Keswick

Flood Investigation Report

High Hill, River Greta Flood Defence

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.

Version	Undertaken by	Reviewed by	Date
Working Draft for discussion with EA	Sejal Shah	Michael Lilley	22nd March 2016
Draft incorporating EA Feedback	Ian McCall	Michael Lilley	5th May 2016
Draft incorporating EA Feedback	Ian McCall	Micheal Lilley	10th May 2016

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Executive Summary

Keswick experienced flooding on the 5th and 6th of December 2015 following 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 flows in both the River Greta and River Derwent on the 6th December were the highest ever recorded. Record levels were also observed in Derwentwater and Bassenthwaite Lake.

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 Keswick 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 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 of the event and recommendations for future action.

The flood event following this rainfall was of a greater magnitude than the Keswick flood defences were designed to defend against. In some locations, defences were successful in reducing the damage, and delayed flooding, which gave residents additional time to prepare and reduced the impact of the flood.

515 properties were directly affected by the flooding.

This report details the flooding that occurred from the Rivers Greta and Derwent, flooding from other watercourses, Derwentwater, and from surface water. It identifies the flow routes and the causes of the flooding throughout Keswick. River banks and flood defences were overtopped or bypassed at the following locations:

- Low Briery Campsite
- Forge Lane
- Cottages along the river bank near Calvert's Bridge
- On Penrith Road river bank and flood defence
- Greta Side
- Southey Hill Trading Area
- Crosthwaite Road
- High Hill Road
- Main Street
- Elliott Park
- Lake Road

In addition to this, surface water flooding also affected numerous properties within the town.

Twenty-Two 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 Keswick 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 being undertaken separately to this report and is already underway, with an expected completion date in July 2016.

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

Any additional information that can be provided 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. Any additional information should be provided to;

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

Introduction

Under Section 19 of the Flood and Water Management Act (2010) Cumbria County Council, as Lead Local Flood Authority (LLFA), has a statutory duty to produce Flood Investigation Reports for areas affected by flooding.

Section 19 of the Flood and Water Management Act states:

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

(a) which risk management authorities have relevant flood risk management functions, and

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

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

(a) publish the results of its investigation, and

(b) notify any relevant risk management authorities.

This section of the Act leaves the determination of the 'extent' of flood investigation to the LLFA. It is not practical or realistic for Cumbria County Council to carry out a detailed investigation into every flood incident that occurs in the County, but every incident with basic details will be recorded by the LLFA. Only those with 5 or more properties/businesses involved will have investigations published.

An investigation will be carried out, and a report prepared and published by the LLFA when the flooding impacts meet the following criteria:

- Where there is ambiguity surrounding the source or responsibility of flood incident
- Internal flooding of one property that has been experienced on more than one occasion
- Internal flooding of five properties has been experienced during one single flood incident
- There is a risk to life as a result of flooding

As a flood Risk Management Authority (RMA), the Environment Agency have partnered with the County Council to produce the 53 flood investigation reports across Cumbria.

Scope of this report

This Flood Investigation Report **is**:

- An investigation on the what, when, why, and how the flooding took place resulting from the 5th - 6th December 2015 flooding event.
- A means of identifying potential recommendations for actions to minimise the risk or impact of future flooding.

This Flood Investigation Report **does not**:

- Interpret observations and measurements resulting from this flooding event. Interpretation will be undertaken as part of the subsequent reports.
- Provide a complete description of what happens next.

The Flood Investigation Reports outline recommendations and actions that various organisations and authorities can do to minimise flood risk in affected areas.
Once agreed, the reports can be used by communities and agencies as the basis for developing future plans to help make areas more resilient to flooding in the future.

For further information on the S19 process, including a timetable of Flood Forum events and associated documentation, please visit the County Council website at;

http://www.cumbria.gov.uk/floods2015/floodforums.asp

To provide feedback on the report please email **LFRM@cumbria.gov.uk** and include the report number.

Flooding History

Keswick has a history of flooding with the first recorded flooding in 1822. Since then, approximately 20 significant flood events have been recorded. Two major events occurred recently in 2005 and 2009.

The 2005 event was estimated to have a 1.33% annual exceedence probability (AEP). 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 recurrance 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 Annual Exceedence Probability

The 2005 event resulted in the flooding of numerous properties in the Millfield Gardens / Penrith Road area, and in excess of 140 properties in the Crosthwaite Road / High Hill area. In addition, flooding from the River Greta caused the United Utilities pumping station at Greta Grove to fail, causing sewage and surface water flooding to 35 properties in the Elliott Park area as well as Booths supermarket. Flooding to some other parts of the town, particularly in the Penrith Road area, also occurred due to surface water exceeding the capacity of the drainage network.

The 2009 event caused flooding to 250 properties of which 200 were flooded from the River Greta and the remainder from other sources. This event had an AEP of 1.43% on the River Greta. The extent of flooding was also greater due to higher flows in the minor watercourses in the area and higher levels in Derwentwater.

Event background

Flooding Incident

The market town of Keswick is located immediately north of Derwentwater, and is in the Lake District National Park. It is a popular tourist destination in Allerdale District, and has a permanent resident population of less than 5000*, which is greatly increased by the tourist trade. There are two main watercourses running close to or through Keswick: the River Derwent which passes to the west and is the outlet from Derwentwater and its tributary the River Greta, which flows east to west through the town. Thirlmere Reservoir, a major United Utilities reservoir, is upstream of the town and feeds the River Greta through St. Johns Beck.

515 residential properties and businesses were affected by flooding on the 5th and 6th December 2015. The majority of this flooding can be attributed to extreme river levels in the River Greta, following extensive rainfall over the preceding 36 hour period.

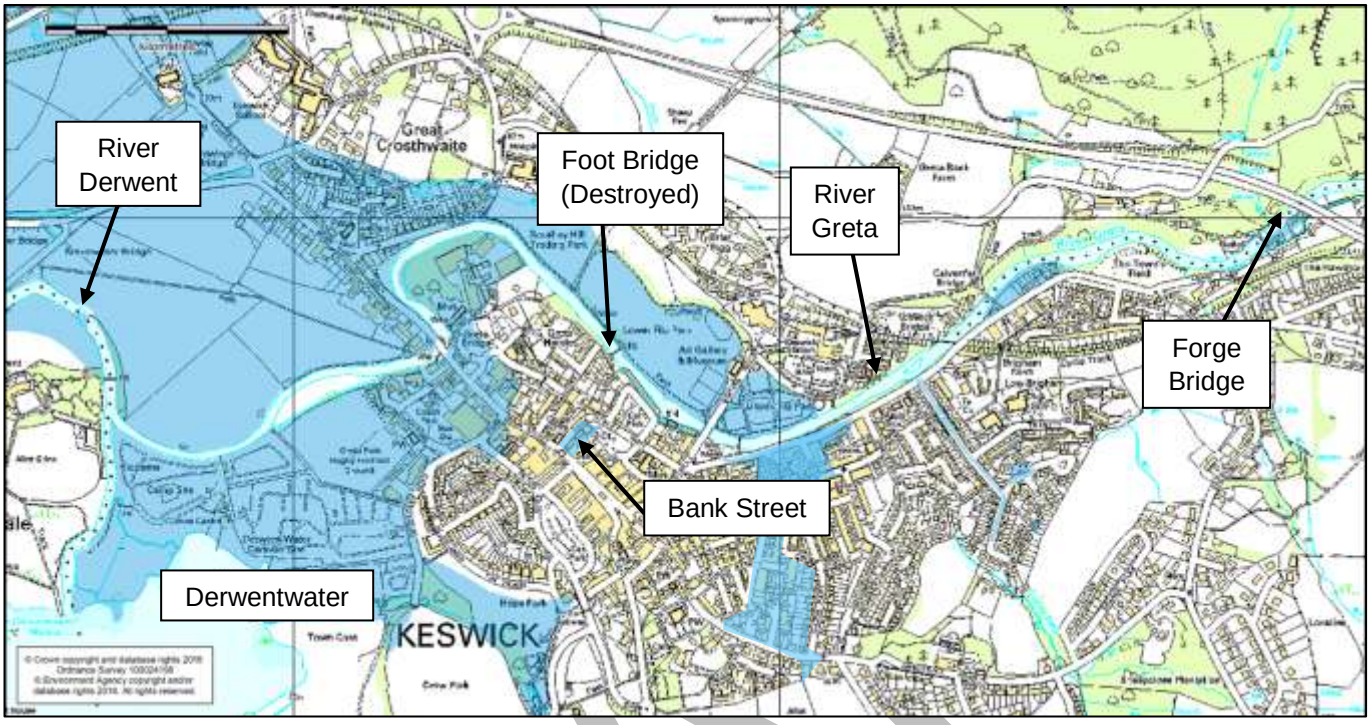


Figure 1 Extent of Flooding in Keswick on 5th & 6th December 2015

Figure 1 shows the approximate extent of the flooding that occurred on the 5th and 6th of December. This includes flooding from rivers, smaller watercourses, surface water and drainage systems. In the Keswick area there were four road bridges, one former railway bridge and two foot bridges crossing the river and of these, the foot bridge at Fitz Park was destroyed during the flood, and Forge Bridge was severely damaged.

For this report, the flooded areas within Keswick have been divided into 10 sub areas for investigation. These are shown in figure 2:

Forge Bridge	The area at the upstream end of the town on the left bank of the River Greta along Forge Lane
Penrith Road	The area upstream of the town on left bank of the River Greta
Windebrowe Avenue & Trinity Way	An area affected by Cuddy Beck and surface water flooding
Brundholme Road	An area affected by surface water flooding
Greta Street to Penrith Road and Ambleside Road	An area on left bank of the River Greta flooded from surface water and drainage as well as from the river
Upper and Lower Fitz Park	The area on right bank of the River Greta
Greta Side	An isolated area of flooding on the left bank of the River Greta opposite Fitz Park
Southey Hill Estate and North of Main Street	The area on the left bank of the River Greta north of Main Street
Elliott Park and South of Main Street	The area on the left bank of the River Greta south of Main Street including The Heads and Lake Road
High Hill and Crosthwaite Road	An area affected predominantly by the River Greta but also impacted from the River Derwent floodplain downstream The area at Quinta was flooded by rising levels of Derwentwater

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

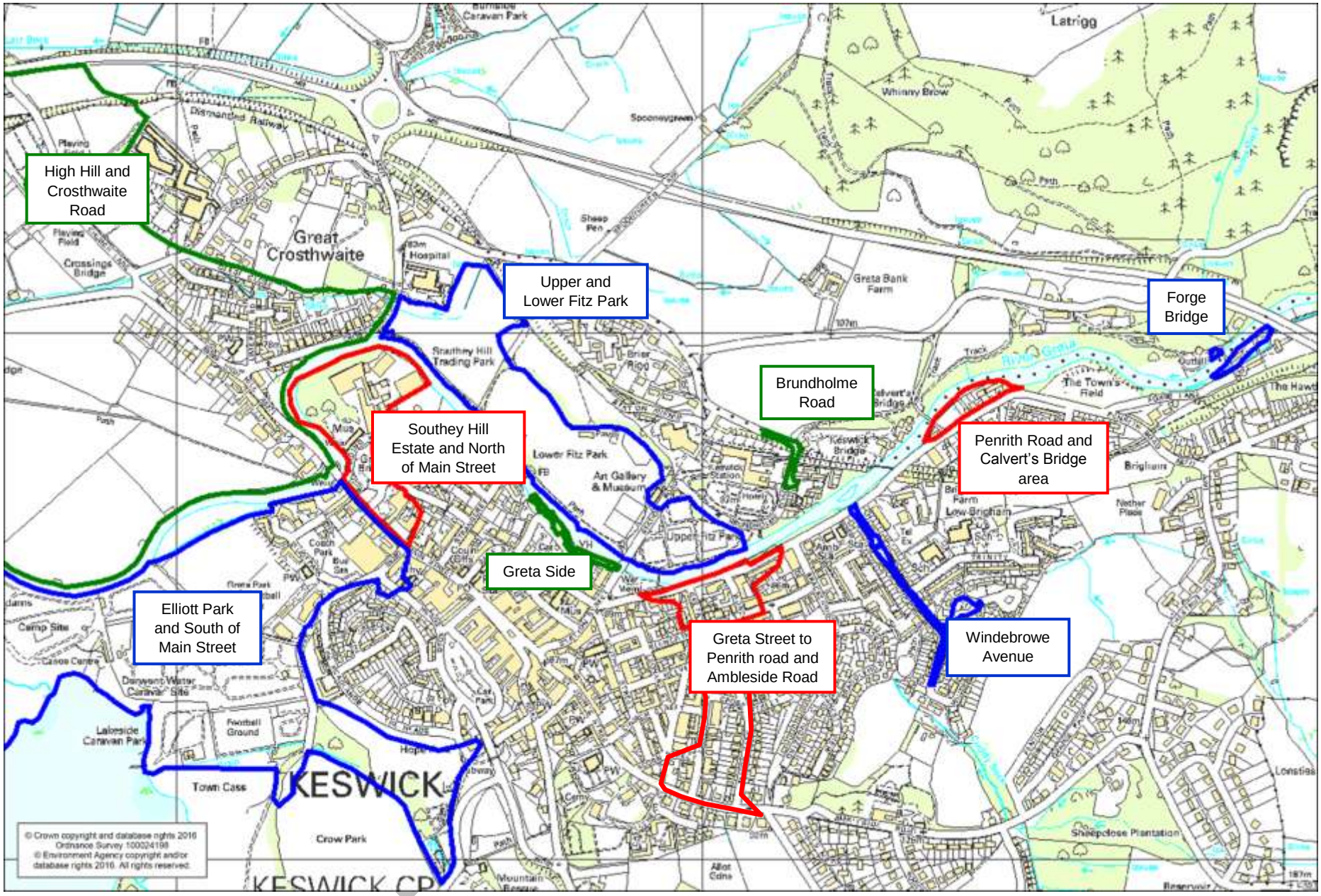


Figure 2 Identification of Areas Flooded

Existing Flood Defences

Keswick Flood Risk Management Scheme was constructed in 2011/12. This scheme reduced the risk of flooding from the River Greta for approximately 182 properties to a 1.3% chance of a flood occurring in any one year. A map of existing flood defences is shown in figure 3.

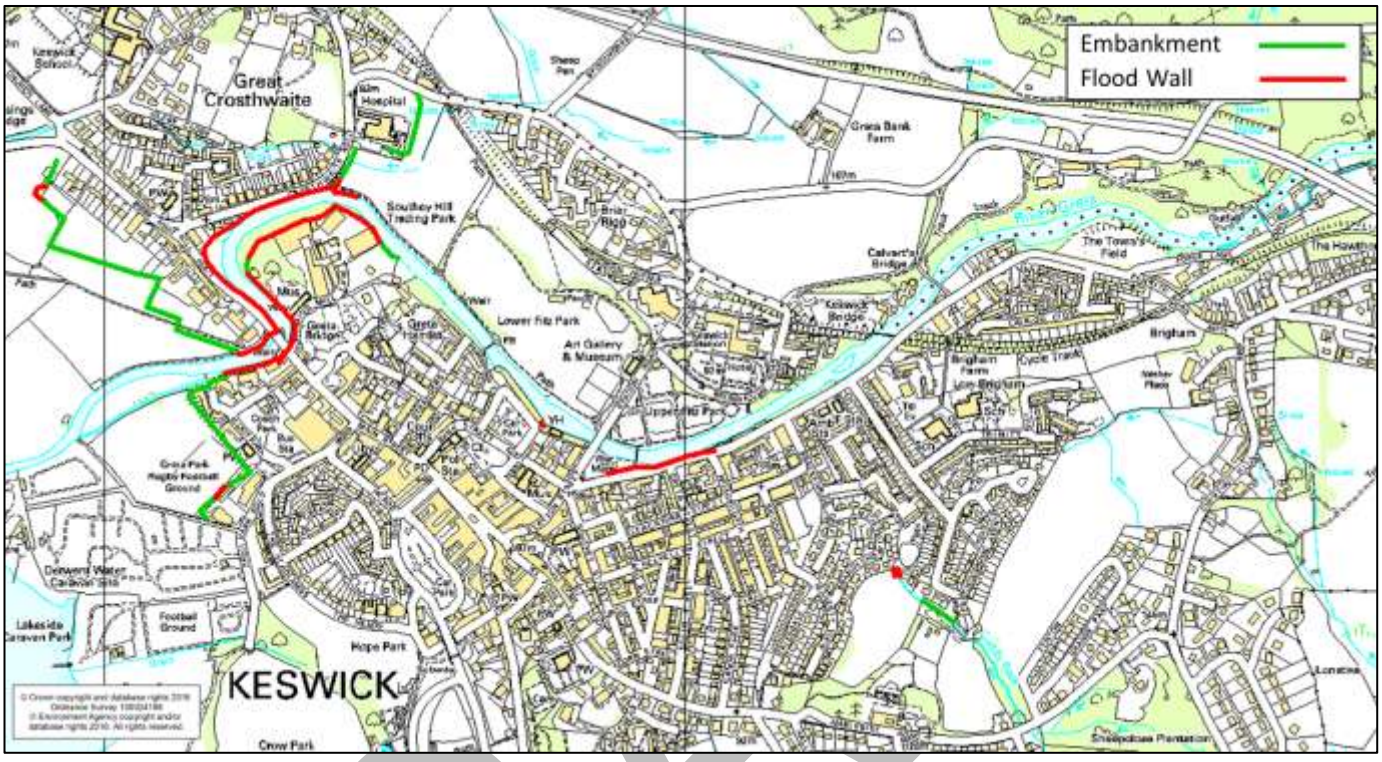


Figure 3 Flood Defences within Keswick

The Keswick Flood Risk Management Scheme carried out in 2011/12 included:

- Penrith Road – Stone clad reinforced concrete defence wall, including a flood gate, adjacent to the footpath.
- Penrith Road – Duckbill non-return valves installed on outfall of Castlehead drain
- Greta Villas – Short section of new defence wall
- Fitz Park Embankment and Crosthwaite Beck outfall – Flood embankment and culvert into the River Greta
- Hospital – Earth embankment with clay core around the eastern and southern side of the hospital, and associated land drainage.
- Crosthwaite Road – Stone clad reinforced concrete wall adjacent to the footpath
- High Hill – Stone clad reinforced concrete wall including glass panels for the upper part
- Southey Hill / Pencil Factory - Stone clad reinforced concrete wall and a short stretch of earth embankment with an access ramp to the river for maintenance
- Carding Mill Lane - Raised defence wall
- Greta Bridge to former Youth Centre - Improved defence wall and blocking up intake of disused mill race culvert
- Former Youth Centre – Stone clad reinforced concrete flood defence wall on the location of a recently demolished building
- Elliott Park Embankment – Raised earth embankment

- Right Bank downstream of Greta Bridge - Raised/rebuilt defence wall and raised stoplog structure


Figure 4 Photos of Keswick Flood Risk Management Scheme - Flood wall along High Hill and Penrith Road

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 Keswick. 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 for the UK, with much of northern England receiving double the average December rainfall. This also followed a particularly wet November and as such, much of the ground 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.

	Previous record			December 2015 Event	
	Date	Location	mm	Location	mm
24 hour rainfall	November 2009	Seathwaite	316.4	Honister Pass	341.4
48 hour rainfall	November 2009	Seathwaite	395.6	Thirlmere	405

Table 2 UK Rainfall Records*

* Taken from met office – **www.metoffice.gov.uk/public/weather/climate-extremes**
http://www.metoffice.gov.uk/climate/uk/interesting/nov2009

Table 2 shows the record levels of rainfall that fell during the flooding event. Table 3 shows the rainfall recorded upstream of Keswick on the 4th and 5th December 2015 with return periods calculated for this event. Figure 5 shows the location of these rain gauges. Two of these locations have recorded rainfall that is estimated to be greater than 0.1% Annual Exceedance Probability (AEP) making these very rare events.

	Rainfall (mm)			Estimated Return Period (AEP) of rolling 24 hour rainfall*
	4th December	5th December	Rolling 24 hour rainfall	
Honister Pass	58.6	294.4	341.4	**<0.1%**
Seathwaite	36.6	185.2	214	1.33%-1.67%
Thirlmere	35.0	317.6	324.8	**<0.1%**

Table 3 Rainfall recorded at gauges upstream of Keswick

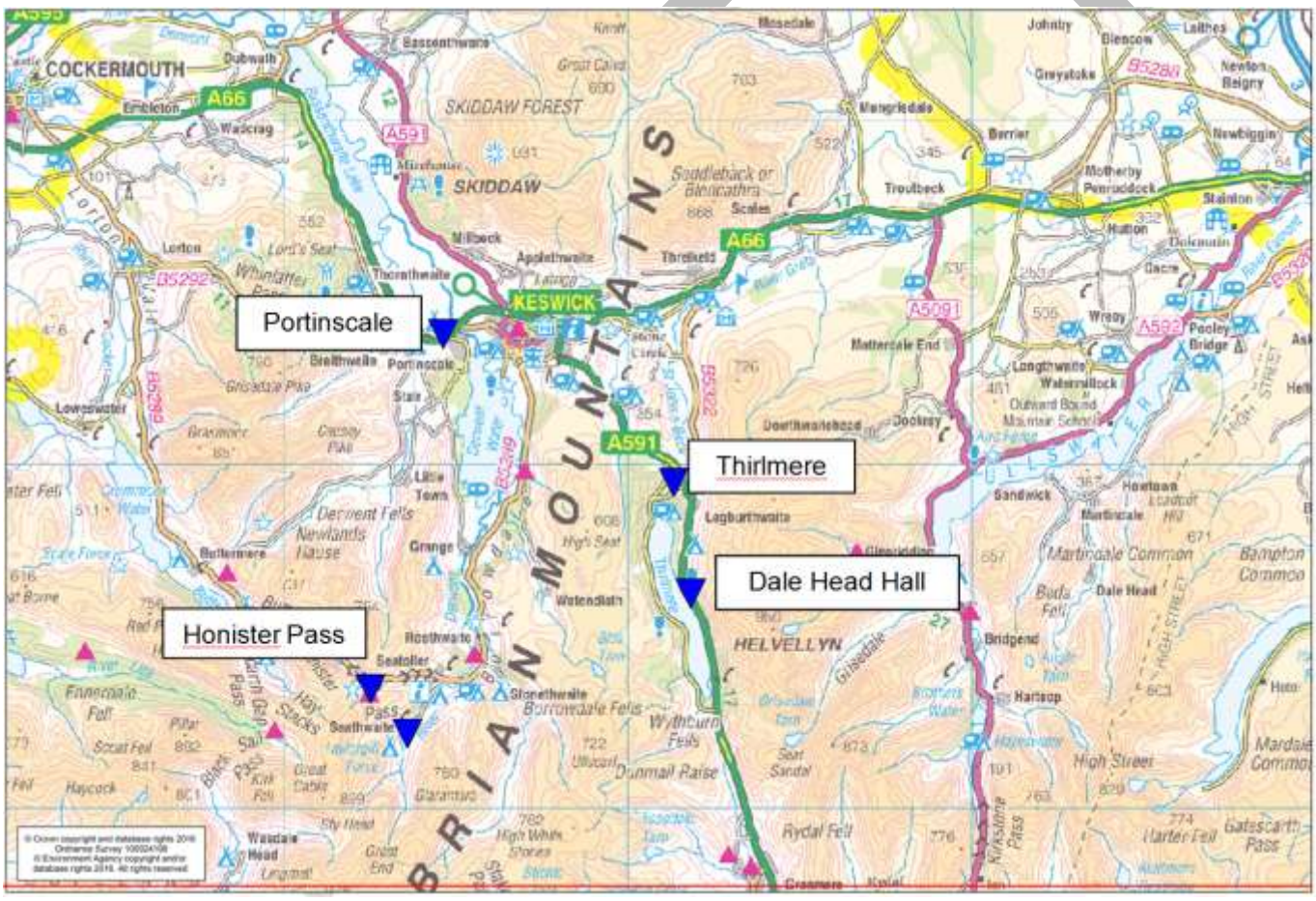


Figure 5 Locations of Rainfall gauges upstream of Keswick

Keswick experienced record levels of rainfall between the 4th and 5th December 2015. This rainfall fell on already saturated ground following 3 previous storms in November, which generated more than twice the monthly average rainfall for November. The wet conditions exacerbated the runoff from Storm Desmond and produced flood levels on the Rivers Greta and Derwent that were the highest ever

* Calculated using FEH DDF methodology, this estimation is not calibrated for values with an AEP less than 0.1%

recorded, breaking records set during the 2009 floods. The levels of Derwentwater and Bassenthwaite Lake also significantly exceeded previous record lake levels.

There are two river gauges close to Keswick on the Rivers Derwent and Greta measuring flow and level. The locations of these are shown in Figure 6. Table 4 shows the peak flows recorded at these gauging stations on the 5th December and for previous flooding events. Flows measured at both of these locations were greater than any flow that has been recorded previously.

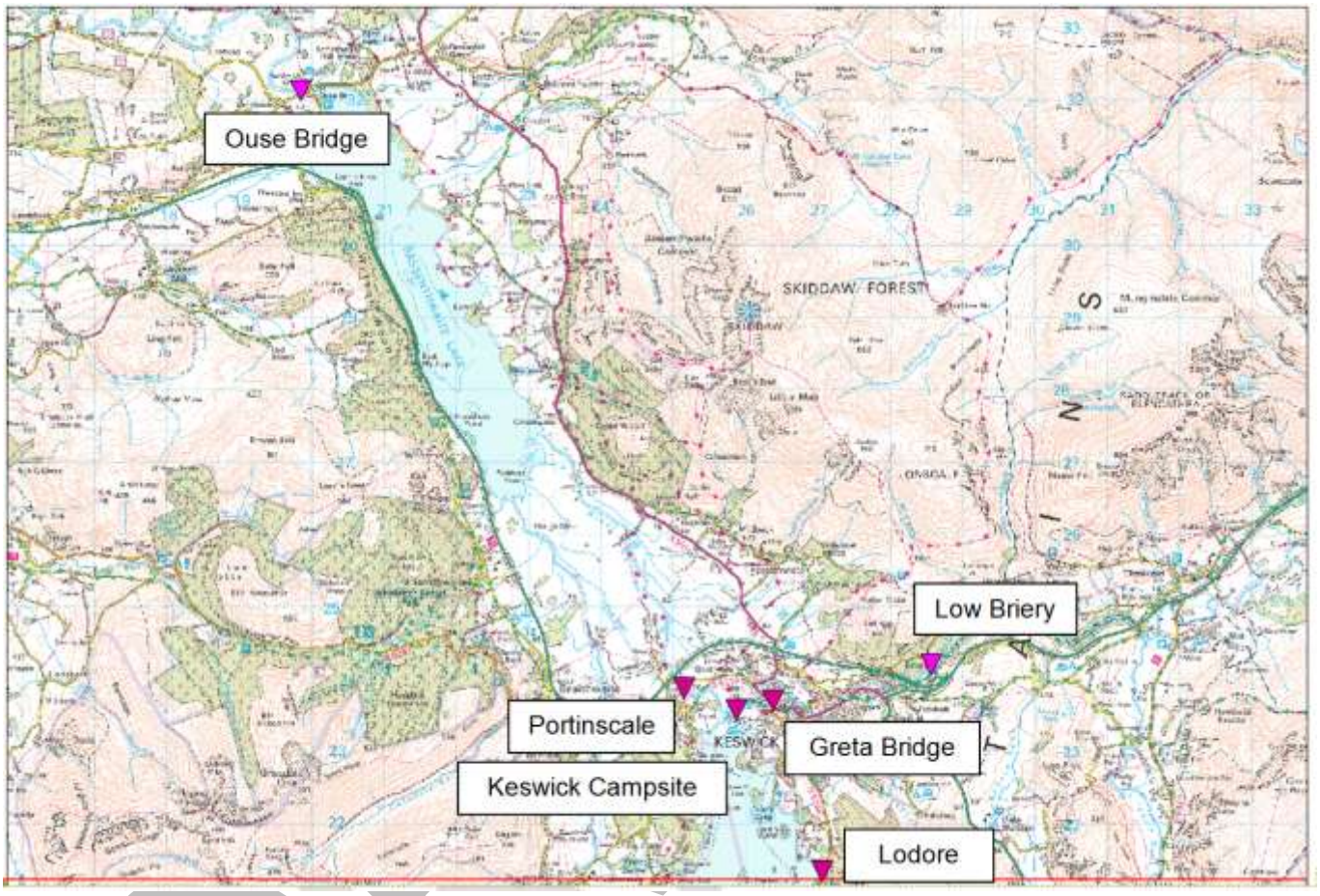


Figure 6 Location of River gauges on the Rivers Greta and Derwent near Keswick

Gauging Station	River	Peak Flow (m³/s)			Estimated return period of Dec 2015 event (AEP)
		December 2015	Past Events		
			November 2009	January 2005	
Low Briery	Greta	**491**	239	242	0.5%
Ouse Bridge	Derwent	**395**	378	196	0.3% to 0.1%

Table 4 Flows recorded at the gauging stations

Map of Flow Routes

There were a number of flooding flow routes during the event. Figure 7 shows a map of these. The details of these flow routes and the flooding within each of the identified areas is discussed in the 'Likely Causes of flooding section'.

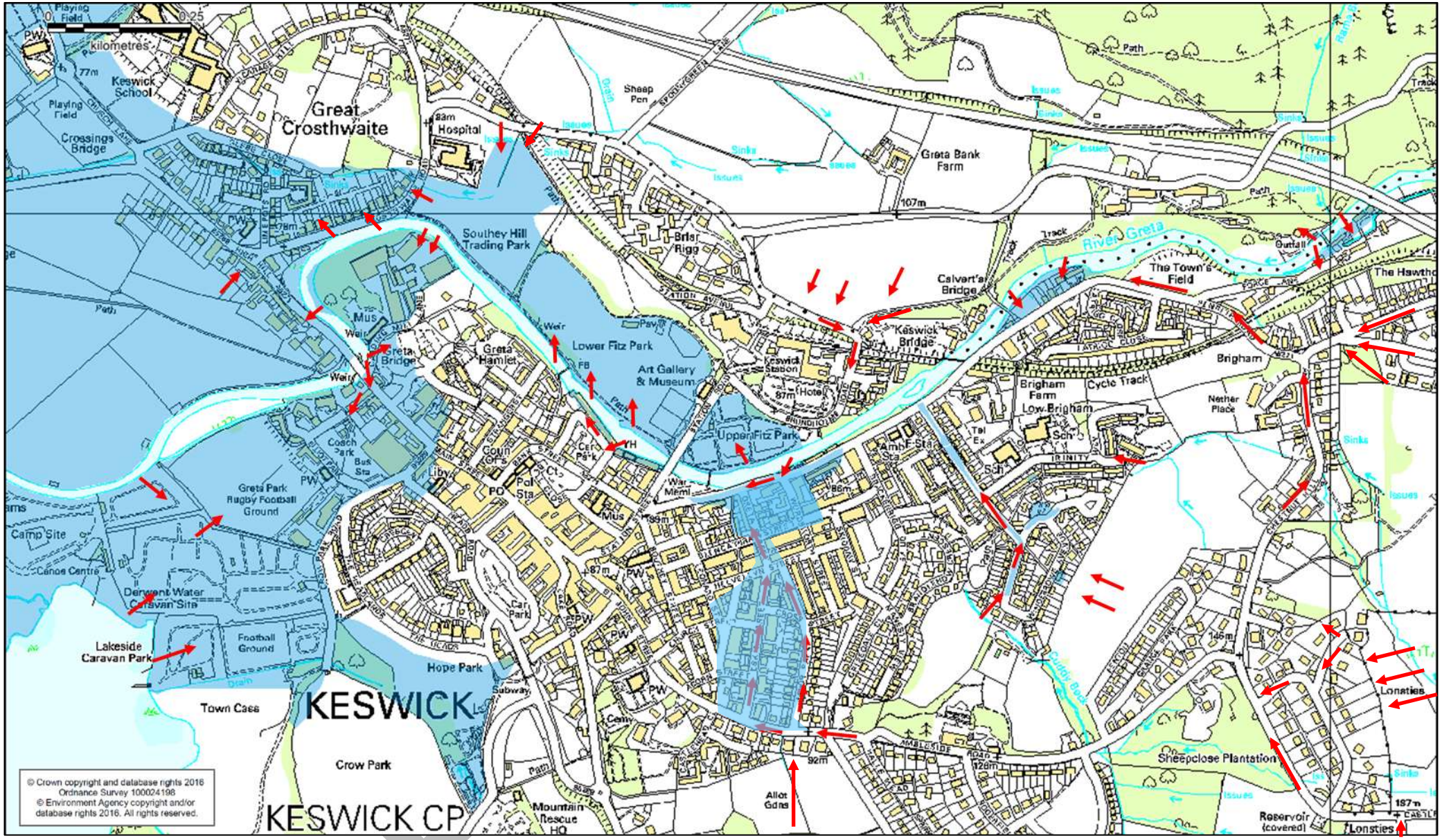


Figure 7 Map of flood flow routes

Impacts and Likely Causes of Flooding

Timeline

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

4th December	Event
1526-1533	Flood Alerts Issued
1930	Flood Gates closed
5th December	**Event**
0229-0610	Flood Warnings Issued
1100	Reported flooding at The Heads
1121	**Severe Flood Warning Issued**
1300	Initial overtopping of flood defences on High Hill
1300	Report Flooding at Limepots Road
1500	Report Flooding at High Hill Farm, &Tithebarn Street
1530	Report Flooding at Church Street
1700	Report Flooding at Lakehead Court
2215	**Peak River Level at Greta Bridge – 5.348m**

The flooding mechanisms included the river overtopping or bypassing existing flood defences and flooding from surface runoff or surface water drainage. The River Greta overtopped the existing flood defence system or river bank at:

- Low Briery Campsite
- Forge Lane
- Left bank at Cottages on Penrith Road
- On Penrith Road river bank and flood defence
- Greta Side
- Southey Hill Trading Area
- Crosthwaite Road
- High Hill Road
- Elliott Park
- Main Street

Flooding at Main Street and High Hill was primarily from the River Greta but the high levels in the River Derwent increased the effect of this flooding. Flooding was observed to be on the outside bend of the river at High Hill.

Surface water flooding occurred at:

- Windebrowe Avenue
- Brundholme Road
- Penrith Road
- Ambleside Road, Church Street, Helvellyn Street, and Shorley Lane
- Briar Rigg
- Millfield Gardens
- The Heads/Lake RoadStanger Street

- Bank Street

There were significant erosion issues experienced during the flood event, with several landslides in the river catchment upstream of Keswick. In Keswick itself, the access bridge at The Forge was badly damaged and the Millbank footbridge at the top of Stanger Street that connects to Fitz Park was washed away. There was also significant erosion and a landslip at Brundholme Woods, Low Briery where the Environment Agency gauging station is sited. Severe river bank erosion also affected Lydia's Cottages on the River Greta, with outhouses, boundary walls and services damaged and destroyed.

As a result of the erosion experienced upstream of Keswick a significant amount of material was deposited along the River Greta corridor through the town. In addition to the gravel/boulders and sediment deposited, a significant amount of woody debris and manmade objects were also transported downstream into the town, all of which caused a potential increase in flood risk due to reduced channel capacity. This debris caused blockages to the bridges within the town increasing the restriction to flow, figure 8.

Figure 8 Blockage of culverts downstream of Greta Bridge

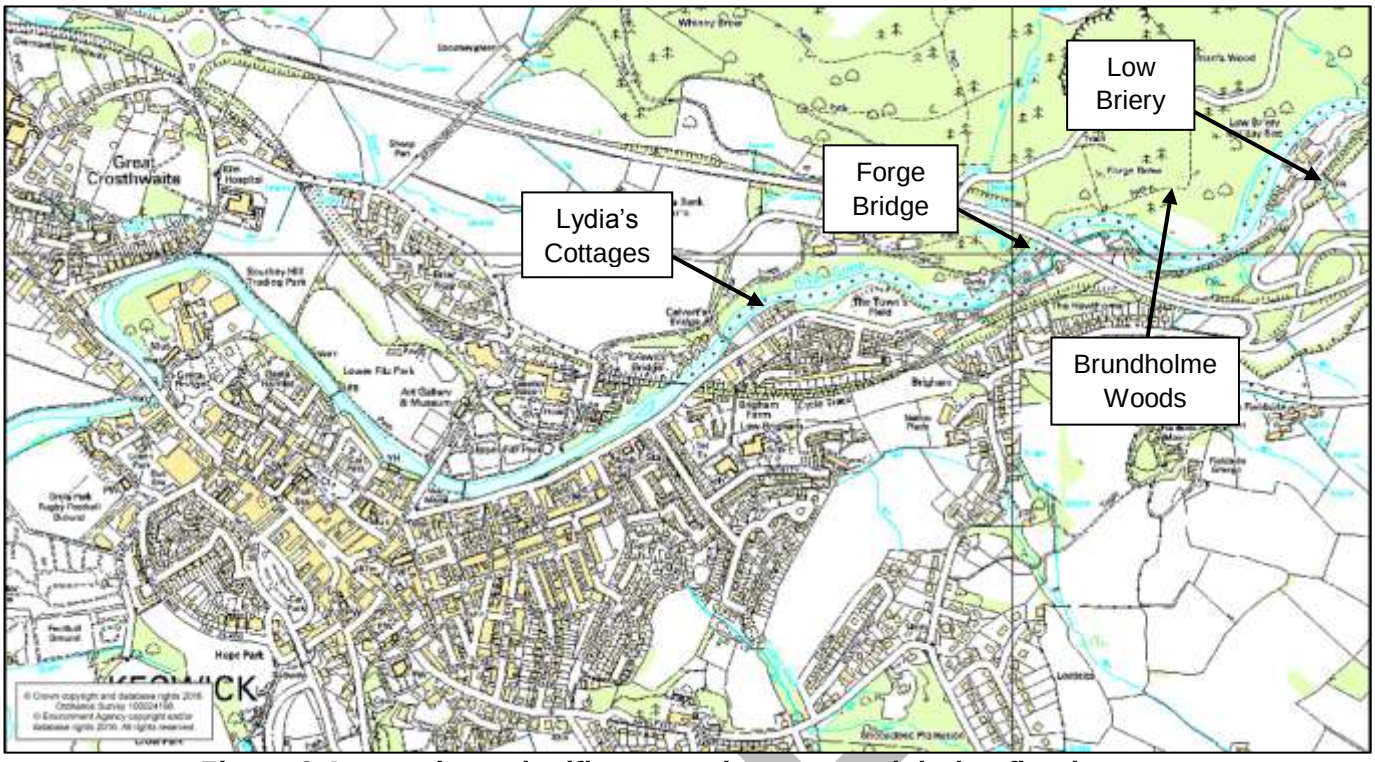


Figure 9 Areas where significant erosion occurred during flood event

Low Briery

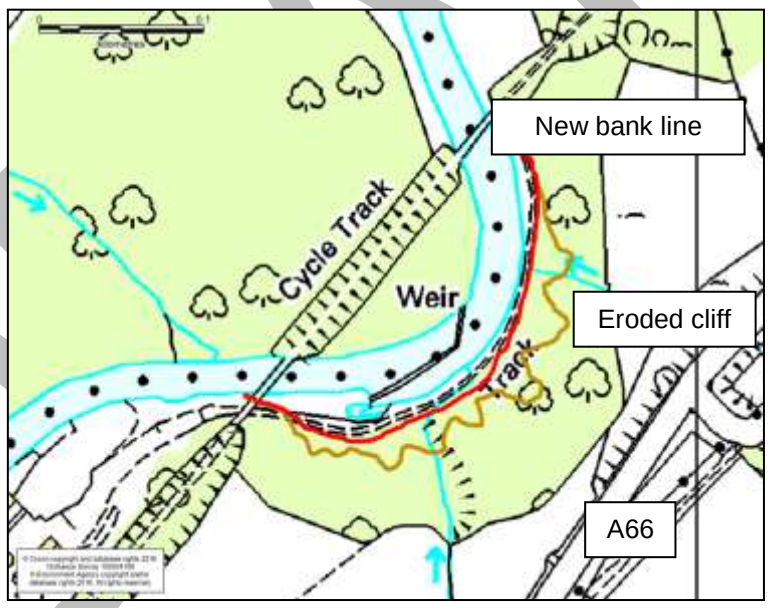


Figure 10 Area of landslip at Low Briery

Low Briery is located approximately 1km upstream of Keswick. This area experienced severe erosion during the flood event and substantial damage and destruction was experienced by the Low Briery Holiday Park. This included the loss of a number of static caravans which were washed downstream into the river.

Bank erosion and landslips are evident at numerous locations within the Low Briery area including directly opposite the Holiday Park site, and upstream of this site below the A66. A significant erosion/landslip feature has been identified on the left bank upstream of the Holiday Park, figures 10 and 11. As a result of the flood event, the river has reverted back to its original course and eroded more material from the base of the landslip. In tandem with the saturation on the eroded face, the erosion has

led to failure of the river slope. The lower part is now over-steepened and is subject to continued erosion from the river. The slope failures have removed a large numbers of trees and high volumes of eroded material, contributing to the flooding impact on Keswick.

Figure 11 Erosion/landslip feature upstream of Low Briery Holiday Park

Forge Bridge

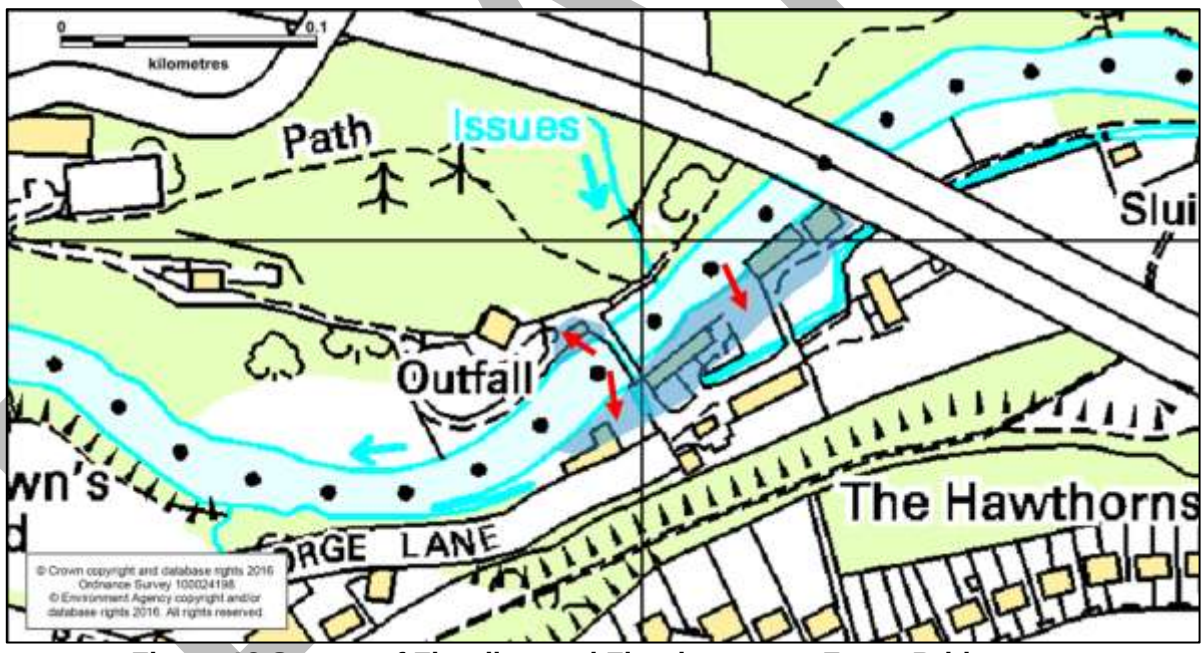


Figure 12 Source of Flooding and Flood extent at Forge Bridge area

This is an area of residential properties upstream of Keswick occupying both banks of the River Greta including Bridge House which is tied into the bridge itself. Forge Bridge forms a constriction to river flows and can cause elevated river levels immediately upstream. During December 2015, river levels exceeded the top of the bridge arch. These elevated levels flooded properties 6 to 9 Forge Lane on the left bank. There was also considerable damage to Forge Bridge, as shown in Figure 10, from both the high water level and debris including large trees and caravans. Significant scouring of the river bank also occurred on both the left and right hand sides.

Figure 13 Forge Bridge Partially Collapsed

The depth of flooding at the Forge was recorded to be in excess of 1.5m. A resident reported that the extent of flooding in the area was more extreme than the 2009 flood event.

Penrith Road

This is an area of flooded properties on the left bank of the River Greta upstream of the town. The river levels exceeded the soffit of Calvert's Bridge, a listed stone arch structure which formed a constriction to flow. Observations during the flood event from local residents were that water levels upstream of the bridge were approximately 3m higher than on the downstream side. This illustrates the likely impact that the structure had on flow mechanisms locally on the River Greta. There are no flood defences at this location and residential properties upstream of the bridge were flooded.

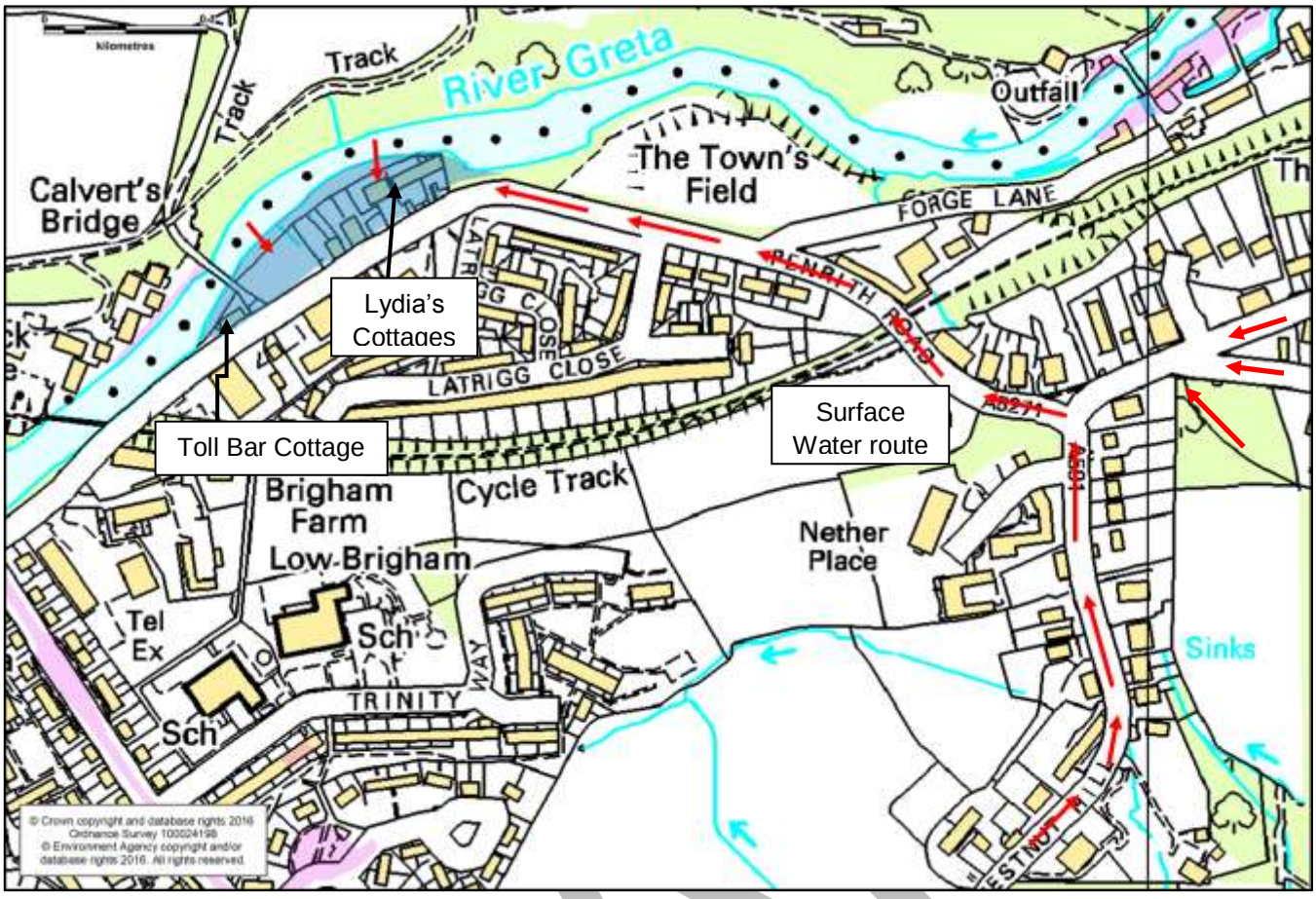


Figure 14 Sources of flooding and Flood extent at Calvert's Bridge

Significant erosion of the river bank upstream of the bridge took place with between 5m and 10m of the gardens of these properties being lost to the river. 3-9 Lydia's Cottages and 'Arkanum' all suffered severe bank erosion, with associated destruction of outhouses, boundary walls, and services. In some cases, very little ground remained to the rear of the property. After the flood event some of these properties were declared structurally unsafe. Damage was also sustained to property at Toll Bar Cottage located on the downstream side of the bridge.

Figure 15 Scour damage to the rear of properties

Windebrowe Avenue

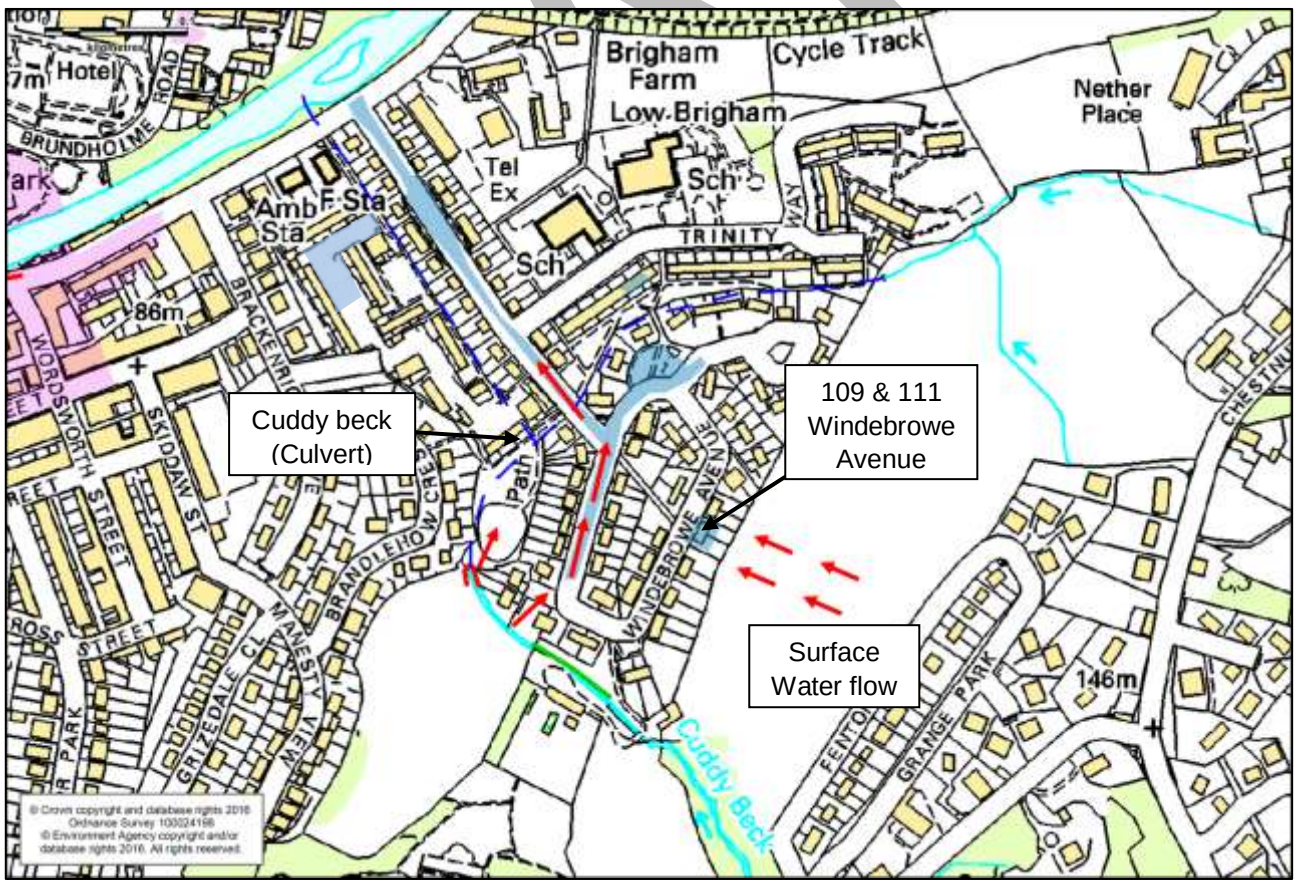


Figure 16 Source of flooding and flood extent at Windebrowe Avenue and Trinity Way

This area flooded from surface runoff that could not drain via the existing surface water drainage system. In this area, Cuddy Beck runs from the southeast towards Windebrowe Avenue and discharges to the

River Greta via a culvert. The culvert could not freely discharge to the river because of elevated river levels, although further investigation will be required to determine whether the capacity of the culvert was also a factor. Surface water that could not enter the culvert ran towards Windebrowe Avenue and on to Penrith Road, and flooded some of the properties on the upper end of Windebrowe Avenue.

Properties including 109, 111 and 159 Windebrowe Avenue were observed to have flooded, most likely due to surface runoff from the steep fields behind the properties. A local resident observed that water from the southern extent of Windebrowe Avenue flowed in a northerly direction towards the River Greta and along a footpath which leads to Trinity Way. This flow route led to flooding on Trinity Way and impeded access to St Herbert's School. The school was intended for use as a rescue centre but due to the risk posed from floodwater in this area alternative buildings were used.

Evidence gathered from surveys following the flood event suggested that the flooding on Windebrowe Avenue was limited to the road and footpaths. However, local reports indicate that speed bumps on the road directed water towards properties. Most properties in this area have relatively high thresholds, often with a step up to enter the property. This provided additional protection to water ingress.

Brundholme Road

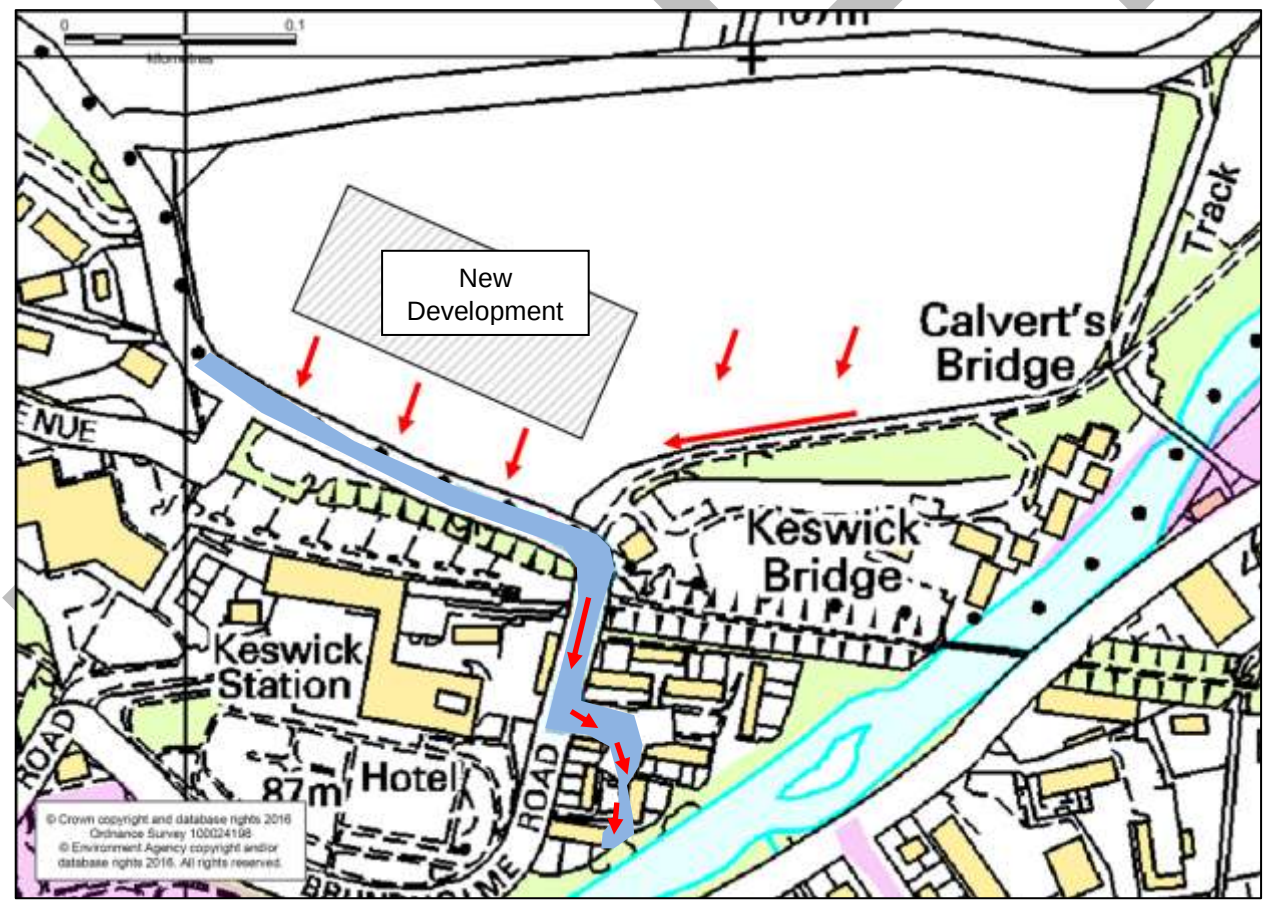


Figure 17 Source of flooding and Flood Extent at Brundholme Road

Flooding was observed on Brundholme Road from surface runoff through the new development area. Surface water from the construction site was silty and this blocked the road gullies on Brundholme Road causing local flooding in the area. A constriction of the drainage pipe taking water from Brundholme road has been identified. Two properties were flooded from surface runoff and one property flooded as a result of ingress from the River Greta.

Ambleside Road to Penrith Road

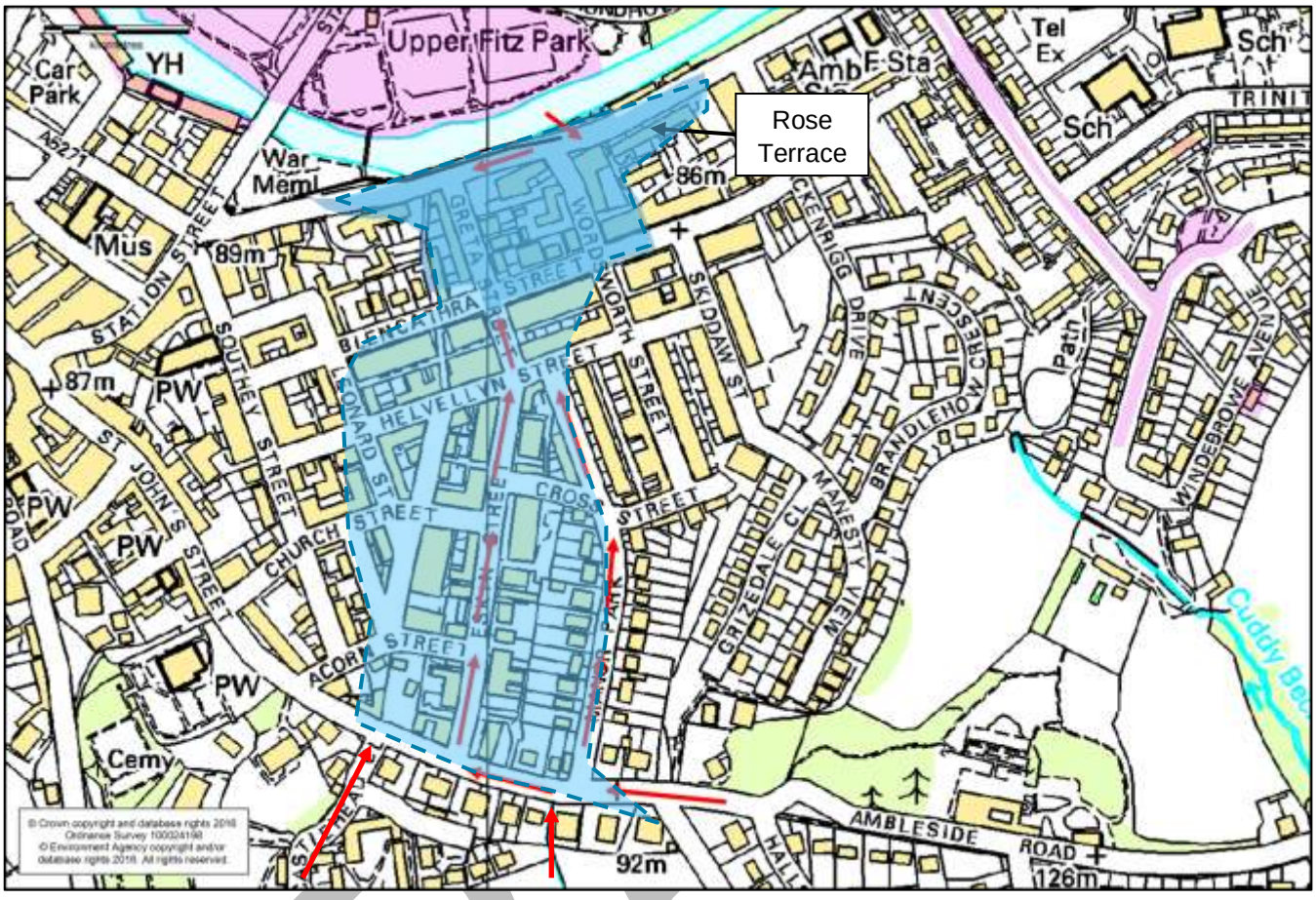


Figure 18 Flood extent map: Ambleside Road to Penrith

This is an area of residential properties on the left bank of the River Greta, outlined by Greta Street, Wordsworth Street, Canister Lane, and Penrith Road. A flood defence wall runs along The River Greta and at its upstream limit, terminating at an area of slightly raised ground as shown in figure 16.

Figure 19 Left bank of River Greta where defences overtopped

The initial cause of flooding was from surcharging of the Castlehead culvert which takes water from a small watercourse in the Ambleside Road area to the River Greta. Flooding was then observed in this

location through the drainage holes at the base of the flood defence wall on Penrith Road. Although non-return valves are fitted to prevent backing-up of water from the river it is thought that they were wedged open by debris which allowed water from the rising river to flow through the outlets and onto Penrith Road. Flood water from these various sources flowed down Penrith Road, flooding properties from Rose Terrace down to the Upper Fitz Park footbridge.

In addition, surface water runoff flowed onto Ambleside Road, continuing in the direction of the River Greta. Surface water flooded numerous properties within the area between Ambleside Road and Penrith Road. It was also noted that a manhole at the junction of Penrith Road and Greta Street shown in figure 20 started surcharging prior to the river overtopping or outflanking the flood wall.
Overtopping of the flood defence wall finally occurred from the River Greta prior to outflanking at the end of the floodwall, figure 19.

Figure 20 Manhole surcharge on Penrith Road

Upper and Lower Fitz Park

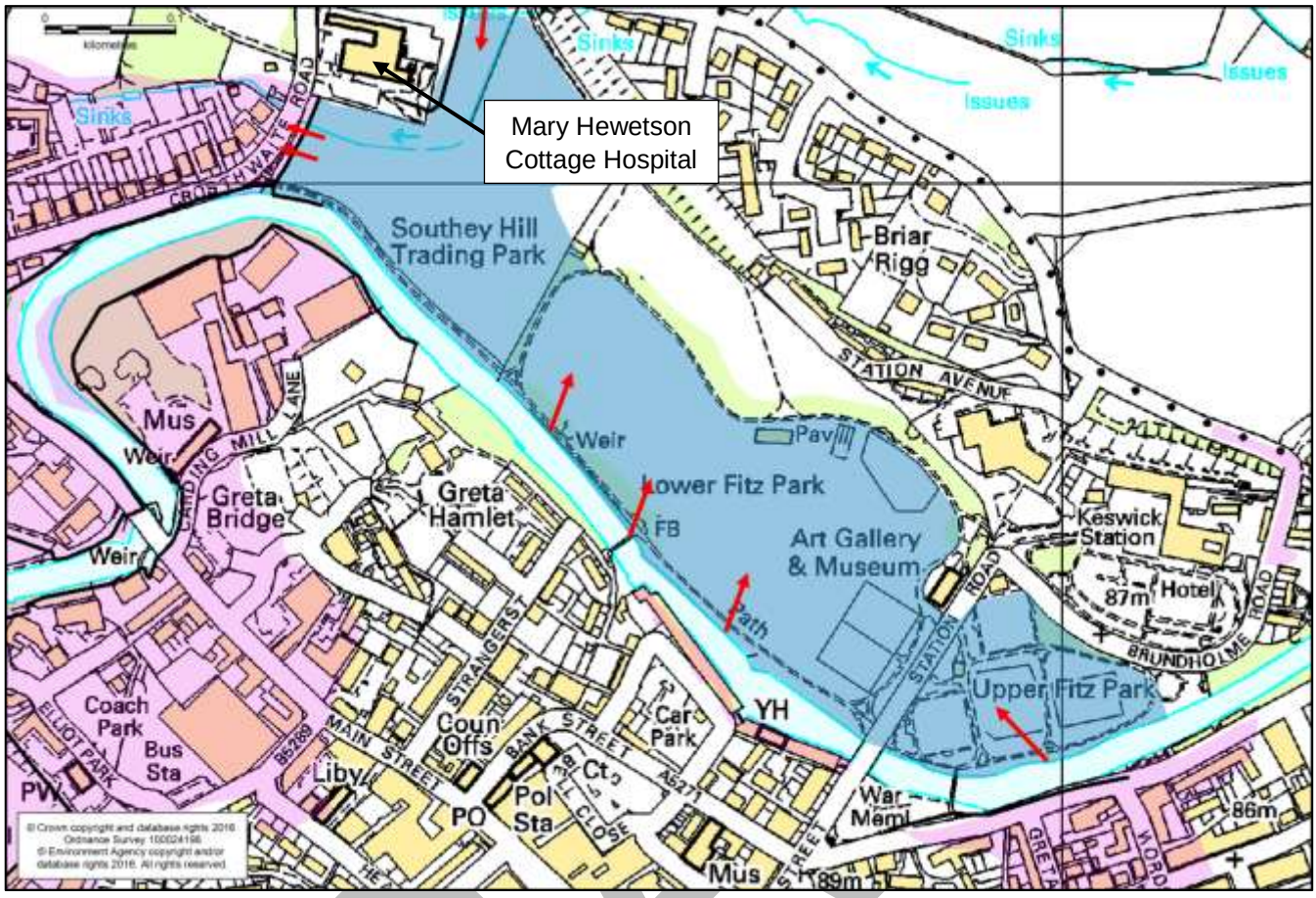


Figure 21 Source of flooding and Flood Extent map at Upper and Lower Fitz Park

This area is on the right bank of the river and is divided into upper and lower Fitz Park by Station Road. Upper and Lower Fitz Park are not defended and are intended to be used as flood plain storage during a flood event. At Lower Fitz Park, 2m depth of flooding was recorded, and at the football club pavilion, 0.25m of flooding was reported inside the building and 1m outside. The floodwater and deposited silts and gravels caused significant damage and destruction to the park facilities.

Mary Hewetson Cottage Hospital is located to the north of the park and this is defended by an embankment that runs across the north-west end of Fitz Park. A flood wall along Crosthwaite Road separates the flood plain area from the residential area to the west of the park, and this wall connects into the embankment at a flood gate, which provide access into Fitz Park.

The flood embankment and defence wall along Crosthwaite Road were both overtopped despite efforts by the Environment Agency to bolster the defences with sandbags during the event. There was also some seepage through the base of the vehicular floodgate at the northern end of Crosthwaite Road. Seepage was also observed through the flood defence wall near the upstream end of Crosthwaite Road, as well as further downstream. Water from these routes led to Crosthwaite Road being flooded from Fitz Park. Upstream headwall damage was also sustained by the Station Road bridge.

Figure 22 Crosthwaite Road Flood defence wall and embankment which were overtopped

Greta Side

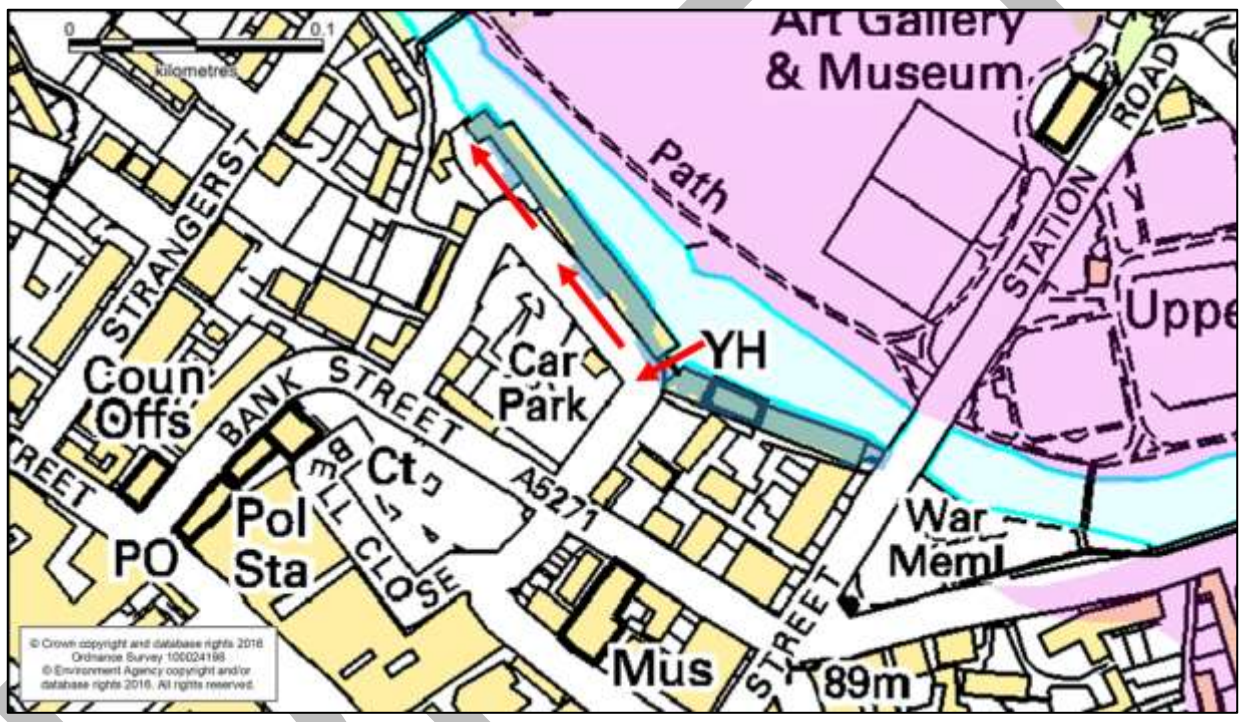


Figure 23 Source of flooding and Flood Extent at Greta Side

This area is on the left bank of the River Greta and many of the properties in this section are built along the river bank and form part of the defence line. As part of the flood defence works, properties at Greta Side were provided with flood proof doors, the mill race beneath them was sealed, and a short section of floodwall was constructed in a gap between properties adjoining the river. It was reported that the river overtopped this short floodwall and then flowed through the gap between properties, flooding properties on Greta Side. However, there was also evidence that water started to collect behind the barrier prior to it being overtopped.

The Environment Agency laid sandbags along this stretch of flood wall to provide additional protection, however this was still overtopped as river levels rose. Residents also reported that floodwater entered the properties through the floors, which, combined with surface water would account for water collecting behind the defences prior to overtopping. The footbridge that connects Millbank at the top of Stanger Street to Lower Fitz Park was washed away during the flood.


Figure 24 Riverside view of the properties and river flow between properties on Greta Side


Figure 25 Riverside view of Youth Hostel and washed out footbridge resting on left bank abutment

Southey Hill Trading Estate and North of Main Street

This includes areas on the left bank of the river Greta, within and adjacent to the large meander of the river. This area contains numerous businesses including the Pencil Museum, Co-operative store, Parish Rooms, and Rawnsley Centre, as well as the residential properties of Coleridge Court and Main Street. A floodwall and a short stretch of flood embankment is present along the left bank.

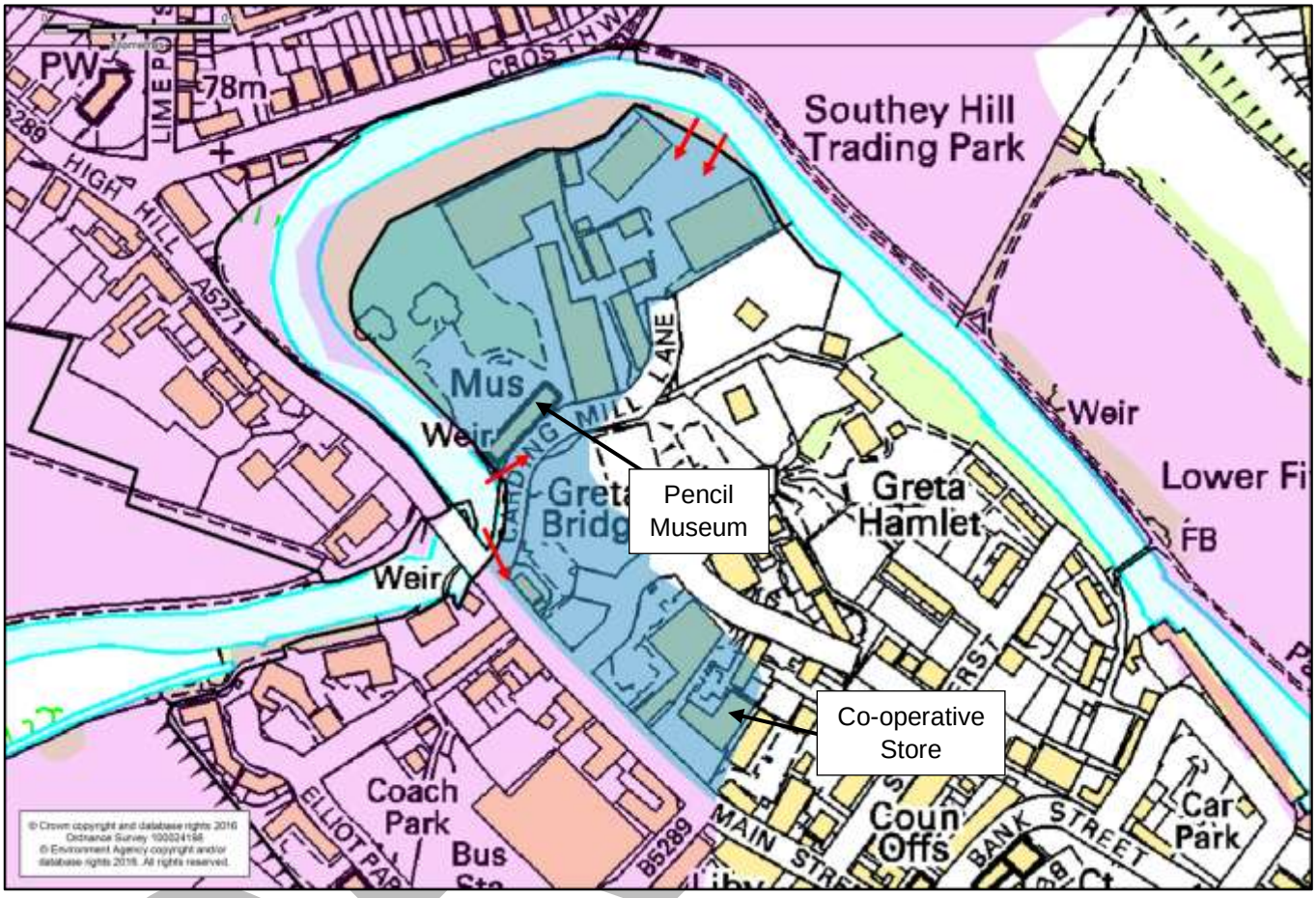


Figure 26 Source of Flooding and Flood Extent at North of Main Street – Southey Hill Trading Estate/area

Two mechanisms of flooding were observed from the river. Firstly, the flood defence walls were overtopped immediately upstream of Greta Bridge. Greta Bridge acts as an obstruction to flow leading to higher river levels upstream of the bridge. This increased the risk of defences being overtopped. The effect of this obstruction was worsened by debris in the river blocking the bridge arches.

Secondly, at the north end of Southey Hill Trading Park, the flood wall ties into a breeze block wall located on high ground. At the time of the event the cladding had been removed from the top of the wall for maintenance purposes.

Water flooded the trading area to a depth of approximately 0.6m - 0.9m. Flooding from upstream of Greta Bridge also crossed Main Street and flooded the area south of this road.

Figure 27 River overtopped its bank/flood wall at Southey Hill Estate and the river wall overtopped at upstream of Greta Bridge

Millcroft Veterinary Surgery was flooded to a depth of 2.5m and the Pencil Museum and factory buildings off Carding Mill Lane were flooded to a depth of 1.0m. The Co-Op supermarket was also flooded which resulted in its closure for subsequent months.

Elliott Park and South of Main Street

This area includes residential and commercial properties. There is a floodwall along the river bank and a flood embankment on the boundary between Elliott Park and the Rugby football Ground.

Figure 28 Source of Flooding and Flood Extent on the South of the Main Street

The River Greta overtopped immediately upstream of the Greta Bridge, and flowed across Main Street towards Elliott Park. This resulted in the flooding of all properties between Tithebarn Street, Main Street and the River Greta, including properties on Elliott Park and Riverside Court as well as Booths supermarket and the rugby football ground. This is shown on figures 29 and 30.

Figure 29 Flooding at Booths store and on Main Street/Tithebarn Street

Cumbria County Council are completing work to build a new surface water pumping station for Elliott Park. During the construction work, Cumbria County Council contractors had temporary pumps on site. These pumps were operated until they were overwhelmed by floodwater. Flood levels at Elliott Park reached approximately 0.9 to 1.2m and houses on Riverside Court and Elm Court being flooded to a depth of approximately 1.2m.

Local residents reported that the onset of flooding in Elliott Park was rapid, with the water level reaching the top of the embankment at the Rugby Football Club within half an hour. The water level on the floodplain downstream of Elliott Park at the Rugby Football Club was reported to be significantly lower than the level within Elliott Park. Water was observed flowing over the embankment crest from Elliott Park side onto the floodplain. It is therefore felt that in this incident, the embankment acted as a barrier to flow and impounded water in Elliott Park, exacerbating the impacts of the flooding to the area.

Flood levels measured inside Booths supermarket were over 1.0m deep. It was reported that the entire stock was written off and the store remained closed until a partial opening commenced on 20 March 2016.

Flooding had occurred to 6 properties (B&B's/Hotels) and a cafe on The Heads/Lake Road, to the east of Hope Park. The flooding mechanism in this location is believed to be from the River Derwent floodplain due to the increase in the level of Derwentwater. This led to backing up of the drains causing flow across Hope Park affecting these low lying properties.

The Rugby football ground and the surrounding area are believed to have been flooded from a combination of flows from the River Greta, and overland flow from Derwentwater, which had flooded across the Keswick lakeside camping and caravan club site.

Foul water and sewage was reported rising up though toilets and sinks in Elliott Park.

Figure 30 Flooding at Keswick Rugby Club

High Hill and Crosthwaite Road

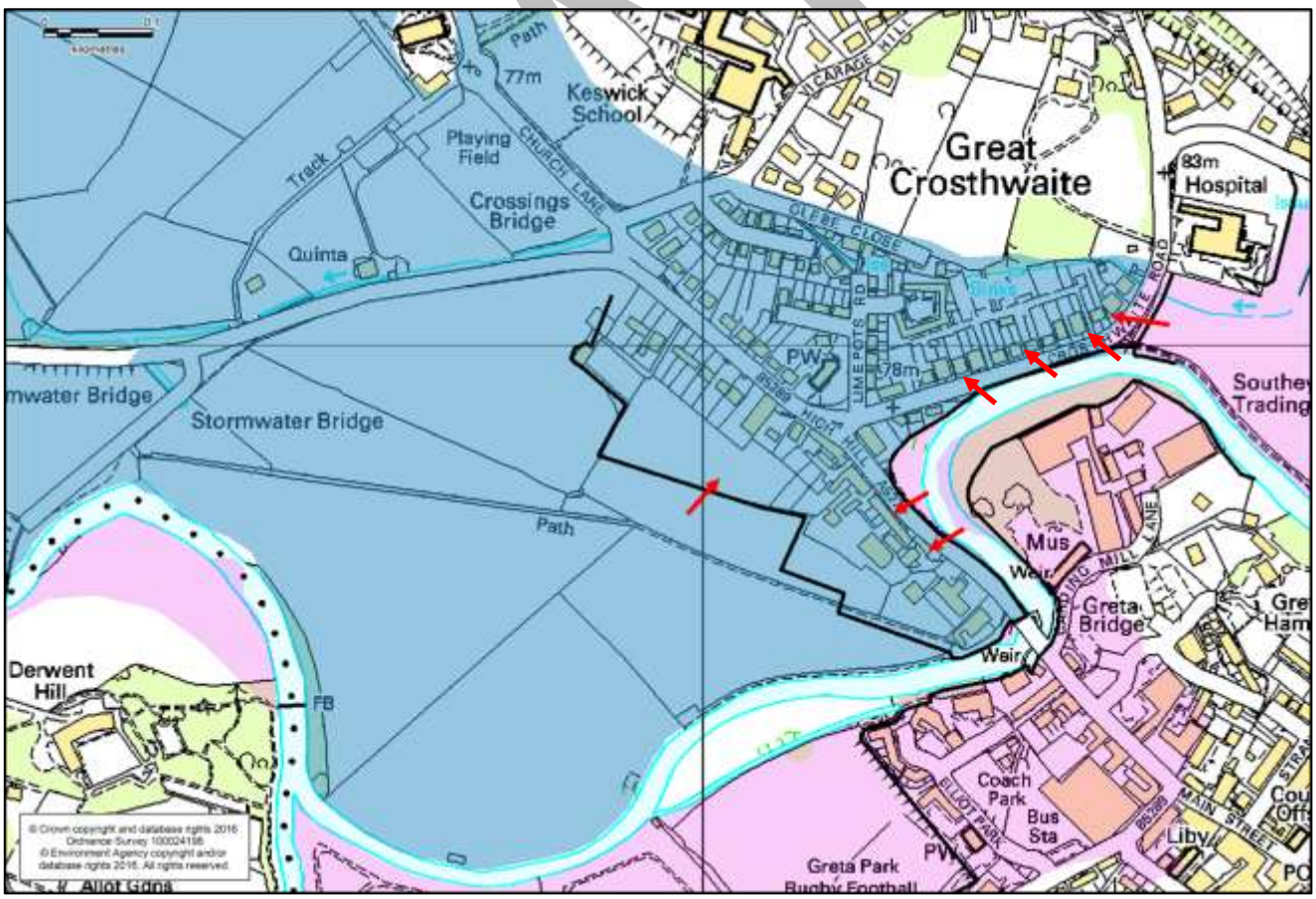


Figure 31 Source of Flooding and Flood Extent at High Hill

This area is on the right bank of the River Greta and includes properties alongside Crosthwaite Road, Limepots, Glebe Close, and the area to the south of High Hill road. There is a flood defence wall along the right bank of the River Greta bounding Crosthwaite Road and High Hill. The section along High Hill

includes glass panel sections to maintain views of the river. There is also a flood defence embankment to the rear of the properties on High Hill road to protect against flows from the River Derwent.
It was reported that flooding to this area started at the flood wall on High Hill road, where it was overtopped at the river bend. Initial overtopping along High Hill Road was observed at 13:00 on 5th December. Here, floodwater scoured out stone pitching on the defended side of the defence along with a section of footpath approximately 10m long. Residents on High Hill Road reported that soon after this the flood embankment on the river Derwent flood plain to the rear was overtopped. The flooding to these properties is therefore understood to be from both rivers.

Flooding along Crosthwaite Road initially commenced from the overtopping of the floodgate at the northern end of the road. The flood defence wall and embankment were also overtopped leading to flooding from Fitz Park. Seepage was observed through the base of the floodgate and through the flood defence wall further south on Crosthwaite Road. As river levels continued to rise, the flood defence wall was overtopped along its length in the Crosthwaite Road area.

Figure 32 Flooding at High Hill Road - Glassed floodwall overtopped and scoured footpath

Environment Agency Flood Incident Response

In advance of potential flooding the Environment Agency closed the floodgates that are part of the Keswick Flood Risk Management Scheme on the evening of 4th December. The Environment Agency also inspected watercourses and operational structures such as debris screens to ensure that there were no blockages which could have caused an increase in flood risk.

The Environment Agency also bolstered defences with sandbags along the crest at the Youth Hostel flood defence wall downstream of Station Road Bridge, and at the upstream end of Crosthwaite Road. A community pump was deployed by CCC Highways to the Penrith Road area on the afternoon of 5th December to pump surface water from behind the flood defence back into the river. This pump was also supported by a Fire Service high volume pump.

The Environment Agency has worked closely with the Keswick Flood Action Group (KFAG) for a number of years to help plan and prepare for flood events. Prior to the event, on receipt of forecast information, the Environment Agency contacted KFAG to raise awareness and provided further information to the group throughout the event. The Environment Agency also sent messages to stakeholders via the Cumbria Community Messaging (CCM) system to raise awareness and provide advice and guidance.

A flood alert for the River Greta, St. John's Beck and Bassenthwaite Lake was issued on the 4th of December at 15:26. This was shortly followed by an alert for the Upper River Derwent, Stonethwaite Beck, and Derwent Water at 15:33. Both these alert areas affect Keswick. Flood warnings were issued to the flood warning areas within Keswick between 02:29 and 06:10 on the 5th December. A severe

flood warning was issued at 11:21 on the 5th December, as flooding to the town was thought to be imminent.
The details of the flood warning areas and the times of these warnings is shown in Appendix 4.

Immediately after the flooding the most critical scour holes were filled including scour damage on the landward side of the flood bank on Crosthwaite Road. Major debris deposits, which posed a risk of future blockages to structures, were removed after the flood event by the Environment Agency once river levels had sufficiently receded. The Environment Agency undertook emergency works to remove accumulated debris from the River Greta channel from Low Briery to the confluence with the River Derwent. This included the removal of an estimated 25,000 tonnes of gravel from the River Greta at Greta Side, the Pencil Works, and Greta Bridge areas.

Regular monitoring of gravel accumulation forms a key part of the Environment Agency's maintenance programme in Keswick. In line with our existing annual gravel monitoring programme through Keswick, we will continue to closely monitor the accumulation of gravel on the River Greta and undertake removal when required to manage flood risk.

Immediately after the flood event in December 2015, the Environment Agency's staff undertook inspections of flood defences in Keswick, and removed debris and blockages to aide conveyance. Repair works were also carried out to scour holes.

Despite the record flows experienced on the Rivers Greta and Derwent in Keswick, only minor damage was experienced to Environment Agency assets. This mainly comprised damage to seals on floodgates and the glass panels on High Hill Road, which will subsequently be repaired by the Environment Agency. The minor damage experienced does not compromise the standard of protection offered by the flood risk management scheme to Keswick.

Prior to, during, and following the flood event the Environment Agency have been in close contact with the Keswick Flood Action Group (KFAG) and have corresponded with numerous residents of Keswick to provide support, advice and guidance. The Keswick Flood and Emergency Recovery Group (KFERG) activated the Keswick Community Emergency Plan and set up a control centre in Keswick Town Hall Chambers, which helped co-ordinate the multi-agency response and volunteers in the town.

As well as attending site meetings at the request of KFAG and local residents, the Environment Agency also attended a Multi-Agency public drop-in event on 22nd January, and a Flood Fair on 1st February. Further public consultation and engagement events will be held, going forward, to provide ongoing support, advice, and guidance to the Keswick community.

Maintenance Activities

The Environment Agency maintains flood risk management structures and sections of river channel where maintenance actively reduces the risk of flooding to people and property. Activities we undertake are summarised below:

- We conduct yearly visual inspections of flood defence embankments and walls and deliver a variety of maintenance tasks which include, as necessary:
    - grass cutting,
    - tree and bush management,
    - invasive species control,
    - vermin control and
    - expansion joint repairs.

- We deliver targeted maintenance on River Channels where the activity is beneficial to the reduction in flood risk. This could include:
    - Weed Control,
    - Grass Control,
    - Tree and Bush Management,
    - Invasive Non Native Species Control,
    - Gravel Removal, when justified through investigation and survey.

In Keswick, we undertake tree and bush management and gravel management on the channel sections between Upper Fitz Park and the Derwent confluence.

- On operational structures, we undertake:
    - quarterly operational inspections and
    - yearly mechanical maintenance

- On Culverts, which could pose a risk of flooding to properties, we monitor the risk of flooding through 6 yearly inspections, and deliver the following on a risk based approach:
    - Cleansing works
    - Repairs and reconditioning works

Facts and Figures for Keswick:

- Gravel naturally collects in the River Greta at the Pencil Mill in Keswick. Between December 2015 and May 2016 we removed around 25,000 tonnes of gravel from the River Greta in Keswick that was washed into the town by Storm Desmond and subsequent events.
    - To put the winter events into perspective, on average we remove around 3000 tonnes approximately every 3 years.
- We maintain 1.1km of Flood Defence Embankment in Keswick.
- We maintain 1.3km of flood defence wall
- We maintain over 60 structures in Keswick

Future Work

- We are working with a team of geologists and geomorphologists to understand the significant changes to the river Greta upstream of Keswick and to develop a plan for the future management of the system, particularly with regard to the huge amount of loose gravel material that is now present.
- Recovery works to repair damaged assets are ongoing.

United Utilities: Thirlmere Reservoir

Background

Thirlmere reservoir was built in 1894 to supply drinking water for Manchester. The reservoir can store up to 40,000 megalitres (million litres) of water and approximately 700,000 people – about 10% of the region's water users - receive drinking water supplies from Thirlmere. Most are in Manchester but other communities include Blackpool and the Fylde coast, Lancaster and of course local communities such as Keswick and Borrowdale.

At the southern end of Thirlmere is the Thirlmere aqueduct. This is a 134 mile long gravity tunnel which links Thirlmere to Manchester. The aqueduct extracts up to 220 megalitres of water from Thirlmere per day.

Thirlmere discharges into St John's Beck, which is a tributary of the River Greta. The River Greta flows through Keswick and joins the River Derwent just after it leaves Derwent Water as it flows towards Bassenthwaite Lake. St John's Beck accounts for about one fifth of the water in the River Greta

How Thirlmere is operated

Thirlmere reservoir is maintained and managed according to legislation and the local arrangements agreed with Keswick Flood Action Group (KFAG). United Utilites operate to a set of flood level drawdown rules agreed with KFAG.

These rules specify reservoir levels for each month at which United Utilities will release more water into St John's Beck. Releases continue until the month target level is achieved and further to maintain it if necessary. This is a best endeavours effort as incoming water from rainfall and the catchment may be greater than the maximum possible releases

In November this level is 3.0m below top water level – equivalent to 76% full. The idea being that this spare capacity can absorb some of the heavy rain which falls during these months. United Utilities operated the reservoir to these agreed levels prior to the December flood event.

However the catchment is in a delicate environmental balance and there is a natural limit to the amount of water United Utilities can release without causing damage to St Johns Beck which is a Special Area of Conservation. The normal compensation flow in St John's Beck is 13.64 megalitres a day. We can increase this to 100 megalitres per day.

Even at this level, it causes some flooding to farmland. Any more than 100 megalitres and more farmland will flood on a more frequent basis. United Utilities also have to consider the impact increased flows have on those who use the Beck for fishing. All releases except the 13.64 million litres compensation are ceased if the reservoir starts to spill

Nov 2015- Levels in Thirlmere Reservoir.

United Utilities can increase the rate at which water is removed from the reservoir up to a certain limit. When the Thirlmere Aqueduct is open, the safe and environmental limit is 320 megalitres a day. If the rain falls faster than this then the reservoir will start to fill until it eventually overflows.

In November 2015 we already had more than twice the normal level of rainfall expected for the month and Thirlmere reservoir was filling throughout November and started to spill on Monday 30 November.

The reservoir level reached during storm Desmond was 1.56m above weir crest, the highest recorded level. This level was still within the design parameters of the Dam and below the potential maximum flood for which it is designed. The parapet (roadside) wall is designed to be an integral part of the dam. It is a substantial, water tight structure that will retain the maximum still-water flood during the probable maximum flood. Studies and inspection reports indicate that the wall is sufficient to withstand the effects of waves to the top and just spilling the wall. This is how the wave wall operated during Storm Desmond and the wall has not suffered damage.

On 5th December alone, around 14,000 million litres of water entered the reservoir, which is more than a third of its capacity. According to the average rainfall for Cumbria for the month of December is 146.1mm, and more than this fell during one day. Over the course of the weekend, flows down St Johns beck were higher than ever recorded before. Clearly, given the amount of rainfall increasing the 320 megalitres daily removal would have made little material difference.

Future investment

United Utilties have been considering options for further flood drawdown releases and possible modifications to the infrastructure at Thirlmere as part of the new pipeline scheme to West Cumbria.

Limitations to the speed of reservoir drawdown, caused by constraints at the dam outlet to St John's Beck, are well understood and following studies potential solutions have been identified. These solutions will be considered as part of the detailed design of the modifications to abstraction infrastructure, new water treatment works and pipelines for the Thirlmere to West Cumbria transfer.

Current flood drawdown releases are approximately 100 Ml/d . The limitation is not the outflow from the low level scour valves on the dam, which can release up to 900 Ml/d in emergency draw down for reservoir safety. The issue at present is infrastructure downstream of the valves, including a bridge that could be washed away if flows higher than the currently agreed releases are made.

Work has progressed to develop the long term provision of water to West Cumbria which will include a solution that could allow a higher rate of release. In essence this is to engineer a channel to accommodate the higher flows, and make modifications to the valves to enable better control. This would allow approximately 500 Ml/d of flood drawdown release to be made whilst still maintaining flows to the WTW to supply customers.

United Utilities are committed to ongoing engagement with KFAG, the Environment Agency and Natural England regarding the volumes of water that can be released in to St. Johns Beck in the future. An environmental assessment will need to be conducted in to the impact of releases downstream of the reservoir and this will involve all parties mentioned above as well as local residents that could potentially be impacted by any changes.

St John's Beck is part of a Special Area of Conservation and therefore any solution needs to be complaint with the Habitats Directive.

We currently estimate that construction of new infrastructure will begin in 2017 and take an estimated 12 months to deliver the work to accommodate the releases in to St John's Beck.

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 or are ongoing.

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 options to improve the flood flow capacity at Greta Bridge.	2016
	Cumbria Planning Group, Allerdale District Council	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
	Environment Agency	Investigate options for managing gravel and sediment upstream of Keswick, to reduce the risk of significant accumulation within the town.	2016
Maintenance	County Council, United Utilities and Allerdale District Council	Review and investigate drainage and sewerge systems to better understand where improvements are required.	2016

	Environment Agency and Cumbria County Council	Review outfalls to the River system within Keswick, and ensure all outfalls are sealed with flap valves or non-return valves to prevent the defence scheme being compromised.	Summer 2016
	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
	Environment Agency	Undertake review of geomorphology to better understand gravel movement in river to inform a gravel management plan.	2016
	Environment Agency	Review maintenance programme for main rivers in response to the flooding events of 2015.	2016
Strengthening Defences	Environment Agency	Review modelling data to ensure that models for the Derwent catchment reflect real conditions as accurately as possible, and use this information to make any improvements to the flood warnings service. This will also be used to inform future investment plans.	August 2016
	Environment Agency	Review scheme performance and consider what worked well, and where improvements to defences are required including Penrith Road.	August 2016
	Environment Agency	Investigate potential for the provision of flood defence measures on the rear side of cottages in the Penrith Road area.	2016
	Environment Agency	Investigate potential to install a drain-down structure through the embankment at the downstream extent of Elliott Park to prevent impoundment of water in the area.	2016
	Environment Agency	Investigate if Derwentwater and Bassenthwaite lake	2016

		levels can be managed differently to reduce flood risk.	
	Environment Agency	Investigate possibility of a flood relief channel through High Hill onto the floodplain downstream of Keswick.	2016
	United Utilities working with Keswick Flood Action Group and the Environment Agency.	Review operational arrangements for Thirlmere Reservoir and investigate possibility of revised arrangements to provide flood risk benefit to areas downstream.	2016
	Environment Agency and Cumbria County Council	Investigate impacts of transport infrastructure downstream of Keswick on flood risk – A66, B5289, old railway embankment, old Portinscale Road.	2016
	Cumbria County Council	Continue with the design and construction of the flood risk scheme planned to protect Penrith Road.	Design 2016/17 Construction 2017/18
	Cumbria County Council	Completion of the Elliott Park surface water pumping station flood risk scheme.	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 the c.£10m Asset Recovery Programme which covers Cumbria & Lancashire. This programme of repairs is scheduled to be complete before winter 2016/17.	

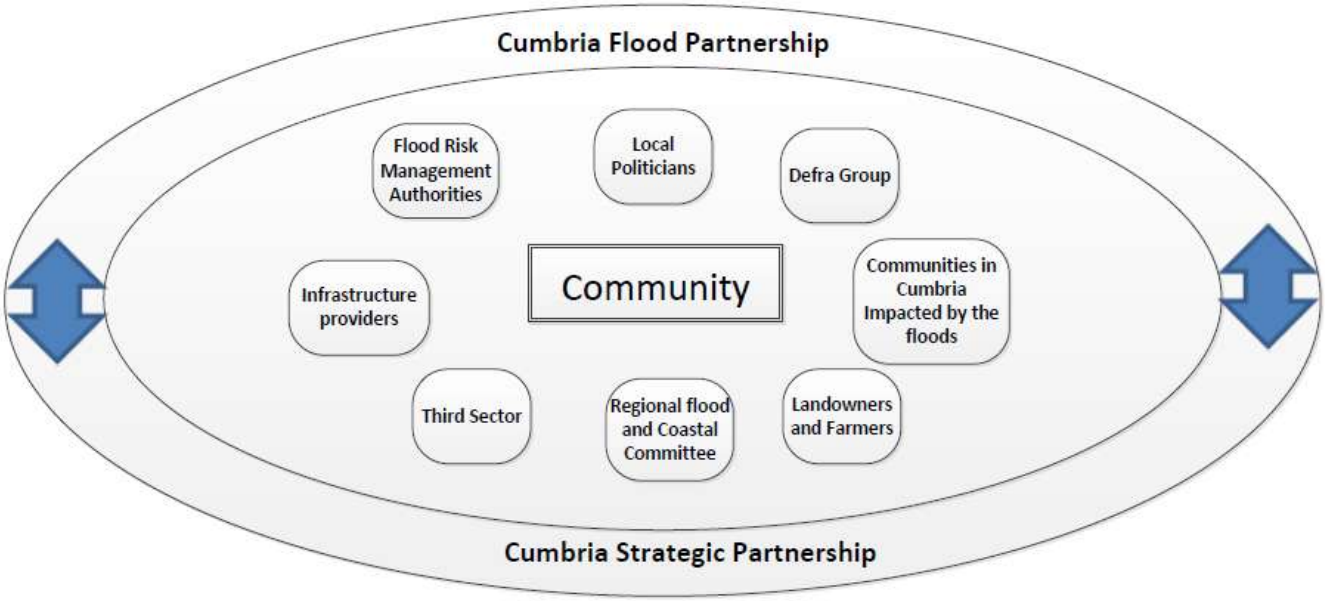
* The Cumbria Local Resilience Forum includes emergency services, Local Authorities, Cumbria County Council, Environment Agency, Maritime Coastguard Agency and health agencies along with voluntary and private agencies. Under the Civil Contingencies Act (2004) every part of the United Kingdom is required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

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
FWMA	Flood and Water Management Act 2010
KFERG	Keswick Flood and Emergency Recovery Group
LDA	Land Drainage Act 1991
LLFA	Lead Local Flood Authority
MSfWG	Making Space for Water Group
RMA	Risk Management Authority
UU	United Utilities
WRA	Water Resources Act 1991

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 are the LLFA for Cumbria. 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 Local Flood Risk 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: Useful contacts and links

Cumbria County Council (Local Flood Risk Management):
lfrm@cumbria.gov.uk, www.cumbria.gov.uk, tel: 01228 211300

Cumbria County Council (Highways):
highways@cumbria.gov.uk, www.cumbria.gov.uk, tel: 0845 609 6609

Cumbria County Council Community Services
Alison.Meadows@cumbria.gov.uk, www.cumbria.gov.uk, tel: 1229 407576

United Utilities: tel: 0845 746 2200

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 to the rights and responsibilities of riverside occupiers
https://www.gov.uk/government/publications/riverside-ownership-rights-and-responsibilities

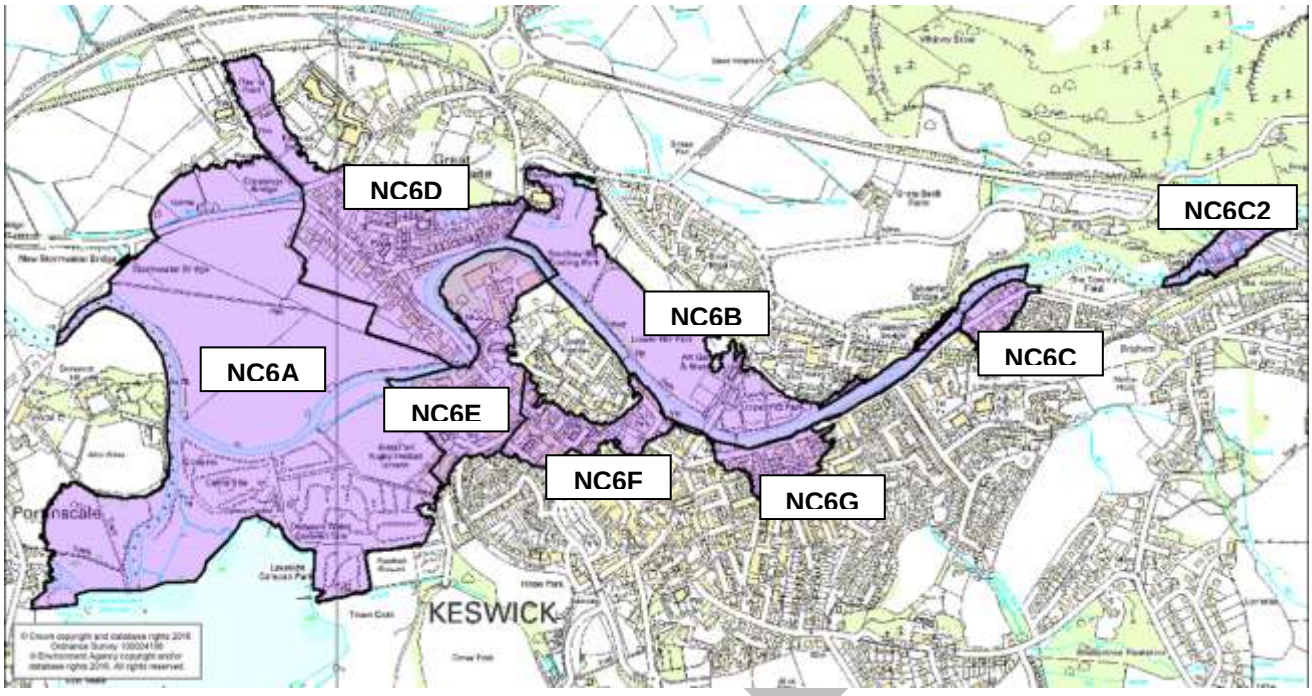
Flood and Water Management Act 2010:
http://www.legislation.gov.uk/ukpga/2010/29/contents

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

Highways Act 1980:
http://www.legislation.gov.uk/all?title=highways%20act

Appendix 4: Flood Warnings and Alerts



Flood Warning Areas within Keswick

Keswick is covered by 2 Flood Alerts and 11 Flood Warnings. Flood Warning areas are well defined following previous events in 2005 and 2009 and were developed in consultation with the Keswick Community Group. There is scope to rationalise the initial areas that flooded as there are only a very small number of properties affected within the undefended areas of the town. It is not until forecast levels approach the main defence levels on the River Greta within the town that a more significant number of properties come into the equation. These thresholds will be reviewed against the post event modelling report and some minor amendments to Flood Warning Areas are anticipated.

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

Flood Warning Area	Flood Warning Issued	Severe Flood Warning Issued (05/12/15)	Properties	Contacts	%Success*
NC6A	03/12/15 20:51	11:21	55	170	74%
NC6B	05/12/15 02:29	11:21	83	209	70%
NC6C		11:21	40	115	70%
NC6C2		11:21	107	225	74%
NC6D	05/12/15 06:05	11:21	233	550	77%
NC6E	05/12/15 06:12	11:21	227	516	72%
NC6F	05/12/15 06:06	11:21	171	303	68%
NC6G	05/12/15 06:10	11:21	142	270	79%

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

Flood Alerts:

*Contact Successful if at least one attempt to contact a fully-registered recipient registered to the property returned a status of "Acknowledged", "Successfully Received", "Successfully Sent" or "Unacknowledged"

011WAFGB- Rivers Greta, St Johns Beck and Bassenthwaite Lake.

Alert issued on Thursday 03/12/2015 at 14:46
Alert removed on Friday 04/12/2015 at 07:05
Alert issued on Friday 04/12/2015 at 15:26
Customers in Flood Alert area registered on FWD: 151
Contacts (landline, mobile, email etc) in Flood Alert area registered on FWD: 506
Successful contacts: 440
Unsuccessful contacts: 66

Alert Message:
A Flood Alert has been issued by the Environment Agency for the Rivers Greta, St Johns Beck and Bassenthwaite Lake.
Flooding is possible for River Derwent from Keswick to Bassenthwaite. The Rivers Greta, Glenderamackin and St Johns Beck including Keswick. Low lying land and roads will be affected first.
Heavy and persistent rainfall along with strong South-Westerly winds are forecast to continue this evening through until Sunday 06/12/2015. With the ground already saturated the river and lake levels are expected to rise further and we may see some significant impacts. The forecast is likely to result in Flood Warnings being issued on Saturday. We advise that you keep an eye on the situation by listening to weather forecasts, checking our web pages or calling Floodline. We are continuing to monitor the situation and have workers on site operating defences and clearing blockages where required.

011WAFDW- Upper River Derwent, Stonethwaite Beck and Derwent Water.

Originally issued on Saturday 28/11/2015 at 17:30
Reissued on Friday 04/12/2015 at 15:33
Customers in Flood Alert area registered on FWD: 28
Contacts (landline, mobile, email etc) in Flood Alert area registered on FWD: 90
Successful contacts: 67
Unsuccessful contacts: 23

Alert Message:
A Flood Alert has been issued by the Environment Agency for the Upper River Derwent, Stonethwaite Beck and Derwent Water.
Flooding is possible for The Upper Derwent from Seathwaite to Derwent Water. Low lying land and roads will be affected first.

Flood Warning Target Areas:

011FWFNC6KC- Keswick Campsite

Flood Warning issued on Saturday 28/11/2015 at 18:48
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:35
Flood Warning removed on Tuesday 29/12/2015 at 13:32
Customers in Flood Warning area registered on FWD: 35
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 115
Successful contacts: 83
Unsuccessful contacts: 32

Severe Warning Message:
A Severe Flood Warning has been issued by the Environment Agency for the Keswick Campsite.
This Severe Flood Warning is for Keswick Campsite flooding from the lake.
We are forecasting significant rainfall during today and tomorrow. Environment Agency staff are currently inspecting and operating our flood defences and clearing debris screens. River levels are expected to rise very quickly so we are issuing severe flood warnings to enable people to take the following preparatory actions by:-
Checking vulnerable family,friends and neighbours
Install flood protection measures to your property if you have them
Only travel if necessary and do not drive through flood water
Considering to activate or get ready to activate your community emergency plan
Reception Centres are open for public use.

011FWFNC6A - River Greta at Keswick, Keswick Campsite, Rugby Club, Greta Side and Quinta.

Flood Warning issued on Thursday 03/12/2015 at 20:51
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:17
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Date/Time Warning Level Reached: 05/12/2015 01:30
Time customers had to take action: 28:39:00
Customers in Flood Warning area registered on FWD: 55
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 170
Successful contacts: 125
Unsuccessful contacts: 45

Warning Message:
A Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Keswick Campsite, Rugby Club and Quinta.
Flooding is expected for Low lying roads, residential, commercial properties & campsite in Keswick adjacent the rivers Greta & Derwent including Greta Park Rugby Football Ground, Keswick Campsite, Keswick School Sports Field, Keswick Show Field & Playing Field areas. Immediate action required.

011FWFNC6B - River Greta at Keswick, Fitz Park and Riverside Flats area

Flood Warning issued on Saturday 05/12/2015 at 02:29
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 18:03
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Date/Time Warning Level Reached: 05/12/2015 03:30
Time customers had to take action: 01:00:22
Customers in Flood Warning area registered on FWD: 83
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 209
Successful contacts: 147
Unsuccessful contacts: 62

Warning Message:
A Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Fitz Park and Riverside Flats Areas.
Flooding is expected for Low lying roads, residential, commercial properties and campsite in Keswick adjacent the rivers Greta and Derwent including Upper and Lower Fitz Park and Keswick Bridge areas. Immediate action required.

011FWFNC6C1 - River Greta at Keswick, The Forge Area

Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:25
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Customers in Flood Warning area registered on FWD: 40
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 115
Successful contacts: 80
Unsuccessful contacts: 35

Severe Warning Message:
Severe Flooding. Danger to life.
A Severe Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, The Forge Area. This Severe Flood Warning is for Low lying roads, residential and commercial properties and campsites adjacent the rivers Greta and Derwent including The Forge area.

011FWFNC6C2 - River Greta at Keswick, Latrigg Close, Brundholme Gardens, Calverts Bridge and Keswick Bridge

Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:18
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Customers in Flood Warning area registered on FWD: 107
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 225
Successful contacts: 166

Unsuccessful contacts: 59

Severe Warning Message:
Severe Flooding. Danger to life.
A Severe Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Lattrigg Close, Brundholme Gardens, Calverts Bridge and Keswick Bridge.
This Severe Flood Warning is for Low lying roads, residential and commercial properties and campsites in Keswick adjacent to the rivers Greta and Derwent including Lattrigg Close, Brundholme Gardens, Calverts Bridge and Keswick Bridge.

011FWFNC6D - River Greta at Keswick, Crosthwaite and Limepots Road, High Hill and Church Lane Area

Flood Warning issued on Saturday 05/12/2015 at 06:05
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 18:23
Flood Warning removed on Tuesday 08/12/2015 at 17:32
Date/Time Warning Level Reached: 05/12/2015 10:15
Time customers had to take action: 04:09:07
Customers in Flood Warning area registered on FWD: 233
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 550
Successful contacts: 426
Unsuccessful contacts: 124

Warning Message:
A Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Crosthwaite Road, Limepots Road, High Hill and Church Lane Areas.
Flooding is expected for Low lying roads, residential & commercial properties and campsites in Keswick adjacent to the rivers Greta & Derwent including Crosthwaite Road, Crosthwaite Gardens, Limepots Road, Glebe Close, High Hill & Church Lane Areas. Immediate action required.

011FWFNC6E - River Greta at Keswick, Elliott Park, Main Street and Pencil Works area

Flood Warning issued on Saturday 05/12/2015 at 06:12
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:17
Flood Warning removed on Tuesday 08/12/2015 at 17:32
Date/Time Warning Level Reached: 05/12/2015 10:15
Time customers had to take action: 04:02:14
Customers in Flood Warning area registered on FWD: 227
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 516
Successful contacts: 372
Unsuccessful contacts: 144

Warning Message:
A Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Elliott Park, Main Street and Pencil Works area.
Flooding is expected for Low lying roads, residential & commercial properties in Keswick adjacent to the rivers Greta & Derwent including Elliott Park, Main Street & Pencil Works. Immediate action required.

011FWFNC6F - River Greta at Keswick, Main Street, Bank Street and Greta Side

Flood Warning issued on Saturday 05/12/2015 at 06:06
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:55
Flood Warning removed on Tuesday 08/12/2015 at 19:30
Date/Time Warning Level Reached: 05/12/2015 10:15
Time customers had to take action: 04:08:16
Customers in Flood Warning area registered on FWD: 171
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 303
Successful contacts: 207
Unsuccessful contacts: 96

Warning Message:
A Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Main Street, Bank Street and Greta Side.
Flooding is expected for Low lying roads, residential & commercial properties and campsites in Keswick adjacent to the rivers Greta & Derwent including Main Street, Bank Street, Bell St, Greta Side, Otley Rd, Brewery Lane, Stranger St & Heads Rd. Immediate action required.

011FWFNC6G - River Greta at Keswick, Penrith Road and Wordsworth Street

Flood Warning issued on Saturday 05/12/2015 at 06:10
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:20
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Date/Time Warning Level Reached: 05/12/2015 10:15
Time customers had to take action: 04:04:36
Customers in Flood Warning area registered on FWD: 142
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 270
Successful contacts: 212
Unsuccessful contacts: 58

Warning Message:
A Flood Warning has been issued by the Environment Agency for the River Greta at Keswick, Penrith Road and Wordsworth Street.
Flooding is expected for Low lying roads, residential & commercial properties and campsites in Keswick adjacent to the rivers Greta & Derwent including Penrith Road, Wordsworth Street, Greta St & Blencathra St. Immediate action required.

011FWFNC6EP - Elliott Park at Keswick

Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:27
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Customers in Flood Warning area registered on FWD: 183
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 416
Successful contacts: 300
Unsuccessful contacts: 116

Severe Warning Message:
Severe Flooding. Danger to life. A Severe Flood Warning has been issued by the Environment Agency for the Elliott Park at Keswick.
This Severe Flood Warning is for Properties in Elliott Park affected by surface water. We are forecasting significant rainfall during today and tomorrow. Environment Agency staff are currently inspecting and operating our flood defences and clearing debris screens.

011FWFNC6GP - Greta Street and Penrith Road at Keswick

Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:28
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Customers in Flood Warning area registered on FWD: 49
Contacts (landline, mobile, email etc) in Flood Warning area registered on FWD: 132

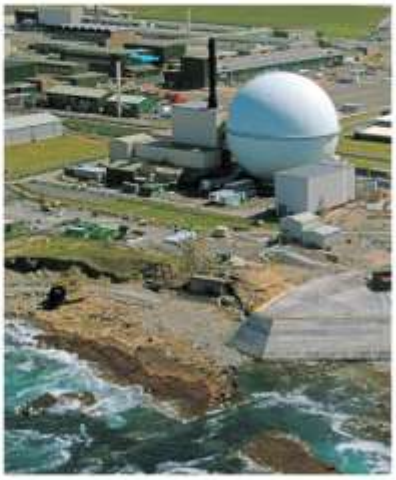
Successful contacts: 95
Unsuccessful contacts: 37

Severe Warning Message:
Severe Flooding. Danger to life. A Severe Flood Warning has been issued by the Environment Agency for the Greta Street and Penrith Road at Keswick.
This Severe Flood Warning is for Properties affected by surface water flooding in Greta Street and Penrith Road.

Appendix 5: CH2M UK Projects and Flood Risk Management Brochure

CH2MHILL.

Key Projects in the UK



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, TBG 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 flooding 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.