Staffordshire County Council

2020 Flood Events:

Flood and Water Management Act

Section 19 – Investigation,

Barton-under-Needwood

Figure 1: Flooding in Barton-under-Needwood after the February 2020 event – supplied by the Barton-under-Needwood Parish Council

This report has been prepared by Staffordshire County Council as Lead Local Flood Authority for Staffordshire County, under Section 19 of the Flood and Water Management Act 2010, with the assistance of Severn Trent Water and the Environment Agency.

This report is based on the information available at the time of preparation. Consequently, there is potential for further information to become available, which may lead to future alterations to the conclusions drawn in this report for which Staffordshire County Council cannot be held responsible.

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Executive Summary

When made aware of flooding, Staffordshire County Council (SCC), in its role as Lead Local Flood Authority (LLFA), has a duty to investigate the flood to determine the causes of the flooding and appropriate actions that may be undertaken by the relevant Risk Management Authorities (RMAs).

Several storms occurred across the Midlands region in 2020 that impacted many areas. These storms occurred as a result of European windstorms that became a series of extratropical cyclones bringing intense, short duration rainfall periods. In February 2020, a long duration, low-to-moderate intensity event, named Storm Dennis, led to severe weather warnings across much of Wales and the Midlands. As a result, a significant number of flooding incidents were recorded across Staffordshire, and reported to SCC, as well as nationwide.

SCC, in partnership with the Environment Agency, Severn Trent Water and appropriate Borough, District and Parish councils, have undertaken flood investigations in the areas where internal property flooding was reported to determine the most likely cause of this flooding (surface water flooding, flooding from rivers, flooding from sewer infrastructure, and/or flooding from highway drainage) singly or in combination.

This report focuses on flooding associated with Storm Dennis that internally affected properties in Barton-under-Needwood on the 16th February 2020. This investigation undertaken has been summarised, outlining the flood extent and flow routes reported, the most likely cause of flooding, and the relevant actions that have been completed or are to be undertaken in the future.

Introduction

Several storms occurred in the Midlands in 2020 that resulted in associated widespread flooding to properties and highways across Staffordshire. As a result, SCC has undertaken investigations in the areas where flooding has occurred to determine the most likely cause of flooding (surface water flooding, flooding from rivers, flooding from sewer infrastructure, and flooding from highway drainage), in accordance with the 2010 Flood and Water Management Act.

This report focuses on the event that occurred in Barton-under-Needwood as a result of Storm Dennis on February 16th 2020. This report aims to provide an investigation into the identified extent, reported flow routes, and potential causes of the flood event, as well as consider the next steps, if any, that need to be taken by the relevant RMAs.

Although this report specifically focuses on Barton-under-Needwood, flooding associated with Storm Dennis resulted in 130 applications for grant support from residential and business properties across East Staffordshire. Many areas also experienced incidents in which five or more properties were internally flooded, reaching the criteria for a Section 19 investigation.

Lead Local Flood Authority

Following Royal Assent of the Flood and Water Management Act in 2010 (FWMA), Staffordshire County Council (SCC) became the Lead Local Flood Authority (LLFA) for Staffordshire. As such, SCC is responsible for the management of surface water food risk, groundwater flood risk and the flood risk from ordinary watercourses[1].

As LLFA, SCC is required to work in partnership with other agencies and authorities to manage flood risk. These agencies and authorities include, but not exclusively:

- Environment Agency, who hold responsibility for Main Rivers;
- Severn Trent Water, who hold responsibility for the public sewer network;
- Emergency service providers; and,
- Other public agencies and bodies.

Section 19 Requirements

The FWMA also places a duty on Lead Local Flood Authorities to investigate incidents of flooding. This is set out in Section 19 of the act and the investigations are therefore typically termed '*Section 19 Reports*.' The Act states:

1) On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate

a) Which risk management authorities have relevant flood risk management functions, and

b) Whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in response to the flood.

[1] An ordinary watercourse is defined as any watercourse not designated as 'Main River,' i.e. watercourse that are not managed by the Environment Agency.

2) Where an authority carries out an investigation under subsection 1) it must

a) Publish the results of its investigation, and

b) Notify any relevant risk management authorities.

It should be noted that not all flooding will require a formal investigation and report. SCC has, set out in its *Local Flood Risk Management Strategy*[2]*,* the process which will be used to determine to what extent it considers is 'necessary or appropriate' to investigate and what constitutes a significant flood event.

Stage 1 is an initial assessment, sufficient to ascertain with some confidence the extent of the flooding consequences. The second stage is to carry out a detailed investigation of the sites where it has been deemed necessary and appropriate. Reporting and publishing is the third, and final, stage. These stages may be described as: -

- Stage 1: Initial assessment
- Stage 2: S19 Investigation
- Stage 3: S19 Report and publish

It follows that there will be requirements for coordination and cooperation between Risk Management Authorities at each stage and, where required, following the outcome of a S19 Investigation. This will be undertaken via day-to-day officer communication, and through the LLFA's governance process for flood risk management.

Flood Investigation Methodology

SCC will undertake/coordinate a Flood Investigation in accordance with Section 19 of the Flood and Water Management Act (2010) when one or more of the following thresholds are exceeded.

<u>Consequence Staffordshire Flood Investigation Thresholds</u>

- Five or more residential properties are reported to have been internally flooded during a single flood event in one location;
- Two or more business properties are reported to have been internally flooded during a single flood event in one location, or;
- One or more items of critical infrastructure are reported to have been adversely affected during a single flood event in one location

SCC may investigate flooding outside these categories, but only when all outstanding issues with a higher priority have been considered. These guidelines set numerical thresholds, however, in recognition of the fact that all floods will be different; a certain amount of discretion will be required in order to implement this policy effectively.

This policy only relates to how flood investigations will be prioritised and does not guarantee that any flood risk mitigation works will be installed at the locations where investigations are undertaken.

This report has been based on the number of reported incidents of flooding; however, it is likely that the actual number of incidents of flooding was higher than that reported. This data is the best currently available and is being verified and quality checked for accuracy.

[2] https://www.staffordshire.gov.uk/environment/Flood-Risk-Management/Local-Flood-Risk-Management-Strategy.aspx

Investigation into Flooded areas

Step 1: During the Flood Event

SCC received a high number of calls during the event, which reported flooding of properties, gardens, and highways.

During the flood event, the LLFA coordinated with multiple Risk Management Authorities (RMAs) to ensure that flooding was managed effectively and the risk to people and properties was mitigated as far as reasonably practicable.

Step 2: Initial Investigations

Using call records, flooding investigation questionnaires and site visits, the LLFA identified the locations where flooding occurred.

Responses were received, providing personal accounts of the flood event including the estimated time, duration, extent, and depth with any other information which was felt pertinent.

Following receipt of the Flood Survey responses, the LLFA identified areas where at least one property experienced internal flooding.

Step 3: Detailed Investigation and Analysis

The LLFA conducted detailed investigation and individual location analysis of each of the areas where a minimum of one property experienced internal flooding. It should be noted that SCC have defined internal property flooding as:

‘Flooding that occurs in a habitable room within a single property, excluding garages, porches and underfloor ingress of water.’

These investigations typically included a review of existing infrastructure and topography, identification of predominant flow paths, site visits and local knowledge gathering.

Through a detailed analysis, the LLFA have identified the types of flooding that occurred at each location during the events of February 2020.

As a general rule, the LLFA does not undertake detailed investigation of external flooding to garages, gardens, and highways due to limited resources and funding. Indeed, gardens often act as flood storage areas and highways can be designed to convey flood waters reducing the extent/level of internal property flooding.

Step 4: Recommended Actions

Following the analysis of the affected area, the LLFA have worked in collaboration with other RMAs to identify opportunities and options to mitigate the potential that a similar rainfall event will result in similar outcomes. These have been summarised as ‘Recommended Actions’ and a lead RMA has been identified to undertake these actions.

Types of Flooding

The following section explores the various types of flooding that may have been experienced during the Storm Dennis event in February 2020.

Surface Water Flooding

Surface water is rainwater which is on the surface of the ground and has not soaked into the ground or entered a watercourse, drainage system or sewer. During a storm event, rainfall will land on the ground and depending on the characteristics of the ground it will behave in different ways.

Permeable surfaces, sometimes colloquially known as *'soft surfaces'*, allow water to soak (infiltrate) into the ground. These are typically in the form of gardens, parks, fields and green spaces,

Impermeable surfaces, sometimes colloquially known as *'hard surfaces'*, do not allow any rainfall to soak into the ground and this rainfall will become (surface water) runoff. Runoff is usually very quick too. These are typically in the form of highways and roads, roofs, car parks and public squares.

Surface water flooding occurs under a number of circumstances, most commonly occurring when:

- There has been a prolonged period of rainfall and the permeable surface becomes saturated therefore no more water can infiltrate into the ground;
- The rainfall intensity is very high, and the rain is falling faster than it can infiltrate into the ground;
- There has been a prolonged warm dry period, the permeable surface may be baked hard and effectively turn the permeable surface into hard impermeable surface;
- It rains on impermeable surfaces, and there is no formal means of managing the rainfall;
- There is heavy rainfall on impermeable surfaces and surface water cannot enter the drainage system provided to manage rainfall as the system is at capacity.

During most storm events, the rainfall rate is low enough to allow surface water to soak into the ground or drain into formal drainage systems (e.g. gully pots). However, during an extreme event, where the intensity of the rainfall is high or there is an excessive volume of water, it is unable to soak into the ground or enter formal drainage systems and as such it will flow across a surface in an uncontrolled manner.

River Flooding

River flooding occurs when the amount of water in a river channel exceeds its capacity. This causes the water level in the river channel to rise above the riverbanks, where water flows from the channel into the surrounding area.

In terms of flood risk management there are two classifications of rivers/watercourses:

Main River; and ***Ordinary Watercourse***.

The Environment Agency holds responsibility for the management of flood risk on Main Rivers. All other watercourses, which are not specified as Main Rivers are termed Ordinary Watercourses. Flood risk management of these watercourses is the responsibility of the LLFA. However, in both cases, the riparian owner, that is anyone who owns land or property next to, or over, a watercourse, is responsible for maintenance of watercourse through their land.

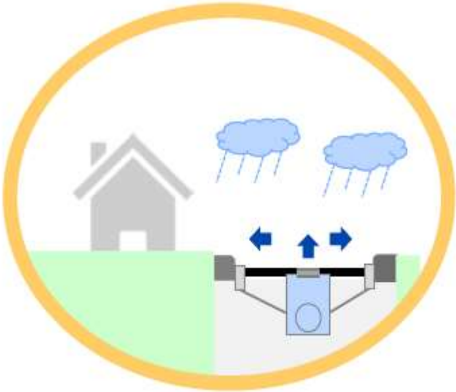
River flooding occurs under a number of circumstances, most commonly occurring when:

- There has been a prolonged period of rainfall and the river levels have risen due to surface water runoff and inflow from sewer infrastructure;
- There has been a prolonged period of rainfall whereby permeable surface become saturated and the rate of surface water runoff increases thereby reaching the river faster;
- There is heavy rainfall on impermeable surfaces and the provided drainage system conveys water to the river quickly;
- There are high flows within the river which become restricted by structures (e.g. bridges and culverts) which results in water levels upstream rising and spilling from the banks;
- Sediment and debris building up in the river channel and reduces the capacity of the river channel causing flows to spill from the banks.

During most storm events, rivers are capable of conveying flows within their channels however, during an extreme event where the volume of water may be significant, flows may exceed the channel capacity and spill from the river in an uncontrolled manner.

Flooding from Sewer Infrastructure

Where rainfall falls on an impermeable surface, it will typically be served by a formal drainage system, most commonly this is a sewer.



There are different types of sewer, including:

Surface Water Sewers carry rainfall and surface water away from properties to watercourses;

Foul Water Sewers carry wastewater away from properties to be treated; and,

Combined Sewers drain both wastewater from properties along with runoff from highways, roofs, car parks and other sources. These systems were typically constructed up to the 1950s and hence are still found in historic areas of cities.

Flooding from sewer infrastructure occurs under a number of circumstances, most commonly when:

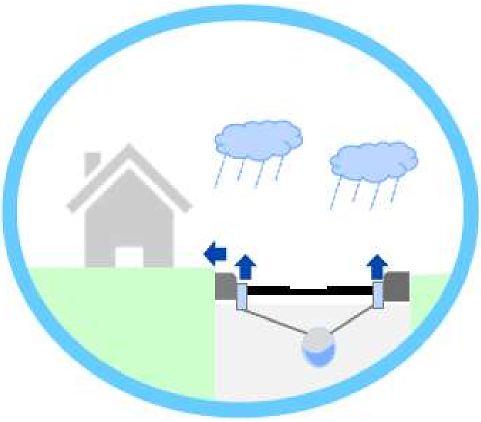
- There is a blockage, or the sewer itself collapses, which restricts or prevents flow within the sewer network. This causes water to back-up through the network and find its way to the surface, typically through a manhole or associated drainage structure.
- There is a period of heavy and/or prolonged rainfall, which results in significant flows that exceed the capacity of the sewer network. This prevents water from entering the sewer network and may result in surface flooding.

Severn Trent Water, as the sewerage company, is responsible for the operation and maintenance of the public sewers within the Staffordshire area.

Surface water and foul water sewers are currently designed in accordance with Sewers for Adoption (8th Edition, published 2018). This guidance states that sewers should have to capacity to deal with all runoff from a storm with a 3.33% or greater probability of occurring in any given year and not cause any above ground flooding. This guidance is relatively recent having been brought into effect in approximately the last 10 to 15 years. In addition, improvements in computer aided design and calculations also ensure designs are in agreement with the existing standards.

Therefore, at the time of construction of much of the sewer network across Staffordshire, the design standards may have been to accommodate a smaller storm event. The designs will likely have been done by hand and may have used “rules of thumb” to determine the required sizes. As a result, the drainage network is complex with some sewers able to accommodate storms well above current design standards and other sewers much lower. Thus, when a large storm event occurs, the existing drainage network (combined or surface water sewers) may be significantly overwhelmed.

Flooding from Highway Drainage



Highway drainage consists of gullies, drainage channels and other features which collect and drain rainfall away from the highway. These features are typically located on one, or both, side(s) of the highway where they connect to an underground highway drainage system which ultimately connects to the public sewer infrastructure or discharges to a watercourse.

Where rainfall falls onto the highway, this will enter the highway drainage system or flow within the highway channel until a point where it enters the system or ponds on the surface.

In new development, it is common practice to use highways to contain and convey heavy rainfall events away from properties, however historically this practice has not happened.

Across Staffordshire, properties can be seen at or below the level of the adjacent road. This means that should a carriageway not be able to contain the water flowing within it, flow will overtop the kerbs on the highway and spill over adjacent land into properties.
Flooding from highway infrastructure occurs under a number of circumstances, most commonly occurring when:

- There is a blockage or build-up of surface debris in the vicinity of a gully, typically trash, leaves and twigs, which prevents, or restricts, the highway runoff from entering the gullies and subsequent highway infrastructure.
- There is a period of heavy and/or prolonged rainfall, whereby the volume of rainfall falling onto the highway overwhelms the highway drainage features and is unable to be captured. The resulting flows are then conveyed or contained within the highway, until such times as the water level overtops the kerbs and flows overland into properties.
- The sewer, culvert or watercourse to which the highway drainage is connected is at full capacity and therefore the highway run-off has no-where to drain to.
- There are insufficient gullies or gullies are not located correctly.

Staffordshire County Council, in their role as the local highway authority, is responsible for the highway drainage and gullies across Staffordshire. This work includes maintenance of the highway drainage including roadside gully pots.

Flood Risk Mapping

Flooding is traditionally very difficult to predict, and while there are many local factors that influence flooding, there are a number of publicly available, national information tools which can enhance our understanding of the potential flood risks within a local area, more specifically risk of flooding from surface water and from rivers.

Surface Water Flood risk

In 2013, the Environment Agency, working with LLFAs, produced the Risk of Flooding from Surface Water map. This is the third national surface water map produced by the Environment Agency under their Strategic Overview role and is the first publicly available surface water flood risk map.

Storms are usually given with an annual probability or the chance of occurring in any given year. Typically, smaller storms have a higher probability of occurring in any given year and larger storms have a lower probability of occurring.

However, the probability only describes the chance a storm will occur and not when. This means that if a large, low probability storm occurs, it can happen again soon after or can happen a long time after.

This mapping assesses surface water flood risk as a result of the chance of rainfall occurring in any given year, and is categorised into the following three scenarios:

High Risk: Flooding occurring as a result of rainfall with a greater than 1 in 30 chance in any given year or 3.3% chance that the storm will occur in a single year

Medium Risk: Flooding occurring as a result of rainfall between 1 in 100 and 1 in 30 chance in any given year or between 1% and 3.3% chance that the storm will occur in a single year

Low Risk: Flooding occurring as a result of rainfall between 1 in 1000 and 1 in 100 chance in any given year or between 0.1% and 1% chance that the storm will occur in a single year

Very Low Risk: Flooding occurring as a result of rainfall with less than 1 in 1000 chance in any given year or less than 0.1% chance that the storm will occur in a single year.

It should be noted that this mapping has been produced at national scale with a number of assumptions and therefore there are some limitations at a local scale and it is not appropriate for identifying individual property level flood risk. This mapping is publicly available for use, and is available online at:
https://flood-warning-information.service.gov.uk/long-term-flood-risk/postcode

Figure 2: Example of Environment Agency updated Flood Map for Surface Water Flooding

River Flood Risk

With regards to river flooding the Environment Agency publish the Flood Risk from Rivers or the Sea map. This shows the flood risk from Environment Agency Main Rivers and from the sea, taking into account any flood defences that may be present.

Storms are usually given with an annual probability or the chance of occurring in any given year. Typically, smaller storms have a higher probability of occurring in any given year and larger storms have a lower probability of occurring. However, the probability only describes the chance a storm will occur and not when. This means that if a large, low probability storm occurs, it can happen again soon after or can happen a long time after.

This mapping assesses flood risk from rivers or the sea as a result of the chance of rainfall occurring in any given year, and is categorised into the following four scenarios:

High Risk: Flooding occurring as a result of rainfall with a greater than 1 in 30 chance in any given year or 3.3% chance that the storm will occur in a single year

Medium Risk: Flooding occurring as a result of rainfall between 1 in 100 and 1 in 30 chance in any given year or between 1% and 3.3% chance that the storm will occur in a single year

Low Risk: Flooding occurring as a result of rainfall between 1 in 1000 and 1 in 100 chance in any given year or between 0.1% and 1% chance that the storm will occur in a single year

Very Low Risk: Flooding occurring as a result of rainfall with less than 1 in 1000 chance in any given year or less than 0.1% chance that the storm will occur in a single year.

This modelling is publicly available as the Environment Agency's Flood Risk from Rivers or the Sea map and is available online at:
https://flood-warning-information.service.gov.uk/long-term-flood-risk/postcode

Figure 3: Example of Environment Agency River Flood Zone mapping

Analysis of Flooding Locations

The following sections describe the flooding event that occurred in the centre of Barton-under-Needwood and flooded properties on Brookside Road, Wales Lane, Collinson Road, Church Lane, St James Road, Efflinch Lane, Meadow Rise, Mill Lane, Mill Crescent, and Lichfield Road on February 16th, 2020. The flood incident on Lichfield Road near Branston has been investigated in a separate Section 19 report. The event has been assessed by reviewing the evidence collected from the Parish Council, local resident surveys, and through consultation with the various RMAs.

Event Background

Several storms occurred in winter 2019-2020 across the UK and the Midlands. The combined impacts of Storm Ciara and Storm Dennis resulted in exceptionally high rainfall totals across the UK, with associated flooding in several areas.

Storm Dennis (15th-16th February 2020) was the fourth named storm in the 2019/20 season, which arrived one week after Storm Ciara and brought with it heavy and persistent rainfall[3]. Twelve and six months prior to Storm Dennis, Staffordshire had exceptionally high rainfall compared to the average (**Figure 3**). Rainfall in December and January was unremarkable. However, rainfall totals in February were exceptionally, with February the wettest month in a series from 1862; the England figure was 258% of the long-term average (1981-2010). Crucially, soil moisture deficit from December 2019 through to February 2020 was generally practically zero/remained close to zero in Central England[3] (**Figure 4**). This means in the time running up to Storm Dennis there was generally little to no capacity within soils to drain or infiltrate rainfall. River flows in large rivers were also exceptionally high through February.

On 14 February, Storm Dennis developed off the west coast of Ireland moving east and arriving in England early afternoon. By mid-afternoon the front swept into Staffordshire and by late Friday night/early hours of Saturday morning this front had passed east out of Staffordshire. On Saturday 15 February a large front of rainfall developed in the morning and approached Staffordshire quickly, sustaining through to mid-day and continuing to remain over Staffordshire until early afternoon on Sunday 16 February. **Figure 5** shows radar-images of the rainfall across the UK. Through the rest of Sunday, the sustained/persistent rainfall moved over the rest of Europe, leaving scattered rainfall showers over Staffordshire through to Monday. For a more detailed account of Storm Dennis please refer to [The Met Office](https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2020/2020_03_storm_dennis.pdf)[4] and [Centre for Ecology and Hydrology](https://nrfa.ceh.ac.uk/sites/default/files/Briefing_Note_V6.pdf)[5].

[3] Met Office – Winter 2019/2020 https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/summaries/uk_monthly_climate_summary_winter_2020.pdf

[4] Met Office – Storm Dennis https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2020/2020_03_storm_dennis.pdf

[5] Centre for Ecology and Hydrology – Briefing note: Severity of the February 2020 floods – preliminary analysis https://nrfa.ceh.ac.uk/sites/default/files/Briefing_Note_V6.pdf

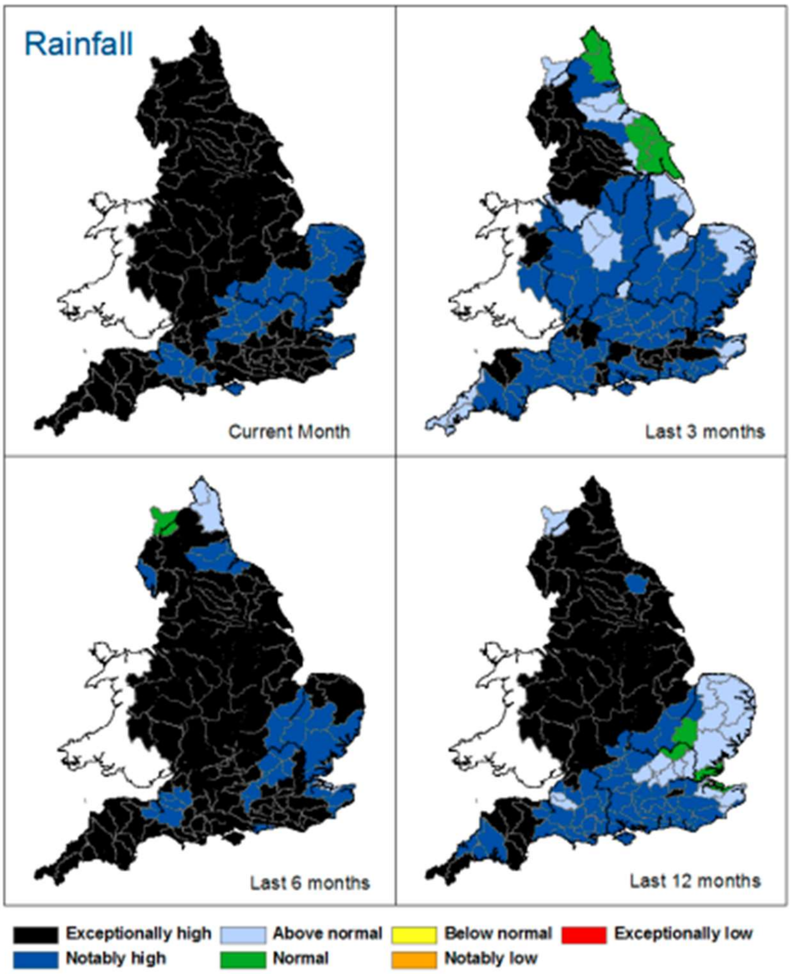


Figure 4: Total Rainfall Across England up to February 28th 2020 (Source: Environment Agency[6])

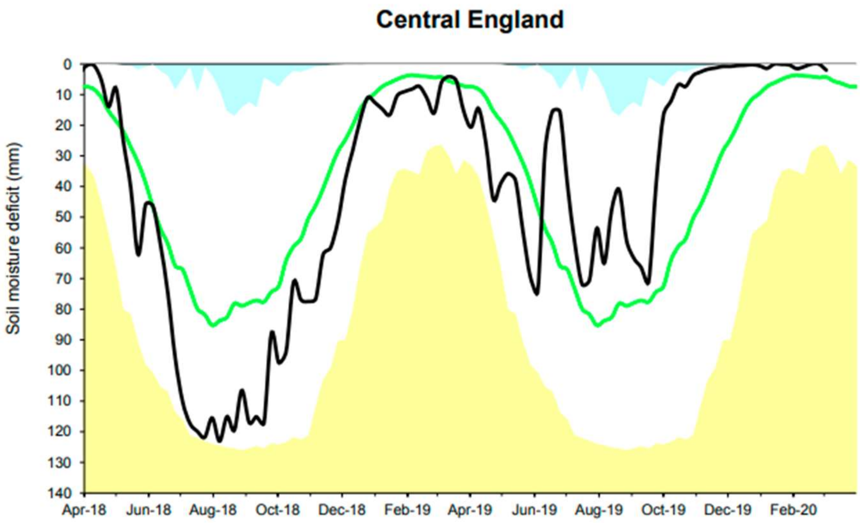


Figure 5: Central England Soil Moisture Deficit (Source: Environment Agency[6])

[6] Environment Agency – Monthly water situation report: England
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/871949/Water_situation_February_2020.pdf

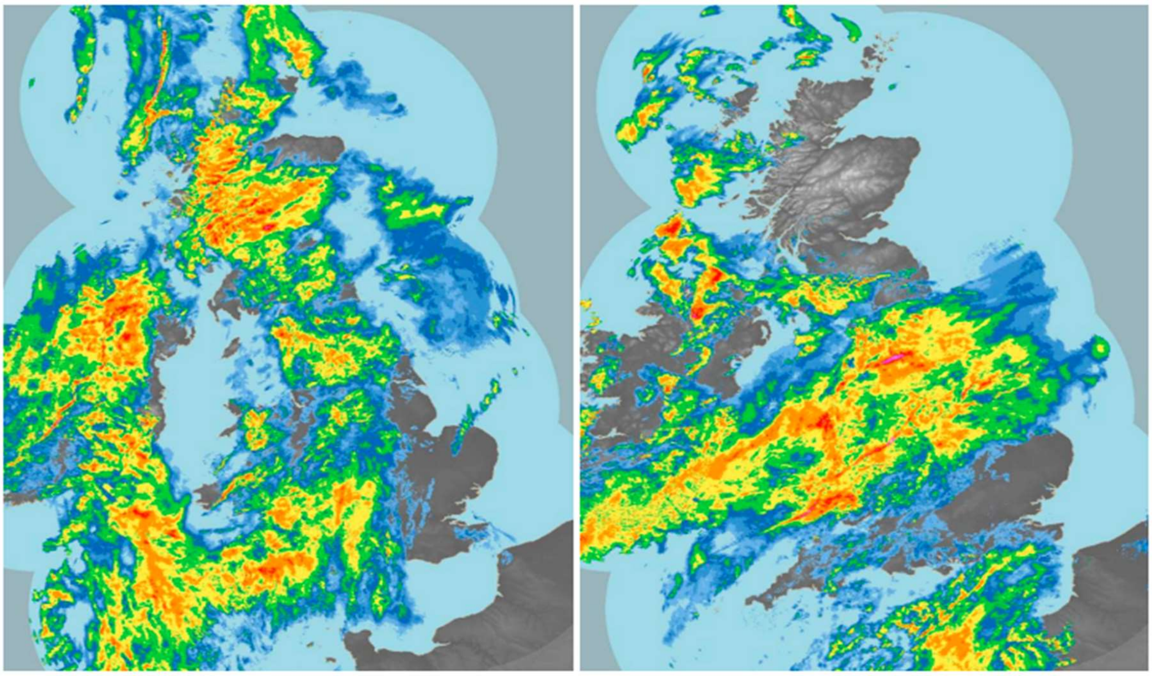


Figure 6: Rain-radar images at 12 UTC 15th and 00 UTC 16th February 2020 show the heavy and persistent rainfall from storm Dennis with the fronts sweeping across the UK (Source: The Met Office[4])

Location Background

Figure 6 shows the location of Barton-under-Needwood, a large village with an area of 1441.8 ha located between Burton-upon-Trent and Lichfield in East Staffordshire. The elevation of Barton-under-Needwood ranges from 50m AOD at the River Trent, east and south-east of the village, to 86m and 94m AOD north of the village. The village is predominately residential, but several independent shops and public houses are located along Main Street and Station Road (the B5016 prior to reaching Barton-under-Needwood). The Parish Council office is located on Crowberry Lane, off Main Street, whilst a community health and care centre and fire station are located on Short Lane.

To the east of Barton-under-Needwood there are several storage ponds and the Barton Marina, that has several independent shops and businesses. The Barton Marina joins the Trent and Mersey Canal above Barton Lock. A Severn Trent Water wastewater treatment plant is also in located by the Barton Marina along Station Road.

The underlying geology is made up of gravel and sand deposits, underlain by mudstone, siltstone, and sandstone bedrock. The sand and gravel are noted to be alluvial and could include a high percentage of silt and clay. A study of limited local borehole records identifies several metres of dense fine silty sand and gravels over mudstone.

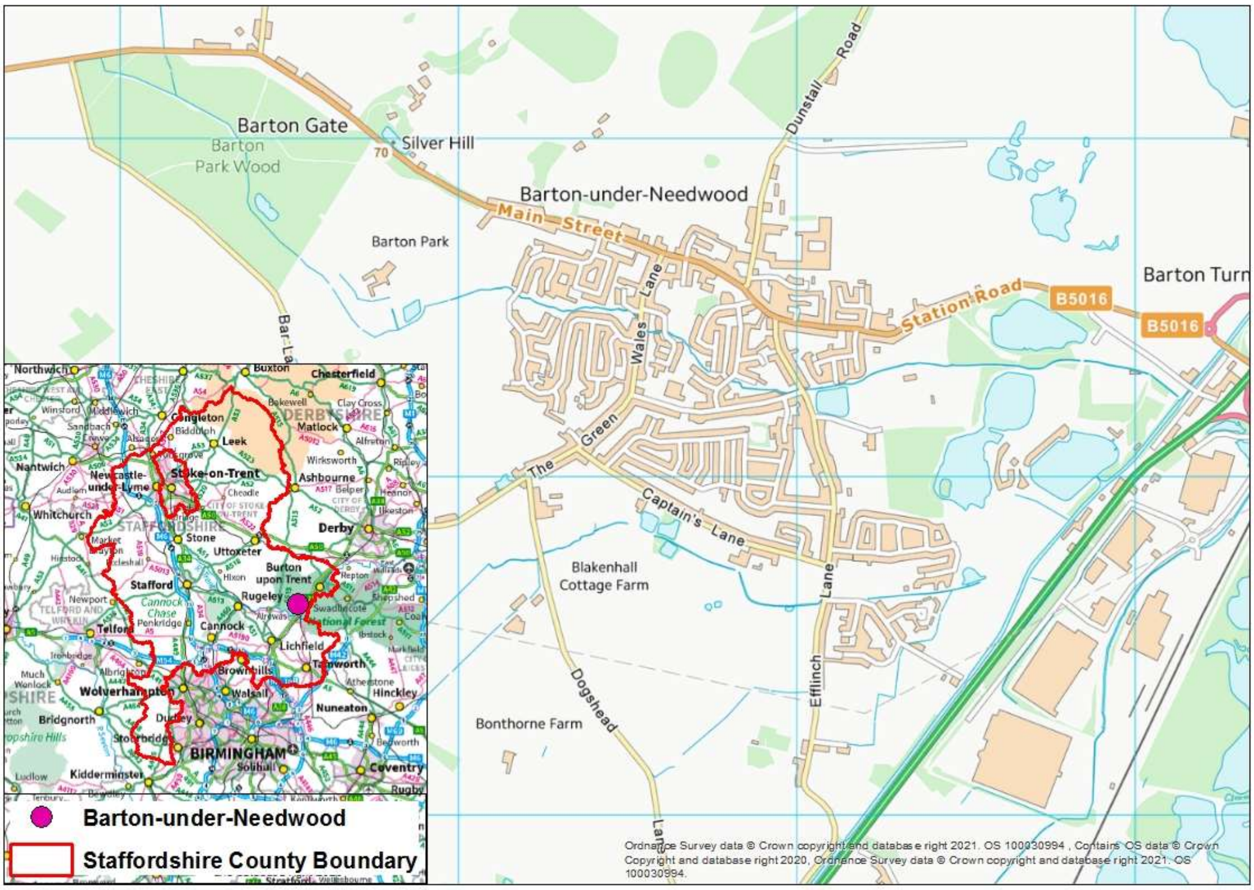


Figure 7: Location map of Barton-under-Needwood

Local Watercourses:

There are several watercourses discharging through and around Barton-under-Needwood (**Figure 7**). The Barton Brook is designated as a main river and discharges through the centre of Barton-under-Needwood, while the Full Brook ordinary watercourse discharges south, adjacent to Barton-under-Needwood, and through the south-east residential area of Mill Lane and Mill Crescent. Additional smaller and unnamed drainage watercourses discharge around the village.

The Barton Brook is a tributary of the River Trent, with a catchment area of approximately 4.55km^2, that originates north of Barton Park Wood on agricultural land, and flows in an eastern direction where it is culverted under the B5016 and through an open section in the wood and Barton Park Farm to reach Barton-under-Needwood. Before reaching Barton-under-Needwood the Barton Brook is designated as an ordinary watercourse and is the responsibility of the riparian landowners. Once entering Barton-under-Needwood, the Barton Brook, from Park Road, is designated as a main river and is the responsibility of the Environment Agency. Through Barton-under-Needwood, the Barton Brook is heavily enclosed with many culverts under several residential roads, including Park Road, Wales Lane, Collinson Road, St James Road, Efflinch Lane, and a proportion of Potters Way.

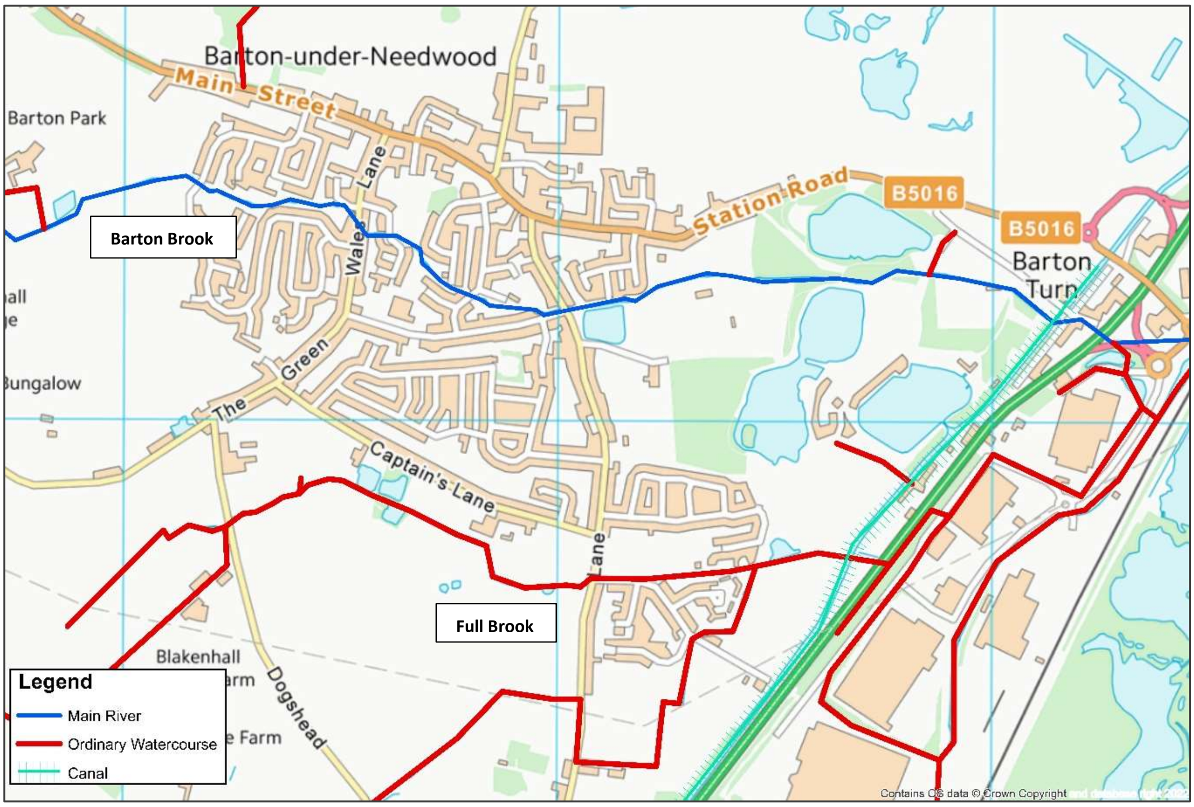


Figure 8: Watercourses discharging through and around Barton-under-Needwood that include the Barton Brook (main river) and the Full Brook (ordinary watercourse). This information is from the Detailed River Network (DRN) that may not include all present flow paths. This includes a discrepancy noted by the Barton Parish Council on the direction of the unnamed watercourse that joins the Full Brook, that has an additional direct flow path across land towards Mill Lane.

When discharging out of the village, the Barton Brook flows towards the Barton Turn and is culverted under the marina entrance, the Severn Trent Water plant entrance, the Trent and Mersey Canal, the Barton Turn, and under the A38 (Lichfield Road). After exiting the culvert under the Lichfield Road, it flows through some storage ponds and under the railway tracks east of Barton-under-Needwood to drain into the River Trent by Walton-under-Trent.

The Full Brook is an ordinary watercourse that flows in an eastern direction, parallel to the Barton Brook, south of Barton-under-Needwood but intercepts the village at Efflinch Lane and flows adjacent to Mill Lane and Mill Crescent. The Full Brook has a catchment area of approximately 1.12 km^2 and originates as agricultural land runoff from surrounding farmland. The Full Brook is culverted under Efflinch Lane and at three small footbridges. The first footbridge joins Mill Lane to a footpath north of the Full Brook, while the second and third cross the Full Brook east of Barton-under-Needwood. An additional, unnamed watercourse is culverted further south under Efflinch Lane, which initially flows through agricultural land. After Efflinch Lane it is culverted under Mill Lane and a small footpath, to then join the Full Brook northeast of Mill Crescent. The Full Brook then flows east and is culverted under the Trent and Mersey Canal and A38 to ultimately join the Barton Brook to drain into the River Trent.

Three small watercourses also discharge around Barton-under-Needwood. The first, named Knoll Brook, drains from land by the Mill House, north of Main Street, and is culverted under Main Street, Wales Lane, and Short Lane until it joins Barton Brook by the confluence of Short Lane and Efflinch Lane. The second, referred to as the Marina Watercourse, discharges from the marina and is culverted under the Trent and Mersey Canal that subsequently enters a ditch around Barton Business Park, and is further culverted through a linear storage ditch that joins the Barton Brook upstream of the railway. The final small watercourse drains from Barton Village towards Barton Turn and then outfalls to the Barton Brook, adjacent to the sewage works entrance east of Barton-under-Needwood.

Highway Drainage and Public Sewer Network:

The local highways drainage network comprises of traditional highway gullies. A series of highway gullies are located along all public roads in Barton-under-Needwood. Staffordshire County Council highways department are responsible for the maintenance of this network and implement a three-year maintenance schedule.

Barton-under-Needwood is fed by gravity foul and surface water sewer systems within the main residential areas, with a combined foul and surface water sewer system present along some main roads.

Previous Watercourse and Sewer System Management:

The Environment Agency, Staffordshire County Council, Severn Trent Water and Barton-under-Needwood Parish Council have previously established a working group to consider options to reduce flood risk to the village. This includes drop-in surgeries for residents in 2014 and 2015 to discuss flood issues and potential improvement plans with all relevant organisations.

An improvement scheme for the Barton Brook drainage system was undertaken in 1989 as part of the residential development around the village centre. A water main obstructing the current drainage system and culverts was diverted as part of this. However, the new system is suggested to have increased peak discharges during heavy precipitation events to the Barton Brook.

In March 2016, Severn Trent Water completed a £1 million improvement scheme around Lichfield Road section of the A38 highway, east of Barton-under-Needwood, to improve the treating of sewage and stormwater and to increase the capacity of sewer pipes. Sewer cleansing around Mill Crescent increased to a 6-month cycle in 2013. Flow monitors were installed on combined foul and stormwater sewer systems throughout Barton-under-Needwood, and Severn Trent Water installed non-return valves to provide short-term mitigation for properties flooded by sewage after flooding in 2012 and 2013. Further sewer flood incidents in the village have been rectified by sewer cleansing such as incidents impacting St Luke’s Road.

In 2020, subsequent to the February flood incident detailed in this report, Staffordshire County Council completed a scheme to mitigate flooding from the Knoll Brook in Barton-under-Needwood. The scheme reduced flood risk to properties along Main Street by upgrading two linear trash screens and a grill, fixing collapsed pipework from damages due to recent utility work, utilising storage already available by reinstating and excavating an open ditch section, constructing an earth bund to deflect flows and improved highway storage with gully improvements and utilising the discovery of an existing tank. The scheme was completed in 2020 but was not completely operational at the time of the flood incident. More information about this scheme is provided in the Knoll Brook Alleviation Scheme section of this report.

Historical Flooding in Barton-under-Needwood

Several previous flood events have occurred in Barton-under-Needwood along the Barton Brook and other watercourses during severe rainfall events. The most notable historic flooding that affected 50 properties reportedly occurred in August 1987. More recently, flooding occurred in the village in December 2007, as well as significant flooding to properties in July 2012 and November 2012 that impacted properties on Main Street from the Knoll Brook. Further flooding of Barton-under-Needwood from the Barton Brook is reported to have occurred in January 2013 and February 2014 that impacted St Luke's Road. During these events, flooding upstream of culvert entrances on Wales Lane, St James Road and Efflinch Lane has been common.

The Full Brook overtopped its banks in 2013 that flooded gardens and drives, but no property flooding occurred. The flood incident also resulted in foul sewer flooding to rear gardens of several properties along Mill Lane and Mill Crescent that subsequently entered properties through airbricks.

The bedrock mixture generally has low permeability and is not conductive to groundwater flooding. The East Staffordshire Strategic Flood Risk Assessment states there are few recorded groundwater flooding incidents in the region.

Environment Agency Flood Maps:

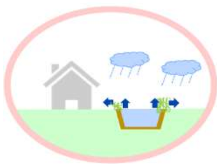
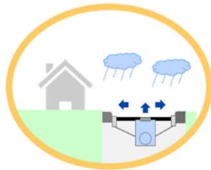
Barton-under-Needwood is at risk from multiple sources of flooding. **Figure 8** and **Figure 9** below display the Environment Agency Risk of Flooding from Rivers and Sea (flood zone mapping) and Risk of Flooding from Surface Water maps for Barton-under-Needwood. The flood zone map shows large parts of central Barton-under-Needwood in Flood Zones 2, that represents a projected flood risk of between 1% and 0.1% Annual Exceedance Probability (AEP) yearly, and Flood Zone 3, that represents a risk of Barton Brook watercourse flooding greater than 1% AEP yearly. Large parts of the village are also at risk of surface water flooding, particularly associated with the ordinary watercourses in the village including the Full Brook.

Figure 9: Environment Agency Risk of Flooding from Rivers and Sea Flood (RoFRS) map that shows the outlines for Flood Zone 2 and Flood Zone 3 for Barton-under-Needwood

Figure 10: Environment Agency Risk of Flooding from Surface Water (RoFSW) map outlines (1 in 30 years, 1 in 100 years and 1 in 1000 years) for Barton-under-Needwood

February 2020 Flood Event

On February 16th, multiple properties in Barton-under-Needwood reported that they had experienced internal flooding. Details suggest the source of flooding was a combination of surface water flooding, river flooding and overwhelmed sewer infrastructure that resulted in sewer flooding.

Identified Flooding Types		
Surface Water	**River**	**Sewer**
		

Reports from residents describe that water entered properties in the early hours of Sunday 16th February 2020. Details provided by affected residents, Barton-under-Needwood Parish Council and East Staffordshire Borough Council (ESBC) to SCC and the Environment Agency indicate that approximately 69 residential properties in Barton-under-Needwood were internally flooded by river flooding from the Barton Brook, the Full Brook and the Knoll Brook, surface water and sewer flooding, with several other properties in the village very close to internally flooding. Affected residential roads include Brookside Road, Church Lane, Collinson Road, Efflinch Lane, Lichfield Road, Main Street, Meadow Rise, Mill Crescent, St James' Road, Wales Lane and Mill Lane. Several gardens, garages, sheds, and driveways external to properties were also reported to have flooded, with floodwater just below the threshold of further properties. Some affected households had to move out of properties following the flood event due to floodwater damages and loss of electricity to ground floors. No commercial properties or critical infrastructure were inundated.

Flood Incident Response:

Barton-under-Needwood is covered by the Burton-upon-Trent River Trent flood alert that is issued based on gauge information near Alrewas, south of Barton-under-Needwood. Consultation with the Environment Agency indicates that a flood alert was issued for the Burton-upon-Trent area on the 15th of February 2020 at 12:39. On the February 16th at 15:01 this was upgraded to a flood warning for the Burton-upon-Trent area.

The flooding was reported to SCC and the Environment Agency by the Barton-under-Needwood Parish Council. During the flooding, residents cleared grills and took note of flood routes and flooded locations. Local volunteers also removed obstructions near the Full Brook as it exits Barton-under-Needwood to allow floodwater to drain into areas towards the east of Barton-under-Needwood. This information was passed to the relevant RMAs by the Parish Council, along with information from residents on which properties reported internal flooding.

Subsequent to the flooding, Environment Agency field teams were deployed to Barton-under-Needwood and cleared the culvert sections of the Barton Brook by the A38 that is maintained by the Highways Agency. SCC attempted to visit during the event but could not get through due to flood waters.

ESBC also collected information from residents that had flooded to assist with processing Flooded Property Claims to help fund repairs for damages caused by the February 2020 event. 130 applications for grant support from residential and business properties across East Staffordshire were received. By the end of the scheme, the DEFRA Property Flood Resilience grant scheme and ESBC will have provided grants to approximately 86 properties that equals an approximate value of £370,840 across the Borough.

Investigation

Following the flood event, Staffordshire County Council (LLFA) has worked in conjunction with the relevant RMAs and Barton Parish Council to obtain data to help understand what happened on 16th February 2020.

The flooding experienced in Barton-under-Needwood has been identified as river flooding from both the Barton Brook and Full Brook, surface water flooding, and overwhelmed sewer systems resulting in flooding. Highway drainage was overwhelmed on Wales Lane, Efflinch Lane and Mill Lane, where is it present, from ingress of watercourse flows from the Barton Brook and Full Brook and is associated with river flooding rather than independent highway flooding. The catchment area received more than average rainfall for February that saturated the catchment prior to the flood incident, and intense precipitation during the Storm Dennis event. Flows rising and overtopping from the Barton Brook and Full Brook were the primary driver during the flooding incident.

In response to the February 2020 flood event, the Environment Agency are further investigating the mechanisms of the flooding from the Barton Brook and have begun to develop options for a flood alleviation scheme to reduce this river flooding. More information about this proposal is available in the following section.

Rainfall event:

On the 15th and 16th of February, Storm Dennis generated a severe weather warning over much of the Midlands. The Storm Dennis event has been characterised as a long duration, low to moderate intensity rainfall event that spread over a large catchment and is typical with winter rainfall storm events. **Figure 10** shows the recorded 15-minute rainfall for Barton-under-Needwood for this event. A total of 29.1mm of rainfall was recorded over the two days, with the peak of 26.5mm falling between 21:00 on February 16th and 13:30 on February 17th. The return period of this rainfall event has been calculated as a 1-year return period by HydroMaster software. Although this presents the event as unsignificant, the average rainfall for February (1981-2010 baseline) for the area, recorded by the closest Staffordshire Met Office climate station in Denstone, is 62.1mm. Therefore >50% of the monthly rainfall fell around the Barton-under-Needwood within two days making it significant to the area.

This intense rainfall was widespread across the catchment and larger area of Staffordshire (**Figure 11**). Verifying this data, similar rainfall totals for the same time-period were recorded by DEFRA Environment Agency rain gauges within the area. The closest gauge to Barton-under-Needwood, Byrkley Park gauge, recorded a total of 40.6mm for the two days of February 15th and 16th. Of this total, a significant 31.8mm peak rainfall was recorded during 21:30 on February 15th and 07:00 February 16th. Comparable rainfall values were also recorded at Overseal rain gauge, that recorded 42.4mm of rainfall, and Clay Mills rain gauge, that recorded 43.8mm of rainfall, for February 15th and 16th of February. This rainfall data for the surrounding area, including the intense period of rainfall recorded at Brykley Park at a similar time to Barton-under-Needwood, shows an excess of 40mm of rainfall fell over the wider area surrounding Barton-under-Needwood prior to the flood event on February 17th, whilst soils were already saturated and river levels remaining high throughout the catchment from Storm Ciara the previous week.

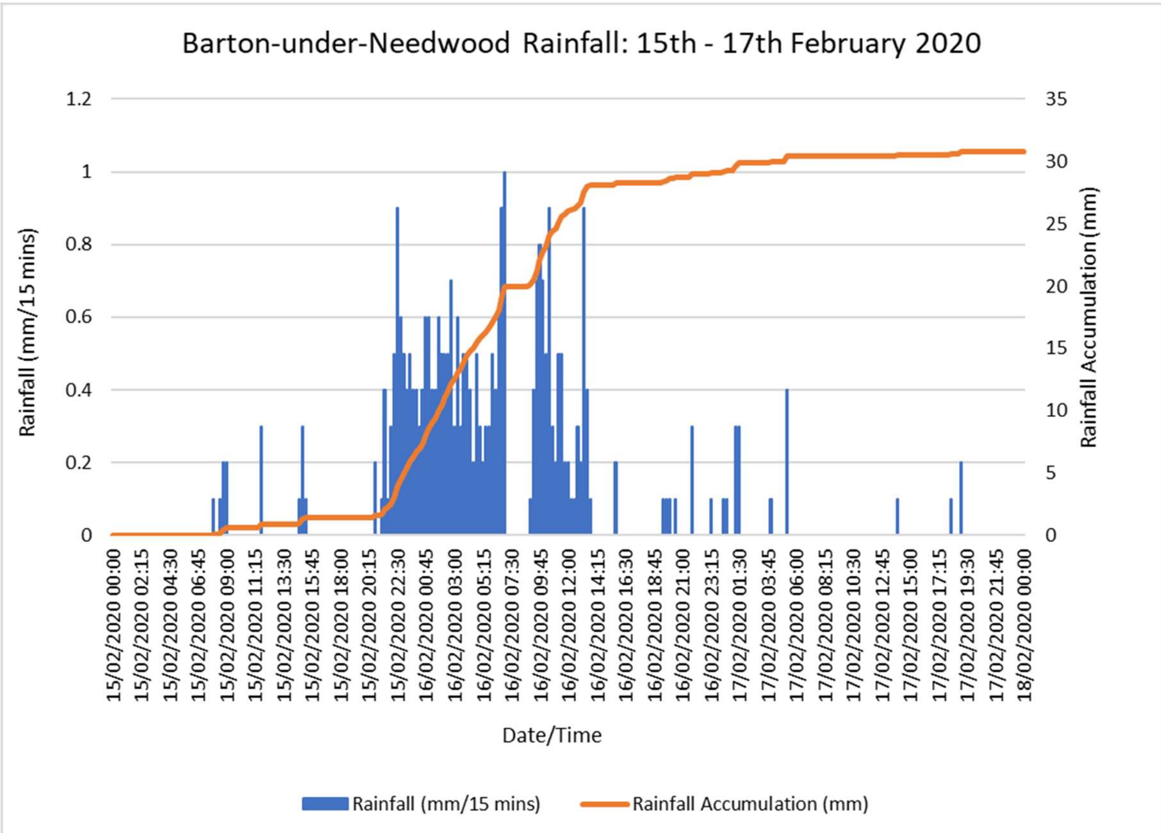


Figure 11: 15-minute rainfall for Barton-under-Needwood on February 15th and 16th 2020 (Data Source: HydroMaster)

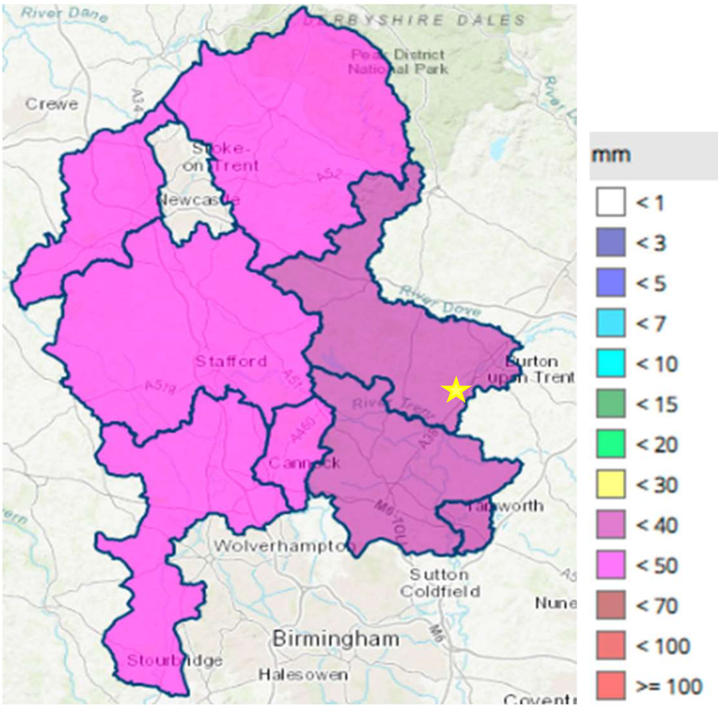


Figure 12: Rainfall totals for districts and boroughs across Staffordshire County with Barton-under-Needwood indicated by a yellow star (Data Source: HydroMaster)

Barton Brook Watercourse:

The Storm Dennis event and associated rainfall impacted watercourse levels and flows in Barton-under-Needwood. The Barton Brook is an ungauged watercourse, but the levels during the event have been modelled. ReFH software has been used to estimate the hydrograph for the Barton Brook catchment from observed rainfall and catchment characteristics. The hydrograph shows rainfall from February 14th to 19th 2020 that had a fast and steep but limited response by Barton Brook levels. Peak discharge for the Barton Brook has been estimated at 0.93m^3/s on the 16th of February at 14:55. Total flow then recedes steadily. The peak event return period of these flows is indicated as less than a 1-year event (**Figure 12**). However it is likely that this is an under-representation of the true magnitude of the event, which was exacerbated by extreme saturation of the catchment and high baseflows in the days and months preceding Storm Dennis.

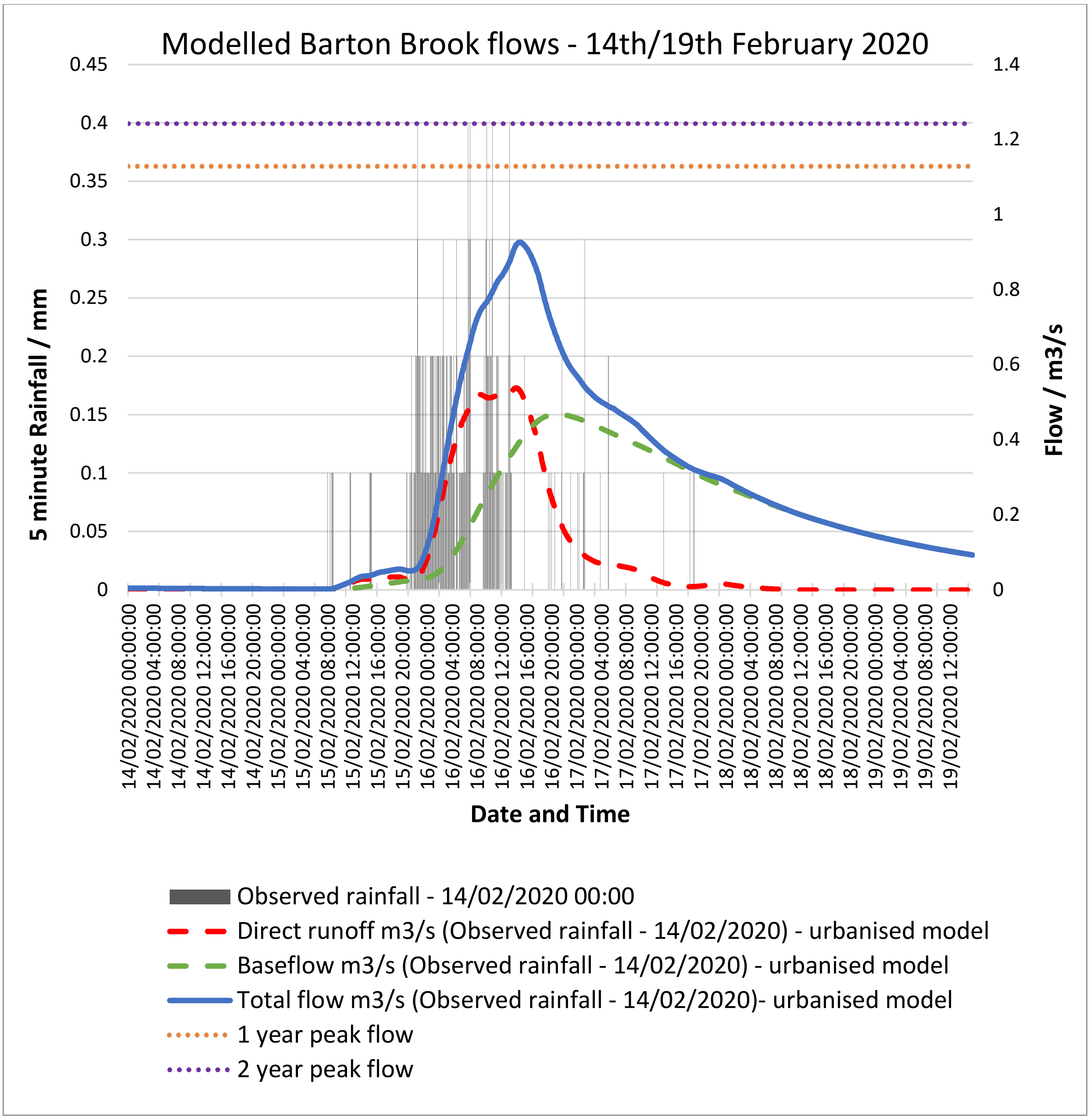


Figure 13: ReFH design flood hydrograph for Barton Brook overtopping event on February 16th following the Storm Dennis rainfall event on 15th-16th February 2020. The modelled return period of flows has been calculated as less than a 1-year peak event (Data Source: Hydromaster and ReFH)

Figure 13 and **Figure 14** demonstrate the main Barton Brook flow routes observed on February 16th. High Barton Brook levels were reported as it first discharges into Barton-under-Needwood around Park Road. The first observed incident of overtopping at the footbridge between Fallowfield Drive to Brookside Road (**Figure 13, number 1**) that caused internal flooding to several properties on Brookside Road. Once out of bank, flows continued eastward through Brookside Road gardens, subsequently knocking over fence panels with the force of flows and inundating further Brookside Road properties. This flow remained out of bank and accumulated behind the Wales Lane culvert (**Figure 13, number 2**), up to a recorded depth of approximately 450mm (>17 inches) at the culvert entrance. These flows damaged further garden fence panels and a front gate, before discharging across Wales Lane to internally flood properties on Wales Lane and Collinson Road to depths ranging from 50mm (2 inches) to 450mm (>17 inches) inside affected properties, garages, and outbuildings. Flows remained out of bank around the footbridge between Wales Lane and Collinson Road, with flows potentially overtopping the southern bank and discharging across Collinson Road rather than through the culvert. Out of bank flows left recorded flow marks of flood depths approximately 300mm 21 meters away from footbridge around properties on Church Lane (**Figure 11, number 3**). Gardens also flooded, with floodwater up to the thresholds of several additional properties.

Figure 14: Observed Barton Brook (blue arrows) and surface water flow (green arrows) routes, between Brookside Road and Church Lane. 1: First reported overtopping at footbridge. 2: Accumulation of flows behind Wales Lane culvert that discharged as overland flow across Wales Lane. 3: Overland flow up to 300mm 21m from the Barton Brook footbridge. Data from residents, the Parish Council and Flood Action group.

Barton Brook flows that would normally discharge under St James' Road culvert reportedly pooled at the south end of Church Lane (**Figure 14, number 1**), up to depths of 450mm (>17 inches) in internally affected properties, before discharging as overland flow across St James' Road and through allotment gardens surrounding an open channel section. During this open channel section between St James' Road and Efflinch Lane (**Figure 14, number 2**), flow is reported to have overtopped the left bank at several places to inundate properties on both roads. This overtopping may have been caused by flows exceeding the channel capacity, particularly at right angle bends in this section of the channel, or the potential of fallen vegetation in channel that obstructed or impeded discharge and caused out of bank flows. Flow exceeded the culvert capacity under Efflinch Lane, with reports levels were above the crown of the culvert at maximum flood level and continued as overland flow from the northern side of the channel, across Efflinch Lane (**Figure 14, number 3),** to internally inundate properties on Efflinch Lane and the south of Meadow Rise. A dwarf garage wall was also knocked over by the force of flows in this area. Reports indicate levels remained high adjacent to Potters Way, with the soffit level of the footbridge between Potters Way and Meadow Rise exceeded, that caused floodwater on Potters Way, the sports fields, and overflowing the fishing pond.

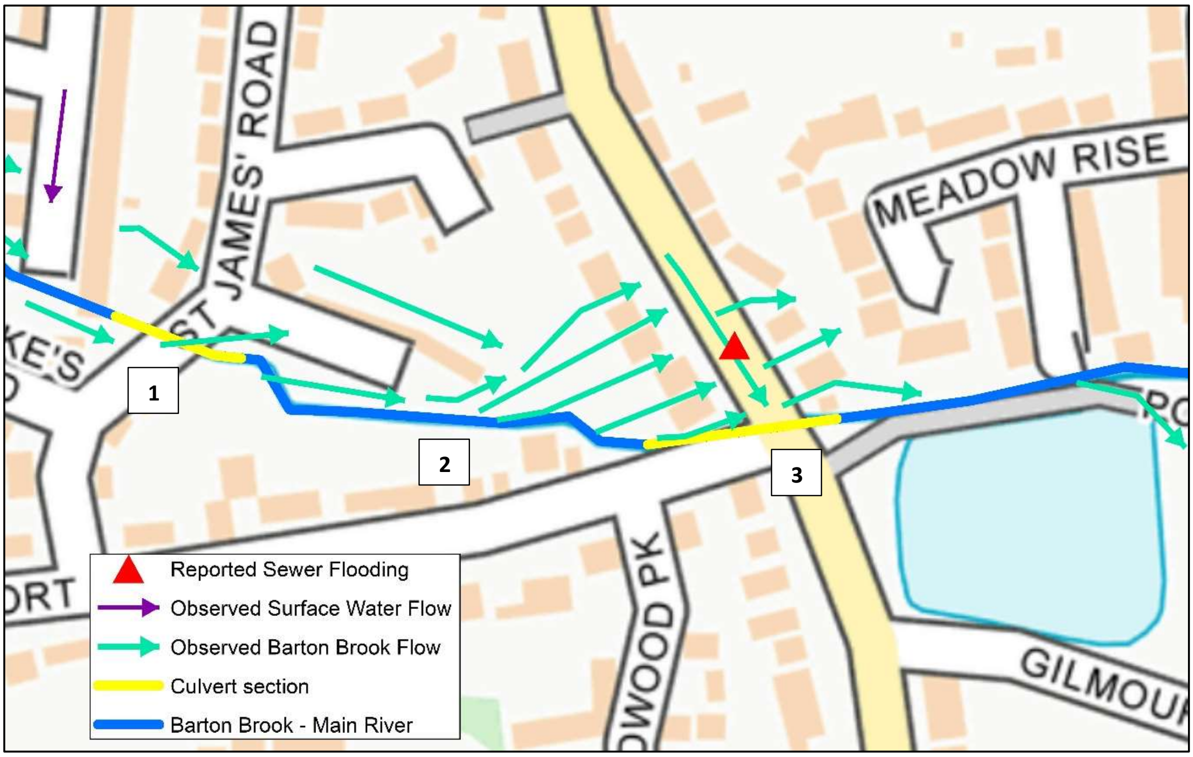


Figure 15: Observed Barton Brook (blue arrows) and surface water flow (green arrows) routes, between Church Lane and Potters Way. 1: Flows accumulated at St James' Road culvert entrance and south of Church Lane. 2: Open channel section that experienced overtopping of the left bank. 3: Efflinch Lane culvert that was exceeded by Barton Brook flows which resulted in overland flow across the highway. Data from residents, the Parish Council and Flood Action group.

The Barton Brook is a heavily culverted watercourse with several additional footbridges across the channel. Thus, flows could potentially be restricted in many areas by these assets, with flows potentially backing up against these structures to spill out of channel. Flood flows are first reported to have overflowed the channel at the footbridge between Brookside Road and Fallowfield Drive, however no notable blockages around this footbridge were reported during the event. The culvert sections under Wales Lane, Collinson Road, St James' Road and Efflinch Lane may also have experienced blockages or exceeded capacity. The Wales Lane box culvert turns approximately 90°

twice when passing under the highway and discharging into a narrow channel. Losses at the bends and the restricted channel at the outlet may force flood waters to mount the banks at the culvert entrance. This was experienced during the event with observed floodwater depths of approximately 450mm (>17 inches) at the Wales Lane entrance that internally affected surrounding properties. Constrictions of the channel by the additional culverts from potential blockages or flows exceeding capacity of the structures are also observed.

Overland flow routes around Collision Road and St James' Road indicate an inability to discharge through the culverts normally. Floodwater levels were also observed to be above the culvert crown and soffit levels of the Efflinch Lane culvert and Potters Way footbridge respectively. An additional blockage by building debris that had blown off a neighbouring plot during the event was also reported at the east end of Short Lane, that runs adjacent to the open section prior to Efflinch Lane. This blockage was cleared before the Environment Agency field team deployed during the event were present to action work to clear it. However, this may have been a factor in disrupting flows out of the channel and resulted in these discharging toward properties on Efflinch Lane. There is further potential that the steep 90^o bends in this section of the channel could have constricted high flows, in addition to any vegetation that could have fallen in the channel in this area to impede flows and cause overtopping. Maintenance of the Barton Brook channel is undertaken annually by the Environment Agency to reduce the potential of blockages in the multiple culverts throughout Barton-under-Needwood. However, the general condition of the Barton Brook channel may have been reduced following Storm Ciara the preceding week.

Once out of bank, the prevailing topography that decreases eastwards towards the River Trent has subsequently directed river flood flows into gardens and properties in Brookside Road, Wales Lane, Collinson Road, Church Lane, St James' Road, Efflinch Lane and Meadow Rise.

The observed impacts from the flood incident suggest it was significant, with some properties experiencing recorded internal flooding for the first time since 1961. However, the resulting modelled ReFH flows indicate a less than 1-year peak event return period. The modelling may therefore be significantly underreporting the event and there are natural causes being underrepresented in the software. This includes the impact of antecedent conditions that resulted in an incredibly saturated catchment, the complicated relationship between these conditions and runoff rates in the catchment, and other dynamics that might not be represented in the model. These natural causes working in combination with limited capacity of the channel could have exacerbated the event to the incident observed, but the weighting of each factor is unknown.

Additional anecdotal comments suggested that sluice gates not being opened contributed to flooding from the Barton Brook. Information from the Environment Agency and South Staffordshire Council indicate that there are no sluice gates along the Barton Brook and therefore would not have been an issue for fluvial flooding. Information from Severn Trent Water also indicates that no such asset exists within their sewer system or in relation to the pumping station and therefore there is no evidence there is a sluice gate that would have impacted flows. However, very high levels in the

River Trent may have resulted in higher levels in the Barton Brook from river flows not being able to outfall into the River Trent, particularly around the Barton Turns area.

Full Brook Watercourse:

Like the Barton Brook, the Full Brook is an ungauged watercourse. ReFH software has also been used to model the hydrograph for the Full Brook catchment from observed rainfall and catchment characteristics. **Figure 15** shows the resulting hydrograph and the impact of rainfall on the 15th and 16th of February associated with Storm Dennis on flow in the Full Brook. The peak event has been calculated between a 2-year and 5-year return period event.

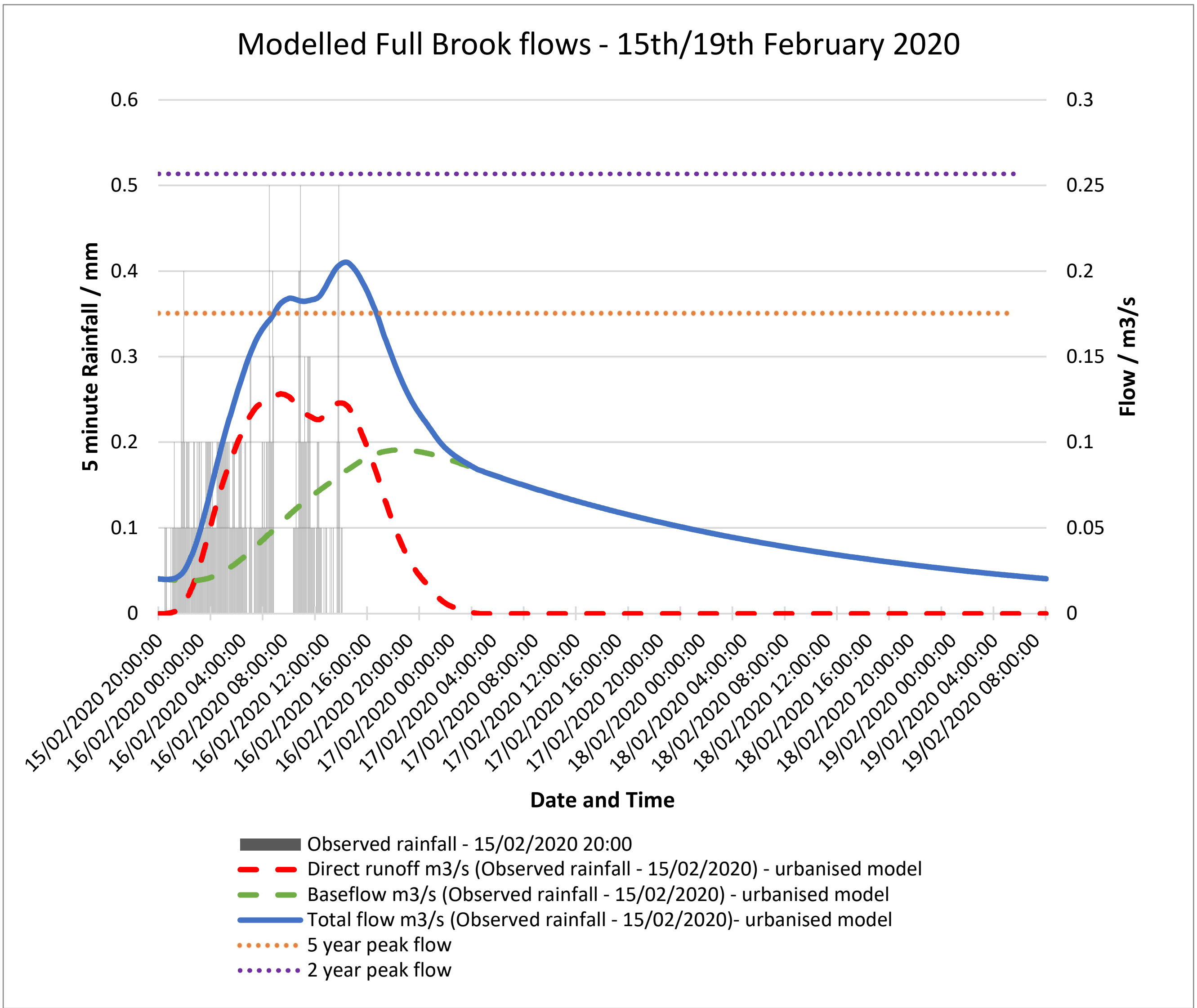


Figure 16: ReFH flood hydrograph for the full Brook ordinary watercourse overtopping event on February 16th following the Storm Dennis rainfall event on the 15th-16th of February 2020. The modelled return period of flows has been calculated as between a 2-year and 5-year peak event (Data Source: Hydromaster and ReFH).

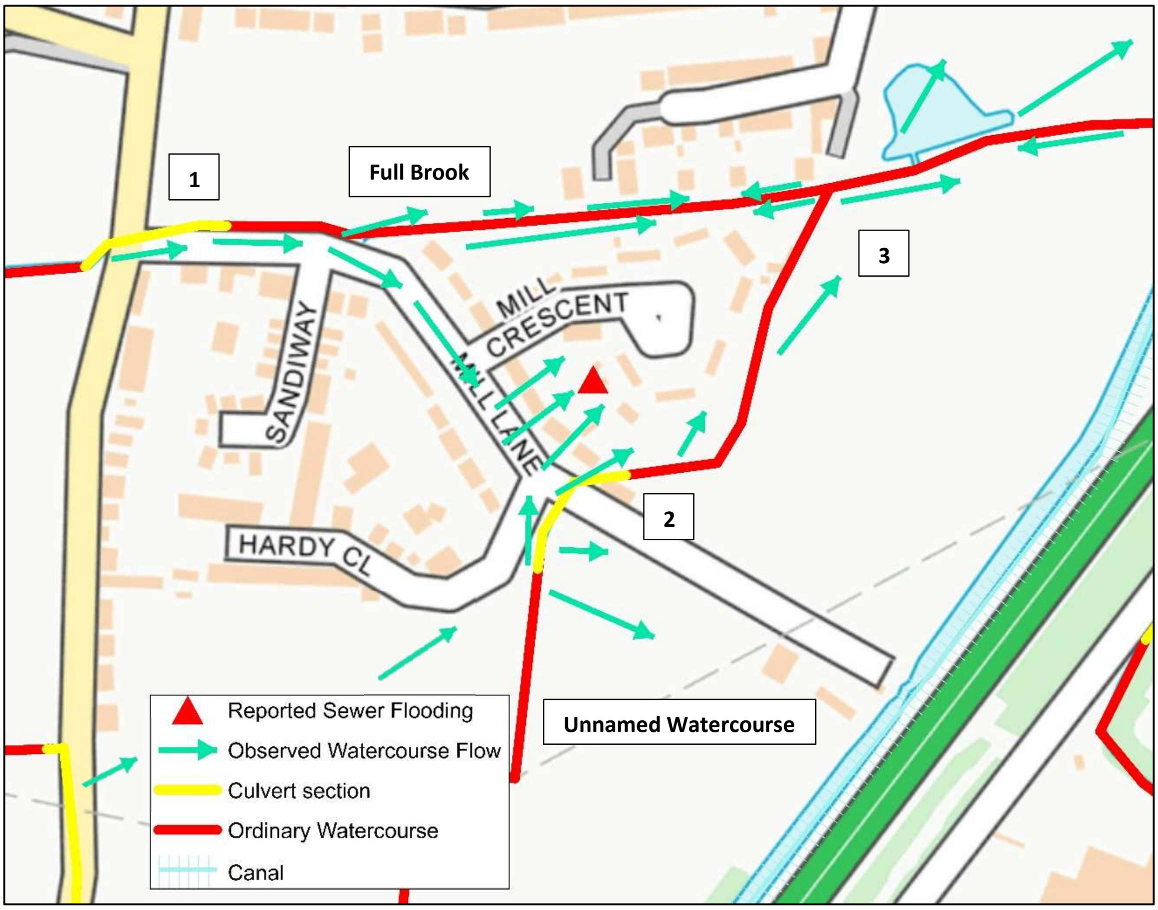


Figure 16: Route of overtopped flows from the Full Brook and unnamed watercourse that resulted in flooding along Mill Lane and Mill Crescent. 1: Flows overwhelming Efflinch Lane/Mill Lane culvert. 2: Flows overwhelming Mill Lane culvert. 3: Flows from both watercourses collected in open land east of Mill Crescent.

Figure 16 illustrates the observed flow routes from the Full Brook on February 16th. Flows initially overtopped the Full Brook at Efflinch Lane, with in bank flows unable to pass through the culvert beneath Efflinch Lane and Mill Lane due to a partial blockage. Full Brook flows unable to enter the culvert overtopped the bank and flowed across Efflinch Lane (**Figure 16, number 1**), and across drives of properties along Mill Lane. Flows continued southeast along Mill Lane, which acted as a path for directing flood flows.

Flood flows also overtopped the unnamed watercourse further southeast along Mill Lane, that discharges into the Full Brook northeast of Mill Lane and Mill Crescent. The culvert under Mill Lane (**Figure 16, number 2**) was also overwhelmed, resulting in flows bypassing and overtopping at the culvert entrance. The prevailing topography of the area directed these flows south to Hardy Close and agricultural land south of Mill Lane, and north of the culvert to inundate an area of Mill Lane that resulted in internal and external flooding to properties. This was exacerbated by the culvert condition, and in-channel blockages downstream of the culvert. Ingress of watercourse flows into the sewer network may also have resulted in sewer flooding that impacted rear gardens of Mill Lane and Mill Crescent. Flows that remained in bank in the Full Brook overtopped the channel along the footpath and contributed to the flooding in Mill Crescent.

Out of bank flows from the Full Brook joined with those out of bank from the unnamed watercourse to collect in an area of open land and lower topography behind properties on Mill Crescent (**Figure 16, number 3**). As previously noted, local volunteers acted to direct flood waters away from properties where flood flows had collected from both the Full Brook and the unnamed watercourse. This allowed floodwater to drain into open land to the east and reduce pressure of floodwater in the around surrounding Mill Crescent. Other remedial work undertaken since includes the clearance of blockages from under both Efflinch Lane and Mill Lane culverts by Staffordshire County Council Highways, clearance of in-channel blockages upstream of the unnamed watercourse Mill Lane culvert, and clearance work undertaken by the Barton-under-Needwood Parish Council, supported by Staffordshire County Council, along the Full Brook channel adjacent to Mill Lane to improve capacity.

Several structures along the Full Brook restrict the conveyance capacity, and therefore contribute to the flood risk from this source. At the downstream end, there is a 400mm siphonic culvert under the canal. The culvert is inspected by the Canal and River Trust and was found to be clear and free flowing. However, the limited size and effect of downstream water levels causes water to back up into the open space between Mill Crescent and the canal when there are high flows in the watercourse. This in turn impacts the flow rates of the Full Brook and tributary upstream. A pond and landscaping undertaken as part of the Barton Manor development provide some additional floodwater storage in this area.

Between the canal and the A38 there was also property flooding reported at Lichfield Road which was believed to be the result of floodwater backing up from the Full Brook culvert beneath the A38.

There are also three culverts forming footpath crossings at Mill Lane, at the confluence of the Full Brook and tributary, and downstream of the pond. The most critical of these constrictions is downstream of the confluence, where the flows from both branches of the watercourse meet and enter the floodplain area via the culvert. As a result of representations by Barton Parish Council the landowner has agreed to replace this culvert with a clear span bridge to increase conveyance.

The Parish Council has worked to identify the issues contributing to the flooding, to report those requiring action from other authorities, and to clear sections of the channel that required maintenance. The improvements to conveyance capacity will reduce the flood risk in future.

There has also been ongoing collaboration between the Parish, District, and County Councils to ensure that riparian landowners are aware of their duties and undertake the necessary maintenance to keep the watercourse clear. This extends downstream beyond the canal and A38 where the watercourse has historically been modified.

Knoll Brook Flooding:

5 properties are reported to have experienced flooding along Main Street from the Knoll Brook watercourse during the 2020 event. The Knoll Brook flood alleviation scheme that began prior to the February 2020 flood event, and was not operational during the event, has now been completed and should mitigate this flooding in future.

Groundwater Flooding:

Possible ground water flooding may also have occurred from a raised water table on Efflinch Lane and contributed to the flood incident. The Environment Agency are investigating groundwater issues in association with modelling of the Barton Brook. However, as previously mentioned, there have been very few recorded groundwater flooding incidents in the region.

Surface Water and Highway Drainage:

Reports suggest surface water flows were observed along Park Road, Westmead Road and Brookside Road (**Figure 13, purple arrows**), and southward along Church Lane (**Figure 14, purple arrows**). These surface water flows followed the prevailing topography the same as the out of bank Barton Brook flows and may have further exacerbated internal property flooding. The highway drainage network was unable to fully capture these flows. Surface water flooding may also have contributed to the flood extent in Mill Lane and Mill Crescent by following prevailing topography and exacerbating flooding from out of bank Full Brook flows. Overland surface water runoff from agricultural land northwest of Barton-under-Needwood are also indicated to have resulted in one property along Main Street experiencing internal flooding.

Highway drainage may have been overwhelmed by ingress from out of bank Barton Brook and Full Brook flows when they exceeded the channel capacities and flowed across the highways. These drainage systems also mostly connect into watercourses. Already high rivers levels in Barton Brook and Full Brook would have reduced the capacity for the drainage systems to discharge into these. However, this is considered as an impact of fluvial river flooding and not independent highway flooding.

Sewer System:

In addition to fluvial flooding and surface water flooding, reports from residents indicate some potential sewer flooding internally affecting properties on Efflinch Lane, Collinson Road, Wales Lane, St James' Road, and Mill Crescent. An ingress of Barton Brook and Full Brook flows may have entered the sewer in these areas that resulted in a surcharge of these systems. Communication with Severn Trent Water indicate they have some records of problems in these areas and are investigated these, and additional problems notified by other RMAs. Other reported issues of sewer flooding that were on private assets were investigated by Severn Trent Water but are the responsibility of the landowner and they were informed of this.

Combined sewer network surcharge was also observed on Efflinch Lane, with a manhole 'fountaining' to a height of 600mm (>23 inches) and flowing onto drives of properties on the East side of Efflinch Lane (**Figure 14, red triangle**). Sewer flooding further south along Efflinch Lane that potentially impacted properties was also reported during the flood incident. This is further confirmation that river flows may have overwhelmed the sewer system in some areas. Severn Trent Water have been made aware of these incidents and are investigating the issue further.

Reports that further sewer flooding from the foul sewer system occurred to rear gardens in Mill Lane and Mill Crescent (**Figure 16, red triangle**) have also been passed to Severn Trent Water. This was also most likely caused by ingress from watercourse flows into the sewer system. Severn Trent Water are investigating this flood incident further.

Previous sewer improvement works to sewer systems and properties undertaken by Severn Trent Water in 2016, for instance the implementation of non-return valves, had no further issues of sewer flooding reported during the February 2020 flood incident.

Conclusion

The flooding incident that occurred in Barton-under-Needwood, East Staffordshire, on February 16th was the result of an exceedance event that caused river flooding from the Barton Brook (designated main river), Full Brook (ordinary watercourse), and Knoll Brook (ordinary watercourse), surface water flooding and overwhelmed sewer drainage systems.

An intense period of rainfall leading up to the event resulted in high river levels in the Barton Brook and surrounding watercourses. Evidence from ReFH modelled hydrographs indicate the event had a peak magnitude of less than a 1-year event for the Barton Brook and between a 2-year and 5-year peak flow magnitude for the Full Brook. However, the model may be underreporting factors of the events, such as catchment wide antecedent conditions, runoff rates or groundwater dynamics.

For the Barton Brook, it is also significantly likely that the heavily culverted channel, in addition to known temporary blockages during the event, limited the capacity of the channel during the intense precipitation event that exceeded all culverts downstream of Park Road. This was further exacerbated by the very high levels in the River Trent which meant the Barton Brook was unable to outfall to the River Trent and resulted in a mechanism of backing up along the Barton Brook. Barton Brook flows that overtopped the channel, particularly at culvert entrances and prior to footbridges, were redirected as overland flow across highways and through gardens to internally flood several properties in the central Barton-under-Needwood area. Reduced capacity at culverts and in-channel blockages along the Full Brook may also have resulted in out of bank flows that were directed along highways and into properties. A mechanism of flows backing up along the Full Brook may have further exacerbated the overtopping event and directed floodwater to low points in the topography.

Surface water flows also followed the prevailing topography of Barton-under-Needwood and increased flows into properties in some areas. Reports of sewer flooding resulting from an ingress of Barton Brook and Full Brook flows into the sewage system are being investigated by Severn Trent Water.

Barton Brook Alleviation Scheme

Several investigations have been undertaken into the flood risk associated with the Barton Brook. In 2012, the Environment Agency initially proposed a flood alleviation scheme to reduce Barton Brook flood flows with the preferred option of an upstream flood storage area around Barton Park Farm. In 2018/2019 the Environment Agency completed an Initial Assessment to consolidate information on flood risk from the Barton Brook and analysis potential solutions. This assessment was updated to include the properties inundated by the flooding in this event (February 2020).

Currently, the Environment Agency are updating the Barton Brook hydraulic model from 2009. This work is collaborative with Jacobs to calibrate and improve the model outputs to represent reported flooding. The implementation of a river level recorder upstream of Efflinch Lane will aid and improve this modelling of the Barton Brook by allowing calibration against logged water levels.

A Strategic Outline Case (SOC) has been completed to identify potential options for technically and economically viable schemes possible for the Barton Brook, such as options of Natural Flood Management (NFM) and Property Flood Resilience (PRF), but no economically viable options were identified through this SOC process. However, this may change following calibration of the hydraulic model which may give a better understanding of the expected costs and benefits of options. In the interim, whilst more data is collected by the new river level recorder, steps have been taken to investigate NFM measures that will have environmental benefits and potential flood risk benefits. Funded by Local Levy and Water & Environment Investment Fund (WEIF) the Environment Agency are working with Staffs Wildlife Trust, Trent Rivers Trust, and the Barton-under-Needwood Parish Council to introduce changes to land management and channel features that will slow the flow. This work is at an early stage, potential interventions are currently being scoped and landowners identified to discuss where these measures would be acceptable and could be introduced.

Knoll Brook Alleviation Scheme

In 2020 Staffordshire County Council completed a scheme to mitigate flooding from the Knoll Brook that impacted properties along Main Street, Barton-under-Needwood. This scheme was completed after the February 2020 flood incident, in which properties along Main Street reported internally flooding. The Knoll Brook watercourse was originally piped under Main Street that discharged into an open ditch south of the Barton Brook but was diverted into a highway drain during the 1970s or 1980s. However, highway drainage was not able to cope with the amount of discharge during heavy precipitation events that overwhelmed the watercourse and has previously inundated the highway and properties with floodwater.

The original scheme strategy presented combined Property Flood Resilience (PFR) measures with additional local measures. However, after consideration and discussion by Staffordshire County Council with the Parish Council and residents a catchment-based community resilience scheme was implemented to mitigate flood risks for more properties in the area. Measures implemented in the scheme include the upgrading of two linear trash screens and a grill, fixing collapsed pipework from recent utility work, reinstatement, and excavation of open ditch section to utilise storage already available, constructed an earth bund to deflect flows away from properties, and improved highway storage with the utilisation of an existing tank discovered during the alleviation scheme and implementation of gully storage along Main Street.

Recommended Actions

As part of the flood investigation into the February 2020 flood incident, recommended actions to continue to alleviate flooding in central Barton-under-Needwood for the relevant RMAs have been provided in **Table 1**.

Table: Recommended actions to address flood issues in central Barton-under-Needwood for relevant RMAs

	Risk to address	Recommended Action	Responsibility
1	River flooding from the Barton Brook	The Environment Agency should continue their collaborative working with partners and relevant RMAs to model the Barton Brook mechanisms and consider options and information for a potential alleviation scheme in Barton-under-Needwood. A live sensor being implemented on the Barton Brook will further support this modelling and aid future flood investigations of the Barton Brook. Support of a potential scheme, including NFM and PFR options, should be provided by Staffordshire County Council.	Environment Agency (EA) supported by various RMAs
2	Culvert capacity of Barton Brook and Full Brook	Investigate the culvert capacity and sharp bends that are insufficient to convey Barton Brook flows, and the capacity of culverts that convey the Full Brook and unnamed watercourse.	Environment Agency (EA) and Staffordshire County Council (SCC)
3	Maintain the Full Brook watercourse for channel capacity	Work with riparian landowners to make them aware of their duty to maintain the channel to maximise conveyance capacity of entire length of the Full Brook.	SCC
4	Highway drainage maintenance	Monitoring, and any necessary maintenance required, of highway drainage and structures should be undertaken regularly to avoid blockages. Consider whether gully frequency and positioning is adequate.	SCC Highways
5	Sewer capacity and cleansing	Severn Trent Water are to investigate the potential sewer flooding and capacity of sewer system. Consider options such as sewer cleansing	Severn Trent Water (STW)

		frequency if any issues are found to be a contributing factor.	
6	Sewer flooding problems associated with the Full Brook	Continue investigations and undertaken any potential actions to reduce the possibility of sewer flooding around Mill Lane and Mill Crescent, as well as reported sewer flooding elsewhere in Barton-under-Needwood.	STW
7	Watercourse maintenance of Barton Brook	Vegetation maintenance and management in open sections of the Barton Brook channel should be undertaken regularly to avoid blockages. Work with riparian landowners for all sections outside main channel section (e.g. Barton Marina).	EA and Barton-under-Needwood Parish Council
8	Community flood risk awareness and information sharing	Work with the community to increase flood risk awareness and improve contingency planning for actions to be undertaken by homeowners during a flood event.	SCC, EA, Civil Contingencies Unit (CCU) and Barton-under-Needwood Parish Council

Risk Management Authorities and Other Parties

In addition to the recommended actions, a RMA or alternative party has been identified to undertake these actions. While some actions require collaboration and partnership, the RMA or alternative party identified will co-ordinate all parties to ensure that the action is completed in a timely manner.

A summary of each of the RMAs, with regard to their role in flood risk management, is provided below:

Staffordshire County Council (LLFA)

https://www.staffordshire.gov.uk/environment/Flood-Risk-Management/Home.aspx

LLFAs are County Councils or unitary authorities which are required to prepare and maintain a strategy for local flood risk management in their areas, investigate significant local flooding incidents and publish the results of such investigations and play a lead role in emergency planning and recovery after a flood event. LLFAs also have regulatory powers to enforce riparian responsibilities.

Staffordshire County Council (Highways)

Highways authorities have the lead responsibility for providing and managing highway drainage.

East Staffordshire Borough Council (ESBC)

https://www.eaststaffsbc.gov.uk

As the Local Planning Authority, ESBC are responsible for determining planning applications within the catchment in accordance with local and national policies.

Environment Agency

https://www.gov.uk/government/organisations/environment-agency

The Environment Agency has a strategic overview of all sources of flooding, and hold responsibility for flood risk management activities on Main Rivers.

Severn Trent Water

https://www.stwater.co.uk/my-supply/pipes-and-drains/help-with-pipes/sewer-flooding/

As a water and sewerage company, Severn Trent Water manage the risk of flooding to water supply and sewerage facilities and the risk to others from the failure of their infrastructure. They ensure their systems have the appropriate level of resilience to flooding, and maintain essential services during emergencies, maintain and manage their water supply and sewerage systems to manage the impact and reduce the risk of flooding and pollution to the environment and they provide advice to LLFAs on how water and sewerage company assets impact on local flood risk.

National Highways (previously Highways England)

https://www.gov.uk/government/organisations/highways-england

National Highways is the highway authority with lead responsibility for maintaining and managing trunk roads and motorways, including drainage.

Riparian Owners

https://www.gov.uk/government/publications/riverside-ownership-rights-and-responsibilities

A riparian owner is any party or individual who has a watercourse within or adjacent to any boundary of their property. They are responsible for maintaining the riverbed and banks within their section of the watercourse to preventing obstruction to the water flow and mitigate flood risk.

Conclusion

Several storms occurred in 2020 across the Midlands region that impacted many areas. In February 2020, a long duration, low-to-moderate intensity event, named Storm Dennis, led to severe weather warnings across much of Wales and the Midlands. As a result, a significant number of associated flooding incidents to properties and highways were recorded across Staffordshire, and reported to SCC, as well as nationwide. This includes the flooding incident that occurred in Barton-under-Needwood, East Staffordshire.

Reports indicate that 69 residential properties were internally flooded in Barton-under-Needwood on February 16th 2020. The main types of flooding have been identified as river flooding from the Barton Brook (main river), Full Brook (ordinary watercourse) and Knoll Brook (ordinary watercourse), flooding from surface water, and flooding from sewer systems. Accumulation of intense rainfall from Storm Dennis, in addition to the previous Storm Ciara that resulted in an already saturated catchment, led to high flows overtopping watercourses, and combined with surface water flows in some areas, followed the prevailing topography of the area to flood residential properties.

Evidence from ReFH hydrographs identify the magnitude of peak flows in the Barton Brook as less than a 1-year event with an initial fast but limited response, and between a 2-year and 5-year event return period for the Full Brook. However, this may be underrepresenting antecedent conditions of the high levels of saturation in the catchment, groundwater dynamics, or the limited channel capacity, impact of culverts and impact of backing up mechanisms from very high levels in the River Trent in both the Barton Brook and Full Brook that could impede flows and result in out of bank flooding. The prevailing topography then directed these flows to collect in areas of lower topography, as well as at culvert entrances, that resulted in residential property flooding along Brookside Road, Wales Lane, Collinson Road, Church Lane, St James' Road, Efflinch Lane, Meadow Rise, Mill Lane, Mill Crescent, and Lichfield Road.

The Environment Agency are currently updating the Barton Brook hydraulic model in collaboration with Jacobs to calibrate and improve the model outputs. A river level recorder has been implemented upstream of Efflinch Lane to aid and improve this modelling and calibration, and to support the SOC process that has currently identified no economically viable options. NFM options are being investigated by the Environment Agency in partnership with Staffs Wildlife Trust, Trent Rivers Trust, and the Barton-under-Needwood Parish Council. Work supported by Staffordshire County Council in collaboration with landowners along the Full Brook is ongoing to ensure proper conditions of the downstream Full Brook channel are maintained to reduce insufficient channel capacity impeding flows. Other remedial work undertaken includes the clearance of in-channel and culvert blockages, and clearance work undertaken by the Barton-under-Needwood Parish Council, supported by Staffordshire County Council, to improve capacity.

Further flooding along Main Street may have been caused by flows overtopping the Knoll Brook, and issues of flooding from surface water that may have contributed to the flood extent by following prevailing topography and exacerbating out of bank flows were also reported across Barton-under-

Needwood. Staffordshire County Council have worked with residents along Main Street to implement scheme to reduce flooding from the Knoll Brook. This was not operational during the flood event in February 2020, but should reduce future flooding in the area.

Flooding from sewer systems, particularly around Mill Crescent, has been reported to Severn Trent Water and they are investigating these incidents. However, incidents of sewer flooding across Barton-under-Needwood most likely resulted from ingress of river flows into sewer systems rather than failures from the system itself.