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Causes of flooding

4 Causes of flooding

High river levels are generally the result of prolonged rainfall. In the summer months the ground may be baked hard by the sun resulting in very high runoff and flash flooding during thunderstorms. In winter the soil conditions are wetter and temperatures lower and a greater proportion of the rainfall will find its way to the river. Recent wetter summers have similarly resulted in wetter ground and greater runoff.

The main source of flooding in the CBC, BDC, and NEDDC SFRA area is fluvial. The reason for this flood risk to people and property is a combination of insufficient channel capacity and the fact that the affected properties are generally on low lying land in the rivers natural floodplain.

Groundwater flooding can be caused by three main contributing factors; prolonged rainfall, higher than average groundwater levels and outcrops of aquifers (in the form of springs).

Flooding can also occur due to failure of infrastructure such as flood defence assets, culverts, sewers, reservoirs and canals.

Flood risk locations for areas outside of the Flood Zone maps have been put into a GIS database. The flood risk locations can be seen in the drawings in Appendix D. Each location has been given a reference number. The table in Appendix A provides more details on the type of flood risk at this location. The other flood risk locations include flooding from sewers, reservoirs, canals, land drainage and ordinary watercourses.

4.1 Overflowing of watercourses (including Breach)

When the flow in a river or stream exceeds the capacity of the channel to convey that flow, either because of limited cross-sectional area, limited fall, or a restricted outfall, then the water level in that channel will rise until the point is reached where the banks of the channel are overtopped. Water will then spill over the channel banks and onto the adjoining land. With an upland river the adjoining land is its natural flood plain. This will be fairly well defined and generally be of limited extent.

Floodplains are characterised by flat, riparian land along the valley floor. In pre-industrial England, such land was regarded as liable to flooding and was traditionally reserved for grazing and stock rearing and human settlements were almost always established beyond the edge of the floodplain. In the industrial age and more recent times with different priorities, pressures for development have resulted in the widespread colonisation of floodplains, often with steps taken to mitigate the associated risks of flooding.

When overtopping of an embanked watercourse occurs, the depth of water flowing over the floodwall or embankment will probably be small, a few centimetres at most. The bank will act like a weir and the rate of flow per unit length will be relatively modest and this, combined with the limited duration of the overtopping, will limit the volume of water cascading over the defences to cause flooding. If overtopping does occur and the protected area is of considerable extent, any resulting flooding will often be disruptive rather than be disastrous. The situation becomes far more critical if overtopping of an earth embankment erodes its crest, leading to a breach in the embankment.

4.1.1 *Development in undefended areas*

Where development is proposed in undefended areas of floodplain, which lie outside of the functional floodplain, the implications of ground raising operations for flood risk elsewhere need to be carefully considered and appropriate guidance provided to developers within the SFRA. There are few circumstances where provision of compensatory flood storage or conveyance will not be required for undefended fluvial floodplain areas. This is because, whilst single developments may have a minimal impact, the cumulative impact of many such developments can be significant. More information for individual potential development sites can be found in the flood risk matrix.

4.1.2 *Development behind defences*

When proposing new development behind flood defences, the impact on residual flood risk (see glossary) to other properties should be considered.

New development behind flood defences can increase the residual flood risk, should these defences breach or overtop, by disrupting conveyance routes (flow paths) and/or by displacing flood water. If conveyance routes that allow flood water to pass back into a river following failure of a flood defence are blocked, this will potentially increase flood risk to existing properties. If there is a finite volume of water able to pass into a defended area following a failure of the defences, then a new development, by displacing some of the flood water, will increase the risk to existing properties. Policy and practice for managing these risks as part of the spatial planning process has been included in the SFRA.

It is recommended that, should any potential development sites be proposed in a defended flood area, the potential cumulative impact of loss of storage at the potential development sites on flood risk elsewhere within the flood cell (area constrained by boundaries that would fill before overtopping into another flood cell) should be considered.

Such assessment should be appropriate to the scale and nature of the proposed development and flood risk. If the potential impact is unacceptable, mitigation should be provided.

4.2 Breaching of Embankments

An earth embankment may be breached as a direct result of overflowing. Overtopping of a bank, especially when concentrated over a short length of bank, results in a rapid flow of water down the rear slope of the bank. This can cause erosion, which starts at the rear of the bank and works its way forward towards the channel. As the crest of the bank is washed away the flow through the small initial gap increases and a small breach is created. This becomes steadily bigger as water flows through it, eroding the sides and base of the breach, and a rapid and progressive failure of the embankment follows. Complete collapse of the bank may take only minutes. The contents of the embanked channel then pour through the breach and across the surrounding land.

A tarmac road or dwarf floodwall along the crest of a floodbank may inhibit the rate of initial erosion and postpone or even prevent the creation of a breach, depending upon the duration of overtopping. Experience, fortunately limited, shows that when a fluvial floodbank breaches, even if not by overtopping, it does so near the peak of the flood when the flow in the river and hence flood levels are at or near their maxima. Experience also suggests that breaches in river embankments usually extend from 20 to 30 metres in length and rarely grow to more than forty metres.

The design of a floodbank (or floodwall) incorporates a certain level of freeboard to allow for uncertainties, bank settlement, wave action, etc. but the height of any floodbank is determined primarily by the peak height of the design flood. Because of freeboard, the return period of the flood which gives rise to overtopping must be greater than that of the design flood. The return period of flooding from a breach caused by overtopping will be essentially the same as for the far less severe flooding resulting from that overtopping alone, but it must be borne in mind that breaches in earth embankments can occur from causes other than overtopping and may thus have return periods significantly less than that for which the embanked channel was designed.

Apart from overtopping, breaches in floodbanks can occur where weak spots in the bank have been created over a long period by gradual leakage through the bank at old, forgotten structures buried in the bank such as culverts or sluices (“slackers”), or where the activities of burrowing animals such as rabbits or rodents have impaired the integrity of a floodbank. These inherent weaknesses may not be readily apparent under normal conditions but when an exceptional level of pressure through the bank arises during flood conditions, a failure may occur, quickly giving rise to a breach. This may well happen in a flood of considerably lesser magnitude and return period than the design flood.

Furthermore, since the inherent weakness tends to increase slowly with age, the fact that a bank did not fail in an earlier flood does not guarantee that it will not fail in a comparable (or even a lesser) flood at some time in the future. If, however, a floodbank is of recent construction it may be assumed that it has been properly engineered and, provided that there is an adequate inspection and maintenance regime, the risk of breaching as a result of the factors outlined above is negligible.

4.3 Mechanical, Structural or Operational Failure

Although less common than overtopping or breaching of defences, flooding can also be caused by the mechanical or structural failure of engineering installations such as land drainage pumps (or their power supplies), sluice gates (or the mechanism for raising or lowering them), lock gates, outfall flap valves etc.

Such failures are, by their nature, more random and thus unpredictable than the failures described in the previous sub-sections, and may occur as a result of any number of reasons. These include poor design, faulty manufacture, inadequate maintenance, improper operation, unforeseen accident, vandalism or sabotage.

Structural failure, in this context, is also taken to include the failure of "hard" defences in urban areas such as concrete floodwalls.

"Hard" defences are the most unlikely to fail by the overtopping / erosion / breaching sequence experienced by earth embankments. Their failure tends to be associated with the slow deterioration of structural components, such as rusting of steel sheet piling and concrete reinforcement, or the failure of ground anchors. Such deterioration is often difficult to detect and failure, when it occurs, may well be sudden and unforeseen. Structural failure of "hard" defences is most likely to happen at times of maximum stress, when water levels are at their highest during a flood. Failure of hydraulic structures and "hard" defences can, under certain circumstances, be precipitated by the scouring of material from beneath their foundations by local high velocity flows or turbulence, especially under flood conditions.

Flooding can also be caused or exacerbated by the untimely or inappropriate manual operation of sluices, or by the failure of the person or organisation responsible to open or close a sluice at a critical time.

Responsibility for the operation of sluices rests with various public bodies as well as riparian landowners. Operational failures of this nature generally occur during a flood event and their results are to exacerbate rather than to cause flooding, and their impact is normally limited in extent.

Flooding especially that caused by overflowing of watercourses, can be exacerbated by other operational failures. These failures can also include neglected or inadequate maintenance of watercourses resulting in a reduction of their hydraulic capacity. Flooding can also be caused or exacerbated by bridge or culvert blockages, although these are not necessarily due to maintenance failures and may be caused by debris, natural or manmade, swept along by flood flows.

The risks associated with this category of failures are almost impossible to quantify, especially as experience has shown that there is a joint probability relationship between this class of failure and flooding resulting directly from extreme meteorological events. It can of course be argued that if a risk of this type was quantifiable and found to be finite then action should already have been taken to alleviate the risk. Even an assessment of relative risk for failures of this type must depend on a current and detailed knowledge of the age and condition of plant, its state of maintenance, operating regime etc at a significant number of disparate installations.

More information on the potential flood risk from mechanical, structural or operational failure of assets within the study area can be seen in Section 6.5.

4.4 Flooding from reservoirs, canals and Other Artificial Sources

Flooding from artificial sources occurs from a facility being overwhelmed and/or as a result of dam or bank failure.

Non-natural or artificial sources of flooding can include reservoirs, canals and lakes where water is retained above natural ground level, operational and redundant industrial processes including mining, quarrying and sand and gravel extraction, as they may increase floodwater depths and velocities in adjacent areas. The potential effects of flood risk management infrastructure and other structures also need to be considered. Reservoir or canal flooding may occur as a result of the facility being overwhelmed and/or as a result of dam or bank failure. The latter can happen suddenly resulting in rapidly flowing, deep water that can cause significant threat to life and major property damage. Industrial flooding can also occur when pumping ceases and groundwater returns to its natural level, for example in former mineral workings and urban areas where industrial water abstraction is reduced from its former rate. Some of this flooding may be contaminated.

4.5 Groundwater Flooding

Groundwater flooding occurs as a result of water rising up from the underlying rocks or from water flowing from springs. Flooding can be both at higher levels (from springs up a scarp slope) or at lower levels e.g. locations of former village ponds etc.

Groundwater flooding tends to occur after much longer periods of sustained high rainfall. Higher rainfall means more water will infiltrate into the ground and cause the water table to rise above normal levels. Groundwater tends to flow from areas where the ground level is high, to areas where the ground level is low. In low-lying areas the water table is usually at shallower depths anyway, but during very wet periods, with all the additional groundwater flowing towards these areas, the water table can rise up to the surface causing groundwater flooding.

Groundwater flooding is most likely to occur in low-lying areas underlain by permeable rocks (aquifers). These may be extensive, regional aquifers, such as Chalk or sandstone, or may be localised sands or river gravels in valley bottoms underlain by less permeable rocks. Groundwater flooding takes longer to dissipate because groundwater moves much more slowly than surface water and will take time to flow away underground.

4.6 Land drainage, sewer and ordinary watercourse flooding

Almost all localised flooding of a serious nature occurs as a result of an exceptionally severe rainfall event, localised in extent and duration and generally during the summer.

This flooding can, however, be exacerbated by two factors, blockages in the local surface water drainage system or by "floodlocking". Each of these factors is considered separately below. In some instances, in what would otherwise have been a relatively moderate rainstorm, these factors can themselves be the cause of flooding.

Intense storm rainfall, particularly in urban areas, can create runoff conditions which temporarily overwhelm the capacity of the local sewer and drainage system to cope with the sudden deluge. Localised “flash” flooding then occurs.

In upland areas with small, relatively steep, impermeable catchments, this may result in quite severe flooding over a limited area, often with a considerable depth and velocity of flood water. The duration of such flooding is usually relatively short but this does not mitigate its impact for those affected, especially when the flooding may have developed suddenly and unexpectedly.

In addition localised urban flooding can occur where the surface water drainage system is overwhelmed and pumps are not sufficient for an extended period of localised heavy rain.

In its natural state, if the channel capacity of a stream is exceeded the channel will overflow along a considerable length and the resultant flooding is distributed over a wide area. If, however, the stream runs through a long culvert and the hydraulic capacity of that culvert is exceeded under flood conditions the culvert becomes surcharged at its upstream end. Water levels will then rise rapidly and localised flooding upstream of the culvert, often quite serious, can occur. The flood water, in attempting to follow the natural line of the culverted watercourse, may also flow through the built-up area above the line of the culvert. This applies equally to many larger surface water sewerage systems in urban areas which are, in effect, culverted watercourses.

4.6.1 Blockages in local surface water drainage

Local flooding is often exacerbated by deficiencies in the local surface water drainage system, but these can usually be remedied by relatively minor works once they have been exposed by a flooding event. Local flooding can also be caused by temporary blockages or obstructions in a drainage system, especially one that has been extensively culverted.

Such flooding can therefore be virtually random in its occurrence, although the prevalence of blockages at a particular location would suggest a systematic problem, justifying action to modify the drainage system at that location in order to resolve it.

4.6.2 Flood-locking

In inland areas, all local surface water drainage systems discharge to a major stream or river. This discharge is by gravity, except where pumps have been installed. If the receiving stream or river is in flood, especially where that watercourse is contained within raised floodwalls or banks, the flow in the local drainage system can no longer drain to the river and is impounded behind the defence line for the duration of the flood. This is known as "floodlocking". This can result in secondary flooding within the defended area, even though the defences may not have been breached or overtopped. Fortunately, this secondary flooding is almost always much less severe or widespread than primary flooding from the main river would have been.

The occurrence of secondary flooding depends on the coincidence of heavy rain over the local drainage catchment with "flood-locking" of its outfall. In most instances, the rainfall event that caused the flood conditions in the river may also have caused high flows in the local drainage system but because of the much slower hydrological response of the river, the rapid runoff from the local catchment may have discharged to the river before the flood peak in the river arrives at the local drainage outfall.

Because secondary flooding depends upon what are either random events or a complex coincidence of events, its probability of occurrence is difficult to quantify and it falls within the category of "residual risk".

4.6.3 *Land drainage and sewer flooding*

The Environment Agency promotes the use of sustainable drainage systems (SuDS) within urban areas.

Drainage systems can be developed in line with the ideals of sustainable development, by balancing the different issues that should be influencing the design. Surface water drainage methods that take account of quantity, quality and amenity issues are collectively referred to as Sustainable Drainage Systems (SuDS). These systems are more sustainable than conventional drainage methods because they:

- Manage runoff flow rates, reducing the impact of urbanisation on flooding.
- Protect or enhance water quality.
- Are sympathetic to the environmental setting and the needs of the local community.
- Encourage natural groundwater recharge (where appropriate).

This is achieved by:

- Dealing with runoff close to where the rain falls.
- Managing potential pollution at its source now and in the future.
- Protecting water resources from point pollution (such as accidental spills) and diffuse sources.

Surface water drainage in the catchment is covered by a variety of different bodies. Severn Trent Water and Yorkshire Water have responsibility for adopted surface water sewers. Drains that exist in association with highways and private surface watercourses could be the responsibility of the LPAs, Highways Agency or private landowners. The adoption of SuDS for maintenance purposes is still under debate and can be a barrier in seeing them implemented for new developments.

More details on the use of SuDS and adoption of SuDS can be found in section 9.3.

Sewers serving a development will either be a combined system or made up of separate foul and surface water sewers. Sewer flooding occurs more commonly in locations that have a combined system. Adopted sewers are designed for a 2 year no surcharge and 30 years no flooding. Areas with separate sewers are less likely to exceed their capacity. However both sewer systems are at a similar risk of flooding as a result of blockages and failed pumping stations.

4.7 Catchment characteristics

The main rivers that drain the catchment areas are the River Rother, River Hipper, River Whitting, River Drone, River Doe Lea, River Moss and River Poulter. The Rivers Amber and Erewash drain to the south. A small part of Bolsover District is drained by the River Meden. In addition, there are numerous other watercourses such as Holme Brook, Pools Brook, Barlow Brook, Riddings Brook, Lough Brook, Sud Brook, Linacre Brook, Tricket Brook, and Smithy Brook.

4.7.1 *River Rother*

The River Rother rises near Pilsley, 7 miles south-east of Chesterfield. The river flows north through a mixed catchment containing rural areas, villages, the town of Clay Cross and industrial areas. The river flows under a railway adjacent to a large disused chemical works (Avenue Coking Plant). Downstream of this point, the Rother passes through a flat-bottomed valley, where the river is surrounded by a marshy floodplain area with reeds, before entering the town of Chesterfield.

The river passes mainly through the industrial areas on the eastern side of Chesterfield, and is open all the way through the town, apart from road and railway crossings. In the south of the town, an unnamed watercourse at Storforth Lane discharges to the River Rother. Nearer to central Chesterfield, Spital Brook connects to the Rother adjacent to the A61 bypass at Horns Bridge. The Rother is joined by the River Hipper on the left bank, and north of the town the river is joined by the River Whitting, also from the left bank.

Downstream of Chesterfield, the River Rother follows the railway to the north-east. There is a gauging station at Whittington, not far below the confluence with the River Whitting, beside a large sewage works. For the next three miles the river is surrounded by large-scale industrial works, with the urban areas of Brimington and Staveley to the south and east, and a rural hilly catchment to the north. At Renishaw, the Rother is joined from the right bank by the River Doe Lea. At Eckington, the Moss enters the Rother from the west.

4.7.2 River Hipper and Holme Brook

The River Hipper flows from uplands in the west in an easterly direction into the centre of Chesterfield, passing to the south of Holymoorside and splitting Brookside and Brampton in the north and Walton and Boythorpe to the south. In the centre of the town it meets the River Rother which is in turn a tributary of the River Don.

The main tributary of the Hipper is Holme Brook. Holme Brook is a continuation of Linacre Brook, which is supplied by three large reservoirs; Upper, Middle and Lower Linacre Reservoir, supplying water to Severn Trent Water. Downstream, Holme Brook flows to the north of Ashgate before joining the Hipper at Queens Park, to the south west of the town centre.

Both the Hipper and Holme Brook flow down steep-sided mainly rural valleys before joining in the Brampton district of Chesterfield.

The catchment is predominantly underlain with impermeable rocks of lower and middle coal measures with small area of Millstone Grit in the upper catchment. Soils in these areas are well drained. Considerable parts of the lower catchment are formally drained by a network of sewers. There have been frequent floods at the confluence of the Rother and the Hipper

The standard average annual rainfall (1961-1990) for the catchment is estimated as 874mm, which is typical for the eastern slopes of the Pennines.

4.7.3 Rivers Whitting, Drone, Barlow Brook and Riddings Brook

The River Whitting is the name given to a short stretch of river linking the confluence of the River Drone and the Barlow Brook to the River Rother. It originates in the high ground to the northwest of Chesterfield. The River Whitting joins the River Rother at a location immediately north of Brimington Road North in Chesterfield.

The River Drone rises in the Batemoor district on the southern extremity of Sheffield. It flows through Dronfield in a steep channel and joins the River Whitting to the east of Sheepbridge Lane in Sheepbridge. The upper part of the catchment is largely urban, and below Dronfield the catchment is largely rural.

The Drone catchment is predominantly permeable and, as such, the effects of urbanisation would be more significant. This is also the case for Barlow Brook.

Riddings Brook is a small watercourse. It originates to the west of Dunston Housing Estate in Chesterfield and follows a steep and largely culverted route along the northern boundary of Chesterfield and discharges into the River Whitting near Armytage Industrial Estate.

4.7.4 River Doe Lea, Hawke Brook and Pools Brook

The River Doe Lea rises to the northeast of Tibshelf and flows north, parallel to the upper Rother, through a gently-sloping valley to the east of Chesterfield. On the either side of the river, the land rises up to an altitude of 180 mAOD. Near Staveley, the Doe Lea is joined by the Hawke Brook from the east and the Pools Brook from the west.

4.7.5 River Poulter

A minor watercourse, known as the River Poulter rises near Upper Langwith, and flows eastwards through Langwith into the main River Poulter that runs outside of the district boundary.

4.8 Flood Protection of the catchment

4.8.1 River Rother

The main flood alleviation measures on the River Rother are controlled washlands downstream of the study area designed to reduce flood risk in Rotherham and Doncaster. There is also a controlled washland on the Rother by Slitting Mill Farm, just upstream of the River Doe Lea confluence. Elsewhere there are areas of uncontrolled washlands, i.e. natural floodplains, for example a marshy area just south of Chesterfield, and an area of grassland in the St Augustines area of Chesterfield. Houses adjacent to this area on Sherwood Street and Hawthorne Street have suffered flooding, but are protected to some extent, by flood defences for an estimated 1 in 50 year flood event.

4.8.2 *River Whitting*

The flood risk along the River Whitting has been reduced as a result of a flood alleviation scheme carried out in the mid 1980. This scheme was designed for an estimated 1 in 50 year flood event, although the Station Road Bridge is recognised to fall short of this standard.

4.8.3 *River Drone*

A flood storage reservoir has been constructed upstream of Dronfield on the River Drone. This, together with some low walls and embankments in the town, is designed to provide a 75-year standard of flood protection along the River Drone. The previous standard of protection in central Dronfield was only 5 years.

4.8.4 *River Doe Lea*

On the River Doe Lea there are significant areas of natural floodplain that allow flood peaks to attenuate. There are a number of designated washlands between Glapwell and Markham Vale development.