P3Eco (Bicester) Ltd and A2Dominion Group

NW Bicester Eco Development

Flood Risk Assessment - Exemplar Site

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Flood Risk Assessment - Exemplar Site

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SUMMARY

A Flood Risk Assessment (FRA) and drainage strategy has been undertaken to accompany the planning application for the proposed NW Bicester eco development. This report has been prepared by Hyder Consulting (UK) Limited on behalf of the P3Eco (Bicester) Ltd and A2Dominion Group in accordance with the guidelines set out in "Planning Policy Statement 25, Development and Flood Risk."

The following table is an overview of the flood risk and drainage strategy for the proposed development of the site, based upon the currently available information.

Item	Response
Site Location	The site is 2 km from the centre of Bicester with an approximate grid reference of 457656 224697
Size and Current Land Use	The site is approximately 21.1 ha and is mainly open agricultural land.
Environment Agency Flood Zone	The majority of the site falls within Flood Zone 1: Low Probability. This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding in any year (<0.1%). There are areas of Flood Zone 2 and 3 adjacent to the watercourses, although no development is proposed for these areas.
Fluvial Flood Risk	**Low** risk of fluvial flooding
Tidal Flood Risk	**Low** risk of tidal flooding
Surface Water Flood Risk	**Low** risk of surface water flooding
Groundwater Flood Risk	**Low** risk of groundwater flooding with suitable mitigation
Artificial Flood Risk	**Low** risk of flooding from artificial sources
Historical Flooding	No record of historical flooding
Proposed Development	Approximately 393 residential units with associated services
PPS25 Flood Risk Vulnerability	More Vulnerable
Sequential & Exception Tests	The proposed development types are permitted within Flood Zone 1 and do not require the exception test.

Based on this assessment, it is concluded the site can be developed safely, without exposing the new development to an unacceptable degree of flood risk or increasing the flood risk to third parties.

1 INTRODUCTION

1.1 Terms of Reference

This report has been prepared by Hyder Consulting (UK) Limited (Hyder) on behalf of the P3Eco (Bicester) Ltd and A2Dominion Group for the proposed NW Bicester eco development.

The NW Bicester eco development will comprise approximately 5,000 homes, secondary school, a number of primary schools, retail and commercial space along with health care and other community facilities. Approximately 40% of the overall site will be green open space, including playing fields, semi private and public open space. The first phase of the eco development will be an Exemplar for future development, which will comprise 393 homes, land for a primary school, a nursery, and areas of commercial and retail property.

This report outlines a Level 3 Flood Risk Assessment (FRA) for the Exemplar Site development only. The remainder of the NW Bicester eco development site will be covered in a separate FRA.

The assessment in this report has been carried out in accordance with the guidelines set out in "Planning Policy Statement 25: Development and Flood Risk" (PPS25).

The aim of this FRA is to demonstrate that the site can be developed safely, without exposing the new development to an unacceptable degree of flood risk or increasing the flood risk to third parties. The objectives are to:

- Identify potential sources of flooding and assess the risk they pose to the site;
- Consider the effect of predicted climate change on future flood risk to the site;
- Determine the impact of the development on flood risk to third parties;
- Determine an appropriate surface water drainage strategy;
- Recommend appropriate flood risk mitigation measures.

This report has been compiled from a number of sources which Hyder believes to be trustworthy. Hyder is unable to guarantee the accuracy of information provided by others.

This report is based on information available at the time of preparation. Consequently, there is potential for further information to become available. These changes may lead to future alteration to the conclusions drawn in this report for which Hyder cannot be held responsible.

1.2 Site Description

The eco development site is situated across 416 ha of mainly greenfield land approximately 1.5 km to the north west of Bicester with a National Grid Reference (NGR) of 457656 224697. The site is located north of the A4095 which forms the current boundary of Bicester, west of the B4100, east of the B4030 and south of Bucknell, encompassing Crowmarsh Farm.

Although the eco development site is largely Greenfield, it includes a number of buildings and areas of hardstanding associated with them. These include Lovelynch House, Himley Farm, Gowell Farm, Aldershot Farm, the police depot, Lord's Farm, Hawkwell Farm, Crowmarsh Farm and Home Farm. The site is bisected by both Bucknell Road and the railway.

The Exemplar Site is situated at the northeast end of the development and covers an area of approximately 21.1 ha of Grade 3 agricultural land.

Within the Exemplar site there are several water features, including the River Bure and its associated tributaries, and various field drains. The Bure flows in a southerly direction from Caversfield House to a culvert beneath the A4095. Downstream from this it flows in an open channel between Lucerine Avenue and Purslane Drive. There is a tributary flowing in an easterly direction from Bucknell which converges with the Bure downstream of Home Farm, and another tributary which flows in an easterly direction from Crowmarsh Farm and converges with the Bure at the A4095 culvert.

The extents of the Exemplar site are shown on Figure 1-1 below.

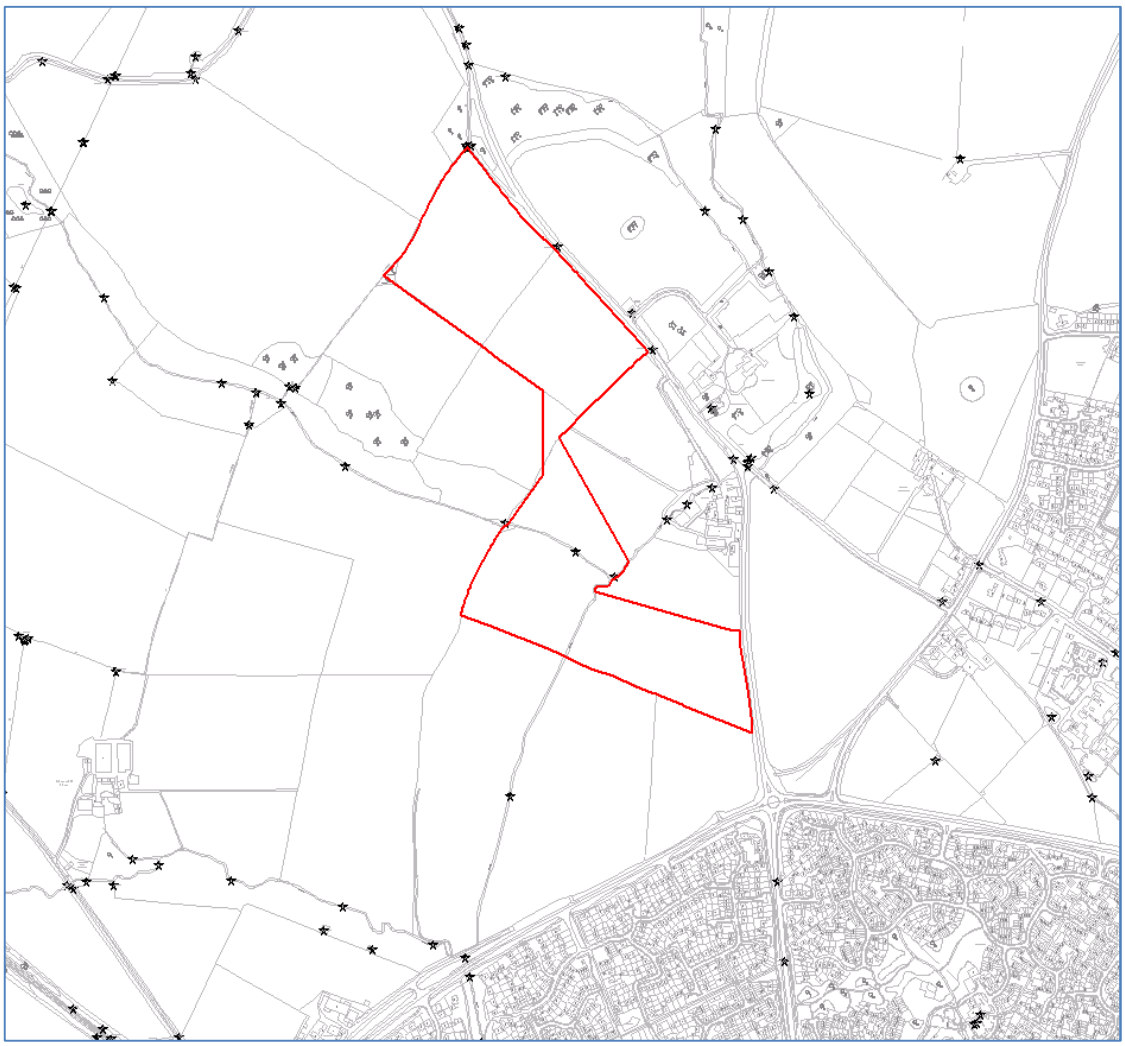


Figure 1-1 Exemplar Site Location

1.3 Site Topography

A topographical survey has been completed for the Exemplar Site. Drawing 7013 in Appendix A shows contours and topological details of the Exemplar Site produced from the topographical survey.

The topography varies between extremes of 92.3 m AOD and 81.7 m AOD, with a general slope downwards from the north western boundary southeast towards Bicester. The watercourses (the River Bure and tributaries) are the lowest points on the site.

1.4 Geotechnical Conditions

Ground conditions have been assessed within a desk study (NW Bicester Eco Development - Phase 1 Desk Study, 2501-UA001881-UP33R-01, Hyder, July 2010) and a factual report summarising the findings of onsite ground investigation (NW Bicester Eco Development - Exemplar Site Factual Report 2504-UA001881-UP33R-01, Hyder, September 2010).

In summary, the investigations indicate that the site comprises stratum of sand and gravel overlying clay bands and limestone.

1.5 Development Proposal

The proposed site layout for the Exemplar site is shown in Appendix B. The development proposal includes residential properties (including flats), a business centre, land for a primary school with associated grounds, nursery, post office, energy centre and service yard, retail premises and associated roads and kerbing.

Residential properties are mostly based in the northwestern and southeastern corners of the site, with the remaining public buildings arranged around the centre of the site.

Two bridges will be constructed over the watercourses, with one over the River Bure and one over the northernmost of its two tributaries.

2 ASSESSMENT OF THE FLOOD RISK

2.1 Planning Policies

2.1.1 Planning Policy Statement 25

PPS25 sets out the Government's national policies for flood risk management in a land use planning context within England.

PPS25 states that developers and local authorities should try to relocate existing development to land in zones with the lowest probability of flooding and to:

> *"reduce the flood risk to and from new development through location, layout and design, incorporating sustainable drainage systems (SUDS)".*

A sequential risk based approach to determine the suitability of land from development in flood risk areas is central to PPS25 and should be applied at all levels within the planning process.

2.1.2 Ecotowns, A supplement to Planning Policy Statement 1

Policy ET 18 (Flood Risk Management) states:

> *"There is a strong expectation that all of the built-up areas of an eco-town (including housing, other public buildings and infrastructure) will be fully within Flood Zone 1 – the lowest risk. Flood Zone 2 (medium risk) should, as far as possible, be used for open spaces and informal recreational areas that can serve as multi-functional spaces, for example, those used for flood storage. There should be no built up development in Flood Zone 3 with the exception of water-compatible development and where absolutely necessary, essential infrastructure."*

2.2 Flood Risk Vulnerability

As the eco development is a mixed use development there will be a variety of flood risk vulnerability classes (as defined in table D.2 of PPS25). These include:

- Residential – Highly vulnerable
- Nursery – More vulnerable
- Shops & offices – Less vulnerable
- Public open space and nature areas – Water compatible

The sequential and exception tests will not be required as in accordance with the precautionary principal (advocated by PPS25) and Ecotowns: A supplement to Planning Policy Statement 1, the development will be located within Flood Zone 1 (areas of low risk).

2.3 Historical Flooding

There are no historical records of flooding within or around the site from either the EA or the SFRA.

2.4 Sources of Flood Risk

2.4.1 Fluvial Flooding

The EA flood maps that cover the site are based upon a coarse DTM and JFLOW modelling and as such do not take account of the impacts of climate change and are therefore not suitable for use within a FRA to determine the extents of flood zones in relation to building location and associated finished floor levels. Therefore, detailed hydraulic modelling has been undertaken as part of this FRA. This modelling is discussed in Section 3.

2.4.2 Tidal Flooding

As the eco development is located significantly inland it is considered to be at **low** risk of Tidal Flooding.

2.4.3 Groundwater Flooding

The Ground Investigation (Hyder, 2010) indicates that with the exception of the Forest Marble Formation cropping out in the floors and sides of the valleys, the whole of the site area is underlain by the Cornbrash Formation. This is a local aquifer and water strikes have been recorded in shallow, site-investigation boreholes drilled within the site area.

The Forest Marble Formation, may hold small quantities of water in any limestone bands present, but the upper part generally acts as an aquiclude between the Cornbrash Formation and the underlying White Limestone Formation. There are no boreholes drilled through the Forest Marble Formation in the site area that record water strikes within it.

The White Limestone Formation constitutes a major aquifer in the area, which provides some sources of public supply. There are several boreholes in the wider area, some within the site area, that penetrate this formation.

The site is isolated from the major aquifer in the White Limestone Formation by clay layers within the Cornbrash and, particularly, the Forest Marble formation. The potential for groundwater flooding is therefore restricted to superficial horizons in or above the Cornbrash, and is therefore quite limited.

The geology is indicated in the sketch cross section (Figure 2-), extracted from the BGS detailed report (BGS 2008). The major aquifer is the White Limestone Formation is confined, isolated from the surface by the aquiclude within the Forest Marble. The Cornbrash and Forest Marble formations have a combined thickness of 6 - 8 metres. The aquifer is therefore unlikely to be a source of groundwater on the site.

Groundwater movement is generally SE down dip, but locally to watercourses, and groundwater within the Cornbrash and Forest Marble is likely to be in continuity with the surface water (BGS 2008).

Groundwater strikes in the site investigation arise from the Cornbrash Formation and more permeable horizons within the Forest Marble. The quantity of water from these sources is limited because the strata are relatively thin, the catchment area is restricted and the permeability is generally only moderate.

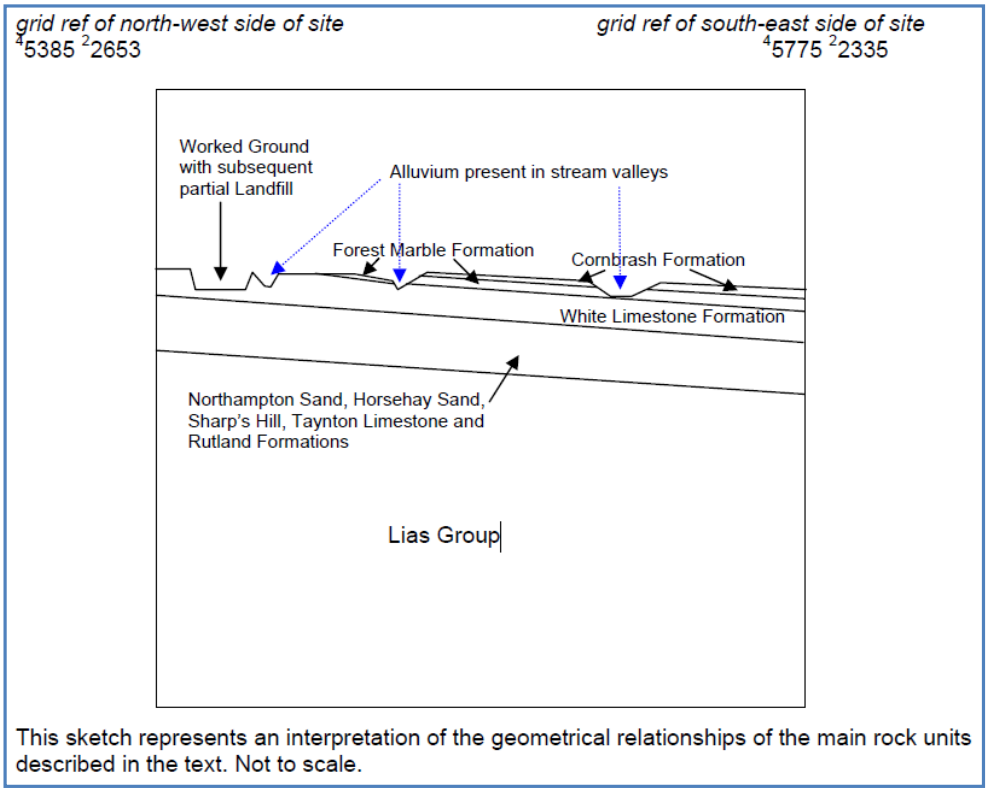


Figure 2-1 Simplified cross section through Exemplar site (BGS 2008)

The Environment Agency (EA) Groundwater Vulnerability Map on the EA website has been reviewed to determine the vulnerability of the groundwater underlying the Site with the following conclusions:

> *The superficial deposits are not classified as an aquifer. The underlying Cornbrash Formation is classified as a Secondary A Aquifer, which comprises "permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers."*

Additional boreholes and trial pits were drilled across the site during August 2010, the location of these are shown in Appendix C. Due to the drilling process, it was not possible to carry out groundwater monitoring of the boreholes during the ground investigation. Five of the six trial pits excavated were found to be dry, with TP1 striking water at a depth of 2.9 m below ground level (bgl).

The observation of high groundwater during a heavy rainfall event during the site investigation work suggested water being held above the more permeable layers in the Cornbrash by less permeable horizons. The observations of groundwater at the boreholes which were left open for monitoring are shown in Table 2-1. Although limited, these indicate fairly steady water levels, mostly well below ground level. Borehole 11, situated in the southern part of the Eco Development area away from the Exemplar site, has the highest levels, but these are still a reasonable distance below the ground surface.

Table 2-1 Groundwater Monitoring Results

	Water level (m bgl)		
Borehole Number	13/09/2011	05/10/2011	10/11/2011
1	3.1	3.1	3.22
3	3.05		2.72
5	6.3	6.5	
10	2.38		2.08
11	1.1	1.42	1.21

The evidence collected therefore indicates the potential for groundwater flooding in the Exemplar site is very limited and is unlikely to be a source of flood risk.

Groundwater monitoring results following completion of the ground investigation are ongoing. Initial results from a monitoring visit on 13 August 2010 showed standing water levels between 3.1 m bgl and 6.3 m bgl, which suggest that excavation for foundations will not encounter groundwater as the excavation required for the proposed development will typically be less than 2 m bgl.

However, excavations undertaken during the ground investigation within the surrounding area were carried out after heavy rain and encountered shallower groundwater levels above the limestone. Therefore, where foundations are based at shallow level on top of the limestone, some groundwater flooding may be expected following heavy rain.

It is therefore expected that parts of the site would be considered at **high** risk of groundwater flooding. However, the proposed houses and other buildings would be located outside of these areas. Potential mitigation measures that would normally be used to protect the portions of site at risk from groundwater flooding would include:

- The provision of preferential flow paths away from the buildings to the surface water drainage system;
- Locating buildings outside the areas of highest risk;
- The provision of damp proof courses and tanking if required.

The drainage strategy for the Exemplar site will include infiltration of surface water as part of its SUDS design to maintain the existing hydrological regime and avoid increased discharges to the watercourses (refer to Section 4). This will change the local groundwater regime by displacing current infiltration from the building footprint to new infiltration areas.

The groundwater data available suggests that groundwater levels will permit infiltration across most of the Exemplar site but local groundwater conditions will be considered during the detailed design to ensure that infiltration is feasible and that discharge of water to superficial aquifers does not present a groundwater flood risk.

With the incorporation of mitigation measures and a SUDS strategy, the site can be considered to be at **low** risk of groundwater flooding.

2.4.4 Surface Water Flooding

The site is located on a slope which drains to a number of local watercourses (the River Bure and its tributaries). As the site is currently farmland, it is likely that there are farm drains that outlet to these watercourses. These provide the main means of drainage on the site presently.

If the capacity of these drains is exceeded then there is potential for localised flooding through the site, although this would drain quickly to the local watercourses due to the slope of the site.

The proposed development will incorporate surface water management measures to ensure that the runoff rates across the site are maintained at the existing Greenfield rates. This will ensure that the flood risk from surface water runoff to the site and surrounding land is maintained at the baseline level.

Details on surface water management are summarised in Section 4 of this report with further detail presented in the Exemplar Site Drainage Strategy report (7501-UA001881-UP21R-02). As with any development, if appropriate SUDS design measures are not incorporated within the proposals, surface water flooding issues may potentially develop where impermeable areas are increased.

Based on the existing surface water runoff regime and providing that, as described above, appropriate SUDS measures are incorporated within the proposed development, it is considered that the site is at **low** risk of surface water flooding.

2.4.5 Flooding from artificial sources

The site is located within a small catchment, in which no artificial sources (which include but are not limited to canals/reservoirs/sewers) have been identified. Once the site is developed there remains the risk of sewer flooding, however, with suitable design this risk can be minimised. It is therefore considered that the site is at **low** risk of flooding from artificial sources.

3 FLUVIAL FLOOD RISK ASSESSMENT

This section outlines the modelling methods used to determine the fluvial flood risk to the site, the results of the modelling, and the impacts of the fluvial flood risk on the proposed development. Additional detail is provided in the Hydraulic Modelling Report in Appendix E.

3.1 Hydrological Assessment

Flood flow estimates for the River Bure and its tributaries were initially derived by applying the FEH Statistical (with a permeable adjustment) and the IOH 124 methods which represent current best practice methodologies for UK flood flow estimation. Consideration was given to the use of the Revitalised Flood Hydrograph (ReFH) method but due to the low SPRHOST values this method is not suitable.

The hydrology used in the model was later updated using information from the Environment Agency's River Bure model. It was determined that the EA had conducted significant temporary gauging in the catchment and used this data in calculating the hydrology for the River Bure model. The gauging data and River Bure hydrology report could not be provided in the timescale available for the NW Bicester eco development modelling, and therefore it was not possible to use the gauged information to inform the hydrological assessment. For this reason, it was decided to use the peak flows supplied from the River Bure model in the Bicester eco development model, as the additional gauging undertaken means that the River Bure model flows are likely to be more accurate.

A summary of the peak flows used in the model is given in Table 3-1 below.

Table 3-1 Modelled Design Events

Return period	T1-3014	T2-2266	T3-0770
1 in 20-year	0.65 m^3/s	0.44 m^3/s	1.36 m^3/s
1 in 100-year	0.94 m^3/s	0.64 m^3/s	1.96 m^3/s
1 in 100-year with climate change (+20 %)	1.13 m^3/s	0.77 m^3/s	2.35 m^3/s
1 in 1000-year	1.70 m^3/s	1.16 m^3/s	3.54 m^3/s

Further details of the hydrological assessment and subsequent adjustments are provided in Section 3 of the Hydraulic Modelling Report.

3.2 Hydraulic Assessment

Full details of the hydraulic modelling process are provided in the Hydraulic Modelling Report in Appendix E.

3.2.1 Model Overview

The assessment of fluvial flood risk was made using an ISIS model (Halcrow, version 3.3) of the appropriate section of the River Bure and its tributaries. The model was run to simulate the following return periods

- 1 in 20 year
- 1 in 100 year
- 1 in 100 year plus climate change (20% increase in flows)

- 1 in 1000 year

An unsteady state modelling approach with variable hydrographs was adopted to gain the best accuracy possible at this site.

The model contains three watercourses and a lake outflow as detailed in Table 3-2 and shown in Figure D1 in Appendix D.

Table 3-2 Watercourses contained in model

Watercourse	Name in model	Length of reach (m)	Upstream extent (NGR)	Downstream extent (NGR)
River Bure	Tributary 3 (T3) down to confluence with Tributary 2 (T2) down to confluence with Tributary 1 (T1) to downstream extent of model	1952	458174, 225414	457695, 223804
Tributary 1	Tributary 1 (T1)	2588 (to confluence with T2)	455409, 224548	457606, 224230
Tributary 2	Tributary 2 (T2)	1510 (to confluence with T3)	456707, 225662	457979, 224508
Lake outflow	Tributary 4 (T4)	260 (to culverted confluence with T3)	458207, 225342	458100, 225070

3.2.2 Topography

The majority of the cross-section data in the model was generated from two cross-section surveys. The majority of the model was informed by Hyder's in-house surveyors, who also conducted a topographical survey of the Exemplar site. Additional survey was collected by Maltbys Land Surveyors to supplement the existing survey information.

A number of sections in the model have been extended using topographical data from a number of sources, including the Hyder topographical survey, LiDAR data, and an existing 5 m DTM.

3.2.3 Model Calibration

Unfortunately no recorded flood water level or flow data was available at the site and therefore model calibration was not possible. To gain further confidence in the model sensitivity analysis was undertaken as detailed in Section 3.4.

3.2.4 Post-Development Modelling

The proposed development for the Exemplar Site includes the removal of an existing bridge structure at T2-0779a, the addition of two large bridge structures where new roads cross the watercourse, and reshaping of the riparian corridor. These alterations have been done to improve the multi-functionality of the riparian corridor to meet wildlife, landscape and conveyance objectives.

The re-profiling helps to protect existing biodiversity (e.g. such as minimising impact to the badger sett) and create habitat opportunities to secure the future long term ecology and green

infrastructure of the river corridor environs. Bat-friendly clear span bridges with appropriate bridge lighting, tree planting and mammal tunnels are proposed for the two new bridge structures.

The re-profiling also helps to minimise the span of the bridges to a fitting scale within the gently sloping river corridors. The landscape setting is greatly enhanced for the long term by localised ground modelling, and the bridge design as an arched span, possibly stone clad, is contemporary but sympathetic to the vernacular.

The re-profiling creates opportunities for a series of SuDS scrapes and habitat ponds (both permanent and ephemeral) which have been factored into the revised SuDS strategy and biodiversity net gain proposals.

The re-profiling also incorporates compensatory storage volume to mitigate the effect of the western abutment for the downstream River Bure bridge encroaching into the flood corridor.

The aim of the adjacent landscape works at both bridges is to enhance the biodiversity of the watercourse corridor with a view to achieving a good ecological status and contribute to the overall biodiversity net gain for the development.

Figure 3-1 below highlights the key changes for modelling. Post-development modelling was undertaken to determine the impact of the riparian corridor on flooding in the area and ensure that any development continued to be out of the flood zones. The results of this modelling are discussed in Section 3.5.

Figure 3-1 Proposed development changes

3.3 Baseline Flood Risk

The aim of the study is to gain an understanding of the degree of flood risk to the development site and confirm the potential flood mechanisms that could lead to its inundation.

The model predicts that floodwater is generally confined to the valleys in which the watercourses flow, with ponding occurring at confluences and upstream of constricting structures. The model does not predict any overland flow occurring.

Figure 3-2 and Figure 3-3 overleaf show the modelled flood extent across the existing site for the 100-year and 1000-year events (i.e. Flood Zones 3 and 2 respectively). Figure 3-2 shows that the northern part of the development site has no flood risk whatsoever. Figure 3-3 shows that, in the southern part of the development site, flooding occurs predominantly on the flatter land around the confluence between the River Bure and the northernmost of the two tributaries. Away from the confluence, flooding is confined to the relatively narrow valley of the watercourse.

Figure 3-2 Modelled flood extents for northern part of development site

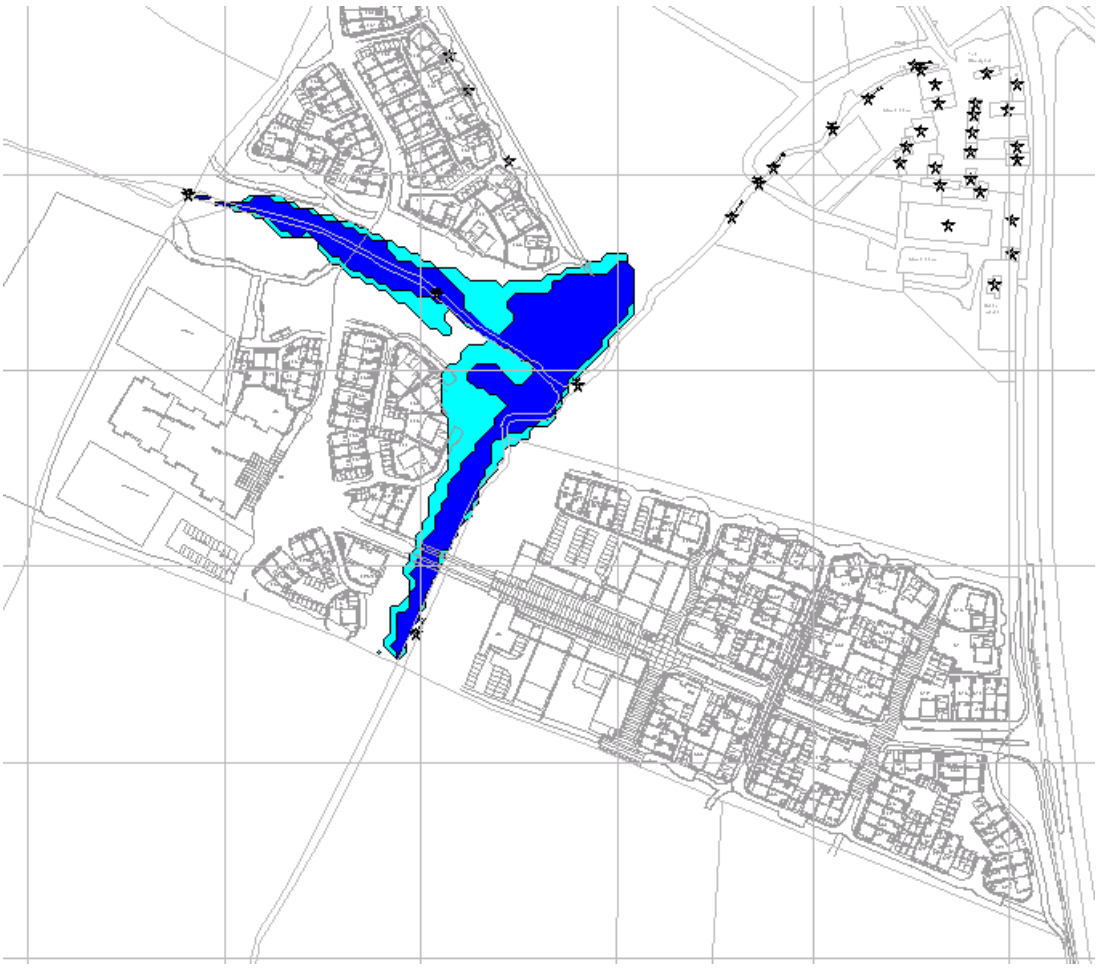


Figure 3-3 Modelled flood extents for southern part of development site

Figure 3-3 also shows that the flooding only impacts on green space within the development, and no buildings are affected by flood water. Without the proposed modification to topography a small section of residential gardens and roads to the west of the River Bure confluence would be impacted by the 1000-year event and therefore be within Flood Zone 2. However, the proposed modification to topography shown in Figure 3-1 will remove this small risk, as discussed in section 3.5 below.

It should be noted that the proposed modification shown in Figure 3-1 is a change to the masterplan to respond to the altered riparian corridor. As these changes to the topography are not included in the baseline the unaltered extents are shown in Figure 3-3. The previously submitted masterplan was wholly outside of the flood zones in the baseline event, as Figure 3-4 shows below, as this did not alter the riparian corridor.

Figure 3-4 Previously submitted Masterplan layout with Flood Zones shown

Table 3-3 below shows the modelled peak water levels through the development site for each return period. Cross-section locations are shown on Figure D2 in Appendix D.

Table 3-3 Development Site Modelled Peak Water Levels

Node Label	100-year	100-year with climate change	1000-year
T2-0952	84.67	84.68	84.70
T2-0779a	83.34	83.38	83.49
T2-0777b	83.34	83.38	83.49
T2-0756a	83.34	83.38	83.49
T2-0756b	83.34	83.38	83.49
T2-0636	82.77	82.81	82.91
T3-0157a	83.54	83.59	83.71
T3-0152b	83.54	83.59	83.71
T3-0011	83.34	83.38	83.49

The model results have confirmed that the proposed development site is predominantly located within the Low Flood Risk Zone, with small areas of Medium and High risk around the watercourses.

3.3.1 Flood Protection

Due to PPS1 restrictions on the siting of development in an Eco-Town, all of the buildings in the proposed development will be sited in Flood Zone 1. Therefore, no flood protection or mitigation measures will be necessary on the site.

3.3.2 Third Party Flood Risk

All development will be sited within Flood Zone 1 and compensatory storage has been provided to alleviate the small restriction to flow caused by the bridges crossing the watercourses (see Section 3.5). Therefore, there will be no loss of floodplain storage caused by the proposed development. Any increased peak surface water runoff caused by the development will also be attenuated to Greenfield rates (see Section 4). Therefore, there will be **no change** in third part flood risk as a result of the development.

3.3.3 Site Access and Egress

As stated in Section 3.3.2 above, all development will be sited within Flood Zone 1, and any roads crossing watercourses will be raised above flood levels. Therefore, emergency access routes will not be affected by flooding.

3.4 Sensitivity Analysis

Model sensitivity tests are undertaken to determine the level of uncertainty in the predicted water levels associated with key model parameters. For consistency, all sensitivity tests have been carried out using the 1 in 100-year flow. A full discussion of the sensitivity analysis undertaken and the model results is presented in the Hydraulic Modelling Report in Appendix E. The following sensitivity tests were undertaken:

- Manning's 'n' values increased by 20%
- Manning's 'n' values decreased by 20%
- Downstream boundary increased by 0.5m
- Spill coefficients increased by 20%
- Spill coefficients decreased by 20%

Table 3-4 overleaf shows the changes in modelled water level through the development site caused by each sensitivity test.

Table 3-4 Sensitivity Test Changes in Modelled Water Level

Node Label	Increased Manning's "n"	Decreased Manning's "n"	Downstream Boundary	Spill Coefficients Increased	Spill Coefficients Decreased
T2-0952	0.00	-0.02	0.00	0.00	0.00
T2-0779a	0.03	-0.06	0.00	0.00	0.00
T2-0777b	0.03	-0.07	0.00	0.00	0.00
T2-0756a	0.03	-0.07	0.00	0.00	0.00
T2-0756b	0.03	-0.07	0.00	0.00	0.00
T2-0636	0.06	-0.03	0.00	-0.01	-0.01
T3-0157a	0.05	-0.07	0.00	0.00	0.00
T3-0152b	0.05	-0.07	0.00	0.00	0.00
T3-0011	0.03	-0.07	0.00	0.00	0.00
Maximum	0.06	-0.02	0.00	0.00	0.00
Minimum	0.00	-0.07	0.00	-0.01	-0.01
Average	0.03	-0.06	0.00	0.00	0.00

The results of the sensitivity test indicate that in the vicinity of the development site the model is not particularly sensitive to the adopted roughness coefficients, the downstream boundary conditions or the adopted spill coefficients. This provides confidence in the model results.

3.5 Post-Development Modelling

Figure 3-5 overleaf shows the change in flood extent caused by the proposed development for the 1000-year flood event, where the revised baseline (see Appendix E, section 4.6) is shown in blue and the post-development extent in black.

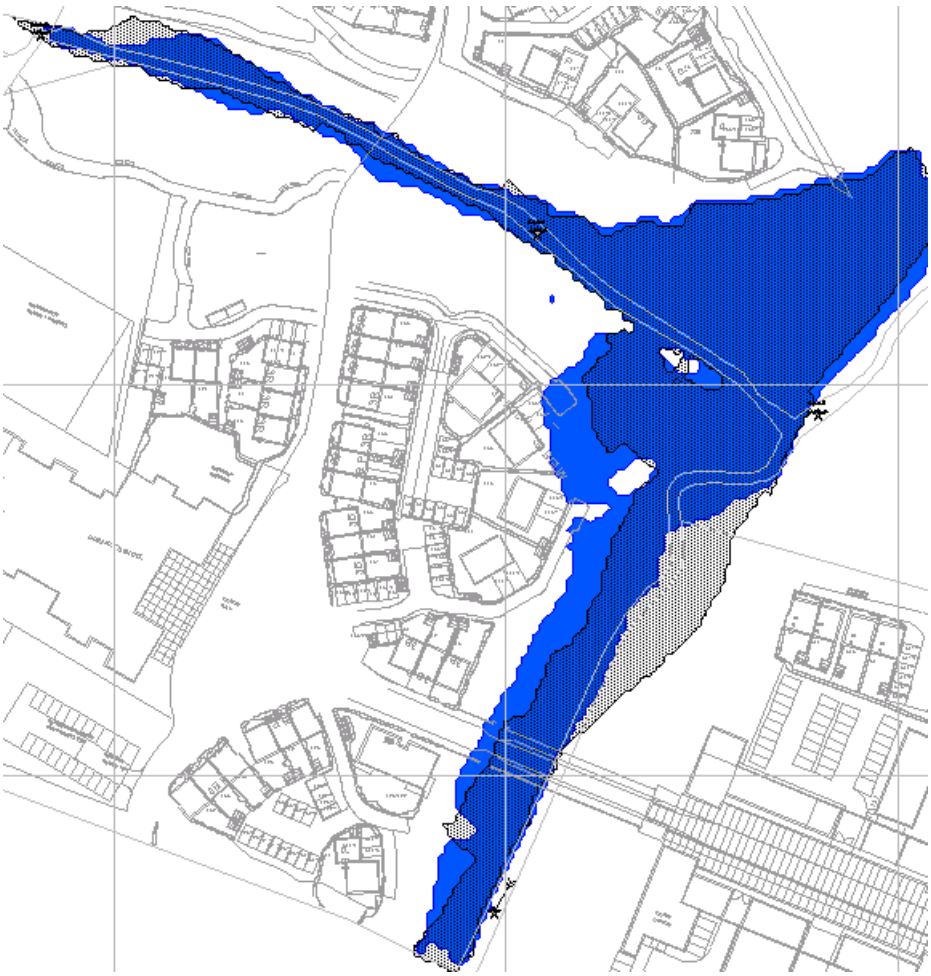


Figure 3-5 Post-development extent comparison

This shows that around the proposed bridge on the tributary, the contouring and bridge structure have little impact on the modelled flood extents. At the confluence with the River Bure, the re-contouring has reduced the flood extent on the western side of the confluence, removing the area of flooding that had impacted on gardens and roads in the proposed development. Downstream of this area, the landscaping associated with the second bridge has decreased the flood extent on the right bank of the River Bure and increased the flood extent on the left bank of the River Bure upstream of the bridge. This also does not threaten the proposed development.

A comparison of modelled flood levels through the development site has shown that modelled water levels through the reach are generally lower, with small increases of 40mm to 50mm immediately upstream of the downstream bridge (T2-0636). This indicates that the combination of this bridge and the re-profiling of the floodplain in this area has very little impact on modelled peak water levels.

A comparison of modelled velocities through the development reach has shown little to no increase in modelled velocities through the development reach, with a maximum increase in the 1000-year event of 0.09 m/s. Table 3-5 overleaf shows the changes in modelled velocities through the development reach.

Table 3-5 Post Development Modelled Velocities Summary – Development Reach

Label	100-year with Climate Change			1000-year		
	Baseline	Post Development	Difference	Baseline	Post Development	Difference
T2-0952	0.71	0.70	0.00	0.79	0.76	-0.03
T2-0902	0.92	0.98	0.07	0.96	1.00	0.04
T2-0887	0.51	0.53	0.02	0.52	0.56	0.04
T2-0887d	0.99	1.05	0.06	0.99	1.05	0.06
T2-0872	0.68	0.72	0.04	0.72	0.71	-0.01
T2-0827	0.51	0.55	0.03	0.52	0.56	0.04
T2-0777b	0.65	0.66	0.00	0.65	0.69	0.04
T2-0756a	0.30	0.30	0.00	0.30	0.31	0.02
T2-0756b	0.73	0.64	-0.09	0.73	0.82	0.09
T2-0686	0.76	0.31	-0.45	0.80	0.33	-0.48
T2-0656	0.67	0.65	-0.03	0.69	0.65	-0.04
T2-0636	0.67	0.64	-0.04	0.68	0.73	0.05
T2-0636d	1.00	1.02	0.02	1.00	1.02	0.02
T2-0611	0.90	0.91	0.01	1.03	1.03	0.01
T2-0462	1.28	1.28	0.00	1.28	1.28	0.00

The impact of the re-profiling of the floodplain on floodplain storage volumes has also been calculated using the baseline modelled flood water levels and ground surface models for the existing and post-development scenarios. Table 3-6 below shows the calculated flood storage volumes for various modelled flood events.

Table 3-6 Changes in Flood Storage Volumes

Flood Event	Existing Storage Volume	Post-Development Storage Volume	Difference
20-year	456	875	+419
100-year plus climate change	1118	1631	+513
1000-year	1838	2298	+460

These results show that the re-profiling increases the available flood storage volumes in the river corridor.

The proposed development causes no significant change in flood extents, levels or velocities downstream of the development site.

All proposed development has been located within Flood Zone 1, as is required for an Eco-Town under PPS1, and therefore the development is considered to be at **low** risk of flooding from fluvial sources.

3.6 Assumptions and Limitations

3.6.1 General

The hydraulic model has been constructed using the best available data, and from a range of sources. Whilst some checks have been made to confirm the suitability of the data, Hyder Consulting cannot be held responsible for errors in third party works.

The model is considered to be a best representation of reality within the current constraints of modelling; accuracy is inherently related to the quality and extent of data available.

3.6.2 Hydrology

There is insufficient hydrometric data available to enable validation or calibration of the model. Therefore, there is a degree of uncertainty associated with the fluvial flow estimates used in this modelling study.

4 DRAINAGE STRATEGY

The surface water drainage strategy for the Exemplar development site is described in the Exemplar Site Drainage Strategy report (7501-UA001881-UP21R). The drainage strategy aims to demonstrate that the site will not increase flood risk within the site as well as at other locations as the post-development runoff rates are maintained at the Greenfield rates. The drainage strategy outlines the provision of a surface water drainage system which includes SUDS measures and attenuation storage within the site. This strategy will be used to inform the final detailed design of the drainage systems and surface water storage areas within the site.

4.1 Greenfield Runoff Rate

The Greenfield runoff rate was calculated for the site based on the Institute of Hydrology 124 method, as recommended by the Environment Agency/DEFRA guidance document: Preliminary Rainfall Runoff Management for Developments. The resultant runoff rates are outlined in Table 4-1 below.

Table 4-1 Greenfield Runoff Rate Estimation

Return Period	Greenfield Runoff	
	(l/s/ha)	(l/s)
Mean Annual Flood	2.29	40.1
1 in 30 year	5.12	89.6
1 in 100 year	7.29	127.6

4.2 Required Storage Volumes

The Exemplar development site has been divided into a number of catchments. Each catchment will contain a linked series of SuDS features for storage and discharge of runoff generated within the catchments. Each will discharge by ground infiltration where feasible. Should it not be feasible to entirely discharge the runoff from a catchment by ground infiltration then the SuDS would discharge at controlled rates to SuDS features in an adjacent catchment for infiltration, or via controlled discharge to the watercourses running through the site. The drainage strategy plans are shown in Appendix F (taken from the drainage strategy report). A large proportion of the site would discharge via ground infiltration, and therefore an allowance has been made within each group of SuDS features for runoff from such areas. A summary of storage volumes for each catchment is shown in Table 4-2.

Table 4-2 Storage Volumes

Catchment	SuDS Type	Storage Volume (m^3)
1	Dry swale, swale, pond, basin	250
2	Swale, pond, basin	245
3	Roadside swale	120
4	Swale, pond, basin	190
5	Site edge swale	165
6	Basin, pond	0 - 590[1]
7	Pond, wetland scrape	135
8	Wetland scrapes, online storage	175
9	Roadside swales, Village Street SuDS, wetland scrape, online storage	415

1. Regional control with limited direct paved area catchment, size will vary depending on flow passed forward from other SuDS features

4.3 Designing for Exceedance

It is not economically viable or sustainable to build a drainage system that can accommodate the most extreme events. Consequently, the capacity of the drainage system may be exceeded on rare occasions have a probability of occurrence of less than once every 100 years, with excess water flowing above ground. The design of the site layout provides an opportunity to manage this exceedance flow, using appropriate flow paths to direct water to watercourses and ensure that indiscriminate flooding of property does not occur.

5 CONCLUSIONS

5.1 Conclusions

The flood risk for the proposed development of NW Bicester eco development has been assessed in accordance with PPS25: Development and Flood Risk.

Hydraulic modelling has been undertaken to delineate the floodplain across the site and ensure that the development will not lead to an increase in flood risk elsewhere. The hydraulic modelling confirms that the areas where development is proposed within the eco development are located in areas of **low** risk of fluvial flooding.

The flood risk to the site is considered to be at **low** from fluvial, tidal, ground and surface water sources. The flood risk from artificial sources is also considered to be **low** as there are no sources within or upstream of the site.

The surface water drainage strategy has demonstrated that an appropriate drainage design can achieve the current Greenfield runoff rates or less.

Based on this assessment, it is therefore concluded that the proposed development can be undertaken in a sustainable manner without increasing the flood risk either at the site or to any other sites.

5.2 Recommendations

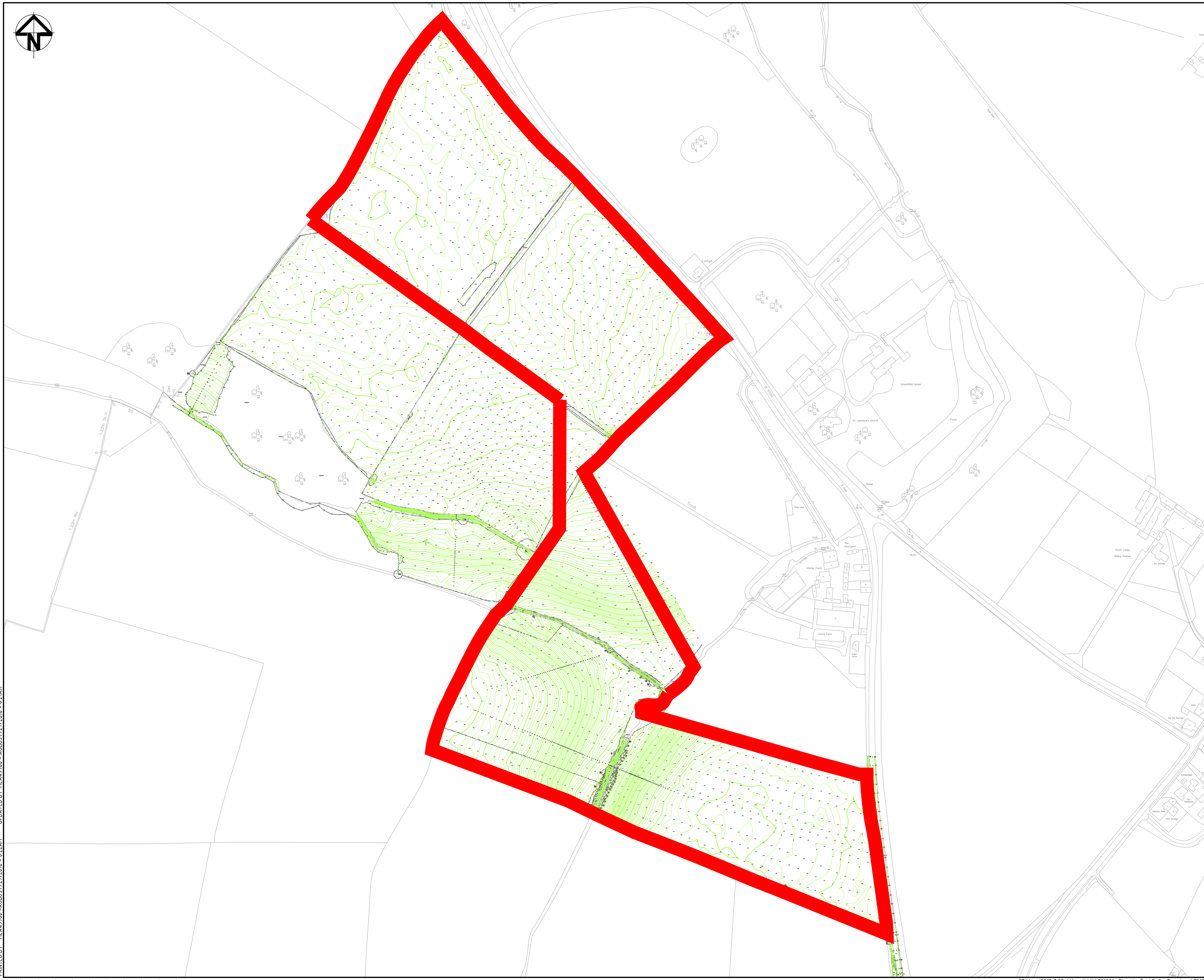
1 The recommendations outlined in the Drainage Strategy report should be adhered to.

2 Any changes in development layout will be subject to additional review.

3 Design of landscaping and storage should be undertaken in such a way to avoid potential for inundation of buildings and evacuation routes, especially during exceedance events.

Appendix A

Topographical Survey



KEY

PHASE 1 EXEMPLAR BOUNDARY

Issue	Description	Date
02	REVISED EXEMPLAR BOUNDARY	27/08/10
01	FIRST ISSUE	06/08/10

Status

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Original Size	A1	Checker M.PEARSON	
Height Datum	-	Approver S.A. DAVIES	
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Project

BICESTER
ECO TOWN

Title

EXEMPLAR AREA

Drawing No.	Project No.	Issue
7013 —	UA001881 —	02

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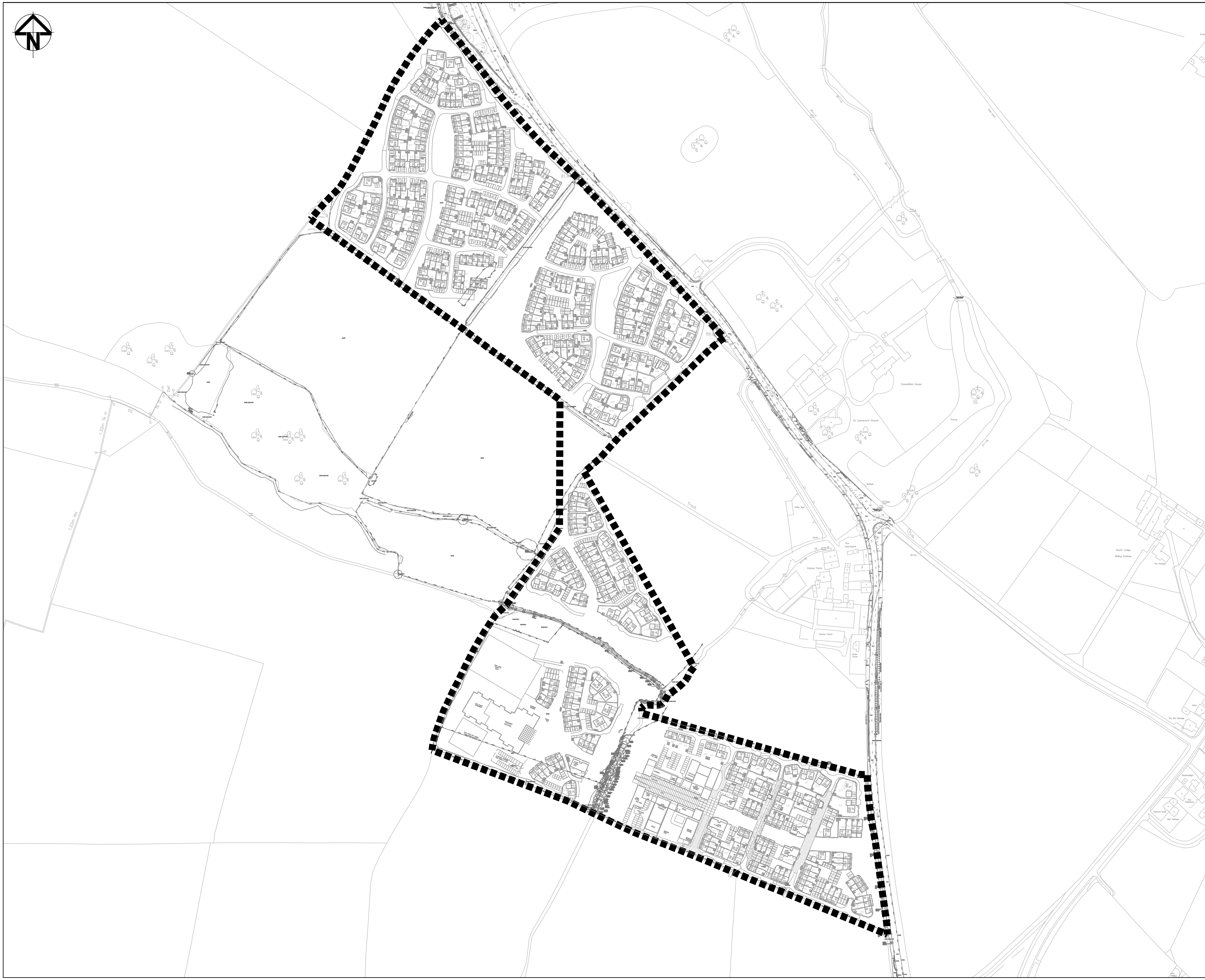
V1

Appendix B

Site Layout



KEY

EXEMPLAR SITE BOUNDARY

NOTE:

HOUSING LAYOUT IS ILLUSTRATIVE ONLY

Issue	Description	Date
07	MASTERPLAN UPDATED	22/06/11
06	MINOR REVISIONS	24/11/10

Status

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Project

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Title

EXEMPLAR AREA

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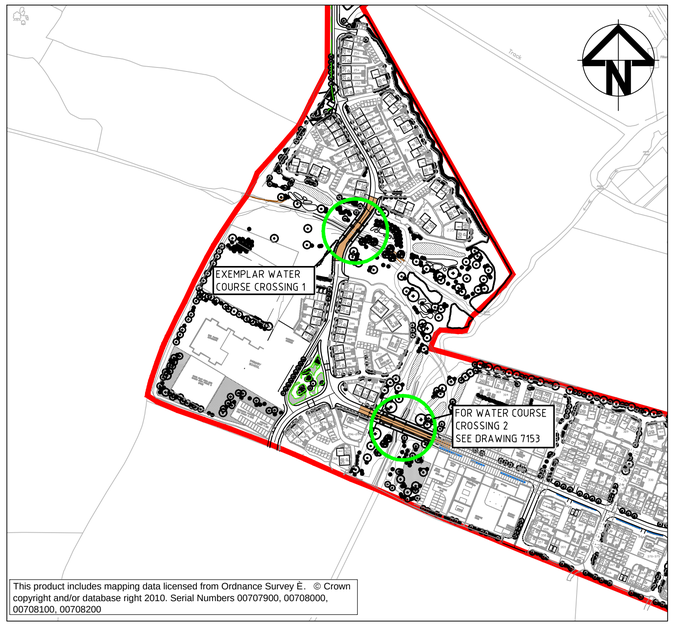
7013	—	UA001881	—	06



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LOCATION PLAN
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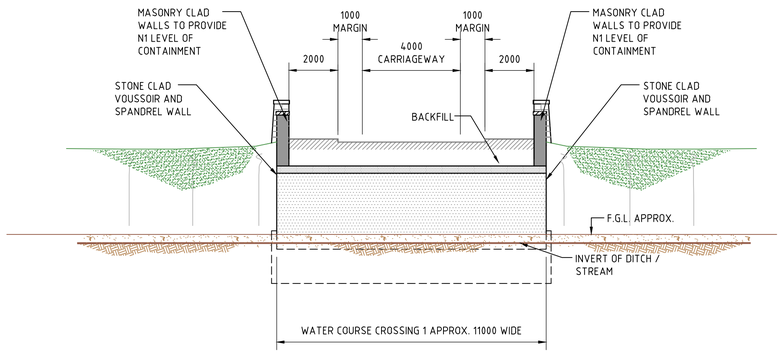

SECTION A-A
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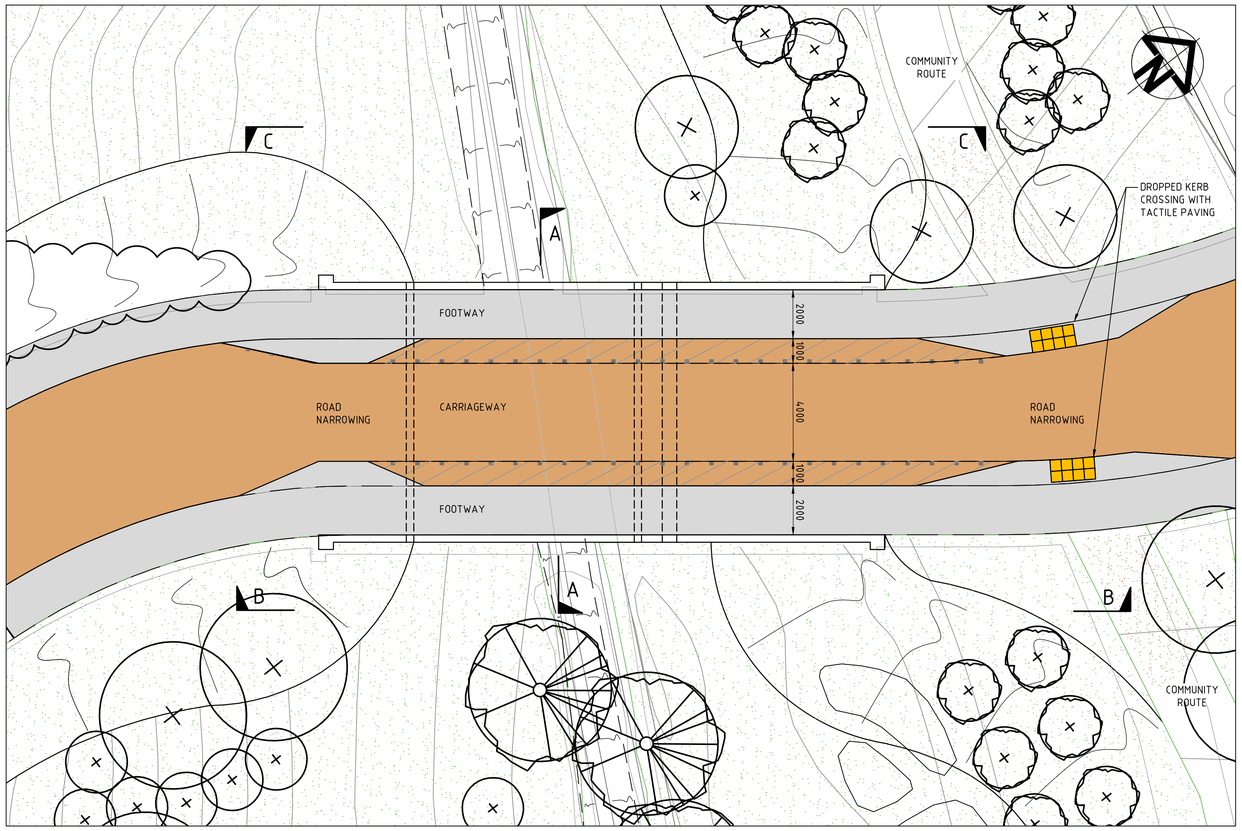

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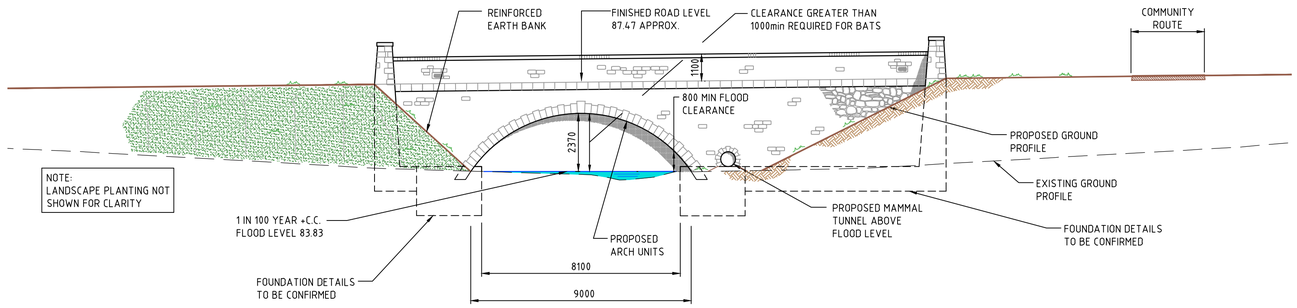

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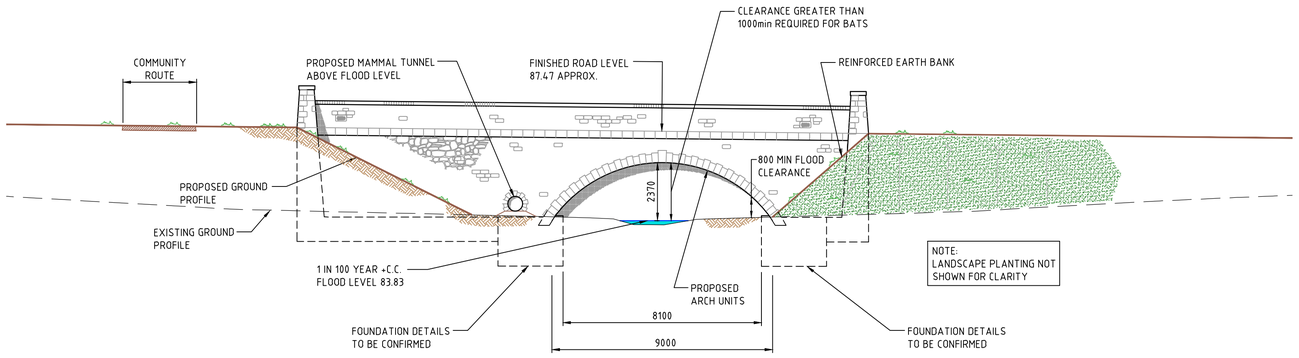

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KEY

PLANNING APPLICATION BOUNDARY

Issue	Description	Date
02	GENERAL REVISIONS	21/06/11
01	FIRST ISSUE	16/05/11

Status

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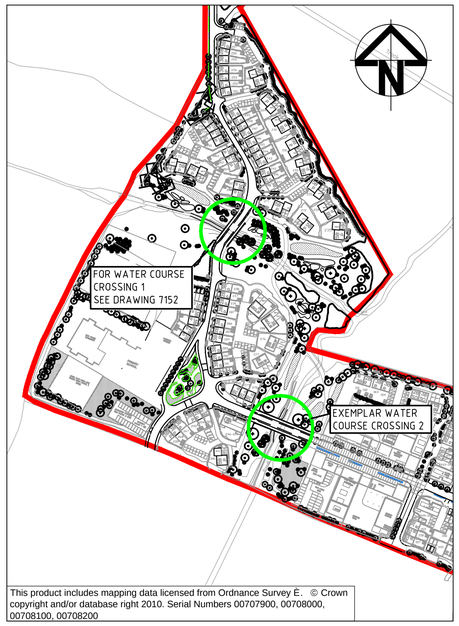
Project

BICESTER
ECO DEVELOPMENT

Title

EXEMPLAR SITE
WATER COURSE CROSSING 1
GENERAL ARRANGEMENT

Drawing No.	Project No.	Issue
7152	UA001881	02



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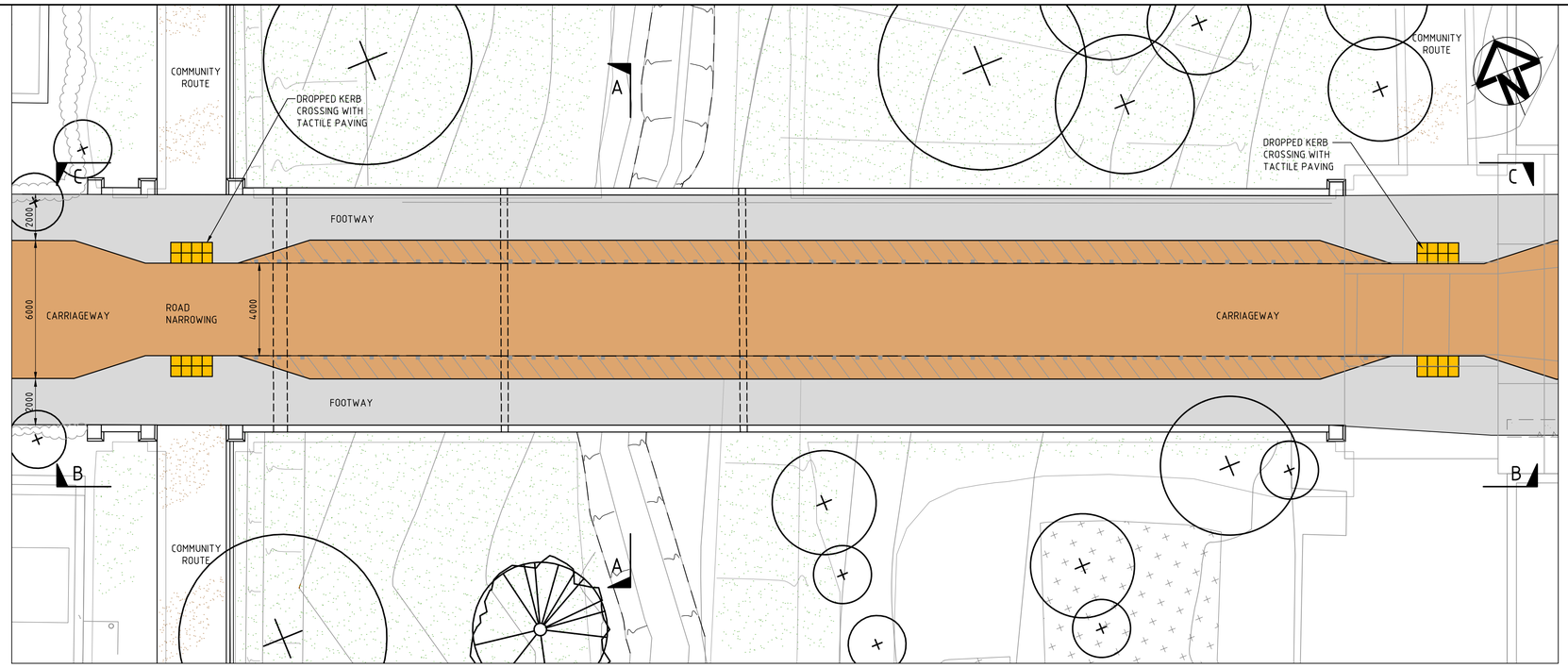

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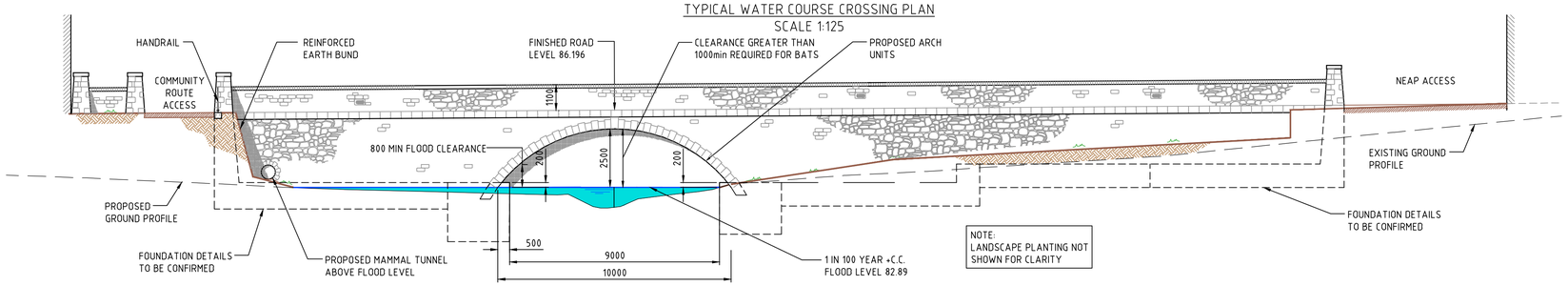

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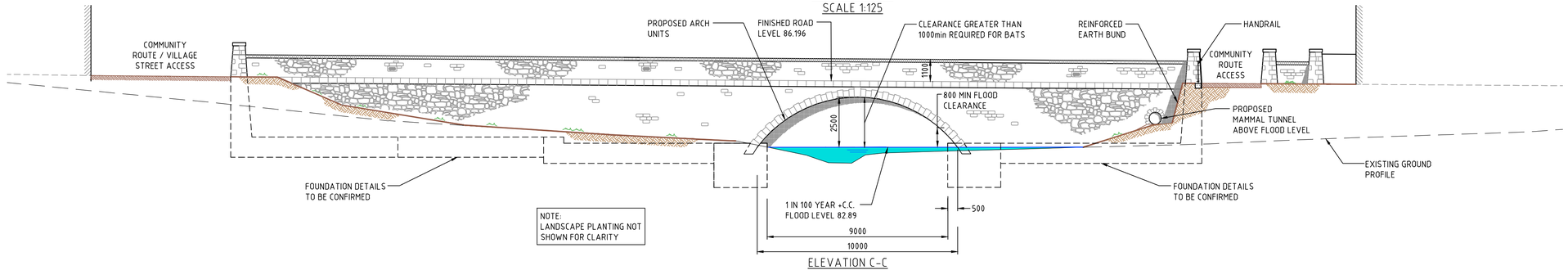

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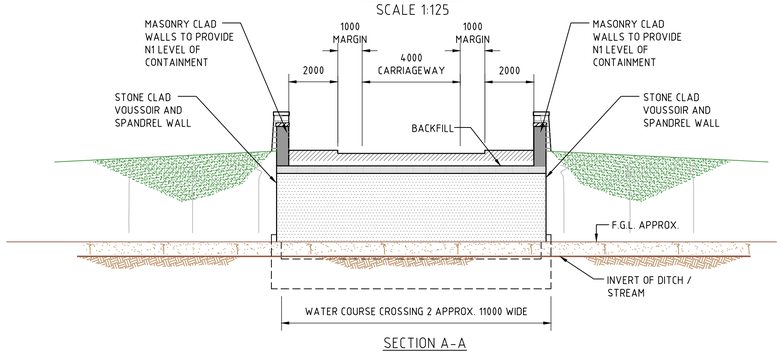

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PLANNING APPLICATION BOUNDARY

Issue	Description	Date
04	GENERAL REVISIONS	21/06/11
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Project

BICESTER
ECO DEVELOPMENT

Title

EXEMPLAR SITE
WATER COURSE CROSSING 2
GENERAL ARRANGEMENT

Drawing No.	Project No.	Issue
7153	UA001881	04

Appendix C

Geotechnical Investigation

KEY

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- MESSERS WILLIAM & TIMOTHY MALINS
- GALLAGHER ESTATES LTD
- MR & MRS BARNES
- OXFORDSHIRE COUNTY COUNCIL
- MR MARK GAMMOND
- MR & MRS RICKETTS
- AVONBURY BUSINESS PARK
- TVPA
- MR BONNER
- MR & MRS MURFITT
- MRS MARIA INES ASTORGA DE PAIN
- MS HENSON
- HON MICHAEL RICHARDS

ACCESS ROUTES TO LOCATIONS

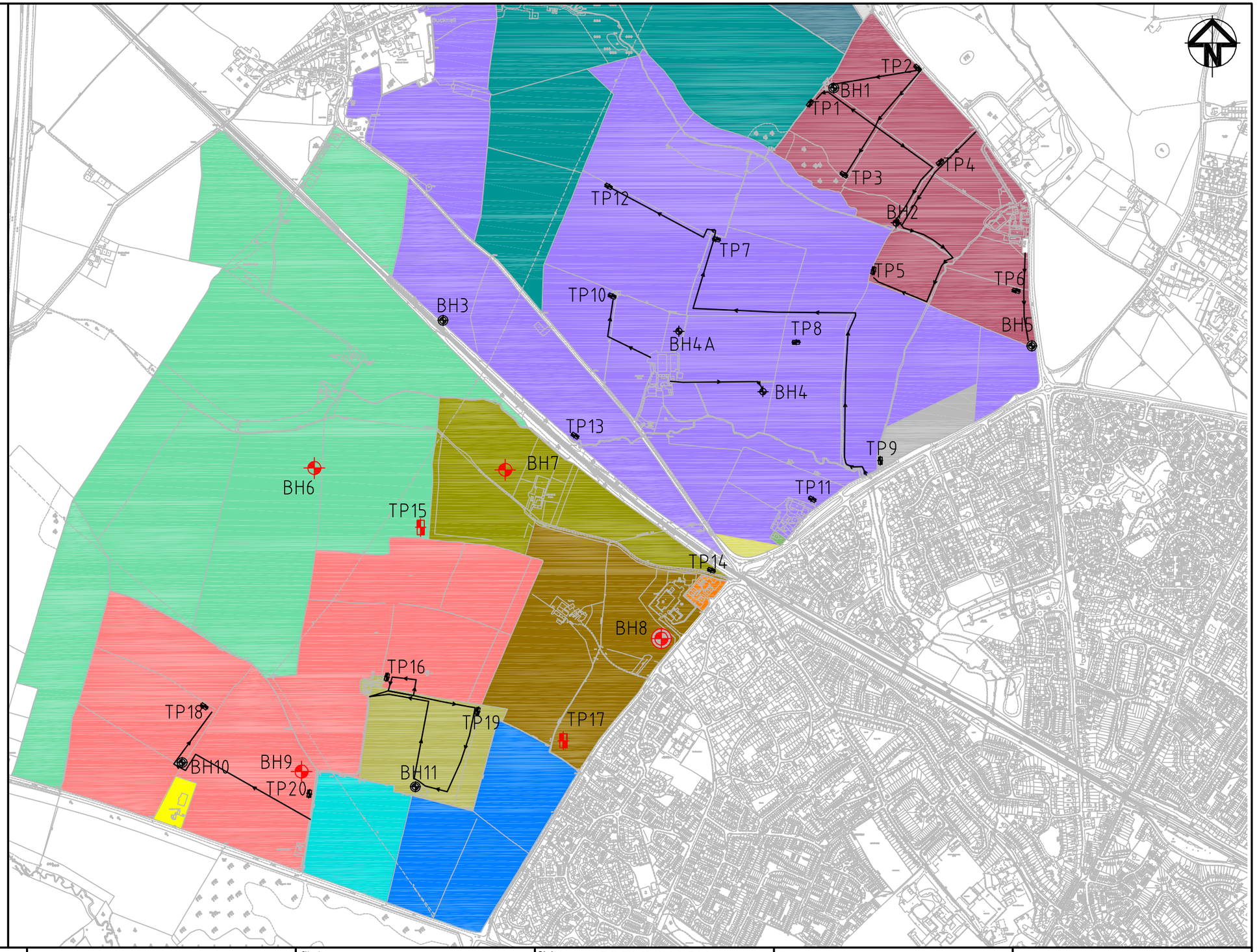
PROPOSED EXPLORATORY HOLES NOT COMPLETED DUE TO ACCESS RESTRICTIONS

BH4 ROTARY BOREHOLE - ALL CORED TO 7.0m

TP1 TRIAL PIT

BH4 ROTARY BOREHOLE - ALL CORED TO 7.0m

TP8, BH4A AND BH4 ARE APPROXIMATE LOCATIONS ONLY ALL OTHER LOCATIONS RECORDED USING GPS.



Issue	Description	Date
02	EXPLORATORY LOCATION REVISED	16/08/10
01	FIRST ISSUE	22/07/10

Client

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Original Size	A3	Checker D.THOMAS	
Height Datum	-	Approver C.PLUMB	
Grid	GRID	© Copyright reserved	

Project: BICESTER ECO TOWN

Title: LANDOWNER BOUNDARIES WITH EXPLORATORY HOLE LOCATIONS

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Drawing No.	Project No.	Issue
2003	UA001881	02

2003-UA001881-UP33D-02-LANDOWNER BOUNDARIES WITH EXPLORATORY HOLE LOCATIONS.DWG

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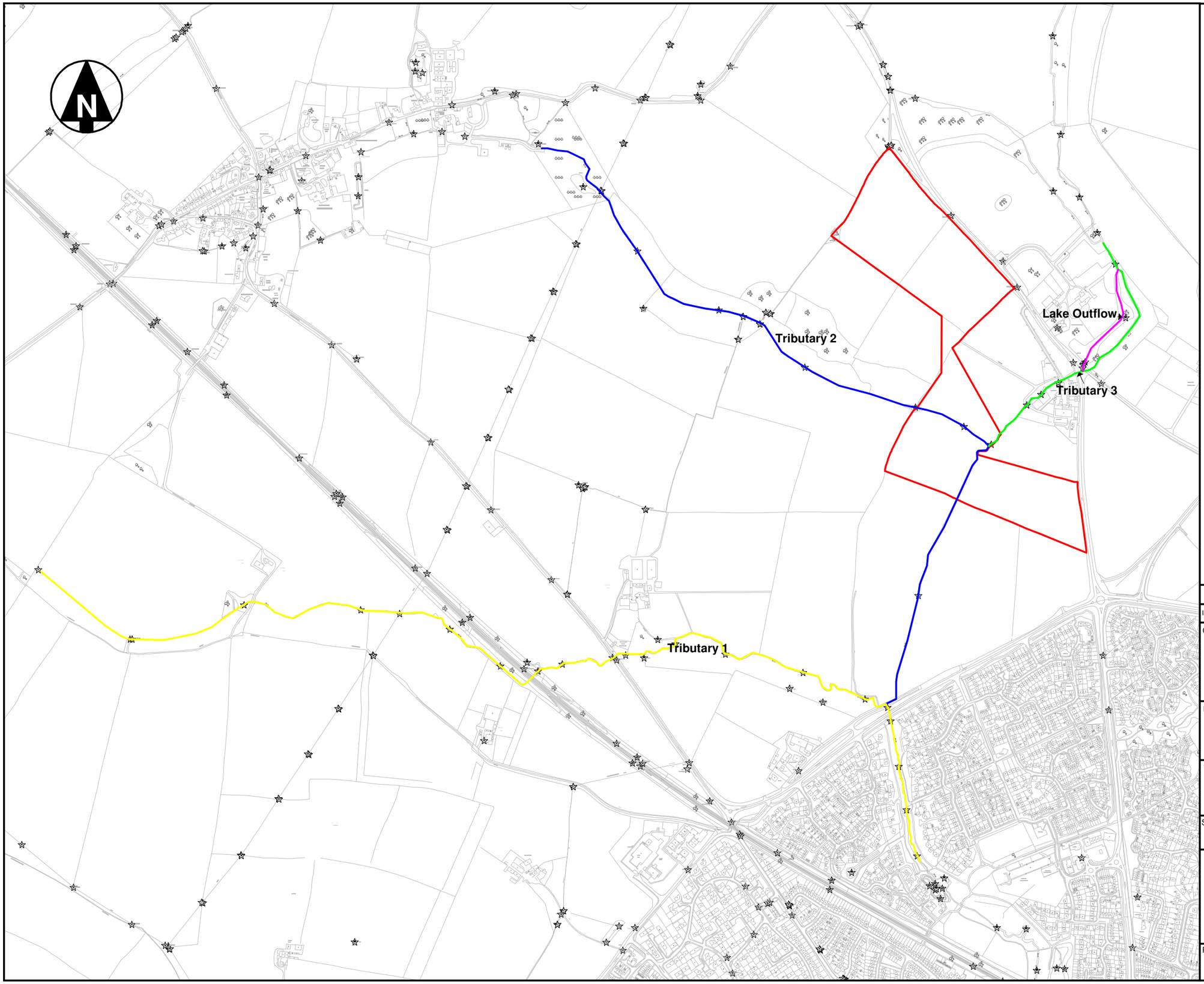
Appendix D

Model Schematics



Issue	Description	Auth.	Ckd.	Appd.	Date
1	First Issue	SB	BS	BS	

Client

azdominion

P3Eco Ltd

Project

NW Bicester Eco Development

Title

Modelled Watercourses

Scale (A3)	Datum
1:5000	Newlyn

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Project Code	Drawing No.	Issue
UA001881	D1	1

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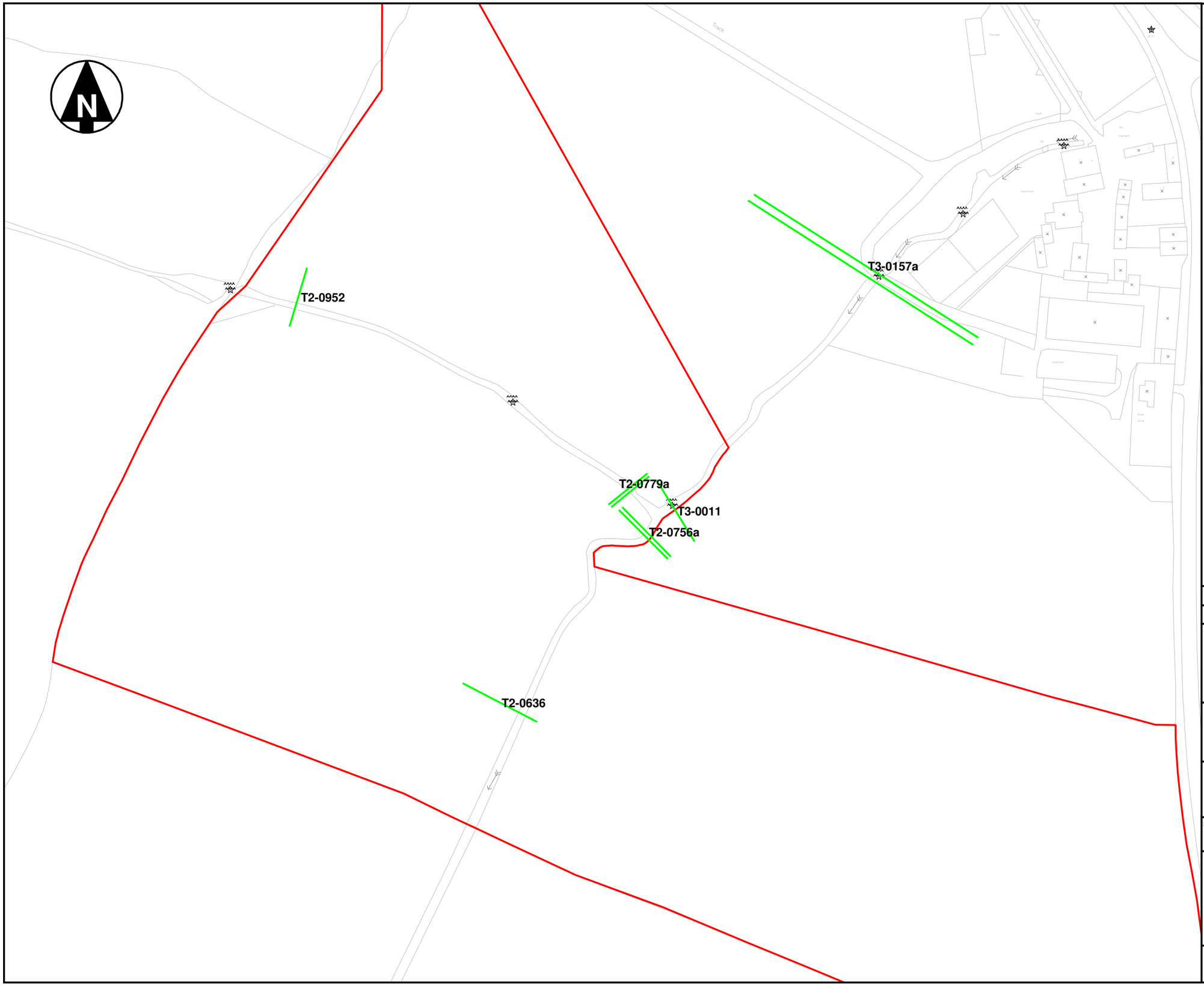

Issue	Description	Auth.	Ckd.	Appd.	Date
1	First Issue	SB	BS	BS	

Client

a2dominion

P3Eco Ltd

Project

NW Bicester Eco Development

Title

Model Section Locations

Scale (A3)	Datum
1:5000	Newlyn

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Project Code	Drawing No.	Issue
UA001881	D2	1

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Appendix E

Hydraulic Modelling Report

P3Eco (Bicester) Ltd and A2Dominion Group

NW Bicester Eco Development

Exemplar Site - Hydraulic Modelling Report

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P3Eco (Bicester) Ltd and A2Dominion Group

NW Bicester Eco Development

Exemplar Site - Hydraulic Modelling Report

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Checker	Leanne Roach	
Approver	Philip Harker	

Report No	3502-UA001881-UU41R-03
Date	June 2011

This report has been prepared for A2Dominion Group and P3Eco (Bicester) Ltd in accordance with the terms and conditions of appointment for NW Bicester Eco Development FRA. Hyder Consulting (UK) Limited (2212959) cannot accept any responsibility for any use of or reliance on the contents of this report by any third party.

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Appendices

Appendix A

Model Results

Appendix B

Drawings

1 INTRODUCTION

1.1 Project Appointment

Hyder Consulting (UK) Limited (HCL) were appointed by A2Dominion Group and P3Eco (Bicester) Ltd to undertake a Flood Risk Assessment (FRA) for the proposed NW Bicester eco development. This FRA required hydraulic modelling of the River Bure and tributaries to determine the baseline flood risk on the property, and model any necessary mitigation works.

1.2 Background to the Study

A2 Dominion Group and P3Eco Ltd intend to construct a residential development to the northwest of Bicester. The NW Bicester eco development will comprise approximately 5,000 homes, secondary school, a number of primary schools, retail and commercial space along with health care and other community facilities. Approximately 40% of the overall site will be green open space, including playing fields, semi private and public open space. The first phase of the eco development will be an Exemplar for future development, which will comprise approximately 393 homes, land for a primary school, a nursery, and areas of commercial and retail property.

The River Bure and two of its tributaries run through the centre of the proposed development. This area is upstream of the extent of the Environment Agency's River Bure hydraulic model, and therefore detailed flood extents have not been produced for the site. The tributaries of the River Bure in this area have not been included in the EA's Flood Zone Maps. Therefore the flood risk to the site has not been fully quantified. Hydraulic modelling of the watercourse was necessary to fully determine the flood risk to the site.

This report outlines the flood risk for the Exemplar Site development only. The remainder of the NW Bicester eco development site will be covered in a separate FRA.

1.3 Aims and Objectives

This study will:

- Estimate design flows for the River Bure and its tributaries for the 20-year, 100-year, 100-year (plus climate change) and 1000-year events;
- Construct a hydraulic model of the River Bure and tributaries and use it to define the baseline flood risk to the site for the design events; and
- Identify and undertake any mitigation modelling necessary to ensure that the development site is protected from flood risk while maintaining the existing hydraulic regime downstream of the development site.

2 STUDY AREA CHARACTERISTICS

2.1 Location

The study area is located on the north-western edge of Bicester, near Caversfield House off the B4100. Figure 1 below shows the location of the proposed development site (marked in red) within the River Bure catchment (outlined in green).

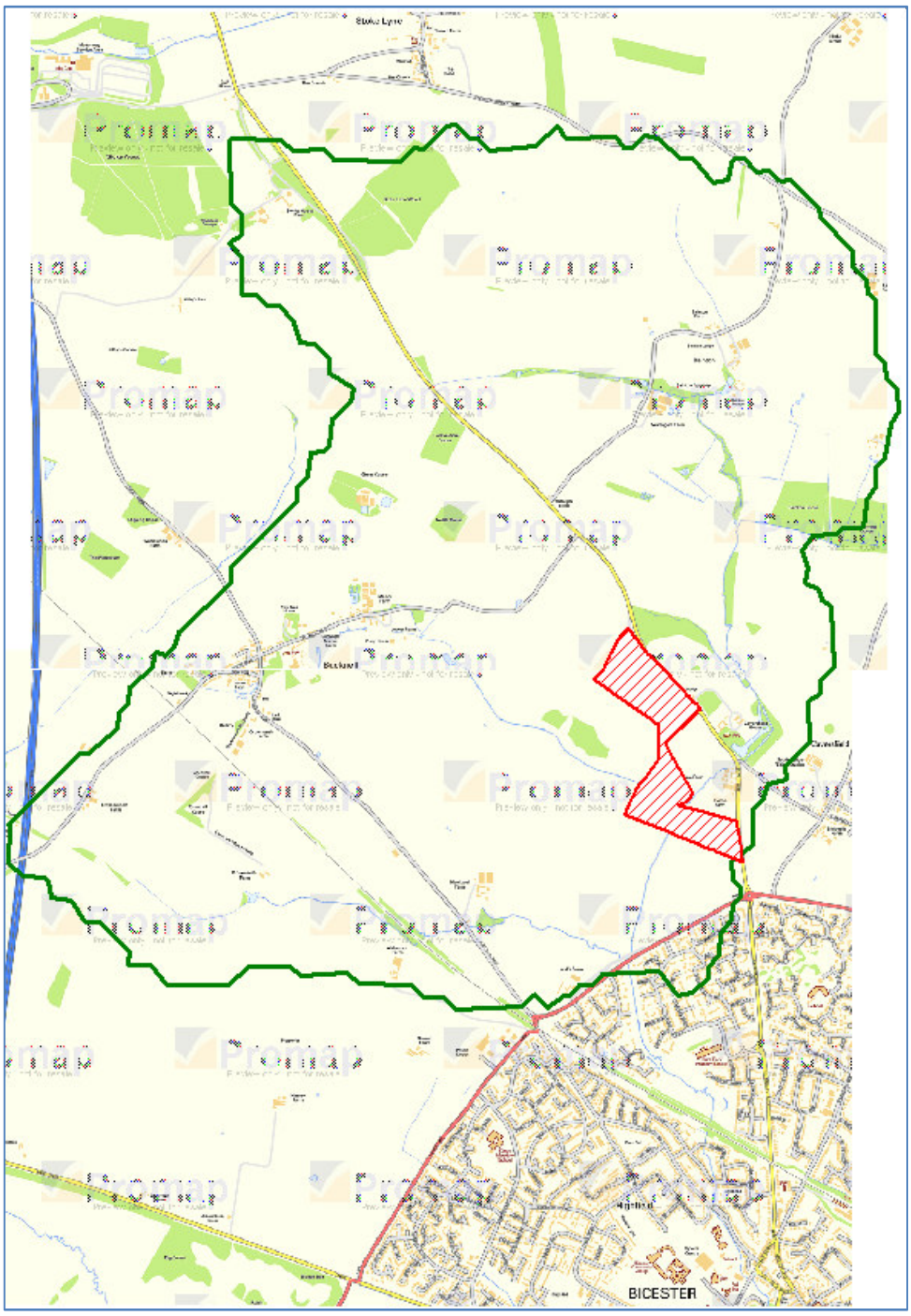

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Figure 1 – Site Location Plan

2.2 Catchment

The River Bure and tributaries drain an area of approximately 10.5 km² (calculated to the A4095) which is predominantly rural. The development site is located towards the downstream end of the catchment. FEH catchment descriptors show that the catchment is permeable. Further detail is provided within the hydrology discussion in Section 3.

2.3 Watercourse

The Bure flows in a southerly direction from Caversfield House to a culvert beneath the A4095. Downstream from this it flows in an open channel between Lucerine Avenue and Purslane Drive. There is a tributary flowing in an easterly direction from Bucknell which converges with the Bure downstream of Home Farm, and another tributary which flows in an easterly direction from Crowmarsh Farm and converges with the Bure at the A4095 culvert.

2.4 Historical Flooding

There are no historical records of flooding within or around the site from either the EA or the SFRA.

2.5 Modelling History

Hydraulic modelling of the River Bure has been undertaken for the Environment Agency. However, the River Bure model does not extent far enough upstream to cover the proposed development site.