climate change event flows, thus maintaining current conditions where no flow constrictions are imposed in these locations.

LCC (LLFA) has indicated that the above method is acceptable with a condition that existing channel capacities be assessed and not reduced by the proposed structures. (See consultation response provided in Appendix C).

3.1.2.2 Existing Capacity Assessment of Ordinary Watercourses at Proposed Crossing Locations

The capacity assessment of the ordinary watercourses, at the proposed crossing locations, has been undertaken using the channel cross-section survey data collected in July-August 2018. This capacity assessment has been undertaken for unnamed Ordinary Watercourses located adjacent to Sysonby Farm and Sysonby Lodge, as well as for Scalford Brook and Thorpe Brook. The Lag Lane watercourse has not been included within this assessment since it has been modelled along with the River Eye. Appendix E2 includes the channel cross section and long section survey data, photographs of the watercourses captured during the survey and calculations of the existing channel capacities using Manning's equations.

The surveyed cross section data was entered into Flood Modeller software to obtain details of the channel geometry required for capacity calculations. The assumed values for Manning's n were based on the condition of the channels from the photographs captured during the survey. The slope values used for the calculations were based on the long sections from the survey where available. Portions of the Sysonby Farm watercourse could not be surveyed due to dense vegetation growth. Based on discussions with LCC it, was decided not undertake the required vegetation clearance prior to the survey due to issues related to land owner permissions. Thus, for the Sysonby Farm watercourse, it has been assumed that the slope of the channel at the proposed location is the same as the portion immediately upstream of it.

Table 3-1 Existing Channel Capacity at Proposed Crossing Locations

Watercourse	Survey Cross-Section ID	Assumed Manning's n	Existing Channel Capacity (m^3/s)
Unnamed Ordinary Watercourse located adjacent to Sysonby Lodge Farm	SF2	0.06	1.15
Unnamed Ordinary Watercourse located near Sysonby Lodge	SL1	0.06	1.23
Scalford Brook	SB2	0.04	20.19
Thorpe Brook	TB2	0.035	12.83

Box culverts sized 1.5m x 1.5m are proposed for the Sysonby Farm and Sysonby Lodge watercourse crossings. The maximum flows that the proposed culverts would allow were calculated using Manning's equation to be $15.4m^3/s$ for C01 and $13.3m^3/s$ for C02, respectively. Thus, the proposed culverts do not reduce the existing channel capacities for these two water courses.

For Scalford Brook and Thorpe Brook, open span structures are being proposed which would not result in reduction of existing channel capacities.

Thus, in compliance with LCC's requirements, this assessment has shown that the proposed culverts and open span structures are sized such that the existing channel capacities at the proposed crossing locations are not being reduced.

3.1.2.3 Thorpe Brook

Thorpe Brook flows in a southerly direction for approximately 2 km before joining the River Wreake in Melton Mowbray.

At the point where the crossing occurs, Thorpe Brook is considered Ordinary Watercourse rather than Main River. The crossing is shown to be in Flood Zones 2 & 3 but doesn't exist in the supplied EA River Wreake model flood outlines. The EA confirmed that the Ordinary Watercourse had been mapped based on broadscale (flood spreading) modelling methodology. The National Flood Zone 3 outline GIS layer confirmed that the width of the floodplain in this area, based on the broadscale modelling, is approximately 100m. Since the accuracy of broadscale modelling is limited, and the source of DTM data used to undertake the modelling is unknown, we consider that these outlines have a high level of uncertainty and are not appropriate for determining structure dimensions or assessing changes to flood risk.

For the Thorpe Brook crossing, given the size of the watercourse, an open-span bridge structure has been proposed to provide the least environmental impact and to be consistent with Water Framework Directive objectives. Therefore, the height was based on the Manning's equation calculation of box culvert size as defined in the technical note in Appendix E. As a validation exercise, the 1% AEP event peak flows from the ReFH2 method was compared with the inflow to Thorpe Brook within the EA's River Wreake model. It was found that there was no significant difference between the two flows, the EA model had a 1% AEP event peak flow of $8.2m^3/s$, based on a 21.25-hour storm applicable to the wider River Eye catchment. The calculation assessment of Thorpe Brook for the 1% AEP event gave a peak flow of 7.8 m^3/s from the ReFH2 method (comparable catchment area but shorter storm duration, more applicable to the Thorpe Brook catchment only).

The span of the proposed bridge crossing Thorpe Brook, north of Thorpe Arnold, is anticipated to be approximately 15.5m. This span was based on calculations provided in the Culvert Sizing Technical Note (Appendix E) to allow 1% AEP + 50% climate change event flows, ecological requirements (minimum setback of 2m on either side of the river channel from top-of-bank to accommodate water vole habitat) and to allow a 5.5m-wide access track to pass beneath one of the open-span structures.

The flood risk to the proposed MMDR from Thorpe Brook is considered low since the proposed structure over Thorpe Brook is a 15.5m clear open-span bridge, and its soffit level is approximately 5.8m above the top-of-bank. This proposed structure does not pose restrictions to the existing channel capacity and is elevated on embankments. Through consultation with the LLFA, hydraulic modelling could be undertaken to confirm the flood risk when applying for Land Drainage Consent.

3.1.2.4 Scalford Brook

Scalford Brook flows in a southerly direction parallel to Thorpe Brook for approximately 2.7 km before its confluence with the River Wreake in Melton Mowbray. The EA Flood Map for Planning shows that where the proposed route crosses Scalford Brook the proposed development will be located within Flood Zones 2 and 3. As with Thorpe Brook, the crossing is shown to be in Flood Zone 3 but doesn't exist in the supplied EA River Wreake model flood outlines.

The span of the proposed bridge crossing Scalford Brook is anticipated to be approximately 9m. This span was based on calculations provided in the Culvert Sizing Technical Note (Appendix E) to allow 1% AEP + 50% climate change event flows, ecological requirements (minimum setback of 2m on either side of the river channel from top-of-bank to accommodate water vole habitat) and to allow an access track to pass beneath one of the open-span structures. The proposed bridge soffit level is approximately 1.75m above the top-of-bank.

The flood risk to the proposed scheme from Scalford Brook is considered low since the proposed structure over it is a 9m clear open-span bridge and its soffit level is approximately 1.75m above the top-of-bank. The proposed structure is unlikely to pose restrictions to the existing channel capacity, and the proposed scheme is elevated on embankments. Through consultation with the LLFA, hydraulic modelling could be undertaken to confirm the flood risk when applying for Land Drainage Consent.

3.1.2.5 Lag Lane Watercourse

As mentioned previously, the Lag Lane watercourse has been included in the River Eye hydraulic modelling. Details of the proposed diversion of the Lag Lane watercourse and the three proposed culverts have been explained in Section 1.3. The baseline model shows that the risk of flooding from Lag Lane Watercourse is moderate in the vicinity of the existing Lag Lane/ Saxby Road junction. However, the proposed scenario model results have shown that the flood risk to the proposed MMDR and the realigned Lag Lane/ Saxby Road junction is low since there is no flooding even in the 1% + 50% CC event.

3.1.2.6 Other Ordinary Watercourses located

Flood Zones are not available for the two Ordinary Watercourses adjacent to Sysonby Lodge Farm that are crossed by the proposed MMDR. They are not covered by EA flood mapping due to the small catchment area. However, the proposed culverts on these two watercourses have been over-sized to convey 1% AEP + 50% climate change event peak flows and thus will maintain existing conditions. These two watercourses are located in agricultural land. The methodology used to size these two culverts has been explained in previous sections and in Appendix E.

During consultation, LCC's Flood Team (LLFA) requested further consideration of the potential of flooding from the Ordinary Watercourses with no flood zones, located close to some of the proposed balancing ponds. The balancing ponds are intended to provide attenuation of surface water runoff from the proposed highway prior to disposal and LCC required confirmation that the capacity will be available for surface water attenuation. Specifically, the Ordinary Watercourses adjacent to proposed balancing ponds A, E, and I.

The 1 in 100 year flows in these watercourses adjacent to the proposed pond locations were calculated using the methodology in the Design Manual for Roads & Bridges, HA106/04 'Drainage of runoff from Natural Catchments', including for a 40% allowance for climate change. The calculated flows were then translated to a depth of flow in the watercourse utilising channel flow calculations in conjunction with surveys of the watercourse cross sections. The calculations showed that for Ponds A and I the forecast flows are comfortably retained within the watercourse sections but for Pond E there is potential for some out of channel flooding.

The peak flow at Pond E exceeded the channel capacity at the narrowest section and only marginally at another section downstream, both on the same side as the pond side. Inspection of the cross-sections and contours indicates there is a slight depression beside the watercourse and localised flooding would occur. Part of Pond E extends into this slight depression and consequently there is a risk that this flooding could impact on the pond. However this can and will be easily mitigated, with a low bund, typically 0.5m high, around the affected part of the pond. The details of these flow calculations and cross section data of the existing channels is provided in the Surface Water Drainage Plan (Appendix F) and (Volume III, Appendix 16.6 of the Environmental Statement).

3.2 Tidal Flood Risk

Due to the distance from the coast the proposed route is located outside of the tidal influence and as such is not considered to be at risk of flooding from this source. Further investigation and specific mitigation for tidal flooding is therefore not required.

3.3 Surface Water Flood Risk

The proposed scheme alignment is entirely on undeveloped (greenfield) land currently used for agricultural purposes.

The Environment Agency Surface Water Flood Risk map[19] indicates that the risk to the highway alignment is generally classed as 'Very Low'. Very Low chance of surface water flooding means that there is a less than 1 in 1000 (<0.1%) annual probability of flooding in any given year.

There are areas of increased flood risk identified along the route, ranging from 'Low' (Between 1 in 100 and 1 in 1000 (1% - 0.1%) annual probability of flooding in any given year) to 'High' (greater than 1 in 30 (>3.3%) Annual Probability of Flooding in any given year). However, it is noted that these are associated with the watercourses that cross the study area and as such the current risk of flooding from surface water is considered to be low.

The drainage of the proposed route will be designed in line with current highway design standards to ensure that the risk of flooding to the MMDR remains low.

3.4 Flooding from Artificial Sources

3.4.1 Reservoirs

Both flood storage areas - Scalford Brook Reservoir and the Brentingby Flood Storage Reservoir - located along the route alignment are classed as reservoirs due to the volume of water that they have the capacity to store. The Environment Agency Risk of Flooding from Reservoirs Map[20] indicates that the proposed scheme is located within the maximum extent of flooding from reservoirs at the location of the River Eye crossing.

Flooding from reservoirs is extremely difficult to predict as it may happen with little or no warning, and evacuation will need to be undertaken immediately. Whilst the risk of flooding from reservoirs is considered unlikely due to their highly regulated nature and strict maintenance controls, the Environment Agency mapping shows a credible worst case scenario. Due to the nature of the development, the risk of flooding from this source would have a lower impact than if considering a residential development for example and, whilst a residual risk of flooding remains, the risk of flooding from this source is considered to be low.

During consultation, the EA recommended that the impact of breach of Brentingby Dam on the flood risk to the proposed scheme be considered in order to decide on whether to ensure any road and road bridge is designed in such a way as to remain operational during such an event or to accept that such an event would lead to road closures. Brentingby Dam breach modelling was undertaken, details of which are provided in a technical note as Appendix G.

A summary of the Brentingby Dam breach modelling is provided below:

[19] Available at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. Last accessed on 05/09/18

[20] Available at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map. Last accessed on 05/09/18

Based on modelling results for the 1% AEP + 30% CC event (the severest event rarity required by the EA), the proposed MMDR would be flooded by a breach of Brentingby Dam. The overtopping of the road would occur close to the River Eye bridge, where the vertical alignment is at its lowest. The proposed junction/roundabout 5 is also inundated in this breach scenario.

In the existing situation, the same breach scenario would have overtopped the Lag Lane and inundated the staggered junction of Lag Lane and Saxby Road.

The extent of flooding in the breach scenario is greater in the proposed model compared to the baseline model, upstream of the proposed scheme. . This is because the embankment creates a larger barrier to the flow path than the existing Lag Lane (southern branch). This is shown in Figure 3-5.

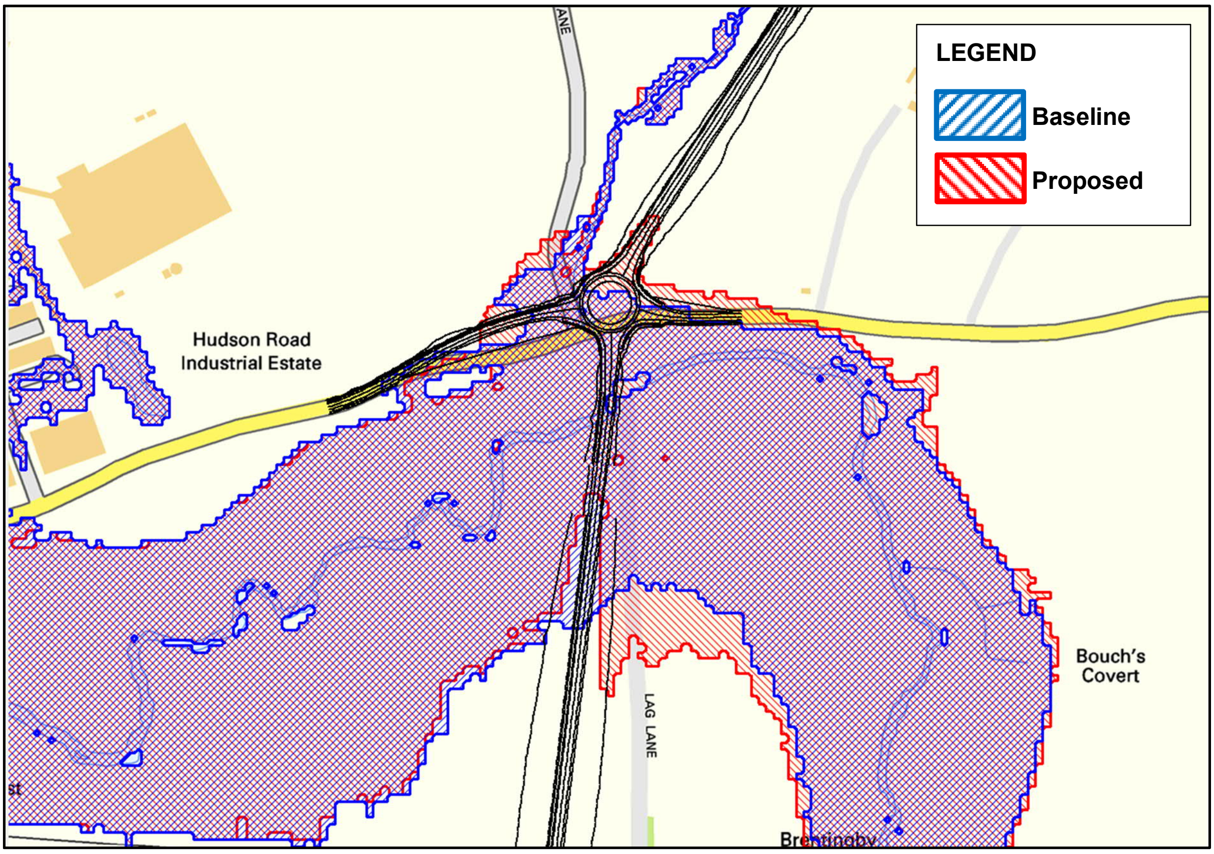


Figure 3-5 Comparison of 1% AEP + 30% climate change event breach scenarios, between baseline and proposed models

Presently, the breach modelling has been based on now superseded versions of both the baseline and proposed models. However, the overall effects are unlikely to be significantly different when applied to the updated models, since the main controls are the breach volume itself (which will not change) and the proposed road embankment geometry (which also has not varied significantly).

The proposed route passes through the northern extent of Melton Country Park where a series of online small lakes form the small Scalford Brook Flood Storage Area. These ponds are permanently wetted areas with a flood defence bund at the downstream extent to retain water during high flow events. At present the storage area is not considered to have an impact on highway alignment based on a review of LiDAR data.

3.4.2 Ponds / Lakes

A review of OS mapping and aerial imagery has identified two large waterbodies along the proposed route.

Two large artificial boating lakes are located approximately 120 m to the north east of the proposed route in the location of the proposed Thorpe Brook crossing. These lakes are part of Twinlakes

Theme Park and are assumed to be highly regulated waterbodies with controlled inflow / outfall and with limited, or no, connectivity to local river systems. As such the risk of flooding from these lakes is considered to be low.

In addition, a small pond (OS Grid Ref: SK 77472 20171) is indicated on OS mapping where the proposed scheme alignment crosses the unnamed ordinary watercourse (Lag Lane watercourse) east of Thorpe Arnold. Aerial view photography doesn't indicate the presence of a pond here so it may just be a small depression where water collects. The development proposals show that the pond will be infilled by the highway embankment. During the detailed design stage, we will investigate if the pond is a formal feature. If required, the pond can be recreated and any connectivity re-established in consultation with LCC. Thus, the risk of flooding from this pond is considered to be low.

No other artificial waterbodies, including canals, have been identified in the vicinity of the proposed route alignment.

Based on the information above the risk of flooding form artificial sources (reservoirs, canals, lakes) is considered to be low.

3.5 Flooding from Groundwater

The underlying geology of the study area is discussed in detail in Chapter 9: Geology & Soils of the Environmental Statement. The bedrock geology across the alignment is mudstone (Blue Lias Formation and Charmouth Mudstone Formation), overlain by superficial geology of predominantly alluvium associate with the River Eye, Thorpe Brook and Scalford Brook with Glaciofluvial deposits (sand and gravel), Head deposits (clay, silt, sand and gravel) and Glaciolacustrine deposits (clay, silt and sand).

The Environment Agency groundwater maps confirm that the route alignment is not located over a Principal aquifer. The superficial geology is classified as a Secondary aquifer (undifferentiated). Due to the variable characteristics of the rock type in this area these aquifers are characterised by either permeable layers capable of supporting water supplies at a local (as opposed to strategic) scale and in some cases form an important source of base flow to rivers, or lower permeability layers which may store or yield limited amounts of groundwater due to localised features (e.g. fissures, thin permeable horizons and weathering).

The Environment Agency's national Areas Susceptible to Groundwater Flooding (AStGWF) dataset provides the basis for assessing future flood risk from groundwater. The mapping is based on the BGS 1:50,000 Groundwater Flood Susceptibility Map and covers consolidated aquifers (chalk, sandstone etc.) and superficial deposits. The mapping does not take account of the chance of flooding from groundwater rebound. It shows the proportion of each 1km grid square where geological and hydrogeological conditions indicate that groundwater might emerge. The PFRA and SFRA include mapping showing susceptibility of the area to groundwater flooding. This shows that the northern part of the proposed alignment, from Thorpe Arnold, is located in an area where the Susceptibility to Groundwater Flooding is less than 25%. The southern part of the route, south of Thorpe Arnold through Brentingby, is shown to have a greater than 25% but less than 50% susceptibility to groundwater flooding. In addition the PFRA states that groundwater rebound is not believed to be an issue within the county.

Ground investigations undertaken for the scheme so far have been summarised in the Ground Investigation Report (Volume III, Appendix 9.1 of the Environmental Statement). The Ground Investigation Report states that across the site in general, a shallow groundwater table is present. It is considered most likely that this water table is perched within the upper layers of superficial materials. Groundwater is also to be expected at depth, and cutting excavations are likely to liberate water in the form of seepages from any higher permeability zones of relatively granular material. It is not yet certain whether the groundwater released in this way will originate from isolated pockets of trapped water or from a wider groundwater table.

It is considered that the shallow groundwater tables encountered are primarily fed by surface infiltration. However, in the vicinity of water courses it is likely that the shallow water tables are connected to these surface flows.

Furthermore it is likely that the artesian flows seen around the River Eye are being fed by lateral infiltration from higher ground, possibly from the Bytham Sands. Artesian water could present a significant risk to the construction of piles in this area. Therefore appropriate de-watering and drainage must be provided during the construction phase.

The Surface Water Drainage Plan (Appendix F) suggests the use of combined surface water and groundwater filter drains to drain the main carriageway and protect the pavement from groundwater ingress. Thus, the risk of emergence of groundwater can be mitigated through implementation of appropriate drainage and appropriate flood routing. A comprehensive groundwater mitigation strategy should be considered at the detailed design stage.

Based on the adoption of appropriate mitigation strategies the risk of flooding from groundwater emergence at this site is considered to be low.

3.6 Flooding from Sewers and Drains

The SFRA contains information on sewer flooding obtained from DG5 Registers provided by Severn Trent Water. The water companies maintain this as a live document as part of a wider register of incidents. It is important to note that the DG5 is a record of past incidents and is not a record of properties at risk of sewer flooding. The water companies carry out a programme of updates based on the information in the DG5 register and so properties on it and / or areas affected may already be subject to mitigation works to alleviate flooding problems. When improvements have been made to rectify a known problem the affected properties are taken off the register.

The PFRA reports that numerous sewer flooding events have been recorded across the Leicestershire area. Areas where flooding is recorded to have affected five or more locations (accurate to 4 – 5 postcode digits) are presented in Table 4-5 of the PFRA. None of the locations reported are within the study area.

Given the rural nature of the route alignment, the current risk from sewers and drains is considered low. However, if not appropriately managed runoff from the highway development has the potential to cause a significant increase in flood risk from this source as a result of increased pressure on existing systems.

3.7 Summary of flood risk to the development

Table 3-2 Summary of Flood Risk to the Proposed Development

Flood Risk	Summary of Risk to Development Site	Notes	Mitigation Required
Fluvial	Very Low – Majority of the proposed alignment except in the vicinity of proposed water course crossings Low – In the vicinity of the proposed River Eye and Ordinary Watercourse crossings	The proposed alignment is located in Flood Zones 1, 2 and 3. Therefore flooding from fluvial sources is a risk. However, hydraulic modelling has shown that the fluvial flood risk to proposed scheme in the vicinity of River Eye and Lag Lane Watercourse crossings is low and the design of these crossings has taken flood risk into consideration. *Flood risk from Thorpe Brook, Scalford Brook and the two Ordinary Watercourses adjacent to Sysonby Lodge Farm is considered to be low since the proposed crossing structures have been over-sized to handle peak flows in the 1%+ 50% climate change event. Through consultation with the LLFA, hydraulic modelling could be undertaken to confirm the flood risk when applying for Land Drainage Consent.	No*

Flood Risk	Summary of Risk to Development Site	Notes	Mitigation Required
Surface Water	Low	The risk of flooding from surface water to the site is 'Low' overall. However, there are small areas of 'Medium' or 'High' associated with the proposed watercourse crossings.	No
Groundwater	Low	Based on the adoption of appropriate mitigation strategies the risk of flooding from groundwater emergence at this site is considered to be low.	No
Sewer and Water Supply Infrastructure	Low	Given the rural nature of the route alignment, the current risk from sewers and drains is considered low.	No
Artificial Sources	Low	The EA Flooding risk from Reservoirs map indicates that the proposed MMDR is located within the maximum extent of flooding from reservoirs at the location of the River Eye crossing due to its proximity to the Brentingby Dam. The risk of flooding from reservoirs is considered unlikely due to their highly regulated nature and strict maintenance controls; the EA mapping shows a credible worst case scenario.	No

4. Flood Risk from the Proposed Scheme

4.1 Impact on Fluvial Flood Risk

4.1.1 River Eye and Lag Lane Watercourse

In the 1% AEP event, in the proposed scenario (See Figure 3-3), hydraulic modelling results showed that there is no overtopping of its banks by from the River Eye except in the inset floodplain between the realigned River Eye channel and the backwater channel that is to be retained upstream of the proposed bridge. The realigned and re-profiled River Eye channel upstream of the proposed River Eye bridge has been designed such that the inset floodplain of the realigned channel floods during a flood event to improve the geomorphological condition of the river channel. Further details of the River Eye realignment design can be found in the Water Framework Directive Assessment Report (AECOM, 2018); Appendix 16.5 of the ES

To investigate whether the proposed highway changed the flood risk on the River Eye, the baseline results have been compared to the proposed development modelling results for the 1% AEP plus 50% climate change event. Figure 4-1 shows the flood depth-difference map between the baseline and proposed highway model results.

Note that the tabulated 1D results are not provided because, since the River Eye has been diverted in the proposed scenario, a like-for-like comparison is not possible in the area immediately upstream of the new bridge.

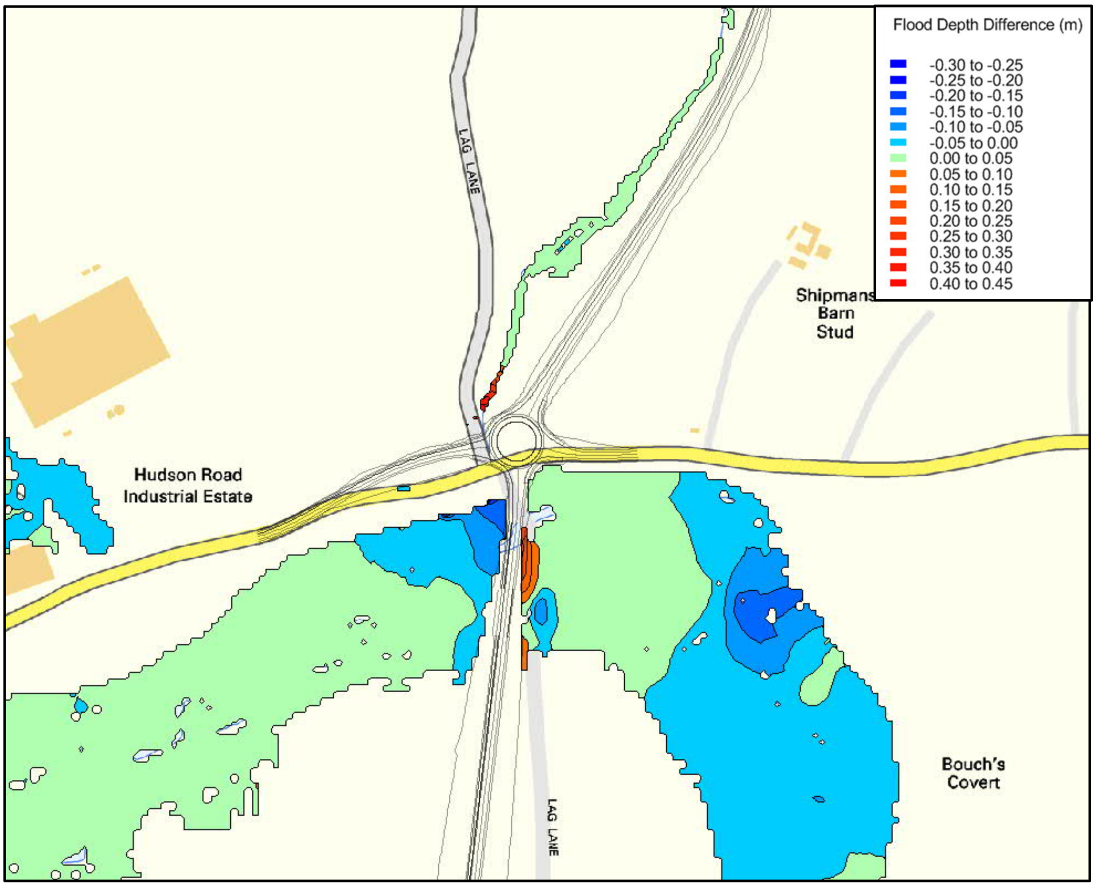


Figure 4-1 Map showing the flood depth difference between the baseline and proposed highway for the River Eye and Lag Lane Brook.

Figure 4-1 shows the proposed highway will increase water depths upstream and downstream of the River Eye Bridge by up to 0.05m. This increase is considered negligible and within modelling tolerances. Very localised water depths may increase by approximately 0.25m adjacent to the proposed highway, south of the removed Lag Lane Bridge.

The localised increase in flood levels upstream and downstream of the proposed bridge may be attributed to land raising within the floodplain for the highway embankments.

An excerpt from EA's response to our consultation query regarding increase of flood levels due to the proposed scheme is provided below:

"There should be no increase in flood depth or extent as a result of the proposed development, this includes impacts on third party land. If you are proposing that there is no other option that would not result in increased depth or extent of flooding we would need the increase in risk to be quantified e.g. area affected and depths, along with evidence that you have explored all possible mitigation options. We may still object to any increase in flood risk to third party land if we feel that risk is unacceptable or there remain possible mitigation options which have not been explored"

The proposed design and the location of the River Eye Bridge has evolved over time taking into account many factors, including the presence of overhead powerlines (OHL), the need to maintain an adequate vertical clearance from the OHLs, and the Environment Agency's afflux and freeboard requirements at the new bridge crossing. Previously, a single span option supported by earth embankments with flood relief culverts was proposed and tested as a potential scenario within the flood model. However, this option performed less well hydraulically than the current option, where modelling has demonstrated that there is no significant upstream afflux and an adequate freeboard consistent with EA requirements. The proposed multi-span River Eye crossing structure is considered to be the optimum solution from a flood risk point of view, since it offers floodplain continuity compared with embanking and disconnection.

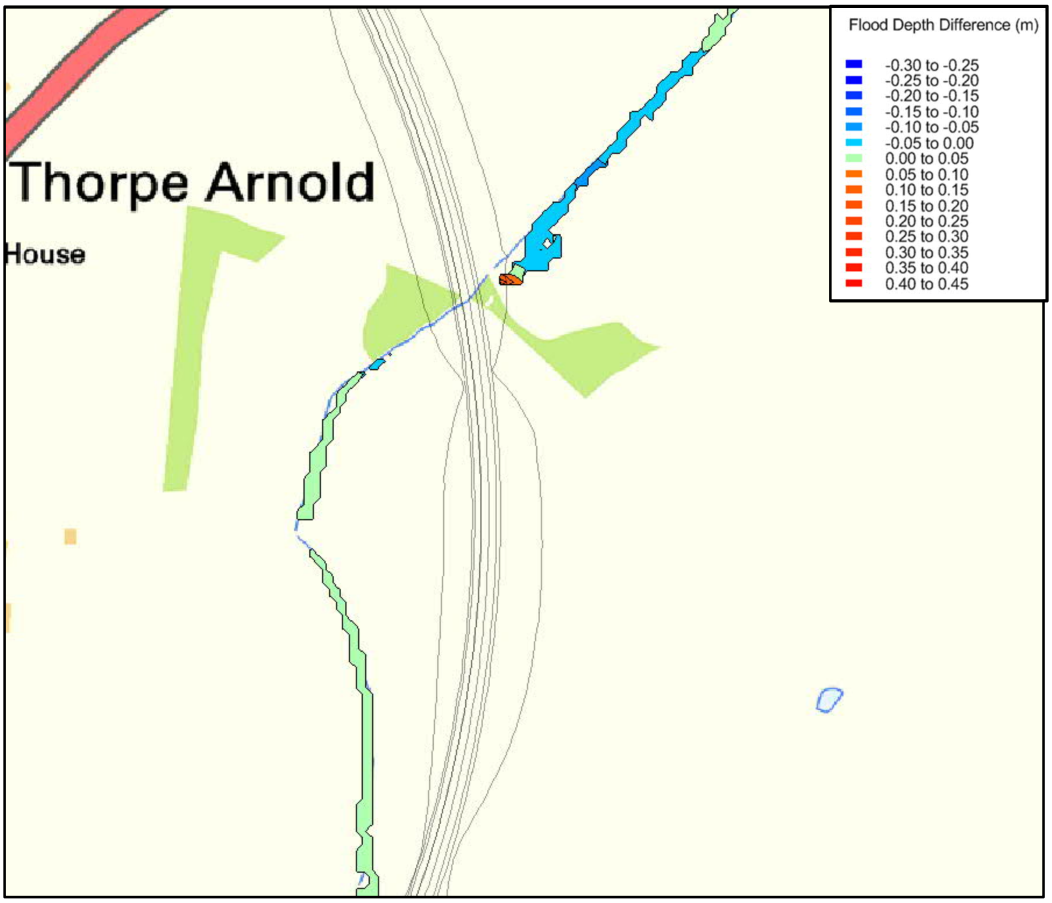


Figure 4-2 Map showing the flood depth difference between the baseline and proposed highway for the Lag Lane watercourse

Figure 4-2 shows the proposed highway will increase flood depths by approximately 0.15m in a very localised area immediately upstream of the proposed culvert on the Lag Lane watercourse under the proposed scheme. Further upstream of the proposed culvert inlet, water depths are reduced by approximately 0.1m. The proposed culvert within the flood model is a 2m x 2.3m box culvert, which has a greater capacity than that which was calculated to be required (in order to convey peak flows during the 1% AEP plus 50% climate change event). The model shows that the culvert is large enough to pass these flows. In both the baseline and proposed scenario, in the section just upstream of the proposed culvert, localised flooding is shown to occur in the 1% AEP + 50% climate change event because the banks of the Lag Lane watercourse in this area are too low. This issue can be further discussed with the LCC Flood Team and any works that may be required to further improve the situation can be taken into consideration during the detailed design stage.

It should be noted that no properties are located in the affected area of Lag Lane Tributary or the River Eye, and there are minimal changes to the flood extents and depths. Therefore, these results show that the proposed scheme does not significantly increase the flood risk to any properties in the vicinity of the proposed River Eye and Lag Lane Watercourse crossings.

4.1.2 Other Ordinary Watercourses

Even though hydraulic modelling was not undertaken to study the impacts of the proposed on the flood risk posed by Thorpe Brook, Scalford Brook and the two minor watercourses located close to Sysonby Lodge Farm to surrounding areas, it is considered that the impact from the proposed scheme is likely to be low. This is because the proposed structures were sized conservatively to convey peak flows during the 1% AEP + 50% climate change event, thus, maintaining the current conditions where no flow constrictions are imposed in these locations.

4.2 Mitigation against Fluvial Flooding

NPPF states that developments should not increase the risk of flooding to the Site or elsewhere. In order to mitigate the effects of raised ground levels within the floodplain resulting from construction of highway embankments, a like-for-like, volume-for-volume floodplain compensatory storage will need to be provided.

The volumetric loss of floodplain as a result of the proposed embankment across the River Eye has been estimated from the model results. Table 4-1 summarises these volumes at 0.1m intervals. These volumes assume total infill of the floodplain, whereas in reality the voids created by the bridge spans will reduce the actual volumetric loss. In order to minimise the required compensation works, these volumes will be further refined to include the voids created by the bridge spans during the detailed design phase.

Table 4-1: Summary of level-for-level floodplain compensation volume requirements

Lower Elevation (m AOD)	Upper Elevation (m AOD)	Volumetric Floodplain Loss (m^3)*
72.0	72.1	5
72.1	72.2	5
72.2	72.3	10
72.3	72.4	10
72.4	72.5	15
72.5	72.6	10
72.6	72.7	15
72.7	72.8	25
72.8	72.9	25
72.9	73.0	25
73.0	73.1	30
73.1	73.2	40
73.2	73.3	55
73.3	73.4	105
73.4	73.5	230
73.5	73.6	455

Lower Elevation (m AOD)	Upper Elevation (m AOD)	Volumetric Floodplain Loss (m^3)*
73.6	73.7	540
73.7	73.8	380
73.8	73.9	60
73.9	74.0	70
74.0	74.1	20
74.1	74.2	5
74.2	74.3	0

* Volumes rounded up to nearest $5m^3$

At this stage, the proposed locations of the compensatory works have not been established, but will likely require re-profiling of existing ground elevations in the vicinity of the embankment, to maintain and potentially increase floodplain volumes on a level-for-level basis. Modelling of these works will be undertaken once the scheme design is finalised.

Management of smaller ordinary watercourses and ditches

In addition to the proposed crossings of Ordinary watercourses discussed above, there is a minor ditch beneath proposed roundabout no.1 (OS Grid Ref: SK 74306 21097) which is proposed to be filled as far as the proposed pond (Appendix C – AECOM response to LCC flood team). This ditch appears to provide an overflow from the existing slurry pits and potentially drain water from the existing farm buildings/hardstanding, all of which will be removed. Earthworks drainage ditches / pipes will be provided on the north side of the proposed road in this area, immediately to the north of the ditch to be backfilled, and these will pick up any overland flow in the vicinity. As a further safety measure the existing ditch will be backfilled with granular material to provide a drainage pathway to the pond/watercourse although it is considered that this will not be necessary as all surface and groundwater flows in the area will be picked up by the highway drainage system. Thus, the impact of the proposed filling of this minor ditch on the upstream flood risk is considered to be low if the proposed mitigation measures as detailed above and within the SWDP (Appendix F) are implemented.

If any additional small ordinary watercourses/ditches affected by the road are discovered during the course of the detailed design they will be treated as appropriate to their particular circumstances and in agreement with LCC Flood Team so as to not increase flood risk to adjacent areas. Wherever viable the current routing of these watercourses will be maintained by conveying them under the proposed road in appropriately sized pipes and/or granular material.

4.3 Impact on Surface Water Runoff Generation and Overland Flow

The proposed MMDR alignment is entirely on undeveloped (greenfield) land currently used for agricultural purposes.

Given that the proposed highway will increase the impermeable area along the entirety of its length, there is the potential for the surface water flood risk, both to the highway alignment and surrounding area, to significantly increase. Regional and local planning policy indicates that surface water runoff will need to be attenuated to greenfield runoff rates and that SuDS must be incorporated into the drainage design wherever practicable.

The surface water flows on the site have been assessed in detail and a Surface Water Drainage Plan has been developed separately in order to manage the risk sensitively and sustainably. This Surface Water Drainage Plan has been provided in Appendix F.

Refer to Appendix F for details regarding the pre- and post-development impermeable areas, greenfield run-off rates, proposed discharge rates, proposed attenuation volumes and other details of the proposed drainage design.

4.4 Mitigation against Surface Water Flooding

The impact on surface water flooding mechanisms due to the proposed development is considered to be low provided all the overland surface water runoff to be generated by the proposed development be captured and attenuated by the proposed drainage network to prevent flooding up to a 1% AEP + Climate Change event as described below.

The principles for the disposal of surface water in order of preference and general acceptability are summarised below:

1) Infiltration into the ground;

2) Discharge to a watercourse;

3) Discharge to a surface water sewer; and

4) Discharge to a combined sewer.

Due to high groundwater levels in the area of the proposed road disposal of surface water via infiltration has been discounted. The six watercourses in the area that are crossed by the proposed scheme have been chosen as the ultimate discharge locations of surface water runoff at greenfield discharge rates.

The Surface Water Drainage Plan (Appendix F) indicates that due to the volume of attenuation required this will be provided with the use of balancing ponds. To provide maximum environmental benefit these will be wet ponds with permanently wet sections varying in depth from 0.5 m to 1.5 m. The locations of ten proposed balancing ponds, preliminary layouts and indicative outfall locations into the six water courses that they discharge into are shown on the accompanying drawings, 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0001 to 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0007 provided in Appendix F.

The ponds have been designed to accommodate a 1% AEP storm event with 40% allowance for climate change as per the requirements of LCC's Flood Risk Management team (LLFA). Discharge from the ponds will be at greenfield runoff rates to nearby watercourses as shown on the drawings.

Hydraulic design of the proposed drainage network will be such that the system is designed not to flood in a 1 in 30 year return period storm event.

Details of the proposed carriage way drainage arrangements can be found in the Surface Water Management Plan provided in Appendix F.

Surface water flows from areas upstream of the proposed scheme will be managed via interception ditches/drainage channels. The proposed drainage arrangement drawings provided in Appendix F use schematic arrows to illustrate surface water flow routes adjacent to the road and the proposed drainage ditch locations.

The proposed highway drainage system will be maintained by LCC.

4.5 Impact on Groundwater Flooding

As stated previously, the Ground Investigation Report shows that a shallow groundwater table is located in the proposed scheme area. The report also suggests that the shallow groundwater tables encountered are primarily fed by surface infiltration. However, in the vicinity of water courses it is likely that the shallow water tables are connected to these surface flows.

Cutting excavations are likely to liberate groundwater in the form of seepages from any higher permeability zones of relatively granular material. It is not yet certain whether the groundwater released in this way will originate from isolated pockets of trapped water or from a wider groundwater table. A comprehensive groundwater mitigation strategy should be considered at the detailed design stage to mitigate the risk of groundwater flooding during both the construction phase and post-construction.

4.6 Mitigation against Groundwater Flooding

The Surface Water Drainage Plan (Appendix F) suggests installation of combined surface water and groundwater filter drains that will convey the combined flows into the proposed drainage network where the flowrates will be attenuated to greenfield run-off rates via balancing ponds and subsequently discharged to a nearby watercourse.

Use of combined surface water and ground water surface drains is common practice for highway drainage and the alternate of carrier pipes with separate fin/narrow filter drains still results in the highway surface water flows and groundwater flows in the vicinity of the road pavement being combined in the same drainage system. After initial draw down of groundwater levels, and in view of the largely cohesive nature of surrounding soils, long term groundwater flow rates adjacent to the road pavement will be negligible in comparison to peak surface water storm flows. Where adjacent ground falls towards the proposed road earthworks drains/ditches will be provided which will take a proportion of groundwater flows and these will be keep separate from the highway surface water drainage system in the majority of cases.

Thus, the impact on groundwater flooding mechanisms due to the proposed scheme is considered to be low provided appropriate mitigation strategies are implemented.

4.7 Impact on Flooding from Artificial Sources

The impact from the proposed scheme on the Brentingby FSA is considered low, since the proposed scheme alignment is located downstream of the dam.

Approximately 400 m south of the proposed location of the Scalford Brook crossing is a small FSA. The Scalford Brook Dam flood retention facility was completed in 1990 to control the rate of discharge into Melton Town centre and offer a 1% AEP standard of protection. Since the proposed Scalford Brook Bridge is over-sized to be able to convey peak flows during 1% + 50% climate change event, thus maintaining the current conditions, impacts of the proposed structure on the Scalford Brook FSA is considered to be low.

4.8 Impact on Flooding from Drainage Infrastructure

Given the rural nature of the route alignment, the impact of the development on current flood risk is low, once mitigation measures are taken into consideration. Also, since the proposed drainage strategy is to discharge directly into watercourses at an attenuated rate via a dedicated highway drainage network, the impact on sewer flood risk from the proposed scheme is considered to be low.

4.9 Summary of flood risk from the development

Table 4-2: Summary of Flood Risk from the Proposed Development

Flood Risk	Summary of Risk from Development Site	Notes	Mitigation Required
Fluvial	Medium – In the vicinity of the proposed River Eye and Ordinary Watercourse crossings	Hydraulic modelling has shown localized increase in flood levels upstream of the proposed River Eye and Lag Lane Tributary crossings. However, it should be noted that no properties are located in the affected area, and there are minimal changes to the flood extents and depths. Therefore, these results show that the proposed scheme does not significantly increase the flood risk to any properties in the vicinity of the proposed River Eye and Lag Lane Watercourse crossings. The impact of the proposed scheme on the fluvial flood risk from Thorpe Brook,	Yes – Floodplain Compensation Storage

Flood Risk	Summary of Risk from Development Site	Notes	Mitigation Required
		Scalford Brook and the two Ordinary Watercourses adjacent to Sysonby Lodge Farm is considered to be low since the proposed crossing structures have been over-sized to handle peak flows in the 1% AEP + 50% climate change event. However, hydraulic modelling is required to confirm this.	
Surface Water	Low	Given that the proposed highway will increase the impermeable area along the entirety of its length, there is the potential for the surface water flood risk, both to the highway alignment and surrounding area, to significantly increase. The impact on surface water flooding mechanisms due to the proposed development is considered to be low provided all the overland surface water runoff to be generated by the proposed development would need to be captured and attenuated by the proposed drainage network to prevent flooding up to a 1%+ climate change event as described in the Surface Water Drainage Plan (Appendix F).	Yes
Groundwater	Low	The impact on groundwater flooding mechanisms due to the proposed development is considered to be low provided appropriate mitigation strategies are implemented.	Yes
Sewer and Water Supply Infrastructure	Low	Given the rural nature of the route alignment and the proposed surface water drainage strategy, the current risk from sewers and drains is considered low.	No
Artificial Sources	Low	The proposed scheme alignment is located downstream of the Brentingby FSA, and hence the flood risk impact from the proposed development is considered to be low. Since the proposed Scalford Brook Bridge is over-sized to be able to convey peak flows during 1% + 50% climate change event, thus, mimicking the current conditions, impacts of the proposed structure on the Scalford Brook FSA is considered to be low.	No

5. Residual Risk

There is residual fluvial risk to the proposed development associated with the Brentingby Dam breach. In case, this extremely low-probability event occurs, it is accepted that the proposed scheme will remain closed till flooding recedes.

There is residual risk associated with failure of the highway drainage system through blockage and / or build-up of sediment as a result of the shallow gradient of the pipes, both of which may cause the capacity of the drainage system to become reduced. The risk of blockage and sedimentation can be reduced by undertaking regular inspection of the drainage system and ensuring that serviceability is maintained. A maintenance plan will need to be developed at detailed design stage to describe the ownership, frequency of and techniques for site drainage maintenance.

6. Conclusions

This FRA has been completed in accordance with the NPPF and the accompanying PPG.

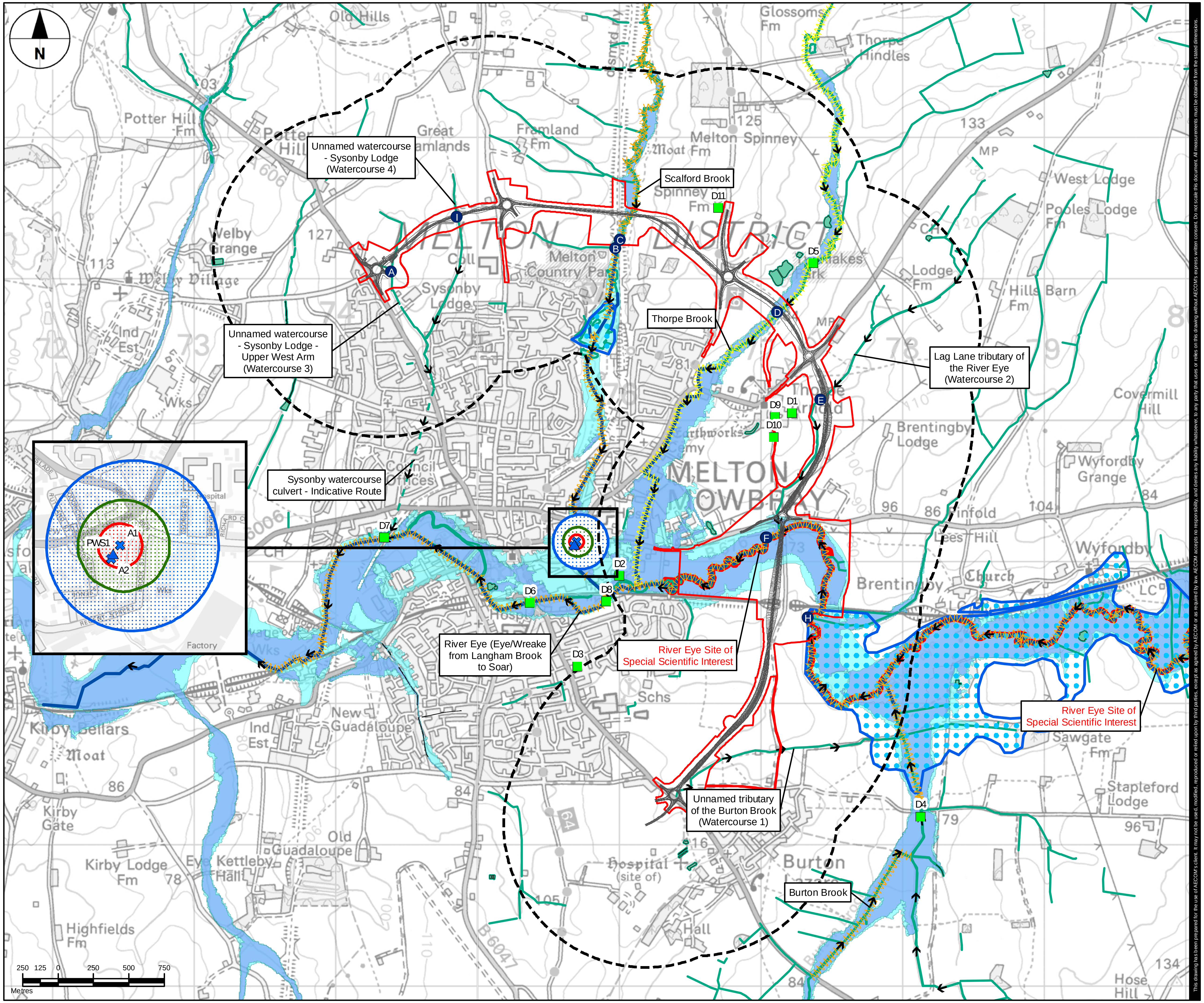
The following conclusions can be made:

- The proposed scheme will be situated on a greenfield site;
- The flood risk to the proposed scheme from fluvial, tidal, surface water, artificial sources, drainage infrastructure and groundwater is considered to be low;
- Hydraulic modelling has shown very localised increases above 0.05m (which is considered a negligible increase within model tolerances) in flood levels immediately upstream of the proposed River Eye and Lag Lane Tributary crossings. However, it should be noted that no properties are located in the affected area, and there are minimal changes to the flood extents and depths. Therefore, these results show that the proposed scheme does not significantly increase the flood risk to any properties in the vicinity of the proposed River Eye and Lag Lane Watercourse crossings;
- The impact of the proposed scheme on the fluvial flood risk from Thorpe Brook, Scalford Brook and the two Ordinary Watercourses adjacent to Sysonby Lodge Farm is considered to be low since the proposed crossing structures have been sized conservatively to accommodate peak flows in the 1% AEP + 50% Climate Change event. However, hydraulic modelling is required to confirm this;
- Floodplain compensation storage will be provided on a like for like, volume for volume basis. The storage volumes have been calculated for the 1% AEP + 50% Climate Change event;
- Ground investigation of the site and its vicinity have identified that ground conditions are unsuitable for infiltration SuDS, and that surface water runoff will need to outfall into the nearest watercourse. The runoff rate will be restricted from the site to greenfield rate using flow control devices. Attenuation will be provided in the form of ten balancing ponds; and
- The drainage strategy demonstrates that it is possible to safely and sustainably manage surface water volumes from the site up to the 1% AEP + 40% for climate change flows.
- There is residual fluvial risk to the proposed development associated with the Brentingby Dam breach. In case, this extremely low-probability event occurs, it is accepted that the proposed scheme will remain closed till flooding recedes.

It is considered that there will be no significant increase in fluvial flood risk to the neighbouring land uses, or an increase in surface water runoff as a result of the proposed development based on application of identified mitigation measures.

Appendix A

Proposed Scheme Drawings



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NOTES

1. ALL DIMENSIONS IN METRES UNLESS STATED OTHERWISE

KEY

- Proposed Scheme
- Red Line Boundary
- 1km Study Area
- River Eye Site of Special Scientific Interest (SSSI)
- Main River
- Ordinary Watercourse
- Ordinary Watercourse Culvert
- Waterbodies
- Approximate position of proposed new highway outfalls
- Active Water Activity (Discharge)
- Licenced Water Abstraction
- Private Water Supply
- Flood Storage Areas
- Flood Zone 3
- Flood Zone 2

Water Framework Directive Status

- WFD Moderate Ecological Status
- WFD Poor Ecological Status

Source Protection Zone

- Zone I - Inner Protection Zone
- Zone II - Outer Protection Zone
- Zone III - Total Catchment
- Zone of Special Interest

PROJECT MANAGEMENT DETAILS

DESIGNED: GB	CHECKED: FB	APPROVED: MS

INTERNAL PROJECT NUMBER	SCALE
60542201	1:25,000
STATUS	BS1192 SUITABLITY
FOR INFORMATION	S2

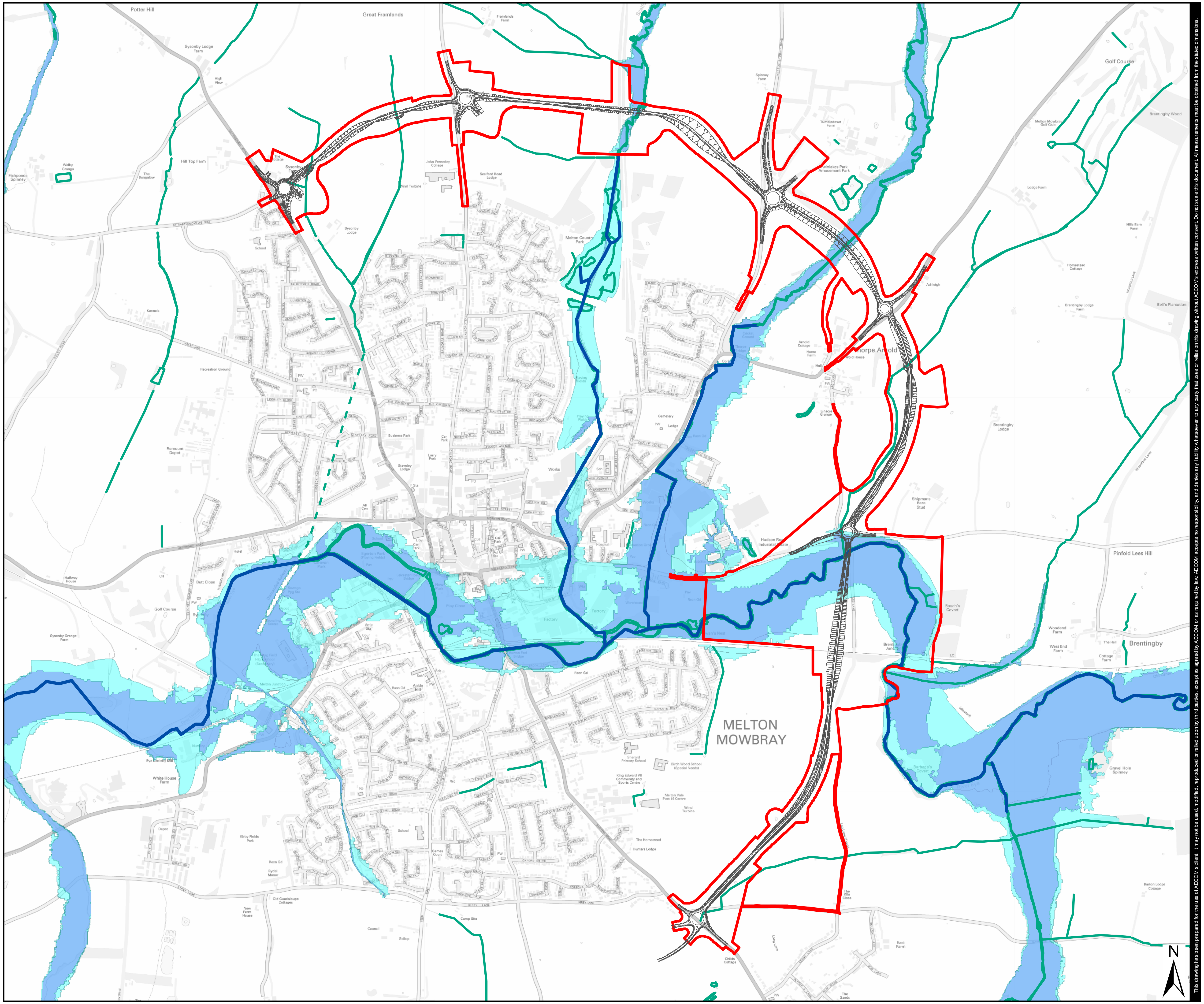
SHEET TITLE

FIGURE 16.1

WATER BODY FEATURES AND INDICATIVE FLOOD ZONES

DRAWING NUMBER	REV
60542201-ACM-EGN-GEN-GEN-ZZ-Z-DR-LE-0054	P01

Filename: K:\GIS Management\60542201 - Melton GIS Folder\GIS\02_Maps\00_Environmental Statement\60542201-ACM-EGN-GEN-ZZ-Z-DR-LE-0054 - Figure 16.1 - Road Drainage.mxd



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NOTES

- Proposed Scheme
- Red Line Boundary
- Main River
- Ordinary Watercourse
- Ordinary Watercourse Culvert
- Other Watercourse
- Flood Zone 2
- Flood Zone 3

PROJECT MANAGEMENT DETAILS

DESIGNED	GB	CHECKED	MS	APPROVED	MS

INTERNAL PROJECT NUMBER	SCALE
60542201	1:18,000

STATUS	BS1192 SUITABLITY

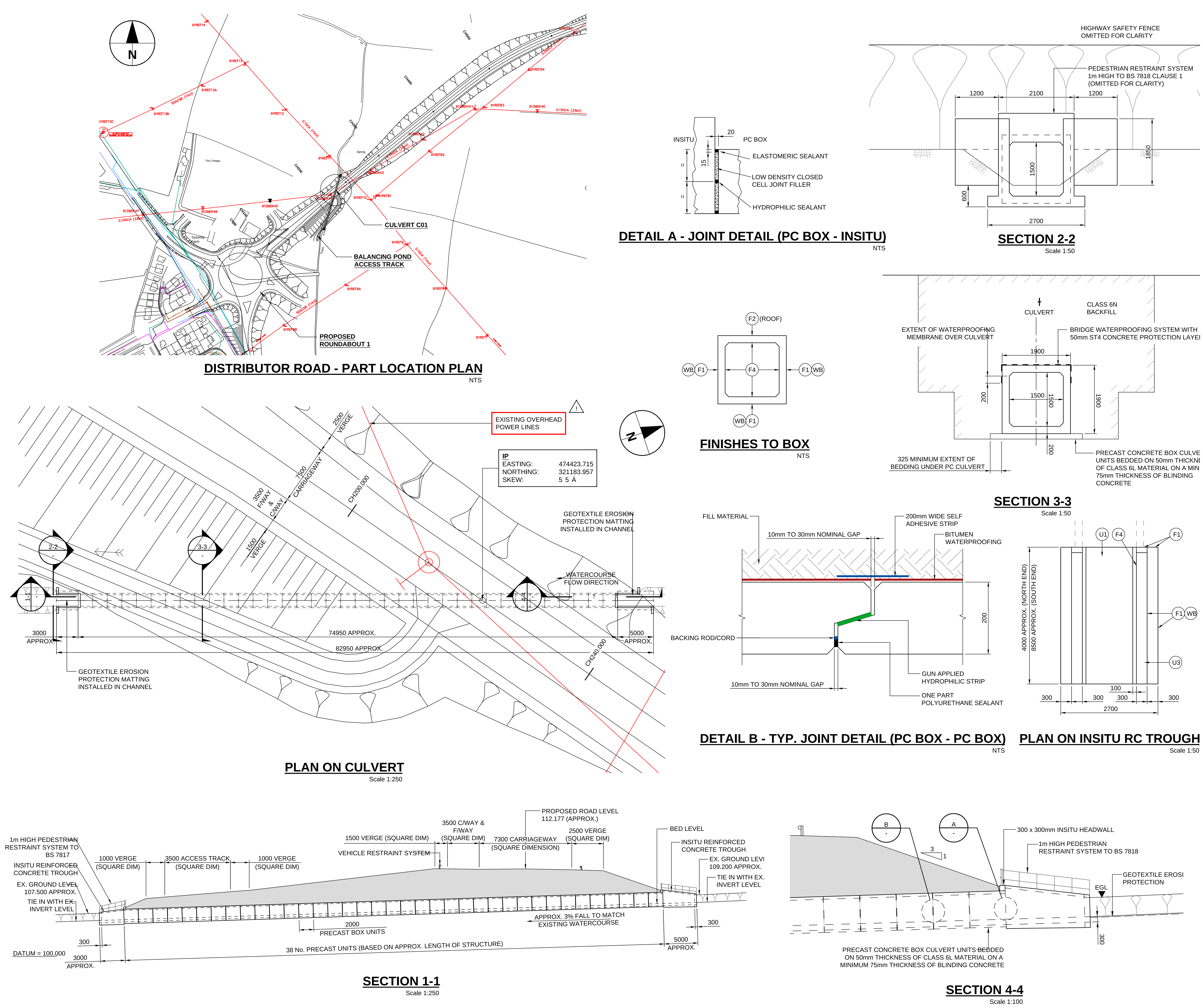
SHEET TITLE

INDICATIVE FLOOD ZONES

DRAWING NUMBER	REV
FIGURE 16.2	00

Filename: K:\GIS Management\60542201 - Melton GIS Folder\GIS\02_Maps\Water\Figure 16.2 - Flood Zones.mxd

ISO A1 594mm x 841mm



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PROJECT
NORTH & EAST MMDR

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www.leicestershire.gov.uk

CONSULTANT
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5. CONCRETE STRENGTH CLASS :-

BOX	C45/55(A)
HEADWALL	C35/45(A)
TROUGH	C35/45(A)
BLINDING CONCRETE	ST4
INFILL CONCRETE	ST4

6. NOTATION :-
CLASS OF FORMED CONCRETE FINISH IS INDICATED THUS :-
F1 FOR CLASS F1
CLASS OF UNFORMED CONCRETE FINISH IS INDICATED THUS :-
U1 FOR CLASS U1
CONCRETE SURFACES BELOW GROUND LEVEL TO BE WATERPROOFED IS INDICATED THUS :-
WB
ALL PARTS OF STRUCTURE IN CONTACT WITH SOIL TO BE COATED PRIOR TO BACK FILLING WITH TWO NUMBER COATS OF A MATERIAL APPROVED FOR WATERPROOFING BELOW GROUND LEVEL. WATERPROOFING TO TERMINATE 150mm BELOW FINISHED GROUND LEVEL.
7. TENSAR MAT 400 TYPICAL THICKNESS OF 18mm WITH UNIT WEIGHT OF 0.43kg/m|. TYPICAL TEN STRAIN SHALL BE 1.3KN/m
8. DESIGN FOR VEHICLE LOADS ASSUMES A MINIMUM COVER ON TOP OF THE BOX OF 600mm AT ALL TIMES.
9. FOR DETAILS ON HIGHWAY CONSTRUCTION AND ROAD DRAINAGE SYSTEM INCLUDING STREET LIGHTING REFER TO OTHER RELEVANT DRAWINGS.
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REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue		29/08/18	P01.1

PROJECT MANAGEMENT INITIALS
DESIGNED: CHECKED:--- APPROVED:---

INTERNAL PROJECT NUMBER — **SCALE**
60542201 — AS SHOWN

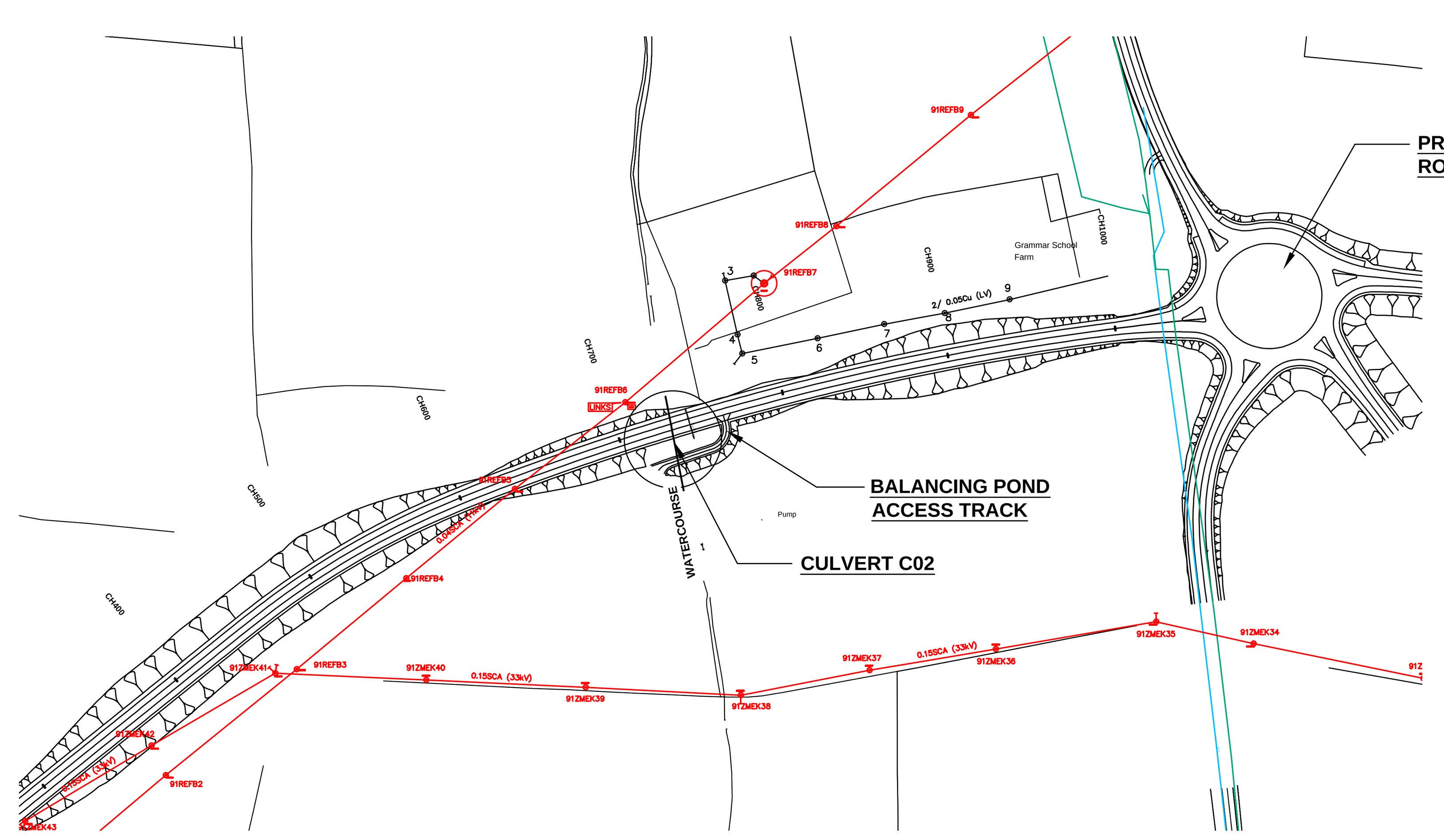
STATUS — **BS1192 SUITABILITY**
INITIAL STATUS OR WIP — S0

SHEET TITLE
CULVERT C01
INDICATIVE GENERAL ARRANGEMENT
(CHAINAGE 220m)

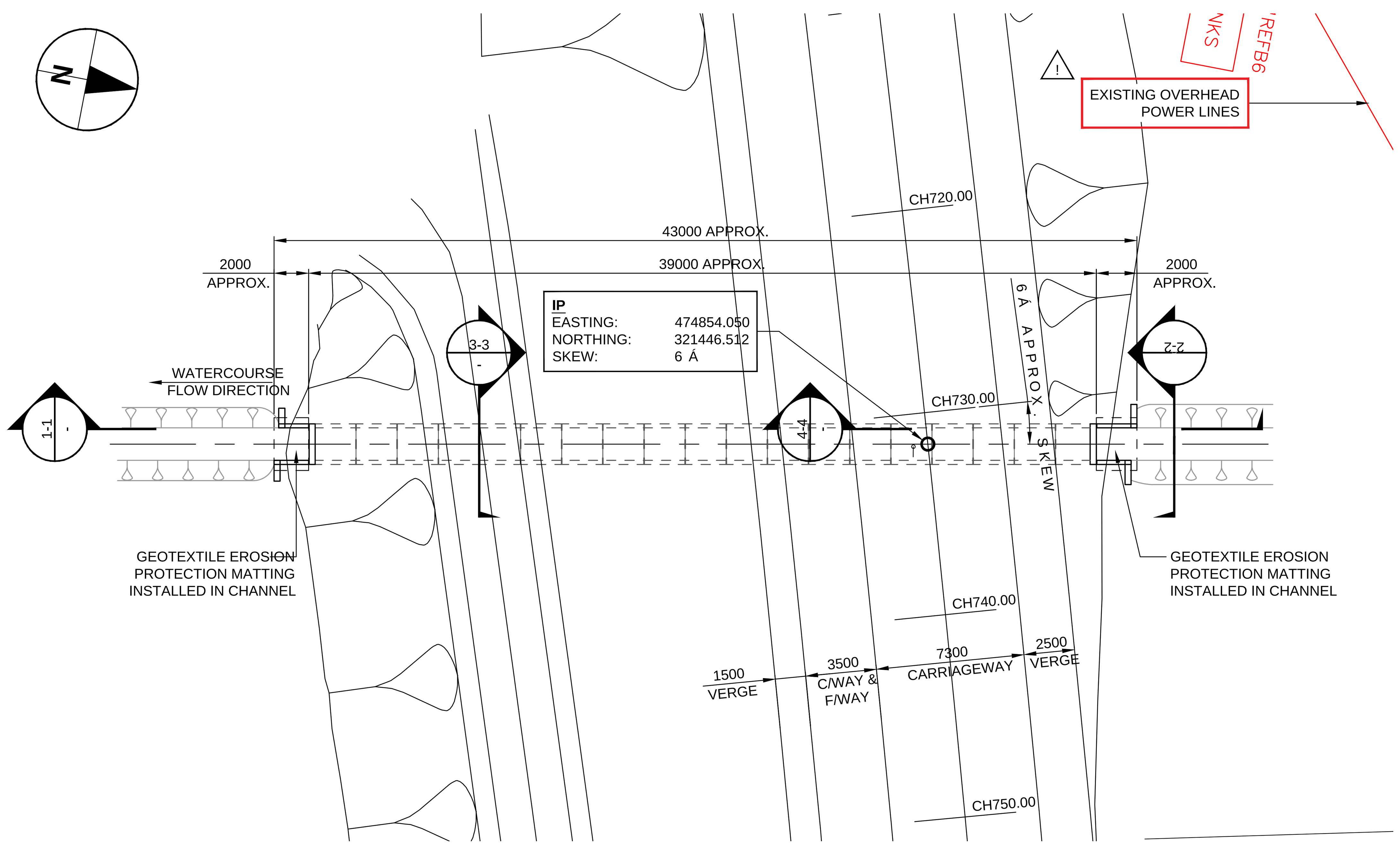
DRAWING NUMBER — **REV**
60542201-ACM-STR-S1_CU_C01_Z -DR-CB-0001 — P01.1

Last saved by: STEPHEN.HARDY(2018-08-29) Last Plotted: 2018-08-29
Filename: C:\PWWORKING\AECOM_EU\STEPHEN.HARDY\D0353810\60542201-ACM-STR-S1_CU_C01_Z-DR-CB-0001.DWG

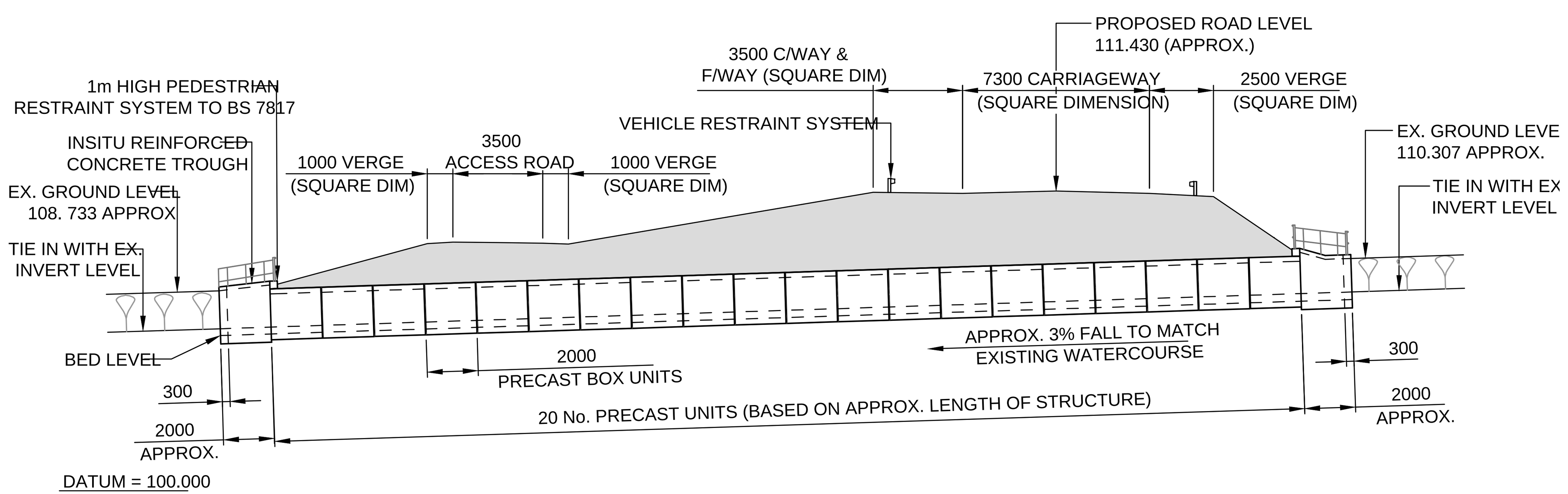
ISO A1 594mm x 841mm



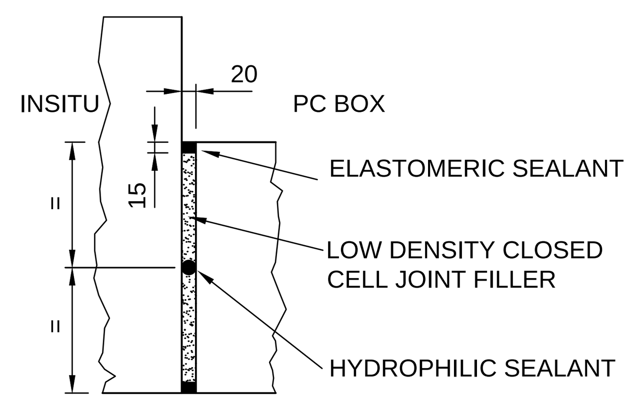
DISTRIBUTOR ROAD - PART LOCATION PLAN
NTS



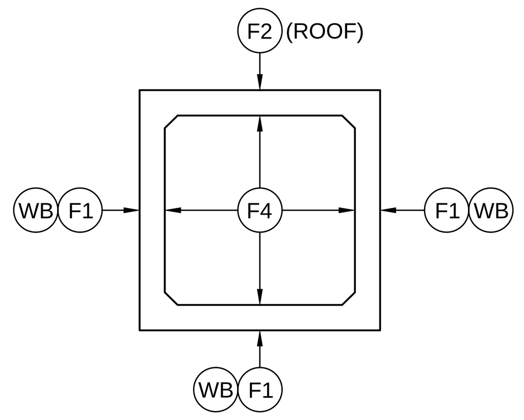
PLAN ON CULVERT
Scale 1:200



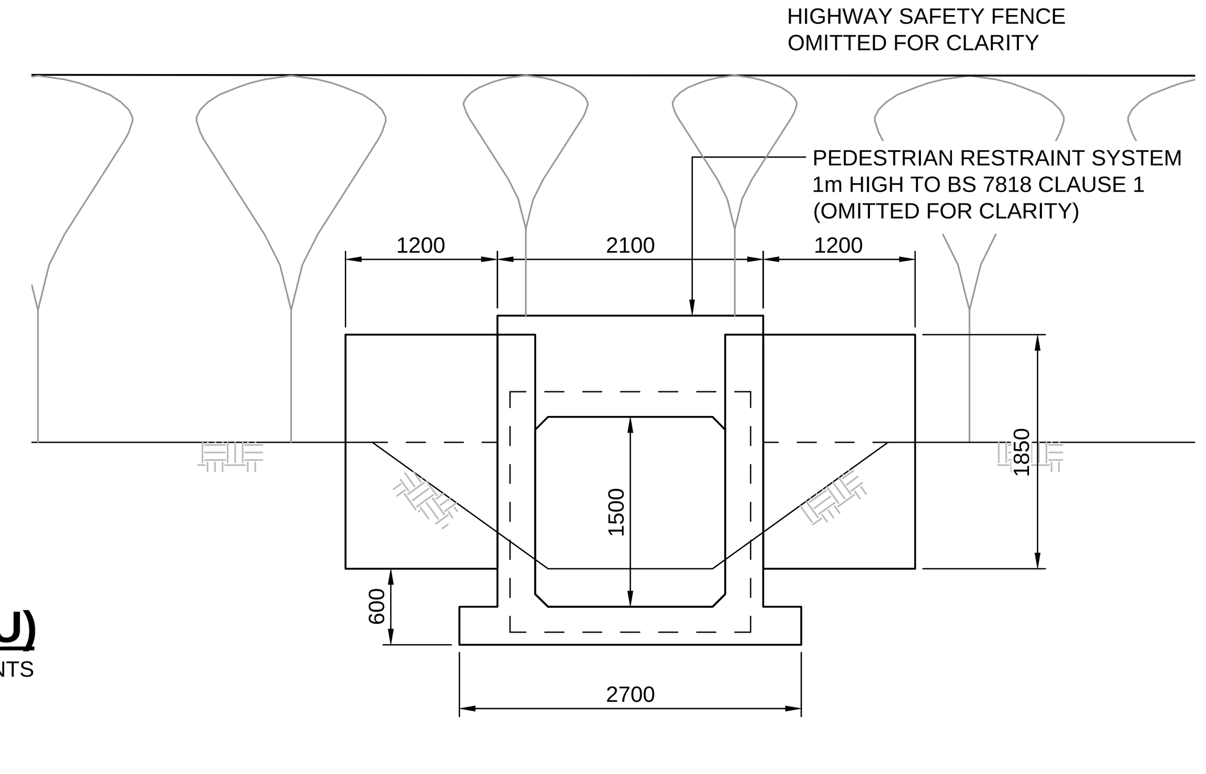
SECTION 1-1
Scale 1:200



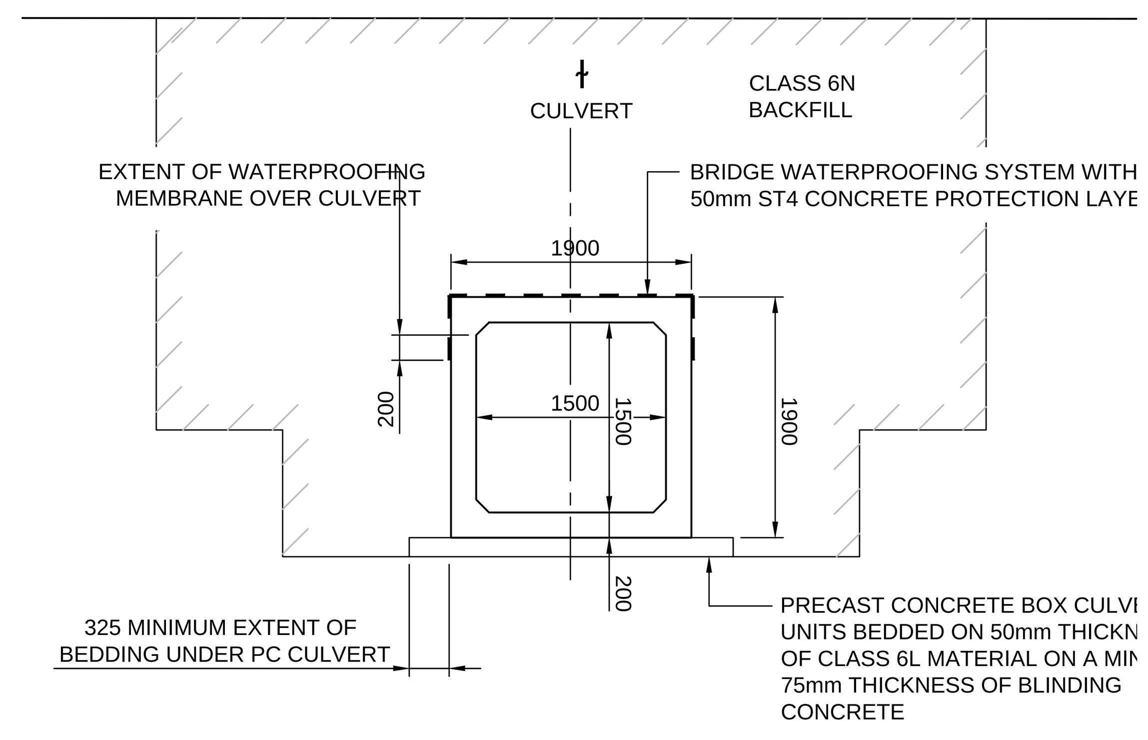
DETAIL A - JOINT DETAIL (PC BOX - INSITU)
NTS



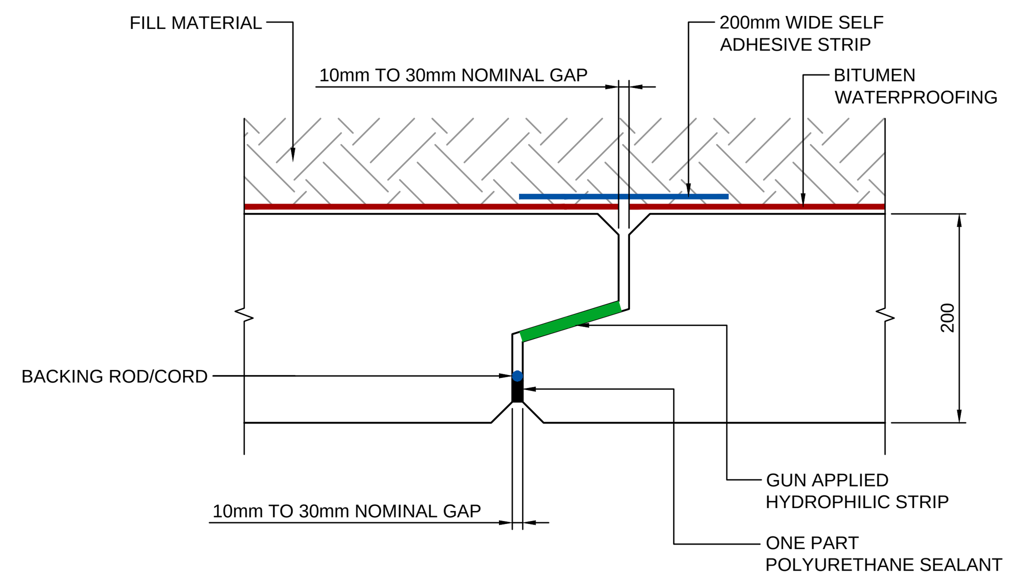
FINISHES TO BOX
NTS



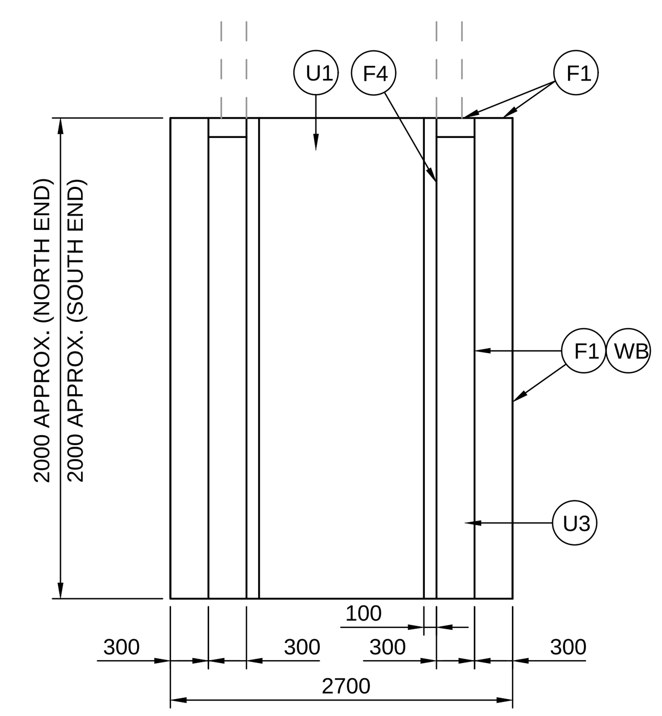
SECTION 2-2
Scale 1:50



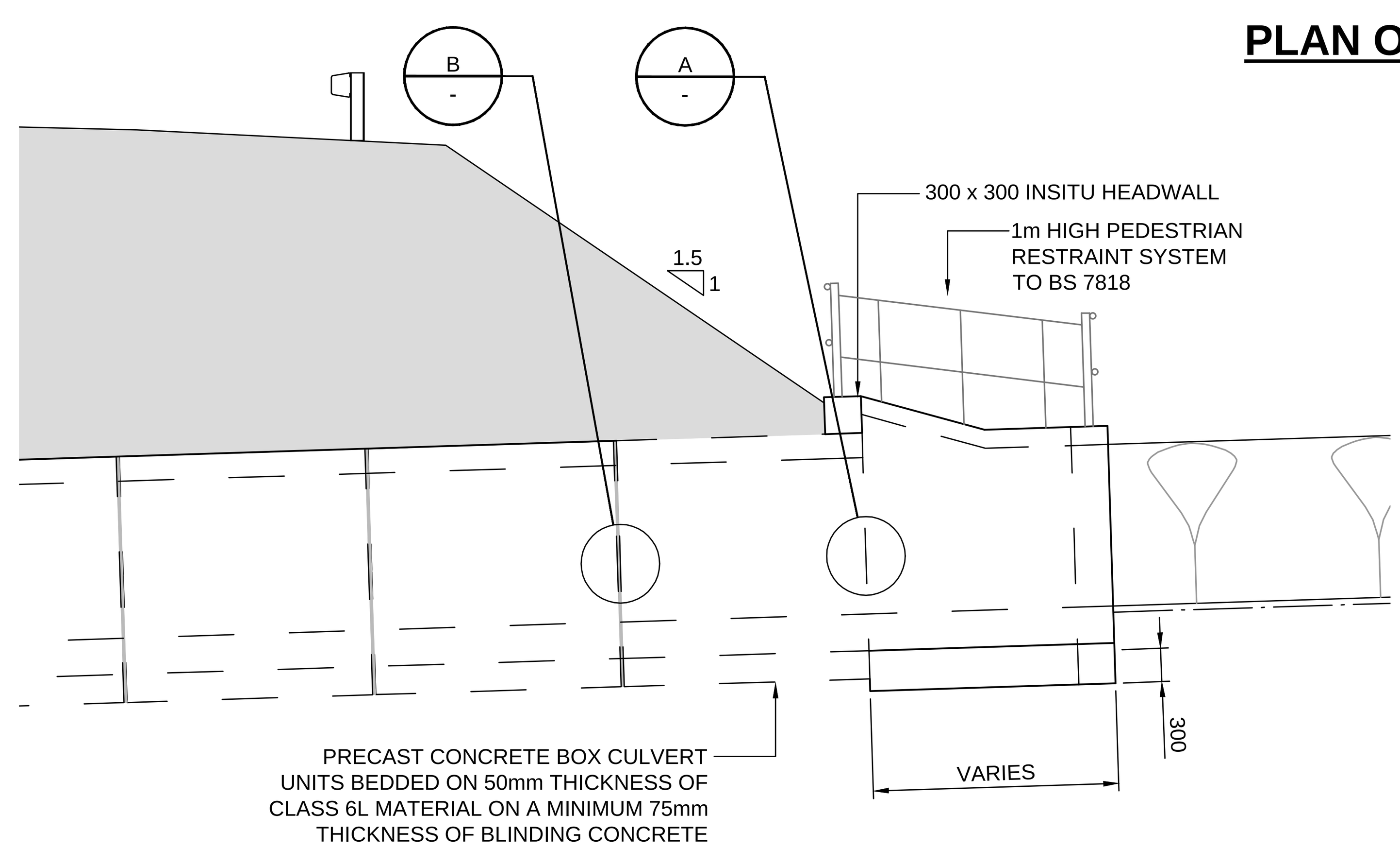
SECTION 3-3
Scale 1:50



DETAIL B - TYP. JOINT DETAIL (PC BOX - PC BOX)
NTS



PLAN ON INSITU RC TROUGH
Scale 1:50



SECTION 4-4
Scale 1:50

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Filename: C:\PWWORKING\AECOM_EU\STEPHEN.HARDY\D0353810\60542201-ACM-STR-S1_CU_C02_Z-DR-CB-0001.DWG

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PROJECT

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Leicester, LE3 8RA
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NOTES

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5. CONCRETE STRENGTH CLASS :-

BOX	C45/55(A)
HEADWALL	C35/45(A)
TROUGH	C35/45(A)
BLINDING CONCRETE	ST4
INFILL CONCRETE	ST4

6. NOTATION :-
CLASS OF FORMED CONCRETE FINISH IS INDICATED THUS :-
F1 FOR CLASS F1
CLASS OF UNFORMED CONCRETE FINISH IS INDICATED THUS:-
U1 FOR CLASS U1
CONCRETE SURFACES BELOW GROUND LEVEL TO BE WATERPROOFED IS INDICATED THUS:-
WB
ALL PARTS OF STRUCTURE IN CONTACT WITH SOIL TO BE COATED PRIOR TO BACK FILLING WITH TWO NUMBER COATS OF A MATERIAL APPROVED FOR WATERPROOFING BELOW GROUND LEVEL. WATERPROOFING TO TERMINATE 150mm BELOW FINISHED GROUND LEVEL.
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REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue		05/09/18	P01.1

PROJECT MANAGEMENT INITIALS

DESIGNED: CHECKED:--- APPROVED:---

INTERNAL PROJECT NUMBER **SCALE**

60542201 ---

STATUS **BS1192 SUITABILITY**

INITIAL STATUS OR WIP S0

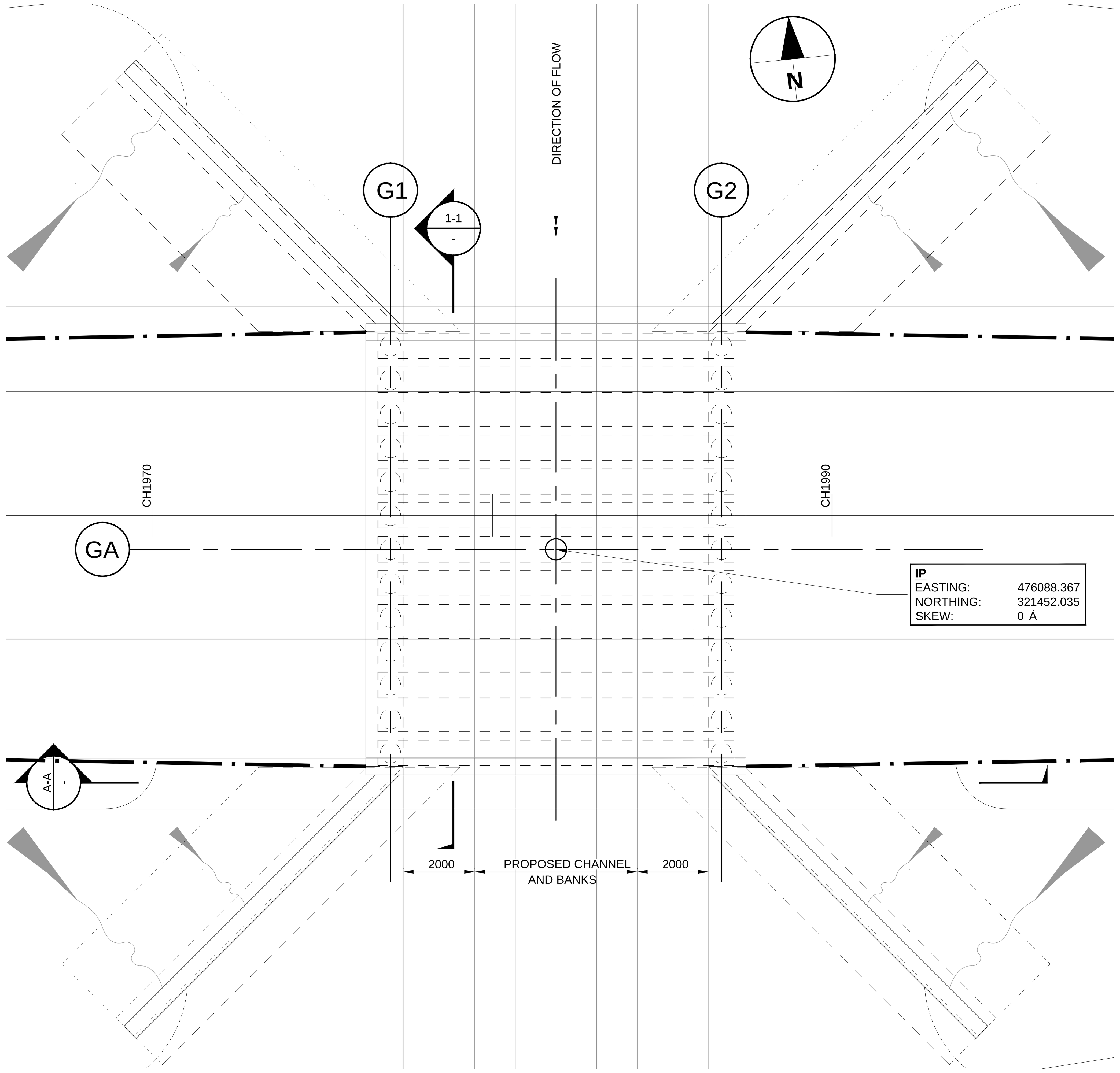
SHEET TITLE

CULVERT C02
INDICATIVE GENERAL ARRANGEMENT
(CHAINAGE 730M)

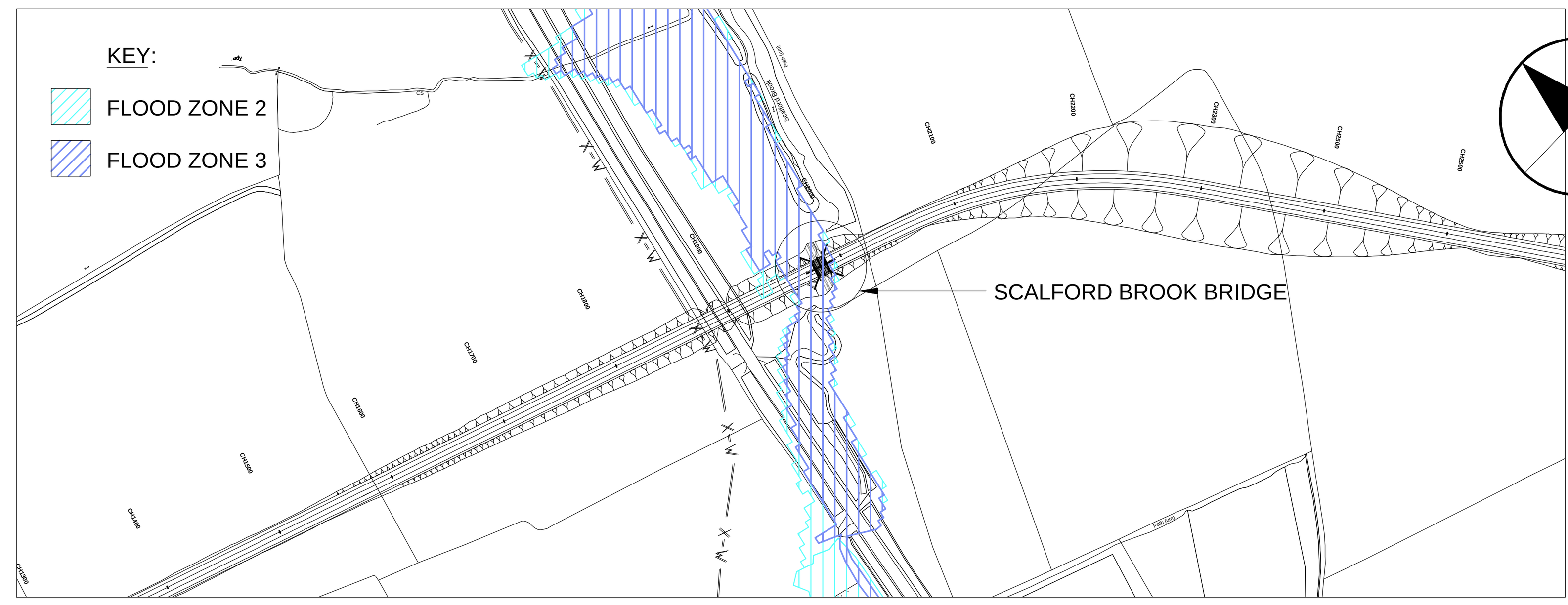
DRAWING NUMBER **REV**

60542201-ACM-STR-S1_CU_C02_Z -DR-CB-0001 P01.1

ISO A1 594mm x 841mm



PLAN ON SCALFORD BROOK BRIDGE
Scale 1:100



DISTRIBUTOR ROAD - PART LOCATION PLAN
NTS

IMPORTANT CDM / HEALTH & SAFETY NOTES

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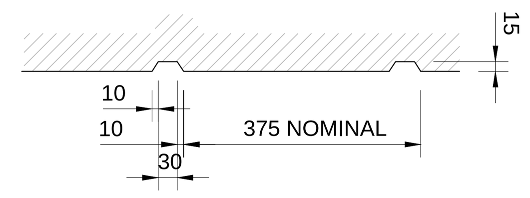
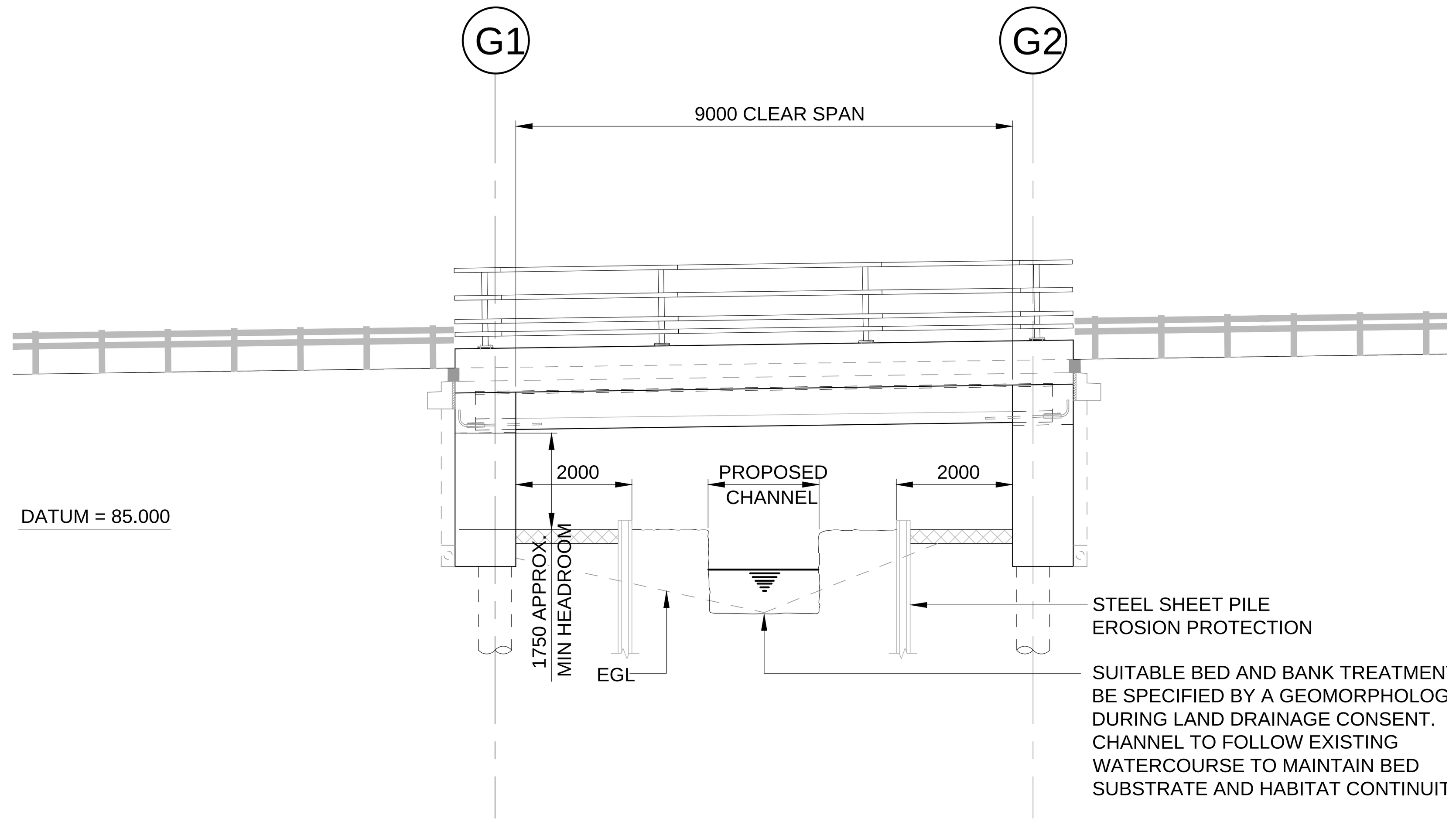
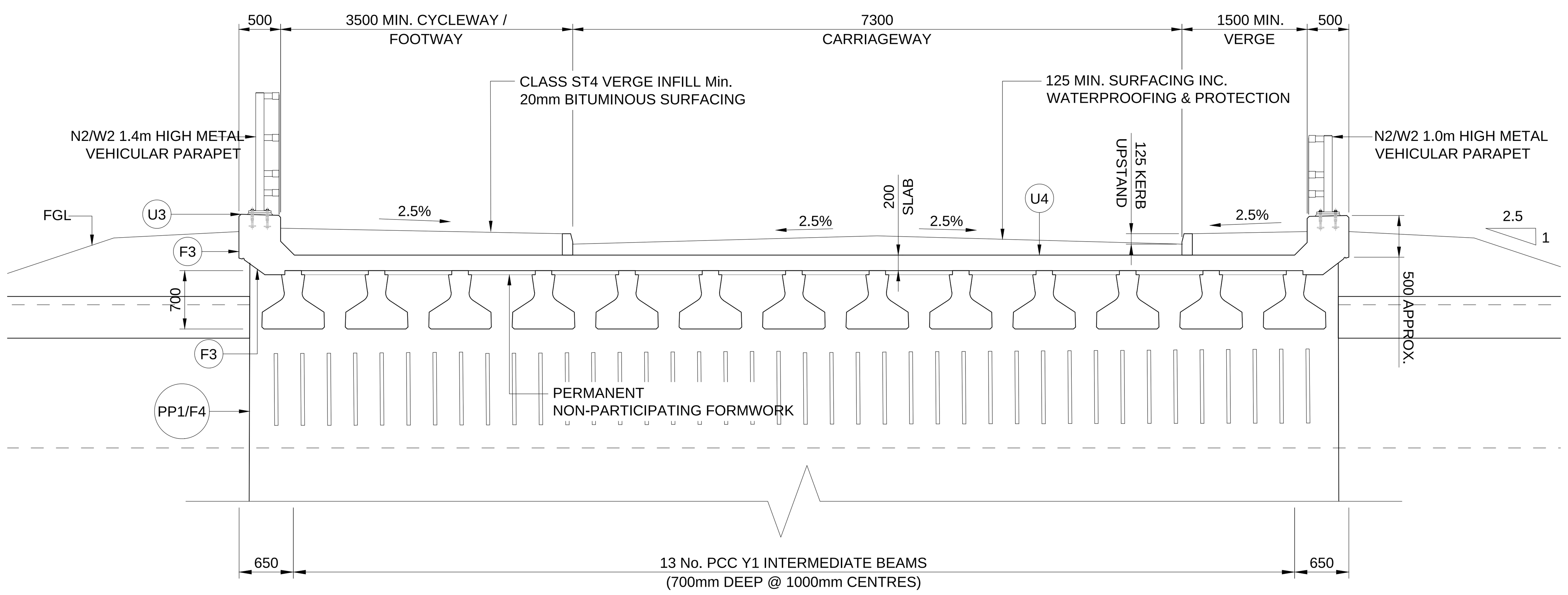
2. EXCEPTIONAL RISKS NOT ELIMINATED DURING THE CURRENT PRELIMINARY DESIGN STAGE ARE HIGHLIGHTED ON THE DRAWING WITH THE SYMBOL
3. NOT ALL BURIED & OVERHEAD SERVICES ARE SHOWN ON THESE DRAWINGS. FOR THE LOCATION OF STATUTORY UNDERTAKERS APPARATUS, REFER TO STATUTORY UNDERTAKERS PLANS.



PP1/F4 PATTERNED PROFILE FINISH
Scale 1:10



ELEVATION A-A
Scale 1:100



SECTION 1-1
Scale 1:50

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PCC BEAMS	C50/60(A)
DECK CANTILEVER	C40/50(A)
PARAPET UPSTAND	C40/50(A)
DECK SLAB	C40/50(B)
COLUMNS/PILECAPS/PILES	C32/40(A)
DIAPHRAGM BEAMS/CROSSHEAD	C32/40(A)
BLINDING CONCRETE	ST4
VERGE INFILL CONCRETE	ST4

6. NOTATION :-
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U1 FOR CLASS U1
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10. CONCRETE SURFACE FINISHES TO DISCOURAGE GRAFFITI SUBJECT TO AGREEMENT WITH THE ENVIRONMENT AGENCY.

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue		10/08/18	P01.1

PROJECT MANAGEMENT INITIALS
DESIGNED: MA CHECKED:--- APPROVED:---

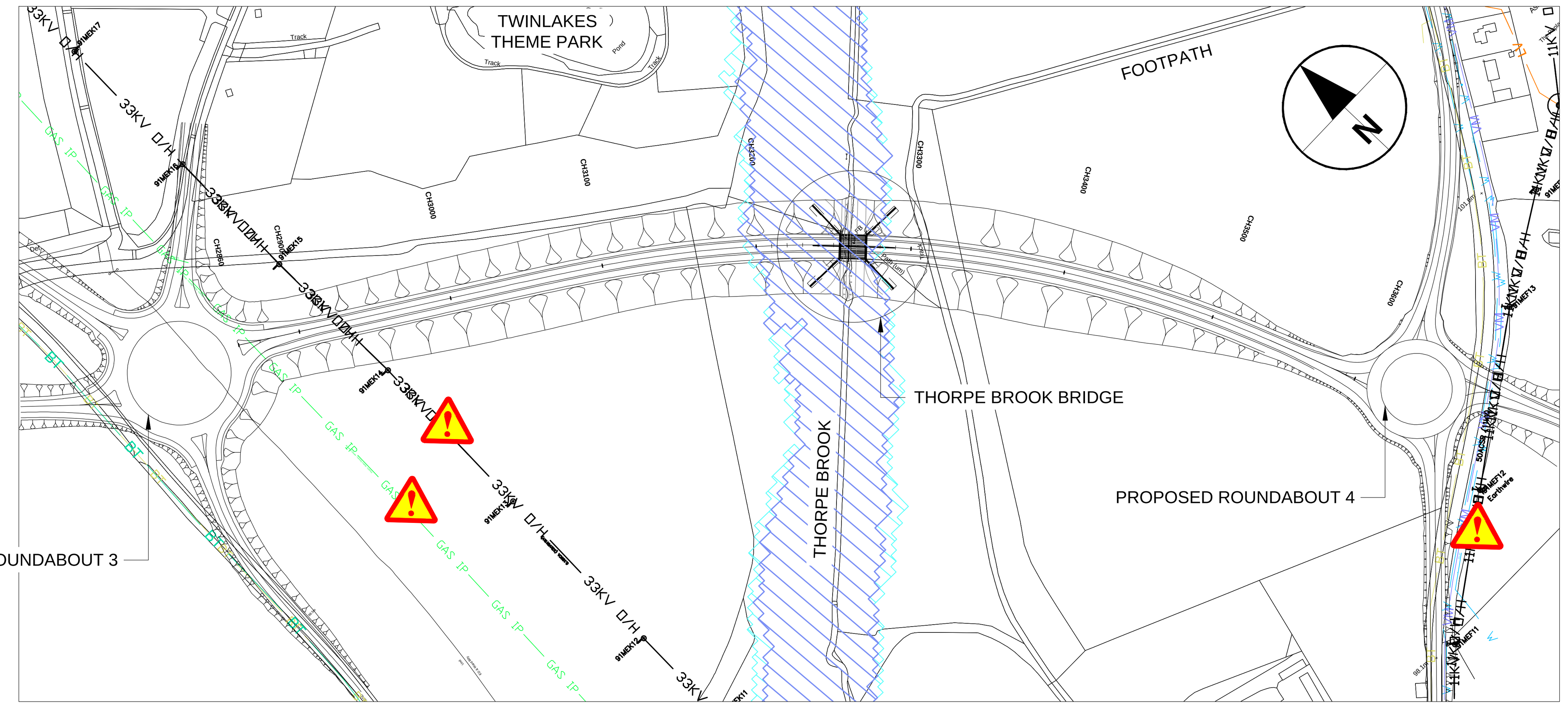
INTERNAL PROJECT NUMBER — **SCALE**
60542201 — AS SHOWN

STATUS — **BS1192 SUITABILITY**
INITIAL STATUS OR WIP — S0

SHEET TITLE
SCALFORD BROOK BRIDGE
INDICATIVE GENERAL ARRANGEMENT

DRAWING NUMBER — **REV**
60542201-ACM-STR-S2_BR_B01_Z -DR-CB-0001 P01.1

ISO A1 594mm x 841mm



KEY:
FLOOD ZONE 2
FLOOD ZONE 3

DISTRIBUTOR ROAD - PART LOCATION PLAN

NTS

IMPORTANT CDM / HEALTH & SAFETY NOTES

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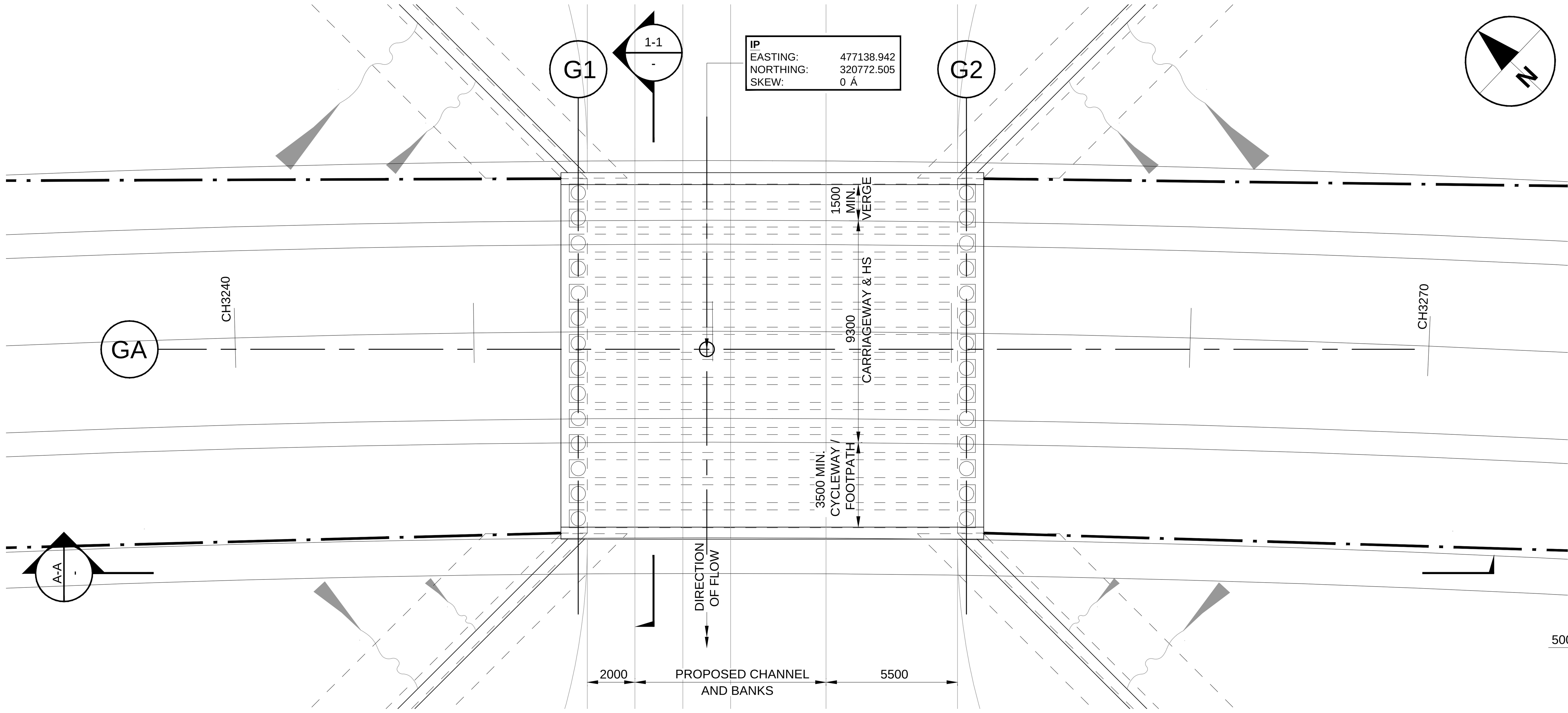
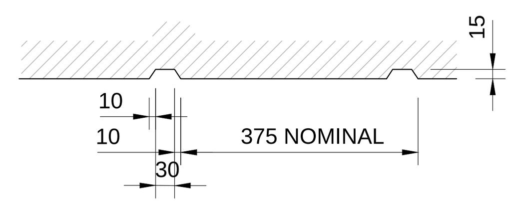


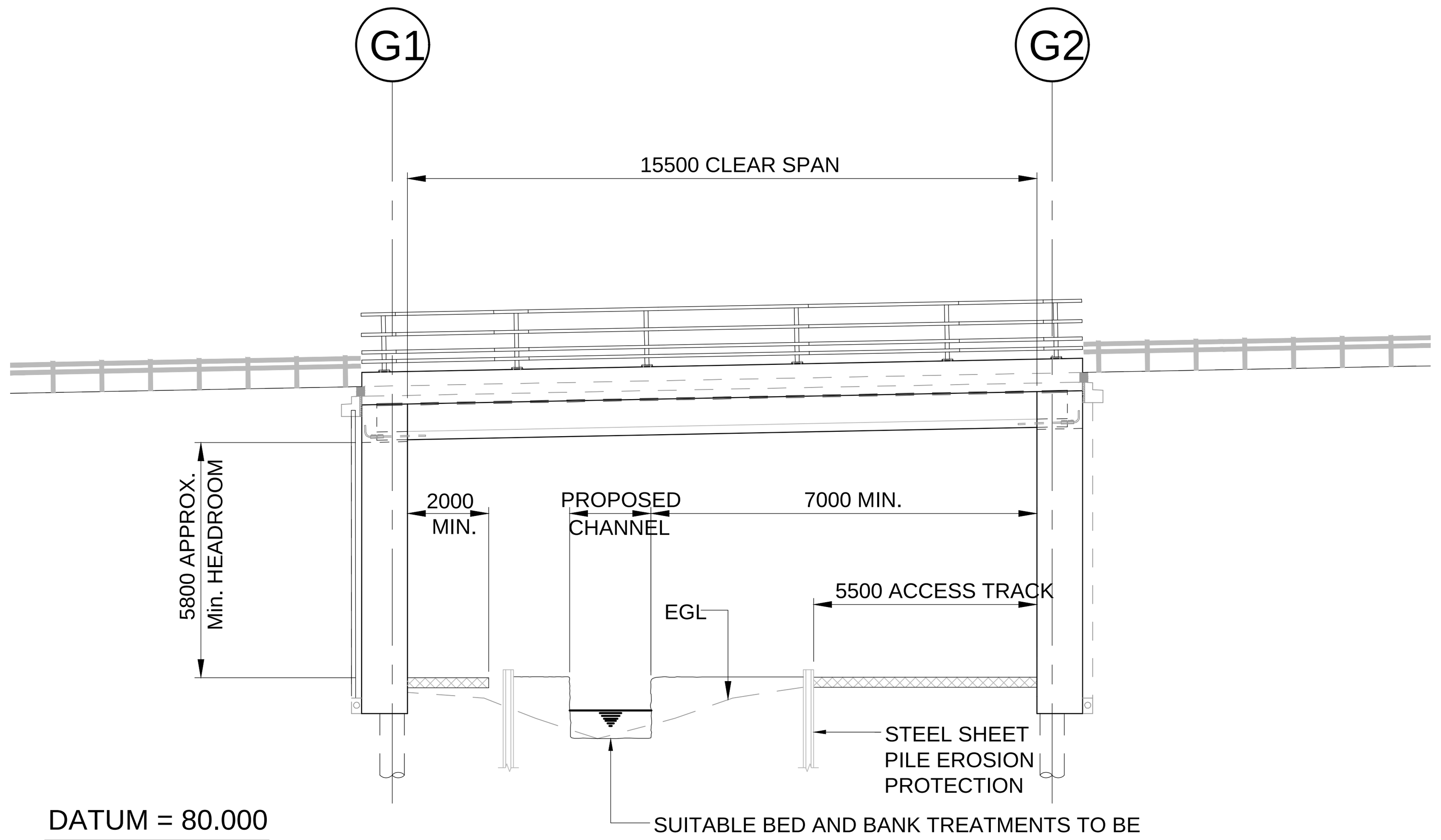
PLAN ON THORPE BROOK BRIDGE

Scale 1:150



PP1/F4 PATTERNED PROFILE FINISH

Scale 1:10

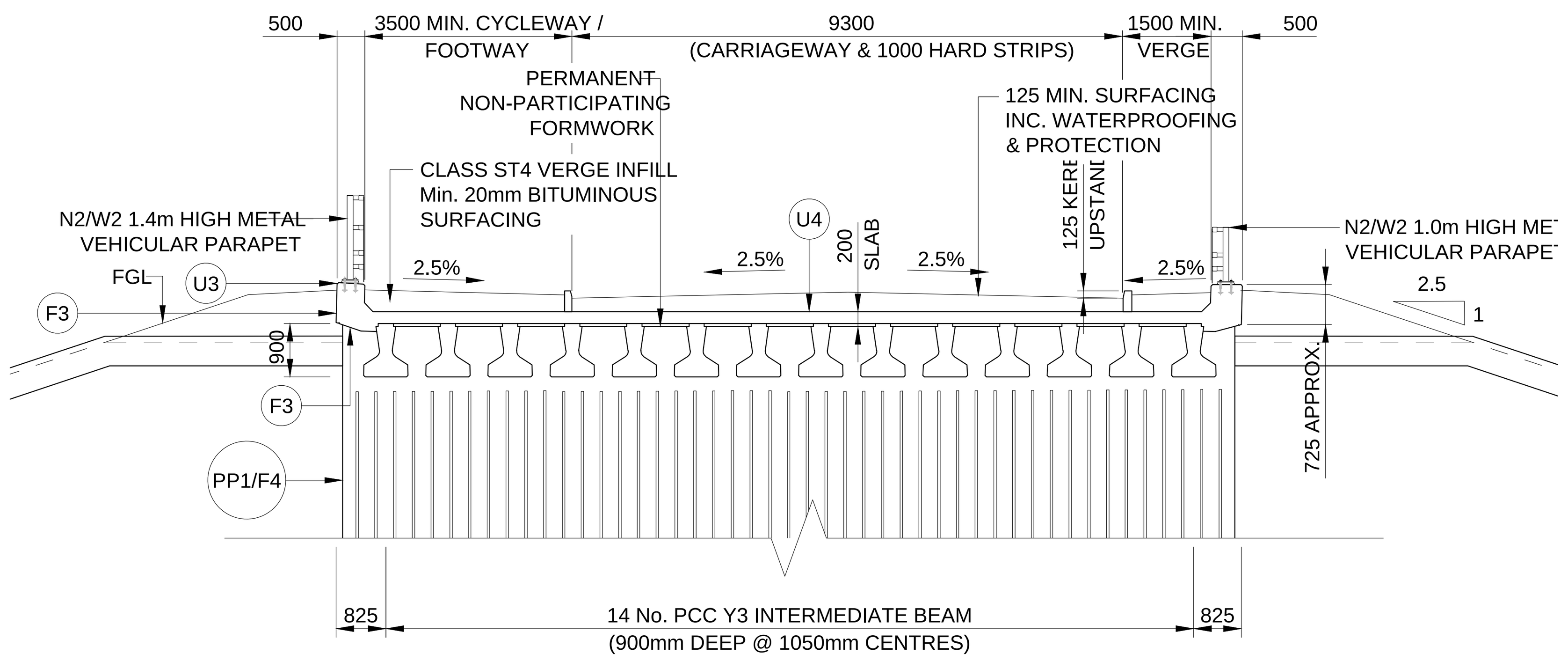


DATUM = 80.000

SUITABLE BED AND BANK TREATMENTS TO BE SPECIFIED BY A GEOMORPHOLOGIST DURING LAND DRAINAGE CONSENT. CHANNEL TO FOLLOW EXISTING WATERCOURSE TO MAINTAIN BED SUBSTRATE AND HABITAT CONTINUITY.

ELEVATION A-A

Scale 1:150



SECTION 1-1

Scale 1:100

AECOM

PROJECT

NORTH & EAST MMDR

CLIENT

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REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue		10/08/18	P01.1

PROJECT MANAGEMENT INITIALS

DESIGNED: MA CHECKED:--- APPROVED:---

INTERNAL PROJECT NUMBER	SCALE
60542201	AS SHOWN

STATUS	BS1192 SUITABILITY
INITIAL STATUS OR WIP	S0

SHEET TITLE

THORPE BROOK BRIDGE
INDICATIVE GENERAL ARRANGEMENT

DRAWING NUMBER	REV
60542201-ACM-STR-S3_BR_B02_Z -DR-CB-0001	P01.1

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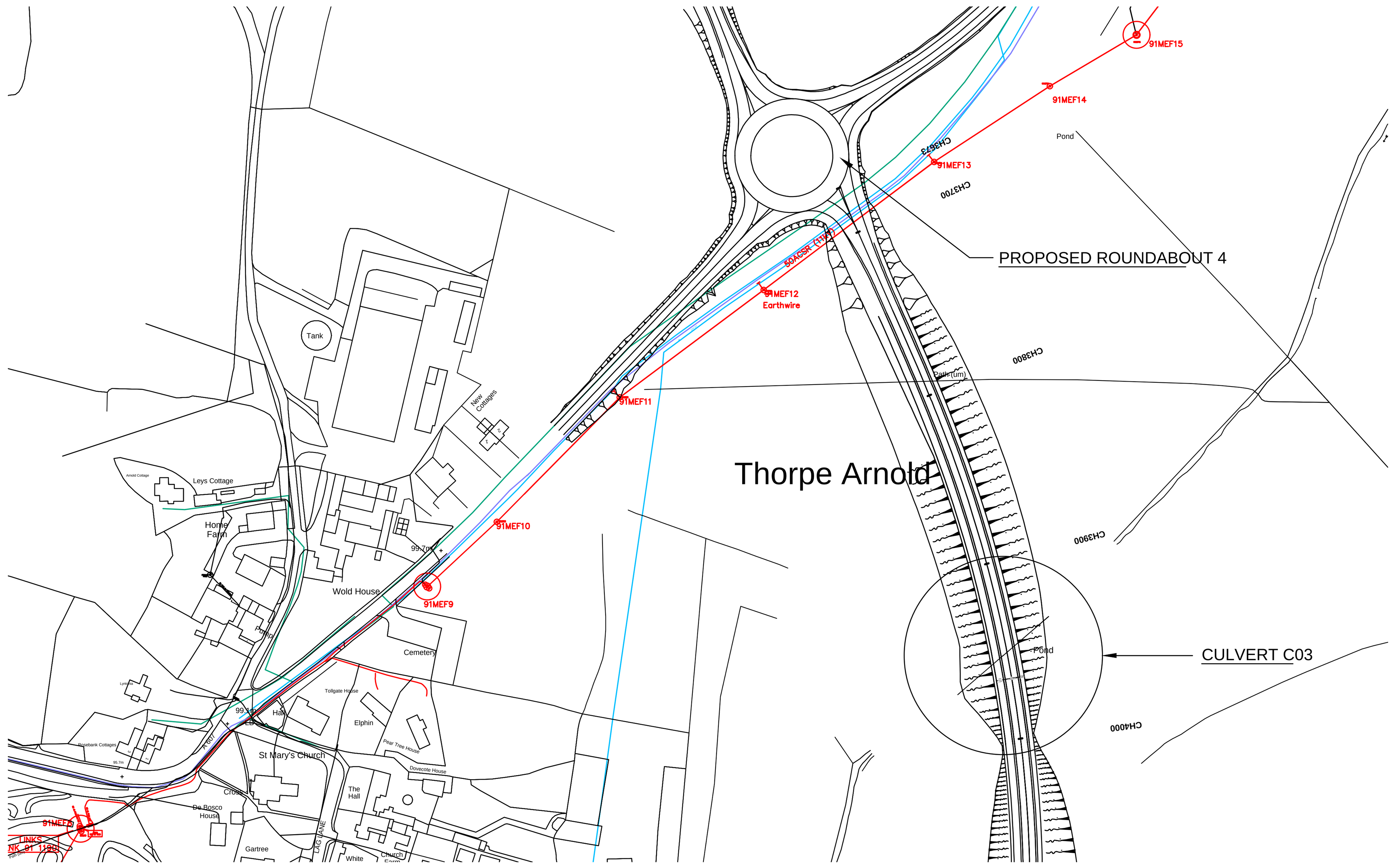
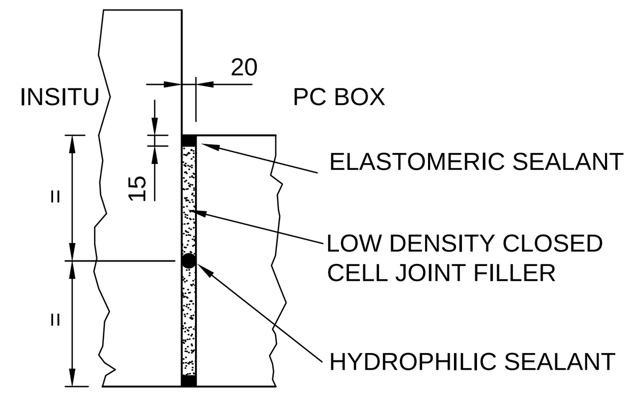
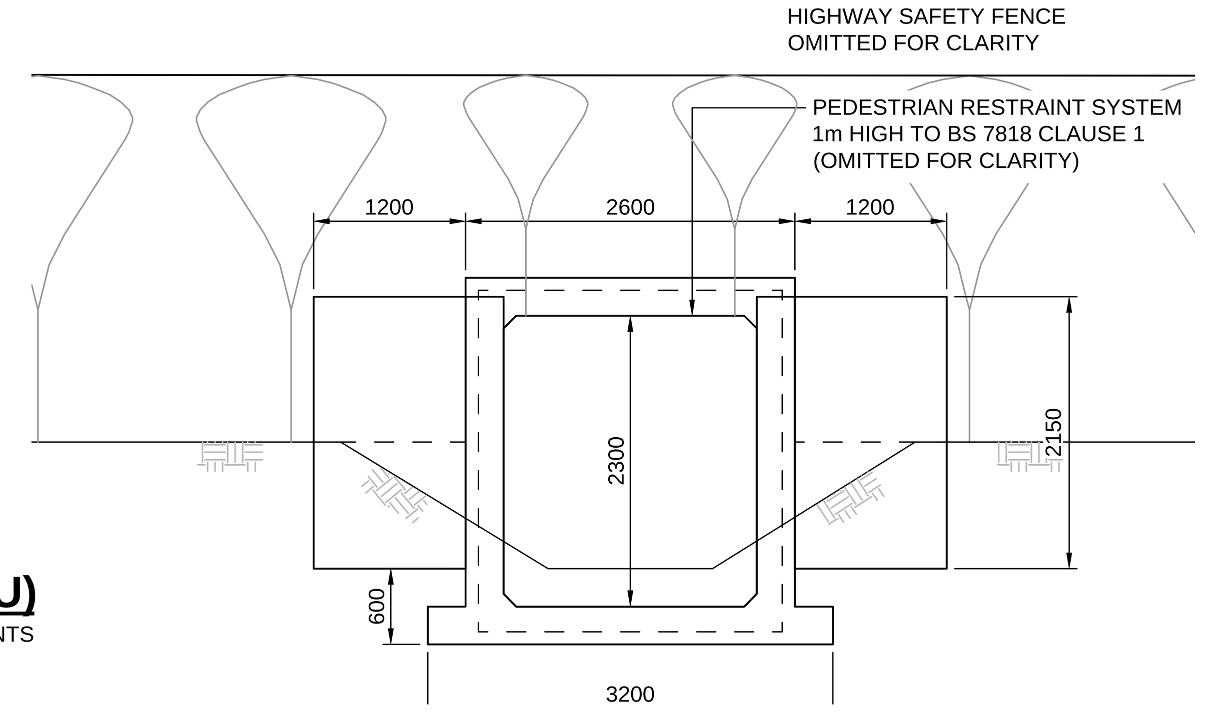
ISO A1 594mm x 841mm



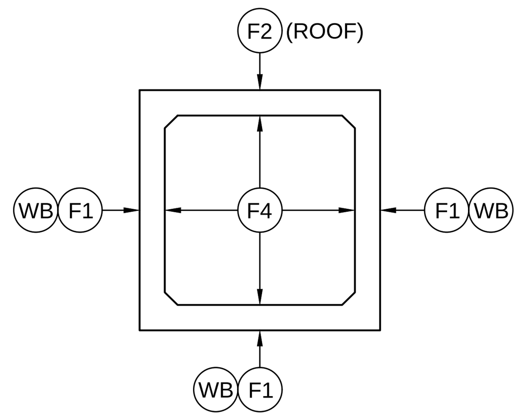
DISTRIBUTOR ROAD - PART LOCATION PLAN
NTS



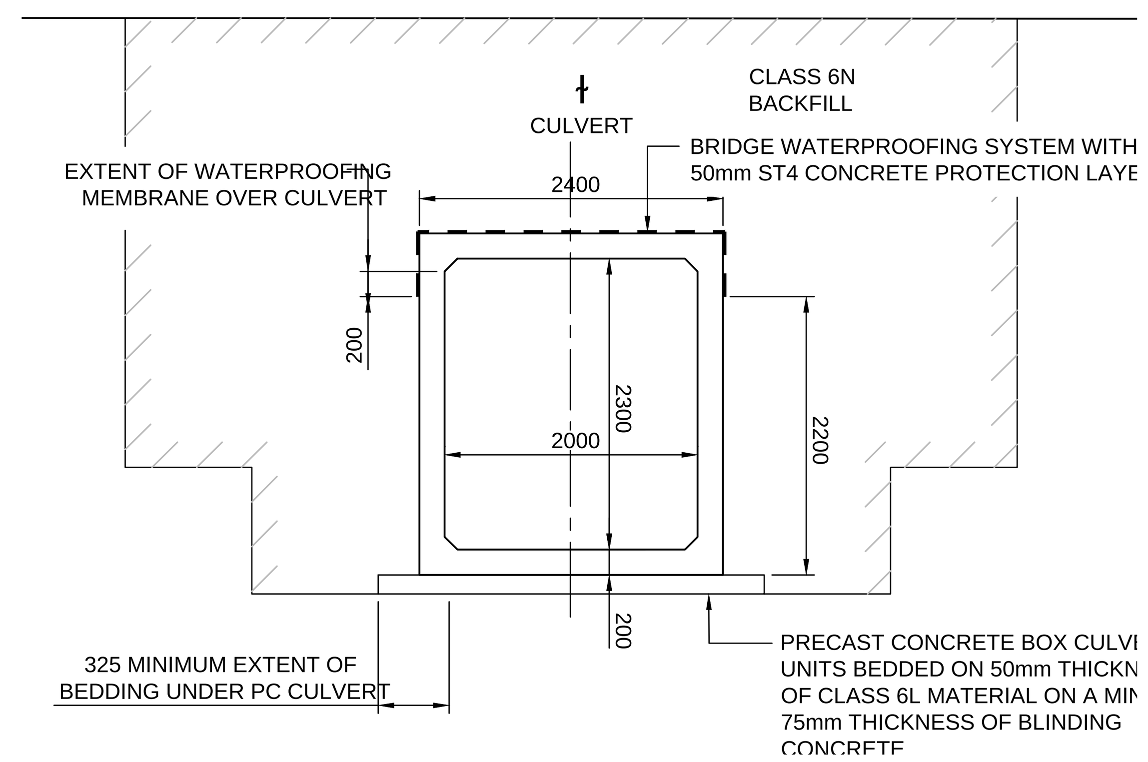
DETAIL A - JOINT DETAIL (PC BOX - INSITU)
NTS



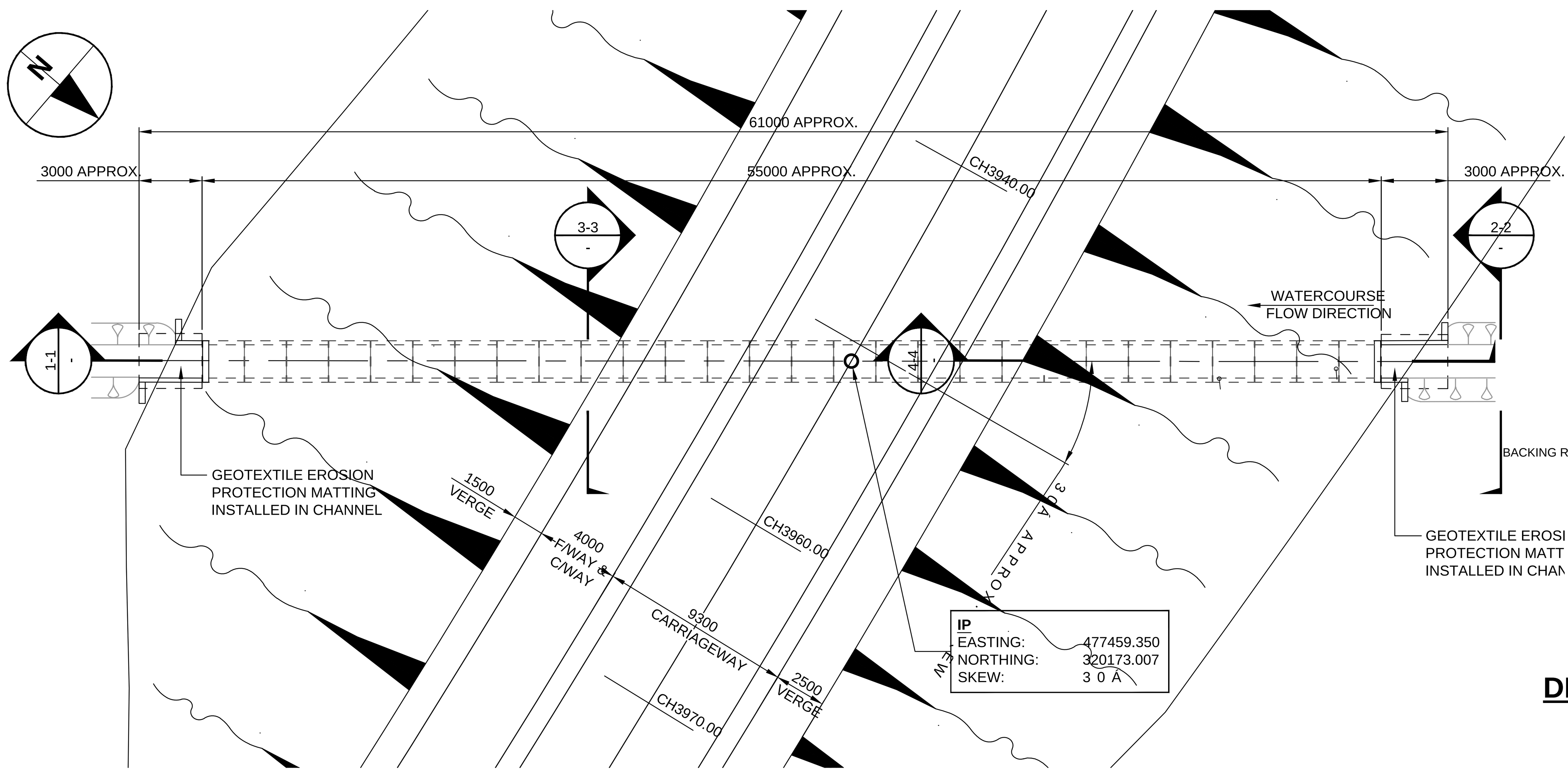
SECTION 2-2
Scale 1:50



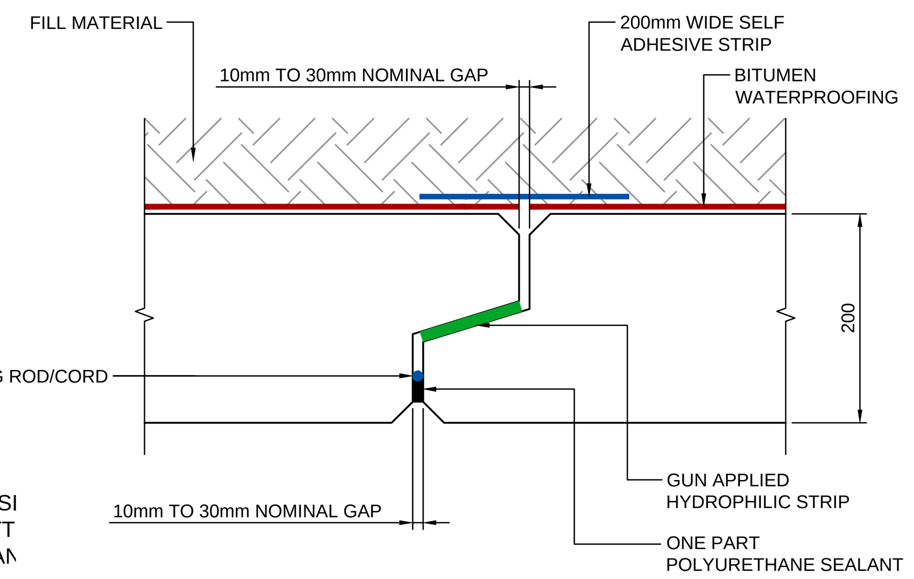
FINISHES TO BOX
NTS



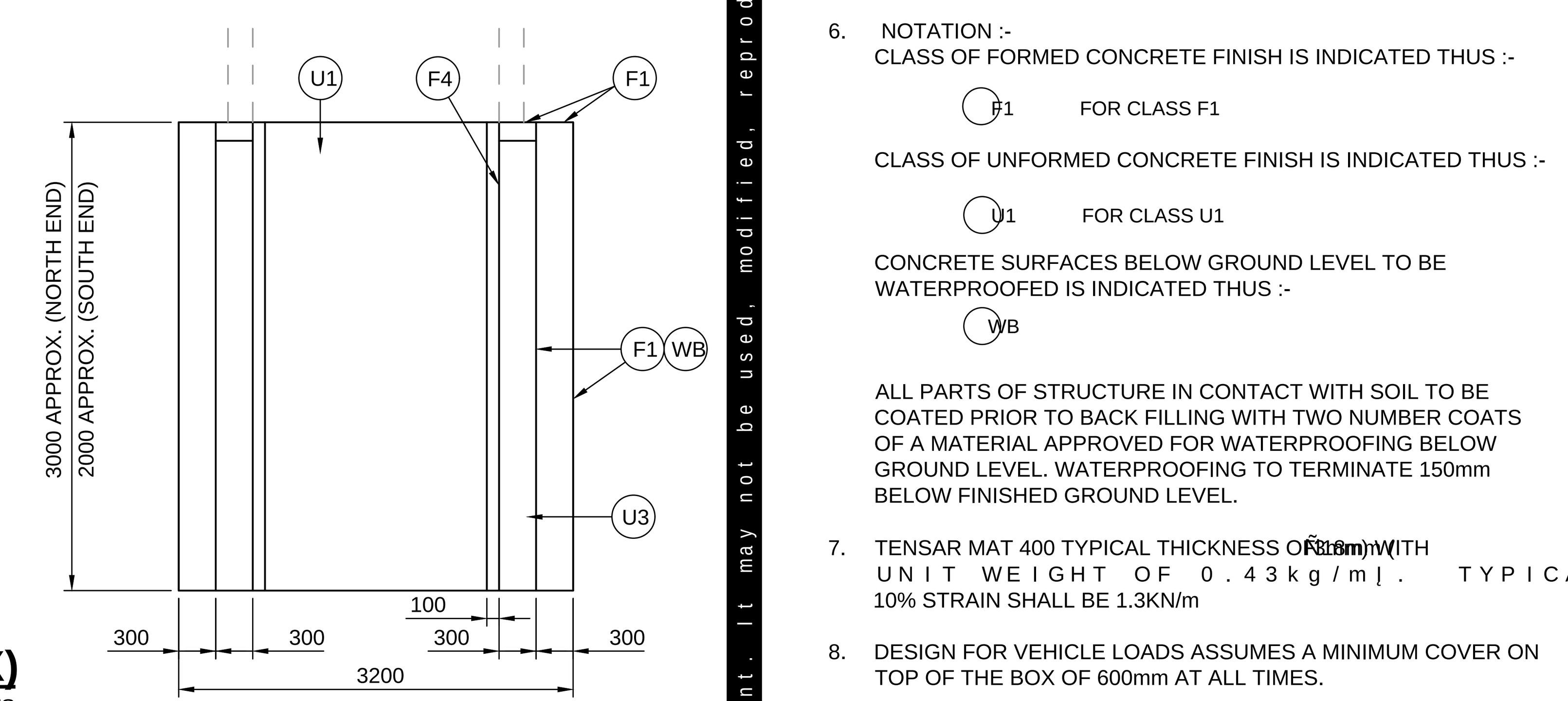
SECTION 3-3
Scale 1:50



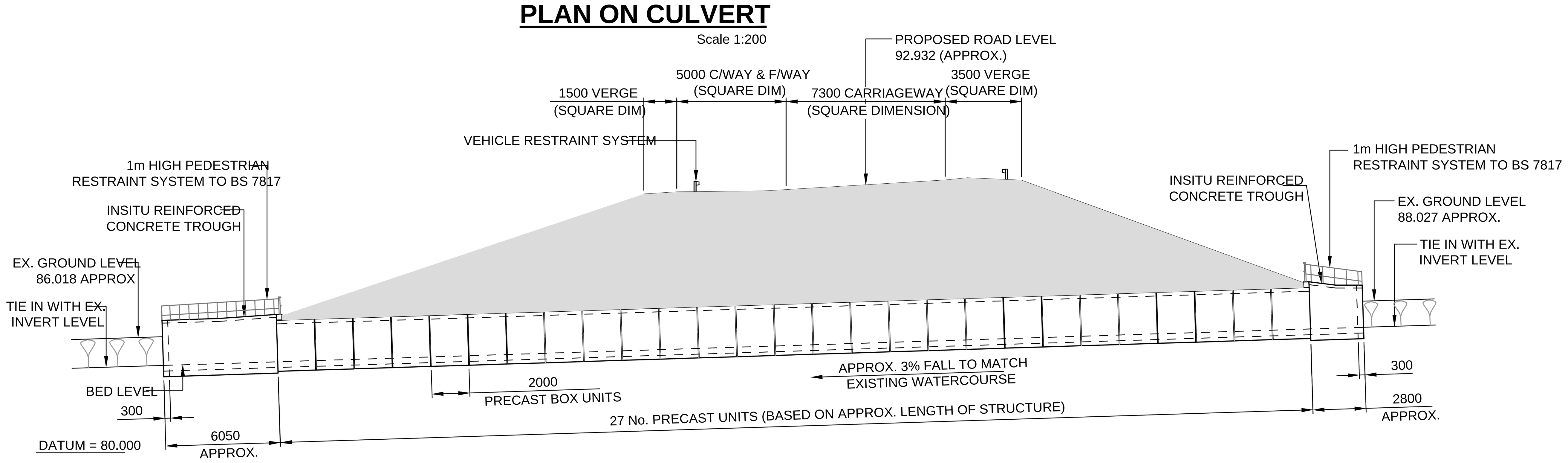
PLAN ON CULVERT
Scale 1:200



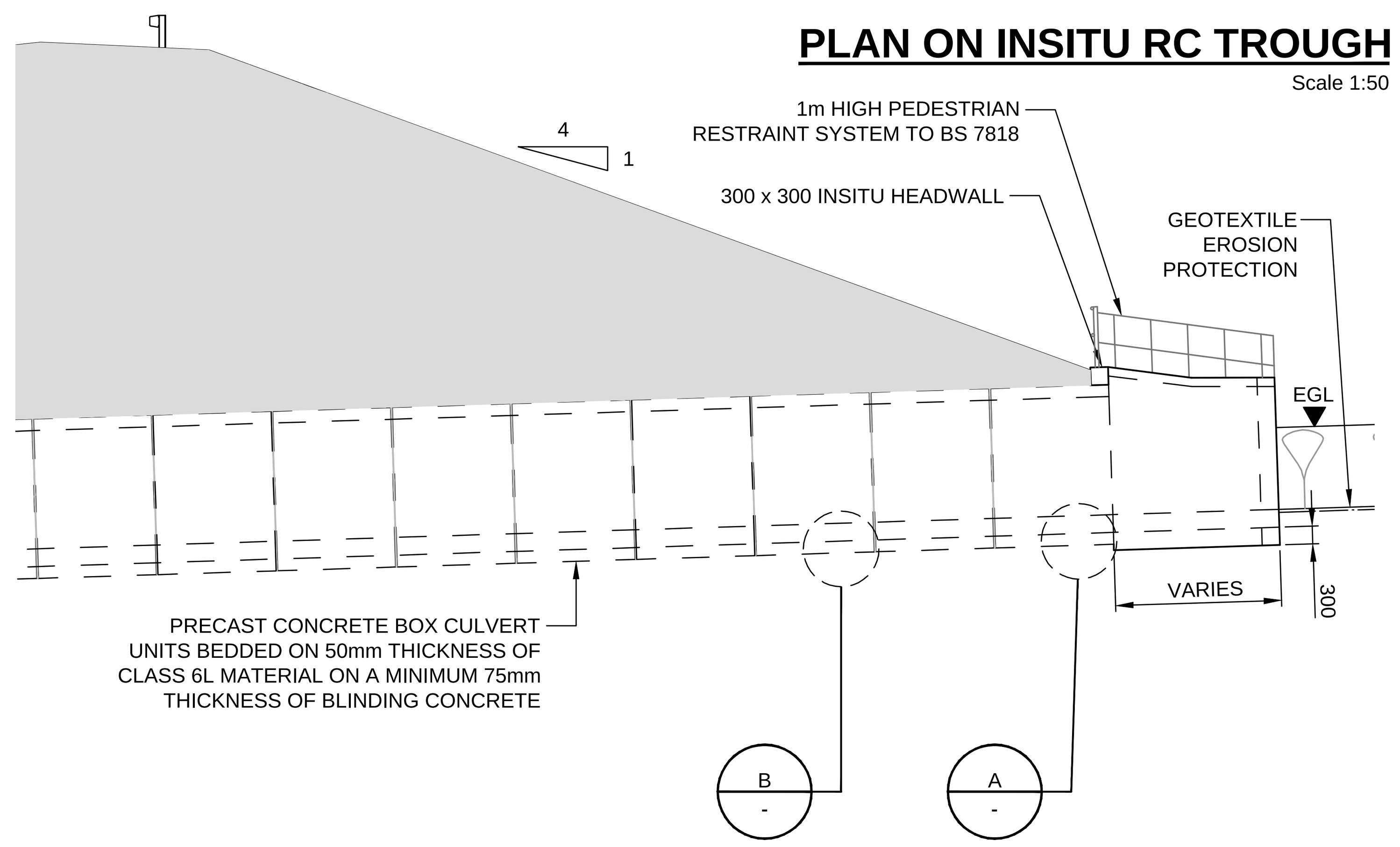
DETAIL B - TYP. JOINT DETAIL (PC BOX - PC BOX)
NTS



PLAN ON INSITU RC TROUGH
Scale 1:50



SECTION 1-1
Scale 1:200



SECTION 4-4
Scale 1:100

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PROJECT

CLIENT

Leicestershire County Council

CONSULTANT

AECOM

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4. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE PROJECT HEALTH & SAFETY FILE FOR ANY IDENTIFIED POTENTIAL RISKS.
5. CONCRETE STRENGTH CLASS :-

BOX	C45/55(A)
HEADWALL	C35/45(A)
TROUGH	C35/45(A)
BLINDING CONCRETE	ST4
INFILL CONCRETE	ST4

6. NOTATION :-
CLASS OF FORMED CONCRETE FINISH IS INDICATED THUS :-
F1 FOR CLASS F1
CLASS OF UNFORMED CONCRETE FINISH IS INDICATED THUS :-
U1 FOR CLASS U1
CONCRETE SURFACES BELOW GROUND LEVEL TO BE WATERPROOFED IS INDICATED THUS :-
WB
ALL PARTS OF STRUCTURE IN CONTACT WITH SOIL TO BE COATED PRIOR TO BACK FILLING WITH TWO NUMBER COATS OF A MATERIAL APPROVED FOR WATERPROOFING BELOW GROUND LEVEL. WATERPROOFING TO TERMINATE 150mm BELOW FINISHED GROUND LEVEL.
7. TENSAR MAT 400 TYPICAL THICKNESS OF 18mm WITH UNIT WEIGHT OF 0.43kg/m², TYPICA 10% STRAIN SHALL BE 1.3KN/m
8. DESIGN FOR VEHICLE LOADS ASSUMES A MINIMUM COVER ON TOP OF THE BOX OF 600mm AT ALL TIMES.
9. FOR DETAILS ON HIGHWAY CONSTRUCTION AND ROAD DRAINAGE SYSTEM INCLUDING STREET LIGHTING REFER TO OTHER RELEVANT DRAWINGS.
10. SPECIFIC BED AND BANK TREATMENTS THROUGH THE STRUCTURE ARE TO BE CONFIRMED WITH LEICESTERSHIRE COUNTY COUNCIL WHEN MAKING ORDINARY WATERCOURSE CONSENT APPLICATION

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue		05/09/18	P01.1

PROJECT MANAGEMENT INITIALS

DESIGNED: CHECKED:--- APPROVED:---

INTERNAL PROJECT NUMBER: 60542201 — SCALE: ---

STATUS: INITIAL STATUS OR WIP — BS1192 SUITABILITY: S0

SHEET TITLE

CULVERT C03
INDICATIVE GENERAL ARRANGEMENT
(CHAINAGE 3950M)

DRAWING NUMBER: 60542201-ACM-STR-S4_CU_C03_Z -DR-CB-0001 — REV: P01.1

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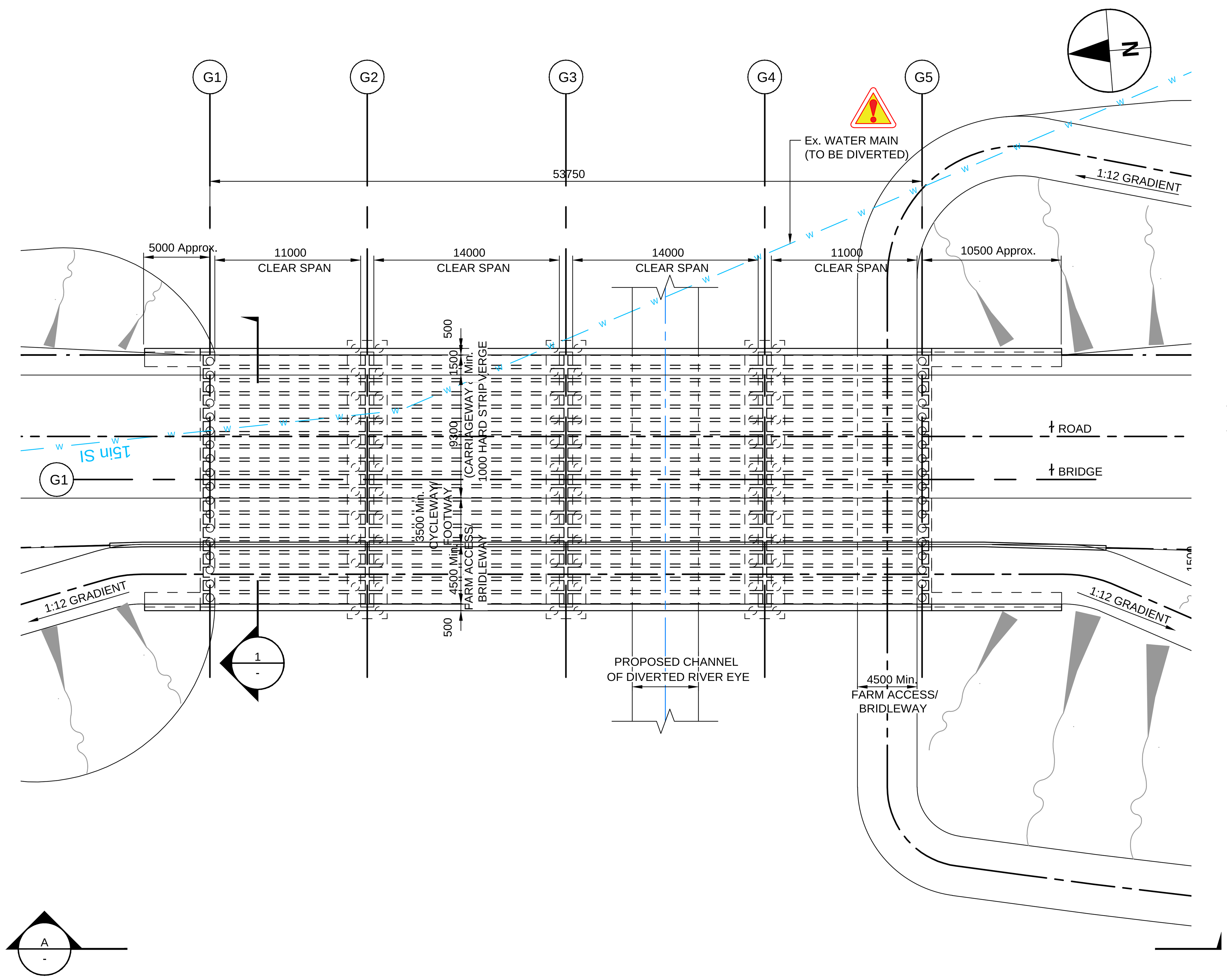
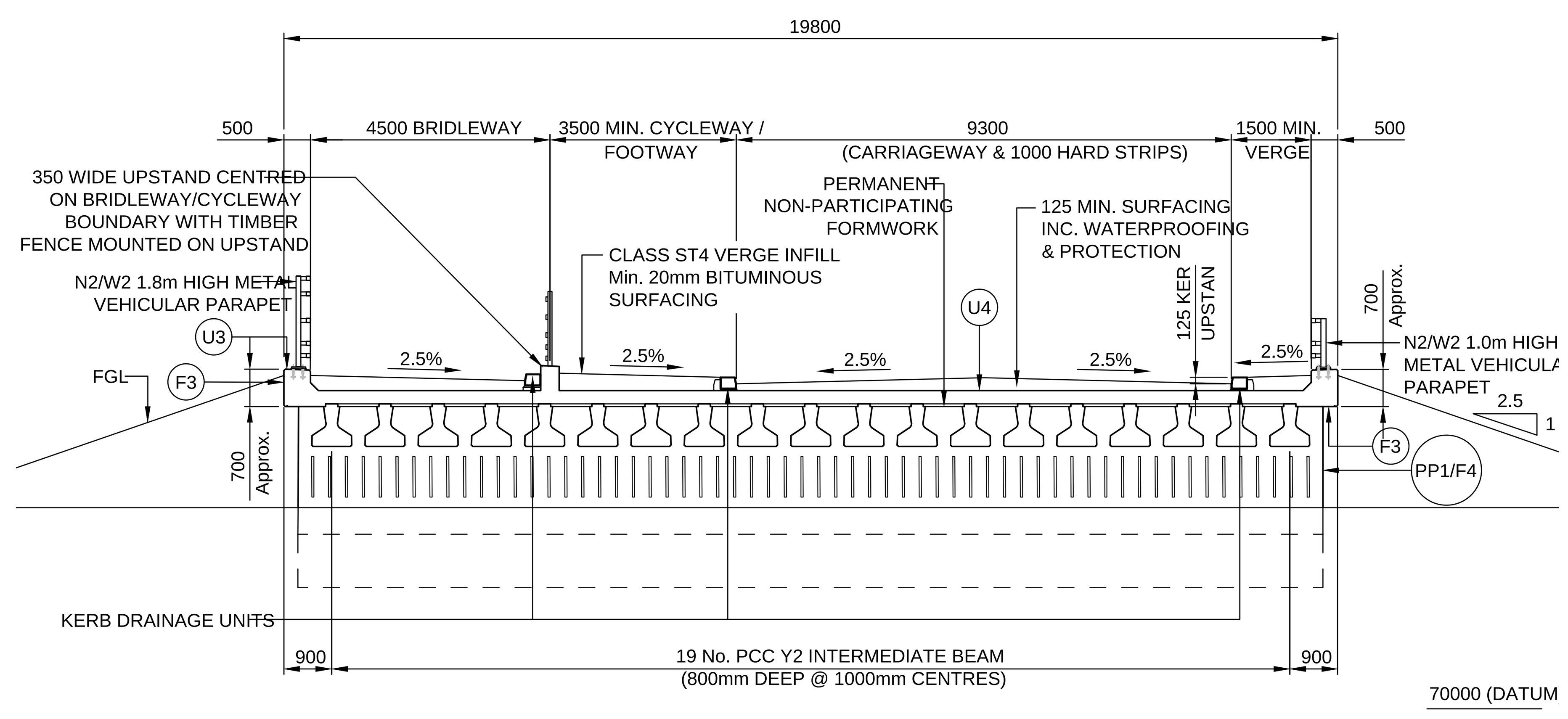
ISO A1 594mm x 841mm



PLAN ON RIVER EYE BRIDGE

Scale 1:250



SECTION 1-1

Scale 1:100

IMPORTANT CDM / HEALTH & SAFETY NOTES
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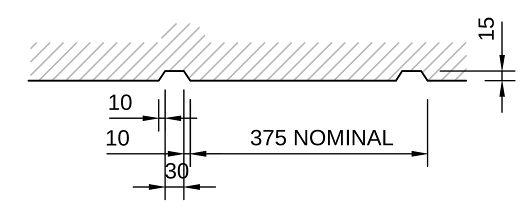
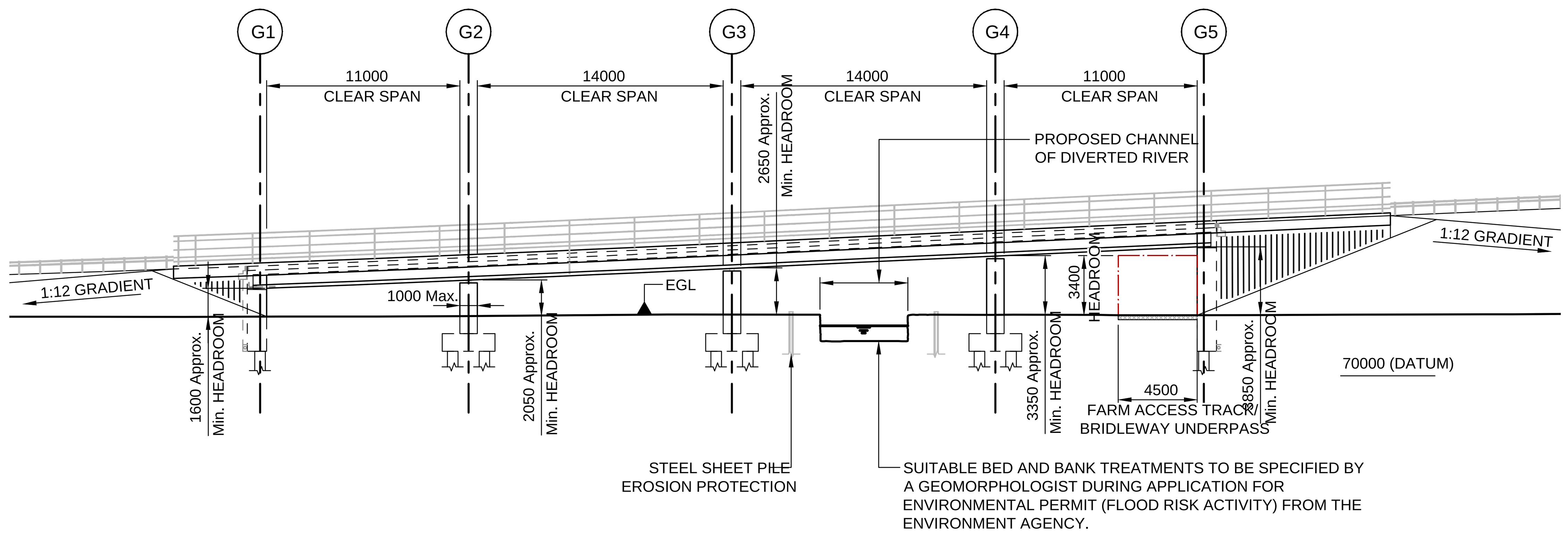
2. EXCEPTIONAL RISKS NOT ELIMINATED DURING THE CURRENT PRELIMINARY DESIGN STAGE ARE HIGHLIGHTED ON THE DRAWING WITH THE SYMBOL ⚠
3. NOT ALL BURIED & OVERHEAD SERVICES ARE SHOWN ON THESE DRAWINGS. FOR THE LOCATION OF STATUTORY UNDERTAKERS APPARATUS, REFER TO STATUTORY UNDERTAKERS PLANS.



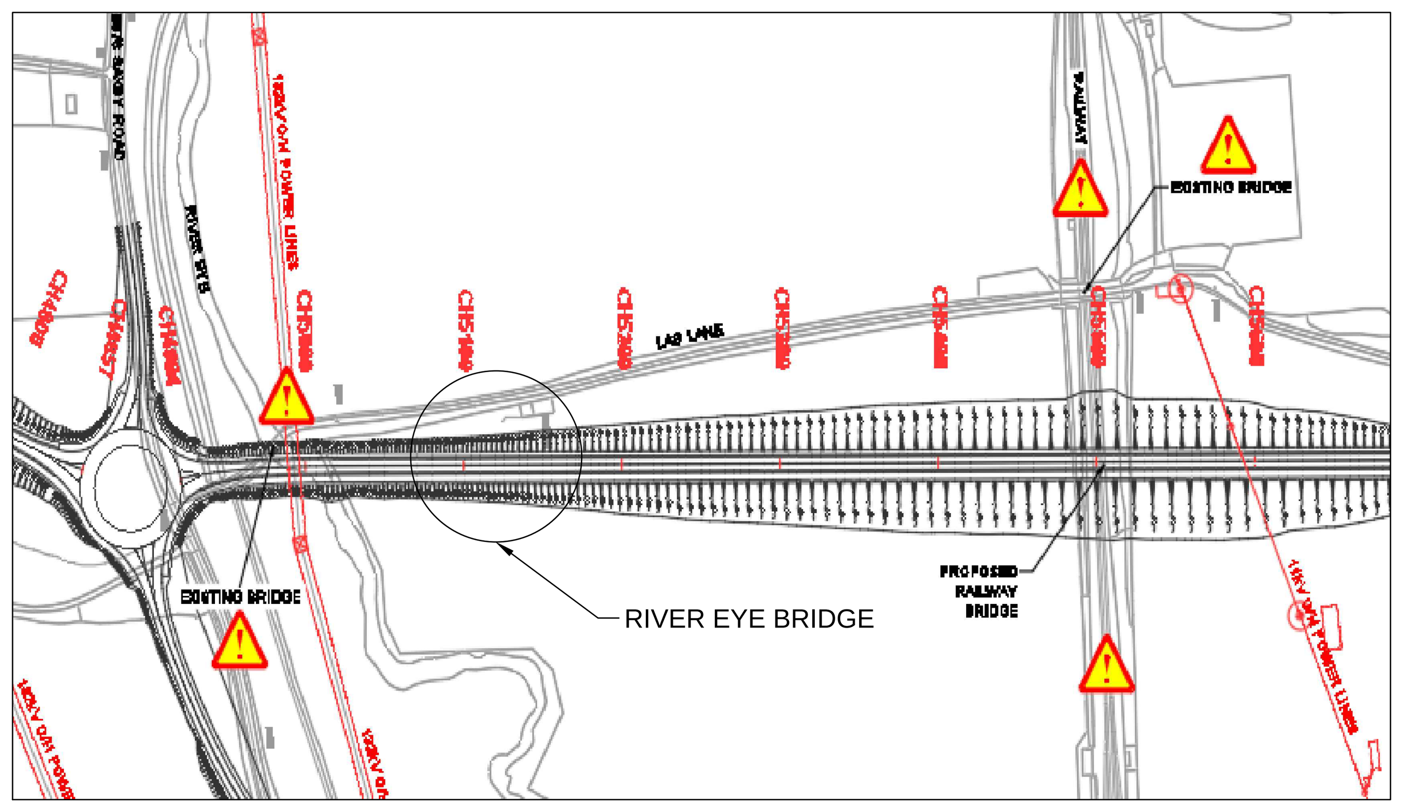
PP1/F4 PATTERNED PROFILE FINISH

Scale 1:10



ELEVATION A-A

Scale 1:250



DISTRIBUTOR ROAD - PART LOCATION PLAN

NTS

AECOM

PROJECT

NORTH & EAST MMDR

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CONSULTANT

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NOTES

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5. CONCRETE STRENGTH CLASS :-

PCC BEAMS	C50/60(A)
DECK CANTILEVER	C40/50(A)
PARAPET UPSTAND	C40/50(A)
DECK SLAB	C40/50(B)
COLUMNS/PILECAPS/PILES	C32/40(A)
DIAPHRAGM BEAMS/CROSSHEAD	C32/40(A)
BLINDING CONCRETE	ST4
VERGE INFILL CONCRETE	ST4

6. NOTATION :-
CLASS OF FORMED CONCRETE FINISH IS INDICATED THUS :-
(F1) FOR CLASS F1
CLASS OF UNFORMED CONCRETE FINISH IS INDICATED THUS :-
(U1) FOR CLASS U1
CONCRETE SURFACES BELOW GROUND LEVEL TO BE WATERPROOFED IS INDICATED THUS :-
(WB)
UNLESS OTHERWISE STATED, ALL PARTS OF STRUCTURE IN CONTACT WITH SOIL TO BE COATED PRIOR TO BACK FILLING WITH TWO NUMBER COATS OF A MATERIAL APPROVED FOR WATERPROOFING BELOW GROUND LEVEL. WATERPROOFING TO TERMINATE 150mm BELOW FINISHED GROUND LEVEL.
7. FOR DETAILS OF HIGHWAY CONSTRUCTION AND ROAD DRAINAGE SYSTEM INCLUDING STREET LIGHTING REFER TO OTHER RELEVANT DRAWINGS.
8. CONCRETE SURFACE FINISHES TO DISCOURAGE GRAFFITI SUBJECT TO AGREEMENT WITH THE ENVIRONMENT AGENCY.

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue	SMH / MA	31/08/18	P01

PROJECT MANAGEMENT INITIALS

DESIGNED: EG CHECKED: MA APPROVED: MA

INTERNAL PROJECT NUMBER 60542201 — **SCALE** AS SHOWN

STATUS FOR INFORMATION — **BS1192 SUITABILITY** S2

SHEET TITLE

RIVER EYE BRIDGE
INDICATIVE GENERAL ARRANGEMENT

DRAWING NUMBER 60542201-ACM-STR-S5_BR_B03_Z-DR-CB-0001 — **REV** P01

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Filename: C:\PWWORKING\AECOM_EU\STEPHEN.HARDY\D0353810\60542201-ACM-STR-S5_BR_B03_Z-DR-CB-0001.DWG

Appendix B

Consultation Responses from the Environment Agency

Appendix B1 – Environment Agency Meeting Minutes to agree the River Eye hydraulic modelling approach

Minutes of Meeting

AECOM

Project:	**Melton Mowbray Distributor Road**	Job No/Ref:	**60542201**
		Date held:	**17-08-2017**
Held at:	Environment Agency, Trentside Offices, Nottingham	Made by:	**Owen Tucker**

Present:	***Environment Agency***: Katie McNamara (KM) Biodiversity Officer. Simon Smeathers (SS) PSO (Flood Risk) Officer. Julia Toone (JT) Hydromorphologist / WFD Specialist. Nick Wakefield (NW2) Planning Specialist. Lucy Weller (LW) Environment Management (Land & Water) Team Leader. ***Natural England:*** Sadie Hobson (SH) Lead Advisor in Environmental Services ***AECOM:*** Owen Tucker (OT) Water Quality / WFD. Neil Williams (NW) Hydromorphology / WFD. Andrew Sherwood (AS) Highways Design. Neal Gates (NG) Ecology Katie Pearson (KP) Flood Risk	Distribution: All present

No.	Originator	Item	Action By
1.	**Introductions**		
2.	**Safety Moment**		
3.	**Project Overview, Key Issues and Design Requirements**		
3.1	AS	AS provided a brief overview of the proposed development. AS explained that there are significant constraints around the River Eye crossing including a railway line and two lines of 132 V overhead power cables and existing properties. The design has considered various options for crossing points but the proximity of the power lines, existing pylons and river make them difficult to avoid. Positioning of an alternative route further east has been discounted since it would cross the Brentingby Flood Storage Area.	
3.2	AS	These cables are significant constraints on construction and represent H&S & CDM concerns. It is not possible to construct a bridge under the overhead power lines due to the combined constraints of flood levels and minimum clearance zone which must be maintained when working beneath the power lines.	
3.3	AS	AS explained that the alternative being considered currently is to divert the River Eye so that the new bridge could be constructed further south and away from the cables. Although constructing a bridge within the available headroom is not possible, it may just be possible to construct the earth embankments. There is approximately 10 m of clearance under the power lines. A 6.2m no-go zone needs to be maintained which leaves only 3.8 m of headroom to work in. Advice from the ECI Contractor supporting the project is that 5m working height is required as a minimum. AECOM is in discussion with Western Power Distribution to see whether the no go zone could be reduced to 5m, although the available space is	

		very limited.	
3.4	OT	In response to a question from NW2, OT explained that the River Eye was Main River but that all other watercourses where Ordinary Watercourses at the point of crossing. In the case of Scalford Brook the Main River designation was just d/s of the historic railway culvert.	
3.5	OT	Stated that open span structures are also proposed for Scalford Brook and Thorpe Brook, with culverts for other minor watercourses and drainage ditches. The design of these culverts will be informed by hydromorphology and ecological surveys and assessments.	
3.6	AS	In response to a question from KM, AS explained the design constraints around the River Eye crossing and stated that significant further changes to the highway alignment were not expected.	
3.7	KM	Stated that there is the potential for significant adverse effects on the SSSI river through habitat loss and effects on protected species. A river diversion will need strong justification. If a diversion was not required the EA would still be seeking support on river restoration from this scheme. The diversion could be counter-productive to the long term aspirations for the SSSI.	
3.8	NW	Explained that further more comprehensive hydromorphological surveys are planned when access is available, but based on an initial desk study and site visit it would appear that the river reach upstream of Lag Lane may already have been altered in the past [e.g. possible realignment linked to former canal] and the habitat may be degraded. Although much of the river is fenced off this reach is not and livestock have access to the banks. In this sense, a diversion could be viewed as a restoration opportunity. Any river restoration or mitigation would consider the combined effects of the scheme on the river channel and floodplain. A diversion may shorten the channel, which would mean direct loss of habitat, and could also mean changing gradients, flow patterns, scour risks, etc. These risks are yet to be assessed.	
3.9	OT	Explained that the current option would avoid the need for a new (additional) bridge and could potentially reduce the risk from construction as the new bridge could be built and the existing Lag Lane bridge demolished offline from the river. Although this would not offset all the potential effects of a diversion, they are beneficial considerations.	
3.10	KM	The attributes of the existing channel will need to be carefully considered. There are records of water vole along this reach, which would also need to be properly managed.	
3.11	NG	NG confirmed that there was evidence of water vole and otter further upstream, but that the reach surrounding the Lag Lane Bridge was much more exposed and thus may have less potential for water vole. There could be opportunities to enhance the bankside habitat for water vole and the SSSI by improving bank stability and riparian habitat.	
3.12	NG	NG also explained that they are considering white-clawed crayfish surveys.	
3.13	SH	Stated that a licence from Natural England will be required for White-clawed crayfish surveys and that applications should be made asap as there could be a delay.	
3.14	AS	Stated that what is currently shown on the plan is a very initial indicative sketch of a diversion only. It is accepted that this would need to be developed based on appropriate survey and assessment,	

		which we are keen to work with the EA/NE to achieve.	
3.15	AS	In response to a question about whether a spur road could be provided instead of the roundabout, AS explained that the position of the railway-river-OHL-properties constrained what was possible.	
3.16	AS	In response to query from KM, AS confirmed that the new bridge over the River Eye would be an open-span structure.	
3.17	AS	In response to a question from KM relating to what the fall back position would be should it not be acceptable to divert the River Eye, AS explained that it would be likely that a diversion to the overhead power lines would be required which would substantially put up the costs of the project and lengthen the construction programme. The project only has funding to develop a Preliminary Design and a competitive application would be made to the Department for Transport for the funding to deliver the scheme. This takes into account the cost-benefit of the scheme.	
4.	**Approach to Flood Risk Modelling**		
4.1	SS	Stated that from a flood risk perspective, were the channel to be diverted it would be important to assess through modelling how this would affect the floodplain including flood flow routes. Changes in flow velocities and the potential for scour should also be considered.	
4.2	KP	KP explained that AECOM is in the process of updating the existing ISIS-TUFLOW River Wreake model. This includes additional topo survey in and around Lag Lane Bridge, due to a significant gap in LiDAR coverage. AECOM is also looking to refine the current 8m grid and to include the ‘Lag Lane Tributary’ which is not currently represented in the model. This is believed to be culverted prior to discharging into the River Eye and a CCTV survey is also proposed.	
4.3	SS	A full range of climate change scenarios will need to be considered including 20, 30, and 50% allowances.	
4.4	KP	Explained that the current highway alignment has been developed based on the existing unmodified model being run for those climate change scenarios. With a 600 mm freeboard that gives a soffit elevation of 74.7 m AOD.	
4.5	SS	The flood storage basin at Scalford is at capacity and effects on this would need to be carefully considered.	
4.6	SS	In response to a question from NW about set back distance for abutments, SS stated that there is no specific guidance. Ideally, we want the banks to remain natural and avoid hard engineering.	
4.7	KM	Ideally, from an ecological perspective the abutments should be set back 10 m from the water’s edge. This is based on anecdotal evidence that water vole may burrow up to 8 m from the bank and this provides a buffer, although a compromise distance is often agreed. This applies to new channels as well.	
4.8	NW	A wider structure may also change channel and floodplain flows, and flood risks upstream and downstream, and this would need to be assessed.	
4.9	AS	This would significantly increase the span from what has been estimated so far (based on existing Lag Lane Bridge). The wider the span the thicker and more expensive the structure.	
4.10	SS	In response to a query regarding approval of the revised model, SS agreed that it can be submitted all in one go. The Environment Agency wishes to advise that the turnaround time for reactive work on model	

		reviews is a minimum of 5 weeks. Whether or not AECOM wish to send in the baseline model and the scheme models in one go or separately will depend on AECOMs timescales and whether or not AECOM think they will need feedback on the baseline model before developing the scheme model too far.	
4.11	KP	KP explained that it is currently proposed to complete the baseline modelling by mid-September but that with scheme scenarios will depend on the development of the scheme, and in particular the design of any river realignment scheme.	
5.	**Approach to WFD Assessment**		
5.1	JT	It will be important that the all of the issues are scoped into the WFD assessment and an appropriate assessment undertaken. At this stage key things to consider will be the SSSI favourable conservation status objective, options assessment, and development of a suitable river restoration strategy. JT also explained that action was being taken in the catchment to reduce phosphorus loads in the River Eye.	
5.2	SH	Stated that NE are promoting a river restoration scheme along the River Eye SSSI and there are concerns that this development could be detrimental to its success. Restoration plans have been awarded funding from the EA for this financial year. A link to the latest plan and technical reports has been issued [at the time of writing this link had not yet been received by AECOM].	
5.3	OT	Explained that at this stage we have only prepared a Preliminary WFD Assessment that sets the context and identifies key issues. We are keen to agree these issues and the scope of assessment with the EA.	OT/NW
5.4	OT	In response to a query from LW, OT explained that there are currently 7 No. surface water outfalls proposed from the new road draining at low points to the various watercourses. This includes three outfalls to the River Eye. An initial DMRB HAWRAT assessment has shown that there is no significant risk from dissolved pollutants, but that sediment-bound pollutants may accumulate in the channel from three outfalls (including Thorpe Brook and Scalford Brook). Treatment ponds are proposed on all outfalls and these should provide the necessary treatment, providing they are well designed. Spillage risk has not yet been considered as the focus to date has been on the schemes footprint. Due to the relatively small size of the road, traffic flows, and number/type of junctions, it is not expected that there will be a significant risk. However, due to the sensitivity of the environment, particularly the SSSI, measures for spillage containment are being considered.	
5.5	OT	In response to a query from KM regarding the need for multiple outfalls to the River Eye, OT said that on another project ditchcourses had been used as the conveyance from the pond to the receiving watercourses and this could be considered here.	
5.6	LW	Stated that pollution prevention will need to be considered, although these comments could wait until a later stage.	
5.7	OT	Explained that the current programme was for an EIA Scoping Report to be issued later this autumn, the outline business case at the end of 2017 and the Environmental Statement in late spring/early summer next year.	
5.8	OT	The pWFD was largely prepared prior to the need for a possible diversion of the River Eye. OT agreed that AECOM would update the	

		pWFD following the outcome of this meeting and would re-issue for comment. This will include greater reference to the issues discussed regarding the River Eye diversion and the options that have been considered previously.	
5.9	NW2	Stated that to review the pWFD would require an amendment to their quotation.	NW2
6.	**Access to Brentingby FSA**		
6.1	NW2	NW2 agreed to look into who is the appropriate person to contact to arrange access.	NW2

Appendix B2 – Environment Agency responses to afflux and freeboard queries

From: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Sent: 23 May 2018 16:42
To: Prabhuswamy, Anupriya; Smeathers, Simon
Cc: Andy Jackson; Heath-Brown, Andrew M; Bentley, Ian; Glossop, Martyn; Sherwood, Andrew; Tucker, Owen; Pearson, Katie
Subject: RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review
Attachments: MMDR_River Eye Crossing_Techincal Note_P01.pdf; MMDR EA Meeting 17.08.17 Final Meeting Minutes.pdf

Hello Anupriya, Owen, all,

Thank you for your emails. I have been notified by our modelling team that it will take them approximately 20 hours to review the submitted model files and associated information and that we should be able to provide you our comments within 4 weeks. I have been informed by Simon Smeathers, our Partnership & Strategic Overview (flooding) Officer that it will take him 2 hours to provide his into this latest submission.

Hi Owen,

Please can you confirm whether you are happy for the above mentioned fee's to be included within the maximum fee of £5,000 which has previously agreed for review work and advice given by the Environment Agency (provisionally until the end of May 2018)?

Hi Anupriya,

Please find below Simons answers to the questions you have raised in your latest email:

¶ Flood Compensation Storage: What return period event would you require us to consider for flood compensation storage volume calculations? No flooding is shown to occur downstream of the Brentingby Dam in the 1 in 100 Year event. Would you require us to use flood levels from the 1 in 100 Year + 50% Climate Change event?
Calculation of flood storage volumes should be based on the design event and include an allowance for climate change. As a minimum we would expect floodplain compensation providing up to the higher central allowance.

¶ Freeboard from the proposed highway: In the current model, the proposed bridge soffit level was set at 600mm above the 100 Year + 50% CC flood level from the baseline model. The baseline model was then revised as described in the attached modelling report. As stated in the attached report, The modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 74.14mAOD, for a 1% AEP plus 50% climate change event. The minimum level of the road in this area is 74.79mAOD (on the eastern side of the roundabout); therefore the freeboard to the proposed highway is at least 0.65m.

However, in the proposed scheme model which does not include any flood relief culverts localised increase in water depths (max increase is approx. 300mm) was found upstream of the proposed structure in the 100 Year + 50% Climate Change event compared to the baseline flood levels.
Does the EA have a requirement for:

a) Minimum freeboard that needs to be maintained from the bridge soffit and 100 Yr.+ 50% Climate Change flood level in the river.
The bridge soffit level should be set 600mm above the 100yr+50% CC level modelled in the proposed scheme option i.e. 600mm freeboard should be maintained post scheme.

b) Minimum allowable increase in water depths in River Eye upstream of the proposed bridge.
The proposed scheme should result in no increase in water levels between the baseline scenario and the post scheme scenario.

Regards
Nick

Nick Wakefield - Planning Advisor
Sustainable Places Team
Environment Agency - East Midlands Area

* Trentside Offices, Scarrington Road, West Bridgford, Nottingham NG2 5BR

(Internal 53354
(External 020302 53354
8 nick.wakefield@environment-agency.gov.uk

East Midlands Technical Leadership Group

From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 23 May 2018 11:26
To: Smeathers, Simon <Simon.Smeathers@environment-agency.gov.uk>; Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Cc: Andy Jackson <Andy.Jackson@leics.gov.uk>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Glossop, Martyn <martyn.glossop@aecom.com>; Sherwood, Andrew <andrew.sherwood@aecom.com>; Tucker, Owen <owen.tucker@aecom.com>; Pearson, Katie <katie.pearson@aecom.com>
Subject: RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review

Nick - Please see attached above the Proposed River Eye Crossing Hydraulic Modelling Report to accompany the modelling files issued last week. Can you please forward it on to the M&F team who will be reviewing the model?

Have you had an indication from the M&F team regarding their availability to undertake the model review? Can you also please provide the estimated fee for the modelling review at your earliest convenience?

Simon

Will you be able to provide a response to the following queries please:

¶ Flood Compensation Storage: What return period event would you require us to consider for flood compensation storage volume calculations? No flooding is shown to occur downstream of the Brentingby Dam in the 1 in 100 Year event. Would you require us to use flood levels from the 1 in 100 Year + 50% Climate Change event?

¶ Freeboard from the proposed highway: In the current model, the proposed bridge soffit level was set at 600mm above the 100 Year + 50% CC flood level from the baseline model. The baseline model was then revised as described in the attached modelling report. As stated in the attached report, The modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 74.14mAOD, for a 1% AEP plus 50% climate change event. The minimum level of the road in this area is 74.79mAOD (on the eastern side of the roundabout); therefore the freeboard to the proposed highway is at least 0.65m.
However, in the proposed scheme model which does not include any flood relief culverts localised increase in water depths (max increase is approx. 300mm) was found upstream of the proposed structure in the 100 Year + 50% Climate Change event compared to the baseline flood levels.
Does the EA have a requirement for:
a) Minimum freeboard that needs to be maintained from the bridge soffit and 100 Yr.+ 50% Climate Change flood level in the river.
b) Minimum allowable increase in water depths in River Eye upstream of the proposed bridge.

Please let me know if you would like to discuss any of these issues, I will be happy to arrange a conference call with the modelling team.

Many thanks,

Anupriya Prabhuswamy, P.E (Texas), MEng
Flood Risk Engineer, Water
D +44-01246-244-712
Anupriya.Prabhuswamy@aecom.com

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From: Prabhuswamy, Anupriya
Sent: 15 May 2018 16:14
To: 'Simon.Smeathers@environment-agency.gov.uk'; 'nick.wakefield@environment-agency.gov.uk'
Cc: Andy Jackson (Andy.Jackson@leics.gov.uk); Heath-Brown, Andrew M; Glossop, Martyn; Sherwood, Andrew; Tucker, Owen; Pearson, Katie
Subject: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review

Melton Mowbray Distributor Road (MMDR) - Proposed Scenario River Eye Crossing Flood Model for EA Review

Hi Simon and Nick,

The proposed scheme scenario flood model for the River Eye crossing has now been completed. The modelling approach was previously discussed with you in the meeting held on 17/08/2017. I have attached the meeting minutes above for your reference.

The MMDR model is now ready for EA review and the model files are available for download using the link below:

FM and TUFLOW files (excluding BASELINE Results): https://we.tl/ZayBSepi3P
BASELINE results: https://we.tl/XAEhZGTlu7

Below is a summary of the of the modelling work undertaken. Further details will be included in a technical note, which will be provided once complete (within the next week).

The model scenarios provided are summarised below:

Scenario	Event	ief	tcf
Baseline	100yr+50% climate change	\FM\IEF\BASELINE MODELLING\MMDR_TRIM_0100Y_CC50_BL_005.ief	\TUFLOW\RUNS\BASELINE MODELLING\
Option C (eastern option of the unnamed tributary diversion)	100yr+50% climate change	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007A.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007A.tcf
Option C (eastern option of the unnamed tributary diversion)	100yr+50% climate change (unnamed tributary peak set to coincide with River Eye)	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007A_LAG.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007A_LAG.tcf

Option C (western option of the unnamed tributary diversion)	100yr+50% climate change	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007B.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007B.tcf
Option C (western option of the unnamed tributary diversion)	100yr+50% climate change (unnamed tributary peak set to coincide with River Eye)	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007B_LAG.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007B_LAG.tcf

A summary of the model changes is provided below.

Updated Baseline Model

The baseline model is based on an existing Environment Agency SFRA model, developed in 2011. The following updates have been carried out for this project:

¶ Extension of the model to include a new, unnamed tributary in the vicinity of Lag Lane (NGR: SK 77121 19362), using survey data captured by Leicestershire County Council.
¶ Truncation of the model to reduce the number of 1D nodes to below 1000. The areas trimmed are:
  ü River nodes WA48 to WA1 (after Hoby village), WA130 and WA131 (top of River Eye) were removed;
  ü Asfordby Brook shortened. River nodes AR664 to AR244 removed; and
  ü Welby Brook shortened. River nodes 01.014 and 0.013 removed.
¶ Reduction of the 2D cell size from 8m to 4m.

Option C Modelling

The current proposed route for the new highway includes a new crossing of the River Eye, Diversion of the River Eye, diversion and new crossings of the unnamed tributary near its confluence with the River Eye and an additional crossing of the unnamed tributary further upstream. Changes to the model (relative to the baseline) were made to reflect these proposals including:

¶ 1D model cross sections representing the River Eye in the vicinity of the proposed crossing were moved and modified to reflect the proposed diversion of the river. The route of the diversion was based on preliminary information provided by the AECOM geomorphology team and included a 1m reduction in channel width. It is noted that, as per the original EA model, channel geometry in this area is represented using a copies of a surveyed cross section from WA108, approximately 200m downstream of the proposed crossing.
¶ Removal of the existing Lag Lane bridge over the River Eye. While the proposed river diversion bypasses this existing structure, it is proposed that the original channel will be left in place as a backwater – this is represented within the 2D model based on the LIDAR data; however, the 2D model has been modified to remove the existing Lag Lane bridge (which is included in the LIDAR data).
¶ Addition of the proposed new highway. Ground levels within the 2D model were modified to represent the proposed highway embankment using information provided by the AECOM design team.
¶ Addition of representation of the proposed new bridge, carrying the proposed highway over the River Eye, to the 1D model.
¶ Removal of an existing culvert (farm access), on the unnamed tributary and replacement with a new culvert under the proposed highway, approximately 1km upstream of the River Eye confluence.
¶ Modification/removal/addition of 1D model cross sections representing the unnamed tributary near its confluence with the River Eye. This included removal of an existing culvert under Saxby Road and addition of new culverts under Lag Lane and Saxby Road. Embankments were also added adjacent to the unnamed tributary to prevent flooding encroaching

onto Saxby Road or the new highway. Details (e.g. horizontal and vertical alignments, embankments heights etc.) of these changes were not provided by the AECOM design team but were determined by the modelling team (in consultation with the geomorphology team), as required to prevent flooding. These details are expected to feed-back into the proposed design. Two alternative routes for the proposed unnamed tributary diversion ('eastern' and 'western' options) have been modelled, as requested by the design team, since the final alignment will be affected by the location of a proposed attenuation basin in this area.

Design Events
The baseline and proposed models have been run for the 1 in 100 year + 50% climate change event. The following four design model runs have been carried out:

- Unnamed tributary western diversion option (original event timing for comparison with the baseline).
- Unnamed tributary eastern diversion option (original event timing for comparison with the baseline).
- Unnamed tributary western diversion option (unnamed tributary event lagged to coincide with the River Eye peak flow, to assess the culvert capacity under worst case conditions).
- Unnamed tributary eastern diversion option (unnamed tributary event lagged to coincide with the River Eye peak flow, to assess the culvert capacity under worst case conditions).

Baseline results have also been provided for a range of additional return periods and climate change scenarios (5yr, 10yr, 20yr, 50yr, 75yr, 100yr, 200yr, 1000yr, 100yr + 20%CC and 100yr +30%CC), for information.

Results
Initial results show that the proposed embankment and bridge crossing the River Eye will cause a localised increase in water levels (max increase is approx. 300mm) upstream of the proposed structure but that there is very little change to the flood extents and no properties are affected. Peak flows passing downstream are slightly reduced relative to the baseline. Flood relief have not been included but can be added if required to reduce the impact on levels in the River Eye. Some localised increases in water level are also predicted on the unnamed tributary, in the vicinity of the proposed new crossings, but flood water is confined to the immediate vicinity of the channel and no properties are affected.

Please note that the Brentingby Dam breach modelling is not included in this current issue. This will be undertaken separately following the initial review of the River Eye crossing model by the EA.

I will follow up with a call to discuss the programme and additional flood related queries that we. The queries are:

- Flood Compensation Storage: What return period event would you require us to consider for flood compensation storage volume calculations? No flooding is shown to occur downstream of the Brentingby Dam in the 1 in 100 Year event. Would you require us to use flood levels from the 1 in 100 Year + 50% Climate Change event?
- Freeboard from bridge soffit: In the current model, the proposed bridge soffit level was set at 600mm above the 100 Year + 50% CC flood level from the baseline model. As stated above in the 'Results' section, in the proposed scheme model localised increase in water levels (max increase is approx. 300mm) was found upstream of the proposed structure in the 100 Year + 50% Climate Change event which encroaches on this freeboard. Does the EA have a requirement for the minimum freeboard that needs to be maintained from the bridge soffit and 100 Yr.+ 50% Climate Change flood level in the river?

Please don't hesitate to contact me if you have any questions.

Kind regards,

Anupriya Prabhuswamy, MEng, PE (Texas)
Flood Risk Engineer, Water

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Prabhuswamy, Anupriya

From:	Smeathers, Simon <Simon.Smeathers@environment-agency.gov.uk>
Sent:	30 July 2018 11:15
To:	Prabhuswamy, Anupriya
Cc:	Wakefield, Nick
Subject:	RE: MMDR River Eye realignment design

Hi Anupriya,

Please see responses to your questions below.

Kind regards,
Simon

Simon Smeathers
Flood Risk Management Officer
(02084 749 935

From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 24 July 2018 15:21
To: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Cc: Smeathers, Simon <Simon.Smeathers@environment-agency.gov.uk>; Andy Jackson (Andy.Jackson@leics.gov.uk) <Andy.Jackson@leics.gov.uk>; Glossop, Martyn <martyn.glossop@aecom.com>; Tucker, Owen <owen.tucker@aecom.com>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Williams, Neil <neil.williams@aecom.com>; Baynton, Mark <Mark.Baynton@environment-agency.gov.uk>
Subject: RE: MMDR River Eye realignment design

Hi Nick,

Thank you for your email.

Baseline flood model
As per recommendations from the model reviewer in the email below, in keeping with best practice, we will revise the baseline flood model to include the new channel survey information once it is available. This revised model will also incorporate comments from Environment Agency that were received on 02/07/2018.

Proposed scenario flood model

We will re-run the proposed scenario model to include the finalised River Eye realignment channel design that is being developed in consultation with the EA and NE.

Simon Smeathers has provided the EA's requirements with regards to minimum freeboard and afflux requirements in an email dated 23/05/2018 (attached above for reference). We have the following questions regarding these:

Minimum freeboard requirements

a) In the previous email the minimum freeboard requirement from the bridge soffit was stated as 600mm above the 100yr+50% CC level modelled in the proposed scheme option. Since there is a drawdown to the bridge occurring upstream of the bridge, will the freeboard be measured above the in-channel water level at the upstream face of the bridge or do we need to consider the higher water level predicted in the floodplain?
   Freeboard should be measured from the highest level, in this case that which is predicted for the adjacent floodplain.
b) Does the EA have a minimum freeboard requirement from the surface of the highway?
   No, provided that the level of freeboard described above can be achieved.

Increase in water levels upstream of the bridge

c) In your email (see attached), it was stated that there should be no increase in water levels between the baseline scenario and the post scheme (i.e. proposed) scenario. The proposed scenario modelling previously undertaken and reviewed by the EA modelling team - in which flood relief culverts were not included – resulted in a maximum water level increase upstream of the proposed bridge of about 0.3m (during in the 1 in 100yr + 50% CC event). In this model scenario, the bridge soffit level was set 600mm above the 1 in 100yr + 50% CC modelled level of the original baseline model. Using the current design of the proposed bridge, we have tested some flood relief culvert options in an attempt to reduce this increase in upstream water levels. It was found that there was a decrease in afflux to 0.16m but it did not completely eliminate it.

   With the updates to the flood model to include the new survey data, realigned river channel design and EA's model review comments, these flood levels and the road design levels are likely to change slightly. However, the biggest constraint to the vertical alignment of the proposed highway and the River Eye bridge is the presence of overhead powerlines (OHLs). A minimum clearance of 11.2 m needs to be maintained between the road and the OHLs and currently the road alignment is set at a height that gives a clearance of approximately 11.3 m, to allow for some uncertainty in construction methods and levels. Clearly this means there is limited scope for the height of the road and bridge soffit to rise. Relocation of the powerlines is an option that LCC is keen to avoid if possible given the significant impact to budget and programme in addition to environmental impacts.

   The area upstream of the proposed River Eye crossing that is shown to flood in the 100yr+50%CC event is agricultural. The current modelling shows that the proposed scheme does not increase the risk of flooding to any residential/non-residential properties located upstream of the proposed River Eye crossing. Even after the inclusion of flood relief culverts, if the model shows an increase to water levels upstream of the proposed bridge compared to the baseline flood levels, would the EA accept this given the absence of properties at risk of flooding in the area and the limited options available to improve the situation from a design perspective?

   There should be no increase in flood depth or extent as a result of the proposed development, this includes impacts on third party land. If you are proposing that there is no other option that would not result in increased depth or extent of flooding we would need the increase in risk to be quantified e.g. area affected and depths, along with evidence that you have explored all possible mitigation options. We may still object to any increase in flood risk to third party land if we feel that risk is unacceptable or there remains possible mitigation options which have not been explored.

Brentingby dam breach model
Although we accept updating the flood model with the new channel survey for scheme design and impact assessment, we still do not consider that it is necessary or an efficient use of resources to update the breach model given the flows/volumes involved.
We agree with this approach.

It would be greatly appreciated if we could get a response to these queries at your earliest convenience.

Many thanks,

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From: Wakefield, Nick [mailto:nick.wakefield@environment-agency.gov.uk]
Sent: 18 July 2018 17:35
To: Prabhuswamy, Anupriya
Cc: Andy Jackson (Andy.Jackson@leics.gov.uk); Glossop, Martyn; Tucker, Owen; Heath-Brown, Andrew M; Bentley, Ian; Williams, Neil; Smeathers, Simon; Baynton, Mark
Subject: RE: MMDR River Eye realignment design

Hello Anupriya,

Thank you for your email dated 26 June 2018.

The model reviewer for the Environment Agency makes the following comments on the points which you have made:

Firstly, we believe that it is certainly best practice to use the updated channel survey if it is available. The concern is that there could be a mismatch between the model used to determine the channel alignment and the baseline flood risk model. From a consistency point of view this clearly isn't ideal. But also, the channel realignment and bridge design form a fundamental part of the proposed redesign of the watercourse. If the option in the flood risk model is based on this understanding, it will be very difficult to compare the option against the baseline if the baseline model is considered to be wrong.

With regards to the significance of the issue, we don't know how different the channel geometry is compared to the proposed new survey. From Neil Williams' email, it implies it is significant enough to question the accuracy of the modelled baseline watercourse. We might suggest that a sensitivity test could be useful. It will be a decision for the Environment Agency as to how much allowance for error they are willing to give the baseline results.

We appreciate that in-channel comparisons cannot be made locally to the new bridge design, as the path of the watercourse will change significantly and as such it is proposed that comparisons will only be made in the floodplain. However, it is not possible to say for certain at this stage how much of an impact the change in channel capacity will have on floodplain levels. We appreciate the flood risk model at the moment is only addressing the 100-year + CC for the option testing, but floodplain depths are generally <0.5m in the area of the proposed change and the floodplain is narrow so the impact could be noteworthy. If there is doubt over the validity of the baseline results in the area of the proposed scheme, this will result in doubt over the validity of the comparison between the option testing and present day scenario.

Overall, our view is that the flood modelling model and any geomorphology model should be in-line with each other, the comparison between the baseline flood risk and option flood risk may not be valid, and that it's best practice to use updated channel survey if it is available.

Kind Regards,

Andrew Waite
Analyst

Regards
Nick

Nick Wakefield - Planning Advisor
Sustainable Places Team
Environment Agency - East Midlands Area

* Trentside Offices, Scarrington Road, West Bridgford, Nottingham NG2 5BR

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East Midlands Technical Leadership Group

From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 26 June 2018 15:52
To: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>; Smeathers, Simon <Simon.Smeathers@environment-agency.gov.uk>
Cc: Andy Jackson (Andy.Jackson@leics.gov.uk) <Andy.Jackson@leics.gov.uk>; Glossop, Martyn <martyn.glossop@aecom.com>; Tucker, Owen <owen.tucker@aecom.com>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Williams, Neil <neil.williams@aecom.com>
Subject: FW: MMDR River Eye realignment design

Hi Nick and Simon,

Further to Neil's email below regarding new channel survey for River Eye, I wanted to clarify a few points from the flood modelling point of view:

- The modelling approach discussed in the meeting with the EA last August (minutes attached) consisted of using the existing River Wreake model as the baseline after updating it to include the Lag Lane watercourse and new LiDAR data in areas of missing coverage only. The baseline modelling that has been submitted to the EA for review on 15/05/2018 and on 19/06/2018 has followed this agreed approach.
- At this stage, we don't intend to revise the baseline flood model using the new channel survey since:
  - It is not likely to make a significant difference to water levels during flood conditions.
  - Since the proposed scenario will include river channel re-alignment, we will be unable to undertake a like-for-like comparison of in-channel water levels between the existing and proposed scenarios. We will compare floodplain water levels/depths, but any differences will be dominated by the impacts of the scheme rather than any differences in channel dimensions (as per the above point).

I hope this is acceptable to the EA's flood team. Please advise.

Kind regards,

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From: Williams, Neil
Sent: 20 June 2018 19:29
To: Banham, Martin (NE); Toone, Julia A; Richard.Jeffries@environment-agency.gov.uk; Butterfield, Ian (NE); Wakefield, Nick
Cc: Gates, Neal; Tucker, Owen; Sherwood, Andrew; Glossop, Martyn; Segre, Marlene; Andy Jackson; Jools Partridge; Heritage, George
Subject: MMDR River Eye realignment design - programme amendment

Dear All

We encountered a set-back last week with what we expected to be our final model runs for the channel realignment design, and unfortunately that has meant a delay to our programme.

The bed levels in the existing River Eye hydraulic model appear inaccurate and far too deep. They do not support the shallow low flows we observed during the site walkovers, and instead show deep ponds much further upstream than we know to exist in reality. This is important, because the shallow and relatively fast flowing channel reaches are those that provide the primary habitat diversity within an otherwise heavily ponded system. It seems that the channel survey in this area dates from 1993, when I suspect there was regular dredging, and the bed elevations measured at that time have subsequently in-filled as dredging has decreased.

The outcome is that we need a new channel survey, to bring the River Eye model up to date with accurate bed levels. I'm sure you will appreciate the importance of this for hydromorphology, ecology and flood risks.

We expect don't expect a new channel survey to completed until 2-3 weeks from now, and we will then need a further 1-2 weeks to re-run our models and finalise the design. This means we will not be circulating the quantified fluvial audit and channel design until around the end of July.

May I ask Julia, Richard, Martin and Ian whether you will have availability in August to review the channel design, so that we can still work with you ahead of the final planning submission deadline, which is in September? Ideally, we will reserve some of your time between August 1st - 10th, but I appreciate that this is in the midst of summer holidays, and we are unable to commit to dates until we get confirmation from surveyors.

Julia and Martin, as a next step I will call you tomorrow to explain the situation in more detail, discuss your summer availability, and see how we can best manage everyone's time.

With many thanks
Neil

Dr Neil Williams
BSc, MSc, PhD, FRGS, MCIWEM, C.WEM, CEnv, CSci, CGeog$_{(Geomorph)}$
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Appendix B3 – Environment Agency responses regarding Brentingby Dam Breach modelling approach

Mr Sam Wash
Leicestershire County Council
Melton Mowbray Distributor Road
Consultation team
County Hall Leicester Road
Glenfield
Leicester
LE3 8RA

Our ref: LT/2017/122659/01-L01
Your ref: Email 01 Sep 2017

Date: 12 October 2017

Dear Mr Wash

MELTON MOWBRAY DISTRIBUTOR ROAD - PUBLIC CONSULTATION ON RECOMMENDED ROUTE
LAND ADJACENT TO MELTON MOWBRAY

Thank you for giving the Environment Agency the opportunity to comment on the recommended route of the Melton Mowbray Distributor Road.

The Environment Agency works to create better places for people and wildlife, and support sustainable development.

We have read the public consultation document and have the following comments to make.

Protected habitat and species

Based on the information currently submitted we have concerns which relate to the direct and indirect impacts of the development on the River Eye in the area of the proposed river diversion and road crossing, south of proposed roundabout ‘5’. In particular we are concerned about the possible adverse effects on protected habitats and species.

The Water Framework Directive and water quality

Any proposed scheme will need to comply with the requirements of the Water Framework Directive (WFD). The WFD stipulates development proposals should not lead to a deterioration in the water quality status of a waterbody. We would not be able to support a scheme that fails to meet WFD obligations. At this point in time, further assessment work is required to demonstrate the effects of the scheme.

Cont/d..

Flood risk

From a flood risk perspective we are pleased that the proposed route avoids crossing our flood defence asset at Brentingby.

However the impact of the proposed development, including the crossing of the River Eye and any proposed changes to the watercourse will need to be assessed. Hydraulic modelling should demonstrate that the development does not increase flood risk elsewhere and is safe for its lifetime including an appropriate allowance for climate change in line with our current guidance.

The project consultants are advised to consider the scenario of a breach of the Brentingby Dam. This is considered a low probability/ high impact event. The consultants will need to decide on whether to ensure any road and road bridge is designed in such a way as to remain operational during such an event or to accept that such an event would lead to road closures.

Where applicable the development should make use of sustainable drainage systems. The Lead Local Flood Authority (Leicestershire County Council) should be consulted for any requirements they may have regarding the disposal of surface water drainage resulting from the project.

In summary, the impacts that are likely to occur from the development will need to be properly identified, managed, mitigated and compensated against as part of the project. All of these elements will need to be integrated into the design of the distributor road.

We are keen to work closely with the project consultants (AECOM) and other environmental consultees to understand how the river catchment, protected habitats and species will be affected, as well as the effect on flood risk in the area, and to ensure the best environmental outcomes for the project.

Yours sincerely

Mr Nick Wakefield
Planning Advisor

Direct dial 02030 253354
Direct fax 0115 846 2681
Direct e-mail nick.wakefield@environment-agency.gov.uk

End

Prabhuswamy, Anupriya

From:	Heath-Brown, Andrew M
Sent:	07 February 2018 14:41
To:	Simon.Smeathers@environment-agency.gov.uk
Cc:	nick.wakefield@environment-agency.gov.uk; Sam.Wash@leics.gov.uk; Tucker, Owen; Prabhuswamy, Anupriya
Subject:	Melton Mowbray Distributor Road - Brentingby Dam breach modelling
Attachments:	Ref 90 MMDR Response.rtf; Brentingby Dam Breach Analysis Memo 2018-02-07.pdf

Simon,

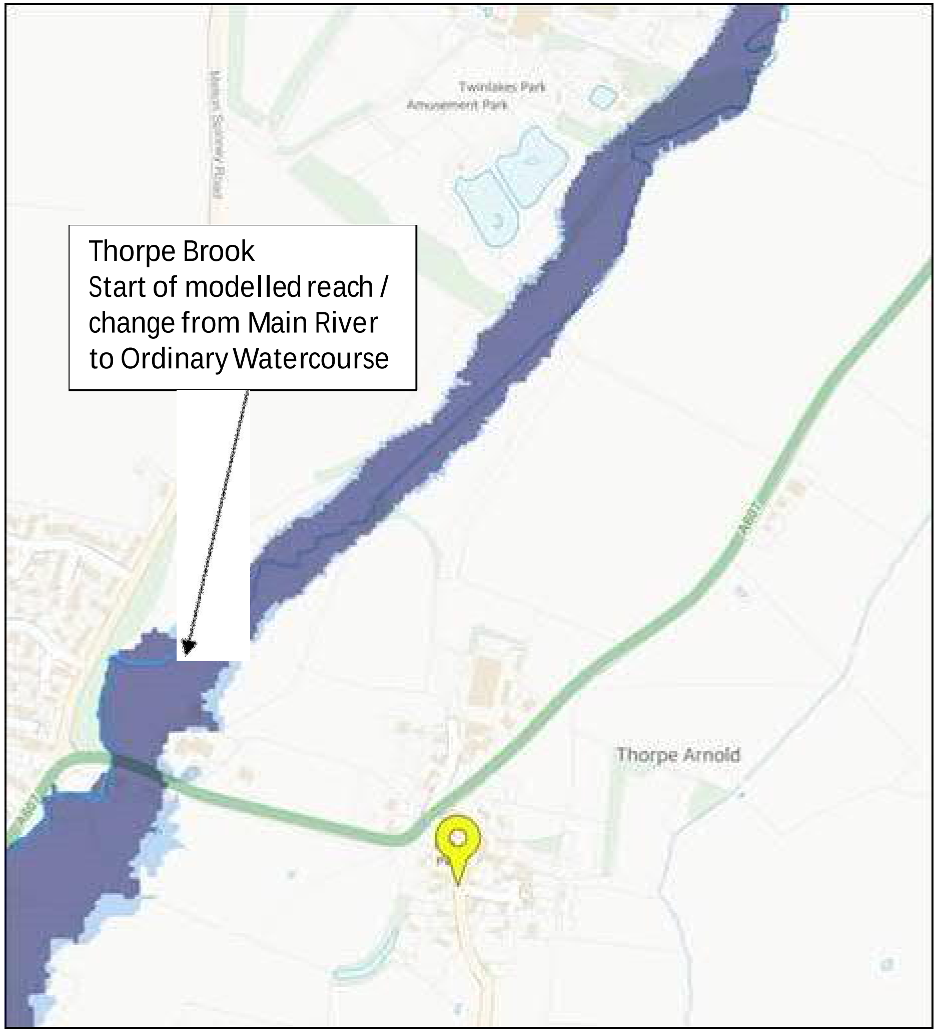
I understand that you will be reviewing the proposed modelling approach for undertaking breach modelling at Brentingby Dam on the River Eye. This was requested by your colleague Nick Wakefield (in his response to Sam Wash at Leicestershire County Council), in a letter dated 12 Oct 2017 (LT/2017/122659/01-L01 – attached for reference). The breach modelling was requested to inform the FRA being prepared with respect to the proposed Melton Mowbray Distributor Road.

I have attached our proposed modelling approach. I would be grateful if you could review and either send approval or recommendations for revision – if the latter, we will update and return to you with the necessary amendments.

In addition, I have a related question that you may be able to help with. As part of the proposed route, the distributor road will be crossing Thorpe Brook, a tributary of the River Eye. The latest model of the River Eye which we have received from the EA includes part of Thorpe Brook, but does not extend upstream to the proposed crossing point. This is presumably because it changes from Main River to Ordinary Watercourse downstream of the crossing point. However, the EA Flood Map for Planning shows flood outlines along the ordinary watercourse part of Thorpe Brook (see screenshot below). As such, I wondered whether you or one of your colleagues would be able to provide flood levels and the flood zone GIS files for the ordinary watercourse section of Thorpe Brook? I assume this part of the watercourse has been mapped based on broadscale (flood spreading) models. LCC have requested that we size the crossing here such that the flood zones are not impacted, therefore we would ideally like to get an accurate flood level and/or flood extent if available.

Any questions, please let me know.

Kind regards
Andrew



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Associate Technical Director, Water
D +44-(0)-113-301-2419
andrew.heath-brown@aecom.com

AECOM
2 City Walk

Prabhuswamy, Anupriya

From:	Tucker, Owen
Sent:	18 April 2018 10:58
To:	Wakefield, Nick
Cc:	Sherwood, Andrew; Glossop, Martyn; Prabhuswamy, Anupriya; Heath-Brown, Andrew M
Subject:	RE: MMDR Brentingby Dam Breach Modelling
Attachments:	FW: Draft modelling scope - Brentingby Dam

Hi Nick,

Thank you for the attached comments on the scope of breach modelling. We've reviewed this and accept all your recommendations and will apply the supplied latest guidance as we work through the breach modelling process.

In response to specifics, we will apply the FD2320 breach analysis method – this is based on the recommendations in the following document regarding FRAs (http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2321_7400_PR_pdf.sflb.ashx).

Finally, we will also apply the 30% climate change allowance against the 1% AEP event only.

Regards,

Owen Tucker BSc (Hon) MSc CEnv MCIWEM
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From: Wakefield, Nick [mailto:nick.wakefield@environment-agency.gov.uk]
Sent: 04 April 2018 11:47
To: Tucker, Owen
Cc: Sherwood, Andrew; Glossop, Martyn; Prabhuswamy, Anupriya; Heath-Brown, Andrew M
Subject: RE: MMDR Brentingby Dam Breach Modelling

Hello Owen,

Thank you for your email and I sincerely apologise for the delay in replying.

Please see the attached email which contains comments from both our flood modelling team and also Simon Smeathers, our PSO Officer.

Again, I apologise for the delay.

Regards
Nick

Nick Wakefield - Planning Advisor
Sustainable Places Team
Environment Agency - East Midlands Area

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East Midlands
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Leadership Group

From: Tucker, Owen [mailto:owen.tucker@aecom.com]
Sent: 21 March 2018 17:52

To: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Cc: Sherwood, Andrew <andrew.sherwood@aecom.com>; Glossop, Martyn <martyn.glossop@aecom.com>; Prabhuswamy, Anupriya <anupriya.prabhuswamy@aecom.com>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>
Subject: RE: MMDR Brentingby Dam Breach Modelling
Importance: High

Hi Nick,

As I was only able to dial in to today's meeting there was not an opportunity to discuss your comments below. I've provided a response below in red. The main thing is that I do not believe we've yet had a response from Simon to our memo describing our proposed approach to the dam breach modelling. I've attached what we believe is the last correspondence on this, which also includes the memo. I would be grateful if you could please chase this up with Simon asap.

Best wishes,

Owen Tucker BSc (Hon) MSc CEnv MCIWEM
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From: Wakefield, Nick [mailto:nick.wakefield@environment-agency.gov.uk]
Sent: 20 March 2018 14:56
To: Andy Jackson; Sean Mahoney (Sean.Mahoney@naturalengland.org.uk); Sean Mahoney (Sean.Mahoney@naturalengland.org.uk); Butterfield, Ian (NE); Toone, Julia A; Brunt, Rebecca J; Tucker, Owen; Glossop, Martyn; Segre, Marlene; Jools Partridge; Kirsty Gamble; Sherwood, Andrew
Subject: RE: Appraisal Report

Hello Andy,

Further to your request below, the group will have already seen the attached email from Jules.

In addition I have also received comments from Simon Smeathers (flood risk Officer) and also our Contaminated Land officer, as follows.

Flood risk

The EA's substantial comments regarding flood risk can only really be made once we have received and reviewed the site specific FRA (and any accompanying modelling work). – The flood modelling of the proposed River Eye crossing options is currently underway. The FRA will be completed once the modelling has been completed and approved by the EA.
Notwithstanding, at this stage we would like to ask whether the FRA will be reviewing the residual risk from breach of the Brentingby flood storage reservoir. The FRA should review the residual risk to the development from breach of this defence and the impact the development will have on third parties should a breach event occur i.e. does it result in increased extent or depth of flooding to others. – Yes, the FRA will be reviewing the residual risk from breach of the Brentingby flood storage reservoir. We issued our proposed breach modelling approach in February but having spoken to the FR team I believe we are yet to receive a response. I've attached what we believe to be the last correspondence and we would be grateful if you could please follow this up at your earliest opportunity.

Contaminated Land (and the protection of controlled waters)

The report demonstrates an understanding of the sensitivity of the area from a groundwater point of view.

For whichever option is chosen, from the perspective of the protection of controlled waters, the EA is likely to request a planning Condition for the scenario that unsuspected contamination were to be found during site works and possibly also a Condition relating to drainage (particularly if infiltration is proposed). Noted.

See you tomorrow.

Regards
Nick

Nick Wakefield - Planning Advisor
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From: Andy Jackson [mailto:Andy.Jackson@leics.gov.uk]
Sent: 20 March 2018 11:36
To: Sean Mahoney (Sean.Mahoney@naturalengland.org.uk) <Sean.Mahoney@naturalengland.org.uk>; Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>; Sean Mahoney (Sean.Mahoney@naturalengland.org.uk) <Sean.Mahoney@naturalengland.org.uk>; Butterfield, Ian (NE) <Ian.butterfield@naturalengland.org.uk>; Toone, Julia A <Julia.Toone@environment-agency.gov.uk>; Brunt, Rebecca J <rebecca.brunt@environment-agency.gov.uk>; Owen Tucker <owen.tucker@aecom.com>; Martyn Glossop (martyn.glossop@aecom.com) <martyn.glossop@aecom.com>; Marlene Segre (marlene.segre@aecom.com) <marlene.segre@aecom.com>; Jools Partridge <Jools.Partridge@leics.gov.uk>; Kirsty Gamble <Kirsty.Gamble@leics.gov.uk>; Andrew Sherwood <andrew.sherwood@aecom.com>
Subject: Appraisal Report

Dear all
If you haven't already done so, if there are any comments on the report that can be distributed before tomorrow that would be very much appreciated. There's no agenda as such, it will just be an opportunity to go through the appraisal and discuss the main areas of concern/comment. If there is anything additional you would like to cover please let me know.

Thanks for your time on this
Regards
Andy

Andy Jackson
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Asset and Major Programmes
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Appendix B4 - Environment Agency Modelling & Forecasting Comments

Prabhuswamy, Anupriya

From:	Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Sent:	02 July 2018 11:01
To:	Prabhuswamy, Anupriya
Cc:	Tucker, Owen; Bentley, Ian; Heath-Brown, Andrew M; Baynton, Mark; Smeathers, Simon
Subject:	RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review.
Attachments:	FW: 2018s0387 Melton Mowbray Distributor Road - Review Submission; 2018s0387_09 _MeltonMowbrayDistributorRoad_Review_Document_1.0.xlsx

Hello Anupriya,

Thank for your email below and which I have previously forwarded on to our modellers for further review.

In the meantime, please find attached the 'formal' findings of the review of the original model files submitted.

Regards
Nick

Nick Wakefield - Planning Advisor
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East Midlands Technical Leadership Group

From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 19 June 2018 17:15
To: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Cc: Tucker, Owen <owen.tucker@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>
Subject: RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review.

Hi Nick,

Links below to the updated model and baseline 2 D files are below:

1. Updated model files and 1D results: https://we.tl/rZz7AWeMd5
2. Updated baseline 2D results: https://we.tl/aD8xUL89jA

Please forward this on to the modelling team for their review.

The Option C results haven't changed, so we haven't included the 2D results for those runs this time. Note that we only sent Option C results for the 1% AEP + 50% climate change event, as noted in our original submission.

Many thanks,
Anupriya

From: Wakefield, Nick [mailto:nick.wakefield@environment-agency.gov.uk]
Sent: 19 June 2018 16:11
To: Prabhuswamy, Anupriya
Cc: Tucker, Owen; Bentley, Ian; Heath-Brown, Andrew M
Subject: RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review.

Hello Anupriya,

Thank you for your email. I have forwarded it on to the Officers who are co-ordinating the model review.

As an aside, but related issue, I thought I would take this opportunity to advise, which no doubt the consultants are already aware of, that any works in, over or under the River Eye, a Main River of the Environment Agency will require an application to be made for a Flood Risk Activity Permit, more information about which can be found on the .gov.uk website.

Regards

Nick

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From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 18 June 2018 11:25
To: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Cc: Tucker, Owen <owen.tucker@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>
Subject: FW: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review.

Hi Nick,

Please see responses to queries regarding the MMDR model in the email chain below.

In case you have further queries please contact me or Ian Bentley.

Kind regards,

Anupriya Prabhuswamy, MEng, PE (Texas)
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From: Bentley, Ian
Sent: 14 June 2018 14:38
To: Prabhuswamy, Anupriya
Subject: RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review.

Hi Anupriya,

I have responded to the queries in green below. Ben is going to re-run the baseline events this week.

We did not refer to the 'LAG' scenarios in the report but there was a brief description in the table of runs we originally sent with the models, as shown below.

Let me know if you need anything else.

Regards,
Ian

The model scenarios provided are summarised below:

Scenario	Event	ief	tcf
Baseline	100yr+50% climate change	\FM\IEF\BASELINE MODELLING\MMDR_TRIM_0100Y_CC50_BL_005.ief	\TUFLOW\RUNS\BASELINE MODELLING\
Option C (eastern option	100yr+50% climate change	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007A.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007A.tcf

of the unnamed tributary diversion)			
Option C (eastern option of the unnamed tributary diversion)	100yr+50% climate change (unnamed tributary peak set to coincide with River Eye)	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007A_LAG.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007A_LAG.tcf
Option C (western option of the unnamed tributary diversion)	100yr+50% climate change	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007B.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007B.tcf
Option C (western option of the unnamed tributary diversion)	100yr+50% climate change (unnamed tributary peak set to coincide with River Eye)	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007B_LAG.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007B_LAG.tcf

From: Wakefield, Nick [mailto:nick.wakefield@environment-agency.gov.uk]
Sent: 14 June 2018 12:33
To: Tucker, Owen; anupriya.prabhuswamy@aecom.co.uk
Subject: FW: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review.
Importance: High

Hello Anupriya and Owen,

I have received the following query from the Officer carrying out the model review:

1. There's a node-mismatch between some of the baseline model results and the supplied baseline DAT file. We can open the 100yr, 100yrCC50 and 200yr results, but not the others. Is it possible for the consultant to check that the DAT supplied was the one used to run all of the modelled return periods? It appears like a different DAT was used for the other events. If this is the case we would need these files supplied for us to be able to fully review all the baseline model results which have been supplied.

The nodes WA108E_U and WA108E_D were added to the baseline model to provide results at the location of the proposed highway bridge, for comparison with the proposed model results, but it appears that we did not re-run the baseline for all return periods and climate change scenarios (note that the comparison was applicable to an earlier version of the proposed model and is not now possible in any case, as the current proposals include diversion of the River Eye). We will re-run the baseline model for the other return periods / climate change scenarios and provide the results when complete.

2. Can AECOM please clarify:
   a. The labelling of the option scenarios. As we understand from the reporting, there are proposed scenarios for Options A and B. However, the results are labelled Option C or OPT_C_007A or OPT_C_007B. I assume that 007A and 007B refer to Options A and B respectively? We are unsure what Option C refers to.
      Option C refers to Highway Alignment Option C – the other options for the highway alignment have now been discounted and all modelled options are variations of Option C.

      Options A and B refer to diversion options of the unnamed tributary located adjacent to Lag Lane as described in the tech note.

   b. What does the 'LAG' in 'MMDR_007A_LAG' results refer to? Just from a first look, we can't spot any difference in model set up (ief, tcf, tgc or tbc) between this and the 'MMDR_007A' model run?
      The results files ending in 'LAG' have the Lag Lane tributary flows lagged so that the peak coincides with the peak flow in the River Eye. This was a test to determine whether this would cause increased flood risk from the Lag Lane tributary. The Lag Lane tributary inflows were not lagged in the baseline scenario, so the 'LAG' results were not used to determine changes relative to the baseline.

I've been advised that if these queries can be answered and resolved it should reduce the time it takes for the Environment Agency to provide a response to the submission.

Regards
Nick

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East Midlands Technical Leadership Group

From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 23 May 2018 11:26
To: Smeathers, Simon <Simon.Smeathers@environment-agency.gov.uk>; Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Cc: Andy Jackson <Andy.Jackson@leics.gov.uk>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Glossop, Martyn <martyn.glossop@aecom.com>; Sherwood, Andrew <andrew.sherwood@aecom.com>; Tucker, Owen <owen.tucker@aecom.com>; Pearson, Katie <katie.pearson@aecom.com>
Subject: RE: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review

Nick - Please see attached above the Proposed River Eye Crossing Hydraulic Modelling Report to accompany the modelling files issued last week. Can you please forward it on to the M&F team who will be reviewing the model?

Have you had an indication from the M&F team regarding their availability to undertake the model review? Can you also please provide the estimated fee for the modelling review at your earliest convenience?

Simon

Will you be able to provide a response to the following queries please:

¶ Flood Compensation Storage: What return period event would you require us to consider for flood compensation storage volume calculations? No flooding is shown to occur downstream of the Brentingby Dam in the 1 in 100 Year event. Would you require us to use flood levels from the 1 in 100 Year + 50% Climate Change event?

¶ Freeboard from the proposed highway: In the current model, the proposed bridge soffit level was set at 600mm above the 100 Year + 50% CC flood level from the baseline model. The baseline model was then revised as described in the attached modelling report. As stated in the attached report, The modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 74.14mAOD, for a 1% AEP plus 50% climate change event. The minimum level of the road in this area is 74.79mAOD (on the eastern side of the roundabout); therefore the freeboard to the proposed highway is at least 0.65m.
However, in the proposed scheme model which does not include any flood relief culverts localised increase in water depths (max increase is approx. 300mm) was found upstream of the proposed structure in the 100 Year + 50% Climate Change event compared to the baseline flood levels.
Does the EA have a requirement for:

a) Minimum freeboard that needs to be maintained from the bridge soffit and 100 Yr.+ 50% Climate Change flood level in the river.
b) Minimum allowable increase in water depths in River Eye upstream of the proposed bridge.

Please let me know if you would like to discuss any of these issues, I will be happy to arrange a conference call with the modelling team.

Many thanks,

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From: Prabhuswamy, Anupriya
Sent: 15 May 2018 16:14
To: 'Simon.Smeathers@environment-agency.gov.uk'; 'nick.wakefield@environment-agency.gov.uk'
Cc: Andy Jackson (Andy.Jackson@leics.gov.uk); Heath-Brown, Andrew M; Glossop, Martyn; Sherwood, Andrew; Tucker, Owen; Pearson, Katie
Subject: Melton Mowbray Distributor Road - Proposed Scenario River Eye Crossing Flood Model for EA Review

Melton Mowbray Distributor Road (MMDR) - Proposed Scenario River Eye Crossing Flood Model for EA Review

Hi Simon and Nick,

The proposed scheme scenario flood model for the River Eye crossing has now been completed. The modelling approach was previously discussed with you in the meeting held on 17/08/2017. I have attached the meeting minutes above for your reference.

The MMDR model is now ready for EA review and the model files are available for download using the link below:

FM and TUFLOW files (excluding BASELINE Results): https://we.tl/ZayBSepi3P
BASELINE results: https://we.tl/XAEhZGTlu7

Below is a summary of the of the modelling work undertaken. Further details will be included in a technical note, which will be provided once complete (within the next week).

The model scenarios provided are summarised below:

Scenario	Event	ief	tcf
Baseline	100yr+50% climate change	\FM\IEF\BASELINE MODELLING\MMDR_TRIM_0100Y_CC50_BL_005.ief	\TUFLOW\RUNS\BASELINE MODELLING\
Option C (eastern option of the unnamed tributary diversion)	100yr+50% climate change	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007A.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007A.tcf
Option C (eastern option of the unnamed tributary diversion)	100yr+50% climate change (unnamed tributary peak set to coincide with River Eye)	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007A_LAG.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007A_LAG.tcf
Option C (western option of the unnamed tributary diversion)	100yr+50% climate change	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007B.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007B.tcf
Option C (western option of the unnamed tributary diversion)	100yr+50% climate change (unnamed tributary peak set to coincide with River Eye)	\FM\IEF\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_c_007B_LAG.ief	\TUFLOW\RUNS\OPTION C\MMDR_TRIM_0100Y_CC50_OPT_C_007B_LAG.tcf

A summary of the model changes is provided below.

Updated Baseline Model
The baseline model is based on an existing Environment Agency SFRA model, developed in 2011. The following updates have been carried out for this project:

¶ Extension of the model to include a new, unnamed tributary in the vicinity of Lag Lane (NGR: SK 77121 19362), using survey data captured by Leicestershire County Council.
¶ Truncation of the model to reduce the number of 1D nodes to below 1000. The areas trimmed are:
  ü River nodes WA48 to WA1 (after Hoby village), WA130 and WA131 (top of River Eye) were removed;
  ü Asfordby Brook shortened. River nodes AR664 to AR244 removed; and
  ü Welby Brook shortened. River nodes 01.014 and 0.013 removed.
¶ Reduction of the 2D cell size from 8m to 4m.

Option C Modelling

The current proposed route for the new highway includes a new crossing of the River Eye, Diversion of the River Eye, diversion and new crossings of the unnamed tributary near its confluence with the River Eye and an additional crossing of the unnamed tributary further upstream. Changes to the model (relative to the baseline) were made to reflect these proposals including:

- 1D model cross sections representing the River Eye in the vicinity of the proposed crossing were moved and modified to reflect the proposed diversion of the river. The route of the diversion was based on preliminary information provided by the AECOM geomorphology team and included a 1m reduction in channel width. It is noted that, as per the original EA model, channel geometry in this area is represented using a copies of a surveyed cross section from WA108, approximately 200m downstream of the proposed crossing.
- Removal of the existing Lag Lane bridge over the River Eye. While the proposed river diversion bypasses this existing structure, it is proposed that the original channel will be left in place as a backwater – this is represented within the 2D model based on the LIDAR data; however, the 2D model has been modified to remove the existing Lag Lane bridge (which is included in the LIDAR data).
- Addition of the proposed new highway. Ground levels within the 2D model were modified to represent the proposed highway embankment using information provided by the AECOM design team.
- Addition of representation of the proposed new bridge, carrying the proposed highway over the River Eye, to the 1D model.
- Removal of an existing culvert (farm access), on the unnamed tributary and replacement with a new culvert under the proposed highway, approximately 1km upstream of the River Eye confluence.
- Modification/removal/addition of 1D model cross sections representing the unnamed tributary near its confluence with the River Eye. This included removal of an existing culvert under Saxby Road and addition of new culverts under Lag Lane and Saxby Road. Embankments were also added adjacent to the unnamed tributary to prevent flooding encroaching onto Saxby Road or the new highway. Details (e.g. horizontal and vertical alignments, embankments heights etc.) of these changes were not provided by the AECOM design team but were determined by the modelling team (in consultation with the geomorphology team), as required to prevent flooding. These details are expected to feed-back into the proposed design. Two alternative routes for the proposed unnamed tributary diversion ('eastern' and 'western' options) have been modelled, as requested by the design team, since the final alignment will be affected by the location of a proposed attenuation basin in this area.

Design Events

The baseline and proposed models have been run for the 1 in 100 year + 50% climate change event. The following four design model runs have been carried out:

- Unnamed tributary western diversion option (original event timing for comparison with the baseline).
- Unnamed tributary eastern diversion option (original event timing for comparison with the baseline).
- Unnamed tributary western diversion option (unnamed tributary event lagged to coincide with the River Eye peak flow, to assess the culvert capacity under worst case conditions).
- Unnamed tributary eastern diversion option (unnamed tributary event lagged to coincide with the River Eye peak flow, to assess the culvert capacity under worst case conditions).

Baseline results have also been provided for a range of additional return periods and climate change scenarios (5yr, 10yr, 20yr, 50yr, 75yr, 100yr, 200yr, 1000yr, 100yr + 20%CC and 100yr +30%CC), for information.

Results

Initial results show that the proposed embankment and bridge crossing the River Eye will cause a localised increase in water levels (max increase is approx. 300mm) upstream of the proposed structure but that there is very little change to the flood extents and no properties are affected. Peak flows passing downstream are slightly reduced relative to the baseline. Flood relief have not been included but can be added if required to reduce the impact on levels in the River Eye. Some localised increases in water level are also predicted on the unnamed tributary, in the vicinity of the proposed new crossings, but flood water is confined to the immediate vicinity of the channel and no properties are affected.

Please note that the Brentingby Dam breach modelling is not included in this current issue. This will be undertaken separately following the initial review of the River Eye crossing model by the EA.

I will follow up with a call to discuss the programme and additional flood related queries that we. The queries are:

- Flood Compensation Storage: What return period event would you require us to consider for flood compensation storage volume calculations? No flooding is shown to occur downstream of the Brentingby Dam in the 1 in 100 Year event. Would you require us to use flood levels from the 1 in 100 Year + 50% Climate Change event?
- Freeboard from bridge soffit: In the current model, the proposed bridge soffit level was set at 600mm above the 100 Year + 50% CC flood level from the baseline model. As stated above in the 'Results' section, in the proposed scheme model localised increase in water levels (max increase is approx. 300mm) was found upstream of the proposed structure in the 100 Year + 50% Climate Change event which encroaches on this freeboard. Does the EA have a requirement for the minimum freeboard that needs to be maintained from the bridge soffit and 100 Yr.+ 50% Climate Change flood level in the river?

Please don't hesitate to contact me if you have any questions.

Kind regards,

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Technical Model Review Report		
Client	Environment Agency	
Single project or WEM package?	WEM Package	
Package name (if applicable)	2018-19 National Modelling and Forecasting Technical Support Contract	
Project name	Review No. 09 - Melton Mowbray Distributor Road	
JBA Project Number (or overarching project)	2018s0387	
JBA Sub-Project Number (if applicable)	9	
Review requirements	A) Previous project - hydrology	
	B) Previous project - hydraulic	
	C) New project - hydrology	Yes
	D) New project - hydraulics	Yes
	E) Survey data	
	F) Reporting	Yes

"RAG" key
1. Major issue – omission that could make the findings subject to challenge and which requires correction/further work.
2. Minor issue – non-standard method or method not following guidance but unlikely to have impacted on results
3. Clarification required – the approach used is unclear and requires further clarification before it can be reviewed
4. Recommendations – suggestion for improved / good practice but which is unlikely to change the project outcomes.
5. Acceptable (but does not meet best practice) – the approach is acceptable, however it is not in line with standard industry best practice
6. Acceptable – suggestion for improved / good practice but which is unlikely to change the project outcomes.

Summary of 1st review findings

Hydrology:
Modelling two different storm areas within the same model is not suitable. Critical storm duration should be determined at the location of interest. Storm area and storm duration should be consistent across each boundary unit.

This review covers the updates made to the model as part of the AECOM study and any elements of the original model that may bring the results (and therefore any FRA) into question. The findings are summarised below:

Major issue:
~ evidence of glass walling in upper reaches of Lag Lane. Sections should be extended or connected to the 2D domain.
~ In this area, active HX boundary lines extend well beyond end of code layer. These boundary cells are shown to receive flow, which then glass walls within boundary cells. Code layer should be extended or HX lines trimmed and 1D cross sections extended

Minor issue:
~ Some discrepancy between 1D section widths and 2D deactivated width - some greater than 2D cell size. Should be amended so that 1D widths and deactivated widths match
~ RP of downstream boundary

Clarification required:
~ survey data (drawings or photographs) not available to check modelled representation of open channel or structures (geometry or roughness)
~ AECOM design drawings not available to check modelled representation of highway and proposed embankment or channel diversion
~Some discussion of implications of model instability at location of interest would improve confidence in results for FRA. For instance, how far downstream, which watercourse etc.
~ Report indicates a finer model resolution to original, 8m to 4m. Current model remains at 8m. The reporting should be consistent or the model changed and re-run.
~ Other recommendations to use event and scenario controls and change labelling of options to avoid confusion of options A, B and C

A	Hydrology
Date of hydrology analysis	May 2018
Name of reviewer	Stuart Marshfield
Date of review	18/06/2018
Date of 2nd review	
Revision	v1.0
Applicable standards or guidance	Flood Estimation Handbook EA Flood Estimation guidelines (Operational instruction 197_08) Making better use of local data in flood frequency estimation: report ,SC130009/R
Nature of study watercourse(s)/constraints	The model covers approximately 30km of the River Eye and River Wreake (and several tributaries) between Saxby and Rotherby, passing through the centre of Melton Mowbray in Leicestershire. The model is truncated version of the full Wreake and Eye model, most recently updated by Halcrow in 2011. The model was truncated (to 1000 nodes), updated and adapted to test two proposed options for a distributor highway around Melton Mowbray, which crosses the River Eye on the
Study objectives	AECOM were commissioned to: ~ Truncate and re-run the baseline model, incorporating Lag Lane tributary and an appropriate inflow ~ Model two proposed options (A and B) for the distributor highway crossing of the River Eye, testing the implications of the latest allowances for climate change ~ Inform the wider Flood Risk Assessment that will accompany the planning application for the scheme
Summary of 1st review	Modelling two different storm areas within the same model is not suitable. Critical storm duration should be determined at the location of interest. Storm area and storm duration should be consistent across each boundary unit.

Category	Detail	ID	1st review		
			Comment	**Suitability**	**Suggested actions**
General comments					
General comments	Method statement	A-1		Acceptable	
	Previous studies	A-2	Hydrological inflow for Lag Lane is a copy from previous modelling study, using a ReFH boundary representing the Lag Lane catchment. All other inflows remain unchanged. It is assumed that this was already accepted by the EA and any parameter adjustment deemed to be appropriate. The flood estimation for this inflow has therefore not been re-reviewed.	Acceptable - but does not meet best practice	Model hydrology is likely to be out of date and would benefit from an update. Understand this is beyond the remit of this study.
	Catchment description (any unusual features such as pumps, reservoirs, heavy urbanisation?)	A-3		Acceptable	
Method statement					
Flow estimation points and descriptors	Location of FEPs / catchment descriptors provided?	A-4		Acceptable	
	Unusual catchment features (which may influence choice of approach)	A-5		Acceptable	
	Checks on catchment descriptors	A-6		Acceptable	
Data review	Hiflows-UK version	A-7		Acceptable	
	Review of hydrometric data	A-8		Acceptable	
	Rating reviews	A-9		Acceptable	
	Flood history	A-10		Acceptable	
Initial choice of methods	Approaches suggested	A-11		Acceptable	
	Justification of approach	A-12		Acceptable	
	Lumped / distributed	A-13		Acceptable	
		A -22		Acceptable	
Flow estimation					
FEH Statistical	Suitable for statistical?	A -24		Acceptable	
	QMED estimation - CDs	A -25		Acceptable	
	QMED estimation - AMAX / POT	A -26		Acceptable	
	Choice of donors	A -27		Acceptable	
	Growth curve methodology	A -28		Acceptable	
	Hydrology shape	A -29		Acceptable	
ReFH method	Suitable for ReFH?	A-14		Acceptable	
	Calibration	A-15		Acceptable	
	Choice of design storm	A-16	As it currently stands, the model incorporates two different storms. One 417km2 for the broader model and one catchment-scale for the Lag Lane tributary. In order to achieve critical storm area for the tributary, this should be tested. However, for this model, the critical storm area and duration should be determined for the location of interest (i.e. the highway crossing) and be consistent across each modelled ReFH inflow. It is not suitable to have different storm areas or durations within the same model.	Major issue	Test critical storm duration at the location of interest and make consistent across each boundary unit.
Urban ReFH variant	Suitable for urban ReFH?	A-17		Acceptable	
	Catchment delineation	A-18		Acceptable	
	Calibration	A-19		Acceptable	
	Choice of URBEXT values	A-20		Acceptable	
	Choice of percentage runoff	A-21		Acceptable	

Final choice of method	Final flows	A-22		Acceptable	
Miscellaneous					
Climate change	Consistent with latest guidance?	A-23	Consistent with latest guidance and documented in report. Multipliers applied appropriately.	Acceptable	
Reporting and follow up actions					
Reporting and Results.	Suitability of reporting	A-24		Acceptable	
	Results	A-25		Acceptable	
	Recommendations	A-26		Acceptable	

B	Review of Melton Mowbray Distributor Road model
Date of model	May 2018
Name of reviewer	Stuart Marshfield
Date of review	18/06/2018
Revision	v1.0
Applicable standards or guidance	OI_379-05 Environment Agency's Operational Instruction on Computational Modelling to Assess Flood and Coastal Risk TUFLOW Users Manual
Nature of study watercourse(s)/constraints	The model covers approximately 30km of the River Eye and River Wreake (and several tributaries) between Saxby and Rotherby, passing through the centre of Melton Mowbray in Leicestershire. The model is truncated version of the full Wreake and Eye model, most recently updated by Halcrow in 2011. The model was truncated (to 1000 nodes), updated and adapted to test two proposed options for a distributor highway around Melton Mowbray, which crosses the River Eye on the upstream outskirts of Melton Mowbray. Part of the update was to include an additional unnamed tributary (referred to as Lag Lane tributary) using recent survey, include an approximate hydrological estimate for Lag Lane and model the implications of the latest allowances for climate change.
Study objectives	AECOM were commissioned to: ~ Truncate and re-run the baseline model, incorporating Lag Lane tributary and an appropriate inflow ~ Model two proposed options (A and B) for the distributor highway crossing of the River Eye, testing the implications of the latest allowances for climate change ~ Inform the wider Flood Risk Assessment that will accompany the planning application for the scheme
Summary of 1st review	This review covers the updates made to the model as part of the AECOM study and any elements of the original model that may bring the results (and therefore any FRA) into question. The findings are summarised below: Major issue: ~ evidence of glass walling in upper reaches of Lag Lane. Sections should be extended or connected to the 2D domain. ~ In this area, active HX boundary lines extend well beyond end of code layer. These boundary cells are shown to receive flow, which then glass walls within boundary cells. Code layer should be extended or HX lines trimmed and 1D cross sections extended Minor issue: ~ Some discrepancy between 1D section widths and 2D deactivated width - some greater than 2D cell size. Should be amended so that 1D widths and deactivated widths match ~ RP of downstream boundary Clarification required: ~ survey data (drawings or photographs) not available to check modelled representation of open channel or structures (geometry or roughness) ~ AECOM design drawings not available to check modelled representation of highway and proposed embankment or channel diversion ~Some discussion of implications of model instability at location of interest would improve confidence in results for FRA. For instance, how far downstream, which watercourse etc. ~ Report indicates a finer model resolution to original, 8m to 4m. Current model remains at 8m. The reporting should be consistent or the model changed and re-run. ~ Other recommendations to use event and scenario controls and change labelling of options to avoid confusion of options A, B and C

Category	Detail	Prompts	ID	Comment	Suitability	Suggested actions
Data to be reviewed						
Data to be reviewed	Software	~ Versions	B-1	Flood Modeller Pro v4.2	Acceptable - but does not meet best practice	Flood Modeller Pro 4.4 now available
			B-2	TUFLOW 2016s-03-AB-iSP-w64	Acceptable - but does not meet best practice	TUFLOW 2017-AC now available
	AEPs provided / reviewed		B-3	5yr, 10yr, 20yr, 50yr, 75yr, 100yr, 100yrCC20, 30 and 50, 200yr and 1000yr baseline	Acceptable	
	Scenarios provided / reviewed		B-4	100yrCC50 options A and B	Acceptable	
	Reports	~ Reference versions ~ Technical reporting ~ General reporting	B-5	MMDR_River Eye Crossing_Technical Note_P01.pdf	Acceptable	
Reporting						
Reporting	Reporting	~ Objectives ~ Constraints ~ Approach Justification (both model scale and structure scale) ~ Clarity ~ Assumptions ~ Interpretation of results	B-7	Melton Mowbray Distributor Road, Proposed River Eye Crossing Hydraulic Modelling Report, May 2018	Acceptable	
			B-8	The objectives of the study are set out in the above report	Acceptable	
			B-9	The implications of model stability are not explored. In this case there is notable instability in the model. The impact this has, if any, on model results, particularly around the Lag Lane area should be explored and documented.	Recommendations	Identify where the model stability is originating from and discuss the implications of stability at the site.
			B-10	Modelling approaches and assumptions are described is some detail. These are reviewed in the modelling section.	Acceptable	
			B-11	The modelling results are clearly interpreted	Acceptable	
General comments						
General comments	File organisation / naming convention	~ Scenarios ~ Naming ~ Flags	B-13	The model is arranged in an industry standard folder structure	Acceptable	
			B-14	File names are largely intuitive. However, mixing of "Option C" and A or B and Lag as both name of watercourse and to denote a lagged hydrograph for runs and results is confusing	Recommendations	Consider revision of option naming
			B-15	FM and TUFLOW input files are otherwise named appropriately	Acceptable	
			B-16	Some relic files in modelling folders need to be removed	Recommendations	Remove relic files
	Survey / topographic data	~ Age ~ Quality ~ Suitability	B-17	Survey for Lag Lane was acquired from Leicestershire County Council, no indication of age and whether to EA survey spec	Clarification required	The age and suitability of the survey data should be discussed in the report
			B-18		Acceptable	
	Other	~ Any significant missing data	B-19	Survey data for Lag Lane not available for review	Clarification required	The survey data should be supplied to check the representation of cross sections and structures in the model.
General modelling approach						
General modelling approach	Model extents	~ Domain boundaries ~ Upstream/downstream boundaries ~ Potential downstream influences on water levels ~ Glass walling	B-21	The 2D domain covers 7.1km^2 and has a time series water level (HT) boundary conditions at the downstream end of the model. The upstream was inherited from the existing model.	Acceptable	
			B-22	The extents of the 2D domain are adequate to cover all areas at risk of fluvial flooding.	Acceptable	
			B-23			
			B-24			
	Modelling approach	~ 1D / 2D / Linked ~ georeferenced (ixy/gxy/2d links)	B-25	1D-2D linked, FM-TUFLOW	Acceptable	
			B-26	The model is fully georeferenced.	Acceptable	
	Application of hydrological estimates	~ Lumped / distributed ~ Applied to 1D or 2D domain ~ Lateral or point inflows	B-27	Lumped inflow applied to upstream extent of 1D domain on Lag Lane.	Acceptable	
			B-28	Application of the inflows in the model is consistent with how they are documented in the accompanying report.	Acceptable	

		~ Lateral or point inflows ~ Consistency with reporting	B-29			
Flood Modeller						
Flood Modeller	Model build	~ Hard bed / soft bed ~ Accuracy of modelled channel length	B-31	In the absence of the survey, it is not known whether hard or soft beds were modelled and also whether the modelled channel length is accurate.	Clarification required	specify hard or soft bed survey
			B-32	However, modelled reach length corresponds to model labelling in trimmed model	Acceptable	
	Schematisation	~ Representation of flow paths ~ Representation of storage	B-33	There is glass walling in the 1D model at a number of sections along Lag Lane at the 100yr CC50 scenario outside the 2D code layer. Sections should either be extended or linked to the 2D domain	Minor issue	extend sections or link to 2D domain
			B-34			
	ISIS Health Check	~ Summarise key findings ~ Take care to interpret findings and consider relevance	B-35	Number of checks referring to wider model. Beyond scope of this study	Acceptable - but does not meet best practice	
			B-36	Orifice P2 check at LAG_1628I	Clarification required	Check geometry of orifice unit
	Boundary conditions	~ Upstream boundary ~ Downstream boundary ~ Phasing of boundary conditions	B-37	Lag Lane boundary includes inflow for whole catchment (to confluence with Eye), as included in previous modelling. The approach is suitable. However, although catchment is small and majority of flow remains in bank, distribution of inflow could be improved using laterals.	**Recommendations**	Consider using lateral inflows
			B-38	No indication of RP of HT downstream boundary. Same boundary used for each modelled RP and scenario. Although the boundary is sufficient distance to not impact the area of interest, this should ideally be a RP specific boundary so that the trimmed model is representative of the original model.	Minor issue	Consider using RP appropriate DS boundaries
			B-39			
			B-40			
	Open channel representation	~ Manning's n ~ Panel markers ~ Section spacing ~ Geometry	B-41	Manning's n values appear sensible from mapping and aerial photography. No available survey or photographs to confirm	Clarification required	The survey data should be supplied to check the representation of cross sections and structures in the model.
			B-42	panel markers used appropriately		
			B-43	Conveyance plots for open channel sections are sensible.		
			B-44			
			B-45			
	Hydraulic structure representation	~ Structure coefficients ~ Bypassing options ~ Choice of model unit ~ Geometry	B-46	No overtopping spill at LDIV1_0040d in Option A and B model. This may be appropriate, as water levels are well within the channel at the 100yr CC50. But should be included to avoid confusion.	Clarification required	Include an overtopping spill unit
			B-47	inlets and outlets are used appropriately at culverts		
			B-48	Not possible to check geometry on Lag Lane or River Eye (highway crossing) due to absence of survey data and design drawings	Clarification required	The survey data and design drawings should be supplied to check the representation of cross sections and structures in the model.
			B-49			
			B-50			
			B-51			
			B-52			
			B-53			
	Floodplain representation	~ Suitability of approach ~ Implementation ~ Glass walling	B-54	Some glass walling along Lag Lane beyond extent of 2D domain (as above).	Minor issue	extend sections or link to 2D domain
			B-55			
			B-56			
ESTRY floodplain structures						
TUFLOW domain (1)						
	General Schematisation	~ Grid orientation ~ Grid resolution ~ Grid extent ~ Active domain extent ~ Use of water level lines	B-66	HX lines for Lag Lane extend beyond active code layer, activating only the boundary cells adjacent to the watercourse. The code layer should be extended or the boundary lines removed. The boundary cells here, as they are, are showing out of bank flow which is glass walling against the 1D-2D boundary cell. The floodplain here needs to be represented.	Major issue	Extend code layer or remove boundary lines and model as extended sections
			B-67	The reporting indicates a reduction in cell size from 8m to 4m, the model tgc indicates an 8m grid. 8m is likely to be sufficient to capture flood extents here and identify where properties may be affected. But needs to be consistent.	Clarification required	Remodel or reword reporting
			B-68	The grid is aligned with the dominant flow direction which is east to west.	Acceptable	
			B-69	2D code layers contain two separate features. One is very small and seems to serve no purpose. Remove if this is correct	Acceptable	Tidy code layers
			B-70	The modelling report states that the ground model is based on 1m resolution LIDAR data. No indication of age but states 'new'	Acceptable	
	Geometry	~ Representation of flow paths ~ Representation of topographic obstructions ~ Other modifications to ground model	B-71	It is assumed that a 2D channel was used here for stability, as the dominant flow direction is east to west across the Eye floodplain.	Acceptable	
			B-72	Channel gully in option model is perched above the River Eye. This representation is based on geomorphology drawings by AECOM. This data was not available for review to check modelling. At flood flows, this channel is well drowned and won't affect flood levels or extents.	Clarification required	The survey data and design drawings should be supplied to check the representation of cross sections and structures in the model.
			B-73	zpoints and zlines used to define channel banks. Unclear as to where this has come from. LIDAR or survey.	Clarification required	include in reporting
			B-74	No survey to check representation of highway embankment or embankment near Saxby Road. No zsh or zln zpt check files available to check modelling.	Clarification required	The survey data and design drawings should be supplied to check the representation of cross sections and structures in the model.
		~ Schematisation of materials layers ~ Manning's n values	B-75	Materials unchanged from original model	Acceptable	

TUFLOW domain (1)	Model parameterisation	~ Manning's n values ~ Flow constriction layers ~ Storage reduction factors	B-76	No other parameter changes	Acceptable	
	Representation of buildings		B-77	Unchanged representation from original model. Modelled as a generic urban (0.08) Manning's value.	Minor issue	Buildings could be individually represented with a 4m grid. Could be useful if looking at numbers of affected properties (if any)
	Boundary conditions	~ Locations & implementation of boundaries ~ Internal boundaries (HX & SX) ~ External boundaries	B-78	Some touching boundary cells on left and right banks of Lag Lane tributary. Ideally these should be separated by extending 1D cross sections. This makes sure that the 1D domain is appropriately accounted for in the deactivated 2D domain.	Minor issue	Consider extending sections and pulling boundary lines out to remove touching boundary cells.
			B-79	A check of the 1D widths against deactivated TUFLOW width. There are some sections that show a discrepancy greater than a 2D cell width (8m). Please check LAG_0157, LAG_0282, LAG_0356, LAG_0511, LAG_0636 (appear to be too narrow) and LAG_1508 and LAG_1638c are too wide.	Minor issue	Check geometry and extend or trim 1D sections (or adjust 2D boundary lines) where required.
			B-80	2D domain trimmed to railway line. Assumption is that this will not be overtopped. Flow through railway culverts is determined by the same downstream boundary at the 1D domain	Acceptable	
			B-81	Dummy reach downstream of railway line and Austen Dyke inflow can be removed. Connect HT boundary to junction at railway	Acceptable - but does not meet best practice	
			B-82			
	Initial conditions	~ IWL	B-83	Initial conditions not used in the TUFLOW (2D) domain - model would seem to initialise unaided, so no need for initial conditions.	Acceptable	
			B-84			
			B-85			
	Use of event and scenario controls		B-86	No event or scenario controls used. Would help to tidy number of tcfs	**Recommendations**	Consider using event and scenario controls to reduce number of tcfs required
			B-87			
	Run parameters and output data	~ Results generated ~ Temporal resolution of results ~ PO lines ~ Run parameters	B-88	The 4s 2D timestep used, is in line with guidelines for the 8m grid resolution of the 2D domain	Acceptable	
			B-89	A 15-minute output interval is specified in the model and is consistent with generation of high resolution results.	Acceptable	
			B-90			
Runs						
	Model simulations	Model simulation runs ~ Existing (baseline) ~ Climate change ~ Sensitivity	B-120	Model is currently run single precision in 1D and 2D, which is not recommended for models with 1D reservoirs.	Minor issue	Consider running double precision for improved accuracy
			B-121	Climate change runs consistent with latest guidance and documented in report. Multipliers applied appropriately.	Acceptable	
Model results, interpretation, verification and stability						
Model results, interpretation, verification and stability	Model stability	~ zzd, eof, tlf ~ Model warnings and errors ~ Non-convergence ~ Mass balance ~ unrealistic oscillations (water level / flow / boundaries / dVol).	B-123	Model instability is significant according to the 1D run window, but as a legacy from the 2011 Halcrow model. Although a stage hydrograph at the bridge is supplied, the implications of this for the option testing for the purposes of the FRA is not explored.	**Recommendations**	Some idea of where this instability is occurring may help to demonstrate confidence in the outputs of the model for the FRA.
			B-124	Poor model convergence at LAG_0859 around 24.5hrs. Minor impact on mode results well after peak.	Acceptable	
			B-125	Flow and stage hydrographs are stable at peak at proposed Lag Lane Bridge	Acceptable	
			B-126	TUFLOW dvol and cum Q ME (%) plots are largely stable. Some improvement could be made to cum Q ME (%) to bring within generally accepted tolerance (+/- 1%), but understand this could be due to the wider model instability.	Acceptable - but does not meet best practice	
			B-127	Two checks in TUFLOW messages. Coincident points.	Acceptable - but does not meet best practice	
			B-128			
			B-129			
			B-130			
	Sensitivity testing	~ Suitability of sensitivity testing undertaken ~ Results & interpretation of sensitivity testing	B-131	Not supplied. Assumed that sensitivity not undertaken in the understanding that it was done as part of the original modelling study.	Acceptable	
	Calibration / performance		B-132	Not supplied	Acceptable	

Prabhuswamy, Anupriya

From:	Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>
Sent:	18 July 2018 17:35
To:	Prabhuswamy, Anupriya
Cc:	Andy Jackson (Andy.Jackson@leics.gov.uk); Glossop, Martyn; Tucker, Owen; Heath-Brown, Andrew M; Bentley, Ian; Williams, Neil; Smeathers, Simon; Baynton, Mark
Subject:	RE: MMDR River Eye realignment design

Hello Anupriya,

Thank you for your email dated 26 June 2018.

The model reviewer for the Environment Agency makes the following comments on the points which you have made:

Firstly, we believe that it is certainly best practice to use the updated channel survey if it is available. The concern is that there could be a mismatch between the model used to determine the channel alignment and the baseline flood risk model. From a consistency point of view this clearly isn't ideal. But also, the channel realignment and bridge design form a fundamental part of the proposed redesign of the watercourse. If the option in the flood risk model is based on this understanding, it will be very difficult to compare the option against the baseline if the baseline model is considered to be wrong.

With regards to the significance of the issue, we don't know how different the channel geometry is compared to the proposed new survey. From Neil Williams' email, it implies it is significant enough to question the accuracy of the modelled baseline watercourse. We might suggest that a sensitivity test could be useful. It will be a decision for the Environment Agency as to how much allowance for error they are willing to give the baseline results.

We appreciate that in-channel comparisons cannot be made locally to the new bridge design, as the path of the watercourse will change significantly and as such it is proposed that comparisons will only be made in the floodplain. However, it is not possible to say for certain at this stage how much of an impact the change in channel capacity will have on floodplain levels. We appreciate the flood risk model at the moment is only addressing the 100-year + CC for the option testing, but floodplain depths are generally <0.5m in the area of the proposed change and the floodplain is narrow so the impact could be noteworthy. If there is doubt over the validity of the baseline results in the area of the proposed scheme, this will result in doubt over the validity of the comparison between the option testing and present day scenario.

Overall, our view is that the flood modelling model and any geomorphology model should be in-line with each other, the comparison between the baseline flood risk and option flood risk may not be valid, and that it's best practice to use updated channel survey if it is available.

Kind Regards,

Andrew Waite
Analyst

Regards
Nick

Nick Wakefield - Planning Advisor
Sustainable Places Team
Environment Agency - East Midlands Area

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East Midlands Technical Leadership Group

From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 26 June 2018 15:52
To: Wakefield, Nick <nick.wakefield@environment-agency.gov.uk>; Smeathers, Simon <Simon.Smeathers@environment-agency.gov.uk>
Cc: Andy Jackson (Andy.Jackson@leics.gov.uk) <Andy.Jackson@leics.gov.uk>; Glossop, Martyn <martyn.glossop@aecom.com>; Tucker, Owen <owen.tucker@aecom.com>; Heath-Brown, Andrew M <andrew.heath-brown@aecom.com>; Bentley, Ian <Ian.Bentley@aecom.com>; Williams, Neil <neil.williams@aecom.com>
Subject: FW: MMDR River Eye realignment design

Hi Nick and Simon,

Further to Neil's email below regarding new channel survey for River Eye, I wanted to clarify a few points from the flood modelling point of view:

¶ The modelling approach discussed in the meeting with the EA last August (minutes attached) consisted of using the existing River Wreake model as the baseline after updating it to include the Lag Lane watercourse and new LiDAR data in areas of missing coverage only. The baseline modelling that has been submitted to the EA for review on 15/05/2018 and on 19/06/2018 has followed this agreed approach.

- At this stage, we don't intend to revise the baseline flood model using the new channel survey since:
  - It is not likely to make a significant difference to water levels during flood conditions.
  - Since the proposed scenario will include river channel re-alignment, we will be unable to undertake a like-for-like comparison of in-channel water levels between the existing and proposed scenarios. We will compare floodplain water levels/depths, but any differences will be dominated by the impacts of the scheme rather than any differences in channel dimensions (as per the above point).

I hope this is acceptable to the EA's flood team. Please advise.

Kind regards,

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From: Williams, Neil
Sent: 20 June 2018 19:29
To: Banham, Martin (NE); Toone, Julia A; Richard.Jeffries@environment-agency.gov.uk; Butterfield, Ian (NE); Wakefield, Nick
Cc: Gates, Neal; Tucker, Owen; Sherwood, Andrew; Glossop, Martyn; Segre, Marlene; Andy Jackson; Jools Partridge; Heritage, George
Subject: MMDR River Eye realignment design - programme amendment

Dear All

We encountered a set-back last week with what we expected to be our final model runs for the channel realignment design, and unfortunately that has meant a delay to our programme.

The bed levels in the existing River Eye hydraulic model appear inaccurate and far too deep. They do not support the shallow low flows we observed during the site walkovers, and instead show deep ponds much further upstream than we know to exist in reality. This is important, because the shallow and relatively fast flowing channel reaches are those that provide the primary habitat diversity within an otherwise heavily ponded system. It seems that the channel survey in this area dates from 1993, when I suspect there was regular dredging, and the bed elevations measured at that time have subsequently in-filled as dredging has decreased.

The outcome is that we need a new channel survey, to bring the River Eye model up to date with accurate bed levels. I'm sure you will appreciate the importance of this for hydromorphology, ecology and flood risks.

We expect don't expect a new channel survey to completed until 2-3 weeks from now, and we will then need a further 1-2 weeks to re-run our models and finalise the design. This means we will not be circulating the quantified fluvial audit and channel design until around the end of July.

May I ask Julia, Richard, Martin and Ian whether you will have availability in August to review the channel design, so that we can still work with you ahead of the final planning submission deadline, which is in September? Ideally, we will reserve some of your time between August 1st - 10th, but I appreciate that this is in the midst of summer holidays, and we are unable to commit to dates until we get confirmation from surveyors.

Julia and Martin, as a next step I will call you tomorrow to explain the situation in more detail, discuss your summer availability, and see how we can best manage everyone's time.

With many thanks
Neil

Dr Neil Williams
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Appendix C

Consultation Responses from the Lead Local Flood Authority (LCC Flood Team)

Appendix C1 – Correspondence between LCC Flood Team and AECOM

From: Michael Warner <Michael.Warner@leics.gov.uk>
Sent: 02 March 2018 15:29
To: Prabhuswamy, Anupriya
Cc: Victoria Coombes; Bernard Evans; Andy Jackson
Subject: RE: MMDR Ordinary Watercourse Assessments

Hi Anupriya

Victoria has reviewed the responses to her previous questions and is satisfied with your responses except in relation to the methodology relating to the culvert sizing which she has asked me to assess on her behalf. On review I find the methodology to assess existing flows within the channels to size the culverts to be suitable, so I have no issues with this aspect. However, in addition to the catchment flow assessments, I would ask that the existing channel capacities are also assessed and not reduced by the proposals.

I trust this helps.

Kind regards

Michael Warner BEng Hons
Flood Risk Engineer
Infrastructure Planning
Leicestershire County Council

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Email: Flooding@leics.gov.uk

www.leicestershire.gov.uk/environment-and-planning/flooding-and-drainage

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From: Prabhuswamy, Anupriya [mailto:anupriya.prabhuswamy@aecom.com]
Sent: 28 February 2018 15:36
To: Victoria Coombes; Bernard Evans
Cc: Andy Jackson; Pearson, Katie; Heath-Brown, Andrew M; Tucker, Owen; Glossop, Martyn; Sherwood, Andrew; Allen, Martin; Hurrell, Gary; Madge, Will
Subject: RE: MMDR Ordinary Watercourse Assessments

Hi Victoria,

Please see attached above responses to your comments about the proposed Melton Mowbray Distributor Road.

Many thanks,

Anupriya Prabhuswamy, P.E (Texas), MEng
Flood Risk Engineer, Water
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AguaAECOM are taking part in WaterAid's Water Innovators 2017 Challenge to help communities in Nicaragua - https://www.justgiving.com/fundraising/Anu-Prabhuswamy

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From: Victoria Coombes [mailto:Victoria.Coombes@leics.gov.uk]
Sent: 30 January 2018 10:40
To: Madge, Will; Bernard Evans
Cc: Andy Jackson; Prabhuswamy, Anupriya; Pearson, Katie; Tucker, Owen
Subject: RE: MMDR Ordinary Watercourse Assessments

Good morning Will

Sincere apologies for the delay in getting back to you.

I have liaised with Bernard and we have concluded the following:

- With regards to the use of simple (non-hydraulic modelling) techniques to estimate culvert sizing on the six new tributary crossings using oversizing to include the 1 in 100 year + 50% for CC, I have conducted a review of our most up to date food risk data and wish to make the following comments:
  - Where the proposed road crosses the ordinary watercourse just north of Thorpe Arnold, d/s of Twin Lakes it crosses identified flood zones. Given that there is a historical incident of flooding downstream of this crossing and designated flood zones, please can you confirm the proposals for sizing this crossing to ensure that the flood zones are not impacted.
  - Where the road is proposed to cross the River Eye flood plain the EA should advise.

- o Where the road is proposed to cross an Ordinary watercourse upstream of Saxby Road, there is a known risk/occurrence of highway flooding. Therefore it is supported that more detailed modelling is required to ensure the crossing is appropriately sized.
- o What about other small ditch crossings of which we are not currently aware of? There are bound to be many small ditches/dykes etc. which will need to be incorporated and assessed as well as granted consent. What are the proposals for those?
- o I have concerns of where using any existing culverts (such as old railway bridges) about exacerbating outstanding flood risk not known about in detail. This is difficult to mitigate however I support that further reviews of such structures will be required to ensure that flood risk is not increased upstream or downstream of the proposed road crossings.

¶ With regards to the role of the Environment Agency and the County Council as part of the planning process, I can confirm that where works are proposed on a Main River or within a fluvial flood zone the relevant authority would be the Environment Agency. The County Council would be required to grant consent for any works proposed within or in close proximity to an ordinary watercourse under the Land Drainage Act (1991). Under the Town and Country Planning Act, the County Council are also defined as the statutory consultee for surface water drainage matters for major development, however, where resources allow and where appropriate the County Council also pass comment on all matters relating to local flood risk.

I trust that the above provides a suitable response to your enquiry and I apologise again for the delay in getting back to you. Please keep me in the loop of any developments and please do not hesitate to contact me should you have any questions.

Kind regards

Tor

Victoria Coombes BSc MSc
Senior Engineer (Flood Risk Management)
Infrastructure Planning
Leicestershire County Council

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From: Madge, Will [mailto:will.madge@aecom.com]
Sent: 19 January 2018 11:22
To: Bernard Evans
Cc: Andy Jackson; Prabhuswamy, Anupriya; Pearson, Katie; Tucker, Owen; Victoria Coombes
Subject: RE: MMDR Ordinary Watercourse Assessments

Hi Bernard,

Thank you for your reply – just following up to see if you/Victoria have had an opportunity to look at this?

Thanks,

Will

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From: Bernard Evans [mailto:Bernard.Evans@leics.gov.uk]
Sent: 08 January 2018 15:56
To: Madge, Will
Cc: Andy Jackson; Prabhuswamy, Anupriya; Pearson, Katie; Tucker, Owen; Victoria Coombes
Subject: RE: MMDR Ordinary Watercourse Assessments

Will,

Happy New Year to you too.

Thanks for your email. I, or my colleague Victoria Coombes, will get back to you as soon as possible. I anticipate that this will be sometime next week.

Regards,

Bernard Evans
Infrastructure Planning Manager
Environment & Transport Department
Leicestershire County Council

0116 305 6834 ḃwww.leics.gov.uk

Infrastructure Planning: overseeing approval, delivery and subsequent adoption of development related highway infrastructure, perform statutory Lead Local Flood Authority duties and initial point-of-contact for all new transport related infrastructure within the County of Leicestershire.

From: Madge, Will [mailto:will.madge@aecom.com]
Sent: 08 January 2018 11:21
To: Bernard Evans
Cc: Andy Jackson; Prabhuswamy, Anupriya; Pearson, Katie; Tucker, Owen
Subject: MMDR Ordinary Watercourse Assessments

Hi Bernard,

Hope you had a good Christmas break and a Happy New Year.

I am following up on the below email regarding the Melton Mowbray Distributor Road project - as part of this scheme a number of culverts are proposed across six ordinary watercourses including Scalford Brook and Thorpe Brook. Earlier last year one of my colleagues contacted you about methods to assess flood risk resulting from the proposed development on these watercourses; it was decided that the following would be the most appropriate (Technical Note attached for reference):

"Use simple (non-hydraulic modelling) techniques to estimate culvert sizing on the six new tributary crossings".

The crossing adjacent to Thorpe Arnold (OP1-CH3760) will now be included in a revised 1D-2D hydraulic model of the Lag Lane watercourse and River Eye main channel, due to concerns regarding flooding of Saxby Road. However, for the other ordinary watercourses it is still proposed to design culvert sizes on the basis of the above methodology. This is because the crossings will be over-sized to convey the 1 in 100yr + 50% climate change flows, thus mimicking the current conditions where no flow constrictions are imposed in these locations (apart from an existing railway embankment over Scalford Brook – this will be further reviewed to ensure that the proposed structure does not increase flood risk downstream of the development).

Please could you advise whether you are happy with this proposed non-hydraulic modelling approach for the remaining ordinary watercourses? Also, when this scheme reaches the Planning Application stage I am wondering whether the LLFA Statutory Consultee role will be deferred to the Environment Agency in this instance, seeing as this is a Leicestershire County Council project?

Thanks,

Will

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From: Andy Jackson [mailto:Andy.Jackson@leics.gov.uk]
Sent: 03 July 2017 16:35
To: Tucker, Owen; Pearson, Katie
Subject: Flood modelling Melton

Hi Katie/Owen
I've spoken to Bernard and he says that the second approach seems sensible given the stage we are in the design process. He just said to make sure we are considering what's happening upstream in terms of providing compensatory washlands in the calculations. He also mentioned that this could have implications for CPO negotiations down the line.

He added that if you have further questions to put them in an email and he will get an answer as soon as possible as he knows the time pressures on the project.

We are struggling staff-wise in the flood section at the moment and have had to employ consultants to provide some of our services as a temporary measure.
Thanks
Andy

Andy Jackson
Senior Engineer (Major Programmes)

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Appendix C2 – AECOM's responses to LCC queries

Prabhuswamy, Anupriya

From:	Prabhuswamy, Anupriya
Sent:	24 September 2018 11:55
To:	Peter Merrick (Peter.Merrick@leics.gov.uk)
Cc:	bernard.evans@leics.gov.uk; Victoria Coombes; Andy Jackson (Andy.Jackson@leics.gov.uk); Glossop, Martyn; Tucker, Owen; Heath-Brown, Andrew M; Segre, Marlene; Leeder, Alison
Subject:	RE: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements

Hi Peter,

Thanks for the prompt review of the FRA and the comments. We are in the process of revising both the FRA and the Surface Water Drainage Plan to incorporate the comments. The revised report will be submitted along with the planning application. Please see below our responses to each of the comments in blue.

Kind regards,

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From: Peter Merrick [mailto:Peter.Merrick@leics.gov.uk]
Sent: 14 September 2018 17:27
To: Prabhuswamy, Anupriya
Cc: Victoria Coombes; Glossop, Martyn; Tucker, Owen; Heath-Brown, Andrew M; Segre, Marlene; Leeder, Alison; Andy Jackson; Bernard Evans
Subject: RE: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements

Anupriya,

Following a review of the draft FRA for the Melton Mowbray Distributor Road please find below my observations and advice. Please note that due to time constraints a full detailed review has not been carried out, as such the LLFA may request further information/clarification on other things following consultation by the local planning authority once the planning application has been submitted.

3.1.2.1 Methodology used to size structures
This section refers to correspondence with LCC (appendix C of FRA) in which LCC confirmed the acceptability of the approach. In Michael Warner's email of 2nd March 2018 it was asked that, "…*the existing channel capacities are also assessed and not reduced by the proposals*." The FRA contains no assessment of the existing channel capacities but states, with respect to the 1% AEP + 50% climate change allowance, "…*thus maintaining current conditions where no flow constrictions are imposed in these locations.*" The proposal isn't strictly in accordance with what LCC had previously confirmed would be acceptable, assessment of existing channel capacities hasn't been undertaken so it is not knows if current conditions are being maintained. This might get picked up on during planning, particularly since it was requested by LCC previously. – The FRA will be revised to include the capacity assessment of the existing channels. The capacity of the ordinary watercourses at the proposed crossing locations have been undertaken using the channel cross-section survey data in July-August 2018. This capacity assessment has been undertaken for Sysonby Farm watercourse, Sysonby Lodge watercourse, Scalford Brook and Thorpe Brook. The Lag Lane watercourse has not been included within this assessment since it has been modelled along with the River Eye.

This assessment has shown that the proposed culverts and open span structures are sized such that the channel capacities are not being reduced.

3.1.2.2 Thorpe Brook
It's acknowledged that the EA fluvial model utilised broadscale (flood spreading) modelling methodology which is likely to be uncertain, and that a clear span bridge is proposed at this watercourse crossing which would have no impact of flows within the channel. The LLFA's concern is what impact the crossing could have on displacing any flood water, without assessment of channel capacity how much certainty is there that this won't be a problem?
Even with assessment of channel capacity, it would not be possible to know how much water might be displaced by the crossing embankment without modelling. Since the proposed clear span bridge means channel flow won't be displaced, the only volume to be displaced will be that occurring in out-of-bank events. Modelling would be needed to establish flood levels, and to subsequently calculate volumetric losses of floodplain. Is there any requirement to provide compensatory works for losses on an ordinary watercourse? Regardless, due to the likely low

conveyance properties of out-of-bank flows, any displacement of flood volume will result in very localised increased in flood levels and/or minor increases in pass forward flows. Since, the area surrounding the proposed crossing location is agricultural, no residential/commercial properties will be impacted.

3.1.2.3 Scalford Brook

Similarly to the Thorpe Brook, it is acknowledged that the Scalford Brook does not exist within the EA's River Wreake model flood outlines. Without any channel assessment though, how much certainty is there that any flooded volumes will not be displaced by the bridge structure/embankments? – Same as Thorpe Brook.

3.1.2.5 Other Ordinary Watercourses located

The third paragraph discusses assessment of flows in other ordinary watercourse and mentions channel flow calculations and surveys of watercourse cross sections. All details (flow calcs, topo surveys, cross sections etc.) should be provided within the FRA to support this approach, without it the LLFA cannot verify the statement that flows are comfortably contained within the watercourse sections. – We will add the channel flow calculations and surveyed cross sections to the document.

With regard to other ordinary watercourses such as smaller ditches etc, I make the following observations:

¶ Minor ditch beneath roundabout no.1 is proposed to be filled as far as the proposed pond (appendix C – AECOM response to LCC flood team). The LLFA expect assurance within the FRA that this will not have an impact on upstream flood risk. – This ditch appears to provide an overflow from the existing slurry pits and potentially drain water from the existing farm buildings/hardstanding, all of which will be removed. Earthworks drainage ditches / pipes will be provided on the north side of the proposed road in this area, immediately to the north of the ditch to be backfilled, and these will pick up any overland flow in the vicinity. As a further safety measure the existing ditch will be backfilled with granular material to provide a drainage pathway to the pond/watercourse although it is considered that this will not be necessary as all surface and groundwater flows in the area will be picked up by the highway drainage system. Within the Surface Water Drainage Plan (SWDP - Appendix F of the FRA) schematic arrows will be added to the drawings to illustrate surface water flow routes adjacent to the road and where these will be picked up and conveyed to watercourses, text will also be added regarding the filling of this ditch.

¶ Nothing has been proposed for the management of other smaller ordinary watercourses/ditches despite this being raised by Victoria Coombes in her email dated 30th January 2018. Full detailed design is not necessary at this stage but a statement/paragraph indicating how these will be appropriately managed is still expected in the FRA - If any additional small ordinary watercourses/ditches affected by the road are discovered during the course of the detailed design they will be treated as appropriate to their particular circumstances and in agreement with LCC Flood Team. Wherever viable the current routing of these watercourses will be maintained by conveying them under the proposed road in appropriately sized pipes and/or granular material. A statement will be added to the FRA regarding is as advised.

3.3 Surface Water Flood Risk

The LLFA would expect an indication of how surface water flows will be managed from upstream of the proposed MMDR alignment. A statement clarifying how to address this would suffice i.e. interception ditches/channels/drains to be used to collect and convey surface water flow routes downstream. – We will add a statement to the SWDP within the FRA and also add schematic arrows to the drawings to illustrate surface water flow routes adjacent to the road and where these will be picked up and conveyed to watercourses.

3.4.2 Ponds / Lakes

Only two large waterbodies have been identified along the proposed route, another small pond is indicated on OS mapping where the proposed MMDR alignment crosses the unnamed ordinary watercourse (Lag Lane watercourse) east of Thorpe Arnold. Aerial view photography doesn't confirm the presence of a pond here so it may just be a small depression where water collects. This seems to correlate with the increased flood depth on this watercourse shown in figure 4-2 (Section 4) so perhaps there is some connectivity between the watercourse and the small pond here. Some indication of how this will be managed should be contained within the FRA. - The development proposals show that the pond will be infilled by the highway embankment. As per the LCC comment below, during the detailed design stage, we will investigate if the pond is a formal feature. If required, the pond can be recreated and any connectivity re-established.

If the pond is more of a formal feature than just a depression, the LLFA would advise a condition to the LPA in order to secure appropriate details relating to the management of it.

4.1.1 River Eye and Lag Lane Watercourse

Figure 4-2 shows a small area of increased flood depth upstream of the proposed MMDR alignment. This doesn't support the statements contained in Section 3.1.2.1 where it is proposed to maintain current conditions and not impose restriction to flows, however I acknowledge that the area is very localised and there is reduced flood depth further upstream. – The proposed culvert within the flood model is a 2m x 2.3m box culvert which has greater capacity than what was originally calculated to be required to allow peak flows during the 1% AEP plus 50% climate change event. The model shows that the culvert is large enough to pass these flows. In both the baseline and proposed scenario, in the section just upstream of the proposed culvert, localised flooding is shown to occur in the 1% + 50%AEP because the banks of the Lag Lane Watercourse in this area are too low. This issue can be further discussed with the LCC Flood team and any works that may be required to further improve the situation can be taken into consideration during the detailed design stage.

Ideally we'd like to see the culvert proposed here altered to address this, this may be something we'd look to advise as a condition to the LPA.

4.4 Mitigation against Surface Water Flooding

The LLFA expect the following basic requirements to be provided in the FRA, proportionate to the scale of the proposal, to demonstrate the proposal will not increase flood risk elsewhere:

- Confirmation of pre and post impermeable areas. – A table of pre and post impermeable areas will be added to the SWDP within the FRA
- Greenfield runoff rates calculations, expressed in l/s and l/s/ha is acceptable. These calculations will be added to the SWDP within the FRA
- Proposed discharge rates from each outfall and supporting calculations, expressed in l/s and l/s/ha is acceptable. Currently it is only stated that greenfield rates will be used without confirming what these rates actually are. The proposed discharge rates will be added to the SWDP within the FRA

- ¶ Attenuation volume calculations demonstrating that the proposed volumes are adequate to accommodate the 1 in 100 year storm event plus 40% climate change allowance, particularly if seeking full planning permission which seeks to approve layout. – Attenuation volume calculations will be added to the SWDP within the FRA
- ¶ The proposed SuDS are considered acceptable but the LLFA typically expect a review/consideration of SuDS to be contained within the FRA. It would be prudent to include any previous correspondence with LCC concerning the drainage proposals in the FRA appendix. The previous correspondence regarding the drainage proposals will be added to the document.
- ¶ Under the assumption that the planning application will be for full planning, the LLFA typically expect modelled storm simulations to be provided for the drainage network to ensure compliance with the non-statutory technical standards for SuDS (S7, S8 and S9), and which could then be used to assess exceedance flow routing. – As discussed (Peter Merrick / Garry Dawson telecom 18/09/18) it is not possible at this stage to provide storm simulations for the full drainage network as this would require finalised road levels in all areas to enable calculation of final cover levels and a near completed detailed drainage design, and these are not yet available. We can however as agreed provide simulations for the ponds, add text to the report confirming the drainage system will be designed to achieve the criteria specified in S7, S8 and S9 and add schematic arrows to the SWDP drawings showing overland flow routing.
- ¶ Proposed level information would generally be expected to be submitted to confirm the feasibility of the outfalls although it is noted that there doesn't appear to be any immediate issues with achieving a gravity drainage system. – Level details will be added showing feasibility of the outfalls.
- ¶ Clarification on the impermeable areas (increase/decrease) proposed to drain to existing drainage network and assessment of impact on these drainage systems. Details of changes to impermeable areas draining to existing networks will be provided. In all cases there is a reduction in overall impermeable area and therefore there will be no negative impacts.

4.6 Mitigation against Groundwater Flooding

Has LCC in their role as highway authority confirmed this combined approach to be acceptable? The LLFA would not require any groundwater flows to be restricted to greenfield runoff rates and it is likely to be difficult to determine groundwater flow rates within such a system. If groundwater ingress and highway runoff could be isolated from each other that would be ideal but the LLFA have no issues with this proposal in principle. - Use of combined surface water and ground water surface drains is common practice for highway drainage and the alternate of carrier pipes with separate fin/narrow filter drains still results in the highway surface water flows and groundwater flows in the vicinity of the road pavement being combined in the same drainage system. After initial draw down of groundwater levels, and in view of the largely cohesive nature of surrounding soils long term groundwater flow rates adjacent to the road pavement will be negligible in comparison to peak surface water storm flows. Where adjacent ground falls towards the proposed road earthworks drains/ditches will be provided which will take a proportion of groundwater flows and these will be keep separate from the highway surface water drainage system in the majority of cases.

Other Observations

- ¶ Whilst it is assumed that LCC will maintain all of the drainage system in the future, this should confirmed within the FRA. – Will be added to the FRA.

If you wish to discuss any of the aboev please don't hesitate to contact me.

Responses to LCC Flood Team Consultation Comments
Melton Mowbray Distributor Road

LCC: With regards to the use of simple (non-hydraulic modelling) techniques to estimate culvert sizing on the six new tributary crossings using oversizing to include the 1 in 100 year + 50% for CC, I have conducted a review of our most up to date food risk data and wish to make the following comments:

- Where the proposed road crosses the ordinary watercourse just north of Thorpe Arnold, d/s of Twin Lakes it crosses identified flood zones. Given that there is a historical incident of flooding downstream of this crossing and designated flood zones, please can you confirm the proposals for sizing this crossing to ensure that the flood zones are not impacted.

AECOM:
At the point where the crossing occurs, Thorpe Brook is considered Ordinary Watercourse rather than Main River. It is shown to be in Flood Zone 3 but doesn't exist in the supplied EA model flood outlines. We checked with the EA, and they confirmed that the Ordinary Watercourse had been mapped based on broadscale (flood spreading) modelling). The National Flood Zone 3 outline GIS layer confirmed that the width of the floodplain in this area, based on the broadscale modelling, is approximately 100m. Since the accuracy of broadscale modelling is limited, and the source of DTM data used to undertake the modelling unknown, we consider that these outlines have a high level of uncertainty and are not appropriate for determining structure dimensions or assessing changes to flood risk.

The span of the proposed bridge crossing Thorpe Brook, north of Thorpe Arnold, is anticipated to be about 18m. This width was based on calculations provided in the attached Culvert Sizing Technical Note, ecological requirements (minimum setback of 5m on either side of the river channel from top-of-bank to accommodate water vole habitat) and to allow an access track to pass beneath one of the open-span structures.

Early on in the course of this project, the attached technical note was produced to provide a starting point for the structural team for sizing of culvert crossings and bridge structures for all watercourses (except River Eye) which were not being modelled at this stage, which included the Thorpe Brook crossing.

A summary of the methods used for sizing of the structures from the technical notes is provided below:

1. Hydrological Analysis: In order to estimate peak flows, the FEH statistical, ReFH and ReFH2 methods were applied for each catchment.

2. Culvert Size Analysis: Three methods were then used to make a rough assessment of the culvert size for the 1% AEP design event:

    a) A simple "pipe flow" program, which involved a trial and error approach, was used to determine the range of diameters which could effectively convey the target flows. This method required a number of assumptions to be made, such as the slope of the culvert, and the finish of the pipe. This method also does not account for inlet losses or backwater effect, and is based on full bore flow. An increase in the diameters may be required to account for these.
    b) The small orifice equation (standard hydraulic theory) method involves determining the pipe diameter which will achieve the required peak flow. ReFH2 was used as it provided the highest flows. This option also requires assumptions on the slope and pipe finish, and does not account for inlet losses or backwater effect, but is based on full bore flow. An increase in the diameters may be required to account for these.
    c) The Manning's equation method involves using standard hydraulic theory. The span culvert width was pre-determined based on assessment of existing watercourse top width. The box culvert rise was then determined in order to achieve a peak flow. ReFH2 based peak flows have been considered here, as they provide the highest flows. The same assumptions and allowances should be made as with methods 1 & 2.

    Ultimately, the Small Orifice equation and Manning's equation were used to determine the required circular pipe size and/or box culvert sizing, as they provided the largest estimations for sizing.

3. Sensitivity Analysis for climate change: To make allowances for climate change, the diameter sizes were increased by 20%, 30% and 50%, and tests were carried out to reveal sensitivities to different Manning's equations.

For the Thorpe Brook crossing, an open-span bridge structure is required for WFD reasons. Therefore, the height could be based on the Manning's equation calculation of box culvert size as per the attached technical note. However, another possibility is to re-calculate the required span and height using the flows from Thorpe Brook (as provided by the EA model), and assuming a box shape as per the proposed bridge structure. This would not yield a significantly different answer, since the inflow to Thorpe Brook within the EA model had a 1% AEP event peak flow of 8.2m^3/s, based on a 21.25-hour storm applicable to the wider River Eye catchment. Our assessment of Thorpe Brook for the 1% AEP event gave a peak flow of 7.8m^3/s from the ReFH2 method (comparable catchment area but shorter storm duration, more applicable to the Thorpe Brook catchment only).

If this is not acceptable, then the existing model of the Thorpe Brook watercourse (included as part of the wider River Eye mdoel) would need to be extended upstream to include the crossing location. Channel cross-sections could be obtained by survey, or approximated by the latest LiDAR data (which appears to have sufficient resolution to represent the channel geometry).

LCC: Where the road is proposed to cross the River Eye flood plain the EA should advise.
AECOM: Consultation with the EA is ongoing. Modelling of the River Eye crossing is currently being undertaken, utilising an updated version of the EA's current River Eye and tributaries model.

LCC: Where the road is proposed to cross an Ordinary watercourse upstream of Saxby Road, there is a known risk/occurrence of highway flooding. Therefore it is supported that more detailed modelling is required to ensure the crossing is appropriately sized.
AECOM: This ordinary watercourse (located adjacent to Lag Lane) has been included in an updated version of the EA's current River Eye and tributaries model.

LCC: What about other small ditch crossings of which we are not currently aware of? There are bound to be many small ditches/dykes etc. which will need to be incorporated and assessed as well as granted consent. What are the proposals for those?

AECOM: From the plans provided (see attached Sketch 0044) there are 8 watercourses, and 9 watercourse crossings (some are likely to be drainage ditches which only flow certain times of the year). Following the outstanding topographic survey and site walkover, it is possible that more watercourses will be identified, and numbers may depend on the final alignment of the road where it crosses the River Eye (see attached for proposed routes).

Each watercourse encountered will be considered individually. For instance, although agreement must be obtained with the LCC Flood team, it is proposed that the minor drainage ditch beneath roundabout no.1 be filled as far as the proposed pond.

Roundabout no.6 has a minor watercourse (thought to be a field ditch) starting directly beneath it. It is thought that the highway drainage outfalls into the ditch. As any existing highway drainage will be replaced, it would be simple to reroute any outfalls from the existing system into the upstream end of the watercourse.

Sketch 0034A shows alignment options at the River Eye. The most likely for progression are Option E (powerline diversion) or Option C (river diversion). Please note that if we progress with the Option E alignment shown in purple on the attached plan, this is likely to require an extended culvert for Thorpe Brook since it will then sit below roundabout 5.

LCC: I have concerns of where using any existing culverts (such as old railway bridges) about exacerbating outstanding flood risk not known about in detail. This is difficult to mitigate however I support that further reviews of such structures will be required to ensure that flood risk is not increased upstream or downstream of the proposed road crossings.

AECOM: There is an existing culvert beneath the disused railway south of the proposed route with approximate chainage 1900. This culvert is downstream (and outside the extents of our scheme) but could in theory impact flows entering this culvert. However, the proposed surface water drainage network and attenuation ponds will need to be designed such that flood risk is not increased to areas outside of the extents of our scheme.

Attachments:

1) MMDR Initial Hydrology Culvert Sizing Technical Note
2) Drawing: 60542201-SKE-20-000-C-0044_DRAFT
3) Drawing: 60542201-SKE-20-000-C-0034_REVA

Appendix D

Hydraulic Modelling Report

Melton Mowbray Distributor Road

Modelling Report

Leicestershire County Council

7 September 2018

Quality information

Prepared by	Checked by	Approved by
Ben Brough Graduate Consultant	Ian Bentley Senior Engineer	Andrew Heath-Brown Associate Technical Director

Revision History

Revision	Revision date	Details	Authorized	Name	Position
1	23/05/2018	1st Issue			
2	07/09/2018	2nd Issue as part of FRA			

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Figures

Tables

1. Introduction

1.1 Background

Leicestershire City Council is proposing to build a distributor highway (referred to as MMDR within the wider study) around the town of Melton Mowbray (National Grid Reference (NGR) SK 752 192), the route of which is affected by the River Eye and a number of its tributaries. The River Eye is an Environment Agency (EA) 'main river' which flows through the centre of Melton Mowbray. Many of the River Eye tributaries originate to the north of Melton Mowbray, flowing southwards to join with the River Eye in the vicinity of the town.

Since the proposed highway would cross an EA main river, a flood risk assessment is required, part of which requires confirmation that the highway does not increase flood risk on or off of the site.

This report describes hydraulic modelling that AECOM has carried out to assess the impacts of the proposed highway on the River Eye and a nearby unnamed tributary, which in turn has informed the MMDR Flood Risk Assessment. From hereon in, the unnamed tributary will be referred to as the Lag Lane tributary, due to its proximity to Lag Lane (**Figure 1**).

Within the main study area, the River Eye flows generally in a westerly direction towards Melton Mowbray, with Saxby Road to the north. Upstream of its existing Lag Lane crossing, the current River Eye bends to flow in a northerly direction, underneath a railway on raised embankment. Upstream of the railway, the Brentingby Dam and associated control sluice gates operate as a defence to control downstream flows in flood conditions.

The Lag Lane tributary flows generally in a southerly direction, passing under the northern branch of Lag Lane via a culvert its confluence with the River Eye. This culvert inlet is at the junction between Lag Lane and Saxby Road (NGR SK 77122 19293), with an outlet on the right bank of the River Eye, located immediately downstream of Lag Lane bridge (NGR SK 77157 19227) (**Figure 1**).

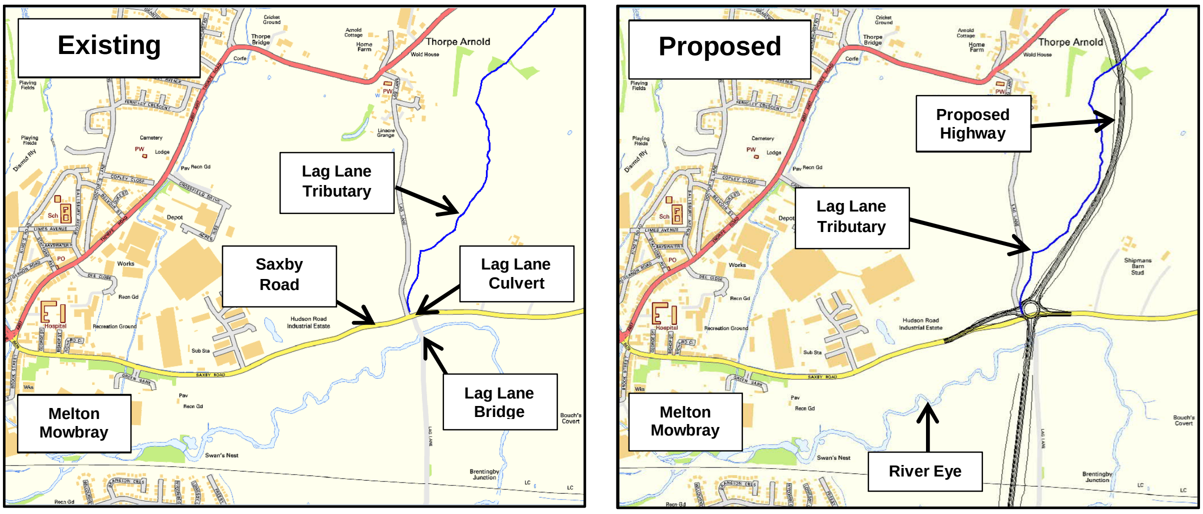


Figure 1 – Location plan showing existing and proposed road arrangement in the vicinity of the River Eye and Lag Lane tributary confluence.

1.2 Development Proposals

The elements of the proposed development covered by this modelling study, and shown in **Figures 2** and **3**, are:

- A new culvert, located on the Lag Lane tributary, approximately 1km upstream of its confluence with the River Eye, where the proposed highway crosses the tributary (upstream culvert, **Figure 2**);
- The removal of the existing Lag Lane bridge crossing the River Eye;
- A proposed new junction replacing the existing junction of Saxby Road and Lag Lane (**Figure 2**);
- Realignment of the existing northern branch of Lag Lane to join the proposed new junction, and replacement of the existing southern branch of Lag Lane with the proposed southbound highway;
- Realignment of Lag Lane tributary to the west of the proposed junction;
- Saxby Road realigned to join the proposed junction/ highway;
- New bridge for the proposed highway to cross the River Eye;
- Realignment of the River Eye channel upstream of the proposed highway; and
- Existing River Eye channel to be retained as a backwater.

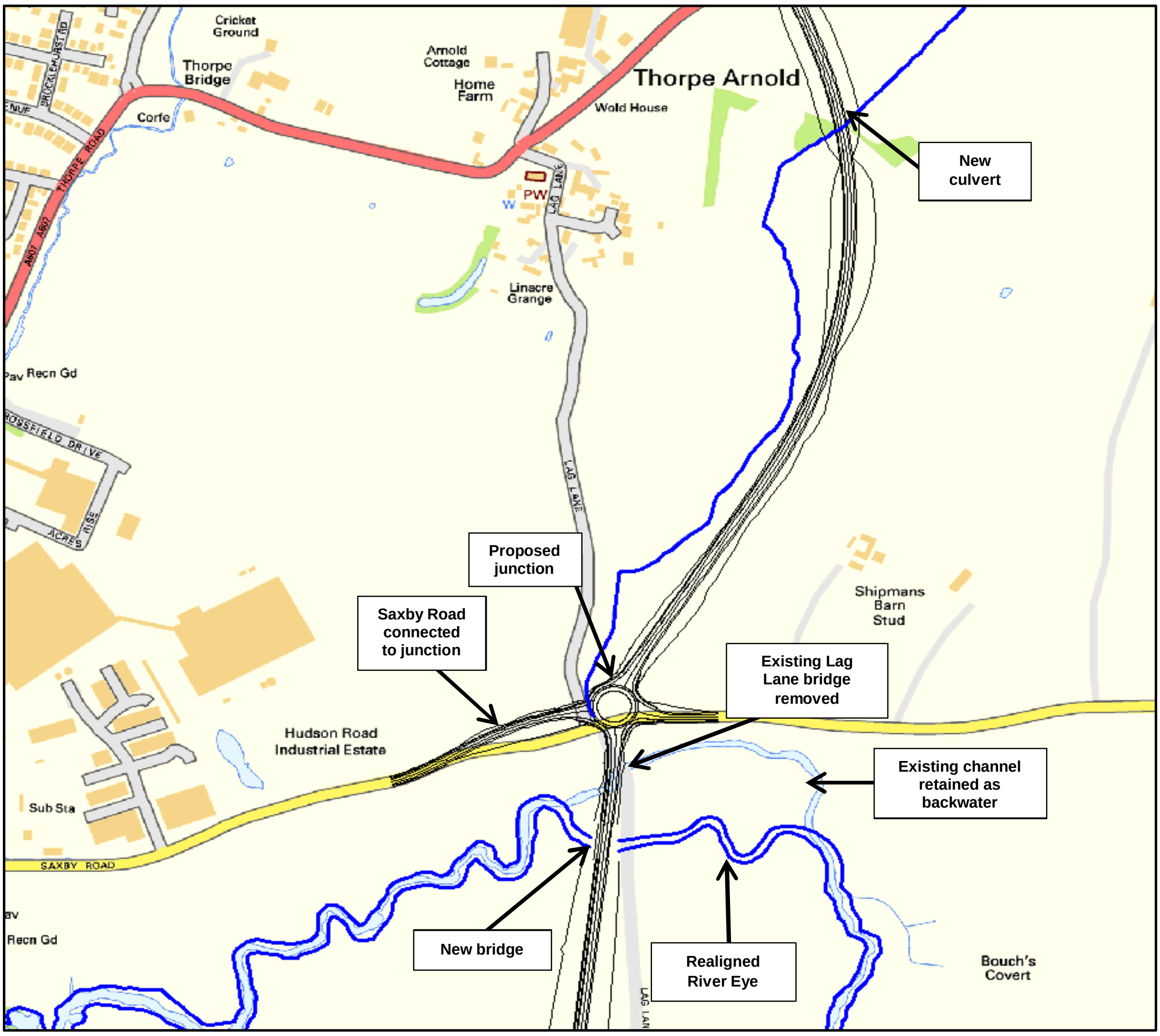


Figure 2 – Outline of the proposed highway.

The realignment of Lag Lane to join the proposed highway at junction 5 will require the crossing of the Lag Lane tributary. In addition, the associated realignment of Saxby Road will also cross the Lag Lane tributary, since the watercourse will need to be diverted to the west. As a result, two new culverts are required to connect the Lag lane tributary to the River Eye downstream of the proposed crossing, replacing the existing culvert passing under Saxby Road. The location of these new culverts is shown in **Figure 3**. The proposed culverts divert the Lag Lane tributary around the proposed junction, under the realigned Saxby Road and west of a proposed balancing pond (which will form part of the highway drainage system).

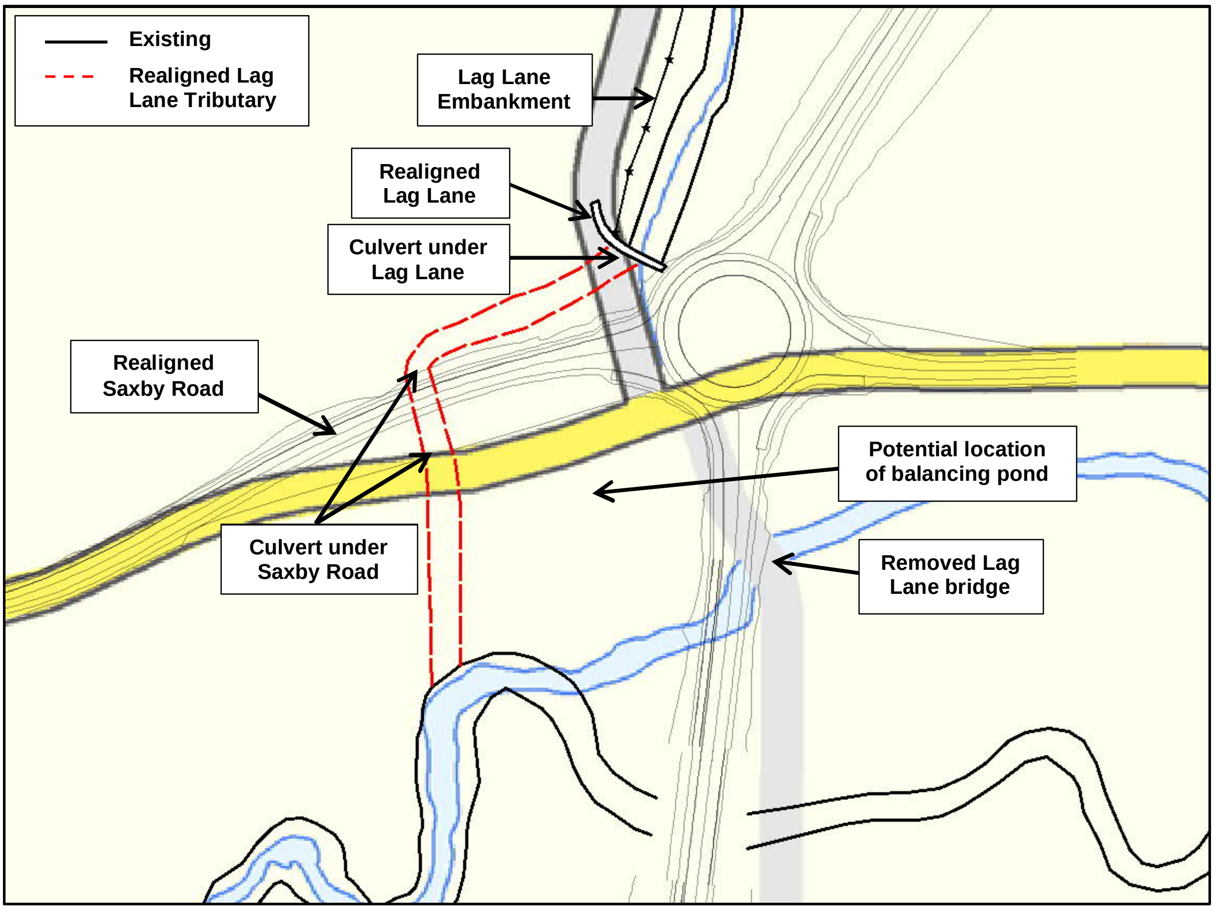


Figure 3 – Map showing the proposed realignment of the Lag Lane tributary.

1.3 Environment Agency Requirements

1.3.1 Site Development

The EA has indicated that for the development to be considered acceptable, the impact of the proposed highway and associated road realignments, including the crossing of the River Eye and any proposed changes to the watercourse, will need to be assessed through hydraulic modelling. This should demonstrate that the development does not increase flood risk elsewhere, is safe for its lifetime, and provides a minimum freeboard of 600mm between the main channel and the proposed bridge soffit. The design standard is the 1% AEP event, with an appropriate allowance for climate change in line with the EA current guidance (confirmed by the EA to be the ‘Upper End’ allowance category for the ‘2080s’ epoch – see section 1.3.2 for details).

1.3.2 Climate Change

The recently revised climate change allowances have been used in this assessment. The new guidelines require consideration of a number of factors to determine the required increase in peak flow:

1. Firstly, the peak flow increases are dependent on location; specifically, the river basin district in which the development is located.

2. Secondly, the peak flow increases are dependent on the appropriate ‘allowance category’ scenarios. The choice of ‘allowance category’ depends on the type of development and its flood risk vulnerability classification.
3. Thirdly, and for each allowance category, there are three total potential change bands. These relate to the lifetime of the development.

The proposed highway is located in the Humber River basin district and assigned a vulnerability classification ‘*essential infrastructure*’. Based on this vulnerability classification, the appropriate climate change estimates are the ‘Upper End’ bandings. **Table 1** shows the EA’s peak river flow allowances for the Humber River Basin District.

Allowance category	*Total potential change anticipated for ‘2020s’ (2015 to 2039)*	*Total potential change anticipated for ‘2050s’ (2040 to 2069)*	*Total potential change anticipated for ‘2080s’ (2070 to 2115)*
Upper end	20%	30%	50%
Higher central	15%	20%	30%
Central	10%	15%	20%

Table 1 – Climate Change allowance for the Humber River Basin District

1.3.3 Modelled Events

The baseline was run for 20%, 10%, 5%, 2%, 1.33%, 1%, 0.5% and 0.1% AEP flood events. Based on **Table 1**, the baseline scenario was also run for three climate change allowances in associated with a 1% AEP flood event (20%, 30% and 50%).

However, only the results of the proposed highway scenario with a 1% AEP event plus 50% climate change scenario have been discussed in this technical report, since this is the design standard required by the EA.

2. Incoming Data

2.1.1 Existing Model

The EA supplied AECOM with the latest model of the River Wreake (Eye) and tributaries, which was last updated by Halcrow in 2011. The model extends from Stapleford to Syston, and has been developed using ISIS (version 3.3) (1D) and TUFLOW (version 2009-07-AE-iSP) (2D) software; however only a proportion of the model used a 1D-2D linked approach, as shown in **Figure 4**.

The model between Brentingby Dam and Austen Dyke bridge, including four out of five tributaries in Melton Mowbray, were included in a 1D ISIS - 2D TUFLOW linked approach. Elsewhere, the model was a 1D only ISIS model, **Figure 4**.

This model did not include Lag Lane tributary and was noted to have poor convergence throughout a significant proportion of the simulation time (including during peak inflow and outflow), at all modelled events (see **Section 5.3** and **Figure 12**).

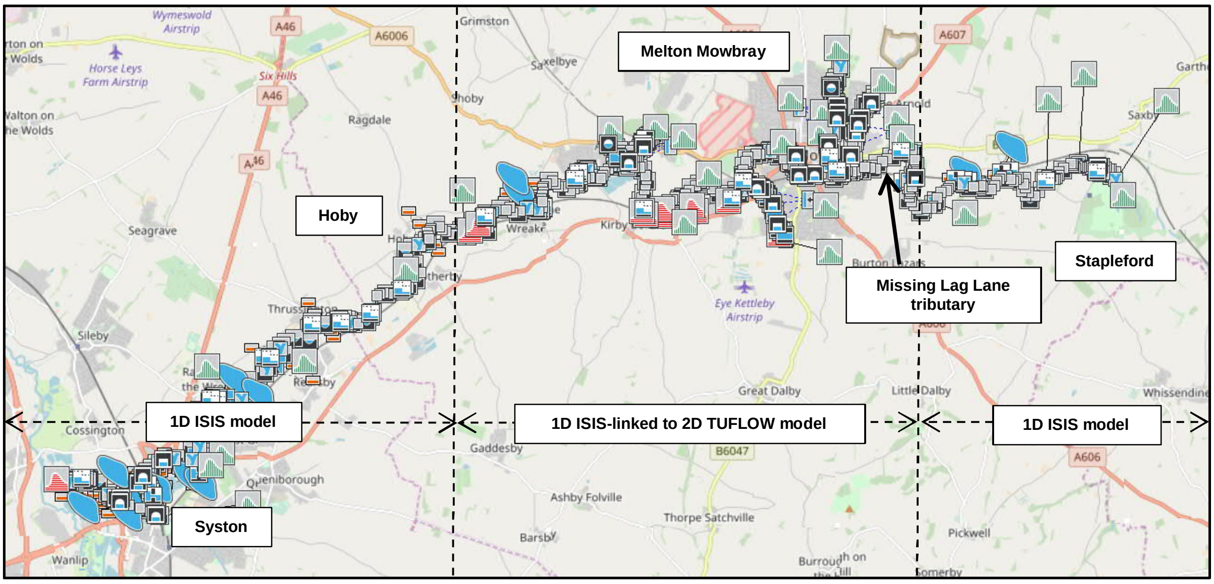


Figure 4 – Outline of the EA hydraulic model provided.

Upon review of the supplied model, it was concluded that modifications would be required in order to include the Lag Lane tributary within the baseline scenario model, as well as update topographic information in the area of interest (i.e. between Melton Mowbray and Brentingby Dam), and subsequently to incorporate the changes related to the scheme for the proposed scenario model. The necessary modifications have been described in **Section 3** and **Section 4**.

2.1.2 Additional Data

The following data was obtained in order to update the baseline scenario model (from the original EA hydraulic model):

- Updated LiDAR data was downloaded from the Survey Open Data platform and merged with new 1m LiDAR data obtained from Bluesky in 2017 (used for baseline model);
- Lag Lane tributary cross sections surveyed between October and December 2017, and obtained from Leicestershire County Council;
- River Eye cross sections between Brentingby Dam and Priors Close Park (centre of Melton Mowbray) was surveyed by Central Surveys between July and August 2018 on behalf of AECOM;

The following data was supplied internally within AECOM for development of the proposed scenario model from the updated baseline scenario model:

- Modified DTM covering the area between Brentingby Dam and Priors Close park, which included the proposed realignment of the River Eye as well as filtering out the existing Lag Lane road elevations to the south of Lag Lane bridge (**Figure 5**). This modified DTM was supplied by the AECOM geomorphology team (and was based on the updated and merged LiDAR datasets described previously); and
- Drawings of the proposed highway and River Eye bridge, supplied by the AECOM highway team (**Appendix 1**).

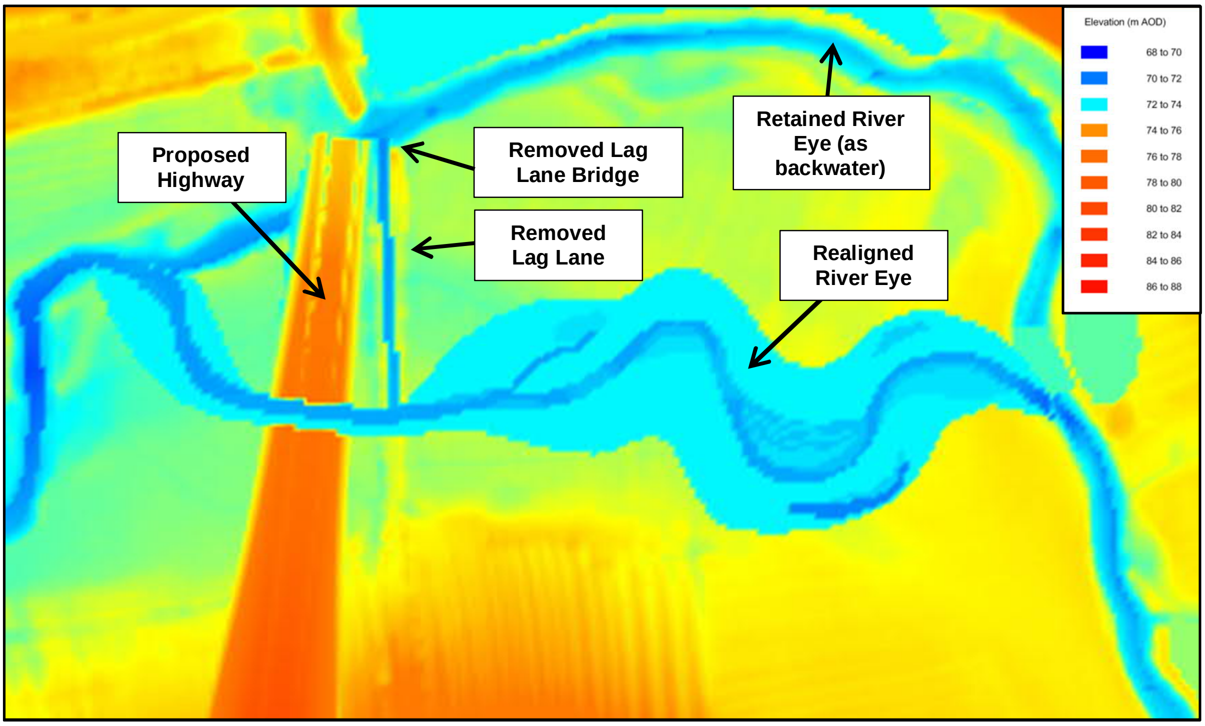


Figure 5 – Modified River Eye DTM.

3. Hydraulic Modelling – Baseline

3.1.1 Updates to EA model

The following changes were made to the model supplied by the Environment Agency, to create an updated baseline scenario model:

- Extension of the model to include Lag Lane tributary using the survey data provided by Leicestershire County Council (see **Figure 6**);
- Updated the models river sections WA_113.01 to WD93U, where applicable, using survey data carried out by Central Surveys between July and August 2018;
- Lag Lane bridge dimensions and geometry were updated based on survey taken by AECOM between July and August 2018;
- The baseline model DTM was updated using the new merged LiDAR DTM dataset (at 1m resolution) supplied by Bluesky, and Survey Open Data LiDAR DTM (for clarity, this merged dataset does not include the realigned River Eye, which is part of the proposed model only).

In addition to the changes made to update the EA model, other noteworthy points regarding the updated model are:

- The following river sections were removed to reduce the number of 1D nodes to below 1000:
  - ➢ Removed nodes WA48 to WA1 (after Hoby village), WA130 and WA131 (top of River Eye);
  - ➢ Asfordby Brook shortened - removed nodes AR664 to AR244; and
  - ➢ Welby Brook shortened – removed nodes 01.014 and 0.013.
- Wider stability/ convergence issues in the original EA model were not addressed as the changes were focussed on the sections relevant to the MMDR flood risk assessment.

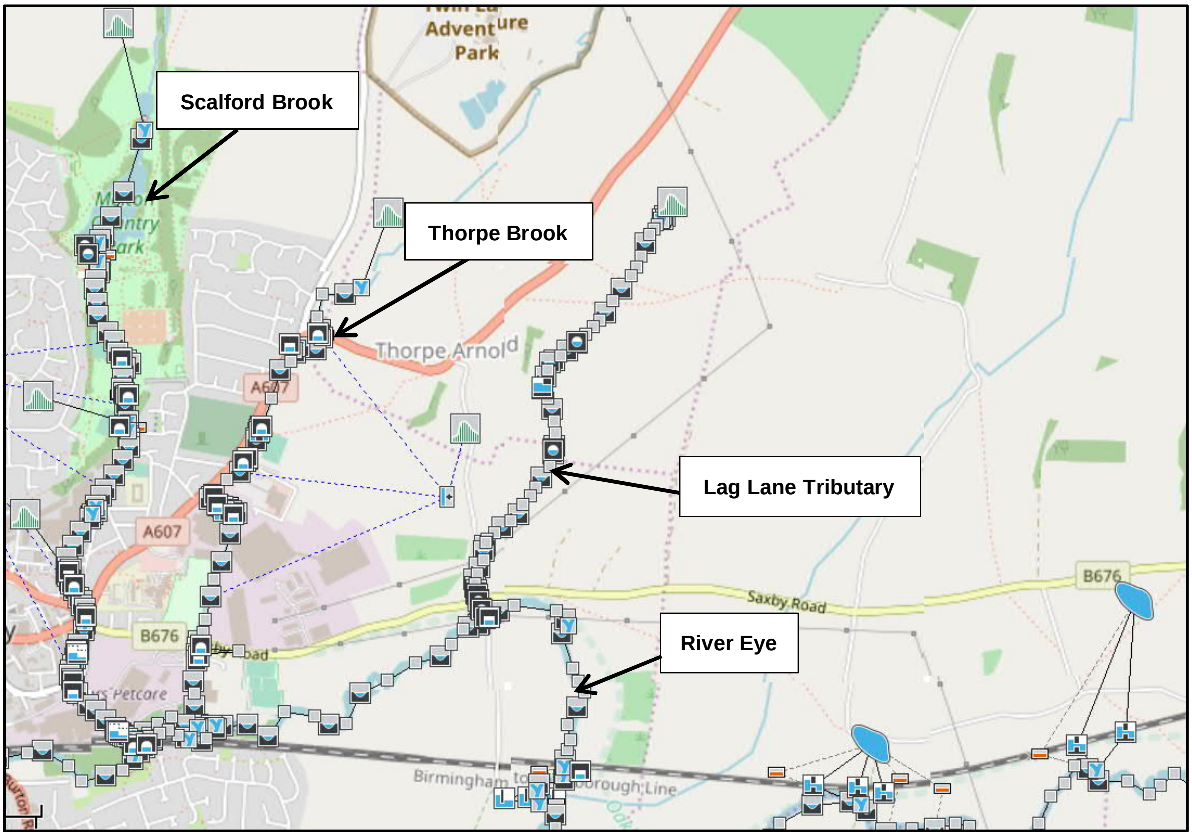


Figure 6 – Model showing the addition of Lag Lane Tributary to existing EA model.

3.1.2 Model Software/ Run Parameters

The model was run using Flood Modeller (version 4.3.0.290) and TUFLOW (version 2016-03-AB-iDP-w64). These were the latest versions available at the commencement of model development.

As per the original model supplied by the EA:

- The 1D time-step was 2 seconds.
- The 2D time-step was 4 seconds.
- The 2D cell size was $8m^2$.
- The simulation time was 60 hours.

No other run parameters were altered from those supplied in the original model run files. However, for the simulations undertaken as part of this study, the TUFLOW software was run with the ‘Double Precision’ option selected.

4. Hydraulic Modelling – Proposed Scheme

The current proposed scheme for the new highway includes:

- A new highway extending north and south of the River Eye, with a new junction close to the existing Lag Lane staggered junction/ confluence of the Lag lane tributary and River Eye
- A new crossing of the River Eye;
- Realignment of the River Eye;
- Diversion and new crossings of the Lag Lane tributary near its confluence with the River Eye, and,
- An additional crossing of Lag Lane tributary further upstream.

The modifications made to the updated baseline model are discussed below for the proposed new highway in general, and more specifically for the River Eye and Lag Lane tributary individually.

4.1.1 Proposed Highway

The updated baseline model was modified to include representation of the proposed new highway. Ground levels within the 2D model were modified to represent the proposed highway embankment using TUFLOW z-shape and z-line geometry files. The geometry of the highway was provided internally from AECOMs highways team (**Figure 7**).

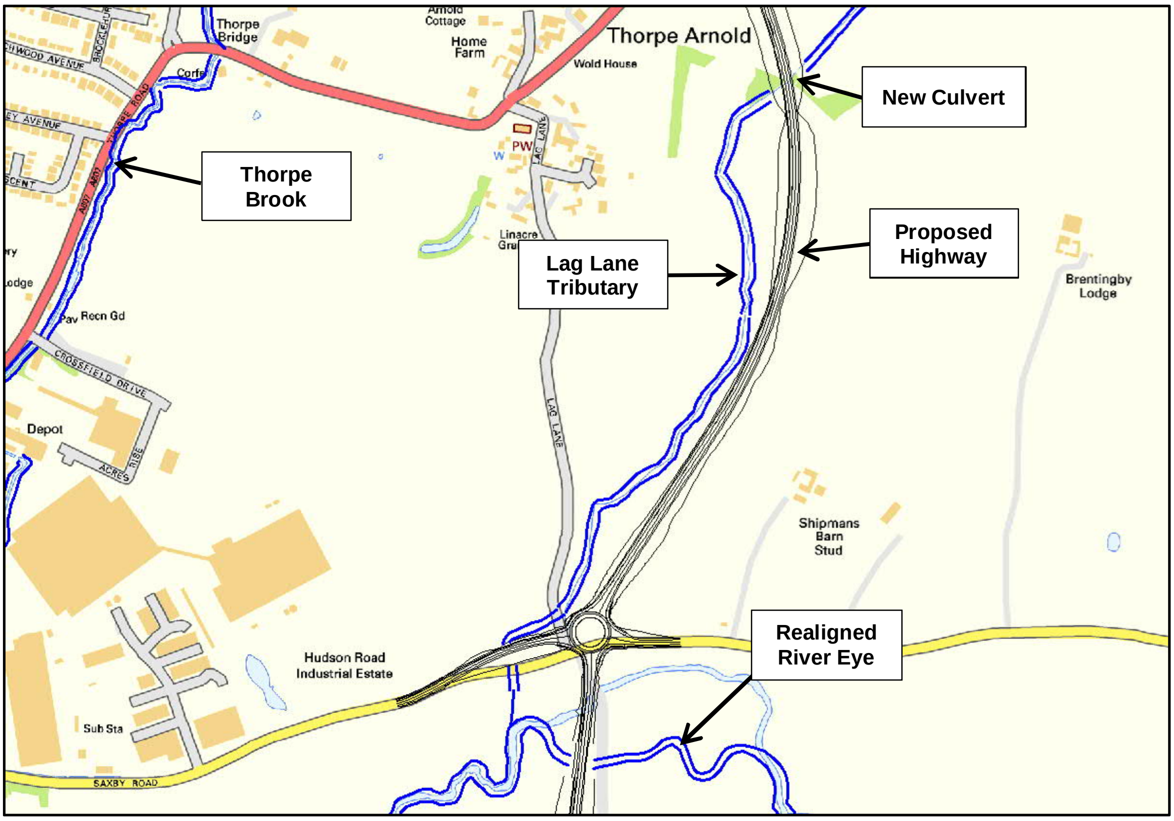


Figure 7 – Outline of proposed highway and re-aligned Lag Lane tributary.

4.1.2 River Eye

The following additional modifications were made to the updated baseline model, in respect of proposed changes primarily affecting the River Eye:

- The route of the River Eye diversion was based on modified DTM provided by AECOMs geomorphology team, which included the River Eye realignment and associated morphology, and filtered out elevations associated with the existing raised Lag Lane road;

- The 1D model river sections for the realigned River Eye were updated using cross sections extracted from the modified DTM;
- The modified DTM (with realigned River Eye and filtered Lag Lane) was stamped on top of the original DTM that was used in the baseline model;
- In the 1D model, the Lag Lane bridge was removed and replaced by a new bridge carrying the proposed highway over the River Eye (see **Figure 8**);
- The new proposed bridge consists of 4 spans over the realigned River Eye and floodplain.
  - ➢ As stated above, the main bridge span was modelled in 1D, whilst the remaining three spans were modelled in 2D.
  - ➢ In the 2D model, the bridge spans were modelled using 2D_SXCN and network (1d_nwk) files, set to a defined geometry which was provided by AECOMs highway team (**Figure 9**);

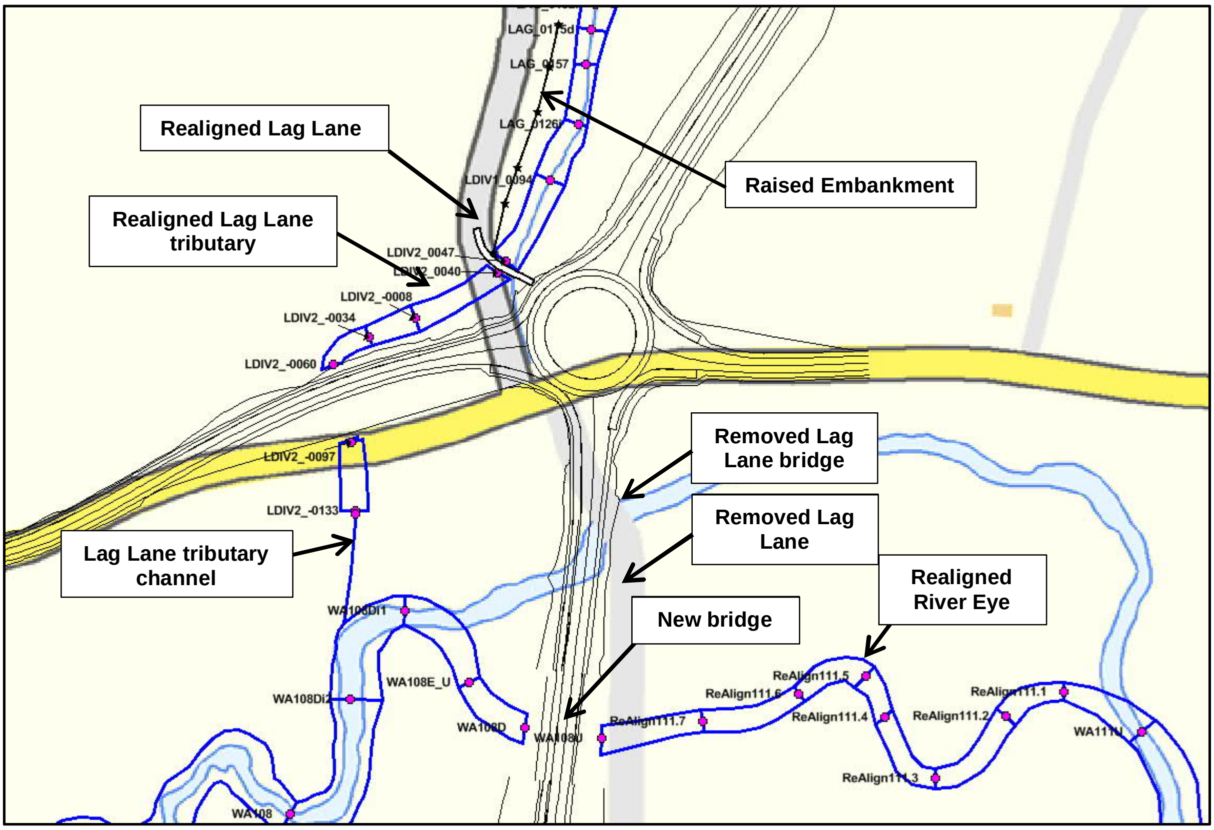


Figure 8 – Map outlining the changes to the EA's current model.

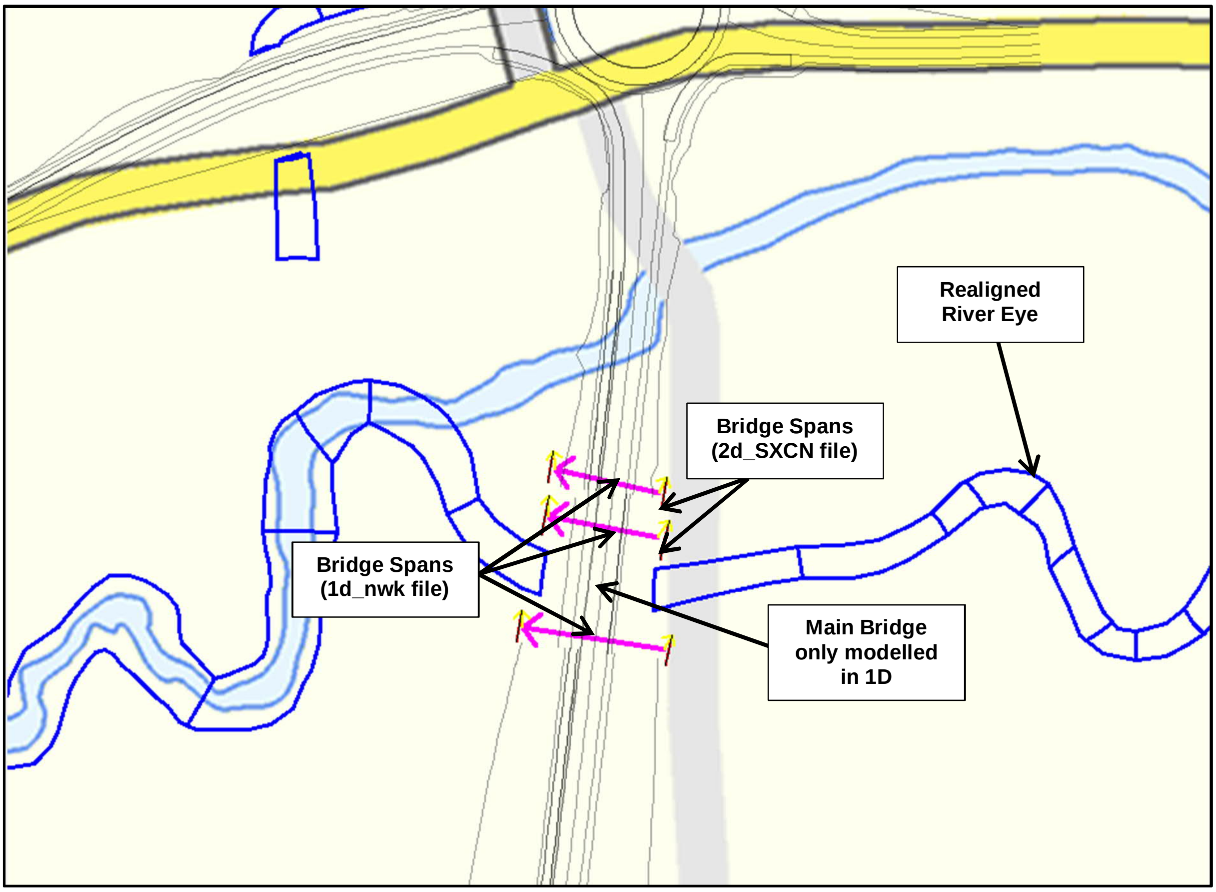


Figure 9 – Map outlining the inclusion of the new highway bridge in the proposed model.

4.1.3 Lag Lane tributary

The following additional modifications were made to the updated baseline model, in respect of proposed changes primarily affecting Lag Lane tributary. Details of the following changes were not provided by the AECOM highway team but were determined by the AECOM modelling team (in consultation with the AECOM geomorphology team), as required to prevent flooding of the new Lag Lane junction:

- Removal of an existing culvert on the Lag Lane tributary and replacement with a new culvert under the proposed highway, approximately 1km upstream of the River Eye confluence (**Figure 7**);
- Realignment of the northern branch of Lag Lane (at its southern end) to merge with the proposed junction (**Figure 8**);
- Removal of an existing culvert under Saxby Road and addition of two culverts for the tributary to flow under the realigned Lag Lane and Saxby Road (**Figure 8** and **Figure 10**);
- Addition of embankments around the lower part of the Lag Lane tributary to prevent flooding encroaching on to Saxby Road or the new highway (**Figure 8**); and
- Connection of the Lag Lane tributary to the River Eye by a channel through the floodplain of the River Eye (**Figure 8**);

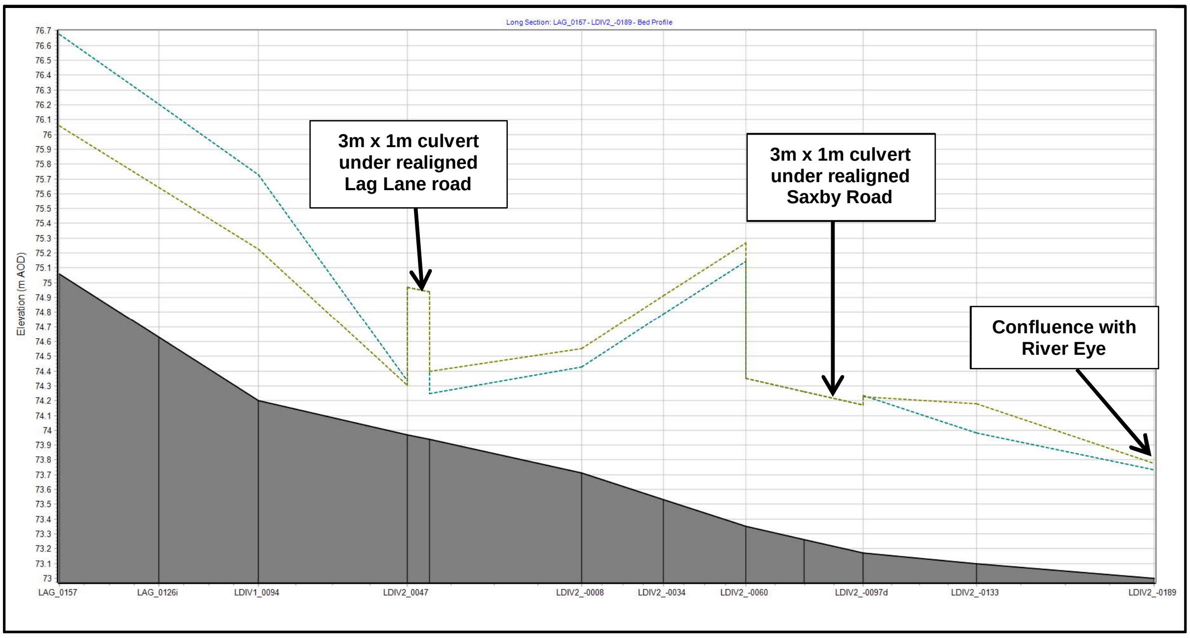


Figure 10 - Long section of realigned Lag Lane tributary.

To assess the flood risk impacts of the proposed highway, outlined above, the baseline and proposed models were run for a 20%, 10%, 5%, 2%, 1.33%, 1%, 1% plus 20% climate change, 1% plus 30% climate change 1% plus 50% climate change, 0.5% and 0.1% AEP events. However, only the 1% plus 50% climate change will be described in this technical report.

5. Results

5.1 Impact on Flood Risk

To investigate whether the proposed highway changed the flood risk on the River Eye, the baseline results have been compared to the proposed highway results for the 1% AEP plus 50% climate change event. **Figure 11** shows the flood depth-difference map between the baseline and proposed highway model results.

Note that the tabulated 1D results are not provided because, since the River Eye has been diverted in the proposed scenario, a like-for-like comparison is not possible in the area immediately upstream of the new bridge.

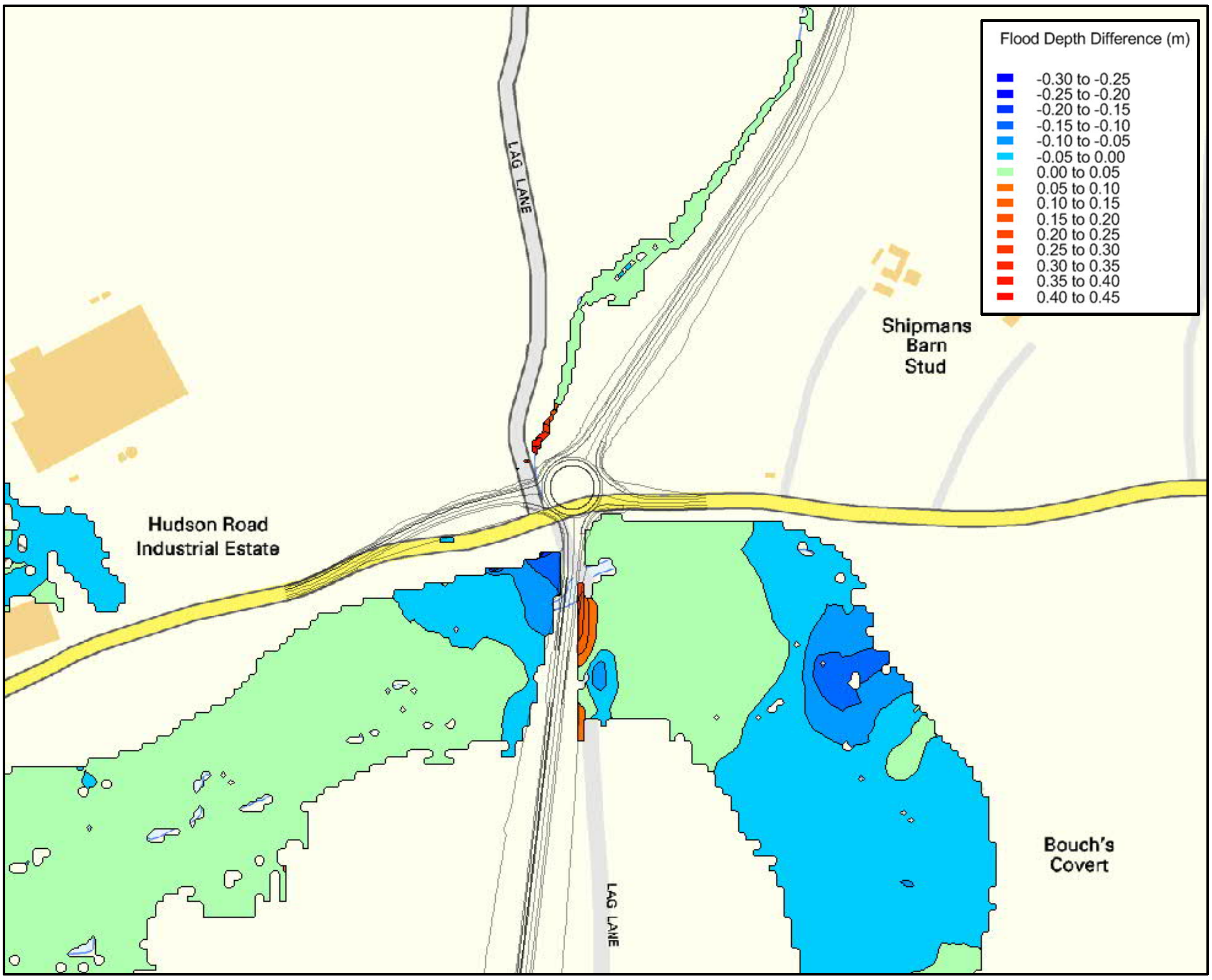


Figure 11 - Map showing the flood depth difference between the baseline and proposed highway in the 1 in 100 Year + 50% CC Event (for the River Eye and Lag Lane tributary)

Figure 11 shows the proposed highway will increase water depths upstream and downstream of the River Eye bridge by up to 50mm. This increase is considered negligible and within modelling tolerances. Very localised water depths may increase by approximately 250mm adjacent to the proposed highway, south of the removed Lag Lane bridge.

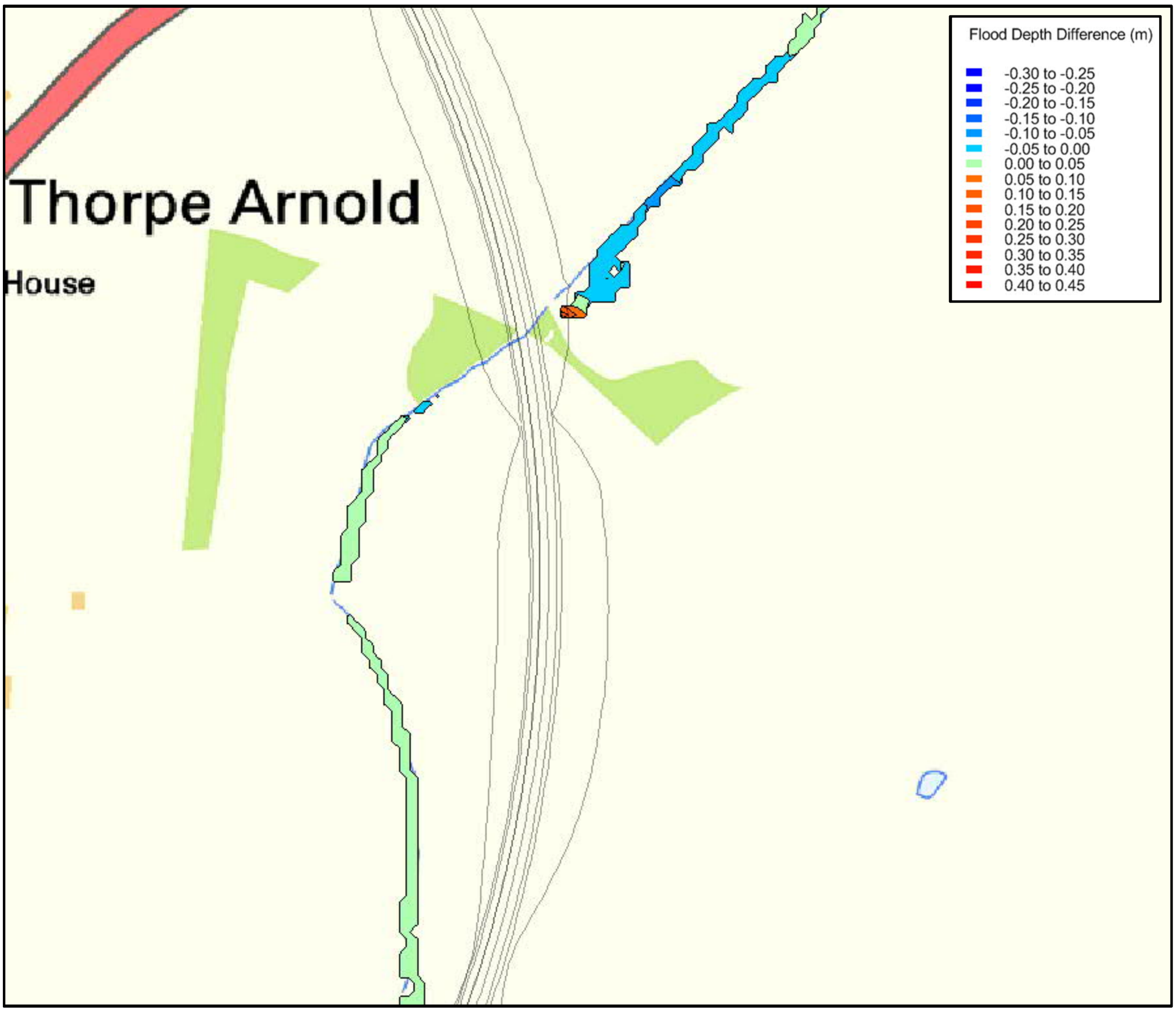


Figure 12 – Map showing the flood depth difference between the baseline and proposed highway (for the upstream crossing of the Lag Lane tributary).

Figure 12 shows the proposed highway will increase flood depths by approximately 150mm in a very localised area immediately upstream of the proposed culvert under the highway. Further upstream of the proposed culvert inlet, water depths are reduced by approximately 100mm.

No properties are located in the affected area of Lag Lane Tributary or the River Eye, and there are minimal changes to the flood extents and depths. Therefore, these results show that the proposed scheme does not significantly increase the flood risk to any properties in the areas covered by this modelling study.

In the current proposed model, floodplain compensation works have not been included. The volumetric losses have been established on a level-for-level basis, and are summarised in the MMDR Flood Risk Assessment. The proposed model will be updated to include the floodplain compensation works once appropriate locations have been established, and the impact on flood risk re-assessed. It is anticipated that the works will at best serve to reduce flood level increases by off-setting the displacement resulting from the proposed highway (although flood extents are likely to marginally increase since the floodplain will need to be widened to accommodate the displaced volumes).

5.2 Flood Risk to Proposed Highway

The modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 74.05m AOD, for a 1% AEP plus 50% climate change event (this flood level was taken from the 2D modelled flood elevation in the vicinity of the bridge). The minimum level of the road in this area is 74.19m AOD (approximately where Lag Lane Bridge was located); hence the freeboard to the proposed highway is at least 140mm.

The soffit level of the main bridge over the River Eye is 76.18m AOD, and therefore has a freeboard of 2130mm. The freeboard of the main bridge successfully meets the standard design requirements outlined by the EA.

The minimum soffit level of any of the bridge spans is 74.97 m AOD (located to the north of the main bridge), and therefore has a minimum freeboard of 920mm.

5.3 Model Performance

It should be noted that the overall model convergence of the EA's River Wreake/ River Eye model (2011), and hence that of the new baseline model, is poor through the peak of the 1% AEP + 50% climate change design event (**Figure 13**).

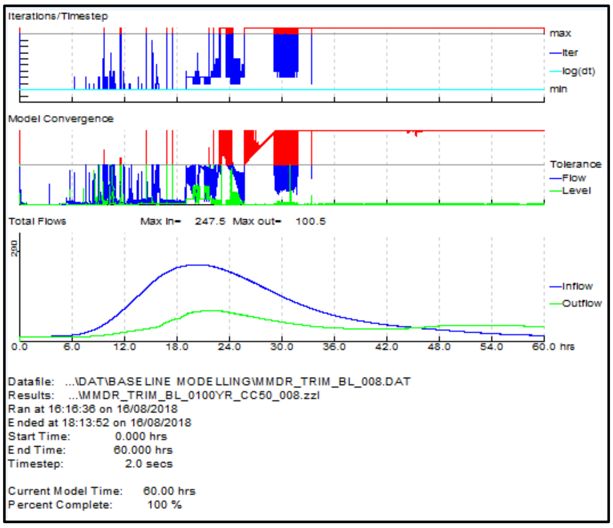


Figure 13 - Baseline Model Convergence Plot (1% AEP + 50CC)

However, the time series plot shown in **Figure 14** shows a stage hydrograph for the baseline model (1% AEP plus 50% climate change event), immediately upstream of the Lag Lane bridge. This shows that 1D in channel flows remain stable throughout the peak of the design events, thus providing confidence in the modelled flood levels within the main study area.

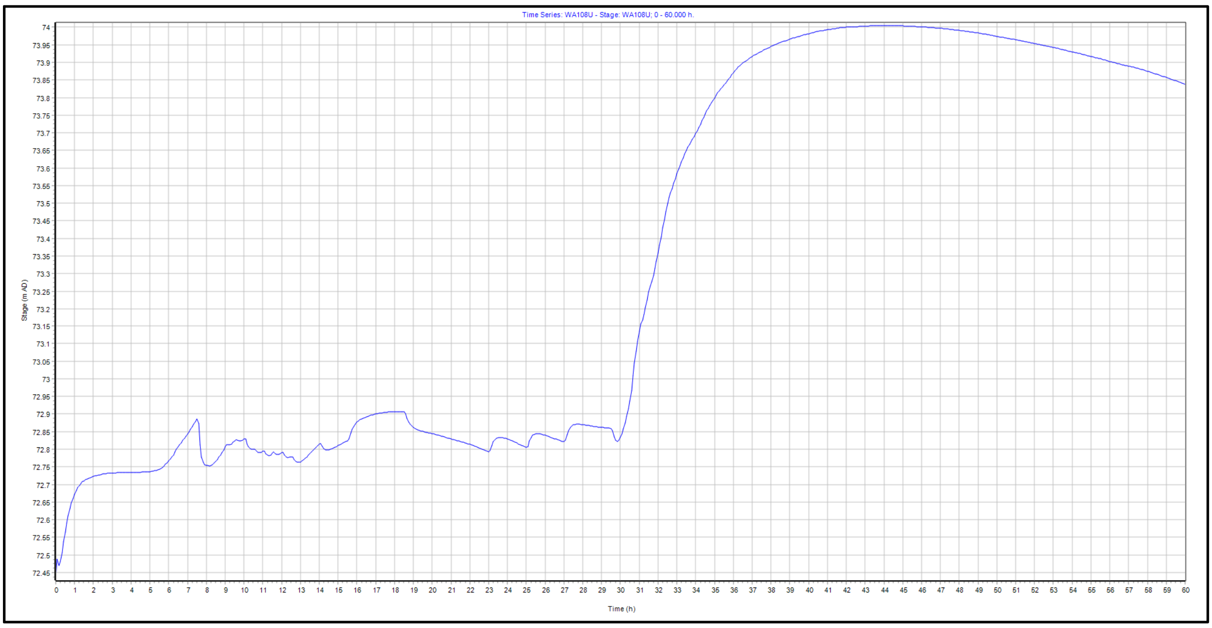
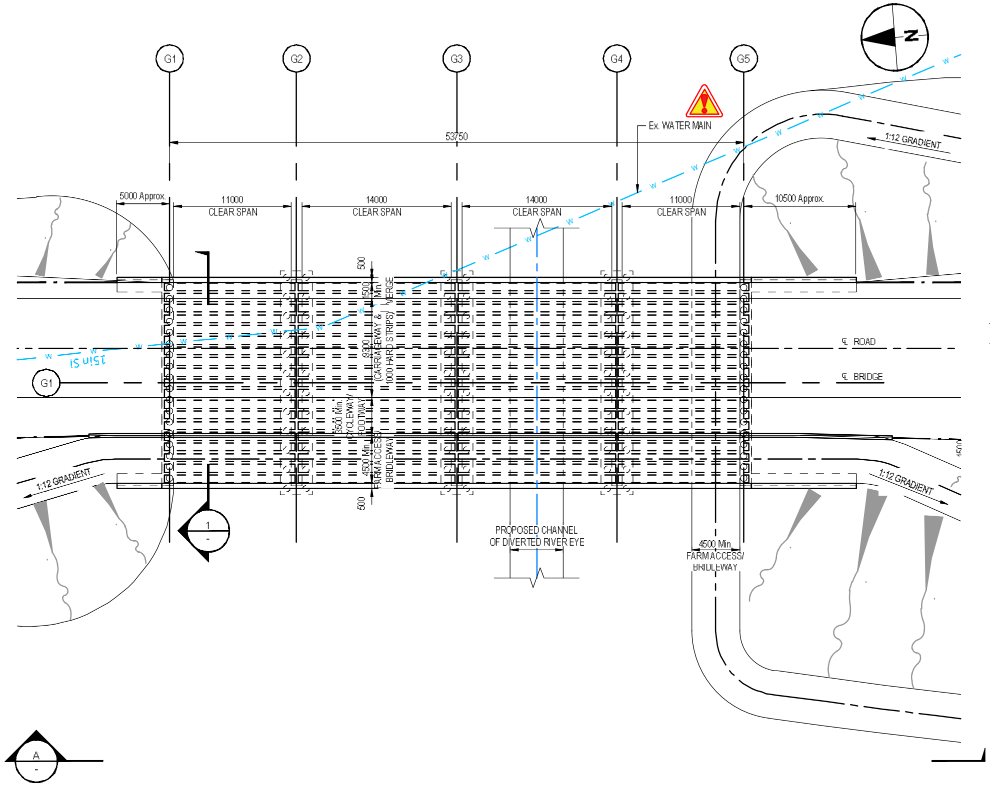


Figure 14 – Stage time series upstream of the Lag Lane bridge (1% + 50% AEP event)

Appendix 1 – Proposed River Eye Bridge details



PLAN ON RIVER EYE BRIDGE

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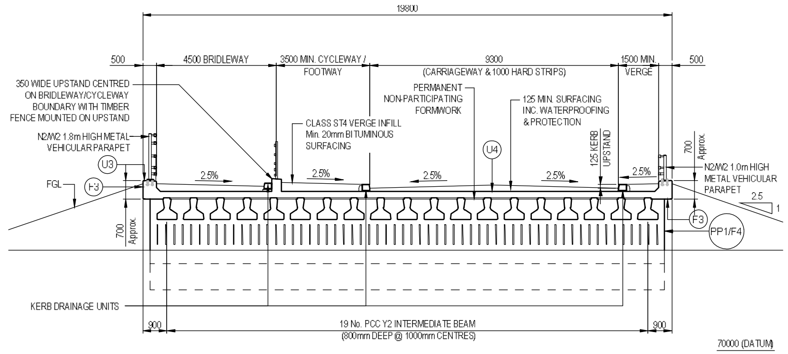
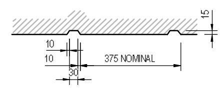


SECTION 1-1

Scale 1:100

IMPORTANT CDM / HEALTH & SAFETY NOTES

1. THESE DRAWINGS ARE ISSUED FOR INFORMATION ONLY AND AS SUCH MUST NOT BE TREATED AS CONSTRUCTION DRAWINGS.
2. EXCEPTIONAL RISKS NOT ELIMINATED DURING THE CURRENT PRELIMINARY DESIGN STAGE ARE HIGHLIGHTED ON THE DRAWING WITH THE SYMBOL
3. NOT ALL BURIED & OVERHEAD SERVICES ARE SHOWN ON THESE DRAWINGS. FOR THE LOCATION OF STATUTORY UNDERTAKERS APPARATUS, REFER TO STATUTORY UNDERTAKERS PLANS.



PP1/F4 PATTERNED PROFILE FINISH

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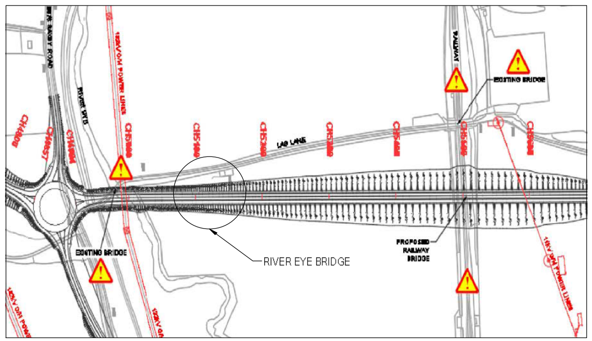
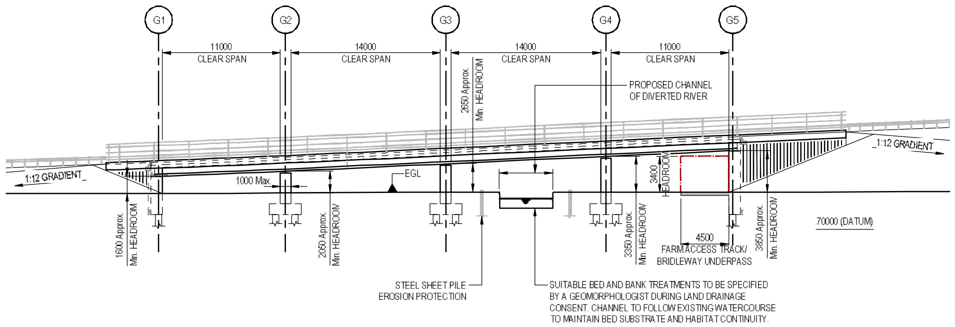


DISTRIBUTOR ROAD - PART LOCATION PLAN

NTS



ELEVATION A-A

Scale 1:250

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AECOM

PROJECT

NORTH & EAST MMDR

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NOTES

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5. CONCRETE STRENGTH CLASS :-

PCC BEAMS	C50/60(A)
DECK CANTILEVER	C40/50(A)
PARAPET UPSTAND	C40/50(A)
DECK SLAB	C40/50(B)
COLUMNS/PILECAPS/PILES	C32/40(A)
DIAPHRAGM BEAMS/CROSSHEAD	C32/40(A)
BLINDING CONCRETE	ST4
VERGE INFILL CONCRETE	ST4

6. NOTATION :-
CLASS OF FORMED CONCRETE FINISH IS INDICATED THUS :-
(F1) FOR CLASS F1
CLASS OF UNFORMED CONCRETE FINISH IS INDICATED THUS :-
(U1) FOR CLASS U1
CONCRETE SURFACES BELOW GROUND LEVEL TO BE WATERPROOFED IS INDICATED THUS :-
(WB)
UNLESS OTHERWISE STATED, ALL PARTS OF STRUCTURE IN CONTACT WITH SOIL TO BE COATED PRIOR TO BACK FILLING WITH TWO NUMBER COATS OF A MATERIAL APPROVED FOR WATERPROOFING BELOW GROUND LEVEL. WATERPROOFING TO TERMINATE 150mm BELOW FINISHED GROUND LEVEL.
7. TENSAR MAT 400 TYPICAL THICKNESS OF 18mm (±3mm) WITH UNIT WEIGHT OF 0.43kg/m². TYPICAL TENSILE STRENGTH AT 10% STRAIN SHALL BE 1.3kN/m.
8. FOR DETAILS ON HIGHWAY CONSTRUCTION AND ROAD DRAINAGE SYSTEM INCLUDING STREET LIGHTING REFER TO OTHER RELEVANT DRAWINGS.

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
First Issue		24/08/18	P01.1

PROJECT MANAGEMENT INITIALS

DESIGNED: CHECKED: --- APPROVED: ---

INTERNAL PROJECT NUMBER — 60542201

SCALE — AS SHOWN

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BS1192 SUITABILITY — S0

SHEET TITLE

RIVER EYE BRIDGE
INDICATIVE GENERAL ARRANGEMENT

DRAWING NUMBER — 60542201-ACM-STR-S5_BR_B03_Z -DR-CB-0001

REV — P01.1

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Appendix E

Culvert Sizing for Ordinary Watercourses

Appendix E1 - Culvert Sizing Technical Note for Ordinary Watercourses to be crossed by the Proposed North & East MMDR

Technical Note

To	Andrew Sherwood	From	Owen Tucker
		Prepared by	Andrew Heath-Brown
		Updated by	Anupriya Prabhuswamy
Copies to	Martin Allen, Katie Pearson, Michael Hancock, Neil Williams, Anna Gee, Tim Jones	Date	V1 – 15th May 2017 revised 22/5/17 V2 – 08th August 2017
Job No	N/A		
Subject	Update to Melton Mowbray Eastern Distribution Road Hydrological Assessment – Sensitivity testing of culvert sizing		

1. BACKGROUND

Two route alignments for a distribution road to bypass Melton Mowbray, Leicestershire have been proposed. There are six known locations where watercourses intersect the proposed routes. For the purpose of this Technical Note, these six locations have been named such that they refer to the associated chainage value along the proposed distribution road (Option 1 alignment – as per MMEDR Water Resources Preliminary Watercourse Crossing Guidance_v1.pdf).

In order to provide the structural design team with an ‘indicative starting point’ for sizing the culvert crossings and bridge structures (excluding the River Eye), a high level hydrological analysis has been undertaken at these six locations. Based on the results of this analysis, standard methods have been used to derive possible culvert size requirements. There is insufficient information however at present to undertake formal design calculations for sizing culverts.

2. HYDROLOGICAL ANALYSIS

The fluvial catchments to the six locations were selected using the FEH Web Service. Table 1 summarises the locations and catchment areas; the catchment boundaries are also shown in Figure 1.

Table 1 Details of the six watercourses intersecting the proposed route

Location	Watercourse	Estimated watercourse slope [1] (1/x)	Area of upstream catchment[2] (km^2)	Grid reference (Easting, Northing)	
OP1-CH150	Unnamed watercourse near Sysonby Farm	41	0.54	474500,	320650
OP1-CH680	Unnamed watercourse near John Fernley	47	0.52	477150,	321300
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	1000	21.13	47650,	321300
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	218	14.18	477150,	320750
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	500	1.3	477500,	320200
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	500	3.27	477850,	318600

[1] Slope estimated from LiDAR contour plan
[2] Assumed slope based on surrounding topography

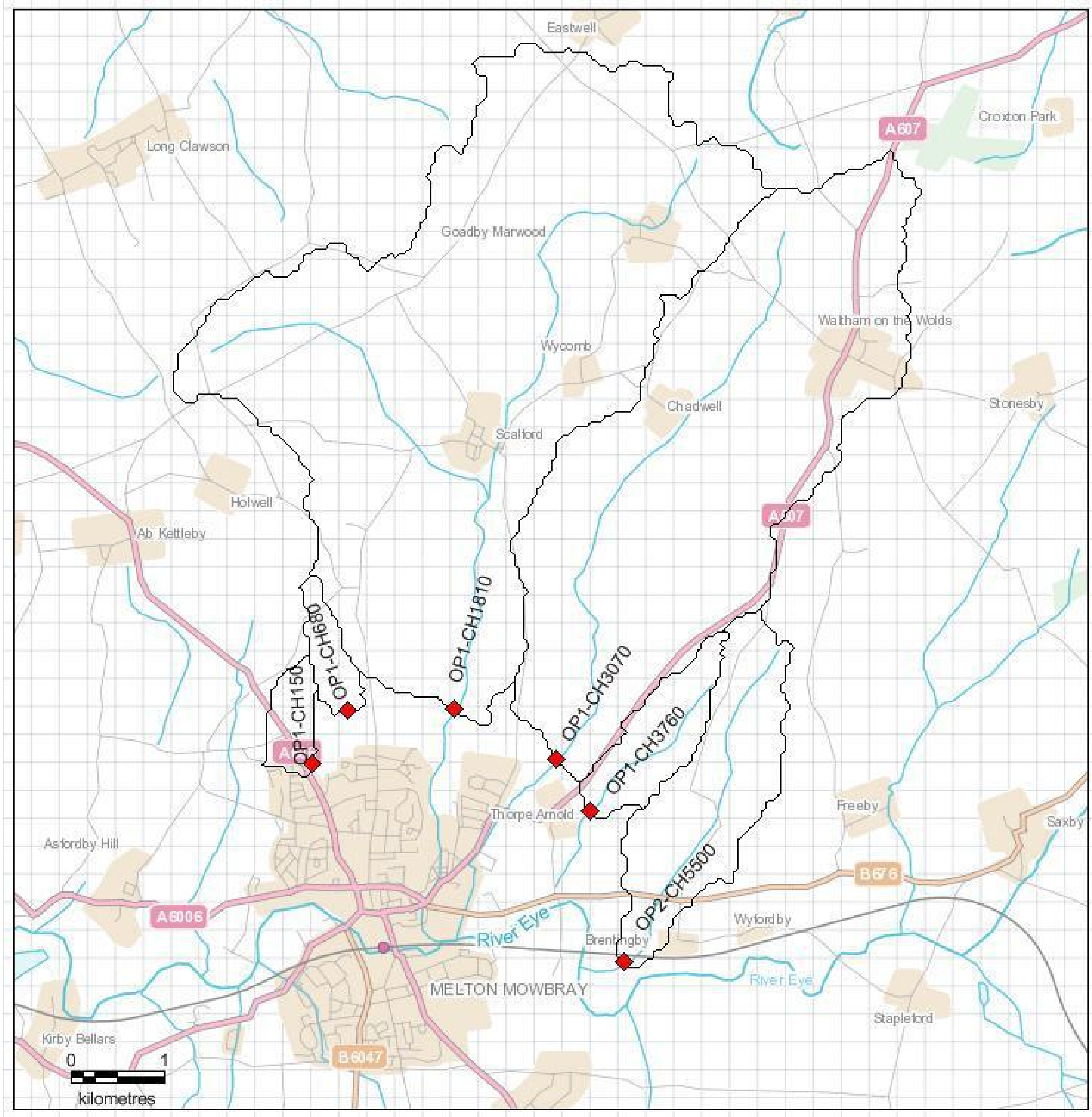


Figure 1 Map showing catchments of the 6 locations where watercourses intersect with the proposed MMDR

In order to estimate peak flows, the FEH statistical, ReFH and ReFH2 methods were applied for each catchments. Design event peak flows were calculated for the following events, with a summary of the procedures used is described further below:

- **1 in 2 year (50% Annual Exceedance probability (AEP));**
- **1 in 5 year (20% AEP);**
- **1 in 10 year (10% AEP);**
- **1 in 20 year (5% AEP);**
- **1 in 25 year (4% AEP);**
- **1 in 30 year (3.3% AEP);**
- **1 in 50 year (2% AEP);**
- **1 in 75 year (1.3% AEP);**
- **1 in 100 year (1% AEP);**
- **1 in 200 year (0.5% AEP); and**
- **1 in 1,000 year (0.1% AEP) events.**

As part of the scheme design, it is likely that allowances for climate change will be a requirement of the statutory bodies. This will ultimately need to be applied for the design standard of the scheme. The allowance will be determined in consultation with the relevant statutory bodies, and may be linked to freeboard provision at the crossing structures. Furthermore, a range of climate change allowances may need to be tested for

multiple design events, to demonstrate the potential impact of climate change across different timescales and climate projections.

In order to provide an idea of potential impacts of climate change allowances on the culvert sizing sensitivity testing has been undertaken. These and other effects are considered later in Section 4.

2.1 FEH statistical method

The FEH statistical method calculates peak flows as a product of a QMED estimate and a flood growth curve. Wherever possible, local data should be used to improve the QMED estimate and this is discussed further in the following sections.

2.2 QMED

None of the tributary watercourses are gauged, and a suitable donor catchment could not be found for the target sites; this is because there are few gauged watercourses within the vicinity Melton Mowbray. As such, QMED has been estimated from catchment descriptors for each site. The URBEXT2000 values were reviewed to determine if the catchments were classified as predominantly urban (i.e. when the URBEXT2000 > 0.3). All the catchments were identified as rural apart from OP1-CH150. An adjustment to the QMED value to account for this urbanisation (updated to 2017 using the FEH Urban Expansion Factor model) was therefore applied at this site.

2.3 Pooling Group and Growth Curve

For all six sites, the catchment descriptors were considered to be similar enough that the same pooling group could be used for each. The pooling group was based on the largest of the catchments (OP1-CH1810). WINFAP-FEH was used to create an initial pooling group for the site. Six sites were removed from the initial pooling group, one because it was discordant and the other five due to BFIHOST values being much higher than at the subject site. Further suitable sites were subsequently added to maintain the required record length.

Data from the pooling group was used to then generate growth curve and associated flood frequency curves, using the Generalised Logistic distribution to generate peak flows for the required return period design events. For the calculation of the growth curves, the site classified as 'urban' (OP1-CH150) used 'urban adjusted' L-moments and associated Generalised Logistic parameters to calculate the growth curve.

2.4 Flood Frequency Curve / Fittings

To calculate the flood frequency curves / fittings (or peak flow estimates) for the sites, the QMED values for the six sites were multiplied by their associated growth curves (refer to Table 2).

2.5 ReFH Method

ReFH rainfall-runoff boundaries were generated for each site, based on parameters calculated from catchment descriptors. The critical storm durations were identified and set (based on the standard FEH approximation formula). For each site, the ReFH boundaries were used to calculate peak flows for the same return periods as for the FEH statistical method, (refer to Table 2).

2.6 ReFH2 Method

ReFH2 rainfall-runoff boundaries were generated for each site, based on parameters calculated from catchment descriptors. The critical storm durations were identified and set (based on the standard FEH approximation formula). For each site, the ReFH2 boundaries were used to calculate peak flows for the same return periods as for the FEH statistical method, (refer to Table 2).

Table 2 the peak return periods at the six sites for each method of calculating design flows

Return Period (years)	OP1-CH150			OP1-CH680			OP1-CH1810		
	Statistical	ReFH	ReFH2	Statistical	RefH	RefH2	Statistical	RefH	RefH2
2	0.2	0.3	0.3	0.2	0.2	0.3	2.1	2.9	2.5
5	0.3	0.4	0.4	0.2	0.3	0.4	2.8	3.7	3.2
10	0.3	0.4	0.5	0.3	0.4	0.5	3.4	4.4	3.9
20	0.4	0.5	0.6	0.3	0.4	0.6	4.0	5.2	4.7
25	0.4	0.5	0.7	0.4	0.5	0.6	4.2	5.4	5.0
30	0.4	0.6	0.7	0.4	0.5	0.6	4.3	5.7	5.3
50	0.4	0.7	0.8	0.4	0.6	0.7	4.8	6.4	6.1
75	0.5	0.7	0.9	0.4	0.6	0.8	5.2	7.0	6.9
100	0.5	0.8	1.0	0.5	0.7	0.9	5.5	7.4	7.5
200	0.6	0.9	1.3	0.5	0.8	1.1	6.3	8.8	9.0
1000	0.8	1.5	1.9	0.7	1.2	1.7	8.4	13.8	13.0

Return Period (years)	OP1-CH3070			OP1-CH3760			OP2-CH5500		
	Statistical	RefH	RefH2	Statistical	RefH	RefH2	Statistical	RefH	RefH2
2	2.2	2.7	2.6	0.4	0.5	0.6	0.8	1.0	1.3
5	3.0	3.5	3.4	0.5	0.6	0.8	1.1	1.3	1.7
10	3.6	4.1	4.1	0.6	0.8	1.0	1.3	1.6	2.0
20	4.3	4.8	4.9	0.7	0.9	1.2	1.6	1.9	2.4
25	4.5	5.0	5.2	0.8	1.0	1.3	1.6	1.9	2.6
30	4.6	5.3	5.5	0.8	1.0	1.3	1.7	2.0	2.7
50	5.1	5.9	6.4	0.9	1.2	1.5	1.9	2.3	3.2
75	5.6	6.5	7.2	1.0	1.3	1.7	2.0	2.5	3.6
100	5.9	6.9	7.8	1.0	1.4	1.9	2.1	2.7	3.9
200	6.7	8.2	9.4	1.2	1.6	2.3	2.4	3.2	4.7
1000	9.0	12.6	13.4	1.6	2.6	3.4	3.3	5.1	6.8

3. CULVERT SIZE ANALYSIS

Three methods were used to make a rough assessment of the culvert size required for the 1 in 100 year design event. Their application is described below.

3.1 Method 1- simple pipe flow program (Pipeflow.exe)

Approach

The program requires the user to specify slope (which was estimated from a LiDAR CAD drawing), roughness (Colebrook-White) and pipe diameter to calculate full bore discharge.

Peak flow estimates calculated using the FEH Statistical, ReFH and ReFH2 methods were targeted, and a 'trial and error' approach was used to determine the range of diameters which could convey those target flows (refer to Table 3).

Table 3 estimated required pipe diameters from Pipeflow.exe

Site		(Method 1 - Pipeflow.exe) Required diameter for a circular conduit / pipe (concrete) - full bore		
		FEH Statistical	ReFH	ReFH2
OP1-CH150	Unnamed watercourse near Sysonby Farm	0.4-0.5m	0.5-0.6m	0.6-0.7m
OP1-CH680	Unnamed watercourse near John Fernley	0.5m	0.5-0.6m	0.6m
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	2.1-2.2m	2.4m	2.4-2.5m
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	1.6-1.7m	1.7-1.8m	1.8-1.9m
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1m	1.1m	1.2-1.3m
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	1.3m	1.4-1.5m	1.6-1.7m

Assumptions and limitations

- The slope was based on estimates from contoured LiDAR data and may therefore be inaccurate. In addition, it is not always the case that a designed culvert under a proposed road will be set to the same slope as the existing watercourse.
- The calculation has assumed a concrete finish to the pipe.
- The calculation has been based on full bore flow. It may be that there is a requirement to provide some freeboard within the pipe; therefore, the calculated diameter would need to be increased to suit.
- The program does not account for any inlet losses or backwater effects from downstream, or take into account velocity head and subsequent impact on required culvert size and losses.

3.2 Method 2 – small orifice equation

Approach

The pipe size has been calculated using the small orifice equation (as per standard hydraulic theory). For this process, a 'goal seek' function was applied in which the pipe diameter was determined in order to achieve the required peak flow. The ReFH2 based peak flow was only used in application of this method, since this hydrological assessment approach gave the highest flows. The calculated diameters are given in Table 4.

Table 4 required diameters using the small orifice calculation

Site		(Method 2 - Small orifice calculation) Required diameter for a circular conduit / pipe (concrete) – full bore
OP1-CH150	Unnamed watercourse near Sysonby Farm	1.2m
OP1-CH680	Unnamed watercourse near John Fernley	1.1m
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	3.2m
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	3.3m
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1.6m
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	2.3m

Assumptions and limitations

- **The slope was based on estimates from contoured LiDAR data and may therefore be inaccurate. In addition, it is not always the case that a designed culvert under a proposed road will be set to the same slope as the existing watercourse.**
- **The calculation has assumed a concrete finish to the pipe (Manning's 'n' roughness of 0.015).**
- **The calculation has been based on full bore flow. It may be that there is a requirement to provide some freeboard within the pipe; therefore, the calculated diameter would need to be increased to suit.**
- **The calculation does not account for any inlet losses or backwater effects from downstream.**

3.3 Method 3 – Manning's equation

Approach

The culvert dimensions have been calculated using the Manning's equation (as per standard hydraulic theory). For this process, the span culvert width was pre-determined based on assessment of existing watercourse top width (using the LiDAR data, online aerial imagery and hydrologic calculations). A 'goal seek' function was then applied in which the box culvert rise (height) was determined in order to achieve the required peak flow. The ReFH2 based peak flow was only used in application of this method, since this hydrological assessment approach gave the highest flows. The calculated sizes are given in Table 5.

Table 5 required spans and heights for a box culvert using Manning's calculation

Site		(Method 3 - Manning's calculation)	
		Required dimensions for a box conduit (concrete) - full bore	
		Span (assumed)	Rise (min)
OP1-CH150	Unnamed watercourse near Sysonby Farm	1.0m	0.37m
OP1-CH680	Unnamed watercourse near John Fernley	1.0m	0.36m
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	3.0m	1.76m
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	3.0m	1.07m
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1.0m	1.44m
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	2.0m	1.24m

Assumptions and limitations

- **The slope was based on estimates from contoured LiDAR data and may therefore be inaccurate. In addition, it is not always the case that a designed culvert under a proposed road will be set to the same slope as the existing watercourse.**
- **The calculation has assumed a concrete finish to the pipe (Manning's 'n' roughness of 0.015).**
- **The calculation has been based on full bore flow. It may be that there is a requirement to provide some freeboard within the pipe; therefore, the calculated diameter would need to be increased to suit.**
- **The calculation does not account for any inlet losses or backwater effects from downstream.**

4. SENSITIVITY TESTING OF CULVERT SIZING

To assess potential worst case scenarios, the culvert sizing was also carried out for a range of climate change allowances. The scenarios chosen were: 100 year + 20%; 100 year + 30%; and 100 year + 50%. The calculations were carried out using Method 2 - small orifice calculation, and Method 3 - Manning's calculation, with the results shown in Table 6 and Table 7 respectively.

Table 6 required diameters for varying flow rates using the small orifice calculation

Site		(Method 2 - Small orifice calculation) Required diameter for a circular conduit / pipe (concrete) – full bore		
		100YR+20% [m]	100YR+30% [m]	100Yr+50% [m]
OP1-CH150	Unnamed watercourse near Sysonby Farm	1.30	1.35	1.45
OP1-CH680	Unnamed watercourse near John Fernley	1.23	1.28	1.37
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	3.55	3.69	3.97
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	3.62	3.77	4.04
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1.79	1.86	2.00
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	2.56	2.66	2.86

Table 7 required spans and heights for a box culvert using Manning's calculation and 100 year +20%, +30%, and +50% flow rates.

Site		(Method 3 - Manning's calculation) Required dimensions for a box conduit (concrete) - full bore			
		Span (assumed) [m]	Rise(min.) [m]		
			100Yr+20%	100Yr+30%	100YR+50%
OP1-CH150	Unnamed watercourse near Sysonby Farm	1.0	0.41	0.44	0.48
OP1-CH680	Unnamed watercourse near John Fernley	1.0	0.40	0.43	0.47
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	3.0	2.00	2.12	2.35
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	3.0	1.21	1.28	1.14
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1.0	1.66	1.77	1.99
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	2.0	1.41	0.50	1.66

Sensitivity testing of the Manning's 'n' value showed that the rise of the box culvert was significantly sensitive to changes in the value of n. Doubling of the 'n' value from 0.015 to 0.03 – a worst case scenario among concrete surfaces, corresponding to an 'n' value for concrete rubble masonry – produced an increase in rise height of over 60 percent.

Table 8 Span and Rise values for box culvert with Manning's 'n' value of 0.03. Compare with Table 5 where the value of 'n' was 0.015.

Site		(Method 3 - Manning's calculation) Required dimensions for a box conduit (concrete) - full bore	
		Span (assumed) [m]	Rise (min) [m]
OP1-CH150	Unnamed watercourse near Sysonby Farm	1.0	0.59
OP1-CH680	Unnamed watercourse near John Fernley	1.0	0.57
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	3.0	2.90
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	3.0	1.72
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1.0	2.53
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	2.0	2.06

Testing of the box culvert rise height's dependence on slope shows that it is relatively insensitive to changes in slope. Varying the slope by ±15 percent caused changes in box culvert rise height of between 5 and 7 percent.

Table 9 Variation in culvert rise compared with variation in value of slope

Site		(Method 3 - Manning's calculation) Required dimensions for a box conduit (concrete) - full bore					
		Span (assumed) [m]	Rise (min) [m]				
			100YR	+15%	% change	-15%	% change
OP1-CH150	Unnamed watercourse near Sysonby Farm	1.0	0.37m	0.35	5	0.39	5
OP1-CH680	Unnamed watercourse near John Fernley	1.0	0.36m	0.34	6	0.38	6
OP1-CH1810	Scalford Brook at the existing embankment along disused railway	3.0	1.76m	1.67	5	1.86	6
OP1-CH3070	Thorpe Brook to the south of Twinlakes Park	3.0	1.07m	0.99	7	1.1	3
OP1-CH3760	Unnamed tributary of the River Eye to the east of Thorpe Arnold	1.0	1.44m	1.36	6	1.53	6
OP1-CH5500	Unnamed tributary of the River Eye to the south of the railway line	2.0	1.24m	1.18	5	1.31	6

5. SUMMARY

Initial hydrological analysis and culvert sizing has been undertaken based on limited data. In particular, a number of assumptions have been made in determining indicative sizes for culvert crossings at the six sites.

If pipe culverts were proposed for smaller watercourses these would need to be between 1m to 2.5m diameter to accommodate1 in 100 year flows, depending on slope and freeboard requirements, based on the calculations and assumptions made therein. Sensitivity testing for 1 in 100 Year storm + 50% allowance for climate change increased the required pipe culvert diameter to between 1.5m to 3m. However, in keeping with best practice crossing designs should seek to minimise any effect on flow, sediment transport and riparian habitat continuity. In this case, for small watercourses it would be most appropriate to achieve this with a form of oversized box culvert. The requirements of the LLFA and Environment Agency are also still to be established.

The Scalford and Thorpe Brook watercourses are larger and designated under the WFD with their own identifier. It is therefore recommended that open span structures are proposed for these watercourses (as well as the River Eye, which is not a subject of this Technical Note). Using this culvert sizing assessment as a guide, the minimum span to convey the 1 in 100 year flow would need to be around 3m wide for both watercourses, depending on slope and freeboard requirements. However, in reality the width of the channel and banks may exceed this and thus the indicative culvert widths of 4.5 m and 5 m, respectively, as described in Jacobs conceptual design should be used as a starting point. As already stated, the requirements of the LLFA and Environment Agency will also need to be taken into account and further assessment undertaken of the effects of the new structure on hydraulic processes (including the potential for scour), sediment transport and riparian habitats.

More detailed engineering calculations and / or hydraulic modelling is required at subsequent design stages to confirm the sizes of culverts and bridges, as well as:

- **Confirmation of design flows;**
- **Confirmation of standard of service;**
- **Confirmation of freeboard requirements;**
- **Confirmation of any local works to channel bed through the road embankment; and**
- **Confirmation of any inlet and outlet arrangements (such as headwall/wingwalls).**

In addition, the final design of crossing structures will also need to take account of any environmental constraints and mitigation that is required.

6. GLOSSARY

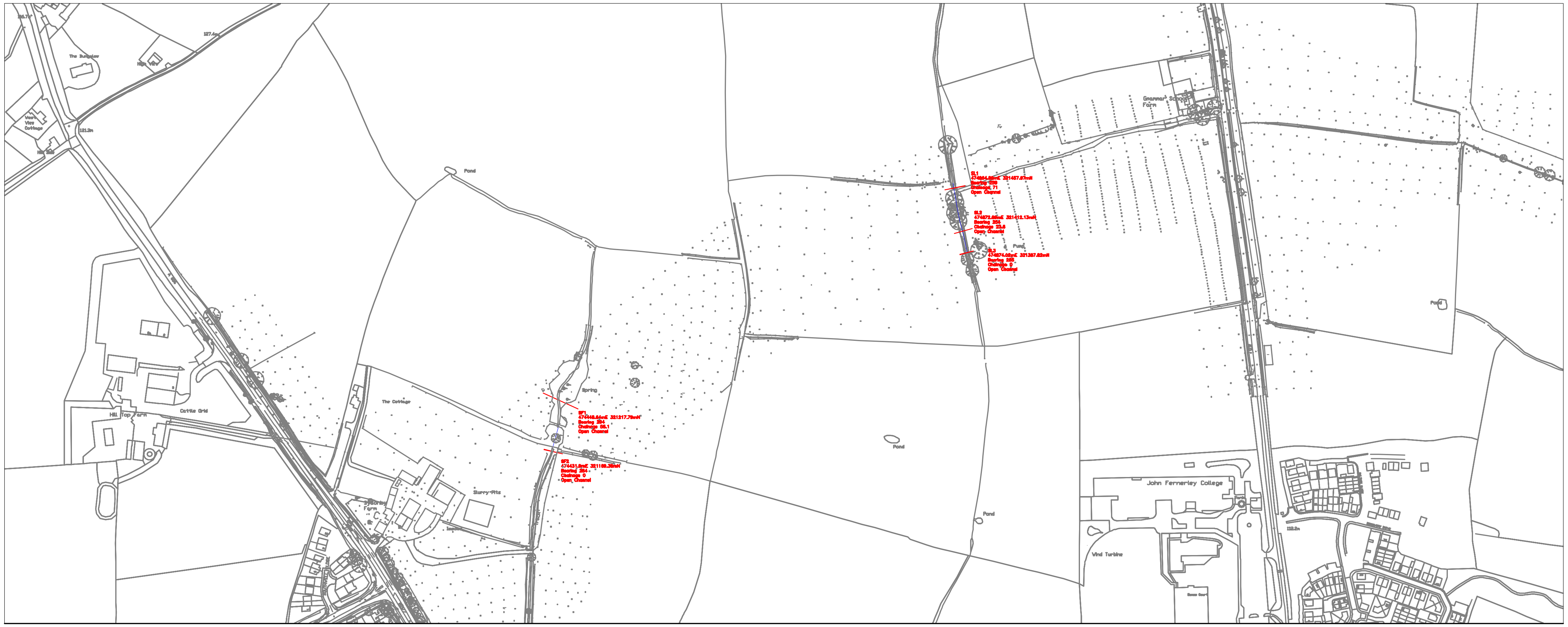
AEP	Annual Exceedance Probability
BFIHOST	Base Flow Index derived using the Hydrology of Soil Types (HOST) classification
FEH	Flood Estimation Handbook
LiDAR	Light Detection And Ranging
LLFA	Lead Local Flood Authority
QMED	Median flow

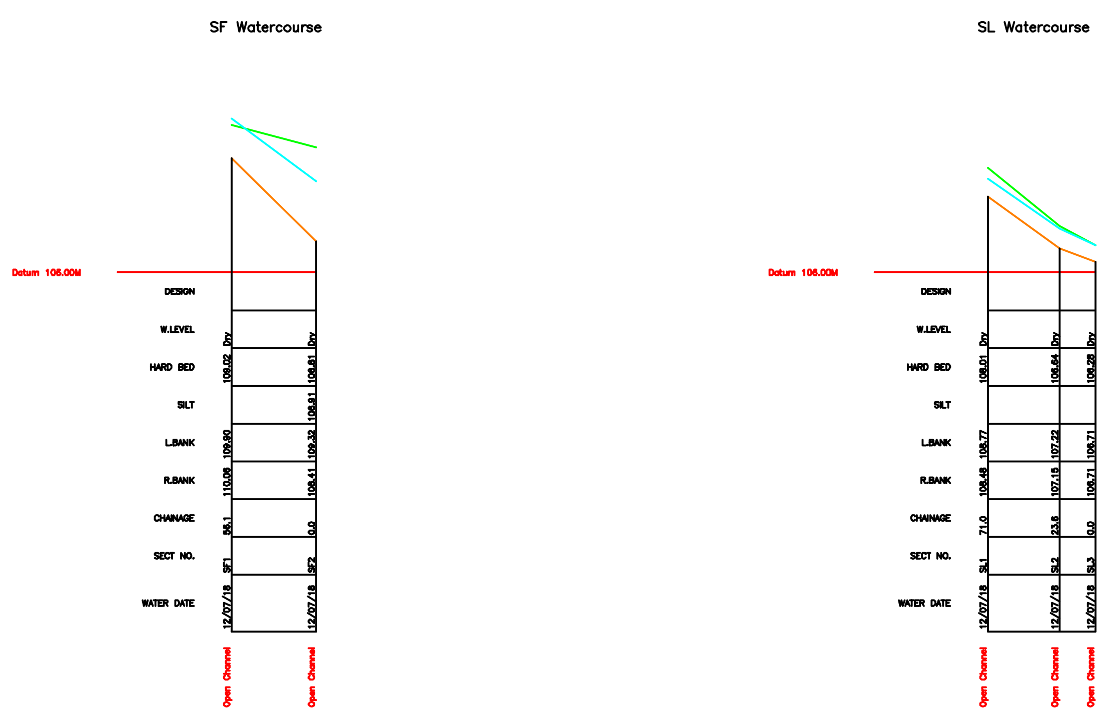
ReFH	The Revitalised Flood Hydrograph method
ReFH2	The Revitalised Flood Hydrograph method version 2
URBEXT 2000	Extent of urban and suburban land cover in the year 2000 expressed as a fraction
WFD	Water Framework Directive (2000/60/EC)

Appendix E2 – Existing Capacity Assessment of Ordinary Watercourses at Proposed Crossing Locations

CHANNEL SURVEY DATA:

- **LONG SECTIONS**
- **CROSS SECTIONS**
- **PHOTOGRAPHS**





KEY TO LONGITUDINAL SECTION:

- LEFT BANK CREST
- RIGHT BANK CREST

} VIEWED LOOKING DOWNSTREAM. POINTS INDICATED BY 'C' ON CROSS SECTIONS.

- WATER LEVEL
- VISIBLE BED (TOP OF SILT)
- HARD BED (DETERMINED BY PROBING)

NOTES:

1. A REPORT HAS BEEN PRODUCED FOR THIS SURVEY.
2. AECOM REF: 60542201.
3. FOR CROSS SECTIONS SEE DRAWING NUMBERS 649-SF-XS-01 AND 649-SL-XS-01.
4. ORDNANCE SURVEY MATERIAL REPRODUCED WITH THE PERMISSION OF THE CONTROLLER OF H.M.S.O. © CROWN COPYRIGHT AND DATABASE RIGHTS 2018 OS 100019271.

SURVEY LEGEND

REV.	AMENDMENT	DRN	CHKD	DATE
0.	Proof Drawing for Approval	PAW	RMW	08-18

CONTROL USED:

TYPE	DESCRIPTION	LEVEL
GRID – Related to OSGB36 (National Grid) via GNSS and OSTN15		
LEVELS – Related to OS Datum via GNSS and OSGM15		

STATIONS ESTABLISHED:

NAME	CO-ORDINATES		LEVEL
XX	XXXXXX.XXX	XXXXXX.XXX	XX.XXX

CENTRAL SURVEYS LIMITED
The Studio, Hall Farm Cottages
Stanton Lane, Potters Marston
Leicestershire LE9 3JR
Tel:01455 274004: enquiries@csurveys.co.uk

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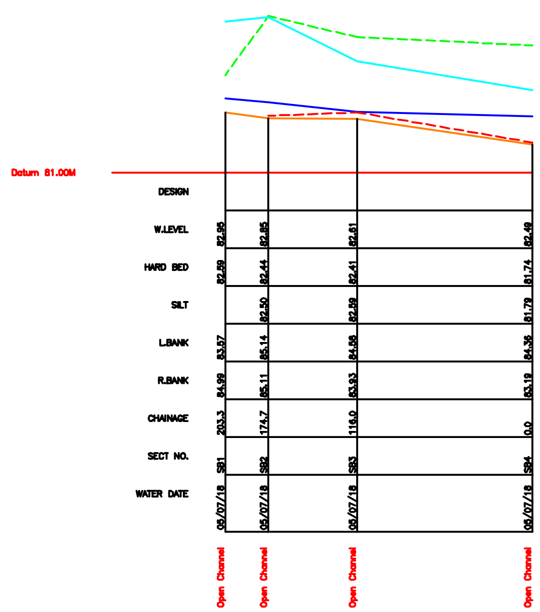
PROJECT

MELTON MOWBRAY DISTRIBUTOR ROAD
SYSONBY FARM AND SYSONBY LODGE
Long Section & Location Plan Sheet 1 of 1

CLIENT

AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire S41 7SL

SURVEYED BY: Central Surveys Ltd. Ref: 649
SURVEY DATE: JULY 2018
SCALE: 1:2500 horiz. 1:100 vert | DRN: P.A.W. | CHKD: R.M.W.
DATUM: ODN | DATE: AUG 18 | DATE: AUG 18
GRID: NATIONAL | DRAWING NO. 649-SF-SL-LS-01 | REV. 0
CAD FILENAME: 649-SF-SL-LS.dwg



SECT NO.	WATER DATE	CHAINAGE	R.BANK	L.BANK	SILT	HARD BED	W.LEVEL
SB1	06/07/18	203.3	84.99	83.57		82.59	82.95
SB2	06/07/18	174.7	85.11	85.14	82.50	82.44	82.85
SB3	06/07/18	116.0	83.93	84.56	82.59	82.41	82.61
SB4	06/07/18	0.0	83.19	84.36	81.79	81.74	82.49

KEY TO LONGITUDINAL SECTION:

- LEFT BANK CREST } VIEWED LOOKING DOWNSTREAM. POINTS INDICATED BY 'C' ON CROSS SECTIONS.
- RIGHT BANK CREST
- WATER LEVEL
- VISIBLE BED (TOP OF SILT)
- HARD BED (DETERMINED BY PROBING)

NOTES:

1. A REPORT HAS BEEN PRODUCED FOR THIS SURVEY.
2. AECOM REF: 60542201.
3. FOR CROSS SECTIONS SEE DRAWING NUMBER 649-SB-XS-01.
4. ORDNANCE SURVEY MATERIAL REPRODUCED WITH THE PERMISSION OF THE CONTROLLER OF H.M.S.O. © CROWN COPYRIGHT AND DATABASE RIGHTS 2018 OS 100019271.

SURVEY LEGEND

REV.	AMENDMENT	DRN	CHKD	DATE
0.	Proof Drawing for Approval	PAW	RMW	08-18

CONTROL USED:

TYPE	DESCRIPTION	LEVEL
GRID – Related to OSGB36 (National Grid) via GNSS and OSTN15		
LEVELS – Related to OS Datum via GNSS and OSGM15		

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XX	XXXXXX.XXX XXXXXX.XXX	XX.XXX

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PROJECT

MELTON MOWBRAY DISTRIBUTOR ROAD
SCALFORD BROOK
Long Section & Location Plan Sheet 1 of 1

CLIENT

AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire S41 7SL

SURVEYED BY: Central Surveys Ltd. Ref: 649
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SCALE: 1:2500 horiz. 1:100 vert | DRN: P.A.W. | CHKD: R.M.W.
DATUM: ODN | DATE: AUG 18 | DATE: AUG 18
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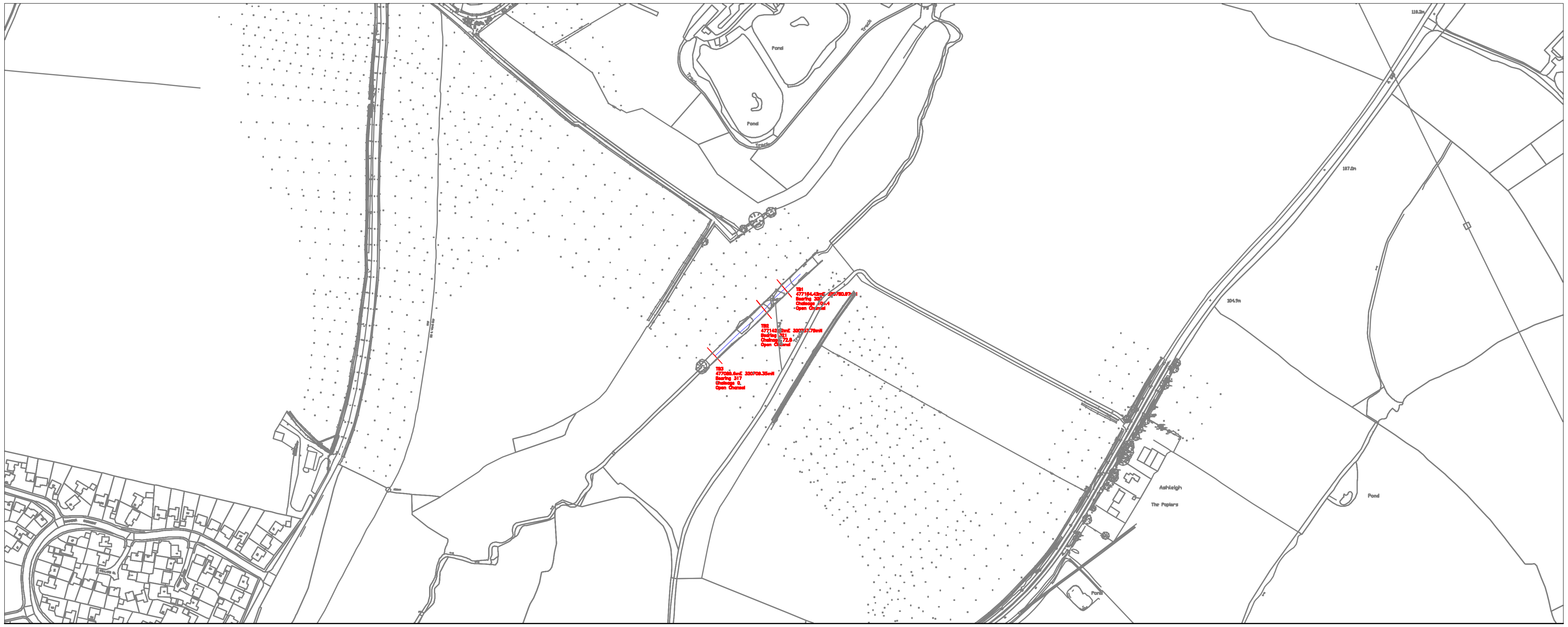
CAD FILENAME: 649-SB-LS.dwg



KEY TO LONGITUDINAL SECTION:

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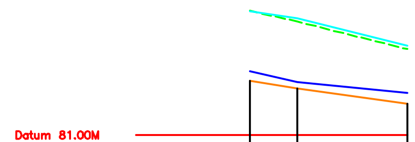
- RIGHT BANK CREST
- WATER LEVEL
- VISIBLE BED (TOP OF SILT)
- HARD BED (DETERMINED BY PROBING)



DESIGN			
W.LEVEL	82.70	82.40	82.11
HARD BED	82.45	82.24	81.63
SILT			
L.BANK	84.30	84.01	83.28
R.BANK	84.29	84.09	83.38
CHAINAGE	104.4	72.8	0.0
SECT NO.	TB1	TB2	TB3
WATER DATE	13/07/18	13/07/18	13/07/18
	Open Channel	Open Channel	Open Channel

NOTES:

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SURVEY LEGEND

AB	AIR BRICK	FH	FIRE HYDRANT	PWF	POST & WIRE FENCE
AV	AIR VALVE	FHM	FIRE HYDRANT MARKER	RB	RIGHT BANK
B	BOLLARD	FL	FLOOR LEVEL	RE	RODDING EYE
BB	BELISHA BEACON	FP	FENCE POST	RS	ROAD SIGN
BDY	BOUNDARY	FWM	FOUL WATER MANHOLE	RTW	RETAINING WALL
BH	BOREHOLE	G	GULLY	RWP	RAINWATER PIPE
BL	BED LEVEL	GL	GROUND LEVEL	SC	STOP COCK
BRK	BRICKWORK	GP	GATE POST	SDP	STAND PIPE
BS	BUS STOP	GM	GAS MARKER	SK	SOAKAWAY
BM	BENCH MARK	GV	GAS VALVE	SL	SOFFIT LEVEL
BW	BRICK WALL	HW	HEAD WALL	SMH	SURFACE WATER MANHOLE
BWF	BARBED WIRE FENCE	IC	INSPECTION CHAMBER	SMP	SHEET METAL PILING
CBF	CLOSE BOARDED FENCE	IL	INVERT LEVEL	SP	SIGN POST
CIF	CORRUGATED IRON FENCE	IRF	IRON RAILING FENCE	STN	STATION
CL	COVER LEVEL	IWF	INTERWOVEN FENCE	SV	SLUICE VALVE
CLF	CHAIN LINK FENCE	JB	JUNCTION BOX	SVP	SOIL VENT PIPE
CONC	CONCRETE	KG	KERB INLET GULLY	SWF	SHEEP WIRE FENCE
CP	CONCRETE POST	LB	LEFT BANK	TBM	TEMPORARY BENCH MARK
CPF	CHESTNUT PALING FENCE	LFB	LIFEBUOY	TCB/TCP	TELEPHONE CALL BOX/POST
CR	CYCLE RACK	LP	LAMP POST	TC	TELECOM CABINET
CTV	CABLE T.V. MANHOLE	MB	MOORING BOLLARD	TMH	TELECOM MANHOLE
CUL	CULVERT	MF	MISCELLANEOUS FENCING	THL	THRESHOLD LEVEL
DK	DROP KERB	MH	MANHOLE	TL	TRAFFIC LIGHT
DL	DECK LEVEL	MKR	MARKER	TLB	TRAFFIC LIGHT BOX
DP	DOWNPIPE	MP	MOORING PILE	TP	TELEGRAPH POLE
DPC	DAMP PROOF COURSE	MRF	METAL RAILING FENCE	TRS	TIMBER RUBBING STRIP
DR	DRAIN	MS	MILE STONE	TS	TREE STUMP
DWB	DOG WASTE BIN	NB	NOTICE BOARD	TSR	TUBULAR STEEL RAILINGS
EA	ENVIRONMENT AGENCY	NRA	NATIONAL RIVERS AUTHORITY	VP	VENT PIPE
EB	ELECTRICITY BOX	OHC	OVERHEAD CABLE	WB	WASTE BIN
ECF	ELECTRIC CABLE FENCE	OS	ORDNANCE SURVEY	WL	WATER LEVEL/WATER LINE
ECP	ELECTRICITY CABLE PIT	OSR	OPEN STEEL RAILINGS	WM	WATER METER
EMH	ELECTRICITY MANHOLE	P	PILE	WMF	WIRE MESH FENCE
EP	ELECTRICITY POLE	PB	PILLAR BOX	WP	WOODEN POST
ER	EARTHING ROD	PM	PARKING METER	WPR	WOODEN POST & RAIL FENCE
ETL	ELECTRICITY TRANSMISSION LINE	PO	POST	WV	WATER VALVE
FB	FLOWER BED	PRF	POST & RAIL FENCE	YG	YARD GULLY
FBR	FOOTBRIDGE	PTM	PARKING TICKET MACHINE		(Abbreviations apply to EA survey data only)

REV.	AMENDMENT	DRN	CHKD	DATE
0.	Proof Drawing for Approval	PAW	RMW	08-18

CONTROL USED:

TYPE	DESCRIPTION	LEVEL
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STATIONS ESTABLISHED:

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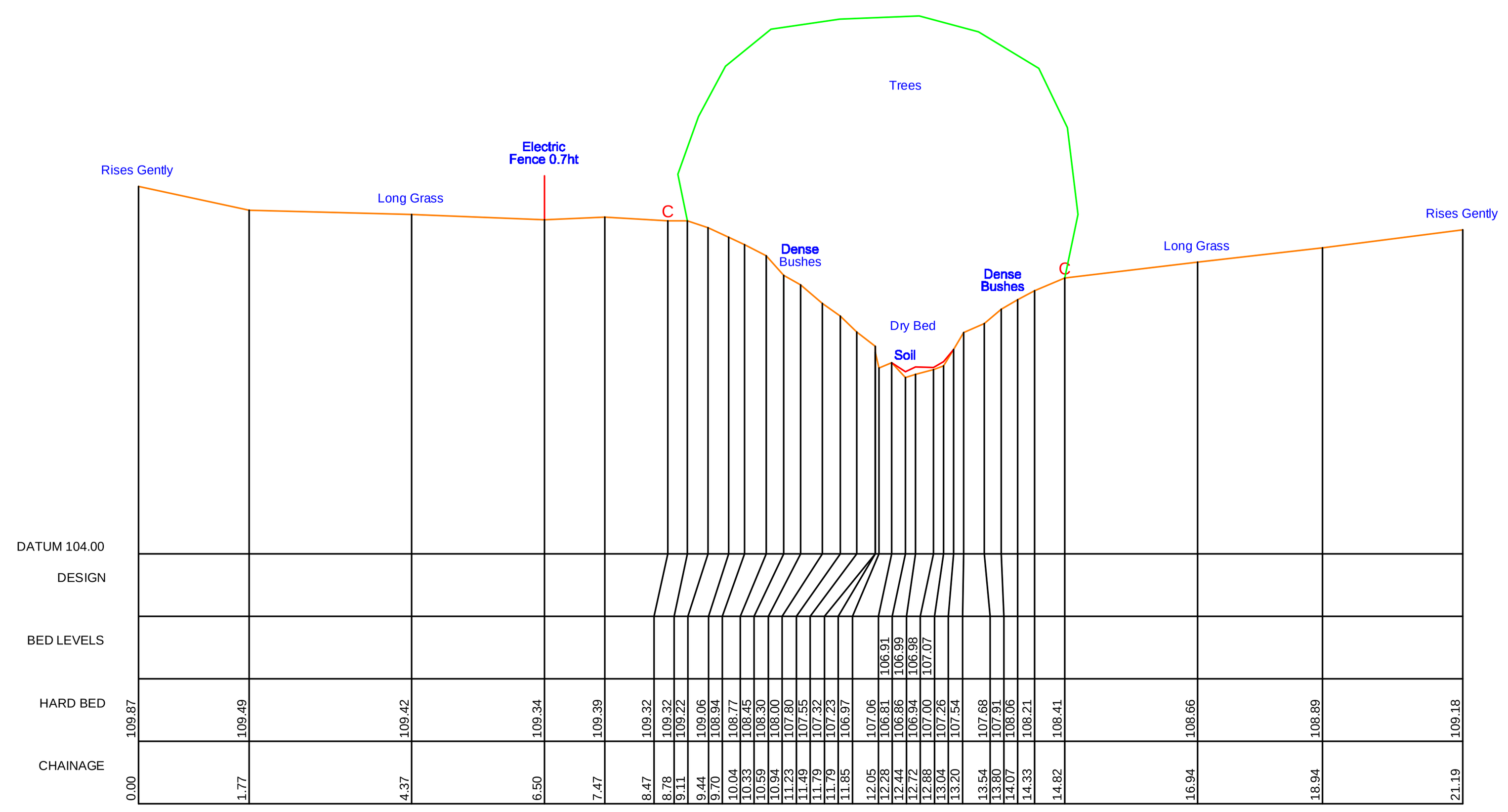
PROJECT

MELTON MOWBRAY DISTRIBUTOR ROAD
THORPE BROOK
Long Section & Location Plan Sheet 1 of 1

CLIENT

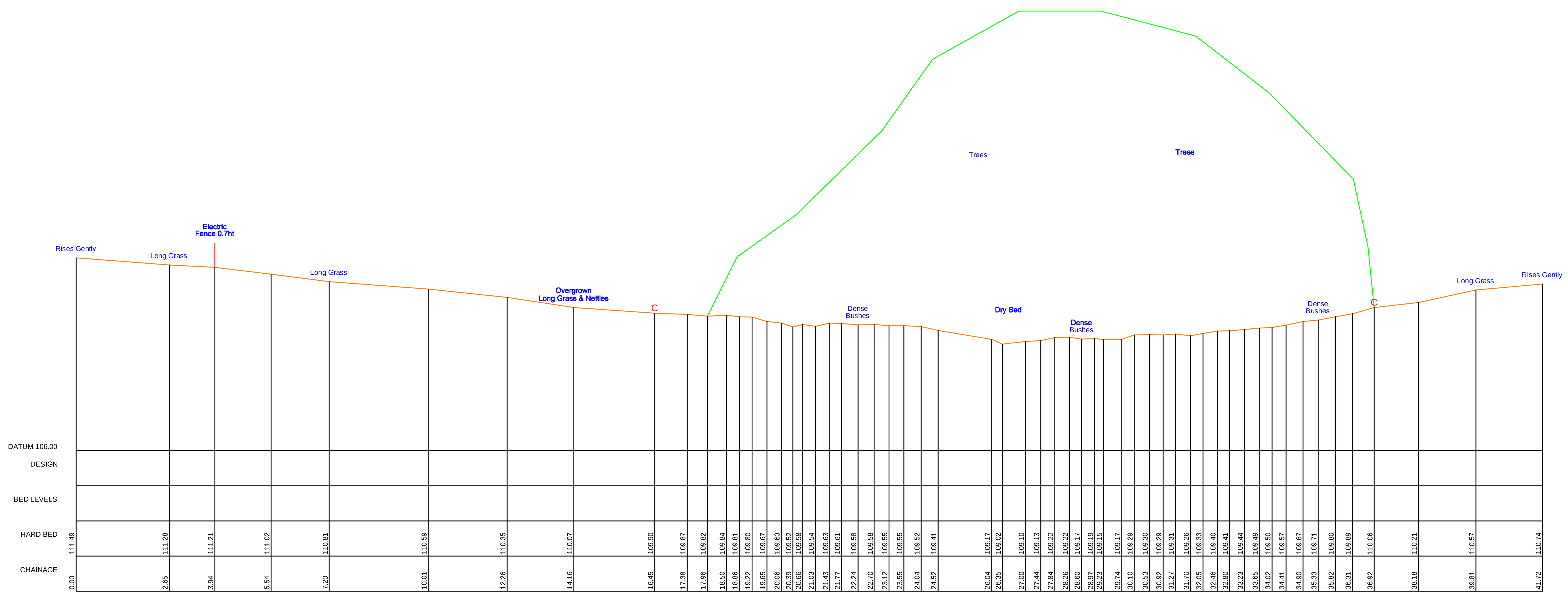
AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire S41 7SL

SURVEYED BY: Central Surveys Ltd. Ref: 649
SURVEY DATE: JULY 2018
SCALE: 1:2500 horiz. 1:100 vert | DRN: P.A.W. | CHKD: R.M.W.
DATUM: ODN | DATE: AUG 18 | DATE: AUG 18
GRID: NATIONAL | DRAWING NO. 649-TB-LS-01 | REV. 0
CAD FILENAME: 649-TB-LS.dwg



CHAINAGE	HARD BED	BED LEVELS
0.00	109.87	
1.77	109.49	
4.37	109.42	
6.50	109.34	
7.47	109.39	
8.47	109.32	
8.78	109.32	
9.11	109.22	
9.44	109.06	
9.70	108.94	
10.04	108.77	
10.33	108.45	
10.59	108.30	
10.94	108.00	
11.23	107.80	
11.49	107.55	
11.79	107.32	
11.79	107.23	
11.85	106.97	
12.05	107.06	
12.28	106.81	106.91
12.44	106.86	106.99
12.72	106.94	106.98
12.88	107.00	107.07
13.04	107.26	
13.20	107.54	
13.54	107.68	
13.80	107.91	
14.07	108.06	
14.33	108.21	
14.82	108.41	
16.94	108.66	
18.94	108.89	
21.19	109.18	

SF2
474431.9mE 321169.36mN Brg 284
Chainage 0
Open Channel



CHAINAGE	HARD BED
0.00	111.49
2.65	111.28
3.94	111.21
5.54	111.02
7.20	110.81
10.01	110.59
12.26	110.35
14.16	110.07
16.45	109.90
17.38	109.87
17.96	109.82
18.50	109.84
18.86	109.81
19.22	109.80
19.65	109.67
20.06	109.63
20.39	109.52
20.66	109.58
21.03	109.54
21.43	109.63
21.77	109.61
22.24	109.58
22.70	109.58
23.12	109.55
23.55	109.55
24.04	109.52
24.52	109.41
26.04	109.17
26.35	109.02
27.00	109.10
27.44	109.13
27.84	109.22
28.26	109.22
28.60	109.17
28.97	109.19
29.23	109.15
29.74	109.17
30.10	109.29
30.53	109.30
30.92	109.29
31.27	109.31
31.70	109.26
32.05	109.33
32.46	109.40
32.80	109.41
33.23	109.44
33.65	109.49
34.02	109.50
34.41	109.57
34.90	109.67
35.33	109.71
35.82	109.80
36.31	109.89
36.92	110.06
38.18	110.21
39.81	110.57
41.72	110.74

SF1
474448.64mE 321217.79mN Brg 294
Chainage 56.1
Open Channel

KEY TO CROSS SECTIONS:

WATER LEVEL
VISIBLE BED (TOP OF SILT)
HARD BED (DETERMINED BY PROBING)

NOTES:
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2. AECOM REF: 60542201.
3. FOR LOCATION PLAN AND LONG SECTION SEE DRAWING NUMBER 649-SF-SL-LS-01.

SURVEY LEGEND

AB	AIR BRICK	FH	FIRE HYDRANT	PWF	POST & WIRE FENCE
AV	AIR VALVE	FHM	FIRE HYDRANT MARKER	RB	RIGHT BANK
B	BOLLARD	FL	FLOOR LEVEL	RE	RODDING EYE
BB	BELISHA BEACON	FP	FENCE POST	RS	ROAD SIGN
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BM	BENCH MARK	GV	GAS VALVE	SL	SOFFIT LEVEL
BW	BRICK WALL	HW	HEAD WALL	SMH	SURFACE WATER MANHOLE
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CLF	CHAIN LINK FENCE	JB	JUNCTION BOX	SVP	SOIL VENT PIPE
CONC	CONCRETE	KIG	KERB INLET GULLY	SWF	SHEEP WIRE FENCE
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FBR	FOOTBRIDGE	PTM	PARKING TICKET MACHINE		

(Abbreviations apply to EA survey data only)

REV.	AMENDMENT	DRN	CHKD	DATE
0.	Proof Drawing for Approval	PAW	RMW	08-18

CONTROL USED:

TYPE	DESCRIPTION	LEVEL
GRID – Related to OSGB36 (National Grid) via GNSS and OSTN15 LEVELS – Related to OS Datum via GNSS and OSGM15		

STATIONS ESTABLISHED:

NAME	CO-ORDINATES		LEVEL
XX	XXXX.XXX	XXXX.XXX	XX.XX

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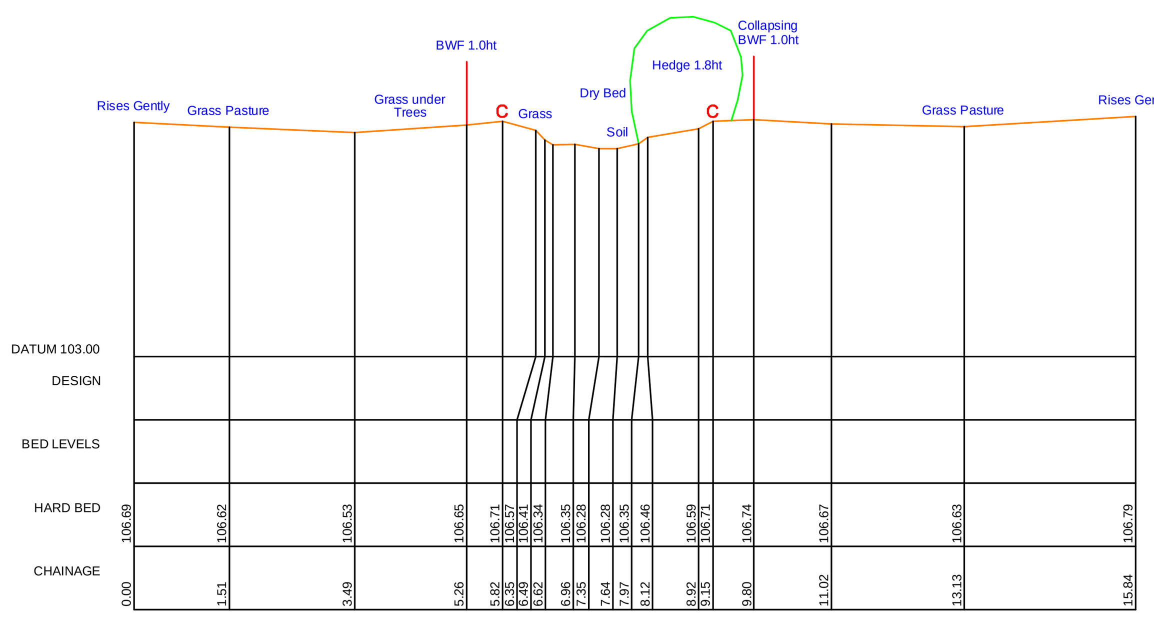
PROJECT
MELTON MOWBRAY DISTRIBUTOR ROAD
Watercourse to east of SYSONBY FARM
Cross Sections Sheet 1 of 1

CLIENT
AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire S41 7SL

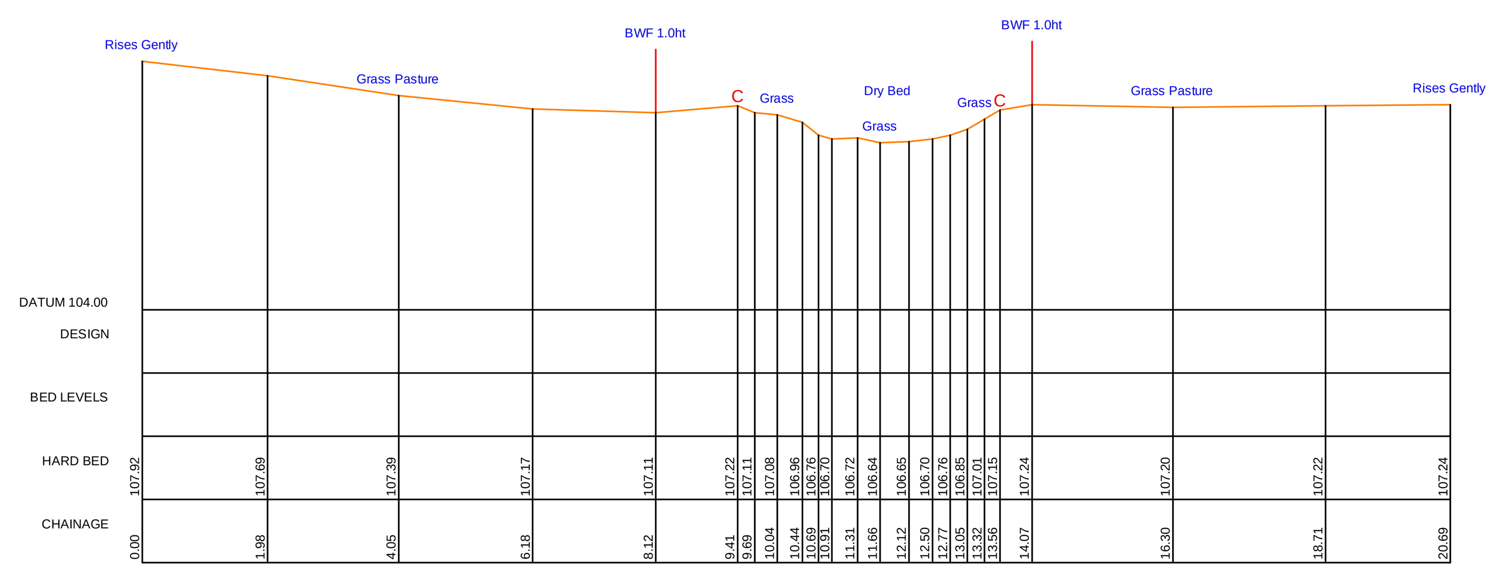
SURVEYED BY: Central Surveys Ltd — Ref: 649
SURVEY DATE: JULY 2018

SCALE: 1:100 @ A1 size	DRN: P.A.W.	CHKD: R.M.W.
DATUM: ODN	DATE: AUG 18	DATE: AUG 18
GRID: NATIONAL	DRAWING NO. 649-SF-XS-01	REV. 0

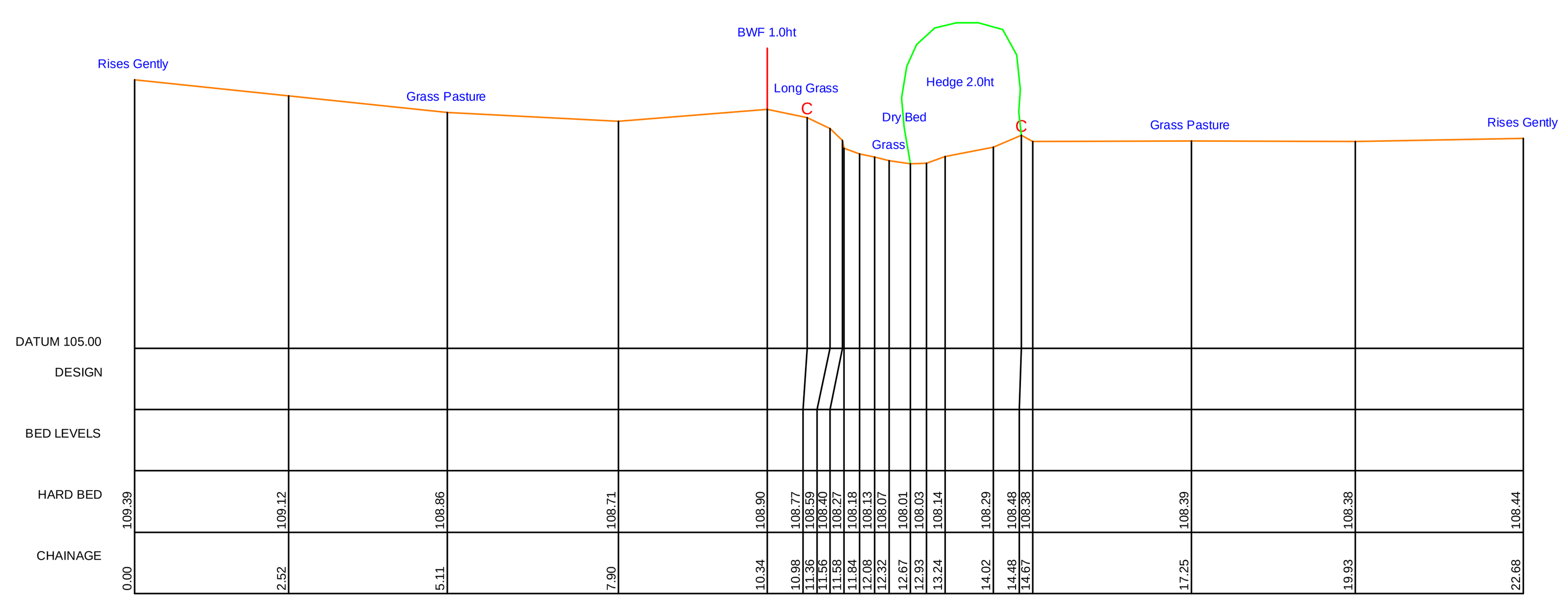
CAD FILENAME: 649-SF-SL-XS.dwg



SL3
474874.02mE 321387.82mN Brg 255
Chainage 0
Open Channel



SL2
474872.69mE 321412.13mN Brg 254
Chainage 23.6
Open Channel



SL1
474864.89mE 321457.97mN Brg 259
Chainage 71
Open Channel

KEY TO CROSS SECTIONS:

- WATER LEVEL
- VISIBLE BED (TOP OF SILT)
- HARD BED (DETERMINED BY PROBING)

NOTES:
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SURVEY LEGEND

REV.	AMENDMENT	DRN	CHKD	DATE
0.	Proof Drawing for Approval	PAW	RMW	08-18

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LEVELS	Related to OS Datum via GNSS and OSGM15	

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Watercourse to east of SYSONBY LODGE
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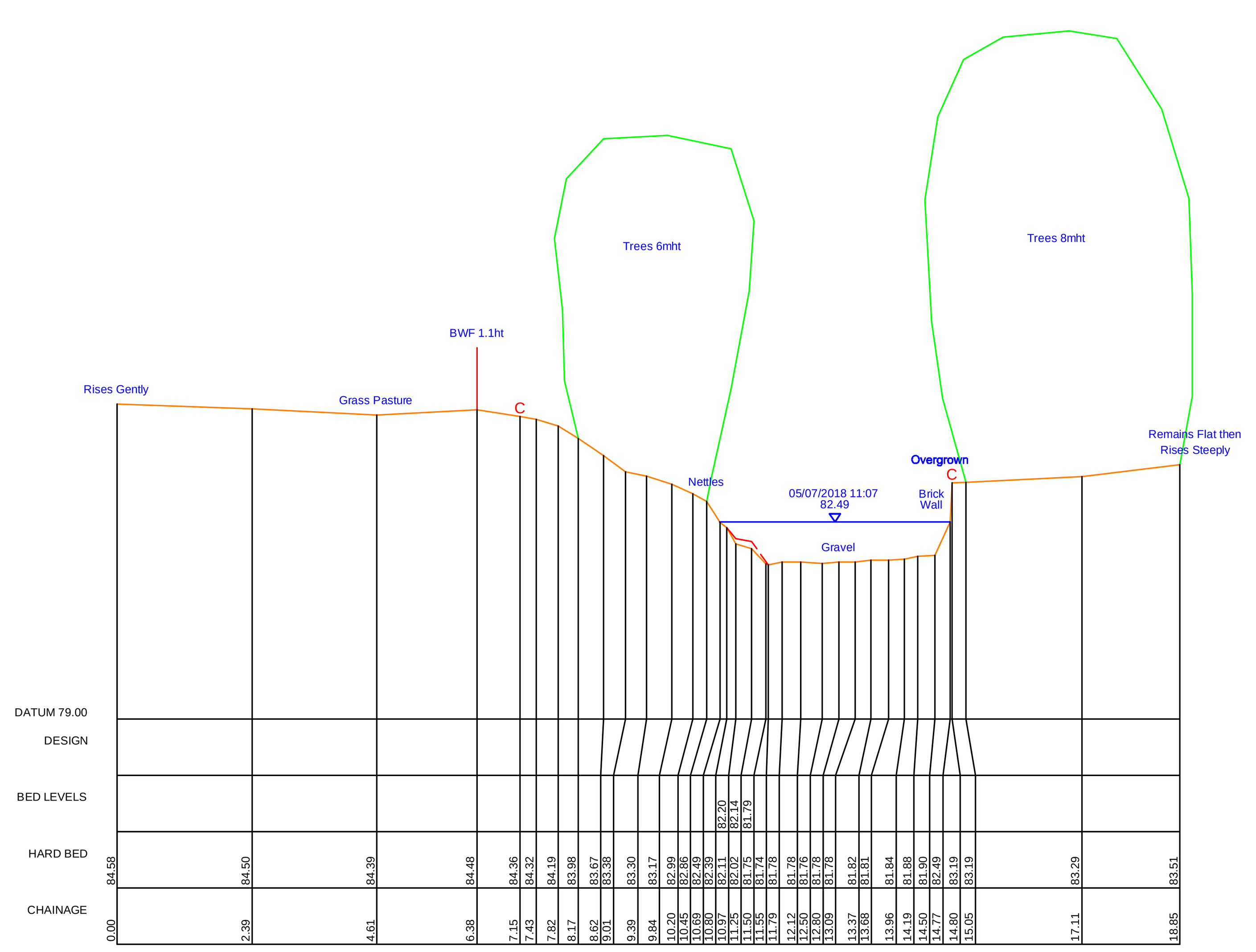
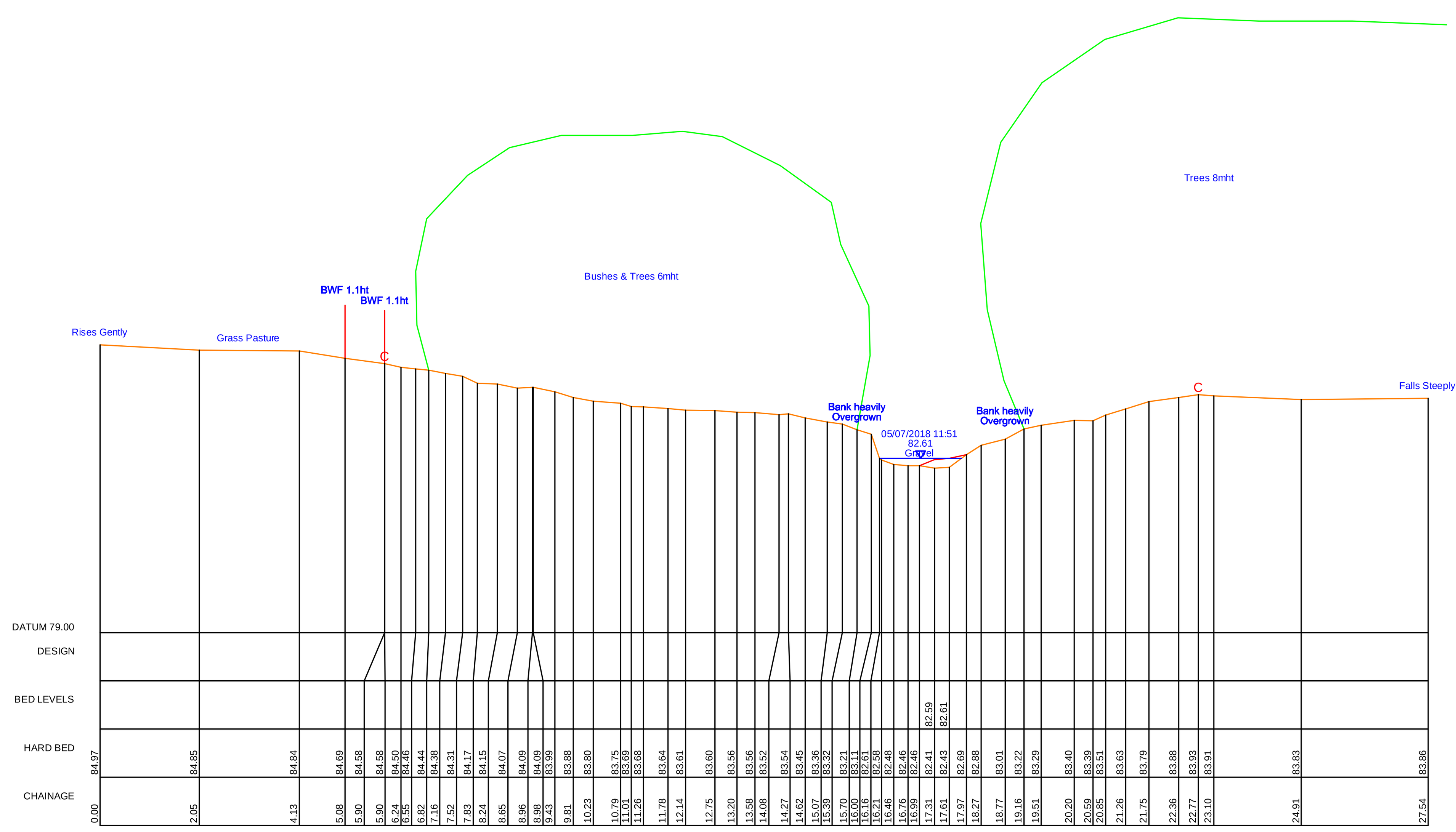
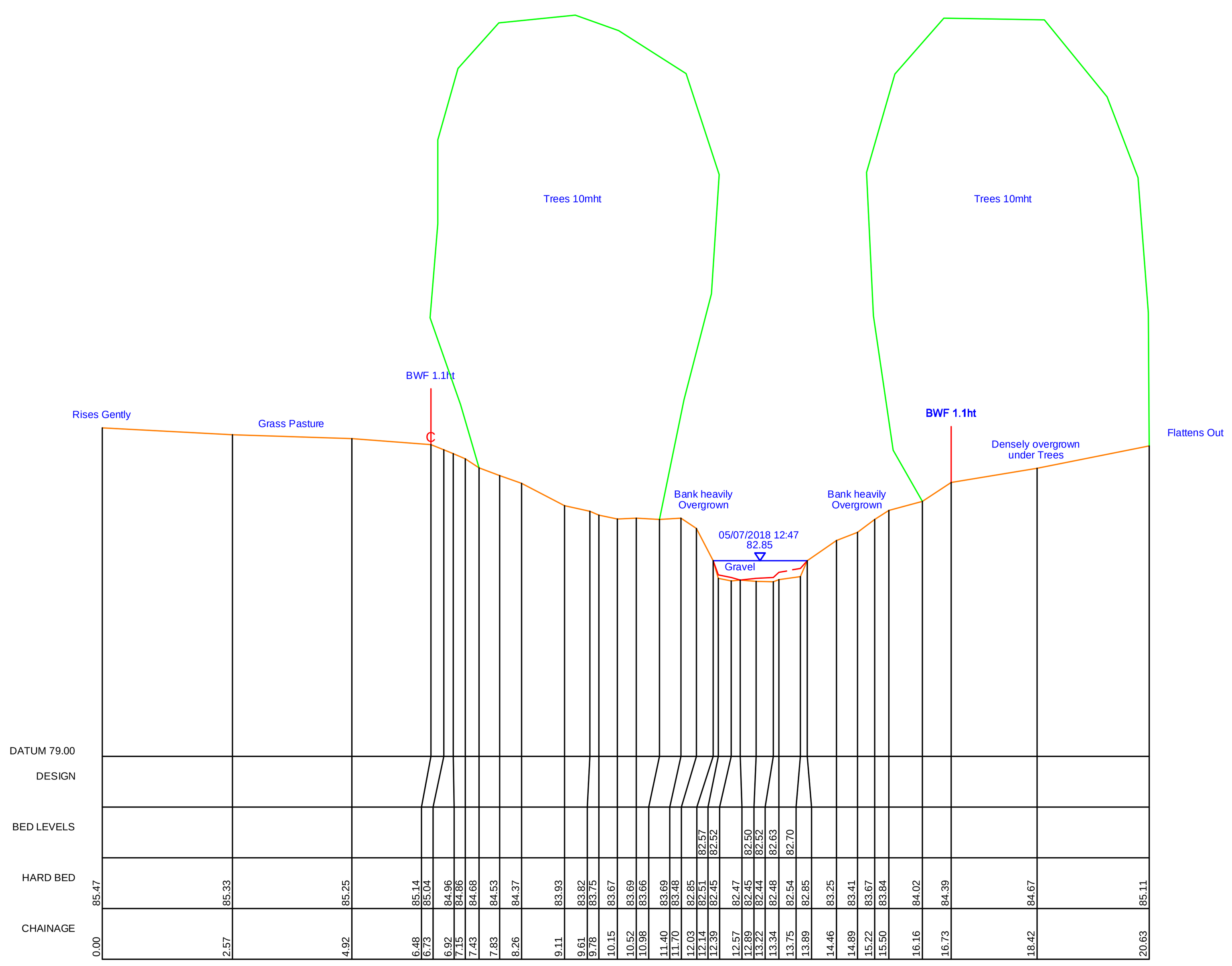
GRID: NATIONAL	DRAWING NO. 649-SL-XS-01	REV. 0
CAD FILENAME: 649-SF-SL-XS.dwg		



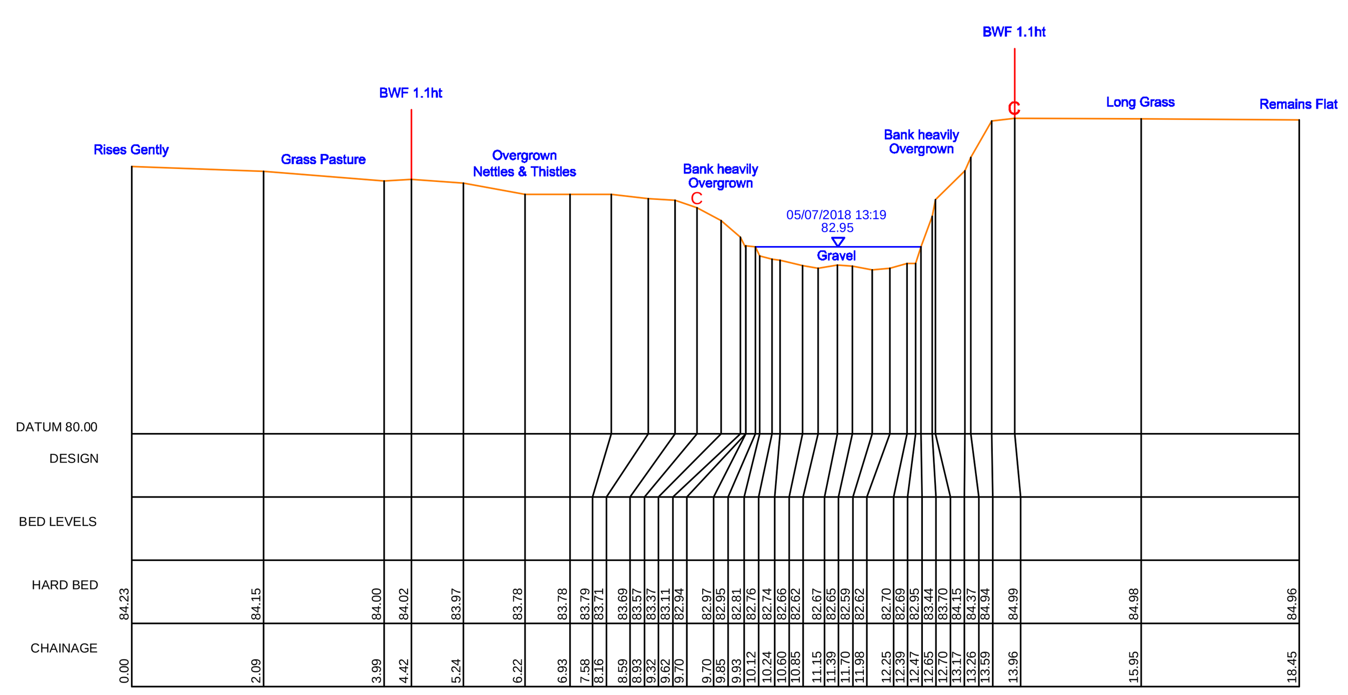
SB4
476039.64mE 321339mN Brg 271
Chainage 0
Open Channel



SB3
476074.59mE 321402.22mN Brg 275
Chainage 116
Open Channel



SB2
476098.74mE 321443.65mN Brg 276
Chainage 174.7
Open Channel



SB1
476097.76mE 321469.99mN Brg 287
Chainage 203.3
Open Channel

KEY TO CROSS SECTIONS:

- WATER LEVEL
- VISIBLE BED (TOP OF SILT)
- HARD BED (DETERMINED BY PROBING)

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SURVEY LEGEND

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MELTON MOWBRAY DISTRIBUTOR ROAD
SCALFORD BROOK
Cross Sections Sheet 1 of 1

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AECOM
Royal Court, Basil Close
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Derbyshire S41 7SL

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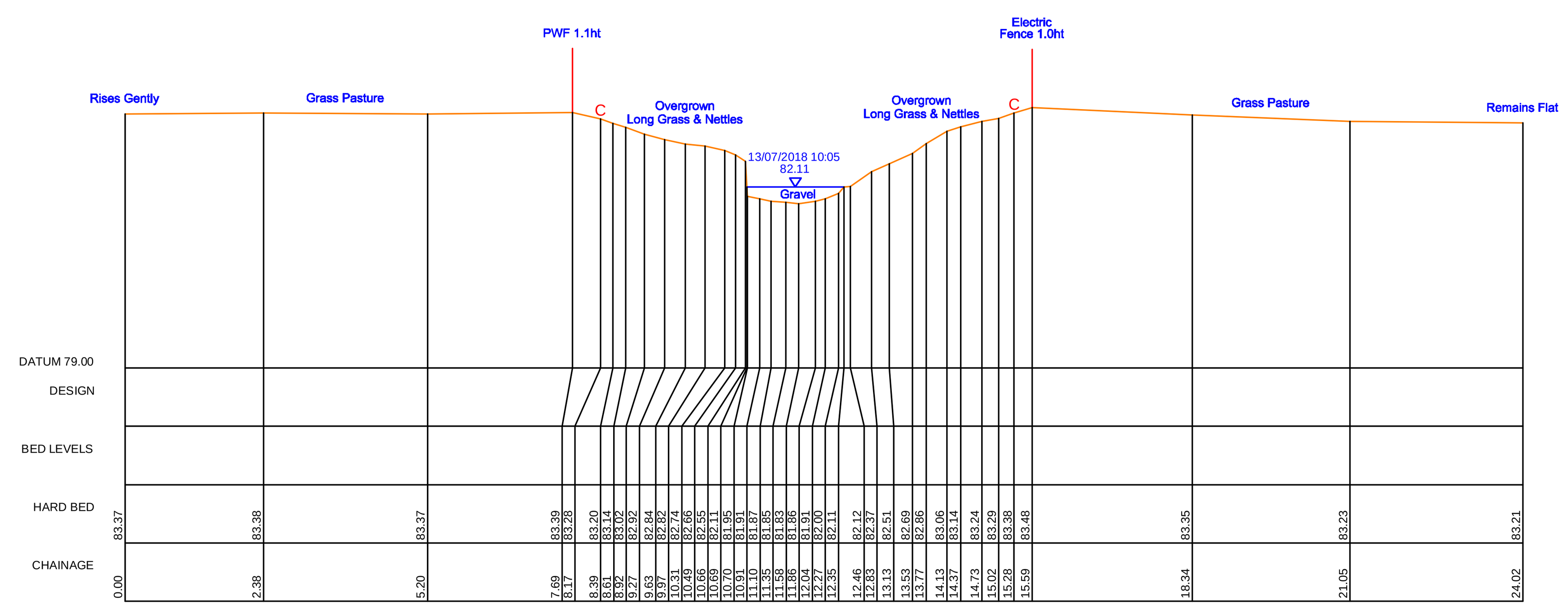

TB3
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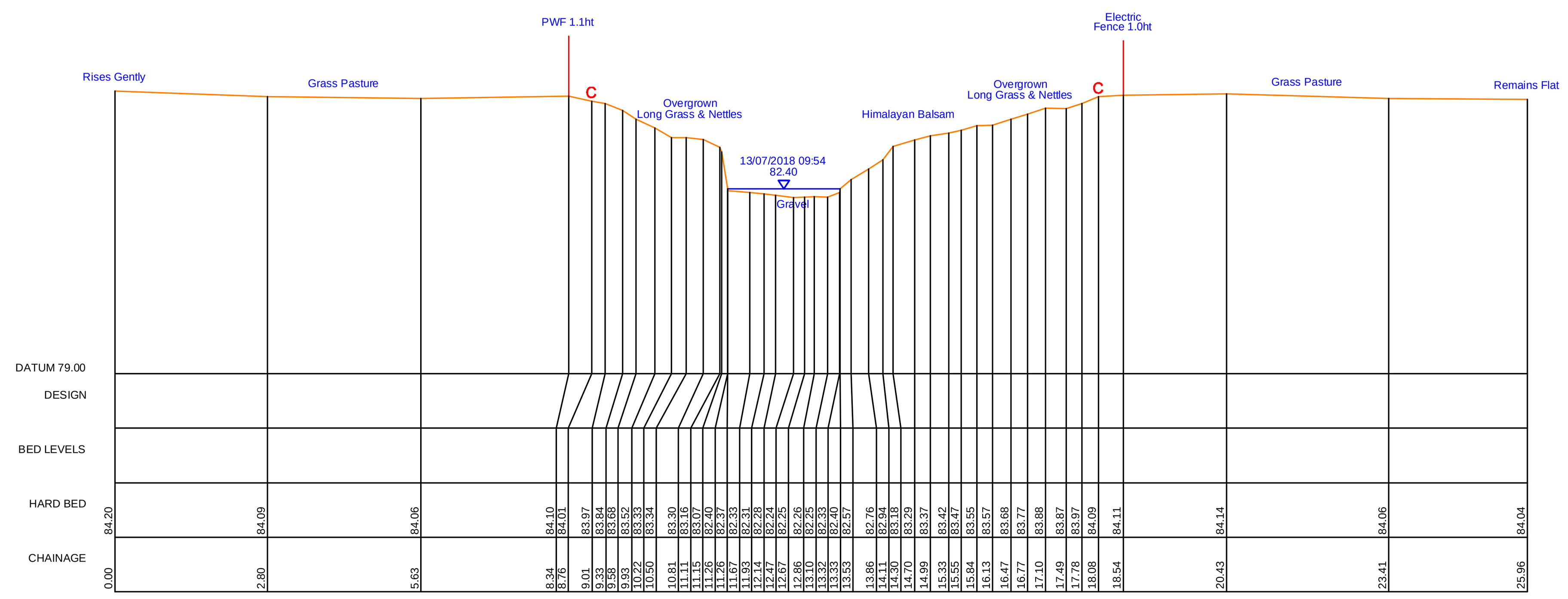
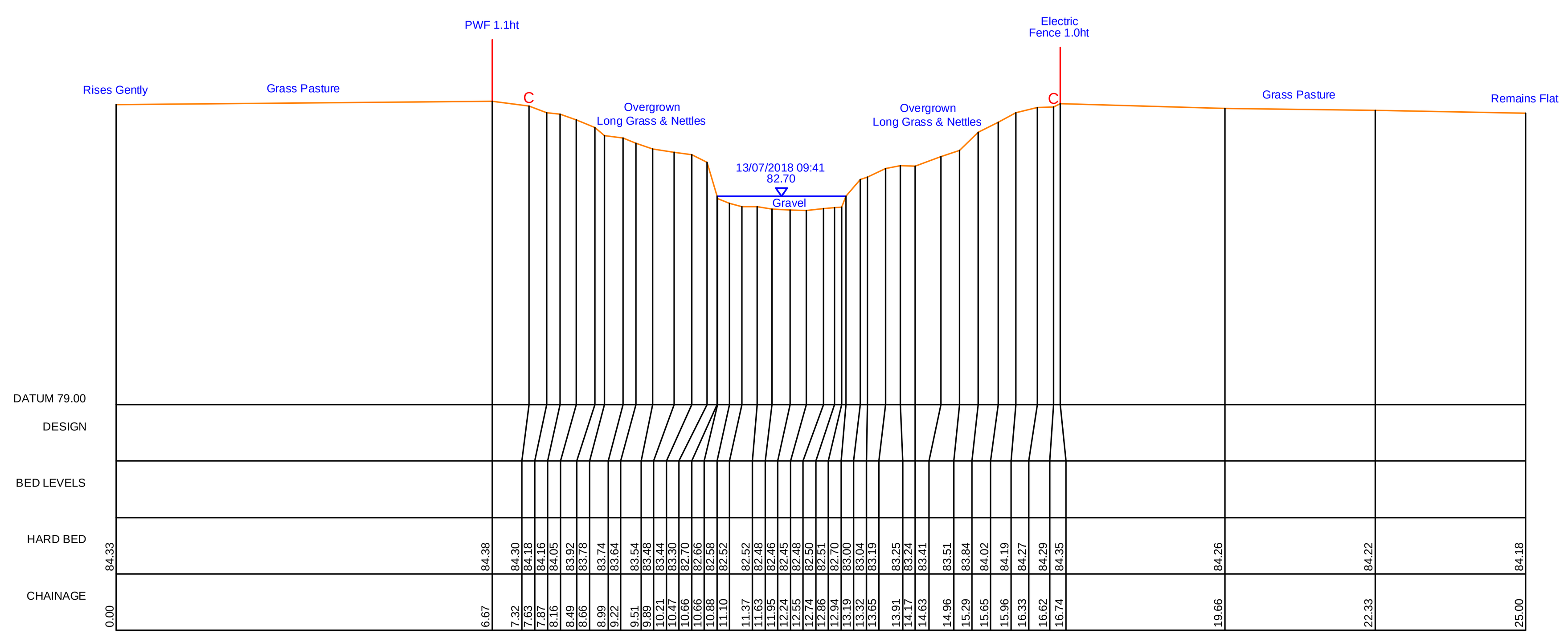
Chainage 0
Open Channel



TB2
477142.62mE 320757.79mN Brg 321
Chainage 72.8
Open Channel



TB1
477164.42mE 320780.97mN Brg 320
Chainage 104.4
Open Channel

KEY TO CROSS SECTIONS:

- WATER LEVEL
- VISIBLE BED (TOP OF SILT)
- HARD BED (DETERMINED BY PROBING)

NOTES:

1. A REPORT HAS BEEN PRODUCED FOR THIS SURVEY.
2. AECOM REF: 60542201.
3. FOR LOCATION PLAN AND LONG SECTION SEE DRAWING NUMBER 649-TB-LS-01.

SURVEY LEGEND

AB	AIR BRICK	FH	FIRE HYDRANT	PWF	POST & WIRE FENCE
AV	AIR VALVE	FHM	FIRE HYDRANT MARKER	RB	RIGHT BANK
B	BOLLARD	FL	FLOOR LEVEL	RE	RODDING EYE
BB	BELISHA BEACON	FP	FENCE POST	RS	ROAD SIGN
BDY	BOUNDARY	FWM	FOUL WATER MANHOLE	RTW	RETAINING WALL
BH	BOREHOLE	G	GULLY	RWP	RAINWATER PIPE
BL	BED LEVEL	GL	GROUND LEVEL	SC	STOP COCK
BRK	BRICKWORK	GP	GATE POST	SDP	STAND PIPE
BS	BUS STOP	GM	GAS MARKER	SK	SOAKAWAY
BM	BENCH MARK	GV	GAS VALVE	SL	SOFFIT LEVEL
BW	BRICK WALL	HW	HEAD WALL	SMH	SURFACE WATER MANHOLE
BWF	BARBED WIRE FENCE	IC	INSPECTION CHAMBER	SMP	SHEET METAL PILING
CBF	CLOSE BOARDED FENCE	IL	INVERT LEVEL	SP	SIGN POST
CIF	CORRUGATED IRON FENCE	IRF	IRON RAILING FENCE	STN	STATION
CL	COVER LEVEL	IWF	INTERWOVEN FENCE	SV	SLUICE VALVE
CLF	CHAIN LINK FENCE	JB	JUNCTION BOX	SVP	SOIL VENT PIPE
CONC	CONCRETE	KIG	KERB INLET GULLY	SWF	SHEEP WIRE FENCE
CP	CONCRETE POST	LB	LEFT BANK	TBM	TEMPORARY BENCH MARK
CPF	CHESTNUT PALING FENCE	LFB	LIFEBUOY	TCB/TCP	TELEPHONE CALL BOX/POST
CR	CYCLE RACK	LP	LAMP POST	TC	TELECOM CABINET
CTV	CABLE T.V. MANHOLE	MB	MOORING BOLLARD	TMH	TELECOM MANHOLE
CUL	CULVERT	MF	MISCELLANEOUS FENCING	THL	THRESHOLD LEVEL
DK	DROP KERB	MH	MANHOLE	TL	TRAFFIC LIGHT
DL	DECK LEVEL	MKR	MARKER	TLB	TRAFFIC LIGHT BOX
DP	DOWNPIPE	MP	MOORING PILE	TP	TELEGRAPH POLE
DPC	DAMP PROOF COURSE	MRF	METAL RAILING FENCE	TRS	TIMBER RUBBING STRIP
DR	DRAIN	MS	MILE STONE	TS	TREE STUMP
DWB	DOG WASTE BIN	NB	NOTICE BOARD	TSR	TUBULAR STEEL RAILINGS
EA	ENVIRONMENT AGENCY	NRA	NATIONAL RIVERS AUTHORITY	VP	VENT PIPE
EB	ELECTRICITY BOX	OHC	OVERHEAD CABLE	WB	WASTE BIN
ECF	ELECTRIC CABLE FENCE	OS	ORDNANCE SURVEY	WL	WATER LEVEL/WATER LINE
ECP	ELECTRICITY CABLE PIT	OSR	OPEN STEEL RAILINGS	WM	WATER METER
EMH	ELECTRICITY MANHOLE	P	PILE	WMF	WIRE MESH FENCE
EP	ELECTRICITY POLE	PB	PILLAR BOX	WP	WOODEN POST
ER	EARTHING ROD	PM	PARKING METER	WPR	WOODEN POST & RAIL FENCE
ETL	ELECTRICITY TRANSMISSION LINE	PO	POST	WV	WATER VALVE
FB	FLOWER BED	PRF	POST & RAIL FENCE	YG	YARD GULLY
FBR	FOOTBRIDGE	PTM	PARKING TICKET MACHINE		

(Abbreviations apply to EA survey data only)

REV.	AMENDMENT	DRN	CHKD	DATE
0.	Proof Drawing for Approval	PAW	RMW	07-18

CONTROL USED:

TYPE	DESCRIPTION	LEVEL
GRID	– Related to OSGB36 (National Grid) via GNSS and OSTN15	
LEVELS	– Related to OS Datum via GNSS and OSGM15	

STATIONS ESTABLISHED:

NAME	CO-ORDINATES	LEVEL
XX	XXXX.XXX XXXX.XXX	XX.XX

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PROJECT

MELTON MOWBRAY DISTRIBUTOR ROAD
THORPE BROOK
Cross Sections Sheet 1 of 1

CLIENT

AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire S41 7SL

SURVEYED BY: Central Surveys Ltd — Ref: 649
SURVEY DATE: JULY 2018

SCALE: 1:100 @ A1 size	DRN: P.A.W.	CHKD: R.M.W.
DATUM: ODN	DATE: AUG 18	DATE: AUG18
GRID: NATIONAL	DRAWING NO. 649-TB-XS-01	REV. 0

CAD FILENAME: 649-TB-XS.dwg

Photographs of surveyed channel cross-sections provided by Central Surveys Limited

Photographs of Sysonby Farm watercourse captured at the proposed crossing location (SF2) on 10/08/2018

Figure Error! No text of specified style in document.1Cross Section SF2 Looking Upstream from Left Bank

Figure 2 Cross Section SF2 Looking Downstream from Left Bank

Figure 3 Cross Section SF2 Looking at Right Bank

Figure 4 Cross Section SF2 Looking at Left Bank

Photographs of surveyed channel cross-sections provided by Central Surveys Limited

Photographs of Sysonby Lodge watercourse captured at the proposed crossing location (SL1) on 10/08/2018

Figure1Cross Section SL1 Looking Upstream from Left Bank

Figure 2 Cross Section SL1 Looking Downstream from Left Bank

Figure 3 Cross Section SL1 Looking Right Bank from Left Bank

Figure 4 Cross Section SL1 Looking at Left Bank

Photographs of surveyed channel cross-sections provided by Central Surveys Limited

Photographs of Thorpe Brook captured at the proposed crossing location (TB2) on 16/07/2018	
 FigureError! No text of specified style in document.5Cross Section TB2 Looking Upstream from Left Bank	 Figure 6 Cross Section TB2 Looking Downstream from Left Bank
 Figure 7 Cross Section TB2 Looking Right Bank from Left Bank	 Figure 8 Cross Section TB2 Looking at Left Bank

EXISTING CHANNEL CAPACITY CALCULATIONS

SYSONBY FARM WATERCOURSE

Project	Melton Mowbray Distributor Road	AECOM	
Subject	Existing Channel Capacity of Ordinary Watercourses	Job No	60542201
Prepared by:	Anupriya Prabhuswamy	Date	Sep-18
Checked by:	Andrew Heath-Brown	Revision	P01

Assumption: Manning's n = 0.06 (Natural Channel, Poor condition)

Node	Cross Section Name	Stage (m AOD)	Depth (m)	Area (m2)	W Perim. (m)	Slope	Manning's n	Hydraulic Radius (m)	Flow (m3/s)	
0	SF2	106.814	0	0	0	0.039	0.06	#DIV/0!	#DIV/0!	
0	SF2	106.863	0.049	0.005	0.235	0.039	0.06	0.02	0.00	
0	SF2	106.902	0.088	0.017	0.437	0.039	0.06	0.04	0.01	
0	SF2	106.941	0.127	0.035	0.64	0.039	0.06	0.05	0.02	
0	SF2	106.971	0.157	0.054	0.766	0.039	0.06	0.07	0.03	
0	SF2	107	0.186	0.076	0.992	0.039	0.06	0.08	0.05	
0	SF2	107.055	0.241	0.129	1.33	0.039	0.06	0.10	0.09	
0	SF2	107.112	0.298	0.192	1.455	0.039	0.06	0.13	0.16	
0	SF2	107.168	0.354	0.258	1.579	0.039	0.06	0.16	0.26	
0	SF2	107.225	0.411	0.326	1.704	0.039	0.06	0.19	0.36	
0	SF2	107.262	0.448	0.372	1.784	0.039	0.06	0.21	0.43	
0	SF2	107.319	0.505	0.444	1.908	0.039	0.06	0.23	0.56	
0	SF2	107.373	0.559	0.516	2.06	0.039	0.06	0.25	0.68	
0	SF2	107.428	0.614	0.595	2.212	0.039	0.06	0.27	0.82	
0	SF2	107.482	0.668	0.678	2.365	0.039	0.06	0.29	0.98	
0	SF2	107.536	0.722	0.768	2.517	0.039	0.06	0.31	1.15	Existing Channel Capacity
0	SF2	107.547	0.733	0.786	2.562	0.039	0.06	0.31	1.18	
0	SF2	107.592	0.778	0.868	2.739	0.039	0.06	0.32	1.33	
0	SF2	107.637	0.823	0.956	2.916	0.039	0.06	0.33	1.50	
0	SF2	107.682	0.868	1.051	3.093	0.039	0.06	0.34	1.69	
0	SF2	107.74	0.926	1.181	3.265	0.039	0.06	0.36	1.98	
0	SF2	107.798	0.984	1.319	3.438	0.039	0.06	0.38	2.30	
0	SF2	107.853	1.039	1.457	3.619	0.039	0.06	0.40	2.63	
0	SF2	107.908	1.094	1.603	3.8	0.039	0.06	0.42	2.98	
0	SF2	107.953	1.139	1.729	3.97	0.039	0.06	0.44	3.29	
0	SF2	107.998	1.184	1.862	4.139	0.039	0.06	0.45	3.62	
0	SF2	108.03	1.216	1.96	4.253	0.039	0.06	0.46	3.87	
0	SF2	108.062	1.248	2.061	4.367	0.039	0.06	0.47	4.13	
0	SF2	108.11	1.296	2.219	4.542	0.039	0.06	0.49	4.55	
0	SF2	108.159	1.345	2.384	4.716	0.039	0.06	0.51	5.00	
0	SF2	108.207	1.393	2.556	4.891	0.039	0.06	0.52	5.49	
0	SF2	108.252	1.438	2.723	5.079	0.039	0.06	0.54	5.94	
0	SF2	108.297	1.483	2.898	5.266	0.039	0.06	0.55	6.44	
0	SF2	108.352	1.538	3.122	5.521	0.039	0.06	0.57	7.06	
0	SF2	108.407	1.593	3.359	5.775	0.039	0.06	0.58	7.74	
0	SF2	108.451	1.637	3.563	6.239	0.039	0.06	0.57	8.11	
0	SF2	108.503	1.689	3.827	6.749	0.039	0.06	0.57	8.67	
0	SF2	108.554	1.74	4.116	7.26	0.039	0.06	0.57	9.33	
0	SF2	108.606	1.792	4.431	7.771	0.039	0.06	0.57	10.08	
0	SF2	108.658	1.844	4.771	8.282	0.039	0.06	0.58	10.93	
0	SF2	108.712	1.898	5.152	8.828	0.039	0.06	0.58	11.90	
0	SF2	108.766	1.952	5.562	9.375	0.039	0.06	0.59	12.99	
0	SF2	108.826	2.012	6.056	10.036	0.039	0.06	0.60	14.31	
0	SF2	108.887	2.073	6.588	10.697	0.039	0.06	0.62	15.78	
0	SF2	108.944	2.13	7.125	11.269	0.039	0.06	0.63	17.36	
0	SF2	109.001	2.187	7.693	11.859	0.039	0.06	0.65	19.07	
0	SF2	109.058	2.244	8.294	12.45	0.039	0.06	0.67	20.93	
0	SF2	109.117	2.302	8.945	13.045	0.039	0.06	0.69	23.01	
0	SF2	109.175	2.361	9.629	13.641	0.039	0.06	0.71	25.25	
0	SF2	109.216	2.402	10.122	13.735	0.039	0.06	0.74	27.32	
0	SF2	109.267	2.453	10.742	13.908	0.039	0.06	0.77	29.91	
0	SF2	109.318	2.504	11.371	14.08	0.039	0.06	0.81	32.62	
0	SF2	109.318	2.504	11.371	14.396	0.039	0.06	0.79	32.14	
0	SF2	109.342	2.528	11.68	14.755	0.039	0.06	0.79	33.06	
0	SF2	109.385	2.571	12.302	17.498	0.039	0.06	0.70	32.18	
0	SF2	109.423	2.609	12.922	18.495	0.039	0.06	0.70	33.66	
0	SF2	109.457	2.643	13.515	19.795	0.039	0.06	0.68	34.66	
0	SF2	109.491	2.677	14.153	21.095	0.039	0.06	0.67	35.88	
0	SF2	109.546	2.732	15.223	21.354	0.039	0.06	0.71	40.19	
0	SF2	109.6	2.786	16.305	21.613	0.039	0.06	0.75	44.70	
0	SF2	109.655	2.841	17.402	21.872	0.039	0.06	0.80	49.43	
0	SF2	109.71	2.896	18.513	22.132	0.039	0.06	0.84	54.37	
0	SF2	109.765	2.951	19.638	22.391	0.039	0.06	0.88	59.52	
0	SF2	109.819	3.005	20.776	22.65	0.039	0.06	0.92	64.88	
0	SF2	109.874	3.06	21.928	22.909	0.039	0.06	0.96	70.45	

SYSONBY LODGE WATERCOURSE

Project	Melton Mowbray Distributor Road	AECOM	
Subject	Existing Channel Capacity of Ordinary Watercourses	Job No	60542201
Prepared by:	Anupriya Prabhuswamy	Date	Sep-18
Checked by:	Andrew Heath-Brown	Rev	P01

Assumption: Manning's n = 0.06 (Natural Channel, Poor condition)

Node	Cross Section Name	Stage (m AOD)	Depth (m)	Area (m2)	W Perim. (m)	Slope	Manning's n	Hydraulic Radius	Flow (m3/s)	
71	SL1	108.025	0.011	0.002	0.328	0.029	0.06	0.01	0.00	
71	SL1	108.047	0.033	0.011	0.535	0.029	0.06	0.02	0.00	
71	SL1	108.069	0.055	0.025	0.742	0.029	0.06	0.03	0.01	
71	SL1	108.089	0.075	0.041	0.882	0.029	0.06	0.05	0.02	
71	SL1	108.108	0.094	0.059	1.023	0.029	0.06	0.06	0.02	
71	SL1	108.128	0.114	0.08	1.164	0.029	0.06	0.07	0.04	
71	SL1	108.135	0.121	0.088	1.221	0.029	0.06	0.07	0.04	
71	SL1	108.156	0.142	0.115	1.431	0.029	0.06	0.08	0.06	
71	SL1	108.176	0.162	0.145	1.642	0.029	0.06	0.09	0.08	
71	SL1	108.199	0.185	0.184	1.828	0.029	0.06	0.10	0.11	
71	SL1	108.222	0.208	0.227	2.014	0.029	0.06	0.11	0.15	
71	SL1	108.245	0.231	0.275	2.199	0.029	0.06	0.13	0.19	
71	SL1	108.268	0.254	0.326	2.385	0.029	0.06	0.14	0.25	
71	SL1	108.291	0.277	0.381	2.526	0.029	0.06	0.15	0.31	
71	SL1	108.313	0.299	0.434	2.606	0.029	0.06	0.17	0.37	
71	SL1	108.335	0.321	0.489	2.685	0.029	0.06	0.18	0.45	
71	SL1	108.356	0.342	0.545	2.765	0.029	0.06	0.20	0.52	
71	SL1	108.378	0.364	0.603	2.845	0.029	0.06	0.21	0.61	
71	SL1	108.382	0.368	0.616	4.345	0.029	0.06	0.14	0.47	
71	SL1	108.385	0.371	0.635	8.303	0.029	0.06	0.08	0.32	
71	SL1	108.401	0.387	0.772	9.223	0.029	0.06	0.08	0.42	
71	SL1	108.418	0.404	0.933	10.208	0.029	0.06	0.09	0.54	
71	SL1	108.435	0.421	1.111	11.193	0.029	0.06	0.10	0.67	
71	SL1	108.458	0.444	1.359	11.333	0.029	0.06	0.12	0.94	
71	SL1	108.48	0.466	1.61	11.474	0.029	0.060	0.14	1.23	(Existing Channel Capacity)
71	SL1	108.507	0.493	1.913	11.514	0.029	0.06	0.17	1.64	
71	SL1	108.534	0.52	2.216	11.554	0.029	0.06	0.19	2.09	
71	SL1	108.561	0.547	2.521	11.594	0.029	0.06	0.22	2.58	
71	SL1	108.588	0.574	2.826	11.634	0.029	0.06	0.24	3.12	
71	SL1	108.613	0.599	3.107	11.69	0.029	0.06	0.27	3.64	
71	SL1	108.638	0.624	3.39	11.746	0.029	0.06	0.29	4.19	
71	SL1	108.662	0.648	3.673	11.802	0.029	0.06	0.31	4.78	
71	SL1	108.687	0.673	3.958	11.858	0.029	0.06	0.33	5.40	
71	SL1	108.712	0.698	4.245	11.914	0.029	0.06	0.36	6.05	
71	SL1	108.732	0.718	4.483	12.601	0.029	0.06	0.36	6.38	
71	SL1	108.752	0.738	4.735	13.288	0.029	0.06	0.36	6.74	
71	SL1	108.772	0.758	5	13.975	0.029	0.06	0.36	7.14	
71	SL1	108.794	0.78	5.301	14.775	0.029	0.06	0.36	7.58	
71	SL1	108.815	0.801	5.62	15.575	0.029	0.06	0.36	8.07	
71	SL1	108.837	0.823	5.955	16.375	0.029	0.06	0.36	8.60	
71	SL1	108.858	0.844	6.308	17.176	0.029	0.06	0.37	9.17	
71	SL1	108.88	0.866	6.675	17.777	0.029	0.06	0.38	9.84	
71	SL1	108.901	0.887	7.056	18.378	0.029	0.06	0.38	10.56	
71	SL1	108.925	0.911	7.499	18.62	0.029	0.06	0.40	11.59	
71	SL1	108.95	0.936	7.947	18.862	0.029	0.06	0.42	12.66	
71	SL1	108.974	0.96	8.402	19.104	0.029	0.06	0.44	13.77	
71	SL1	108.999	0.985	8.862	19.346	0.029	0.06	0.46	14.92	
71	SL1	109.023	1.009	9.328	19.588	0.029	0.06	0.48	16.12	
71	SL1	109.048	1.034	9.801	19.829	0.029	0.06	0.49	17.36	
71	SL1	109.072	1.058	10.279	20.071	0.029	0.06	0.51	18.64	
71	SL1	109.097	1.083	10.763	20.313	0.029	0.06	0.53	19.97	
71	SL1	109.121	1.107	11.252	20.555	0.029	0.06	0.55	21.33	
71	SL1	109.148	1.134	11.794	20.808	0.029	0.06	0.57	22.89	
71	SL1	109.174	1.16	12.342	21.061	0.029	0.06	0.59	24.49	
71	SL1	109.201	1.187	12.897	21.314	0.029	0.06	0.61	26.14	
71	SL1	109.228	1.214	13.459	21.567	0.029	0.06	0.62	27.85	
71	SL1	109.255	1.241	14.028	21.82	0.029	0.06	0.64	29.61	
71	SL1	109.281	1.267	14.603	22.073	0.029	0.06	0.66	31.42	
71	SL1	109.308	1.294	15.185	22.326	0.029	0.06	0.68	33.28	
71	SL1	109.335	1.321	15.773	22.579	0.029	0.06	0.70	35.19	
71	SL1	109.361	1.347	16.369	22.832	0.029	0.06	0.72	37.15	
71	SL1	109.388	1.374	16.971	23.085	0.029	0.06	0.74	39.17	

SCALFORD BROOK

Project	Melton Mowbray Distributor Road	AECOM	
Subject	Existing Channel Capacity of Ordinary Watercourses	Job No	60542201
Prepared by:	Anupriya Prabhuswamy	Date	Sep-18
Checked by:	Andrew Heath-Brown	Revision	P01

Assumption: Manning's n = 0.04 (Natural Channel). Photographs not provided with channel survey data

Node	Cross Section Name	Stage (m AOD)	Depth (m)	Area (m2)	W Perim. (m)	Slope	Manning's n	Hydraulic Radius	Flow (m3/s)	
174.7	SB2	82.448	0.011	0.002	0.367	0.002	0.04	0.01	0.00	
174.7	SB2	82.452	0.015	0.004	0.434	0.002	0.04	0.01	0.00	
174.7	SB2	82.471	0.034	0.017	1.018	0.002	0.04	0.02	0.00	
174.7	SB2	82.476	0.039	0.023	1.056	0.002	0.04	0.02	0.00	
174.7	SB2	82.508	0.071	0.062	1.406	0.002	0.04	0.04	0.01	
174.7	SB2	82.541	0.104	0.112	1.628	0.002	0.04	0.07	0.02	
174.7	SB2	82.592	0.156	0.197	1.666	0.002	0.04	0.12	0.05	
174.7	SB2	82.644	0.207	0.284	1.704	0.002	0.04	0.17	0.10	
174.7	SB2	82.695	0.258	0.372	1.742	0.002	0.04	0.21	0.15	
174.7	SB2	82.747	0.31	0.463	1.78	0.002	0.04	0.26	0.21	
174.7	SB2	82.799	0.362	0.556	1.818	0.002	0.04	0.31	0.29	
174.7	SB2	82.85	0.413	0.65	1.856	0.002	0.04	0.35	0.37	
174.7	SB2	82.85	0.413	0.65	1.856	0.002	0.04	0.35	0.37	
174.7	SB2	82.907	0.47	0.759	1.968	0.002	0.04	0.39	0.46	
174.7	SB2	82.964	0.527	0.875	2.08	0.002	0.04	0.42	0.56	
174.7	SB2	83.021	0.584	0.996	2.191	0.002	0.04	0.45	0.67	
174.7	SB2	83.078	0.641	1.124	2.303	0.002	0.04	0.49	0.79	
174.7	SB2	83.135	0.698	1.259	2.415	0.002	0.04	0.52	0.93	
174.7	SB2	83.192	0.755	1.4	2.527	0.002	0.04	0.55	1.07	
174.7	SB2	83.249	0.812	1.547	2.638	0.002	0.04	0.59	1.23	
174.7	SB2	83.302	0.865	1.69	2.807	0.002	0.04	0.60	1.37	
174.7	SB2	83.354	0.917	1.843	2.975	0.002	0.04	0.62	1.52	
174.7	SB2	83.407	0.97	2.004	3.143	0.002	0.04	0.64	1.69	
174.7	SB2	83.445	1.008	2.123	3.21	0.002	0.04	0.66	1.83	
174.7	SB2	83.482	1.045	2.244	3.278	0.002	0.04	0.68	1.98	
174.7	SB2	83.528	1.091	2.397	3.405	0.002	0.04	0.70	2.15	
174.7	SB2	83.574	1.137	2.556	3.532	0.002	0.04	0.72	2.34	
174.7	SB2	83.619	1.182	2.72	3.659	0.002	0.04	0.74	2.53	
174.7	SB2	83.665	1.228	2.891	3.786	0.002	0.04	0.76	2.74	
174.7	SB2	83.668	1.231	2.902	3.919	0.002	0.04	0.74	2.70	
174.7	SB2	83.674	1.237	2.927	4.188	0.002	0.04	0.70	2.62	
174.7	SB2	83.686	1.249	2.983	5.163	0.002	0.04	0.58	2.35	
174.7	SB2	83.686	1.249	2.983	5.163	0.002	0.04	0.58	2.35	
174.7	SB2	83.716	1.28	3.143	5.363	0.002	0.04	0.59	2.50	
174.7	SB2	83.747	1.31	3.31	5.564	0.002	0.04	0.59	2.66	
174.7	SB2	83.785	1.348	3.521	5.713	0.002	0.04	0.62	2.89	
174.7	SB2	83.822	1.385	3.738	5.862	0.002	0.04	0.64	3.14	
174.7	SB2	83.842	1.405	3.857	5.985	0.002	0.04	0.64	3.27	
174.7	SB2	83.887	1.45	4.131	6.354	0.002	0.04	0.65	3.52	
174.7	SB2	83.931	1.494	4.422	6.724	0.002	0.04	0.66	3.80	
174.7	SB2	83.974	1.537	4.717	6.968	0.002	0.04	0.68	4.13	
174.7	SB2	84.017	1.58	5.022	7.212	0.002	0.04	0.70	4.48	
174.7	SB2	84.076	1.639	5.456	7.417	0.002	0.04	0.74	5.05	
174.7	SB2	84.136	1.699	5.902	7.621	0.002	0.04	0.77	5.65	
174.7	SB2	84.195	1.758	6.36	7.825	0.002	0.04	0.81	6.29	
174.7	SB2	84.254	1.817	6.83	8.03	0.002	0.04	0.85	6.96	
174.7	SB2	84.314	1.877	7.313	8.234	0.002	0.04	0.89	7.67	
174.7	SB2	84.373	1.936	7.807	8.439	0.002	0.04	0.93	8.41	
174.7	SB2	84.393	1.956	7.977	8.525	0.002	0.04	0.94	8.66	
174.7	SB2	84.438	2.001	8.367	8.92	0.002	0.04	0.94	9.10	
174.7	SB2	84.482	2.045	8.774	9.315	0.002	0.04	0.94	9.57	
174.7	SB2	84.527	2.09	9.199	9.71	0.002	0.04	0.95	10.07	
174.7	SB2	84.576	2.139	9.682	10.129	0.002	0.04	0.96	10.67	
174.7	SB2	84.624	2.187	10.185	10.549	0.002	0.04	0.97	11.29	
174.7	SB2	84.673	2.236	10.708	10.968	0.002	0.04	0.98	11.96	
174.7	SB2	84.683	2.246	10.818	11.044	0.002	0.04	0.98	12.11	
174.7	SB2	84.741	2.304	11.474	11.428	0.002	0.04	1.00	13.06	
174.7	SB2	84.8	2.363	12.152	11.812	0.002	0.04	1.03	14.06	
174.7	SB2	84.858	2.421	12.852	12.195	0.002	0.04	1.05	15.11	
174.7	SB2	84.908	2.471	13.471	12.565	0.002	0.04	1.07	16.02	
174.7	SB2	84.958	2.521	14.108	12.934	0.002	0.04	1.09	16.97	
174.7	SB2	84.997	2.56	14.618	13.223	0.002	0.04	1.11	17.74	
174.7	SB2	85.036	2.599	15.14	13.511	0.002	0.04	1.12	18.54	
174.7	SB2	85.075	2.638	15.666	13.802	0.002	0.04	1.14	19.35	
174.7	SB2	85.113	2.676	16.203	14.094	0.002	0.040	1.15	20.19	(Existing Channel Capacity)
174.7	SB2	85.136	2.699	16.527	14.152	0.002	0.04	1.17	20.81	
174.7	SB2	85.195	2.758	17.378	14.934	0.002	0.04	1.16	21.82	
174.7	SB2	85.253	2.816	18.275	15.715	0.002	0.04	1.16	22.94	
174.7	SB2	85.292	2.855	18.91	16.889	0.002	0.04	1.12	23.15	
174.7	SB2	85.331	2.894	19.592	18.064	0.002	0.04	1.08	23.48	
174.7	SB2	85.377	2.94	20.449	18.919	0.002	0.04	1.08	24.45	
174.7	SB2	85.424	2.987	21.345	19.775	0.002	0.04	1.08	25.50	
174.7	SB2	85.47	3.033	22.281	20.63	0.002	0.04	1.08	26.63	

THORPE BROOK

Project	Melton Mowbray Distributor Road	AECOM	
Subject	Existing Channel Capacity of Ordinary Watercourses	Job No	60542201
Prepared by:	Anupriya Prabhuswamy	Date	Sep-18
Checked by:	Andrew Heath-Brown	Revision	P01

Assumption: Manning's n = 0.035

Node	Cross Section Name	Stage (m AOD)	Depth (m)	Area (m2)	W Perim. (m)	Slope	Manning's n	Hydraulic Radius	Flow (m3/s)	
72.8	TB2	82.245	0.005	0.001	0.246	0.006	0.035	0.00	0.00	
72.8	TB2	82.245	0.005	0.001	0.246	0.006	0.035	0.00	0.00	
72.8	TB2	82.257	0.017	0.007	0.816	0.006	0.035	0.01	0.00	
72.8	TB2	82.277	0.037	0.025	1.048	0.006	0.035	0.02	0.00	
72.8	TB2	82.305	0.065	0.059	1.345	0.006	0.035	0.04	0.02	
72.8	TB2	82.33	0.09	0.096	1.654	0.006	0.035	0.06	0.03	
72.8	TB2	82.332	0.092	0.099	1.675	0.006	0.035	0.06	0.03	
72.8	TB2	82.366	0.126	0.162	2.114	0.006	0.035	0.08	0.06	
72.8	TB2	82.4	0.16	0.232	2.183	0.006	0.035	0.11	0.11	
72.8	TB2	82.4	0.16	0.232	2.183	0.006	0.035	0.11	0.11	
72.8	TB2	82.434	0.194	0.304	2.271	0.006	0.035	0.13	0.17	
72.8	TB2	82.468	0.228	0.377	2.359	0.006	0.035	0.16	0.24	
72.8	TB2	82.503	0.263	0.452	2.447	0.006	0.035	0.18	0.31	
72.8	TB2	82.537	0.297	0.528	2.535	0.006	0.035	0.21	0.40	
72.8	TB2	82.571	0.331	0.606	2.624	0.006	0.035	0.23	0.49	
72.8	TB2	82.61	0.37	0.696	2.738	0.006	0.035	0.25	0.60	
72.8	TB2	82.648	0.408	0.789	2.852	0.006	0.035	0.28	0.72	
72.8	TB2	82.687	0.447	0.885	2.966	0.006	0.035	0.30	0.85	
72.8	TB2	82.725	0.485	0.983	3.08	0.006	0.035	0.32	0.98	
72.8	TB2	82.764	0.524	1.084	3.194	0.006	0.035	0.34	1.13	
72.8	TB2	82.798	0.558	1.176	3.291	0.006	0.035	0.36	1.27	
72.8	TB2	82.832	0.592	1.27	3.387	0.006	0.035	0.37	1.42	
72.8	TB2	82.867	0.627	1.366	3.484	0.006	0.035	0.39	1.57	
72.8	TB2	82.901	0.661	1.463	3.58	0.006	0.035	0.41	1.73	
72.8	TB2	82.935	0.695	1.563	3.676	0.006	0.035	0.43	1.89	
72.8	TB2	82.97	0.73	1.666	3.755	0.006	0.035	0.44	2.08	
72.8	TB2	83.005	0.765	1.769	3.834	0.006	0.035	0.46	2.26	
72.8	TB2	83.039	0.799	1.874	3.912	0.006	0.035	0.48	2.46	
72.8	TB2	83.074	0.834	1.98	3.991	0.006	0.035	0.50	2.66	
72.8	TB2	83.102	0.862	2.066	4.056	0.006	0.035	0.51	2.83	
72.8	TB2	83.129	0.889	2.152	4.12	0.006	0.035	0.52	2.99	
72.8	TB2	83.157	0.917	2.239	4.185	0.006	0.035	0.54	3.16	
72.8	TB2	83.18	0.94	2.313	4.268	0.006	0.035	0.54	3.30	
72.8	TB2	83.218	0.978	2.438	4.494	0.006	0.035	0.54	3.48	
72.8	TB2	83.255	1.015	2.572	4.719	0.006	0.035	0.55	3.68	
72.8	TB2	83.293	1.053	2.714	4.945	0.006	0.035	0.55	3.90	
72.8	TB2	83.302	1.062	2.749	5.002	0.006	0.035	0.55	3.95	
72.8	TB2	83.334	1.094	2.881	5.431	0.006	0.035	0.53	4.05	
72.8	TB2	83.335	1.095	2.886	5.72	0.006	0.035	0.50	3.92	
72.8	TB2	83.369	1.129	3.046	5.92	0.006	0.035	0.51	4.19	
72.8	TB2	83.396	1.156	3.179	6.143	0.006	0.035	0.52	4.39	
72.8	TB2	83.423	1.183	3.318	6.366	0.006	0.035	0.52	4.61	
72.8	TB2	83.448	1.208	3.451	6.53	0.006	0.035	0.53	4.84	
72.8	TB2	83.473	1.233	3.588	6.695	0.006	0.035	0.54	5.08	
72.8	TB2	83.495	1.256	3.714	6.821	0.006	0.035	0.54	5.31	
72.8	TB2	83.518	1.278	3.843	6.947	0.006	0.035	0.55	5.55	
72.8	TB2	83.554	1.314	4.055	7.166	0.006	0.035	0.57	5.95	
72.8	TB2	83.567	1.327	4.135	7.485	0.006	0.035	0.55	5.97	
72.8	TB2	83.604	1.364	4.37	7.69	0.006	0.035	0.57	6.43	
72.8	TB2	83.64	1.4	4.612	7.895	0.006	0.035	0.58	6.91	
72.8	TB2	83.677	1.437	4.861	8.1	0.006	0.035	0.60	7.42	
72.8	TB2	83.679	1.439	4.875	8.111	0.006	0.035	0.60	7.44	
72.8	TB2	83.71	1.47	5.088	8.273	0.006	0.035	0.62	7.89	
72.8	TB2	83.74	1.5	5.307	8.435	0.006	0.035	0.63	8.36	
72.8	TB2	83.771	1.531	5.529	8.598	0.006	0.035	0.64	8.83	
72.8	TB2	83.805	1.565	5.782	8.767	0.006	0.035	0.66	9.39	
72.8	TB2	83.839	1.599	6.039	8.937	0.006	0.035	0.68	9.97	
72.8	TB2	83.87	1.63	6.279	9.116	0.006	0.035	0.69	10.50	
72.8	TB2	83.882	1.642	6.375	9.606	0.006	0.035	0.66	10.40	
72.8	TB2	83.911	1.671	6.615	9.771	0.006	0.035	0.68	10.94	
72.8	TB2	83.939	1.699	6.86	9.935	0.006	0.035	0.69	11.49	
72.8	TB2	83.968	1.728	7.109	10.099	0.006	0.035	0.70	12.06	
72.8	TB2	83.968	1.728	7.109	10.099	0.006	0.035	0.70	12.06	
72.8	TB2	83.989	1.749	7.295	10.284	0.006	0.035	0.71	12.44	
72.8	TB2	84.01	1.77	7.484	10.468	0.006	0.035	0.71	12.83	Existing Channel Capacity
72.8	TB2	84.038	1.798	7.743	10.679	0.006	0.035	0.73	13.40	
72.8	TB2	84.056	1.816	7.934	13.366	0.006	0.035	0.59	12.02	
72.8	TB2	84.058	1.818	7.959	13.452	0.006	0.035	0.59	12.03	
72.8	TB2	84.09	1.85	8.44	19.402	0.006	0.035	0.44	10.39	
72.8	TB2	84.094	1.854	8.514	20.216	0.006	0.035	0.42	10.26	
72.8	TB2	84.1	1.86	8.63	21.131	0.006	0.035	0.41	10.19	
72.8	TB2	84.113	1.873	8.894	22.213	0.006	0.035	0.40	10.36	
72.8	TB2	84.14	1.9	9.505	25.815	0.006	0.035	0.37	10.47	
72.8	TB2	84.167	1.927	10.187	26.578	0.006	0.035	0.38	11.53	
72.8	TB2	84.195	1.955	10.891	27.342	0.006	0.035	0.40	12.64	

Appendix F

Surface Water Drainage Plan

1. Introduction

This document sets out the proposals for the surface water drainage for the proposed North & East Melton Mowbray Distributor Road.

The proposed road is located to the north and east of Melton Mowbray. It runs from the A606 Nottingham Road at its junction with St Bartholomew's Way to the A606 Burton Road at its junction with Sawgate Road. The scheme includes six at-grade roundabouts, one at each end at the tie-ins to the existing network and four where it intersects existing roads; Scalford Road, Melton Spinney Road, A607 Melton Road, B676 Saxby Road.

2. Existing Environment & Assets

The proposed scheme is intersected by the River Eye, which is located in an approximately east-west orientation through the centre of Melton Mowbray, at an elevation of between 70 and 80 m AOD (above ordnance datum). The River Eye has a relatively wide and flat flood plain beyond which the land rises away from the river to the south to a peak of 148 m AOD at Gartree Hill between Great Dalby and Little Dalby, to the northwest towards Holwell (170 m AOD), and to the northeast towards Waltham on the Wolds (177 m AOD). Small tributaries flow into the River Eye from both the north and south of the proposed scheme creating gentle topographic landscape undulations along the route(s).

The land use in the area consists of predominantly mixed arable and livestock (dairy cattle and sheep rearing) which surrounds the urban fringe of Melton Mowbray to the east and north. The proposed scheme crosses a number of arterial roads (Scalford Road, Melton Spinney Road, the A607 and the B676), a railway line, and the former now disused Melton Mowbray Navigation and Oakham Canal. To the northeast of Melton Mowbray just beyond the route alignment is the Twinlakes Theme Park. To the north of Melton Mowbray just south of the route alignment is the Melton Mowbray Country Park. The Melton Mowbray Country Park acts as a flood storage area, in addition to the larger flood storage area contained within a large flat area within the inside of a meander of the River Eye to the south of the Brentingby Railway Junction.

The MET Office website indicates that the nearest weather station is located at Wittering, 35 km southeast of Melton Mowbray. Using data from this weather station it is estimated that the study area experiences an average of 610 mm of rainfall per year, with it raining more than 1 mm on around 113 days per year. Highest rainfall volumes are expected during the late summer to early autumn period, with it being driest in late winter and early spring. Melton Mowbray typically gets around 50 days of frost (air) each year distributed evenly across December, January and February.

Geological mapping viewed on the British Geological Survey's website indicates that the bedrock across the site consists of two main formations, which are separated along an east-west axis just south of Thorpe Arnold. The southern section of the study area consists of Blue Lias Formation (Mudstone). This comprises of thinly interbedded limestone and calcareous mudstone or siltstone. The north of the site consists of the Charmouth Mudstone Formation. This comprises of dark grey laminated shales, and dark, pale and bluish grey mudstones; locally concretionary and tabular limestone beds; argillaceous limestone; phosphatic or ironstone nodules in some areas; and organic-rich paper shales at some levels.

Superficial deposits consist of alluvium (clay, silt, sand and gravel) around the River Eye and its tributaries Scalford Brook and Thorpe Brook. Adjacent to these areas of alluvium are small patches of Glaciolacustrine deposits (clay, silt and sand), Head deposits (clay, silt, sand and gravel) and Glaciofluvial deposits (sand and gravel). Away from the watercourses and their immediate surrounds the dominant superficial geology is Oadby Member – Diamicton. Please refer to the Melton Mowbray Distributor Road Ground Investigation Report (Document Reference 60542201/ACM/VGT/GEN/GEN/ZZ/Z/RP/GE/0001) for further details.

Within the study area the following surface water features are present:

- River Eye (Main River), to be crossed south of the existing Lag Lane and Saxby Road junction (approximate chainage CH4850-CH5030);

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- Scalford Brook (Ordinary Watercourse at crossing), to be crossed north of Melton Country Park (approximate chainage CH2000);
- Thorpe Brook (Ordinary Watercourse at crossing), to be crossed south of Twinlakes Park (approximate chainage 3250);
- Four other more minor Ordinary Watercourses, three of which will need to be crossed (approximate chainages CH230, CH720 and CH3950) and one adjacent to the proposed route. These are labelled as Watercourses 1 to 4 on Figure 16.1 of the ES;
- Burton Brook (Ordinary Watercourse), which is not crossed or culverted but is located within 800 m of the proposed scheme to the southeast; and
- Various ponds and still waters including a series of small lakes within the Melton Country Park that are online with Scalford Brook, and a number of offline ponds within the Twinlakes Theme Park.

Descriptions of the watercourses that are directly crossed by the proposed scheme are provided below and illustrated on Figure 16.1 of the ES (please refer to Chapter 16 of the Environmental Statement and the WFD Assessment for further information):

River Eye - The largest watercourse in the study area is the River Eye, which is a Main River and is designated under the Water Framework Directive (WFD) as 'Eye/Wreake from Langham Brook to Soar' (GB104028047550) within the Humber River Basin District (although WFD objectives apply to all tributaries within the catchment). The designated waterbody extends from Stapleford to the east of Melton Mowbray, and flows in an approximately westerly direction through the middle of Melton Mowbray, and on to Asfordby and then southwest to its confluence with the River Soar at Rothley (NGR SK 59557 12729).

The Environment Agency's Catchment Explorer website indicates that the 'Eye/Wreake from Langham Brook to Soar' is not designated as an artificial or heavily modified water body. It is 38.67 km in length and drains a catchment of 98.08 km^2. The water body is currently of Poor Ecological Status (from Moderate in 2009) but is at Good Chemical Status. Water vole and otter are known to be present. The River Eye at the point where it would cross the channel is a SSSI for which Natural England published a strategic restoration plan in 2015. The SSSI is designated for the Eye's characteristics as an exceptional example of a semi-natural lowland river, and covers 13.65 ha and 7.5 km between Stapleford and Melton Mowbray, which is approximately 40% of the total river length. The SSSI designation is mapped for the river channel only, but the channel should not be considered in any way separate from the floodplain.

At the point of the proposed road crossing of the river the floodplain is extensive, and the land use upstream and downstream (for at least 500 m) is agricultural with no residential or other property. The area benefits from the protection afforded by the upstream Brentingby Dam, which regulates flow through Melton Mowbray.

The SSSI designations and reasons for non-improvement for the River Eye include commentary that biological and chemical General Quality Assessment (GQA) targets have largely been met, except for phosphates, which are noted to be decreasing. Suspended solids targets are reported to have been met, but site observations suggest that this could still be a significant issue with cost effective catchment improvements still possible. The citation states that the river profile target has not been met due to over-dredging and impoundment. There is an ongoing issue with siltation which is exacerbated by the lack of flow and in channel structures, which impede the river's hydrological functioning. Water quality of the River Eye is being addressed, but the physical character of the river channel needs to be restored to secure good ecological and hydrological functioning. There are numerous Active Discharge Consents to the River Eye, mainly relating to storm sewage discharge and domestic sewage treatment systems.

Thorpe Brook - Thorpe Brook is crossed by the Proposed Development north of Thorpe Arnold. It rises to the west of Waltham on the Wolds and flows in a generally southwest direction to meet the River Eye at the eastern edge of Melton Mowbray (NGR SK 76137 18835). Thorpe Brook is an Ordinary Watercourse at the point of crossing, not becoming a Main River until west of Thorpe Arnold just upstream of the A607.

Thorpe Brook is designated as a WFD water body (although WFD objectives apply to all tributaries within the catchment) and is part of the Humber River Basin District (GB104028047590). The Environment Agency's Catchment Data Explorer website states that the watercourse is 9.704 km in length with a 15.775 km^2 catchment area and is not heavily modified. The waterbody is currently at Moderate Ecological Status (and was also

Moderate in 2009) but at Good Chemical Status. At the point of the proposed crossing the channel has been straightened and deepened, presumably to benefit commercial use (agriculture, both arable and pastoral) of the adjacent floodplain. It is set in a tree-lined riparian corridor with fenced riparian buffer strips, which gives some marginal and riparian diversity. The floodplain upstream and downstream of the proposed road crossing is predominantly agricultural with no residential or other property, but becomes more built up downstream at Thorpe Arnold. There is an Active Discharge Consent to Thorpe Brook for secondary treated sewage and trade effluent upstream of the proposed crossing point, at Twinlakes Theme Park.

Biological monitoring data and water quality data for Thorpe Brook suggest that it is impacted to some extent by excess nutrients, and is most probably a result of the surrounding agriculture (predominantly inorganic phosphate based fertilisers applied to arable fields), although the discharge consent information indicates that sewerage discharges may also play a role.

Scalford Brook – The Proposed Development crossed Scalford Brook just north of Melton Country Park. It rises to the north of Wycomb at Goadby Hall Farm and flows generally south through Scalford and continuing to meet the River Eye in the centre of Melton Mowbray (SK 75864 18808). Scalford Brook is an Ordinary Watercourse at the current point that the new road will cross the channel, but does become a Main River from its crossing of the dismantled railways line near Melton Country Park to its discharge into the River Eye.

The watercourse is designated under the WFD (although WFD objectives apply to all tributaries within the catchment) and is part of the Humber River Basin District (GB104028047600). The Environment Agency's Catchment Explorer website states that Scalford Brook is 9.574 km in length, drains a catchment 23.926 km^2 in area, and is not heavily modified. The waterbody is currently at Poor Ecological Status (having been at Good status in 2009) but is meeting Good Chemical Status. Scalford Brook as observed at the proposed crossing location is a Main River with a catchment area of approximately 20 km^2 and a channel bank full width of approximately 2.5-3 m.

Similarly to the River Eye and Thorpe Brook, the floodplain of Scalford Brook in the vicinity of the point of crossing is agricultural with no known property close by. Immediately downstream of the crossing the Scalford Brook flows through an undersized pipe culvert beneath a historic railway that provides a partial barrier to land to the south and east. The watercourse is set in a tree-lined riparian corridor which gives some boundary diversity, although the riparian zones, and flow, sediment and floodplain continuity, are all cut-off by the culvert. Downstream of the historic railway line is the Melton Mowbray Country Park which includes online lakes including the Scalford Brook Flood Storage Reservoir. Further downstream the land use is more urbanised.

Biological monitoring data and water quality data for Scalford Brook suggest that it is impacted to some extent by excess nutrients, and as with Thorpe Brook and the River Eye this is most probably a result of the surrounding agriculture, with fertiliser application to the arable fields. There are no known active discharge consents to Scalford Brook.

Watercourse 2 - Lag Lane Tributary of the Eye – This watercourse rises at Melton Mowbray golf club and flows generally in a southwest direction to pass Thorpe Arnold on its eastern side, before continuing south to meet the River Eye just south of Saxby Road (where it is culverted). Its total length is approximately 2 km. The watercourse will be crossed by the proposed Scheme to the east of Thorpe Arnold, in an area of agricultural land. The watercourse is not designated as Main River. There are two active discharge consents located on Watercourse 2 which are for discharge of treated sewage effluent. Water quality data indicates agricultural pressures causing elevated nutrients and high concentrations of certain metals, which are likely to be derived from the nearby A607.

Watercourse 3 – Sysonby Lodge Upper West Arm – This watercourse rises north of Sysonby Farm at the northwest extent of Melton Mowbray. The watercourse flows generally south and will be intersected by the proposed Scheme at Syonsby Farm to the east of the A606 Nottingham Road, where the surrounding floodplain consists of agricultural land. The watercourse then flows south into Melton Mowbray. From Ordnance Survey maps it then appears to flow below ground to meet the River Eye. It is not designated as Main River. Geology maps and surface topography suggest that a spring would be situated approximately 1 km upstream of the crossing. At the location of the proposed crossing the watercourse is essentially a drainage ditch with heavily incised banks, and is overgrown with hedgerow vegetation. No active discharge consents have been identified along this watercourse. Water quality data for the watercourse indicate agricultural pressures causing elevated nutrients and high concentrations of certain metals, which are likely to be derived from the nearby A606.

Watercourse 4 – Sysonby Lodge – This watercourse is a tributary of Watercourse 3 and rises at Great Framlands to the north of Melton Mowbray town. It flows south to meet the unnamed watercourse NE of Sysonby

Farm south of Sysonby Lodge. It has a total length of approximately 1 km. The proposed Scheme will cross the watercourse to the northwest of John Fernerley College in an area of agricultural land. It is not designated as Main River. The catchment area upstream of the proposed crossing is approximately 0.5 km^2, and naturally this would be a small, spring-fed headwater stream developed in head deposits of clay, silt, sand and gravel. The spring is approximately 250 m upstream. The surface watercourse appears to be highly modified for agricultural drainage, as an enlarged channel, contaminated by fine sediment and most likely diffuse agricultural pollutants. It is an ephemeral channel and has been observed to be dry on numerous site visits, and so no water quality data is available. No active discharge consents have been identified along this watercourse.

Flood Risk

A FRA is provided in Appendix 16.4 of the ES and assesses the present risk of flooding from all sources including fluvial, tidal, surface water, groundwater, artificial sources and sewer and water supply infrastructure. Please refer to the FRA in Appendix 16.4 for a full description of the flood risk baseline, and to Figure 16.1 for the Environment Agency's indicative flood zones and the location of the Scalford Brook Flood Storage Reservoir.

Tidal Flood Risk - Due to the distance from the coast the proposed route is located outside of the tidal influence and as such is not considered to be at risk of flooding from this source.

Fluvial Flood Risk - The majority of the proposed route is located within Flood Zone 1 and is therefore considered to have a low risk of flooding. Flood Zone 1 comprises land assessed as having a less than 1 in 1000 year, or <0.1% Annual Exceedance Probability (AEP) of fluvial or tidal flooding in any given year. However, where the route crosses the River Eye, Thorpe Brook and Scalford Brook it passes through areas of Flood Zone 2 and 3. Flood Zone 2 is an area of medium risk and is defined as Land having between a 1 in 100 (1% AEP) and 1 in 1,000 (0.1% AEP) annual probability of river flooding or land having between a 1 in 200 (0.5% AEP) and 1 in 1,000 (0.1% AEP) annual probability of sea flooding. Flood Zone 3 is an area of higher risk and is divided into Flood Zone 3a (i.e. Land having a 1 in 100 or greater annual probability of river flooding or land having a 1 in 200 (0.5% AEP) or greater annual probability of sea flooding) and Flood Zone 3b (land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency).

River Eye (Main River) - The proposed crossing location is such that the highway would intersect Flood Zones 2 and 3, including Flood Zone 3b (Functional Floodplain). However, the proposed route alignment takes the highway through an area shown to benefit from flood defences which is afforded a 1% AEP standard of protection as a result of the Melton Mowbray Flood Alleviation Scheme (FAS) at Brentingby located approximately 250 m upstream of the existing Lag Lane Bridge. To achieve a comprehensive understanding of flood risk posed by River Eye to its immediate surroundings in the vicinity of the proposed MMDR, AECOM has undertaken an update to the existing hydraulic modelling of the current channel conditions.

In the 1% AEP event (1 in 100 Year Return Period), the hydraulic model results indicate that River Eye does not overtop its banks, which can be attributed to the presence of the Brentingby Dam upstream. However, localised flooding of the Lag Lane and Saxby Road junction is shown to occur from the existing culvert that joins the Lag Lane watercourse to the River Eye (Please refer to Figure 3-1 in the FRA).

In the 1% AEP + 50% Climate Change event (1 in 100 Year + 50% CC), the floodplain along the River Eye is inundated (Please refer to Figure 3-2 in the FRA); the modelled maximum peak water level in the River Eye immediately upstream of the proposed highway is 73.8 mAOD (this flood level was taken from the 2D modelled flood elevation in the vicinity of the bridge).

Thorpe Brook - At the point where the crossing occurs, Thorpe Brook is shown to be in Flood Zones 2 and 3 by The Environment Agency Flood Map for Planning, but doesn't exist in the supplied Environment Agency River Wreake model flood outlines. The Environment Agency confirmed that the Ordinary Watercourse had been mapped based on broadscale (flood spreading) modelling methodology. The National Flood Zone 3 outline GIS layer confirmed that the width of the floodplain in this area, based on the broadscale modelling, is approximately 100m. Since the accuracy of broadscale modelling is limited, and the source of Digitial Terrain Model (DTM) data used to undertake the modelling is unknown, we consider that these outlines have a high level of uncertainty.

Scalford Brook - The Environment Agency Flood Map for Planning shows that where the proposed route crosses Scalford Brook the proposed development will be located within Flood Zones 2 and 3. As with Thorpe Brook, the crossing is shown to be in Flood Zone 3 but doesn't exist in the supplied Environment Agency's River Wreake model flood outlines.

Approximately 400 m south of the proposed location of the Scalford Brook crossing is a small Flood Storage Area (FSA). The Scalford Brook Dam flood retention facility was completed in 1990 to control the rate of discharge into Melton Town centre and offer a 1% AEP standard of protection.

Other Ordinary Watercourses (Watercourses 2, 3 and 4) - Environment Agency Indicative Flood Zones are not available for Watercourses 2, 3 and 4. They are not covered by Environment Agency flood mapping due to the small catchment area. The Lag Lane tributary of the River Eye (Watercourse 2 on Figure 16.1) has been included in the River Eye hydraulic modelling. The baseline model shows that the risk of flooding from Lag Lane Watercourse is moderate in the vicinity of the existing Lag Lane /Saxby Road junction.

Surface Water Flood Risk - The proposed MMDR route is entirely on undeveloped (greenfield) land currently used for agricultural purposes. The Environment Agency Surface Water Flood Risk map indicates that the risk to the highway alignment is generally classed as 'Very Low'. Very Low chance of surface water flooding means that there is a less than 1 in 1000 (<0.1%) annual probability of flooding in any given year. There are areas of increased flood risk identified along the route, ranging from 'Low' (Between 1 in 100 and 1 in 1000 (1% - 0.1%) annual probability of flooding in any given year) to 'High' (greater than 1 in 30 (>3.3%) Annual Probability of Flooding in any given year). However, it is noted that these are associated with the watercourses that cross the study area and as such the current risk of flooding from surface water is typically low, with small areas of Medium and High risk associated with these crossings.

Flooding from Artificial Sources – *Reservoirs* - According to the Reservoirs Act 1975 (as amended) both the Scalford Brook Reservoir and the Brentingby Flood Storage Reservoir that are located along the route alignment are classed as reservoirs due to the volume of water that they have the capacity to store. The Environment Agency Risk of Flooding from Reservoirs Map indicates that the proposed MMDR is located within the maximum extent of flooding from reservoirs at the location of the River Eye crossing.

Flooding from reservoirs is extremely difficult to predict as it may happen with little or no warning, and evacuation will need to be undertaken immediately. Whilst the risk of flooding from reservoirs is considered unlikely due to their highly regulated nature and strict maintenance controls, the Environment Agency mapping shows a credible worst case scenario. Due to the nature of the development, the risk of flooding from this source would have a lower impact than if considering a residential development, for example, whilst a residual risk of flooding remains, the risk of flooding from this source is considered to be low.

Other Artificial Water Bodies - Two large artificial boating lakes are located approximately 120 m to the north east of the proposed route in the location of the proposed Thorpe Brook crossing. These lakes are part of Twinlakes Theme Park and are assumed to be highly regulated waterbodies with controlled inflow / outfall and with limited, or no, connectivity to local river systems. As such the risk of flooding from these lakes is considered to be low.

The proposed route passes through the northern extent of Melton Country Park where a series of online small lakes form a small Flood Storage Area. These ponds are permanently wetted areas with a flood defence bund at the downstream extent to retain water during high flow events. At present the storage area is not considered to have an impact on the highway alignment.

No other artificial waterbodies, including canals, have been identified in the vicinity of the proposed route alignment.

Based on the information above the risk of flooding form artificial sources (reservoirs, canals, lakes) is considered to be low.

Flooding from Groundwater - The underlying geology of the study area is discussed in detail in Chapter 9 Soils and Geology of the Environmental Statement. The bedrock geology across the alignment is mudstone (Blue Lias Formation and Charmouth Mudstone Formation), overlain by superficial geology of predominantly alluvium associate with the River Eye, Thorpe Brook and Scalford Brook with Glaciofluvial deposits (sand and gravel), Head deposits (clay, silt, sand and gravel) and Glaciolacustrine deposits (clay, silt and sand).

The Environment Agency groundwater maps confirm that the route alignment is not located over a Principal aquifer. The superficial geology is classified as a Secondary aquifer (undifferentiated). Due to the variable characteristics of the rock type in this area these aquifers are characterised by either permeable layers capable of supporting water supplies at a local (as opposed to strategic) scale and in some cases form an important source of base flow to rivers, or lower permeability layers which may store or yield limited amounts of groundwater due to localised features (e.g. fissures, thin permeable horizons and weathering).

The Environment Agency's national Areas Susceptible to Groundwater Flooding (AStGWF) dataset provides the basis for assessing future flood risk from groundwater. Section 3.5 of the FRA discusses the evidence reported in the local Strategic Flood Risk Assessment and Preliminary Flood Risk Assessment. This shows that the northern part of the proposed alignment, from Thorpe Arnold, is located in an area where the Susceptibility to Groundwater Flooding is less than 25%. The southern part of the route, south of Thorpe Arnold through Brentingby, is shown to have a greater than 25% but less than 50% susceptibility to groundwater flooding. In addition the PFRA states that groundwater rebound is not believed to be an issue within the county.

Based on the adoption of appropriate mitigation strategies the risk of flooding from groundwater emergence at this site is considered to be low.

Flooding from Sewers and Water Supply Infrastructure - Section 3.6 of the FRA describes known sewer flooding events with reference to the DG5 registers provided by Severn Trent Water when the local Strategic Flood Risk Assessment and Preliminary Flood Risk Assessment were prepared. None of the locations reported are within the study area. It is however, important to note that the DG5 is a record of past incidents and is not a record of properties at risk of sewer flooding. During the MMDR public exhibition event some local residents reported flooding along a drain adjacent to Freeby Close. However, this is remote from the proposed development and it will not impact the flow along this drain. Overall, given the rural nature of the route alignment, the current risk from sewers and drains is considered to be low.

3. Surface Water Drainage Proposals

The principles used in the design of the surface water drainage system for Melton Mowbray Distributor Road are set out below. The drainage flow paths, proposed pond layouts and locations and outfall locations are shown in the accompanying drawings, 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0001 to 0007 contained in Appendix 5. Typical highway cross section drawings 60542201-ACM-HML-S1-ML_M01_Z-DR-T-0001 to 0005 which include proposed drainage details are also contained in Appendix 5. Previous correspondence with Leicestershire County Council regarding the surface water drainage proposals are contained in Appendix 3.

3.1 Carriageway Drainage Methods

Due to the high groundwater levels in the area of the proposed road, combined surface water and groundwater filter drains are to be used to drain the main carriageway and protect the road pavement from groundwater ingress. On its south/west side the main carriageway will be kerbed due to the presence of a cycleway/footway. This side of the carriageway will therefore be drained with gullies outfalling to combined ground and surface water filter drains under the footway/cycleway. Over any particularly flat areas of road where use of gullies becomes uneconomic they will be replaced with combined kerb and gully units draining to the combined ground and surface water filter drains.

When in cutting the footway / cycleway will fall towards the carriageway and drain into the carriageway gullies. When on embankment the footway / cycleway will fall away from the carriageway and be allowed to drain down the embankment slope (i.e. over the edge).

On the north / east side of the road there is no kerb so the carriageway will drain straight into the combined ground and surface water filter drains.

Where wide cutting slopes are proposed on the south / west side of the road an additional filter drain will be provided at the bottom of the slopes to capture the cutting runoff and prevent high flows running across the footway / cycleway. For relatively narrow cutting slopes the runoff will be allowed to flow across the footway / cycleway and into the carriageway gullies.

On higher embankments the combined surface water and groundwater filter drains on the kerbed side of the road could be replaced with a carrier pipe and separate fin/narrow filter drain system. Where combined surface water and groundwater filter drains are used on higher embankments they will have an impermeable geotextile backing and base to prevent washout of water from the drains through the sides of the embankment.

At the roundabout junctions the carriageway will be kerbed and hence will be drained by gullies or combined kerb and gully units in flatter areas, draining to carrier pipes.

Swales were considered as an alternative to the use of combined ground and surface water filter drains but have not been proposed for carriageway drainage for the following reasons:

- The kerbed footway/ cycleway on the south / west side of the road prevents their use here.
- Space limitations.
- On previous schemes we have been involved in swales have become an 'eyesore' due to a tendency for litter and sediment to collect within them, partly due to difficulties in cleaning them.
- Concerns regarding overrunning/parking vehicles causing rutting in the swales and causing localised water ponding and safety issues.
- Concerns over ponding/drainage inefficiencies caused by swale outfall chambers ending up slightly higher than adjacent swale due to settlement/compaction of bottom of swale during maintenance or vehicle overrun.

The drainage pipes will be designed for the Design Manual for Roads & Bridges (DMRB) criteria of no surcharging for 1 in 1 year storms and no surcharging above base of pavement levels in filter drains or above cover levels for carrier drains for a 1 in 5 year storm. Furthermore the drainage system will be designed to meet the Sewers for Adoption criteria of no flooding for a 1 in 30 year storm. To ensure compliance with the Non-Statutory Technical Standards for SuDS criteria S7, S8 and S9 the system will also be designed to ensure no flooding of sensitive areas such as buildings or utility plant susceptible to flooding for a 1 in 100 year storm.

Gully spacings will be designed to DMRB HA 102 using a 0.75 m design breadth of flow for a 1 in 5 year return period storm as the road is more rural than urban, a separate cycleway is provided for cyclists and cyclists and pedestrians will be separated from the edge of the carriageway by a 0.5 m wide verge/separation strip.

3.2 Pond Design

Due to the volume of attenuation required this will be provided with the use of balancing ponds. To provide maximum environmental benefit these will be wet ponds with permanently wet sections varying in depth from 0.5 m to 1.5 m. The locations and preliminary layouts for the balancing ponds are shown on the accompanying drawings, 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0001 to 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0007.

The ponds have been designed to accommodate a 1 in 100 year storm with 40% allowance for climate change as per the requirements of Leicestershire County Council's Flood Risk Management team. Inflow to the ponds has been based on 100% runoff from impermeable areas and 20% runoff from permeable areas. The areas contributing to each drainage network and its associated pond are shown in the table below. For initial pond sizing it has been conservatively assumed that all contributing areas are currently permeable and therefore will only be contributing greenfield runoff to watercourses at present.

Pond	Contributing Impermeable Area (Ha)	Contributing Permeable Area (Ha)	Total Contributing Area (Ha)	Total Contributing Equivalent Impermeable Area (Ha)
A	1.111	1.068	2.179	1.325
I	0.841	0.811	1.652	1.003
B	0.812	0.236	1.048	0.859
C	0.594	2.307	2.901	1.055
D1	1.355	1.500	2.855	1.655
D2	0.678	0.275	0.952	0.732
E	0.391	0.112	0.503	0.413
F	1.867	2.862	4.729	2.440
G	0.379	0.061	0.440	0.391
H	2.371	2.455	4.825	2.861

Discharge from the ponds will be at greenfield runoff rates to nearby watercourses as shown on the drawings. Greenfield runoff rates have been calculated using both the Institute of Hydrology 50Ha Method and the Flood Studies Report Method and the lowest rate of the two used, which was the IoH50 result in all cases. The calculated rates are shown in the table below.

Pond	Calculated Greenfield Runoff Rate (l/s)	Calculated Greenfield Runoff Rate (l/s/Ha)
A	22	10.1
I	16	9.7
B	10	9.5
C	29	10.0
D1	28	9.8
D2	9	9.5
E	5	9.9
F	47	9.9
G	4	9.1
H	48	9.9

Spreadsheet output showing the greenfield runoff calculations are included in Appendix 2. Micro Drainage output showing the pond sizing input values and sizing results are also included in Appendix 2.

The ponds are currently sized based on no infiltration occurring but infiltration tests have recently been carried out as part of the ground investigation at or near to pond locations so we can assess the suitability of the ground for having an infiltration basin as part of the pond layouts. If ground conditions and ground water levels are shown to be suitable we will incorporate infiltration within the ponds. Preliminary results indicate however that ground conditions are unsuitable for the use of infiltration.

The ponds have been designed taking into account best practice guidance to optimise their treatment potential. Measures include:

- Allowance has been made within the pond design for a sediment forebay sized at 10% of the total pond size and separated from it by baffles or earthworks berms to prevent pollution loadings to the main ponds.
- Ponds are currently designed to have wet ponds with depths that range at each pond from 0.5m at the upstream end to between 1 and 1.5 m at the downstream end with 1 in 4 side slopes.
- A 2 m wide vegetation shelf has been allowed for at the edge of the wet ponds.
- The depths of the attenuation provision above the wet ponds ranges from 0.5 m to 1.0 m for the different ponds with 1 in 4 side slopes and a 300 mm freeboard allowance.
- Outfalls from the ponds to the receiving watercourse will be in the form of shallow ditches rather than pipes to avoid the need for construction of concrete headwalls at the existing watercourses.
- A 3.5 m maintenance track has been allowed for around the edge of each pond. A 1m strip has been allowed for around the outside edge of the maintenance tracks for protective planting and/or fencing.

The ponds have also been located such that they are out of the flood zones 2/3 of the adjacent watercourses except for Ponds F and G at the River Eye where the width of the Flood Zone 3 makes this impractical and the ponds have been moved as far as possible to the edges of the flood zone.

Flooding Checks for Ordinary Watercourses adjacent to Ponds

For the Ordinary Watercourses adjacent to Ponds A, I and E no flood zone is shown on flood mapping however this may be because flood modelling has never been carried out for these watercourses. To ensure that flooding

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from these watercourses will not affect the functioning of the ponds an assessment was carried out to establish the risk of flooding in these areas. The methodology and findings of this exercise are summarised below.

The watercourses were evaluated for a peak flow calculated using either the ADAS or IOH 124 method, as appropriate for the catchment area in accordance with HA 106/04 Drainage of Runoff from Natural Catchments and then factored up for a 1 in 100 year return period plus climate change. The catchment areas were determined from 1:25,000 scale Ordnance Survey plans. The capacity of the watercourses was assessed from cross sections taken in the vicinity of the proposed ponds, as part of the topographical survey. The peak flow was compared with the capacity of the narrowest section and provided this was contained within the channel no further action was taken. Where the channel capacity was exceeded other sections were inspected to determine whether or not this was an isolated issue. Where flows exceeded the channel capacity the extent of potential flooding was estimated by inspection. The outputs from spreadsheet calculations of peak flows and depths of flow in the watercourses, and watercourse cross sections are contained in Appendix 1.

The watercourses adjacent to Pond A and I were found to contain the 1 in 100 year peak flow with climate change but not at Pond E. The peak flow at Pond E exceeded the channel capacity at the narrowest section and only marginally at another section downstream, both on the same side as the pond side. Inspection of the cross-sections and contours indicates there is a slight depression beside the watercourse and localised flooding would occur. Part of Pond E extends into this slight depression and consequently there is a risk that this flooding could impact on the pond. However this can and will be easily mitigated, with a low bund, typically 0.5m high, around the affected part of the pond.

3.3 Preliminary Level Design

In order to ensure feasibility of a gravity fed drainage system a preliminary level design of the drainage system has been carried out. Appendix 4 contains calculations showing a check on the workability of levels between key points on each of the ten drainage networks that form the highway drainage system; the key points being from the low point on the road adjacent to the ponds, to the pond inlets and outlets and then to the outfalls to the existing watercourses.

3.4 Water Quality / Treatment

As described above the Proposed Development will drain highway runoff through nine outfalls, discharging to River Eye, Scalford Brook, Thorpe Brook, Watercourse 2, Watercourse 3 and Watercourse 4. The water quality / treatment proposals consist of trapped gullies and/or filter drains, catchpits and wet ponds with separate sediment forebays. Our design currently also allows for provision of oil separators and penstocks (that can be closed in the event of a large chemical spillage) upstream of the ponds.

The efficiency of the treatment proposals has been assessed to determine whether they sufficiently reduced environmental risk to the receiving waterbodies, following guidance in DMRB HD45/09 Road Drainage and the Water Environment, DMRB 103/06 Vegetated Drainage Systems for Highway Runoff and DMRB HD33/16 Design of Highway Drainage Systems. The Highways Agency's Water Risk Assessment Tool (HAWRAT) was developed for this purpose and the methodology behind it has been derived from a collaborative research programme undertaken by the Highways Agency and Environment Agency, which investigated the effects of routine road runoff on receiving waters and their ecology. It specifically assesses the probable impact of routine road runoff in terms of pollution from dissolved metals (notably copper and zinc) and sediment-bound pollutants (e.g. hydrocarbons).

An assessment of the potential impact to water resources from routine runoff was undertaken following Method A from HD45/09. The efficiency of treatment measures was included in the assessment and was based on the efficiencies described in DMRB HD33/16 Design of Highway Drainage Systems. For example, wet ponds are expected to have a treatment efficiency of 60% for chronic sediment impact and 40% for removal of dissolved copper. However, professional judgement was used when attributing a treatment performance taking account of the sits specific design of each pond and how 'optimised' this is with regards to the best practice design described in the DMRB's HA103/06.

The results of the quantitative assessment indicated that with the inclusion of the proposed mitigation measures all outfalls pass the assessment for acute and long term metal impact and chronic sediment-bound pollutant impact from routine road runoff to the receiving watercourses. No adverse impacts would be anticipated for any of the surface watercourses. Where outfalls discharge to the same watercourse within 1 km of each other, they require assessment for cumulative impacts. This is the case for outfalls to the River Eye, which also passed the cumulative assessment with inclusion of the proposed treatment measures.

The risk of a serious road traffic accident that could lead to a serious water pollution incident occurring was assessed using Method D of HD45/09. This method combines various risk factors, including the volume of traffic flows in a 24 hour period, the percentage of heavy goods vehicles, and the risk attributed to different types of road to determine the probability of an accident resulting in a serious pollution incident. The acceptable standard is measured as a return period with 1 in 100 years the minimum threshold for non-sensitive water environments, increasing to 1 in 50 years for sensitive receptors (e.g. SSSIs such as the River Eye). In all cases, the proposed treatment measures are sufficient for the spillage risk to be deemed acceptable.

The drainage designs have allowed for provision of bypass oil interceptors and penstocks upstream of the ponds. HAWRAT tests have shown that these are not strictly necessary on any of the outfalls, however we have allowed for potential provision of them should they be requested by the relevant consultees.

3.5 Side Roads

Where side roads are being realigned and they fall towards the new link road the drainage from the realigned sections will connect into the mainline drainage system.

Where side roads are being realigned and they fall away from the new link road the drainage from the realigned sections will outfall into the existing side road drainage system but we will ensure that there is no increase in overall flows in the existing system. Where the existing side road drainage system consists of over the edge drainage with no piped network this system will be retained for the realigned sections falling away from the new link road.

Preliminary estimates of changes in impermeable areas draining to existing side road drainage systems have been made and show a decrease in all cases. The additional and removed areas for each side road are shown in the table below.

Side Road	Impermeable Area Removed (Ha)	Impermeable Area Added (Ha)	Difference in Impermeable Area (Ha)
A606 Nottingham Road	0.361	0.083	-0.277
Scalford Road	0.364	0.031	-0.333
Melton Spinney Road	0.521	0.062	-0.459
A607	0.289	0.068	-0.221
B676 Saxby Road	0.282	0.061	-0.221
A606 Melton Road	0.280	0.000	-0.280

3.6 Earthworks Drainage

Where adjacent land falls towards the proposed road earthworks drainage will be provided at the top of cutting slopes and bottom of embankments either in the form of filter drains or ditches to collect and convey overland flow to nearby watercourses.

Wherever possible, and in most cases, the earthworks drainage system will be kept completely separate from the carriageway drainage system and will have separate outfalls to nearby watercourses, or if feasible to the new outfall ditches from the ponds, to reduce the number of new outfalls to existing watercourses This is in accordance with consultation with statutory consultees. However, an exercise has been undertaken to consider where highway and land drainage outfalls can be combined downstream of the ponds, which will likely be possible at two locations. In total 13 new outfalls will likely be required, of which there will be 11 dedicated outfalls to local watercourses.

Indicative earthworks drainage provision lines and directions of overland surface flow arrows are shown on the accompanying drawings, 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0001 to 60542201-ACM-VOL-SEC_TYP_ID_D-DR-RO-0007.

3.7 Backfilling of Existing Ditches

A minor ditch beneath roundabout number 1 is proposed to be backfilled as far as proposed pond A. This ditch appears to provide an overflow from the existing slurry pits and potentially drain water from the existing farm buildings/hardstanding, all of which will be removed. Earthworks drainage ditches / pipes will be provided on the north side of the proposed road in this area, immediately to the north of the ditch to be backfilled, and these will pick up any overland flow in the vicinity. As a further mitigation measure the existing ditch will be backfilled with granular material to provide a drainage pathway to the pond/watercourse although it is considered that this will not be necessary as all surface and groundwater flows in the area will be picked up by the highway drainage system.

If any additional small ordinary watercourses/ditches affected by the road are discovered during the course of the detailed design they will be treated as appropriate to their particular circumstances and in agreement with Leicestershire County Council's Flood Team. Wherever viable the current routing of these watercourses will be maintained by conveying them under the proposed road in appropriately sized pipes and/or granular material.

3.8 Construction Phase Effects

Chapter 16 of the ES discusses the potential risks from construction works in detail including mitigation measures. The following is a summary of this assessment.

The risk of significant, acute pollution to watercourses is greatest during the construction stages of the project, particularly works within and adjacent to water bodies. Examples of the potential adverse effects that may arise during construction include:

- Impacts on surface water quality due to deposition or spillage of soils, sediments, oils, fuels, or other construction chemicals, or through mobilisation of contamination following disturbance of contaminated ground or groundwater, or through uncontrolled site run-off;
- Potential changes in on-site and off-site flood risk due to changes in the volume, rate and flow of surface water runoff from the construction site;
- Construction activities such as earth works, excavations, site preparation, levelling and grading operations resulting in the disturbance of soils. Exposed soil is more vulnerable to erosion during rainfall events due to loosening and removal of vegetation to bind it, compaction and increased runoff rates. Surface runoff from such areas can contain excessive quantities of fine sediment, which may eventually be transported to watercourses where it can result in adverse impacts on water quality, flora and fauna. Construction works within, along the banks and across watercourses can also be a direct source of fine sediment mobilisation;
- Contamination of surface waters, groundwater and soil could result from leakage and spills of fuels, oils, chemicals and concrete during construction affecting watercourses indirectly via site runoff or directly where works are close to and within a water body. Contamination may reduce water quality and impact aquatic fauna and flora; and
- Any construction works that impede on the floodplain have the potential to increase rate and volume of runoff, and increase risk of blockages in watercourses that could lead to flow being impeded, and a potential rise in flood risk. Earthworks may also alter flow pathways and the compaction of the ground and vegetation clearance will also increase the rate and volume of runoff.

To mitigate these risks a Construction Environmental Management Plan (CEMP) would be developed by the Contractor. The CEMP would be reviewed, revised and updated once the project progresses towards construction to ensure all potential impacts and effects are summarised and minimised by proposed mitigation as far as practicable in keeping with best practice at that point in time and compliance with the Environmental Statement. The principles of mitigation are the minimum standards that the Contractor would be required to meet with regards to protection of the water environment.

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The CEMP would include a Water Management Plan (WMP) as a technical appendix that would provide site specific information of how the risks to the water environment from potential pollution and the risk of physical damage will be managed. These measures require Contractor input and thus the WMP would not be developed until during the detailed design phase and pre-construction planning period. However, the CEMP does describe the principles of what will be delivered and the broad approaches that may be adopted by the Contractor to deliver the required protection. An Emergency Response Plan would also be prepared and included in the CEMP.

Relevant Consents

Prior to commencing works it will be necessary to apply for the relevant consents, including:

- Under the Environmental Permitting (England and Wales) Regulations 2016 an Environmental Permit (flood risk activity) is required from the Environment Agency if a regulated activity is to be undertaken on or near a Main River, on or near a flood defence structure, or in a flood plain, and exemptions do not apply. This includes any activity within 8 m of the bank of a main river, flood defence structure or culvert on a main river, or activities carried out on the floodplain of a main river, more than 8m from the river bank, culvert or flood defence structure if you do not have planning permission;
- An Environment Permit may also be required for the discharge to surface waters or ground of any unclean construction site runoff, again where exemptions do not apply. However, local highways authorities do not require permission from the Environment Agency to discharge runoff from highways to Controlled Waters (i.e. all watercourses, canals, lakes, groundwater etc.) under the Highways Act 1980 providing water pollution does not occur;
- For diverting the River Eye it may be necessary to apply for a full water abstraction licence or a transfer licence from the Environment Agency under the Water Resources Act 1991 (as amended). Under the same legislation, it may also be necessary to obtain an impoundment license for any temporary or permanent structures that can permanently or temporarily change the water level of flow along Main Rivers. This includes dams, sluices, penstocks and retaining walls, and is most likely to apply to the temporary works. Consultation with the National Permitting Service will be required to understand the licences that are required; and
- Land drainage consent will be required from Leicestershire County Council (LCC) as the lead Local Flood Authority (LLFA) for certain works that may affect the flow in Ordinary Watercourses (i.e. all other watercourses that are not Main Rivers) under The Floods and Water Management Act 2010 and The Land Drainage Act 1991.

Water Quality Monitoring

In advance of any construction works, a programme of pre-construction water quality monitoring will be required to augment existing data and to provide a robust baseline against which changes in water quality during construction works can be compared. This monitoring should include regular monthly (as a minimum) visits to all watercourses and major water bodies that could be impacted by the Proposed Development for the collection of visual and olfactory observation, in situ monitoring and water samples for laboratory analysis.

During construction it is proposed to undertake further water quality monitoring to ensure that mitigation measures are operating as planned and preventing pollution. The purpose of the monitoring programme will also be to ensure that should pollution occur it is identified as quickly as possible and appropriate action is taken in line with the Emergency Response Plan. Although regular site visits to all water bodies that may be affected should be continued (as in the pre-construction monitoring), it is expected that daily observations by the Environmental Management / Environmental Clerk of Works will be carried out while works are ongoing that may cause impact, together with ad hoc sampling as required or in response to signs of pollution (e.g. as part of an investigation).

It is anticipated that post completion of the works water quality monitoring will continue to verify that the works have been completed without adversely affecting water quality. The monitoring period is to be confirmed but should be a minimum of three months and at least three water samples from each water body.

It is important following completion of the improvement scheme that there is a requirement for regular inspection and maintenance of the drainage systems and culverts. This would be carried out in accordance with good practice guidance. Information regarding the maintenance regime will be provided in Operation and Maintenance manuals. Systems will be designed in accordance with current guidance to ensure that the potential for siltation and blockages is minimised under normal operation.

The maintenance regime for ponds, culverts and road drainage networks will be identified to reduce the residual risk from failure or improper function of the drainage system due to blockages. This risk of flooding can also be alleviated during design by improving the existing drainage system where impermeable areas are increased.

Appendix 1 Ordinary Watercourse Flooding Check Calculations

Project	Melton Mowbray	AECOM	
Subject	Pond A Flow Estimation	Job No	60542201
Prepared by:	Lewis Bacon	Date	10/09/2018
Checked by:	David Carribine	Revision	A

Catchment parameters

HA 71/95 App D	SOIL				
	Proportion of catchment covered by soil class	S1			
		S2			
		S3			
		S4		1.000	
		S5			
	Proportion of catchment covered by water or pavement	Su		0.000	
HA 106/04 App A		SAAR		700	
		AREA		0.359	km²
		W		860.000	m
		Z		27.000	m
	Regional Growth Factor	F_{75}		3.20	
	Return	1 in	100	200	yrs
	Climate change	%	40	40	%
Fig D4 Ciria 168	Regional Growth Factor	F	3.56	4.19	
	ADAS		**0.842**	**0.991**	m³/s
	IOH50ha		**0.786**	**0.925**	m³/s
	IOH		**0.815**	**0.959**	m³/s

Project	**Melton Mowbray**		
Subject	**Channel capacity at Pond A - Cross section SF2**	Job No	**60542201**
Prepared by:	**Lewis Bacon**	Date	**10/09/2018**
Checked by:	**David Carribine**	Revision	**A**

AECOM

Calculation of channel flow for a range of depths

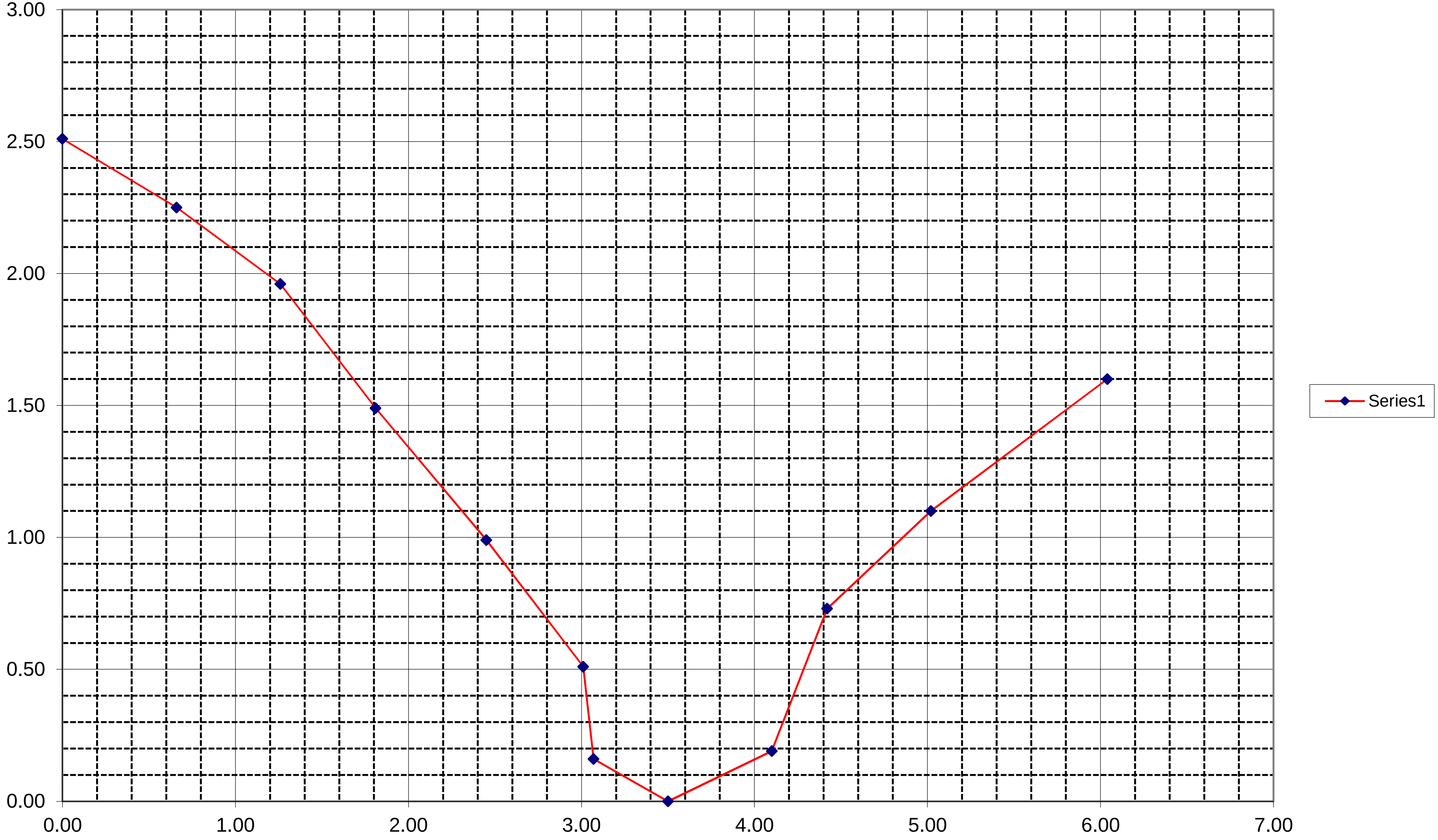
Channel characteristics

Upstream bed level =	0		
Downstream bed level =	0		
Length =	0		
Slope S =	#DIV/0!	0.033	(value used)
1/S =		30.303	
Manning's n =	0.08		
Starting depth of flow =	0.2		
Depth of flow increment =	0.1		

Channel profile

Point	X	Y
A	0.00	2.51
B	0.66	2.25
C	1.26	1.96
D	1.81	1.49
E	2.45	0.99
F	3.01	0.51
G	3.07	0.16
H	3.50	0.00
I	4.10	0.19
J	4.42	0.73
K	5.02	1.10
L	6.04	1.60

Depth of flow	width of flow	Xsect area	wetted perimeter	Q	v
0.20	1.043	0.115	1.140	0.056	0.491
0.30	1.119	0.223	1.358	0.152	0.681
0.40	1.196	0.339	1.576	0.276	0.815
0.50	1.272	0.462	1.793	0.425	0.919
0.60	1.438	0.597	2.058	0.594	0.995
0.70	1.614	0.750	2.328	0.800	1.067
0.80	1.862	0.922	2.650	1.036	1.124
0.90	2.141	1.122	2.994	1.325	1.181
1.00	2.421	1.350	3.339	1.677	1.242
1.10	2.711	1.607	3.692	2.096	1.304
1.20	3.043	1.895	4.082	2.579	1.361
1.30	3.375	2.216	4.471	3.150	1.422
1.40	3.707	2.570	4.861	3.815	1.485
1.50	4.038	2.957	5.250	4.579	1.549
1.60	4.359	3.377	5.631	5.453	1.615
1.70	4.476	3.819	5.785	6.573	1.721
1.80	4.593	4.272	5.939	7.788	1.823
1.90	4.710	4.737	6.093	9.095	1.920
2.00	4.863	5.215	6.277	10.464	2.007
2.10	5.070	5.711	6.507	11.889	2.082
2.20	5.277	6.229	6.737	13.423	2.155
2.30	5.507	6.767	6.988	15.041	2.223
2.40	5.761	7.331	7.261	16.752	2.285
2.50	6.015	7.919	7.534	18.591	2.348
2.60	6.040	8.523	7.561	20.963	2.460
2.70	6.040	9.127	7.561	23.497	2.574
2.80	6.040	9.731	7.561	26.145	2.687
2.90	6.040	10.335	7.561	28.906	2.797
3.00	6.040	10.939	7.561	31.776	2.905
3.10	6.040	11.543	7.561	34.753	3.011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Project	Melton Mowbray	AECOM	
Subject	Pond E Flow Estimation	Job No	60542201
Prepared by:	Lewis Bacon	Date	10/09/2018
Checked by:	David Carribine	Revision	A

Catchment parameters

HA 71/95 App D	SOIL				
	Proportion of catchment covered by soil class	S1			
		S2			
		S3			
		S4		1.000	
		S5			
	Proportion of catchment covered by water or pavement	Su		0.000	
HA 106/04 App A		SAAR		700	
		AREA		1.490	km²
		W		267.000	m
		Z		14.000	m
	Regional Growth Factor	F_{75}		3.20	
	Return	1 in	100	200	yrs
	Climate change	%	40	40	%
Fig D4 Ciria 168	Regional Growth Factor	F	3.56	4.19	
	ADAS		**5.571**	**6.557**	m³/s
	IOH50ha		**3.262**	**3.840**	m³/s
	IOH		**2.893**	**3.405**	m³/s

Project	Melton Mowbray	AECOM	
Subject	Channel capacity at Pond E - Cross section LL1	Job No	60542201
Prepared by:	Lewis Bacon	Date	10/09/2018
Checked by:	David Carribine	Revision	A

Calculation of channel flow for a range of depths

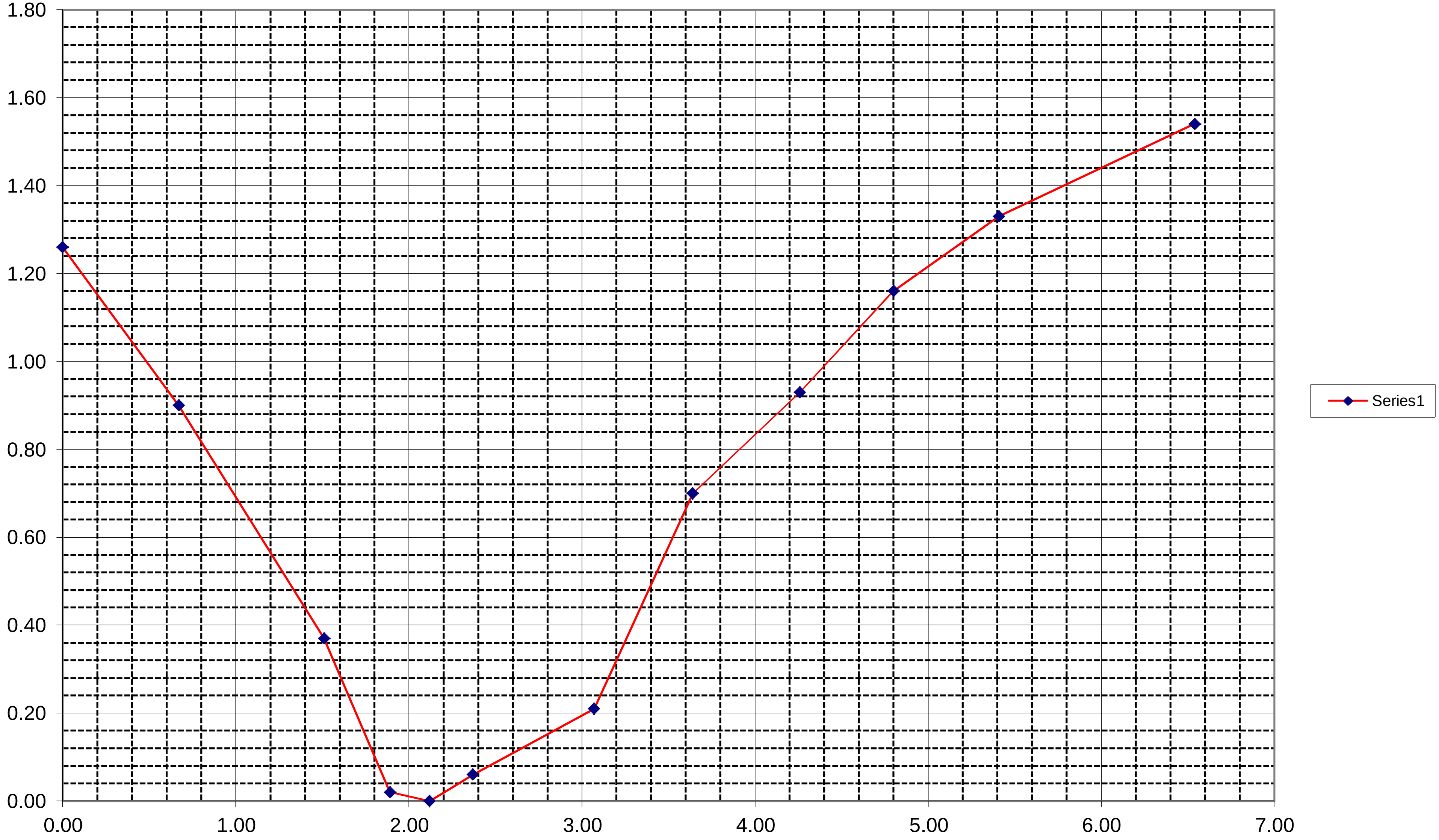
Channel characteristics

Upstream bed level =	0		
Downstream bed level =	0		
Length =	0		
Slope S =	#DIV/0!	0.012	(value used)
1/S =		83.3333	
Manning's n =	0.08		
Starting depth of flow =	1		
Depth of flow increment =	0.05		

Channel profile

Point	X	Y
A	0.00	1.26
B	0.67	0.90
C	1.51	0.37
D	1.89	0.02
E	2.12	0.00
F	2.37	0.06
G	3.07	0.21
H	3.64	0.70
I	4.26	0.93
J	4.80	1.16
K	5.41	1.33
L	6.54	1.54

Depth of flow	width of flow	Xsect area	wetted perimeter	Q	v
1.00	3.940	2.129	4.517	1.765	0.829
1.05	4.151	2.331	4.750	1.986	0.852
1.10	4.361	2.544	4.983	2.225	0.875
1.15	4.572	2.767	5.216	2.483	0.897
1.20	4.832	3.002	5.496	2.746	0.915
1.25	5.104	3.250	5.788	3.029	0.932
1.30	5.302	3.511	5.996	3.365	0.958
1.35	5.518	3.781	6.217	3.716	0.983
1.40	5.787	4.063	6.491	4.072	1.002
1.45	6.056	4.359	6.764	4.454	1.022
1.50	6.325	4.669	7.038	4.863	1.042
1.55	6.540	4.992	7.257	5.326	1.067
1.60	6.540	5.319	7.257	5.920	1.113
1.65	6.540	5.646	7.257	6.539	1.158
1.70	6.540	5.973	7.257	7.183	1.203
1.75	6.540	6.300	7.257	7.850	1.246
1.80	6.540	6.627	7.257	8.541	1.289
1.85	6.540	6.954	7.257	9.255	1.331
1.90	6.540	7.281	7.257	9.991	1.372
1.95	6.540	7.608	7.257	10.750	1.413
2.00	6.540	7.935	7.257	11.531	1.453
2.05	6.540	8.262	7.257	12.334	1.493
2.10	6.540	8.589	7.257	13.159	1.532
2.15	6.540	8.916	7.257	14.004	1.571
2.20	6.540	9.243	7.257	14.871	1.609
2.25	6.540	9.570	7.257	15.758	1.647
2.30	6.540	9.897	7.257	16.665	1.684
2.35	6.540	10.224	7.257	17.593	1.721
2.40	6.540	10.551	7.257	18.541	1.757
2.45	6.540	10.878	7.257	19.509	1.793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Project	Melton Mowbray	AECOM
Subject	**Channel capacity at Pond E - Cross section LL2**	Job No **60542201**
Prepared by:	**Lewis Bacon**	Date **10/09/2018**
Checked by:	**David Carribine**	Revision **A**

Calculation of channel flow for a range of depths

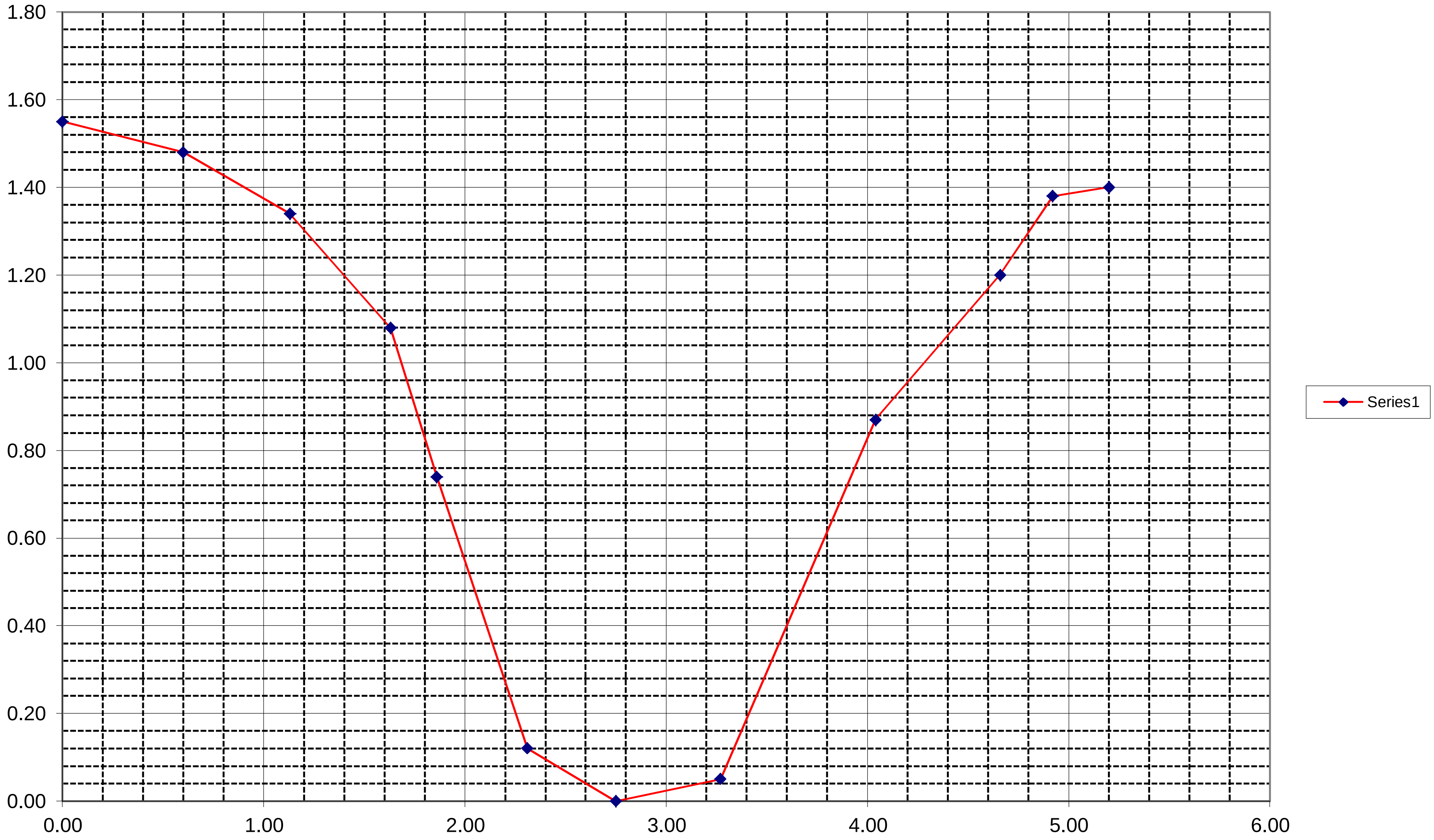
Channel characteristics

Upstream bed level =	0		
Downstream bed level =	0		
Length =	0		
Slope S =	#DIV/0!	0.012	(value used)
1/S =		83.3333	
Manning's n =	0.08		
Starting depth of flow =	0.2		
Depth of flow increment =	0.1		

Channel profile

Point	X	Y
A	0.00	1.55
B	0.60	1.48
C	1.13	1.34
D	1.63	1.08
E	1.86	0.74
F	2.31	0.12
G	2.75	0.00
H	3.27	0.05
I	4.04	0.87
J	4.66	1.20
K	4.92	1.38
L	5.20	1.40

Depth of flow	width of flow	Xsect area	wetted perimeter	Q	v
0.20	1.159	0.165	1.283	0.058	0.350
0.30	1.325	0.290	1.544	0.130	0.449
0.40	1.492	0.431	1.805	0.227	0.527
0.50	1.658	0.588	2.065	0.349	0.593
0.60	1.825	0.762	2.326	0.496	0.651
0.70	1.991	0.953	2.587	0.671	0.704
0.80	2.155	1.160	2.846	0.874	0.753
0.90	2.345	1.384	3.126	1.101	0.796
1.00	2.600	1.632	3.460	1.354	0.830
1.10	2.881	1.905	3.813	1.642	0.862
1.20	3.261	2.212	4.242	1.962	0.887
1.30	3.598	2.555	4.635	2.352	0.921
1.40	4.297	2.937	5.378	2.687	0.915
1.50	4.771	3.387	5.864	3.216	0.950
1.60	5.200	3.896	6.295	3.874	0.994
1.70	5.200	4.416	6.295	4.774	1.081
1.80	5.200	4.936	6.295	5.747	1.164
1.90	5.200	5.456	6.295	6.791	1.245
2.00	5.200	5.976	6.295	7.904	1.323
2.10	5.200	6.496	6.295	9.083	1.398
2.20	5.200	7.016	6.295	10.327	1.472
2.30	5.200	7.536	6.295	11.634	1.544
2.40	5.200	8.056	6.295	13.003	1.614
2.50	5.200	8.576	6.295	14.431	1.683
2.60	5.200	9.096	6.295	15.919	1.750
2.70	5.200	9.616	6.295	17.465	1.816
2.80	5.200	10.136	6.295	19.067	1.881
2.90	5.200	10.656	6.295	20.725	1.945
3.00	5.200	11.176	6.295	22.438	2.008
3.10	5.200	11.696	6.295	24.205	2.069



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Project	Melton Mowbray	AECOM
Subject	**Channel capacity at Pond E - Cross section LL3**	Job No **60542201**
Prepared by:	**Lewis Bacon**	Date **10/09/2018**
Checked by:	**David Carribine**	Revision **A**

Calculation of channel flow for a range of depths

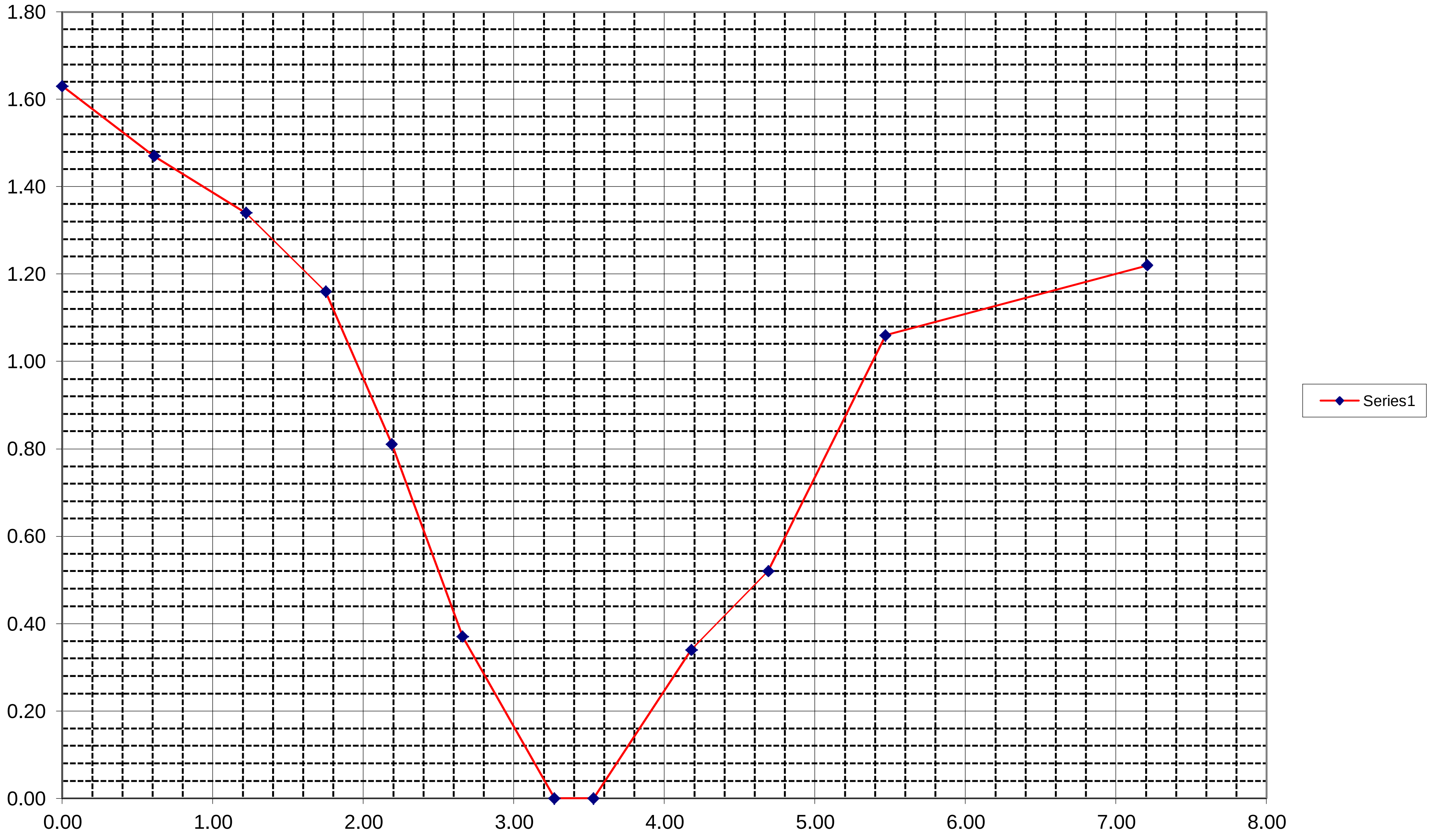
Channel characteristics

Upstream bed level =	0		
Downstream bed level =	0		
Length =	0		
Slope S =	#DIV/0!	0.012	(value used)
1/S =		83.3333	
Manning's n =	0.08		
Starting depth of flow =	1		
Depth of flow increment =	0.05		

Channel profile

Point	X	Y
A	0.00	1.63
B	0.61	1.47
C	1.22	1.34
D	1.75	1.16
E	2.19	0.81
F	2.66	0.37
G	3.27	0.00
H	3.53	0.00
I	4.18	0.34
J	4.69	0.52
K	5.47	1.06
L	7.21	1.22

Depth of flow	width of flow	Xsect area	wetted perimeter	Q	v
1.00	3.432	1.969	4.040	1.670	0.848
1.05	3.567	2.144	4.208	1.873	0.874
1.10	4.080	2.333	4.743	1.991	0.853
1.15	4.686	2.553	5.369	2.129	0.834
1.20	5.360	2.803	6.056	2.297	0.819
1.25	5.725	3.084	6.430	2.587	0.839
1.30	5.872	3.374	6.585	2.958	0.877
1.35	6.037	3.671	6.758	3.347	0.912
1.40	6.272	3.979	6.997	3.739	0.940
1.45	6.506	4.298	7.237	4.158	0.967
1.50	6.714	4.629	7.452	4.615	0.997
1.55	6.905	4.970	7.649	5.105	1.027
1.60	7.096	5.320	7.846	5.622	1.057
1.65	7.210	5.678	7.964	6.206	1.093
1.70	7.210	6.039	7.964	6.876	1.139
1.75	7.210	6.399	7.964	7.574	1.184
1.80	7.210	6.760	7.964	8.298	1.228
1.85	7.210	7.120	7.964	9.049	1.271
1.90	7.210	7.481	7.964	9.825	1.313
1.95	7.210	7.841	7.964	10.627	1.355
2.00	7.210	8.202	7.964	11.453	1.396
2.05	7.210	8.562	7.964	12.305	1.437
2.10	7.210	8.923	7.964	13.180	1.477
2.15	7.210	9.283	7.964	14.079	1.517
2.20	7.210	9.644	7.964	15.002	1.556
2.25	7.210	10.004	7.964	15.949	1.594
2.30	7.210	10.365	7.964	16.918	1.632
2.35	7.210	10.725	7.964	17.910	1.670
2.40	7.210	11.086	7.964	18.925	1.707
2.45	7.210	11.446	7.964	19.961	1.744



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Series1

Project	Melton Mowbray	AECOM	
Subject	Pond I Flow Estimation	Job No	60542201
Prepared by:	Lewis Bacon	Date	10/09/2018
Checked by:	David Carribine	Revision	A

Catchment parameters

HA 71/95 App D	SOIL				
	Proportion of catchment covered by soil class	S1			
		S2			
		S3			
		S4		1.000	
		S5			
	Proportion of catchment covered by water or pavement	Su		0.000	
HA 106/04 App A		SAAR		700	
		AREA		0.423	km²
		W		693.000	m
		Z		28.000	m
	Regional Growth Factor	F_{75}		3.20	
	Return	1 in	100	200	yrs
	Climate change	%	40	40	%
Fig D4 Ciria 168	Regional Growth Factor	F	3.56	4.19	
	ADAS		**1.130**	**1.329**	m³/s
	IOH50ha		**0.926**	**1.090**	m³/s
	IOH		**0.943**	**1.110**	m³/s

Project	Melton Mowbray	AECOM	
Subject	**Channel capacity at Pond I - Cross section SL3**	Job No	**60542201**
Prepared by:	**Lewis Bacon**	Date	**10/09/2018**
Checked by:	**David Carribine**	Revision	**A**

Calculation of channel flow for a range of depths

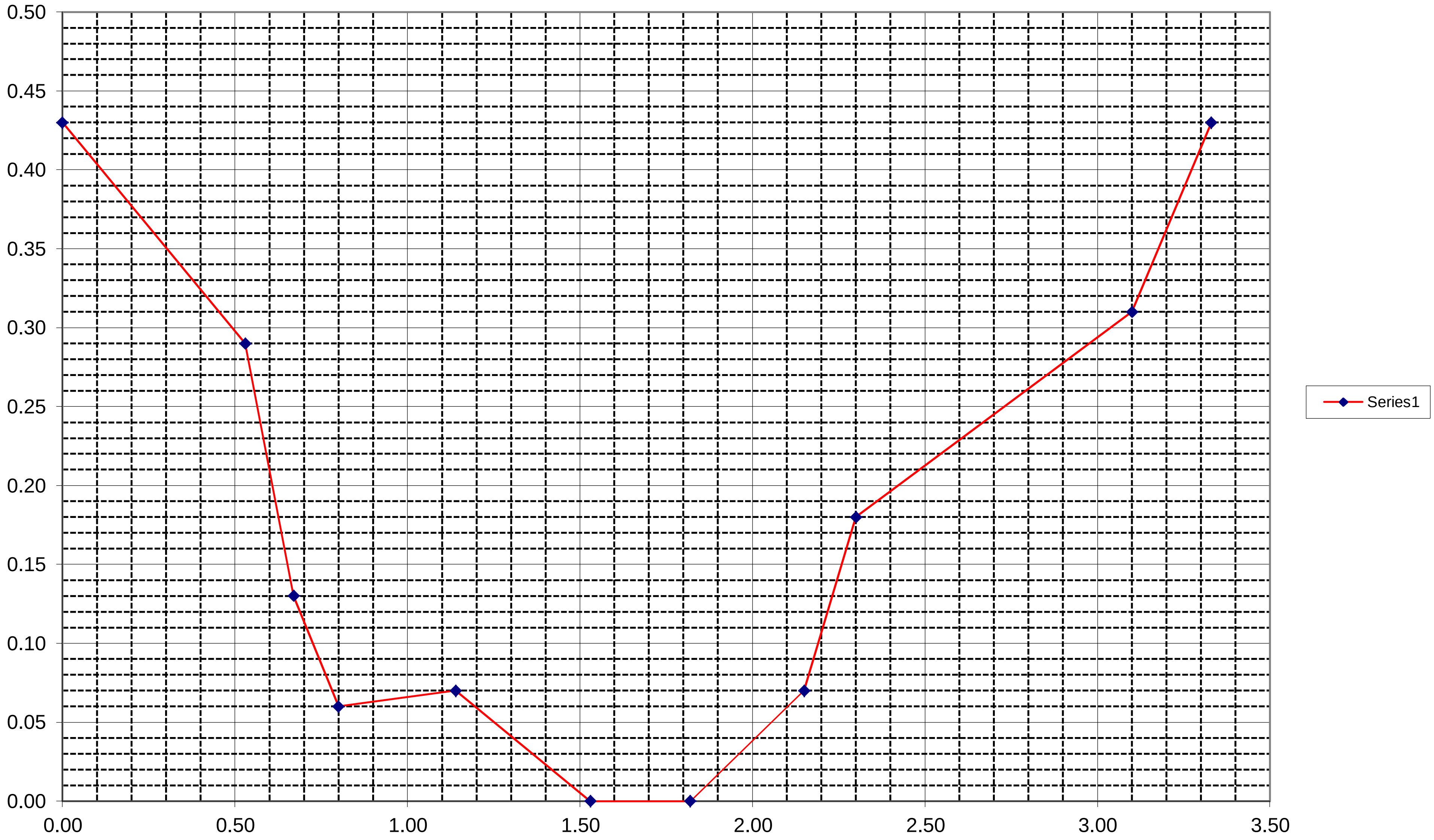
Channel characteristics

Upstream bed level =	0		
Downstream bed level =	0		
Length =	0		
Slope S =	#DIV/0!	0.023	(value used)
1/S =		43.4783	
Manning's n =	0.014		
Starting depth of flow =	0.1		
Depth of flow increment =	0.01		

Channel profile

Point	X	Y
A	0.00	0.43
B	0.53	0.29
C	0.67	0.13
D	0.80	0.06
E	1.14	0.07
F	1.53	0.00
G	1.82	0.00
H	2.15	0.07
I	2.30	0.18
J	3.10	0.31
K	3.33	0.43
L		

Depth of flow	width of flow	Xsect area	wetted perimeter	Q	v
0.10	2.240	0.129	2.280	0.205	1.593
0.11	2.349	0.151	2.396	0.260	1.719
0.12	2.459	0.176	2.512	0.323	1.838
0.13	2.569	0.201	2.628	0.391	1.950
0.14	2.668	0.227	2.736	0.467	2.060
0.15	2.768	0.254	2.844	0.550	2.164
0.16	2.868	0.282	2.953	0.639	2.264
0.17	2.968	0.311	3.061	0.735	2.361
0.18	3.068	0.342	3.169	0.838	2.453
0.19	3.215	0.373	3.323	0.940	2.521
0.20	3.363	0.406	3.477	1.050	2.587
0.21	3.511	0.440	3.631	1.168	2.654
0.22	3.659	0.476	3.784	1.295	2.720
0.23	3.806	0.513	3.938	1.430	2.785
0.24	3.954	0.552	4.092	1.574	2.850
0.25	4.102	0.592	4.245	1.727	2.915
0.26	4.250	0.634	4.399	1.889	2.978
0.27	4.397	0.677	4.553	2.061	3.042
0.28	4.545	0.722	4.707	2.242	3.105
0.29	4.693	0.768	4.860	2.434	3.167
0.30	4.870	0.816	5.040	2.627	3.218
0.31	5.046	0.866	5.219	2.831	3.270
0.32	5.181	0.917	5.358	3.061	3.339
0.33	5.315	0.969	5.497	3.302	3.407
0.34	5.450	1.023	5.636	3.554	3.473
0.35	5.584	1.078	5.775	3.816	3.539
0.36	5.719	1.135	5.914	4.090	3.604
0.37	5.853	1.193	6.053	4.375	3.668
0.38	5.988	1.252	6.191	4.672	3.732
0.39	6.122	1.313	6.330	4.981	3.795



0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
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0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Series1

Appendix 2 Greenfield Runoff & Pond Sizing Calculations

Job No	60542201	Revision	-
Project Name	Melton Mowbray		
Watercourse	Network A		
Date	24-Sep-18		

Catchment parameters

HA 71/95 App D	SOIL				
		S1			
		S2			
		S3			
		S4		1.000	
		S5			
		Su			
HA 106/04 App A		SAAR		669	
		AREA		0.022	km^2
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m^3/s
	IOH50ha		**0.022**	**0.020**	m^3/s
	IOH		**0.031**	**0.028**	m^3/s

Job No	60542201
Project Name	Melton Mowbray
Watercourse	Network B
Date	24-Sep-18
Revision	-

Catchment parameters

Reference	Parameter	Symbol		Value	Unit
HA 71/95 App D	SOIL	S1			
		S2			
		S3			
		S4		1.000	
		S5			
		Su			
HA 106/04 App A		SAAR		669	
		AREA		0.011	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.010**	**0.009**	m³/s
	IOH		**0.016**	**0.014**	m³/s

Job No	60542201
Project Name	Melton Mowbray
Watercourse	Network C
Date	24-Sep-18

Revision -

Catchment parameters

HA 71/95 App D	SOIL				
		S1 S2 S3 S4 S5 Su		1.000	
HA 106/04 App A		SAAR		669	
		AREA		0.029	km²
		W Z			m m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.029**	**0.026**	m³/s
	IOH		**0.039**	**0.036**	m³/s

Job No	60542201	Revision	-
Project Name	Melton Mowbray		
Watercourse	Network D1		
Date	20-Jul-17		

Catchment parameters

HA 71/95 App D	SOIL				
		S1			
		S2			
		S3			
		S4		1.000	
		S5			
		Su			
HA 106/04 App A		SAAR		669	
		AREA		0.029	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.028**	**0.026**	m³/s
	IOH		**0.039**	**0.035**	m³/s

Job No	60542201	Revision	-
Project Name	Melton Mowbray		
Watercourse	Network D2		
Date	20-Jul-17		

Catchment parameters

HA 71/95 App D	SOIL				
		S1 S2 S3 S4 S5 Su		1.000	
HA 106/04 App A		SAAR		669	
		AREA		0.010	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.009**	**0.009**	m³/s
	IOH		**0.015**	**0.013**	m³/s

Job No	60542201	Revision	-
Project Name	Melton Mowbray		
Watercourse	Network E		
Date	24-Sep-18		

Catchment parameters

HA 71/95 App D	SOIL				
		S1			
		S2			
		S3			
		S4		1.000	
		S5			
		Su			
HA 106/04 App A		SAAR		669	
		AREA		0.005	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.005**	**0.004**	m³/s
	IOH		**0.008**	**0.007**	m³/s

Job No	60542201	Revision	-
Project Name	Melton Mowbray		
Watercourse	Network F		
Date	24-Sep-18		

Catchment parameters

HA 71/95 App D	SOIL				
		S1			
		S2			
		S3			
		S4		1.000	
		S5			
		Su			
HA 106/04 App A		SAAR		669	
		AREA		0.047	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.047**	**0.043**	m³/s
	IOH		**0.061**	**0.055**	m³/s

Job No	60542201	Revision	-
Project Name	Melton Mowbray		
Watercourse	Network G		
Date	24-Sep-18		

Catchment parameters

HA 71/95 App D	SOIL				
		S1 S2 S3 S4 S5 Su		1.000	
HA 106/04 App A		SAAR		669	
		AREA		0.004	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.004**	**0.004**	m³/s
	IOH		**0.007**	**0.007**	m³/s

Job No	60542201		Revision	-
Project Name	Melton Mowbray			
Watercourse	Network H			
Date	20-Jul-17			

Catchment parameters

HA 71/95 App D	SOIL				
		S1 S2 S3 S4 S5 Su		1.000	
HA 106/04 App A		SAAR		669	
		AREA		0.048	km²
		W Z			m m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.048**	**0.043**	m³/s
	IOH		**0.062**	**0.056**	m³/s

Job No	60542201
Project Name	Melton Mowbray
Watercourse	Network I
Date	24-Sep-18

Revision -

Catchment parameters

HA 71/95 App D	SOIL				
		S1			
		S2			
		S3			
		S4		1.000	
		S5			
		Su			
HA 106/04 App A		SAAR		669	
		AREA		0.017	km²
		W			m
		Z			m
	Regional Growth Factor	F_{75}		1.87	
	Return	1 in	100	30	yrs
	Climate change	%	0	20	%
Fig D4 Ciria 168	Regional Growth Factor	F	2.38	1.8	
	ADAS		**#DIV/0!**	**#DIV/0!**	m³/s
	IOH50ha		**0.016**	**0.015**	m³/s
	IOH		**0.024**	**0.022**	m³/s

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.378	0.378	12.9	0.0	12.9	320.9	O K
30 min Summer	99.490	0.490	14.9	0.0	14.9	416.7	O K
60 min Summer	99.598	0.598	16.7	0.0	16.7	508.4	O K
120 min Summer	99.687	0.687	18.0	0.0	18.0	583.7	O K
180 min Summer	99.719	0.719	18.4	0.0	18.4	611.1	Flood Risk
240 min Summer	99.727	0.727	18.6	0.0	18.6	618.3	Flood Risk
360 min Summer	99.729	0.729	18.6	0.0	18.6	619.3	Flood Risk
480 min Summer	99.725	0.725	18.5	0.0	18.5	616.6	Flood Risk
600 min Summer	99.718	0.718	18.4	0.0	18.4	610.4	Flood Risk
720 min Summer	99.708	0.708	18.3	0.0	18.3	601.7	Flood Risk
960 min Summer	99.683	0.683	17.9	0.0	17.9	580.5	O K
1440 min Summer	99.628	0.628	17.1	0.0	17.1	533.7	O K
2160 min Summer	99.551	0.551	15.9	0.0	15.9	468.2	O K
2880 min Summer	99.487	0.487	14.9	0.0	14.9	413.6	O K
4320 min Summer	99.390	0.390	13.1	0.0	13.1	331.3	O K
5760 min Summer	99.322	0.322	11.7	0.0	11.7	273.9	O K
7200 min Summer	99.273	0.273	10.6	0.0	10.6	232.2	O K
8640 min Summer	99.237	0.237	9.7	0.0	9.7	201.5	O K
10080 min Summer	99.209	0.209	8.9	0.0	8.9	177.6	O K
15 min Winter	99.424	0.424	13.8	0.0	13.8	360.0	O K
30 min Winter	99.550	0.550	15.9	0.0	15.9	467.7	O K
60 min Winter	99.673	0.673	17.8	0.0	17.8	571.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	311.7	0.0	25
30 min Summer	87.778	0.0	413.4	0.0	38
60 min Summer	54.957	0.0	536.1	0.0	66
120 min Summer	33.261	0.0	650.4	0.0	124
180 min Summer	24.473	0.0	718.5	0.0	182
240 min Summer	19.572	0.0	766.5	0.0	234
360 min Summer	14.207	0.0	835.0	0.0	288
480 min Summer	11.325	0.0	887.6	0.0	352
600 min Summer	9.491	0.0	929.8	0.0	418
720 min Summer	8.212	0.0	965.3	0.0	488
960 min Summer	6.530	0.0	1022.9	0.0	624
1440 min Summer	4.720	0.0	1106.8	0.0	896
2160 min Summer	3.406	0.0	1212.5	0.0	1296
2880 min Summer	2.700	0.0	1280.6	0.0	1676
4320 min Summer	1.943	0.0	1377.1	0.0	2420
5760 min Summer	1.537	0.0	1462.7	0.0	3120
7200 min Summer	1.281	0.0	1522.7	0.0	3832
8640 min Summer	1.103	0.0	1572.0	0.0	4584
10080 min Summer	0.972	0.0	1611.1	0.0	5256
15 min Winter	133.616	0.0	350.6	0.0	25
30 min Winter	87.778	0.0	464.5	0.0	38
60 min Winter	54.957	0.0	601.4	0.0	66

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.775	0.775	19.2	0.0	19.2	658.9	Flood Risk
180 min Winter	99.815	0.815	19.7	0.0	19.7	692.6	Flood Risk
240 min Winter	99.828	0.828	19.9	0.0	19.9	703.7	Flood Risk
360 min Winter	99.823	0.823	19.8	0.0	19.8	699.2	Flood Risk
480 min Winter	99.816	0.816	19.7	0.0	19.7	693.5	Flood Risk
600 min Winter	99.803	0.803	19.6	0.0	19.6	682.3	Flood Risk
720 min Winter	99.786	0.786	19.3	0.0	19.3	667.7	Flood Risk
960 min Winter	99.746	0.746	18.8	0.0	18.8	634.0	Flood Risk
1440 min Winter	99.663	0.663	17.7	0.0	17.7	563.7	O K
2160 min Winter	99.554	0.554	16.0	0.0	16.0	471.0	O K
2880 min Winter	99.467	0.467	14.5	0.0	14.5	397.3	O K
4320 min Winter	99.346	0.346	12.2	0.0	12.2	293.9	O K
5760 min Winter	99.268	0.268	10.5	0.0	10.5	228.2	O K
7200 min Winter	99.217	0.217	9.2	0.0	9.2	184.7	O K
8640 min Winter	99.182	0.182	8.1	0.0	8.1	154.9	O K
10080 min Winter	99.158	0.158	7.3	0.0	7.3	134.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	729.4	0.0	122
180 min Winter	24.473	0.0	805.6	0.0	178
240 min Winter	19.572	0.0	859.4	0.0	234
360 min Winter	14.207	0.0	936.2	0.0	304
480 min Winter	11.325	0.0	995.1	0.0	372
600 min Winter	9.491	0.0	1042.4	0.0	450
720 min Winter	8.212	0.0	1082.1	0.0	526
960 min Winter	6.530	0.0	1146.7	0.0	676
1440 min Winter	4.720	0.0	1240.7	0.0	960
2160 min Winter	3.406	0.0	1358.6	0.0	1368
2880 min Winter	2.700	0.0	1435.0	0.0	1760
4320 min Winter	1.943	0.0	1544.1	0.0	2508
5760 min Winter	1.537	0.0	1638.7	0.0	3232
7200 min Winter	1.281	0.0	1706.0	0.0	3960
8640 min Winter	1.103	0.0	1761.6	0.0	4600
10080 min Winter	0.972	0.0	1806.5	0.0	5336

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.325

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.547	4	8	0.547	8	12	0.231

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.263	0.263	6.0	0.0	6.0	210.0	O K
30 min Summer	99.342	0.342	7.0	0.0	7.0	273.5	O K
60 min Summer	99.420	0.420	7.8	0.0	7.8	336.2	Flood Risk
120 min Summer	99.490	0.490	8.5	0.0	8.5	391.9	Flood Risk
180 min Summer	99.521	0.521	8.8	0.0	8.8	416.7	Flood Risk
240 min Summer	99.535	0.535	8.9	0.0	8.9	428.1	Flood Risk
360 min Summer	99.542	0.542	9.0	0.0	9.0	433.2	Flood Risk
480 min Summer	99.543	0.543	9.0	0.0	9.0	434.1	Flood Risk
600 min Summer	99.541	0.541	9.0	0.0	9.0	433.1	Flood Risk
720 min Summer	99.539	0.539	9.0	0.0	9.0	430.9	Flood Risk
960 min Summer	99.529	0.529	8.9	0.0	8.9	423.4	Flood Risk
1440 min Summer	99.503	0.503	8.7	0.0	8.7	402.5	Flood Risk
2160 min Summer	99.460	0.460	8.2	0.0	8.2	367.8	Flood Risk
2880 min Summer	99.419	0.419	7.8	0.0	7.8	335.5	Flood Risk
4320 min Summer	99.352	0.352	7.1	0.0	7.1	281.7	Flood Risk
5760 min Summer	99.301	0.301	6.5	0.0	6.5	240.9	O K
7200 min Summer	99.262	0.262	6.0	0.0	6.0	209.4	O K
8640 min Summer	99.231	0.231	5.6	0.0	5.6	184.5	O K
10080 min Summer	99.206	0.206	5.2	0.0	5.2	164.5	O K
15 min Winter	99.294	0.294	6.4	0.0	6.4	235.5	O K
30 min Winter	99.384	0.384	7.5	0.0	7.5	306.9	Flood Risk
60 min Winter	99.472	0.472	8.4	0.0	8.4	377.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	193.7	0.0	26
30 min Summer	87.778	0.0	257.5	0.0	39
60 min Summer	54.957	0.0	342.9	0.0	68
120 min Summer	33.261	0.0	416.5	0.0	126
180 min Summer	24.473	0.0	460.3	0.0	184
240 min Summer	19.572	0.0	491.1	0.0	242
360 min Summer	14.207	0.0	535.0	0.0	340
480 min Summer	11.325	0.0	568.5	0.0	394
600 min Summer	9.491	0.0	595.4	0.0	456
720 min Summer	8.212	0.0	617.8	0.0	520
960 min Summer	6.530	0.0	653.9	0.0	656
1440 min Summer	4.720	0.0	704.8	0.0	928
2160 min Summer	3.406	0.0	782.9	0.0	1340
2880 min Summer	2.700	0.0	826.5	0.0	1732
4320 min Summer	1.943	0.0	887.9	0.0	2508
5760 min Summer	1.537	0.0	946.9	0.0	3232
7200 min Summer	1.281	0.0	985.5	0.0	3968
8640 min Summer	1.103	0.0	1016.7	0.0	4672
10080 min Summer	0.972	0.0	1040.9	0.0	5440
15 min Winter	133.616	0.0	218.2	0.0	25
30 min Winter	87.778	0.0	289.4	0.0	39
60 min Winter	54.957	0.0	385.0	0.0	66

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.552	0.552	9.1	0.0	9.1	441.3	Flood Risk
180 min Winter	99.588	0.588	9.4	0.0	9.4	470.5	Flood Risk
240 min Winter	99.606	0.606	9.6	0.0	9.6	484.7	Flood Risk
360 min Winter	99.617	0.617	9.7	0.0	9.7	493.3	Flood Risk
480 min Winter	99.614	0.614	9.6	0.0	9.6	491.5	Flood Risk
600 min Winter	99.610	0.610	9.6	0.0	9.6	488.3	Flood Risk
720 min Winter	99.605	0.605	9.6	0.0	9.6	484.2	Flood Risk
960 min Winter	99.589	0.589	9.4	0.0	9.4	471.4	Flood Risk
1440 min Winter	99.548	0.548	9.1	0.0	9.1	438.2	Flood Risk
2160 min Winter	99.484	0.484	8.5	0.0	8.5	386.8	Flood Risk
2880 min Winter	99.426	0.426	7.9	0.0	7.9	340.9	Flood Risk
4320 min Winter	99.336	0.336	6.9	0.0	6.9	268.5	O K
5760 min Winter	99.271	0.271	6.1	0.0	6.1	217.0	O K
7200 min Winter	99.225	0.225	5.5	0.0	5.5	179.8	O K
8640 min Winter	99.190	0.190	4.9	0.0	4.9	152.2	O K
10080 min Winter	99.164	0.164	4.5	0.0	4.5	131.5	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	467.4	0.0	124
180 min Winter	24.473	0.0	516.4	0.0	180
240 min Winter	19.572	0.0	550.9	0.0	238
360 min Winter	14.207	0.0	600.0	0.0	348
480 min Winter	11.325	0.0	637.6	0.0	446
600 min Winter	9.491	0.0	667.6	0.0	478
720 min Winter	8.212	0.0	692.7	0.0	554
960 min Winter	6.530	0.0	733.0	0.0	706
1440 min Winter	4.720	0.0	789.6	0.0	1004
2160 min Winter	3.406	0.0	877.4	0.0	1432
2880 min Winter	2.700	0.0	926.4	0.0	1844
4320 min Winter	1.943	0.0	995.9	0.0	2632
5760 min Winter	1.537	0.0	1061.0	0.0	3352
7200 min Winter	1.281	0.0	1104.4	0.0	4104
8640 min Winter	1.103	0.0	1139.6	0.0	4840
10080 min Winter	0.972	0.0	1167.7	0.0	5544

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.859

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.345	4	8	0.345	8	12	0.169

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.265	0.265	15.6	0.0	15.6	254.5	O K
30 min Summer	99.341	0.341	18.3	0.0	18.3	327.3	O K
60 min Summer	99.410	0.410	20.4	0.0	20.4	393.4	O K
120 min Summer	99.457	0.457	21.8	0.0	21.8	439.0	O K
180 min Summer	99.469	0.469	22.1	0.0	22.1	450.0	O K
240 min Summer	99.472	0.472	22.2	0.0	22.2	453.5	O K
360 min Summer	99.470	0.470	22.1	0.0	22.1	451.4	O K
480 min Summer	99.463	0.463	21.9	0.0	21.9	444.4	O K
600 min Summer	99.453	0.453	21.6	0.0	21.6	434.4	O K
720 min Summer	99.441	0.441	21.3	0.0	21.3	422.9	O K
960 min Summer	99.415	0.415	20.6	0.0	20.6	398.5	O K
1440 min Summer	99.367	0.367	19.1	0.0	19.1	352.2	O K
2160 min Summer	99.309	0.309	17.2	0.0	17.2	296.4	O K
2880 min Summer	99.266	0.266	15.6	0.0	15.6	255.7	O K
4320 min Summer	99.211	0.211	13.3	0.0	13.3	202.2	O K
5760 min Summer	99.180	0.180	11.6	0.0	11.6	172.5	O K
7200 min Summer	99.161	0.161	10.0	0.0	10.0	155.0	O K
8640 min Summer	99.148	0.148	8.7	0.0	8.7	142.0	O K
10080 min Summer	99.138	0.138	7.9	0.0	7.9	132.2	O K
15 min Winter	99.297	0.297	16.8	0.0	16.8	285.3	O K
30 min Winter	99.383	0.383	19.6	0.0	19.6	367.7	O K
60 min Winter	99.461	0.461	21.9	0.0	21.9	442.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	244.9	0.0	22
30 min Summer	87.778	0.0	326.6	0.0	36
60 min Summer	54.957	0.0	425.5	0.0	64
120 min Summer	33.261	0.0	516.7	0.0	120
180 min Summer	24.473	0.0	571.1	0.0	156
240 min Summer	19.572	0.0	609.4	0.0	186
360 min Summer	14.207	0.0	664.0	0.0	252
480 min Summer	11.325	0.0	705.9	0.0	320
600 min Summer	9.491	0.0	739.6	0.0	388
720 min Summer	8.212	0.0	767.8	0.0	456
960 min Summer	6.530	0.0	813.7	0.0	590
1440 min Summer	4.720	0.0	880.4	0.0	852
2160 min Summer	3.406	0.0	964.6	0.0	1220
2880 min Summer	2.700	0.0	1018.6	0.0	1588
4320 min Summer	1.943	0.0	1094.0	0.0	2296
5760 min Summer	1.537	0.0	1164.6	0.0	3000
7200 min Summer	1.281	0.0	1212.1	0.0	3744
8640 min Summer	1.103	0.0	1250.9	0.0	4416
10080 min Summer	0.972	0.0	1281.2	0.0	5152
15 min Winter	133.616	0.0	276.2	0.0	22
30 min Winter	87.778	0.0	367.8	0.0	35
60 min Winter	54.957	0.0	477.6	0.0	64

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.518	0.518	23.4	0.0	23.4	496.9	O K
180 min Winter	99.530	0.530	23.7	0.0	23.7	509.3	O K
240 min Winter	99.531	0.531	23.7	0.0	23.7	509.3	O K
360 min Winter	99.522	0.522	23.5	0.0	23.5	501.6	O K
480 min Winter	99.507	0.507	23.1	0.0	23.1	487.2	O K
600 min Winter	99.489	0.489	22.6	0.0	22.6	469.4	O K
720 min Winter	99.469	0.469	22.1	0.0	22.1	450.6	O K
960 min Winter	99.430	0.430	21.0	0.0	21.0	413.0	O K
1440 min Winter	99.361	0.361	18.9	0.0	18.9	347.0	O K
2160 min Winter	99.285	0.285	16.3	0.0	16.3	273.9	O K
2880 min Winter	99.234	0.234	14.3	0.0	14.3	224.4	O K
4320 min Winter	99.178	0.178	11.4	0.0	11.4	170.7	O K
5760 min Winter	99.153	0.153	9.2	0.0	9.2	147.1	O K
7200 min Winter	99.137	0.137	7.8	0.0	7.8	131.4	O K
8640 min Winter	99.125	0.125	6.7	0.0	6.7	120.1	O K
10080 min Winter	99.116	0.116	6.0	0.0	6.0	111.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	579.8	0.0	118
180 min Winter	24.473	0.0	640.6	0.0	172
240 min Winter	19.572	0.0	683.5	0.0	194
360 min Winter	14.207	0.0	744.8	0.0	270
480 min Winter	11.325	0.0	791.8	0.0	346
600 min Winter	9.491	0.0	829.5	0.0	420
720 min Winter	8.212	0.0	861.2	0.0	492
960 min Winter	6.530	0.0	912.7	0.0	630
1440 min Winter	4.720	0.0	987.8	0.0	898
2160 min Winter	3.406	0.0	1081.2	0.0	1276
2880 min Winter	2.700	0.0	1141.8	0.0	1640
4320 min Winter	1.943	0.0	1227.2	0.0	2300
5760 min Winter	1.537	0.0	1304.8	0.0	3048
7200 min Winter	1.281	0.0	1358.2	0.0	3752
8640 min Winter	1.103	0.0	1402.0	0.0	4496
10080 min Winter	0.972	0.0	1437.2	0.0	5168

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.056

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.528	4	8	0.528

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.464	0.464	18.5	0.0	18.5	399.3	O K
30 min Summer	99.601	0.601	21.4	0.0	21.4	516.9	O K
60 min Summer	99.730	0.730	23.8	0.0	23.8	627.6	Flood Risk
120 min Summer	99.831	0.831	25.5	0.0	25.5	714.8	Flood Risk
180 min Summer	99.863	0.863	26.1	0.0	26.1	742.5	Flood Risk
240 min Summer	99.870	0.870	26.2	0.0	26.2	747.8	Flood Risk
360 min Summer	99.868	0.868	26.1	0.0	26.1	746.4	Flood Risk
480 min Summer	99.860	0.860	26.0	0.0	26.0	739.8	Flood Risk
600 min Summer	99.847	0.847	25.8	0.0	25.8	728.5	Flood Risk
720 min Summer	99.831	0.831	25.5	0.0	25.5	714.3	Flood Risk
960 min Summer	99.794	0.794	24.9	0.0	24.9	682.5	Flood Risk
1440 min Summer	99.717	0.717	23.6	0.0	23.6	616.9	Flood Risk
2160 min Summer	99.617	0.617	21.7	0.0	21.7	530.9	O K
2880 min Summer	99.537	0.537	20.1	0.0	20.1	462.1	O K
4320 min Summer	99.422	0.422	17.5	0.0	17.5	362.6	O K
5760 min Summer	99.343	0.343	15.5	0.0	15.5	295.4	O K
7200 min Summer	99.289	0.289	13.9	0.0	13.9	248.2	O K
8640 min Summer	99.248	0.248	12.6	0.0	12.6	213.3	O K
10080 min Summer	99.218	0.218	11.6	0.0	11.6	187.9	O K
15 min Winter	99.521	0.521	19.7	0.0	19.7	448.0	O K
30 min Winter	99.675	0.675	22.8	0.0	22.8	580.6	O K
60 min Winter	99.821	0.821	25.4	0.0	25.4	706.2	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	395.2	0.0	26
30 min Summer	87.778	0.0	523.3	0.0	40
60 min Summer	54.957	0.0	672.9	0.0	68
120 min Summer	33.261	0.0	816.0	0.0	124
180 min Summer	24.473	0.0	901.2	0.0	182
240 min Summer	19.572	0.0	961.3	0.0	216
360 min Summer	14.207	0.0	1047.1	0.0	276
480 min Summer	11.325	0.0	1112.9	0.0	342
600 min Summer	9.491	0.0	1165.9	0.0	410
720 min Summer	8.212	0.0	1210.4	0.0	478
960 min Summer	6.530	0.0	1282.8	0.0	616
1440 min Summer	4.720	0.0	1389.0	0.0	884
2160 min Summer	3.406	0.0	1516.3	0.0	1276
2880 min Summer	2.700	0.0	1601.7	0.0	1648
4320 min Summer	1.943	0.0	1723.7	0.0	2384
5760 min Summer	1.537	0.0	1828.0	0.0	3112
7200 min Summer	1.281	0.0	1903.2	0.0	3824
8640 min Summer	1.103	0.0	1965.3	0.0	4504
10080 min Summer	0.972	0.0	2015.5	0.0	5248
15 min Winter	133.616	0.0	444.2	0.0	26
30 min Winter	87.778	0.0	587.8	0.0	39
60 min Winter	54.957	0.0	754.6	0.0	68

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.940	0.940	27.3	0.0	27.3	808.0	Flood Risk
180 min Winter	99.981	0.981	27.9	0.0	27.9	843.2	Flood Risk
240 min Winter	99.989	0.989	28.0	0.0	28.0	850.9	Flood Risk
360 min Winter	99.979	0.979	27.9	0.0	27.9	841.8	Flood Risk
480 min Winter	99.964	0.964	27.7	0.0	27.7	829.2	Flood Risk
600 min Winter	99.942	0.942	27.3	0.0	27.3	809.9	Flood Risk
720 min Winter	99.915	0.915	26.9	0.0	26.9	787.0	Flood Risk
960 min Winter	99.858	0.858	26.0	0.0	26.0	737.7	Flood Risk
1440 min Winter	99.746	0.746	24.1	0.0	24.1	641.5	Flood Risk
2160 min Winter	99.607	0.607	21.5	0.0	21.5	522.2	O K
2880 min Winter	99.502	0.502	19.3	0.0	19.3	431.8	O K
4320 min Winter	99.362	0.362	16.0	0.0	16.0	310.9	O K
5760 min Winter	99.277	0.277	13.6	0.0	13.6	237.8	O K
7200 min Winter	99.222	0.222	11.7	0.0	11.7	191.2	O K
8640 min Winter	99.187	0.187	10.4	0.0	10.4	160.4	O K
10080 min Winter	99.165	0.165	9.4	0.0	9.4	142.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	914.8	0.0	122
180 min Winter	24.473	0.0	1010.2	0.0	178
240 min Winter	19.572	0.0	1077.5	0.0	232
360 min Winter	14.207	0.0	1173.6	0.0	290
480 min Winter	11.325	0.0	1247.5	0.0	366
600 min Winter	9.491	0.0	1306.8	0.0	442
720 min Winter	8.212	0.0	1356.7	0.0	518
960 min Winter	6.530	0.0	1437.9	0.0	664
1440 min Winter	4.720	0.0	1556.9	0.0	944
2160 min Winter	3.406	0.0	1698.9	0.0	1344
2880 min Winter	2.700	0.0	1794.7	0.0	1732
4320 min Winter	1.943	0.0	1932.3	0.0	2468
5760 min Winter	1.537	0.0	2047.8	0.0	3176
7200 min Winter	1.281	0.0	2132.2	0.0	3888
8640 min Winter	1.103	0.0	2202.1	0.0	4576
10080 min Winter	0.972	0.0	2259.5	0.0	5160

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.655

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.521	4	8	0.521	8	12	0.613

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.299	0.299	5.4	0.0	5.4	179.4	O K
30 min Summer	99.389	0.389	6.3	0.0	6.3	233.3	O K
60 min Summer	99.477	0.477	7.0	0.0	7.0	286.1	O K
120 min Summer	99.554	0.554	7.6	0.0	7.6	332.4	O K
180 min Summer	99.587	0.587	7.8	0.0	7.8	352.5	O K
240 min Summer	99.602	0.602	7.9	0.0	7.9	361.2	O K
360 min Summer	99.607	0.607	8.0	0.0	8.0	364.2	O K
480 min Summer	99.607	0.607	8.0	0.0	8.0	364.4	O K
600 min Summer	99.605	0.605	7.9	0.0	7.9	362.9	O K
720 min Summer	99.601	0.601	7.9	0.0	7.9	360.4	O K
960 min Summer	99.588	0.588	7.8	0.0	7.8	352.8	O K
1440 min Summer	99.555	0.555	7.6	0.0	7.6	333.2	O K
2160 min Summer	99.503	0.503	7.2	0.0	7.2	302.0	O K
2880 min Summer	99.456	0.456	6.8	0.0	6.8	273.7	O K
4320 min Summer	99.379	0.379	6.2	0.0	6.2	227.6	O K
5760 min Summer	99.322	0.322	5.6	0.0	5.6	193.2	O K
7200 min Summer	99.278	0.278	5.2	0.0	5.2	166.7	O K
8640 min Summer	99.243	0.243	4.8	0.0	4.8	146.0	O K
10080 min Summer	99.215	0.215	4.5	0.0	4.5	129.2	O K
15 min Winter	99.335	0.335	5.8	0.0	5.8	201.2	O K
30 min Winter	99.436	0.436	6.7	0.0	6.7	261.8	O K
60 min Winter	99.536	0.536	7.4	0.0	7.4	321.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	169.7	0.0	22
30 min Summer	87.778	0.0	224.8	0.0	37
60 min Summer	54.957	0.0	295.0	0.0	66
120 min Summer	33.261	0.0	357.9	0.0	124
180 min Summer	24.473	0.0	395.4	0.0	182
240 min Summer	19.572	0.0	421.8	0.0	242
360 min Summer	14.207	0.0	459.4	0.0	330
480 min Summer	11.325	0.0	488.2	0.0	386
600 min Summer	9.491	0.0	511.3	0.0	448
720 min Summer	8.212	0.0	530.7	0.0	514
960 min Summer	6.530	0.0	561.9	0.0	650
1440 min Summer	4.720	0.0	606.6	0.0	924
2160 min Summer	3.406	0.0	669.0	0.0	1324
2880 min Summer	2.700	0.0	706.5	0.0	1728
4320 min Summer	1.943	0.0	759.8	0.0	2472
5760 min Summer	1.537	0.0	807.9	0.0	3232
7200 min Summer	1.281	0.0	841.0	0.0	3960
8640 min Summer	1.103	0.0	868.0	0.0	4672
10080 min Summer	0.972	0.0	889.5	0.0	5352
15 min Winter	133.616	0.0	190.9	0.0	22
30 min Winter	87.778	0.0	252.4	0.0	36
60 min Winter	54.957	0.0	330.9	0.0	64

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.624	0.624	8.1	0.0	8.1	374.6	O K
180 min Winter	99.664	0.664	8.3	0.0	8.3	398.3	O K
240 min Winter	99.682	0.682	8.5	0.0	8.5	409.4	O K
360 min Winter	99.692	0.692	8.5	0.0	8.5	415.1	O K
480 min Winter	99.687	0.687	8.5	0.0	8.5	412.3	O K
600 min Winter	99.682	0.682	8.5	0.0	8.5	409.5	O K
720 min Winter	99.675	0.675	8.4	0.0	8.4	405.2	O K
960 min Winter	99.655	0.655	8.3	0.0	8.3	392.8	O K
1440 min Winter	99.604	0.604	7.9	0.0	7.9	362.5	O K
2160 min Winter	99.528	0.528	7.4	0.0	7.4	316.9	O K
2880 min Winter	99.462	0.462	6.9	0.0	6.9	277.0	O K
4320 min Winter	99.359	0.359	6.0	0.0	6.0	215.5	O K
5760 min Winter	99.287	0.287	5.3	0.0	5.3	172.3	O K
7200 min Winter	99.236	0.236	4.7	0.0	4.7	141.3	O K
8640 min Winter	99.198	0.198	4.2	0.0	4.2	118.6	O K
10080 min Winter	99.169	0.169	3.8	0.0	3.8	101.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	401.4	0.0	122
180 min Winter	24.473	0.0	443.3	0.0	180
240 min Winter	19.572	0.0	472.9	0.0	236
360 min Winter	14.207	0.0	515.0	0.0	346
480 min Winter	11.325	0.0	547.3	0.0	438
600 min Winter	9.491	0.0	573.2	0.0	472
720 min Winter	8.212	0.0	594.8	0.0	548
960 min Winter	6.530	0.0	629.7	0.0	702
1440 min Winter	4.720	0.0	679.5	0.0	998
2160 min Winter	3.406	0.0	749.7	0.0	1428
2880 min Winter	2.700	0.0	791.7	0.0	1824
4320 min Winter	1.943	0.0	852.0	0.0	2600
5760 min Winter	1.537	0.0	905.1	0.0	3344
7200 min Winter	1.281	0.0	942.3	0.0	4104
8640 min Winter	1.103	0.0	972.8	0.0	4760
10080 min Winter	0.972	0.0	997.5	0.0	5544

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.732

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.366	4	8	0.366

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.203	0.203	3.0	0.0	3.0	101.3	O K
30 min Summer	99.263	0.263	3.5	0.0	3.5	131.7	O K
60 min Summer	99.323	0.323	3.9	0.0	3.9	161.6	Flood Risk
120 min Summer	99.376	0.376	4.3	0.0	4.3	187.9	Flood Risk
180 min Summer	99.399	0.399	4.4	0.0	4.4	199.3	Flood Risk
240 min Summer	99.409	0.409	4.5	0.0	4.5	204.4	Flood Risk
360 min Summer	99.412	0.412	4.5	0.0	4.5	206.2	Flood Risk
480 min Summer	99.413	0.413	4.5	0.0	4.5	206.6	Flood Risk
600 min Summer	99.412	0.412	4.5	0.0	4.5	205.9	Flood Risk
720 min Summer	99.409	0.409	4.5	0.0	4.5	204.7	Flood Risk
960 min Summer	99.401	0.401	4.4	0.0	4.4	200.7	Flood Risk
1440 min Summer	99.380	0.380	4.3	0.0	4.3	190.0	Flood Risk
2160 min Summer	99.346	0.346	4.1	0.0	4.1	172.8	Flood Risk
2880 min Summer	99.314	0.314	3.9	0.0	3.9	156.9	Flood Risk
4320 min Summer	99.262	0.262	3.5	0.0	3.5	130.9	O K
5760 min Summer	99.223	0.223	3.2	0.0	3.2	111.5	O K
7200 min Summer	99.193	0.193	2.9	0.0	2.9	96.6	O K
8640 min Summer	99.170	0.170	2.7	0.0	2.7	84.9	O K
10080 min Summer	99.151	0.151	2.5	0.0	2.5	75.5	O K
15 min Winter	99.227	0.227	3.2	0.0	3.2	113.5	O K
30 min Winter	99.296	0.296	3.7	0.0	3.7	147.8	O K
60 min Winter	99.363	0.363	4.2	0.0	4.2	181.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	93.8	0.0	22
30 min Summer	87.778	0.0	124.7	0.0	37
60 min Summer	54.957	0.0	165.3	0.0	66
120 min Summer	33.261	0.0	200.7	0.0	124
180 min Summer	24.473	0.0	221.8	0.0	182
240 min Summer	19.572	0.0	236.6	0.0	242
360 min Summer	14.207	0.0	257.8	0.0	330
480 min Summer	11.325	0.0	274.0	0.0	386
600 min Summer	9.491	0.0	286.9	0.0	448
720 min Summer	8.212	0.0	297.8	0.0	512
960 min Summer	6.530	0.0	315.2	0.0	650
1440 min Summer	4.720	0.0	340.1	0.0	924
2160 min Summer	3.406	0.0	376.7	0.0	1324
2880 min Summer	2.700	0.0	397.7	0.0	1728
4320 min Summer	1.943	0.0	427.3	0.0	2472
5760 min Summer	1.537	0.0	455.4	0.0	3224
7200 min Summer	1.281	0.0	474.0	0.0	3960
8640 min Summer	1.103	0.0	489.0	0.0	4672
10080 min Summer	0.972	0.0	500.7	0.0	5352
15 min Winter	133.616	0.0	105.7	0.0	22
30 min Winter	87.778	0.0	140.2	0.0	36
60 min Winter	54.957	0.0	185.5	0.0	64

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.423	0.423	4.6	0.0	4.6	211.6	Flood Risk
180 min Winter	99.450	0.450	4.7	0.0	4.7	225.1	Flood Risk
240 min Winter	99.463	0.463	4.8	0.0	4.8	231.5	Flood Risk
360 min Winter	99.470	0.470	4.8	0.0	4.8	234.8	Flood Risk
480 min Winter	99.467	0.467	4.8	0.0	4.8	233.4	Flood Risk
600 min Winter	99.464	0.464	4.8	0.0	4.8	232.0	Flood Risk
720 min Winter	99.459	0.459	4.8	0.0	4.8	229.7	Flood Risk
960 min Winter	99.446	0.446	4.7	0.0	4.7	223.0	Flood Risk
1440 min Winter	99.412	0.412	4.5	0.0	4.5	206.2	Flood Risk
2160 min Winter	99.362	0.362	4.2	0.0	4.2	180.8	Flood Risk
2880 min Winter	99.317	0.317	3.9	0.0	3.9	158.4	Flood Risk
4320 min Winter	99.248	0.248	3.4	0.0	3.4	123.8	O K
5760 min Winter	99.199	0.199	3.0	0.0	3.0	99.5	O K
7200 min Winter	99.164	0.164	2.7	0.0	2.7	82.0	O K
8640 min Winter	99.139	0.139	2.4	0.0	2.4	69.3	O K
10080 min Winter	99.120	0.120	2.2	0.0	2.2	59.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	225.2	0.0	122
180 min Winter	24.473	0.0	248.8	0.0	180
240 min Winter	19.572	0.0	265.4	0.0	236
360 min Winter	14.207	0.0	289.1	0.0	344
480 min Winter	11.325	0.0	307.2	0.0	436
600 min Winter	9.491	0.0	321.7	0.0	472
720 min Winter	8.212	0.0	333.9	0.0	548
960 min Winter	6.530	0.0	353.4	0.0	702
1440 min Winter	4.720	0.0	381.1	0.0	998
2160 min Winter	3.406	0.0	422.2	0.0	1428
2880 min Winter	2.700	0.0	445.8	0.0	1820
4320 min Winter	1.943	0.0	479.3	0.0	2596
5760 min Winter	1.537	0.0	510.2	0.0	3344
7200 min Winter	1.281	0.0	531.1	0.0	4040
8640 min Winter	1.103	0.0	548.1	0.0	4760
10080 min Winter	0.972	0.0	561.7	0.0	5456

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.413

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.235	4	8	0.178

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.282	0.282	28.7	0.0	28.7	585.0	O K
30 min Summer	99.365	0.365	34.4	0.0	34.4	756.4	Flood Risk
60 min Summer	99.443	0.443	38.9	0.0	38.9	918.8	Flood Risk
120 min Summer	99.505	0.505	42.2	0.0	42.2	1046.9	Flood Risk
180 min Summer	99.524	0.524	43.1	0.0	43.1	1086.8	Flood Risk
240 min Summer	99.530	0.530	43.4	0.0	43.4	1099.0	Flood Risk
360 min Summer	99.532	0.532	43.6	0.0	43.6	1104.2	Flood Risk
480 min Summer	99.530	0.530	43.4	0.0	43.4	1099.1	Flood Risk
600 min Summer	99.523	0.523	43.1	0.0	43.1	1085.9	Flood Risk
720 min Summer	99.515	0.515	42.7	0.0	42.7	1068.0	Flood Risk
960 min Summer	99.494	0.494	41.7	0.0	41.7	1025.3	Flood Risk
1440 min Summer	99.450	0.450	39.3	0.0	39.3	934.2	Flood Risk
2160 min Summer	99.392	0.392	36.0	0.0	36.0	813.0	Flood Risk
2880 min Summer	99.346	0.346	33.2	0.0	33.2	717.6	Flood Risk
4320 min Summer	99.282	0.282	28.8	0.0	28.8	585.6	O K
5760 min Summer	99.245	0.245	25.4	0.0	25.4	508.0	O K
7200 min Summer	99.222	0.222	22.0	0.0	22.0	460.0	O K
8640 min Summer	99.204	0.204	19.5	0.0	19.5	423.7	O K
10080 min Summer	99.190	0.190	17.5	0.0	17.5	394.6	O K
15 min Winter	99.316	0.316	31.2	0.0	31.2	655.3	Flood Risk
30 min Winter	99.409	0.409	37.0	0.0	37.0	848.7	Flood Risk
60 min Winter	99.498	0.498	41.8	0.0	41.8	1032.9	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	536.7	0.0	32
30 min Summer	87.778	0.0	723.0	0.0	45
60 min Summer	54.957	0.0	965.9	0.0	72
120 min Summer	33.261	0.0	1175.7	0.0	126
180 min Summer	24.473	0.0	1300.5	0.0	180
240 min Summer	19.572	0.0	1388.5	0.0	206
360 min Summer	14.207	0.0	1513.8	0.0	268
480 min Summer	11.325	0.0	1609.8	0.0	336
600 min Summer	9.491	0.0	1686.8	0.0	404
720 min Summer	8.212	0.0	1751.4	0.0	472
960 min Summer	6.530	0.0	1855.9	0.0	608
1440 min Summer	4.720	0.0	2006.2	0.0	870
2160 min Summer	3.406	0.0	2218.4	0.0	1252
2880 min Summer	2.700	0.0	2340.8	0.0	1620
4320 min Summer	1.943	0.0	2507.2	0.0	2340
5760 min Summer	1.537	0.0	2684.4	0.0	3056
7200 min Summer	1.281	0.0	2792.6	0.0	3760
8640 min Summer	1.103	0.0	2879.9	0.0	4496
10080 min Summer	0.972	0.0	2943.4	0.0	5240
15 min Winter	133.616	0.0	608.1	0.0	32
30 min Winter	87.778	0.0	816.9	0.0	45
60 min Winter	54.957	0.0	1085.8	0.0	72

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.569	0.569	45.3	0.0	45.3	1181.0	Flood Risk
180 min Winter	99.593	0.593	46.5	0.0	46.5	1230.6	Flood Risk
240 min Winter	99.597	0.597	46.6	0.0	46.6	1239.3	Flood Risk
360 min Winter	99.595	0.595	46.5	0.0	46.5	1233.6	Flood Risk
480 min Winter	99.586	0.586	46.1	0.0	46.1	1215.5	Flood Risk
600 min Winter	99.572	0.572	45.5	0.0	45.5	1187.2	Flood Risk
720 min Winter	99.556	0.556	44.7	0.0	44.7	1154.0	Flood Risk
960 min Winter	99.522	0.522	43.0	0.0	43.0	1082.4	Flood Risk
1440 min Winter	99.455	0.455	39.6	0.0	39.6	944.7	Flood Risk
2160 min Winter	99.375	0.375	35.0	0.0	35.0	777.7	Flood Risk
2880 min Winter	99.316	0.316	31.2	0.0	31.2	656.0	Flood Risk
4320 min Winter	99.247	0.247	25.6	0.0	25.6	511.9	O K
5760 min Winter	99.214	0.214	20.9	0.0	20.9	443.6	O K
7200 min Winter	99.192	0.192	17.7	0.0	17.7	397.4	O K
8640 min Winter	99.175	0.175	15.4	0.0	15.4	363.7	O K
10080 min Winter	99.163	0.163	13.6	0.0	13.6	337.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	1320.8	0.0	124
180 min Winter	24.473	0.0	1460.8	0.0	178
240 min Winter	19.572	0.0	1559.4	0.0	228
360 min Winter	14.207	0.0	1699.9	0.0	284
480 min Winter	11.325	0.0	1807.6	0.0	362
600 min Winter	9.491	0.0	1894.0	0.0	436
720 min Winter	8.212	0.0	1966.4	0.0	510
960 min Winter	6.530	0.0	2083.8	0.0	652
1440 min Winter	4.720	0.0	2253.2	0.0	924
2160 min Winter	3.406	0.0	2487.5	0.0	1312
2880 min Winter	2.700	0.0	2625.2	0.0	1680
4320 min Winter	1.943	0.0	2815.0	0.0	2376
5760 min Winter	1.537	0.0	3008.5	0.0	3104
7200 min Winter	1.281	0.0	3130.3	0.0	3824
8640 min Winter	1.103	0.0	3229.3	0.0	4576
10080 min Winter	0.972	0.0	3304.0	0.0	5256

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 2.440

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.522	8	12	0.522	16	20	0.352
4	8	0.522	12	16	0.522			

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.161	0.161	2.1	0.0	2.1	96.4	O K
30 min Summer	99.210	0.210	2.4	0.0	2.4	125.8	O K
60 min Summer	99.259	0.259	2.7	0.0	2.7	155.2	O K
120 min Summer	99.304	0.304	3.0	0.0	3.0	182.5	Flood Risk
180 min Summer	99.326	0.326	3.1	0.0	3.1	195.8	Flood Risk
240 min Summer	99.338	0.338	3.2	0.0	3.2	203.0	Flood Risk
360 min Summer	99.349	0.349	3.2	0.0	3.2	209.1	Flood Risk
480 min Summer	99.351	0.351	3.2	0.0	3.2	210.5	Flood Risk
600 min Summer	99.351	0.351	3.2	0.0	3.2	210.8	Flood Risk
720 min Summer	99.351	0.351	3.2	0.0	3.2	210.6	Flood Risk
960 min Summer	99.349	0.349	3.2	0.0	3.2	209.1	Flood Risk
1440 min Summer	99.339	0.339	3.2	0.0	3.2	203.2	Flood Risk
2160 min Summer	99.319	0.319	3.1	0.0	3.1	191.3	Flood Risk
2880 min Summer	99.298	0.298	2.9	0.0	2.9	178.8	O K
4320 min Summer	99.260	0.260	2.7	0.0	2.7	156.0	O K
5760 min Summer	99.229	0.229	2.5	0.0	2.5	137.2	O K
7200 min Summer	99.203	0.203	2.4	0.0	2.4	121.8	O K
8640 min Summer	99.182	0.182	2.2	0.0	2.2	109.3	O K
10080 min Summer	99.165	0.165	2.1	0.0	2.1	98.9	O K
15 min Winter	99.180	0.180	2.2	0.0	2.2	108.1	O K
30 min Winter	99.235	0.235	2.6	0.0	2.6	141.0	O K
60 min Winter	99.290	0.290	2.9	0.0	2.9	174.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	83.0	0.0	22
30 min Summer	87.778	0.0	110.1	0.0	37
60 min Summer	54.957	0.0	153.0	0.0	66
120 min Summer	33.261	0.0	186.0	0.0	124
180 min Summer	24.473	0.0	205.6	0.0	184
240 min Summer	19.572	0.0	219.3	0.0	242
360 min Summer	14.207	0.0	238.7	0.0	362
480 min Summer	11.325	0.0	253.4	0.0	456
600 min Summer	9.491	0.0	265.0	0.0	506
720 min Summer	8.212	0.0	274.7	0.0	568
960 min Summer	6.530	0.0	289.6	0.0	692
1440 min Summer	4.720	0.0	308.2	0.0	968
2160 min Summer	3.406	0.0	354.0	0.0	1372
2880 min Summer	2.700	0.0	373.5	0.0	1788
4320 min Summer	1.943	0.0	400.2	0.0	2556
5760 min Summer	1.537	0.0	430.1	0.0	3344
7200 min Summer	1.281	0.0	447.4	0.0	4104
8640 min Summer	1.103	0.0	461.3	0.0	4832
10080 min Summer	0.972	0.0	471.7	0.0	5544
15 min Winter	133.616	0.0	93.6	0.0	22
30 min Winter	87.778	0.0	123.4	0.0	37
60 min Winter	54.957	0.0	171.9	0.0	66

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.342	0.342	3.2	0.0	3.2	205.2	Flood Risk
180 min Winter	99.368	0.368	3.3	0.0	3.3	220.6	Flood Risk
240 min Winter	99.382	0.382	3.4	0.0	3.4	229.1	Flood Risk
360 min Winter	99.395	0.395	3.4	0.0	3.4	237.0	Flood Risk
480 min Winter	99.399	0.399	3.4	0.0	3.4	239.7	Flood Risk
600 min Winter	99.399	0.399	3.4	0.0	3.4	239.3	Flood Risk
720 min Winter	99.396	0.396	3.4	0.0	3.4	237.7	Flood Risk
960 min Winter	99.392	0.392	3.4	0.0	3.4	235.0	Flood Risk
1440 min Winter	99.375	0.375	3.3	0.0	3.3	225.2	Flood Risk
2160 min Winter	99.344	0.344	3.2	0.0	3.2	206.6	Flood Risk
2880 min Winter	99.314	0.314	3.0	0.0	3.0	188.2	Flood Risk
4320 min Winter	99.260	0.260	2.7	0.0	2.7	156.2	O K
5760 min Winter	99.219	0.219	2.5	0.0	2.5	131.1	O K
7200 min Winter	99.186	0.186	2.3	0.0	2.3	111.7	O K
8640 min Winter	99.161	0.161	2.1	0.0	2.1	96.4	O K
10080 min Winter	99.141	0.141	1.9	0.0	1.9	84.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	208.8	0.0	122
180 min Winter	24.473	0.0	230.7	0.0	180
240 min Winter	19.572	0.0	246.0	0.0	238
360 min Winter	14.207	0.0	267.6	0.0	352
480 min Winter	11.325	0.0	284.0	0.0	460
600 min Winter	9.491	0.0	297.0	0.0	564
720 min Winter	8.212	0.0	307.5	0.0	592
960 min Winter	6.530	0.0	323.7	0.0	736
1440 min Winter	4.720	0.0	343.3	0.0	1042
2160 min Winter	3.406	0.0	396.9	0.0	1488
2880 min Winter	2.700	0.0	418.7	0.0	1908
4320 min Winter	1.943	0.0	448.7	0.0	2724
5760 min Winter	1.537	0.0	482.1	0.0	3512
7200 min Winter	1.281	0.0	501.5	0.0	4248
8640 min Winter	1.103	0.0	517.2	0.0	5008
10080 min Winter	0.972	0.0	529.4	0.0	5744

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.391

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.216	4	8	0.175

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.454	0.454	30.4	0.0	30.4	681.4	O K
30 min Summer	99.589	0.589	35.4	0.0	35.4	884.2	O K
60 min Summer	99.719	0.719	39.7	0.0	39.7	1078.8	Flood Risk
120 min Summer	99.825	0.825	42.8	0.0	42.8	1238.0	Flood Risk
180 min Summer	99.863	0.863	43.9	0.0	43.9	1294.4	Flood Risk
240 min Summer	99.872	0.872	44.1	0.0	44.1	1308.2	Flood Risk
360 min Summer	99.873	0.873	44.2	0.0	44.2	1309.9	Flood Risk
480 min Summer	99.868	0.868	44.0	0.0	44.0	1302.2	Flood Risk
600 min Summer	99.857	0.857	43.7	0.0	43.7	1286.1	Flood Risk
720 min Summer	99.843	0.843	43.3	0.0	43.3	1264.7	Flood Risk
960 min Summer	99.810	0.810	42.4	0.0	42.4	1214.5	Flood Risk
1440 min Summer	99.738	0.738	40.2	0.0	40.2	1106.9	Flood Risk
2160 min Summer	99.641	0.641	37.2	0.0	37.2	961.4	O K
2880 min Summer	99.562	0.562	34.5	0.0	34.5	842.8	O K
4320 min Summer	99.447	0.447	30.1	0.0	30.1	669.8	O K
5760 min Summer	99.369	0.369	26.7	0.0	26.7	552.8	O K
7200 min Summer	99.314	0.314	24.1	0.0	24.1	470.4	O K
8640 min Summer	99.273	0.273	21.9	0.0	21.9	410.2	O K
10080 min Summer	99.244	0.244	20.2	0.0	20.2	366.5	O K
15 min Winter	99.510	0.510	32.6	0.0	32.6	764.4	O K
30 min Winter	99.662	0.662	37.9	0.0	37.9	993.3	O K
60 min Winter	99.809	0.809	42.4	0.0	42.4	1213.8	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	667.8	0.0	37
30 min Summer	87.778	0.0	887.9	0.0	50
60 min Summer	54.957	0.0	1154.8	0.0	76
120 min Summer	33.261	0.0	1401.5	0.0	130
180 min Summer	24.473	0.0	1548.5	0.0	184
240 min Summer	19.572	0.0	1652.1	0.0	226
360 min Summer	14.207	0.0	1800.0	0.0	284
480 min Summer	11.325	0.0	1913.4	0.0	350
600 min Summer	9.491	0.0	2004.6	0.0	418
720 min Summer	8.212	0.0	2081.1	0.0	486
960 min Summer	6.530	0.0	2205.4	0.0	624
1440 min Summer	4.720	0.0	2386.5	0.0	892
2160 min Summer	3.406	0.0	2616.2	0.0	1280
2880 min Summer	2.700	0.0	2762.6	0.0	1660
4320 min Summer	1.943	0.0	2969.1	0.0	2392
5760 min Summer	1.537	0.0	3156.9	0.0	3120
7200 min Summer	1.281	0.0	3286.0	0.0	3824
8640 min Summer	1.103	0.0	3392.0	0.0	4512
10080 min Summer	0.972	0.0	3475.0	0.0	5248
15 min Winter	133.616	0.0	752.1	0.0	37
30 min Winter	87.778	0.0	998.5	0.0	50
60 min Winter	54.957	0.0	1295.7	0.0	76

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.932	0.932	45.8	0.0	45.8	1397.3	Flood Risk
180 min Winter	99.977	0.977	47.0	0.0	47.0	1466.0	Flood Risk
240 min Winter	99.990	0.990	47.3	0.0	47.3	1485.7	Flood Risk
360 min Winter	99.983	0.983	47.1	0.0	47.1	1475.1	Flood Risk
480 min Winter	99.972	0.972	46.8	0.0	46.8	1457.5	Flood Risk
600 min Winter	99.952	0.952	46.3	0.0	46.3	1428.0	Flood Risk
720 min Winter	99.928	0.928	45.7	0.0	45.7	1391.8	Flood Risk
960 min Winter	99.874	0.874	44.2	0.0	44.2	1311.7	Flood Risk
1440 min Winter	99.768	0.768	41.1	0.0	41.1	1151.3	Flood Risk
2160 min Winter	99.632	0.632	36.9	0.0	36.9	947.8	O K
2880 min Winter	99.528	0.528	33.2	0.0	33.2	791.5	O K
4320 min Winter	99.387	0.387	27.6	0.0	27.6	580.2	O K
5760 min Winter	99.301	0.301	23.4	0.0	23.4	451.7	O K
7200 min Winter	99.247	0.247	20.4	0.0	20.4	370.2	O K
8640 min Winter	99.215	0.215	18.2	0.0	18.2	322.9	O K
10080 min Winter	99.198	0.198	16.1	0.0	16.1	296.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	1572.1	0.0	130
180 min Winter	24.473	0.0	1736.7	0.0	182
240 min Winter	19.572	0.0	1852.8	0.0	236
360 min Winter	14.207	0.0	2018.5	0.0	298
480 min Winter	11.325	0.0	2145.6	0.0	374
600 min Winter	9.491	0.0	2247.8	0.0	450
720 min Winter	8.212	0.0	2333.6	0.0	526
960 min Winter	6.530	0.0	2473.0	0.0	672
1440 min Winter	4.720	0.0	2676.1	0.0	954
2160 min Winter	3.406	0.0	2931.7	0.0	1352
2880 min Winter	2.700	0.0	3096.2	0.0	1736
4320 min Winter	1.943	0.0	3329.7	0.0	2472
5760 min Winter	1.537	0.0	3536.9	0.0	3176
7200 min Winter	1.281	0.0	3682.0	0.0	3888
8640 min Winter	1.103	0.0	3801.5	0.0	4504
10080 min Winter	0.972	0.0	3897.1	0.0	5248

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 2.861

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.464	8	12	0.464	16	20	0.464
4	8	0.464	12	16	0.464	20	24	0.541

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.203	0.203	9.4	0.0	9.4	244.0	O K
30 min Summer	99.264	0.264	11.2	0.0	11.2	316.2	O K
60 min Summer	99.322	0.322	12.6	0.0	12.6	386.0	O K
120 min Summer	99.370	0.370	13.7	0.0	13.7	444.3	O K
180 min Summer	99.389	0.389	14.1	0.0	14.1	466.5	O K
240 min Summer	99.394	0.394	14.2	0.0	14.2	473.3	O K
360 min Summer	99.397	0.397	14.3	0.0	14.3	476.8	O K
480 min Summer	99.398	0.398	14.3	0.0	14.3	477.2	O K
600 min Summer	99.395	0.395	14.2	0.0	14.2	474.6	O K
720 min Summer	99.392	0.392	14.1	0.0	14.1	469.8	O K
960 min Summer	99.381	0.381	13.9	0.0	13.9	456.8	O K
1440 min Summer	99.354	0.354	13.3	0.0	13.3	425.3	O K
2160 min Summer	99.316	0.316	12.5	0.0	12.5	378.8	O K
2880 min Summer	99.282	0.282	11.6	0.0	11.6	338.7	O K
4320 min Summer	99.232	0.232	10.3	0.0	10.3	278.3	O K
5760 min Summer	99.197	0.197	9.2	0.0	9.2	236.8	O K
7200 min Summer	99.173	0.173	8.4	0.0	8.4	207.4	O K
8640 min Summer	99.156	0.156	7.8	0.0	7.8	186.7	O K
10080 min Summer	99.145	0.145	7.1	0.0	7.1	173.4	O K
15 min Winter	99.228	0.228	10.1	0.0	10.1	273.4	O K
30 min Winter	99.296	0.296	12.0	0.0	12.0	354.9	O K
60 min Winter	99.361	0.361	13.5	0.0	13.5	433.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	133.616	0.0	218.1	0.0	26
30 min Summer	87.778	0.0	293.7	0.0	40
60 min Summer	54.957	0.0	394.9	0.0	68
120 min Summer	33.261	0.0	480.9	0.0	124
180 min Summer	24.473	0.0	532.0	0.0	182
240 min Summer	19.572	0.0	568.0	0.0	232
360 min Summer	14.207	0.0	619.3	0.0	288
480 min Summer	11.325	0.0	658.6	0.0	350
600 min Summer	9.491	0.0	690.0	0.0	418
720 min Summer	8.212	0.0	716.3	0.0	486
960 min Summer	6.530	0.0	758.8	0.0	624
1440 min Summer	4.720	0.0	819.7	0.0	892
2160 min Summer	3.406	0.0	909.9	0.0	1284
2880 min Summer	2.700	0.0	960.0	0.0	1672
4320 min Summer	1.943	0.0	1028.7	0.0	2388
5760 min Summer	1.537	0.0	1102.1	0.0	3120
7200 min Summer	1.281	0.0	1146.5	0.0	3824
8640 min Summer	1.103	0.0	1181.9	0.0	4504
10080 min Summer	0.972	0.0	1207.9	0.0	5248
15 min Winter	133.616	0.0	247.1	0.0	26
30 min Winter	87.778	0.0	331.7	0.0	39
60 min Winter	54.957	0.0	444.1	0.0	68

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Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.417	0.417	14.7	0.0	14.7	500.9	O K
180 min Winter	99.440	0.440	15.1	0.0	15.1	527.6	O K
240 min Winter	99.448	0.448	15.3	0.0	15.3	537.1	O K
360 min Winter	99.447	0.447	15.3	0.0	15.3	536.1	O K
480 min Winter	99.445	0.445	15.2	0.0	15.2	533.7	O K
600 min Winter	99.439	0.439	15.1	0.0	15.1	526.9	O K
720 min Winter	99.431	0.431	15.0	0.0	15.0	517.4	O K
960 min Winter	99.412	0.412	14.6	0.0	14.6	494.4	O K
1440 min Winter	99.371	0.371	13.7	0.0	13.7	444.7	O K
2160 min Winter	99.315	0.315	12.4	0.0	12.4	377.5	O K
2880 min Winter	99.270	0.270	11.3	0.0	11.3	323.6	O K
4320 min Winter	99.207	0.207	9.5	0.0	9.5	247.9	O K
5760 min Winter	99.168	0.168	8.2	0.0	8.2	201.2	O K
7200 min Winter	99.146	0.146	7.2	0.0	7.2	175.8	O K
8640 min Winter	99.133	0.133	6.3	0.0	6.3	159.8	O K
10080 min Winter	99.123	0.123	5.6	0.0	5.6	147.6	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	33.261	0.0	540.3	0.0	124
180 min Winter	24.473	0.0	597.7	0.0	180
240 min Winter	19.572	0.0	638.0	0.0	234
360 min Winter	14.207	0.0	695.5	0.0	300
480 min Winter	11.325	0.0	739.5	0.0	372
600 min Winter	9.491	0.0	774.8	0.0	450
720 min Winter	8.212	0.0	804.3	0.0	526
960 min Winter	6.530	0.0	852.0	0.0	674
1440 min Winter	4.720	0.0	920.3	0.0	958
2160 min Winter	3.406	0.0	1020.3	0.0	1364
2880 min Winter	2.700	0.0	1076.7	0.0	1740
4320 min Winter	1.943	0.0	1154.9	0.0	2472
5760 min Winter	1.537	0.0	1235.2	0.0	3176
7200 min Winter	1.281	0.0	1285.2	0.0	3832
8640 min Winter	1.103	0.0	1325.3	0.0	4584
10080 min Winter	0.972	0.0	1355.8	0.0	5312

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.400	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 1.002

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.334	4	8	0.334	8	12	0.334

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Appendix 3 Correspondence with Leicestershire County Council

Dawson, Garry

From:	Dawson, Garry
Sent:	30 June 2017 15:00
To:	flooding@leics.gov.uk
Subject:	Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements
Attachments:	scan3098.jpg

Dear Sirs,

I am currently carrying out the preliminary highway drainage design for Melton Mowbray Distributor Road on behalf of Leicestershire County Council and am writing to request some initial information regarding your attenuation requirements for outfalling of the highway drainage runoff.

The proposed distributor road is approximately 7km long and will run to the north and east of Melton Mowbray and Thorpe Arnold from the A606 Nottingham Road near its junction with St Bartholomew's Way to the A606 Burton Road near its junction with Sawgate Road. The approximate boundary within which the road will be constructed is shown on the attached plan.

Our currently proposed locations for outfall of highway and earthworks drainage are indicated on the attached drawing and are as follows:

- Watercourse to east of Sysonby Farm
- Watercourse to east of Sysonby Lodge
- Scalfold Brook
- Thorpe Brook
- Watercourse to north & east of Thorpe Arnold
- River Eye

It is our understanding that the proposed outfall locations at the River Eye and Scalford Brook are classified as main river but the other outfall locations are not.

I would be grateful if you could confirm what your requirements would be in terms of attenuating the discharge from the highway runoff and earthworks runoff prior to outfall.

Our current drainage methodology involves the carriageway, verge, footway/cycleway and cutting slope runoff draining either directly to filter drains or to filter drains via trapped gullies, or combined kerb and gully units with trapped outfalls, in the carriageway. Catchpits will be provided along the filter drains at maximum intervals of 90m. The filter drains will outfall, via carrier drains and bypass oil separators to wet ponds, prior to outfall to the watercourses. Separate earthworks filter drains will be provided at the top of cutting slopes and bottom of embankment slopes where adjacent land falls towards them. It is proposed to discharge this separate earthworks drainage directly to the watercourses.

Should you have any queries on the above please do not hesitate to contact me.

Regards

Garry

Garry Dawson BEng (Hons) CEng MICE
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Dawson, Garry

From:	Peter Merrick <Peter.Merrick@leics.gov.uk>
Sent:	16 August 2017 13:24
To:	Dawson, Garry
Subject:	RE: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements
Attachments:	2017_MMDR_RoFSW_01.pdf; 2017_MMDR_RoFSW_02.pdf; 2017_MMDR_RoFSW_03.pdf; 2017_MMDR_RoFSW_04.pdf

Dear Gary,

I apologise for the delay in having a response to your enquiry below, I was under the impression it had already been responded to but it appears not.

Runoff from all proposed impermeable areas should be discharged in to the nearby watercourses at equivalent greenfield runoff rates to ensure downstream flood risk is not increased, attenuation should be sized to accommodate a 1 in 100 year (plus a 40% allowance for climate change) design storm event. I would expect to see some assessment of infiltration drainage in line with the drainage hierarchy. BGS maps indicate areas of clay, silts, sands and gravels at various locations along the proposed alignment (primarily along the line of watercourses) so there may be opportunities for infiltration drainage.

Please note that the road alignment is proposed over more than one operational catchment (please refer to the link below for further information and to view the catchments). The proposed discharge rates should be restricted to the greenfield rate associated with that catchment; or if combining runoff from more than one catchment, restricting discharge to the existing greenfield rate of the catchment discharging to. This will help prevent an increase in runoff rates and volumes discharging to each catchment.

http://environment.data.gov.uk/catchment-planning/OperationalCatchment/3546

In terms of attenuation features and drainage methodology, the use of SuDS will need to be considered to ensure adequate treatment of the runoff is provided prior to discharge in to the watercourses. Wet ponds would be suitable but additional upstream SuDS should be used also to prevent pollution loadings to the pond which could lead to them becoming unpleasant and unsightly. Basins with sediment forebays and permanent wet pools may be suitable also.

Filter drains might be appropriate but may not provide the required level of treatment to surface runoff (on their own or in combination with wet ponds), the build-up of sediment/pollutants is difficult to see which may lead to neglected maintenance. Gullies, trapped outfalls, catchpits and oil separators (separators should be used as a last resort where SuDS are not feasible) are not be considered SuDS however that doesn’t necessarily preclude their use but alternative SuDS should be assessed and used where appropriate and feasible. Where the road can be drained over the edge (or via gullies) the use of swales should be considered, their use is likely to be dependent on available space but if they can be designed as low maintenance they would be preferred over filter drains.

The proposal to discharge earthworks filter drains directly to watercourses seems appropriate, providing they would only be draining greenfield runoff. Ideally these should be kept separate from the other highway drainage systems so as to not interfere with attenuation features and flow controls.

I've attached some surface water flood maps for reference, in case you don't already have them. The proposed alignment will need to consider and effectively manage any existing overland flow routes to ensure surface water flood risk is not increased.

I hope the above is informative, I would be happy to discuss further so don't hesitate to contact me for any further advice or information.

Kind regards,

Peter Merrick
Senior Technician
Infrastructure Planning (Flood Risk Management)
Environment & Transport Department
Leicestershire County Council
E-mail: flooding@leics.gov.uk
Tel: 0116 305 0562

From: Dawson, Garry [mailto:garry.dawson@aecom.com]
Sent: 30 June 2017 15:00
To: Flooding
Subject: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements

Dear Sirs,

I am currently carrying out the preliminary highway drainage design for Melton Mowbray Distributor Road on behalf of Leicestershire County Council and am writing to request some initial information regarding your attenuation requirements for outfalling of the highway drainage runoff.

The proposed distributor road is approximately 7km long and will run to the north and east of Melton Mowbray and Thorpe Arnold from the A606 Nottingham Road near its junction with St Bartholomew's Way to the A606 Burton Road near its junction with Sawgate Road. The approximate boundary within which the road will be constructed is shown on the attached plan.

Our currently proposed locations for outfall of highway and earthworks drainage are indicated on the attached drawing and are as follows:

- Watercourse to east of Sysonby Farm
- Watercourse to east of Sysonby Lodge
- Scalfold Brook
- Thorpe Brook
- Watercourse to north & east of Thorpe Arnold
- River Eye

It is our understanding that the proposed outfall locations at the River Eye and Scalford Brook are classified as main river but the other outfall locations are not.

I would be grateful if you could confirm what your requirements would be in terms of attenuating the discharge from the highway runoff and earthworks runoff prior to outfall.

Our current drainage methodology involves the carriageway, verge, footway/cycleway and cutting slope runoff draining either directly to filter drains or to filter drains via trapped gullies, or combined kerb and gully units with trapped outfalls, in the carriageway. Catchpits will be provided along the filter drains at maximum intervals of 90m. The filter drains will outfall, via carrier drains and bypass oil separators to wet ponds, prior to outfall to the watercourses. Separate earthworks filter drains will be provided at the top of cutting slopes and bottom of

Dawson, Garry

From:	Dawson, Garry
Sent:	12 March 2018 17:31
To:	'Peter Merrick'
Subject:	RE: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements
Attachments:	Rev1 Drainage Ponds-06.pdf; Rev1 Drainage Ponds-05.pdf; Rev1 Drainage Ponds-04.pdf; Rev1 Drainage Ponds-03.pdf; Rev1 Drainage Ponds-02.pdf; Rev1 Drainage Ponds-01.pdf; Burton Brook Catchment.pdf

Peter,

Further to previous correspondence I am writing to update you regarding the drainage proposals for Melton Mowbray Distributor Road and how your previous comments have been addressed and to ask for any further comments you may have at this stage on our proposals.

I have attached the current preliminary drainage drawings. The road alignment is still undergoing changes along some of its route and hence the drainage is still subject to layout change but the overall principles will remain the same. We will be commencing detailed design of the scheme drainage towards the end of March.

Regarding the design I have set out below the principles used:

Ponds

- The ponds have been designed to accommodate a 1 in 100 year storm with 40% allowance for climate change as per your requirements.
- Discharge from the ponds will be at greenfield runoff rates to nearby watercourses as shown on the drawings. I would be grateful for your confirmation that you are happy with all the proposed discharge points.
- As per your requirements the pond sizing and greenfield runoff calculations allow for restricting runoff at each watercourse to the greenfield runoff equivalent for that catchment only. There is one exception to this which we previously discussed on the phone and for which you requested a plan sending detailing the proposals. This is in regard to the Burton Brook Catchment. The southern end of the scheme falls within the Burton Brook catchment but the only watercourse within this catchment close to the line of the road and therefore suitable to outfall to is a very minor tributary of the Burton Brook which is shown further downstream on 1:25,000 OS mapping to intermittently stop and start again. Because of this, rather than outfall this section of the road to this watercourse we proposed to drain it northwards to Pond H which outfalls to the River Eye within the Eye/Wreake from Langham Brook to Soar Catchment. If we did outfall to the tributary of the Burton Brook the water would end up at this same point anyway via the Burton Brook and River Eye. Because of this we request that the greenfield runoff equivalent from the portion of the road within the Burton Brook catchment can be allowed for within the discharge from Pond H which outfalls to the River Eye within the Eye/Wreake from Langham Brook to Soar catchment. The attached sketch illustrates the situation.
- The ponds are currently sized based on no infiltration occurring but infiltration tests are being carried out as part of the ground investigation at or near to pond locations so we can assess the suitability of the ground for having an infiltration basin as part of the pond layouts. If ground conditions and ground water levels are suitable we will incorporate infiltration within the ponds.
- Allowance has been made within the pond design for a sediment forebay sized at 10% of the total pond size and separated from it by baffles or earthworks berms to prevent pollution loadings to the main ponds.
- Ponds are currently designed to have wet ponds with depths that range at each pond from 0.5m at the upstream end to between 1 and 1.5m at the downstream end with 1 in 4 side slopes
- A 2m wide vegetation shelf has been allowed for at the edge of the wet ponds

- The depths of the attenuation provision above the wet ponds ranges from 0.5m to 1.0m for the different ponds with 1 in 4 side slopes and a 300mm freeboard allowance.
- A 3.5m maintenance track has been allowed for around the edge of each pond. This has been/ will be widened on the corners as necessary to allow for a land rover with trailer to negotiate, although this has not yet been detailed for all ponds. For some of the ponds these tracks have been extended to show connections to access points from the highway however some connections have not yet been detailed
- A 1m strip has been allowed for around the outside edge of the maintenance tracks for protective planting and/or fencing.
- The ponds have been located such that they are out of the flood zones 2/3 of the adjacent watercourses except for Ponds F and G at the River Eye where the width of the Flood Zone 3 makes this impractical and the ponds have just been moved as far as possible to the edges of the flood zone. We currently show some earthwork bunding around these 2 ponds to help prevent inundation and sediment washout during flood events, however we have on other schemes been allowed to have ponds within the flood zone without such bunding which obviously reduces the available flood volume and can therefore increase the extent of the flood. I would therefore welcome your advice as to whether bunding would be required around these ponds or whether this is a question for the Environment Agency.

<u>Carriageway Drainage Methods</u>

- As previously advised and as shown on the attached drawings, it is our intention to drain the carriageway with a combination of filter drains and gullies/combined kerb & gully units.
- On the south/west side of the road carriageway a kerb is to be provided due to the presence of a cycle/footway and therefore the road is to be drained with gullies outfalling to combined ground and surface water filter drains under the footway/cycleway. Over any particularly flat areas of road where use of gullies becomes uneconomic they will be replaced with combined kerb and gully units.
- When in cutting the footway / cycleway will fall towards the carriageway and drain into the carriageway gullies, when on embankment the footway / cycleway will fall away from the carriageway and be allowed to drain down the embankment slope.
- On the north/east side of the road there is no kerb so the carriageway will drain straight into the combined ground and surface water filter drains.
- Where wide cutting slopes are proposed on the south/west side of the road an additional filter drain will be provided at the bottom of the slopes to capture the cutting runoff and prevent high flows running across the footway/cycleway. For relatively narrow cutting slopes the runoff will be allowed to flow across the footway/cycleway and into the carriageway gullies.
- Swales have not been proposed for carriageway drainage for the following reasons:
    - The kerbed footway/ cycleway on the south/west side of the road prevents their use here
    - Space limitations
    - Concern over introducing polluted carriageway runoff to the ground before it has passed through suitable treatment
    - On previous schemes we have been involved in swales have become an eyesore due to tendency for litter and sediment to collect within them, partly due to difficulties in cleaning them
    - Concerns regarding overrunning/parking vehicles causing rutting in the swales and causing localised water ponding and safety issues
    - Concerns over ponding/drainage inefficiencies caused by swale outfall chambers ending up slightly higher than adjacent swale due to settlement/compaction of bottom of swale during maintenance or vehicle overrun.
- We would intend to design the highway drainage for the DMRB criteria of no surcharging for 1 in 1 year storms and no surcharging above base of pavement levels in filter drains or above cover levels for carrier drains for a 1 in 5 year storm. I would be grateful if you could let me know if you would also require us to meet the Sewers for Adoption criteria of no surcharging above cover levels (i.e. no flooding) for a 1 in 30 year storm?
- I would be grateful if you could let me know if 150 dia pipes are acceptable or if you have a minimum 225 dia pipe size requirement.
- We intend to design gully spacings to DMRB HA 102 using a 0.75m design breadth of flow for a 1 in 5 year return period storm as the road is more rural than urban, a separate cycleway is provided for cyclists and

cyclists and pedestrians will be separated from the edge of the carriageway by a 0.5m wide verge/separation strip.

Earthworks Drainage

- Where adjacent land falls towards the proposed road we propose to provide earthworks drainage at the top of cutting slopes and bottom of embankments either in the form of filter drains or ditches.
- Wherever possible, and in most cases, the earthworks drainage system will be kept completely separate from the carriageway drainage system and will have separate outfalls to nearby watercourses as shown on the attached drawings.

Water Quality / Treatment

- As described above and shown on the attached drawings our water quality / treatment proposals consist of trapped gullies and/or filter drains, catchpits and wet ponds with separate sediment forebays. Our drawings currently show provision of oil separators upstream of the ponds however our environment team are carrying out water quality risk assessments to determine if they are necessary in addition to the other proposals. If the risk assessment shows they are unnecessary we would proposed to remove them.
- Penstocks will be provide upstream of the ponds in easily accessible locations for use if necessary after any spillage incidents.

Side Roads

- Where side roads are being realigned and they fall towards the new link road the drainage from the realigned sections will connect into the mainline drainage system.
- Where side roads are being realigned and they fall away from the new link road we will outfall the drainage from the realigned sections into the existing side road drainage system but we will ensure that there is no increase in overall flows in the existing system.
- We have not yet obtained any information on existing highway drainage on the side roads and I was wondering if you may be able to provide this or let me know who would be the best person to contact to obtain it?

If you think there is anyone else at Leicestershire County Council that we need to contact for comment on our drainage proposals I would be grateful if you could either pass on the information to them or let me know who else we should consult so I can do this.

Should you have queries on any of the above please do not hesitate to contact me.

Regards

Garry

Garry Dawson BEng (Hons) CEng MICE
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From:	Peter Merrick <Peter.Merrick@leics.gov.uk>
Sent:	10 August 2018 11:34
To:	Bacon, Lewis A; Victoria Coombes
Cc:	Dawson, Garry
Subject:	RE: Melton Mowbray Ponds

Lewis,

I'm in the process of putting together comments to all points. With regard to the 4 specific points I can provide the following initial comments.

1. We have no objection to the proposal to discharge the southern portion of the road directly to the River Eye in the Eye/Wreake catchment.

2. Ideally any attenuation should at a minimum be outside of flood zone 3 to ensure it can function to its design parameters (i.e. up to 1% storm event) without impact from fluvial flooding. The bunding on ponds F and G would therefore help with this and as you say mitigate against sediment washout so is something we are keen to see but can compromise if constraints mean this is not feasible. Being in flood zone 3 though will need discussion with the Environment Agency as they might require flood compensation.

   One thing I have noticed is there are ordinary watercourses which don't have any flood zones associated with them close to some of the proposed ponds. It might be that these watercourses just haven't been modelled rather than them not having any flood zone extents. The watercourses adjacent to ponds A, E, and I are the areas of note. I understand some watercourse assessments were carried out for culvert sizing but this doesn't appear to assess channel capacities, is any further work proposed to clarify if out of bank flows are anticipated on the ordinary watercourses?

3. Hydraulic design should be such that the system is designed not to flood in a 1 in 30 year return period storm event.

4. 225mm is the minimum pipe diameter required other than for gully connections which can be 150mm.

I'll have a more detailed response to you later.

Regards,

Peter Merrick
Senior Technician
Infrastructure Planning (Flood Risk Management)
Environment & Transport Department
Leicestershire County Council
E-mail: flooding@leics.gov.uk
Tel: 0116 305 0562

https://www.leicestershire.gov.uk/environment-and-planning/flooding-and-drainage

Dawson, Garry

From:	Peter Merrick <Peter.Merrick@leics.gov.uk>
Sent:	10 August 2018 15:32
To:	Bacon, Lewis A; Dawson, Garry
Cc:	Victoria Coombes; Andy Jackson
Subject:	RE: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements
Attachments:	RE: Melton Mowbray Ponds; MMDR Existing LCC Highway Drainage Records.xls

Lewis,

Please find my comments in red below. I've attached my email from earlier today as well for completeness.

If you want further advice or clarification on these comments please don't hesitate to contact me.

Regards,

Peter Merrick
Senior Technician
Infrastructure Planning (Flood Risk Management)
Environment & Transport Department
Leicestershire County Council
E-mail: flooding@leics.gov.uk
Tel: 0116 305 0562

https://www.leicestershire.gov.uk/environment-and-planning/flooding-and-drainage

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From: Dawson, Garry [mailto:garry.dawson@aecom.com]
Sent: 12 March 2018 17:32
To: Peter Merrick
Subject: RE: Melton Mowbray Distributor Road - Highway Drainage Attenuation Requirements

Peter,

Further to previous correspondence I am writing to update you regarding the drainage proposals for Melton Mowbray Distributor Road and how your previous comments have been addressed and to ask for any further comments you may have at this stage on our proposals.

I have attached the current preliminary drainage drawings. The road alignment is still undergoing changes along some of its route and hence the drainage is still subject to layout change but the overall principles will remain the same. We will be commencing detailed design of the scheme drainage towards the end of March.

Regarding the design I have set out below the principles used:

Ponds

- The ponds have been designed to accommodate a 1 in 100 year storm with 40% allowance for climate change as per your requirements. – noted and acceptable. As already highlighted by Robert Reeves back in June, more natural shaped ponds would be preferred.
- Discharge from the ponds will be at greenfield runoff rates to nearby watercourses as shown on the drawings. I would be grateful for your confirmation that you are happy with all the proposed discharge

points. – please confirm if proposing to discharge at equivalent rates (i.e. at respective 1, 30 and 100 year greenfield, or just a single rate for all storm events i.e. Qbar). With regard to the discharge points:

- Pond A – is the road off the roundabout downstream of the outfall only indicative at this stage, are there any current proposals for a structure under this indicative road over the watercourse? We typically like to see outfalls downstream of structures like culverts if possible to ensure the drainage system can outfall in the event of culvert blockage. If a clear span structure can be proposed then the risk would be less and an outfall upstream would not be as much of a concern.
- Pond B – the Scalford Brook at this point (from the Dismantled Railway downstream) is main river. LCC as the lead local flood authority have no concerns over the outfall but unless not already done so you'll need to contact the Environment Agency to discuss the proposal and any environmental permits that might be required.
- Pond C – ok
- Pond D – ok
- Pond E – ok
- Ponds F, G & H – no concerns from LCC, as with Pond B though the River Wreake here is main river so discussions with EA should be had.
- Pond I – ok
- In all cases, try to ensure that the outfalls are between 30° and 60° to the direction of flow to reduce the effect of scour and erosion to the watercourses. This seems to have been generally illustrated on the preliminary drawings.
- For any basins which outfall via a proposed open channel between the basin and the watercourse, will highway easements be in place along the channels to ensure access for maintenance and improvement purposes?

- As per your requirements the pond sizing and greenfield runoff calculations allow for restricting runoff at each watercourse to the greenfield runoff equivalent for that catchment only. There is one exception to this which we previously discussed on the phone and for which you requested a plan sending detailing the proposals. This is in regard to the Burton Brook Catchment. The southern end of the scheme falls within the Burton Brook catchment but the only watercourse within this catchment close to the line of the road and therefore suitable to outfall to is a very minor tributary of the Burton Brook which is shown further downstream on 1:25,000 OS mapping to intermittently stop and start again. Because of this, rather than outfall this section of the road to this watercourse we proposed to drain it northwards to Pond H which outfalls to the River Eye within the Eye/Wreake from Langham Brook to Soar Catchment. If we did outfall to the tributary of the Burton Brook the water would end up at this same point anyway via the Burton Brook and River Eye. Because of this we request that the greenfield runoff equivalent from the portion of the road within the Burton Brook catchment can be allowed for within the discharge from Pond H which outfalls to the River Eye within the Eye/Wreake from Langham Brook to Soar catchment. The attached sketch illustrates the situation. – this proposal is acceptable. With the highway runoff discharging directly to the River Eye downstream of its current eventual point of connection with the River Eye there is unlikely to be any impact of flood risk. Although a small proportion of runoff will be removed from the Burton Brook catchment but I don't envisage this will have any impact on low flows in the Burton Brook or it's tributary. Where is it proposed to outfall the earthworks filter drain on the northern/western edge of the road which will also take runoff from the adjacent fields?
- The ponds are currently sized based on no infiltration occurring but infiltration tests are being carried out as part of the ground investigation at or near to pond locations so we can assess the suitability of the ground for having an infiltration basin as part of the pond layouts. If ground conditions and ground water levels are suitable we will incorporate infiltration within the ponds. – noted and acceptable.
- Allowance has been made within the pond design for a sediment forebay sized at 10% of the total pond size and separated from it by baffles or earthworks berms to prevent pollution loadings to the main ponds. – noted and acceptable
- Ponds are currently designed to have wet ponds with depths that range at each pond from 0.5m at the upstream end to between 1 and 1.5m at the downstream end with 1 in 4 side slopes. – noted and acceptable.
- A 2m wide vegetation shelf has been allowed for at the edge of the wet ponds. – noted and acceptable
- The depths of the attenuation provision above the wet ponds ranges from 0.5m to 1.0m for the different ponds with 1 in 4 side slopes and a 300mm freeboard allowance. - noted and acceptable.

- A 3.5m maintenance track has been allowed for around the edge of each pond. This has been/ will be widened on the corners as necessary to allow for a land rover with trailer to negotiate, although this has not yet been detailed for all ponds. For some of the ponds these tracks have been extended to show connections to access points from the highway however some connections have not yet been detailed. – noted and acceptable.
- A 1m strip has been allowed for around the outside edge of the maintenance tracks for protective planting and/or fencing. – noted and acceptable. Pond A doesn't appear to show this 1m strip.
- The ponds have been located such that they are out of the flood zones 2/3 of the adjacent watercourses except for Ponds F and G at the River Eye where the width of the Flood Zone 3 makes this impractical and the ponds have just been moved as far as possible to the edges of the flood zone. We currently show some earthwork bunding around these 2 ponds to help prevent inundation and sediment washout during flood events, however we have on other schemes been allowed to have ponds within the flood zone without such bunding which obviously reduces the available flood volume and can therefore increase the extent of the flood. I would therefore welcome your advice as to whether bunding would be required around these ponds or whether this is a question for the Environment Agency.

Carriageway Drainage Methods

- As previously advised and as shown on the attached drawings, it is our intention to drain the carriageway with a combination of filter drains and gullies/combined kerb & gully units. – noted and acceptable.
- On the south/west side of the road carriageway a kerb is to be provided due to the presence of a cycle/footway and therefore the road is to be drained with gullies outfalling to combined ground and surface water filter drains under the footway/cycleway. Over any particularly flat areas of road where use of gullies becomes uneconomic they will be replaced with combined kerb and gully units. – noted and acceptable
- When in cutting the footway / cycleway will fall towards the carriageway and drain into the carriageway gullies, when on embankment the footway / cycleway will fall away from the carriageway and be allowed to drain down the embankment slope. – noted and acceptable.
- On the north/east side of the road there is no kerb so the carriageway will drain straight into the combined ground and surface water filter drains. – noted and acceptable.
- Where wide cutting slopes are proposed on the south/west side of the road an additional filter drain will be provided at the bottom of the slopes to capture the cutting runoff and prevent high flows running across the footway/cycleway. For relatively narrow cutting slopes the runoff will be allowed to flow across the footway/cycleway and into the carriageway gullies. – it doesn't seem ideal to allow runoff from the cutting embankments to drain across the footway/cycleway. This could impact on pedestrians/cyclists particularly if over time the footway/cycleway degrades leading to standing water which during colder periods could ice over. Has this proposal been accepted by anyone else at LCC yet?
- Swales have not been proposed for carriageway drainage for the following reasons:
  - The kerbed footway/ cycleway on the south/west side of the road prevents their use here
  - Space limitations
  - Concern over introducing polluted carriageway runoff to the ground before it has passed through suitable treatment
  - On previous schemes we have been involved in swales have become an eyesore due to tendency for litter and sediment to collect within them, partly due to difficulties in cleaning them
  - Concerns regarding overrunning/parking vehicles causing rutting in the swales and causing localised water ponding and safety issues
  - Concerns over ponding/drainage inefficiencies caused by swale outfall chambers ending up slightly higher than adjacent swale due to settlement/compaction of bottom of swale during maintenance or vehicle overrun.

  I think some of the constraints could probably be overcome through suitable design, construction and maintenance; however I acknowledge that space limitations will limit their use and if there is not scope to incorporate swales into the design because of this then that's acceptable.

- We would intend to design the highway drainage for the DMRB criteria of no surcharging for 1 in 1 year storms and no surcharging above base of pavement levels in filter drains or above cover levels for carrier drains for a 1 in 5 year storm. I would be grateful if you could let me know if you would also require us to meet the Sewers for Adoption criteria of no surcharging above cover levels (i.e. no flooding) for a 1 in 30 year storm? – we require the system to be designed so no flooding during 1 in 30 year return period storm.

- I would be grateful if you could let me know if 150 dia pipes are acceptable or if you have a minimum 225 dia pipe size requirement. – 225mm diameter minimum other than gully connections which can be 150mm.
- We intend to design gully spacings to DMRB HA 102 using a 0.75m design breadth of flow for a 1 in 5 year return period storm as the road is more rural than urban, a separate cycleway is provided for cyclists and cyclists and pedestrians will be separated from the edge of the carriageway by a 0.5m wide verge/separation strip. – seems an acceptable approach although this sort of detail is something that our highway design team would review.

Earthworks Drainage

- Where adjacent land falls towards the proposed road we propose to provide earthworks drainage at the top of cutting slopes and bottom of embankments either in the form of filter drains or ditches. – noted and acceptable, where feasible and appropriate ditches or other open channels would be preferred.
- Wherever possible, and in most cases, the earthworks drainage system will be kept completely separate from the carriageway drainage system and will have separate outfalls to nearby watercourses as shown on the attached drawings. – noted and acceptable. The only sections of note at this stage are the earthworks filter drain from approx. chainage CH2300 to the roundabout adjacent to Twinlakes which is shown to connect to the highway drainage, and the earthworks filter drain along the western side of the southernmost portion of carriageway which isn't shown to outfall anywhere.

Water Quality / Treatment

- As described above and shown on the attached drawings our water quality / treatment proposals consist of trapped gullies and/or filter drains, catchpits and wet ponds with separate sediment forebays. Our drawings currently show provision of oil separators upstream of the ponds however our environment team are carrying out water quality risk assessments to determine if they are necessary in addition to the other proposals. If the risk assessment shows they are unnecessary we would proposed to remove them. – noted and acceptable.
- Penstocks will be provide upstream of the ponds in easily accessible locations for use if necessary after any spillage incidents. – this will probably need to be discussed with and reviewed by our highway design team to confirm if they're happy for penstocks to be proposed. In principle it seems fine as a measure to manage large pollution incidents but it could be seen as just another maintenance asset, also, would there need to be some form of bypass to prevent the drainage system backing up on to the road?

Side Roads

- Where side roads are being realigned and they fall towards the new link road the drainage from the realigned sections will connect into the mainline drainage system. – noted and acceptable
- Where side roads are being realigned and they fall away from the new link road we will outfall the drainage from the realigned sections into the existing side road drainage system but we will ensure that there is no increase in overall flows in the existing system. – noted and acceptable, is it envisaged that there will need to be any flow controls to restrict these flows to existing rates into to existing systems?
- We have not yet obtained any information on existing highway drainage on the side roads and I was wondering if you may be able to provide this or let me know who would be the best person to contact to obtain it? – please find attached a spreadsheet which outlines what information we hold, unfortunately we only have gully GIS data. In the first instance it's probably best to request this data from Andy as the project manager for the scheme.

If you think there is anyone else at Leicestershire County Council that we need to contact for comment on our drainage proposals I would be grateful if you could either pass on the information to them or let me know who else we should consult so I can do this. – I mentioned to Andy Jackson that our highway design/engineering services team should probably carry out a design check. Your email was passed on to them, I understand they provided some very brief comments back in April but I'm not sure if a more detailed response has been provided since.

Appendix 4 Drainage Networks Key Levels Checks

Pond		Low pt in road				Dist from low road low pt to pond inlet	Pipe gradient	Pond inlet level	Pond depth	Pond outlet invert	Dist to watecourse	Gradient	Watercourse outfall	Est watercourse bank level	Difference between anticipated outfall invert and bank level	
		Road Level	Cover	Pipe dia	Drain invert											
A	1	112.04	1	0.525	110.515	70	200	110.165	1	109.165	0	200	109.165	106.8	2.365	OK
I	2	111.4	1	0.525	109.875	40	200	109.675	0.5	109.175	0	200	109.175	107	2.175	OK
B	3	88.15	1	0.375	86.775	110	200	86.225	0.65	85.575	170	200	84.725	84	0.725	OK
C	4	88.15	1	0.45	86.7	160	200	85.9	0.75	85.15	75	200	84.775	84	0.775	OK
D1	5	91.04	1	0.45	89.59	211	200	88.535	1	87.535	100	200	87.035	84	3.035	OK
D2	6	91.04	1	0.525	89.515	170	200	88.665	0.75	87.915	80	200	87.515	84	3.515	OK
E	7	92.9	1	0.3	91.6	100	200	91.1	0.5	90.6	40	200	90.4	86	4.4	OK
F	8	Relatively flat area therefore refined assessment carried out - see separate sheet														
G	9	Relatively flat area therefore refined assessment carried out - see separate sheet														
H	10	87.5	1	0.45	86.05	300	200	84.55	1	83.55	100	200	83.05	74	9.05	OK

(yellow)	Inserted figures
(green)	Calculated figures

CALCULATIONS

Project	Melton Mowbray																		
JEN	?	?	?	?	?	?	?					Date		Page No					Rev
Originator		Checked			Revision	Suffix	Orig												
						Date	Check												

Ref.		Output

Pond 8/F Refine check on outfall from pond to River Eye

From xsections water level in River Eye

Eye 09 71.930

Eye 08 71.880

Assume pond outfall into River Eye at 72m AOD

Ditch across the flood plain

Length from pond to river bank 80.000

Length say 61.000 from river bank to edge of pond

Invert level of pond outlet 72.535

Ground level of flood plain 73.400

Assume channel 1m deep at edge of pond 72.400

Flood plain levels dictate channel depth

∴ channel invert at River Eye $72.400 - \frac{61.000}{200.000} = 72.095$

Conclusion: Levels workable but limited contingency as river level 72m AOD. Note however pond inlet assumed to be above storage volume, improvement in levels could be achieved by setting inlet at same level as outlet

CALCULATIONS

Project	Melton Mowbray			
JEN	? ? ? ? ? ? ?	Date	Page No	Rev
Originator	Checked	Revision	Suffix / Date	Orig / Check

Ref. | Output

Pond 9/G   Refine check on outfall from pond to River Eye

From xsections water level in River Eye

Eye 09	71.880
Eye 08	71.890

Assume pond outfall into River Eye at 72m AOD

Ditch across the flood plain

Length from pond to river bank 60.000

Length say 45.000 from river bank to edge of pond

Invert level of pond outlet 72.660

Ground level of flood plain 73.400

Assume channel 1m deep at edge of pond 72.400

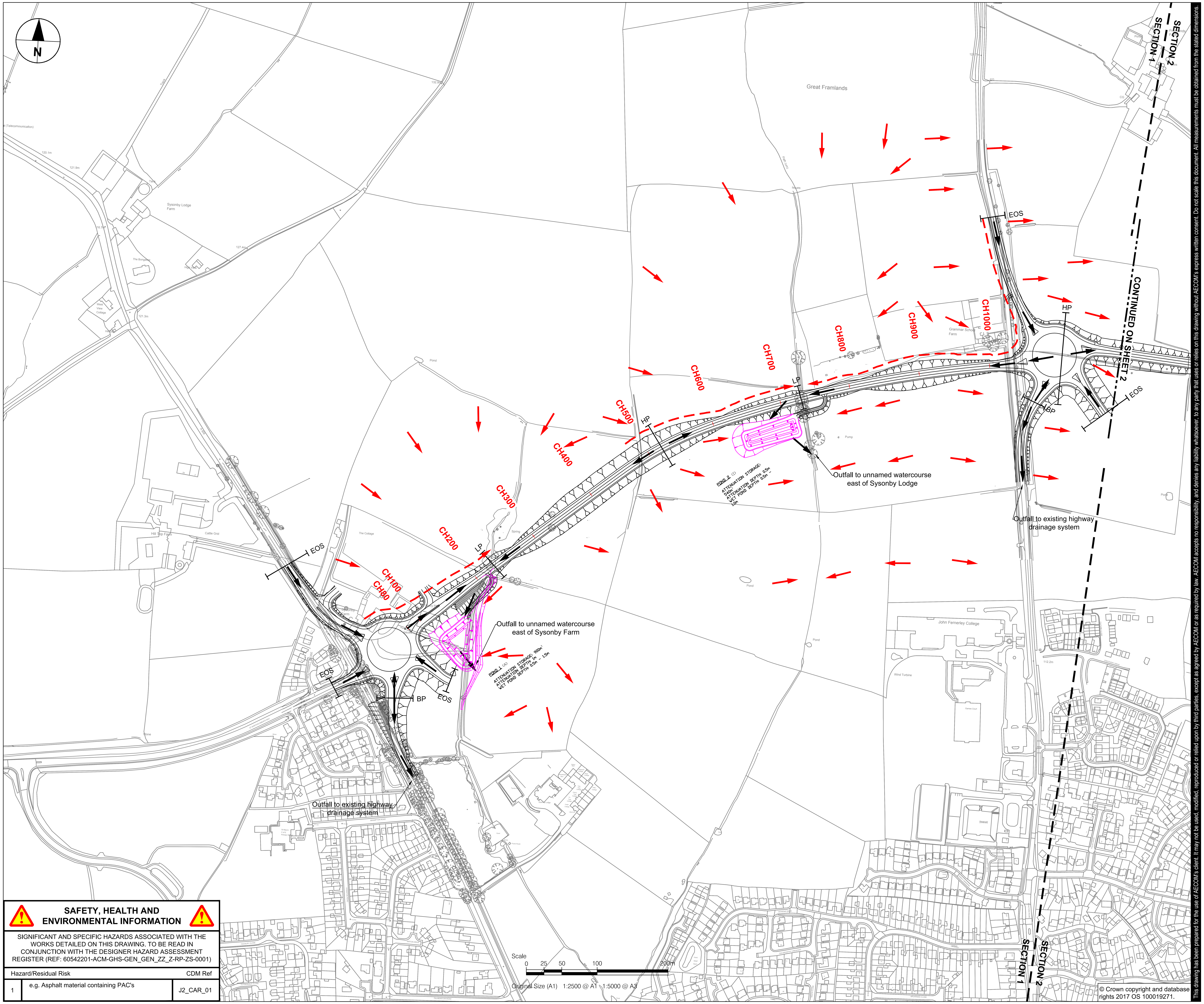
Flood plain levels dictate channel depth

∴ channel invert at River Eye $72.400 - \frac{45.000}{200.000} = 72.175$

Conclusion: Levels workable but limited contingency as river level 72m AOD. Note however pond inlet assumed to be above storage volume, improvement in levels could be achieved by setting inlet at same level as outlet

Appendix 5 Drawings

ISO A1 594mm x 841mm



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

SIGNIFICANT AND SPECIFIC HAZARDS ASSOCIATED WITH THE WORKS DETAILED ON THIS DRAWING. TO BE READ IN CONJUNCTION WITH THE DESIGNER HAZARD ASSESSMENT REGISTER (REF: 60542201-ACM-GHS-GEN_GEN_ZZ_Z-RP-ZS-0001)

	Hazard/Residual Risk	CDM Ref
1	e.g. Asphalt material containing PAC's	J2_CAR_01

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PROJECT

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NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE.
2. THIS DRAWING IS BASED ON ORDNANCE SURVEY DATA AND THE COMBINED AECOM AND LCC TOPOGRAPHICAL SURVEY .

Key:

EOS	Extent of Scheme
HP	High Point
LP	Low Point
BP	Drainage Break Point
(black arrow)	Routing of highway runoff through proposed drainage system
(red arrow)	Direction of overland surface flow
(red dashed arrow)	Proposed earthworks cut off ditches/ drains

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
OVERLAND FLOW AND EARTHWORKS DRAINAGE ADDED	CN / GD	25/09/18	3
POND NUMBERS ADDED, MINOR CORRECTIONS	CN / GD	07/09/18	2

PROJECT MANAGEMENT INITIALS

DESIGNED: CN CHECKED: GD APPROVED: GD

INTERNAL PROJECT NUMBER 60542201

SCALE 1:2500

STATUS INFORMATION

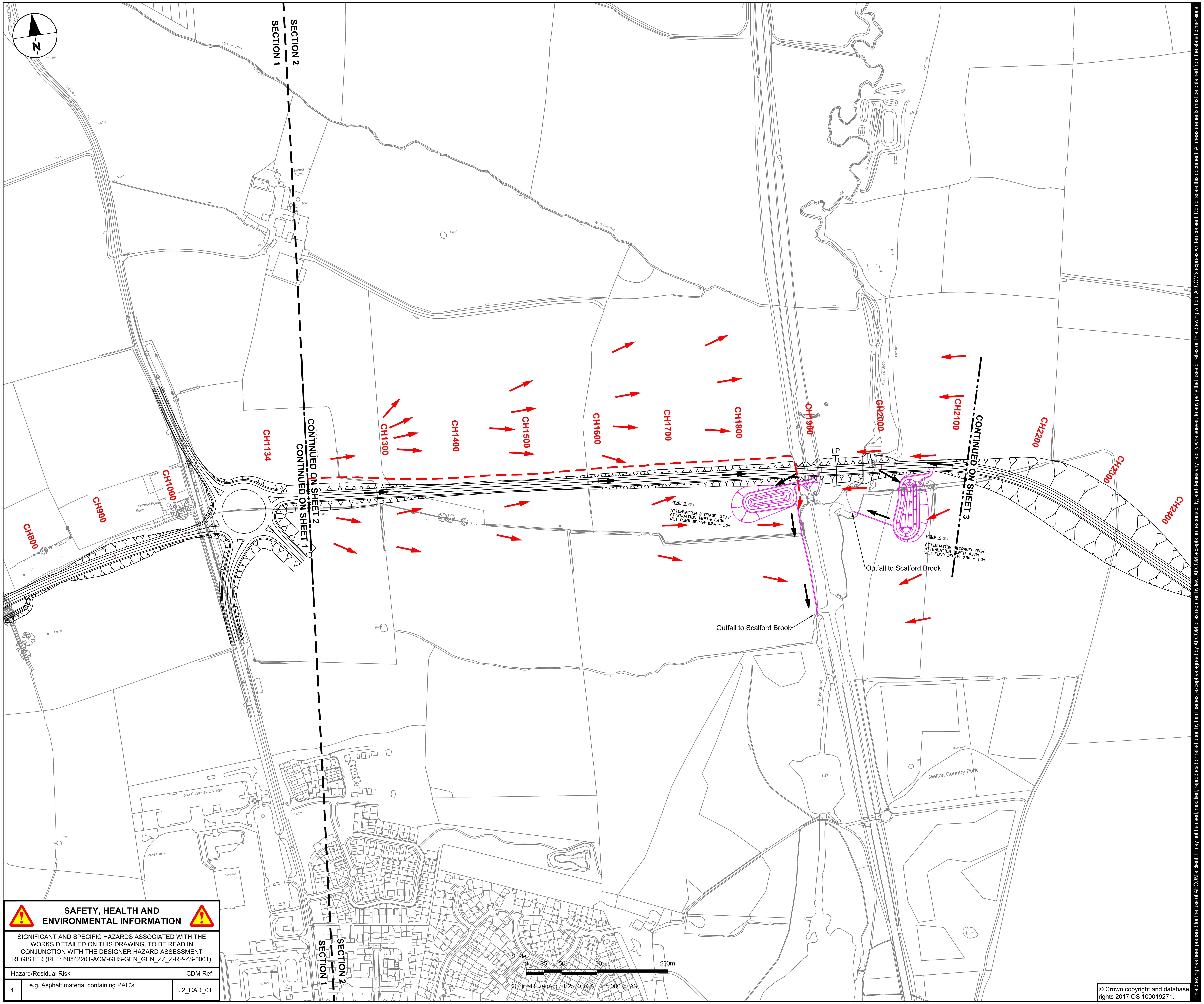
BS1192 SUITABILITY S0

SHEET TITLE

SURFACE WATER DRAINAGE PLAN
SHEET 1 OF 7

DRAWING NUMBER 60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0001

REV 3



ISO A1 594mm x 841mm

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

SIGNIFICANT AND SPECIFIC HAZARDS ASSOCIATED WITH THE WORKS DETAILED ON THIS DRAWING. TO BE READ IN CONJUNCTION WITH THE DESIGNER HAZARD ASSESSMENT REGISTER (REF: 60542201-ACM-GHS-GEN_GEN_ZZ_Z-RP-ZS-0001)

Hazard/Residual Risk		CDM Ref
1	e.g. Asphalt material containing PAC's	J2_CAR_01

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NOTES

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Key:

EOS	Extent of Scheme
HP	High Point
LP	Low Point
BP	Drainage Break Point
(black arrow)	Routing of highway runoff through proposed drainage system
(red arrow)	Direction of overland surface flow
(red dashed arrow)	Proposed earthworks cut off ditches/ drains

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
OVERLAND FLOW AND EARTHWORKS DRAINAGE ADDED	CN / GD	25/09/18	3
POND NUMBERS ADDED, MINOR CORRECTIONS	CN / GD	07/09/18	2

PROJECT MANAGEMENT INITIALS

DESIGNED: CN   CHECKED: GD   APPROVED: GD

INTERNAL PROJECT NUMBER | **SCALE**

60542201 | 1:2500

STATUS | **BS1192 SUITABILITY**

INFORMATION | S0

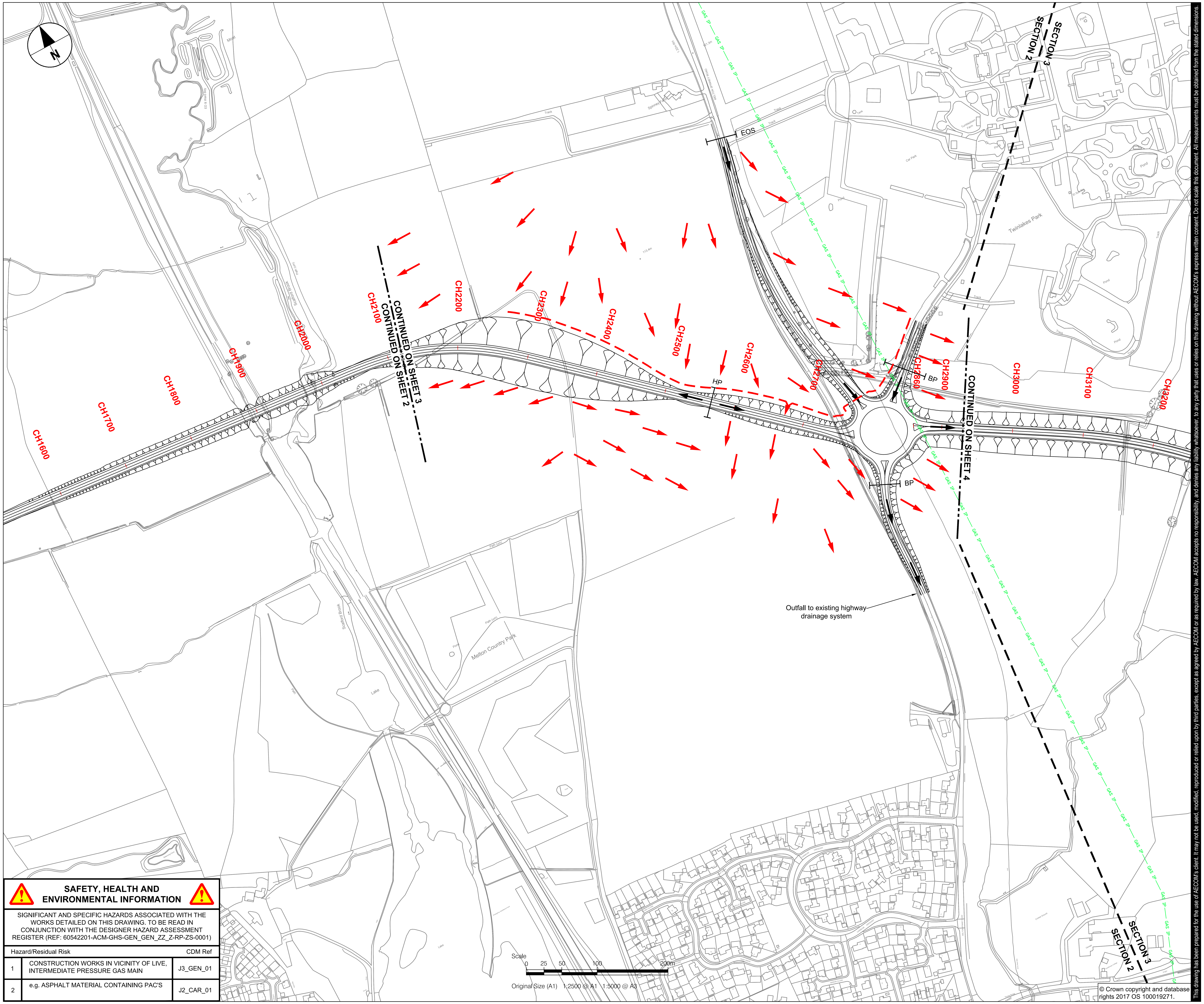
SHEET TITLE

SURFACE WATER DRAINAGE PLAN
SHEET 2 OF 7

DRAWING NUMBER | **REV**

60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0002 | 3

ISO A1 594mm x 841mm



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION		
SIGNIFICANT AND SPECIFIC HAZARDS ASSOCIATED WITH THE WORKS DETAILED ON THIS DRAWING. TO BE READ IN CONJUNCTION WITH THE DESIGNER HAZARD ASSESSMENT REGISTER (REF: 60542201-ACM-GHS-GEN_GEN_ZZ_Z-RP-ZS-0001)		
Hazard/Residual Risk		CDM Ref
1	CONSTRUCTION WORKS IN VICINITY OF LIVE, INTERMEDIATE PRESSURE GAS MAIN	J3_GEN_01
2	e.g. ASPHALT MATERIAL CONTAINING PAC'S	J2_CAR_01

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OVERLAND FLOW AND EARTHWORKS DRAINAGE ADDED	CN / GD	25/09/18	3
POND NUMBERS ADDED, MINOR CORRECTIONS	CN / GD	07/09/18	2

PROJECT MANAGEMENT INITIALS

DESIGNED: CN CHECKED: GD APPROVED: GD

INTERNAL PROJECT NUMBER 60542201

SCALE 1:2500

STATUS INFORMATION

BS1192 SUITABILITY S0

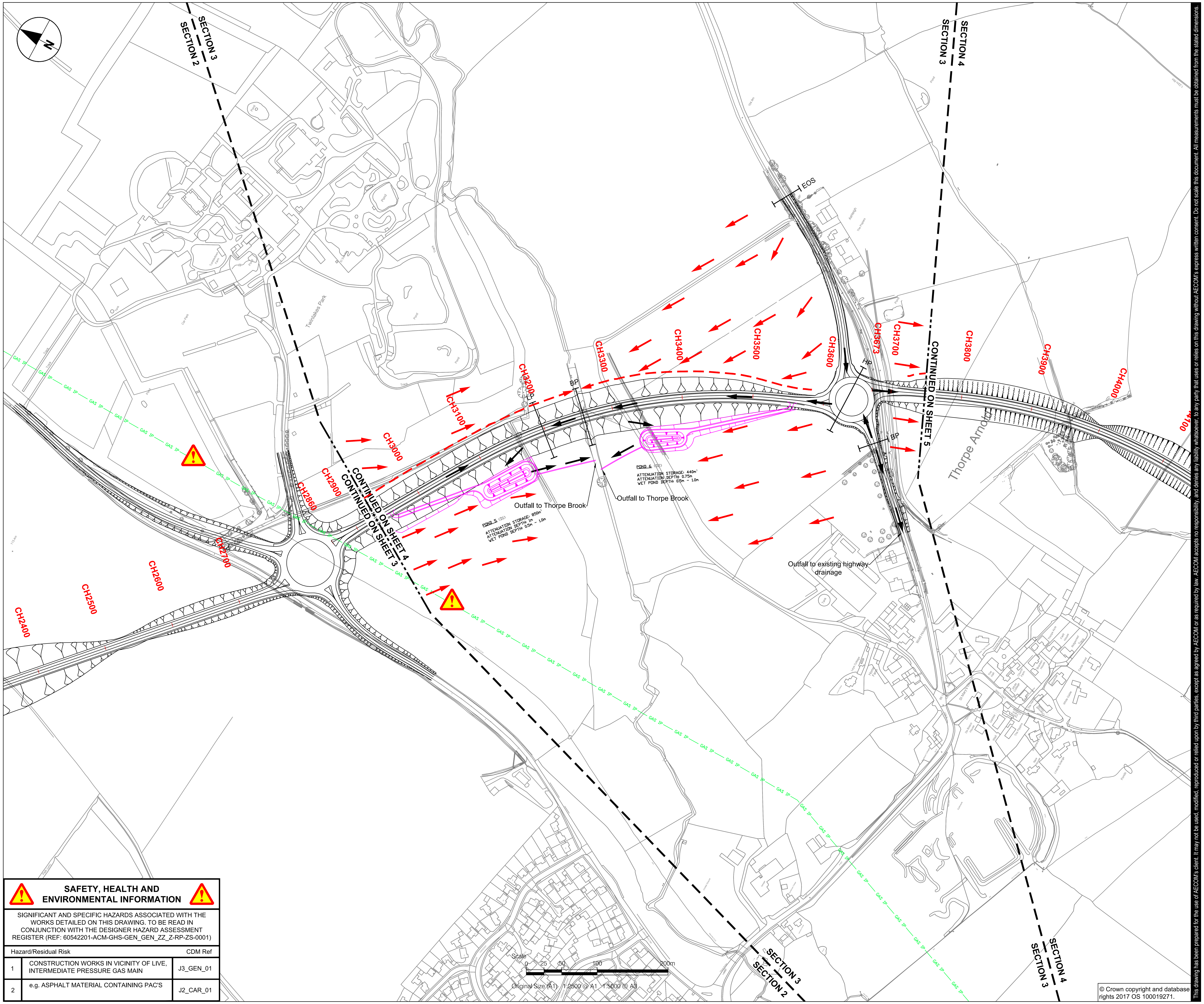
SHEET TITLE

SURFACE WATER DRAINAGE PLAN
SHEET 3 OF 7

DRAWING NUMBER 60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0003

REV 3

ISO A1 594mm x 841mm



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	Hazard/Residual Risk	CDM Ref
1	CONSTRUCTION WORKS IN VICINITY OF LIVE, INTERMEDIATE PRESSURE GAS MAIN	J3_GEN_01
2	e.g. ASPHALT MATERIAL CONTAINING PAC'S	J2_CAR_01

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POND NUMBERS ADDED, MINOR CORRECTIONS	CN / GD	07/09/18	2

PROJECT MANAGEMENT INITIALS

DESIGNED: CN CHECKED: GD APPROVED: GD

INTERNAL PROJECT NUMBER 60542201

SCALE 1:2500

STATUS INFORMATION

BS1192 SUITABILITY S0

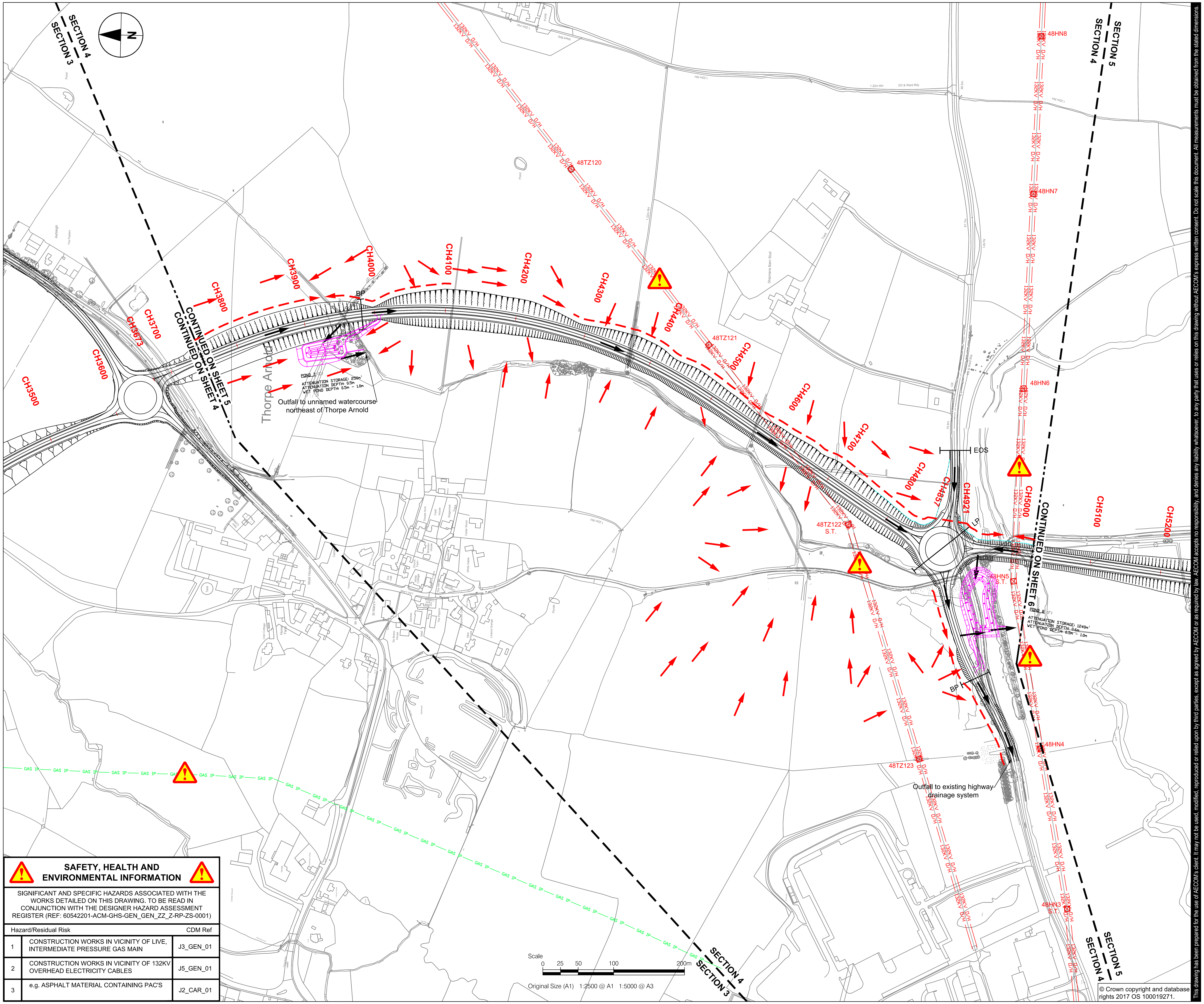
SHEET TITLE

SURFACE WATER DRAINAGE PLAN
SHEET 4 OF 7

DRAWING NUMBER 60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0004

REV 3

ISO A1 594mm x 841mm



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	Hazard/Residual Risk	CDM Ref
1	CONSTRUCTION WORKS IN VICINITY OF LIVE, INTERMEDIATE PRESSURE GAS MAIN	J3_GEN_01
2	CONSTRUCTION WORKS IN VICINITY OF 132KV OVERHEAD ELECTRICITY CABLES	J5_GEN_01
3	e.g. ASPHALT MATERIAL CONTAINING PAC'S	J2_CAR_01

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REVISION DETAILS	BY / CHECK	DATE	SUFFIX
OVERLAND FLOW AND EARTHWORKS DRAINAGE ADDED	CN / GD	25/09/18	3
POND NUMBERS ADDED, MINOR CORRECTIONS, POND F AMENDED	CN / GD	07/09/18	2

PROJECT MANAGEMENT INITIALS

DESIGNED: CN CHECKED: GD APPROVED: GD

INTERNAL PROJECT NUMBER 60542201

SCALE 1:2500

STATUS INFORMATION

BS1192 SUITABILITY S0

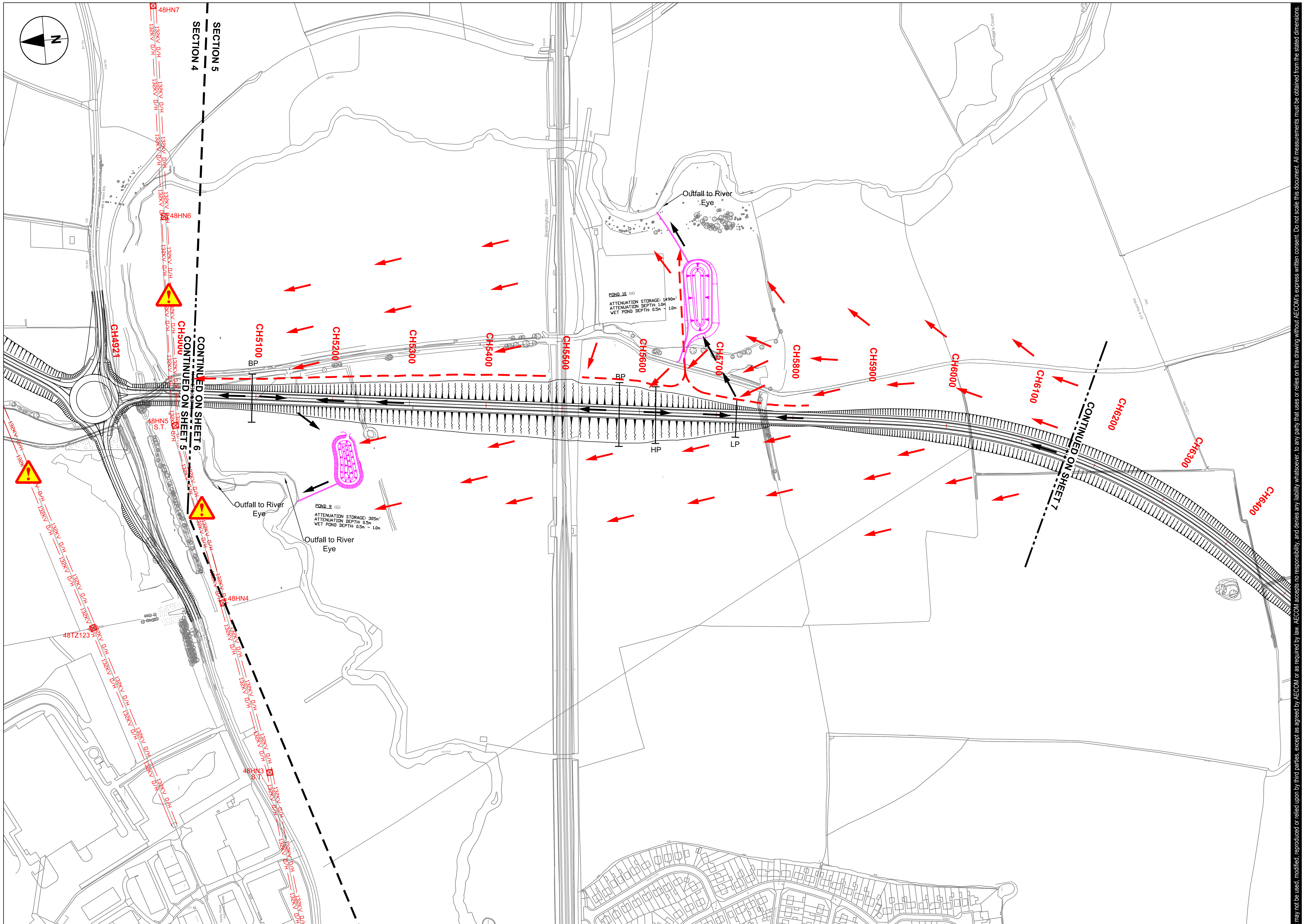
SHEET TITLE

SURFACE WATER DRAINAGE PLAN
SHEET 5 OF 7

DRAWING NUMBER 60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0005

REV 3

ISO A1 594mm x 841mm



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

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	Hazard/Residual Risk	CDM Ref
1	CONSTRUCTION WORKS IN VICINITY OF LIVE, INTERMEDIATE PRESSURE GAS MAIN	J3_GEN_01
2	CONSTRUCTION WORKS IN VICINITY OF 132KV OVERHEAD ELECTRICITY CABLES	J5_GEN_01
3	e.g. ASPHALT MATERIAL CONTAINING PAC'S	J2_CAR_01

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REVISION DETAILS	BY / CHECK	DATE	SUFFIX
OVERLAND FLOW AND EARTHWORKS DRAINAGE	CN / GD	25/09/18	3
POND NUMBERS ADDED, MINOR CORRECTIONS, POND G AMENDED	CN / GD	07/09/18	2

PROJECT MANAGEMENT INITIALS

DESIGNED: CN CHECKED: GD APPROVED: GD

INTERNAL PROJECT NUMBER 60542201

SCALE 1:2500

STATUS INFORMATION

BS1192 SUITABILITY S0

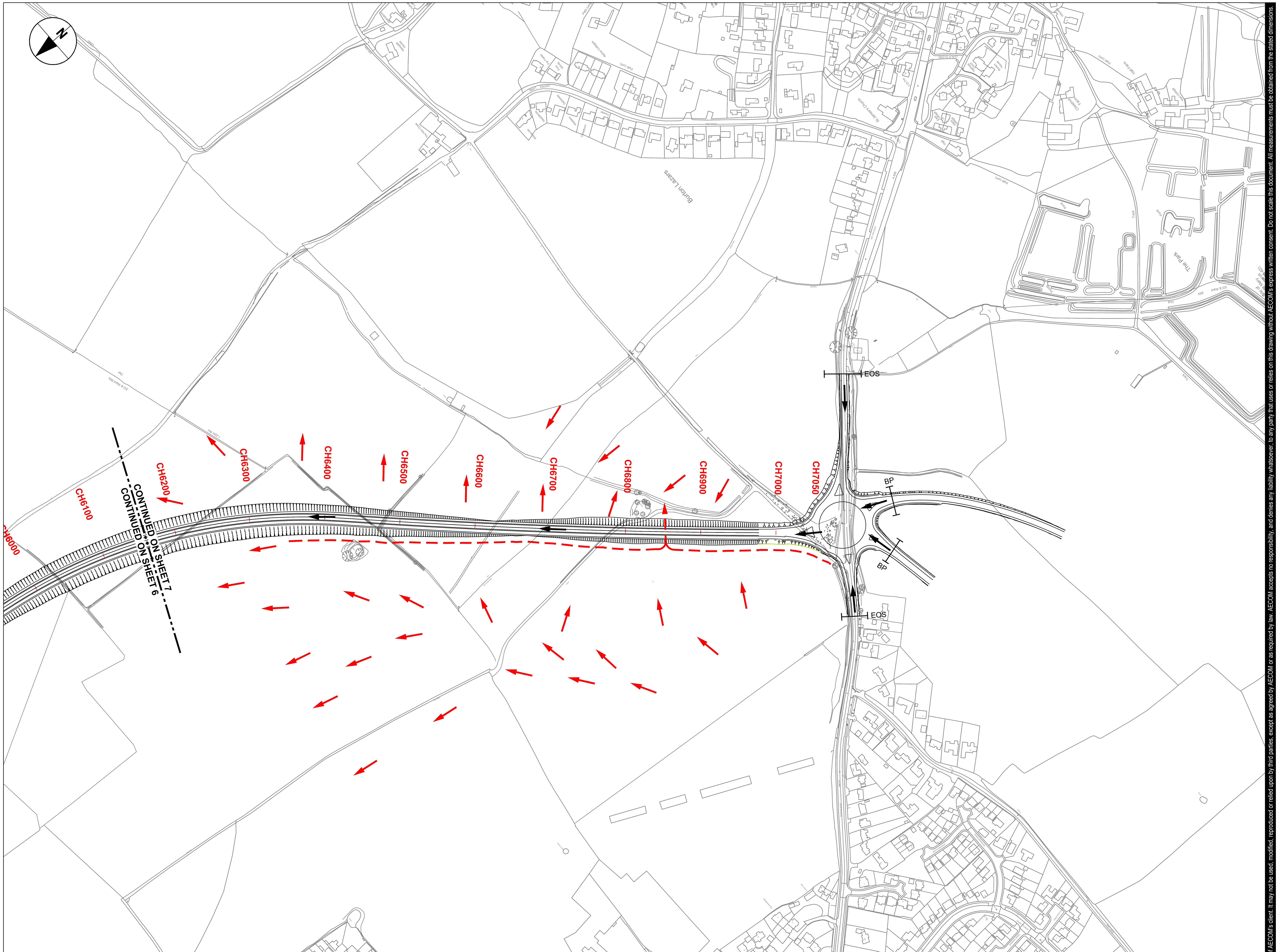
SHEET TITLE

SURFACE WATER DRAINAGE PLAN
SHEET 6 OF 7

DRAWING NUMBER 60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0006

REV 3

ISO A1 594mm x 841mm



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

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	Hazard/Residual Risk	CDM Ref
1	e.g. Asphalt material containing PAC's	J2_CAR_01

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	BY / CHECK	DATE	SUFFIX
OVERLAND FLOW AND EARTHWORKS DRAINAGE	CN / GD	25/09/18	3
POND NUMBERS ADDED, MINOR CORRECTIONS	CN / GD	07/09/18	2
REVISION DETAILS	BY / CHECK	DATE	SUFFIX

PROJECT MANAGEMENT INITIALS

DESIGNED: CN CHECKED:GD APPROVED: GD

INTERNAL PROJECT NUMBER **SCALE**

60542201 1:2500

STATUS **BS1192 SUITABILITY**

INFORMATION S0

SHEET TITLE

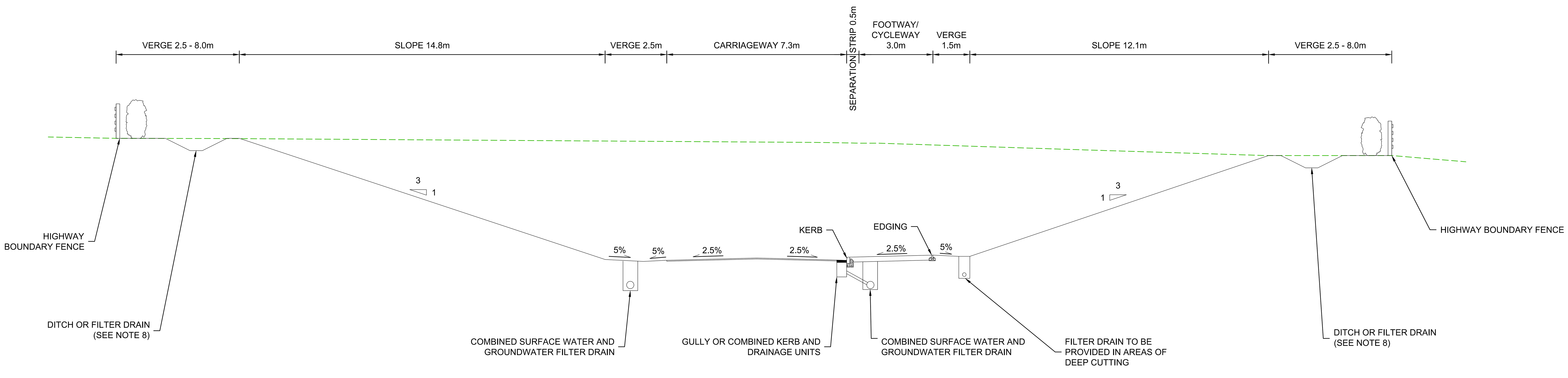
SURFACE WATER DRAINAGE PLAN
SHEET 7 OF 7

DRAWING NUMBER **REV**

60542201-ACM-VOL -SEC_TYP_ID_D -DR-RO-0007 3

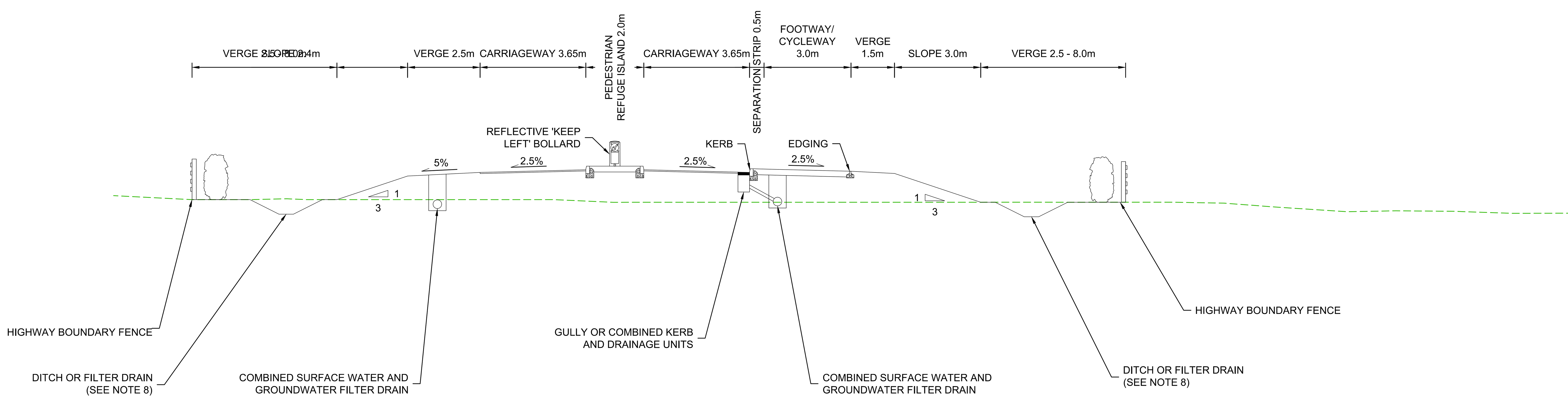
ISO A1 594mm x 841mm

TYPICAL CROSS SECTION A-A
INDICATIVE 4.7m CUTTING @ CIRCA CH400



Scale
0 1 2 4 8m
Original Size (A1) 1:100 @ A1 1:200 @ A3

TYPICAL CROSS SECTION B-B
INDICATIVE 1.1m EMBANKMENT @ CIRCA CH800



Scale
0 1 2 4 8m
Original Size (A1) 1:100 @ A1 1:200 @ A3

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3. LIGHTING TO BE INSTALLED IN THE VERGE - AT THE APPROACHES TO ROUNDABOUTS.
4. ROAD RESTRAINT SYSTEMS TO BE INSTALLED WHERE REQUIRED.
5. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE PLANNING GENERAL ARRANGEMENT DRAWINGS 60542201-ACM-GEN-XX_XX_ZZ_Z-DR-T-0001 TO 0021, WHERE XX_XX IS THE SECTIONAL LOCATION REFERENCE.
6. VERGES TO BE WIDENED AS REQUIRED TO INCORPORATE TRAFFIC SIGNS, LIGHTING COLUMNS AND ENVIRONMENTAL BARRIERS.
7. CARRIAGEWAY TO BE WIDENED AS REQUIRED TO INCORPORATE PEDESTRIAN REFUGES AT NMU CROSSING POINTS.
8. DRAINAGE REQUIREMENTS AND SIZE OF DRAINAGE AT HIGHWAY BOUNDARY VARY DEPENDANT ON ADJACENT TOPOGRAPHY.

KEY

EXISTING GROUND LEVEL
PROPOSED GROUND LEVEL

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
FOR PLANNING	II / AS	20/09/18	P02

PROJECT MANAGEMENT INITIALS

DESIGNED: MM CHECKED: MH APPROVED: AS

INTERNAL PROJECT NUMBER — **SCALE**

60542201 — 1:100

STATUS — **BS1192 SUITABILITY**

FOR INFORMATION — S2

SHEET TITLE

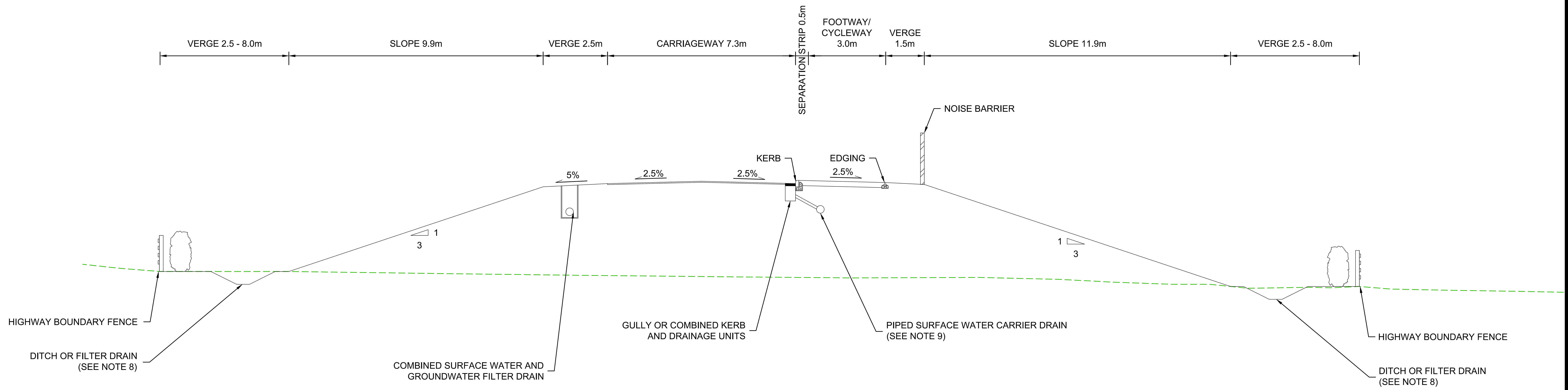
HIGHWAY CROSS SECTIONS
SECTION 1 MAINLINE

DRAWING NUMBER — **REV**

60542201-ACM-HML-S1_ML_M01_Z -DR-T -0001 — P02

ISO A1 594mm x 841mm

TYPICAL CROSS SECTION C-C
INDICATIVE 3.7m EMBANKMENT @ CIRCA CH1250



Scale
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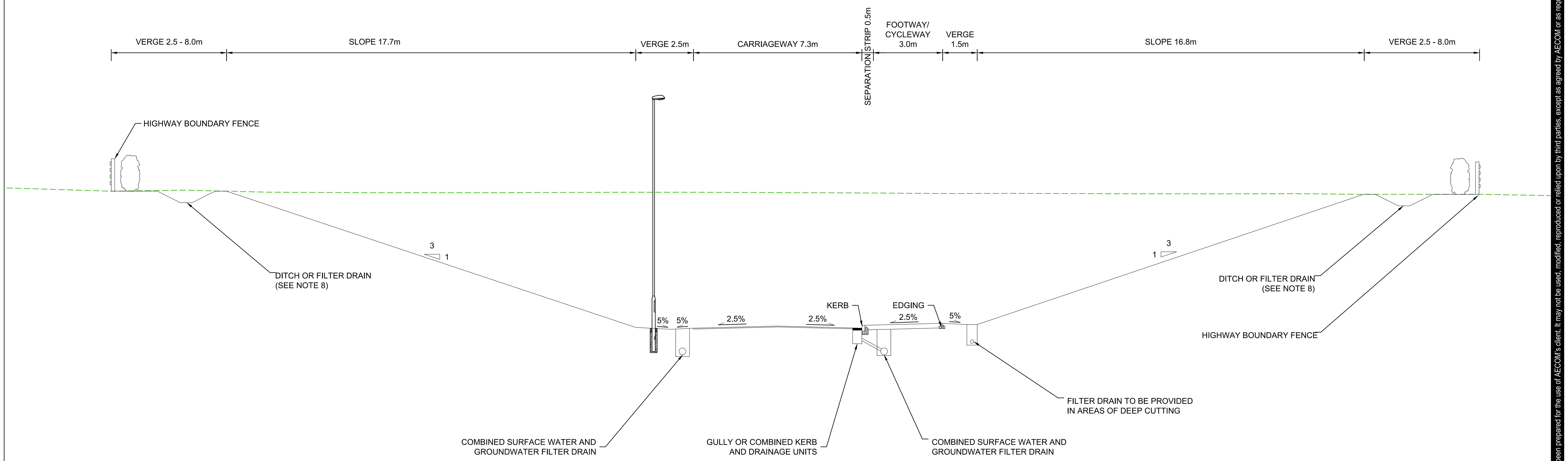
Original Size (A1) 1:100 @ A1 1:200 @ A3

TYPICAL CROSS SECTION D-D
INDICATIVE 5.7m CUTTING @ CIRCA CH2440



Scale
0 1 2 4 8m
Original Size (A1) 1:100 @ A1 1:200 @ A3

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7. CARRIAGEWAY TO BE WIDENED AS REQUIRED TO INCORPORATE PEDESTRIAN REFUGES AT NMU CROSSING POINTS.
8. DRAINAGE REQUIREMENTS AND SIZE OF DRAINAGE AT HIGHWAY BOUNDARY VARY DEPENDANT ON ADJACENT TOPOGRAPHY.
9. OPTION TO SWITCH TO COMBINED SURFACE WATER AND GROUNDWATER FILTER DRAIN TO MAINTAIN CONTINUITY WHERE REQUIRED.

KEY

EXISTING GROUND LEVEL
PROPOSED GROUND LEVEL

REVISION DETAILS	BY / CHECK	DATE	SUFFIX
FOR PLANNING	II / AS	20/09/18	P02

PROJECT MANAGEMENT INITIALS

DESIGNED: MM CHECKED: MH APPROVED: AS

INTERNAL PROJECT NUMBER 60542201

SCALE 1:100

STATUS FOR INFORMATION

BS1192 SUITABILITY S2

SHEET TITLE

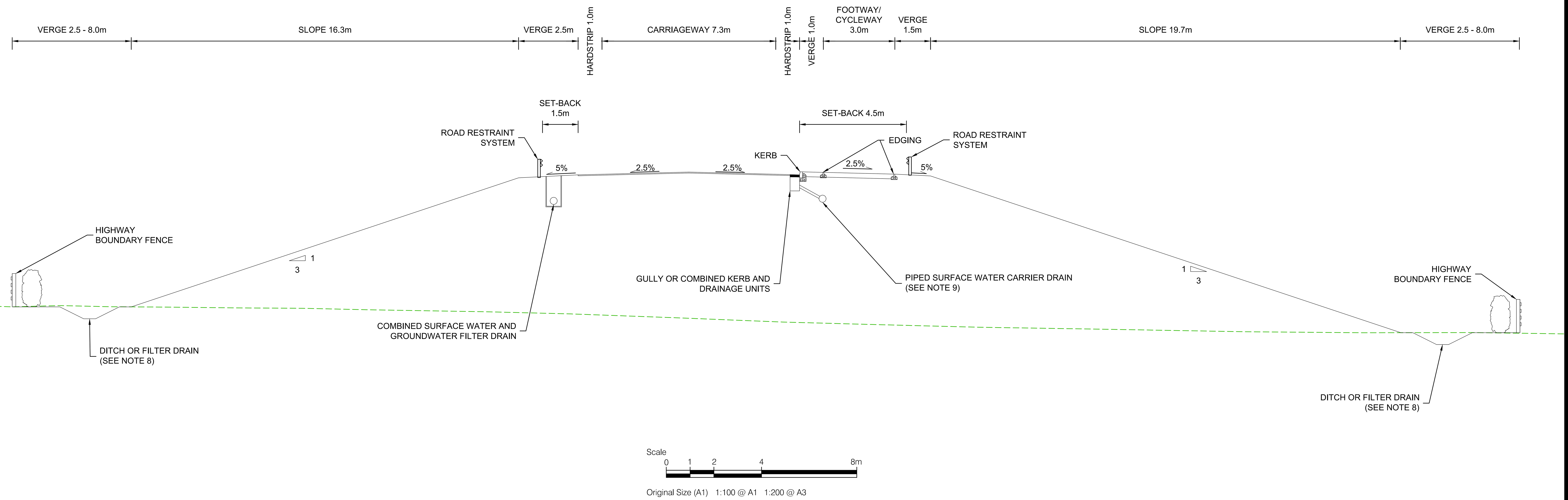
HIGHWAY CROSS SECTIONS
SECTION 2 MAINLINE

DRAWING NUMBER 60542201-ACM-HML-S2_ML_M02_Z -DR-T -0002

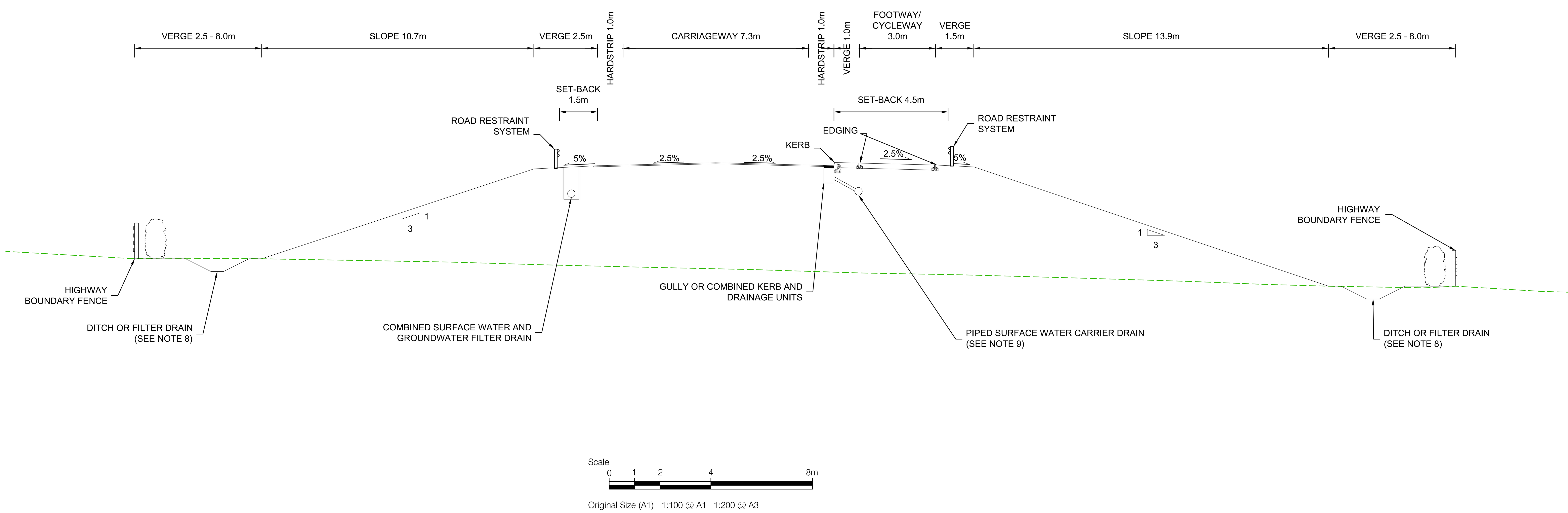
REV P02

ISO A1 594mm x 841mm

TYPICAL CROSS SECTION E-E
INDICATIVE 6.1m EMBANKMENT @ CIRCA CH3000



TYPICAL CROSS SECTION F-F
INDICATIVE 4.2m EMBANKMENT @ CIRCA CH3500



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4. ROAD RESTRAINT SYSTEMS TO BE INSTALLED WHERE REQUIRED.
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8. DRAINAGE REQUIREMENTS AND SIZE OF DRAINAGE AT HIGHWAY BOUNDARY VARY DEPENDANT ON ADJACENT TOPOGRAPHY.
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KEY

- - - - EXISTING GROUND LEVEL
——— PROPOSED GROUND LEVEL

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PROJECT MANAGEMENT INITIALS

DESIGNED: MM CHECKED:MH APPROVED: AS

INTERNAL PROJECT NUMBER 60542201

SCALE 1:100

STATUS FOR INFORMATION

BS1192 SUITABILITY S2

SHEET TITLE

HIGHWAY CROSS SECTIONS
SECTION 3 MAINLINE

DRAWING NUMBER 60542201-ACM-HML-S3_ML_M03_Z -DR-T -0003

REV P02

ISO A1 594mm x 841mm

TYPICAL CROSS SECTION G-G
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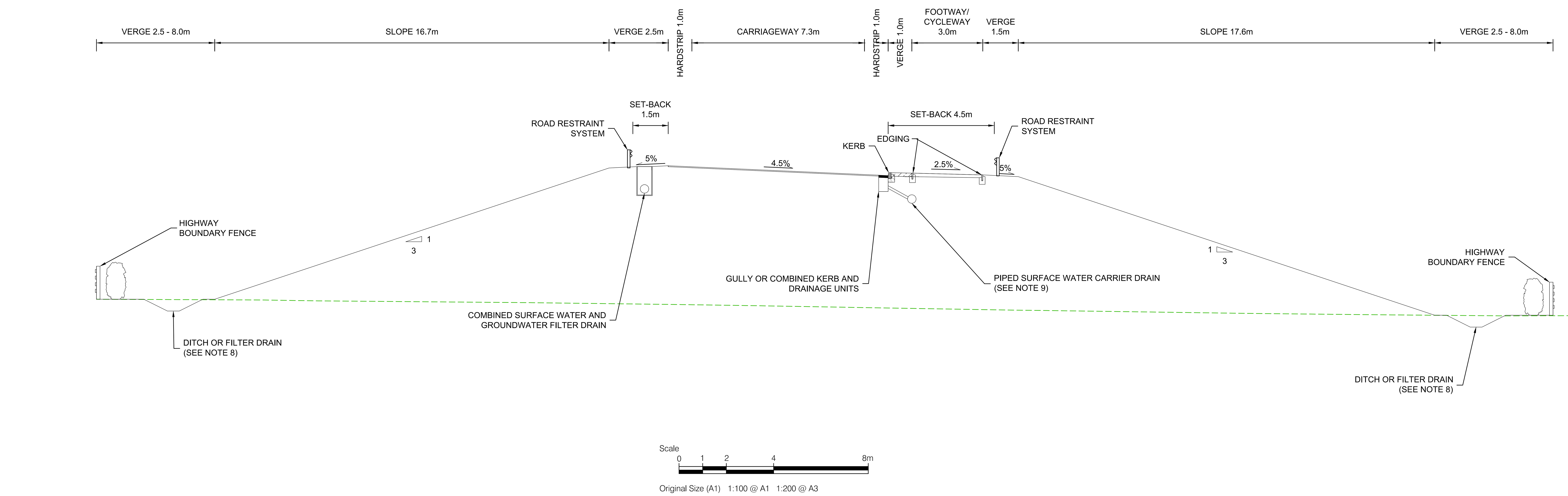
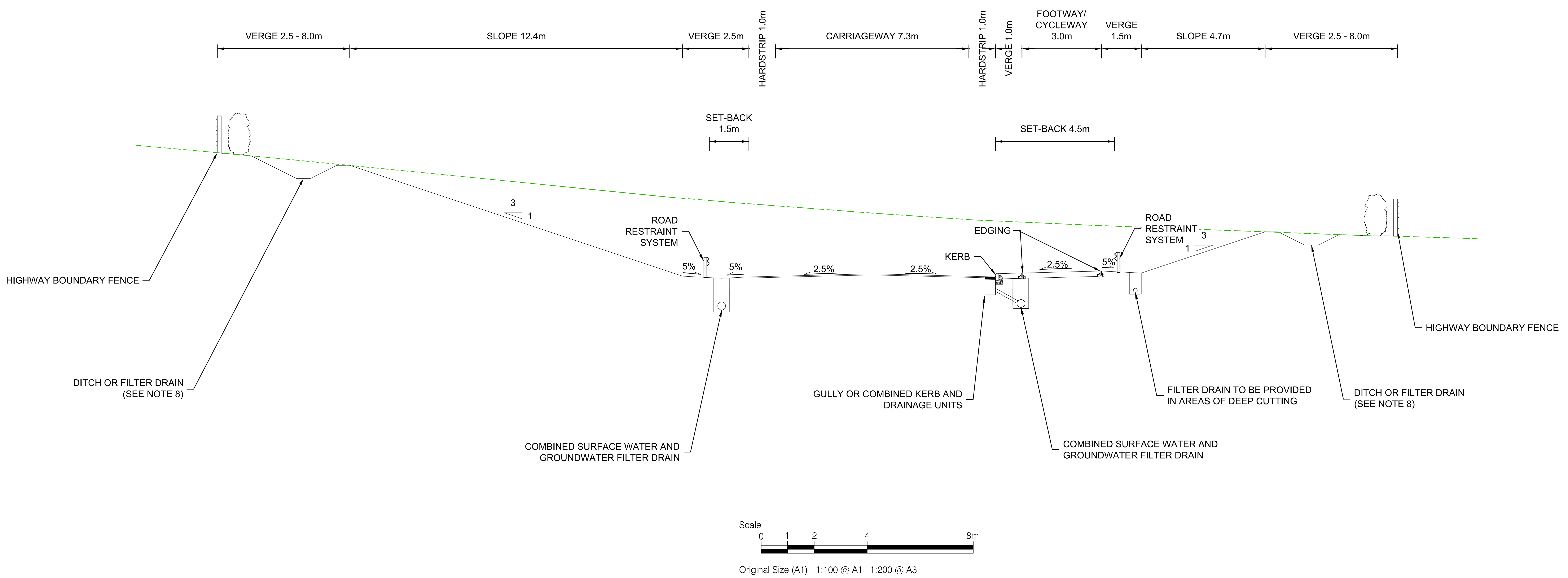
(SUPER ELEVATED SECTION)



TYPICAL CROSS SECTION H-H
INDICATIVE 2.3m CUTTING @ CIRCA CH4550



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SHEET TITLE

HIGHWAY CROSS SECTIONS
SECTION 4 MAINLINE

DRAWING NUMBER 60542201-ACM-HML-S4_ML_M04_Z -DR-T -0004

REV P02

ISO A1 594mm x 841mm

TYPICAL CROSS SECTION I-I
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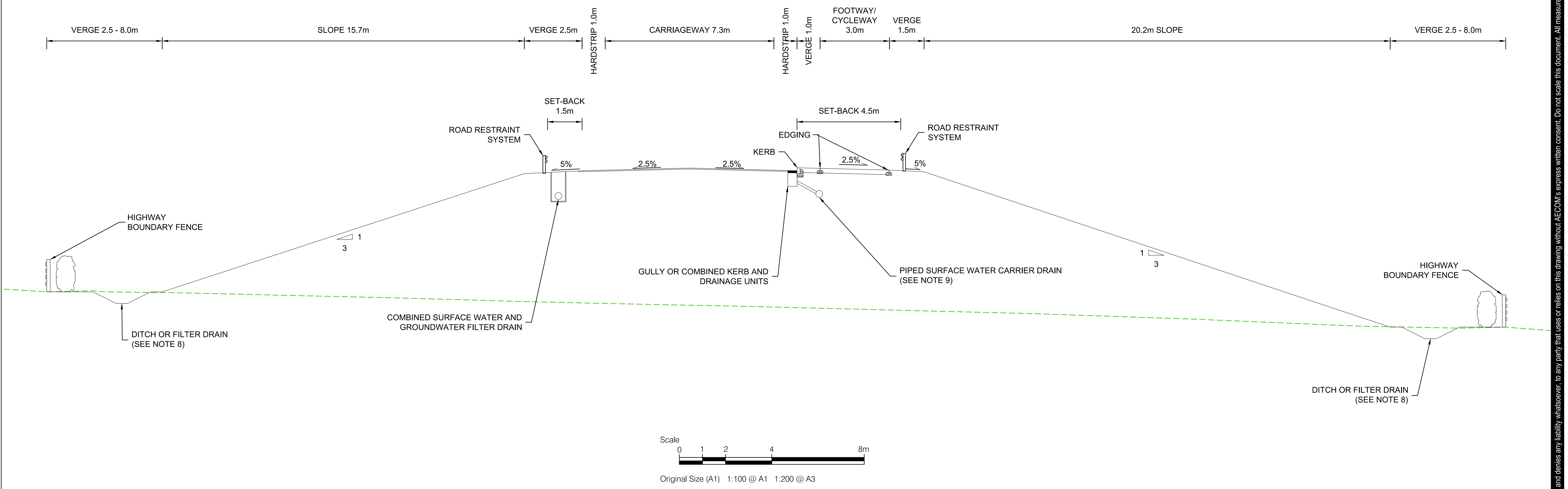

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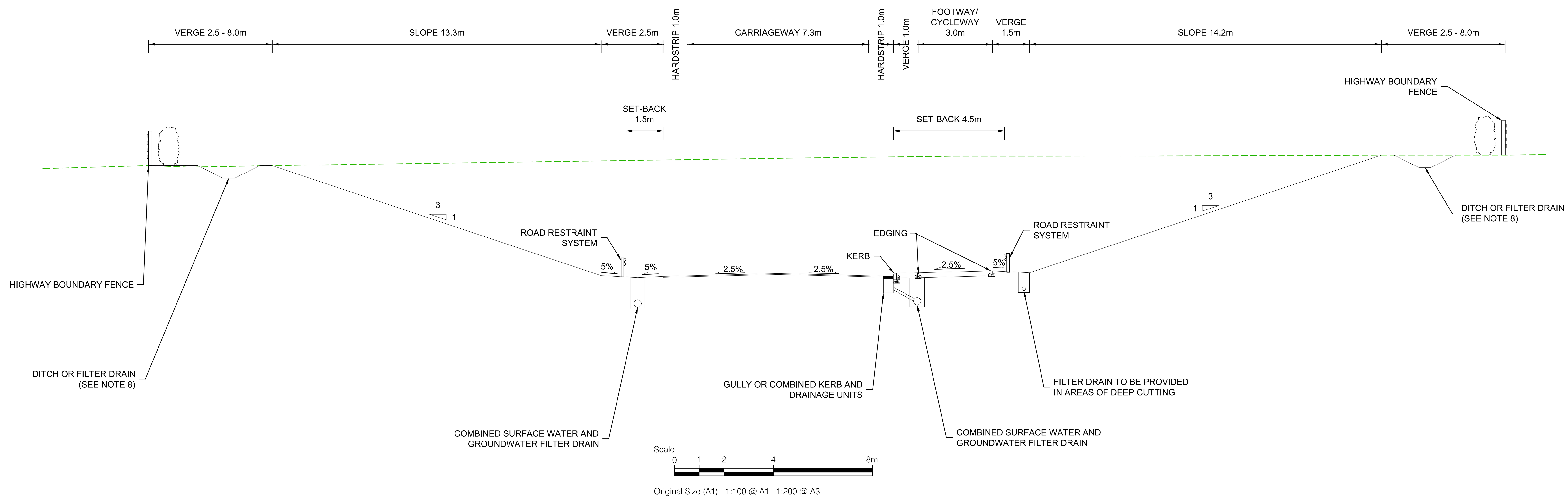

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HIGHWAY CROSS SECTIONS
SECTION 5 MAINLINE

DRAWING NUMBER 60542201-ACM-HML-S5_ML_M05_Z -DR-T -0005

REV P02

Appendix G

Brentingby Dam Breach Modelling Tech Note

AECOM Imagine it. Delivered.

Melton Mowbray Distributor Road

Breach Modelling Report

Leicestershire County Council

21 September 2018

Quality information

Prepared by	Checked by	Approved by
Ben Brough Graduate Consultant	Ian Bentley Senior Engineer	

Revision History

Revision	Revision date	Details	Authorized	Name	Position
0	7th September 2018				

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Figures

Tables

1. Introduction

This report sets out the methodology and results of the breach modelling that has been carried out in support of the Melton Mowbray Distributor Road FRA. The main purpose of the analysis is to determine the risk to the proposed development in the event of a breach at Brentingby Dam and assess any change to the wider flood risk caused by the development, in the event of such a breach.

1.1 Background

Leicestershire City Council is proposing to build a distributor highway (referred to as MMDR within the wider study) around the town of Melton Mowbray (National Grid Reference SK 752 192). The current route of the highway crosses the River Eye at Lag Lane Bridge, approximately 800 metres (m) downstream of Brentingby Dam (see **Figure 1**). Since the highway crosses the River Eye in close proximity to a dam, a breach analysis is required to improve understanding of potential risks associated with the highway.

Through consultation with the Environment Agency (EA) regarding breach modelling, the EA have commented:

"*The consultants will need to decide on whether to ensure any road and road bridge is designed in such a way as to remain operational during such an event or to accept that such an event would lead to road closures*."

As such, this report will outline the steps used by AECOM to assess the impacts on and surrounding the highway during a Brentingby Dam breach.

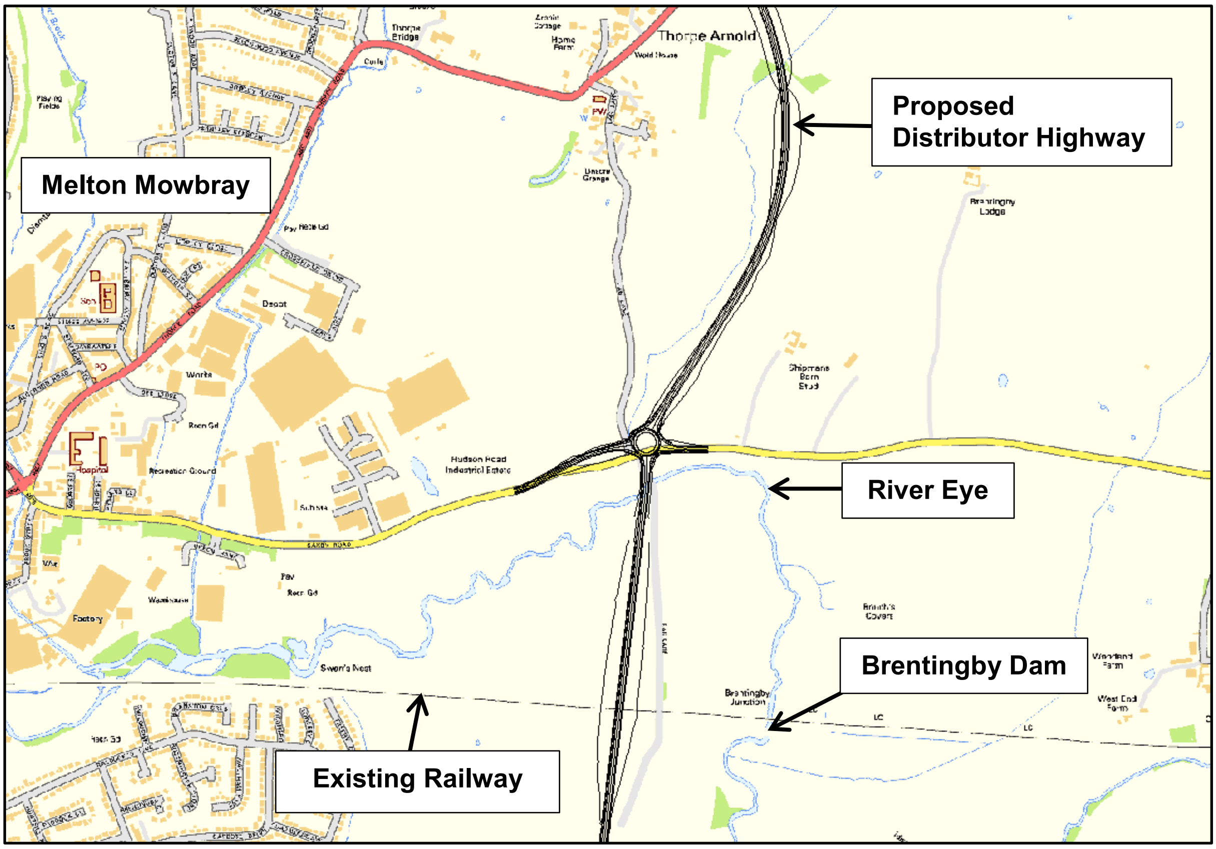

Figure 1 – Location of proposed River Eye crossing and Brentingby Dam.

1.2 Breach Modelling Scope Overview

The Environment Agency approved scope for the breach modelling is included in **Appendix A**. The approved scope required the use of an updated breach guide released in 2017, superseding the EA (Anglian Region – Northern Area) guidance, providing a consistent approach to breach modelling. The updated breach document is included in **Appendix B** (document: **Breach guidance 2017**).

An overview of the key aspects of the scope, as applied to the current analysis, is:

- The base of the breach was set to the typical ground level along the 'toe' of the embankment (based on LiDAR);
- The breach commenced when the flood level within the storage area behind the dam reached three quarters of the dam height (calculated to be 78 m AOD). Timings were based on previous baseline model runs;
- The breach width was 40m and will remain open for 56 hours (at which point it is assumed the breach will have been closed);
- The dam breach scenario runs comprise the 5%, 1.3%, 1%, 0.1% AEP events, and the 1% AEP plus 30% climate change scenario (as agreed with the EA); and
- Flood depth and hazard maps have been produced for the baseline and proposed scenarios, for all modelled events.

2. Brentingby Dam Breach Modelling

The Brentingby Dam breach models are based on versions of the Baseline and Proposed models submitted to the EA in May/ June 2018, which had been developed to assess the impact on flood risk to and as a result of the proposed MMDR scheme. These model versions are referred to from hereon in as the Baseline Breach and Proposed Breach models.

Subsequent to the submission of models to the EA in May/ June 2018, a number of changes occurred that affected both the Baseline and Proposed scenarios. Firstly, both models were updated to address EA comments received on the submitted versions. Secondly, the Baseline model was further developed to include new River Eye survey data undertaken by Central Surveys between July and August 2018. Thirdly, the Proposed model was updated to include the most recent River Eye realignment and morphological profile, the most recent proposals for the scheme horizontal and vertical alignment, and the associated revised proposals for the River Eye and Lag Lane tributary bridge/ culvert structures. These models are referred to from hereon in as the Baseline Design and Proposed Design models

Following consultation with the EA (email from Simon Smeathers, 30/07/18) it was agreed that it would not be necessary to update and re-run the original versions of the breach models (Baseline Breach and Proposed Breach) in relation to this specific Flood Risk Assessment (FRA).

2.1 Baseline Breach Model

For clarification, the following updates that were made to the Baseline Design model (as used in the design hydraulic modelling) were **not** updated in the Baseline Breach model:

- The use of new survey data for the rivers sections between WA_113.01 and WD93U. Instead, the existing geometry from the original EA model was retained; and
- Updated Lag Lane Bridge geometry based on the new survey data. Instead, the original Lag Lane bridge geometry was retained.

However, it was necessary to modify the previous version of the submitted baseline model to make it suitable for the breach modelling and production of outputs in accordance with the agreed scope. The following modifications were made to the baseline model to form the Baseline Breach model:

- A breach node was added to the 1D network and connected to the existing spill unit to represent overtopping of Brentingby Dam. The spill unit weir coefficient was increased from 0.3 to 1.4 as this was judged more appropriate for representing breach flows;
- The breach was set to:
    - occur on Brentingby Dam immediately to the east of the River Eye channel;
    - open to a base width of 40 m over a period of 12 minutes;
    - remain open for 56 hours;
- The timing of the breach varied for each AEP event because the breach has been modelled to occur when flood levels upstream of the dam reached three quarters of the dam height. Based on previous baseline results, each return period reached this level at different times.

  To model each return period breach, the breach baseline model was duplicated for each AEP event and the 1D breach node modified accordingly. The breach occurs at the following timings:
    - 5% AEP event – 37.5 hours;
    - 1.3% AEP event – 28 hours;
    - 1% AEP event – 26.8 hours;
    - 1% AEP plus 30% Climate Change event – 23.6 hours; and

- 0.1% AEP event – 20.4 hours.

- The breach model was run for 60 hours. Based on the breach timings outlined above for each AEP event, the model would run to completion before the breach would close. The model was not run for longer because past 60 hours, the breach water levels within the study area would have already reached its peak;
- HX boundaries from Brentingby Dam to Lag Lane Bridge were given an “a” flag value of 0.2 to increase the stability of the model;
- The boundary viscosity factor was set to 2.0;
- The breach model was run with lowered time-steps for some events in order to reduce instabilities and enable the model to run through to completion. **Table 1** shows the time-step used for each model run.

Table 1 – Time-steps used for each run.

	Baseline Time-Step (s)		Proposed Time-Steps (s)	
Event	**1D**	**2D**	**1D**	**2D**
5%	0.5	1.0	0.5	1.0
1.33%	2.0	4.0	1.0	2.0
1%	1.0	2.0	1.0	2.0
1% plus CC	1.0	2.0	1.0	2.0
0.1%	1.0	2.0	1.0	2.0

2.2 Proposed Breach Model

For clarification the following changes which were made to the Proposed Design model (as used in the design hydraulic modelling) were **not** updated in the Proposed Highway Breach model:

- The use of the most recent MMDR over the River Eye (although this did not vary significantly);
- The updated MMDR bridge over the River Eye (consisting of four bridge spans rather than just one);
- The most recent realignment of the River Eye and corresponding 1D river sections which was based on DTM modifications made by AECOMs geomorphology team; and
- The updated Lag Lane tributary realignment under Saxby Road.

To update the proposed model to make it suitable for breach modelling, the same steps that were taken for the baseline model were also applied to the proposed modelling. Other, additional modifications to the proposed model included:

- Interpolate nodes were added along the proposed re-aligned River Eye, upstream of the proposed highway; and
- As Brentingby Dam is located behind an existing railway track, a spillway was connected to either side of the railway track to allow breach water to flow across the railway embankment (note: the proposed results showed that no water spilled across the railway. In order to keep the total number of nodes below 1000, this modification was not included in the Baseline Breach model.

All other modifications made to the Baseline Breach Model set-up were retained in the Proposed Highway Breach Model.

3. Results and Discussion

This section of the report summarises the results of the breach modelling.

3.1 Breach Modelling Flood Extents

In order to determine the change in the breach flood extent as a result of the proposed highway, the Baseline Breach model flood extent has been compared to the Proposed Breach model flood extent for the 1% AEP+ 30% Climate Change event.

Figure 1 shows the proposed highway would increase the flood extent upstream of the highway. However, no properties are located within the increased flood extent, indicating the proposed scheme would not raise the flood risk to any properties in the areas covered by this modelling study during a breach.

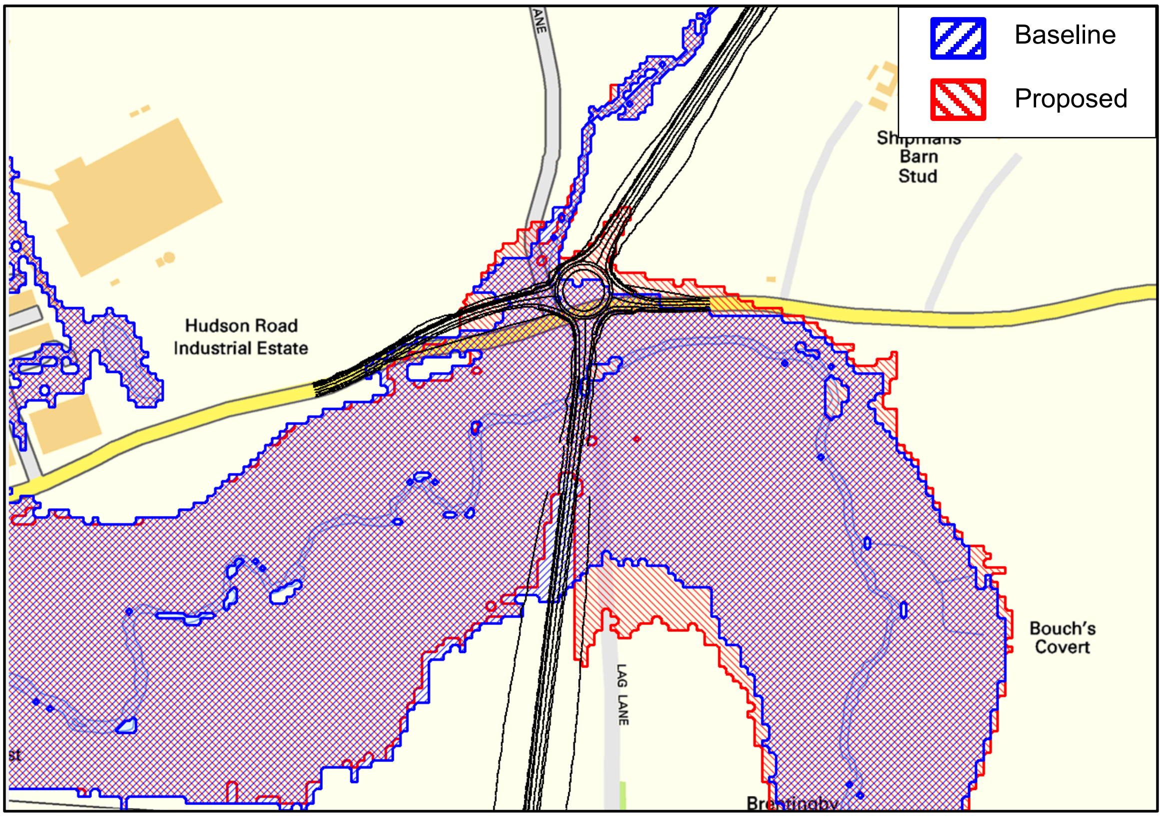

Figure 2 – Map showing the flood depth of the baseline breach model in the 1 in 100 Year + 30% CC Event (for the River Eye and Lag Lane Tributary)

The breach models were also run for the 5%, 1.3%, 1% and 0.1% AEP events. The maximum flood extent and flood hazard for all breach AEPs are shown in **Appendix C**.

Appendix C indicates the flood extent of both breach models do not vary significantly for any of the AEPs. The flood extents are approximately the same for each AEP event because the breach is set to occur when flood levels upstream of the dam reached three quarters of the dam height. Therefore, the volume of water released when the breach occurs will be similar for all the AEP events, and will inundate downstream to the same extent

Although the maximum flood extent of the proposed model is similar for all AEP events, **Table 2** shows that the duration of inundation of the proposed highway and junction varies between AEP scenarios.

AEP Event	Time of Breach*	Time of highway inundation*	Time at which highway is no longer inundated*	Time at which junction is no longer inundated*
5%	37:30	37:45	42:30	43:15
1.3%	28:00	28:15	34:15	35:00
1%	26:45	27:00	33:15	34:00
1% plus 30% CC	23:45	24:00	33:00	34:45
0.1%	20:30	20:45	39:15	41:00

*time measured from the start of the model simulation (hours:minutes)

Table 2 – Table showing the proposed breach models time until breach, inundation of proposed highway, and retreat of flood waters from the highway and junction.

3.2 Conclusions

The outputs from breach modelling show the proposed highway would increase the flood extent upstream of the proposed highway in the event of a breach on Brentingby Dam, however would not increase the flood risk to any properties.

The results have also shown that a breach of the Brentingby Dam would cause flooding of the proposed distributor road, River Eye bridge and Saxby Road junction for all modelled AEP events. It is therefore expected that road closures will be necessary in the event of a breach.

Appendix A – Approved Dam Breach Analysis Scope

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Melton Mowbray Distirbutor Road

Project ref:
60542201

From:
Andrew Heath-Brown

Date:
7 February 2018

To:
Simon Smeathers (email only)
Environment Agency

CC:
Nick Wakefield (email only)
Environment Agency

Sam Wash (email only)
Leicestershire County Council

Owen Tucker (email only)
Anupriya Prabhuswamy (email only)
AECOM

Memo

Subject: Brentingby Dam Breach Analysis

Dear Mr Smeathers,

Further to your correspondence ((LT/2017/122659/01-L01, 12 October 2017) with Sam Wash at Leicestershire County Council, regarding the proposed Melton Mowbray Distributor Road (MMDR), we wish to get the Environment Agency's (EA) comments and approval on our proposed approach and methodology to modelling a breach scenario at Brentingby Dam. This was requested as part of your response in the aforementioned correspondence.

Our proposed approach is based on guidance we have previously received from the EA (Anglian Region – Northern Area), but is assumed to be applicable elsewhere. A summary of the approach/ methodology is given below:

- We will obtain design drawings/information of the Brentingby Dam structure from the EA, if available.
- We will obtain the latest LiDAR DTM covering the Brentingby Dam.
- We will set up the breach based on the EA guidance previously received, of which the key parameters would be as follows:
  - Base level for the breach would be determined by review of the LiDAR and any available drawings, but will ultimately be the 'typical' ground level along the toe of the embankment.
  - The breach would assume to commence when the flood level within the storage area behind the dam first reaches its peak (the current model of the dam obtained from the EA represents this as on online storage area formed by extended cross-sections, therefore the long section water surface profile would be reviewed as part of this process).
  - Assuming an earth embankment (to be confirmed by drawings) which supports a fluvial river, the breach width will be 40m.
  - The duration of the breach will be 72 hours (at which point it is assumed the breach will have been closed), although this is likely to be longer than the duration of the hydrograph and therefore will not need to be applied.
- We will use the 'Breach' unit within the Flood Modeller software to model the breach.
- We will assume that the breach passes immediately downstream and through the railway bridge, or spill over the top of it (the current 'spill' unit in the model is not long enough, and may need to be extended using LiDAR DTM); it can then enter the existing 1D-2D linked domain (see Figures 1 and 2).
- We will apply the breach to both the baseline and proposed scenario models, to understand how the proposed MMDR affects the inundation extent. The proposed model will include the new road embankment and bridge structure crossing the River Eye

Comment [GL1]: EA breach guidance was updated in 2017 to provide a consistent approach to breach modelling. Attached to email.

Comment [GL2]: Updated guidance provides information regarding determining the toe level

Comment [GL3]: Updated guidance suggests that breach commencement should be determined by loading on asset (3/4 loading of asset or peak if lower)

Comment [GL4]: Updated guidance suggests 56 hours to closure for a rural location

- We will apply the breach during the 4%, 1.3%, 1% and 0.1% AEP events, as per recommendations in the EA guidance. Climate change scenarios will not be modelled.
- We will undertake depth and hazard mapping of the breach inundation area for both the baseline and proposed scenarios.
- We will produce a short Technical Note to summarise the method, analysis and results of the breach modelling; this will form an Appendix to the FRA.

We would be grateful if the Environment Agency could provide a response to the proposed methodology set out above, and confirm whether the stated AEP events to be modelled are appropriate, or if more/ fewer are required.

Yours sincerely,

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Comment [GL5]: Taken from the Anglian Requirements for Hazard Mapping so acceptable. Area to decide whether further (+CC) runs are required.

Comment [GL6]: FD2320 or FD2321?

Figure 1: Existing EA model schematisation

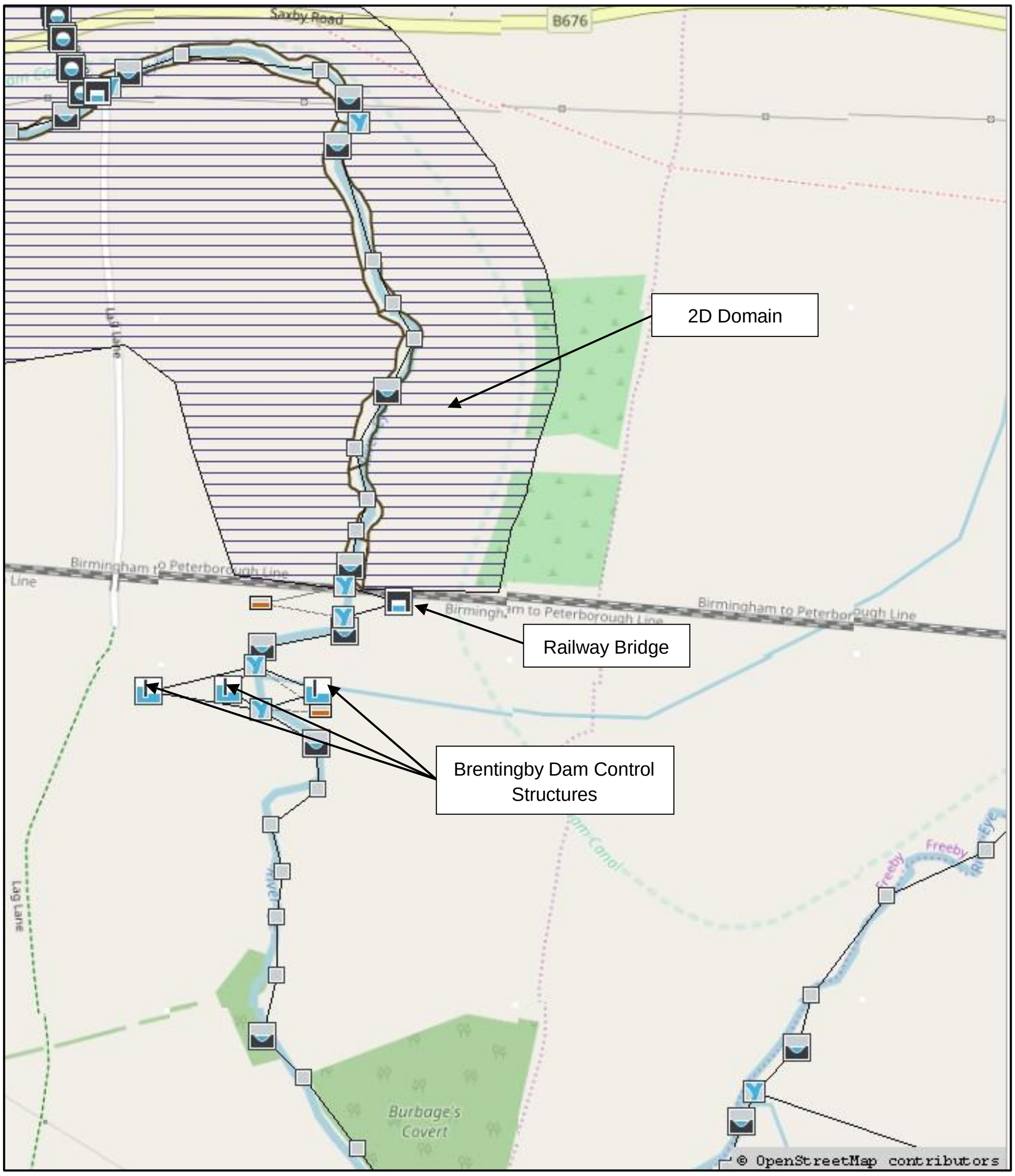


Figure 1: Areal imagery of Brentingby Dam (with existing EA model schematisation superimposed)

Appendix B – Breach Guidance 2017.

Breach of Defences Guidance

Modelling and Forecasting Technical Guidance Note

What's this document about?

This document summarises some of the existing documentation available and concepts on breach concluding with guidance on assessing breach to further use in flood risk assessments in England. It does not prescribe all aspects of the problem which will be unique to each situation and neither does it prescribe model types

Who does this apply to?

The target audience for use of this guidance are those who produce flood risk assessments within and on behalf of the Environment Agency and for use externally as recommended guidance

Document details

Relate

Feedback

Contact for queries:
-Antonia Chatzirodou
-Tim Hunt

Contents

Introduction

Overview

Chapter contents

This chapter contains two topics:

Why assessment of breach of defences is important?

What is breaching?

Man-made raised flood defences rarely offer complete protection against flooding as there is residual risk from flooding that can either exceed the defence standard or overload them (defence failure). This is known as breaching. Residual risk needs to be estimated in flood risk assessments. Breaches rarely occur but can happen in extreme events and it is important for incident planning, response and engagement to understand the residual risk in locations behind the defences. The impacts of a breach can be high given the sudden release of water with no warning. This hazard could be life threatening.

Why is it challenging to assess breach?

Assessments for breach of defences have long been problematic largely due to the lack of understanding and data that exists in what is a complex failure mechanism problem. There are many reasons why a defence might fail and it becomes necessary to find simplified and generic methods to use in flood modelling studies. Data on real breaches to assist assessments are not plentiful as they are rare. That is largely due to our ongoing inspection and maintenance regime to ensure our defences are resilient.

Precautionary simplifications of breach based on the little data that has been collected in the past have often been used and more recently methods that include fragility employed. Neither of these on their own can be considered detailed breach assessments which would normally be prohibitive in cost terms in most modelling/mapping studies. Detailed breach studies are often reserved for high impact, more localised and specific situations, for example dam breach assessments.

How we calculate risk of breach within the Environment Agency?

Areas Benefitting from Defences have been a core deliverable for detailed flood mapping models to inform the Flood Map for Planning in the Environment Agency but these assessments do not take into account breach and assume the defences remain in-tact and operate as designed.

Risk of defence failure and overtopping is assessed at a national scale through our national flood risk assessment, NaFRA, which uses the RASP method and fragility curves to calculate residual risk for each $50m^2$ of floodplain. The recent State of the Nation project to update NaFRA has calculated the fail and non-fail (overtopping) damage (annual average £) associated with each individual asset. This information can be used to prioritise where damages are greatest and detailed breach analysis might be required.

Detailed local flood modelling increasingly demands more detail and rigour than methods used in NaFRA. There is a need to routinely consider breach where there are defences and understand the residual risk both within Flood and Coastal Risk Management (FCRM) and the wider industry. Therefore a consistent suite of methods is now needed to fit the level of assessment required. This document is an initial attempt to standardise these methods which are expected to evolve and be updated as other science, data and improvements become available.

The development of basic 'without defences' and 'with defences' modelling and mapping, is not a surrogate for this residual risk assessment and can both overestimate and in some cases underestimate the 'true' flood risk and hazard. In addition the hazard from a sudden release of water from a failure is often not properly appreciated in assessments of flood defences.

NaFRA2 will now largely dictate future modelling direction within the Environment Agency and this will demand a generally higher level of detail with multiple breach considerations included to inform the national annual probability assessments. This will continue to use fragility curves, at least in the medium term for minimum requirements, but further breach detail can be added where required locally. It should be possible to be more compatible and future proofed with a common approach to breach through this guidance.

Review of the existing literature on defence breach

List of references

A great number of guides that include information on defence breach are available and a few have been reviewed for this guidance note. A number of important and salient points have been extracted from them and the guidance has been built up from what appears to be best practise from these and previous modelling studies.

Some existing guidance and reports that have been collected for reference are included in the table below along with some quick comments on what they are and if of use. This is not exhaustive but also retains documents that are only of related interest for the topic which can also inform future updates of this guidance note.

References	Comments
Levy Design Handbook, USACE, 2013	Very comprehensive guide on flood defences. Good for understanding failure modes of defences and how breaches form.
Flood Risk Assessment Guidance for New Development, Defra, 2005	Simplified methods on potential hazard behind defences for new development. Useful to help describe hazard zone with respect to loss of life potential. This should be translated into model/mapped output of any products (NPPF, 2012)
Southern Region Defended Areas (SoDA), Royal Haskoning, 2003	Freeboard considerations, not a great deal of use for breach but useful background on flood mapping history.
NaFRA and MDSF2, various documents and RASP R&D	Fragility methods used but complete defence lengths considered and weighted between no defence and with defences scenarios based on potential failure (fragility). Flood spreading is simplistic. Fragility outputs for defences could be useful for identifying relative risk if all defences protecting a flood cell are considered. New coastal outputs from State of the Nation include improved loading conditions.
Asset Performance Tool, HRW, (Draft) 2016	Asset performance tool in development for determining custom fragility curves at individual defences. A useful tool for better identifying the vulnerable defences in a system. Currently in draft.
Section 105 Tidal Flood Warning Tidal Flood Risk Pilot Report, NRA SW, 1999	Good explanation of breach and concepts in tidal situations. Posford Duvivier principles used in many other studies around England and forms basis in this guidance.
Requirements for Hazard Mapping, EA Anglian Region, 2009	Summary of requirements similar to others used throughout EA and NRW. All sourcing from original work done by David Worth at Posford Duvivier in the former Anglian region. Time to close breach values often longer due to local decisions.
Modelling Blockage and Breach Scenarios, NRW, 2015	Similarly based on Posford Duvivier
Devon Tidal Flood Zones, ABD and FRA Improvements, 2008	Guidance on when to consider breach potential and shingle beaches advice included in Appendix A.
Various FLOODsite studies and reports, including Breaching of coastal dikes: state of the art, 2005	Academic studies but very comprehensive and useful reference with theoretical descriptions of defence failure. http://www.floodsite.net/html/publications2.asp?documentType=1
Flood Modelling Guidance for Responsible Authorities, SEPA, 2016	No guidance on breaching.
Thames Tidal Breach Modelling, CH2M Hill, 2014 (see Appendix B)	Includes a review of the available breach literature undertaken previously by Helen Winter and reconsidered by Matt Horritt, concluded that

	there is no reason or evidence to justify a departure from the current guidance.
Tidal Great Ouse Breach Modelling, JBA, 2015	Extensive multiple breaching study for lowland drainage tidal flood risk areas. Good practise.
Guide to risk assessment for reservoir safety management, 2013	Simple breach methods for instantaneous breach of structures. No identified use in coastal/tidal situations. Maybe relevant in some fluvial modelling situations.
EurOtop II, 2016	Guidance on defence potential defence damage with various overtopping rates.
Reservoir Flood Mapping Specification, 2016	Instantaneous breach hydrograph derivation from fixed volume of water. Designed for dam breach but may have other uses.
Breaching Flood Defences, 2011	Literature review on breaching by Evidence Team. Useful links and background. Quite a bit of US experience from hurricanes and of less direct relevance to UK due to scale. But salient points extracted for the guidance.
IMPACT Project WP2: Breach Formation, 2005	Field and lab tests and modelling for dam and defence breach, good background.

Conceptual Features of Breach

Overview

Chapter contents

This chapter contains two topics:

What causes breach in terms of loading?

Which are the primary loads on flood defences?

There are four primary loads on flood defences according to HR Wallingford (2002):

1. Water pressure from flood levels
2. Wave action (coastal defences)
3. Seepage - increasing the load internally
4. Self-weight of the defence

What causes breach in terms of failure mode?

Which are the principle failure modes in flood defences?

Additionally, HR Wallingford (2002) outline 5 principle failure modes in flood defences:

1. Overtopping (causing erosion of the landward side)
2. Piping – internal erosion
3. Erosion of the inward face
4. Slope instability
5. Foundation failure

Considerations for Assessing Breach

Overview

Chapter contents

This chapter contains eleven topics:

Uncertainties around topics discussed

There is a great deal of uncertainty around answering all of these questions and choosing the most suitable parameters. This is in addition to the uncertainty of the other hydrological/source data and hydraulic elements of modelling. Therefore more simplistic and precautionary methods are often favoured that allow us to choose credible but ‘safe’ scenarios. The key features of consideration in breach assessment include loading and exposure to waves, high water levels, type of defence, crest level, defence height, crest width, foundation stability, structural integrity, condition and maintenance regime. With this information failure mechanisms can be established and breach potential estimated. In practice this is not easy to establish and is more than can reasonably be done in most studies. We will rarely have the budget to carry out detailed structural assessments to establish factors of safety of all the defences/structures and their likelihood of failure. We therefore look to what is more readily available and ensure that we are suitably precautionary with our approach given the uncertainties. Below are some thoughts and considerations to assist in answering the questions above.

How to assess the scale of impact of a breach?

This assessment includes looking at a 'no defences' flood zone map to initially determine the impacts. This may not always reveal the worst case due to the modelling method and/or local topography so some care is required especially where water maybe falsely lost from a system stripped of defences into upstream floodplain before it reaches the point of interest.

The scale of potential impacts should dictate the rigour given to breach modelling in a risk based approach. If reliable NaFRA data are available for the defences being studied a review of the annual damages data associated with each defence will be able to give a scale of impact.

Where is location of breach?

By far the most pragmatic approach includes observation on the ground and local knowledge. Particular hot spots of high flood impact and defence vulnerability, deterioration or damage are clear on site. Depending on the mapping required, breaches can also be carried out at regular intervals along a complete defence system to establish a 'worst case' resulting impact but the extra cost and effort of this may be prohibitive for all studies. In absence or not of local observations, AIMs asset information such as the condition grade can be as well used to pick up locations with poor condition and therefore prioritize them for breach assessment.

Another technique for identifying potential breach locations is by use of fragility testing for each defence in a system and then collecting the most vulnerable defences to be tested in more detail. Fragility is a way of describing defences with load-performance curves. Although It can be very powerful it can also be quite generic, in its current application in NaFRA for example, and rarely fits the situation that well enough for a detailed study. A new set of tools based on local fragility called the Asset Performance Tools (APT) (Project Ref: SC140005) will build in more flexibility and could be incorporated more routinely in the long-term in breach assessments. This could be applied to any defence given the correct input data. This is an ongoing FCERM R & D project and is expected to finish by October 2017.

What is the potential that defence will breach (type/condition)?

Table

Fragility methods can be used or alternatively other assumptions including defence type, condition, exposure and loading could be used. Breach can occur due to still water overflowing the defence or waves exceeding allowable overtopping rates in EurOtop 2007 table (Table 1). This should be modified by engineering judgement if required, i.e. a narrow crest or poor condition of defence will be vulnerable to breach with less loading, e.g. flood levels within design freeboard or lower, or a bank with a good condition grade but with vermin damage will be more vulnerable to breach. The advice from EurOtop could also be usefully employed in fluvial situations where the flood level at the defence can be converted to an overflowing rate with a simple weir equation or output from a model.

Further developments in the 2nd edition of EurOtop (EurOtop II (pre-released version, 2016), suggest that tolerable overtopping in coastal situations will depend very strongly on the peak volume, and hence on the wave height that causes the overtopping. For example, for a given mean overtopping discharge, small waves only give small overtopping volumes, whereas large waves may give many cubic metres of overtopping water in one wave. In that sense a mean tolerable overtopping discharge should be coupled to a wave height causing that discharge (EurOtop II, 2016). This insight changes the limits for tolerable overtopping and will be, as already mentioned, subject to engineering judgement.

Table 1

Type of structure	Maximum Mean Overtopping Discharge (l/s/m)
Unprotected embankments	2
Embankments with protected crests	20
Fully protected embankments	50
Revetments with unpaved promenade	50
Revetments with protected promenade	200
Seawalls	200

When will the breach occur and for how long before closure?

There are various ideas on setting the start time for a breach simulation. This ranges from prior to the event when there are no elevated water levels to the point of overtopping/overflowing of a defence with other points in between. If we consider breach is to be modelled for a defence then a start time should be that point where there is at least some loading on the defence to ensure we are not overly precautionary. In a river or 'non wave' tidal situation this can be considered to be a water level at ¾ of the defence height (consider datum is toe level from depth of breach consideration). Where there is a wave loading we can consider the breach starts either when still water level reaches half defence height or when any overtopping begins whichever is first. For the time it takes to close the breach the guidance has been set from experience of past breaches. This is a starting point and if local data or evidence exists to suggest this is not reasonable then this can be altered and documented. For example it may be that a location would be particularly difficult to repair or access for repair.

What is the depth of breach (toe level)?

We have to assume an eroded breach base level. In past studies this level is mostly considered to be the landward toe level of natural land behind a raised defence. However, in the Thames breach modelling (2014) a method was developed to help find the lowest land level. The level is found within a radius semicircle from the centre point of the chosen defence breach point. The radius would be equal to the chosen breach width for the type of defence and should result in a consistent measure of toe level on the landward side. This does need sense checking as well with some local knowledge to ensure the values are credible. The method developed in Thames is recommended as suitable on small rivers, open coasts or soft defences. The method also lends itself to an initial GIS assessment of LiDAR or topographic levels which can be taken out and checked on site.

What are the loadings on the defence?

Water levels for rivers would normally come from an in channel 1D model (hydrodynamic with full hydrograph). At the open coast or where waves are a feature a wave overtopping model and extreme sea levels (possibly combined river levels) would supply the loading data. Wave overtopping rates can also be considered for checking fragility with Table 1 values. To derive the full tidal water level curve, guidance exists in Coastal Flood Boundary Conditions for UK Mainland and Islands (2011). Any local information on other potential loading factors should also be considered, documented and accounted for in the assessment. It is interesting to note that in order to automate this type of assessments a spreadsheet had been previously developed in the former South West Region. The spreadsheet additionally provided a first pass estimate of flood volumes that might pass through a breach into the floodplain (Parameters for Tidal Flood Risk Assessment, 2012, Project name: South West Tidal Parameters, No: 9W6111). This was a useful tool to quickly review flood cells and relative impact of breach locations on a floodplain which could be further updated and extended in the future for national use but not as a substitute for 2D floodplain modelling.

What are the defence failure mechanisms?

Engineering judgment is required here from site assessment and any other knowledge of the defence, its construction, condition grading and exposure to loading and damage. See Conceptual Features of Breach section. This helps to inform likelihood of breach but could default to fragility methods.

What is the evolution of the breach failure?

In most modelling studies an instantaneous breach is considered as a necessary simplification. This is much easier for modelling and suitably precautionary given the uncertainties of a breach. In reality an embankment breach would generally be over a longer period although a concrete or masonry defence could fail very quickly.

Will there be multiple breaches?

This is possible in reaches of similar defence structure and exposure or multiple areas of weakness in a system. This should be considered around the flood cell or embayment. It may need multiple model runs to establish the worst case or a range of scenarios as required by the question being asked.

Are there vulnerable secondary defences and potential for cascade failure?

It is not a usual consideration but it would need an assessment to check. Closely positioned reservoirs in on-line cascade have this consideration applied routinely. It is recommended that if defence breach is a possibility, the same assessment can be applied to any secondary defences using the modelled results from the primary defence breach assessment.

In the case of multiple scenarios and breach locations it may be good to manage the uncertainty with Monte-Carlo simulation methods to give a probabilistic result. An example of Monte-Carlo simulation methods is found in Gouldby, Wyncoll, Panzeri et al. (2017). There are advantages in this approach given so many uncertainties in a deterministic breach assessment but clearly it is an intensive and potentially time consuming technique and should perhaps be reserved for high impact studies (see ''How to assess the scale of impact of a breach?'' pg. 9) . But also note that elements of this are built into the fragility curve science to help manage some of the uncertainties for 'off the shelf' use.

What will be the breach width and time to close for different types of defences?

The following table 2 contains the recommended breach parameters (width and time to close) to be applied for different types of defences. To ensure consistency, these should only be deviated from if there are good reasons to do so based on local evidence and this should be documented.

Table 2

Source	Defence Type	Breach Width (m)	Time to close – urban (hrs)	Time to close – rural (hrs)
Estuary/Tidal River	Earth Bank	50	30	30
	Reinforced Concrete	20	18	18
Open Coast	Earth Bank	200	44	56
	Earth Bank with facing	100	44	56
	Dunes	100	44	56
	Shingle Bank	100	30	30
	Reinforced Concrete	50	18	30
River	Earth Bank	40	30	56
	Reinforced Concrete	20	18	18
Tidal/Coastal	Tidal Gates	Gate width	Gates fail on low tide preceding the peak level with emergency closure effected during the following low tide	

Notes for table above:

1. Only the front line defence is assumed to fail.
2. If it is noted on inspection that a particular breach site will not extend to the values above or otherwise then judgement should be used in the assessment. Documented evidence should back up the decision.
3. See Appendix A for notes on shingle beaches.
4. Breach width has been studied in the Thames modelling studies and conclusions are usefully summarized in Appendix B. The conclusions reconcile with minor modification to the more extensive criteria given in this table

Recommendations for future work on breach guidance

Overview

Chapter contents

This chapter contains two topics:

Embedding breach guidance in Modelling and Forecasting standards

In the future the aim is to include the breach guidance in the Modelling and Forecasting Modelling Standards documents. Also with regard to inundation modelling beyond the breach, which already forms part of the standards, particular attention must be given to likely flow routes from a focussed breach location into the floodplain. However, a site visit to check this on the ground will be again an important element of this work.

Developing a standardised template for breach modelling

A template for summarising breach assumptions and results has been already developed for the Thames modelling. It is suggested that similar template could be further developed in a standardised report format for modelling studies. See Appendix C for an example.

Appendices

Appendix A

Section below copied from Devon Tidal Flood Zones, ABD &FRA report (2008)

9.7 Assessment of Shingle Bank or Sand Dune

Storms in the winter of 1989-1990 at Hurst Spit in Hampshire provided a considerable volume of field data on the short term profile response of a shingle barrier and prompted further research by Bradbury and Powell. The work introduced a parameter (Cf) based on crest freeboard and inshore wave conditions from which it is possible to estimate the conditions that would result in crest accumulation, crest lowering and breaching.

More recently research has been undertaken by Bradbury. This is based on extensive physical model test results and verified against the field measurements recorded in 1989. The research introduced a dimensionless barrier inertia parameter (Bi) based on freeboard, barrier cross section and wave height and derived a relationship with the wave steepness parameter. This relationship enables the production of the conditions under which crest lowering would occur. The two methods have different approaches to predict the response of a shingle ridge defence to storm events in terms of the parameters considered, both in terms of the shingle ridge and the incident wave conditions. The research and empirical relationships outlined in the Bradbury paper have been chosen for the following reasons:

•The Bradbury paper takes into account variables which are important in assessing the stability of the shingle ridge, such as the crest width and the height of the incident waves – both of which were not used in the earlier paper by Bradbury and Powell.
•The method outlined in the Bradbury paper is based on up to date background theory. The relationship between barrier inertia and wave steepness can be used to predict when overwashing is likely to occur and so failure of the defence. This is illustrated by the Bradbury chart. Data points that are plotted below the mean line (lower regression curve) indicate situations where overwashing is likely to occur. However, points above the higher curve (upper confidence limit) denote conditions where overwashing is unlikely to happen.

In order to calculate the barrier cross section area, several profiles of the beach were taken from LiDAR. Also from these profiles the mean depth of water at the toe of the beach was determined. Then using the Bradbury chart the defence was classified. When a point is plotted above the upper confidence limit the defence is considered to be stable and not likely to be breached.

Appendix B

Section below copied from Thames Tidal Breach Modelling, CH2M Hill, 2014

There are many factors that will influence the final breach width. These include:
- The type of defence
- The construction material of the defence
- The condition of the defence
- The size of the flood plain behind the defence
- The hydraulic gradient across the defence profile
- The mode of failure/cause of breach

The understanding of breach formation and accurate predictions for final breach widths is limited and research has made little progress over the past few decades. This makes it difficult to give a defined set of breach parameters for different scenarios.

Observations and Recommendations

1. It has not been possible to define better breach parameters for modelling purposes. However, following the review of the available literature some observations and recommendations have been made:

2. In the absence of any more detailed parameters for use in breach modelling, the current suggested widths (20m for hard defences and 50m for soft defences) should be used on the Estuary; however

3. Local knowledge of any given defence should be used to adjust modelled widths accordingly.

4. Breach profiles are not often trapezoidal as is often believed. Most breaches will exhibit vertical sides, with near uniform width at the top and base of the defence.

5. The size and character of the floodplain should be taken into account when choosing a model breach width. Large, flat floodplains behind the defence will result in larger breach widths and conversely constrained and steep gradient flood plains will give smaller final breach widths

6. Armoured earthen banks are likely to have smaller breach widths due to the greater resistance to erosion.

7. Earthen banks of non-cohesive materials are likely to have wider breaches as they are more vulnerable to surface erosion, whereas cohesive materials will erode less quickly.

8. Defences in the Thames Estuary should be considered separately to defences in other locations in the UK. The Thames Estuary defences tend to be higher but are also built on a complex geology of clays and water bearing gravels. Breaching scenarios in this area may behave differently to a breach in another area.

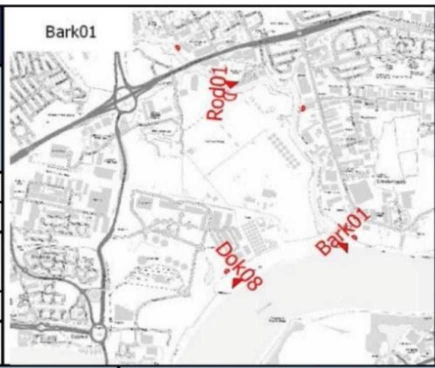
The conclusions and recommendations reinforce the justification for adopting the 20m and 50m breach widths for flood defences along the Thames Estuary. The report also highlights why developers and other third parties should be encouraged to review the assumptions behind these breach widths, and undertake further site specific analysis when considering local sites along the Thames estuary.

Appendix C

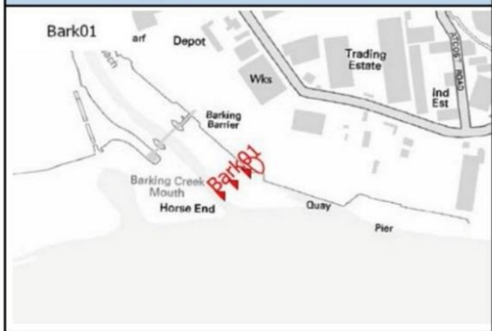
Section below copied from Thames Tidal Breach Modelling, CH2M Hill, 2014

Bark01

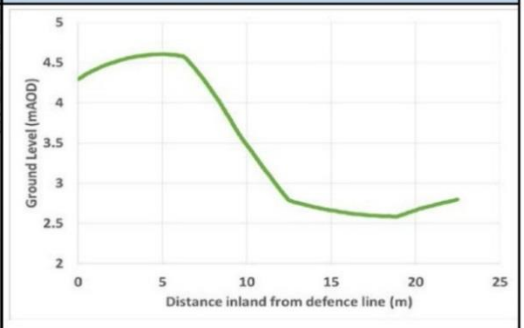
Physical Parameters		BREACH ID
Basic Information		Bark01
Defence Type	wall	**BREACH LOCATION**
Breach Width (m)	20	Barking Creek Mouth, Barking
Breach Sill Level adopted in model (mAOD)	2.58	
Breach Duration (hrs)	35	Breach Coordinates
Breach Scenarios	Single Breach	545747.51, 181652.20



Breach Location Map



Typical Section View of Flood Defence at Breach Location

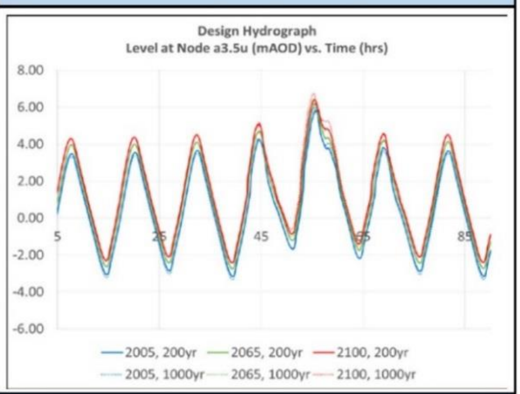


Key:
Breach Location:
Breach Flow Direction:

Non-physical Parameters

Return Period	Extreme Still Water Levels (mAOD)
1 in 200 annual chance (0.5% AEP) present day (2014) climate conditions	5.85
1 in 1000 annual chance (0.1% AEP) present day (2014) climate conditions	6
1 in 200 annual chance (0.5% AEP) 2065 climate conditions	6.22
1 in 1000 annual chance (0.1% AEP) 2065 climate conditions	6.47
1 in 200 annual chance (0.5% AEP) 2100 climate conditions	6.44
1 in 1000 annual chance (0.1% AEP) 2100 climate conditions	6.74
Tidal Curve Extracted from ISIS Node	a3.5u

Tide Design Hydrograph

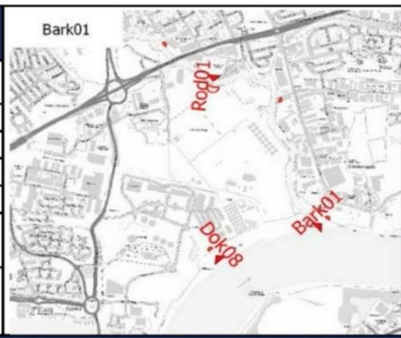


Additonal Information/Comments

Revision Record

Revision	Date	Originator	Checker	Approver

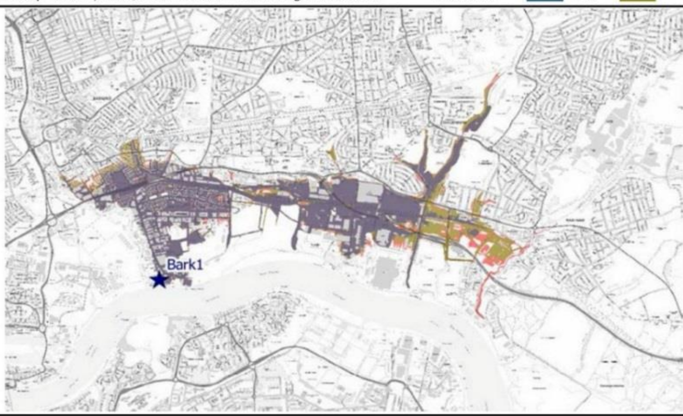
Model Parameters	
Tuflow Version	2013-12-AA-iDP-w64
Model Name	Bark01
Grid Cell Size (m)	5
Simulation Duration	35
Numerical Timestep	0.5
Manning's n	Floodplain: 0.05 Buildings: 1.00
Buildings retained in ground model	Yes



BREACH ID
Bark01
BREACH LOCATION
Barking Creek Mouth, Barking
Breach Coordinates
545747.51, 181652.20

Flood Extent Map

Key:
- 1 in 200yr return period, under present day (2014) climate change conditions.
- 1 in 200yr return period, under 2065 climate change conditions. Plus all of [present day]
- 1 in 200yr return period, under 2100 climate change conditions. Plus all of [present day] and [2065]

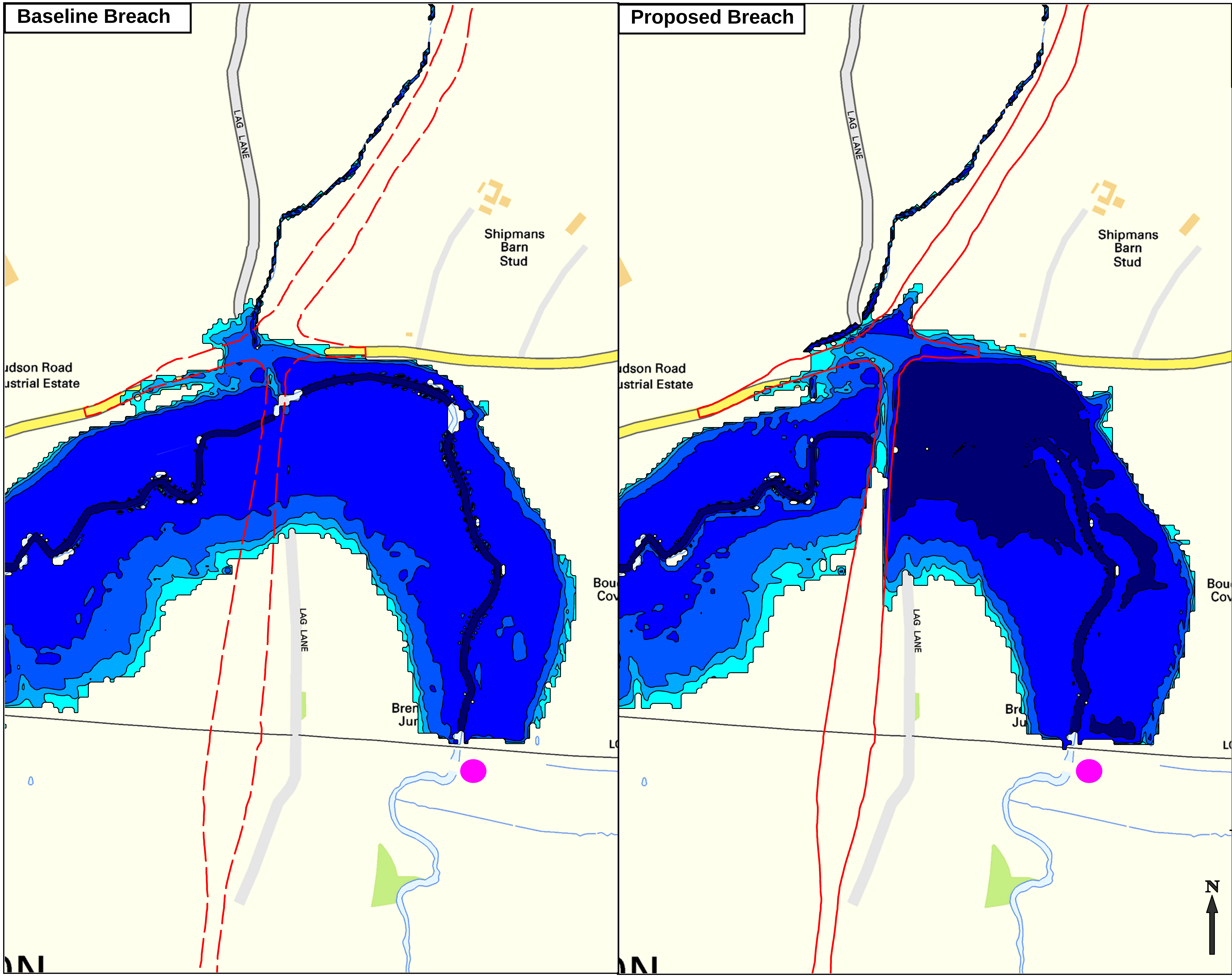


Key:
- 1 in 1000yr return period, under present day (2014) climate change conditions.
- 1 in 1000yr return period, under 2065 climate change conditions. Plus all of [present day]
- 1 in 1000yr return period, under 2100 climate change conditions. Plus all of [present day] and [2065]

Back to Main Menu

Bark01

Appendix C – Brentingby Dam Breach Analysis.



Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Depth (m)

- < 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Notes

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Revision Details	By / Check	Date	Suffix

Drawing Status

FINAL

Drawing Title

Figure C1
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
5% AEP Flood Depth Results

Client

Leicester City Council

Scale at A3	AS SHOWN
Drawn: AA	Approved: AP
Stage 1 Check: BB / Stage 2 Check: AH	Date: 09-2018

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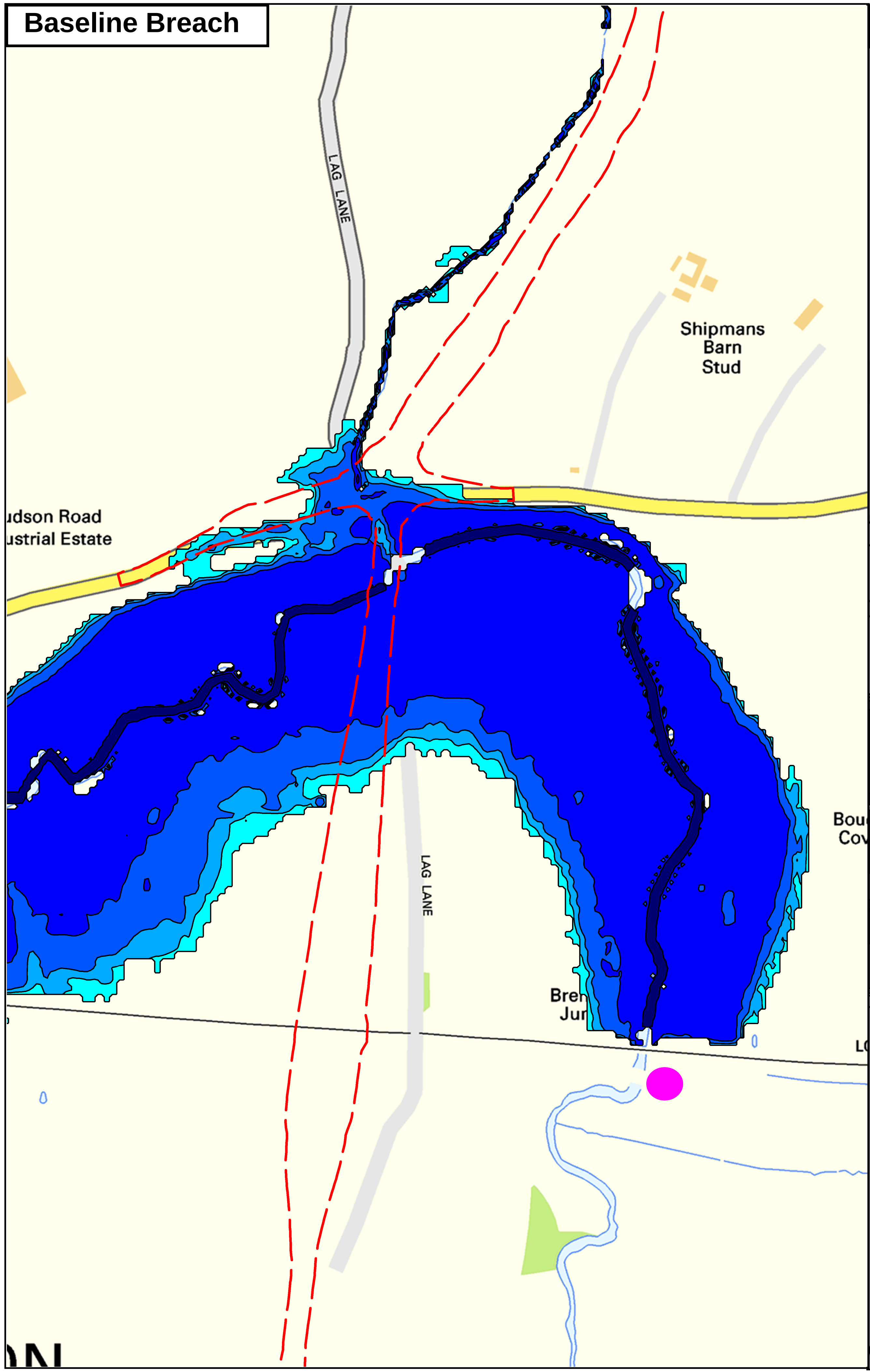
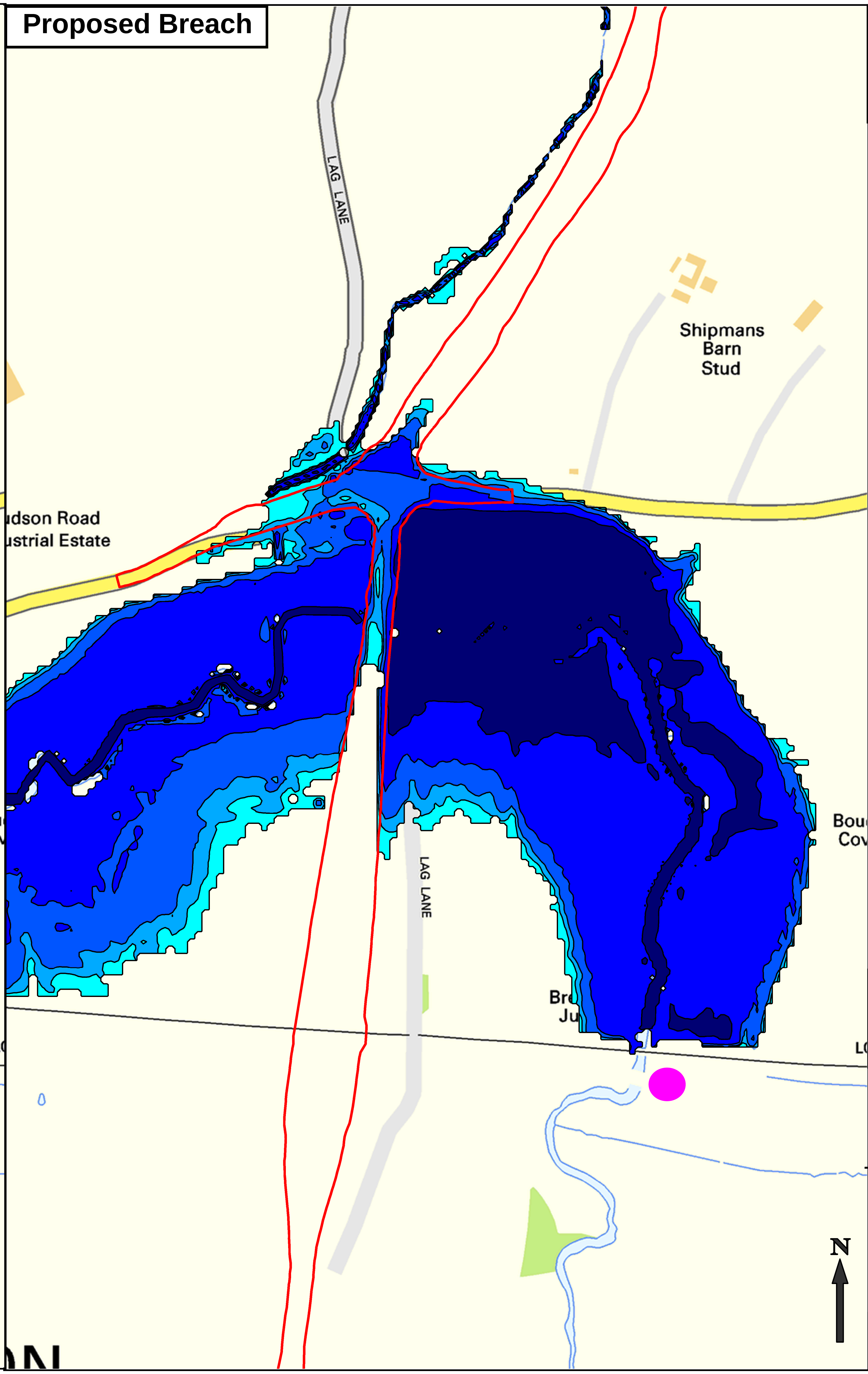
Project Number: 60542201

Rev: 0

Baseline Breach



Proposed Breach



Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Depth (m)

- < 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Notes

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Drawing Status

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Drawing Title

Figure C2
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
1.3% AEP Flood Depth Results

Client

Leicester City Council

Scale at A3: AS SHOWN

Drawn	AA	Approved	AP
Stage 1 Check: BB	Stage 2 Check: AH	Date	09-2018

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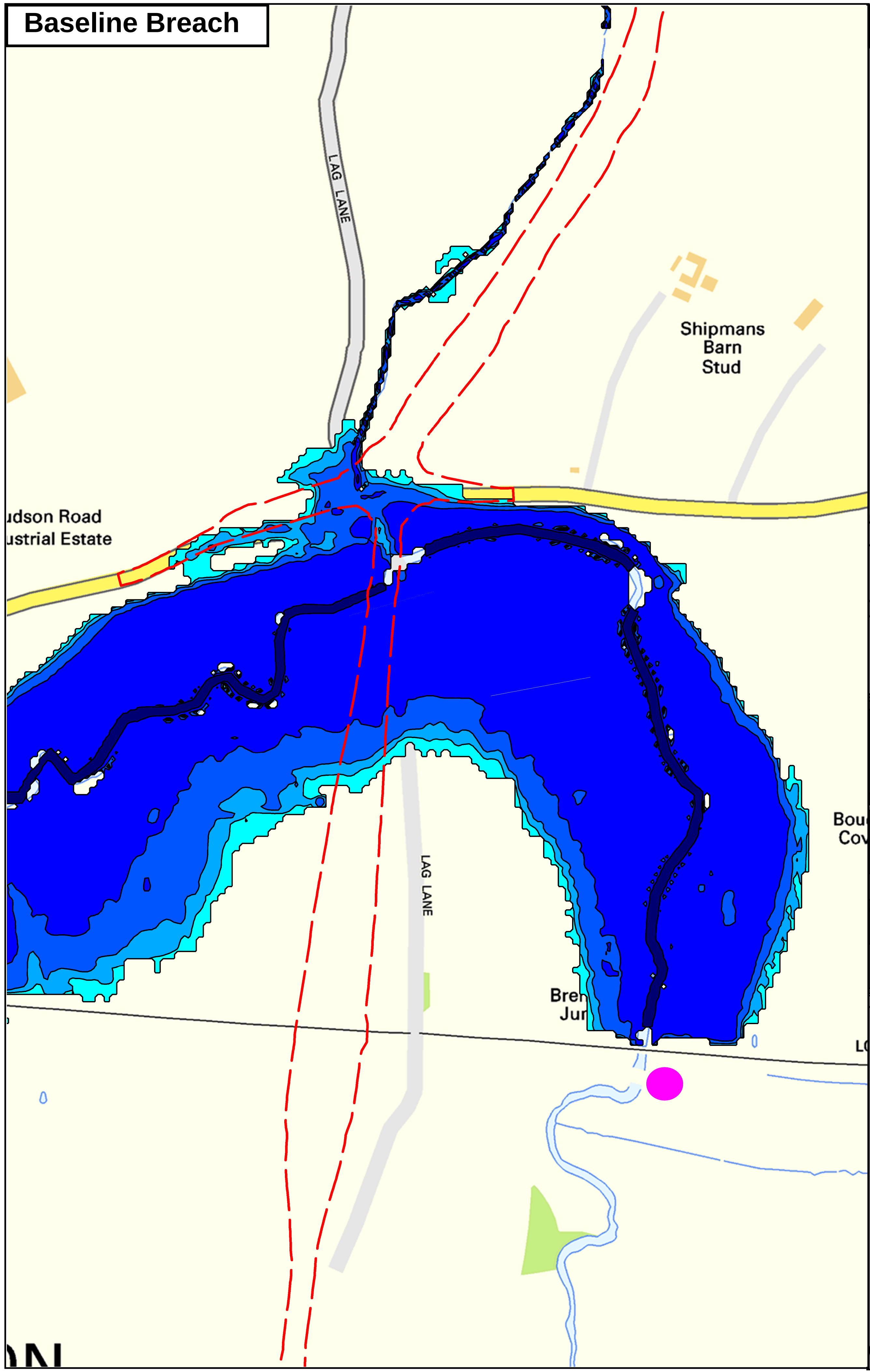
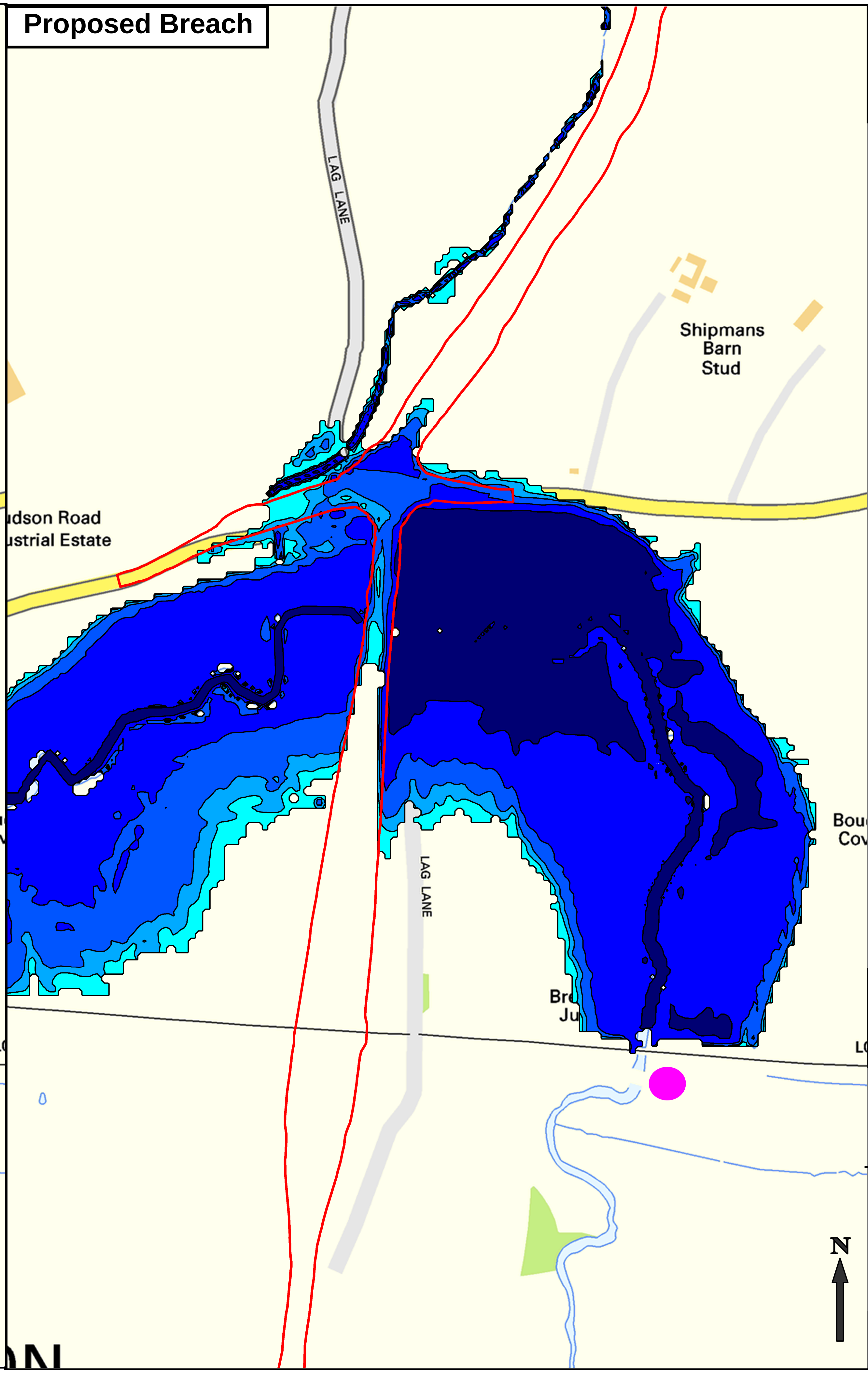
Project Number: 60542201

Rev: 0





Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Depth (m)

- < 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Notes

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Revision Details	By / Check	Date	Suffix

Drawing Status

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Drawing Title

Figure C3
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
1% AEP Flood Depth Results

Client

Leicester City Council

Scale at A3	AS SHOWN		
Drawn	AA	Approved	AP
Stage 1 Check BB	Stage 2 Check AH	Date	09-2018

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Project Number 60542201

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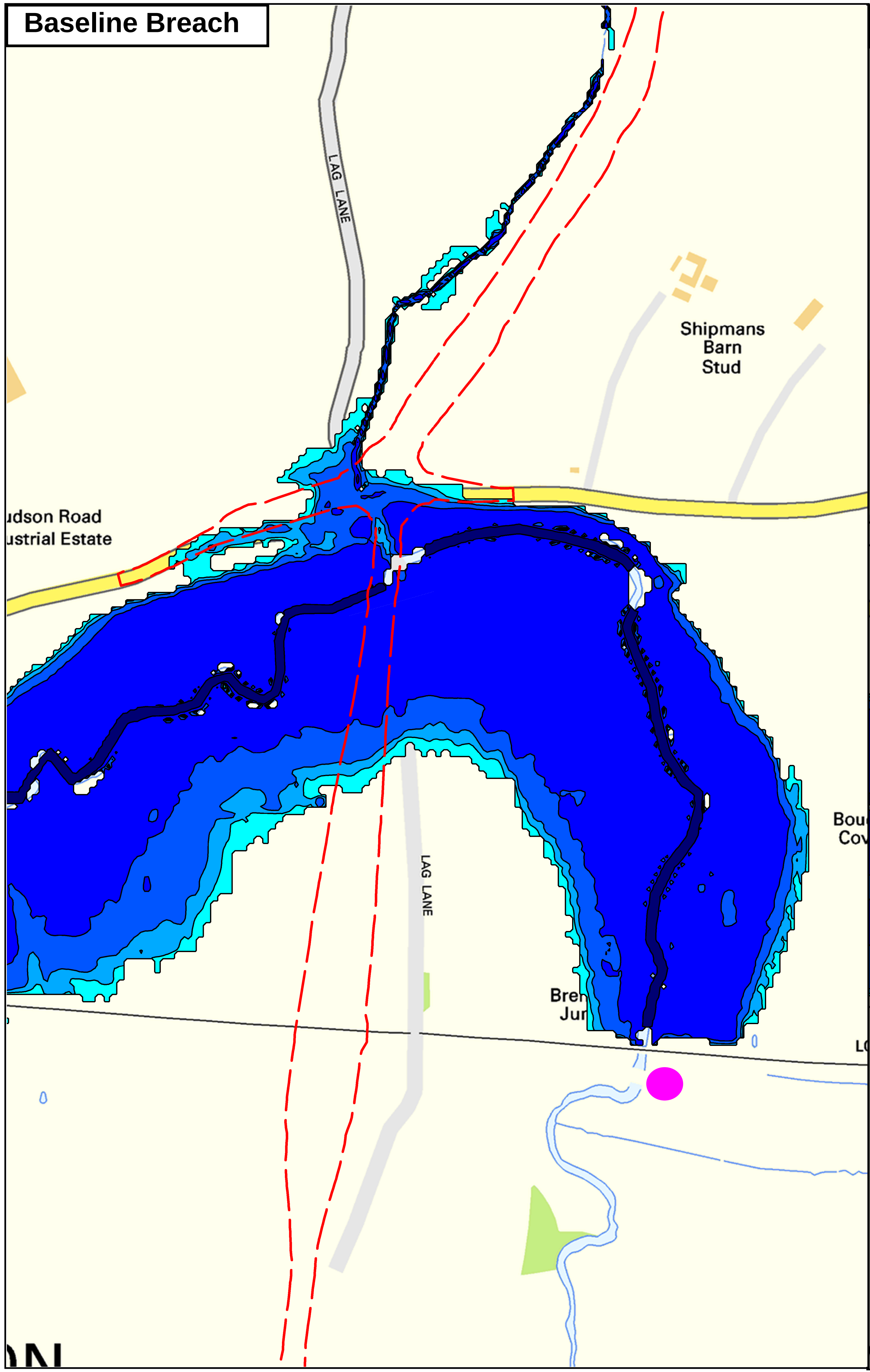

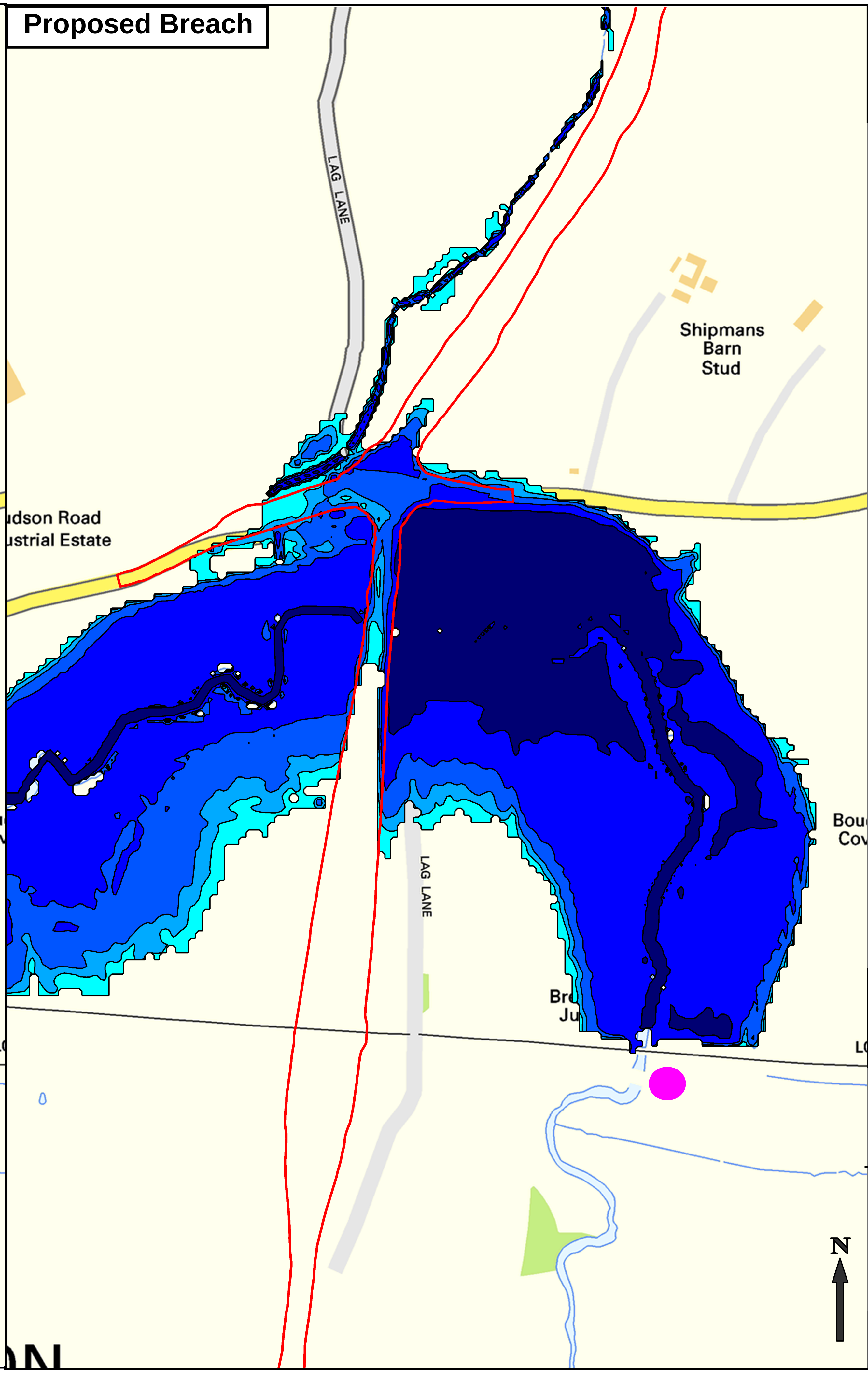

Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Depth (m)

- < 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

Notes

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Drawing Status

FINAL

Drawing Title

Figure C4
Brentingby Dam Breach Analysis MMDR Baseline and Proposed 1% AEP plus Climate Change Flood Depth Results

Client

Leicester City Council

Scale at A3	AS SHOWN		
Drawn	AA	Approved	AP
Stage 1 Check BB	Stage 2 Check AH	Date	09-2018

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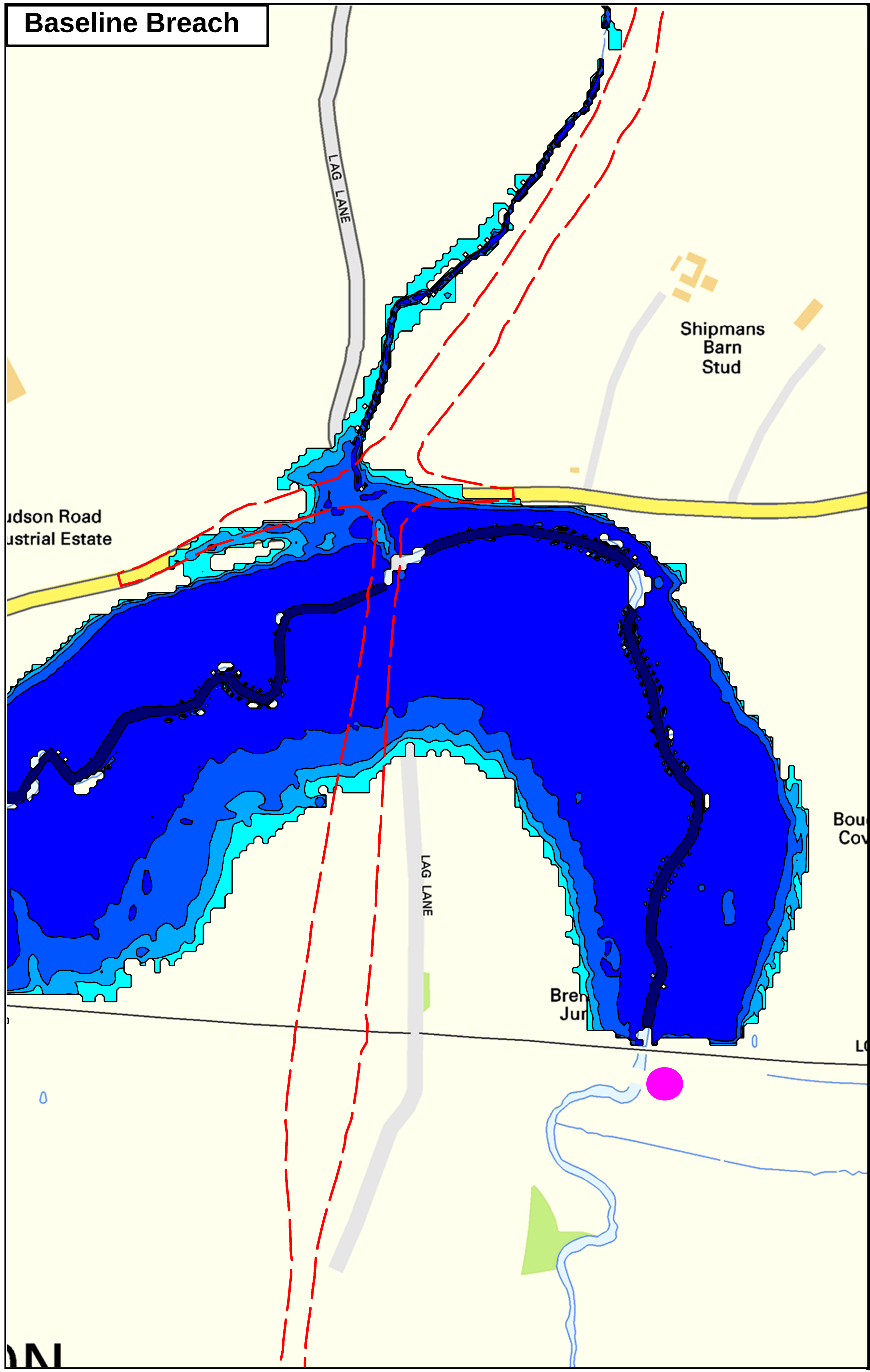

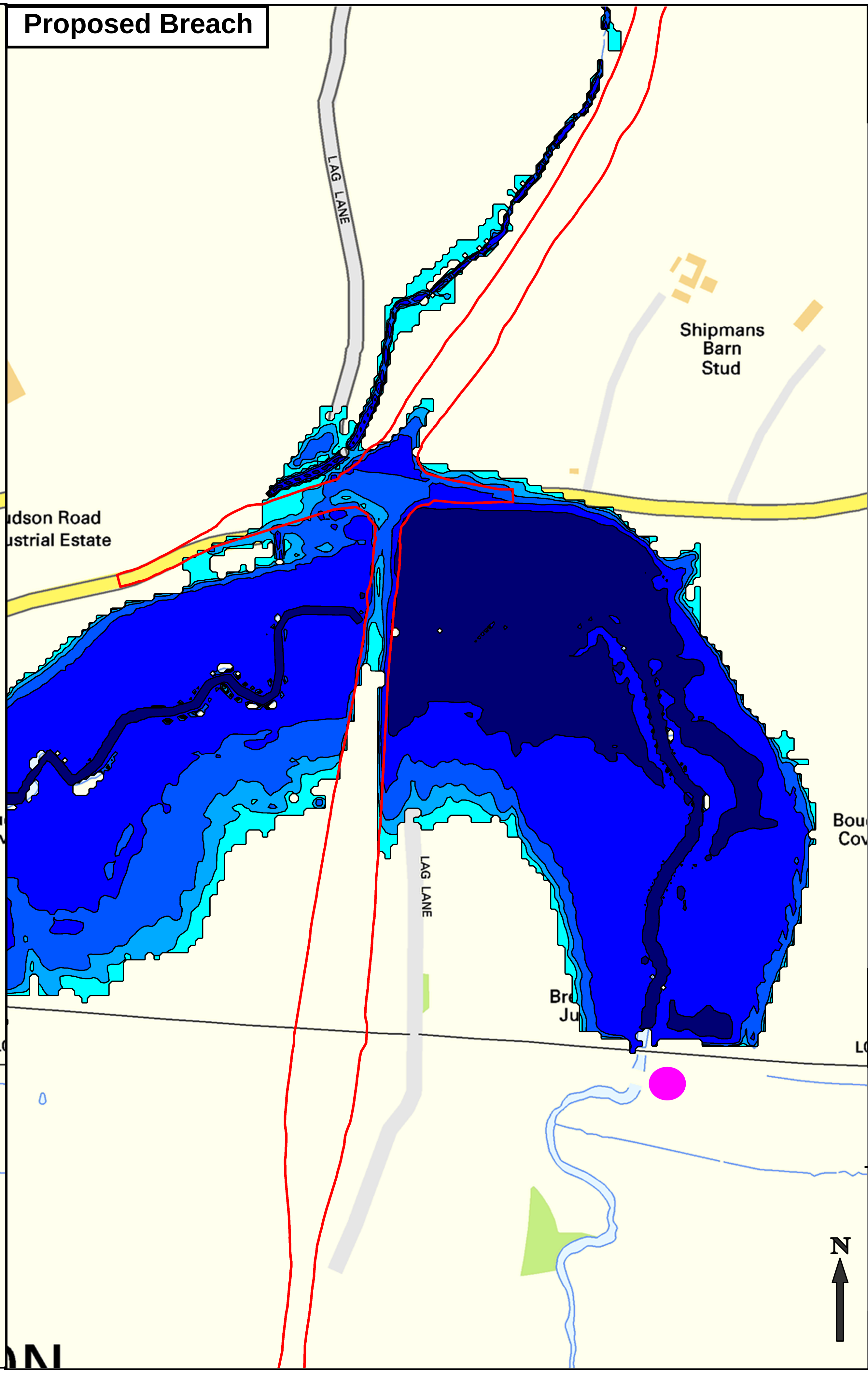

Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Depth (m)

- < 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- > 2.0

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Revision Details	By / Check	Date	Suffix

Drawing Status

FINAL

Drawing Title

Figure C5
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
0.1% AEP plus Climate Change
Flood Depth Results

Client

Leicester City Council

Scale at A3	AS SHOWN
Drawn: AA	Approved: AP
Stage 1 Check: BB / Stage 2 Check: AH	Date: 09-2018

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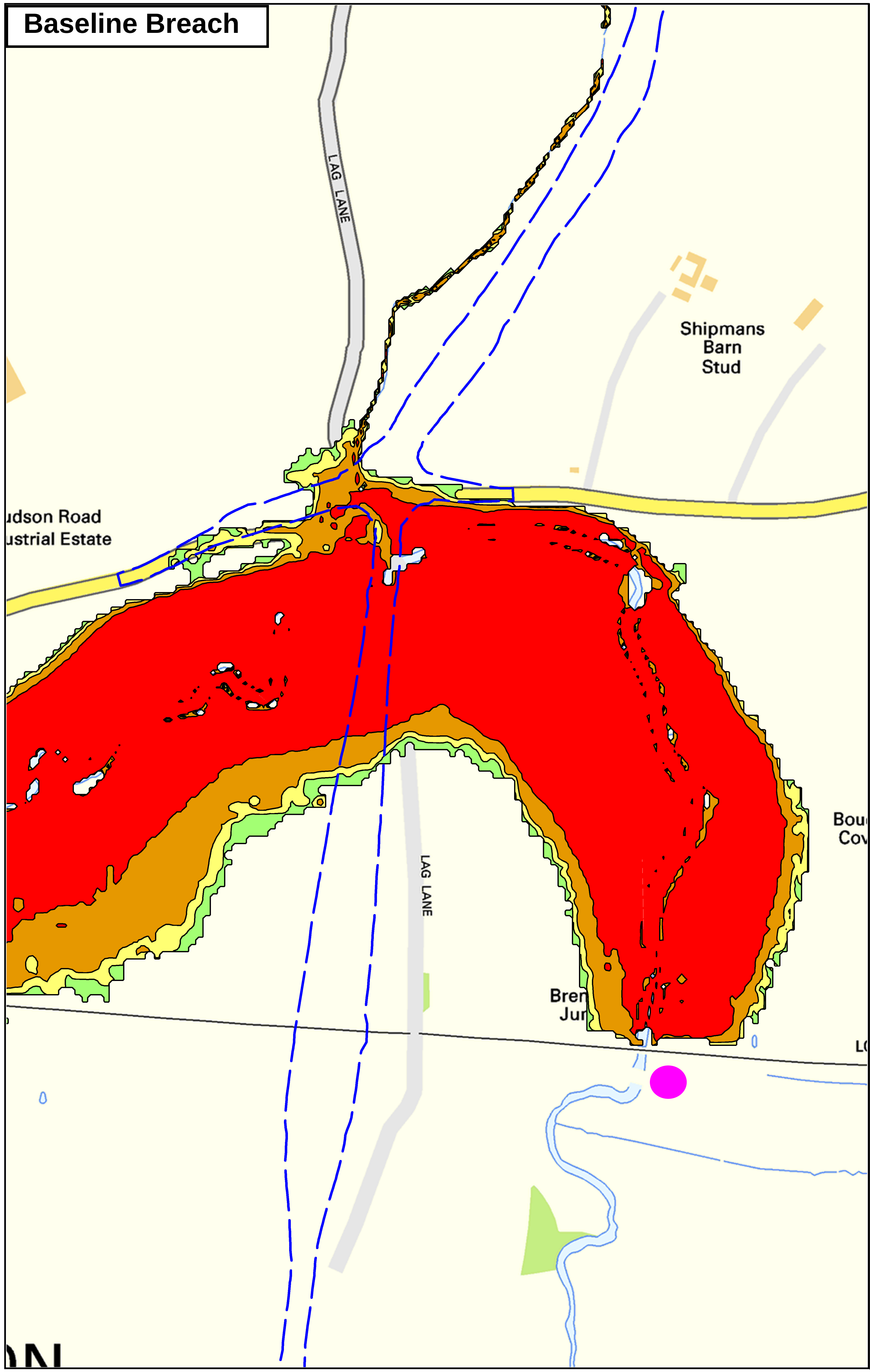
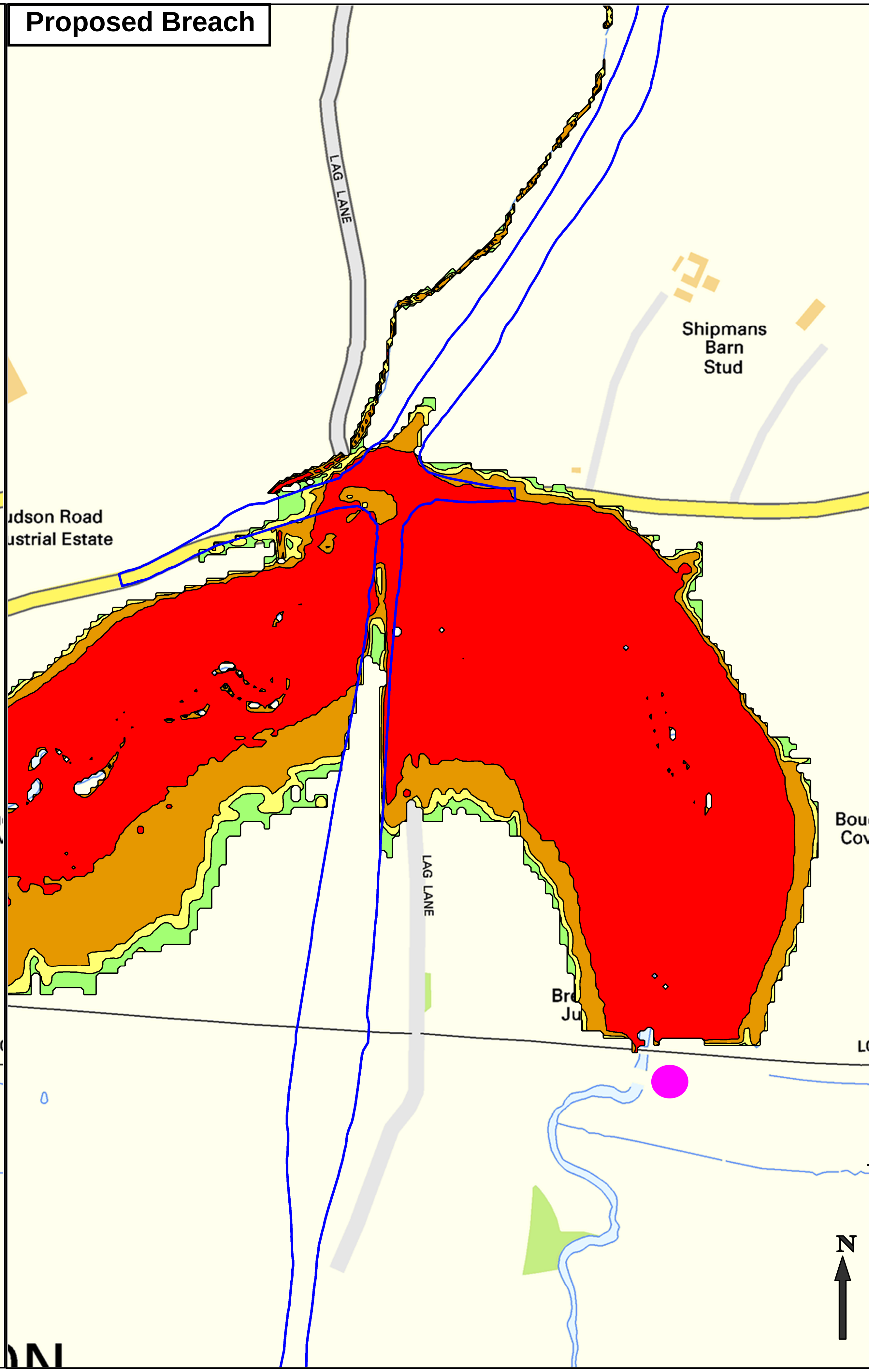
Project Number: **60542201**

Rev: **0**





Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Hazard

- Caution
- Danger for some
- Danger for most
- Danger for all

Notes

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Drawing Status

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Drawing Title

Figure C6
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
5% AEP Flood Hazard Results

Client

Leicester City Council

Scale at A3	AS SHOWN		
Drawn	AA	Approved	AP
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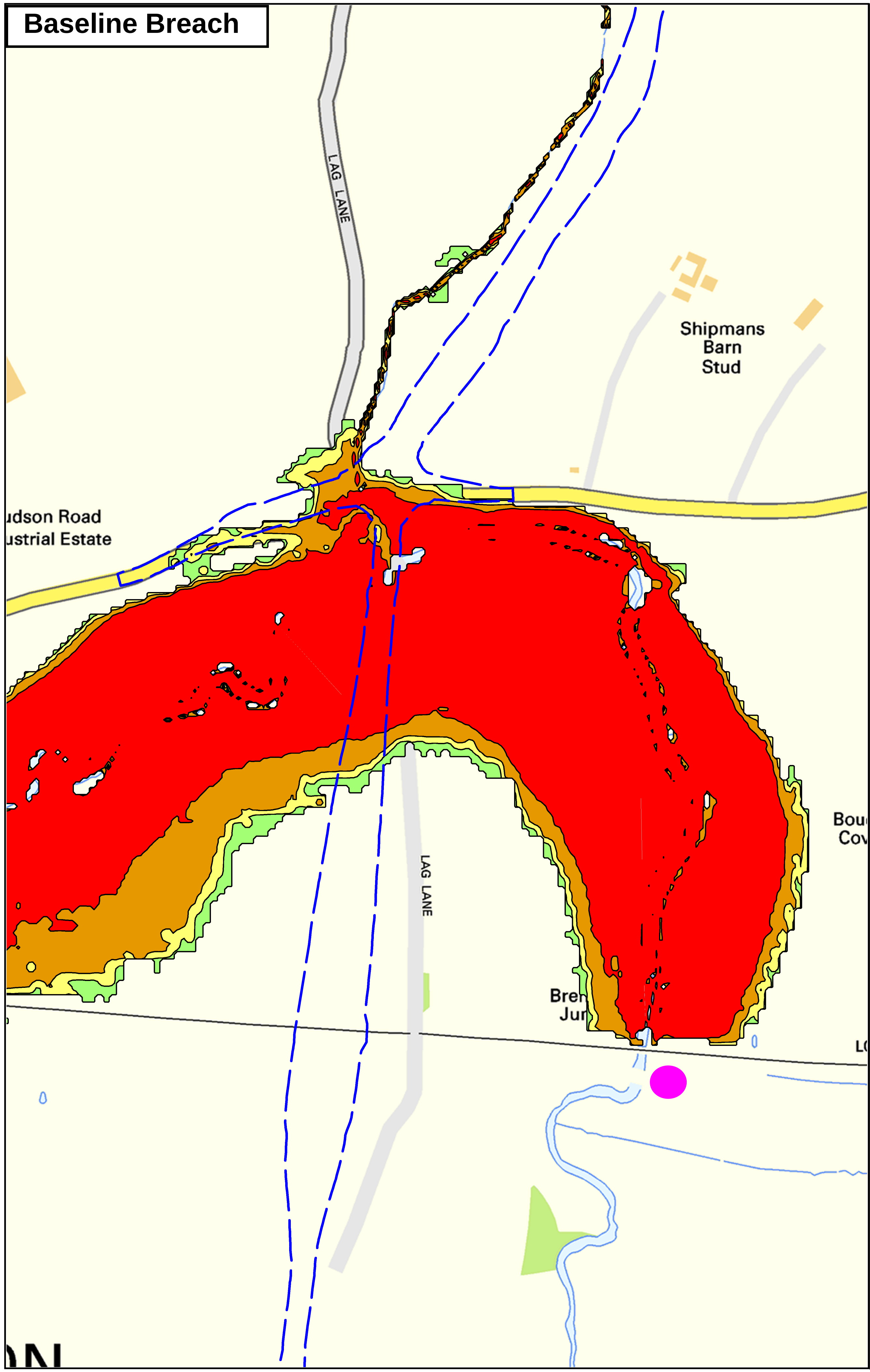
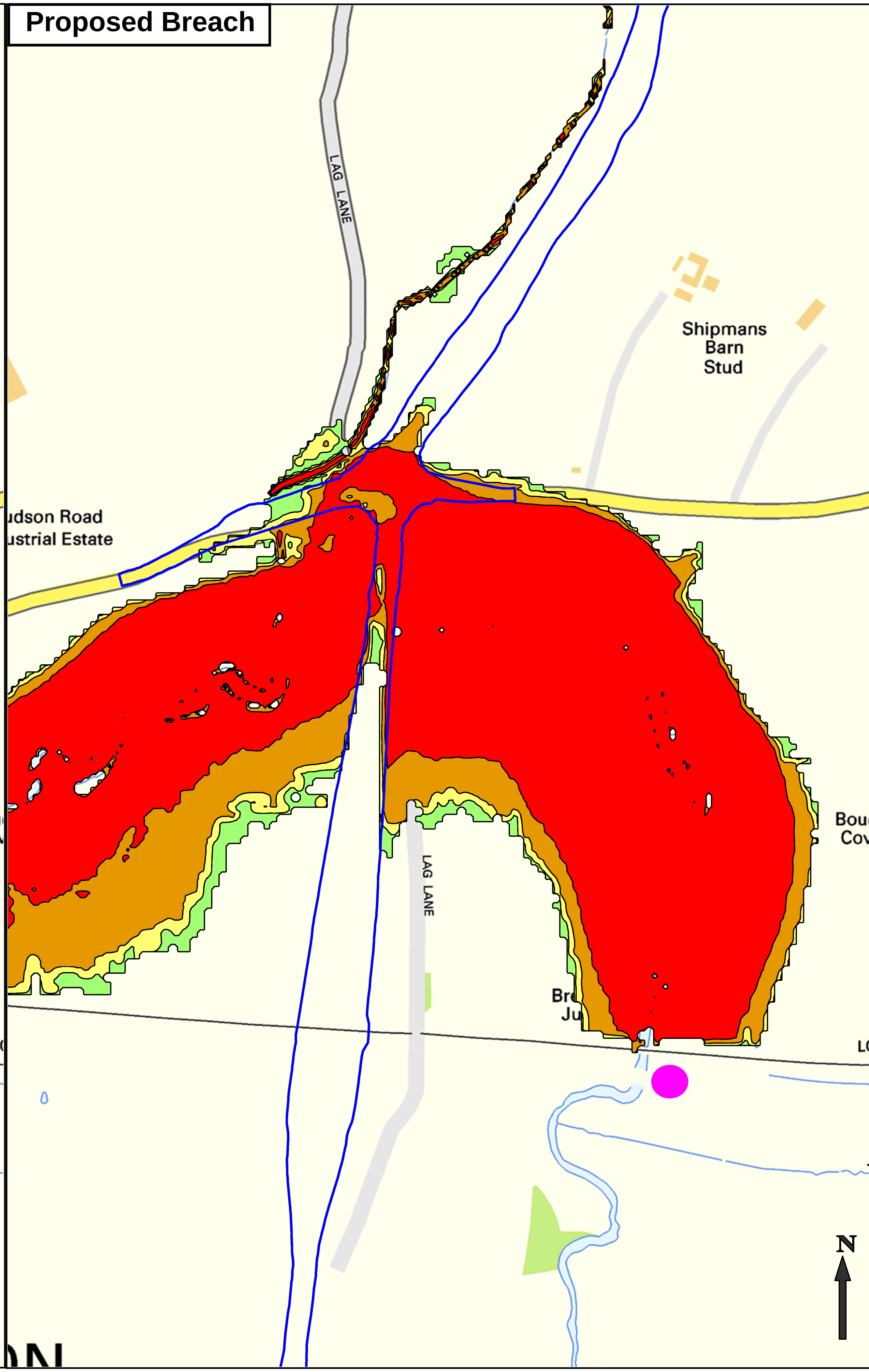
Baseline Breach



Proposed Breach



Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Hazard

- Caution
- Danger for some
- Danger for most
- Danger for all

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Drawing Status: FINAL

Drawing Title

Figure C7
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
1.3% AEP Flood Hazard Results

Client: Leicester City Council

Scale at A3	AS SHOWN
Drawn: AA	Approved: AP
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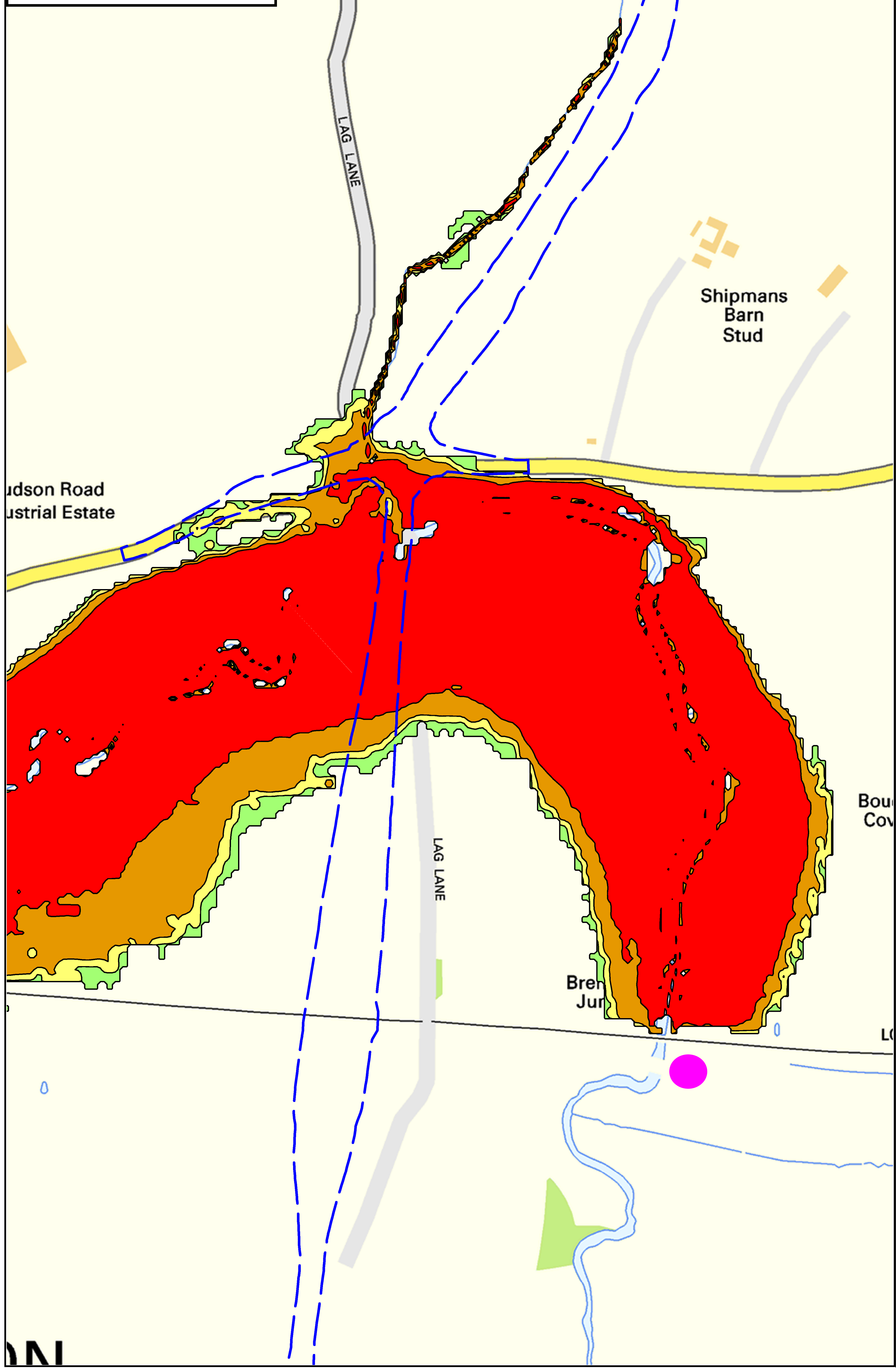
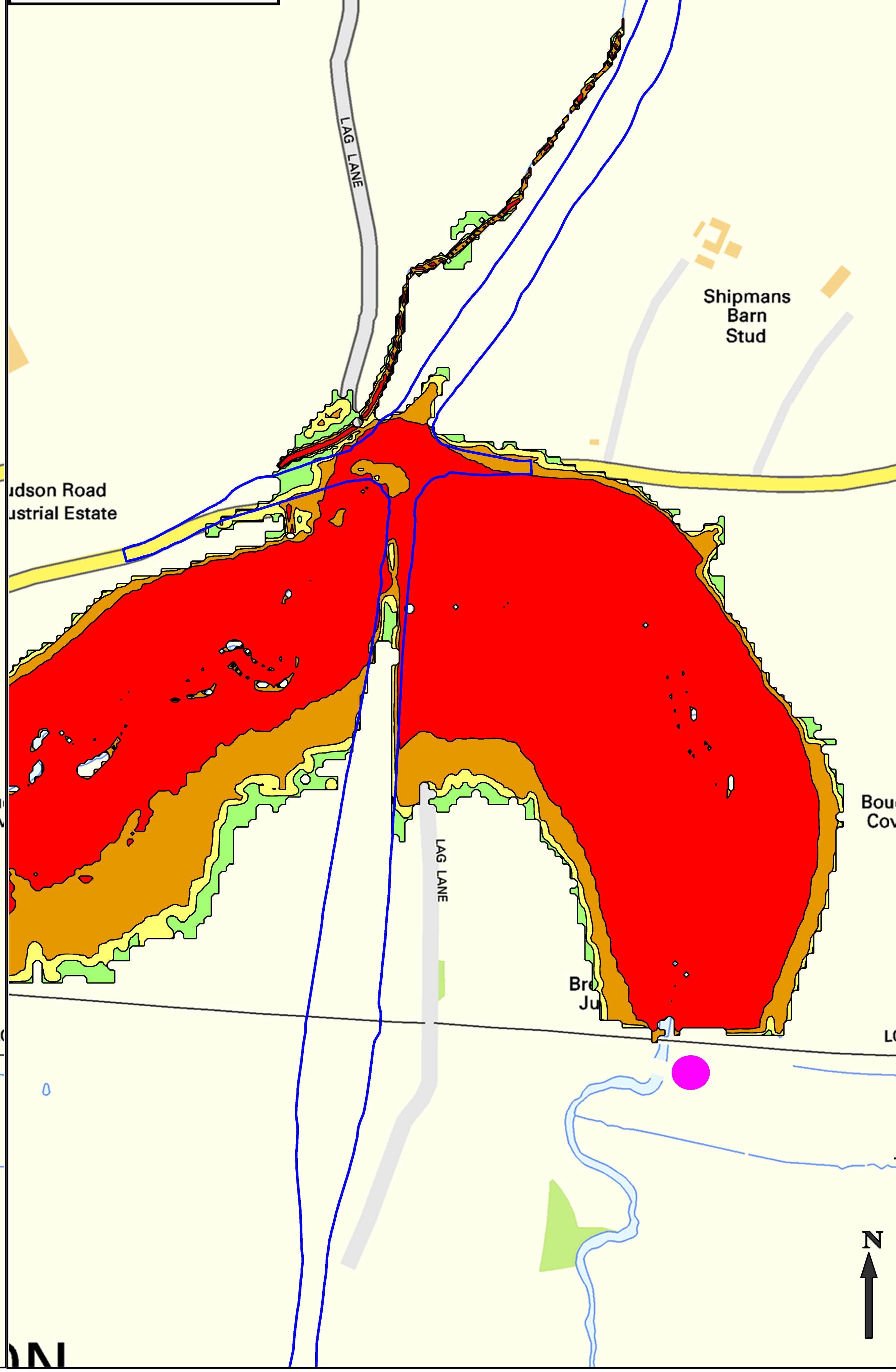
Baseline Breach



Proposed Breach



Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Hazard

- Caution
- Danger for some
- Danger for most
- Danger for all

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Drawing Status: FINAL

Drawing Title: Figure C8 Brentingby Dam Breach Analysis MMDR Baseline and Proposed 1% AEP Flood Hazard Results

Client: Leicester City Council

Scale at A3	AS SHOWN
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Stage 1 Check: BB / Stage 2 Check: AH	Date: 09-2018

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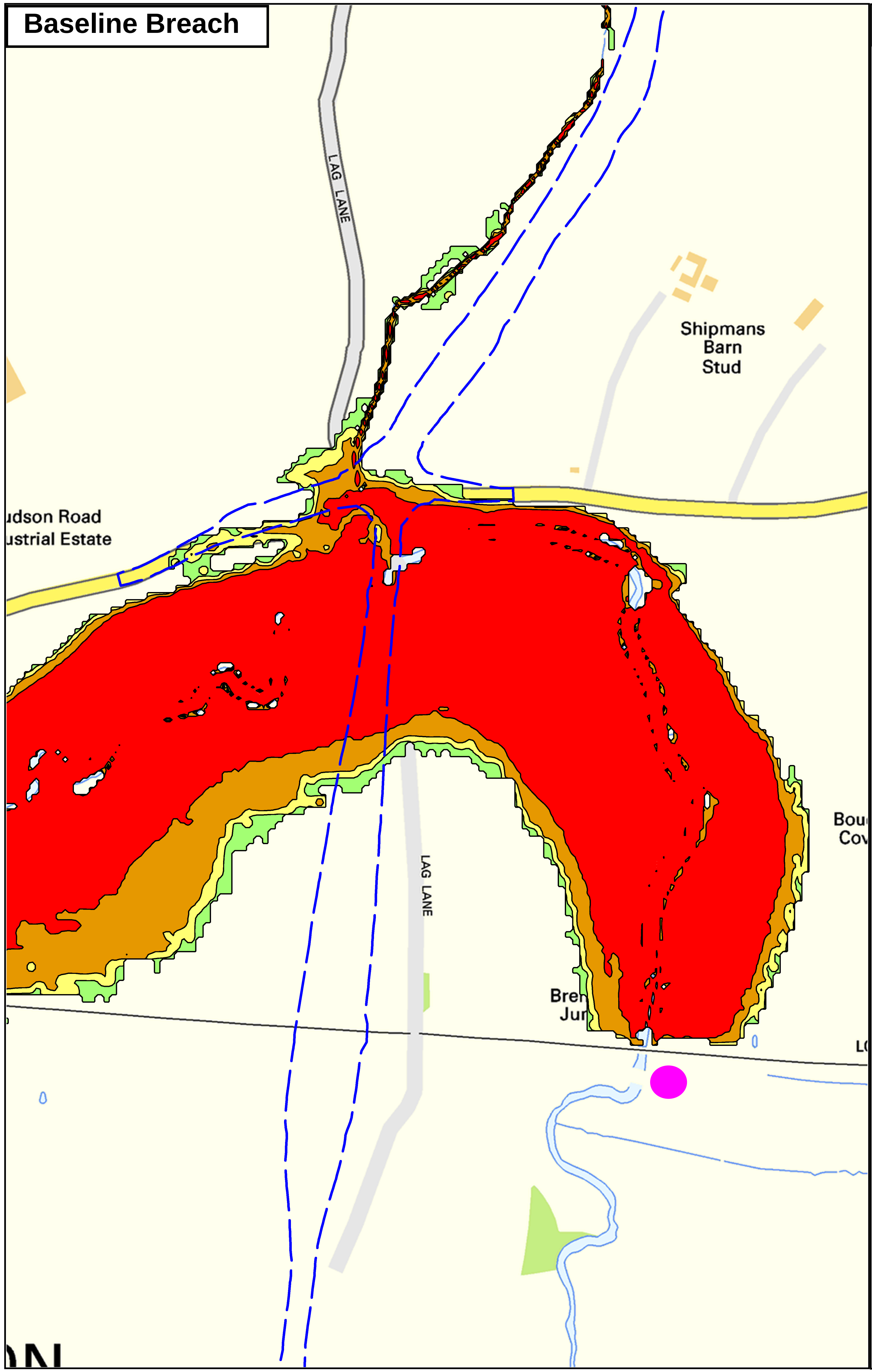
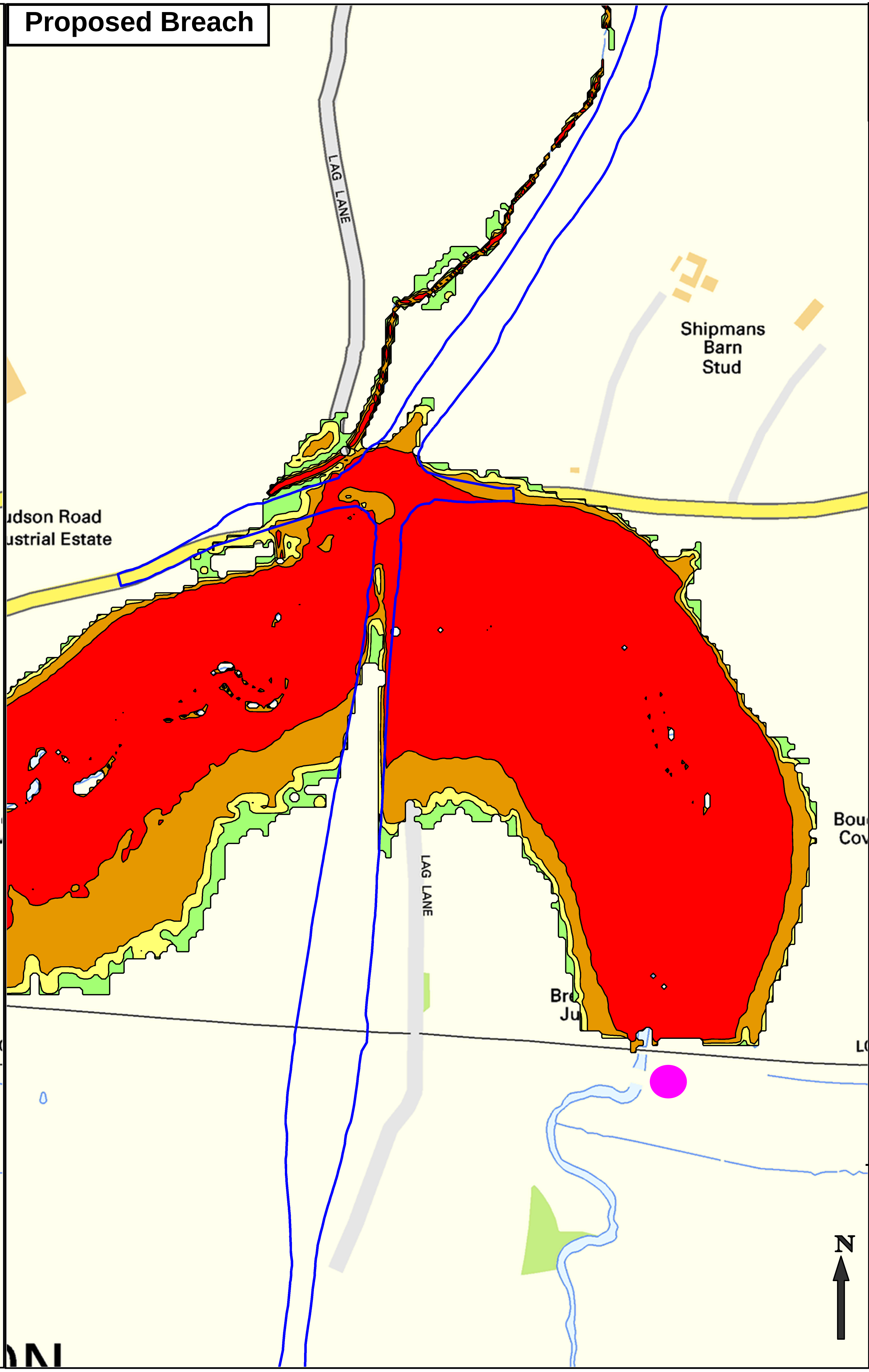
Project Number: 60542201 Rev: 0





Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Hazard

- Caution
- Danger for some
- Danger for most
- Danger for all

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Drawing Status

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Drawing Title

Figure C9
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
1% AEP plus Climate Change
Flood Hazard Results

Client

Leicester City Council

Scale at A3	AS SHOWN
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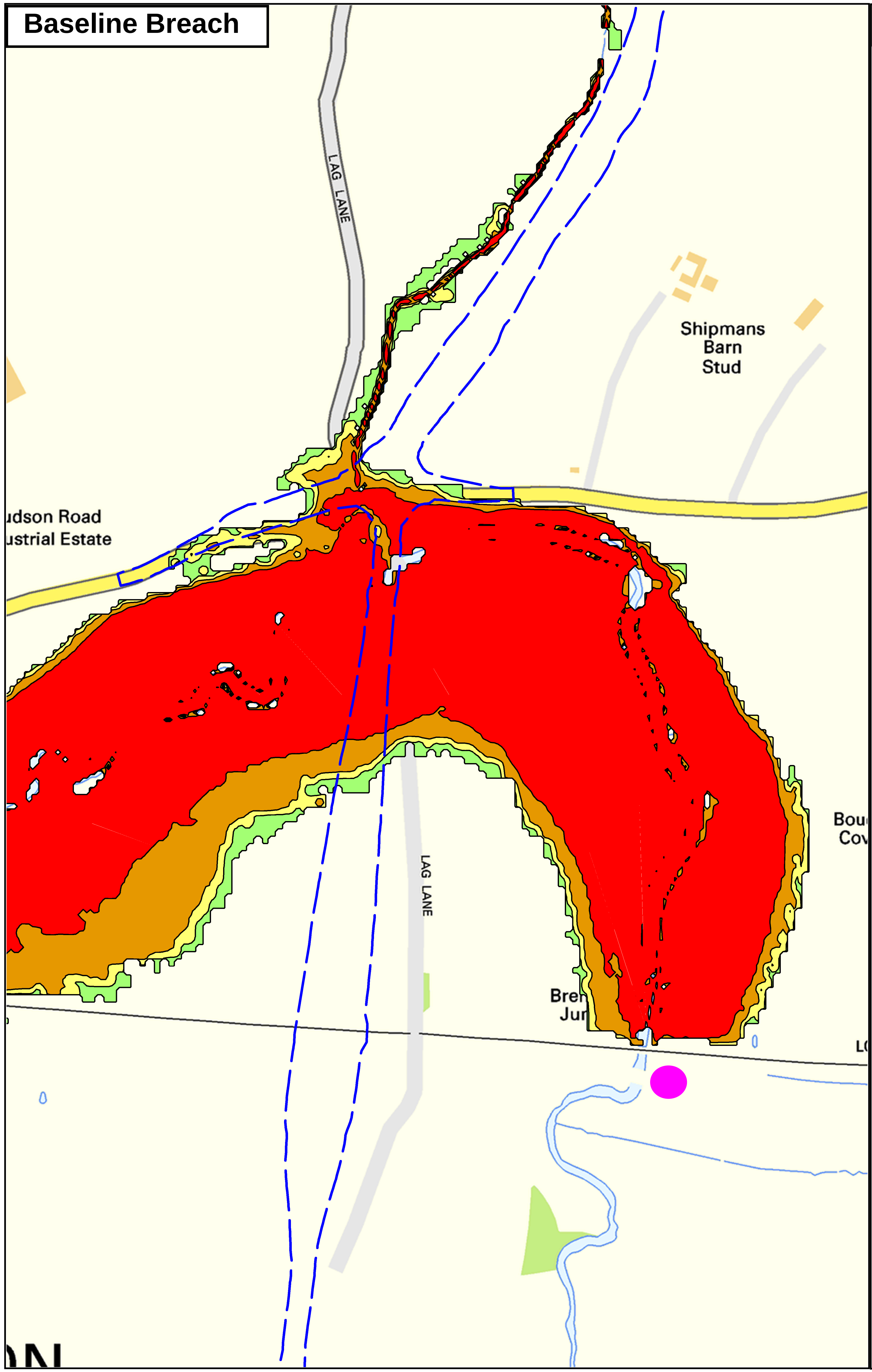

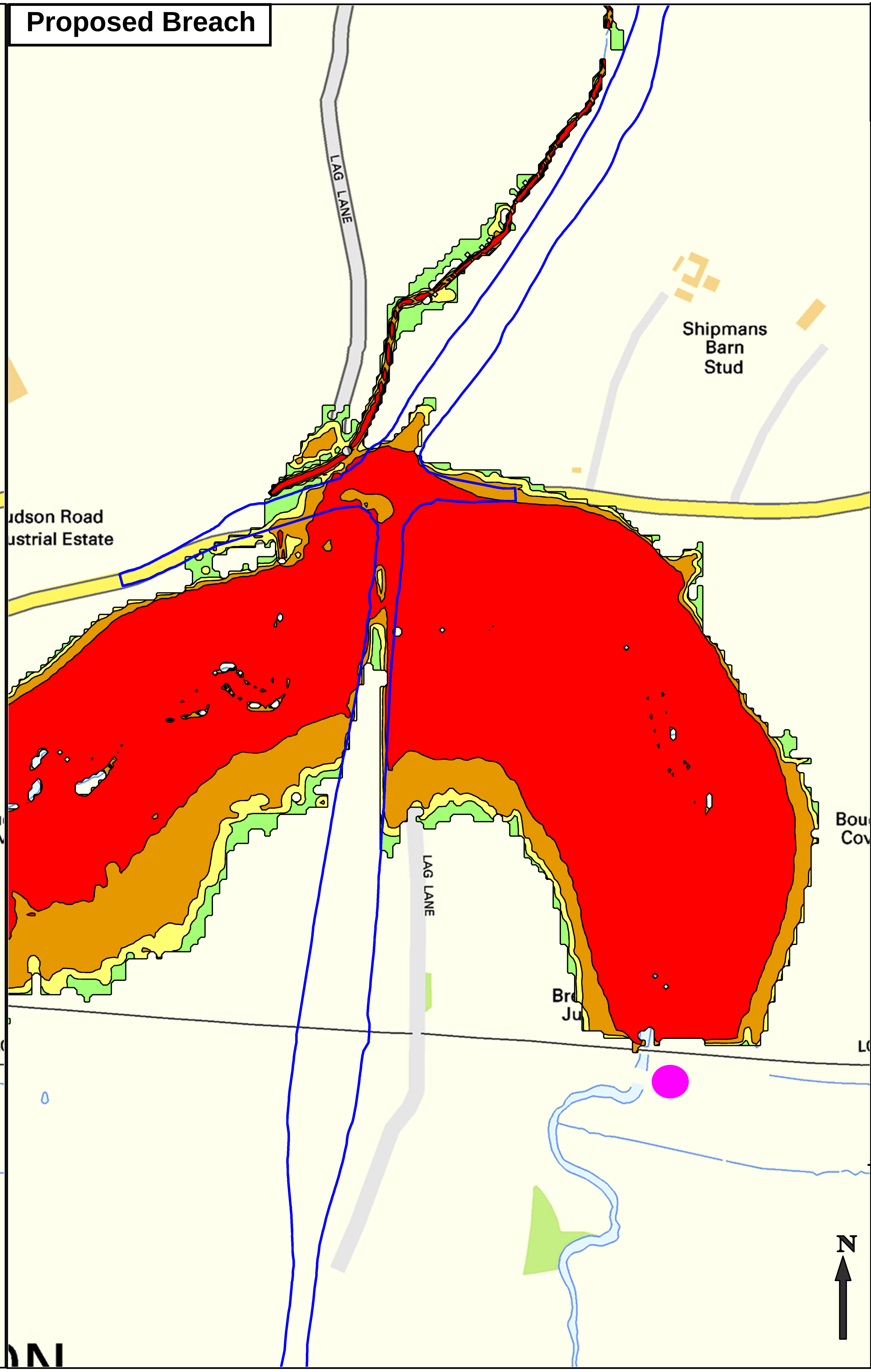

Job Title

Melton Mowbray Distributor Road - Brentingby Dam Breach Analysis

Legend

- Breach Location
- Proposed Distributor Road for comparison
- Proposed Distributor Road

Flood Hazard

- Caution
- Danger for some
- Danger for most
- Danger for all

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Drawing Title

Figure C10
Brentingby Dam Breach Analysis
MMDR Baseline and Proposed
0.1% AEP plus Climate Change
Flood Hazard Results

Client

Leicester City Council

Scale at A3	AS SHOWN		
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