Elliot Park Appraisal of Surface Water Flood Risks

Final

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Cumbria County Council

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Contract

This report describes work commissioned by Doug Coyle, on behalf of Cumbria County Council. Anneka Lowis, Sam Wingfield and Howard Keeble of JBA Consulting carried out this work.

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Purpose

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JBA Consulting has no liability regarding the use of this report except to the Cumbria County Council.

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1 Introduction and scope

1.1 Introduction

The residential development at Elliot Park in Keswick has a long standing history of repeated internal flooding.

The site is located at the lowest point within the town centre, and is sited behind the engineered flood embankments that form the Environment Agency's flood defence for the River Greta. The Elliot Park estate is also located adjacent to a United Utilities (UU) pumping station, which is currently being upgraded as part of UU's wider investment plans for Keswick.

There are three primary sources of flooding at Elliot Park, these comprise;

- Surface water flooding, which results from overland runoff from a topographically driven catchment.

  Surface water flooding appears to have occurred on a regular basis and is mainly caused by the River Greta "tide locking" of the highway drainage network. Flooding has also been caused by sewer capacity exceedance. The relative low ground level at Elliot Park aids migration of surface water flows to this area. When river levels are high, outfalls become blocked or at least outflows are significantly impeded. Under these conditions surface water tends to pond within the Elliot Park and flood levels continue to increase until either river levels subside or temporary pumps are activated allowing surface water to discharge to the river.
- Fluvial flood risk stems from the River Greta that flows behind the raised flood embankment that boarders Elliot Park. This embankment is designed to offer a degree of protection to Elliot Park and Keswick in general. Overtopping of the embankment has previously resulted in direct inundation and flooding to residential areas.
- There is also a pumping station within the Elliot Park area that forms part of UU surface water network. This system is currently being upgraded. The surface water drainage system at Elliot Park has not been adopted by UU and during the construction phase of the new larger capacity pumping station temporary pumps have been installed for the duration of their network upgrade work. UU have confirmed that these pumps assist flood risk management only and have insufficient capacity for high intensity events, during which sewer capacities will be exceeded.

  Based on anecdotal accounts, confirmed by photographs at the start of 2013, it is likely that sewer exceedance of UU assets has historically contributed to flooding in the area. The extent and scale is very difficult to quantify without UU network modelling.

  Having discussed refurbishment plans with them, UU have confirmed that the network upgrade will prevent sewer exceedance at Elliot Park. Any additional capacity, above a 30yr standard within this new network remains unknown and cannot be assumed to provide further benefit to residential development at Elliot Park.

The current standard for flood defence within Keswick ranges from 1:10 to 1:100 years and approximately 150 residential and 40 commercial properties are currently at risk from flooding.

Despite improvements to UU's network and pumping facilities, residual surface water and fluvial flooding problems will remain. As the Lead Local Flood Authority, Cumbria County Council have undertaken further review and analysis of residual flooding problems to determine what further work may be possible to manage flood risk to an acceptable level.

Cumbria CC has commissioned JBA Consulting to identify and quantify the surface water flood risk and then undertake an options appraisal of measures required to potentially manage residual risks associated with surface water flooding. The results to this analysis are summarised in this report.

The analysis presented in this report is a feasibility appraisal and results will need to be verified by future detailed design calculations. Since the last significant flooding to the area, the EA have constructed a new flood defence on the River Greta and United Utilities are constructing a new surface water pumping station for the town. The residual risks, associated with a range of flooding events have been appraised in this report in order to determine the likely mitigation measures required to manage surface water flood risks.

1.2 Appraisal scope

In accordance with the brief there are four key aspects to this appraisal process:

- to understand the flood limiting impacts of the proposed UU sewer capacity improvement work and opportunities for optimisation with Cumbria CC proposals at Elliot Park; (Note following initial discussion with UU, UU has confirmed that the ongoing improvements to the sewer capacity and upgrade to the pumping station will not have any substantive impact on exceedance flood risk with the Elliot Park area.)
- to understand the impact of the EA's Flood Alleviation Scheme enhancement work on flood risks and interactions with the surface water system (Note this tends to influence the frequency and duration of tide locking to the surface water outfalls);
- to develop further the work undertaken as part of the Surface Water Management Plan in order to more fully understand the mechanism of flooding and to quantify the volume of surface water/exceedance flows; and
- to undertake an options appraisal for Elliot Park of the various measures available to manage the residual risks associated with surface water flooding.

1.3 Managing expectations

An initial data collection exercise has been led by Cumbria CC and have included meetings with the Keswick Flood Action Group and UU to review the available data, develop existing knowledge and understand key constraints. Developing a comprehensive understanding of flood risk, including analysis of available records, photographs and anecdotal accounts of flooding enables a more complete understanding of flood risks. This understanding forms an essential step in defining the scope of the surface water improvements.

Residual risks cannot be considered in isolation. Whilst fluvial risk may be controlled, to some extent by improvements to the EA's Flood Alleviation Scheme (FAS), the risk of surface water flooding remains dependent on the interaction with river levels.

Expectations will need to be carefully managed as flood risk may only be controlled and not eliminated. The scale of any further investment will also need to be commensurate with the extent of the likely damages.

2 Elliot Park Scope and Methodology

2.1 Scope

The purpose of this appraisal was to identify the mechanisms of flooding at Elliot Park and quantify surface water flood risk and the volume of surface water that would need to be effectively managed, by pumping or attenuation for example, so that risk can be reduced to an acceptable level.

Consideration has also been given to the practicalities associated with managing flood risk at this challenging location and the likely funding implementations associated with further investment.

2.2 Detailed mapping and contributing rainfall

Elliot Park is a residential development, comprising mainly of flats, in the north west of Keswick in a low lying area adjacent to the River Greta. It is protected from direct inundation by the River Greta by fluvial flood defences. We understand these defences provide a 1 in 75 year standard of protection (SoP) at this location.

However, Elliot Park also has a history of surface water flooding. Its low-lying topography compared to other areas of the town means that surface water from the surrounding streets will naturally tend to flow towards this area.

In order to do develop a detailed understanding of surface water interactions a 2 dimensional direct rainfall TuFLOW model of the study area has been developed. The modelled area comprises a much larger extent than just Elliot Park as it needed to reflect the extent of the natural topographic catchment that contributes to flood risk at Elliot Park.

Modelling has been used to identify the extent and depth of surface water flooding according to a variety of design rainfall events. The model has been designed to identify the extent and to quantify the likely volumes of surface water flood risk to the area. Whilst account has been taken of the drainage networks the drainage systems have not been modelled in detail as understanding exceedance flows during a variety of events (including "tide" locking) forms the basis of understanding. The TuFLOW model is sufficiently detailed to model surface water flow paths, pooling areas as well as interactions with building and raised areas of land.

Rainfall events have been defined using ReFEH methods to determine rainfall for a range of different return periods. Predicted rainfall events have also been assessed against known flooding events, such as that which occurred November 2009, in order to try and replicate observed flooding and confirm the likely mechanism and cause.

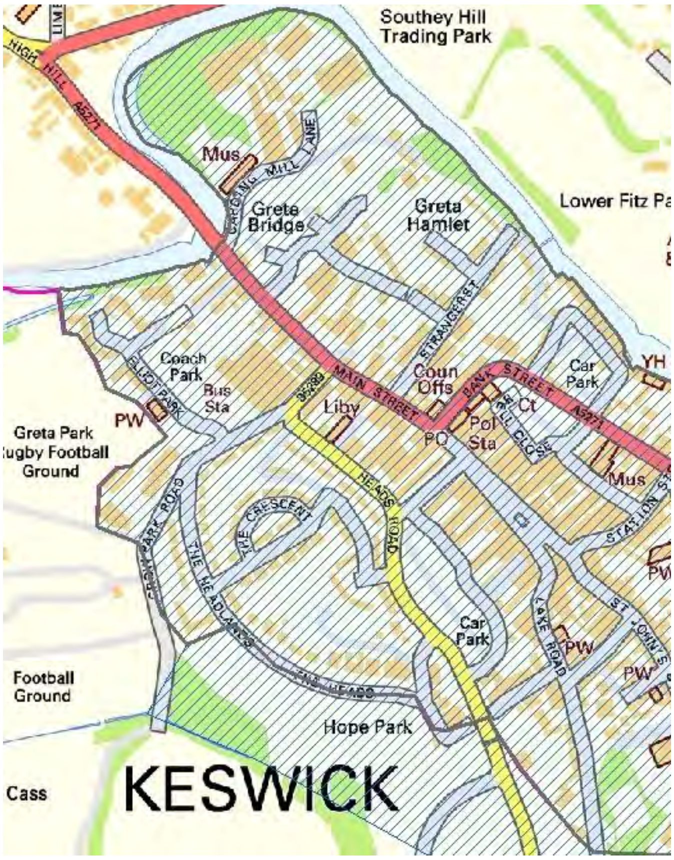
2.3 Contributing catchment

In order to accurately model surface water flooding in Keswick it was first necessary to investigate the topography of the area and define the catchment areas that contribute to the overland flows at Elliot Park. A desk study was undertaken with reference to mapping and LIDAR data, existing flood maps and available highway network details.

Topographic analysis of the LIDAR data was undertaken using Arc Hydro to identify natural catchments and drainage paths. The desk study identified that the surface water runoff that reaches Elliot Park is generated by a relatively defined catchment and comprises a combination of urban and rural areas.

Contributing catchments were checked for connectivity and additional flow routes, such as roads that connect to the topographic catchment, so that an accurate extent could be defined. The extent of the topographic catchment for Elliot Park is included as Figure 2-1.

Figure 2-1: Indicative catchment area upstream of Elliot Park



2.4 Hydrology - design events

Catchment descriptors were extracted for Keswick based on FEH techniques (FEH CD v3). These descriptors were used to generate rainfall hyetographs using ReFEH methods for the design storm events that were used as inputs to the model.

Urban flooding is often caused by short duration rainfall events of 1 hour or less. This is because a short duration event has a much higher intensity then a longer duration event of the same return period and is, therefore, more likely to exceed the capacity of the urban drainage network.

However, longer duration events tend to generate greater volumes and depths of flooding. As flooding in Elliot Park appears to be volume driven, with water accumulating in the depression behind the defence, a longer duration event was chosen to more appropriately represent the volume of water entering Elliot Park. This approach reflects more closely the observed extents of historical flooding.

Once the total rainfall hyetographs had been generated standard runoff percentages were applied to generate net direct rainfall hyetographs to be used in the modelling. The Keswick study area was divided into urban and rural areas according to the land use. The urban area, which represents the majority of the study area, had a runoff percentage of 70% applied to it and the rural area 39%. The difference in percentage runoff reflects the fact that the urban areas are covered in impermeable surfaces such as the roofs of buildings, roads and car parks, whereas in the rural areas water is more able to infiltrate into the soil and will have a less tendency to be converted to direct runoff.

The rural areas surrounding Keswick are relatively steep and therefore the rural runoff percentage could be higher. However, the sensitivity of the model to the runoff percentage was tested. When compared to the majority of the catchment, which is urban, the contribution from rural areas was considered minimal.

The urban rainfall hyetographs were further reduced by a constant value of 16mm/hour over each time step of the hyetograph (1.6mm/0.1hr) to take into account the amount of water that would be lost to urban drainage. This corresponded to a 1 in 5 year (20% AEP) 1 hour event.

Applying urban drainage to the rainfall hyetographs dramatically reduced the amount of water available to direct runoff.

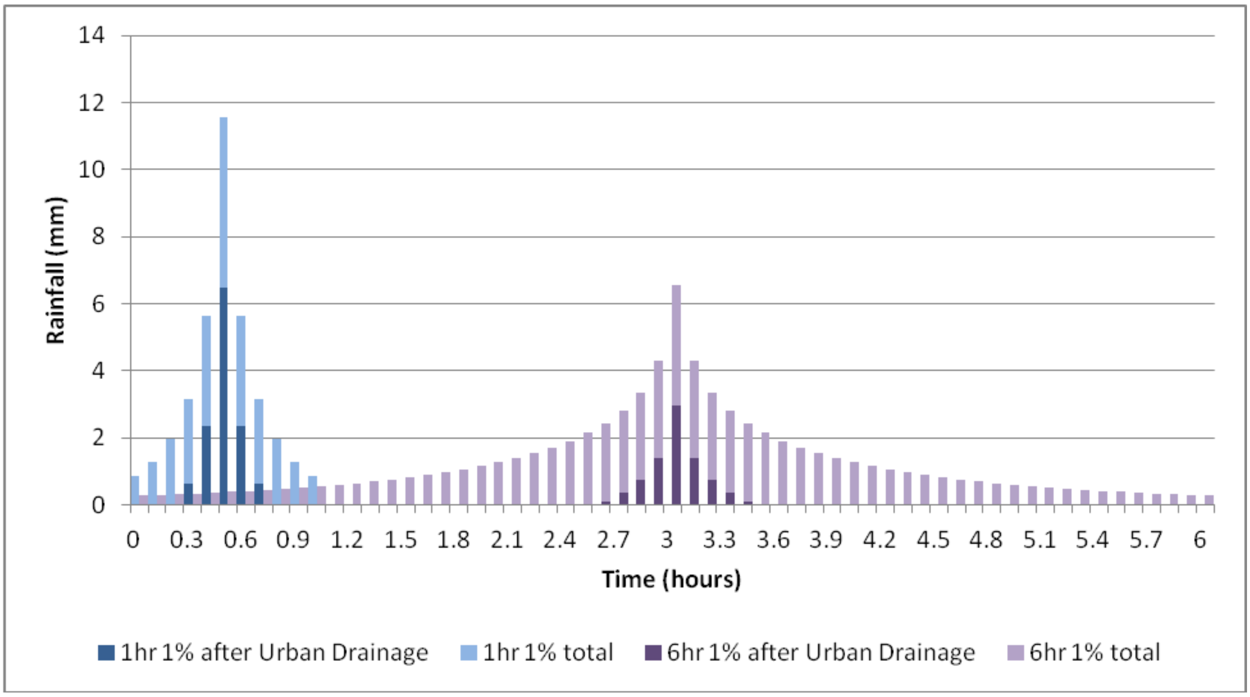
Contributing drainage areas have been calculated using ArcHydro and are based on the most recent version of LIDAR. The catchment area and predicted rainfall events have been used to calculate the total volume of rainfall over this area, for a range of return periods and durations.

Table 2-1: Rainfall depths (mm) for a 1% AEP storm

	1% AEP Event	70% runoff	16mm/hour drainage
1 Hour storm duration	37	26	12
6 Hour storm duration	76	53	8

Table 2-1 shows that when urban drainage is applied the total depth of water for a 1 hour storm is actually greater than that for 6 hour storm even though the design total for a 6 hour storm is more than double the total for a 1 hour storm. This is because the rainfall intensities are much lower for the 6 hour storm. The effect of applying 70% runoff and urban drainage to the rainfall hyetograph storm profiles is shown in Figure 2-2.

Figure 2-2: Rainfall hyetographs for a 1% event



2.5 Model development

A 2D surface water model was developed using TuFLOW to represent the ground surface in Keswick. A cell size of 2m was chosen for the model; a small cell size was necessary in order to accurately represent the flow paths across the surface.

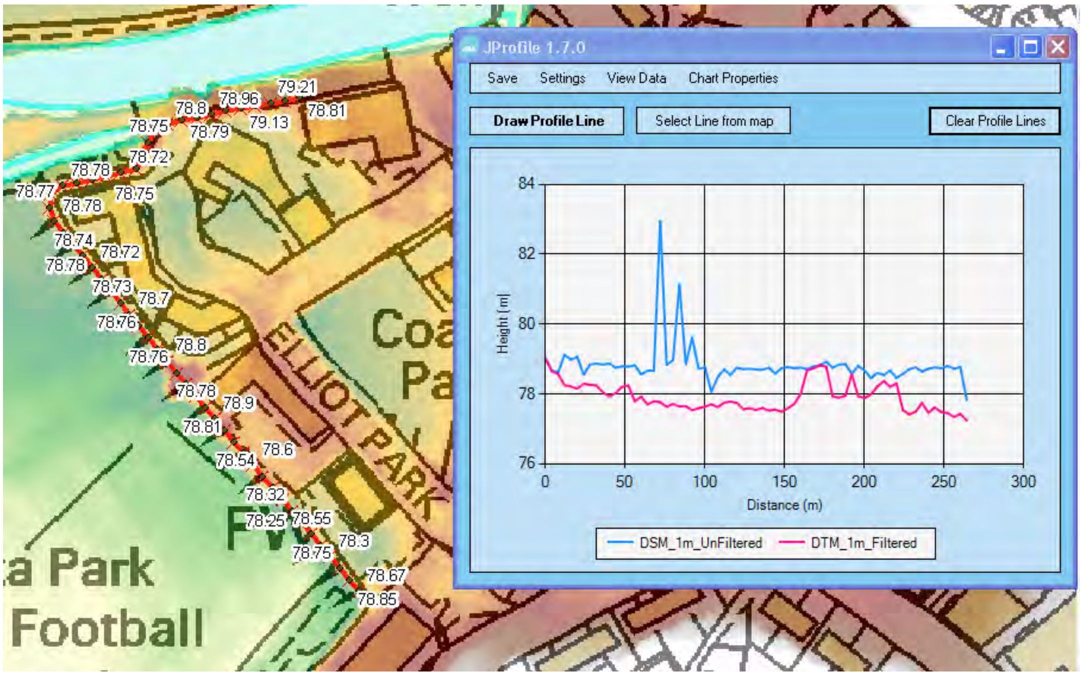
The model was developed using 1m resolution filtered LIDAR. Master Map data was used to represent buildings in the model by raising their Manning's n (roughness) values to prevent the flow of water through them. In the same way roads were represented by lowering their Manning's n values to accurately represent the preferential flow paths along roads.

Following an initial model run, the ground surface used in the model was altered with reference to aerial photography, Google Streetview[tm] and the unfiltered LIDAR to more accurately represent the reality.

The embankment surrounding Elliot Park was raised to the level in the unfiltered LIDAR (following the removal of anomalous high values representing trees) as it was not accurately represented in the filtered LIDAR this is shown in Figure 2-3:.

The model was first run to identify the main flow paths, a number of monitor lines were then placed across these flow paths in order to record the flow rates and total volume of water flowing into Elliot Park.

Figure 2-3: LIDAR levels for the Elliot Park embankment



2.6 Detailed surface water modelling

The TuFLOW model was run for both a 6 hour and 1 hour storm with and without urban drainage for the 1 in 100 year storm. In addition 6 hour storm profiles for a number of smaller events including the 1 in 20, 1 in 50 and 1 in 75 year storm were completed so that a range of flood scenarios could be assessed against known flood events.

3 Flood Extents and Volumes

3.1 Flow paths and flooding patterns

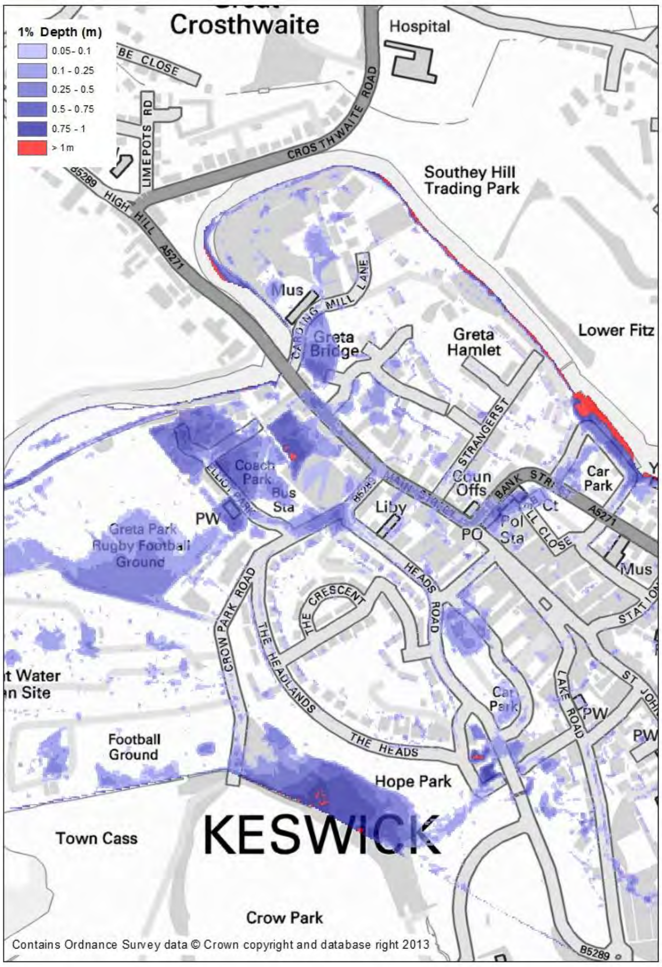
Based on modelling results the main flow routes to the Elliot Park area were identified. Water follows the roads, flowing from the south and east along Bank Street, Main Street, Heads Road and the B5289. From the west, water flows along The Headlands and Crow Park Road. However, much of the flow along Crow Park Road doesn't reach Eliot Park and flows further west along a track and into the rugby ground.

3.2 1% AEP event 6 hr duration without discharge to the river (tide locked)

The water from the east pools at the junction of Heads Road and the B5289 to the side of Booths supermarket. It then flows along Elliot Park road and into the coach park and the bus station car park. During the 100yr 6 hour event, without drainage (the outfall is effectively tide locked by the Greta), the water then pools in the Coach Park before it reaches a sufficient depth to flow over the Elliot Park road into the Elliot Park housing estate where it continues to accumulate and pool. Further cross connection via the road gullies in Elliot Park also contribute to flooding.

Figure 3-1 indicates the maximum depths of flooding for this event. The flow paths and patterns of flooding for the 1% AEP event without drainage correlate well with aerial photographs of the November 2009 event, which shows extensive ponding of water in the Coach Park, alongside Booths supermarket and in the Elliot Park housing estate.

Figure 3-1: Maximum depths for the 1% AEP 6 hour storm event without drainage (tide locked)

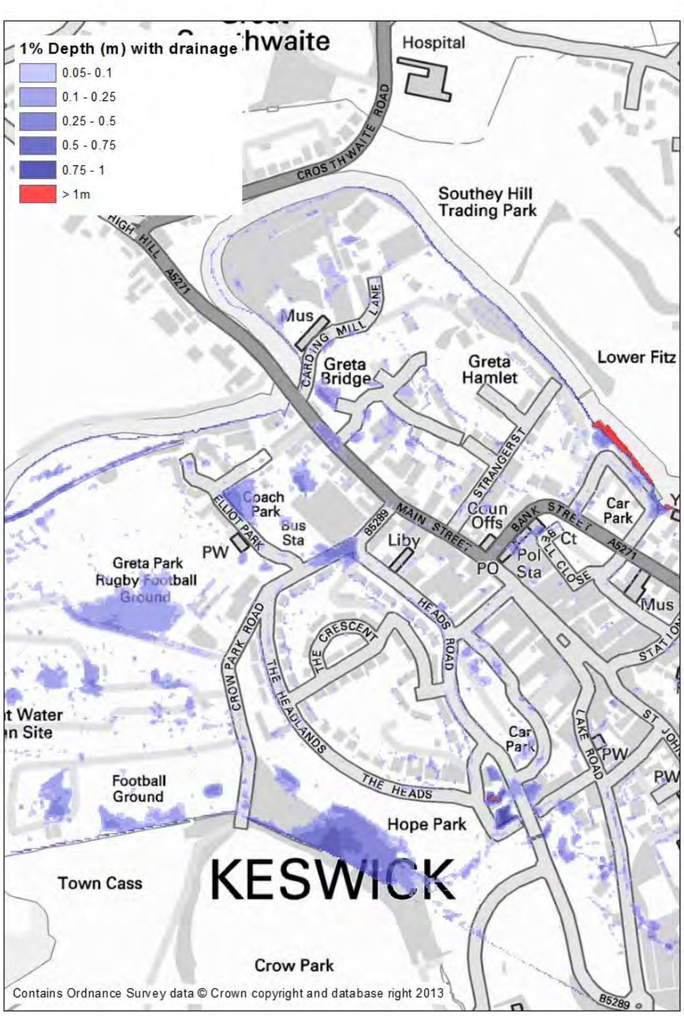


3.3 1% AEP event 6 hr duration with discharge to the river

During the 1% AEP 6 hour event, with drainage (i.e. the outfall is freely discharging to the River Greta), water does not reach a sufficient level in the Coach Park to breach the road, resulting in minimal flooding to the Elliot Park housing estate. Maximum water levels are approximately 0.4m higher in the Coach Park during the 1% AEP event without drainage scenario.

Figure 3-2: shows the maximum depths for the 1% AEP 6 hour storm event with drainage and illustrates the limited extent of flooding when compared to the without drainage scenario.

Figure 3-2: Maximum depths for the 1% AEP 6 hour storm event with drainage (flowing outfall)

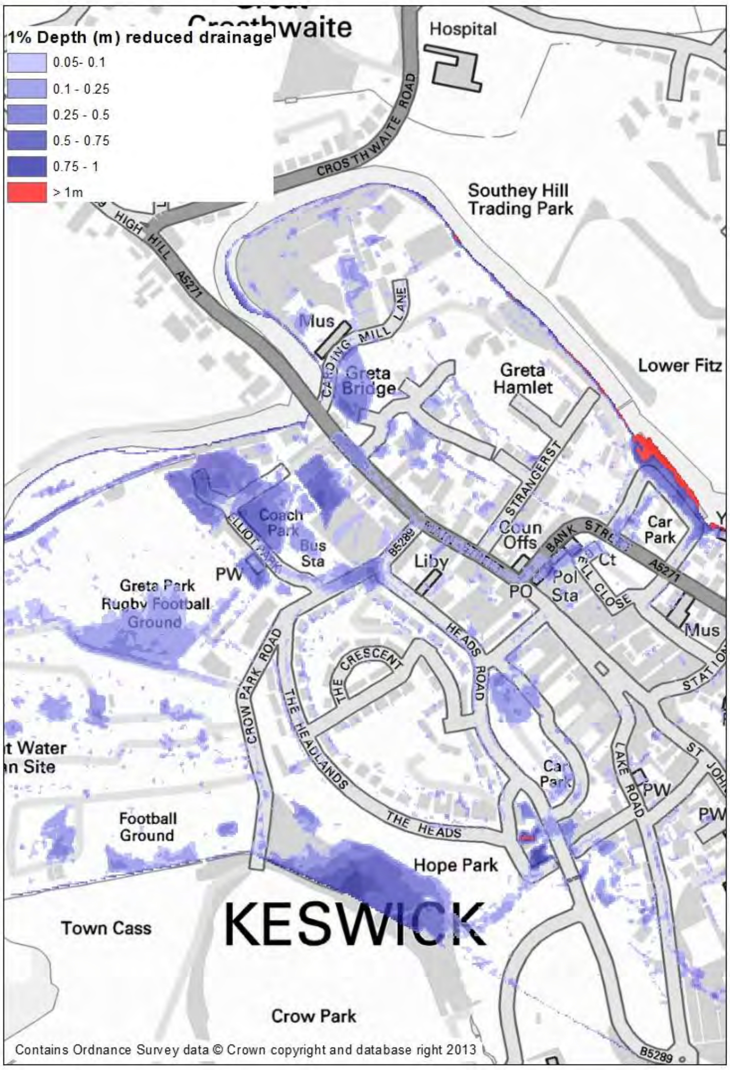


3.4 1% AEP event 6 hr duration with 3 hour discharge to the river

Further sensitivity testing has also been undertaken in order to determine the likely impact of a partially impeded outfall to the River Greta. In this scenario we have assumed free discharge over only a 3 hour period.

Figure 3-2: shows the maximum depths for the 1% AEP 6 hour storm with this impeded outfall and again illustrates the limited extent of flooding.

Figure 3-3: Maximum depths for the 1% AEP 6 hour storm event with reduced drainage (tide locked for 3 hours)



3.5 Comparison of depths and volumes

A monitor line was used in the model to record the total volume of flow into Elliot Park over the road from the coach park. In addition, the maximum depth and total volume of water within the Elliot Park housing estate at the time of maximum depth was calculated. A variety of model scenarios were compared as shown in Table 3-1.

The model was also run with further reduced manning's n values along the roads to make sure the flow paths were properly defined, however, this was found to have only limited impact on model depths.

Table 3-1: Depths and volumes within Elliot Park for a variety of modelled events

Model event/scenario	Maximum inflow rate (m3/s)	Total inflow Volume (m3) from coach park area	Elliot Park Flood Volume (m3)	Depth (m)
1% AEP 6hr with outfall to river	0	0	125	0.15
1% AEP 1hr with outfall to river	0	60	220	0.3
1% AEP 6hr tide locked	0.6	2210	2550	0.87
2% AEP 6hr tide locked	0.5	2110	2420	0.85
1% AEP 6hr tide locked for 3 hrs	0.25	1810	2050	0.79
1% AEP 6hr with outfall with manhole surcharge 0.5m3/s	--	--	2400	0.85

The anticipated depths and volumes of surface water within Elliot Park are sensitive to the volume of water entering the model. However, once a certain depth is exceeded, water starts flowing back towards the town centre. This occurs during the 1% AEP 6 hour with tide locking (i.e. no drainage) and means that there is a small difference in volumes and depths between the 1% AEP and 0.1% no outfall scenario.

From Table 3-1, the volume of surface water inflow to Elliot Park typically ranges between 2,000m3 and 2,500m3.

4 Review of Historical Events

4.1 November 2009

The November 2009 event caused significant flooding within Keswick including to the Elliot Park area. An assessment of rainfall data for this event has been analysed further so that comparison between the predicted flood scenarios and the observed extents of flooding could be made.

Contemporary accounts of the sequencing of flooding have been provided by members of Keswick Flood Action Group (KFAG). Photographs of this event have also been provided by the FAG, Figure 4-1.

Figure 4-1: Flooding November 2009 (Photos provided by KFAG)

4.1.1 Rainfall analysis

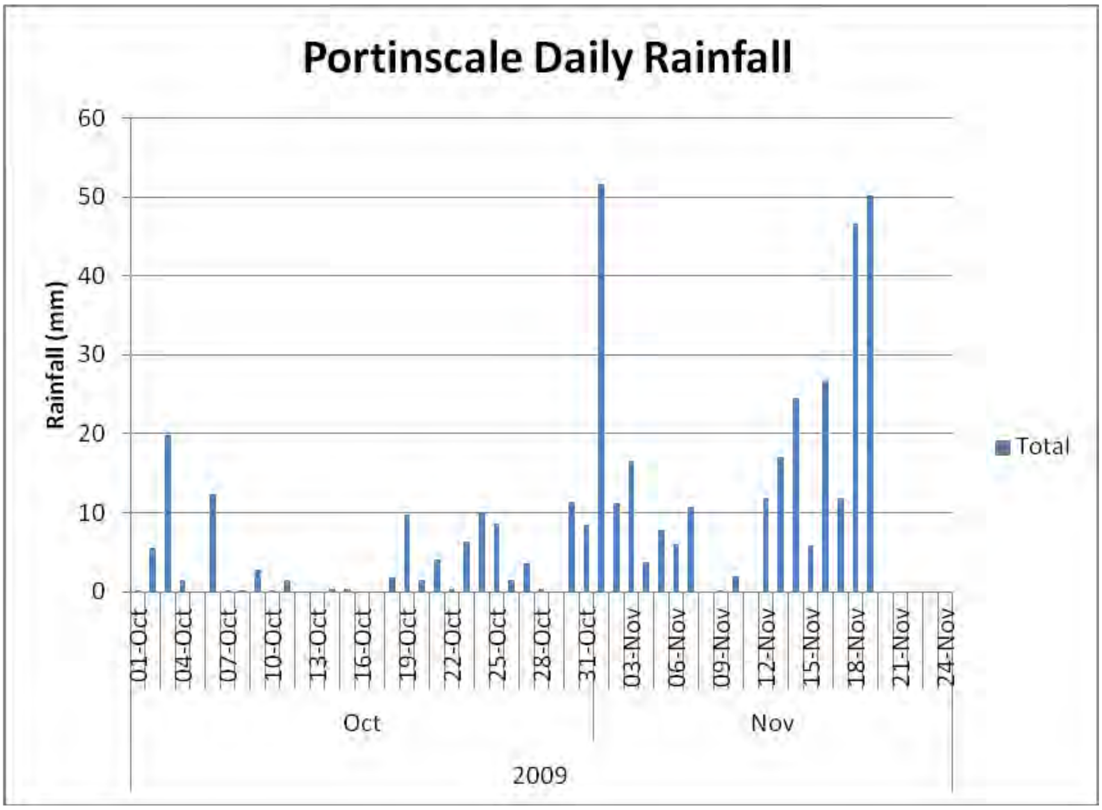
Gauged 15 minute rainfall data was obtained from the Portinscale Tipping Bucket Rainfall gauge for the November 2009 event. Portinscale is located approximately 1.5km to the West of Keswick at a similar elevation and the site is sufficiently close to Keswick to be representative of the rain that falls in Keswick itself.

In total 417mm of rain fell between the beginning of October and the 19th of November 2009 resulting in very wet antecedent conditions and, therefore, high runoff values. The gauged daily rainfall totals for Portinscale for this period are shown in Figure 4-2.

However, the gauged data for the 19th of November is described as suspect. A total of 50.2mm of rain is recorded between midnight and 10am on the 19th of November. Then the gauge seems to stop recording with no more rain recorded until the 1st of December.

In contrast, a private gauge in Portinscale[1] recorded 111.3mm of rain on the 19th of November and the preceding days of data correlate very well with the official gauged data received. In addition the met office reports 107.8mm of rain falling in Keswick for the 24 hour period between 8am on the 19th and 8am on the 20th of November[2] a time period for which the received gauge data only records 17.4mm.

Figure 4-2: Portinscale Daily Rainfall



Due to the unreliability of the gauged data it cannot be used to accurately replicate the observed flooding that occurred in Elliot Park in November 2009. The alternative rainfall data that has been obtained is only reported on a daily basis and is, therefore, not to a high enough resolution to be used in the modelling. The intensity of the rainfall over shorter time periods is not known.

Depth Duration Frequency analysis of a 24 hour storm total of 111.3mm (as recorded by the private Portinscale gauge) gives a return period of 1 in 20 years. Whilst the total rainfall is greater than the 1% AEP 6 hour event storm depth of 76mm, it occurred over a much longer period. The intensity is, therefore, likely to be much lower. Rainfall should have been conveyed within the urban drainage system, provided that free discharge was achievable.

In order for the observed flooding to have been caused from surface water runoff it seems that either the urban drainage capacity is lower than assumed, or it was already near to capacity from previous rainfall events. However, based on anecdotal accounts and email records held by KFAG river levels were high and this would have prevented the outfalls from discharging surface water into the river.

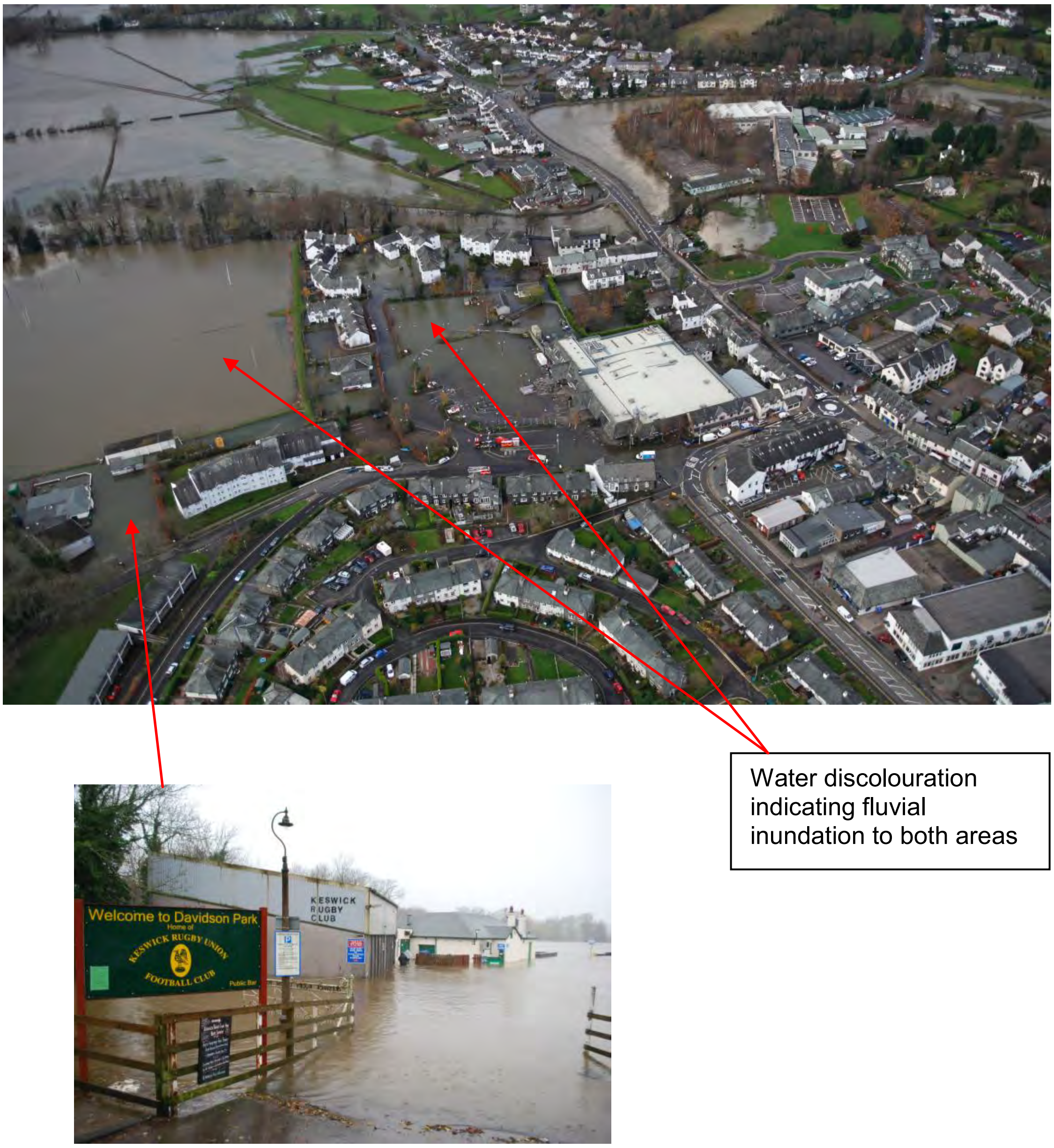
Based on the available rain gauge data, surface water inflow was insufficient to cause the extensive flooding during this event. Again contemporary records demonstrate that residents were aware of manhole capacities being exceeded at earlier stages of the flood event, indicating that river levels were sufficiently high to prevent effective discharge.

Water levels for the river during the 2009 event are available for Greta Bridge gauging station, located approximately 150m upstream from Elliot Park. The peak water level exceeds 79mAOD and is the highest level ever recorded at the gauge. ISIS modelling undertaken following the event supports the observed water levels.

[1] http://www.lakedistrict-weather.co.uk/monthsums/2009/11-2009.html
[2] http://www.metoffice.gov.uk/news/releases/archive/2009/heavy-rain-and-gales

In contrast, ground levels in Elliot Park are in the region of 77.3m AOD, which indicates the vulnerability of the area to fluvial inundation. River levels rose until the estate was inundated by the river. Once this happened the impact of surface water inflow and sewer exceedance of the UU system cannot be determined with any significant level of certainty.

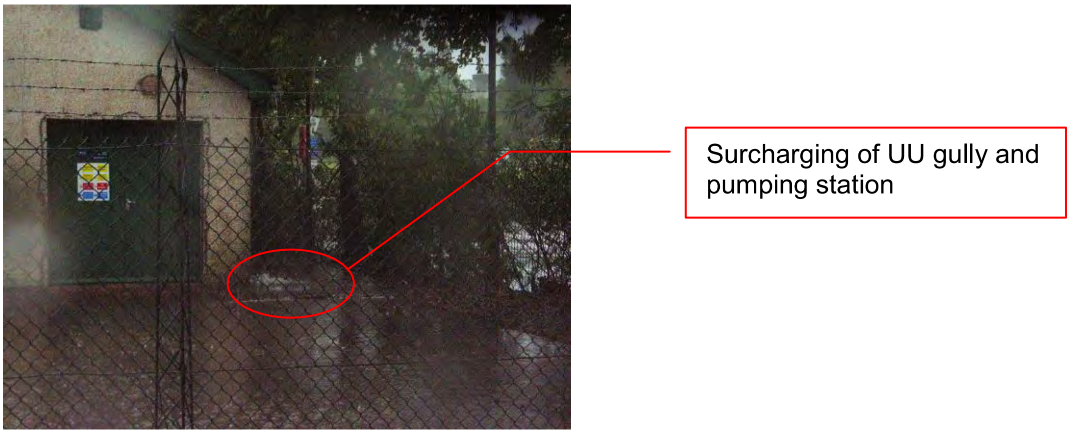
Figure 4-3: Flooding November 2009 (Photos provided by KFAG)



4.2 June 2012 and New Year 2013

As well as a numerous photographs of manholes surcharging within Elliot Park, which again demonstrates that the outfall is constrained by river levels, residents have also been able to provide photographs demonstrating surcharging of UU assets such as the gully connection for the existing pumping station. Whilst we understand that this should be resolved by UU's current upgrade work it does provide documented evidence that the existing UU system has contributed to surface water flooding at Elliot Park in the past.

Figure 4-4: Surcharging of gullies on UU system



5 Review of CCTV

5.1 Available information

Cumbria County Council have undertaken Jetting and CCTV surveys of the Elliot Park drainage system in order to confirm its condition and to ensure there are not significant structural or blockage issues that could impede discharge.

Having reviewed the CCTV footage, the existing system is generally in good condition. Provided that the flapped outfall is not submerged then the system will drain by gravity.

The EA have also confirmed that all outfalls are fitted with flaps to prevent direct inflow from the River Greta.

6 Review of Options

6.1 Developing options

There are numerous options and scenarios affecting flood risk at Elliot Park, these are based on the historical flooding from either the River Greta, the UU historical surface water system and overland or surface water flood risks.

Various combinations of flood risk, including low and high river levels, sewer capacity exceedance and a variety of pluvial events; combine with Elliot Park's vulnerable location to result in numerous scenarios.

River defences have been improved by the EA to a 75 year standard and UU has also invested in significant improvements to the local infrastructure. However, without knowing what excess capacity has been built into the sewer system it is difficult to quantify the resultant impacts, if any, in terms of a reduction in flood risk at Elliot Park. As a result surface water inflow (pluvial flooding) has been assessed for a range of events. The impacts of which will invariably exceed the capacity of the existing highways network at Elliot Park during high intensity rainfall events (particularly when the outfall is river locked by the Greta).

Being at the low spot within Keswick, and located behind the Greta flood defences, options for Elliot Park need to include for significant levels of uncertainty, including scenarios where the river is in flood or alternatively when free discharge to the river can be maintained.

Following our initial review of potential surface water flooding we have assessed available outline options to mitigate flood risk. Potential options depend on a range of factors including flood storage connectivity, available land and space, and anticipated mitigation costs.

It should be noted at this stage that, as demonstrated by the 2009 event, Elliot Park was at risk from fluvial inundation irrespective of surface water risks. Options may result in a reduction in the frequency of flooding, but they cannot prevent flooding and all stakeholders need to be aware of this.

It should also be noted that whilst the UU upgrade will result in a more efficient system, the surface water network is still likely to surcharge during high intensity events. This may potentially increase discharge rates to the area, increasing the required volume of storage or alternatively the required pumped discharge rates.

Options for Elliot Park are, therefore, based on the anticipated volume of surface water that results from exceedance flows from the surrounding local catchment only. They are also based on the assumption that outfalls to the River Greta are tide locked for the duration of the event and that the UU system is capable of discharging throughout a flood event.

The biggest constraint to managing surface water flooding is the potential volume that would required to mitigate flood risk. In accordance with Table 3-1 a potential surface water volume of 2500m3 is representative of both a 2% AEP and 1% AEP events with a 6 hr duration. A peak inflow rate for surface water exceedance flow is approximately 500l/s. It should be noted that this does not include allowance for additional surcharging from UU system.

6.1.1 Option 1: SUDs and attenuation

The area surrounding Elliot Park is located within the EA defined Flood Zone 3. Unsuitable conditions and a lack of available permeable land (presuming vast areas of the Rugby field remain unavailable or are unsuitable for use for attenuation). Ground water levels adjacent to the river are likely to be shallow and hence, this approach is considered unfeasible.

Attenuation would also only provide a finite volume in terms of storage and the provision of attenuation does not include allowance for uncertainty, any variations in the functional capacity of the enhanced UU system.

6.1.2 Option 2: Flood attenuation within the Mill Leat

This option considers using the Mill Leat, which runs parallel to the River Greta, to manage surface water flooding. The Council has proposed the use of an attenuation tank within the Mill Leat as a means of attenuating flood water from the Elliot Park area.

The Mill Leat is located adjacent to the River Great and extends for a distance of approximately 250m. The Mill Leat is located within the EA's designated Flood Zone 3 area (Figure 6-1). The River Greta itself is located within a Special Conservation Area (SCA) and the boundary of the SCA falls between the river and Mill Leat (Figure 6-2).

Figure 6-1: Flood Zone extent 2009 - (Photos provided by KFAG)

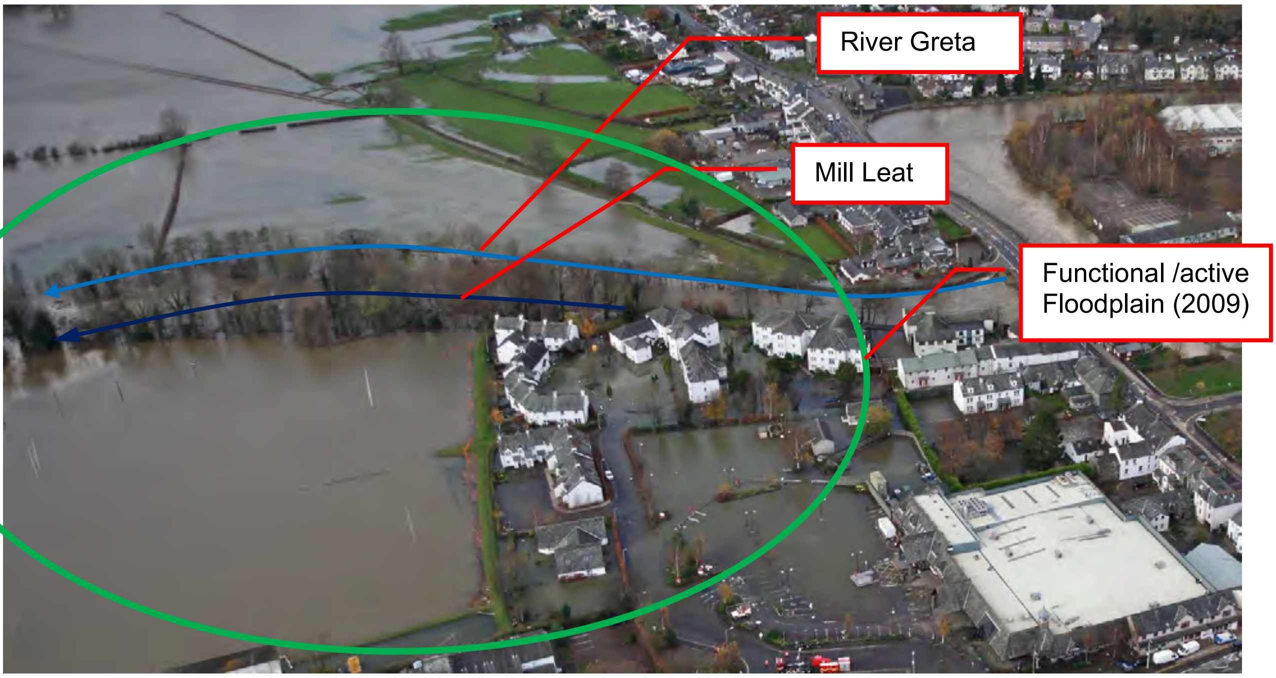
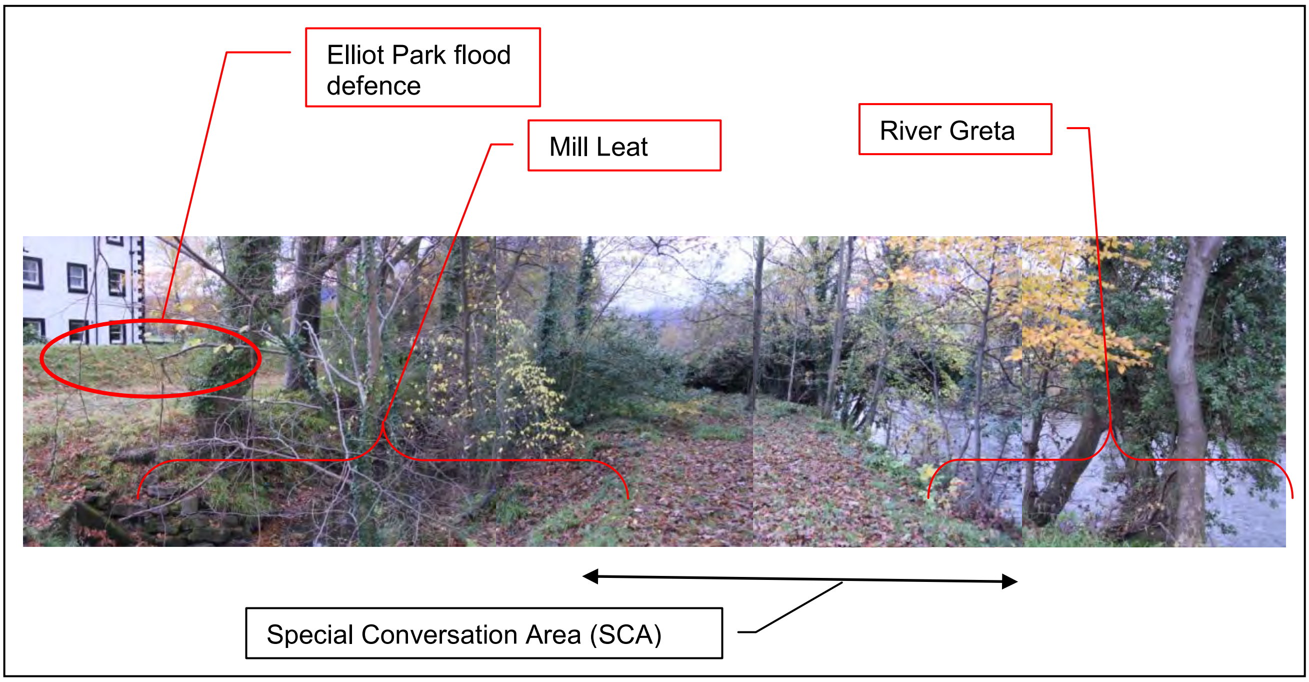


Figure 6-2: Mill Leat and the River Greta at Elliot Park



The Mill Leat is lined with trees and provides existing flood storage to the river. Infilling the leat would, therefore, reduce the available flood storage capacity of the river corridor. Without providing compensatory storage, this approach would, in itself, be unacceptable to the Environment Agency.

The leat is lined with established trees and we understand from the Council that the leat is not located within the SCA itself. The boundary of the SCA is defined by the dividing strip of land located between the leat and the river channel (Figure 6-2). However, removal of established trees, combined with excavation of the leat itself with installation of very large attenuation tank, is likely to encounter in-depth scrutiny and criticism at planning stage. The Council would, therefore, need to first confirm the likely implications on habitat and on the SCA prior to considering this option further.

Despite this, excavating the leat and installation of a surface water attenuation tank along its length can only ever provide a finite volume of storage. This, in itself, results in significant residual risk to Elliot Park as discharge will again be restricted. This risk is compounded by the combined uncertainty relating to the restricted fluvial defence level, to exceedance/operational capacity of UU's updated system and overland flow routes to Elliot Park.

Based on the observed size of the Mill Leat, the depth of potential storage would need to be restricted to an approximate depth of 1m so that an outfall from the attenuation tanks could be achieved without surcharging the Elliot Park highway drains. The Mill Leat is between 2 to 3m wide (assuming trees are removed). The length of attenuation could potentially extend for approximately 200m and attenuation at this scale could provide an approximate storage volume of 500m3. In accordance with Table 3-1 a potential surface water volume of 2500m3 is representative of both a 2% AEP and 1% AEP events with a 6hr duration. The difference between the available and required flood storage volumes demonstrates that there remains a significant residual risks associated with this approach.

As indicated by Figure 6-1 flooding from the river has the potential to significantly curtail discharge capacity. This is primarily based on the knowledge that the existing outfalls become periodically surcharged by the river. Evidence based on historical photographs of flooding (Figure 6-2) also indicates that the discharge potential for any attenuation tank within the Mill Leat will be primarily depend on river locking of any outfall.

Attenuation would also only provide a finite volume of storage and the provision of attenuation does not include allowance for uncertainty, any variations in the functional capacity of the enhanced UU system.

Figure 6-4: Out falls at the upstream extent of the Mill Leat

6.1.3 Option 3: Pumping

This option could see the construction of a pumping chamber within the existing car parking area. This option could provide practical flood mitigation, provided that fluvial levels do not exceed defence levels. Whilst temporary pumping measures may continue to be used they are unlikely to provide a suitable standard of protection and a reliance on the fire brigade and standby pumping appliances will continue to be required.

Temporary Pumping

UU have two temporary pumps installed at Elliot Park for the duration of their construction scheme (Figure 6-5). These temporary pumps provide limited discharge from the lowest manhole within the estate to the river. On completion of the UU scheme it is understood that these pumps will be removed.

The Council is currently investigating the requirements for continued temporary pumping, including replacement of the current temporary pumps and a continued reliance on high capacity appliances during flood events. The trigger level for temporary pumping will remain emergence of flood water from manholes within Elliot Park.

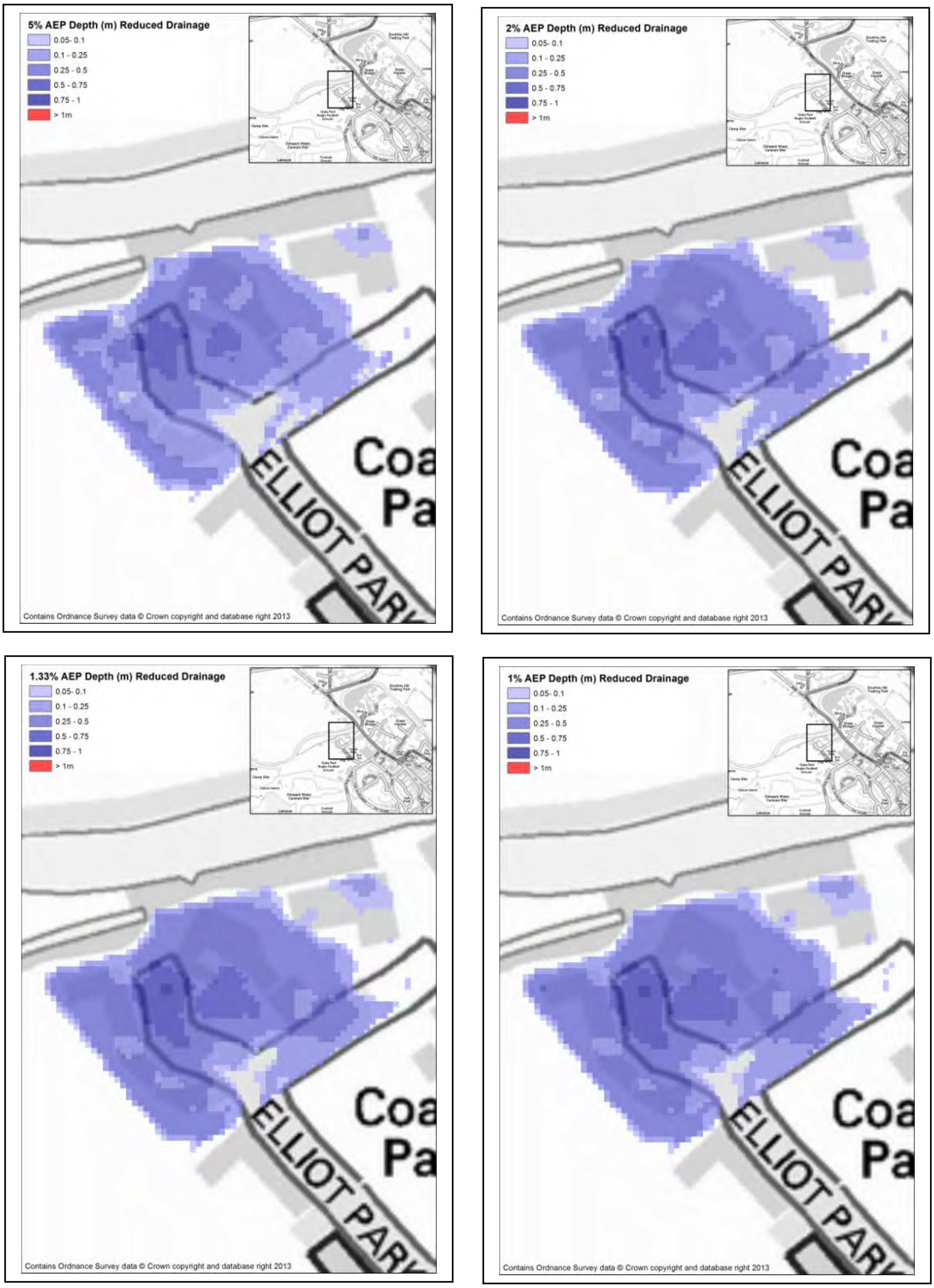
Figure 6-5: Existing temporary UU pumps

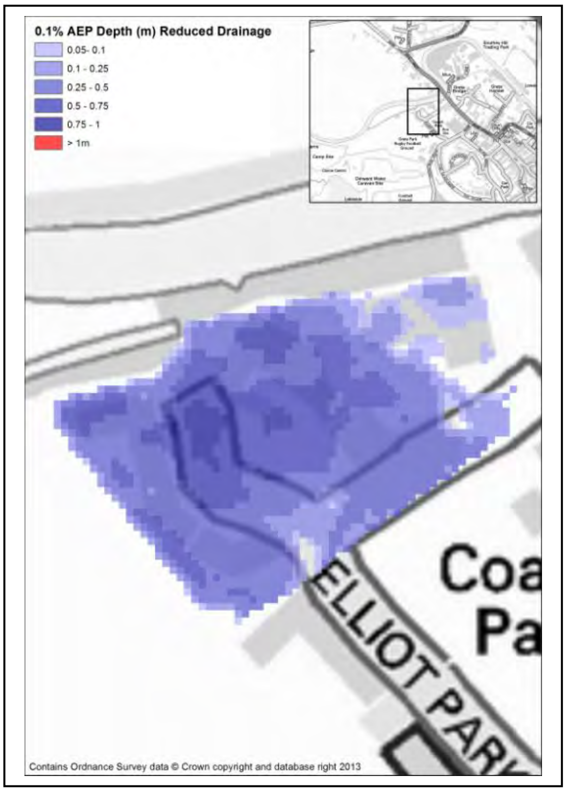
Baseline/do minimum scenario

In order to understand the impact of temporary pumping on flood extents a series of flood outlines/depth maps have been generated to represent a do minimum scenario in which temporary pumping of 100l/s is maintained during a 1 in 20yr, 1 in 50 yr, 1 in 75, 1 in 100 and 1 in1,000 return year events (5%, 2%, 1.33%, 1% and 0.1% Annual Exceedance Probabilities (AEP) Figure 6-6). Outlines are based on elevated river levels (but no fluvial inundation) with allowance for the UU drainage network. (It should be noted that the flood extents have been cropped to enable easier comparison and do not necessarily represent the limit of flood risk).

Flood outlines for all events indicate significant residual risk despite continued temporary pumping. For this reason a higher capacity permanent pumping station will need to be considered that has sufficient capacity, to manage flood risk and uncertainty at this location.

Figure 6-6: Do minimum flood depths (5%, 2%, 1.33% 1% and 0.1% events) assuming temporary pumping of 100l/s





6.1.4 Uncertainty and Climate Change

A review of the likely impact of climate change has also been undertaken based on the EA's available river model. We understand that the existing EA flood defences have been designed to a 75 year standard. Water levels that exceed this design flood level will result in fluvial inundation to Elliot Park. In this eventuality any proposed surface water mitigation measures will also fail as there will be no spare capacity within the river corridor and floodplain to store or discharge surface water.

In accordance with Table 6-1, the current 75 year standard on the river at Elliot Park equates to a design flow rate of 220m3/s and a flood level of 78.24m AOD. Based on a predicted 20% increase in flow rate due to climate change, then the future standard of the existing defence at this location is likely to only be equivalent to a 25 year standard.

Table 6-1: Depths and volumes within Elliot Park for a variety of modelled events

Fluvial Return period (yr)	2 (50% AEP)	5 (20% AEP)	10 (10% AEP)	25 (4% AEP)	50 (2% AEP)	75 (1.33% AEP)	100 (1% AEP)
EA ISIS modelling Model Node Gret01_0630	Flow 107m3/s Level 77.86m	Flow 131m3/s Level 78.01m	Flow 158m3/s Level 78.11m	Flow 187m3/s Level 78.18m	Flow 207m3/s Level 78.22m	Flow 220m3/s Level 78.24m	Flow 229m3/s Level 78.25m
EA ISIS modelling + 20% climate change Model Node Gret01_0630	Flow 128m3/s	Flow 157m3/s	Flow 190m3/s	Flow 224m3/s	Flow 249m3/s	Flow 264m3/s	Flow 275m3/s

Initial cost estimate - pumping station

The following initial cost estimate is based on a design pumping rate of 500l/s. Ideally a 3 pump configuration, standby-duty-assist, would be implemented to ensure that 2 pumps are available are all times. Each pump has an assumed capacity of 250l/s with the additional discharge capacity available as a result of the inherent uncertainty of the UU, surface water and fluvial risk scenarios. Pumps would need to operate continuously against the static heads varying from approximately 1m to 3m.

Construction of a pumping station would probably need to be located within the car parking area as this appears to be the only location within Elliot Park where there is sufficient room for development.

Pumping station and the associated construction works are subject to future detailed design. A typical sump size of 4m by 4m would be required for a series of 3 pumps (based on an approximate capacity of 700l/s). The visible pump building may be of a similar size and electrics/controls will need to be set at a higher level than the flood bund to ensure pumps remain operational.

It is unlikely that pumps will be adopted by UU and Cumbria County Council will need to consider ongoing maintenance requirements. (Note: maintenance costs have not been included for in the outline construction cost estimate and cost benefit below).

Outline construction costs are based on similar pumping schemes, however, the costs included for are subject to detailed design at this stage. A significant contingency would usually be applied at this preliminary feasibility stage especially as in this instance there are some significant cost uncertainties, such as provision of a suitable electrical supply to the pumping station and pump optimisation and configuration.

6.1.5 Outline construction cost estimate

M&E costs	£ 80,000
Civil costs	£250,000
Drainage infrastructure	£ 35,000
Design and planning	£ 25,000
Total	**£390,000 + contingency allowance**

6.2 Cost benefit analysis

In addition to understanding the scale and source of flooding, a cost benefit analysis will be required. At this stage we will need to assume that fluvial risks are effectively managed by the EA's FAS, and that the UU system upgrade will effectively mange sewer flows. It is assumed that damages are based surface water flooding only.

To apply for FDGiA, Defra’s Partnership Funding Calculator needs to be populated so that the amount of grant potential available can be identified. This does not guarantee the funding but estimates the maximum that would be offered based on the scheme benefits. In order to release the funding, the Partnership Funding (PF) score needs to exceed 100%. The PF score is calculated based on the scheme costs, benefits and the amount of outside funding available. This analysis is based on our best estimate to date. Outcomes will need to be reviewed and refined by the Council and EA as the potential scheme develops.

In order to justify public spending on flood defence schemes, there needs to be a high proportion of flood benefits (damages avoided) compared to scheme costs. The flood benefits have been calculated using flood depth grids (for the full range of return periods), the national receptor dataset property points and MasterMap building polygons. Depth damage calculations are made with ArcGIS using standard Multi Coloured Manual value for different property types.

An initial Cost Benefit Analysis has been developed, assuming Grant-in-Aid criteria. We have based this initial assessment on the outputs from the existing risk and TuFLOW models to estimate Annual Average Damages (AADs). Undertaking an initial appraisal at this stage will allow options that are likely to be financially viable, to be compared. If the outcome measure (OM) scores are very low, the scheme is unlikely to attract any FDGiA, especially with the current limits on government funding. If this is the case, then it will be uneconomical to undertake a full Project Appraisal Report, based on modelling and full economical appraisal.

If the scheme is unlikely to attract FDGiA but the case for a scheme is still strong, it could be funded through local levy, funding through the RFCC, especially if supplemented with other partnership funding sources. Current time frame for GiA projects is June 2013 and possible in year funding opportunities may also be explored with the EA.

In this instance, based on a cost of £390k the partnership funding score is 93%. Maximum funding of £366k would be available if the rest of the funding could be found elsewhere.

The partnership funding score is based on 41 ground floor properties in Elliot Park which, according to the National Receptor Database comprise:

- 19 properties: Definite ground level
- 22 properties: Potential ground level
- 25 properties: Potential upper (i.e. upper floor)

Completion of the EA's flood defence scheme in Keswick may not have included the surface water risk to Elliot Park. This means a strategic approach may not have been undertaken and that double counting of benefits has not been avoided. The FDGiA contribution may, therefore, be reduced to 45% of total scheme cost giving a maximum funding of £176k. The specific requirements for FDGiA funding calculator need to be refined by the Council and EA.

No contingency cost have been included for at this stage.

7 Summary

The residential development at Elliot Park in Keswick has a long standing history of repeated internal flooding. The site is located at the lowest point within the town centre, and is sited behind the engineered flood embankments that form the Environment Agency's flood defence for the River Greta.

There are three primary sources of flooding at Elliot Park, these comprise;

- Surface water flooding, which results from overland runoff from a topographically driven catchment;
- Fluvial flood risk, which stems from the River Greta; and,
- Surcharging of the UU combined sewerage system at Elliot Park. (UU have confirmed that the network upgrade will prevent similar sewer exceedance at Elliot Park in the future).

The purpose of this appraisal was to identify the mechanisms of flooding at Elliot Park and quantify surface water flood risk and the volume of surface water that would need to be effectively managed, by pumping or attenuation for example, so that risk can be reduced to an acceptable level.

In order to do develop a detailed understanding of surface water interactions a 2 dimensional direct rainfall TuFLOW model of the study area has been developed. Modelling has been used to identify the extent and depth of surface water flooding according to a variety of design rainfall events. The model has been designed to identify the extent and quantify the likely volumes of surface water flood risk to the area.

The anticipated depths and volumes of surface water within Elliot Park are sensitive to the volume of water entering the model. However, flooding is also dependent on the discharge scenario used to allow surface water to discharge into the river. Closing of the flapped outfall by high water levels effectively prevents a gravity discharge to the river, resulting in ponding, to significant depths, behind the defence.

Residual risks cannot be considered in isolation. Whilst fluvial risk may be controlled, to some extent, by improvements to the EA's Flood Alleviation Scheme (FAS), the risk of surface water flooding remains dependent on the interaction with river levels.

Expectations will need to be carefully managed as flood risk may only be controlled and not eliminated. The scale of any further investment will also need to be commensurate with the extent of the likely damages.

Options for managing flood risk are limited by the anticipated volume of surface water that can flow into Elliot Park. Options are also based on the assumption that outfalls to the River Greta are tide locked for the duration of the event.

The biggest constraint to managing surface water flooding is the potential volume of surface water requiring either attenuation or pumping. In accordance with Table 3-1 a potential surface water volume of 2,400m3 to 2,500m^3 is representative of both a 2% AEP and 1% AEP events with a 6 hour duration. A peak inflow rate for surface water exceedance flow is approximately 500l/s.

An initial cost estimate has be developed based on the construction of a pumping station. This is considered the only viable approach to managing flood risk at this difficult location. The initial cost estimate is based on 3 pump configuration, standby-duty-assist. Each pump has an assumed capacity of 250l/s

The FDGiA, Defra's Partnership Funding Calculator has been populated so that the amount of grant potential available could be identified. The outcome measure (OM) score is low, and the scheme is unlikely to attract any FDGiA funding.

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