

- 3.8 A DTM created from the available topographical survey was used to update the LiDAR data.
- 3.9 A 4.0m resolution grid was adopted for the TUFLOW model; this is considered to be more than sufficient given the semi-rural nature of the floodplain, but necessary due to the channel width (in the region of 8m).
- 3.10 Although the 4.0m cell size will pick up most of the significant topographic features, river banks were reinforced using a 'Z-line'. This was primarily informed from the watercourse survey, but where survey coverage was limited the LiDAR data was used to supplement bank levels.

#### Roughness

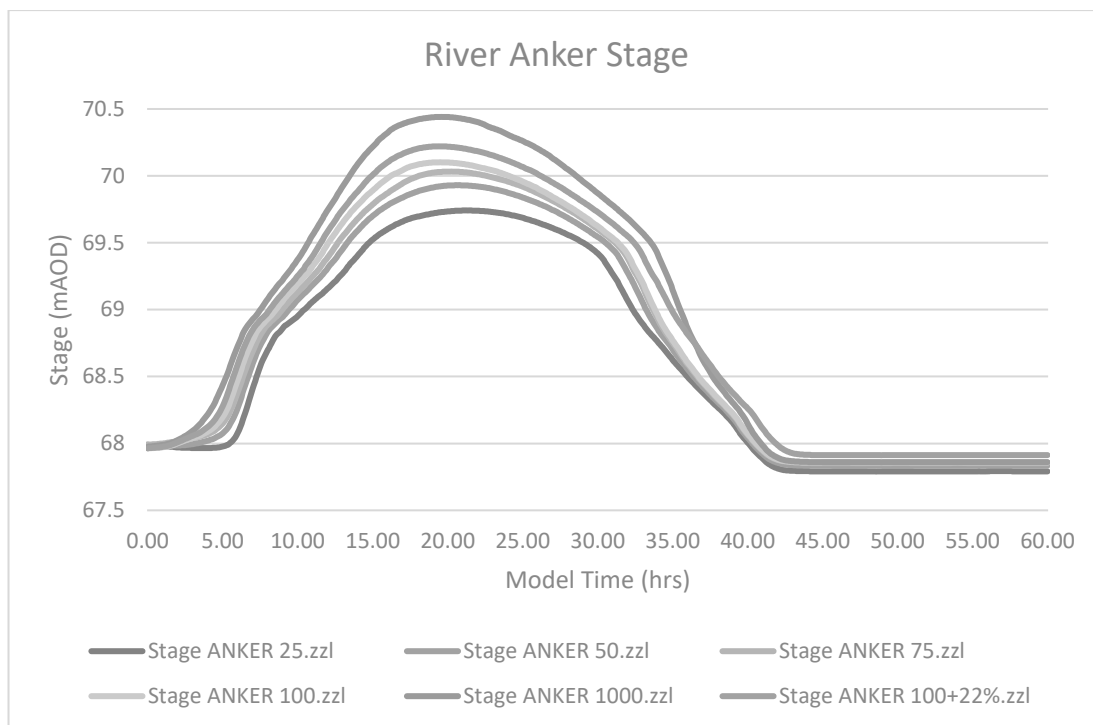
- 3.11 Ordnance survey 1:1250 scale mapping was used to digitise land use areas within the floodplain and apply suitable Manning's 'n' roughness values.
- 3.12 Buildings were modelled as ground level with an elevated roughness value, in line with best practise.

#### ESTRY Interface

- 3.13 The ESTRY-TUFLOW interface was digitised on top of the bank lines; a HX (External Head) boundary was adopted as the interface type.
- 3.14 The 1D channel was removed from the TUFLOW domain using a 'code' layer, and 'NWK' and 'WLL' layers were used to display the ESTRY results within TUFLOW to aid in floodplain mapping.

#### Boundary Conditions

- 3.15 A head-time boundary was used at the downstream extent of the ESTRY model domain (i.e.: The River Anker). The head time boundary was extracted from the EA's River Anker flood model. Results were available for the 1:25yr, 1:50yr, 1:100yr, 1:100 and 1:1000yr events. These are illustrated within **Figure 3-3**.
- 3.16 To account for the latest allowances in climate change on the downstream boundary, it was necessary to simulate the new 1:100yr+22% flows on the Anker. Due to the update in Flood Modeller software (Version 5.0 at the time of writing), all return period events were simulated.



**Figure 3-3: River Anker Stage Hydrographs**

- 3.17 The flood hydrographs, as described in **Section 2.0**, were used as the upstream boundary conditions (flow-time boundaries) for the 1D domain.
- 3.18 The model was run for 35 hours to ensure the impacts of the Anker river levels were fully captured.

### Model Calibration/Verification

- 3.19 As no hydrometric data or detailed historic flood mapping were available, the model could not be directly calibrated against historic flood events.
- 3.20 Although limited data is available for calibration or verification, the modelled extents have been compared to areas noted to have flooded historically as noted in the EA's IAR. The following observations have been made:
- Historical instances of flooding have been reported on several road junctions, including the following:
    - Chapel Lane/Atterton Lane
    - Chapel Lane/Kennel Lane
    - Chapel Lane/Mythe Lane
  - These areas are all shown to flood within the model in return periods greater than a 1 in 20yr event, with some flooding of Mythe Lane precited in the 1 in 20yr event.
  - The EA's IAR also references residents reporting between 0.60-0.90m of floodwater in the roadway along Mythe Lane. The modelled flood depths at this location peak at 0.75m during a 1 in 50yr event during the combined event.

- Based on the above and despite limited available data, the model results are considered to show reasonable agreement with areas that have flooded in the past.

3.21 It is believed that the conservative approach to the model build should offer a sufficiently robust model for the purposes of assessing flood risk at a site-specific level.

## Design Events

3.22 Due to the potential interactions between the River Anker and the Witherley Brook a wide variety of scenarios were tests, these are detailed within **Table 3.1**.

**Table 3.1 - Design events**

| Witherley Brook Return Period (Yrs) | River Anker Return Period (Yrs) |
|-------------------------------------|---------------------------------|
| <i>Witherley Brook Events</i>       |                                 |
| 1:10                                | 1:25                            |
| 1:20                                | 1:25                            |
| 1:50                                | 1:25                            |
| 1:75                                | 1:25                            |
| 1:100                               | 1:25                            |
| 1:100+22%                           | 1:25                            |
| 1:1000                              | 1:25                            |
| <i>River Anker Events</i>           |                                 |
| 1:20                                | 1:50                            |
| 1:20                                | 1:75                            |
| 1:20                                | 1:100                           |
| 1:20                                | 1:100+22%                       |
| 1:20                                | 1:1000                          |
| <i>Combined Events</i>              |                                 |
| 1:20                                | 1:25                            |
| 1:100                               | 1:100                           |

| Witherley Brook Return Period (Yrs) | River Anker Return Period (Yrs) |
|-------------------------------------|---------------------------------|
| 1:100+22%                           | 1:100+22%                       |
| 1:1000                              | 1:1000                          |

## Model Stability and Limitations

### Simulation Parameters

- 3.23 TUFLOW version 2020-AA-10-iSP-w64 was used in all the simulations. All parameters were retained as default.
- 3.24 TuFLOW's Heavily Paralysed Compute (HPC) solver was used due to the significant improvement upon run times offered. However, as the initial model was run using the "classic" solver, a sensitivity test using the classic solver has been included in **Section 5**.

### Model Stability

- 3.25 No negative depths were reported, and the model flux (flow in and out) did not show any significant evidence of an unstable/fluctuating ESTRY-TUFLOW interface.
- 3.26 The ESTRY-TUFLOW cumulative mass error remained within -0.1 to +0.1% for all the simulations, which is well within the acceptable range of -3% to +3%.
- 3.27 Stage and flow hydrographs were also reviewed for the cross sections throughout the model and appear reasonable.

### Limitations

- 3.28 The modelling exercise has made use of the available data at the time of construction and simulation.
- 3.29 The model contains no formal representation of the conveyance within minor watercourses or ditches other than that captured by the model grid and within the ESTRY model domain.
- 3.30 As no hydrometric data or recorded flood levels were available, the model has not been calibrated. However, a conservative approach to the model build has been adopted where appropriate, and a range of sensitivity tests have been undertaken to help to compensate for this limitation. The modelled extents have also been compared to historic flood patterns in the area.
- 3.31 The 4.0m resolution of the model may negate any small scale topographic features, although all the significant features are believed to have been captured. A sensitivity test has also been carried out using a 2m grid to improve confidence in the model results.

- 
- 3.32 The baseline floodplain levels are derived from LiDAR which has limited accuracy (+/- 0.15m). This is considered to be sufficient for the purpose of this exercise.
- 3.33 This modelling exercise has been undertaken to produce a good representation of flood risk mechanisms in and around the study site. It has not been designed to accurately map flooding in the wider catchment.

## 4. BASELINE CONDITIONS

### Witherley Brook Events

- 4.1 The modelling results from the Witherley Brook events are mapped within **Appendix 3** and are summarised within **Figure 4-1**.



**Figure 4-1: Floodplain extents: Witherley Brook events**

- 4.2 The modelling has shown that the flood levels on the southern tributary watercourse are largely controlled by both the capacity of the Atterton Lane culvert and the farm crossing culvert adjacent to the site, which has a smaller diameter at 0.5m. This results in a broadly consistent level water surface upstream of Atterton Lane. There is a head difference of approximately 0.5m between peak water levels either side of the Atterton Lane culvert on most flood events.
- 4.3 The capacity of the 0.5m diameter culvert adjacent to the site is exceeded above the 1:20yr event leading to some localised out of bank flooding. In a 1:100yr event flows are sufficient to overtop the culvert and flow through the existing residential area onto

Atterton Lane. From this point, flood water is largely contained on the carriageway and is routed in a westerly direction onto Mythe Lane and into the River Anker floodplain.

- 4.4 The modelled floodplain extents show a fair correlation with the EA surface water flood risk maps.

### River Anker Events

- 4.5 The modelling results from the River Anker events are mapped within **Appendix 3** and are summarised within **Figure 4-2**.



**Figure 4-2: Floodplain extents: River Anker events**

- 4.6 The modelling has shown that the flood levels upstream of Atterton Lane are not significantly affected by the River Anker. Flood levels at all flood events remain broadly the same (that of a 1:20yr event on the Witherley Brook, which the Anker events were simulated against).

- 4.7 The River Anker events are shown to impact flooding on Atterton Lane and the downstream village. However, the peak flood levels are not as significant as the equivalent return period event on the Witherley Brook upstream of Atterton Lane.

### Combined River Anker & Witherley Brook Events

- 4.8 The modelling results from the Combined River Anker and Witherley Brook events are mapped within **Appendix 3** and are summarised within **Figure 4-3**.
- 4.9 A comparison against the standalone Witherley Brook events show little difference in the peak flood levels generated within the study area. This is a result of the differing timings of the hydrographs associated with the River Anker (132.4km<sup>2</sup>) and Witherley Brook (8.4km<sup>2</sup>) catchments, and the differing critical storm durations required to generate peak flows. For this reason, the approach taken where the same return period event occurs on each watercourse was considered conservative enough without matching the timing of the peak flows exactly, due to the differences in catchment size and hydrological response.



**Figure 4-3: Floodplain extents: Combined events**

## 5. SENSITIVITY TESTS

- 5.1 In order to provide further confidence in the predicted flood levels and extents, the updated baseline has been tested against a number of key variables/scenarios. These are outlined below:
- Manning's n – Seasonal variation in vegetation density will have an impact on the hydraulic roughness of the channel and floodplain. Therefore, roughness values have been both increased and decreased by a value of 20%.
  - Blockage – A complete blockage of the Atterton Lane culvert was modelled to identify the impact on flood risk in the event of a blockage caused by debris.
  - Grid size – The grid size was halved to 2m to identify any impacts this would have on modelled extents.
  - Solver – The Classic solver has been compared to the HPC solver to understand the robustness of the results.
- 5.2 It was not considered necessary to undertake further analysis of the downstream boundary, as this was comprehensively tested within the design events (the River Anker Events).
- 5.3 The sensitivity tests were undertaken using a combined 1:100yr+22% (design) event, and the results were compared against the baseline design event to determine the potential impact. The change in peak water levels are mapped within **Appendix 4**.
- 5.4 The modelling has shown that a reduction in channel and floodplain roughness (representative of winter seasonal conditions or following maintenance) results in a general decrease of flood levels in and around the site by 80-100mm. This is a result of the increased efficiency of conveyance through the floodplain corridor and Atterton Lane culvert.
- 5.5 Similarly, an increase in Manning's 'n' (representative of summer seasonal conditions, and a period without maintenance) is shown to result in a general increase of flood levels at and around the site by 50mm. This is a result of the increased resistance to water flowing over a surface.
- 5.6 A 100% blockage of the Atterton Lane culvert is shown to result in upstream flood levels increasing by 160mm. The downstream channel shows a reduction in water level by 20mm. Flood levels also increase on Chapel Lane by 10-20mm.
- 5.7 A reduction in grid size is shown to reduce flood levels at the site in the region of 2-5mm, having negligible impact.
- 5.8 The Classic solver is shown to reduce flood levels by 2-5mm. Given the tolerance of the modelling, this impact is considered negligible.

## 6. SUMMARY & CONCLUSIONS

- 6.1 The aim of the modelling exercise was to identify the fluvial flood risk within the vicinity of Chapel Lane, in Witherley, Leicestershire. This was achieved through the creation of a bespoke 1D-2D hydraulic model.
- 6.2 The model includes the flood flows generated from the Witherley Brook catchment as well as the backwater effect of the River Anker.
- 6.3 The modelling has shown that flood levels to the south of Atterton Lane are largely controlled by the Atterton Lane culvert and its overflow route through the Atterton Lane residential properties.
- 6.4 The River Anker is shown to not have a significant effect upstream of the Atterton Lane culvert.
- 6.5 Sensitivity tests have shown that flood levels are sensitive to changes in roughness, as well as blockage of the Atterton Lane culvert. However, the comparisons to the baseline using the classic solver and reduced grid size are shown to have a negligible impact.

## **Appendix 1: Hydrology Report**

## **ENVIRONMENT**

A R Cartwright (Construction) LTD  
Chapel Lane  
Wetherley  
Flow Estimation Record

## ENVIRONMENT

### Chapel Lane Witherley Flow Estimation Record

Birmingham  
Livery Place, 35 Livery Street, Colmore Business District  
Birmingham, B3 2PB  
T: 0121 233 3322

Leeds  
Whitehall Waterfront, 2 Riverside Way  
Leeds, LS1 4EH  
T: 0113 233 8000

London  
11 Borough High Street  
London, SE1 9SE  
T: 0207 407 3879

Manchester  
11 Portland Street  
Manchester, M1 3HU  
T: 0161 233 4260

Nottingham  
5<sup>th</sup> Floor, Waterfront House, Station Street  
Nottingham, NG2 3DQ  
T: 0115 924 1100

August 2021

## DOCUMENT ISSUE RECORD

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## 1. METHOD STATEMENT

### Overview of requirements

- 1.1 Flow estimates are required for input into a hydraulic model of the Witherley Brook, to support a Flood Risk Assessment (FRA) for residential development to a site off Chapel Lane, Witherley.
- 1.2 The location of the site of interest and the watercourses to be modelled are provided in **Figure 1-1**.
- 1.3 Return periods to be assessed include: 10, 20, 50, 75, 100, and 1000-years. To inform the design event and potential future floodplain, the 1 in 100-year event plus an allowance for climate change will also be simulated. Hydrographs are required as well as peak flows.
- 1.4 The hydrological assessment was undertaken in August 2021.

**Figure 1-1: Site Location Plan**



## Climate change

- 1.5 Predicted future change in peak river flows caused by climate change are provided by the Environment Agency (EA), with a range of projections applied to regionalised 'Management Catchments'<sup>1</sup>.
- 1.6 The catchment falls within the Tame, Anker and Mease Management Catchment. **Table 1-1** identifies the relevant peak river flow allowances from this Management Catchment.

**Table 1-1: Peak River Flow Allowance for the Tame, Anker and Mease Management Catchment**

| Allowance Category | Total potential change anticipated for the '2020s' (2015 to 2039) | Total potential change anticipated for the '2050s' (2040 to 2069) | Total potential change anticipated for the '2080s' (2070 to 2115) |
|--------------------|-------------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------|
| Upper End          | 24%                                                               | 30%                                                               | 51%                                                               |
| Higher Central     | 15%                                                               | 17%                                                               | 30%                                                               |
| Central            | 10%                                                               | 11%                                                               | 22%                                                               |

- 1.7 When determining the appropriate allowance, the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of a future development should be considered.
- 1.8 **Table 1-2** provides a matrix summarising the EA's guidance on determining the appropriate allowances.

**Table 1-2: Appropriate Allowances for the Tame, Anker and Mease Management Catchment**

| Flood Zone | Essential Infrastructure                                                                    | Highly Vulnerable                                                          | More Vulnerable                     | Less Vulnerable                     | Water Compatible          |
|------------|---------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------------------------|-------------------------------------|---------------------------|
| 1          | Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future. |                                                                            |                                     |                                     |                           |
| 2 or 3a    | Use the higher central allowance                                                            | Use the central allowance (development should not be permitted in Zone 3a) | Use the central allowance           | Use the central allowance           | Use the central allowance |
| 3b         | Use the higher central allowance                                                            | Development should not be permitted                                        | Development should not be permitted | Development should not be permitted | Use the central allowance |

<sup>1</sup> <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>. Accessed August 2021.

\*If development is considered appropriate when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the upper end allowance.

### Available hydrometric data

- 1.9 There are no hydrometric gauges within the catchment. Therefore, there are no current hydrometric records of river flows or levels for the watercourse on which a hydrological assessment of flood flows can be made.
- 1.10 The National River Flow Archive (NRFA) Peak Flow Dataset Version 9 will also be utilised in this assessment for the purposes of identifying any potential donor stations and for the development of pooling groups.

### Initial choice of approach

**Table 1-3: Method statement**

|                                               |                                                                                                                                      |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| Is FEH appropriate?                           | Yes                                                                                                                                  |
| <b>Initial choice of method(s) and reason</b> | Comparative method between the rainfall runoff method (ReFH2) and the statistical method (WINFAP), in accordance with best practice. |
| <b>Software to be used</b>                    | WINFAP version 4 and ReFH2 version 2.3                                                                                               |

### Previous Hydrological Assessments

- 1.11 This hydrological assessment is a revision to a previous BWB peak flow estimate undertaken in 2016. Key details are included below:
- The assessment was undertaken in April 2016.
  - The catchment was taken from the confluence of the Witherley Brook and River Anker.
  - ReFH and WINFAP v3 were used, revisions of both have since been released.
  - The ReFH method was used as this resulted in the worst case flows.

## 2. LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED

### Location of Flow Estimates

**Table 2-1: Summary of subject sites**

| Site code                      | Watercourse     | Site                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Easting | Northing | Area on FEH Web Service | Revised area (if altered) |
|--------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|----------|-------------------------|---------------------------|
| W01                            | Witherley Brook | Total catchment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 432315  | 298055   | 8.4km <sup>2</sup>      | -                         |
| W_TRIB                         | Witherley Brook | North east catchment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 432780  | 297685   | 6.6km <sup>2</sup>      | 6.7km <sup>2</sup>        |
| Reasons for choosing locations |                 | <p>Given the short section of the watercourse to be modelled and relatively small difference in catchment area, once the tributary is accounted for, taking a flow estimate point at the downstream extent reduces the need to define catchment descriptors for the intervening area and the uncertainty that would introduce. Instead, once the hydrograph for the tributary is subtracted from the downstream hydrograph the remaining hydrograph can be pro-rata'd based on the relevant catchment areas (for more information on application of flows to model see <b>section 5.3</b>).</p> |         |          |                         |                           |

**Figure 2-1: Flow Estimation Locations**



## Checking Catchment Descriptors

**Table 2-2: Catchment Descriptor Checks**

|                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Record how catchment boundary was checked and describe any changes.                                                                       | Slight amendments were made to the catchment boundary using LiDAR data at a 2m resolution; however, this did not result in a change in catchment area at the downstream flow estimation point. The amendments did result in a slight change in the northeast catchment which increased by 0.1km <sup>2</sup> in area. Please see <b>Figure 2-2</b> .                                                                                                                   |
| Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary. | Soils are generally loamey and clayey within the catchment and with slightly impeded or impeded drainage. BFIHOST values are considered appropriate.<br>The presence of reservoirs or large bodies of water that could influence attenuation within the catchment were reviewed on aerial imagery. The current FARL value is considered appropriate.<br>The potential to update the URBEXT value for the slightly amended catchment was considered, however, the minor |

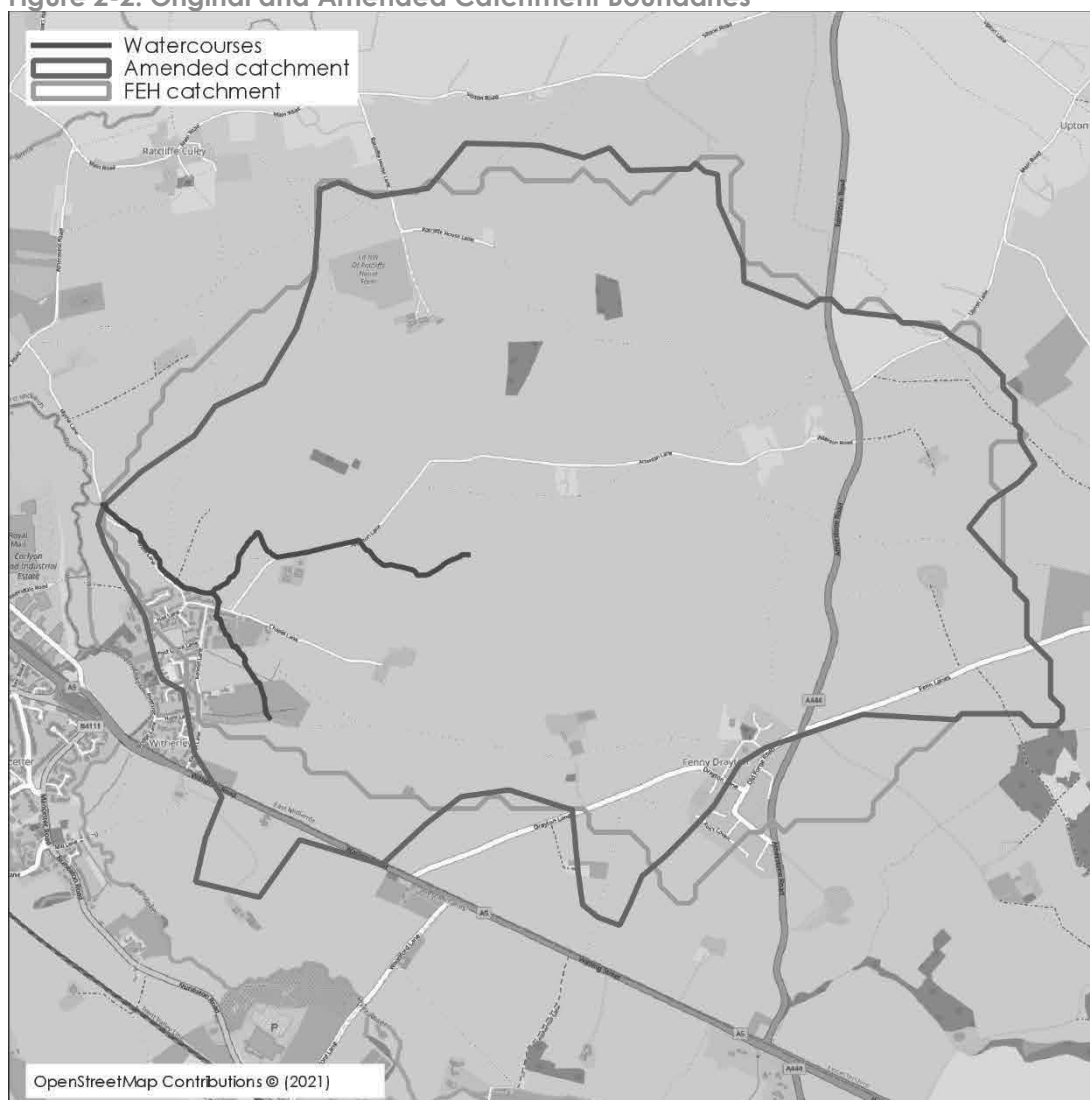
|                                                      |                                                                                                                                                                                                                                                                                                                                  |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                      | urban area removed would be balanced by the minor urban area and road added. Therefore, URBEXT was not updated. DPLBAR was considered given the slight update to catchment area for the tributary, however, the negligible change in catchment area meant that the impact on DPLBAR was limited. Therefore, DPLBAR was retained. |
| <b>Source of URBEXT</b>                              | URBEXT <sub>2000</sub>                                                                                                                                                                                                                                                                                                           |
| <b>Method for updating of URBEXT to present day.</b> | CPRE formula from 2006 CEH report on URBEXT <sub>2000</sub>                                                                                                                                                                                                                                                                      |

**Table 2-3: Important catchment descriptors at each subject (changes made are highlighted in red)**

| Site Code | FARL  | PROPWET | BFIHOST | DPLBAR (km) | DPSBAR (m/km) | SAAR | SPRHOST | URBEXT '2000 * | FPEXT |
|-----------|-------|---------|---------|-------------|---------------|------|---------|----------------|-------|
| W1        | 0.998 | 0.3     | 0.39    | 2.81        | 14.9          | 630  | 43.4    | 0.014          | 0.20  |
| W_TRIB    | 0.998 | 0.3     | 0.38    | 2.32        | 16.1          | 629  | 43.5    | 0.001          | 0.18  |

\* URBEXT<sub>2000</sub> updated to 2021

**Figure 2-2: Original and Amended Catchment Boundaries**



### 3. STATISTICAL METHOD

- 3.1 WINFAP version 4 was utilised to undertake a statistical analysis of the catchment using a hydrometric record of gauged catchments with similar characteristics. The latest version of the NRFA Peak Flow dataset (v9) was used to provide an up-to-date hydrometric record.

#### QMED Development

- 3.2 Catchment descriptors were originally used to estimate the rural QMED of the study site using the revised equation from Science Report (SC050050). The FEH states that flood frequency is best estimated by gauged data and estimation of key variables from catchment descriptors alone should be a method of last resort. As such, a search was undertaken to identify any potential donor sites that could be used to adjust QMED.
- 3.3 The research underlying the revised data transfer method (SC050050) found that identification of potential donor catchments should be based on geographical closeness rather than on hydrological similarity, as defined by catchment descriptors. More recent research on small catchments (SC090031) has supported the findings of SC050050, again recommending that donors are selected purely based on proximity. The EA FEH Guidelines advises similarity in catchment descriptors is not essential for donors. However, in view of the sometimes-uncertain relationship between BFIHOST and runoff, similarity in geology or soil type may be relevant. The guidelines also advise considering more than one donor.
- 3.4 With the guidance in mind, a search was undertaken within WINFAP 4 for suitable donor stations for QMED data transfer. The six nearest donors were reviewed based on similarity in BFIHOST to the subject site and data quality. Of the recommended donors the following were rejected:
- 54102: Flows are influenced by the Stanford reservoir, introducing higher uncertainty.
  - 31005: Flows are influenced by abstractions at the Eye Brook reservoir. Subject to moderate industrial and agricultural abstractions.
  - 28002: Blithe reservoir controls 75% of the catchment area, introducing higher uncertainty.
  - 32029: Limited data with only 5 years available.
- 3.5 Details for the donor stations are provided in **Table 3-1**.

**Table 3-1: Donor Station Details**

| Station Number | QMED from Observed Data (A) | QMED from Catchment Descriptors (B) | Adjustment Ratio (A/B) |
|----------------|-----------------------------|-------------------------------------|------------------------|
| 54102          | 12.3                        | 13.2                                | 0.93                   |
| 31005          | 37.2                        | 43.5                                | 0.86                   |
| 28024          | 34.5                        | 37.7                                | 0.91                   |

| Station Number | QMED from Observed Data (A) | QMED from Catchment Descriptors (B) | Adjustment Ratio (A/B) |
|----------------|-----------------------------|-------------------------------------|------------------------|
| 28002          | 17.5                        | 29.4                                | 0.60                   |
| 32029          | 2.5                         | 1.4                                 | 1.79                   |
| 31025          | 9.9                         | 5.4                                 | 1.84                   |

**Table 3-2: Overview of estimation of QMED at each subject site**

| Table 6-2. Overview of estimation of QMED at each subject site                                                |                |                                                |                                                                            |                                                |        |                         |                                              |
|---------------------------------------------------------------------------------------------------------------|----------------|------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------|--------|-------------------------|----------------------------------------------|
| Site Code                                                                                                     | Method         | Initial Estimate of QMED (m³/s)<br><br>(Rural) | Data Transfer                                                              |                                                |        |                         | Final estimate of QMED (m³/s)<br><br>(URBAN) |
|                                                                                                               |                |                                                | Donor site NRFA no                                                         | Distance between centroids d <sub>j</sub> (km) | Weight | Final Adjustment Factor |                                              |
| W01                                                                                                           | Donor Transfer |                                                |                                                                            |                                                |        | 1.06                    | 1.7                                          |
|                                                                                                               |                |                                                | 28024                                                                      | 46.12                                          | 0.18   |                         |                                              |
|                                                                                                               |                |                                                |                                                                            |                                                |        |                         |                                              |
|                                                                                                               |                |                                                | 31025                                                                      | 49.02                                          | 0.17   |                         |                                              |
| W_TRIB                                                                                                        | Donor Transfer |                                                |                                                                            |                                                |        | 1.06                    | 1.4                                          |
|                                                                                                               |                |                                                | 28024                                                                      | 45.89                                          | 0.18   |                         |                                              |
|                                                                                                               |                |                                                |                                                                            |                                                |        |                         |                                              |
|                                                                                                               |                |                                                | 31025                                                                      | 48.82                                          | 0.17   |                         |                                              |
| Are the values of QMED consistent, for example at successive points along the watercourse and at confluences? |                |                                                | Yes                                                                        |                                                |        |                         |                                              |
| Which version of the urban adjustment was used for QMED?                                                      |                |                                                | Urban adjustment was applied using Kjeldsen (2010), as applied in WINFAP4. |                                                |        |                         |                                              |

- 3.6 Although the FEH only mentions performing the urban adjustment for urban catchments, the EA's FEH Guidelines recommend applying it on all catchments to avoid a discontinuity when URBEXT<sub>2000</sub> exceeds the threshold value of 0.030. As such, urban adjustment has been applied to all subject site(s).

### Derivation of Pooling Groups

- 3.7 A pooled group of hydrologically similar gauged sites was generated by the WINFAP software for the subject sites using the 'OK for Pooling' dataset. A single pooling group for both flow estimation points due to the similarity in catchment descriptors and their proximity to one another.

- 3.8 The pooling group was reviewed to identify sites which may be inappropriate due to being significantly hydrologically dissimilar to the study site, or if they have any inaccuracies, uncertainties, or limitations in their data record.
- 3.9 The growth curve derived from the pooling group was also adjusted to reflect the urban influence using the methods adopted in WINFAP<sup>2</sup> which is based on those published by Kjeldsen 2010<sup>3</sup>.
- 3.10 Further detail on pooling group composition is provided in **Section 6**.

**Table 3-3: Derivation of pooling groups**

| Name of group | Site code from whose descriptors the group was derived | Subject site treated as gauged? (enhanced single site analysis) | Change made to default pooling group with reasons, including any sites investigated but retaining in the group                                                                                                                                                                                                                                                                                                                         | Weighted average L-moments L-CV and L-skew (before urban and permeable adjustment) |
|---------------|--------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| PG01          | W01<br>W_TRIB                                          | N/A                                                             | <p>Stations Removed: 49005 (discordant, which appears to be due to the site having a very low (negative) kurtosis compared to the other stations in the pooling group.)</p> <p>44008 (non flood years represent &gt; 20% of station record).</p> <p>Stations Added: 33054</p> <p>Comments: Following review the catchment is classed as heterogenous. However, it is not considered possible to further improve the pooling group.</p> | <p>L-CV: 0.253<br/>L-Skew: 0.226</p>                                               |

<sup>2</sup> Wallingford HydroSolutions (2016), WINFAP 4 Urban adjustment procedures, Wallingford HydroSolutions Ltd 2016.

<sup>3</sup> Kjeldsen, T.K., 2010. Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrology Research, volume 41, issue 5, pp391-405

**Table 3-4: Derivation of flood growth curves at subject sites**

| Site code | Method (SS, P, ESS) | If P, ESS or J, name of pooling group) | Distribution used and reason for choice                      | Note any urban or permeable adjustment                                                              | Growth factor for 1% AEP event |
|-----------|---------------------|----------------------------------------|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------|
| W01       | P                   | PG01                                   | Generalised Logistic as per permeable adjustment spreadsheet | Urban adjustment using methods adopted in WINFAP which is based on those published by Kjeldsen 2010 | 3.06                           |
| W_TRIB    | P                   | PG01                                   | Generalised Logistic as per permeable adjustment spreadsheet | Permeable adjustment using WHS Permeable Adjustment Worksheet Beta v1.1                             | 3.07                           |

**Table 3-5: Flood estimates from the Statistical method**

| Site Code | Flood peak (m3/s) for the following return periods |     |     |     |     |     |     |     |      |
|-----------|----------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|------|
|           | 2                                                  | 5   | 10  | 20  | 50  | 75  | 100 | 200 | 1000 |
| W01       | 1.7                                                | 2.4 | 3.0 | 3.6 | 4.5 | 4.9 | 5.3 | 6.3 | 9.2  |
| W_TRIB    | 1.4                                                | 2.0 | 2.4 | 2.9 | 3.7 | 4.1 | 4.4 | 5.2 | 7.6  |

## 4. Revitalised Flood Hydrograph (ReFH) Method

- 4.1 The ReFH2 Revitalised Flood Hydrograph Modelling Software (Version 2.3) was used to undertake an estimation of the peak flows for the subject sites.

**Table 4-1: Overview of parameters for ReFH2 method**

| Site code | Method<br>OPT: Optimisation<br>BR: Baseflow recession fitting<br>CD: Catchment descriptors<br>DT: Data transfer | T <sub>p</sub> (hours)<br>Time to peak | C <sub>max</sub> (mm)<br>Maximum storage capacity | BL (hours)<br>Baseflow lag | BR<br>Baseflow recharge |
|-----------|-----------------------------------------------------------------------------------------------------------------|----------------------------------------|---------------------------------------------------|----------------------------|-------------------------|
| W01       | CD                                                                                                              | 5.8                                    | 303                                               | 37.2                       | 1.4                     |
| W_TRIB    | CD                                                                                                              | 5.1                                    | 298                                               | 35.2                       | 1.3                     |

**Table 4-2: Recommended storm durations**

| Site code       | Season of design event                      | Storm duration | Selected interval |
|-----------------|---------------------------------------------|----------------|-------------------|
| W01             | Winter                                      | 9 hours        | 1 hour            |
| W_TRIB          | Winter                                      | 9 hours        | 1 hour            |
| <b>Comments</b> | Recommended duration applied to all inflows |                |                   |

**Table 4-3: Flood estimates from the ReFH method (based on recommended duration for individual catchments)**

| Site Code | Flood peak (m <sup>3</sup> /s) for the following return periods |     |     |     |     |     |     |     |      |
|-----------|-----------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|------|
|           | 2                                                               | 5   | 10  | 20  | 50  | 75  | 100 | 200 | 1000 |
| W01       | 1.9                                                             | 2.1 | 2.8 | 3.2 | 4.7 | 5.2 | 5.6 | 6.8 | 9.9  |
| W_TRIB    | 1.7                                                             | 1.9 | 2.4 | 2.9 | 4.2 | 4.6 | 5.0 | 6.0 | 8.8  |

## 5. DISCUSSION AND SUMMARY OF RESULTS

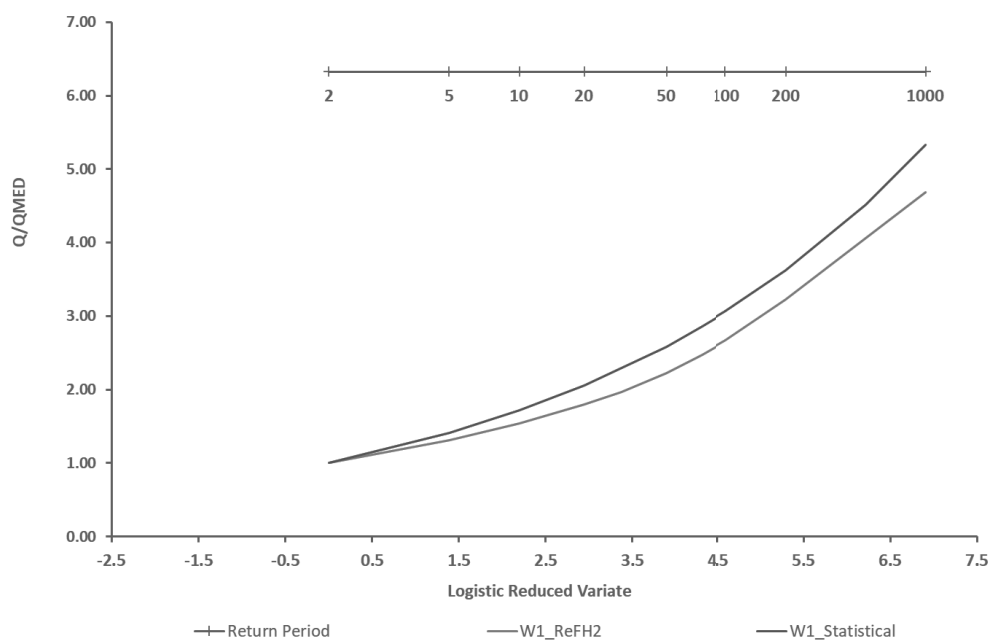
### Comparison of method

- 5.1 A comparison of the peak flow results for the different estimation methods for the 1 in 2-year and 1 in 100-year events is provided in **Table 5-1**. Comparisons of the growth curves for both methods and flow estimation points are shown in **Figure 5-1**. Due to the similarity in growth curves, only the growth curves for W01 are compared.
- 5.2 The Statistical growth factors are higher than ReFH2 across all return periods. However, as the 2-year (QMED) estimate was up to 40% higher using the ReFH2 method, the flows produced by the ReFH2 method were higher for all events.

**Table 5-1: Comparison of results**

| Site code | 1 in 2-year peak flows |      |       | 1 in 100-year peak flows |      |       |
|-----------|------------------------|------|-------|--------------------------|------|-------|
|           | Statistical            | ReFH | Ratio | Statistical              | ReFH | Ratio |
| W01       | 1.7                    | 2.1  | 1.2   | 5.3                      | 5.6  | 1.1   |
| W_TRIB    | 1.4                    | 1.9  | 1.4   | 4.4                      | 5.0  | 1.1   |

**Figure 5-1: Comparison of Statistical method and ReFH growth curves**



## Final method and flows

**Table 5-2: Final choice of method**

|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Choice of method and justification | <p>EA Guidelines state results from the Statistical method are preferred as the method is based on a much larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments.</p> <p>Whilst, both Statistical and ReFH2 methods are considered suitable for the catchments, the final choice of peak flows for input into the model is the Statistical method, in line with the EA FEH Guidelines recommendation. The Statistical method benefits from an up-to-date flood peak dataset, using growth curves from hydrologically similar catchments to derive a growth curve. The Statistical method also benefits by avoiding the need to make assumptions about factors such as rainfall duration, time of concentration and the nature of the design flood, unlike the ReFH2 method.</p> <p>ReFH2 will be used to provide a hydrograph shape for the model inflows, scaled to the Statistical peak.</p> |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Table 5-3: Final Peak Flows from Chosen Method (Statistical)**

| Site Code | Flood peak (m <sup>3</sup> /s) for the following return periods |     |     |     |     |     |     |     |      |
|-----------|-----------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|------|
|           | 2                                                               | 5   | 10  | 20  | 50  | 75  | 100 | 200 | 1000 |
| W01       | 1.7                                                             | 2.4 | 3.0 | 3.6 | 4.5 | 4.9 | 5.3 | 6.3 | 9.2  |
| W_TRIB    | 1.4                                                             | 2.0 | 2.4 | 2.9 | 3.7 | 4.1 | 4.4 | 5.2 | 7.6  |

**Table 5-4: Assumptions, limitations and uncertainty**

|                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| List the main assumptions made                                                                                                     | <ul style="list-style-type: none"> <li>The pooling groups are representative of the catchments.</li> <li>The ReFH2 hydrograph shape is representative of the catchment response.</li> <li>Tp and storm duration is representative of the catchment response.</li> <li>A pro rata'd approach to the south eastern catchment (totalling 1.74km<sup>2</sup>) is appropriate.</li> </ul>                                                                                                                                                                 |
| Discuss any limitations e.g. applying methods outside the range of catchment types or return periods for which they were developed | <ul style="list-style-type: none"> <li>The FEH Statistical and ReFH2 methods are believed to be suitable up to the 1 in 200-year event. Estimates of flow beyond these events are extrapolations and, therefore, have a higher level of uncertainty.</li> <li>There are only a small number of gauged sites in the UK. As such the representation in the pooling is not ideal given the small size of some of the study catchments.</li> <li>There is no observed flow data within the catchment with which to verify the flow estimates.</li> </ul> |

|                                                                     |                                                                                                                                                                                                                                                                                                                    |
|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Give what information you can on uncertainty in the results</b>  | <p>According to Table 4 of the EA FEH Guidelines, confidence intervals for the 1 in 100 year for a rural site when calculated from catchment descriptors are quoted as 0.45-2.23 (for the 95% confidence interval).</p> <p>Confidence is considered to be improved when using observed data from a donor site.</p> |
| <b>Comment on the suitability of the results for future studies</b> | <p>The design flow estimates have been derived for the purpose of providing flow hydrographs into a hydraulic model to support a planning application at Witherley.</p> <p>Users for different studies should, as a minimum, review results to assess suitability for the purpose of the study.</p>                |

**Table 5-5: Checks**

|                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                |                       |                   |                     |
|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------|---------------------|
| Are the results consistent?                                                                                                    | Yes, estimates of QMED progress as expected with increasing catchment area                                                                                                                                                                                                                                                                                     |                       |                   |                     |
| What do the results imply regarding the return periods of floods during the period of record?                                  | The lack of gauging stations in the study catchment, and lack of detail within the flood history, mean it is not possible to imply a return period for past flood events.                                                                                                                                                                                      |                       |                   |                     |
| What is the 1 in 100-year growth factor? (the guidance suggests a typical range or 2.1 to 4.0)                                 | ReFH: 2.9<br>Statistical: 3.1                                                                                                                                                                                                                                                                                                                                  |                       |                   |                     |
| If 1 in 1000-year flows have been derived, what is the range of ratios for 1 in 1000-year flow over 1 in 100-year flow?        | ReFH: 1.8<br>Statistical: 1.7 and 1.6                                                                                                                                                                                                                                                                                                                          |                       |                   |                     |
| How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred | <b>Return Period</b>                                                                                                                                                                                                                                                                                                                                           | <b>PREVIOUS STUDY</b> | <b>This Study</b> | <b>% difference</b> |
|                                                                                                                                | <b>Peak Flow (m<sup>3</sup>/s)</b>                                                                                                                                                                                                                                                                                                                             |                       |                   |                     |
|                                                                                                                                | 1 in 100yr                                                                                                                                                                                                                                                                                                                                                     | 5.5                   | 5.3               | -4%                 |
|                                                                                                                                | The results have been compared at the downstream flow estimation point i.e. the entire catchment draining to the confluence with the River Anker. However, the previous flows relate to the ReFH2 model and, therefore, the comparisons are not like for like. Given the updates in software, methods and the peak flow database, the new flows are preferred. |                       |                   |                     |
| Are the results consistent with the longer-term flood history?                                                                 | The lack of gauging stations in the study catchment mean there is no observed data to assess results against the long term flood history.                                                                                                                                                                                                                      |                       |                   |                     |

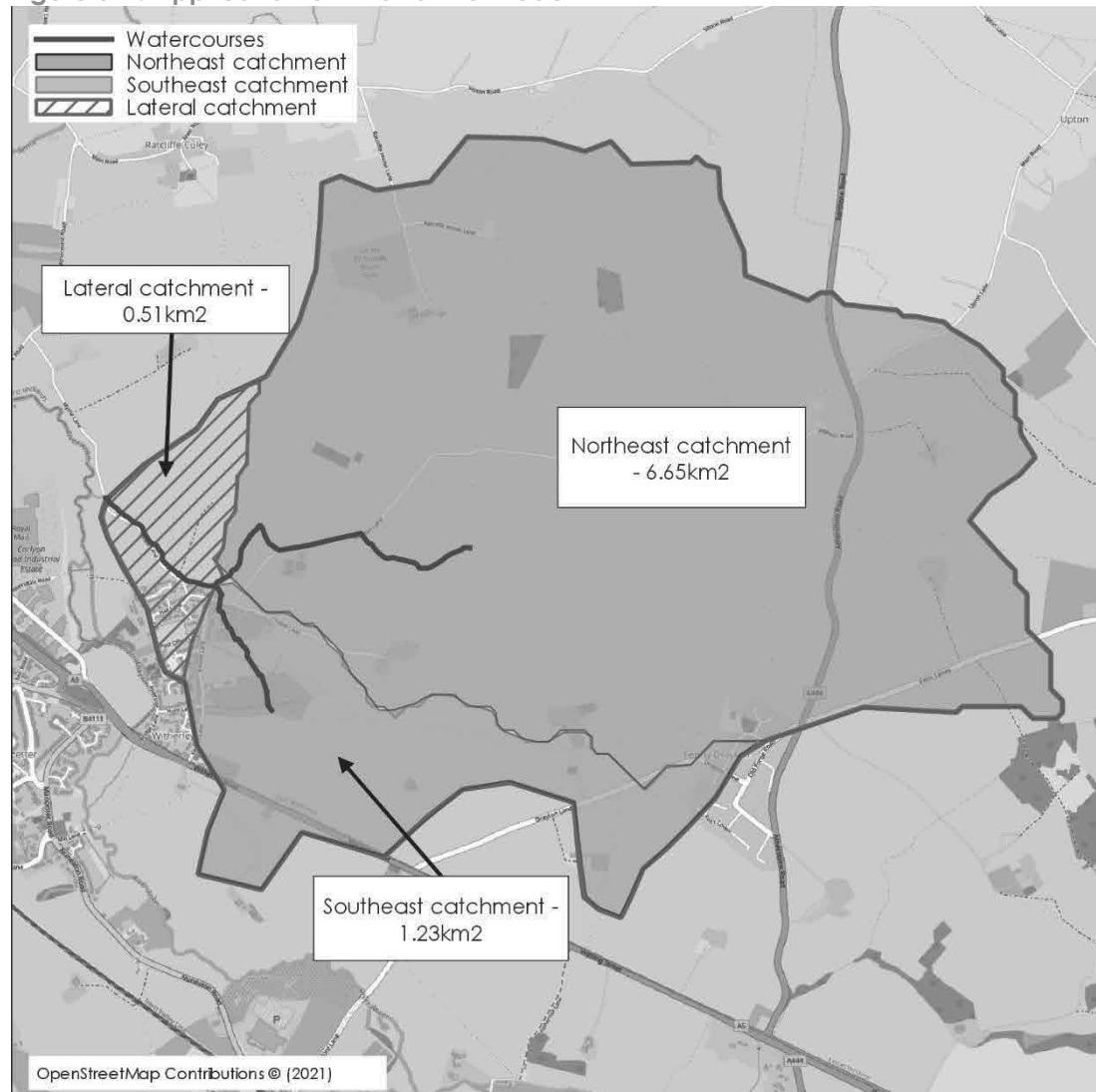
## Application of flows to model

5.3 Flows will be applied to the model in the following way.

- i. ReFH hydrographs will be scaled to the peaks obtained using the statistical event
- ii. Two point inflows will be applied with a further lateral region covering the area between the river Anker and Witherley Brook inflow downstream of the site.
- iii. The hydrograph for the north eastern catchment will be subtracted from the overall catchment hydrograph to leave a hydrograph for the remaining area at the site.
- iv. This remaining area will then be pro rata'd to provide an inflow upstream of the site and lateral catchment downstream of the site.

5.4 **Figure 5-2** demonstrates how the flows will be applied to the model, with the catchment area included.

**Figure 5-2: Application of inflows into model**



## 6. Supporting information

### Flood history

- 6.1 The site does not appear within historic flood extents held by the EA, as these relate to the River Anker downstream. However, an initial assessment document prepared by the EA references instances of historical flooding.
- 6.2 The Witherley Brook has been subject to flooding in November 2012, January 2014 and February 2016.
- 6.3 **Figure 6-1** below shows an image of flooding along Chapel lane in February 2016.

**Figure 6-1 - Flooding along Chapel Lane in February 2016**



### Detailed pooling group information

- 6.4 The final pooling group following review is provided below.
- 6.5 Permeable adjusted L-CV and L-Skew are provided in **Table 6-3**.

**Table 6-1: Default pooling group (before permeable adjustment): PG01**

| Station                                              | Distance             | Years of Data | QMED AM | L-CV                  | L-Skew | Discordancy |
|------------------------------------------------------|----------------------|---------------|---------|-----------------------|--------|-------------|
| 27073 (Brompton Beck @ Snainton Ings)                | 0.474                | 39            | 0.812   | 0.215                 | 0.035  | 1.451       |
| 26016 (Gypsy Race @ Kirby Grindalythe)               | 2.144                | 22            | 0.1     | 0.321                 | 0.266  | 0.260       |
| 27051 (Crimple @ Burn Bridge)                        | 2.19                 | 47            | 4.524   | 0.218                 | 0.156  | 0.321       |
| 25019 (Leven @ Easby)                                | 2.263                | 41            | 5.09    | 0.342                 | 0.386  | 0.750       |
| 49005 (Bolingey Stream @ Bolingey Cocks Bridge)      | 2.403                | 9             | 5.777   | 0.271                 | 0.151  | 3.192       |
| 36010 (Bumpstead Brook @ Broad Green)                | 2.426                | 52            | 7.395   | 0.382                 | 0.181  | 2.066       |
| 45816 (Haddeo @ Upton)                               | 2.487                | 26            | 3.456   | 0.3                   | 0.406  | 0.917       |
| 72014 (Conder @ Galgate)                             | 2.505                | 51            | 16.646  | 0.231                 | 0.16   | 0.300       |
| 41020 (Bevern Stream @ Clappers Bridge)              | 2.546                | 50            | 13.575  | 0.207                 | 0.182  | 0.742       |
| 73015 (Keer @ High Keer Weir)                        | 2.567                | 28            | 12.375  | 0.204                 | 0.26   | 0.497       |
| 27010 (Hodge Beck @ Bransdale Weir)                  | 2.58                 | 41            | 9.42    | 0.224                 | 0.293  | 0.434       |
| 44008 (South Winterbourne @ Winterbourne Steepleton) | 2.589                | 40            | 0.434   | 0.411                 | 0.337  | 1.485       |
| 28033 (Dove @ Hollinsclough)                         | 2.616                | 44            | 4.177   | 0.228                 | 0.371  | 1.091       |
| 47022 (Tory Brook @ Newnham Park)                    | 2.627                | 25            | 6.176   | 0.257                 | 0.191  | 0.494       |
|                                                      |                      |               |         |                       |        |             |
| Total                                                |                      | 515           |         |                       |        |             |
| Weighted Means                                       |                      |               |         | 0.269                 | 0.241  |             |
| H2 value                                             | 2.65                 |               |         |                       |        |             |
| Goodness of Fit                                      | Generalised Logistic |               |         | General Extreme Value |        |             |
|                                                      | 1.32                 |               |         | -0.26                 |        |             |

**Table 6-2: Final pooling group (before permeable adjustment): PG01**

| Station                                 | Distance | Years of Data | QMED AM | L-CV  | L-Skew | Discordancy |
|-----------------------------------------|----------|---------------|---------|-------|--------|-------------|
| 27073 (Brompton Beck @ Snainton Ings)   | 0.474    | 39            | 0.812   | 0.215 | 0.035  | 1.056       |
| 26016 (Gypsy Race @ Kirby Grindalythe)  | 2.144    | 22            | 0.1     | 0.321 | 0.266  | 0.439       |
| 27051 (Crimple @ Burn Bridge)           | 2.19     | 47            | 4.524   | 0.218 | 0.156  | 0.436       |
| 25019 (Leven @ Easby)                   | 2.263    | 41            | 5.09    | 0.342 | 0.386  | 1.023       |
| 36010 (Bumpstead Brook @ Broad Green)   | 2.426    | 52            | 7.395   | 0.382 | 0.181  | 2.541       |
| 45816 (Haddeo @ Upton)                  | 2.487    | 26            | 3.456   | 0.3   | 0.406  | 0.980       |
| 72014 (Conder @ Galgate)                | 2.505    | 51            | 16.646  | 0.231 | 0.16   | 0.151       |
| 41020 (Bevern Stream @ Clappers Bridge) | 2.546    | 50            | 13.575  | 0.207 | 0.182  | 0.759       |
| 73015 (Keer @ High Keer Weir)           | 2.567    | 28            | 12.375  | 0.204 | 0.26   | 0.445       |
| 27010 (Hodge Beck @ Bransdale Weir)     | 2.58     | 41            | 9.42    | 0.224 | 0.293  | 0.381       |
| 28033 (Dove @ Hollinsclough)            | 2.616    | 44            | 4.177   | 0.228 | 0.371  | 1.206       |
| 47022 (Tory Brook @ Newnham Park)       | 2.627    | 25            | 6.176   | 0.257 | 0.191  | 2.490       |
| 33054 (Babingley @ Castle Rising)       | 2.653    | 43            | 1.129   | 0.206 | 0.08   | 1.095       |
|                                         |          |               |         |       |        |             |

|                 |                      |  |                       |       |
|-----------------|----------------------|--|-----------------------|-------|
| Total           | 509                  |  |                       |       |
| Weighted Means  |                      |  | 0.253                 | 0.226 |
| H2 value        | 2.4                  |  |                       |       |
| Goodness of Fit | Generalised Logistic |  | General Extreme Value |       |
|                 | 0.8                  |  | -0.8                  |       |

**Table 6-3: PG01 Permeable adjusted L-CV and L-Skew**

| Station                                 | Adjusted L-CV | Adjusted L-Skew |
|-----------------------------------------|---------------|-----------------|
| 27073 (Brompton Beck @ Snainton Ings)   | 0.20          | 0.07            |
| 26016 (Gypsey Race @ Kirby Grindalythe) | 0.29          | 0.31            |
| 33054 (Babingley @ Castle Rising)       | 0.19          | 0.13            |



## **Appendix 2: Survey**

| <p><b>NOTES</b></p> <ol style="list-style-type: none"> <li>Do not scale this drawing. All dimensions must be checked/verified on site, if in doubt ask.</li> <li>This drawing is to be read in conjunction with all relevant architect, engineers and specialist drawings and specifications.</li> <li>All dimensions on this drawing unless stated otherwise. All levels in millimetres unless stated otherwise.</li> <li>Any discrepancies noted on site are to be reported to the engineer immediately.</li> </ol> |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------|-------|-----|--|--|--|--|--|----|------|-----------------------------|-------|-----|----|----------|-------------|-----|----|
| <p><b>Key Plan</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Legend</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Issues &amp; Revisions</b></p> <table border="1"> <thead> <tr> <th>No</th> <th>Date</th> <th>Details of Issue / Revision</th> <th>Drawn</th> <th>Rev</th> </tr> </thead> <tbody> <tr> <td>01</td> <td>19/11/15</td> <td>First Issue</td> <td>006</td> <td>01</td> </tr> </tbody> </table>                                                                                                                                                                                                                       |          |                             |       |     |  |  |  |  |  | No | Date | Details of Issue / Revision | Drawn | Rev | 01 | 19/11/15 | First Issue | 006 | 01 |
| No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Date     | Details of Issue / Revision | Drawn | Rev |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| 01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 19/11/15 | First Issue                 | 006   | 01  |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Client</b></p> <p><b>A R CARTWRIGHT<br/>(A CONSTRUCTION) LTD</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Drawing Title</b></p> <p><b>CHAPEL LANE, WITHERLY</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                       |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Drawing Title</b></p> <p><b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b></p>                                                                                                                                                                                                                                                                                                                                                                                                               |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Drawn:</b> J. D. Smith      <b>Reviewed:</b> J. Draycott</p> <p><b>BWB Ref:</b> BMW 2465      <b>Date:</b> 19/11/15      <b>Scale:</b> 1:2000</p> <p><b>Drawing Status</b></p>                                                                                                                                                                                                                                                                                                                                  |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |
| <p><b>Information</b></p> <p>Project: Clogmore Zone: Lower Type: Main Number: 621<br/>         ARC100-BWB-XXX-00-DR-SU-060 621 P1</p>                                                                                                                                                                                                                                                                                                                                                                                 |          |                             |       |     |  |  |  |  |  |    |      |                             |       |     |    |          |             |     |    |

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| Date | P-value  | First issue | DS | JG | Date |
|------|----------|-------------|----|----|------|
| p1   | 19.11.15 | First issue |    |    |      |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                             |  |                                                      |  |                                                                                           |              |  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|--|------------------------------------------------------|--|-------------------------------------------------------------------------------------------|--------------|--|
| <b>Issues &amp; Revisions</b><br><br><br><b>COMMERCIAL / INDUSTRIAL<br/>INFRASTRUCTURE / BUILDINGS</b><br><br><input type="checkbox"/> Birmingham (0121 233 3322)<br><input type="checkbox"/> Leeds (0113 233 1000)<br><input type="checkbox"/> London (020 7617 3679)<br><input type="checkbox"/> Manchester (0161 233 4200)<br><input type="checkbox"/> Newcastle (0191 233 1100)<br><input type="checkbox"/> New Zealand building.com | <b>A R CARTWRIGHT<br/>(CONSTRUCTION) LTD</b><br><br>Client                  |  | <b>CHAPEL LANE, WITHERLY</b><br><br>Project Title    |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b><br><br>Drawing Title | Drawing Date |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Drawn: <b>D. Smith</b><br>BWB Ref: <b>BWV 2465</b><br>Date: <b>19.11.15</b> |  | Reviewed: <b>J. Draycott</b><br>Scale: <b>1:2000</b> |  |                                                                                           |              |  |
| <b>INFORMATION</b><br>Project: <b>CG100-XX-XX-00-DR-SU-060</b> Title: <b>P1</b><br>Project: <b>CG100-XX-XX-00-DR-SU-060</b> Title: <b>P1</b>                                                                                                                                                                                                                                                                                                                                                                              |                                                                             |  |                                                      |  |                                                                                           |              |  |



|                                              |  |                              |  |                                                                      |  |                      |  |                                                                                                            |  |
|----------------------------------------------|--|------------------------------|--|----------------------------------------------------------------------|--|----------------------|--|------------------------------------------------------------------------------------------------------------|--|
| <b>A R CARTWRIGHT<br/>(CONSTRUCTION) LTD</b> |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>INFORMATION</b>   |  | <b>Project:</b> Cognition Zone Load Type: Blm Number: 10000<br><b>Printed:</b> 00-BWB-XX-00-DR-SU-060 52 1 |  |
| <b>Client</b>                                |  | <b>Project Title</b>         |  | <b>Drawing Title</b>                                                 |  | <b>Drawn:</b>        |  | <b>Project:</b> Cognition Zone Load Type: Blm Number: 10000<br><b>Printed:</b> 00-BWB-XX-00-DR-SU-060 52 1 |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
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| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL LANE, WITHERLY</b> |  | <b>WATERCOURSE SURVEY<br/>SECTION LOCATION PLAN<br/>SHEET 1 OF 6</b> |  | <b>Drawing Title</b> |  | <b>Drawn:</b>                                                                                              |  |
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| <b>www.zooconsulting.com</b>                 |  | <b>CHAPEL L</b>              |  |                                                                      |  |                      |  |                                                                                                            |  |

|                                                         |                                                      |                                |  |
|---------------------------------------------------------|------------------------------------------------------|--------------------------------|--|
| <h1>A R CARTWRIGHT<br/>(CONSTRUCTION) LTD</h1>          |                                                      | <h1>CHAPEL LANE, WITHERLY</h1> |  |
| Project Title                                           |                                                      | Drawing Title                  |  |
| <h2>WATERCOURSE SURVEY</h2>                             |                                                      | <h2>SECTION LOCATION PLAN</h2> |  |
| <h3>SHEET 1 OF 6</h3>                                   |                                                      |                                |  |
| Drawn: J. Smith<br>BWS Ref: BMW/2455<br>Drawing Status: | Reviewed: J. Drycott<br>19.11.15<br>Drawing No: 2000 |                                |  |
| <h3>INFORMATION</h3>                                    |                                                      |                                |  |
| Project: Coganwre Zoon Type: Site Number:               |                                                      |                                |  |
| AR100-BWB-XX-00-DR-SU-060                               |                                                      | Status: Rev:                   |  |

|                                                                                                                                                                                                                                      |          |                                                             |             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------------------------------------------------------|-------------|
| Project Title                                                                                                                                                                                                                        |          | CHAPEL LANE, WITHERLY                                       |             |
| Drawing Title                                                                                                                                                                                                                        |          | WATERCOURSE SURVEY<br>SECTION LOCATION PLAN<br>SHEET 1 OF 6 |             |
| Drawn:                                                                                                                                                                                                                               | G. Smith | Reviewed:                                                   | J. Draycott |
| Byw Ref:                                                                                                                                                                                                                             | BMW 2465 | Date:                                                       | 19.11.15    |
|                                                                                                                                                                                                                                      |          | Scale:                                                      | 1:2000      |
| <div> <div>INFORMATION</div> <div>           Project: C100-BWB-XX-004-DU-SR-060<br/>           Zone: 004<br/>           Cover: DU<br/>           Type: SR<br/>           Number: 060<br/>           Status: P1         </div> </div> |          |                                                             |             |

|                            |                                                                                  |                         |
|----------------------------|----------------------------------------------------------------------------------|-------------------------|
| Drawing Title              | <b>WATERCOURSE SURVEY</b><br><b>SECTION LOCATION PLAN</b><br><b>SHEET 1 OF 6</b> |                         |
| Drawn by                   | D. Smith                                                                         | Reviewed by J. Draycott |
| Issue No.                  | BW17/2455                                                                        | 19.11.15                |
| Issue Date                 |                                                                                  | 15/11/2000              |
| <b>INFORMATION</b>         |                                                                                  |                         |
| Project                    | RIVER CROFTING ZONE (cont.) Type: New                                            |                         |
| Project Reference          | Zone (cont.)                                                                     | Map No.                 |
| ARC100-BWB-XX-00-DR-S0-060 |                                                                                  | 52                      |
|                            |                                                                                  | P1                      |

|                                                                                                                                                                      |                |          |             |        |        |       |      |  |  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------|-------------|--------|--------|-------|------|--|--|
| <h1 style="text-align: center;">WATERCOURSE SURVEY</h1> <h2 style="text-align: center;">SECTION LOCATION PLAN</h2> <h3 style="text-align: center;">SHEET 1 OF 6</h3> |                |          |             |        |        |       |      |  |  |
| Drawn                                                                                                                                                                | D. Smith       | Reviewed | J. Draycott |        |        |       |      |  |  |
| BWWS Ref.                                                                                                                                                            | BWWS 2465      | Date     | 19/11/15    | Scale  |        |       |      |  |  |
| Drawing Status                                                                                                                                                       |                |          | Scale       | 1:2000 |        |       |      |  |  |
| <h2>INFORMATION</h2>                                                                                                                                                 |                |          |             |        |        |       |      |  |  |
| Project                                                                                                                                                              | Corporate Zone | Local    | Type        | Rate   | Number | Scale | Rate |  |  |
| ARC100-BWPB-XX-00-DL-SU-060                                                                                                                                          |                | S2       | P1          |        |        |       |      |  |  |

|                |          |                  |             |
|----------------|----------|------------------|-------------|
| Drawn:         | D. Smith | Reviewed:        | J. Draycott |
| BWB Ref:       | BMW 2465 | Date:            | 19.11.15    |
| Drawing Status |          | Scale@A1: 1:2000 |             |

|                                                            |        |     |
|------------------------------------------------------------|--------|-----|
| Project - Originator - Zone - Level - Type - Role - Number | Status | Rev |
| ARC100-BWB-XX-00-DR-SU-060                                 | S2     | P1  |

|                                                            |        |     |
|------------------------------------------------------------|--------|-----|
| Project - Originator - Zone - Level - Type - Role - Number | Status | Rev |
| ARC100-BWB-XX-00-DR-SU-060                                 | S2     | P1  |



Notes

1. Do not scale this drawing. All dimensions must be checked/verified on site. If in doubt ask.
2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

### Key Plan

Continued on next page

Legend

1000

| Rev | Date     | Details of issue / revision | Draw | DS | JD |
|-----|----------|-----------------------------|------|----|----|
| P1  | 19.11.15 | First issue                 |      |    |    |

## Issues & Revisions



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Project Title

CHAPEL LANE, WITHERLY

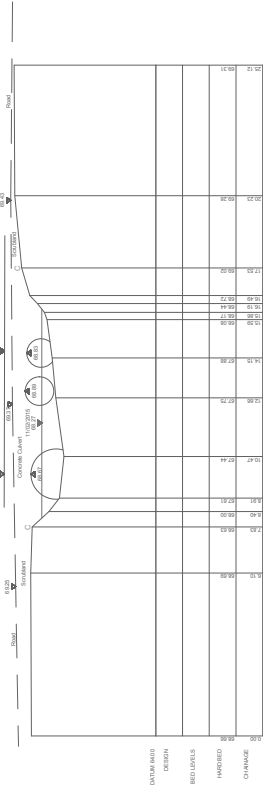
Drawing Title

**WATERCOURSE SURVEY  
SECTIONS 1-6  
SHEET 2 OF 6**

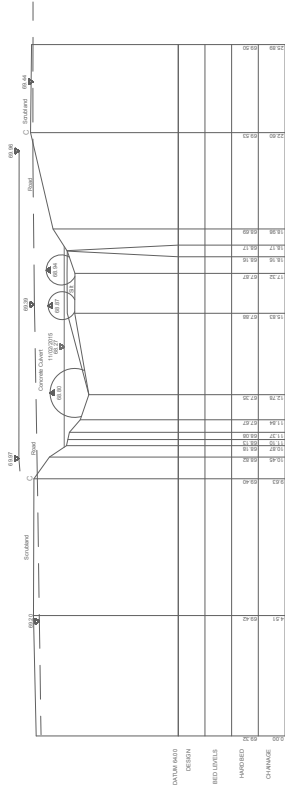
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| Drawn:   | D. Smith | Reviewed: | J. Draycott |
| BWB Ref: | BMW 2465 | Date:     | 19.11.15    |
|          |          | Scale:    | 1:100       |

## INFORMATION

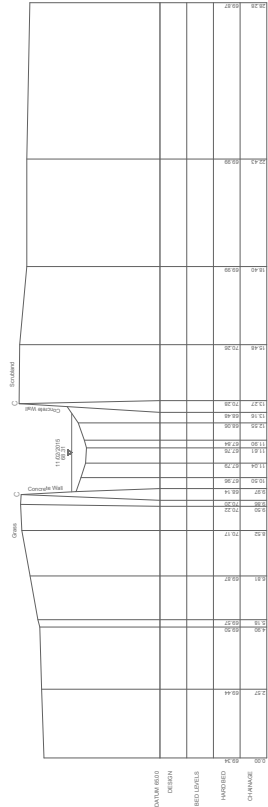
| Projed - Originator - Zone - Level - Type - Role - Number | Status | Rev |
|-----------------------------------------------------------|--------|-----|
| ARC100-BWB-XX-00-DR-SU-061                                | S2     | P1  |



1 432318.26mE 298044.62mN Brg 345  
Chainage2.1m  
Open Channel



2 432325.33 mE 298042.57 mN Brg 348  
Chainage 9.3m  
Open Channel



3 432432.74mE 297946.89mN Brg 34  
Chainage 167.7m  
Open Channel

Notes

- Do not leave this drawing. All dimensions must be checked/verified on site. In doubt ask.
- Do not alter this drawing. Any changes must be made by the engineer and signed by the engineer and the draughtsman.
- All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
- Any discrepancies noted on site are to be reported to the engineer immediately.

Key Plan

Legend

| Rev | Date     | Details of Issue / Revision | By  | Rev |
|-----|----------|-----------------------------|-----|-----|
| 1   | 19.11.15 | First Issue                 | JSB | 1   |

Issues & Revisions

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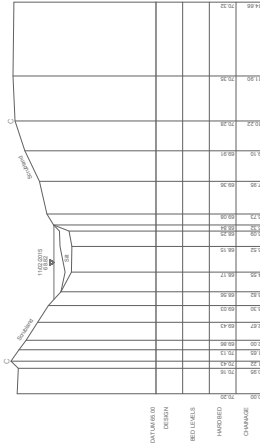
Project Title  
**CHAPEL LANE, WITHERLY**

Drawing Title  
**WATERCOURSE SURVEY  
SECTIONS 7-12  
SHEET 3 OF 6**

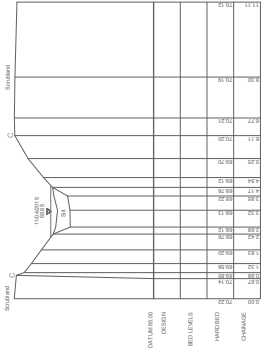
| Drawn   | Checked  | Reviewed | By     | Rev   |
|---------|----------|----------|--------|-------|
| BWB Ref | BMW 2465 | 19.11.15 | ScamgA | 1/100 |

Project - Originator - Zone - Level - Type - Revis - Number

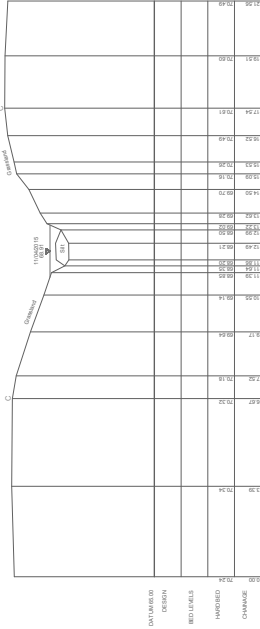
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ARC100-BWB-XX-00-DR-0062 S2 P1



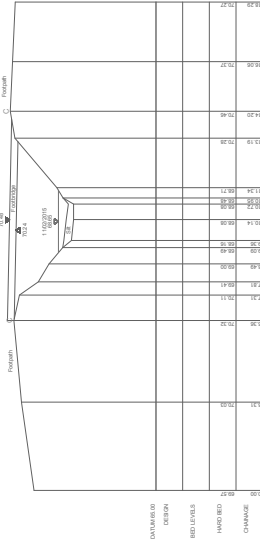
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Chainage337.5m  
Open Channel



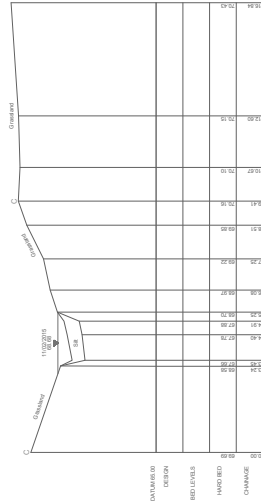
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Open Channel



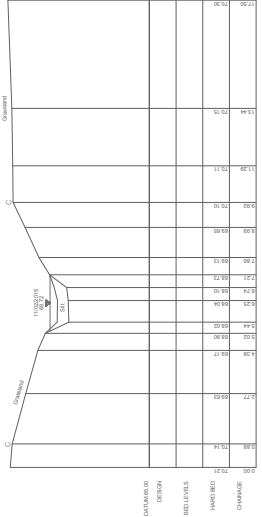
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Open Channel



7  
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Chainage479.2m  
Open Channel



8  
432655.1mE 297709.28mN Brg 36  
Chainage511.2m  
Open Channel



9  
432719.73mE 297667.02mN Brg 18  
Chainage511.2m  
Open Channel

## Notes

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3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
4. Any discrepancies noted on site are to be reported to the engineer immediately.

## Key Plan

Legend

|     | 19.11.15 | First issue                 | DS | JD  |
|-----|----------|-----------------------------|----|-----|
| P1  |          |                             |    |     |
| Rev | Date     | Details of issue / revision | Dw | Rev |

### Issues & Revisions

## Issues & Revisions



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Client \_\_\_\_\_

**A R CARTWRIGHT  
(CONSTRUCTION) LTD**

|              |
|--------------|
| Projed Title |
|--------------|

CHAPEL LANE, WITHERLY

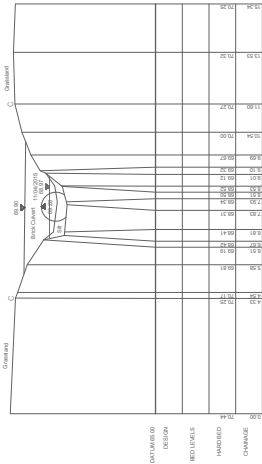
| Drawing Title |
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|---------------|

WATERCOURSE SURVEY  
SECTIONS 13-18  
SHEET 4 OF 6

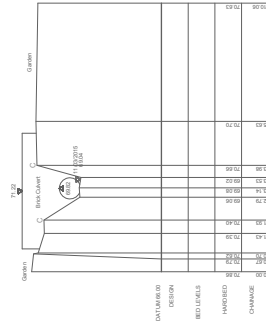
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| Drawn:   | D. Smith | Reviewed: | J. Draycott |
| BWB Ref: | BMW 2465 | Date:     | 19.11.15    |
|          |          | Scale@A1: | 1:100       |

## INFORMATION

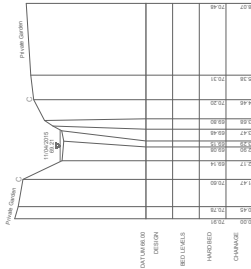
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| Project - Originator - Zone - Level - Type - Role - Number | Status | Rev |
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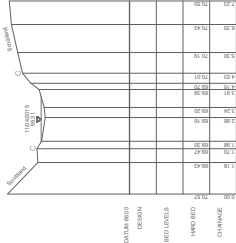
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Chainage 689.6m  
Open Channel



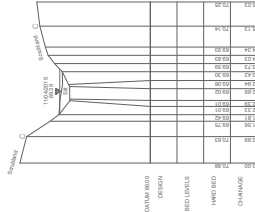
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Open Channel



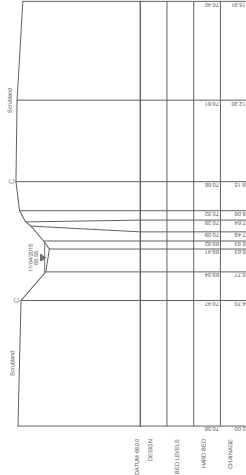
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Open Channel



16  
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Chainage 791.2m  
Open Channel



17  
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Chainage814.5m  
Open Channel



18  
432865.31mE 297461.22mN Brg 50  
Chainage896.6m  
Open Channel