TECHNICAL NOTE

WATER | ENVIRONMENT

Water Environment Limited
6 Coppergate Mews
Brighton Road
Surbiton
London
KT6 5NE

Tel: 020 8545 9720

www.WaterEnvironment.co.uk

PROJECT	Bradley Petrol Filling Station Huddersfield, South Yorkshire	CLIENT	MBH Design Studio Ltd			
TITLE	Flood Risk Assessment	REFERENCE	23030-FRA-TN-01			C01
AUTHOR		CHECKER	APPROVER			
Ewan Andrew BEng (Civil) MSc (Env Acoustics)		Gabriel Eve MEng (Civil & Environmental)	Tony Clothier PhD, BSc Eng, (Civil) CEng, CEnv, C.WEM			
REV	COMMENTS		DATE	AUTH	CHKR	APPR
P01	First issue		13/05/2023	EA	GE	TC

1 Introduction

1.1 Water Environment was commissioned by MBH Design Studio to produce a Flood Risk Assessment (FRA) for the proposed development on the site at Bradley Petrol Filling Station (PFS) located on Leeds Road in Huddersfield (HD5 0RL). The site is located within the jurisdiction of the Kirklees Council (KC), who also fulfil the role of Lead Local Flood Authority (LLFA).

1.2 The GOV.UK Flood Map for Planning[1] shows the site to lie within Flood Zone 2 and therefore a Flood Risk Assessment (FRA) is required to support a planning application on the site.

1.3 This document has been prepared with due consideration of the National Planning Policy Framework[2] (NPPF), associated planning practice guidance (PPG) for Flood Risk and Coastal Change[3] and the Environment Agency's (EA) Flood Risk Standing Advice (FRSA)[4]. In addition, this FRA will address local requirements for planning including the KC Policy LP27 – Flood Risk.

1.4 The proposed development is deemed as a "minor" development and is therefore able to follow the Environment Agency (EA) FRSA.

2 Description of Development

2.1 The site is known locally as the BP Petrol Filling Station. The site is bounded by Leeds Road to the south, Lower Quarry Road to the west, Fearnley Mill Drive to the east along with commercial properties adjacently located to the north.

2.2 The River Colne is a tributary of the River Calder.

[1] https://flood-map-for-planning.service.gov.uk/ accessed 15/05/2023
[2] Ministry of Housing, Communities and Local Government, Updated National Planning Policy Framework, July 2021
[3] Flood risk and coastal change - GOV.UK (www.gov.uk) accessed 15/05/2023
[4] https://www.gov.uk/guidance/flood-risk-assessment-standing-advice accessed 15/05/2023

2.3 The River Calder lies approximately 25 m northeast of the site at its closest point. The River Colne lies approximately 400 m southeast of the site. The exact location of the site in relation to the surrounding area and the watercourses can be seen in Figure 1.

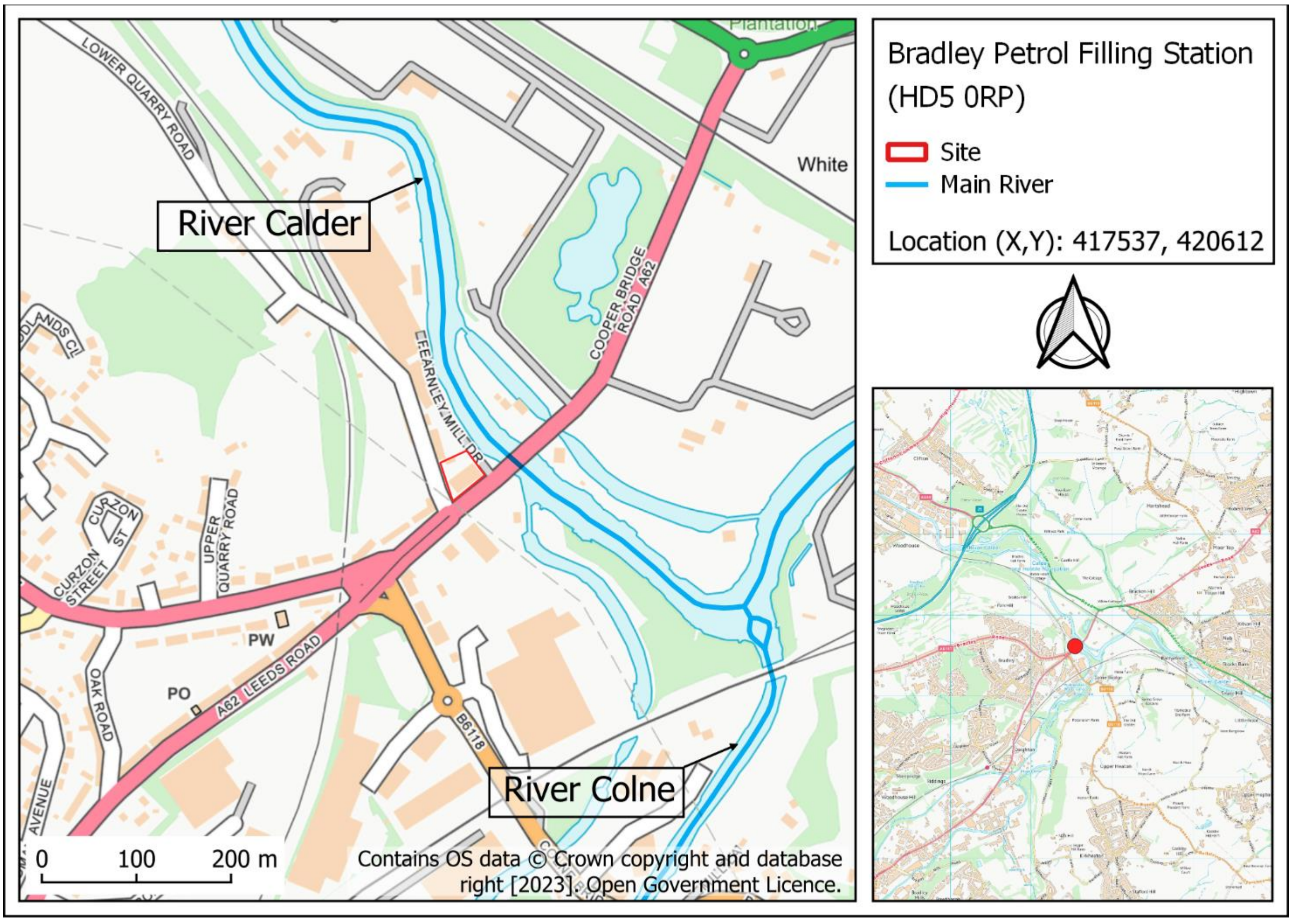


Figure 1: Site Location

2.4 The existing site is in use as a petrol filling station with sales building, car wash and customer parking.

2.5 The proposals include the removal of the existing car wash bay and the creation of two new jet washers with the installation of five new electric vehicle charging bays, with an associated electrical sub-station, power packs and charging points, which are to be located along the northern boundary of the site. The proposed electric vehicle charging bays and new jet washers which have also been proposed to be located along the northern boundary of the site.

2.6 The existing access routes to the site, from Leeds Road, are to be maintained post-development. The current and proposed development drawings are in the appendix of this technical note.

2.7 No topographic survey of the site has been undertaken; as such, the latest available LiDAR data has been used to determine ground levels around the site. The LiDAR for the site and surrounding area is shown in Figure 2.

2.8 Ground levels are shown to range from 51.7 m Above Ordnance Datum (AOD), around the location of the existing sales building along the eastern boundary, to 54.5 m AOD around the north western corner of the site, at the location of the proposed jet wash bays.

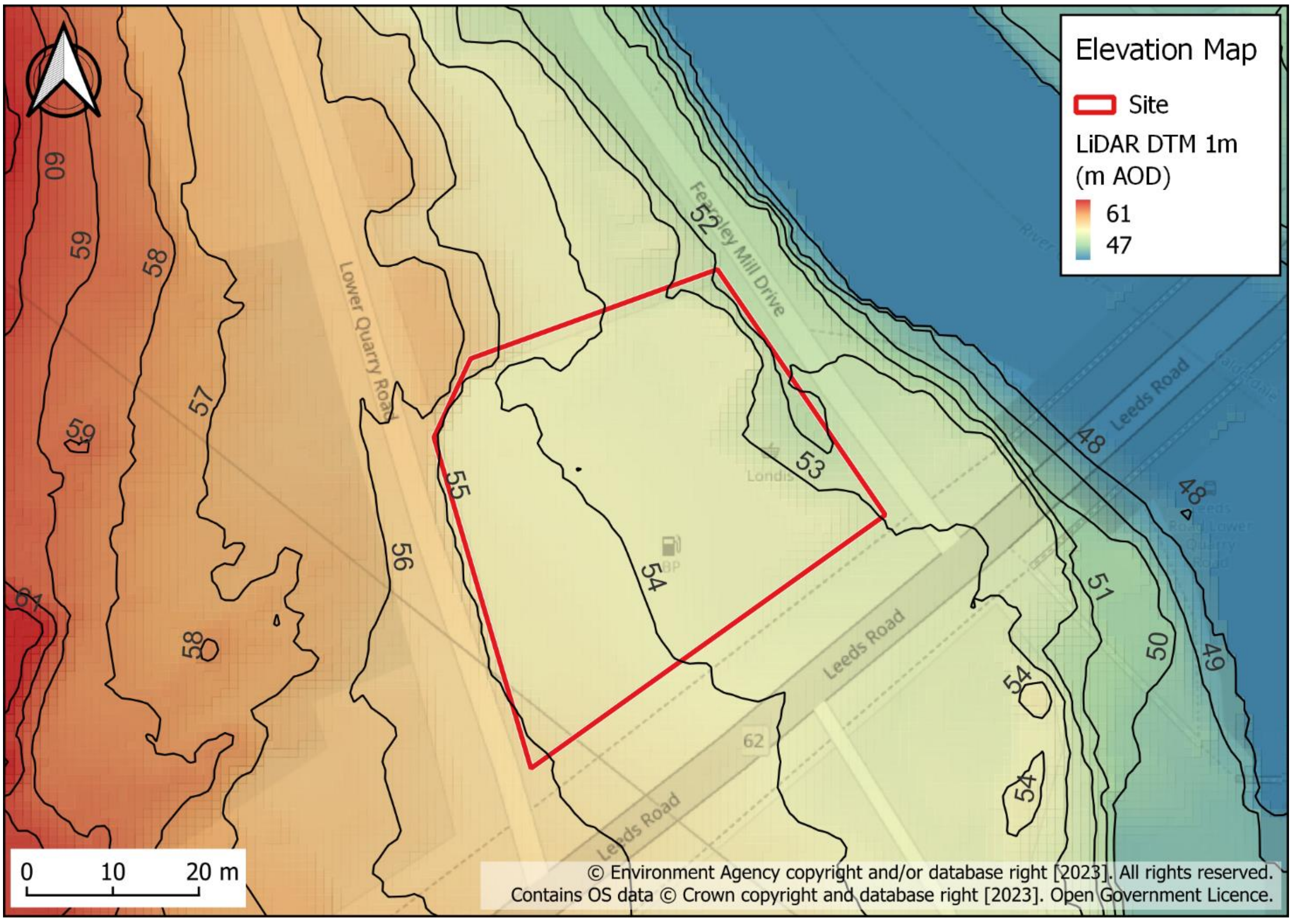


Figure 2: Elevation Map

3 Assessment of Flood Risk

3.1 In assessing the risk of flooding for the site, the Preliminary Flood Risk Assessment (PFRA)[5] and Strategic Flood Risk Assessment (SFRA)[6] (joint venture with Wakefield Council and Calderdale Council) have been reviewed alongside the latest EA flood data.

3.2 No section 19 Flood Investigation Reports have been discovered which relate to the site's location.

History of Flooding

3.3 The EA Historic Flood Map show the site to lie within the recorded extent of a flood event in December 2015. Flooding is shown to have originated from the River Calder and is assumed to have been fluvial in nature.

3.4 The PFRA includes details of past flooding incidents within Kirklees. The site is shown to lie in an area which is noted to have been affected by two previous flooding events which occurred in the summers of 2004 and 2007.

3.5 The flooding which occurred in July 2007 was noted as having been the most severe flooding event on record, with over 400 properties across the Kirklees district having been noted to have flooded. The Flooding event was reported to have stemmed from a heavy rainfall event which inundated the sewer system and was retained within roadways. Neither the PFRA nor SFRA note specific properties which

[5] Kirklees Council, Calderdale Council, Wakefield Council. Preliminary Flood Risk Assessment, 2011
[6] Kirklees Council, Calderdale Council, Wakefield Council. Calder Catchment Strategic Flood Risk Assessment, April 2016

were affected during this event so it cannot be confirmed whether the site was affected specifically by surface water event.

3.6 No further historic flood records have been identified for the site.

Risk of Flooding from Rivers & Sea

3.7 The site is not at risk of flooding from the sea due to its high elevation above sea level.

3.8 The published GOV.UK Flood Map for Planning shows the site is located wholly within Flood Zone 2 (Figure 3). At this location, Flood Zone 2 is defined as land having between 1% and 0.1% annual probability (medium probability) of river flooding. No flood storage areas are present in the proximity of the site. A section of flood defences along the western bank of the River Calder are shown adjacent to the site.

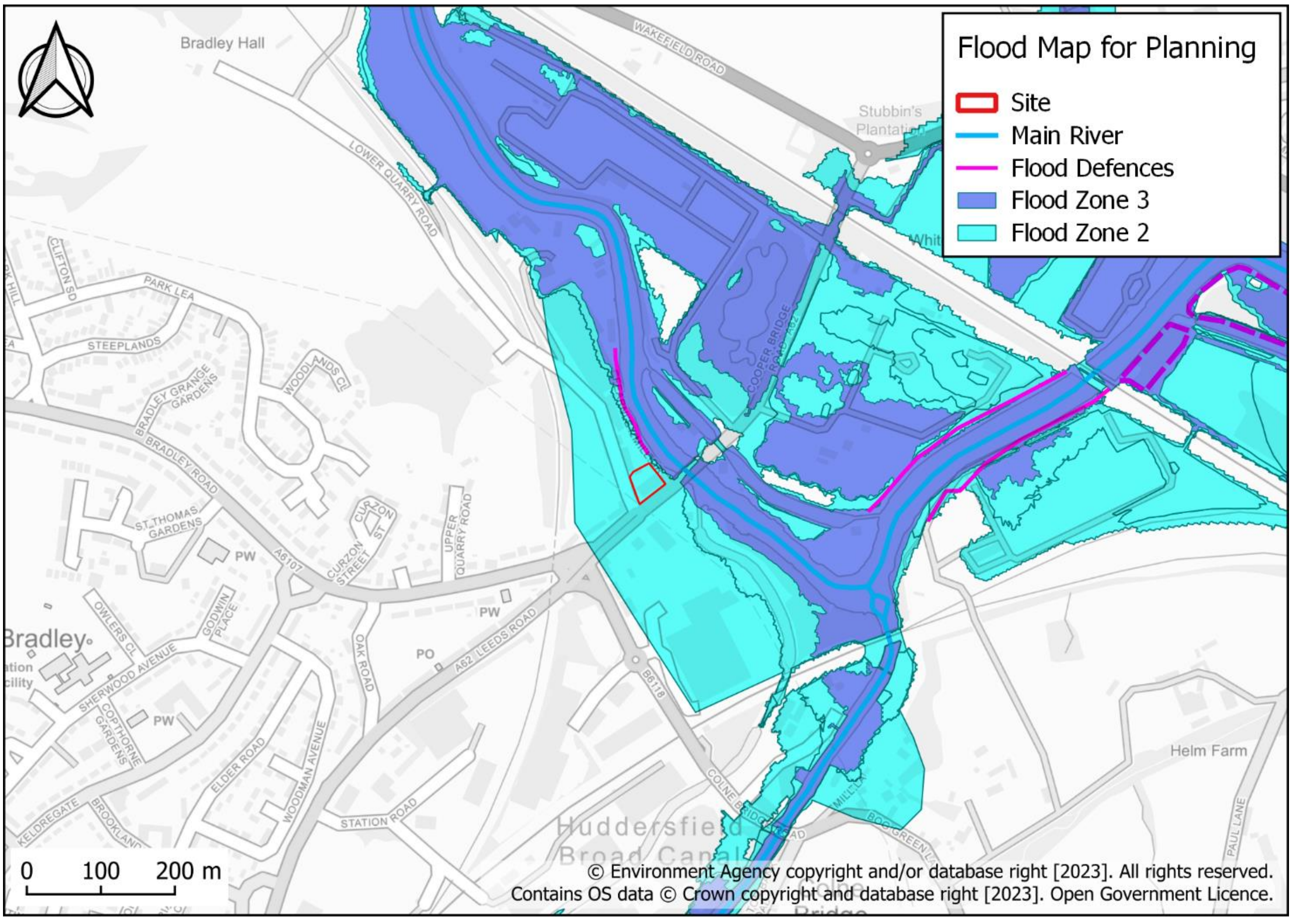


Figure 3: Flood Map for Planning

3.9 Flood Zone 3 equates to 'high' risk (which for fluvial sources equates to a greater than 1% Annual Exceedance Probability - AEP). Areas in Flood Zone 1 (not highlighted) equate to less than 0.1% AEP of fluvial or tidal flooding.

3.10 Detailed hydraulic modelling has been undertaken by the EA as part of the River Calder and Canals Model Study (JBA Consulting 2015). The EA have provided the latest detailed flooding information relevant to the site via a flood risk information Product 4 request (see Appendix). The data provided includes modelled floodplain extents, depths and flood flows. Modelled events include defended and undefended scenarios for the 20% AEP (annual exceedance probability), 5% AEP, 3.33% AEP, 2% AEP, 1.33% AEP, 0.5% AEP and 0.1% AEP events.

3.11 The NPPF requires the current and future impacts of climate change to be assessed over the lifetime of the development. These modelled levels include a peak river flow climate change allowance of 20%, which was in use until February 2016 and has now been superseded. The EA climate change allowances guidance[7] contains the most up-to-date information on assessing the impacts of climate change in Flood Risk Assessments. Peak river flow allowances show the anticipated changes to peak flow in each management catchment.

3.12 The River Calder belongs to the Aire and Calder Management Catchment and the expected lifetime for the proposed scheme is 75 years due to the non-residential use. The 2080s epoch allowances will be used to assess fluvial flood risk over the lifetime of the development. The peak river flow climate change allowances for the development are shown in Table 1.

Table 1: Peak river flow allowances by management catchment

Management Catchment	Allowance Category	Total potential change anticipated for the '2080s'
Aire and Calder	Upper	51%
	Higher	31%
	Central	23%

3.13 According to the flood risk vulnerability classification (Annex 3 of NPPF), the proposed development is classified as 'less vulnerable' in terms of flood risk. For development located in Flood Zone 2 or Flood Zone 3a, the use of the 'central' allowance is recommended on peak river flow, it is therefore estimated that the total potential increase would be 23%. The current 1% AEP plus 20% climate change scenario will therefore be used to assess the 'design event' with consideration also given to the more extreme 0.1% AEP event.

3.14 The flood water depth during the 0.1% AEP event in relation to corresponding ground levels is shown in Figure 4. As shown, the site is not within the flood extent of the 0.1% AEP event, and by comparing with LiDAR contour levels, the maximum flood level adjacent to the site is less than 52 m AOD. The 1% AEP + 20% climate change flood depths are significantly less than in the 0.1% AEP event, therefore the site is not expected to flood from a fluvial event up to the design event (1% AEP plus 23% climate change event).

3.15 Furthermore, the site is not expected to flood in the 0.1% AEP event. Ground levels at the location of the electrical substation are approximately 53.18 m AOD, greater than 1 m above the estimated 0.1% AEP flood water level.

3.16 While the hydraulic modelling data from the River Calder and Canals Model Study shows the site is not expected to flood in the extreme 0.1% AEP event, the EA historic flood map shows the site to lie within the recorded extent of the flood event in December 2015, which is shown in Figure 5, in relation to corresponding ground levels. The flood outline would be expected to generally follow the contour of a certain level of ground, as can be seen with the 2020 February flood incident and the 49 m AOD contour line. The recorded flood outline for the December 2015 flood event is shown to span across ground levels varying from 52 m AOD to 65 m AOD. This implies a flood level up to 13 m higher than the 0.1% AEP event – an implausible level - therefore the recorded flood outline is not considered a reliable record in this area. No further information was found to back up the recorded flood extent, however it is considered implausible to be from fluvial flooding only, but may represent a broader area of development that

[7] Environment Agency. Flood risk assessments: Climate change allowances. https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances. Accessed 5/05/2023.

simultaneously experienced flooding from surface water or surcharging sewers due to the high river levels. These other sources of flooding are considered in later sections of the report.

3.17 The proposed development is considered to be at low risk from fluvial flooding.

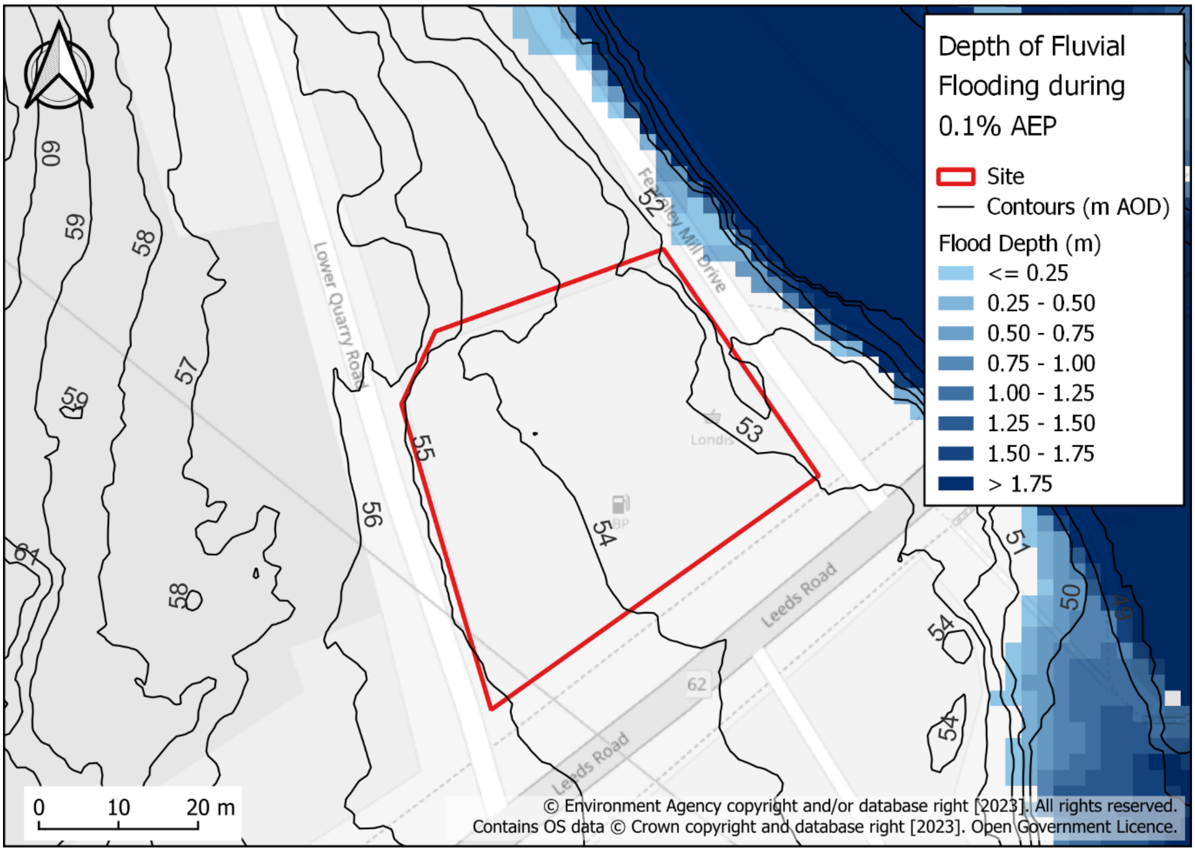


Figure 4: Modelled depth of flooding during 0.1% AEP fluvial event

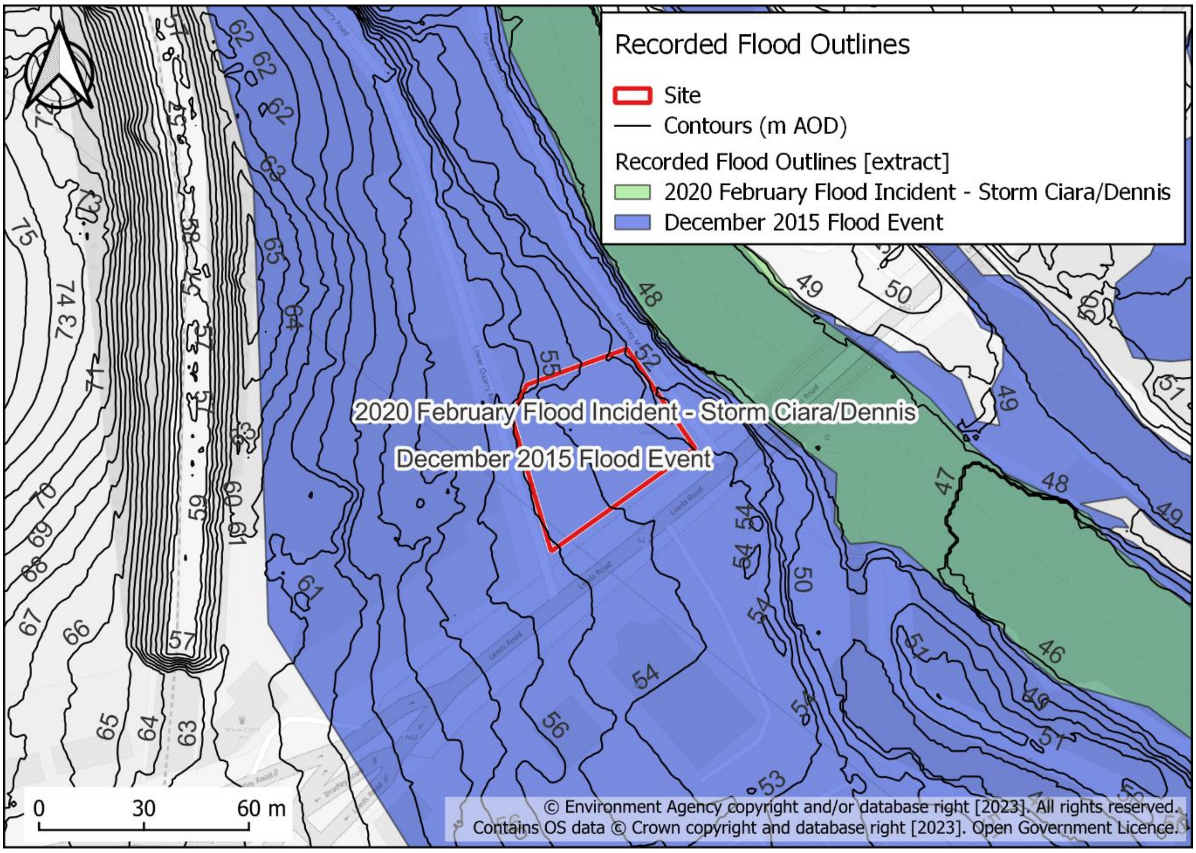


Figure 5: Recorded Flood Outlines

Risk of Flooding from Surface Water

3.18 Flooding from surface water can occur following intense local rainfall events when floodwater is unable to infiltrate into the ground or discharge into natural or artificial drainage infrastructure. In an urban environment, the risk of flooding from surface water and from overloaded sewers is closely related, and both are included in the relevant surface water flooding datasets. Floodwater subsequently follows the topography of the local area. Surface water flooding events are typically of a short duration but can be severe.

3.19 A CDA is an area that has critical drainage problems, and which has been notified to the local planning authority by such statutory consultees such as the Environment Agency. Typically, these areas are at high risk of surface water flooding. The SFRA noted that Bradley is not located within a Critical Drainage Area (CDA).

3.20 The GOV.UK online flood mapping includes the risk of surface water flooding. These maps are a useful tool in assessing the extent and frequency of flooding in a general area but do come with a caveat that they should not be used for site specific development or property level. Therefore, engineering judgement is required when using these maps for this purpose.

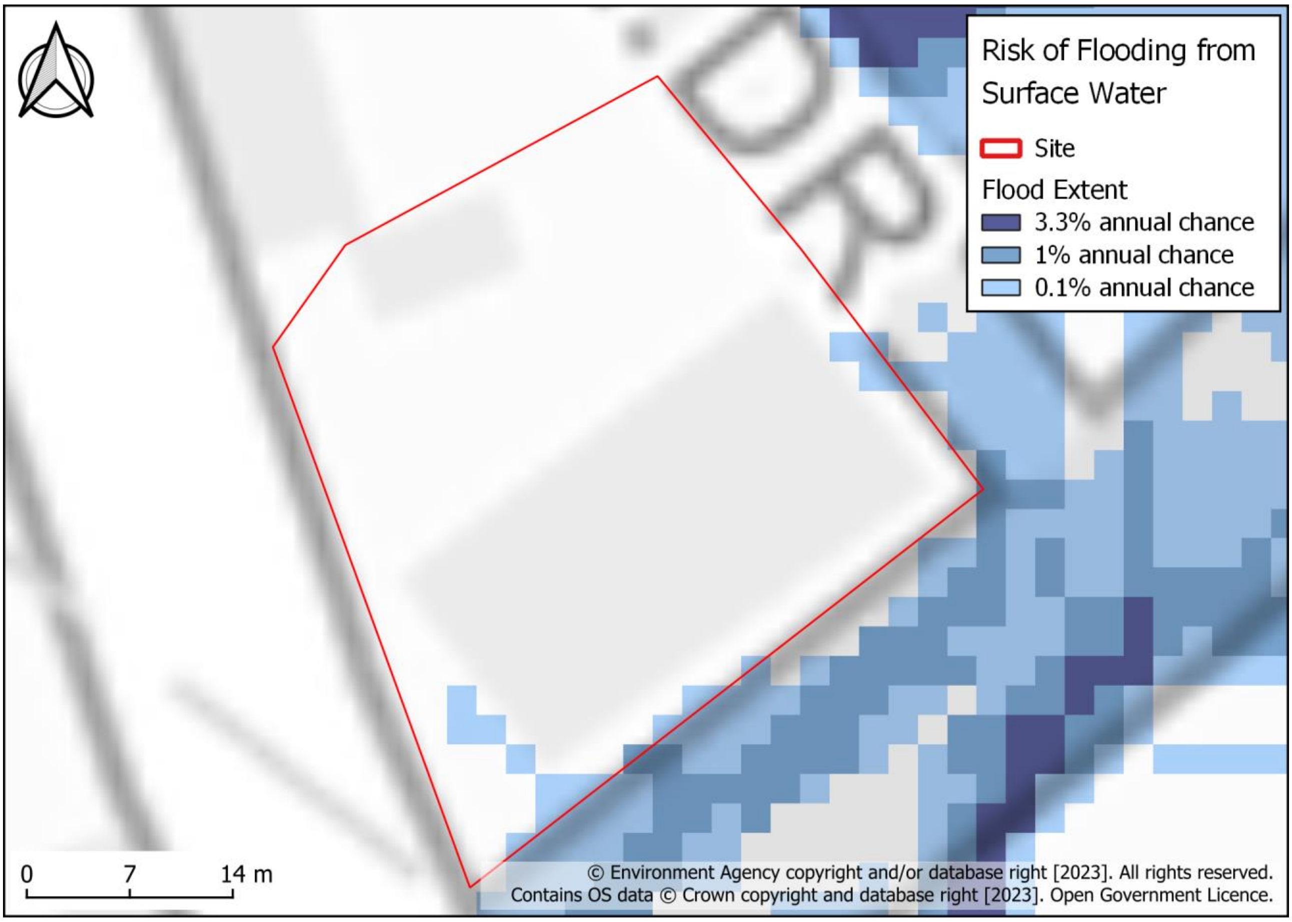


Figure 6: Risk of Flooding from Surface Water - Extent

3.21 Figure 6 illustrates the GOV.UK surface water flooding extent map for the site and surrounding area (RoFSW). The dark blue shaded areas show locations of high surface water flood risk, which have a greater than 3.3% (1 in 30) annual probability of flooding, lighter blue areas show medium risk of between 3.3% and 1% (1 in 100) annual probability of flooding and the pale blue areas indicate low risk regions of between 1% and 0.1% (1 in 1000) annual probability of flooding. Areas that are not highlighted in blue are classed as having a very low risk of surface water flooding, with a less than 0.1% annual probability of flooding.

3.22 Figure 6 shows the majority of the site to be at "very low" risk of flooding from surface water, while areas closest to the access ways onto the site are shown to be at "low" risk of flooding from surface water. As such, further investigation of the GOV.UK maps will be required.

3.23 The design event is the 1% AEP plus climate change event. It is important to note that surface water maps do not include future climate change, therefore it is common practice to evaluate the 1% AEP event as well as the 0.1% AEP event as a sensitivity test for what might happen in the future over the lifetime of the development. In this way it is possible to use the worst-case scenario (0.1% AEP) as a surrogate for the design 1% AEP plus climate change event.

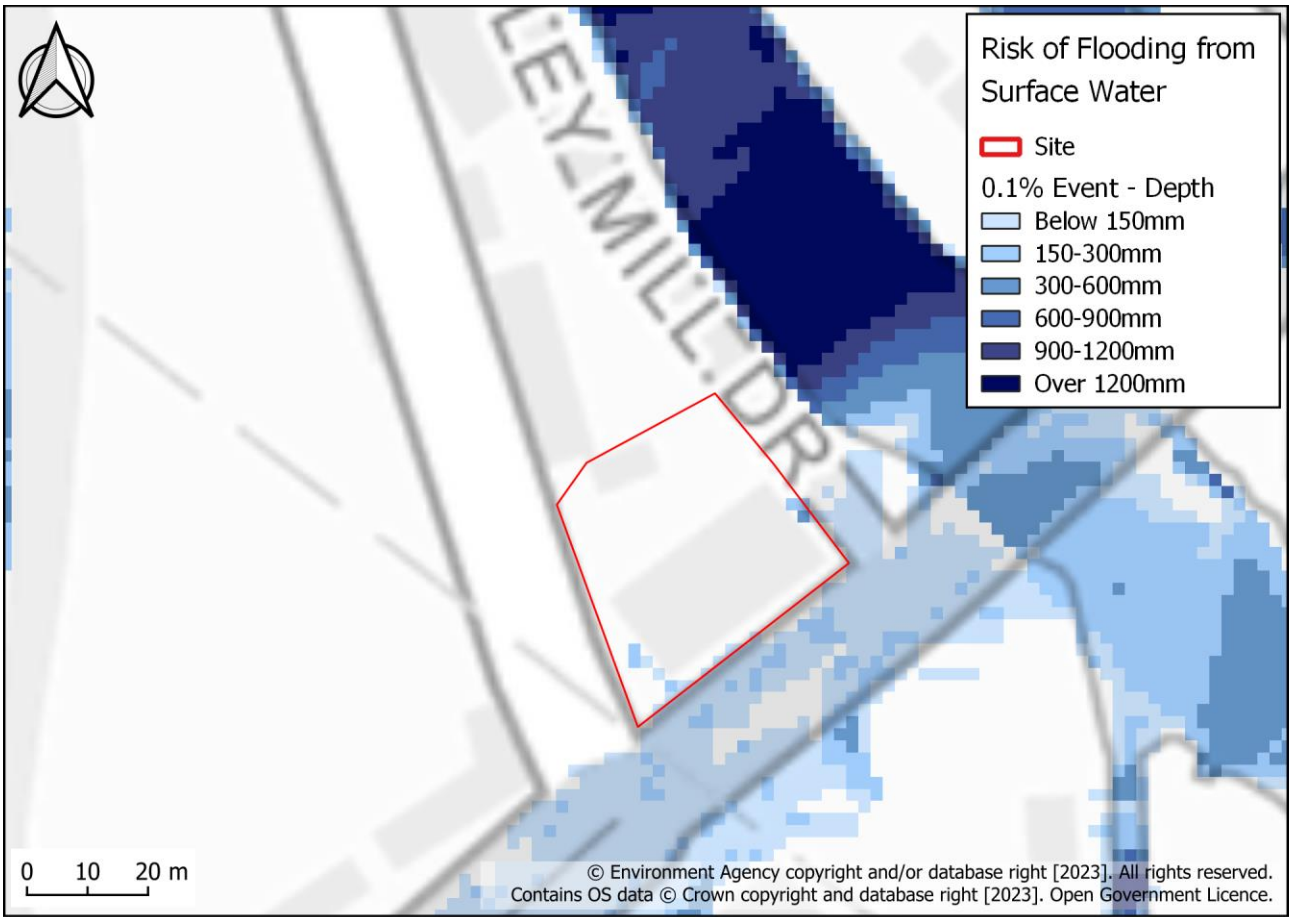


Figure 7: Risk of Flooding from Surface Water depth of flooding – 0.1% annual exceedance event

3.24 A map indicating the estimated surface water flood depths in the 'Low' risk event (0.1% AEP event), provided by GOV.UK, is shown in Figure 7. This figure shows that, although the majority of the site is expected not to flood, a couple of low spots could reach up to 600 mm depth of flooding, located to the rear of the on-site sales building.

3.25 Ground levels around the area affected by 600 mm of surface water flooding is found to be approximately 51.7 m AOD. Ground levels around the proposed location of the electrical sub-station are approximately 52.8 m AOD. This means that the electrical substation is positioned on ground raised 500 mm above the surface water flood level during the 'low' occurrence 0.1% AEP event.

3.26 The event shown in Figure 7 (0.1% AEP event) is more extreme than the design flood event (1% AEP event including climate change) and is considered a precautionary substitute for this assessment.

3.27 The surface water flooding shown is part of the widespread surface water flooding along the banks of the River Calder. Depths of flooding are shown to rise the closer it gets to the River Calder. The direction of surface water flow is therefore away from the site, towards the River Calder due to the local topography.

3.28 The proposed on-site development is not located on a surface water flow path and is above the surface water flood level and is therefore the risk of flooding from surface water is considered to be low.

Risk of Flooding from Sewers

3.29 Sewer flooding generally results in localised short-term flooding caused by intense rainfall events overloading the capacity of sewers. Flooding from sewers and highways is linked to the risk of flooding from surface water in urban areas, with the exact source of flooding often indistinguishable.

3.30 A plan showing the location of Yorkshire Water sewer assets close to the site is provided in the Appendix. The plans show a 225 mm foul sewer running from north to south along Lower Quarry Road which connects to a foul sewer running from east to west along Leeds Road. The plans also show a 225 mm surface water sewer running along Leeds Road in an easterly direction.

3.31 The SFRA was reviewed for DG5 records stating whether any surcharges or other relevant flooding incidents had been recorded in the area, but no such data was found.

3.32 In the event of sewer flooding along Leeds Road, any flow surcharging of the local drainage system at ground level would follow the local topography of the local area and likely drain towards the River Calder as it would follow localised flow paths.

3.33 It is considered that the risk to the development from sewer flooding, as a separate source of flooding from surface water, is low. However, due it's proximity to the River Calder, there is potential for surcharging sewers during an extreme fluvial event.

Risk of Flooding from Groundwater

3.34 Groundwater flooding occurs as a result of water rising up from an underlying aquifer or flowing from springs. This tends to occur after much longer periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is likely to be at shallow depth.

3.35 Groundwater flooding can interact with other sources of flooding, exacerbating their risk by reducing the infiltration of flood water to ground. The primary mechanisms for elevated groundwater at the site are associated with periods of above average rainfall in permeable superficial deposits and hydraulic continuity of these deposits with high river water levels.

3.36 The online 1:50k British Geology Society (BGS) map[8] indicates that the site has no superficial deposits directly beneath the site. The bedrock geology is the Pennine Lower Coal Measures Formation. The Pennine Lower Coal Measures Formation typically consists of mudstone. This is shown in Figure 8.

3.37 The DEFRA Magic Maps[9] show that the bedrock is classified as a 'Secondary A' aquifer, which is defined as having a permeable stratum capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

3.38 The DEFRA Magic Maps show that the site is not located within a groundwater Source Protection Zone (SPZ).

3.39 There is no onsite ground investigation available. Therefore, publicly available BGS borehole records have been used to verify local ground conditions. The nearest BGS borehole record (SE12SE894) to the site is located to the south, within 175 m of the site. the borehole confirmed the presence of silty mudstone located beneath the superficial layer of made ground. Groundwater was noted as having been encountered at a depth of 4.4 m Below Ground Level (BGL). This should be below any proposed underground utilities.

[8] Available at: https://mapapps.bgs.ac.uk/geologyofbritain/home.html accessed: 15/05/2023
[9] https://magic.defra.gov.uk/MagicMap.aspx accessed 15/05/2023

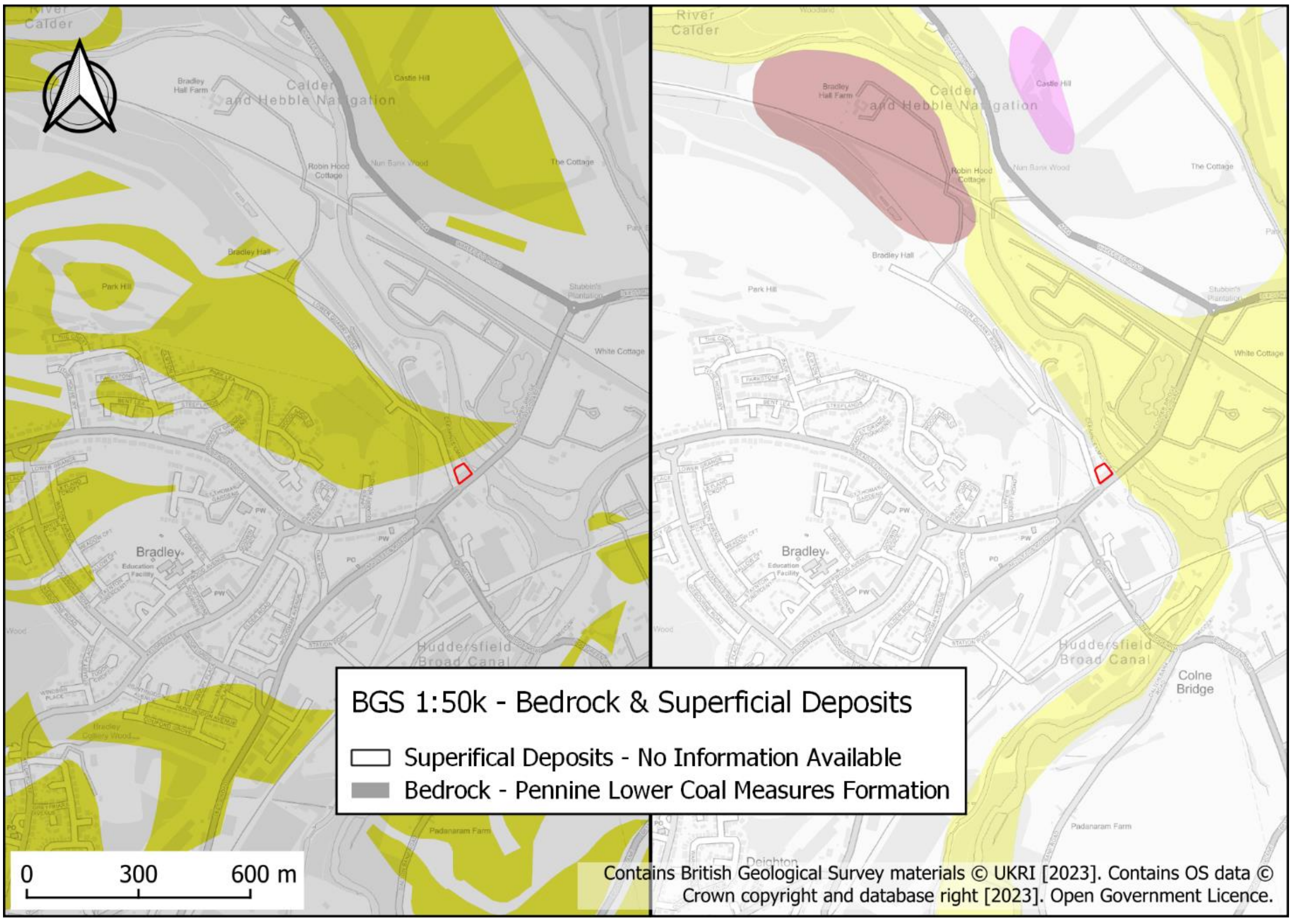


Figure 8 BGS Geology

3.40 The site and the immediate surrounding area are predominantly hard paved, which reduces the risk of emergence of groundwater at the surface. In the unlikely event that groundwater does emerge at the surface, it would follow localised flow paths such as those shown in the surface water flooding maps; therefore, any flooding experienced would likely be like that shown on surface water risk mapping. This would flow overground and discharge to the local sewer system.

3.41 The main concern in relation to high levels of groundwater is the potential exacerbation of fluvial flooding associated with the River Calder. In this case it is not seen as appropriate to separate these causes of flood risk. Therefore, the response to groundwater flooding is considered as an extension of the response to fluvial flood risk, covered in proceeding sections of this technical note.

Risk of Flooding from Artificial Waterbodies

3.42 The GOV.UK 'Risk of Flooding from Reservoirs' online map shows that the development location does not lie directly within an area affected by flooding in the event of the failure of reservoirs. However, when there is high rainfall event and local watercourses are susceptible to out of bank flooding, the site could be affected by these two sources of flooding occurring simultaneously, as shown in Figure 9.

3.43 The Environment Agency are the enforcement authority for the Reservoirs Act 1975 in England, they ensure that reservoirs are inspected regularly, and that all essential safety work is carried out. All reservoirs must be inspected and supervised by reservoir panel engineers. There has been no loss of life in the UK from reservoir flooding since 1925.

3.44 As detailed in preceding sections, the infrastructure is raised as far as possible to protect against the risk of river flooding, with management plans in place in ensure the development is protected in the event of flooding on the site. No further mitigation is required to protect against reservoir flooding.

3.45 The site is not considered to be at risk of flooding from reservoirs and there are no further artificial waterbodies in the area that would constitute a significant risk of flooding to the site.

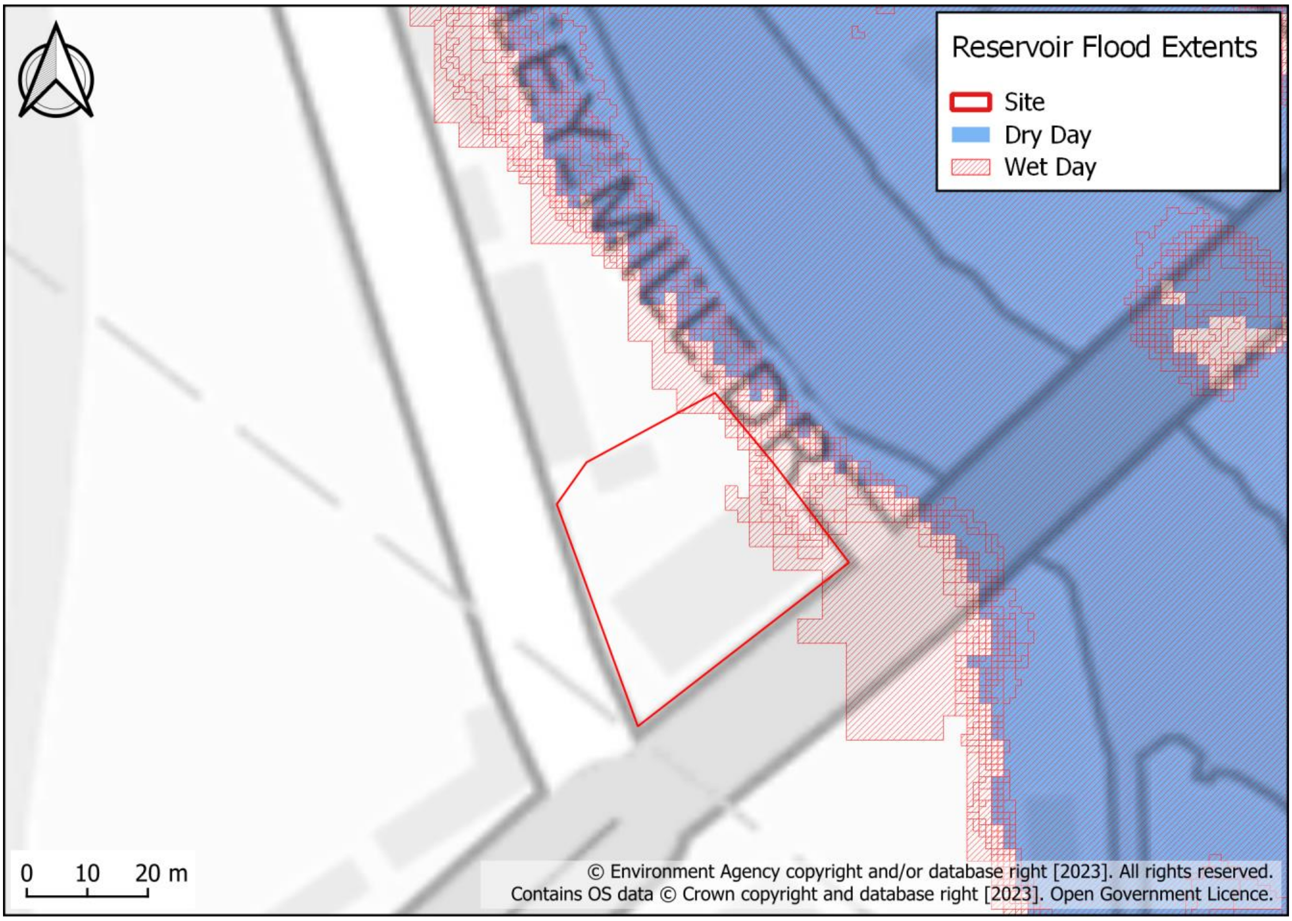


Figure 9: Risk of Flooding from Reservoirs

4 Conclusions

4.1 This technical note has assessed the risk of flooding from all sources.

4.2 The site in shown to be in Flood Zone 2 (medium risk of fluvial flooding) and has been shown not to be at risk of fluvial flooding during the design event (1% AEP plus 20% Climate Change) nor is it at risk during the larger 0.1% AEP event. The Flood Zone 2 designation at the site is based on the recorded flood outline for the December 2015 fluvial flood event, however the reliability of this extent has been questioned due to the implausibility of the implied flood levels.

4.3 The site is shown to be slightly affected by surface water flooding during the 0.1% AEP event; however, the area of development on the site is shown to be located in an area with ground levels raised higher than the surface water flood level during an extreme rainfall event.

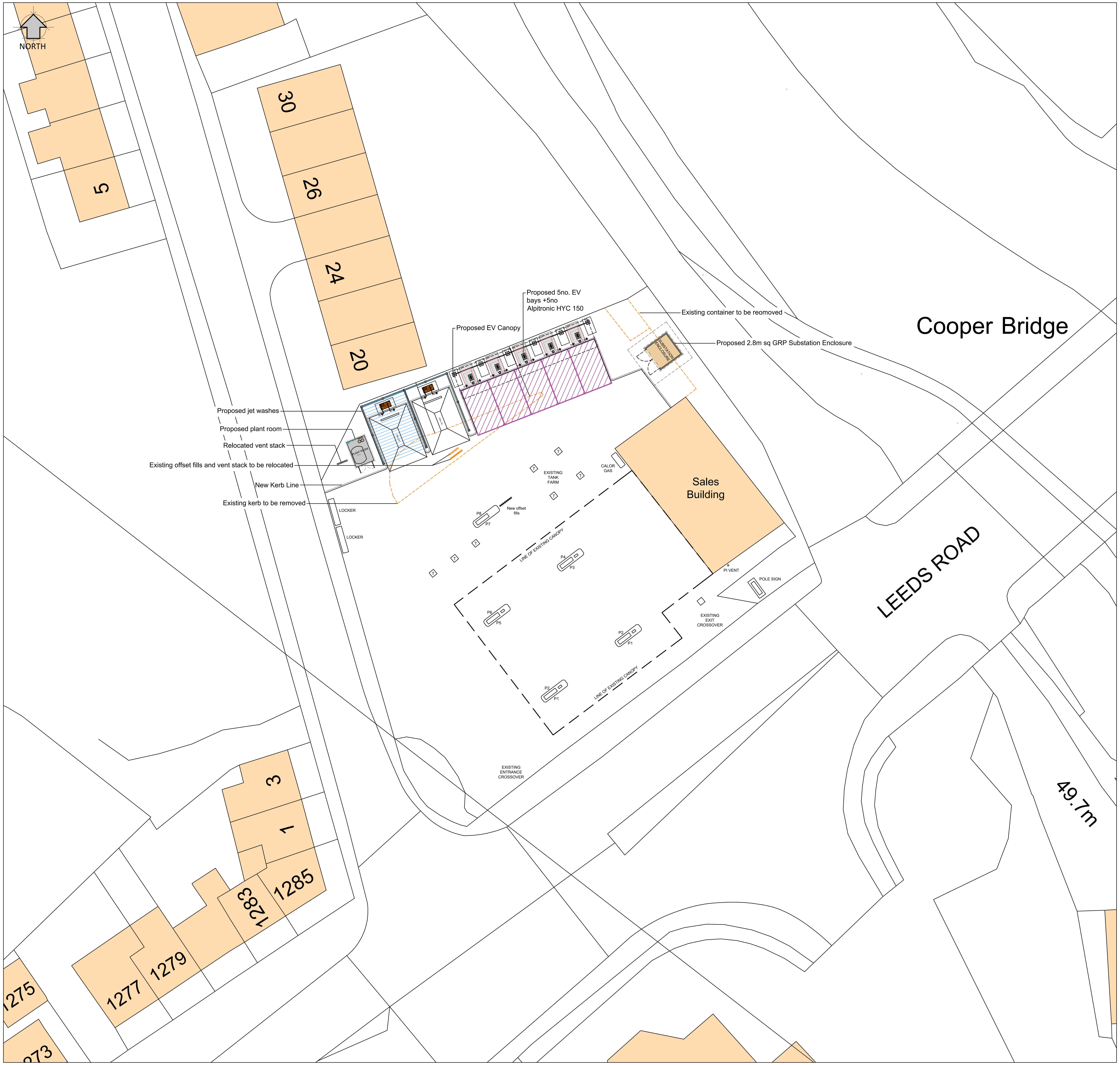
4.4 There are no other sources of flood risk which, in isolation, represent a risk to the proposed development.

4.5 The electrical substation and sales building are to be raised above the forecourt levels which provides some protection from any unforeseen flooding, in accordance with CIRIA guidance.

4.6 The information contained in this report demonstrates that the development proposals comply with the requirements of KC and the NPPF in relation to flood risk.

Appendix

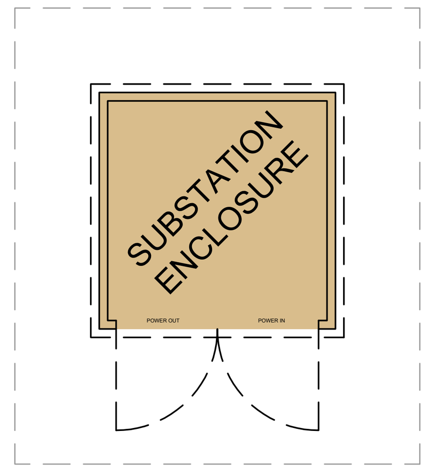
- MBH Design Studio Ltd – Bradley petrol service station, Existing site plan
- MBH Design Studio Ltd – Bradley petrol service station, Proposed site plan
- EA data
- Yorkshire Water– Asset Location Search



EV DRAWING LEGEND

- EXISTING KERB
- PROPOSED KERB
- PROPOSED DROPPED KERB
- DEMOLISHED
- EXISTING LINE WORK
- PROPOSED LINE WORKS
- B PROPOSED EV BOLLARD - RAL 5015
- EXISTING FLOOD LIGHT
- PROPOSED FLOOD LIGHT
- EXISTING FENCE LINE
- PROPOSED FENCE LINE

EV INFRASTRUCTURE LEGEND



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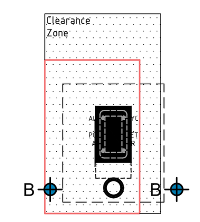

DENOTES CHARGING POST
ALPITRONICS HYC 150

DRAWING NOTES

This drawing has been produced for the project listed below, is submitted in support of this application application to the Local Planning Authority and is not intended for use by any other person or for any other purpose.

Every effort has been made to ensure the accuracy of these drawings, however MBH Design Studio Ltd. accept no responsibility for any discrepancies arising from the reuse of survey information and preliminary drawings commissioned by the Applicant from others.

This drawing is an initial feasibility scheme and is subject to technical review and internal approvals. DNO application process may affect feasibility, provide additional information and require further review of scheme. Feasibility may be affected by other factors as the scheme progresses to working drawing stage and may also be compromised by unforeseen elements encountered on site during installation of works

Scheme Based on OS Map Dated XX.XX.XXXX

REV	DATE	DESCRIPTION	DRAWN/CHECKED
-	-	-	-

REVISION NOTES

PLANNING

MBH Design Studio Ltd.
Rosemount House, Rosemount Avenue, West Byfleet, Surrey, KT14 6LB
www.mbhltd.com t: 01932 352 727 f: 01932 351 545

CLIENT
motor fuel group

PROJECT
FS 665- BRADLEY SERVICE STATION
LRRDS ROAD
HUDDERSFIELD, WEST YORKSHIRE
HD5 0RP

DRAWING TITLE
PROPOSED SITE PLAN

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SCALE - METRES - 1:200 @ A1

DRAWN BY	DATE	SCALE	PAPER SIZE
TN	09.02.2023	1:200	A1
CHECKED BY	DRAWING NUMBER		REV.
RRB	13664-FS 665-21		-

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Scheme Based on OS Map Dated 24.11.2022

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REV	DATE	DESCRIPTION	DRAWN/CHECKED
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REVISION NOTES

PLANNING

mbh

MBH Design Studio Ltd.
Rosemount House, Rosemount Avenue, West Byfleet, Surrey, KT14 6LB
www.mbhltd.com t: 01932 352 727 f: 01932 351 545

CLIENT

mfg motor fuel group

PROJECT
FS 665- BRADLEY SERVICE STATION
LEEDS ROAD
HUDDERSFIELD, WEST YORKSHIRE
HD5 0RP

DRAWING TITLE
EXISTING SITE PLAN

DRAWN BY	DATE	SCALE	PAPER SIZE
TN	09.02.2023	1:200	A1
CHECKED BY	DRAWING NUMBER		REV.
RRB	13664-FS 665-20		-

1 Introduction

1.1 Background

Previous modelling and mapping work has helped to identify those locations along the Calder Valley which have a significant flood risk. The flood history is well documented and the Environment Agency has a good understanding of the mechanisms of flooding. In particular the meteorological conditions leading to and the catchment response during the most recent large event (June 2012) have been investigated in detail by the Regional Hydrology Team.

During the June 2012 flood event the canal system captured a proportion of the runoff that would normally flow directly into the river. This was then readily routed downstream, thereby exacerbating and extending flooding in known problem areas. To better represent flood risk mechanisms caused by interactions between the river and the canal system, the existing River Calder 1D model is being updated to include the Rochdale Canal and the Calder and Hebble Navigation. At the same time the river model is being extended to include Ramsden Clough and Midgelden Brook near Todmorden.

The design flood hydrographs that were applied in the previous mapping (JBA, 2009) are still considered robust, however it was deemed appropriate to derive new hydrological estimates for the updated model. The main reasons for this are:

i) Revised Flood Estimation Guidelines (as detailed in OI_197_08) were issued in June 2012. These reflect a number of recent changes to the FEH methodologies that post-date the previous study, for example see Kjeldsen et al (2008).

ii) A further 4 years of flood peak data has become available since the last study. This period includes a number of notable high flow events including the 2012 flood.

iii) Inflows from a number of small tributary watercourses need to be represented explicitly within the new model (to give the right level of detail with regards to interactions with the canal system). Previously, as is normally preferred, the discharges contributed by such tributaries were quantified based on the difference in the estimated main channel flood peaks up and downstream of the confluence. The inputs from smaller tributaries were lumped together and treated as lateral inflows over a particular length of model. This preserves the statistical design estimates moving downstream but does not necessarily give a realistic estimate of flood flows on the tributary.

1.2 Overview of approach

This study has required slightly more than the adoption of a conventional approach to design flood estimation. The third point raised above is the one that provides most difficulty, chiefly for two reasons, as follows:

i) FEH approaches, whilst deemed more reliable than other potential methods, may give rise to large uncertainties when applied to small catchments, particularly if no suitable donor records are available for refining QMED. A further complication is the nature of the tributaries in this area, which drain exceptionally steep sided valleys and are therefore of a catchment type poorly represented in HiFlows-UK.

ii) Even allowing for the physical representation of flow routing and attenuation processes within the model, specifying tributaries at the 100-year design level (for example) is unlikely to give a combined flow on the Calder that is equivalent to the 100-year design flow based on gauging station data (e.g. Methley) in terms either of hydrograph volumes or peaks.

The aim is to utilise knowledge and calibration data from the 2012 event to determine inflow combinations that are robust and justified.

1.3 Reporting

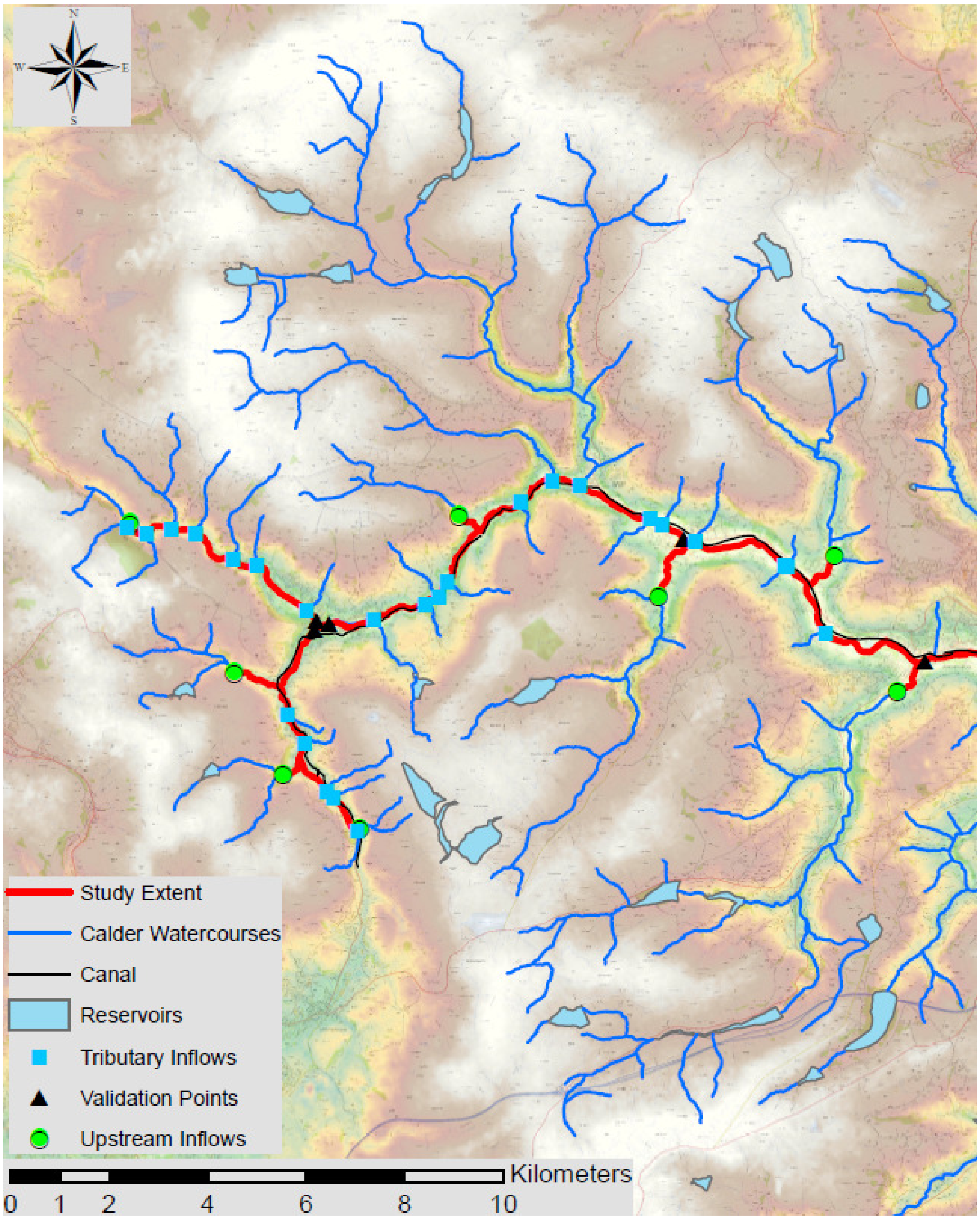
As the hydrological work is being carried out in parallel with the modelling, rather than produced a formal hydrology report, it was agreed the calculations would be reported in the form of an extended FEH calculation supported by a short note outlining the main approach and assumptions.

2 Conceptualisation of the system

2.1 Extent of model

The Calder is being modelled in two sections. The first of these relates to the upper Calder and extends as far downstream as the River Ryburn confluence at Sowerby Bridge. As shown in Figure 1, the lower portions of Walsden Water, Ramsden Clough, Midgelden Brook, Jumble Hole Clough, Cragg Brook, Luddenden Brook and the River Ryburn are included in the model.

Figure 1 - Map of the study area



2.2 Estimation points

Design flood hydrographs are required to define inflow boundaries at the upper limit of each of these 8 reaches. These estimation points are highlighted in green on Figure 1.

Estimates are also required for key tributaries that will need to be represented as independent point inflows to the main river and/or the canal system (depending on the flow magnitude). These tributaries include Colden Clough, Hebden Water, Beaumont Clough, Stoodley Clough and a number of others. In these cases the estimation point is at the very downstream limit of the tributary so that all the contributing upstream catchment is captured in the estimate. The Calder catchment has been divided into a large number of sub-catchments to facilitate this analysis, each contributing its own inflow hydrograph to the model. Catchment sizes range between 59 and 5 km^2. The points highlighted in blue in Figure 1, represent where these inflow points are located. Using aerial photography, maps and survey drawings, attempts have been made to identify whether or not a tributary is influent into the Calder system or the adjacent canal.

Drainage from those remaining parts of the catchment that don't drain to the inflow points shown on the map are lumped together and treated as a diffuse lateral inflow to the model.

Design estimates were also derived for a number of other locations along the main river including:

- Locations of level gauges
- Locations of flow gauging stations
- Key locations (population centres and main flood risk areas)

These were used as validation points rather than to represent model inflows and are highlighted in black on Figure 1.

2.3 Catchment descriptors

Catchment descriptors were derived for each estimation point to the model using Version 3 of the FEH CD-Rom and checked manually. The CD-Rom can only resolve boundaries for catchments above 0.5km^2 in area. Catchment boundaries and descriptors were determined manually for inflow points draining areas smaller than this threshold. Catchment boundaries and areas were derived from a GIS analysis of the 30m resolution ASTER DEM, the DPLBAR descriptor (which represents the mean drainage path length) was estimated from the regression relationship presented as Equation 7.1 in Vol. 5 of the FEH, whilst the remaining descriptors were taken from the smallest FEH catchment resolvable for each specified estimation point. As the total catchment area of these small streams sums to less than 10 km^2 (making up a small proportion of the overall catchment area of the Calder at almost 260 km^2 to Sowerby Bridge). Hence, the final modelling should be relatively insensitive to uncertainties relating to catchment descriptors for these small streams.

3 Design flood estimation

3.1 Overall approach

A range of possible approaches to deriving design flood hydrographs for the stated estimation points were considered. The method adopted was as follows:

- The FEH statistical method is employed to estimate the peak flood flow at each estimation point for a given return period.
- A design event hydrograph is derived for each estimation point using the ReFH method for a given return period.
- A modified hydrograph is derived by scaling the ReFH hydrograph to the FEH peak flow.

The use of ReFH alone was considered (particularly for the smaller watercourses) however the statistical method is considered to be slightly more robust for such catchments, as it requires estimates of fewer parameters compared to the ReFH model. The combination of the FEH statistical method with a ReFH hydrograph shape helps to mitigate some other potential issues, for example the FARL catchment descriptor and level of urbanisation can be explicitly taken into account in the statistical method (when estimating QMED and the shape of a flood growth curve).

3.2 Flood peak estimation (Statistical Approach)

3.2.1 QMED estimation

For gauged sites QMED was derived from recorded AMAX data. The Regional Hydrology Team were consulting on the best flood peak series to use (not necessarily the ones in HiFlows-UK) and provided the corresponding flood peaks for recent water years.

For ungauged sites, QMED was estimated at each inflow point using the 2008 QMED regression model with donor adjustments where deemed appropriate. The following catchments were considered as donor sites for QMED adjustments:

- Calder @ Elland
- Calder @ Mytholmroyd
- Pendle Water @ Barden Lane
- Eastburn Beck @ Cross Hills
- Tame @ Broomstair Bridge

For these, AMAX series were also updated to include the 2011-12 water year. The exact combination of donors varied from site to site; in some cases two or more donors were applied whilst in others no suitable donor sites could be identified. Donor adjustments were applied in the line with the recommendations given in OI_197_08.

3.2.2 Construction of pooling groups

Rather than derive a unique pooling group for every single estimation point of interest, pooling groups were derived to serve groups of estimation points:

- A first pooling group was derived to serve estimation points on the River Calder between Todmorden and Sowerby Bridge. This was an Enhanced Single Site pooling group based on the gauged record for Mytholmroyd.
- A second pooling group for estimation points on the Calder upstream of the Walsden Water confluence at Todmorden.
- A third pooling group for the Walsden Water.
- Additional individual pooling groups for tributaries exceeding 5km^2 in area.
- A common pooling group to represent all tributaries not exceeding 5km^2 in size. As the FEH pooling method begins to draw in the same stations for very small catchments, it was decided to take an average of catchment descriptors for all of the minor tributaries, and construct a single pooling group that would be representative for all of these sites.

In all cases, the default pooling group was examined for the presence of stations whose presence might be skewing results (such as those with short AMAX records or those on chalk catchments). Where deemed appropriate, these stations were replaced.

The AMAX data currently available in HiFlows-UK extend to the 2008-09 water year only. AMAX data for 2010-12 was obtained for all sites included in the above pooling groups (not just those in Yorkshire and North East Region), to ensure that any derived growth curves reflected flood peak series that were as up to date as possible.

3.2.3 Dealing with FARL

A number of tributaries flowing into the Calder system contain lakes or reservoirs in their headwaters and therefore have a value of FARL that is significantly below 1. During extreme flood events, it is possible that these reservoirs will be full (depending on antecedent conditions) and hence provide little attenuation for an incoming flood hydrograph or able to provide a degree of flood attenuation that is negligible compared to the size of the event. For example in the June 2012 flood event, evidence demonstrates that most reservoirs were already spilling before the event and so offered no attenuation.

By accounting for FARL, flood estimation procedures may underestimate flood peaks. Alternative pooling groups were derived for all estimation points were FARL was strongly below 1. The FARL catchment descriptor was overwritten unity for all target sites during this portion of the analysis, so that catchments with low FARL values would not be drawn into a pooling group. As the revised pooling procedure gives little weight to catchment similarity in terms of the FARL descriptor, this adjustment will make little difference to the overall shape of a flood growth curve, but should provide pooling groups that are slightly more homogeneous.

3.3 Flood hydrograph shape

3.3.1 Application of ReFH

The spreadsheet version of ReFH was applied to estimate an appropriate hydrograph shape for each design event. Model parameters were based on catchment descriptors, and assuming a winter rainfall profile (75%). Where possible the modelled Tp was checked by comparing it with the equivalent value from the observed lag between rainfall and flow response.

3.3.2 Tp from Lag

Comparing the lag time predicted by the ReFH model to actual data provides a useful method to check whether or not the model predicts a realistic time to peak for a flood hydrograph. This procedure was carried out at six locations in the Calder catchment where there was a level gauge close to catchment outlet (two level sites surrounding Todmorden, one each near the outlets of the Ryburn, Hebden Water and Cragg Brook, and a site on the Calder near Sowerby Bridge) and a recording raingauge in the upper catchment.

Ideally catchment lag should be calculated from a long record of rainfall and river level/flow data. In this case six months worth of data was used as an initial check. The lag predicted from this data matched well to those estimated within ReFH model, so no further investigation was made. Average lag times of around 2 hours were found to occur for the Upper Calder and Walsden Water catchments, with 4.5 hours typical in the larger tributaries further down the system.

4 Next steps

Once the hydraulic model of the Calder system is operational, it will be possible to run it with the calculated design hydrographs and evaluate whether this gives a sensible result for a given return period. What defines a "sensible" result is open to interpretation, but the accumulated modelled flow on the Calder will basically need to be broadly aligned to design flow estimates for corresponding estimation points.

Model calibration is being carried out with reference to observations from the June 2012 event. The event was known to vary in severity spatially, as described in the report produced by the Regional Hydrology Team. Selection of the most appropriate hydrograph for each inflow point will be informed by the findings of the report.

YORKSHIRE WATER
PROTECTION OF MAINS AND SERVICES

1. The position of Yorkshire Water Services Ltd (YWS) apparatus shown on the existing mains record drawing(s) indicates the ***general*** position and nature of our apparatus and the accuracy of this information cannot be guaranteed. Any damage to YWS apparatus as a result of your works may have serious consequences and you will be held responsible for all costs incurred. Prior to commencing major works, the exact location of apparatus must be determined on site, if necessary by excavating trial holes. The actual position of such apparatus and that of service pipes which have not been indicated must be established on site by contacting the Customer Helpline on 0845 124 24 24 for both water and sewerage.

2. The public sewer and water network is lawfully retained in its existing position and the sewerage and water undertaker is entitled to have it remain so without any disturbance. The provisions of section 159 of the Water Industry Act 1991 provides that the undertaker may "inspect, maintain, adjust, repair or alter" the network. Those rights are given to enable the undertaker to perform its statutory duties. Any development of the land or any other action that unacceptably hindered the exercise of those rights would be unlawful. The provisions contained in Section 185 of the Water Industry Act 1991 state that where it is reasonable to do so, a person may require the water supply undertaker to alter or remove a pipe where it is necessary to enable that person to carry out a proposed change of use of the land. The provisions contained in Section 185 also require the person making the request to pay the full cost of carrying out the necessary works.

3. Ground levels over existing YWS apparatus are to be maintained. Sewers in highways will ***generally*** be laid to give 1200mm of cover from finished ground level working to kerb races, other permanent identification of the limits of the road or to an agreed line and level. Substantial increases or decreases to this 1200mm depth of cover will result in the sewer being re-laid at your expense. Water mains and services will ***generally*** be laid with a minimum of 750mm depth of cover however some mains and services usually those installed over 50 years ago may have less ground cover.

4. If surface levels are to be decreased / increased significantly the effects on existing water supply apparatus will be carefully considered and if any alterations are necessary, the costs of the alterations will be recharged to you in full. Outlets on fire hydrants must be no more than 300mm below the new levels and all surface boxes must be adjusted as part of the scheme.

5. To enable future repair works to be carried out without hindrance; any pipe, cable, duct, etc. installed parallel to a water main or service pipe should not be installed directly over or within 300mm of a water main or service pipe or 1000mm of a waste water asset. Where a pipe, cable, duct, etc. crosses a main or service it should preferably cross perpendicular or at an angle of no less than 45o and with a minimum clearance of 150mm. These requirements apply to activities within an existing highway and are relevant to the installation of pipes, cables, ducts, etc. up to and including 250mm in diameter *(see illustration below).* Necessary protection measures for installations greater than 250mm in diameter and/or in private land will need to be agreed on an individual basis. Installations within a new development site must comply with the National Joint Utilities Group publication Volume 2: NJUG Guidelines On The Positioning Of Underground Utilities Apparatus For New Development Sites.

6. All excavation works near to YW apparatus should be by hand digging only.

7. Backfilling with a suitable material to a minimum 300mm above YW apparatus is required.

8. Adequate support must be provided where any works pass under YW apparatus.

9. Jointing chambers, lighting columns and other structures must be installed in such a way that future repair or maintenance works to YW apparatus will not be hindered.

10. Apparatus such as; railings, sign posts, etc. must not be placed in such a way that they prevent access to or full operation of controlling valves, hydrants or similar apparatus. YWS surface boxes must not be covered or buried. Any adjustment, alteration or replacement of manhole covers must be agreed on site prior to the commencement of the works with a YWS Inspector who may be contacted via our Call Centre on 0845 124 24 24.

11. Explosives shall not be used within 100 metres of any Yorkshire Water Services apparatus or installations.

12. Vibrating plant should not be used directly over any apparatus. Movement or operation by vehicles or heavy plant is not to be permitted in the immediate vicinity of YWS plant or apparatus unless there has been prior consultation and, if necessary, adequate protection provided without cost to YWS.

13. ***Under no circumstances*** should thrust boring or similar trenchless techniques commence until the actual position of the Company's mains/services along the proposed route have been confirmed by trial holes.

14. Any alterations to the highway should be notified following the procedures outlined in the New Road and Street Works Act 1991 Code of Practice; Measures Necessary Where Apparatus Is Affected By Major Works (Diversionary Works).

15. You will be held responsible for any damage or loss to YWS apparatus during and after completion of work, caused by yourselves, your servant or agent. Any damage caused or observed to YWS plant or apparatus should be immediately reported to YWS. Should YW incur any costs as a result of non-compliance with the above, all costs will be rechargeable in full.

16. You should ensure that nothing is done on the site to prejudice the safety or operation of YWS employees, plant or apparatus.

17. In accordance with the New Roads and Street Works Act 1991, Chapter 22, Part 3, Section 80. The location of any identified YW asset "*which is not marked, or is wrongly marked, on the records made available*" should be communicated back to Yorkshire Water. The location of the apparatus should be identified on copies of the supplied plans which should be returned to Yorkshire Water (Asset Records Team) with photographic supporting evidence where possible.

18. The Government has decided that responsibility for private sewers serving two or more properties and lateral drains (the section of pipe beyond the boundary of a single property, connecting it to the public sewer) will be transferred to the water companies on Oct 1 2011.

Private pumping stations will also transfer during the period 1 October 2011 – 1 Oct 2016. Records of these assets may not yet be shown on the existing mains record drawing(s). If you encounter any of these assets you must inform Yorkshire Water Services Ltd (YWS).

19. Please note that the information supplied on the enclosed plans is reproduced from Ordnance Survey material with the permission of the Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office, © Crown Copyright. Unauthorised reproduction infringes Crown Copyright and may lead to prosecution or civil proceedings. Licence Number 1000019559.

20. This information is for guidance only and the position and depth of any YW apparatus is approximate only. Likewise, the nature and condition of any YW apparatus cannot be guaranteed. YW has no responsibility for recording the locations of privately owned apparatus. As of 1 October 2011, there may be some lateral drains and/or public sewers which are not documented on YW records but may still be present. For the avoidance of doubt, this information is not a substitute for appropriate professional and/or legal advice. YW accepts no responsibility for any inaccuracy or omissions in this information. The actual position of YW apparatus must be determined on site by excavating trail holes by hand. YW requires a minimum of two working days' written notice of the intention to excavate any trial holes before any excavation can be undertaken. If there are any queries in this respect please contact Yorkshire Water on 0845 124 24 24.

Property Identfier

or

Sewer Legend

Combined Sewer

S24 Combined Sewer

Surface Water Sewer

S24 Surface Water Sewer

Foul Sewer

S24 Foul Sewer

Section 104 Sewer

Rising Main

Overflow Sewer

Abandoned Sewer

Syphone Sewer &
Vacuum Sewer

Pumping Station

STW Public Sewer Tretment Works

Please note that the direction of flow arrows may not always appear depending on the scale of the map.

Water Legend

Water Main 4" and below

Water Main 4" and above

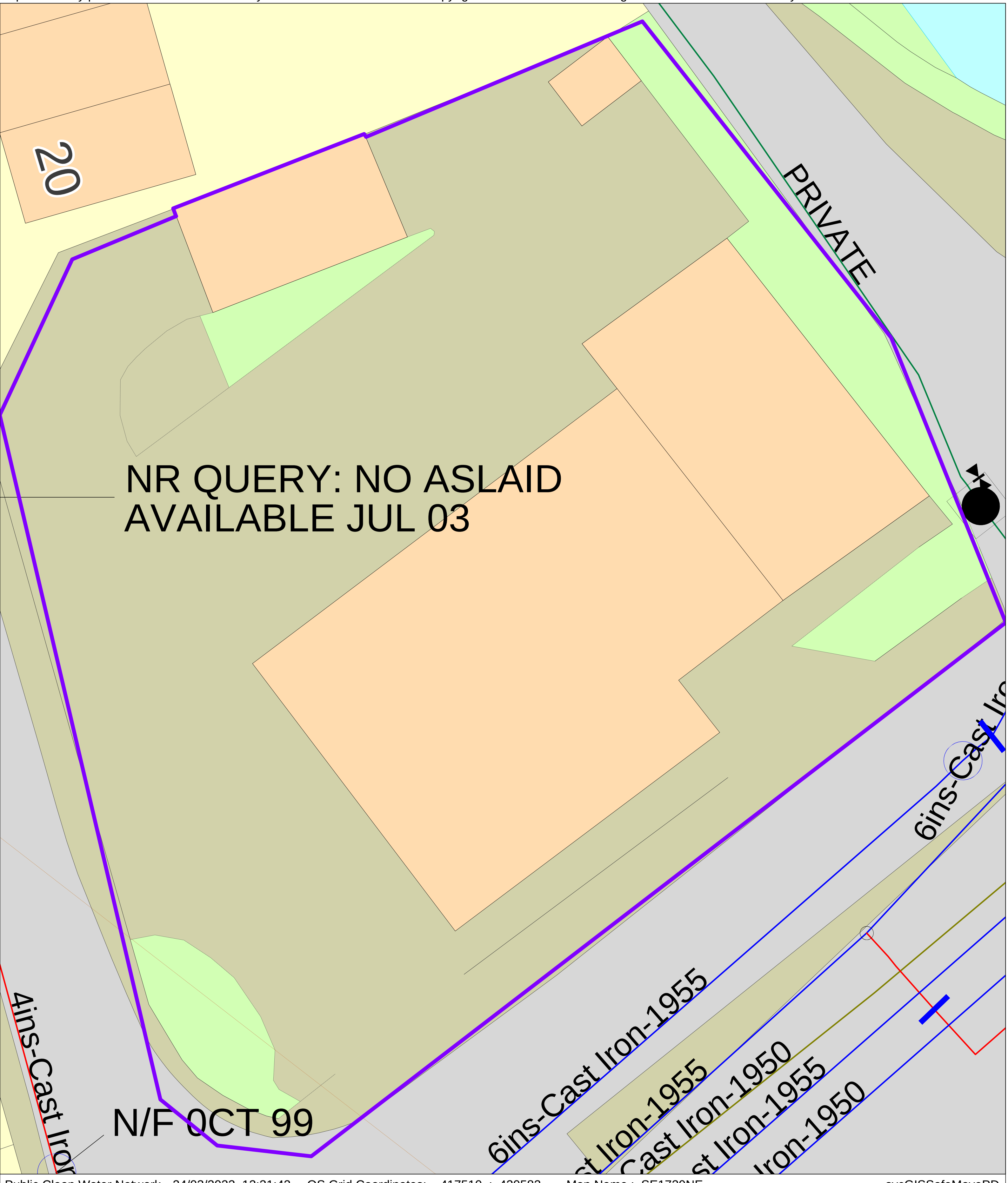
Raw Water Main

Private Water Main

H Fire Hydrant

Pumping Station

NAV The assets in this area are the responsibility of another Water Undertaker



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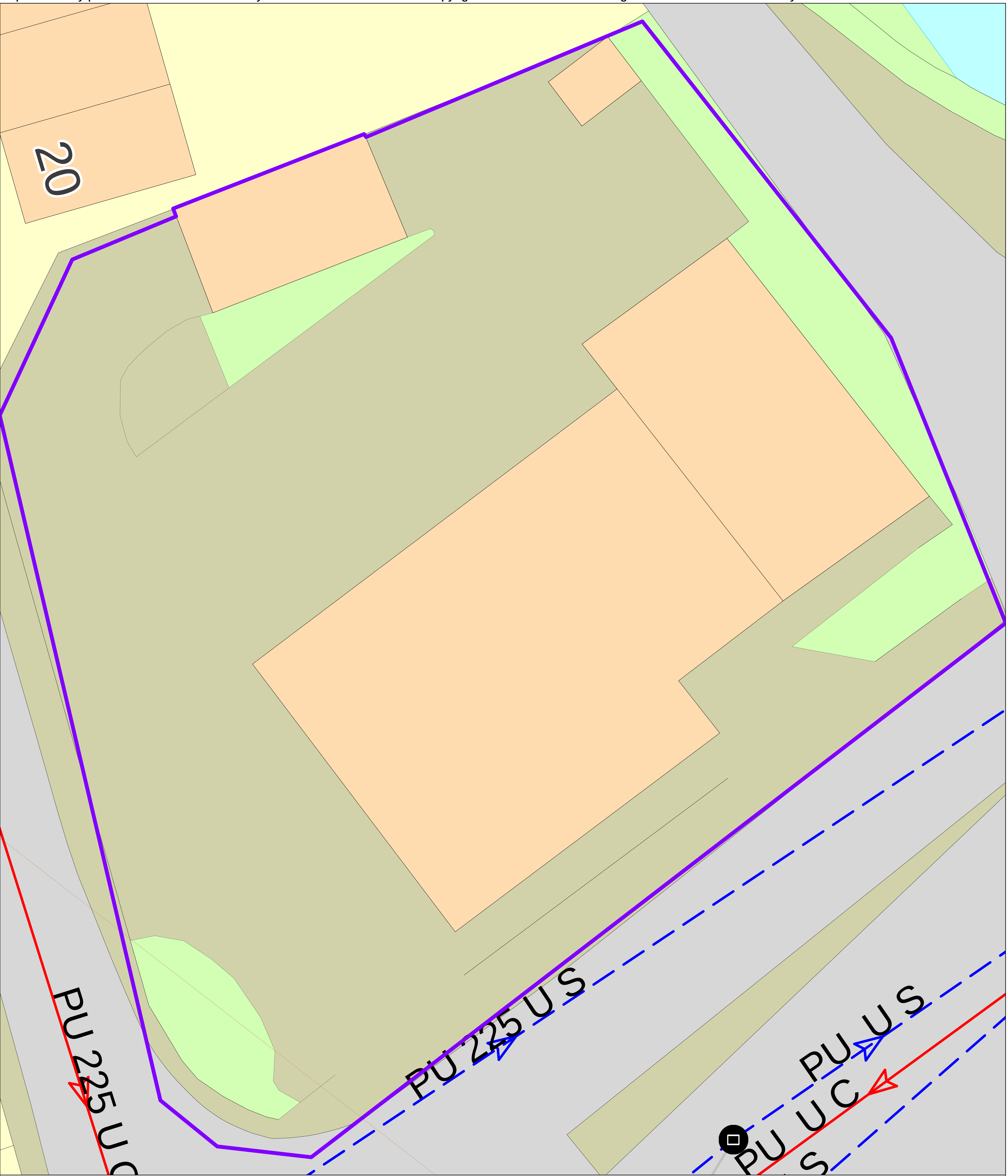

Public Waste Water Network 24/03/2023 12:31:43 OS Grid Coordinates: 417510 : 420582 Map Name : SE1720NE svcGISSafeMovePD