



Coldharbour Farm
Emsworth
Planning Reference: APP/19/01226

FLOOD RISK ASSESSMENT

On behalf of
Telstar Ltd.

MT/5314/FRA.5
September 2022

Experience and expertise working together

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1.0 INTRODUCTION

- 1.1** Bellamy Roberts LLP has been instructed by Telstar Ltd. to prepare a Flood Risk Assessment (FRA) in support of the current planning application for a residential scheme of 44 units on land west of Coldharbour Farm Road, Emsworth.
- 1.2** The planning application was submitted in December 2019 (planning reference: APP/19/01226). A Flood Risk Assessment was initially undertaken and submitted by Cannon Consulting Engineers and considered EA flood data which indicated a worst case flood level of 6.9m AOD for the 1 in 100 year rainfall event, albeit this included a 105% climate change allowance.
- 1.3** Compensatory flood storage was proposed towards the eastern boundary of the site, to allow the site to be developed and sited outside of the flood affected area.
- 1.4** The Environment Agency issued consultation comments dated 11th February 2020 and suggested three planning conditions, two of which referred to the worst case flood level of 6.9m AOD, stating that the finished floor levels and access road should be at or above this level.
- 1.5** The modelling reviewed by Cannon Consulting Engineers was the EA's 2D flood model. The 2D EA mapping available from the EA is generalised flood modelling and does not include detail of influential features within the catchment such as flood storage areas and structures. Telstar Ltd commissioned JBA Consulting to undertake additional, more detailed, flood modelling of the West Brook for the pre-development scenario.
- 1.6** The Environment Agency has confirmed by email dated 21st April 2022 that the modelling of the West Brook undertaken by JBA is suitable for its intended use and agreed with the output of the model. This is discussed in further detail later in the FRA.
- 1.7** The latest formal consultation comments received from the EA are dated 21st April 2022 and the EA requested further information of the proposed access route including details of what is proposed to go over the watercourse, the potential

impact on the watercourse and information on the design of the proposed access route. Such matters were address in the letter dated 4th July 2022 prepared by Bellamy Roberts.

1.8

A meeting was held with EA officers on 18th July 2022 and subsequent email correspondence was received on 16th August 2022 (see **Appendix 1**) from the EA setting out the further information required to enable their current objection to be removed as follows:

- *An explanation that demonstrates why a larger culvert is proposed as opposed to a clear span crossing (bridge) that includes the whole flood plain and would otherwise allow flood waters to flow through.*
- *Modelling re-run for post development - The size and capacity of the proposed culvert, and the design of the access roads, needs to be justified by demonstrating there is no increase to flood risk elsewhere.*
 - o *An assessment is required that demonstrates the new raised access road on the TRH Bank (which will act as an embankment) will not increase flood risk by diverting the flood flows to the True Left-Hand Bank (TLH) if the proposed culvert capacity is inadequate. There is a potential increase in flood risk to existing properties along Coldharbour Farm Road, and further downstream if the proposed culvert capacity is inadequate. Albeit the new proposed culvert is a betterment to the existing culvert, we cannot assume that it reduces flood risk especially considering the access roads causing flood water diversion.*
 - o *The approved JBA model needs to be re-run with the new proposed culvert and access roads in place. Currently the JBA model for a 1% AEP 25% flood event shows the river breaking bank on both sides, but more so on the True Right-Hand (TRH) Bank flood plain which will be closed off by the new access road acting as an embankment. We need to see what it shows post development.*
- *Culvert size - If a culvert is proposed as opposed to a full flood plain clear span bridge, flood levels for current and future flood events including climate change need to be shown on the design drawings allowing for a suitable freeboard (applicant to determine this). There also needs to be*

consideration for a gravel bed (minimum 200mm) on the base of the new culvert that will need approval from our internal fisheries team. The size of the proposed culvert needs to take these aspects into account that still has adequate capacity.

- *Increased flood risk downstream - The widening of culvert, combined with no flood flows over the original flood plain (slower flowing water) could increase flood risk to properties downstream. This needs to be assessed. There is a history of flooding south of the A27 mostly along Bridge Road. The model re-run should show this.*
- *Flood storage compensation - The new raised roads on the TRH Bank, and to a lesser extent the TLH Bank, will take up a large proportion of flood plain storage capacity which will need to be compensated for within the flood plain. There is already proposed flood storage compensation for the development from the land raising proposed, so this will need to be increased. These volumes need to be calculated and shown in the revised FRA. It is important that flood storage capacity is not reduced by the development.*

1.9 This current version of the FRA (version 5) has been prepared to address the outstanding matters raised by the EA in their email of 16th August 2022 and set out above.

Flood Risk Assessment Methodology and Objectives

1.10 It is recognised that developments that are designed without regard to flood risk may endanger lives, damage property, cause disruption to the wider community, damage the environment, be difficult to insure and require additional expense on remedial works. Current guidance on development and flood risk identifies several key aims for a development to ensure that it is sustainable in flood risk terms. These aims are as follows:

- the development should not be exposed to flood risk such that the health, safety, and welfare of the users of the development, or the population elsewhere, are threatened;
- the development should not be at a significant risk of flooding and should not be susceptible to damage due to flooding;

- safe access to and from the development should be possible during flood events;
- the development should not increase flood risk elsewhere;
- the development should not prevent safe maintenance of watercourses or maintenance and operation of flood defences;
- the development should not be associated with an onerous or difficult operation and maintenance regime to manage flood risk. The responsibility for any operation and maintenance required should be clearly defined;
- future users of the development should be made aware of any flood risk issues relating to the development;
- the development design should be such that future users will not have difficulty obtaining insurance or mortgage finance, or in selling all or part of the development, because of flood risk issues;
- the development should not lead to degradation of the environment, and
- the development should meet all the above criteria for its entire lifetime, including consideration of the potential effects of climate change.

1.11 This Assessment has been prepared with due consideration of these sustainability aims, to inform the proposed scheme. A development lifetime of 100 years has been assumed in line with PPG guidance on residential development life cycles.

Site Location and Consideration of Environment Agency Mapping

1.12 The site is located on land to the west of Coldharbour Farm, Emsworth. The Ordnance Survey National Grid Reference (NGR) for the centre of the site is 474517, 106524. For clarity, a plan showing the location of the site is provided at Figure 1 (see **Appendix 2**).

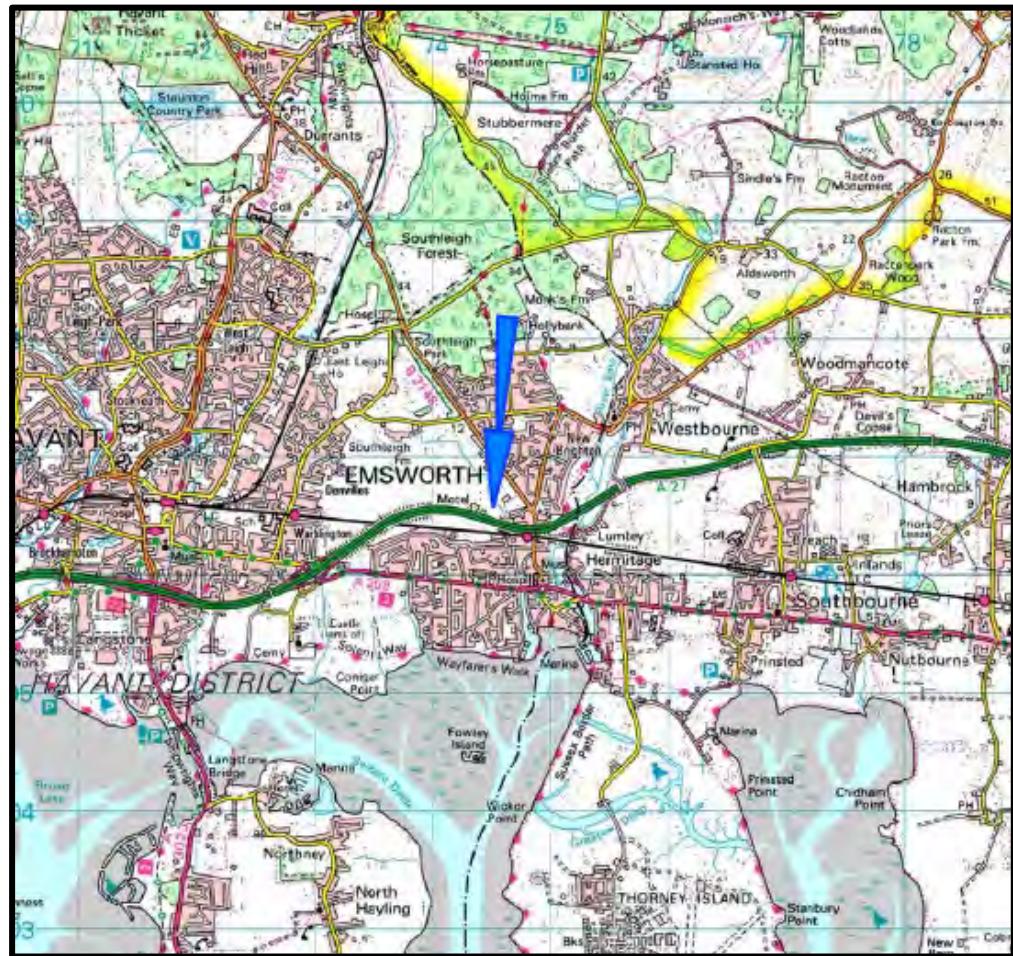


Figure 1: Site Location Plan

- 1.13** Levels at the site fall from approximately 9.0m AOD in the north-western corner, to approximately 4.8m AOD in the south-eastern corner. The topographical survey is attached at **Appendix 3**.
- 1.14** Environment Agency (EA) mapping reveals the majority of the application site is within Flood Zone 1, indicating most of the application site has a low probability of flooding from rivers or the sea (see **Appendix 4**). The EA mapping also shows the site is affected by Flood Zones 2 and 3 which emanate from the West Brook. As will be discussed later in the FRA, detailed modelling undertaken by JBA of the West Brook identifies the extent of Flood Zones 2 and 3 is less than shown on the EA mapping.

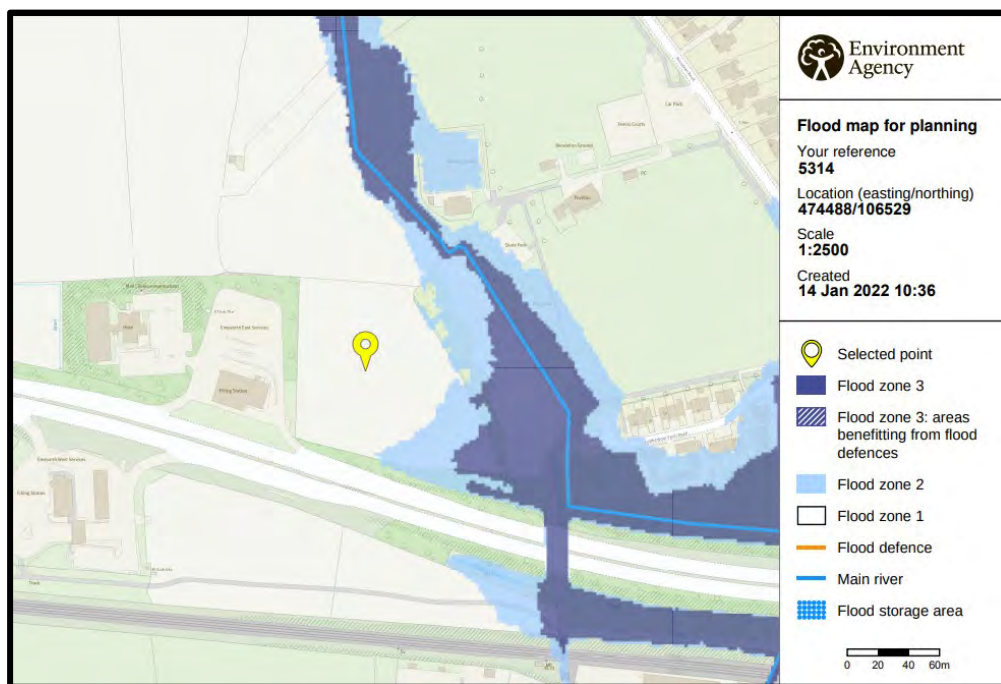


Figure 2: EA Flood Zone Plan (Source: EA)

Surface Water Flood Risk

1.15

In addition to river flooding, other sources of flooding must be considered, such as surface water flood risk. The EA surface water flood map is provided at Figure 2, revealing the site is also affected by areas of surface water flooding, which broadly follow the outline of the flood zones identified in Figure 3.



Figure 3: Surface Water Flood Risk Map (Source: EA)

Historic Flooding

1.16 No instances of historic flooding have been recorded. See Figure 4.



Figure 4: Historic Flooding Map (Source: gov.uk)

Existing Foul Water Sewer

1.17 Southern Water asset plans show the presence of surface water and foul water sewers in Coldharbour Farm Road. See **Appendix 5**.

Ground Conditions

1.18 Intrusive ground investigations were carried out in December 2012 and the results were set out in the FRA prepared by Cannon Consulting Engineers. In summary, the results of the intrusive investigation show the underlying strata comprises sandy clay over firm clay. The results of this assessment reveal that infiltration does not represent a viable means of discharging surface water from this site.

2.0 DETAILED MODELLING OF WEST BROOK

Pre-Development Scenario

2.1 As set out earlier in this FRA, Telstar Ltd commissioned JBA Consulting to undertake a more detailed assessment of the West Brook. The results of this modelling were submitted to the LPA and EA in a letter dated 29th November 2021, and for completeness has been summarised in the following paragraphs. The EA responded with comments on 27th January 2022 and a revised model was submitted on 9th February 2022. The EA has confirmed via email of 21st April 2022 that the baseline modelling is acceptable.

2.2 The full results of the revised JBA assessment are provided at **Appendix 6**, however of particular interest for the purposes of addressing the EA's previously suggested conditions are the results of the 1% AEP + 25% flood event. The result of this assessment reveals that only a small area of the site is predicted to flood during this event. The depth of this flooding is shallow, being less than 0.2m, and is not expected to extend onto the footpath at the western end of Coldharbour Farm Road, or indeed the road itself. See Figure 5.

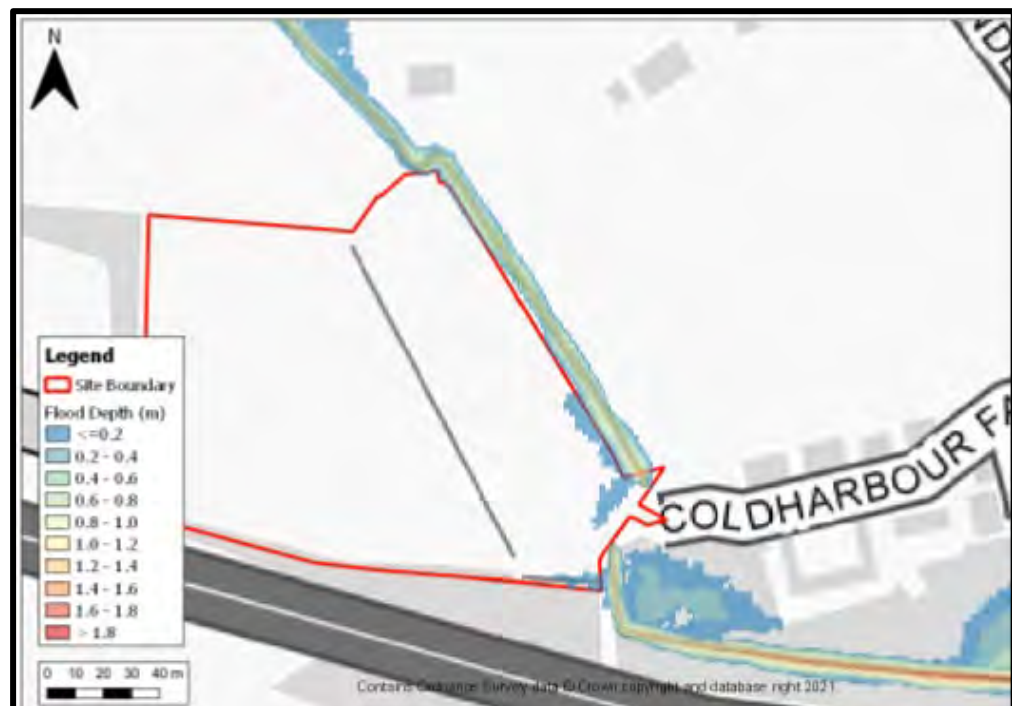


Figure 5: 1% AEP + 25% Flows (Source: JBA Modelling Report)

Post-Development Scenario

2.3 As set out in paragraph 1.8 of this FRA, the EA has requested detailed analysis of the post-development scenario. This detailed analysis was undertaken by JBA and three proposed development scenarios were assessed by making modifications to the baseline model (see Appendix 6). The proposed development (PD) scenarios assessed by JBA are summarised in Figure 6.

	PD2	PD3	PD4
Access road	✓	✓	✓
Cellular storage	✓	✓	✓
West Brook culvert	Modified: 2m wide x 1m high	Modified: 2m wide x 1m high	Existing
Fluvial flood storage area	✓	X	✓

Figure 6: Summary of Post Development Scenarios (Source: JBA Modelling Report)

2.4 For reference, the 'Access Road' as referenced in Figure 6 is that shown on drawing 5314/1001 rev. A, and the 'Cellular Storage' is that shown on drawing 5314/1002 rev. B. Both of which are provided at **Appendix 7**.

2.5 At the location of the proposed site access, the West Brook currently passes through a culvert under the Public Right of Way (route 108/71/1). The existing culvert is a 1m x 1m box culvert. The post-development modelling has assessed a widened/improved culvert of 2m wide x 1m high (PD2 & PD3) and the existing 1m x 1m culvert (PD4).

2.6 The fluvial flood storage area will be set at a level of 4.85m AOD. This is 0.15m above the 4.70m AOD indicated in earlier drawings and is required to enable a pipe (modelled as 150mm diameter) to drain from the base of the storage area to the West Brook watercourse, which at the location of the proposed outlet has an invert level of 4.7m AOD.

2.7 Set out at Appendix F of the JBA Modelling Report are the scenario flood maps showing changes in flood depths and extents compared with the base line model previously agreed with the EA. These are considered and discussed in the following paragraphs.

Post-Development Scenario 2

2.8 The results of the 1% AEP + 25% climate change post development assessment are summarised by JBA as follows:

- The fluvial flood storage area is partially filled.
- Flooding across the site access road is not predicted.
- Reductions in flood extents and depths are predicted upstream and downstream.

Post-Development Scenario 3

2.9 The results of the 1% AEP + 25% climate change post development assessment are summarised by JBA as follows:

- Reductions to in-channel water levels are predicted upstream due to the increased size of the culvert.
- Flooding across the site access road is not predicted.
- Relatively small increases in flood depths and extents are predicted in the developed and open space/parkland downstream.

Post-Development Scenario 4

2.10 The results of the 1% AEP + 25% climate change post development assessment are summarised by JBA as follows:

- The fluvial flood storage area is partially filled, to a greater depth than the PD2 scenario.
- Flooding across the site access road is not predicted.
- Reductions in flood extents and depths are predicted upstream and downstream. These reductions in flooding are larger in magnitude than the PD2 scenario.

2.11 In all modelled post-development scenarios, no flooding of the proposed site access road is predicted, ensuring that safe access and egress can be achieved to the development.

2.12 The modelling demonstrates that increasing the size of the culvert would have limited benefit. Indeed, the modelling shows that maintaining the size of the existing culvert (1m x 1m) together with the fluvial flood storage area (PD4)

provides the greatest reduction in flood extents and depths both upstream and downstream due to the increased use of the fluvial flood storage area.

- 2.13** The modelling undertaken by JBA demonstrates there is no material benefit in providing a widened culvert at this location. It is therefore proposed that the existing culvert, or a replacement of the same cross-section, be utilised to serve the scheme. This is approach supported by the modelling results.

Consideration of EA Comments

- 2.14** The results of the modelling undertaken by JBA and summarised in this section of the FRA provide all the details requested by the EA in the email correspondence of 16th August 2022. Nevertheless, and to provide the EA with comfort that all matters have now been addressed, each item raised by the EA has been addressed in turn below. For reference, the EA comments are provided in **bold**.

An explanation that demonstrates why a larger culvert is proposed as opposed to a clear span crossing (bridge) that includes the whole flood plain and would otherwise allow flood waters to flow through.

- 2.15** The post development modelling undertaken by JBA demonstrates a greater reduction in flood extent and depth upstream and downstream when the existing culvert is considered, due to the increased use of the fluvial flood storage area.
- 2.16** The modelling results do not support the notion that an improved crossing is necessary in this instance. Indeed, there is a greater benefit to those properties downstream when the existing culvert remains i.e., a widened culvert is not necessary.
- 2.17** Therefore, it is proposed that the existing culvert, or a replacement of the same cross-section, be utilised to serve the scheme. This approach is supported by the modelling results.

Modelling re-run for post development - The size and capacity of the proposed culvert, and the design of the access roads, needs to be justified by demonstrating there is no increase to flood risk elsewhere.

- o **An assessment is required that demonstrates the new raised access road on the TRH Bank (which will act as an embankment) will not increase flood risk by diverting the flood flows to the True Left-Hand Bank (TLH) if the proposed culvert capacity is inadequate. There is a potential increase in flood risk to existing properties along Coldharbour Farm Road, and further downstream if the proposed culvert capacity is inadequate. Albeit the new proposed culvert is a betterment to the existing culvert, we cannot assume that it reduces flood risk especially considering the access roads causing flood water diversion.**

2.18 The modelling undertaken by JBA for the PD4 scenario demonstrates a significant reduction in flood depths upstream and downstream of the culvert, thereby providing a betterment to existing properties along Coldharbour Farm Road and not increasing flood risk elsewhere.

- o **The approved JBA model needs to be re-run with the new proposed culvert and access roads in place. Currently the JBA model for a 1% AEP + 25% flood event shows the river breaking bank on both sides, but more so on the True Right-Hand (TRH) Bank flood plain which will be closed off by the new access road acting as an embankment. We need to see what it shows post development.**

2.19 Post-development scenarios 2 (PD2) and 3 (PD3) include the widened culvert, albeit PD2 also includes the proposed fluvial flood storage area whereas PD3 does not. The modelling results for the PD2 scenario shows a decrease in flood depth downstream in the order of 0.005 – 0.05m, with a greater decrease immediately upstream. The PD3 modelling shows a negligible change in flood depth downstream, albeit a decrease in the order of 0.25 – 0.5m immediately upstream.

2.20 When the results of the PD4 analysis is considered (i.e., with the existing 1m x 1m box culvert), there are significant improvements in flood depths downstream and similar improvements upstream, over and above those shown in PD2 and PD3.

Culvert size - If a culvert is proposed as opposed to a full flood plain clear span bridge, flood levels for current and future flood events including climate change need to be shown on the design drawings allowing for a suitable freeboard (applicant to determine this). There also needs to be consideration for a gravel bed (minimum 200mm) on the base of the new culvert that will need approval from our internal fisheries team. The size of the proposed culvert needs to take these aspects into account that still has adequate capacity.

- 2.21** Summarised at Table 5-1 of the JBA Modelling Report are the predicted changes to in-channel water levels for the current baseline and future development scenarios.
- 2.22** With reference to the 1% AEP + 25% climate change event, the peak water level during each post-development scenario shows either a reduction or no change both upstream and downstream (ref. PD2 and PD4 scenarios). The PD3 scenario shows a decrease in peak water level upstream and a minor increase downstream.
- 2.23** Scenarios PD2 and PD4 both include the fluvial flood storage area set at a level of 4.85m AOD. During the PD2 scenario, the depth of water will be between 0.10m and 0.25m. Assuming the worst case depth of 0.25m, the water level will be 5.1m AOD. During the PD4 scenario, the water depth is predicted as being greater than 0.5m, albeit will not overtop the underground surface water attenuation area which is set at a level of 5.5m AOD. Therefore, the depth of water will not exceed 0.65m, as such the maximum depth of water within the attenuation area will be 5.5m AOD.
- 2.24** With reference to drawing 5314/1001 rev. A, the access road will be set at a level of 6.1m AOD at the location of the culvert crossing. This includes a freeboard allowance of 600mm when considering the worst case predicted flood level, which is considered suitable given the reliability of the JBA modelling.
- 2.25** Along the eastern side of the developed area, the carriageway will be set at a level of between 6.91m AOD and 7.84m AOD. Such a level will provide a freeboard ranging from between 1.41m and 2.34m which is more than sufficient particularly given the EA quote 900mm as the largest freeboard allowance in their freeboard guidance.

- 2.26** The JBA modelling has included the EA's request for a 200mm gravel bed at the base of the culvert. In practical terms within the modelling, the height of the culvert has been set to 800mm, assuming that 200mm height of the culvert would be below the current invert of the culvert (otherwise it is assumed that gravel would be transported away). The hydraulic roughness of the culvert invert has been increased to account for the likely presence of gravel. Refer to section 3.4 of the JBA Modelling Report for further details.

Increased flood risk downstream - The widening of culvert, combined with no flood flows over the original flood plain (slower flowing water) could increase flood risk to properties downstream. This needs to be assessed. There is a history of flooding south of the A27 mostly along Bridge Road. The model re-run should show this.

- 2.27** The JBA modelling for all post-development scenarios show no increased flood risk downstream during the modelled 1% AEP + 25% climate change rainfall events.

- 2.28** The scheme will therefore not increase flood risk to properties downstream.

Flood storage compensation - The new raised roads on the TRH Bank, and to a lesser extent the TLH Bank, will take up a large proportion of flood plain storage capacity which will need to be compensated for within the flood plain. There is already proposed flood storage compensation for the development from the land raising proposed, so this will need to be increased. These volumes need to be calculated and shown in the revised FRA. It is important that flood storage capacity is not reduced by the development.

- 2.29** The approximate area of the base of the proposed fluvial flood storage area is 1,800m². Assuming a maximum water depth of 0.65m, the volume of the proposed storage area will be circa 1,170m³.

- 2.30** The existing fluvial storage area is harder to calculate. Nevertheless, the baseline flood water level mapping contained at Appendix E of the JBA Modelling Report for the 1% AEP + 25% climate change event and 0.1% AEP event shows significant flooding downstream due to insufficient capacity within the existing flood plain.

- 2.31** The JBA modelling of scenarios PD2 and PD4 includes the proposed fluvial storage area set at a level of 4.85m AOD. The modelling reveals that this area provides sufficient storage capacity during all modelled flood events and provides a betterment for those properties downstream.

Summary

- 2.32** In summary, the results of the post-development modelling undertaken by JBA demonstrate that an improved/widened culvert is not necessary. A widened culvert would marginally reduce flood depths downstream, however a greater reduction in flood depth is realised when utilising the existing culvert.
- 2.33** It has therefore been demonstrated that the proposed development will be compliant with paragraph 167 of the NPPF as it will not increase flood risk elsewhere.

3.0 SURFACE WATER DRAINAGE STRATEGY

3.1 Surface water drainage at the site will be based on SuDS principles and in this regard, the aim will be to discharge the surface water run-off as high up the following hierarchy of drainage options as possible:

- Infiltration into the ground;
- To a surface water body, such as a river, ditch, pond or stream;
- To a surface water sewer;
- To a combined sewer.

3.2 As set out in the Cannon Consulting Engineers' FRA, the site geology will not support disposal of surface water runoff via infiltration. As such, the surface water strategy will comprise underground attenuation, with a restricted discharge into the West Brook.

3.3 This strategy has been amended following receipt of the detailed hydraulic modelling of the West Brook and has been modelled for the 1 in 1, 1 in 30 and 1 in 100 year + climate change rainfall events.

3.4 Summarised at Table 1 are the estimated greenfield discharge rates (see **Appendix 8**).

Table 1: Summary of Greenfield Runoff Rates

Site Area (Ha)	Return Period (Years)	Greenfield Runoff Rate (l/s)
2.17	Qbar	5.2
	Q1	4.4
	Q30	11.7
	Q100	16.5

3.5 A detailed drainage layout has been prepared, which includes manhole cover and invert levels, pipe diameters, lengths and gradients and is attached Appendix 7.

3.6 Microdrainage analyses of the Q1, Q30 and Q100 (+ 40 climate change) rainfall events have been undertaken, and the attenuation storage area has been sized

accordingly, based on the Qbar figures set out in Table 1. The Microdrainage analyses are at **Appendix 9**.

Maintenance and Management

3.7

Maintenance of the proposed drainage system will be undertaken in accordance with the guidance set out in Table 21.3 of the CIRIA SuDS Manual 2015, which is provided at Figure 7.

TABLE 21.3 Operation and maintenance requirements for attenuation storage tanks			
	Maintenance schedule	Required action	Typical frequency
	Regular maintenance	Inspect and identify any areas that are not operating correctly. If required, take remedial action	Monthly for 3 months, then annually
		Remove debris from the catchment surface (where it may cause risks to performance)	Monthly
		For systems where rainfall infiltrates into the tank from above, check surface of filter for blockage by sediment, algae or other matter; remove and replace surface infiltration medium as necessary.	Annually
		Remove sediment from pre-treatment structures and/or internal forebays	Annually, or as required
	Remedial actions	Repair/rehabilitate inlets, outlet, overflows and vents	As required
	Monitoring	Inspect/check all inlets, outlets, vents and overflows to ensure that they are in good condition and operating as designed	Annually
		Survey inside of tank for sediment build-up and remove if necessary	Every 5 years or as required

Figure 7: Attenuation Tank Maintenance Regime (Source: Table 21.3 CIRIA SuDS Manual)

4.0 SUMMARY AND CONCLUSIONS

Summary

4.1 Bellamy Roberts LLP has been instructed by Telstar Ltd. to prepare a Flood Risk Assessment (FRA) in support of the current planning application for a residential scheme of 44 units on land west of Coldharbour Farm Road, Emsworth.

4.2 This current version of the FRA (version 5) has been prepared to address the outstanding matters raised by the EA in their email of 16th August 2022.

4.3 Post-development flood modelling has been undertaken by JBA which has demonstrated that an improved/widened culvert is not necessary to serve the scheme. A widened culvert would marginally reduce flood depths downstream, however a greater reduction in flood depth is realised when utilising the existing culvert.

Conclusions

4.4 The proposed development accords with the guidance set out at paragraph 167 of the NPPF, in that:

- It does not increase flood risk elsewhere;
- the most vulnerable development is located in areas of lowest flood risk;
- the development is appropriately flood resistant and resilient;
- it incorporates sustainable drainage systems; and
- safe access and escape routes are included.

4.5 The proposed development accords with the guidance set out at paragraph 169 of the NPPF, in that the scheme incorporates sustainable drainage systems, has maintenance arrangements in place to ensure an acceptable standard of operation for the lifetime of the development and the scheme provides multifunctional benefits.

4.6 The scheme therefore accords with all relevant policies within the NPPF and is acceptable in flooding and drainage terms.

APPENDICES

APPENDIX 1

Subject: FW: Coldharbour Farm Road, Emsworth (BR 5314)

Hi Matt,

Thank you for submitting the drawings of the proposed culvert.

As we discussed at the meeting we require the applicant to demonstrate that flood risk is not increased (or impacted) elsewhere, or downstream. This needs to be demonstrated in the revised FRA as below. Sophie Williams has left the Environment Agency now, but the Flood Risk Officer dealing with this application now (and before Sophie) will be happy to speak with you if you need more information.

In principle we have no objection to the proposal, however in order for us to remove our objection we would need a revised Flood Risk Assessment (FRA) will need to be submitted following more assessment that demonstrates flood risk is not increased elsewhere.

This updated and approved FRA will also be required for the application of an Environmental Permit (Flood Risk Activity Permit). It is preferred and beneficial to get this revised FRA approved at this stage. We advise the FRA, which is now out of date with the new proposal (last one submitted April 2022), is revised with the following:

1. An explanation that demonstrates why a larger culvert is proposed as opposed to a clear span crossing (bridge) that includes the whole flood plain and would otherwise allow flood waters to flow through.
2. Modelling re-run for post development - The size and capacity of the proposed culvert, and the design of the access roads, needs to be justified by demonstrating there is no increase to flood risk elsewhere.
 1. An assessment is required that demonstrates the new raised access road on the TRH Bank (which will act as an embankment) will not increase flood risk by diverting the flood flows to the True Left-Hand Bank (TLH) if the proposed culvert capacity is inadequate. There is a potential increase in flood risk to existing properties along Coldharbour Farm Road, and further downstream if the proposed culvert capacity is inadequate. Albeit the new proposed culvert is a betterment to the existing culvert, we cannot assume that it reduces flood risk especially considering the access roads causing flood water diversion.
 2. The approved JBA model needs to be re-run with the new proposed culvert and access roads in place. Currently the JBA model for a 1% AEP 25% flood event shows the river breaking bank on both sides, but more so on the True Right-Hand (TRH) Bank flood plain which will be closed off by the new access road acting as an embankment. We need to see what it shows post development.
3. Culvert size - If a culvert is proposed as opposed to a full flood plain clear span bridge, flood levels for current and future flood events including climate change need to be shown on the design drawings allowing for a suitable freeboard (applicant to determine this). There also needs to be consideration for a gravel bed (minimum 200mm) on the base of the new culvert that will need approval from our internal fisheries team. The size of the proposed culvert needs to take these aspects into account that still has adequate capacity.
4. Increased flood risk downstream - The widening of culvert, combined with no flood flows over the original flood plain (slower flowing water) could increase flood risk to properties downstream. This needs to be assessed. There is a history of flooding south of the A27 mostly along Bridge Road. The model re-run should show this. This link shows media coverage of flooding here: [Clean up begins following Emsworth floods - BBC News](#)

5. Flood storage compensation - The new raised roads on the TRH Bank, and to a lesser extent the TLH Bank, will take up a large proportion of flood plain storage capacity which will need to be compensated for within the flood plain. There is already proposed flood storage compensation for the development from the land raising proposed, so this will need to be increased. These volumes need to be calculated and shown in the revised FRA. It is important that flood storage capacity is not reduced by the development.

Also worth a note that the drain to the west of the West Brook is shown as an ordinary water course. The applicant needs to consult with the council as this drain will be covered over by the land raising of the development.

Lesley, just to confirm we are able to remove our objection following the submission of the above.

Kind regards

Sophie

Sophie Brown | Planning Advisor | Sustainable Places | Solent and South Downs Area | Environment
Planning and Engagement
Environment Agency | Oving Road | Chichester | West Sussex | PO20 2AG
Tel: Mob:

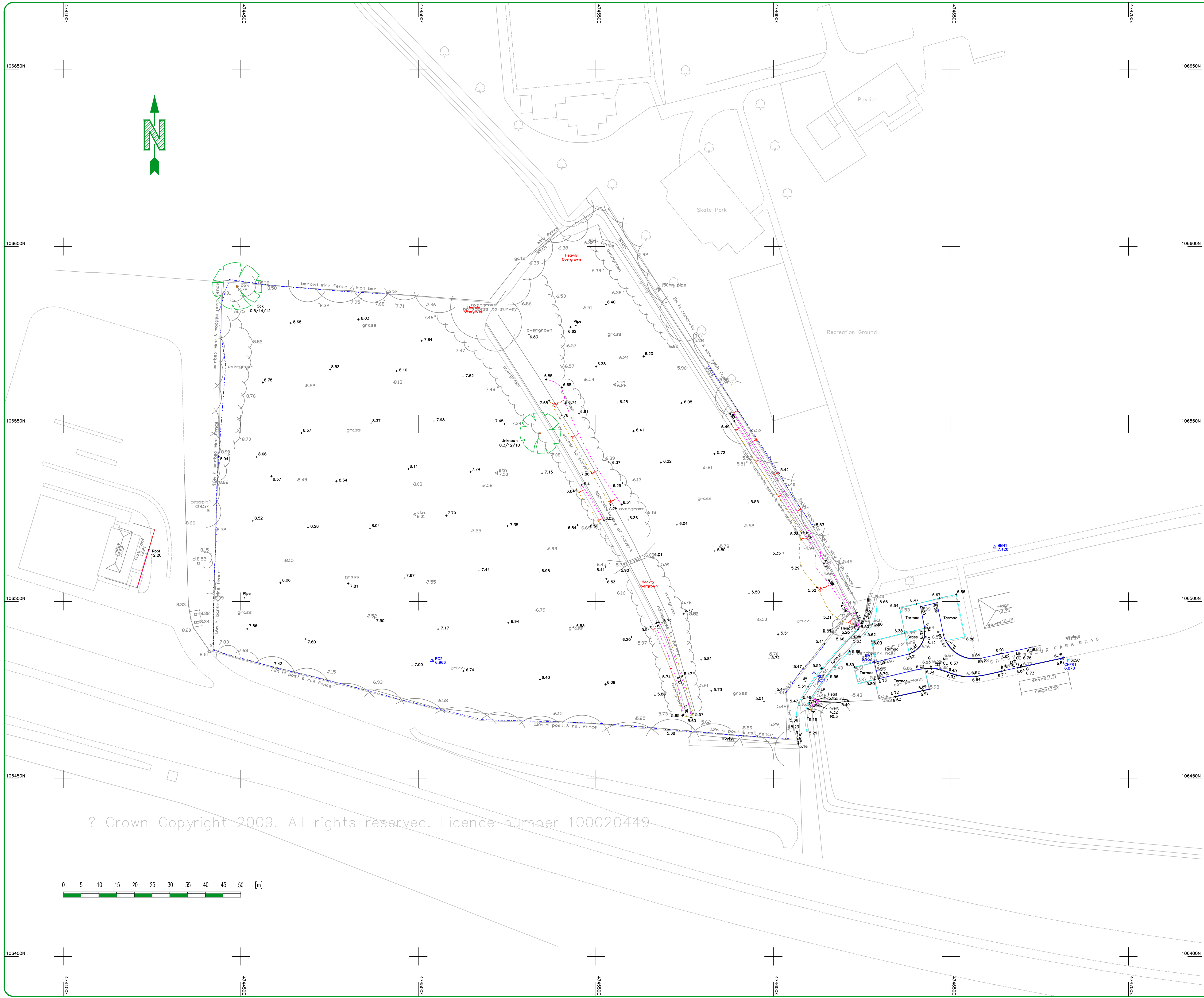
Please be aware I work Part Time hours and will be available Monday, Tuesday, Wednesday and Thursday, only. If you have any urgent enquiries outside of those hours please email planningSSD@environment-agency.gov.uk

APPENDIX 2



PROJECT Coldharbour Farm Road, Emsworth	DATE 20/05/19	DRAWN BY ARM
TITLE Site Location Plan	SCALE 1:50,000 @ A4	CHK BY MT
bellamy roberts	Clover House Western Lane Odiham Hampshire, RG29 1TU	CLIENT Telstar
	Tel: 01256 703355 Email: info@bellamyroberts.co.uk	DRAWING No. 5314 / 301
		REV No. A

APPENDIX 3



Survey Station Coordinates			
Station	Easting	Northing	Level
BEN1	474602.280	106515.258	7.128
BM1	474620.358	106482.925	5.953
CHFR1	474681.324	106483.812	6.870
RC1	474611.436	106479.804	5.517
RC2	474603.880	106483.373	6.966

LEGEND

	Building		Tree
	Glass Roof		Leaning Tree
	Open Sided Buildings		Hedges
	Survey Station		Canopy Line
	Top		Walls
	Bottom		Fences
	Spot Levels		Sapling
	Steps Up		

ABBREVIATIONS (WHERE APPLICABLE)

BOLLARD	BRITISH TELECOM BOX	BRITISH TELECOM IC	CABLE TELEVISION BOX	CABLE TELEVISION IC	CONCRETE	CHANGE POINT	CONCRETE PAVING SLABS	COVER LEVEL	DAMP PROOF COURSE	ELECTRICITY POLE	EARTH ROAD	FLOWER BED	FINISHED FLOOR LEVEL	FIRE HYDRANT	GAS VALVE	GULLY	INSPECTION COVER	INVERT LEVEL	PIPE INVERT LEVEL	HERB OUTLET	LAMP POST
BOL	BTB	BT	CTB	TV	CONC	CP	CPS	CL	DPC	EP	ER	FB	FFL	FI	GV	G	IC	IL	INV	KO	LP
LETTER BOX	MANHOLE	MARKER	NOTICE BOARD	OVERHEAD CABLES	PARKING METER	ROAD SIGN	ROAD NAME PLATE	ROAD SIGN	RAINWATER PIPE	STOP COCK	STRUCTURAL SLAB LEVEL	STOP VALVE	TELEPHONE CALL BOX	TRAFFIC LIGHTS	TOP OF WALL	TELEGRAPH POLE	UNKNOWN	UNABLE TO LIFT	VENT PIPE	WATER METER	WASH OUT
LB	MH	MKR	NB	OHC	PM	RE	RNP	RS	RWP	SC	SSL	SV	TCB	TL	TOW	TP	UNK	UTL	VP	WM	WO

DATUM USED : ALL LEVELS BASED ON OS DATUM. HORIZONTAL GRID IS BASED ON OS COORDINATES. ALL INFORMATION CREATED BY GPS DATA.

FOR USERS OF THIS DRAWING IN DIGITAL FORMAT: THIS DRAWING HAS BEEN SURVIVED TO A DEGREE OF ACCURACY COMMENSURATE WITH THE SCALE INDICATED IN THE TITLE PANEL AND ANY DIMENSIONS EXTRACTED SHOULD BE TREATED AS SUCH.

Revisions		
Date	Revision	Amendment

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Member of

Client
TELSTAR LTD

Surveyed RMC	Drawn CSG	Checked RMC	Date 18/04/19
------------------------	---------------------	-----------------------	-------------------------

Project
COLDHARBOUR FARM ROAD, EMSWORTH

Title
DETAIL SURVEY

Job No 19/042	Drawing No 19/042/01	Revision	Scale/Size 1:500 A1
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APPENDIX 4

Flood map for planning

Your reference
5314

Location (easting/northing)
474488/106529

Created
14 Jan 2022 10:36

Your selected location is in flood zone 1, an area with a low probability of flooding.

This means:

- you don't need to do a flood risk assessment if your development is smaller than 1 hectare and not affected by other sources of flooding
- you may need to do a flood risk assessment if your development is larger than 1 hectare or affected by other sources of flooding or in an area with critical drainage problems

Notes

The flood map for planning shows river and sea flooding data only. It doesn't include other sources of flooding. It is for use in development planning and flood risk assessments.

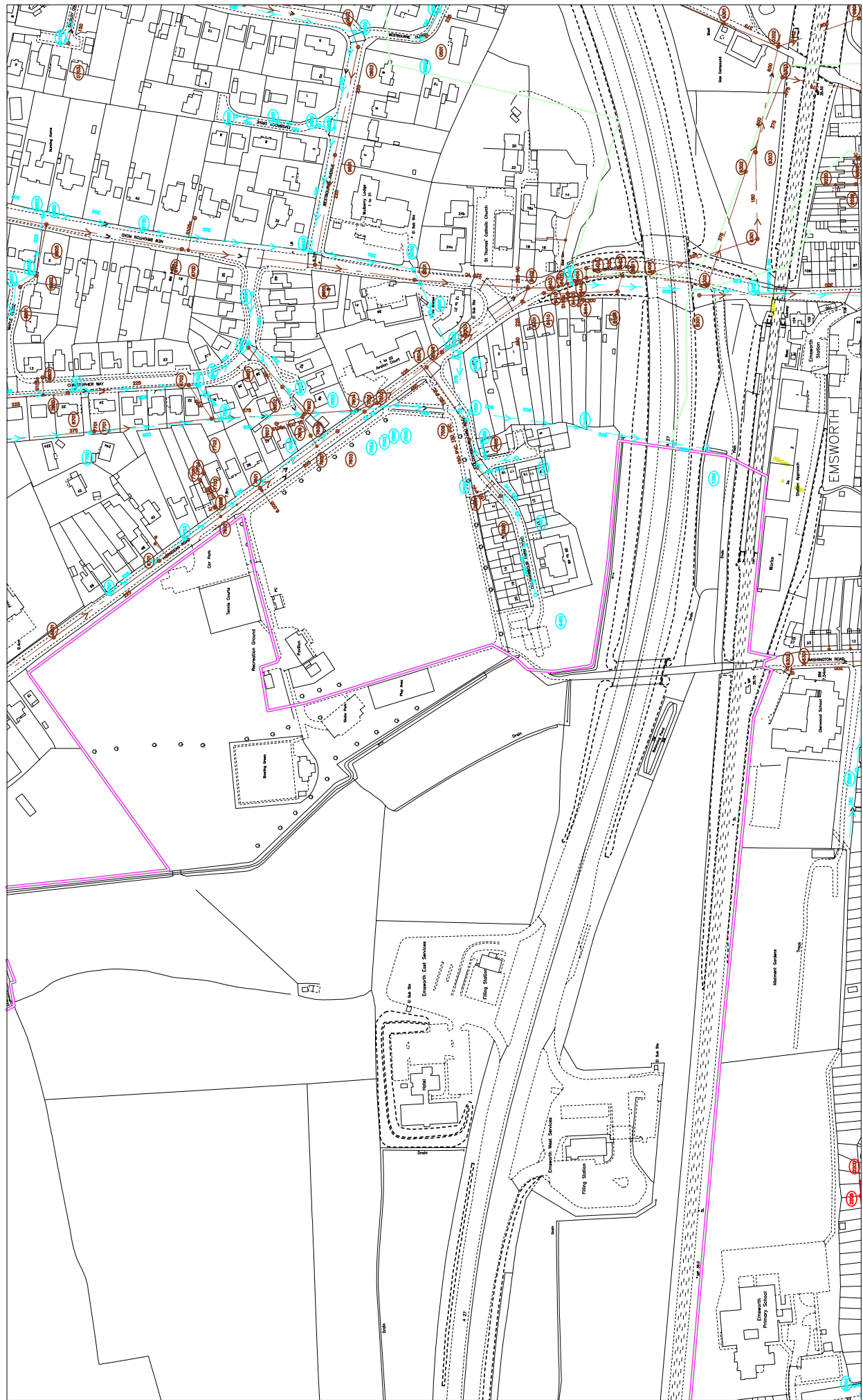
This information relates to the selected location and is not specific to any property within it. The map is updated regularly and is correct at the time of printing.

Flood risk data is covered by the Open Government Licence which sets out the terms and conditions for using government data. <https://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/>

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APPENDIX 5

SEWER RECORDS PAGE 1 OF 2



106840

106262

O.S. REF.
SU7406NE

474120

Drawn by: kumaria

Scale: 1:2500

Date: 25/06/2019



475064



N

The positions of pipes shown on this plan are believed to be correct, but Southern Water Services Ltd accept no responsibility in the event of inaccuracy.
The actual positions should be determined on site.
WARNING: BAC pipes are constructed of Bonded Asbestos Cement
WARNING: Unmarked (UNM) materials may include Bonded Asbestos Cement

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SEWER RECORDS PAGE 2 OF 2

[illegible][illegible]

APPENDIX 6

West Brook, Emsworth fluvial flood risk modelling report

Final report

September 2022

www.jbaconsulting.com

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Revision History

Revision Ref / Date	Amendments	Issued to
P01 / November 2021	Final Report	Richard Brown (Telstar Ltd)
P02 / February 2022	Final Report, with updates made to reflect final modelling following Environment Agency review of the model	Richard Brown (Telstar Ltd)
P03 / March 2022	Final Report, with further updates made to reflect final modelling following Environment Agency re-review of the model	Richard Brown (Telstar Ltd)
P04 / September 2022	Draft Report, incorporating the outputs from the proposed development modelling scenarios	Richard Brown (Telstar Ltd)
C04 / September 2022	Final Report	Richard Brown (Telstar Ltd)

Contract

This report describes work commissioned by Matt Twinberrow of Bellamy Roberts, on behalf of Telstar Limited, by an email dated 9 June 2021. Telstar Limited's representative for the contract was Matt Twinberrow. Ben Gibson, Gwyn Jones and Lucy Archer-Lock of JBA Consulting carried out this work.

Prepared by Ben Gibson BSc MSc MCIWEM C.WEM
Principal Analyst

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Chartered Senior Analyst

Purpose

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Executive summary

Introduction

JBA Consulting was commissioned to prepare fluvial (river) flood modelling and mapping for the West Brook watercourse, Emsworth. This watercourse flows along the eastern boundary of a proposed development site, which is located to the west of Coldharbour Farm Road.

The existing mapping available from the Environment Agency is based on generalised 2D flood modelling, and so does not include the detail of channel hydraulics or other influential features in the catchment such as a flood storage area and structures. The existing mapping displays significant flood extents from the West Brook watercourse, extending onto the south-eastern corner of the site. The updated modelling prepared as part of this project provides a notable improvement on the predictions from the existing generalised flood modelling for reasons described in the section below. The updated modelling provides a robust basis for informing planning decisions regarding proposed development at the site.

Approach

A 1D-2D hydraulic model of the watercourse was developed using Flood Modeller-TUFLOW software packages. The hydraulic modelling was developed using new topographic survey of the watercourse and its structures, and ground levels at Coldharbour Farm Road and nearby area. This data was supplemented with elevations from the latest LIDAR data obtained from the Environment Agency to inform floodplain and river bank elevations. The project also included a hydrological analysis to derive peak flow estimates for use in the hydraulic model.

Baseline (as-now) modelling scenarios were simulated for the 5%, 1% and 0.1% Annual Exceedance Probability (AEP) flood events, and the 1% AEP flood event with flows increased by 25% to account for projected changes in flood flows due to climate change. Three proposed development scenarios (referred to as scenarios PD2, PD3 and PD4) were assessed by making modifications to the baseline model, to include proposed elements of the development. The model predictions of the three scenarios were compared to the baseline to understand the changes in predicted flooding.

The table below summarises features associated with each proposed development scenario.

	PD2	PD3	PD4
Access road	✓	✓	✓
Cellular storage	✓	✓	✓
West Brook culvert	Modified: 2m wide x 1m high	Modified: 2m wide x 1m high	Existing
Fluvial flood storage area	✓	✗	✓

Sensitivity analyses were prepared using the baseline model and involved changing the downstream model boundary condition and hydraulic roughness values. Predictions at the area of interest were not greatly affected in the sensitivity scenarios, giving confidence to the flood modelling predictions prepared.

Results

For the baseline (as now) scenario, the site is not predicted to flood during the 5% or 1% AEP event. A small area at the southeast of the site is predicted to flood in the 1% AEP +25% flows event (the event against which the scheme is designed), representing the potential effects of climate change. The depth of flooding is shallow (less than 0.15m), but is predicted to extend onto the footpath west of Coldharbour Farm Road, or the road itself.

During the 0.1% AEP event (a residual risk event), flooding is widespread, and the south and southeast corner of the site are predicted to flood.

Main observations from testing of the three proposed development scenarios are as follows:

Proposed development scenario 2

- Flood water remains in-channel for the 1% AEP event, but peak water levels are reduced due to the increased culvert size.
- For the larger magnitude events tested, including the blockage scenario:
 - o the fluvial flood storage area is either partially, or fully, filled;
 - o reductions in flooding depths and extents are predicted in areas downstream, including areas of existing development;
 - o for the 1% AEP +25% flows events (design and blockage scenarios), reductions in flood depths and extents are predicted upstream, and
 - o for the 0.1% AEP event some flooding across the eastern side of the road is predicted and increased flood depths and extents are predicted in the open space parkland area upstream.

Proposed development scenario 3

- Flood water remains in-channel for the 1% AEP event, but peak water levels are reduced due to the increased culvert size. Reductions in flood levels are also predicted upstream for the 1% AEP +25% flows event.
- For the 1% AEP +25% flows and 0.1% AEP events tested, increases in flood depths and extents are predicted in the developed and open space/parkland downstream.
- For the blockage scenario, slight reductions in flood depths and extents are predicted downstream.

Proposed development scenario 4

- The main messages are largely the same as Proposed Development 2, described above. However, maintaining the size of the existing culvert acts to encourage greater storage of flood water in the fluvial flood storage area, providing greater reductions in flood depths and extents downstream, including areas of existing development.
- For the two residual risk scenarios (0.1% AEP and 1% AEP +25% flows blockage), there are increases in flood depths and extents upstream of the proposed access road, in areas of open space/parkland.

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Abbreviations

1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
FEH	Flood Estimation Handbook
Flood Modeller	Proprietary modelling software developed by Jacobs (all instances of Flood Modeller in this report refer specifically to Flood Modeller 1D)
JBA	Jeremy Benn Associates Limited
LIDAR	Light Detection And Ranging
mAOD	metres Above Ordnance Datum
ReFH	Revitalised Flood Hydrograph method
TUFLOW	Two-dimensional Unsteady FLOW (Proprietary 2D modelling software developed by WBM BMT)

1 Introduction

1.1 Overview

JBA Consulting was commissioned by Bellamy Roberts on behalf of Telstar Limited to prepare fluvial (river) flood modelling and mapping for the West Brook watercourse, Emsworth. This watercourse flows along the eastern boundary of the proposed development site, which is located to the west of Coldharbour Farm Road. The information prepared from this modelling will be used by Telstar Limited as part of development planning at the site.

The existing mapping available from the Environment Agency in their Flood Map for Planning is based on generalised 2D flood modelling, and so does not include the detail of channel hydraulics or other influential features in the catchment such as a flood storage area and structures. The mapping displays significant flood extents from the West Brook watercourse, extending onto the south-eastern corner of the site.

Specific objectives of the project were to:

- Prepare flood flow hydrology inputs for the West Brook catchment to be used within the flood risk model;
- Develop a baseline flood risk model reflecting the current site condition;
- Modify the baseline model to represent development scenarios proposed at the site – these are referred to as proposed development scenarios 2, 3 and 4;
- Simulate the baseline and proposed development scenario models for the 5% Annual Exceedance Probability (AEP), 1% AEP and 0.1% AEP present day events, and the 1% AEP event with an increase to flood flows of 25% (reflecting the Environment Agency's guidance for considering the influence of climate change on flood flows in Flood Risk Assessments¹);
- Prepare flood risk mapping for the baseline modelling to communicate the current level of flood risk at the site;
- Prepare flood risk mapping presenting the change in predicted flooding (peak flood depths and extents) predicted to result from the implementation of proposed development scenarios, and
- Prepare a report documenting the hydrology and flood risk modelling.

¹ Flood risk assessments: climate change allowances, Environment Agency, November 2021. Available: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>

2 Site description

2.1 Development site

The development site is located west of Coldharbour Farm Road, which lies just north of the A27. The site comprises open space grassland which generally slopes from west to east. A ditch is displayed on mapping to intersect the centre of the site. Although this could not be observed on site due to access issues and long vegetation, it is expected to be a minor channel, based on the absence of formal connectivity back to the West Brook watercourse. The red line boundary for the development site is displayed in Figure 2-1.

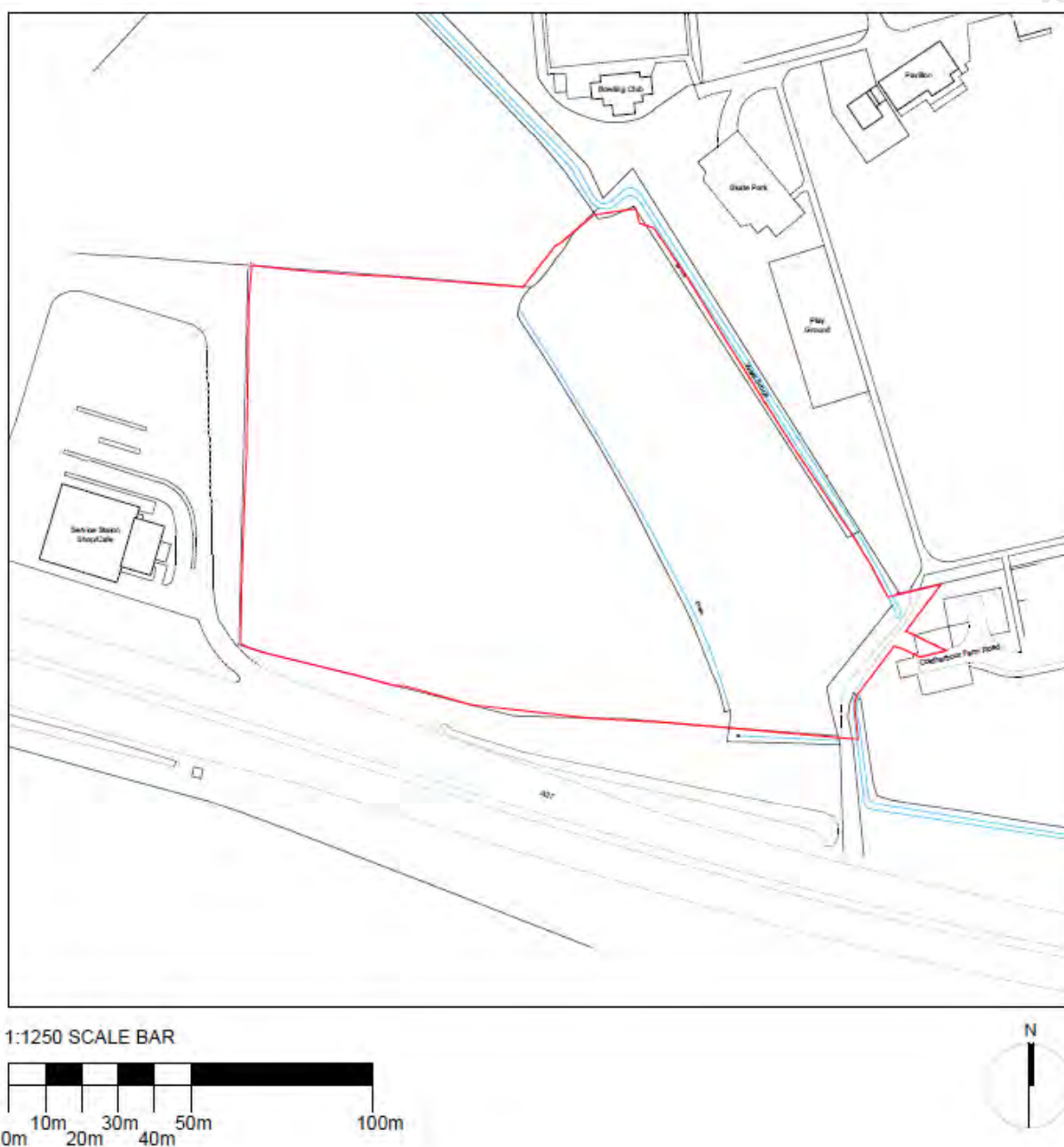


Figure 2-1: Site location plan

2.2 West Brook watercourse and catchment

The West Brook watercourse, catchment and topography are displayed in Figure 2-2.

The catchment is primarily composed of London Clay formation – clay, silt and sand. In the upper part of the catchment soils are slowly permeable and seasonally wet, while in the lower part of the catchment the soils are loamy soils with naturally high groundwater. The catchment topography is relatively steep in the upper catchment, and fairly flat in the lower catchment.

The West Brook (Environment Agency main river) flows in a south easterly direction adjacent to the site. The watercourse rises north west of Emsworth and flows south through Emsworth to its outfall at Emsworth Mill Pond, which discharges into Chichester Harbour. There are a number of drains, notably in the west of the catchment, which mapping indicates joins the West Brook. However, the flow paths and connectivity of these drains is unclear.

The channel banks along West Brook adjacent to the development site (Figure 2-3) and downstream within woodland north of the A27 (Figure 2-4) are overgrown, although the channel itself is relatively clear from vegetation.

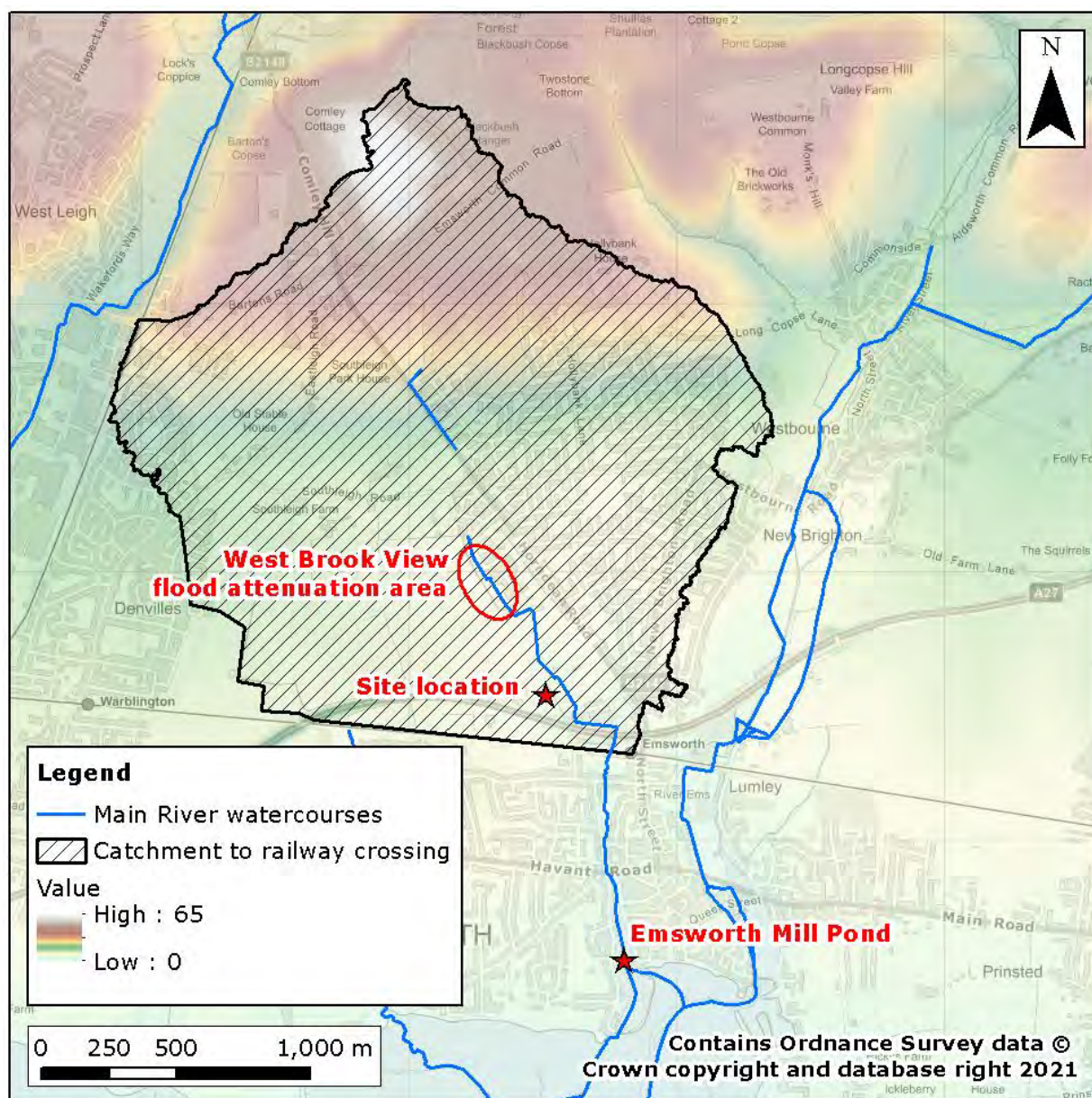


Figure 2-2: West Brook watercourse and catchment



Figure 2-3: West Brook watercourse, north of Coldharbour Farm Road and adjacent to the proposed development site (02/07/2021)



Figure 2-4: West Brook watercourse, north of the A27 (02/07/2021)

2.3 Upstream flood attenuation feature

A residential development has relatively recently been built at West Brook View, upstream of the proposed development site. As part of this, a flood attenuation feature has been constructed, which appears as though it would attenuate flow from the West Brook. The location of this in the catchment is presented in Figure 2-2. The flood attenuation feature comprises a circa 330m long wide basin with embanked sides in places, and a 0.6m diameter outlet culvert (invert level of 7.50mAOD) which has a penstock gate installed on the upstream face to allow the culvert outlet area to be adjusted. Figure 2-5 presents a view of the attenuation area and Figure 2-6 presents an image of the downstream control structure.

At the time of visiting the site (on 02/07/2021) the gate was partially lowered reducing the outflow area of the culvert. The opening area on site appeared consistent with the design drawings which indicate that the normal opening position would be 0.25m above the culvert invert (7.75mAOD). At a level 2.1m (9.60mAOD) above the culvert invert level a weir is present which would act as a spillway should levels rise sufficiently high. The minimum level of the embankments surrounding flood attenuation area are reported to be 0.2m above the weir (9.80mAOD).

Drawings for the development scheme and flood attenuation feature are available as part of planning application reference 14/00547 and 17/00358 on Havant Borough Council's planning portal website. The drawings most relevant to the geometry of the feature included drawing "APP_14_00547-CONDITION_14_-_LONG_SECTION-1032556.pdf" displaying a location plan and long-section of the flood attenuation, and drawing "APP_17_00358-FLOOD_STORAGE_AREA_CONTROL_STRUCTURE-1032788.pdf" displaying the downstream control structure. Key images of the control structure drawing are presented in Appendix A.



Figure 2-5: View of the flood attenuation area, look downstream (02/07/2021)



Figure 2-6: Flood attenuation area control structure (02/07/2021)

2.4 Proposed development scenarios

Three potential development scenarios have been tested within the flood risk mapping model and are presented in this report. These development scenarios are referred to as scenarios 2, 3 and 4, with modelling files given the reference 'PD2', 'PD3' and 'PD4', where 'PD' refers to 'Proposed Development'. Key aspects of each scenario are discussed below. Figure 2-7 presents the location of features associated with the proposed development scenarios. In all scenarios, some features of the proposed development remain constant. These are:

- Access road to the development: route and elevations are informed by drawing "5314 / 1001 Rev A" (dated March 2021)
- Ground levels above the cellular storage for private house drainage: Ground elevations informed by drawing "5314 / 1002 Rev B" (dated March 2021)
- Ground levels above the cellular storage for road drainage: Ground elevations informed by drawing "5314 / 1002 Rev B" (dated March 2021)

Note that because flood water does not extend westwards beyond the proposed road in any of the events tested, the actual residential development areas proposed are not represented in the model. The representation of these regions remain unchanged from the baseline modelling.

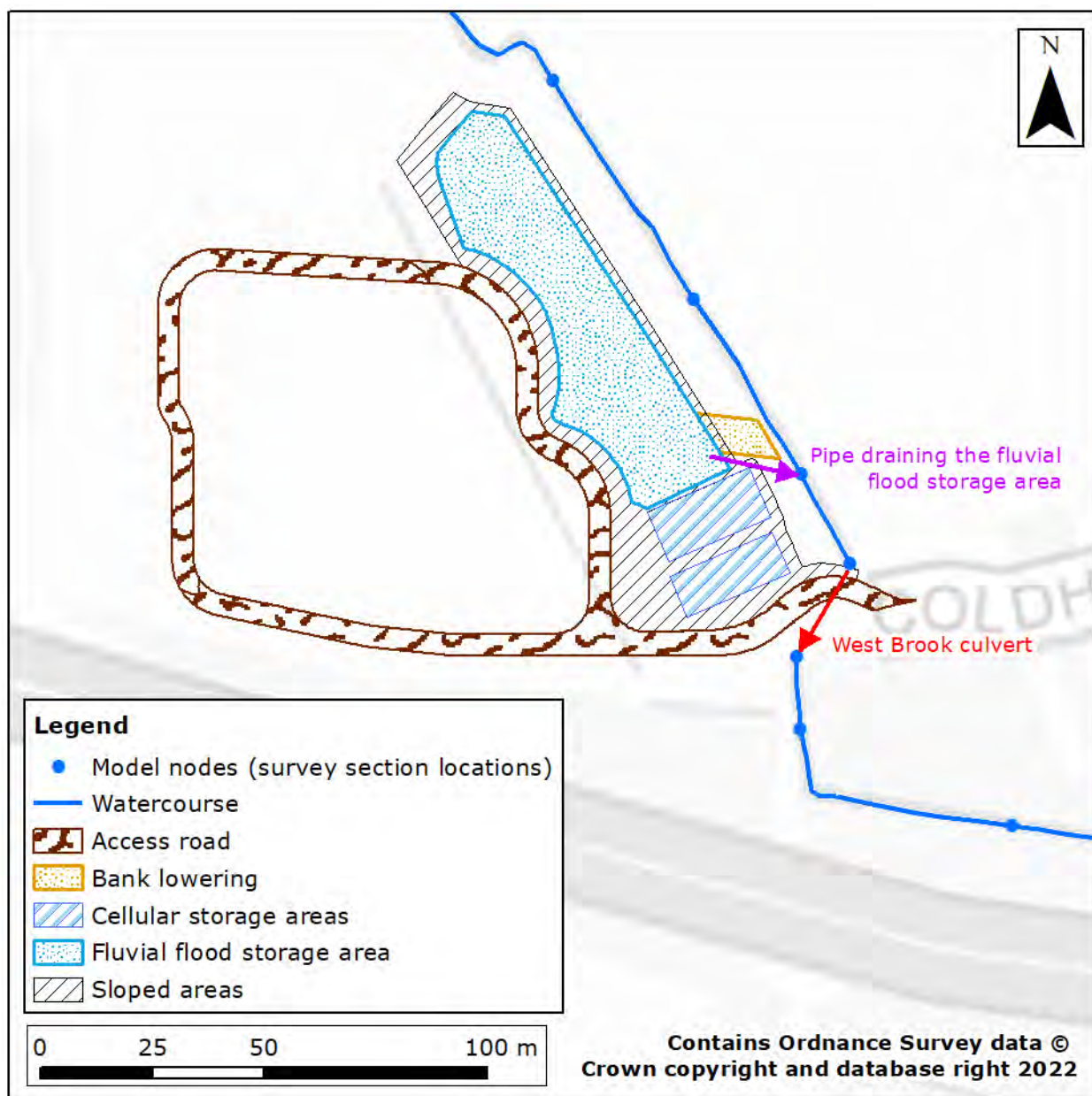


Figure 2-7: Features associated with one or more proposed development scenarios

A summary of which features are included in each development scenario is provided in Table 2-1.

Table 2-1: Summary of features associated with the proposed development scenarios

Feature	PD2	PD3	PD4
Access road	✓	✓	✓
Cellular storage	✓	✓	✓
West Brook culvert	Modified: 2m wide x 1m high	Modified: 2m wide x 1m high	Existing
Fluvial flood storage area	✓	✗	✓

2.4.1 West Brook culvert

For development scenarios where the culvert through which West Brook flows under the footpath (and which the proposed access road would cross) is adjusted, a 2m wide x 1m high culvert is implemented. The current culvert is 1m wide x 1m high. The Environment Agency have indicated that there needs to be consideration of a 0.2m deep gravel bed to the culvert. Therefore, in practical terms within the modelling, the height of the culvert has been set to 0.8m, assuming that 0.2m height of the culvert would be below the current invert of the culvert (otherwise it is assumed that gravel would be transported away). The hydraulic roughness of the culvert invert has been increased to account for the likely presence of gravel. Refer to section 3.4 for further details.

2.4.2 Fluvial flood storage area

A fluvial flood storage area is proposed to the east of the access road and north of the cellular storage areas. It is intended that flood water at the peak of flooding from West Brook would flow into this storage area in order to mitigate potential adverse impacts of the proposed scheme. Sloped sides down to the invert of the storage area are proposed, and the eastern side of the storage area would commence 8m beyond the bank of the West Brook watercourse, again with sloped sides to the invert of the storage area. The invert of the storage area would be set at 4.85mAOD. This is 0.15m above the 4.70mAOD indicated in earlier drawings. This higher invert level is required to enable a pipe (modelled as 0.15m diameter) to drain from the base of the storage area to the West Brook watercourse, which at the location of the proposed outlet has an invert level of 4.7mAOD. A flapped outfall is represented to prevent backflow of fluvial water from the watercourse into the storage area. The approximate area of the base of the storage area is 1,800m². An 8m length of the West Brook watercourse's left bank is lowered to a level of 5.35mAOD to facilitate water from West Brook entering the flood storage area. The 5.35mAOD level is slightly above the peak water level predicted for the 1% AEP event from the latest modelling. No out of bank flooding at the site is predicted for the 1% AEP event in the latest modelling. Therefore, the flow route was schematised so that it only starts filling for larger magnitude events, when potential effects of the proposed development may occur.

3 Data and methodology

3.1 Available data

Data available to inform the baseline flood risk modelling is presented within Table 3-1.

Table 3-1: Data available to inform the flood modelling assessment

Data type	Details
Ground elevations	LIDAR data - Source: Environment Agency - Details: National LIDAR Programme 1m DTM data (2020)
	Limited topographic survey at Coldharbour Farm Road and the footpath south towards the underpass at the A27 - Source: Lewis Brown Limited - Details: Collected August 2021 (ref: C21201) The topographic survey data is presented in Appendix B The location of point elevations is presented in Figure 3-1.
Channel survey for West Brook	Channel and structure survey data - Source: Lewis Brown Limited - Details: Collected August 2021 (ref: C21201) - Open channel sections, plus structure sections at A) the culvert under the footpath beside Coldharbour Farm Road, B) the culvert under the A27 and C) the culvert under the railway line The location of survey sections is presented in Figure 3-1.
Details of the proposed access road	Drawing of the proposed access road to the development site, presenting location and elevations. - Source: Bellamy Roberts - Details: Drawing ref 5314/1001 Rev A, March 2021 - File: "5314-1001 Rev A BOUND.dwg"
Details of the cellular storage areas	Drawing of the cellular storage areas, presenting location and elevations. - Source: Bellamy Roberts - Details: Drawing ref 5314/1002 Rev B, March 2021 File: "5314-1002 Rev B BOUND.dwg"

3.2 Site walkover and survey

A site walkover was undertaken by JBA Consulting on 02/07/2021, with Lewis Brown Limited, to inform the specification of survey (delivery ref C21021) required to inform the modelling.

3.3 Hydrology (flood flows)

Refer to the hydrology report (calculation record) provided in Appendix C for full details of the hydrology assessment.

West Brook drains a total area of 1.6km² to the downstream of the West Brook View flood attenuation area, and circa 2.3km² to the downstream extent of the site. A region of catchment, without the presence of watercourses being present, also slopes towards West Brook upstream of the railway line, meaning the total area of catchment upstream of the railway line is 3.9km².

There are a network of drains within the catchment to the west of West Brook. The connectivity of these drains is uncertain, and these may have a significant impact on the catchment area. A conservative approach to deriving the catchment boundaries was adopted, where it assumes all of these drainage channels would direct flood water towards West Brook watercourse.

Hydrological inflows for the hydraulic model were prepared for the following events:

- 5% Annual Exceedance Probability (AEP)
- 1% AEP
- 0.1% AEP
- 1% AEP, with flows increased by 25% to account for the predicted effects of climate change.

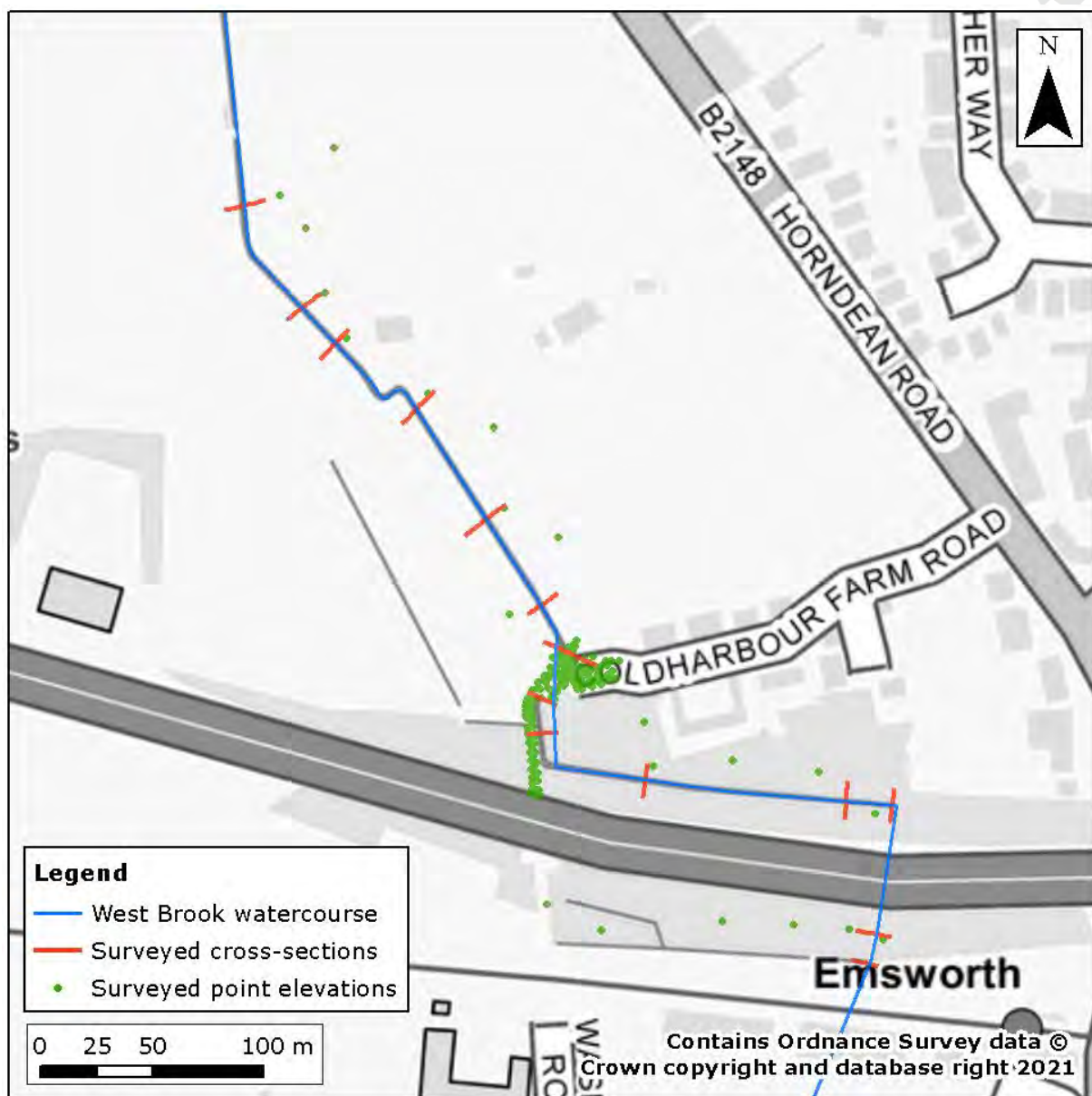


Figure 3-1: Location of survey sections and point elevation data (Lewis Brown Limited, August 2021, ref: C21021)

3.3.1 Flood estimation and model inflow locations

Three flood flow inputs were derived, as described below:

- 1 Inflow WEST01, representing the West Brook catchment to the downstream of the flood attenuation area
- 2 Inflow TRIB01, representing the urbanised eastern part of the catchment. This catchment does not appear to have watercourses, but the topography slopes towards West Brook where it flows under the A27
- 3 Inflow WEST02_IA, representing the intervening area of catchment between WEST01 and TRIB01.

3.3.2 Choice of method

Flood estimates were prepared using both the Flood Estimation Handbook (FEH) Statistical and Revitalised Flood Hydrograph (ReFH) 2 methods. Flood flows from the FEH Statistical method were larger than those for the ReFH2 method and were taken forward. For inflows WEST01 and TRIB01, hydrographs from the ReFH2 method were scaled to fit the statistical peaks, which for WEST02_IA, ReFH2 hydrographs were applied to the model.

3.3.3 Storm duration testing

Testing of storm durations using the ReFH2 method was completed for the 1% AEP +25% flows event, for both the flood attenuation area penstock open and partially closed scenarios. Storm durations of 7.5-hours, 11.5-hours and 15.5-hours were tested. In both scenarios, the 7.5-hour event was found to produce greatest flood flows, levels and extents at the site, and so was taken forward.

3.3.4 Inflows from TRIB01 catchment

The TRIB01 catchment is heavily urbanised and a watercourse draining to West Brook is not present, so any flood water resulting from rainfall would runoff overland. In light of the absence of a channel system, consideration was given to removing the TRIB01 inputs from the model. This was considered to be an extreme approach (although potentially justifiable).

However, a compromise approach was taken forward whereby flows originating from the TRIB01 catchment are still applied to the model, but it was assumed that the surface water sewer system in the urbanised area captures a proportion of the runoff, meaning there are losses in terms of the flow rate that enters the watercourse.

The capacity of the sewer system was assumed to accept rainfall associated with the 3.3% AEP event (an event magnitude often considered for sewer capacity), and so the 3.3% AEP peak inflow rate for TRIB01 (1.302m³/s) was subtracted from the flood inflow rates applied to the model.

3.3.5 Final peak flood flow estimates

Final peak flow inputs to the flood mapping model for the three boundary inflows are presented in Table 3-2. Note that these inflows represent the peak flows applied to the model and may not be representative of the lumped catchment estimates presented within the hydrology report.

Table 3-2: Final flood flow estimates applied to the model

Inflow	Peak flow (m ³ /s) for the following AEP events			
	5% AEP	1% AEP	1% (+25%)	0.1%
WEST01	1.2	1.9	2.2	3.3
TRIB01* (*after subtraction of 3.3% AEP flow)	0	0.5	0.9	1.9
WEST02_IA	0.4	0.6	0.7	0.9

3.4 Hydraulic (flood risk) modelling

A linked 1D-2D Flood Modeller (1D) and TUFLOW (2D) model was developed and has been built in accordance with standard methods adopted for flood risk modelling and mapping. Some key aspects of the model schematisation are presented in Table 3-3. The schematisation of the flood risk mapping model is presented in Figure 3-2.

Table 3-3: Key aspects of the baseline and proposed development model schematisation

Aspect of model	Details
DTM data	LIDAR: National LIDAR Programme 2020 data, 1m resolution
Resolution of the model grid	2m
Orientation of the model grid	The 2d_loc line, and so the grid orientation, is positioned so that it follows the direction of the channel and floodplain south from Coldharbour Farm Road, and including potential overland flow across Coldharbour Farm Road and the proposed development site. This approach, in addition to the 2m model grid means that flow routes and elevations are well defined in the model.
Length of model watercourse	1.3km
Changes to default run parameters	Flood Modeller run parameters alpha and minitr were adjusted to values of 1 and 4, from their defaults of 0.7 and 3, respectively. This is a positive adjustment to reduce the mass error of the model simulation, which is particularly important given the presence of the flood attenuation area at the upstream of the model.
1D channel roughness (Manning's n)	Bed: 0.040-0.045 Banks: 0.060-0.080 These values were informed by observations while on site, and used Cowan's (1956) ² method and Chow (1959) ³ sources as guidance. Note that the hydraulic roughness values for both the channel and floodplain at the flood attenuation area are set to $n=0.040$. While it might typically be expected that the floodplain roughness is higher than the channel, the amount of vegetation is similar across the flood attenuation area and the significant flood depths expected during times that water is stored means the use of the same values is appropriate.
2D floodplain roughness (Manning's n)	Four land cover categories, each with different hydraulic roughness values: #1, 0.050 representing grass #2, 0.080 representing woodland #3, 0.030 representing paths and roads #4, 0.300 representing buildings There is little formal guidance for the selection of hydraulic roughness for 2D domains, so the values selected are consistent with those used for other flood risk mapping projects.

² Cowan, W. L. (1956). Estimating hydraulic roughness coefficients: Agricultural Engineering, v. 37, no. 7, p. 473-475.

³ Chow, V.T. (1959) Open-Channel Hydraulics. McGraw-Hill, New York

Aspect of model	Details
Existing flood attenuation area	Flood Modeller 1D River Sections describing the channel: - Numerous cross-section profiles were extracted from the LIDAR data which includes elevations of the flood attenuation area - Levels of the channel invert were inspected from drawing "APP_14_00547-CONDITION_14_-_LONG_SECTION-1032556.pdf" and the LIDAR section data modified at the channel to provide a 1.5m wide base with the relevant invert applied This approach was selected as LIDAR captures the geometry of the floodplain the flood storage area well, and the flow direction is known - upstream to downstream - with water levels rising and attenuation occurring. Detailed predictions of flooding are not required on the floodplain here, and it was not necessary to increase the complexity of the model (and potentially introduce instability) by representing this as a 1D-2D linked area. Flood Modeller 1D structures representing flow routes allowing water out of the FSA, connected to the 2D domain downstream with SX links: - Outlet culvert (when open): Circular orifice unit - Outlet culvert (when partially closed): Rectangular orifice unit with invert and soffit levels, and bore area adjusted to reflect the partial opening - Overtopping weir: SPILL unit - Adjacent embankments: 2 no. SPILL units
West Brook downstream of existing flood attenuation area	From the flood attenuation area outlet to the upstream extent of survey (circa 300m length of channel): 2D Z-Shape used to modify the model DEM to route water over the model grid surface, and back into the 1D channel downstream via HX links across to top of the river reach. - A 2m width is applied to channel, which is consistent with the width of the channel bed in the 1D channel sections downstream. The 2m width is an approximate width based on surveyed channel sections downstream, and is appropriate in light of the 2m model grid size. - Bed levels of the channel are informed by the invert level at the outlet of the FSA and the invert level of the 1D channel downstream (section WB01_0523). - The 'MIN' command is applied in TUFLOW so that if any model cells within elevations initially informed by LIDAR data have elevations lower than produced by the Z-Shape, these are retained. - This approach is appropriate given that the reach of channel is upstream of the proposed development site, and flood water is directed back into the 1D channel downstream. The purpose of the 2D model area is to route water from the FSA to the 1D-2D linked area of the model, but not to provide definition predictions of flood extents/depths. The approach is conservative, with the upstream flow remaining in bank, and so increasing the flow rate at the proposed development site, compared with a circumstance where the influence of structure or wetting of the floodplain results in attenuation of flows.

Aspect of model	Details
	Surveyed reach to model downstream boundary: • 1D River Sections connected to the 2D floodplain domain via HX links. • Culvert units are applied at the three culverts present within the reach. Culvert inlet and outlet units are applied where applicable. Note that testing was completed on the outlet loss unit applied to model culvert "WB01_0274" (downstream of the footpath at Coldharbour Farm Road) which was producing a spurious headloss and spike in water level predictions. The approach found to be most representative, and stable was to remove culvert outlet loss unit. This approach is representative given that the culvert discharges to a channel where little or no expansions losses are expected.
Bypassing at structures	At the flood attenuation area, SPILL units are used to represent the flow routes of water exceeding the control structure of embankment levels and flowing downstream. At structures within the 1D-2D model area, SPILL units are not applied for the following reasons: Structure WB01_0274cu: Coldharbour Farm Road culvert. Bypassing flow is permitted in the 2D domain. Applying a SPILL unit which would assume water flows directly from the upstream channel to the downstream channel would be a simplistic assumption, and would potentially mean that potential for flood water to flow over the footpath adjacent to Coldharbour Farm Road would be underestimated. Structures WB01_0071cu and WB01_0000cu: Culverts located at the A27 and railway line, respectively. Peak flood levels do not exceed the level of these features and so SPILL units are not needed. Flow could pass over them in the 2D domain if predicted.
A27 and railway underpasses	TUFLOW 2D Z-Shape features apply a flow route through these features, with elevations extracted from topographic survey and LIDAR data where required.
Downstream boundary and channel sections downstream of the railway line	Two River Sections, with interpolate units, are applied to the model downstream of the railway line culvert (model culvert "WB01_0000") to extend the model and provide an appropriate downstream boundary condition. The width of these sections is informed by Ordnance Survey mapping, site observations and satellite imagery, while the invert levels are extracted from LIDAR data. Although the coast is located circa 750m south of the downstream boundary, a tidal influence is not evident in telemetry data at the West Brook gauge located 200m south of the downstream boundary, which is likely to be due to presence of the mill pond at the outlet to the coast. The downstream boundary applied is a normal depth boundary with the slope (0.003m/m or 1 in 333 slope) informed by the channel gradient downstream of the railway line.

Aspect of model	Details
Proposed development scenario modelling	
Proposed access road	A Z-Shape feature is used to apply elevations from the drawing 5314/1001 Rev A, March 2021. This access road connects to Coldharbour Farm Road, elevations for which are informed by topographic survey (see above). Files applied: 2d_zsh_proposed_road_5314_1001_WB_003_R.shp 2d_zsh_proposed_road_5314_1001_WB_003_L.shp 2d_zsh_proposed_road_5314_1001_WB_003_P.shp
Proposed cellular storage areas	The ground level above the surface water cellular storage areas are applied via Z-Shape features: 2d_zsh_proposed_ground_lowering_PD#_invert_WB_002_P.shp 2d_zsh_proposed_ground_lowering_PD#_invert_WB_002_L.shp 2d_zsh_proposed_ground_lowering_PD#_invert_WB_002_R.shp Where # denotes Proposed Development scenarios 2 or 3.
Proposed fluvial flood storage area	The ground level at the base of the fluvial flood storage areas is applied via Z-Shape features: 2d_zsh_proposed_ground_lowering_PD#_invert_WB_002_P.shp 2d_zsh_proposed_ground_lowering_PD#_invert_WB_002_L.shp 2d_zsh_proposed_ground_lowering_PD#_invert_WB_002_R.shp Where # denotes Proposed Development scenarios 2 or 3.
Proposed sloped regions between the river, road, and cellular and fluvial storage areas	The sloped areas of ground are applied via Z-Shape features: 2d_zsh_proposed_ground_lowering_PD#_slope_WB_002_P.shp 2d_zsh_proposed_ground_lowering_PD#_slope_WB_002_L.shp 2d_zsh_proposed_ground_lowering_PD#_slope_WB_002_R.shp Where # denotes Proposed Development scenarios 2 or 3.
Proposed fluvial flood storage area outlet pipe	The 0.15m diameter pipe is applied within the Flood Modeller model as an orifice unit (node label "Outfall_u_2D"). The orifice unit is connected at its upstream end to the base level of the 2D fluvial flood storage area via an SX link, and connects to a Flood Modeller junction on West Brook watercourse at its downstream end. A flapped outfall is specified so water can only drain positively from the fluvial flood storage area into the watercourse.
Increased capacity culvert under the footpath adjacent to Coldharbour Farm Road	The existing culvert units and inlet have been adjusted from 1m wide and 1m high to 2m wide and 0.8m high (this has not been set to 1m high to reflect the likely requirement for 0.2m depth of gravel). The hydraulic roughness (Manning's n) of the culvert invert has been increased from $n=0.015$ to $n=0.030$.

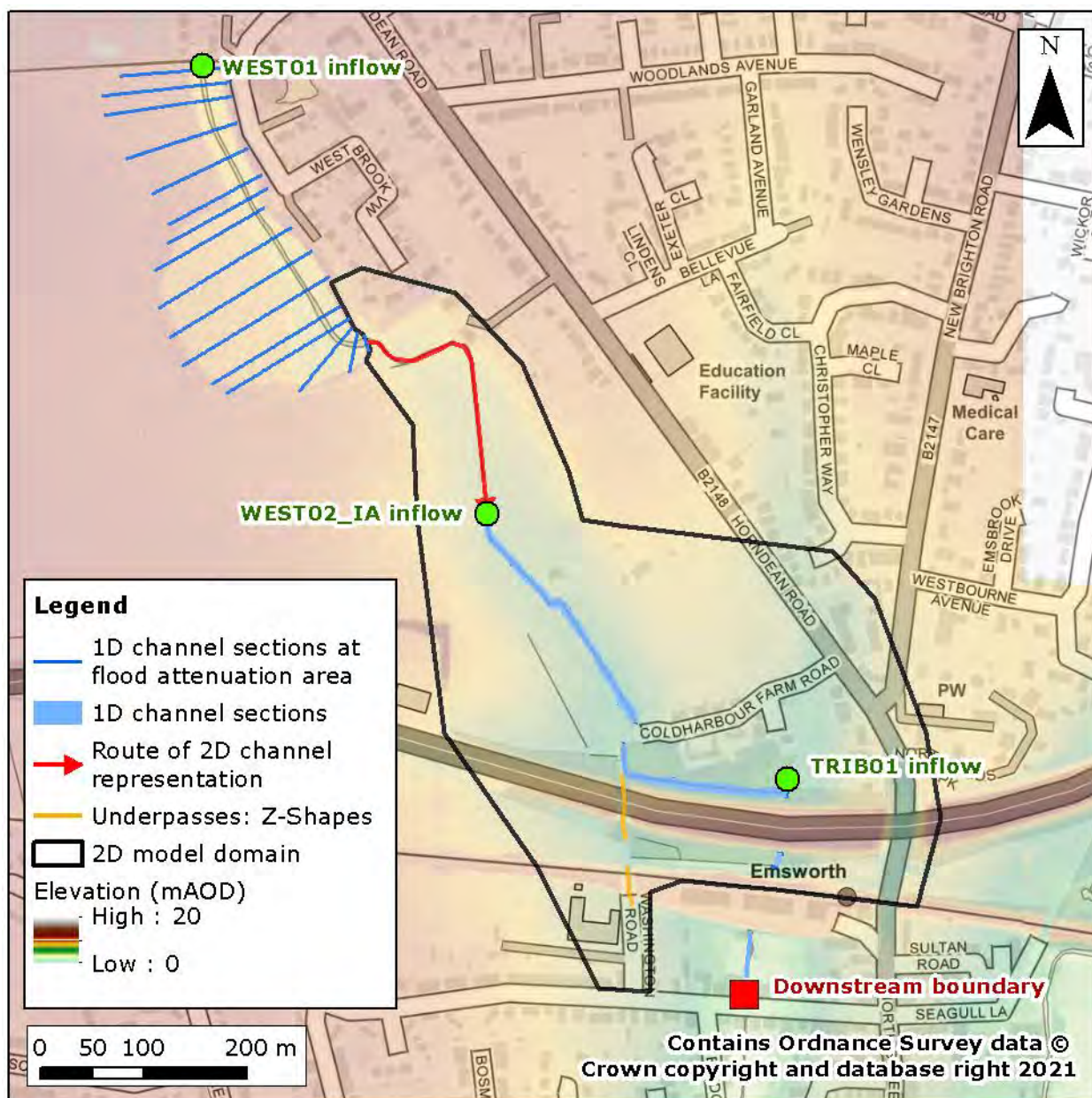


Figure 3-2: Schematisation of the baseline flood risk mapping model

3.4.1 Existing flood attenuation area outlet position

The drawings available for the outlet of the flood attenuation area indicate that the normal position for the penstock gate is positioned partially obscuring the culvert, with the bottom of the gate 0.25m above the invert level of the culvert. No operating procedures for the attenuation area could be identified and so it is considered unlikely that during a flood event the penstock would be manually operated to modify the storage of flood water. However, it is possible that the penstock could be in a different position than 'normal' at the onset of a flood event, which would influence the rate of storage, and therefore attenuation upstream. This would in turn also influence the likelihood and timing of exceedance of the maximum storage level before flow passes across the weir and potentially embankments. In light of this possibility, the flood modelling prepared as part of this assessment simulated two scenarios for the penstock: 1) as per the design drawings (penstock set 0.25m above the culvert invert) and 2) penstock fully open. From these scenarios, the worst-case flood predictions are then presented.

3.5 Sensitivity testing of the baseline model

Sensitivity testing was completed for the baseline modelling using the 1% AEP +25% flows design event, given that this event is likely to be most influential for decision-making at the proposed development site. The results described are for the scenario in which the flood attenuation area penstock gate is open, as this produces worst-case flood levels at the site. Two sensitivity test scenarios were completed, in addition to a blockage scenario, as presented below.

3.5.1 Hydraulic roughness (1D and 2D)

Hydraulic roughness for both the channel and the floodplain was increased by 20%. The change in flood extents between the baseline and sensitivity test are displayed in Figure 3-3. Conclusions drawn from comparison of these results with those of the baseline model are as follows:

- Peak water levels at the upstream and downstream of the culvert under the footpath beside Coldharbour Farm Road (model node WB01_0274) increase by 0.05m.
- The extent of flooding increases, with the shallow (<0.15m) depth flooding from the western bank of West Brook which extends onto the site in the baseline, flowing onto and across the footpath south of Coldharbour Farm Road. Flood depths on the footpath remain below 0.25m.
- The hydraulic roughness values selected to inform the baseline model are considered representative, but the sensitivity of predictions to hydraulic roughness should be kept in mind. The 1% AEP +25% flows event appears to represent an event where the watercourse is 'at capacity' and so any increase in flood water levels results in a more notable increase in flood extent.

3.5.2 Downstream boundary slope

The slope value assigned to the downstream boundary was adjusted from 0.003m/m (1 in 333 slope) to 0.002m/m (1 in 500 slope). The change in flood extents between the baseline and sensitivity test are displayed in Figure 3-4. Conclusions drawn from comparison of these results with those of the baseline model are as follows:

- Peak water levels at the upstream and downstream of the culvert under the footpath beside Coldharbour Farm Road (model node WB01_0274) increase by 0.04m and 0.05m, respectively.
- The extent of flooding increases, with the shallow (<0.15m) depth flooding from the western bank of West Brook which extends onto the site in the baseline, flowing onto and across the footpath south of Coldharbour Farm Road. Flood depths on the footpath remain below 0.25m.
- The downstream boundary value selected to inform the baseline model is considered representative, but the sensitivity of predictions to adjustment of this boundary should be kept in mind, as any reduction in efficiency of the system downstream (e.g. through blockage) may influence water levels at the site. The 1% AEP +25% flows event appears to represent an event where the watercourse is 'at capacity' and so any increase in flood water levels results in a more notable increase in flood extent.

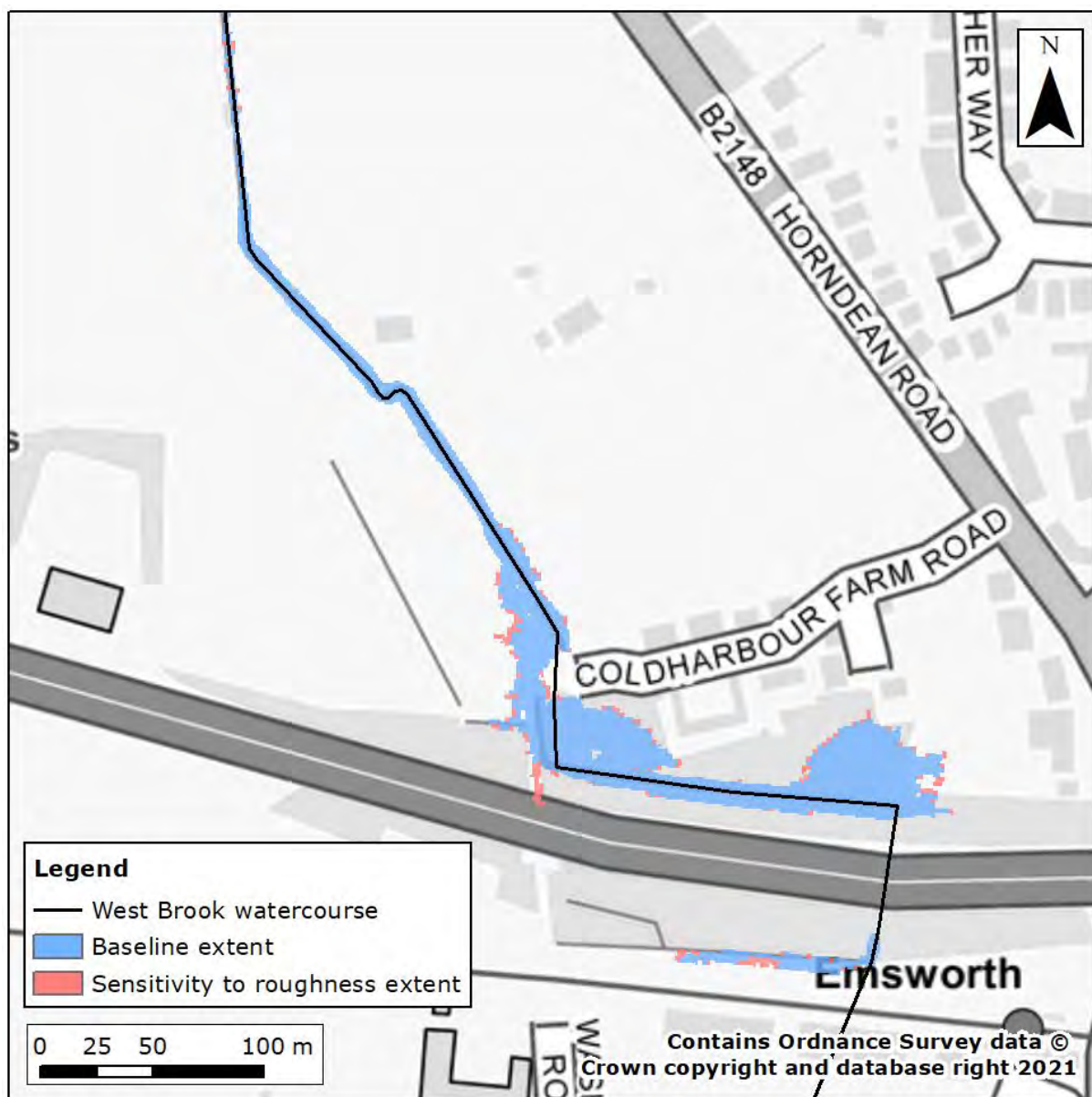


Figure 3-3: Flood extents – sensitivity to hydraulic roughness test (FSA Open / 1% AEP plus 25% flows)

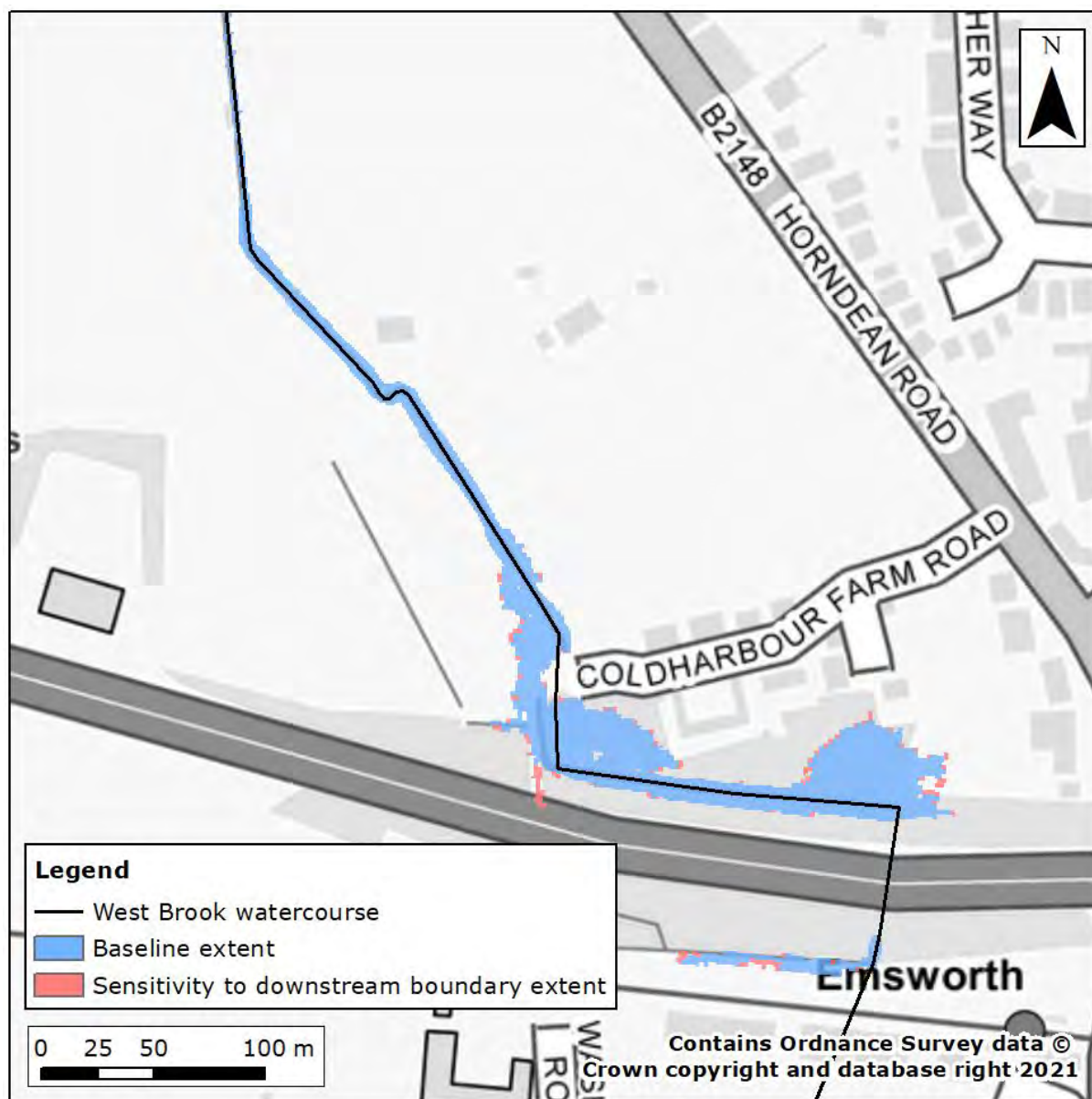


Figure 3-4: Flood extents – sensitivity to downstream boundary test (FSA Open / 1 % AEP plus 25 % flows)

3.5.3 Blockage of the culvert at Coldharbour Farm Road

A blockage of 50% was applied at the upstream of the culvert at Coldharbour Farm Road, by specifying a blockage proportion of 0.5 within the culvert inlet loss unit. The change in flood extents between the baseline and sensitivity test are displayed in Figure 3-5. Conclusions drawn from comparison of these results with those of the baseline model are as follows:

- Peak water levels at the upstream and downstream of the culvert under the footpath beside Coldharbour Farm Road (model node WB01_0274) increase by 0.12m and 0.01m, respectively.
- The extent of flooding increases, with the shallow (<0.15m) depth flooding from the western bank of West Brook which extends onto the site in the baseline, flowing onto and across the footpath south of Coldharbour Farm Road. Flood depths on the footpath remain below 0.25m.
- Representing the culvert as free from blockage in the baseline model is appropriate, but the sensitivity of predictions to blockage (which is a residual risk) should be kept in mind.

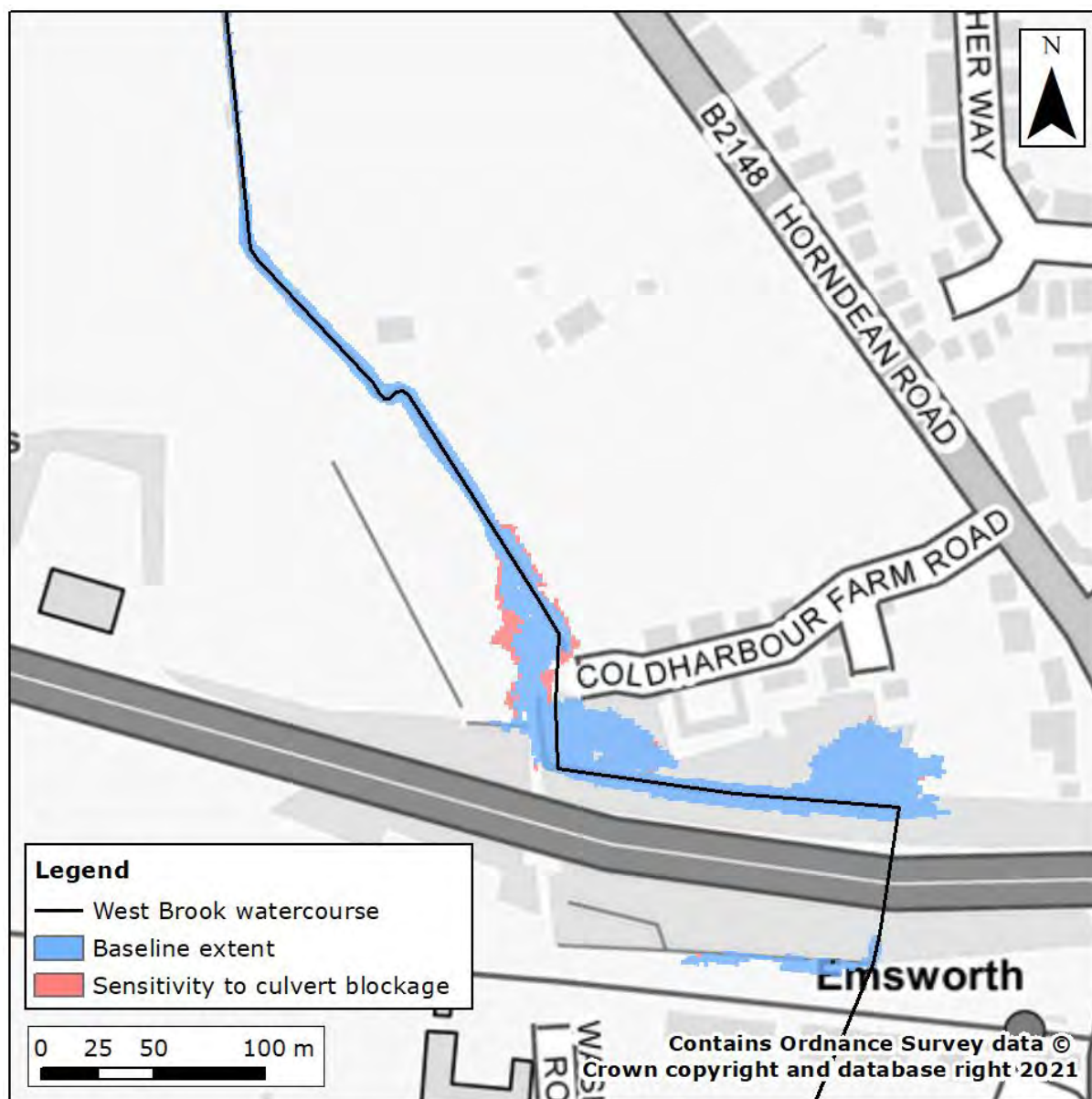


Figure 3-5: Flood extents – sensitivity to 50 % blockage of the inlet to the culvert at Coldharbour Farm Road (FSA Open / 1 % AEP plus 25 % flows)

3.6 Modelling uncertainty

While the flood predictions presented within this report show information that appears definitive, in practice there are uncertainties inherent within all modelling which could mean that model predictions of extents, depth, water levels and so on, differ from what would occur in reality. Uncertainty may be introduced through aspects of the modelling including; the data used to inform the geometry of the model (e.g. ground levels), choices made regarding model parameterisation (e.g. hydraulic roughness), as well as the hydrology (flood flow) inputs.

While uncertainty is present within the modelling, the data, parameterisation and schematisation of the model is considered to be appropriate, and the model can be used to assess impacts of any proposed development with confidence. Moreover, conservative approaches to the modelling have been adopted, which will tend towards producing greater flooding than might otherwise be the case e.g. with the selection of hydrological catchment area (section 3.3) and representation of the upstream flood attenuation feature (section 3.4.1). This conservative approach should give confidence that predicted flooding, and therefore potential effects of a proposed development, are not underestimated.

Management of the uncertainty (and sensitivity) with the flood modelling predictions could be addressed by taking a precautionary approach to site design/levels, and/or including measures within the site design to help manage flooding, should flood levels exceed those modelled (including events that exceed the design standard).

4 Baseline scenario flood predictions

4.1 Predicted flooding: updated baseline

Flood depth mapping for the 1% AEP, 1% AEP +25% flows and 0.1% AEP events is presented in Appendix D. Flood water level mapping for the 1% AEP, 1% AEP +25% flows and 0.1% AEP events is presented in Appendix E.

Predicted flooding from the latest detailed modelling is notably reduced compared with the existing flood mapping published by the Environment Agency in their Flood Map for Planning.

The following observations are made regarding flooding in the updated modelling:

- Apart from for the 0.1% AEP event, flood levels within the watercourse are slightly greater in the scenario where the flood attenuation area culvert is fully open, compared with partially closed. The outputs of the scenario which provides greatest water levels in watercourse at the site have therefore been considered as they provided a conservative (more worst-case) scenario of flooding.
- Water levels within West Brook, adjacent to, and beyond the site remain in-bank for the 5% and 1% AEP events i.e. water does not flow onto the floodplain.
- For the 1% AEP +25% flow event, flood water flows out of bank of the western side of West Brook, into the site immediately upstream of the culvert at Coldharbour Farm Road. Flood depths are relatively shallow (less than 0.15m) and encroach onto the footpath. Flood water flows out of bank through parts of the woodland north of the A27.
- Blockage of the culvert at Coldharbour Farm Road would increase flood levels at the eastern side of proposed development site and on the footpath adjacent to the site. This forms a residual risk.
- For the 0.1% AEP event, channel exceedance is widespread and flooding of the south-eastern side of the proposed development site is predicted, including parts of Coldharbour Farm Road and the footpath west of this. Flood depths along Coldharbour Farm Road and the footpath exceed 0.5m.

4.2 Hazard rating at the proposed access road

Figure 4-1 presents the hazard rating at the location of the proposed access road in the baseline modelling for the 1% AEP +25% flows event. Hazard rating is based on the formula from Environment Agency research project guidance FD2320⁴/FD2321⁵, with a 'Conservative' debris factor approach applied. Flood depths below 0.15m and flood velocities below 0.15m/s result in a low hazard rating (less than 0.75) according to guidance FD2320/TR2. The hazard to people is 'low' and guidance (refer to Table 4-1) indicates that the area should be described as 'Caution', but based on the other higher hazard categories, risk to people is not necessarily applicable.

⁴ Defra (2005) Framework and Guidance for Assessing and Managing Flood Risk for New Development, Flood Risk Assessment Guidance for New Development, FD2320 Technical Report 2, HR Wallingford et al. prepared the report for Defra/Environment Agency Flood and Coastal Defence R&D Programme, October 2005.

⁵ Defra (2006) The Flood Risks to People Methodology, Flood Risks to People Phase 2, FD2321 Technical Report 1, HR Wallingford et al. prepared the report for Defra/Environment Agency Flood and Coastal Defence R&D Programme, March 2006.

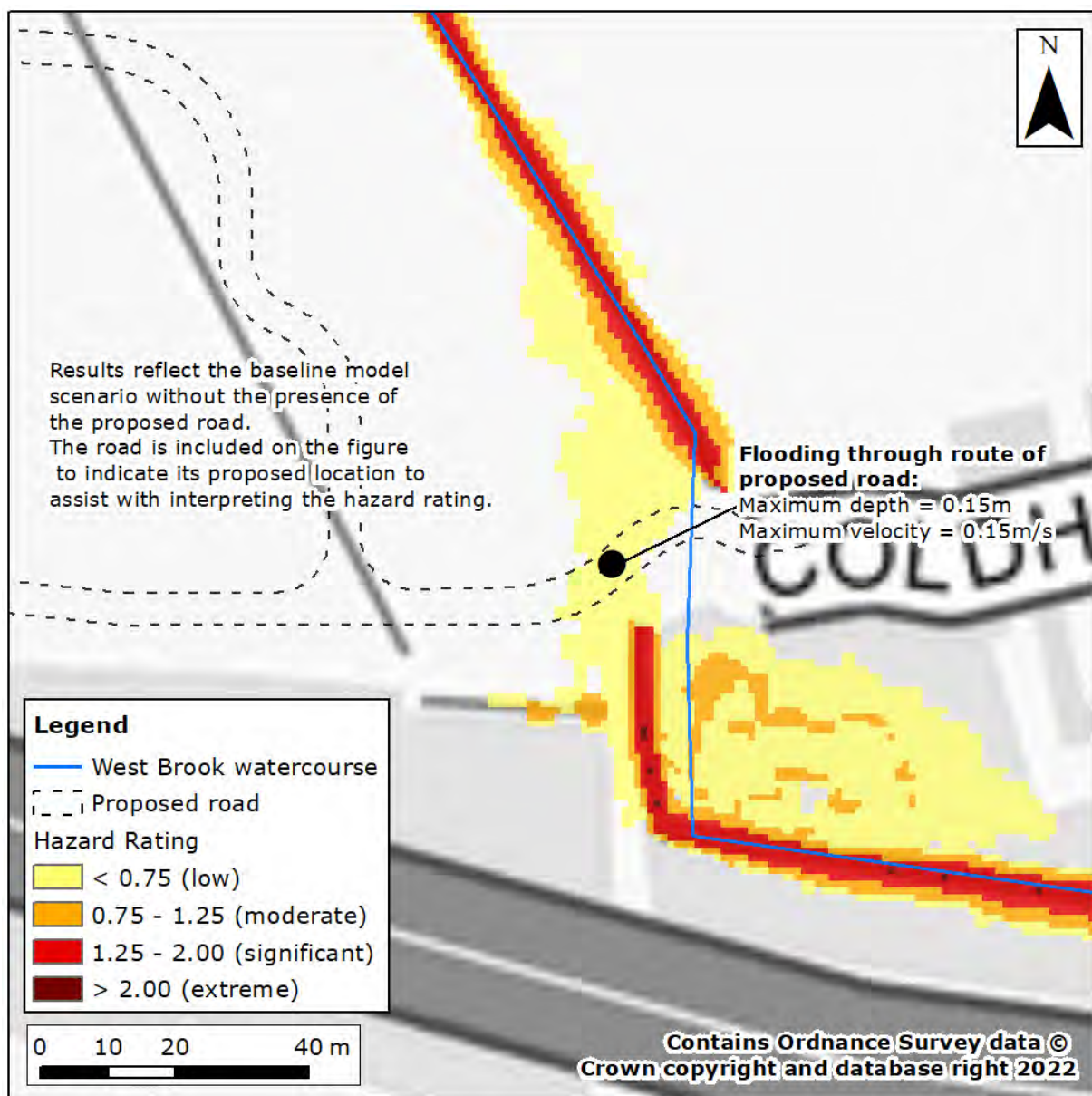


Figure 4-1: Hazard rating in the 1% AEP + 25% flows baseline scenario at the location of the proposed access road

Table 4-1: Hazard to People table extracted from Table 3.2 in FD2321/TR1

Thresholds for Flood Hazard Rating $H = d \times (v + 0.5) + DF$		Degree of Flood Hazard	Description
FD2321	FD2320		
<0.75	<0.75	Low	Caution - "Flood zone with shallow flowing water or deep standing water"
0.75 - 1.25	0.75 - 1.25	Moderate	Dangerous for some (i.e. children) - "Danger: Flood zone with deep or fast flowing water"
1.25 - 2.5	1.25 - 2.0	Significant	Dangerous for most people - "Danger: flood zone with deep fast flowing water"
>2.5	>2.0	Extreme	Dangerous for all - "Extreme danger: flood zone with deep fast flowing water"

5 Proposed development scenario flood predictions

5.1 Changes in flood depths and extents: scenarios vs baseline

The sub-sections below discuss the changes in flood depths and extents for the proposed development scenarios compared to the baseline. The 1% AEP +25% flows event forms the design event, which is the focus for the design of scheme and assessment of its performance. The 0.1% AEP event represents a residual risk scenario, that being an event which exceeds a design standard. Additionally, the 50% blockage scenario tested at the culvert under Coldharbour Farm Road also forms a residual risk event.

5.1.1 Proposed development scenario 2 (PD2)

Changes in maximum flood depths and extents between the proposed development scenario 2 predictions and the baseline scenario are presented in mapping contained in Appendix F. This also includes comparison of the 50% blockage scenarios applied to both the proposed development and baseline scenario modelling, discussed in the sub-section below. Refer to section 5.2 for a table which presents changes to in-channel water levels.

Main observations are as follows:

1 % AEP

- Reductions to in-channel water levels are predicted upstream due to the increased size of the culvert.

1 % AEP + 25 % flows

- The fluvial flood storage area is partially filled.
- Flooding across the road is not predicted.
- Reductions in flood extents and depths are predicted upstream and downstream.

0.1 % AEP

- The fluvial flood storage area is filled.
- Flooding across the road is predicted only at its eastern extent.
- Increased flood depths and extents are predicted in the open space/parkland upstream.
- Decreased flood depths and extents are predicted in the developed and open space areas downstream.

1 % AEP + 25 % flows, with 50 % blockage at the culvert

- The fluvial flood storage area fills to a greater depth than the comparisons without blockage.
- Flooding across the road is not predicted.
- Reductions in flood extents and depths upstream and downstream are enhanced compared with the comparisons without blockage.

5.1.2 Proposed development scenario 3 (PD3)

Changes in maximum flood depths and extents between the proposed development scenario 3 predictions and the baseline scenario are presented in mapping contained in Appendix G. This also includes comparison of the 50% blockage scenarios applied to both the proposed development and baseline scenario modelling, discussed in the sub-section below. Refer to section 5.2 for a table which presents changes to in-channel water levels.

Main observations are as follows:

1 % AEP

- Reductions to in-channel water levels are predicted upstream due to the increased size of the culvert.

1 % AEP + 25 % flows

- Reductions to in-channel water levels are predicted upstream due to the increased size of the culvert.
- Flooding across the road is not predicted.
- Relatively small increases in flood depths and extents are predicted in the developed and open space/parkland downstream.

0.1 % AEP

- Flooding across the road is predicted only at its eastern extent.
- Increased flood depths and extents are predicted in the open space/parkland upstream and in the developed and open space/parkland downstream.

1 % AEP + 25 % flows, with 50 % blockage at the culvert

- Flooding across the road is not predicted.
- Reductions in flood extents and depths upstream and downstream are enhanced compared with the comparisons without blockage.

5.1.3 Proposed development scenario 4 (PD4)

Changes in maximum flood depths and extents between the proposed development scenario 4 predictions and the baseline scenario are presented in mapping contained in Appendix H. This also includes comparison of the 50% blockage scenarios applied to both the proposed development and baseline scenario modelling, discussed in the sub-section below. Refer to section 5.2 for a table which presents changes to in-channel water levels.

Main observations are as follows:

1 % AEP

- Reductions to in-channel water levels are predicted upstream due to the increased size of the culvert.

1 % AEP + 25 % flows

- The fluvial flood storage area is partially filled, to a greater depth than the PD2 scenario.
- Flooding across the road is not predicted.
- Reductions in flood extents and depths are predicted upstream and downstream. These reductions in flooding are larger in magnitude than the PD2 scenario.

0.1 % AEP

- The fluvial flood storage area is filled.
- Flooding across the road is predicted only at its eastern extent.
- Increased flood depths and extents are predicted in the open space/parkland upstream. These increases in flooding are larger in magnitude than the PD2 scenario.
- Decreased flood depths and extents are predicted in the developed and open space areas downstream. These reductions in flooding are larger in magnitude than the PD2 scenario.

1 % AEP + 25 % flows, with 50 % blockage at the culvert

- The fluvial flood storage area is partially filled, to a greater depth than the PD2 scenario.
- Flooding across the road is not predicted.
- Relatively small increases in flood depths and extents are predicted in the open space/parkland upstream.
- Decreased flood depths and extents are predicted in the developed and open space areas downstream. These reductions in flooding are larger in magnitude than the PD2 scenario.

5.2 Changes to in-channel water levels: scenarios vs baseline

At the model node locations presented in Figure 5-1, which are the location of surveyed watercourse sections, peak water levels and differences in these are presented for the proposed development scenarios 2, 3 and 4 compared with the baseline scenario in Table 5-1, Table 5-2 and Table 5-3, respectively. Information is presented to three decimal places to enable changes in flood levels to more clearly seen and prevent rounding discrepancies. The changes in water levels align with the trends in floodplain depths discussed in section 5.1, and so the main observations are not repeated here.

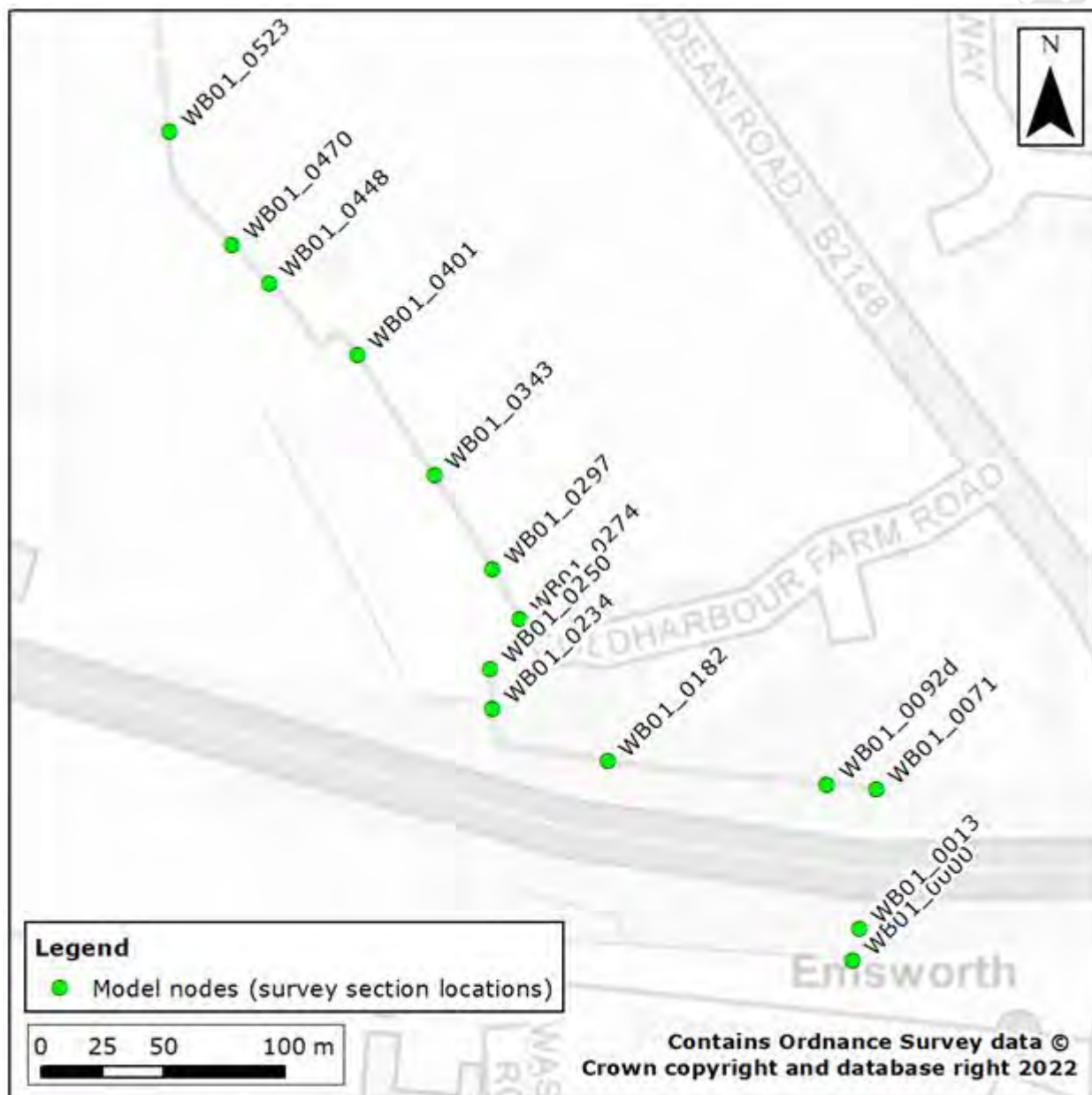


Figure 5-1: Model nodes referred to for water level comparisons

Table 5-1: Peak water level comparisons – Proposed development scenario 2 vs baseline

Model node	1 % AEP			1 % AEP +25 % flows			0.1 % AEP		
	Baseline	Scenario	Diff (m)	Baseline	Scenario	Diff (m)	Baseline	Scenario	Diff (m)
WB01_0523	6.646	6.646	0.000	6.760	6.761	+0.001	7.046	7.046	0.000
WB01_0470	6.192	6.192	0.000	6.288	6.288	0.000	6.578	6.587	+0.009
WB01_0448	6.033	6.033	0.000	6.132	6.131	-0.001	6.413	6.440	+0.027
WB01_0401	5.773	5.772	-0.001	5.875	5.876	+0.001	6.199	6.291	+0.092
WB01_0343	5.416	5.368	-0.048	5.611	5.477	-0.134	6.120	6.254	+0.134
WB01_0297	5.324	5.111	-0.213	5.586	5.414	-0.172	6.115	6.253	+0.138
WB01_0274	5.104	5.003	-0.101	5.519	5.384	-0.135	6.123	6.247	+0.124
WB01_0250	4.991	4.956	-0.035	5.342	5.311	-0.031	6.139	6.147	+0.008
WB01_0234	4.912	4.912	0.000	5.335	5.306	-0.029	6.137	6.125	-0.012
WB01_0182	4.810	4.810	0.000	5.323	5.293	-0.030	6.115	6.111	-0.004
WB01_0092	4.733	4.733	0.000	5.313	5.284	-0.029	6.114	6.118	+0.004
WB01_0071	4.705	4.705	0.000	5.308	5.278	-0.030	6.196	6.182	-0.014
WB01_0013	4.147	4.147	0.000	4.384	4.374	-0.010	5.316	5.277	-0.039
WB01_0000	4.137	4.137	0.000	4.383	4.373	-0.010	5.298	5.261	-0.037

Table 5-2: Peak water level comparisons – Proposed development scenario 3 vs baseline

Model node	1 % AEP			1 % AEP +25 % flows			0.1 % AEP		
	Baseline	Scenario	Diff (m)	Baseline	Scenario	Diff (m)	Baseline	Scenario	Diff (m)
WB01_0523	6.646	6.646	0.000	6.760	6.759	-0.001	7.046	7.047	+0.001
WB01_0470	6.192	6.192	0.000	6.288	6.288	0.000	6.578	6.589	+0.011
WB01_0448	6.033	6.033	0.000	6.132	6.132	0.000	6.413	6.444	+0.031
WB01_0401	5.773	5.772	-0.001	5.875	5.876	+0.001	6.199	6.299	+0.100
WB01_0343	5.416	5.368	-0.048	5.611	5.504	-0.107	6.120	6.261	+0.141
WB01_0297	5.324	5.111	-0.213	5.586	5.453	-0.133	6.115	6.259	+0.144
WB01_0274	5.104	5.003	-0.101	5.519	5.424	-0.095	6.123	6.254	+0.131
WB01_0250	4.991	4.956	-0.035	5.342	5.342	0.000	6.139	6.158	+0.019
WB01_0234	4.912	4.912	0.000	5.335	5.339	+0.004	6.137	6.149	+0.012
WB01_0182	4.810	4.810	0.000	5.323	5.328	+0.005	6.115	6.127	+0.012
WB01_0092	4.733	4.733	0.000	5.313	5.318	+0.005	6.114	6.133	+0.019
WB01_0071	4.705	4.705	0.000	5.308	5.313	+0.005	6.196	6.193	-0.003
WB01_0013	4.147	4.147	0.000	4.384	4.385	+0.001	5.316	5.328	+0.012
WB01_0000	4.137	4.137	0.000	4.383	4.385	+0.002	5.298	5.311	+0.013

Table 5-3: Peak water level comparisons – Proposed development scenario 4 vs baseline

Model node	1 % AEP			1 % AEP +25 % flows			0.1 % AEP		
	Baseline	Scenario	Diff (m)	Baseline	Scenario	Diff (m)	Baseline	Scenario	Diff (m)
WB01_0523	6.646	6.646	0.000	6.760	6.761	+0.001	7.046	7.047	+0.001
WB01_0470	6.192	6.192	0.000	6.288	6.288	0.000	6.578	6.591	+0.013
WB01_0448	6.033	6.033	0.000	6.132	6.130	-0.002	6.413	6.450	+0.037
WB01_0401	5.773	5.772	-0.001	5.875	5.872	-0.003	6.199	6.313	+0.114
WB01_0343	5.416	5.384	-0.032	5.611	5.497	-0.114	6.120	6.280	+0.160
WB01_0297	5.324	5.235	-0.089	5.586	5.448	-0.138	6.115	6.279	+0.164
WB01_0274	5.104	5.184	+0.080	5.519	5.424	-0.095	6.123	6.279	+0.156
WB01_0250	4.991	4.956	-0.035	5.342	5.253	-0.089	6.139	6.144	+0.005
WB01_0234	4.912	4.911	-0.001	5.335	5.244	-0.091	6.137	6.135	-0.002
WB01_0182	4.810	4.810	0.000	5.323	5.228	-0.095	6.115	6.116	+0.001
WB01_0092	4.733	4.733	0.000	5.313	5.217	-0.096	6.114	6.117	+0.003
WB01_0071	4.705	4.705	0.000	5.308	5.210	-0.098	6.196	6.185	-0.011
WB01_0013	4.147	4.146	-0.001	4.384	4.350	-0.034	5.316	5.289	-0.027
WB01_0000	4.137	4.137	0.000	4.383	4.349	-0.034	5.298	5.272	-0.026

6 Conclusions

6.1 Baseline model updates

The updated hydraulic modelling, supported by new flood flow hydrology, new survey data and modelling and mapping using latest methods, has shown an improvement in the understanding of flood risk along West Brook and within the area of the proposed development site located west of Coldharbour Farm Road. The flood predictions are considered to be a notable improvement on the predictions from the existing generalised flood modelling which informs the Flood Map for Planning.

For the baseline (as now) scenario, the site is not predicted to flood during the 5% or 1% AEP event. A small area at the southeast of the site is predicted to flood in the 1% AEP +25% flows event (the event against which the scheme is designed), representing the potential effects of climate change. The depth of flooding is shallow (less than 0.15m), but is predicted to extend onto the footpath west of Coldharbour Farm Road, or the road itself. During the 0.1% AEP event (a residual risk event), flooding is widespread, and the south and southeast corner of the site are predicted to flood.

Sensitivity testing was conducted for hydraulic roughness (influencing channel and floodplain conveyance) and model conditions at the downstream extent of the model. This was completed for the 1% AEP +25% flows event, and predicted flooding at the site was not found to be sensitive to the scenarios tested.

6.2 Proposed development modelling

Three potential development scenarios, referred to as proposed development scenarios 2, 3 and 4, were schematised in the hydraulic model and the flooding predictions for different event magnitudes compared against the baseline scenario to understand changes in flooding. The elements included in the three proposed development scenarios are summarised as follows:

- Proposed development scenario 2 (PD2): all scheme elements
 - o access road;
 - o the culvert under the footpath adjacent to Coldharbour Farm Road is increased in size to 2m wide x 1m high;
 - o ground levels are applied above the cellular storage for private house and road drainage, and
 - o a fluvial flood storage area located at the eastern side of the development site, with associated bank lowering and outlet pipe for drainage.
- Proposed development scenario 3 (PD3) – fluvial flood storage area omitted / culvert size increased
 - o access road;
 - o the culvert under the footpath adjacent to Coldharbour Farm Road is increased in size to 2m wide x 1m high;
 - o ground levels are applied above the cellular storage for private house and road drainage, and
- Proposed development scenario 4 (PD4) – fluvial flood storage area present / existing culvert retained
 - o access road;
 - o ground levels are applied above the cellular storage for private house and road drainage, and
 - o a fluvial flood storage area located at the eastern side of the development site, with associated bank lowering and outlet pipe for drainage.

6.2.1 Proposed development modelling results

Main observations from testing of the three proposed development scenarios are as follows:

Proposed development scenario 2

- flood water remains in-channel for the 1% AEP event, but peak water levels are reduced due to the increased culvert size;
- for the larger magnitude events tested, including the blockage scenario:
- the fluvial flood storage area is either partially, or fully, filled;
- reductions in flooding depths and extents are predicted in areas downstream, including areas of existing development
- for the 1% AEP +25% flows events (design and blockage scenarios), reductions in flood depths and extents are predicted upstream, and
- for the 0.1% AEP event some flooding across the eastern side of the road is predicted and increased flood depths and extents are predicted in the open space parkland area upstream.

Proposed development scenario 3

- flood water remains in-channel for the 1% AEP event, but peak water levels are reduced due to the increased culvert size. Reductions in flood levels are also predicted upstream for the 1% AEP +25% flows event;
- for the 1% AEP +25% flows and 0.1% AEP events tested, increases in flood depths and extents are predicted in the developed and open space/parkland downstream, and
- for the blockage scenario, slight reductions in flood depths and extents are predicted downstream.

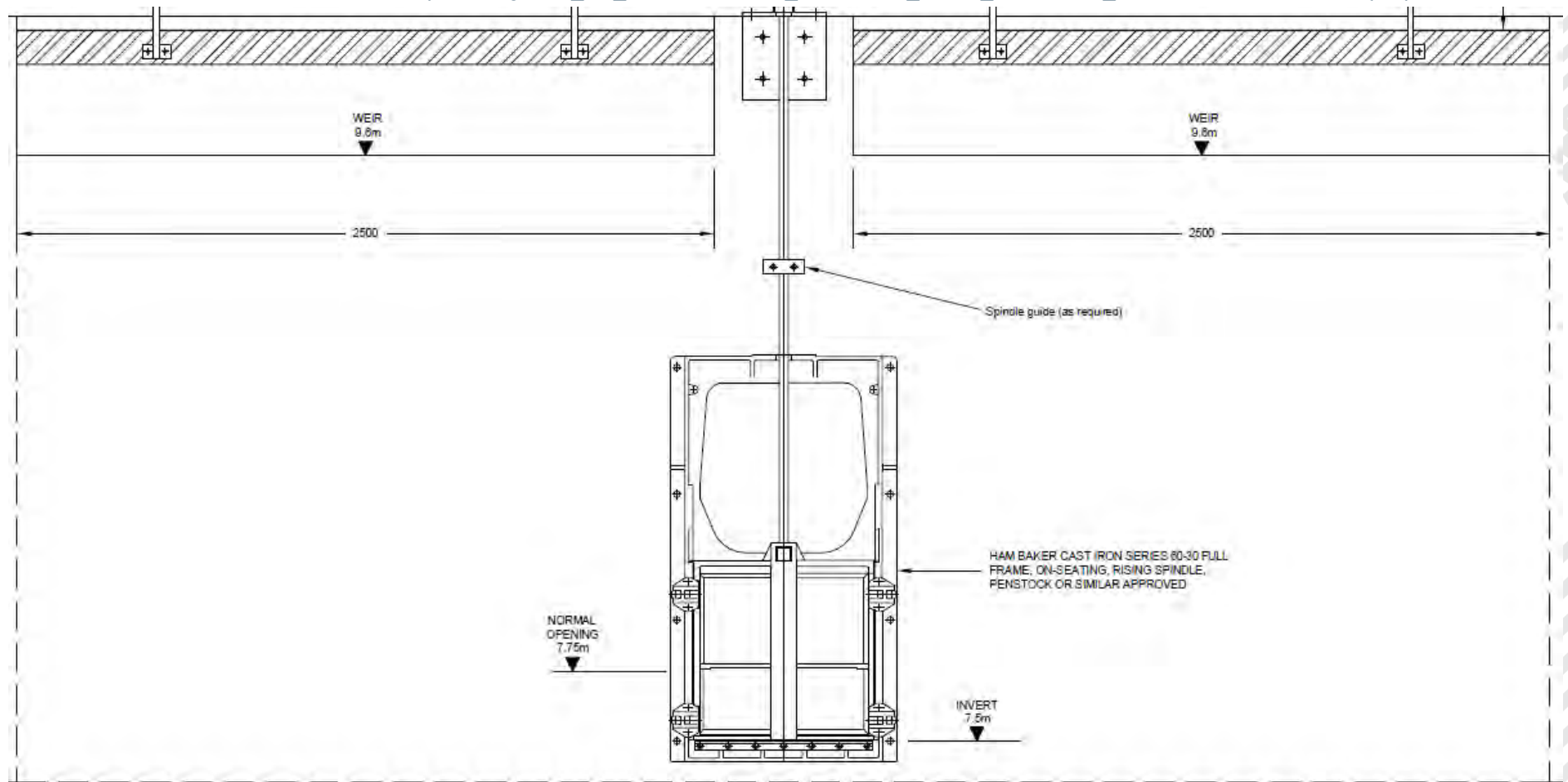
Proposed development scenario 4

- The main messages are largely the same as Proposed Development 2, described above. However, maintaining the size of the existing culvert acts to encourage greater storage of flood water in the fluvial flood storage area, providing greater reductions in flood depths and extents downstream, including areas of existing development. For the two residual risk scenarios, there are increases in flood depths and extents upstream of the proposed access road, in areas of open space/parkland.

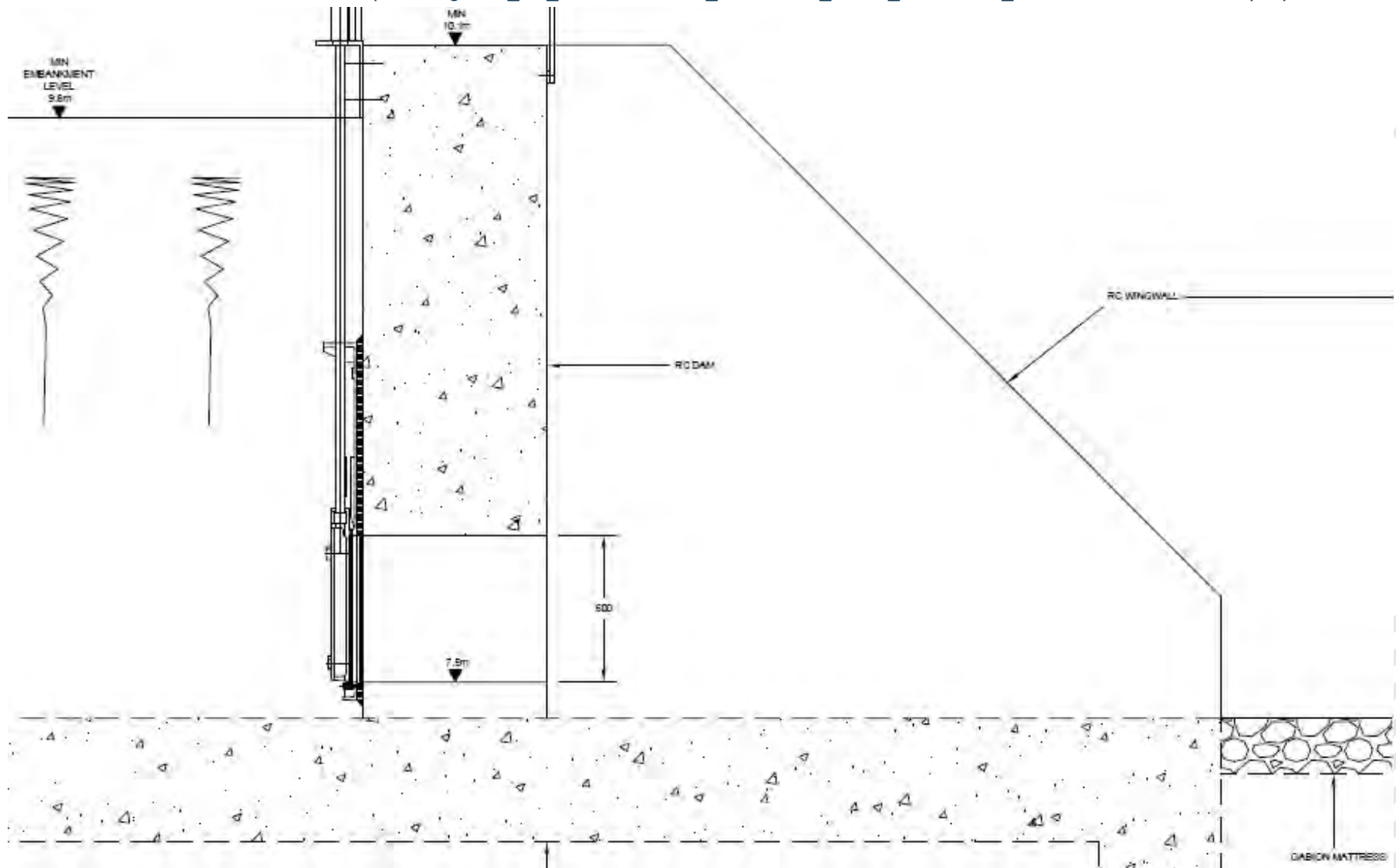
Appendices

A West Brook View flood attenuation area drawings

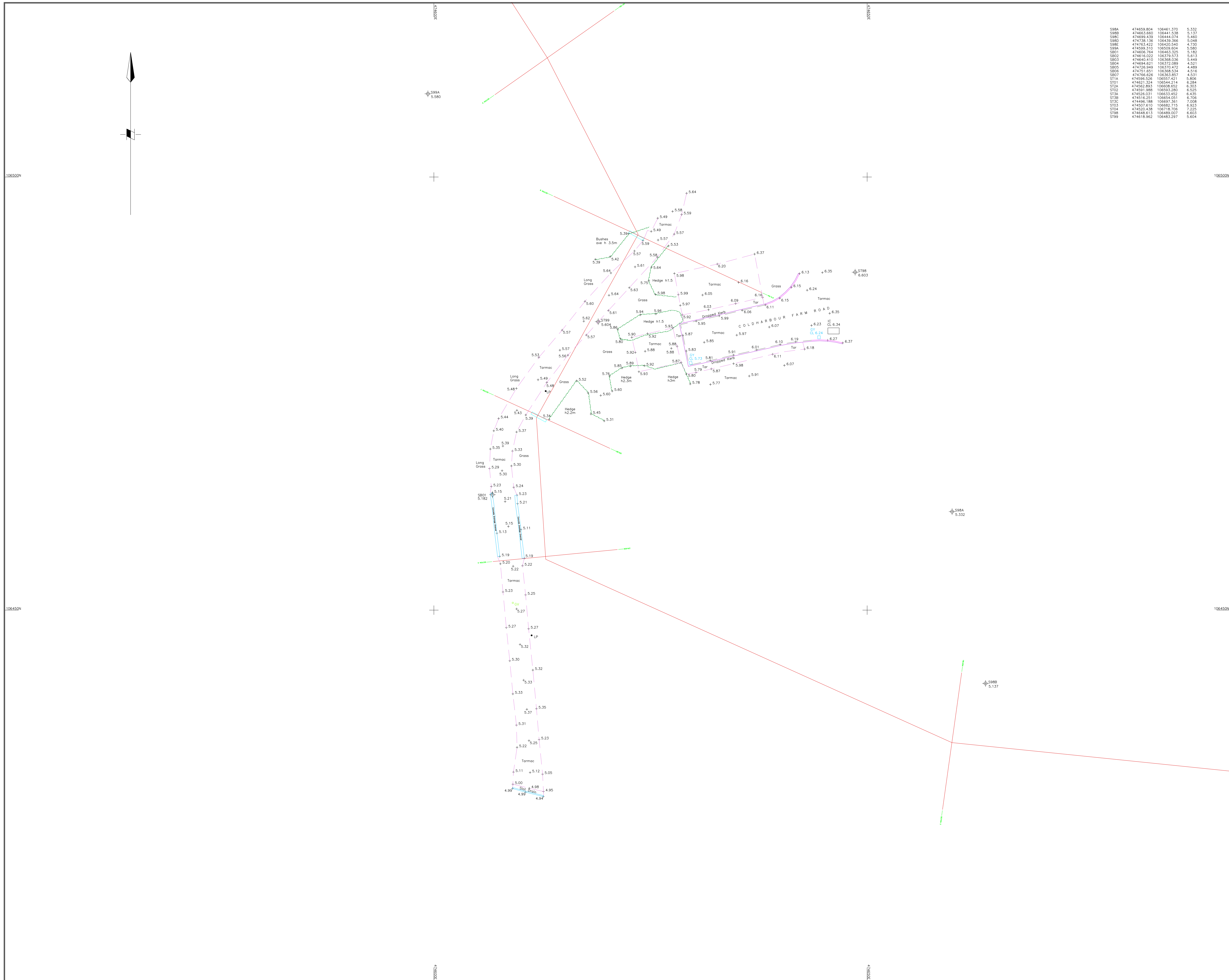
A.1 Flood control structure elevation (drawing APP_17_00358-FLOOD_STORAGE_AREA_CONTROL_STRUCTURE-1032788.pdf)



A.2 Flood control structure section (drawing APP_17_00358-FLOOD_STORAGE_AREA_CONTROL_STRUCTURE-1032788.pdf)



B Topographic survey at Coldharbour Farm Road and footpath south towards A27 underpass (Lewis Brown Limited)



LEVEL INFORMATION

Heights in Metres
Datum Derived From: GPS Derived
OSBM Location: ST99
Value: 5.80m A.O.D.
Active Station Locations: SANO,SOTN,POOL,HARD
Conversions Used: OSTN15,OSGM15;

COORDINATE INFORMATION

Values in Metres
All Coordinates are: TRUE NATIONAL GRID
Scale Factor:

SURVEY STATION SCHEDULE

STN	TYPE	EASTINGS	NORTHINGS	LEVEL

ABBREVIATIONS

General
(A) Aggravate
AF Angle Iron Fence
(A) Average
BD Building
BL Bitar Ball
BD Building
BW Black Wall
BS Bush
BT British Telecom Inspection Chamber
BW Black Wall
BWF Borbed Wire Fence
Cab Cabinet
CB Cash Barrier
CBS Cable Bearded Fence
CDC Concrete Drainage Channel
CE Concrete Edging
CF Chestnut Paling
CI Cable Into Ground
CIF Corrugated Iron Fence
CL Cover Level
CF Chain Link Fence
CM Cable Marker
CO Column
CC Concrete Post
CS Concrete Paving Slabs
CT Cable T/I Inspection Chamber
CW Concrete Wall
D Depth
DI Displaced
DK Drop Kerb
DP Downhand Down Pipe
DSW Dry Stone Wall
EA Electricity Meter
EC Electricity Pole
ED Electricity Pole
BF Earth Rod
ETL Electricity Transmission Lines
F Fence
FL Fire Hydrant
FRHK Fire Hydrant Marker
FL Floor Level
FL Flowerbed
FL Floodlight
FP Footpath
FWIF Foot Water Inspection Chamber
GM Gas Meter
GM Gas Meter
GM Gas Meter
GV Gravel
GV Gas Valve
GV Grass
GV Gully
H Height
HC Handicap
IB Illuminated Barrier

IC Inspection Cover
IL Invert Level
IR Iron Rail Fence
IRW Inter Woven Fence
KO Kerb Outlet
L Ladder
LP Lamp Post
ME Mancro
MHR Metal Hand Rail
ME Metal
MMP Metal Post & Rail Fence
MP Metal Post
o/h Overhead
o Outline
OSBR Ordnance Survey Bench Mark
PaF Palisade Fence
PE Paved Eye
PI Pipe Into Ground
R Records
RD Road Ditch
RS Road Sign
RSD Rebar Steel Joint
RW Retaining Wall
SD Skid Drain
SE Stone Edging
Self Security Fence
Sh Shrub
SL Soill Level
SA Spotlight
SN Sign
SVME Stop Valve Marker
SW Stone Wall
SWM Storm Water Inspection Chamber
SY Stay
Tar Tarmac
TL Threshold Level
TL Traffic Light
TMIC Traffic Management IC
T Telegraph Post
TTS Tactile Paving Slabs
U Underground
UTL Unable To Lift
V Vegetation
VP Vent Pipe
VT Vent
W Wall
WE Wood Edging
WL Water Level
WM Water Meter
WRF Wire Mesh Fence
WMK Water Meter Marker
WSD Wash Ditch
W Wooden Post
WR Wooden Post & Rail Fence

Station Abbreviations
HN HRB Nail
PSR Permanent Ground Marker
PWN Parker Kail Nail
WP Wooden Peg

NOTES

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SCALE
Information has been gathered for the quoted scale.
Any enlargement should be verified on site.
DRAINAGE
Pipe sizes and connections are determined from surface level inspection and service records where available.
UNDERGROUND SERVICES
Any underground services shown on this survey are from information on service enquiries and tracing with Electrolocation equipment.
Some underground services may be undetectable, e.g. non-conductive pipes or cables and therefore NOT SHOWN
CONTOURS
Any contours depicted on this drawing have been interpolated from surveyed points, levels and features.
The contour line positions have been generated by ground modelling software and are INDICATIVE only.

Rev.

Date

Amendments

SBC

5.460

THE SURVEY

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6

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CLIENT:

BELLAMY ROBERTS

CLOVER HOUSE
WESTERN LANE
ODIHAM, HAMPSHIRE RG29 1TU

TITLE:

EMSWORTH
COLDHARBOUR FARM ROAD

TOPOGRAPHICAL SURVEY

Drawing Number:

Revision:

C21201_2D_SX

Scale:

Sheet:

Survey Date:

1:200

A1 10F1

08/2021

Drawn:

Checked:

Project Number:

SBB

RDJB

C21201

C Hydrology report (FEH Calculation Record)

Flood estimation report: Coldharbour Farm Road

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

1	Method statement	3
2	Locations where flood estimates required	8
3	Statistical method	10
4	Revitalised flood hydrograph 2 (ReFH2) method	14
5	Discussion and summary of results	16
6	Annex	19

Approval

	Name and qualifications	Date
Method statement prepared by:	Lucy Archer-Lock BSc	08/07/2021
Method statement reviewed by:	James Molloy BE(Hons) MEngSc	08/07/2021
Calculations prepared by:	Lucy Archer-Lock BSc	12/07/2021
Calculations reviewed by:	James Molloy BE(Hons) MEngSc	12/07/2021
Updated calculations prepared by:	Lucy Archer-Lock BSc	02/02/2022
Updated calculations reviewed by:	James Molloy BE(Hons) MEngSc	03/02/2022

Revision History

Revision reference	Date issued	Amendments	Issued to
P01	November 2021	-	Telstar Ltd
P02	February 2021	Updates following EA comments	Telstar Ltd

Abbreviations

AMAX	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification (BFIHOST19 is an updated version and addresses a number of issues in the original BFIHOST)
CPRE.....	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
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)
Tp(0)	Time to peak of the instantaneous unit hydrograph
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

Note on flood probability

This document quotes the probability of a flood magnitude in terms of a return period based on analysis of annual maximum (AMAX) floods. The return period of a flood on the AMAX scale is the average interval between AMAX floods of that magnitude or greater. The inverse of the AMAX return period is the annual exceedance probability (AEP).

Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. AEP can be helpful when presenting results to non-specialists who may associate the concept of return period with a regular rather than an average interval.

Return period can also be measured on the peaks-over-threshold (POT) scale as the average interval between floods of that magnitude or greater. The difference between AMAX and POT return periods is only important for short return periods (under 10 years).

The table below is provided to enable quick conversion between these different measures.

AMAX return period (years)	n/a	2	5	10	20	30	50	75	100	200	1,000
AEP (%)	n/a	50	20	10	5	3.33	2	1.33	1	0.5	0.1
POT return period (years)	1	1.5	4.5	9.5	20	30	50	75	100	200	1,000

1 Method statement

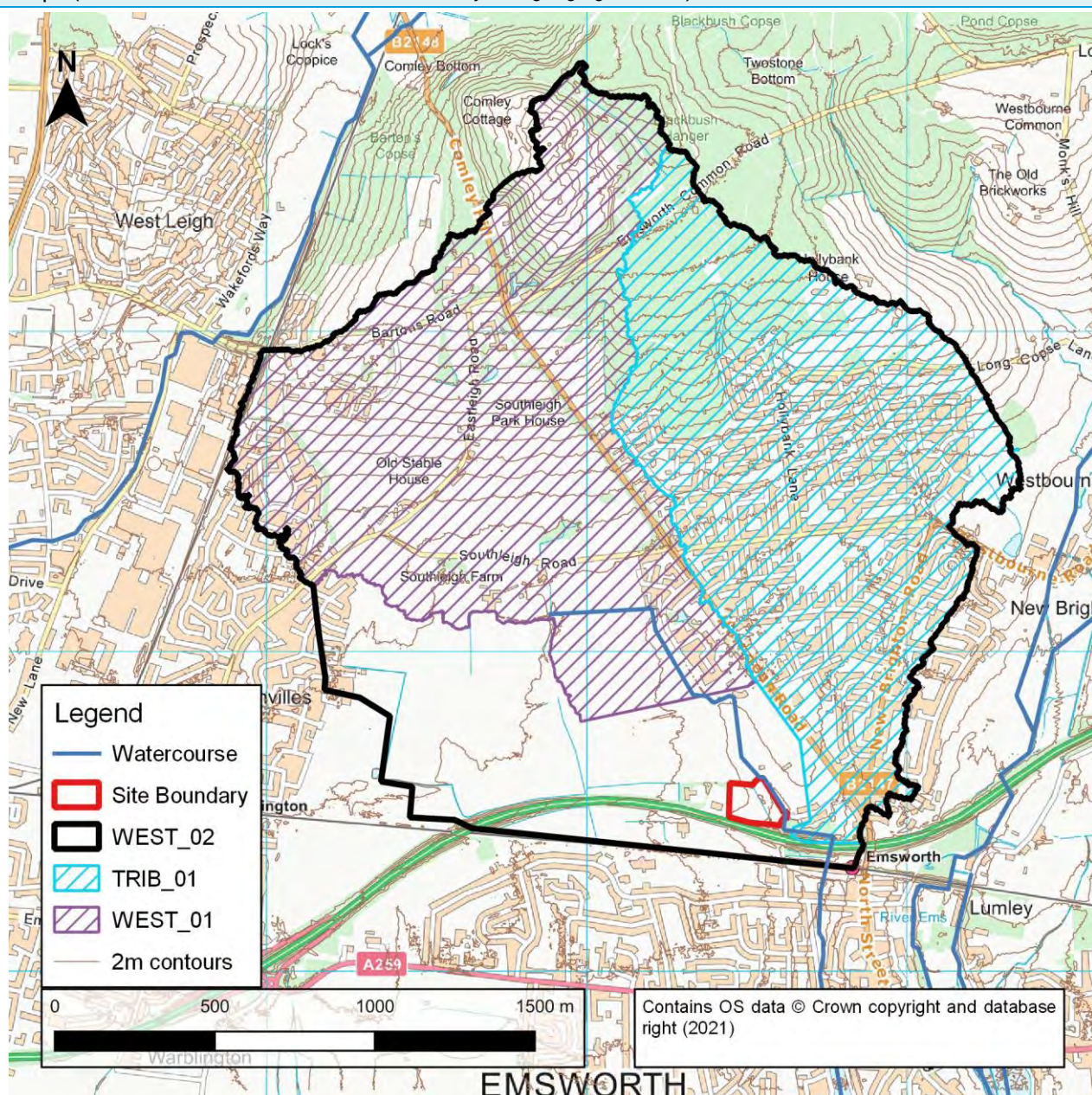
1.1 Requirements for flood estimates

Overview	The purpose of this study is to undertake a hydrological assessment of the West Brook at Emsworth, Hampshire. The aim is to provide peak flows and hydrograph shapes for input into a hydraulic model, for a flood risk assessment in relation to the proposed development site and access route at Coldharbour Farm Road, Emsworth. Design peak flow estimates and hydrographs are required at 3 locations for the following annual exceedance probability (AEP) events (%): 50, 20, 5, 1, 0.1. The effects of climate change will be assessed using the 1% AEP event and accounted for using the latest guidance¹. The Environment Agency Flood Map for Planning shows the development site to be partially located in Flood Zone 2 and 3 in the east of the site in the vicinity of the West Brook. The west of the site is located in Flood Zone 1.
Client scope	There are no NRFA river gauges in the study catchment, therefore rating reviews and ReFH parameter estimation are not relevant. It is only within the scope of this hydrological assessment to consider fluvial flows.

¹ Environment Agency (2020), "<https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances>".

1.2 The catchment

Map (Include river network, catchment boundary and gauging stations)



Description

Emsworth is a town located just north of Chichester Harbour. The development site is located west of Coldharbour Farm Road, which lies just north of the A27. The West Brook (EA main river) flows in a south easterly direction through the site. The watercourse rises north west of Emsworth in Southleigh Forest, and flows south through Emsworth to its outfall in Chichester Harbour. There are a number of drains, notably in the west of the catchment, which mapping indicates joins the West Brook. However, the flow paths and connectivity of these drains is unclear. The FEH Webservice also indicates there is a left bank tributary which joins the West Brook at Coldharbour Road Farm, but it is unknown if this watercourse exists.

A new development has recently been built at West Brook View, upstream of the proposed development site. As part of this, a flood

	attenuation features has been constructed, which may attenuate flow from the West Brook. The British Geological Survey website² 1:50,000 geology mapping shows that the West Brook catchment is primarily composed of London Clay formation – clay, silt and sand. In the upper part of the catchment soils are slowly permeable, seasonally wet, slightly acid but base-rich, loamey and clayey soils.³ In the lower part of the catchment the soils and loamy soils with naturally high groundwater. The catchment topography is relatively steep in the upper catchment, and fairly flat in the lower catchment. The eastern side of the catchment is heavily urbanised. This area drains approximately 38% of the overall catchment at WEST_02.
--	--

1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 10, released August 2021. This contains data up to water year 2019-20.
--------	---

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 (km ²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
There are no NRFA gauges in the catchment.						

1.5 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	N/A	N/A	N/A
Historic flood data	Yes	Yes	Havant Borough Council – Emsworth Flood Risk Strategy Review (2015) ⁴	Flooding has occurred along the West Brook around Bridge Road, downstream of the proposed development site, where the capacity of the culvert has been exceeded. The date and frequency of the flooding is not known. No records of flooding specifically at the development site could be found.
Flow or river level data	Yes	Yes	N/A	There is an EA level gauging

² <http://mapapps.bgs.ac.uk/geologyofbritain/home.html>

³ <http://www.landis.org.uk/soilscapes/>

⁴ <https://cdn.havant.gov.uk/public/documents/Emsworth%20Flood%20Risk%20Strategy%20Review%20-%20March%202015.pdf>

for events				station on the West Brook downstream of the development site. The data from this gauge appears to be artificially influenced by a gate or similar feature, and also by the tide.
Rainfall data for events	Yes	No	N/A	N/A
Potential evaporation data	Yes	No	N/A	N/A
Results from previous studies	Yes	No	N/A	There are no known hydrological assessments of the catchment. The existing flood mapping has been produced using broadscale JFLOW modelling and is not suitable for a site-specific Flood Risk Assessment.
Other data or information (e.g. groundwater, tides, channel widths, low flow statistics)	Yes	No	N/A	N/A

1.6 Hydrological understanding of catchment

Outline the conceptual model	The main site of interest is the development site off Coldharbour Farm Road. Fluvial flooding is likely to be the main source of flooding to the site. This may be exacerbated by structures across the watercourses which can cause constriction to flow, and blockages of structures.
Any unusual catchment features to take into account?	There are a network of drains within the catchment. The connectivity of these drains is uncertain but these may have a significant impact on the catchment area. It is proposed to adopt a conservative approach to deriving the catchment boundaries (assuming a larger drainage area where uncertainties exist in drainage connections). There is also a storage area on the West Brook which has recently been constructed upstream of the development site which may attenuate flows. It is proposed that a simple 1D model of the storage area is built to assess how much flow may attenuate.

1.7 Initial choice of approach

Is FEH appropriate?	FEH flood frequency methods are considered appropriate, given the catchment area is greater than 0.5km ² (the lower limit of applicability of the methods)
Initial choice of method(s) and reasons	Both the FEH Statistical method and the ReFH2

How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	method will be applied. There is no NRFA peak flow data available in the catchment to improve the QMED estimate under the statistical method. Local donors, from nearby catchments, will, therefore, be assessed for suitability for data transfer. Consideration was given to using the level gauge at Emsworth for updating the ReFH2 Tp parameter. However, as the data appears to be influenced by an artificial structure, such as a gate, and there may be a tidal influence on the gauge, then it was decided that this data is not suitable for this purpose. As highlighted in the Environment Agency's latest flood estimation guidelines, the statistical method is generally preferred to rainfall-runoff techniques, although the performance of the ReFH2 method in such cases is greatly improved compared with ReFH1. The flow estimates from the statistical method and ReFH2 will be compared. Hydrograph shapes will be generated using the ReFH2 method, using the recommended design storm duration from catchment descriptors. These hydrographs will be fitted to the FEH Statistical peaks, if this is chosen as the preferred method, Inflows will be derived as follows: • A point inflow will be calculated at the model upstream extent. This will represent runoff from the rural area to the north-west of the site • A separate point inflow will be calculated to represent runoff from the densely urbanised eastern part of the catchment, applied as a point inflow to a downstream section of the model. • A final (laterally-applied) inflow representing the rural land in the south of the catchment, not represented in the point inflows above.
Software to be used (with version numbers)	FEH Web Service⁵ / WINFAP v5⁶ / ReFH2.3

⁵ CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

⁶ WINFAP-FEH v5 © Wallingford HydroSolutions Limited 2021.
GBQ-JBAU-XX-XX-RP-HO-0001-S3-P02_Emsworth_Hydrology_Report

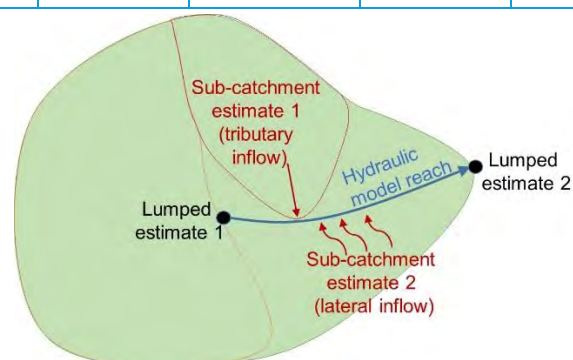
2 Locations where flood estimates required

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 (km ²)
WEST_01	L	West Brook	Downstream of flood attenuation feature	474400	106850	1.31	1.62
TRIB_01	L	Unknown	Densely urbanised eastern part of catchment	474700	106500	1.06	1.45
WEST_02	L	West Brook	Downstream model extent	474750	106350	2.68	3.85
WEST_02_IA	S	West Brook	Intervening area between WEST_01 and TRIB_01.	474750	106350	-	0.78

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.



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

Values shown in red have been updated

Site code	FARL	PROPWET	BFIHOST 19	DPLBAR (km)	DPSBAR (m / km)	SAAR (mm)	URBEXT 2000	FPEXT
WEST_01	1.00	0.34	0.476	1.41	20.7	764	0.085	0.1051
TRIB_01	1.00	0.34	0.511	1.71	23.4	765	0.246	0.1769
WEST_02	1.00	0.34	0.509	2.28	21	762	0.130	0.1458
WEST_02_IA*	-	0.34	0.574	0.46	17.2	752	0.008	-

*Only those catchment descriptors needed for input into the ReFH2 model have been derived for the intervening area

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	The FEH Webservice catchment boundary was checked against LIDAR and OS mapping. OS mapping and LIDAR indicates there are a number of drains in the west of the catchment not included in the FEH catchment which could potentially drain into the catchment. This would increase the catchment area. A site visit ⁷ was undertaken to understand the connectivity of the drains, but these could not be accessed on site. Although the connectivity of these drains is unknown, and there is uncertainty into where these drain, they have been included in the study catchment, in order to provide a conservative approach (i.e., giving an upper bound on runoff estimates).
Record how other catchment descriptors were checked and describe any changes.	As the catchment area was updated, DPLBAR was re-calculated using the ratio of areas (previous divided by updated catchment area). URBEXT2000 was manually calculated using OS50k mapping and Bayliss <i>et al.</i>'s (2006)⁸ mapping relationship between URBAN_{50k} and URBEXT2000. A qualitative check of the FEH BFIHOST19 value was undertaken by comparing it to the geology and soils detailed in Section 1.2. The FEH value (0.476-0.509) seems sensible given the underlying geology is shown to be clay, silt and sand. Although the catchment area has been updated, BFIHOST19 has not been recalculated as it doesn't significantly vary spatially (a comparison of the BFIHOST19 values was done for the FEH catchments purchased). This was sense checked using soilscales and the increase in catchment area would not significantly alter the composition of soil types in the catchment (see Section 6.3). The FARL value is 1.000. The FEH webservice does not indicate there are any online lakes/ponds in the catchment, therefore the FARL value is considered appropriate. The storage area at West Brook view is going to be considered in the hydraulic model rather than the hydrology.
Version of URBEXT	URBEXT2000
Method for updating of URBEXT	Manually derived URBAN values from OS50k mapping
Source of BFIHOST	BFIHOST19 was used in the ReFH2 calculations, since the current release (ReFH2.3) was calibrated using BFIHOST19, and also in the FEH Statistical method, since this has been found to improve the results ⁹ .

⁷ B Gibson, JBA Consulting, 02/07/2021

⁸ Bayliss, A.C; Black, K.B; Fava-Verde, A. & Kjeldsen, T.R. (2006) *URBEXT2000 – A new FEH catchment descriptor. Calculation, dissemination and application*. R&D Technical Report FD1919/TR. London: Defra.

⁹ Griffin, A., Young, A. and Stewart, E. (2019). Revising the BFIHOST catchment descriptor to improve UK flood frequency estimates. Hydrology Research.

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m ³ /s) (from catchment descriptors)	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	Weighted ave. adjustment		
WEST_01	0.54	CD	N/A	N/A	N/A	N/A	N/A	1.099	0.59
TRIB_01	0.44	CD	N/A	N/A	N/A	N/A	N/A	1.322	0.58
WEST_02	1.01	CD	N/A	N/A	N/A	N/A	N/A	1.163	1.17
Are the values of QMED spatially consistent?					Yes, QMED increases downstream				
Method used for urban adjustment for subject and donor sites					WINFAP v4 ¹⁰				
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 x QMED _{initial} x UAF									
Important note on urban adjustment									
The method used to adjust QMED for urbanisation published in Kjeldsen (2010) ¹¹ 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.									

¹⁰ Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

¹¹ 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	There are no river flow gauging stations within the study catchment. Gauging stations in adjacent hydrometric areas were therefore, assessed for suitability for data transfer to the study watercourse. There are 11 rural NRFA stations within 40km of the study area, based on the distance between catchment centroids. Comparison of QMED_{obs} and QMED_{cds} shows there is no consistent trend among the donor stations – 4 stations show QMED_{cds} overestimates QMED_{obs} and 7 show this underestimates QMED_{obs}. Recommendations from current research¹² (and new research¹³ to be published soon) indicate that the geographically closest station to the study site tends to produce the best results. The latest research highlights that descriptors, such as AREA, are included in the regression equation for QMED, so the donor adjustment process accounts for the differences in values between the donor and subject catchments. It also explains that the overarching pattern of QMED model residuals across the UK follows a smooth spatial pattern, hence the recommendation to choose donors by proximity. The closest gauging station is 41015 (Ems @ Westbourne). The observed QMED for this station (2.25 m³/s) is slightly lower than QMED from catchment descriptors (2.41 m³/s). Given that there is no consistent trend among donor stations, it has been decided not to apply this station as a donor. Applying this donor would not have a significant impact on the results, and this would slightly reduce the flow estimates.
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3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjustment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)
No suitable donors where found						

¹² Kjeldsen, T.R., Jones, D.A. and Bayliss, A.C. 2008. Improving the FEH statistical procedures for flood frequency estimation. Science Report SC050050, Environment Agency.

¹³ Stewart, Lisa, Duncan Faulkner, Giuseppe Formetta, Adam Griffin, Tracey Haxton, Ilaria Prosdoci, Gianni Vesuviano and Andy Young (TBC). Estimating flood peaks and hydrographs for small catchments (Phase 2). Report – SC090031/R0, Environment Agency.

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Sensitivity tests were carried out on the pooling groups, and small catchment method gave a slightly more conservative results than the default method so was taken forward.

Name of group	Site code from whose descriptor's 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)
WEST_02 (Small catchment method)	WEST_02	No	A brief review of the pooling group was performed. 49005 (Bolingey Stream @ Bolingey Cocks Bridge) was highlighted as discordant by WINFAP. This gauge was retained as it fitted well into the growth curve and L-moments graphs, the AMAX series looked normal, and no major issues were identified on the NRFA website. The discordancy is thought to be due to the low number of years of data (10 years). 7011 (Black Burn @ Pluscarden Abbey) was removed as it had less than 8 years of data All other gauges were deemed to be suitable; no changes were made to the default pooling group	L-CV: 0.266 L-skew: 0.225
WEST_02 (Default method)	WEST_02	No	A brief review of the pooling group was performed. No changes were made to the default pooling group.	L-CV: 0.235 L-skew: 0.253

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	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
WEST_01	P	WEST_02 (small catchment method)	GL – gives acceptable fit and is recommended distribution for UK catchments	Urban Adjustment (WINFAP v4)	Location: 1.00 Scale: 0.254 Shape: -0.270	3.13
TRIB_01	P	WEST_02 (small catchment method)		Urban Adjustment (WINFAP v4)	Location: 1.00 Scale: 0.225 Shape: -0.240	3.05

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	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
WEST_02	P	WEST_02 (small catchment method)		Urban Adjustment (WINFAP v4)	Location: 1.00 Scale: 0.246 Shape: -0.248	3.11

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 WINFAP 4 urban adjustment procedures.

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 AEP (%) events				
	50	20	5	1	0.1
WEST_01	0.6	0.8	1.2	1.8	3.2
TRIB_01	0.6	0.8	1.2	1.8	3.2
WEST_02	1.2	1.6	2.4	3.6	6.5

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Parameters for ReFH2 model

Site code	Method	C _{max} (mm)	T _{p_{rural}} (hours)	BL (hours)	Area of catchment modelled as urban (km ²)
WEST_01	CD	383.78	3.05	34.9	0.10
TRIB_01	CD	420.31	3.27	38.0	0.56
WEST_02	CD	418.13	3.99	40.36	0.78
Link to details of any lag or flood event analysis		N/A – no suitable catchment gauges to undertake lag analysis as the West Brook at Emsworth level gauge located further downstream appears to be significantly artificially influenced.			
Version of the ReFH2 model applied		ReFH2.3 using the water balance option. This treats BR (baseflow recharge) as a state variable rather than a parameter, setting it automatically in order to conserve volume. The values of BR vary with return period and so are not reported here.			
Parameters for urban runoff model		The impervious fraction of urban areas, IF, was kept at its default of 0.4. The impervious runoff factor, IRF, (which can also be interpreted as the fraction of the impervious surface that is positively drained) was kept at its default of 0.7. The depression storage was kept at its default of 0.5mm. Tp for runoff from areas modelled as positively drained was calculated as 0.75 times Tp _{rural} .			
Methods: OPT: Optimisation from fitting to observed flow data, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)					

4.2 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours:minutes)
WEST_02	Rural	Winter	07:30
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			No, a uniform storm duration and ARF will be applied to the model. A storm duration of 7:30 and ARF of 0.97 (based on the critical duration at WEST_02) was selected. Storm duration testing was undertaken for 07:30, 11:30 and 15:30 duration storms, and 07:30 was identified to be the critical duration, producing the greatest flood flows, levels and extents at the site, so was taken forward.

4.3 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. The critical duration for each catchment has been used to derive the flows shown below.

Site code	Flood peak (m ³ /s) for the following AEP (%) events				
	50	20	5	1	0.1
WEST_01	0.5	0.7	0.9	1.2	2.0
TRIB_01	0.5	0.6	0.9	1.2	1.9
WEST_02	1.0	1.4	1.8	2.4	4.0

5 Discussion and summary of results

5.1 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.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH2	ReFH2
WEST_01	0.86	0.67
TRIB_01	0.82	0.66
WEST_02	0.88	0.67

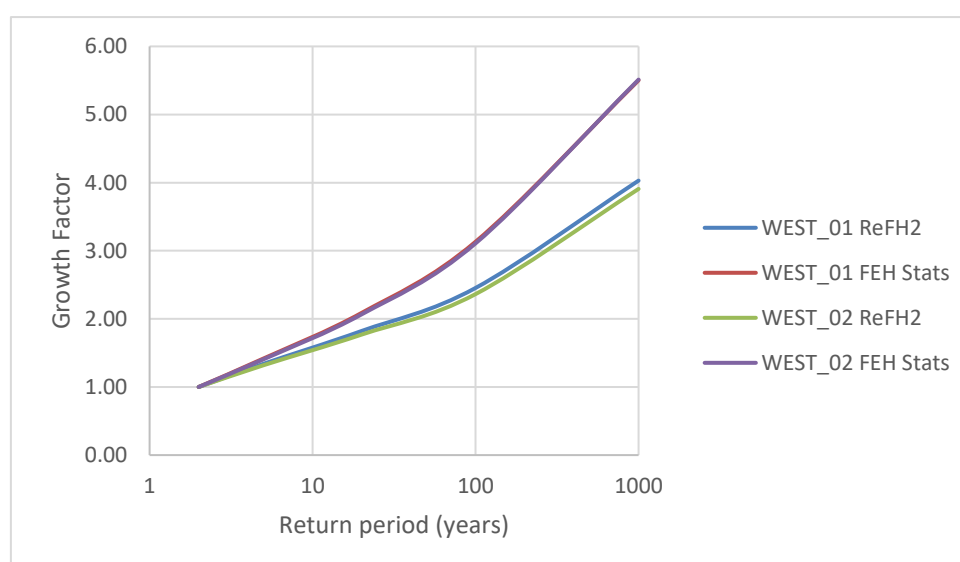


Figure 5-1: Growth factors

5.2 Final choice of method

Choice of method and reasons	FEH Statistical is the preferred method for generating the design peak flow estimates for the study catchment. The comparison of design flows presented in Section 5.1 shows that the Statistical method gives higher flows than the ReFH2 method. Figure 5-1 shows that as well as the higher QMED value, this is also due to higher growth factor. The FEH Statistical method is based on a larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments. Although the statistical method is preferred here over the ReFH2 model, there can be significant uncertainties associated with applying it to events beyond the 200-year return period, due to the typically short length of river gauge records. To reduce these uncertainties, a hybrid approach can be taken to deriving the 1000-year return period flows. The ReFH2 0.1%/1% AEP growth factors can be applied to the 1% FEH Statistical method flows, if these produce a larger flow compared to the unadjusted FEH statistical method 0.1% AEP peak flows. However, as these produce a smaller flow, the hybrid approach will not be applied.
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How will the flows be applied to a hydraulic model?	For upstream model inflows (WEST_01 and TRIB_01) ReFH2 hydrographs, scaled to fit the statistical peaks, will be applied to the model. For the intervening area, ReFH2 hydrographs will be applied to the model, with flows derived from stand-alone descriptors. The intervening area flow will be distributed across the modelled reach according to catchment area.
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5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: • The catchment boundary is representative of the topographic catchment, given the uncertainty in the drain network within the catchment • The densely urbanised region to the east is assumed to drain towards the stream being modelled, as indicated by a review of the local LIDAR data. This will have a significant effect on flows in the lower reach of the model. • BFIHOST19 can be used in the FEH Statistical method
Discuss any particular limitations	The main limitation is the lack of river flow gauge data specific to the study area. There are no river flow gauges on the watercourse at or near the area of interest and, therefore, the catchment response is unknown. There is a level gauge downstream of the study area on the West Brook, but as this record appears to be significantly artificially influenced it was deemed not to be suitable for use in this study.
Give what information you can on uncertainty in the results	It is not possible to directly quantify the uncertainty for the ReFH2 method. There is no method provided in the FEH for estimating uncertainty for the common situation of an ungauged catchment, pooled growth curve and QMED estimated from catchment descriptors. The uncertainty will depend on many factors, for example, how unusual the study catchment is relative to the pooling group, and the uncertainty in flow measurement at other gauges. A UK average measure of uncertainty is presented in a technical guidance report 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 ($0.03 \leq URBEXT2000 < 0.15$). The 95% confidence limits for a 1% AEP flood estimate for a rural catchment are: • Without donor adjustment of QMED: 0.45 – 2.23 times the best estimate. • With donor adjustment of QMED (one donor): 0.47 – 2.12 times the best estimate. The 95% confidence limits for a 1% AEP flood estimate for a moderately urbanised catchment are: • Without donor adjustment of QMED: 0.33 – 3.01 times the best estimate

	With donor adjustment of QMED (one donor): 0.34 – 2.94 times the best estimate.
Comment on the suitability of the results for future studies,	The design peak flow estimates and hydrographs were derived for the purposes of this modelling study. If peak flow estimates and hydrographs are required for a different purpose it is recommended that, at a minimum, a review of the results is carried out.
Give any other comments on the study	There is a lack of hydrometric data within the catchment. Confidence in flow estimates and understanding of catchment response could be improved with local hydrometric data collection.

5.4 Checks

Are the results consistent, for example at confluences?	Yes, QMED increases downstream.
What do the results imply regarding the return periods of floods during the period of record?	There is no local flow data (within the study area) against which to compare the design peak flow estimates.
What is the range of 100-year growth factors? Is this realistic?	The 1% AEP growth factor range for the methods is: - FEH Statistical: 3.0-3.1 - ReFH2: 2.4-2.5 The typical range is 2.1 to 4.0. The growth factors for both methods are within this range.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1%/1% AEP growth factor range for the methods is: - FEH Statistical: 1.8 - ReFH2: 1.6-1.7
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	There are no known studies of the West Brook catchment to compare with the results of this study.
Are the results compatible with the longer-term flood history?	There is no local flow data against which to compare the design flow estimates.
Describe any other checks on the results	Modelled levels and flood extents should be sensibility-checked to ensure that flow inputs result in realistic outputs, consistent with the local flood history.

5.5 Final results

Site code	Flood peak (m ³ /s) for the following AEP (%) events				
	50	20	5	1	0.1
WEST_01	0.6	0.8	1.2	1.8	3.2
TRIB_01	0.6	0.8	1.2	1.8	3.2
WEST_02	1.2	1.6	2.4	3.6	6.5

If flood hydrographs are needed for the next stage of the study, where are they provided?	To be supplied in a spreadsheet accompanying this document
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6 Annex

6.1 Pooling group – WEST_02 (standard method)

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27073 (Brompton Beck @ Snainton Ings)	1.457	40	0.816	0.214	0.215	0.02
76011 (Coal Burn @ Coalburn)	1.605	43	1.84	0.167	0.167	0.303
27051 (Crimple @ Burn Bridge)	1.83	48	4.544	0.219	0.22	0.146
45816 (Haddeo @ Upton)	1.917	27	3.456	0.298	0.299	0.417
28033 (Dove @ Hollinsclough)	2.142	45	4.15	0.225	0.225	0.373
26016 (Gypsy Race @ Kirby Grindalythe)	2.361	23	0.101	0.312	0.312	0.258
25019 (Leven @ Easby)	2.38	42	5.384	0.338	0.339	0.386
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.499	10	5.972	0.256	0.257	0.136
47022 (Tory Brook @ Newnham Park)	2.535	26	5.88	0.257	0.259	0.195
25011 (Langdon Beck @ Langdon)	2.568	34	15.878	0.228	0.228	0.316
25003 (Trout Beck @ Moor House)	2.596	47	15.164	0.166	0.166	0.291
71003 (Croasdale Beck @ Croasdale Flume)	2.67	37	10.9	0.212	0.212	0.323
27010 (Hodge Beck @ Bransdale Weir)	2.736	41	9.42	0.224	0.224	0.293
206006 (Annalong @ Recorder)	2.771	48	15.33	0.189	0.189	0.052

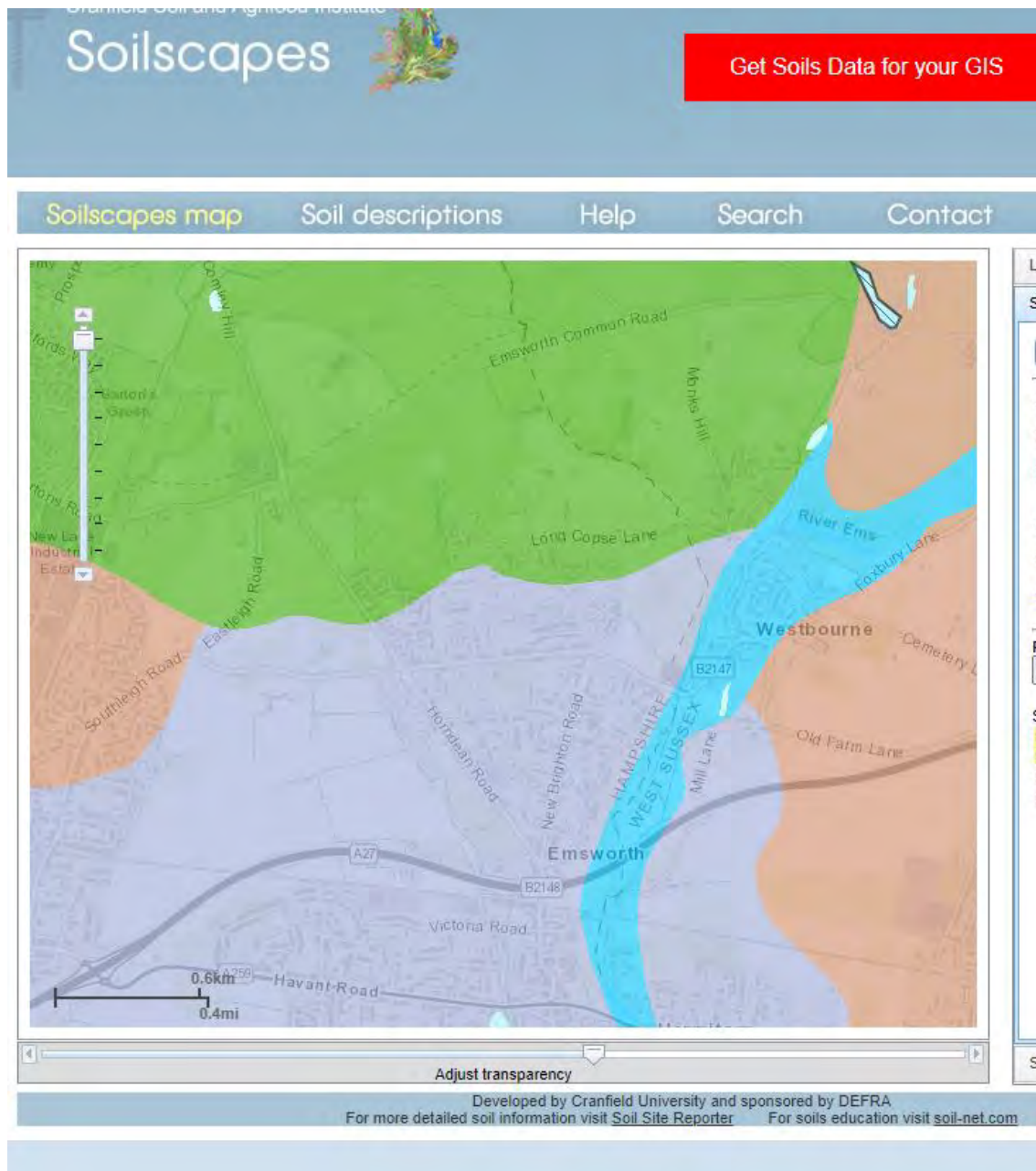
6.2 Pooling group – WEST_02 (small catchment method)

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27073 (Brompton Beck @ Snainton Ings)	0.606	40	0.816	0.214	0.215	0.02
27051 (Crimple @ Burn Bridge)	0.681	48	4.544	0.219	0.22	0.146
25019 (Leven @ Easby)	1.108	42	5.384	0.338	0.339	0.386
26016 (Gypsy Race @ Kirby Grindalythe)	1.12	23	0.101	0.312	0.312	0.258
76011 (Coal Burn @ Coalburn)	1.244	43	1.84	0.167	0.167	0.303

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
45816 (Haddeo @ Upton)	1.4	27	3.456	0.298	0.299	0.417
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	1.447	10	5.972	0.256	0.257	0.136
27010 (Hodge Beck @ Bransdale Weir)	1.458	41	9.42	0.224	0.224	0.293
44008 (South Winterbourne @ Winterbourne Steepleton)	1.542	41	0.448	0.407	0.408	0.319
26014 (Water Forlornes @ Driffild)	1.693	22	0.431	0.298	0.299	0.12
36010 (Bumpstead Brook @ Broad Green)	1.726	53	7.5	0.377	0.379	0.173
28033 (Dove @ Hollinsclough)	1.727	45	4.15	0.225	0.225	0.373
41020 (Bevern Stream @ Clappers Bridge)	1.809	51	13.66	0.204	0.205	0.174
28058 (Henmore Brook @ Ashbourne)	1.879	13	8.838	0.188	0.19	-0.109

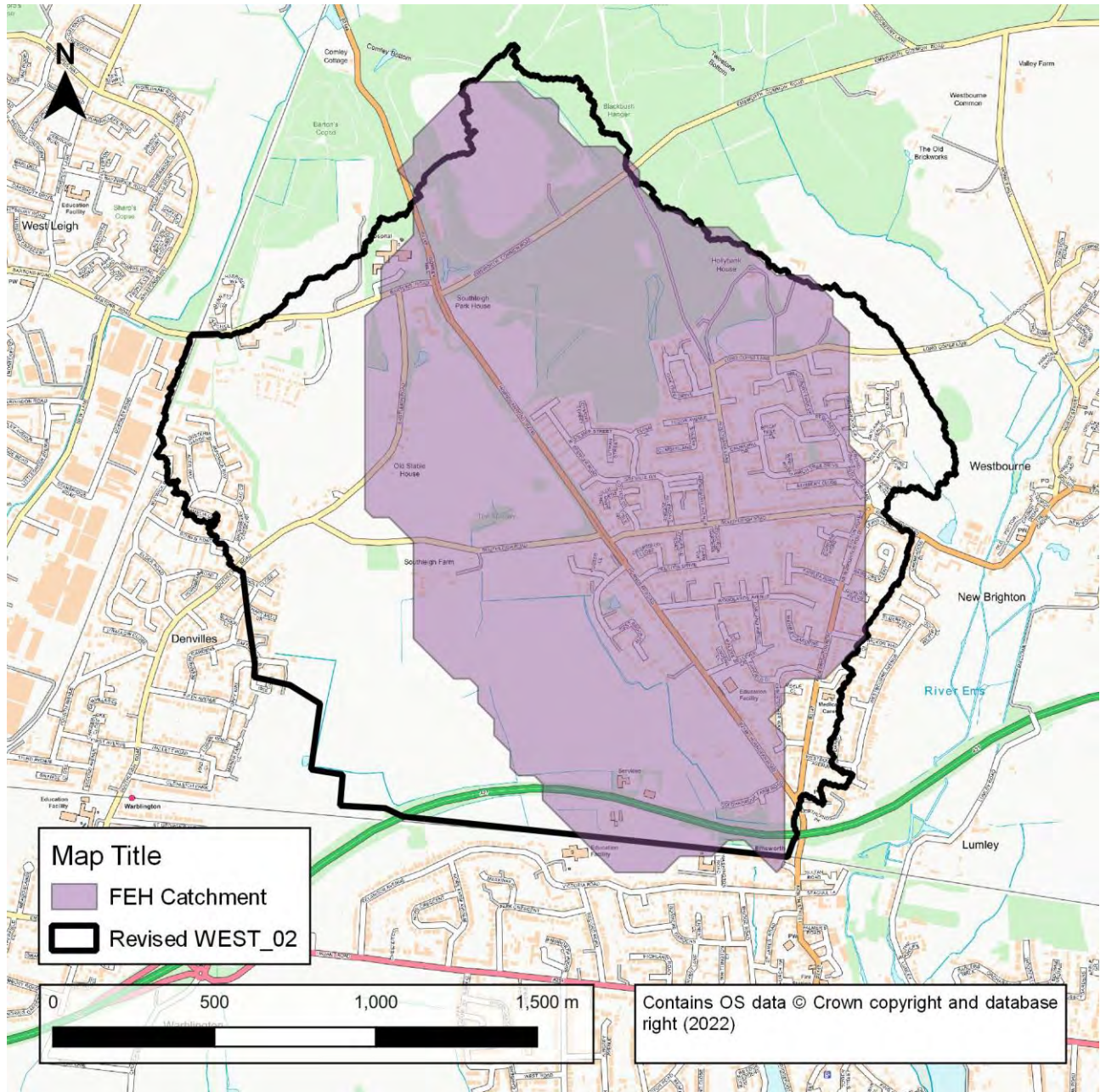
6.3 Soils

Figure 6-1: Soil types in catchment



(Source: <http://www.landis.org.uk/soilscape/>, accessed 01/02/2022)

Figure 6-2 Revised Catchment Boundary



6.4 Site Walkover

A site walkover was undertaken by JBA Consulting on 2nd July 2021. It was not possible to identify the connectivity of the drains within the catchment during the site visit. The western side of West Brook watercourse was fenced off and even if access had been possible, vegetation was high so it was unlikely to be clearly visible as shown in Figure 6-3.

Figure 6-3 Site Visit



Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
1 Broughton Park
Old Lane North
Broughton
SKIPTON
North Yorkshire
BD23 3FD
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:  

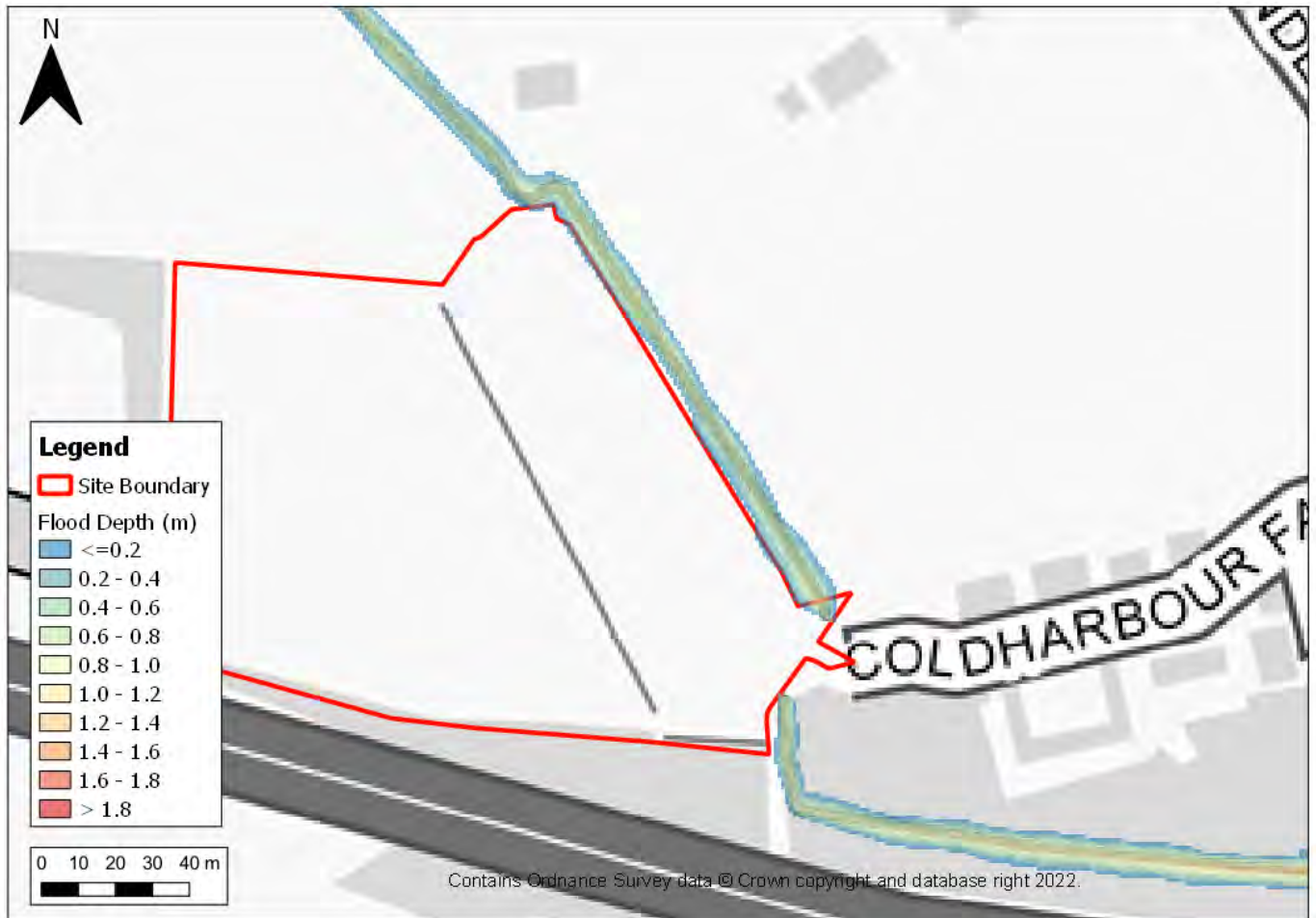
Jeremy Benn Associates Limited

Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
ISO 45001: 2018

D Baseline flood mapping: flood depths

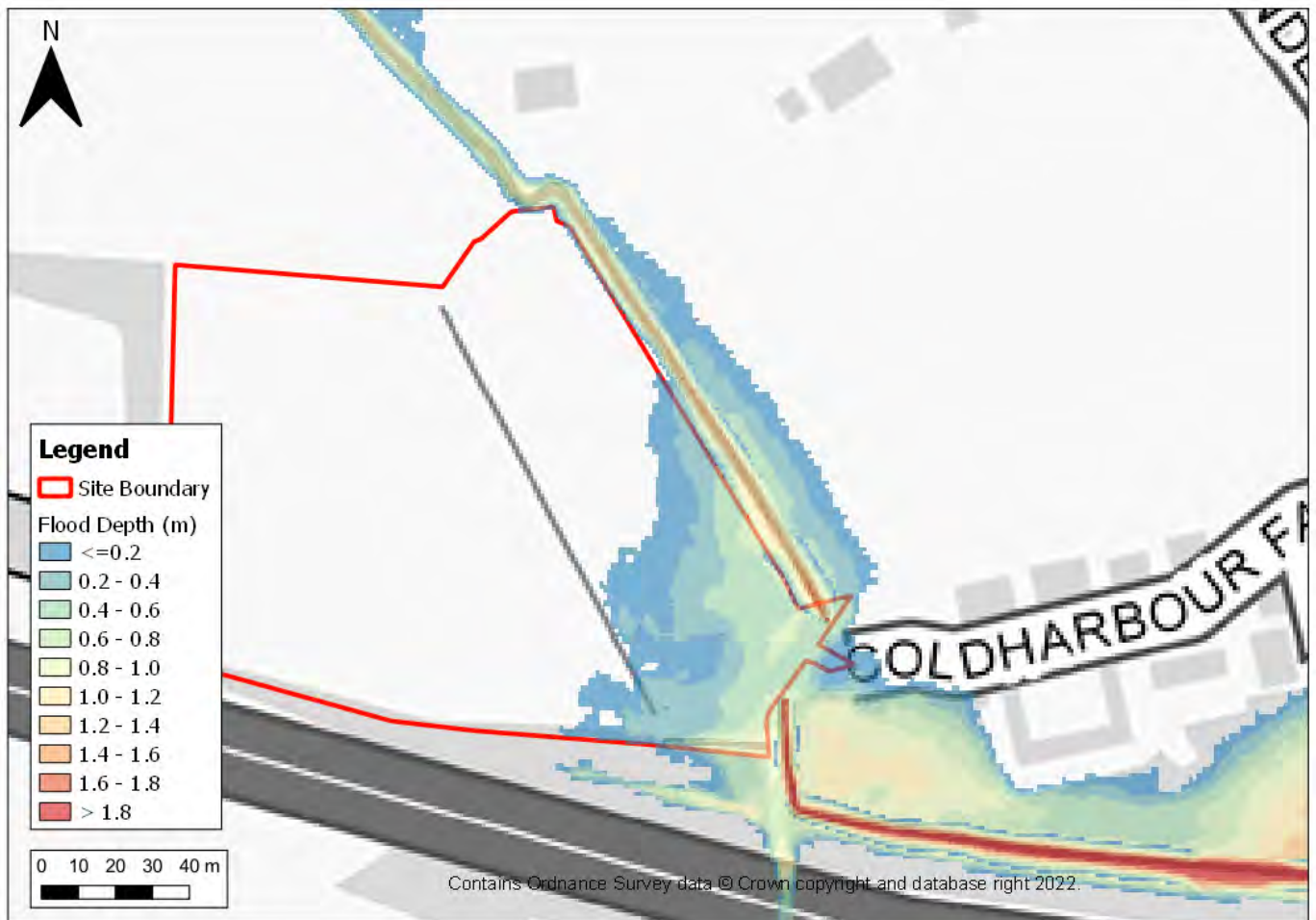
D.1 1 % AEP (present day)



D.2 1 % AEP +25 % flows (climate change)

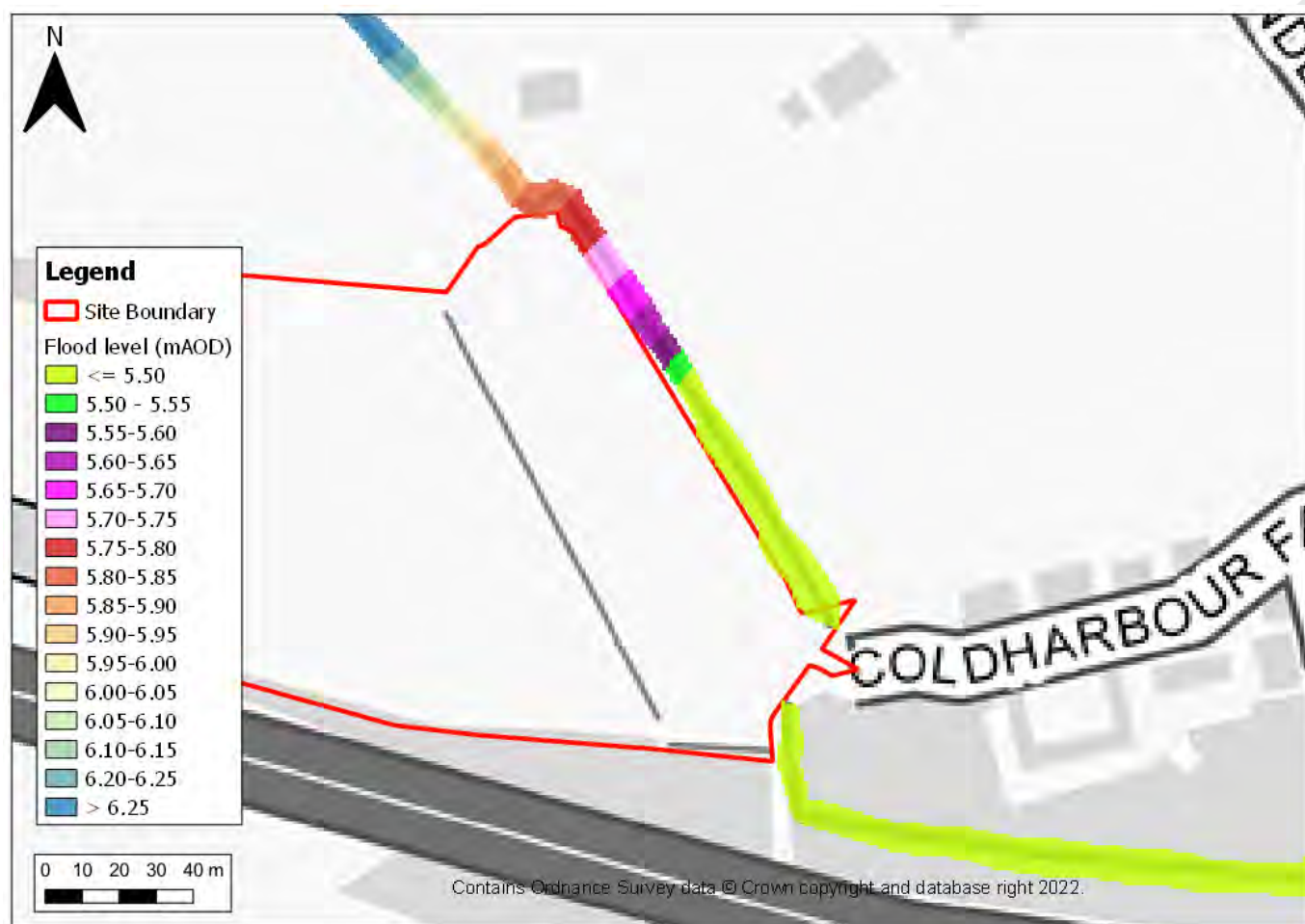


D.3 0.1 % AEP (present day)

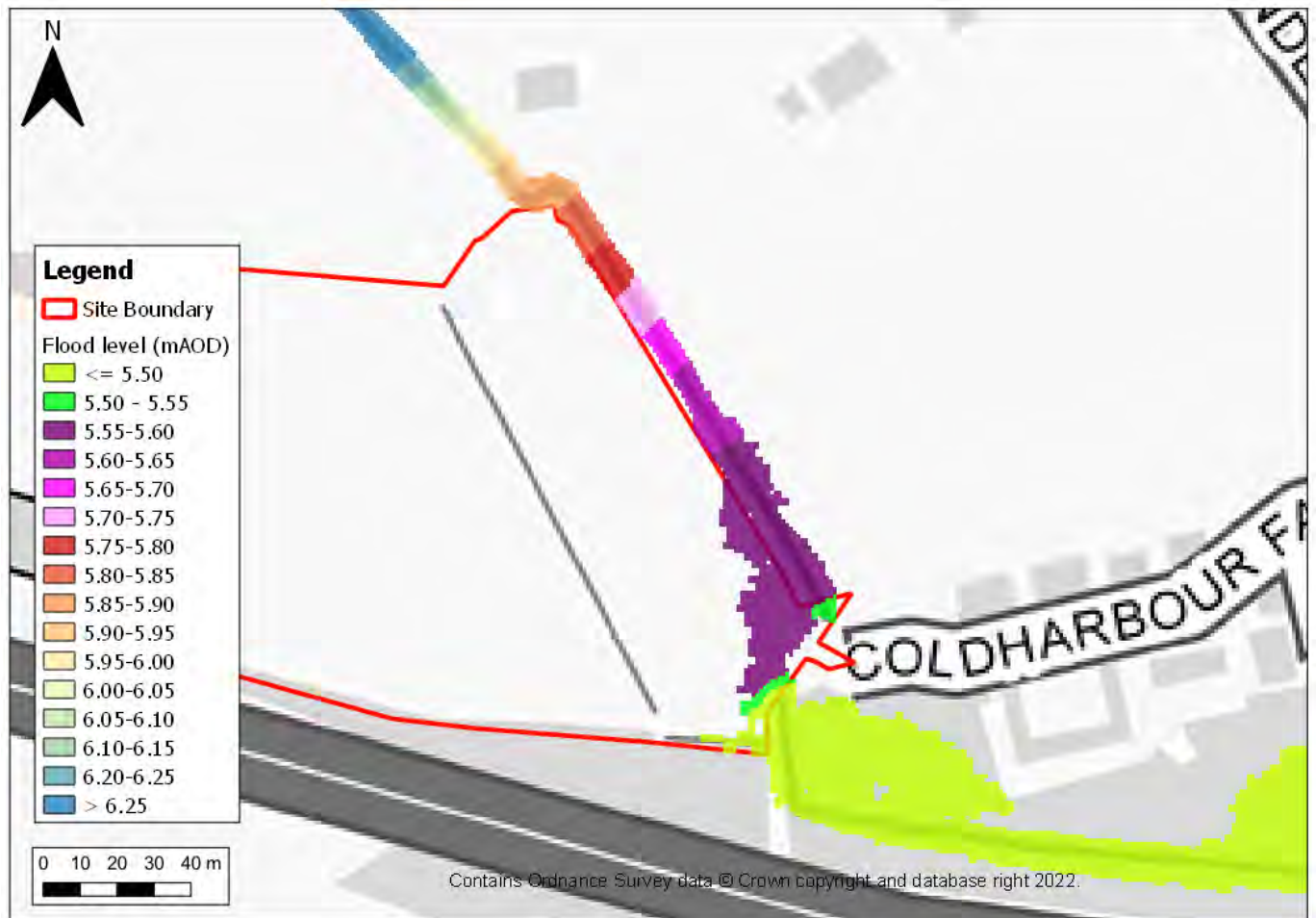


E Baseline flood mapping: flood water levels

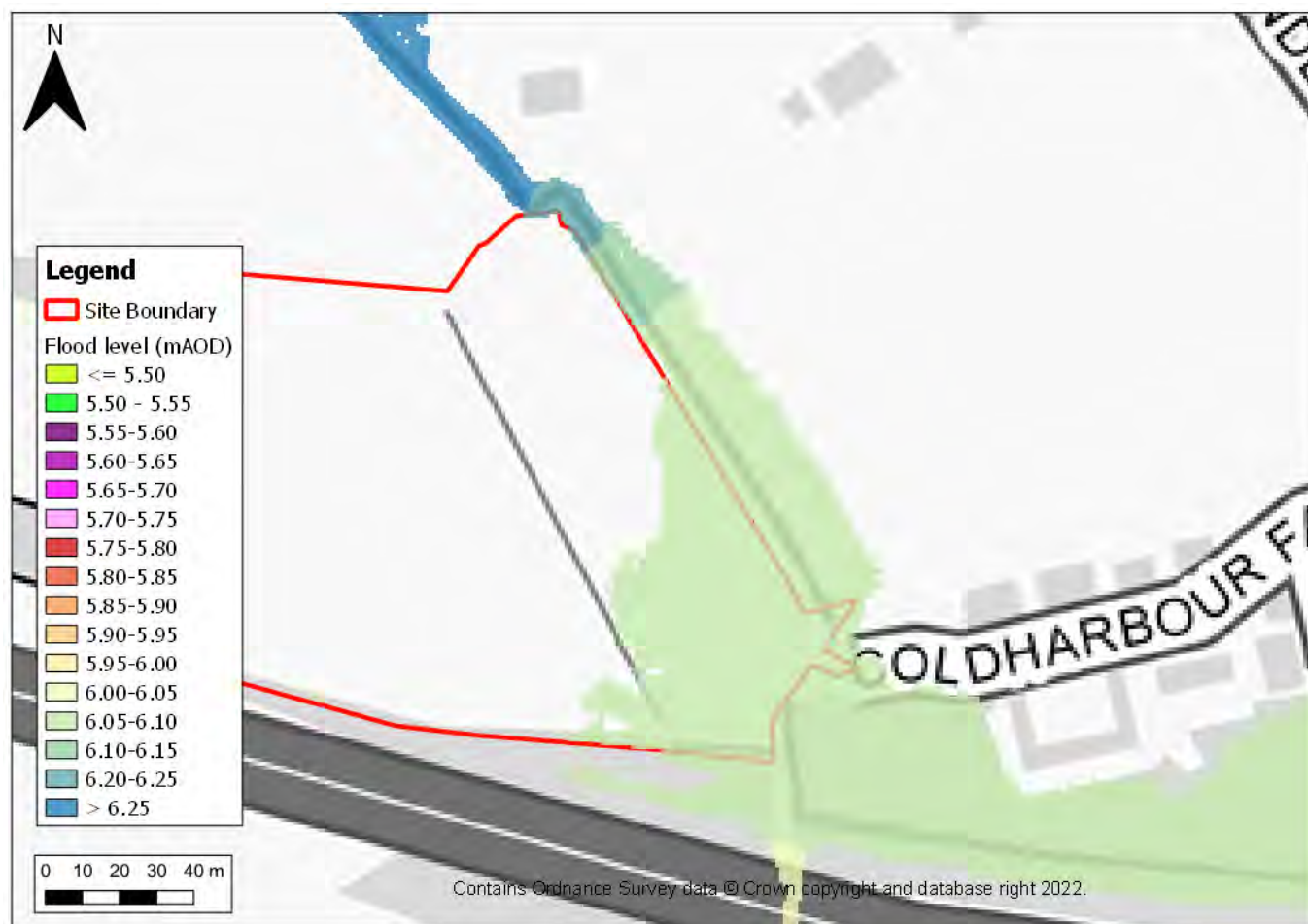
E.1 1 % AEP (present day)



E.2 1 % AEP +25 % flows (climate change)



E.3 0.1 % AEP (present day)

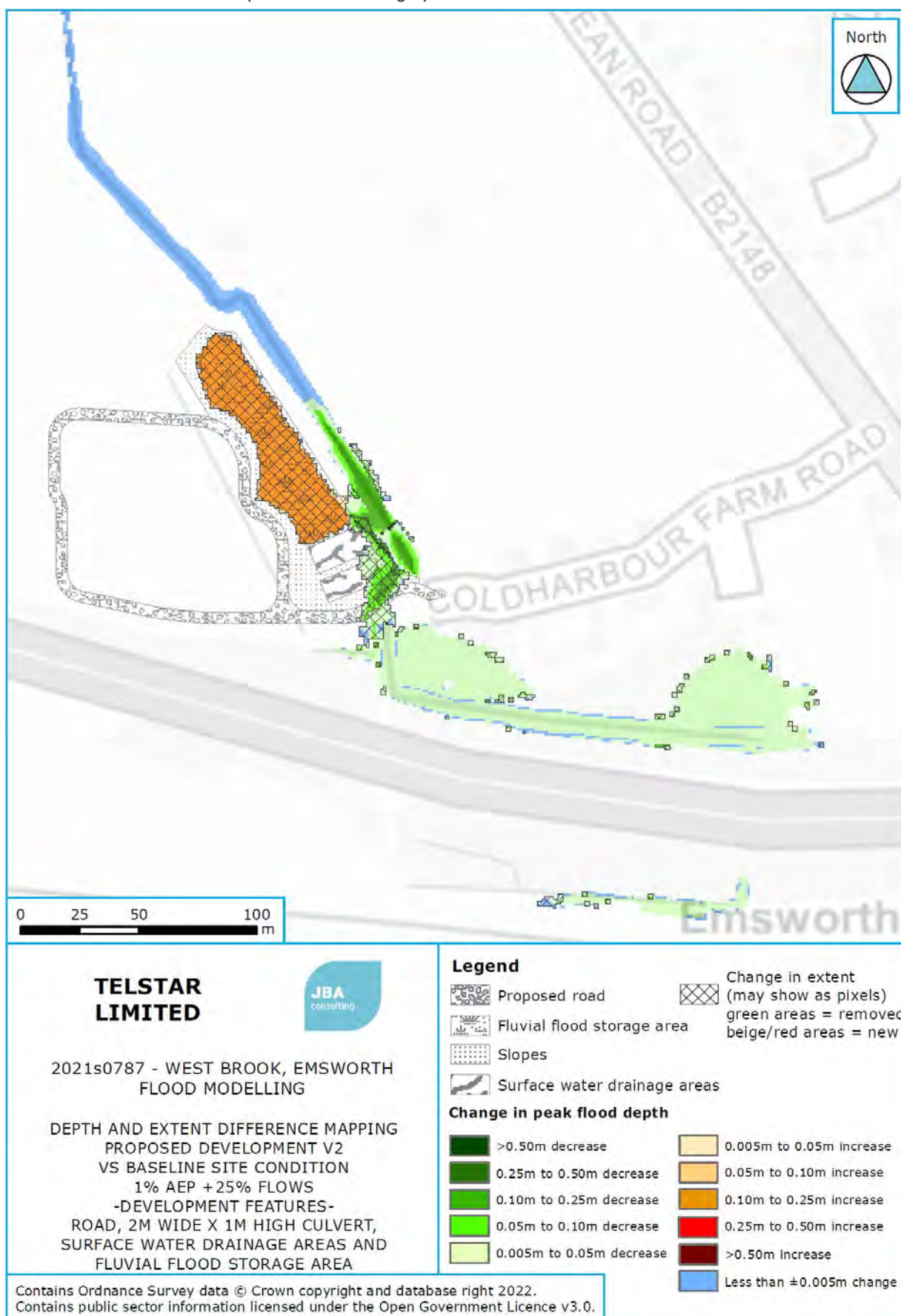


F Scenario flood mapping: changes in flood depths and extents compared with the baseline – Proposed Development Scenario 2

F.1 1 % AEP (present day)



F.2 1 % AEP +25 % flows (climate change)



F.3 0.1 % AEP (present day)

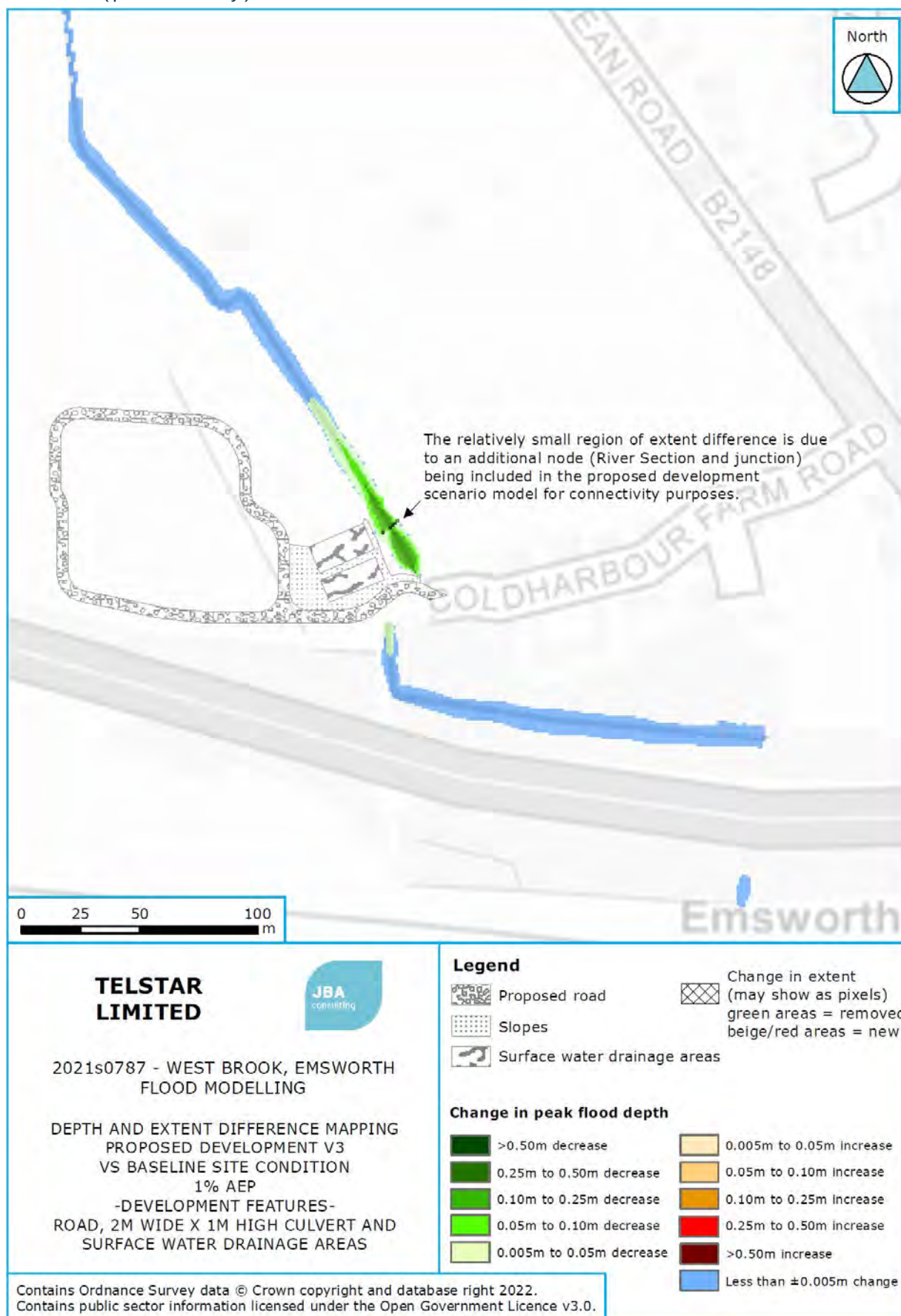


F.4 1 % AEP +25 % flows (climate change) with 50 % blockage at West Brook culvert



G Scenario flood mapping: changes in flood depths and extents compared with the baseline – Proposed Development Scenario 3

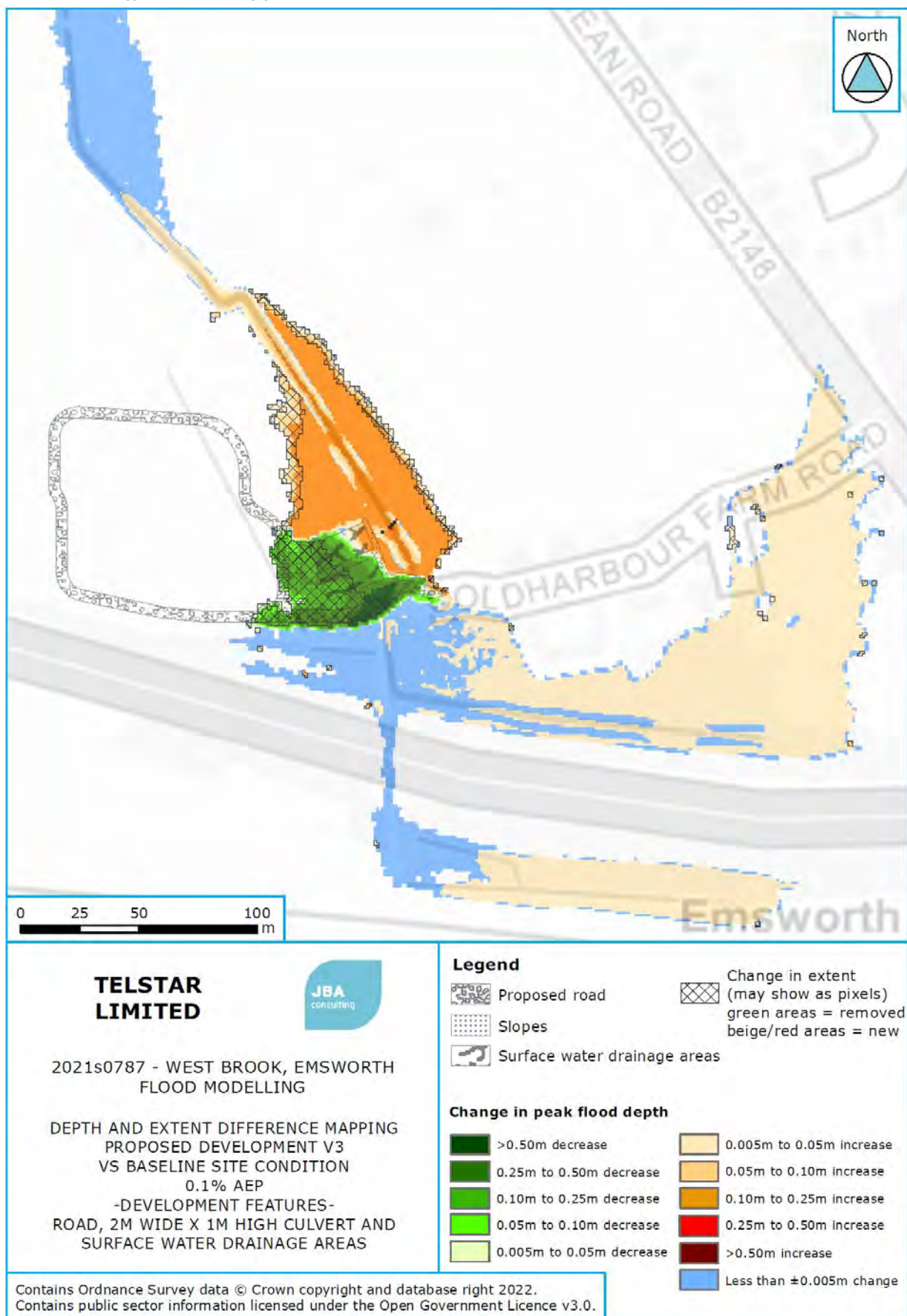
G.1 1 % AEP (present day)



G.2 1 % AEP +25 % flows (climate change)



G.3 0.1 % AEP (present day)

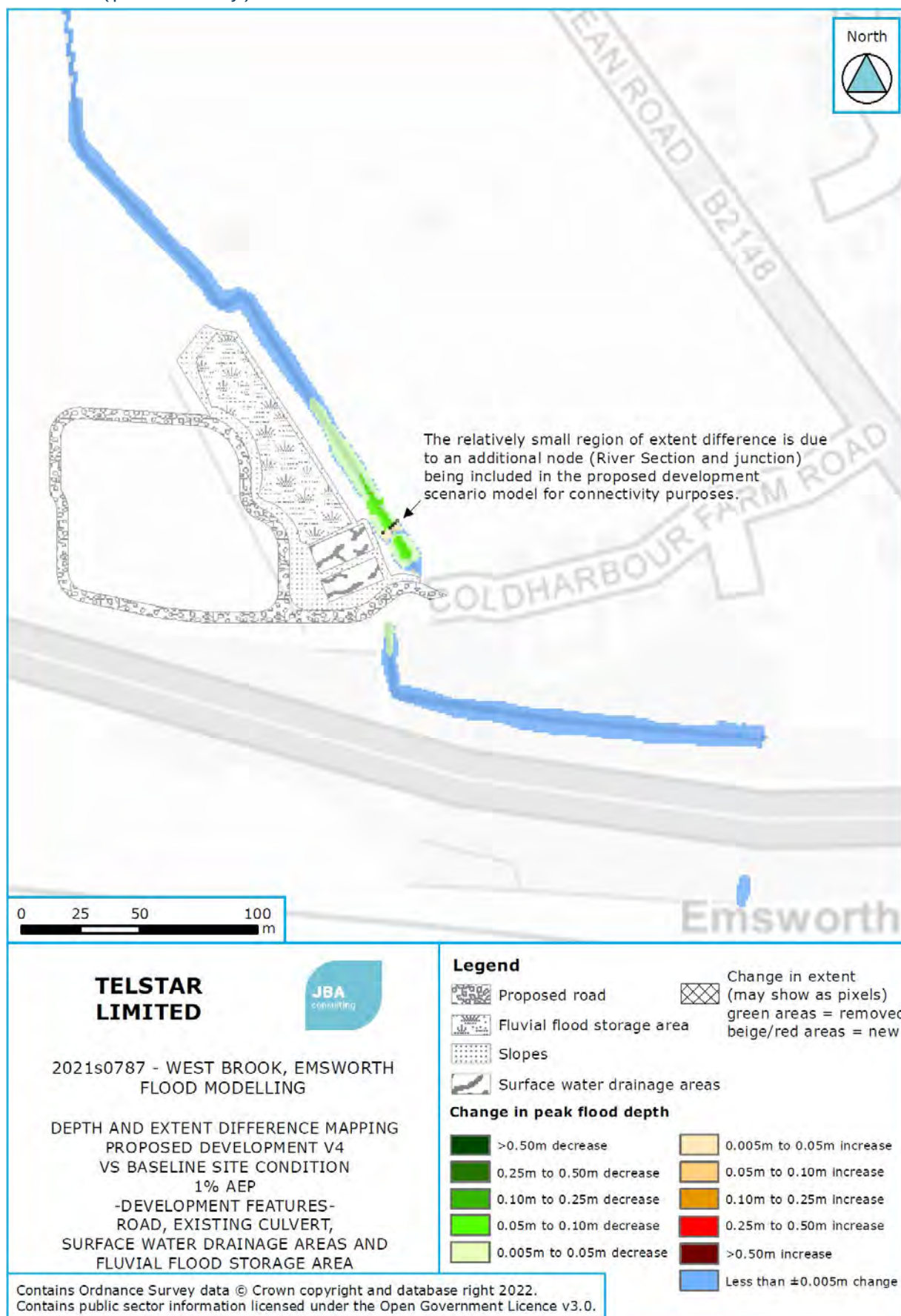


G.4 1 % AEP +25 % flows (climate change) with 50 % blockage at West Brook culvert

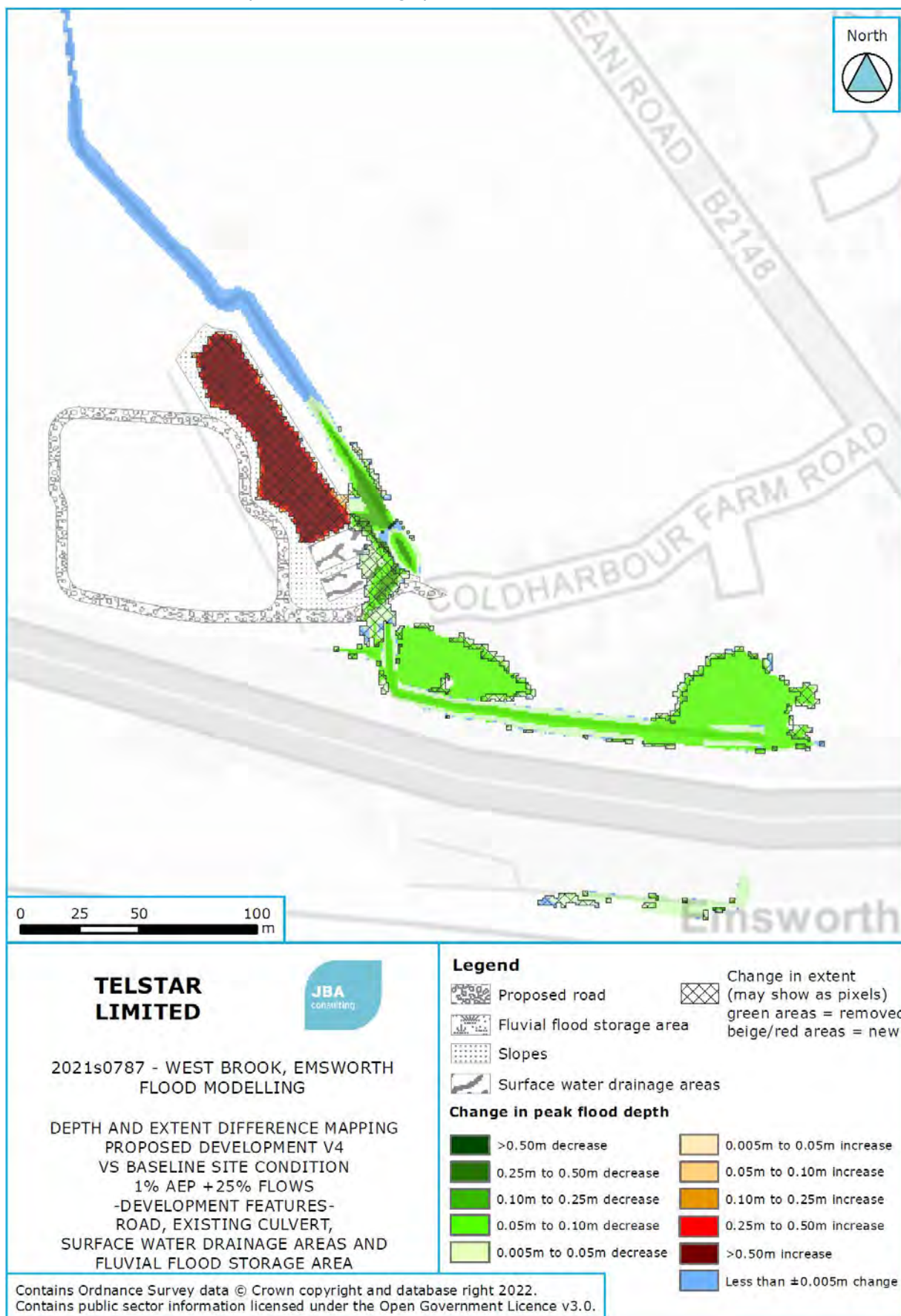


H Scenario flood mapping: changes in flood depths and extents compared with the baseline – Proposed Development Scenario 4

H.1 1 % AEP (present day)



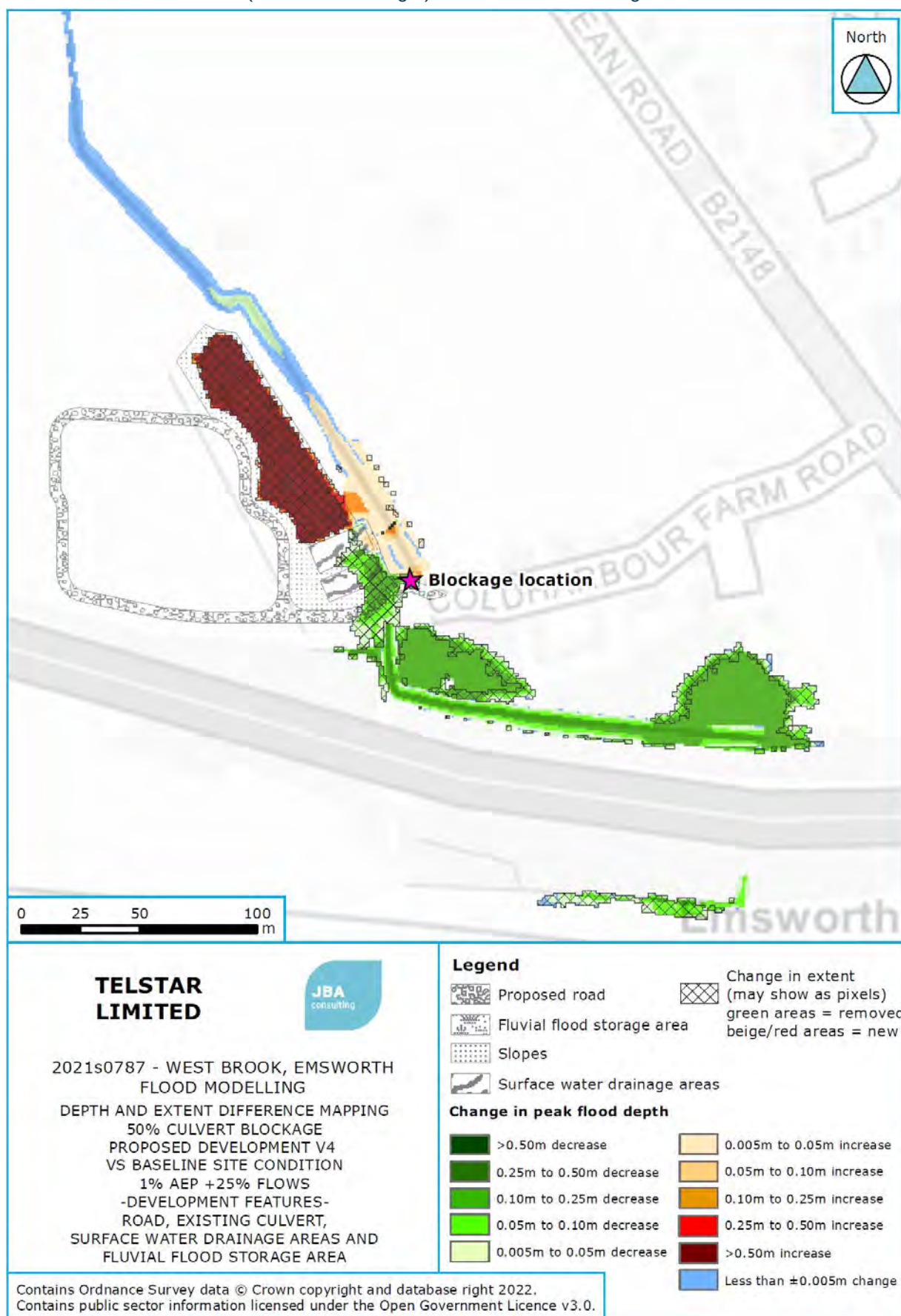
H.2 1 % AEP +25 % flows (climate change)



H.3 0.1 % AEP (present day)



H.4 1 % AEP +25 % flows (climate change) with 50 % blockage at West Brook culvert



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Dublin
Edinburgh
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Glasgow
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Limerick
Newcastle upon Tyne
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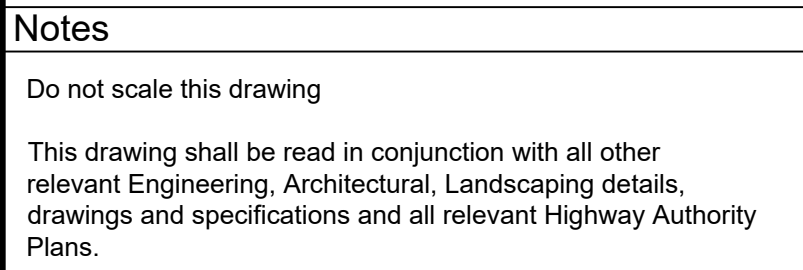
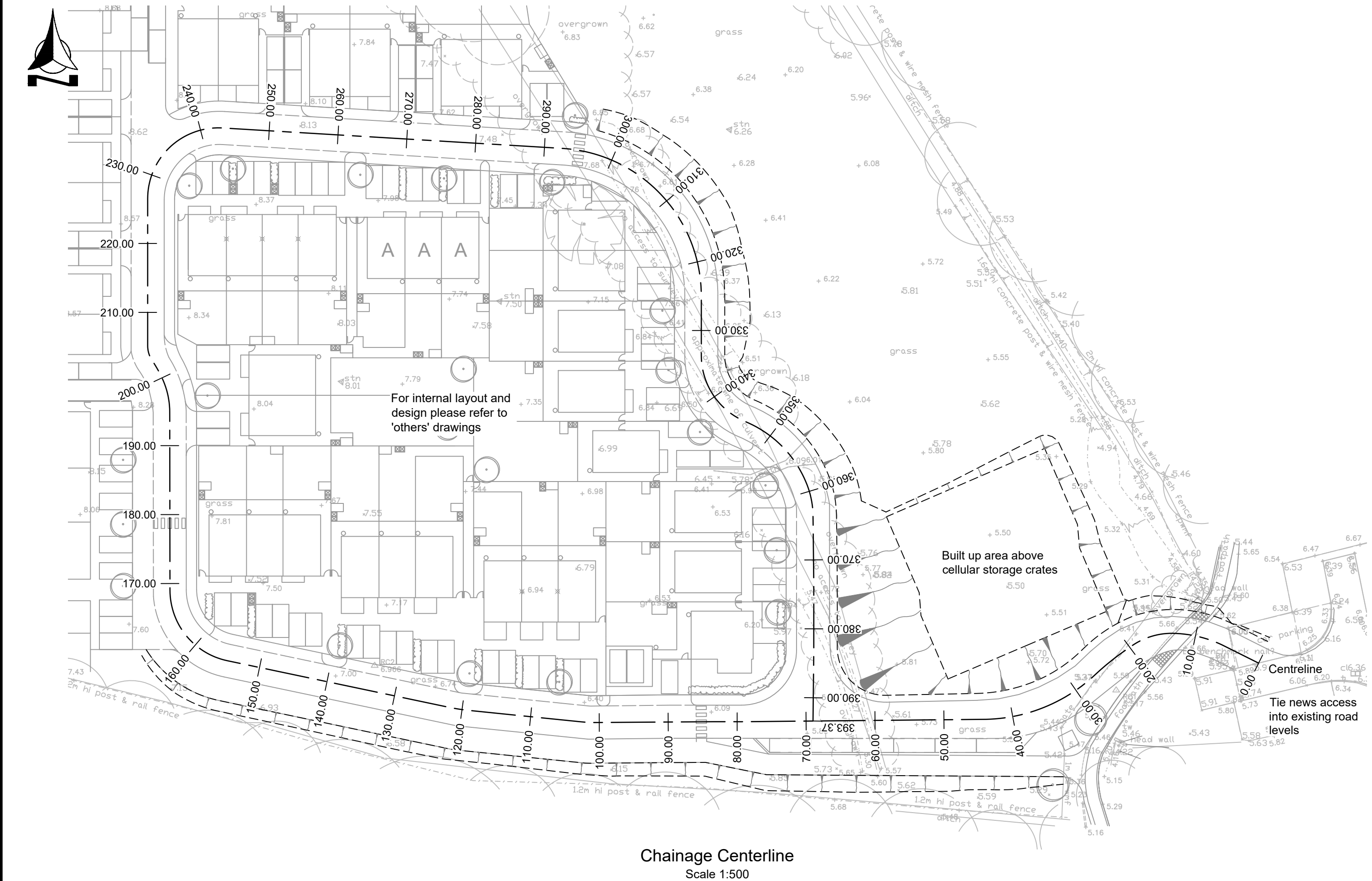
Jeremy Benn Associates Limited

Registered in England 3246693

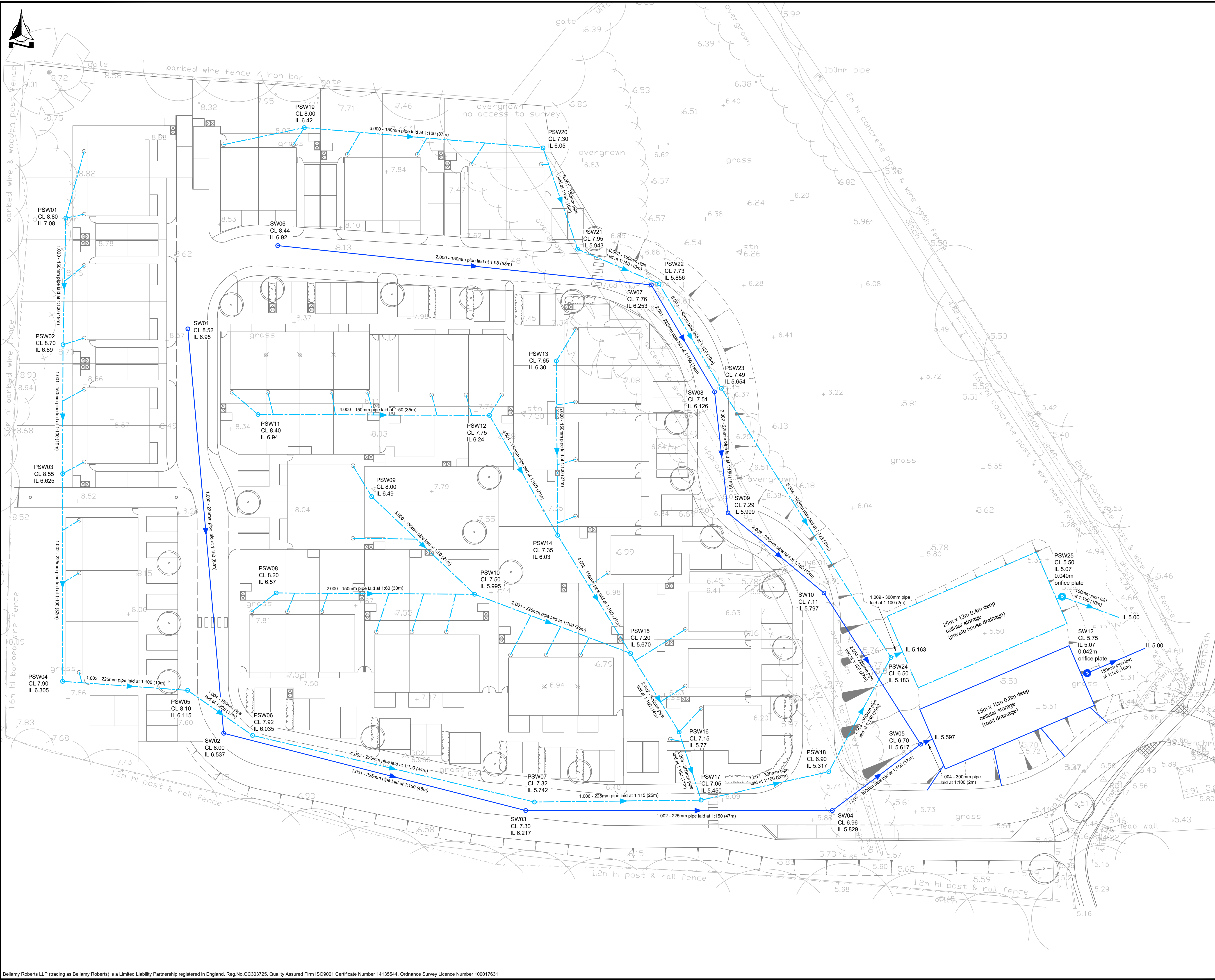
JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007



APPENDIX 7



Bellamy Roberts LLP (trading as Bellamy Roberts) is a Limited Liability Partnership registered in England. Reg.No.OC303725, Quality Assured Firm ISO9001 Certificate Number 14135544, Ordnance Survey Licence Number 100017631



Do not scale this drawing

This drawing shall be read in conjunction with all other relevant Engineering, Architectural, Landscaping details, drawings and specifications and all relevant Highway Authority Plans.

All adoptable drainage works to be constructed as detailed in Sewers for Adoption, 7th edition or as stipulated in Thames Water Addendum.

Any works constructed prior to technical approval are at the contractors own risk.

All parking spaces are to be permeable block paving depth by design (dark). Manhole locations are approximate.

- Surface water drain, gully and Manhole (Roads)
- Surface water drain, gully with inspection chambers (Private)
- Orifice Plate control device

B	Minor revision	JCB	MT
A	Road design updated, surface water drainage added	JCB	MT
REVISION	AMENDMENT	DRN DATE	CHK

 bellamy roberts Clover House Western Lane Odiham Hampshire, RG29 1TU Tel: 01256 703355 Email: info@bellamyroberts.co.uk			
CLIENT Telstar			
PROJECT Coldharbour Farm Road, Emsworth			
TITLE Access Design Surface Water Drainage Strategy			
DRAWN BY JCB	DESIGN BY JCB	CHK BY	MT
DATE 26/03/21	DRAWING No. 5314 / 1002		REV No. B
SCALE 1:500 @ A1			

APPENDIX 8

Bellamy Roberts		Page 1
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU		
Date 20/01/2022 15:42 File	Designed by jason Checked by	
Innovyze		Source Control 2020.1.3
<u>ICP SUDS Mean Annual Flood</u> Input Return Period (years) 100 Soil 0.340 Area (ha) 1.900 Urban 0.000 SAAR (mm) 783 Region Number Region 7 Results l/s QBAR Rural 5.2 QBAR Urban 5.2 Q100 years 16.5 Q1 year 4.4 Q30 years 11.7 Q100 years 16.5		
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APPENDIX 9

Bellamy Roberts

50 Sandy Hill Close
Waltham Chase, Southampton
Hampshire, SO31 2GU

Date 17/01/2022 09:31
File CELLULAR STORAGE HOUSE....

Innovyze

Coldharbour Farm
Emsworth
Private House Drainage

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Source Control 2020.1.3

Page 1



Summary of Results for 1 year Return Period

Half Drain Time : 60 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	5.432	0.032	0.0	2.1	2.1	9.1	O K
30 min Summer	5.440	0.040	0.0	2.2	2.2	11.4	O K
60 min Summer	5.444	0.044	0.0	2.2	2.2	12.7	O K
120 min Summer	5.445	0.045	0.0	2.2	2.2	12.9	O K
180 min Summer	5.445	0.045	0.0	2.2	2.2	12.8	O K
240 min Summer	5.443	0.043	0.0	2.2	2.2	12.3	O K
360 min Summer	5.439	0.039	0.0	2.2	2.2	11.1	O K
480 min Summer	5.434	0.034	0.0	2.1	2.1	9.6	O K
600 min Summer	5.429	0.029	0.0	2.1	2.1	8.2	O K
720 min Summer	5.424	0.024	0.0	2.1	2.1	6.9	O K
960 min Summer	5.416	0.016	0.0	2.1	2.1	4.6	O K
1440 min Summer	5.405	0.005	0.0	2.1	2.1	1.5	O K
2160 min Summer	5.400	0.000	0.0	1.9	1.9	0.0	O K
2880 min Summer	5.400	0.000	0.0	1.6	1.6	0.0	O K
4320 min Summer	5.400	0.000	0.0	1.2	1.2	0.0	O K
5760 min Summer	5.400	0.000	0.0	1.0	1.0	0.0	O K
7200 min Summer	5.400	0.000	0.0	0.9	0.9	0.0	O K
8640 min Summer	5.400	0.000	0.0	0.7	0.7	0.0	O K
10080 min Summer	5.400	0.000	0.0	0.7	0.7	0.0	O K
15 min Winter	5.437	0.037	0.0	2.2	2.2	10.5	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	28.417	0.0	11.5	21
30 min Summer	18.860	0.0	15.4	33
60 min Summer	12.227	0.0	20.1	58
120 min Summer	7.783	0.0	25.6	90
180 min Summer	5.952	0.0	29.4	126
240 min Summer	4.917	0.0	32.3	160
360 min Summer	3.727	0.0	36.9	228
480 min Summer	3.055	0.0	40.1	294
600 min Summer	2.619	0.0	43.1	360
720 min Summer	2.309	0.0	45.6	422
960 min Summer	1.894	0.0	49.8	540
1440 min Summer	1.433	0.0	56.6	768
2160 min Summer	1.083	0.0	64.3	0
2880 min Summer	0.888	0.0	70.3	0
4320 min Summer	0.672	0.0	79.8	0
5760 min Summer	0.552	0.0	87.4	0
7200 min Summer	0.474	0.0	93.8	0
8640 min Summer	0.417	0.0	99.0	0
10080 min Summer	0.374	0.0	103.7	0
15 min Winter	28.417	0.0	13.0	21

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Bellamy Roberts		Page 3
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU	Coldharbour Farm Emsworth Private House Drainage	
Date 17/01/2022 09:31 File CELLULAR STORAGE HOUSE....	Designed by JCB Checked by MT	
Innovyze	Source Control 2020.1.3	

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	1	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.200	Shortest Storm (mins)	15
Ratio R	0.350	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.220

Time (mins) Area			Time (mins) Area			Time (mins) Area		
From:	To:	(ha)	From:	To:	(ha)	From:	To:	(ha)
0	4	0.100	4	8	0.100	8	12	0.020

Bellamy Roberts		Page 4
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU	Coldharbour Farm Emsworth Private House Drainage	
Date 17/01/2022 09:31 File CELLULAR STORAGE HOUSE....	Designed by JCB Checked by MT	
Innovyze		Source Control 2020.1.3

Model Details

Storage is Online Cover Level (m) 6.000

Cellular Storage Structure

Invert Level (m) 5.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	300.0	0.0	0.410	0.0	0.0
0.400	300.0	0.0			

Orifice Outflow Control

Diameter (m) 0.040 Discharge Coefficient 0.600 Invert Level (m) 5.000

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Page 1

50 Sandy Hill Close
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Coldharbour Farm
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Source Control 2020.1.3

Summary of Results for 30 year Return Period

Half Drain Time : 192 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	5.490	0.090	0.0	2.3	2.3	25.7	O K
30 min Summer	5.517	0.117	0.0	2.4	2.4	33.4	O K
60 min Summer	5.541	0.141	0.0	2.4	2.4	40.1	O K
120 min Summer	5.554	0.154	0.0	2.4	2.4	43.9	O K
180 min Summer	5.553	0.153	0.0	2.4	2.4	43.6	O K
240 min Summer	5.550	0.150	0.0	2.4	2.4	42.6	O K
360 min Summer	5.543	0.143	0.0	2.4	2.4	40.9	O K
480 min Summer	5.537	0.137	0.0	2.4	2.4	39.1	O K
600 min Summer	5.531	0.131	0.0	2.4	2.4	37.2	O K
720 min Summer	5.524	0.124	0.0	2.4	2.4	35.3	O K
960 min Summer	5.510	0.110	0.0	2.3	2.3	31.5	O K
1440 min Summer	5.485	0.085	0.0	2.3	2.3	24.2	O K
2160 min Summer	5.453	0.053	0.0	2.2	2.2	15.1	O K
2880 min Summer	5.430	0.030	0.0	2.1	2.1	8.4	O K
4320 min Summer	5.403	0.003	0.0	2.1	2.1	1.0	O K
5760 min Summer	5.400	0.000	0.0	1.8	1.8	0.0	O K
7200 min Summer	5.400	0.000	0.0	1.5	1.5	0.0	O K
8640 min Summer	5.400	0.000	0.0	1.3	1.3	0.0	O K
10080 min Summer	5.400	0.000	0.0	1.2	1.2	0.0	O K
15 min Winter	5.502	0.102	0.0	2.3	2.3	29.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	69.605	0.0	28.5	22
30 min Summer	46.335	0.0	38.0	36
60 min Summer	29.553	0.0	48.7	64
120 min Summer	18.298	0.0	60.2	122
180 min Summer	13.667	0.0	67.6	160
240 min Summer	11.055	0.0	72.7	192
360 min Summer	8.183	0.0	81.0	258
480 min Summer	6.606	0.0	87.0	328
600 min Summer	5.592	0.0	92.1	396
720 min Summer	4.877	0.0	96.3	464
960 min Summer	3.929	0.0	103.5	600
1440 min Summer	2.893	0.0	114.4	858
2160 min Summer	2.127	0.0	126.1	1232
2880 min Summer	1.708	0.0	135.2	1584
4320 min Summer	1.253	0.0	148.9	2212
5760 min Summer	1.005	0.0	159.2	0
7200 min Summer	0.846	0.0	167.6	0
8640 min Summer	0.736	0.0	174.9	0
10080 min Summer	0.654	0.0	181.4	0
15 min Winter	69.605	0.0	32.0	22

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Coldharbour Farm
Emsworth
Private House Drainage

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Page 2



Summary of Results for 30 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	5.533	0.133	0.0	2.4	2.4	38.0	O K
60 min Winter	5.562	0.162	0.0	2.5	2.5	46.0	O K
120 min Winter	5.580	0.180	0.0	2.5	2.5	51.4	O K
180 min Winter	5.582	0.182	0.0	2.5	2.5	52.0	O K
240 min Winter	5.578	0.178	0.0	2.5	2.5	50.6	O K
360 min Winter	5.568	0.168	0.0	2.5	2.5	47.9	O K
480 min Winter	5.559	0.159	0.0	2.5	2.5	45.2	O K
600 min Winter	5.548	0.148	0.0	2.4	2.4	42.3	O K
720 min Winter	5.538	0.138	0.0	2.4	2.4	39.2	O K
960 min Winter	5.516	0.116	0.0	2.4	2.4	33.2	O K
1440 min Winter	5.478	0.078	0.0	2.3	2.3	22.1	O K
2160 min Winter	5.433	0.033	0.0	2.1	2.1	9.3	O K
2880 min Winter	5.405	0.005	0.0	2.1	2.1	1.3	O K
4320 min Winter	5.400	0.000	0.0	1.6	1.6	0.0	O K
5760 min Winter	5.400	0.000	0.0	1.3	1.3	0.0	O K
7200 min Winter	5.400	0.000	0.0	1.1	1.1	0.0	O K
8640 min Winter	5.400	0.000	0.0	1.0	1.0	0.0	O K
10080 min Winter	5.400	0.000	0.0	0.8	0.8	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
30 min Winter	46.335	0.0	42.6	36
60 min Winter	29.553	0.0	54.5	64
120 min Winter	18.298	0.0	67.6	120
180 min Winter	13.667	0.0	75.6	174
240 min Winter	11.055	0.0	81.6	220
360 min Winter	8.183	0.0	90.7	278
480 min Winter	6.606	0.0	97.5	356
600 min Winter	5.592	0.0	103.1	430
720 min Winter	4.877	0.0	108.0	504
960 min Winter	3.929	0.0	115.9	646
1440 min Winter	2.893	0.0	128.1	912
2160 min Winter	2.127	0.0	141.3	1276
2880 min Winter	1.708	0.0	151.4	1560
4320 min Winter	1.253	0.0	166.7	0
5760 min Winter	1.005	0.0	178.3	0
7200 min Winter	0.846	0.0	187.7	0
8640 min Winter	0.736	0.0	195.9	0
10080 min Winter	0.654	0.0	203.1	0

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Date 17/01/2022 09:31 File CELLULAR STORAGE HOUSE....	Designed by JCB Checked by MT	
Innovyze		Source Control 2020.1.3

Model Details

Storage is Online Cover Level (m) 6.000

Cellular Storage Structure

Invert Level (m) 5.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	300.0	0.0	0.410	0.0	0.0
0.400	300.0	0.0			

Orifice Outflow Control

Diameter (m) 0.040 Discharge Coefficient 0.600 Invert Level (m) 5.000

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Emsworth
Private House Drainage

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Page 1



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

Half Drain Time : 354 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (1/s)	Max Control (1/s)	Max Σ Outflow (1/s)	Max Volume (m³)	Status
15 min Summer	5.571	0.171	0.0	2.5	2.5	48.7	O K
30 min Summer	5.627	0.227	0.0	2.6	2.6	64.6	O K
60 min Summer	5.681	0.281	0.0	2.7	2.7	80.1	O K
120 min Summer	5.726	0.326	0.0	2.8	2.8	92.8	Flood Risk
180 min Summer	5.740	0.340	0.0	2.8	2.8	97.0	Flood Risk
240 min Summer	5.742	0.342	0.0	2.8	2.8	97.4	Flood Risk
360 min Summer	5.733	0.333	0.0	2.8	2.8	95.0	Flood Risk
480 min Summer	5.723	0.323	0.0	2.8	2.8	92.0	Flood Risk
600 min Summer	5.714	0.314	0.0	2.8	2.8	89.4	Flood Risk
720 min Summer	5.705	0.305	0.0	2.8	2.8	86.9	Flood Risk
960 min Summer	5.688	0.288	0.0	2.7	2.7	82.2	O K
1440 min Summer	5.656	0.256	0.0	2.7	2.7	73.0	O K
2160 min Summer	5.610	0.210	0.0	2.6	2.6	59.9	O K
2880 min Summer	5.570	0.170	0.0	2.5	2.5	48.3	O K
4320 min Summer	5.504	0.104	0.0	2.3	2.3	29.5	O K
5760 min Summer	5.457	0.057	0.0	2.2	2.2	16.2	O K
7200 min Summer	5.425	0.025	0.0	2.1	2.1	7.1	O K
8640 min Summer	5.406	0.006	0.0	2.1	2.1	1.7	O K
10080 min Summer	5.400	0.000	0.0	2.0	2.0	0.0	O K
15 min Winter	5.593	0.193	0.0	2.5	2.5	54.9	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	126.074	0.0	51.9	23
30 min Summer	84.745	0.0	69.8	37
60 min Summer	54.368	0.0	89.7	66
120 min Summer	33.674	0.0	110.9	124
180 min Summer	25.065	0.0	123.9	182
240 min Summer	20.180	0.0	133.1	240
360 min Summer	14.839	0.0	146.7	308
480 min Summer	11.923	0.0	157.3	370
600 min Summer	10.054	0.0	165.6	434
720 min Summer	8.741	0.0	173.0	504
960 min Summer	7.003	0.0	184.8	642
1440 min Summer	5.114	0.0	202.5	914
2160 min Summer	3.727	0.0	221.1	1316
2880 min Summer	2.973	0.0	235.3	1704
4320 min Summer	2.159	0.0	256.3	2424
5760 min Summer	1.718	0.0	272.1	3120
7200 min Summer	1.438	0.0	284.6	3816
8640 min Summer	1.245	0.0	295.7	4416
10080 min Summer	1.102	0.0	305.5	0
15 min Winter	126.074	0.0	58.1	23

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Coldharbour Farm
Emsworth
Private House Drainage

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Page 2



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

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	5.656	0.256	0.0	2.7	2.7	73.0	O K
60 min Winter	5.719	0.319	0.0	2.8	2.8	90.9	Flood Risk
120 min Winter	5.773	0.373	0.0	2.9	2.9	106.3	Flood Risk
180 min Winter	5.793	0.393	0.0	2.9	2.9	112.1	Flood Risk
240 min Winter	5.799	0.399	0.0	2.9	2.9	113.7	Flood Risk
360 min Winter	5.794	0.394	0.0	2.9	2.9	112.3	Flood Risk
480 min Winter	5.782	0.382	0.0	2.9	2.9	108.7	Flood Risk
600 min Winter	5.769	0.369	0.0	2.9	2.9	105.1	Flood Risk
720 min Winter	5.755	0.355	0.0	2.9	2.9	101.2	Flood Risk
960 min Winter	5.731	0.331	0.0	2.8	2.8	94.3	Flood Risk
1440 min Winter	5.681	0.281	0.0	2.7	2.7	80.2	O K
2160 min Winter	5.613	0.213	0.0	2.6	2.6	60.6	O K
2880 min Winter	5.554	0.154	0.0	2.4	2.4	43.8	O K
4320 min Winter	5.464	0.064	0.0	2.2	2.2	18.3	O K
5760 min Winter	5.410	0.010	0.0	2.1	2.1	2.8	O K
7200 min Winter	5.400	0.000	0.0	1.9	1.9	0.0	O K
8640 min Winter	5.400	0.000	0.0	1.6	1.6	0.0	O K
10080 min Winter	5.400	0.000	0.0	1.4	1.4	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
30 min Winter	84.745	0.0	78.2	37
60 min Winter	54.368	0.0	100.3	66
120 min Winter	33.674	0.0	124.4	122
180 min Winter	25.065	0.0	138.7	180
240 min Winter	20.180	0.0	149.1	236
360 min Winter	14.839	0.0	164.3	342
480 min Winter	11.923	0.0	176.3	390
600 min Winter	10.054	0.0	185.7	464
720 min Winter	8.741	0.0	193.7	542
960 min Winter	7.003	0.0	207.0	696
1440 min Winter	5.114	0.0	226.6	990
2160 min Winter	3.727	0.0	247.9	1408
2880 min Winter	2.973	0.0	263.7	1792
4320 min Winter	2.159	0.0	287.0	2512
5760 min Winter	1.718	0.0	304.6	3112
7200 min Winter	1.438	0.0	318.9	0
8640 min Winter	1.245	0.0	331.3	0
10080 min Winter	1.102	0.0	342.2	0

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Bellamy Roberts		Page 3
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU	Coldharbour Farm Emsworth Private House Drainage	
Date 17/01/2022 09:30 File CELLULAR STORAGE HOUSE....	Designed by JCB Checked by MT	
Innovyze Source Control 2020.1.3		

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.200	Shortest Storm (mins)	15
Ratio R	0.350	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.220

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From: To:	(ha)	From: To:	(ha)	From: To:	(ha)
0 4	0.100	4 8	0.100	8 12	0.020

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Bellamy Roberts		Page 4
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU	Coldharbour Farm Emsworth Private House Drainage	
Date 17/01/2022 09:30 File CELLULAR STORAGE HOUSE....	Designed by JCB Checked by MT	
Innovyze Source Control 2020.1.3		

Model Details

Storage is Online Cover Level (m) 6.000

Cellular Storage Structure

Invert Level (m) 5.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	300.0	0.0	0.410	0.0	0.0
0.400	300.0	0.0			

Orifice Outflow Control

Diameter (m) 0.040 Discharge Coefficient 0.600 Invert Level (m) 5.000

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Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type	Auto Design
S1.008	20.000	0.133	150.0	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	🟢
S6.000	37.000	0.370	100.0	0.033	4.00	0.0	0.600	o	150	Pipe/Conduit	🟡
S6.001	16.000	0.107	149.5	0.000	0.00	0.0	0.600	o	150	Pipe/Conduit	🟢
S6.002	13.000	0.087	149.4	0.000	0.00	0.0	0.600	o	150	Pipe/Conduit	🟢
S6.003	19.000	0.127	150.0	0.000	0.00	0.0	0.600	o	150	Pipe/Conduit	🟢
S6.004	49.000	0.396	123.7	0.000	0.00	0.0	0.600	o	225	Pipe/Conduit	🟢
S1.009	2.000	0.020	100.0	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	🟢

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S1.008	50.00	7.02	5.317	0.191	0.0	0.0	10.3	1.28	90.6	36.2
S6.000	50.00	4.61	6.420	0.033	0.0	0.0	1.8	1.00	17.8	6.3
S6.001	50.00	4.94	6.050	0.033	0.0	0.0	1.8	0.82	14.5	6.3
S6.002	50.00	5.20	5.943	0.033	0.0	0.0	1.8	0.82	14.5	6.3
S6.003	50.00	5.59	5.856	0.033	0.0	0.0	1.8	0.82	14.5	6.3
S6.004	50.00	6.29	5.654	0.033	0.0	0.0	1.8	1.17	46.7	6.3
S1.009	50.00	7.04	5.183	0.224	0.0	0.0	12.1	1.57	111.1	42.5

Manhole Schedules for Storm											
MH Name	MH CL (m)	MH Depth (m)	MH Connection	MH Diam., L*W (mm)	PN	Pipe Out Invert Level (m)	Diameter (mm)	PN	Pipes In Invert Level (m)	Diameter (mm)	Backdrop (mm)
S1	8.800	1.720	Open Manhole	1200	S1.000	7.080	150				
S2	8.700	1.810	Open Manhole	1200	S1.001	6.890	150	S1.000	6.890	150	
S3	8.550	1.925	Open Manhole	1200	S1.002	6.625	225	S1.001	6.700	150	
S4	7.900	1.595	Open Manhole	1200	S1.003	6.305	225	S1.002	6.305	225	
S5	8.100	1.985	Open Manhole	1200	S1.004	6.115	225	S1.003	6.115	225	
S6	7.920	1.885	Open Manhole	1200	S1.005	6.035	225	S1.004	6.035	225	
S7	7.320	1.578	Open Manhole	1200	S1.006	5.742	225	S1.005	5.742	225	
S8	8.200	1.630	Open Manhole	1200	S2.000	6.570	150				
S9	8.000	1.510	Open Manhole	1200	S3.000	6.490	150				
S10	7.500	1.505	Open Manhole	1200	S2.001	5.995	225	S2.000	6.070	150	
								S3.000	6.070	150	
S11	8.400	1.460	Open Manhole	1200	S4.000	6.940	150				
S12	7.750	1.510	Open Manhole	1200	S4.001	6.240	150	S4.000	6.240	150	
S13	7.650	1.350	Open Manhole	1200	S5.000	6.300	150				
S14	7.350	1.320	Open Manhole	1200	S4.002	6.030	150	S4.001	6.030	150	
								S5.000	6.030	150	
S15	7.200	1.530	Open Manhole	1200	S2.002	5.670	300	S2.001	5.745	225	
								S4.002	5.820	150	
S16	7.150	1.573	Open Manhole	1200	S2.003	5.577	300	S2.002	5.577	300	
S17	7.050	1.600	Open Manhole	1200	S1.007	5.450	300	S1.006	5.525	225	
								S2.003	5.450	300	
S18	6.900	1.583	Open Manhole	1200	S1.008	5.317	300	S1.007	5.317	300	
S19	8.000	1.580	Open Manhole	1200	S6.000	6.420	150				
S20	7.300	1.250	Open Manhole	1200	S6.001	6.050	150	S6.000	6.050	150	
S21	7.950	2.007	Open Manhole	1200	S6.002	5.943	150	S6.001	5.943	150	
S22	7.730	1.874	Open Manhole	1200	S6.003	5.856	150	S6.002	5.856	150	
S23	7.490	1.836	Open Manhole	1200	S6.004	5.654	225	S6.003	5.729	150	
S24	6.500	1.317	Open Manhole	1200	S1.009	5.183	300	S1.008	5.184	300	
								S6.004	5.258	225	
S	6.500	1.337	Open Manhole	0		OUTFALL		S1.009	5.163	300	

No coordinates have been specified, layout information cannot be produced.

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Bellamy Roberts		Page 4
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU	Cold Harbour Farm Network House SW	
Date 17/01/2022 15:18 File network House drainage.MDX	Designed by JCB Checked by MT	
Innovyze	Network 2020.1.3	

PIPELINE SCHEDULES for Storm

Upstream Manhole

PN	Hyd Sect	Diam (mm)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	o	150	S1	8.800	7.080	1.570	Open Manhole	1200
S1.001	o	150	S2	8.700	6.890	1.660	Open Manhole	1200
S1.002	o	225	S3	8.550	6.625	1.700	Open Manhole	1200
S1.003	o	225	S4	7.900	6.305	1.370	Open Manhole	1200
S1.004	o	225	S5	8.100	6.115	1.760	Open Manhole	1200
S1.005	o	225	S6	7.920	6.035	1.660	Open Manhole	1200
S1.006	o	225	S7	7.320	5.742	1.353	Open Manhole	1200
S2.000	o	150	S8	8.200	6.570	1.480	Open Manhole	1200
S3.000	o	150	S9	8.000	6.490	1.360	Open Manhole	1200
S2.001	o	225	S10	7.500	5.995	1.280	Open Manhole	1200
S4.000	o	150	S11	8.400	6.940	1.310	Open Manhole	1200
S4.001	o	150	S12	7.750	6.240	1.360	Open Manhole	1200
S5.000	o	150	S13	7.650	6.300	1.200	Open Manhole	1200
S4.002	o	150	S14	7.350	6.030	1.170	Open Manhole	1200
S2.002	o	300	S15	7.200	5.670	1.230	Open Manhole	1200
S2.003	o	300	S16	7.150	5.577	1.273	Open Manhole	1200
S1.007	o	300	S17	7.050	5.450	1.300	Open Manhole	1200
S1.008	o	300	S18	6.900	5.317	1.283	Open Manhole	1200
S6.000	o	150	S19	8.000	6.420	1.430	Open Manhole	1200
S6.001	o	150	S20	7.300	6.050	1.100	Open Manhole	1200
S6.002	o	150	S21	7.950	5.943	1.857	Open Manhole	1200
S6.003	o	150	S22	7.730	5.856	1.724	Open Manhole	1200
S6.004	o	225	S23	7.490	5.654	1.611	Open Manhole	1200
S1.009	o	300	S24	6.500	5.183	1.017	Open Manhole	1200

Downstream Manhole

PN	Length (m)	Slope (1:X)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	19.000	100.0	S2	8.700	6.890	1.660	Open Manhole	1200
S1.001	19.000	100.0	S3	8.550	6.700	1.700	Open Manhole	1200
S1.002	32.000	100.0	S4	7.900	6.305	1.370	Open Manhole	1200
S1.003	19.000	100.0	S5	8.100	6.115	1.760	Open Manhole	1200
S1.004	12.000	150.0	S6	7.920	6.035	1.660	Open Manhole	1200
S1.005	44.000	150.2	S7	7.320	5.742	1.353	Open Manhole	1200
S1.006	25.000	115.4	S17	7.050	5.525	1.300	Open Manhole	1200
S2.000	30.000	60.0	S10	7.500	6.070	1.280	Open Manhole	1200
S3.000	21.000	50.0	S10	7.500	6.070	1.280	Open Manhole	1200
S2.001	25.000	100.0	S15	7.200	5.745	1.230	Open Manhole	1200
S4.000	35.000	50.0	S12	7.750	6.240	1.360	Open Manhole	1200
S4.001	21.000	100.0	S14	7.350	6.030	1.170	Open Manhole	1200
S5.000	27.000	100.0	S14	7.350	6.030	1.170	Open Manhole	1200
S4.002	21.000	100.0	S15	7.200	5.820	1.230	Open Manhole	1200
S2.002	14.000	150.5	S16	7.150	5.577	1.273	Open Manhole	1200
S2.003	11.000	86.6	S17	7.050	5.450	1.300	Open Manhole	1200
S1.007	20.000	150.4	S18	6.900	5.317	1.283	Open Manhole	1200
S1.008	20.000	150.0	S24	6.500	5.184	1.016	Open Manhole	1200
S6.000	37.000	100.0	S20	7.300	6.050	1.100	Open Manhole	1200
S6.001	16.000	149.5	S21	7.950	5.943	1.857	Open Manhole	1200
S6.002	13.000	149.4	S22	7.730	5.856	1.724	Open Manhole	1200
S6.003	19.000	150.0	S23	7.490	5.729	1.611	Open Manhole	1200
S6.004	49.000	123.7	S24	6.500	5.258	1.017	Open Manhole	1200
S1.009	2.000	100.0	S	6.500	5.163	1.037	Open Manhole	0

Area Summary for Storm

Pipe Number	PIMP Type	PIMP Name	PIMP (%)	Gross Area (ha)	Imp. Area (ha)	Pipe Total (ha)
1.000	-	-	100	0.022	0.022	0.022
1.001	-	-	100	0.011	0.011	0.011
1.002	-	-	100	0.011	0.011	0.011
1.003	-	-	100	0.010	0.010	0.010
1.004	-	-	100	0.000	0.000	0.000
1.005	-	-	100	0.000	0.000	0.000
1.006	-	-	100	0.000	0.000	0.000
2.000	-	-	100	0.028	0.028	0.028
3.000	-	-	100	0.011	0.011	0.011
2.001	-	-	100	0.014	0.014	0.014
4.000	-	-	100	0.031	0.031	0.031
4.001	-	-	100	0.000	0.000	0.000
5.000	-	-	100	0.023	0.023	0.023
4.002	-	-	100	0.010	0.010	0.010
2.002	-	-	100	0.012	0.012	0.012
2.003	-	-	100	0.008	0.008	0.008
1.007	-	-	100	0.000	0.000	0.000
1.008	-	-	100	0.000	0.000	0.000
6.000	-	-	100	0.033	0.033	0.033
6.001	-	-	100	0.000	0.000	0.000
6.002	-	-	100	0.000	0.000	0.000
6.003	-	-	100	0.000	0.000	0.000
6.004	-	-	100	0.000	0.000	0.000
1.009	-	-	100	0.000	0.000	0.000
				Total	Total	Total
				0.224	0.224	0.224

Free Flowing Outfall Details for Storm

Outfall Pipe Number	Outfall Name	C. Level (m)	I. Level (m)	Min I. Level (m)	D,L (mm)	W (mm)
S1.009	S	6.500	5.163	0.000	0	0

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.750	Manhole Headloss Coeff (Global)	0.500	Inlet Coeffiecient	0.800
Areal Reduction Factor	1.000	Foul Sewage per hectare (l/s)	0.000	Flow per Person per Day (l/per/day)	0.000
Hot Start (mins)	0	Additional Flow - % of Total Flow	40.000	Run Time (mins)	60
Hot Start Level (mm)	0	MADD Factor * 10m³/ha Storage	2.000	Output Interval (mins)	1

Number of Input Hydrographs	0	Number of Offline Controls	0	Number of Time/Area Diagrams	0
Number of Online Controls	0	Number of Storage Structures	0	Number of Real Time Controls	0

Synthetic Rainfall Details

Rainfall Model	FSR	M5-60 (mm)	19.500	Cv (Summer)	0.750
Return Period (years)	100	Ratio R	0.350	Cv (Winter)	0.840
Region	England and Wales	Profile Type	Summer Storm	Duration (mins)	30

STORM SEWER DESIGN by the Modified Rational Method

Design Criteria for Storm

Pipe Sizes STANDARD Manhole Sizes STANDARD

FSR Rainfall Model - England and Wales					
Return Period (years)	100	Foul Sewage (l/s/ha)	0.000	Maximum Backdrop Height (m)	1.500
M5-60 (mm)	19.500	Volumetric Runoff Coeff.	0.750	Min Design Depth for Optimisation (m)	1.200
Ratio R	0.350	PIMP (%)	100	Min Vel for Auto Design only (m/s)	1.00
Maximum Rainfall (mm/hr)	50	Add Flow / Climate Change (%)	40	Min Slope for Optimisation (1:X)	500
Maximum Time of Concentration (mins)	30	Minimum Backdrop Height (m)	0.200		

Designed with Level Soffits

Time Area Diagram for Storm

Time (mins)	Area (ha)	Time (mins)	Area (ha)
0-4	0.132	4-8	0.108

Total Area Contributing (ha) = 0.240

Total Pipe Volume (m³) = 12.785

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section	Type	Auto Design
S1.000	62.000	0.413	150.1	0.060	4.00	0.0	0.600	o	225	Pipe/Conduit		🔒
S1.001	48.000	0.320	150.0	0.030	0.00	0.0	0.600	o	225	Pipe/Conduit		🔒
S1.002	47.000	0.313	150.2	0.040	0.00	0.0	0.600	o	225	Pipe/Conduit		🔒
S1.003	17.000	0.113	150.4	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit		🔒
S2.000	58.000	0.592	98.0	0.060	4.00	0.0	0.600	o	150	Pipe/Conduit		🔒
S2.001	19.000	0.127	149.6	0.014	0.00	0.0	0.600	o	225	Pipe/Conduit		🔒
S2.002	19.000	0.127	149.6	0.013	0.00	0.0	0.600	o	225	Pipe/Conduit		🔒
S2.003	19.000	0.127	149.6	0.023	0.00	0.0	0.600	o	225	Pipe/Conduit		🔒
S2.004	27.000	0.180	150.0	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit		🔒
S1.004	2.000	0.020	100.0	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit		🔒

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	Σ I.Area (ha)	Σ Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
S1.000	50.00	4.97	6.950	0.060	0.0	0.0	3.2	1.06	42.3	11.4
S1.001	50.00	5.72	6.537	0.090	0.0	0.0	4.9	1.07	42.4	17.1
S1.002	50.00	6.46	6.217	0.130	0.0	0.0	7.0	1.06	42.3	24.6
S1.003	50.00	6.68	5.829	0.130	0.0	0.0	7.0	1.28	90.4	24.6
S2.000	50.00	4.95	6.920	0.060	0.0	0.0	3.2	1.02	17.9	11.4
S2.001	50.00	5.25	6.253	0.074	0.0	0.0	4.0	1.07	42.4	14.0
S2.002	50.00	5.55	6.126	0.087	0.0	0.0	4.7	1.07	42.4	16.5
S2.003	50.00	5.84	5.999	0.110	0.0	0.0	6.0	1.07	42.4	20.9
S2.004	50.00	6.19	5.797	0.110	0.0	0.0	6.0	1.28	90.6	20.9
S1.004	50.00	6.70	5.617	0.240	0.0	0.0	13.0	1.57	111.1	45.5

Manhole Schedules for Storm

MH Name	MH CL (m)	MH Depth (m)	MH Connection	MH Diam., L*W (mm)	Pipe Out PN	Pipe Out Invert Level (m)	Pipe Out Diameter (mm)	Pipes In PN	Pipes In Invert Level (m)	Pipes In Diameter (mm)	Backdrop (mm)
S1	8.520	1.570	Open Manhole	1200	S1.000	6.950	225				
S2	8.000	1.463	Open Manhole	1200	S1.001	6.537	225	S1.000	6.537	225	
S3	7.300	1.083	Open Manhole	1200	S1.002	6.217	225	S1.001	6.217	225	
S4	6.960	1.131	Open Manhole	1200	S1.003	5.829	300	S1.002	5.904	225	
S5	8.440	1.520	Open Manhole	1200	S2.000	6.920	150				
S6	7.760	1.507	Open Manhole	1200	S2.001	6.253	225	S2.000	6.328	150	
S7	7.510	1.384	Open Manhole	1200	S2.002	6.126	225	S2.001	6.126	225	
S8	7.290	1.291	Open Manhole	1200	S2.003	5.999	225	S2.002	5.999	225	
S9	7.110	1.313	Open Manhole	1200	S2.004	5.797	300	S2.003	5.872	225	
S10	6.700	1.083	Open Manhole	1200	S1.004	5.617	300	S1.003	5.716	300	99
								S2.004	5.617	300	
S	6.700	1.103	Open Manhole	0		OUTFALL		S1.004	5.597	300	

No coordinates have been specified, layout information cannot be produced.

PIPELINE SCHEDULES for Storm

Upstream Manhole

PN	Hyd Sect	Diam (mm)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	o	225	S1	8.520	6.950	1.345	Open Manhole	1200
S1.001	o	225	S2	8.000	6.537	1.238	Open Manhole	1200
S1.002	o	225	S3	7.300	6.217	0.858	Open Manhole	1200
S1.003	o	300	S4	6.960	5.829	0.831	Open Manhole	1200
S2.000	o	150	S5	8.440	6.920	1.370	Open Manhole	1200
S2.001	o	225	S6	7.760	6.253	1.282	Open Manhole	1200
S2.002	o	225	S7	7.510	6.126	1.159	Open Manhole	1200
S2.003	o	225	S8	7.290	5.999	1.066	Open Manhole	1200
S2.004	o	300	S9	7.110	5.797	1.013	Open Manhole	1200
S1.004	o	300	S10	6.700	5.617	0.783	Open Manhole	1200

Downstream Manhole

PN	Length (m)	Slope (1:X)	MH Name	C.Level (m)	I.Level (m)	D.Depth (m)	MH Connection	MH DIAM., L*W (mm)
S1.000	62.000	150.1	S2	8.000	6.537	1.238	Open Manhole	1200
S1.001	48.000	150.0	S3	7.300	6.217	0.858	Open Manhole	1200
S1.002	47.000	150.2	S4	6.960	5.904	0.831	Open Manhole	1200
S1.003	17.000	150.4	S10	6.700	5.716	0.684	Open Manhole	1200
S2.000	58.000	98.0	S6	7.760	6.328	1.282	Open Manhole	1200
S2.001	19.000	149.6	S7	7.510	6.126	1.159	Open Manhole	1200
S2.002	19.000	149.6	S8	7.290	5.999	1.066	Open Manhole	1200
S2.003	19.000	149.6	S9	7.110	5.872	1.013	Open Manhole	1200
S2.004	27.000	150.0	S10	6.700	5.617	0.783	Open Manhole	1200
S1.004	2.000	100.0	S	6.700	5.597	0.803	Open Manhole	0

Area Summary for Storm

Pipe Number	PIMP Type	PIMP Name	PIMP (%)	Gross Area (ha)	Imp. Area (ha)	Pipe Total (ha)
1.000	-	-	100	0.060	0.060	0.060
1.001	-	-	100	0.030	0.030	0.030
1.002	-	-	100	0.040	0.040	0.040
1.003	-	-	100	0.000	0.000	0.000
2.000	-	-	100	0.060	0.060	0.060
2.001	-	-	100	0.014	0.014	0.014
2.002	-	-	100	0.013	0.013	0.013
2.003	-	-	100	0.023	0.023	0.023
2.004	-	-	100	0.000	0.000	0.000
1.004	-	-	100	0.000	0.000	0.000
				Total	Total	Total
				0.240	0.240	0.240

Free Flowing Outfall Details for Storm

Outfall Pipe Number	Outfall Name	C. Level (m)	I. Level (m)	Min I. Level (m)	D,I (mm)	W (mm)
---------------------	--------------	--------------	--------------	------------------	----------	--------

S1.004	S	6.700	5.597	0.000	0	0
--------	---	-------	-------	-------	---	---

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.750	Manhole Headloss Coeff (Global)	0.500	Inlet Coeffiecient	0.800
Areal Reduction Factor	1.000	Foul Sewage per hectare (l/s)	0.000	Flow per Person per Day (l/per/day)	0.000
Hot Start (mins)	0	Additional Flow - % of Total Flow	40.000	Run Time (mins)	60
Hot Start Level (mm)	0	MADD Factor * 10m³/ha Storage	2.000	Output Interval (mins)	1

Number of Input Hydrographs	0	Number of Offline Controls	0	Number of Time/Area Diagrams	0
Number of Online Controls	0	Number of Storage Structures	0	Number of Real Time Controls	0

Synthetic Rainfall Details

Rainfall Model	FSR	M5-60 (mm)	19.500	Cv (Summer)	0.750
Return Period (years)	100	Ratio R	0.350	Cv (Winter)	0.840
Region	England and Wales	Profile Type	Summer Storm	Duration (mins)	30

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<u>Summary of Results for 1 year Return Period</u>								
Half Drain Time : 60 minutes.								
Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status	
15 min Summer	5.432	0.032	0.0	2.1	2.1	9.1	O K	
30 min Summer	5.440	0.040	0.0	2.2	2.2	11.4	O K	
60 min Summer	5.444	0.044	0.0	2.2	2.2	12.7	O K	
120 min Summer	5.445	0.045	0.0	2.2	2.2	12.9	O K	
180 min Summer	5.445	0.045	0.0	2.2	2.2	12.8	O K	
240 min Summer	5.443	0.043	0.0	2.2	2.2	12.3	O K	
360 min Summer	5.439	0.039	0.0	2.2	2.2	11.1	O K	
480 min Summer	5.434	0.034	0.0	2.1	2.1	9.6	O K	
600 min Summer	5.429	0.029	0.0	2.1	2.1	8.2	O K	
720 min Summer	5.424	0.024	0.0	2.1	2.1	6.9	O K	
960 min Summer	5.416	0.016	0.0	2.1	2.1	4.6	O K	
1440 min Summer	5.405	0.005	0.0	2.1	2.1	1.5	O K	
2160 min Summer	5.400	0.000	0.0	1.9	1.9	0.0	O K	
2880 min Summer	5.400	0.000	0.0	1.6	1.6	0.0	O K	
4320 min Summer	5.400	0.000	0.0	1.2	1.2	0.0	O K	
5760 min Summer	5.400	0.000	0.0	1.0	1.0	0.0	O K	
7200 min Summer	5.400	0.000	0.0	0.9	0.9	0.0	O K	
8640 min Summer	5.400	0.000	0.0	0.7	0.7	0.0	O K	
10080 min Summer	5.400	0.000	0.0	0.7	0.7	0.0	O K	
15 min Winter	5.437	0.037	0.0	2.2	2.2	10.5	O K	

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	28.417	0.0	11.5	21
30 min Summer	18.860	0.0	15.4	33
60 min Summer	12.227	0.0	20.1	58
120 min Summer	7.783	0.0	25.6	90
180 min Summer	5.952	0.0	29.4	126
240 min Summer	4.917	0.0	32.3	160
360 min Summer	3.727	0.0	36.9	228
480 min Summer	3.055	0.0	40.1	294
600 min Summer	2.619	0.0	43.1	360
720 min Summer	2.309	0.0	45.6	422
960 min Summer	1.894	0.0	49.8	540
1440 min Summer	1.433	0.0	56.6	768
2160 min Summer	1.083	0.0	64.3	0
2880 min Summer	0.888	0.0	70.3	0
4320 min Summer	0.672	0.0	79.8	0
5760 min Summer	0.552	0.0	87.4	0
7200 min Summer	0.474	0.0	93.8	0
8640 min Summer	0.417	0.0	99.0	0
10080 min Summer	0.374	0.0	103.7	0
15 min Winter	28.417	0.0	13.0	21

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Summary of Results for 1 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max E Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	5.446	0.046	0.0	2.2	2.2	13.2	O K
60 min Winter	5.453	0.053	0.0	2.2	2.2	15.1	O K
120 min Winter	5.453	0.053	0.0	2.2	2.2	15.2	O K
180 min Winter	5.452	0.052	0.0	2.2	2.2	14.8	O K
240 min Winter	5.449	0.049	0.0	2.2	2.2	13.9	O K
360 min Winter	5.441	0.041	0.0	2.2	2.2	11.7	O K
480 min Winter	5.433	0.033	0.0	2.1	2.1	9.3	O K
600 min Winter	5.425	0.025	0.0	2.1	2.1	7.1	O K
720 min Winter	5.418	0.018	0.0	2.1	2.1	5.1	O K
960 min Winter	5.407	0.007	0.0	2.1	2.1	1.9	O K
1440 min Winter	5.400	0.000	0.0	1.9	1.9	0.0	O K
2160 min Winter	5.400	0.000	0.0	1.4	1.4	0.0	O K
2880 min Winter	5.400	0.000	0.0	1.2	1.2	0.0	O K
4320 min Winter	5.400	0.000	0.0	0.9	0.9	0.0	O K
5760 min Winter	5.400	0.000	0.0	0.7	0.7	0.0	O K
7200 min Winter	5.400	0.000	0.0	0.6	0.6	0.0	O K
8640 min Winter	5.400	0.000	0.0	0.5	0.5	0.0	O K
10080 min Winter	5.400	0.000	0.0	0.5	0.5	0.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
30 min Winter	18.860	0.0	17.2	34
60 min Winter	12.227	0.0	22.5	60
120 min Winter	7.783	0.0	28.6	98
180 min Winter	5.952	0.0	32.8	136
240 min Winter	4.917	0.0	36.1	174
360 min Winter	3.727	0.0	41.1	246
480 min Winter	3.055	0.0	45.0	316
600 min Winter	2.619	0.0	48.2	380
720 min Winter	2.309	0.0	51.0	440
960 min Winter	1.894	0.0	55.8	550
1440 min Winter	1.433	0.0	63.6	0
2160 min Winter	1.083	0.0	72.1	0
2880 min Winter	0.888	0.0	78.8	0
4320 min Winter	0.672	0.0	89.4	0
5760 min Winter	0.552	0.0	97.9	0
7200 min Winter	0.474	0.0	105.0	0
8640 min Winter	0.417	0.0	110.9	0
10080 min Winter	0.374	0.0	116.1	0

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	1	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.200	Shortest Storm (mins)	15
Ratio R	0.350	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+0

Time Area Diagram

Total Area (ha) 0.220

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From: To: (ha)		From: To: (ha)		From: To: (ha)	
0 4 0.100		4 8 0.100		8 12 0.020	

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Model Details

Storage is Online Cover Level (m) 6.000

Cellular Storage Structure

Invert Level (m) 5.400 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	300.0	0.0	0.410	0.0	0.0
0.400	300.0	0.0			

Orifice Outflow Control

Diameter (m) 0.040 Discharge Coefficient 0.600 Invert Level (m) 5.000

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Summary of Results for 30 year Return Period

Half Drain Time : 406 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	5.149	0.149	0.0	1.3	1.3	35.4	O K
30 min Summer	5.196	0.196	0.0	1.5	1.5	46.6	O K
60 min Summer	5.245	0.245	0.0	1.7	1.7	58.1	O K
120 min Summer	5.289	0.289	0.0	1.9	1.9	68.6	O K
180 min Summer	5.309	0.309	0.0	2.0	2.0	73.3	O K
240 min Summer	5.318	0.318	0.0	2.0	2.0	75.5	O K
360 min Summer	5.326	0.326	0.0	2.0	2.0	77.4	O K
480 min Summer	5.330	0.330	0.0	2.0	2.0	78.3	O K
600 min Summer	5.331	0.331	0.0	2.0	2.0	78.6	O K
720 min Summer	5.330	0.330	0.0	2.0	2.0	78.4	O K
960 min Summer	5.325	0.325	0.0	2.0	2.0	77.3	O K
1440 min Summer	5.310	0.310	0.0	2.0	2.0	73.5	O K
2160 min Summer	5.282	0.282	0.0	1.9	1.9	67.1	O K
2880 min Summer	5.257	0.257	0.0	1.8	1.8	61.0	O K
4320 min Summer	5.215	0.215	0.0	1.6	1.6	51.1	O K
5760 min Summer	5.183	0.183	0.0	1.5	1.5	43.6	O K
7200 min Summer	5.159	0.159	0.0	1.4	1.4	37.8	O K
8640 min Summer	5.140	0.140	0.0	1.3	1.3	33.3	O K
10080 min Summer	5.125	0.125	0.0	1.2	1.2	29.7	O K
15 min Winter	5.167	0.167	0.0	1.4	1.4	39.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	69.605	0.0	34.0	26
30 min Summer	46.335	0.0	45.8	40
60 min Summer	29.553	0.0	60.8	68
120 min Summer	18.298	0.0	75.5	126
180 min Summer	13.667	0.0	84.7	182
240 min Summer	11.055	0.0	91.4	240
360 min Summer	8.183	0.0	101.5	304
480 min Summer	6.606	0.0	109.3	366
600 min Summer	5.592	0.0	115.6	432
720 min Summer	4.877	0.0	121.0	500
960 min Summer	3.929	0.0	129.9	638
1440 min Summer	2.893	0.0	143.1	912
2160 min Summer	2.127	0.0	160.0	1316
2880 min Summer	1.708	0.0	171.3	1704
4320 min Summer	1.253	0.0	187.8	2464
5760 min Summer	1.005	0.0	202.1	3184
7200 min Summer	0.846	0.0	212.7	3904
8640 min Summer	0.736	0.0	221.8	4664
10080 min Summer	0.654	0.0	229.3	5352
15 min Winter	69.605	0.0	38.3	26

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Model Details

Storage is Online Cover Level (m) 6.000

Cellular Storage Structure

Invert Level (m) 5.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	250.0	0.0	0.810	0.0	0.0
0.800	250.0	0.0			

Orifice Outflow Control

Diameter (m) 0.042 Discharge Coefficient 0.600 Invert Level (m) 5.000

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

Half Drain Time : 554 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	5.272	0.272	0.0	1.8	1.8	64.5	O K
30 min Summer	5.362	0.362	0.0	2.2	2.2	86.0	O K
60 min Summer	5.456	0.456	0.0	2.4	2.4	108.3	O K
120 min Summer	5.544	0.544	0.0	2.7	2.7	129.3	O K
180 min Summer	5.586	0.586	0.0	2.8	2.8	139.3	O K
240 min Summer	5.607	0.607	0.0	2.8	2.8	144.2	O K
360 min Summer	5.624	0.624	0.0	2.9	2.9	148.3	O K
480 min Summer	5.630	0.630	0.0	2.9	2.9	149.6	O K
600 min Summer	5.632	0.632	0.0	2.9	2.9	150.0	O K
720 min Summer	5.631	0.631	0.0	2.9	2.9	149.9	O K
960 min Summer	5.625	0.625	0.0	2.9	2.9	148.4	O K
1440 min Summer	5.601	0.601	0.0	2.8	2.8	142.7	O K
2160 min Summer	5.557	0.557	0.0	2.7	2.7	132.2	O K
2880 min Summer	5.513	0.513	0.0	2.6	2.6	121.8	O K
4320 min Summer	5.437	0.437	0.0	2.4	2.4	103.9	O K
5760 min Summer	5.378	0.378	0.0	2.2	2.2	89.7	O K
7200 min Summer	5.330	0.330	0.0	2.0	2.0	78.4	O K
8640 min Summer	5.292	0.292	0.0	1.9	1.9	69.4	O K
10080 min Summer	5.261	0.261	0.0	1.8	1.8	62.0	O K
15 min Winter	5.305	0.305	0.0	2.0	2.0	72.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	126.074	0.0	62.8	26
30 min Summer	84.745	0.0	84.7	40
60 min Summer	54.368	0.0	112.6	68
120 min Summer	33.674	0.0	139.7	126
180 min Summer	25.065	0.0	156.1	184
240 min Summer	20.180	0.0	167.6	244
360 min Summer	14.839	0.0	184.8	358
480 min Summer	11.923	0.0	198.0	410
600 min Summer	10.054	0.0	208.6	472
720 min Summer	8.741	0.0	217.5	534
960 min Summer	7.003	0.0	232.0	668
1440 min Summer	5.114	0.0	252.7	942
2160 min Summer	3.727	0.0	280.8	1352
2880 min Summer	2.973	0.0	298.5	1760
4320 min Summer	2.159	0.0	324.5	2520
5760 min Summer	1.718	0.0	345.9	3288
7200 min Summer	1.438	0.0	361.8	4032
8640 min Summer	1.245	0.0	375.6	4760
10080 min Summer	1.102	0.0	387.2	5456
15 min Winter	126.074	0.0	70.5	26

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

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control (l/s)	Max Σ Outflow (l/s)	Max Volume (m³)	Status
30 min Winter	5.406	0.406	0.0	2.3	2.3	96.5	O K
60 min Winter	5.512	0.512	0.0	2.6	2.6	121.7	O K
120 min Winter	5.614	0.614	0.0	2.8	2.8	145.7	O K
180 min Winter	5.663	0.663	0.0	2.9	2.9	157.4	O K
240 min Winter	5.688	0.688	0.0	3.0	3.0	163.5	O K
360 min Winter	5.712	0.712	0.0	3.1	3.1	169.2	Flood Risk
480 min Winter	5.718	0.718	0.0	3.1	3.1	170.5	Flood Risk
600 min Winter	5.716	0.716	0.0	3.1	3.1	170.0	Flood Risk
720 min Winter	5.714	0.714	0.0	3.1	3.1	169.6	Flood Risk
960 min Winter	5.702	0.702	0.0	3.0	3.0	166.8	Flood Risk
1440 min Winter	5.664	0.664	0.0	3.0	3.0	157.6	O K
2160 min Winter	5.596	0.596	0.0	2.8	2.8	141.6	O K
2880 min Winter	5.533	0.533	0.0	2.6	2.6	126.5	O K
4320 min Winter	5.428	0.428	0.0	2.3	2.3	101.6	O K
5760 min Winter	5.350	0.350	0.0	2.1	2.1	83.0	O K
7200 min Winter	5.290	0.290	0.0	1.9	1.9	69.0	O K
8640 min Winter	5.246	0.246	0.0	1.7	1.7	58.3	O K
10080 min Winter	5.211	0.211	0.0	1.6	1.6	50.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
30 min Winter	84.745	0.0	94.9	40
60 min Winter	54.368	0.0	126.3	68
120 min Winter	33.674	0.0	156.6	124
180 min Winter	25.065	0.0	174.9	182
240 min Winter	20.180	0.0	187.8	238
360 min Winter	14.839	0.0	207.1	350
480 min Winter	11.923	0.0	221.8	454
600 min Winter	10.054	0.0	233.6	492
720 min Winter	8.741	0.0	243.6	564
960 min Winter	7.003	0.0	259.7	718
1440 min Winter	5.114	0.0	282.4	1020
2160 min Winter	3.727	0.0	314.5	1456
2880 min Winter	2.973	0.0	334.5	1876
4320 min Winter	2.159	0.0	363.5	2680
5760 min Winter	1.718	0.0	387.4	3416
7200 min Winter	1.438	0.0	405.3	4184
8640 min Winter	1.245	0.0	420.8	4920
10080 min Winter	1.102	0.0	434.0	5648

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Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.200	Shortest Storm (mins)	15
Ratio R	0.350	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.280

Time (mins)	Area	Time (mins)	Area	Time (mins)	Area
From: To:	(ha)	From: To:	(ha)	From: To:	(ha)
0 4	0.100	4 8	0.100	8 12	0.080

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Bellamy Roberts		Page 4
50 Sandy Hill Close Waltham Chase, Southampton Hampshire, SO31 2GU	Coldharbour Farm Emsworth Road Drainage	
Date 17/01/2022 09:01 File CELLULAR STORAGE ROADS....	Designed by JCB Checked by MT	
Innovyze		Source Control 2020.1.3

Model Details

Storage is Online Cover Level (m) 6.000

Cellular Storage Structure

Invert Level (m) 5.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	250.0	0.0	0.810	0.0	0.0
0.800	250.0	0.0			

Orifice Outflow Control

Diameter (m) 0.042 Discharge Coefficient 0.600 Invert Level (m) 5.000

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