APPENDIX F

JBA CONSULTING
FLOOD RISK IMPACT ASSESSMENT
FEBRUARY 2020

Flood Risk Impact Assessment at Catalyst Bicester

Final report

February 2020

www.jbaconsulting.com

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Revision History

Revision Ref/Date	Amendments	Issued to
S3-P01 Feb. 2020	Draft Report	W. Bailey (Bailey Johnson Hayes)
A1-C01 Feb. 2020	Final Report	W. Bailey (Bailey Johnson Hayes)

Contract

This report describes work commissioned by Bill Bailey on behalf of Albion Land (Three) Ltd by an email dated 28 January 2020. Albion Land (Three) Ltd's representative for the contract was Bill Bailey of Bailey Johnson Hayes.

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Chartered Senior Analyst

Purpose

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Executive summary

A commercial development is being proposed at Catalyst Bicester, Wendlebury Road, Bicester.

To support the loss in floodplain capacity generated by the proposed commercial units (and associated ground raising), Bailey Johnson Hayes designed a level-for-level floodplain compensation scheme for up to the 1,000-year fluvial flood levels (which range between 64.19m AOD and 64.46m AOD across the site).

The Environment Agency (EA) commented on their proposal and raised the following comments:

1. The 1 in 100 plus 35% climate change in relation to the site needs to be modelled, not interpolated;
2. The impact of the proposal on the during the 1 in 100 plus 35% climate change fluvial flood scenario needs to be modelled to ensure third-party land is not affected.
3. The proposed level-for-level floodplain compensation scheme needs to be designed to accommodate the 1 in 100 plus 35% climate change fluvial flood.

JBA Consulting was subsequently commissioned by Bailey Johnson Hayes in January 2020 to model the 100-year with (+35%) climate change flood risk and assess the impact of a proposed commercial development at Catalyst Bicester, Wendlebury Road, Bicester.

To support this, the EA's hydraulic model was upgraded using new channel survey data, new topographic survey data and a finer grid cell size.

Results from the Quality Assessment phase indicate that:

- Topographic survey data compares relatively well with LiDAR data.
- Model results at the site are relatively insensitive to changes in grid cell size.
- Modelled flows upstream of the site are conservative (when compared with the hydrological assessment carried out by JBA in 2019).

As a result, an 'upgraded' version of the EA model using topographic survey data, LiDAR data, new channel survey data and a 4m grid cell size was used to represent flood risk in relation to the site.

The model was subsequently amended to represent the raised development plateaus and proposed floodplain compensation scheme on site and then re-run for the pre- and post-development 100-year with (+35%) climate change scenarios. Model results indicate that:

- The proposed floodplain compensation scheme completely offsets the impact of the raised development plateaus.
- The proposal does not generate any detrimental impacts across third-party land.
- The 100-year with (+35%) Climate Change peak water levels on site vary between 64.04 and 64.19m AOD. This is significantly less than the 1,000-year flood levels (i.e. between 64.19m AOD and 64.46m AOD) used by Bailey Johnson Hayes to design their floodplain compensation scheme. Not surprisingly, the floodplain compensatory storage areas located along the western site boundary will remain dry or will just start filling up during the peak of the 100-year with (+35%) Climate Change fluvial flood event.

In conclusion, it is considered that the proposed floodplain compensation scheme designed by Bailey Johnson Hayes will be able to offset the impact of the proposal during the 100-year with (+35%) Climate Change fluvial flood scenario and even provide additional floodplain storage capacity during more extreme flood events.

Contents

List of Figures

Abbreviations

EA	Environment Agency
FFL	Finished Floor Level
AEP	Annual Exceedance Probability
CC	Climate Change
FRA	Flood Risk Assessment
ha	hectare
JBA	Jeremy Benn Associates
LLFA	Lead Local Flood Authority
LFRMS	Local Flood Risk Management Strategy
SFRA	Strategic Flood Risk Assessment
m AOD	metres Above Ordnance Datum
NPPF	National Planning Policy Framework
PPG	Planning Policy Guidance
SuDS	Sustainable Drainage System
CDM 2015	Construction, Design and Management Regulations 2015

1 Introduction

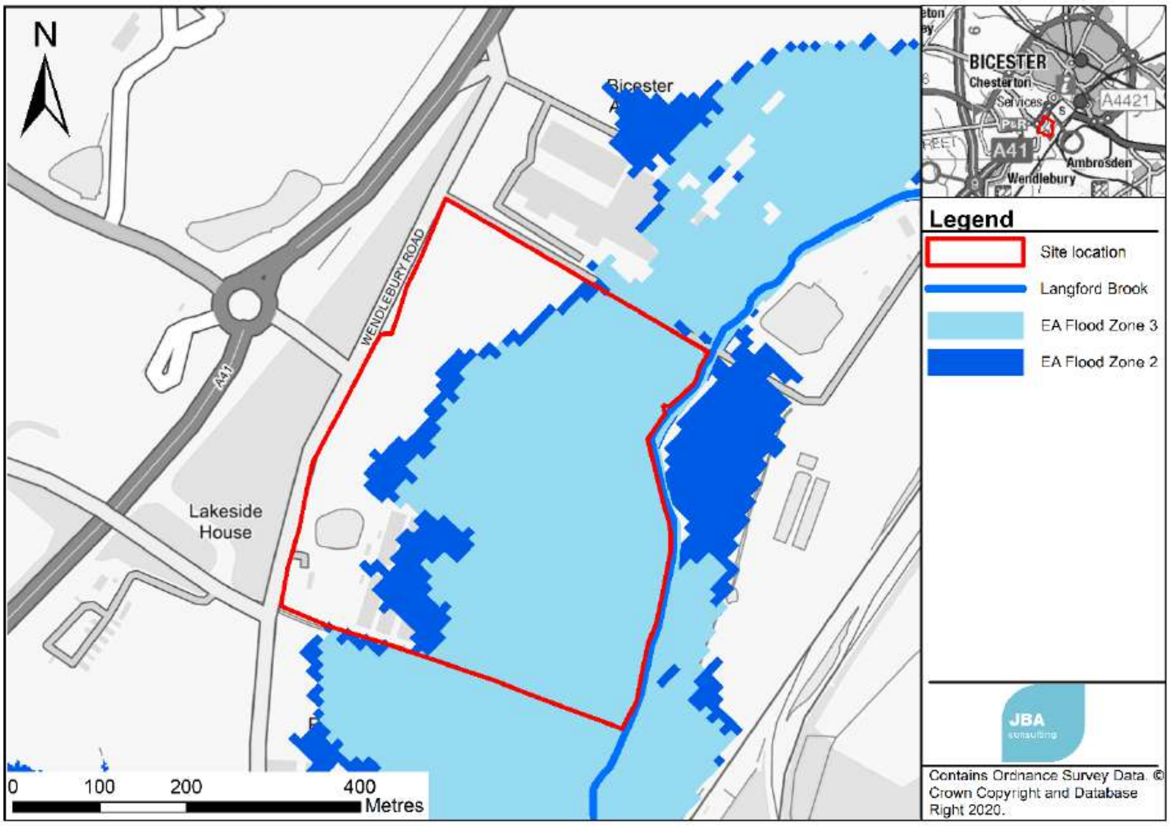
1.1 Terms of Reference

JBA Consulting was commissioned by Bailey Johnson Hayes in January 2020 to model the 100-year with (+35%) climate change flood risk and assess the impact of a proposed commercial development at Catalyst Bicester, Wendlebury Road, Bicester.

1.2 Context

A planning application for a commercial development was submitted to Cherwell District Council in August 2019 (ref: 19/01740/HYBRID). The proposed development site is adjacent to the Langford Brook ('main river' designated watercourse) and partially falls within the Environment Agency's Flood Zones 2 and 3.

Figure 1-1: Site location



To support the loss in floodplain capacity generated by the proposed commercial units (and associated ground raising), Bailey Johnson Hayes designed a level-for-level floodplain compensation scheme for up to the 1,000-year fluvial flood levels (which range between 64.19m AOD and 64.46m AOD across the site).

As part of the consultation process, the Environment Agency (EA) responded on 27 December 2019 with an objection (see Appendix A). The key points of objection can be summarised as follow:

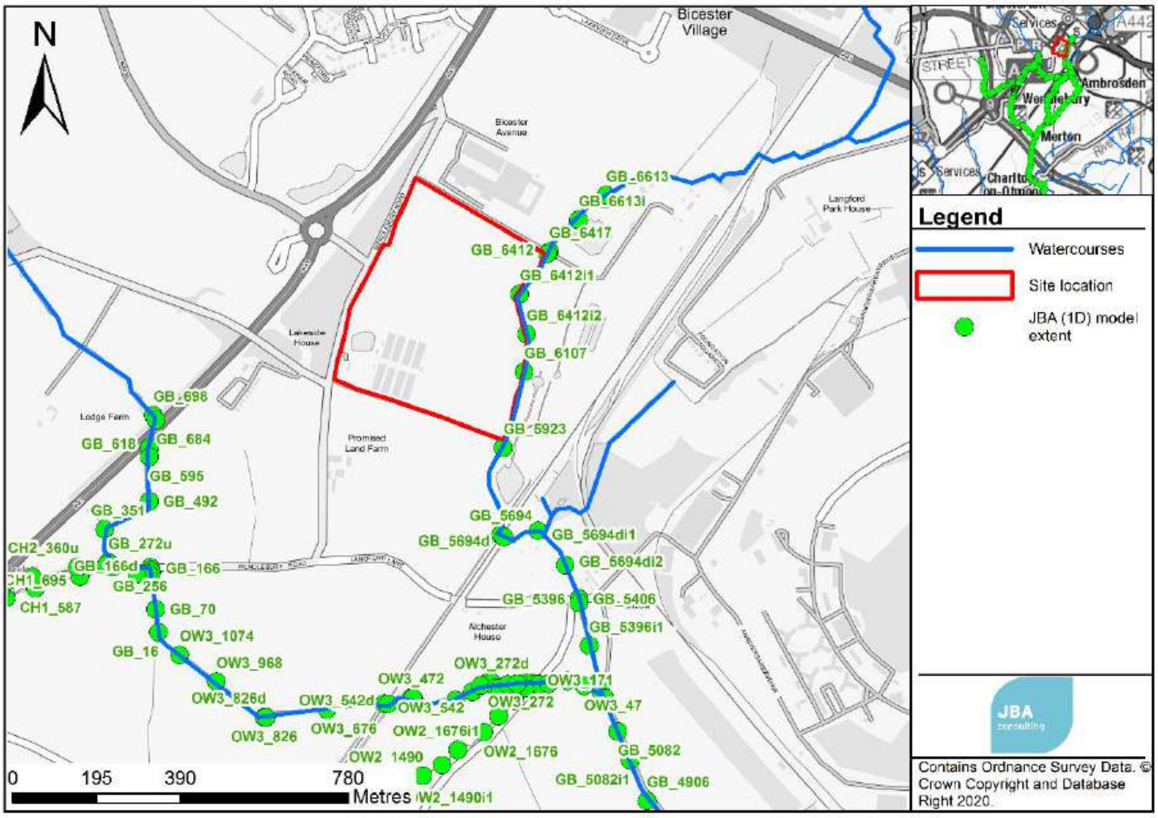
- The 1 in 100 plus 35% climate change in relation to the site needs to be modelled, not interpolated;
- The impact of the proposal on the during the 1 in 100 plus 35% climate change fluvial flood scenario needs to be modelled to ensure third-party land is not affected.

- The proposed level-for-level floodplain compensation scheme needs to be designed to accommodate the 1 in 100 plus 35% climate change fluvial flood.

The EA have a hydraulic model representing the Langford Brook (ref: Langford Brook (Bicester) & Pingle-Back-Bure 2010) which is dated 2010 and stops approximately 220m downstream of the site, at the railway bridge. The bridge (and thus losses associated with the bridge) are not represented in the EA model.

JBA undertook a new hydraulic modelling study of the Langford Brook in 2019 extending further downstream of the railway line (see extent in Figure 1-2).

Figure 1-2: JBA Model – Langford Brook - Wendlebury Brook confluence



Information collected as part of the 2019 study are deemed more representative of the current conditions and thus were used to support this analysis.

1.3 Approach

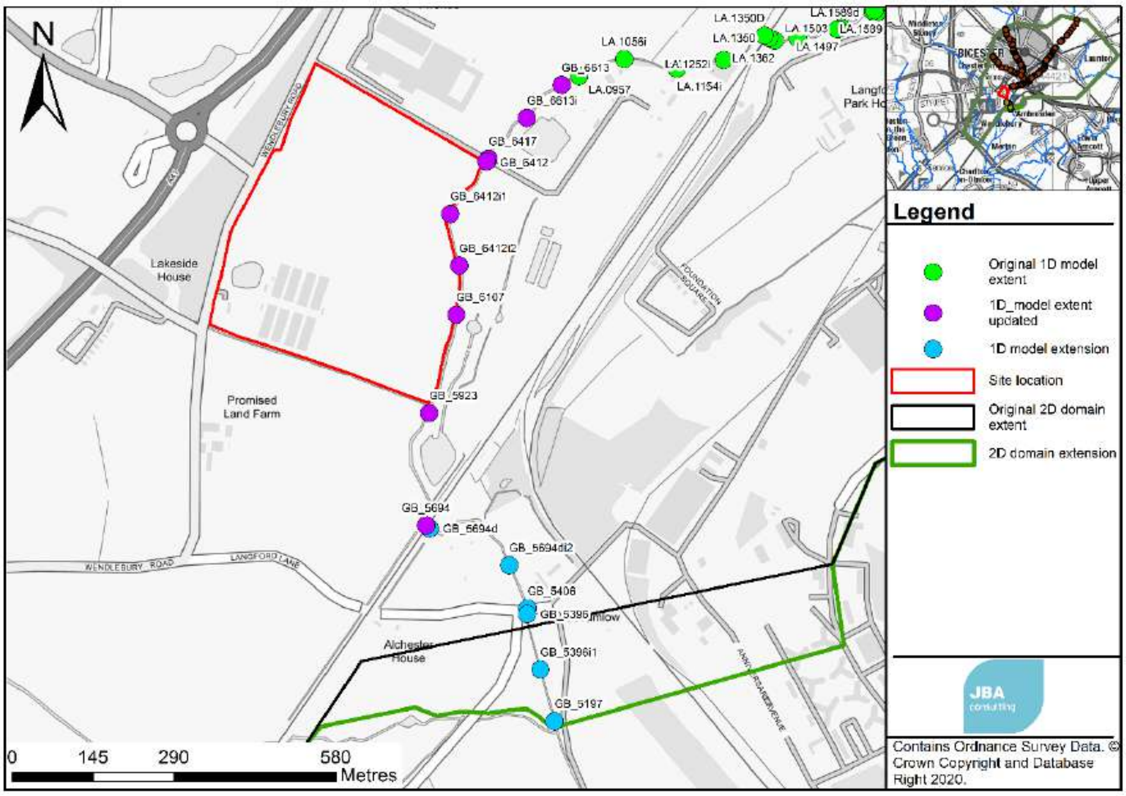
Given the age of the channel cross sections used in the EA model and the distance between its downstream boundary and the site, it was decided to upgrade the EA model using new topographical survey data (provided by the client), new channel survey data (from the 2019 JBA modelling study) and extending the model beyond the railway embankment to increase confidence in the model results at the site. The upgraded model was then run for the 100-year with (+35%) climate change fluvial flood evet in order to assess the impact of the proposed development.

2 Amendments made the EA model

2.1 Baseline scenario

The Langford Brook model (2010) was extended using new survey data over the area represented in Figure 2-1.

Figure 2-1: Model Extension



The following amendments were made to the EA model

- Channel survey data collected in 2019 along the Langford Brook from GB_6613 to GB_5197 (see Appendix B and Figure 1-2 for location) was used to extent the EA's model and more accurately represent losses associated with the railway bridge.
- Given the distance between nodes LA.1350D and LA.0957 (i.e. 393m) when compared to other channel section chainages (>100m) near the site, 4 interpolates were added for consistency purpose, to improve the overall model stability and to improve confidence in the model results.
- The channel cross section width at LA.0957 was reduced from 20.130m to 7.521m to remain consistent with the nearest channel cross section width downstream (i.e. 7.196 at GB_6613).
- The 1D-2D link, inactive domain, ZP elevations along the riverbank in the 2d_bc_Z_HX_Bicester_012.MIF file was amended using the new channel survey data.
- Two new 2D (HQ) downstream boundaries were added to the 2d_bc_Z_HX_Bicester_012.MIF model file along the downstream end of the 2D domain extension.

- A new 'normal-depth' downstream boundary condition was set up within the 1D domain at the downstream end of the model (i.e. node: GB_5197), using a slope of 1 in 1936 (taken between surveyed sections GB_5396 and GB_4906)
- Initial conditions in the channel (formerly read from "Bicester_007.iic") are now integrated and read from the DAT file.
- The grid cell size of the model, originally set to 10m, was reduced to 4m to more accurately represent the proposed floodplain compensation scheme (Note: Attempts to reduce it to 2m led to modelling instabilities). To allow the model to run with a finer cell-size, LiDAR data from the Defra Survey Data Download webpage was read in the model instead of the original z-point files (i.e. 2d_zpt_Bicester_003.MID). According to the website, the age of the LiDAR DTM pre-dates the construction of the EA hydraulic model.
- Site-specific topographic survey data (See Appendix C) was converted into a 3D ascii grid file (2019s0133-topo_survey.asc) and read into the TUFLOW geometry file.

Amended files were renamed with the word "extended" (e.g. "Bicester_ 008.tgc" became "Bicester_extended_008.tgc"). These include:

Table 3 1: Model log files

File name	Description
Bicester_012_100yr+35%CC_17hr_extended_Pre_001.ief	New Flood Modeller event file referring to the 100yr+35%CC pre-development scenario
Bicester_012_100yr35pctCC_17hr_extended_Pre_001.tcf	New TUFLOW control file referring to the 100yr+35%CC pre-development scenario, including: - Reference to the new tgc and tbc files - Reference to a new PO line (2d_po_Bicester_extended_003.MIF) for QA purpose (See Section 3.2 below)
Bicester_012_100yr35pctCC_17hr_extended_Pre_001.ecf	New ESTRY control file referring to the 100yr+35%CC pre-development scenario
Bicester_extended_Pre_008.tgc	New TUFLOW geometry file, including: - 2d_code_Bicester_extended_002: New 2D domain file extended 500m (approx.) downstream of railway embankment
Bicester_extended_Pre_007.tbc	New TUFLOW boundary control file, including: - 2d_bc_Z_HX_Bicester_extended_012.MIF: New 1D-2D link file extended 500m (approx.) downstream of railway embankment

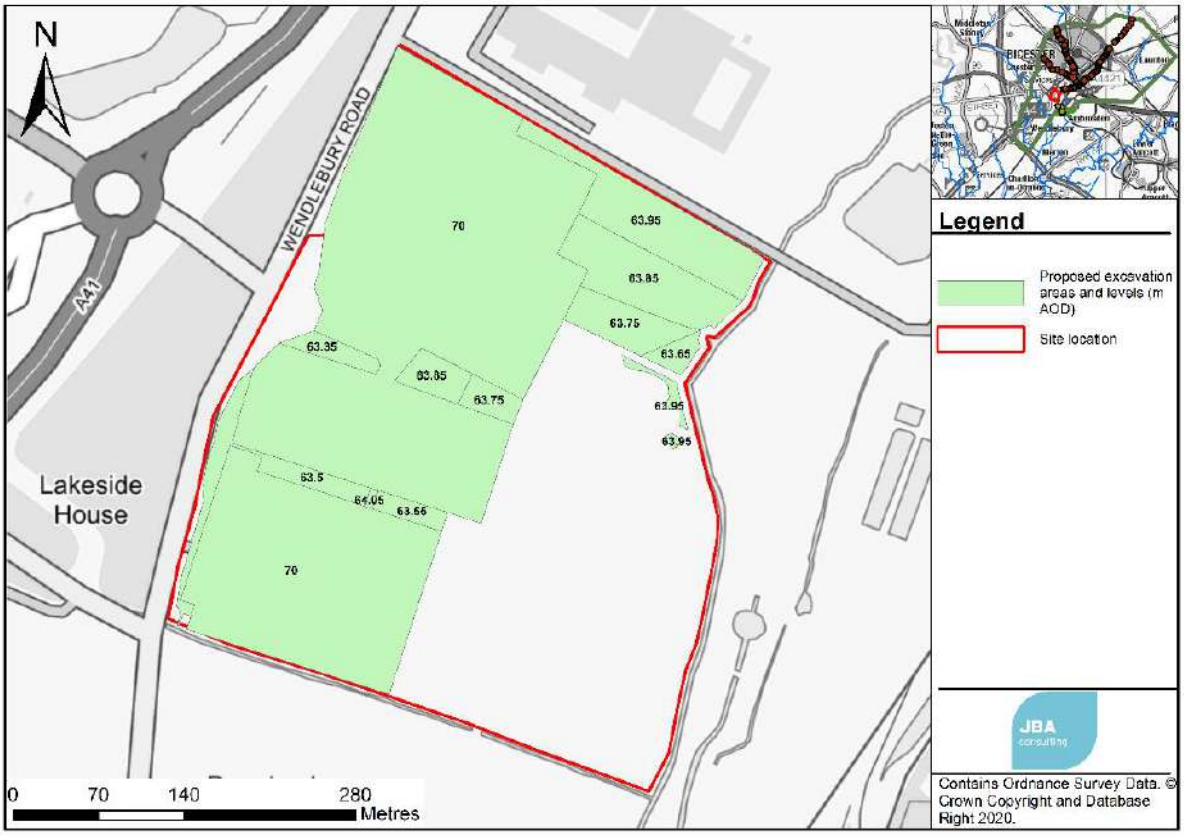
2.2 Post-development scenario

The following amendments were made to the upgraded baseline model in order to represent the post-development scenario:

- The development plateaus were modelled as 100% flood resilient (and thus 'virtually' raised to 70m AOD in the model);
- The floodplain compensatory storage areas were modelled as represented in Bailey Johnson Hayes' drawing ref S1358-Ext-45 (see Appendix D) using a combination a z-shape file (2d_zsh_FPCAscheme_001.MIF) to represent the plateaus and excavation areas, a z-line (2d_zln_FPCwall_001.MIF) to represent overflow locations and a z-line (gully) to reinforce the representation of narrow channels between storage areas within the 4m grid.

The location of the development plateaus and floodplain compensatory storage areas as represented in the model is shown in Figure 2-2.

Figure 2-2: Proposed site ground levels in the model



3 Quality Assessment

3.1 Review of site topographic survey versus model z-point elevations

A comparison of the topographic survey data and the z-point elevations used in the original EA hydraulic model was made to understand if there were any significant differences. Results (whereby an ascii grid generated from the EA model z-points was subtracted from the topographic survey) are represented in Figure 3-1.

Figure 3-1: Model Extension

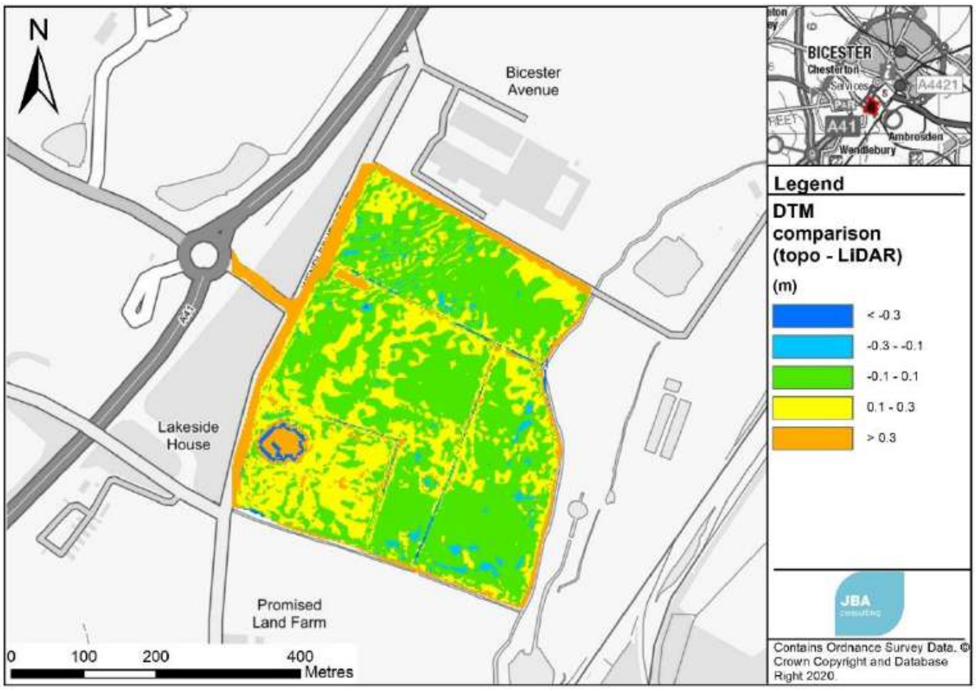


Figure 3-1 indicates that both datasets correlate relatively well. As a result, the topographic survey data was used in the extended model to inform ground levels within site.

3.2 Hydrology review

JBA carried out a hydrological assessment in 2019 (see Appendix E). The assessment estimates that the 100-year peak flow near the site (at node GB_6613, approximately 190m upstream of the site) is $7.06m^3/s$. When factored by 1.35 to account for the (higher central) climate change, the 100-year with (+35) climate change peak flow is $9.53m^3/s$.

The upgraded EA model was therefore “equipped” with PO line to monitor the flow on both sides of the channel. The combined flow (i.e. flow in the channel + flow in the floodplain) is represented in Figure 3-2.

Figure 3-2: Combined in-bank and out-of-bank flow near node GB_6613

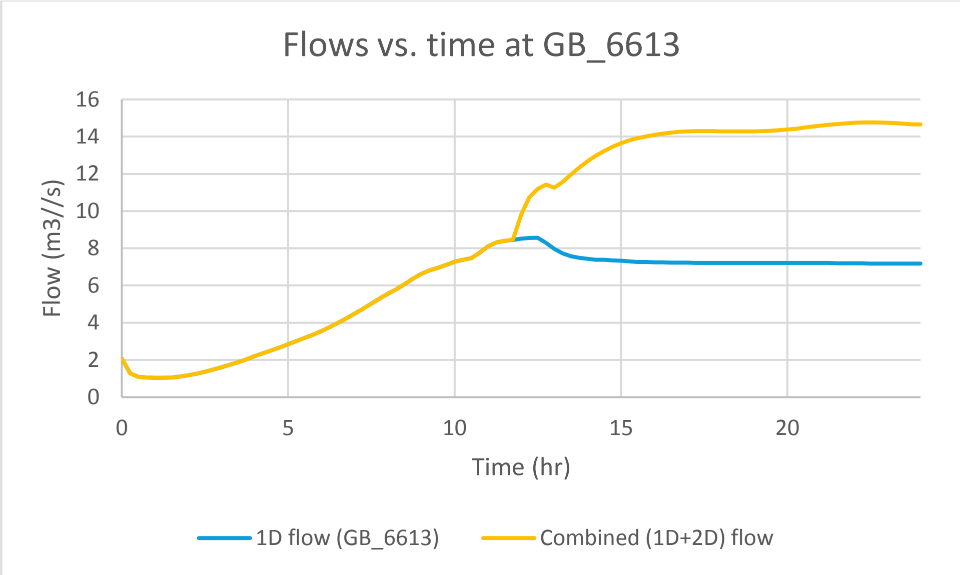


Figure 3-2 suggest that the modelled 100-year with (+35%) climate change flows are over-estimated in the upgraded EA model. This could be due to changes in hydrological methods and the use of hydrological flow records since the hydrological assessment used in the EA model was produced.

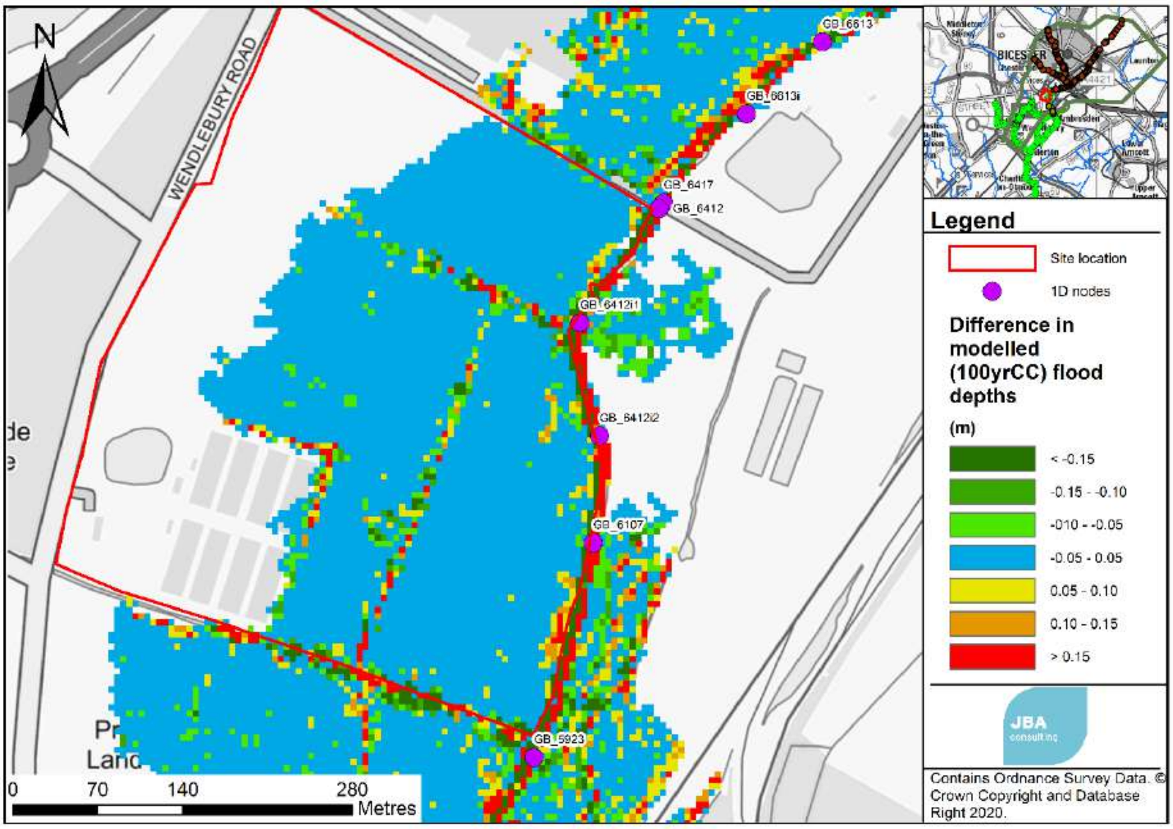
As a result, model flood extents, levels and flows documented in this report should be considered as conservative.

3.3 Sensitivity to grid cell size

Attempts to reduce the model grid cell-size to 2m were unsuccessful. To ensure this does not affect the outcome of this analysis, the sensitivity of the model results to changes in grid cell size was tested using 10m (i.e. the original grid cell size) and 4m (i.e. the new grid cell size in the upgraded model).

Figure 3-3 shows the difference in modelled flood depths between the pre-development (10m grid cell size) model and the pre-development (4m grid cell size) model.

Figure 3-3: Sensitivity to grid cell size (10m vs. 4m)



Although the reduction in grid cell size offers a more accurate representation of drainage features (e.g. existing ditches on site) and overtopping locations (e.g. along the river bank at node GB_5923), Figure 3-3 indicates that the difference in modelled flood depths within the site is within the +/-50mm range. As a result, model results at the site are considered to be relatively insensitive to changes in model grid cell size and a 4m grid resolution is deemed adequate to model the impact of the proposal.

4 Model Results

4.1 Flood Risk Impact Analysis

The impact of the proposal (i.e. raised development plateaus and proposed floodplain compensation scheme) was modelled for the 100-year with(+35%) climate change fluvial flood scenario (see Figure 4-1).

Figure 4-1: Impact of proposal on 100-year with(+35%) climate change fluvial flood depths

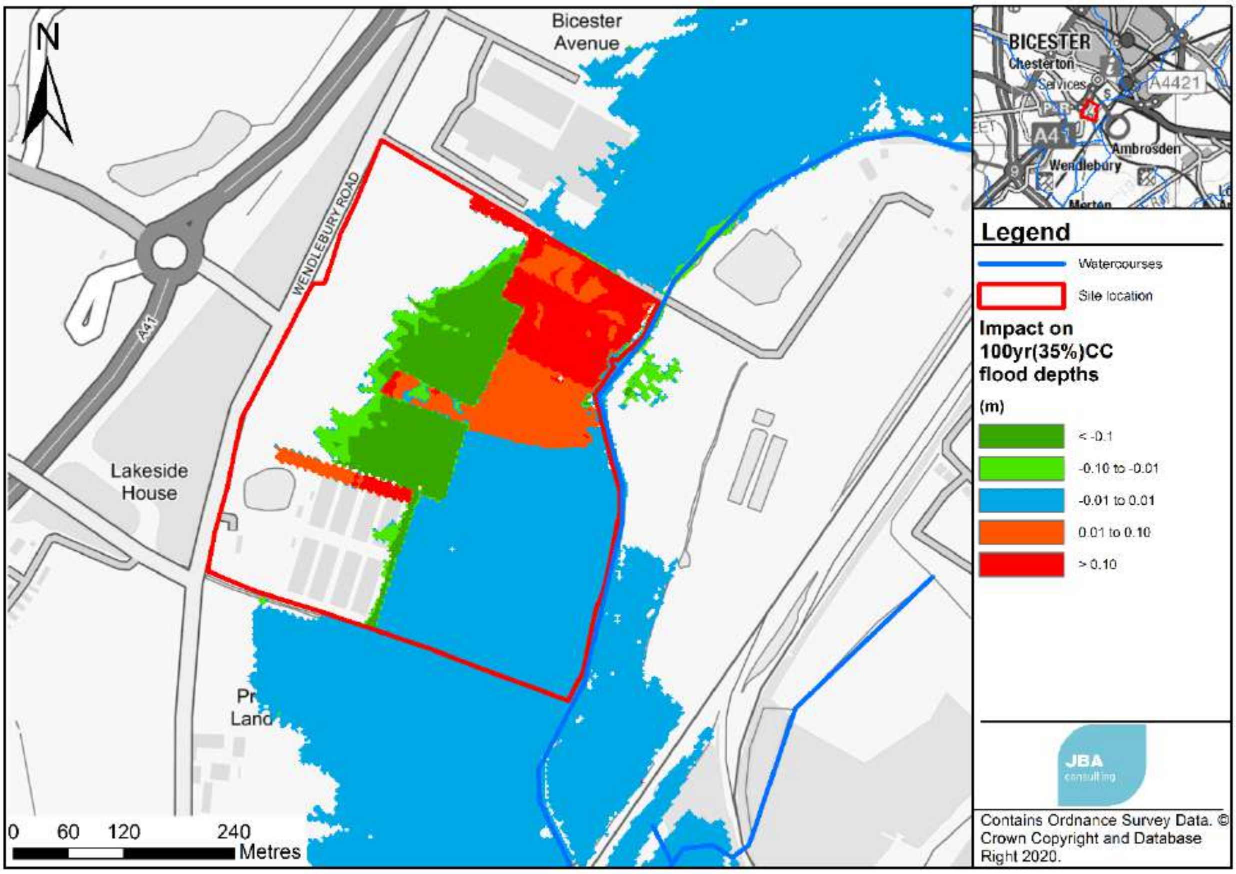


Figure 4-1 shows:

- The proposed floodplain compensation scheme completely offsets the impact of the raised development plateaus;
- The proposal will not generate any detrimental impacts across third-party land.

4.2 Modelled flood levels

In line with the Environment Agency's letter dated 27 December 2020, the 100-year with (+35%) climate change fluvial flood levels were modelled and mapped for the post-development scenario (see Figure 4-2).

Figure 4-2: 100-year with(+35%) climate change fluvial flood levels – post-development scenario

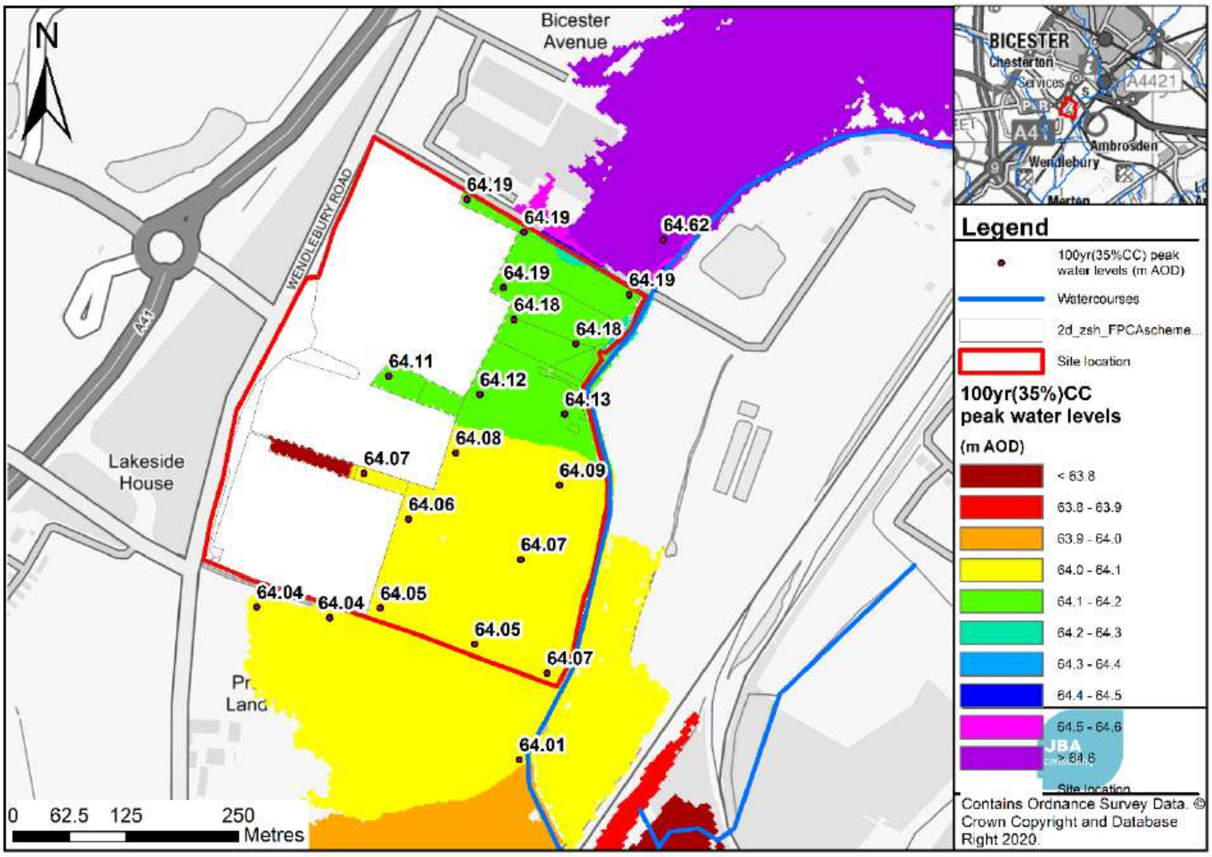


Figure 4-2 shows that the 100-year with (+35%) climate change peak water levels on site vary between 64.04 and 64.19m AOD. This is significantly less than the 1,000-year flood levels (i.e. between 64.19m AOD and 64.46m AOD) used by Bailey Johnson Hayes to design their floodplain compensation scheme. Not surprisingly, the floodplain compensatory storage areas located along the western site boundary will remain dry and will just start filling during the peak of 100-year with (+35%) Climate Change fluvial flood event.

5 Conclusions and Recommendations

Results from the Quality Assessment phase indicate that:

- Topographic survey data compares relatively well with LiDAR data.
- Model results at the site are relatively insensitive to changes in grid cell size.
- Modelled flow upstream of the site are conservative (when compared with the hydrological assessment carried out by JBA in 2019).

As a result, model results documented in this report should be considered as conservative.

The hydraulic modelling was run for both the pre- and post-development 100-year with (+35%) climate change scenarios. Model results indicate that:

- The proposed floodplain compensation scheme appears to completely offset the impact of the raised development plateaus.
- The proposed development does not exacerbate flood risk across third-party land.
- The 100-year with (+35%) Climate Change peak water levels on site vary between 64.04 and 64.19m AOD. This is significantly less than the 1,000-year flood levels (i.e. between 64.19m AOD and 64.46m AOD) used by Bailey Johnson Hayes to design their floodplain compensation scheme. Not surprisingly, the floodplain compensatory storage areas located along the western site boundary will remain dry or will just start filling up during the peak of the 100-year with (+35%) Climate Change fluvial flood event.

In conclusion, it is considered that the proposed floodplain compensation scheme designed by Bailey Johnson Hayes will be able to offset the impact of the proposal during the 100-year with (+35%) Climate Change fluvial flood scenario and even provide additional floodplain storage capacity during more extreme flood events.

Appendices

A Environment Agency's letter dated 27 December 2019

creating a better place

Environment Agency

Ms Bernadette Owens
Cherwell District Council
Planning & Development Services
Bodicote House White Post Road
Bodicote
Banbury
OX15 4AA

Our ref: WA/2019/127046/02-L01
Your ref: 19/01740/HYBRID

Date: 27 December 2019

Dear Ms Owens

Outline planning permission (all matters reserved except for access) for up to 23,400sq.m of B1 development (Use Classes B1a and/or B1b and/or B1c); highway works (including provision of a new roundabout at the junction between Vendee Drive and Wendlebury Road); creation of a wetland and landscaped areas; and associated infrastructure works. - Full planning permission for a health and racquets club, associated access and car parking, outdoor tennis courts, air dome, outdoor swimming pool, spa garden and terrace, and associated landscaping

Land Adj To Promised Land Farm, Wendlebury Road, Chesterton

Thank you for re-consulting us on the above application on 12 December 2019, following the submission of:

- Surface water drainage design, prepared by Bailey Johnson Hayes, reference S1358, dated July 2019.
- The concept SW drainage scheme, prepared by Bailey Johnson Hayes, reference S1358-Ext-46, dated 28 November 2019.
- The gained flood storage plan, prepared by Bailey Johnson Hayes, reference S1358-Ext-45, dated 18 October 2019.
- The lost flood storage plan, prepared by Bailey Johnson Hayes, reference S1358-Ext-44, dated 20 November 2019.
- North and west site boundary sections, prepared by Bailey Johnson Hayes, reference S1358-Ext-43, dated 12 November 2019.
- Extent of Flood Zone 3 after completion of development, prepared by Bailey Johnson Hayes, reference S1358-Ext-42A, revision A, dated 28 November 2019.
- Extent of Flood Zone 3 prior to start of development, prepared by Bailey Johnson Hayes, reference S1358-Ext-41A, revision A, dated 28 November 2019.
- Tech scheme option 8 – proposed drainage plan, prepared by Bailey Johnson Hayes, reference S1358-Ext-34, dated 26 March 2019.
- EA flood data (Product 4) contour overlay, prepared by Bailey Johnson Hayes, reference S1358-Ext-13B, revision B, dated 28 November 2019.

In our previous response, our reference WA/2019/127046/01-L01, dated 23 September 2019, we raised two flood risk objections to this application. We have since reviewed our previous response and withdrawn our first objection - the proposed development

Cont/d..

falls within a flood risk vulnerability category that is inappropriate to the Flood Zone in which the application site is located.

However, the documents listed above **do not satisfactorily** address our earlier concerns with regards to our second objection. We therefore **maintain our objection** set out in our response dated 23 September 2019.

Environment agency position
In the absence of an acceptable Flood Risk Assessment (FRA) we **object** to the grant of planning permission and recommend refusal on this basis for the following reasons:

Reason
The FRA submitted with this application does not comply with the requirements set out in Paragraph 9 the Technical Guide to the National Planning Policy Framework. The submitted FRA does not therefore, provide a suitable basis for assessment to be made of the flood risks arising from the proposed development. In particular, the submitted FRA fails to:

- Take the impacts of climate change into account
- Consider how a range of flooding events (including extreme events) will affect people and property

Overcoming our objection
<u>Climate Change Allowances</u>
The applicant has not carried out a detailed assessment of the impact of climate change on the proposed development for this site.

The applicant has interpolated data from the Langford Brook (Bicester) and Pingle-Back-Bure 2010 flood model to calculate the 1 in 100 plus 25% and 1 in 100 plus 35% flood levels. However, for a development of this size and scale, we expect modelling of the relevant climate change scenarios to be carried out. Detailed hydraulic modelling should be undertaken, through either re-running Environment Agency hydraulic models (if available) or constructing a new model.

<u>Floodplain Compensatory Storage</u>
We are pleased to see that level for level floodplain compensation can be provided up to the 1 in 100 plus 35% flood level.

However, as mentioned above, the 1 in 100 plus 35% flood level has been derived from interpolation of data from the Langford Brook (Bicester) and Pingle-Back-Bure 2010 flood model. The applicant will need to undertake detailed hydraulic modelling to calculate the 1 in 100 plus 35% flood level. This should be used to inform level for level floodplain compensation. The applicant will need to amend their floodplain compensation plans and/or drawings to reflect this.

We require this information to ensure that any loss of floodplain storage volume within the 1% annual probability (1 in 100) flood level with an appropriate allowance for climate change can be directly compensated for.

Advice to Local Planning Authority
In accordance with the National Planning Policy Framework (paragraph 158), development should not be permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower probability of flooding.

Cont/d..

It is for the local planning authority to determine if the sequential test has to be applied and whether or not there are other sites available at lower flood risk. Our flood risk standing advice reminds you of this and provides advice on how to apply the test.

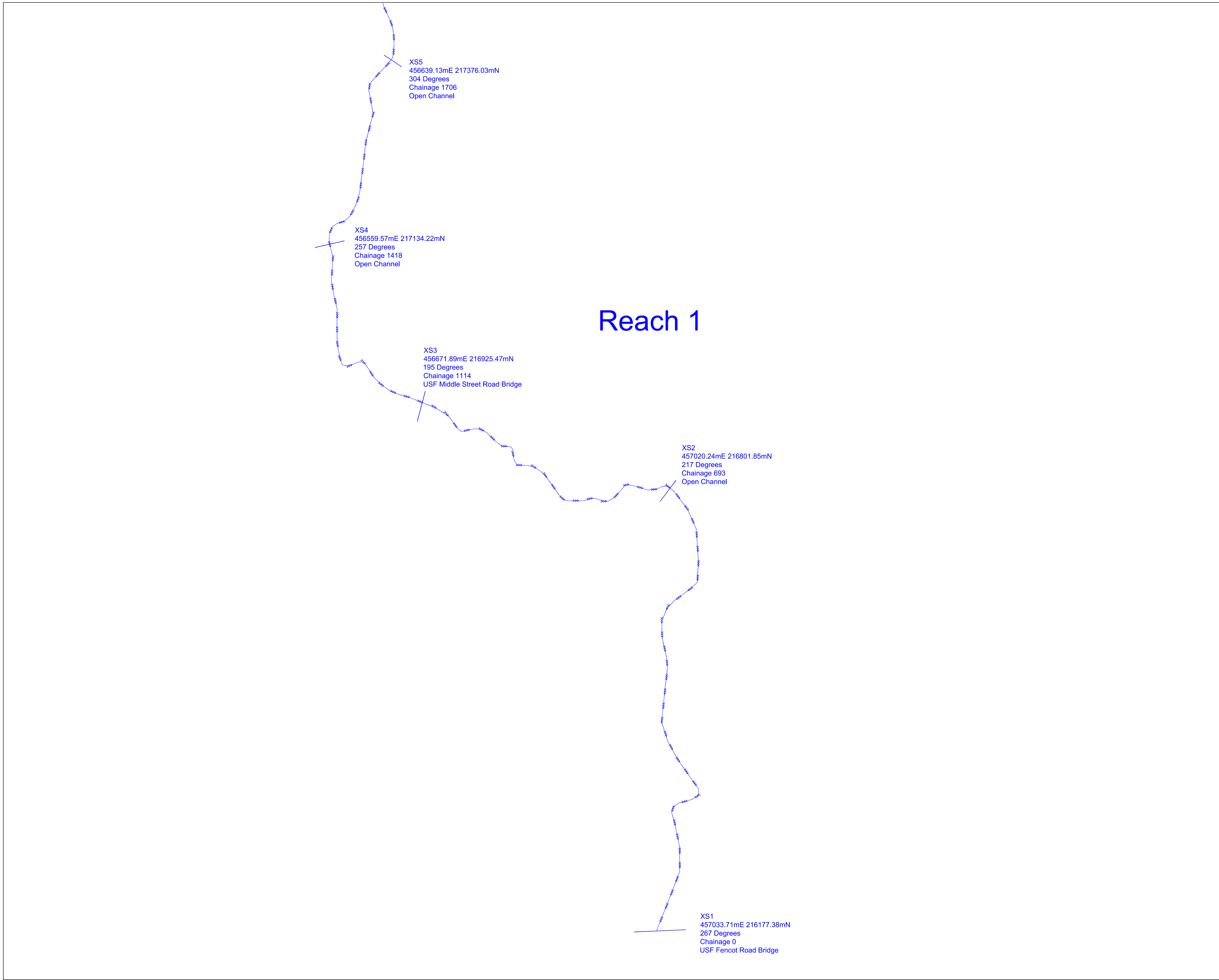
Final comments
Should you require any additional information, or wish to discuss these matters further, please do not hesitate to contact me on the number below.

Yours sincerely

Mr Samuel Pocock
Planning Advisor

Direct dial 0208 474 5075
Direct e-mail Planning_THM@environment-agency.gov.uk

B Channel Survey Data



Notes

This survey should only be relied upon for its original purpose. Grantham Coates Surveys Limited accepts no responsibility for use of this plan outside of the original remit, or by use of any party other than the original client.

Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information as been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	X X
STUMP	SP	FENCE	/ /
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH OH
SIGNAL POST	SIG	FOUL WATER	FW FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL TEL
SIGN POST	SN	WATER MAIN	WM WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: ***OS National Grid*** **Datum:** ***Ordnance Datum Newlyn***

Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.

A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.

No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT WENDLEBURY (Key Plan)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD

Grantham Coates Surveys Ltd

Land - Engineering - Building Surveyors

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Tel: 01789 764420

E-Mail: info@gcsurveys.co.uk
Web Site: www.gcsurveys.co.uk

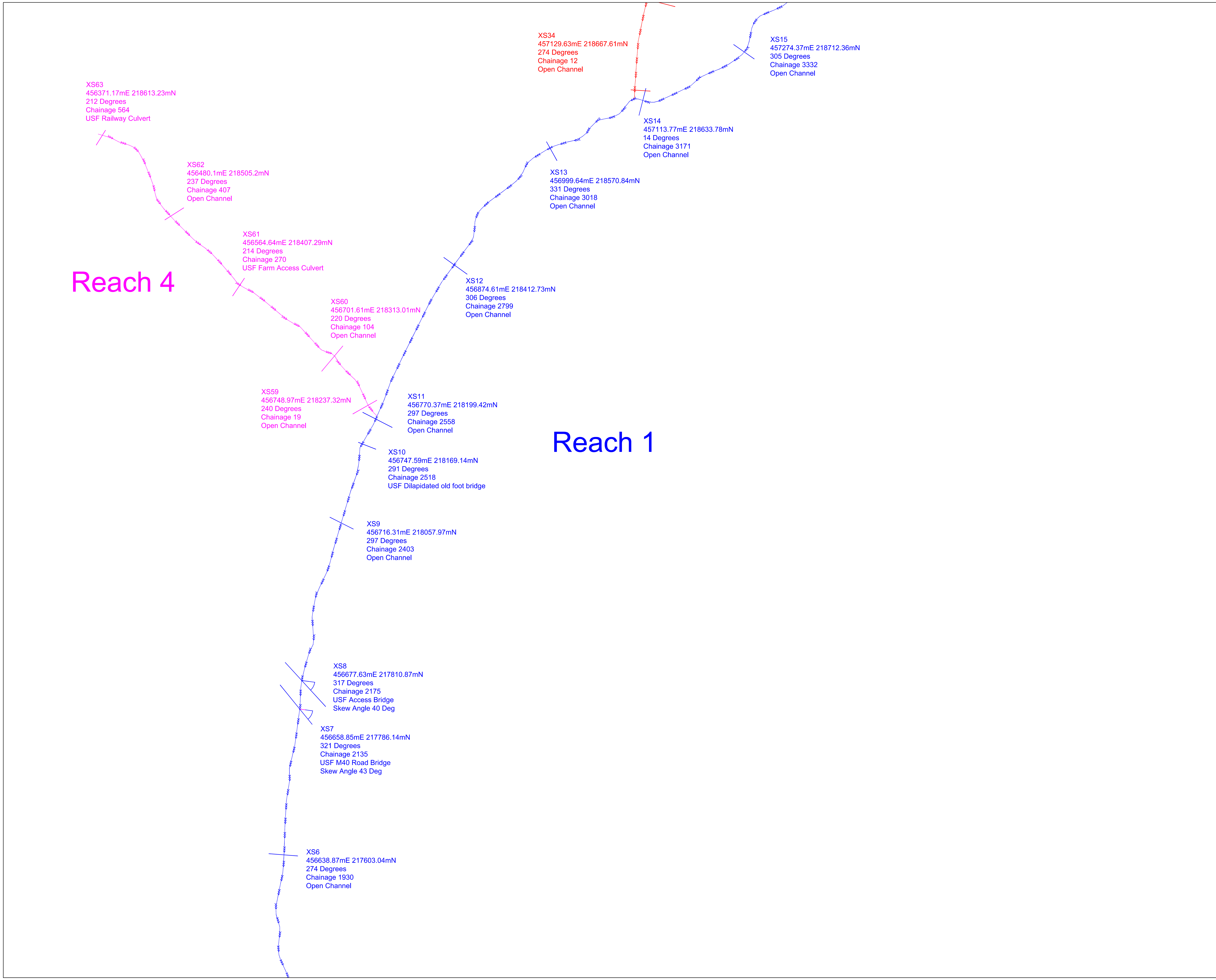
THE SURVEY ASSOCIATION

chartered ices

Drawing No:	Rev:
GCS/JBA/0342/1	-

Date:	Notes:	Name:	Rev:

Drawn:	Checked:	Scale:	Date:
MC	CC	1:2500	17/09/19
File Name: GCS-JBA-0342-1		Sheet size: A1	Sheet: 1 of 26



N

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Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

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Title:

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Client:

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Coleshill
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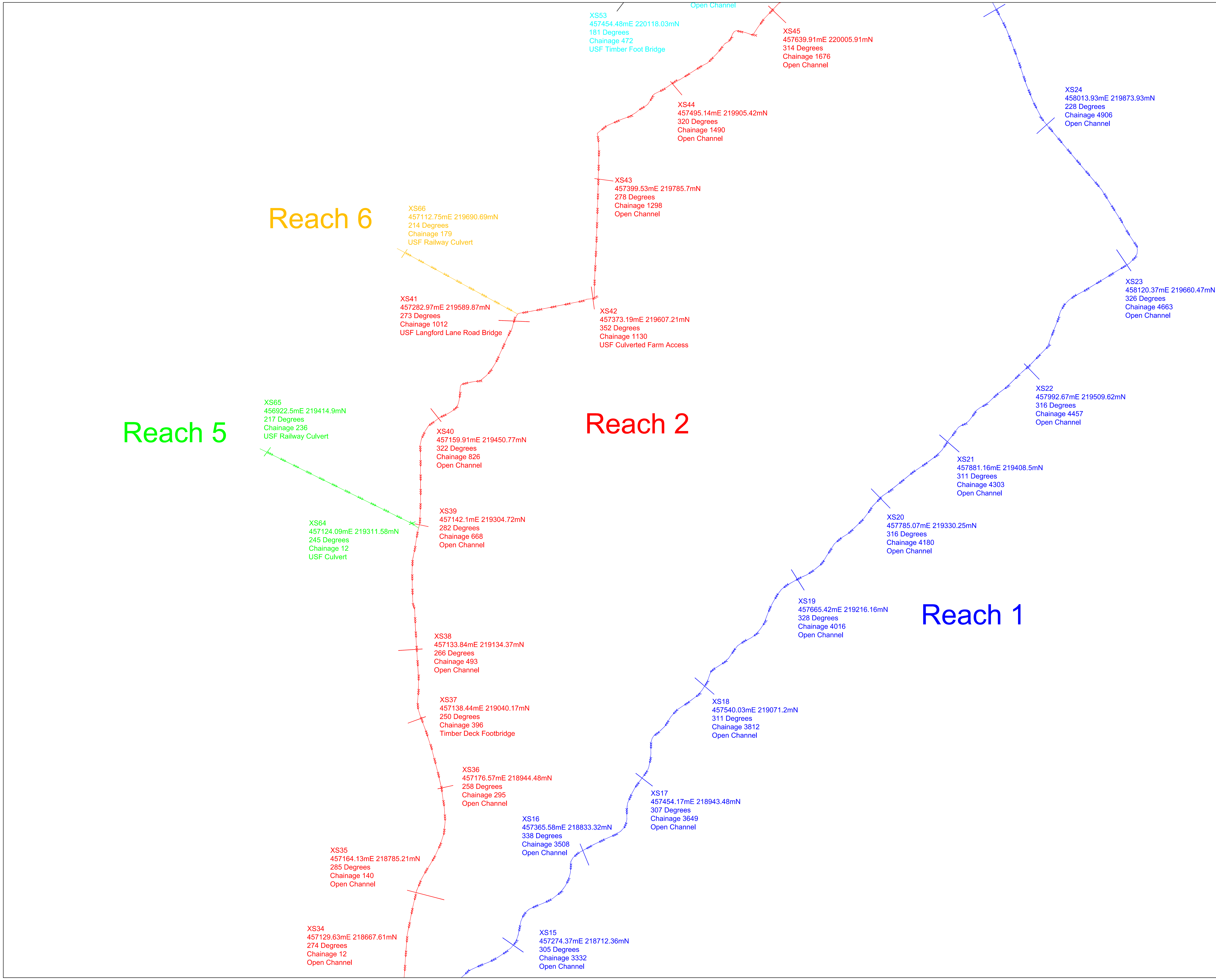
Drawn:	Checked:	Scale:	Date:
MC	CC	1:2500	17/09/19
File Name: GCS-JBA-0342-1		Sheet size: A1	Sheet: 2 of 26



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Legend

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x x
STUMP	SP	FENCE	/ /
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH OH
SIGNAL POST	SIG	FOUL WATER	FW FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL TEL
SIGN POST	SN	WATER MAIN	WM WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

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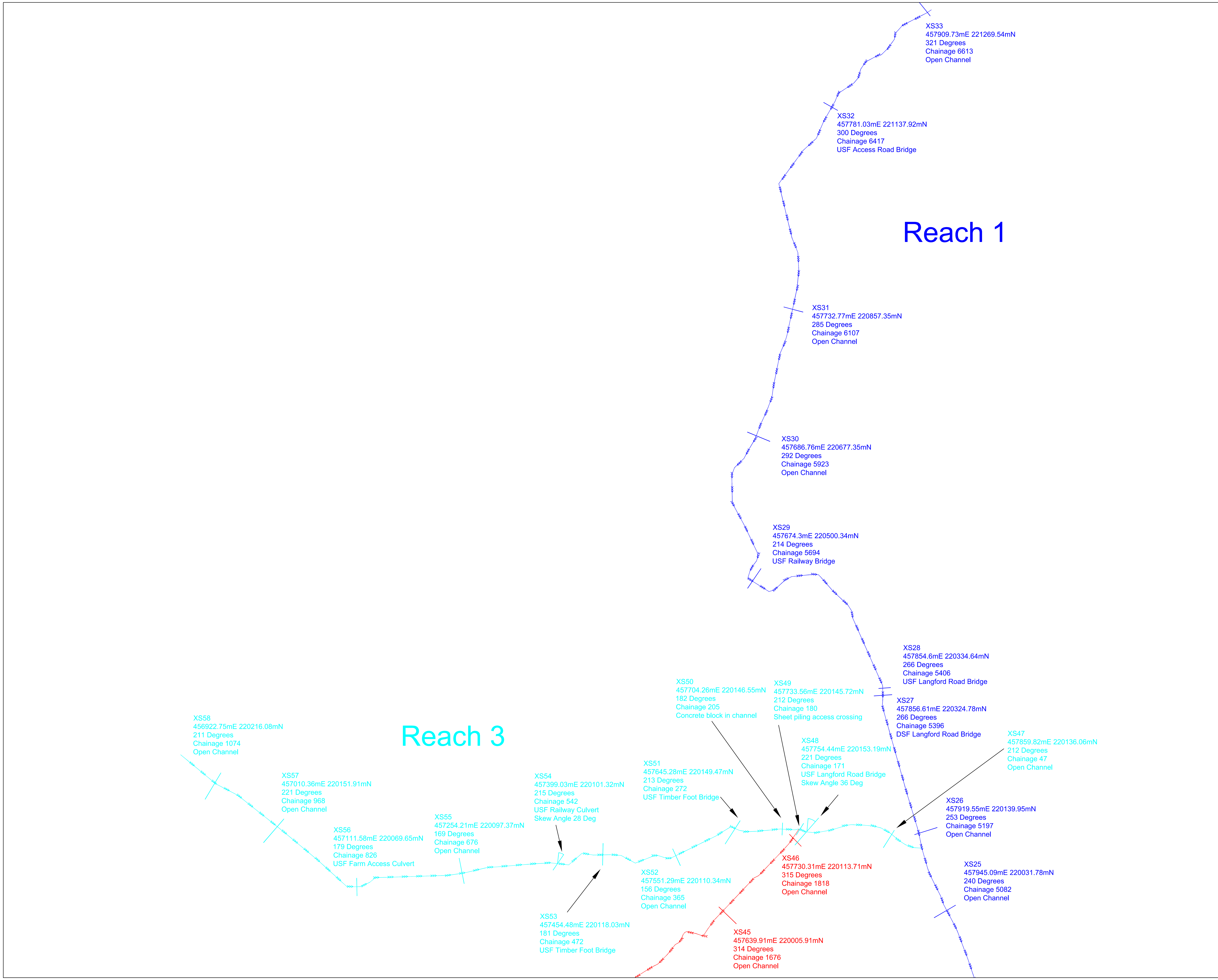
GCS-JBA-0342-1	A1	3 of 26



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Legend

AIR VALVE AV, BOLLARD BD, BORE HOLE BHL, BUS STOP BS, BT INSPECTION COVER BT, BT BOX BTB, CABLE TV INSPECTION COVER CTV, COVER LEVEL CL, DOWN PIPE DP, DROPPED KERB DK, ELECTRICITY CONTROL BOX ECB, EAVES HEIGHT EH, ELECTRICITY MANHOLE EM, ELECTRICITY POLE EP, EARTH ROD ER, FINISHED FLOOR LEVEL FFL, FIRE HYDRANT FH, FOUL WATER FW, GULLY GY, GATE POST GP, GAS VALVE GV, INSULATED BLOCK JOINT IBJ, INSPECTION COVER IC, INVERT LEVEL IL, KERB OUTLET KO, LAMPPOST LP, LITTER BIN LB, MARKER POST MK, MILE POST MP, POST PO, RODDING EYE RE, RIDGE HEIGHT RH, ROAD NAMEPLATE RN, ROAD SIGN RS, STUMP SP, SOFFIT LEVEL SF, SIGNAL POST SIG, RAIL SLEEPER LEVEL SLP, SIGNALS AND TELECOMS BOX STB, SIGNALS AND TELECOMS CABLE STC, SIGNALS AND TELECOMS POST STP, SIGN POST SN, STOP TAP ST, STOP VALVE SV, STAY SY, STORM WATER SW

WATER TAP TAP, TEMPORARY BENCH MARK TBM, TELEPHONE CALL BOX TCB, TELEPHONE POST TEL, THRESHOLD LEVEL THL, TRAFFIC LIGHT TL, TOP OF WALL TOW, TELEGRAPH POLE TP, UNABLE TO LIFT UTL, VENT PIPE VP, RAIL WELD WE, WATER METER WM, WASHOUT WO

SURVEY STATION (GCS1), BUSHES, HEDGES, TREES (Height, Species, (Spread to scale)), GATE, SECURITY FENCE, FENCE, OVERHEAD CABLES, FOUL WATER, GAS MAIN, U/G POWER LINE, STORM WATER, U/G TELEPHONE, WATER MAIN

Control Table

Station	Description	Eastings	Northings	Height

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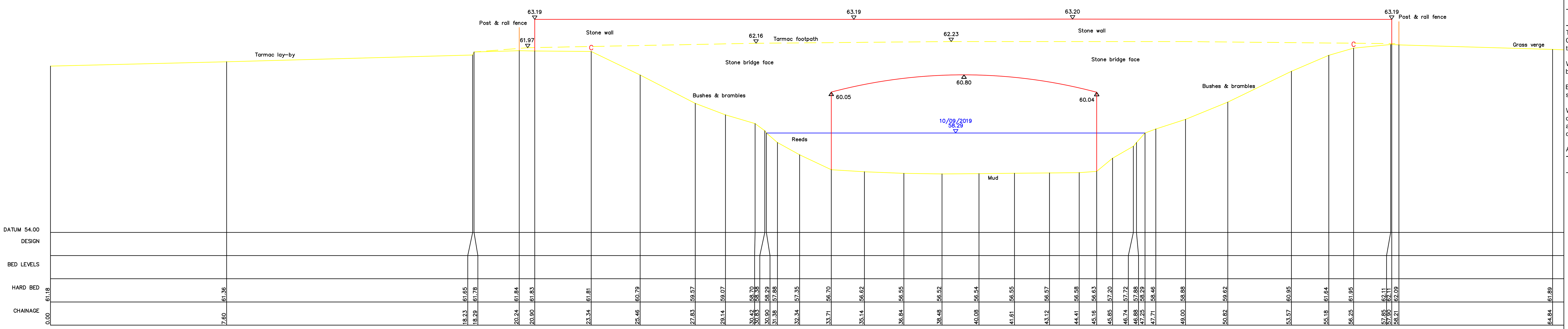
GCS-JBA-0342-1	A1	4 of 26

Reach 1



XS1
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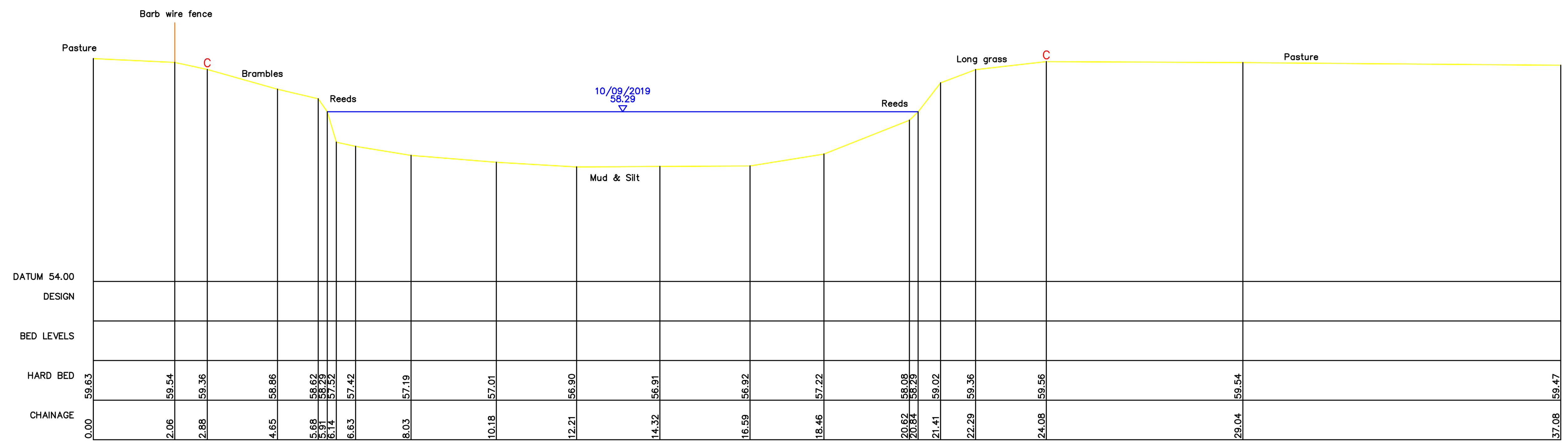
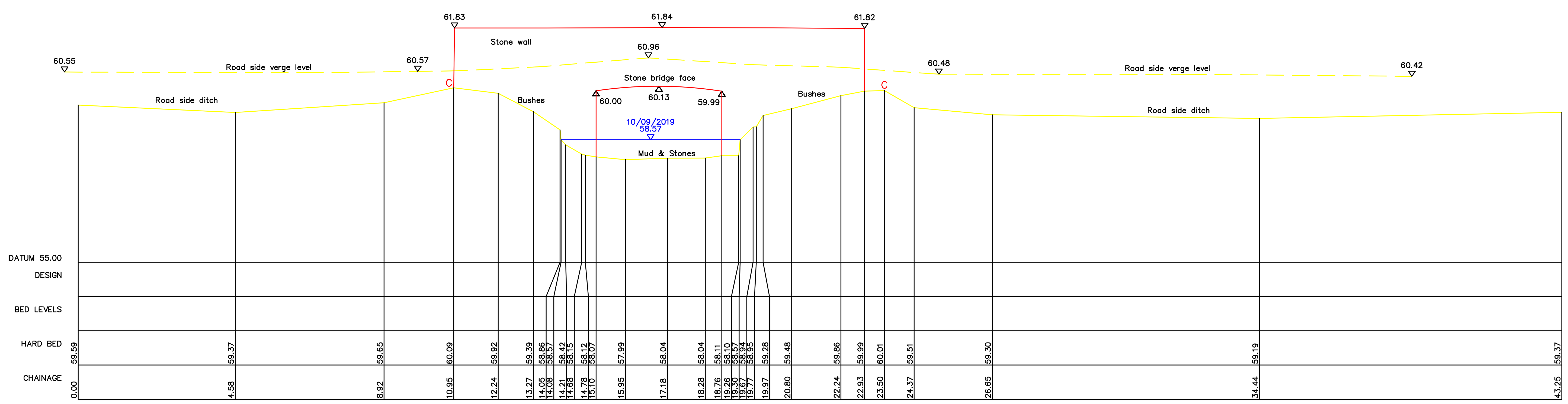
Chainage 0
USF Fencot Road Bridge
Bridge Length 10.3m



XS2
457020.24mE 216801.85mN Brg 217
Chainage 693.4
Open Channel



XS3
456671.89mE 216925.47mN Brg 195
Chainage 1114.5
USF Middle Street Road Bridge
Bridge Length 9.8m

N

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Legend

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

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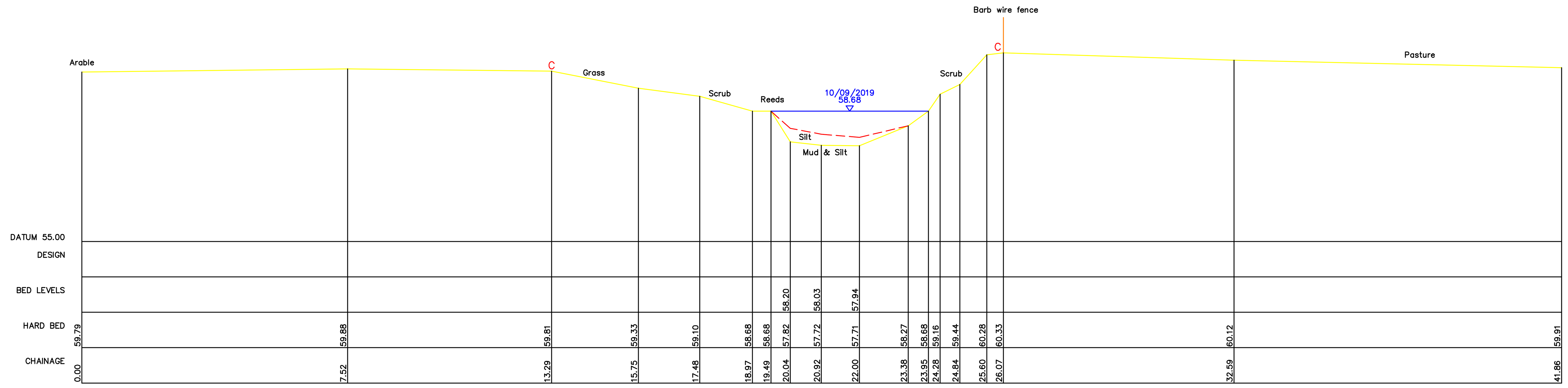
GCS-JBA-0342-1	A1	5 of 26

Reach 1



XS4
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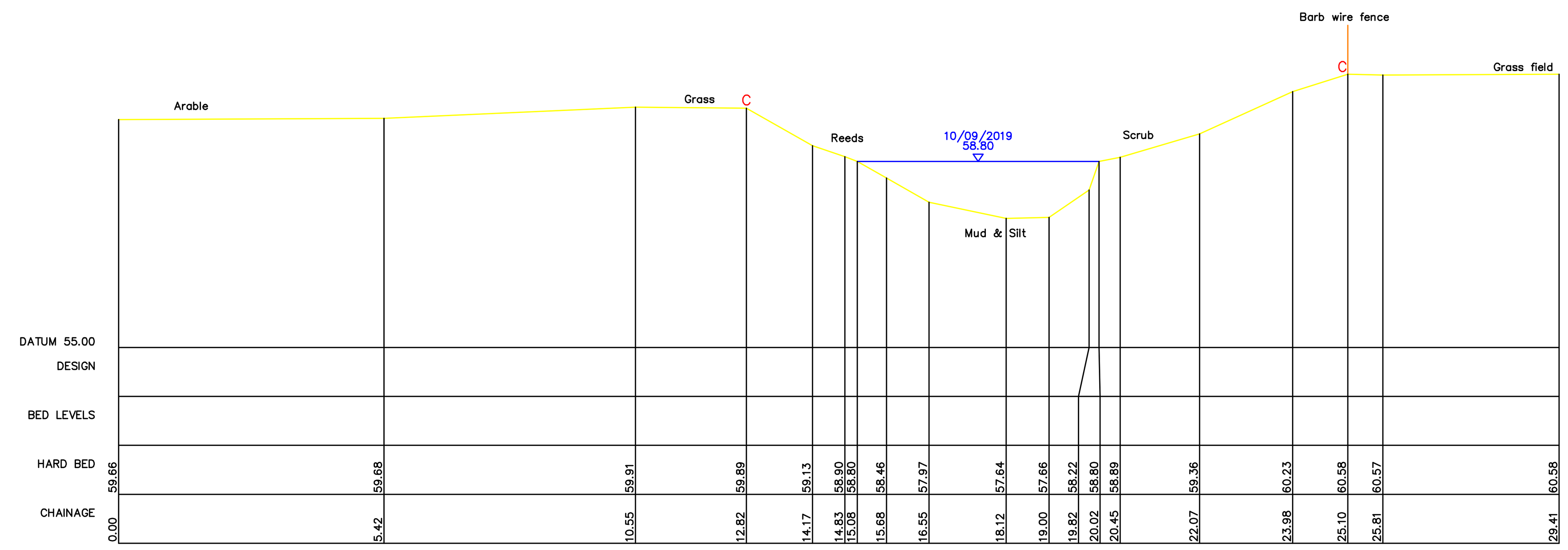
Chainage 1417.6
Open Channel



XS5
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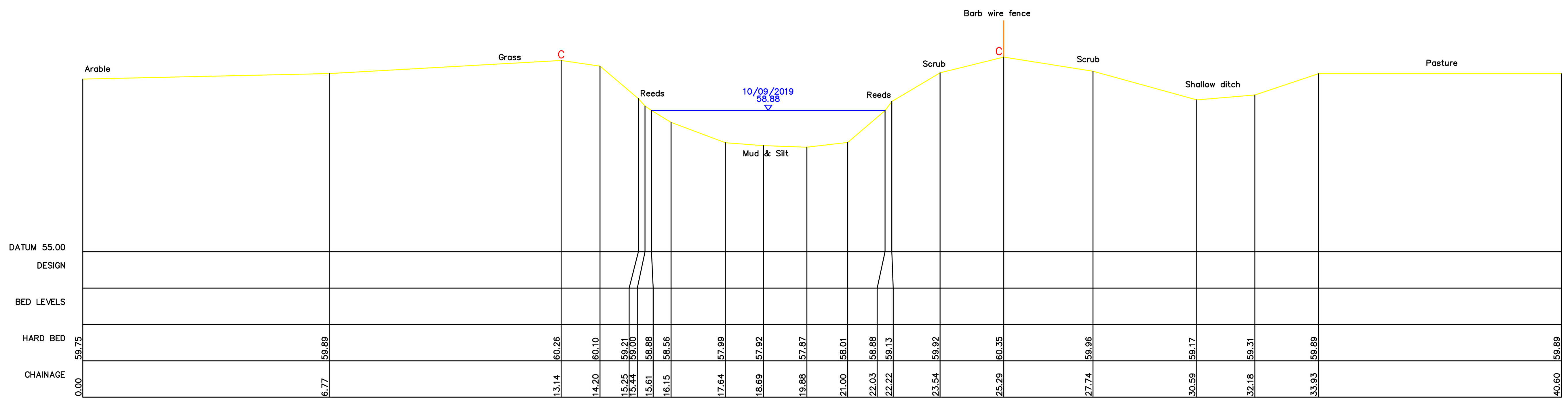
Chainage 1705.6
Open Channel



XS6
456638.87mE 217603.04mN Brg 274
Chainage 1930
Open Channel

N

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY	BUSHES	
GATE POST	GP		
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ	HEDGES	
INSPECTION COVER	IC		
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—x—x—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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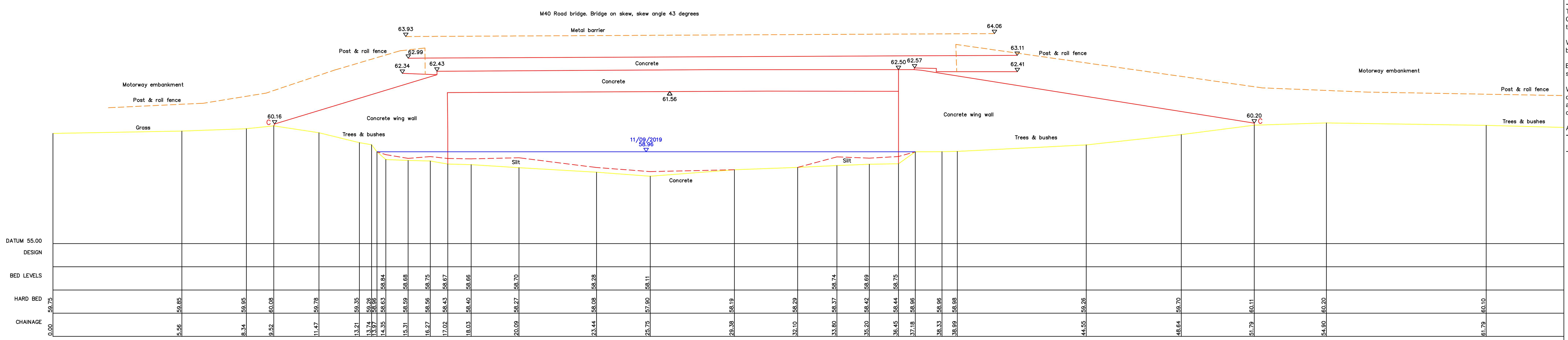
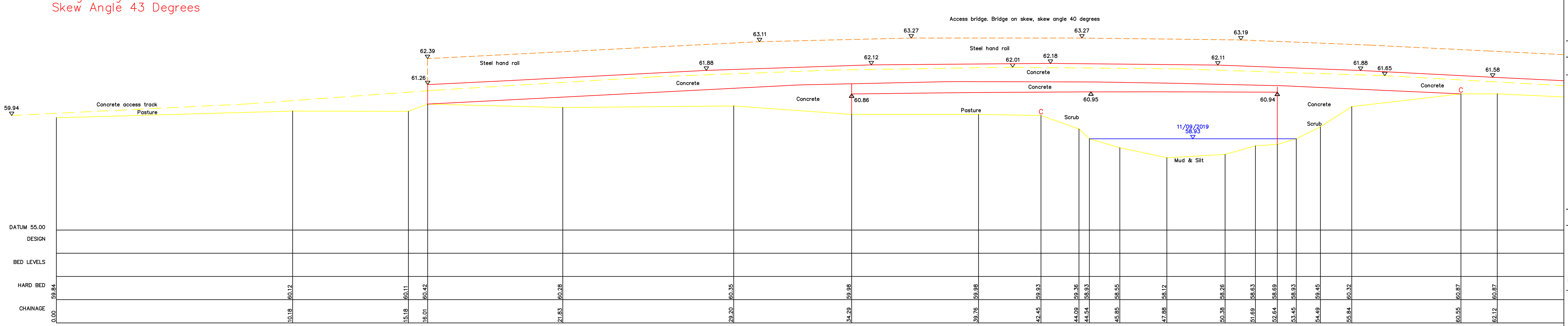
GCS-JBA-0342-1	A1	6 of 26

Reach 1



XS7
456658.85mE 217786.14mN Brg 321
Chainage 2134.7
USF M40 Road Bridge
Bridge length 46m
Skew Angle 43 Degrees



XS8
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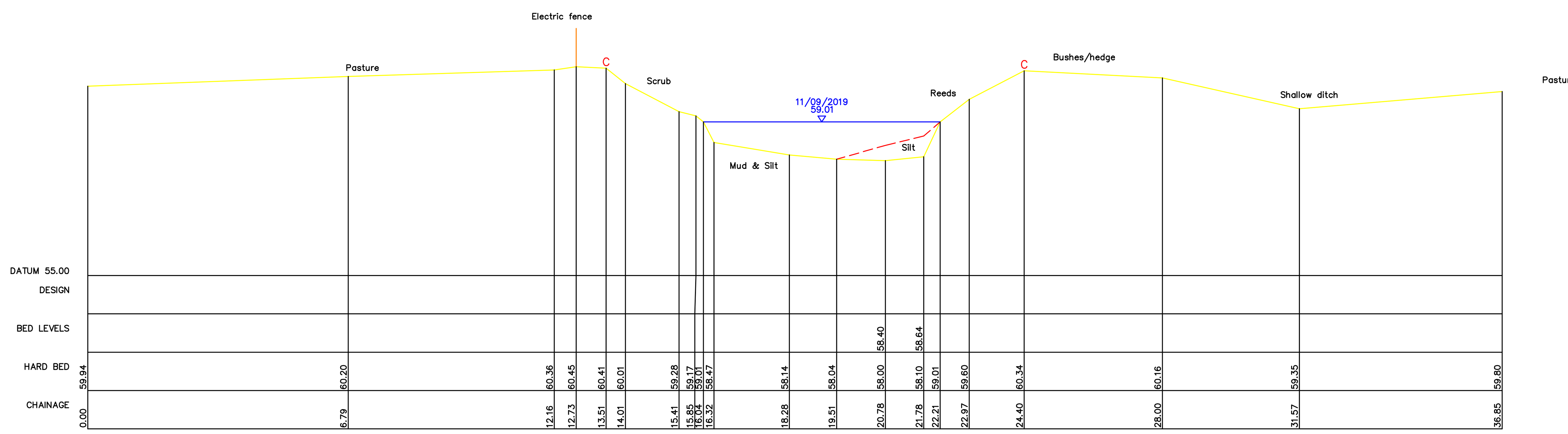
Chainage 2174.5
USF Access Bridge
Bridge length 8.6m
Skew Angle 40 Degrees



XS9
456716.31mE 218057.97mN Brg 297
Chainage 2403.4
Open Channel

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BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
STUMP	SP	FENCE	
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: ***OS National Grid*** **Datum:** ***Ordnance Datum Newlyn***

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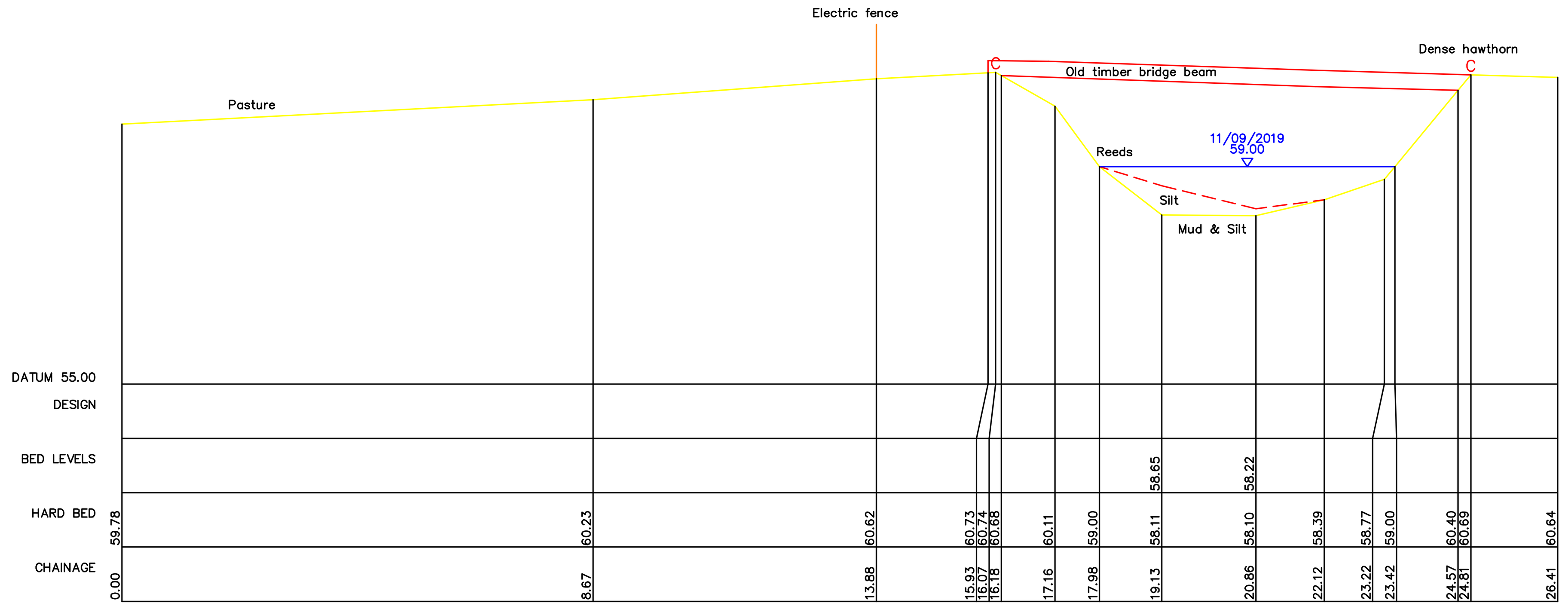
GCS-JBA-0342-1	A1	7 of 26

Reach 1



XS10
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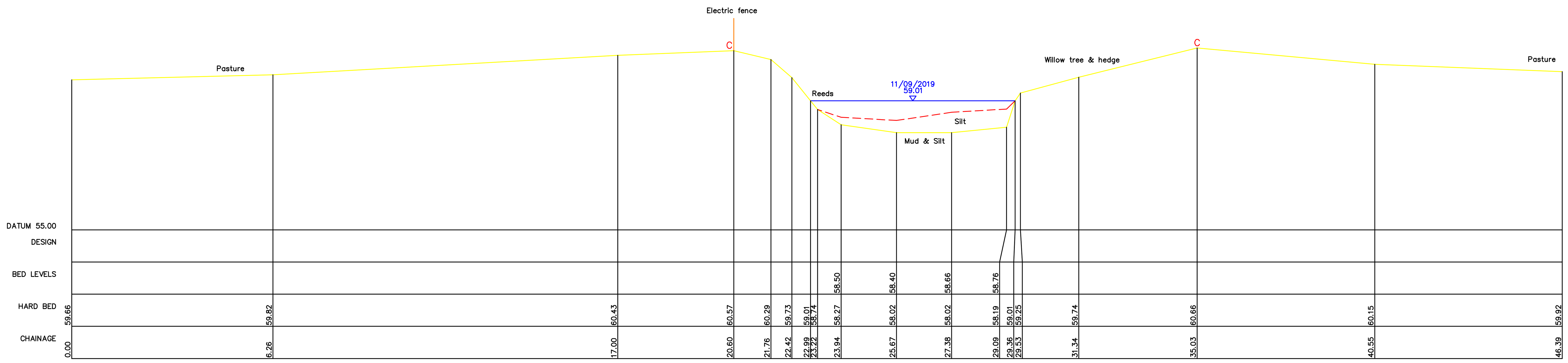
Chainage 2518.1
USF Dilapidated old foot bridge
Structure Length Approx 1m



XS11
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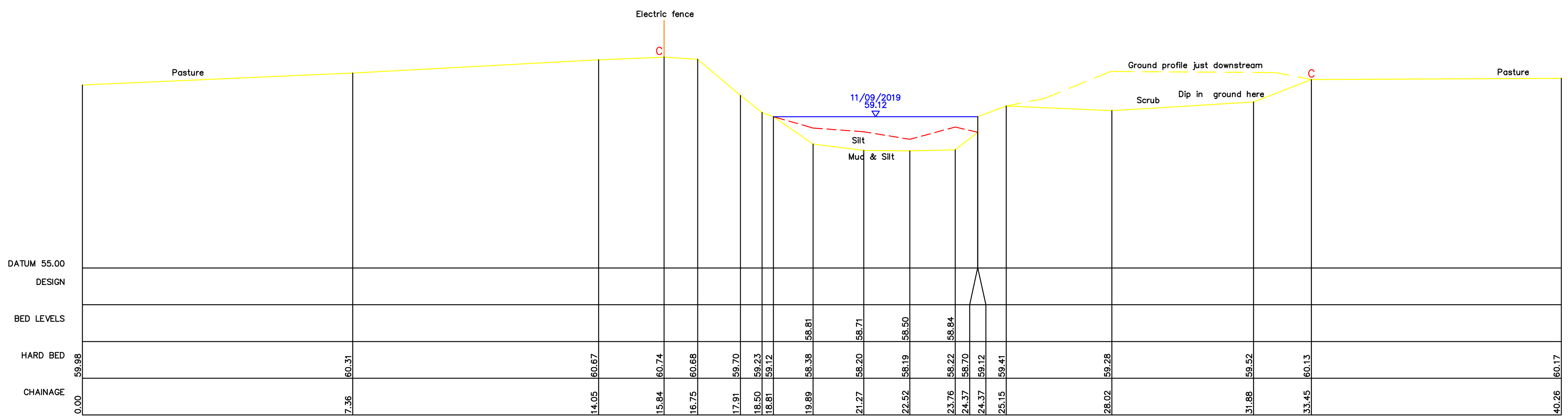
Chainage 2557.5
Open Channel



XS12
456874.61mE 218412.73mN Brg 306
Chainage 2798.9
Open Channel

N

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
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FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
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KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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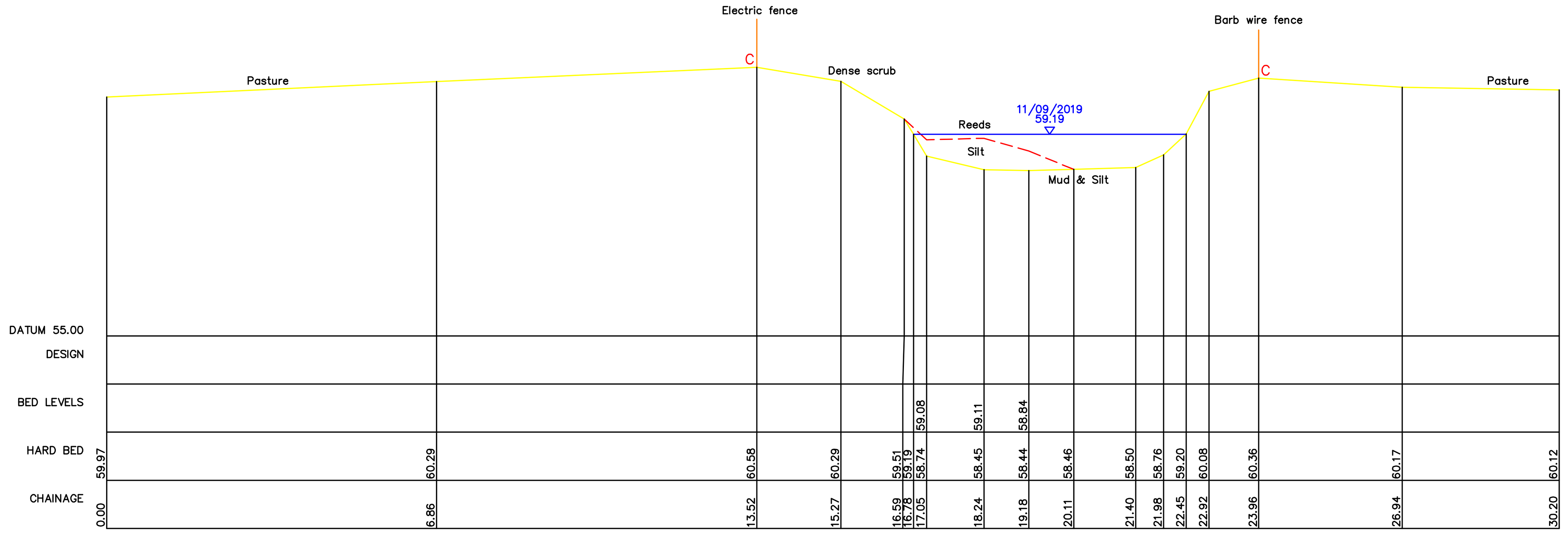
GCS-JBA-0342-1	A1	8 of 26

Reach 1



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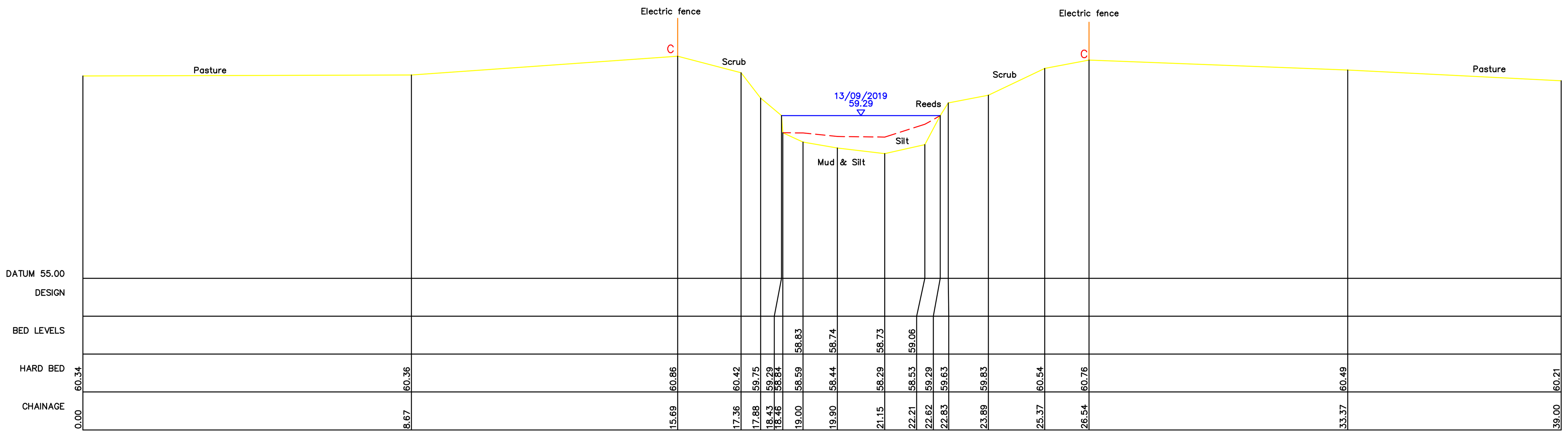
Chainage 3017.8
Open Channel



XS14
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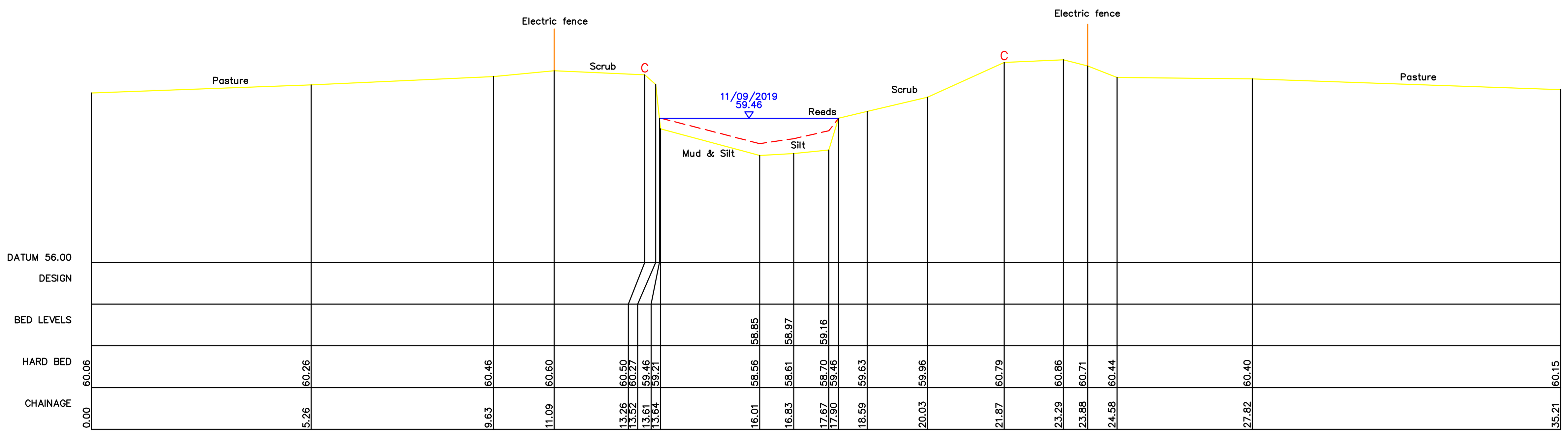
Chainage 3171
Open Channel



XS15
457274.37mE 218712.36mN Brg 305
Chainage 3332.2
Open Channel

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BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
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EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
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FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
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POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
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SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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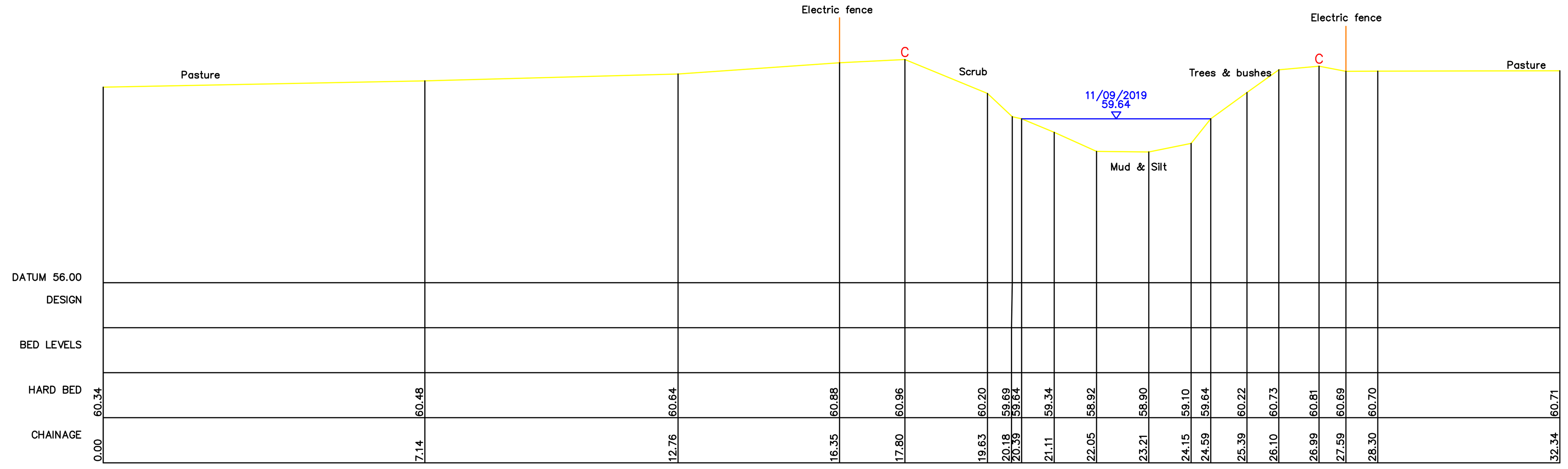
GCS-JBA-0342-1	A1	9 of 26

Reach 1



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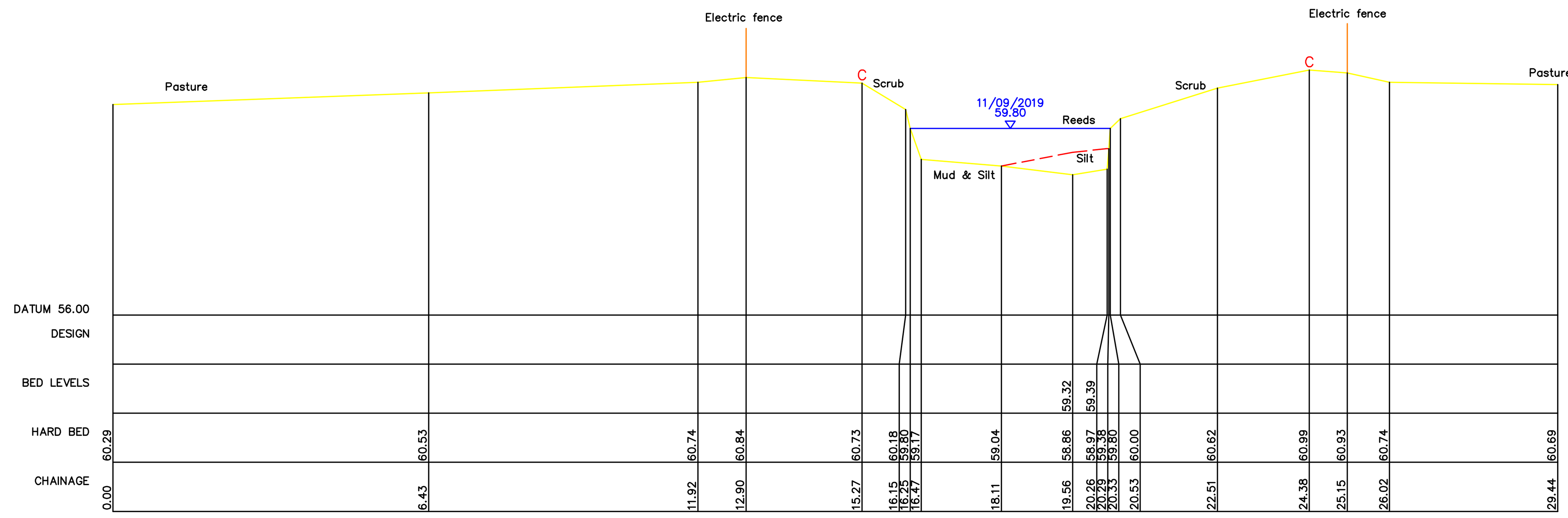
Chainage 3507.8
Open Channel



XS17
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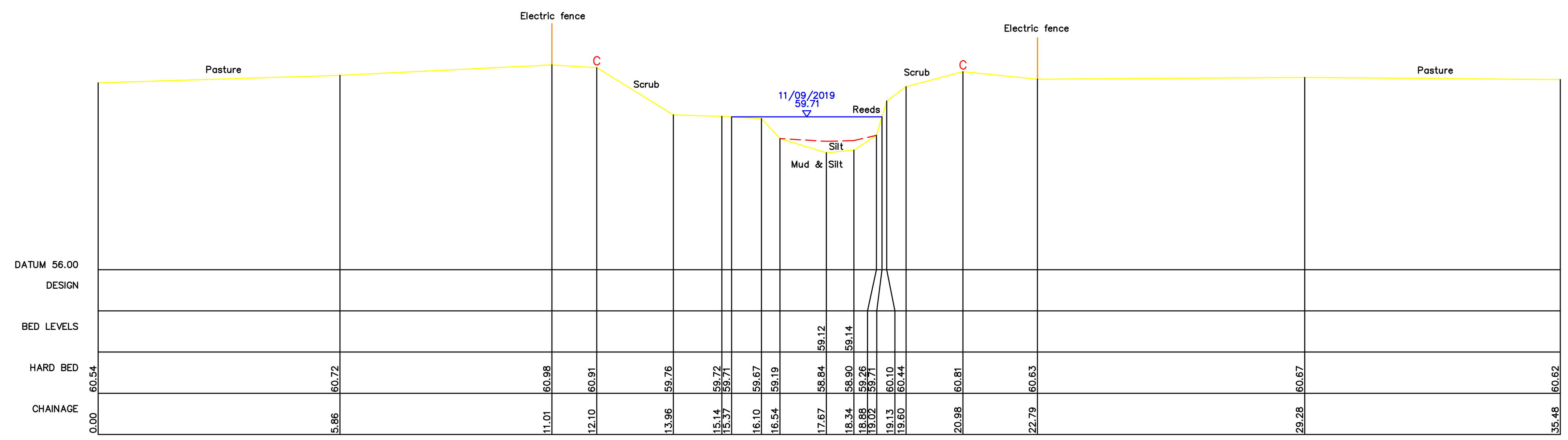
Chainage 3649.2
Open Channel



XS18
457540.03mE 219071.2mN Brg 311
Chainage 3812.2
Open Channel

N

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RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
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STOP TAP	ST		
STOP VALVE	SV		
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GCS-JBA-0342-1	A1	10 of 26

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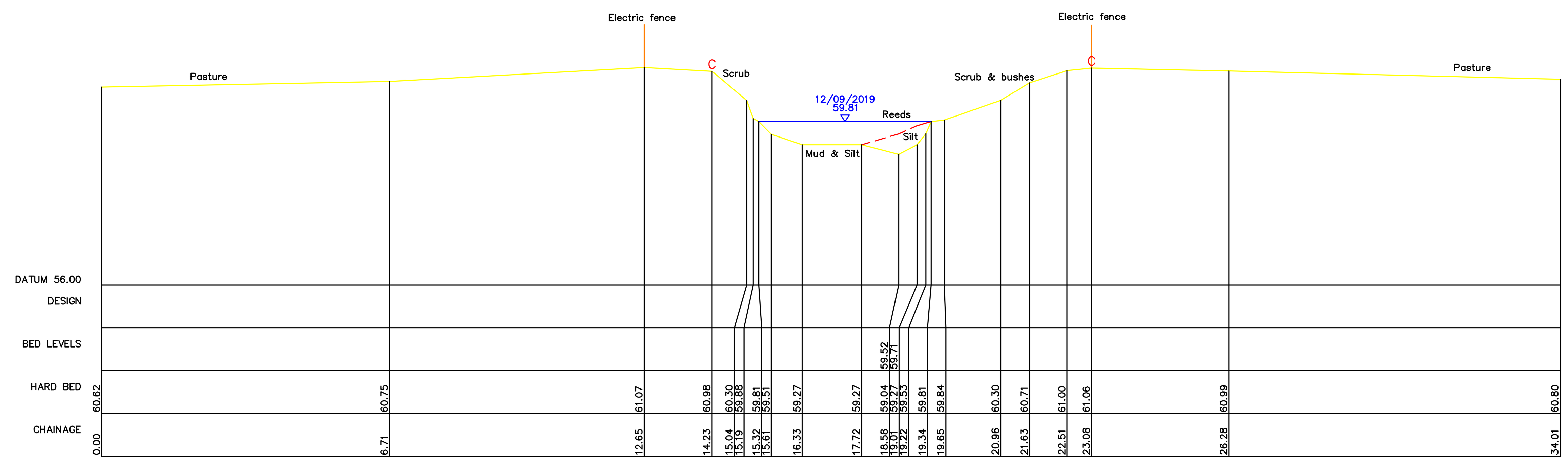

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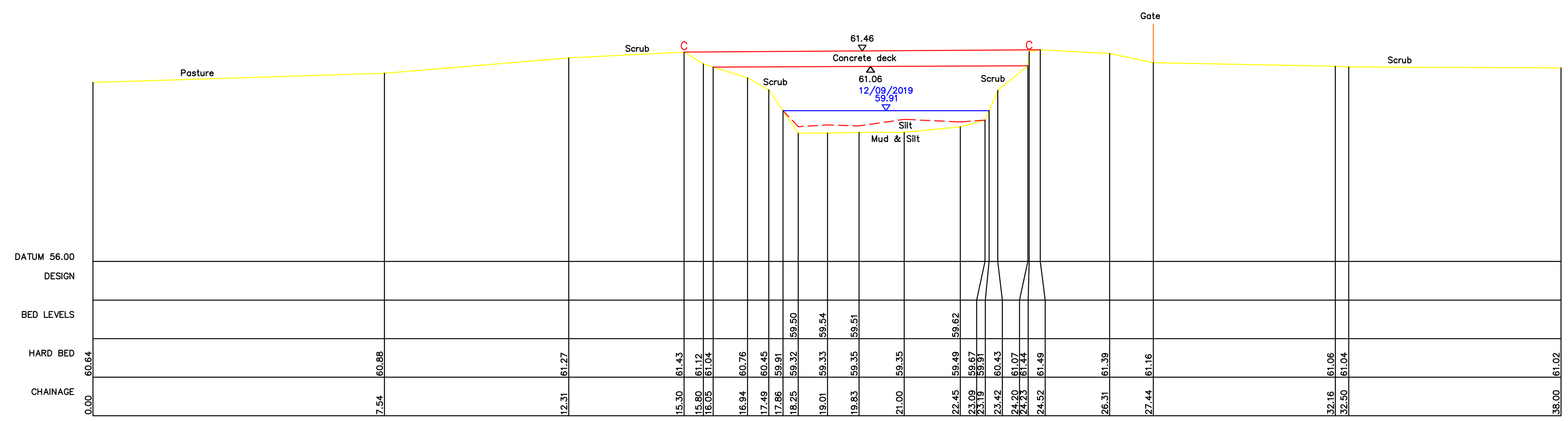
Chainage 4015.8
Open Channel



XS20
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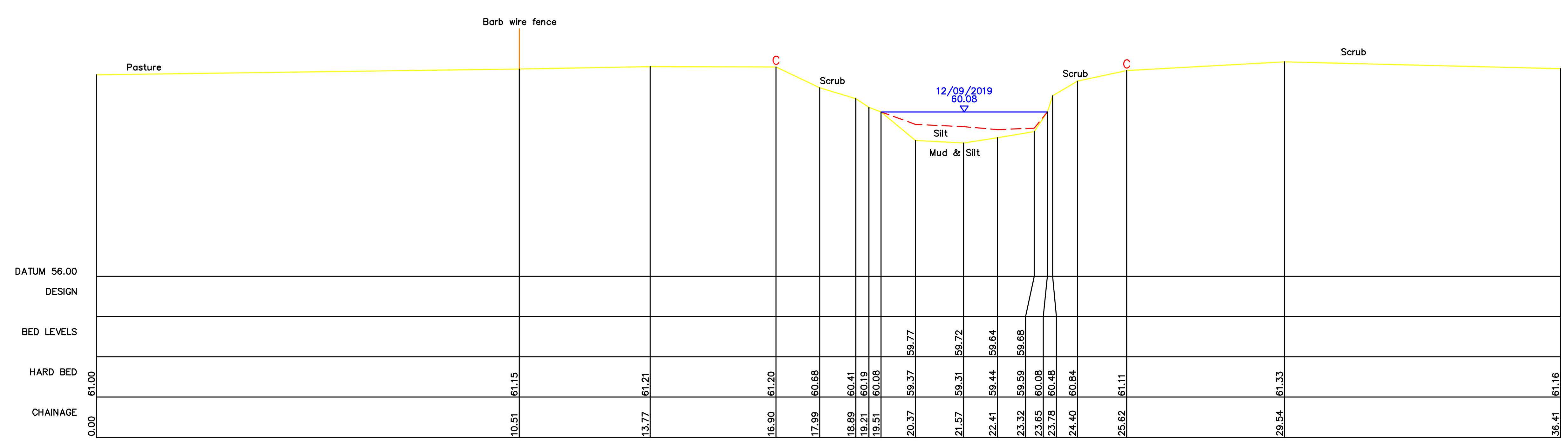
Chainage 4179.9
USF Access Bridge
Bridge Length 3.7m



XS21
457881.16mE 219408.5mN Brg 311
Chainage 4302.8
Open Channel

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ROAD SIGN	RS	SECURITY FENCE	—x—x—
STUMP	SP	FENCE	—/—/—
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SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
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STOP VALVE	SV		
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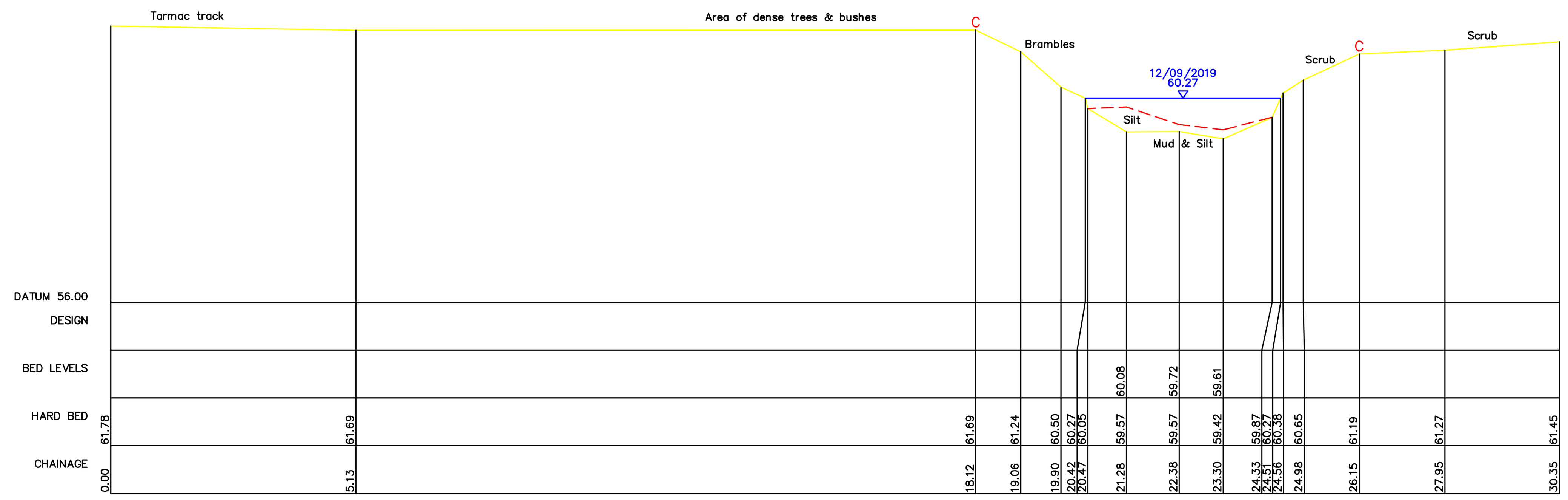

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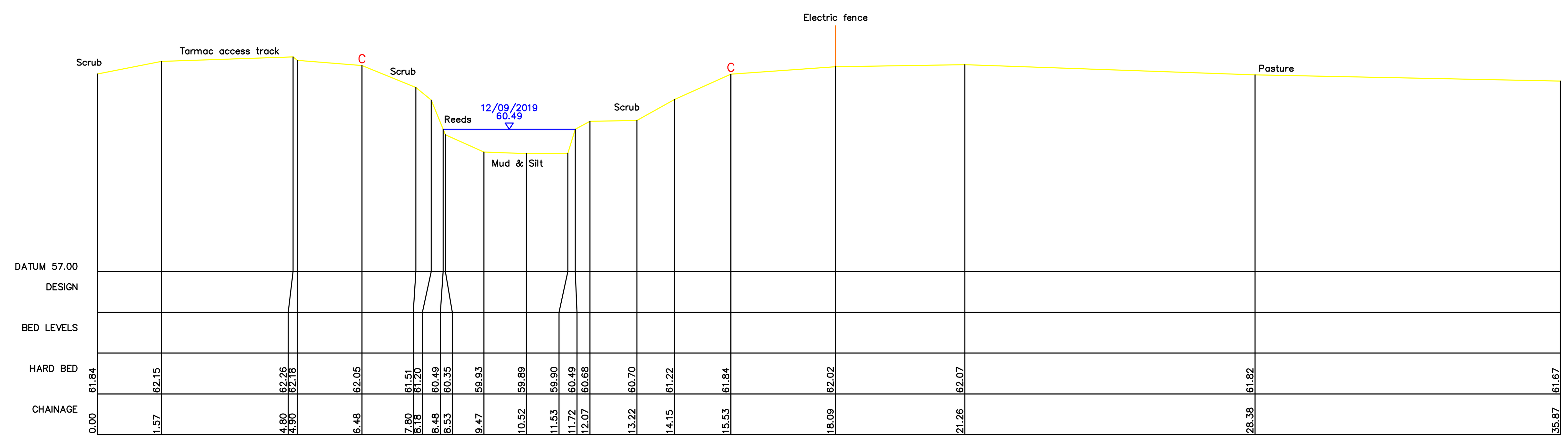
Open Channel



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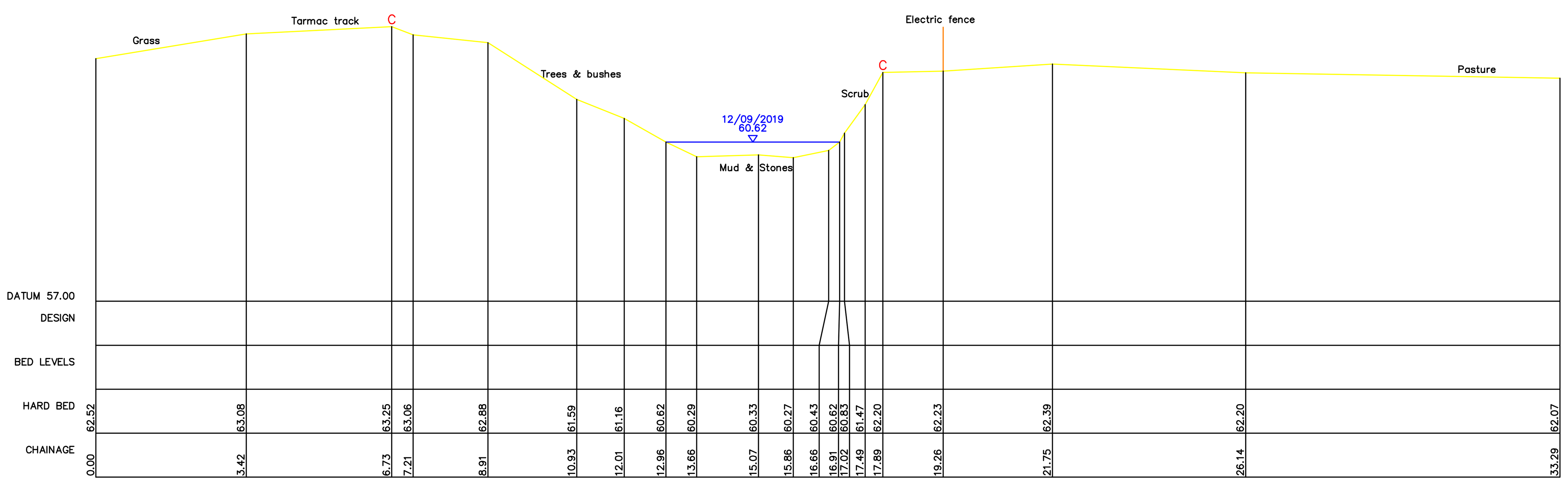
Chainage 4663.4
Open Channel



XS24
458013.93mE 219873.93mN Brg 228
Chainage 4906.5
Open Channel

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Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—x—x—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

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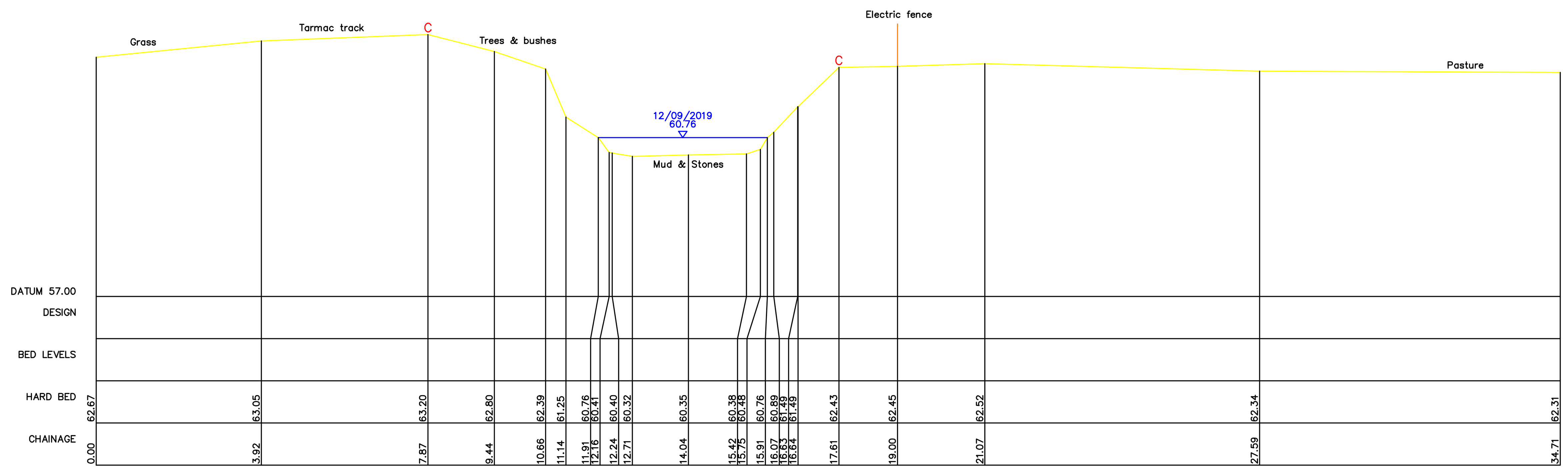
File Name:	Sheet size:	Sheet:
GCS-JBA-0342-1	A1	12 of 26

Reach 1



XS25
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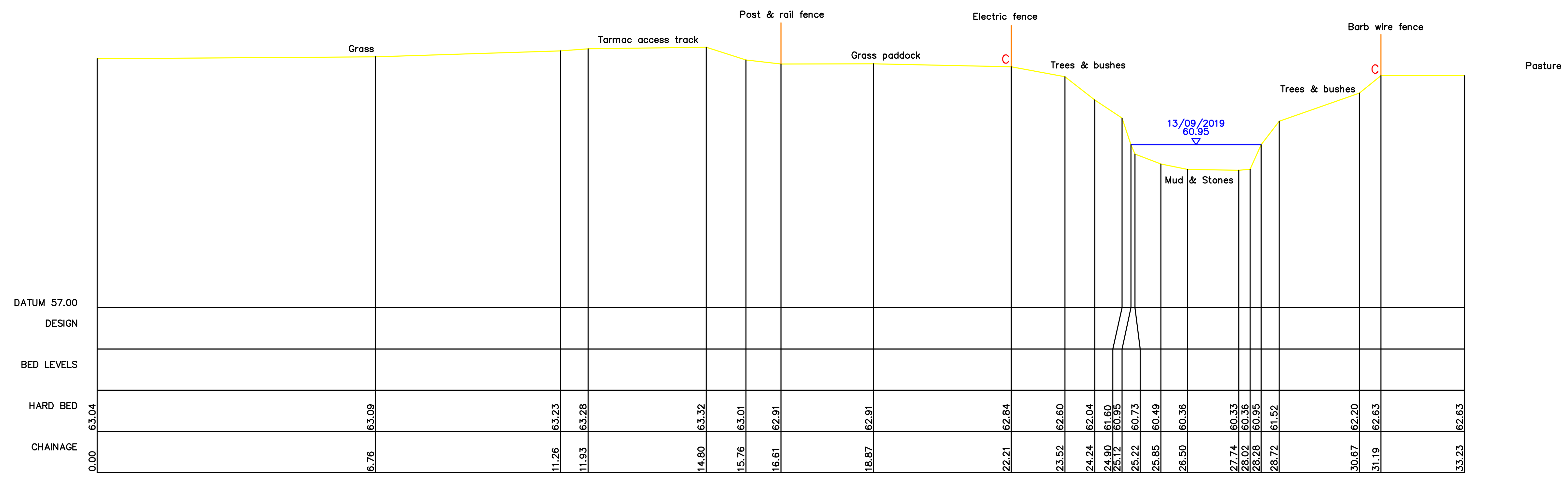
Chainage 5082.3
Open Channel



XS26
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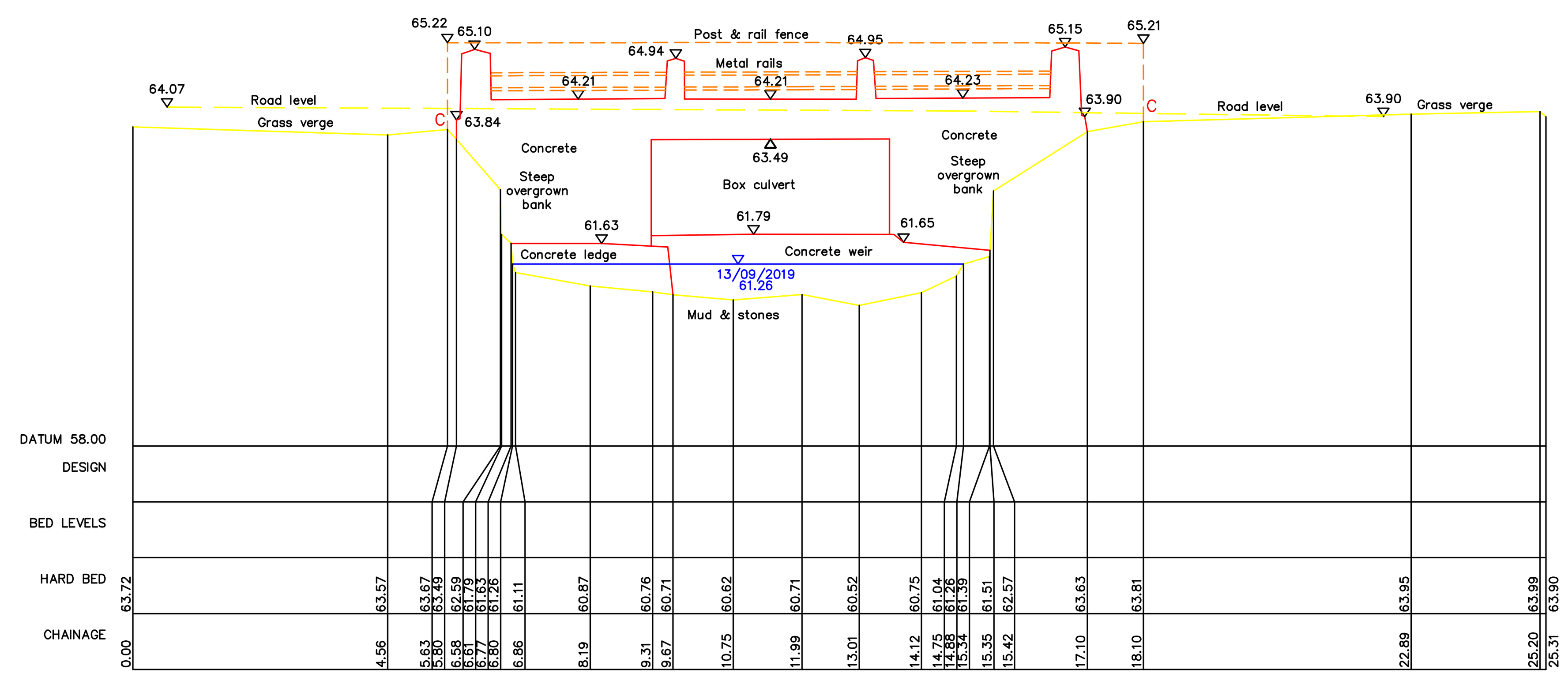
Chainage 5197.1
Open Channel



XS27
457856.61mE 220324.78mN Brg 266
Chainage 5396.3
DSF Langford Road Bridge
Bridge Length 10m

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

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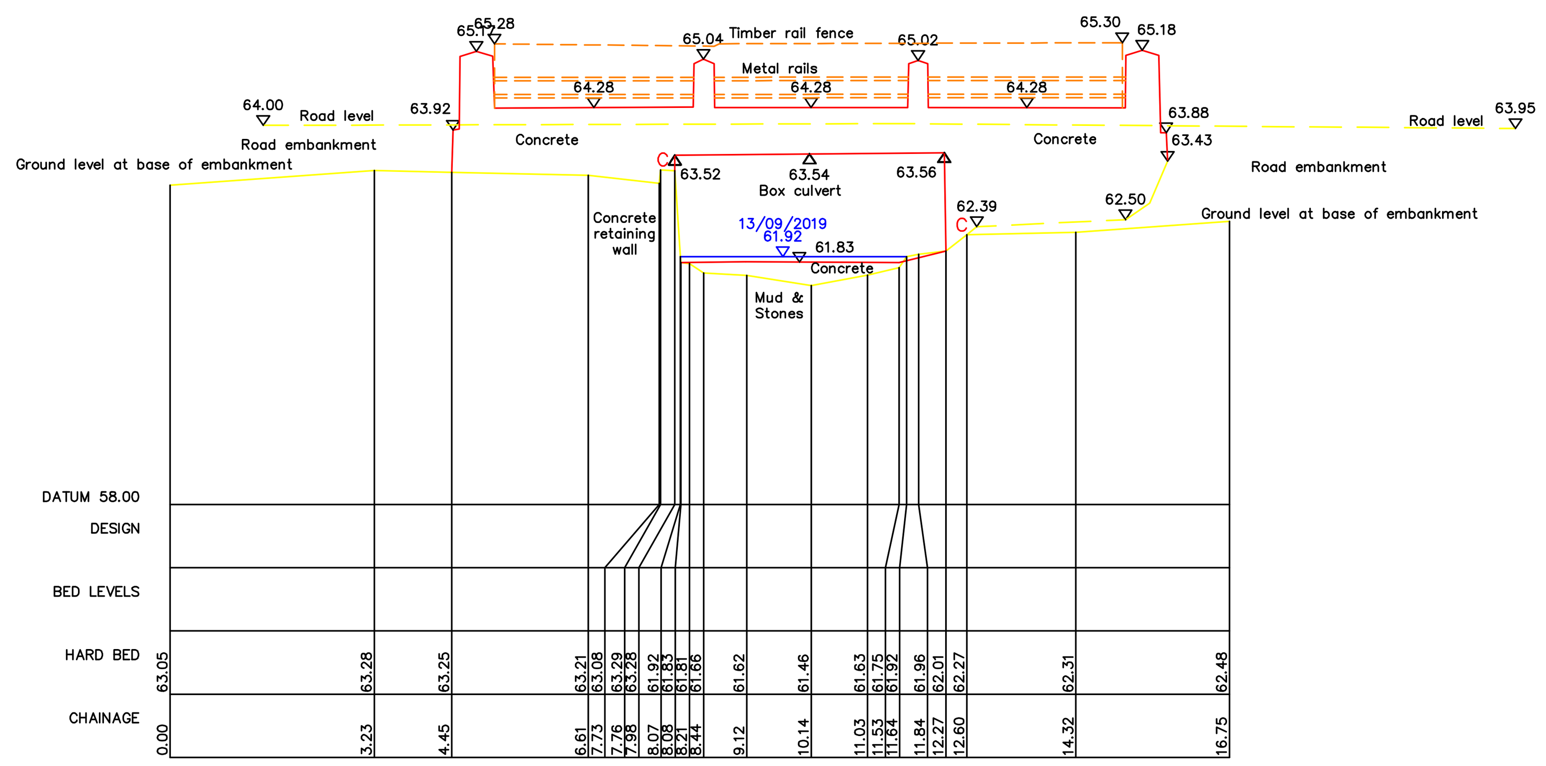
GCS-JBA-0342-1	A1	13 of 26

Reach 1



XS28
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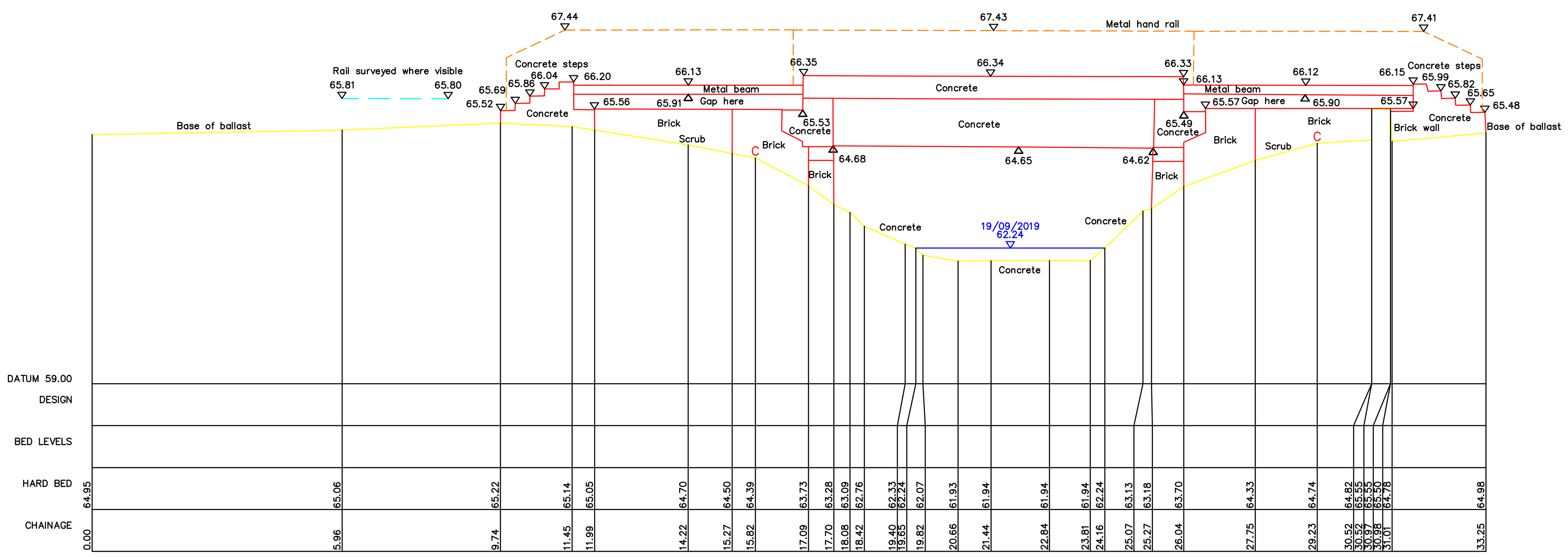
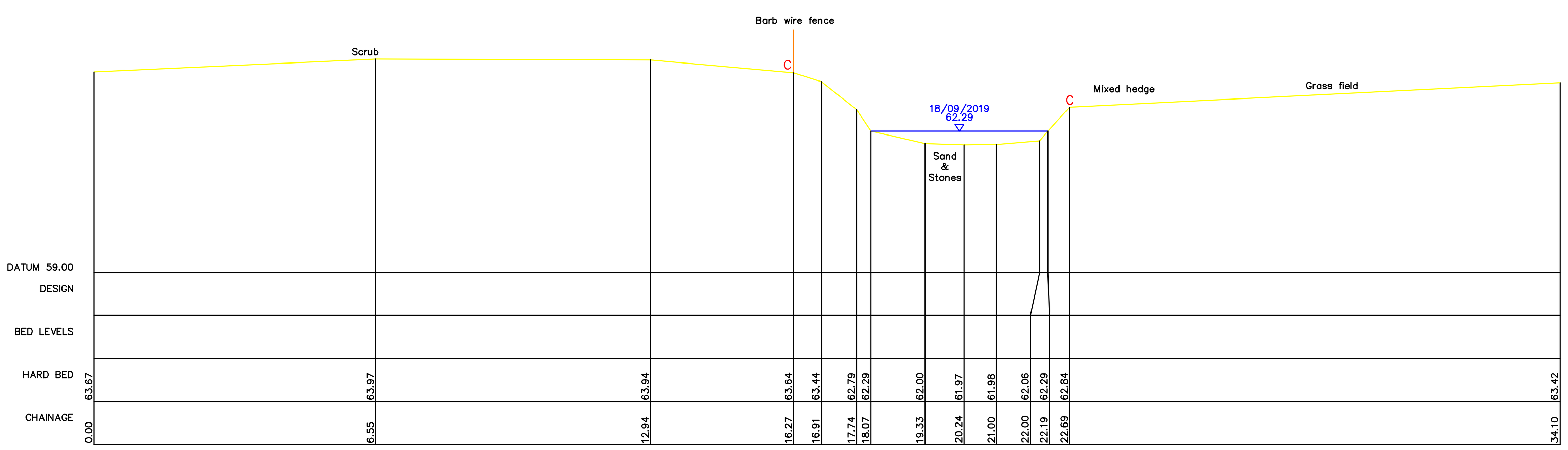
Chainage 5406.3
USF Langford Road Bridge
Bridge Length 10m



XS29
457674.3mE 220500.34mN Brg 214
Chainage 5694.3
USF Railway Bridge
Bridge Length 8.9m



XS30
457686.76mE 220677.35mN Brg 292
Chainage 5922.8
Open Channel

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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Station	Description	Eastings	Northings	Height

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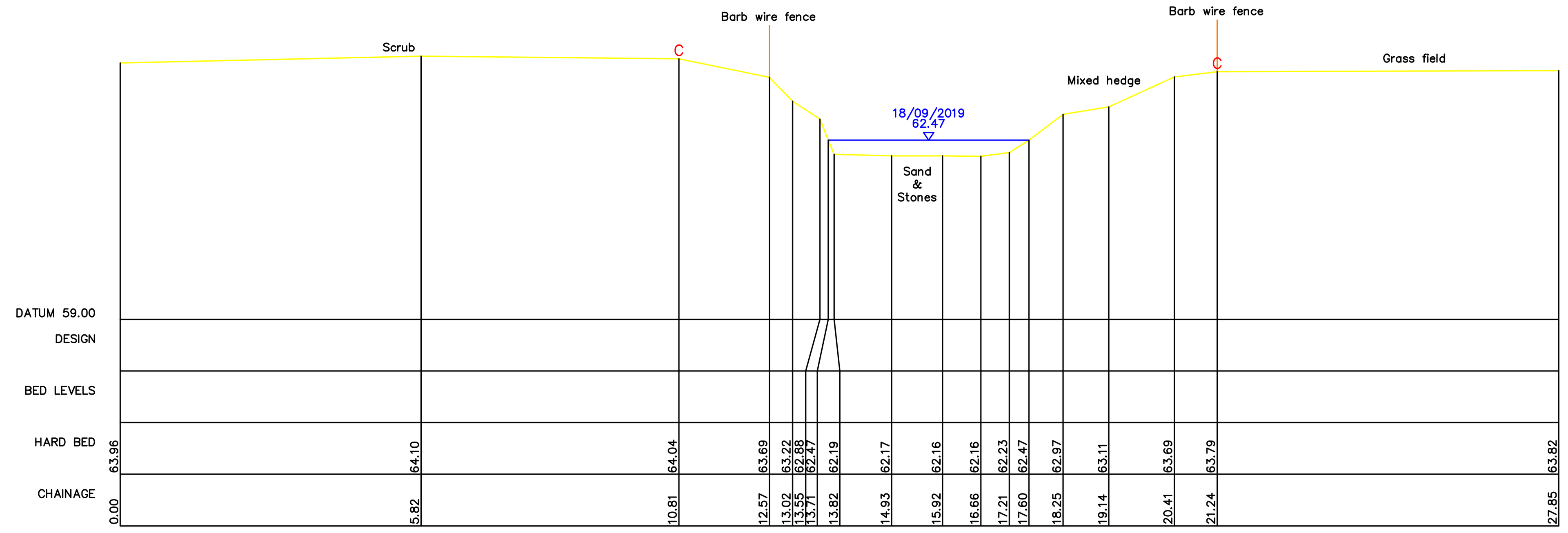
GCS-JBA-0342-1	A1	14 of 26

Reach 1



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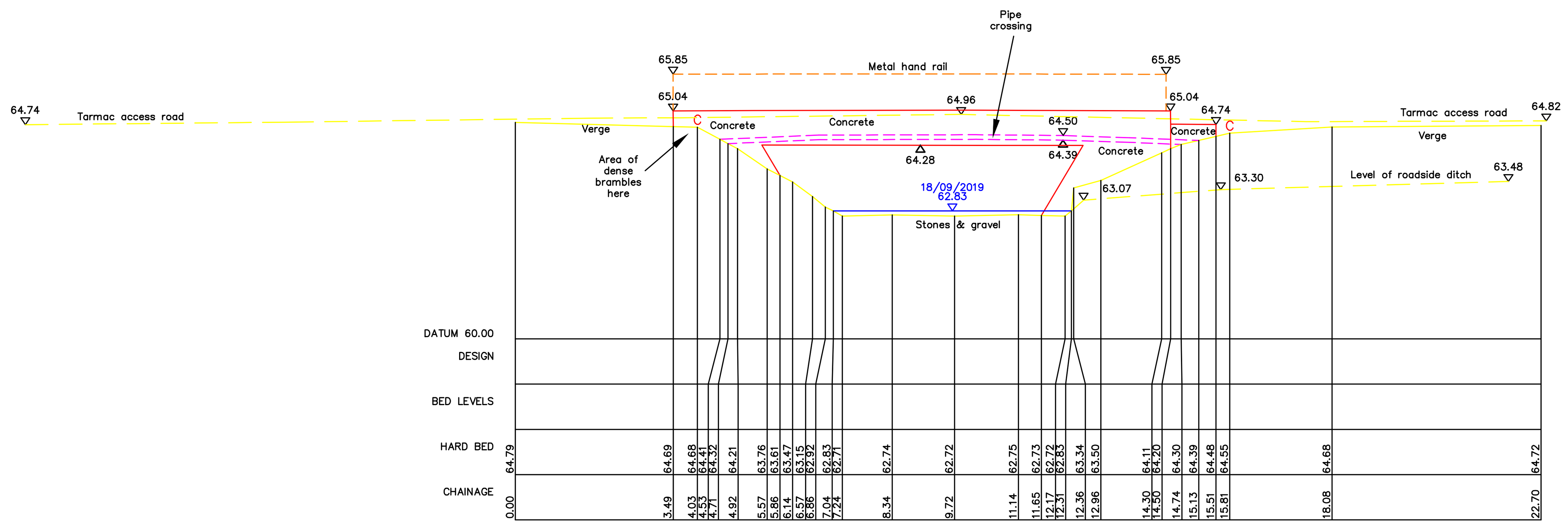
Chainage 6106.8
Open Channel



XS32
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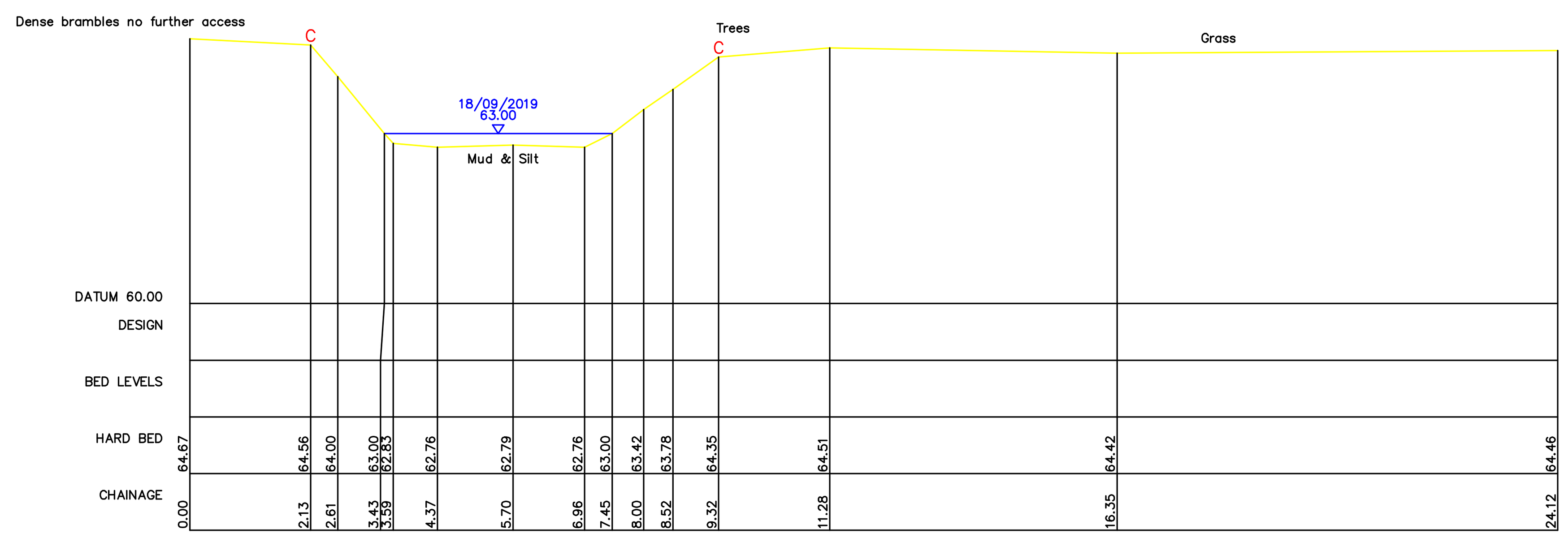
Chainage 6417.1
USF Access Road Bridge
Bridge Length 5.3m



XS33
457909.73mE 221269.54mN Brg 321
Chainage 6613.3
Open Channel

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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GCS-JBA-0342-1	A1	15 of 26

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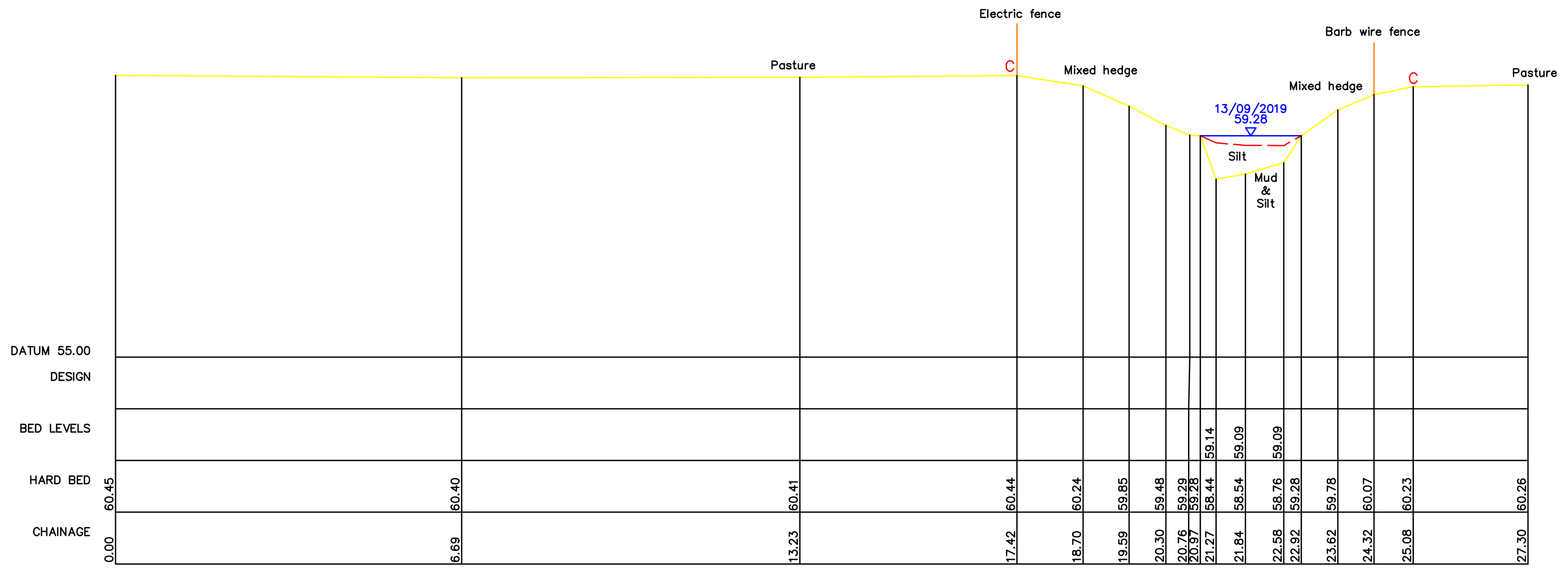

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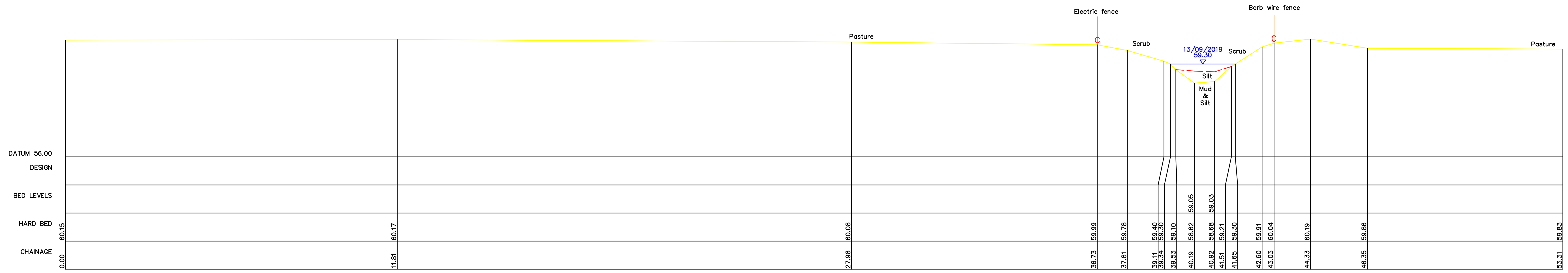
Chainage 12.5
Open Channel



XS35
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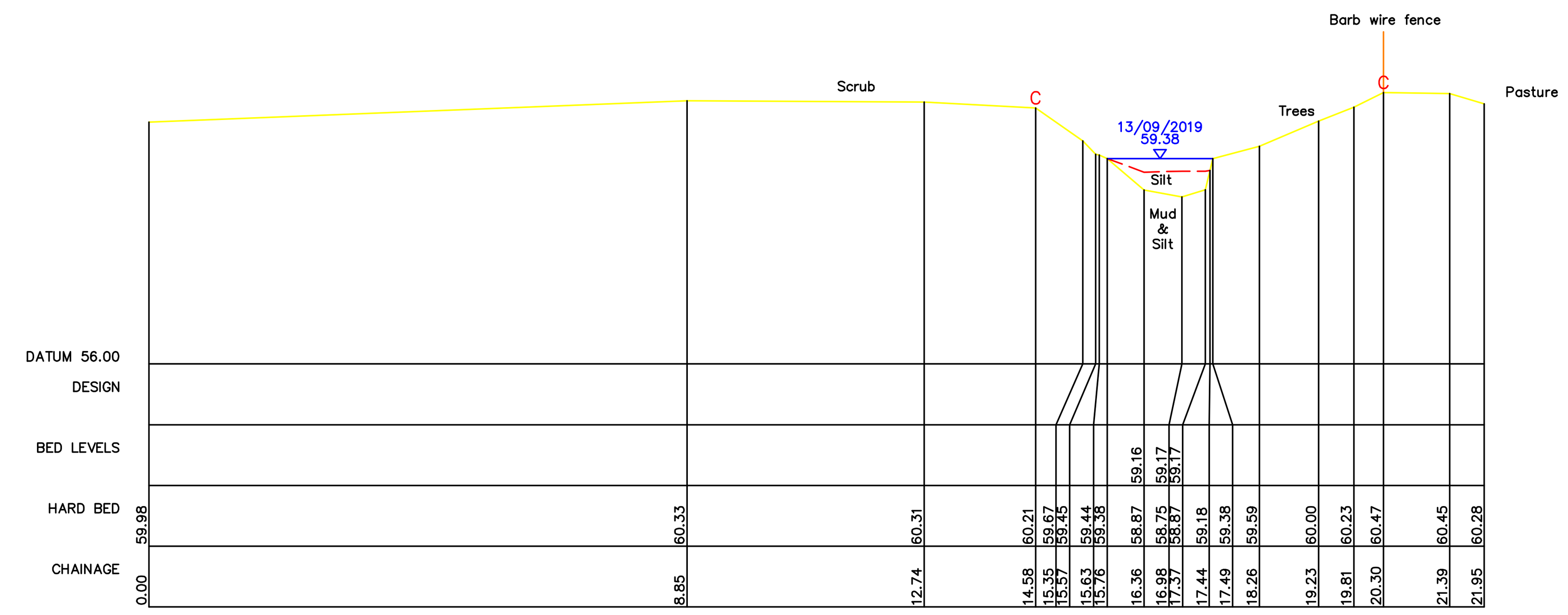
Chainage 140.3
Open Channel



XS36
457176.57mE 218944.48mN Brg 258
Chainage 295.2
Open Channel

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BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
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ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
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ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
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RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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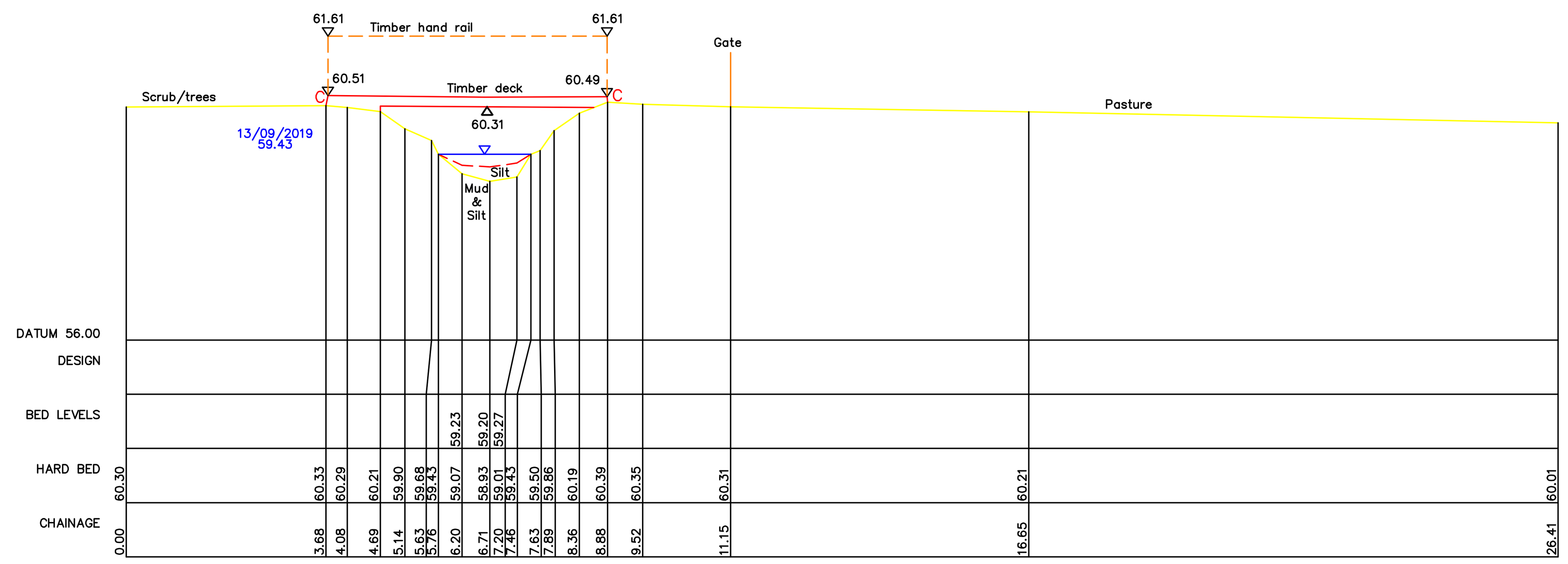
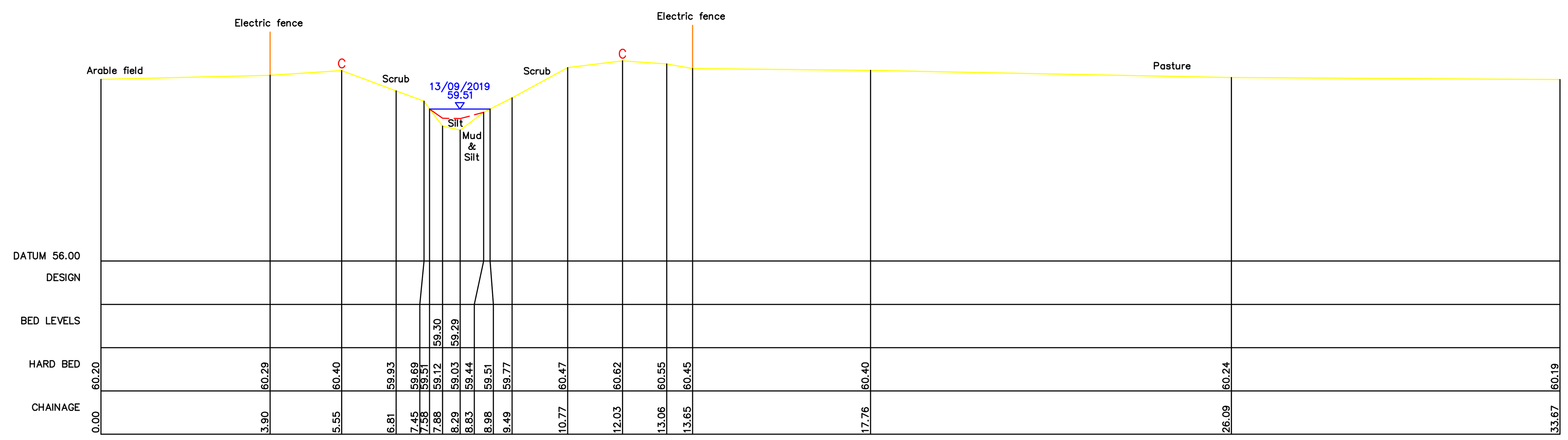
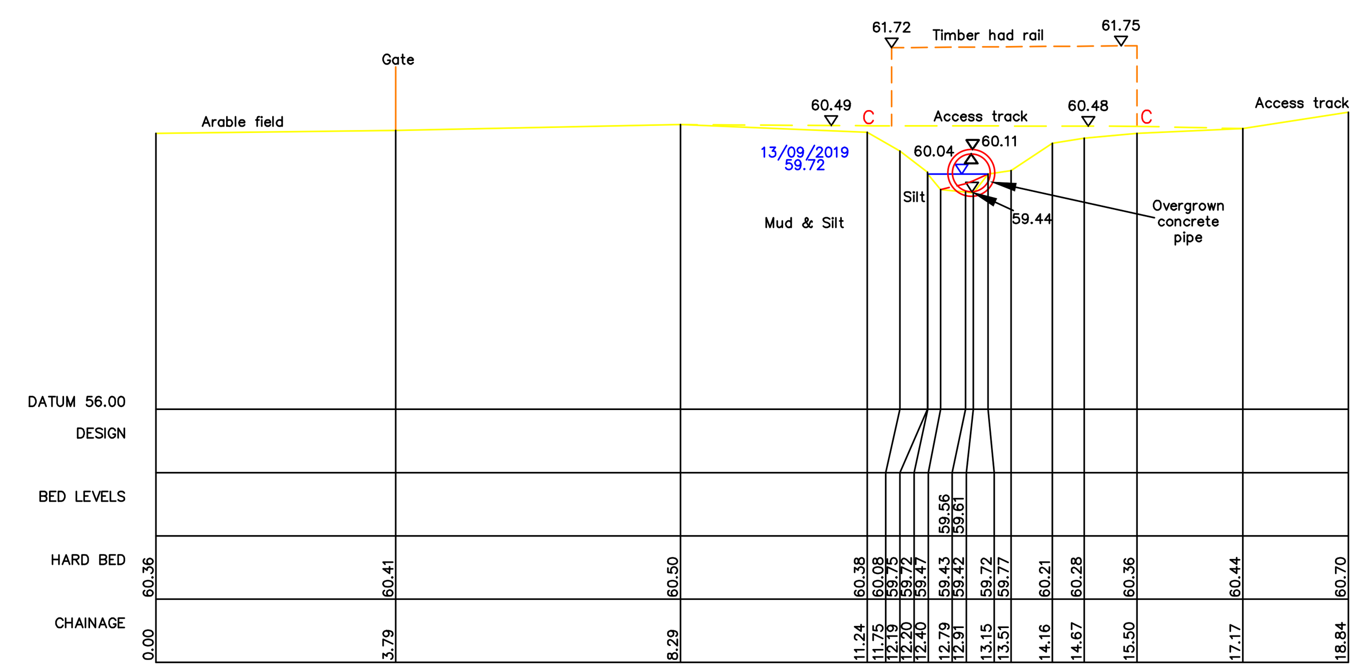


XS37
457138.44mE 219040.17mN Brg 250
Chainage 396.3
Timber Deck Footbridge
Bridge Length 1m



XS38
457133.84mE 219134.37mN Brg 266
Chainage 493.2
Open Channel



XS39
457142.1mE 219304.72mN Brg 282
Chainage 668.1
Farm Access Culvert
Pipe Length 10.2m

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Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

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Coleshill
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Grantham Coates Surveys Ltd

Land - Engineering - Building Surveyors

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Drawing No:	Rev:
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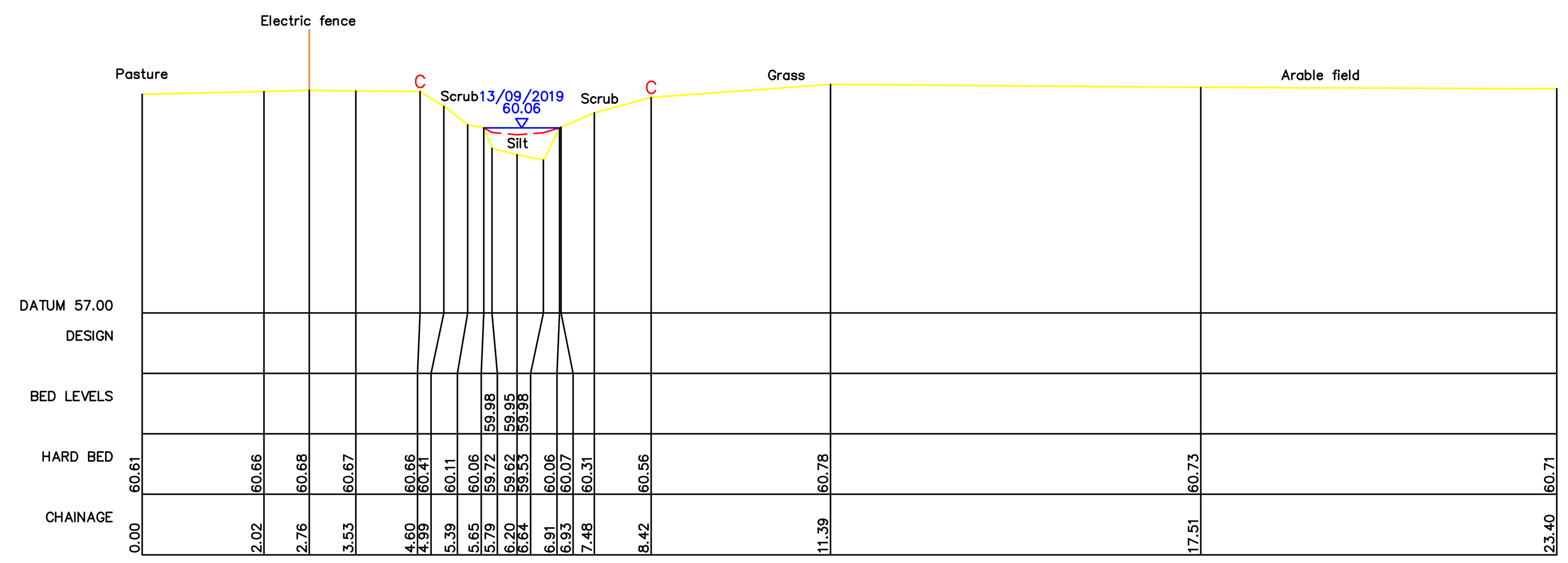
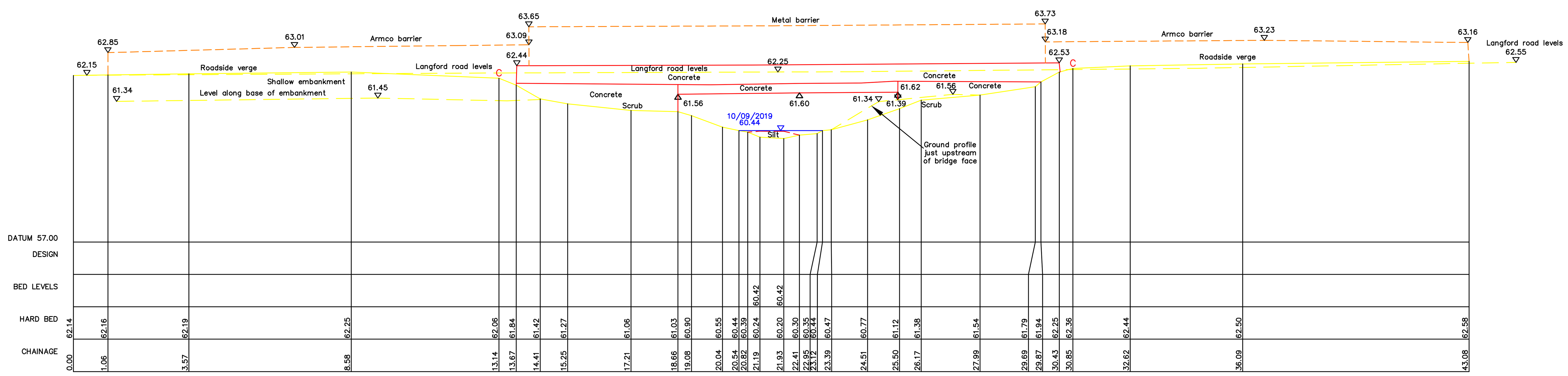
Drawn:	Checked:	Scale:	Date:
MC	CC	1:100	17/09/19
File Name: GCS-JBA-0342-1		Sheet size: A1	Sheet: 17 of 26

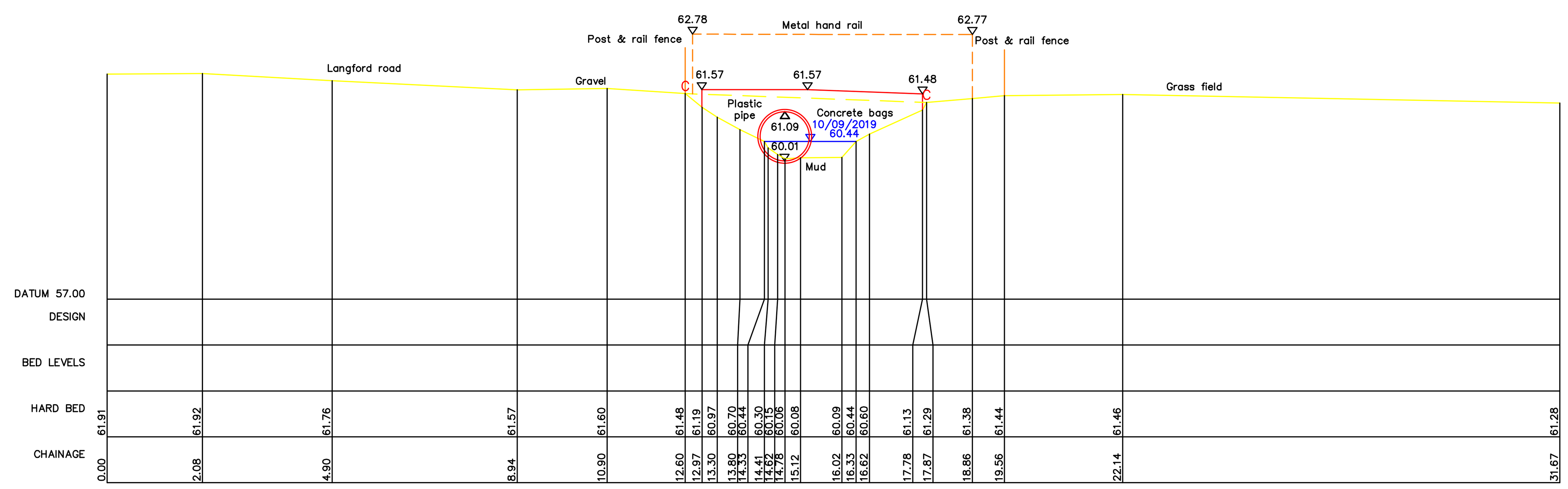
Reach 2



XS40
457159.91mE 219450.77mN Brg 322
Chainage 826.1
Open Channel



XS41
457282.97mE 219589.87mN Brg 273
Chainage 1012
USF Langford Lane Road Bridge
Bridge Length 11m



XS42
457373.19mE 219607.21mN Brg 352
Chainage 1130.3
USF Culverted Farm Access
Culvert Length 7.9m

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—x—x—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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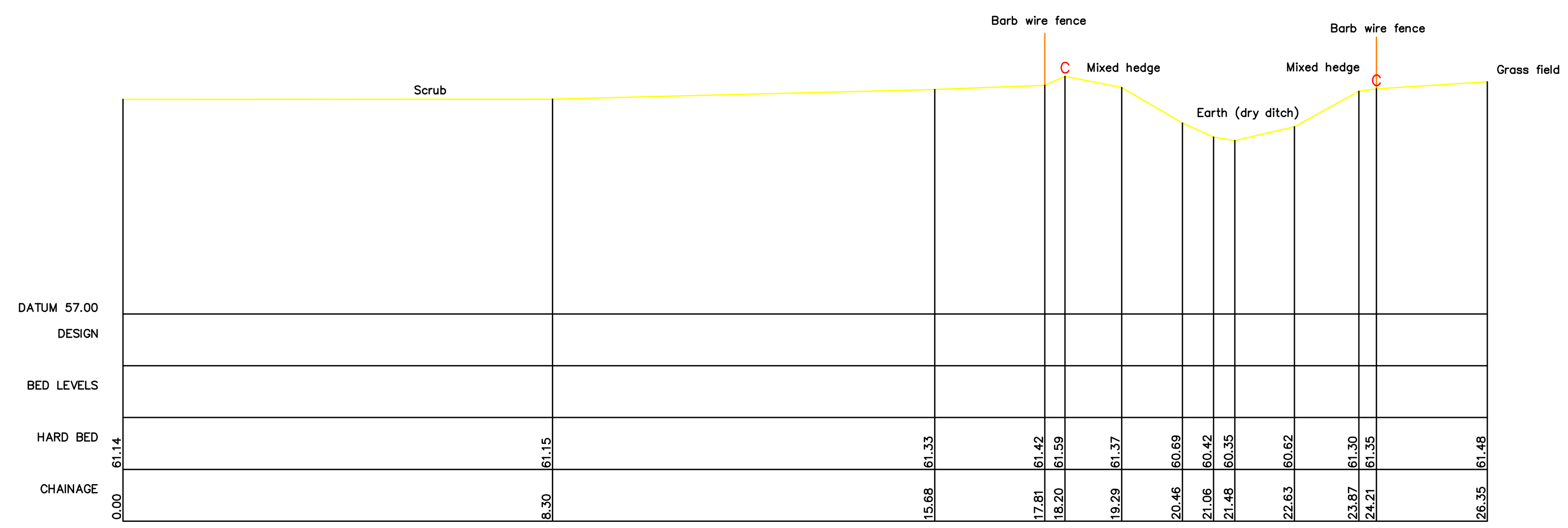
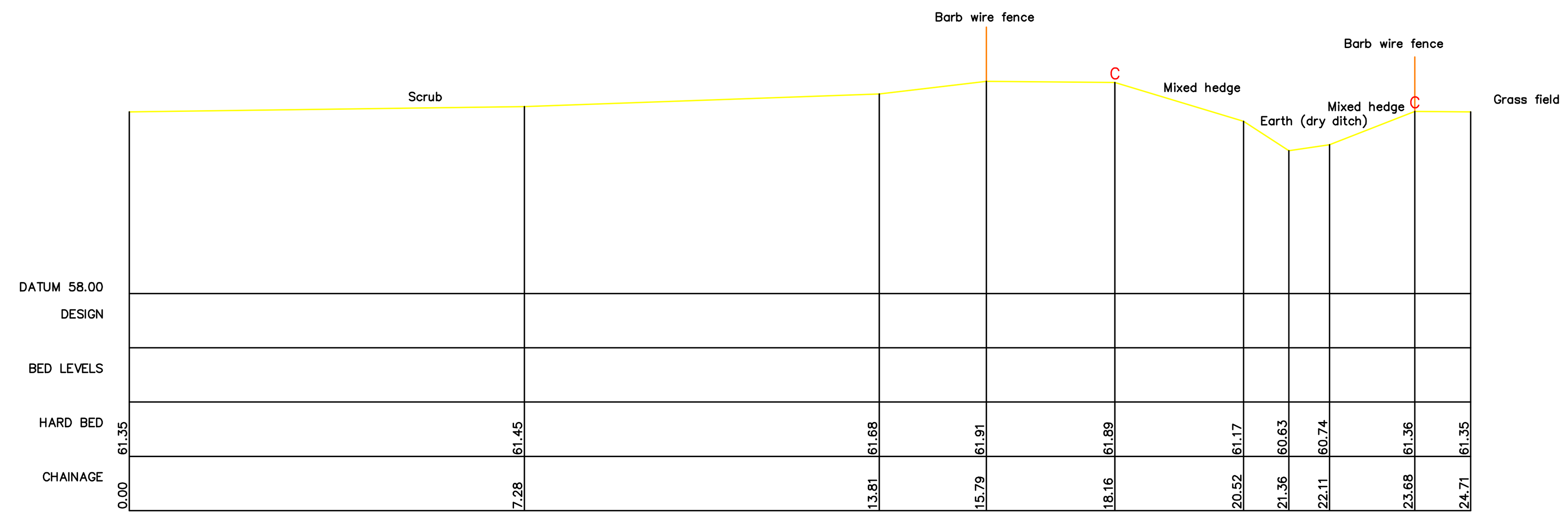
GCS-JBA-0342-1	A1	18 of 26

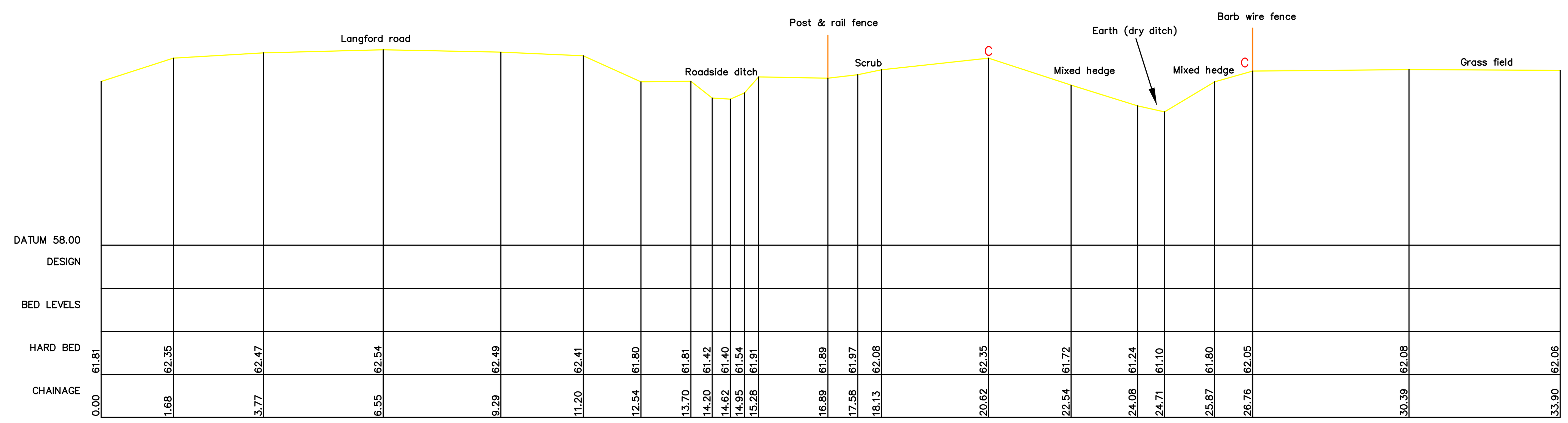
Reach 2



XS43
457399.53mE 219785.7mN Brg 278
Chainage 1298.2
Open Channel



XS44
457495.14mE 219905.42mN Brg 320
Chainage 1489.8
Open Channel



XS45
457639.91mE 220005.91mN Brg 314
Chainage 1676.2
Open Channel

N

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Legend

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
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BT BOX	BTB	TRAFFIC LIGHT	TL
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COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
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EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x
STUMP	SP	FENCE	/
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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Station	Description	Eastings	Northings	Height

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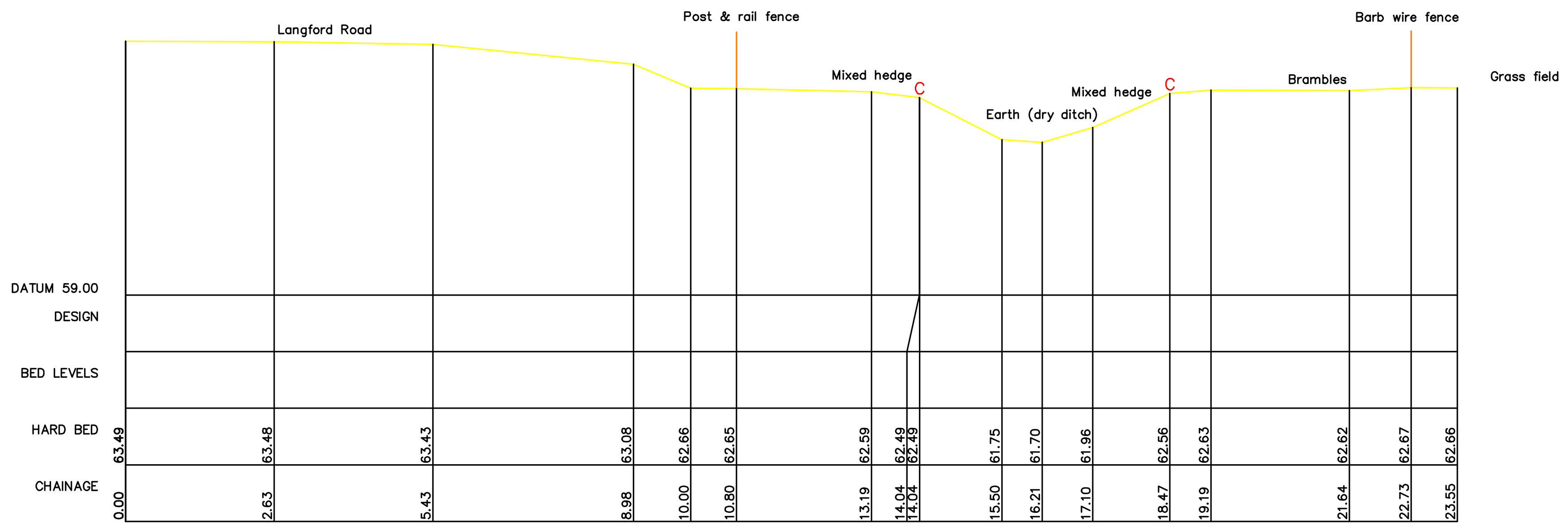
GCS-JBA-0342-1	A1	19 of 26

Reach 2



XS46
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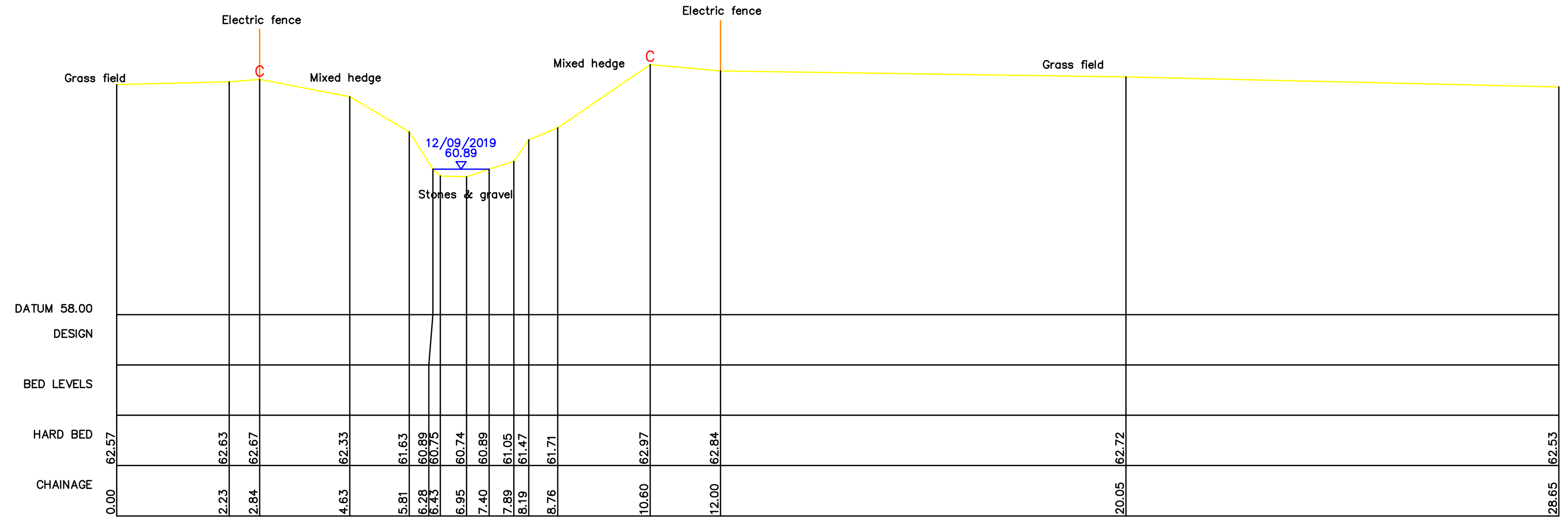
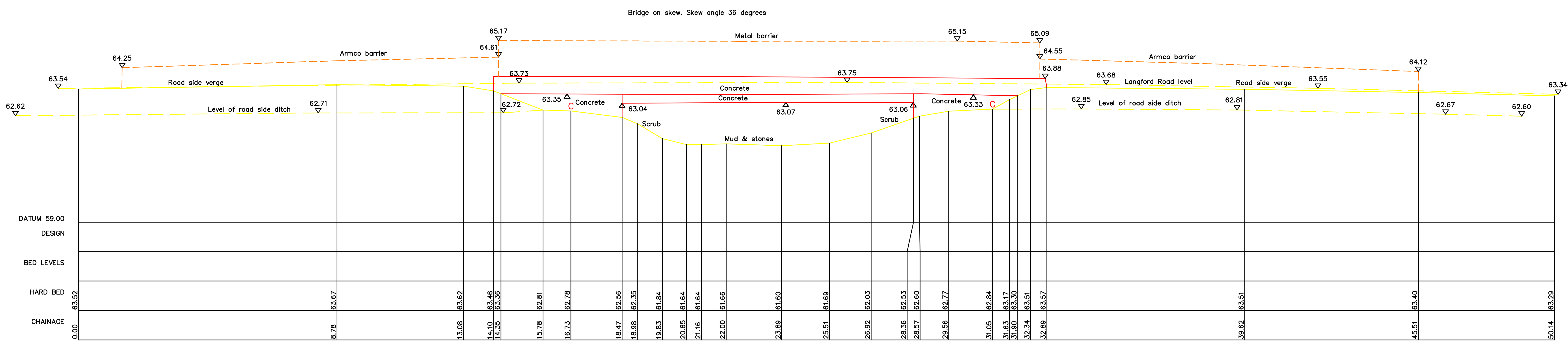
Chainage 1817.5
Open Channel

Reach 3



XS47
457859.82mE 220136.06mN Brg 212
Chainage 47.4
Open Channel



XS48
457754.44mE 220153.19mN Brg 221
Chainage 170.5
USF Langford Road Bridge
Skew Angle 36 Degrees
Bridge Length 12.9m

N

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
STUMP	SP	FENCE	
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

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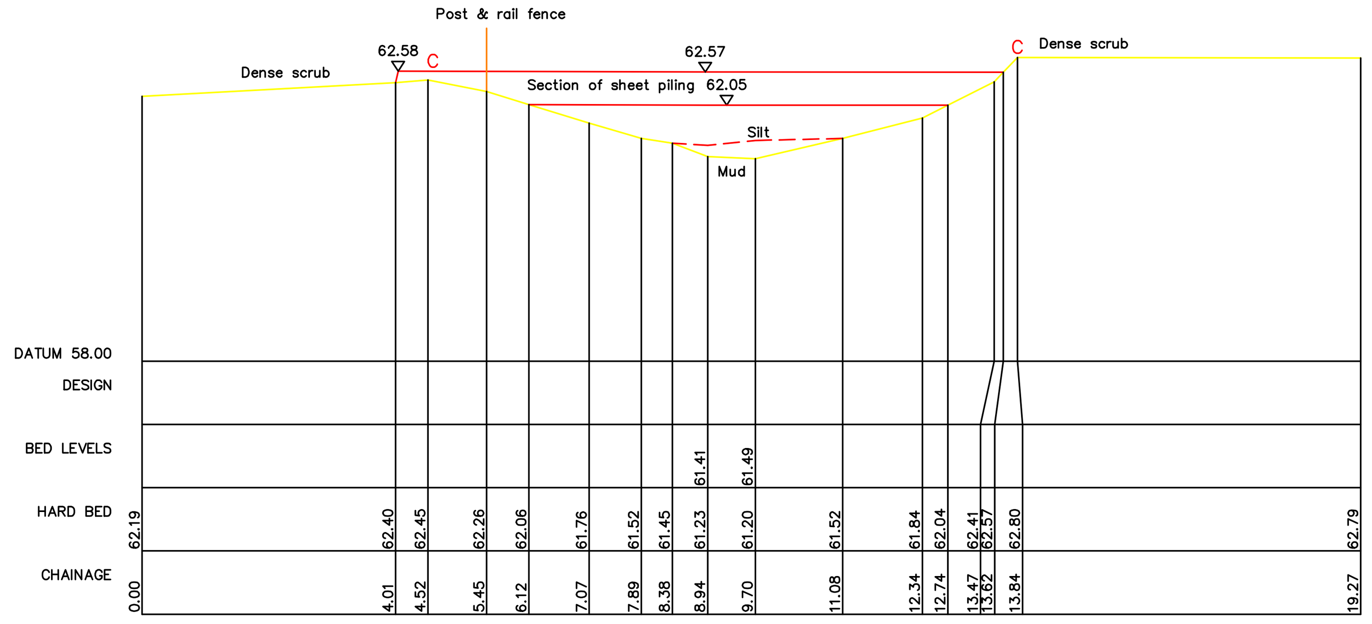
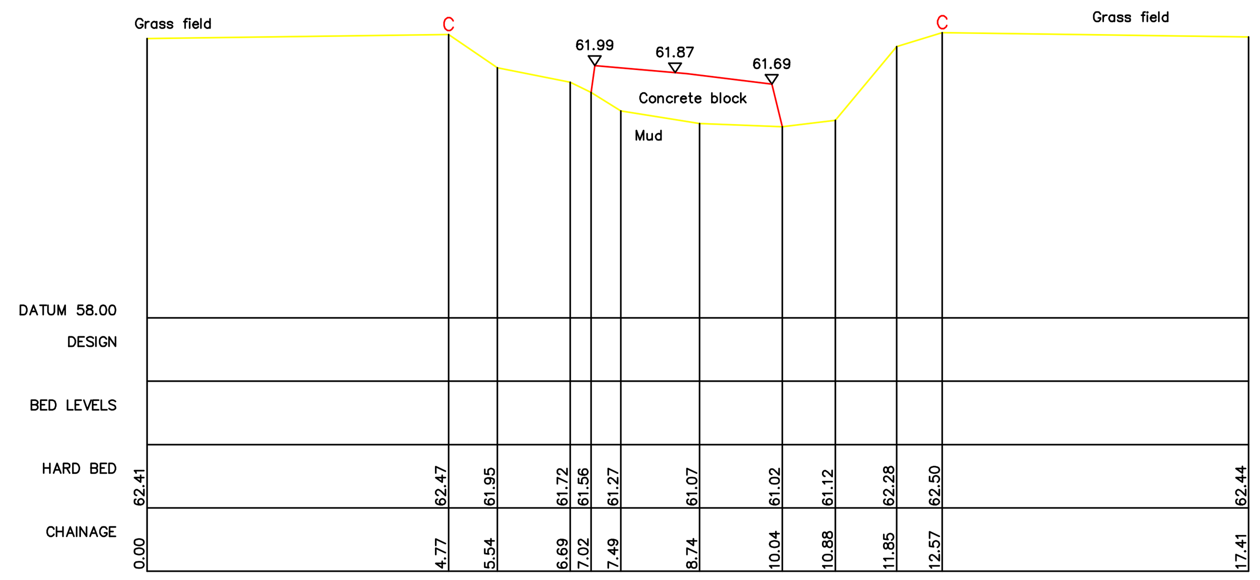
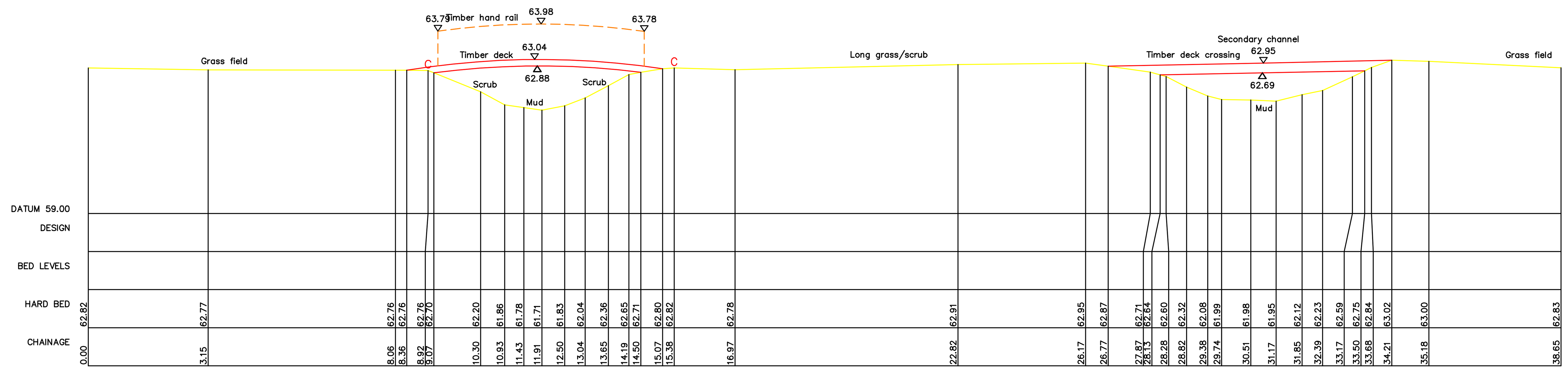


XS49
457733.56mE 220145.72mN Brg 212
Chainage 180.4
Sheet piling access crossing
Bridge Crossing 1.5m



XS50
457704.26mE 220146.55mN Brg 182
Chainage 205.1
Concrete Block in Channel
Block length 0.6m



XS51
457645.28mE 220149.47mN Brg 213
Chainage 271.6
USF Timber Foot Bridge
Bridge Length 1.2m

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BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
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GAS VALVE	GV		
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INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
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MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—x—x—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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Date:	Notes:	Name:	Rev:

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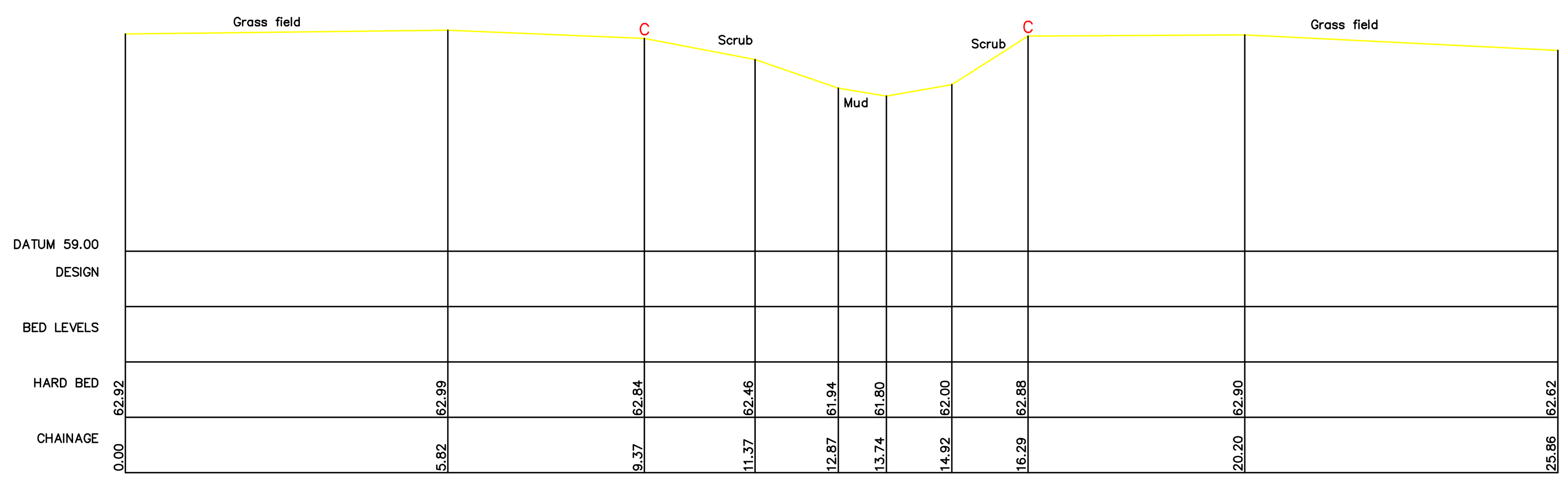
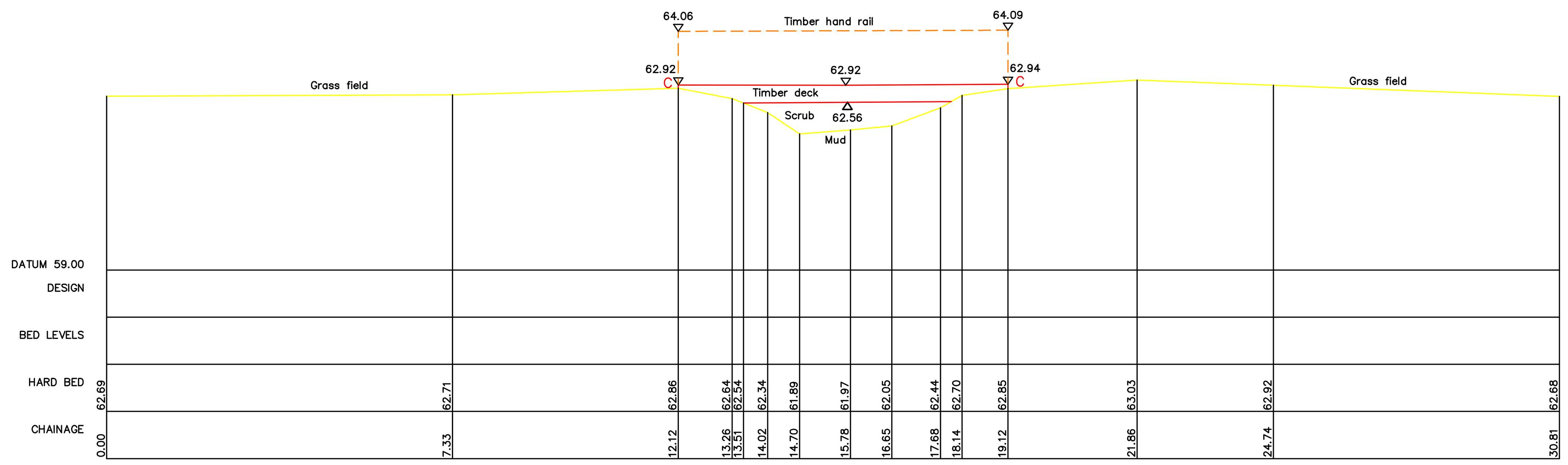
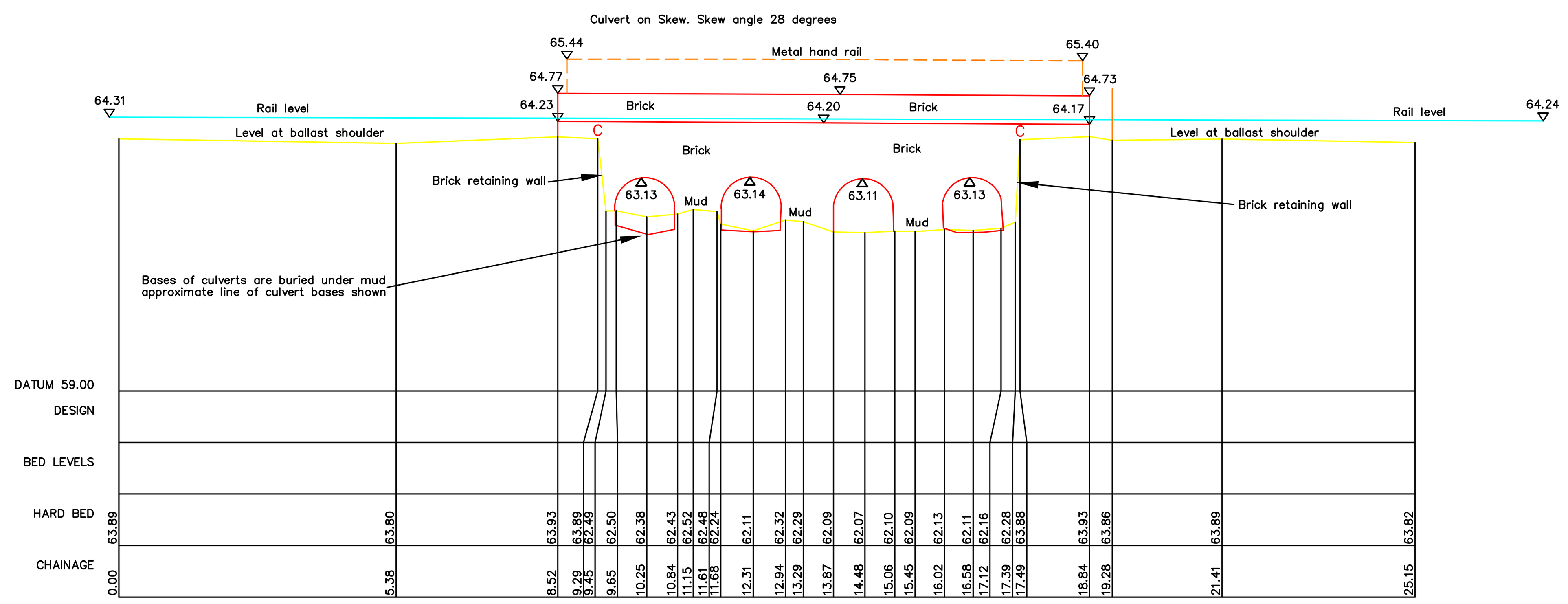
File Name:	Sheet size:	Sheet:
GCS-JBA-0342-1	A1	21 of 26



XS52
457551.29mE 220110.34mN Brg 156
Chainage 364.7
Open Channel



XS53
457454.48mE 220118.03mN Brg 181
Chainage 472.4
USF Timber Foot Bridge
Bridge Length 3.4m



XS54
457399.03mE 220101.32mN Brg 215
Chainage 541.8
USF Railway Culvert
Culvert length 9.8m
Skew Angle 28 Deg

Notes

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Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—×—×—
STUMP	SP	FENCE	—/—/—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SIG	FOUL WATER	—FW—FW—
RAIL SLEEPER LEVEL	SLP	GAS MAIN	—GM—GM—
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	—SW—SW—
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	—TEL—TEL—
SIGN POST	SN	WATER MAIN	—WM—WM—
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: ***OS National Grid*** **Datum:** ***Ordnance Datum Newlyn***
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Title:

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(Cross Sections)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD

Grantham Coates Surveys Ltd
Land - Engineering - Building Surveyors
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Warwickshire, B49 6HN
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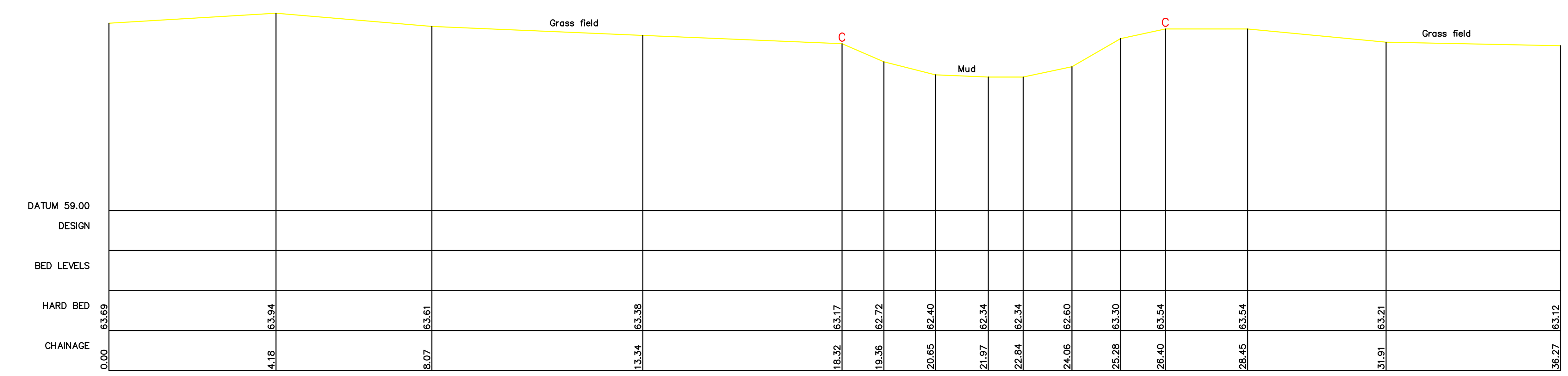
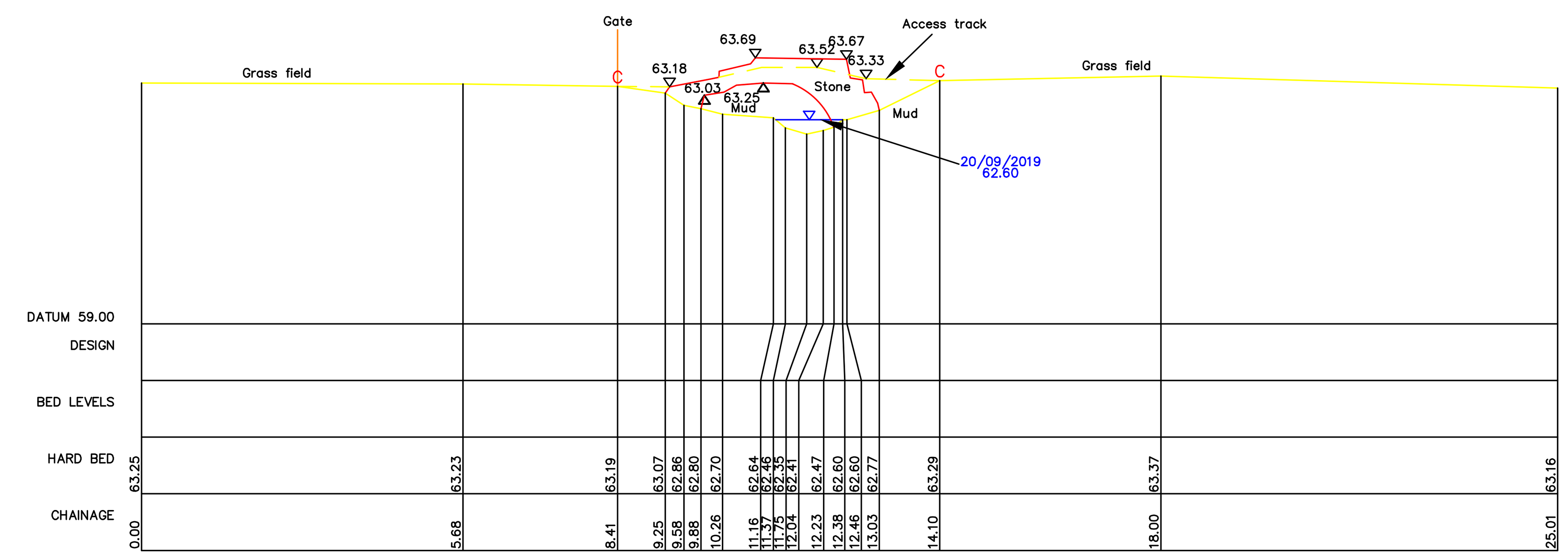
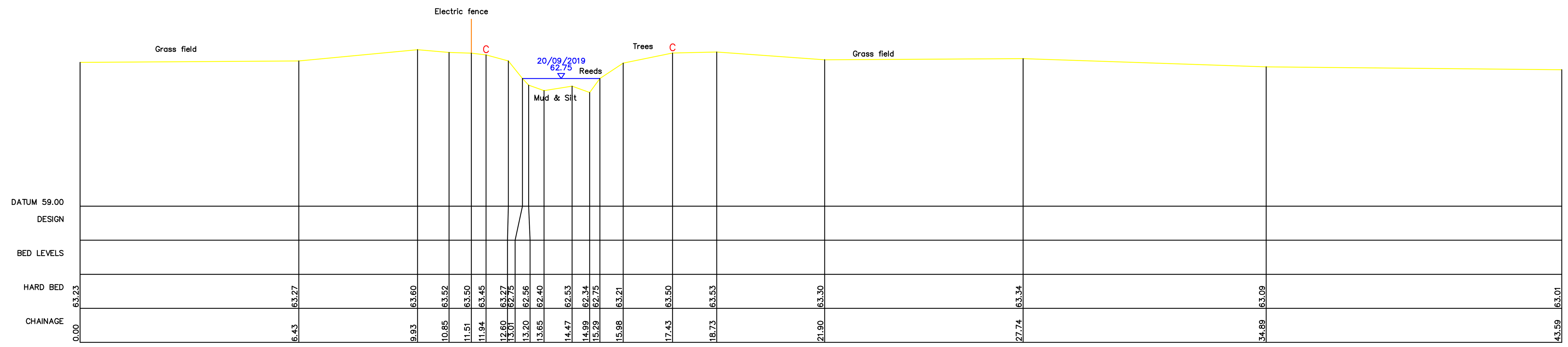
GCS-JBA-0342-1	A1	22 of 26



XS55
457254.21mE 220097.37mN Brg 169
Chainage 675.7
Open Channel



XS56
457111.58mE 220069.65mN Brg 179
Chainage 826.2
USF Farm Access Culvert
Culvert Length 4.9m



XS57
457010.36mE 220151.91mN Brg 221
Chainage 968
Open Channel

N

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
STUMP	SP	FENCE	
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

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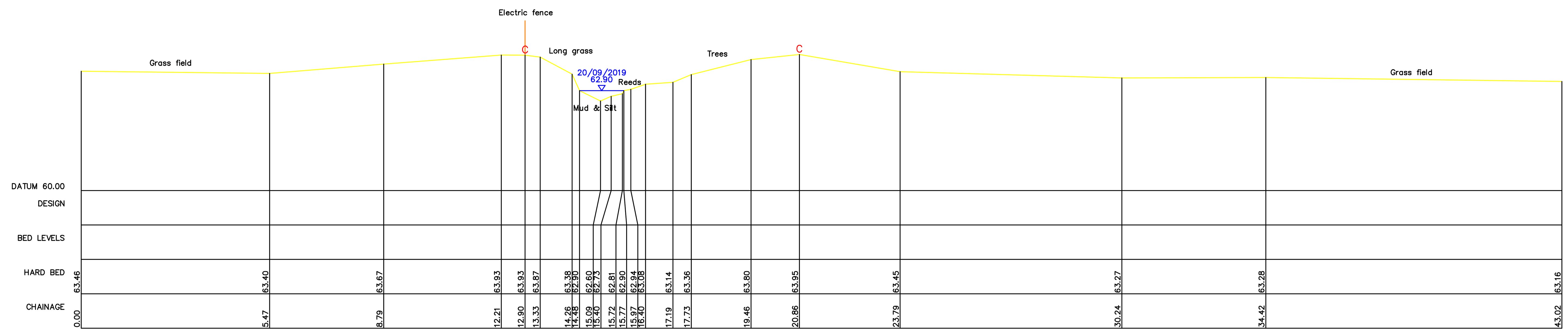
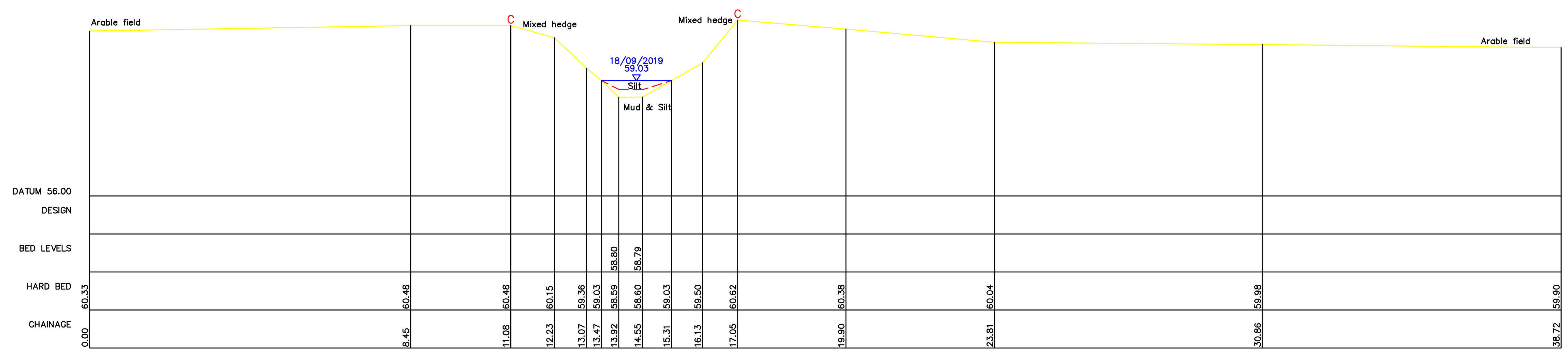
GCS-JBA-0342-1	A1	23 of 26

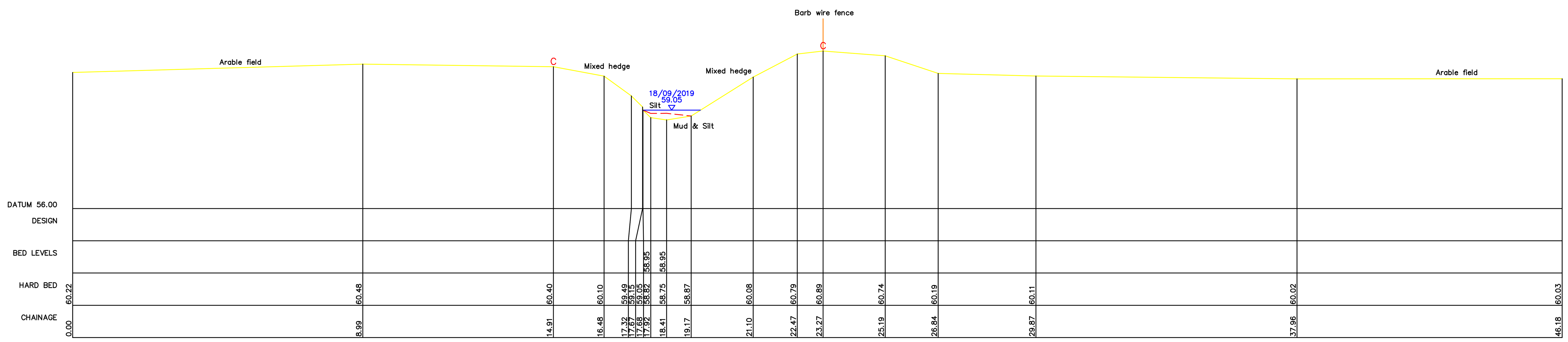


XS58
456922.75mE 220216.08mN Brg 211
Chainage 1074.4
Open Channel

Reach 4



XS59
456748.97mE 218237.32mN Brg 240
Chainage 19.5
Open Channel



XS60
456701.61mE 218313.01mN Brg 220
Chainage 103.5
Open Channel

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Legend

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x
STUMP	SP	FENCE	/
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

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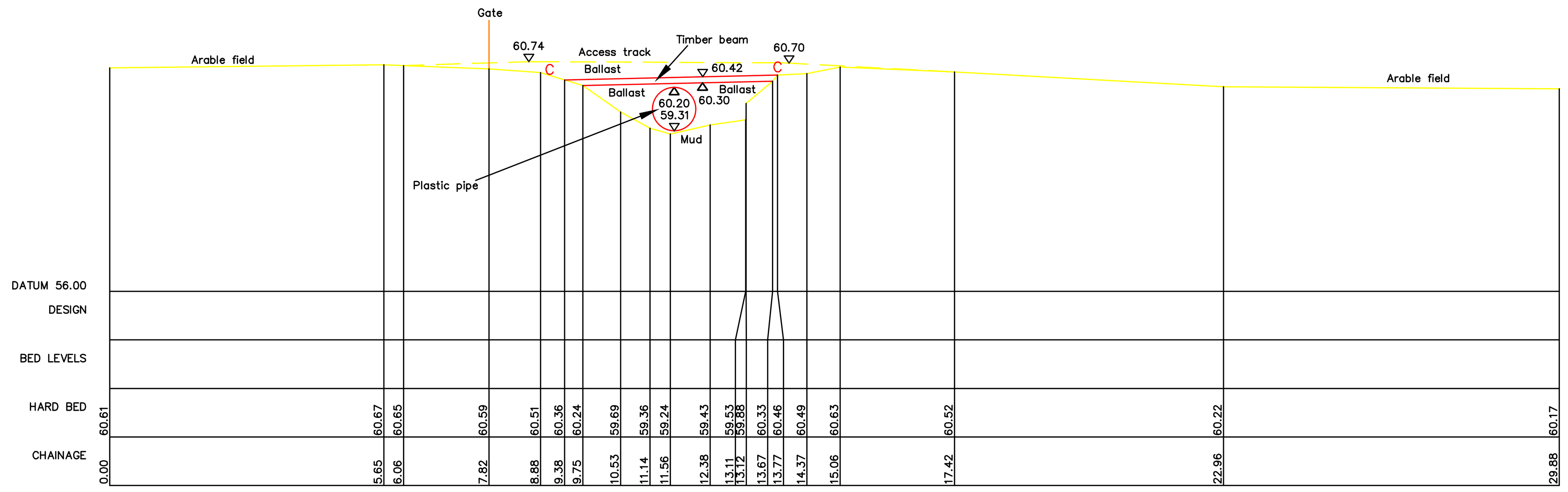
GCS-JBA-0342-1	A1	24 of 26



XS61
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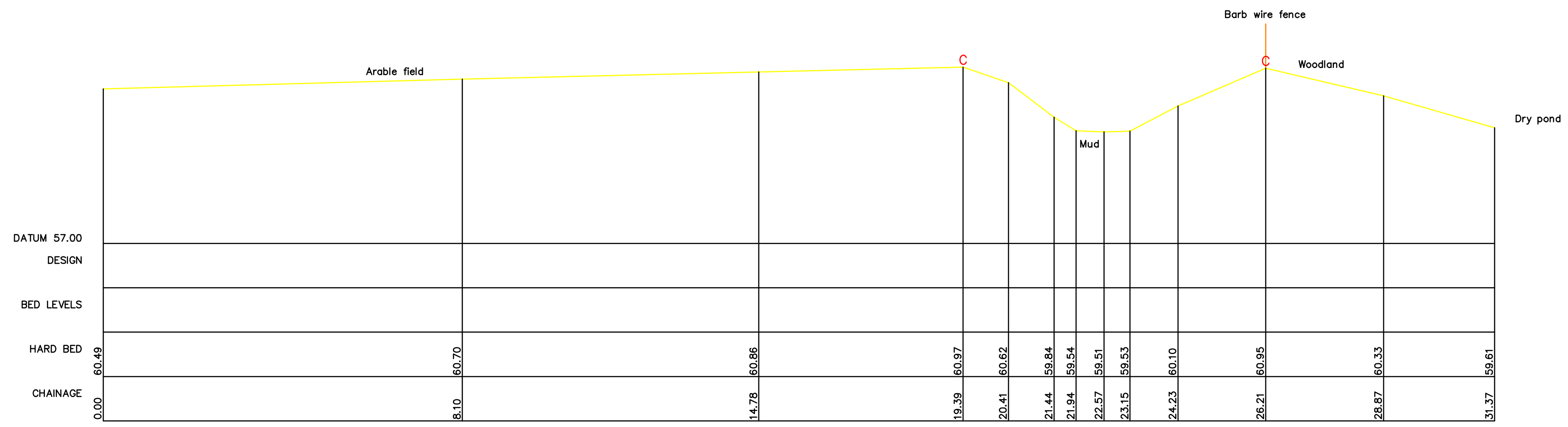
Chainage 270
USF Farm Access Culvert
Culvert Length 6.3m



XS62
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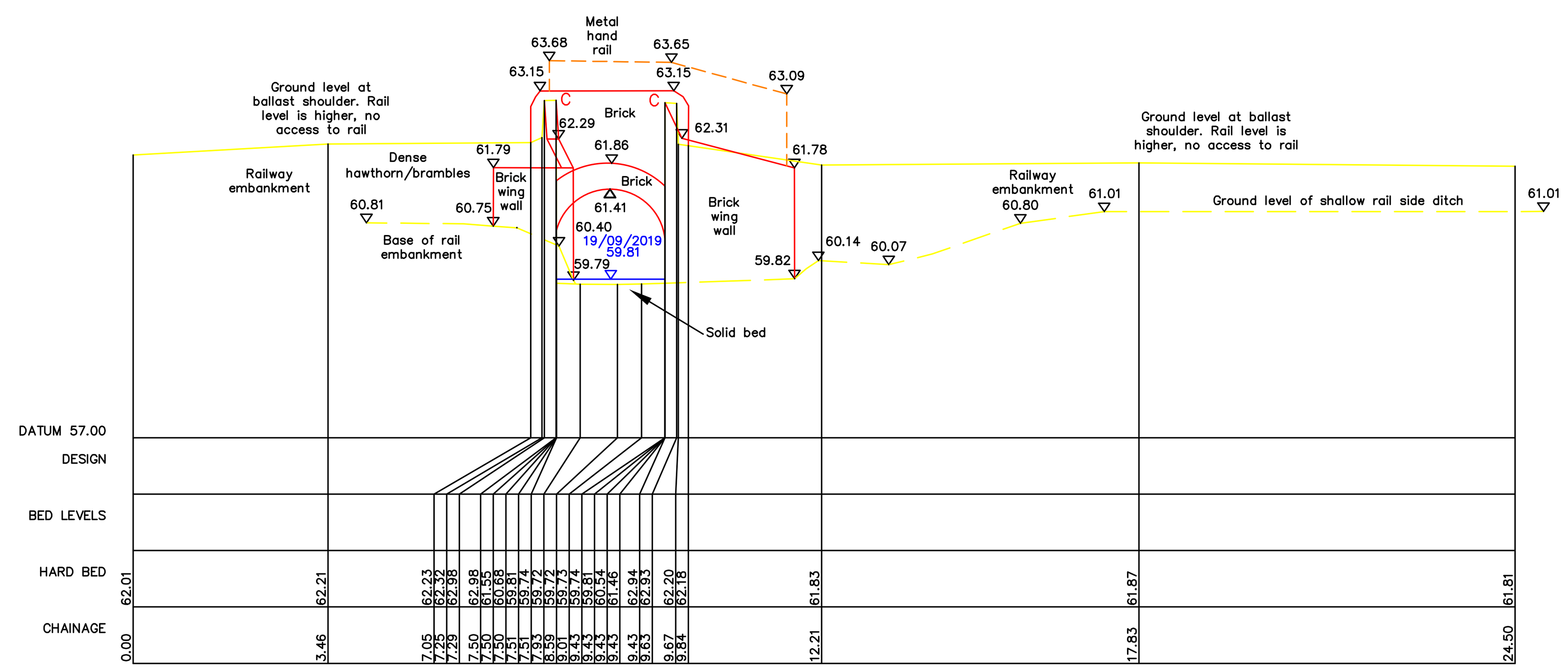
Chainage 406.5
Open Channel



XS63
456371.17mE 218613.23mN Brg 212
Chainage 564.3
USF Railway Culvert
Culvert Length 10.6m

N

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BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	Height Species (Spread to scale)
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE		
RIDGE HEIGHT	RH	GATE	
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x
STUMP	SP	FENCE	/
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

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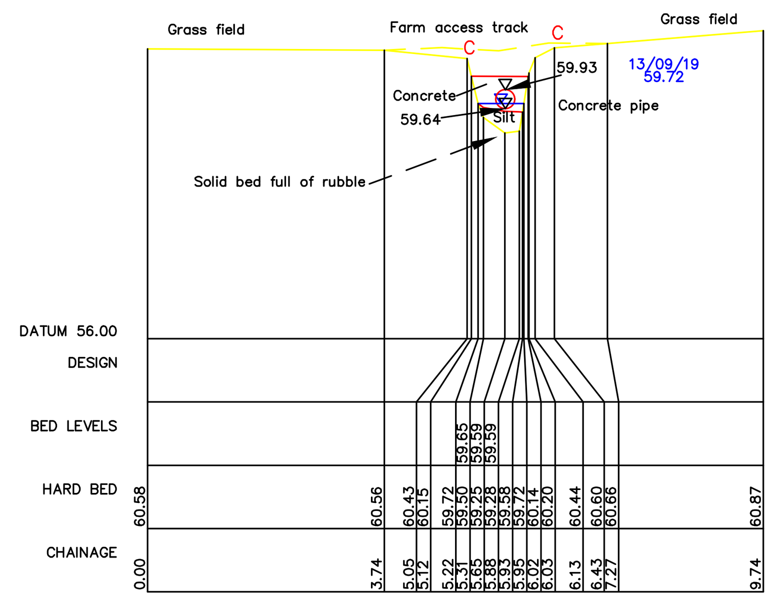
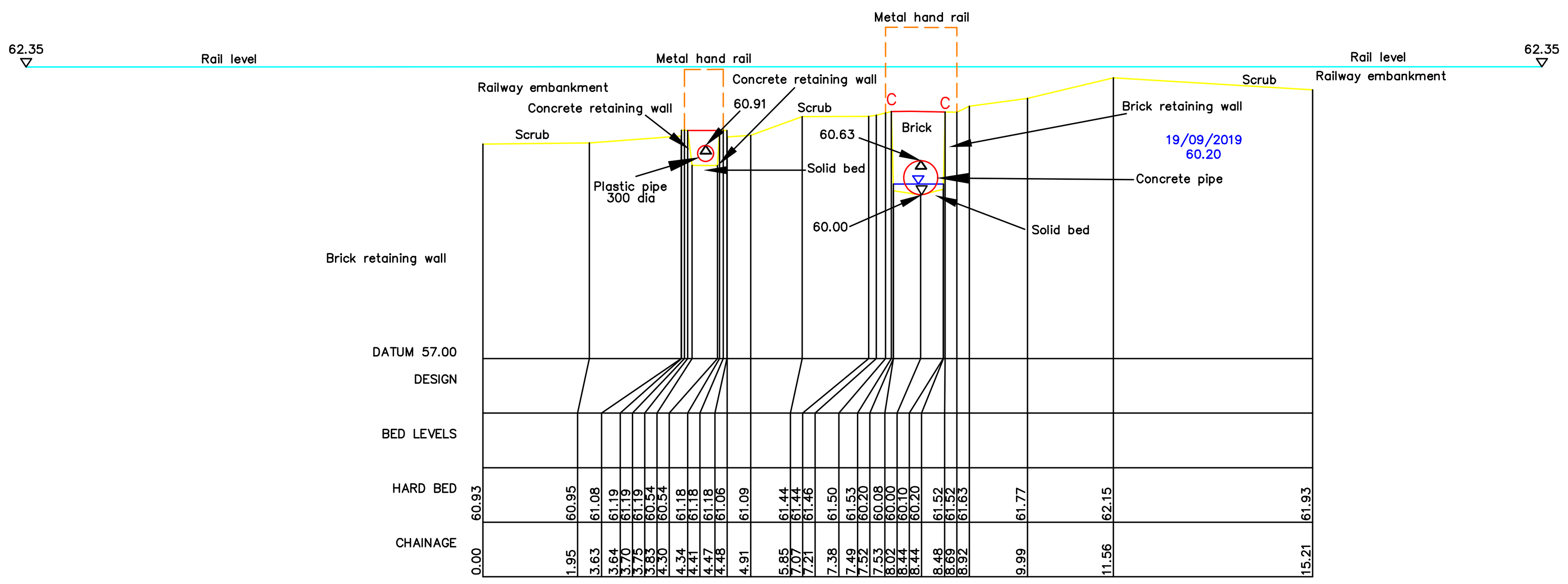
GCS-JBA-0342-1	A1	25 of 26

Reach 5

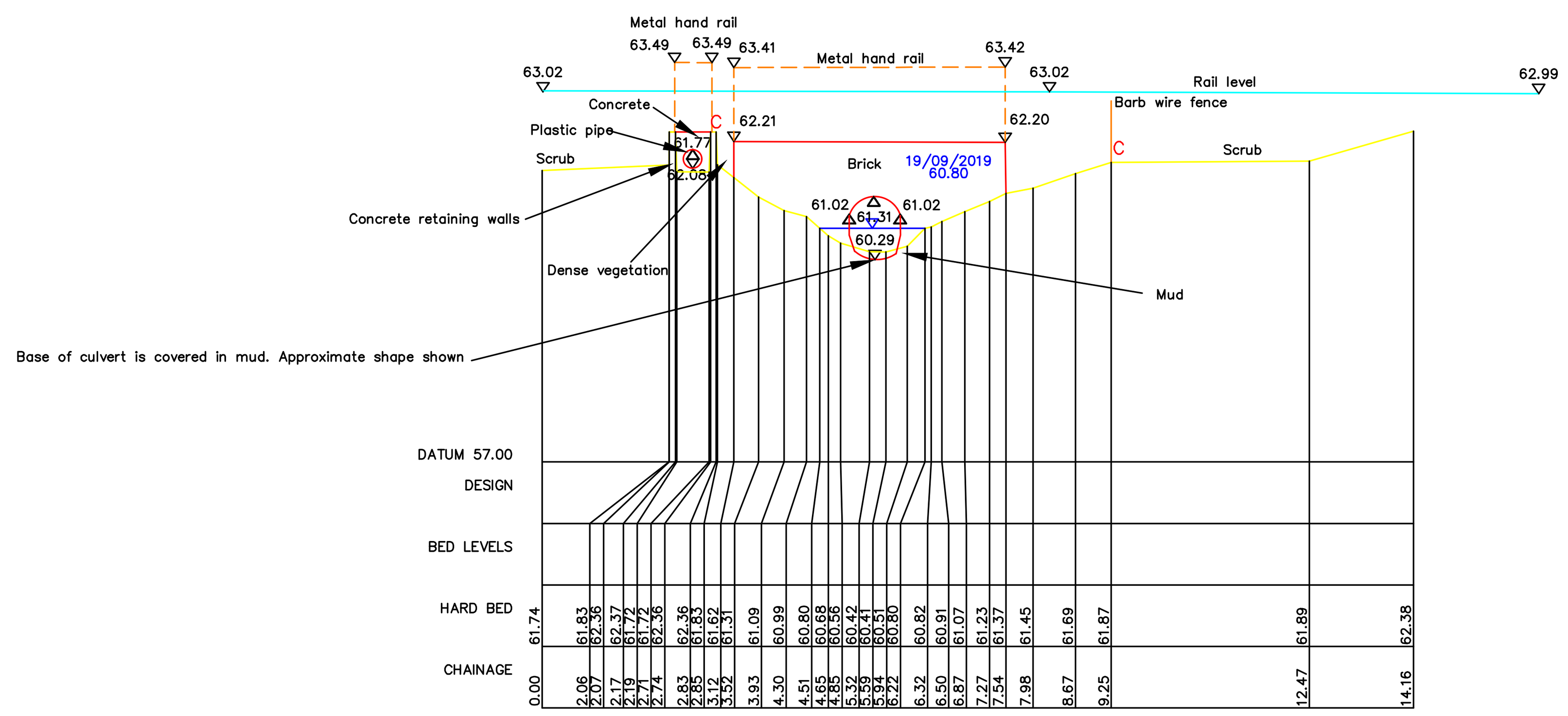


XS64
457124.09mE 219311.58mN Brg 245
Chainage 11.6
USF Culvert



XS65
456922.5mE 219414.9mN Brg 217
Chainage 236
USF Railway Culvert
Culvert Length 14m

Reach 6



XS66
457112.75mE 219690.69mN Brg 214
Chainage 178.7
USF Railway Culvert
Culvert length13.9m

N

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BUS STOP	BS	TELEPHONE POST	TEL
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BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
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ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
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ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
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FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x
STUMP	SP	FENCE	/
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
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RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT WENDLEBURY (Cross Sections)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD

Grantham Coates Surveys Ltd

Land - Engineering - Building Surveyors

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Tel: 01789 764420

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Web Site: www.gcsurveys.co.uk

THE SURVEY ASSOCIATION FULL MEMBER

chartered ICES

Drawing No:	Rev:
GCS/JBA/0342/1	-

Date:	Notes:	Name:	Rev:

Drawn:	Checked:	Scale:	Date:
MC	CC	1:100	17/09/19

File Name:	Sheet size:	Sheet:
GCS-JBA-0342-1	A1	26 of 26

C Topographic Survey

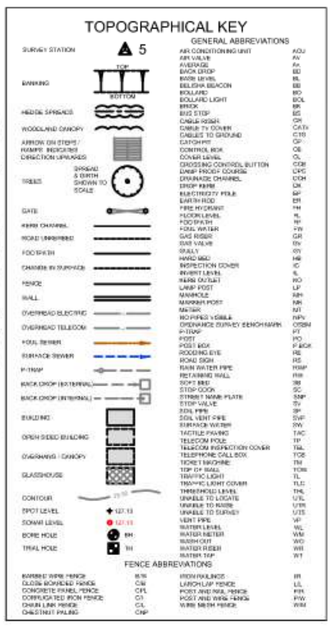
Notes:

1. GRID AND LEVELS BASED ON ORDNANCE DATUM, DERIVED FROM THE NATIONAL GNSS NETWORK. LOCAL SCALE FACTOR (0.999641) APPLIED.
2. TREE AND HEDGE SPECIES HAVE BEEN IDENTIFIED AS ACCURATELY AS POSSIBLE BUT SHOULD BE CROSS CHECKED IN CRITICAL AREAS.

Coordinate Table

Station	Description	Easting	Northing	Level
S1	Road Nail	457513.694	221474.669	66.995
S2	Road Nail	457532.187	221462.286	67.332
S3	Road Nail	457454.128	221321.077	67.168
S4	Road Nail	457359.027	221113.977	65.693
S5	Road Nail	457270.750	221176.614	66.852
S6	Road Nail	457310.688	221033.701	65.720
S8	Road Nail	457275.693	220909.081	65.301
S9	Road Nail	457361.577	220888.513	64.417
T1	Road Nail	457530.882	221281.546	65.833
T2	Peg	457631.512	221055.602	64.424
T4	Peg	457475.216	220861.016	64.263
J1	Road Nail	457624.764	221651.620	67.469
J2	Road Nail	457573.430	221647.149	67.210
J3	Road Nail	457521.657	221555.462	66.990
J4	Road Nail	457438.699	221428.494	67.409
J6	Road Nail	457244.200	221239.839	66.219

TOPOGRAPHICAL KEY



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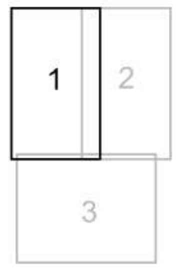

Revision	Description	Surv. by	Appr. by	Date

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Topographical Survey

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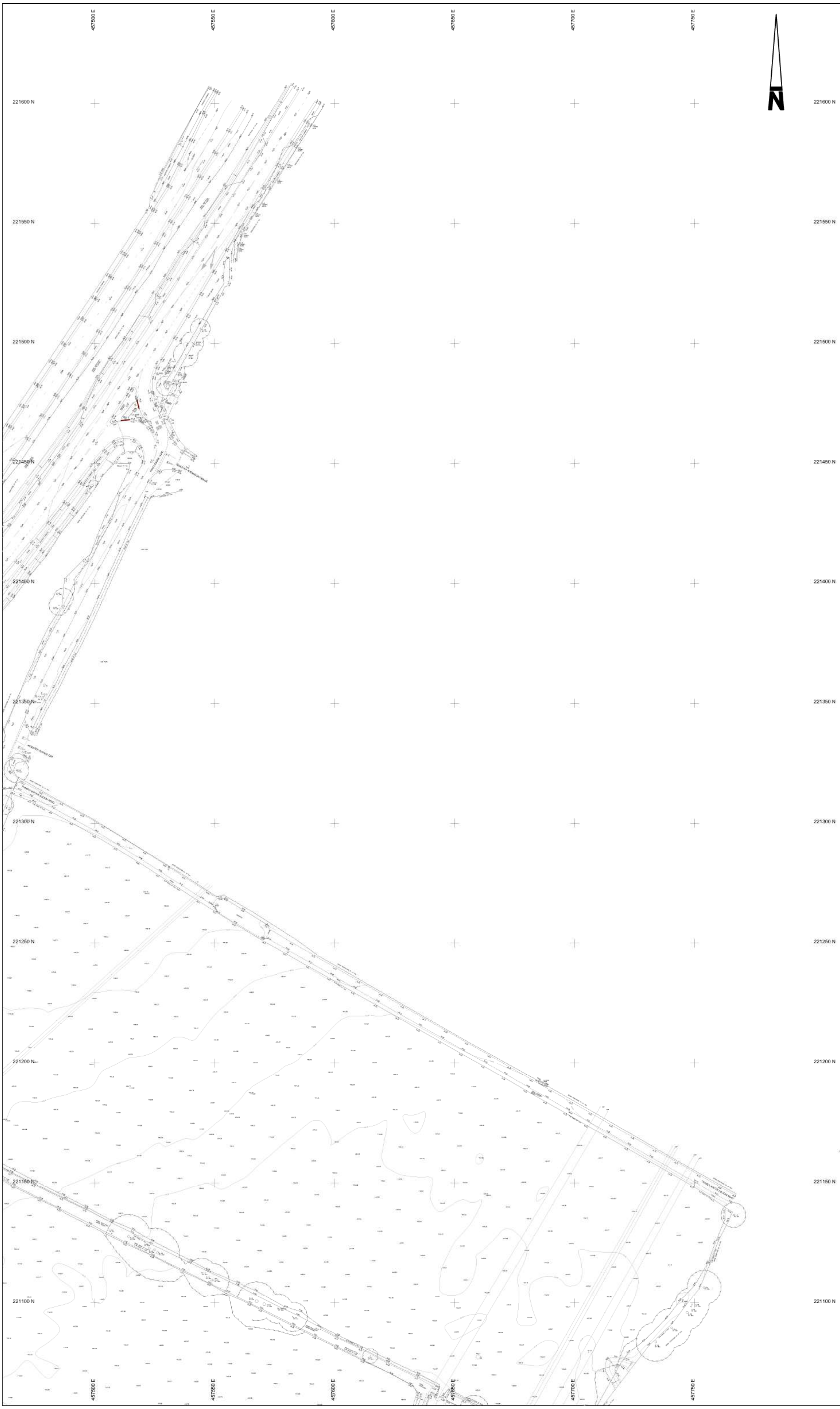
1:500	A0	1	June 2018

Project Number:	Rev:	Surveyed By:	Approved By:
25646	-	MKS	AJ / JS



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S8	Road Nail	457275.693	220909.081	65.301
S9	Road Nail	457361.577	220888.513	64.417
T1	Road Nail	457530.882	221281.546	65.833
T2	Peg	457631.512	221055.602	64.424
T4	Peg	457475.216	220861.016	64.263
J1	Road Nail	457624.764	221651.620	67.469
J2	Road Nail	457573.430	221647.149	67.210
J3	Road Nail	457521.657	221555.462	66.990
J4	Road Nail	457438.699	221428.494	67.409
J6	Road Nail	457244.200	221239.839	66.219

TOPOGRAPHICAL KEY

GENERAL ABBREVIATIONS

FENCE ABBREVIATIONS

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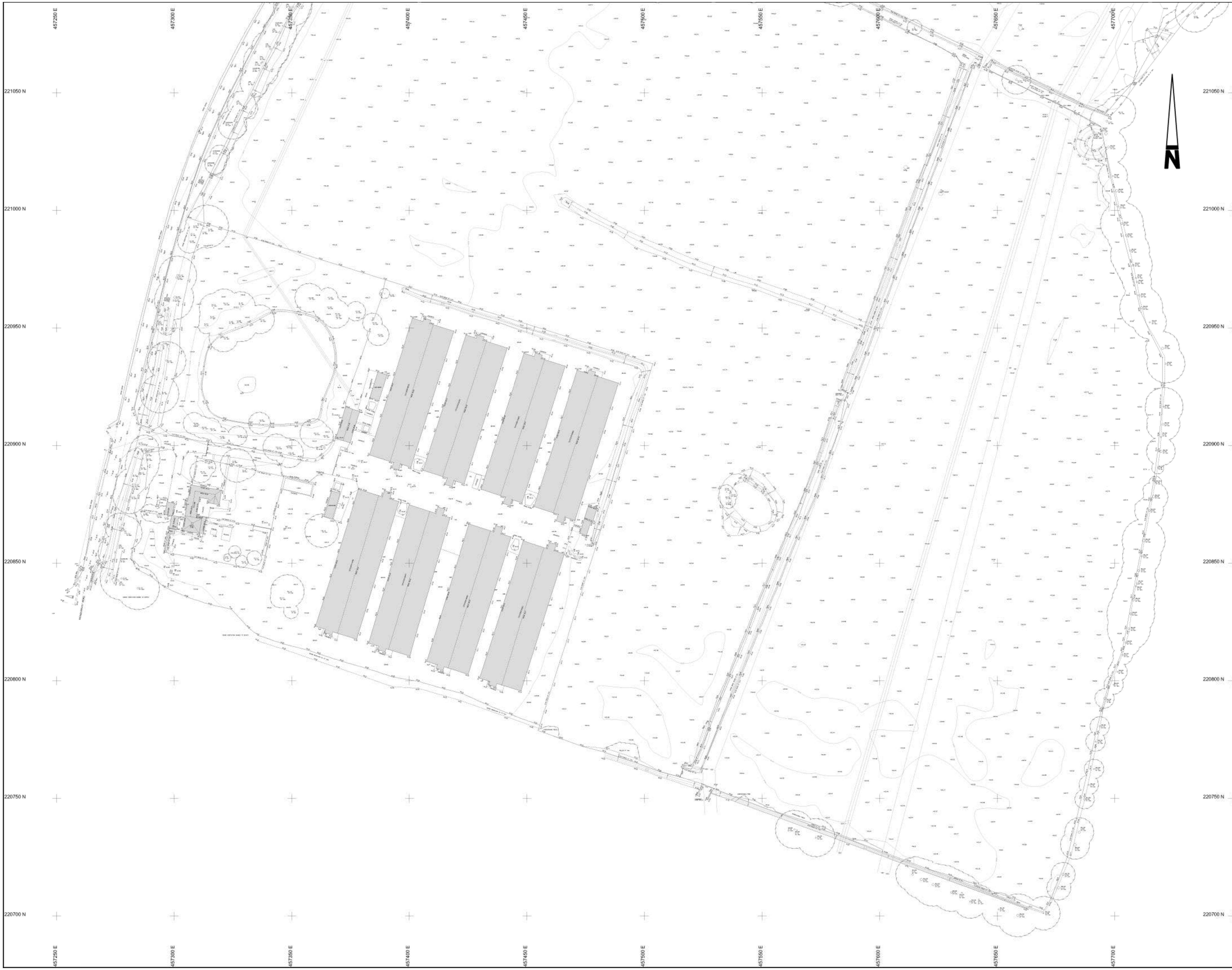
Scale:	Sheet Size:	Sheet Number:	Date:
1:500	A0	2	June 2018

Project Number:	Rev:	Surveyed By:	Approved By:
25646	-	MKS	AJ / JS



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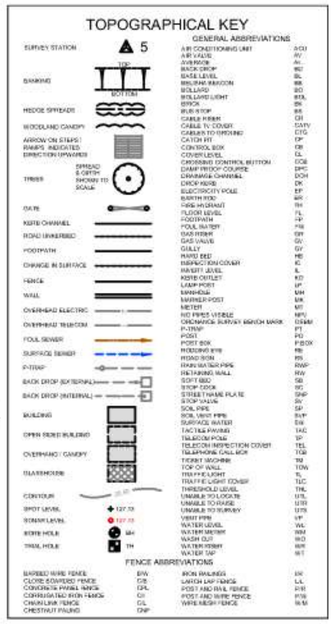
TOPOGRAPHICAL KEY



Sheet Layout (Not to Scale)

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Scale	Sheet Size	Sheet Number	Date
1:500	A0	3	June 2018

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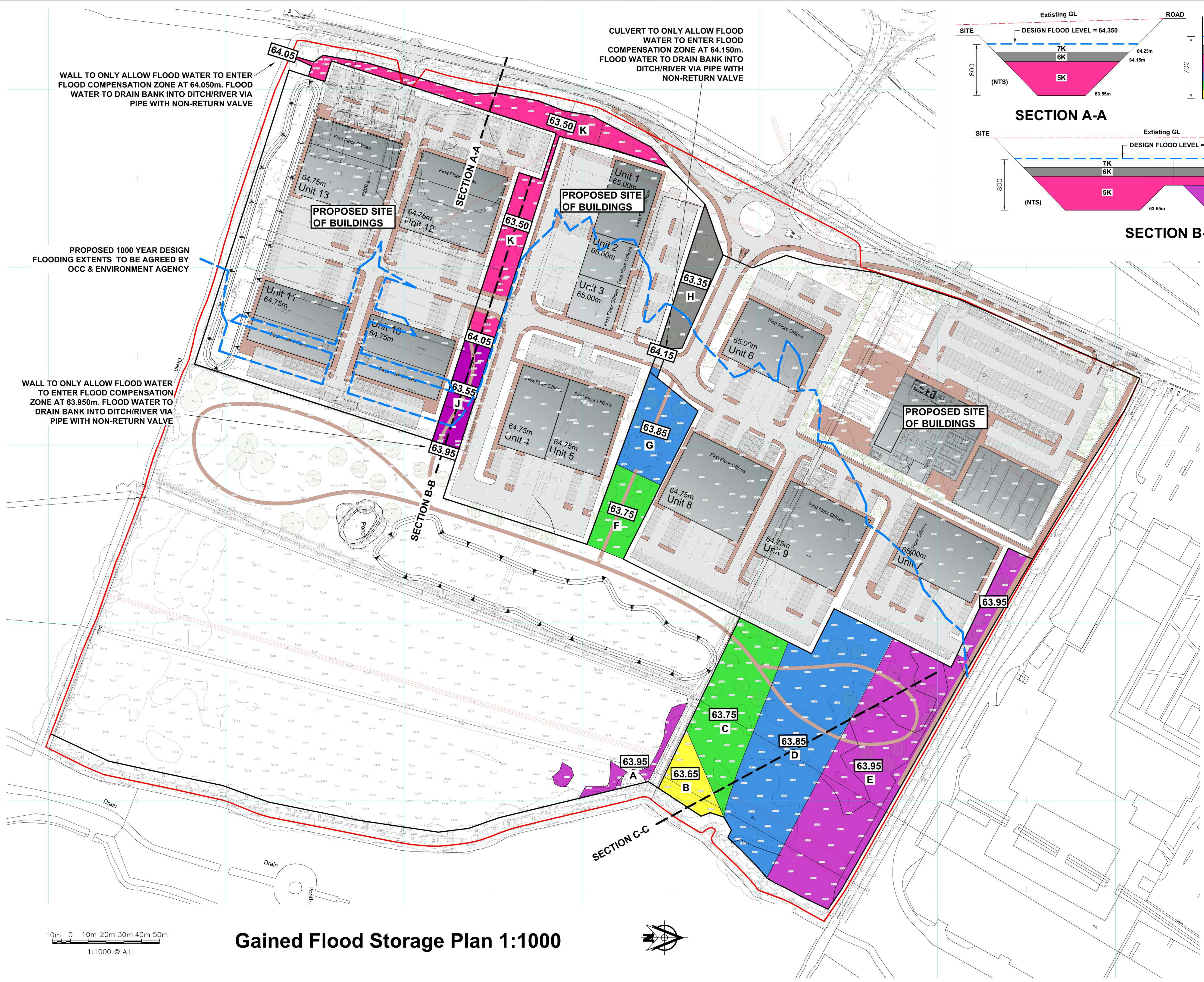
25646	-	MKS	AJ / JS

D Proposed floodplain compensation scheme



Gained Flood Storage Plan 1:1000

SECTION A-A

SECTION C-C

SECTION B-B

KEY

- (7) Area between 64.35 and 64.25
- (6) Area between 64.25 and 64.15
- (5) Area between 64.15 and 64.05
- (4) Area between 64.05 and 63.95
- (3) Area between 63.95 and 63.85
- (2) Area between 63.85 and 63.75
- (1) Area between 63.75 and 63.65
- 63.75 Proposed Compensation Level

#	Level (mAOD)	Lost Vol.	Gained Vol.
7	64.25 - 64.35	191 m3	462 m3
6	64.15 - 64.25	1643 m3	1648 m3
5	64.05 - 64.15	2629 m3	2635 m3
4	63.95 - 64.05	1685 m3	1687 m3
3	63.85 - 63.95	889 m3	928 m3
2	63.75 - 63.85	338 m3	410 m3
1	63.65 - 63.75	71 m3	81 m3
	TOTAL	7446 m3	7878 m3

PRELIMINARY

Rev	Date	Revision Description

Revision Schedule

Catalyst Bicester
Wendlebury Road, Bicester

Client:

Albion Land Plc.

GAINED FLOOD STORAGE PLAN
(1000 YEAR EVENT)

BAILEY JOHNSON HAYES
Consulting Engineers
ST.ALBANS: Suite 4, Phoenix House, 63 Campfield Rd, ST.ALBANS, Herts AL1 5FL
MANCHESTER: Grange House, John Dalton Street, MANCHESTER, M2 6FW

Scale 1:1000 @A1
Date 18.10.19
Drawn JNG

S1358-Ext-45

E JBA Hydrological Assessment 2019

Flood estimation report: Wendlebury Brook and Gagle Brook, Wendlebury, Bicester

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

Approval

	Name and qualifications	Date
Method statement prepared by:	Kristie Darling BSc	22/08/2019
Method statement reviewed by:	James Molloy BE(Hons) MEngSc	23/08/2019
Calculations prepared by:	Kristie Darling BSc	10/09/2019
Calculations reviewed by:	James Molloy BE(Hons) MEngSc	11/09/2019

Revisions

Revision	Amendments	Date
V1	Draft hydrology	11/09/2019
V2	FEH Statistical estimates derived for additional catchment (RAY01) and respective reporting updated.	02/12/2019

Abbreviations

AM.......................... Annual Maximum

AREA .... Catchment area (km^2)

BFI .... Base Flow Index

BFIHOST .... Base Flow Index derived using the HOST soil classification

CFMP .... Catchment Flood Management Plan

CPRE .... Council for the Protection of Rural England

FARL........................ FEH index of flood attenuation due to reservoirs and lakes

FEH .... Flood Estimation Handbook

FSR .... Flood Studies Report

HOST....................... Hydrology of Soil Types

NRFA .... National River Flow Archive

POT .... Peaks Over a Threshold

QMED .... Median Annual Flood (with return period 2 years)

ReFH........................ Revitalised Flood Hydrograph method

SAAR .... Standard Average Annual Rainfall (mm)

SPR .... Standard percentage runoff

SPRHOST .... Standard percentage runoff derived using the HOST soil classification

Tp(0) .... Time to peak of the instantaneous unit hydrograph

URBAN .... Flood Studies Report index of fractional urban extent

URBEXT1990 .... FEH index of fractional urban extent

URBEXT2000 .... Revised index of urban extent, measured differently from URBEXT1990

WINFAP-FEH .... Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

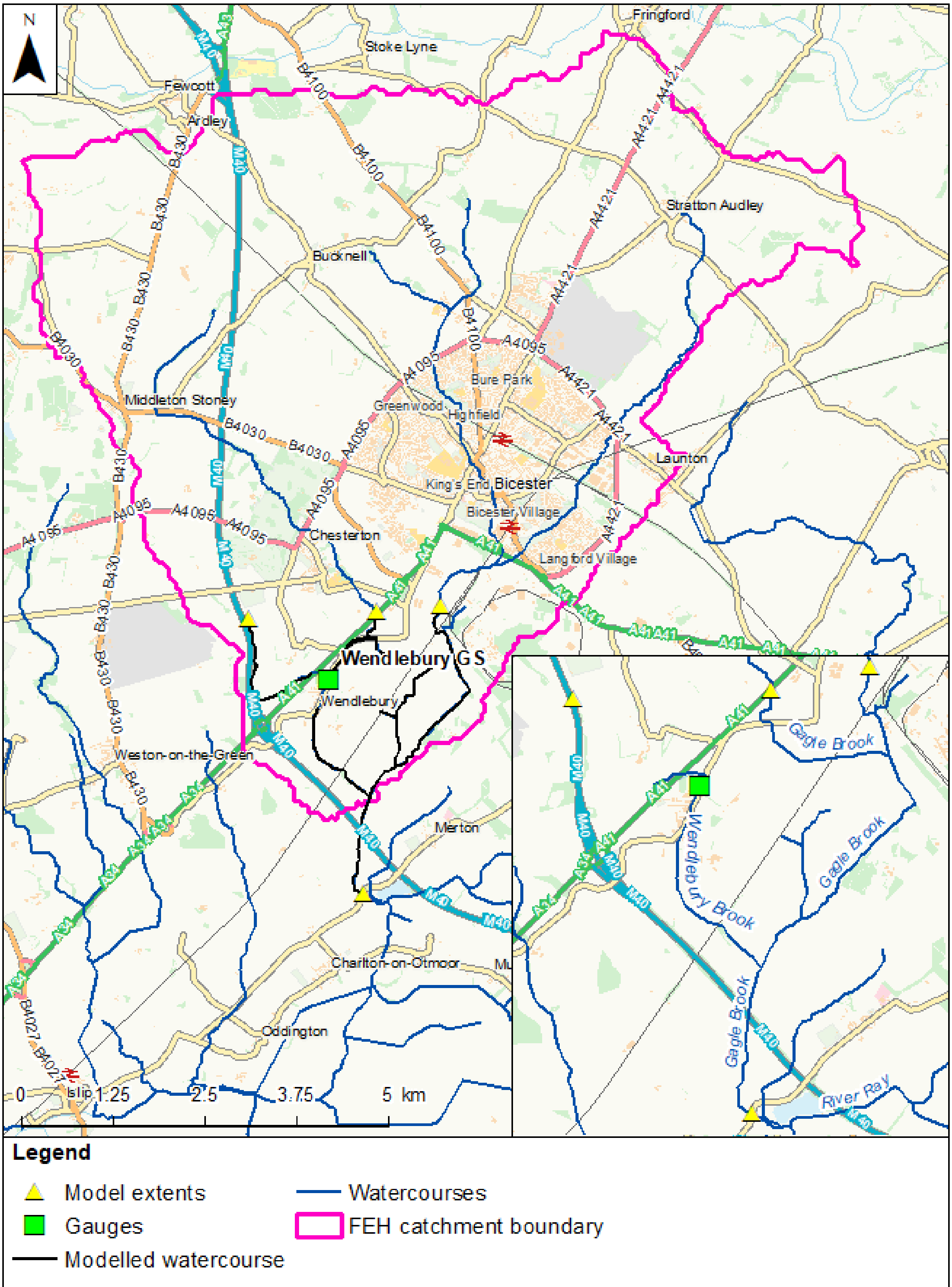
1.1 Requirements for flood estimates

Overview	JBA Consulting were commissioned to prepare updated hydraulic modelling with appropriate hydrology, in order to understand the flood risk at Wendlebury, Bicester. Detailed modelling of the Wendlebury Brook was carried out by JBA Consulting in 2013/14 and currently informs the EA's Flood Maps for Planning. It is understood that the Flood Zones associated with the Gagle Brook are derived from broadscale modelling techniques which do not accurately represent the channel and the structures crossing it. The current study seeks to prepare a new hydrological assessment for the watercourses, in order to derive inflows for the updated hydraulic model. The 2013/14 JBA Consulting model for the Wendlebury Brook will be extended to cover the Gagle Brooke. In addition, an estimate of flow for the River Ray is required for input to the updated hydraulic model. The hydrological assessment will utilise current methods and software to provide estimates of design peak flows and hydrograph shapes. In addition, the information provided in the hydrology record for the 2013/14 study will be used to help inform catchment understanding. Estimates are required for the 5%, 1%, and 0.1% Annual Exceedance Probability events (20-year, 100-year, and 1000-year Return Periods). In addition, the effects of climate change will be considered for the 1% AEP event. The higher central and upper end allowances are required for the 2080s epoch. As the watercourse is located within the Thames River Basin District, the change factors for these events are of +35% and +70%. This is based on the Flood risk assessments: climate change allowances guidance, initially released in February 2016[1]. The locations where flow estimates are required are detailed within Section 2.

[1] Environment Agency (2016). Flood risk assessments: climate change allowances. https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

1.2 The catchment

Map



Description	**Main study area – Wendlebury Brook and Gagle Brook** The upstream model extents are located on the Wendlebury Brook (NGR 455079 220610), Gagle Brook (NGR 456847 220698) and Langford Brook (NGR 457725 220907). The catchment at the downstream model extent (NGR 456676 216898) drains a total area of approximately 70km^2. Just downstream of here, the watercourse joins the River Ray. There is little topographic fall along the entire length of catchment. The highest point in the catchment is approximately 130mAOD down to the lowest point of the catchment of 59mAOD. Mapping is provided in the Annex (8.3). The catchment is permeable (BFIHOST = 0.74 / SPRHOST = 20.44) and is underlain by limestones in the northern part of the catchment and mudstones with isolated patches of limestones, sandstones and siltstones in the southern part of the catchment. Mapping of the catchment geology is provided in the Annex (8.2). There are loamy, well-drained, calcareous soils observed in the north and slightly wet clayey soils observed throughout the rest of the catchment except where the Wendlebury and Gagle brooks meet. Here there are floodplain soils with naturally high groundwater. The catchment to the downstream boundary is classed as moderately urbanised (URBEXT2000 = 0.0544). The main urban extent is associated with the Langford Brook which flows through the town of Bicester. However, catchments on the Gagle and Wendlebury Brook are predominantly rural with smaller isolated urbanised areas at Wendlebury and Little Chesterton. In these urban areas, the watercourses may be slightly more responsive to rainfall events and would be expected to demonstrate a faster response than the rest of the catchment. The catchment is bisected by the M40 and there is some uncertainty in where (or if) the Wendlebury Brook crosses the M40. OS mapping suggests it crosses the M40 just to the south of Green Lane (A4095) but no culvert beneath the motorway can be evidenced. After further investigation undertaken by the EA, it is thought that this northern culvert does not exist and that upper catchment could flow through a southern culvert beneath the M40 at E:455196, N:219531. The topography suggests that certainly in larger flow events much of the flow in the ditch to the west of the M40 could drain south-west to another watercourse passing to the west of Oddington and joining the River Ray. This would introduce a degree of uncertainty with regards to the contributing flows from the western catchment. A detailed analysis of the contributing catchments west of the M40 was completed during the previous 2013/14 study, during which the hydrology was prepared. The study made the assumption that flow entered the watercourse via the northern sewer near Green Lane, as the FEH catchment would suggest. Sensitivity testing was completed during the 2014 study to understand the influence of this and therefore the approach adopted was agreed with the Environment Agency and considered suitable for the purposes of updating the detailed flood mapping for the catchment. Subsequently, this same assumption will be adopted for the current study. A map displaying the locations of each of the potential flow routes is shown in the Annex. It is believed that a cross transfer of flow from the Gagle Brook into the Wendlebury catchment can occur due to drainage ditches along the A41. This transfer is most likely to occur during high return period events. The catchment area of the Gagle Brook is approximately 17km^2 at the point at which it is understood this transfer may take place. This

	transfer location is displayed in the Annex (8.1). **River Ray** The study has been extended to include preparation of design flow estimates for the River Ray (located towards the east of the catchment). This is a confluence of the Gagle Brook and was included within the study due to the proximity of the watercourse to the modelled area. As a result of this, initial modelling outputs predicted flows passing along the floodplain (from the Wendlebury and Gagle Brooks) and being conveyed along the channel of the Ray, which was previously unmodelled and subsequently 'dry'. Therefore, in order to better represent these flood mechanisms, and to ensure a more conservative modelled output / flood extent, it was considered appropriate to represent flow within the River Ray. Mapping showing the River Ray catchment is provided in the Annex. As this is secondary objective of this hydrological assessment and is not to be discretely represented within the updated hydraulic model (represented in with a 2D solution only), estimation of peak flows has been provided within an Annex to this document. The River Ray catchment is large (area = ~133km²) and is characterised by impermeable mudstone and sandstone geology (BFIHOST = 0.283). This contrasts the Wendlebury Brook, which is the catchment is underlain by permeable limestones. The catchment is predominantly rural (URBEXT2000= 0.008), although parts of Bicester are located within its boundaries, as well as the villages of Ambrosden and Arncott. Results for the River Ray are presented separately from the main calculations in the Appendix.

1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 7, released October 2018. This contains data up to water year 2016-17.

1.4 Gauging stations (flow or level)

(at or very near to the sites of flood estimates)

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
Wendlebury Brook	Wendlebury	1486TH	N/A	E: 456200, N: 219830	Headwater Level	05/12/06 - present
Note: hydrometric data has been requested for use within this study and has been provided for the period .						

1.5 Data available at each flow gauging station in Table 1.4

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Other comments on station and flow data quality
Wendlebury	N/A	No	No	No	No	The period of record available is from 05/12/06 to 06/09/2019. The previous study report notes that information received from the Environment Agency confirms that a reliable rating has not been achieved at this gauge due to several reasons. This includes: • Low gradient • Seasonal effects of vegetation and weed cuts • Blockages at small culverts / low bridges that span the Wendlebury brook
Tabulate any updated or revised flood peak series in the Annex. Give link/reference to any further data quality checks carried out.					N/A	

1.6 Rating equations

Station name	Type of rating	Rating review needed?	Comments and link to any rating reviews
Wendlebury	N/A	N/A	The modelled rating curve from the 2014 JBA Consulting study has been used to inform values of flow for peak events, based on stage data provided for use within the current study.

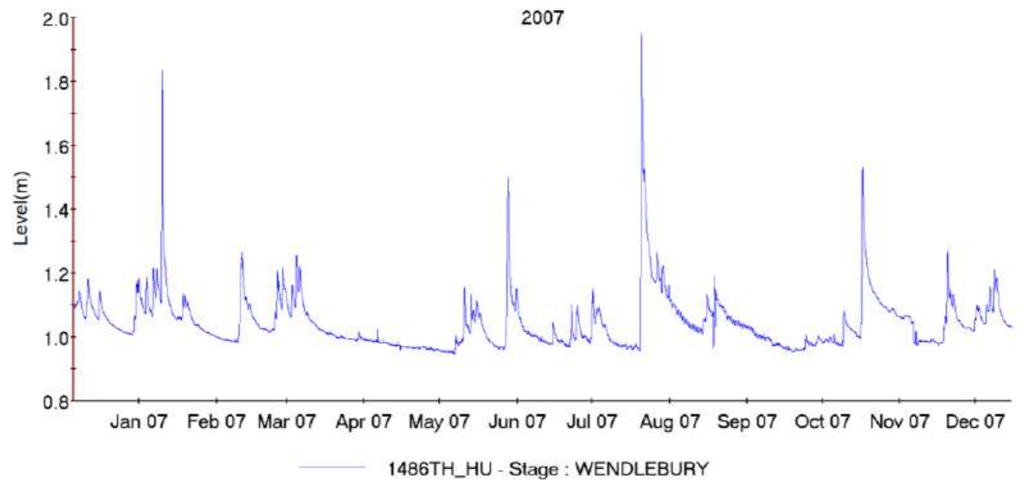
1.7 Other data available and how it has been obtained

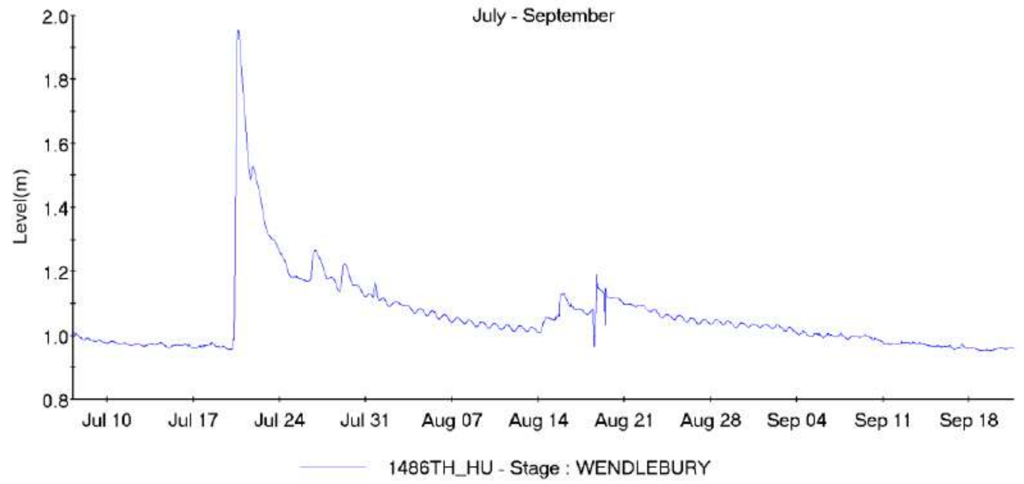
Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings	No	No	N/A	N/A – data not available and no rating reviews required for this study.
Historic flood data	Yes	Yes	Historic Flood Map, Environment Agency	A review of historic flood information is not required for this study. However, a chronology of flood events

			Recorded Flood Outlines, Environment Agency	is summarised in the Annex.
Flow or river level data for events	Yes	No flow data is available. However, level data is.	Environment Agency	Level gauge at Wendlebury, see above.
Rainfall data for events	Yes	No	N/A	N/A – data not requested.
Potential evaporation data	No	N/A	N/A	N/A – data not requested.
Results from previous studies	Yes	Yes	Wendlebury Brook Flood Study (PBA, 2001).	An investigation into the effect of drainage from the A41 and M40 into the Wendlebury Brook. The study was split into two stages: 1 – Desktop inspection study 2- hydraulic assessment Estimates of peal flow were derived using the Rational Method equations.
			Wendlebury Brook Flood Study (JBA Consulting, 2014)	Project aimed to improve Environment Agency Flood Maps for Planning and have a robust baseline model suitable for future options testing. The final design flows used for input to the model were derived using the FEH Statistical method; using an improved QMED estimate derived from a modelled rating of the Wendlebury Brook level gauge.
Other data or information	No	N/A	N/A	N/A

1.8 Hydrological understanding of catchment

Plots of flow data	


2007
Level(m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Jan 07 Feb 07 Mar 07 Apr 07 May 07 Jun 07 Jul 07 Aug 07 Sep 07 Oct 07 Nov 07 Dec 07
1486TH_HU - Stage : WENDLEBURY


July - September
Level(m)
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1.8
1.6
1.4
1.2
1.0
0.8
Jul 10 Jul 17 Jul 24 Jul 31 Aug 07 Aug 14 Aug 21 Aug 28 Sep 04 Sep 11 Sep 18
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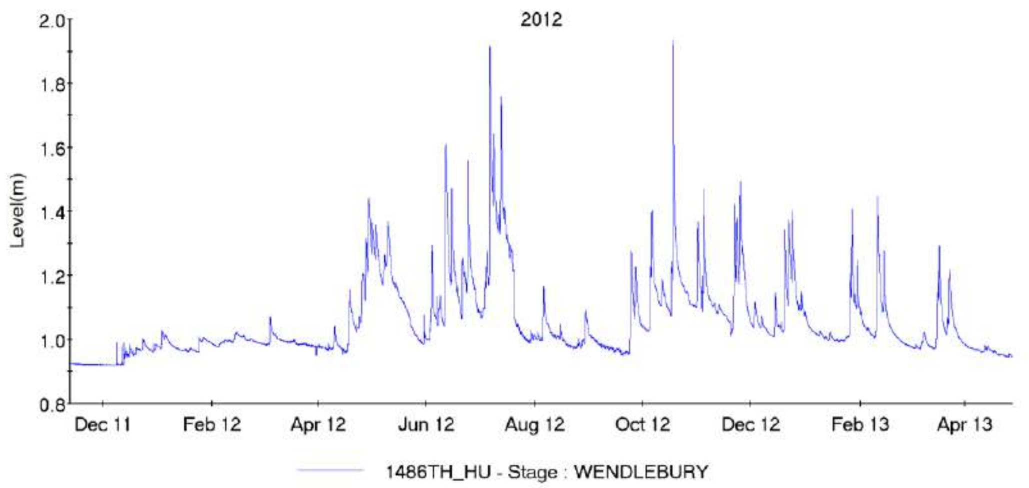
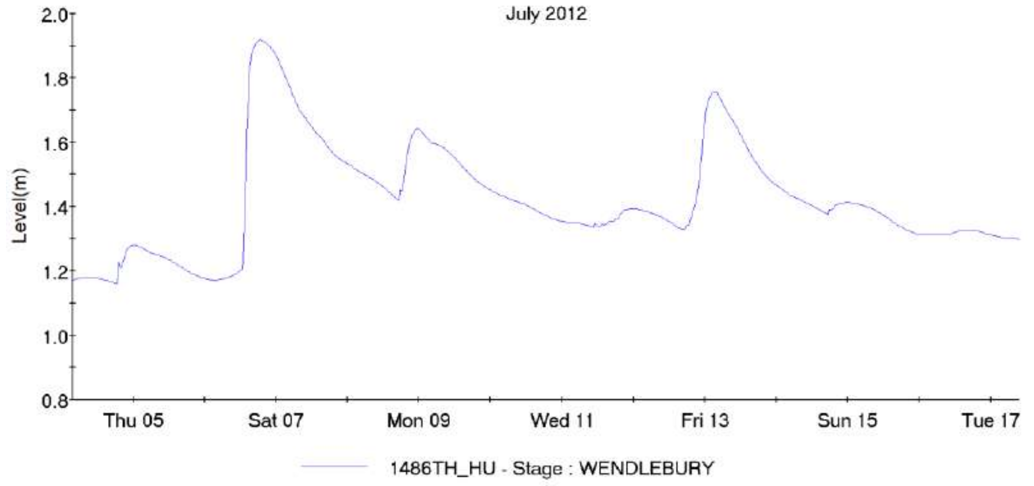

2012
Level(m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Dec 11 Feb 12 Apr 12 Jun 12 Aug 12 Oct 12 Dec 12 Feb 13 Apr 13
1486TH_HU - Stage : WENDLEBURY

	
Hydrological interpretation	The data seems to be recording the flood events well based on the comparison between flood history records and the top 10 events from the water level record. A visual inspection of the data (above) suggests it to be of reasonable quality. There is very little noise (oscillations) within the data and there appears to be no step changes. The recorded water level does not drop below 0.9m during the record which suggests that the channel bed does not correspond to the zero level. It should also be noted that the minimum level appears to have changed during the record. In the earlier years it was closer to 1m but since the middle of 2009 it has been closer to 0.9m. The level trace suggests there is a mixes response in the catchment: 1. large baseflow component; a result of the high permeability of the underlying geology 2. a faster response super-imposed on the baseflow component; likely from the saturated and/or more urban parts of the catchment. Despite the permeability of the catchment the majority of the largest events have occurred in the summer suggesting that the influence of groundwater on flooding is negligible and that flooding is dominated from runoff from urban surfaces.

Outline the conceptual model	The main cause of flooding in Wendlebury is considered to be as a result of the channel capacity being exceeded by peak flows. This mechanism is likely to be exacerbated by the constrictions and potential blockage of a number of the access bridges and culverts in the village, as noted in the flood history information (Annex 8.4). Flooding as a result of groundwater is also expected to be a factor for this catchment given its high BFIHOST. As a result, flood events are likely to be strongly influenced by antecedent conditions and the catchment is likely to be most susceptible to flooding from longer duration winter storm events and larger flood volumes. The previous study (JBA Consulting, 2014) carried out testing on antecedent conditions to understand the sensitivity to increased Cini values on design flows. This was not adopted within the design hydrology but used to gain a better understanding of sensitivity to antecedent conditions and soil moisture on flood flow. The test found that there was some inconsistency in the results from between different inflow locations i.e. a decrease in flows at more impermeable locations, which would have resulted in smaller flood extents. In light of the permeable geology and rural catchment characteristics, it could be assumed that the catchment is relatively slow responding to heavy rainfall events. However, in the urban areas noted, the extent of impermeable surfaces may contribute to a flashier response locally. There may be a cross transfer of flow from the Gagle Brook via drainage

	ditches running parallel to the A41, particularly for higher return period events. This potential transfer of flow is located upstream of the Wendlebury gauge and therefore may explain some of the more 'peaky' behaviour observed in the level record.
Any unusual catchment features to take into account?	Yes. The catchment is highly permeable, with BFIHOST values >0.65; this is the recommended limit for the application of the ReFH1 method and therefore this method may not be suitable. All locations within the catchment have SPRHOST values <20% and therefore permeable adjustment for the FEH Statistical method may be considered.

1.9 Initial choice of approach

Is FEH appropriate?	Yes.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	Owing to the permeability of the catchment the FEH Statistical method is preferred over the use of ReFH1 for this study. The FEH Statistical method is generally preferred over the ReFH1 method because it is more direct and makes fewer assumptions. In addition, the recommended BFIHOST limit for the ReFH1 method is 0.65, which this catchment exceeds. However, the ReFH2 method is now available and offers an improved performance on permeable catchments compared to the original ReFH/ReFH1 method. The performance of ReFH2 across both permeable and impermeable catchments within the NRFA Peak Flows dataset is evaluated in Section 6 of the ReFH2 Technical Guidance[2]. This demonstrates that the ReFH2 permeable catchment performance is a considerable improvement on the original ReFH1 method. This is particularly the case when used with the FEH13 rainfall model, where performance is comparable to the current FEH statistical method. In addition, the ReFH2 software has enhanced support for estimating the impact of runoff from urban/pervious surfaces; which will possibly provide a better representation of the multi-peak behaviour of the catchment in urban areas. Subsequently, it is recommended that estimates of peak flow for design events are derived using both the FEH statistical method and ReFH2 method. For the FEH Statistical method, pooled analysis will be undertaken. In addition, the use of a 'permeable' pooling group will be considered in comparison to the default pooling group derived using WINFAP FEH. This would be dependent on the ability to produce a sufficient period of record from the pooling group using only permeable catchments. As noted previously, the Wendlebury gauge records water levels only and no rating has been adopted for the site to derive a flow series. However, during the previous 2014 study a modelled rating was developed for the gauge and it was agreed in conjunction with the Environment Agency at that time to adopt this to help inform estimates of QMED. It is therefore deemed appropriate to adopt this rating to help inform QMED for this study, while at the same time noting hydraulic uncertainties affected by the issues listed in Section 1.5. The rating will therefore be used to extend the POT series for the available period of record at the gauge to inform QMED and the updated hydrology prepared as part of this study. It should be noted that the rating has not been adopted by the Environment Agency and no check flows are available to validate the rating. However, it was considered

[2] The Revitalised Flood Hydrograph Model. ReFH 2.2: Technical Guidance. Available from: http://files.hydrosolutions.co.uk/refh2/ReFH2_Technical_Report.pdf

	that this is still an improvement on estimating QMED from catchment descriptors alone; particularly given the permeable nature of the catchment. Details regarding the estimation of QMED using the modelled rating (2014) are provided in the Annex (8.9.1). For the ReFH2 model, it is anticipated that ReFH2 parameters will be calibrated using the available gauge data where possible. Estimates of catchment lag and Tp(0) will be adopted for use within this study to make the best use of the available information. Flow will be estimated at several key points across the catchment. The locations of flow estimates are detailed in Section 2. These include the upper and downstream model extents, gauge location and other areas deemed to be of importance. For example, to understand uncertainties regarding the connectivity of the catchment across the M40. Hydrograph shapes will be obtained by using ReFH2 model. It should be noted that the assumptions made during the previous study (e.g. where flow from the contributing catchment west of the M40 is applied) will be adopted for this study detailed sensitivity testing of these processes was completed and given the approach approved by the Environment Agency for use within flood mapping. It is not considered within the scope of this study to investigate these processes further e.g. through site analysis or additional sensitivity testing.
Software to be used	FEH Web Service[3] / WINFAP-FEH v3.0.003[4] / ReFH2.2

[3] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

[4] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting / Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
WB01	L	Wendlebury Brook	Upstream model extent of Wendlebury Brook (upstream of M40)	454950 / 220750	1.41	1.20
WB02	L	Wendlebury Brook	Downstream of confluence with tributary watercourse (TRIB01) and upstream of Wendlebury village	455950 / 219900	3.84	N/A
WBGS	L	Wendlebury Brook	Wendlebury gauge station	456250 / 219850	4.46	N/A
LB01	L	Langford Brook	Upstream model extent of the Langford Brook	457700 / 220850	39.22	36.77
GB01	L	Gagle Brook	Upstream model extent of the Gagle Brook	456850 / 220700	17.04	N/A
GB02	L	Gagle Brook	Gagle Brook upstream of confluence with the Langford Brook.	457650 / 220150	17.83	N/A
GB03	L	Gagle Brook	Gagle Brook at confluence with smaller ordinary watercourse.	457100 / 218650	59.99	N/A
GB04	L	Gagle Brook	Confluence of the Wendlebury Brook on the Gagle Brook	456750 / 218200	67.24	N/A
GB05	L	Gagle Brook	Downstream model extent on the Gagle Brook	456650 / 216950	69.38	N/A
TRIB01	S	Tributary of the Wendlebury Brook	Tributary of the Wendlebury Brook	455850 / 219900	1.48	1.79

NOTE: Refer to Section 2.3 for details of any revisions to catchment area.

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.

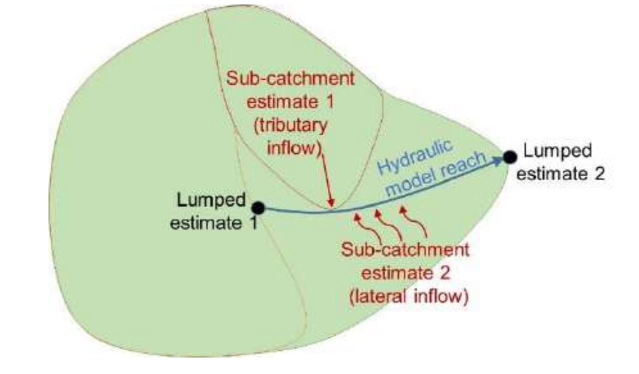
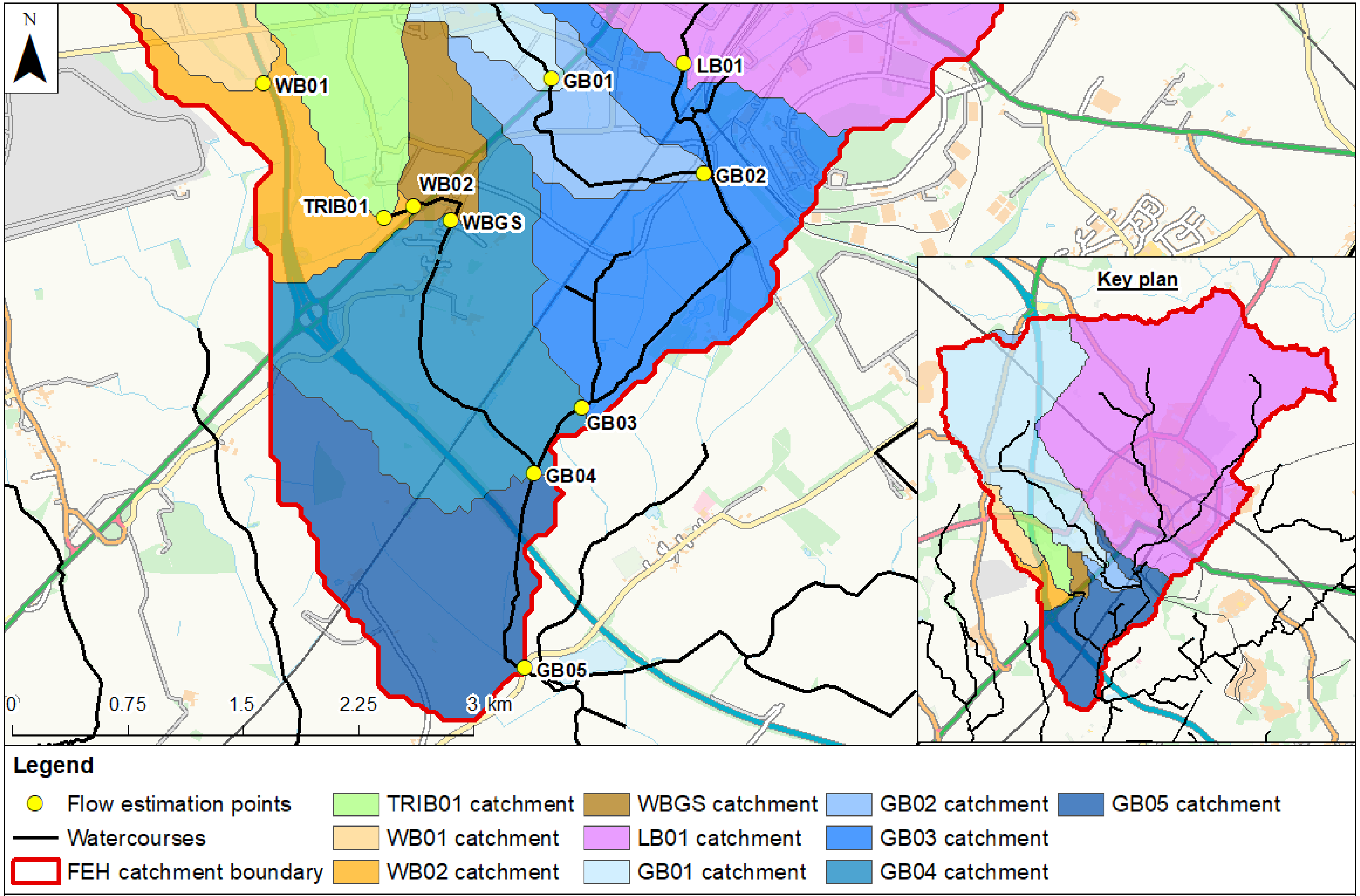


Figure 2-1: Location of flow estimation points



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
WB01	1.000	0.32	0.952	1.50	13.4	636	0.004	0.177
WB02	1.000	0.32	0.791	2.49	13.4	631	0.010	0.165
WBGS	1.000	0.32	0.745	2.60	13.4	630	0.014	0.160
LB01	0.975	0.32	0.716	6.29	15.3	634	0.095	0.145
GB01	0.970	0.32	0.944	6.47	20.0	653	0.010	0.061
GB02	0.971	0.32	0.922	7.65	19.6	651	0.010	0.069
GB03	0.975	0.32	0.768	8.97	16.5	638	0.065	0.136
GB04	0.974	0.32	0.749	8.94	15.9	637	0.060	0.151
GB05	0.975	0.32	0.740	10.16	15.5	636	0.058	0.164
TRIB01	1.000	0.32	0.817	1.67	11.9	628	0.019	0.128
RAY01	0.986	0.32	0.283	16.48	20.3	625	0.027	0.277
Note: Red text indicates that values have been amended from the FEH values. URBEXT values have been updated to the current year (2019). Refer to Section 2.3 for further details of these amendments.								

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	The FEH catchment boundaries have been checked against topographic information for the area (including the Environment Agency 2m LIDAR data), OS mapping and river network information. Some amendments were made to the catchment boundaries in order to better reflect the topographic catchments shown in LIDAR (following the topographically high points). However, in most cases this resulted in negligible difference to the overall catchment area (less than ±5%) and the original FEH values were retained. Where the changes in catchment area were greater than this, the revised AREA values have been adopted. This applies to: • WB01 • LB01 • TRIB01 Changes to the catchment boundaries are shown in the Annex (8.4).

Record how other catchment descriptors were checked and describe any changes.	**DPLBAR** As the changes to the catchment boundaries are relatively small (<20%), the original FEH DPLBAR values were retained as this was considered more accurate than updating DPLBAR values using the regression equation (below) published in Volume 5 of the FEH: $DPLBAR = AREA^{0.548}$ **URBEXT** A qualitative check of the URBEXT values was made by comparing the FEH values and URBEXT layers to current OS mapping. There were some changes across the catchment compared to the URBEXT extents. Therefore it was deemed appropriate to amend the URBEXT values across the study area using URBAN50k values. Subsequently, URBEXT2000 values were recalculated using the following equations[5]: $URBEXT_{2000} = 0.629\ x\ URBAN_{50k}$ A summary of the differences in the URBEXT values obtained is shown below. The URBEXT values estimated using these mapping relationships produce practically similar URBEXT values for locations on the Gagle Brook and Langford Brook, but in general give slightly increased values elsewhere across the catchment.

Site code	FEH values (updated to 2019)	Updated values based on $URBAN_{50k}$
	URBEXT2000	URBEXT2000
WB01	0.000	0.004
WB02	0.002	0.010
WBGS	0.005	0.014
LB01	0.094	0.095
GB01	0.009	0.010
GB02	0.009	0.010
GB03	0.064	0.065
GB04	0.058	0.060
GB05	0.057	0.058
TRIB01	0.000	0.019

BFIHOST / SPRHOST

A qualitative check of the FEH BFIHOST values was undertaken by comparing them to the soil types detailed in Section 1.2. The BFIHOST values range between 0.74 – 0.95. These are supported by the soils shown to underlie the catchment and the FEH values have not been amended.

FARL

The FARL values and the online lakes on the FEH webservice were checked against OS 50k mapping for surface water features within the study catchments. There were negligible differences between the two maps. Therefore the FEH values were retained.

Source of URBEXT	URBEXT2000
Method for updating of URBEXT	URBEXT2000 - manually derived URBAN values from OS 50k mapping and Bayliss et al's (2006) mapping relationships to calculate URBEXT2000.

[5] Bayliss et al (2006), DEFRA R&D Technical Report FD1919/TR – "URBEXT2000 – A new FEH catchment descriptor".

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m^3/s) (from catchment descriptor)	Final method	Data transfer					Urban adjust-ment factor (UAF)	Final QMED estimate (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor: Weight	If more than one donor: Weighted ave. adjustment		
WB01	0.03	DT	1486TH	1.05	1.874	-	-	1.026	0.06
WB02	0.20	DT	1486TH	0.20	2.152	-	-	1.026	0.43
WBGS	0.27	DT	1486TH	0.00	2.245	-	-	1.031	0.62
LB01	1.76	DT	1486TH	5.32	1.446	-	-	1.193	3.03
GB01	0.30	DT	1486TH	3.78	1.517	-	-	1.062	0.49
GB02	0.36	DT	1486TH	3.57	1.530	-	-	1.051	0.58
GB03	2.14	DT	1486TH	4.23	1.491	-	-	1.148	3.67
GB04	2.56	DT	1486TH	3.74	1.519	-	-	1.128	4.38
GB05	2.73	DT	1486TH	3.56	1.531	-	-	1.120	4.69
TRIB01	0.09	DT	1486TH	0.26	2.130	-	-	1.054	0.20

Are the values of QMED spatially consistent?	Yes
Method used for urban adjustment for subject and donor sites	WINFAP v4[6]

Parameters used for WINFAP v4 urban adjustment if applicable

Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: $(A/B)^a \times QMED_{initial} \times UAF$

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[7] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.

[6] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

[7] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	A brief assessment of donor stations has been carried out for this study using WINFAP-FEH to assess the stations that are classified as suitable for QMED within the NRFA peak flows dataset. The Wendlebury gauge station was chosen as the most suitable station for use as a donor, as it is located within the study catchment. However, this station is level only and is not within the HiFlows database. During the previous study (2014) a rating was developed using the model outputs for the Wendlebury Brook. This was used to derive a flow / POT series with which to inform QMED. It is considered acceptable to adopt the same rating as part of this study, given the EA reviewed and approved the rating for use within the hydrology for the flood mapping study. It should be noted that, following a check on the NRFA, there are no other suitable QMED donor gauges in the vicinity.

3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
N/A	The donor site is situated within the study catchment. As noted previously, the 2014 study for the Wendlebury Brook developed a rating using the hydraulic model outputs. This was used to inform QMED at the gauge, and as a donor station for QMED at the other flow estimation locations. This same approach is to be adopted for this study. It should also be noted that there are a number of factors that may affect the ability to produce a stable rating at Wendlebury (refer to Section 1.5). Whilst there will still be considerable uncertainty in the use of local data to estimate flows, it is considered more reliable than using estimates from catchment descriptors alone.	POT	N/A – see below comment.	0.62	0.27	2.245
Note: Climatic adjustment has been considered for the donor site given the short period of record (7 years) available to inform the POT series. Information from longer gauge records can be used to improve QMED estimates at short record sites. However, as the subject catchment is very small and permeable, no nearby suitable sites were identified and adjustment has not been applied. NRFA stations 39034 and 39006 where investigated but rejected on this basis.						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group. The composition of the pooling groups is given in the Annex.

Name of group	**Site code from whose descriptor group was derived**	**Subject site treated as gauged?** (enhanced single site analysis)	**Changes made to default pooling group, with reasons.**	**Weighted average L-moments,** L-CV and L-skew, (before urban adjustment)

WBGS_PG	WBGS	No	The stations included within the pooling group were considered and the following observations / amendments were made.
			Stations removed
			• 49005 (Bolingey Stream @ Bolingey Cocks Bridge). This station has a short period of record (7 years). In addition, it is situated away from the main pooling group cluster in the L-CV and L-kurtosis plots.
			• Owing to the permeable nature of the subject site, highly impermeable stations with a BFIHOST value < 0.25 were removed from the pooling group. This includes:
			    ○ 76011 (Coal Burn @ Coalburn)
			    ○ 25011 (Langdon Beck @ Langdon)
			Following amendments to the pooling group composition, there is a total of 440 years of data. This is 60 years below the recommended record length of 500-years. This was considered acceptable as inclusion of other sites is unlikely to improve the pooling group, particularly given the permeable nature of the subject catchment.
			It should be noted that the following stations were considered for use in the pooling group, but were not included:
			• 71003 (Croasdale Beck @ Croasdale Flume)
			• 206006 (Annalong @ Recorder)
			The total record length with these included is 525-years. The adjusted L-CV and L-skew values following inclusion of these stations are 0.257 and 0.201 respectively. Therefore, addition of these stations has little difference on the final L-CV and L-skew.
				L-CV = 0.266
				L-skew = 0.204

Name of group	**Site code from whose descriptor group was derived**	**Subject site treated as gauged?** (enhanced single site analysis)	**Changes made to default pooling group, with reasons.**	**Weighted average L-moments,** L-CV and L-skew, (before urban adjustment)

GB02_PG	GB02	No	<u>Stations removed</u>
			• 7011 (Black Burn @ Pluscarden Abbey). This station has a short period of record (7 years). In addition, this contributes to a much steeper growth curve compared to the other sites in the pooling group.
			• Owing to the permeable nature of the subject site, highly impermeable stations with a BFIHOST value < 0.35 were removed from the pooling group. A higher threshold BFIHOST value was used here as the Gagle Brook catchment is more permeable than the Wendlebury Brook catchment. Had a consistent threshold been used the impact on the results would have been negligible however. The gauges removed include:
			    o 27010 (Hodge Beck @ Bransdale Weir)
			    o 27051 (Crimple @ Burn Bridge)
			This results in a total of 454 years worth of data. No additional stations were added as these were unlikely to improve the pooling group (45 years off recommended record length). As with WBGS_PG, the L-CV and L-Skew values following inclusion of additional stations showed to have little influence.
				L-CV = 0.295
				L-skew = 0.198

GB04_PG	GB04	No	<u>Stations removed</u> • 26013 (Driffield Trout Stream @ Driffield). This station has a very short period of record (6 years). In addition, it is situated away from the main pooling group cluster in the L-CV and L-kurtosis plots. No other amendments to the composition of the pooling group were made. There is a total of 503 years' worth of data.	L-CV = 0.256 L-skew = 0.053

Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
WB01	P	WBGS_PG	GL has been deemed as most suitable for this pooling group.	Growth curve adjusted using v4 urban adjustment.	Location = 1.000 Scale = 0.271 Shape = -0.205	3.07
WB02	P				Location = 1.000 Scale = 0.270 Shape = -0.206	3.07
WBGS	P				Location = 1.000 Scale = 0.269 Shape = -0.206	3.06
LB01	P	GB04_PG	GL has been deemed as most suitable for this pooling group.	Growth curve adjusted using v4 urban adjustment.	Location = 1.000 Scale = 0.247 Shape = -0.068	2.33
GB01	P	GB02_PG	GL has been deemed as most suitable for this pooling group.	Growth curve adjusted using v4 urban adjustment.	Location = 1.000 Scale = 0.303 Shape = -0.200	3.28
GB02	P				Location = 1.000 Scale = 0.303 Shape = -0.200	3.28
GB03	P	GB04_PG	GL has been deemed as most suitable for this pooling group.	Growth curve adjusted using v4 urban adjustment.	Location = 1.000 Scale = 0.251 Shape = -0.063	2.34
GB04	P				Location = 1.000 Scale = 0.252 Shape = -0.062	2.34
GB05	P				Location = 1.000 Scale = 0.252 Shape = -0.062	2.34
TRIB01	P	WBGS_PG	GL has been deemed as most suitable for this pooling group.	Growth curve adjusted using v4 urban adjustment.	Location = 1.000 Scale = 0.268 Shape = -0.207	3.06

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	200	1000
WB01	0.06	0.09	0.11	0.13	0.14	0.16	0.17	0.18	0.22	0.31
WB02	0.43	0.62	0.75	0.90	1.00	1.12	1.24	1.32	1.54	2.21
WBGS	0.62	0.88	1.08	1.29	1.42	1.61	1.77	1.89	2.21	3.16
LB01	3.03	4.12	4.80	5.47	5.86	6.36	6.77	7.06	7.79	9.61
GB01	0.49	0.73	0.90	1.09	1.21	1.37	1.51	1.61	1.89	2.71
GB02	0.58	0.85	1.06	1.27	1.41	1.60	1.76	1.89	2.21	3.17
GB03	3.67	5.00	5.84	6.65	7.12	7.73	8.22	8.57	9.45	11.63
GB04	4.38	5.98	6.98	7.95	8.52	9.24	9.83	10.26	11.30	13.90
GB05	4.69	6.40	7.48	8.51	9.12	9.90	10.52	10.98	12.10	14.88
TRIB01	0.20	0.28	0.35	0.41	0.46	0.52	0.57	0.61	0.71	1.02

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Catchment sub-divisions for ReFH2 model

Site code	Area (km²)			
	Rural or un-developed	Paved	Only relevant if significant transfers of water via sewers crossing catchment boundaries…	
			Paved with sewers draining out of topographic catchment	Paved outside topographic catchment with sewers draining into catchment
WB01	1.19	0.01	N/A	N/A
WB02	3.78	0.06	N/A	N/A
WBGS	4.36	0.10	N/A	N/A
LB01	31.30	5.47	N/A	N/A
GB01	16.77	0.27	N/A	N/A
GB02	17.55	0.28	N/A	N/A
GB03	53.88	6.11	N/A	N/A
GB04	60.92	6.32	N/A	N/A
GB05	63.07	6.31	N/A	N/A
TRIB01	1.74	0.05	N/A	N/A
Sources of information for creating sub-divisions	URBEXT2000		**Sewer capacity**	N/A Sewer information was not available for this study and therefore it has been assumed that there are no cross-boundary transfers of water in/out of the catchment.

4.2 Parameters for ReFH2 model

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	C_{max} (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)	BR
WB01	CD and DT	3.88	1.94	1338.50	70%	55.35	2.53
WB02	CD and DT	5.19	2.60	881.03	70%	55.25	2.05
WBGS	CD and DT	5.32	2.66	781.81	70%	53.79	1.91
LB01	CD and DT	8.43	4.23	725.07	70%	63.63	1.82
GB01	CD and DT	7.89	3.95	1310.97	70%	75.74	2.51
GB02	CD and DT	8.74	4.37	1238.16	70%	77.45	2.44

GB03	CD and DT	10.11	5.06	829.94	70%	71.74	1.98
GB04	CD and DT	10.21	5.11	789.97	70%	70.64	1.92
GB05	CD and DT	11.08	5.54	771.72	70%	72.11	1.89
TRIB01	CD and DT	4.29	2.14	942.59	70%	51.64	2.12
Brief description of any flood event analysis carried out	Tp(0) has been estimated based on an analysis of lag at the Wendlebury level gauge and Bicester TBR, for the top 10 events observed at Wendlebury. The Tp(0) value estimated for the Wendlebury Gauge (WBGS) using the flood event analysis is 5.28 hours. This is shorter than the estimate of Tp(0) from the previous 2014 study (5.85 hours). Since that study, two large events have been observed and have been included within the analysis. The default ReFH2 value of Tp(0) (based on catchment descriptors) is 5.32 hours. Therefore, the ratio between Tp_{cds} and Tp_{obs} is 0.99. It should be noted that the Tp_{cds} values derived as part of this study are different to the Tp_{cds} from the 2014 study (4.307 hours). This is in part due to the transfer to the ReFH2 model (in replacement of ReFH1); which provides considerable improvement for permeable catchments. Furthermore, the ratio of Tp_{cds} and Tp_{obs} / Tp scaling factor for this study is reduced compared to the previous study (1.357); a result of the factors mentioned above. Given the ratio of Tp_{cds} and Tp_{obs} is negligible, it is considered acceptable to retain the default Tp estimates derived from catchment descriptors. The lag analysis completed as part of this study is detailed in the Annex of this report (8.6).						
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

4.3 Design events for ReFH2 method: Sub-catchments and intervening areas

Site code	Urban or rural	Season of design event	Default Storm duration (hours)	Storm area for ARF (if not catchment area)
WB01	Rural	Winter	09:00	-
WB02	Rural	Winter	09:00	-
WBGS	Rural	Winter	09:00	-
LB01	Urban	Winter	13:00	-
GB01	Rural	Winter	13:00	-
GB02	Rural	Winter	13:00	-
GB03	Urban	Winter	18:00	-
GB04	Urban	Winter	18:00	-
GB05	Urban	Winter	18:00	-
TRIB01	Rural	Winter	09:00	-

Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?	Yes. The individual storm durations above are the recommended storm durations following Tp(0) adjustment. It should be noted that the recommended storm duration at WBGS before Tp adjustment is also 09:00 (WBGS). The recommended durations for each site have been used to generate peak flow estimates for comparison with the FEH Statistical method estimates. However, for application to the hydraulic model a uniform storm duration and areal reduction factor (ARF) will be used. It should be noted that the storm durations reported are based on a winter storm profile; given each of the catchments within the study area are rural (URBEXT2000 <0.3). It is anticipated that two or three storm durations will be tested within the hydraulic model for the 1% AEP event to determine the critical duration and key locations (in terms of flood risk). The storm durations proposed for testing are: • 09:00 • 13:00 • 18:00

4.4 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	200	1000
WB01	0.04	0.06	0.07	0.09	0.10	0.11	0.12	0.13	0.15	0.23
WB02	0.20	0.29	0.35	0.42	0.46	0.52	0.58	0.62	0.73	1.09
WBGS	0.29	0.41	0.49	0.59	0.64	0.72	0.79	0.85	1.00	1.48
LB01	2.30	3.14	3.74	4.38	4.78	5.32	5.80	6.16	7.16	10.35
GB01	0.38	0.53	0.64	0.77	0.85	0.96	1.07	1.14	1.37	2.07
GB02	0.39	0.55	0.67	0.80	0.89	1.01	1.11	1.20	1.43	2.16
GB03	2.55	3.47	4.14	4.86	5.31	5.93	6.49	6.92	8.07	11.78
GB04	3.04	4.13	4.91	5.75	6.28	7.02	7.66	8.15	9.52	13.84
GB05	3.06	4.14	4.91	5.74	6.26	7.00	7.64	8.13	9.50	13.84
TRIB01	0.10	0.14	0.17	0.21	0.23	0.26	0.28	0.30	0.36	0.54

5 Revitalised flood hydrograph (ReFH1) method

Note: Estimates of flow for WBGS have been derived for comparison with the ReFH2 design flow estimates only. However, the ReFH2 model is preferred given its improved performance on permeable catchments such as this.

5.1 Parameters for ReFH model (rural catchments)

Site code	Method OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
WBGS	DT	4.476	593.02	47.98	1.81
Brief description of any flood event analysis carried out	Tp has been estimated from lag analysis at the Wendlebury level gauge (see discussion in the Annex of this report [8.6]). The Tp(0) value estimated for Wendlebury Gauge (WBGS) using the flood event analysis is 5.28 hours. The original ReFH1 value of Tp(0) (based on catchment descriptors) is 4.48 hours. Therefore, the ratio between Tp_{cds} and Tp_{obs} is 1.18. Tp(0) has been informed from the estimate based on lag analysis at the Wendlebury gauge (WBGS).				

5.2 Design events for ReFH method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
WBGS	Rural	Winter	8.75

5.3 Flood estimates from the ReFH method: lumped catchments

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	200	1000
WBGS	0.26	0.36	0.44	0.52	0.57	0.66	0.73	0.78	0.95	1.56

6 Hydrograph shapes

This section details the method used to derive hydrograph shapes for use as input within the hydraulic model. To derive the hydrograph shape, design hydrograph were derived using the ReFH2 method, for which the hydrograph would need to be scaled to the FEH Statistical / ReFH2 peak flow estimates. These have been derived using the model parameters detailed in Section 4.

The hydrograph shapes for the 2, 50, 100 and 1000-year return period design events are shown in the graph below. These use the Tp(0) values estimated from catchment descriptors, given the Tp(0) adjustment value based on observed data was negligible.

Figure 6-1: ReFH2 design hydrographs - WBGS

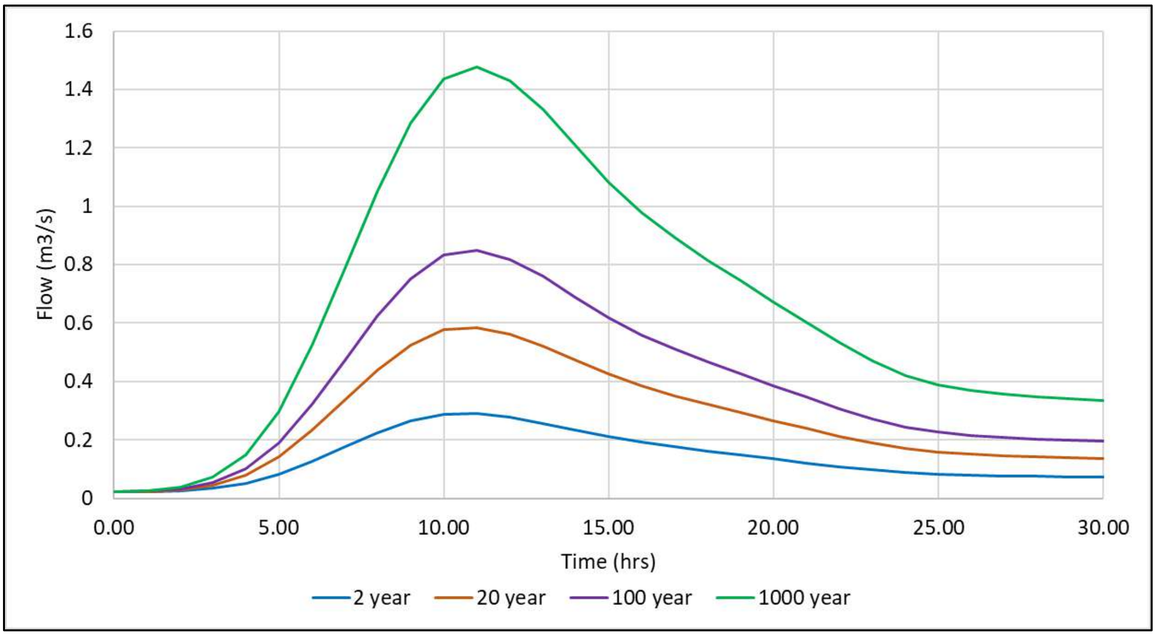


Figure 6-2: ReFH2 design hydrographs – GB02

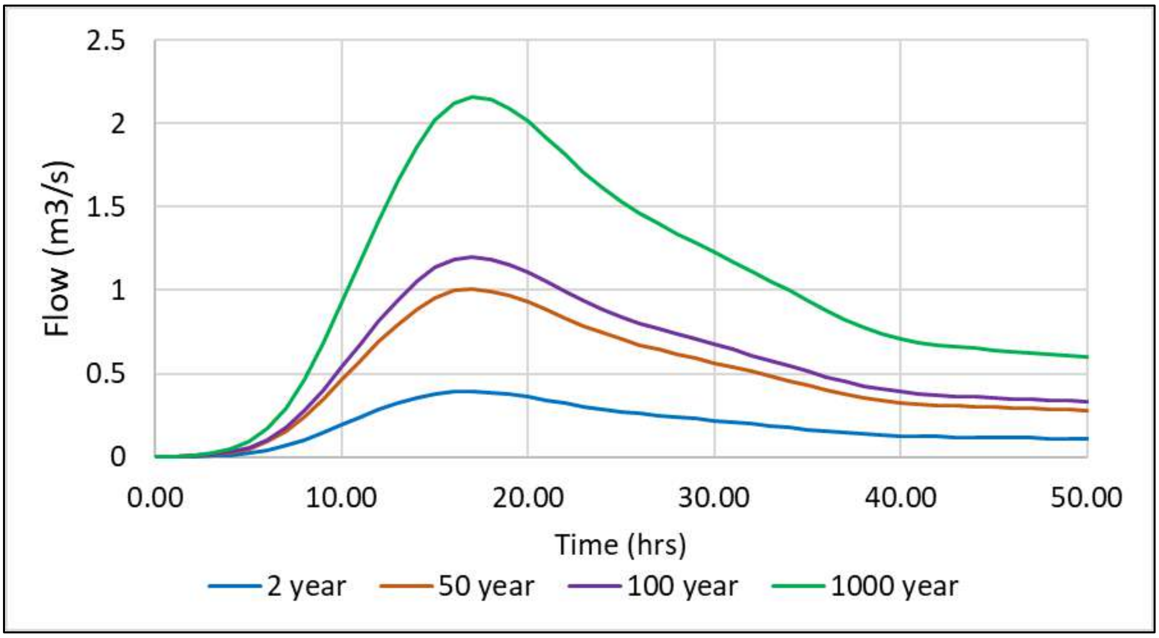
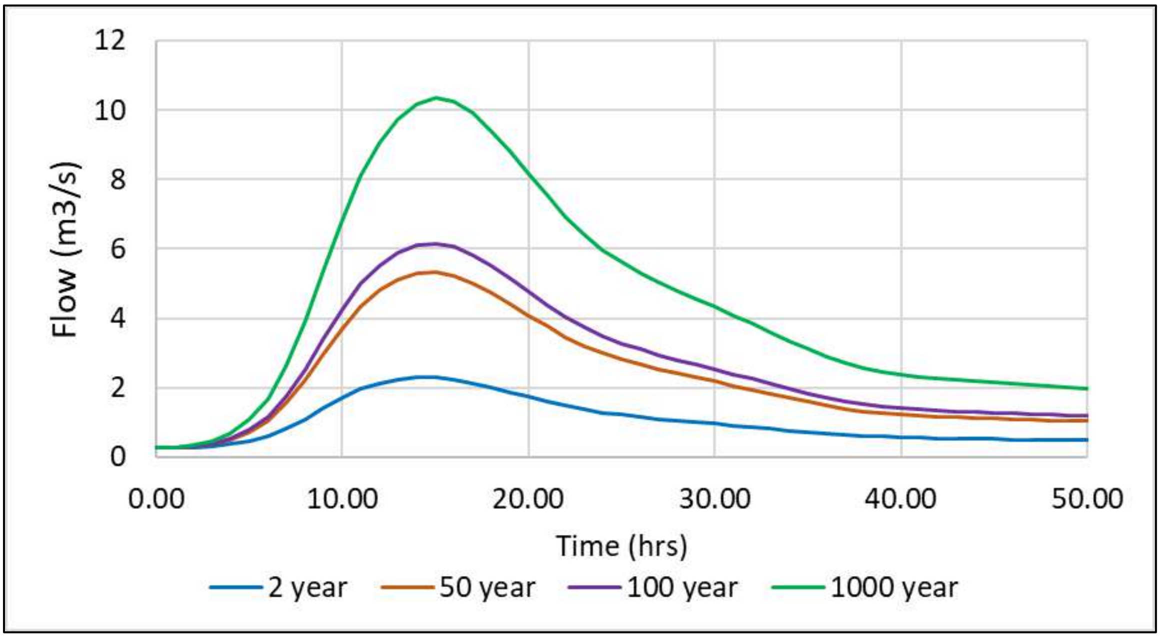


Figure 6-3: ReFH2 design hydrographs - LB01



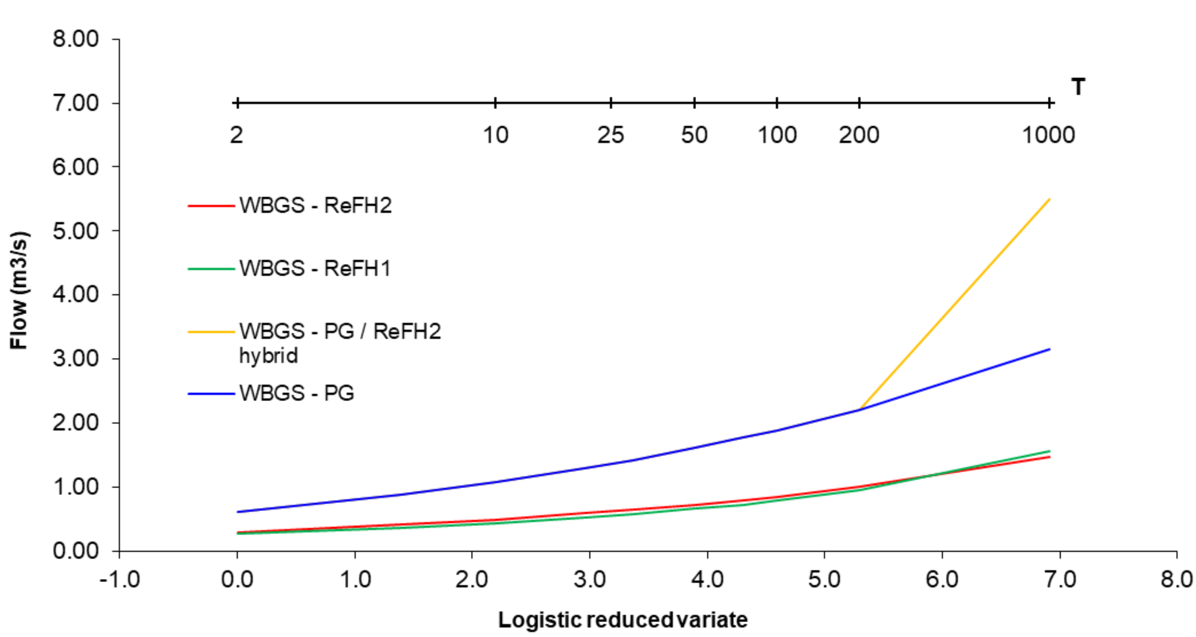
7 Discussion and summary of results

7.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak			
	Return period 2 years		Return period 100 years	
	ReFH2	ReFH1	ReFH2	ReFH1
WB01	0.67	-	0.70	-
WB02	0.47	-	0.47	-
WBGS	0.47	0.43	0.45	0.41
LB01	0.76	-	0.87	-
GB01	0.77	-	0.71	-
GB02	0.68	-	0.63	-
GB03	0.69	-	0.81	-
GB04	0.69	-	0.80	-
GB05	0.65	-	0.74	-
TRIB01	0.49	-	0.50	-

Flood frequency curves - WBGS



Note: Flood frequency curves for the other flood estimation locations are provided in the Annex.

7.2 Final choice of method

Choice of method and reasons	The key points regarding the methods and the recommendations for this study are detailed below: • The ReFH2 model has been utilised given its much improved performance for areas of high BFIHOST compared to the

	ReFH1 model. The performance of ReFH2 across both permeable and impermeable catchments within the NRFA Peak Flows dataset is evaluated in Section 6 of the ReFH2 Technical Guidance. This demonstrates that the ReFH2 permeable catchment performance is a considerable improvement on the original ReFH method. This is particularly the case when used with the FEH13 rainfall model (which have been used in this study), where performance is comparable to the current FEH statistical method. • For comparison, ReFH1 has also been utilised at the Wendlebury Gauge (WBGS) and produces a similar flood frequency curve to the ReFH2 method. • However, the FEH Statistical Method benefits from being calibrated with a large dataset of flood events (from approximately 960 catchments across the UK), sourcing flow estimates and growth curves from hydrologically similar catchments (pooled analysis) and making fewer assumptions. • In addition, gauge data from the Wendlebury level site has been used to help improve the estimates of QMED at each subject site. • The FEH statistical estimates are slightly higher, and therefore more conservative, and their use is justified as the flood behaviour of permeable catchments can tend to produce steeper growth curves than non-permeable catchments. • Given the above, the FEH statistical estimates are proposed to be initially adopted and tested within the hydraulic model. • It is also recommended that for the 1000-year estimate, a hybrid approach should be adopted. This applies the flood growth curve from the ReFH2 method (based on the 1000:100-year ratio) to the FEH Statistical method estimates, in view of the greater confidence in rainfall-runoff models for assessing flood growth at long return periods. This is further justified given the growth curve produced by the FEH Statistical method is flatter for the higher magnitude events. The hybrid 1000-year flow estimates are presented in Section 7.5. • Once model results are available, the hydrological inflows and flood extents should be sense checked to consider whether the FEH Statistical method estimates are more appropriate in relation to historic flood information the local understanding of flooding.
How will the flows be applied to a hydraulic model?	Hydrographs are required to apply inflows to the hydraulic model. It is proposed to derive hydrograph shapes using the ReFH2 model; scaled to match the FEH statistical method peak flows. Lumped catchment hydrographs will be applied to the top of the model: WB01, GB01 and LB01. In addition, a discrete lumped catchment inflow will be applied for TRIB01. The design flood hydrographs constructed for successive lumped catchments will be used to derive intervening catchment inflows for the remaining locations; by subtracting the upstream hydrograph from the downstream hydrograph at each pair of locations to calculate a model inflow representing flow from intervening areas. Flows will be applied to the hydraulic model using Flow-Time Boundaries (QTBDYs) in Flood Modeller modelling software. These will apply a uniform design storm duration across the entire

	catchment. Checks on the modelled flows will be completed at key FEPs, to compare the modelled flow versus estimates of flow; understanding whether attenuation within the model causes a drop-off in the T-year flow.

7.3 Assumptions, limitations and uncertainty

List the main assumptions made	The main assumptions are: • QMED values are suitably representative for this highly permeable, and in some locations urbanised, catchment. QMED has been enhanced for the FEH statistical method by using a donor data transfer from the Wendlebury gauge. • It is assumed that QMED donor ratio information gained at the Wendlebury gauging site is applicable across the whole catchment. • Pooling groups are suitably representative of the permeable and urban subject sites. • It is assumed that the Tp donor adjustment is appropriate for all subject sites, including those on the Gagle Brook and Langford Brook, despite differences in catchment area and urban extent. • ReFH2 hydrograph shape is representative of the catchment response. • In specific reference to the study catchment, it is possible that with the highly permeable catchment containing a number of springs fed from groundwater, that the groundwater catchment could be significantly different in size to the surface catchment. • It has been assumed that the catchment area to the west of the M40 drains towards the subject sites, as the FEH boundaries would suggest. However, there is some uncertainty around this; particularly for larger events where much of the flow in the ditch to the west of the M40 could drain south-west to another watercourse passing to the west of Oddington and joining the River Ray. • As noted in Section 2.3, the FEH Web Service catchment boundaries appeared to have some minor inaccuracies and subsequently were adjusted using the LIDAR DTM. This resulted in a minor change in catchment area for most sites, although some catchments were modified by up to 20%. It is therefore assumed that the changes to the topographic catchment are representative. • It is assumed that the bias between the Tp from observed data and the FEH Rainfall Runoff method (catchment descriptors) is similar to the bias in the ReFH2 method.
Discuss any particular limitations	The main limitations relate to the lack of quantitative flood history information. This limits the ability to verify design peak flow estimates, hydrographs, and model results based on these estimates. The modelled rating for Wendlebury GS produced during the previous study (2014) has been used to derive a flow series and POT series with which to inform estimates of QMED. However, the site is considered by the EA to be unsuitable for developing a rating there are a number of factors which could affect the ability to produce a stable rating here. In addition, there were no spot check gaugings available with which to verify the rating produced. Although there is

	still be considerable uncertainty the use of local data to estimate flows, it is considered more reliable than using estimates from catchment descriptors alone given the high permeability of the catchment in this study, and the high variability of catchment-descriptor estimates in these cases.
Give what information you can on uncertainty in the results	It is important to consider the implications of the uncertainty in hydrological estimates on the outputs from a study. It is possible to try and quantify the uncertainty in the results of the FEH Statistical method in some more standard situations. The uncertainty will depend on a variety of factors, for example how unusual the catchment is relative to the pooling group and donor catchment, and the uncertainty in flow measurement at other gauges. A UK average measure of uncertainty is presented in a technical guidance report[8] generated by a R&D project into the FEH, local data and uncertainty (Environment Agency funded consortium of JBA, CEH and others). The report presents results for rural catchments (URBEXT2000 <0.03) and moderately urbanised catchments (0.03 ≤ URBEXT2000 < 0.15). The 95% confidence limits for flood estimates for a moderately urbanised catchment are: • Without donor adjustment of QMED: 0.39 – 2.54 times the best estimate for the 50% AEP event and 0.33 - 3.01 for the 1% AEP event. • With donor adjustment of QMED (one donor): 0.40 – 2.51 times the best estimate for the 50% AEP event and 0.34 – 2.94 for the 1% AEP event. Methods to try and quantify uncertainty in design flows from the ReFH rainfall-runoff model have not yet been developed[8].
Comment on the suitability of the results for future studies	The design peak flow estimates and hydrographs have been derived for the purposes of this modelling study to improve understanding of flood risk in Wendlebury, near Bicester. If peak flow estimates and hydrographs are required for different purposes it is recommended that, at a minimum, a review of the results is carried out. The results in this study have been produced using up-to-date flow estimation methods, the Environment Agency's Flood Estimation Guidelines, and the most recent release of the NRFA peak flow dataset. However, given that the nature of the flow data available to adjust the design peak flow estimates and hydrographs from this study, there is a level of uncertainty associated with these estimates. Therefore, it is worth revising both QMED and peak flow estimates for the study catchment in future studies, particularly if better quality observed flow and level data is made available in the future.
Give any other comments on the study	N/A

7.4 Checks

Are the results consistent, for example at confluences?	Yes, the flood peaks increase with both catchment size and return period at all FEPs for each method utilised.
What do the results imply regarding the	A modelled rating was developed during the previous study (2014) and this was used to derive estimates of flow for the largest observed

[8] Environment Agency. 2017. Using local data to reduce uncertainty in flood frequency estimation

<table>
<tr><td>return periods of floods during the period of record?</td><td>events in the available period of record at Wendlebury gauge. However, the rating was not formally parameterised and therefore it has not been possible to to formally check the design flow estimates against the observed data. It is therefore recommended that the modelled outputs are sense checked are revised accordingly if considered to be obviously erroneous. For example, typically in an unmodified channel, QMED flow will be around about bank full level.

The derived flow estimates should also be checked during future studies, particularly if better quality data is made available for the gauge, or if new methods are developed.</td></tr>
<tr><td>What is the range of 100-year growth factors? Is this realistic?</td><td>The range of 1% AEP event growth factors are as follows:
• FEH statistical: 2.33 – 3.28
• ReFH2: 2.66 – 3.20
These values are all within the expected range for small catchments (<20km2), which is between 2 - 5.</td></tr>
<tr><td>If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?</td><td>The range of 0.1% / 1% AEP event ratios are:
• FEH statistical: 1.36 – 1.68
• ReFH2: 1.68 – 1.82
A typical range of 0.1% / 1% AEP ratios for UK catchments is 1.3 – 2.1.</td></tr>
<tr><td>How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.</td><td>Results for the Wendlebury catchment are available from the 2014 JBA Consulting study, as well as from a prior PBA study completed in 2001. Previous flow estimates for the Gagle Brook are limited to the upstream model extent and there are no previous flow estimates available for the Langford Brook.

For the purposes of this study, focus will be given to the difference in flows produced in comparison to the 2014 study. The estimates of flow derived during this study are available in the Annex (8.8.2).

A comparison of flow estimates is provided in the table below. This shows that the FEH Statistical flow estimates produced as part of this study are typically somewhere between the FEH Statistical estimates from the 2014 study; with donor (final estimates) and without donor (initial estimates) QMED adjustment.

Flow comparison
<table>
<tr><th rowspan="2">Site code / model</th><th rowspan="2">Method</th><th colspan="5">Return period (years)</th></tr>
<tr><th>2</th><th>20</th><th>50</th><th>100</th><th>1000</th></tr>
<tr><td rowspan="2">WB01a (2014)</td><td>FEH Stats without donor adj.</td><td>0.05</td><td>0.10</td><td>0.13</td><td>0.15</td><td>0.27</td></tr>
<tr><td>FEH Stats with donor adj.</td><td>0.10</td><td>0.23</td><td>0.29</td><td>0.34</td><td>0.61</td></tr>
<tr><td>WB01 (2019)</td><td>FEH Stats with donor adj.</td><td>0.06</td><td>0.16</td><td>0.19</td><td>0.18</td><td>0.56</td></tr>
<tr><td rowspan="2">TRIB01 (2014)</td><td>FEH Stats without donor adj.</td><td>0.07</td><td>0.15</td><td>0.19</td><td>0.23</td><td>0.41</td></tr>
<tr><td>FEH Stats with donor adj.</td><td>0.18</td><td>0.40</td><td>0.51</td><td>0.61</td><td>1.07</td></tr>
<tr><td>TRIB01 (2019)</td><td>FEH Stats with donor adj.</td><td>0.20</td><td>0.41</td><td>0.52</td><td>0.61</td><td>1.80</td></tr>
</table></td></tr>
</table>

	WB02 (2014)	FEH Stats without donor adj.	0.22	0.49	0.62	0.74	1.30
		FEH Stats with donor adj.	0.52	1.10	1.36	1.59	2.60
	WB02 (2019)	FEH Stats with donor adj.	0.43	0.90	1.12	1.32	3.89
	WB_LG (2014)	FEH Stats without donor adj.	0.28	Not reported.			
		FEH Stats with donor adj.	0.83	Not reported.			
	WBGS (2019)	FEH Stats with donor adj.	0.62	1.29	1.61	1.89	5.49
	GB01 (2014)	FEH Stats without donor adj.	0.38	0.85	1.08	1.28	2.21
		FEH Stats with donor adj.	0.65	1.45	1.84	2.19	3.78
	GB01 (2019)	FEH Stats with donor adj.	0.49	1.09	1.37	1.61	4.90
Are the results compatible with the longer-term flood history?	There is limited anecdotal evidence of flooding found through online research. However, a chronology of flood history is provided in the Annex (8.5). Local residents, records offices and the Environment Agency may hold more information on occurrences of flooding within/in the vicinity of the study area.						
Describe any other checks on the results	No other checks have been undertaken to date; however, sensibility checks are to be applied to the flood outlines once the flows have been routed through the model. This aims to ensure that the model inflows result in realistic outputs.						

7.5 Final results

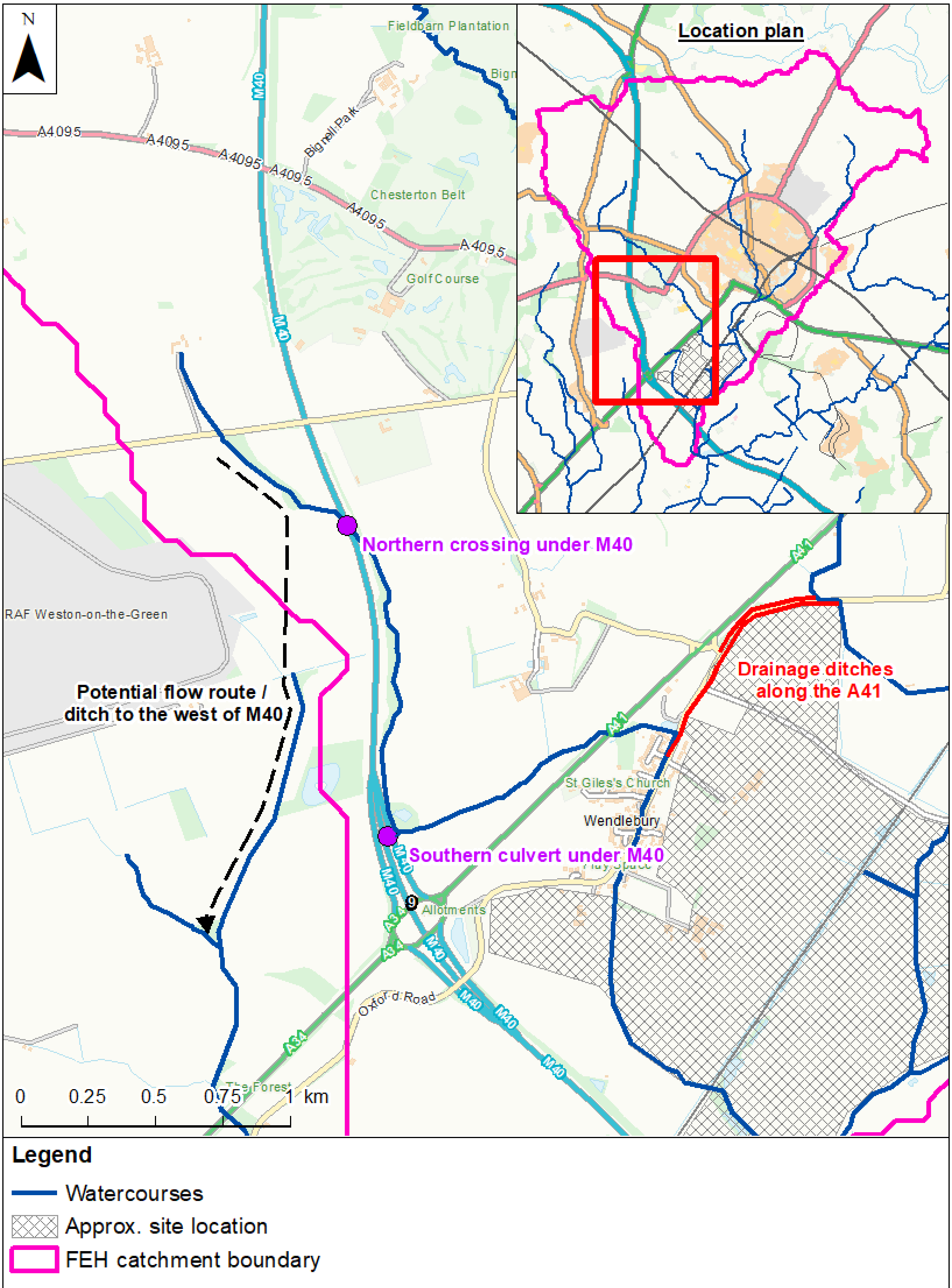
Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	200	1000
WB01	0.06	0.09	0.11	0.13	0.14	0.16	0.17	0.18	0.22	0.57
WB02	0.43	0.62	0.75	0.90	1.00	1.12	1.24	1.32	1.54	3.84
WBGS	0.62	0.88	1.08	1.29	1.42	1.61	1.77	1.89	2.21	5.51
LB01	3.03	4.12	4.80	5.47	5.86	6.36	6.77	7.06	7.79	16.16
GB01	0.49	0.73	0.90	1.09	1.21	1.37	1.51	1.61	1.89	4.91
GB02	0.58	0.85	1.06	1.27	1.41	1.60	1.76	1.89	2.21	5.70
GB03	3.67	5.00	5.84	6.65	7.12	7.73	8.22	8.57	9.45	19.85
GB04	4.38	5.98	6.98	7.95	8.52	9.24	9.83	10.26	11.30	23.70
GB05	4.69	6.40	7.48	8.51	9.12	9.90	10.52	10.98	12.10	25.17
TRIB01	0.20	0.28	0.35	0.41	0.46	0.52	0.57	0.61	0.71	1.79

Site code	**Flood peak (m^3/s) for the following return periods (in years)**									
	2	**5**	**10**	**20**	**30**	**50**	**75**	**100**	**200**	**1000**
Note: these estimates have been derived using the FEH statistical approach. However, the 1000-year flow estimates have been modified using a ReFH2 hybrid approach; applying the flood growth curve from the ReFH2 method (based on the 1000:100-year ratio) to the FEH Statistical method estimates (refer to Section 7.2). Refer to Annex (8.11) for estimates for the River Ray.										

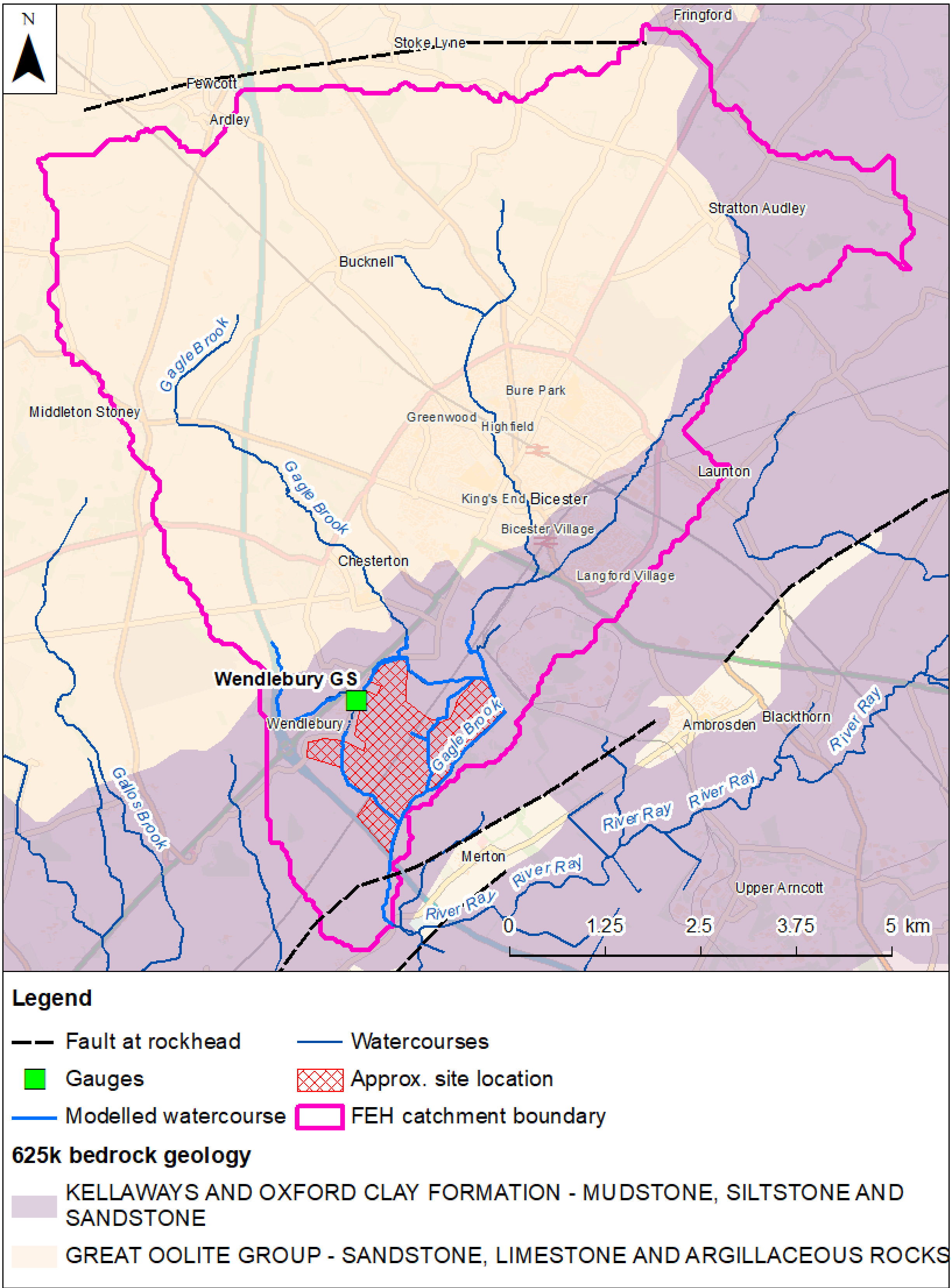
If flood hydrographs are needed for the next stage of the study, where are they provided?	Flood hydrographs will be required for the hydraulic modelling and will be provided in the Flood Modeller data (.DAT) files. Using this file, individual Flood Modeller Event Data (.IED) files can be produced for the hydraulic model boundary units. The ReFH2 design hydrographs are to be taken forward for this study. A common design storm is to be applied within the model (in terms of storm area and storm duration). Diverted flows for the Gagle Brook transfer will be determined through the hydraulic modelling, as the Gagle Brook and the drains will be incorporated within the model.

8 Annex

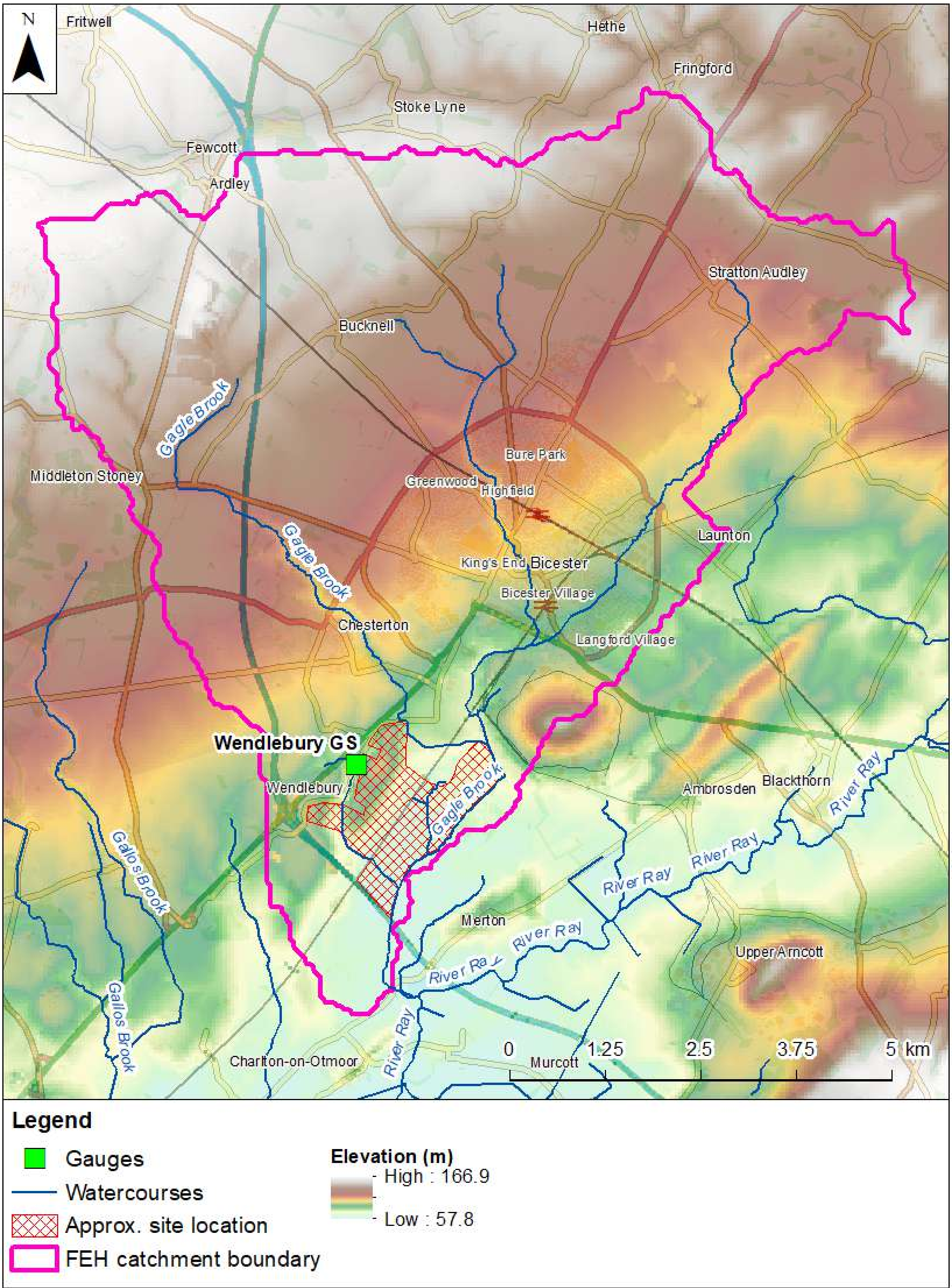
8.1 Potential flow routes (uncertainty)



8.2 Bedrock geology

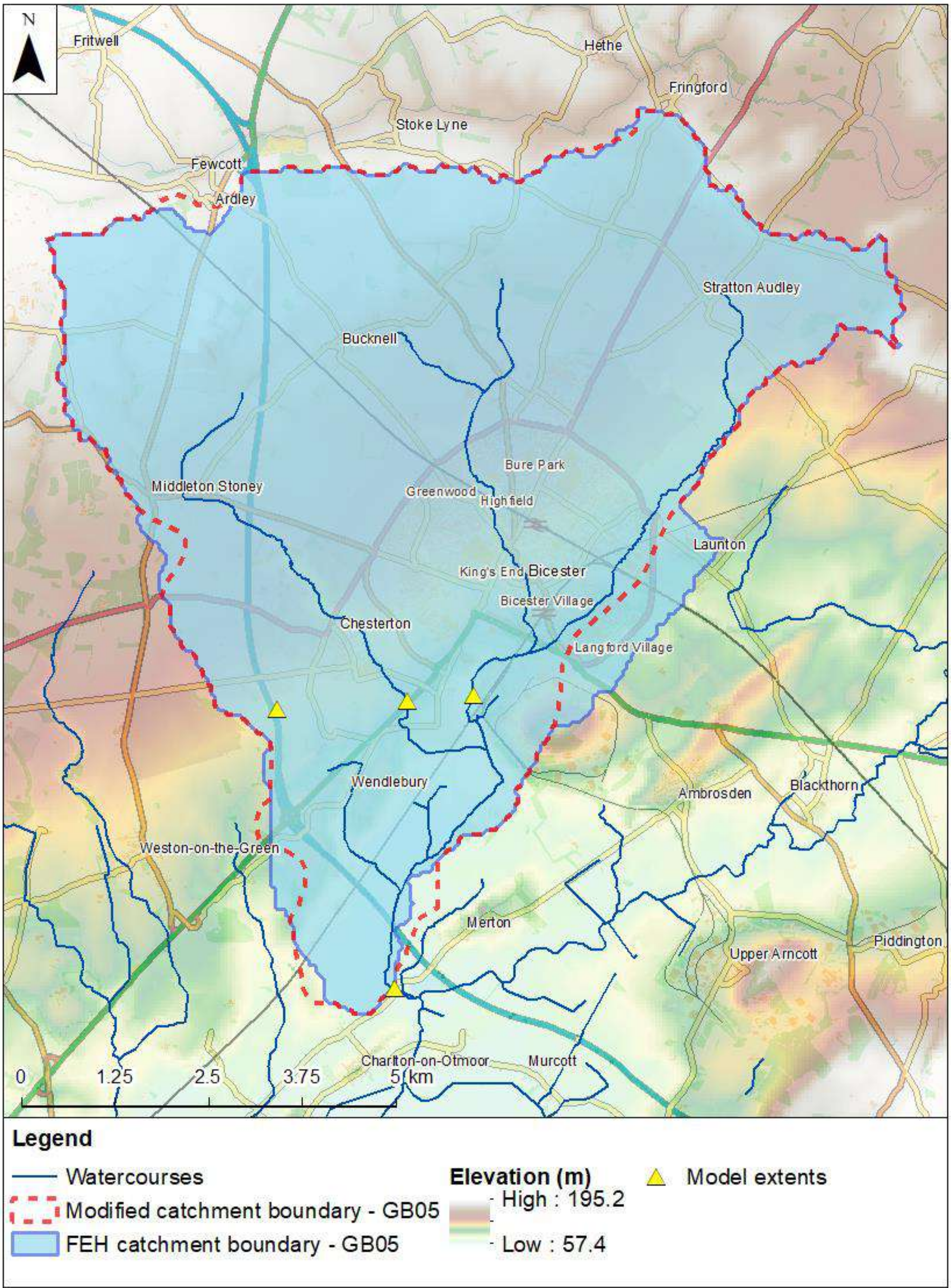


8.3 Topography



8.4 Modified catchment boundaries

8.4.1 GB05 – Gagle Brook - downstream extent



8.5 Pooling groups

8.5.1 WBGS_PG

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27073 (Brompton Beck @ Snainton Ings)	1.161	36	0.816	0.203	0.06	0.412
27051 (Crimple @ Burn Bridge)	1.898	45	4.564	0.221	0.144	0.113
76011 (Coal Burn @ Coalburn)	2.076	40	1.84	0.166	0.31	1.372
45816 (Haddeo @ Upton)	2.138	24	3.489	0.306	0.387	0.466
26802 (Gypsey Race @ Kirby Grindalythe)	2.246	18	0.108	0.316	0.217	0.214
25019 (Leven @ Easby)	2.311	39	5.677	0.34	0.377	0.612
28033 (Dove @ Hollinsclough)	2.35	38	4.225	0.234	0.405	0.938
20002 (West Peffer Burn @ Luffness)	2.373	41	3.299	0.292	0.015	1.522
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.485	7	5.777	0.282	0.189	3.413
203046 (Rathmore Burn @ Rathmore Bridge)	2.568	35	10.72	0.147	0.144	0.711
47022 (Tory Brook @ Newnham Park)	2.63	24	6.651	0.265	0.138	0.22
49006 (Camel @ Camelford)	2.635	11	11.154	0.124	-0.185	2.38
25011 (Langdon Beck @ Langdon)	2.688	28	15.878	0.238	0.318	0.605
27010 (Hodge Beck @ Bransdale Weir)	2.694	41	9.42	0.224	0.293	0.395
44008 (South Winterbourne @ Winterbourne Steepleton)	2.742	38	0.434	0.417	0.336	1.371
36010 (Bumpstead Brook @ Broad Green)	2.775	50	7.543	0.371	0.177	1.257
Total (before amendment)		515				
Weighted means (before amendment)				0.258	0.219	
Total (following amendment)		440				
Weighted means (following amendment)				0.266	0.204	

8.5.2 GB02_PG

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
26802 (Gypsey Race @ Kirby Grindalythe)	0.575	18	0.108	0.316	0.217	0.033
36010 (Bumpstead Brook @ Broad Green)	0.718	50	7.543	0.371	0.177	0.88
25019 (Leven @ Easby)	0.782	39	5.677	0.34	0.377	0.766
20002 (West Peffer Burn @ Luffness)	0.838	41	3.299	0.292	0.015	2.077
203046 (Rathmore Burn @ Rathmore Bridge)	0.976	35	10.72	0.147	0.144	0.7
27010 (Hodge Beck @ Bransdale Weir)	1.057	41	9.42	0.224	0.293	0.878
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.058	7	5.777	0.282	0.189	2.399
26803 (Water Forlornes @ Driffield)	1.061	18	0.418	0.312	0.133	0.355
44008 (South Winterbourne @ Winterbourne Steepleton)	1.068	38	0.434	0.417	0.336	0.412
7011 (Black Burn @ Pluscarden Abbey)	1.124	5	5.205	0.582	0.464	2.623
41020 (Bevern Stream @ Clappers Bridge)	1.139	48	13.78	0.203	0.175	0.512
28058 (Henmore Brook @ Ashbourne)	1.311	12	9.006	0.155	-0.064	1.624
73015 (Keer @ High Keer Weir)	1.322	26	12.285	0.177	0.178	0.544
72014 (Conder @ Galgate)	1.337	49	16.283	0.22	0.111	0.213
27051 (Crimple @ Burn Bridge)	1.373	45	4.564	0.221	0.144	0.187
44013 (Piddle @ Little Puddle)	1.376	25	0.857	0.5	0.273	1.278
39033 (Winterbourne Stream @ Bagnor)	1.391	55	0.399	0.345	0.388	1.52
Total (before amendment)		552				

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
Weighted means (before amendment)				0.295	0.205	
Total (following amendment)		454				
Weighted means (following amendment)				0.295	0.198	

8.5.3 GB04_PG

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
34005 (Tud @ Costessey Park)	0.132	56	3.129	0.269	0.176	0.314
33032 (Heacham @ Heacham)	0.487	49	0.449	0.307	0.12	0.521
37003 (Ter @ Crabbs Bridge)	0.507	52	5.637	0.272	-0.011	0.334
26003 (Foston Beck @ Foston Mill)	0.558	57	1.718	0.25	0.01	0.285
33054 (Babingley @ Castle Rising)	0.627	41	1.129	0.204	0.08	1.058
37014 (Roding @ High Ongar)	0.676	54	10.928	0.239	-0.159	1.02
34012 (Burn @ Burnham Overy)	0.682	51	1.037	0.214	-0.152	1.344
36003 (Box @ Polstead)	0.727	56	3.905	0.308	0.092	1.046
26013 (Driffield Trout Stream @ Driffield)	0.746	6	2.685	0.317	0.34	2.617
39042 (Leach @ Priory Mill Lechlade)	0.831	45	3.1	0.195	0.059	1.179
33057 (Ouzel @ Leighton Buzzard)	0.848	36	7.84	0.281	0.246	1.283
Total (before amendment)		503				
Weighted means (before amendment)				0.259	0.061	
Total (following amendment)		497				
Weighted means (following amendment)				0.256	0.053	

8.6 ReFH parameterisation

As there are 15-minute water level and rainfall data for the subject catchment, lag analysis could be carried out to estimate Tp(0) for use within the rainfall runoff model (ReFH1/2).

The top 10 events were extracted from the Wendlebury level record. The corresponding rainfall event was taken from the Bicester TBR. The time of the rainfall centroid was subtracted from the peak flow time to estimate the lag time for each of the 10 flood events. A catchment lag value (LAG) was estimated as the geometric mean of the event lag times. This LAG value was then substituted into the following equation, as stated in FEH vol.4, to calculate Tp(0):

$$Tp(0) = \ 0.879\ x\ LAG\text{^}0.951$$

Table 8-1: Lag analysis and Tp(0) calculations

Rank	Peak Flow	Rainfall Centroid	Catchment Lag [hours]
1	20/07/2007 15:30	20/07/2007 07:45	6.17
2	18/10/2012 06:15	17/10/2012 22:30	6.38
3	03/06/2008 16:15	03/06/2008 10:45	7.12
4	24/12/2013 04:30	23/12/2013 18:45	8.35
5	06/07/2012 18:30	06/07/2012 13:15	5.32
6	10/01/2007 05:45	10/01/2007 00:15	4.63
7	13/07/2012 03:15	12/07/2012 21:30	7.40
8	12/06/2012 00:00	11/06/2012 11:00	13.65
9	09/03/2016 11:45	09/03/2016 09:15	5.90
10	16/01/2008 00:00	15/01/2008 19:15	4.52
		Geometric mean	**6.59**
		Tp(0)	**5.28**

The Tp(0) value estimated using flood event analysis is 5.28 hours. The catchment lag was derived by calculating the difference between rainfall centroid and the time of peak flow for the top 10 events.

8.7 Flood history chronology

Date of event	Information	Source of information
February 2001	Flood event occurred on Monday 12th February 2001 which has been described as the worst flood event in approximately 35 years or more. • 5 properties reported internal flooding to approximately 100mm depth. • Gardens of most of the properties in Rectory Close were flooded but no water entered the properties. It is noted that there are 24 structures crossing the brook as it flows through Wendlebury which could cause a considerable flow constriction during flood events. It was also noted by local residents that further flood water could down into the Wendlebury catchment from the Gagle Brook catchment via the road drainage ditches. However, this was not observed during this particular flood event.	Wendlebury Brook Flood Study (PBA, 2001) Wendlebury Brook Flood Study (JBA Consulting, 2014)
July 2006	Two properties on Church Lane reported as flooded on 6th July 2006.	Wendlebury Brook Flood Study (JBA Consulting, 2014)

July 2007	Records show flooding at property at Wendlebury among several other locations in the Cherwell and West Oxfordshire Districts. Four properties were reported as flooded although no watercourse is stated. The only information is that it was fluvial flooding from a Main River. The estimated return period for Wendlebury was calculated to be between 100 – 300 years based on the Cherwelll Flood Review. The return period analysis undertaken within the 2014 study (JBA Consulting) on the 15-minute rainfall data at Bicester TBR showed that the return period of the rainfall for the event is 27 years. Approximately 52mm of rainfall fell within a 9-hour period.	Cherwell and West Oxfordshire, Level 1 Strategic Flood Risk Assessment (2009). Available online. Cherwell Flood Review Wendlebury Brook Flood Study (JBA Consulting, 2014)
June 2008	The 2008 Historic Flood Outline (EA) shows the flooding along Wendlebury Road, Church Lane and Rectory Close.	Historic Flood Map
July 2012	Three properties reported as flooded in Church Lane.	Wendlebury Brook Flood Study (JBA Consulting, 2014)
18 October 2012	Wendlebury Brook overtopped after 33mm (1.3 inches) of rain fell in six hours. As a result houses and streets in the village were left underwater. The flooding was the second in the village that year. Five properties were reported as flooded in Church Lane and Rectory Close.	BBC news. Available from: https://www.bbc.co.uk/news/uk-england-oxfordshire-20002686 Wendlebury Brook Flood Study (JBA Consulting, 2014)
November 2012	One commercial property was flooded.	Wendlebury Brook Flood Study (JBA Consulting, 2014)

8.8 Estimates from previous studies

8.8.1 Wendlebury Brook Flood Study (PBA, 2001)

These estimates are from the 'Wendlebury Brook Flood Study' (Final Report, June 2001) which was carried out by Peter Brett Associates (PBA).

Site code	Flood peak (m^3/s) for the following return periods (in years)						
	2	5	10	25	50	75	100
Natural Catchment D/S of Wendlebury	0.541	0.799	0.988	1.262	1.498	1.651	1.767
Combined flows D/S of Wendlebury (including Gagle Brook transfer and A41 runoff)	0.60	0.87	1.07	1.34	1.83	1.98	2.10

8.8.2 Wendlebury Brook Flood Study (JBA Consulting, 2014)

Final flow estimates; using Wendlebury level gauge as a donor for QMED (based on modelled rating produced during the study).

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	100+CC (20%)	100+CC (30%)	1000
WB01a	0.10	0.15	0.19	0.23	0.25	0.29	0.32	0.34	0.41	0.45	0.61

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	100+CC (20%)	100+CC (30%)	1000
WB01b	0.12	0.17	0.21	0.25	0.28	0.32	0.36	0.38	0.46	0.50	0.67
WB02a	0.25	0.37	0.45	0.55	0.61	0.70	0.77	0.83	0.99	1.08	1.45
TRIB01	0.18	0.27	0.33	0.40	0.45	0.51	0.57	0.61	0.73	0.79	1.07
WB03	1.32	1.90	2.33	2.78	3.06	3.45	3.78	4.03	4.83	5.23	6.58
GB01	0.65	0.97	1.20	1.45	1.62	1.84	2.04	2.19	2.62	2.84	3.78

Flow estimates before development of rating for Wendlebury gauge.

Site code	Flood peak (m^3/s) for the following return periods (in years)										
	2	5	10	20	30	50	75	100	100+CC (20%)	100+CC (30%)	1000
WB01a	0.05	0.07	0.08	0.10	0.11	0.13	0.14	0.15	0.18	0.20	0.27
WB01b	0.05	0.07	0.09	0.11	0.12	0.14	0.15	0.16	0.20	0.21	0.29
WB02a	0.11	0.16	0.19	0.23	0.26	0.30	0.33	0.35	0.43	0.46	0.62
TRIB01	0.07	0.10	0.13	0.15	0.17	0.19	0.22	0.23	0.28	0.30	0.41
WB03	0.57	0.83	1.01	1.21	1.33	1.50	1.64	1.75	2.10	2.28	2.86
GB01	0.38	0.56	0.70	0.85	0.94	1.08	1.19	1.28	1.53	1.66	2.21

8.9 Additional supporting information

This section summarises the information used to inform this study that has been taken from the 2014 JBA Consulting study on the Wendlebury Brook. This has been chosen as the best source of information in the absence of hydrometric data for the current study.

8.9.1 Derivation of a rating for Wendlebury Level Gauge

The information presented in this section has been taken from Section 6 of the 2014 Wendlebury Brook FEH calculation record (JBA Consulting).

A modelled rating curve was derived from the 2014 hydraulic model for the purposes of the hydrological test. Whilst there will still be considerable uncertainty, the use of local data to estimate flows is considered more reliable than using estimates from catchment descriptors alone.

QMED was estimated from observed POT data (period of record 05/12/2006 - 11/08/2013) using the equation provided within FEH (vol. 3).

$$Q_{MED} = wQ_i + (1 - w)Q_{i+1}$$

This produces a QMED estimate of 0.83m^3/s at the site of Wendlebury level gauge.

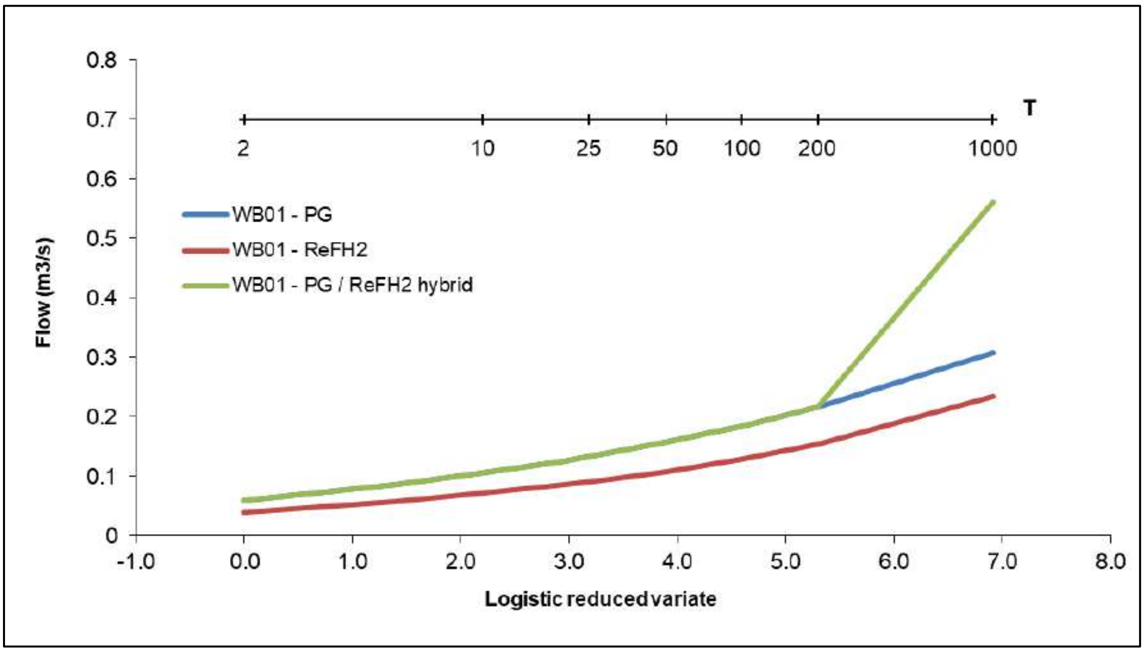
In order to update other flow estimates in the catchment the Wendlebury level gauge was then used as a donor catchment for all other inflow locations. In order to undertake this it was necessary to estimate QMED from catchment descriptors at the level gauge. The estimate of QMED from catchment descriptors is 0.28m^3/s.

As expected, informing flow estimates using the modelled rating resulted in an increase in the flow estimates. These were then run through the hydraulic model to determine the effects on flood outlines. The derivation of a rating for the level gauge using this method is a standard approach. However, it would be advisable to collect some spot flow gauging in the future to confirm the modelled rating.

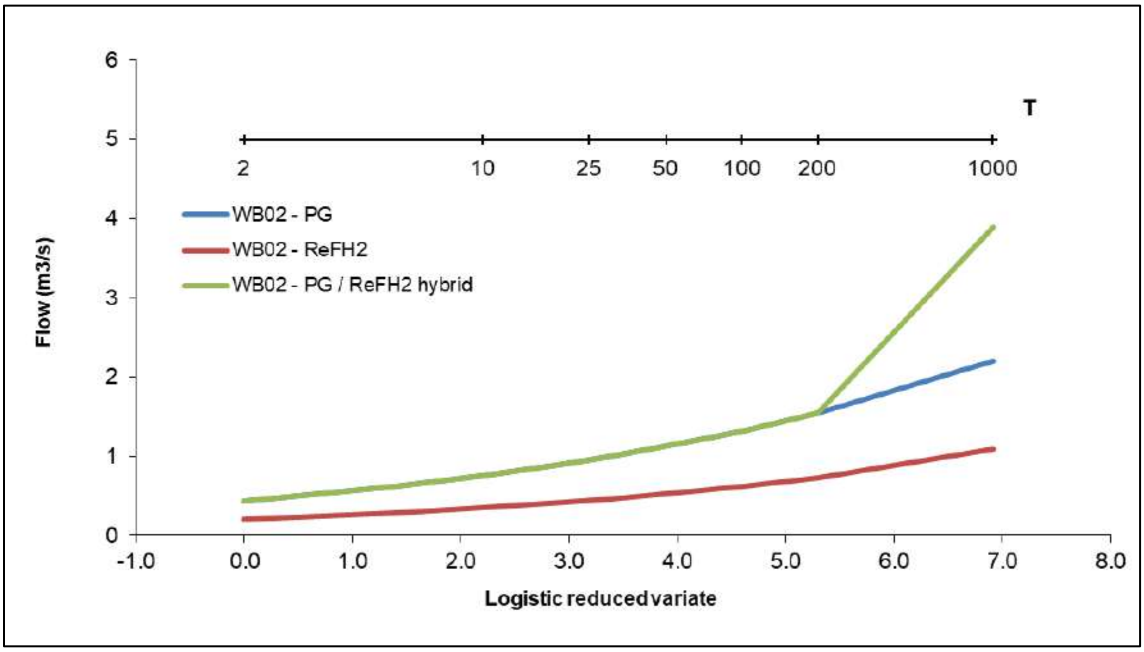
Further information on the analysis undertaken for these hydrological tests is contained within the Hydrological Investigation note (2013s7414-U-N002-3-Addtional_Options.pdf, 06/12/2013).

8.10 Flood frequency curves

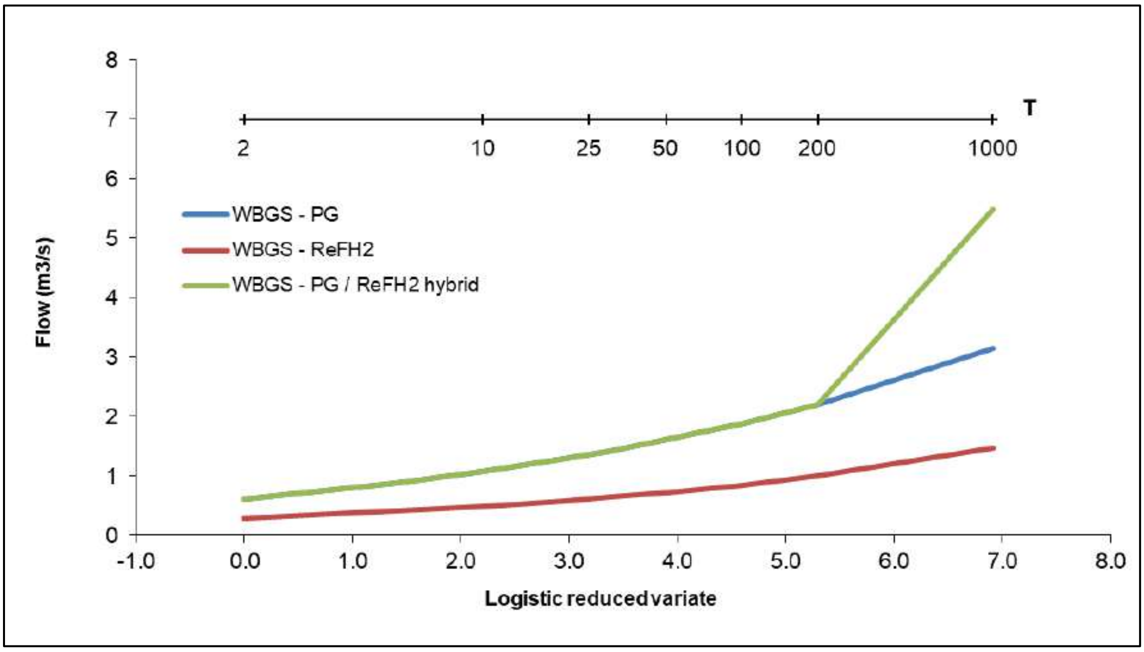
8.10.1 WB01



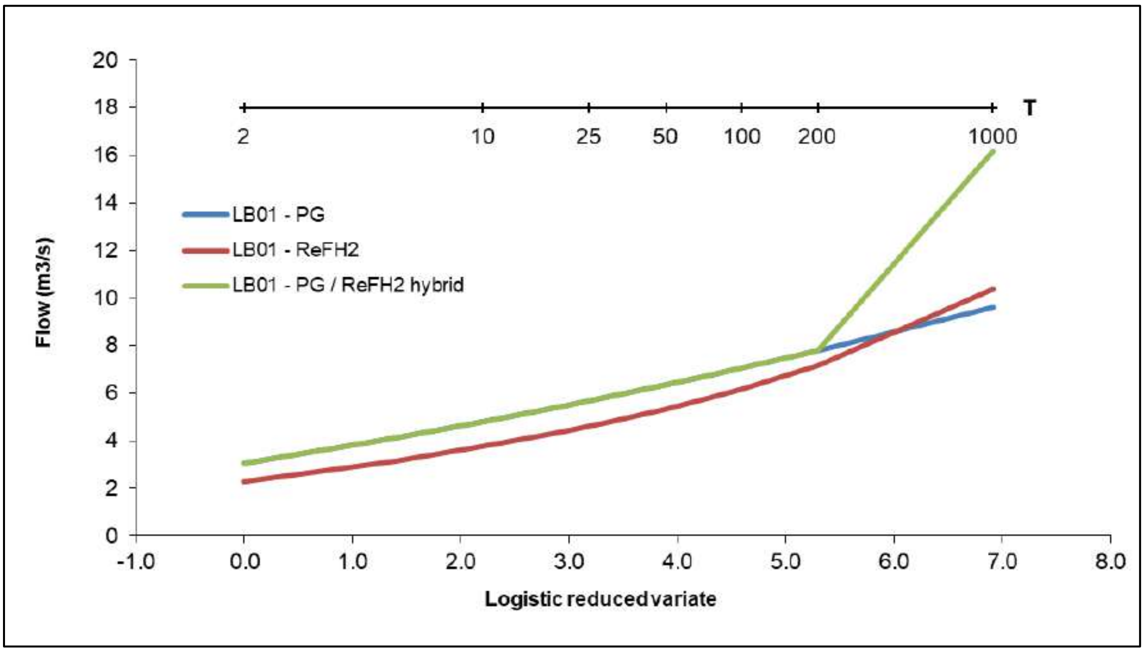
8.10.2 WB02



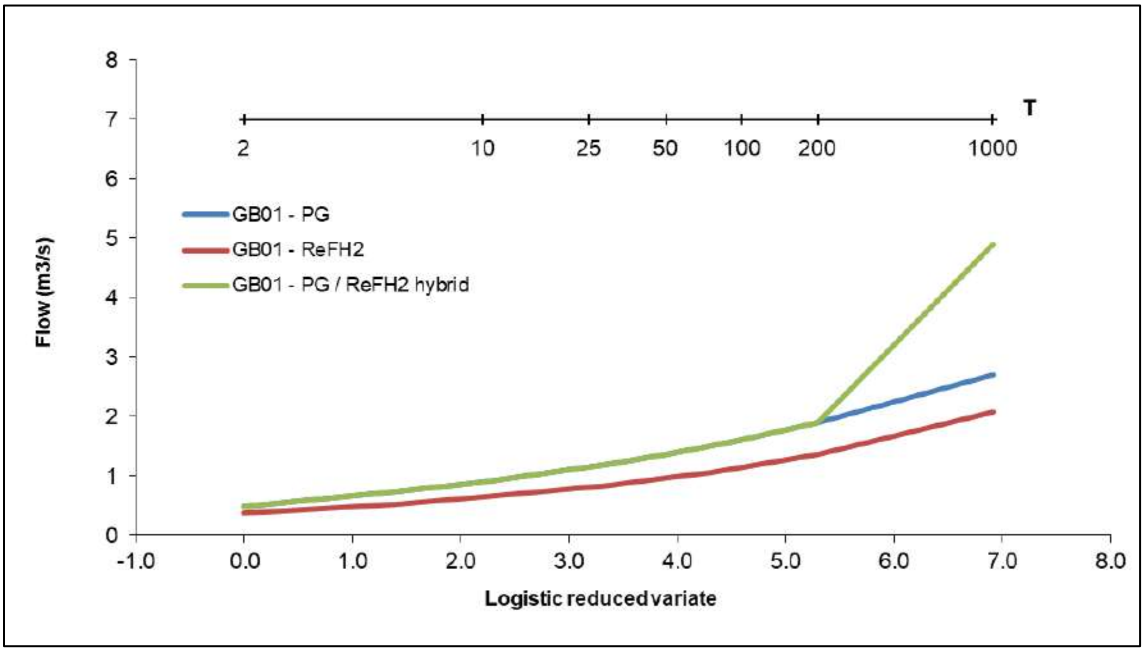
8.10.3 WBGS



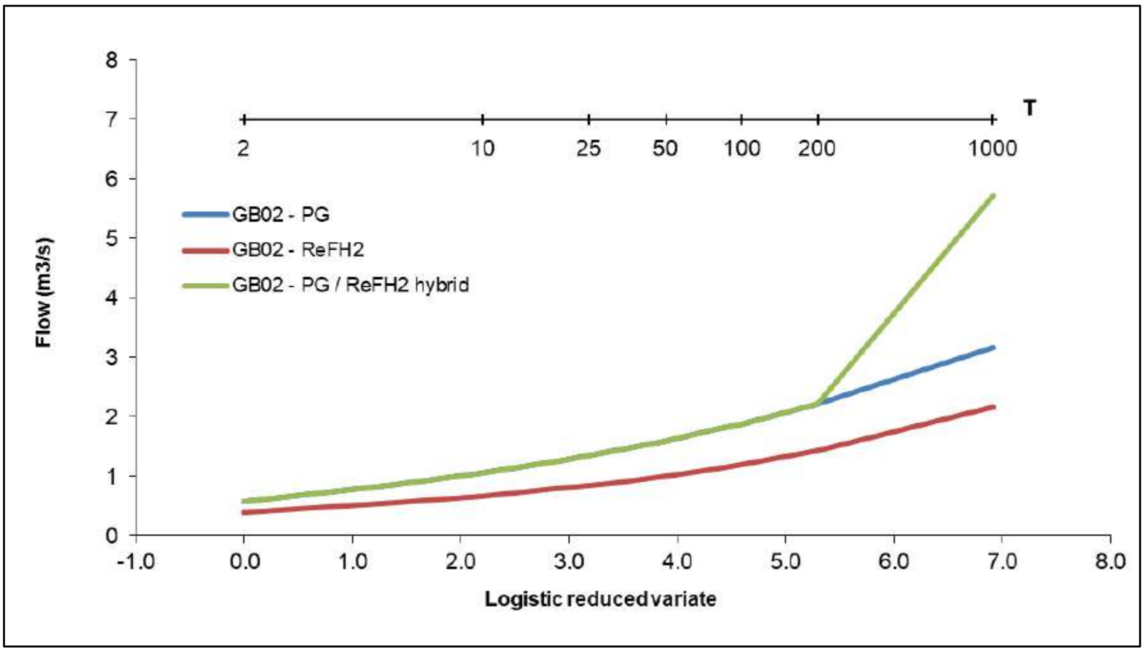
8.10.4 LB01



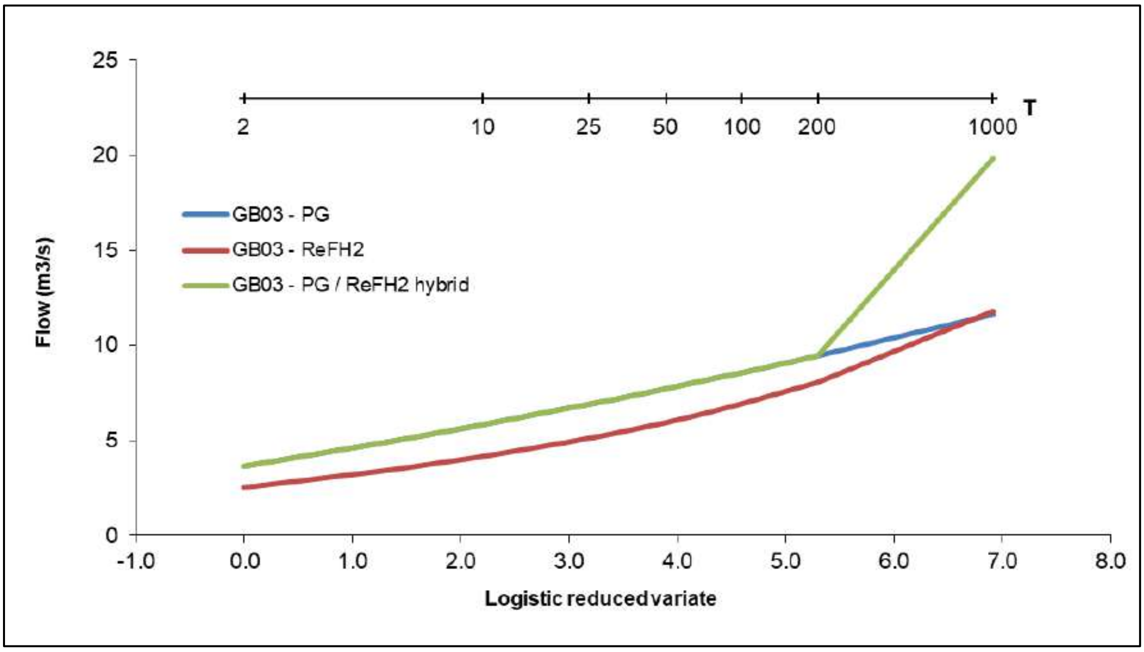
8.10.5 GB01



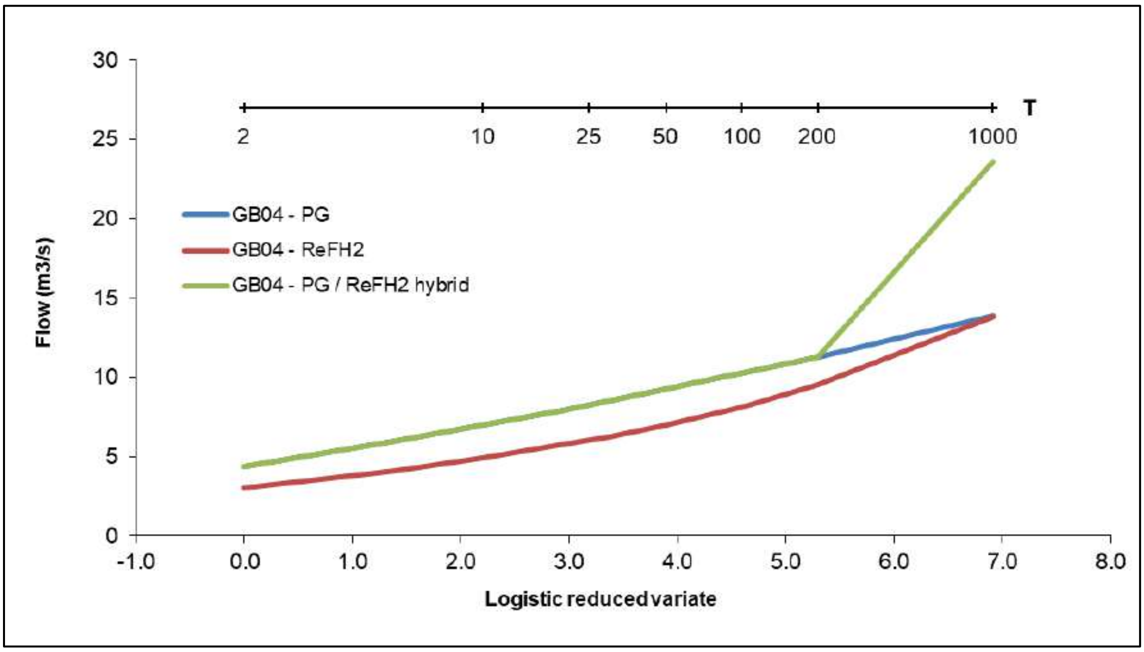
8.10.6 GB02



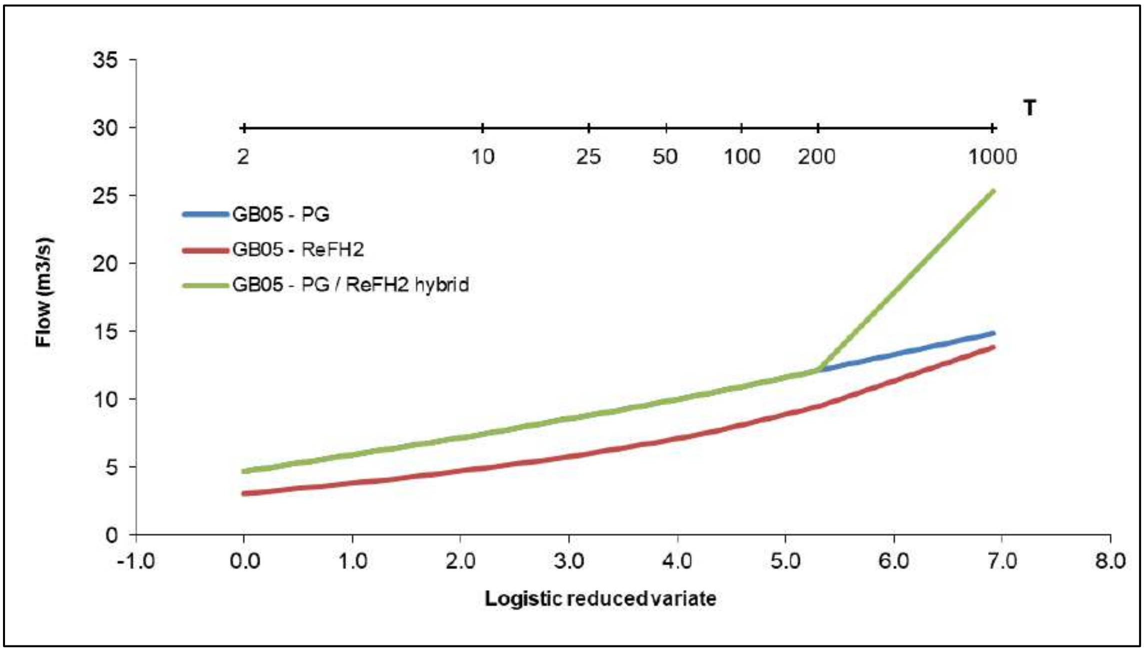
8.10.7 GB03



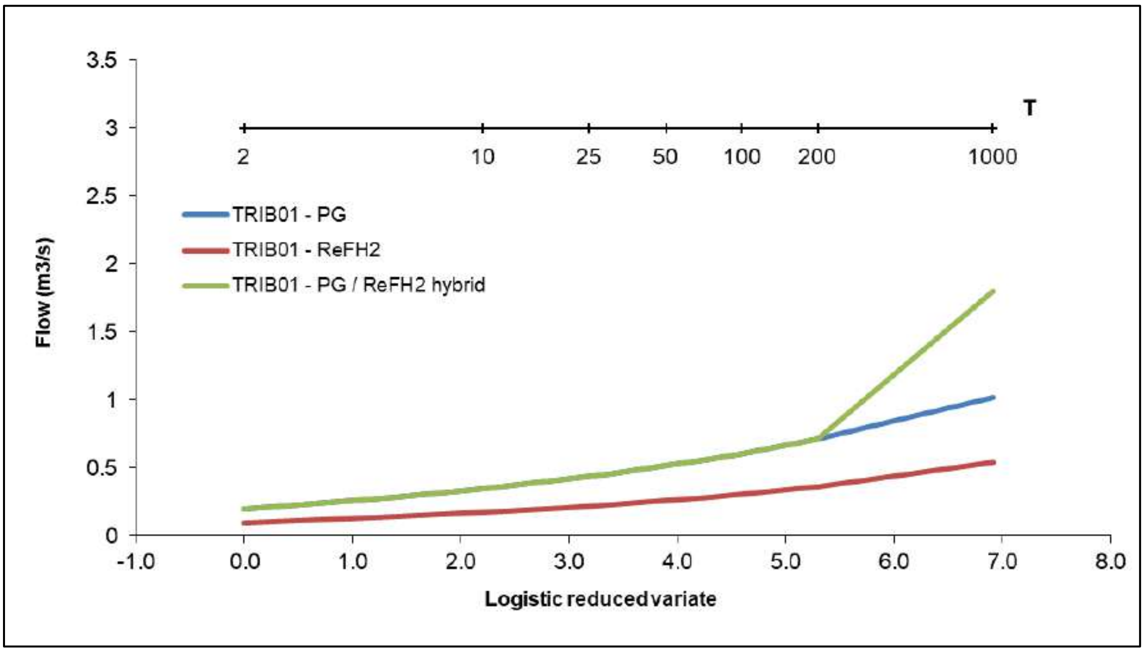
8.10.8 GB04



8.10.9 GB05



8.10.10 TRIB01

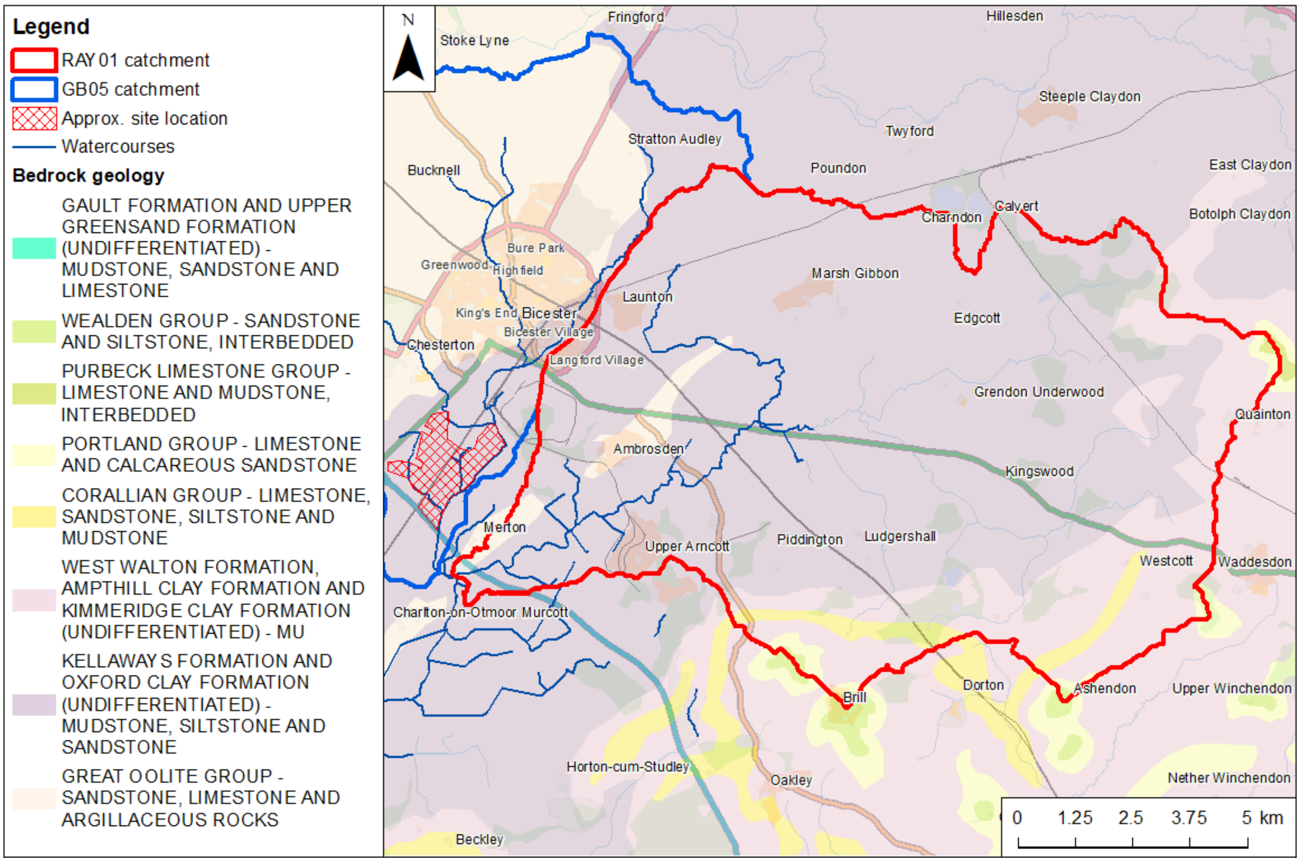


8.11 Flow estimation for the River Ray catchment

As noted in Section 1.1 of this report, the study has been extended to include preparation of design flow estimates for the River Ray (located towards the east of the catchment). This section summarises the methods applied for estimating peak flow for use within the hydraulic model.

It should be noted that, as this was a secondary objective of this study identified after project inception and preparation of initial hydrology, it was deemed appropriate to apply the same methods as utilised in the main stage of the study. Subsequently, estimates of peak flow have been derived using the FEH Statistical method.

8.11.1 Catchment map



8.11.2 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Water course	Name or description of site	Easting / Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
RAY02	L	River Ray	Downstream extent of the River Ray	457000 / 216850	131.63	133.76

8.11.3 Catchment descriptors

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
RAY01	0.986	0.32	0.283	16.48	20.3	625	0.027	0.277
Note: Red text indicates that values have been amended from the FEH values. URBEXT values have been updated to the current year (2019).								

Record how catchment boundary and descriptors were checked and describe any changes	The FEH catchment boundaries have been checked against topographic information for the area (including the Environment Agency 2m LIDAR data), OS mapping and river network information. Some amendments were made to the catchment boundaries in order to better reflect the topographic catchments shown in LIDAR. These correspond with the changes in catchment area made to the main Wendlebury catchments. As the changes to the catchment boundaries are relatively small the original FEH DPLBAR values were retained. A qualitative check of the URBEXT values was made by comparing the FEH values and URBEXT layers to current OS mapping. There were some changes across the catchment compared to the URBEXT extents. Therefore it was deemed appropriate to amend the URBEXT values across the study area using URBAN50k values. This is consistent also with the approach for the main study. The FEH URBEXT2000 value (updated to 2019) is 0.008. This compares to 0.027 from the URBAN50k method.

8.11.4 FEH Statistical method

Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m³/s) (from catchment descriptor)	Final method	Data transfer					Urban adjust-ment factor (UAF)	Final QMED estimate (m³/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, (A/B)[a]	If more than one donor			
						Weight	Weighted ave. adjustment		
RAY01	19.90	DT	33018	28.32	0.963	-	-	1.022	19.58

Search for donor sites for QMED

Comment on potential donor sites	For the River Ray (RAY01), a separate search for donor stations has been completed given its difference in catchment characteristics compared to the Wendlebury Brook catchments. 33018 (Tove @ Cappenham Bridge) has been selected as the most suitable donor site given it was most similar to the subject site in terms of its catchment descriptors (area, BFIHOST and URBEXT etc). In addition, this site has 54 years' worth of data. Two alternative sites were also identified due to being located in closer proximity to the River Ray catchment, these are 33005 (Bedford Ouse @ Thornborough Mill) and 33057 (Ouzel @ Leighton Buzzard). However, these sites were not selected for the following reasons: • 33005: although this is located in closest proximity to the subject site (12km away), the catchment is almost 3 times the size of the subject catchment and less similar in terms of BFIHOST. Therefore, it is considered less likely to be hydrologically similar. • 33057: This catchment is located 27km away from the subject site, however the 33018 gauge (which has been selected as the donor site) is only 1km further away than this and considered to be more representative of the River Ray.

Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
33018	33018 (Tove @ Cappenham Bridge) has been selected as the most suitable donor site given it was most similar to the subject site in terms of its catchment descriptors (area, BFIHOST and URBEXT etc). See discussion in Section above.	AM	N/A	16.95	19.61	0.864

Derivation of pooling groups

Name of group	Site code from whose descriptor group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons.	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
RAY01_PG	RAY01	No	The stations included within the pooling group were considered and the following observations / amendments were made. Stations removed • Owing to the impermeable nature of the subject site, highly permeable stations with a BFIHOST value >0.65 were removed from the pooling group. This includes: o 33029 (Stringside @ Whitebridge) o 33019 (Thet @ Melford Bridge) o 33021 (Rhee @ Burnt Mill) o 33007 (Nar @ Marham) Stations added • Following removal of the less suitable stations noted above, several alternative and impermeable stations were added to provide additional years worth of data to inform the pooling group to the recommended length of 500-years. o 15008 (Dean Water @ Cookston) o 37003 (Ter @ Crabbs Bridge) o 37014 (Roding @ High Ongar) The total record length with these included is 497-years.	L-CV = 0.219 L-skew = 0.119

Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
RAY01	P	RAY01_PG	GL has been deemed as most suitable for this pooling group.	Growth curve adjusted using v4 urban adjustment.	Location = 1.000 Scale = 0.220 Shape = -0.123	2.36

Notes
Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis
A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.
Urban adjustments are all carried out using the method of Kjeldsen (2010).
Growth curves were derived using the procedures from Science Report SC050050 (2008).

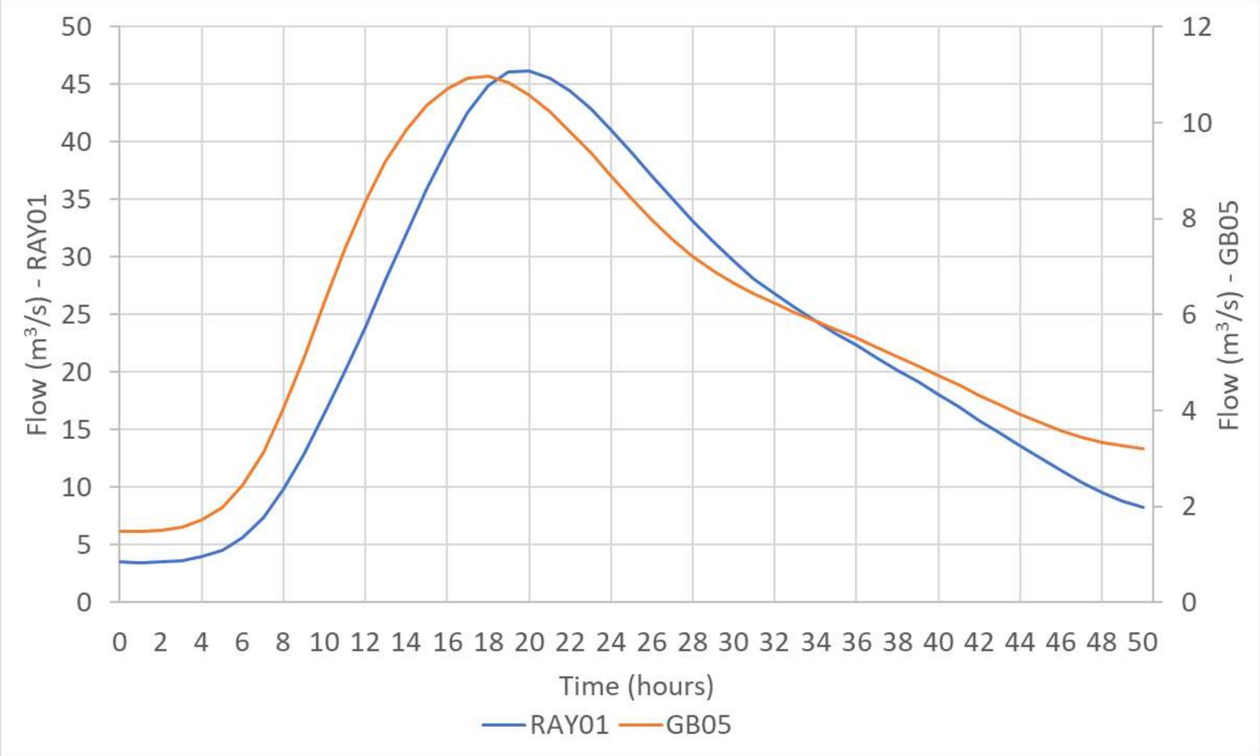
Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	30	50	75	100	200	1000
RAY01	19.58	26.09	30.44	34.86	37.55	41.08	44.02	46.19	51.72	66.47

8.11.5 Choice of method

Choice of method and reasons	An additional estimate has been derived for the River Ray for input to the hydraulic model. This has been derived using the FEH Statistical Method for consistency with the main modelling / hydrology approach. This is also considered appropriate given the catchment is impermeable and therefore the use of the REFH2 method may overestimate flows/volumes for this type of catchment.
How will the flows be applied to a hydraulic model?	Hydrographs are required to apply inflows to the hydraulic model. For the River Ray (RAY01) it is recommended that the REFH1 model is used to derive hydrograph shapes, given that REFH2 has been known to overestimate for catchments with low BFIHOST (such as the Ray). However, it should be noted that this is not considered to be of significance given that the hydrograph is going to be scaled to match the FEH Statistical peak flow anyway. The REFH hydrographs for the Ray catchment will use the same storm duration as used within the main catchment inflows. A comparison of the hydrographs at RAY01 and GB05 is provided below and shows that the RAY01 catchment peaks around 2-hours prior to the GB05 estimation point, located on the main watercourse just upstream of the confluence with the River Ray. This is justified given the change in catchment characteristics (e.g. permeability) and catchment area between the two catchments, resulting in the catchments peak at roughly the same time.

Comparison of RAY01 and GB05 hydrographs (1% AEP event)



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