

Carlisle

Flood Investigation Report



Brunton Park football ground 6th December

Flood Event 5-6th December 2015

This flood investigation report has been produced by the Environment Agency as a key Risk Management Authority under Section 19 of the Flood and Water Management Act 2010 in partnership with Cumbria County Council as Lead Local Flood Authority.

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Executive Summary

The flooding experienced in Carlisle on the 5th and 6th of December 2015 was unprecedented, and was the result of the effects of Storm Desmond. This storm caused a period of prolonged, intense rainfall across Northern England, falling on an already saturated catchment, and led to high river levels and flooding throughout Cumbria and beyond. The flow in the River Eden in Carlisle on the 6th of December was the highest ever recorded, resulting in flood levels in some locations that were approximately 600mm higher than those experienced during the previous record set in January 2005.

In response to the flood event, this *flood investigation report* has been completed by the Environment Agency as a key Risk Management Authority (RMA) working in partnership with Cumbria County Council as the Lead Local Flood Authority, under the duties as set out in Section 19 of the Flood and Water Management Act 2010. This report provides details on the flooding that occurred in Carlisle on the 5th and 6th of December, and has used a range of data collected from affected residents, site visits, surveys of the area, and data collected by observers and river & rainfall telemetry during the flood event. This data has been compiled by CH2M, specialist consultants in flood risk management who have provided advice in understanding the event and recommendations for future action.

The existing flood defences in Carlisle were designed to protect the city from a flooding event greater than that which was experienced in January 2005, taking into account climate change and an allowance for freeboard. The river levels experienced in December 2015 exceeded the design level of the existing defences, resulting in the extensive flooding of the City. Although defences were overtopped no defences were breached. In some locations defences were successful in reducing the damage, and delayed flooding, which gave residents additional time to prepare and reduce the impact of the flood.

Approximately 2,100 properties were directly affected by the flooding, and approximately 1,450 properties were protected by the existing flood defences, mainly in the Denton Holme area of the city.

This report details the flooding that occurred from the Rivers Eden, Petteril, and Caldew, flooding from other watercourses and from surface water. It identifies the flow routes and the causes of the flooding where flood defences were overtopped or bypassed in a number of locations in Carlisle:

- The embankments on both sides of the River Petteril upstream of Botcherby Bridge
- The left bank of the River Eden at the Sands Leisure Centre upstream of Eden Bridge and the flood defences downstream in Bitts Park
- Etterby Terrace on the right bank of the River Eden downstream of Eden Bridge
- The River Eden flood defences along Warwick Road, including Durrhill storage basin
- Caldew Maltings including Willow Holme Industrial Estate on the left bank of the River Caldew
- Defences at Carlisle sewage works from Parham Beck and the River Eden

Please note references to left and right bank are taken looking downstream with the flow of water.

Seventeen actions have been recommended in this report to manage future flood risk, which will require the involvement of a number of organisations and local communities. One of the main actions is a review of the performance of the existing Carlisle Flood Risk Management Scheme to identify what worked well, and any areas that could be improved. This review will also include potential improvements to processes such as flood warnings and gravel management. This review is already underway and is expected to be complete by July 2016.

Government is investing £3bn in flood defences in the six years to 2021 to protect the whole nation from flooding, which includes a boost of £700m announced in the last budget. Up to £25million of this funding has been earmarked to improve flood risk management in Carlisle and a further £33million has been earmarked for other Cumbrian communities.

In response to the flooding, a number of community meetings have taken place, and these will continue in order to ensure that all those affected are given the opportunity to be involved in reducing the flood risk in their area of the city.

Any additional information that residents and others can provide to the Environment Agency and Cumbria County Council to help develop our understanding of the flooding is welcomed. A lot of information has already been provided, much of which has been used to inform this report. The scale of this report means that not every piece of information can be incorporated into the document. Any additional information should be provided to;

<http://www.cumbria.gov.uk/planning-environment/flooding/floodriskassessment.asp>

Flooding History

Carlisle is at the confluence of three major rivers, the Rivers Eden, Caldew and Petteril, and is therefore highly prone to flooding. The city has a long history of flooding with notable floods in 1771, 1822, 1856, 1925, 1968 and more recently in 2005. The 2015 flood level on the River Eden was 0.6m higher than in 2005.

The flood event in January 2005 affected approximately 1600 properties and led to the loss of 3 lives. That event had an estimated Annual Exceedence Probability (AEP) of 0.59% (1 in 170) of flooding occurring in any one year. Much of the city’s current flood defences were developed following this flood event. **They were designed to reduce the flood risk for an event with a 0.5% probability of flooding occurring in any one year.**

The annual exceedence probability (AEP) describes the likelihood of a specified flow rate (or volume of water with specified duration) being exceeded in a given year. There are several ways to express AEP as shown in Table 1. Throughout this report AEP is expressed as a percentage. As such an event having a 1 in 100 chance of occurring in any single year will be a 1% AEP event.

AEP (as percent)	AEP (as probability)	Annual recurrence interval (ARI)
50%	0.5	2-year
20%	0.2	5-year
10%	0.1	10-year
4%	0.04	25-year
2%	0.02	50-year
1%	0.01	100-year
0.1%	0.001	1000-year

Table 1 Probabilities of Exceedance

The city’s defences were tested in November 2009. The flood defence scheme developed following the 2005 floods, significantly reduced the impact of this flood event .There were a small number of properties that were affected by flooding mainly in public amenity areas that are not protected by flood defences.

There was also an event in June 2012, where severe rainfall led to high river levels within Carlisle. The 2012 event was primarily on the River Caldew, whereas the 2005, 2009 and 2015 events were driven by all three rivers.

During the 2012 event, the Caldew remained within its channel and there was minimal flooding. This was partly due to the lower levels in the River Eden and also due to the flood defence scheme along the Caldew.

The 2015 event was of significantly greater magnitude than past events and the flow in the River Eden was the highest level recorded.

Table 3 shows the recorded maximum flows in the 3 rivers during these past flooding events and the numbers of properties affected.

Flooding Event	Number of Properties Flooded	Peak Flow in River Eden @Sheepmount (m ³ /s)	Peak Flow in River Eden @Great Corby (m ³ /s)	Peak Flow in River Calder @Cummersdale (m ³ /s)
January 2005	1600	1516.4	1372.9	252.6
November 2009	15	1029.3	815.6	175.8
December 2015	2128	1680.0	1490.0	279.0

Table 2 Recent Flood Events affecting Carlisle

Event background

This section describes the location of the flood incident and identifies the properties that were flooded.

Flooding Incident

Carlisle is the county town of Cumbria and a major city with a population of approximately 74,000*. The city is an economic and industrial centre for Northern England and the Scottish Borders and is also a tourist destination due to its roman heritage and nearby Lake District National Park. Due to the numerous watercourses and drainage systems within the city there are several areas at risk of flooding.

* From ONS (Office of National Statistics) Population estimates for UK, England and Wales, Scotland and Northern Ireland 2014

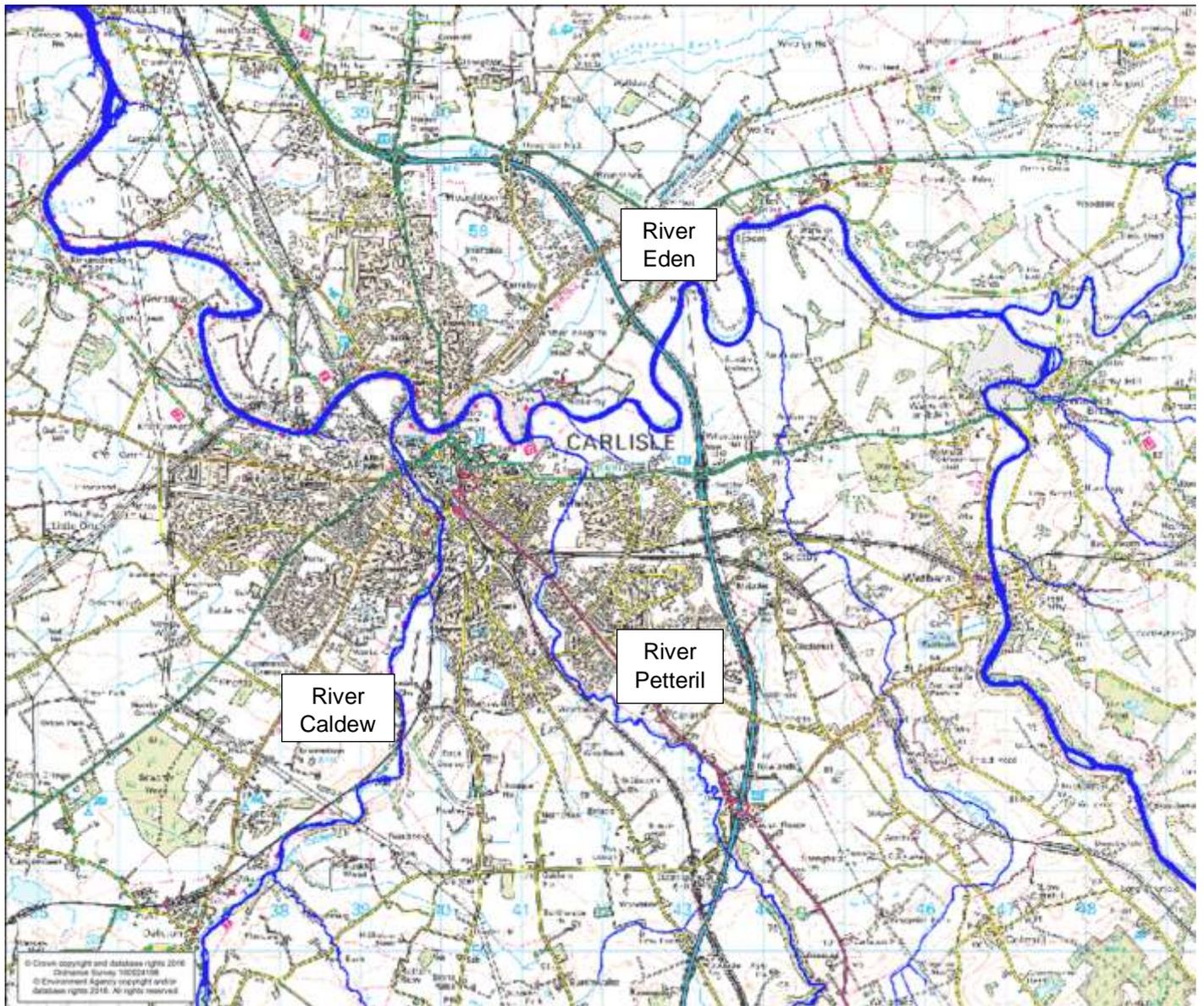


Figure 1 Location of Carlisle and Major Rivers

On 5th and 6th December 2015, approximately 2,100 properties suffered flooding. This flooding can be attributed to a record-breaking rainfall event from Storm Desmond. This led to widespread flooding from the Rivers Eden, Petteril, and Caldew, plus flooding from other watercourses, surface water and drainage systems. Figure 2 shows the approximate extent of the flooding.

Flooding was primarily associated with fluvial (river) sources and it should be noted that Carlisle lies upstream of any tidal influence on the River Eden so flood risk is not impacted by tides on the Solway Estuary.

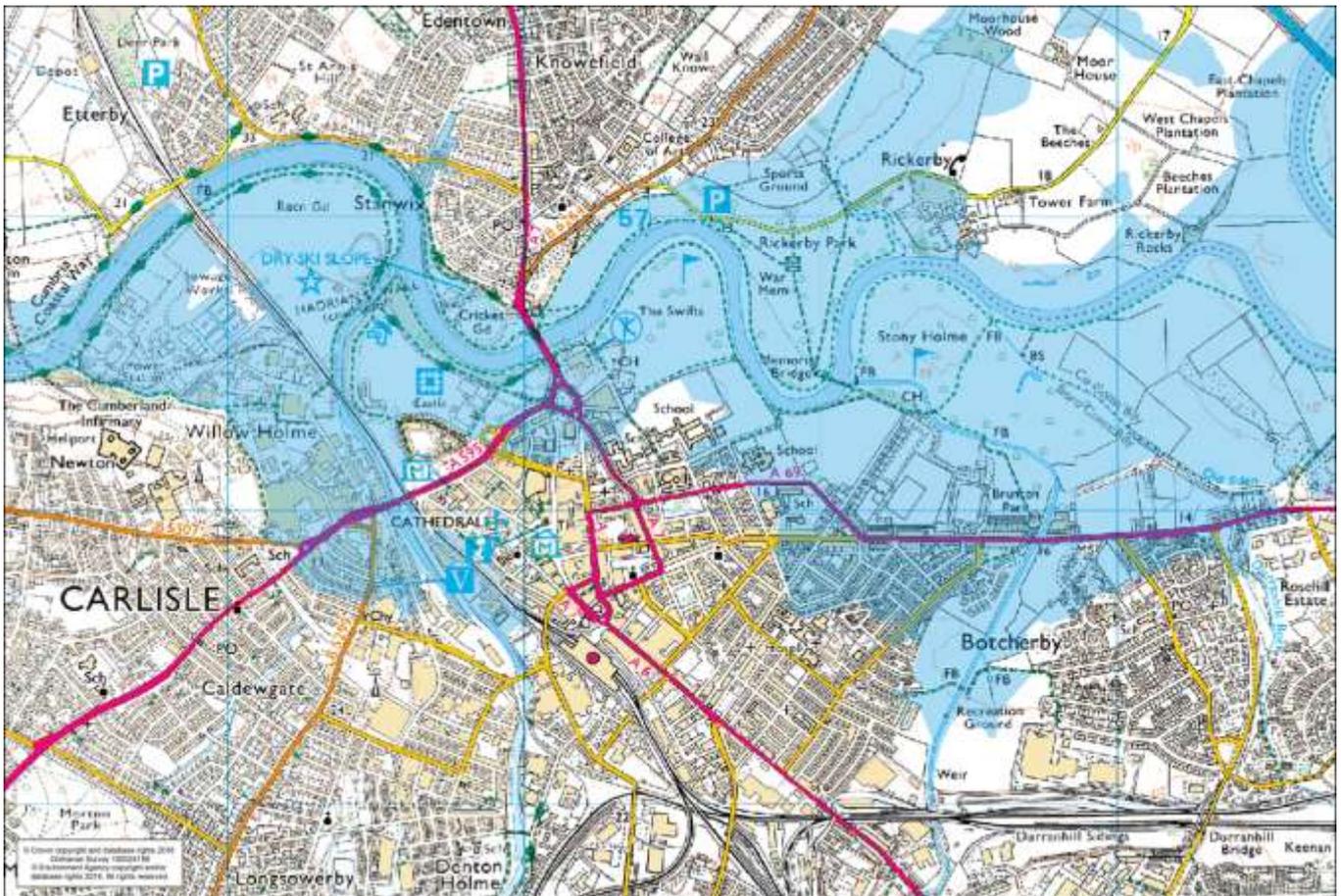


Figure 2 Extent of Fluvial (River) Flooding in Carlisle on 5-6th December 2015

For this report the flooded area has been divided into 7 sub-areas for investigation. These are shown in Figure 3.

- **Warwick Road East** – Warwick Road on the right bank of the River Petteril and surrounding area
- **Warwick Road West** – Warwick Road on the left bank of the River Petteril and surrounding area
- **Hardwick Circus** – The area south of Eden Bridge
- **Rickerby** – Rickerby village north of the River Eden
- **Etterby Terrace** – The flooded area on the right bank of the River Eden located downstream of Eden Bridge
- **Viaduct Estate** – The area on the right bank of the River Caldew around Caldew Bridge
- **Willow Holme** - The left bank of the River Caldew and the left bank of the River Eden where these two rivers meet

Please note references to left and right bank are taken looking downstream with the flow of water.

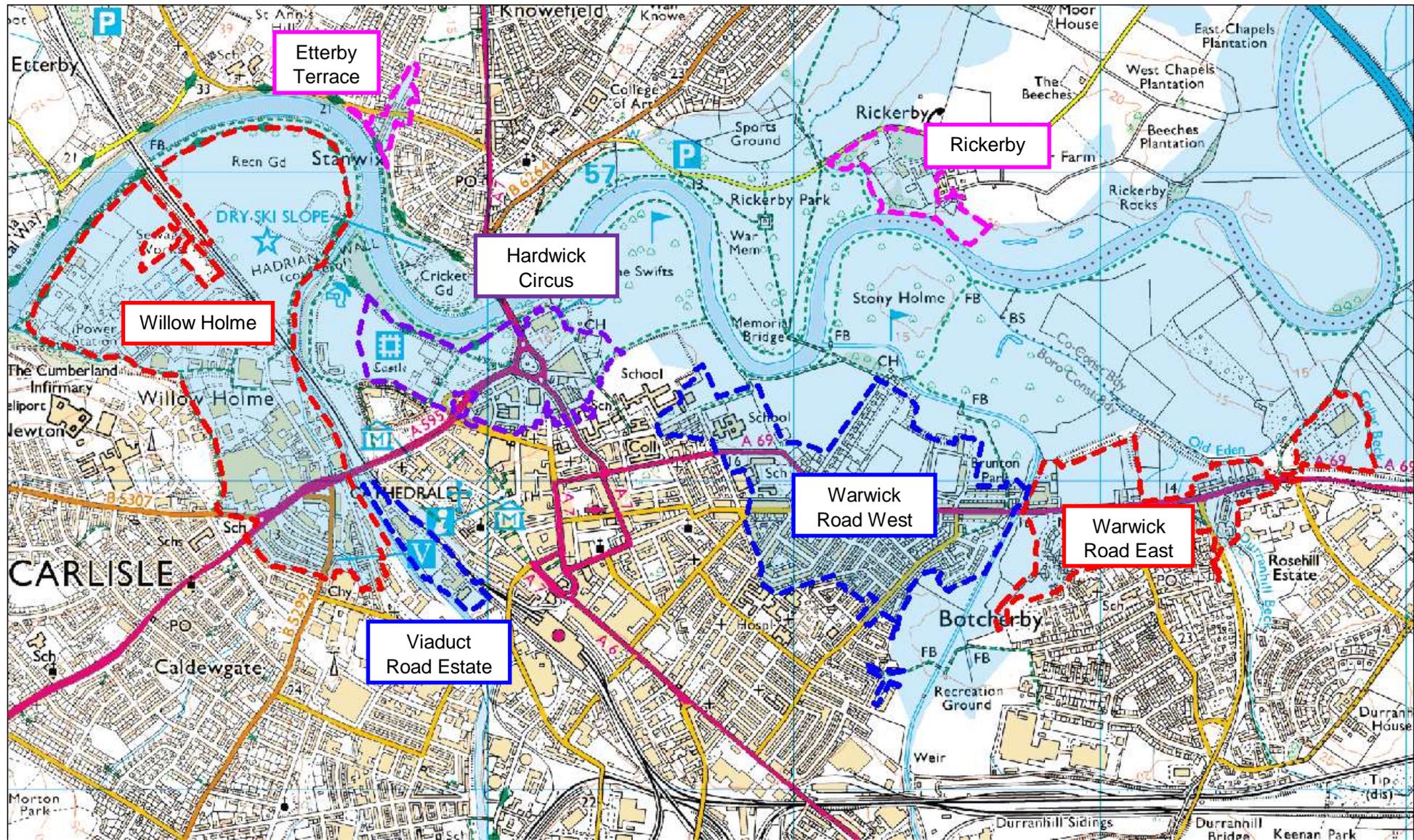


Figure 3 Identification of Areas Flooded

Current Flood Defences

Carlisle's flood defences were constructed in several phases with the majority being built following the severe flooding that occurred in January 2005. These provide protection to the city against a flood event greater than that which was experienced in January 2005. They were designed to reduce the flood risk from an event with 0.5% probability of occurring in any one year with an allowance for climate change and freeboard.

The first of these was the Eden & Petheril Flood Alleviation Scheme in the east of the city (completed in 2007) and this was followed by the Caldew & Carlisle City Flood Alleviation Scheme to the west (completed in 2010). In addition to this there are smaller schemes at Etterby Terrace and Harrayb Green, which were completed before the 2009 storms.

A map of existing defences is shown in Figure 4.

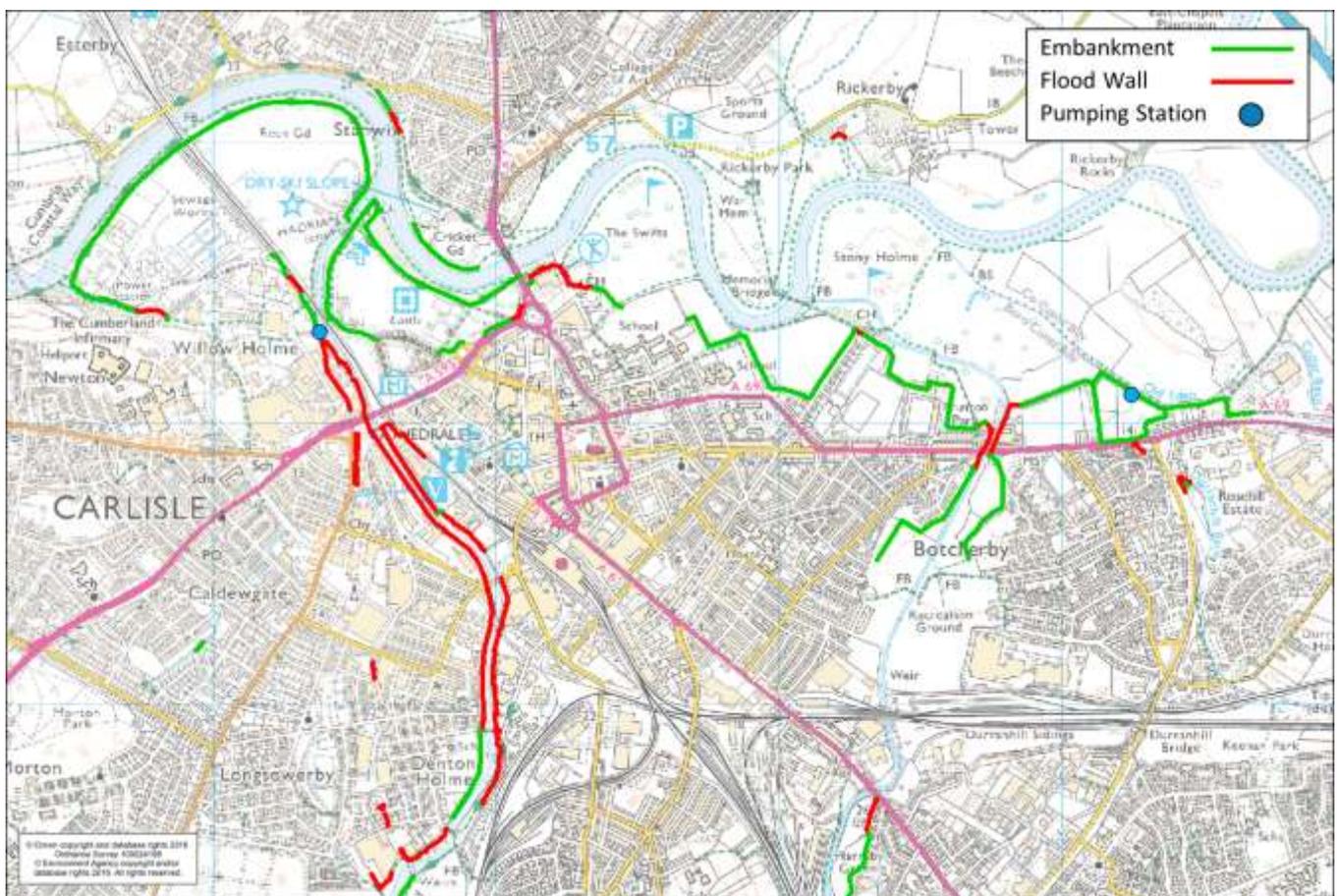


Figure 4 Flood Defences within Carlisle

Investigation

This section provides details of the rainfall event, the likely causes of flooding and the history of flooding in the area.

This investigation was carried out by the Environment Agency through surveys of the area and data collected from the communities affected with help from Cumbria County Council.

This report has been compiled by CH2M from the data collected by the Environment Agency. CH2M are a global civil engineering consultancy providing a full range of flood management consultancy services in the UK and overseas. CH2M's range of experienced specialists have provided input into understanding this event and producing recommendations for future flood management in Carlisle. More details of CH2M's work in the UK is included in Appendix 5.

Rainfall Event

December 2015 was the wettest calendar month on record with much of the northern UK receiving double the average December rainfall. This also followed a particularly wet November and as such much of the soil within the Cumbria catchments was already saturated.

From the 4th to the 7th of December there was a period of prolonged, intense rainfall caused by Storm Desmond. Over this period, new 24 hour and 48 hour rainfall records were set for the UK. Both of these were within Cumbria and broke the previous records, also within Cumbria, set during the November 2009 floods.

Record breaking rainfall fell across Cumbria which caused exceptionally high river flows across the county and widespread flooding. The level of the River Eden peaked at 7.8m on the gauge at Sheepmount gauging station at 9:15am on Sunday 6th December. This was the highest river level ever recorded at this location, exceeding the previous record level of 7.2m recorded in 2005.

Table 3 shows the levels of rainfall that fell prior to the flooding event in four monitoring locations on the Eden upstream of Carlisle. These locations are shown in figure 5. The equivalent rainfall at these stations prior to the 2009 event is also shown demonstrating that the 2015 rainfall is significantly more severe. The rainfall for several of these locations has an estimated Annual Exceedance Probability of less than 0.1% (1 in 1000) and as such this level of rainfall would be expected to be extremely rare.

Location	24 hour Rainfall during November 2009 Event	24 hour Rainfall during December 2015 Event	
	mm	mm	Estimated AEP
Scalebeck	60.8	147.6	0.2% to 0.1%
Skelton	42.2	137.8	<0.1%
Brotherswater	200.8	293.4	<0.1%
Aisgil	61.2	105.7	20% to 5%

Table 3 Rainfall over 24 hours in the Eden catchment prior to the December 2015 event

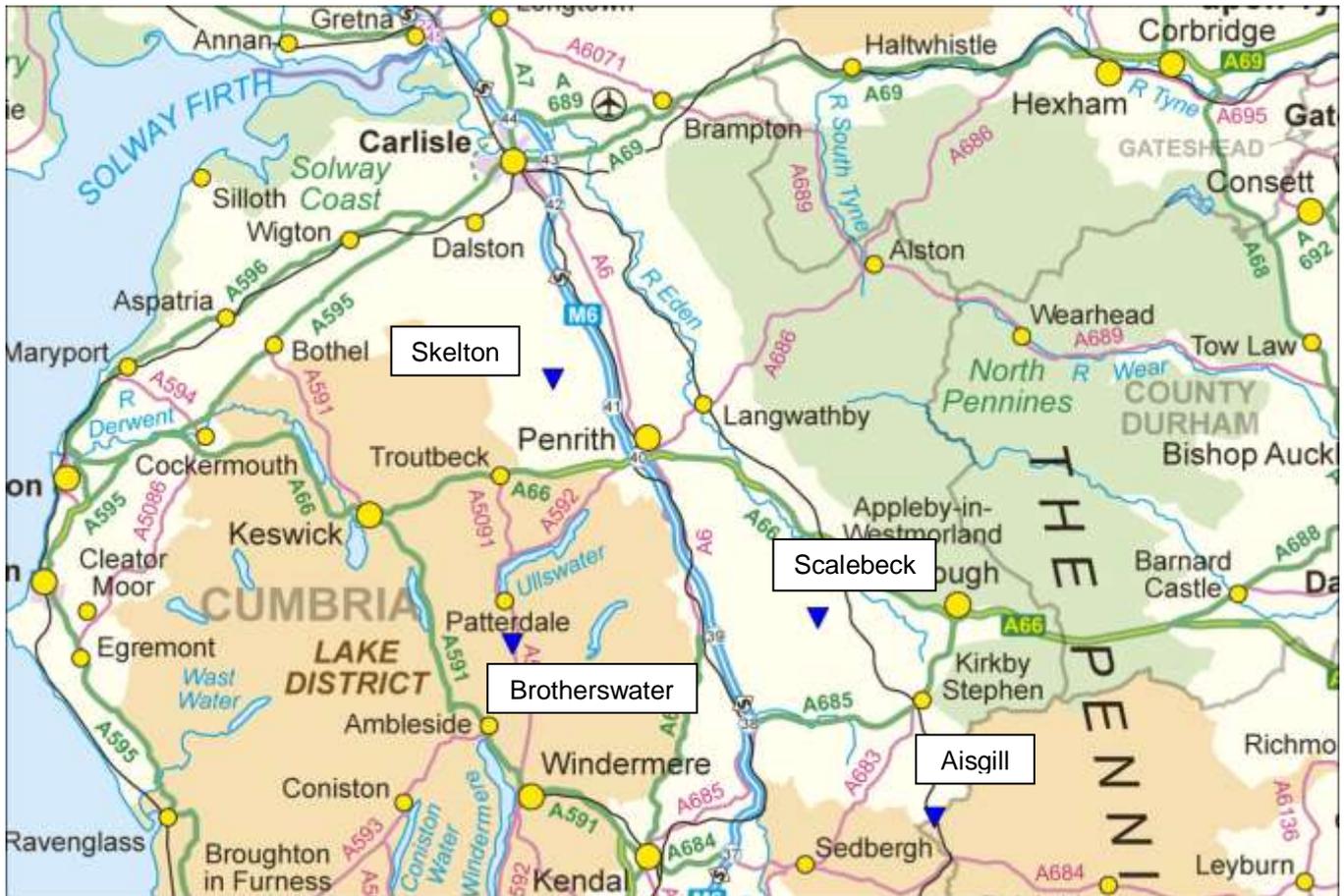


Figure 5 Location of rain gauges in the Eden catchment upstream of Carlisle

There are 4 river monitoring gauges in the Carlisle area, these are shown in Figure 6. The peak flows recorded on the Rivers Eden and Caldew are shown in Table 4, along with the flows from past flooding events.

Figure 7 shows the flow recorded by these river monitoring gauges from the 4th to the 8th of December. This shows the time and duration of the flood event on the 5th and 6th of December. This illustrates the magnitude of the flood event and the relative sizes of the three rivers.

The December 5th 2015 event has been estimated to be close to a 0.33% (1 in 300) Annual Exceedance Probability (AEP) event. An event of this magnitude therefore has a 0.33% chance of being exceeded in any year. The flow during this event was greater than any flow previously recorded on the River Eden. This is a greater magnitude event than the scheme was designed to protect against (0.5% AEP - 1 in 200). As such, river levels would be expected to be higher than the flood defence level and some overtopping of the defences would be expected to occur.

Gauging Station	River	Peak flow (m ³ /s)		
		Dec 2015	Past Events*	
			June 2012	Jan 2005
Great Corby	Eden	1490	N/A	1373
Cummersdale	Caldew	279	313	253
Sheepmount	Eden	1680	615	1514

Table 4 Peak Flow in River Gauges around Carlisle

* Flows for past events taken from CEH National River Flow Archive <http://nrfa.ceh.ac.uk/data/search>

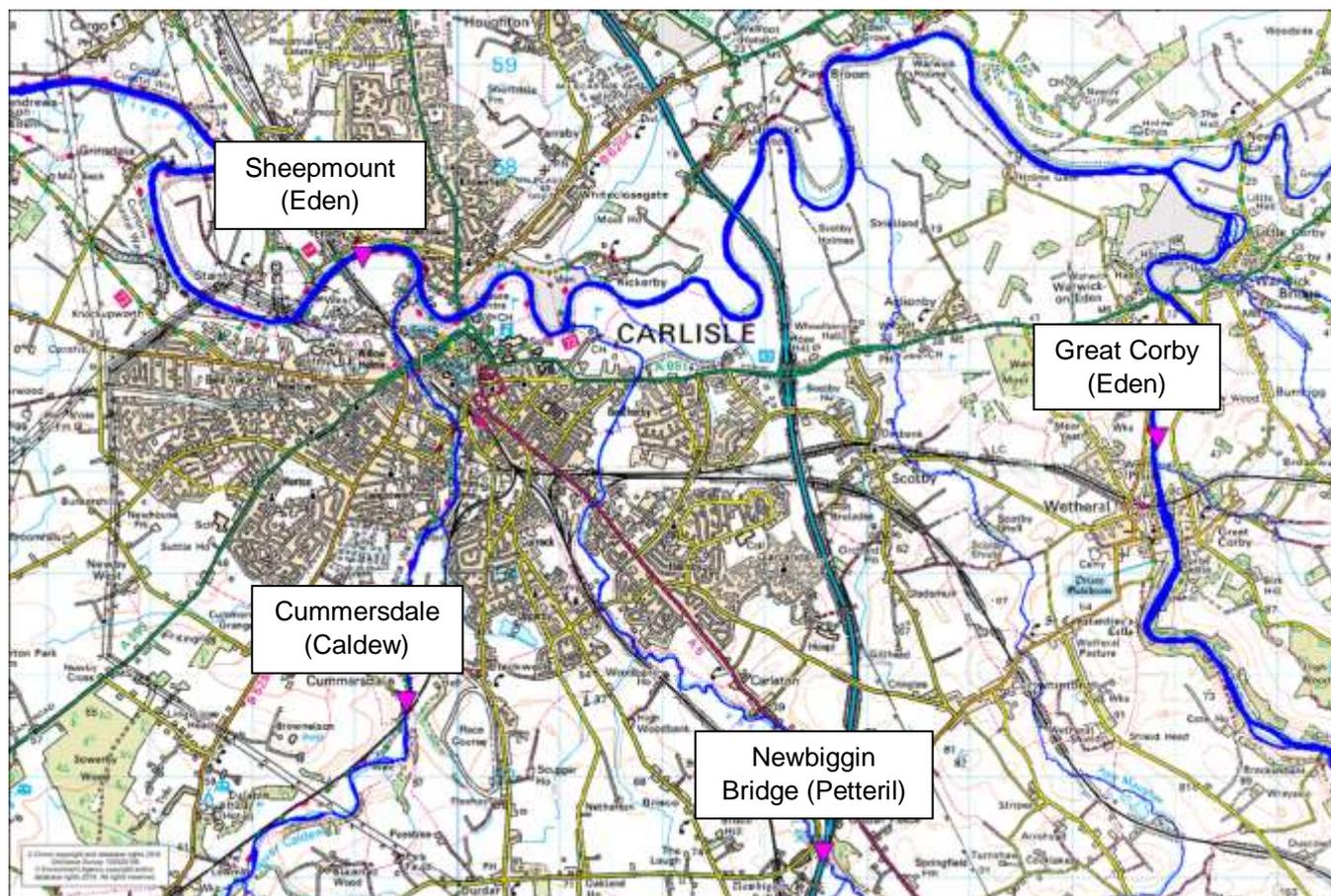


Figure 6 Location of river gauges around Carlisle

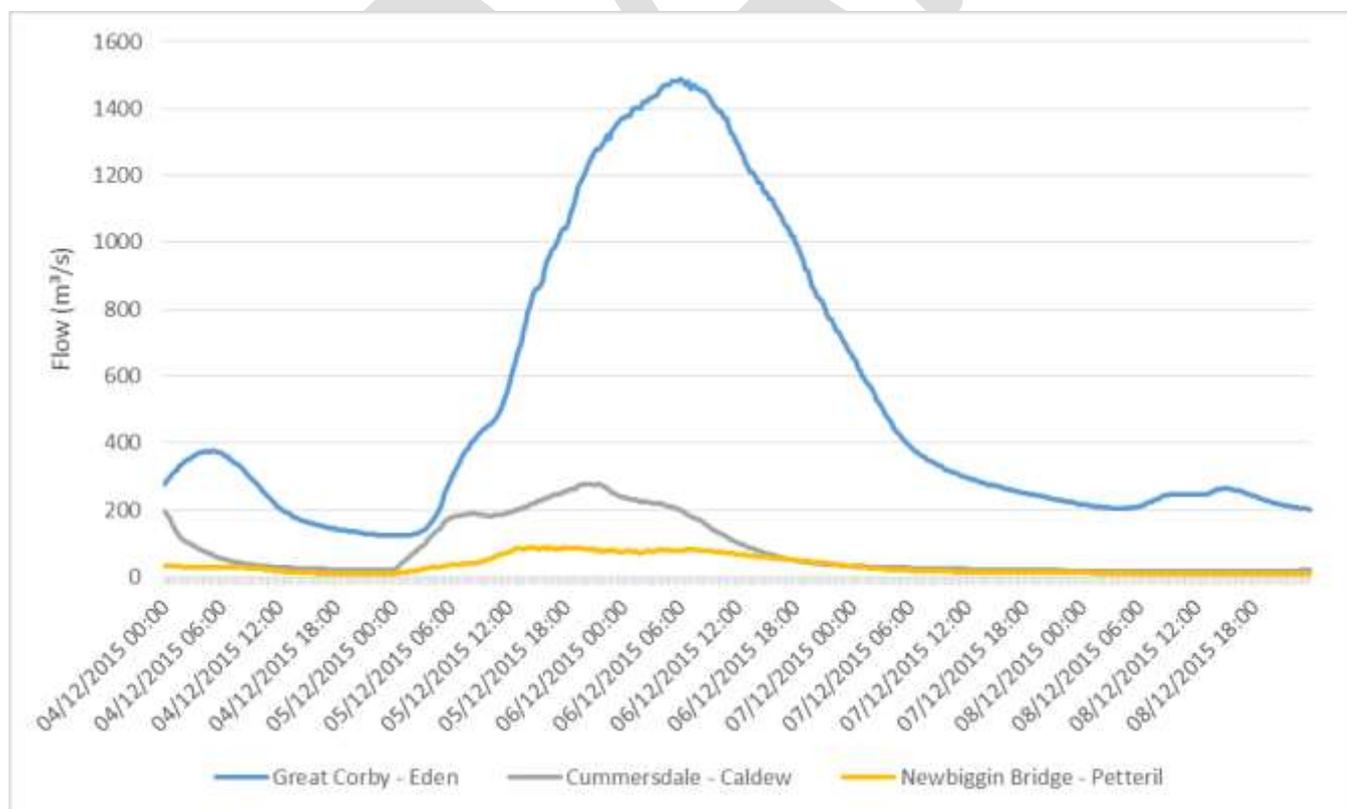


Figure 7 Flow recorded upstream of Carlisle during the December flood event

Flooding Flow Routes

There were a number of flood flow routes during the event. For investigation purposes, the flooded areas have been divided into the 7 sub areas shown in Figure 3.

The details of the flow routes into these areas, the likely causes, and the properties flooded are discussed in the 'Likely Causes of Flooding' section. There may also have been other flooding mechanisms that were not identified during this investigation.

Likely Causes of Flooding

Warwick Road East

Timeline

5th December	Event
1528	Flood Warning Issued
1734	Severe Flood Warning Issued
6th December	Event
0400	Flooding from drains reported on Tilbury Road
0400	River Petteril overtops right bank at Botcherby Bridge
0800	Flow from direction of flooded Tesco superstore
0800-0900	River Eden embankment overtopped
0815	River Petteril peak at Botcherby Bridge – 4.36m
0915	River Eden peak at Sheepmount – 7.80m
1000-1030	Reported flooding to Eden Park Crescent at the South-Eastern extent of the flooded area

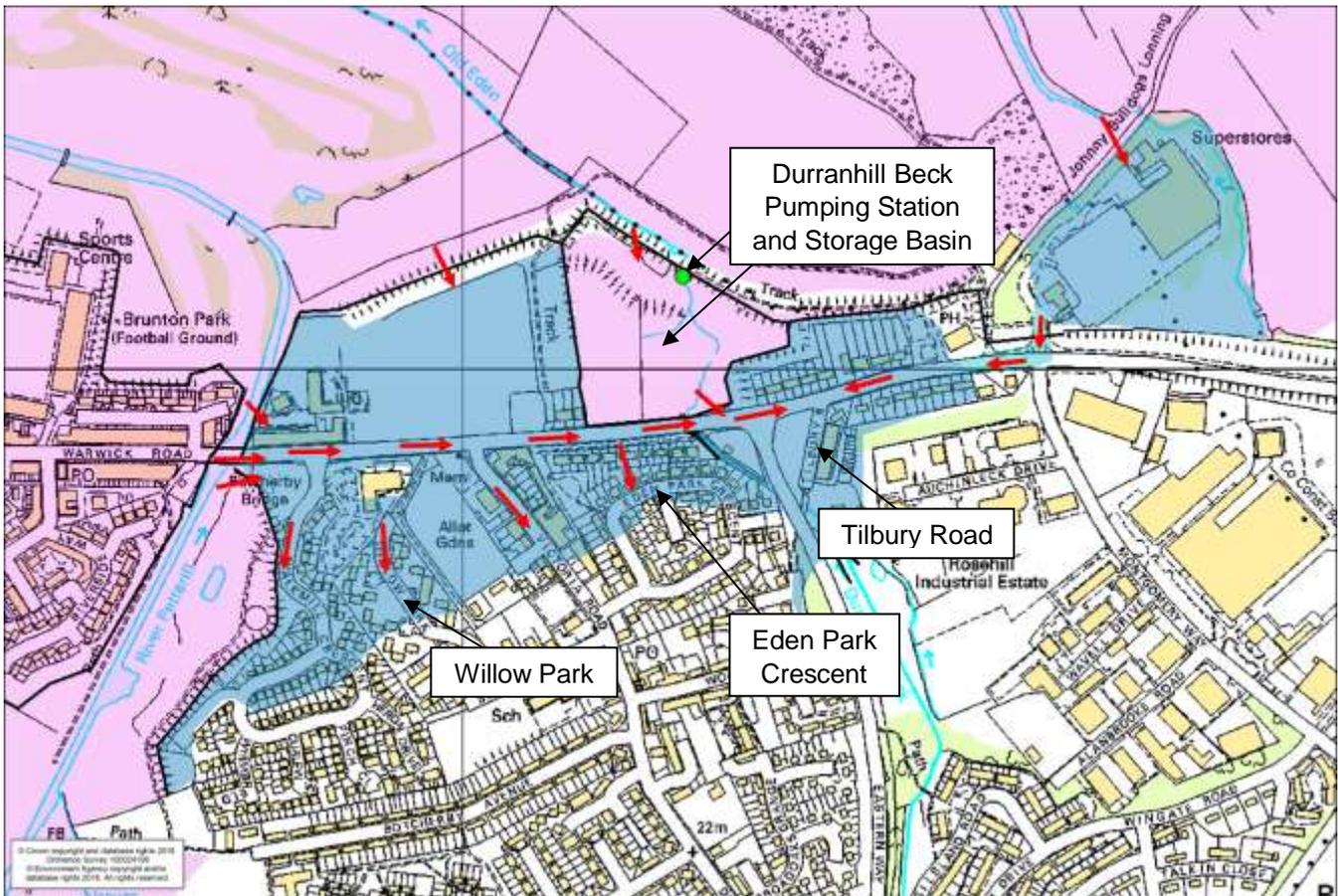


Figure 8 Flood Flow Routes in Warwick Road East area

This area is on the right bank of the River Petteril and left bank of the River Eden. There is also a smaller watercourse, Durranhill Beck, which flows through the area. Warwick Road crosses the River Petteril at Botcherby Bridge in this location. This area is primarily residential and was flooded from the River Petteril and also from the River Eden in the latter stages of the flood event.

This area is defended by a combination of embankments and walls along both rivers. There are also defences around Durranhill Beck creating a storage basin with a pumping station to discharge water from Durranhill Beck into the Eden during times of elevated water levels in the River Eden.

There was initial flooding from drains and road gullies surcharging before the defences were overtopped. This was reported in Willow Park and Tilbury Road.

The main flow route into this area was from the Petteril overtopping the defences upstream of Botcherby Bridge. Floodwater spilled onto Warwick Road, flowing in an easterly direction and flooding properties on Warwick Road and adjoining roads in the area.

Early in the event, Botcherby Bridge acted as an obstruction to flow leading to higher water levels upstream of the bridge and over topping of the left bank . However the defences on the right bank were not overtopped until high water levels in the River Eden caused flow in the River Petteril to back up.

The left bank of the River Petteril had flooded prior to the defences on the right bank being overtopped. This led to flood flows over Botcherby Bridge from the West of Warwick Road. This route, as well as the route from the overtopped defences, led to flows East down Warwick Road flooding the surrounding area.

The pumping station on Durrhill Beck pumps water stored in the storage basin when water cannot naturally flow into the River Eden during periods of high river levels. During the flood event the power supply to the area failed; following this the pumping station continued to run on an emergency generator until it exhausted its fuel and stopped pumping. This occurred in the early hours of Sunday morning, but the exact time that pumping stopped was not recorded. Whilst the pump was operational the storage basin for Durrhill Beck worked well and did not fill to capacity. Following the failure of the pumping station the basin filled and overtopped leading to additional flooding on Warwick Road.

The Tesco store at the east of this area was flooded directly from the River Eden. This store is not protected by flood defences. During the latter stages of the event on Sunday morning flood water overtopped the raised access road to the store (which forms part of the flood defence scheme). The access ramp may have formed a low point in the River Eden defences in this area. This flow route will have contributed to the flooding on the eastern extent of the flooded area of Warwick Road.



Figure 9 Flooded Tesco store with the flow route onto Warwick Road visible

The defences along the River Eden in this area were overtopped at the time of the peak flow in the River Eden. This was after the onset of flooding from the River Petteril.

This flooding occurred overnight with defences on the River Petteril reported to have been overtopped at 04:00 on Sunday 6th December. Affected residents described the flood as a gradual increase in levels. The properties furthest from the river were not flooded until later in the morning with properties in Eden Park Crescent not reported to have flooded until after 10am on the 6th December. These properties were flooded from the direction of Warwick Road but this may have occurred through the flow paths that developed later in the flood event.

Warwick Road West

Timeline

5 th December	Event
1528	Flood Warning Issued
1600	Flooding from drains reported in Adelaide Street
1600	River Petteril begins to flood Melbourne Park from left bank
1734	Severe Flood Warning Issued
6 th December	Event
0000	Reported flooding to Tullie Street, Greystone Road and Riverside Way from left bank of River Petteril
0300	Reported flooding to St Aidans Road from River Petteril
0815	River Petteril peak at Botcherby Bridge – 4.36m
0915	River Eden peak at Sheepmount – 7.80m

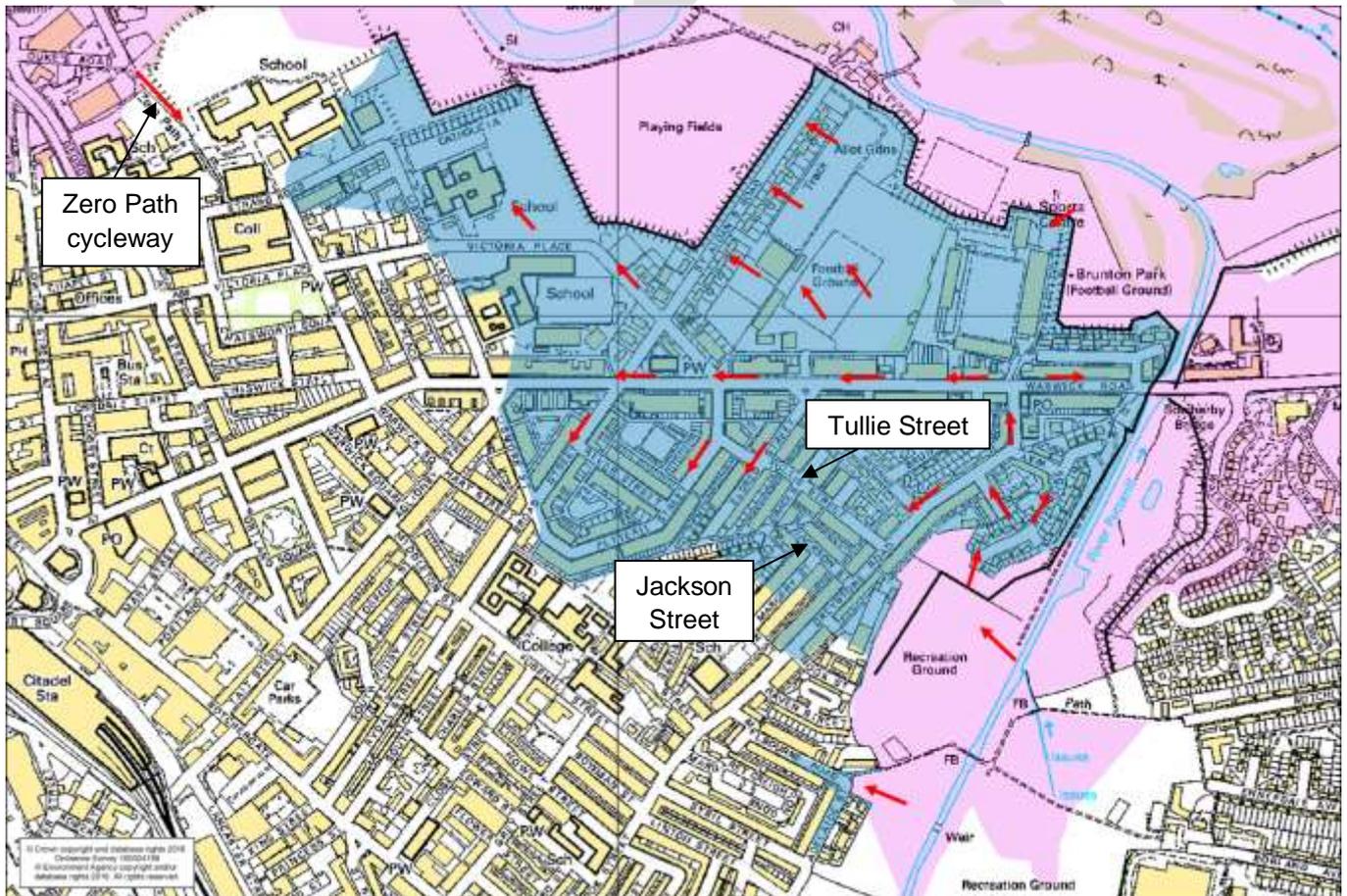


Figure 10 Flood Flow Routes in Warwick Road West area

This area is located on the left bank of the River Petteril on the opposite side of Botcherby Bridge. The flooded area is primarily residential with a number of schools also affected. There are flood defences along the banks of both rivers consisting of earth embankments and sheet piled walls. There were a number of properties that flooded during the flood event of the 5th and 6th December that had never flooded historically in this part of the city. This is a reflection of the size of the event experienced in December 2015.

This area is a relatively densely populated urban area with several blocks of terraced housing. Due to this, a large number of properties were flooded. This area accounts for a large proportion of the total flooded properties within Carlisle.

There was flooding reported early on Saturday afternoon to Adelaide Street. This was from the River Petteril outflanking the flood defences at Melbourne Park via a flow route upstream of these defences. There was also flooding from drains reported in the area at this time. This was reported to have occurred at 16:00 on the 5th December, significantly before the peak river levels in the Petteril and Eden. Residents in Jackson Street and Vasey Crescent reported that the properties in these streets closest to the River Petteril had water rising through the floorboards prior to flooding from the river.

The main flow route into this area was from defences being overtopped upstream of Botcherby Bridge. Melbourne Park was also flooded with the defences here being overtopped near the end of Riverside Way. As with the Warwick Road East area, this was exacerbated by the high levels in the River Eden. The defences within Melbourne Park were also out-flanked, as the river levels were greater than the ground level upstream of these defences. In addition to this, there was some leakage through the defences immediately upstream of Botcherby Bridge; some water was seeping through the corner joint of the defence wall before properties were flooded from the Melbourne Park route.



Figure 11 Melbourne Park and River Petteril during flood event

The overtopping of this defence led to flooding in Riverside Way, Greystone Road and Tullie Street at midnight. This flood route then continued to Warwick Road and flooded the neighbouring streets. This flooding extended as far as St Aidans Road and Newman & Trinity Schools. This also led to flood water flowing over Botcherby Bridge into the Warwick Road East area.

There was also flood flow reported down Zero Path from the direction of Hardwicke Circus. This also contributed to the flooding to the schools. The time of this flow was not recorded but is expected to have been after the onset on flooding from the River Petteril.

In this area, there was no evidence of overtopping along the River Eden defences. As such the majority of flooding is believed to have come from the River Petteril. Properties on St. Aidan’s Road (alongside the River Eden) reported that flooding had come across the sports fields from the direction of the River Petteril. There were reports of the Carlisle City Rugby Club and Carlisle United football grounds flooding on Saturday night. This was possibly due to drainage systems backing up from where they outfall into the River Petteril.

Hardwick Circus

Timeline

5 th December	Event
1528	Flood Warning Issued
1734	Severe Flood Warning Issued
1800	Flooding from drains reported in Hardwick Circus area
6 th December	Event
0000-0030	Overtopping of defences between Bitts Park and Hardwick Circus
0215	Sands Centre defences overtopped
0215	Evacuation of properties on Corporation Road
0915	River Eden peak at Sheepmount – 7.80m

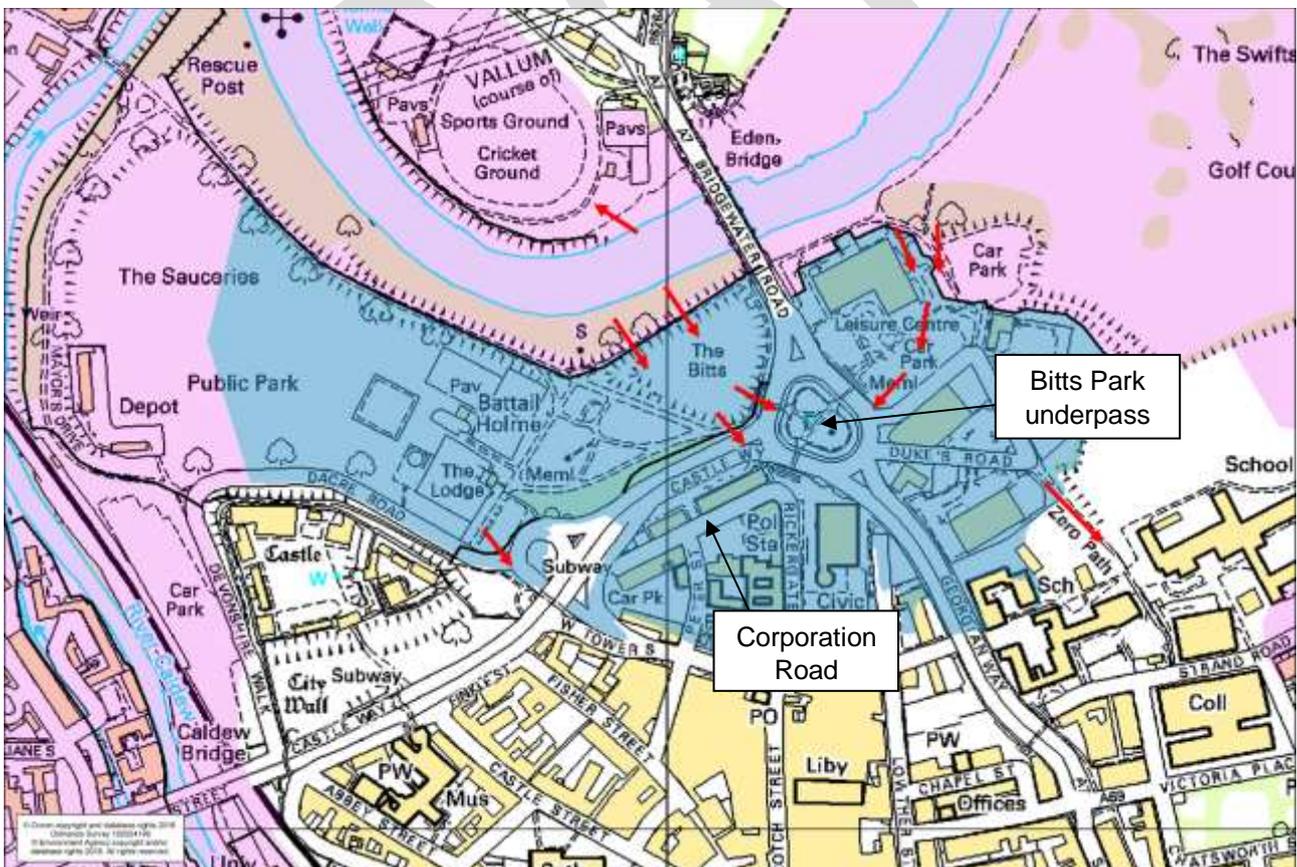


Figure 12 Flood Flow Routes in Hardwick Circus area

This is the area south of Eden Bridge and consists of commercial and retail buildings as well as Carlisle City Civic centre. To the north of the River Eden is the Cricket Ground which was badly affected during the flooding. The area is alongside the River Eden and there are flood defences along this riverbank in the form of embankments and reinforced concrete walls.

This area was initially flooded with surface water on Saturday evening then flooded from the River Eden when defences were overtopped. Defences were initially overtopped downstream of Eden Bridge at Bitts Park and at Dacre Road near Carlisle Castle. From this area, the flood water spreads under Castle Way and onto West Tower Street and Corporation Road. The water cascaded down the subway and rapidly filled the underpass and surrounding area. This flooding occurred around midnight and led to depths of up to 2m to the properties in this area. Subsequently, at around 02:15 on the 6th December, defences at the Sands Centre upstream of Eden Bridge were overtopped.

This area is adjacent to Eden Bridge, which carries the A7 trunk road. The left arch of this bridge was reported to have been blocked by debris during the flood event. This, combined with the flood flow level reaching to the top of the bridge arches will have increased river levels upstream of the bridge, and may have contributed to the overtopping of defences at the Sands Centre.

From this area there was flow down Zero Path towards Trinity School. This contributed to the flooding in the Warwick Road West area. The time of this flow was not recorded.



Figure 13 Hardwick Circus area during flood event



Rickergate at 23:07 on the 7th December



Peter Street facing towards Corporation Road at 03:23 on the 6th December

Figure 14 Photographs of Hardwick Circus area during the flood event

Rickerby

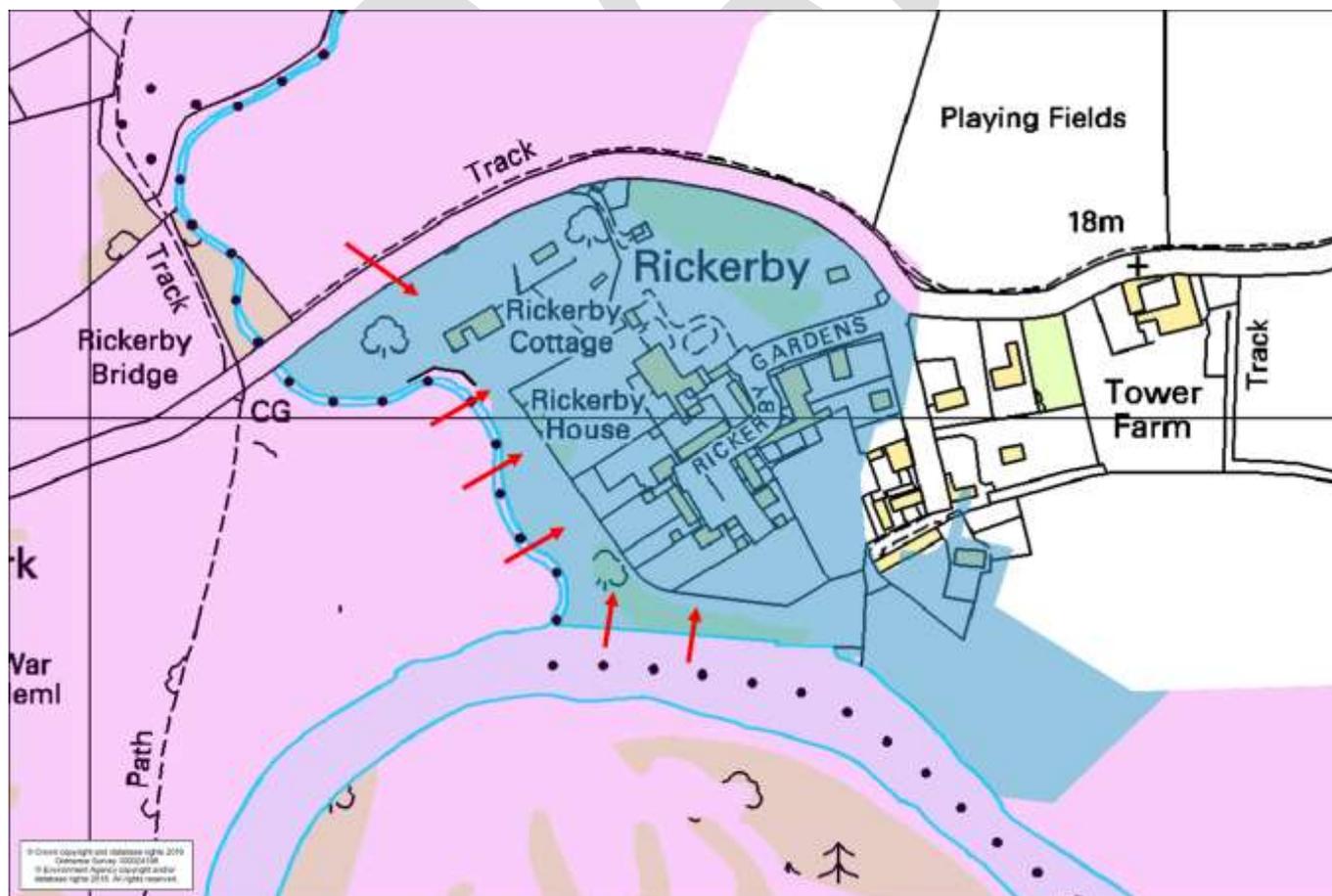


Figure 15 Flood Flow Routes in Rickerby

The majority of properties in Rickerby village are relatively new, and located in a residential development completed in 2004. Despite the village's close proximity to the River Eden there are limited flood defences in this area. The only raised defences consist of a small raised embankment to protect Rickerby House against minor flooding. As the area is at risk of flooding, many of the properties have property level protection.

As there are no significant defences for the Rickerby area, the village was flooded from both the River Eden and from the adjacent Brunstock Beck due to the high river levels in the River Eden. All but 2 properties within Rickerby Gardens were flooded as shown in Figure 15. Flood depths of up to 1.5m were recorded within these properties. The flooding extended to Rickerby Park where properties are at a higher ground level.

The onset of flooding to Rickerby is believed to have been around 21:00 hrs on the 5th December 2015 across the road to the north of the village. This was soon followed by water flooding from the Rickerby Park side of the village. Parts of the older Rickerby village were flooded on the Sunday at roughly 04:00 hrs.

Etterby Terrace

Timeline

5 th December	Event
1522	Flood Warning Issued
1600	Reported flooding to Etterby Terrace properties from Gosling Syke
1734	Severe Flood Warning Issued
2130-2200	Reported overtopping of River Eden defences at Etterby Terrace
6 th December	Event
0915	River Eden peak at Sheepmount – 7.80m

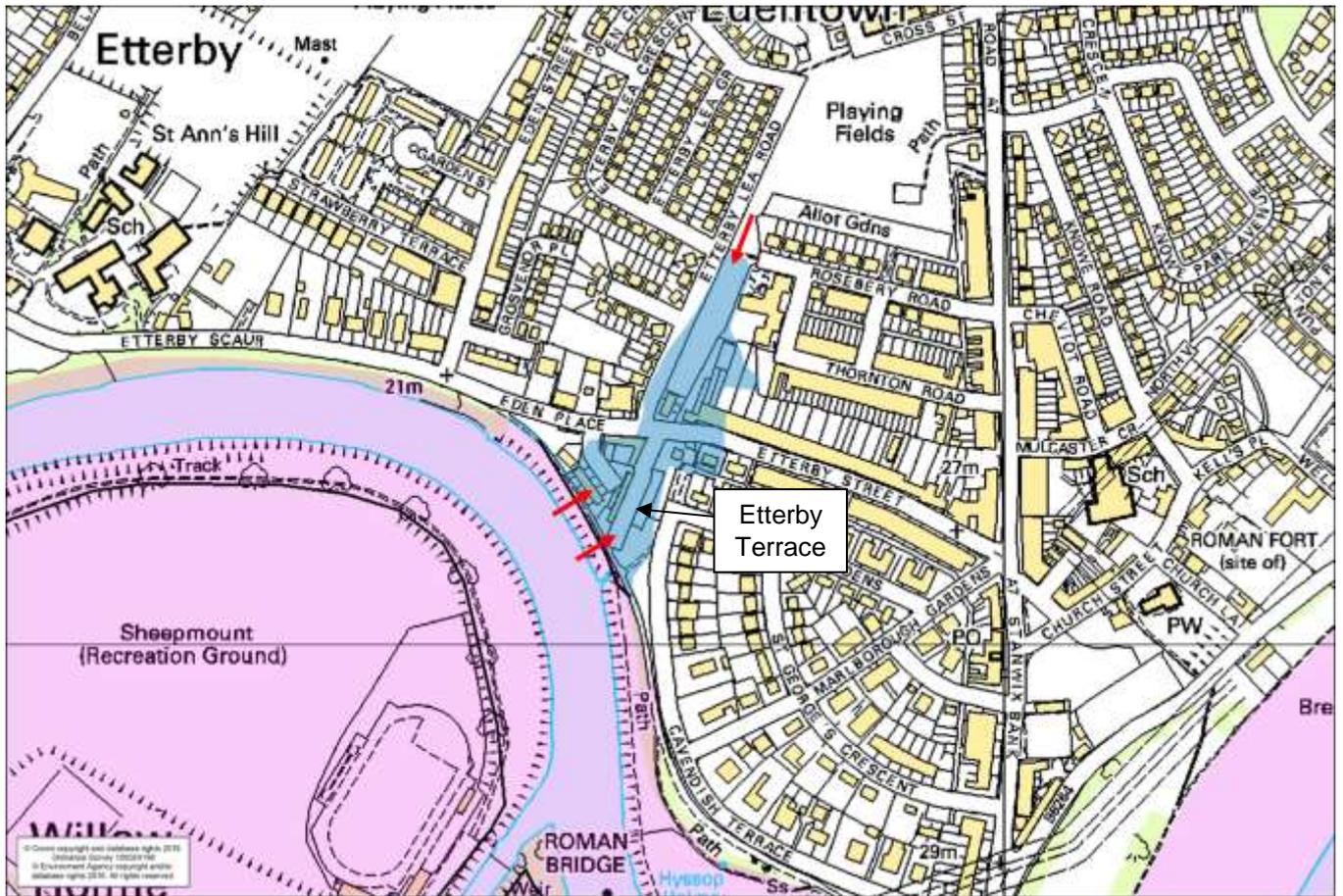


Figure 16 Flood Flow Routes in Etterby Terrace

This is an area of residential properties north of the River Eden. There is a flood defence wall along the River Eden at Etterby Terrace, constructed following flooding to this area in January 2005. There is also a culverted watercourse, Gosling Syke, which passes underneath this area and into the River Eden.

The River Eden overtopped this defence wall due to high river levels. This led to flooding in the area around the defence as shown in figure 16. However, the properties within this area reported that they had flooded prior to the defences overtopping.

Prior to the overtopping of the defences the properties within this area were flooded from surcharging surface water drains and from water rising through floors. This flooding was from Gosling Syke, a watercourse which passes underneath the area that was flooded. Residents reported that the Gosling Syke outfall is often blocked. However, this flooding may have been caused by high river levels in the Eden causing Gosling Syke to back up.

Willow Holme

Timeline

5 th December	Event
1655	Flood Warning
1734	Severe Flood Warning
2100	River Caldew peak at Skew Bridge – 5.04m
2230	Defences overtopped on left bank of River Caldew at Caldew Maltings
2330	Little Caldew Pumping station fails due to flooding
6 th December	Event
0915	River Eden peak at Sheepmount – 7.80m

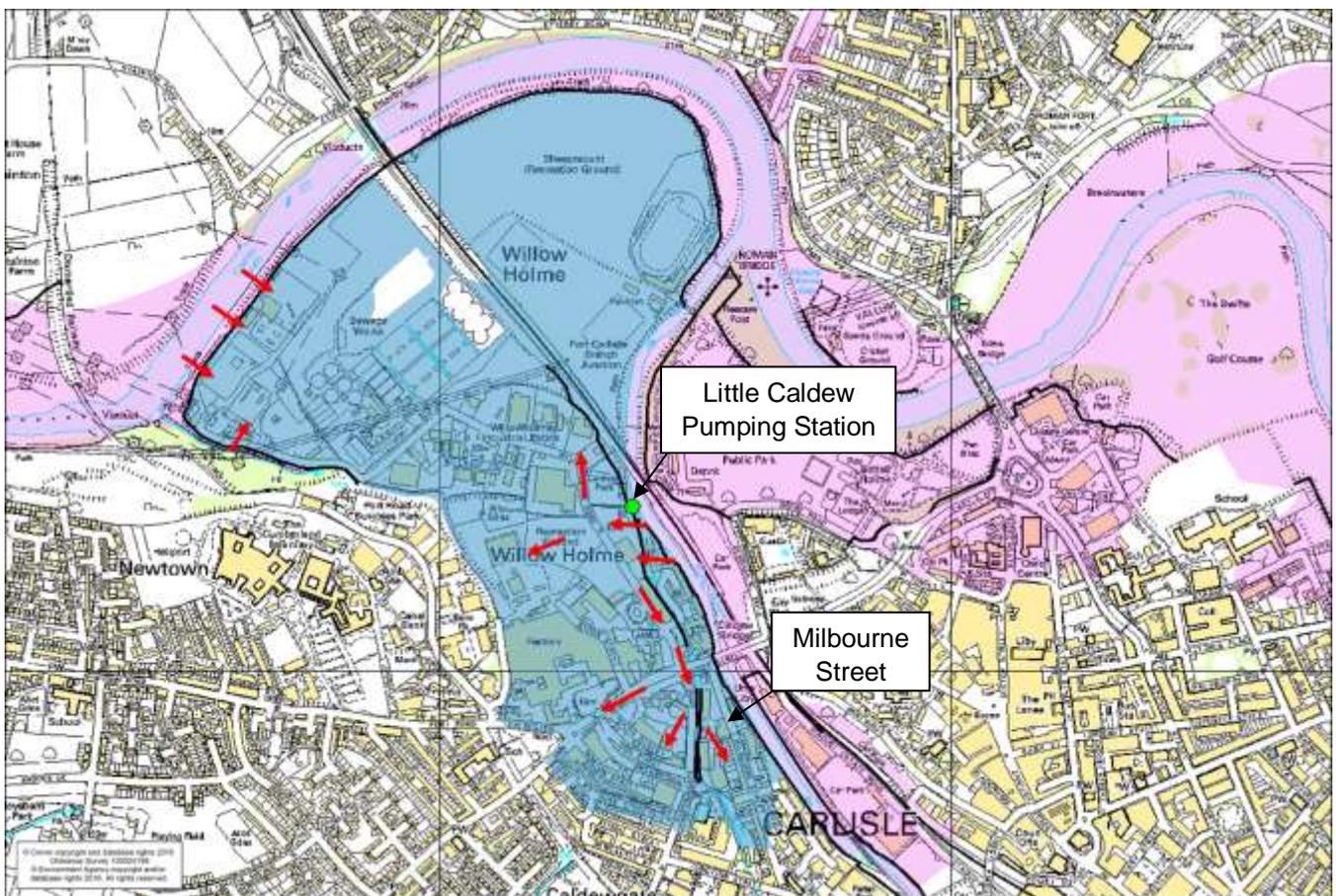


Figure 17 Flood Flow Routes in Willow Holme

This area is adjacent to both the River Caldew and River Eden. A large area was flooded including Carlisle sewage treatment works, Sainsbury's, Willow Holme industrial estate, the United Biscuits factory, and some of the Caldewgate residential area. In addition to the Rivers Eden and Caldew, there are also three smaller watercourses in this area, Parham Beck, Dow Beck, and the Little Caldew.

This area is protected by defences that were built following the floods in January 2005. There are walls and embankments along both banks of the River Caldew and a flood bund around the left bank of the River Eden. In addition to this, there are defence walls along Parham Beck, and a pumping station on

the Little Caldew mill race at the Caldew Maltings. This allows water from the mill race and Dow Beck to continue to discharge into the River Caldew when its water level is elevated. The Little Caldew flows from the River Caldew at Holme Head Weir via a sluice structure. This sluice structure is closed prior to high river levels and remains closed for the duration of flood events.

This area was flooded from both the River Caldew and River Eden due to flood defences being overtopped. The main locations where defences were overtopped are:

- The left bank of the River Caldew downstream of Caldew Bridge at Caldew Maltings and the Old Brewery
- The Sewage treatment works from the left bank of the River Eden
- Parham Beck running alongside the Sewage Treatment works and Willow Holme road

The areas where defences were overtopped are shown in Figure 17. Prior to the river flooding there was flooding reported from surface water drains. This was reported on Milbourne Street and in the Caldewgate area along the route of Dow Beck.

The defences on the River Caldew at Caldew Maltings overtopped at 22:30 on the 5th December. This is thought to be the main route through which most of this area was flooded. The time at which the Eden defences were overtopped was not recorded, but is thought to have occurred on Sunday morning after the flooding from the Caldew.

This was one of the first areas of the city that was flooded, with flooding occurring on the 5th December. This was due to this area being at risk from the River Caldew, which peaked before the Rivers Eden and Petteril. Despite this, defences were not overtopped until after the peak flow in the River Caldew, suggesting that flooding was due to restriction of flow caused by high levels in the River Eden.

This area of Carlisle contains several pieces of infrastructure that play a role in how flooding occurs. These include road and rail bridges and railway embankments. The Environment Agency needs to work with Network Rail to better understand the role that their bridges played to the flooding in this location. It also needs to understand how the West Coast main line embankment and railway line acted as flow routes into the city (see page 26 Viaduct Estate).

During the event, the pumping station on the Little Caldew at the Caldew Maltings stopped operating, as this was flooded. This pumping station failed due to flooding of the electrical components at 23:30 on the 5th December shortly after the defences at Caldew Maltings were overtopped. A number of properties flooded from the direction of the Little Caldew after this, and it is thought that this pumping station reduced the extent of this flooding whilst it was operational.

Properties at the Barrel House in the Maltings form part of the riverside wall at this location. They also form part of the defended line for the flood defence scheme along the left hand bank of the River Caldew. These properties suffered internal flooding through the floors and walls prior to the flood defences at the Maltings over topping.

There was a large amount of oil and diesel reported in this area following the flooding. This was from flooded commercial properties dealing in motor vehicles. This created pollution within the flooded area and additional challenges for properties recovering from flooding.



Figure 18 Cars in Willow Holme area covered with oil following flooding

Viaduct Estate

Timeline

5 th December	Event
1530	Flood Warning
1600	Flooding of West Coast Main Line on right bank of River Caldew
1734	Severe Flood Warning
2100	River Caldew peak at Skew Bridge – 5.04m
6 th December	Event
0915	River Eden peak at Sheepmount – 7.80m

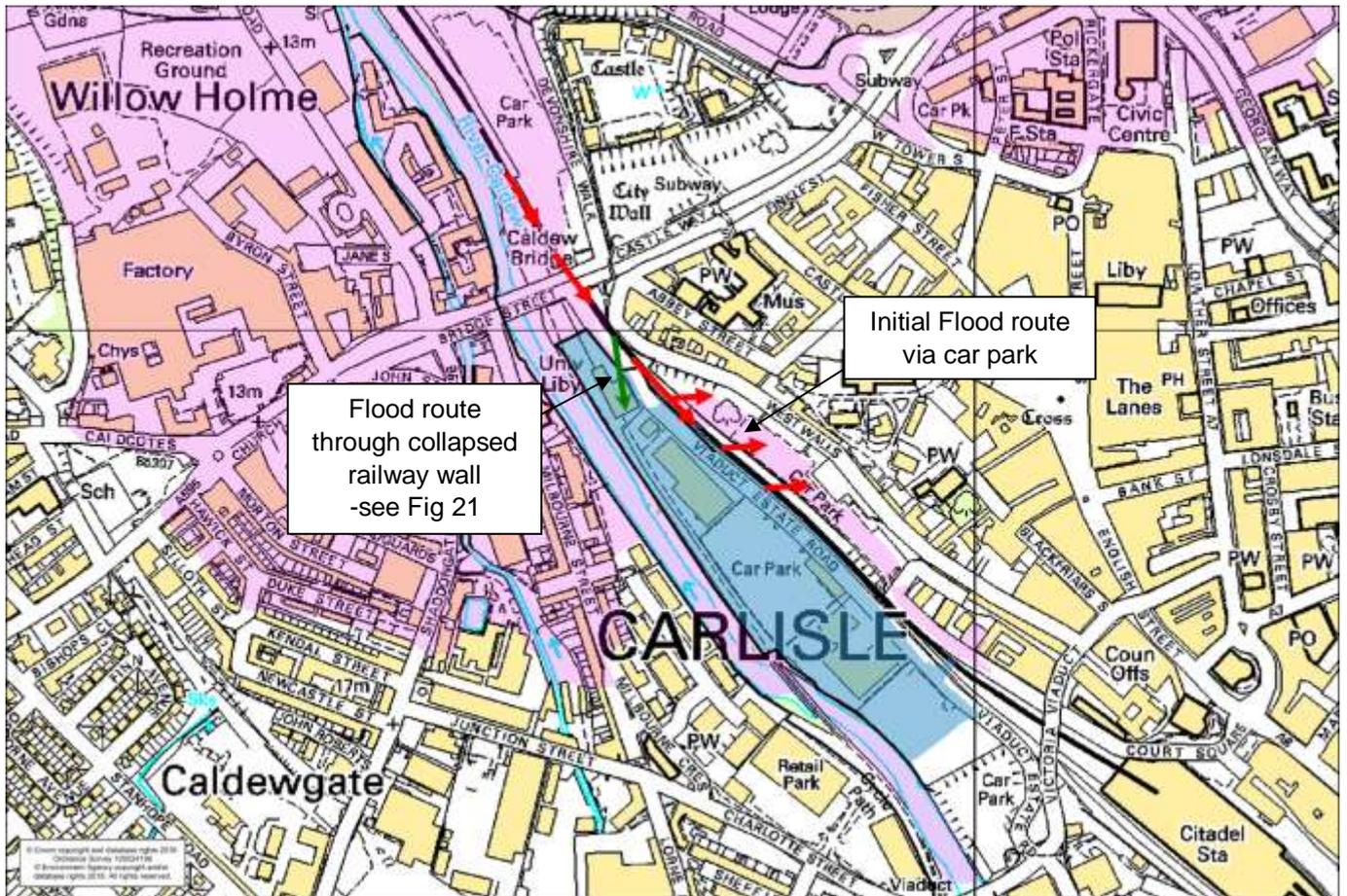


Figure 19 Flood flow routes into Viaduct Estate

The Viaduct Estate is a retail and leisure area located between the River Caldew and the West Coast Main Line railway. The area is protected from direct flooding from the River Caldew by a flood defence wall along the right bank (when looking downstream) of the River Caldew.

The flood defence wall upstream of Caldew Bridge on the right hand bank was not overtopped. The flooding of the Viaduct Estate was due to this defence being outflanked by water flooding out of bank downstream of Caldew Bridge, then flowing along the railway line and into the West Walls car park to the east of the railway. This is the route shown in red on Figure 19. From this car park, the water rose to a level where it passed through the open arches beneath the railway and into Viaduct Estate, flooding the properties within this area.

Later in the flood event, a section of the railway wall was breached at this location. The wall collapsed onto the footpath indicating that the breach was caused by the water on the railway line. Following this, the flow path into the viaduct estate would be directly from the railway line through this breach. This is the route shown in green on Figure 19.

When this area has been flooded previously, this was partly due to surcharging drains. This was not reported during this event but may have occurred prior to the river flooding.



Figure 20 Viaduct Estate during flood event



Figure 21 Wall along railway at entrance to Viaduct Estate that collapsed during the flood event

Environment Agency Flood Incident Response

The Environment Agency's response to the flood event on the 5th and 6th December 2015 started well in advance of the event. This response included the closure of flood gates and clearing of grids in the city. Additional resources including manpower and machinery such as pumps were also brought to the city.

The Environment Agency and Cumbria County Council are members of the Cumbria Local Resilience Forum. The Cumbria Local Resilience Forum (LRF) is a partnership, made up of all the organisations needed to prepare for and respond to any major emergency in the LRF area. All services and organisations worked together prior to and during the flooding to ensure that the best possible preparations and plans were in place.

A flood alert for the lower River Eden was issued on the 4th of December at 15:08. Flood warnings were issued to the flood warning areas within Carlisle between 13:11 and 16:55 on the 5th December. The details of the flood warning areas and the timings of these warnings is shown in Appendix 4.

A severe flood warning was issued at 17:34. The majority of properties reported that they had received these warnings within good time.

There were additional challenges with flood warnings, due to parts of the city flooding overnight. A number of residents did not respond to flood warnings because of this, and they therefore wrongly assumed that as the area was not flooded on Saturday evening following the severe flood warning, the risk of flooding had passed.

A number of properties affected by the flood event did not receive flood warnings as the residents were not registered with the Environment Agency's flood warning system. It was also recognised that the details stored for some residents were not up to date. The Environment Agency's Flood Resilience team have already made improvements to the flood warning service with 437 new customers registered to receive Flood Warnings Direct. The total of fully registered customers for Carlisle is up to 4330.

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Timeline

The table below shows the times of key events during the Carlisle flooding.

4th December	Event
1508	Flood Alert Issued
5th December	Event
1311-1655	Flood Warnings
1600	Flooding from left bank of River Petteril via route upstream of defences in Melbourne Park
1600	Flooding from drains reported in Warwick Road West area
1600	Flooding of West Coast Main Line on right bank of River Caldew
1600	Reported flooding to Etterby Terrace properties from Gosling Syke through drainage system
1734	Severe Flood Warning issued for Carlisle
1800	Flooding from drains reported in Hardwick Circus area
2100	River Caldew peak at Skew Bridge – 5.04m
2100	Reports of flooding at Rickerby
2130-2200	Reported overtopping of River Eden defences at Etterby Terrace
2230	Defences overtopped on left bank of River Caldew at Caldew Maltings (Willow Holme)
2330	Little Caldew Pumping station (Willow Holme) fails due to flooding
6th December	Event
0000	Reported flooding to Tullie Street from overtopping of defences on left bank of River Petteril
0000-0030	Overtopping of defences between Bitts Park and Hardwick Circus
0215	Overtopping of defences at the Sands Centre
0300	Reported flooding to St. Aidans road from River Petteril
0400	Flooding from drains reported on Tilbury Road in Warwick Road East area
0400	River Petteril overtops right bank at Botcherby Bridge leading to flooding of Warwick Road East area
0800	Flow into Warwick Road East area from direction of flooded Tesco superstore
0800-0900	River Eden embankment overtopped in Warwick Road East area
0815	River Petteril peak at Botcherby Bridge – 4.36m
0915	River Eden peak at Sheepmount – 7.80m
1000-1030	Reported flooding to Eden park Crescent on eastern extent of Warwick Road East area

Recommended Actions

The following table details recommended actions for various organisations and members of the public to consider using the Cumbria Floods Partnerships 5 Themes: Community Resilience, Upstream Management, Strengthening Defences, Maintenance, and Internal Drainage Boards (IDB's). Some of these recommendations may have already been carried out and or are ongoing.

Some of the actions referred to below are identified on the location map (fig. 22) following this table.

Cumbria Flood Partnership Theme	Action by	Recommended Action	Timescale
Community Resilience	Cumbria Local Resilience Forum *	Review and update plans to enable homes & business to be better prepared for flooding & reduce the impacts of flooding	2016
	Environment Agency and Cumbria County Council Highways, Network Rail and Electricity North West.	To review the flood risk and resilience of critical transport and power supply infrastructure.	Autumn 2016
	Environment Agency and Cumbria County Council Highways	Investigate potential to increase the flood flow capacity of Botcherby Bridge and Eden Bridge	Summer 2016
	Cumbria Planning Group, Carlisle City Council, Cumbria County Council and Environment Agency	Review Local Development Plans and Strategic Flood Risk Assessment to reflect current understanding of flooding	2016
	Environment Agency	Ensure all properties at risk can register to receive flood warnings and details are up-to-date.	Summer 2016
Upstream Management	Cumbria Floods Partnership (CFP)	The CFP action plan will consider natural flood management options to reduce flood risk across the catchment. This may also include land use changes and or flood storage.	July 2016
Maintenance	County Council, United Utilities and Carlisle City Council	Review and investigate drainage and sewage systems for which they are responsible to better understand where improvements are required.	2016
	Environment Agency and Cumbria County Council	Review outfalls to the River system within Carlisle and	Summer 2016

		ensure all outfalls are sealed with flap valves or non-return valves to prevent the defence scheme being compromised.	
	Environment Agency, United Utilities and Cumbria County Council	Complete on-going inspections and repairs to assets which may have been damaged during the flood event	2016
Strengthening Defences	Environment Agency	Review modelling data to ensure that models for Carlisle reflect real conditions as accurately as possible and use this information to make any improvements to the flood warnings service. This will be used to inform future investment plans.	July 2016
	Environment Agency	Review scheme performance and consider what worked well, and where improvements to defences are required	July 2016
	Environment Agency	Investigate potential to improve defences upstream of Botcherby Bridge to prevent overtopping and outflanking of defences in Melbourne Park.	July 2016
	Environment Agency in consultation with Network Rail	Investigate potential to extend the defences at Viaduct Road Estate to prevent flooding from the railway line. This could potentially consist of defence walls along the railway line or temporary barriers across the archways between the car park and viaduct road estate.	July 2016
	Environment Agency	Promote a flood defence scheme at Rickerby village.	Summer 2016
	Environment Agency	Improve resilience of pumping stations at Durrhill Beck and Little Caldew so that these assets remain in operation longer during severe flood events.	Summer 2016

	Environment Agency	Etterby Terrace experienced flooding from the drainage system, Gosling Syke and latterly the River Eden. All these sources of flooding need to be investigated	Summer 2016
	Environment Agency	The Environment Agency is carrying out a series of repairs to flood defence assets that were damaged during the floods as part of a c.£10m Asset Recovery Programme which covers Cumbria & Lancashire. This programme of repairs is scheduled to be complete before winter 2016/17 and includes work such as repairing the pumping station at the confluence of the Little Caldew and the River Caldew, reinstating embankments which suffered scour damage and removing large debris and silt/gravel build up from within the river channels.	Winter 2016

* The Cumbria Local Resilience Forum includes emergency services, Local Authorities, Cumbria County Council, Environment Agency, Maritime Coastguard Agency and health agencies along with voluntary and private agencies. Under the Civil Contingencies Act (2004) every part of the United Kingdom is required to establish a resilience forum.

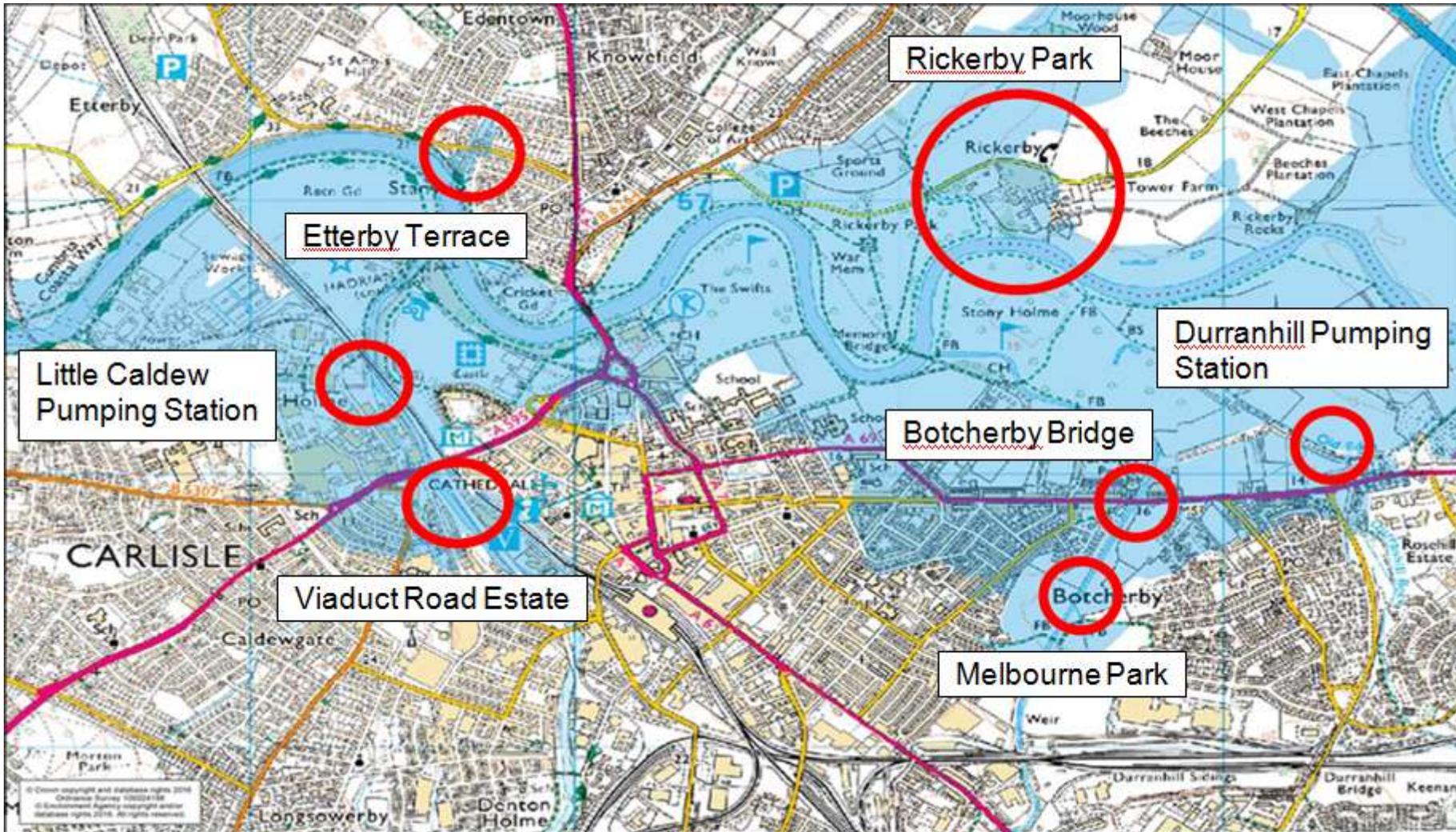


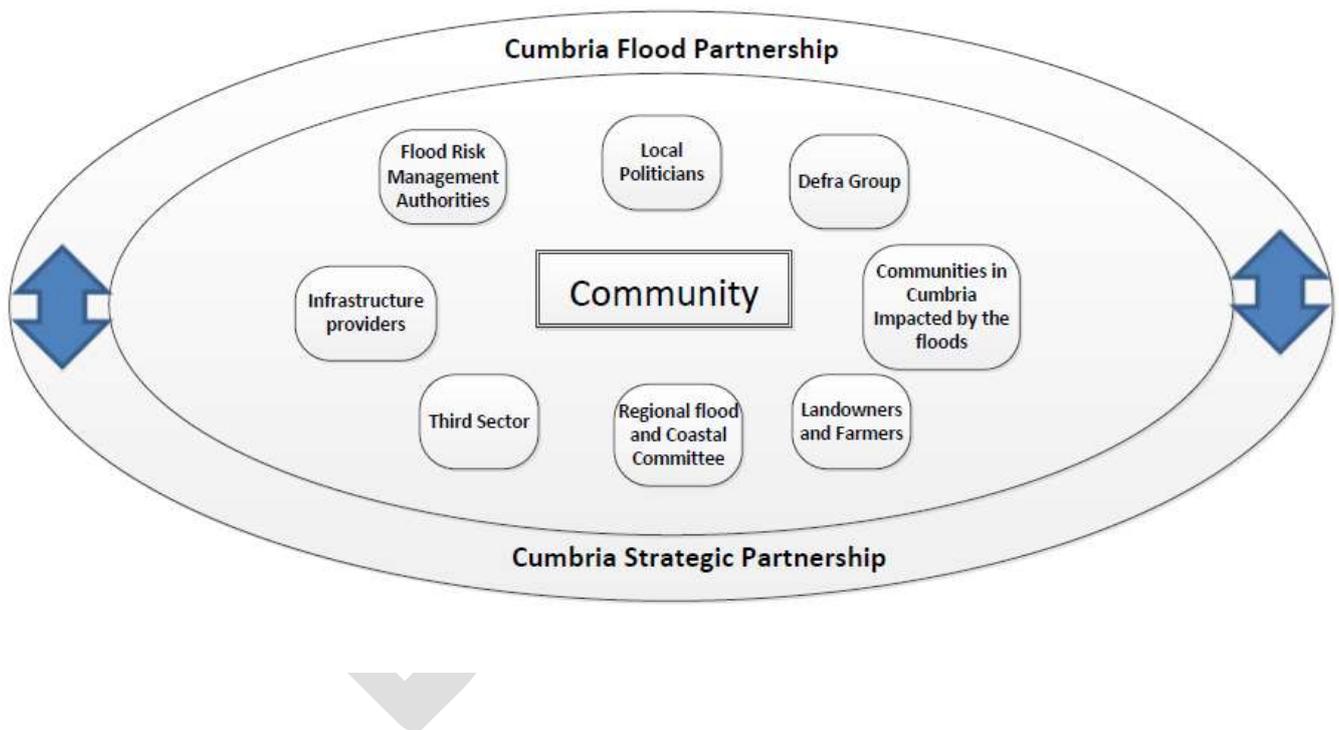
Fig. 22 Recommended Action Locations

Next Steps

The Cumbria Floods Partnership has brought together a wide range of community representatives and stakeholders from a variety of sectors to plan and take action to reduce flood risk. The Cumbria Floods Partnership, led by the Environment Agency, is producing a 25 year flood action plan for the Cumbrian catchments worst effected by the December 2015 flooding, including Carlisle. The plan will consider options to reduce flood risk across the whole length of a river catchment including upstream land management, strengthening flood defences, reviewing maintenance of banks and channels, considering water level management boards and increasing property resilience. The Cumbria Floods Partnership structure below details how these 5 themes are being delivered in the Flood Action plans which will be completed in July.

The 'Cumbria Floods Partnership' was set up by Flood Minister Rory Stewart following December's floods and includes all of Cumbria's Flood Risk Management Authorities. They are working alongside the existing 'Cumbria Strategic Partnership', which was formed as part of the Flood and Water Management Act and comprises of the county's Flood Risk Management Authorities (RMAs) including the Environment Agency, Cumbria County Council, Local Authorities and United Utilities. Both partnerships are working with communities, businesses and relevant stakeholders to understand and reduce flood risk across Cumbria.

This diagram below helps demonstrate how the two partnerships are working together:



Appendices

Appendix 1: Glossary

AEP	Annual Exceedance Probability
ARI	Annual Recurrence Interval
AOD	Above Ordnance Datum
CCC	Cumbria County Council
EA	Environment Agency
FAG	Flood Action Group
FWD	Flood Warnings Direct
LLFA	Local Lead Flood Authority
LRF	Local Resilience Forum
MsfWG	Making space for Water Group
RMA	Risk Management Authority

Appendix 2: Summary of Relevant Legislation and Flood Risk Management Authorities

The table below summarises the relevant Risk Management Authority and details the various local source of flooding that they will take a lead on.

Flood Source	Environment Agency	Lead Local Flood Authority	District Council	Water Company	Highway Authority
RIVERS					
Main river					
Ordinary watercourse					
SURFACE RUNOFF					
Surface water					
Surface water on the highway					
OTHER					
Sewer flooding					
The sea					
Groundwater					
Reservoirs					

The following information provides a summary of each Risk Management Authority's roles and responsibilities in relation to flood reporting and investigation.

Government – DEFRA develop national policies to form the basis of the Environment Agency's and the LLFA's work relating to flood risk.

Environment Agency has a strategic overview of all sources of flooding and coastal erosion as defined in the Act. As part of its role concerning flood investigations this requires providing evidence and advice to support other Risk Management Authorities (RMA's). The EA also collates and reviews assessments, maps, and plans for local flood risk management (normally undertaken by LLFA).

Lead Local Flood Authorities (LLFAs) – Cumbria County Council is the LLFA for Cumbria under the Flood & Water Management Act 2010. Part of their role requires them to investigate significant local flooding incidents and publish the results of such investigations. LLFAs have a duty to determine which RMA has relevant powers to investigate flood incidents to help understand how they happened, and whether those authorities have, or intend to, exercise their powers. LLFAs work in partnership with communities and flood RMA's to maximise knowledge of flood risk to all involved. This function is carried out at CCC by the Development Management Team.

District and Borough Councils – These organisations perform a significant amount of work relating to flood risk management including providing advice to communities and gathering information on flooding. These organisations are classed as RMA's.

Water and Sewerage Companies manage the risk of flooding to water supply and sewerage facilities and the risk to others from the failure of their infrastructure. They make sure their systems have the appropriate level of resilience to flooding and where frequent and severe flooding occurs they are required to address this through their capital investment plans. It should also be noted that following the Transfer of Private Sewers Regulations 2011 water and sewerage companies are responsible for a larger number of sewers than prior to the regulation. These organisations are classed as RMA's

Highway Authorities have the lead responsibility for providing and managing highway drainage and certain roadside ditches that they have created under the Highways Act 1980. The owners of land adjoining a highway also have a common-law duty to maintain ditches to prevent them causing a nuisance to road users. These organisations are classed as RMA's

Flood risk in Cumbria is managed through the Making Space for Water process, which involves the cooperation and regular meeting of the Environment Agency, United Utilities, District/Borough Councils and CCC's Highway and LFRM Teams to develop processes and schemes to minimise flood risk. The MSfWGs meet approximately 4 times per year to cooperate and work together to improve the flood risk in the vulnerable areas identified in this report by completing the recommended actions. CCC as LLFA has a responsibility to oversee the delivery of these actions.

Where minor works or quick win schemes can be identified, these will be prioritised and subject to available funding and resources will be carried out as soon as possible. Any major works requiring capital investment will be considered through the Environment Agency's Medium Term Plan process or a partners own capital investment process.

Flood Action Groups are usually formed by local residents who wish to work together to resolve flooding in their area. The FAGs are often supported by either CCC or the EA and provide a useful mechanism for residents to forward information to the MSfWG.

Appendix 3: Links to Other Information on Flooding

Sign up for Flood Warnings

<https://www.gov.uk/sign-up-for-flood-warnings>

Environment Agency – Prepare your property for flooding; a guide for householders and small businesses to prepare for floods

<https://www.gov.uk/government/publications/prepare-your-property-for-flooding>

Environment Agency – What to do before, during and after a flood: Practical advice on what to do to protect you and your property

<https://www.gov.uk/government/publications/flooding-what-to-do-before-during-and-after-a-flood>

Environment Agency – Living on the Edge: A guide of the rights and responsibilities of riverside occupiers

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

Flood and Water Management Act 2010:

<http://www.legislation.gov.uk/ukpga/2010/29/contents>

Water Resources Act 1991:

<http://www.legislation.gov.uk/all?title=water%20resources%20act>

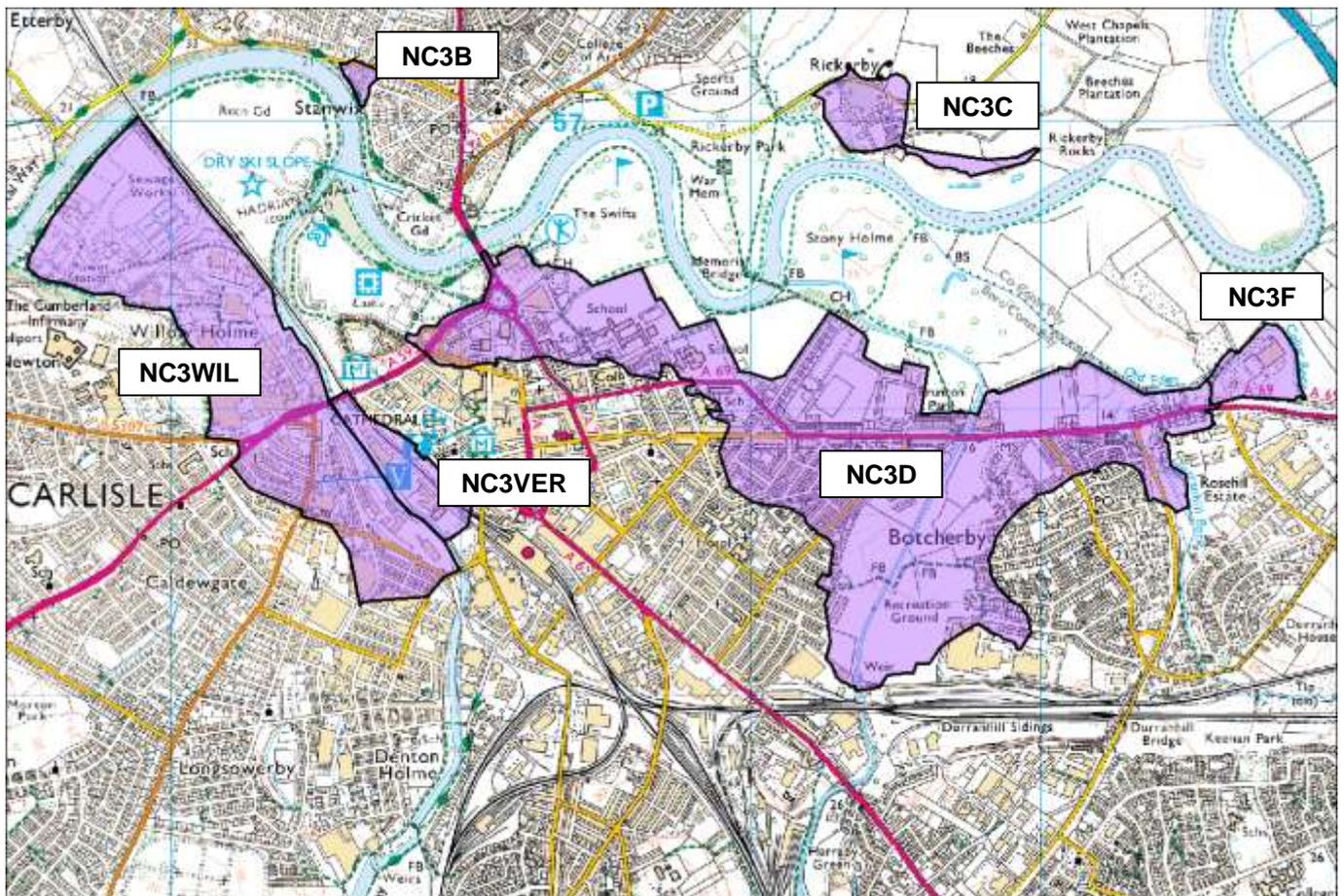
Land Drainage Act:

<http://www.legislation.gov.uk/all?title=land%20drainage%20act>

Appendix 4: Flood Warnings and Alerts

Carlisle is covered by a Flood Alert, and certain areas are additionally served by 13 Flood Warnings including the 6 shown in the map above. Flood Warning Areas are well defined following the major flood event in 2005. Flood Warning Levels will be reviewed in terms of revised modelling for the Rivers Eden, Caldew and Petteril and some amendments to these areas are anticipated.

The table below summarises the times of the flood warnings issued during this flood event:



Flood Warning Areas within Carlisle

Flood Warning Area	Flood Warning Issued (05/12/15)	Severe Flood Warning Issued (05/12/15)	Properties	Contacts	%Success
NC3B River Eden at Etterby Terrace and Eden Place	15:22	17:34	53	104	68%
NC3C River Eden at Rickerby Village	13:11	17:34	72	145	72%
NC3F River Eden at Tesco Store Warwick Road	15:28	17:34	29	70	69%
NC3VER The River Caldw at Viaduct Estate Road Area	15:30	17:34	33	76	68%
NC3D River Eden and Petteril at City Centre, Botcherby and Warwick Road Area	15:28	17:34	1887	2488	73%
NC3WIL The River Caldw and Eden at Willowholme, Caldewgate, Shaddongate	16:55	17:34	781	922	67%

The following pages show additional details on the flood alerts and warnings issued during this event.

Flood Alerts:

011WAFLE- Lower River Eden

Alert issued on Thursday 03/12/2015 at 14:46

Alert issued on Friday 04/12/2015 at 15:08

Customers in Flood Alert area registered on FWD: 332

Contacts (landline, mobile, email etc) in Flood Alert area registered on FWD: 1051

Successful contacts: 911

Unsuccessful contacts: 140

Alert Message:

A Flood Alert has been issued by the Environment Agency for the Lower River Eden.

Flooding is possible for River Eden and its tributaries from its confluence with the River Irthing through Crosby-on-Eden and Carlisle to the Solway Firth at Rockcliffe.

Flood Warning Target Areas:

011FWFNC3A- River Eden at Carlisle, Rickerby Park, Swifts and Stoneyholme Golf Courses

Flood Warning issued on Thursday 03/12/2015 at 23:59

Flood Warning removed on Friday 04/12/2015 at 12:05

Date/Time Warning Level Reached: 04/12/2015 03:00

Time customers had to take action: 03:01:00

Customers in Flood Warning area registered on FWD: 52

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 169

Successful contacts: 115

Unsuccessful contacts: 54

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Eden at Carlisle, Rickerby Park, Swifts and Stoneyholme Golf Courses.

Flooding is expected for Low lying roads and car parks, Residential and commercial properties. Flooding is expected from 03:00 on Friday. Immediate action required.

Following heavy rainfall throughout the river catchment on Thursday evening the river level has risen and is likely to cause flooding in this area in the early hours on Friday 4th December 2015. The river level is likely to start falling by mid morning with Friday being a mainly dry day. However, further significant rainfall is expected from late Friday and throughout Saturday which will probably result in the river level rising to higher levels.

Flood Warning issued on Friday 04/12/2015 at 21:50

Severe Flood Warning issued on Saturday 05/12/2015 at 17:34

Severe Flood Warning removed on Tuesday 08/12/2015 at 16:51

Date/Time Warning Level Reached: 05/12/2015 09:00

Time customers had to take action: 11:10:00

Customers in Flood Warning area registered on FWD: 52

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 171

Successful contacts: 116

Unsuccessful contacts: 55

Severe Warning Message:

Severe Flooding. Danger to life. A Severe Flood Warning has been issued by the Environment Agency for the River Eden at Carlisle, Rickerby Park, Swifts and Stoneyholme Golf Courses.

This Severe Flood Warning is for Low lying roads and car parks, Residential and commercial properties.

011FWFNC3B - River Eden at Carlisle, Etterby Terrace and Eden Place

Flood Warning issued on Saturday 05/12/2015 at 15:22

Severe Flood Warning issued on Saturday 05/12/2015 at 17:34

Severe Flood Warning removed on Tuesday 08/12/2015 at 16:55

Date/Time Warning Level Reached: 05/12/2015 23:00

Time customers had to take action: 07:37:25

Customers in Flood Warning area registered on FWD: 53

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 153

Successful contacts: 104

Unsuccessful contacts: 49

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Eden at Carlisle, Etterby Terrace and Eden Place.

Flooding is expected for Low lying roads, residential & commercial properties adjacent the rivers Eden & Caldew including areas of Stanwix, Etterby Terrace and Eden Place. Immediate action required. Heavy and persistent rainfall is expected throughout Saturday. River levels will continue to rise and further Flood Warnings are likely. Please check for updates throughout the weekend. Operational Teams have closed flood defences and are checking watercourses for blockages.

011FWFNC3BP - River Eden and Caldew at Carlisle, Devonshire Walk, West Coast Mainline, Bitts Park, Cricket Club

Flood Warning issued on Friday 04/12/2015 at 22:58
Severe Flood Warning issued on Saturday 05/12/2015 at 17:34
Severe Flood Warning downgraded to Flood Warning on Tuesday 08/12/2015 at 17:11
Flood Warning removed on Wednesday 09/12/2015 at 11:27

Date/Time Warning Level Reached: 05/12/2015 15:15
Time customers had to take action: 16:16:04
Customers in Flood Warning area registered on FWD: 31
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 109
Successful contacts: 80
Unsuccessful contacts: 29

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Eden and Caldew at Carlisle, Devonshire Walk, West Coast Mainline, Bitts Park, Cricket Club. Flooding is expected for River Eden and Caldew at Carlisle, Devonshire Walk and West Coast Mainline, Bitts Park, Cricket Club, Sheepmount. Immediate action required.

011FWFNC3C - River Eden at Carlisle, Rickerby Village

Flood Warning issued on Saturday 05/12/2015 at 13:11
Severe Flood Warning issued on Saturday 05/12/2015 at 17:34
Severe Flood Warning removed on Tuesday 08/12/2015 at 17:04
Date/Time Warning Level Reached: 05/12/2015 17:45
Time customers had to take action: 04:33:30
Customers in Flood Warning area registered on FWD: 72
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 201
Successful contacts: 145
Unsuccessful contacts: 56

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Eden at Carlisle, Rickerby Village. Flooding is expected for Low lying roads, agricultural land, residential and commercial properties around the River Eden at Rickerby Village. Immediate action required.

011FWFNC3CUM - River Caldew at Cummersdale, Factory

Flood Warning issued on Thursday 03/12/2015 at 20:29
Flood Warning removed on Friday 04/12/2015 at 08:23
Date/Time Warning Level Reached: 03/12/2015 20:45
Time customers had to take action: 00:15:22
Customers in Flood Warning area registered on FWD: 29
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 104
Successful contacts: 74
Unsuccessful contacts: 30

Flood Warning issued on Thursday 05/12/2015 at 01:21
Flood Warning removed on Friday 06/12/2015 at 19:04

Date/Time Warning Level Reached: 05/12/2015 04:45
Time customers had to take action: 03:23:32
Customers in Flood Warning area registered on FWD: 29
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 104
Successful contacts: 77
Unsuccessful contacts: 27

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Caldew at Cummersdale, Factory.

Flooding is expected for River Caldew at Cummersdale, Factory. Immediate action required.

011FWFNC3D - River Eden and Petteril at Carlisle, City Centre, Botcherby and Warwick Road Area

Flood Warning issued on Saturday 05/12/2015 at 15:28
Severe Flood Warning issued on Saturday 05/12/2015 at 17:34
Severe Flood Warning downgraded to Flood Warning on Tuesday 08/12/2015 at 16:54
Flood Warning removed on Wednesday 09/12/2015 at 11:27

Date/Time Warning Level Reached: 06/12/2015 00:15
Time customers had to take action: 08:47:00
Customers in Flood Warning area registered on FWD: 1887
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 3421
Successful contacts: 2488
Unsuccessful contacts: 933

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Eden and Petteril at Carlisle, City Centre, Botcherby and Warwick Road Area.

Flooding is expected for Low lying roads, agricultural land, residential & commercial properties in Carlisle adjacent Rivers Eden and Petteril including City Centre, Botcherby and Warwick Road Areas. Immediate action required.

011FWFNC3DH - River Caldew at Carlisle, Denton Holme, Bousteads Grassing, James Street Area

Flood Warning issued on Saturday 05/12/2015 at 15:28
Severe Flood Warning issued on Saturday 05/12/2015 at 17:34
Severe Flood Warning removed on Tuesday 08/12/2015 at 16:49

Date/Time Warning Level Reached: Did not reach threshold.
Time customers had to take action: N/A
Customers in Flood Warning area registered on FWD: 2019
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 3273
Successful contacts: 2247
Unsuccessful contacts: 1026

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Caldew at Carlisle, Denton Holme, Bousteads Grassing, James Street Area.

Flooding is expected for River Caldew at Carlisle, Denton Holme, Bousteads Grassing, James Street Area. Immediate action required.

011FWFNC3F - River Eden at Carlisle, Tesco Store Warwick Road

Flood Warning issued on Saturday 05/12/2015 at 15:28
Severe Flood Warning issued on Saturday 05/12/2015 at 17:34
Severe Flood Warning removed on Tuesday 08/12/2015 at 16:55

Date/Time Warning Level Reached: 05/12/2015 20:45

Time customers had to take action: 05:16:18

Customers in Flood Warning area registered on FWD: 29

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 102

Successful contacts: 70

Unsuccessful contacts: 32

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Eden at Carlisle, Tesco Store Warwick Road.

Flooding is expected for Low lying roads and agricultural land, adjacent to the River Eden at Tesco Store, Warwick Road. Immediate action required.

011FWFNC3VER - River Caldew at Carlisle, Viaduct Estate Road Area

Flood Warning issued on Saturday 05/12/2015 at 15:30

Severe Flood Warning issued on Sunday 05/12/2015 at 17:34

Severe Flood Warning removed on Tuesday 08/12/2015 at 16:59

Date/Time Warning Level Reached: Did not reach threshold.

Time customers had to take action: N/A

Customers in Flood Warning area registered on FWD: 33

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 112

Successful contacts: 76

Unsuccessful contacts: 36

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Caldew at Carlisle, Viaduct Estate Road Area.

Flooding is expected for River Caldew at Carlisle, Viaduct Estate Road Area. Immediate action required.

011FWFNC3WIL - River Caldew and Eden at Carlisle, Willowholme, Caldewgate, Shaddongate

Flood Warning issued on Saturday 05/12/2015 at 16:55

Severe Flood Warning issued on Saturday 05/12/2015 at 17:34

Severe Flood Warning removed on Tuesday 08/12/2015 at 16:57

Date/Time Warning Level Reached: Did not reach threshold.

Time customers had to take action: N/A

Customers in Flood Warning area registered on FWD: 781

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 1386

Successful contacts: 922

Unsuccessful contacts: 464

Warning Message:

A Flood Warning has been issued by the Environment Agency for the River Caldew and Eden at Carlisle, Willowholme, Caldewgate, Shaddongate.

Flooding is expected for River Caldew and Eden at Carlisle, Willowholme, Caldewgate, Shaddongate. Immediate action required.

011FWFNC3LC - Little Caldew

Severe Flood Warning issued on Saturday 05/12/2015 at 17:36

Severe Flood Warning removed on Tuesday 08/12/2015 at 16:55

Customers in Flood Warning area registered on FWD: 255

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 483

Successful contacts: 400

Unsuccessful contacts: 183

Warning Message:

Severe Flooding. Danger to life. A Severe Flood Warning has been issued by the Environment Agency for the Little Caldeu.

This Severe Flood Warning is for Flooding of properties from the Little Caldeu.

011FWFNC3DUR - Durranhill

Flood Warning issued on Sunday 06/12/2015 at 17:15

Flood Warning removed on Tuesday 08/12/2015 at 17:32

Date/Time Warning Level Reached: Do not forecast for this threshold.

Customers in Flood Warning area registered on FWD: 431

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 848

Successful contacts: 571

Unsuccessful contacts: 277

Warning Message:

A Flood Warning has been issued by the Environment Agency for the Durranhill. Flooding is expected for Flooding of properties adjacent to Durranhill Beck. Immediate action required.

Durranhill pumping station is no longer operational. Water levels will continue to rise in this area for several hours.

011FWFNC3WH - Willowholme Surface Water

Flood Warning issued on Saturday 05/12/2015 at 15:30

Severe Flood Warning issued on Saturday 05/12/2015 at 17:34

Severe Flood Warning removed on Tuesday 08/12/2015 at 16:48

Date/Time Warning Level Reached: Do not forecast for surface water, no threshold.

Customers in Flood Warning area registered on FWD: 73

Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 218

Successful contacts: 147

Unsuccessful contacts: 71

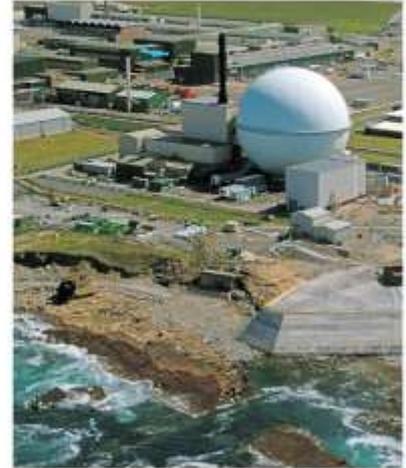
Warning Message:

A Flood Warning has been issued by the Environment Agency for the Willowholme Surface Water. Flooding is expected for Flooding of Willowholme area due to surface water and drainage issues.

Immediate action required.

Appendix 5: CH2M Hill UK Projects and Flood Risk Management brochure

DRAFT



We partner with your industry

- Municipal Water, Wastewater, and Water Supply
- Aviation, Ports, Transit, and Rail
- Nuclear Decontamination and Decommissioning
- Chemical Manufacturing
- Environmental Remediation and Compliance Management
- Environmental Industrial Systems
- Commercial Nuclear
- Oil and Gas
- Electronics and Advanced Technologies
- Manufacturing
- Life Sciences
- Communications Infrastructure
- Security Systems

Employee-owned CH2M HILL is one of the world's leading consulting, design, design-build, operations, and programme management companies serving government, civil, industrial and energy clients, employing over 28,000 people worldwide. Our work is concentrated in the areas of water, transportation, environmental, energy, facilities and resources.

Having operated in the UK for over 20 years, we acquired Halcrow in 2011 and continue to base our European headquarters in London, now employing over 3,300 people in the UK. CH2M HILL is working on some of the most iconic infrastructure programmes including High Speed 2, Thames Tideway Tunnels, the decommissioning of Dounreay and was one of the leading partners in CLM, Delivery Partner to the ODA for the London 2012 Olympic & Paralympic Games.

We serve as a single point of contact and responsibility, managing your project through planning, financing, permitting, design, construction, and operations. We use technology transfer and leverage established relationships with local firms to deliver industrial and enterprise management solutions throughout the United Kingdom.

CH2M HILL is an active member of Business in the Community and the Employee Ownership Association.

Urban Programmes

Key endorsements:

"From the outset of the project, the Olympic Park has set new standards in sustainability, including delivery of lightweight venues, recycling or reuse of waste materials, using concrete with a high recycled content and delivering materials by rail or water. We have achieved new standards for a project of this size and scale and have raised the bar for the industry."

– John Armitt, ODA Chairman

"The ODA did a fantastic job in delivering the Olympic venues and infrastructure on time and within budget. They did our nation proud."

– Margaret Hodge MP, Chair of the Public Accounts Select Committee



London 2012 Olympic and Paralympic Games

CH2M HILL was one of the three first constituting the international consortium CLM, the Delivery Partner to the Olympic Delivery Authority (ODA). CLM oversaw the design and construction of the nine venues across the 500-acre Olympic Park for the London 2012 Olympic and Paralympic Games. CH2M HILL provided the consortium and ODA with global engineering, construction and programme management expertise.

Completed one year ahead of the games, the programme was delivered at an impressive £1Bn under the baseline budget of £7.2Bn with notably zero construction fatalities, the first of such records of any modern Olympics.



Water

Thames Tideway Tunnel and Lee Tunnel

CH2M HILL is the programme manager for the London Tideway Tunnels Programme, one of the biggest and most historic public works initiatives in London's history. With the Rivers Lee and Thames currently overflowing approximately 50-60 times annually, the London Tideway Tunnels Programme looks to reduce overflows to three or less per year.

The programme will see the construction of the Lee Tunnel and the Thames Tideway Tunnel and aims to greatly improve the river quality and reduce the environmental impact of sewerage overflows. Both tunnels will be more than seven metres wide, running beneath a vast network of existing tunnels, including six Underground lines and utilities. The programme includes constructing numerous collection and diversion facilities, a large high-head underground pumping station, and a major upgrade at Beckton sewage treatment works. Ultimately, CH2M HILL will manage over 300 work packages. So far, CH2M HILL have delivered £700M of savings on a £4.1Bn budget and carried out exemplary stakeholder relations across 14 London Boroughs.

Transport

Crossrail

As Europe's largest engineering project, Crossrail will connect 37 stations, including Heathrow airport and Maidenhead in the west with Canary Wharf, Abbey Wood and Shenfield in the east—reducing journey times across London while delivering extensive economic benefits.

The Transcend team, which includes CH2M HILL, AECOM and The Nichols Group, was appointed as the programme partner to work alongside Crossrail to oversee the construction of a 21 kilometre-long tunnel beneath central London, build eight new stations and integrate Crossrail with London's existing transport systems. Additionally, the team is responsible for programme controls, encompassing the functions of scope, cost and schedule control, as well as risk and value management.

When Crossrail opens in 2018, the £14.8Bn rail link will boost London's rail-based network capacity by ten percent—transporting 200 million passengers annually, bolster the capital's position as a world-leading financial center, and significantly reduce journey times across the city.



High Speed 2 (HS2)



HS2 will be the UK's new high speed rail network and is being designed and built to resolve impending capacity issues for both passengers and freight on existing routes, particularly the West Coast Main Line.

The network will provide enhanced infrastructure links between London and the West Midlands (Phase One), as well as the Channel Tunnel, expanding in future to connect Manchester, Leeds and the North with Birmingham, the south of England and Heathrow Airport (Phase Two).

CH2M HILL is development partner with HS2 Ltd and is leading the development of the next phase of engineering, design and environmental work on the London to the West Midlands line. The 80 strong team, working alongside HS2 Ltd, largely consists of project management and engineering specialists from the UK. The team project manage the professional services companies who are carrying out the design, environmental and land referencing work for the London to West Midlands line. CH2M HILL's expertise ensures that the work is fully integrated and delivered to the required quality.

On appointing CH2M HILL, HS2 Ltd's Chief Executive Alison Munro said: "The appointment means that we will have world class project managers and technical experts working alongside us to deliver the design, engineering and environmental work necessary for the hybrid bill. They will bring, in particular, their highly regarded experience of working on HS1 and Crossrail, two major UK infrastructure projects that have direct relevance to our work."

We provide services for your success

- Programme and Project Management
- Site Selection
- Infrastructure Planning
- Economic Development
- Energy Management and Planning
- Information Systems
- Master Planning
- Licensing and Permitting
- Management Consulting
- Project Financing
- Project Development
- Architecture and Programming
- LEED and BREEAM Facility Certification
- Civil, Structural, Mechanical, and Electrical Engineering



Water Resources-Ecosystem Management Services

Flood Risk Management

CH2M is a world leader in flood risk management, providing integrated and sustainable solutions for both the built and natural environment. Our large team of specialists and scientists, who are primarily based in the UK and USA, deliver projects around the world. They are supported by environmental scientists, surveyors, geotechnical engineers, and business planning, finance and contract, and other specialists. Our work includes the full cycle of flood risk mapping and strategic planning; capital works delivery; and operation, maintenance and asset management.

The solutions we develop recognize the effect climate change is increasingly having on the built and natural environment within river catchments and estuaries, and thus our focus is on developing long-term solutions that work with nature and continue to leave a sustainable legacy to protect future generations from the effects of climate change.

A core focus is delivering fully integrated solutions that maximize both direct and indirect benefits for the clients that we serve in WBG, T&S and Strategic Consulting. This means we are linked with several technologies including IWRM, Dams and Levees (Conveyance), Water Resilience, H&H modeling (Software Applications and Integration), Urban Watershed Management, and Coastal Planning and Engineering.

Sub-technologies

The FRM technology group has three key sub-technology areas that we steward, offering several capabilities in each:

Flood mapping and appraisal

- Watershed-scale flood risk management planning
- Flood hazard modeling/mapping and hydraulic analysis
- Flood risk management alternatives development and testing
- Risk vulnerability and damage analysis
- Flood forecasting/warning
- Flood incident management and exercise

Capital works delivery

- Program/project management
- Conceptual, preliminary and final design
- Contract preparation and administration
- Construction supervision
- Due diligence and other pre-bid assistance

O&M and asset management (AM)

- Asset management
- Strategic and tactical investment advice
- Disaster recovery

Challenges, Trends, Opportunities

Floods are increasing in frequency around the world and it is forecast that these will only get worse as a result of climate change. As the frequency of floods increases, the tolerance of the public, governments, the private sector, and insurance companies is reducing, prompting action.

A key market differentiator is being able to deliver multiple outcomes to clients through a river basin management approach which links together flood risk management needs with regeneration, recreational, and environmental enhancement opportunities and combines the associated available funding to generate both efficiencies and the financial support necessary for scheme delivery.

To achieve this we need to combine our flood risk management capabilities and technology with our knowledge of what the issues are within the river basins.

Did You Know?

- A review by the Organization for Economic Cooperation and Development on 136 coastal cities found that the estimated damage from sea level rise, storm surge and subsidence for 1 in 100 year flood event in 2070 was estimated at \$35,000 billion.
- In 2070 it is estimated that over 150 million people will live in these 136 coastal cities at risk.
- River flooding is the most common type of flood event.
- Floods are the number one natural disaster in the US, and just a few inches of water from a flood can cause tens of thousands of dollars in damage.
- The flooding in Alberta, Canada in 2013 flooded displaced 100,000 people and is estimated to cost \$6 billion.
- According to the House of Commons library, £2.34 billion has been spent on new flood defenses in England alone since 2011.