TECHNICAL NOTE

Job Name: Church End, Hilton

Job No: 332610757

Note No: TN001 Rev 3

Date: June 2024

Prepared By: M Davison

Subject: Hydraulic Modelling Updates and Results

1. Introduction

1.1 Stantec UK Limited was instructed by Burmor Construction (Client) to update the baseline modelling that had been previously carried out by Stantec in 2019 (see 'Baseline Hydraulic Model Report' included in Appendix A). In accordance with latest guidance, and to undertake subsequent post-development modelling to support a residential development at the site, demonstrating the proposed development is safe and does not increase flood risk elsewhere.

1.2 Previous hydraulic modelling was not submitted in support of the outline planning application, as the application was approved prior to completion of the model. However, there has been consultation previously with the Lead Local Flood Authority (LLFA) to inform the modelling process. This consultation has therefore been used to inform the latest modelling scope of works, in accordance with our fee agreement (dated: 8th September 2023).

1.3 The Stantec modelling updates include changes to the hydrological analysis, climate change allowances, LiDAR, and general modelling assumptions. The post-development modelling was completed to assess the potential impacts of the proposed development and inclusion of selected flood mitigation measures.

1.4 This Technical Note describes the updates conducted to the hydraulic modelling of the site, including the model hydrology, and a summary of the baseline scenario and preferred post-development scenario results.

1.5 All figures shown within this note are included in Appendix B in greater resolution.

DOCUMENT ISSUE RECORD

Technical Note No	Rev	Date	Prepared	Checked	Reviewed (Discipline Lead)	Approved (Project Director)
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2. Hydrological Analysis Updates

2.1 Since the previous work was completed, there has been a number of changes to flood estimation methodologies, guidance, and software. The previous flood estimates were made using earlier versions of the FEH Statistical Method and ReFH2 and these methods and datasets have been updated since.

2.2 The hydrological assessment has been updated so it is based on current best practise, as the flow input is a key element in determining the requirements for flood mitigation at the site. Full details of the hydrological assessment have been reported in the EA Flood Estimation Calculation Record included in Appendix C.

2.3 Considering the small, rural nature of the catchment, the updated hydrological assessment makes use of the NRFA v12.1 dataset within WINFAP 5, and ReFH2.3 with FEH22 rainfall data as a second suitable method for deriving peak flow estimates and to define hydrograph shapes.

Catchment Overview

2.4 The catchment of interest is an unnamed ordinary watercourse that flows in a north-easterly direction through Hilton, Cambridgeshire. The watercourse flows into the Hall Green Brook through Fenstanton before joining the River Great Ouse. The catchment area for this ordinary watercourse is approximately 3.2km^2. The study derived peak flow estimates and hydrographs at the downstream point of the catchment to provide inflows for the hydraulic model (Figure 2.1).

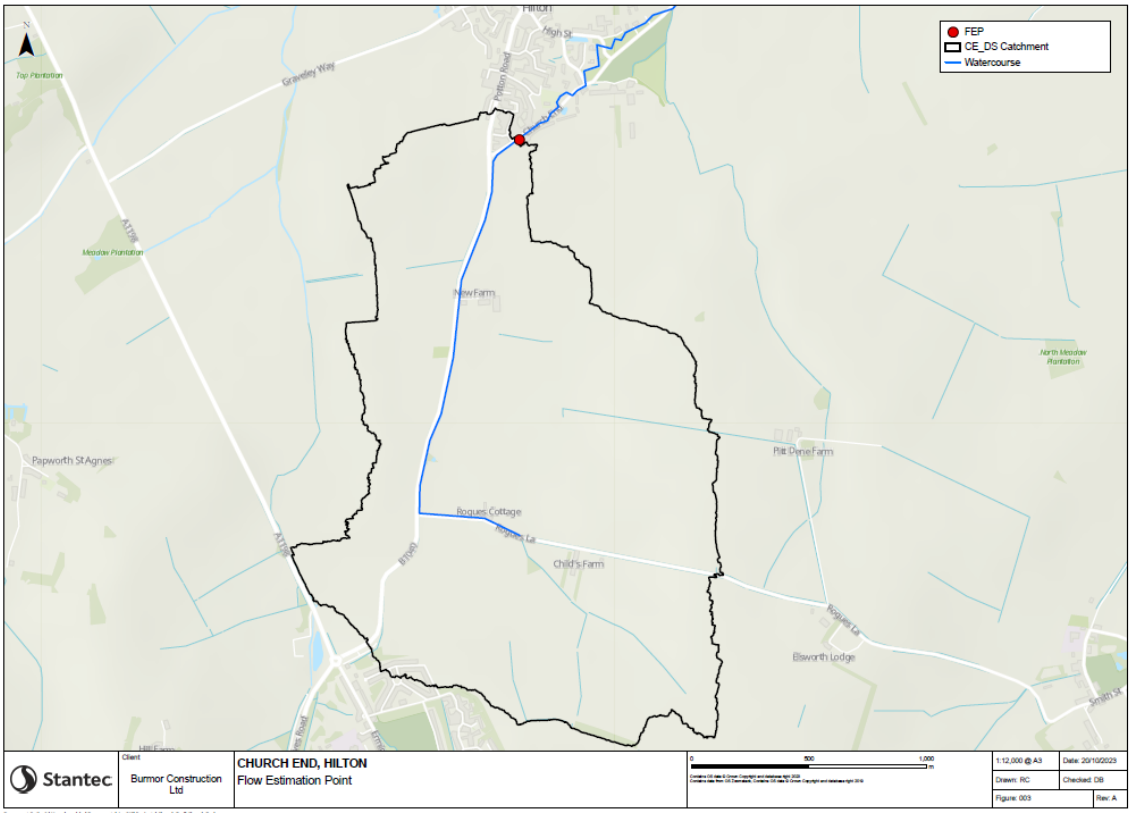

Figure 2.1: Study catchment and flow estimate point (FEP)

2.5 The catchment is relatively flat, ranging in elevation between approximately 55m AOD in its upper reaches and 12m AOD at its downstream point (Figure 2.2).

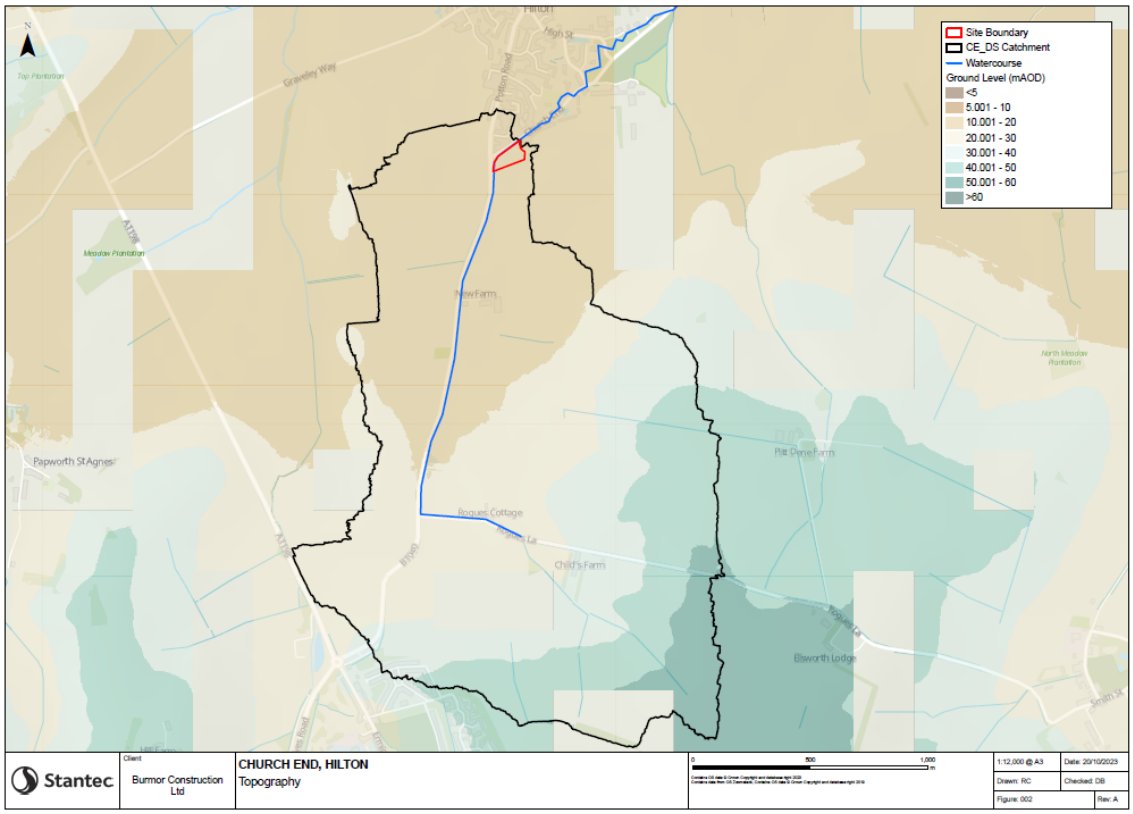

Figure 2.2: Catchment topography

2.6 The British Geological Survey (BGS) Geology of Britain mapping indicates that the catchment is predominantly underlain by clay (Oxford Clay Formation, West Walton Formation, and Ampthill Clay Formation). The catchment has a BFIHOST19 value of 0.306, indicating low permeability. The soils within the catchment are classified as lime-rich loamy and clayey soils with impeded drainage (Soilscapes 9 classification).

2.7 The catchment is categorised as rural, with small areas of suburban land from Papworth Everard included within the catchment area's upper reaches and from Hilton in its lower reaches, resulting in an URBEXT2000 value of 0.011. The watercourse exists largely as an open channel, with small, culverted reaches at road crossings in its lower reaches.

Catchment Descriptors

2.8 Catchment descriptors for the study catchment were obtained from the FEH Webservice website.

2.9 The overall catchment boundary for the watercourse was reviewed using available LiDAR data (1m resolution). Discrepancies were found and therefore LiDAR derived catchments were completed to inform the updates that should be made to make the catchments more representative of the topographic catchment areas. Figure 2.4 indicates that the FEH catchment was underestimated in comparison to the topographical catchment, largely in the western extent. The catchment area was amended accordingly, resulting in an overall increase from 2.50km^2 to 3.16km^2.

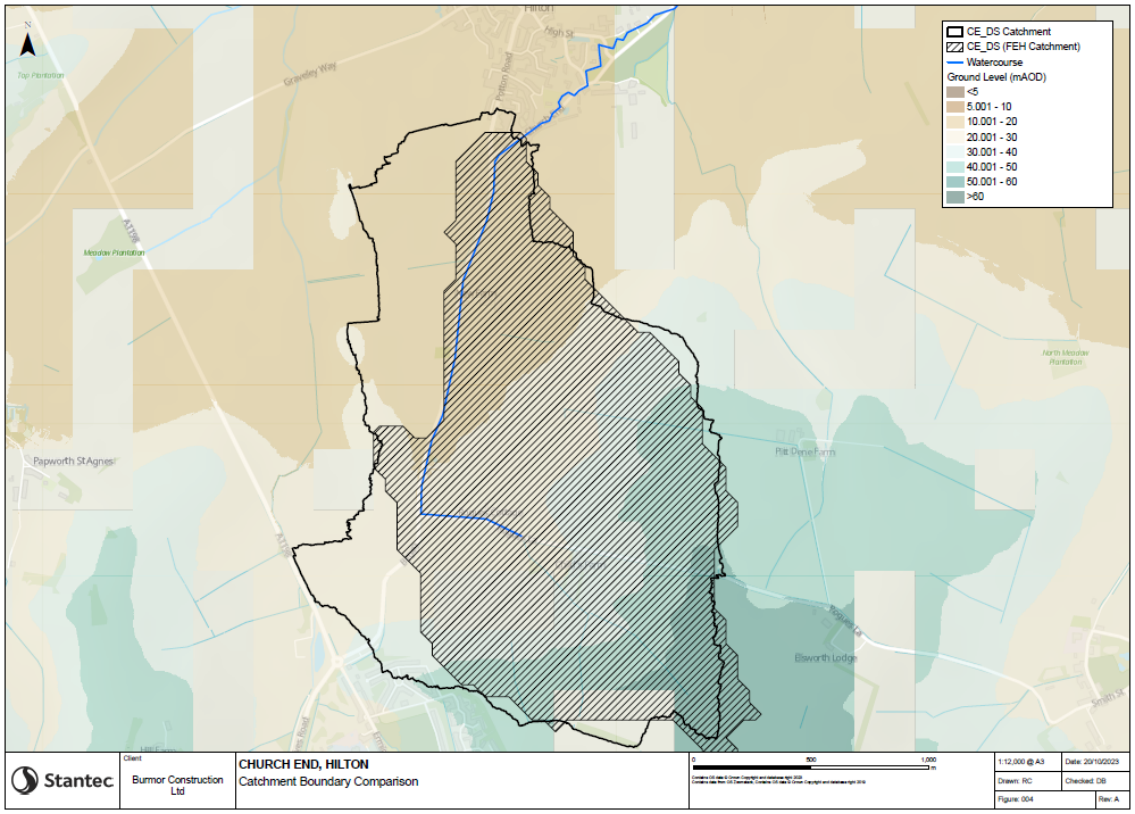

Figure 2.1: FEH catchment compared to topographical catchment

2.10 The key final, adjusted, catchment descriptors used in the assessment are shown in Table 2.1.

Table 2.1: Catchment descriptors used in hydrological assessment

Version	Area (km^2)	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
FEH Original	2.50	1.000	0.24	0.306	1.77	24.20	545	0.0015	0.0105	0.119
Adjusted	3.16	1.000	0.24	0.306	2.24	24.20	545	0.0016	0.0108	0.119

2.11 The BFIHOST and SPRHOST values were checked using the 1:250,000 Soil Survey of England and Wales map, in accordance with the IoH126 method. The values calculated were similar to those provided by the FEH Web Service, and therefore the original BFIHOST and SPRHOST values were accepted.

2.12 DPLBAR was adjusted to account for the minor change in area, using the ratio between the original area and the updated area to recalculate the original DPLBAR value provided by the FEH Web Service. This resulted in a slight increase in the DPLBAR value from 1.77 to 2.24.

2.13 FARL was checked using OS mapping and satellite imagery. There are no reservoirs or lakes observed within the catchment, therefore, the FEH FARL value of 1 was accepted.

2.14 The URBEXT value was manually recalculated. A review of OS mapping indicated that the development in Papworth Everard that the FEH Web Service classified as urban land may be more suitably classified as suburban land. The updated value was calculated as 0.012, which was similar to the original FEH URBEXT2000 value with the 2023 Urban Adjustment Factor (UAF) of 1.04 applied (URBEXT2000 = 0.011). Hence the UAF-updated URBEXT values were accepted and used within the calculations.

Peak Flow Estimation

2.15 Flows were estimated using both the FEH Statistical and ReFH2 methods.

2.16 The ReFH2 method was selected as the preferred method to derive peak flows for the study catchment. It is considered suitable for deriving peak flows and hydrographs for small, ungauged catchments and the flows derived by the ReFH2 method were more conservative than those derived by the FEH Statistical method (Figure 2.4). Moreover, there was low confidence in the FEH Statistical method representing flows within the catchment.

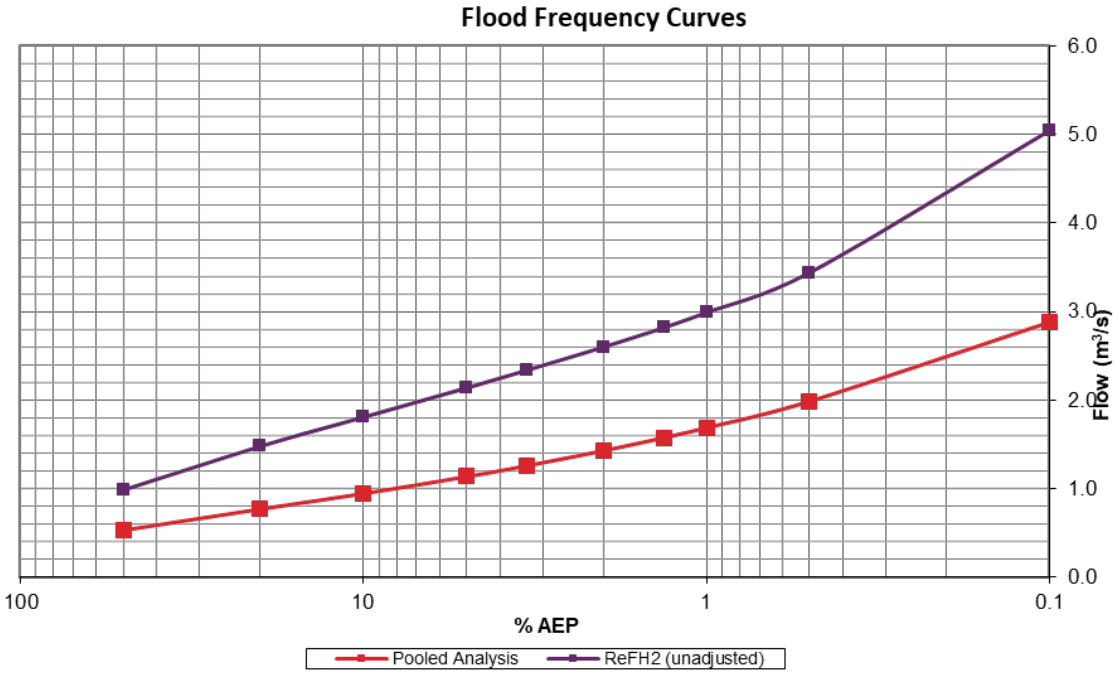

Figure 2.1: Comparison of FEH Statistical and ReFH2 flood frequency curves

2.17 The ReFH2 method was applied for the lumped (whole) study catchment, utilising the adjusted catchment descriptors and FEH22 rainfall parameters.

2.18 The season of the design event was selected based on the URBEXT2000 and BFIHOST19 values, in accordance with the latest EA guidance. The winter storm profile was accepted for deriving peak flows due to the catchment being classified as rural.

2.19 The storm duration was iteratively optimised to find the critical duration that produced the greatest peak flows. This was found to be 7.5 hours with a 0.5-hour interval, producing peak low estimates for the 1% (1 in 100yr) annual exceedance probability (AEP) event of 2.99m^3/s.

2.20 Final peak flow estimates using ReFH2 are shown in Table 2.2 below.

Table 2.1: Final ReFH2 peak flow estimates

Site code	Peak Flow per AEP Event (m^3/s)			
	50%	3.3%	1%	0.1%
CE_DS	0.99	2.34	2.99	5.04

Climate Change Allowances

2.21 The previous work completed in 2020 used climate change allowances for the 2080s epoch (2070-2115), equating to increases of 35% and 65% in peak flows for the 'Central' and 'Higher' allowances, respectively; applicable to the Anglian River Basin District.

2.22 Since this study was completed, climate change guidance has been updated by the EA and uses the more detailed UKCP18 dataset which can give allowances for individual management catchments.

2.23 The catchment lies in the Upper and Bedford Ouse Management Catchment. For the 2080s (2070-2115) epoch, based on the different emissions scenarios, the current allowances are:

- Central: 19% increase in peak river flow
- Higher: 30% increase in peak river flow
- Upper: 58% increase in peak river flow

2.24 Though the site is situated within Flood Zone 1, due to the potential surface water flood risk associated with a pluvial event and overland flow from the unnamed watercourse, it is proposed that the 'Central' scaling factor of 19% for the 2080s epoch is acceptable to represent the climate change scenarios for the design event. This follows the latest EA guidance (Flood Risk Assessments: Climate Change Allowances, May 2022), for a 'More Vulnerable' development.

2.25 The 'Higher' allowance has been applied to the study as a sensitivity check to assess the development and potential mitigation measures if a more extreme future scenario occurs.

3. Baseline Model Updates

3.1 The original hydraulic model was constructed using a hydrodynamic 1D-2D modelling approach, with the following considerations:

- The length of the Hilton Drain channel to be modelled and the number of bridges and culvert structures along it require the use of an unsteady 1D approach for in-channel areas, for which simpler hydraulic analysis (e.g. steady-state) or 2D-only representation are inappropriate.
- The pattern of flow and pooling of surface water across the floodplain areas is not expected to follow the drain direction, requiring the use of a 2D representation for out-of-bank areas to allow detailed simulation and mapping of flow pathways and flood depths.

3.2 Flood Modeller software was utilised for the 1D (in-channel) domain and TuFLOW for the 2D (floodplain) domain. This methodology was considered appropriate to assess flood risk within the catchment and the majority of the hydraulic model has been unchanged for this updated study.

3.3 The grid size of 2m has been retained.

3.4 The original baseline model construction was detailed in the 'Baseline Flood Modelling Report.' Updates to this previous baseline model are outlined in the below sections.

Model Schematisation

3.5 Firstly, the underlying survey and LiDAR information was checked. There has been no new survey information to update the model with, however the latest LiDAR DTM 1m resolution information has been applied to the model, superseding the previous dataset.

3.6 The previous model used three inflows, a point inflow at the upstream node that applied flows at the upstream model extent, and two additional lateral inflows to spread the remaining catchment flows across the model. This was amended to only include a single inflow point at the upstream of the model extent as a conservative approach. This is discussed further below.

3.7 The previous model upstream boundary was set approximately 100m upstream of the site, also from reviewing baseline results from 2020 it appeared that the inflow is significantly above the capacity of the ditch, as it overtops both banks easily and the overland flow spills in both directions (towards the site on the east, and towards the St Ives Road and the further farmland on the west). This may lead to overestimating flood risk to the site.

3.8 As a result, the upstream model boundary has been extended to approximately 1km upstream of the site. The extended channels (on both sides of St Ives Road) have been represented in the 2D domain by using gully line utilising elevations from the latest LiDAR DTM. Related TUFLOW geometry layers (active areas, materials, and boundary controls) were adjusted in response to extending the model upstream.

3.9 The inflow location has also been updated accordingly, using a 2D line inflow across the gully line; and a dummy 1D Flood Modeller inflow is still required in the 1D domain at the beginning of the network to maintain model stability; the flow in this has be set as the flow value at the first timestep of the hydrograph (0.148m^3/s), and is maintained for 5hrs before decreasing over time to 0m^3/s at 9hrs, so that it does not affect peak results.

3.10 The Flood Modeller nodes upstream of node H_048 have been removed and are now represented in the 2D domain. This was done to provide a better connection between the 1D and 2D domains, using the culvert previously modelled in Flood Modeller (Culv_01_US/Culv_01_DS), which is now being modelled in the ESTRY, as a 1D-2D link.

Structures

3.11 The structures represented in the previous hydraulic model have been retained in this study, as these were found to have been adequately represented (Table 3.1). The only adjustments made were to the bridges, where section data was trimmed to match upstream or downstream channel widths (depending on which was used in the node) to improve channel conveyance.

Table 3.1: 1D model representation of key structures

Model Node	Structure	Description	Model representation
H_041	Culvert	6.7m long culvert underneath an access path adjacent to the B1040; 0.9m diameter. Invert levels were measured as 12.284mAOD and 12.282mAOD, for the upstream inlet and downstream outlet respectively.	Modelled with circular conduit units, with culvert inlet and outlet representing losses. Spill unit included due to the ability of flow being able to overtop structure.
H_321	Bridge	7.2m bridge with fence used as private driveway to property; soffit height is 12.228mAOD.	Represented as a USBPR unit with a spill unit, due to the fence allowing flows to overtop structure.
H_345	Bridge	4.9m bridge with railing used as private driveway to property; soffit height is 12.285mAOD.	Represented as a USBPR unit with a spill unit, due to the railing allowing flows to overtop structure.
H_371	Culvert	5.7m long culvert underneath private driveway; 0.725m diameter. Invert levels were measured as 11.160mAOD and 11.159mAOD, for the upstream inlet and downstream outlet respectively.	Modelled with circular conduit units, with culvert inlet and outlet representing losses. No spill unit was included due to brick wall that would prevent flows over structure.
H_420	Bridge	3.9m bridge with brick wall used as private driveway to property; soffit height is 11.801mAOD.	Represented as a USBPR unit. No spill unit was included due to brick wall that would prevent flows over structure.
H_459	Bridge	8.7m bridge with bridge wall used as private driveway to properties; soffit height is 11.949mAOD.	Represented as a USBPR unit. No spill unit was included due to brick wall that would prevent flows over structure.

3.12 A check on how spills over structures was conducted, all spills are represented in the 2D domain, and these were considered appropriate.

3.13 As the model extent has been increased, there are additional structures that could be represented within the model. To allow the most flow to reach the site to provide more conservative results, structures upstream of the 2020 model extent have not been modelled and are only represented via a new gully line as a conservative approach; all ditches that were outside of the topographical survey extent were assumed to be open channel by applying gully lines across the full length of the ditch.

3.14 As mentioned above, there is a culvert that was previously modelled in Flood Modeller (Culv_01_US/Culv_01_DS), that is now being modelled in ESTRY. This was updated to provide a better connection between the 2D and 1D domains, the structure details (invert level, diameter, length) were retained.

Manning's Roughness

3.15 The Manning's n roughness values have been retained from the 2020 study. Values are estimated based on Chow (1959).

3.16 Manning's roughness values were set either at 0.030, 0.035, or 0.040 for in-channel (1D) areas, reflecting typical roughness observed at the site as vegetation density varied along the channel.

3.17 Roughness values for surfaces in the 2D domain are listed below:

Pasture	0.060	Heavy vegetation	0.080
Roads and paths	0.022	Light vegetation	0.050
Buildings	1.000	Water	0.020

Downstream Boundary

3.18 The original downstream boundary control layer in the 2D domain has been adjusted to reflect changes in the active area. The downstream boundary in the 1D domain is unchanged from the 2020 model.

4. Post-Development Modelling

4.1 The flood mitigation measures tested are based on the latest site layout and drainage plan provided by the Client (please refer to JPP's Preliminary Engineering Layout drawing 26448/102 in Appendix D) and previous calculations from the original 2020 study. The updated layout introduces a revised shaped SuDS pond, in the north east of the site, and a culvert too allow for a new site access from Church End in the north.

4.2 Using the proposed mitigation features which formed part of the original outline planning application, approved by the Lead Local Flood Authority (Cambridgeshire County Council), it comprises the construction of a cut-off drain on the southern edge of the site to intercept overland flow and divert the flow into the drains adjacent to the site. Potential drain widening and check dams were also considered when planning the latest mitigation measures.

4.3 Various mitigation options were iteratively tested by adjusting the baseline model. The final arrangement of mitigation measures, to eliminate flood risk from the site and to not cause detriment to third party land, was a combination of a cut-off drain to the south, connected to both the eastern and western drains, and drain lowering along ~40m of the eastern drain where it connects with the cut off drain in the south, all within the red line boundary. This was selected as the preferred option and is discussed further below.

Model Schematisation

4.4 The 1D domain was changed from the baseline modelling. A 1.8mW x 1mH box culvert under the site access has been included within the 1D model at node H_246, with a length of 33m, as per details provided by the client on the 27/03/2024 and 08/05/2024 (see correspondence in Appendix D).

4.5 The 2D domain was largely unchanged from the baseline modelling, with the exception of including the cut-off drain geometry and associated connection to the surrounding drains.

4.6 The proposed cut-off drain is located along the southern edge of the site, generally falling in an east-west direction, and includes a 5m offset on each side to allow for future maintenance access (Figure 4.1). As shown in the long section of the cut-off drain (Figure 4.2), it ties into the existing eastern drain at approximately 12.8 mAOD and increase to 12.81 mAOD across a distance of approximately 20m to where the proposed culvert crossing is located. After this, levels again slope to 12.8 mAOD across a

distance of approximately 115m to the west, where it cuts into the bank of the western drain to create a connection. The cut-off drain is 10m in width from tops of banks, with the base width being ~6.7m in the east and ~5.3m in the west. Bank slopes are set at a gradient of 1:3. For modelling purposes, top of bank levels are approximately 13.35 in the east and 13.60 in the west, with bank levels along the cut-off drain tying into existing ground levels, Figure 6.5, Figure 6.6, and Figure 6.7 in section 6 show the indicative long section and cross-sections based on modelled levels.

4.7 With the cut-off drain being relatively flat across its length, connected to both the western and easter drain, any flow intercepted from the south or water backing up from the proposed access culvert can utilise the storage within this drain and freely discharge to either the western or easter drain depending on levels.

4.8 A culvert crossing is incorporated into the cut-off drain, modelled with an internal diameter of 300mm, to allow access across the feature for maintenance. This is discussed further in the subsequent section.

4.9 Unused space in the south-east corner of the proposed development have been incorporated into the cut-off drain to maximise storage. The top of bank is still set a minimum of 5m from the proposed development or associated infrastructure to maintain space for maintenance.

4.10 A ~40m section along the eastern drain adjacent to where the cut-off drain connects has been lowered by between 10mm-150mm.

4.11 The development proposal comprises a proposed Sustainable Drainage System (SuDS) pond in the north-east, please refer to JPP's Preliminary Engineering Layout drawing 26448/102 in Appendix D, and incorporated into the 2D model build. For modelling purposes it has been modelled as completely full, preventing the overland flow being underestimated by the SuDS feature.

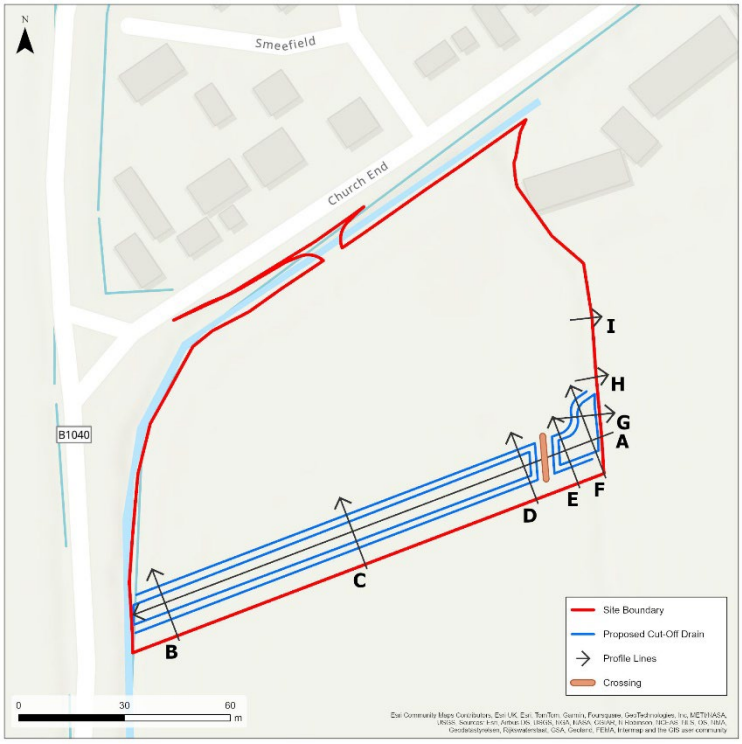

Figure 4.1: Post-development cut-off drain alignment, with profile locations, and associated structures

Structures

4.12 The structures represented in the baseline model have been retained, the only addition being the proposed access culvert and the proposed culvert crossing the cut-off drain.

4.13 The proposed access culvert comprises a single barrelled 1.8mW x 1mH box culvert, across a length of 33m. The upstream and downstream invert levels have been proposed at 11.55 mAOD and 11.46 mAOD respectively. Details were obtained from the client via a design layout provided on 08/05/2024 (Appendix D).

4.14 For the cut-off drain crossing, initial testing using a clear-span bridge, but the final version utilises a culvert to enable access for maintenance of both sides. As part of iterating mitigation options, a culvert diameter of 300mm was found to be suitable for conveying flows without causing any determent to flood risk on third party land and hold back some flow within the western side of the cut-off drain.

4.15 The location of these are features are highlighted in Figure 4.1.

Manning's Roughness

4.16 Manning's roughness values were retained from the baseline model.

Downstream Boundary

4.17 The downstream boundaries were unchanged from the baseline model.

5. Scenario Testing and Simulation Parameters

5.1 The Baseline and Post-Development scenarios have been modelled. These were simulated for the below Annual Exceedance Probability (AEP) events:

- 1% (1 in 100) AEP event;
- 1% (1 in 100) AEP event plus 19% climate change;
- 1% (1 in 100) AEP event plus 30% climate change; and
- 0.1% (1 in 1,000) AEP event.

5.2 Sensitivity testing on the baseline model and post-development model was also undertaken. For the baseline model the same tests have been simulated as in the original work for consistency, these included:

- +20% Manning's roughness;
- -20% Manning's roughness; and
- 80% culvert blockage, at the same location as previously tested.

5.3 For the post-development model a single sensitivity test investigating the impact of a blockage to the cut-off drain culvert crossing was conducted.

5.4 All sensitivity tests were simulated for the 1% (1 in 100) AEP event only.

5.5 The simulations used Flood Modeller version 7.0 and TUFLOW version 2023-03-AE and ran for 18 hours. The model is stable with mass balance errors for the modelled events shown in Table 5.1 for key events. These are within appropriate ranges and are considered acceptable. There seems to be some minor stability issues related to the 2D drain features, causing the higher mass balance errors. However, this does not impact results on the site.

Table 5.1: 2D Mass Balance Errors

Scenario	Modelled Event	1D Mass Balance Error (%)	Non-Convergence (%)	2D Mass Balance Error (%)
Baseline	1% AEP	0.00	0.00	-4.56
	1% AEP +19% CC	0.00	0.00	-6.99
	1% AEP +30% CC	-0.01	0.00	-7.61
	0.1% AEP	-0.01	0.00	-8.52
Post-Development	1% AEP +19% CC	0.00	0.50	-6.89

Model Calibration

5.6 Calibration of the model has not been carried out as there is no gauge data available to support this process.

Limitations

5.7 All models are simplifications of reality and include numerous assumptions and limitations. The most significant limitations are in relation to the flow estimates. As the catchment is ungauged, catchment descriptors have been used to estimate inflows. It is noted that industry standard methods have been used in this study.

5.8 Within the hydraulic model, the most significant assumptions are related to the use of LiDAR data, to represent topography. The uncertainties in these could be improved by using a smaller grid size that can show greater variation in ground levels within a finer grid. However, the uncertainties relating to these are minor in comparison to the flow estimation assumptions.

6. Results

6.1 For the purpose of this note, only the modelling results of the design event of 1% (1 in 100) AEP plus 19% climate change are reported. The mechanisms of flooding are similar across the modelled events, with only the depth and subsequent extent of flooding varying between them. Results for the remaining events are included in Table 6.1, Table 6.2, and Table 6.3.

Baseline

6.2 Figure 6.1 shows the maximum flood extent for the baseline 1% (1 in 100) AEP plus 19% climate change event. Flooding is largely located within the low-lying areas along St Ives Road, showing a clear overland flow route from the south and to the north-east corner of the site. The ditch capacity is limited, thus during high flow events the ditches are more easily overwhelmed, resulting in flows overtopping bank levels and flooding the adjacent areas. The impact of existing hydraulic structures also exaggerates the flooding shown within these areas, as most of the structures are small culverts which could restrict flow and lead to water back-up within the ditch. This pattern of flooding is similar across the simulated events.

6.3 The maximum flood depths for the 1% (1 in 100) AEP event plus 19% climate change are presented in Figure 6.1, the typical depth of flooding across the site is shown to be less than 0.1m. The maximum depth, excluding within the eastern drain, is approximately 0.4m towards the north-east corner of the site. The maximum flood level within the site is 13.6 mAOD (Figure 6.2).

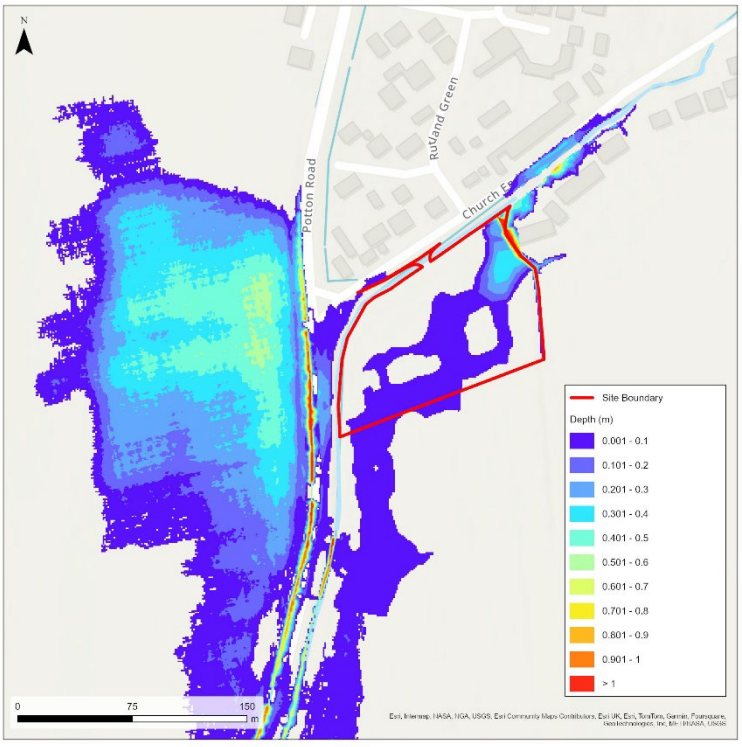

Figure 6.1: Baseline 1% AEP event plus 19% climate change maximum flood depths

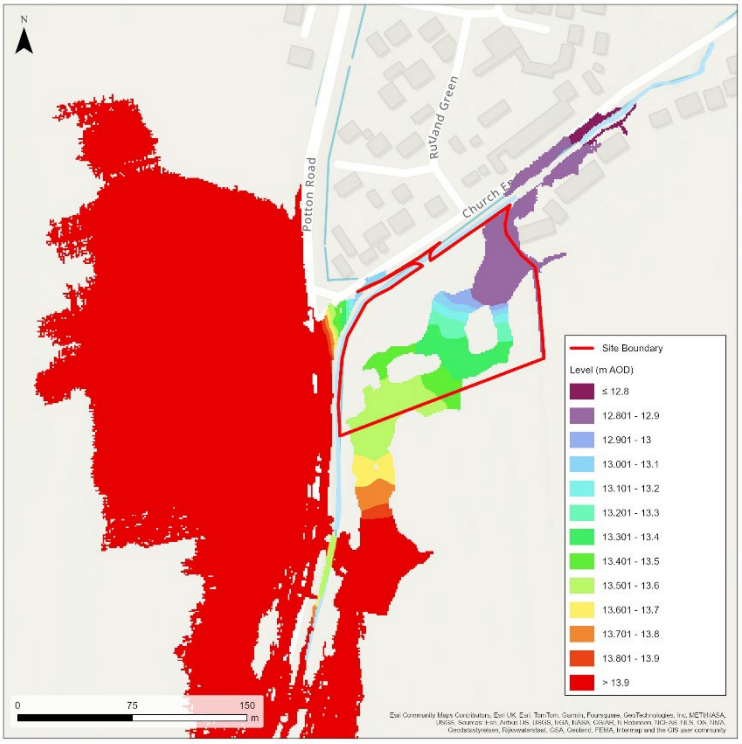

Figure 6.2: Baseline 1% AEP event plus 19% climate change maximum flood levels

Post-Development

6.4 Figure 6.3 shows the maximum flood extent for the post-development 1% (1 in 100) AEP event plus 19% climate change (design) event. Flooding is shown to be completely removed from the proposed development area, with flooding being contained within the cut-off drain and eastern drain.

6.5 The maximum flood depths for the 1% (1 in 100) AEP event plus 19% climate change (design event) are presented in Table 6.1, with Figure 6.3, this suggests the maximum depth of flooding within the cut-off drain is up to 0.43m. The maximum flood level within the cut-off drain is 13.23 mAOD (Figure 6.4).

6.6 A long section of the proposed cut-off drain is shown on Figure 6.5, which illustrates the maximum flood level (design event of 1% (1 in 100) AEP event plus 19% climate change), and the comparison to existing ground levels. Indicative cross sections are also shown in Figure 6.6 and Figure 6.7.

6.7 Within the main drain, the maximum water level upstream of the proposed access culvert is 13.04m AOD for the design event and drops to 12.91m AOD downstream of the culvert.

6.8 Figure 6.8 indicates that the proposed mitigation measures reduce flood risk to the development, removing flooding from the site. There are no increases to flood risk in the surrounding areas, upstream or downstream, on third party land.

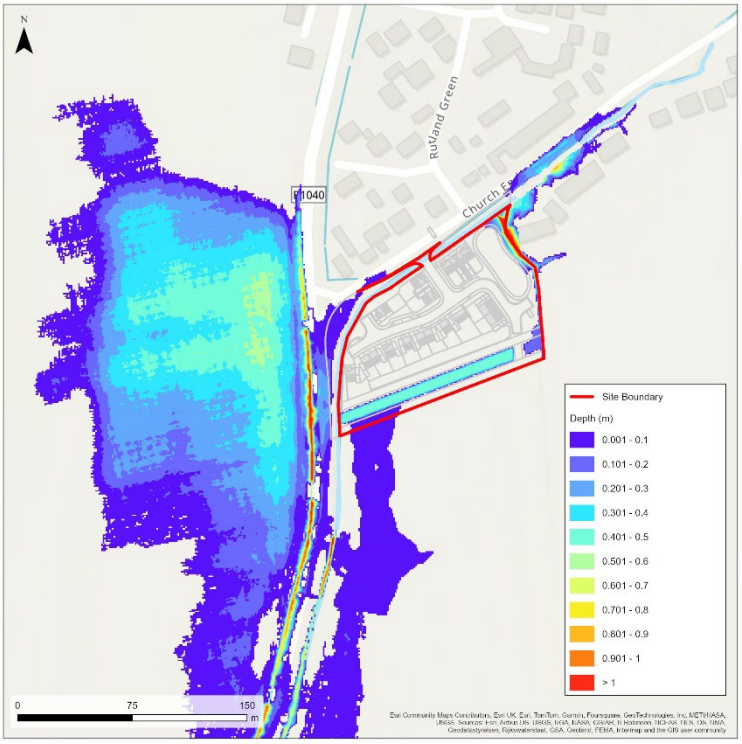

Figure 6.1: Post-development 1% AEP event plus 19% climate change maximum flood depths

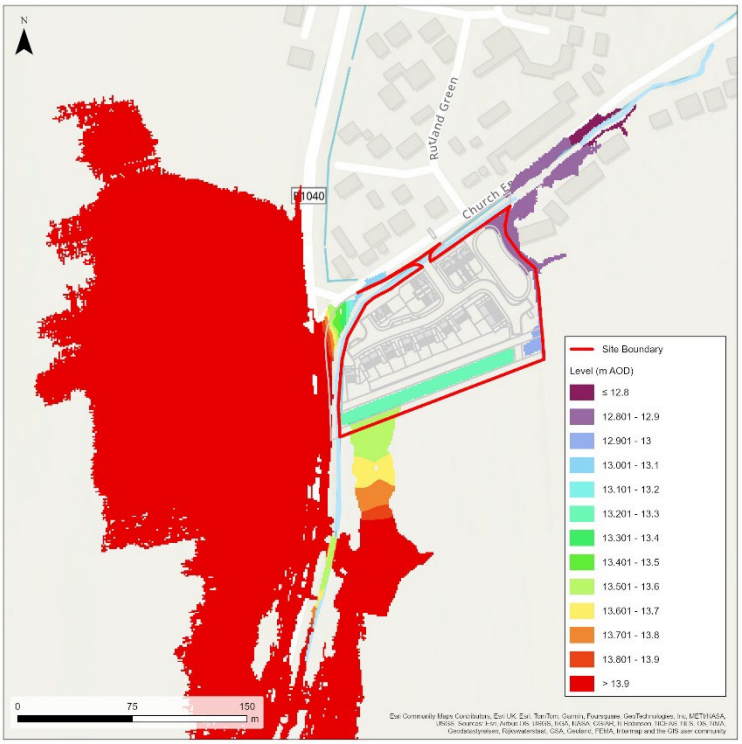

Figure 6.2: Post-development 1% AEP event plus 19% climate change maximum flood levels

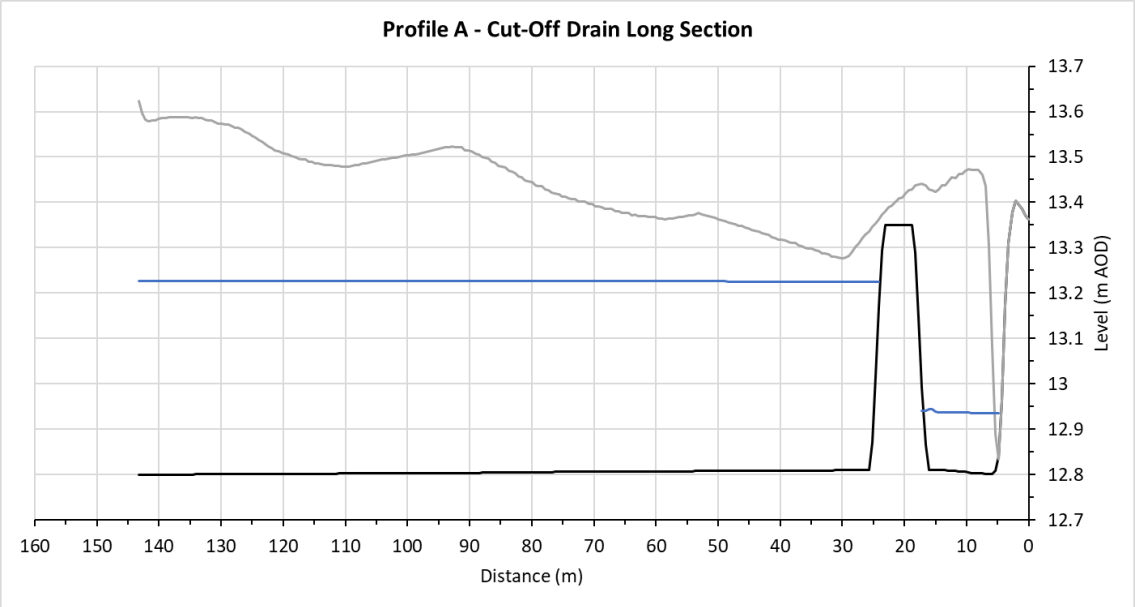

Figure 6.3: Cut-off drain long section profile (A), with the 1% (1 in 100) AEP Event Maximum Flood Level

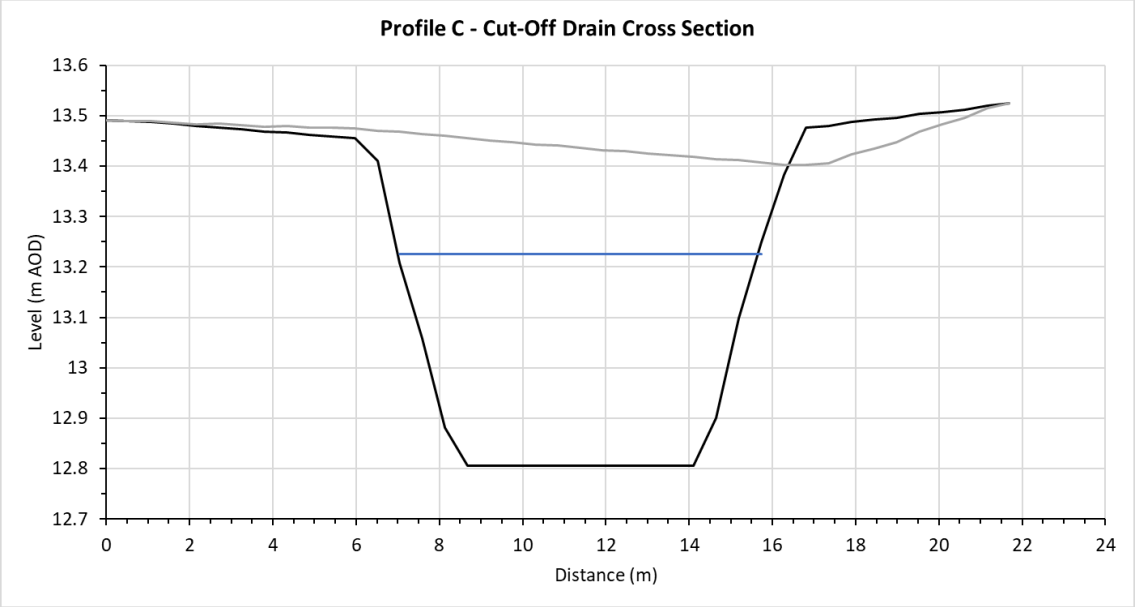

Figure 6.4: Cut-off drain cross section profile (C), with the 1% (1 in 100) AEP Event Maximum Flood Level

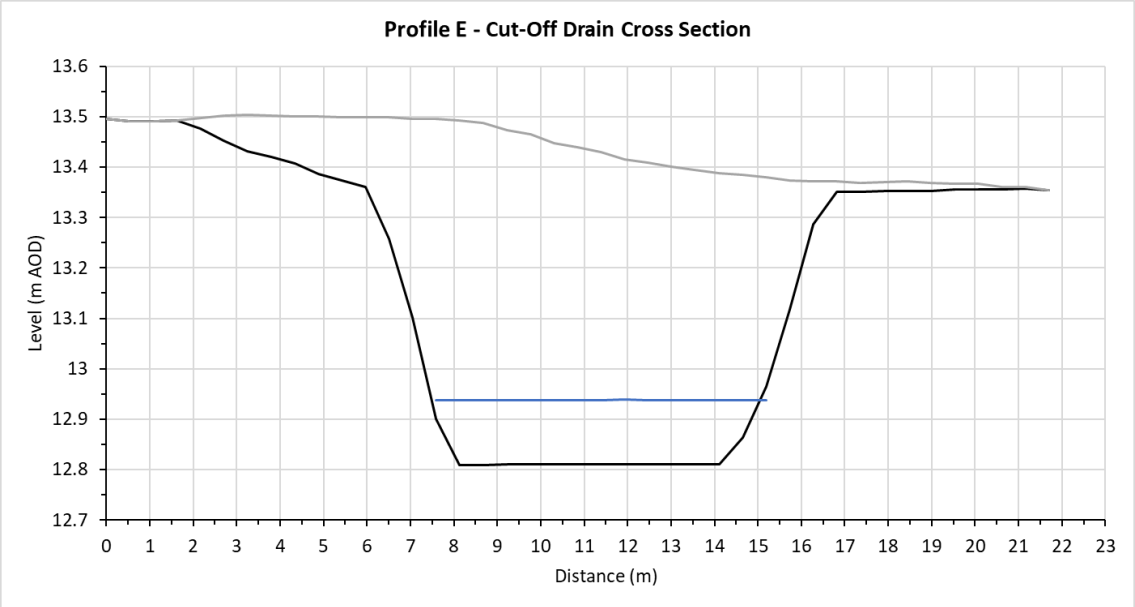

Figure 6.5: Cut-off drain cross section profile (E), with the 1% (1 in 100) AEP Event Maximum Flood Level

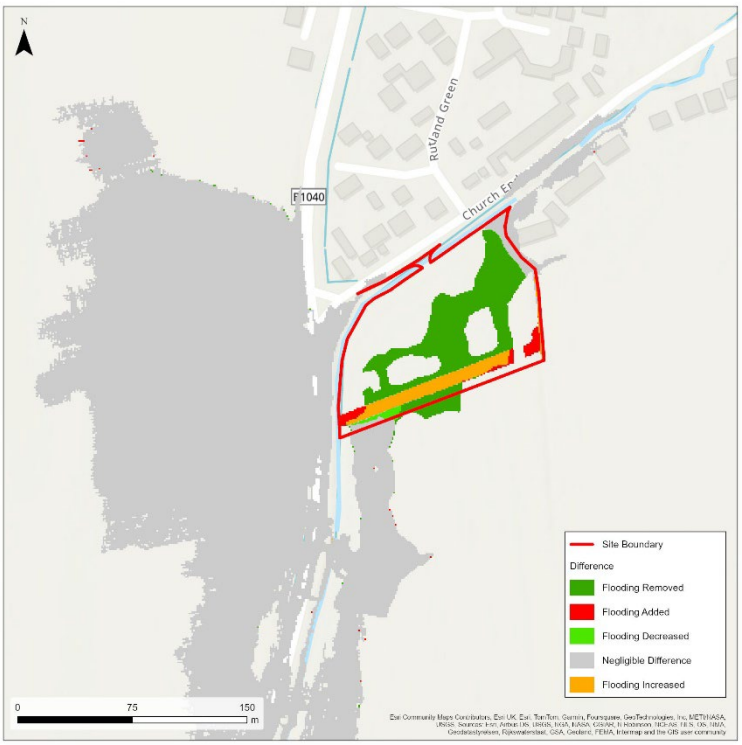

Figure 6.6: Comparison between post-development and baseline 1% AEP event plus 19% climate change flooding

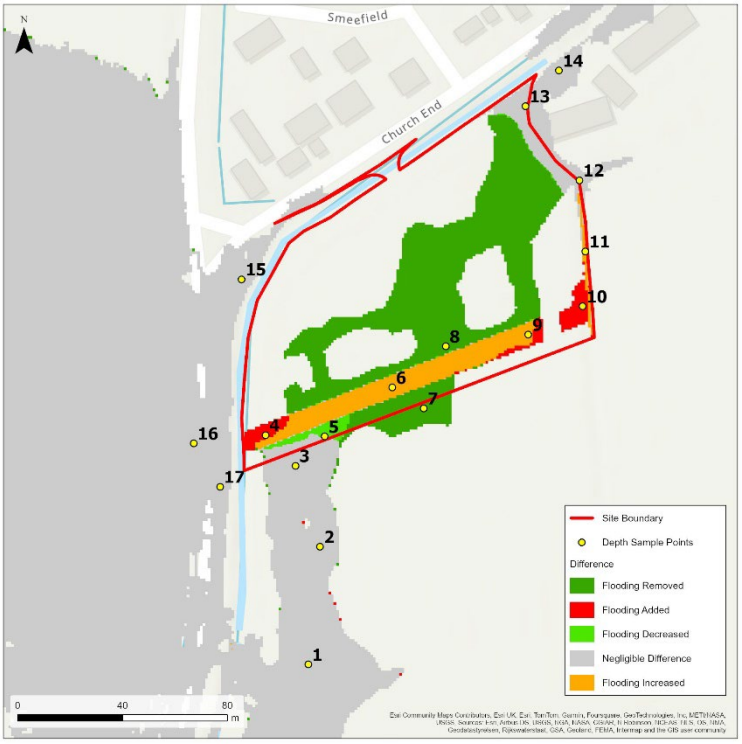

Figure 6.7: Sample point locations

Table 6.1: Maximum flood depths at each sampled point, locations shown in Figure 6.9

Sample Point	Maximum Flood Depths (m)											
	Baseline							Post-Development				
	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [-20% Mannings]	1% AEP [+20% Manning's]	1% AEP [80% Culvert	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [80% Culvert
1	0.07	0.07	0.08	0.10	0.07	0.07	0.07	0.07	0.07	0.08	0.10	0.07
2	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00
3	0.04	0.05	0.05	0.08	0.04	0.05	0.04	0.04	0.04	0.05	0.07	0.04
4	n/a	n/a	0.00	0.03	n/a	n/a	n/a	0.40	0.43	0.48	0.60	0.40
5	0.03	0.04	0.05	0.08	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.02
6	0.01	0.01	0.01	0.03	0.00	0.01	0.01	0.39	0.42	0.47	0.60	0.39
7	0.01	0.01	0.01	0.02	0.00	0.01	0.01	n/a	n/a	n/a	0.00	n/a
8	0.05	0.05	0.06	0.08	0.04	0.05	0.05	n/a	n/a	n/a	0.00	n/a
9	0.02	0.03	0.03	0.06	0.02	0.03	0.02	0.39	0.42	0.47	0.59	0.39
10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.12	0.13	0.17	0.25	0.12
11	0.08	0.10	0.13	0.20	0.09	0.08	0.16	0.10	0.12	0.15	0.23	0.10

Sample Point	Maximum Flood Depths (m)											
	Baseline							Post-Development				
	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [-20% Mannings]	1% AEP [+20% Manning's]	1% AEP [80% Culvert	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [80% Culvert
12	0.52	0.53	0.56	0.63	0.52	0.51	0.59	0.52	0.53	0.56	0.63	0.52
13	1.23	1.24	1.27	1.35	1.23	1.22	1.30	1.23	1.25	1.27	1.34	1.23
14	0.37	0.38	0.41	0.49	0.38	0.36	0.44	0.37	0.39	0.41	0.49	0.37
15	0.04	0.04	0.04	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.04
16	1.14	1.14	1.15	1.16	1.14	1.14	1.14	1.14	1.14	1.15	1.16	1.14
17	0.13	0.13	0.13	0.14	0.12	0.13	0.13	0.13	0.13	0.13	0.14	0.13

Table 6.1: Maximum flood levels at each sampled point, locations shown in Figure 6.9

Sample Point	Maximum Flood Levels (m AOD)											
	Baseline							Post-Development				
	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [-20% Mannings]	1% AEP [+20% Manning's]	1% AEP [80% Culvert	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [80% Culvert
1	14.06	14.06	14.07	14.09	14.05	14.06	14.06	14.06	14.06	14.07	14.09	14.06
2	13.70	13.70	13.70	13.72	13.70	13.70	13.70	13.70	13.70	13.70	13.72	13.70
3	13.58	13.58	13.59	13.62	13.57	13.58	13.58	13.58	13.58	13.58	13.61	13.58
4	n/a	n/a	13.59	13.62	n/a	n/a	n/a	13.20	13.23	13.28	13.40	13.20
5	13.56	13.56	13.57	13.60	13.55	13.56	13.56	13.55	13.55	13.55	13.57	13.55
6	13.50	13.50	13.50	13.52	13.49	13.50	13.50	13.20	13.23	13.28	13.40	13.20
7	13.49	13.49	13.50	13.51	13.49	13.49	13.49	n/a	n/a	n/a	n/a	n/a
8	13.39	13.39	13.40	13.42	13.39	13.39	13.39	n/a	n/a	n/a	n/a	n/a
9	13.30	13.31	13.31	13.34	13.29	13.30	13.30	13.20	13.23	13.28	13.40	13.20
10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	12.92	12.94	12.97	13.05	12.92
11	12.87	12.89	12.91	12.99	12.87	12.86	12.94	12.89	12.91	12.93	13.01	12.89

Sample Point	Maximum Flood Levels (m AOD)											
	Baseline							Post-Development				
	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [-20% Mannings]	1% AEP [+20% Manning's]	1% AEP [80% Culvert	1% AEP	1% AEP +19% Climate Change	1% AEP +30% Climate Change	0.1% AEP	1% AEP [80% Culvert
12	12.87	12.89	12.91	12.99	12.87	12.86	12.94	12.87	12.89	12.91	12.99	12.87
13	12.87	12.89	12.91	12.99	12.87	12.86	12.94	12.87	12.89	12.91	12.98	12.87
14	12.87	12.89	12.92	12.99	12.88	12.86	12.95	12.87	12.89	12.92	12.99	12.87
15	13.43	13.43	13.43	13.44	13.43	13.44	13.43	13.43	13.43	13.43	13.44	13.43
16	14.05	14.05	14.05	14.07	14.04	14.05	14.05	14.05	14.05	14.05	14.06	14.05
17	14.05	14.05	14.05	14.07	14.04	14.05	14.05	14.05	14.05	14.05	14.07	14.05

7. Conclusions

7.1 Stantec was commissioned by Burmor Construction (Client) to update previous hydraulic modelling and hydrological analysis completed by Stantec in 2020 for the site at Church End, Hilton. The aim was to provide an updated baseline model in line with the latest software, methodology, and guidance. This included updating the hydrological analysis, revising the model schematisation to prevent over exaggerating flood risk to the site, and using updated climate change allowances.

7.2 The updated baseline modelling exercise informed the post-development modelling. The preferred mitigation option that was tested, and fits with the current site layout, was a cut-off drain along the southern edge of the site which intercepts overland flow during high flow events. This cut-off drain was graded so that it connects to the eastern drain, and slopes to the western drain and connects at a level of 12.8m AOD, to allow gravity discharge to either end. Unused space in the south-east corner of the proposed development has also been incorporated into the cut-off drain to maximise storage. A ~40m section along the eastern drain adjacent to where the cut-off drain connects has been lowered by between 10mm-150mm. This option includes a culvert crossing to allow access to both banks for maintenance purposes; this has been sized to 300mm internal diameter.

7.3 By implementing these mitigation measures, the overland flooding would be removed from the proposed development area without causing any detriment to third party lands during the design event (1% (1 in 100) AEP event plus 19% climate change).

7.4 Overall, this hydraulic modelling exercise indicates the proposed development would not be at risk of flooding and surrounding land would not be at increased flood risk.

7.5 It is recommended prior to next steps (for example detailed design and/or Flood Risk Assessment), the updated baseline and post-development models be submitted to the LLFA for review; this will involve consultation with the LLFA and any comments they might have will need to be addressed prior to approval.

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Appendix A

now part of

Church End, Hilton

Baseline Flood Modelling Report

On behalf of **Axis Land Partnerships**

Project Ref: 45973 | Rev: A | Date: December 2019

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Document Control Sheet

Project Name: **Church End, Hilton**
Project Ref: **45973**
Report Title: **Baseline Flood Modelling Report**
Doc Ref: **4003**
Date: **December 2019**

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Prepared by:	M Davison	Graduate Engineer	MD	Dec 2019
Reviewed by:	C Waller	Associate	CW	Dec 2019
Approved by:	S Darch	Director	SD	Dec 2019
For and on behalf of Peter Brett Associates LLP				

Revision	Date	Description	Prepared	Reviewed	Approved
A	Dec 2019	First draft for client review	MD	CW	SD

This report has been prepared by Peter Brett Associates LLP ('PBA') on behalf of its client to whom this report is addressed ('Client') in connection with the project described in this report and takes into account the Client's particular instructions and requirements. This report was prepared in accordance with the professional services appointment under which PBA was appointed by its Client. This report is not intended for and should not be relied on by any third party (i.e. parties other than the Client). PBA accepts no duty or responsibility (including in negligence) to any party other than the Client and disclaims all liability of any nature whatsoever to any such party in respect of this report.

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1 Introduction

1.1 Background

1.1.1 Peter Brett Associates, now part of Stantec, (PBA), have been commissioned by Axis Land Partnerships to model and map surface water flood risk at a proposed site adjacent to Church End to the south of the village of Hilton, Huntingdonshire (Figure 1). The site is not situated within any of the Environment Agency (EA) Flood Zones (Figure 2).

1.2 Catchment Characteristics

1.2.1 The Hilton Drain is sourced from north-east of Papworth Everard (Figure 3) and flows towards the north through largely agricultural fields; it is predominately a rural catchment. The drain follows parallel to the B1040 road where it flows under numerous structures, mainly culverts and a small bridge, before reaching the proposed development site. The drain then bears to the east and flows along Church End adjacent to the site. Downstream, it continues to flow alongside the road and passes under several bridges and a culvert used as private driveways to properties.

1.2.2 The catchment area of the Hilton Drain upstream of Church End is small, approximately 3km^2. The catchment is underlain by mudstone bedrock, specifically Oxford Clay, West Walton and Ampthill Clay formations. In addition, extensive diamicton superficial deposits of the Oadby member are located towards the south-east of the whole catchment, with a localised patch on the western edge of Hilton. The site and its catchment are therefore considered impermeable.

1.2.3 The drain is designated as an 'Ordinary Watercourse' and is subject to regulation, consenting and enforcement by the Lead Local Flood Authority (LLFA), Cambridgeshire County Council. The drain discharges into the West Brook, which flows into the River Great Ouse north of Fenstanton. The drain is therefore within the EA Anglian Region.

1.3 Flood History

1.3.1 There is no known history of flooding at the site itself, although there is a recorded history of flooding within the village of Hilton downstream. A flood risk assessment (FRA) conducted by Highways England (2015, see further details below) indicates Hilton has a history of flooding, supported by data collected by the Highways Agency, EA, Cambridge County Council and Huntingdonshire County Council.

1.3.2 The most significant known flood event occurred in October 2001, where multiple properties were flooded due to surface water flooding. The 2015 Highways England FRA attributed this to culvert and/or drain blockages as a result of inadequate maintenance, rather than the exceedance of channel capacity.

1.4 Previous Studies

1.4.1 The FRA prepared by Highways England, as part of the Cambridge to Huntingdon A14 improvement scheme, modelled the flood risk of the Hilton Drain downstream of the proposed site. The hydraulic model indicated 1% Annual Exceedance Probability (AEP, 1 in 100) water levels of 8.35mAOD in the Hilton Drain downstream of the village. However, the study did not extend upstream to include the proposed development site considered here.

1.4.2 PBA undertook a Flood Risk and Drainage Appraisal study in June 2019, which comprised a desk-based appraisal of potential sources of flood risk to the site. The study identified the site as potentially at risk of flooding from surface water. The site is shown to be at high risk of surface water flooding on the EA's Risk of Flooding from Surface Water maps (Figure 4). The

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study recommended hydraulic modelling be undertaken to assess the magnitude of the flood risk and identify flow pathways and constraints.

1.5 Scope of Study

1.5.1 The scope of the study is as follows:

- Assess inflows to the Hilton Drain using the latest hydrological methods (ReFH2 and Improved Statistical methods) for the 1% (1 in 100), 1% (1 in 100) plus climate change and 0.1% (1 in 1000) AEP events, identifying the critical storm duration at the site. Review catchment areas and land-use based upon available topographic data and mapping.
- Construct a linked 1D-2D model of the watercourse, structures and floodplain of the Hilton Drain extending from upstream and to the west of the proposed development site to a suitable distance downstream.
- Simulate the 1% (1 in 100), 1% (1 in 100) plus climate change and 0.1% (1 in 1000) AEP events for the critical storm duration at the site and produce maximum flood extent maps.
- Undertake standard sensitivity testing to examine the effects of varying channel roughness (±20%) and the blockage of both the two nearby culverts (blockages of 20% and 50%) on flooding.

1.5.2 The study does not include modelling of the proposed development and any mitigation measures but seeks to establish a baseline against which mitigation measures can be compared to assess detrimental impacts on downstream or adjacent third party land.

1.5.3 The purpose of this study is to support a Flood Risk Assessment for planning at the site. The model should not be applied for other purposes without reviewing its assumptions and limitations. This report does not itself constitute as a Flood Risk Assessment.

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Figure 1: Site Location Plan

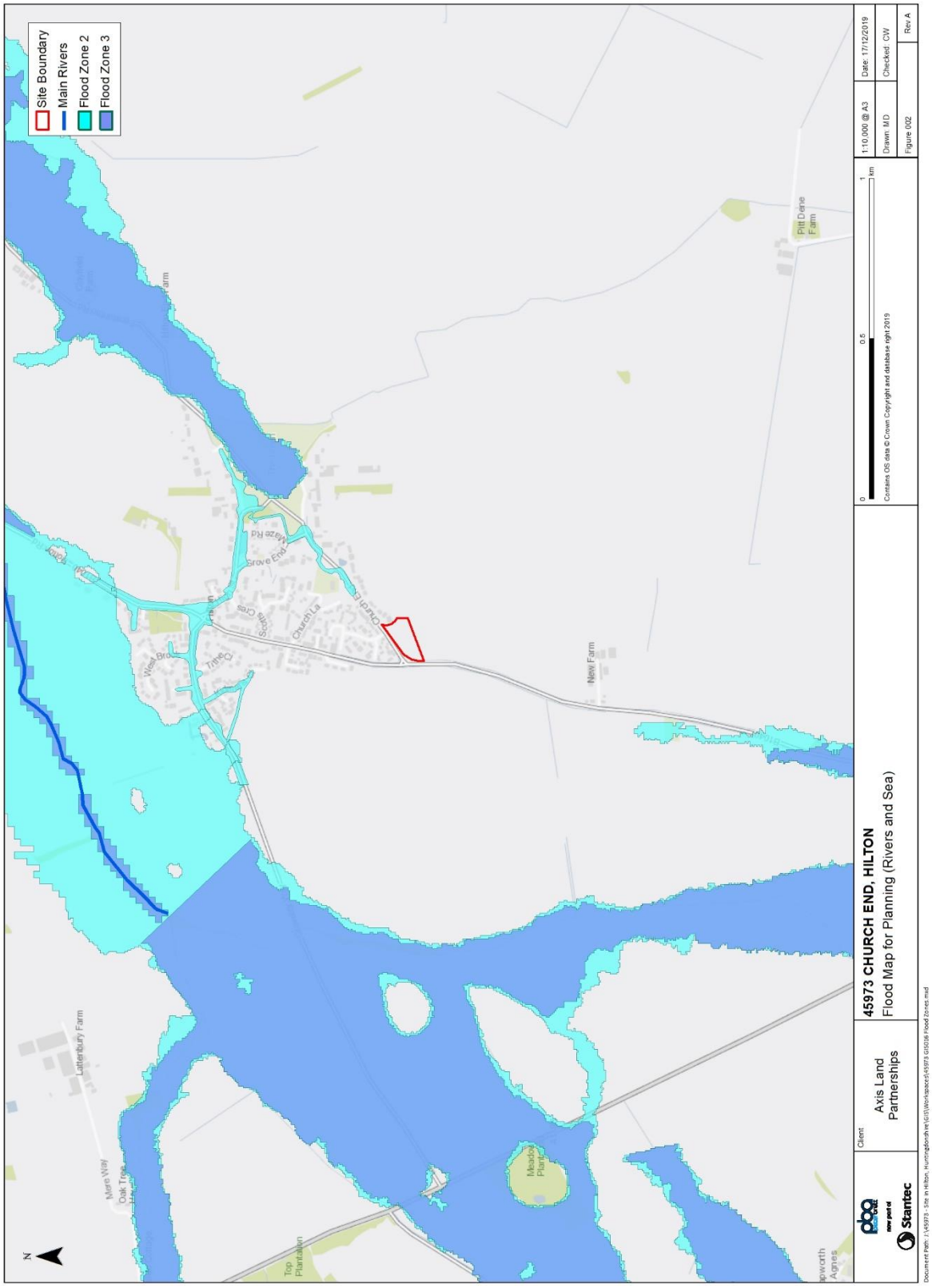

Figure 2: Environment Agency Flood Zones

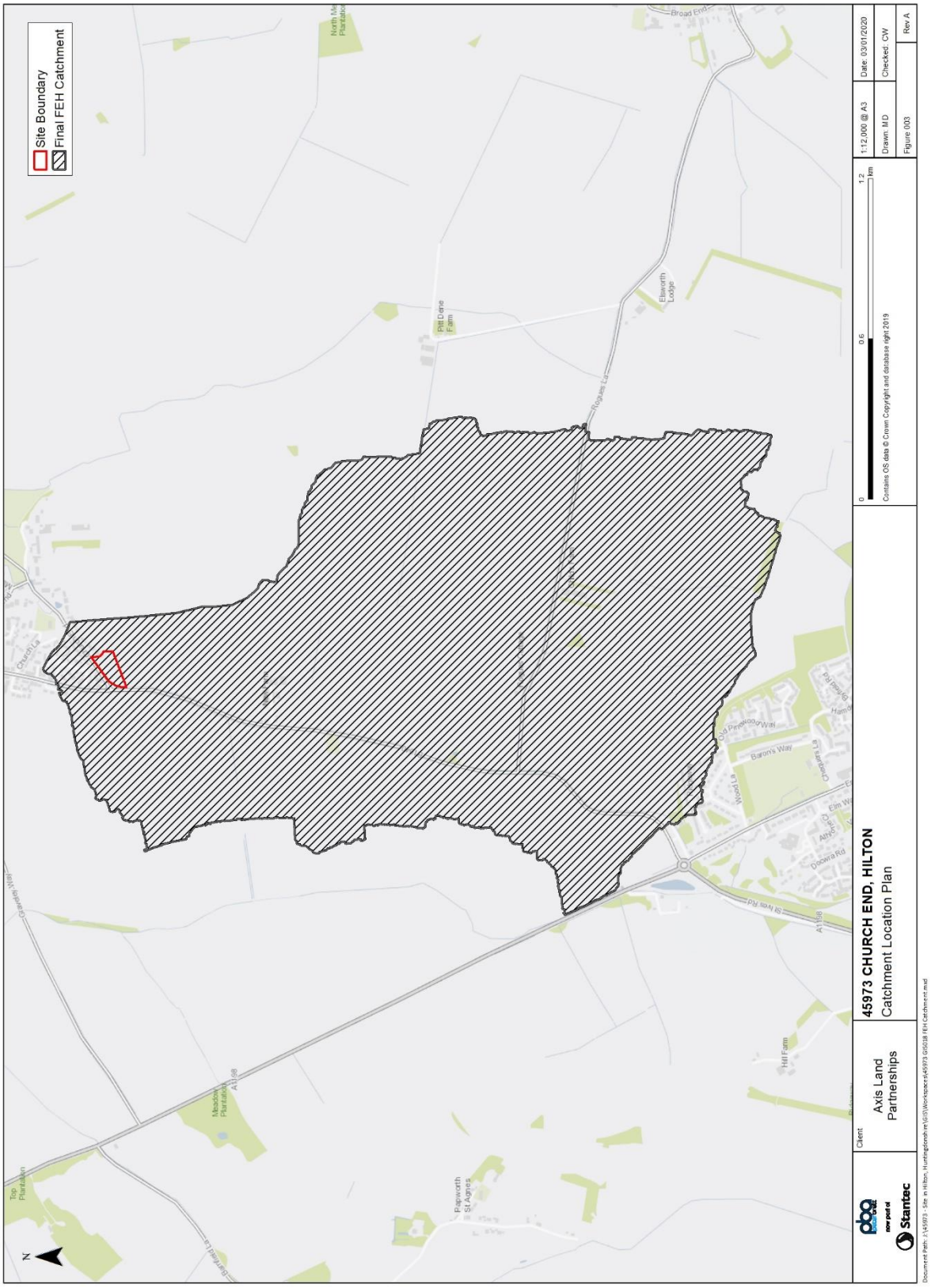

Figure 3: Catchment Location Plan

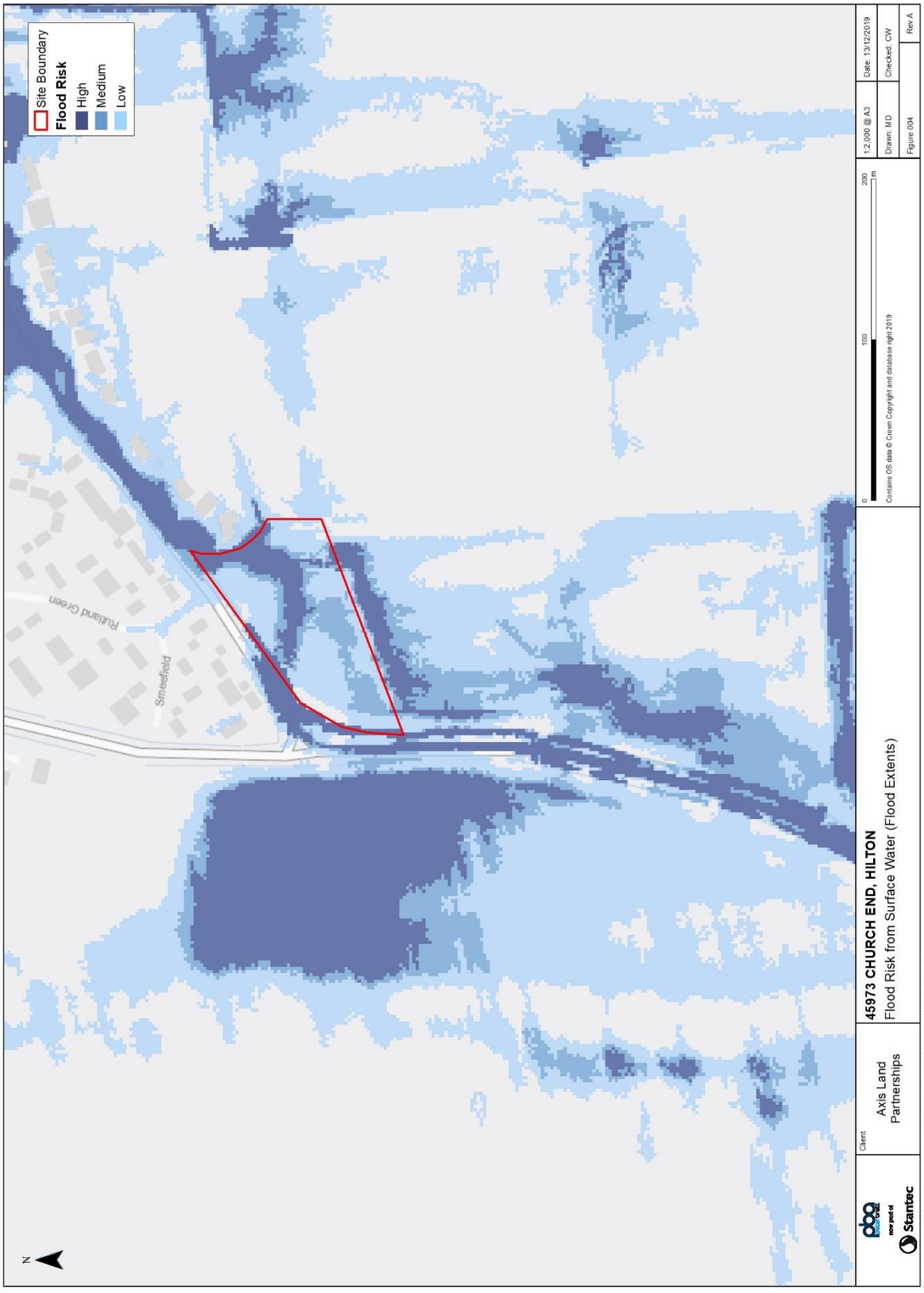

Figure 4: Environment Agency Risk of Flooding from Surface Water Flood Maps

2 Data Collection and Review

2.1 Flow or Level Gauging Stations

2.1.1 The Hilton Drain is ungauged and as a result there are no flow or level records from which to estimate design events.

2.2 Topographic Data

2.2.1 Data for the Hilton Drain cross-sections were drawn from a survey conducted by BES Geomatics, for Strutt and Parker, within October 2019 (Appendix A). The survey extends from upstream of Hilton, along the B1040, and downstream of Church End (Figure 5). Additionally, the survey included structure details for the various bridges and culverts.

2.2.2 Topographic data for areas that were not included within the survey was drawn from the EA 1m resolution LiDAR data, downloaded on the 27th November 2019 (Figure 6).

2.2.3 Comparing the survey topography and LiDAR datasets, differences in levels of up to ±0.4m are shown (Figure 7). However, these differences are considered acceptable as they are located in areas where:

- The LiDAR data does not accurately measure the channel bed or ground heights due to heavy vegetation.
- The LiDAR does not penetrate the water in the channel, causing it to represent the channel bed at higher level than in reality.

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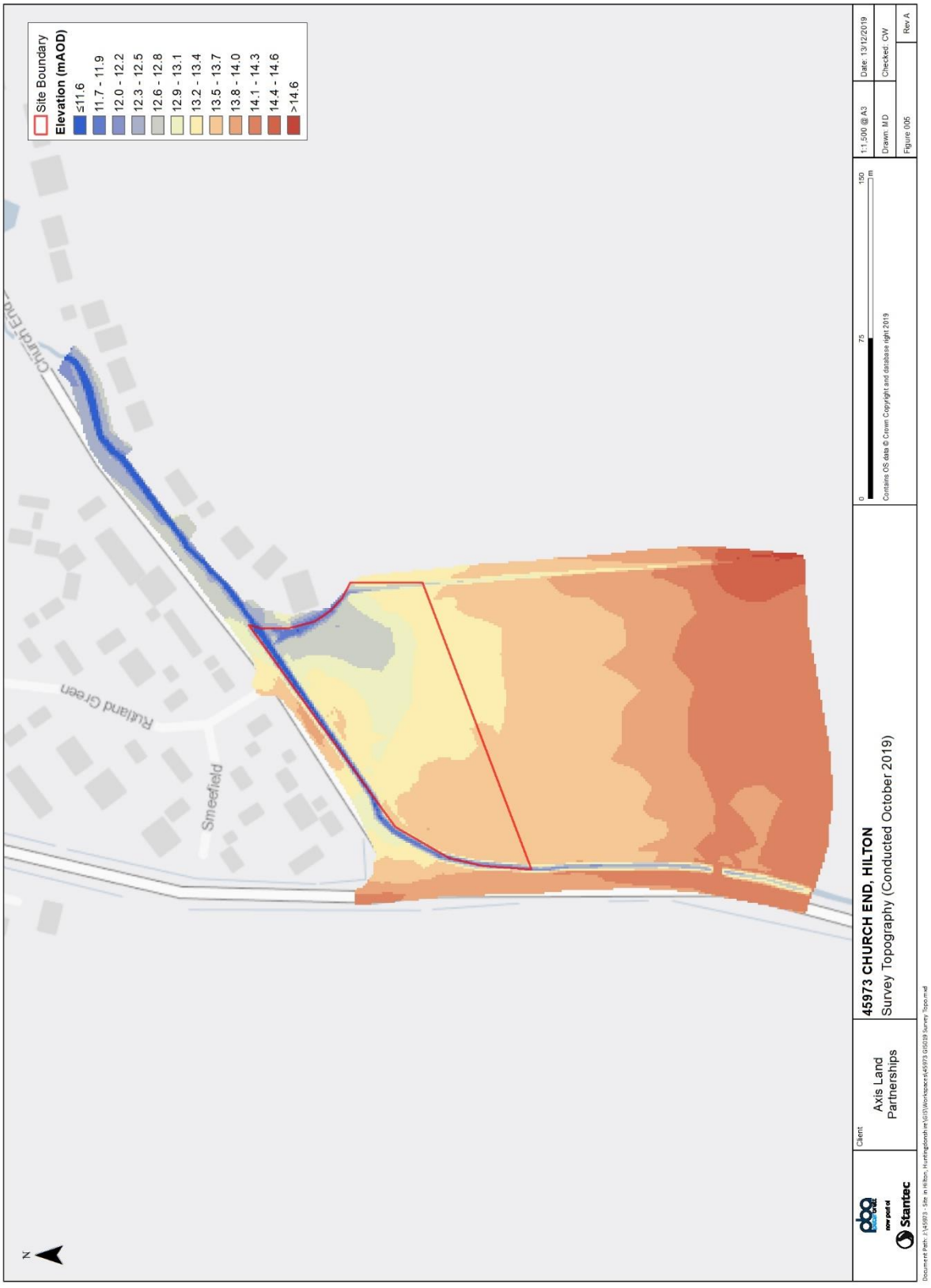

Figure 5: Survey topography

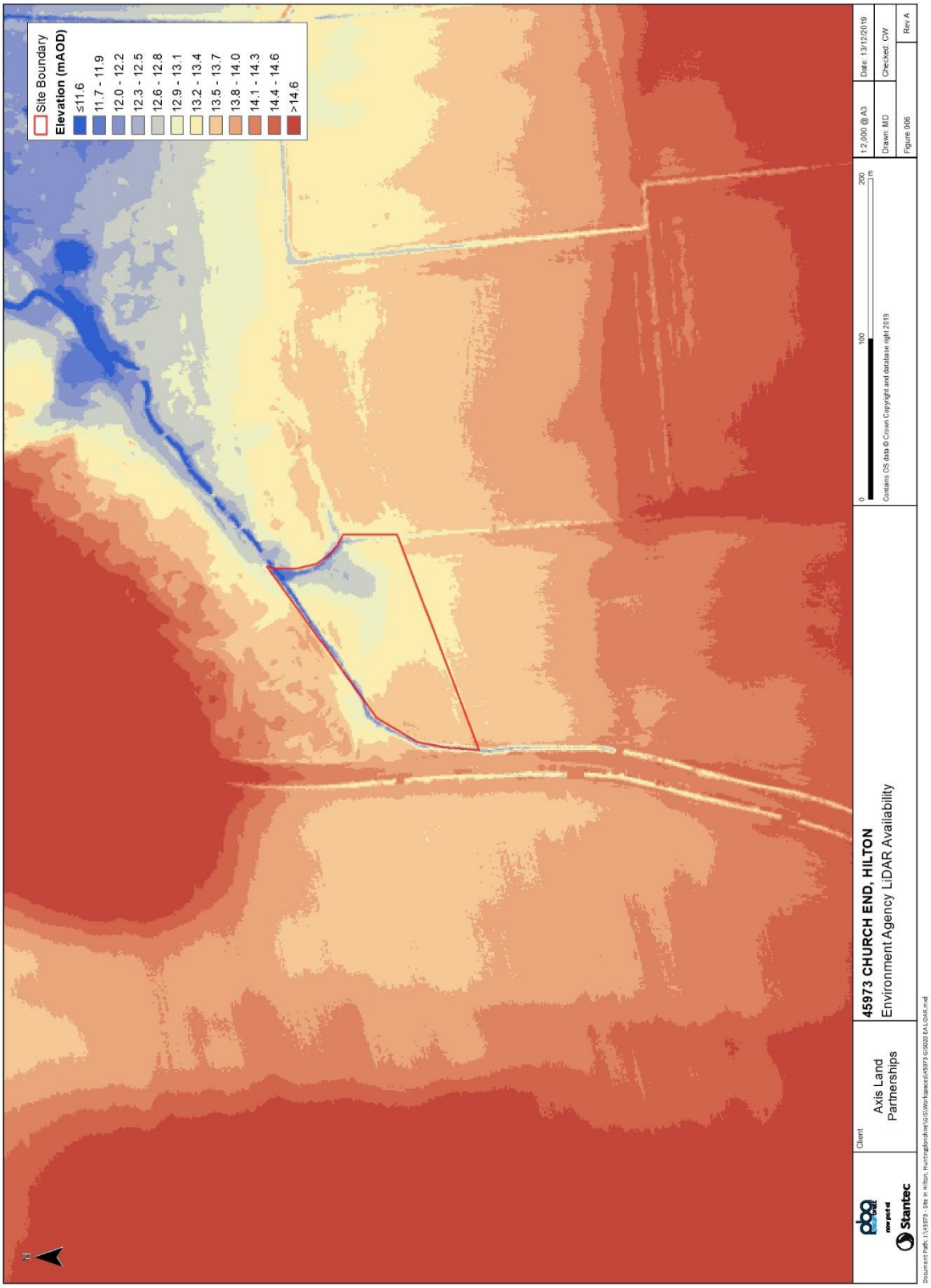

Figure 6: LiDAR topography and availability for the hydrological catchment

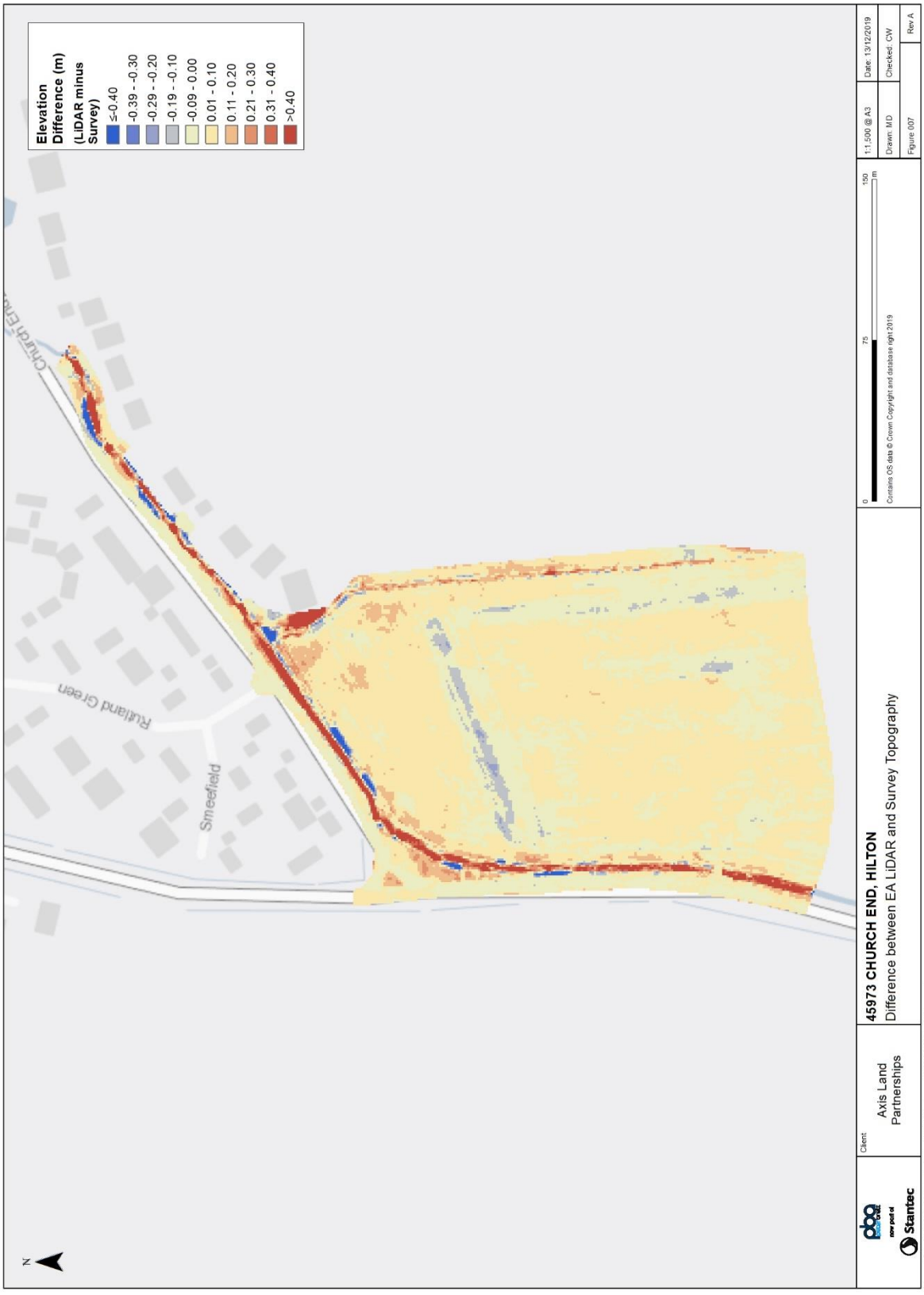

Figure 7: Comparison of LiDAR with survey data

3 Hydrology

3.1 Overview

3.1.1 A whole catchment analysis was undertaken to compare the FEH statistical and rainfall-runoff (ReFH2) methods. The preferred methods were then applied to the individual sub-catchments. A whole catchment method was used because of the small catchment size, which meant that a better pooling group fit could be found than if individual sub-catchments were analysed.

3.1.2 The catchment is ungauged; therefore, all calculations are based upon catchment descriptors.

3.1.3 Full calculation details are contained within the Hydrology Calculation Record in Appendix B

3.2 Whole Catchment Analysis

3.2.1 Catchment descriptors for the whole catchment to Church End were obtained from the FEH Webservice; these were adjusted to better represent the catchment and these final descriptors are detailed in Table 1. For full details on making the adjustments see Appendix B

Area	FARL	PROP-WET	BFI-HOST	DPL-BAR	DPS-BAR	SAAR	SPR-HOST	URBEXT 2000	FPEXT
3.198	1.00	0.24	0.29	1.891	35.14	545	52.47	0.01328	0.1192

Table 1: Whole Catchment FEH Descriptors

3.2.2 The FEH Improved Statistical and ReFH2 flow estimation methods were compared for the whole catchment, resulting in the peak flow estimates shown in Table 2. As the ReFH2 gave a more conservative flow estimate, this method was chosen to be applied to the sub-catchments defined for the hydraulic model.

Method	Flood peak (m3/s) for the following AEP									
	50%	20%	10%	5%	3.33%	2%	1.34%	1%	0.5%	0.1%
Statistical	0.554	0.783	0.958	1.155	1.284	1.464	-	1.746	2.080	3.118
ReFH2	1.35	1.89	2.32	-	3.15	3.65	4.11	4.47	5.40	7.63

Table 2: Whole Catchment Peak Flow Estimates

3.3 Sub-catchment Analysis

3.3.1 The whole catchment was divided into three sub-catchments following a review of the topography and the hydraulic model extents. Catchment descriptors were estimated for these sub-catchments using soil association maps, topographic and mapping data. Full details are included in Appendix B.

Sub-catchment	Area	FARL	PROP-WET	BFI-HOST	DPL-BAR	DPS-BAR	SAAR	URBEXT 2000
Upstream Boundary (USBD)	2.786	1.00	0.24	0.30	1.75	36.60	545	0.0085
Left-hand Side (LHS)	0.34	1.00	0.24	0.28	0.55	24.60	545	0.0047
Right-hand Side (RHS)	0.072	1.00	0.24	0.28	0.24	28.69	545	0.0037

Table 3: Sub-catchment FEH Descriptors

3.4 Climate Change

3.4.1 The catchment lies in the Anglian River Basin District, for which the following climate change factors are currently applied by the EA to 2115:

- Central: +25% increase in peak river flow
- Higher Central: +35% increase in peak river flow
- Upper End: +65% increase in peak river flow

3.4.2 The Upper End scaling factor of 65% was used in this study to represent the climate change scenario.

3.4.3 The EA peak flow increase allowances have not yet been updated to the UKCP18 projections, which were published in November 2018. This is anticipated to be released early 2020, although changes to peak flow increases are anticipated to be minor.

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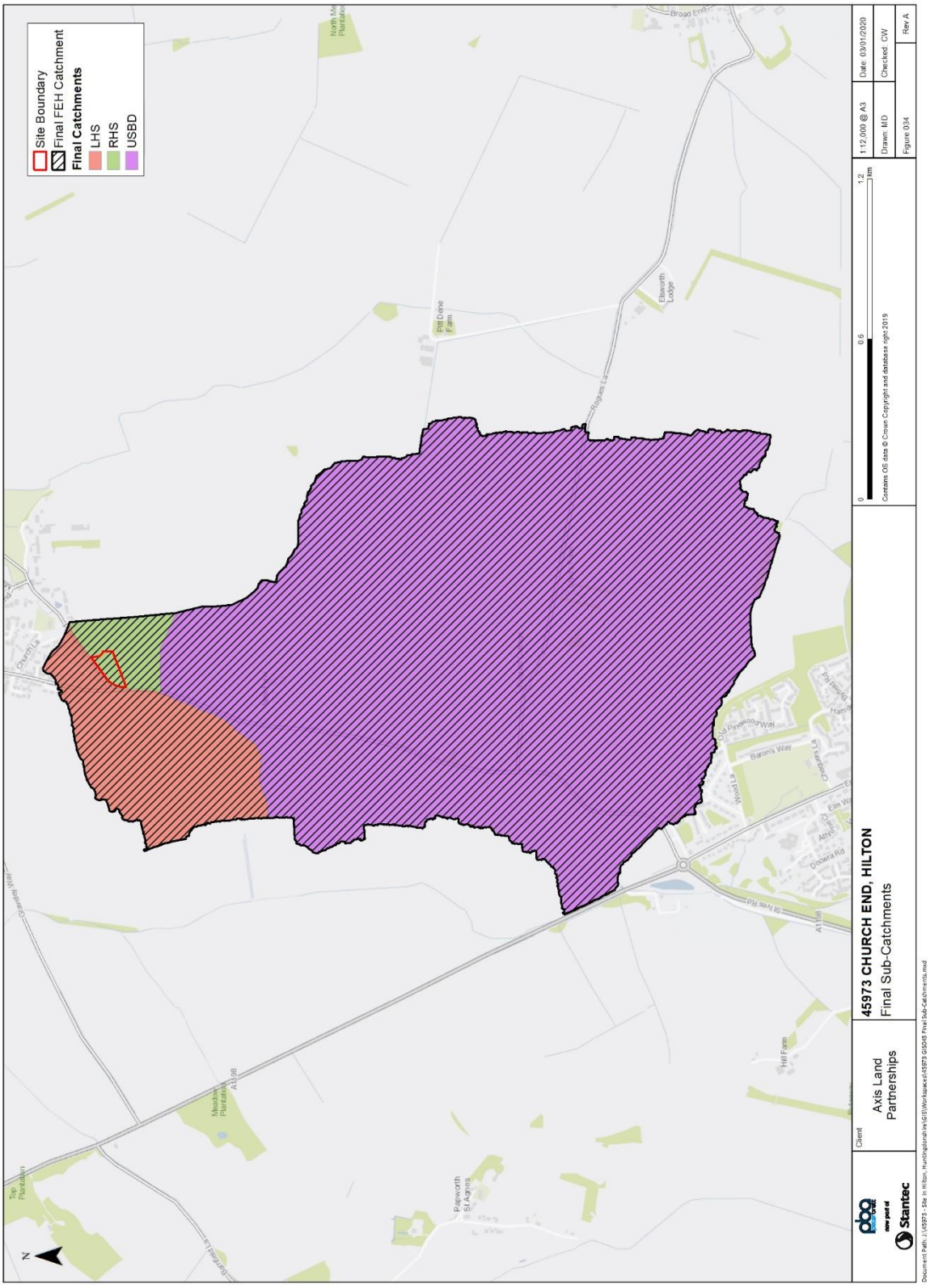

Figure 8: Sub catchments and FEH Catchment

4 Hydraulic Modelling

4.1 Modelling Approach

4.1.1 A hydrodynamic 1D-2D modelling approach has been implemented, with the following considerations:

- The length of the Hilton Drain channel to be modelled and the number of bridges and culvert structures along it require the use of an unsteady 1D approach for in-channel areas, for which simpler hydraulic analysis (e.g. steady-state) or 2D-only representation are inappropriate.
- The pattern of flow and pooling of surface water across the floodplain areas is not expected to follow the drain direction, requiring the use of a 2D representation for out-of-bank areas to allow detailed simulation and mapping of flow pathways and flood depths.

4.1.2 The channel, bridges and culvert structures were represented within the 1D domain using the Flood Modeller Pro (FMP) software, whereas the floodplain and secondary drain were represented in the 2D domain through the TuFLOW software.

4.1.3 The model upstream extents are approximately 210m south of the Potton Road and Church End junction, along the B1040, and the model extends downstream, approximately 324m down Church End, to include the proposed development site (as shown in Figure 12).

4.2 1D FMP Model

4.2.1 The 1D FMP model was constructed using cross-sectional data provided from the site survey; model node locations are highlighted in Figure 9. Manning's roughness values were set either at 0.030, 0.035, or 0.040 for in-channel areas, reflecting typical roughness observed at the site as vegetation density varied along the channel (see photographs in Appendix C). Moreover, river cross-sections were cropped to only the in-bank areas through utilising deactivation markers.

4.2.2 Modelled structures are shown in Figure 10 with their representation being is summarised in Table 4; photos of each structure are displayed within Appendix C .

4.2.3 A QT inflow boundary was applied to the 1D FMP model, at the upstream node in towards the south of the site; lateral flows from adjacent fields were modelled with additional QT inflow boundaries. The downstream boundary was set up as a normal depth (ND) boundary with the slope automatically calculated from the bed of the river sections.

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Model Node	Structure	Description	Model representation
H_041	Culvert	6.7m long culvert underneath an access path adjacent to the B1040; 0.9m diameter. Invert levels were measured as 12.284mAOD and 12.282mAOD, for the upstream inlet and downstream outlet respectively.	Modelled with circular conduit units, with culvert inlet and outlet representing losses. Spill unit included due to the ability of flow being able to overtop structure.
H_321	Bridge	7.2m bridge with fence used as private driveway to property; soffit height is 12.228mAOD.	Represented as a USBPR unit with a spill unit, due to the fence allowing flows to overtop structure.
H_345	Bridge	4.9m bridge with railing used as private driveway to property; soffit height is 12.285mAOD.	Represented as a USBPR unit with a spill unit, due to the railing allowing flows to overtop structure.
H_371	Culvert	5.7m long culvert underneath private driveway; 0.725m diameter. Invert levels were measured as 11.160mAOD and 11.159mAOD, for the upstream inlet and downstream outlet respectively.	Modelled with circular conduit units, with culvert inlet and outlet representing losses. No spill unit was included due to brick wall that would prevent flows over structure.
H_420	Bridge	3.9m bridge with brick wall used as private driveway to property; soffit height is 11.801mAOD.	Represented as a USBPR unit. No spill unit was included due to brick wall that would prevent flows over structure.
H_459	Bridge	8.7m bridge with bridge wall used as private driveway to properties; soffit height is 11.949mAOD.	Represented as a USBPR unit. No spill unit was included due to brick wall that would prevent flows over structure.

Table 4: 1D model representation of key structures

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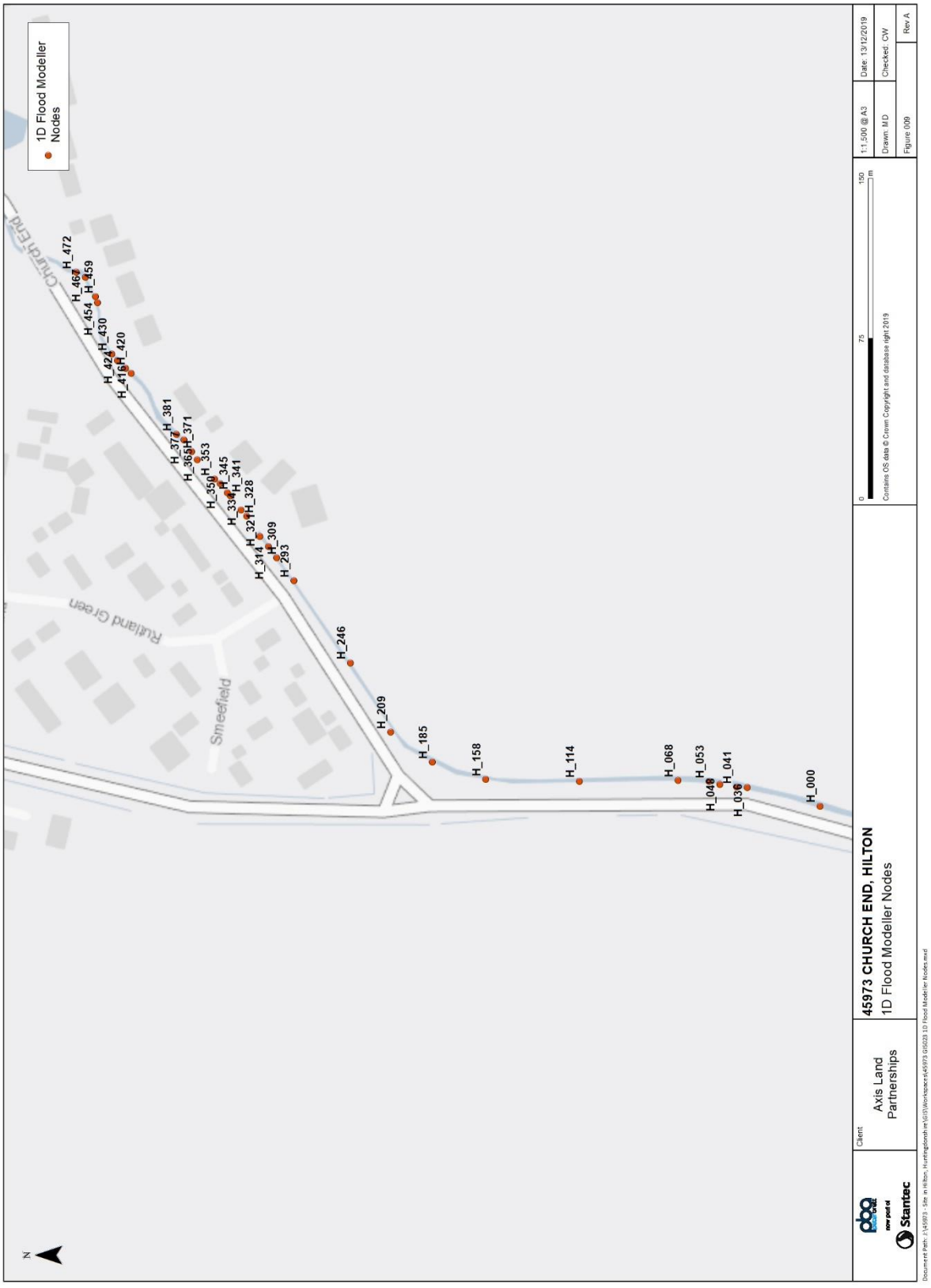

Figure 9: 1D Model Node Locations

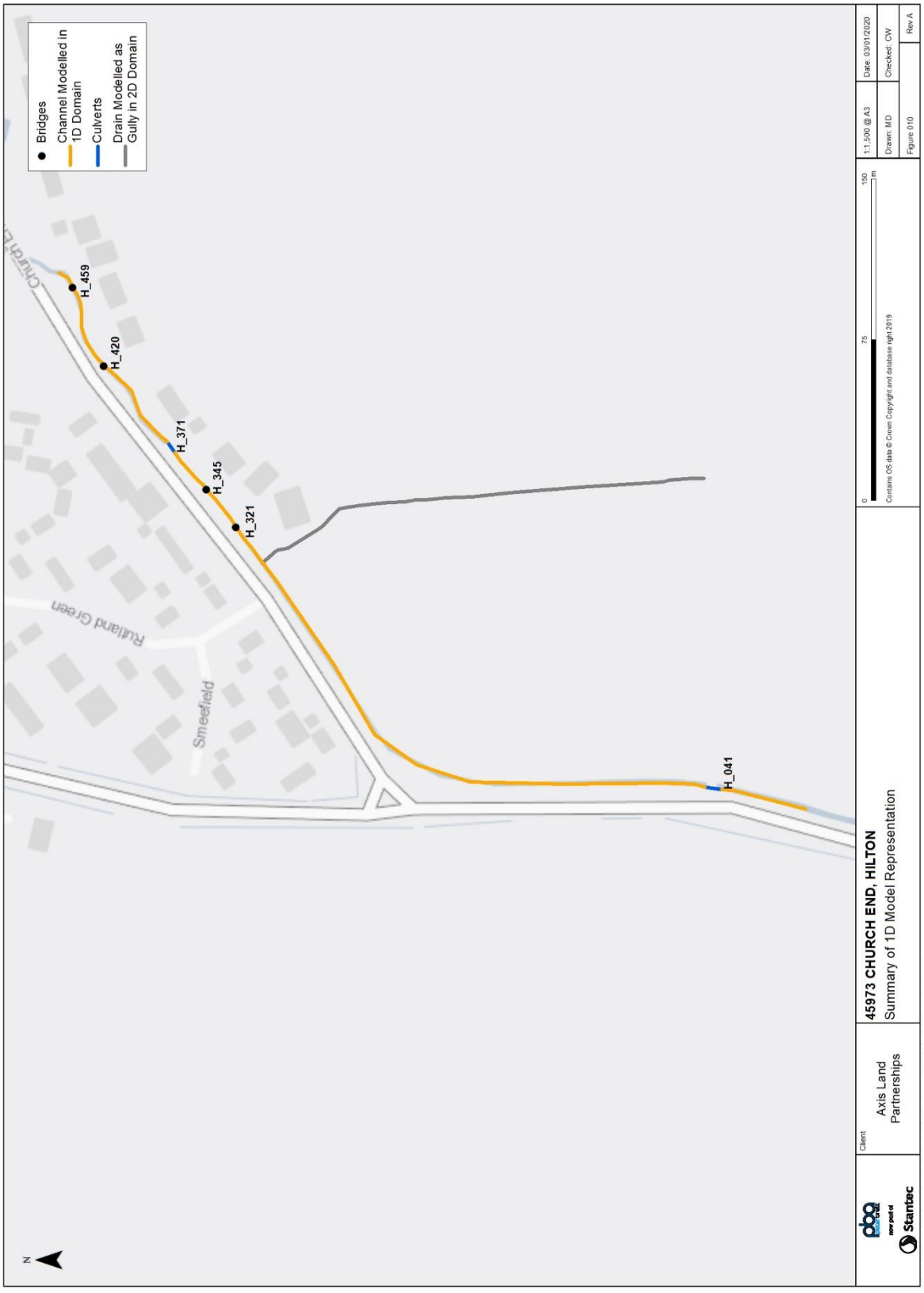

Figure 10: 1D model representation: 1D units, culverts, bridges, and channel modelled in 2D

4.3 2D TuFLOW Model

4.3.1 The 2D TuFLOW model was built using available topographic data, combined with LiDAR data obtained from the EA (Figure 11). A cell size of 2m was selected as a compromise between precision and model run times.

4.3.2 The TuFLOW geometry layers used are highlighted in Figure 12, including:

- 2D Domain Active Area;
- 2D Domain Inactive Area;
- Z-Line and Z-Points representing the small drain to the east of the site, depicted as a gully line to maintain channel connectivity and set bed levels;
- Z-Points that set the channel bank levels, matching the 1D cross-section extents.

4.3.3 Figure 13Figure 15 show the Ordnance Survey Mastermap land-use types utilised within the model, appropriate Manning's roughness values were specified for each using industry standard values associated with such land types as shown in the Figure. Buildings were represented as areas of very high roughness (n = 3).

4.3.4 TuFLOW boundary and connection layers are shown in Figure 14 and include:

- HQ boundaries representing the downstream boundaries of the 2D domain; the slope was calculated by using the elevation upstream and downstream of the HQ boundary line and doing the difference of these divided by the distance between them.
- HX and CN connection lines that link the 1D FMP cross-sections to the 2D domain.

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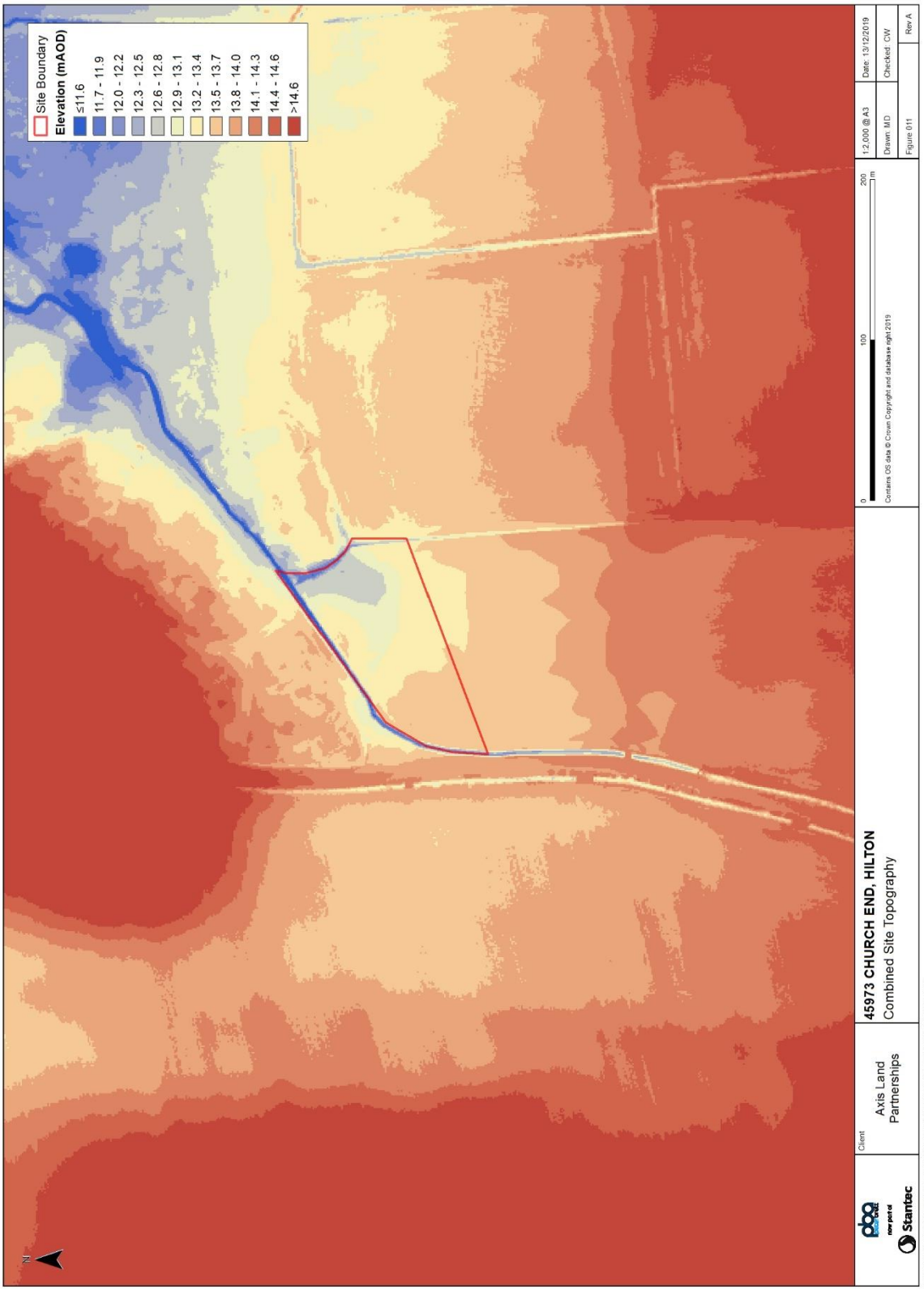

Figure 11: Combined LiDAR and site topographic data used in 2D model

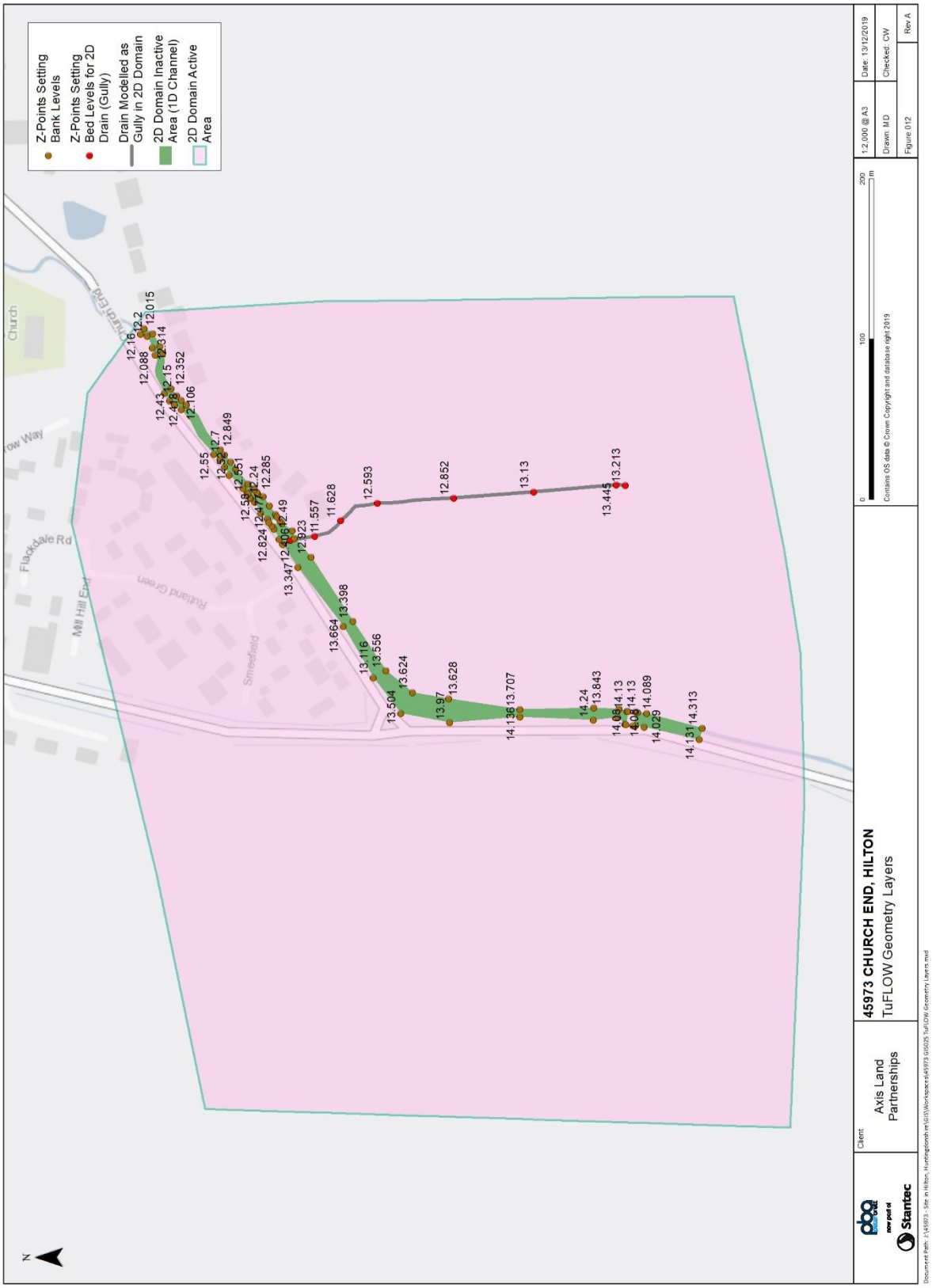

Figure 12: TuFLOW geometry layers



Figure 13: TuFLOW materials layers

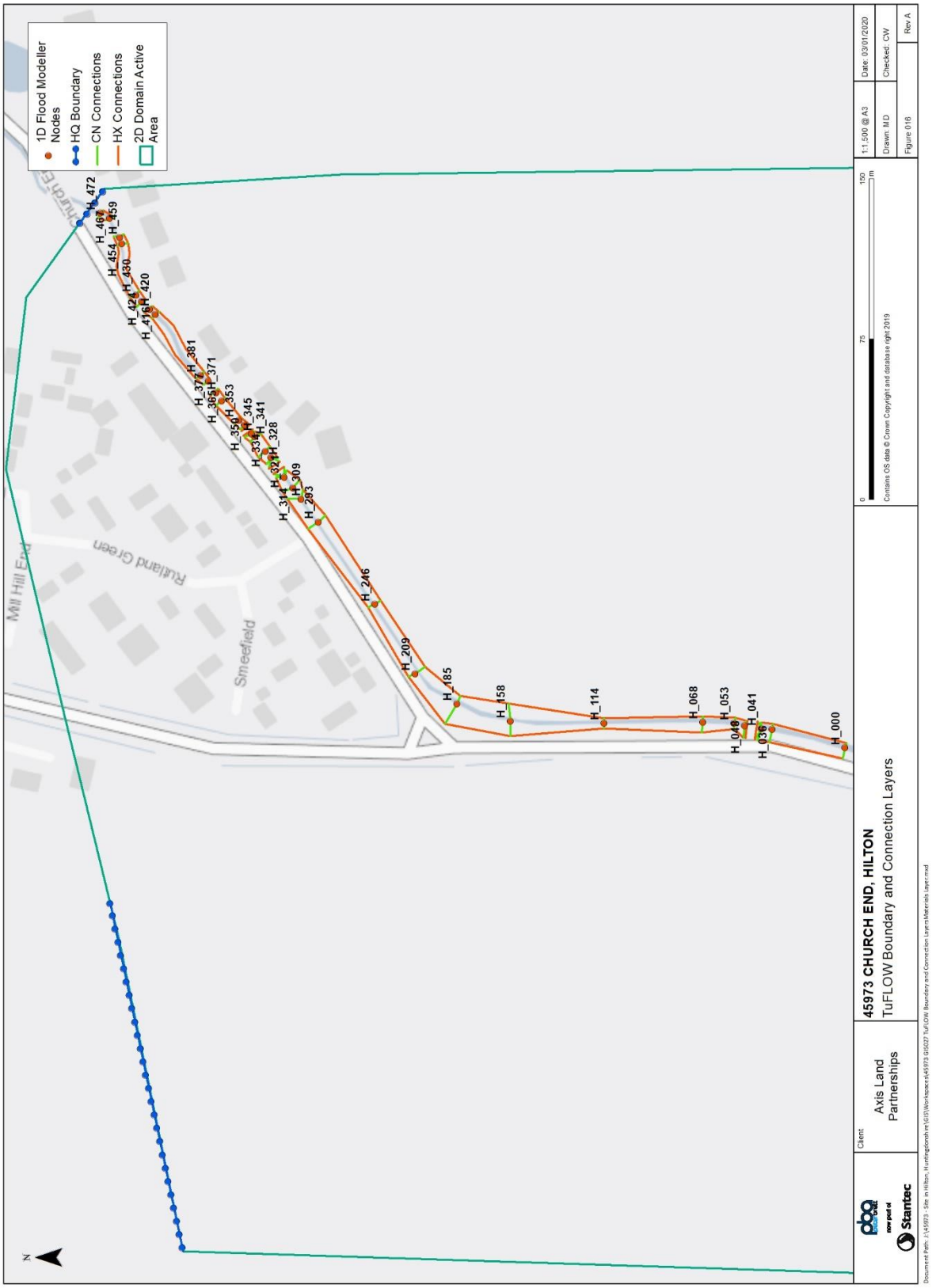

Figure 14: TuFLOW boundary and connection layers

4.4 Sensitivity Testing

4.4.1 Sensitivity testing was undertaken to identify how the results responded to changes in assumptions regarding Manning's roughness values and culvert blockage.

4.4.2 Four sensitivity tests were carried out:

- Manning's roughness values were increased and decreased by 20% in both the 1D and 2D domains.
- The two culverts (H_041 and H_371) were simultaneously modelled with 20% and 50% blockages. Blockages were modelled by using a blockage unit with respective blockage proportions (20% and 50%); loss coefficients are displayed in Table 5.

Inlet Loss Coefficient	Outlet Loss Coefficient
1.5	1

Table 5: Loss coefficients used in blockage units

4.4.3 The baseline 1% (1 in 100) AEP scenario was used in such sensitivity tests.

4.5 Simulation Details

4.5.1 Firstly, the critical storm duration was evaluated through simulating the 1% (1 in 100) AEP event with various durations, ranging from 4 to 18 hours. The maximum flood peak occurred for the 10-hour event, the variation between this duration with the others was relatively small with the greatest difference being ~0.35m^{3}s^{-1} (Figure 15).

4.5.2 The simulations utilised FMP version 4.5.7 and TuFLOW version 2018-03-AE; simulation parameters are summarised in Table 5.

4.5.3 Non-convergence and mass balance errors were assessed for each simulation, these were found to be acceptable (Table 7).

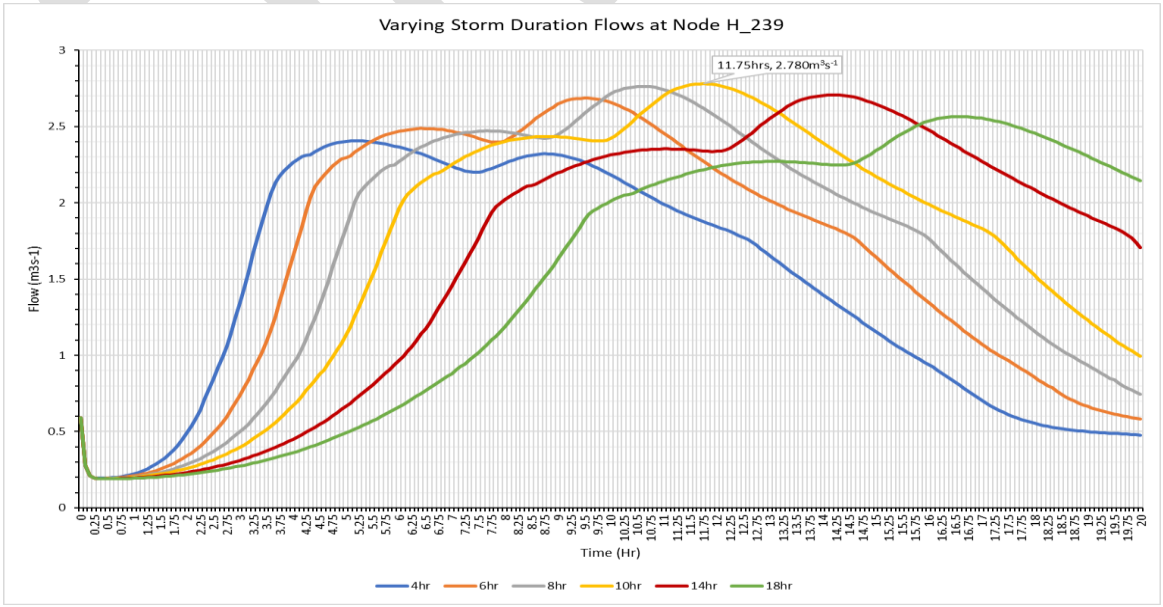

Figure 15: Timeseries plot of flow at FMP node H_246 for each modelled storm durations

	1D FMP	2D TuFLOW
Simulation duration	25 hours	25 hours
Timestep	0.5 seconds	1 second
Simulation parameters	▪ Double precision version	▪ Double precision version

Table 6: Simulation Parameters

Scenario	Event (AEP)	1D non-convergence (%)	1D Mass Balance (%)	2D Mass Balance (%)
Baseline	1%	0.00	-0.04	-1.22
	1%+65%	0.00	-0.33	-1.30
	0.1%	0.00	-0.30	-1.30
Manning's +20%	1%	0.00	-0.11	-1.25
Manning's -20%	1%	0.00	0.03	-0.96
Culvert 20% Blockage	1%	0.00	-0.04	-1.26
Culvert 50% Blockage	1%	0.00	-0.40	-1.33

Table 7: Mass Balance Errors

4.6 Limitations

4.6.1 The limitations of the modelling approach include:

- Surface water drains have not been included in the model.
- The drain to the left of the B1040 road on the opposite side to the proposed site was not included in the model. This would influence inflow, as the proportion of inflow from this side of the road would likely flow into this other drain, and flooding to the left of the road, which would be underestimated.

4.6.2 Due to such limitations, this give a conservative estimate for flooding in the area to the right of the B1040 and the proposed site.

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5 Results

5.1 Baseline Model

5.1.1 Figure 16 to 18 illustrate the baseline flood depths and extents for each of the modelled events, with Figure 19 comparing the different flood extents; detailed results are included in Appendix D.

5.1.2 Flooding is caused by restriction of flow due to the small size of the two culverts. This results in the backing up of water, firstly to the north-east where water is forced into the gully before flowing out of bank along the drain and gully into the site; secondary, water backs up and overtops banks from the culvert to the south-west then flow across the site, and into the drain and field to the left of the road. The areas either side of the road are flat and low-lying, therefore this flood water is stored on such floodplains until the peak has surpassed, only then do levels begin to recede.

5.2 Sensitivity Testing

5.2.1 Flood maps and detailed results for each of the sensitivity tests are contained in Appendix D and Appendix E respectively.

5.2.2 A 20% increase in Manning's roughness indicated typical increases in flood levels of 0.030m-0.034m in the north-east corner of the proposed site, and ~0.005m-0.009m for the rest of the site. On the other hand, a 20% decrease in Manning's roughness resulted in lower levels with reductions of 0.016m-0.020m and ~0.008, for the north-east corner and rest of the proposed site respectively. These changes are small and indicate that flood levels are not sensitive to Manning's roughness assumptions.

5.2.3 The impacts of blockages were also small. When both culverts were blocked to 20%, there was an increase of up to 0.04 m in the north east corner of the site, but elsewhere levels were increased by only 0.012 m. For the 50% blockage scenario, peak increases of up to 0.052 m occurred in the north east corner of the site, with levels elsewhere raised by about 0.02 m. These changes are small and indicate that culvert blockage does not significantly increase flood risk to the site.

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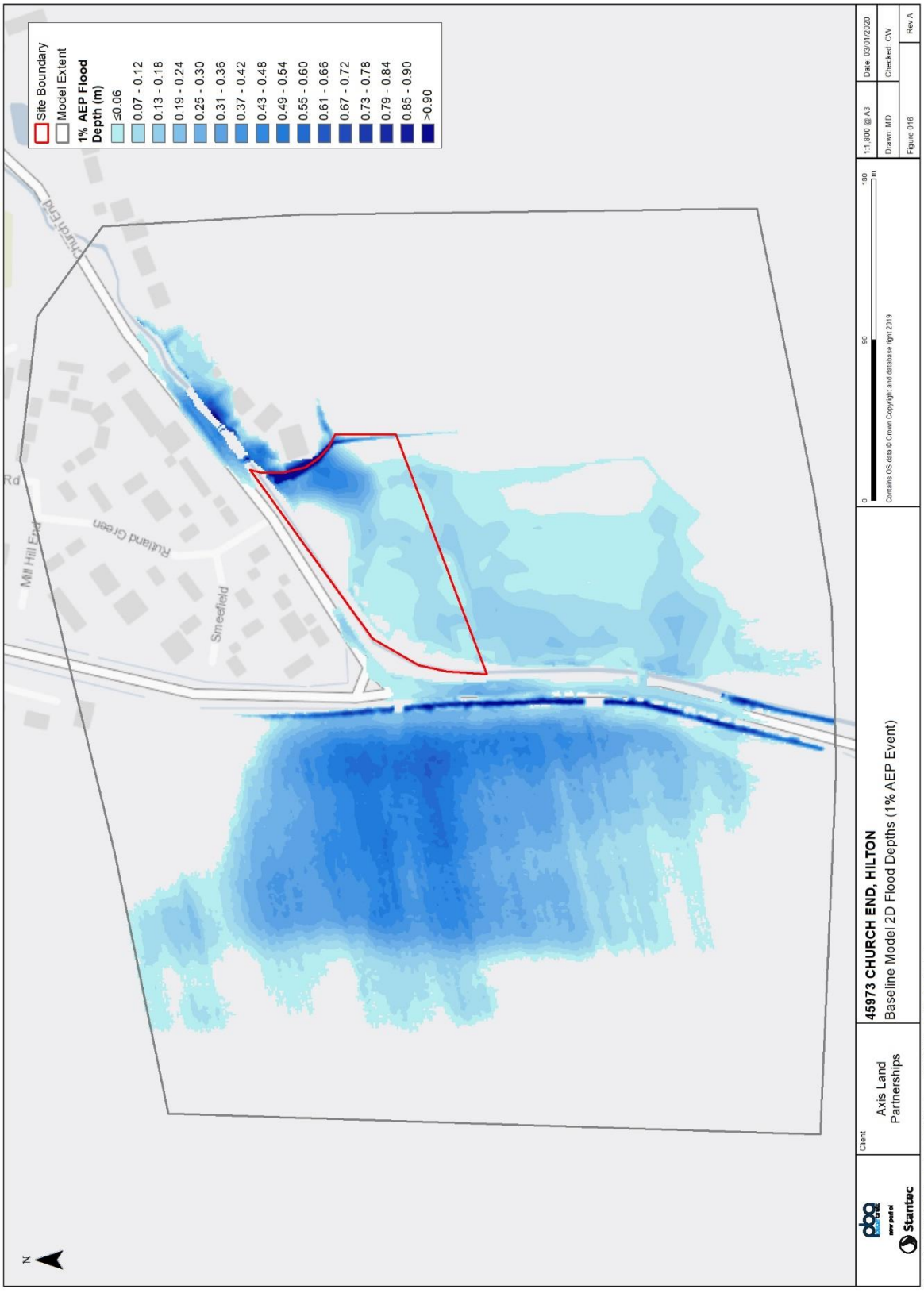

Figure 16: Baseline scenario: 1% AEP Flood Depths

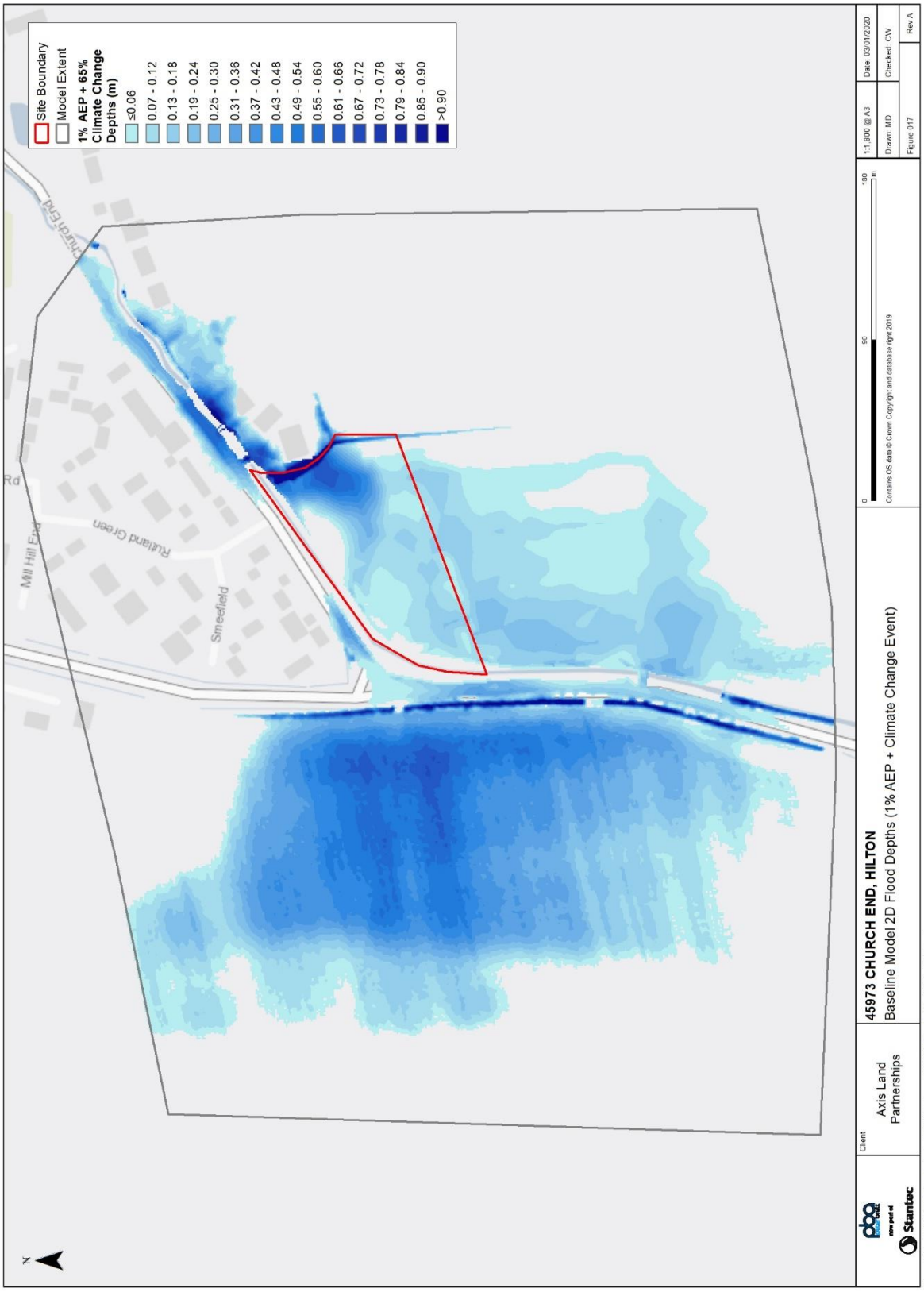

Figure 17: Baseline scenario: 1% AEP +65% Flood Depths

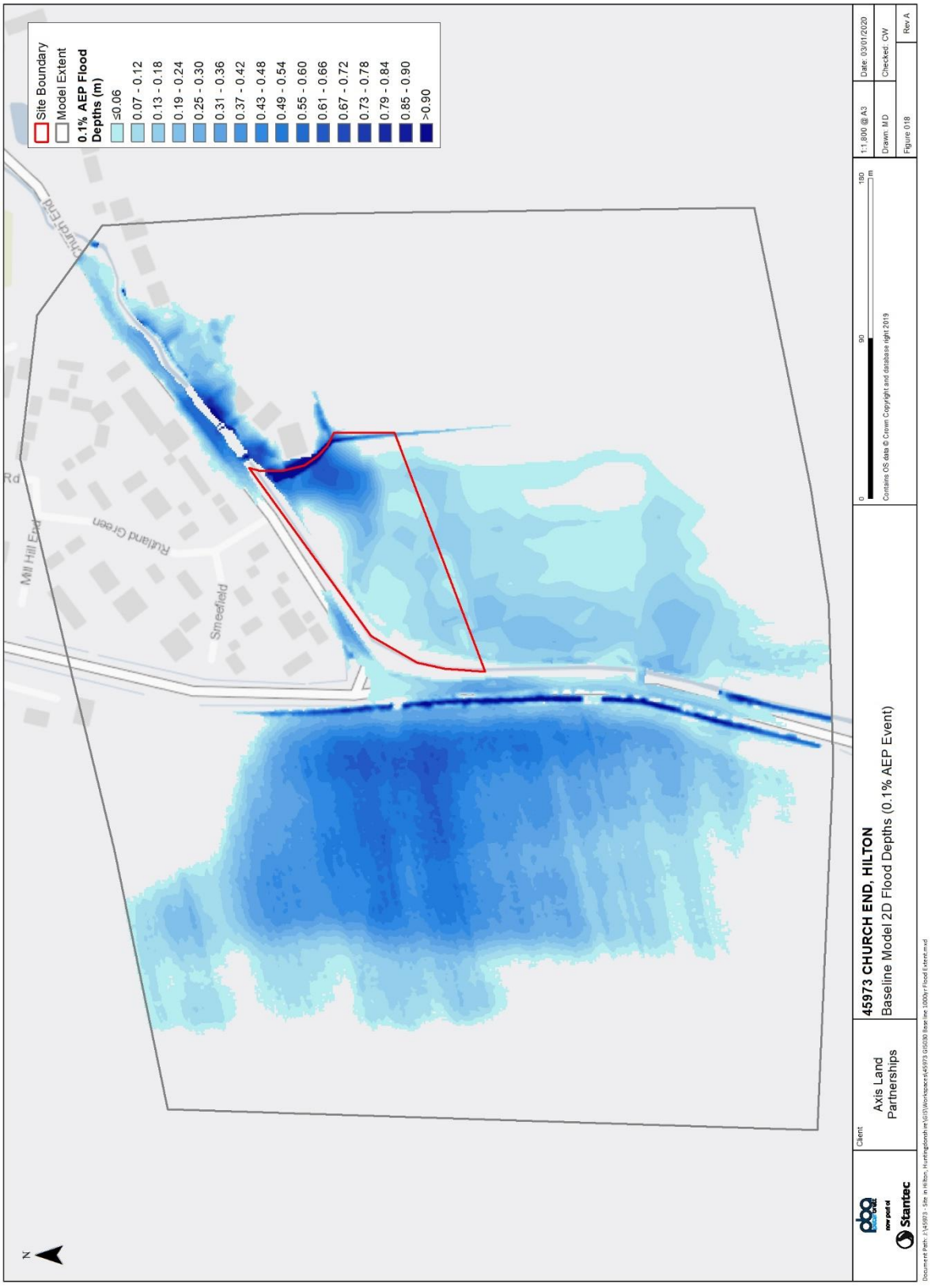

Figure 18: Baseline scenario: 0.1% AEP Flood Depths

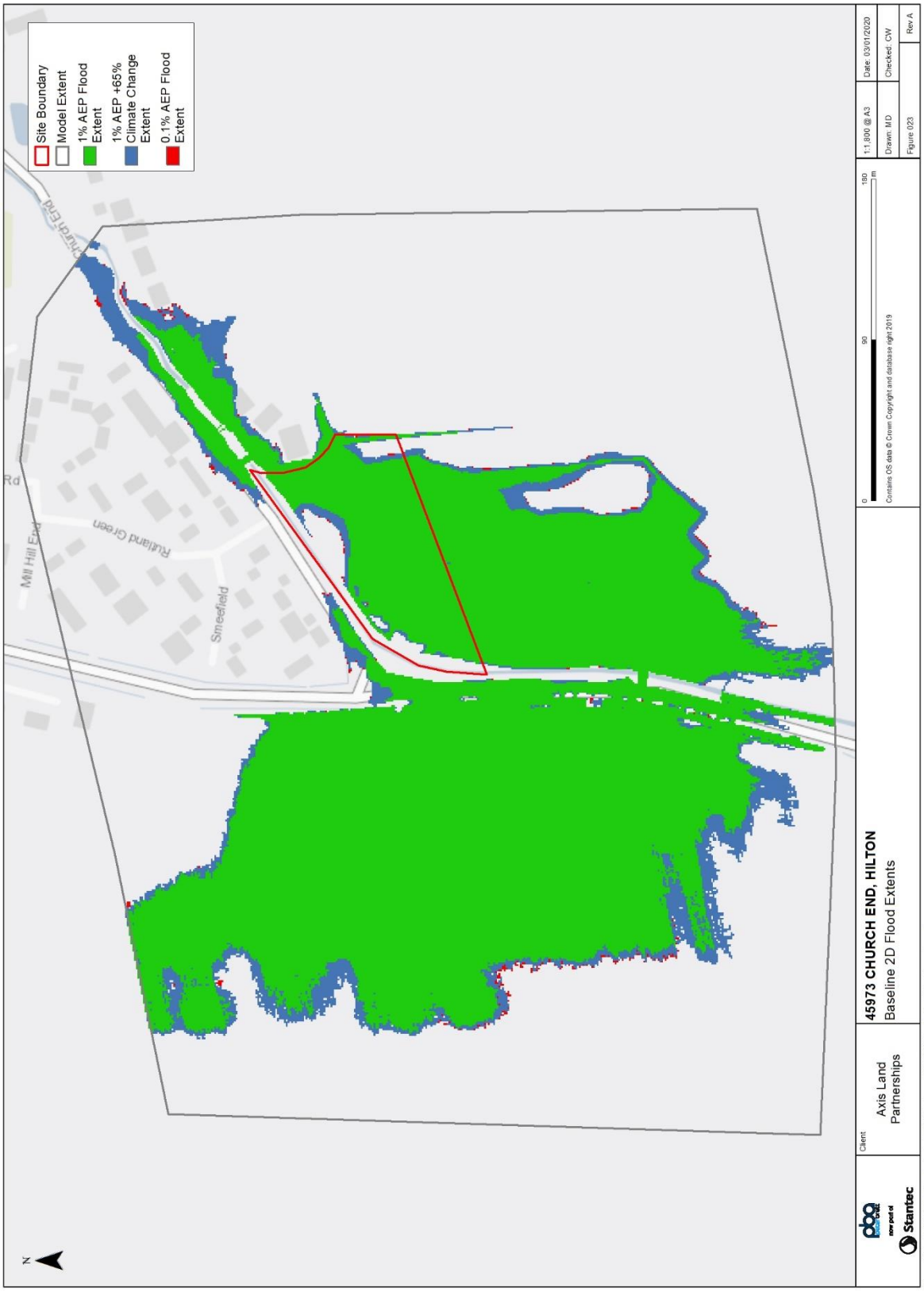

Figure 19: Baseline Flood Extents Comparison

Model Run	Flood Event	Peak Flood Volume within Floodplain 1 (m^3)	Peak Flood Volume within Floodplain 2 (m^3)
Baseline	1% AEP	7,817	42,966
	1% AEP +65%	11,769	52,667
	0.1% AEP	11,942	53,029
+20% Manning's n	1% AEP	8,540	45,682
-20% Manning's n	1% AEP	7,154	39,645
Culvert 20% Blockage	1% AEP	9,014	46,500
Culvert 50% Blockage	1% AEP	9,801	48,817

Table 8: Peak Flood Volumes (m^3) for all Baseline Model Runs

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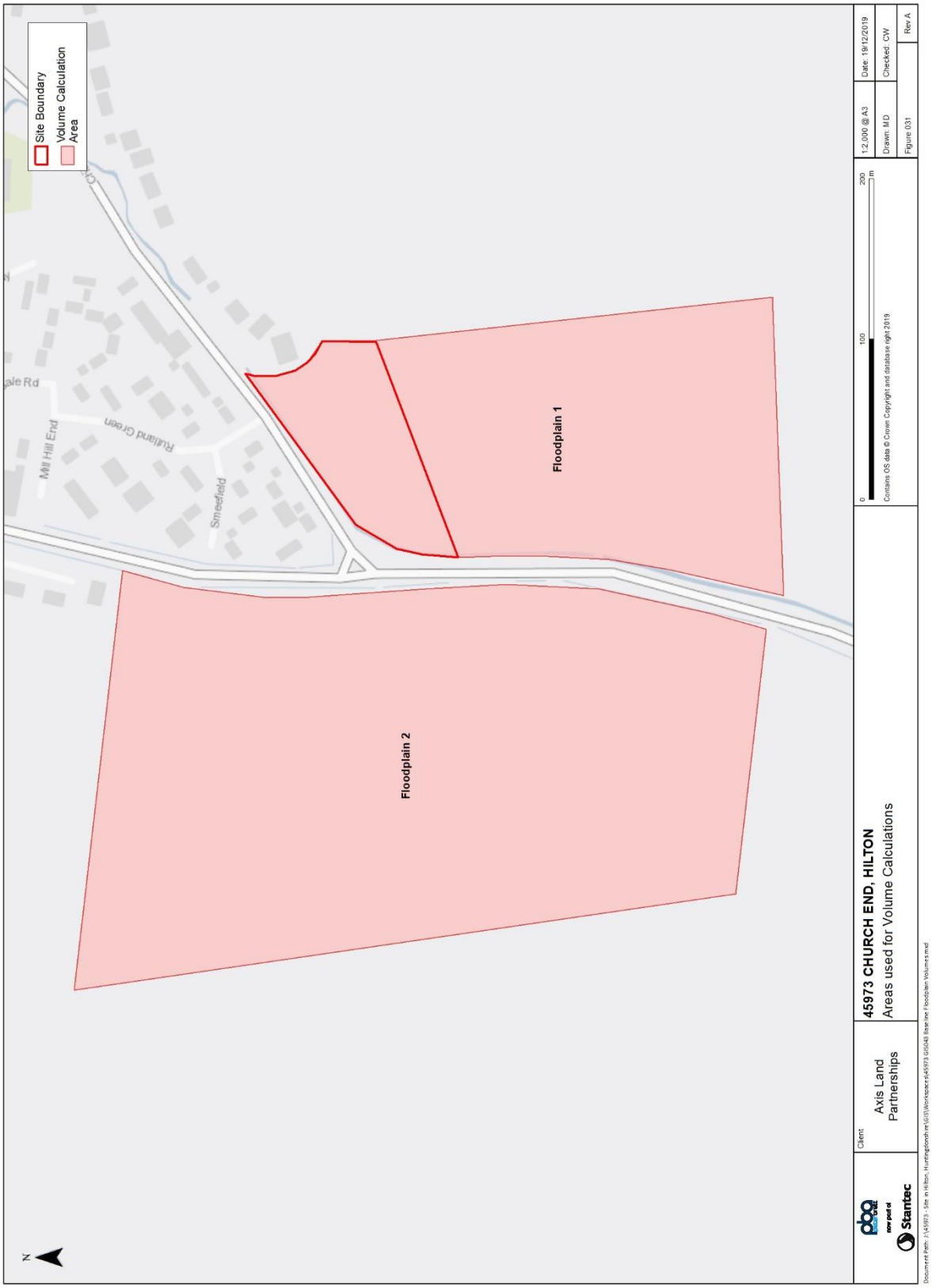

Figure 20: Areas used to Calculate Volume during Flooding

6 Conclusions

6.1 Conclusions

6.1.1 The modelling has indicated that the site is at risk of flooding during 1% (1 in 100), 1% (1 in 100) +65% climate change and 0.1% (1 in 1000) AEP events. However, the risk of flooding is not sensitive to culvert blockages or channel roughness, although adequate channel and structure maintenance and removal of vegetation should nevertheless be included within the development proposals.

6.1.2 Modelling of mitigation measures is now required to identify solutions that will reduce the risk of flooding to the site with no detrimental impacts on third party land upstream or downstream of the site.

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Appendix A Topographic Survey

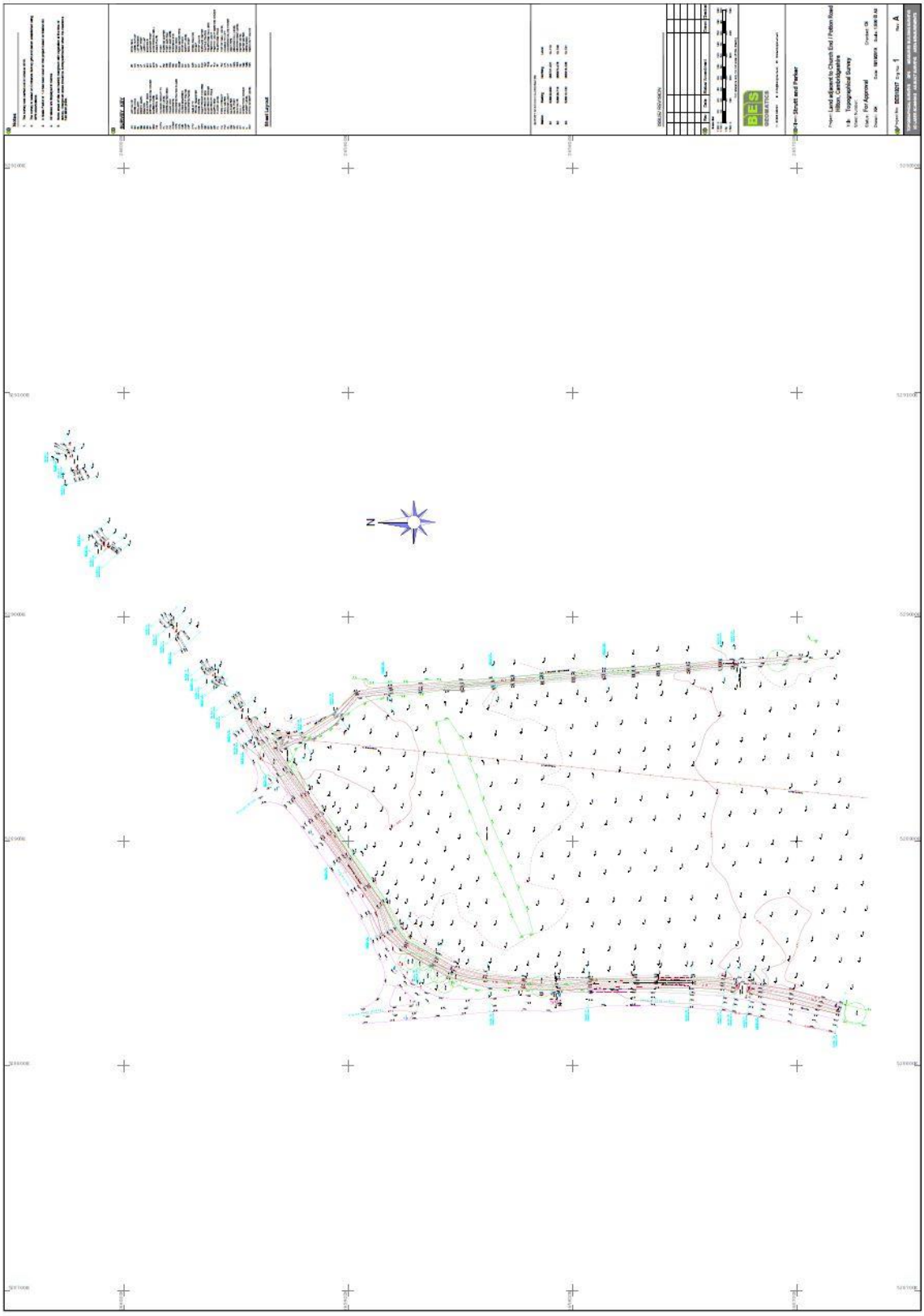

Figure 21: Site Topographic Survey

Appendix B Hydrology Calculation Record

Flood estimation calculation record for single sites

Introduction

This document is a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at a single location.

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Approval

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:	FvA	FvA	N/A

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Calculations checked by:	CW	CW	N/A
Calculations approved by:	CW	CW	N/A

Environment Agency competence levels are covered in Section 2.1 of the flood estimation guidelines:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

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Abbreviations

AM	Annual Maximum
AREA	Catchment area (km^2)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

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1 METHOD STATEMENT

1.1 Overview of requirements for flood estimate

Item	Comments
Give an overview which includes: • Purpose of study • Peak flow or hydrograph? • Range of return periods • Approx. time available	The purpose of the study is to create hydrograph inflows for a site south of Hilton, Cambridgeshire. The return periods required for the modelling are 100yr and 1000yr, with climate change to be added within the model.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	The catchment lies between Cambridge and Huntington, to the south of Hilton. The total catchment size is 3.2 km^2 and therefore a small catchment. The catchment land use is agricultural, with small pockets of sub-urban areas. The catchment soils are lime-rich loamy and clayey soils with impeded drainage.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? Record any changes made.	Yes – Version 7 (although version 8 was released during the study, the analysis was not updated as the statistical method was not selected).

1.4 Gauging stations (flow or level)

The site is ungauged. The NRFA was used to search for nearby gauges that could be potential donors.

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
Great Ouse	Bedford Ouse at Offord	33026	33026	TL313705	2860	Broad crested weir	01/1936 - N/A
Great Ouse	Alconbury Brook at Brampton	33020	33020	TL216669	2570	Offord Flow	01/1970 - N/A

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1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality – e.g. information from HiFlows-UK, trends in flood peaks, outliers.
Bedford Ouse at Offord	01/1936 - N/A	No	No	No	No	Rejected as the site is a considerable distance away, is a large catchment and is not suitable for QMED
Alconbury Brook at Brampton	01/1970 - N/A	No	No	No	No	Rejected as the site is a considerable distance away, is a large catchment and is not suitable for QMED
Give link/reference to any further data quality checks carried out			N/A			

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons – e.g. availability of recent flow gaugings, amount of scatter in the rating.
33026	N/A	N/A	N/A – site not used
33020	N/A	N/A	N/A – site not used
Give link/reference to any rating reviews carried out		N/A	

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data and licence reference if from EA	Date obtained	Details
Check flow gaugings (if planned to review ratings)	No	N/A	N/A	N/A	Watercourse is ungauged.
Historic flood data – give link to historic review if carried out.	Yes	No	N/A	N/A	No known history of flooding – catchment is small and rural.
Flow data for events	Yes	No	N/A	N/A	Watercourse is ungauged.
Rainfall data for events	Yes	No	N/A	N/A	Watercourse is ungauged.
Potential evaporation data	No	N/A	N/A	N/A	Watercourse is ungauged.
Results from previous studies (e.g. CFMPs, Strategies)	Yes	No	N/A	N/A	No previous modelling undertaken at this site. No details for this catchment included in CFMP or SFRA.

Other data or information (e.g. groundwater, tides)	No	N/A	N/A	N/A	Catchment is not permeable or in a tidal area.

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	FEH methods are appropriate. Although the site is small and ungauged, the latest Small Catchments study outcomes from the Environment Agency indicate that the FEH methods are preferable to alternatives such as the IoH124 methods.
Outline the conceptual model, addressing questions such as: • What is likely to cause flooding at the site (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might the site flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	Flooding at the site is likely due to peak flows exceeding the channel and structure capacities. There may be backing up of water from small culverts and bridges immediately downstream of the site, and also potential overland flow affecting the site from rural land to the south. The site is not downstream of a reservoir. There is no need to consider temporary debris dams.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	The catchment is not highly permeable, highly urbanised, pumped, with major reservoir influence or extensive floodplain storage.
Initial choice of method(s) and reasons	The ReFH2 rainfall runoff method will be used to generate inflow hydrographs. The FEH statistical method has also been calculated for comparison.
Software to be used (with version numbers)	ReFH version 2.3 WINFAP version 4

1.9 Site details

Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
Hilton Drain	Site south of Hilton, Cambridgshire	528950	265900	2.495	3.198

1.10 Catchment descriptors (incorporating any changes made)

FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT	FPEXT
1	0.24	0.29 (FEH 0.312)	1.89 (FEH 1.77)	35.144 (FEH 24.2)	545	52.47	0.0616 (FEH 0.0105)	0.1192

1.11 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	The catchment boundary was checked using LiDAR data to estimate the catchment using flow directions and with the IDB's drain network. The catchment boundary was seen to be similar with some extra flows to the west.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	The BFIHOST was recalculated using the soil association maps, The new BFIHOST was seen to have very little difference to the value within the FEH webservice catchment descriptors. The DPLBAR was calculated using the estimation method lane out in FEH where DPLBAR=$Area^{0.548}$. The DPSBAR was estimated by calculating the average slope of the LiDAR within the catchment.
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from FEH Volume 4

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2 STATISTICAL METHOD

2.1 Search for donor sites for QMED

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, URBEXT, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	Three potential donor sites within 10km of the site. All sites are not suitable for QMED or pooling. The smallest site has a catchment of 200km2 

2.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
33017	Rejected – Rejected as the catchment is a large catchment and is not suitable for QMED					
33026	Rejected – Rejected as the catchment is a large catchment and is not suitable for QMED					
33020	Rejected – Rejected as the catchment is a large catchment and is not suitable for QMED					
Which version of the urban adjustment was used for QMED at donor sites, and why? Note: The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8).				WINFAP-FEH v4		

2.3 Overview of estimation of QMED

Method	Initial estimate of QMED (m^3/s)	Data transfer						Final estimate of QMED (m^3/s)
		NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B)[a]	If more than one donor		
						Weight	Weighted average adjustment factor	
CD	0.554							0.554

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Which version of the urban adjustment was used for QMED, and why?	WINFAP-FEH v4

Notes
Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.
When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added.
When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050**Error! Bookmark not defined.** should be used. If the original FEH equation has been used, say so and give the reason why.
The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data.
The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.
If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

2.4 Derivation of pooling group

The composition of the pooling group is given in the Annex.

Subject site treated as gauged? (enhanced single site analysis)	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments**, L-CV and L-skew, (before urban adjustment)
No	49005 and 49004 removed 46010 added	L-CV 0.258 L-SKEW 0.24

Notes
The pooling group was derived using the revised procedures from Science Report SC050050 (2008).
The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.

2.5 Derivation of flood growth curves

Method (SS, P, ESS, J)	**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**
P	GL	None	See annex	3.118

Notes
Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis
Urban adjustments to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).
Growth curves were derived using the revised procedures from Science Report SC050050 (2008).

2.6 Flood estimates from the statistical method

Flood peak (m^3/s) for the following return periods (in years)								
2	**5**	**10**	**20**	**30**	**50**	**100**	**200**	**1000**
0.554	0.783	0.958	1.155	1.284	1.464	1.746	2.080	3.118

3 REVITALISED FLOOD HYDROGRAPH (REFH) METHOD

3.1 Parameters for ReFH model

Note: If parameters are estimated from catchment descriptors, they are easily reproducible, so it is not essential to enter them in the table.

Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	**Tp (hours)** Time to peak	**C_{max} (mm)** Maximum storage capacity	**BL (hours)** Baseflow lag	**BR** Baseflow recharge
CD	-	-	-	-
Brief description of any flood event analysis carried out (further details should be given below or in a project report)	-			

3.2 Design events for ReFH method

Urban or rural	**Season of design event (summer or winter)**	**Storm duration (hours)**	**Storm area for ARF** (if not catchment area)
Rural	Winter	6 hrs	0.97

3.3 Flood estimates from the ReFH method

Flood peak (m^3/s) for the following return periods (in years)								
2	**5**	**10**	**30**	**50**	**75**	**100**	**200**	**1000**
1.35	1.89	2.32	3.15	3.65	4.11	4.47	5.40	7.63

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4 DISCUSSION AND SUMMARY OF RESULTS

4.1 Comparison of results from different methods

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

Return period 2 years		Return period 100 years	
ReFH2	**Pooled Statistical**	**ReFH2**	**Pooled Statistical**
1.35	0.554	4.47	1.746

4.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	ReFH2 – The catchment is small and ungauged therefore making it difficult to find an appropriate donor site or pooling group. The ReFH2 values are the most conservative values.

4.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Catchment is ungauged and therefore catchment descriptors have been used to estimate flows. While efforts have been made to check and improve the descriptors, the residual uncertainty remains high.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	No particular limitations.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH **3** 12.5 or the factorial standard error from Science Report SC050050 (2008).	<table><tr><th>Flow Node</th><th>Final QMED (m^3/s)</th><th>65% Lower</th><th>65% Upper</th><th>95% Lower</th><th>95% Upper</th></tr><tr><td>DSBD</td><td>0.583</td><td>0.50</td><td>0.68</td><td>0.43</td><td>0.79</td></tr></table> The table above gives confidence limits for the statistical method. The ReFH flow estimate lies outside the 95% upper confidence limit, indicating high uncertainty in flows.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The results should be reviewed before application at other sites or other purposes.
Give any other comments on the study, for example suggestions for additional work.	No additional work suggested.

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4.4 Checks

What do the results imply regarding the return periods of floods during the period of record?	No history of flooding for comparison.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	3.31 Yes similar growth factor for pooled method
If 1000-year flows have been derived, what is the ratio for 1000-year flow over 100-year flow?	1.70
What specific runoff (l/s/ha) does the design flow equate to?	Not required
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No other studies available.
Are the results compatible with the longer-term flood history?	No longer term flood history available.
Describe any other checks on the results	QA checks undertaken on calculation inputs and outputs.

4.5 Final results

Flood peak (m^3/s) for the following return periods (in years)								
2	**5**	**10**	**30**	**50**	**75**	**100**	**200**	**1000**
1.35	1.89	2.32	3.15	3.65	4.11	4.47	5.40	7.63

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Appendix C Site Photographs

Section (Structure)	Upstream	Downstream	Manning's Roughness
1			0.03
2 (Bridge)			0.03
3 (Bridge)			0.03
4			0.03

5			0.04
6 (Bridge)			0.04
7 (Bridge)			0.04
8			0.04
10 (Culvert)			0.04

11 (Culvert)			0.04
12			0.04
13			0.04
14 (Bridge)			0.04
15 (Bridge)			0.035

16			0.03
17			0.03
18 (Bridge)			0.03
19 (Bridge)			0.03
20			0.03

21			0.03
22			0.03
23			0.04
24			0.04
25			0.035

26			0.045
27			0.06
28			0.06
29			0.035
30 (Culvert)			0.04

31 (Culvert)			0.04
32			0.04

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Appendix D Tables of Detailed Results

	Model Run						
	Baseline			+20% Manning's n	-20% Manning's n	Culvert 20% Blockage	Culvert 50% Blockage
Flood Event	1% AEP	1% AEP +65%	0.1% AEP	1% AEP	1% AEP	1% AEP	1% AEP
H_000	14.19	14.23	14.23	14.22	14.16	14.21	14.22
H_036	14.20	14.25	14.25	14.21	14.19	14.22	14.23
H_041	14.21	14.29	14.30	14.22	14.21	14.23	14.24
H_048	13.66	13.85	13.86	13.73	13.58	13.60	13.50
H_053	13.64	13.83	13.84	13.71	13.56	13.58	13.49
H_068	13.61	13.80	13.81	13.68	13.53	13.55	13.46
H_114	13.37	13.62	13.63	13.45	13.27	13.36	13.32
H_158	13.21	13.47	13.48	13.29	13.13	13.23	13.23
H_185	13.15	13.38	13.39	13.22	13.08	13.17	13.17
H_209	13.12	13.36	13.37	13.19	13.06	13.14	13.15
H_246	13.04	13.19	13.19	13.08	13.00	13.06	13.08
H_293	13.00	13.15	13.16	13.03	12.98	13.03	13.06
H_309	12.99	13.12	13.13	13.02	12.97	13.03	13.05
H_314	12.97	13.03	13.03	13.00	12.95	13.01	13.03
H_321	13.01	13.17	13.18	13.03	13.00	13.04	13.06
H_321_Spl_U	13.01	13.17	13.18	13.03	13.00	13.04	13.06
H_321_Spl_D	12.99	13.15	13.16	13.02	12.98	13.03	13.05
H_328	12.99	13.15	13.16	13.02	12.98	13.03	13.05
H_334	12.98	13.13	13.13	13.00	12.90	13.01	13.03
H_341	12.97	13.09	13.09	12.99	12.84	13.00	13.02
H_345	12.99	13.14	13.15	13.01	12.97	13.02	13.04
H_345_Spl_U	12.99	13.14	13.15	13.01	12.97	13.02	13.04
H_345_Spl_D	12.97	13.11	13.12	12.99	12.94	13.00	13.02
H_350	12.97	13.11	13.12	12.99	12.94	13.00	13.02
H_353	12.97	13.12	13.12	12.99	12.94	13.00	13.02
H_365	12.96	13.10	13.11	12.98	12.94	12.99	13.01
H_371	12.97	13.12	13.13	12.99	12.95	13.01	13.03
H_377	12.54	12.86	12.87	12.60	12.44	12.56	12.57
H_381	12.52	12.84	12.85	12.57	12.41	12.53	12.55
H_416	12.43	12.69	12.69	12.48	12.32	12.45	12.46
H_420	12.41	12.77	12.78	12.47	12.30	12.43	12.44
H_424	12.02	12.37	12.38	12.09	11.91	12.03	12.04
H_430	11.87	12.12	12.13	11.95	11.81	11.88	11.88
H_454	11.76	11.98	11.99	11.78	11.73	11.77	11.77
H_459	11.67	11.89	11.91	11.70	11.65	11.68	11.68
H_467	11.50	11.67	11.68	11.56	11.42	11.50	11.51
H_472	11.37	11.54	11.54	11.43	11.29	11.37	11.38
Lat_Inflow	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lat_Inflow2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Culv_01_US	13.73	13.91	13.92	13.79	13.66	13.64	13.52
Culv_01_DS	13.66	13.85	13.86	13.73	13.58	13.60	13.50

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Culv_02_US	12.60	12.90	12.91	12.65	12.51	12.59	12.58
Culv_02_DS	12.54	12.86	12.87	12.60	12.44	12.56	12.57
Lat_01_L	14.19	14.23	14.23	14.22	14.16	14.21	14.22
Lat_02_R	14.20	14.25	14.25	14.21	14.19	14.22	14.23
Lat_02_L	14.20	14.25	14.25	14.21	14.19	14.22	14.23
Lat_03_R	13.66	13.85	13.86	13.73	13.58	13.60	13.50
Lat_03_L	13.66	13.85	13.86	13.73	13.58	13.60	13.50
Lat_04_R	13.64	13.83	13.84	13.71	13.56	13.58	13.49
Lat_04_L	13.64	13.83	13.84	13.71	13.56	13.58	13.49
Lat_05_R	13.61	13.80	13.81	13.68	13.53	13.55	13.46
Lat_05_L	13.61	13.80	13.81	13.68	13.53	13.55	13.46
Lat_06_R	13.37	13.62	13.63	13.45	13.27	13.36	13.32
Lat_06_L	13.37	13.62	13.63	13.45	13.27	13.36	13.32
Lat_07_R	13.21	13.47	13.48	13.29	13.13	13.23	13.23
Lat_07_L	13.21	13.47	13.48	13.29	13.13	13.23	13.23
Lat_08_R	13.15	13.38	13.39	13.22	13.08	13.17	13.17
Lat_08_L	13.15	13.38	13.39	13.22	13.08	13.17	13.17
Lat_09_R	13.12	13.36	13.37	13.19	13.06	13.14	13.15
Lat_10_R	13.04	13.19	13.19	13.08	13.00	13.06	13.08
Lat_11_R	13.00	13.15	13.16	13.03	12.98	13.03	13.06
Lat_12_R	12.99	13.12	13.13	13.02	12.97	13.03	13.05
H_321_Bg_U	13.01	13.17	13.18	13.03	13.00	13.04	13.06
H_321_Bg_D	12.99	13.15	13.16	13.02	12.98	13.03	13.05
H_345_Bg_U	12.99	13.14	13.15	13.01	12.97	13.02	13.04
H_345_Bg_D	12.97	13.11	13.12	12.99	12.94	13.00	13.02
Lat_01_R	14.19	14.23	14.23	14.22	14.16	14.21	14.22
Culv_01_D	13.66	13.85	13.86	13.73	13.58	13.60	13.50
Culv_01_U	14.21	14.29	14.30	14.22	14.21	14.23	14.24
Culv_1_Spl_U	14.21	14.29	14.30	14.22	14.21	14.23	14.24
Culv_1_Spl_D	13.66	13.85	13.86	13.73	13.58	13.60	13.50

Table 9: Peak Level for every 1D Node

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	Model Run						
	Baseline			+20% Manning's n	-20% Manning's n	Culvert 20% Blockage	Culvert 50% Blockage
Flood Event	1% AEP	1% AEP +65%	0.1% AEP	1% AEP	1% AEP	1% AEP	1% AEP
H_000	3.86	6.37	6.52	3.86	3.86	3.86	3.86
H_036	2.67	4.41	4.54	2.46	2.90	2.48	2.24
H_041	1.66	1.66	1.66	1.57	1.76	1.34	0.87
H_048	1.66	1.66	1.66	1.57	1.76	1.34	0.87
H_053	1.86	2.24	2.27	1.76	1.96	1.58	1.18
H_068	1.92	2.38	2.42	1.83	2.01	1.65	1.25
H_114	2.07	2.64	2.68	1.98	2.16	1.81	1.41
H_158	2.23	3.28	3.35	2.14	2.32	1.97	1.66
H_185	2.75	4.63	4.72	2.80	2.67	2.71	2.58
H_209	2.82	4.28	4.34	2.87	2.74	2.79	2.67
H_246	2.83	4.81	4.91	2.89	2.74	2.80	2.68
H_293	2.78	4.24	4.32	2.78	2.71	2.71	2.57
H_309	3.29	5.50	5.61	3.18	3.44	3.25	3.21
H_314	4.54	9.12	9.35	4.35	4.76	4.49	4.58
H_321	1.56	2.25	2.29	1.61	1.62	1.61	1.59
H_321_Spl_U	0.95	1.51	1.54	1.00	0.98	1.00	1.01
H_321_Spl_D	0.95	1.51	1.54	1.00	0.98	1.00	1.01
H_328	1.56	2.25	2.29	1.61	1.62	1.61	1.59
H_334	2.92	4.33	4.41	2.94	5.19	2.94	2.93
H_341	3.49	5.84	5.96	3.55	6.94	3.66	3.70
H_345	1.87	2.69	2.73	1.92	2.15	1.93	1.92
H_345_Spl_U	1.02	1.66	1.69	1.07	1.15	1.09	1.10
H_345_Spl_D	1.02	1.66	1.69	1.07	1.15	1.09	1.10
H_350	1.87	2.69	2.73	1.92	2.15	1.93	1.92
H_353	1.46	2.04	2.07	1.55	1.51	1.55	1.53
H_365	2.20	3.03	3.06	2.32	2.10	2.41	2.40
H_371	1.20	1.20	1.20	1.18	1.21	0.95	0.60
H_377	1.20	1.20	1.20	1.18	1.21	0.95	0.60
H_381	2.13	2.67	2.67	2.15	2.13	2.03	1.87
H_416	3.43	5.83	6.03	3.41	3.37	3.48	3.50
H_420	3.57	3.76	3.76	3.50	3.56	3.62	3.64
H_424	3.57	3.76	3.76	3.50	3.56	3.62	3.64
H_430	3.63	5.19	5.25	3.63	3.56	3.69	3.74
H_454	3.63	5.66	5.77	3.63	3.56	3.69	3.74
H_459	3.63	5.66	5.77	3.63	3.56	3.69	3.74
H_467	3.63	5.66	5.77	3.63	3.56	3.69	3.74
H_472	3.63	5.66	5.77	3.63	3.56	3.69	3.74
Lat_Inflow	0.18	0.30	0.31	0.18	0.18	0.18	0.18
Lat_Inflow2	0.70	1.15	1.18	0.70	0.70	0.70	0.70
Culv_01_US	1.66	1.66	1.66	1.57	1.76	1.34	0.87
Culv_01_DS	1.66	1.66	1.66	1.57	1.76	1.34	0.87
Culv_02_US	1.20	1.20	1.20	1.18	1.21	0.95	0.60
Culv_02_DS	1.20	1.20	1.20	1.18	1.21	0.95	0.60

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Lat_01_L	0.12	0.20	0.21	0.12	0.12	0.12	0.12
Lat_02_R	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Lat_02_L	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Lat_03_R	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Lat_03_L	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Lat_04_R	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Lat_04_L	0.05	0.09	0.09	0.05	0.05	0.05	0.05
Lat_05_R	0.03	0.05	0.05	0.03	0.03	0.03	0.03
Lat_05_L	0.16	0.26	0.27	0.16	0.16	0.16	0.16
Lat_06_R	0.03	0.04	0.04	0.03	0.03	0.03	0.03
Lat_06_L	0.15	0.25	0.26	0.15	0.15	0.15	0.15
Lat_07_R	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Lat_07_L	0.09	0.15	0.15	0.09	0.09	0.09	0.09
Lat_08_R	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Lat_08_L	0.08	0.14	0.14	0.08	0.08	0.08	0.08
Lat_09_R	0.02	0.04	0.04	0.02	0.02	0.02	0.02
Lat_10_R	0.03	0.05	0.05	0.03	0.03	0.03	0.03
Lat_11_R	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Lat_12_R	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H_321_Bg_U	1.03	1.03	1.02	1.02	1.03	0.92	0.61
H_321_Bg_D	1.03	1.03	1.02	1.02	1.03	0.92	0.61
H_345_Bg_U	1.07	1.07	1.08	1.07	1.07	0.95	0.82
H_345_Bg_D	1.07	1.07	1.08	1.07	1.07	0.95	0.82
Lat_01_R	0.02	0.04	0.04	0.02	0.02	0.02	0.02
Culv_01_D	1.66	1.66	1.66	1.57	1.76	1.34	0.87
Culv_01_U	1.66	1.66	1.66	1.57	1.76	1.34	0.87
Culv_1_Spl_U	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Culv_1_Spl_D	0.35	0.35	0.35	0.35	0.35	0.35	0.35

Table 10: Peak Flows for every 1D Node

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Appendix E Flood Maps

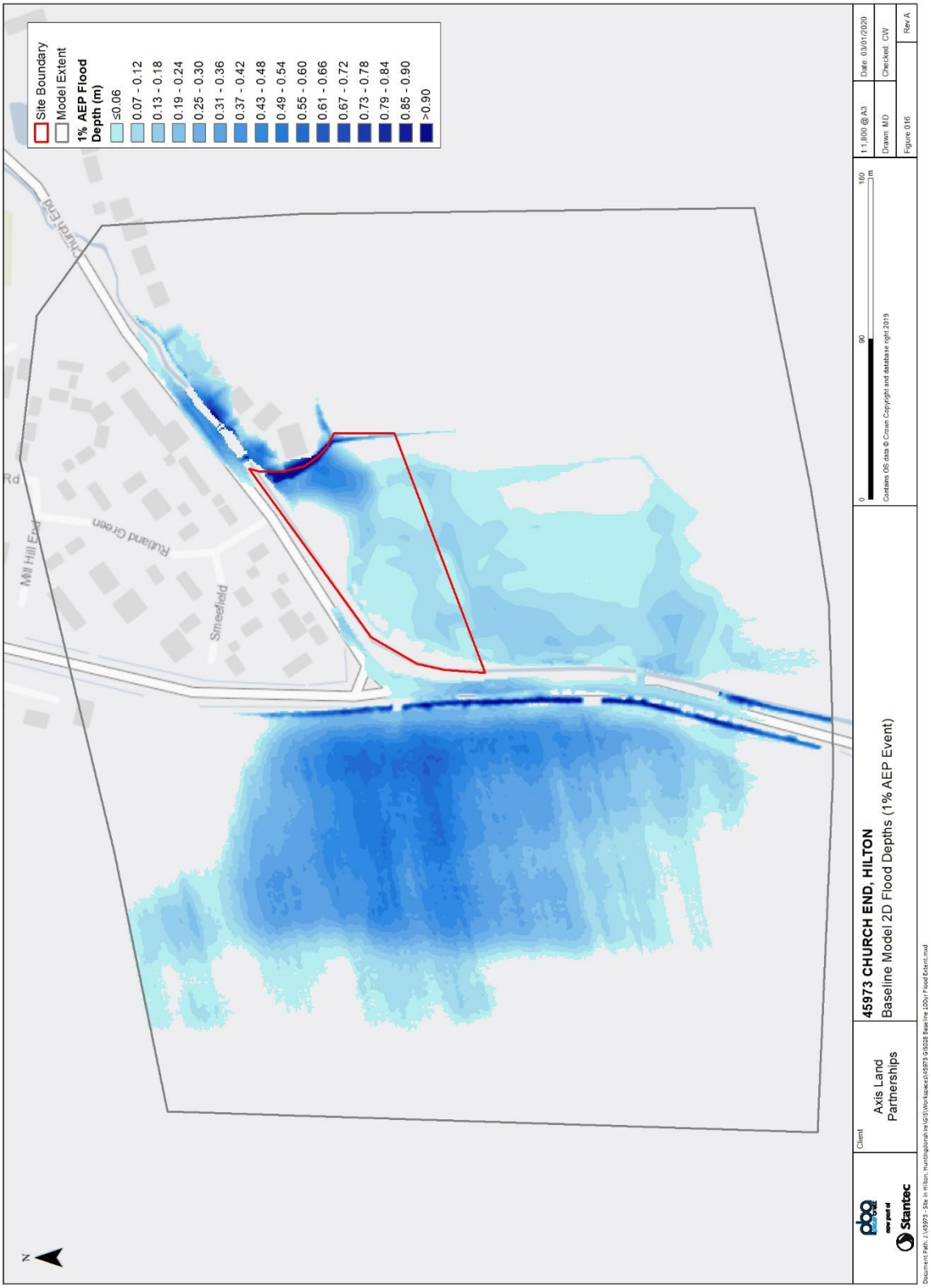


Figure 22: 1% Baseline Flood Depths

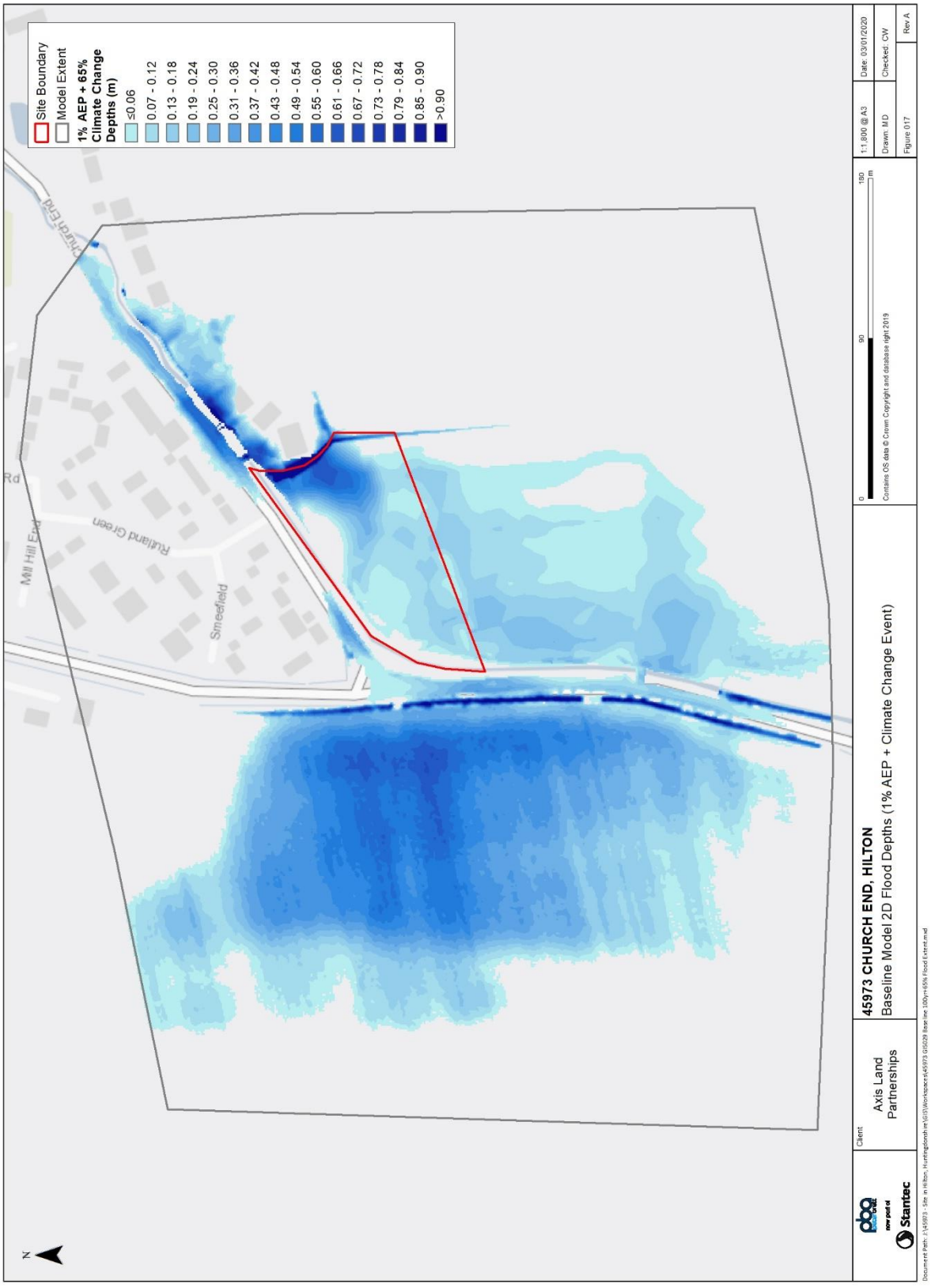


Figure 23: 1% Baseline Flood Depth + 65% Climate Change

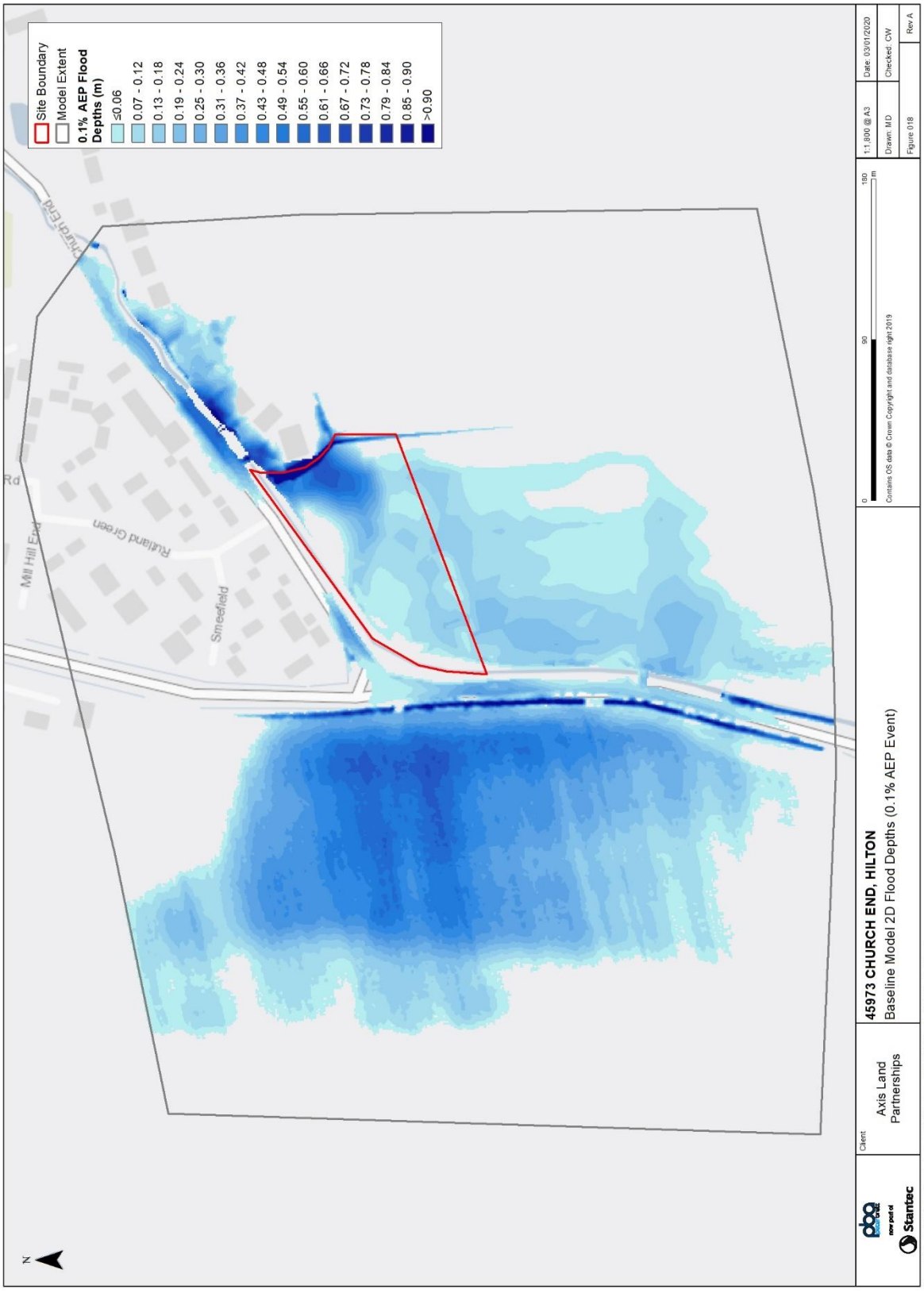


Figure 24: 0.1% Baseline Flood Depth

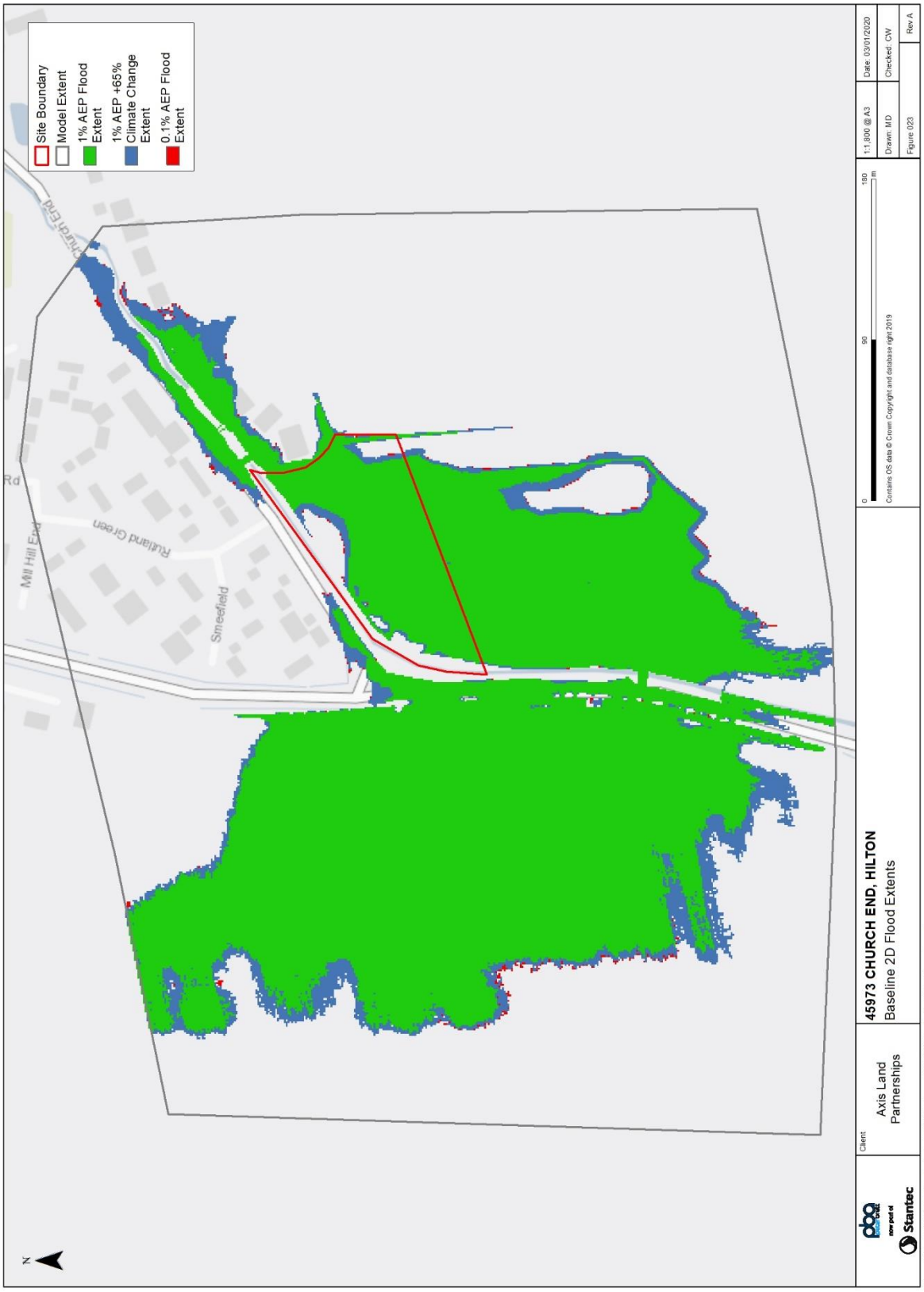


Figure 25: Baseline Flood Extents Comparison

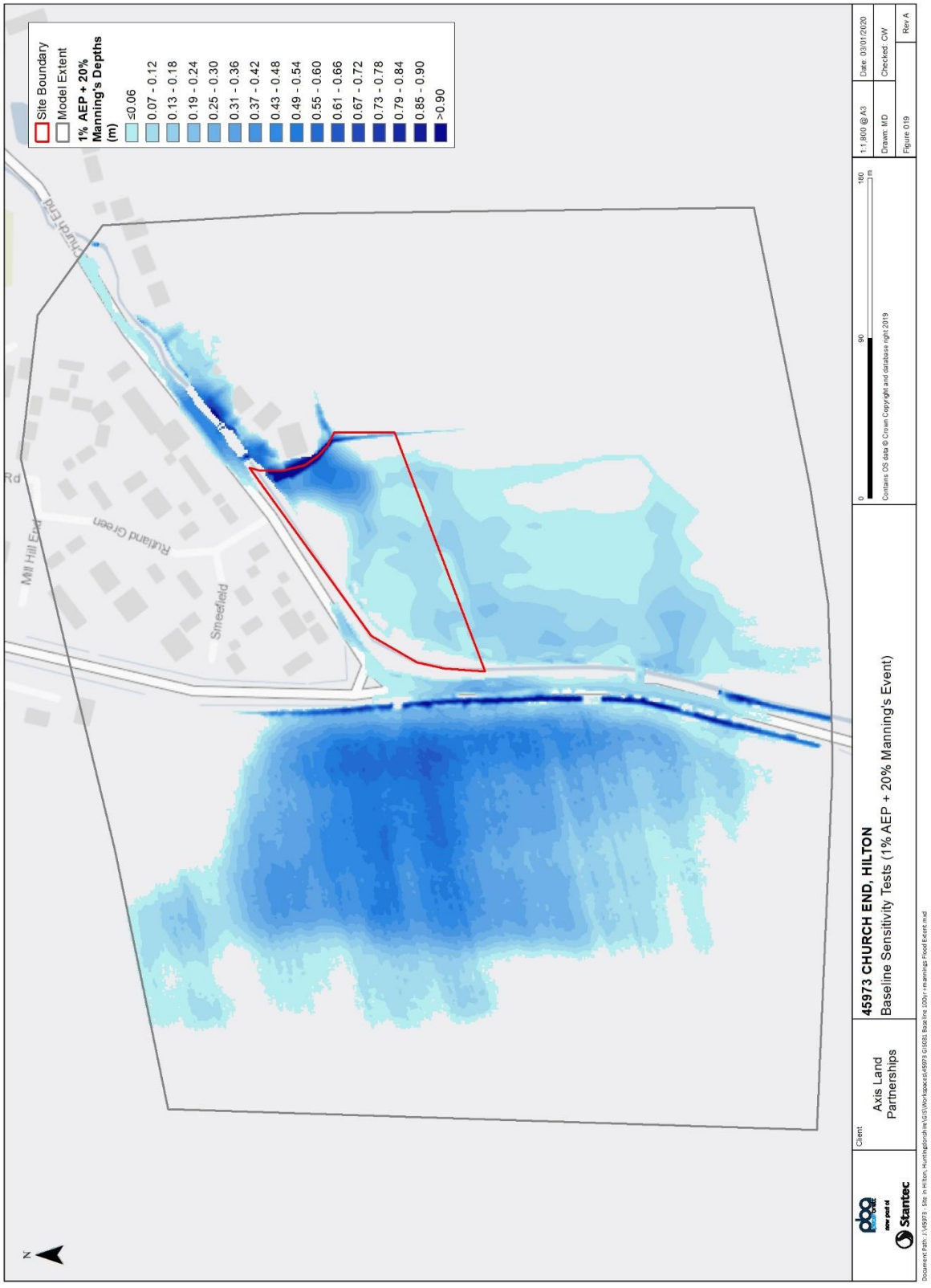


Figure 26: Baseline Sensitivity Test: 1% AEP +20% Manning's Roughness Flood Depths

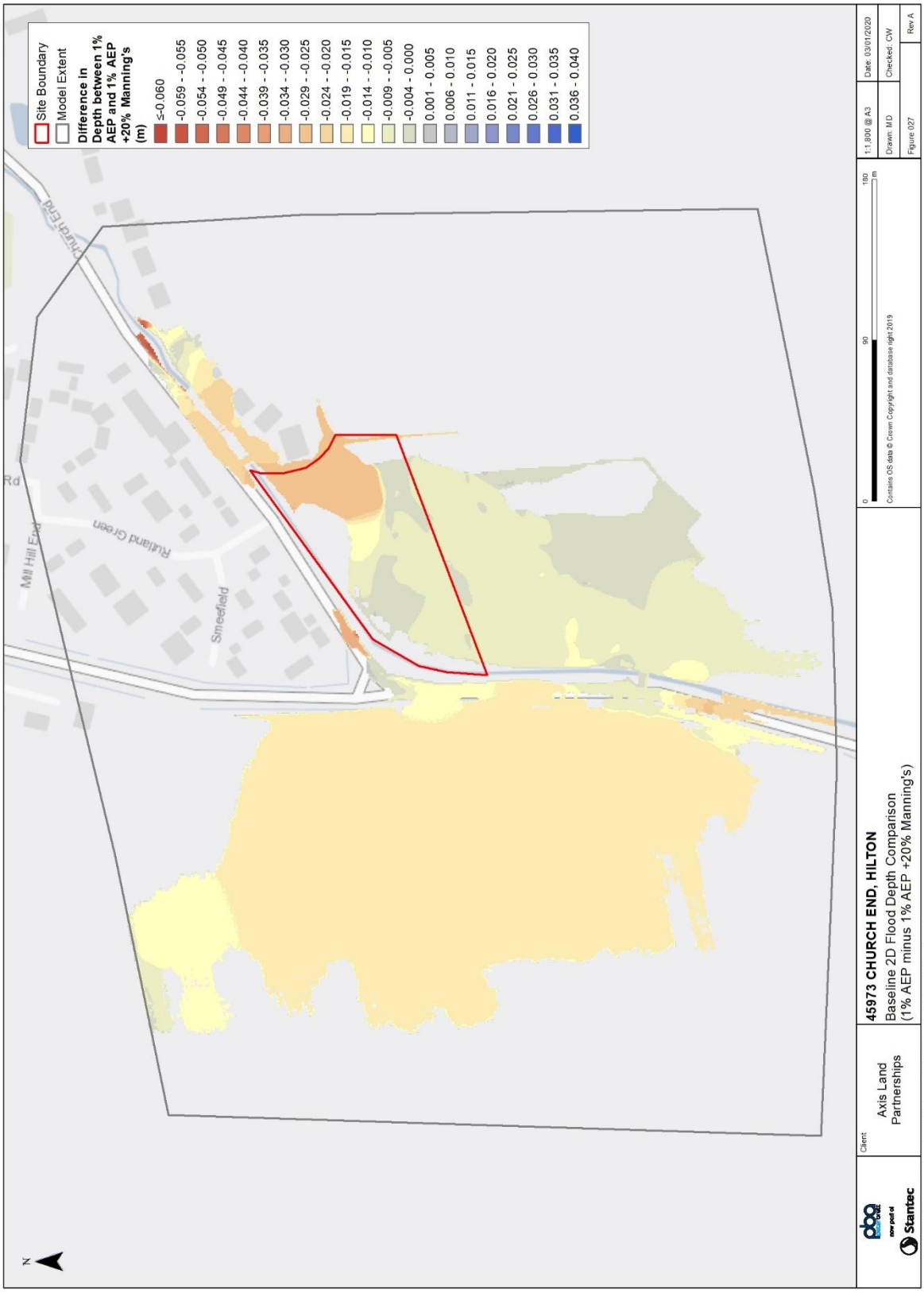


Figure 27: Difference between 1% AEP and 1% AEP +20% Manning's Roughness Flood Depths

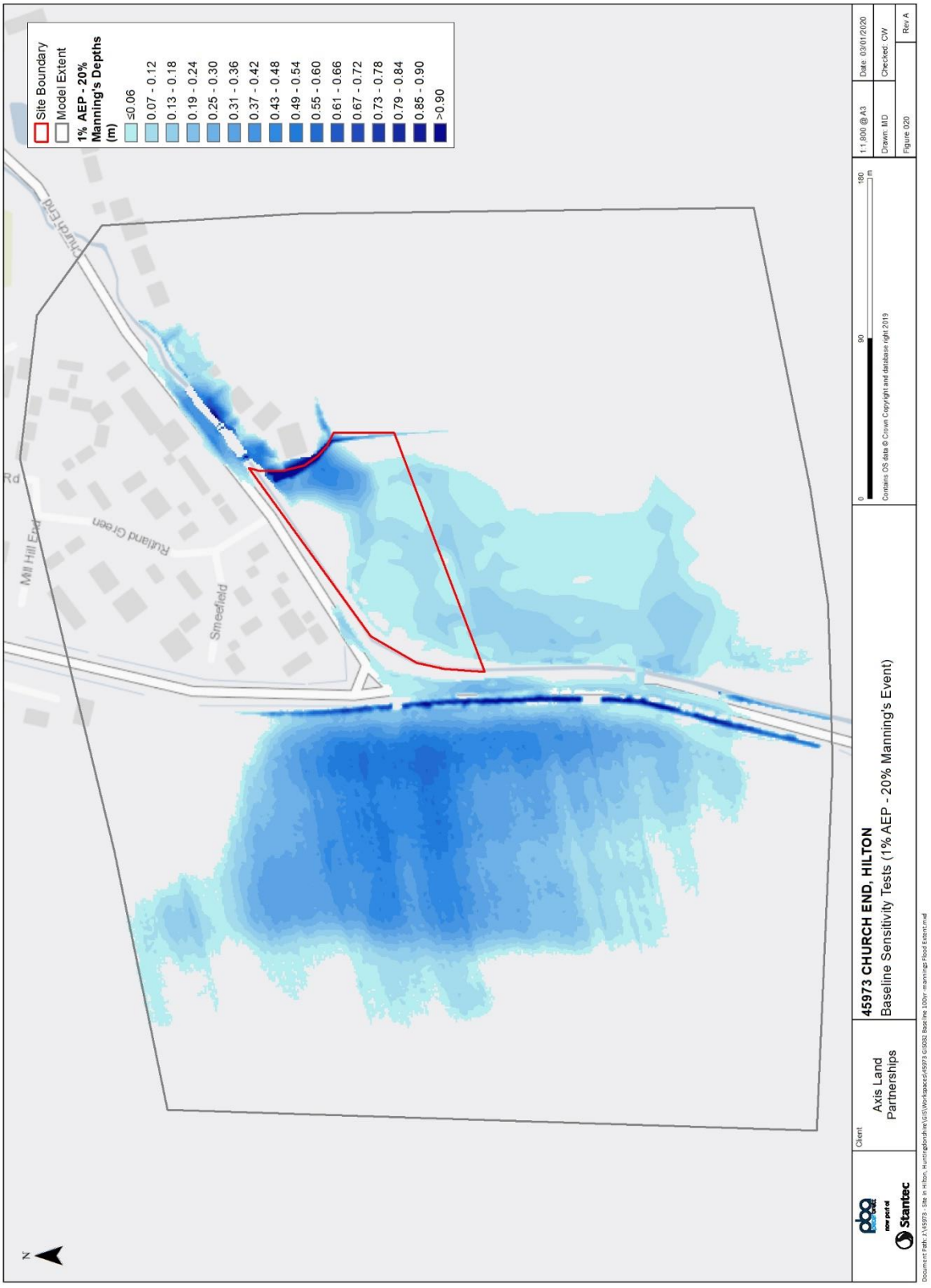


Figure 28: Baseline Sensitivity Test: 1% AEP -20% Manning's Roughness Flood Depths

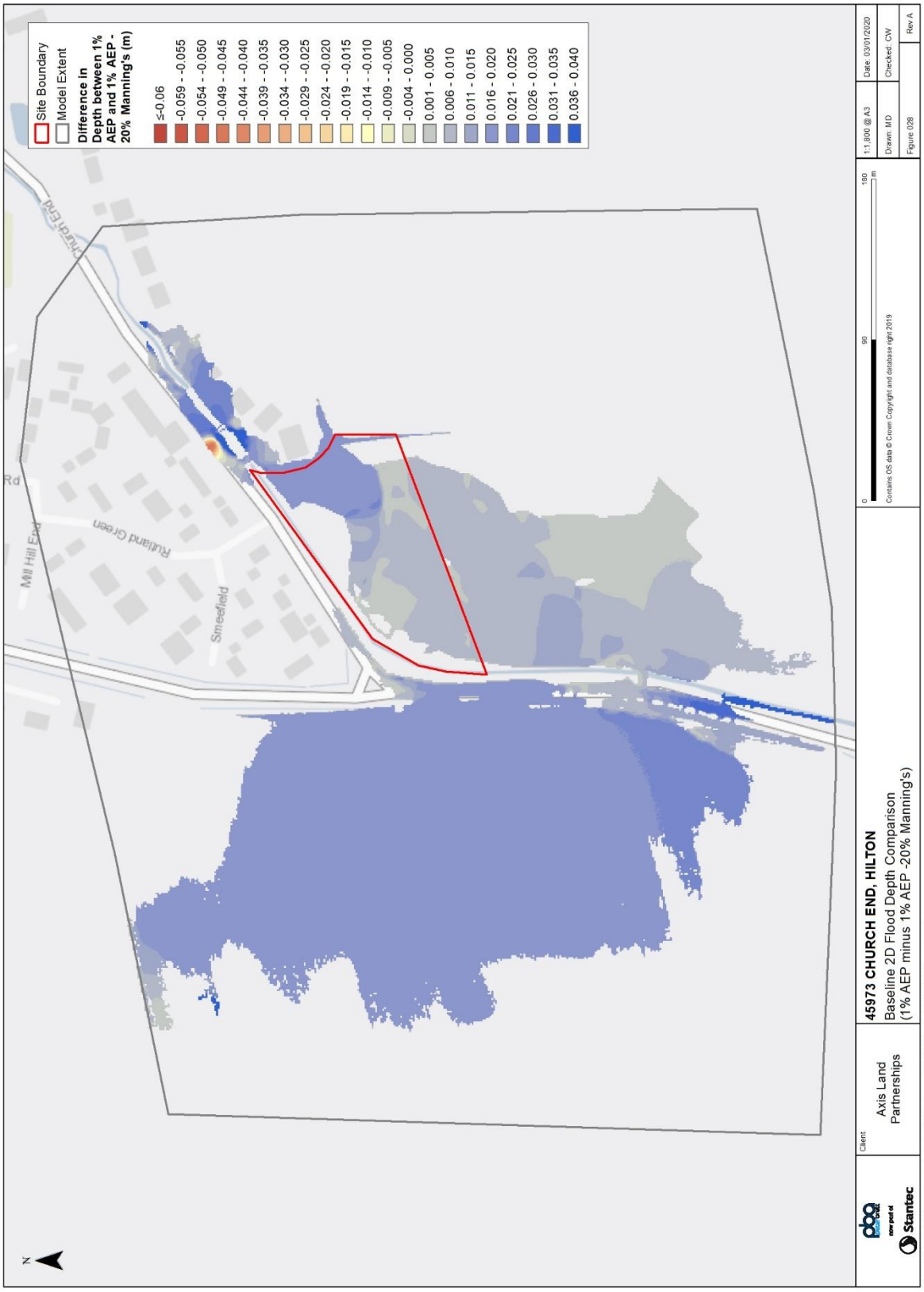


Figure 29: Difference between 1% AEP and 1% AEP -20% Manning's Roughness Flood Depths

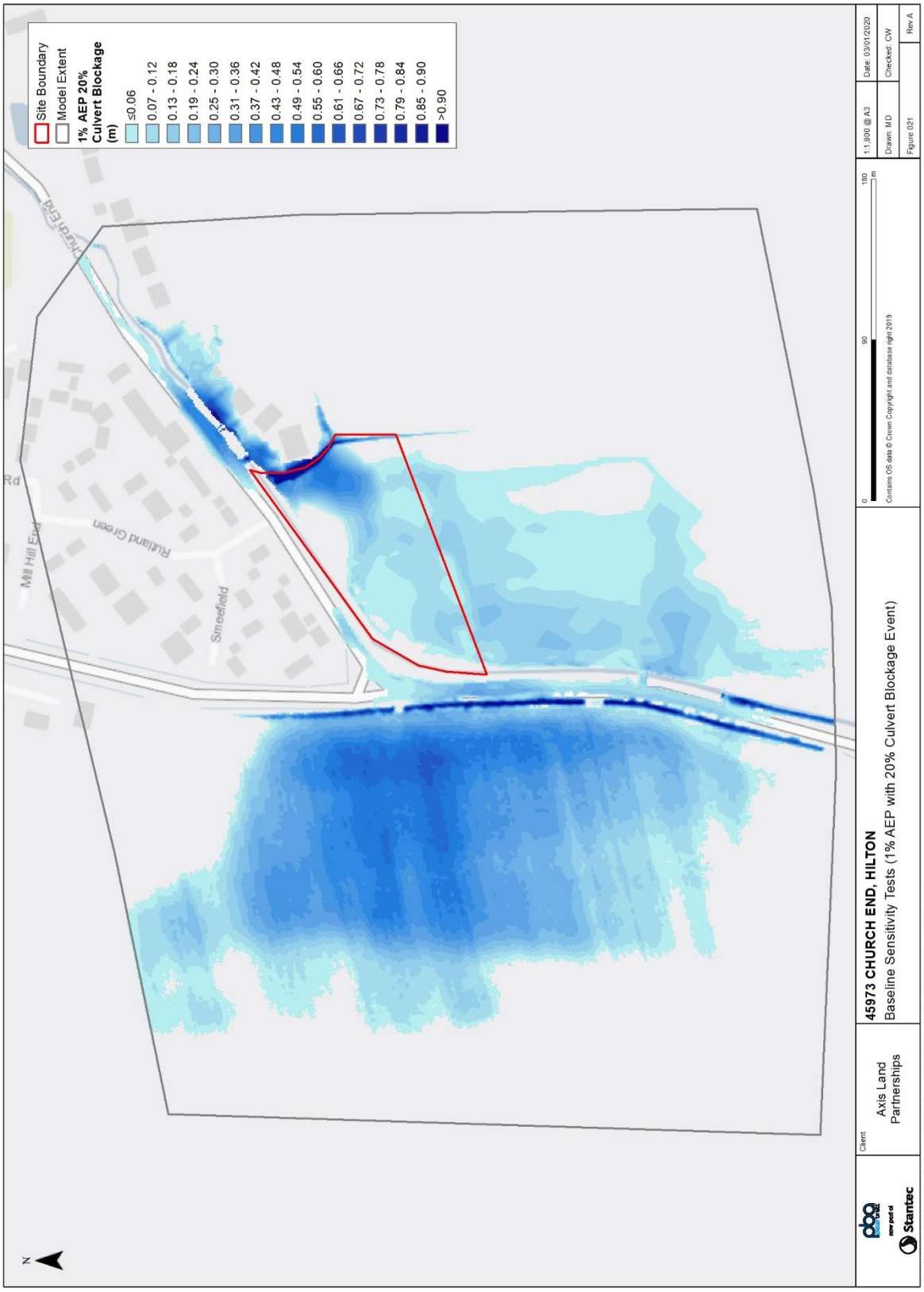


Figure 30: Baseline Sensitivity Test: 1% AEP Culvert 20% Blockage Flood Depths

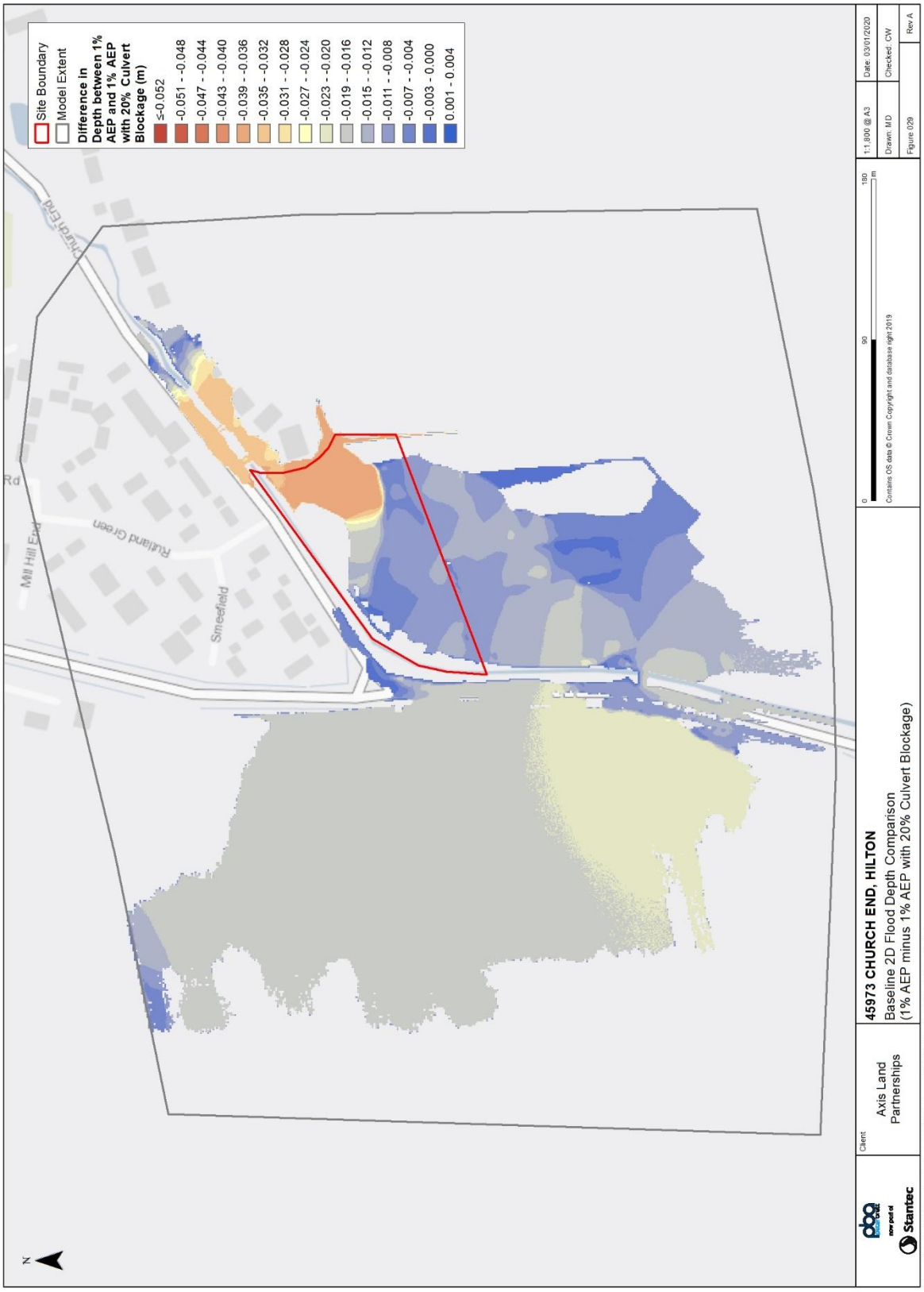


Figure 31: Difference between 1% AEP and 1% AEP Culvert 20% Blockage Flood Depths

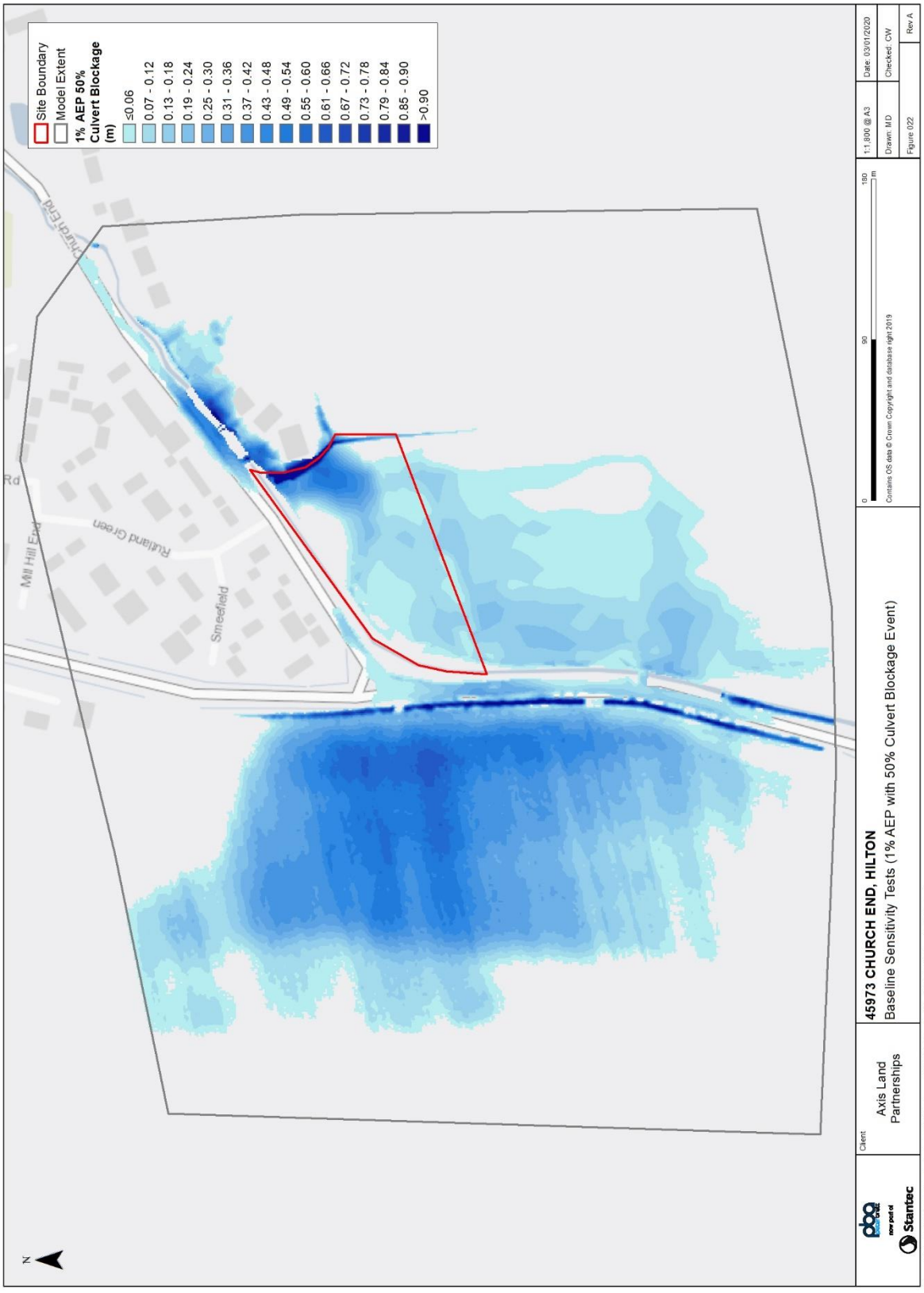


Figure 32: Baseline Sensitivity Test: 1% AEP Culvert 50% Blockage Flood Depths

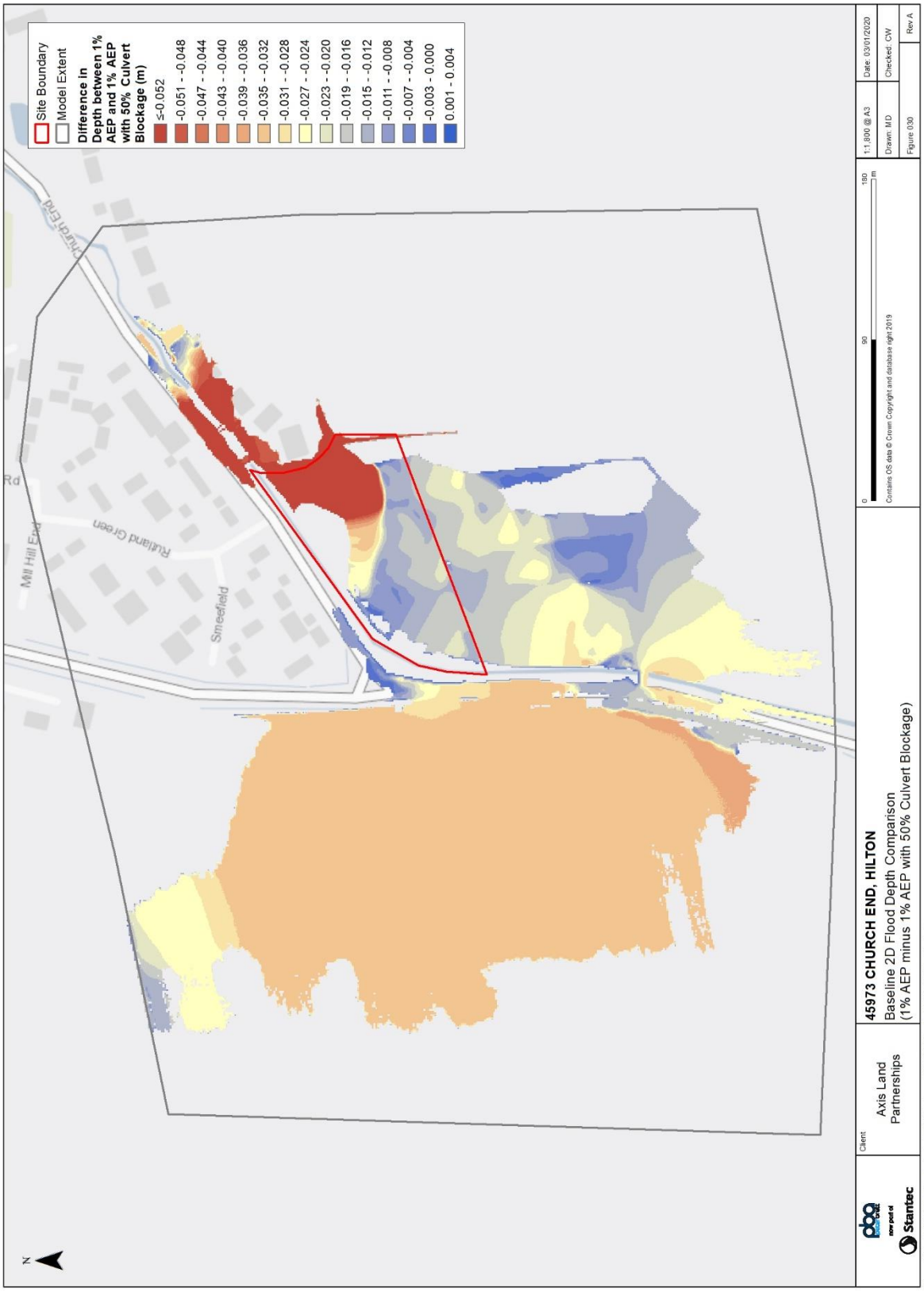


Figure 33: Difference between 1% AEP and 1% AEP Culvert 50% Blockage Flood Depths

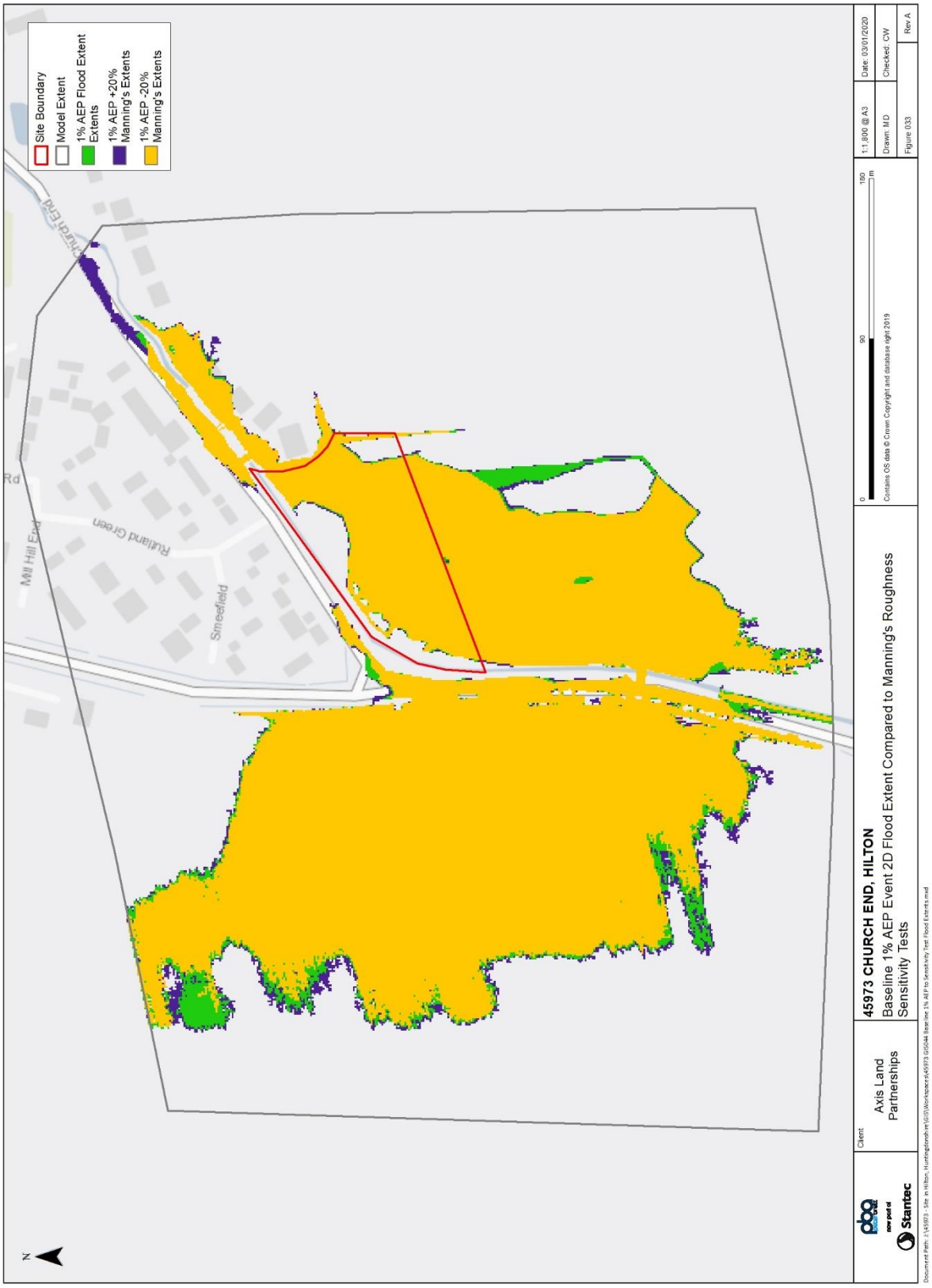


Figure 34: Comparing Baseline 1% AEP Event and ±20% Manning's Roughness Flood Extents

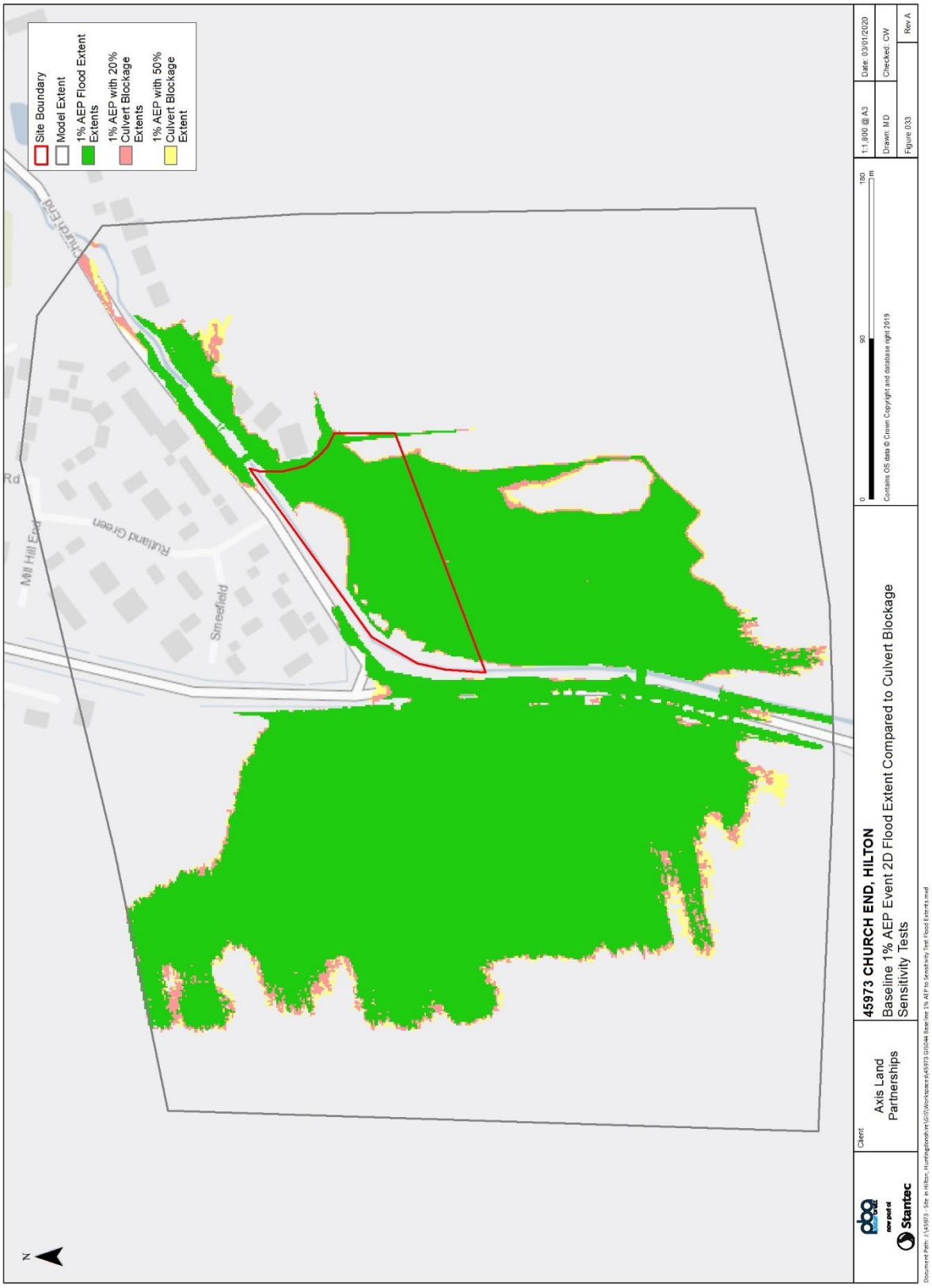
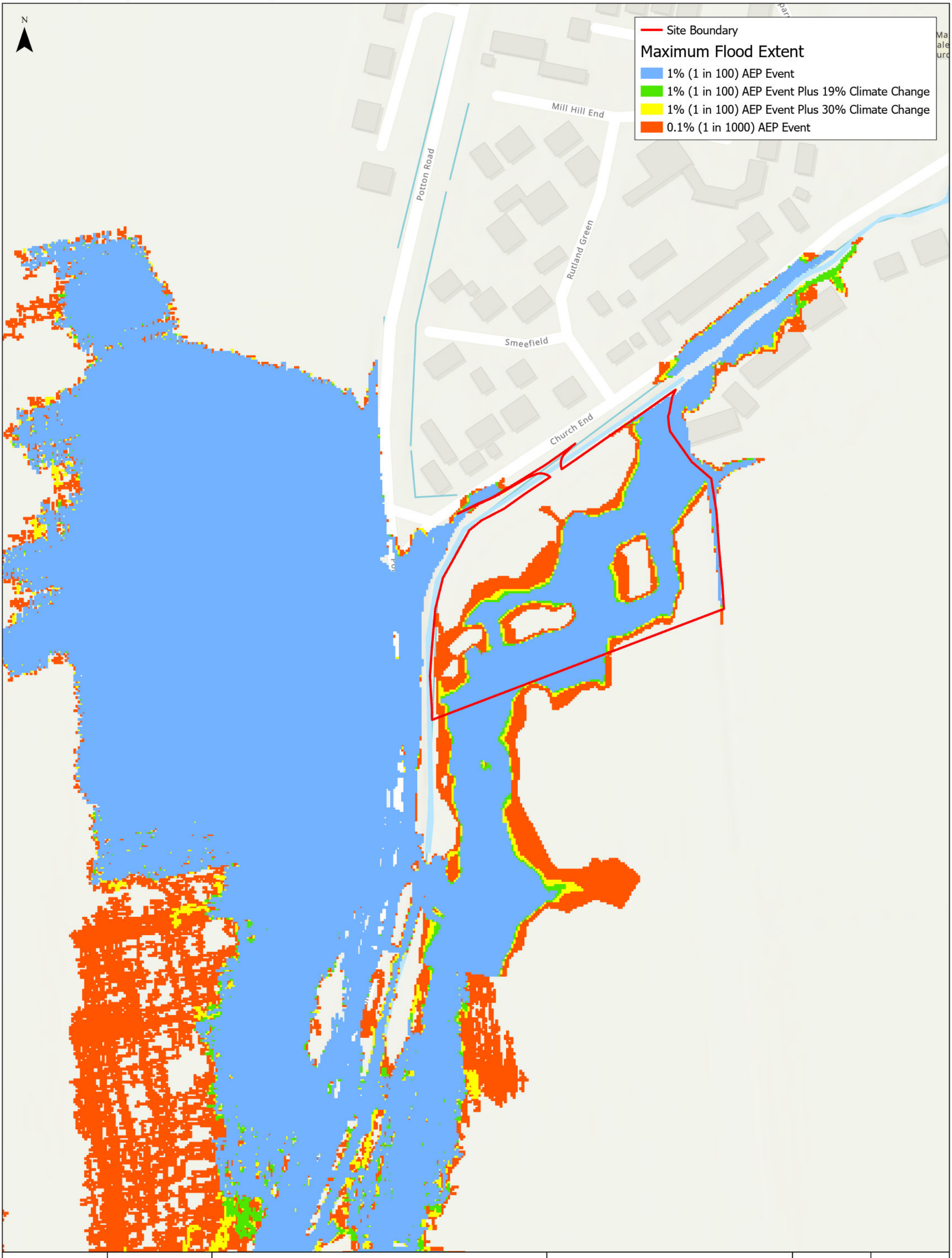


Figure 35: Comparing Baseline 1% AEP Event and Culvert Blockage Flood Extents

Appendix B

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 001 Baseline Flood Extents.aprx



Stantec

Client: Burmor Construction Limited

CHURCH END, HILTON

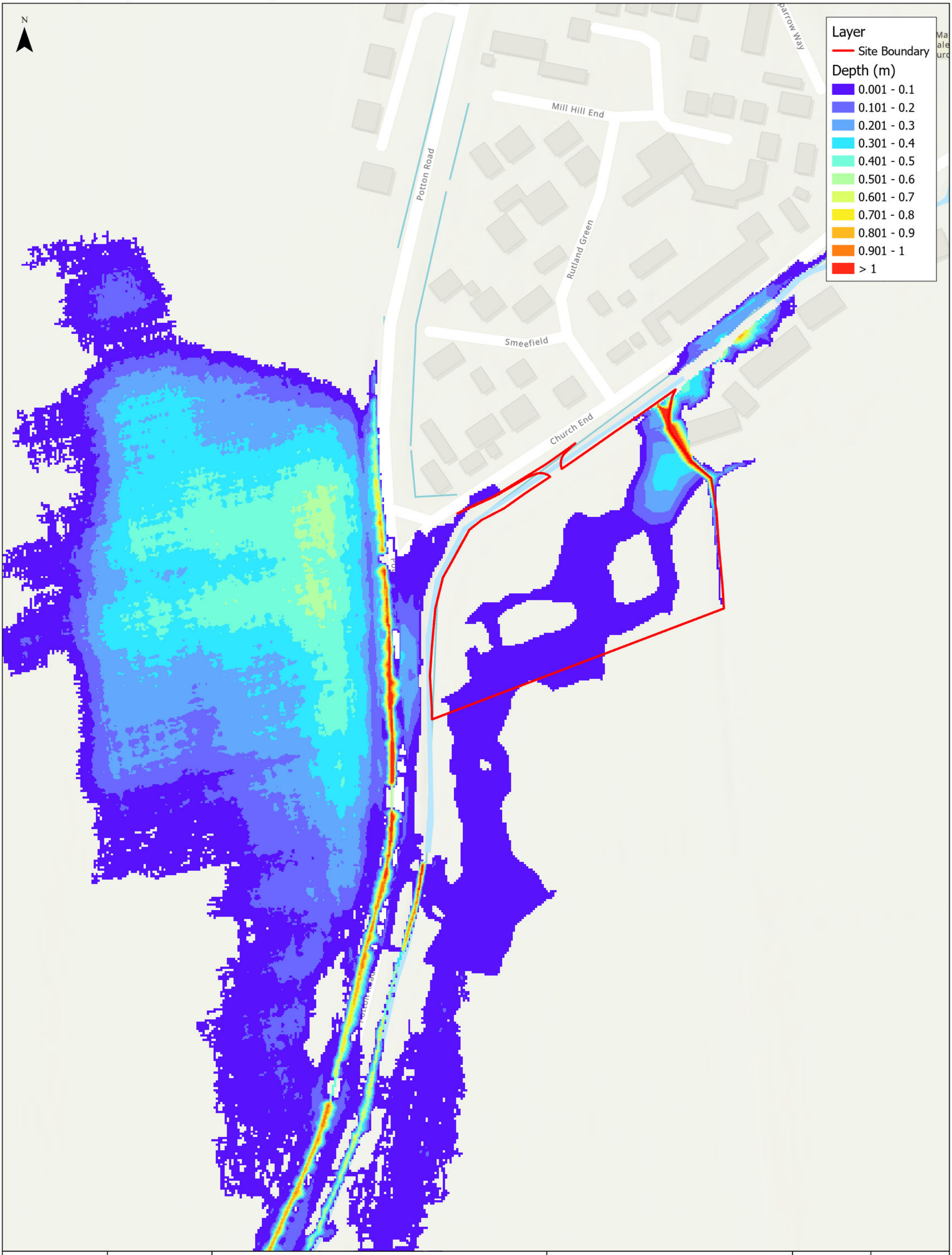
Baseline Maximum Flood Extents

0 50 100 m

World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS
World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,

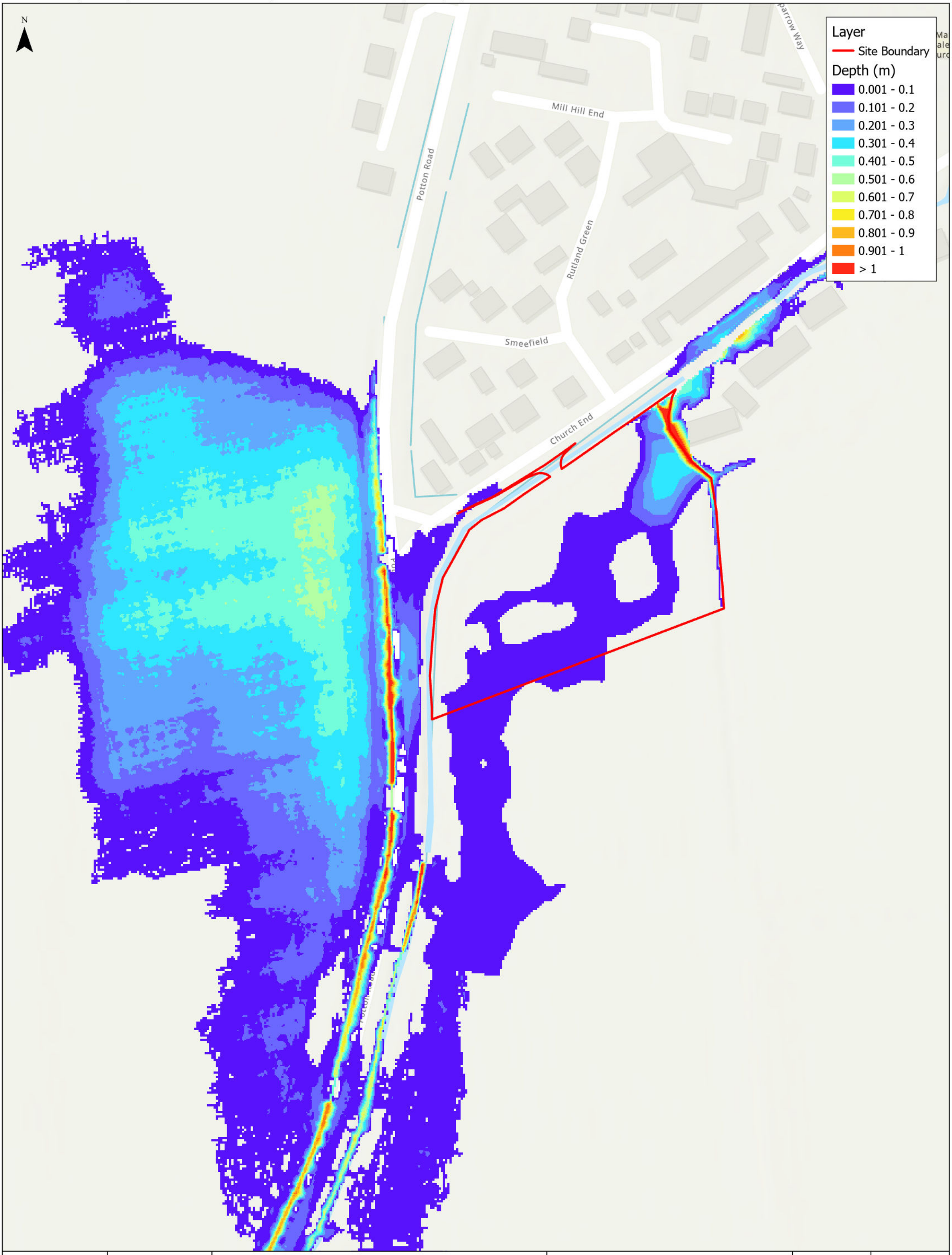
1:1,500 @ A3	Date: 15/12/2023
Drawn: MD	Checked: SK
Figure 332610757/300/001	Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 002 Baseline Q0100 Flood Depths.aprx



Stantec	Client: Burmor Construction Limited	**CHURCH END, HILTON** Baseline 1% (1 in 100) AEP Event Maximum Flood Depths	0 50 100 m World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,	1:1,500 @ A3	Date: 15/12/2023
				Drawn: MD	Checked: SK
				Figure 332610757/300/002	Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 003 Baseline Q0100+19pct Flood Depths.aprx



Stantec

Client: Burmor Construction Limited

CHURCH END, HILTON

Baseline 1% (1 in 100) AEP Event Plus 19% Climate Change Maximum Flood Depths

0 50 100 m

World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS
World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,

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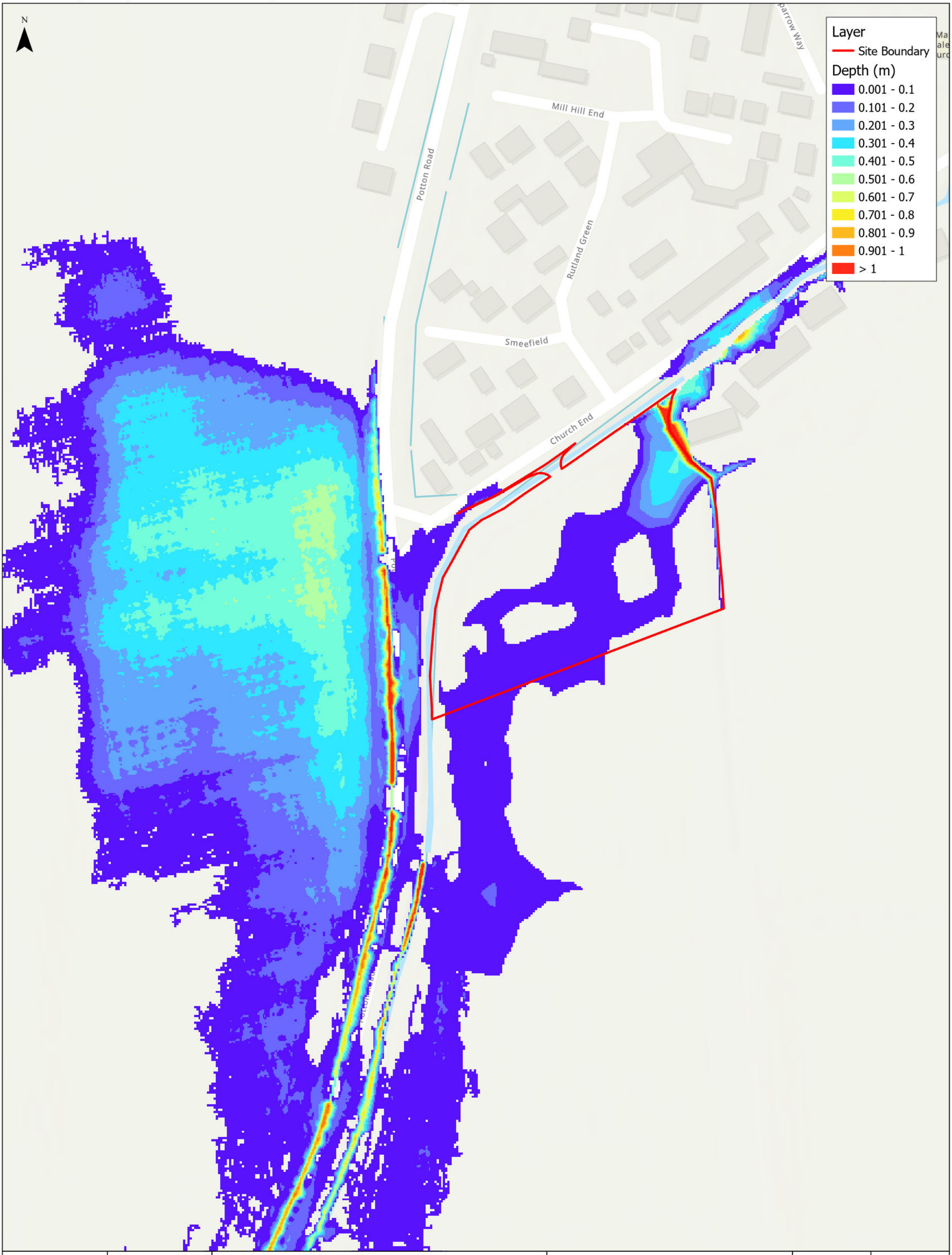
Drawn: MD	Checked: SK
Figure 332610757/300/003	Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 004 Baseline Q0100+30pct Flood Depths.aprx



Stantec

Client: Burmor Construction Limited

CHURCH END, HILTON

Baseline 1% (1 in 100) AEP Event Plus 30% Climate Change Maximum Flood Depths

0 50 100 m

World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS
World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,

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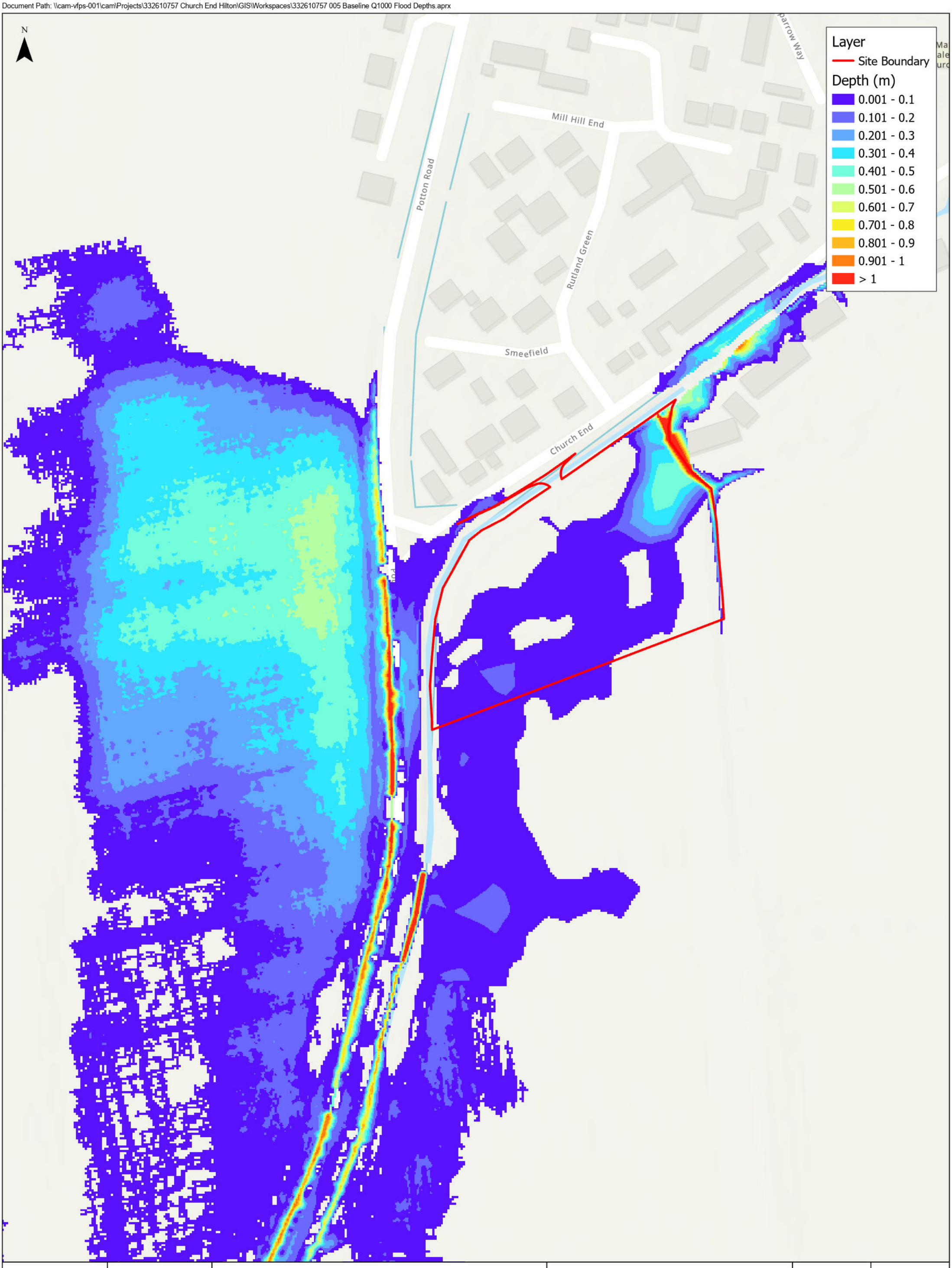

Stantec

Client: Burmor Construction Limited

CHURCH END, HILTON

Baseline 0.1% (1 in 1000) AEP Event Maximum Flood Depths

0 50 100 m

World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS
World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,

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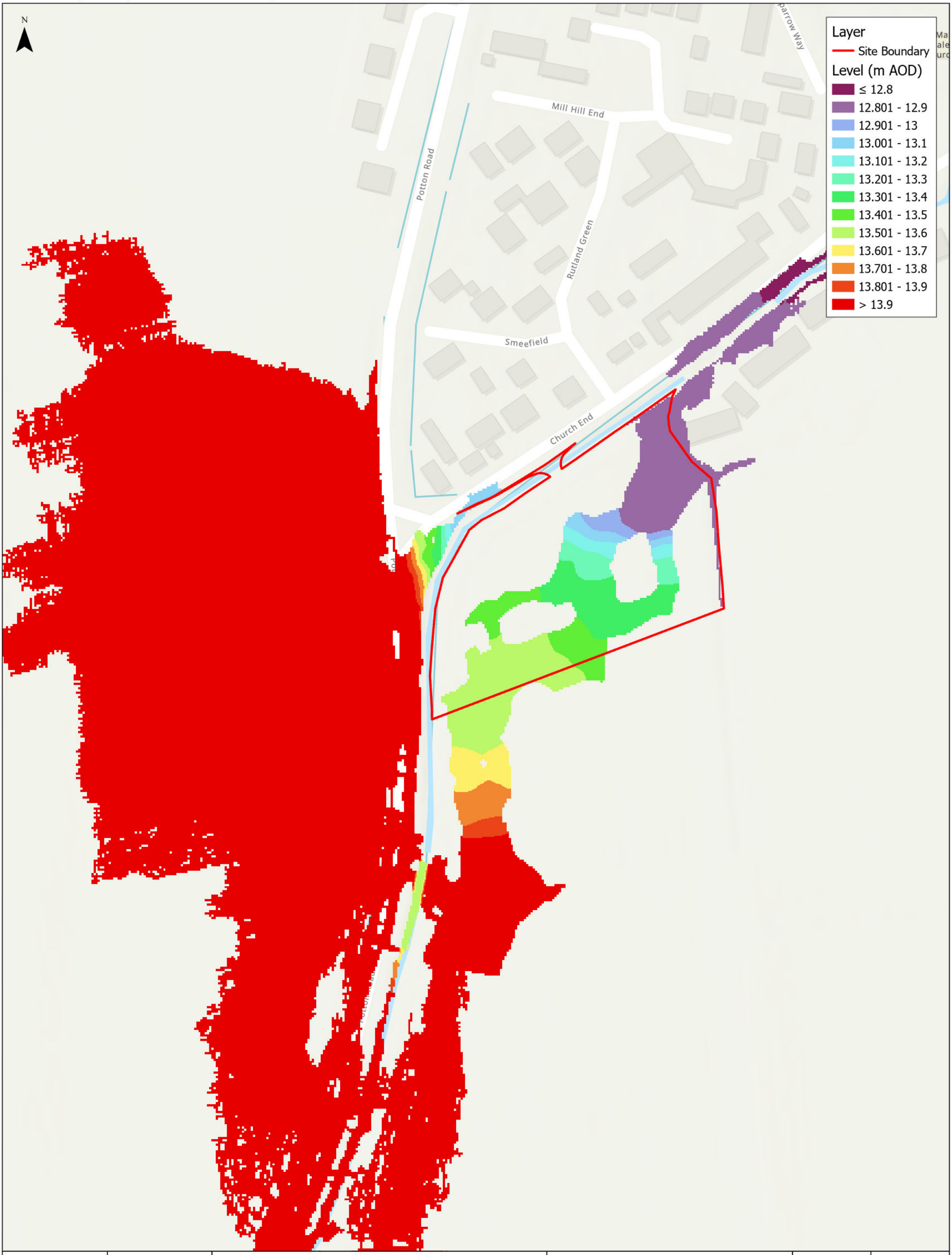
Figure 332610757/300/005	Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 006 Baseline Q0100+19pct Flood Levels.aprx



Stantec	Client: Burmor Construction Limited	**CHURCH END, HILTON** Baseline 1% (1 in 100) AEP Event Plus 19% Climate Change Maximum Flood Levels	0 50 100 m World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,	1:1,500 @ A3	Date: 15/12/2023
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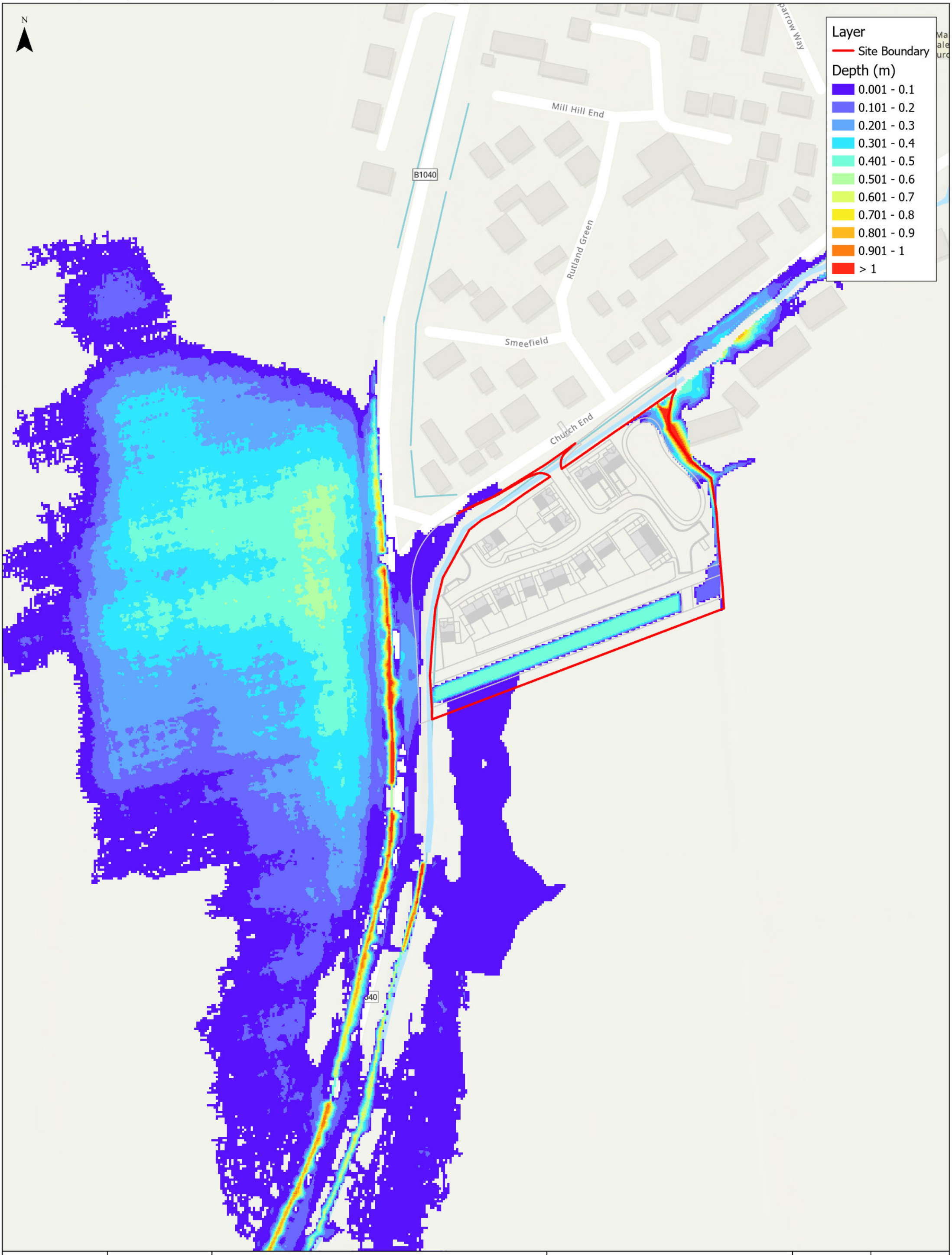
				Figure 332610757/300/006	Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 009 Post-Dev Q0100+19pct Flood Depths.aprx



Stantec

Client: Burmor Construction Limited

CHURCH END, HILTON

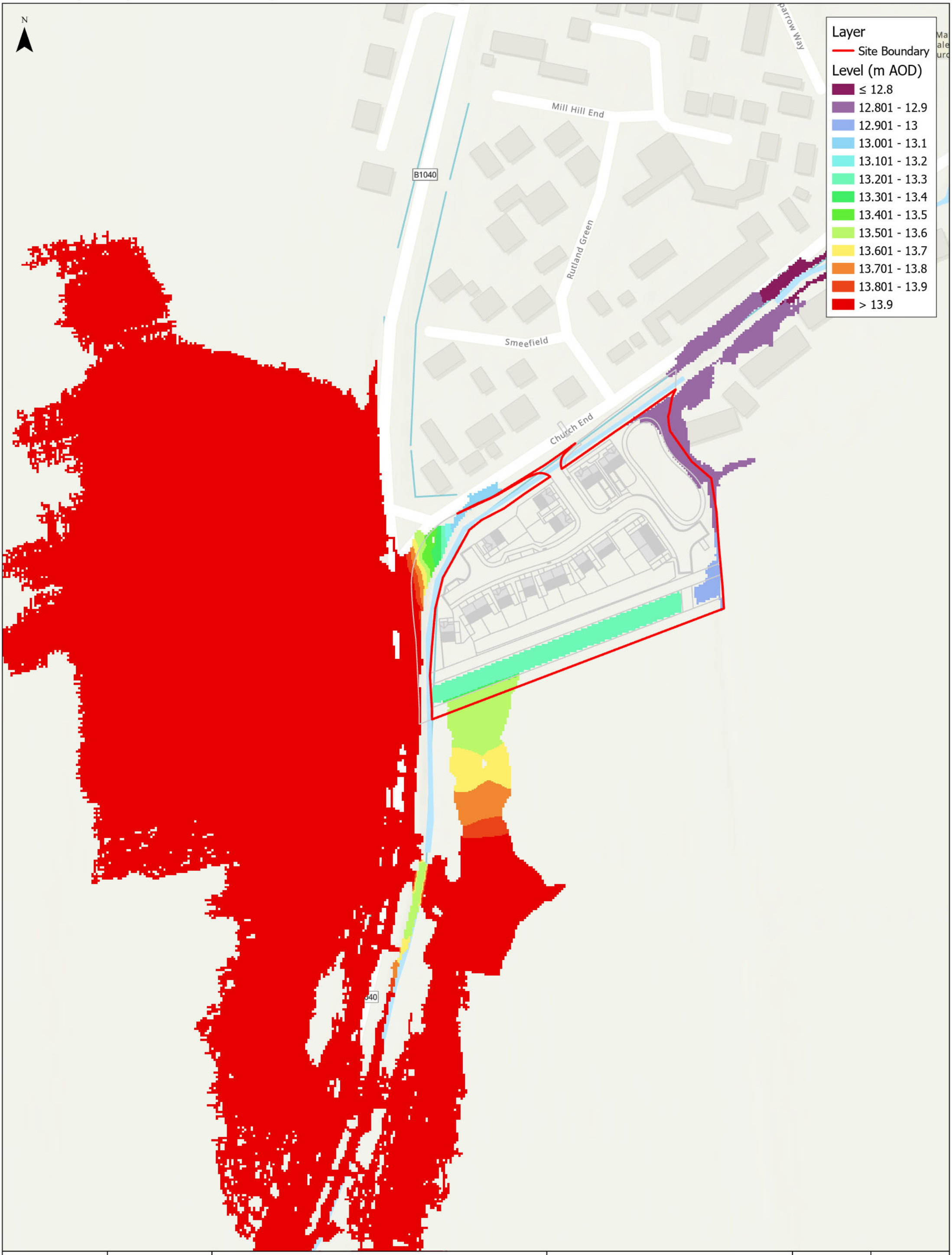
Post-Development 1% (1 in 100) AEP Event Plus 19% Climate Change Maximum Flood Depths

1:1,500 @ A3 | Date: 19/06/2024

Drawn: MD | Checked: SK

Figure 332610757/300/009 | Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 012 Post-Dev Q0100+19pct Flood Levels.aprx



Stantec	Client: Burmor Construction Limited	**CHURCH END, HILTON** Post-Development 1% (1 in 100) AEP Event Plus 19% Climate Change Maximum Flood Levels	0 50 100 m World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,	1:1,500 @ A3	Date: 13/06/2024
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				Figure 332610757/300/012	Rev A

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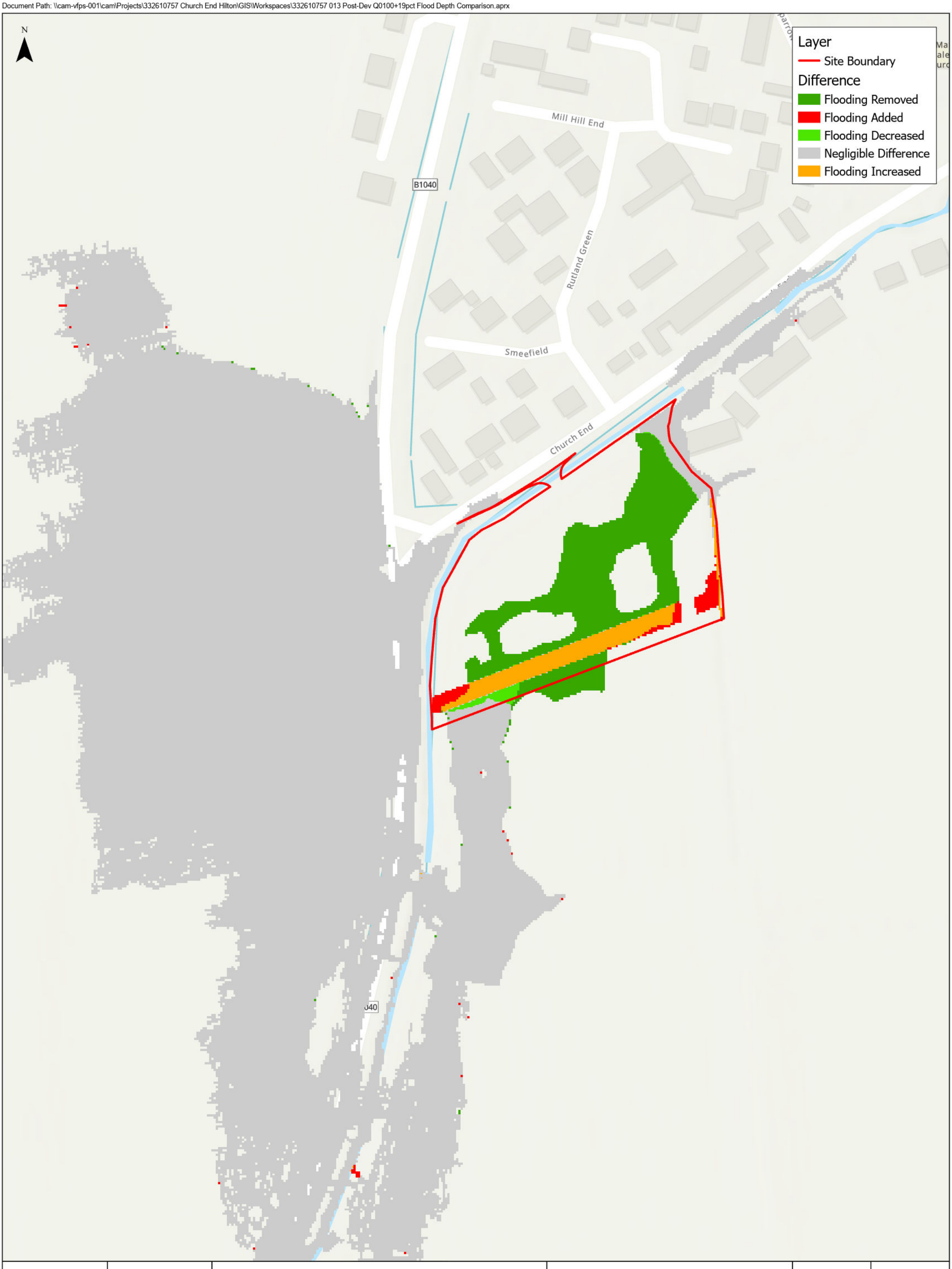


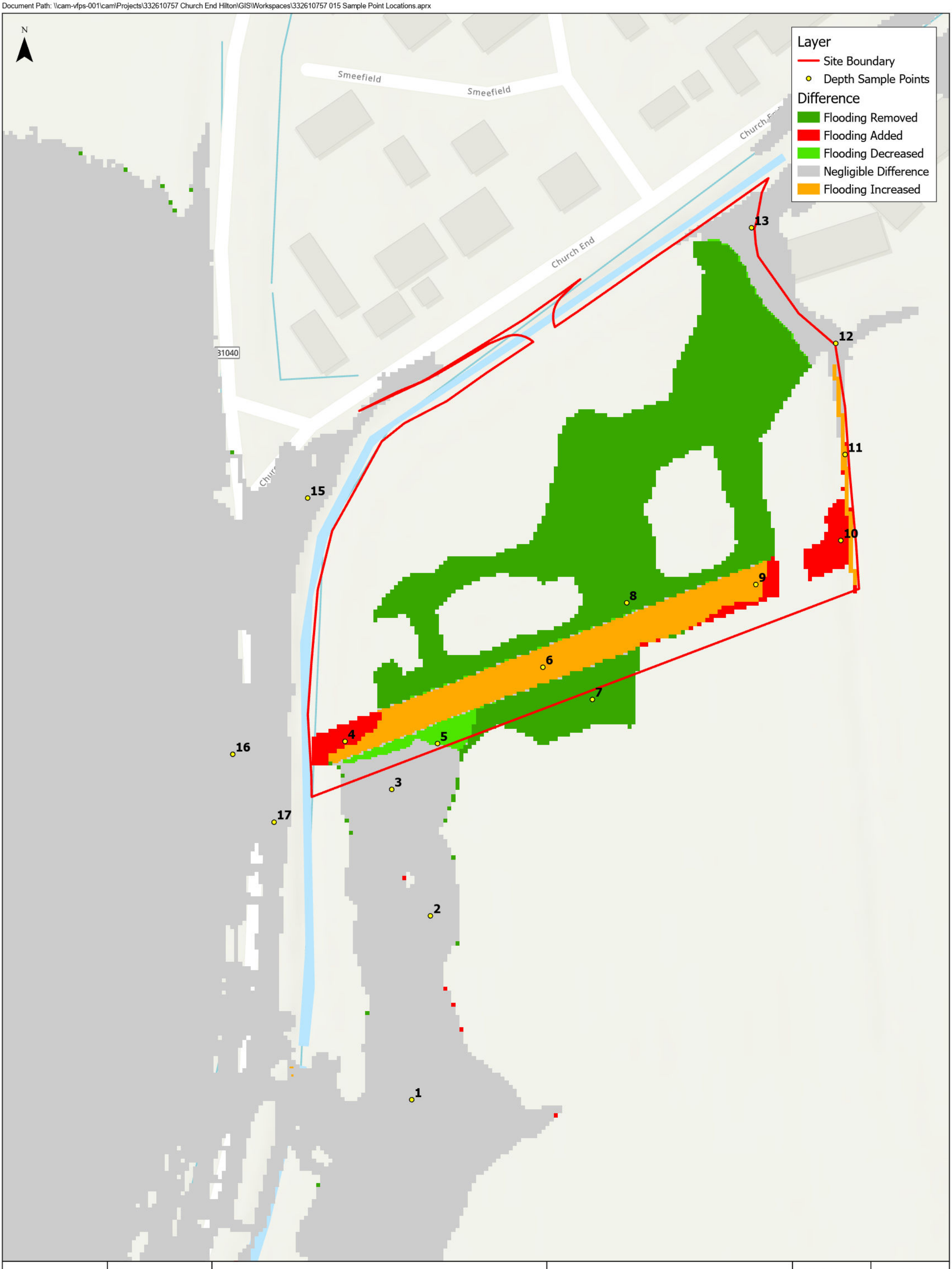
Stantec	Client: Burmor Construction Limited	**CHURCH END, HILTON** Baseline to Post-Development 1% (1 in 100) AEP Event Plus 19% Climate Change Comparison	0 50 100 m World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,	1:1,500 @ A3 Drawn: MD Figure 332610757/300/013	Date: 13/06/2024 Checked: SK Rev A

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 014 Ground Profile Locations.aprx



Stantec	Client: Burmor Construction Limited	**CHURCH END, HILTON** Proposed Cut-Off Drain and Profile Line Locations	0 20 40 m World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,	1:750 @ A3 Drawn: MD Figure 332610757/300/014	Date: 17/06/2024 Checked: SK Rev B

Document Path: \\cam-vfps-001\cam\Projects\332610757 Church End Hilton\GIS\Workspaces\332610757 015 Sample Point Locations.aprx



Stantec	Client: Burmor Construction Limited	**CHURCH END, HILTON** Sample Point Locations	0 20 40 m World Topographic Map: Esri Community Maps Contributors, Esri UK, Esri, TomTom, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS World Hillshade: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA,	1:800 @ A3	Date: 13/06/2024
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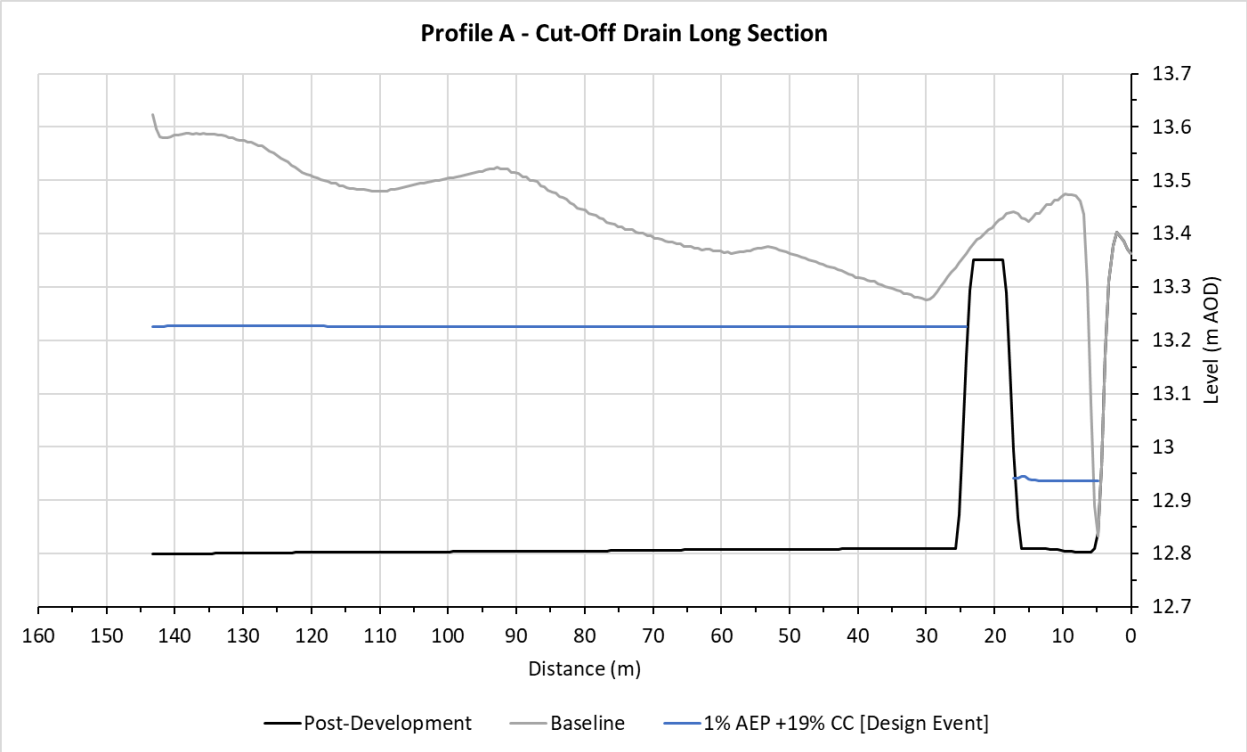
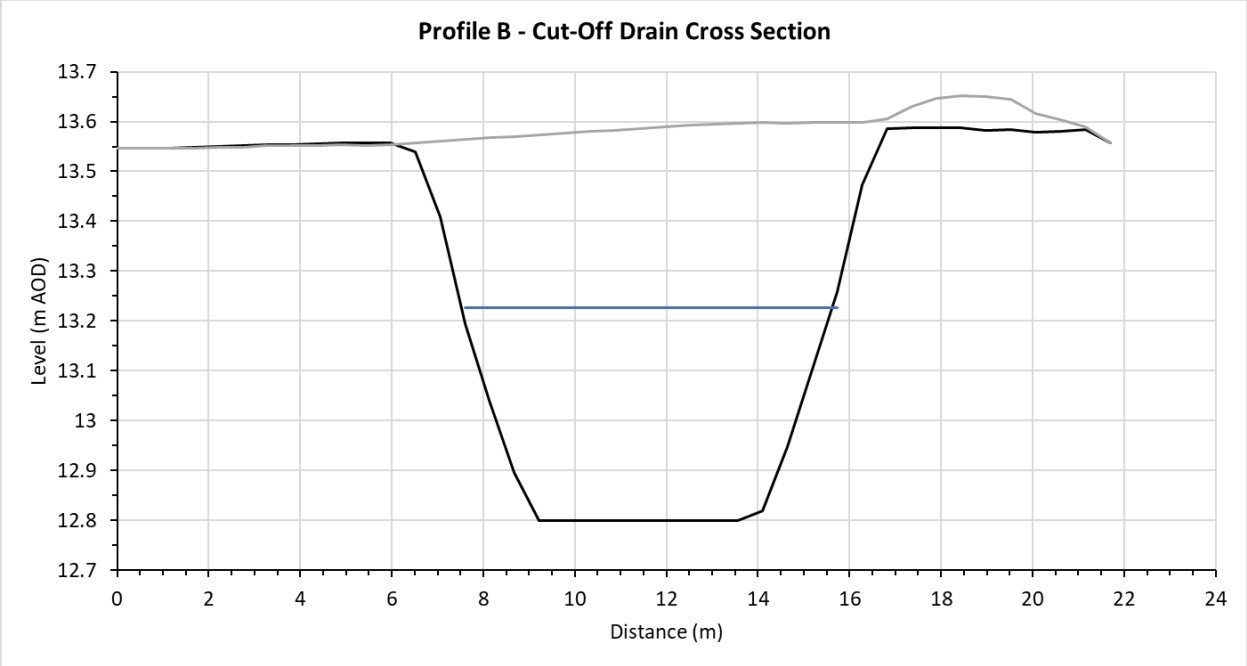
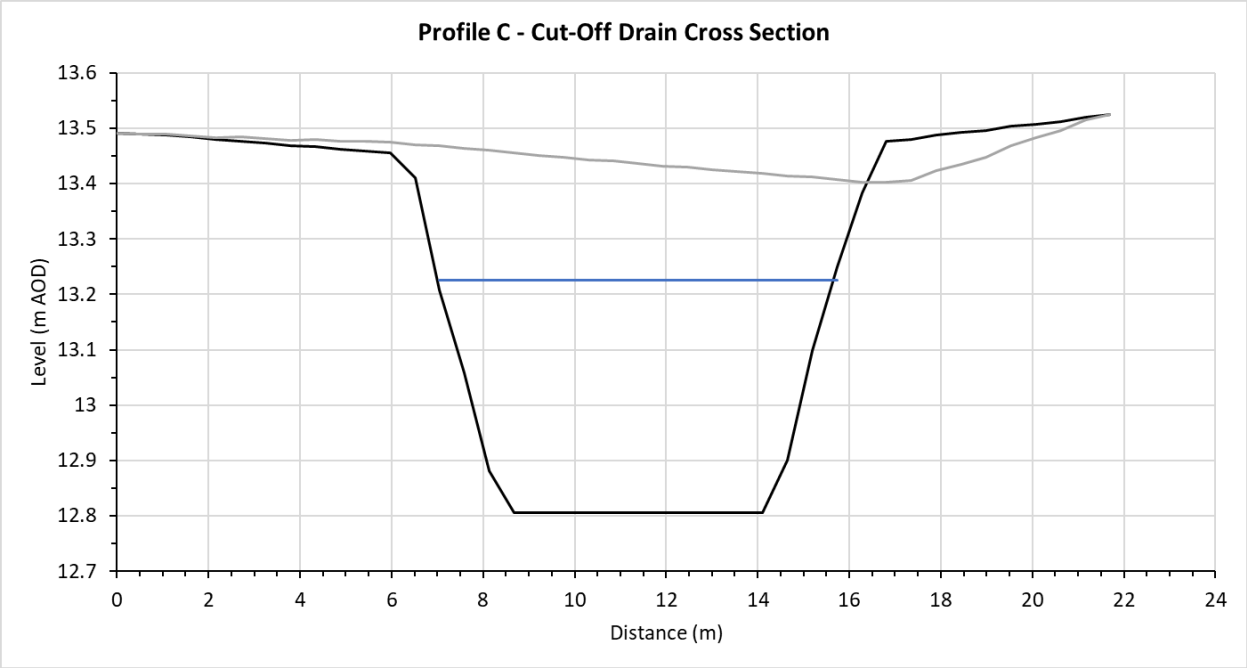
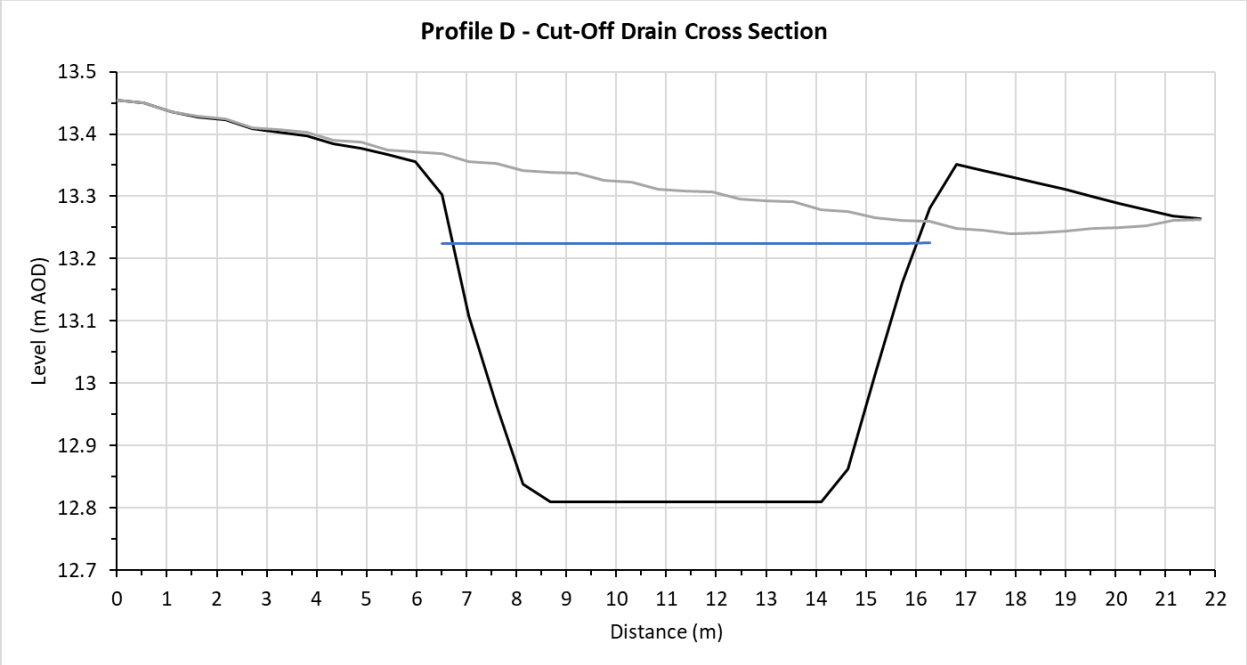
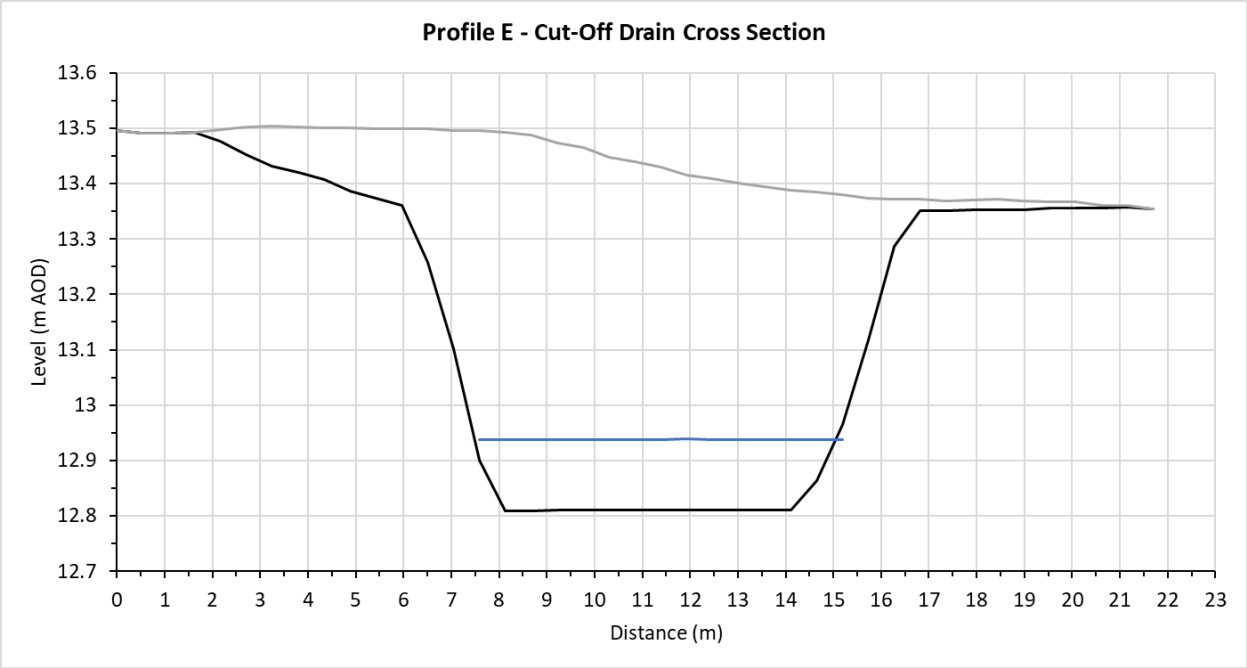
				Figure 332610757/300/015	Rev A

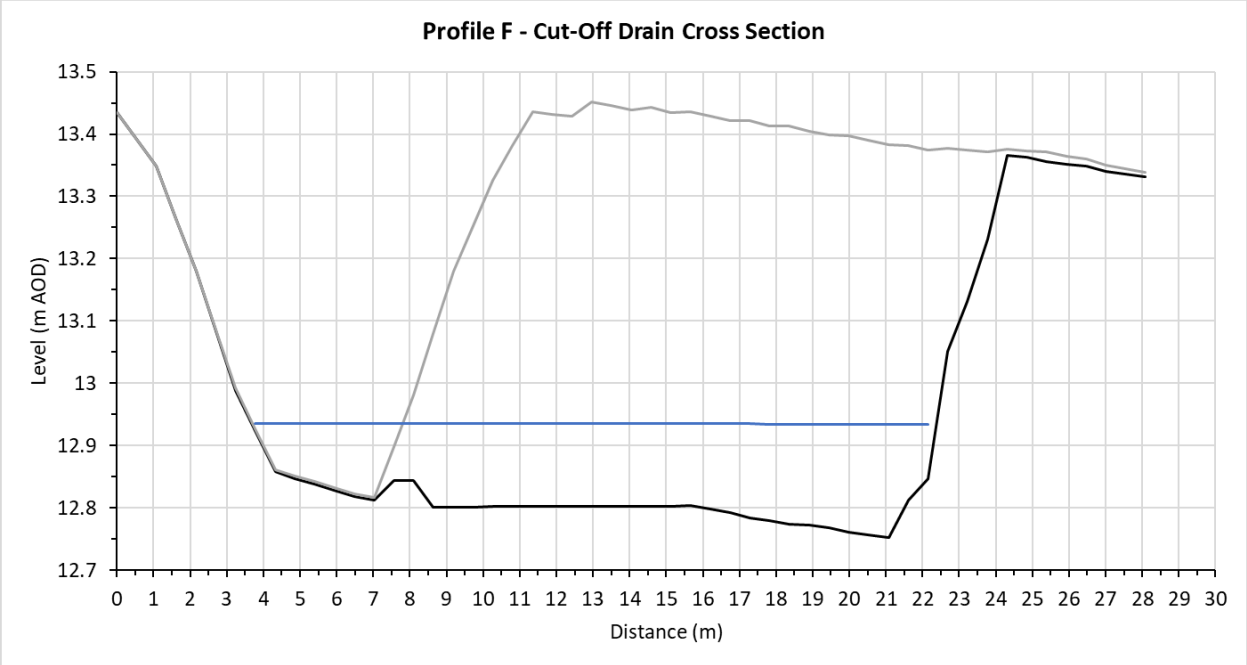

Profile A - Cut-Off Drain Long Section
13.7
13.6
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
Level (m AOD)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Distance (m)
Post-Development
Baseline
1% AEP +19% CC [Design Event]

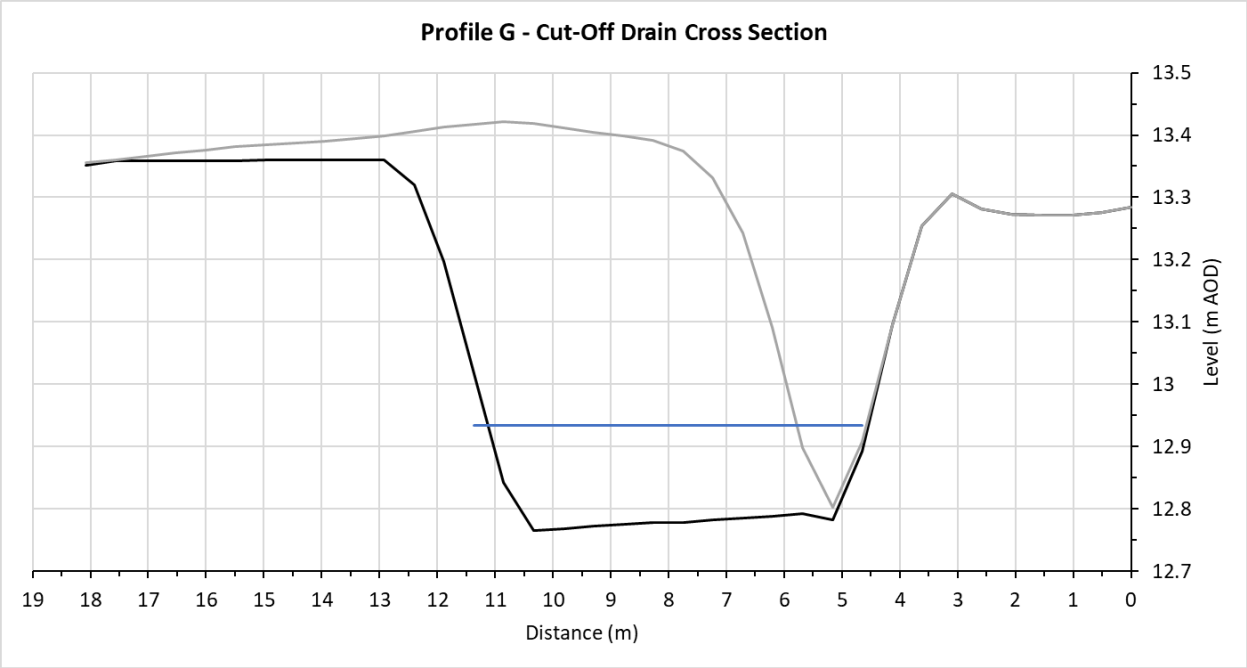

Profile B - Cut-Off Drain Cross Section
13.7
13.6
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
Level (m AOD)
0
2
4
6
8
10
12
14
16
18
20
22
24
Distance (m)

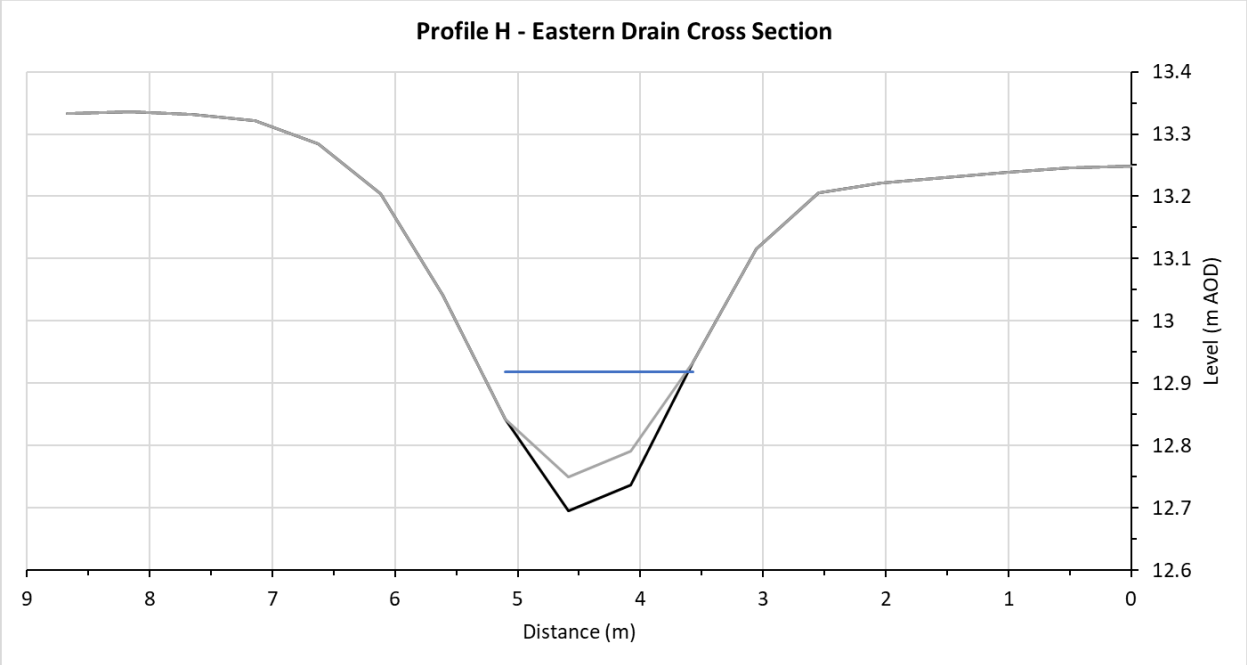

Profile C - Cut-Off Drain Cross Section
Level (m AOD)
13.6
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
0
2
4
6
8
10
12
14
16
18
20
22
24
Distance (m)

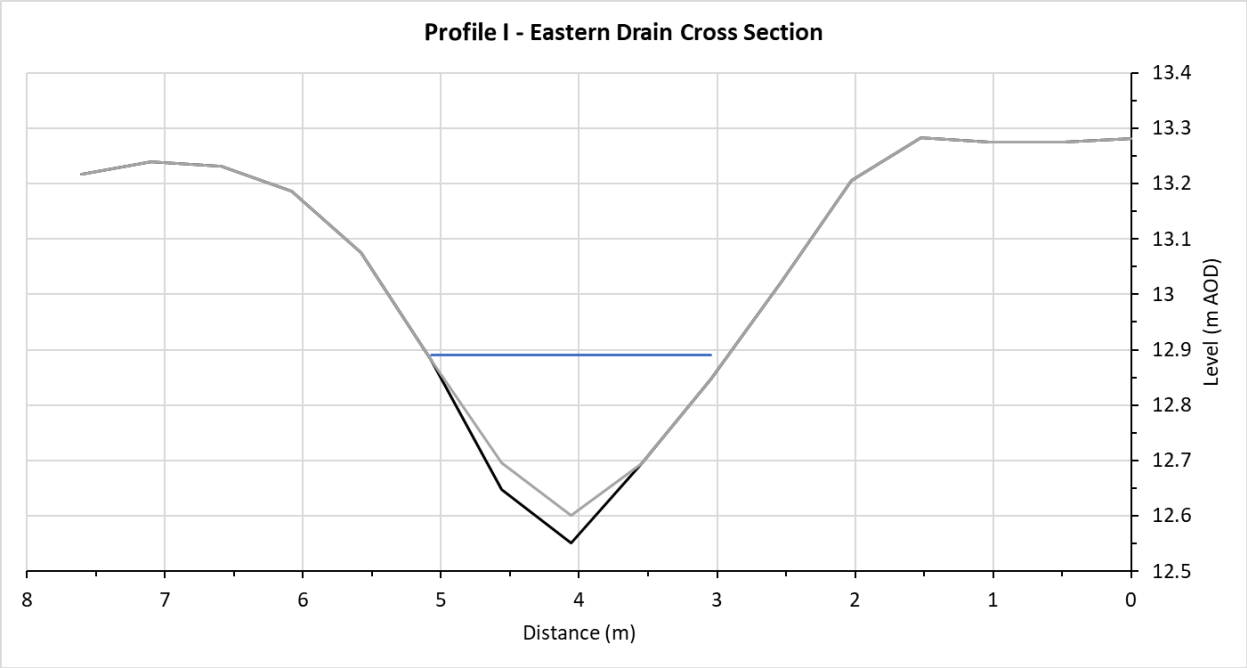

Profile D - Cut-Off Drain Cross Section
Level (m AOD)
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Distance (m)


Profile E - Cut-Off Drain Cross Section
Level (m AOD)
13.6
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Distance (m)


Profile F - Cut-Off Drain Cross Section
Level (m AOD)
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Distance (m)


Profile G - Cut-Off Drain Cross Section
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
Level (m AOD)
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Distance (m)


Profile H - Eastern Drain Cross Section
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
12.6
Level (m AOD)
9 8 7 6 5 4 3 2 1 0
Distance (m)


Profile I - Eastern Drain Cross Section
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
12.6
12.5
Level (m AOD)
8
7
6
5
4
3
2
1
0
Distance (m)

Appendix C

Description: This report template is a supporting document to the Environment Agency's Flood Estimation Guidelines (LIT 11832). It provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation. This document can be used for one site or multiple sites.

Guidance notes to help you complete this template are available separately.

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Approval

Revision stage	Analyst:	Approved by:	Amendments	Date
Method statement	R Crabbe			
Calculations - Revision 1	R Crabbe			
Calculations - Revision 2				

Abbreviations

Abbreviation	Short for
AEP	annual exceedance probability
AMAX	Annual Maximum
AREA	Catchment area (km2)
BFI	Base Flow Index
BFIHOST19	Base Flow Index derived using the HOST soil classification, revised in 2019
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
GEV	Generalised Extreme Value
GLO	Generalised Logistic
HOST	Hydrology of Soil Types
IF	Impervious Fraction
IRF	Impervious Runoff Factor
LF	Low flow statistics (flow duration curve)
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	Standard Average Annual Rainfall (mm)
Tp	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP	Windows Frequency Analysis Package (software that can be used for FEH statistical method)

1. Summary of assessment

1.1 Summary

Catchment location:

The catchment of interest is an unnamed ordinary watercourse that flows in a north-easterly direction through Hilton, Cambridgeshire. The watercourse flows into the Hall Green Brook through Fenstanton before joining the River Great Ouse. The catchment area for this ordinary watercourse is approximately 3.2 km^2.

Purpose of study and complexity:

The aim of this study is to derive peak flow estimates and hydrographs for a site located to the south of the Hilton, Cambridgeshire. These will provide inflows for a hydraulic model that will be developed by Stantec to support the design of a residential development at Church End, Hilton.

Key catchment features:

The catchment is small (less than 5 km^2), and the selected method should therefore be suitable for use in small catchments.

Flooding mechanisms:

Flooding is likely due to flows exceeding channel capacity.

Gauged / ungauged:

The National River Flow Archive (NRFA) indicates that there are no flow or level gauging stations along the watercourse. The catchment has therefore been treated as ungauged.

Final choice of method:

The ReFH2 method is used to derive peak flow values and hydrographs.

Key limitations / uncertainties in results:

The catchment is ungauged, which is the largest source of uncertainty.

1.2 Flood frequencies

- The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.
- Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval.
- Results tables in this document contain both return period and AEP titles; both rows can be retained, or the relevant row can be retained and the other removed, depending on the requirement of the study.
- The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.013	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2. Method Statement

2.1 Requirements for flood estimates

Overview and Project Scope:

The aim of this study is to derive peak flow estimates and hydrographs for the unnamed ordinary watercourse that flows through the south of Hilton, Cambridgeshire. The peak flow estimates and hydrographs will be used to inform hydraulic modelling of the watercourse, which will be carried out by Stantec to support the design of a residential development at Church End, Hilton.

Peak flow estimates and hydrographs will be derived for the full suite of events. This report will focus on the 1 in 2, 30, 100 and 1000-year events. The impacts of climate change will be modelled based on the latest available guidance[1]. The site is located within the Upper and Bedford Ouse Management Catchment, therefore, peak river flow allowances of 19% (central) and 30% (higher central) are applicable to this study for the 2080s epoch (2070-2115).

The study derives peak flow estimates and hydrographs at the downstream point of the catchment to provide inflows for the hydraulic model. See **Figure 1** for the catchment area.

The purpose of this document is to detail the methods followed, the outcomes and results, and the decision-making process and justification of the final accepted flows. Note that it does not include any additional analysis completed using the hydraulic modelling, which is reported and provided separately.

The study is considered to be a simple hydrological assessment, due to the small, rural nature of the catchment. The hydrological assessment makes use of the NRFA v12 dataset within WINFAP 5. ReFH2.3 with FEH22 rainfall data will be applied as a second suitable method for deriving peak flow estimates and to define hydrograph shapes. The catchment is ungauged and therefore hydrograph shapes are defined using the latest available rainfall-runoff method.

2.2 The Catchment

Maps

[1] Environment Agency (2023) Peak river flow climate change allowances by management catchment.

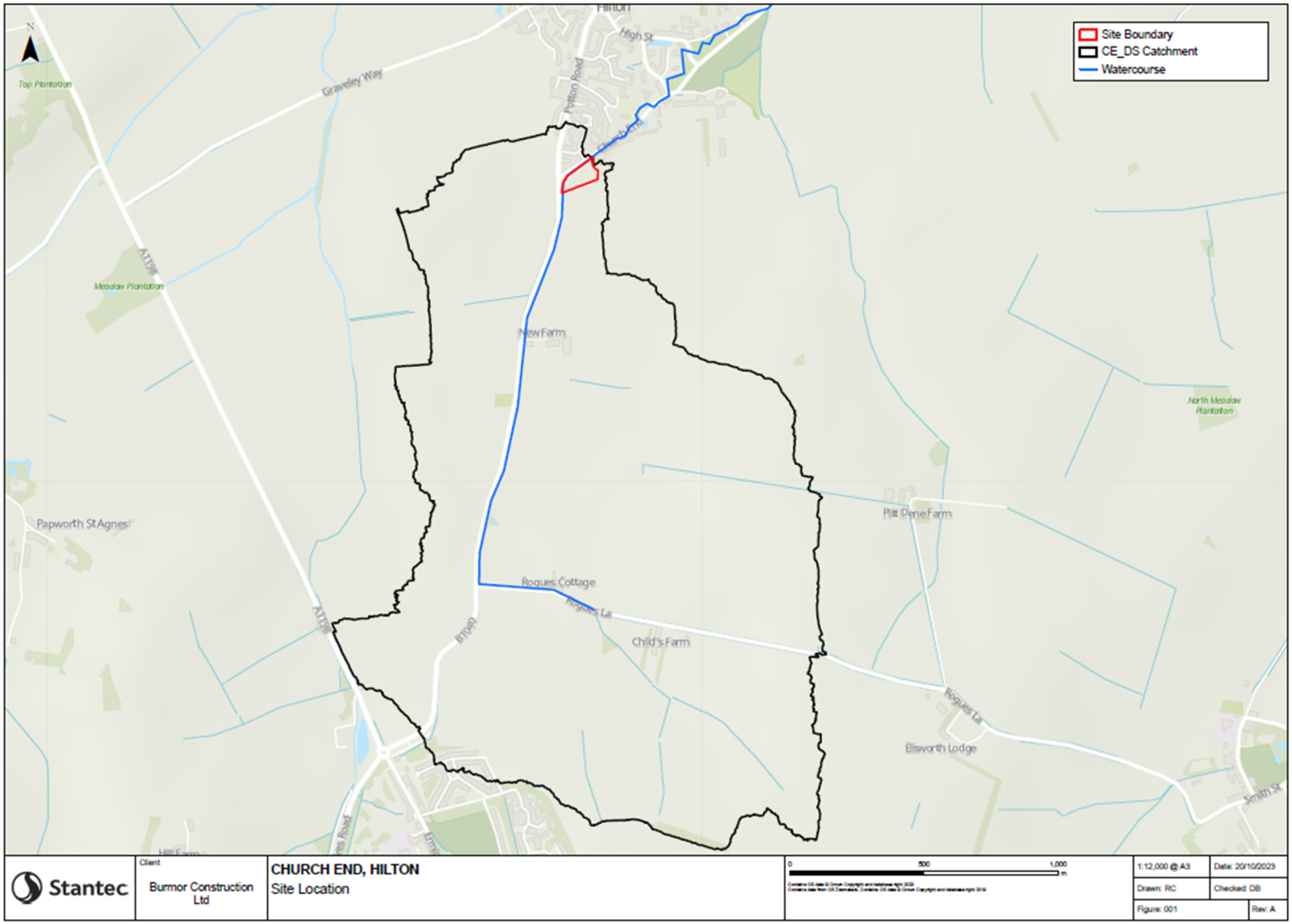

Figure 1 – Site Location

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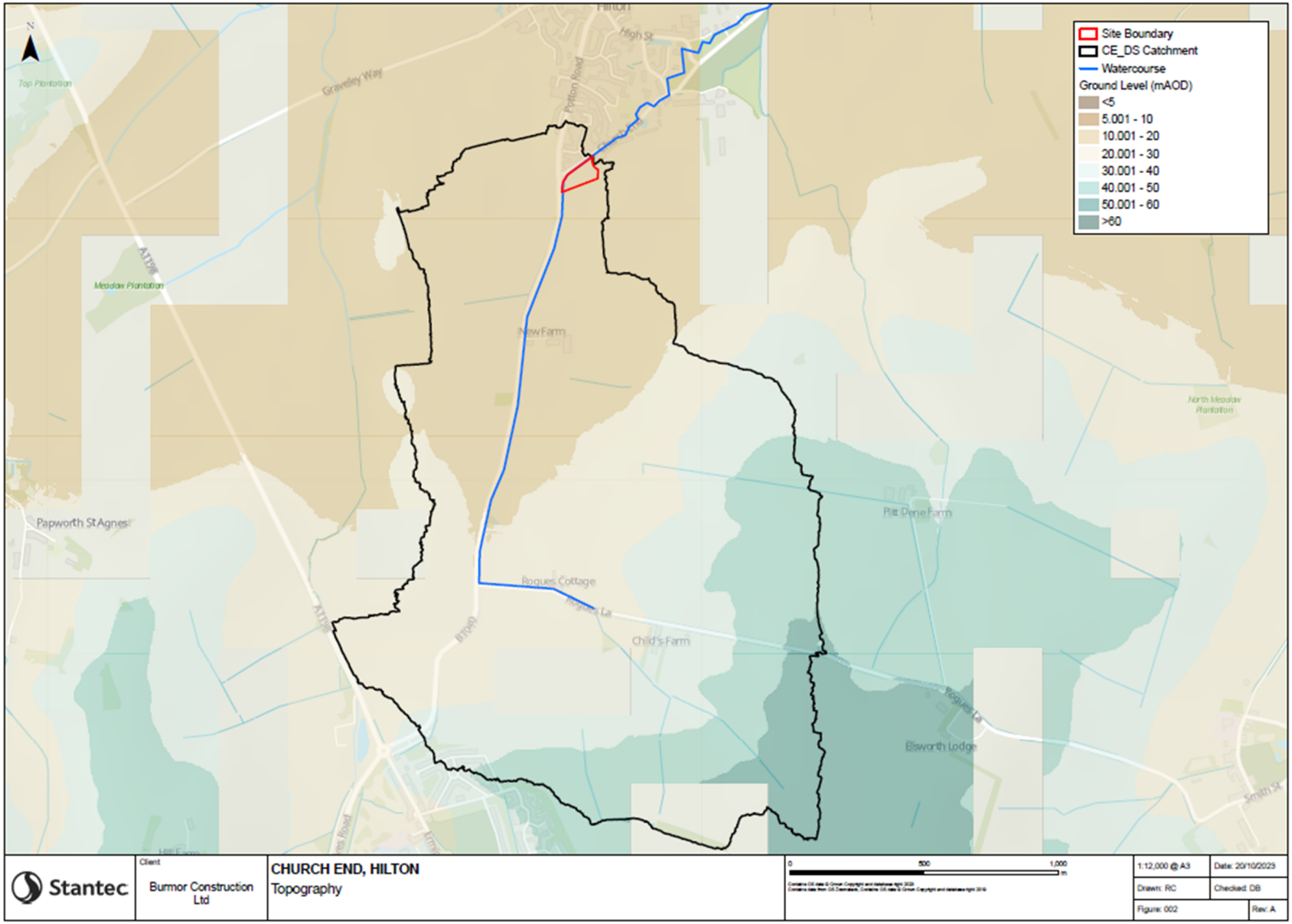

Figure 2 – Site Topography

Catchment Description:

The watercourse flows in a generally north-easterly direction along Church End Road through Hilton, Cambridgeshire and into the Hall Green Brook through Fenstanton before joining the River Great Ouse. The catchment area for this ordinary watercourse is approximately 3.2 km^2. The catchment is relatively flat, ranging in elevation between approximately 55 mAOD in its upper reaches and 12 mAOD at its downstream point (**Figure 2**).

The British Geological Survey (BGS) Geology of Britain mapping indicates that the catchment is predominantly underlain by clay (Oxford Clay Formation, West Walton Formation, and Ampthill Clay Formation). The catchment has a BFIHOST19 value of 0.306, indicating low permeability. The soils within the catchment are classified as lime-rich loamy and clayey soils with impeded drainage (Soilscapes 9 classification).

The catchment is categorised as rural, with small areas of suburban land from Papworth Everard included within the catchment area's upper reaches and from Hilton in its lower reaches, resulting in an URBEXT2000 value of 0.011. The watercourse exists largely as an open channel, with small, culverted reaches at road crossings in its lower reaches.

The catchment is not known to be pumped or mined.

2.3 Hydrometric Data

Source of flood peak data:

NRFA version 12, released September 2023 and contains data up to water year 2021-22 (ends September 2022).

Gauging stations (flow and level):

N/A – catchment is ungauged.

Data available at each flow gauging station:

N/A – catchment is ungauged.

Updates or revisions to flood peak data:

N/A – catchment is ungauged.

Data quality checks carried out:

N/A – catchment is ungauged.

Rating Equations:

N/A – catchment is ungauged.

Rating reviews:

N/A – catchment is ungauged.

Other data available and how it has been obtained:

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings	-	No	-	No spot flow gauging available.
Historical flood data	-	No	-	No historical flooding data available.
Flow or river level data for events	-	No	-	No flow or river level gauging available.
Rainfall data for events	No	-	-	
Potential evaporation data	No	-	-	
Results from previous studies	Yes	Yes	Church End, Hilton Flood Risk Assessment and Surface Water Drainage Strategy – Stantec 2020	Reporting details the hydrological assessment completed to provide model inflows, allowing for comparison to be made to the previous study in terms of hydrology methods used.
Other data or information				

Conclusions of hydrometric data review:

N/A – catchment is ungauged.

2.4 Hydrological understanding of the catchment

Plots of flood peak data and interpretation:

N/A – catchment is ungauged.

Plots of flow data and interpretation:

N/A – catchment is ungauged.

Plots of stage data and interpretation:

N/A – catchment is ungauged.

Conceptual model:

The main site of interest is the area of proposed development to the south of Church End Road shown in **Figure 1**.

The likely cause of flooding is from flows exceeding channel capacity. The low permeability of the catchment is likely to lead to overland flow processes increasing the amount of direct runoff that enters the channel.

Unusual catchment features:

The catchment is not pumped or influenced by reservoirs/lakes. It does not have historical or operational mining activities.

2.5 Initial choice of approach

Are FEH methods appropriate?

The FEH methods are considered to be suitable for application. Appropriate care and consideration will be given to the small nature of the catchment.

Initial choice of method(s) and reasons:

The FEH Statistical method will be used to derive QMED and peak flow estimates at the flow estimation point, through the use of pooled analysis.

The ReFH2 method will also be applied to derive peak flow estimates at the flow estimation point. The ReFH2 method will be applied using the latest available version of the software (ReFH2.3) and data (FEH22 rainfall).

Both methods are consistent with the 2020 study but making use of updated data and software available since then.

How will hydrograph shapes be derived if needed?

The ReFH2 software will be used to derive hydrograph shapes due to the ungauged nature of the catchment.

Will the catchment be split into sub-catchments? If so, how?

The catchment is not intended to be split into sub-catchments.

Software to be used:

FEH Web Service[2] / WINFAP 5[3] / ReFH2.3[4]

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[2] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology and Hydrology, Wallingford UK.
[3] WINFAP 5, © Wallingford HydroSolutions Limited 2023.
[4] ReFH2.3, © Wallingford HydroSolutions Limited 2023.

3. Locations where flood estimates are required

3.1 Summary of subject sites

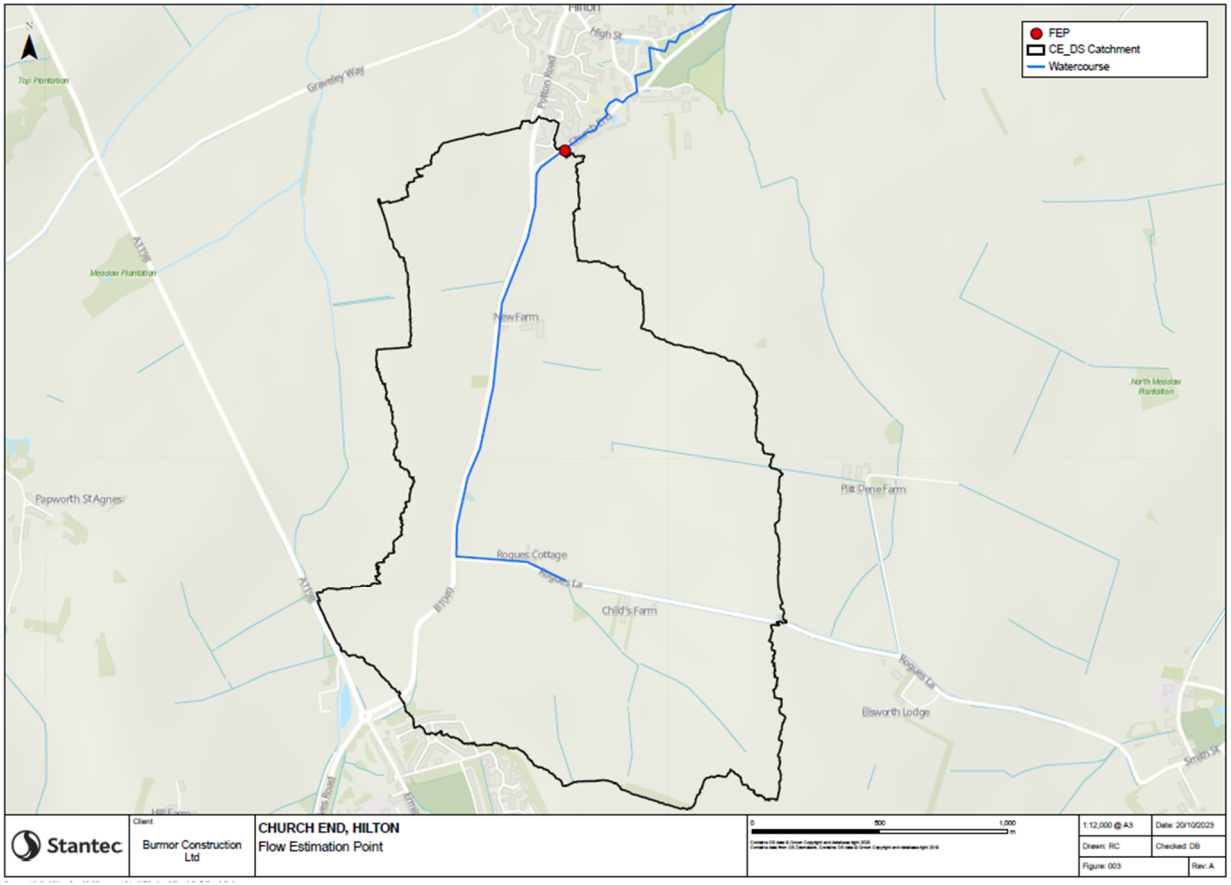

Figure 3 – Flow Estimation Point

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Site code	Type of estimate: lumped (L) or sub-catchment (S)	Water-course	Site name / description	Easting	Northing	AREA on FEH Web Service (km^2)	Revised AREA (if altered) (km^2)
CE_DS	L	Unnamed ordinary watercourse	Catchment area to its downstream point at approximate NGR 528953E, 265942N.	528953	265942	2.50	3.16

3.2 Catchment Descriptors

Final catchment descriptors at each subject site:

Note: Red text denotes catchment descriptors which have been manually calculated and changed from the FEH values, with original FEH values shown in brackets where possible.

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
CE_DS	1.000	0.24	0.306	2.24 (1.77)	24.20	545	0.0016 (0.0015)	0.0108 (0.0105)	0.119

Catchment boundary checks and revisions:

The overall catchment boundary for the watercourse was reviewed using available LiDAR data (1m resolution). Discrepancies were found and therefore LiDAR derived catchments were completed to inform the updates that should be made to make the catchments more representative of the topographic catchment areas.

Figure 4 indicates that the FEH catchment was underestimated in comparison to the adjusted catchment. This is largely in the western extent. The catchment area was amended accordingly, resulting in an overall increase from 2.50km^2 to 3.16km^2.

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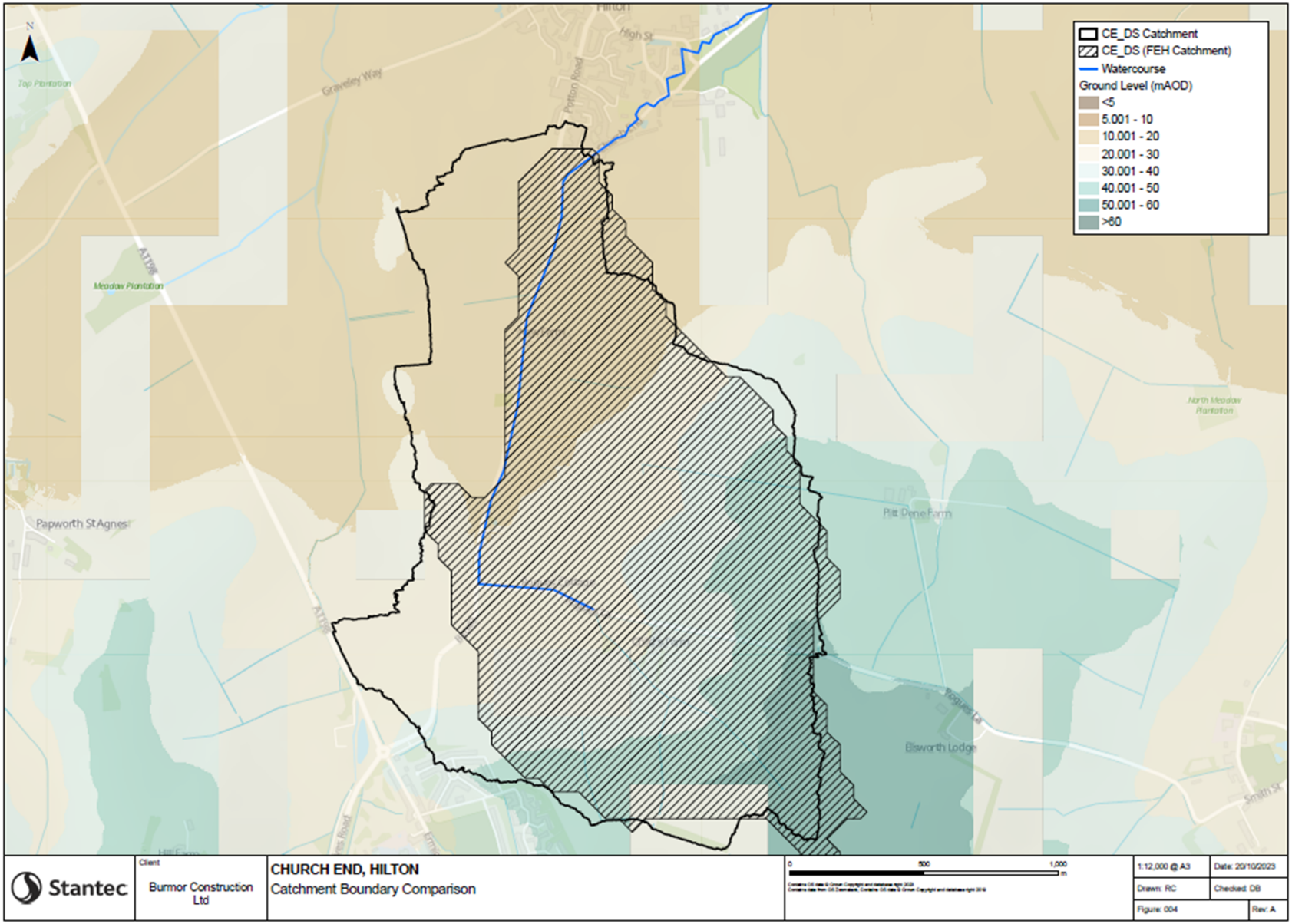

Figure 4 – Comparison of original FEH catchment and amended catchment

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URBEXT source and method for updating:

The URBEXT values provided by the FEH Web Service were checked using OS mapping and information provided by the FEH Web Service. Only minor areas of suburban development from Hilton are included within the northern boundary of the catchment area, whilst minor areas of urban development from Papworth Everard are included within the southern boundary of the catchment area. The increase in catchment area did not include any additional areas of development.

A review of OS mapping indicated that the development in Papworth Everard that the FEH Web Service classified as urban land may be more suitably classified as suburban land. The URBEXT value was therefore manually recalculated, which produced a value of 0.012. This value was similar to the original FEH URBEXT2000 value with the 2023 Urban Adjustment Factor (UAF) of 1.04 applied (URBEXT2000 = 0.011). Hence the UAF-updated URBEXT values were accepted and used within the calculations.

BFIHOST source, checks and updates:

The BFIHOST and SPRHOST values were checked using the 1:250,000 Soil Survey of England and Wales map, in accordance with the IoH126 method. The values calculated were similar to those provided by the FEH Web Service, and therefore the original BFIHOST and SPRHOST values were accepted.

Checks and revisions to other catchment descriptors:

DPLBAR was adjusted to account for the minor change in area, using the ratio between the original area and the updated area to recalculate the original DPLBAR value provided by the FEH Web Service. This resulted in a slight increase in the DPLBAR value from 1.77 to 2.24.

FARL was checked using OS mapping and satellite imagery. There are no reservoirs or lakes observed within the catchment, therefore, the FEH FARL value of 1 was accepted.

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4. Stationary statistical methods

4.1 Method overview

What is the purpose of applying these methods?

The FEH Statistical method is applied to derive QMED and peak flow estimates for the catchment.

What methods will be used to estimate QMED and growth curves?

Site code	Methods used for QMED	Methods used for growth curves
CE_DS	Catchment Descriptors	Pooled Analysis

4.2 Estimating QMED

QMED at gauged subject sites:

Site code	Method (AM/ POT/LF)	Initial QMED (m^3/s)	Number of water years of data used	Adjustment for climatic variation?	Final QMED (m^3/s)

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

Not applicable – no gauged flow data available within catchment.

QMED at ungauged subject sites:

Site code	Method (CD/ DT/BCW)	Initial QMED (rural) from CDs (m^3/s)	Donors used (NRFA numbers)	Donor distances from subject centroid (km)	Individual donor weights	Combined and weighted donor adjustment factor	Urban adjustment factor	Final QMED (m^3/s)
CE_DS	CD	0.53	-	-	-	-	1.009	0.53

Methods: CD - Catchment descriptors alone; DT - catchment descriptors with donor transfer; BCW - catchment descriptors with bankfull channel width.

Urban adjustment of QMED:

The catchment is classified as rural (URBEXT2000 = 0.011) and therefore there was no urban adjustment of QMED.

Search for donor sites:

A donor search was completed within WINFAP5. One donor was recommended as the closest station – 33021 Rhee @ Burnt Mill – however, review of this station revealed that it had a catchment area over 100 times larger than the subject catchment and a much higher BFIHOST value of 0.792, which is not hydrologically similar to the subject catchment. This station was therefore rejected as a donor.

The remainder of the potential donors identified were not considered to be hydrologically similar due to significant differences in their catchment areas and BFIHOST values. Stations rejected include:

- 33027 Rhee @ Wimpole – catchment area >40 times greater than subject catchment, much higher BFIHOST (0.693)
- 33012 Kym @ Meagre Farm – catchment area >46 times larger than subject catchment
- 33052 Swaffham Lodge @ Swaffham Bulbeck – catchment area >7 times larger than subject catchment, significantly higher BFIHOST (0.922)
- 33055 Granta @ Babraham – catchment area >30 times larger than subject catchment, much higher BFIHOST (0.709)
- 33051 Cam @ Chesterford – catchment area >45 times larger than subject catchment, much higher BFIHOST (0.637)

Overall, it was decided that none of the potential donors suggested by WINFAP were suitable for informing QMED due to poor hydrological similarity. Therefore, QMED was informed by the catchment descriptors alone, due to the small nature

of the subject catchment and the fact that the NRFA dataset does not contain many small catchments.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method (AM/ POT/LF)	Adjustment for climatic variation?	QMED from flow data (m^3/s)	De-urbanised QMED from flow data (m^3/s) (A)	QMED from catchment descriptors (m^3/s) (B)	Adjustment ratio (A/B)

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

Not applicable – no suitable donors found for donor adjustment of QMED. QMED calculated based on catchment descriptors alone.

4.3 Estimating growth curves

Derivation of growth curves at subject sites:

Site code	Method (SS, P, ESS, H.)	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-flood years adjustments	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
CE_DS	P	CE_DS_EDIT	GL – acceptable fit	N/A	Location = 1 Scale = 0.276 Shape = -0.216	3.17

Methods: SS - Single Site; P - Pooled; ESS - Enhanced Single Site; H - Historical. Pooled and ESS growth curves were derived using the procedures from Science Report SC050050 (2008). Urban adjustments are carried out using the method of Kjeldsen (2010).

Flood frequency curve plots:

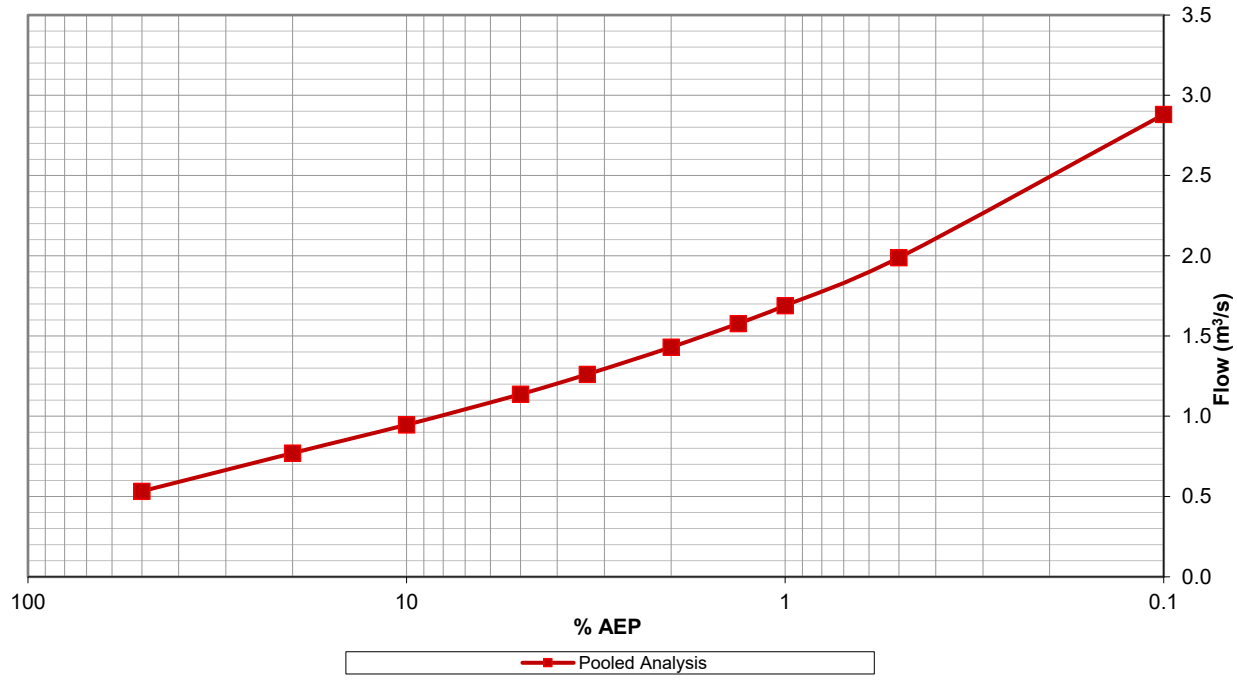

Figure 5 – CE_DS FEH Statistical Flood Frequency Curve

Derivation of pooling groups:

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (ESS)	URBEXT2000 threshold applied to pooling group selection?	L-moments deurbanised (including subject site for ESS)?	Small catchment pooling procedure applied?
CE_DS_EDIT	CE_DS	No	0.03	L-CV: 0.270 L-SKEW: 0.216	No

Methods: Unless otherwise stated, pooling groups were derived using the procedures from Science Report SC050050 (2008). The small catchment pooling procedure is given in the report on Phase 2 of project SC090031 (2021) and implemented in WINFAP v5.

Pooling group composition:

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
CE_DS_EDIT	Stations with low years of data (less than 15) were removed and suitable stations were added to have a pooling group with over 500 years of data. <u>Removed</u> • 7011 – removed as only 10 years of data • 49005 – removed as only 12 years of data <u>Reviewed and Retained</u> • 27023 – groundwater driven (BFIHOST19 = 0.811) • 26016 – extremely groundwater driven (BFIHOST19 = 0.927) • 26014 – extremely groundwater driven (BFIHOST19 = 0.924) • 76011 – significantly higher SAAR and steeper catchment, therefore faster responding catchment than subject catchment • 27010 – much higher SAAR and significantly steeper catchment, therefore faster responding catchment than subject catchment • 39033 – groundwater driven (BFIHOST19 = 0.812) • 33054 – groundwater driven (BFIHOST19 = 0.895) and much lower FARL (0.944)	L-CV: 0.270 L-SKEW: 0.216

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
	Added • 24007 – added due to hydrological similarity and distance value.	

A review of the stations for the pooling group showed that a large number of years of data were not from stations considered to be hydrologically similar to the subject catchment. These stations are referred to above as 'reviewed and retained'. It was considered preferable to remove these stations due to the anticipated differences in hydrological response, however, this would result in the inclusion of stations with a higher distance value. The distance value is the value derived by WINFAP that is based upon the attributes and catchment descriptors considered to be most important when compiling a pooling group.

Due to the extent of years that would be removed, it was considered that those with low years of data, and hence of low quality, would be removed and replaced with a station that was relatively hydrologically similar and had a lower distance value. This retained stations that WINFAP considers to be suitable as defined by the lower distance values.

Overall, it is considered that there is low confidence in the FEH Statistical method for deriving peak flows for the catchment, due to the catchment being relatively small and the fact that the NRFA dataset used to create the pooling group does not contain many small catchments.

4.4 Final choice of QMED and growth curves

Method choice and reasons:

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
CE_DS	QMED derived from catchment descriptors. Donors suggested by WINFAP all had considerably larger catchment areas and there is no local observed data to inform QMED adjustment.	Pooled – no gauged data available for use within the catchment.

Final flood estimates from stationary statistical methods:

Site code	2 50%	30 3.3%	100 1%	1000 0.1%
CE_DS	0.53	1.26	1.69	2.88

Flood peak in m^3/s for the return periods in years or AEP (%) events.

5. Non-stationary statistical methods

Section 4.1 of the latest EA guidance indicates that non-stationary methods should be completed for fluvial flood alleviation projects (short form or outline business case) and flood and coastal erosion risk management strategies if not already submitted to the EA for approval. This study is not being undertaken to support either of these types of projects and therefore isn't considered to be required in this instance.

Due to a lack of reliable, long-term, and suitable quality flow data records in the catchment, non-stationary statistical analysis cannot be completed.

6. Revitalised flood hydrograph (ReFH1) method

Not completed. The updated ReFH2 method has been applied as presented in **Section 7**.

7. Revitalised flood hydrograph 2 (ReFH2) method

7.1 Method Overview

What is the purpose of applying this method?

The ReFH2 method will be used to derive peak flow estimates at the flow estimation point (**Figure 3**), applied using the latest available version of the software (ReFH2.3) and the latest available rainfall data (FEH22). ReFH2 will also be used to define the hydrograph shapes for the hydraulic model inflows.

Rural and urban catchment sub-divisions:

The ReFH2 method was applied with peak flow estimates derived for a lumped catchment. The catchment was therefore not sub-divided.

Version of ReFH2 applied:

ReFH2.3 with FEH22 rainfall.

7.2 Model Parameters

Summary of model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)	Area modelled as urban (km2)	TP urban scaling factor	IF	IRF	DS
CE_DS	CD	4.89	265.58	34.60	0.06	0.75	0.4	0.7	0.5

Methods: OPT: Optimisation from event analysis, BR: Baseflow recession fitting, LAG: TP from lag analysis, CD: Catchment descriptors, DT: Data transfer, CAL: model calibration.

Analysis undertaken to derive model parameters:

No gauged data is available for the catchment to inform model parameter optimisation or calibration.

7.3 Model inputs for design events

Design events for lumped catchments:

Site code	Rainfall DDF model	Urban or rural	Highly permeable?	Season of design event	Storm duration (hrs)	Initial soil moisture Cini	Initial baseflow BFO
CE_DS	FEH22	Rural	No	Winter	7.5	147.02	0.148

The season of the design event was selected based on the URBEXT2000 and BFIHOST19 values, in accordance with the latest EA guidance (Section 4.3). The winter storm profile was accepted for deriving peak flows due to the catchment being classified as rural.

Design events for sub-catchments and intervening areas:

N/A – no sub-catchments or intervening areas.

Storm duration testing:

The storm duration recommended by ReFH2 was 9 hours, with a 1-hour interval. This value was optimised to derive the critical duration in terms of peak flow, which was found to be 7.5 hours with a 0.5-hour interval. This increased peak flow estimates for the 1 in 100-year event from 2.97 m^3/s to 2.99 m^3/s.

7.4 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
CE_DS	Model parameters derived from catchment descriptors. Critical storm durations and storm profiles optimised in ReFH2 through iteration, resulting in a final storm duration of 7.5 hours with a 0.5-hour interval.

Final flood estimates from ReFH2 method:

Site code	2 50%	30 3.3%	100 1%	1000 0.1%
CE_DS	0.99	2.34	2.99	5.04

Flood peak in m^3/s for the return periods in years or AEP (%) events.

8. Other Rainfall-Runoff or Hydrograph Methods

None applied.

9. Discussion and summary of results

9.1 Comparison of results from different methods

Site code	Ratio of ReFH2 to stationary statistical peak, 50% AEP	Ratio of ReFH2 to stationary statistical peak, 1% AEP
CE_DS	1.86	1.77

9.2 Final choice of method

Choice of method and reasons:

The ReFH2 method is suitable for deriving peak flows and hydrographs for small, ungauged catchments. The flows derived by the ReFH2 method were more conservative than those derived by the FEH Statistical method (**Figure 6**).

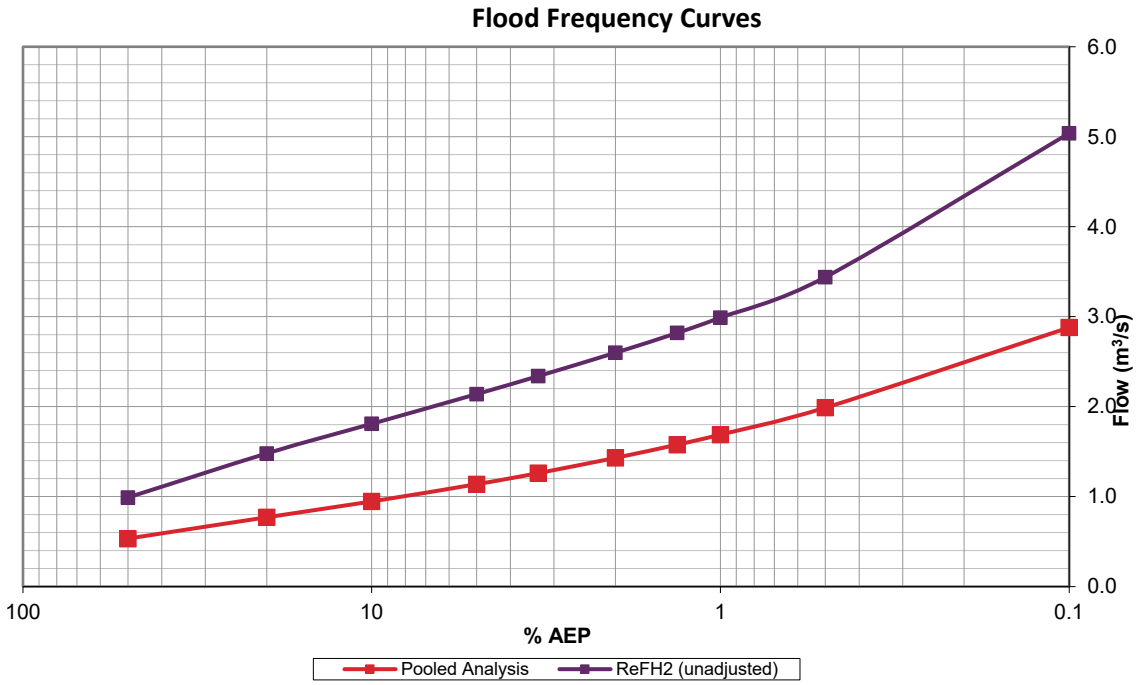

Figure 6 – Comparison of Pooled Analysis and ReFH2 Flood Frequency Curves

There is low confidence in the FEH Statistical method, as the pooling group review showed that there was low confidence in the hydrological similarity of the pooling group composition. This would result in a large number of years of data being removed and increasing the distance values of those stations added to provide a pooling group with 500 years of data. This is likely due to the small

catchment area of the subject site and the fact that the NRFA dataset does not contain many small catchments. Hence, the overall confidence level in the pooling group and the resultant peak flows is low.

The ReFH2 method was therefore considered to be the preferred method for deriving peak flow estimates for the subject catchment.

How will the 0.1% AEP flows be estimated?

ReFH2 is suitable for estimating 0.1% AEP flows and will be used to inform the 0.1% AEP flow.

How will the flows be applied to a hydraulic model?

The flows have been calculated to the downstream point of the catchment. To maintain consistency with the previous hydraulic modelling approach, final flow estimates from this assessment will be area weighted based on the contributing area upstream of the modelled extent, and the remaining catchment areas to the right and left of the watercourse. The upstream area will be inputted to the hydraulic model at the upstream extent of the modelled watercourse. The remaining flows from the right and left areas shall be applied via lateral inflows, connected to reaches upstream and around the proposed site.

9.3 Final results

Site code	2 50%	30 3.3%	100 1%	1000 0.1%
CE_DS	0.99	2.34	2.99	5.04

Flood peak in m^3/s for the return periods in years or AEP (%) events.

Design storms applied in the hydraulic model:

Site code(s)	Season of design event	Storm duration (hrs)	Storm area for ARF (km2)	Return period(s)	Reason for selecting storm
CE_DS	Winter	7.5	0.972	100, 1000, 100-year +19% allowance for climate change, and 100-year +30% allowance for climate change.	Winter storm based on URBEXT2000 value <0.15 (Section 4.3 of EA guidance).

Climate change allowances:

Based on the latest available guidance[5], as the site is located within the Upper and Bedford Ouse Management Catchment, peak river flow allowances of 19% (central) and 30% (higher central) are applicable to this study for the 2080s epoch (2070-2115).

9.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio
CE_DS	3.02	1.47

Specific discharge:

Site code	2 50%	30 3.3%	100 1%	1000 0.1%
CE_DS	3.13	7.40	9.45	15.93

Flood peak in l/s/ha for the return periods in years or AEP (%) events.

Spatial consistency of results:

N/A – peak flows only derived for the downstream extent of the catchment.

Return periods for notable historic floods:

N/A – no observed flow data.

Compatibility with longer-term flood history:

N/A – no gauged data or recorded flood outlines available for the catchment.

The model outputs will be compared to the Flood Map for Planning as a comparison after the hydraulic modelling has been completed.

Comparisons with previous studies:

Comparison of the flood frequency curve between this hydrological assessment and the previous hydrological assessment carried out by Stantec in 2020 (**Figure 7**) shows that the updated methodology, software, and datasets resulted in less

[5] Environment Agency (2023) Peak river flow climate change allowances by management catchment.

conservative peak flow estimates. Note that the previous study did not calculate flows for the 20-year return period, hence the gap in the flood frequency curve.

Comparison of the growth curves in **Figure 8** shows that the growth curves derived within this study and the previous study are similar for lower order events. The 2020 study producing a higher growth curve estimates for higher order events (50, 100, 200 and 1000-year return periods).

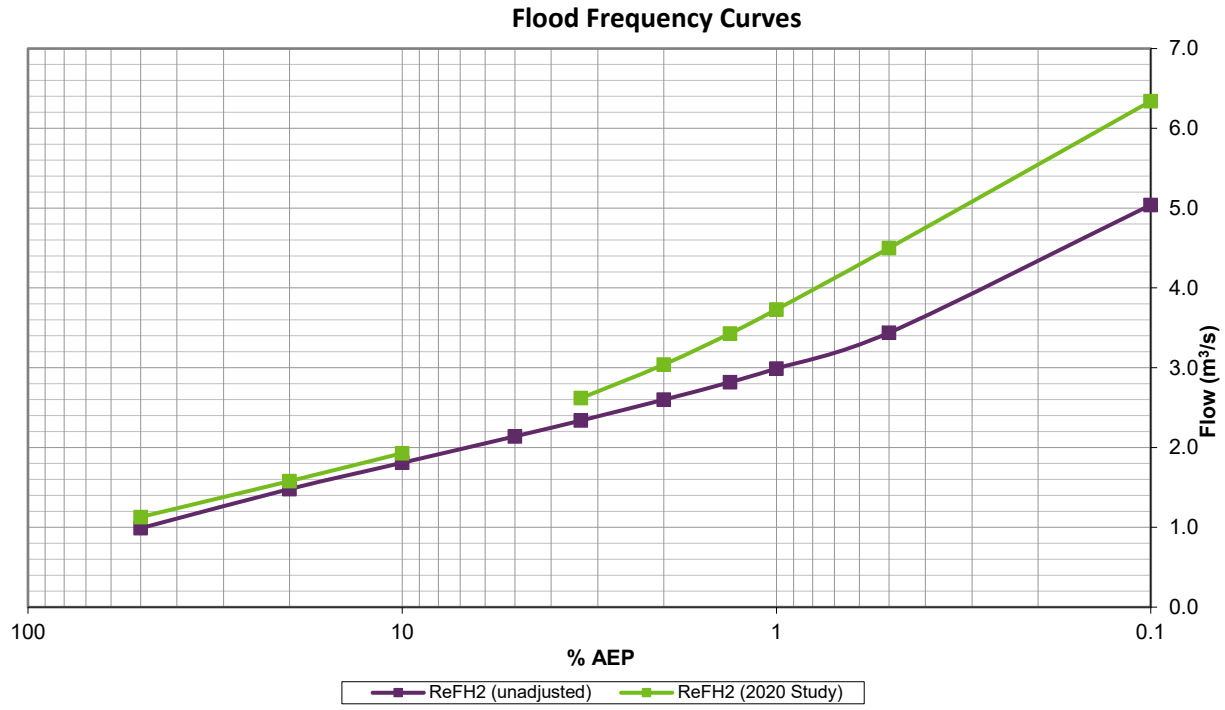

Figure 7 – Comparison of 2020 and 2023 ReFH2 Flood Frequency Curves

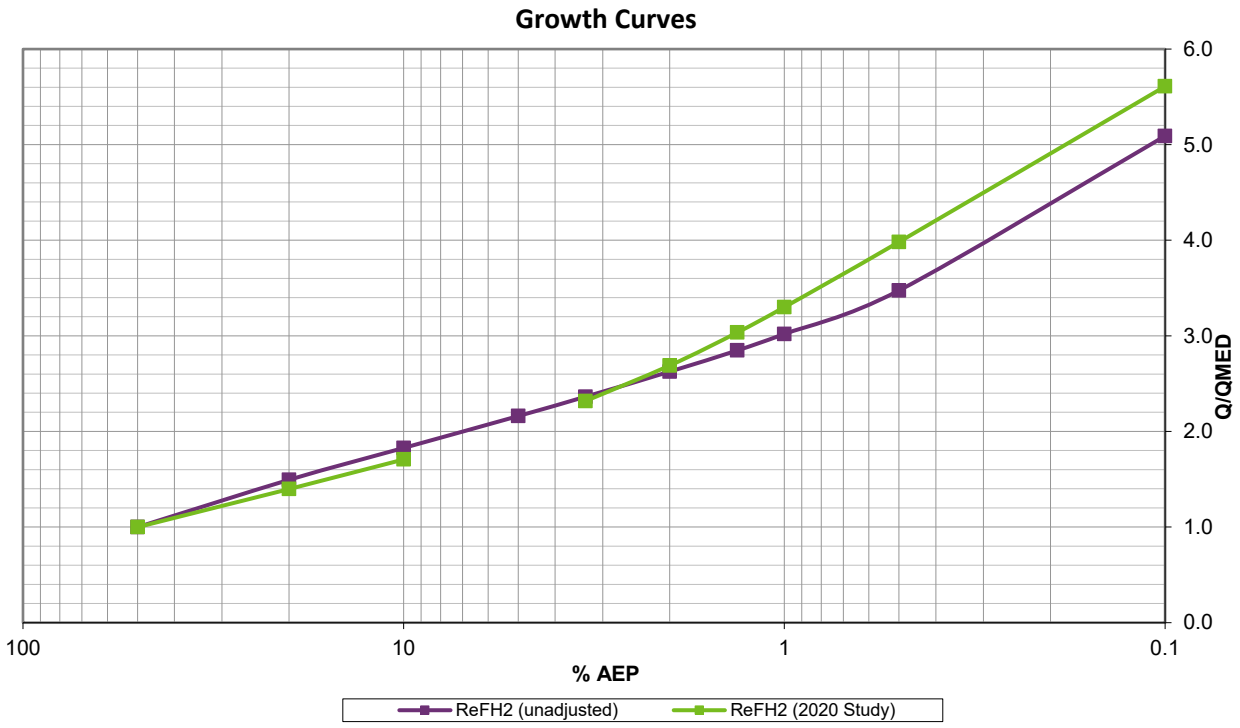

Figure 8 – Comparison of 2020 and 2023 ReFH2 Growth Curves

The results within this study are based on the latest guidance and make use of the latest available software, methods, and data, and are therefore preferred.

Checks on hydraulic model results:

Modelled levels and extents will be sense checked to confirm that flow inputs result in realistic results. This will be reported within the hydraulic modelling report.

9.5 Assumptions, limitations, and uncertainty

Assumptions (specific to this study):

- The catchment descriptors are representative of the catchment
- The ReFH2 hydrograph shapes are representative of the catchment's response to rainfall

Limitations:

The catchment does not have reliable gauged data available for use for deriving peak flow estimates or informing hydrograph shapes. The catchment has been treated as ungauged, which is the most significant limitation to this study.

While a temporary gauge could be installed on the watercourse, the data required to inform a hydrological study is significant and not in line with the timescales of this scheme.

The study has been completed using the available data as far as possible and appropriate, as well as the latest available software and methods, in line with EA guidance. The study is therefore considered to be an appropriate and robust assessment, despite the limitations that exist within the catchment, methods, and data available.

Uncertainty:

Note that the uncertainty bounds provided below are based upon the FEH Statistical method, which was not selected for use. The uncertainty bounds are therefore provided for information only.

Site code	50% AEP Lower 95%	50% AEP Upper 95%	5% AEP Lower 95%	5% AEP Upper 95%	1% AEP Lower 95%	1% AEP Upper 95%	0.1% AEP Lower 95%	0.1% AEP Upper 95%
CE_DS	0.26	1.12	0.52	2.47	0.76	3.77	1.24	6.71

Upper and lower 95% confidence bounds for the flood peak in m^3/s for the AEP (%) events.

The ReFH2 peak flow estimates are within the uncertainty bounds outlined above.

Suitability of results for future studies:

The peak flow estimates and hydrographs have been derived for the downstream extent of the watercourse. The hydrology should be reviewed as a minimum for any future studies.

Recommendations for future work:

The main limitation to this study is the lack of gauged data for the watercourse. If a flow monitoring station was installed upon the watercourse, the data could be used to refine peak flow estimates derived from this study. This was outside the scope of this study.

10. Appendix

10.1 Digital files

Files can be provided on request.

10.2 Pooling Group Information

Pooling Group ID	Default Pooling Group – CE_DS					
	Pooling Group Stations	Years of AMAX Data	Heterogeneity	Goodness of Fit		
				GL	GEV	K3
CE_DS	27073 (Brompton Beck @ Snainton Ings)	42	2.3849	0.11	-1.40	-0.41
	27051 (Crimple @ Burn Bridge)	50				
	26016 (Gypsey Race @ Kirby Grindalythe)	25				
	36010 (Bumpstead Brook @ Broad Green)	55				
	25019 (Leven @ Easby)	44				
	26014 (Water Forlornes @ Driffield)	24				
	76011 (Coal Burn @ Coalburn)	45				
	36004 (Chad Brook @ Long Melford)	55				
	27010 (Hodge Beck @ Bransdale Weir)	41				
	7011 (Black Burn @ Pluscarden Abbey)	10				
	39033 (Winterbourne Stream @ Bagnor)	60				
	33054 (Babingley @ Castle Rising)	46				
	49005 (Bolingey Stream @ Bolingey Cocks Bridge)	12				
	TOTAL	509				

Pooling Group ID	Final Pooling Group – CE_DS						
	Pooling Group Stations	Years of AMAX Data	Heterogeneity	Goodness of Fit			
				GL	GEV	K3	Final Chosen Distribution
CE_DS_EDIT	27073 (Brompton Beck @ Snainton Ings)	42	2.1105	0.03	-1.50	-0.51	GL
	27051 (Crimple @ Burn Bridge)	50					
	26016 (Gypsey Race @ Kirby Grindalythe)	25					
	36010 (Bumpstead Brook @ Broad Green)	55					
	25019 (Leven @ Easby)	44					
	26014 (Water Forlornes @ Driffield)	24					
	76011 (Coal Burn @ Coalburn)	45					
	36004 (Chad Brook @ Long Melford)	55					
	27010 (Hodge Beck @ Bransdale Weir)	41					
	39033 (Winterbourne Stream @ Bagnor)	60					
	33054 (Babingley @ Castle Rising)	46					
	24007 (Browney @ Lanchester)	15					
	TOTAL	502					

TECHNICAL NOTE

Appendix D



This drawing is copyright of DT Architects. Do not scale from this drawing. Check all dimensions onsite. The contractor shall bring any discrepancies immediately to the notice of the Architect.

Key

- House Type 1 - 1b2p (1 Storey)
- House Type 2 - 2b4p (2 Storeys)
- House Type 3 - 2b4p (2 Storeys)
- House Type 4 - 3b5p (2 Storeys)
- House Type 5 - 3b5p (2 Storeys)
- Site Boundary
- Site Ownership
- Potential green space
- Drainage easement line and basin boundary
- Footpath
- Adopted Road
- Private Drive
- Drainage easement
- Attenuation Pond / Drainage
- Plants
- Indicative Proposed Tree

revision	note	date
F02	Updated layout to engineers' and clients' comments	26.07.23
F01	Preliminary issue for comment	21.07.23

client

Oakwater Projects

project title

Residential Development, Church End Hilton

drawing title

Site Layout - Concept 5

drawing status

Feasibility

scale	date	
1:250 @ A1	June 2023	
project number	drawing number	revision
2748	AK0005	F02

DT ARCHITECTS

01733 393010

www.dtarchitects.co.uk

S106 Foul Connection
New adoptable manhole to be constructed online of existing foul sewer subject to S106 consent with Anglian Water. Connection to serve 16 No. dwellings.

IL: 10.598 (Interpolated between MH 8801 and 8901 from Anglian Water Sewer Records)

Exact line and level of sewer is to be confirmed on site by the contractor at least 4 weeks prior to commencement of works.

Proposed 750Ø culvert under proposed access road.

Existing ditch

Existing ditch

S23 Consent
New headwall to be constructed in existing ditch subject to S23 consent.

Surface water flows from proposed development are to be restricted to a rate of 1l/s.

Outfall IL: 11.418
Existing ditch bed level: 11.190

Hydrobrake Flow Control
CL: 13.150
IL: 11.435
Discharge Rate: 1l/s
Design Head: 1.47m
Hydrobrake reference: MD-SHE-0043-1000-1470-1000

Detention Basin
Designed to accommodate all storm events up to 1 in 100 year return period, plus 20% climate change allowance.

Basin IL = 11.450
Top of bank = 13.150
Basin Depth: 1.7m
1 in 100 year +20% max water level = 12.776
Freeboard: 374mm

Sensitivity check carried out for 1 in 100 year return period, plus 40% climate change.

1 in 100 year +40% max water level = 12.902
Freeboard = 248mm

Overhead cables to be diverted around development. Design to be undertaken by services consultant

Design of culvert required for footpath link to the south is to be confirmed following overland flow modelling being under taken by others

Cut-off drain is to be provided to protect the development from overland flows from the south. Design to be confirmed following completion of modelling exercise being undertaken by others.

Drawing is not to be used for construction until status is CONSTRUCTION

General Notes

1. All dimensions are in metres unless otherwise stated.
2. All levels are in metres.
3. This drawing is to be read in conjunction with all relevant Engineers and Architect's drawings, Specifications, Reports and Engineering Details.
4. Do not scale from this drawing.

Drawing Key

- Site Boundary - Taken from site layout referenced
- Existing Foul Water Sewer (taken from Anglian Water sewer records)
- 150Ø @ 1 in 150 F1 — Adoptable S104 Foul Water Sewer with pipe diameter, gradient, material and manhole details
- 150Ø @ 1 in 150 S1 — Adoptable S104 Surface Water Sewer with pipe diameter, gradient, material and manhole details
- Adoptable S104 Headwall
- Private Culvert
- Private Lined Permeable Paving
- Proposed Road Contours
- 14.10 — Existing Ground Levels
- Indicative Retaining Wall
- FFL=113.600 — Finished Floor Levels (+/- 0/5m subject to detailed design)
- Extent of Detention Basin
- Extent of Basin Earthworks to tie into surrounding ground levels
- Cut-off Drain (design to be confirmed following completion of modelling)

Health, safety & the environment

In accordance with the Construction (Design and Management) Regulations 2015, the designs and details on this drawing have been the subject of a Designers Risk Assessment, to identify risks in the construction, use, or demolition of the scheme.

It is not considered necessary for Designers to highlight obvious and/or common risks (such as deep excavations, manual handling and working around heavy plant) which Contractors should be familiar with, and be able to control by good management and site practice.

So far as is reasonably practicable, the risks inherent in the design have been eliminated. Where it has been considered that elimination of a risk (or part of a risk) is not reasonably practicable, it has been reduced.

This drawing has been based/developed using the following external drawings

Type	Company	Drawing date	Drawing title	Date received	Rev
Site Layout	DT Architects	June 2023	'2748AK0005 F02 - Site Layout-Concept S'	08.08.2023	F02
Topographical survey	BES Geomatics	18.10.2019	BES19217_1A	10.08.2023	A

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- Development Planning
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- Geotechnical & Environmental
- Surveying

Northampton
Grand Union Works, Whilton Locks, Daventry
Northamptonshire, NN11 2NH
T: 01604 781811
Poole Milton Keynes Warwick
E: mail@jppuk.net **W:** jppuk.net

Client	Burmor Construction
Project	Church End Hilton
Title	Preliminary Engineering Layout

Scale at A1	Drawn by	Checked by	Date
1:250	ARJ	LC	August 2023

Status	Project ref	Drawing no.	Revision
FOR PLANNING	26448	102	-

Davison, Max

From: Luke Clarke <Luke.Clarke@jppuk.net>
Sent: 27 February 2024 17:33
To: Knowles, Stephanie; Patrick Burke
Cc: Deanna Jones; Davison, Max
Subject: RE: 23006 - Hilton - Hydraulic Modelling review

Follow Up Flag: Follow up
Flag Status: Completed

You don't often get email from luke.clarke@jppuk.net. Learn why this is important

Hi Stephanie,

Further to the Teams call earlier, I have reviewed the largest box culvert size which will work with the existing level constraints:

- The height of the culvert needs to be limited to 1.0m
- Ideally the width of the culvert would be limited to 1.5m, although we could widen the ditch further into site to accommodate a larger culvert, either 1.8m wide or 2.1m wide.

Please can you re-run the model to see if these culvert sizes removes the offsite flooding, or how much the existing ditch would need to be widened?

Kind regards

Luke Clarke MEng (Hons) | **Associate Director**
On behalf of JPP Consulting Ltd
T: 01908 889433 | **M:** 07393 019650 | www.jppuk.net |



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with their registered office at Grand Union Works, Whilton Locks, Daventry, Northamptonshire, NN11 2NH.

From: Knowles, Stephanie <stephanie.knowles@stantec.com>
Sent: Friday, February 23, 2024 5:14 PM
To: Patrick Burke <patrick.burke@burmor.co.uk>; Luke Clarke <Luke.Clarke@jppuk.net>
Cc: Deanna Jones <Deanna.Jones@jppuk.net>; Davison, Max <Max.Davison@stantec.com>
Subject: RE: 23006 - Hilton - Hydraulic Modelling review

HI – I have sent an invite for 11am and will see if I can get someone to cover me for my meeting which is for then. Think it should be ok.

Luke if an issue for you then I will change back to 12pm slot – but thought I should get it in the dairy now rather than later.

Speak next week and will respond to your queries on Monday Luke, once I have looked through all our previous modelling runs, but from memory the reason we went West rather than East was the ditch caused detriment to offsite areas again, probably because capacity of the ditch was an issue, but I will double check for you.

Noted regarding costs of clear span, appreciate that and will see what we can do.

Steph

Stephanie Knowles
Associate
Direct: +44 1223 802917
Mobile: +44 7876 576305
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3rd Floor, 50-60 Station Road, Cambridge, CB1 2JH
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From: Patrick Burke <patrick.burke@burmor.co.uk>
Sent: Friday, February 23, 2024 5:04 PM
To: Luke Clarke <Luke.Clarke@jppuk.net>; Knowles, Stephanie <stephanie.knowles@stantec.com>
Cc: Deanna Jones <Deanna.Jones@jppuk.net>; Davison, Max <Max.Davison@stantec.com>
Subject: RE: 23006 - Hilton - Hydraulic Modelling review

> You don't often get email from patrick.burke@burmor.co.uk. Learn why this is important

Hi Luke, Stephanie,

If there is any possibility of making it an hour earlier (11am) I could make the call, but at midday I will be driving to a site meeting.

If you can't make 11am please set up the invites for 12pm and if I can leave earlier and set up somewhere near my site meeting I will join the call.

Davison, Max

From: Luke Clarke <Luke.Clarke@jppuk.net>
Sent: 08 May 2024 16:41
To: Davison, Max
Cc: Knowles, Stephanie; patrick.burke@burmor.co.uk
Subject: RE: 23006 - Hilton - Hydraulic Modelling review
Attachments: XREF_Drainage.dwg

Follow Up Flag: Follow up
Flag Status: Completed

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Hi Max,

I've reviewed shortening the culvert length, and unfortunately we can't shorten the culvert on the western side of the site access due to the widening of the existing road required. We need to provide clearance from the new kerbline to the existing top of ditch line, and this sets where the upstream end of the culvert must to be located.

We can shorten the culvert on the eastern side by moving the proposed pedestrian crossing closer to the site access and shortening the new footway, however this would still require a total culvert length of 33m.

The only way to shorten the culvert further would be to shift the existing ditch over further into site by circa 2m, however this would impact on the developable area.

I have attached a CAD file showing the shortened culvert, although note the site access layout included hasn't yet been updated.

Please let me know if you require anything else.

Kind regards

Luke Clarke MEng (Hons) | **Associate Director**
On behalf of JPP Consulting Ltd
T: 01908 889433 | **M:** 07393 019650 | www.jppuk.net |

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with their registered office at Grand Union Works, Whilton Locks, Daventry, Northamptonshire, NN11 2NH.

From: Davison, Max <Max.Davison@stantec.com>
Sent: Wednesday, May 8, 2024 10:20 AM
To: Luke Clarke <Luke.Clarke@jppuk.net>
Cc: Knowles, Stephanie <stephanie.knowles@stantec.com>; patrick.burke@burmor.co.uk
Subject: RE: 23006 - Hilton - Hydraulic Modelling review

Morning Luke,

I hope you're doing well.

I just wanted to follow up on the below query Steph raised a while back.

I can give you a ring today it's easier to go over everything on a call?

Kind regards,

Max Davison
BSc(Hons) MSc GradCIWEM
Senior Flood Risk Consultant

3rd Floor, 50-60 Station Road, Cambridge, CB1 2JH
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Office | +44 1223 882000
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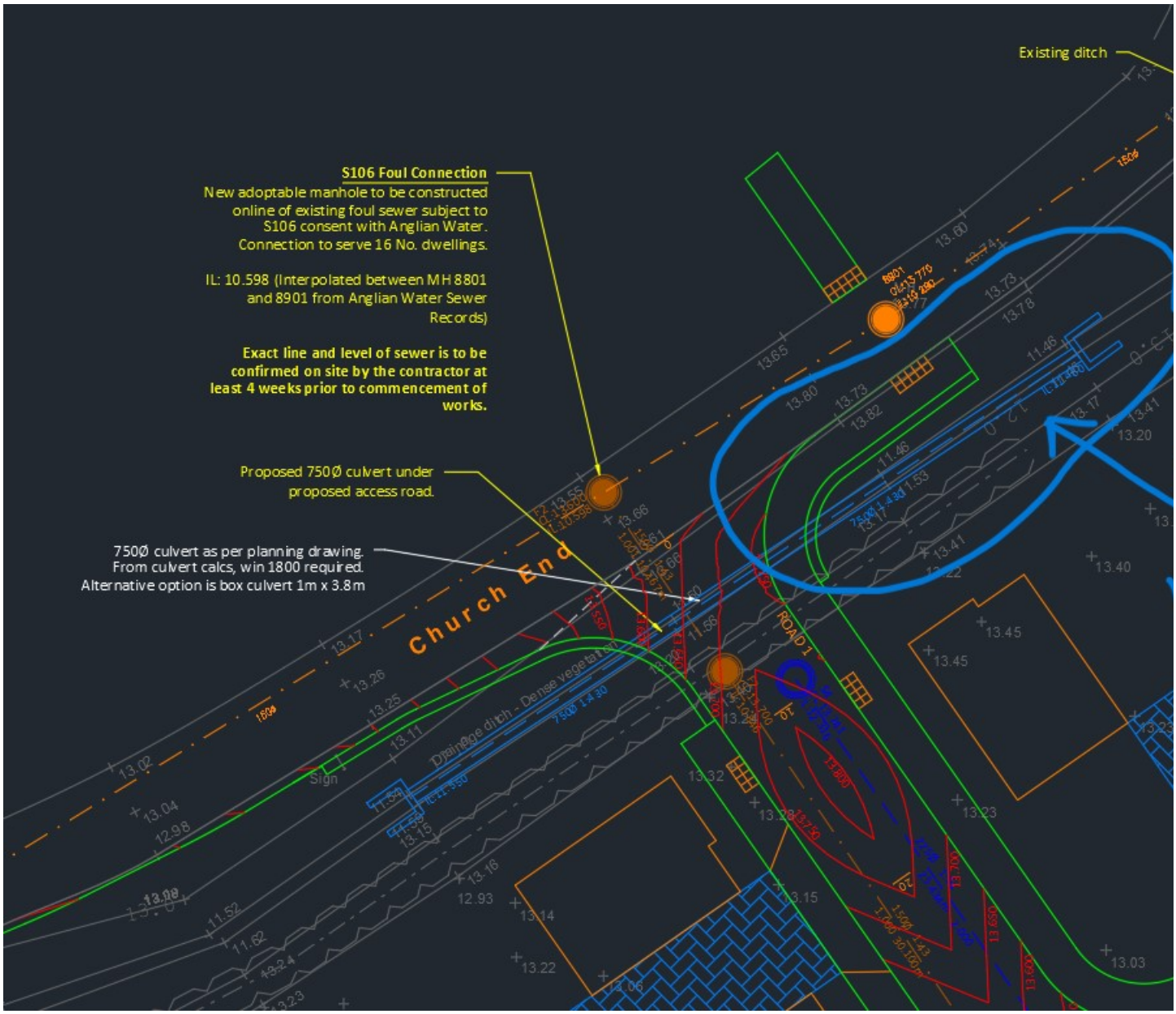
From: Knowles, Stephanie <stephanie.knowles@stantec.com>
Sent: Friday, April 19, 2024 1:04 PM
To: Luke Clarke <Luke.Clarke@jppuk.net>
Cc: Davison, Max <Max.Davison@stantec.com>
Subject: FW: 23006 - Hilton - Hydraulic Modelling review

Hi Luke,

Thanks for talking to me earlier today – was appreciated.

As discussed, the modelling team are looking to provide Patrick an update on the works/ costs for the further review which we need to do, but in the meantime the modellers have suggested it might be possible to reduce the potential flood

risk (subject to our modelling runs), if the longer length of culvert is to the eastern side of the new access and shorter length to the western side, due to low bank levels along the to the west. Mark up below.



If you could have a look at getting your 30m length culvert to work with this in mind and send us a drawing showing this, we can then run the model and try to reduce the mitigation works needed to accommodate.

Any queries then please do let me know.

Kind Regards

Steph

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Cambridge