Keswick

Sec 19 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 Sec 19 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 2015, 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. Also feedback by the community affected by the flooding.

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 (may have flooded due to ground water pressure – the lake did not overtop)

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

25 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

A draft version of the Keswick Flood Investigation Report was published online in May 2015 for public consultation. Following the draft publication, public meetings, chaired by Cumbria County Council, were held in Keswick on 17 May 2015, where the Environment Agency formally presented the report to the local community. Other Risk Management Authorities were also present at these meetings to answer any questions raised during a question and answer session following presentation of the report. Through the public meetings and local consultation with the community, including with local Flood Action Groups, a range of feedback has been provided on the reports. The Environment Agency have reviewed this feedback and, where appropriate, updated the Final version of the report to reflect the required amendments. In some cases, feedback and information provided would not be relevant for direct inclusion in the main body of the report, for example when relating to a very specific issue or historic information provided for local context. In these instances, to ensure this information is still captured in the report, we have included this feedback in Appendix 2 'Additional information from the community'. Specific hydrology reports were produced by the community and informed the production of this report. These have not been incorporated into this document but are referenced in the Appendix 2, and are available through the Keswick Flood Action Group.

The Flood Investigation Report

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 for the December 2015 rainfall event.

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**.

Introduction

Geographical Setting

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 4821[*1]. The population is greatly increased by several thousand by the tourist trade, with many camping/caravanning sites occupying low lying floodplain areas.

The River Greta flows through Keswick and is fed by the River Glenderamackin, Thirlmere via St. Johns Beck and the Glenderaterra Beck. Below the River Glenderamackin and St. Johns Beck confluence the river becomes relatively confined within a steep incised valley before opening out into the town, where it continues to fall relatively steeply before levelling out in the Greta Bridge area and entering the River Derwent. Lake levels can impede on the drainage of numerous watercourses in the catchment and the land between Derwentwater and Bassenthwaite Lake becomes inundated as a result of large floods. Cuddy Beck and water draining through the Castlehead, Hawthorns and Chestnut Hill culverts also flow into the River Greta in Keswick, contributing to flooding independently of the River Greta.

Figure 1 provides an overview of Keswick and the surrounding catchment.

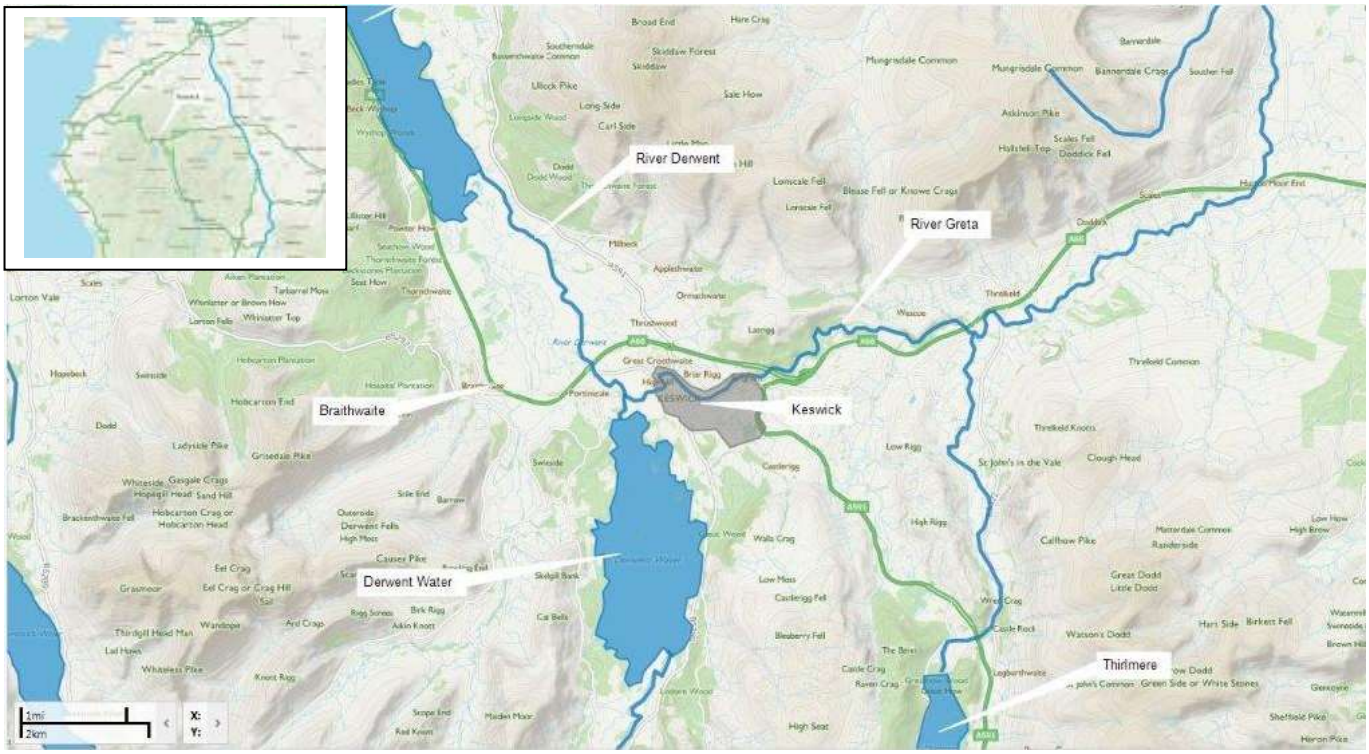


Figure 1: Location of Keswick and surrounding catchment

[*1] Source: UK National Statistics

Flooding History

Keswick has a history of flooding with records dating back to the 1700s. 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 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)
50%	0.5
20%	0.2
10%	0.1
4%	0.04
2%	0.02
1%	0.01
0.1%	0.001

Table 1: Annual Exceedance Probability

The 2005 event resulted in the flooding of numerous properties in the Millfield Gardens / Penrith Road area including Greta Side, 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 320 properties of which circa 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 than in 2005 due to higher flows in the minor watercourses in the area and higher levels in Derwentwater.

Flood Event 5th-6th December 2015

Background

On the 5th and 6th December 2015, 515 residential properties and businesses were affected by flooding. The majority of this flooding can be attributed to extreme river levels in the River Greta, following extensive rainfall over the preceeding 36 hour period. **Figure 2** provides an overview of the approximate extent of the flooding both in Keswick and further upstream, showing the areas of significant erosion at Low Briery and an indicative flood extent at the confluence of St John's Beck and the River Glenderamackin at New Bridge.

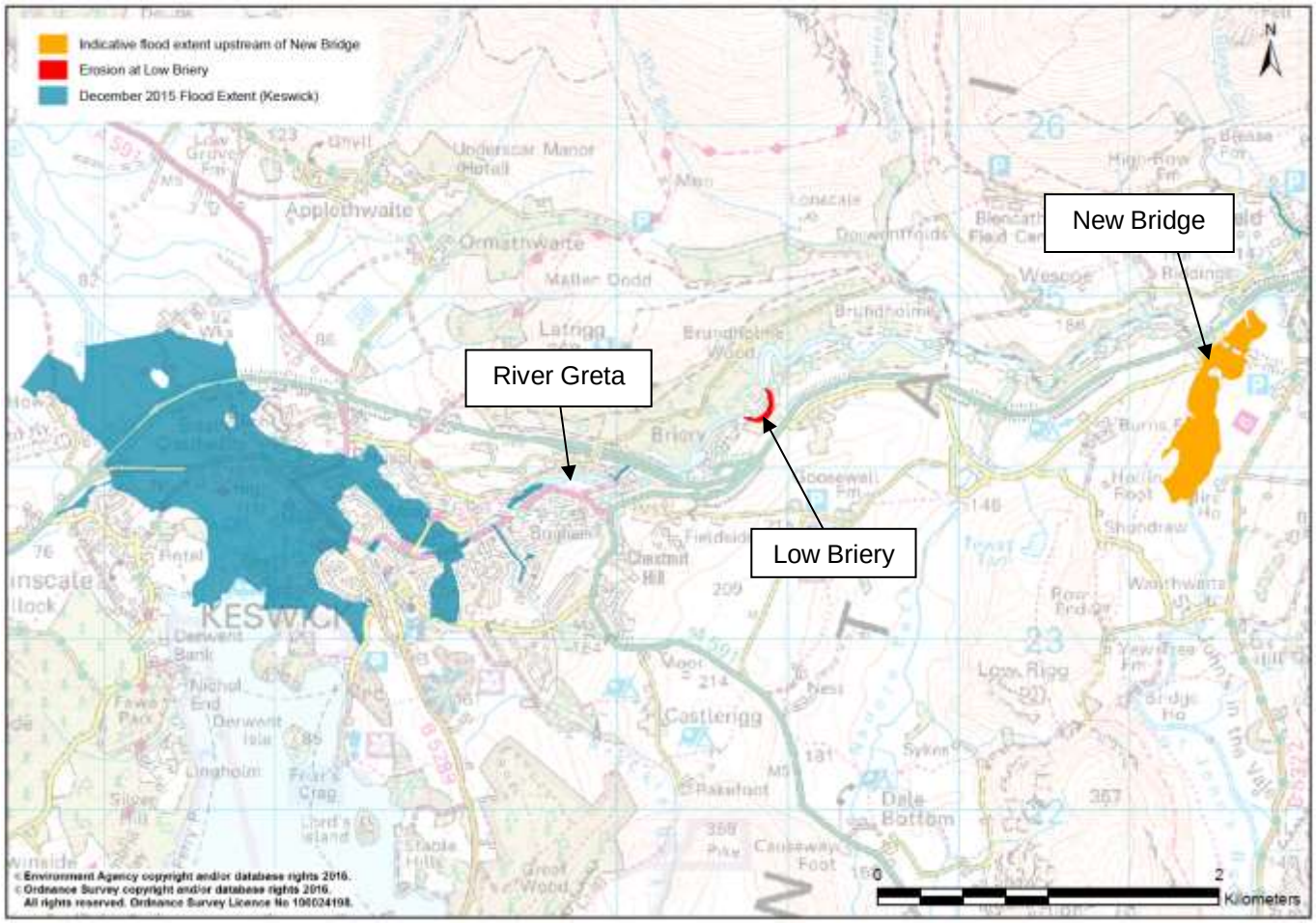


Figure 2: Extent of flooding upstream of Keswick on 5th & 6th December 2015

The extent of the flooding in Keswick, shown in **Figure 3,** includes flooding from rivers and smaller watercourses, as well as surface water and drainage systems.

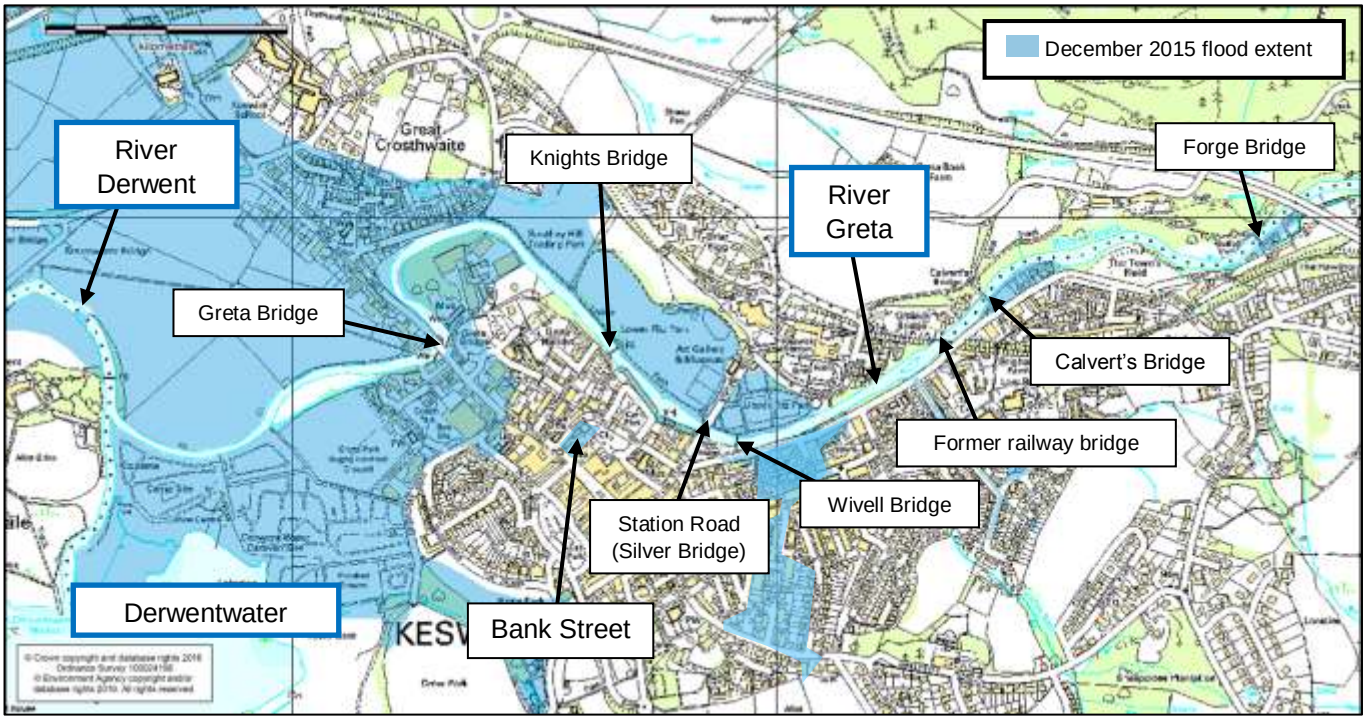


Figure 3: Extent of Flooding in Keswick on 5th & 6th December 2015 and location of bridges

In the Keswick area there a number of bridges crossing the River Greta.

- Forge Bridge - Packhorse bridge
- Calvert's Bridge - Packhorse bridge
- Former railway bridge - Disused. Currently walkway / cycleway
- Wivell Bridge - Footbridge, Fitz Park
- Station Road (Silver) Bridge - Road Bridge (Station Road)
- Knights Bridge - Footbridge, Fitz Park
- Greta Bridge - Road Bridge (A5271)

All bridges suffered damage to varying degrees. Knights Bridge was destroyed during the flood and Forge Bridge was severely damaged. The bridges contributed to the effects of the flooding by causing a constriction to the channel which affected flows under the structures . This constriction resulted in elevated river levels experienced immediately upstream and greater scour downstream. Elevated floodwater levels had a significant impact on the upstream areas above the Greta, Wivell, Calvert's and Forge bridges.

Services were also affected with the mains water supply for parts of the town unavailable until approximately lunchtime on 8th December. Penrith Road, which forms one of the key access routes into the town, became inundated with flood water.

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. **Table 2** shows the record levels of rainfall that fell during the flooding event.

	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*

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

	Rainfall (mm)			Estimated Return Period (AEP) of max. rainfall in 24 hours†
	4th December (09:00 – 08:59)	**5th December (09:00-08:59)**	**Max. rainfall in 24 hours**	
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%**
Portinscale	Data not within validation tolerances			
Dale Head Hall	Data not within validation tolerances			
Mosedale	Monthly storage – no telemetry			

Table 3: Rainfall recorded at gauges upstream of Keswick

Rainfall graphs can be found in Appendix 6.

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

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

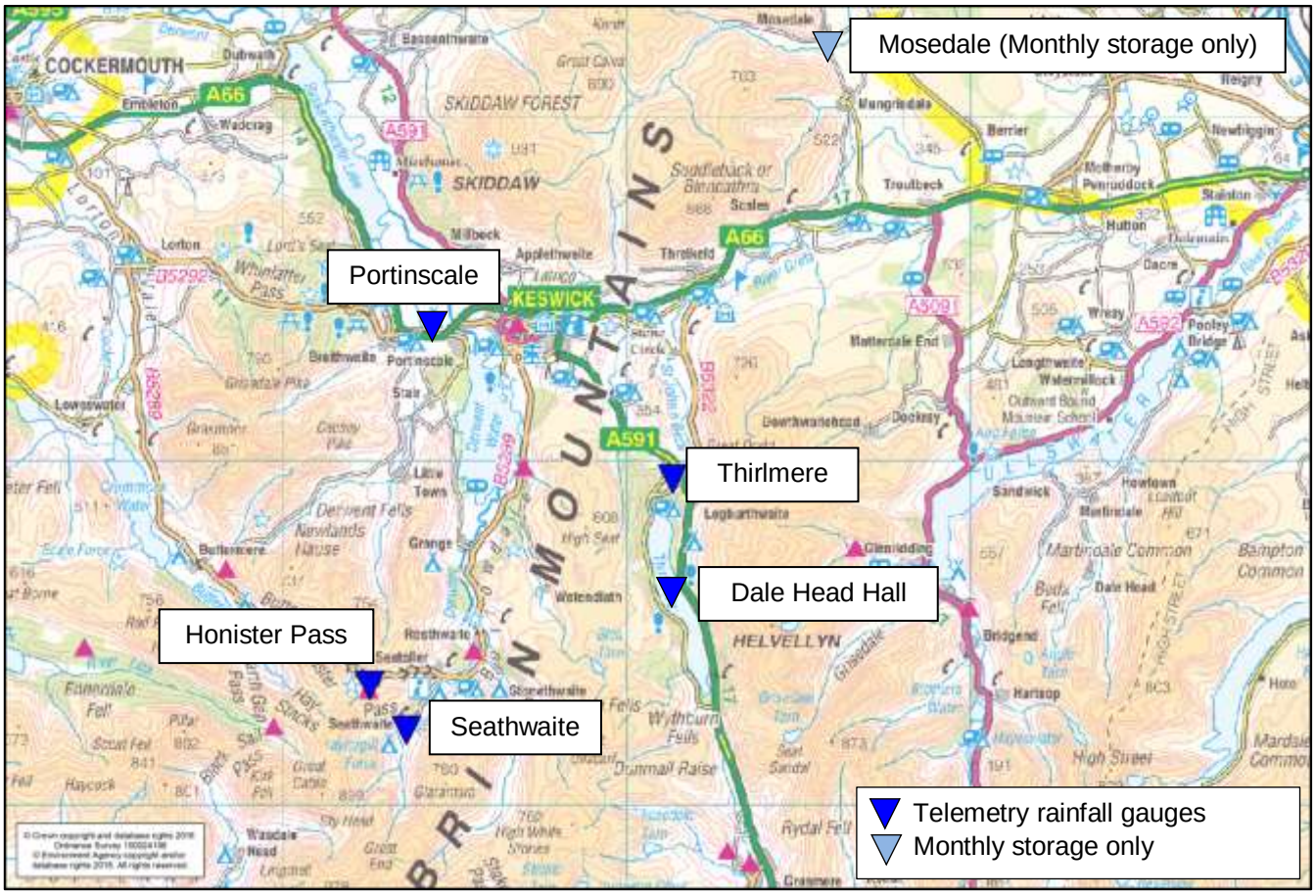


Figure 4: Locations of telemetry rainfall gauges in the Keswick area

River and Lake Levels

Keswick experienced record levels of rainfall between the 4th and 5th December 2015. This rainfall fell on already saturated ground following three 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 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 5**. Other gauges within the immediate catchment record river/lake level only. **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. Telemetry became unavailable at the Thirlmere gauge station during the rainfall event. Although data was still recording and subsequently downloaded, the lack of telemetry made it impossible for local residents to monitor the event at this location.

Figure 5: Location of River gauges on the Rivers Greta and Derwent near Keswick

Gauging Station	River/ Waterbody	Peak Flows (m^3/s) / Levels (m)						Estimated return period of Dec 2015 event (AEP)
		December 2015		November 2009		January 2005		
		(m^3/s)	(m)	(m^3/s)	(m)	(m^3/s)	(m)	
Low Briery	R. Greta	**491**	**3.750**	239	2.587	242	-	0.5%
Ouse Bridge	R. Derwent	**395**	**3.891**	378	3.807	196	-	0.3% to 0.1%
Portinscale	R. Derwent	**-**	**4.103**	-	4.271	-	-	-
Greta Bridge	R. Greta	**-**	**5.348**	-	4.655	-	4.367	-
Keswick Campsite	R. Greta	**-**	**4.028 E**	-	3.889	-	-	-
Lodore	Derwentwater	**-**	**4.050**	-	3.948	-	-	-

E = Estimated

Table 4: Flows and levels recorded at the gauging stations

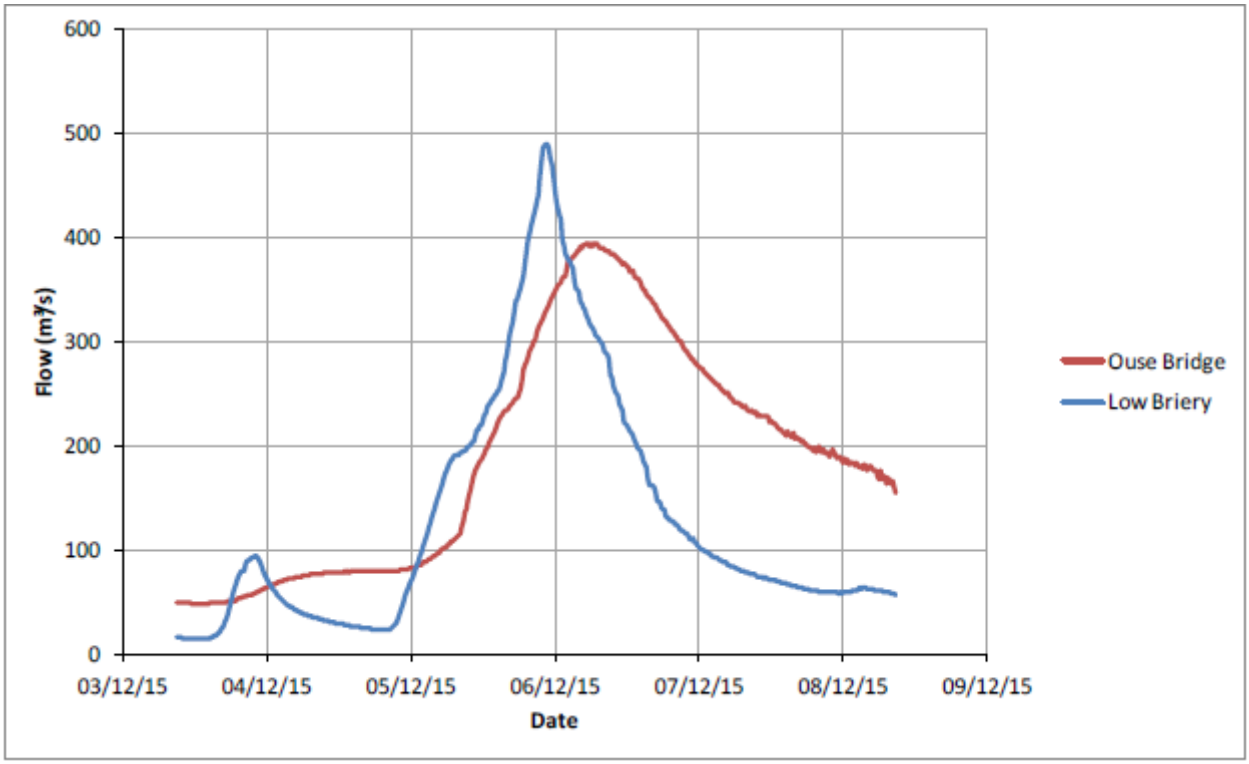


Figure 6: Recorded River Flows for the December 2015 Event. Note Attenuation of Flows by Bassenthwaite

Existing Flood Defences

Keswick Flood Risk Management Scheme was constructed in 2011/12 and included:

- Penrith Road (West) – Stone clad reinforced concrete defence wall, including a flood gate, adjacent to the footpath.
- Drainage holes to allow post flood drain down of Penrith road.
- Penrith Road – Duckbill non-return valves installed on outfall of Castlehead drain.
- Penrith Road (West) – Backflow valves on the lower (river bed) surface water outlets.
- Greta Villas – Short section of new defence wall. Property level protection provided.
- 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 with floodgates installed at the western extent.
- 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

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 the existing flood defences is shown in **Figure 7**. **Photographs 1** and **2** show the existing flood wall along High Hill and Penrith Road.

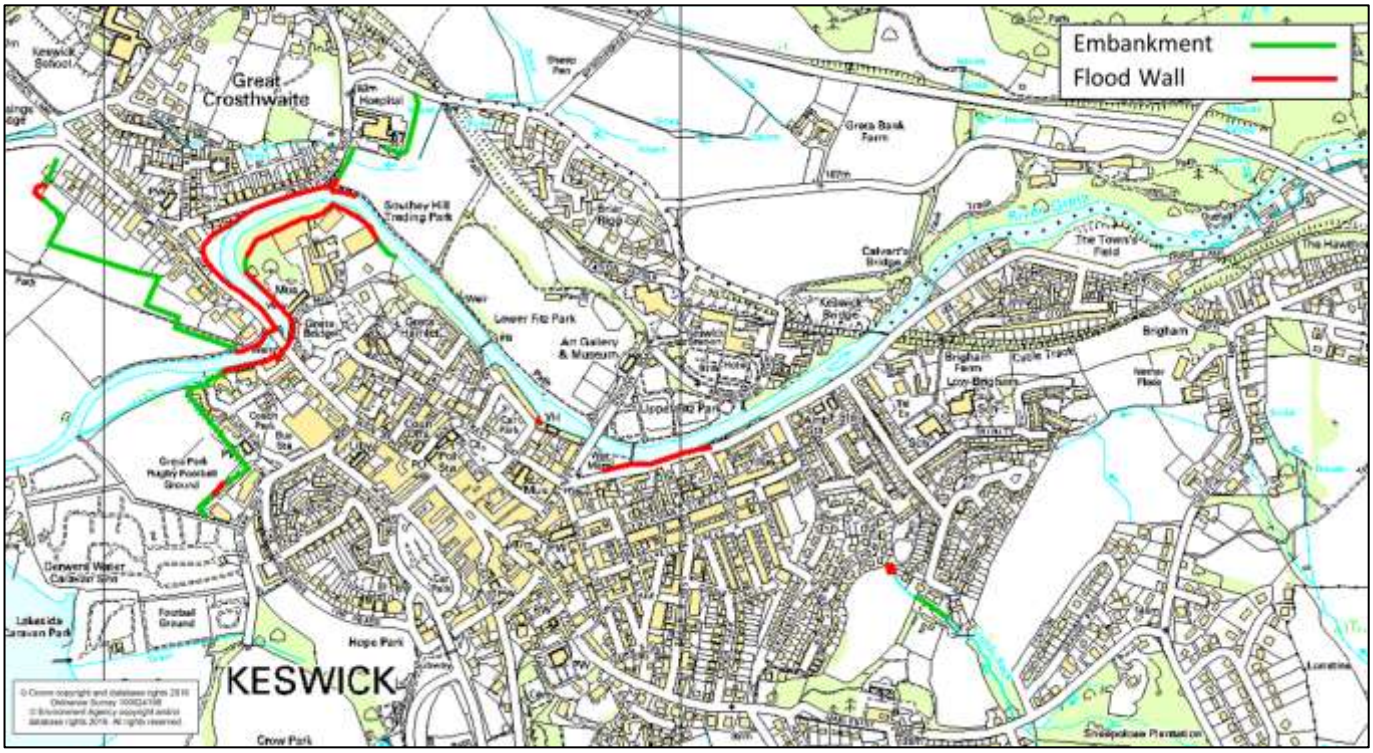


Figure 7: Location of Flood Defences within Keswick


Photographs 1 and 2: Keswick Flood Risk Management Scheme – Flood wall along High Hill (left) and Penrith Road (right)

The flood event on 5th-6th December was of a greater magnitude than the Keswick Flood Risk Management Scheme defences were designed to defend against meaning that defences were overtopped and outflanked. In some locations however, defences were successful in reducing the damage, and delayed flooding, which gave residents additional time to prepare and reduced the impact of the flood.

Investigation

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 6.

For the purposes of this report, the flooded areas within Keswick have been divided into 12 sub areas for investigation, **Table 5**. These are shown in **Figure 8** and are examined in detail in the following sections of this report.

Sub-area	Sub-area Name	Description**
A	**New Bridge**	Capacity of the bridge arches was exceeded resulting in severe flooding upstream of the structure
B	**Low Briery**	An area 1km upstream of Keswick affected by severe erosion and landslips
C	**Forge Bridge**	The area at the upstream end of the town on the left bank of the River Greta along Forge Lane
D	**Penrith Road (East) & Calvert's Bridge**	The area upstream of the town on the left bank of the River Greta and areas affected by the Hawthorns and Chestnut Hill culverts
E	**Windebrowe Avenue & Trinity Way**	An area affected by Cuddy Beck and surface water flooding
F	**Brundholme Road**	An area affected by surface water flooding
G	**Greta Street to Penrith Road (West) and Ambleside Road**	An area on left bank of the River Greta, initially flooded from surface water and drainage prior to outflanking of defences by the River Greta
H	**Upper and Lower Fitz Park**	The area on right bank of the River Greta
I	**Greta Side**	An isolated area of flooding on the left bank of the River Greta opposite Fitz Park
J	**North of Main Street, Southey Hill Trading Estate and Elliott Park**	The area on the left bank of the River Greta, north of Main Street including Southey Hill Estate and Elliott Park
K	**South of Main Street**	The area on the left bank of the River Greta south of Main Street including The Heads and Lake Road
L	**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

Table 5: Identified sub-areas for investigation

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

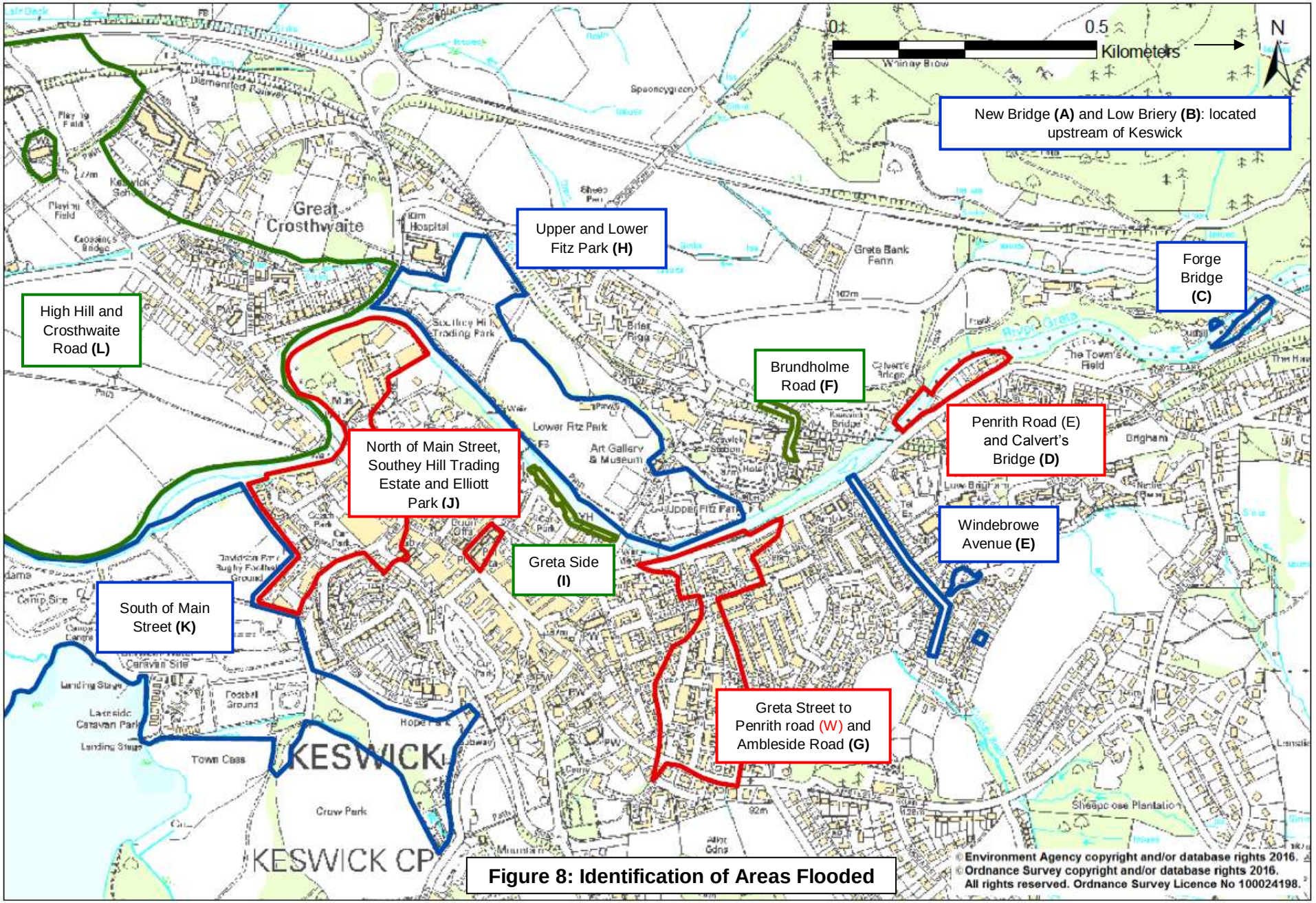


Figure 8: Identification of Areas Flooded

Impacts and Likely Causes of Flooding

Timeline

Table 6 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
1130	Reported flooding at The Heads
1121	**Severe Flood Warning Issued**
1255	Initial overtopping of floodwall on High Hill
1300	Reports of flooding at Limepots Road
1343	Overtopping into Southey Hill Trading Estate (Unverified CCTV footage)
1400	Reported overtopping of flood defences on Greta Side
1420	Overtopping of flood defences on Crosthwaite Road
1500	Report Flooding at High Hill Farm & Tithebarn Street
1505	Report flooding at Elliott Park
1525	Overtopping of bund onto Rugby Field at Elliott Park
1530	Report Flooding at Church Street
1700	Report Flooding at Lakehead Court
2215	**Peak River Level at Greta Bridge – 5.348m**

Table 6: Keswick 5th-6th December flood incident timeline

Table 7 below shows the total number of properties flooded compared to other recent flood events.

Year	**2015**	2009	2005
Total number of flooded properties	**515**	320	198

Table 7: Number of flooded properties

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 and Fitz Park
- Southey Hill Trading Area
- Crosthwaite Road
- High Hill Road
- Elliott Park
- Carding Mill Lane at Greta Bridge
- Brundholme Gardens

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:

- Glebe Close
- Limepots
- Windebrowe Avenue
- Brundholme Road
- Penrith Road
- Ambleside Road, Church Street, Helvellyn Street, and Shorley Lane
- Briar Rigg
- Millfield Gardens
- The Heads/Lake Road
- Stanger Street
- Bank Street / Main Street

Erosion

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 Knight's Bridge, the 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. The locations are shown in **Figure 9** below.

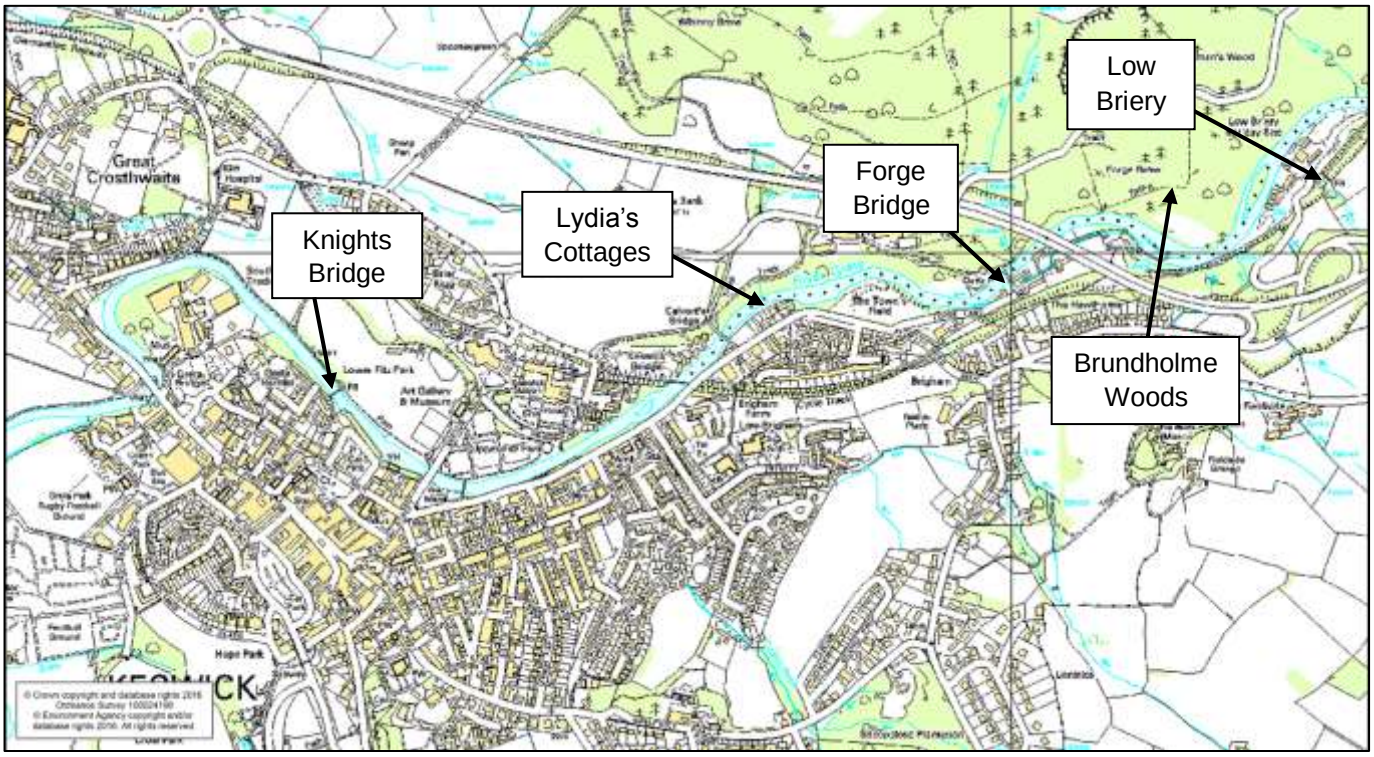


Figure 9: Areas where significant erosion occurred during flood event

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 and culverts, including those associated with the A66, within the town and wider catchment, increasing the impact of flooding by restricting flows and impeding conveyance of water flowing downstream, **Photograph 3**.

Photograph 3: Damaged storm water bridge, Howrahs

Overview of Flow Routes

There were a number of flooding flow routes during the event as shown by **Figure 10**. The details of these flow routes and the flooding within each of the identified areas are discussed in greater detail in the following sections of this report.

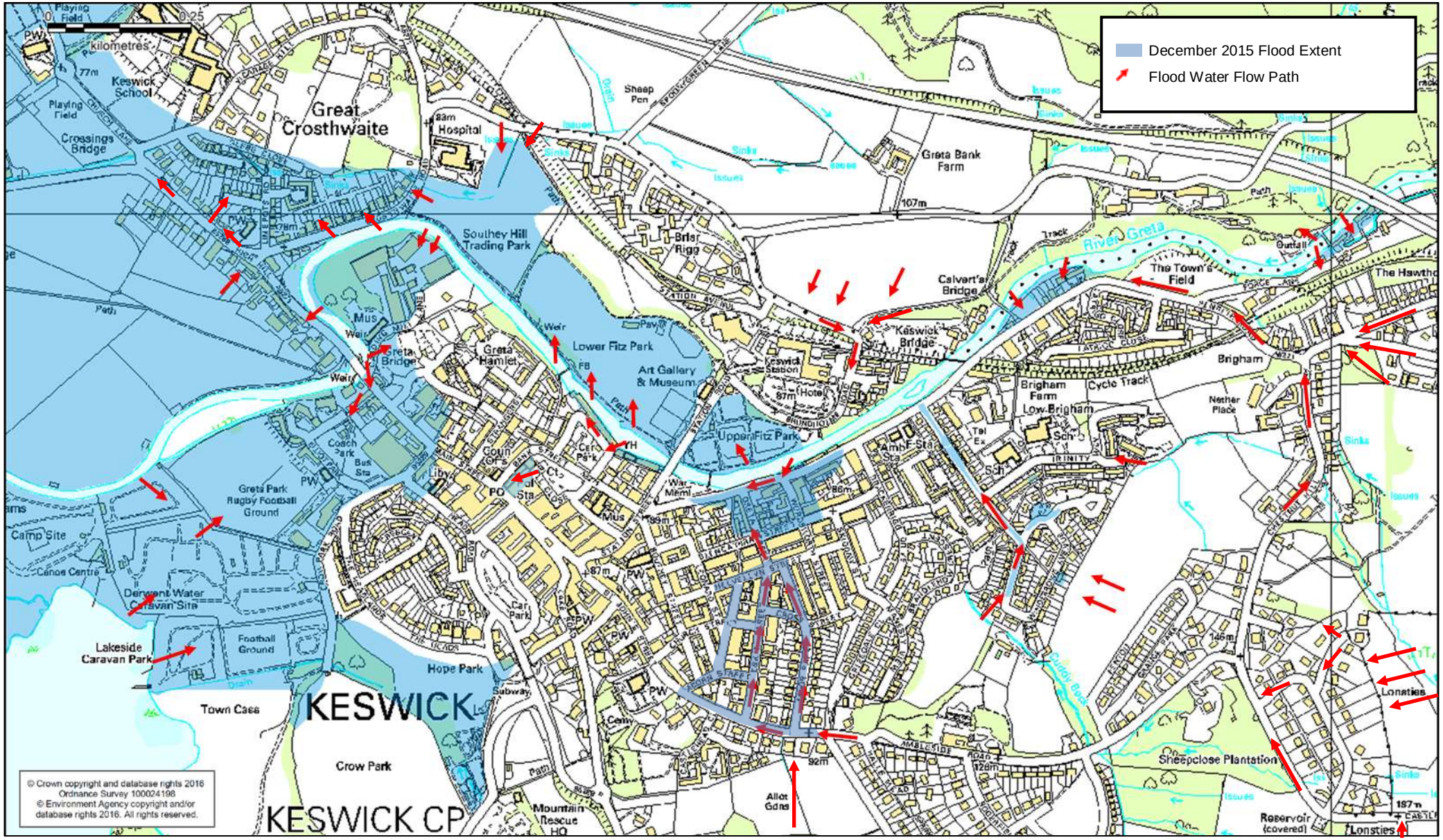


Figure 10: Map of flood flow routes*

*The flood outline identifies the maximum extent of flooding. Not all properties within the extent area were flooded.

Sub-area A: New Bridge

Figure 11: Location of New Bridge

New Bridge is located at the confluence of the Rivers Glenderamackin and St John's Beck, **Figure 11**. The capacity of the structure to permit flows through the arches was exceeded. This resulted in substantial backing up of water and flooding of land upstream, **Photograph 4**. The Glenderamackin sub-catchment comprises a significant portion of the upstream area feeding the Greta and Derwent catchment, and incorporates drainage from the south and east slopes of Blencathra, Trout Beck and Mosedale Beck.

Photograph 4: New Bridge 5th December 2015

Sub-area B: Low Briery

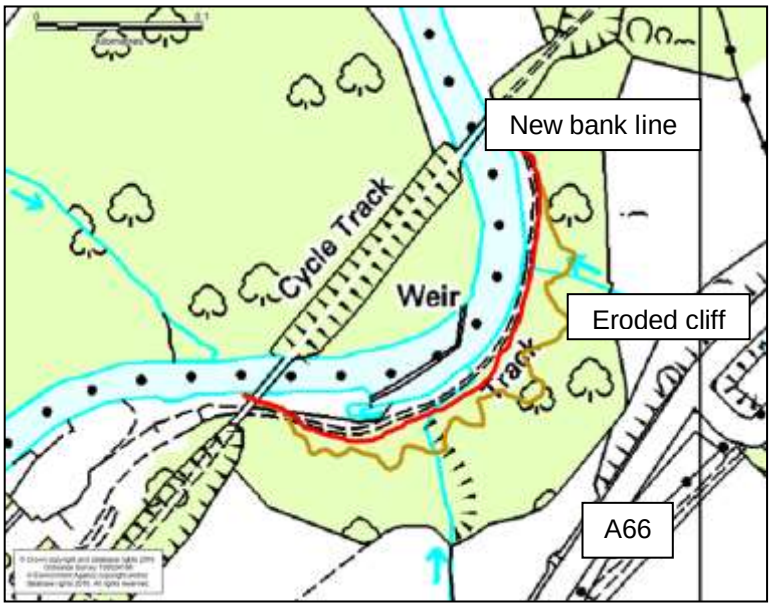


Figure 12: Area of landslip at Low Briery

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. The force of water in this location was such that extensive damage was caused to the Keswick to Threlkeld railway path including two old railway bridges that were washed away and one remaining railway bridge left severely damaged. Approximately 200 metres of the path surface was also washed downstream. The railway path forms part of the Coast to Coast cycle route and is a popular multi-access trail for locals and tourists. Due to the extent of the damage, half of the route is expected to remain closed for up to two years.

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, **Figure 12** and **Photograph 5**.

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 and the river is now significantly wider in places. 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 number of trees and high volumes of eroded material, contributing to the flooding impact on Keswick.

Photograph 5: Erosion/landslip feature upstream of Low Briery Holiday Park

Sub-area C: Forge Bridge

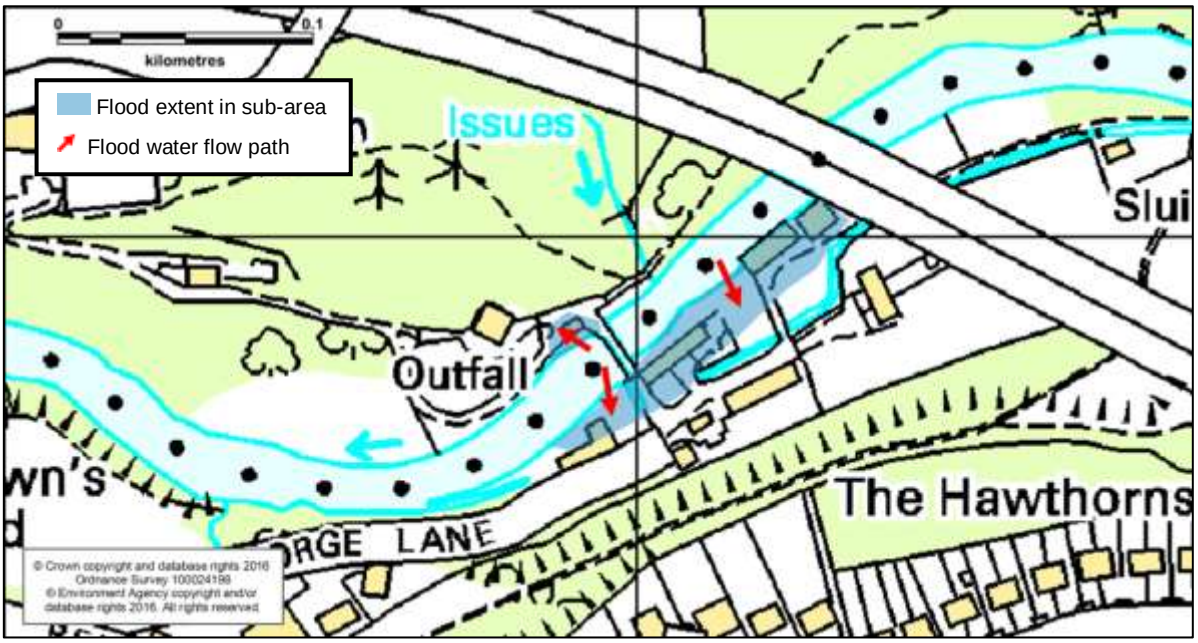


Figure 13: Source of Flooding and Flood extent at Forge Bridge area

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, **Figure 13**. 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 **Photograph 6**, 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.

Photograph 6: Forge Bridge Partially Collapsed

Forge Bridge resulted in water being held back so that the upstream river level greatly exceeded that of downstream. Complete failure of the bridge may have had a severe impact on downstream structures and the town itself. It was reported by a resident that the extent of flooding in the area was much more

extreme than the 2009 flood event. The flooding in this area was intensified by the failure of the weir located upstream of Forge Bridge which was reported to cause a 3ft wave of water.

Sub-area D: Penrith Road (East)

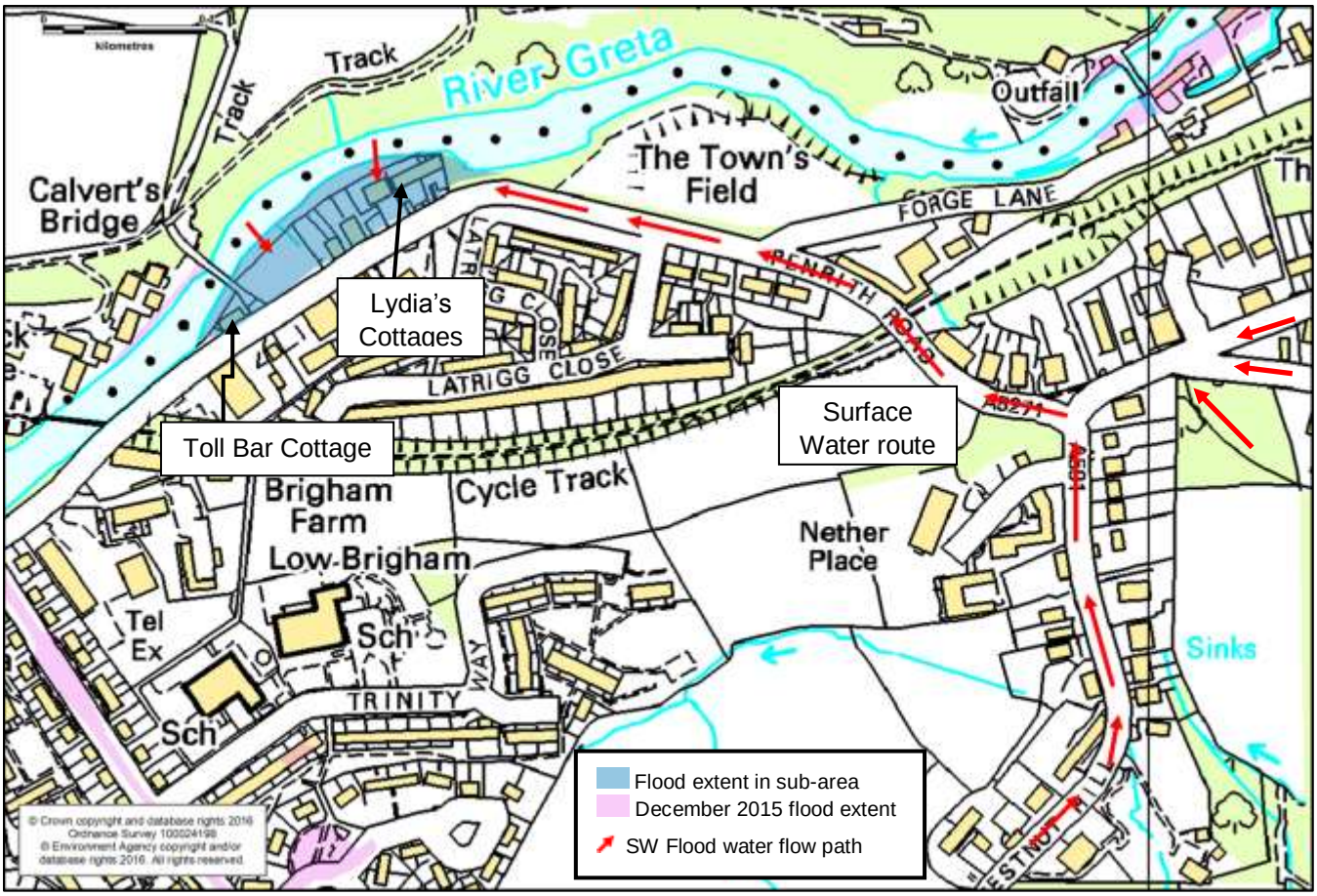


Figure 14: Sources of flooding and Flood extent at Calvert's Bridge

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, **Figure 14**. Calvert's Bridge suffered some structural damage as a result.

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, as well as the potential heightened risk of flooding critical infrastructure, including the petrol station on Penrith Road which also serves as a supermarket. The petrol station store was the only supermarket available in the town for several weeks due to the closure of both Booths and the Co-operative Store due to flooding.

There are no flood defences at this location and residential properties upstream of the bridge were flooded from the River Greta for the first time during the 2015 event. These properties had been unaffected by the river in previous flood events. In this location, the primary risk is surface water flooding from Penrith Road, local residents however worked tirelessly throughout the flood event to keep the drainage systems flowing and as a result surface water flooding was not observed in this location.

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,

Photographs 7 and 8. 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.

Photographs 7 and 8: Scour damage to the rear of properties

Sub-area E: Windebrowe Avenue & Trinity Way

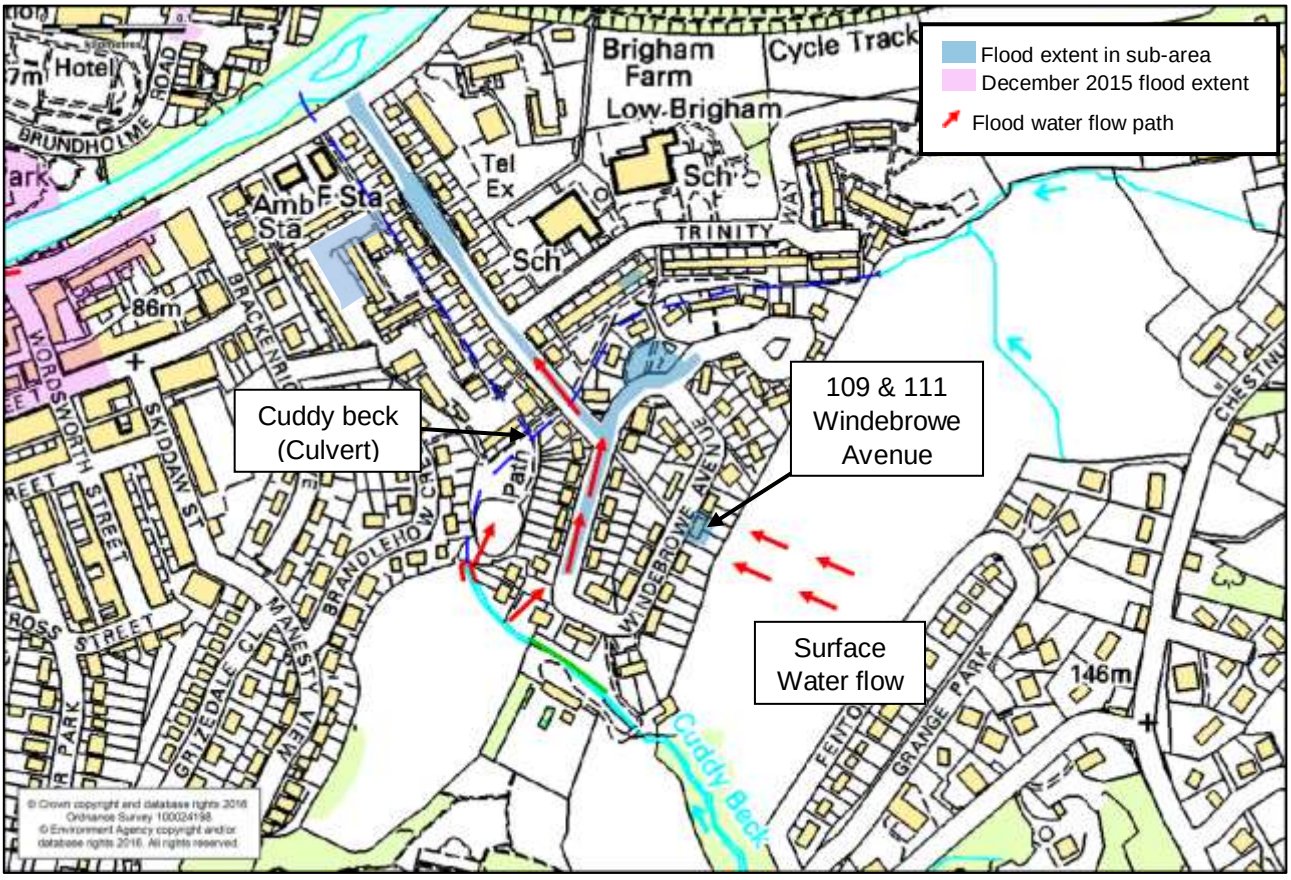


Figure 15: Source of flooding and flood extent at Windebrowe Avenue and Trinity Way

This area flooded from surface water 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, **Figure 15**. 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 and possible blockages of the culvert were also factors. 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, which was designated as a rescue centre. It was also reported that water was ponding to the rear of the school.

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.

A flood mechanism that is usually present in this area is the ponding of water on Millfield Gardens to the rear of the ambulance station. During this event however local residents prevented ponding by maintaining clearance of the drainage system.

Sub-area F: Brundholme Road

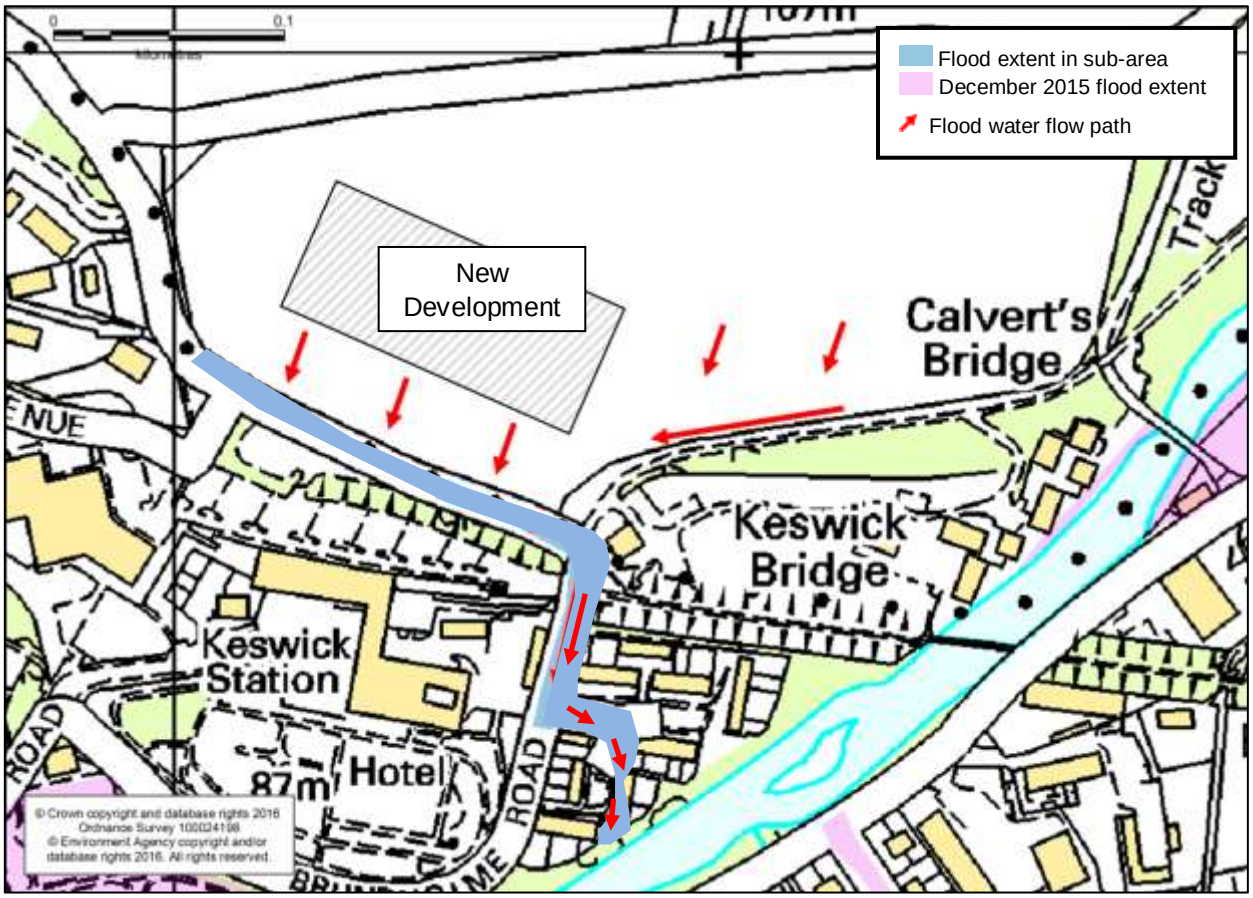


Figure 16: Source of flooding and Flood Extent at Brundholme Road

Flooding was observed on Brundholme Road, from surface runoff through the new development area, **Figure 16** and **Photograph 9**. 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 surface water runoff in addition to ingress from the River Greta.

Photograph 9: Surface water flooding through the new development area

Sub-area G: Ambleside Road to Penrith Road (West)

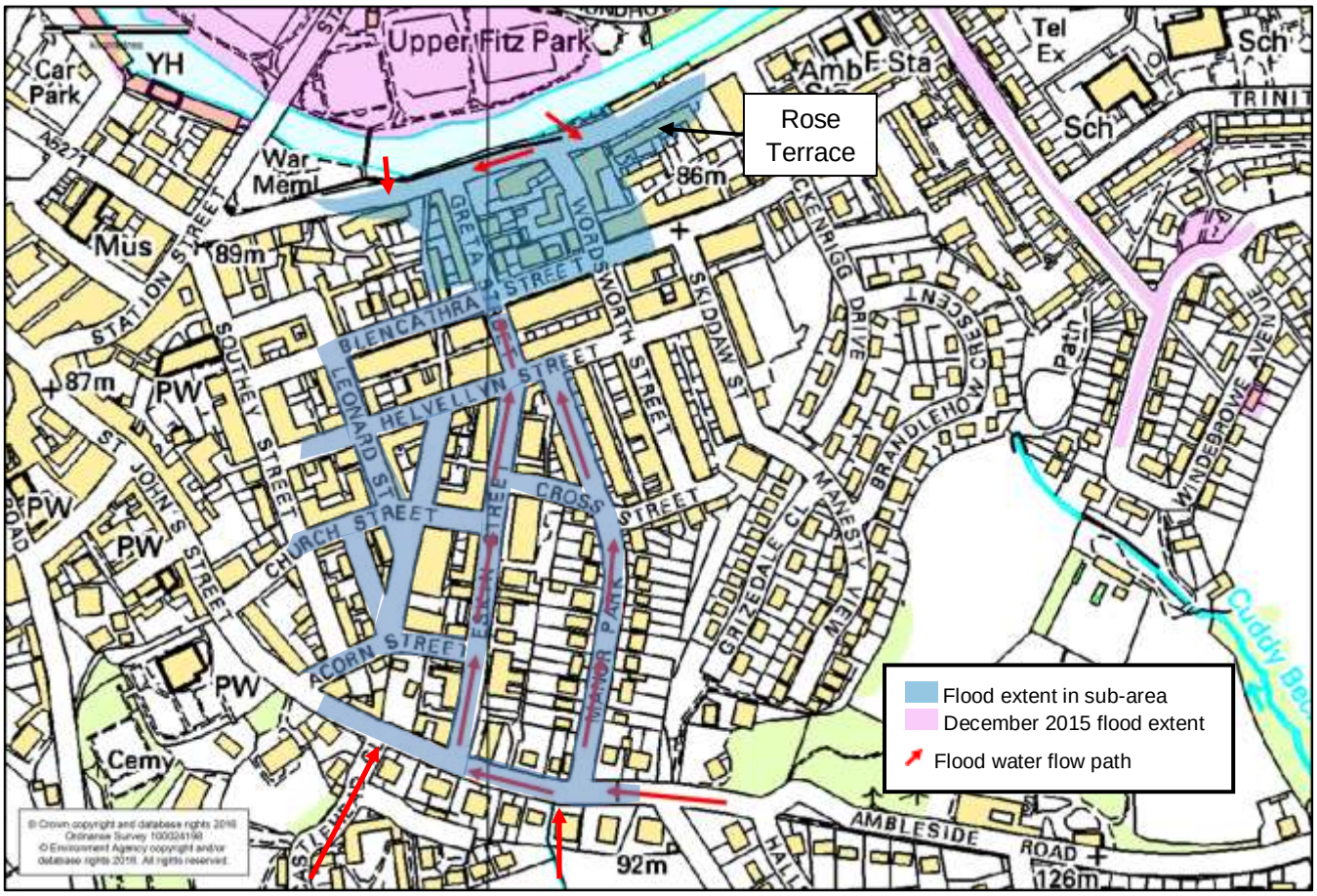


Figure 17: F flood extent map: Ambleside Road to Penrith

This is an area of residential properties and businesses on the left bank of the River Greta, outlined by Greta Street, Wordsworth Street, Canister Lane, and Penrith Road, **Figure 17,** which acts as a key access route into the town. 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 **Photographs 10 & 11**.

Photographs 10 and 11: Left bank of River Greta where defences were outflanked

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 also 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 **Photograph 12** started surcharging prior to the river overtopping or outflanking the flood wall.

Photograph 12: Manhole surcharge and flooding through drainage holes at the base of the flood defence wall on Penrith Road

The River Greta continued to rise, eventually resulting in the outflanking of the wall at its eastern extent. The flood wall was not overtopped at this location, with the exception of a wave created by the access ramp on the left bank of Wivell Bridge, see **Photograph 13**.

Photograph 13: Wave created by the access ramp on the left bank at Wivell Bridge

Sub-area H: Upper and Lower Fitz Park

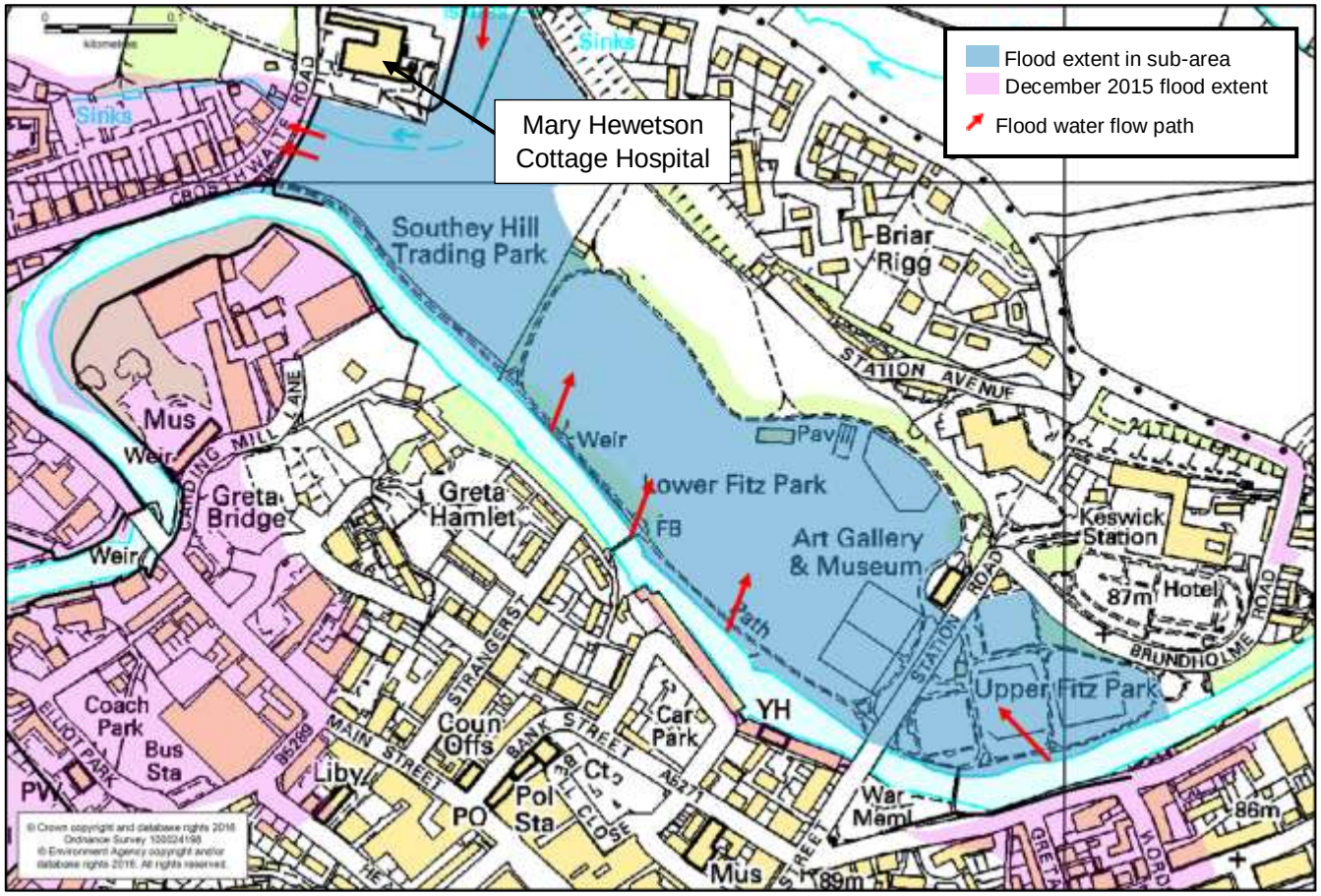


Figure 18: Source of flooding and Flood Extent map at Upper and Lower Fitz Park

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, **Figure 18**. 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 deposited mud, silts and gravels up to a depth of approximately 300-450mm across the entire park and caused significant damage and destruction to the park facilities, all of which were uninsured, see **Photograph 14.** Approximately 1,200 tonnes of silt was removed in the clear up.

Photograph 14: Accumulation of debris in Fitz Park

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, **Photograph 15**. 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.

Photograph 15: Overtopping of the defences along Crosthwaite Road

Sub-area I: Greta Side

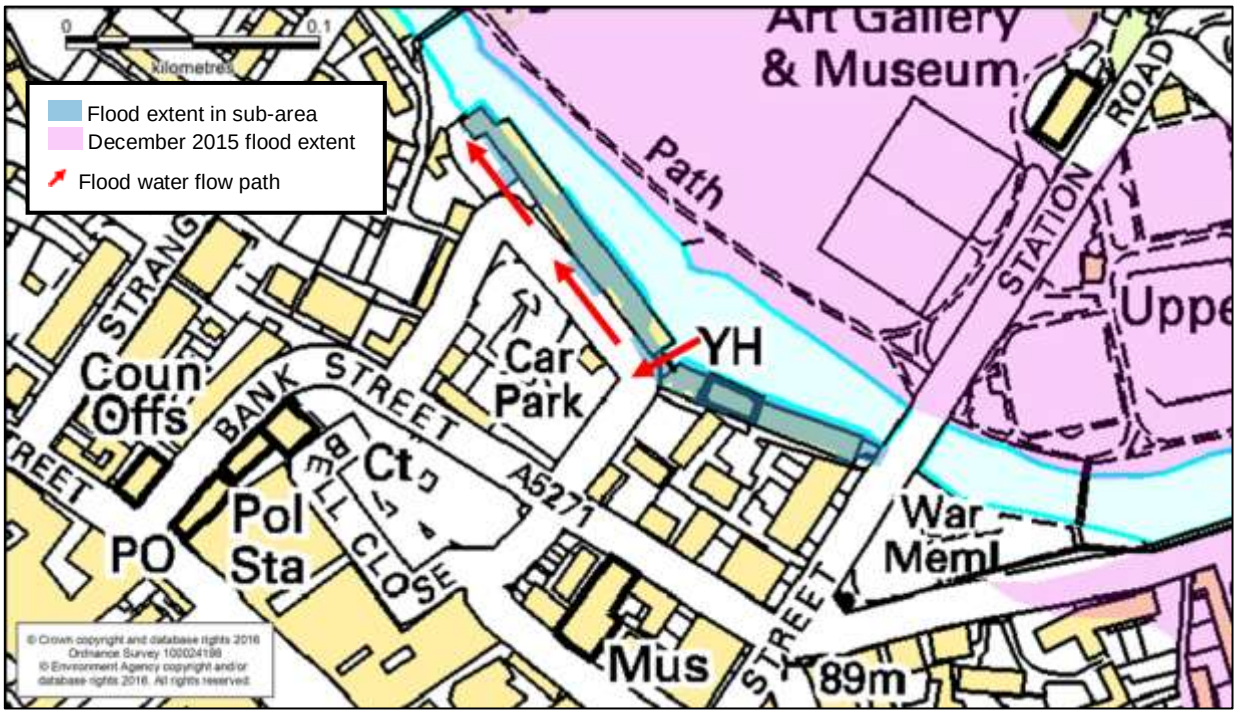


Figure 19: Source of flooding and Flood Extent at Greta Side

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, **Figure 19**. 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. All property level protection, including a pump in the mill leat, were overwhelmed. It was reported that the river overtopped this short floodwall and then flowed through the gap between properties, flooding properties on Greta Side, **Photographs 16 & 17**. 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. Knight's Bridge, the footbridge that connects Millbank at the top of Stanger Street to Lower Fitz Park was washed away during the flood, **Photographs 18 & 19**.

Photographs 16 and 17: Riverside view of the properties and river flow between properties on Greta Side

Photographs 18 and 19: Riverside view of Youth Hostel (left) and washed out footbridge resting on left bank abutment (right)

Sub-area J: North of Main Street, Southey Hill Trading Estate and Elliott Park

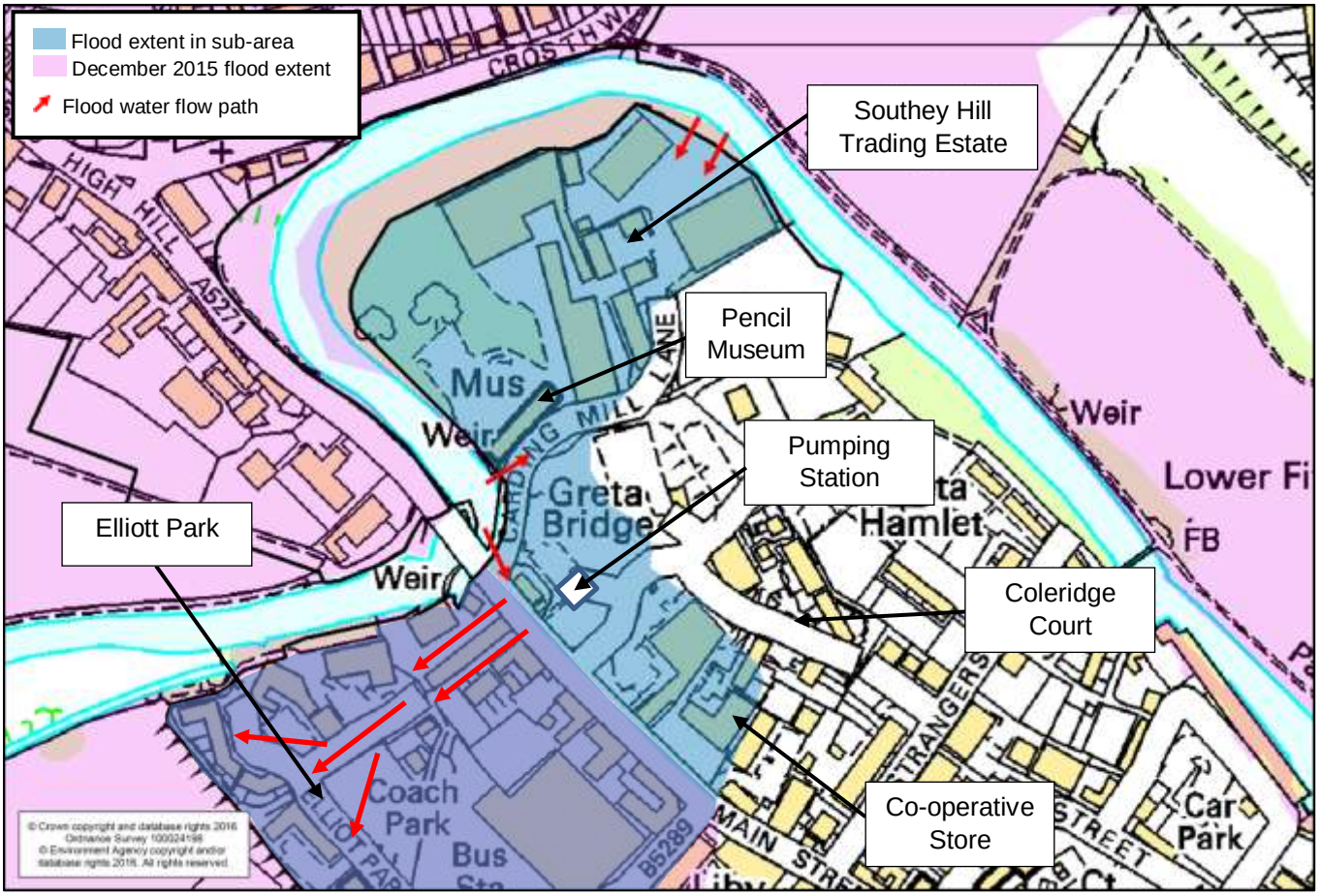


Figure 20: Source of Flooding and Flood Extent at North of Main Street – Southey Hill Trading Estate/area

This includes areas on the left bank of the river Greta, within and adjacent to the large meander of the river**, Figure 20**. This area contains numerous businesses including Booths Supermarket, the Pencil Museum, Co-operative store, Parish Rooms, and Rawnsley Centre, as well as the residential properties of Coleridge Court, Main Street and Elliott Park. A floodwall is present along the left bank and a flood embankment is present on the boundary between Elliott Park and the rugby football ground.

Two mechanisms of flooding were observed from the river. The flood defence walls were overtopped at the top of the trading estate and immediately upstream of Greta Bridge on the left bank on Carding Mill Lane. Greta Bridge acts as an obstruction to flow leading to higher river levels upstream of the bridge. This increased the risk of the defences being overtopped. The effect of this obstruction was worsened by debris in the river blocking the bridge arches.

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, making the defences more susceptible to early overtopping at this location, **Photograph 20**.

Photographs 20 and 21: River overtopped its bank/flood wall at Southey Hill Estate (left) and the river wall overtopped at upstream of Greta Bridge (right)

Water flooded the trading area to a depth of approximately 0.6m - 0.9m. The flood water in this location passed over the town's sewage storage chambers. Sewage was also reported by residents to be coming up through ground floor sanitary wares.

United Utilities Wastewater Pumping Station

On the 5th December, Rawnsley Hall Pumping Station was fully compliant with its consent. Due to the weather the flow in the sewer became so great it overwhelmed the storm pumps and filled up the storm tank. The storm tank was fully utilised from 13:30 onwards. In combination with this, the river burst its banks at the pencil factory which caused water to enter the Storm pump junction boxes which resulted in the storm pumps tripping. The first pump tripped at 16:06 and the standby was called into operation thus having no effect on operation of the site. The second tripped at 17:09 and the last at 23:26. Operations attempted to access site at 16:00 however were not able to reach the site due to the severity of the storm and all roads being flooded.

Flood water from overtopping of the defences upstream of Greta Bridge, **Photograph 21,** 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, Coleridge Court and Riverside Court as well as Booths supermarket. This is shown on **Photograph 22**.

Photograph 22: Flooding at Booths store and on Main Street/Tithebarn Street

Millcroft Veterinary Surgery was flooded to a depth of approximately 60mm and the Pencil Museum and factory buildings off Carding Mill Lane were flooded to a depth of up to 1.0m. The Co-Op supermarket was also flooded which resulted in its closure for subsequent months. 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.

Cumbria County Council were 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 flooded to a depth of approximately 1.2m.

Local residents reported that the onset of flooding was rapid with flood water entering Elliott Park at 15:05, water was observed flowing over the embankment crest from Elliott Park side onto the floodplain by 15:25. 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. It is therefore felt that in this incident, as was the case in the 2009 flood event, the embankment acted as a barrier to flow and impounded water in Elliott Park, exacerbating the impacts of the flooding to the area.

Photograph 23: Flooding level differences at Elliott Park

Foul water and sewage was reported rising up though toilets and sinks in Elliott Park and residents could not access properties for two days following the event due to the trapping of flood water behind the flood embankment which had to be pumped out by the Fire & Rescue Service.

Sub-area K: South of Main Street

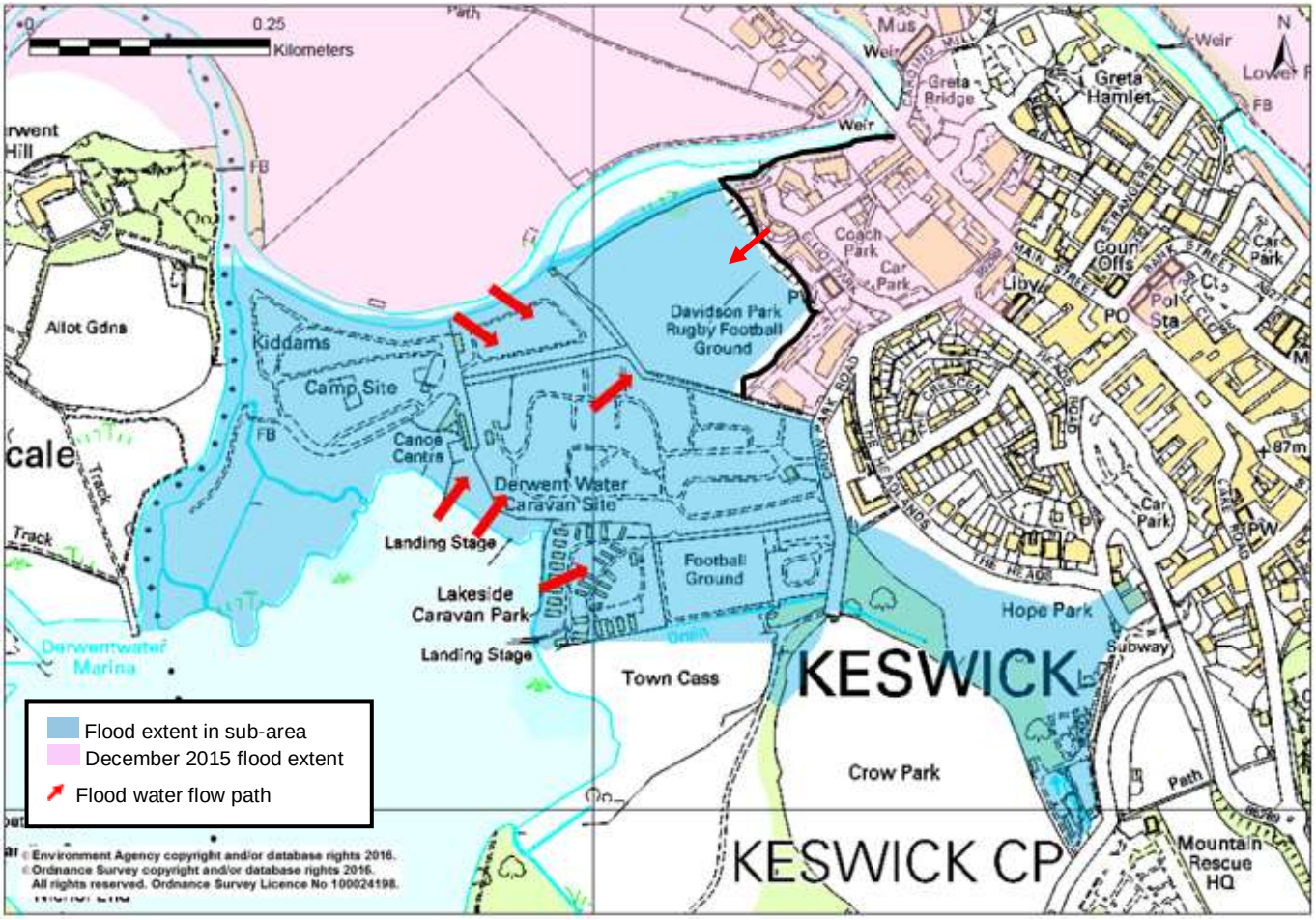


Figure 21: Source of Flooding and Flood Extent on the South of the Main Street

This area forms part of the sacrificial flood plain and comprises a number of commercial properties including low lying camping and caravanning sites. There is a flood embankment on the boundary between Elliott Park and the Rugby football Ground, **Figure 21,** designed to prevent flood water from the floodplain entering Elliott Park.

In this area, flooding was experienced by 6 properties (B&B's/Hotels) and a cafe on The Heads/Lake Road, to the east of Hope Park together with several camping/caravan sites, Keswick rugby football ground and Hope Park. The properties affected experienced flooding to their basements, which was reported to start at 11:30am on 5th December. 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. Hope Beck also emerges through a pipe into a rough area of the golf course in Hope Park. It is possible that water backed up this pipe contributing to the flooding in this area.

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, **Photograph 24**.

Photograph 24: Flooding at Keswick Rugby Club

In the latter stages of the flood event, flood waters were reported to overtop the flood defence embankment resulting in a flow of water from the Elliott Park side of the defences on to the rugby football club ground.

Sub-area L: High Hill and Crosthwaite Road

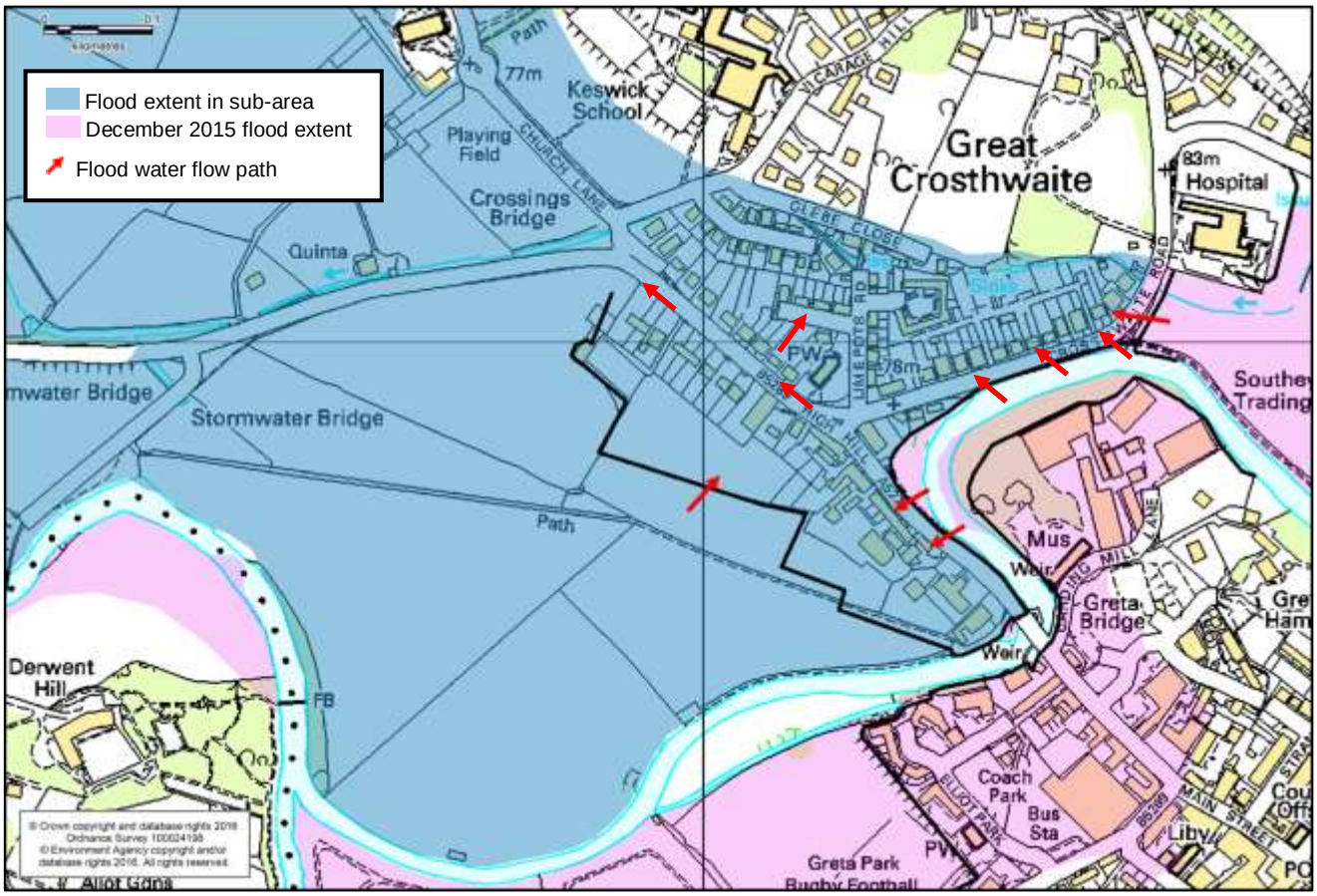


Figure 22: Source of Flooding and Flood Extent at High Hill

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, **Figure 22**. 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 immediately upstream of Greta Bridge where the glass panels finish, **Photograph 25**. Initial overtopping along High Hill Road was observed at around 12:55 on 5th December. As river levels continued to rise, significant overtopping of the defences was observed (**Photographs 27-29**). Here, floodwater scoured out stone pitching on the defended side of the defence along with a section of footpath approximately 10m long, **Photograph 26**. 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 at 14:20 from overtopping of the embankment immediately north of the floodgate (**Photographs 30** and **31**). The dropped level of wall, where the river turns to run parallel with Crosthwaite Road, was also reported as a susceptible low point. 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 at around 15:00 (**Photograph 33**). The flood defence wall and embankment were also overtopped leading to flooding from Fitz Park, **Photograph 32**.

Photograph 25 and 26: Flooding at High Hill Road - Floodwall first overtopped where glass panels finish (left) and scoured footpath (right)

Photograph 27: Overtopping of flood defences on High Hill Road

Photograph 28: Overtopping of flood defences on High Hill Road

Photograph 29: Overtopping of flood defences on High Hill Road

Photograph 30: Crosthwaite Road flood defence wall

Photograph 31: Crosthwaite Road flood defence embankment that was overtopped

Photograph 32: Overtopping of flood defences on Crosthwaite Road

Photograph 33: Overtopping of flood defences on Crosthwaite Road

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. During the event, a headquarters was established by the Keswick responders, incorporating Rotary and Lions volunteers, in the Town Hall in order to coordinate the community response.

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 5.

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 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 (million litres) 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 Utilities 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 2015 this level was 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 2015 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 John's Beck which is a Special Area of Conservation. The normal compensation flow in St John's Beck is 13.64 megalitres a day. This can be can increased this to 140 megalitres per day.

Even at this level, it causes some flooding to farmland. Any more than 140 megalitres per day will cause 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 megalitres 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, whilst Thirlmere reservoir releases were managed in exact accordance with the agreed KFAG protocol, the catchment experienced more than twice the normal level of rainfall expected for the month, and Thirlmere reservoir continued filling and started to spill on Monday 30 November. On 5th December alone, around 14,000 million litres of water entered the reservoir, which is more than a third of its capacity. 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 John's Beck were higher than ever recorded before. Given the amount of rainfall, increasing the 320 megalitres daily removal would have made little material difference.

Future investment

United Utilities 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 140 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 an operational foot bridge that provides essential access to Bridge End Water Treatment Works (WTW), which could be damaged and access be lost 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. John's Beck in the future.

- United Utilities have committed to undertaking a study to investigate the hydrology, geomorphology and ecology of river function at different flow rates and locations.
- We have prepared a scope for the study, which has been agreed with Natural England and the Environment Agency.
- The first stage of the study will propose the maximum drawdown release rate to provide ecological benefits, to inform design of new release infrastructure. This stage will commence in winter 2016, and is scheduled to report in summer 2017.
- The second stage of the study will include monitoring and assessments from 2017 to 2022, including during the periods when higher flood drawdown releases will be made in order to

monitor the influence of these releases and determine the best high flow management regime to provide the range of flows necessary to provide ecological benefits in St John's Beck.

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.

In addition, recommendations arising out of a report on Thirlmere by Aecom, commissioned by the Environment Agency following the floods in December 2015, considers the role of the Mill Gill open aqueduct in supporting flood attenuation at Thirlmere. A proportion of Mill Gill flows can be directed to bypass Thirlmere or to flow into Thirlmere depending on conditions but more detailed modelling work is required to fully understand this and to develop a protocol for management by United Utilities staff. This is being actively pursued by the Environment Agency and United Utilities following site visits in October and November 2016. In the interim United Utilities are using the initial recommendations of the Aecom report to operate Mill Gill to best advantage.

In the interim we are reviewing the potential to use the two top level scour valves in the dam at Thirlmere to increase releases and a test is planned for early 2017. This test will have to coincide with the hydrology study referred to above as the results of this will ultimately determine release rates.

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.	Complete
	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.	2016 to 2017
	Environment Agency and Cumbria County Council Highways	Investigate options to improve the flood flow capacity at Greta Bridge.	2016/17
	Lake District National Park Authority	Review Local Development Plans and Strategic Flood Risk Assessment to reflect current understanding of flooding.	2016/17
	Environment Agency	Ensure all properties at risk can register to receive flood warnings and details are up-to-date.	Complete
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.	Complete
	Environment Agency	Undertake review of geomorphology to better understand gravel movement in the river to inform a gravel management/maintenance plan including upstream of Keswick.	Ongoing

	Environment Agency	Investigate if Derwentwater and Bassenthwaite Lake levels can be managed differently to reduce flood risk creating additional storage to benefit both Keswick and downstream settlements.	March/April 2017
	Environment Agency	Investigate potential for attenuation possibilities upstream of Keswick.	March/April 2017
Maintenance	County Council, United Utilities and Allerdale Borough Council	Review and investigate drainage and sewerge systems to better understand where improvements are required.	2016/17
	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.	Complete
	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.	Complete
	Environment Agency	Continual monitoring of gravel build up within the River Greta.	Ongoing
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.	March/April 2017
	Environment Agency	Review scheme performance and consider what worked well, and where improvements to defences are required including Penrith Road.	December 2016

	Environment Agency	Investigate potential for the provision of flood defence measures on the rear side of cottages in the Penrith Road area.	March/April 2017
	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.	March/April 2017
	Environment Agency	Investigate possibility of a flood relief channel through High Hill onto the floodplain downstream of Keswick.	March/April 2017
	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.	Ongoing
	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.	2016/17
	Cumbria County Council	Continue with the design and construction of the flood risk scheme planned to decrease flood risk, Penrith Road.	Design 2016/17 Construction 2017/18
	Cumbria County Council	Completion of the Elliott Park surface water pumping station flood risk scheme.	Complete Spring 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.	Complete
	Environment Agency	Review options list	March/April 2017

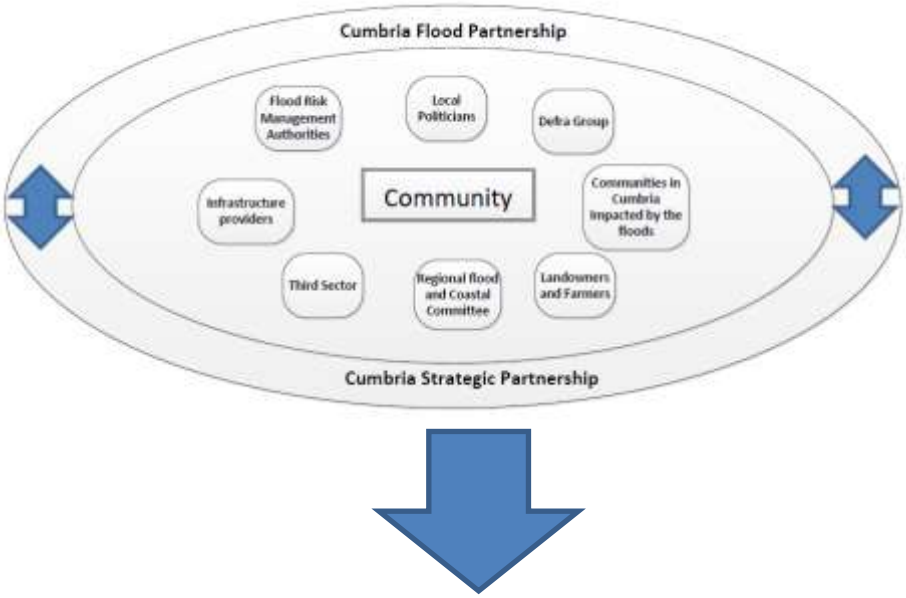
		incorporated within the Keswick Strategy 2006 and Project Appraisal Report 2010	
	Environment Agency	Work with partner organisations wherever possible to reinstate infrastructure including walk/cycleway bridges within the Greta gorge with the Lake District National Park Authority.	Ongoing

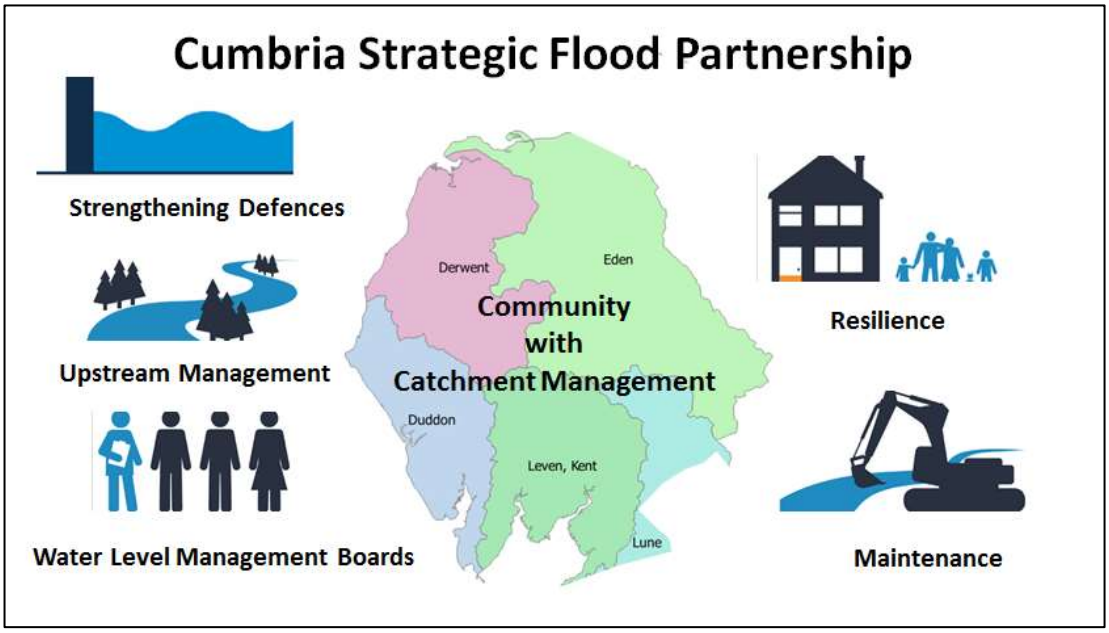
* The Cumbria Local Resilience Forum includes emergency services, Local Authorities, Cumbria County Council, Environment Agency, Maritime Coastguard Agency and health agencies along with voluntary and private agencies. Under the Civil Contingencies Act (2004) every part of the United Kingdom is required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

Next Steps – Community & Catchment Action Plan

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 affected 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 diagrams below helps demonstrate how the two partnerships have now come together:





Cumbria Strategic Flood Partnership

RFCC

Cumbria Strategic Partnership Board

Catchment Management Group

Eden

Catchment Management Group

Derwent

Catchment Management Group

Kent and Leven

Steering Groups

(Various per Catchment)

MSFWG

Community

'Farmers, environmental charities, landowners, private companies, councils and government agencies have joined together with a common goal.
To look at the evidence and potential funding sources to find flood solutions for defences, resilience, maintenance, upstream management and water level management boards, so they can work together to help communities at risk of flooding.'

In an dynamic move the Cumbria Strategic Flood Partnership have created three groups whose aim is to look at all options for how flood risk can be reduced in Cumbria.

This group the first of its kind in the country brings together the expertise of all those whose water and land management experience to look at what can be done to protect communities both residential and farming.

They will then discuss their findings to the communities at risk and plan a way forward.

This landmark move will ensure that fully integrated solutions for land and water management are utilised to protect people and the environment in which they live and rely on.

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

Term	Definition
Aquifer	A source of groundwater comprising water-bearing rock, sand or gravel capable of yielding significant quantities of water.
Attenuation	In the context of this report - the storing of water to reduce peak discharge of water.
Catchment Flood Management Plan	A high-level planning strategy through which the EA works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
Culvert	A channel or pipe that carries water below the level of the ground.
De Facto Flood Defence	A feature or structure that may provide an informal flood defence benefit but is not otherwise designed or maintained by the Environment Agency
Flood Defence	Infrastructure used to protect an area against floods as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Floodplain	Area adjacent to river, coast or estuary that is naturally susceptible to flooding.
Flood Resilience	Measures that minimise water ingress and promotes fast drying and easy cleaning, to prevent any permanent damage.

Term	Definition
Flood Risk	The level of flood risk is the product of the frequency or likelihood of the flood events and their consequences (such as loss, damage, harm, distress and disruption)
Flood Risk Regulations	Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically address flood risk by prescribing a common framework for its measurement and management.
Flood and Water Management Act	Part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England.
Flood Storage	A temporary area that stores excess runoff or river flow often ponds or reservoirs.
Flood Zone	Flood Zones are defined in the NPPF Technical Guidance based on the probability of river and sea flooding, ignoring the presence of existing defences.
Flood Zone 1	Low probability of fluvial flooding. Probability of fluvial flooding is < 0.1%
Flood Zone 2	Medium probability of fluvial flooding. Probability of fluvial flooding is 0.1 – 1%. Probability of tidal flooding is 0.1 – 0.5 %
Flood Zone 3a	High probability of fluvial flooding. Probability of fluvial flooding is 1% (1 in 100 years) or greater. Probability of tidal flooding is 0.5%(1 in 200 years)
Flood Zone 3b	Functional floodplain. High probability of fluvial flooding. Probability of fluvial flooding is >5%
Fluvial	Relating to the actions, processes and behaviour of a water course (river or stream)
Fluvial flooding	Flooding by a river or a watercourse.
Freeboard	Height of flood defence crest level (or building level) above designed water level
Functional Floodplain	Land where water has to flow or be stored in times of flood.
Groundwater	Water that is in the ground, this is usually referring to water in the saturated zone below the water table.
Inundation	Flooding.
Lead Local Flood Authority	As defined by the FWMA, in relation to an area in England, this means the unitary authority or where there is no unitary authority, the county council for the area, in this case Lancashire County Council.
Main River	Watercourse defined on a ‘Main River Map’ designated by DEFRA. The EA has permissive powers to carry out flood defence works, maintenance and operational activities for Main Rivers only.
Mitigation measure	An element of development design which may be used to manage flood risk or avoid an increase in flood risk elsewhere.

Term	Definition
Overland Flow	Flooding caused when intense rainfall exceeds the capacity of the drainage systems or when, during prolonged periods of wet weather, the soil is so saturated such that it cannot accept any more water.
Residual Flood Risk	The remaining flood risk after risk reduction measures have been taken into account.
Return Period	The average time period between rainfall or flood events with the same intensity and effect.
River Catchment	The areas drained by a river.
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
Sustainability	To preserve /maintain a state or process for future generations
Sustainable drainage system	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques.
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations meeting their own needs.
Sustainable Flood Risk Management	Sustainable Flood Risk Management promotes a catchment wide approach to flooding that uses natural processes and systems (such as floodplains and wetlands) to slow down and store water.
Topographic survey	A survey of ground levels.
Tributary	A body of water, flowing into a larger body of water, such as a smaller stream joining a larger stream.
Watercourse	All rivers, streams, drainage ditches (i.e. ditches with outfalls and capacity to convey flow), drains, cuts, culverts and dykes that carry water.
Wrack Marks	An accumulation of debris usually marking the high water line.
1 in 100 year event	Event that on average will occur once every 100 years. Also expressed as an event, which has a 1% probability of occurring in any one year.
1 in 100 year design standard	Flood defence that is designed for an event, which has an annual probability of 1%. In events more severe than this the defence would be expected to fail or to allow flooding.

Appendix 2: Additional information from the community

Keswick Flood Action Group

Suggestions for the Management of the Derwent Catchment Following Storm Desmond

Keswick Flood Action Group

March, 2016

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1 Introduction

In the light of the floods of 2005, 2009 and 2015 which have severely damaged communities and the environment, we welcome the review into managing the entire catchment area and the opportunity to offer a local view of how the situation may be improved.

While it is recognised that there are many potential schemes for improved catchment management, it is our view that the main requirements are the installation of significant schemes such as a structure in the Glenderaterra valley to hold the bulk of the water back and manage peak flows together with a more efficient means of passing water through the restrictions of the Greta Bridge and consideration of how to enable Derwentwater and Bassenthwaite to cope with high winter flows.

Broadly speaking, we are looking to combine the storage or attenuation to slow the flows in upstream areas with the appropriate removal of accumulated river sediment further downstream especially in areas where history shows a regular build-up of these sediments. We request that this initial removal of sediment is followed up with regular channel maintenance and the emptying of gravel traps.

There is evidence from the high fells that catchment management must start with the very small watercourses which eventually form the small becks which carry runoff from the fells. Natural means of slowing the flows and spreading the water over the fell-side and in flood plain areas by increasing storage are needed throughout the whole area from Skiddaw House around to Helvellyn and the Borrowdale fells. Such measures should not inconvenience farming; the high pastures are poor and simply used for grazing. The need for improvements to the management of Thirlmere Reservoir in the context of flood storage is also highlighted.

Much of the catchment upstream of Keswick is designated as a SSSI or SAC. We do not accept that this should be used as a reason for inaction. *We believe that the protection of communities should be the primary consideration in the future management of our river systems and we believe that flood risk management and habitat improvement do not have to be mutually exclusive.*

We accept the view from the submission from Eric Hope (appended) that gravel extraction is better done between May and August and suggest, since he has evidence that fish benefit from the additional flows from Thirlmere during the autumn, that the daily compensation flows currently agreed for fish are inadequate, particularly with the river beds not routinely cleared of gravel, etc.

This report is principally aimed at the part of the Derwent catchment above Keswick (see Figure 1) which includes, the Glenderamackin, Glenderaterra Beck and St John's Beck and other smaller river. Significantly, the catchment also includes Thirlmere reservoir.

2 Hydrological Aspects of Storm Desmond

It is recognised that Storm Desmond was an extreme event. During Storm Desmond, the Environment Agency rain gauge at Honister Pass recorded 341.4 mm in 24 hours. A gauge at Thirlmere recorded 405 mm in 38 hours. These are new record values for the UK. It has been suggested by the Met Office that this level of rainfall has a probability of recurrence of 0.005%. The 24-hour total rainfall recorded at Honister falls within the range of the 1975 Flood Studies Report Probable Maximum Precipitation (PMP) for Cumbria. It is also close to the current estimates of the PMP. The PMP was calculated as an amount of rainfall so extreme that it was unlikely ever to occur. It is used in the design of structures such as dams and bridges on the basis that if they are designed to survive a PMP event, they can be regarded as safe. This is part of the reason why several old bridges have been destroyed by recent flood events while modern bridges survived.

The Storm Desmond event was highly significant, setting new rainfall records, the highest record peak river levels in the affected catchments and causing major flooding in urban and rural areas. Flood defences built to cope with 1 in 100 year river flows were overtopped in Carlisle and Keswick. Substantial flooding also occurred in Kendal and Appleby. The Storm Desmond flood event was the third flood event with a return period greater than 1 in 50 years in north Cumbria in the last ten years.

Recent estimates of peak flow rates calculated by KFAG based on an assessment of return periods suggest peak river discharges of around 333 cumecs at Low Briery, 140 cumecs for the Glenderamackin at Threlkeld and 86-116 cumecs in St John's in the Vale (Smaithwaite). An analysis of return periods for KFAG has suggested that the peak river flow rates during Storm Desmond had return periods between 1 in 100 years and 1 in 200 years. This analysis also highlighted that all the river gauges provide underestimates of actual peak flow rates when rivers go out-of-channel during large events. Also, the river gauge on the Glenderamackin at Threlkeld is not be accurate at high flows even before the flow becomes out-of-channel. Figure 2 shows the extent of flooding in Keswick during Storm Desmond (the map is as accurate as possible but is not definitive).

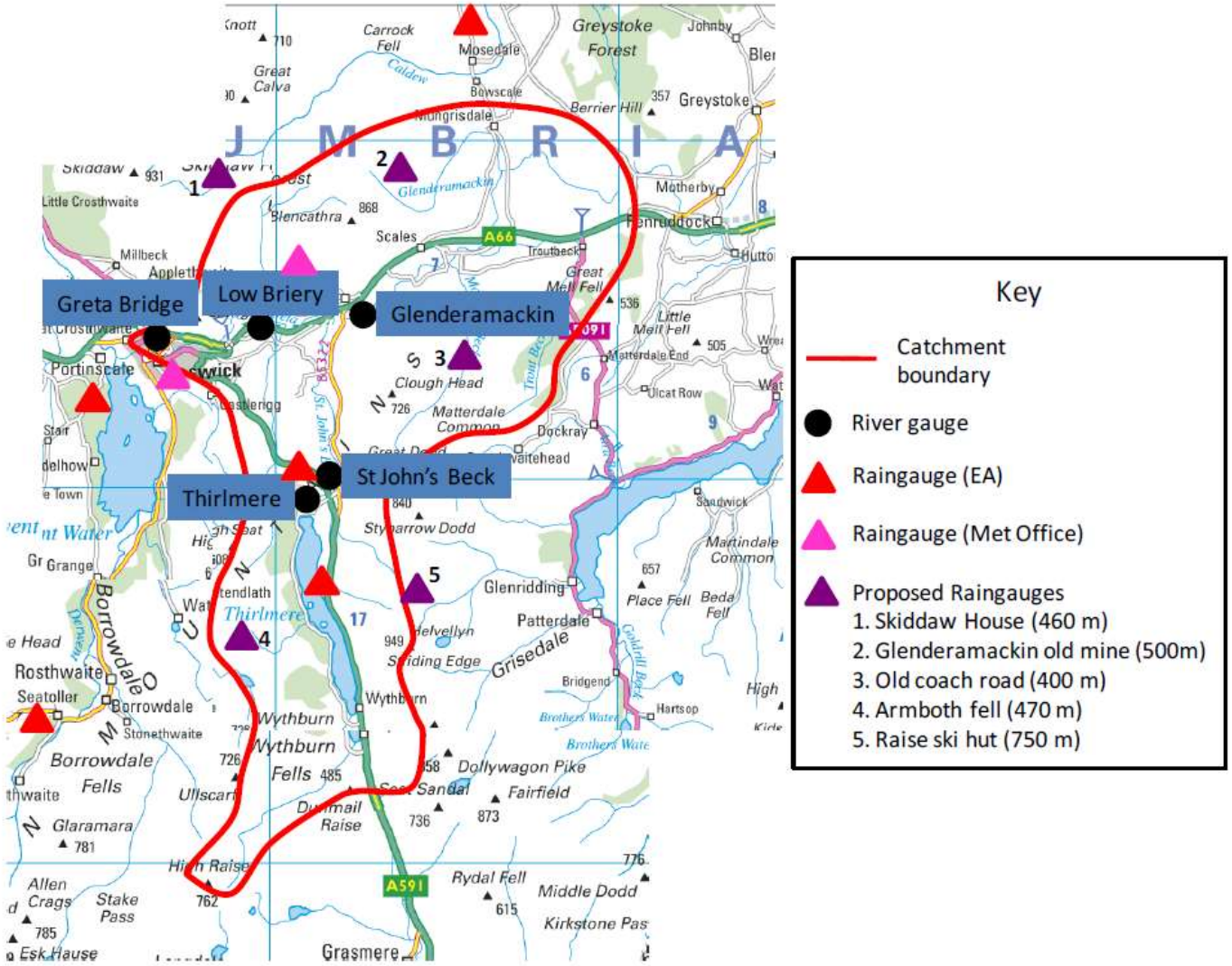


Figure 1: Approximate catchment of the River Greta upstream from Keswick, river gauges and existing and proposed raingauges within the catchment.

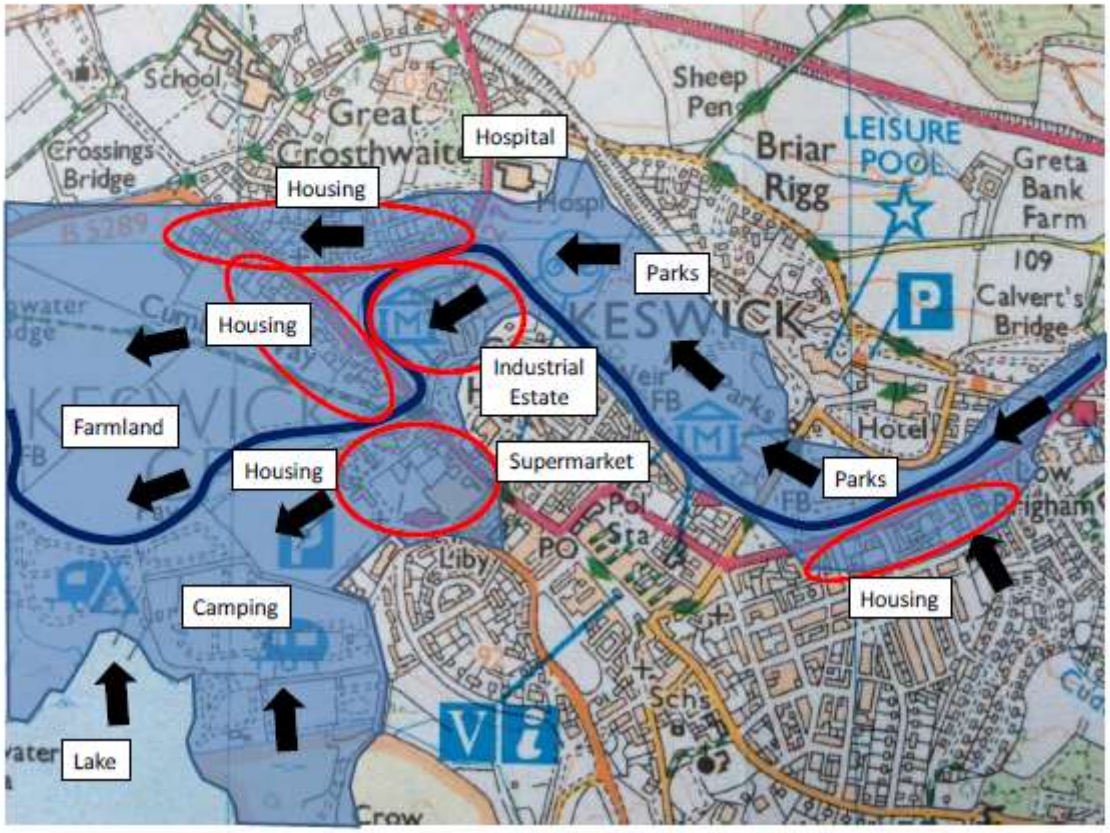


Figure 2: Extent of flooding in Keswick during Storm Desmond.

3 Lakes and Rivers

3.1 Glenderamackin

Given the substantial deposition of river gravel debris in the river at Mungrisdale (see Figure 3) it is clear that there were massively damaging flows from way above the village which need to be considered. We would like to see reforestation and natural 'leaky' dams on the high fells slowing the flows from Bannerdale Beck, Buffell Beck and the higher reaches of the Glenderamackin.

We understand that at Mosedale there is still evidence of concrete piles which were put in to make the upper valley into a reservoir about 100 years ago. We would like to see the potential for flood attenuation structures in this and other similar locations. It is understood that these can be constructed so that they lose water between storms to create storage for subsequent storms. The potential for the creation of schemes similar to those at Thacka Beck in Penrith and at Morpeth in Northumberland should be investigated in all areas (not just Glenderamackin). We would also like to see reforestation and the creation of 'natural' 'leaky' dams on the high fells slowing the flows from Bannerdale Beck, Buffell Beck and the higher reaches of the Glenderamackin.

Figure 3: Overbank gravel deposits in the River Glenderamackin near Mungrisdale.

Below Mungrisdale there is evidence of new scouring from the becks off Souther Fell. The valley floor here is an ideal location for designing a series of mini reservoirs by natural barriers across the main water course and possibly installing banks of soil across the fields which can hold the water back in a series of ponds/tree planting to slow the flow.

The point where the water course is just about to go under the A66 always looks an ideal point for a barrier to prevent massive flows. Another possible place to attenuation flows for short term water retention (particularly in winter months) would be Guardhouse.

Further water catchment schemes/tree planting could be installed from Troutbeck Moor onwards. This might help protect Threlkeld Cricket Ground and farm land in that area from the worst excesses of flooding.

3.2 Glenderaterra

Again, upland management of small watercourses is required. This beck has a steep outfall near Threlkeld and probably causes a lot of scouring/debris to be washed down. There has been some tree planting in this valley but it only covers a very small area. Steep slopes are vulnerable to erosion and this has been demonstrated by a number of landslips (see Figure 4).

Figure 4: The bare slopes and erosion features of the Glenderaterra valley.

KFAG have been advised that trees can be grown at least up to an elevation of 600 mAOD and possibly up to 800 mAOD. Figure 5 shows the possible limit of tree planting (600 mAOD contour) and the catchment boundary for the Greta above Keswick. This shows that it is theoretically possible for trees to be grown across most of the catchment with the exception of the high peaks of the Helvellyn range and Blencathra. This is not intended to show that reforestation is expected everywhere only that elevations generally do not restrict tree planting.

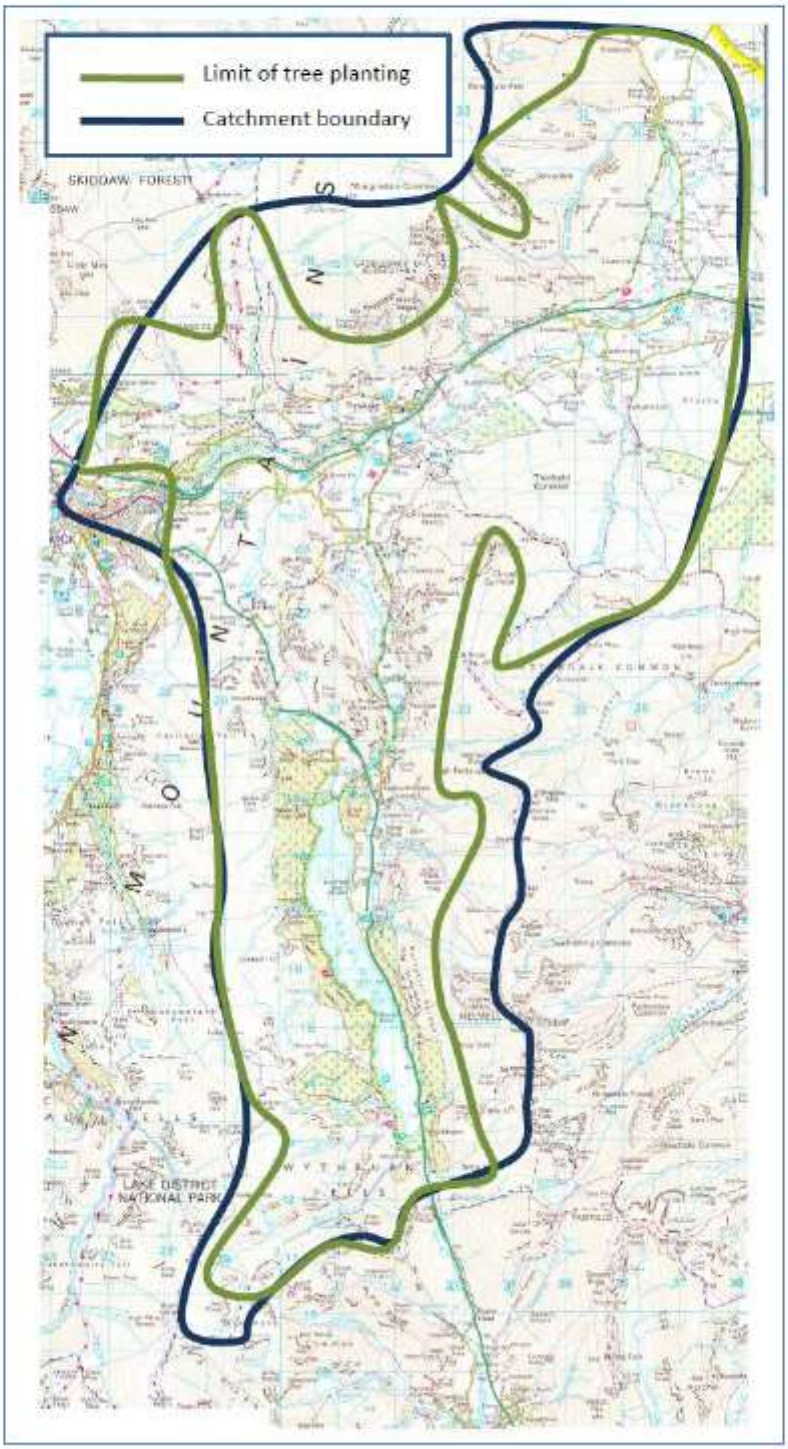


Figure 5: 600 mAOD contour compared with catchment boundary.

3.3 Thirlmere

Thirlmere is a large and significant water supply reservoir located above the valley of St John's in the Vale. Thirlmere has a catchment area of 41 km^2 which is approximately 30% of the total catchment area above Keswick. There were several large landslides around the reservoir during Storm Desmond and the A591 which runs along the side of the reservoir was severely damaged leading to its closure for several months. At the beginning of the storm, the reservoir was already full and so offered no storage. Inflows into the reservoir on 5th and 6th December 2015 were extreme and it is believed that the maximum discharge capacity of the spillway was exceeded leading the reservoir to overfill. The dam was within centimetres of uncontrolled overtopping.

Watercourses on Helvellyn and throughout the area were intensely eroded during Storm Desmond with the resultant landslides and becks gouging out small ravines with the water flow. Tree planting is taking place but the upper fells would benefit from proper management of the watercourses with full consideration of land management (fields, fells and woodland).

We believe that, at the height of the storm on December 5th 2015, the reservoir was within 15 inches of the top of the wall which runs along the road over the reservoir dam. Photographs in Figure 6 show the level of debris on the Thirlmere road wall (right up into the top corner beside the rock outcrop in the photo on the left and on the bank close to the top of the wall in the photo on the right). Figure 7 shows Environment Agency water level data for Thirlmere illustrating how the level was higher than the dam road level during Storm Desmond.

Figure 6: Photographs of flood debris close to the top of the wall that runs along the top of the dam at Thirlmere.

The exceedance of the 1975 PMP for the Cumbrian Fells (against which the reservoir was operated for many years) during Storm Desmond illustrates how the Thirlmere dam and spillway was tested. It is believed that there was little or no management reaction to the water level in Thirlmere during the storm which is a great concern to many local residents. It is requested that the EA examine United Utilities (UU's) management of the Thirlmere water levels and the operation of emergency procedures during Storm Desmond and the future operation of the reservoir given forecasts of the likely total precipitation in future storms in the context of climate change.

There have been many years of discussions between KFAG, the EA and UU regarding the operation of Thirlmere as a flood mitigation tool. UU have investigated the release of water from the reservoir before forecast storms to create storage space but for various reasons this has not worked. The potential of Thirlmere in a flood mitigation role was illustrated in November 2015 during Storm Abigail (15th November). During this storm, Thirlmere was not full and therefore was able to hold

back storm water. This is illustrated in Figure 8 which shows daily precipitation and river levels in St John's Beck (Smaithwaite) and in the Glenderamackin (Threlkeld) in November and early December 2015. This shows that while the Glenderamackin reacted to rainfall between 7th-19th November (leading to some flooding), St John's Beck did not (no flooding in St John's in the Vale) illustrating how the reservoir can store storm water when it has some spare capacity.

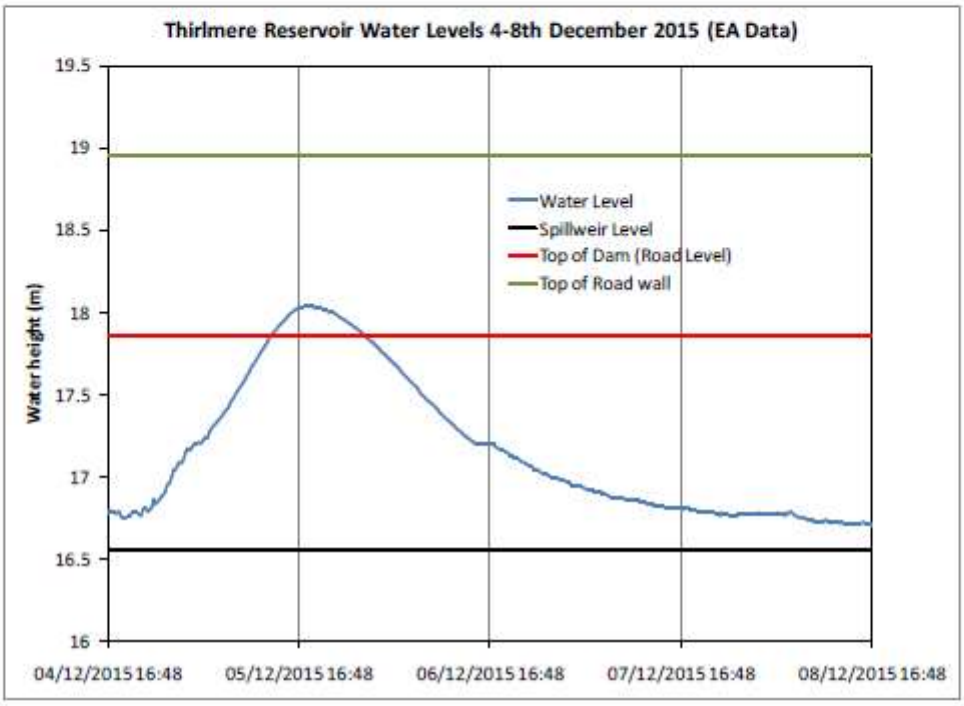


Figure 7: Environment Agency water level data for Thirlmere showing how the level was higher than the dam road level during Storm Desmond.

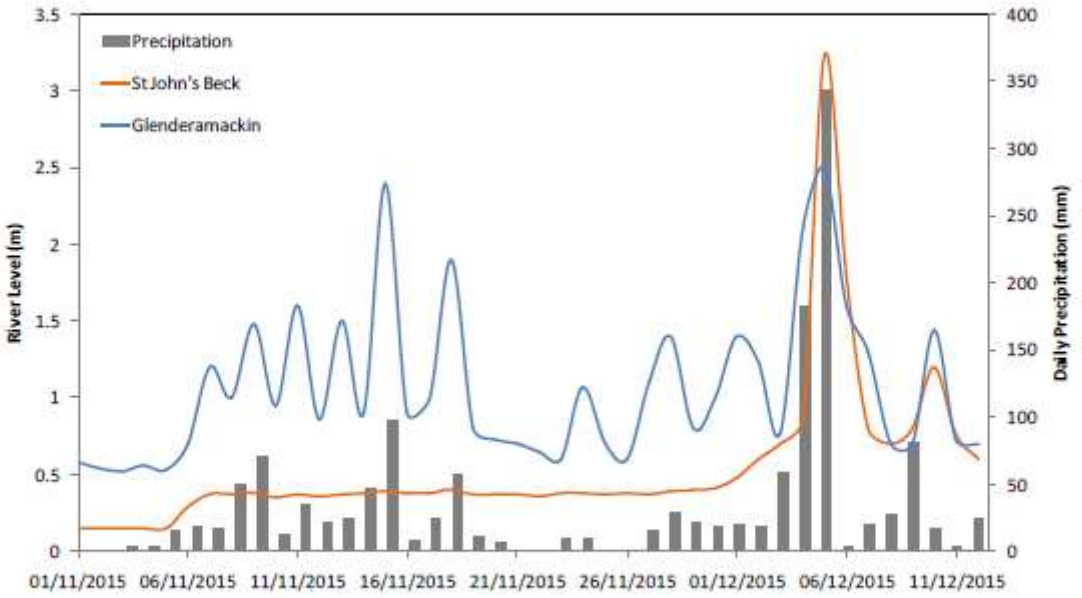


Figure 8: Daily precipitation and river levels in St John's Beck (Smaithwaite) and in the Glenderamackin (Threlkeld) in November and early December 2015.

We do not want excuses for the reservoir not to be managed for flood alleviation. St John's Beck may be a SSSI with areas designated as SAC but there has to be a way of working within the framework of these regulations to make flood prevention a priority. Having UU quote that they need permission from the EA to make additional releases of water from the reservoir is no longer an acceptable situation.

3.4 Raise Beck (above Thirlmere)

This watercourse clearly had a hugely damaging effect on the road and the immediate environment because of the considerable volume of water in the beck through the storm. We question whether adequate permission was sought for the watercourse to be re-routed into Thirlmere. The 1879 Act of Parliament for Thirlmere reservoir says (section 15) that no becks should be re-routed to increase flows into the reservoir. Raise Beck was still going into Grasmere on the 1952 maps. The Act also dictated that the reservoir should not be allowed to overflow (uncontrollably).

We need:

- UU to be prepared to manage the reservoir to help prevent the damaging torrents that result when the reservoir is overtopping in an uncontrolled and unmanaged way.
- For there to be a Statutory Duty for reservoirs to be managed to help with flood mitigation.
- For UU to invest in the mechanisms needed to be able to release meaningful flows to create storm storage space within the reservoir.
- For the EA to not simply agree to these additional flows but to require them to be made, thus really putting the protection of the public and property at the forefront of reservoir management.
- For UU to take measures to baffle the outflow channel to slow the flows down and reduce scouring and sediment in the fields below the reservoir.
- For the trigger level for additional releases to be three metres in December (the trigger level offered to KFAG for additional releases for December is two metres, for October/November it is three metres) This not only gives the chance of more storm space but it also helps the salmon who have spawned in the becks to have a substantial flow. Landowners and users in St John's Vale have previously agreed to higher river levels to allow more water to be released between storms and so create usable storm storage space in the reservoir.
- The volumes of releases for fish to be reconsidered with a view to increasing the compensation flows so the river system is better for wildlife.

3.5 St John's in the Vale

Becks cleared in some places but natural storage and flow barriers created in others. The removal of levees and canalisation should be considered. Figure 9 shows gravel deposited on fields by St John's Beck during Storm Desmond. St John's in the Vale is immediately downstream of Thirlmere and as such it suffers greatly from the failure to manage storm flows through the reservoir. The size and distribution of the gravel in the photograph illustrates the power of the water despite the fact that this location is only 1.5 km from Thirlmere Dam. There is a clear need for improved regulation and management of Thirlmere Reservoir.

Figure 9: Gravel deposited on fields by St John's Beck during Storm Desmond.

3.6 Brundholme Woods Slope Instability

In addition to flooding and damaging infrastructure, Storm Desmond also caused erosion and deposition. While there are many examples of erosion and deposition, e.g. visible river erosion damage to roads, landslips and fields covered in gravel, another less visible effect could be the further weakening of the large slope in Brundholme Woods above the River Greta at Low Briery. One of the landslips in Brundholme is illustrated in Figure 10 below.

Figure 10: The top of the Brundholme Woods landslip visible in the minor road through the woods.

The concern is that this very large slope could all become unstable and slump into the river. This could threaten the Low Briery caravan and camping area and could then block the river. If a large volume of water was to collect behind the slump, a sudden breakthrough of water could cause erosional damage and flooding downstream. Figure 11 shows the slope erosion at Low Briery caused by the Storm Desmond floods.

Figure 11: Part of the bottom of the Brundholme woods slope where the river has eroded the bottom of the slope (the brown hut is the EA gauging station).

Slope monitoring is required to determine the risk of slope failure in the Brundholme Woods.

3.7 Borrowdale

Upland management to attenuate the flow and removal of gravel build-up from lower level watercourses. For example, it should be relatively easy to slow the flow of Watendlath Beck through the woods above Lodore where there are no implications for damage to farmland.

3.8 Derwentwater

The level of Derwentwater and its ability to drain into the floodplain has a significant effect on the Greta's ability to flow into the Howrahs. All the lakes and rivers are choked with debris from the winter storms and the outlet will, no doubt, need gravel clearance. Whilst, historically, the outlet was maintained we believe that boulders used to be put into the river to hold water back for the summer months and maintain levels for good access to the jetties but the boulders were removed each year before autumn so that the lake level could drop and provide more storm space. This is not an expensive, technical solution but it is something which might work. If radical ideas are to be used they do not have to be new ones.

3.9 Bassenthwaite

The sill on the outflow needs to be dredged to drop the lake level for the winter months and provide water storage. The lake outlet used to be maintained but, as with most of our rivers this has not been done for years. Again measures need to be taken on the surrounding fells to manage/slow the flows.

We understand that Bassenthwaite was made into a SSSI in 1998 and that there was to be a review of its status as such after five years. We would be interested in the outcome of this review if it ever took place.

4 Keswick

4.1 The Forge Area

There was significant damage to the whole community. Figure 12 shows damage to the bridge in The Forge area. There is a history of some of the lower lying properties in this area being flooded but the devastation was never on this scale with riverside walls being washed away and properties being flooded for the first time. The arch of the bridge was completely filled with water as it was bombarded with an array of debris including trees and caravans. The riverbed in the immediate area around the bridge has been scoured clean of all debris and vegetation. Uprooted tree trunks need to be removed from the upstream side of the severely damaged bridge.

Figure 12: Damage to bridge in The Forge area.

It is our view that the community would be best protected by improved upstream river and land use management. We would be interested in schemes to construct flow barriers and river flood channels in Brundholme Woods. One suggestion for locating a barrier was just upstream of the obliterated old weir where the ground rises steeply on either side. The A66 main road runs precariously close to the top of the left bank, which is a concern considering the number of landslides that have taken place. Other suggestions were made that the railway path could be reinstated with a partial dam structure where bridges need to be replaced.

4.2 Calvert Bridge

Figure 13: Calvert Bridge.

Properties upstream of the bridge, none of which have ever been known to suffer flooding from the river, did so in December. According to the Environment Agency, the water level on the upstream side of the bridge was 3 metres higher than on the downstream side. Whilst this no doubt benefitted the centre of town, it was at the expense of the upstream properties. If the water level upstream had been just 0.6 m lower, none of the properties would have suffered (unlike their gardens or riverside retaining wall in the case of Lydia's Cottages).

Figure 14: Lydia's Cottages Feb 2010

Figure 15: Lydia's Cottages Feb 2016

This raises two questions: (i) should this beautiful old bridge, which is part of what makes the Lake District so special, be removed and (ii) would some removal of river gravel help to lower the riverbed under the bridge making it less of a constriction? During the worst of the storm, the river totally filled the arch leaving the bridge vulnerable to collapse. It certainly is now in need of some maintenance work, if it is to survive another similar event.

Figure 16: Front face of bridge.

Figure 17: Underside of bridge.

The second option is by far the more attractive but on the subject of stone/gravel removal there is a very serious problem in the whole of the area that needs to be dealt with and this is clearly exemplified by the banks of stones just upstream from Lydia's Cottages.

Figure 18: Stone deposits above Lydia's Cottages

Figure 19: Stone deposits on opposite bank.

4.3 Greta Bridge

During the December storms the water level downstream of the bridge was witnessed as constant whilst the telemetry levels upstream continued to rise showing that the bridge clearly obstructs the flows of the river at high flows (see Figure 20). It is our view that the bridge should be replaced with a single span bridge and/or supplemented with additional storm culverts to get as much of the flow away from the town itself. Consideration should also be given to compulsory purchase of properties to allow an additional channel to be created, possibly straightening out the river at High Hill Corner to avoid the sharp bends and allow the water an additional, faster route into the flood plain beyond (see Figure 21). Ravensfield being derelict may well provide a useful option for an additional flow. Gravel extraction to be carried out routinely. The flood gates to the car park on Crosthwaite Road leaked at the base. For some inexplicable reason the gates are lower than the flood wall and thus provided a point at which the river overspills first. The bund to the side of the gates also needs repairing where pedestrians have worn it away. Our river defences overtopped where we said they would, the glass panels finished with one lower section and overspilled at a point where more properties were put at risk than before. On Crosthwaite Road the bend that needed additional height has been bolstered with rows of sandbags.

Figure 20: The river Greta at Greta bridge during storm flow and the subsequent removal of gravel.

Figure 21: The River Greta meander between the old Pencil Factory and Crosthwaite Rd.

4.4 Western Penrith Road (Greta St Area):

The EA has previously acknowledged that surface water would be trapped behind the river defences. Far from dealing with the issue when the defences were constructed drainage holes were left just above the pavement level in the wall (properties in the area being below pavement height) (see Figure 22). The river flowed back towards homes and flooded them.

- We had asked for the drainage flaps to be 'one way' but they blocked open with debris so local pumping was under pressure with volumes of water from the river. These need to be sealed as soon as possible.
- The Penrith Road side of the walkway up to Wivell Bridge should be of a skeleton construction to let flood water pass through.
- Consideration should be given to a storm drain from the bottom of the lane behind Greta Street going diagonally across the road exiting between Wivell Bridge and the Pups Shelter as this is the lowest point.

Figure 22: Drain holes left under flood defence wall (sandbags in place).

We have been campaigning for ten years for a solution to surface water flooding here. The water spurts up from the local manhole covers and cascades down the alley behind properties in Greta Street. There have been numerous meetings over upstream storage for this area and an underground pump similar to that which has just been installed at Elliott Park. *We need support to get this scheme underway before next winter.* We do not accept that there needs to be any revisiting of data from the 5th December floods. That was an extreme event and the pump capacity to cope with the flooding is known. There have been too many delays in achieving this protection already.

5 Surface Water Flood Issues Within Keswick

5.1 Eastern End Penrith Rd

Several times over November, December and January, all of the well-documented troublesome culverts on the Eastern side of Keswick required the intervention of members of the public to keep their screens and sumps clear. For example, on the morning of 26th January, two locals struggled unaided to keep as much water off the roads as possible by clearing culverts and helping redirect water off Penrith Rd into Townsfield.

Cumbria's Better Highways is providing the best possible service it can with the resources it has at its disposal but this proves inadequate in times of emergency. That is why a detailed review needs to be carried out to identify schemes, including culvert modifications, to reduce the dependency on human intervention. There are, for example, such things as self-clearing culvert screens – has any investigation been carried out to see if they might be worth installing in Cumbria?

5.1.1 Chestnut Hill culvert

The watercourse was managed years ago by the estate workers (evidence of this still exists where it flows through the wood). The flow of water was slowed down by restrictions being constructed on alternate sides all the way down the watercourse. The positioning of large stones/boulders also helped to slow it down. At the Screes, for example, debris could now be encouraged to build up behind such blockages allowing it to be removed periodically at these specific points thus reducing the debris that now reaches the culvert. The problem is who would do the clearing? This principal could and should be applied to all watercourses, however small. The culvert's screen needs to be extended to reduce the frequency of it getting blocked.

5.1.2 The Hawthorns Culvert

This needs regular screen clearance BUT the best solution would be to build a single span bridge here and change this from a constricted channel to one which can cope with significant flows unaided. As a simple, inexpensive first step the removal of the fence below the culvert could help to reduce the build-up of debris in the sump and in the pipes under the road.

5.1.3 Fieldside Culvert and Culvert behind Hazelwood

The Fieldside culvert has been known for ages to be inadequate and too easily overwhelmed. Normally the small culvert behind Hazelwood works very efficiently as long as its screens are kept clear – difficult as the watercourse flows through a wood. However on 26 January the culvert could not cope with the quantity of water even though the screens were totally clear.

5.2 Lake Road

Properties built in 1880 flooded for the first time ever in 2009. They flooded again on 5th December 2015 with further flooding later that month. Suggestion is that the drains have a back flow valve or a pump fitted.

5.3 Brundholme Gardens

Drains on Brundholme Road were already proving inadequate for the volumes of water that come off the fields and this had been flagged up by KFAG at the Planning stage before The Calvert Way development commenced. It appears that the drains are 6 inch diameter going into 4 inch diameter. This was a bad enough problem before the new development was started. *Drainage should be the first consideration in any new build,* not something to be dealt with at a later stage when considerable damage has already been done.

5.4 Briar Rigg

Crosthwaite Road end of Briar Rigg where blocked / useless drains in the 'dip' meant that the first two houses came close to flooding.

5.5 Windebrowe Avenue

Area around 159 Windebrowe Avenue had already been reported as a significant problem. The whole avenue experienced flooding – the traffic calming measures ('sleeping policemen') directed water flowing down the road around onto the pavements and towards other properties.

5.6 Otley Road

We understand that the pump which the EA provided for this area didn't work during the flood event. We always had concerns that properties in this area were not afforded proper protection from flooding. Flood gates for doors were supplied but there was no offer to 'tank' properties so water would have seeped in via the walls even if the doorways were protected. We understand that the EA had been required to protect any properties which were at greater risk through the construction of the river defences as this area clearly was.

5.7 Elliott Park

The electrical housing for the new underground pump system is below the level at which flooding occurs if the river overtops. Whilst we accept the system is built to 1:75 year risk, it is very disappointing that the electrical supply was not erected at a much higher level. The cost would have

been minimal, the reasoning we thought obvious. Given that the EA has greatly underestimated the frequency of large storms this situation needs to be rectified.

5.8 Crosthwaite Road

Some work has taken place on surface water flooding here. It is a key route into Keswick and needs monitoring.

5.9 The Howrahs Flood Plain

The roads (the old Portinscale Road, the B5289 and the A66) and the old railway embankment impede drainage into the wider flood plain - new culverts are needed (see Figure 23).

Figure 23: Howrahs culvert and damaged storm water bridge.

6 Summary

Increasing the height of river defences is not the solution to the volumes of rainfall in the storms we have experienced over the last few years. There are three main issues which need to be addressed:

Firstly the significant flows upstream need to be managed. For St John's in the Vale the operation of Thirlmere reservoir clearly has a vital role to play in protecting the communities downstream. United Utilities should be reminded that they have a network through which they can manage water supply and that it is far easier to route drinking water to where it is needed than it is to prevent or reduce flooding. They have a corporate responsibility to those who live downstream of the reservoir.

Secondly it is necessary to get water through Keswick (and into the flood plain beyond) as efficiently as possible. This requires dealing with the restriction of Greta Bridge and also consideration to the constraints created by the roads and old rail embankment between Derwentwater and Bassenthwaite.

Thirdly the levels of both Derwentwater and Bassenthwaite need to be lower in winter to aid flows into the valley floor.

However, IF there is a true commitment to make community protection a PRIORITY all agencies have to recognise that, when responding to the needs of communities suffering from flooding, to suggest that nothing can be done due to SSSI or SAC status etc. is not only totally insensitive but also completely inappropriate.

7 Appendices

Appendix 1

Notes on Fish Habitat, Eric Hope, Professional Angler

Recent dramatic flood events have highlighted the effects of shifts in rainfall patterns. This might be naturally cyclical, or as a result of climate change. Whatever the cause, we are seeing and suffering, the effects of cataclysmic flood events of geological proportions. This is having a dramatic effect on both people and wildlife in the affected areas and calls for changes in the way water is managed are being demanded.

Thirty years ago the chosen strategy was to speed the escapement of flood water – hence the straightening of many rivers- Newlands beck being a typical local example. However, this might not be the wisest move as with an increase in the volume per second coming through our river channels, the erosive and carrying capacity of a river increases dramatically. Think back to 2009 and Little Braithwaite bridge. Here flood defence works constricted the river in a geometric flood channel which permitted a little spreading of water but retained the river between the flood banks. The resulting power was sufficient to cause the first lot of Braithwaite's' recent flood events. Incidentally, the historic straightening of Newlands beck also led to an increase in the amount of silt entering Bassenthwaite Lake with the ultimate result being siltation of spawning gravels leading to the reduction in the number of Vendace in the lake.

Gravel removal is often seen as the best way forwards and in places this might be the case but another strategy – slowing the water down in the higher reaches of a river course might also be of use. Re-establishing bends, ditches, storm channels and allowing a river to spread naturally over its flood plain would all help. It also fertilises the land as well. But perhaps the best strategy might be to combine slowing in upriver areas with appropriate removal of accumulated material further downstream and especially in areas where history shows a regular build-up of gravels and silt. Hence the Coledale gravel trap in Braithwaite village. But these need to be maintained. In the case of Braithwaite, I asked about removal of gravel a few years back and was told the gravels were contaminated with mine waste and unsuitable for use as driveway material!

Looking at the wider catchment, removing gravel build up has been a traditional activity is places for centuries and as recent events in Keswick have illustrated, water will always find a way through especially when bridges are blocked by debris. Greta Bridge should be a single span and until recently gravel has always been taken from the Pencil Mill bend. There is also a storm water beck on the map cutting through Crossthwaite- you can just about find it on the ground, but why has it not been incorporated in the towns flood defence strategy?

So assuming the ideal solution is a combination of both slowing and removing gravel build up, the issue becomes where and when to apply these methods. In the light of recent floods, urgency is also an element. To my mind, the slowing aspect of water management is an ongoing situation to be done in partnership with statutory bodies and local landowners/tenants. Gravel removal is a more complicated matter as natural events have to be considered, especially the spawning times of trout and salmon. Both species are autumn spawning (October, November early December). Until recently it was possible to stand on Lower Braithwaite Bridge and watch this activity each November. However, the Derwent is classed as an SAC river (Special Area of Conservation). This designation is based on the catchment supporting:

- Marsh Fritillary Butterfly
- Sea Lamprey
- Brook Lamprey
- River lamprey
- Atlantic salmon
- Otter
- Floating Water Plantain (northern limit of species). Also present in Derwentwater.

This designation means that it is an offence to alter or interfere with the habitat within the SAC boundary. So gravel extraction or deepening of river channels where these species occur is illegal without consultation with, and approval from Natural England and the Environment Agency.

If gravel extraction is to be carried out it makes sense to carry out this work when and where it is most appropriate. Most flood events occur in the autumn –it is these 'normal' floods which bring the salmon and trout upstream to spawn on gravels at the upper end of the catchment, so if gravel is to be removed in upriver areas it should be done between May and August. Where necessary, if the area to be deepened is for example above a known spawning area, carrying out the job in summer would have minimum impact on fish populations and prepare the way for autumn.

When the matter of water releases is considered, the already threatened salmon populations need to be incorporated into the equation. A 2015 electrofishing survey of the Derwent catchment by the West Cumbria Rivers Trust showed the highest juvenile populations of Salmon to be in St John's Beck and the Naddle highlighting the importance of these streams. In some years UU have released water from Thirlmere in early autumn then stopped the flow during December resulting in salmon Redds (the spawning nests) being left high, dry and dead. From the fish perspective *any releases are best from October onwards and the levels maintained over the winter months* to avoid this drying out.

In summary, it is the old argument of drainage against wildlife. I have no real answers but there has to be more balance between slowing down the flow to less damaging levels by spreading the load upstream and speeding up escapement of flood water by removing material where appropriate further down in areas where historically this has proved worthwhile and environmentally acceptable. I doubt it will solve the problem entirely but it might just help.

Trouble is the cost and as we all know we live in austere times and the EA are suffering huge cut-backs in funding. Perhaps we should return to a locally-funded River Board whose responsibility is developed around local knowledge for local conditions.

Appendix 2

Parish Council Flood Report 9th June, 2010

St. John's, Castlerigg and Wythburn Parish Council.

Following the disastrous flood episode of November 2009, the Parish Council carried out a survey of farmers who own land watered by St. John's Beck. This SSSI is a heavily-engineered watercourse which acts as the overflow channel for Thirlmere Reservoir which is owned by United Utilities.

In order to achieve a very welcome measure of flood alleviation for Keswick, UU have offered, in consultation with the Environment Agency, the Keswick Flood Action Group and Lord Campbell-Savours' Working Group, to target a reservoir draw down capacity of up to three meters.

To achieve this capacity, engineering works have been completed to divert Mill Gill into St. John's Beck and valve works have been completed at the dam to enable up to 700 megalitres (Ml) of water to be released per day, as needed. Trials for these water flows have yet to be carried out but clearly this will alter the pattern of river flows.

Farmers are faced with different issues which need to be examined and resolved and the purpose of this document is to ask for discussion leading to an accepted, workable range of land management.

If the EA estimated 20% increase in rainfall is to happen, action needs to be taken now to prepare ourselves. We also need to do all we can to avoid a repeat of the huge amounts of damage that the 10,000 Ml overflow caused on November 19th 2009.

The survey asked farmers for comments concerning the flood episode and its aftermath. The findings are:

Flood Warnings

Farmers were aware of the weather forecast but were not aware of the actual severity and extent of the rainfall. It was not known that the EA and UU had been discussing the release of extra water from Thirlmere earlier in the week. This would have rung alarm bells very loudly indeed. Landowners have been told that UU will now give warnings about the releases of water (up to 700 mega litres) on a daily basis. Whatever form that takes, (telephone, email, text) could be used in our local case for severe weather warnings.

A major advantage of accurate flood warnings will be to enable farmers to move endangered livestock. Their loss can be harrowing, not only to the owner but also to tourists and visitors. The distress and manner of their death should be avoided at all cost. As farm travel was severely affected by the floodwaters, accurate advance warning would be really helpful. For example, visitors could decide to go home to avoid flooding as in some cases holidaymakers were trapped for up to three days.

Agency Response

The meeting for farmers held at Threlkeld gave rise to severe misgivings. To have the EA give permission for various works involving the beck and for that to be withdrawn by Natural England was exasperating to say the least. There was shock that the agencies did not seem to have prepared a combined case outlining a way forwards. Many views have been expressed that the Newsletters gave an almost entirely negative angle when what was needed were positive offers of help. There was concern that the £6800 clean-up grant figure did not seem to relate to the amount of work required at different locations. It was reported that aerial surveys of flood damage stopped short of our area.

We were promised a "myth buster" publication to clarify what had occurred during the flood episode, but that came very belatedly and only from UU who published a small article in the Keswick Reminder. Although the application process for the "clear-up" money was generally found to be easy and workable, the amounts of money were considered to be quite insufficient for some locations although to be fair, it was adequate elsewhere.

It was felt that the EA and Natural England did not work well together at all. There was criticism of Natural England's apparent refusal to allow work to restore the river flow, although this was granted at other locations (Cockermouth bridge).

River Management

Farmers felt very strongly that river banks should be restored for land drainage and for farming needs. They felt very strongly that watercourses should be dredged for drainage. There is a continuing problem with the huge volumes of stone and gravel that came down the beck. If nothing is done to relieve this problem, the very least that can be said is that farmers down the beck consider the unwanted accumulation of stone to be very threatening and indeed un-neighbourly. They are well aware of the habitat needs and ask for a well thought out balance to achieve both ends. They feel that gravel should be removed to ease drainage rather than to be deposited on flower rich meadows. They feel that flood defences should be restored. They have not been removed by managed agreement but by flooding, which sent huge volumes of sediment to the already troubled Bassenthwaite Lake.

A clearly expressed view is that farming and environmental needs should be better balanced and a local management plan evolved to meet farm production needs. There are also concerns about alterations to the bed of the river that compromise field drains. The concept of re-wetting needs to be examined and agreed by management rather than coming about as a result of an unplanned flood.

The Aftermath

Farmers felt strongly that given the anticipated changes in river flows and having to deal with climate change, there needs to be a reserve fund available to cope with the aftermath of flooding. It does not seem good practise to siphon money away from one budget and apparently then return an unspent balance without properly finishing the job.

There needs to be a published, agreed plan about to how to restore this SSSI after a damaging flood event. The National Park also needs to be able to quickly examine and restore the important footpath networks.

It was felt that stock exclusion fencing, compromised by flooding, needs to be reviewed. It was strongly felt that on this occasion, flooding caused far more damage than livestock ever did.

Farmers felt that although they could recognise the impact that flooding had made on their health and that of their families, they were aware of how to get help. They also reported a considerable loss of confidence in their ability to manage their holdings if these weather events are to become more frequent.

Conclusion.

The Parish Council is strongly aware of the importance of St. John's Beck to the environment, the visitor and to farmers. We ask for an agreed plan to be drawn up within the catchment to manage this stretch of river (if necessary farm by farm) in view of the proposed increased water flows and to minimise the impact of severe flooding events.

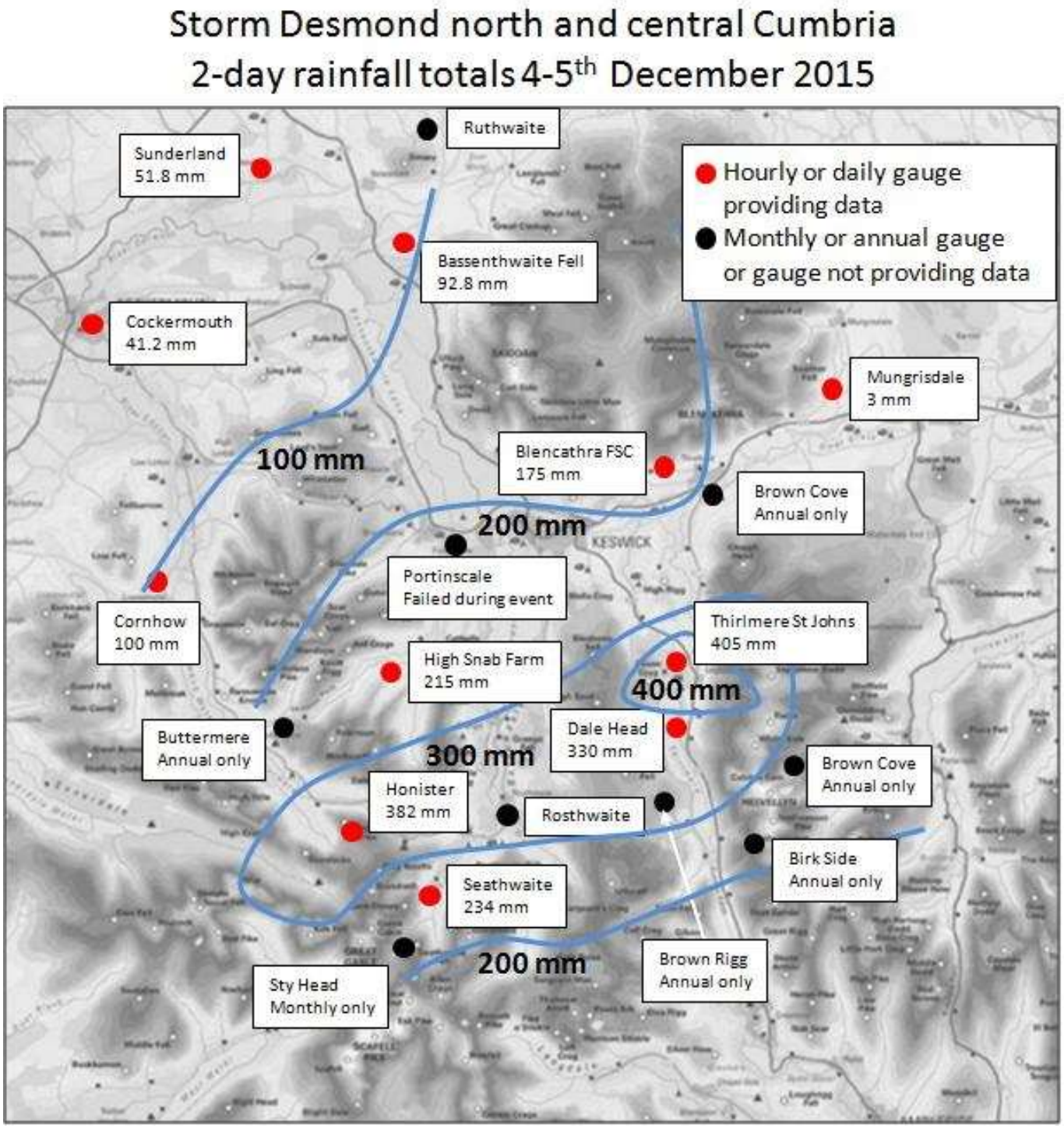
We need to agree what can be done and to conserve the wonderful asset that we have.

After all what, what price can you put on the joy of a visitor who says:

"We've just seen a kingfisher *and* an otter!"

Parish Clerk; Mrs. Sally Bickerdyke (Tel 017687 73537 email sally.bickerdyke@btinternet.com

2 Day rainfall totals provided by Keswick Flood Action Group



Additional reports produced by the community used to inform the production of this document include:

- Henderson, D.E, 2016. Hydrological aspects of the Storm Desmond floods in and upstream of Keswick.
- Henderson, D.E, 2016. Hydrology and the Storm Desmond floods in the Derwent catchment above Keswick.

These can be obtained through Keswick Flood Action Group.

Appendix 3: 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 4: 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

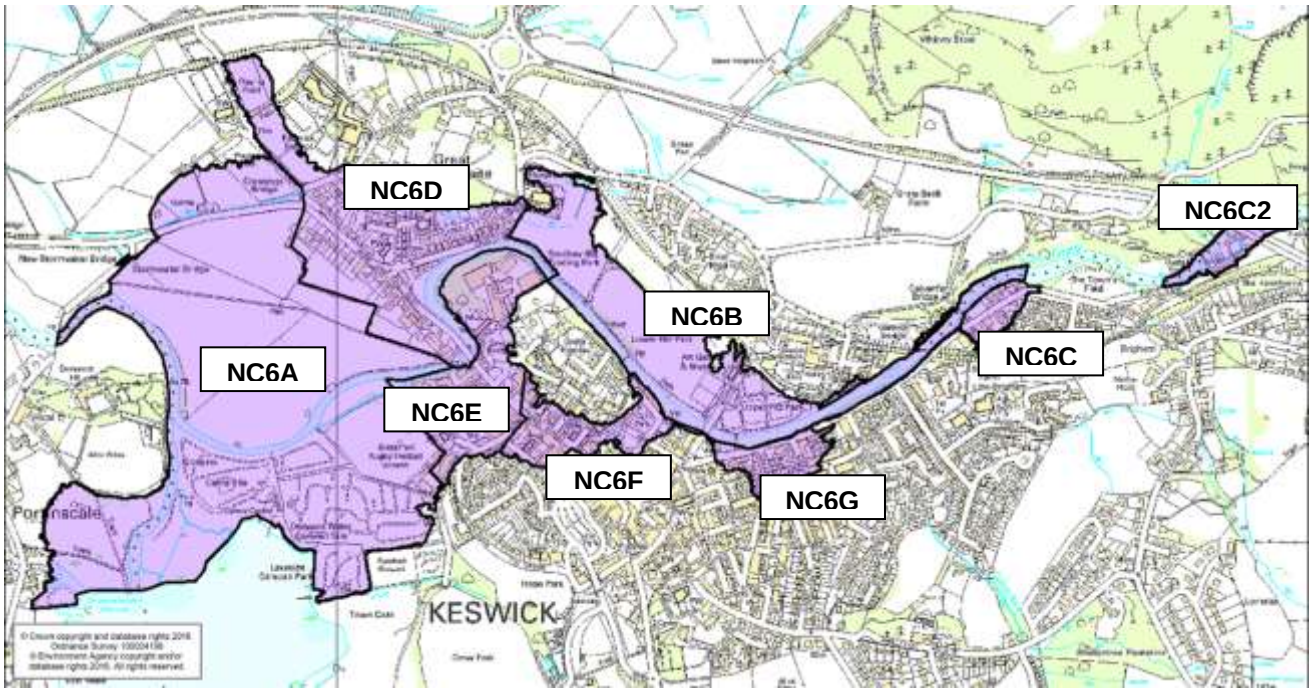
Flood and Water Management Act 2010:
http://www.legislation.gov.uk/ukpga/2010/29/contents

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 5: 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.

*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"

Flood Alerts:

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

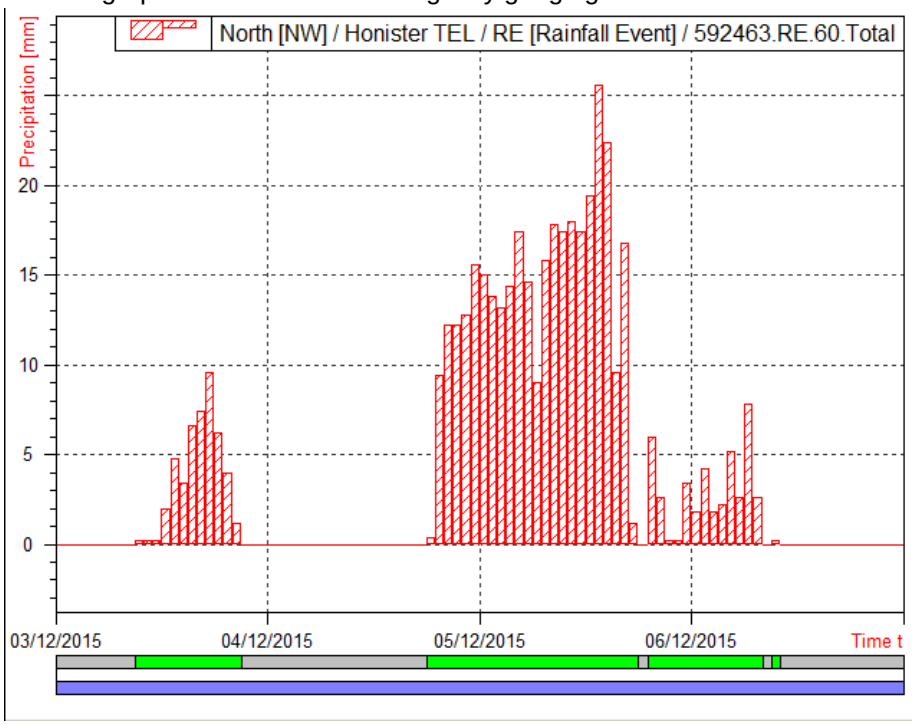
Severe Flood Warning issued on Saturday 05/12/2015 at 11:21
Severe Flood Warning downgraded to Flood Warning on Monday 07/12/2015 at 17:28
Flood Warning removed on Tuesday 08/12/2015 at 17:46
Customers in Flood Warning area registered on FWD: 49
Contacts (landline, mobile, email etc) in Flood Warning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

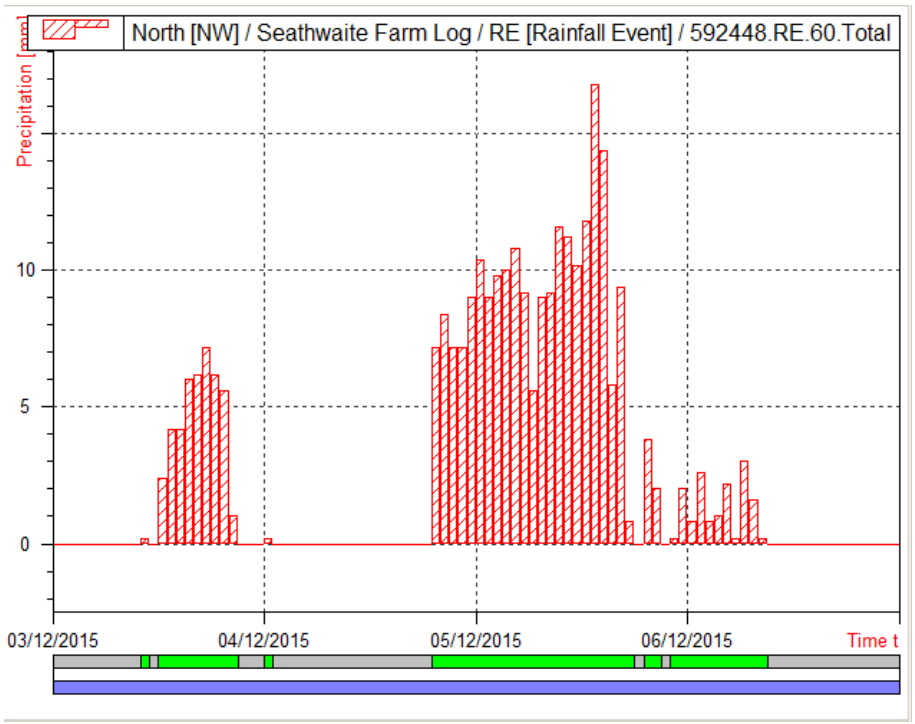
Successful contacts: 95
Unsuccessful contacts: 37

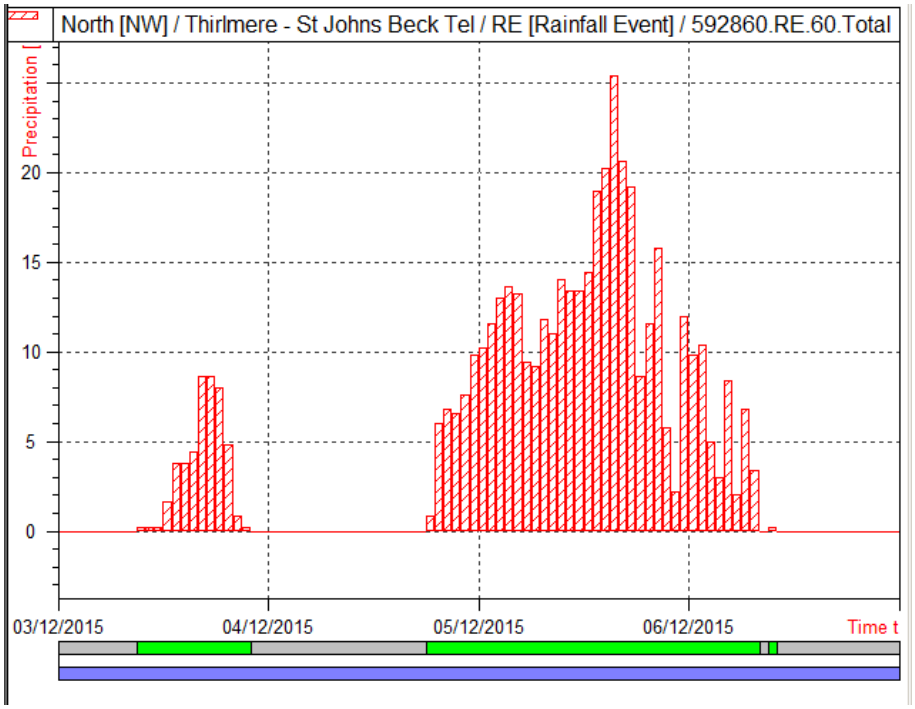
Severe Warning Message:
Severe Flooding. Danger to life. A Severe Flood Warning has been issued by the Environment Agency for the Greta Street and Penrith Road at Keswick.
This Severe Flood Warning is for Properties affected by surface water flooding in Greta Street and Penrith Road.

Appendix 6: Rainfall graphs

Rainfall graphs from Environment Agency gauging stations



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Precipitation [
20
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