B411 Land at Teversham Road, Fulbourn, Cambridgeshire
Flood Risk and Surface Water Management Update
January 2017
For Castlefield International Ltd

Introduction

This note and accompanying information has been prepared to support an outline planning application for a proposed residential development on land to the east of Teversham Road, Fulbourn, Cambridgeshire.

The note provides a summary of the recent planning history for the site with regards to flooding and surface water management. The note also presents an updated surface water management strategy which includes the most recent allowance for climate change 40 %.

The 2017 application follows an outline application which was previously refused, and which was subsequently unsuccessful at appeal. The planning application was submitted in 2014 under South Cambridgeshire District Council (SCDC) reference S/2273/14/OL. No flood risk related grounds for refusal were raised, and positive consultation responses were received from both the Environment Agency (EA) and the SCDC drainage officer (Mr Pat Matthews). It is worth noting that whilst the planning appeal was unsuccessful (reference APP/W0530/W/15/339730), no deficiencies on flood risk and surface water management matters were identified by the Planning Inspector.

The 2017 application replicates the previous application in that it is an outline application for the same housing numbers with the same illustrative plot layout. It is therefore appropriate that the flood risk and surface water management pack which supports the 2017 application comprises the 2014 Flood Risk Assessment (reference CCE/B411/FRA-03) and the additional information (summarised below) appended to this note.

Additional available information

As part of the planning appeal process, in order to provide robust responses to any concerns about flood risk (of which there were none raised by the Planning Inspector), two flood risk related investigations were commissioned/progressed, namely:

- Continued groundwater level monitoring at the site (a total of twelve monitoring visits were carried out); and
- A site specific flood model undertaken by H R Wallingford.

Forms of Flooding

Appended to this report are a number of updated flood maps (Figures 1 to 4) which demonstrate that the assertions and discussion in Section 2 of the 2014 FRA ("Forms of Flooding") are still relevant to the site and the illustrative proposals.

As noted in the FRA, the most notable flood risk to the site is from inundation as a result of surface water flooding as a result of overland flow from the land to the south. As discussed in the Flood Management section of the FRA (pages 6 and 7), the illustrative layout has been planned around the need to maintain space for the surface water floodwater to flow into, and through the site to avoid diverting the floodwater elsewhere. The key flood management measures involve the creation of development platforms (in the order of 500 mm above existing site levels) around a central flood management area.

The purpose of the H R Wallingford flood model was two-fold. Firstly to establish a site specific flood outline/extent at the site, and secondly to check that the proposed flood management measures would be effective in managing flood risk. In the case of the latter more critical purpose of the flood model, the report concluded that the proposed flood management would indeed avoid increasing off-site flood risk.

Surface water management

The surface water management scheme presented in the FRA comprises shallow bio-retention areas/attenuation basins which discharge to the central Award Drain running through the site. Flows would be conveyed to the bio-retention areas/attenuation basins via permeable paving and planted rills. There is also the option to include grassed filter drains alongside the roads in order to provide additional treatment of road runoff.

The appended revised surface water management scheme and calculations include two main alterations/updates to the 2014 strategy:

- The surface water management scheme presented in the FRA includes a 30 % increase in rainfall in order to account for the potential result of climate change. The calculations have been revised to include the new requisite 40 % allowance for climate change introduced in 2016.
- The area of the bio-retention area/attenuation basin in the south-east of the site has been reduced in order to avoid disturbing/removing an area of potentially interesting vegetation. The reduction in basin volume has been offset with the inclusion of some shallow storage crates beneath the permeable paving in the adjacent development parcel.

Appended information

Figures

2014 Flood Risk Assessment, CCE/B411/FRA-03

2016 H R Wallingford flood modelling report, MAM7720-RT001-R02-00

Revised surface water calculations (with 40 % allowance for climate change)

Updated surface water management strategy B411-004-Rev A

2016 Geosphere groundwater monitoring report

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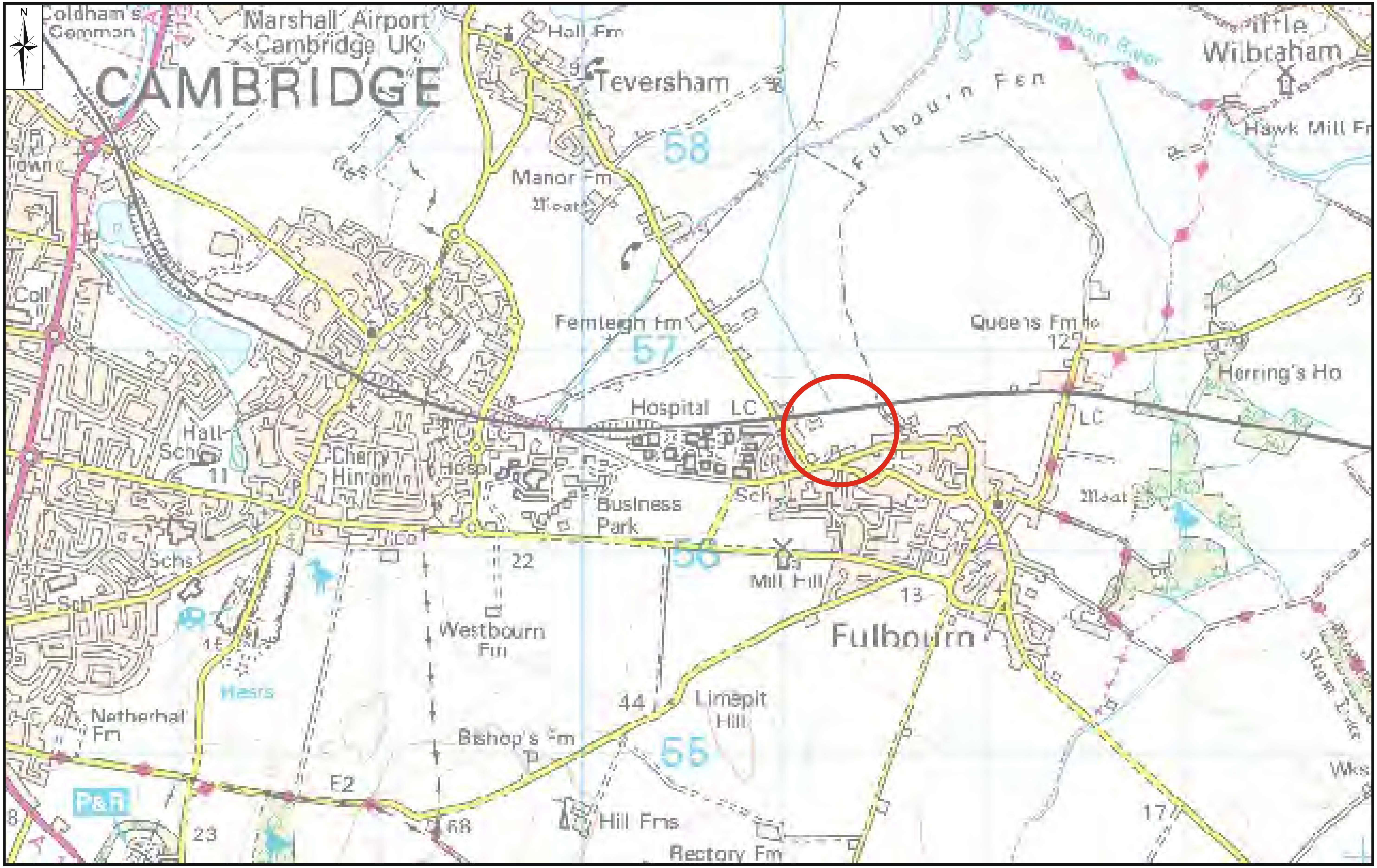
Figures



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Date: 09/01/2017	Report: FLOOD RISK ASSESSMENT		Tel: 01638 555107		Figure No: FIGURE 1
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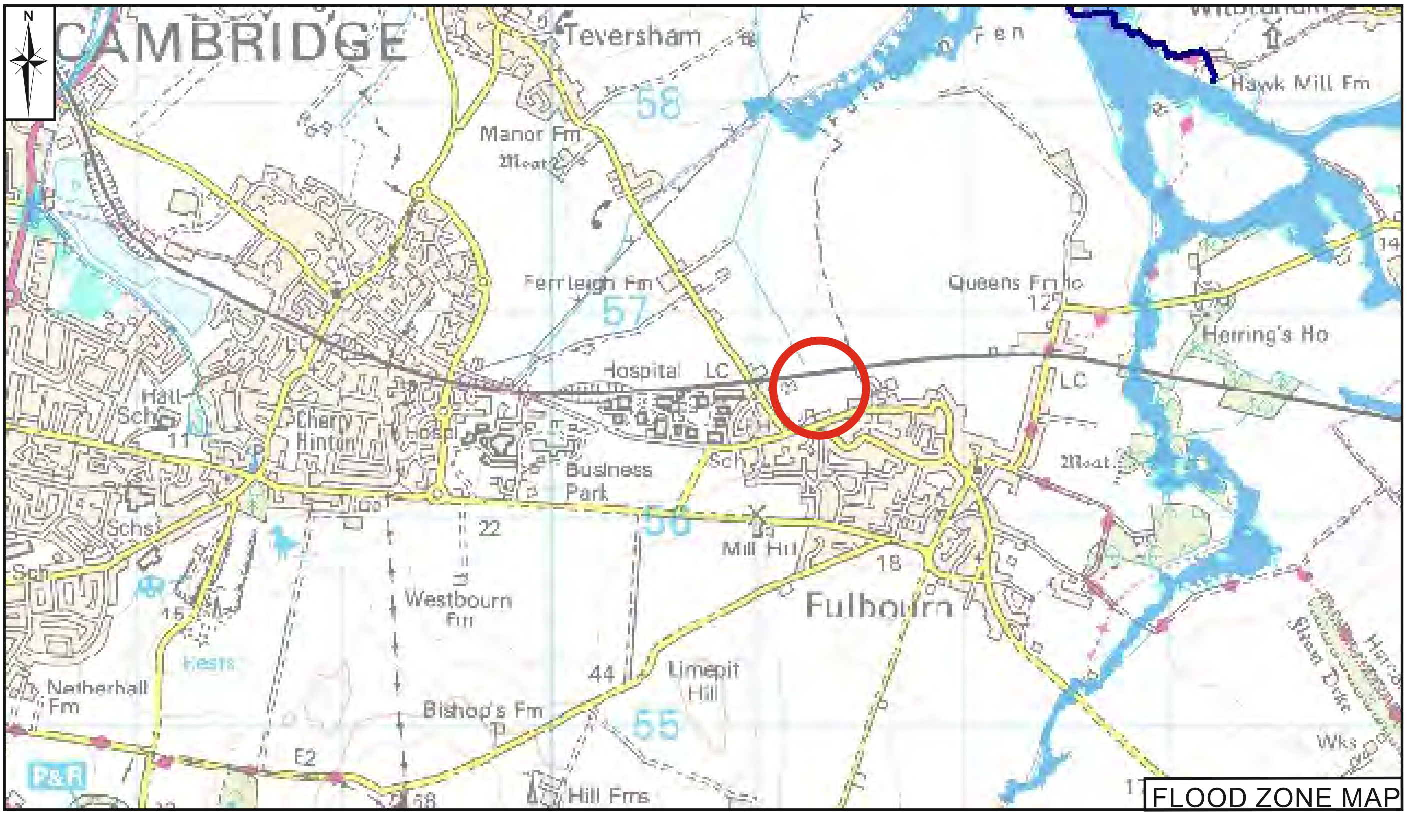
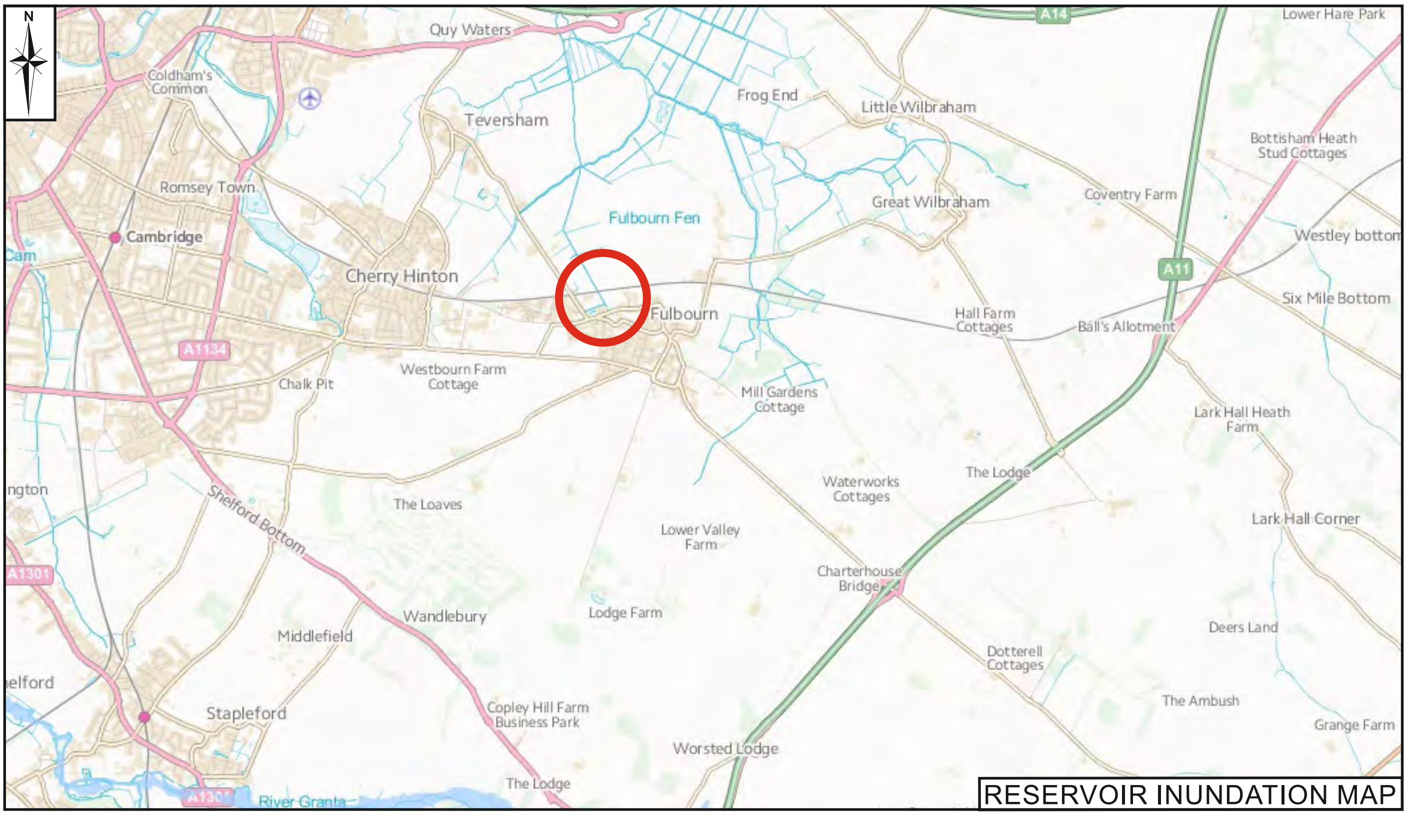


FLOOD ZONE MAP



RESERVOIR INUNDATION MAP

KEY

- SITE
- FLOOD ZONE 3
- FLOOD ZONE 2
- AREAS BENEFITING FROM FLOOD DEFENCES
- MAIN RIVERS
- EXTENT OF RESERVOIR FLOODING

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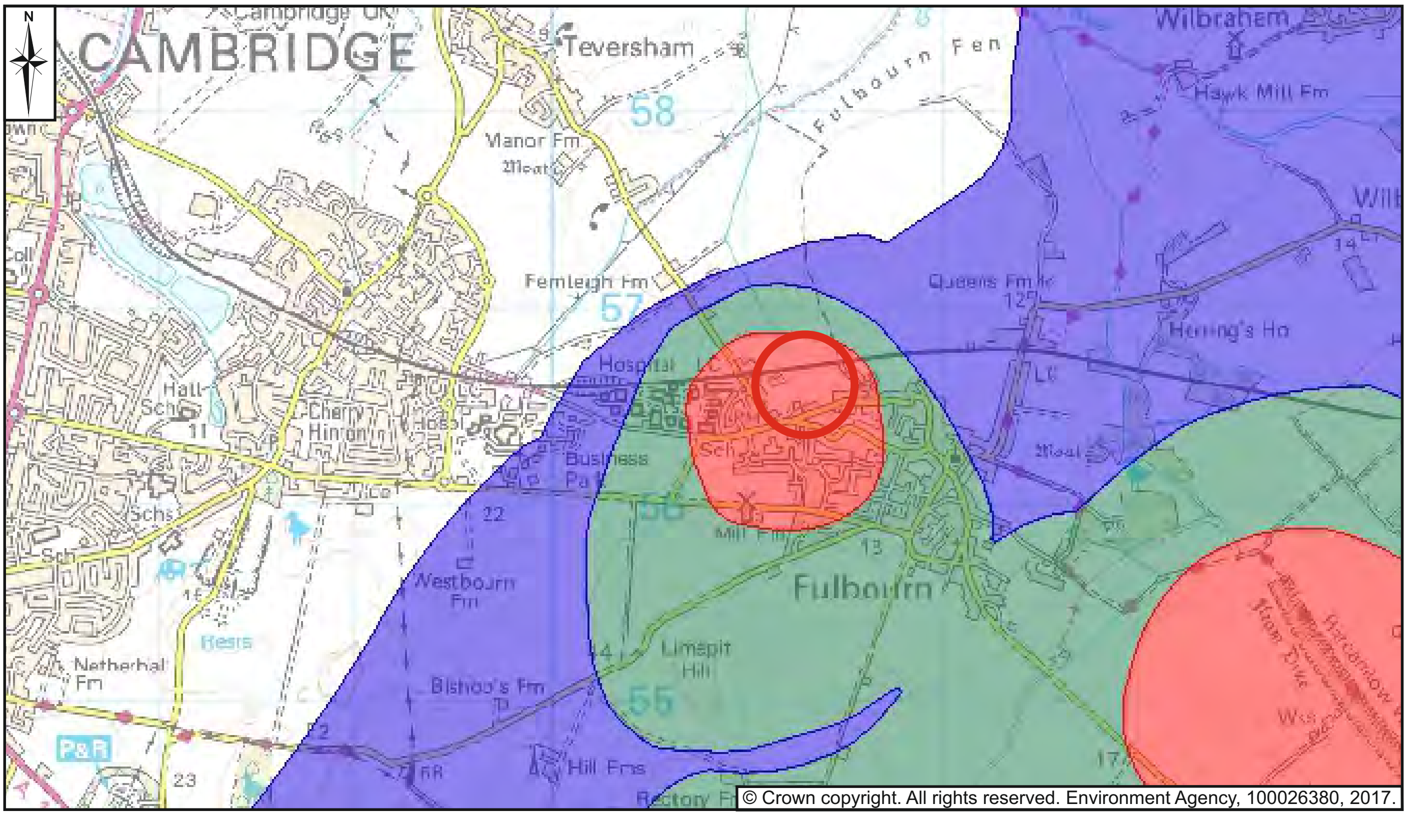
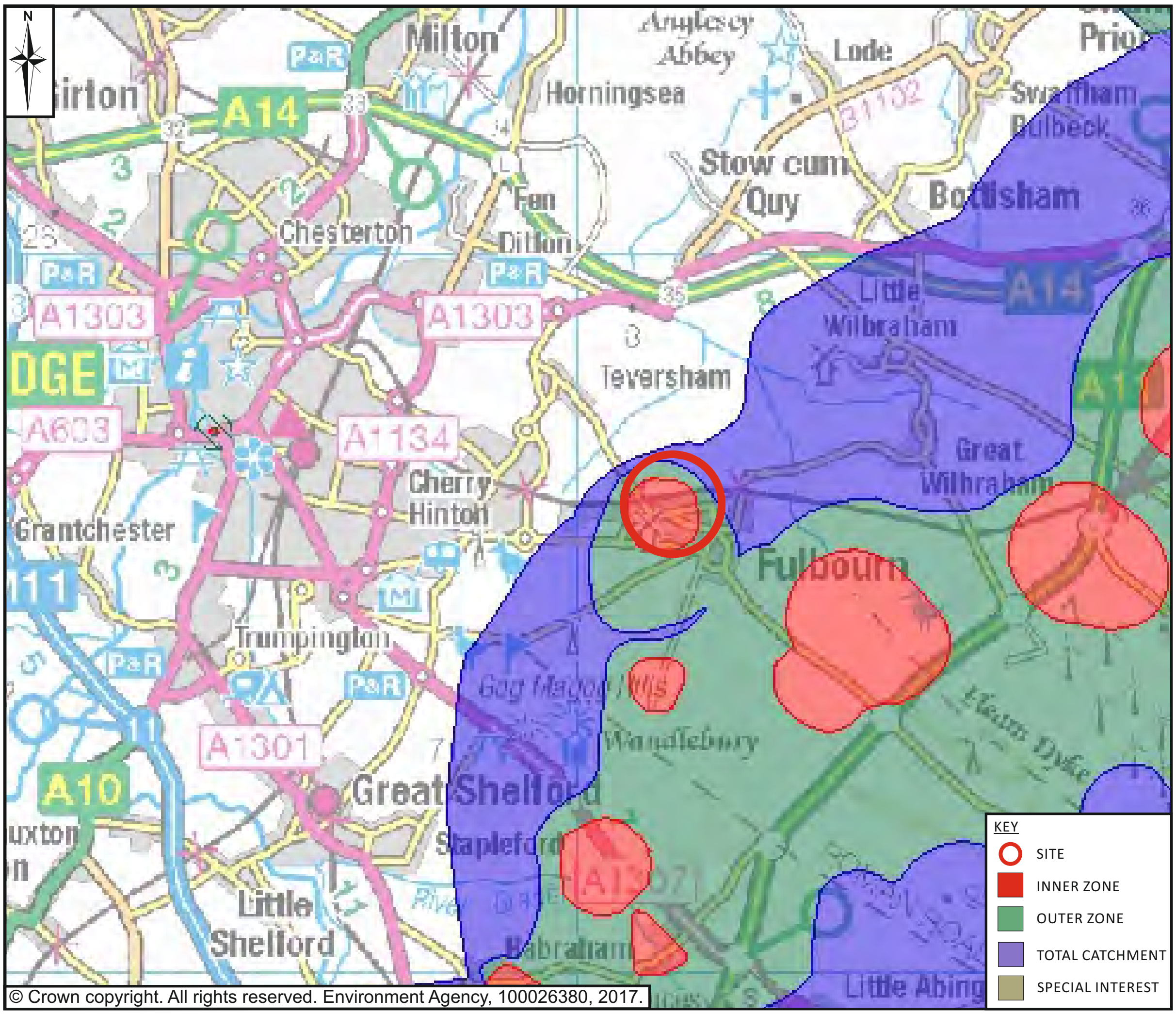
Drawn By: DP	Report: FLOOD RISK ASSESSMENT				Figure No: FIGURE 2





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Date: 09/01/2017	Report: FLOOD RISK ASSESSMENT		Tel: 01494 677 255 Fax: 01494 677 779		Figure No: FIGURE 3
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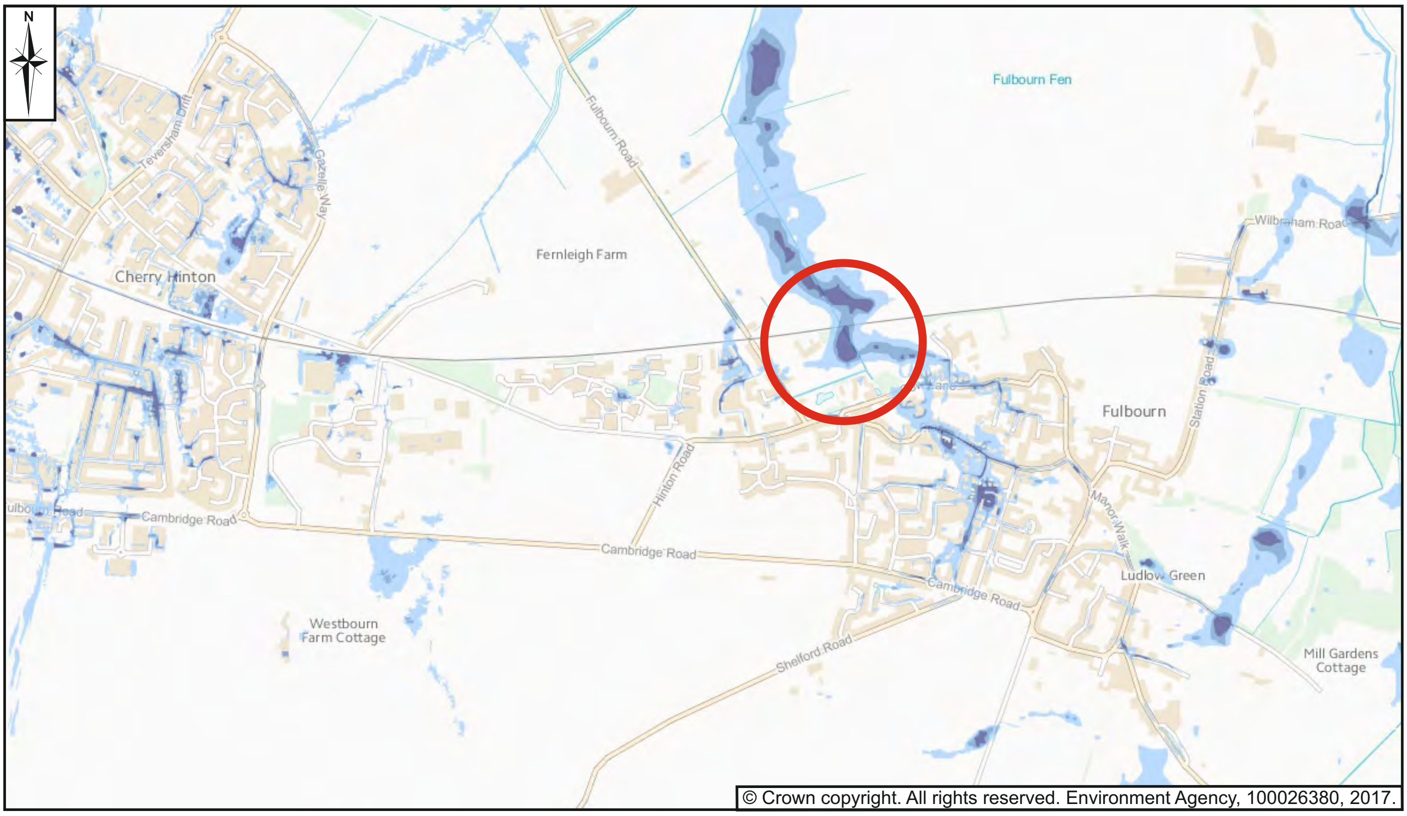

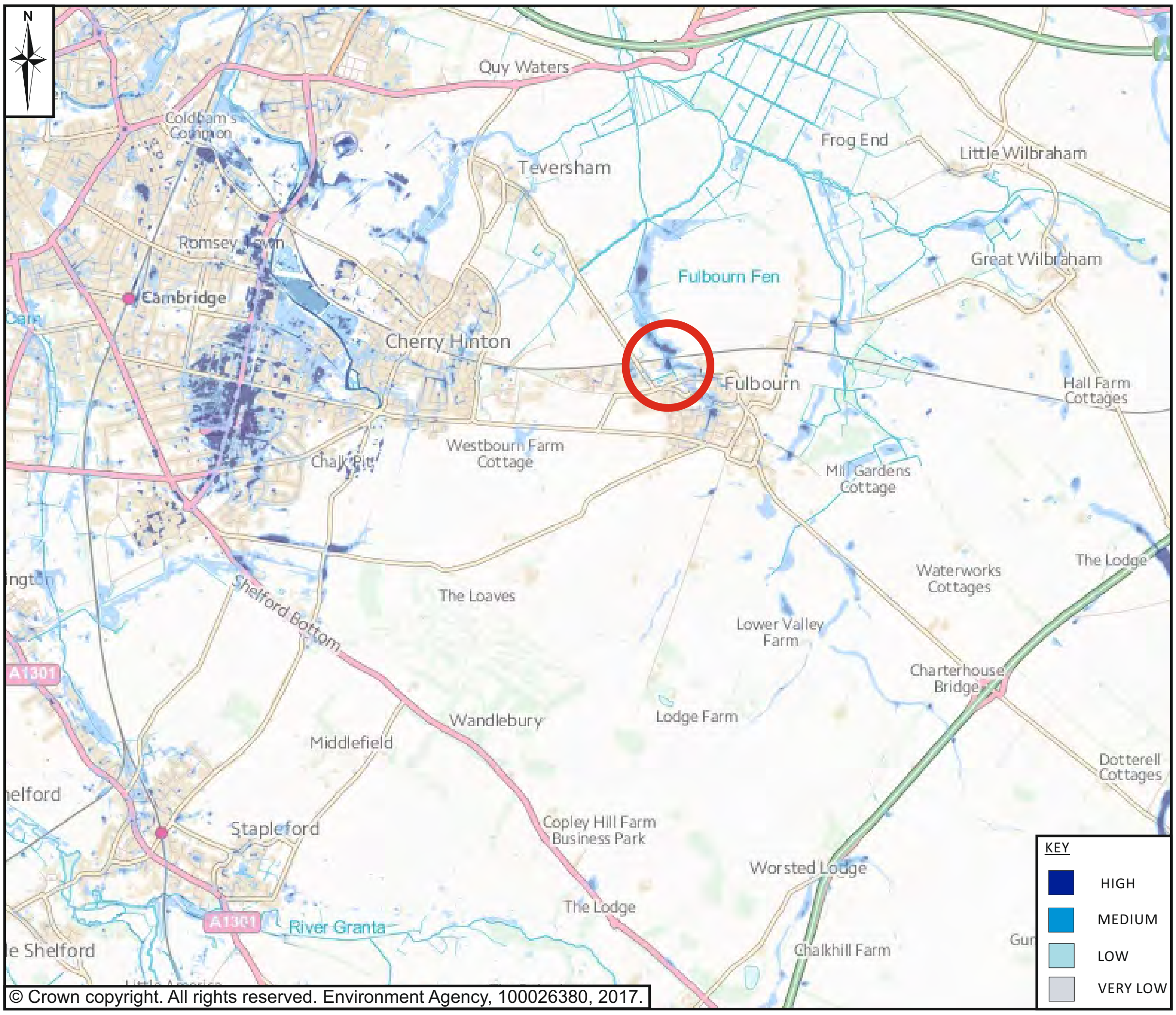

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2014 Flood Risk Assessment, CCE/B411/FRA-03

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Highways, Transport & Infrastructure Planning

Land at Teversham Road,
Fulbourn, Cambridgeshire

Flood Risk Assessment

September 2014

For Castlefield International Ltd

Ref: CCE/B411/FRA-03

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Document Review Sheet:

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Reference	Date	Author	Checked
CCE/B411/FRA-01	July 2014	JOH	RBT
CCE/B411/FRA-02	August 2014	JOH	RBT
CCE/B411/FRA-03	September 2014	JOH	RBT

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Appendices

Summary Table

Site location	Land east of Teversham Road, Fulbourn, Cambridgeshire Grid reference – 551315,256609
Planning application	Outline
Existing site	Undeveloped
Site area	Approximately 6.85 ha
Proposed development	Residential
Flood Zone	Zone 1
Reservoir Inundation Zone	None
Other sources of flooding	Surface water Shallow groundwater potential
Surface water management	Bioretention areas sized to manage the 100 year storm plus 30% climate change with outfalls to the central watercourse.

1.0 Introduction

1.1 This Flood Risk Assessment (FRA) has been prepared on behalf of Castlefield International Ltd to support an outline planning application for a proposed residential development .

1.2 The application seeks outline planning permission for a high quality residential development of up to 110 homes, with areas of landscaping and public open space, one new access point and associated infrastructure works on land off Teversham Road, Fulbourn in the South Cambridgeshire district. It is proposed that all detailed matters (other than means of access) including layout, scale, appearance and landscaping will be determined as part of a reserved matters application.

1.3 The report has been prepared following site visits, on-site groundwater monitoring, two public consultation events, and a review of the Cambridgeshire Preliminary Flood Risk Assessment (PFRA), South Cambridgeshire Strategic Flood Risk Assessment (SFRA) and liaison with South Cambridgeshire.

1.4 This assessment takes account of the National Planning Policy Framework (NPPF) and the definitions of sources of flooding within the Flood and Water Management Act (FWMA) 2010.

1.5 The Environment Agency (EA) Flood Map (refer to Figure 3) shows that the site lies within Flood Zone 1 (the low probability zone).

1.6 The site is approximately centred on Ordnance Survey grid reference 551315,256609 and extends to approximately 6.85 ha in total. The proposed development site is currently undeveloped and predominantly laid to grassland and scrub.

1.7 The red line boundary includes two areas in which built development is not proposed:

- Poorwell water, a low lying wetland area which extends southwards from the southern boundary of the eastern section of the site; and
- A former ornamental pond (now overgrown) which sits to the west of the former Pumping Station on Cow Lane.

1.8 The site is bounded by the Cambridge to Ipswich rail line to the north, Cox's Drove with commercial development beyond to the east, and residential development to the south and west.

1.9 British Geological Survey mapping shows that the site is underlain by the West Melbury Marly Chalk Formation. An intrusive site investigation has confirmed the geology.

1.10 The site slopes inwards from the western and eastern boundaries to the central watercourse which flows generally northwards through the site. Levels in the western part of the site range from approximately 10.0 to 9.3 m AOD and levels in the eastern part of the site range from approximately 10.5 m AOD to 9.3 m AOD.

1.11 The site is at a lower level than the majority of Fulbourn and lies at the foot of a (Chalk) hill the 'crest' of which reaches to approximately 60 m AOD at a point approximately 2.4 km to the south of the site.

1.12 There are three watercourses/ditches which run through/around the site:

- The central watercourse (an award drain maintained by South Cambridgeshire) which runs northwards through the site, beneath the rail line (refer to Figure 2) and goes on to join Cawdle Ditch some 1.3 km to the north of the site. Anecdotal evidence from the public consultations suggests that the watercourse is spring fed (see paragraph 1.14 below).
- The ditch (also an award drain) which runs along the southern boundary of the western section of the site and joins the central watercourse.
- The Teversham Road ditch which runs northwards along Teversham Road and also joins Cawdle Ditch.

It is not proposed to remove or pipe any of the existing watercourses. Where roads and footpaths cross the central watercourse they will be bridged. Currently it is envisaged that the underside of the deck of each bridge will be in the order of 300 mm above ground levels in order to accommodate and surface water flood flows.

1.13 The topographical survey notes the presence of a surface water sewer/pipe in the eastern section of the site. The line of the pipe is apparently generally parallel to the southern boundary. The chamber associated with the pipe lies approximately 50 m north of the southern boundary and 30 m west of Cox's Drove. The pipe outfall could not be located but during both the survey and a subsequent site visit (during a moderate rainfall event) no flow was evident/audible in the pipe. From historic mapping (refer to the GeoSphere report which is included in the planning submission for the site) the pipe appears to have been installed in place of a land drain/boundary ditch which was present in the early 1900's. As part of the proposals (depending on the results of a later stage survey of the pipe to determine whether it accepts any incoming connections from off-site sources) it is proposed to either relocate, or preferably replace the pipe with a new, shallow (and ephemeral) watercourse (a suggested route for which is shown on the surface water management plan in Appendix B).

1.14 The other notable sewer/pipe in the area is the 750 mm diameter pipe which forms the head of the central watercourse. Anecdotal evidence from the public consultations suggests that the pipe conveys flows from a nearby spring to the south.

1.15 The Flood Estimation Handbook (FEH) data CD shows that the site lies within a catchment of approximately 0.5 km^2 (outlined in white on image 1 below). The neighbouring catchments are approximately 19.5 km^2 to the east (image 2) and 2.9 km^2 to the west (image 3).

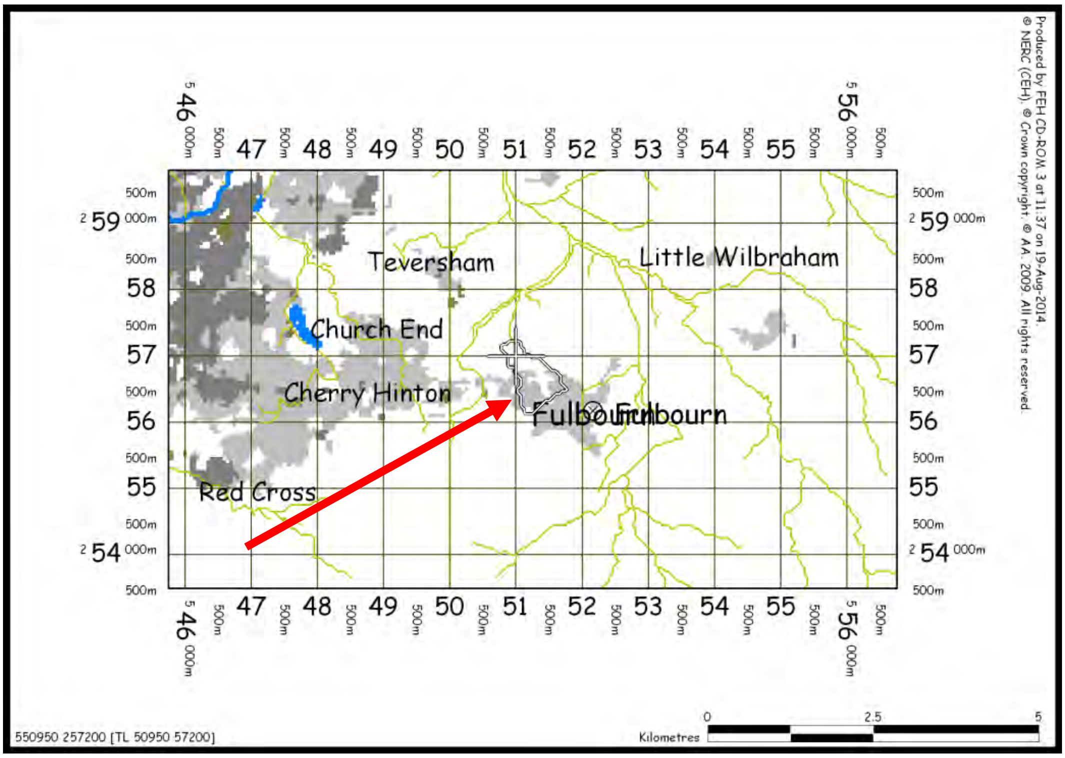


Image 1 – site catchment

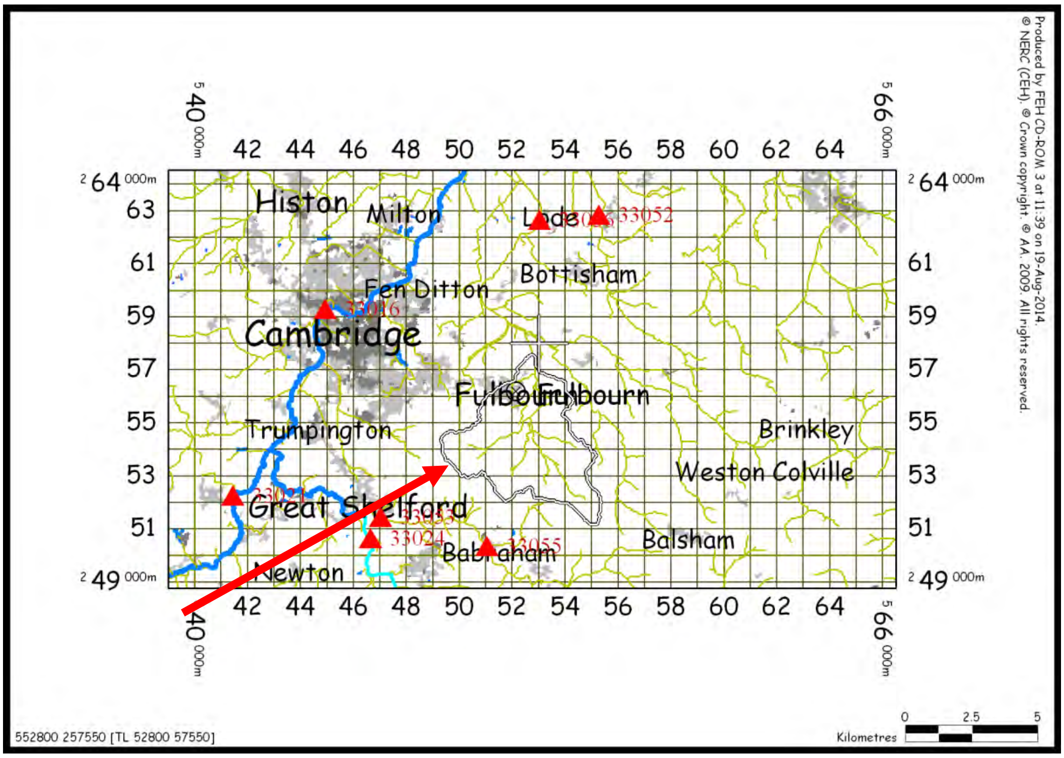


Image 2 – eastern neighbouring catchment

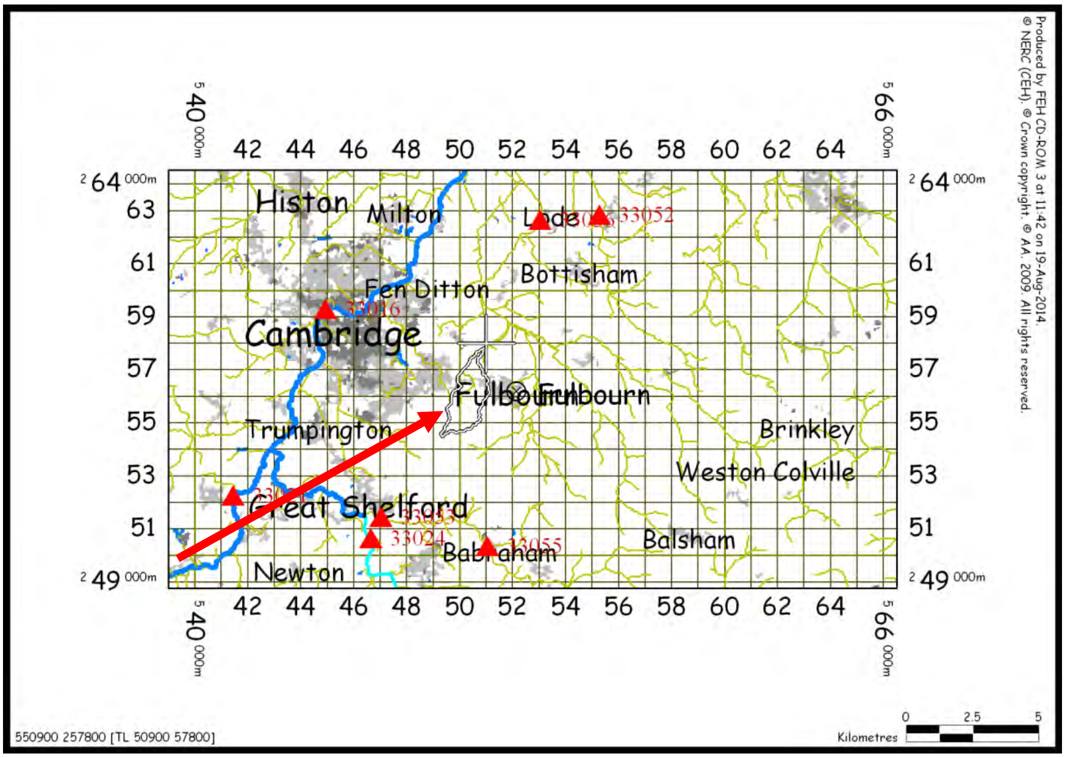


Image 3 – western neighbouring catchment

2.0 Forms of Flooding

Watercourses

2.1 The site lies in Flood Zone 1 (see Figure 3) and is therefore not considered to be at risk of inundation from a tidal source or river with a catchment of more than 3 km^2.

2.2 Flows in the two award drains on the site will tend to be the result of a combination of rural runoff and groundwater. The source of the groundwater elements of flow would realistically comprise the off-site spring and the water table beneath the site itself.

Surface Water

2.3 The EA surface water flood map (refer to Appendix A) shows that the site may be prone to surface water flooding. Judging from the shape and orientation of the surface water flood area and on and off-site ground levels, there are two potential pathways for runoff from the surrounding area (run-on) this is expected to enter the site as:

- Flows being routed along Cox's Drove tipping onto the site at the south-eastern corner of the site; and
- Flows gathering in an apparent low point on Cow Lane and tipping northwards (between the existing properties on Cow Lane) at a point adjacent to the Cow Lane-Cox's Drove junction.

Groundwater

2.4 As the site lies towards the base of a Chalk hill, it is likely to be exposed to elevated groundwater levels. To investigate this potential source of flooding and also ascertain any potential impact on the surface water management scheme associated with elevated groundwater levels, three measurements have been taken from three on-site boreholes. The measurements were taken in June and July 2014. The results of the groundwater level monitoring (refer to Appendix A for an extract of the Geosphere Environmental site investigation report) show that maximum groundwater levels were between 0.67 m and 1.2 m below ground level (bgl).

2.5 Groundwater level information provided by the EA for three boreholes in the wider area show that the levels recorded at the site are representative of a period of high regional groundwater. Rainfall data for Cambridge from the NIAB site (see summary table overleaf) also shows that the rainfall during May and June 2014 is above the mean rainfall over the last 14 years. It is therefore fair to treat the highest recorded groundwater level on the site of 0.67 mbgl as the 'design groundwater flood' level, and conclude that groundwater flooding (the expression of groundwater at the surface) is not a significant threat to the proposals.

Month-Yr	Rainfall (mm)	Month-Yr	Rainfall (mm)	Month-Yr	Rainfall (mm)
May-00	83.8	Jun-00	17.5	Jul-00	60.7
May-01	17.5	Jun-01	22.8	Jul-01	55.1
May-02	53.5	Jun-02	28.5	Jul-02	94.6
May-03	39.9	Jun-03	60.7	Jul-03	66.8
May-04	44.5	Jun-04	34	Jul-04	59.3
May-05	47.4	Jun-05	47.1	Jul-05	43.7
May-06	62.8	Jun-06	18.9	Jul-06	45.1
May-07	124.3	Jun-07	59	Jul-07	62.1
May-08	62.9	Jun-08	34.6	Jul-08	52.1
May-09	28.4	Jun-09	40.8	Jul-09	71
May-10	28.6	Jun-10	25.4	Jul-10	10.8
May-11	12.8	Jun-11	53	Jul-11	38.4
May-12	42.6	Jun-12	91.4	Jul-12	101.4
May-13	52	Jun-13	14.2	Jul-13	32.8
May-14	84.6	Jun-14	44.4		
Mean	52.4	Mean	39.5	Mean	56.7

Rainfall depth summary table

Surface Water Sewers

2.6 Anglian Water records (included in Appendix A) show that there is no adopted surface water sewer network in the area (and therefore no associated flood risk).

Reservoirs / Canals

2.7 The site does not lie in a reservoir inundation zone according to EA mapping (refer to Figure 3) and there are no canals in the area.

Flood Management

2.8 The proposed layout has been based around the need to provide space for surface water runoff shed from the surrounding development (run-on) and for runoff generated by the proposed development itself (run-off). By making space for water the proposals avoid the potential displacement of run-on to the surrounding development.

2.9 The flood routing and storage areas included in the layout (refer to the surface water management drawing in Appendix B) focus on leaving the majority of the high and medium surface water flood areas free of built development. The notable exception to this is parcel C (the southern most of the parcels in the eastern section of the site) where existing ground levels between Cox's Drove and the parcel will be modified (lowered by 150 to 300 mm) in order to route potential run-on northwards towards the intra parcel open space and parkland.

2.10 Finished floor levels will be set at or above 300 mm above current ground levels as an added precaution against surface water flooding.

2.11 The proposed road links between the two parcels in the east and Cox's Drove access will be bridged (we envisage this being achieved with either a clear span arrangement or with part buried box culverts). As discussed, the crossings over the central watercourse will be via a clear span bridge.

2.12 The majority of the various walkways throughout the site will be raised. We envisage that the level of the walkways passing through the bio retention areas (see Section 3.0) will be set with reference to the top water level of the facilities.

2.13 All proposals are subject to detailed design and approval of relevant parties (in particular South Cambridgeshire District Council as part of their land drainage consenting function).

3.0 Surface Water Management

3.1 The underlying geology means that infiltration rates at the site are likely to be relatively high. This is supported by the low greenfield runoff rate calculated for the area. The inference is that the majority of rain falling on undeveloped land percolates into the ground.

3.2 Despite the probability that infiltration rates in the area would support an infiltration drainage solution, the proposed surface water management scheme relies on an outfall to the central watercourse because of the potentially high groundwater levels in the area.

3.3 It is worth noting that, because a low runoff rate and a 48 hour drain-down time are mutually exclusive, the proposed surface water attenuation facilities have been sized to accommodate a long duration storm (as suggested in Section 4 of the Ciria SuDS Manual).

3.4 The surface water scheme comprises three bioretention areas (A, B and C) which will each serve to take flows from one of the three proposed development parcels. The design depth of each facility is 600 mm with side slopes of between 1 in 4 and 1 in 2. The steeper side slopes will be used along sides which are unlikely to be used to access the bioretention basin. The flows leaving the bioretention basins will be controlled by a filter control (a depth of permeable material feeding a perforated pipe). WinDes simulations of each bioretention area are included in Appendix B.

3.5 Although losses to infiltration are not allowed for within the WinDes simulations of the bioretention basins infiltration will clearly occur. In order to address the potential concerns of Network Rail about infiltration facilities It is envisaged that bioretention Basin B will be lined in order to prevent infiltration

3.6 Flows will be conveyed to the bioretention basins via a series of rills/canals. Two main types of rill/canal are envisaged:

- Planted 'residential' rills serving to collect runoff shed from roofs and private hadstanding; and
- Roadside rills (inspired by Hobson's Conduit) serving the roads (with the possibility to also convey runoff from the planted rills. Where each highway rill outfalls to a bioretention area a sediment forebay will be created (using either a micropool or low bund).

3.7 As the discharge from the site is being limited to the annual greenfield rate (the 1 in 1 year greenfield rate) long term storage is not required.

3.8 All proposals are subject to detailed design and the approval of relevant parties. With the delay in the introduction of SABs it is envisaged that adoption and maintenance of the majority of 'public' surface water management features will be offered to Anglian Water however South Cambridgeshire District council may wish to combine maintenance of the bioretention basins with their current maintenance of the two award drains. The latter will be subject to later stage discussions with the relevant parties. Any shortfall in maintenance will be accounted for by a private management company.

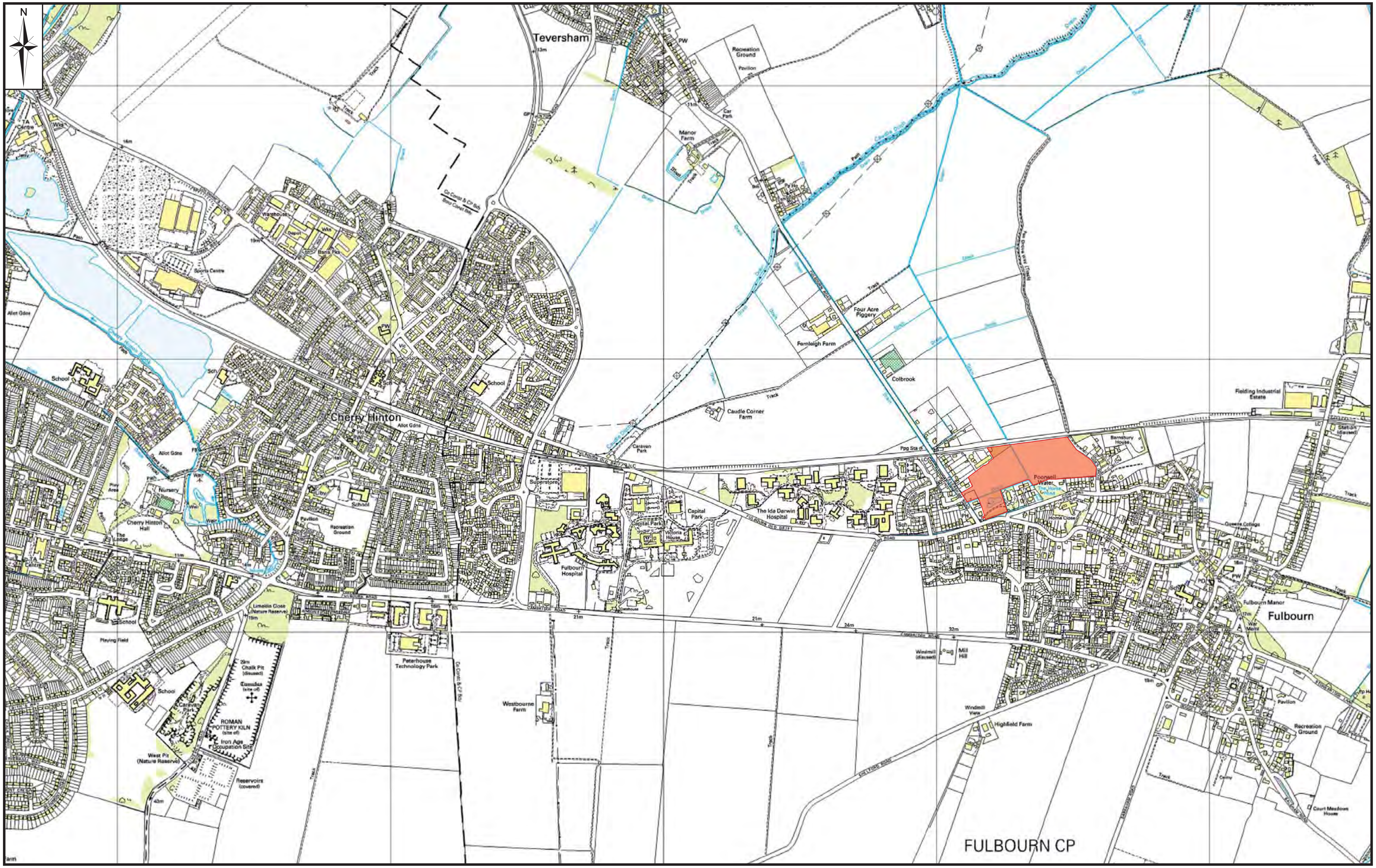
4.0 Conclusions

4.1 The development site is located entirely within Flood Zone 1 and is therefore not considered to be at risk of flooding from main rivers or watercourse with a significant catchment.

4.2 The proposed development is not considered to be at a significant or unmanageable risk of flooding from other sources of flooding. The surface water flood risk shown on EA mapping will be addressed by maintaining space for potential floodwater within the layout and setting finished floor levels 300 mm above ground levels.

4.3 Surface water runoff will be managed via three bioretention basins all sized to manage the 1 in 100 year storm plus 30 % allowance for climate change.

Figures and Drawings



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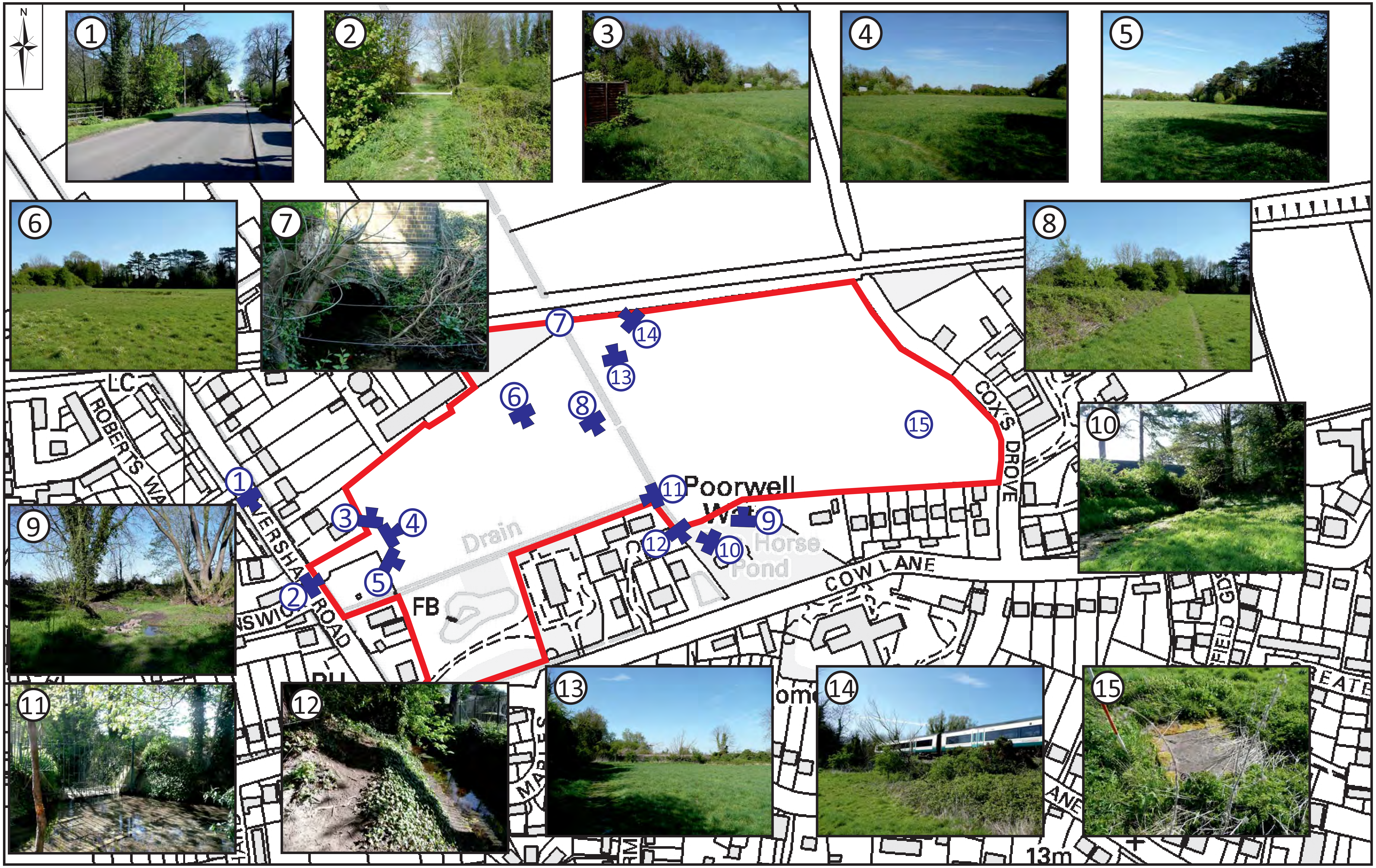

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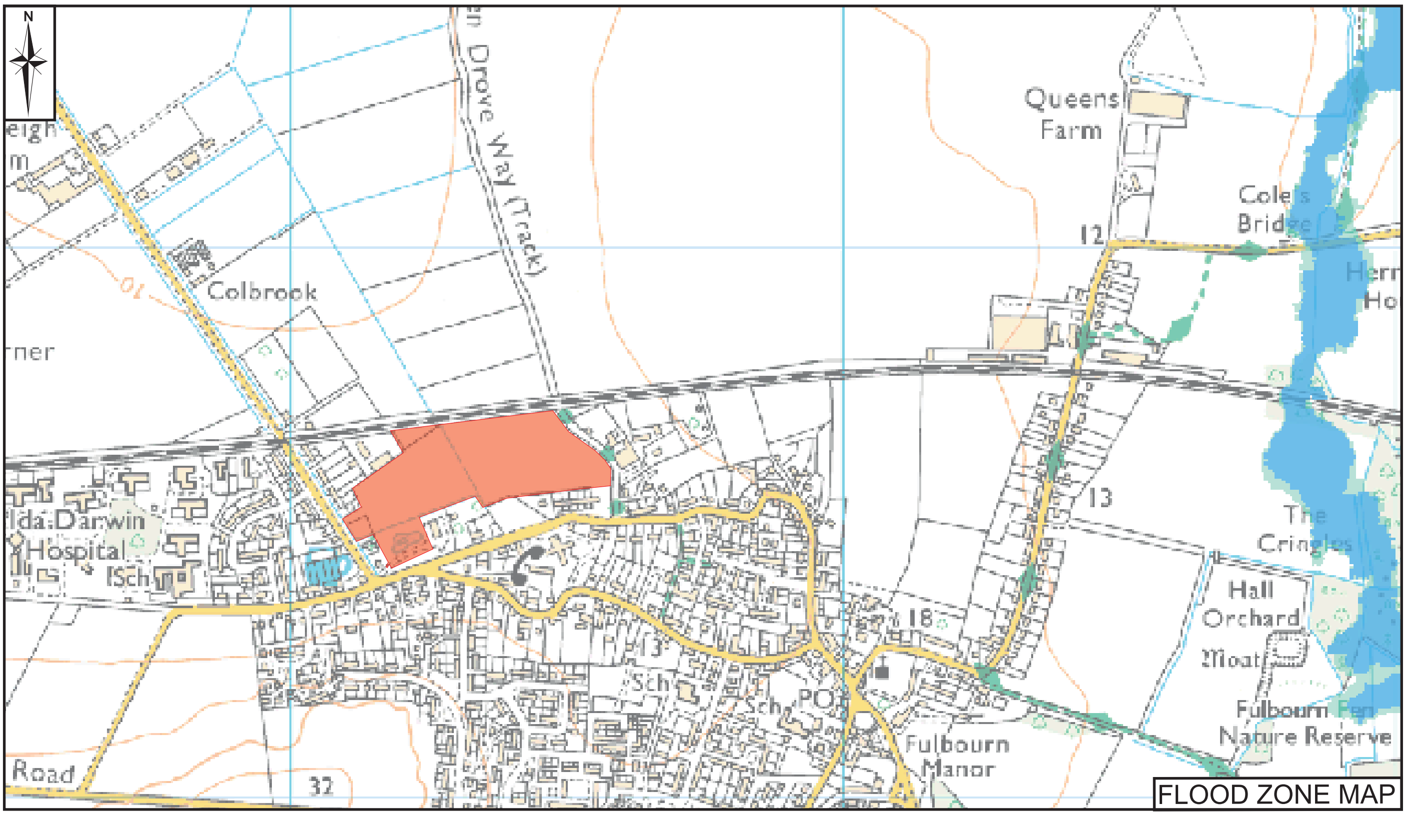

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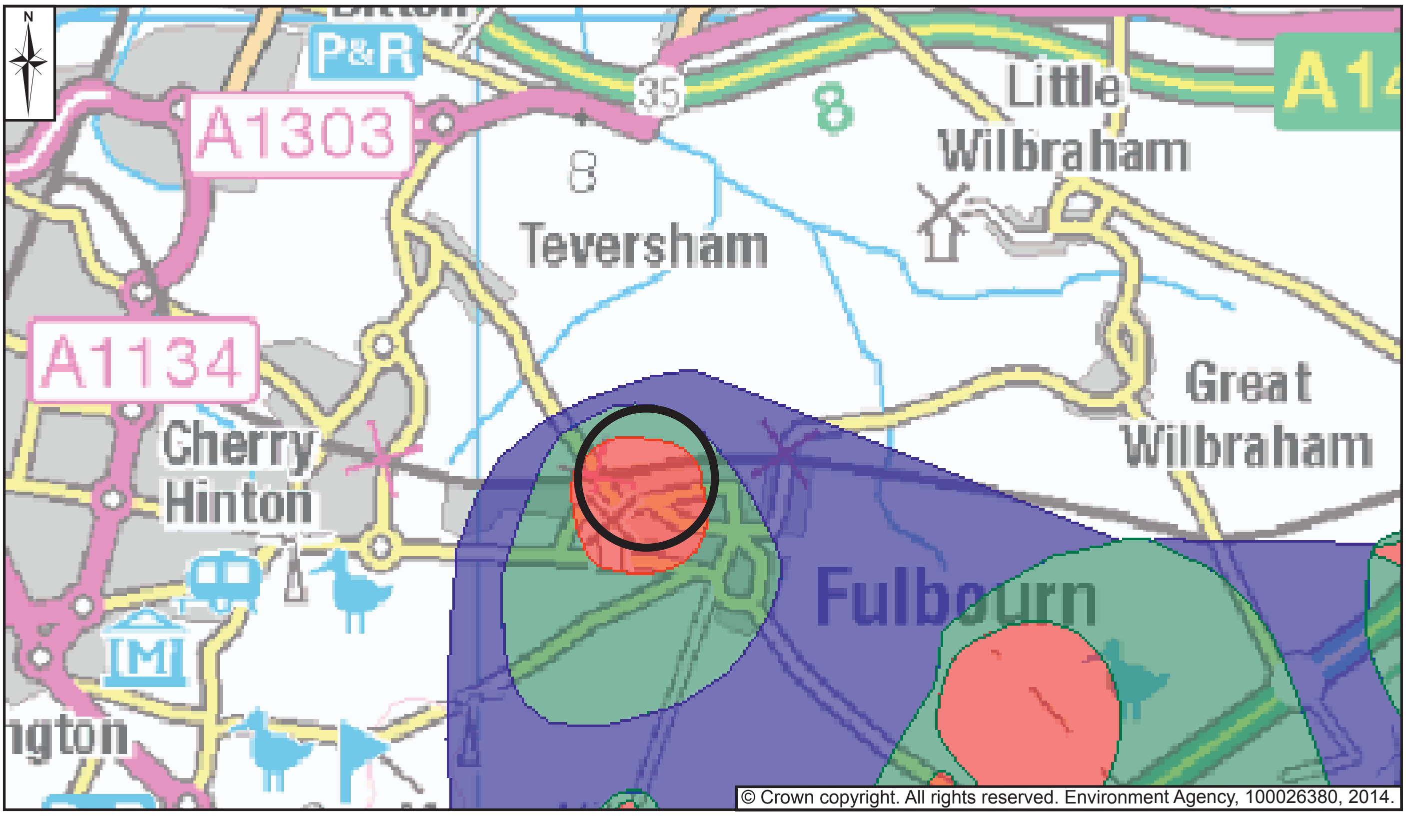

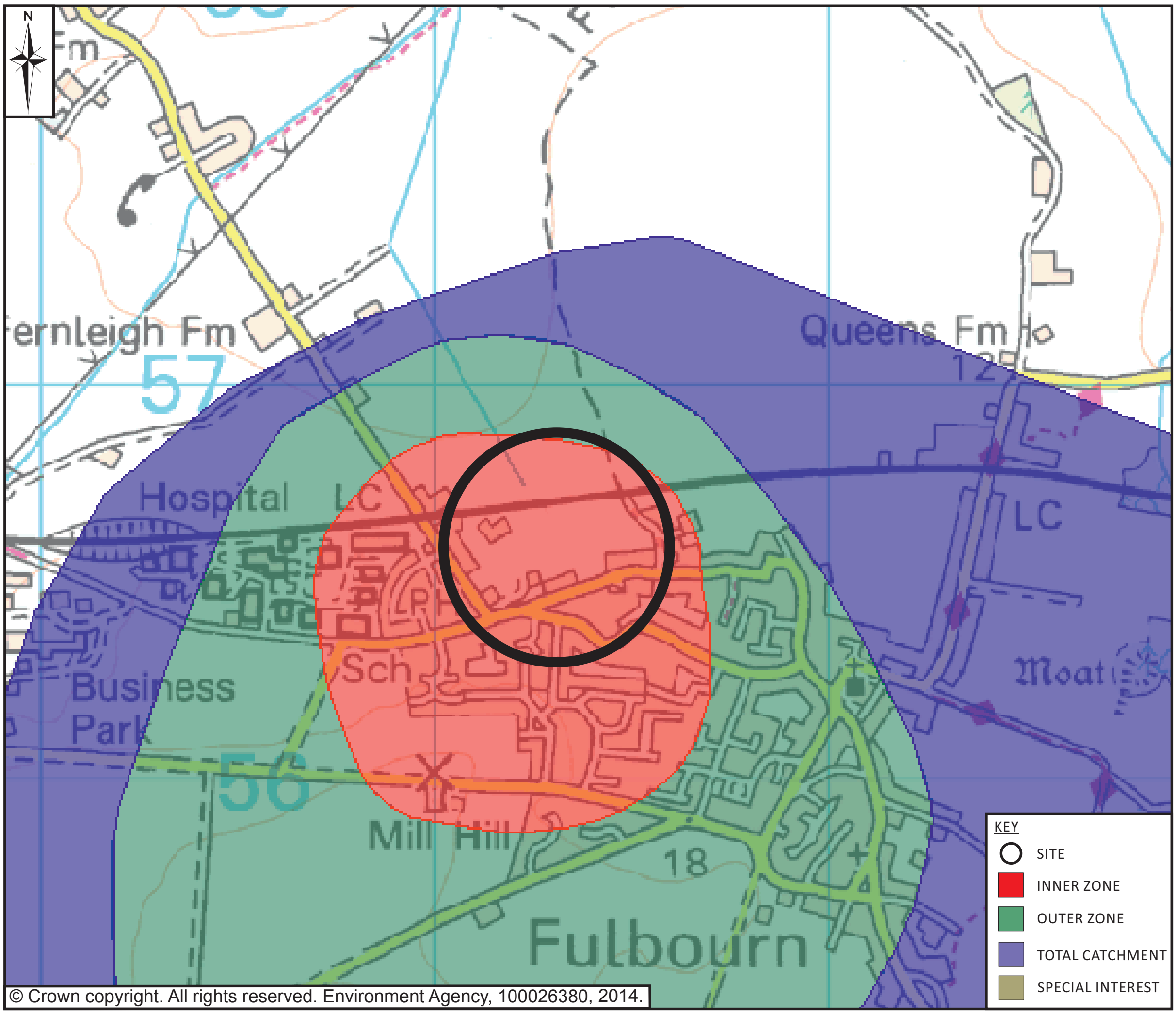

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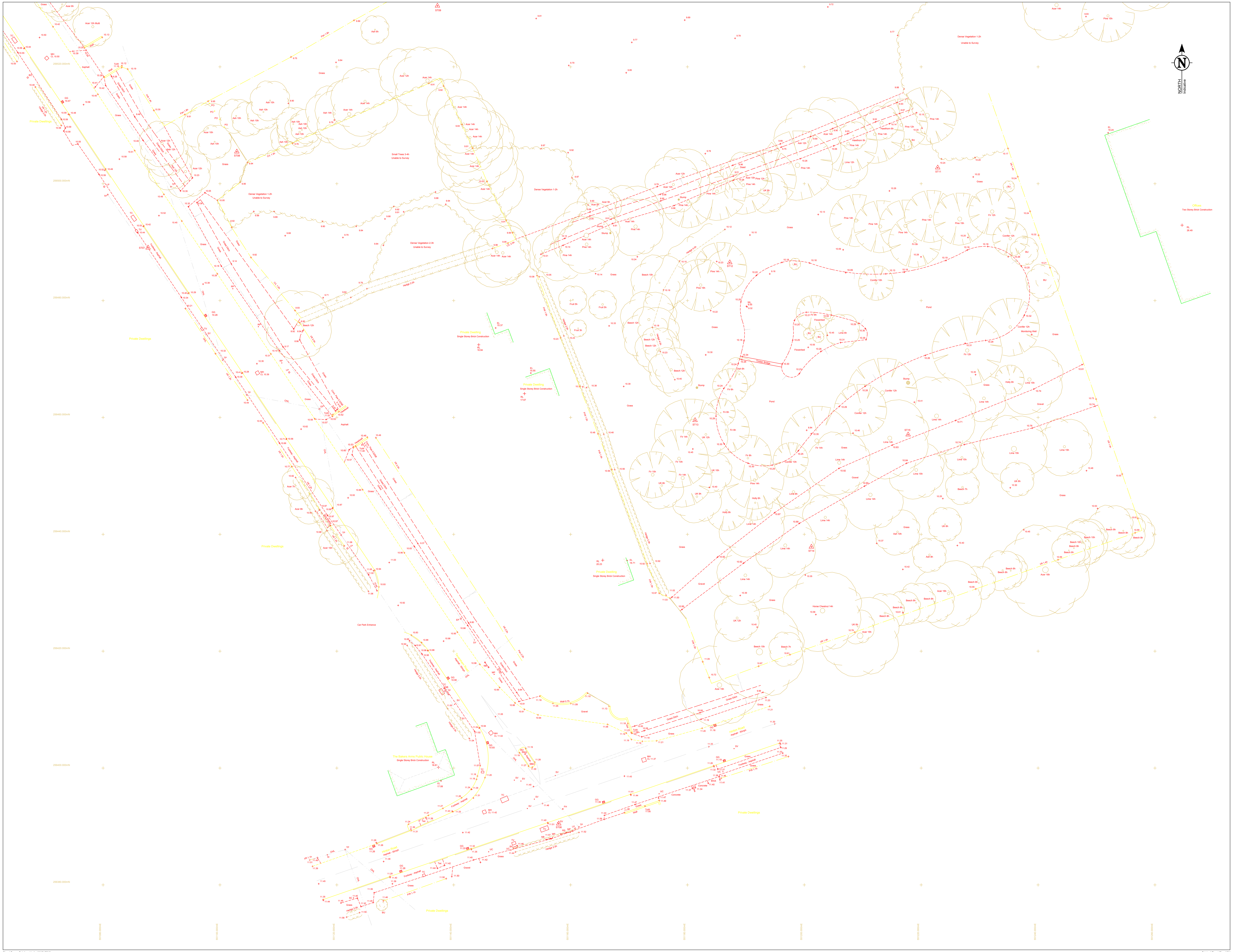
Appendices

A Existing Site

Topographical Survey
Adopted Sewer Plans
Ground Investigation Data
EA Surface Water Flood Map
EA Groundwater Data



TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

AH	Arch Head Height	FH	Fire Hydrant	RSJ	Rolled Steel Joist
AR	Assumed Route	FBD	Floor Board Direction	SI	Sign Post
AV	Air Valve	FH	Fire Hydrant	SP	Arch Spring Point Height
BB	Belisha Beacon	FL	Floor Level	SV	Stop Valve
BH	Bore Hole	FP	Flag Pole	SW	Surface Water
BL	Bed Level	FW	Foul Water	SY	Stay
BO	Bollard	GG	Gully Grate	Tac	Tactile Paving
BrP	Brace Post	GV	Gas Valve	TC	Telecom Cover
BS	Bus Stop	HH	Head Height	TH	Trial Pit
BU	Bush	IC	Inspection Cover	THL	Threshold Level
B/W	Barbed Wire Fence	IL	Invert Level	TL	Traffic Light
BX	Box (Utilities)	I/R	Iron Railings	ToW	Top of Wall
C/B	Close Board Fence	KO	Kerb Outlet	TP	Telegraph Pole
CH	Cill Height	LP	Lamp Post	TV	Cable TV Cover
CL	Cover Level	MH	Manhole	UB	Universal Beam
C/L	Chain Link Fence	MP	Marker Post	UC	Unknown Cover
C-Lev	Ceiling Level	NB	Name Board	UK	Unknown Tree
Col	Column	OHL	Overhead Line (approx)	USB	Under Side Beam
C/P	Chestnut Paling Fence	Pan	Panel Fence	UTL	Unable To Lift
CR	Cable Riser	PB	Post Box	VP	Vent Pipe
DC	Drainage Channel	PM	Parking Meter	WB	Waste Bin
DH	Door Head Height	PO	Post	WH	Weep Hole
DP	Down Pipe	P/R	Post & Rail Fence	WL	Water Level
DR	Drain	P/W	Post & Wire Fence	WM	Water Meter
EL	Eaves Level	P/Wall	Partition Wall	WO	Wash Out
EP	Electric Pole	RE	Rodding Eye	(X.XX)	Floor to Ceiling Height
ER	Earth Rod	RL	Ridge Level		
ET	EP+Transformer	RP	Reflector Post	(X.XX)F/C	Floor to False Ceiling Ht
FB	Flower Bed	RS	Road Sign		
FBD	Floor Board Direction	RSD	Roller Shutter Door	△	Survey Control Station

DRAWING NOTE

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SHEET LAYOUT

CONTROL CO-ORDINATES

STATIONS	EASTINGS	NORTHINGS	LEVEL	DESCRIPTION
GCP1	551339.924	256595.128	9.812	Peg & Nail
ST01	551511.229	256587.992	10.310	PK Nail
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ST03	551593.339	256584.501	10.637	PK Nail
ST04	551588.010	256544.664	10.717	PK Nail
ST05	551592.268	256501.756	10.921	PK Nail
ST06	551157.979	256390.469	11.490	PK Nail
ST07	551087.701	256489.037	10.442	PK Nail
ST08	551102.890	256505.472	10.196	Peg & Nail
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ST13	551181.304	256459.515	10.708	Peg & Nail
ST14	551201.206	256437.850	10.572	Peg & Nail
ST15	551217.759	256457.045	11.053	Peg & Nail

SURVEY GRID AND LEVEL DATUM

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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

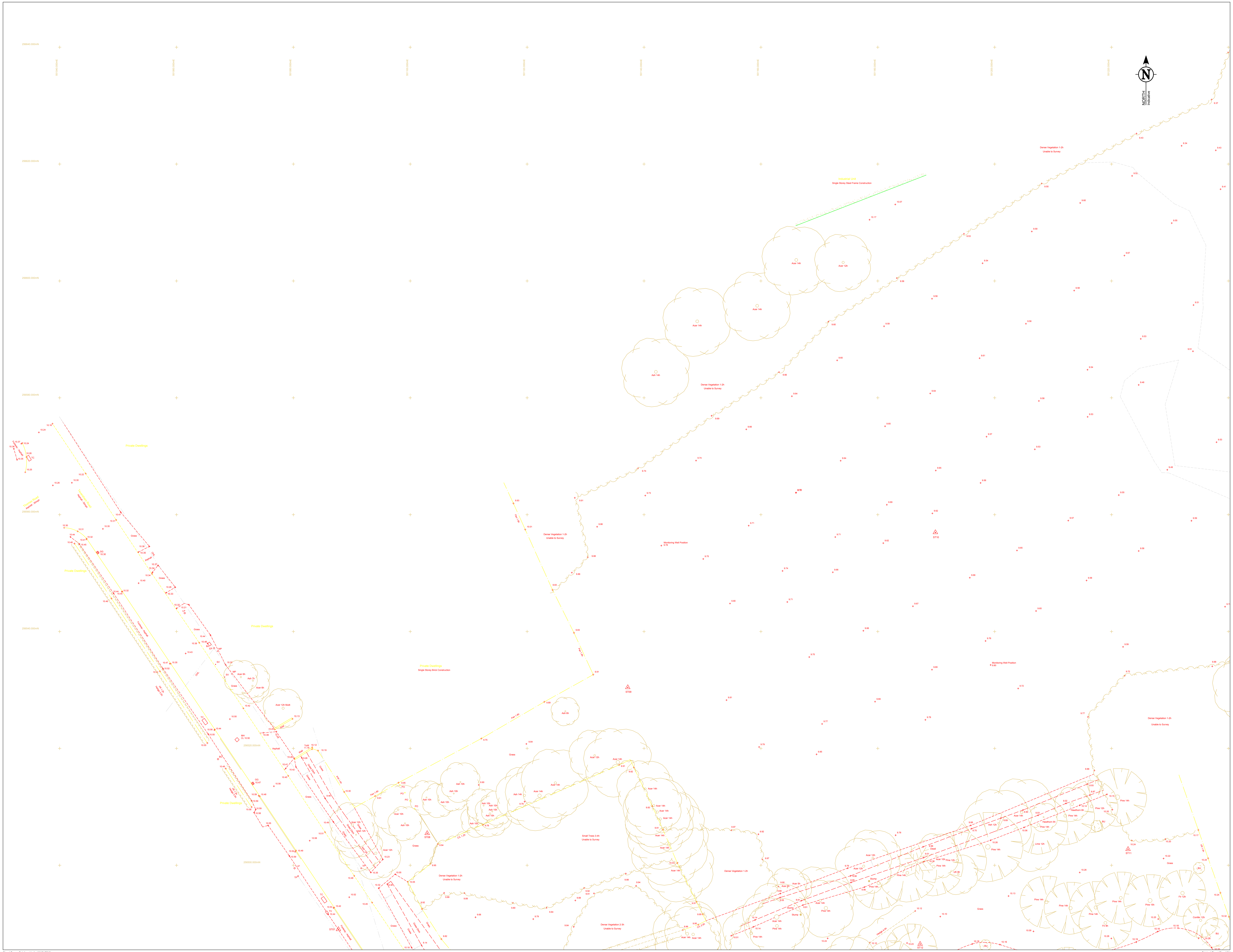
Ipswich Coventry Yeovil Norwich Perth Nottingham Brentwood

Tel No: 0845 0405 969
Fax No: 0845 0405 970
www.survey-solutions.co.uk
enquiries@survey-solutions.co.uk

LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE COX'S DROVE, FULBOURN, CAMBRIDGESHIRE.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 1 of 6				
CLIENT CASTLEFIELD INTERNATIONAL LTD				SCALE 1:200
SURVEYOR MG	SURVEY DATE 25/05/2014	CHECKED BY MWK	APPROVED BY GJN	DWG STATUS FINAL
DRAWING NUMBER 14282ea-01			REVISION	ISSUE DATE 29/05/2014

Original Sheet Size A0H



Original Sheet Size A0H

TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

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SHEET LAYOUT

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REV	DESCRIPTION	DRAWN	APPR	DATE

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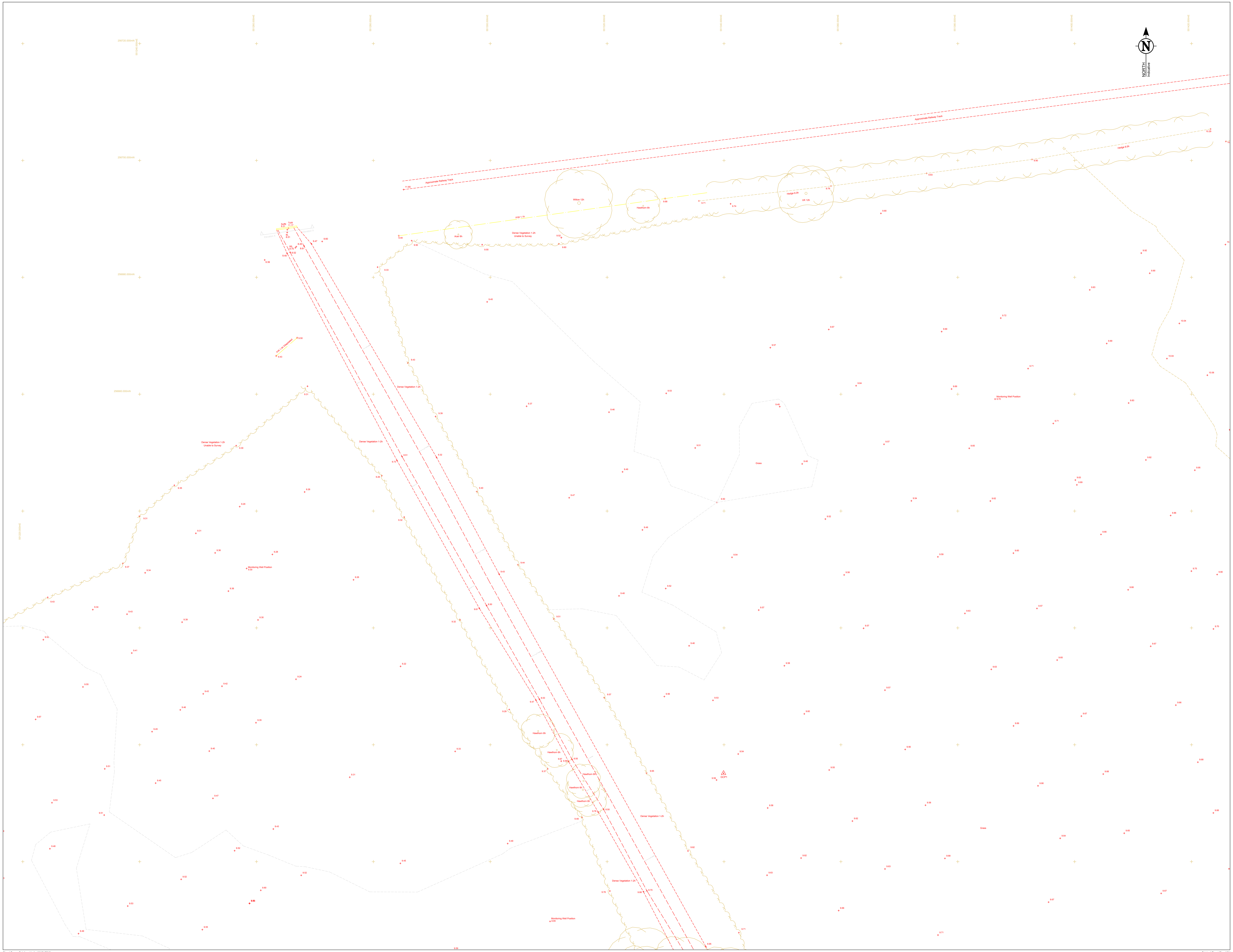
enquiries@survey-solutions.co.uk

LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE COX'S DROVE, FULBOURN, CAMBRIDGESHIRE.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 2 of 6				
CLIENT CASTLEFIELD INTERNATIONAL LTD				SCALE 1:200
SURVEYOR MG	SURVEY DATE 25/05/2014	CHECKED BY MWK	APPROVED BY GJN	DWG STATUS FINAL
DRAWING NUMBER 14282ea-02			REVISION	ISSUE DATE 29/05/2014



TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

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SURVEY SOLUTIONS

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www.survey-solutions.co.uk enquiries@survey-solutions.co.uk

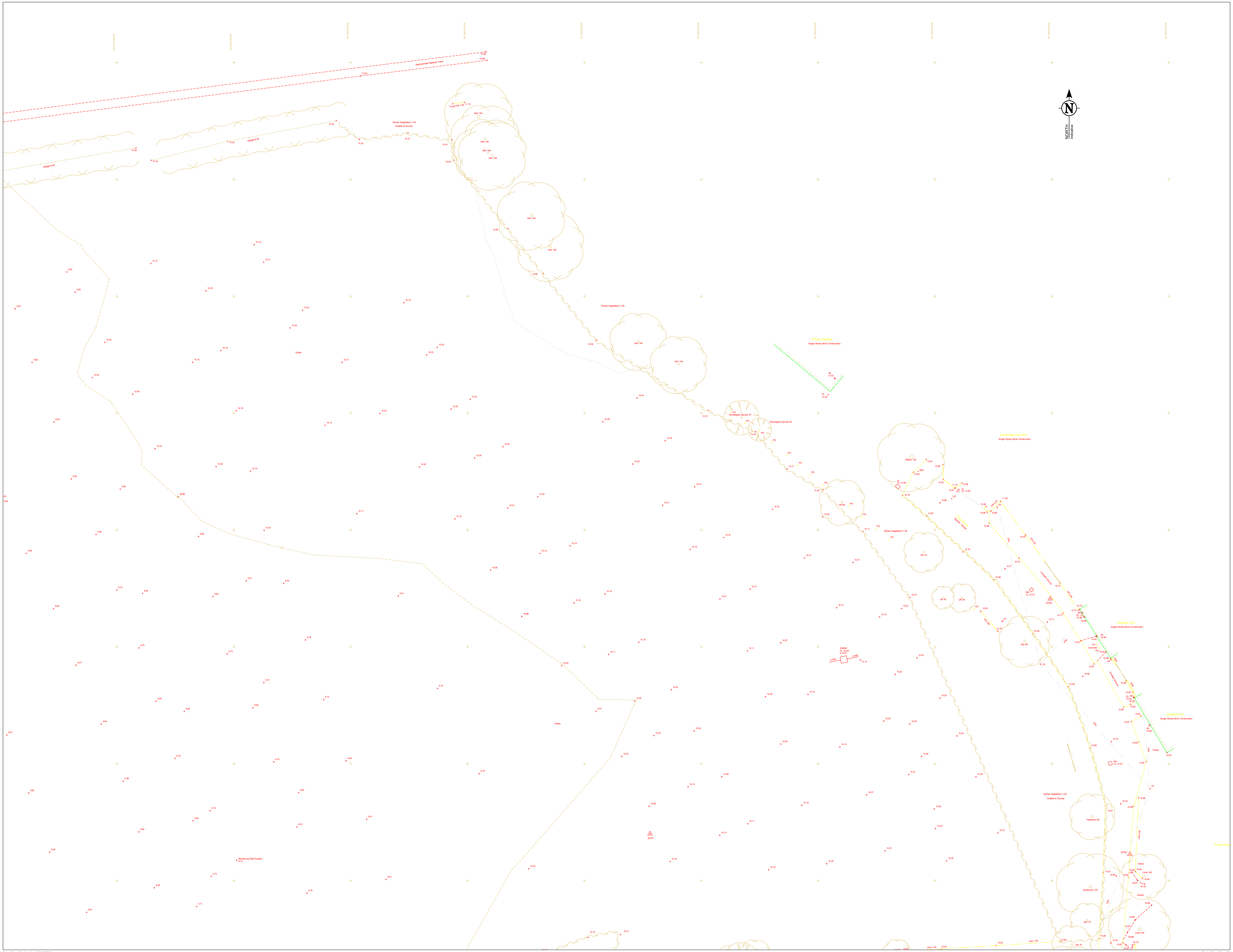
LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE
COX'S DROVE,
FULBOURN, CAMBRIDGESHIRE.

DRAWING DETAIL
TOPOGRAPHICAL SURVEY
Sheet 3 of 6

CLIENT				SCALE
CASTLEFIELD INTERNATIONAL LTD				1:200
SURVEYOR	SURVEY DATE	CHECKED BY	APPROVED BY	DWG STATUS
MG	25/05/2014	MWK	GJN	FINAL
DRAWING NUMBER			REVISION	ISSUE DATE
14282ea-03				29/05/2014

Original Sheet Size A0H



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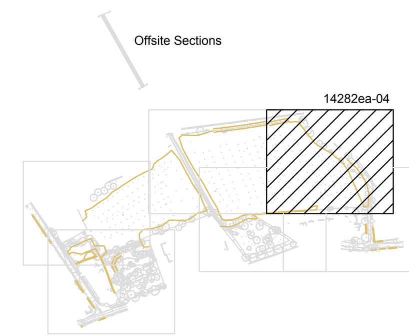
SHEET LAYOUT



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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

Ipswich Coventry Yeovil Norwich Perth Nottingham Brentwood

Tel No: 0845 0405 969 Fax No: 0845 0405 970
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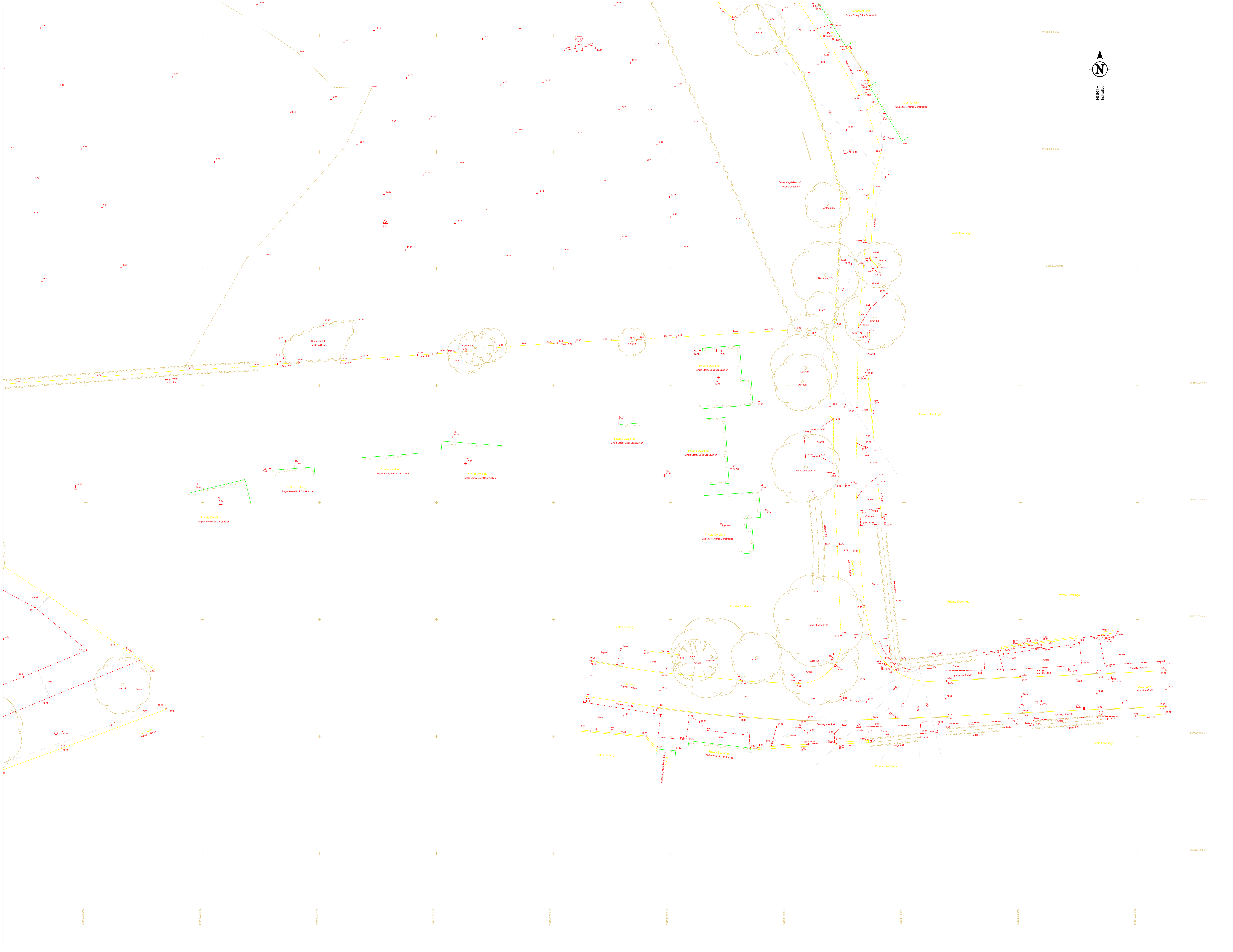
LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE COX'S DROVE, FULBOURN, CAMBRIDGESHIRE.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 4 of 6				
CLIENT CASTLEFIELD INTERNATIONAL LTD				SCALE 1:200
SURVEYOR MG	SURVEY DATE 25/05/2014	CHECKED BY MWK	APPROVED BY GJN	DWG STATUS FINAL
DRAWING NUMBER 14282ea-04		REVISION		ISSUE DATE 29/05/2014

Original Sheet Size A0H



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ER	Earth Rod	RL	Ridge Level		
ET	EP+Transformer	RP	Reflector Post	(X.XX)F/C	Floor to False Ceiling Ht
FB	Flower Bed	RS	Road Sign		
FBD	Floor Board Direction	RSD	Roller Shutter Door	△	Survey Control Station

DRAWING NOTE

Topographical Surveys

Trees are drawn to scale showing the average canopy spread. Descriptions and heights should be used as a guide only.

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General

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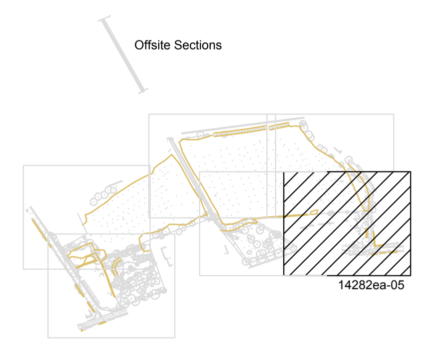
Do not scale from this drawing.

SHEET LAYOUT



CONTROL CO-ORDINATES

STATIONS	EASTINGS	NORTHINGS	LEVEL	DESCRIPTION
GCP1	551339.924	256595.128	9.812	Peg & Nail
ST01	551511.229	256587.992	10.310	PK Nail
ST02	551579.712	256628.221	10.744	PK Nail
ST03	551593.339	256584.501	10.637	PK Nail
ST04	551588.010	256544.664	10.717	PK Nail
ST05	551592.268	256501.756	10.921	PK Nail
ST06	551157.979	256390.469	11.490	PK Nail
ST07	551087.701	256489.037	10.442	PK Nail
ST08	551102.890	256505.472	10.196	Peg & Nail
ST09	551137.219	256530.439	10.190	Peg & Nail
ST10	551189.855	256556.963	9.865	Peg & Nail
ST11	551222.824	256502.742	10.407	Peg & Nail
ST12	551187.243	256486.512	10.463	Peg & Nail
ST13	551181.304	256459.515	10.708	Peg & Nail
ST14	551201.206	256437.850	10.572	Peg & Nail
ST15	551217.759	256457.045	11.053	Peg & Nail

SURVEY GRID AND LEVEL DATUM

Ordnance Survey (OS) national grid coordinates have been established for survey control point ST01 using GPS and related to OSTN02(GB) and OSGM02(GB). The survey grid is orientated to Grid North with a scale factor of 1.000.

All levels relate to the Ordnance Survey (OS) level datum at survey control point ST01 established by GPS using OSGM02(GB).

REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

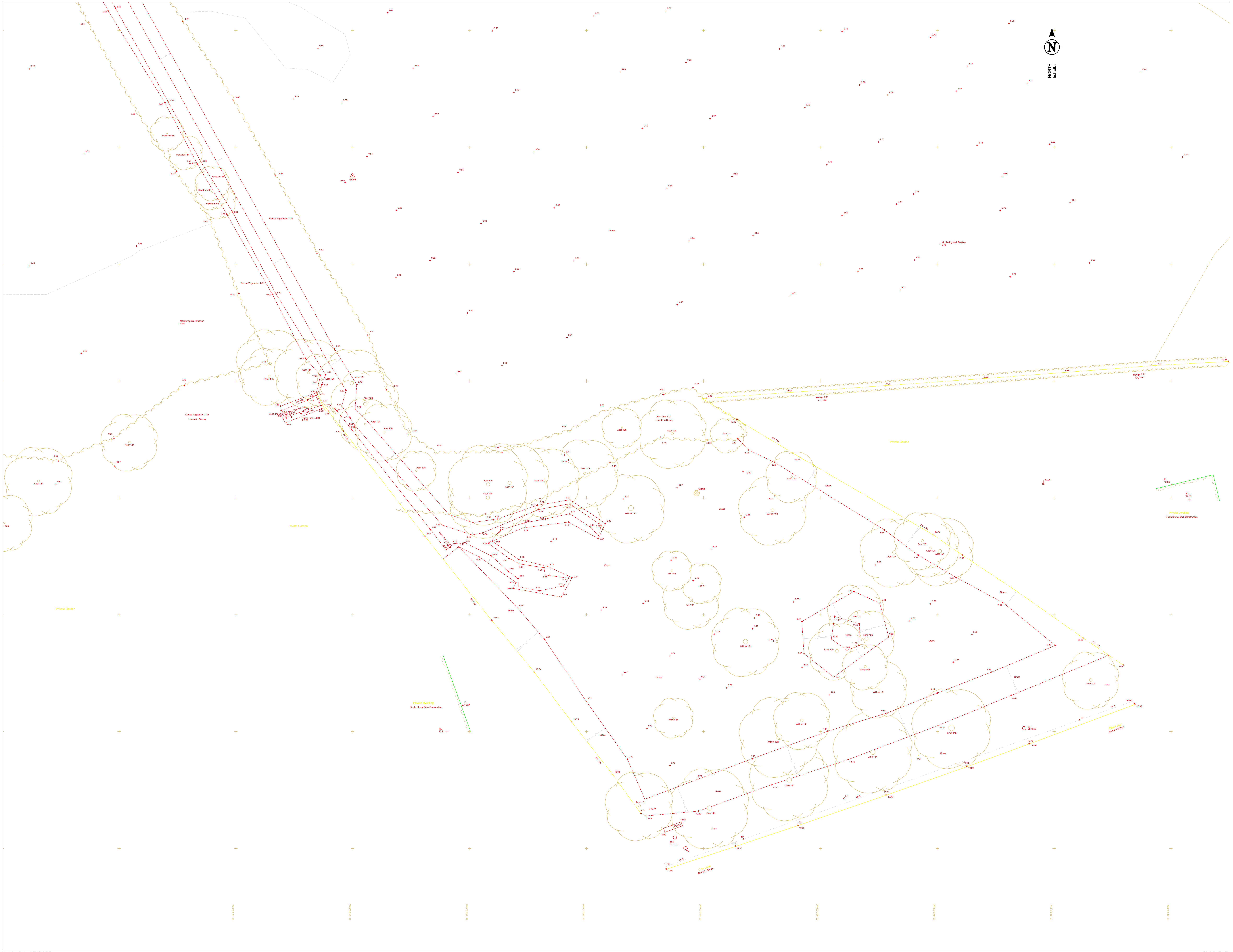
Ipswich Coventry Yeovil Norwich Perth Nottingham Brentwood

Tel No: 0845 0405 969 Fax No: 0845 0405 970
www.survey-solutions.co.uk enquiries@survey-solutions.co.uk

LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE COX'S DROVE, FULBOURN, CAMBRIDGESHIRE.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 5 of 6				
CLIENT CASTLEFIELD INTERNATIONAL LTD				SCALE 1:200
SURVEYOR MG	SURVEY DATE 25/05/2014	CHECKED BY MWK	APPROVED BY GJN	DWG STATUS FINAL
DRAWING NUMBER 14282ea-05			REVISION	ISSUE DATE 29/05/2014

Original Sheet Size A0H



TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

AH	Arch Head Height	FH	Fire Hydrant	RSJ	Rolled Steel Joist
AR	Assumed Route	FBD	Floor Board Direction	SI	Sign Post
AV	Air Valve	FH	Fire Hydrant	SP	Arch Spring Point Height
BB	Belisha Beacon	FL	Floor Level	SV	Stop Valve
BH	Bore Hole	FP	Flag Pole	SW	Surface Water
BL	Bed Level	FW	Foul Water	SY	Stay
BO	Bollard	GG	Gully Grate	Tac	Tactile Paving
BrP	Brace Post	GV	Gas Valve	TC	Telecom Cover
BS	Bus Stop	HH	Head Height	TH	Trial Pit
BU	Bush	IC	Inspection Cover	THL	Threshold Level
B/W	Barbed Wire Fence	IL	Invert Level	TL	Traffic Light
BX	Box (Utilities)	I/R	Iron Railings	ToW	Top of Wall
C/B	Close Board Fence	KO	Kerb Outlet	TP	Telegraph Pole
CH	Cill Height	LP	Lamp Post	TV	Cable TV Cover
CL	Cover Level	MH	Manhole	UB	Universal Beam
C/L	Chain Link Fence	MP	Marker Post	UC	Unknown Cover
C-Lev	Ceiling Level	NB	Name Board	UK	Unknown Tree
Col	Column	OHL	Overhead Line (approx)	USB	Under Side Beam
C/P	Chestnut Paling Fence	Pan	Panel Fence	UTL	Unable To Lift
CR	Cable Riser	PB	Post Box	VP	Vent Pipe
DC	Drainage Channel	PM	Parking Meter	WB	Waste Bin
DH	Door Head Height	PO	Post	WH	Weep Hole
DP	Down Pipe	P/R	Post & Rail Fence	WL	Water Level
DR	Drain	P/W	Post & Wire Fence	WM	Water Meter
EL	Eaves Level	P/Wall	Partition Wall	WO	Wash Out
EP	Electric Pole	RE	Rodding Eye	(X.XX)	Floor to Ceiling Height
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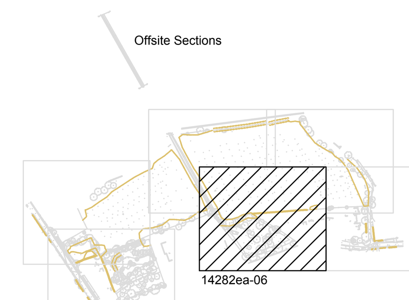
SHEET LAYOUT



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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

Ipswich Coventry Yeovil Norwich Perth Nottingham Brentwood

Tel No: 0845 0405 969 Fax No: 0845 0405 970
www.survey-solutions.co.uk enquiries@survey-solutions.co.uk

LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE
COX'S DROVE,
FULBOURN, CAMBRIDGESHIRE.

DRAWING DETAIL
TOPOGRAPHICAL SURVEY
Sheet 6 of 6

CLIENT				SCALE
CASTLEFIELD INTERNATIONAL LTD				1:200
SURVEYOR	SURVEY DATE	CHECKED BY	APPROVED BY	DWG STATUS
MG	25/05/2014	MWK	GJN	FINAL
DRAWING NUMBER			REVISION	ISSUE DATE
14282ea-06				29/05/2014

Original Sheet Size A0H

(c) Crown Copyright and database rights 2011 Ordnance Survey 100018507 | Date: 23/04/14 | Scale: 1:1250 | Map Centre: 551340,256630 | Data updated: 01/04/14 | Our Ref: 96638 - 1 | Wastewater Plan A1

Foul Sewer
Surface Sewer
Combined Sewer
Final Effluent
Rising Main (Colour denotes effluent type)
Private Sewer (Colour denotes effluent type)
Decommissioned Sewer (Colour denotes effluent type)
Outfall (Colour denotes effluent type)
Inlet (Colour denotes effluent type)
Manhole (Colour denotes effluent type)
Sewage Treatment Works
Pumping Station

jenni.askew@cannonce.co.uk

Fulbourn

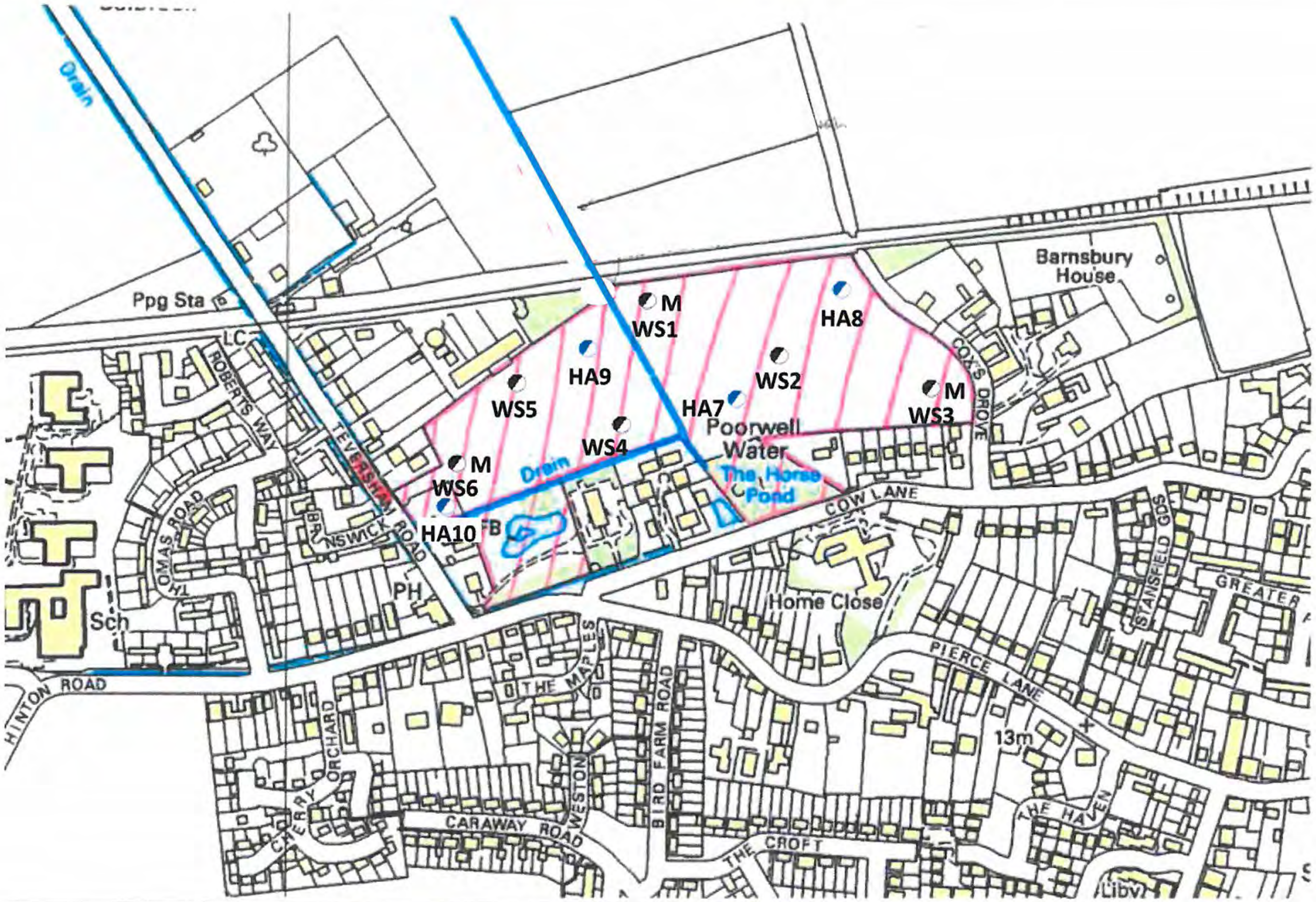
love every drop
anglianwater

Manhole Reference	Easting	Northing	Liquid Type	Cover Level	Invert Level	Depth to Invert
0201	551040	256302	F	-	-	-
0301	551041	256363	F	11.753	8.873	2.88
0302	551035	256341	F	-	-	-
0501	551031	256582	F	10.198	6.956	3.242
0502	551072	256521	F	10.492	7.122	3.37
1301	551146	256389	F	11.225	8.175	3.05
1302	551102	256374	F	11.446	8.486	2.96
1401	551108	256469	F	10.394	7.291	3.103
1402	551145	256409	F	10.998	7.471	3.527
1403	551171	256403	F	11.234	7.544	3.69
2401	551257	256427	F	11.04	7.76	3.28
2402	551266	256415	F	11.348	8.684	2.664
3301	551358	256393	F	11.951	9.165	2.786
3302	551381	256383	F	11.963	9.263	2.7
3303	551320	256346	F	-	-	-
3304	551327	256400	F	-	-	1.42
3401	551343	256456	F	11.082	7.992	3.09
4301	551409	256355	F	12.213	9.464	2.749
4302	551434	256342	F	12.344	9.565	2.779
4303	551467	256342	F	12.268	9.72	2.548
4304	551482	256351	F	12.29	9.781	-
4401	551421	256481	F	10.849	8.199	2.65
5301	551507	256383	F	12.402	9.955	2.447
5302	551533	256385	F	12.631	10.077	2.554
5303	551589	256366	F	12.463	10.296	2.167
5304	551537	256323	F	-	-	-
5501	551511	256515	F	10.637	8.437	2.2
5502	551590	256506	F	10.735	8.635	2.1
5503	551592	256599	F	-	-	-
5601	551580	256629	F	-	-	-
5602	551530	256668	F	-	-	-
6301	551630	256345	F	12.576	10.464	2.112
6401	551684	256432	F	-	-	-
6501	551638	256508	F	10.556	8.876	1.68
6502	551697	256512	F	10.753	9.193	1.56
7301	551784	256377	F	-	-	-
7401	551703	256479	F	-	-	-
7501	551701	256513	F	-	-	-
7502	551742	256528	F	11.392	9.452	1.94
8401	551827	256424	F	-	-	-
8402	551800	256433	F	-	-	-
8501	551841	256510	F	11.936	9.976	1.96
9301	550971	256348	F	11.567	9.357	2.21
9302	550932	256346	F	11.561	9.601	1.96
9601	550965	256684	F	10.212	6.602	3.61
9602	550997	256633	F	10.362	6.762	3.6

Manhole Reference	Easting	Northing	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Easting	Northing	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Easting	Northing	Liquid Type	Cover Level	Invert Level	Depth to Invert



LEGEND:

Windowless sample locations — Hand auger locations

M — Monitoring well

REMARKS: Fieldwork carried out on 25 May 2014; Initial Phase of works.

N

geosphere environmental ltd

Brightwell Barn, Ipswich Road, Brightwell, Suffolk, IP10 0BJ
T 01603 298 076 F 01603 289 075
E info@geosphere-environmental.co.uk

SITE	TITLE	REPORT NO.	DRAWING NO.	DATE
Teversham Road, Fulbourn, Cambridgeshire	Exploratory Hole Location Plan	638,SI	004 / Rev 0	29 July 2014
	CLIENT	**DRAWN BY**	**CHECKED**	**SCALE**
	Hutchison Whampoa Ltd	LF	AD	Not to scale

geosphere environmental ltd

APPENDIX 7 – GAS AND GROUNDWATER MONITORING DATA

GROUND GAS AND GROUNDWATER MONITORING DATA

geosphere environmental ltd

Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

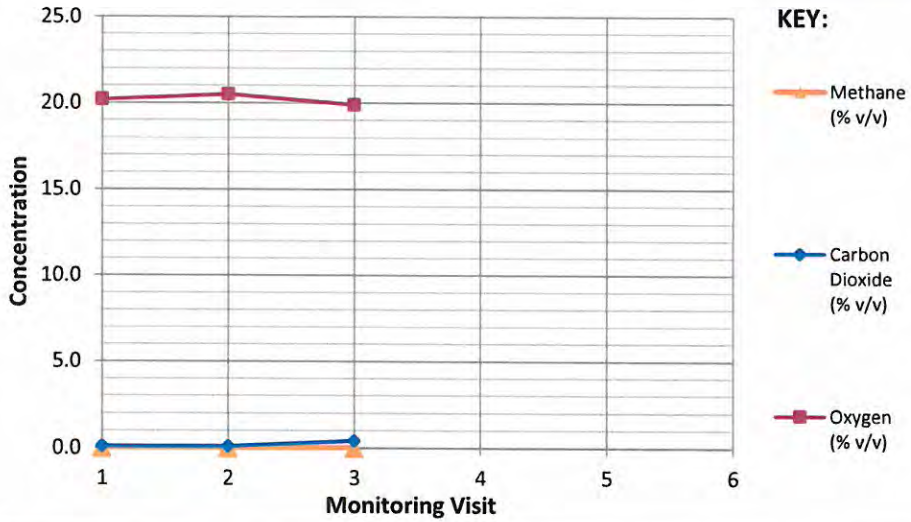
Exploratory Hole Location	WS1	Date of Installation	29/05/2014

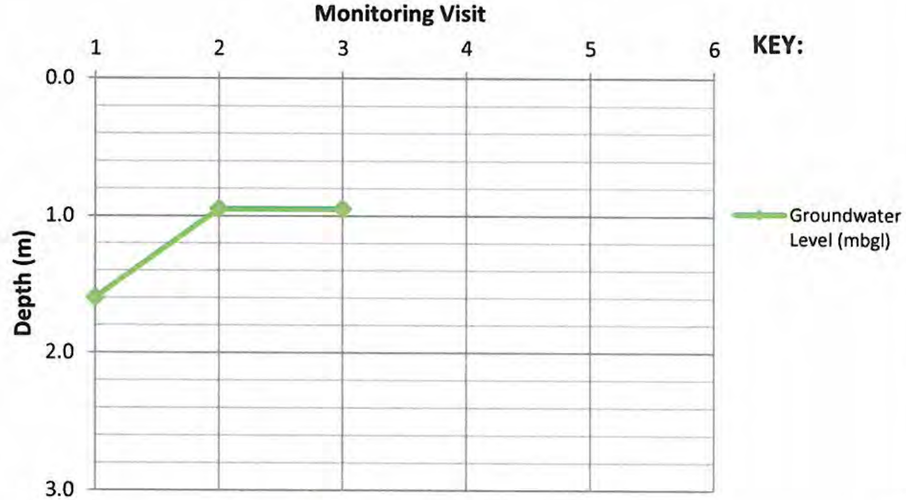
Return Visit #	Monitoring Date	Atmospheric Pressure (mb)	Methane Content (% v/v)	Methane Content (% LEL)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Flow Rate (l/hr)	Water Level (mbgl)	Comments
1st visit	06/06/2014	1012	<0.1	<2	0.1	20.2	+0.3	1.60	Hot, sunny, dry and calm
2nd visit	24/06/2014	1018	<0.1	<2	0.1	20.5	0.0	0.95	Warm, cloudy, dry and calm
3rd visit	28/07/2014	1014	<0.1	<2	0.4	19.9	-0.4	0.95	Warm, overcast, damp and breezy
4th visit									
5th visit									
6th visit									

Instrument Used: GA2000 gas analyser

NOTE: **n/a** Not applicable; **nm** Not measured

REMARKS:





SITE	REPORT	DATE
Land off Teversham Road, Fulbourn, Cambridgeshire	638,SI	28 July 2014

GROUND GAS AND GROUNDWATER MONITORING DATA

geosphere environmental ltd

Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

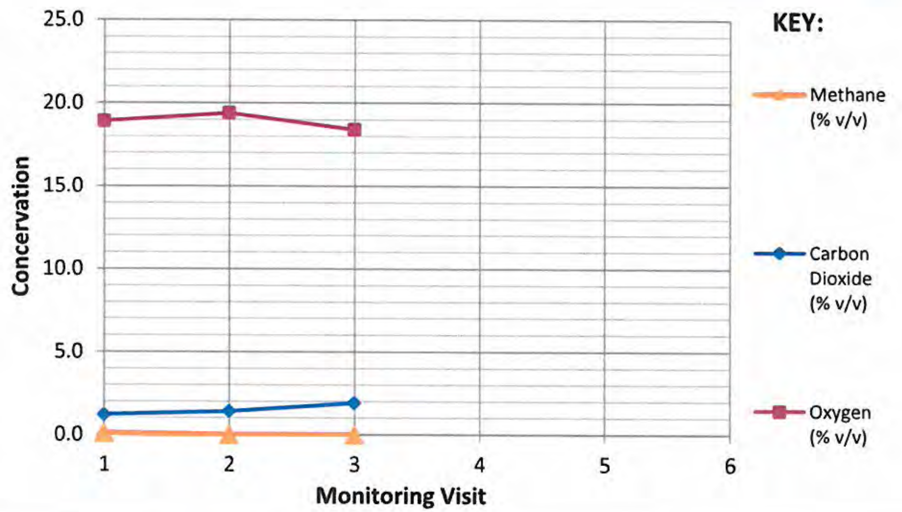
Exploratory Hole Location WS3 — **Date of Installation** 29/05/2014

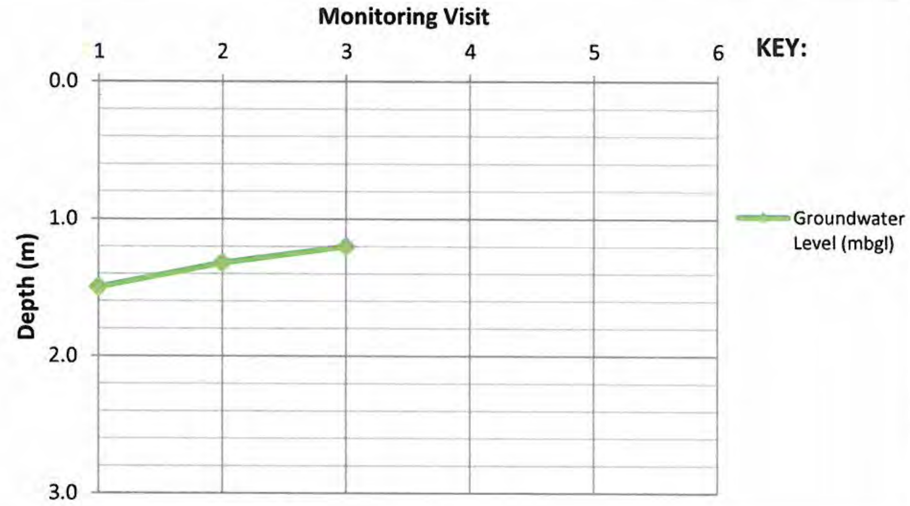
Return Visit #	Monitoring Date	Atmospheric Pressure (mb)	Methane Content (% v/v)	Methane Content (% LEL)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Flow Rate (l/hr)	Water Level (mbgl)	Comments
1st visit	06/06/2014	1012	0.1	2	1.2	18.9	+0.0	1.50	Hot, sunny, dry and calm
2nd visit	24/06/2014	1017	<0.1	<2	1.4	19.4	-0.1	1.32	Warm, cloudy, dry and calm
3rd visit	28/07/2014	1014	<0.1	<2	1.9	18.4	-0.4	1.20	Warm, overcast, damp and breezy
4th visit									
5th visit									
6th visit									

Instrument Used: GA2000 gas analyser

REMARKS:

NOTE: n/a Not applicable; nm Not measured





SITE
Land off Teversham Road, Fulbourn, Cambridgeshire

REPORT
638,SI

DATE
28 July 2014

C:\Geocloud\Shared\GeoCloud\Reports\638,SI, Various, Fulbourn,Hutchingson Whampoa,7-5-14\GEL Report\Gas\638,SI - Gas Monitoring, 3 visits

GROUND GAS AND GROUNDWATER MONITORING DATA

geosphere environmental ltd

Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

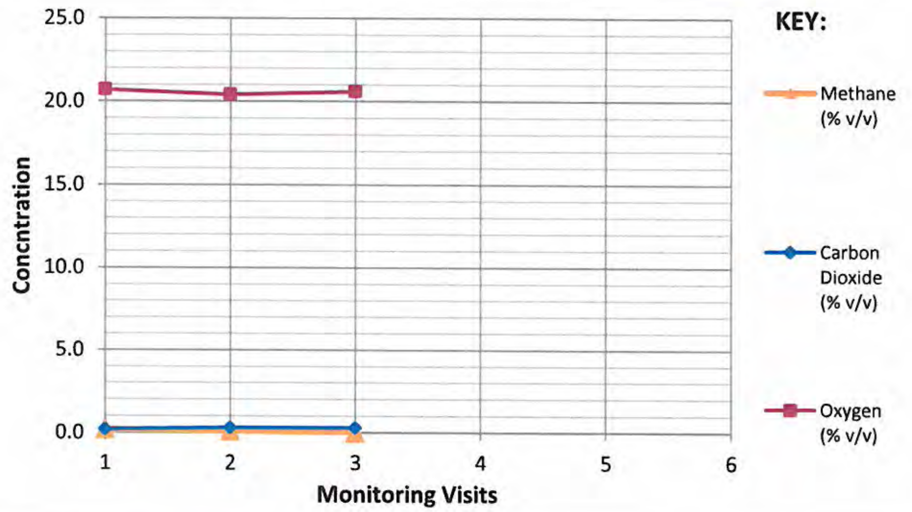
Exploratory Hole Location WS6 **Date of Installation** 29/05/2014

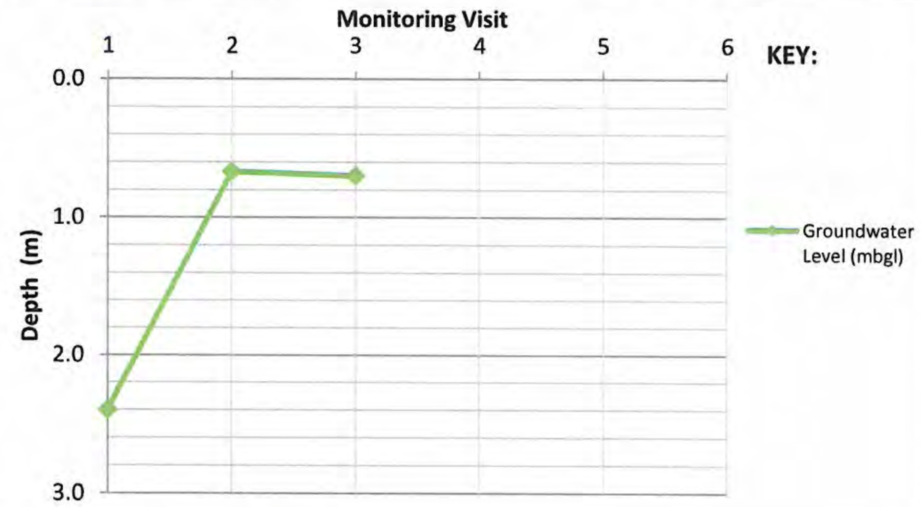
Return Visit #	Monitoring Date	Atmospheric Pressure (mb)	Methane Content (% v/v)	Methane Content (% LEL)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Flow Rate (l/hr)	Water Level (mbgl)	Comments
1st visit	06/06/2014	1013	0.2	4	0.2	20.7	-0.0	2.40	Hot, sunny, dry and calm
2nd visit	24/06/2014	1018	0.1	2	0.3	20.4	-0.2	0.67	Warm, cloudy, dry and calm
3rd visit	28/07/2014	1014	<0.1	<2	0.3	20.6	-0.3	0.70	Warm, overcast, damp and breezy
4th visit									
5th visit									
6th visit									

Instrument Used: GA2000 gas analyser

REMARKS:

NOTE: **n/a** Not applicable; **nm** Not measured

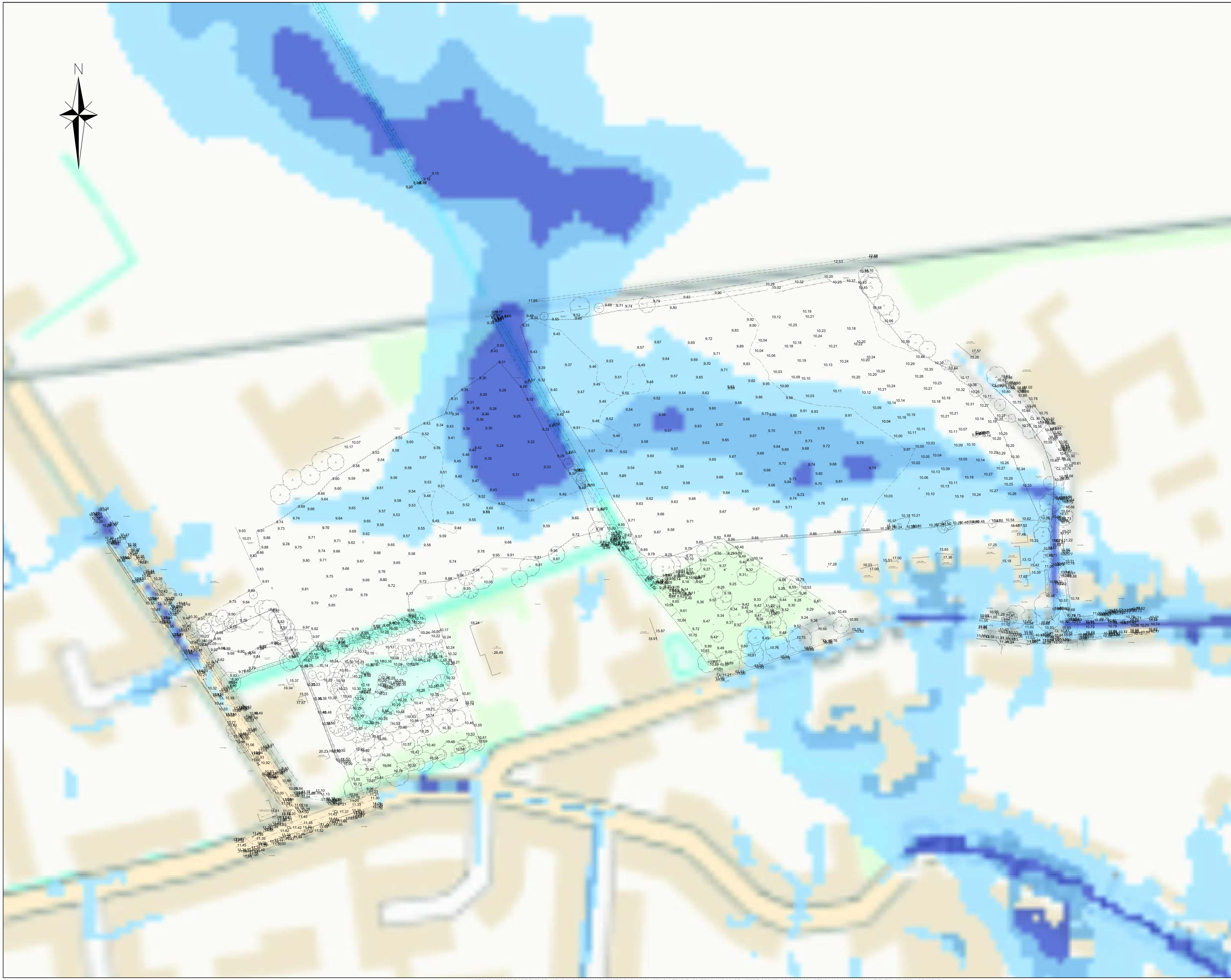




SITE Land off Teversham Road, Fulbourn, Cambridgeshire

REPORT 638,SI

DATE 28 July 2014



KEY:

- High
- Medium
- Low
- Very Low

REV	DESCRIPTION	DE	DR	CH	PA	DATE
.	.	.	.	.	.	.

DESIGNED BY	DRAWN BY	CHECKED BY	PASSED BY
-	JA-M	RBT	-

SCALES @ A1 SIZE	DATE	ISSUE STATUS
1:1000	05/06/2014	PRELIMINARY

PROJECT TITLE

LAND AT TEVERSHAM ROAD, FULBOURN, CAMBS

DRAWING TITLE

ENVIRONMENT AGENCY SURFACE WATER FLOOD MAP

CLIENT

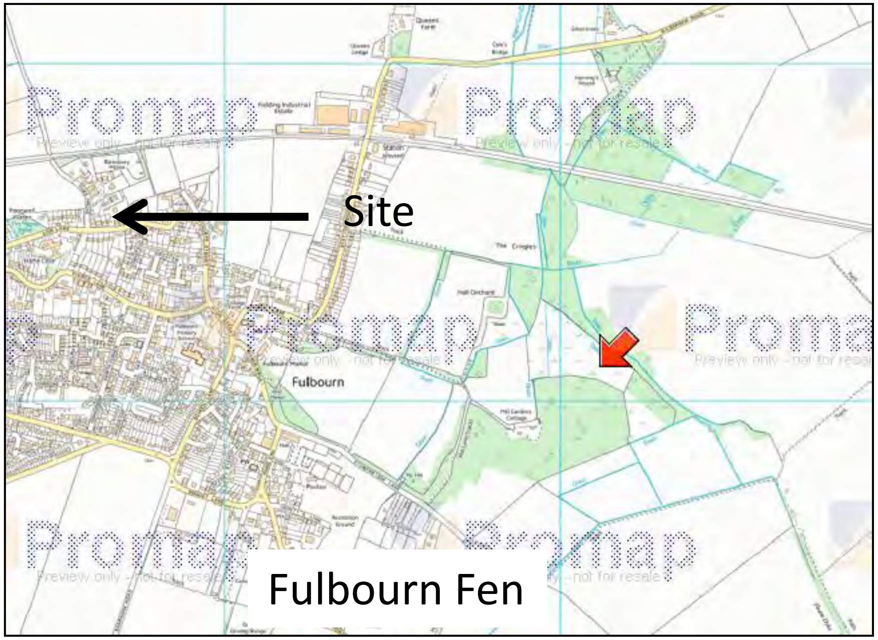
CASTLEFIELD INTERNATIONAL LTD

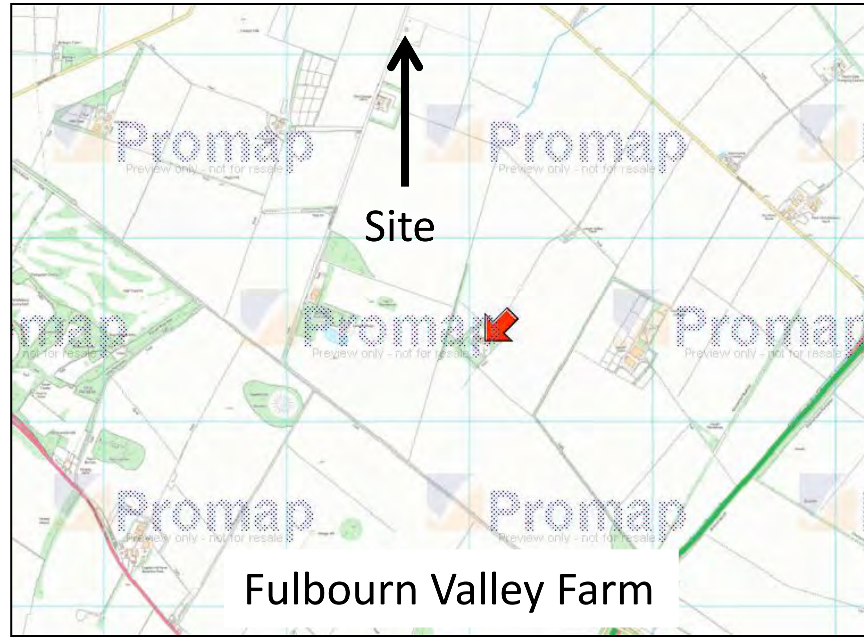
CANNON
CONSULTING ENGINEERS
Highways, Transport & Infrastructure Planning

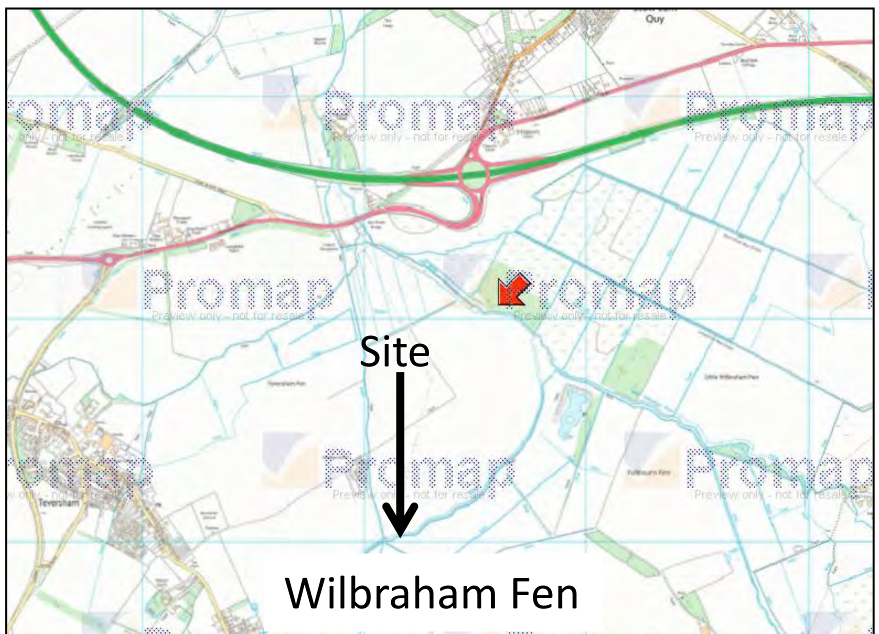
Cannon Consulting Engineers
Cambridge House, Kentford, Newmarket, Cambs, CB8 7PN
Tel: +44 (0)1638 555 107 Fax: +44 (0)1638 555 106
info@cannonce.co.uk www.cannonce.co.uk

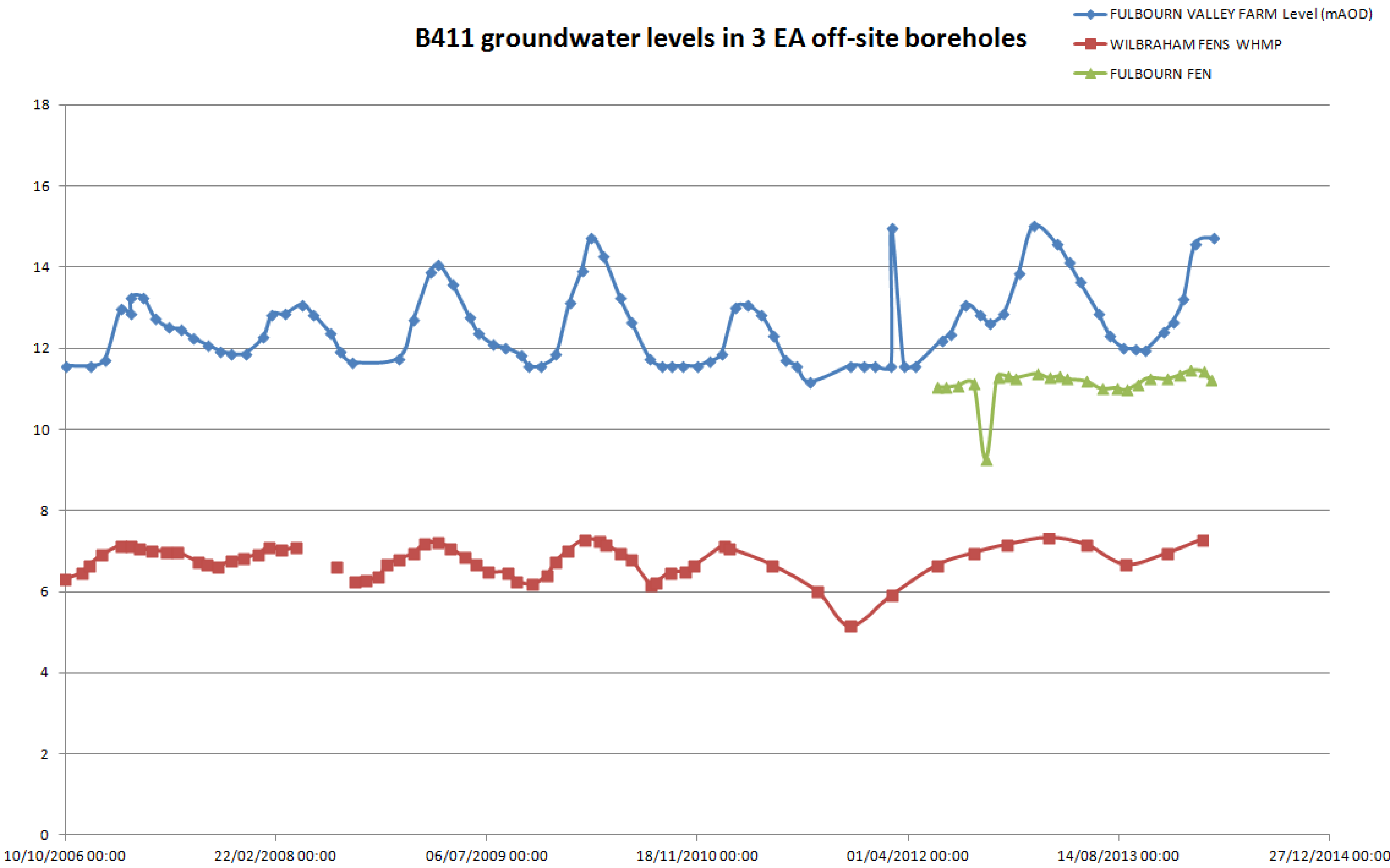
DRAWING NUMBER	REV.
B411 / 002	-

EA groundwater borehole locations



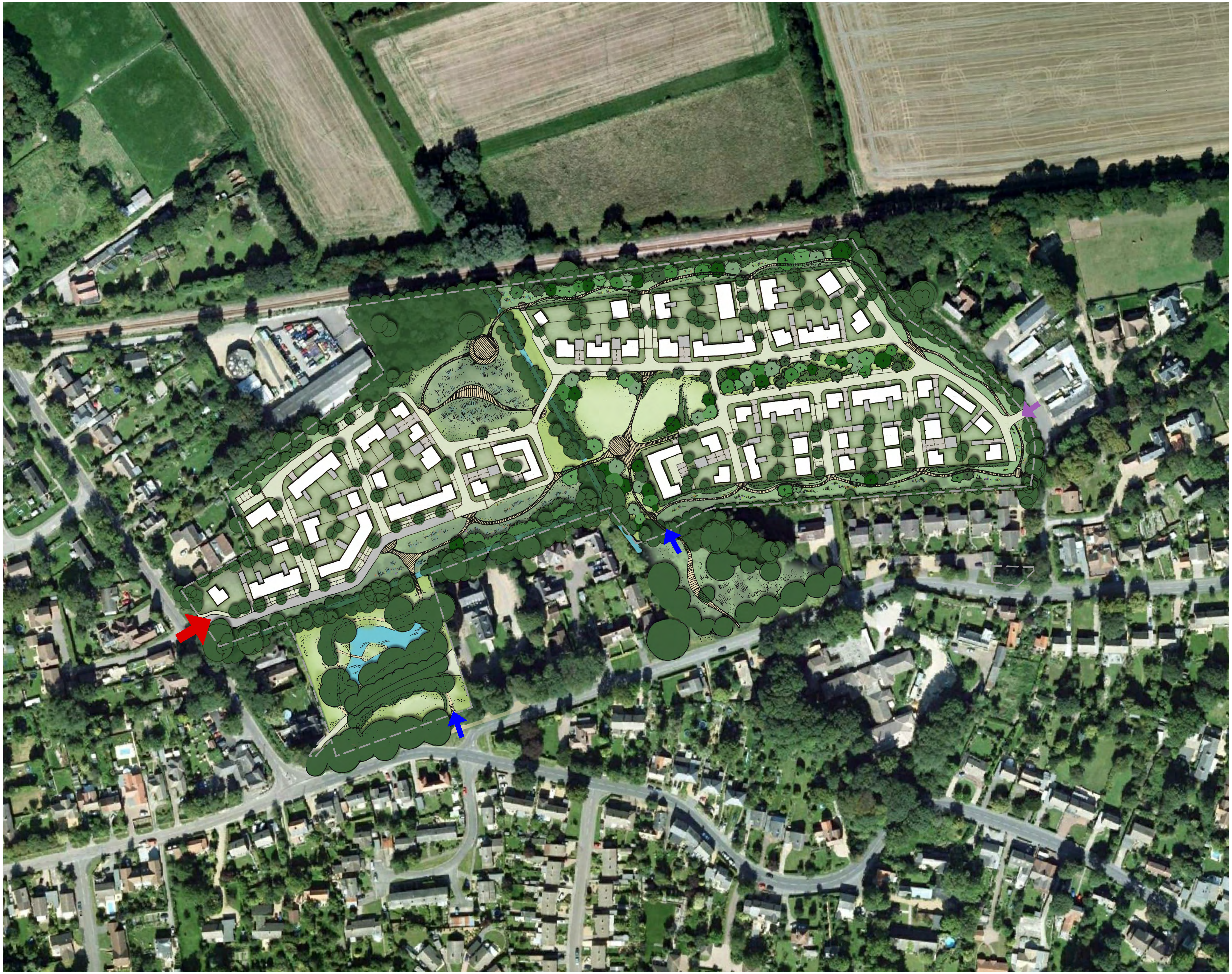





B411 groundwater levels in 3 EA off-site boreholes
FULBOURN VALLEY FARM Level (mAOD)
WILBRAHAM FENS WHMP
FULBOURN FEN
18
16
14
12
10
8
6
4
2
0
10/10/2006 00:00
22/02/2008 00:00
06/07/2009 00:00
18/11/2010 00:00
01/04/2012 00:00
14/08/2013 00:00
27/12/2014 00:00

B Proposed Site

Proposed Development Layout
Surface Water Management Plan
WinDes Simulations – Basin A
WinDes Simulations –Basin B
WinDes Simulations –Basin C
Greenfield Runoff Rates



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The scaling of this drawing cannot be assured

Revision	Date	Drn	Ckd
A	25.07.14	HS	CA

N

LEGEND

- Site Boundary
- Dwellings
- Rear Gardens
- Garages
- Primary Vehicular Access
- Emergency Access
- Pedestrian Access
- Primary Street
- Shared Surface
- Neighbourhood Green
- Boardwalk
- Existing Stream
- Pond
- Marsh
- Structural Planting

Project
Land at Teversham Road Fulbourn

Drawing Title
Illustrative Layout

Date	Scale	Drawn by	Check by
16.06.14	1:1000@A1	HS	CA
Project No	**Drawing No**		**Revision**
22430	M03		A

0 10 20 30 40 50m

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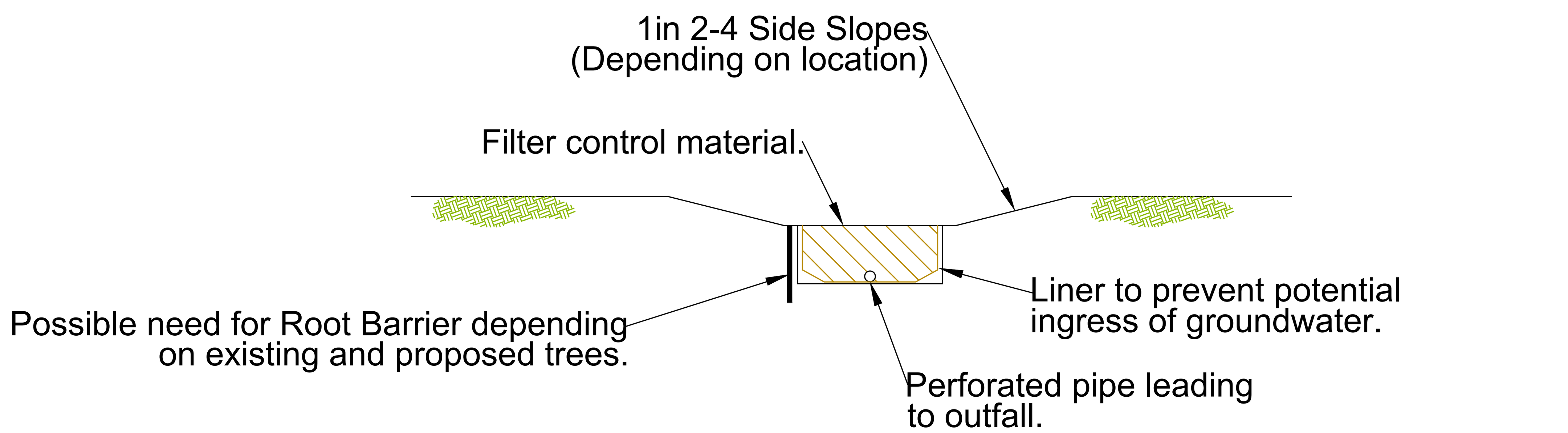
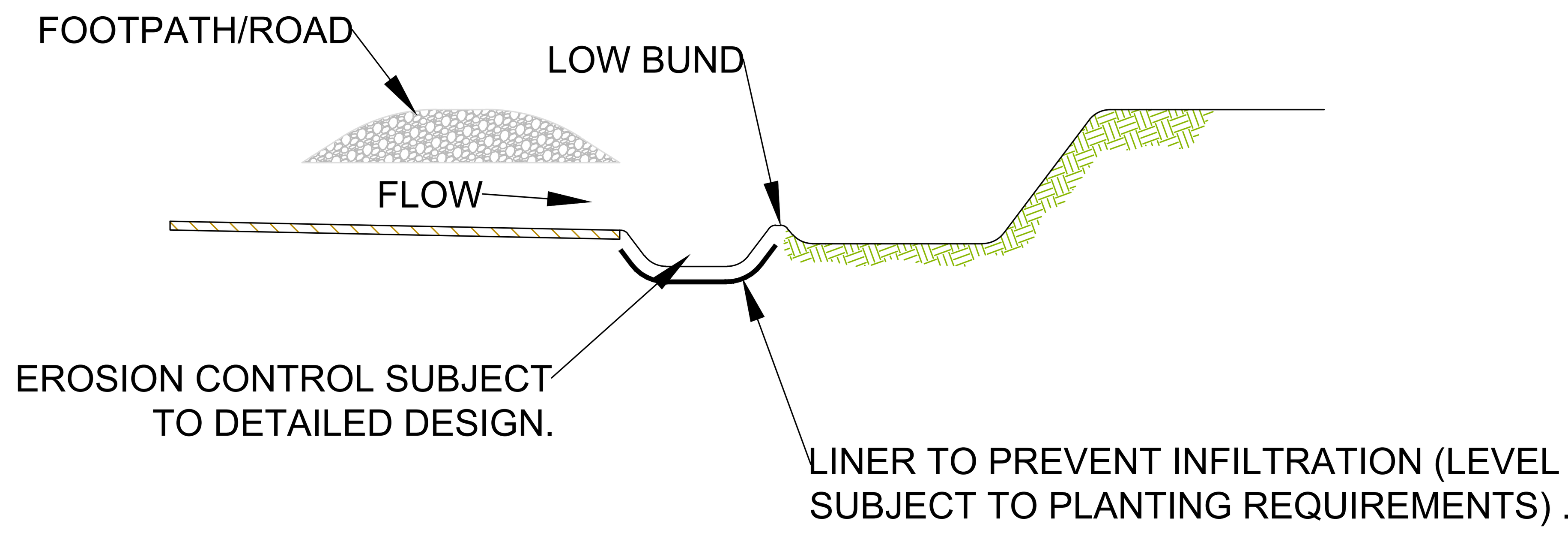
K:\22000-22999\22400-22499\22430 - Cow Lane, Fulbourn\A4 - Dwgs & Registers\Architecture\Working\22430 M03A Illustrative Layout.dwg - A1

KEY:

- SITE BOUNDARY
- POTENTIAL NEW WATERCOURSE ROUTE
- MAINTAINED SURFACE WATER FLOOD STORAGE AND ROUTE FOR SITE RUN-ON
- BIORETENTION AREAS
- FILTER CONTROL
- OUTFALL



TYPICAL SECTION THROUGH DOWNSTREAM END OF BIORETENTION AREA



TYPICAL HIGHWAY RILL/BIORETENTION AREA INTERACTION

REV	DESCRIPTION	DE	DR	CH	PA	DATE

DESIGNED BY	DRAWN BY	CHECKED BY	PASSED BY
-	DP	JH	-

SCALES @ A1 SIZE	DATE	ISSUE STATUS
N.T.S.	30/07/2014	PRELIMINARY

PROJECT TITLE

LAND AT TEVERSHAM ROAD, FULBOURN, CAMBS

DRAWING TITLE

SURFACE WATER MANAGEMENT AND SURFACE WATER FLOOD MANAGEMENT PLAN

CLIENT

CASTLEFIELD INTERNATIONAL LTD

CANNON CONSULTING ENGINEERS
Highways, Transport & Infrastructure Planning

Cannon Consulting Engineers
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Tel: +44 (0)1638 555 107 Fax: +44 (0)1638 555 106
info@cannonce.co.uk www.cannonce.co.uk

DRAWING NUMBER	REV.
B411 - 004	-

Summary of Results for 100 year Return Period (+30%)

Half Drain Time exceeds 7 days.

Outflow is too low. Design is unsatisfactory.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.594	0.194	0.0	0.1	0.0	0.1	298.5	O K
30 min Summer	99.617	0.217	0.0	0.1	0.0	0.1	336.4	O K
60 min Summer	99.642	0.242	0.0	0.1	0.0	0.1	379.2	O K
120 min Summer	99.671	0.271	0.0	0.1	0.0	0.1	427.1	O K
180 min Summer	99.689	0.289	0.0	0.1	0.0	0.1	457.8	O K
240 min Summer	99.702	0.302	0.0	0.1	0.0	0.1	480.9	Flood Risk
360 min Summer	99.721	0.321	0.0	0.1	0.0	0.1	515.1	Flood Risk
480 min Summer	99.736	0.336	0.0	0.1	0.0	0.1	540.7	Flood Risk
600 min Summer	99.747	0.347	0.0	0.1	0.0	0.1	561.3	Flood Risk
720 min Summer	99.757	0.357	0.0	0.1	0.0	0.1	578.5	Flood Risk
960 min Summer	99.773	0.373	0.0	0.1	0.0	0.1	607.5	Flood Risk
1440 min Summer	99.796	0.396	0.0	0.2	0.0	0.2	650.0	Flood Risk
2160 min Summer	99.820	0.420	0.0	0.2	0.0	0.2	694.1	Flood Risk
2880 min Summer	99.837	0.437	0.0	0.2	0.0	0.2	725.9	Flood Risk
4320 min Summer	99.856	0.456	0.0	0.2	0.0	0.2	761.3	Flood Risk
5760 min Summer	99.868	0.468	0.0	0.2	0.0	0.2	784.8	Flood Risk
7200 min Summer	99.877	0.477	0.0	0.2	0.0	0.2	801.6	Flood Risk
8640 min Summer	99.883	0.483	0.0	0.2	0.0	0.2	813.9	Flood Risk
10080 min Summer	99.888	0.488	0.0	0.2	0.0	0.2	823.1	Flood Risk
15 min Winter	99.616	0.216	0.0	0.1	0.0	0.1	334.3	O K
30 min Winter	99.641	0.241	0.0	0.1	0.0	0.1	376.8	O K
60 min Winter	99.669	0.269	0.0	0.1	0.0	0.1	424.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	206.868	0.0	9.8	0.0	31
30 min Summer	116.611	0.0	10.1	0.0	46
60 min Summer	65.734	0.0	21.0	0.0	76
120 min Summer	37.054	0.0	21.8	0.0	136
180 min Summer	26.498	0.0	22.2	0.0	196
240 min Summer	20.887	0.0	22.5	0.0	256
360 min Summer	14.937	0.0	22.9	0.0	376
480 min Summer	11.774	0.0	23.1	0.0	496
600 min Summer	9.790	0.0	23.3	0.0	616
720 min Summer	8.420	0.0	23.3	0.0	736
960 min Summer	6.647	0.0	23.3	0.0	976
1440 min Summer	4.763	0.0	23.0	0.0	1454
2160 min Summer	3.413	0.0	48.4	0.0	2176
2880 min Summer	2.694	0.0	47.7	0.0	2892
4320 min Summer	1.907	0.0	45.4	0.0	4332
5760 min Summer	1.493	0.0	98.0	0.0	5776
7200 min Summer	1.234	0.0	95.7	0.0	7208
8640 min Summer	1.057	0.0	93.0	0.0	8648
10080 min Summer	0.927	0.0	90.0	0.0	10088
15 min Winter	206.868	0.0	10.1	0.0	31
30 min Winter	116.611	0.0	10.5	0.0	46
60 min Winter	65.734	0.0	21.8	0.0	76

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	99.700	0.300	0.0	0.1	0.0	0.1	478.5	Flood Risk
180 min Winter	99.720	0.320	0.0	0.1	0.0	0.1	512.9	Flood Risk
240 min Winter	99.735	0.335	0.0	0.1	0.0	0.1	538.7	Flood Risk
360 min Winter	99.756	0.356	0.0	0.1	0.0	0.1	577.1	Flood Risk
480 min Winter	99.772	0.372	0.0	0.1	0.0	0.1	605.9	Flood Risk
600 min Winter	99.785	0.385	0.0	0.1	0.0	0.1	629.0	Flood Risk
720 min Winter	99.795	0.395	0.0	0.2	0.0	0.2	648.4	Flood Risk
960 min Winter	99.813	0.413	0.0	0.2	0.0	0.2	681.0	Flood Risk
1440 min Winter	99.838	0.438	0.0	0.2	0.0	0.2	728.9	Flood Risk
2160 min Winter	99.865	0.465	0.0	0.2	0.0	0.2	778.7	Flood Risk
2880 min Winter	99.884	0.484	0.0	0.2	0.0	0.2	814.9	Flood Risk
4320 min Winter	99.904	0.504	0.0	0.2	0.0	0.2	855.4	Flood Risk
5760 min Winter	99.918	0.518	0.0	0.2	0.0	0.2	882.8	Flood Risk
7200 min Winter	99.928	0.528	0.0	0.2	0.0	0.2	902.6	Flood Risk
8640 min Winter	99.936	0.536	0.0	0.2	0.0	0.2	917.5	Flood Risk
10080 min Winter	99.941	0.541	0.0	0.2	0.0	0.2	928.8	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	37.054	0.0	22.7	0.0	136
180 min Winter	26.498	0.0	23.2	0.0	194
240 min Winter	20.887	0.0	23.5	0.0	254
360 min Winter	14.937	0.0	23.9	0.0	374
480 min Winter	11.774	0.0	24.2	0.0	492
600 min Winter	9.790	0.0	24.3	0.0	612
720 min Winter	8.420	0.0	24.3	0.0	730
960 min Winter	6.647	0.0	24.3	0.0	970
1440 min Winter	4.763	0.0	23.9	0.0	1446
2160 min Winter	3.413	0.0	50.6	0.0	2164
2880 min Winter	2.694	0.0	49.9	0.0	2868
4320 min Winter	1.907	0.0	47.3	0.0	4288
5760 min Winter	1.493	0.0	102.7	0.0	5712
7200 min Winter	1.234	0.0	100.2	0.0	7136
8640 min Winter	1.057	0.0	97.2	0.0	8560
10080 min Winter	0.927	0.0	93.8	0.0	9984

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 550950 257200 TL 50950 57200
C (1km)	-0.025
D1 (1km)	0.288
D2 (1km)	0.293
D3 (1km)	0.263
E (1km)	0.312
F (1km)	2.488
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.770

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.200	4	8	0.200	8	12	0.200	12	16	0.170

Model Details

Storage is Online Cover Level (m) 100.000

Complex Structure

Bio-Retention Area

Invert Level (m) 99.400 Porosity 1.00

Depth (m)	**Area (m²)**	**Depth (m)**	**Area (m²)**
0.000	1448.0	0.600	2062.0

Filtration Outflow Control

Permeability Coefficient (m/s) 0.000010 Area (m²) 80.000
Safety Factor 10.000 Invert Level (m) 99.400
Bed Depth (m) 0.450

Weir Overflow Control

Discharge Coef 0.544 Width (m) 5.000 Invert Level (m) 100.000

Summary of Results for 100 year Return Period (+30%)

Half Drain Time exceeds 7 days.

Outflow is too low. Design is unsatisfactory.

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	99.633	0.233	0.1	0.0	0.1	186.1	O K
30 min Summer	99.656	0.256	0.1	0.0	0.1	209.7	O K
60 min Summer	99.681	0.281	0.1	0.0	0.1	236.3	O K
120 min Summer	99.708	0.308	0.1	0.0	0.1	266.2	Flood Risk
180 min Summer	99.724	0.324	0.1	0.0	0.1	285.4	Flood Risk
240 min Summer	99.737	0.337	0.1	0.0	0.1	299.7	Flood Risk
360 min Summer	99.754	0.354	0.1	0.0	0.1	321.0	Flood Risk
480 min Summer	99.767	0.367	0.1	0.0	0.1	337.0	Flood Risk
600 min Summer	99.777	0.377	0.1	0.0	0.1	349.8	Flood Risk
720 min Summer	99.785	0.385	0.1	0.0	0.1	360.5	Flood Risk
960 min Summer	99.799	0.399	0.1	0.0	0.1	378.5	Flood Risk
1440 min Summer	99.818	0.418	0.1	0.0	0.1	404.9	Flood Risk
2160 min Summer	99.838	0.438	0.1	0.0	0.1	432.3	Flood Risk
2880 min Summer	99.852	0.452	0.1	0.0	0.1	452.1	Flood Risk
4320 min Summer	99.867	0.467	0.1	0.0	0.1	474.0	Flood Risk
5760 min Summer	99.876	0.476	0.1	0.0	0.1	488.5	Flood Risk
7200 min Summer	99.883	0.483	0.1	0.0	0.1	498.7	Flood Risk
8640 min Summer	99.888	0.488	0.1	0.0	0.1	506.3	Flood Risk
10080 min Summer	99.892	0.492	0.1	0.0	0.1	511.9	Flood Risk
15 min Winter	99.655	0.255	0.1	0.0	0.1	208.4	O K
30 min Winter	99.680	0.280	0.1	0.0	0.1	234.9	O K
60 min Winter	99.707	0.307	0.1	0.0	0.1	264.7	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	206.868	0.0	6.5	0.0	31
30 min Summer	116.611	0.0	6.7	0.0	46
60 min Summer	65.734	0.0	13.9	0.0	76
120 min Summer	37.054	0.0	14.3	0.0	136
180 min Summer	26.498	0.0	14.6	0.0	196
240 min Summer	20.887	0.0	14.7	0.0	256
360 min Summer	14.937	0.0	14.9	0.0	376
480 min Summer	11.774	0.0	15.0	0.0	496
600 min Summer	9.790	0.0	15.1	0.0	616
720 min Summer	8.420	0.0	15.1	0.0	736
960 min Summer	6.647	0.0	15.1	0.0	976
1440 min Summer	4.763	0.0	14.8	0.0	1454
2160 min Summer	3.413	0.0	31.0	0.0	2176
2880 min Summer	2.694	0.0	30.6	0.0	2896
4320 min Summer	1.907	0.0	29.1	0.0	4332
5760 min Summer	1.493	0.0	62.4	0.0	5776
7200 min Summer	1.234	0.0	60.9	0.0	7208
8640 min Summer	1.057	0.0	59.3	0.0	8648
10080 min Summer	0.927	0.0	57.4	0.0	10088
15 min Winter	206.868	0.0	6.7	0.0	31
30 min Winter	116.611	0.0	6.9	0.0	46
60 min Winter	65.734	0.0	14.3	0.0	76

Summary of Results for 100 year Return Period (+30%)

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	99.735	0.335	0.1	0.0	0.1	298.2	Flood Risk
180 min Winter	99.753	0.353	0.1	0.0	0.1	319.7	Flood Risk
240 min Winter	99.766	0.366	0.1	0.0	0.1	335.8	Flood Risk
360 min Winter	99.785	0.385	0.1	0.0	0.1	359.7	Flood Risk
480 min Winter	99.798	0.398	0.1	0.0	0.1	377.6	Flood Risk
600 min Winter	99.809	0.409	0.1	0.0	0.1	392.0	Flood Risk
720 min Winter	99.818	0.418	0.1	0.0	0.1	404.1	Flood Risk
960 min Winter	99.832	0.432	0.1	0.0	0.1	424.4	Flood Risk
1440 min Winter	99.853	0.453	0.1	0.0	0.1	454.1	Flood Risk
2160 min Winter	99.874	0.474	0.1	0.0	0.1	485.1	Flood Risk
2880 min Winter	99.889	0.489	0.1	0.0	0.1	507.6	Flood Risk
4320 min Winter	99.905	0.505	0.1	0.0	0.1	532.7	Flood Risk
5760 min Winter	99.916	0.516	0.1	0.0	0.1	549.6	Flood Risk
7200 min Winter	99.923	0.523	0.1	0.0	0.1	561.9	Flood Risk
8640 min Winter	99.929	0.529	0.1	0.0	0.1	571.0	Flood Risk
10080 min Winter	99.933	0.533	0.1	0.0	0.1	578.0	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
120 min Winter	37.054	0.0	14.8	0.0	136
180 min Winter	26.498	0.0	15.1	0.0	194
240 min Winter	20.887	0.0	15.3	0.0	254
360 min Winter	14.937	0.0	15.5	0.0	374
480 min Winter	11.774	0.0	15.6	0.0	492
600 min Winter	9.790	0.0	15.7	0.0	612
720 min Winter	8.420	0.0	15.7	0.0	732
960 min Winter	6.647	0.0	15.6	0.0	970
1440 min Winter	4.763	0.0	15.3	0.0	1446
2160 min Winter	3.413	0.0	32.2	0.0	2164
2880 min Winter	2.694	0.0	31.7	0.0	2868
4320 min Winter	1.907	0.0	30.1	0.0	4288
5760 min Winter	1.493	0.0	64.8	0.0	5712
7200 min Winter	1.234	0.0	63.3	0.0	7136
8640 min Winter	1.057	0.0	61.4	0.0	8560
10080 min Winter	0.927	0.0	59.5	0.0	9984

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 550950 257200 TL 50950 57200
C (1km)	-0.025
D1 (1km)	0.288
D2 (1km)	0.293
D3 (1km)	0.263
E (1km)	0.312
F (1km)	2.488
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.480

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.120	4	8	0.120	8	12	0.120	12	16	0.120

Model Details

Storage is Online Cover Level (m) 100.000

Bio-Retention Area Structure

Invert Level (m) 99.400 Porosity 1.00

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	620.0	0.300	1120.0	0.600	1820.0

Filtration Outflow Control

Permeability Coefficient (m/s) 0.000010 Area (m²) 50.000
Safety Factor 10.000 Invert Level (m) 99.400
Bed Depth (m) 0.450

Weir Overflow Control

Discharge Coef 0.544 Width (m) 5.000 Invert Level (m) 100.000

Summary of Results for 100 year Return Period (+30%)

Half Drain Time exceeds 7 days.

Outflow is too low. Design is unsatisfactory.

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	99.648	0.248	0.1	232.6	O K
30 min Summer	99.673	0.273	0.1	262.2	O K
60 min Summer	99.701	0.301	0.1	295.5	Flood Risk
120 min Summer	99.730	0.330	0.1	332.9	Flood Risk
180 min Summer	99.749	0.349	0.1	356.9	Flood Risk
240 min Summer	99.762	0.362	0.1	374.9	Flood Risk
360 min Summer	99.782	0.382	0.1	401.7	Flood Risk
480 min Summer	99.796	0.396	0.1	421.7	Flood Risk
600 min Summer	99.807	0.407	0.1	437.8	Flood Risk
720 min Summer	99.817	0.417	0.1	451.4	Flood Risk
960 min Summer	99.832	0.432	0.1	474.1	Flood Risk
1440 min Summer	99.854	0.454	0.1	507.6	Flood Risk
2160 min Summer	99.877	0.477	0.1	542.6	Flood Risk
2880 min Summer	99.893	0.493	0.1	568.1	Flood Risk
4320 min Summer	99.910	0.510	0.1	596.9	Flood Risk
5760 min Summer	99.922	0.522	0.1	616.5	Flood Risk
7200 min Summer	99.931	0.531	0.1	630.9	Flood Risk
8640 min Summer	99.937	0.537	0.1	641.8	Flood Risk
10080 min Summer	99.942	0.542	0.1	650.2	Flood Risk
15 min Winter	99.672	0.272	0.1	260.5	O K
30 min Winter	99.699	0.299	0.1	293.7	O K
60 min Winter	99.729	0.329	0.1	331.0	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	206.868	0.0	6.6	31
30 min Summer	116.611	0.0	6.9	46
60 min Summer	65.734	0.0	14.2	76
120 min Summer	37.054	0.0	14.7	136
180 min Summer	26.498	0.0	15.0	196
240 min Summer	20.887	0.0	15.2	256
360 min Summer	14.937	0.0	15.4	376
480 min Summer	11.774	0.0	15.6	496
600 min Summer	9.790	0.0	15.6	616
720 min Summer	8.420	0.0	15.6	736
960 min Summer	6.647	0.0	15.6	976
1440 min Summer	4.763	0.0	15.3	1456
2160 min Summer	3.413	0.0	32.2	2176
2880 min Summer	2.694	0.0	31.7	2896
4320 min Summer	1.907	0.0	30.1	4332
5760 min Summer	1.493	0.0	65.1	5776
7200 min Summer	1.234	0.0	63.5	7216
8640 min Summer	1.057	0.0	61.6	8648
10080 min Summer	0.927	0.0	59.6	10088
15 min Winter	206.868	0.0	6.9	31
30 min Winter	116.611	0.0	7.1	46
60 min Winter	65.734	0.0	14.8	76

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
120 min Winter	99.761	0.361	0.1	372.9	Flood Risk
180 min Winter	99.780	0.380	0.1	399.8	Flood Risk
240 min Winter	99.795	0.395	0.1	420.0	Flood Risk
360 min Winter	99.816	0.416	0.1	450.0	Flood Risk
480 min Winter	99.831	0.431	0.1	472.5	Flood Risk
600 min Winter	99.843	0.443	0.1	490.6	Flood Risk
720 min Winter	99.853	0.453	0.1	505.8	Flood Risk
960 min Winter	99.870	0.470	0.1	531.4	Flood Risk
1440 min Winter	99.893	0.493	0.1	569.2	Flood Risk
2160 min Winter	99.918	0.518	0.1	608.6	Flood Risk
2880 min Winter	99.935	0.535	0.1	637.5	Flood Risk
4320 min Winter	99.954	0.554	0.1	670.4	Flood Risk
5760 min Winter	99.967	0.567	0.1	693.1	Flood Risk
7200 min Winter	99.976	0.576	0.1	709.8	Flood Risk
8640 min Winter	99.983	0.583	0.1	722.7	Flood Risk
10080 min Winter	99.989	0.589	0.1	732.9	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
120 min Winter	37.054	0.0	15.3	136
180 min Winter	26.498	0.0	15.6	196
240 min Winter	20.887	0.0	15.8	254
360 min Winter	14.937	0.0	16.1	374
480 min Winter	11.774	0.0	16.2	494
600 min Winter	9.790	0.0	16.2	612
720 min Winter	8.420	0.0	16.3	732
960 min Winter	6.647	0.0	16.2	970
1440 min Winter	4.763	0.0	15.9	1448
2160 min Winter	3.413	0.0	33.6	2164
2880 min Winter	2.694	0.0	33.0	2880
4320 min Winter	1.907	0.0	31.3	4292
5760 min Winter	1.493	0.0	67.8	5712
7200 min Winter	1.234	0.0	66.1	7136
8640 min Winter	1.057	0.0	64.1	8560
10080 min Winter	0.927	0.0	61.9	9984

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 550950 257200 TL 50950 57200
C (1km)	-0.025
D1 (1km)	0.288
D2 (1km)	0.293
D3 (1km)	0.263
E (1km)	0.312
F (1km)	2.488
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.600

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.150	4	8	0.150	8	12	0.150	12	16	0.150

Model Details

Storage is Online Cover Level (m) 100.000

Bio-Retention Area Structure

Invert Level (m) 99.400 Porosity 1.00

Depth (m)	**Area (m²)**	**Depth (m)**	**Area (m²)**
0.000	750.0	0.600	1840.0

Filtration Outflow Control

Permeability Coefficient (m/s)	0.000010	Area (m²)	50.000
Safety Factor	10.000	Invert Level (m)	99.400
Bed Depth (m)	0.450		

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.150
Area (ha)	1.000	Urban	0.000
SAAR (mm)	545	Region Number	Region 5

Results	**l/s**
QBAR Rural	0.3
QBAR Urban	0.3
Q100 years	1.1
Q1 year	0.3
Q30 years	0.7
Q100 years	1.1

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2016 H R Wallingford flood modelling report, MAM7720-RT001-R02-00

Review of surface water flood management

Fulbourn

MAM7720-RT001-R02-00

August 2016

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Client representative	Daniel Coulson
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Contents

Figures

Tables

Photographs

1. Introduction

The overall objective of this work was to define the extent of surface water flooding, and determine the efficacy of the outline flood management measures for a proposed development site located in the village of Fulbourn located to the east of the city of Cambridge in Cambridgeshire. The Environment Agency's surface water flood map, shown in Figure 1.1, indicates that the site will be affected by surface water flooding during periods of extreme rainfall.

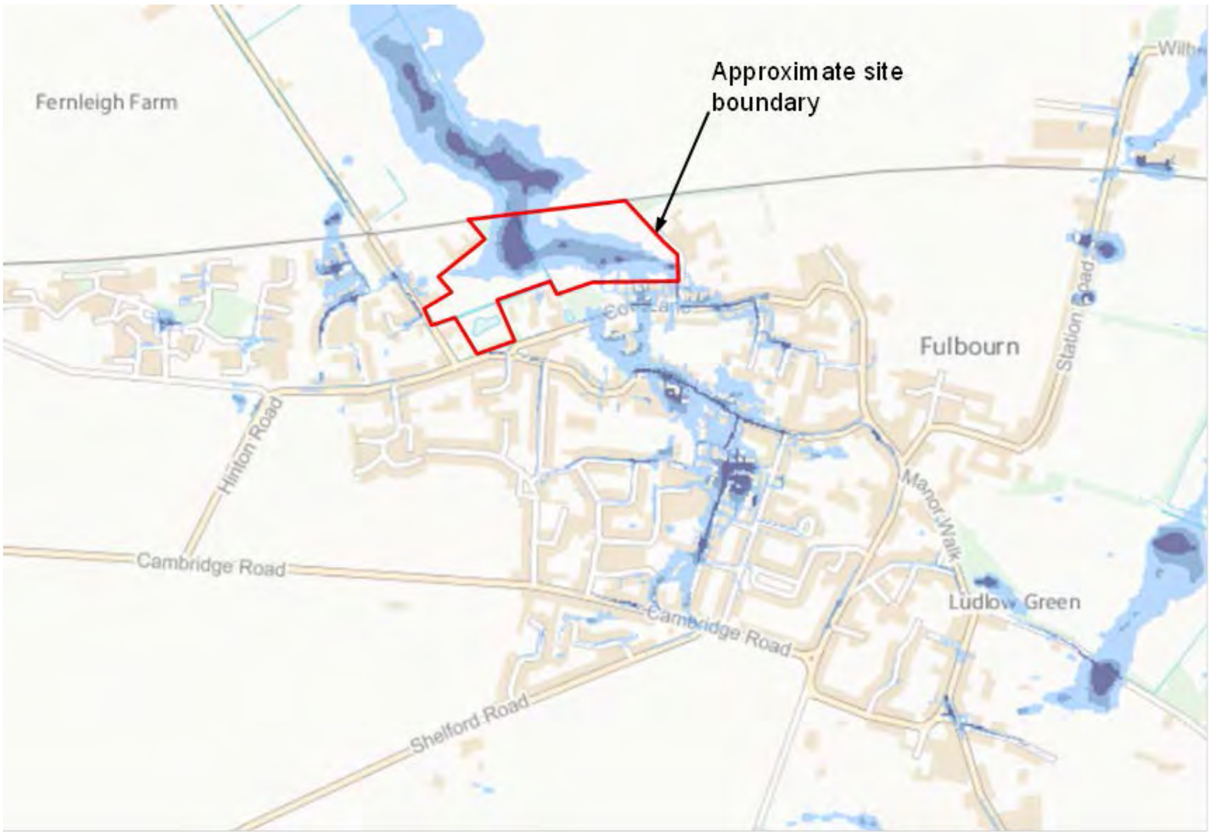

Figure 1.1: Environment Agency surface water flood map

Source: Environment Agency, 2015

As part of the study it will be necessary to estimate the 1 in 30 year (3.33% annual probability), 1 in 100 year (1% annual probability), 1 in 100 year climate change flows (i.e. +40%) and 1 in 1,000 year (0.1% annual probability) return period flood depths and extents associated with surface water flooding on the site, as well as assessing flood management measures to protect the proposed development from inundation by surface water floodwater, whilst also helping to avoid an increase in downstream flood risk.

We undertook a visit to the site on 28 April 2016. The objective of this site visit was to gain a better understanding of the hydrology of the catchment and the hydraulics of the watercourse including the downstream culvert that carries the drainage ditch under the railway to the north of the site.

2. Hydrology

2.1. Background to the catchment

The ungauged catchment draining to the site covers an area of some 1 km^2. The underlying geology is free draining chalk, although the catchment is quite heavily urbanised. This makes estimating flood flow hydrographs for the catchment challenging. Our approach is detailed below.

The catchment boundary in the Flood Estimation Handbook (FEH) draining to the site was found to be undersized when checked against a higher resolution LiDAR Digital Terrain Model (DTM). The catchment area derived from the LiDAR data was found to be 1.06 km^2 compared with 0.5 km^2 from the FEH. A comparison of the FEH and LiDAR-derived catchment boundaries is shown in Figure 2.1.

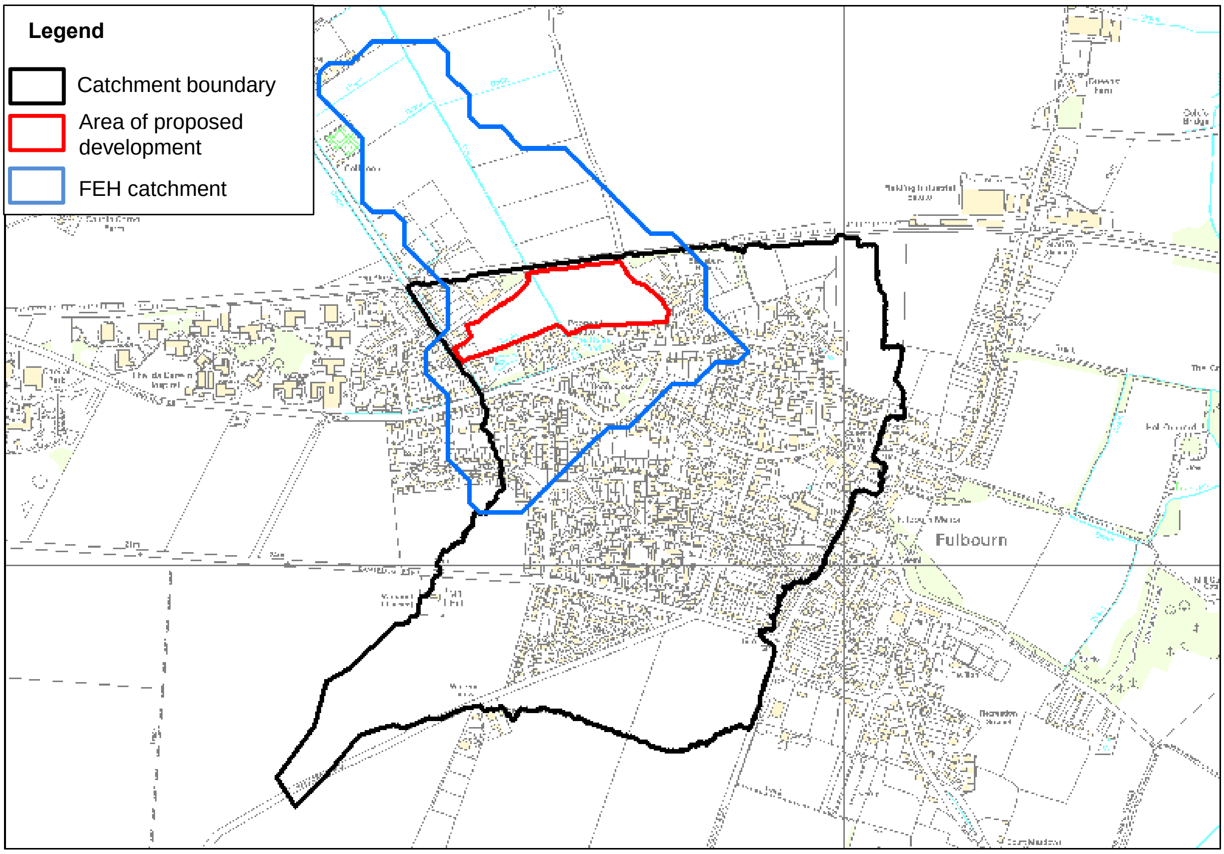

Figure 2.1: Catchment boundary from FEH and LiDAR

The UK soils map was used to check the Standard Percentage Runoff (SPR) for the catchment. This shows that the predominant soils class in the catchment is very permeable (511e with Host class of 1) and that using a FEH-derived SPR of 4.81 from catchment descriptors is appropriate.

2.1.1. Hydrological approaches to estimating flood flows

There are a number of hydrological approaches that can be used to estimate flood flows for the site including:

- **Direct rainfall approach** using a two dimensional (2D) model of the entire catchment to simulate the surface flow paths towards the drainage channel that runs through the site.
- **The FEH Revitalised Flood Hydrograph model (ReFH2**) rainfall runoff method – It is acceptable to use this method because the catchment is small, highly permeable and has a large proportion of urban area. ReFH2 has improvements for modelling the urban component of runoff compared to previous versions of the FEH rainfall-runoff methods.
- **The FEH statistical method** – This method is unlikely to be suitable for a catchment of this nature given the extent of the urban area, the high permeability of the soil and its small area.

We have thus undertaken ReFH2 and a direct rainfall approach to the hydrology.

2.1.2. Adjustment of catchment descriptors

The catchment descriptors from the FEH were adjusted to account for the catchment area because this is twice the value that is given in the FEH. The parameters that are most likely to be influenced by the change in catchment area are:

- DPLBAR – Average drainage path length
- DPSBAR – Average catchment slope
- URBEXT2000 – Urban extent

The DPLBAR for the revised catchment area has been estimated using the equation in FEH1999 volume 1

$DPLBAR = AREA^{0.548}$

Assuming a catchment area of 1.06 km^2 gives a revised DPLBAR for the catchment of 1.032 km.

DPSBAR has been checked for the revised catchment area and found to be similar to that in the FEH catchment descriptors.

The urban area within the catchment was measured using the Ordnance Survey (OS) OS50K map as described in the ReFH2 Technical Report. The urban area within the revised catchment is 0.604 km^2 and the impermeable extent of the urban has been measured from the OS10K maps as 0.14 km^2 (These are shown in Figure 2.2). This is 29% of the urban area and is very similar to the default of 30% assumed in the ReFH2 Technical Report. The default value has been used in the calculations because this will result in slightly higher flows.

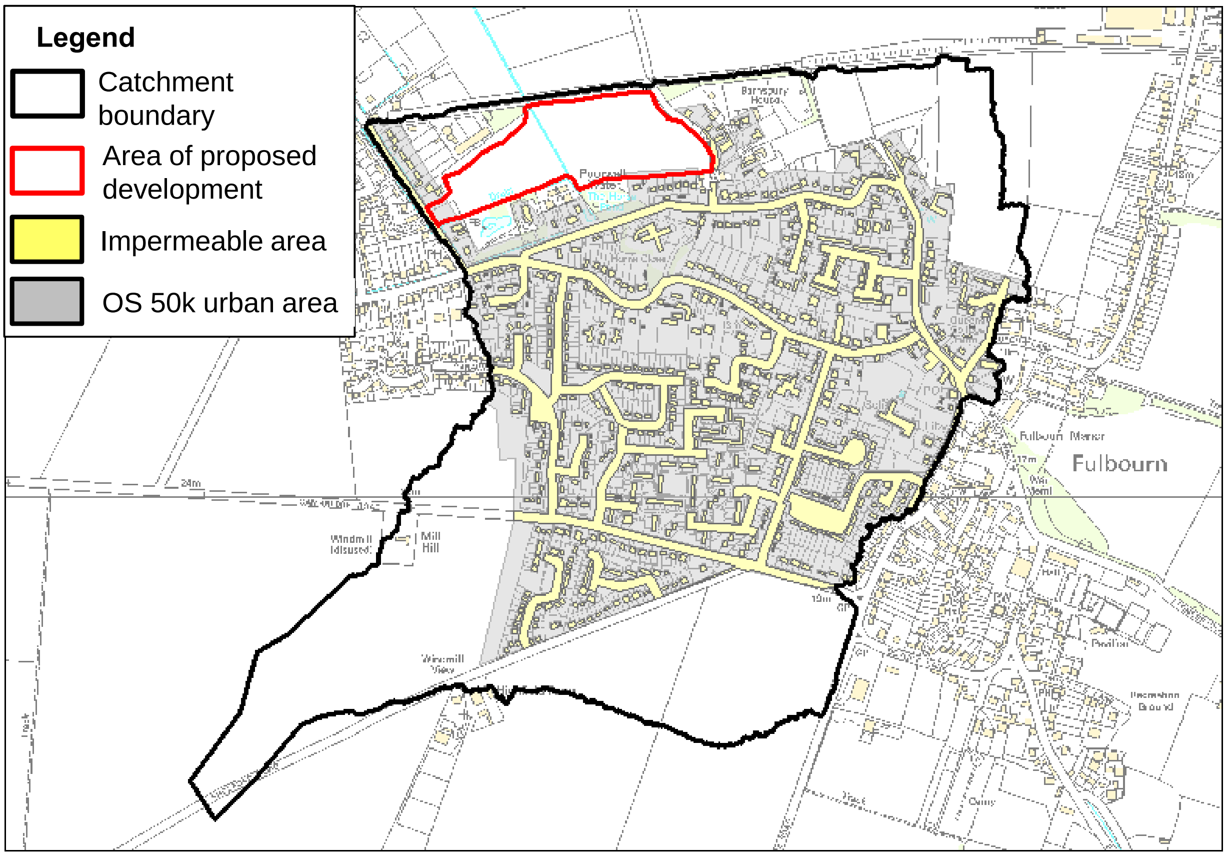

Figure 2.2: Urban area and the impermeable area within the catchment

2.2. Revitalised Flood Hydrograph model (ReFH2)

The revised catchment descriptors were entered into the FEH ReFH2 version 2.1 software and hydrographs were simulated for the following range of storm durations:

- 1.25 hour
- 3.25 hours
- 5.5 hours
- 9 hours

The summer rainfall profile produced a higher peak flow than the winter storm profile for the rainfall depth-duration-frequency (DDF) information for the catchments derived from the new FEH rainfall model (FEH, 2013). This is because it is more “peaky” than the winter profile, owing to the prevalence of intense convective storms during the summer. This means the intensity is greater in the middle of the storm, thus the summer profile is more likely to be critical for surface water flooding in a small urbanised catchment such as that of Fulbourn. The resulting hydrographs, shown in Figure 2.3, show that the 3.25 hour storm duration is critical in terms of peak flow.

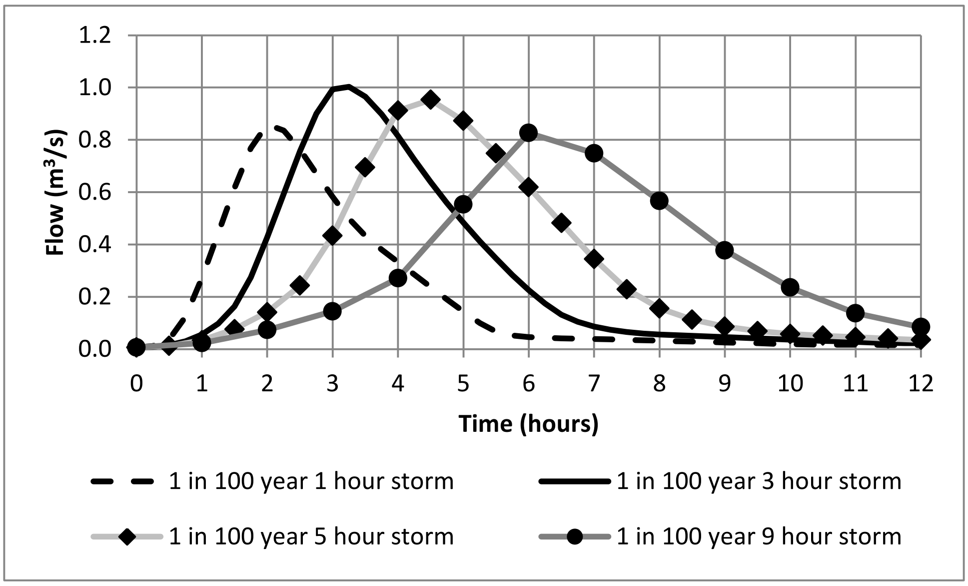

Figure 2.3: ReFH2 flow hydrographs

2.3. Direct runoff

The new FEH rainfall (FEH, 2013) was applied directly to a two dimensional (2D) hydrodynamic model mesh of the whole catchment. The ground elevations of the 2D mesh are based on LiDAR topographic data with a (0.5m horizontal resolution). The average triangular mesh element area is 16 m^2. The model does not include the drainage ditches or channels that run through the site or along-side roads. The main drainage ditch crossing the site has been included as a one dimensional (1D) hydraulic model. A base flow of 0.1 m^3/s has been included in this ditch.

The percentage runoff applied was based on that from ReFH2 model. The rural areas use the percentage runoff of 6.1% calculated from a ‘rural’ ReFH2 run for the 3.25 hour 1 in 100 year return period summer storm. The urban areas follow the ReFH2 Technical Report where the area is split by the impermeable area, which is given a percentage runoff of 70% and the permeable area which has the same percentage runoff as the rural areas of the catchment. These values were combined to give an overall percentage runoff of 25.3% for the urban50K area.

Urban drainage systems vary in nature and their effectiveness in different storm events is linked to very local characteristics such as the arrangement and capacity of road gullies and whether drainage is via combined or separate sewerage systems. The Environment Agency has found that the calculated range of sewer capacities, in terms of rainfall, is in the range of 5 mm/hour to 54 mm/hour; with a typical drainage removal rate of 12 mm/hour across catchments in England and Wales. Anglian Water sewer plans do not indicate any surface water sewers within the identified catchment. We have therefore not accounted for drainage removal of rainfall in the model.

The advantage of the direct rainfall approach is that it is similar to the method that was used to produce the Environment Agency’s surface water maps and it shows the flow paths of surface water flowing onto the site. This is shown in Figure 2.4, the main flow path is through the depression at the south of the site (Poorwell Water), where the drainage channel starts. A second flow path is across the site from the east towards the drainage channel in the centre of the site. Approximately 70% of the total flow across the site follows the drainage path from the south and 20% follows the drainage path from the east and 10% from the south-west.

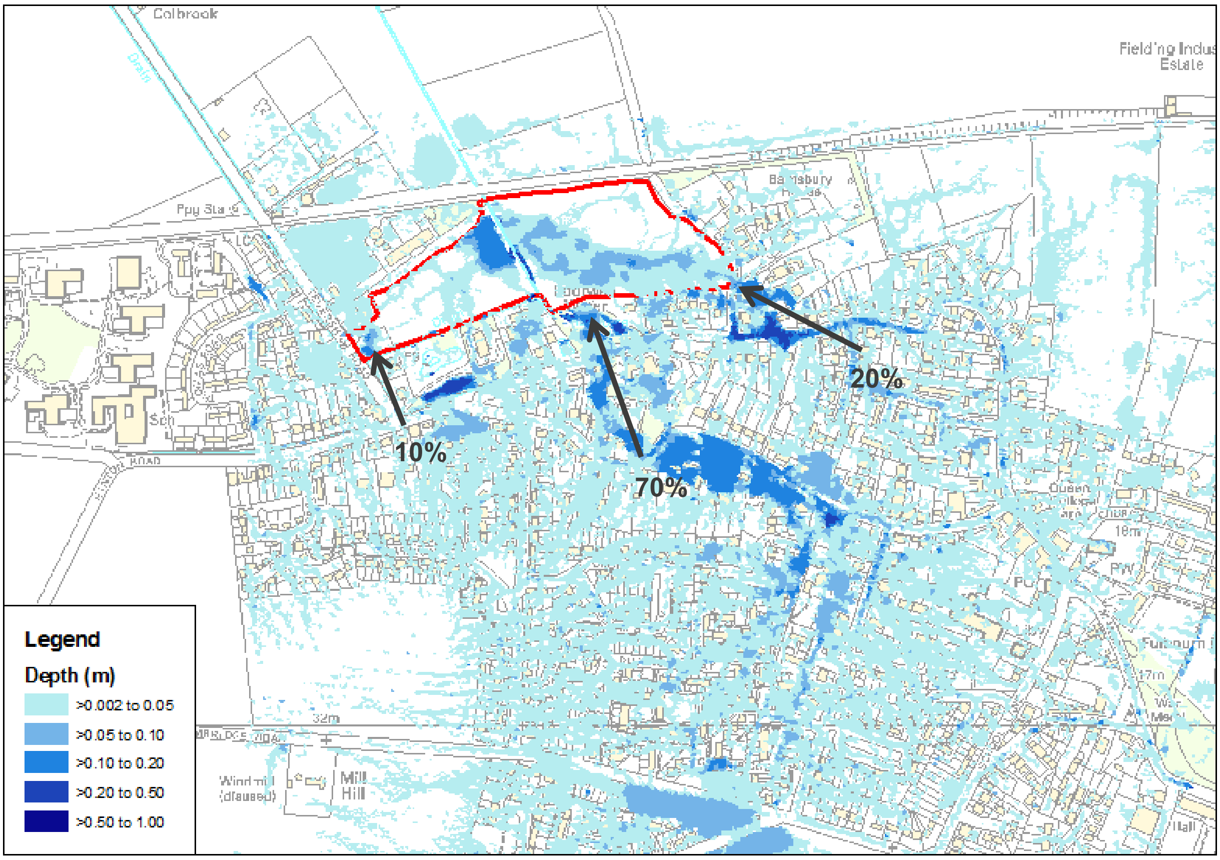

Figure 2.4: Surface water flow paths on the site

2.4. Comparison of flows

A comparison of the hydrographs generated using the ReFH2 and direct runoff methods is shown in Figure 2.5.

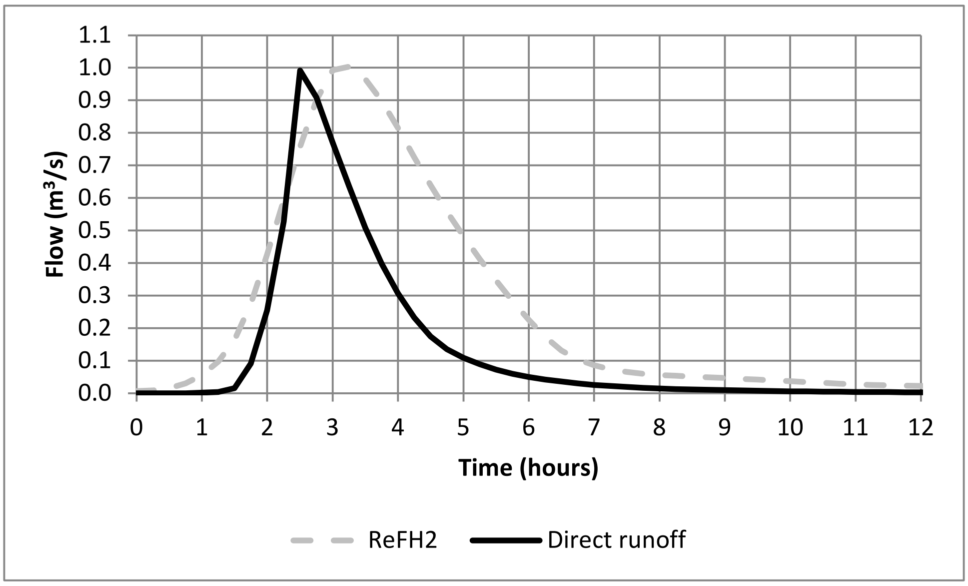

Figure 2.5: Flow hydrographs from ReFH and the Direct Rainfall method for the 3.25 hour 100 year storm

The main difference between the direct runoff approach and the ReFH2 is that not all of the catchment area defined by the DTM contributes flow along defined flow routes or even through the site because of the flat land at the base of the hill. Some of the difference between the hydrographs is also because ReFH2 includes the baseflow component, although this is very low approximately 0.02 m^3/s.

2.5. Final method

Owing to the complexity of the catchment geology and its high degree of urbanisation we carried out two dimensional (2D) hydraulic modelling of the entire 1 km^2 catchment using the InfoWorks ICM software with an appropriate terrain sensitive triangular grid. This size of the grid used in the model was more detailed where the changes in slope are largest and also areas of particular interest such as the site itself.

3. Integrated Catchment Model (ICM) hydraulic of the Fulbourn catchment

3.1. Hydrological components

The catchment has been divided up into permeability zones, depending on the land use, as described in Section 2.3.

3.2. Representation of the site

The 2D model hydraulic model described in Section 2.3 was revised to include high resolution mesh cells on and around the development site and to include the local drainage network through the site. The drainage network through the site was represented with 1D river sections and culverts in the ICM modelling software. A base flow of 0.1 m^3/s was assumed for the drainage channels. The open channels are dynamically linked to the 2D mesh of the site and the surrounding catchment. At the time of the site visit there was dense vegetation on the banks of the channel with the channel bed relatively clear of vegetation. The Manning's 'n' roughness was therefore set to 0.03 on the channel bed and 0.05 to 0.075 on the sides of the channel, depending on the location. A typical view of the drainage channel through the site is shown in Photograph 3.1.

Photograph 3.1: Typical view of the drainage channel through the site

The culvert through the railway embankment was modelled with an arch culvert with a radius of 0.8 m and an invert level of 8.51 m AD. The Manning's n on the base was set to 0.03 and 0.018 on the arch. The 520 mm diameter circular culverts that link open drainage channels on the site was modelled with a Manning's n of 0.012.

The 2D mesh on the site was formed of a triangular mesh with the size of the triangles varying between 4 m^2 and 9 m^2. The ground levels have been taken from the local site topographic survey provided to us. The existing vegetation on the site is typically rough grass for which a Manning's n roughness of 0.04 is appropriate. Photograph 3.2 and 3.3 show typical views of the eastern and western parts of the site.

Photograph 3.2: Eastern area of the site, looking to the east

Photograph 3.3: Western areas of the site, looking towards the centre of the site

3.3. Representation of the post development site

Post development ground levels were provided by Cannon Consulting Engineers. The ground levels show three raised development platforms that are to be raised by a few hundred millimetres above the original ground level. The boundary of each platform indicated below includes the surface water (runoff) attenuation facilities for each platform. A revised hydraulic model of the site was setup with the proposed development platforms, a lowered landscaped area/wide based channel to convey flows from the south-eastern corner of the site, and five 150 mm diameter pipes beneath a bunded footpath that joins the two platforms in the eastern part of the site. These are shown in Figure 3.1. The height of the footpath was set at 10.1 m AOD and the invert levels of the culverts are 9.58 m AOD.

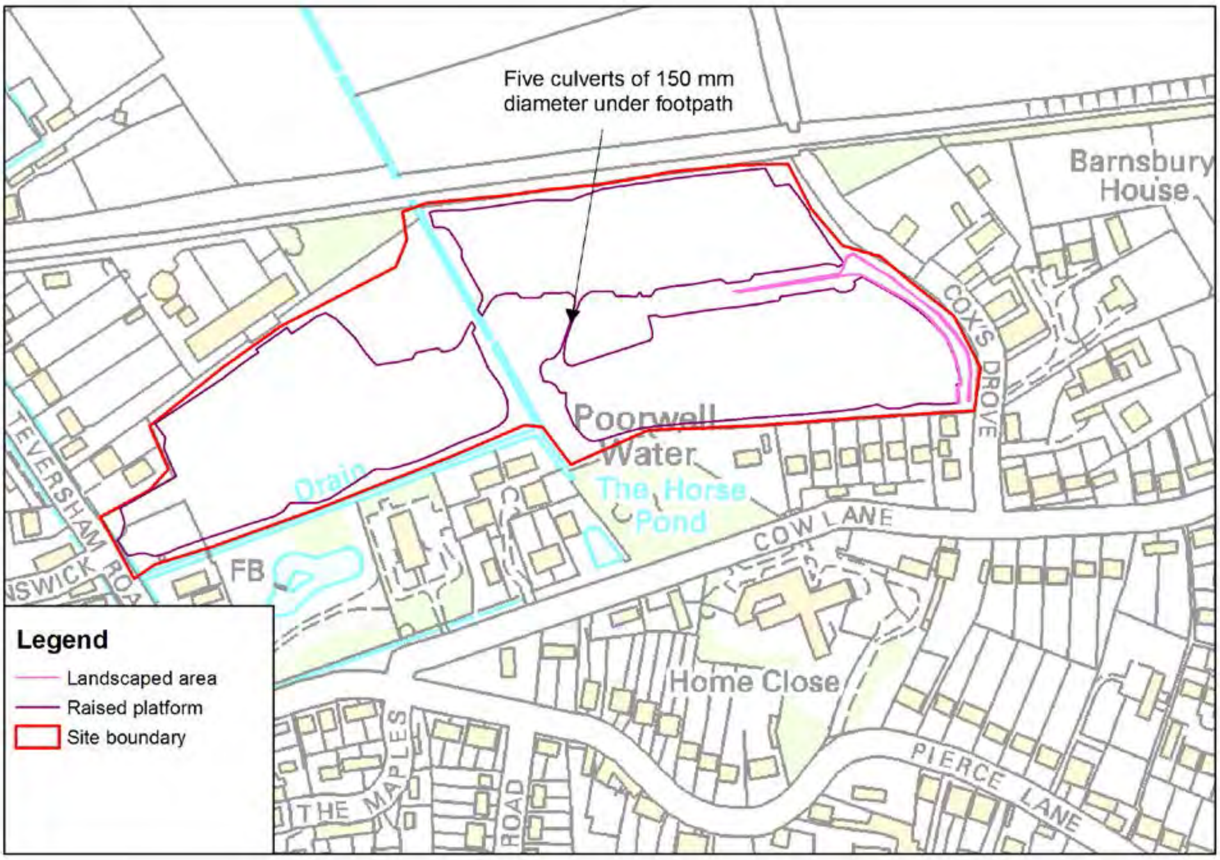

Figure 3.1: Development scheme

4. Results

4.1. Existing conditions

The InfoWorks ICM hydraulic model for existing conditions was run using FEH 2013 design rainfall profiles for the following return periods:

- 1 in 30 years
- 1 in 100 years
- 1 in 100 years plus 40% (Upper climate change scenario from the Environment Agency (2016))
- 1 in 1,000 years.

Flood extents and depths owing to surface water flooding on the site are shown in Figure 4.1 to Figure 4.4. The source of the water that causes the surface water flooding to the site is mainly from the adjacent housing and the site itself. Figure 4.1 to Figure 4.4 show that for the 1 in 30 year and 1 in 100 year annual probability return period rainfall events there is relatively shallow flow (i.e. < 10cm) across the site from the east towards the central channel. For the 1 in 1,000 year annual probability return period rainfall event this water is slightly deeper in places (i.e. up to 50 cm). The results of the modelling indicated that on the western part of the site there is an area of ponding next to the central channel in all rainfall events, where the bank level is higher than the surrounding land preventing the water draining into the channel. The depth of water in this area increases as the rainfall depth increases.

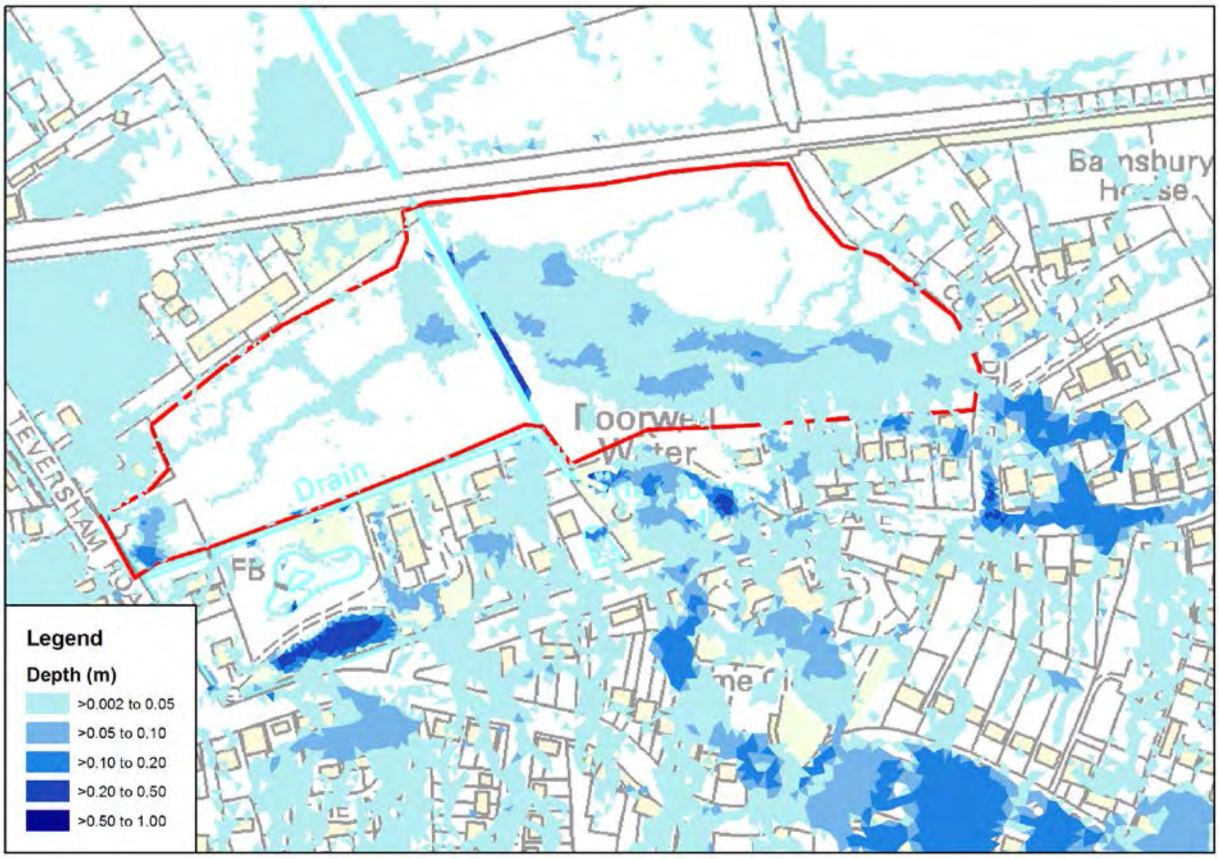

Figure 4.1: Surface water flood depths for the 1 in 30 year rainfall

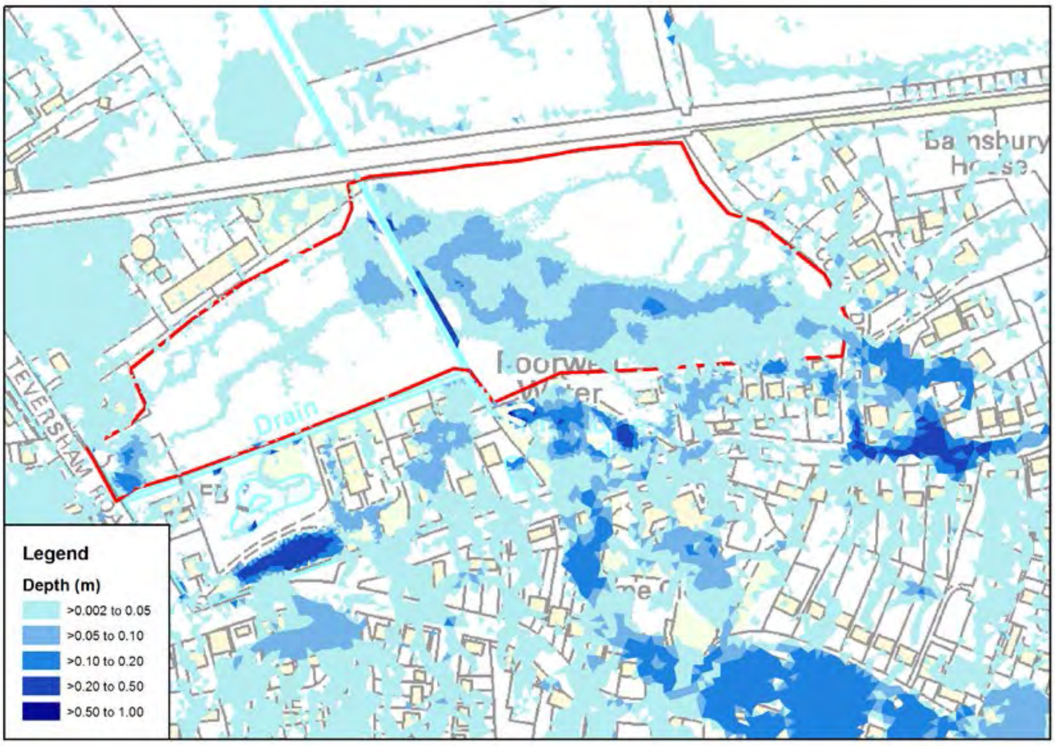

Figure 4.2: Surface water flood depths for the 1 in 100 year rainfall

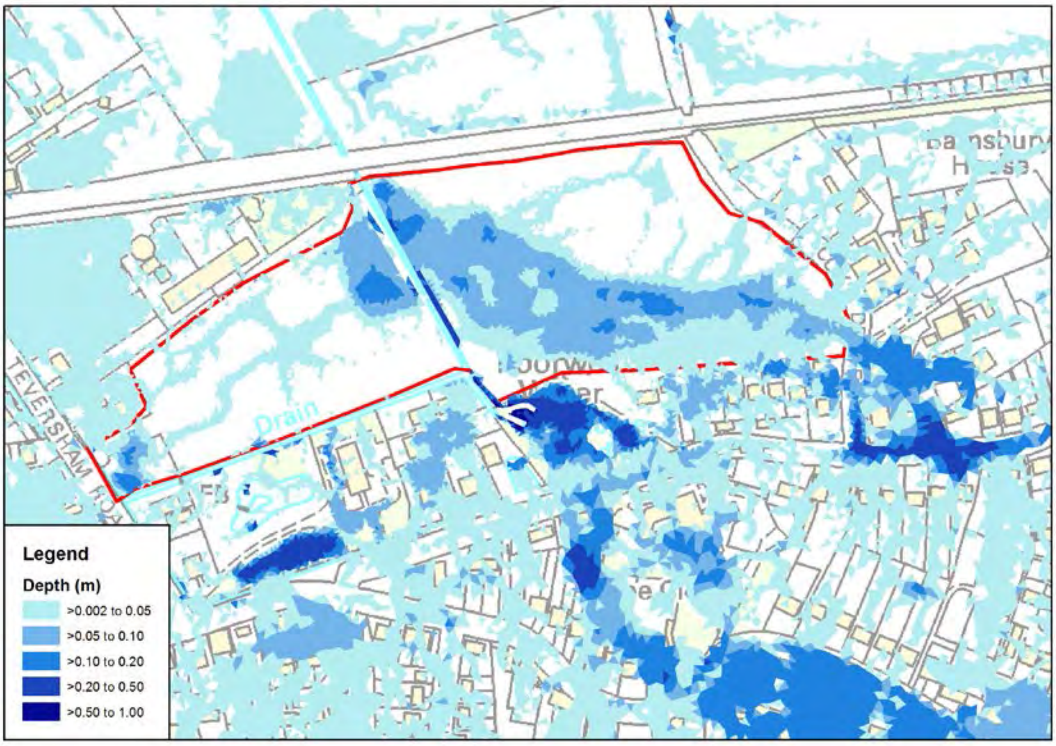

Figure 4.3: Surface water flood depths for the 1 in 100 year rainfall plus 40% climate change

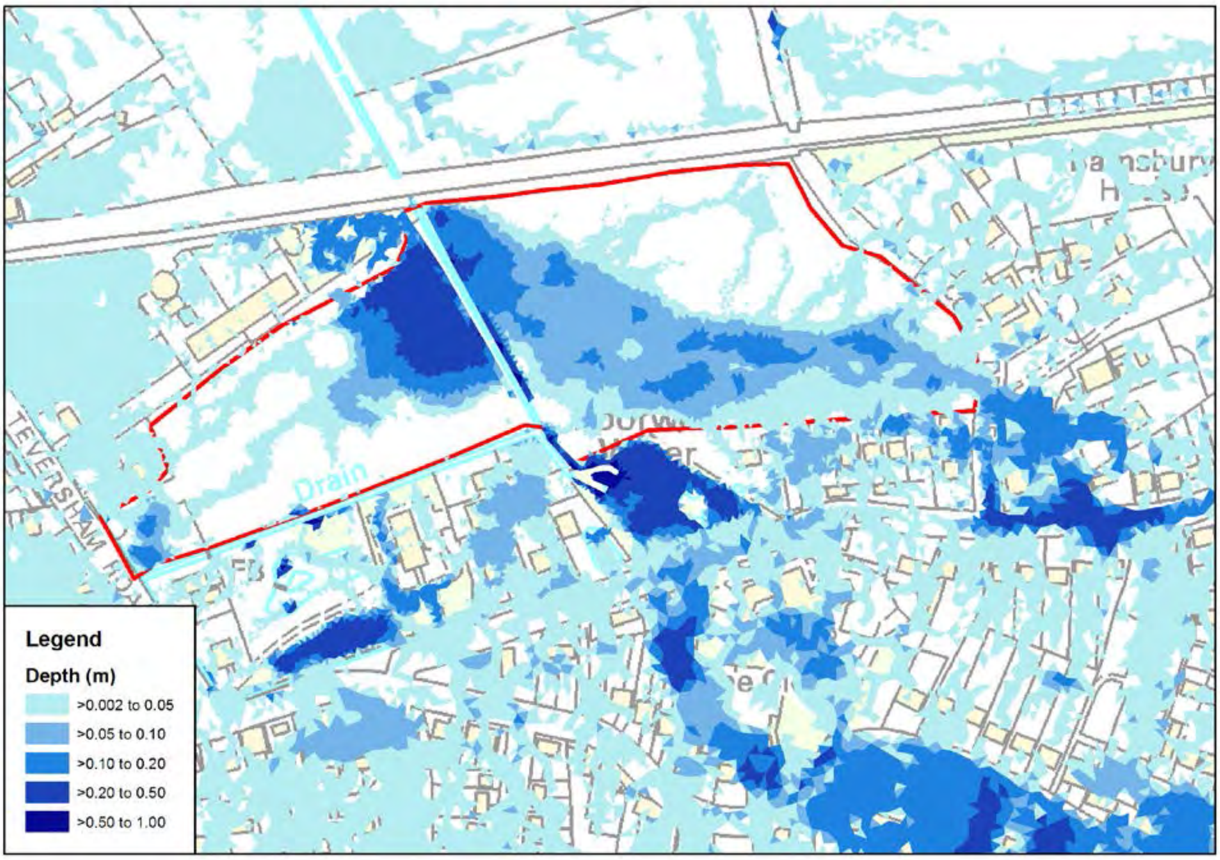

Figure 4.4: Surface water flood depths for the 1 in 1,000 year rainfall

4.2. Post development flood modelling

The InfoWorks ICM hydraulic model for the post development conditions (i.e. with the ares to be developed raised out of the surface floodwater) was run using the FEH 2013 design rainfall profiles for the following return periods:

- 1 in 30 years
- 1 in 100 years
- 1 in 100 years plus 40% (Upper climate change scenario from the Environment Agency (2016))
- 1 in 1,000 years.

Flood extents and depths owing to surface water flooding on the site are shown in Figure 4.5 to Figure 4.8.

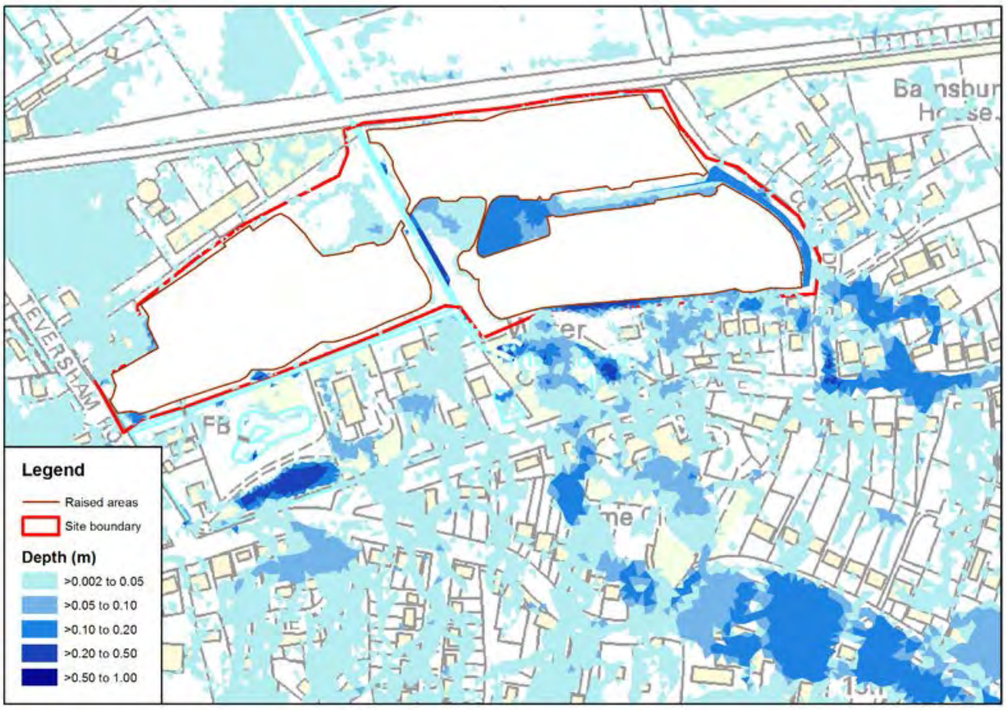

Figure 4.5: Surface water flood depths for the 1 in 30 year rainfall with the development in place

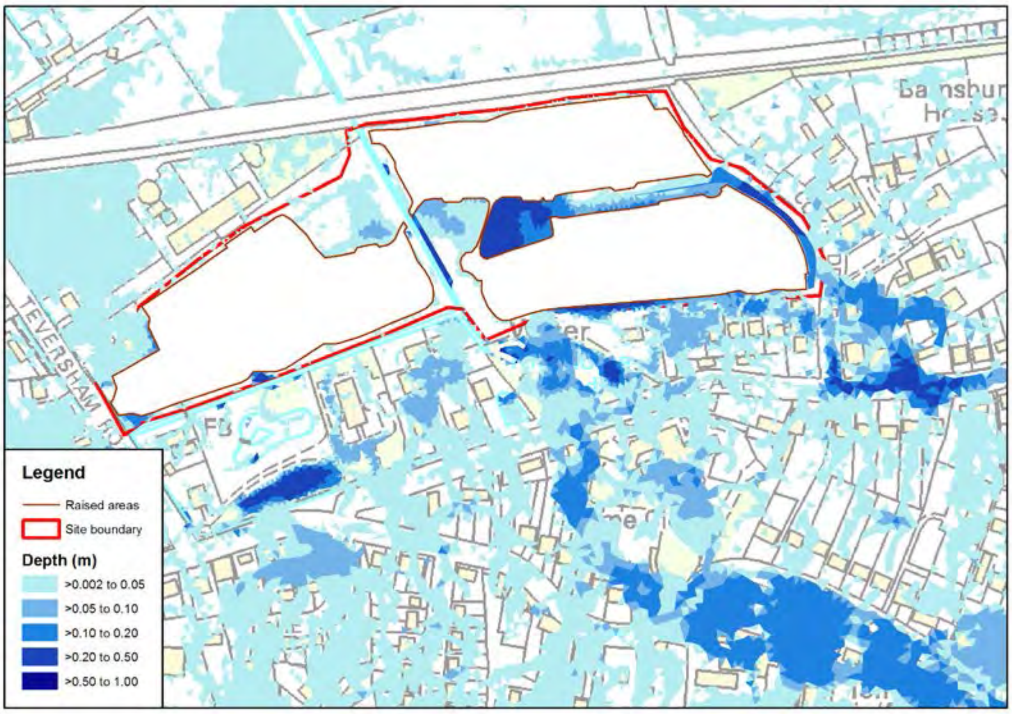

Figure 4.6: Surface water flood depths for the 1 in 100 year rainfall with development in place

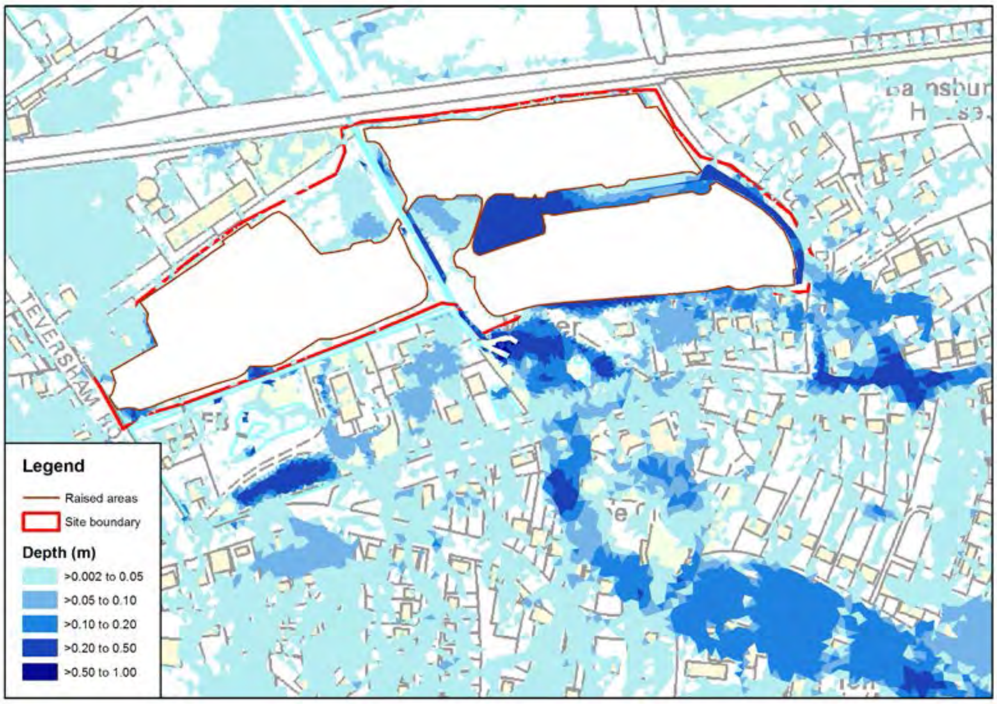

Figure 4.7: Surface water flood depths for the 1 in 100 year climate change rainfall with development in place

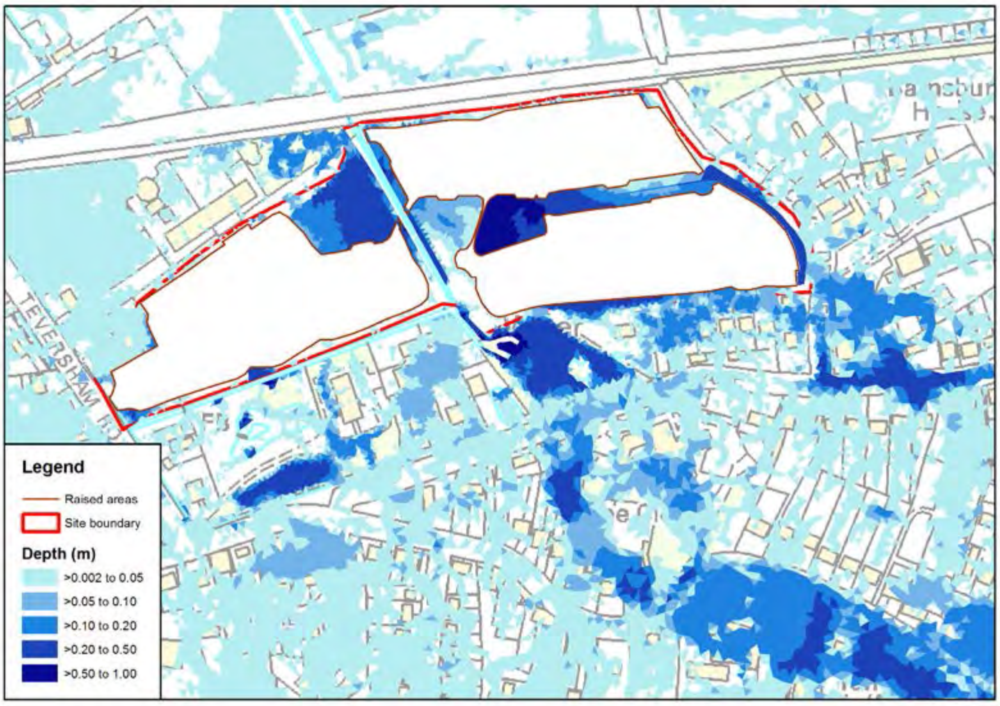

Figure 4.8: Surface water flood depths for the 1 in 1,000 year climate change rainfall with development in place

The peak flows through the railway embankment with the proposed development in place have been compared to existing conditions(see Table 4.1). The comparison shows that the configuration of the proposed development platforms leads to a slight decrease in peak flows downstream of the site.

Table 4.1: Change in peak flow downstream of the site

Return period (years)	Peak flow in existing conditions (m^3/s)	Change in peak flow with the development in place at the culvert passing under the railway embankment at the downstream end of the site (%)
1 in 30 year	0.68	-3.8%
1 in 100 year	1.12	-6.7%
1 in 100 year plus 40% climate change	1.58	-3.6%
1 in 1,000 year	1.66	-0.9%

5. Conclusions

Design flows through the site have been assessed with a direct rainfall approach and the ReFH2, both methods give similar magnitude of peak flow at the culvert through the railway embankment at the downstream end of the site.

An integrated 1D-2D hydraulic model of the catchment has been used to simulate the surface water flood extents and depths on the proposed development site for existing conditions. The model includes the detail of the drainage channel system through the site and under the railway embankment. The resulting 1 in 100 year flood extent for the existing situation is larger than that shown on the Environment Agency's surface water flood map. It is possible to raise the development so that it is unaffected by surface water flooding. The hydraulic modelling of design floods shows that post-development there would be a slight reduction in peak flow downstream of the site for all return periods. This reduction in downstream flow may allow for an increased discharge rate from the proposed surface water attenuation facilities.

6. References

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Revised surface water calculations (with 40 % allowance for climate change)

Summary of Results for 100 year Return Period (+40%)

Half Drain Time exceeds 7 days.

Outflow is too low. Design is unsatisfactory.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.613	0.213	0.0	0.1	0.0	0.1	407.2	O K
30 min Summer	99.638	0.238	0.0	0.1	0.0	0.1	459.0	O K
60 min Summer	99.667	0.267	0.0	0.1	0.0	0.1	517.4	O K
120 min Summer	99.698	0.298	0.0	0.1	0.0	0.1	582.9	O K
180 min Summer	99.722	0.322	0.0	0.1	0.0	0.1	624.9	Flood Risk
240 min Summer	99.740	0.340	0.0	0.1	0.0	0.1	656.5	Flood Risk
360 min Summer	99.766	0.366	0.0	0.1	0.0	0.1	703.5	Flood Risk
480 min Summer	99.785	0.385	0.0	0.1	0.0	0.1	738.6	Flood Risk
600 min Summer	99.800	0.400	0.0	0.2	0.0	0.2	767.0	Flood Risk
720 min Summer	99.813	0.413	0.0	0.2	0.0	0.2	790.8	Flood Risk
960 min Summer	99.835	0.435	0.0	0.2	0.0	0.2	830.8	Flood Risk
1440 min Summer	99.866	0.466	0.0	0.2	0.0	0.2	889.8	Flood Risk
2160 min Summer	99.898	0.498	0.0	0.2	0.0	0.2	951.6	Flood Risk
2880 min Summer	99.921	0.521	0.0	0.2	0.0	0.2	996.7	Flood Risk
4320 min Summer	99.947	0.547	0.0	0.2	0.0	0.2	1048.1	Flood Risk
5760 min Summer	99.964	0.564	0.0	0.2	0.0	0.2	1083.5	Flood Risk
7200 min Summer	99.977	0.577	0.0	0.2	0.0	0.2	1109.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	222.781	0.0	10.1	0.0	31
30 min Summer	125.581	0.0	10.5	0.0	46
60 min Summer	70.790	0.0	21.8	0.0	76
120 min Summer	39.904	0.0	22.6	0.0	136
180 min Summer	28.536	0.0	23.2	0.0	196
240 min Summer	22.494	0.0	23.6	0.0	256
360 min Summer	16.086	0.0	24.2	0.0	376
480 min Summer	12.680	0.0	24.5	0.0	496
600 min Summer	10.543	0.0	24.7	0.0	616
720 min Summer	9.067	0.0	24.8	0.0	736
960 min Summer	7.158	0.0	24.8	0.0	976
1440 min Summer	5.129	0.0	24.5	0.0	1456
2160 min Summer	3.675	0.0	52.1	0.0	2176
2880 min Summer	2.901	0.0	51.4	0.0	2896
4320 min Summer	2.054	0.0	48.7	0.0	4332
5760 min Summer	1.607	0.0	106.5	0.0	5776
7200 min Summer	1.329	0.0	103.8	0.0	7216

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Summer	99.987	0.587	0.0	0.2	0.0	0.2	1129.5	Flood Risk
10080 min Summer	99.994	0.594	0.0	0.2	0.0	0.2	1145.2	Flood Risk
15 min Winter	99.613	0.213	0.0	0.1	0.0	0.1	407.2	O K
30 min Winter	99.638	0.238	0.0	0.1	0.0	0.1	459.0	O K
60 min Winter	99.667	0.267	0.0	0.1	0.0	0.1	517.4	O K
120 min Winter	99.698	0.298	0.0	0.1	0.0	0.1	582.9	O K
180 min Winter	99.722	0.322	0.0	0.1	0.0	0.1	624.9	Flood Risk
240 min Winter	99.740	0.340	0.0	0.1	0.0	0.1	656.5	Flood Risk
360 min Winter	99.766	0.366	0.0	0.1	0.0	0.1	703.5	Flood Risk
480 min Winter	99.785	0.385	0.0	0.1	0.0	0.1	738.6	Flood Risk
600 min Winter	99.801	0.401	0.0	0.2	0.0	0.2	767.0	Flood Risk
720 min Winter	99.813	0.413	0.0	0.2	0.0	0.2	790.8	Flood Risk
960 min Winter	99.835	0.435	0.0	0.2	0.0	0.2	830.8	Flood Risk
1440 min Winter	99.866	0.466	0.0	0.2	0.0	0.2	889.9	Flood Risk
2160 min Winter	99.898	0.498	0.0	0.2	0.0	0.2	951.7	Flood Risk
2880 min Winter	99.921	0.521	0.0	0.2	0.0	0.2	996.8	Flood Risk
4320 min Winter	99.947	0.547	0.0	0.2	0.0	0.2	1048.3	Flood Risk
5760 min Winter	99.964	0.564	0.0	0.2	0.0	0.2	1083.8	Flood Risk
7200 min Winter	99.977	0.577	0.0	0.2	0.0	0.2	1110.0	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Summer	1.138	0.0	100.6	0.0	8648
10080 min Summer	0.998	0.0	96.9	0.0	10088
15 min Winter	222.781	0.0	10.1	0.0	31
30 min Winter	125.581	0.0	10.5	0.0	46
60 min Winter	70.790	0.0	21.8	0.0	76
120 min Winter	39.904	0.0	22.6	0.0	136
180 min Winter	28.536	0.0	23.2	0.0	194
240 min Winter	22.494	0.0	23.6	0.0	254
360 min Winter	16.086	0.0	24.2	0.0	374
480 min Winter	12.680	0.0	24.5	0.0	492
600 min Winter	10.543	0.0	24.7	0.0	612
720 min Winter	9.067	0.0	24.8	0.0	732
960 min Winter	7.158	0.0	24.8	0.0	970
1440 min Winter	5.129	0.0	24.5	0.0	1448
2160 min Winter	3.675	0.0	52.1	0.0	2164
2880 min Winter	2.901	0.0	51.4	0.0	2880
4320 min Winter	2.054	0.0	48.6	0.0	4292
5760 min Winter	1.607	0.0	106.5	0.0	5712
7200 min Winter	1.329	0.0	103.8	0.0	7136

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Winter	99.987	0.587	0.0	0.2	0.0	0.2	1130.2	Flood Risk
10080 min Winter	99.995	0.595	0.0	0.2	0.0	0.2	1146.1	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Winter	1.138	0.0	100.5	0.0	8560
10080 min Winter	0.998	0.0	96.8	0.0	9984

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 550950 257200 TL 50950 57200
C (1km)	-0.025
D1 (1km)	0.288
D2 (1km)	0.293
D3 (1km)	0.263
E (1km)	0.312
F (1km)	2.488
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.950
Cv (Winter)	0.950
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.770

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.200	4	8	0.200	8	12	0.200	12	16	0.170

Model Details

Storage is Online Cover Level (m) 100.000

Complex Structure

Bio-Retention Area

Invert Level (m) 99.400 Infiltration Coefficient Base (m/hr) 0.00000
Porosity 1.00 Infiltration Coefficient Side (m/hr) 0.00000
Safety Factor 2.0

Depth (m)	Area (m²)	Perimeter (m)	Depth (m)	Area (m²)	Perimeter (m)
0.000	1448.0	134.893	0.600	2062.0	160.972

Cellular Storage

Invert Level (m) 99.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Inf. Area (m²)	Depth (m)	Area (m²)	Inf. Area (m²)
0.000	382.0	382.0	0.301	0.0	405.5
0.300	382.0	405.5			

Filtration Outflow Control

Permeability Coefficient (m/s) 0.000010 Area (m²) 80.000
Safety Factor 10.000 Invert Level (m) 99.400
Bed Depth (m) 0.450

Weir Overflow Control

Discharge Coef 0.544 Width (m) 5.000 Invert Level (m) 100.000

Summary of Results for 100 year Return Period (+30%)

Half Drain Time exceeds 7 days.

Outflow is too low. Design is unsatisfactory.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.599	0.199	0.0	0.1	0.0	0.1	235.7	O K
30 min Summer	99.621	0.221	0.0	0.1	0.0	0.1	265.7	O K
60 min Summer	99.646	0.246	0.0	0.1	0.0	0.1	299.5	O K
120 min Summer	99.673	0.273	0.0	0.1	0.0	0.1	337.4	O K
180 min Summer	99.690	0.290	0.0	0.1	0.0	0.1	361.7	O K
240 min Summer	99.703	0.303	0.0	0.1	0.0	0.1	380.0	Flood Risk
360 min Summer	99.733	0.333	0.0	0.1	0.0	0.1	407.1	Flood Risk
480 min Summer	99.754	0.354	0.0	0.1	0.0	0.1	427.5	Flood Risk
600 min Summer	99.771	0.371	0.0	0.1	0.0	0.1	443.8	Flood Risk
720 min Summer	99.785	0.385	0.0	0.1	0.0	0.1	457.6	Flood Risk
960 min Summer	99.807	0.407	0.0	0.1	0.0	0.1	480.7	Flood Risk
1440 min Summer	99.839	0.439	0.0	0.1	0.0	0.1	514.8	Flood Risk
2160 min Summer	99.870	0.470	0.0	0.1	0.0	0.1	550.3	Flood Risk
2880 min Summer	99.892	0.492	0.0	0.1	0.0	0.1	576.2	Flood Risk
4320 min Summer	99.916	0.516	0.0	0.1	0.0	0.1	605.6	Flood Risk
5760 min Summer	99.932	0.532	0.0	0.1	0.0	0.1	625.7	Flood Risk
7200 min Summer	99.943	0.543	0.0	0.1	0.0	0.1	640.4	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
15 min Summer	206.868	0.0	6.2	0.0	31
30 min Summer	116.611	0.0	6.4	0.0	46
60 min Summer	65.734	0.0	13.2	0.0	76
120 min Summer	37.054	0.0	13.7	0.0	136
180 min Summer	26.498	0.0	13.9	0.0	196
240 min Summer	20.887	0.0	14.1	0.0	256
360 min Summer	14.937	0.0	14.5	0.0	376
480 min Summer	11.774	0.0	14.8	0.0	496
600 min Summer	9.790	0.0	14.9	0.0	616
720 min Summer	8.420	0.0	15.0	0.0	736
960 min Summer	6.647	0.0	15.1	0.0	976
1440 min Summer	4.763	0.0	14.9	0.0	1456
2160 min Summer	3.413	0.0	31.7	0.0	2176
2880 min Summer	2.694	0.0	31.3	0.0	2896
4320 min Summer	1.907	0.0	29.6	0.0	4332
5760 min Summer	1.493	0.0	64.7	0.0	5776
7200 min Summer	1.234	0.0	63.1	0.0	7216

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Summer	99.952	0.552	0.0	0.1	0.0	0.1	651.7	Flood Risk
10080 min Summer	99.959	0.559	0.0	0.1	0.0	0.1	660.4	Flood Risk
15 min Winter	99.599	0.199	0.0	0.1	0.0	0.1	235.7	O K
30 min Winter	99.621	0.221	0.0	0.1	0.0	0.1	265.7	O K
60 min Winter	99.646	0.246	0.0	0.1	0.0	0.1	299.5	O K
120 min Winter	99.673	0.273	0.0	0.1	0.0	0.1	337.4	O K
180 min Winter	99.690	0.290	0.0	0.1	0.0	0.1	361.7	O K
240 min Winter	99.703	0.303	0.0	0.1	0.0	0.1	380.0	Flood Risk
360 min Winter	99.733	0.333	0.0	0.1	0.0	0.1	407.1	Flood Risk
480 min Winter	99.754	0.354	0.0	0.1	0.0	0.1	427.5	Flood Risk
600 min Winter	99.771	0.371	0.0	0.1	0.0	0.1	443.8	Flood Risk
720 min Winter	99.785	0.385	0.0	0.1	0.0	0.1	457.6	Flood Risk
960 min Winter	99.807	0.407	0.0	0.1	0.0	0.1	480.7	Flood Risk
1440 min Winter	99.839	0.439	0.0	0.1	0.0	0.1	514.8	Flood Risk
2160 min Winter	99.870	0.470	0.0	0.1	0.0	0.1	550.4	Flood Risk
2880 min Winter	99.892	0.492	0.0	0.1	0.0	0.1	576.3	Flood Risk
4320 min Winter	99.916	0.516	0.0	0.1	0.0	0.1	605.8	Flood Risk
5760 min Winter	99.932	0.532	0.0	0.1	0.0	0.1	626.0	Flood Risk
7200 min Winter	99.944	0.544	0.0	0.1	0.0	0.1	640.8	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Summer	1.057	0.0	61.1	0.0	8648
10080 min Summer	0.927	0.0	59.0	0.0	10088
15 min Winter	206.868	0.0	6.2	0.0	31
30 min Winter	116.611	0.0	6.4	0.0	46
60 min Winter	65.734	0.0	13.2	0.0	76
120 min Winter	37.054	0.0	13.7	0.0	136
180 min Winter	26.498	0.0	13.9	0.0	196
240 min Winter	20.887	0.0	14.1	0.0	254
360 min Winter	14.937	0.0	14.5	0.0	374
480 min Winter	11.774	0.0	14.8	0.0	494
600 min Winter	9.790	0.0	14.9	0.0	612
720 min Winter	8.420	0.0	15.0	0.0	732
960 min Winter	6.647	0.0	15.1	0.0	970
1440 min Winter	4.763	0.0	14.9	0.0	1448
2160 min Winter	3.413	0.0	31.7	0.0	2164
2880 min Winter	2.694	0.0	31.3	0.0	2880
4320 min Winter	1.907	0.0	29.6	0.0	4292
5760 min Winter	1.493	0.0	64.7	0.0	5712
7200 min Winter	1.234	0.0	63.0	0.0	7136

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Overflow (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Winter	99.952	0.552	0.0	0.1	0.0	0.1	652.1	Flood Risk
10080 min Winter	99.959	0.559	0.0	0.1	0.0	0.1	661.0	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Overflow Volume (m³)	Time-Peak (mins)
8640 min Winter	1.057	0.0	61.1	0.0	8560
10080 min Winter	0.927	0.0	58.9	0.0	9984

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 550950 257200 TL 50950 57200
C (1km)	-0.025
D1 (1km)	0.288
D2 (1km)	0.293
D3 (1km)	0.263
E (1km)	0.312
F (1km)	2.488
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.950
Cv (Winter)	0.950
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.480

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	0.120	4	8	0.120	8	12	0.120	12	16	0.120

Model Details

Storage is Online Cover Level (m) 100.000

Complex Structure

Bio-Retention Area

Invert Level (m) 99.400 Infiltration Coefficient Base (m/hr) 0.00000
Porosity 1.00 Infiltration Coefficient Side (m/hr) 0.00000
Safety Factor 2.0

Depth (m)	Area (m²)	Perimeter (m)	Depth (m)	Area (m²)	Perimeter (m)
0.000	233.0	162.000	0.600	651.0	177.000

Cellular Storage

Invert Level (m) 99.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Inf. Area (m²)	Depth (m)	Area (m²)	Inf. Area (m²)
0.000	612.0	612.0	0.301	0.0	641.7
0.300	612.0	641.7			

Bio-Retention Area

Invert Level (m) 99.400 Infiltration Coefficient Base (m/hr) 0.00000
Porosity 1.00 Infiltration Coefficient Side (m/hr) 0.00000
Safety Factor 2.0

Depth (m)	Area (m²)	Perimeter (m)	Depth (m)	Area (m²)	Perimeter (m)
0.000	252.0	197.000	0.600	751.0	217.000

Filtration Outflow Control

Permeability Coefficient (m/s) 0.000010 Area (m²) 50.000
Safety Factor 10.000 Invert Level (m) 99.400
Bed Depth (m) 0.450

Weir Overflow Control

Discharge Coef 0.544 Width (m) 5.000 Invert Level (m) 100.000

Summary of Results for 100 year Return Period (+40%)

Half Drain Time exceeds 7 days.

Outflow is too low. Design is unsatisfactory.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	99.604	0.204	0.0	0.1	0.1	317.4	O K
30 min Summer	99.627	0.227	0.0	0.1	0.1	357.7	O K
60 min Summer	99.653	0.253	0.0	0.1	0.1	403.2	O K
120 min Summer	99.682	0.282	0.0	0.1	0.1	454.4	O K
180 min Summer	99.700	0.300	0.0	0.1	0.1	487.2	O K
240 min Summer	99.720	0.320	0.0	0.1	0.1	511.8	Flood Risk
360 min Summer	99.750	0.350	0.0	0.1	0.1	548.6	Flood Risk
480 min Summer	99.772	0.372	0.0	0.1	0.1	576.1	Flood Risk
600 min Summer	99.789	0.389	0.0	0.1	0.1	598.3	Flood Risk
720 min Summer	99.803	0.403	0.0	0.1	0.1	617.0	Flood Risk
960 min Summer	99.826	0.426	0.0	0.1	0.1	648.5	Flood Risk
1440 min Summer	99.859	0.459	0.0	0.1	0.1	695.1	Flood Risk
2160 min Summer	99.892	0.492	0.0	0.1	0.1	744.1	Flood Risk
2880 min Summer	99.916	0.516	0.0	0.1	0.1	780.1	Flood Risk
4320 min Summer	99.943	0.543	0.0	0.1	0.1	822.0	Flood Risk
5760 min Summer	99.961	0.561	0.0	0.1	0.1	851.4	Flood Risk
7200 min Summer	99.975	0.575	0.0	0.1	0.1	873.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	222.781	0.0	6.2	31
30 min Summer	125.581	0.0	6.5	46
60 min Summer	70.790	0.0	13.4	76
120 min Summer	39.904	0.0	13.9	136
180 min Summer	28.536	0.0	14.1	196
240 min Summer	22.494	0.0	14.4	256
360 min Summer	16.086	0.0	14.8	376
480 min Summer	12.680	0.0	15.1	496
600 min Summer	10.543	0.0	15.2	616
720 min Summer	9.067	0.0	15.3	736
960 min Summer	7.158	0.0	15.4	976
1440 min Summer	5.129	0.0	15.2	1456
2160 min Summer	3.675	0.0	32.4	2176
2880 min Summer	2.901	0.0	32.0	2896
4320 min Summer	2.054	0.0	30.3	4336
5760 min Summer	1.607	0.0	66.5	5776
7200 min Summer	1.329	0.0	64.7	7216

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Summer	99.985	0.585	0.0	0.1	0.1	890.9	Flood Risk
10080 min Summer	99.994	0.594	0.0	0.1	0.1	905.0	Flood Risk
15 min Winter	99.604	0.204	0.0	0.1	0.1	317.4	O K
30 min Winter	99.627	0.227	0.0	0.1	0.1	357.7	O K
60 min Winter	99.653	0.253	0.0	0.1	0.1	403.2	O K
120 min Winter	99.682	0.282	0.0	0.1	0.1	454.4	O K
180 min Winter	99.700	0.300	0.0	0.1	0.1	487.2	O K
240 min Winter	99.720	0.320	0.0	0.1	0.1	511.8	Flood Risk
360 min Winter	99.750	0.350	0.0	0.1	0.1	548.6	Flood Risk
480 min Winter	99.772	0.372	0.0	0.1	0.1	576.1	Flood Risk
600 min Winter	99.789	0.389	0.0	0.1	0.1	598.3	Flood Risk
720 min Winter	99.803	0.403	0.0	0.1	0.1	617.0	Flood Risk
960 min Winter	99.826	0.426	0.0	0.1	0.1	648.5	Flood Risk
1440 min Winter	99.859	0.459	0.0	0.1	0.1	695.1	Flood Risk
2160 min Winter	99.892	0.492	0.0	0.1	0.1	744.1	Flood Risk
2880 min Winter	99.916	0.516	0.0	0.1	0.1	780.2	Flood Risk
4320 min Winter	99.943	0.543	0.0	0.1	0.1	822.1	Flood Risk
5760 min Winter	99.961	0.561	0.0	0.1	0.1	851.5	Flood Risk
7200 min Winter	99.975	0.575	0.0	0.1	0.1	873.8	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
8640 min Summer	1.138	0.0	62.7	8656
10080 min Summer	0.998	0.0	60.4	10096
15 min Winter	222.781	0.0	6.2	31
30 min Winter	125.581	0.0	6.5	46
60 min Winter	70.790	0.0	13.4	76
120 min Winter	39.904	0.0	13.9	136
180 min Winter	28.536	0.0	14.1	196
240 min Winter	22.494	0.0	14.4	254
360 min Winter	16.086	0.0	14.8	374
480 min Winter	12.680	0.0	15.1	494
600 min Winter	10.543	0.0	15.2	614
720 min Winter	9.067	0.0	15.3	732
960 min Winter	7.158	0.0	15.4	972
1440 min Winter	5.129	0.0	15.2	1450
2160 min Winter	3.675	0.0	32.4	2168
2880 min Winter	2.901	0.0	32.0	2884
4320 min Winter	2.054	0.0	30.2	4296
5760 min Winter	1.607	0.0	66.4	5720
7200 min Winter	1.329	0.0	64.7	7144

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
8640 min Winter	99.985	0.585	0.0	0.1	0.1	891.3	Flood Risk
10080 min Winter	99.994	0.594	0.0	0.1	0.1	905.5	Flood Risk

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
8640 min Winter	1.138	0.0	62.6	8568
10080 min Winter	0.998	0.0	60.3	9992

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 550950 257200 TL 50950 57200
C (1km)	-0.025
D1 (1km)	0.288
D2 (1km)	0.293
D3 (1km)	0.263
E (1km)	0.312
F (1km)	2.488
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.950
Cv (Winter)	0.950
Shortest Storm (mins)	15
Longest Storm (mins)	10080
Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.600

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	0.150	4	8	0.150	8	12	0.150	12	16	0.150

Model Details

Storage is Online Cover Level (m) 100.000

Complex Structure

Bio-Retention Area

Invert Level (m) 99.400 Infiltration Coefficient Base (m/hr) 0.00000
Porosity 1.00 Infiltration Coefficient Side (m/hr) 0.00000
Safety Factor 2.0

Depth (m)	Area (m²)	Perimeter (m)	Depth (m)	Area (m²)	Perimeter (m)
0.000	763.0	97.081	0.600	1689.0	152.060

Cellular Storage

Invert Level (m) 99.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Inf. Area (m²)	Depth (m)	Area (m²)	Inf. Area (m²)
0.000	695.0	695.0	0.301	0.0	726.7
0.300	695.0	726.6			

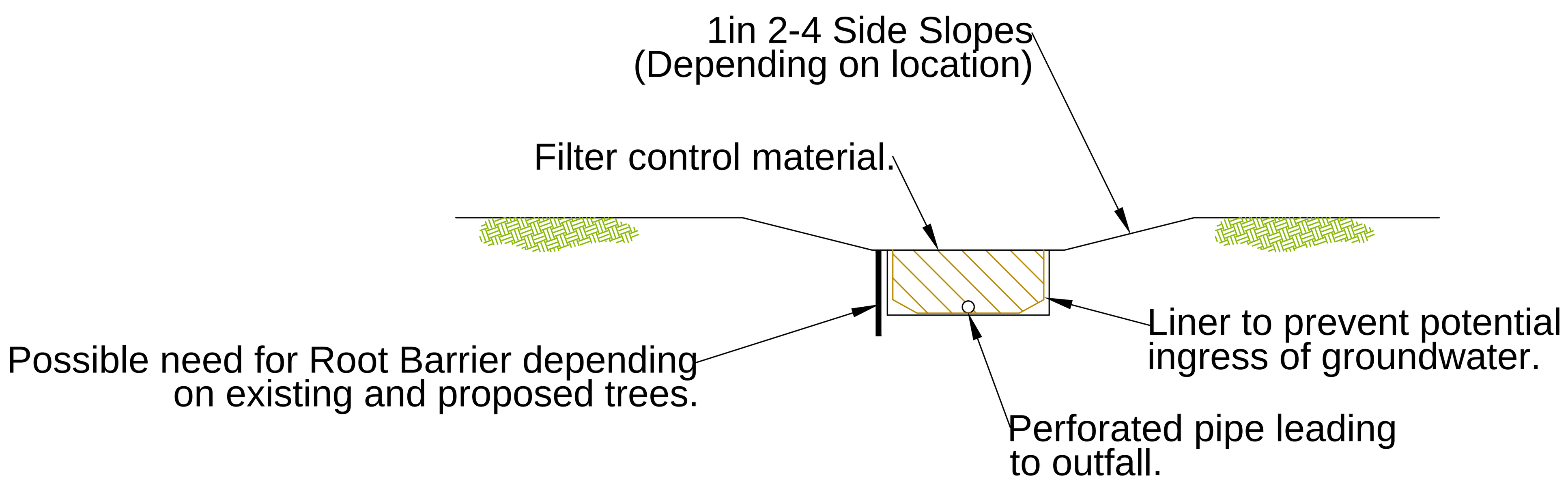
Filtration Outflow Control

Permeability Coefficient (m/s) 0.000010 Area (m²) 50.000
Safety Factor 10.000 Invert Level (m) 99.400
Bed Depth (m) 0.450

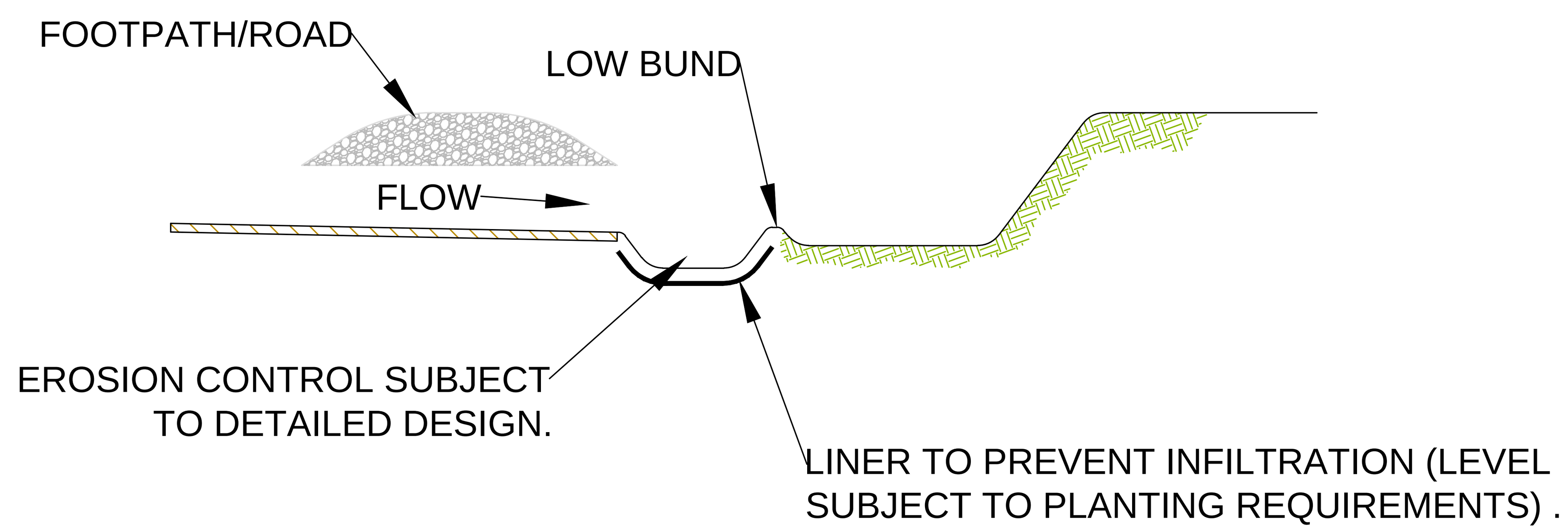
Updated surface water management strategy B411-004-Rev A

KEY:

- SITE BOUNDARY
- POTENTIAL NEW WATERCOURSE ROUTE
- MAINTAINED SURFACE WATER FLOOD STORAGE AND ROUTE FOR SITE RUN-ON
- BIORETENTION AREAS
- FILTER CONTROL
- OUTFALL
- CELLULAR STORAGE



TYPICAL SECTION THROUGH DOWNSTREAM END OF BIORETENTION AREA



TYPICAL HIGHWAY RILL/BIORETENTION AREA INTERACTION

REV	DESCRIPTION	DE	DR	CH	PA	DATE
A	CELLULAR STORAGE ADDED	-	DP	-	-	01/2017

DESIGNED BY	DRAWN BY	CHECKED BY	PASSED BY
-	DP	JH	-

SCALES @ A1 SIZE	DATE	ISSUE STATUS
N.T.S.	30/07/2014	PRELIMINARY

PROJECT TITLE

LAND AT TEVERSHAM ROAD, FULBOURN, CAMBS

DRAWING TITLE

SURFACE WATER MANAGEMENT AND SURFACE WATER FLOOD MANAGEMENT PLAN

CLIENT

CASTLEFIELD INTERNATIONAL LTD

CANNON
CONSULTING ENGINEERS
Highways, Transport & Infrastructure Planning

Cannon Consulting Engineers
Cambridge House, Kentford, Newmarket, Cambs, CB8 7PN
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info@cannonce.co.uk www.cannonce.co.uk

DRAWING NUMBER	REV.
B411 - 004	A

2016 Geosphere groundwater monitoring report

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Our Ref 1630,MO/Ltr01/JG,JD,PD/21-06-16/V1
Your Ref

Date 21 June 2016

Castlefield International Ltd c/o Cannon Consulting Engineers
Cambridge House
Lanwades Business Park
Kennett
Newmarket
Suffolk
CB8 7PN

For the attention of James Howard

By Email
- james.howard@cannonce.co.uk

Dear Mr Howard

GROUNDWATER MONITORING AT TEVERSHAM ROAD, FULBOURNE, CAMBRIDGESHIRE, CB21 5HE

1. Introduction

This factual letter report has been prepared for the Client, Castlefield International Ltd c/o Cannon Consulting Engineers.

Geosphere Environmental was commissioned to undertake additional groundwater monitoring visits at the subject site, outlined by and located by Drawing reference 1630,MO/001, attached.

This was to be achieved by:

- Undertaking monthly monitoring of the groundwater levels over a period of six months to assess the changes in groundwater.

This is a continuation of monitoring groundwater levels with the previous data included below.

2. Groundwater Level Monitoring

The groundwater level monitoring involved multiple visits to the site over six months, and using a dipmeter to determine the depth to groundwater below the surrounding ground level. The monitoring points were WS1a and WS3a, as illustrated by the attached Exploratory Hole Location Plan, Drawing ref. 1630,MO 001/Rev 0.
Another monitoring point, WS6a, was available during previous phases of groundwater monitoring, but could not be located during any of the recent monitoring visits, despite numerous additional visits by Geosphere Environmental personnel to search for the monitoring pipe.

2.1 Groundwater Monitoring Data Summary

Groundwater was measured within the locatable monitoring wells on six occasions, within this phase of works and this is summarised below. In addition to which, the data from the previous phases, (report or project reference 1058,CO), are displayed below to assist assessment:

Summary of groundwater depth results			
Date of visit	**WS1a (mbgl)**	**WS3a (mbgl)**	**WS6a (mbgl)**
05/02/2015	0.65	0.92	0.63
16/02/2015	0.75	1.00	0.66
13/03/2015	0.74	1.03	0.67
28/04/2015	0.79	n/m	0.60
28/05/2015	0.81	1.14	0.59
05/06/2015	0.88	1.08	0.66
16/11/2016	0.80	1.10	n/m
18/01/2016	1.03	0.68	n/m
24/02/2016	0.71	1.00	n/m
23/03/2016	0.98	0.78	n/m
19/04/2016	0.68	0.99	n/m
20/05/2016	1.00	1.25	n/m

The stream running through the site was observed however the best access point was obstructed by a fallen tree. Where the stream was observable it was flowing northwards, with clear water and at a moderate rate.

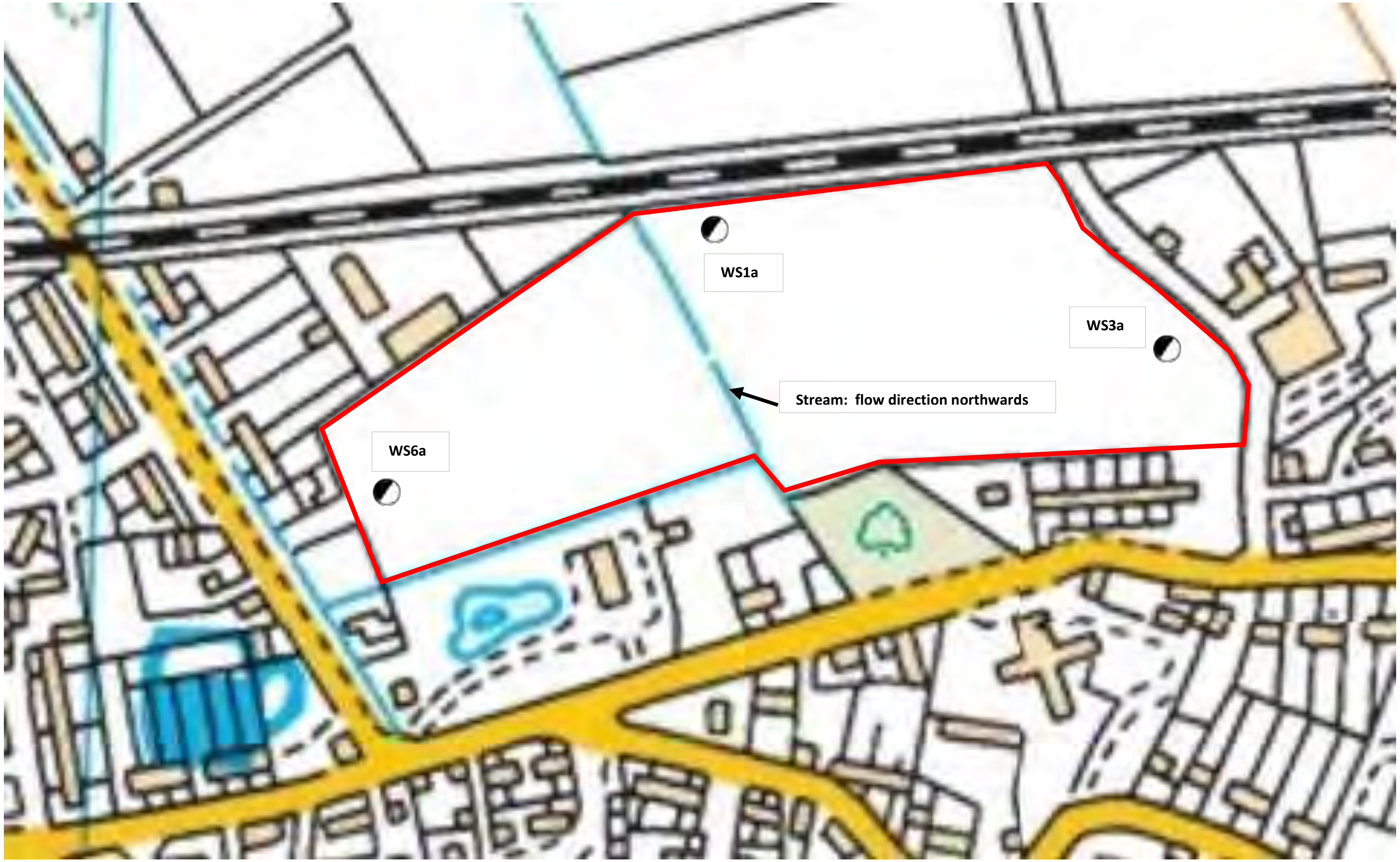
The results are provided as an attachment. Our standard report conditions and limitations apply to this letter report and these are available upon request.

We trust the above is clear and acceptable, however if you have any comments or queries please do not hesitate to contact us.

Yours sincerely

Jim Dawson
Principal Geoenvironmental Consultant
Geosphere Environmental Ltd

Enclosures/Attachments:
Exploratory Hole Location Plan - Drawing 1630,MO/001 (June 2016)
Groundwater monitoring data, project 1630,MO
Groundwater monitoring data, project 1058,CO



LEGEND:

Site boundary

Monitoring well locations — Approximate site boundary

N

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E info@geosphere-environmental.co.uk

SITE	TITLE	REPORT NO.	DRAWING NO.	DATE
Teversham Road, Fulbourne, Cambridgeshire, CB21 5HE	Exploratory Hole Location Plan	1630, MO	001.	June2016
	CLIENT	**DRAWN BY**	**CHECKED**	**SCALE**
	Castlefield International Ltd c/o Cannon Consulting Engineers.	JG	LF, JD	Not to scale

geosphere environmental ltd

geosphere environmental ltd

Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

Exploratory Hole Location WS1a

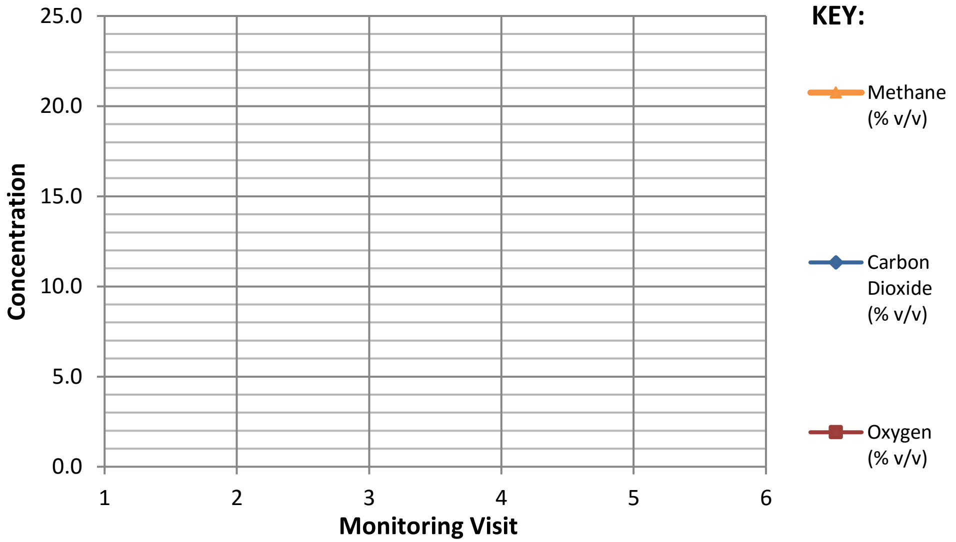
Return Visit #	Monitoring Date	Atmospheric Pressure (mb)	Methane Content (% v/v)	Methane Content (% LEL)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Flow Rate (l/hr)	Water Level (mbgl)	Comments
1st visit	16/11/2015							0.80	Cool, cloudy, dry, calm
2nd visit	18/01/2016							1.03	Cold, overcast, damp, breezy
3rd visit	24/02/2016							0.71	Cool, sunny, damp, calm
4th visit	23/03/2016							0.98	Cool, cloudy, damp, calm
5th visit	19/04/2016							0.68	Sunny, cool, dry, still
6th visit	20/05/2016							1.00	Cool, overcast, damp, calm

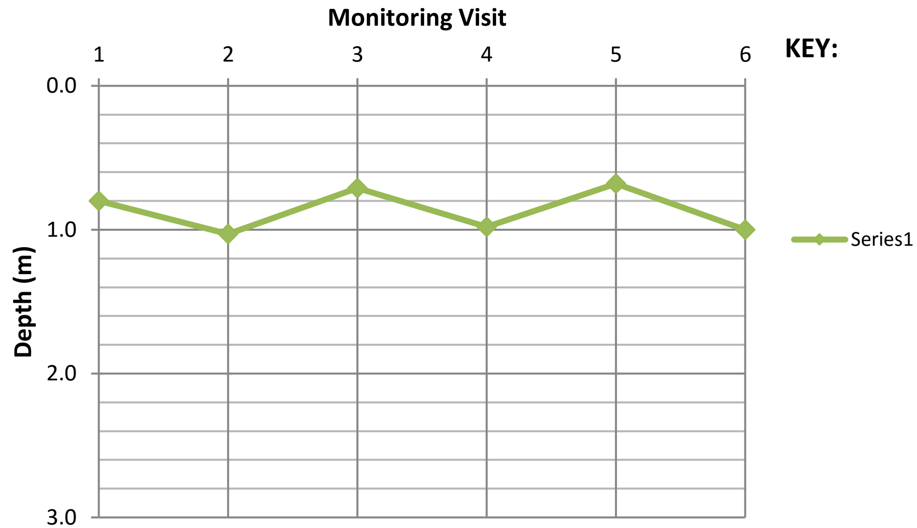
Instrument Used: Dipmeter

NOTE: **n/a** Not applicable

REMARKS: WS1 located approximately 10m from rail line at NW corner of Cox Drove field

nm Not measured





SITE
Land off Teversham Road, Fulbourn, Cambridgeshire

REPORT
1630,MO

DATE
20 June 2016

GROUND GAS AND GROUNDWATER MONITORING DATA

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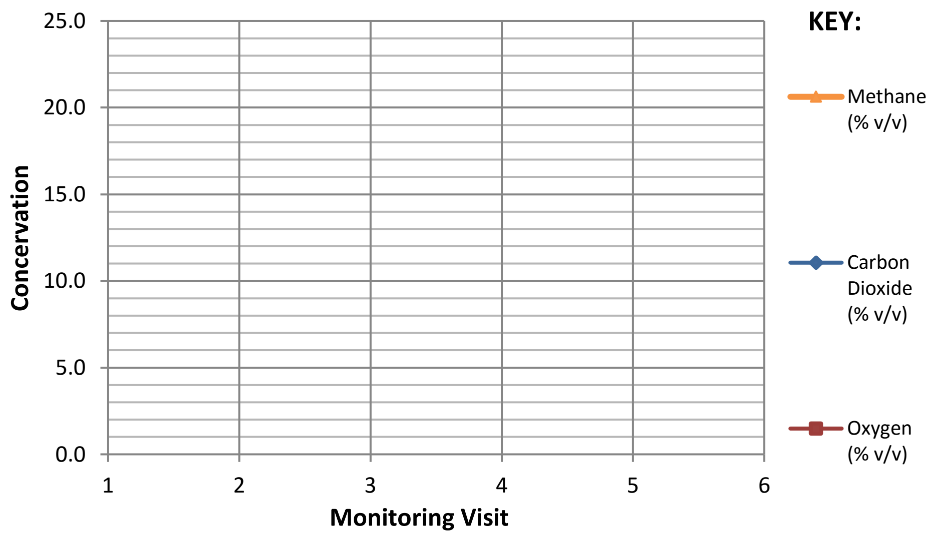
Exploratory Hole Location WS3a

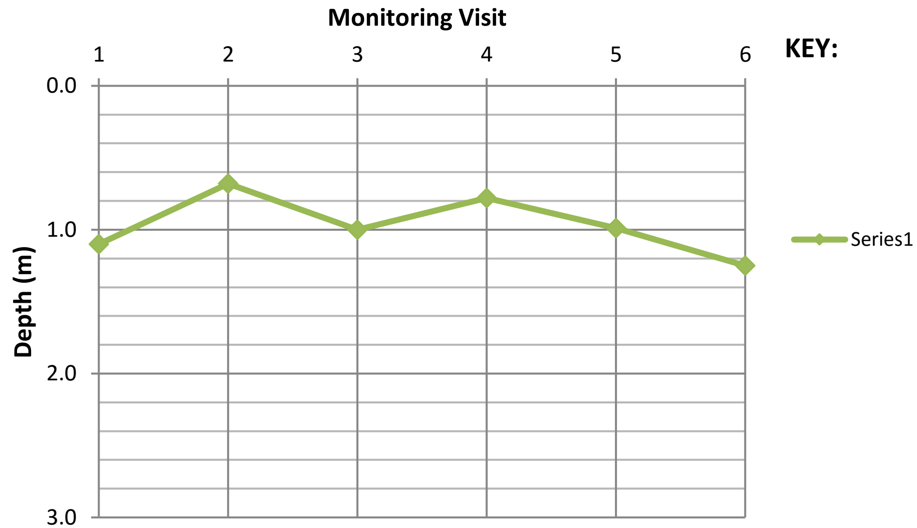
Return Visit #	Monitoring Date	Atmospheric Pressure (mb)	Methane Content (% v/v)	Methane Content (% LEL)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Flow Rate (l/hr)	Water Level (mbgl)	Comments
1st visit	16/11/2015							1.10	Cool, cloudy, dry, calm
2nd visit	18/01/2016							0.68	Cold, overcast, damp, breezy
3rd visit	24/02/2016							1.00	Cool, sunny, damp, calm
4th visit	23/03/2016							0.78	Cool, cloudy, damp, calm
5th visit	19/04/2016							0.99	Sunny, cool, dry, still
6th visit	20/05/2016							1.25	Cool, overcast, damp, calm

Instrument Used: Dipmeter

REMARKS: WS3 located approx approx 25m from Cox Drove access point

NOTE: **n/a** Not applicable; **nm** Not measured





SITE
Land off Teversham Road, Fulbourn, Cambridgeshire

REPORT 1630,MO

DATE 20 June 2016

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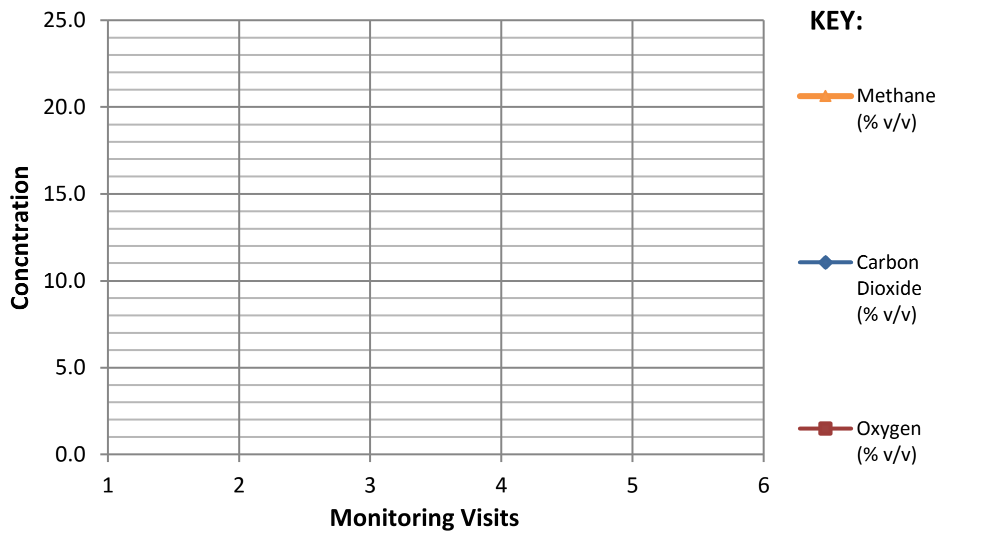
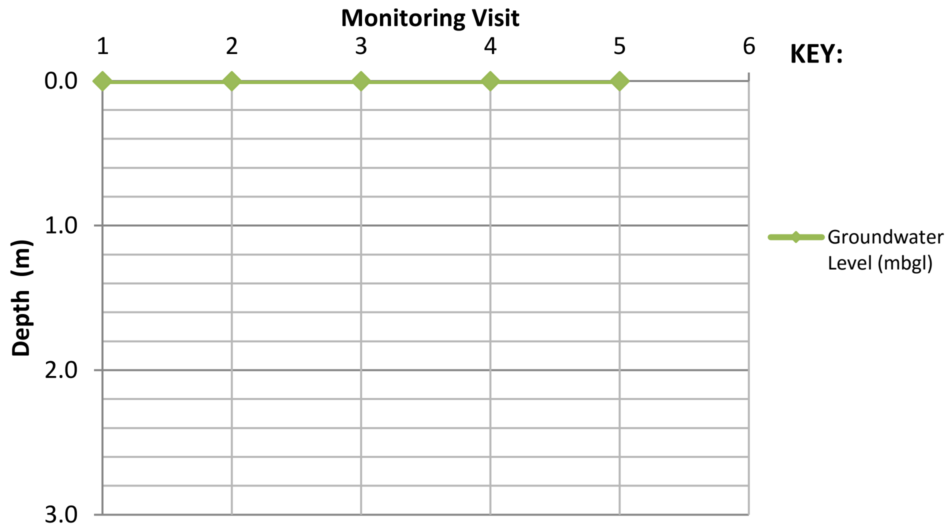
Exploratory Hole Location WS6A

Return Visit #	Monitoring Date	Atmospheric Pressure (mb)	Methane Content (% v/v)	Methane Content (% LEL)	Carbon Dioxide (% v/v)	Oxygen (% v/v)	Flow Rate (l/hr)	Water Level (mbgl)	Comments
1st visit								n/m	Not located during this phase of monitoring; searched-for by at least three consultants, with previous experience of the site on separate occasions.
2nd visit								n/m	
3rd visit								n/m	
4th visit								n/m	
5th visit								n/m	
6th visit								n/m	





SITE
Land off Teversham Road, Fulbourn, Cambridgeshire

GROUNDWATER MONITORING DATA

geosphere environmental ltd

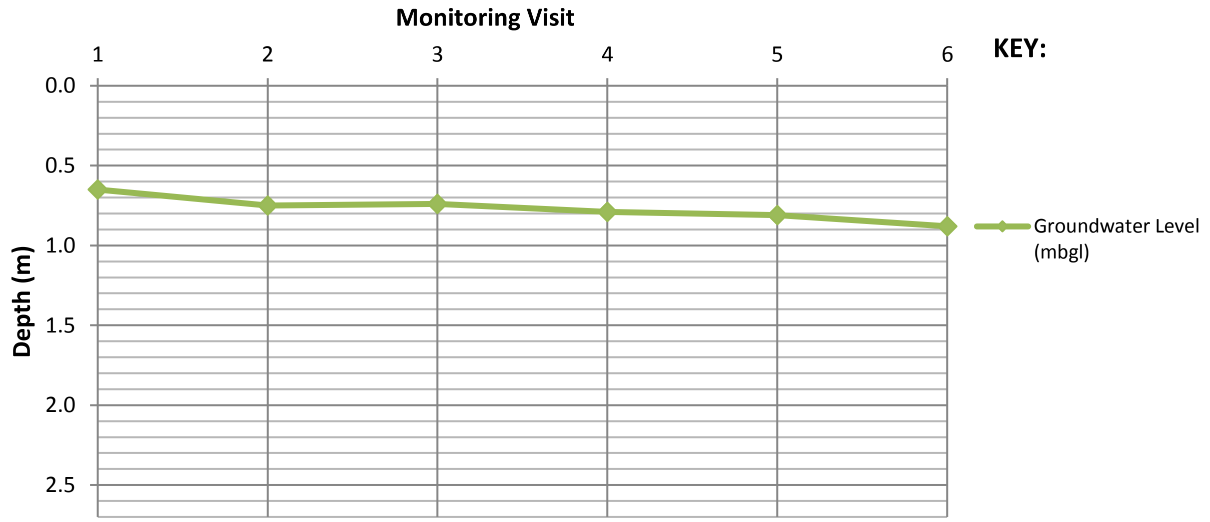
Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

Exploratory Hole Location **WS1a** **Date of Installation** 04/02/2015

Return Visit #	Monitoring Date	Depth of Monitoring Well (mbgl)	Water Level (mbgl)	Comments
1st visit	05/02/2015	2.70	0.65	Cool, overcast, damp and breezy
2nd visit	16/02/2015	2.70	0.75	Cool, cloudy, damp and calm
3rd visit	13/03/2015	2.70	0.74	Cool, overcast, dry and calm
4th visit	28/04/2015	2.70	0.79	Cool, cloudy, dry and breezy
5th visit	28/05/2015	2.70	0.81	Warm, cloudy, dry and breezy
6th visit	05/06/2015	2.70	0.88	Hot, overcast, damp and calm

Instrument Used: GA2000 gas analyser **n/a** Not applicable

REMARKS: **nm** Not measured



SITE Teversham Road, Fulbourn

REPORT 1058,CO

DATE 10 November 2015

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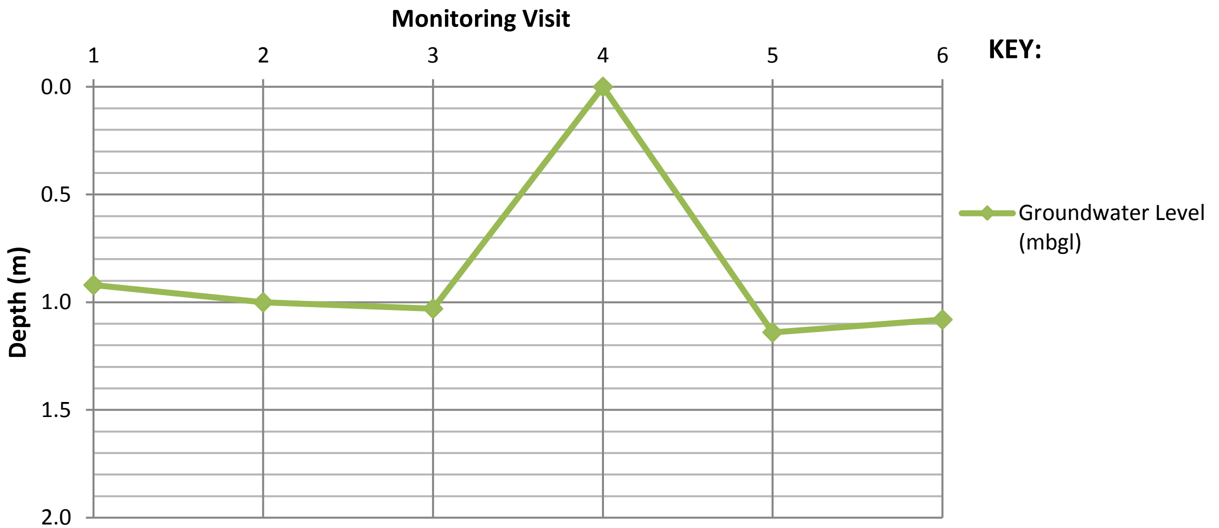
Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

Exploratory Hole Location **WS3a** **Date of Installation** 04/02/2015

Return Visit #	Monitoring Date	Depth of Monitoring Well (mbgl)	Water Level (mbgl)	Comments
1st visit	05/02/2015	2.00	0.92	Cool, overcast, damp and breezy
2nd visit	16/02/2015	2.00	1.00	Cool, cloudy, damp and calm
3rd visit	13/03/2015	2.00	1.03	Cool, overcast, dry and calm
4th visit	28/04/2015	2.00	n/m	Cool, cloudy, dry and breezy
5th visit	28/05/2015	2.00	1.14	Warm, cloudy, dry and breezy
6th visit	05/06/2015	2.00	1.08	Hot, overcast, damp and calm

Instrument Used: GA2000 gas analyser **n/a** Not applicable

REMARKS: **nm** Not measured



SITE Teversham Road, Fulbourn

REPORT 1058,CO

DATE 10 November 2015

GROUNDWATER MONITORING DATA

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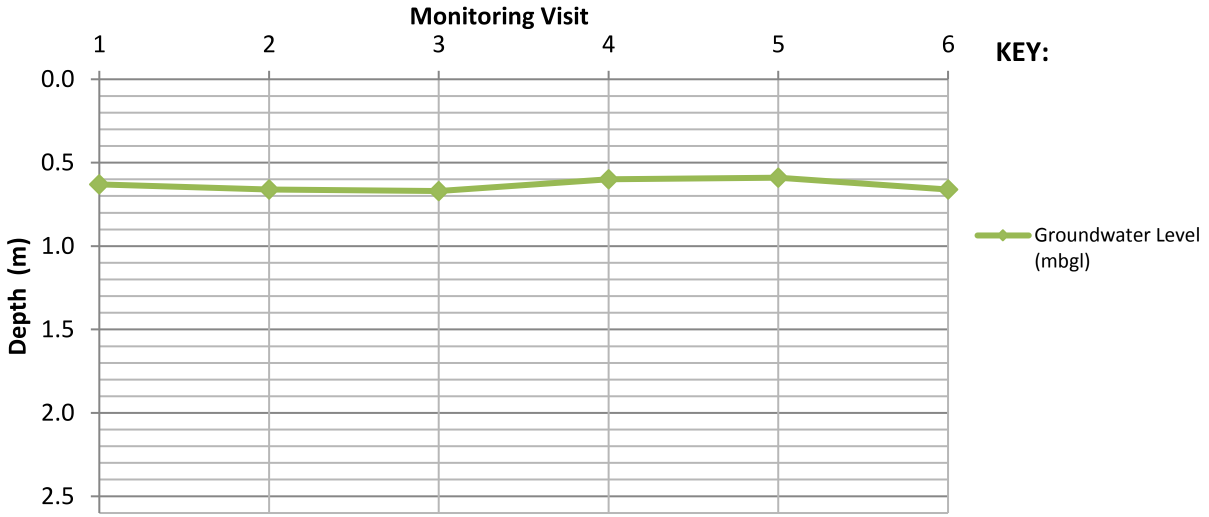
Geosphere Environmental Ltd, Brightwell Barns, Ipswich Road, Brightwell, Suffolk, IP10 0BJ

Exploratory Hole Location **WS6a** **Date of Installation** 04/02/2015

Return Visit #	Monitoring Date	Depth of Monitoring Well (mbgl)	Water Level (mbgl)	Comments
1st visit	05/02/2015	2.60	0.63	Cool, overcast, damp and breezy
2nd visit	16/02/2015	2.60	0.66	Cool, cloudy, damp and calm
3rd visit	13/03/2015	2.60	0.67	Cool, overcast, dry and calm
4th visit	28/04/2015	2.60	0.60	Cool, cloudy, dry and breezy
5th visit	28/05/2015	2.60	0.59	Warm, cloudy, dry and breezy
6th visit	05/06/2015	2.60	0.66	Hot, overcast, damp and calm

Instrument Used: GA2000 gas analyser **n/a** Not applicable
REMARKS: **nm** Not measured



SITE
Teversham Road, Fulbourn

REPORT
1058,CO

DATE
10 November 2015

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