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Flood Risk Assessment

Startifants Farm, Longridge Road, Chipping

Report Ref: 18073/CR/01 Rev 02

Prepared For:
J Hadfield Engineering/Surveying

Date:
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Executive Summary

Paul Waite Associates Ltd has been appointed by Johnathan Hadfield of J Hadfield Engineering/Surveying, to provide a Flood Risk Assessment in support of a planning application for a development at the former Startifants Farm, Longridge Road, Chipping, Lancashire.

The site with a red-line boundary area of 0.645 Hectares; is shown to be situated within Flood Zone 3 of the Flood Map for Planning and therefore is considered to have a high risk of fluvial flooding.

An initial assessment indicates that the primary flood risk at the proposed development is from Chipping Brook (fluvial source); and also, from surface water flooding.

Chipping Brook is classed as 'main river' and bisects the development site at Startifants Farm.

The existing site is comprised a farmhouse on the right bank of the watercourse; with 6no farm buildings located on the left bank of Chipping Brook,

Proposals include the demolition of 5no buildings; with replacement of the farmhouse to provide a single dwelling on a slightly larger footprint; and conversion of 2no farm buildings to provide a single work/live unit; and detached garage.

Sequential & Exceptions Test

The site is considered to be exempt from the Sequnetial Test as it comprises a replacement dwelling; and buildings where a change of use will be applied.

It is considered that the site presents a number of opportunities and sustainability benefits, which outweigh flood risk at the development site; and that suitable measures can be applied within the proposals to mitigate against fluvial and surface water flood risk at the development. As such it is also considered that the site passes the Exceptions Test.

Fluvial: Chipping Brook

Chipping Brook traverses through the centre of the application site in a south direction, entering through the north boundary, it flows under 2No structures: Startifants Bridge, UU WWTW bridge, before flowing out of the south boundary.

The site is located within Flood Zone 3, and therefore a detailed assessment if the risk associated with this flood source is required.

A 1D/2D modelling has been undertaken by Jacob's on behalf of United Utilities to assess the impact of constructing a new bridge to serve their WWTW site, which is situated a short distance downstream if the proposed development.

Reviewing the model results it is indicated that within the Startifants Farm site, overtopping of the river bank occurs in only one location, with flood water flowing across the site during all modelled return period events. For flooding up to and including the 1 in 100-year + 20% climate change flood event, out of bank water depths within the site along the left bank do not exceed 0.1m. Flood depths along the right bank however reach 0.1-0.25m.

The Jacob's model does not provide an allowance for the latest climate change requirements i.e. 35%-70% increase in flows within Chipping Brook. A copy of the hydraulic model is not available; and therefore, in order to provide an assessment, it has been assumed that there is a relationship between flow and water level. The estimated rise of the in-channel 1D flood level is estimated to be 50mm; and it is anticipated that the resulting impact to the flood extent and water depths across the floodplain will be minimal.

Therefore, for the increased climate change climate scenario, a similar depth of flooding across the floodplain, identified for the 1 in 100-year plus 20% has also been applied to the 1 in 100-year + 70% climate change flood event.

The site is shown and confirmed to be within Flood Zone 3.

The development incorporates the demolition of a number of buildings, with redevelopment of 2no barns along the left bank; and replacement of the existing farmhouse on the right bank of Chipping Brook, within a slightly larger footprint. On balance the site will provide an increased capacity for flood storage; and therefore, it is concluded that flood storage compensation will not be required.

Pluvial: Overland Flow

Surface Water Flood Maps indicate that there is a flow route which passes around the north side of the existing farmhouse/replacement dwelling, which then flows southwards across the site access from Longridge Road.

The depth of flooding across the access for the low, medium and high-risk events is estimated to be less than 300mm.

Undertaking an assessment of hazard associated with this flood source, it is concluded that the hazard to people is low, however caution should always be taken when traversing through moving water.

Drainage

The development is considered to be brownfield development; and comprises and number of buildings; access roads which serve the Farm & WWTW; and areas of hardstanding.

Although there is no complete survey of the existing drainage system serving the site it is believed that surface water runoff is directed to Chipping Brook, which bisects Startifants Farm.

It is also considered that foul flows are directed to an existing combined sewer, which flows down Longridge Road prior to cutting across the site to flow south along the WWTW access site.

The hierarchy for surface water management outlined within the NPPF and Building Regulations dictates that runoff is dissipated to ground using infiltration methods, is preferable. Where ground conditions are poor, surface water runoff should be discharged to watercourse; and only to sewer as a final possibility.

A desk-top assessment indicates that the underlying ground is comprised of clay, and therefore infiltration methods are not considered to be suitable. Therefore, surface water runoff for the development should continue to be directed to Chipping Brook, utilising existing outfall locations, where possible.

Flows leaving the development must not exceed existing discharge rates incorporating a 30% reduction in order to provide a betterment. Flows in excess of this must be attenuated on-site prior to discharge. Undertaking an evaluation of sustainable drainage methods (SUDS) which may be used within the development, it is recommended that consideration is given to source control methods i.e. green roof, or rainwater harvesting, to provide a level of interception storage at the site.

Foul flows from the development should be directed to the public combined sewer, re-utilising the connection, which serves the existing site where possible.

Mitigation Measures

- FFL replacement dwelling (farmhouse) = **99.67mAOD**; with flood proofing up to **99.67mAOD**.
- FFL redeveloped barn (live/work unit) = **98.73mAOD**; with flood proofing up to **98.73mAOD**.
- FFL redeveloped barn (detached garage) = **98.21mAOD**; with flood proofing up to **98.51mAOD**.
- Flood resistance/resilience to be incorporated into all buildings under development.
- Residents advised to sign up to receive Flood Alerts via the Environment Agency's Flood Warning's Direct Service.
- Residents advised to prepare a personal flood plan.
- Installation of a flood alarm.
- Careful consideration of boundary treatments to avoid increasing flood risk on the Startifants Farm site for or others.
- Surface water runoff to be directed to watercourse, and restricted to existing runoff rates minus 30%. Flows in excess of this will need to be attenuated on-site.
- It is recommended that source control measures such as green roof or rainwater harvesting are considered for application at the site.

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1.0 Introduction

1.1 Terms of Reference

Paul Waite Associates Ltd has been appointed by Johnathan Hadfield of J Hadfield Engineering/Surveying, to provide a Flood Risk Assessment in support of a planning application for a development at the former Startifants Farm, Longridge Road, Chipping, Lancashire.

The site has an area within the red-line boundary which approximates 0.645 Hectares; is shown to be situated within Flood Zone 3 of the Flood Map for Planning and therefore is considered to have a high risk of fluvial flooding.

It is usual for the Environment Agency to raise an objection to development applications within the floodplain, or Zones 2 and 3 of the flood maps, until the issue of flood risk has been properly evaluated.

The relevant Statutory Consultees will also object to residential development with 10+ dwellings or where the site area is in excess of 1 Hectare, until suitable consideration has been given to the management of surface water runoff.

1.2 Objectives

The objective of this assessment is to evaluate the following issues in regard to flood risk at the application site.

- Suitability of the proposed development in accordance with current planning policy.
- Identify the risk to both the proposed development and people from all forms of flooding.
- Provide a preliminary assessment of foul and surface water management.
- Increasing the risk of flooding elsewhere e.g. surface water flows and flood routing.
- Recommendation of appropriate measures to mitigate against flooding both within the proposed development, and neighbouring land and property.

1.3 Data Sources

This assessment is based on desk-top study of information from the following sources:

- National Planning Policy Framework (2018)
- Planning Practice Guidance at www.gov.uk
- Building Regulations Approved Document H
- Environment Agency Flood Mapping
- Ribble Valley Strategic Flood Risk Assessment May 2010
- British Geological Society – Historic Borehole Logs
- Cranfield University's Soilscape Viewer
- CIRIA C697 The SUDS Manual
- Chronology of British Hydrological Events (Dundee University)

- R&D Technical Report FD2320/TR2 (2005)
- Chipping WWTW Maintenance Hydraulic Modelling Report for United Utilities (Jacobs January 2016)

2.0 Planning Policy Context

2.1 Approach to the Assessment

An initial assessment indicates that the primary flood risk at the proposed development is from the fluvial source known as Chipping Brook, that traverses through the centre of the site; and also, from surface water flow routes originating from the area to the north of the development.

Consideration has also been given to the site flooding from secondary sources such as groundwater; artificial water bodies; infrastructure failure and ponding.

The requirements for flood risk assessments are generally as set out in the 'Technical Guidance to the National Planning Policy Framework', updated in July 2018; and in more detail from the Environment Agency's 'Standing Advice on Flood Risk' available from www.gov.uk.

2.2 National Planning Policy Framework (NPPF)

The information provided in the flood risk assessment should be credible and fit for purpose.

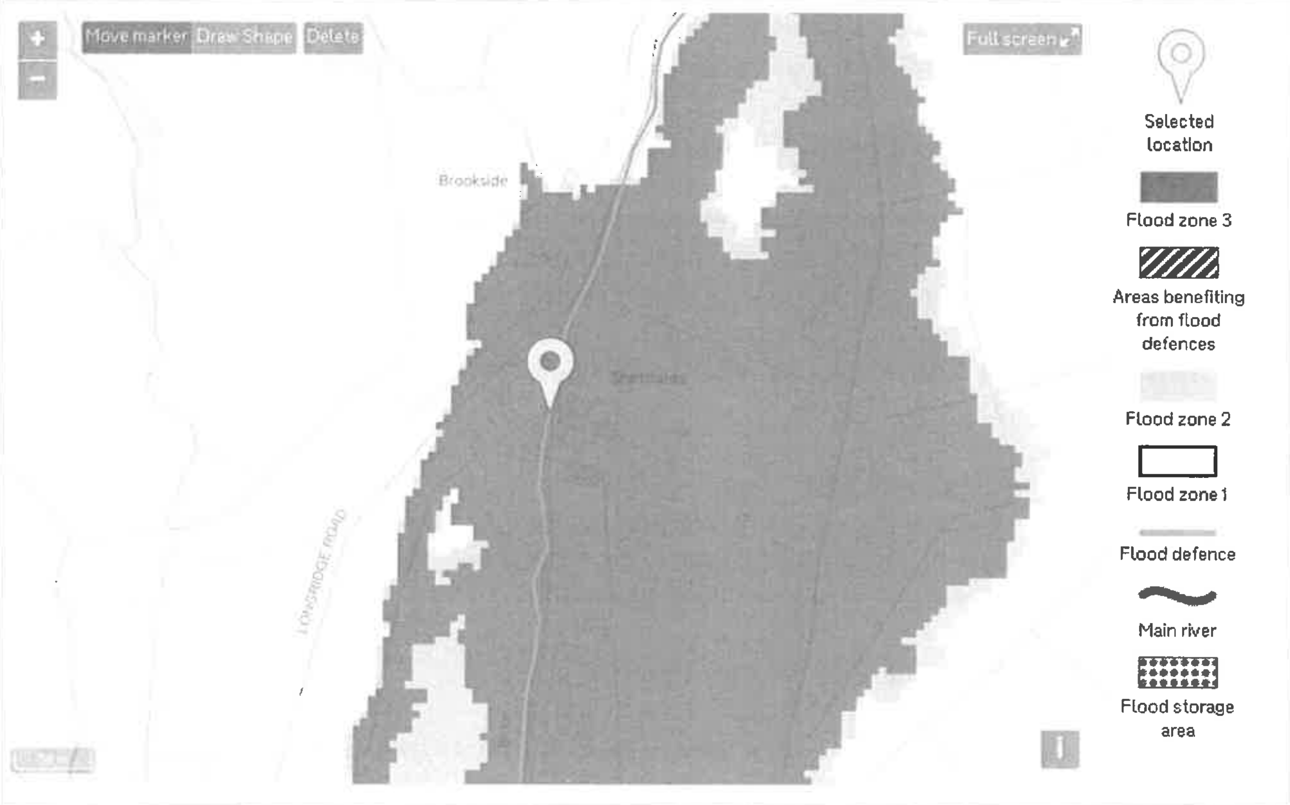
Site-specific flood risk assessments should always be proportionate to the degree of flood risk and make optimum use of information already available, including information in a Strategic Flood Risk Assessment for the area, and the interactive flood risk maps available on the Environment Agency's website.

A flood risk assessment should also be appropriate to the scale, nature and location of the development.

2.2.1 Sources of Flooding

- **Rivers (fluvial):** Flooding occurs when flow within river channels exceeds capacity; and the type of flood event experienced e.g. flash flooding; depends upon the characteristics of the river catchment.
- **The Sea (tidal):** Flooding at low lying coastline and tidal estuaries is caused by storm surges and high tides; with overtopping and breach failure of sea defences possible during extreme storm events.
- **Pluvial (surface flooding or overland flows):** Heavy rainfall, which is unable to soak away via infiltration or enter drainage systems can flow overland, resulting in localised flooding. Topography generally influences the direction and depth of flooding caused by this mechanism.
- **Groundwater:** Caused when ground water levels rise to the surface; and is most likely to occur in low lying areas underlain by aquifers.
- **Sewers and drains:** Generally, occurs in more urban areas; where sewers and drains are overwhelmed by heavy rainfall or blocked pipes and gullies.
- **Artificial Sources (reservoirs, canals, lakes and ponds):** Reservoir and canal flooding may occur as a result of capacity exceedance or structural failure.

Figure 2.1: The Environment Agency Flood Map



Source: www.gov.uk

2.2.2 Flood Zones

- **Flood Zone 1:** Low probability (less than 1 in 1000 year (<0.1% AEP) annual probability of river or sea flooding in any year.
- **Flood Zone 2:** Medium probability (between 1 in 100 year (1.0% AEP) and 1 in 1000 year (0.1% AEP) annual probability of river flooding; or between 1 in 200 year (0.2% AEP) and 1 in 1000 year (0.1% AEP) annual probability of sea flooding in any year).
- **Flood Zone 3a:** High probability (1 in 100 year (1.0% AEP) or greater annual probability of river flooding in any year or 1 in 200 year (0.5% AEP) or greater annual probability of sea flooding in any year).
- **Flood Zone 3b:** This zone comprises land where water has to flow or be stored in times of flood. Land which would flood with an annual probability of 1 in 20 (5% AEP), or is designed to flood in an extreme flood (0.1%) should provide a starting point for discussions to identify functional floodplain.

2.2.3 Vulnerability of Different Development Types

- **Essential Infrastructure:** Transport infrastructure (railways and motorways etc…); utility infrastructure (primary sub-stations, water treatment facilities; power stations; and wind turbines).
- **Water Compatible Development:** Flood control infrastructure; water and sewage infrastructure; navigation facilities.
- **Highly Vulnerable:** Emergency services; basement dwellings; mobile home parks; industrial or other facilities requiring hazardous substance consent.
- **More Vulnerable:** Hospitals; residential dwellings; educational facilities; landfill sites caravan and camping sites.
- **Less Vulnerable:** Commercial premises; emergency services not required during a flood; agricultural land.

2.2.4 Sequential & Exceptions Test

As set out in the National Planning Policy Framework, the aim of the Sequential Test is to steer new development to areas at the lowest probability of flooding.

The Flood Zones are the starting point for the sequential approach.

The Environment Agency Flood Map shows the development site to be located within Flood Zone 3.

In accordance with Table 2 'Flood Risk Vulnerability Classification' of the Technical Guidance to the National Planning Policy Framework, residential developments are defined as 'More Vulnerable' developments.

The following development types are however considered to be exempt from the Sequential Test:

- The proposal is for a **change of use** of an existing building; however, this only applies to proposals that involve no extension to the building (above and beyond that considered to be a "minor extension or alteration")
- The proposal is for a **minor extension or alteration** to an existing building or its associated structures, defined as:
  - Minor non-residential extensions: industrial/commercial/leisure etc… and residential extensions with a footprint less than 250m^2;
  - Householder development: e.g. sheds, garages, games rooms etc. within the curtilage of the existing dwelling in addition to physical extensions to the existing dwelling itself. This definition excludes any proposed development that would create a separate dwelling within the curtilage of the existing dwelling e.g. subdivision of houses into flats.
  - Alterations: development that does not increase the size of buildings e.g. alterations to external appearance or a replacement boundary treatment.
- The proposal is for the **replacement of an existing building**; however, only applies where there would be no increase in the intensity of use of the site, such as the replacement of an existing single dwelling house.

- The proposal is for a **renewable energy project** (e.g. wind turbines).
- The council has already sequentially tested the site as part of an **allocation for development** within the development plan.
- The proposal is for a site with an **existing planning permission** (full or outline) for a comparable mix and intensity of uses.

The development is residential in nature and incorporates the following proposals:

- Demolition and **replacement of an existing dwelling** (proposed increase in footprint <250m^2)
- **Change of use** of a barn structure to provide a single work/live unit.
- **Change of use** of an agricultural building to provide a detached garage

It is considered therefore that the development proposals are exempt from the Sequential Test; however, the site must still pass the Exceptions Test.

Table 1: Flood Risk Vulnerability and Flood Zone 'Compatibility'[1]

Flood Risk Vulnerability Classification		Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test required	✓	✓
	Zone 3a	Exception Test required	✓	×	**Exception Test required**	✓
	Zone 3b	Exception Test required	✓	×	×	×

✓ Development is appropriate
× Development should not be permitted

The Exceptions Test:

There are 2no parts to the Exceptions Test:

- Part 1: Show that the sustainability benefits of the development to the community outweigh the flood risk.
- Part 2: show that the development will be safe for its lifetime taking into account the vulnerability of its users and that it won't increase flood risk elsewhere.

[1] Extracted from Table 3 of the Technical Guidance to the National Planning Policy Framework Document (March 2012)

Part 1:

There are a number of benefits presented by the proposed development, which include:

- Provision of valuable housing stock within the rural areas associated with the Ribble Valley District.
- Replacement dwelling will have a better standard of protection against flooding, than the existing farmhouse dwelling; thereby reducing the number of people likely to be impacted by flooding within the local area.
- Proposed live/work unit provides business/employment opportunities; and will contribute to the rural economy within the Ribble Valley District.

Part 2:

- Section 7 of this report provides details of suitable measures which are recommended for inclusion within the development proposals; and are summarised below:
- Finished floor levels for residential units will be set a minimum of 600mm above the 2D depth of flooding; or depth of surface water flooding anticipated to impact each of the buildings.
    - Replacement Farmhouse Proposed FFL – **99.67mAOD**
    - Change of Use Barn to single live/work unit Proposed FFL – **98.73mAOD**
- For non-habitable buildings, the finished floor level will be set to match the 2D depth of flooding; or surface water flood depth anticipated to impact the building.
    - Detached garage FFL – 98.21mAOD
- Flood resistant/resilient material and construction methods will be incorporated into the development plans
- Residents to sign up to receive flood alerts from the Environment Agency via the Flood Warnings Direct service
- Residents to prepare a personal flood plan
- Installation of a flood alarm along the banks of Chipping Brook to provide advance notification of water level rises within the watercourse
- Careful consideration of boundary treatments to prevent impedance of flood routes through the site, to prevent increasing the risk of flooding on and off-site.
- Surface water to be discharged into Chipping Brook at existing rates minus 30% to provide a betterment; with on-site attenuation of flows (as required)
- Source control SUDS measures to be considered i.e. green roof or rainwater harvesting.

2.2.5 Climate Change

The NPPF requires the application of climate change over the lifetime of a development.

Chipping is located within the North West River Basin District; and the current climate change allowances for this district are tabulated overleaf.

The selection of climate change allowance should be chosen appropriate to the expected lifespan of the proposed development.

Residential development is anticipated to have a lifespan approximating 100 years; and as such an additional 40% should be applied to peak rainfall intensities to assess the surface water management requirements for the development.

The site is located within Flood Zone 3, is residential in nature ('more vulnerable' type of development) and therefore climate change allowances should be applied for the higher central and upper end categories; and therefore 35-70% to should be applied to peak river flow.

Table 2: North West Basin Climate Change Allowances[2]

Parameter	Allowance Category	2010 - 2039	2040 - 2059	2060 - 2069	2070 - 2115
Peak Rainfall Intensity	Upper end	+ 10%	+ 20%	**+ 40%**	
	Central	+ 5%	+ 10%	+ 20%	
Peak River Flow	Upper end	+ 20%	+ 35%		**+ 70%**
	Higher Central	+ 20%	+ 30%		**+ 35%**
	Central	+ 15%	+ 25%		+ 30%

[2] Extracted from Tables 1-4 of the Technical Guidance for flood risk assessments: Climate change allowances Document (February 2016)

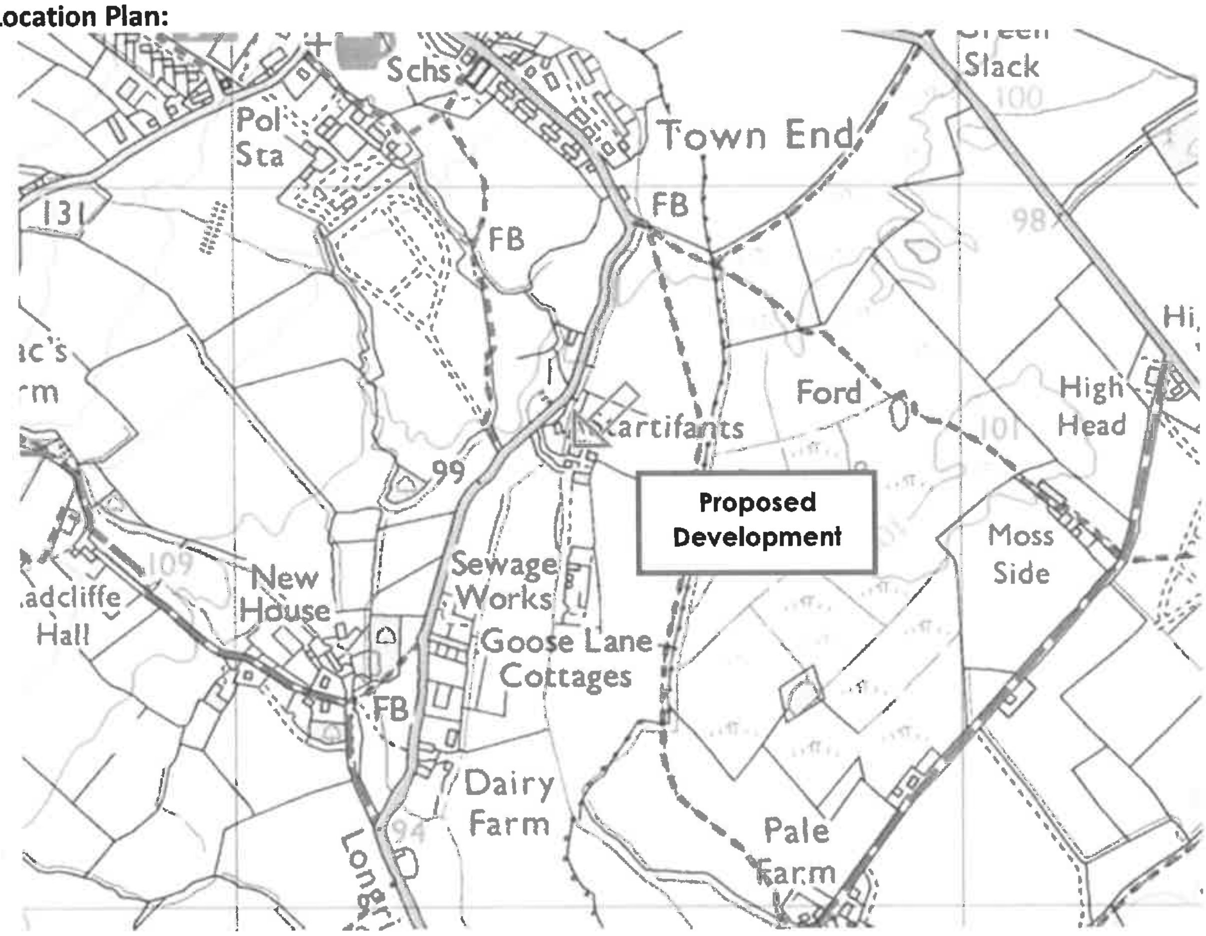
3.0 Details of the Site

3.1 Site Details

Table 3: Development Location

Site Name:	Startifants Farm, Longridge Road , Chipping
Purpose of Development:	Residential
Existing Land Use:	Residential & Agricultural
OS NGR:	SD 624 426
Country:	England
County:	Lancashire
Local Planning Authority:	Ribble Valley Borough Council
Internal Drainage Board:	Not Applicable
Other Authority (e.g. British Waterways/ Harbour Authority)	Not Applicable

Location Plan:



Source: http://www.streetmap.co.uk/

3.2 Site Description

The application site is located east of Longridge Road within the southern extent of the rural village known as Chipping, in Lancashire.

The redline boundary covers an area approximating 0.645 Hectares; and comprises an existing farm house, associated barns and outbuildings, interspersed by grass and hardstanding.

Table 4: Boundaries

North	Longridge Road forms the boundary to the northern corner of the development site. The southern fringe of the rural Lancashire village known as Chipping is located a distance of 700m north of Startifants Farm
West	Longridge Road also bounds the site to the west, beyond which the area is considered very rural, with Beacon Fell located approximately 5.8km; and Garstang a distance of 13.5km to the west of the site.
South	Chipping Waste Water Treatment Works is located immediately to the south of Startifants Farm, with a field which will remain undeveloped providing a buffer of 60m from the south boundary of the site. A small hamlet known as Hesketh Lane is located 1.4km, and the larger town of Longridge approximately 5.6km south of the site.
East	Land east of the development is largely agricultural in nature the urban centre of Clitheroe set a distance of 11.8km to the east of the application site.

A topographical survey has been provided; and the following pertinent levels have been extracted for use within the flood risk assessment:

- North corner of site: 99.26mAOD
- West Boundary (Longridge Road): 99.03 – 99.26mAOD
- West Boundary (Longridge Road to concrete bridge): 98.90 – 99.00mAOD
- Concrete bridge deck: 99.00mAOD
- Wooden bridge deck: 99.24mAOD
- West Boundary (bridge to south west corner): 97.91 – 99.00mAOD
- South west corner of site: 97.91mAOD
- South East corner of site: 97.02mAOD
- East boundary of site: 97.02 – 99.26mAOD
- FFL Existing house & garage: 98.77mAOD & 99.05mAOD
- FFL Existing barn (to be redeveloped): 98.03mAOD & 98.25mAOD
- FFL Existing building (proposed detached garage): 98.11mAOD

The site is bisected by Chipping Brook, which flows in a southward's direction, towards its confluence the River Loud near to Dobson's Hall. There are 2no bridges crossing the watercourse within close proximity.

The first bridge is of wooden construction and provides access to and from the farmyard located within the site on the east side of the brook. The second bridge is of concrete construction and forms part of the access arrangements for the WWTW to the south side of the application site.

Vehicular access to all parts of the development is available from Longridge Road.

Figure 3.1: Aerial View

Source: Google Earth

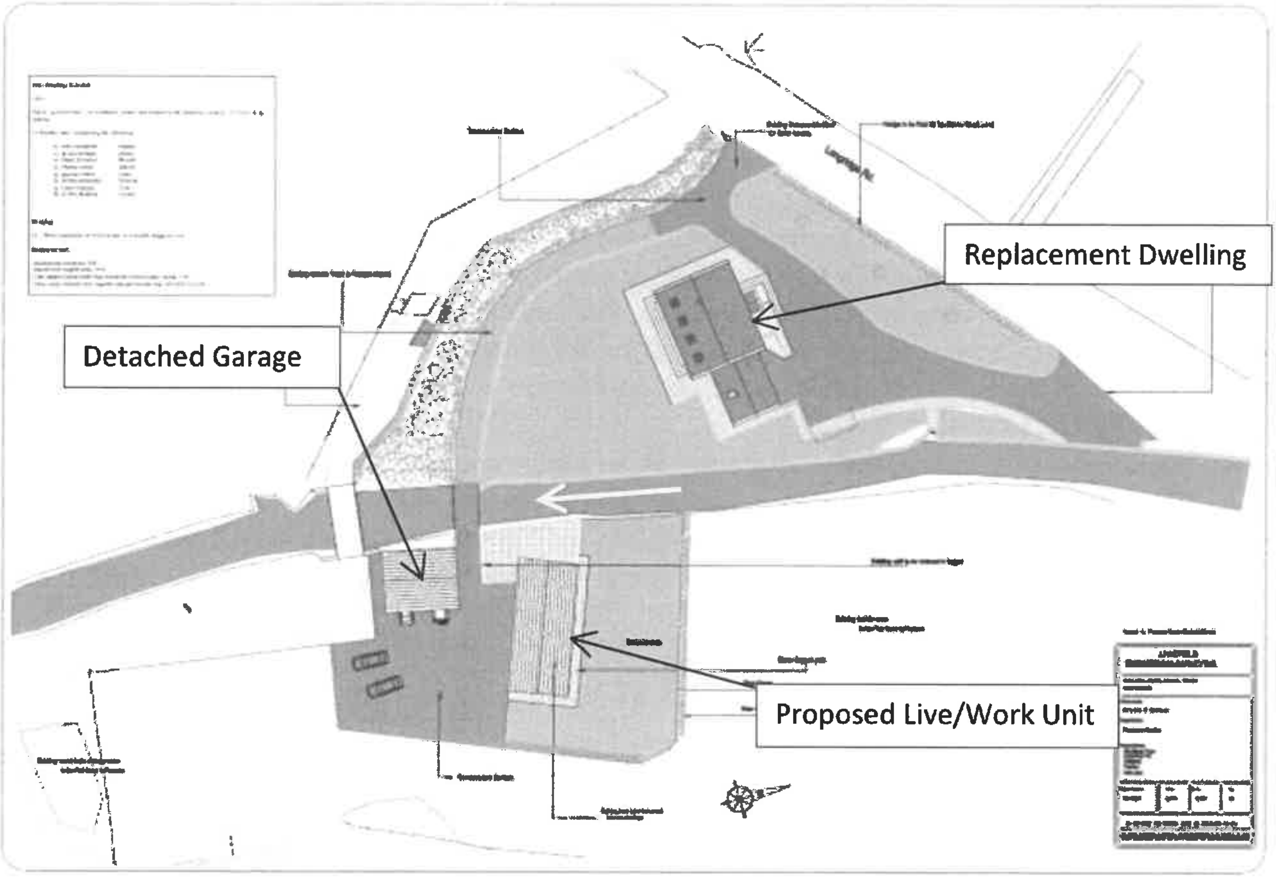
3.3 Proposed Development Details

The planning application involves the following:

- Replacement dwelling - demolish existing farmhouse and rebuild with a larger footprint
- Change of Use – barn conversion to provide single work/live unit
- Change of Use – farm building to detached garage
- Demolition of 5no farm buildings

A plan illustrating the latest development proposals is provided overleaf for reference and also within Appendix B of this report.

Figure 3.2: Development Proposals



Source: J Hadfield Engineering

4.0 Historic Flooding

4.1 Internet Search

An internet search for historic flooding within the area of Chipping found the following results:

- **January 2008** (Longridge and Ribble Valley News) – Torrential rain
  'TORRENTIAL rain brought chaos to the Longridge area on Monday as homes flooded, roads were blocked and schools and businesses were forced to close. Although conditions - following 24 hours of relentless rain - were some of the worst in recent memory, police praised the public response and said most people, particularly motorists, had 'acted sensibly'. In ***Chipping****, villagers reported never having seen anything like the floods. Brooks were at bursting point and water was cascading down the hilly streets. The Cobbled Corner cafe and St Mary's and Brabin's schools were forced to close at lunchtime.'*
- **September 2015** (Lancashire Telegraph) - River Ribble burst its banks
  'The water is threatening homes in Sawley, near Clitheroe, although there are no reports of any flooded properties at the moment. Elsewhere, fire crews were called out to a man trapped in a silver BMW in ***Chipping Road, east of Chipping****. The vehicle was submerged in three feet of water and the man was trapped.'*

4.2 Ribble Valley Borough Council SFRA May 2010

The Strategic Flood Risk Assessment (SFRA) was completed by Ribble Valley Borough Council in May 2010.

Section 4.3 entitled Historic Flooding, does not identify any historic flood events specifically within or in proximity to the application site.

4.3 Open Data (www.gov.uk)

4.3.1 Historic Flood Map

The site is not shown to lie within the areas shown to have been affected by historic flooding.

4.3.2 Recorded Flood Outlines Map

The site is not shown to lie within the areas shown to be located within recorded flood extents.

5.0 Initial Evaluation of Flood Risk

5.1 The Environment Agency Flood Map

The Environment Agency Flood Map illustrated within Figure 2.1, indicates that proposed development at Startifants Farm is located in Flood Zone 3.

The definition for each of the flood zones highlighted above is provided for reference within Section 2.2.2 of this report.

5.2 Sources of Flooding

Table 5: Possible Flooding Mechanisms

Source/Pathway	Significant?	Comment/Reason
Fluvial	Yes	Flood Zone 3 (Chipping Brook)
Canal	No	Not Applicable
Tidal/Coastal	No	Not Applicable
Reservoir	No	Long Term Flood Map indicates that the site is outside of the extent associated with reservoir flooding
Pluvial: Surface Water Flooding	Yes	Site is located within an area that is shown to have a high risk of flooding from this source
Pluvial: Overland Flow	No	Site is located within a relatively flat area, and therefore the risk of flooding from overland flow from elevated areas is overall considered to be low
Pluvial: Rainfall Ponding	No	No existing pond systems or depressed area where ponding could occur identified within the site.
Pluvial: Urban Drainage	Yes	Site will require the management of surface water runoff; however, it is identified that the area of roof/hardstanding within the red-line boundary overall will be reduced.
Groundwater	No	SFRA indicates a low risk of groundwater flooding within the area comprising the development.
Blockage	Yes	Possibility of blockage at the access bridge
Infrastructure failure	Yes	Operational issues at Chipping WWTW

From the initial assessment it is concluded that the primary source of flood risk will be from the fluvial source, Chipping Brook, and also from surface water flooding.

5.2.1 Fluvial: Chipping Brook & Tributaries

The watercourse rises as a number of springs approximately 4km north west of the site, within the heights of Wolf Fell, and flows in a south-east direction as White Stone Clough.

The stream becomes Greenhough Clough, at a location just south of Grouse Butt, when joined by a smaller unnamed watercourse which rises near to Saddle Fell.

Greenhough Clough flows south, and to the east of Parlick, becomes Chipping Brook. At Malt Kiln Brow located to the north end of Chipping Village, the watercourse is joined by Dobson's Brook; and continues through the village.

Chipping Brook is predominantly open channel along its length, and bisects the proposed development site at Startifants Farm. Downstream of the application site the watercourse flows south east for approximately 1km, and close to Dobson's Hall the watercourse converges with the River Loud, which forms part of the Hodder Catchment.

A small unnamed tributary of Chipping Brook has its upstream end at Brickhouse Gardens and flows southwards to the west side of Longridge Road. At Startifants Farm, the watercourse is culverted under the highway and flows through the fields to the south of the site and west of Chipping WWTW. The watercourse joins with a larger stream at Dairy House Farm, and converges with Chipping Brook at a location approximately 780m south east of the application site, near to Sandy Bank Farm.

The site is considered to lie within Flood Zone 3 associated with Chipping Brook and therefore the risk associated with fluvial flooding is considered to be high and has been evaluated in more detail within Section 6 of this report.

5.2.2 Groundwater

Section 4.2.5 of the Ribble Valley Borough Council SFRA provides a statement with regard to groundwater flood risk within the district:

'Following consultation with the EA, no evidence of groundwater flooding in the area has been identified. While no risk has been demonstrated, this is not to say that unrecorded groundwater flooding events may have taken place or that groundwater flooding may not occur in the future, but using the best available information they are not considered to be a significant risk at this time.'

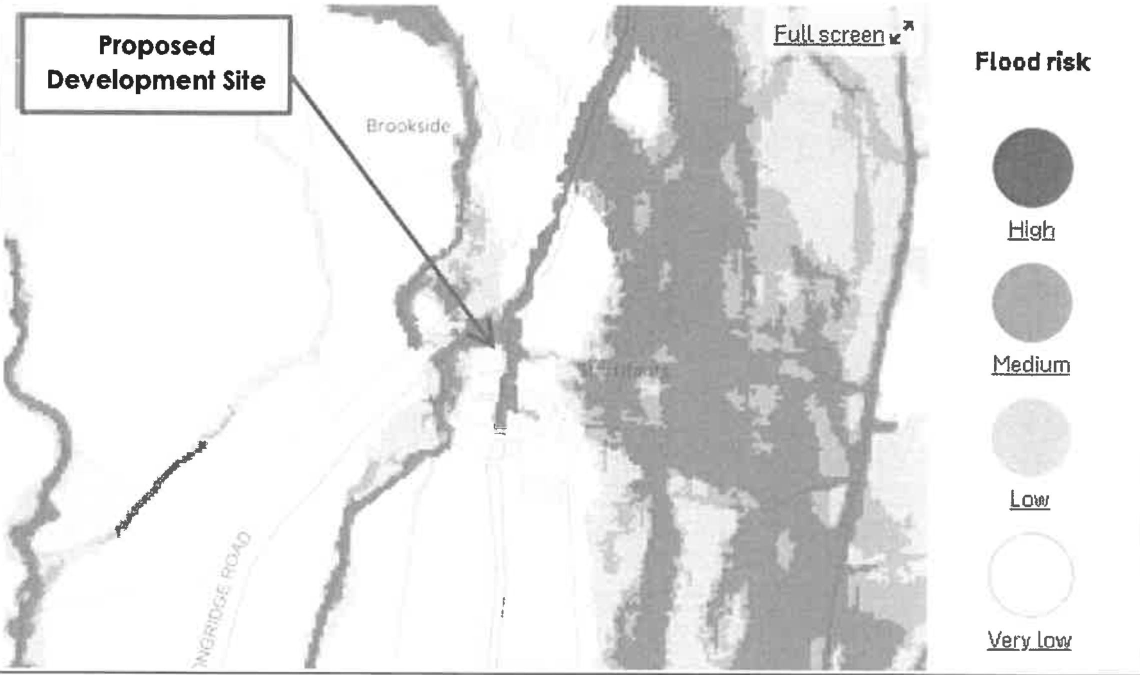
A review of local borehole logs using the BGS online service found one approximately 300m south east of the site, which states that water was struck 21m BGL.

It is concluded overall that the risk associated with groundwater flooding at the site is low; and therefore, has not been considered further within the assessment.

5.2.3 Surface Water Flooding and Overland Flow

The Surface Water Flood Map identifies that the proposed development site ranges from very low to a high risk from surface water flooding; as illustrated within Figure 5.1 below.

Figure 5.1: Environment Agency Surface Water Flood Map



Source: www.gov.uk

Further evaluation of flood risk from this source has been undertaken within Section 6 of this report.

5.2.4 Pluvial: Exceedance and Local System Failure (Sewer Flooding)

The following text has been extracted from CIRIA 2906 'Managing Extreme Events by Designing for Exceedance January 2013':

'Climate change and urbanisation is already contributing to increased surface water flooding, where the capacity of the existing drainage systems are overwhelmed (or exceeded).

The traditional approach to fixing the problem is to build bigger pipes or provide underground storage. Ofwat, the Environment Agency and others believe that this approach is unsustainable and unaffordable and are encouraging sewerage undertakers, Lead Local Flood Authorities and highway authorities to look at different approaches to managing sewer and surface water flooding. One approach being promoted is "designing for exceedance".

Designing for exceedance is an approach to manage flood risk (particularly from extreme events) by planning, designing and retrofitting drainage schemes that can safely accommodate rainfall and flooding that exceeds their design capacity (normally a 1 in 30 rainfall event). This is often achieved by considering flood pathways (such as managing runoff on highways) or providing additional storage (preferably on the surface through car parks, or multifunctional detention basins).

In England and Wales Sewers for Adoption and the National Planning Policy Framework encourage the consideration of drainage exceedance, it is a flexible approach to manage extreme events that can be used to reduce the need for more traditional, expensive underground approaches to manage surface water and often complement sustainable drainage and other local urban design initiatives.'

The impact of extreme rainfall events and/or local system failure will therefore need to be assessed as part of the overall surface water management strategy for the proposed development.

6.0 Quantitative Flood Risk Assessment

6.1 National Planning Policy Framework

Flood Risk Assessments should be undertaken in accordance with the checklist outlined within the NPPF Guidance document.

6.2 Fluvial: Chipping Brook

6.2.1 General

Chipping Brook flows south through the application site.

The watercourse is predominantly open channel, however to provide vehicular access to the easy side of the application site and also to Chipping WWTW, there are 2no bridge structures, located within the development boundary:

- Wooden bridge structure with deck level of 99.24mAOD
- Concrete bridge structure with deck level of 99.00mAOD

The primary mechanisms flor flooding from Chipping Brook are identified to be from overtopping of the river banks; and blockage at the bridge structures.

6.2.2 Modelled Data

A hydraulic model of Chipping Brook was undertaken by Jacobs in 2016, for United Utilities for the following purpose:

United Utilities are planning an expansion to the Chipping Waste Water Treatment Works (WWTW) site and the construction of a new access bridge.

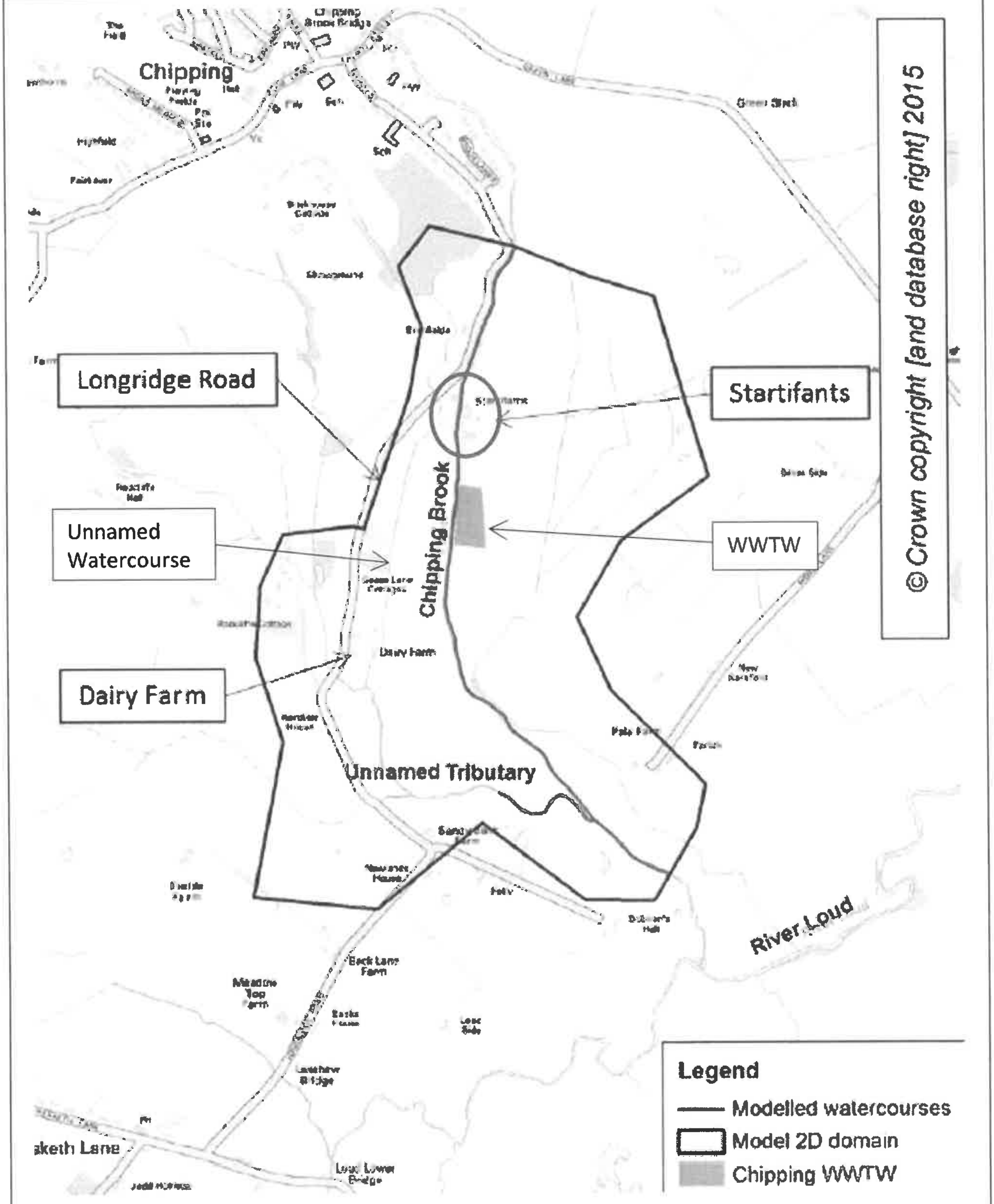
Following the delivery of the Level 1 Flood Risk Assessment (FRA), United Utilities commissioned Jacobs to build a linked 1-dimensional/2-dimensional (1D/2D) hydraulic model to determine the:

- Existing flood risk (extents and depths) in the Chipping Brook floodplain; and the
- Maximum in-channel water levels for the 1% Annual Exceedance Probability (AEP) and the 1% AEP plus Climate Change flood events at the new proposed bridge location.

In lieu of any other flood studies which have been undertaken at Chipping, model results obtained by the Jacob's hydraulic model have been extracted and used to assess flood risk at the Startifants Farm Site.

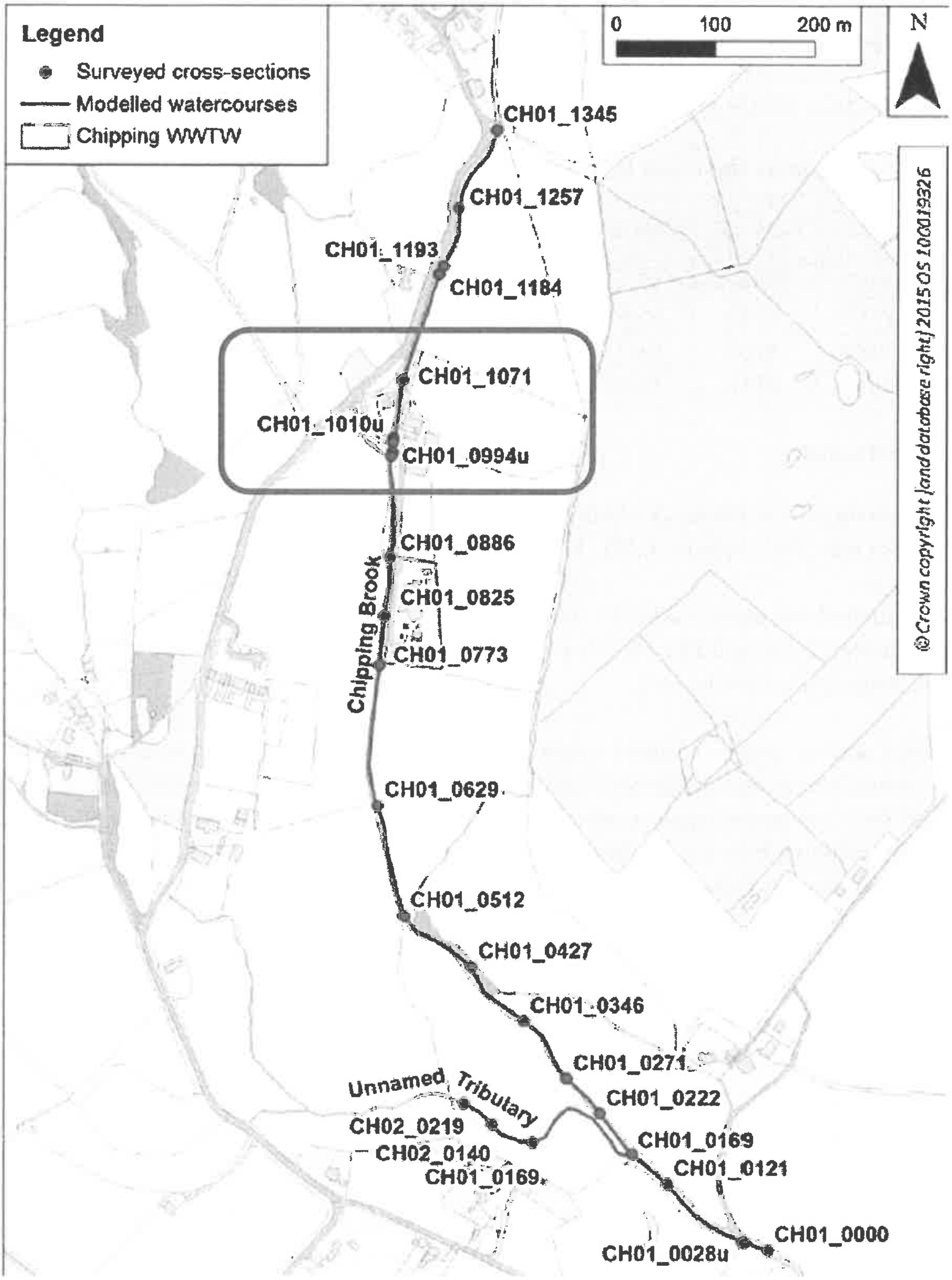
A copy of the Jacob's report is provided for reference within Appendix C of this report; and Figure 6.1 overleaf illustrates the extent along Chipping Brook; and across its floodplain which was incorporated within the model.

Figure 6.1: Flood Model Extents Map



Source: Jacob's Chipping WWTW Hydraulic Modelling Report

Figure 6.2: Modelled Cross Sections / Node Location Map



Source: Jacob's Chipping WWTW Hydraulic Modelling Report

6.2.3 Modelled Flood Levels

Figure 6.2 above illustrates the model nodes which are relevant to the Startifants Farm site; and Table 6 below provides modelled flood levels for those nodes.

- Node CH01_1071 – located at the upstream extent of the Startifants Farm Site

Table 6: Chipping Brook Maximum In Channel Water Levels (Existing Scenario)

Node Ref	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + CC
CH01_1071	99.32	99.44	99.48	99.50	99.51	99.52	99.54
CH01_1010u	98.67	99.08	99.14	99.17	99.19	99.21	99.24
CH01_1007	98.65	98.72	98.75	98.77	98.78	98.79	98.80
CH01_0994u	98.55	98.64	98.68	98.69	98.71	98.72	98.73

6.2.4 Overtopping

Mapping obtained from the Jacob's Hydraulic Modelling report indicates that overtopping occurs from the northern most river node i.e. CH01_1071.

At the location of this model node, the river bank levels, extracted from the topographical survey, are 98.85mAOD (left bank) and 98.64mAOD (right bank); which are both lower than the modelled water levels all return period flood events.

- **50% AEP (1 in 2-year) flood event**: the 1D in-channel flood depth is anticipated to cause overtopping of the river banks. A wall with crest level 99.40mAOD, is located along the right bank; which is marginally higher than the estimated flood level for the baseline model. This concurs with mapping from the Jacob's Hydraulic modelling report, where the 2D model indicates that flooding occurs from the left bank only. Most of the site appears to be unaffected by flooding during the 1 in 2-year return period, including the access route leading to Longridge Road. Flooding is illustrated to exit the site into the adjoining field, to the north side of the farm buildings, with a depth of flooding less than 0.1m.
- **20% AEP (1 in 5 year) flood event:** the 1D in-channel flood depth is anticipated to cause flooding across both river banks. The 2D flood map indicates that the flood route from overtopping of the left bank, surrounds the existing farm buildings, with a depth less than 0.1m. Flooding is also shown to occur along the right bank of Chipping Brook, with out of bank flow directed around the north side of the farmhouse, changing direction to flow south across the site access towards an unnamed watercourse, where flow is directed back into Chipping Brook, via the tributary which joins the brook near to Sandy Bank Farm. The depth of flooding is predicted to be less than 0.1m, increasing to 0.1-025m within a localised topographical depression within a landscaped area on the north side of the farmhouse.

- **10% AEP (1 in 10 year) flood event:** The flood maps presented within Appendix B of the Jacob's report, indicates that the flood route from the left bank, results in a flood depth surrounding the farm buildings less than 0.1m, increasing to 0.1-0.25m within the adjoining field. Flooding is also shown to occur along the right bank of Chipping Brook, with out of bank flow continued to be directed around the north side of the existing farmhouse, and routes back to the watercourse system via the unnamed watercourse. The depth of flooding overall is estimated to be less than 0.1m along the flood route, with a depth of 0.1-0.25m to the north of the access road; and 0.25-0.5 in the landscaped area on the north side of the farmhouse.
- **5% AEP (1 in 20 year) flood event:** The pattern, and depth of out of bank flooding is similar to the 10% AEP or 1 in 10-year flood event.
- **2% AEP (1 in 50 year) flood event:** The pattern, and depth of out of bank flooding is similar to the 10% AEP or 1 in 10-year flood event; however, on the right bank, the extent of the flood route across the access road is extended and is divided to create 2no flood routes south through the adjacent field.
- **1% AEP (1 in 100 year) flood event:** The pattern, and depth of out of bank flooding is similar to the 10% AEP or 1 in 50-year flood event. The 2D modelled flood depth within the farmyard area on the left bank is predicted to be less than 0.1m; and 0.1-0.25m surrounding the farmhouse on the right bank.
- **1% AEP + 20% (1 in 100 year + 20% Climate Change) flood event:** The pattern, and depth of out of bank flooding is similar to the 10% AEP or 1 in 50-year flood event; as the difference in estimated flood levels for Chipping Brook for these events is only 0.06m. The 2D flood depth within the farmyard area on the left bank is predicted to be less than 0.1m, but increases to 0.10-0.25m at isolated areas south of the farm buildings; and 0.1-0.25m surrounding the farmhouse on the right bank; with an area of depth 0.25-0.5m anticipated within the landscaped area on the north side of the farmhouse building.

6.2.5 Application of Climate Change

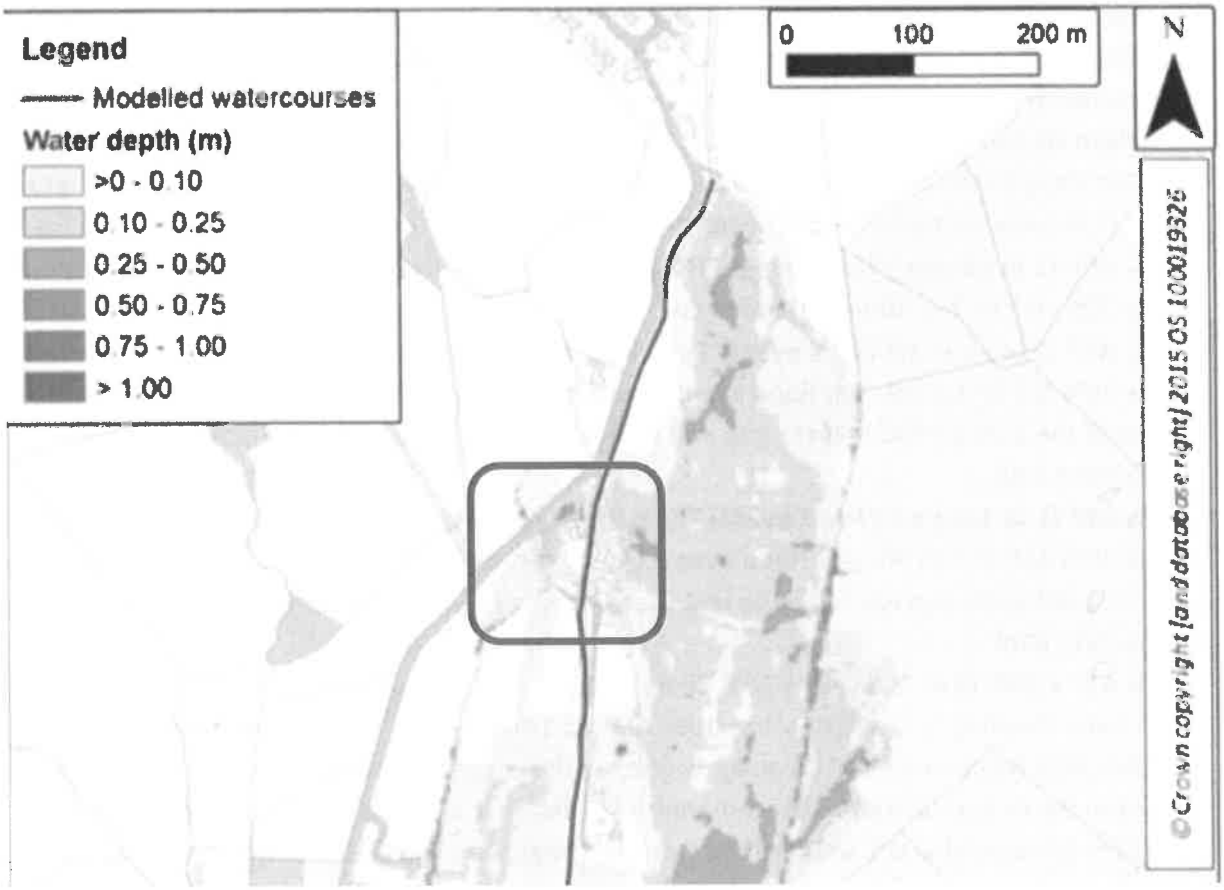
NPPF requirement is for climate change of 35% and 70% to be applied to 'more vulnerable' development located in Flood Zone 3.

Unfortunately, a copy of the Jacob's model is unavailable to provide a detailed assessment of climate change impact on the 2D floodplain comprising Startifants Farm.

For the purposes of assessment, it is presumed that there is a relationship between flow and flood level within Chipping Brook. Extrapolation of the available data indicates the following:

- 1 in 100-year + 35% flood event – 99.55mAOD
- 1 in 100-year + 70% flood event – 99.59mAOD

Figure 6.3: 2D Flood Map for the 1 in 100-year + 20% Climate Change Event



Source: Jacobs Flood Modelling Report

It is consistent with the relative increases in depth across the range of modelled return period events; and is deemed to provide a sensible assessment.

Overall the increased allowance for climate change results in only a 50mm increase to in-channel water levels for the 1D model comparison to the 1 in 100-year + 20% climate change scenario; and therefore, it is considered that there will be relatively little change to the flood extents and resulting flood depths across the 2D floodplain.

6.2.6 Flood Hazard – Access & Egress

Safe access and egress from the development is considered to be paramount. Flood mapping for the 1 in 100-year + 20% climate change event indicates a maximum depth of flooding of 0.1m.

Flood Hazard Rating (HR) = d x (v + 0.5) + DF

Where,

HR = flood hazard rating
d = depth of flooding (m)
v = velocity of floodwater (m/s)
DF = debris factor

From Table 3.1 of the DEFRA/EA document Flood Risks to People Phase 2 (FD2321/TR2), the debris factor for the site has been taken as zero i.e. flood depth less than 0.25m for areas comprising pasture and arable land

Details pertaining to the velocity of flow within the floodplain has not been provided within the Jacob's report. Using the Long-Term Flood Maps the velocity for surface water flooding is predicted to be more than 0.25m/s; and therefore, to provide a conservative approach, a velocity of 1m/s has been utilised within the hazard calculation.

HR = 0.1 x (1 + 0.5) + 0 = <u>**0.15**</u>

Using Table 4 from DEFRA/EA Supplementary Note on Flood Hazard Ratings (see Table 7 below), the hazard to people at the Startifants Farm site is considered to present a 'Very Low Hazard'.

Table 7: Hazard to People (Fluvial Flood Risk)

Hazard Rating	**Depth of Flooding (m)**			
	DF = 0			
Velocity v (m/s)	**0.05**	**0.10**	**0.20**	**0.25**
0.00	0.025	0.050	0.100	0.125
0.10	0.030	0.060	0.120	0.150
0.30	0.040	0.080	0.160	0.200
0.50	0.050	0.100	0.200	0.250
1.00	0.075	0.150	0.300	0.375
1.50	0.100	0.200	0.400	0.500

<0.75	Very low hazard - caution
0.75 – 1.25	Danger for some – includes children, the elderly, and the infirm
1.25 – 2.00	Danger for most – includes the general public
2.00+	Danger for all - includes the emergency services

6.2.7 Blockage

The impact of blockage at the existing bridge structures on flows and flood levels within Chipping Brook was not considered within the sensitivity analysis undertaken within the Jacob's report.

It is anticipated that during flood events, debris may be washed downstream and become trapped under the structures, resulting in blockage which will likely restrict flows within the channel. The impact will be to elevate water levels within the channel upstream of the bridges.

Figure 6.4: Wooden Access Bridge Startifants Farm

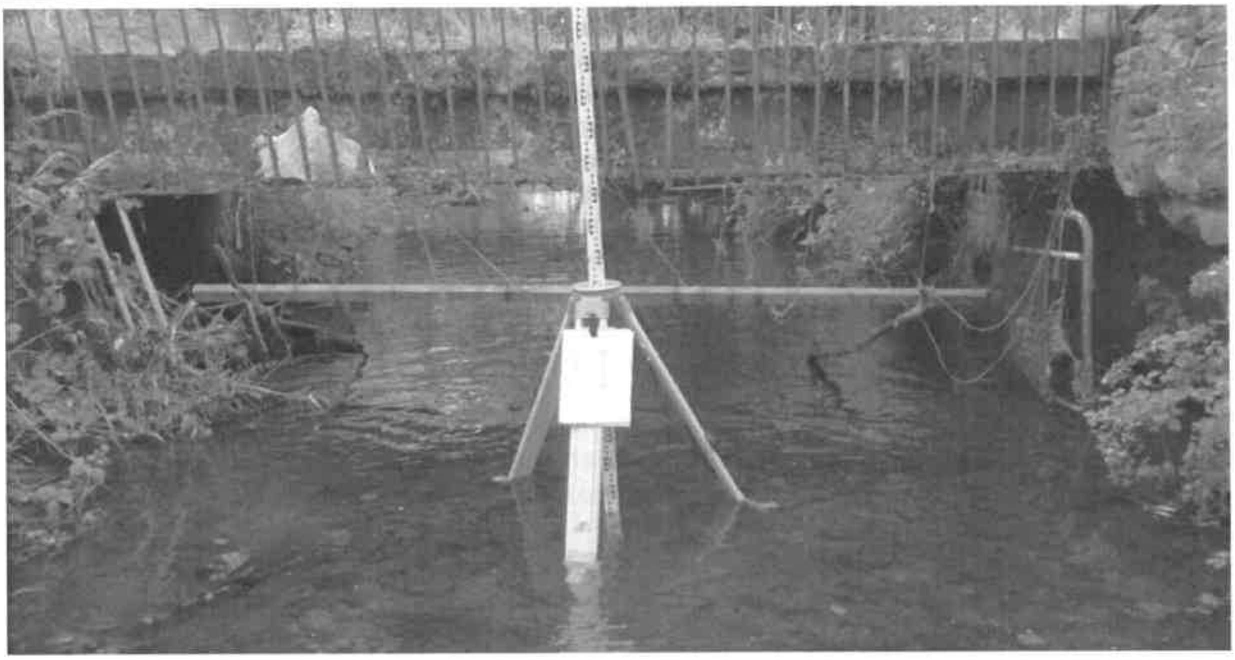
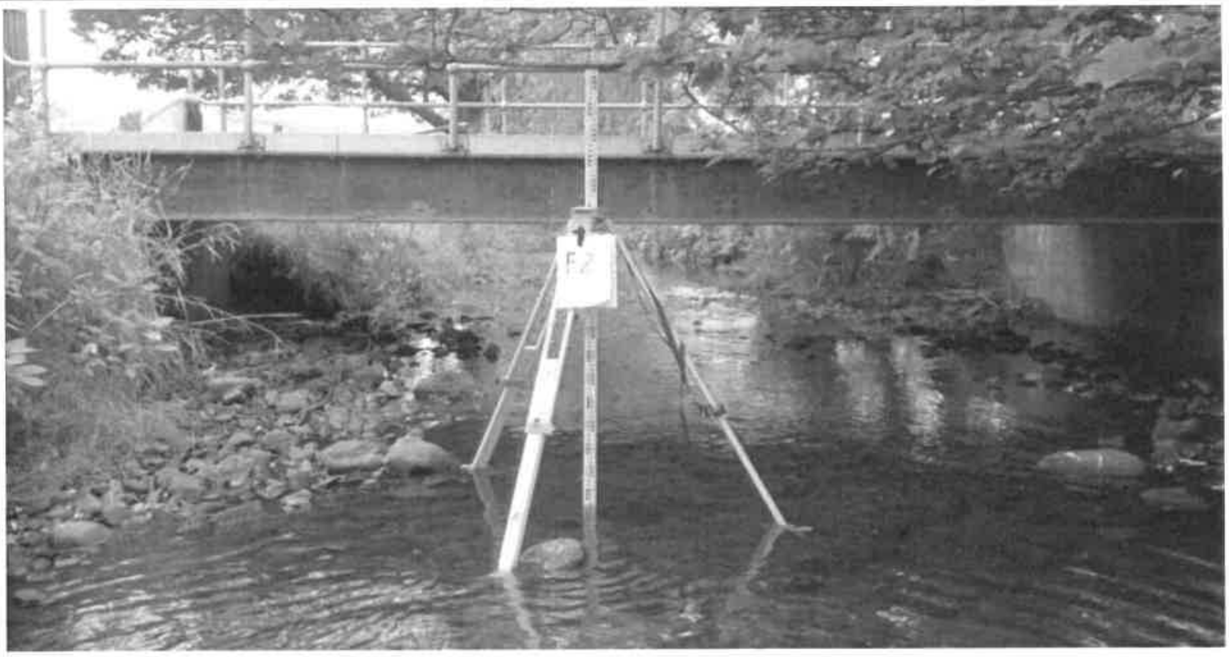


Figure 6.5: Concrete Access Bridge WWTW



Source: Jacob's Hydraulic Modelling Report

It is noted that both bridge structures are open sided and therefore in the event that water levels are elevated above bank top level, then flow will overtop the ridge deck/s and return to the channel downstream.

As such is considered that blockage will increase flood risk, however this is likely to be localised to the areas in close proximity to the bridge structures.

6.2.8 Fluvial: Conclusion

The assessment confirms that the development at Startifants Farm is located within Flood Zone 3; and has a high risk of flooding.

However, the 2D model indicates that the depth of flooding across the development site is predominantly <0.1m, with localised areas showing an increased depth of flooding 0.1-0.25m up to the 1 in 100-year event and 0.25-0.5m with the addition of climate change in the landscaped areas contained within the site.

The flood risk at the site is exacerbated as a result of blockage.

It is considered that with the application of suitable measures the flood risk associated with Chipping Brook may be mitigated sufficiently within the development site.

6.3 Pluvial Flood Risk

6.3.1 Long-Term Flood Risk Map

The Long-Term Flood Map provides a detailed indication of flooding from surface water flooding for the high, medium and low risk events. Mapping illustrates the chance of occurrence, potential depths, velocities and direction of flow for surface water flood routes. The definitions for varying probability events are outlined for reference below:

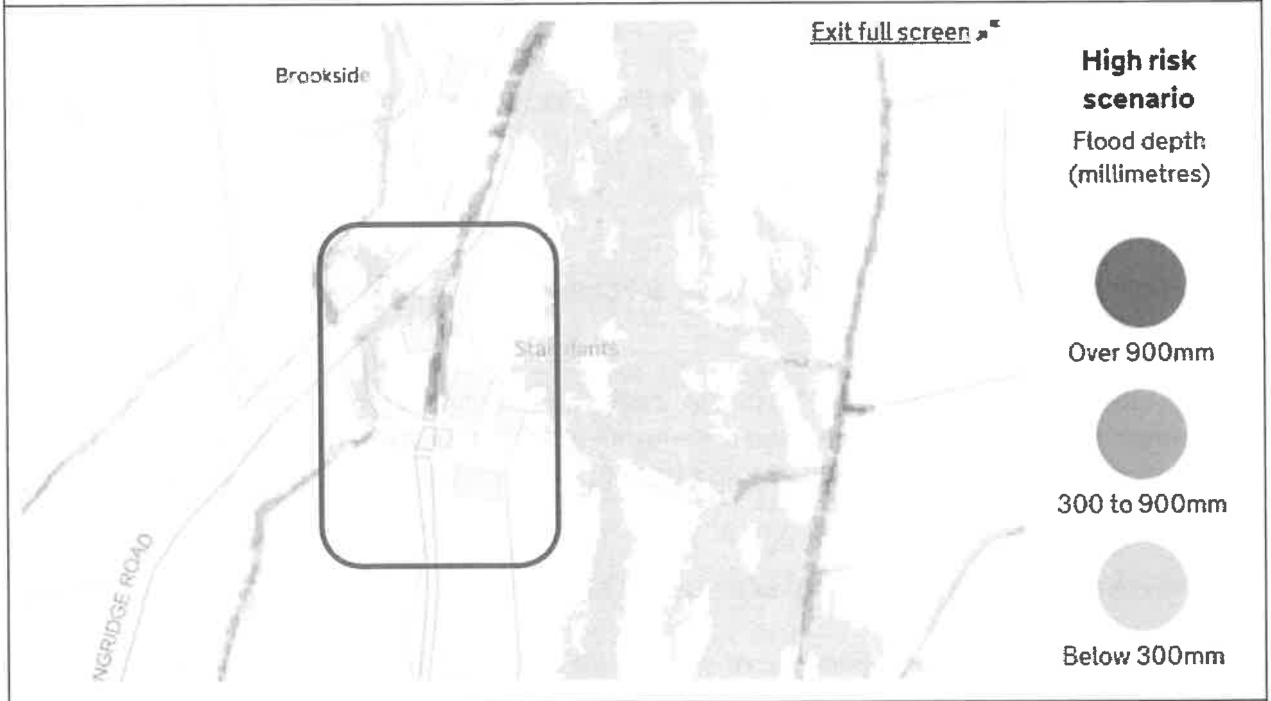
- High – Flood risk is greater than 1 in 30 in any one year (3.3% AEP).
- Medium – Flood risk is between 1 in 100 (1% AEP) and 1 in 30 (3.3% AEP) in any one year.
- Low – Flood risk is between 1 in 1000 (0.1% AEP) and 1 in 100 (1% AEP in any one year).
- Very Low – Flood risk less than 1 in 1000 (0.1% AEP) in any one year.

6.3.2 High Probability Event

Flood route extends around the north of the farmhouse and across the access road southwards; with a depth less than 0.3m and velocity more than 0.25m/s

The flooding is not illustrated to directly impact the existing building footprints within the site.

Figure 6.6: Surface Water Depth – High Probability Event Depth



Source: https://flood-warning-information.service.gov.uk

6.3.3 Medium Probability Event

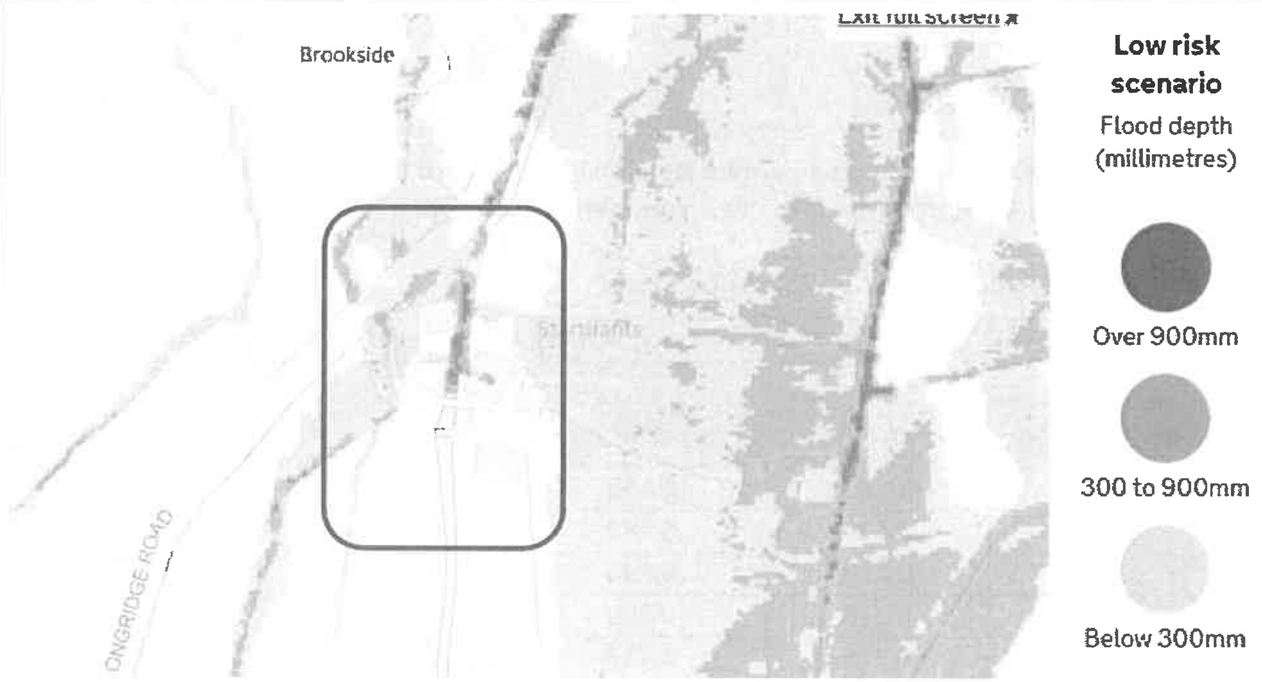
Figure 6.7: Surface Water Depth – Medium Probability Event Depth

Source: https://flood-warning-information.service.gov.uk

During the medium probability event the extent of the surface water flood route is slightly increased, around the farmhouse and across the access road, however the flow depth and anticipated velocities remain the same.

6.3.4 Low Probability Event

Figure 6.8: Surface Water Depth – Low Probability Event Depth



Source: https://flood-warning-information.service.gov.uk

During the low probability event the extent of the surface water flood route is significantly increased, around the farmhouse and across the access road; with an additional flood route extending east towards the adjacent field. It is noted that the depth of flow is considered largely to be less than 0.3m, with 0.3-0.9m at some isolated areas within the site where the topography is lower.

6.3.5 Flood Hazard Rating

Safe access and egress from the development is considered to be paramount. Flood mapping for the all surface water flood events event indicates a maximum depth of flooding of 0.3m.

Flood Hazard Rating (HR) = d x (v + 0.5) + DF

Where,

HR = flood hazard rating
d = depth of flooding (m)
v = velocity of floodwater (m/s)

DF = debris factor

From Table 3.1 of the DEFRA/EA document Flood Risks to People Phase 2 (FD2321/TR2), the debris factor for the site has been taken as zero i.e. flood depth 0.25m to 0.75m for areas comprising pasture and arable land.

Using the Long-Term Flood Maps the velocity for surface water flooding is predicted to be more than 0.25m/s; and therefore, to provide a conservative approach, a velocity of 1m/s has been utilised within the hazard calculation.

HR = 0.3 x (1 + 0.5) + 0 = **0.45**

Using Table 4 from DEFRA/EA Supplementary Note on Flood Hazard Ratings (see Table 7 overleaf), the hazard to people at the Startifants Farm site is considered to present a 'Very Low Hazard'.

Table 8: Hazard to People (Surface Water Flood Risk)

Hazard Rating	Depth of Flooding (m) DF = 0			
Velocity v (m/s)	**0.25**	**0.30**	**0.40**	**0.50**
0.00	0.125	0.150	0.200	0.250
0.10	0.150	0.180	0.240	0.300
0.30	0.200	0.240	0.320	0.400
0.50	0.250	0.300	0.400	0.500
1.00	0.375	0.450	0.600	0.750
1.50	0.500	0.600	0.800	1.000

<0.75	Very low hazard - caution
0.75 – 1.25	Danger for some – includes children, the elderly, and the infirm
1.25 – 2.00	Danger for most – includes the general public
2.00+	Danger for all - includes the emergency services

6.3.6 Pluvial: Conclusion

It is concluded that there is a risk associated with surface water flooding at the application site; and suitable measures should be applied at the development site in order to mitigate against flood risk from this source.

6.4 Surface Water Runoff

6.4.1 General & Contributing Areas

The red line boundary covers an area approximating approximates 0.645 Hectares; and is considered to be brownfield in nature.

An assessment of the roof, hardstanding and other drained areas has been undertaken from the topographical survey.

Table 9: Existing Drained Areas (Hectares)

Surface Type	% Impermeable	Area (Hectares)	Contributing Area (Ha)
Roof (yellow)	100	0.110	0.110
Concrete/Tarmac Paving (cyan)	100	0.180	0.180
Grass & Landscaped Areas (green)	0	0.287	0
Rough Ground (pink)	50	0.013	0.007
River Channel (blue)	0	0.055	0
	Total	**0.645**	**0.297**

6.4.2 Existing On-site Drainage Regime

It is considered that the existing site is positively drained, and assumed due to proximity that surface water from the roof, farmyard and driveway areas is directed to Chipping Brook.

A review of the sewer records indicates that a combined sewer flows south along Longridge Road, connecting Chipping with the WWTW. The sewer crosses land and the watercourse to the south of the development; and enters the WWTW via the access road. It is understood that foul flows are directed to the combined sewer.

Figure 6.9: Drained Area Plan at Startifants Farm

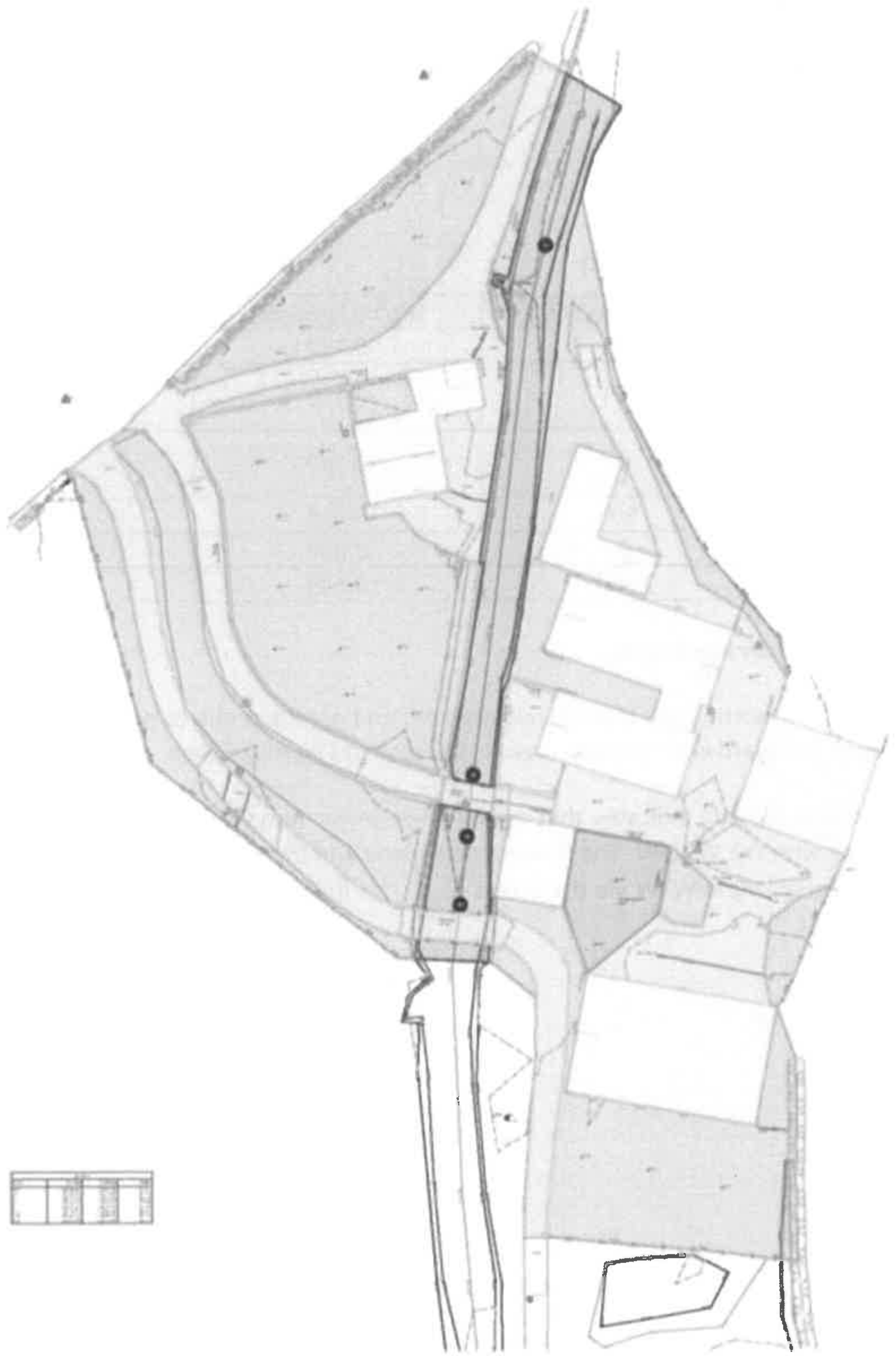


Figure 6.10: United Utilities Sewer Records

6.4.3 Existing Runoff Rates

In order to assess discharge rates, it is standard practice to model existing drainage systems using hydraulic modelling software such as MicroDrainage. It is noted however that there is insufficient information available to undertake this modelling exercise; and therefore, the Modified Rational Method has been utilised to estimate surface water discharge rates.

Discharge Q = 2.78 x A x i

Q = discharge rate (m^3/s)
A = Drained Area (Ha)
i = rainfall intensity (mm/hr)

Depths for the 2013 rainfall profile have been obtained from the FEH Web Service; and given the small scale of the existing site, the storm duration has been taken to match the time of entry, where:

Time of Entry = Time of Concentration + Time of Flow.

With a time of concentration of 4 minutes, it is considered that the time of flow from the roof and hardstanding areas to Chipping Brook is likely to be less than 11 minutes.

As such, the storm duration, for calculation purposes has been taken as 15 minutes:

- 1 in 1-year rainfall depth = 5.55mm
- 1 in 30-year rainfall depth = 18.95mm
- 1 in 100-year rainfall depth = 24.43mm

Table 10: Existing Surface Water Runoff

Return Period	Area (Ha)	Rainfall Intensity (mm/hr)	Discharge Rate (l/s)	Reduced Discharge Rate (l/s)
1-year	0.297	22.2	18.3	12.8
30-year		75.8	62.5	43.8
100-year		97.7	80.7	56.5

In order to provide a betterment, it is recommended that a reduction in discharge rates of 30% leaving the development is applied.

6.4.4 Surface Water Drainage Hierarchy

The hierarchy for managing surface water runoff from new developments is outlined within the Building Regulations Approved Document H and within the NPPF and specifies the following methods in order of preference:

- Infiltration via soakaway or other suitable infiltration device
- Discharge to watercourse
- Discharge to public surface water sewer
- Discharge to public combined sewer

Infiltration

A non-intrusive desk-top study has been undertaken to review the underlying ground conditions at the Startifants Farm site.

- Soilscape Maps: ground at the site is considered to be *'Slowly permeable seasonally wet acid loamy and clayey soils.'*
- Historic BGS Borehole Logs: Underlying ground comprises of clay to a considerable depth below surface ground level.

It is concluded that infiltration at the site is unlikely to be feasible.

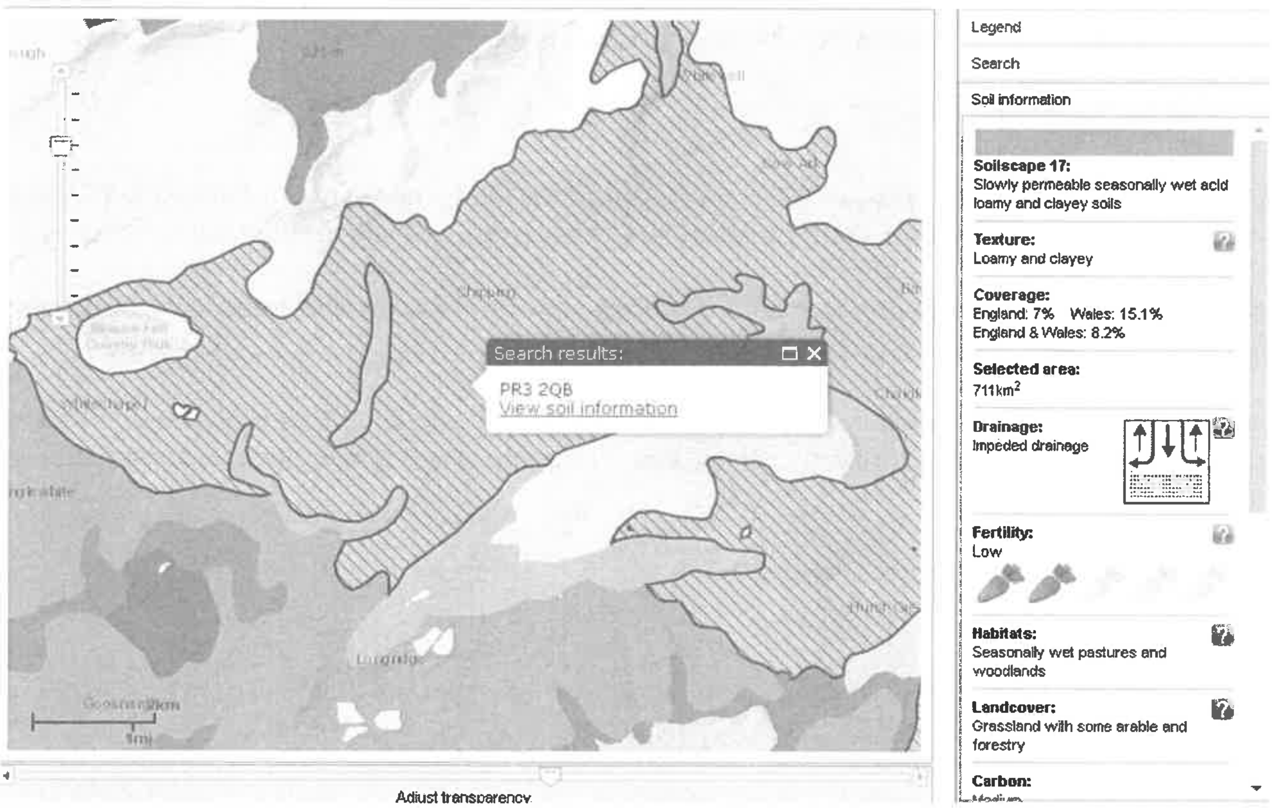
It is advised however that the statutory authorities may request evidence in the form of on-site percolation tests, in accordance with BRE Digest 365, to confirm the outcome of the desk-top assessment, prior to the detailed design stages of the project.

Watercourse

Chipping Brook bisects the proposed development site; and therefore, due to proximity it has been presumed that surface water runoff rom the roof and hardstanding areas within the site are directed to watercourse

Therefore, it is recommended that surface water flows from the development are continued to discharge to Chipping Brook, re-utilising existing outfalls, where available.

Figure 6.11: Soilscape Map



Source: Soilscape

6.4.5 Sustainable Urban Drainage Systems (SUDS)

SUDS act to reduce the impact of surface water runoff from the development by limiting runoff volumes and rates from leaving the site.

Undertaking an assessment using the SUDS Planner Module within MicroDrainage indicates that a number of different methods could be used within the development. A summary of the results is tabulated below:

Table 11: SUDS Planner

SUDS Criteria	Rank 1	Rank 2	Rank 3
Hydrological	Permeable Pavements	Infiltration Trench/Soakaway	Infiltration Basin
Land Use	Infiltration Trench/Soakaway	Bioretention Area	Infiltration Basin
Site Features	Permeable Pavements	Green Roofs	Filtration Techniques
Community & Environment	Bioretention Area	Grassed Filter Strips	Stormwater Wetlands
Economics & Maintenance	Wet Ponds	Grassed Filter Strips	Dry Detention
Total	**Online/Offline Storage**	**Permeable Pavements**	**Green Roofs**

1. Source Control

The inclusion of source control in SUDS schemes is one of the more important principles of SUDS design, and source control components should be upstream of any pond, wetland or other SUDS component.

Source control can help provide interception storage which can handle and treat some of the more frequent but smaller, polluting events (at least 5mm).

Most source control components will be located within the curtilage of private properties or driveway and highway areas. Their purpose is to manage rainfall close to where it falls, not allowing it to become a problem elsewhere.

The main types of source control include:

- Green roofs
- Rainwater harvesting
- Permeable paving
- Other permeable surfaces

Source control methods look to maximize permeability within a site to promote attenuation, treatment and infiltration, thereby reducing the need for off-site conveyance.

a) Green Roofs

Green roof solutions generally comprise of a multi-layered system that covers the roof of a building with vegetation cover, and/or landscaping over a drainage layer, designed to intercept and retain rainfall.

It is unlikely that a green roof solution will be suitable for application on the existing barn structures to be redeveloped, however here is an opportunity for incorporation within the replacement dwelling, through careful design.

Any inclusion of this SUDS method will be the decision of the architect and developer.

b) Rainwater Harvesting

Rainwater harvesting provides a source of non-potable water, for purposes such as car washing; and landscaped area irrigation etc... and can be used for some industrial processes to reduce consumption of water from conventional supplies.

This SUDS solution, like green roof technology, is also designed to provide interception storage i.e. acts to reduce the volume of surface water leaving the proposed development; thereby helping to alleviate the current pressures on the receiving watercourse.

There are many proprietary rainwater harvesting systems available; which may be incorporated into the drainage strategy for the development.

c) Pervious Paving

Pervious surfaces can be either porous or permeable.

Porous surfacing is a surface that infiltrates water across the entire surface; whereas permeable surfacing is formed of material that is itself impervious to water but, by virtue of voids formed through the surface, allows infiltration through the pattern of voids.

Pervious surfaces provide a surface suitable for pedestrian and/or vehicular traffic, while allowing rainwater to infiltrate through the surface and into underlying layers.

The water can be temporarily stored before infiltration to the ground, reused, or discharged to a watercourse or other drainage system. Surfaces with an aggregate sub-base can provide good water quality treatment.

As the proposed development is shown to lie within Flood Zone 3, and there is a risk of surface water flooding, there is a risk that silt deposits left behind flooding, may reduce the efficacy of the permeable paving system; and hence its lifetime within he site.

Therefore, this type of SUDS solution is not recommended for inclusion within the drainage strategy for the development.

2. On/Offline Storage

This is a traditional form of surface water attenuation and may be provided via online or offline structures such as oversized pipes; or shallow attenuation structures such as geo-cellular crate systems e.g. Hydro-International's Stormcell System or similar. These structures may be easily placed within either hardstanding or landscaped areas to provide ease of access for maintenance purposes; with outflow to receiving sewer or watercourse restricted using a vortex device, orifice plate or other type of flow control.

6.4.6 Proposed Drained Areas

It is noted that a number of buildings are to be demolished as part of the development proposals; and following development it is estimated that the drained area will be reduced to approximately 0.19Ha.

6.4.7 Indicative Attenuation Volumes

Indicative attenuation volumes have been estimated based on the proposed impermeable areas, restricted to existing greenfield runoff rates for a range of return periods, these are shown within the table below:

Table 12: Indicative Attenuation Volumes

Return Period	Allowable Discharge Rates (l/s)	Indicative Attenuation Volumes (m^3)
100 Year +40% Climate Change	56.5	1.3 – 36.0

It is noted that the volumes shown above are indicative only; and will need to be re-calculated during the detailed design to reflect any changes in drained area and any requirements specified by the Statutory Consultees.

6.4.8 Drainage Strategy

It is anticipated that the surface water drainage strategy for the development will include a traditional gravity system comprising pipes and manholes, with discharge to Chipping Brook; with a recommendation to re-utilise existing outfalls to watercourse where available.

Source control should be incorporated into the design where possible, to reduce the impact of development on the receiving watercourse and provide an element of interception storage. The methods recommended for consideration are rainwater harvesting and/or a green roof solution.

Infiltration is not considered to be feasible for use within the site due to poor underlying ground conditions, and therefore any attenuation of surface water runoff should be undertaken using an underground tank system; or oversized pipes, with a flow control upstream of the discharge point, to regulate discharge rates into the watercourse.

The on-site drainage system will remain under private ownership and the responsibility for inspection and maintenance will lie with the site or property owners.

6.4.9 Drainage System Design Constraints

The proposed drainage system should be designed as follows:

- Contain surface water flow within the pipes and manholes for the 1 in 1-year storm event.
- Be allowed to surcharge but not flood for the 1 in 30-year storm event; and

- Be permitted to flood during the 1 in 100-year event, however any flooding must not impact development on-site or be allowed to migrate beyond the site boundary, where it may increase the risk of flooding for others.

6.4.10 Maintenance

Private system and maintenance will be the responsibility of the property owners.

6.4.11 Pollution Control

The site is small in nature and it is considered that the extent of trafficked area within the boundary is also small and as such the risk of pollution to watercourse is overall low.

As such no site-specific pollution control measures are considered necessary for inclusion within the drainage strategy for the development.

6.5 Foul

It is recommended that foul flows from the site connected to the public combined sewer in close proximity to the development, utilising existing connections where available.

7.0 Development Constraints & Flood Mitigation

7.1 Residential Development Finished Floor Levels

7.1.1 Replacement Dwelling - Farmhouse Building

- Existing FFL (Farmhouse) = 99.05mAOD
- Existing FFL (Garage) = 98.77mAOD (assumed level access)

Flooding associated with fluvial sources is shown to have a depth 0.1-0.25m; with depths of <0.3m anticipated for surface water flooding.

The existing dwelling is shown to be elevated 0.28m above the adjoining garage and therefore is not considered to provide sufficient freeboard allowance to reduce the risk of inundation from either flood mechanism.

It is therefore recommended that the Finished Floor Level for the new replacement dwelling is set at **99.67mAOD**; which elevates the building 0.9m above the existing garage/ground level and provides a minimum 0.6m freeboard above the worst-case flood depth.

7.1.2 Redevelopment of Barn – Single Live/Work Unit

- Existing FFL (Barn) = 98.03 – 98.25mAOD
- Existing ground level = 98.03mAOD

Flooding associated with fluvial sources is shown to have a depth <0.1m; with minimal surface water flooding in proximity to the existing building.

It is recommended that the Finished Floor Level is set at a minimum of **98.73mAOD;** which elevates the building 0.7m above the existing ground level and provides a minimum 0.6m freeboard above the worst-case flood depth.

7.1.3 Detached Garage

- Existing FFL (Barn) = 98.11mAOD
- Existing ground level = 98.11mAOD

Flooding associated with fluvial sources is shown to have a depth <0.1m; with minimal surface water flooding in proximity to the existing building.

It is recommended that the Finished Floor Level is set at a minimum of **98.21mAOD;** which elevates the building 0.1m above the existing ground level and provides for vehicular access into and out of the building, but not freeboard allowance. It is therefore recommended that a minimum 0.3m floodproofing is provided.

7.2 Flood Storage Compensation

The development comprises redevelopment of an existing dwelling within a larger footprint; and redevelopment of a 2no existing farm buildings to provide a live/work unit and detached garage.

A further 5no buildings are to be demolished as part of the project and the footprint of the replacement dwelling will be increased by <250m^2;

Therefore, it is considered that flood storage compensation will not be required.

7.3 Flood Resistance/Resilience Measures

- Dry-proofing with flood depths <0.6m
- Wet-proofing with flood depths >0.6m

Flood depths are anticipated to be 0.1-0.25 (right bank) and <0.1m (left bank) respectively and as such dry proofing is considered to be appropriate.

Dry proofing methods are designed to keep water out of the building, and wet proofing methods are designed to improve the ability of the property to withstand effects of flooding once the water has entered the building. It is recommended that dry proofing is required up to the following levels:

- Replacement dwelling = **99.67mAOD**
- Redeveloped Barn (live/work unit) = **98.73mAOD**
- Detached Garage = **98.51mAOD**

The table below summarises recommendations for flood proofing measures which can be incorporated within the design for the proposed redevelopment works. Such measures are put forward in accordance with 'Development and Flood Risk Guidance for the Construction Industry' CIRIA C624, London 2004.

The most appropriate measures for the Startifants Farm development have been highlighted for reference.

It would be preferable to avoid external doors as this would remove a potential point of flood inflows. However, since free access and egress into the building will be required, flood resistant doors and/or the use of flood resistant stop logs or flood boards should be considered.

Full details of manufacturer's or suppliers of flood protection equipment may be obtained from the Flood Protection Association (website: www.thefpa.org.uk).

Table 13: Typical Flood Proofing Measures

Feature	Considerations to Improve Flood Proofing
External Doors	The use of flood proof doors provides an effective way of ensuring that flood water cannot enter through the thresholds of the property at all times of the day, weather residents are at home or not; and provides passive flood protection.
External Walls	Careful consideration of materials: use low permeability materials to limit water penetration if dry proofing required. Avoid using timber frame and cavity walls. Consider applying a water-resistant coating. Provide fitting for flood boards or other temporary barriers across openings in the walls.
Internal Walls	Avoid use of gypsum plaster and plasterboards; use more flood resistant linings (e.g. hydraulic lime, ceramic tiles). Avoid use of stud partition walls.
Floors	Avoid use of chipboard floors. Use concrete floors with integrated and continuous damp proof membrane and damp-proof course. Solid concrete floors are preferable; if a suspended floor is to be used, provide facility for drainage of sub-floor void. Use solid insulation materials.
Fitting, Fixtures and Services	If possible, locate all fittings, fixtures and services above design floor level. Avoid chipboard and MDF. Consider use of removable plastic fittings. Use solid doors treated with waterproof coatings. Avoid using double-glazed window units that may fill with flood water. Use solid wood staircases. Avoid fitted carpets. Locate electrical, gas and telephone equipment and systems above flood level. Fit anti-flooding devices to drainage systems.

Source: www.floodsense.co.uk

7.4 Safe Access and Egress

Dry access and egress will not be available at all times, and therefore it is recommended that a flood warning and evacuation plan is prepared by the residents.

7.5 Flood Warning & Evacuation

The site is located within the floodplain associated with Chipping Brook; and although flood warnings are not currently available at this location, the Environment Agency is able to provide flood alerts, via the Flood Warning's Direct Service.

Flood alerts are less specific than flood warnings and provide an indication that flooding is possible.

It is considered prudent therefore that all residents are advised to sign up to this free service; and a link to the relevant web page is provided below.

- https://www.fws.environment-agency.gov.uk/app/olr/doDetails

7.6 Evacuation Plan

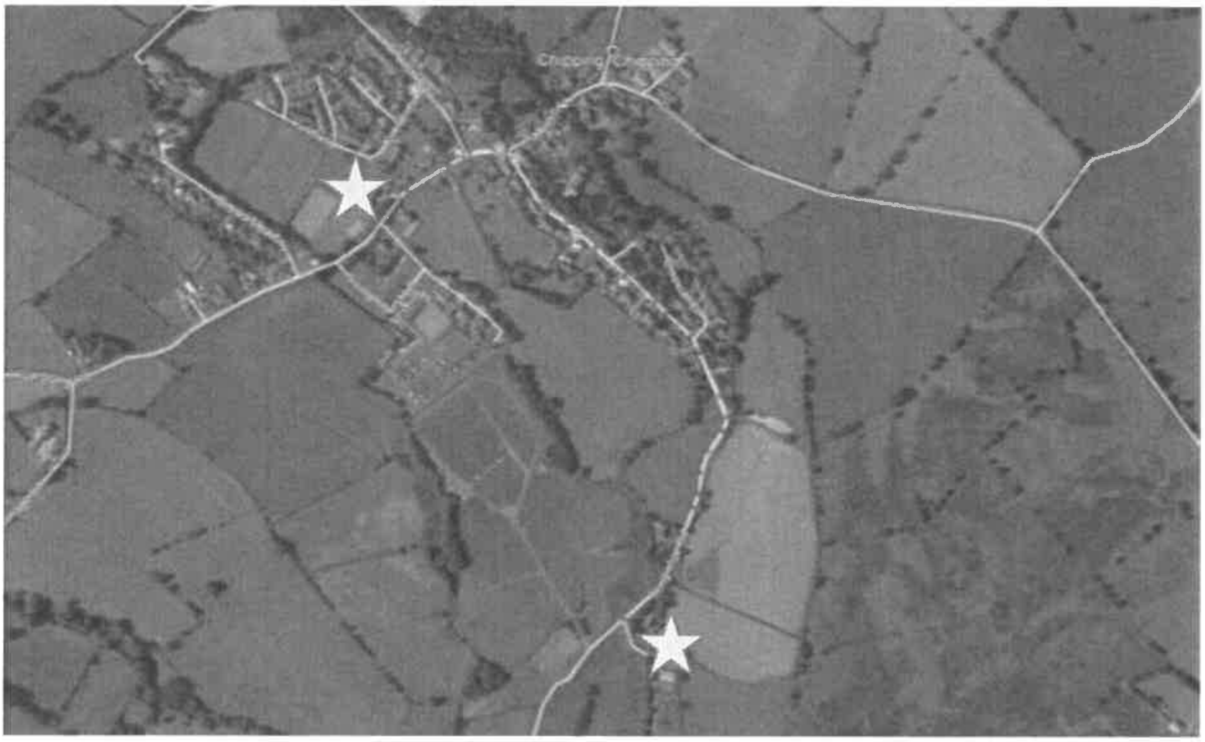
Residents should also be advised to prepare a personal flood plan. Guidance and a template for preparing a plan are available from the following link:

- https://www.gov.uk/government/publications/personal-flood-plan

It is advised that following the issue of a flood alert and/or onset of flooding at the development site, residents should relocate to an area which is within Flood Zone 1 and hence outside of the flood risk area. The nearest population centre is north, within the village of Chipping; and the village hall is located off Club Lane a distance of 950m from the application site.

Figure 7.1 below illustrates the route from the site at Startifants Farm to the Village Hall.

Figure 7.1: Preferred Access Route North of the Site



Source: Google Earth

7.7 Flood Alarm

Flood alerts are available; however, in order to provide more site-specific warnings regarding potential flooding at the site, it is recommended that a flood alarm is installed.

There are many proprietary alarm systems available; and the most appropriate location for installation would be near to the position of modelled flood node CH01_1071, where overtopping of the river bank is considered the most likely. A flood alarm and would provide the added benefit and precautionary approach for residents to ensure that any flood proofing measures, such as temporary barriers can be deployed; or valuables relocated from the ground floor locations within the dwellings; prior to the onset of flooding.

7.8 Boundary Treatment

During the design phase of the project, boundary treatments should be carefully considered, to facilitate the free flow of flood water through the site; and minimise obstruction of flows from their natural course, thereby minimising increased flood risk within the development site; and the wider area.

It is also advised that any <u>new</u> solid walls, within 8m from the top of the river bank will require permission from the Environment Agency. It is noted that the replacement dwelling is located 5m from the existing top of bank which is a significant improvement from the existing scenario.

7.9 Easement Requirements

7.9.1 Sewers

Existing United Utilities sewers that traverse through the site will require an easement of 3m either side of the pipe.

7.9.2 Watercourse

Chipping Brook is classed as 'main river' and therefore there is a statutory easement of 8m from the top of the river bank.

7.10 Environmental Permit

Any works within 8m from the top of the river bank will require an Environmental Permit from the Environment Agency.

8.0 Conclusions & Recommendations

8.1 Site Details

8.1.1 Existing

- Site Name: Startifants Farm
- Location: Chipping, Lancashire
- Site Area: 0.625 Hectares
- Flood Zone: 3 – high risk from Chipping Brook

8.1.2 Proposed

- Demolition of no farm buildings
- Provision of a replacement dwelling
- Barn conversion to provide a single live/work unit
- Barn conversion to provide detached garage

8.2 Fluvial: Chipping Brook

- Classification: main river
- Model data: 1D/2D Hydraulic River Model (Jacobs for United Utilities WWTW)
- 2D flood depth (left bank) 100-year + 20%: less than 0.1m
- 2D flood depth (right bank) 100-year + 20%: 0.1-0.25m
- Climate change allowance 35%-70% increase in river flow; assessed to represent 50mm increase in 1D water levels within the channel; and therefore, considered to present simile flood depths and extent as the 20% climate change scenario.
- Assessment confirms site is located within Flood Zone 3.
- Flood storage compensation will not be required.

8.3 Pluvial: Overland Flow

- Surface water flooding occurs on the right bank of the watercourse, with flood depths anticipated to be less than 0.3m; and flow velocities greater than 0.25m/s.
- Hazard to people from this flood source is assessed to be low

8.4 Drainage

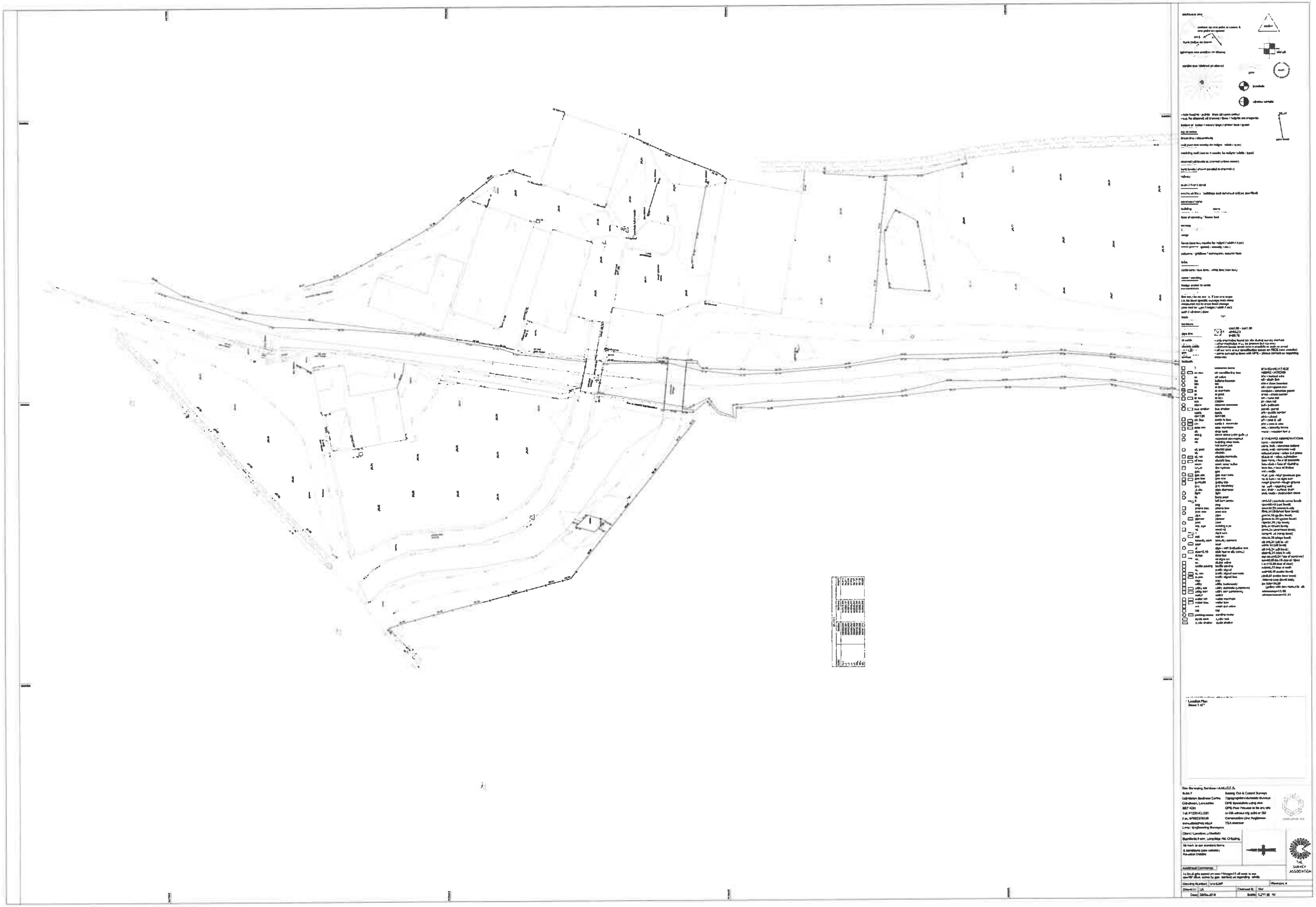
- Brownfield development.
- Surface water from the existing site is believed to discharge to watercourse.
- Foul flows from the existing site are believed to be directed to an existing combined sewer in proximity to the development; and existing connection should be retained and re-utilised.

- The hierarchy for surface water management (NPPF and Building Regulations) must be applied:
    - Infiltration to ground
    - Discharge to watercourse
    - Discharge to sewer
- Desk-top assessment indicates poor ground conditions; so existing outfalls to watercourse should be re-utilised.
- Surface water discharge from the site must not exceed existing discharge rates minus 30%.
- Flows in excess of allowable discharge rate must be attenuated on-site.
- SUDS – source control methods i.e. rainwater harvesting or green roof should be considered.

8.5 Mitigation Measures

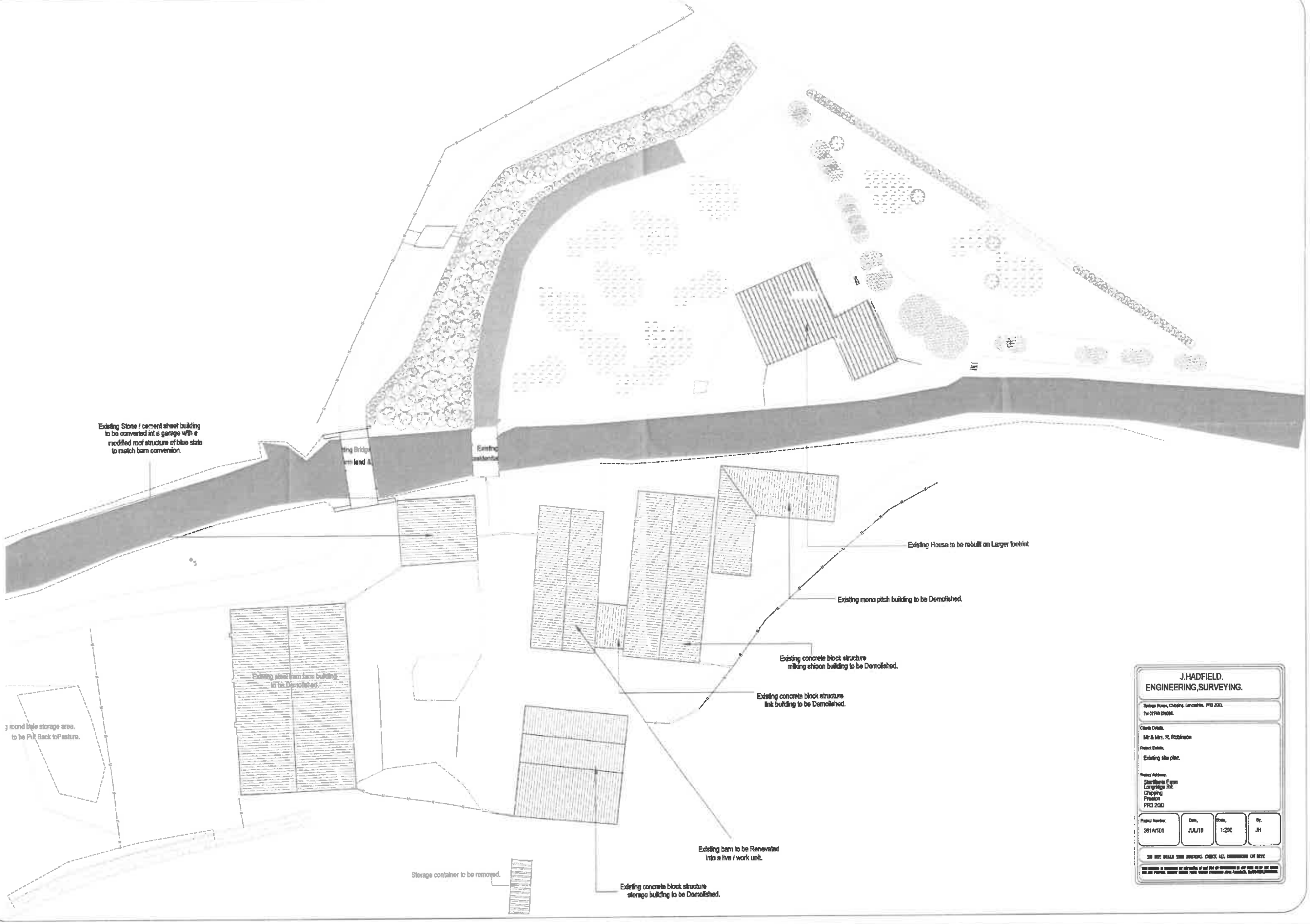
- FFL replacement dwelling (farmhouse) = **99.67mAOD**; with flood proofing up to **99.67mAOD**.
- FFL redeveloped barn (live/work unit) = **98.73mAOD**; with flood proofing up to **98.73mAOD**.
- FFL redeveloped barn (detached garage) = **98.21mAOD**; with flood proofing up to **98.51mAOD**.
- Flood resistance/resilience to be incorporated into all buildings under development.
- Residents advised to sign up to receive Flood Alerts via the Environment Agency's Flood Warning's Direct Service.
- Residents advised to prepare a personal flood plan.
- Installation of a flood alarm.
- Careful consideration of boundary treatments to avoid increasing flood risk on the Startifants Farm site for or others.
- Surface water runoff to be directed to watercourse, and restricted to existing runoff rates minus 30%. Flows in excess of this will need to be attenuated on-site.
- It is recommended that source control measures such as green roof or rainwater harvesting are considered for application at the site.

Appendix A
Topographical Survey



Location Plan
Setting Out & Control Surveys
Drawing Number:
Revision: A
Drawn By: LK
Checked By:
Date:
Scale:
THE SURVEY ASSOCIATION

Appendix B
Proposed Development



J.HADFIELD.
ENGINEERING,SURVEYING.

Clients Details.
Mr & Mrs. R. Robinson

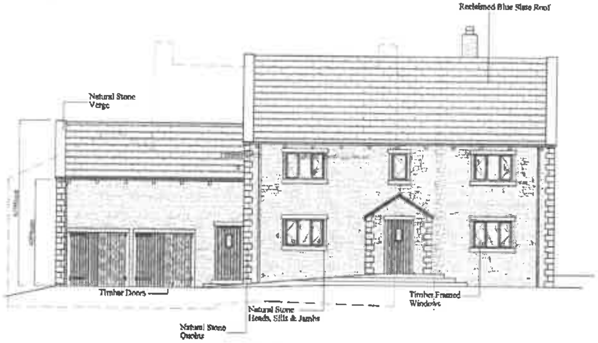
Project Details.
Existing site plan.

Project Address.
Startifants Farm
Longridge Rd.
Chipping
Preston
PR3 2QD

Project Number.	Date,	Scale,	By.
361A/101	JUL/18	1:200	JH

DO NOT SCALE THIS DRAWING. CHECK ALL DIMENSIONS ON SITE

PROPOSED REPLACEMENT HOUSE
(Building No. 1)

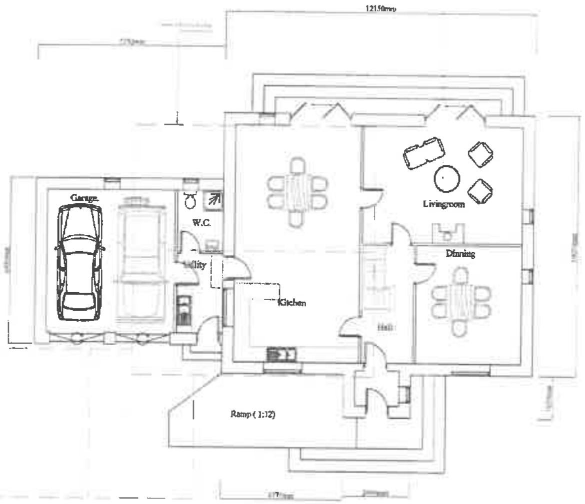


Front Elevation (North)

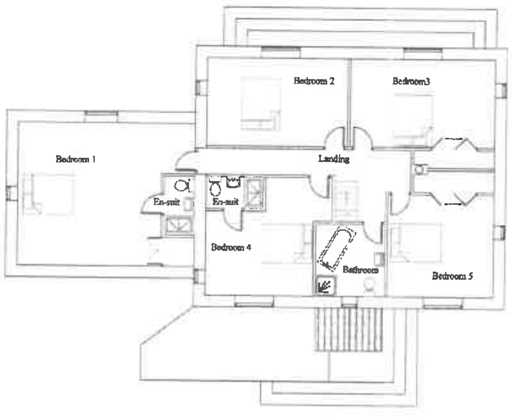

Side Elevation (East)

Rear Elevation (South)

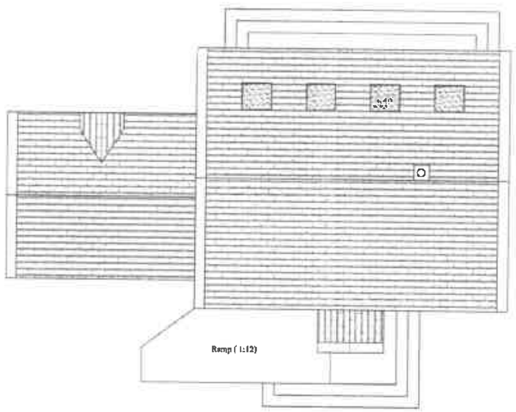

Side Elevation (West)



Ground Floor Plan.



First Floor Plan.



Roof Scape

J.HADFIELD.
ENGINEERING,SURVEYING.

Client Details,
Mr & Mrs R. Robinson.

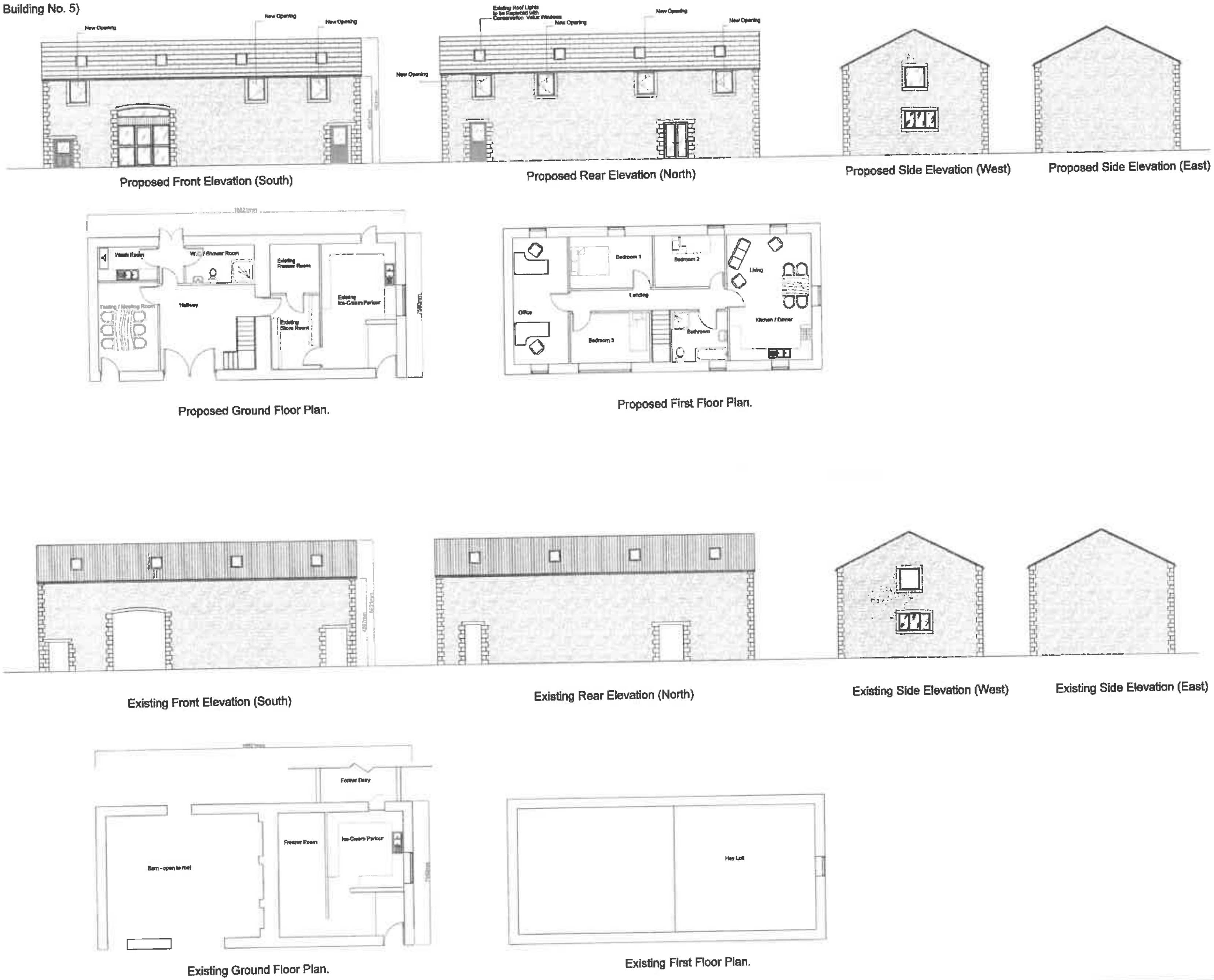
Project Details,
Proposed replacement house
Plans & Elevations

Project Address,
Startifants Farm
Longridge Rd.
Chipping

Project Number,	Date,	Scale,	By,
361A/202	Jul/18	1:100	JH

DO NOT SCALE THIS DRAWING, CHECK ALL DIMENSIONS ON SITE

PROPOSED LIVE / WORK UNIT
(Building No. 5)



J.HADFIELD. ENGINEERING,SURVEYING.

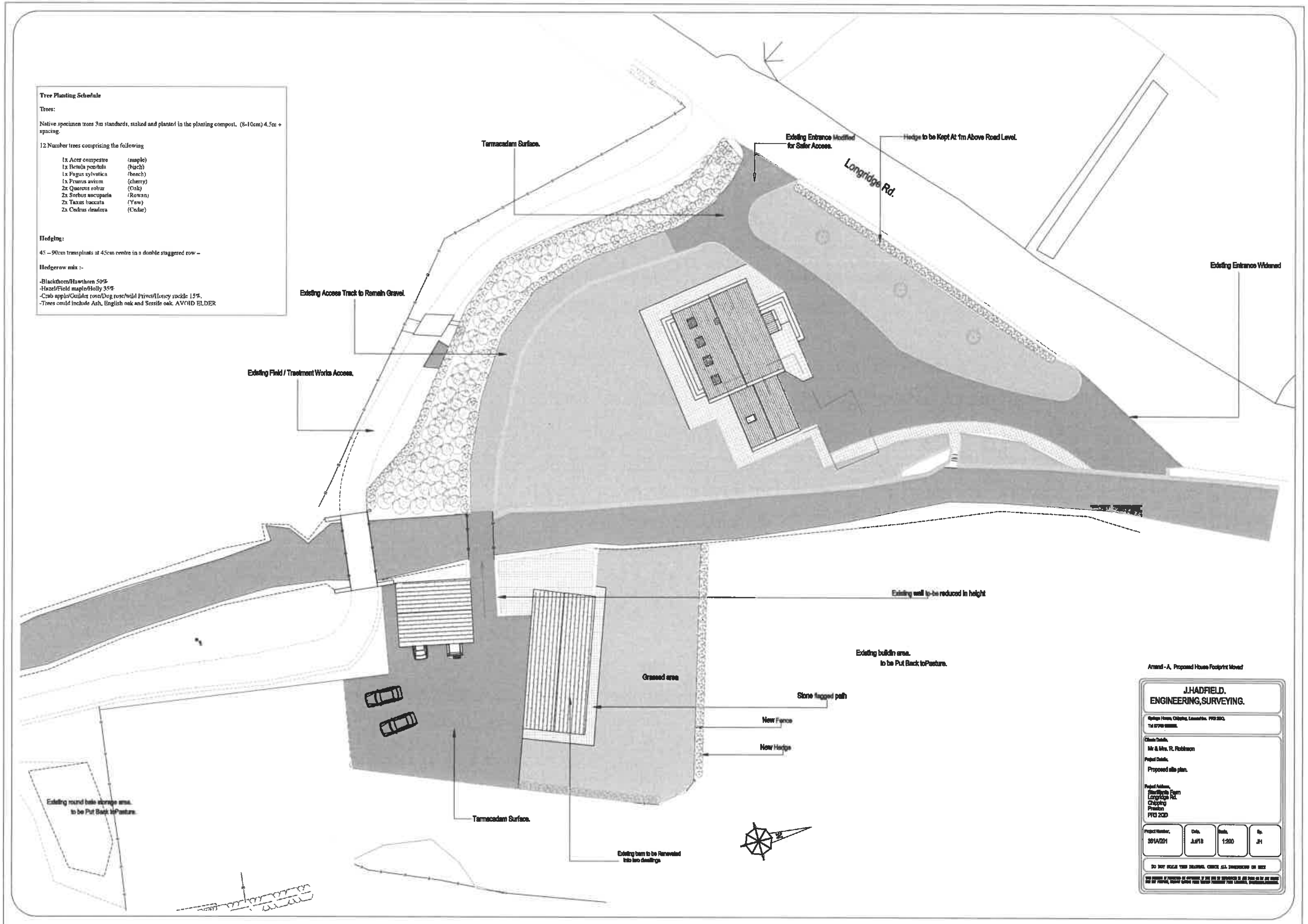
Springs House, Chipping, Lancashire. PR3 2QG
Tel 07740 929099

Clients Details.
Mr & Mrs. R. Robinson

Project Details.
Existing & Proposed Plans & Elevations
Live / Work Unit (Building No. 5)

Project Address.
Startifants Farm
Longridge Rd.
Chipping

Project Number.	Date.	Scale.	By.
361/402	NOV/18	1:100	JH



Tree Planting Schedule

Trees:

Native specimen trees 3m standards, staked and planted in the planting compost. (8-10cm) 4.5m + spacing.

12 Number trees comprising the following

1x Acer compestre	(maple)
1x Betula pendula	(birch)
1x Fagus sylvatica	(beech)
1x Prunus avium	(cherry)
2x Quercus robur	(Oak)
2x Sorbus aucuparia	(Rowan)
2x Taxus baccata	(Yew)
2x Cedrus deodora	(Cedar)

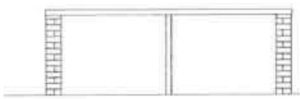
Hedging:

45 – 90cm transplants at 45cm centre in a double staggered row –

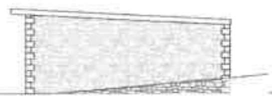
Hedgerow mix :-

-Blackthorn/Hawthorn 50%
-Hazel/Field maple/Holly 35%
-Crab apple/Guilder rose/Dog rose/wild Privet/Honey suckle 15%.
-Trees could include Ash, English oak and Sessile oak. AVOID ELDER

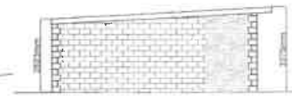
Existing & Proposed Garage Building (Building No. 7)



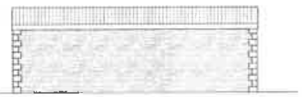
EXISTING FRONT ELEVATION (East)



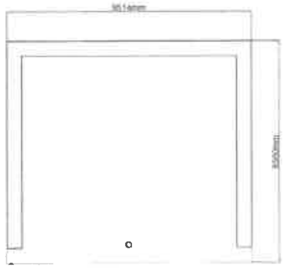
EXISTING SIDE ELEVATION (North)



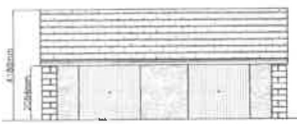
EXISTING SIDE ELEVATION (South)



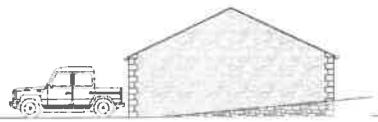
EXISTING REAR ELEVATION (West)



EXISTING PLAN.

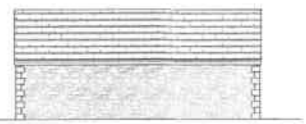


PROPOSED FRONT ELEVATION (East)

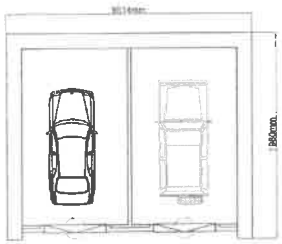


PROPOSED SIDE ELEVATION (North)

PROPOSED SIDE ELEVATION (South)



PROPOSED REAR ELEVATION (West)



PROPOSED PLAN.

J.HADFIELD.
ENGINEERING,SURVEYING.

Springs House, Chipping, Lancashire. PR3 2GQ
Tel 07740 921066.

Clients Details,
Mr & Mrs. R. Robinson

Project Details,
Existing & Proposed Garage Building (Building No. 7)
Plans & Elevations

Project Address,
Standlands Farm
Longridge Rd.
Chipping

Project Number,	Date,	Scale	By
361/206	JUL/17	1:100	JH

DO NOT SCALE THIS DRAWING. CHECK ALL DIMENSIONS ON SITE.

Appendix C
Jacob's Hydraulic Modelling Report (Chipping Brook)

JACOBS

Chipping WWTW Maintenance

United Utilities

Hydraulic Modelling Report

D02 | V01

January 2016

Client Ref: 4500004123

Document history and status

Revision	Date	Description	By	Review	Approved
D01	18/12/2015	Draft for Client Review	Antoinette Benoit de Coignac	Mathieu Valois	Chris Isherwood
D02	08/01/2016	Final Report	Antoinette Benoit de Coignac	Mathieu Valois	Chris Isherwood

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments

JACOBS

Chipping WWTW Maintenance

Project no:	B2707137
Document title:	Hydraulic Modelling Report
Document No.:	D02
Revision:	V01
Date:	January 2016
Client name:	United Utilities
Client no:	4500004123
Project manager:	Chris Isherwood
Author:	Antoinette Benoit de Coignac
File name:	2016-01-08_B2707137_Chipping_Modellingreport_D02.Docx

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Contents

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1. Introduction

United Utilities are planning an expansion to the Chipping Waste Water Treatment Works (WWTW) site and the construction of a new access bridge. Following the delivery of the Level 1 Flood Risk Assessment (FRA), United Utilities commissioned Jacobs to build a linked 1-dimensional/2-dimensional (1D/2D) hydraulic model to determine the:

1) Existing flood risk (extents and depths) in the Chipping Brook floodplain; and the
2) Maximum in-channel water levels for the 1% Annual Exceedance Probability (AEP) and the 1% AEP plus Climate Change flood events at the new proposed bridge location.

The complete model has been handed over to United Utilities Design and Build contractor for them to use to carry out their design and FRA. Figure 1-1 shows the coverage of the hydraulic model and the location of the Chipping WWTW site. The model represents Chipping Brook from downstream of Chipping Village to approximately 200m upstream of its confluence with the River Loud, an unnamed tributary of Chipping Brook (right bank) and the surrounding floodplain areas. The model was built using Flood Modeller1 (1D) and TUFLOW2 (2D) software.

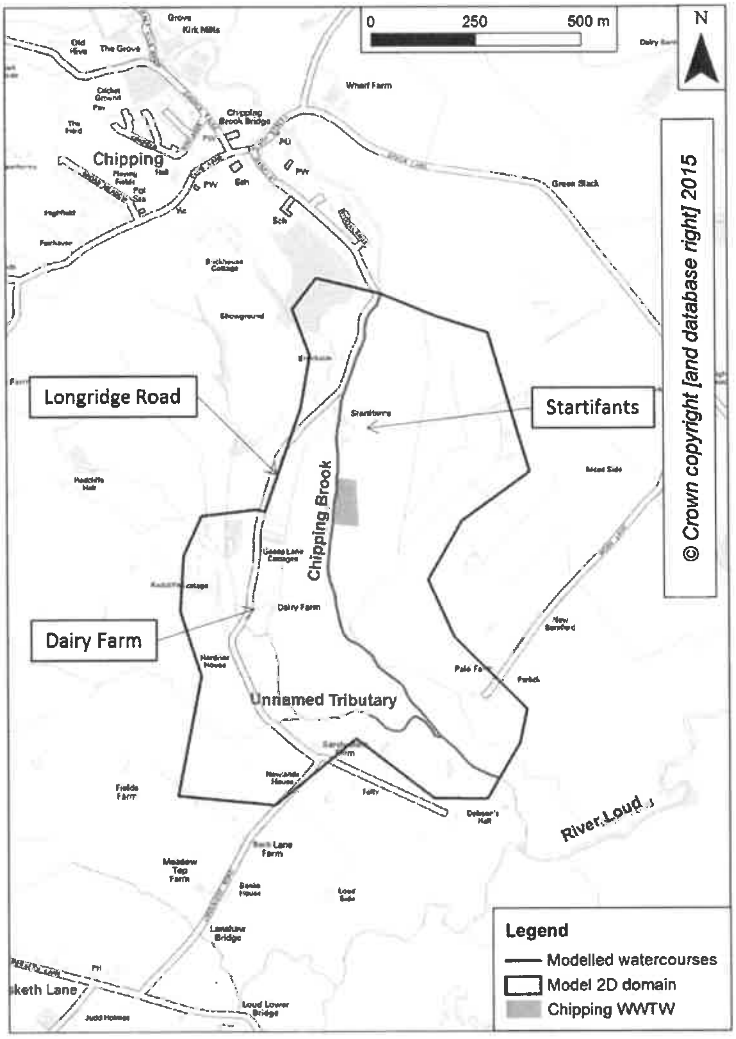


Figure 1-1: Chipping WWTW Site Location

[1] Flood Modeller Pro v4 by CH2M HILL (2015)
[2] TUFLOW Build 2013-12-AE by BMT WBM (2013)

2. Input Data

The data used to construct the hydraulic model are summarised in Table 2-1.

Table 2-1: Data used to build the hydraulic model

Data	Description	Source
Topographic survey data	In channel cross sections and hydraulic structures. See Section 2.1.1.	RPS
LiDAR	LiDAR (Light Detection And Ranging) data: 2m horizontal resolution. See Section 2.1.2.	Environment Agency
Hydrological Inflows	Hydrological analysis carried out for Chipping Brook. See Section 2.3.	Jacobs
OS Mapping	Mastermap data and 1 to 10,000 Scale Raster	United Utilities

2.1 Topography

2.1.1 Topographic survey

River cross sections and in-channel structures were surveyed by RPS (August 2015) to inform the hydraulic model with in-bank topographic details of Chipping Brook and one of its unnamed tributary (see Figure 1-1). The cross section information was provided by the surveyors in standard Flood Modeller format and CAD drawings. Photographs of the watercourses and the structures were also provided for the surveyed reaches. The modelled reach of Chipping Brook is 1350m long and the modelled reach of the unnamed tributary is 220m long. A total of 26 cross sections were surveyed for these reaches. Survey was also provided for three bridges along Chipping Brook.

Figure 2-1 shows the location of the surveyed cross sections. Surveyed cross-sections show that Chipping Brook is perched at cross-sections CH01_0629 and CH01_0512.

2.1.2 LiDAR

LiDAR data (2008) was used to inform the hydraulic model with floodplain topography. Filtered LiDAR data with 2m horizontal resolution was used in which the vegetation and buildings have been removed from the topography in order to model the overland flow routes. Figure 2-2 shows the digital terrain model (DTM) used for modelling. As shown by the surveyed cross-sections, LiDAR data confirms that a section of Chipping Brook is perched over the floodplain from approximately the WWTW site to the confluence with the unnamed tributary.

2.2 Hydrology

Inflows at the upstream ends of the modelled watercourses (see locations in Figure 2-3) have been estimated for the 50%, 20%, 10%, 5%, 2% and 1% AEP flood events.

The Flood Estimation Handbook (FEH) statistical method along with the Revitalised Flood Hydrograph Method (ReFH1) was used to derive the inflow hydrographs that were applied to the model. The methodology used to determine these inflow hydrographs is further detailed in Appendix C of this report.

In order to calculate the impact of climate change, a 20% uplift of the hydrological inflows was applied on the 1% AEP event. This climate change uplift factor is based on the latest Environment Agency Guidance[3]. Table 2-2 shows the estimated inflow peak flows in the modelled watercourses for all the AEP events simulated.

[3] Environment Agency (2011) Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities

Table 2-2: Estimated peak flows in m³/s for all locations

Hydrological Inflow	Peak Flow (m3/s)						
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + Climate Change
CB01	11.9	15.9	18.9	22.2	27.3	31.8	38.2
TRIB	2.8	3.8	4.5	5.2	6.4	7.5	9.0

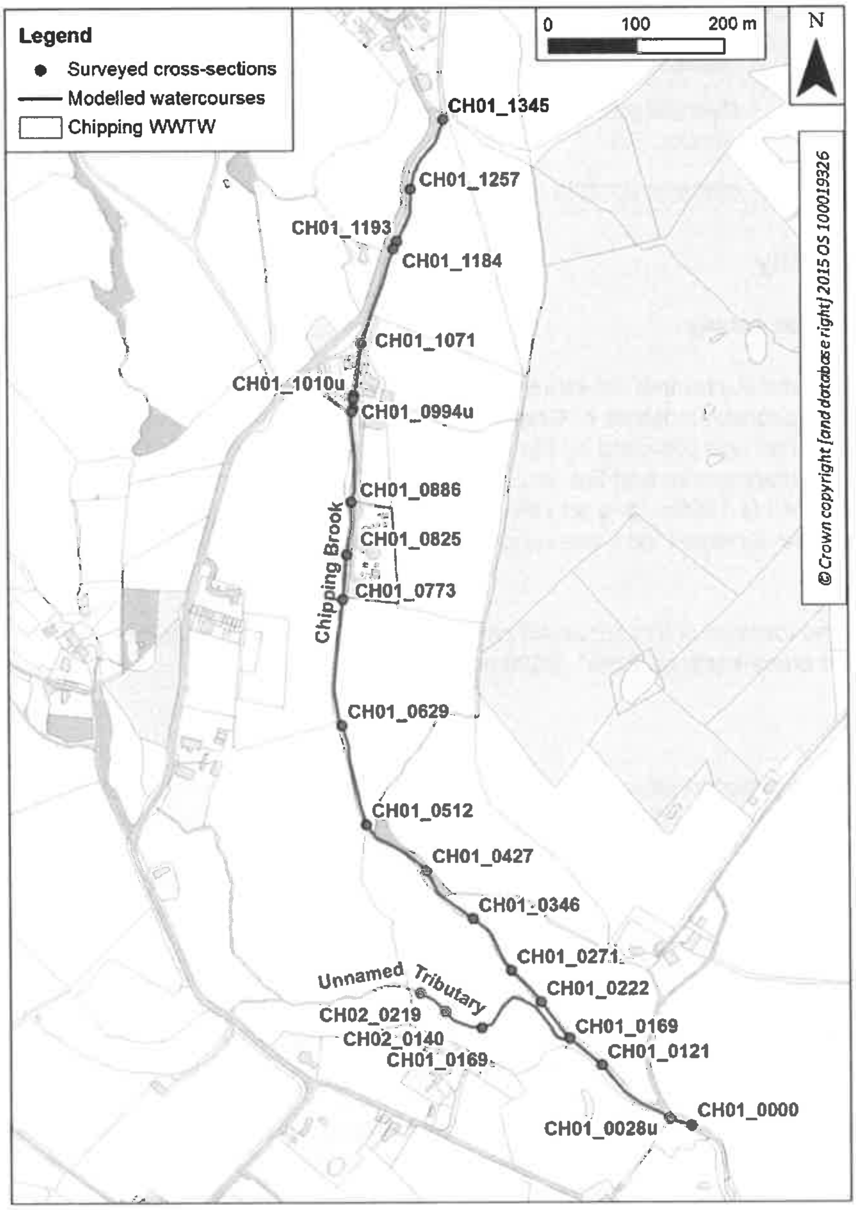


Figure 2-1: Location of surveyed cross-sections used for modelling in-channel watercourses

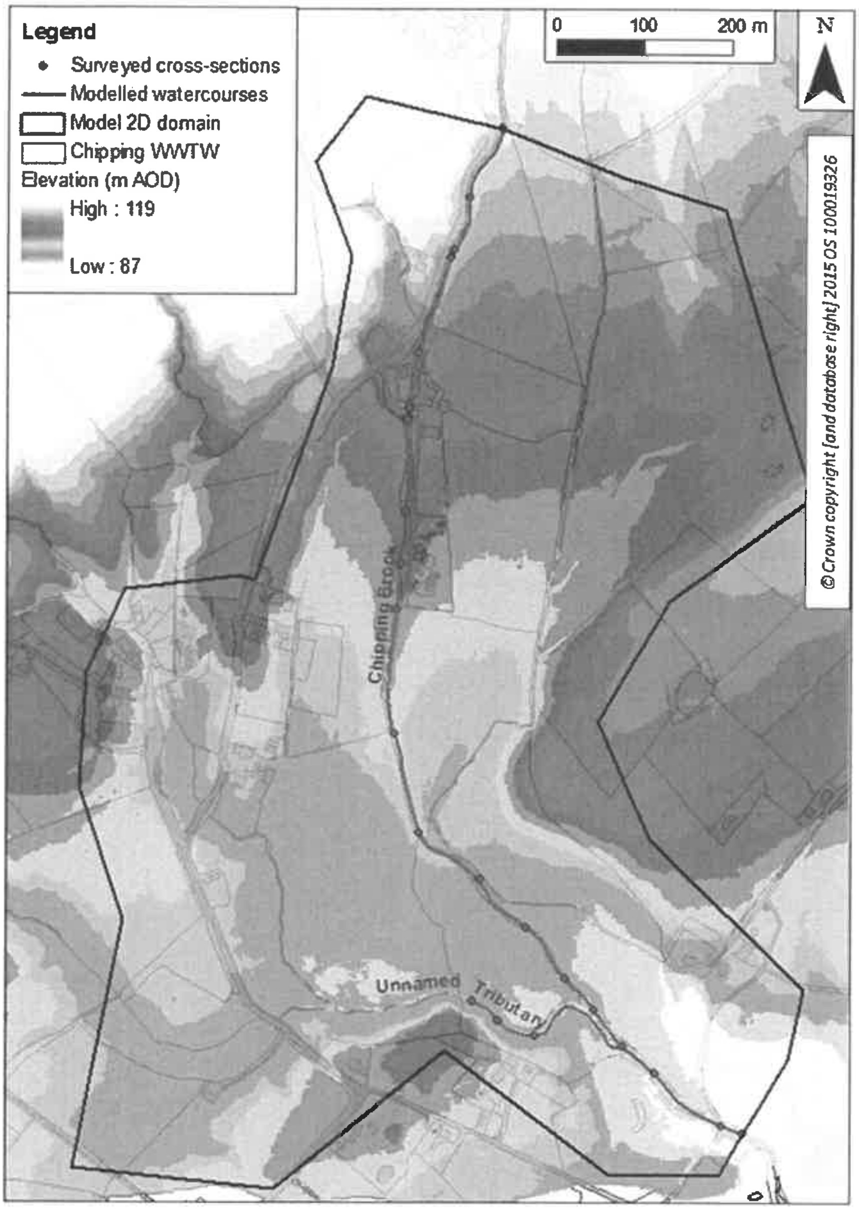


Figure 2-2: LiDAR data used for modelling floodplain topography

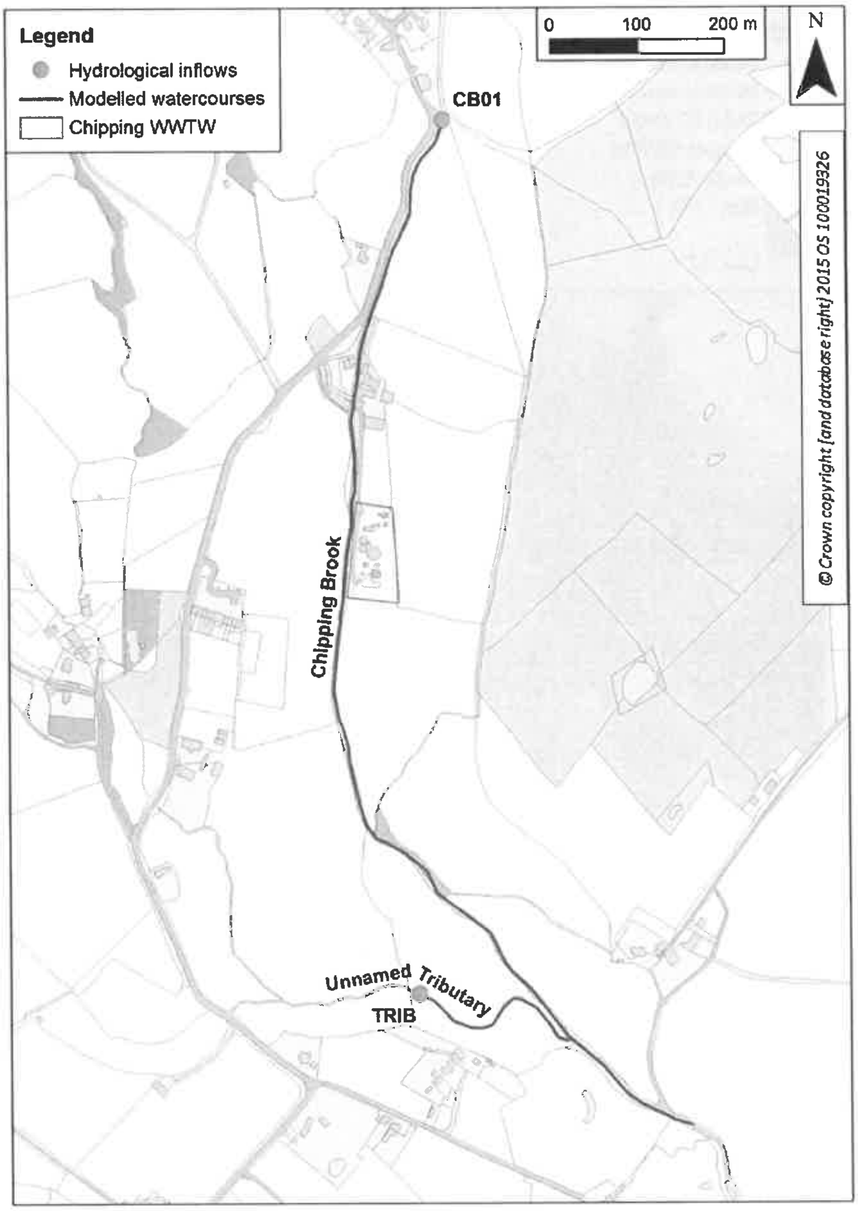


Figure 2-3: Location of hydrological inflows to the hydraulic model

3. Hydraulic Model

3.1 Methodology

A hydraulic model has been constructed using the ISIS-TUFLOW link based on the combination of the one dimensional (1D) river modelling package Flood Modeller Pro (version 4.1) and the two dimensional (2D) modelling software TUFLOW (version 2013-12-AE-iDP-w64).

The methodology adopted for the hydraulic modelling of the river system is based on the approaches described by the TUFLOW modelling manual[4]. The user sets up a model as a combination of 1D network domain representing the river channels, dynamically linked to a 2D TUFLOW domain representing the adjacent floodplain, using the hydrodynamic programme to form one model.

The 1D model covers a 1350m reach of Chipping Brook and a 220m reach of its unnamed tributary (see Figure 2-1). The 2D model extends from downstream of Chipping village to 200m upstream of River Loud and covers an area of approximately 0.7km^2 (see Figure 2-2).

3.2 Watercourses Schematisation

3.2.1 In-channel geometry

Surveyed cross section data has been used to inform the modelled watercourses with in-channel geometry. The location of the surveyed cross-sections is shown in Figure 2-1. A few interpolated cross sections were also created to ensure stability of the model. Table 3-1 shows the Flood Modeller nodes associated with Chipping Brook and the unnamed tributary.

Table 3-1: Flood Modeller nodes

Reach	Upstream Node	Downstream Node
Chipping Brook	CH01_1345	CH01_0000 (200 m upstream of River Loud confluence)
Unnamed Tributary	CH02_0219	CH02_0000 (confluence with Chipping Brook at CH01_0169)

3.2.2 In-channel roughness

Hydraulic roughness (Manning's 'n' coefficient) values were determined primarily using the photographs taken during the survey. Information was also taken from Google Earth and Street View mapping and guidance (Chow, 1959). The Manning's 'n' coefficients used in the model are shown in Table 3-2.

Table 3-2: Manning's 'n' coefficients – 1D domain

Flood Modeller nodes	Bed Manning's 'n'	Banks Manning's 'n'
CH01_1345 to CH01_0773	0.05	0.025 to 0.10
CH01_0629	0.04	0.04 to 0.10
CH01_0512	0.05	0.10
CH01_0427	0.04	0.06
CH01_0346	0.05	0.06
CH02_0271 to CH02_0000	0.04	0.06

[4] TUFLOW User Manual, GIS based 2D/1D Hydrodynamic Modelling, BMT WBM November 2010

Generally, some stones can be seen in the bed of Chipping Brook and its banks are covered by high grass, bushes or trees (see Figure 3-1). The banks of the unnamed tributary are covered by high grass (see Figure 3-2).

Figure 3-1: Photo of Chipping Brook near Chipping WWTW (model node CH01_0886)

Figure 3-2: Photo of unnamed tributary (model node CH02_0140)

3.2.3 In-channel structures

There are three hydraulic structures on Chipping Brook that were included in the model. Table 3-3 provides details regarding these structures. Their locations are shown in Figure 3-3. Figure 3-4 to Figure 3-5 show the three bridges included in the model.

Table 3-3: In-channel hydraulic structures

Structure	Flood Modeller Node	Model Schematisation
Bridge to Startifants	CH01_1010u	Arch bridge with flat soffit
Bridge to Chipping WWTW	CH01_0994u	Arch bridge with flat soffit
Footbridge	CH01_0028u	Arch bridge with flat soffit

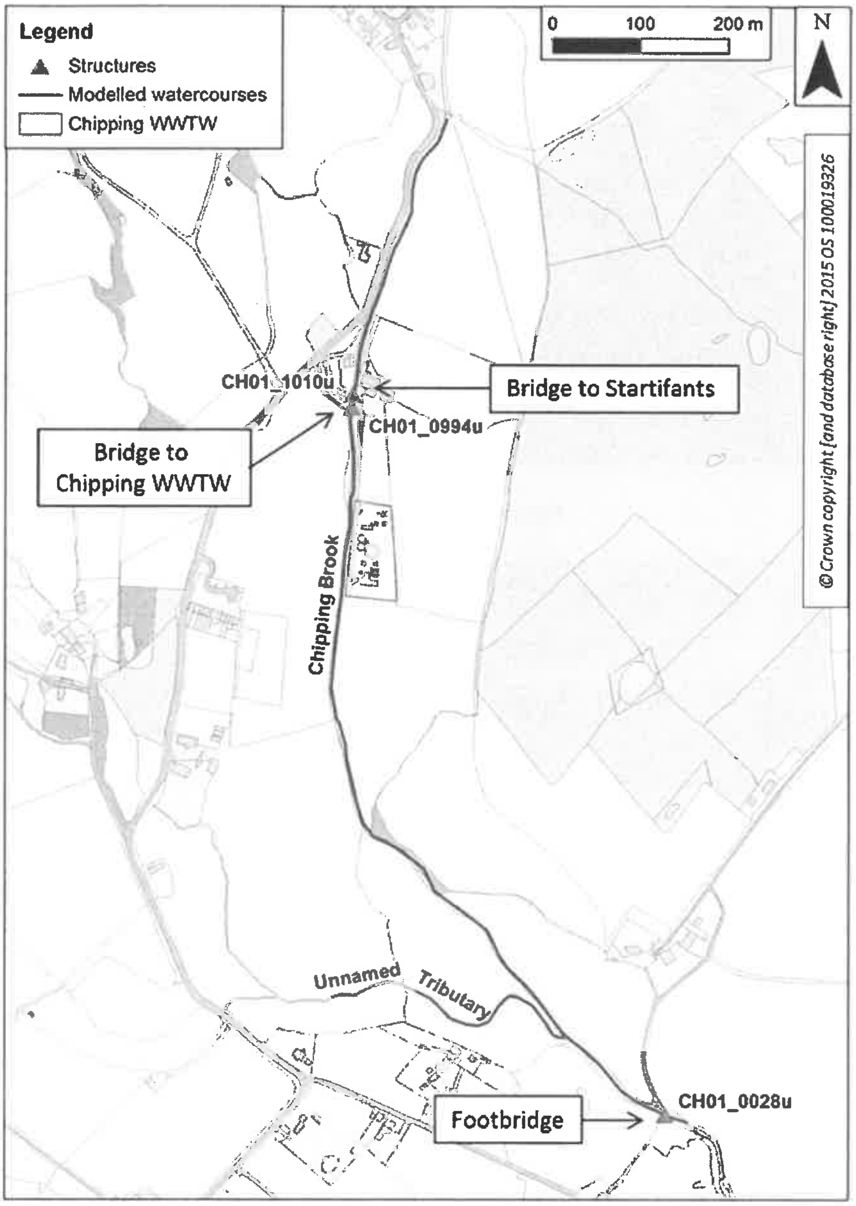


Figure 3-3: Location of modelled hydraulic structures

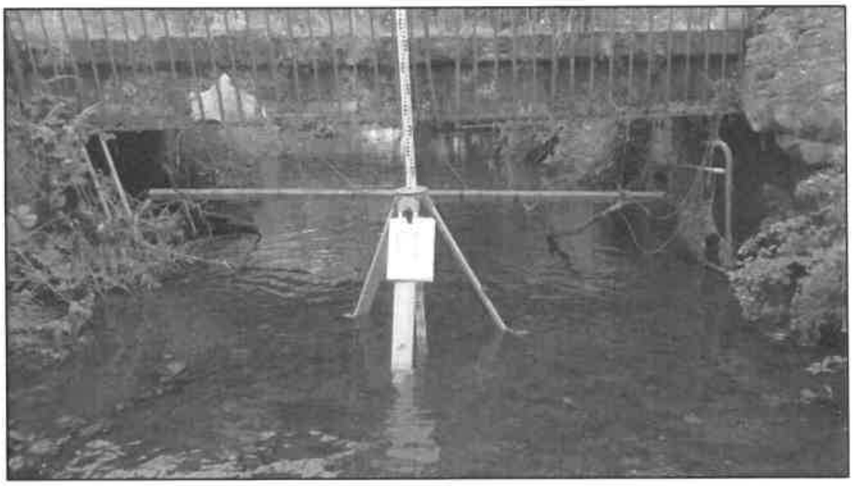


Figure 3-4: Bridge to Startifants

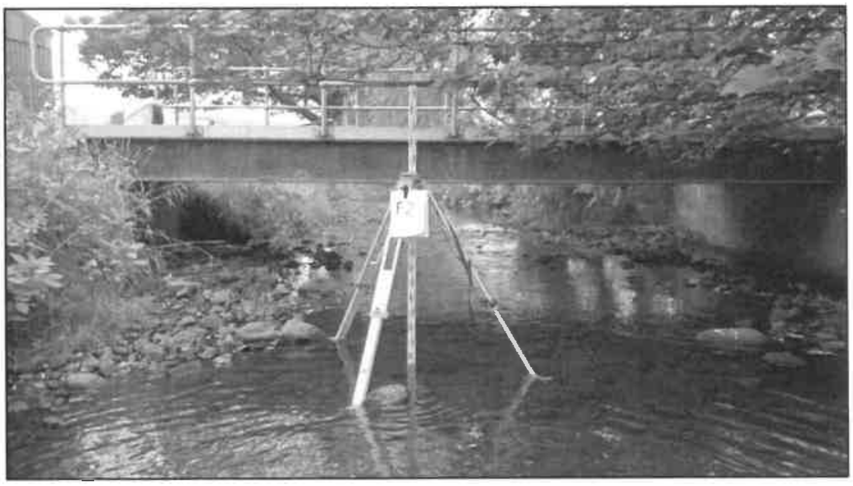


Figure 3-5: Bridge to Chipping WWTW

Figure 3-6: Footbridge

3.2.4 Boundary conditions – 1D Domain

The upstream and downstream boundary conditions applied to the 1D domain are described in Table 3-4. The use of a Normal Depth Boundary as downstream conditions implies that the influence of the River Loud on Chipping Brook is not considered in this study. Sensitivity tests were carried out to ascertain that any change in the downstream boundary conditions will not impact the water levels predicted by the model near the area of interest i.e. Chipping WWTW (see Section 4.4.1).

Table 3-4: Boundary conditions – 1D domain

Type of Boundary	Flood Modeller Node	Description
ReFH Boundary	CB01	CB01 ReFH inflow boundary was applied at the upstream end of Chipping Brook at node CH01_1345 (see Section 2.3).
ReFH Boundary	TRIB	TRIB ReFH inflow boundary was applied at the upstream end of unnamed tributary at node CH02_0219 (see Section 2.3).
Normal Depth Boundary	CH01_0000	Normal depth boundary condition applied to the downstream end of Chipping Brook at node CH01_0000

3.3 Floodplain Schematisation

3.3.1 Floodplain topography

The topography is represented using a 4m resolution square grid. The levels for the grid cells are based on a Digital Terrain Model (DTM) derived from Light Detection and Ranging (LiDAR) data with a 2m horizontal resolution. Floodplain topography is shown in Figure 2-2.

Breaklines were used in the 2D domain to accurately represent geographical features that have a significant impact on the propagation of flow across the floodplain. It is particularly useful where the TUFLOW fixed grid discretisation (in our case 4m) does not guarantee that the elevations along a key feature are picked up from the LiDAR data, for example along a narrow ditch.

The link between the 1D and the 2D domains was defined along Chipping Brook and the unnamed tributary with a breakline using the bank top levels from the surveyed cross-sections. In particular, a wall along Chipping Brook right bank from cross-section CH01_1345 to cross-section CH01_0990 was included in the model.

The breaklines included in the 2D domain are summarised in Table 3-5 below.

Table 3-5: Breaklines – 2D domain

Break Line Type	Geographical Feature
Bank top	Right and left bank levels along the modelled watercourses using bank top data from the surveyed cross-sections
Drains	Drains / ditches running in the modelled area and not implemented in the 1D domain have been represented using breaklines to create continuous flow paths

3.3.2 Floodplain roughness

A hydraulic roughness coefficient is applied at each cell of the 2D domain depending on land use. The coefficients (Manning's 'n') used in the model are given in Table 3-6.

Table 3-6: Manning's 'n' coefficients – 2D domain

Land Use	Manning's N
Roads, tracks and paths	0.025
Buildings, manmade structures	1.000
Multiple surface (garden), orchard	0.050
Manmade surface or step	0.030
Natural surface	0.035
Non coniferous trees	0.100
Rough grassland	0.055
Marsh reeds or saltmarsh	0.055
Land unclassified	0.035

Remark:

It should be noted that the use of filtered LiDAR data to inform the 2D model DTM means that buildings are not inherently represented in the grid. Given the fact that any building is an obstruction to the flow and would have a major impact on the overland flow routes, a very high roughness value has been attributed to each building/house within the study area to model the effect of the obstruction.

3.3.3 Floodplain structures

Where identified, hydraulically significant structures in the floodplain have been embedded inside the TUFLOW 2D domain as ESTRY elements. ESTRY is the 1D component of TUFLOW software. The locations of these floodplain structures have been informed through examination of preliminary model results and Google Earth, Street View and OS mapping. The dimensions for these structures were assumed (1m diameter circular pipes with invert levels taken from DTM) as no survey data was available for them.

Three culverts under Longridge Road have been included in the model. Their locations are shown on Figure 3-7.

3.3.4 Boundary condition – 2D Domain

No inflows have been applied directly in the 2D domain. Table 3-7 describes the downstream boundary condition used in the 2D domain. Its location is shown in Figure 3-7.

Table 3-7: Boundary Condition - 2D domain

Type of Boundary	TUFLOW Feature	Description
Stage-Discharge	HQ Boundary	Free flow boundary applied at the downstream extent of the model. This boundary assigns a water level to the 2D cells based on a stage–discharge curve generated using the ground slope.

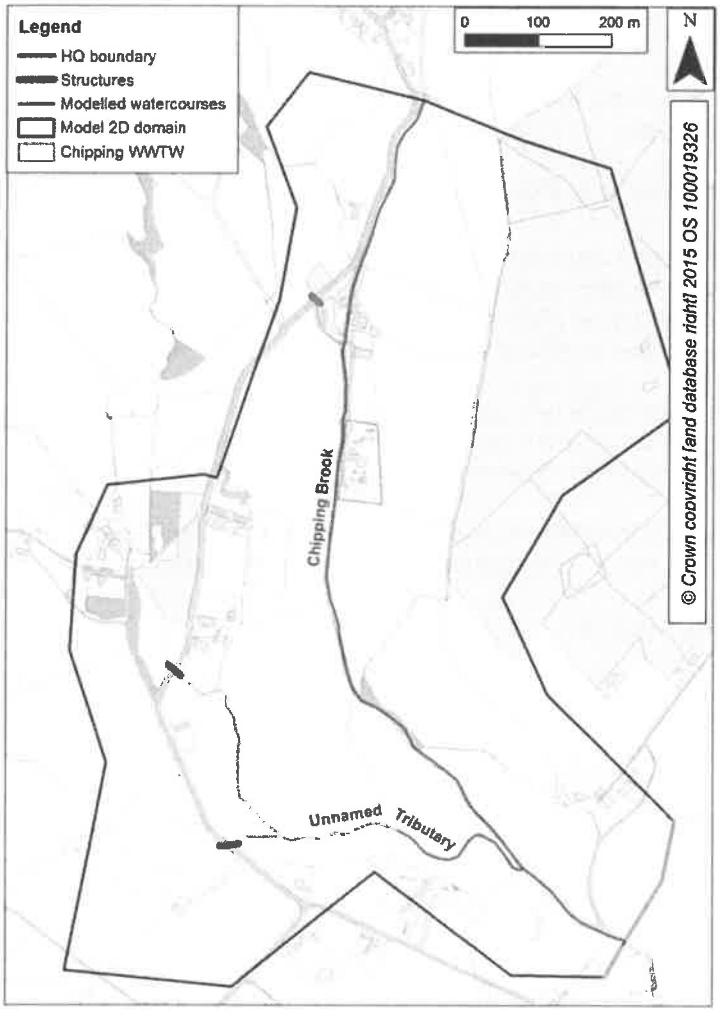


Figure 3-7: Structures in flow path

3.4 Modelled Events

Table 3-8 shows the AEP events that were simulated with the hydraulic model in the existing scenario. In order to test the model sensitivity to key hydraulic parameters, a series of simulations were undertaken for the 1% AEP event. The assessed hydraulic parameters were: Manning's n roughness coefficients, hydrological inflows and downstream boundary slope.

Table 3-8: Modelled events

Model	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1% AEP + Climate Change*
Existing Scenario	✓	✓	✓	✓	✓	✓	✓
Roughness Sensitivity						✓	
Hydrological Inflow Sensitivity						✓	
Downstream Boundary Sensitivity						✓	

*Climate change scenario for which a 20% uplift of the hydrological inflows to the model is considered.

4. Model Results

The following sections discuss the model results for the existing scenario simulations as well as the results for the sensitivity test simulations.

4.1 Model Verification & Flow Reconciliation

Chipping Brook is an ungauged catchment therefore no gauge data was available in the modelled area to carry out any calibration. As a verification exercise, flood extent maps for the 50%, 20% and 10% AEP events were sent to the United Utilities site team of the Chipping WWTW for review. The feedback was that the predicted flood extents looked reasonable and the areas where channel banks were overtopped were accurate.

In order to check consistency of the hydraulic model results with the flood frequency curve predicted by the hydrological analysis, the flows routed through the hydraulic model were compared with the peak flow estimates from the hydrological analysis at the downstream end of the model.

The comparison showed that the differences between peak flows ranged from -1.4% in the 20% AEP event to 1.1% in the 2% AEP event. As such, no adjustment of hydrological inflows to the model was required.

4.2 Model Performance

Run performance has been monitored throughout the model build process and then during each simulation carried out, to ensure the optimum model convergence was achieved. In the 1D model the convergence plots produced as .bmp files were checked. As shown in Figure 4-1 below, there are no non-convergence issues with the 1D model.

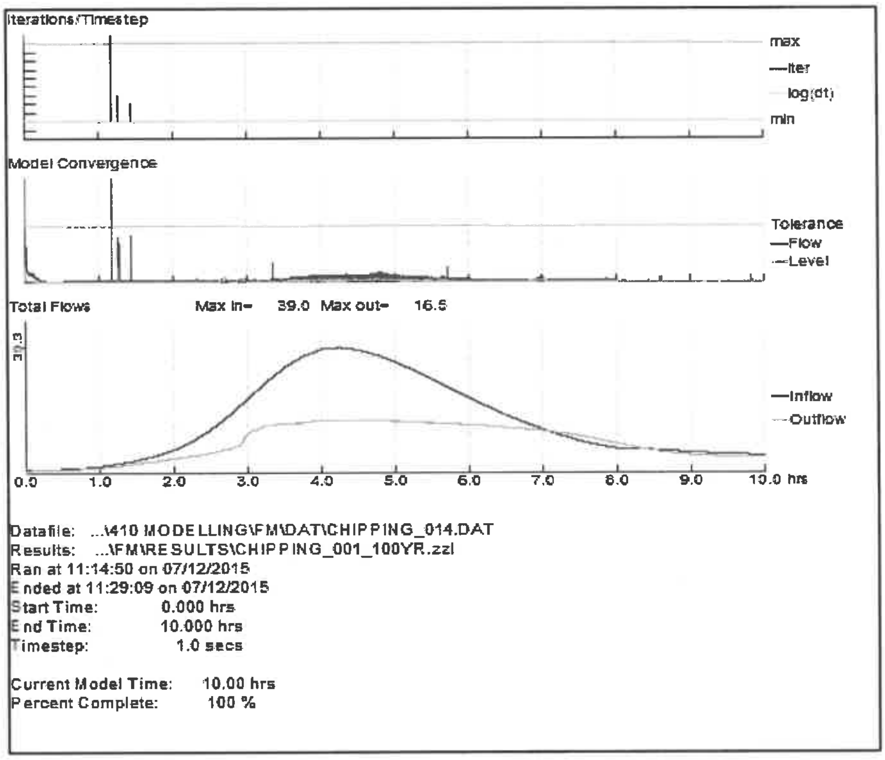


Figure 4-1: 1D model convergence – 1 % AEP event

The cumulative mass error reports output from the TUFLOW 2D model have been also checked. The recommended tolerance range is +/- 1% Mass Balance error. The change in volume through the model simulation has also been checked.

Figure 4-2 shows that the cumulative mass error is within the tolerance range for most part of the simulation. The change in volume curve shows a smooth increase, which is another indicator of stable computation during the simulation process.

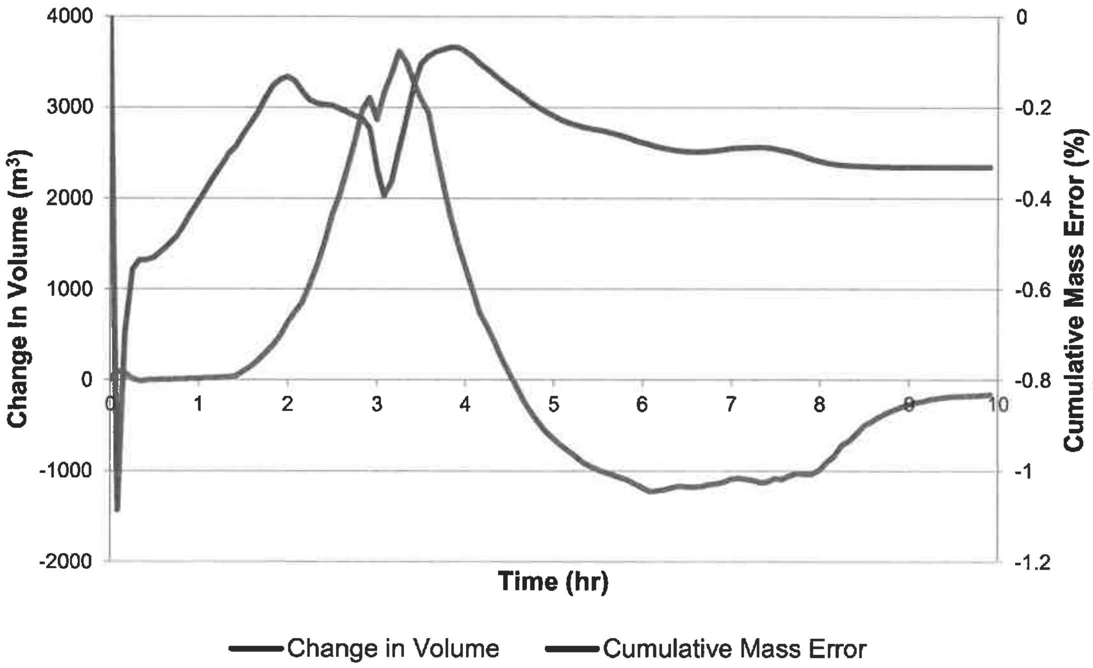


Figure 4-2: 2D cumulative mass error and change in volume – 1 % AEP event

4.3 Model Results

4.3.1 Model outputs

Maximum water levels have been extracted at each model node of the 1D domain for all simulated events. These are provided in Appendix A of this report. Maximum flood depth maps were produced for all the simulated events and they are provided in Appendix B of this report.

4.3.2 Existing scenario flood risk

This section summarises the key findings from the model simulations.

- The model simulation results for the 50% AEP event show that the flow begins to spill into the floodplain via a small drain that meets Chipping Brook around cross-sections CH01_0427 and CH01_0512 (approximately 380m downstream of the WWTW). The water then spills out of Chipping Brook on both banks where the watercourse is perched (node CH01_0629). At peak flow, the water overtops just upstream of the WWTW site (node CH01_0886) on both banks, as well as over the left bank immediately upstream of Startifants (node CH01_1071).
- The 50% AEP results show significant flooding in the modelled area especially near the unnamed tributary modelled. Due to the topography of the area, the flood water originating from Chipping Brook flows south and ponds near the unnamed tributary (left bank). Here, predicted water depth is as high as 750mm.
- The simulation results for the 20% AEP event show that, in addition to flooding described above for the 50% AEP event, the water also spills over the right bank of Chipping Brook at the location of Startifants.

The results for the 10% AEP and higher order events show that water overtops the left bank of Chipping Brook near the upstream end of the model as well.

- Simulation results show that flood water from Chipping Brook is transferred upstream through the modelled floodplain culverts for almost all the modelled AEP events.
- Longridge Road is overtopped west of the modelled unnamed tributary during the 1% AEP event plus climate change with approximately 100mm of water depth.
- The bridge leading to Startifants is surcharged during the 20% AEP event. The bridge leading to the WWTW site is not surcharged for any of the simulated AEP events.
- A few properties in Startifants get flooded for the 20% and higher order AEP events with maximum flood depths greater than 100mm.
- The Chipping WWTW site is partially flooded (north side) for all the simulated AEP events. The maximum water depth is generally less than 100mm and only a local depression shows depths ranging from 500mm to 750mm. Figure 4-3 shows predicted maximum flood depths in the vicinity of WWTW site for the 1% AEP event.

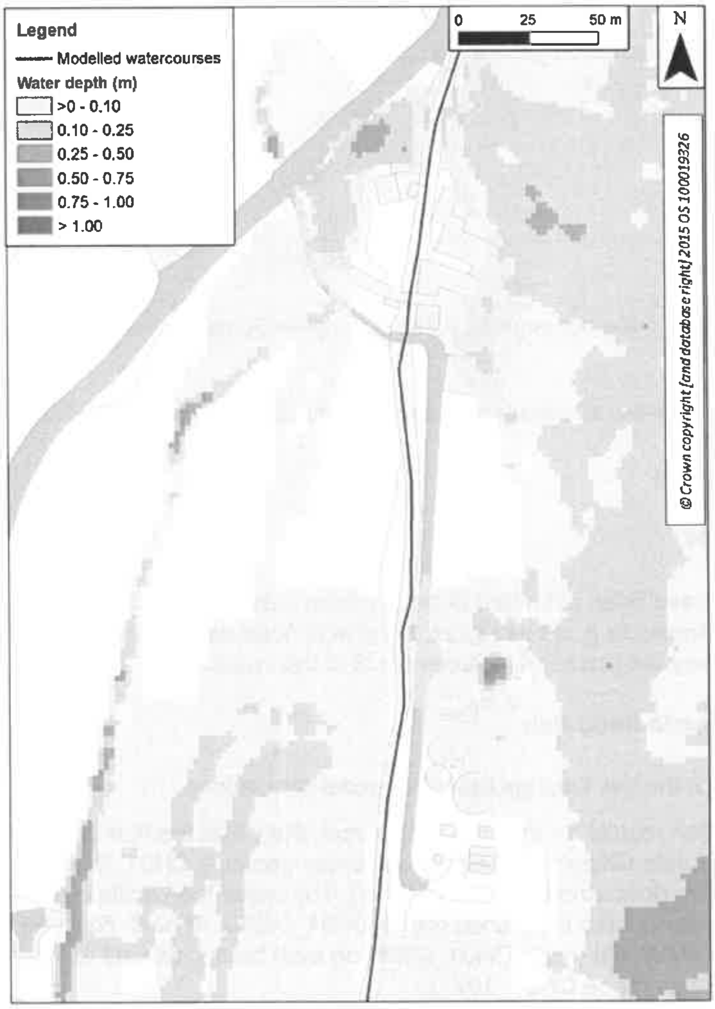


Figure 4-3: Predicted Maximum Flood depth - 1 % AEP event

4.3.3 Peak river water levels at the new proposed bridge location

Chipping WWTW site is located on Chipping Brook left bank between cross-sections CH01_0886 and CH01_0773 in the hydraulic model. A new access bridge is proposed in place of the existing access bridge, which is located approximately 110m upstream of the northern end of the site (node CH01_0994u). Table 4-1 below provides peak river water level for all the simulated events at the new proposed bridge location.

Table 4-1: Peak river water level for all the simulated events at the new proposed bridge location

Node	Existing Scenario Maximum Water Level (m AOD)						
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1 % AEP + Climate Change
CH01_0994u	98.55	98.64	98.68	98.69	98.71	98.72	98.73

4.4 Sensitivity Analysis

In order to test the model sensitivity to key hydraulic parameters, a series of simulations were undertaken for the 1% AEP event. These tests were carried out for the 1D and 2D domain. Table 4-2 provides a summary of the sensitivity runs results. These are discussed in the following sections. The analysis gives an indication of the level of confidence that can be placed in the water levels predicted by the model for the existing scenario.

Table 4-2: Summary of results for the sensitivity test runs

Sensitivity Test	Average Water Level Difference (mm)	Maximum Water Level Difference (mm)	Cross Section where the Maximum Difference Occurs
Downstream Boundary's Slope -20 %	0	-37	CH01_0000
Downstream Boundary's Slope +20 %	0	43	CH01_0000
Roughness - 20%	18	-176	CH01_0427
Roughness + 20%	3	-126	CH01_1010u
Inflow - 20 %	26	-95	CH01_0427
Inflow + 20 %	-30	51	CH01_0427

4.4.1 Downstream boundary conditions sensitivity test

The effect of the downstream boundary's slope on the water levels in the Chipping Brook was tested by increasing and decreasing the existing scenario's slope by 20%.

For both cases, the effect of modifying the slope remains local to the downstream end of the model. The effect of the changes only extends approximately 30m from the downstream boundary. Therefore, it can be concluded that the hydraulic model results are not sensitive to the downstream boundary conditions of the model.

4.4.2 Roughness sensitivity test

Manning's 'n' roughness coefficients were sensitivity tested for a 20% increase and a 20% decrease in value for the full modelled reaches of the watercourses and their floodplain (1D and 2D domain).

The 1D results suggest that the model is not sensitive to changes in roughness. For both cases, the average change in water levels in Chipping Brook is less than +20mm. For the 2D floodplain model, the roughness makes a small difference to the flood extent. Figure 4-4 shows the changes in flood extent as a result of the roughness sensitivity testing.

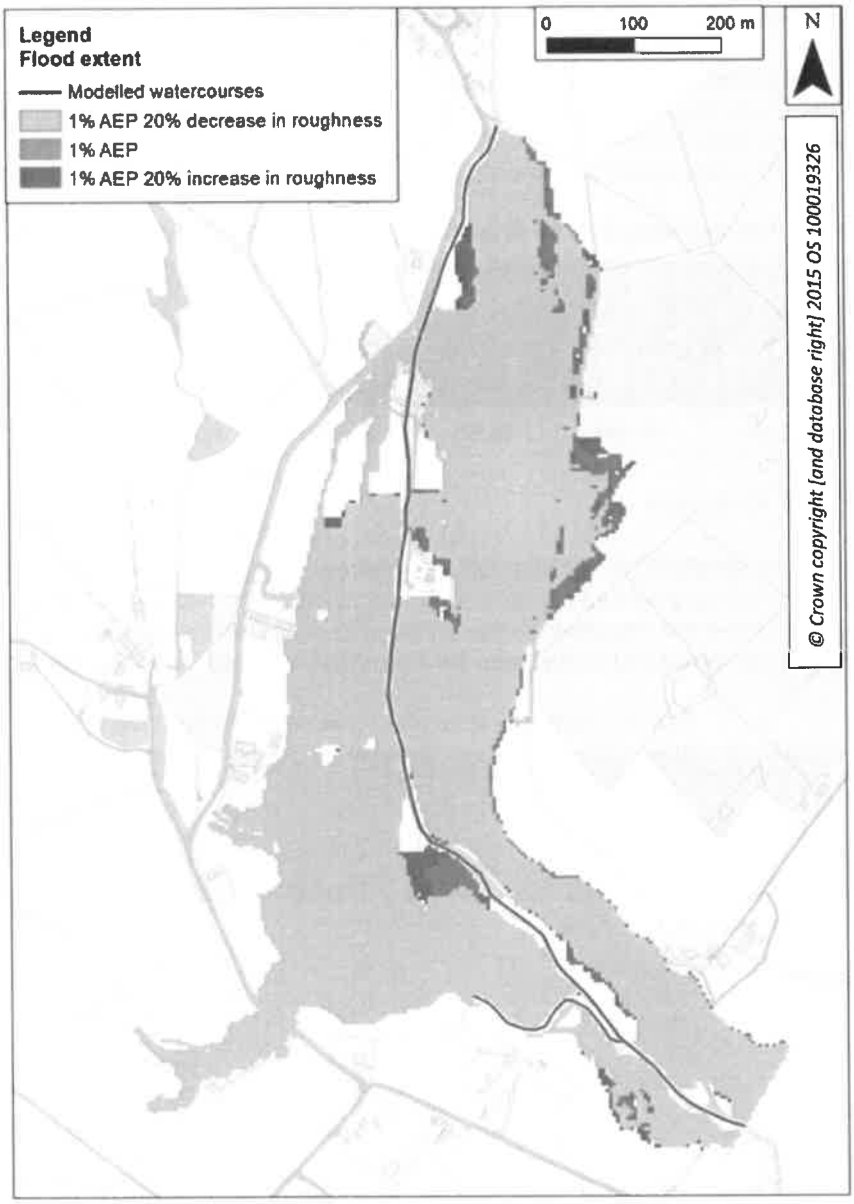


Figure 4-4: Flood extents - roughness sensitivity testing

4.4.3 Inflow sensitivity test

All hydrological inflows included in the model were tested for a 20% increase and a 20% decrease in peak flows. The hydrograph profile shape was not changed but scaled to the corresponding peak flows.

The 1D results suggest that the model is not sensitive to changes in peak flow. For both cases the maximum change in water is less than +/-50mm. For the 2D floodplain model, the inflow makes a small difference to the flood extent. Figure 4-5 shows the changes in flood extent as a result of the inflow sensitivity testing.

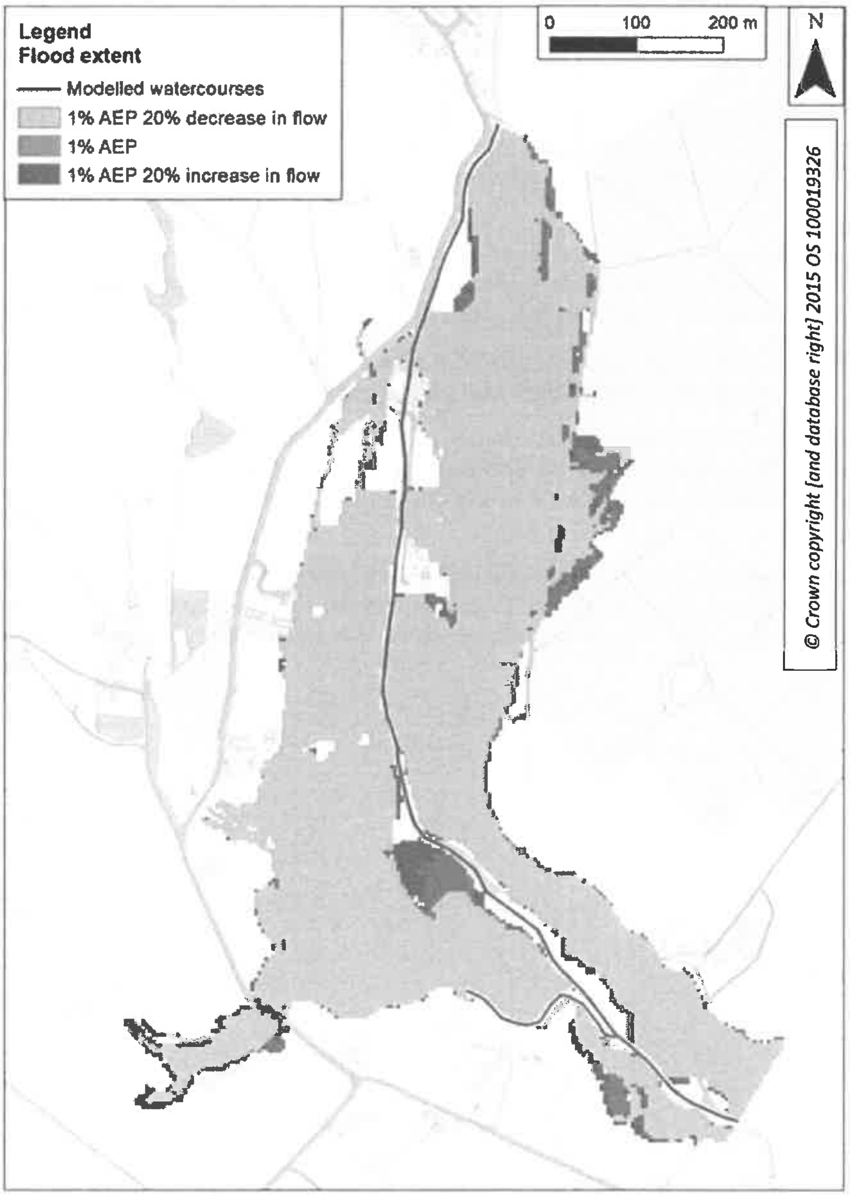


Figure 4-5: Flood extents - flow sensitivity testing

4.4.4 Sensitivity test results at the new proposed bridge location

This section discusses the sensitivity test results for the 1% AEP event specifically at the upstream face of the existing access bridge to the WWTW:

- A 20% decrease in inflows for 1% AEP event results in a 14mm lowering of water levels at the upstream face of the bridge and a 20% increase in inflows results in 12mm increase in maximum water level at the upstream face of the bridge.
- A 20% decrease in roughness results in a 58mm lowering of water levels at the upstream face of the bridge and a 20% increase in roughness results in negligible change in maximum water level at the upstream side of the bridge.
- The sensitivity tests for the downstream boundary show no impact on the water levels at the upstream face of the existing access bridge to WWTW.

5. Assumptions & Limitations

The accuracy and validity of the model results is heavily dependent on the accuracy of the hydrological, surveyed and topographic data included in the model. While the most appropriate available information has been used to construct the model, there are assumptions and limitations associated with the model. These are listed below:

1) The LiDAR data used to inform the 2D model domain with ground elevation information has a horizontal resolution of 2m. In the 2D model, this was further resampled using a 4m square grid in TUFLOW. This resolution is appropriate for predicting the flooding mechanism in the modelled area;
2) The model has not been quantitatively calibrated as the Chipping Brook catchment is ungauged. However, model performance has been checked as well as the consistency of model results;
3) Culverts in floodplain, included in the 2D domain as ESTRY 1D elements, were not surveyed. Their dimensions have been estimated using Google Earth, Street View and OS mapping. However considering the extensive flooding in the floodplain it is considered that model results are not sensitive to these assumptions.
4) The downstream boundary of the model assumes free flow and the impact of River Loud on the downstream boundary is not considered. However, sensitivity tests have demonstrated that model predictions at Chipping WWTW are not influenced by the downstream boundary conditions.

6. Conclusions

A linked 1-dimensional / 2-dimensional (1D/2D) hydraulic model has been built to represent Chipping Brook, one of its unnamed tributary and their floodplain using Flood Modeller Pro (1D) and TUFLOW (2D) software.

The key conclusions from the hydraulic modelling carried out are the following:

- The modelled flood extents are significant during the 50% AEP event due insufficient capacity of the river channels and the topography of the floodplain areas that allow widespread flooding.
- Chipping WWTW site is partially flooded, in the northern part of the site, for all the modelled AEP events, including the 50% AEP event. For all the modelled events, maximum flood depths are generally less than 100mm and very locally (in topographic depressions) reach values as high as 750mm.
- A few properties in Startifants get flooded for the 20% and higher order AEP events with maximum flood depths greater than 100mm.
- The new access bridge will replace the existing bridge. At this location, maximum river water level for the 1% AEP event is 98.72m AOD and for the 1% AEP plus climate change event, it is 98.73m AOD.

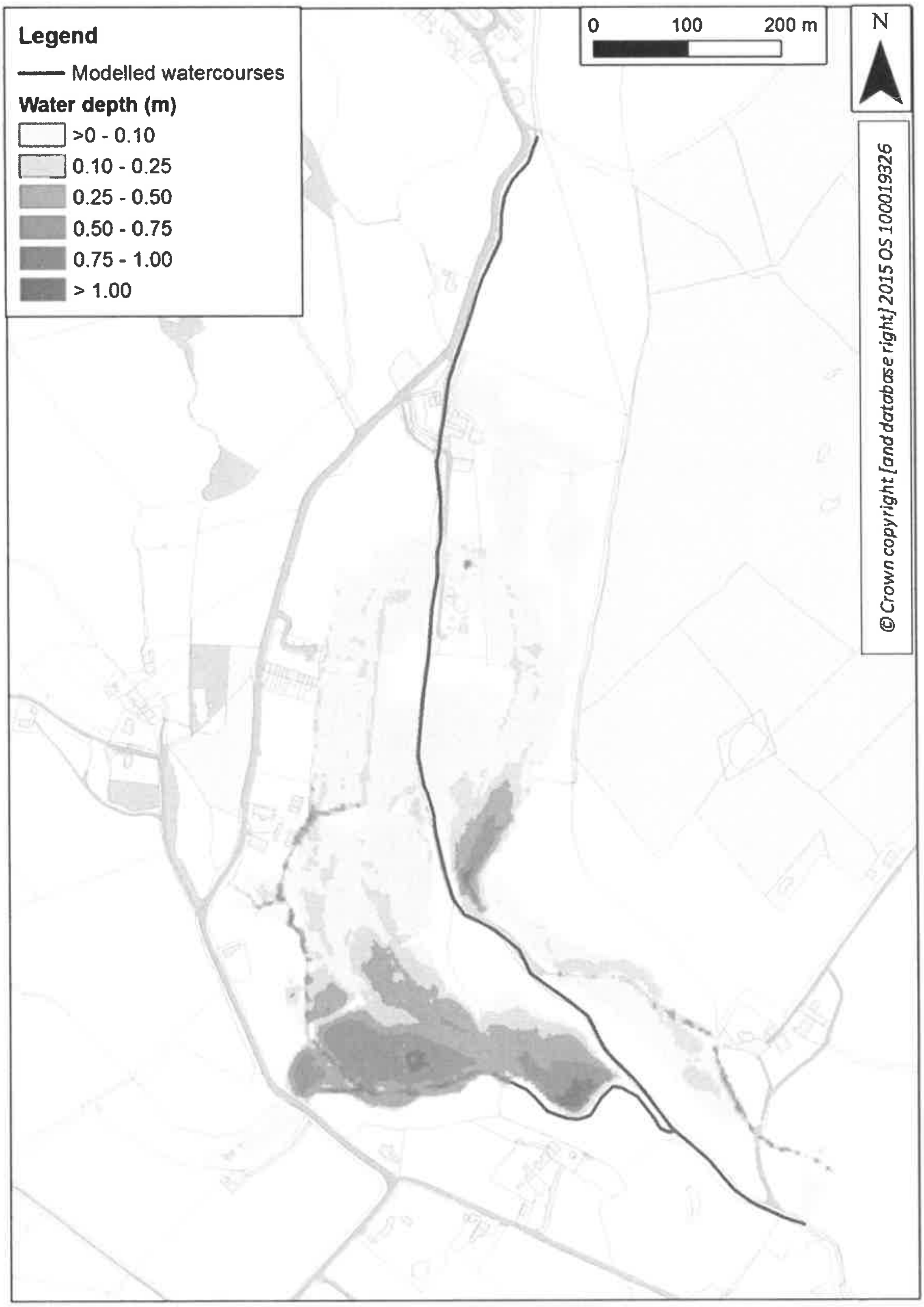
Appendix A. Maximum River Water Levels

Node	Chipping Brook - Existing Scenario Maximum Water Level (m AOD)						
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1 % AEP + Climate Change
CH01_1345	101.94	102.16	102.28	102.34	102.38	102.41	102.45
CH01_1257	100.98	101.18	101.29	101.35	101.42	101.45	101.49
CH01_1193	100.40	100.54	100.55	100.55	100.56	100.57	100.60
CH01_1184	100.25	100.29	100.30	100.31	100.32	100.32	100.33
CH01_1071	99.32	99.44	99.48	99.50	99.51	99.52	99.54
CH01_1010u	98.67	99.08	99.14	99.17	99.19	99.21	99.24
CH01_1007	98.65	98.72	98.75	98.77	98.78	98.79	98.80
CH01_0994u	98.55	98.64	98.68	98.69	98.71	98.72	98.73
CH01_0990	98.55	98.64	98.68	98.69	98.71	98.72	98.73
CH01_0886	97.51	97.52	97.52	97.52	97.53	97.53	97.53
CH01_0825	96.76	96.79	96.80	96.80	96.80	96.80	96.81
CH01_0773	96.12	96.14	96.15	96.16	96.18	96.18	96.19
CH01_0629	94.81	94.81	94.81	94.81	94.81	94.81	94.81
CH01_0512	93.49	93.52	93.54	93.57	93.64	93.67	93.72
CH01_0427	92.74	92.79	92.81	92.86	92.95	93.01	93.06
CH01_0346	92.06	92.11	92.15	92.20	92.25	92.28	92.32
CH01_0271	91.43	91.58	91.67	91.75	91.80	91.82	91.86
CH01_0222	91.18	91.28	91.33	91.36	91.40	91.43	91.47
CH01_0170	91.05	91.15	91.17	91.18	91.21	91.24	91.27
CH01_0169	91.05	91.15	91.17	91.18	91.21	91.24	91.27
CH01_0121	90.83	90.98	91.01	91.03	91.04	91.06	91.07
CH01_0028u	90.13	90.18	90.21	90.22	90.25	90.28	90.32
CH01_0026	90.13	90.18	90.21	90.22	90.25	90.28	90.32
CH01_0000	90.09	90.16	90.19	90.20	90.22	90.24	90.27

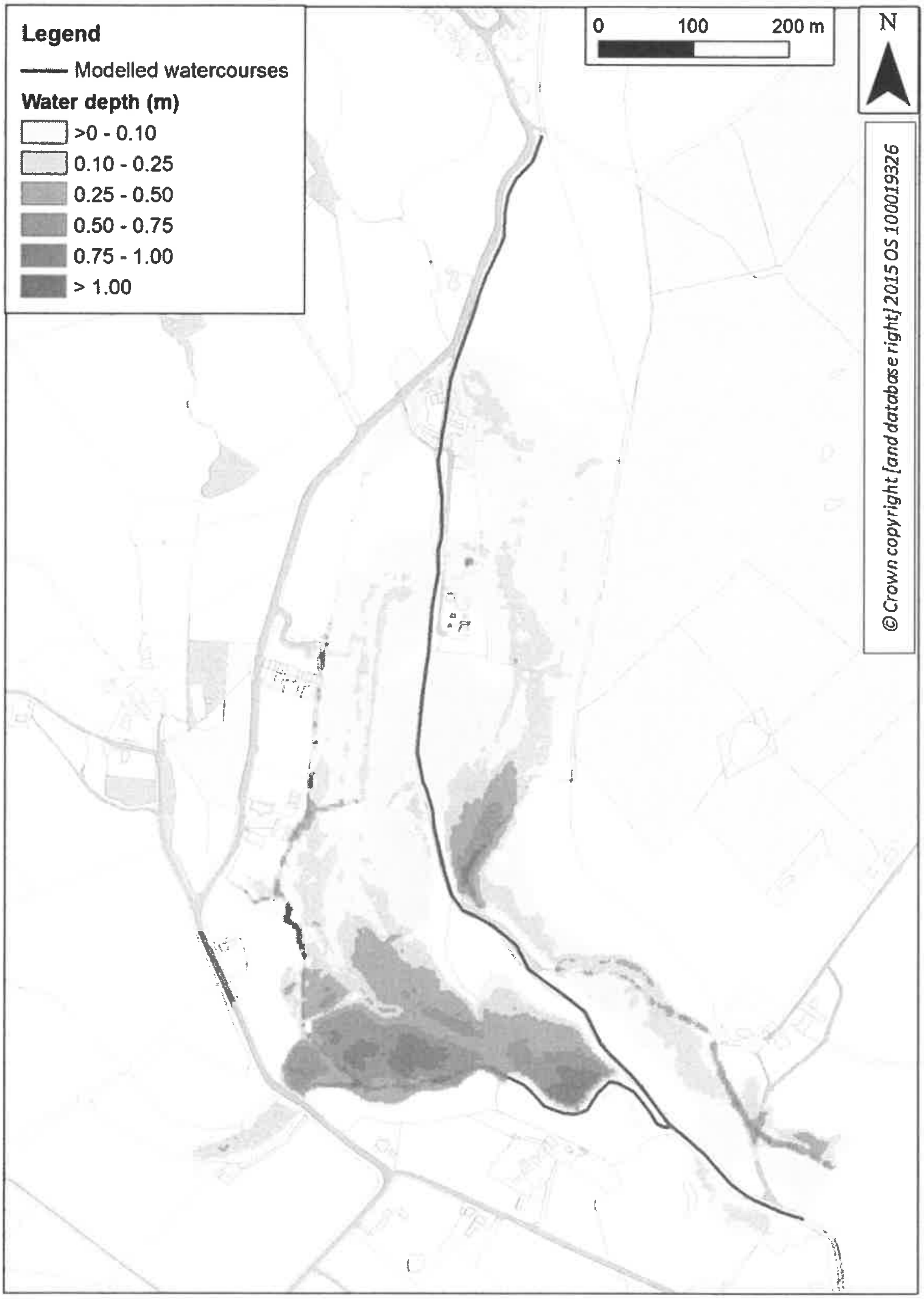
Node	Unnamed Tributary - Existing Scenario Maximum Water Level (m AOD)						
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1 % AEP + Climate Change
CH02_0219	91.65	91.74	91.78	91.80	91.84	91.87	91.93
CH02_0183	91.64	91.74	91.78	91.81	91.85	91.88	91.97
CH02_0140	91.64	91.70	91.72	91.73	91.74	91.74	91.75
CH02_0000	91.05	91.15	91.17	91.18	91.21	91.24	91.27

Appendix B. Flood Maps

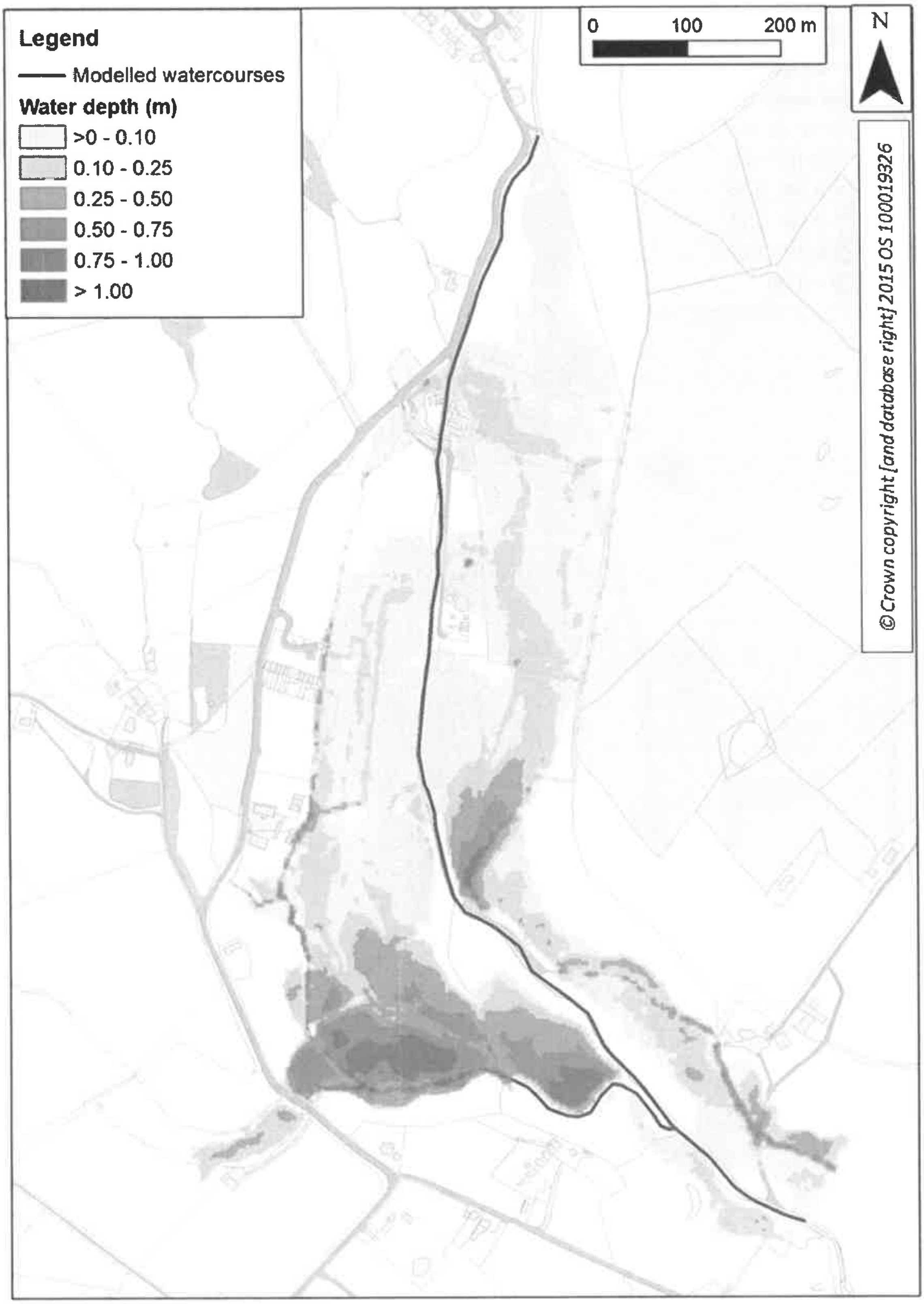
Maximum Flood Depth – 50 % AEP Event



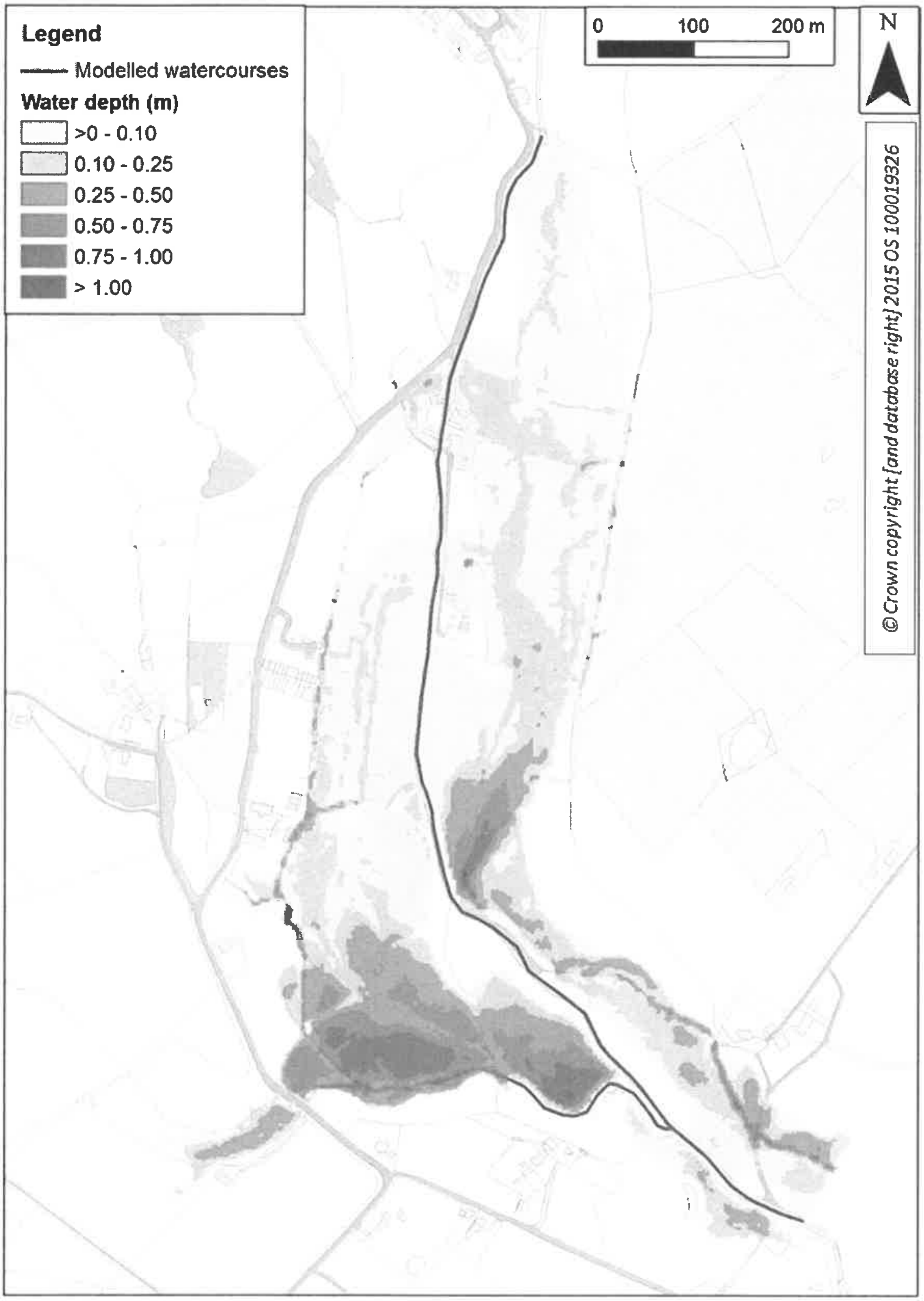
Maximum Flood Depth – 20 % AEP Event



Maximum Flood Depth – 10 % AEP Event



Maximum Flood Depth – 5 % AEP Event



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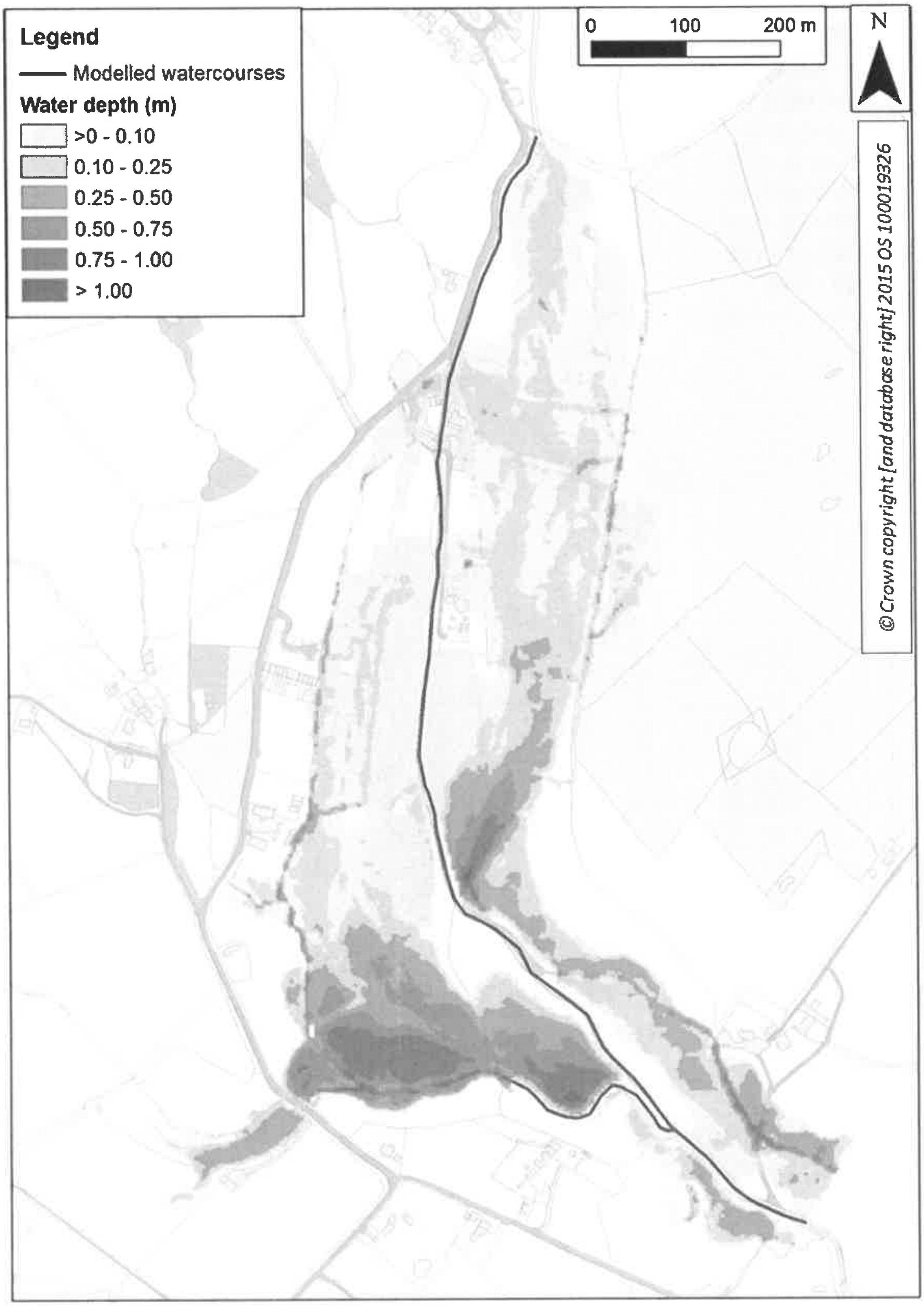
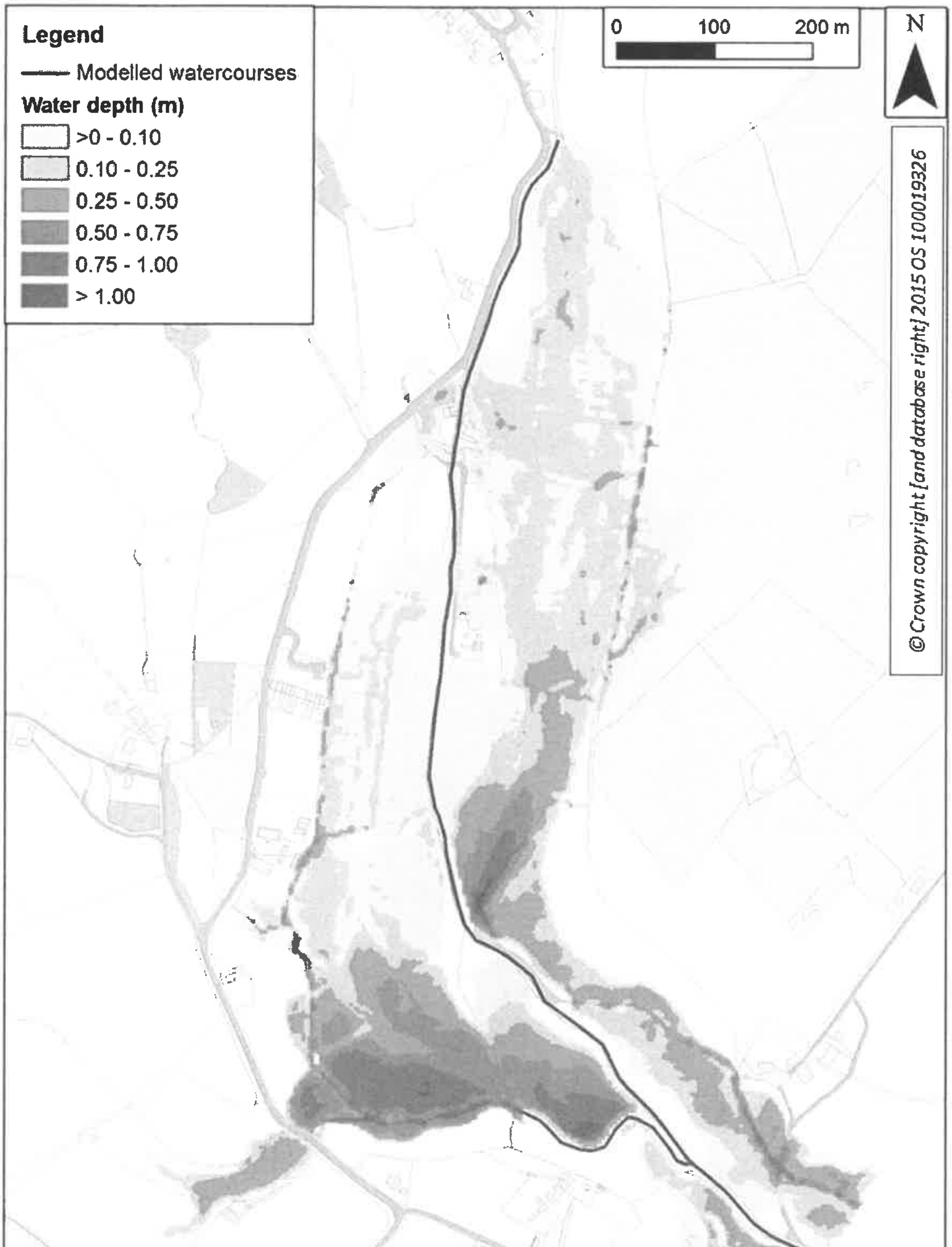
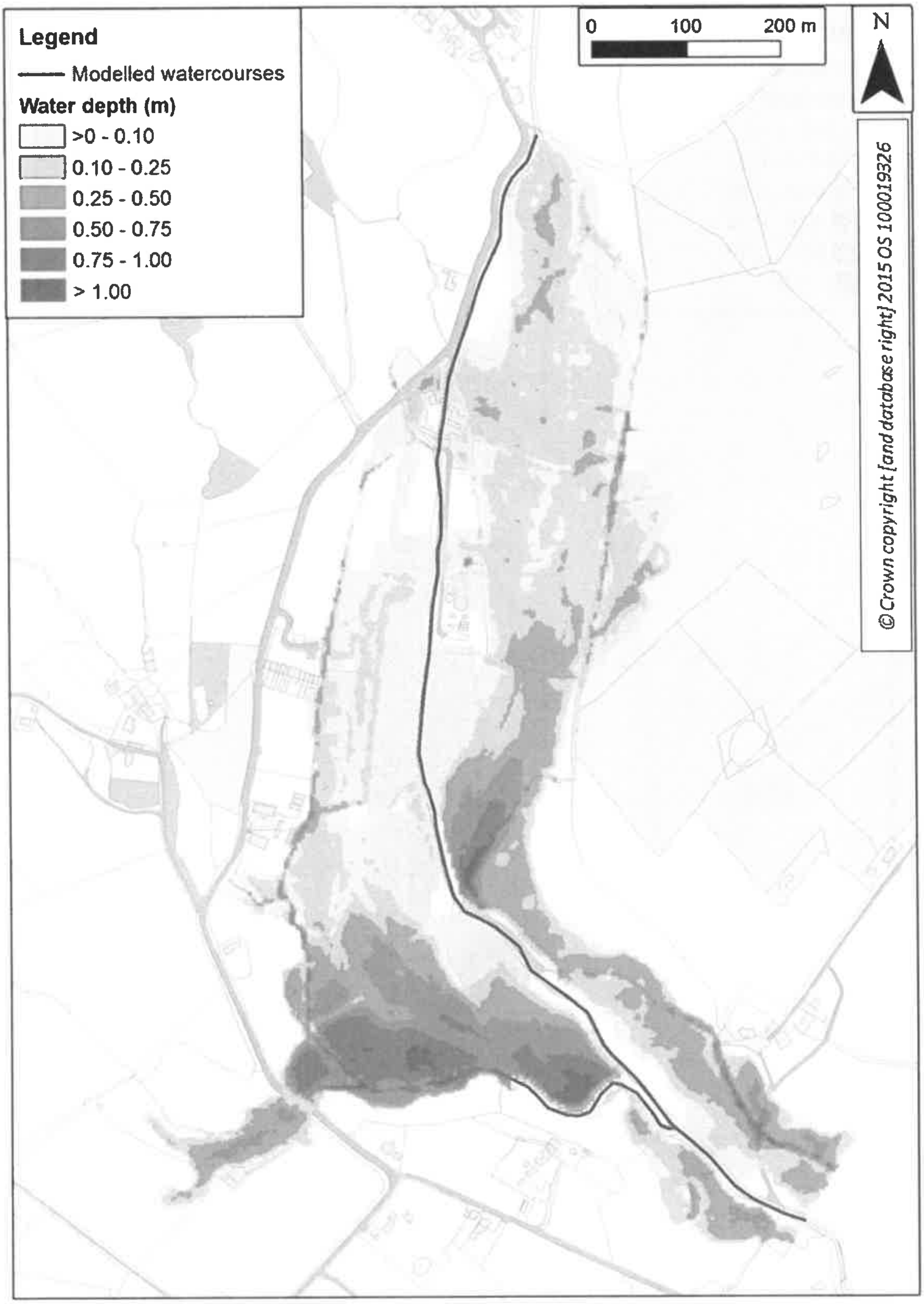
Maximum Flood Depth – 2 % AEP Event



Maximum Flood Depth – 1 % AEP Event



Maximum Flood Depth – 1 % AEP plus Climate Change Event



Appendix C. Chipping Brook Hydrology

C.1 Objectives

As an input to the hydraulic model, hydrological assessments are required to determine the design flows for the 20%, 10%, 5%, 2%, 1% and 1% plus climate change AEP at specified locations on the Chipping Brook and its tributary.

C.2 Catchment Description

Chipping Brook is located in Lancashire and originates on the hills in the Forest of Bowland (Figure C.1). The Brook drains an area of approximately 10.8km^2 to its confluence with the River Loud. The catchment is predominately rural with the main area of settlement being Chipping village, located in the lower half of the catchment.

$URBEXT_{2000}$ values are up to 0.0097 immediately downstream of the Chipping at location CB01. The brook flows south east through Chipping before joining the River Loud. There is an unnamed tributary which joins the brook from the right bank approximately 1km downstream of Chipping village at NGR SD626419 (Figure C.1).

Soils within the catchment are classed as slowly permeable, seasonally wet acid loamy and clayey soils. The bedrock of the catchment is Bowland High Group and Craven (Mudstone, Siltstone and Sandstone) and the superficial geology comprises a combination of Till-Diamicton and Alluvium (Clay, Silt and Sand) with areas of Peat in the upper reaches of the catchment. The SPRHOST value ranges from 35.59% to 47.06%. The BFIHOST value is between 0.323 and 0.367.

The topography of the catchment ranges from 520m AOD in the upper reaches to 90m AOD at the confluence with the River Loud (i.e. location CB02). The standard average annual rainfall (SAAR) of the catchment ranges from 1381mm to 1592mm.

C.3 Flow Estimation Locations

Flow estimates were required at three locations in the Chipping Brook catchment. These are shown in Table C.1 below and mapped on Figure C.1.

Table C.1 : Locations of flow estimates

Flow Estimation Point	Description	Grid Reference	Catchment Area (km^2)
CB01	Chipping Brook approximately 500m downstream of Chipping Brook Bridge.	SD625429	8.45
CB02	Chipping Brook upstream of the confluence with River Loud	SD628417	10.79
TRIB	Unnamed tributary upstream of the confluence with Chipping Brook.	SD625419	2.14

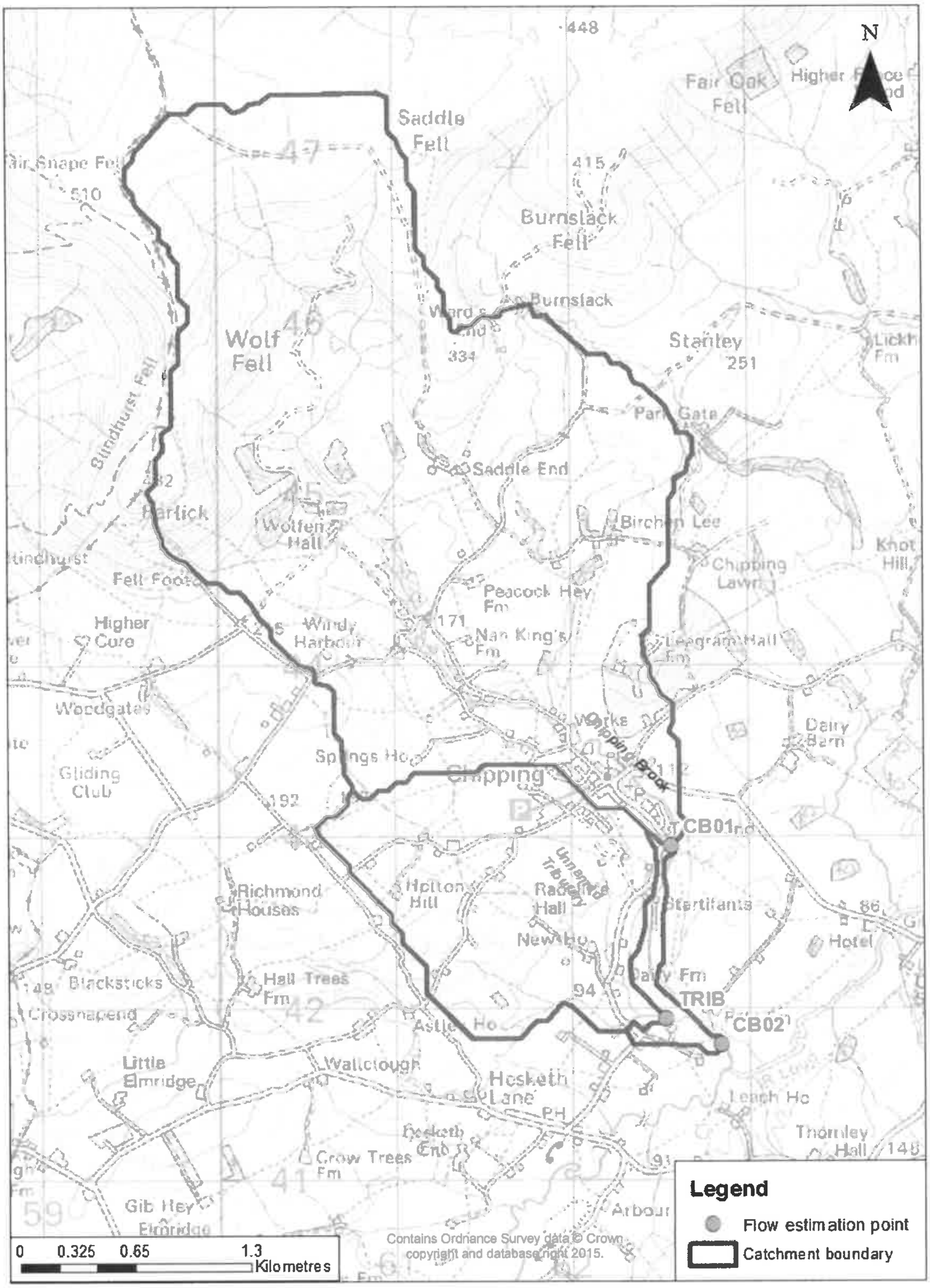


Figure C.1 : Locations of flow estimates

C.4 Methodology

The following bullet points details the methodology used for this assessment.

- Catchment areas were extracted from the FEH CD-ROM Version 3.0 (2009) for the three locations listed in Table C.1 and checked against the 1:50,000 OS mapping and contours. No amendments were required to the catchment AREAs.
- The median annual maximum flow (QMED) was calculated from the Flood Estimation Handbook (FEH) catchment descriptors. Gauging station 72007 was identified as a reliable donor catchment for a data transfer in the calculation of QMED. The data transfer was implemented for both the Chipping Brook catchment and its tributary.
- The catchments in the study are classed as "*essentially rural*" therefore no urban adjustment was made to QMED.
- A statistical pooling group analysis was undertaken using WINFAP-FEH Version 3.0.003 (2009). The Jacobs WINFAP-FEH database currently uses Peak Flow data version 3.3.4 dated August 2014, published on the Centre for Hydrology and Ecology (CEH) website.
- The whole river catchment (CB02) was used to generate a pooling group and the resultant growth curve applied to all locations.
- Revitalised Flood Hydrograph ReFH1 boundary units were set up in ISIS v3.7.0.233 for all catchments using a catchment-wide design storm duration of 4.4 hours.
- Revitalised Flood Hydrograph ReFH2 analysis was undertaken for all three catchments using a catchment-wide design storm duration of 4.75 hours. Resultant flows were compared with the flows produced using ReFH1.

A climate change adjustment, based on the Environment Agency's Adoption for Climate Change guidance of 20% in the North West England was applied[5] to the 1% AEP event flows.

C.5 Results

The following section provides a summary of the results of the hydrological assessment. The detailed analyses are described in the audit trail in Appendix D.

C.5.1 QMED results

Table C.2 shows the QMED values calculated for all three locations calculated using the FEH statistical analysis with a data transfer from gauging station 72007.

Table C.2 : Catchment QMED values from FEH statistical method

Flow Estimation Point	QMED Catchment Descriptors (m^3/s)	QMED with Data Transfer from 72007 (m^3/s)
CB01	11.42	11.87
CB02	13.32	13.85
TRIB	2.70	2.81

C.5.2 FEH pooling analysis

Table C.3 shows the growth factors determined using a pooling group of hydrologically similar catchments at CB02 and estimated peak flows for all three catchments.

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[5] Environment Agency (2011) Adapting to Climate Change Advice for Flood and Coastal Erosion Management Authorities

Table C.3 : Growth factors and flow estimates at locations CB01-02 and TRIB using the pooling group method

AEP Event	Growth Factors CB02	FEH - Estimated Peak Flows (m^3/s)		
		CB01	CB02	TRIB
20%	1.337	15.9	18.5	3.8
10%	1.590	18.9	22.0	4.5
5%	1.868	22.2	25.9	5.2
2%	2.297	27.3	31.8	6.4
1%	2.680	31.8	37.1	7.5
1% + Climate Change	–	38.2	44.6	9.0

C.5.3 Calculated flows for catchment using ReFH1 method

ReFH1 analysis was undertaken at all three locations using a catchment-wide design storm of 4.4 hours. Results are shown in Table C.4 below.

Table C.4 : ReFH1 results at CB01-02 and TRIB

AEP Event	ReFH1 - Estimated Peak Flows (m^3/s)		
	CB01	CB02	TRIB
20%	14.0	15.9	3.5
10%	16.9	19.1	4.2
5%	19.9	22.6	4.9
2%	24.8	28.1	6.0
1%	29.3	33.2	7.1
1% + Climate Change	35.1	39.8	8.5

C.5.4 Calculated flows for catchments using ReFH2 methods

Results of ReFH2 analysis undertaken at all three locations are shown in Table C.5 using a catchment-wide design storm of 4.75 hours.

Table C.5 : ReFH2 results at CB01-02 and TRIB

AEP Event	ReFH2 - Estimated Peak Flows (m^3/s)		
	CB01	CB02	TRIB
20%	12.5	14.3	3.2
10%	14.9	17.0	3.8
5%	17.4	19.8	4.4
2%	20.8	23.7	5.3
1%	26.7	26.9	6.0
1% + Climate Change	32.0	32.3	7.2

C.5.5 Comparison of calculated flows using FEH and ReFH methods

Different formulae are used in the calculation of the catchment storm duration at CB02 for both methodologies. 4.4 hours and 4.75 hours were calculated using ReFH1 and ReFH2 respectively. Results at CB02 show higher flows for all return periods using the FEH approach in comparison to the ReFH methods for all return periods. This is detailed in Table C.6 below.

Table C.6 : Results at CB02 using all methods

AEP Event	CB02 - Estimated Peak Flows (m^3/s)		
	FEH Pooling	ReFH1	ReFH2
20%	18.5	15.9	14.3
10%	22.0	19.1	17.0
5%	25.9	22.6	19.8
2%	31.8	28.1	23.7
1%	37.1	33.2	26.9
1% + Climate Change	44.6	39.8	32.3

C.6 Conclusions and Recommendation

The hydrological analysis has been undertaken using the FEH pooling group and ReFH methodologies. The results show higher flows using the FEH pooling group method for all return periods for the Chipping Brook. However, for the smaller catchment, location TRIB, flows were similar for both methods with an average of 5% difference for the 1% AEP event.

Catchments within the study area are ungauged. No allowances have been made within ReFH to amend model parameters based on recorded data. Flows are estimated solely based on catchment descriptors.

The Environment Agency guidelines state that, the use of FEH statistical pooling analysis is essential for ungauged sites[6]. The pooling group uses gauged data from hydrologically similar stations in the construction of a growth curve. The approach also allows for the improvement of QMED value by the use of a donor catchment. For this study, the estimation of QMED was improved by using gauged data from a neighbouring catchment, improving the reliability of assessment using the statistical pooling group method.

The FEH approach is therefore deemed appropriate and recommended for use for this study.

[6] Environment Agency (2015) Flood Estimation Guidelines, Technical Guidance 197_08

Appendix D. Chipping Brook Hydrology – FEH Audit Trail

Flood estimation calculation record

Introduction

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

Contents

Approval

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:		Agnes Adjei	
Calculations checked by:		Alison Janes	
Calculations approved by:		Phil Raynor	

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

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

ABBREVIATIONS

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

1 Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • Purpose of study • Approx. no. of flood estimates required • Peak flows or hydrographs? • Range of return periods and locations • Approx. time available	Proposed expansion works are required to the United Utility Chipping Waste Water Treatment Works (WWTW) site located in Lancashire. As part of the planning application process a hydraulic mode is required to determine the level of flood risk to surrounding area and properties. As an input to this model, hydrological assessments were required to determine the design flows for the following Annual Exceedance Probability 20%, 10%, 5%, 2%, 1% and 1% plus climate. Estimated flows are required at these locations: • Chipping Brook approximately 500m downstream of Chipping Brook Bridge. • Unnamed Tributary upstream of confluence with Chipping Brook. • Chipping Brook upstream of confluence with River Loud.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	Chipping Brook drains an area of approximate 10.8km^2 to its confluence with the River Loud. The catchment is predominately rural with the only area of settlement being the Chipping town located in the lower half of the catchment. The Brook runs from the hills in the Forest of Bowland then flows south easterly in the River Loud. There is an unnamed Tributary that joins the Brook approximately 1km downstream of Chipping town on the right bank. Soils within the catchment as classed as slowly permeable, seasonally wet acid loamy and clayey soils. The bedrock of the catchment is Bowland High Group and Craven-Mudstone, Siltstone and Sandstone. The superficial geology mainly comprises of a combination of Till-Diamicton and Alluvium (Clay, Silt and Sand) with areas of Peat in the upper reaches of the catchment. The topography of the catchment ranges from 520 mAOD in the upper reaches to 90 mAOD downstream of catchment.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Yes – Version 3.3.4 downloaded August 2014

1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

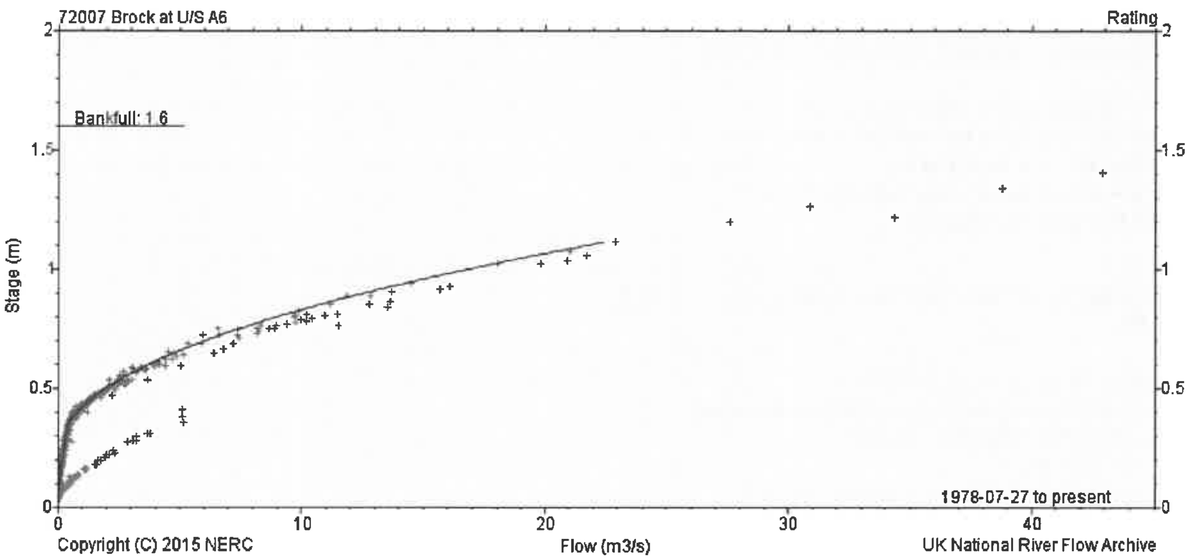
Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
Brock	U/S A6		72007	SD512405	32.0	Broad crested weir	1978 - 2014

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality – e.g. information from HiFlows-UK, trends in flood peaks, outliers.
U/S A6	1978-2011	N	Y	Y	N	Yes - Gauged to within 20% of AMAX3. No bypassing reported
Give link/reference to any further data quality checks carried out						

1.6 Rating equations

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons – e.g. availability of recent flow gaugings, amount of scatter in the rating.
N/A	Single rating for the period of record based on current meter gaugings	N	

Station name	Type of rating e.g. theoretical, empirical; degree of extrapolation	Rating review needed?	Reasons – e.g. availability of recent flow gaugings, amount of scatter in the rating.
			
Give link/reference to any rating reviews carried out	N/A		

1.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data and licence reference if from EA	Date obtained	Details
Check flow gaugings (if planned to review ratings)	N/A				
Historic flood data – give link to historic review if carried out.	N/A				
Flow data for events	N/A				
Rainfall data for events	N/A				
Potential evaporation data	N/A				
Results from previous studies	N/A				
Other data or information (e.g. groundwater, tides)	N/A				

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	FEH is appropriate for quick estimation of design flows.

Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	N/A
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	N/A
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	
Software to be used (with version numbers)	FEH CD-ROM v3.0[1] WINFAP-FEH v3.0.002[2] /ReFH Design Flood Modelling Software / ISIS

[1] FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

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

2 Locations where flood estimates required

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

2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
CB01	Chipping Brook	Chipping Brook approximately 500m downstream of Chipping Brook Bridge.	362550	442900	8.45	-
CB02	Chipping Brook	Unnamed Tributary upstream of confluence with Chipping Brook.	362850	441750	10.79	-
TRIB	Unnamed Tributary	Chipping Brook upstream of confluence with River Loud.	362550	441900	2.14	-
Reasons for choosing above locations		Locations requested by modelling team.				

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

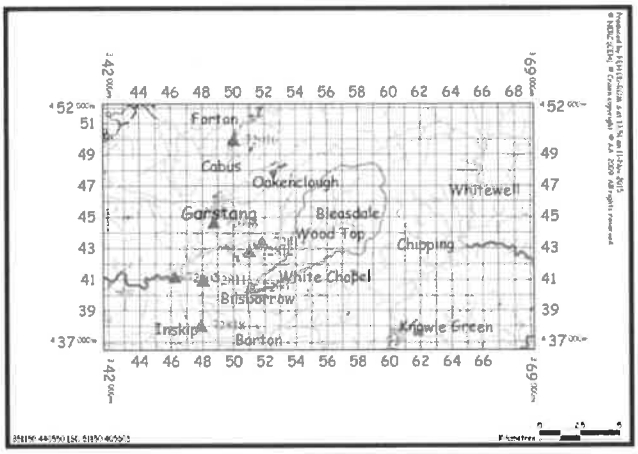
Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT	FPEXT
CB01	1.000	0.6	0.323	3.87	137.6	1592	47.06	0.0065	0.0283
CB02	1.000	0.6	0.332	4.50	117.8	1545	44.66	0.0097	0.0541
TRIB	1.000	0.6	0.367	1.56	52.3	1381	35.59	0.0064	0.1014

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	Catchment boundaries were checked with the 1:50,000 OS mapping and contours. No changes made.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	N/A
Source of URBEXT	URBEXT1990 / URBEXT2000 Updated URBEXT 2000 to 2015 CB01 – 0.0067 – Essentially rural CB02 – 0.0100 – Essentially rural TRIB – 0.0066 – Essentially rural
Method for updating of URBEXT	CPRE formula from FEH Volume 4 / CPRE formula from 2006 CEH report on URBEXT2000

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	Station 72007 drains the neighbouring River Brock catchment to the subject site was identified as suitable donor for the Chipping Brook and unnamed tributary catchment. The following are the characteristics of donor site. AREA = 31.53 FARL = 1.00 URBEXT = 0 (essentially rural) SPRHOST = 49.42 BFIHOST = 0.319 

3.2 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
72007	Accepted for QMED adjustment to Chipping Brook and Unnamed Tributary	AM	N	31.41	28.90	1.09

Which version of the urban adjustment was used for QMED at donor sites, and why? Note: The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8).	WINFAP-FEH v3.0.003 / Kjeldsen (2010) / other (delete as applicable)

3.3 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m^3/s)	Data transfer						Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor		
							Weight	Weighted average adjustment factor	
CB01	DT	11.42	72007	4.62	0.48	1.04	N/A	N/A	11.87
CB02	DT	13.32	72007	4.70	0.48	1.04	N/A	N/A	13.85
TRIB	DT	2.70	72007	5.61	0.45	1.04	N/A	N/A	2.81

Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?	
Which version of the urban adjustment was used for QMED, and why?	WINFAP-FEH v3.0.003 / Kjeldsen (2010) / other (delete as applicable)

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.

When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added.

When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050[Error! Bookmark not defined.] should be used. If the original FEH equation has been used, say so and give the reason why.

The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data.

The data transfer procedure is from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.

If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

3.4 Derivation of pooling groups

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

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
CB-02.feh	CB02	Ungauged	Discordant station; 48009 Stations removed; 49006 short record years 47022, FARL<0.95 54022, 57017, SAAR>2100 Stations added to increase pooling group to target years 27010, 27051	L-CV = 0.208 L-Skew = 0.228

Notes

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable.

The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape) after adjustments	Growth factor for 100-year return period
CB_02	P	CB_02.feh	GL distribution generally recommended for the UK	N/A	Location = 1.000 Shape = -0.228 Scale = 0.207	2.680

Notes

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

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

Urban adjustments to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008). Amend if not applicable.

Any relevant frequency plots from WINFAP-FEH, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot), should be shown here or in a project report.

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)					
	5	**10**	**20**	**50**	**100**	**100+20%cc**
Growth Factors	1.337	1.590	1.868	2.297	2.680	-
CB01	15.9	18.9	22.2	27.3	31.8	38.2
CB02	18.5	22.0	25.9	31.8	37.1	44.6
TRIB	3.8	4.5	5.2	6.4	7.5	9.0

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH1 model

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

Site code	Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
CB01	CD	1.512	230.538	25.541	0.921
CB02	CD	1.711	236.636	26.247	0.949
TRIB	CD	1.149	260.275	22.410	1.057

Brief description of any flood event analysis carried out (further details should be given below or in a project report)	

4.2 Design events for ReFH method

ReFH1

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
CB01	Rural	Winter	4.4	8.45
CB02	Rural	Winter	4.4	10.79
TRIB	Rural	Winter	4.4	2.14

Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?	

ReFH2

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
CB01	Rural	Winter	4.75	8.45
CB02	Rural	Winter	4.75	10.79
TRIB	Rural	Winter	4.75	2.14

Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?	

4.3 Flood estimates from the ReFH method

ReFH 1

Site code	Flood peak (m^3/s) for the following return periods (in years)					
	5	10	20	50	100	100+20%cc
CB01	14.0	16.9	19.9	24.8	29.3	35.1
CB02	15.9	19.1	22.6	28.1	33.2	39.8
TRIB	3.5	4.2	4.9	6.0	7.1	8.5

ReFH2

Site code	Flood peak (m^3/s) for the following return periods (in years)					
	5	10	20	50	100	100+20%cc
CB01	12.5	14.9	17.4	20.8	23.6	28.3
CB02	14.3	17.0	19.8	23.7	26.9	32.3
TRIB	3.2	3.8	4.4	5.3	6.0	7.2

5 FEH rainfall-runoff method

5.1 Parameters for FEH rainfall-runoff model

Methods:
FEA : Flood event analysis
LAG : Catchment lag
DT : Catchment descriptors with data transfer from donor catchment
CD : Catchment descriptors alone
BFI : SPR derived from baseflow index calculated from flow data

Site code	Rural (R) or urban (U)	Tp(0): method	Tp(0): value (hours)	SPR: method	SPR: value (%)	BF: method	BF: value (m^3/s)	If DT, numbers of donor sites used (see Section 5.2) and reasons

5.2 Donor sites for FEH rainfall-runoff parameters

No.	Watercourse	Station	Tp(0) from data (A)	Tp(0) from CDs (B)	Adjustment ratio for Tp(0) (A/B)	SPR from data (C)	SPR from CDs (D)	Adjust-ment ratio for SPR (C/D)
1								
2								

5.3 Inputs to and outputs from FEH rainfall-runoff model

Site code	Storm duration (hours)	Storm area for ARF (if not catchment area)	Flood peaks (m^3/s) or volumes (m^3) for the following return periods (in years)							
			2							

Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?	

6 Discussion and summary of results

6.1 Comparison of results from different methods

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

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 5 years			Return period 100 years		
	ReFH1	ReFH2	FEH	ReFH1	ReFH2	FEH
CB01	14.0	12.5	15.9	29.3	26.7	31.8
CB02	15.9	14.3	18.5	33.2	26.9	37.1
TRIB	3.5	3.2	3.8	7.1	7.2	9.0

6.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	The estimated flows using the FEH statistical method is recommended for use for this study. This approach is suitable for ungauged catchment and allows QMED from catchment descriptors to be improved through the use of data transfer from a donor site. A suitable donor site from a neighbouring rural catchment was identified and used to improve the estimation of QMED, thereby, improving the reliability of the assessment using FEH statistical approach.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The donor catchment for QMED estimation is sufficiently similar to the study catchment that it has similar hydrological response
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	N/A
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008).	CB_01: 68% confidence interval = (7.98, 16.34) 95% confidence interval = (5.58, 23.38) CB_02: 68% confidence interval = (9.31, 19.06) 95% confidence interval = (6.50, 27.28) TRIB: 68% confidence interval = (1.89, 3.89) 95% confidence interval = (1.32, 5.53)
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	N/A
Give any other comments on the study, for example suggestions for additional work.	N/A

6.4 Checks

Are the results consistent, for example at confluences?	The sum of flows from catchments CB01 and TRIB are roughly equal to the estimate at catchment CB02.
What do the results imply regarding the return periods of floods during the period of record?	N/A
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	The 100 year growth factor is 2.680. This is within the typical guidance range.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	N/A
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	The 2 year runoff rate for CB02 from the FEH pooling group method equates to13 l/s/ha. This is felt to be a high value but within published guidance.
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	N/A
Are the results compatible with the longer-term flood history?	N/A
Describe any other checks on the results	N/A

6.5 Final results

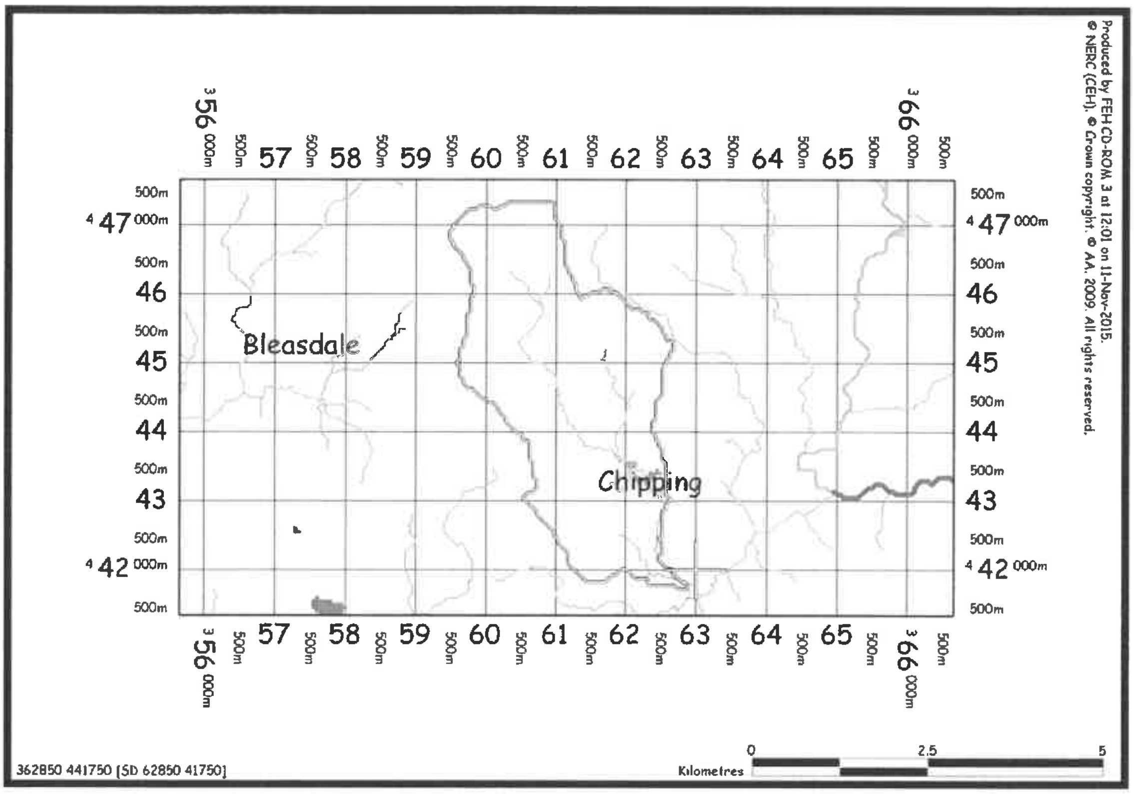
Site code	**Flood peak (m^3/s) for the following return periods (in years)**					
	5	**10**	**20**	**50**	**100**	**100+20%cc**
CB01	15.9	18.9	22.2	27.3	31.8	38.2
CB02	18.5	22.0	25.9	31.8	37.1	44.6
TRIB	3.8	4.5	5.2	6.4	7.5	9.0

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)	

7 Annex - supporting information

7.1 Pooling group composition

Location of CB_02 Catchment



Pooling Group – AM Data Table

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
25003 (Trout Beck @ Moor House)	0.433	39	15.164	0.176	0.291	0.630
206006 (Annalong @ Recorder)	0.532	48	15.330	0.189	0.052	2.063
25011 (Langdon Beck @ Langdon)	0.533	26	15.878	0.241	0.326	0.833
28033 (Dove @ Hollinsclough)	0.725	33	4.666	0.266	0.415	0.905
45816 (Haddeo @ Upton)	0.927	19	3.456	0.324	0.434	0.732
49003 (de Lank @ de Lank)	0.982	46	13.559	0.232	0.241	0.161
51002 (Horner Water @ West Luccombe)	1.070	31	8.354	0.382	0.326	1.401
27032 (Hebden Beck @ Hebden)	1.085	46	4.082	0.211	0.258	0.368
48009 (st Neot @ Craigshill Wood)	1.117	12	8.469	-0.245	-0.373	3.614
46005 (East Dart @ Bellever)	1.176	48	38.510	0.162	0.082	0.935
25012 (Harwood Beck @ Harwood)	1.209	43	33.265	0.189	0.251	0.902
48004 (Warleggan @ Trengoffe)	1.222	43	9.799	0.268	0.287	0.589
27010 (Hodge Beck @ Bransdale Weir)	1.261	41	9.420	0.224	0.293	0.179
27051 (Crimple @ Burn Bridge)	1.281	40	4.539	0.222	0.149	0.687
Total		515				
Weighted means				0.208	0.228	

Pooling Group - Catchment Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
25003 (Trout Beck @ Moor House)	0.433	11.460	1904	0.041	1.000	0.000
206006 (Annalong @ Recorder)	0.532	13.660	1720	0.024	0.980	0.000
25011 (Langdon Beck @ Langdon)	0.533	12.790	1463	0.013	1.000	0.001
28033 (Dove @ Hollinsclough)	0.725	7.930	1346	0.007	1.000	0.000
45816 (Haddeo @ Upton)	0.927	6.810	1210	0.011	1.000	0.005
49003 (de Lank @ de Lank)	0.982	21.610	1628	0.064	0.998	0.000
51002 (Horner Water @ West Luccombe)	1.070	20.380	1485	0.003	0.978	0.000
27032 (Hebden Beck @ Hebden)	1.085	22.200	1433	0.021	0.997	0.000
48009 (st Neot @ Craigshill Wood)	1.117	22.910	1512	0.022	0.982	0.002
46005 (East Dart @ Bellever)	1.176	22.270	2095	0.042	1.000	0.000
25012 (Harwood Beck @ Harwood)	1.209	24.580	1577	0.021	1.000	0.000
48004 (Warleggan @ Trengoffe)	1.222	25.260	1445	0.035	0.978	0.003
27010 (Hodge Beck @ Bransdale Weir)	1.261	18.840	987	0.009	1.000	0.001
27051 (Crimple @ Burn Bridge)	1.281	8.150	855	0.013	1.000	0.006

Appendix D
Borehole Logs & Soilscape Maps

ACC NO 46602 ACC NO 46621

British Geological Survey

HYDROGEOLOGY RESEARCH GROUP

SD64/69

Form WR-38 (BGS)

BOREHOLE RECORD

NORTHWESTERN. SD64SW/14

A SITE DETAILS	
Borehole drilled for	TOBY OLLERTON
Location	POLE FARM, CHIPPING, PRESTON.
NGR (8 fig.)	SD 6271 4200 — Please attach site plan
Ground Level (if known)	
Drilling Company	DALES WATER SERVICES LTD
Date of Drilling	Commenced 9 9 2000 Completed 14 9 2000

B CONSTRUCTION DETAILS

Borehole Datum (if not ground level) ______ above / m below GL

(point from which all measurements of depth are taken e.g. flange, edge of chamber, etc.)

Borehole drilled diameter 150 mm from GL to 63 m/depth
______ mm from ______ to ______ m/depth
______ mm from ______ to ______ m/depth

Casing material and type (e.g. if plain steel, plastic slotted) PLAIN STEEL diameter 150 mm from GL to 19.50 m/depth
______ diameter ______ mm from ______ to ______ m/depth
______ diameter ______ mm from ______ to ______ m/depth
______ diameter ______ mm from ______ to ______ m/depth

Grouting details ______

Water struck at 21 m (depth below datum — mbd)
45 m (depth below datum — mbd)

Rest water level on completion ______ mbd

C TEST PUMPING SUMMARY (Please supply full details on Forms WR-39)

Test Pumping Datum (if different from borehole datum) ______ m above / below borehole datum (mbd)

Pump Suction depth 35 mbd

Water Level (Start of Test) ______ mbd

Water Level (End of Test) ______ mbd

Pumping rate ______ m^3/d:l/s

for ______ days/hours

Recovery to (from end of pumping) ______ mbd in ______ mins: hrs: days

Date(s) of measurements ______

Please supply chemical Analysis if available.

D STRATA LOG SD64/69

Geological Classification (BGS only)	Description of strata	Thickness m	Depth m
	SAND & SILTY CLAY	6.00	6.00
	BOULDER CLAY	9.00	15.00
	MILLSTONE GRIT	48.00	63.00

(continue on separate page if necessary)

Other comments (e.g. gas encountered, saline water intercepted, etc.)

FOR OFFICIAL USE ONLY

FILE

CONSENT NO.

NGS REF NO.

LIC NO.

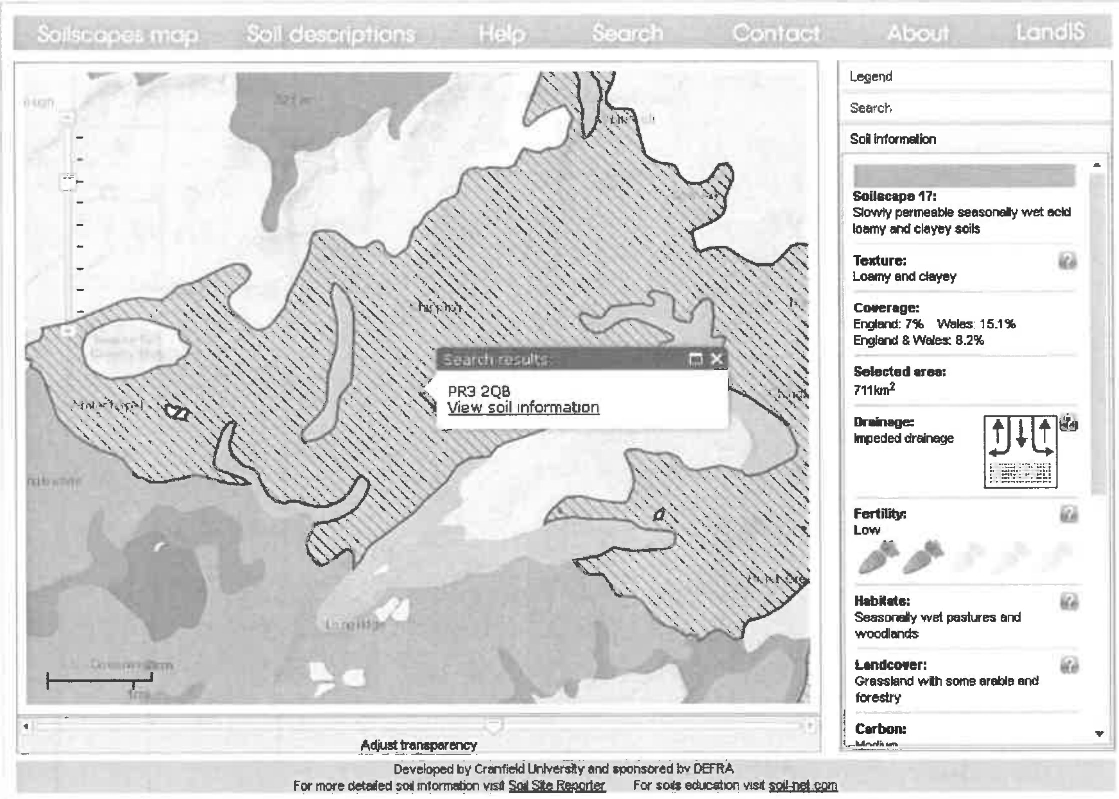
PURPOSE

NRA REF NO.

DATE REC:

COPY TO:

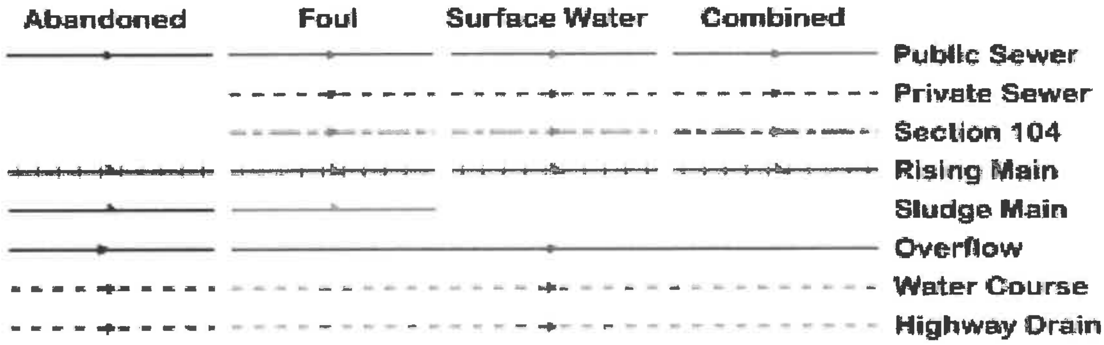
ENTERED BY:


Soilscapes map
Soil descriptions
Help
Search
Contact
About
LandIS
Legend
Search
Soil information
Soilscape 17:
Slowly permeable seasonally wet acid loamy and clayey soils
Texture:
Loamy and clayey
Coverage:
England: 7% Wales: 15.1%
England & Wales: 8.2%
Selected area:
711km2
Drainage:
Impeded drainage
Fertility:
Low
Habitats:
Seasonally wet pastures and woodlands
Landcover:
Grassland with some arable and forestry
Carbon:
Search results
PR3 2QB
View soil information
Adjust transparency
Developed by Cranfield University and sponsored by DEFRA
For more detailed soil information visit Soil Site Reporter For soils education visit soil-net.com

Appendix E
United Utilities Sewer Maps

United Utilities
helping life flow smoothly

Wastewater Symbology



All point assets follow the standard colour convention: red – combined, brown - foul, blue – surface water, purple - overflow

- Manhole
- HS Head of System
- ES Extent of Survey
- RE Rodding Eye
- IN Inlet
- DP Discharge Point
- VX Vortex
- PE Penstock
- WO Washout Chamber
- VA Valve
- AV Air Valve
- NRV Non Return Valve
- SO Soakaway
- GU Gully
- CA Cascade
- FM Flow Meter
- HA Hatch Box
- OI Oil Interceptor
- SM Summit
- DS Drop Shaft
- OP Orifice Plate
- Side Entry Manhole
- Outfall
- Screen Chamber
- IC Inspection Chamber
- Bifurcation Chamber
- LH Lamp Hole
- T Junction / Saddle
- Catchpit
- Valve Chamber
- Vent Column
- Vortex Chamber
- Penstock Chamber
- Network Storage Tank
- Sewer Overflow
- Ww Treatment Works
- Ww Pumping Station
- Septic Tank
- Control Kiosk
- Change of Characteristic

United Utilities
helping life flow smoothly

SEWER RECORDS

Address or Site Reference

Startifants Startifants Longridge Road,
Chipping,
PR3 2QB

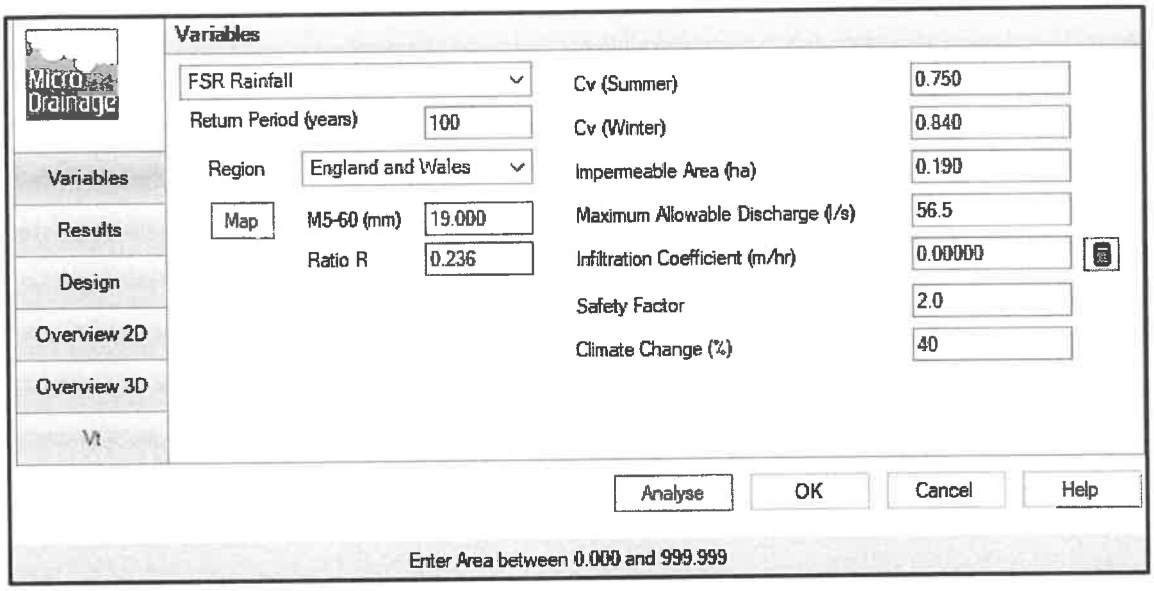
Scale: 1:5000
Date: 06/09/2018

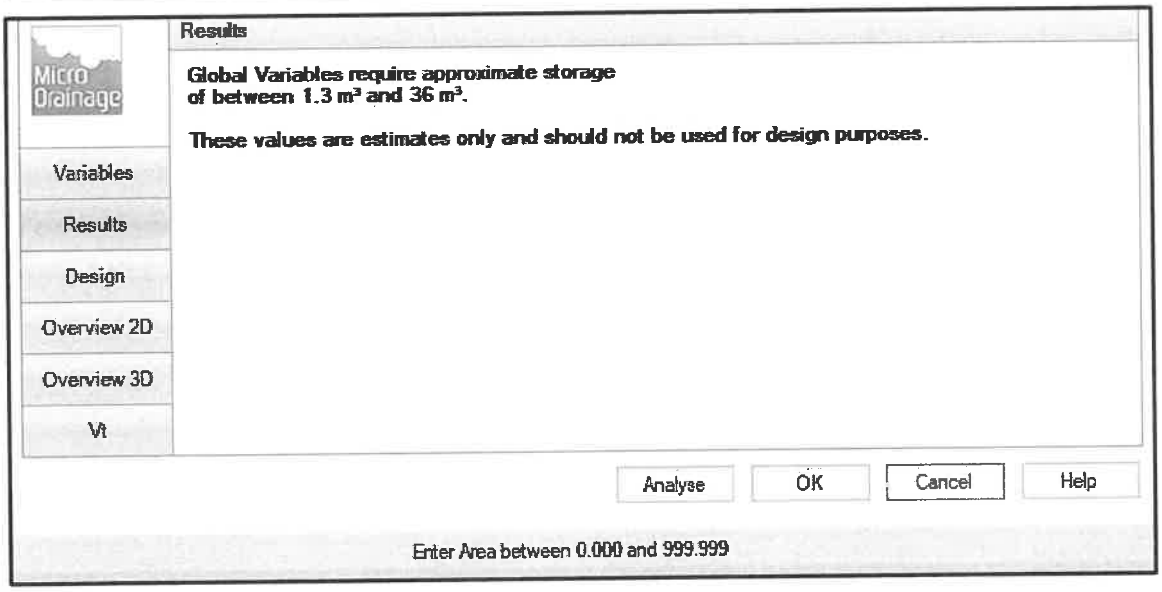
Printed by: Property Searches

The position of the underground apparatus shown on this plan is approximate only and is given in accordance with the best information currently available. United Utilities Water will not accept liability for any loss or damage caused by the actual position being different from those shown.

Appendix F
Indicative Attenuation Volumes

Indicative Attenuation Volumes





Appendix G
Flood Evacuation Guidance

Personal flood plan

Name

Environment Agency

Are you signed up to receive flood warnings? ☐
If not call Floodline on 0345 988 1188 to see if your area receives free flood warnings.

Let us know when you've completed your flood plan by calling Floodline on **0345 988 1188**.
This will help us learn more about how people are preparing for flooding.

General contact list	Company name	Contact name	Telephone
Floodline	Environment Agency		0345 988 1188
Electricity provider			
Gas provider			
Water company			
Telephone provider			
Insurance company and policy number			
Local council			
Local radio station			
Travel/weather info			

Key locations

Service cut-off	Description of location
Electricity	
Gas	
Water	

Who can help/who can you help?

Relationship	Name	Contact details	How can they/you help?
Relative			
Friend or neighbour			

Be prepared for flooding. Act now

Personal flood plan

What can I do NOW?

Environment Agency

- [ ] Put important documents out of flood risk and protect in polythene
- [ ] Check your insurance covers you for flooding
- [ ] Look at the best way of stopping floodwater entering your property
- [ ] Make a flood plan and prepare a flood kit
- [ ] Find out where you can get sandbags
- [ ] Identify who can help you/ who you can help
- [ ] Identify what you would need to take with you if you had to leave your home
- [ ] Understand the flood warning codes

What can you do if a flood is expected in your area?

Actions	Location
Home	
• Move furniture and electrical items to safety	
• Put flood boards, polythene and sandbags in place	
• Make a list now of what you can move away from the risk	
• Turn off electricity, water and gas supplies	
• Roll up carpets and rugs	
• Unless you have time to remove them hang curtains over rods	
• Move sentimental items to safety	
• Put important documents in polythene bags and move to safety	
Garden and outside	
• Move your car out of the flood risk area	
• Move any large or loose items or weigh them down	
Business	
• Move important documents, computers and stock	
• Alert staff and request their help	
• Farmers move animals and livestock to safety	
Evacuation - Prepare a flood kit in advance	
• Inform your family or friends that you may need to leave your home	
• Get your flood kit together and include a torch, warm and waterproof clothing, water, food, medication, toys for children and pets, rubber gloves and wellingtons	

There are a range of flood protection products on the market to help you protect your property from flood damage. A directory of these is available from the **National Flood Forum** at **www.bluepages.org.uk**

Be prepared for flooding. Act now

GEHO0709BQPU-E-E

Paul Waite Associates Ltd
Summit House, Riparian Way,
Cross Hills, Keighley,
West Yorkshire, BD20 7BW

t: 01535 633350
e: info@pwaite.co.uk
w: www.pwaite.co.uk

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