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The impact on the Chapelton Spring of the Burn of Mosset Flood Alleviation Scheme

Groundwater Programme

Commissioned Report CR/11/129

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BRITISH GEOLOGICAL SURVEY

GROUNDWATER MANAGEMENT PROGRAMME

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The impact on the Chapelton Spring of the Burn of Mosset Flood Alleviation Scheme

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New sealed pipes from Spring 1 and Spring 2 going to the Benromach distillery

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Contents

FIGURES

TABLES

1 Introduction

1.1 THE BRITISH GEOLOGICAL SURVEY

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and the United Kingdom's premier centre for earth science information and expertise. As a public sector organisation BGS is responsible for advising the UK government on all aspects of geoscience as well as providing impartial geological advice to industry, academia and the public. The BGS is part of the Natural Environment Research Council (NERC), which is the UK's main agency for funding and managing research, training, and knowledge exchange in the environmental sciences. The NERC reports to the UK government's Department for Business, Innovation and Skills.

Dr Alan MacDonald is a principal hydrogeologist and has worked with BGS for 19 years. He is a Charted Geologist, Fellow of the Geological Society of London and Member of the International Association of Hydrogeologists. Dr MacDonald has worked extensively on Scottish groundwater issues advising SEPA, the Scottish Government, Scottish Water and local councils on groundwater development and management. He has published 2 books, 40 scientific papers and more than 100 BGS Technical Reports.

1.2 BGS'S INVOLVEMENT IN THE BURN OF MOSSET FLOOD ALLEVIATION SCHEME

BGS were first involved in the Burn of Mosset Flood Alleviation Scheme (FAS) in 2005 when they were commissioned by Moray Flood Alleviation (MFA) to investigate the source and chemistry of water for the Benromach distillery which was poorly understood by all parties at this time. This work was carried out collaboratively with Gordon & MacPhail and together the series of pipes and ditches which made up the spring supply were identified (CR/05/65C).

A detailed investigation programme was undertaken in 2006 to collect new geological, hydrogeological and chemistry data for the area, investigate the spring supply and to use these data to model the impact of the FAS on groundwater and the existing network of springs and drains (CR/06/130C).

During 2005 and 2006, BGS also oversaw the drilling and testing of a potential standby borehole supply for the Benromach distillery, and concluded after testing that it was not a reliable alternative (CR/05/216C, CR/06/132C).

BGS were involved with the Public Local Inquiry in 2006 and provided advice to improve the general standard of the spring supply and to estimate the impact of flooding on the spring network. Agreement was reached with Gordon & MacPhail to modify the scheme to give protection to a portion of the Chapelton Spring for an event of return period up to 1 in 66 years. This part of the spring network is now known as Spring 1.

In 2011, BGS were commissioned by MFA to develop a groundwater model to specifically represent flows in the Benromach Spring 1 in response to an overtopping event (i.e. an event of magnitude greater than 1 in 66 years). This was in response to the hydrological claims by AMEC, based on an interpretation of the initial BGS data and general 2006 model and used by Gordon & MacPhail in their claims for compensation (Salmon 2011).

In addition to the direct involvement with the Chapelton Moss study, BGS hydrogeologists and modellers have worked on other aspects of the hydrogeology in the Forres area including the impact of flooding in Pilmuir (CR/08/023), the hydrochemistry of the Devonian Sandstone aquifer (OR/10/031).

1.3 ISSUES ADDRESSED

This report addresses the following issues, based on the original BGS investigations in 2005 and 2006, the data supplied by Gordon & MacPhail and the specific groundwater modelling of the spring response carried out in 2011:

- The general hydrogeology of the Chapelton area.
- The spring system prior to the scheme.
- The impact of flooding and heavy rainfall on spring flows and electrical conductivity of the spring water, prior to the scheme.
- The spring network after the scheme was constructed.
- The impact of heavy rainfall on spring flows and electrical conductivity in Spring 1, after modifications to the spring and the construction of the Flood Alleviation Scheme.
- The impact of a 1 in 100 year flood event[1] (which overtops the embankment) on spring flows and electrical conductivity in Spring 1, after modifications to the spring and the construction of the FAS.
- The report concludes by estimating the additional length of time that the conductivity of Spring 1 is likely to be below 675[2] µS cm^{-1} following a 1 in 100 year flood event, compared to a similar flood event prior to the construction of the scheme.

1.4 SOURCES OF INFORMATION

In addressing these issues two main sources of information have been drawn on:.

1. The extensive ground investigations undertaken by BGS in 2005 and 2006 and reported in CR/05/65C, MHHG/05/12, CR/06/130C, CR/05/216C and CR/06/132C.
2. The results of a numerical groundwater model designed in 2011 specifically to represent the springflows before and after the construction of the scheme. This new model was constructed because the original modelling work undertaken in 2006 was designed to examine the groundwater behaviour of a much larger area, only represented conditions prior to the construction of the scheme, and was not focussed on detailed representation of Spring 1. The detail of the groundwater model is reported separately in CR/11/130.

A groundwater model represents the hydrogeology of an area numerically, thus enabling the conceptual understanding to be tested and the impacts of different scenarios to be investigated. Groundwater modelling is an internationally recognised method within the scientific field of hydrogeology and is widely used in a range of sub-disciplines of hydrogeology. Within the UK, there has been a long history of the use of groundwater models and within the last decade the Environment Agency of England and Wales, Scottish Environmental Protection Agency (SEPA) and water companies have all relied on them to help understand water resource issues.

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[1] A 1 in 100 year flood event was agreed with AMEC as an appropriate flood event to examine.

[2] 675 µS cm^{-1} is the conductivity that Gordon & MacPhail have stated is the minimum they can operate with for extended periods.

2 The hydrogeology of the Chapelton area

The understanding of the hydrogeology of the area draws on investigations carried out by BGS in 2005 and 2006. There is general agreement between AMEC (Salmon, 2011) and BGS regarding these data and the conceptual model. The setting of the Chapelton area is shown in Figure 1 and a simplified cross section of groundwater flow in Figure 2.

There are two main aquifers below Chapeltonmoss: the deeper Devonian Sandstone aquifer overlain by a shallow unconsolidated sand and gravel aquifer. The underlying Devonian bedrock comprises medium-grained sandstone and forms an important regional aquifer in the area. Across Chapeltonmoss, the overlying superficial deposits generally comprise permeable sands and gravels. These deposits can be up to 20 m thick, but are more commonly 10 m thick in the lower lying areas. The sands and gravels are permeable with a transmissivity of 150 m^2/d measured around Wright's Hill. Peat deposits up to 1.5 m thick have developed in the low-lying areas (Figures 1 & 2).

Modelling of rainfall data has indicated that effective rainfall (rainfall minus evapotranspiration) is likely to be approximately 250 mm $year^{-1}$ (CR/06/130C) and is likely to have been higher in the past 2 years when rainfall has been 30 – 40% higher than the 1961-1990 mean. Since most of the catchment is underlain by highly permeable soils, much of the effective rainfall is likely to recharge the shallow aquifer. This is evidenced by the lack of development of natural streams and rivers in the area.

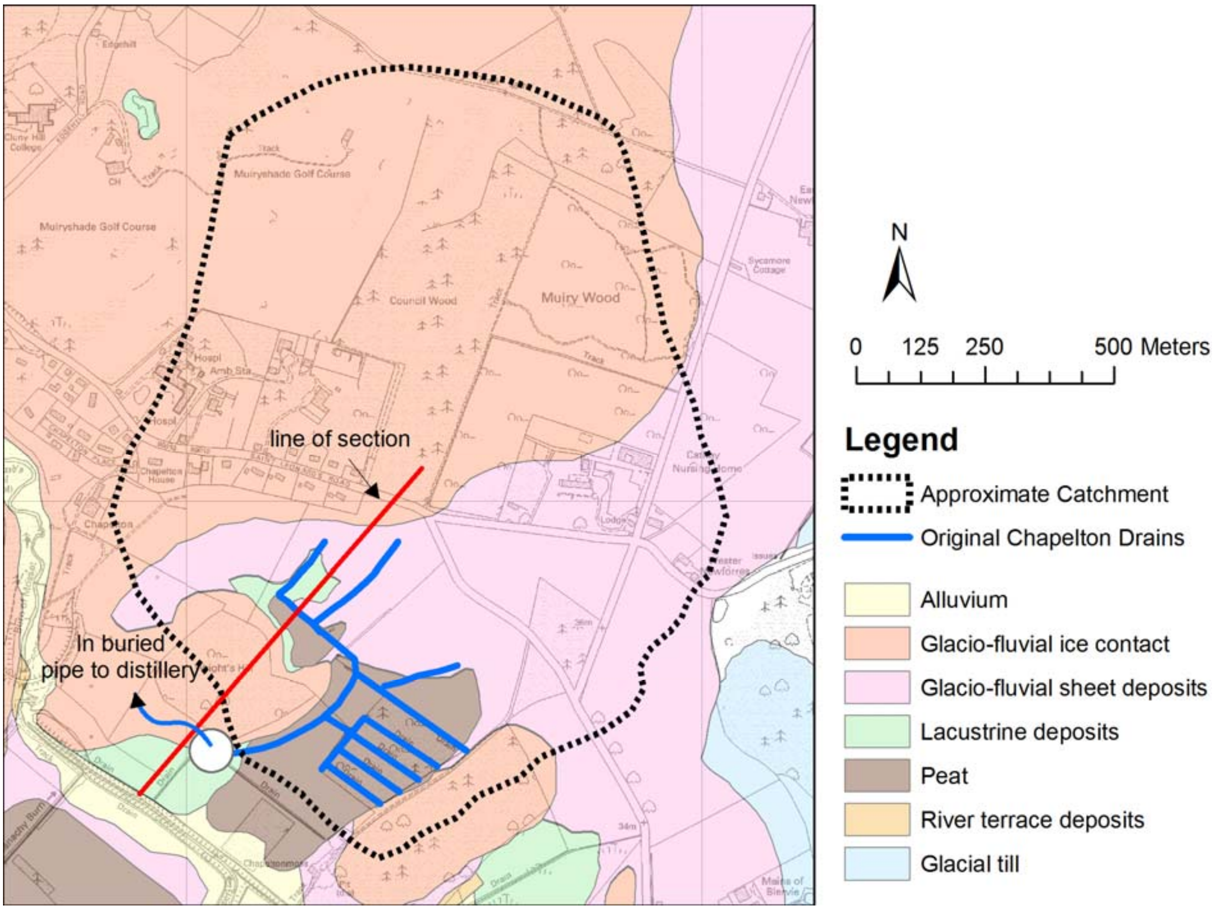

Figure 1 A map showing the setting of the original Chapelton Spring, with the superficial geology, the original drains and approximate catchment area for the Chapelton Spring system. The map also indicates the location of the cross section shown in Figure 2.

Groundwater flow in the superficial deposits in Chapeltonmoss is dominated by discharges to drains and ditches. Groundwater gradients are almost flat across the area, due to the high permeability of the sands and gravels; therefore groundwater gradients will not always reflect the same gradient as the topography, but rather will be dominated by the location and elevation of drains and ditches. Residence time indicators show that groundwater is young in the superficial deposits – less than 15 years old.

On the basis of observed distinctive chemistry, there appears to be little exchange of groundwater between the bedrock and superficial aquifer. Groundwater in the bedrock is weakly mineralised, dominated by calcium and bicarbonate ions and has pH of around 7.5. Groundwater in the superficial deposits has pH of around 6.5, is generally dominated by sodium and chloride and has greater mineralisation than the bedrock groundwater, expressed as a higher electrical conductivity.

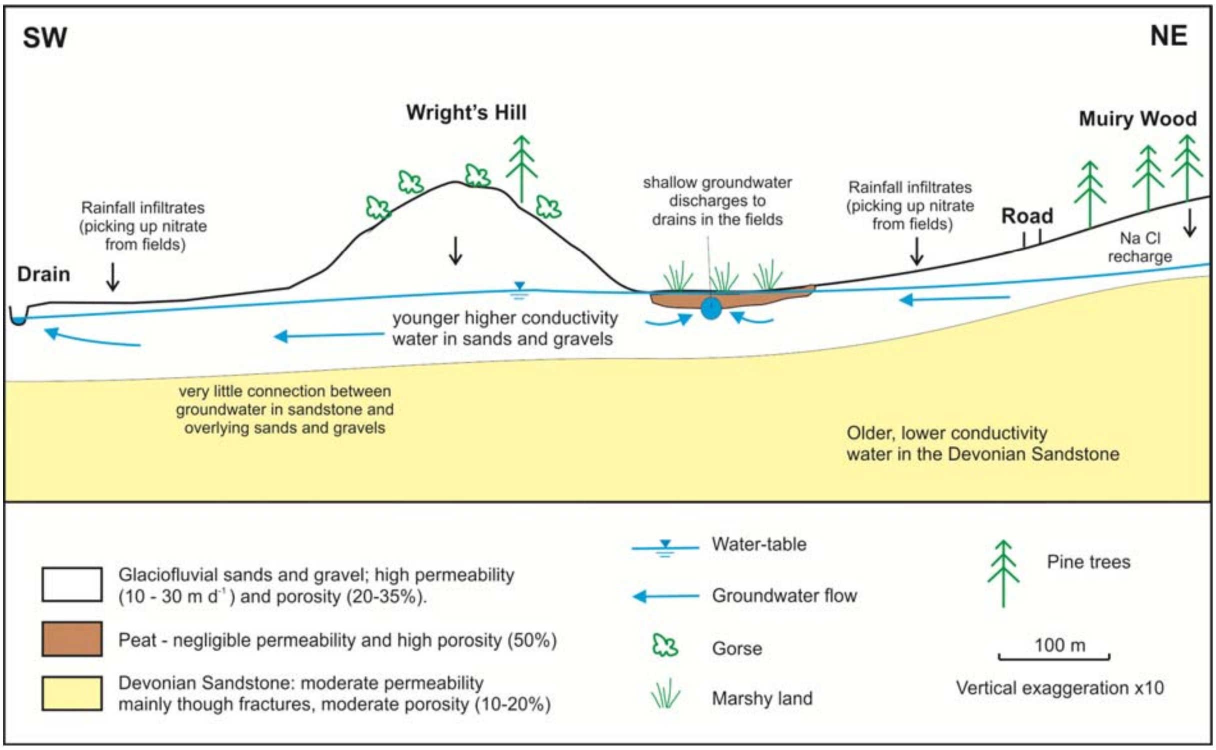

Figure 2 A schematic cross section of the hydrogeology of the Chapelton Spring area.

3 The spring system prior to the scheme

3.1 A DESCRIPTION OF THE CHAPELTON SPRING SYSTEM

The spring supply for the Benromach distillery prior to the Flood Alleviation Scheme (FAS) took the form of an intake at the outlet of a pipe discharging to a drainage ditch flowing to the Burn of Mosset. Little was known about the source of water prior to the investigations by MFA, BGS and Gordon & MacPhail in 2005 and 2006. Prior to the construction of the FAS, the outlet was fed from various shallow groundwater sources (springs) through a network of buried pipes and ditches that stretched across much of Chapeltonmoss (see Figure 1 and Figure 3). The overall flow was not monitored, but the flow rate arriving at the distillery was estimated by Gordon & MacPhail as between 2 and 6 l/s. Additional water would have discharged to the Burn of Mosset. The volume licensed by SEPA for abstraction by Benromach distillery is 1.2 L/s.

Figure 3 provides a map of the spring network, with photographs of various features. Below is a summary of information on the spring system prior to the construction of the FAS.

Flow is perennial from the spring drainage network. Although there are no quantitative data for annual flow from the spring system, Gordon & MacPhail indicate that there is perennial flow. The flow from the upper part of network (from the marshy area Figure 3) was estimated by field measurements to be 3 L/s by BGS on 8 June 2006 after seven months of low rainfall.

The major ion chemistry of the water from the spring drainage network was similar to that measured directly from groundwater in piezometers installed in the superficial deposits (CR/06/130C). Residence time indicators show that the shallow groundwater was young (< 15 years old).

Historical monitoring data on groundwater quality from the spring are lacking and the groundwater quality data are only available from Gordon & MacPhail on 6 occasions prior to 2004. However, the sporadic measurements that are available demonstrate high natural variability in major ion chemistry, reflected in the electrical conductivity (Table 1). Concentrations of minor elements have varied significantly, with iron frequently exceeding the Scottish maximum admissible concentrations for drinking water; nitrate concentrations are also high and variable, indicating contamination from fertiliser or possibly animal manure. The high degree of natural variability in chemistry from the spring reflects the natural mixing of water from recent rainfall events with groundwater in the superficial deposits.

Table 1 Measured electrical conductivity (EC) of the Chapelton Spring supply at the outlet.

Date	**EC (μS cm^{-1})**		**Date**	**EC (μS cm^{-1})**
06/09/1992	501		12/01/2005	687
17/09/1996	596		25/01/2005	722
05/08/1998	581		23/05/2005	751
09/12/1999	523		01/04/2006	770
13/02/2002	638		30/10/2007	866
26/03/2003	560		05/06/2008	735
06/07/2004	674		27/11/2008	734
17/11/2004	800		20/04/2009	688
03/12/2004	782			

Prior to the FAS, the Chapeltonmoss spring drainage network was highly vulnerable to contamination along much of its length. Of particular concern were the open ditches where grazing animals could directly contaminate the source, and the open marshy area which forms the headwaters for much of the flow (see Figure 3).

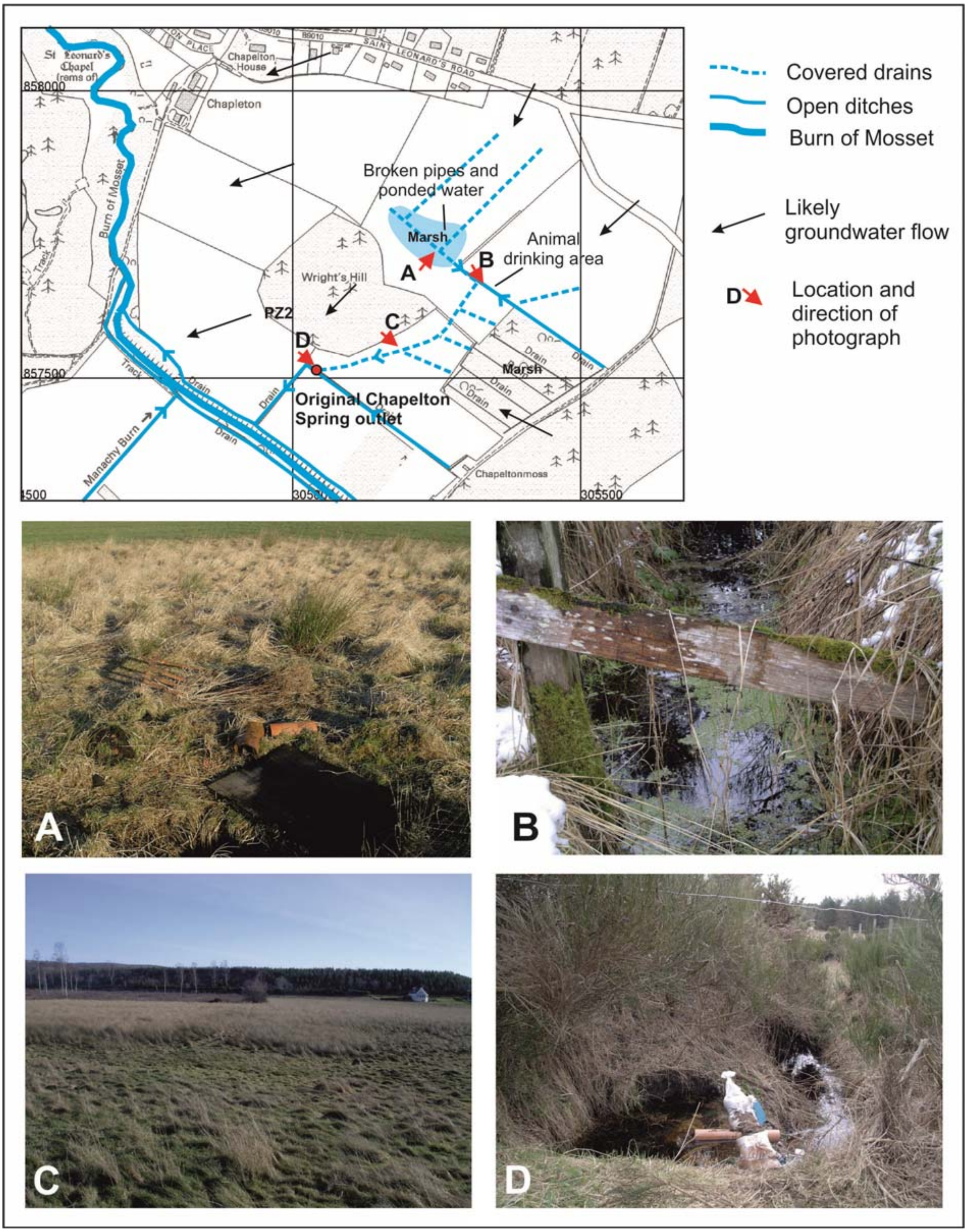

Figure 3 The Chapelton Spring system prior to the flood alleviation scheme. The letters on the photographs refer to locations on the map.

3.2 THE SPRING RESPONSE TO HEAVY RAINFALL

Rainfall events of greater than 30 mm appear to cause groundwater levels to rise, spring flow to increase and the electrical conductivity of the spring water to decrease. Measurements of groundwater levels in the Chapelton area during 2005 and 2006 showed an increase of 0.2 m in water levels in response to 7 days rainfall totalling greater than 50 mm. The bulk of the groundwater recession after heavy rainfall events took 2-4 weeks, with a long tail thereafter (CR/06/130C). Gordon & MacPhail noted that the spring flow increased after heavy rainfall and the water became cloudy (turbid) and unusable for several days after heavy rainfall. The farmer at Chapelton Farm indicated that marshy area would be flooded after heavy rainfall.

Heavy rainfall causing recharge of 43.5mm was simulated in the groundwater model[3]. This reproduced a rise of 0.2 m in groundwater levels observed in the Chapelton area (CR/06/130C). The modelled estimates of discharge from the old Chapelton spring system under these conditions increased from 7.6 L/s to 13.7 L/s followed by a rapid reduction in flow, again representing well the actual observations made by Gordon & MacPhail.

The impact of heavy rainfall on the electrical conductivity of the spring water was estimated by constructing a mixing model. This assumed[4] that the flow in the spring prior to flooding was groundwater with an electrical conductivity of 800 µS cm^{-1}. The additional flow in the spring caused by the flooding was assumed to come from the heavy rainfall or flooding. This additional input of water was given an electrical conductivity of 100 µS cm^{-1}. The mixing model then estimates electrical conductivity based on the proportion of floodwater and groundwater discharging through the spring network.

For a heavy rainfall event causing recharge of 43.5 mm, the groundwater model and mixing model indicate that the spring water would initially have an electrical conductivity of around 600 µS cm^{-1} after the heavy rainfall event. As the spring flows subside the electrical conductivity would rise to above 675 µS cm^{-1} after 30 days. This response represents well the observed natural variability of electrical conductivity observed in the spring system (see Table 1).

3.3 THE SPRING RESPONSE TO A 1 IN 100 YEAR FLOOD EVENT

Prior to the FAS a 1 in 100 year flood event would cause significant flooding to Chapeltonmoss. Figure 4 shows the likely flood extent from the Burn of Mosset overtopping its banks. There are no recorded data on the impact on the spring of a flood event of such magnitude, therefore the groundwater model has been used to simulate the likely response. The rainfall[5] required to generate a 1 in 100 year river flood event is at least 87 mm. However, much higher rainfall over 2 or 3 days may occur and not give rise to a 1 in 100 year flood event. For example: the rainfall for the flood event in 2009 was 93 mm for a 1 in 20 year river flood event; the rainfall for the 1997 flooding was greater than 130 mm;. Three different scenarios have been run and the results are shown in Figure 5:

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[3] The following sections include the results of the groundwater modelling undertaken to aid the hydrogeological understanding of the spring system and its response to heavy rainfall and flooding. The details of the modelling are described in a separate report (CR/11/130).

[4] The values of 800 µS cm^{-1} for groundwater and 100 µS cm^{-1} for floodwater were agreed with AMEC.

[5] A storm of 87 mm falling in 12 hours across the catchment was used in the initial design of the scheme to give flows that would represent a 1 in 100 year flood event

1. Only half the rainfall infiltrates (43.5 mm), the rest of the water runs off rapidly and discharges through the spring system within a few days. This conservative estimate would take the electrical conductivity of the water below Gordon & MacPhail's threshold of 675 µS cm^{-1} for 30 days.
2. All the rainfall infiltrates (87 mm). Spring flows would stay elevated for longer and it would take 100 days for the electrical conductivity to rise above 675 µS cm^{-1}
3. All the rainfall infiltrates (87 mm) and also a proportion of the inundated water infiltrates to the groundwater (0.15 m). Springflows increase rapidly initially to discharge the floodwater and the electrical conductivity would remain below the 675 µS cm^{-1} for 120 days.

The modelling results may help to explain the low electrical conductivity measurements in the Chapeltonmoss Spring between 1998 and 2005 which may be impacted by the flooding events area in this period which led to the construction of the scheme.

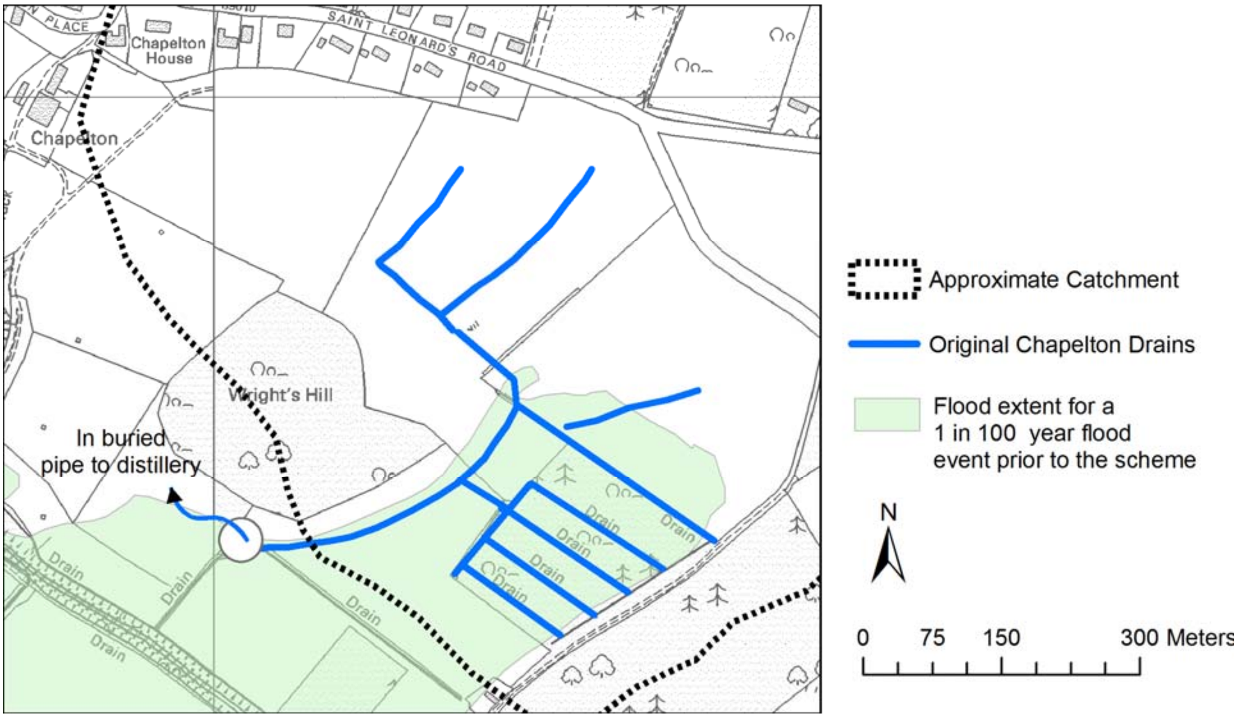

Figure 4 The pre-scheme extent of flooding from the Burn of Mosset for a 1 in 100 year extent.

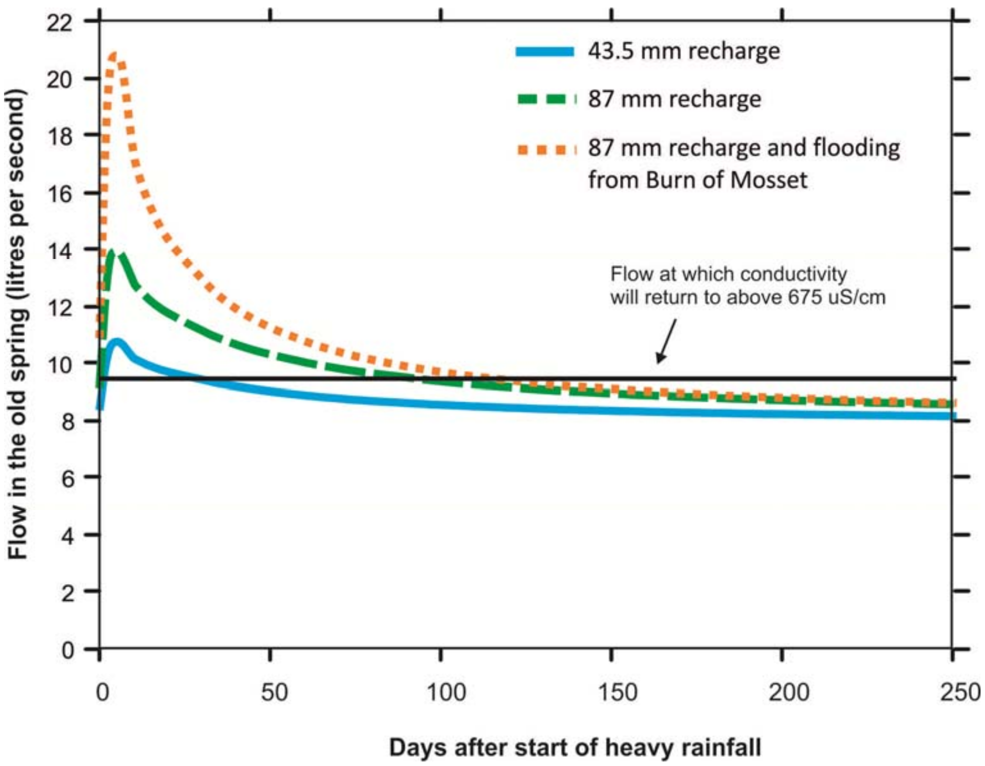

Figure 5 Spring flows in the old Chapelton Spring system in response to heavy rainfall and flooding prior to the FAS being built.

4 The spring system after the construction of the FAS

4.1 IMPROVEMENTS TO THE INFRASTRUCTURE

Figure 6 shows a schematic representation of the Benromach spring supply after the improvements made by Moray Flood Alleviation and the construction of the flood alleviation scheme. There are several modifications:

1. The supply now only comes from the upper catchment of the old system, further from the Burn of Mosset with separate pipes for Spring 1 and Spring 2. Spring 1 is the main supply giving approximately 2-5 L/s; Spring 2 gives less than 1 L/s.
2. Spring chambers have been constructed for Spring 1 and 2 and the pipes downstream of these chambers are sealed and flow under gravity.
3. An embankment has been constructed between the Spring 1 catchment and the Burn of Mosset with an elevation of 30 m which has been designed to protect Spring 1 from flood events with a return period of 1 in 66 years or greater.

The spring is now much less vulnerable to contamination and better protected from flooding. Direct inundation of the spring drainage network will not now routinely occur from flooding from the Burn of Mosset, and the spring is protected from direct contamination from animals and other sources.

Monthly measurements of the electrical conductivity of Spring 1 during 2011 have varied from 704 to 794 µS cm^{-1} with an average of 747 µS cm^{-1}. The average flow from Spring 1 from June 2009 to October 2011 was 4 L/s. Flow is still variable within the spring, and depends in part on recent rainfall.

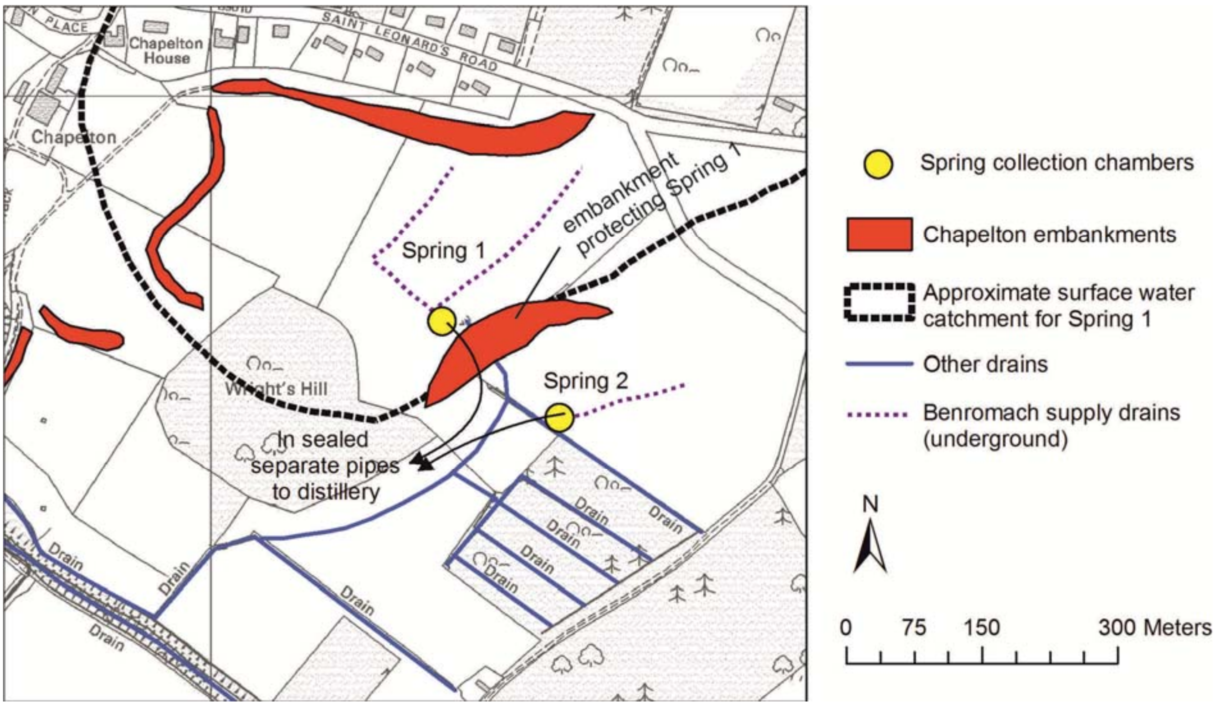

Figure 6 The Benromach supply after the improvements made by Moray Flood Alleviation and the construction of the Flood Alleviation Scheme.

4.2 SPRING 1 RESPONSE TO HEAVY RAINFALL

The flow and electrical conductivity in Spring 1 will still respond to heavy rainfall, regardless of whether the embankment has overtopped because the groundwater system naturally responds rapidly to these events. The observed variation in flow and electrical conductivity recorded in Section 4.1 support this. However, the improvements made to the spring network, and the removal of the open ditches within the low lying downstream sections of the drain network are likely to modulate the response of the spring to rainfall.

The groundwater model was used to help investigate the impact of heavy rainfall on Spring 1. As before, the impact of the electrical conductivity of the spring water was estimated by assuming mixing between flood water and groundwater at the spring source. The modelled baseflow of 3.1 L/s was used as the groundwater component with a conductivity of 800 µS cm^{-1}. Flow above this base level was assumed to come from the heavy rainfall or flooding and was given a conductivity of 100 µS cm^{-1}.

A rainfall event of 87 mm (corresponding to the minimum that could give rise to a 1 in 100 year flood) would generate 78,300 m^3 of water on the surface catchment area of Spring 1. Two flood events are modelled: (1) half of the water infiltrates; and (2) all of the water infiltrates.

1. For 43.5 mm of infiltration there is a muted rise in spring flow and the electrical conductivity reduces to 688 µS cm^{-1}.
2. For 87 mm of infiltration, the conductivity reduces to 600 µS cm^{-1} and stays below 675 µS cm^{-1} for 50 days.

The modelling confirms that heavy rainfall should not impact the electrical conductivity of Spring 1 for as long a period as it impacted the water supply before the FAS was constructed. An 87 mm recharge event which would have altered the electrical conductivity of the Chapelton Spring for 100 days prior to the scheme works, will now only affect Spring 1 for 50 days. A smaller event of 43.5 mm which before the modifications would have reduced the conductivity to below 675 µS cm^{-1} for 30 days is now unlikely to impact the supply at all.

4.3 SPRING 1 RESPONSE TO A 1 IN 100 YEAR FLOOD EVENT

With the FAS in place, a 1 in 100 year flood event will overtop the embankment protecting Spring 1 after about 2 days of flooding, and should inundate the groundwater over the Spring 1 source for approximately 6 days (Figure 7). This was simulated by modelling a a pulse of floodwater into the aquifer for 6 days sufficient to fill the unsaturated zone and ensuring that the agreed total of 45,000 m^3 infiltrates the aquifer behind the embankment. Two model scenarios were run: the impact of inundation with no rainfall in the local catchment, and the impact of inundation after 87 mm of rainfall. The results are shown in Figure 7.

1. By modelling 45,000 m^3 of flood water infiltrating behind the embankment with no rainfall in the catchment, the electrical conductivity of the water from Spring 1 will remain below 675 µS cm^{-1} for 90 days.
2. By modelling 45,000 m^3 of flood water infiltrating with rainfall of 87 mm, the conductivity of the water from Spring 1 will remain below 675 µS cm^{-1} for 160 days.

If examining the effect of inundation on the Spring 1 system in isolation from flooding in the catchment then scenario 1 can be used. However, to directly compare the situation before and after the construction of the FAS it is better to use scenario 2 which also includes the effect of general flooding.

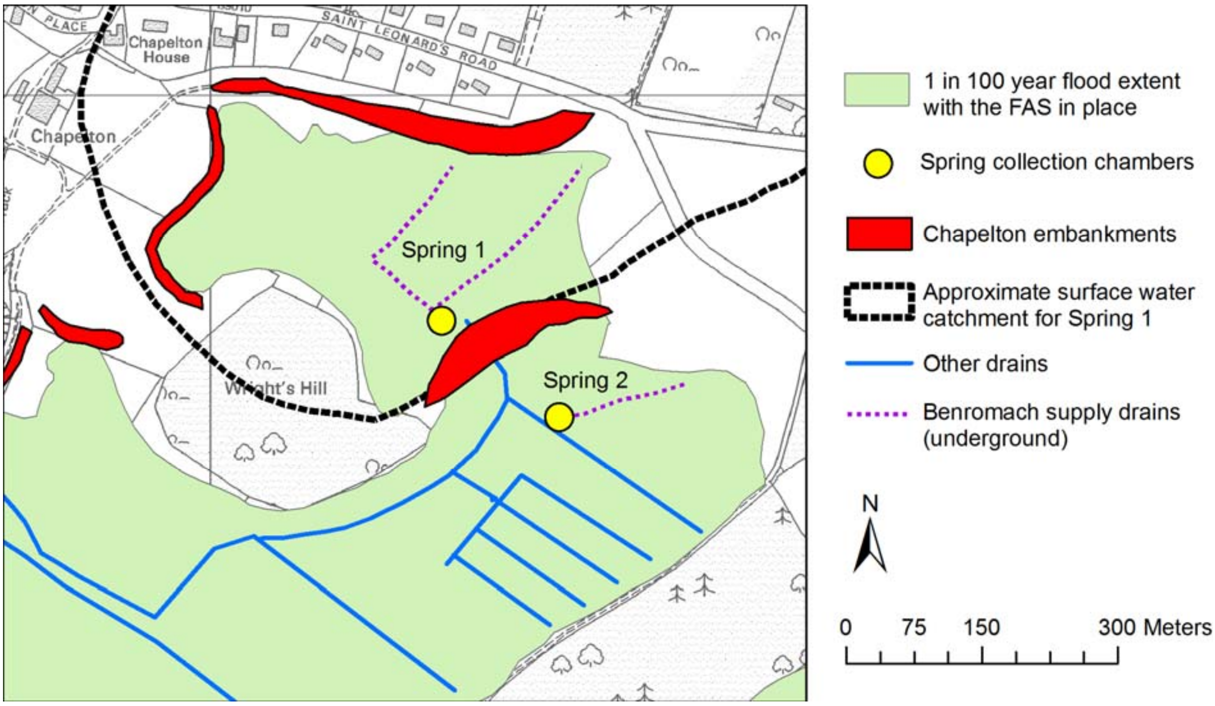

Figure 7 The maximum extent of flooding of a 1 in 100 year flood event from the Burn of Mosset after the construction of the Flood Alleviation Scheme.

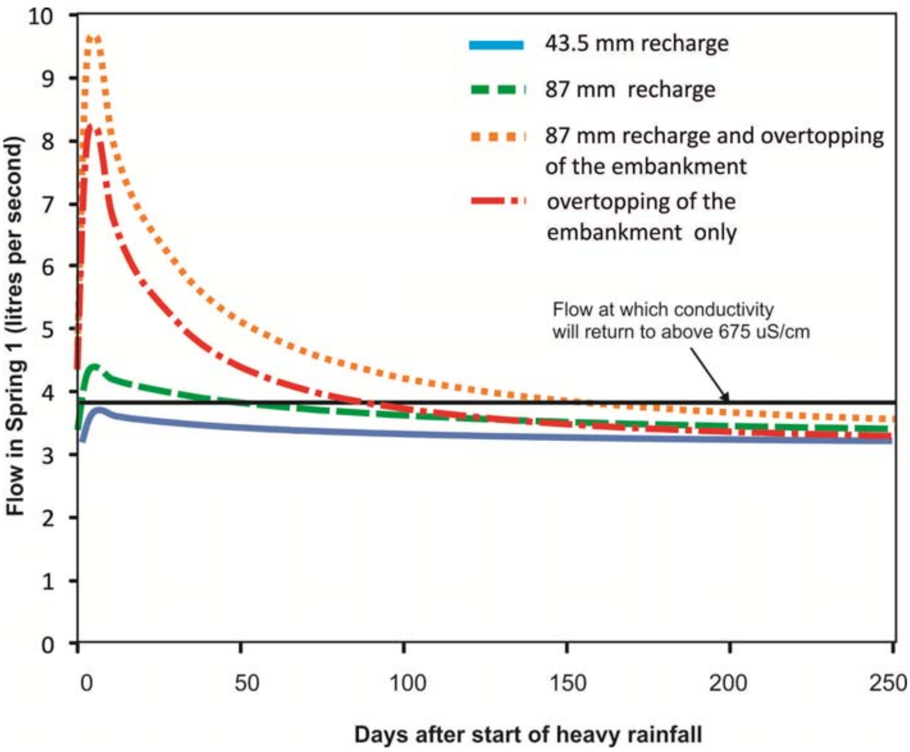

Figure 8 Spring flows in Spring 1 in response to heavy rainfall and flooding after the construction of the FAS.

5 Summary and conclusions

5.1 PRIOR TO THE FLOOD ALLEVIATION SCHEME

Prior to the flood alleviation scheme Chapelton Spring supply came from a network of drains and open ditches in the Chapeltonmoss area. The supply was highly vulnerable to contamination.

The electrical conductivity and flow of the spring was not routinely measured prior to the FAS, but the data that do exist show high variability in electrical conductivity with more than 40% of the conductivity measurements below 675 µS cm^{-1}. This suggests that the spring discharge was impacted by recent rainfall events and flooding.

A groundwater model of the spring system has been constructed to specifically model the impact of heavy rainfall and inundation on the old and new spring system in the Chapeltonmoss area. The model reproduces baseline conditions and observations of rising groundwater levels in response to heavy rainfall.

A mixing model has been used to estimate the effect of changes in spring flow on electrical conductivity of the water. This has assumed that the base flow at the springs is groundwater and has an electrical conductivity of 800 µS cm^{-1}, and the additional flow in the spring is from floodwater with an electrical conductivity of 100 µS cm^{-1}.

Results from the groundwater model indicate that moderate infiltration (43.5 mm) would result in the electrical conductivity being below 675 µS cm^{-1} for 30 days. Higher infiltration in line with a 1 in 100 year flood event would result in the spring being below 675 µS cm^{-1} for 100 days, or 120 days if including inundation from the Burn of Mosset. These modelling results are in line with the available electrical conductivity measurements recorded for the old spring system.

5.2 AFTER MODIFICATIONS TO THE SPRING SYSTEM AND THE CONSTRUCTION OF THE FAS

Engineering work has been undertaken on the spring system and groundwater is now taken only from the upper catchment, further from the Burn of Mosset. The spring is now much less vulnerable to contamination and direct inundation of the spring drainage network will not now routinely occur from flooding from the Burn of Mosset.

Modelling the impact of heavy rainfall on Spring 1 indicates that moderate infiltration (43.5 mm) will now be unlikely to cause the electrical conductivity of the spring to reduce below 675 µS cm^{-1}, and higher infiltration of 87 mm will reduce the conductivity to below 675 µS cm^{-1} for 50 days. Therefore the modifications to the spring system will reduce the number of days that the electrical conductivity of the spring system is below 675 µS cm^{-1} for heavy rainfall events that do not give rise to overtopping of the embankment.

Modelling the impact of infiltration from flood waters which overtop the embankment and give rise to 45,000 m^3 of infiltration behind the embankment suggest that the electrical conductivity of the spring water will be below 675 µS cm^{-1} for 90 days after overtopping. If the effect of local rainfall within the spring catchment is also included (87 mm infiltration) then the electrical conductivity of the spring will be below 675 µS cm^{-1} for 160 days.

5.3 THE IMPACT OF THE FAS ON THE TIME THAT THE ELECTRICAL CONDUCTIVITY OF THE SPRING IS BELOW 675 µS cm^{-1}

It is clear from the available electrical conductivity data that prior to the construction of the flood alleviation scheme the water supply to Benromach distillery was often below 675 µS cm^{-1}. This is supported by modelling of the impact of moderately heavy rainfall on the old spring system which could result in the electrical conductivity being below 675 µS cm^{-1} for up to 50 days. Similar rainfall events are now unlikely to reduce conductivity to below 675 µS cm^{-1} in Spring 1. ***Therefore, without an overtopping flood event the new supply is likely to have a more consistent water quality and suffer fewer days below 675 µS cm^{-1} .***

Modelling an overtopping event in isolation suggests that Spring 1 will be below 675 µS cm^{-1} for a period of 90 days following overtopping. However, when comparing model results of a similar magnitude flood event with and without the flood alleviation scheme the period that the spring is below 675 µS cm^{-1} are 160 days and 100-120 days respectively. ***Therefore, the additional time after the construction of the FAS that the spring flow is below 675 µS cm^{-1} following a 1 in 100 year flood event is 40 – 60 days.***

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List of abbreviations and units

BGS	British Geological Survey
EC	Electrical conductivity
FAS	Flood Alleviation Scheme
MFA	Moray Flood Alleviation
SEPA	Scottish Environment Protection Agency
m^2/d	metres squared per day, a measure of how easily groundwater can flow through rocks and sediments.
L/s	litres per second, a measure of flow
$\mu S\ cm^{-1}$	micro Seimens per centimetre, a measured of the electrical conductivity of water
mm	millimetres, in this context used to describe the depth of rainfall.

Selected Glossary

Abstraction	The removal of water from a groundwater body, usually by pumping. Measured in m^3/day, or L/s.
Aquifer	A rock formation that is sufficiently porous and permeable to be useful for water supply.
Base flow	Natural discharge of groundwater from an aquifer, via springs and seepages to rivers.
Borehole	A cylindrical hole (usually > 10 m and < 0.5 m diameter) constructed to allow groundwater to be abstracted from an aquifer.
Effective rainfall	The proportion of rainfall that is available for run-off and groundwater recharge after satisfying evaporation and any soil moisture deficit.
Electrical conductivity	A measure of how easily electricity is conductivity by water. It is directly related to the concentration of ions in the water.
Groundwater	The name given to water stored in an aquifer in pore spaces or fractures in rocks and sediments.
Permeability	Generally, the term is used loosely to mean the ease with which a rock or soil can transmit groundwater.
Piezometer	A cylindrical hole (usually greater than 5 m deep and less than 0.5 m diameter) constructed to monitor groundwater conditions
Porosity	A measure of the void spaces in a rock or sediment. It is measured as the ratio of volume of the pore spaces to the total volume of rock, usually expressed as a percentage. Effective porosity includes only the interconnected pore spaces available for groundwater transmission
Recharge	Water that is added to groundwater resources, for example from sources such as direct infiltration of rainfall or from streams and rivers.
Spring	A place where groundwater naturally overflows at ground surface.
Transmissivity (T)	Describes the ability of an aquifer to transmit volumes of groundwater throughout its entire thickness and is calculated by multiplying the hydraulic conductivity by the aquifer thickness. It is usually measured in m^2/day.
Unconsolidated	A deposit consisting of loose grains that are not held together by cement. River terrace deposits are a typical example of an unconsolidated aquifer
Water table	The surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere. It can be measured by the static water level in a well or borehole in an unconfined aquifer.
Yield	The volume of water produced by a spring, borehole or well. Usually measured in m3/day or L/s.