Guidance For Planners on Groundwater Flood Risk in Northamptonshire

Following the introduction of the Flood and Water Management Act (2010), the responsibility for managing the coordination of flood risk from groundwater has transferred from the Environment Agency (EA) to the Lead Local Flood Authority (LLFA), which in Northamptonshire is the County Council. However, groundwater flood risk is generally less well understood at a local level compared with surface water and fluvial flood risk. Therefore, there is a need to improve the understanding of the risk from groundwater flooding in the county.

The importance of groundwater flooding at the county scale was assessed and documented in the ESI (2016) Groundwater Flood Risk Study for Northamptonshire. The project identified the areas of the county at highest risk of groundwater flooding, estimated the potential economic impacts and provided information on appropriate mitigation methods. A series of groundwater flood risk maps were produced for use in conjunction with the guidance document presented here.

1.1 Introduction to groundwater flooding

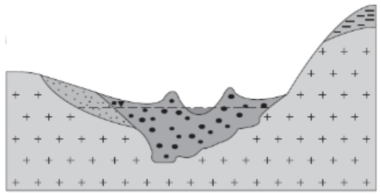
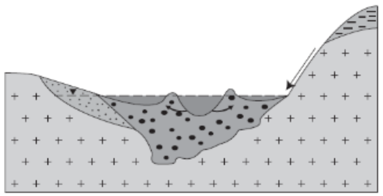
Whilst there has been considerable attention given to mitigation for fluvial (river), and to a lesser extent, pluvial (surface water) flooding much less notice has been taken regarding groundwater flooding. To some extent this is because groundwater flooding is often not recognised as such, especially if it occurs during flooding from other sources, and it is also the case that groundwater flooding is often more localised and difficult to deal with.

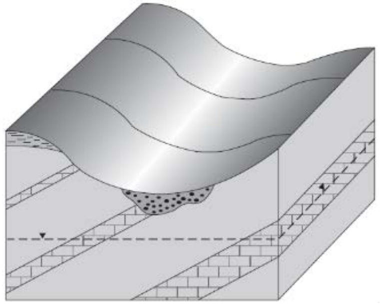
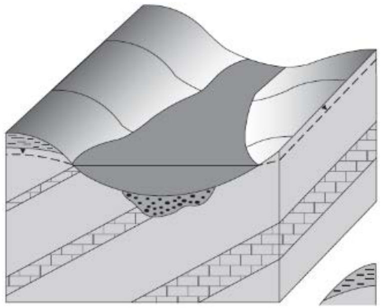
Groundwater flooding occurs when sub-surface water emerges from the ground at the surface or into Made Ground and structures. This may be as a result of persistent rainfall that recharges aquifers until they are full; or may be as a result of high river levels, or tides, driving water through near-surface deposits. Water flows to the surface or into basements, services ducts and other subsurface infrastructure rising up through floors or directly from the ground. Flooding may last a long time compared to surface water flooding, from weeks to months. Hence the amount of damage that is caused to property may be substantially higher. Likewise closures of access routes may be prolonged.

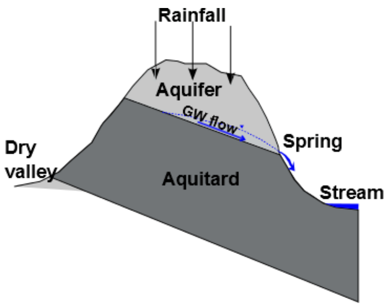
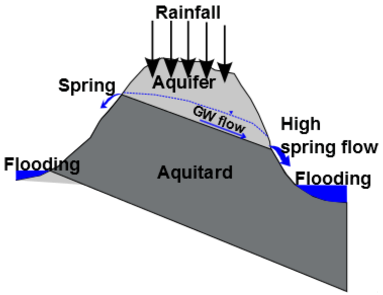
Emergent groundwater tends to be clear but potential contamination by sewers and brownfield sites poses additional hazards. Groundwater flooding prevents rainfall infiltration and increases the risk of surface water flooding. The following impacts may be associated with groundwater flooding: Damage to basements, buried services and other structures below ground; Sewer flooding; Water damage to property, cultural heritage, crops or sensitive habitats due to saturated conditions; Leaching of contamination from brownfield sites and other sources of contamination; Slope stability issues; Increased likelihood, intensity and duration of surface water flooding due to saturated ground conditions and failure of infiltration drainage systems; Increased cost of construction projects, which will need to incorporate groundwater control measures.

Groundwater flooding occurs naturally although various mechanisms can be involved. Three key sources of groundwater flooding have been identified in Northamptonshire: bedrock, spring-line and permeable superficial deposits. These are presented in Table 1 below. Not only are the sources distinct but the character of the flooding, in terms of depth, velocity and longevity, from each can vary enormously. It is necessary to establish the type of groundwater flooding that is most likely at a particular site as knowing what the source is can help greatly in identifying the best mitigation.

Table 1 Groundwater flood mechanisms

Groundwater Flood mechanism	**Description**	**Duration**	**Illustration**
Permeable Superficial deposits (PSD)	This mechanism of groundwater flooding is associated with shallow unconsolidated sedimentary aquifers overlying non-aquifers. These aquifers (typically sand and gravel) have a relatively high permeability, are often in good hydraulic connection with the adjacent watercourse and can have groundwater levels close to the ground surface. When the level of the river is high, groundwater flooding can happen: - The river water, moving through the ground, may emerge at locations behind flood defences (unless these have been designed to seal off the aquifer). - The high river levels induced by periods of intense rainfall cause a rapid rise in groundwater levels in the surrounding shallow aquifer. Groundwater that cannot discharge to the flooded river may 'back up'. The groundwater then emerges in depressions at locations not necessarily connected with the main flood plain. In Northamptonshire, this type of groundwater flooding would be associated with Sand and Gravel of the River Terrace Deposits, the Glaciofluvial Sand and Gravels or the Alluvium with a high sand content. Where these are underlain by low permeability bedrock, such as mudstones from the Lias or Ancholme Groups, a risk of groundwater flooding occurs. Till and Diamicton can have a wide range of permeability and a conservative approach is to consider these formations as high permeability and susceptible to groundwater flooding.	This type of groundwater flooding is relatively short lived and comparable in duration to the associated fluvial flooding (a few days to a week). However, the good hydraulic connection between the stream and the aquifer means that while the river levels drive the groundwater levels, the high groundwater levels slow down the drainage of excess water through the stream network.	Normal conditions  Flooded conditions  (Illustration from McKenzie et al, 2010)

Groundwater Flood mechanism	Description	Duration	Illustration
High groundwater levels in bedrock aquifers	Bedrock flooding, also referred to as clearwater flooding, is associated with the rise of the water table in permeable bedrock aquifers in response to long periods of high rainfall conditions. Flooding is enhanced by antecedent conditions of high groundwater levels. Once the groundwater emerges, over-land flow of surface water can occur and water may flow in valleys which are usually dry. This type of groundwater flooding, which is typical from Chalk aquifer, can be exceptionally long lasting and may linger for months. Chalk is not present in Northamptonshire, however, a significant part of the county is covered by permeable Jurassic Limestones which can also give rise to bedrock flooding. These generally have limited thickness, and tend to form hills which would limit the extent of area potentially susceptible to bedrock flooding.	2- 3 weeks or more	Normal conditions  Flooded conditions  (Illustration from McKenzie et al, 2010)

Groundwater Flood mechanism	Description	Duration	Illustration
High spring flow	Spring lines are likely to occur at the outcrop boundary of a permeable formation with an underlying low permeability formation. Chances of spring occurrence are higher on the hill side down dip of the aquitard, in the direction of groundwater flow. Permanent springs are more likely to occur on the dip slope of valley sides and water will generally be discharged to the nearby watercourse. Groundwater levels rise during the winter in response to increasing rainfall and decreasing losses in the soil zone due to evapotranspiration. Heavy, persistent, (generally) winter rainfall causes groundwater levels to rise higher than normal. The water table may then reach the ground surface to discharge at springs that do not normally flow. As groundwater levels rise, spring flows increase and when the drainage system cannot convey this water to a river, groundwater flooding occurs. Flooding will occur when the capacity of the stream is exceeded. The discharge from the spring will then become a contributing factor to what would be considered fluvial flooding. In locations where the bedrock spring line is masked by overlying superficial deposits, flow may occur through the superficial deposits before emerging down gradient.	2 – 3 weeks or more	Normal conditions  Flooded conditions 
Excess Soil Water	Can cause surface ponding or well up into basements, and forms another source of flooding that is not strictly groundwater but those affected are unlikely to appreciate the fine distinction. Many of the mitigation measures suggested for groundwater flooding, particularly those for permeable deposits, will be appropriate in these cases as the two sources share much in common and may be indistinguishable in practice.		

1.2 Planning guidance on the appraisal of groundwater flood risk

The ESI Groundwater Flood Risk Map for Northamptonshire is a 5x5m classification of groundwater flooding risk into six categories (Negligible, Very Low, Low, Moderate, High and Very High) described in the Table 2 below. These classifications are based on the level of risk, combining severity and uncertainty that a site has a chance of groundwater flooding greater than 1 in 100 (>1% probability of occurrence). Note that other forms of flooding are subject to different definitions of risk, which are not directly comparable. For example the Environment Agency interactive fluvial (river) flood maps define risk categories based on chances of flooding from different return periods: high risk represents chance of flooding of greater than 1 in 30 (3.3%) each year, medium risk between 3.3% and 1%, low risk between 1% and 0.1 % and very low at less than 0.1%.

The groundwater map is a general purpose indicative screening tool, and is intended to provide a useful initial view for a wide variety of applications. The risk classification shows the areas within which property may be at risk, but this should not be mistaken to mean that groundwater floods will occur across the whole of the Very High or High Risk area. Mapping limitations and a number of local factors may reduce groundwater flood risk to land and property even where it lies within mapped groundwater flood risk zones.

If a property is classified as High or Very High Risk, while groundwater heads might be indicative of groundwater seepage, the actual amount of flow emerging from the ground might not be sufficient to cause flooding at that location (although the accumulated flows downstream might be). Local variations in elevation and ground conditions may cause groundwater emergence to be localised away from the property, keeping the water table below hazardous levels. Properties with subsurface structures such as basements and utility ducts will be at greater risk of groundwater flooding. Properties with foundations and floor levels significantly above ground level will be at a lower risk. Drains, impermeable break layers or membranes incorporated in the building may act to prevent water reaching locations where impacts would otherwise occur. Even if emergent groundwater was at a rate sufficient to cause local flooding, the nature of the urban man-made subsurface tends to drain water away before it reaches the surface. Sewers, granular fill around utilities and road sub-grade are all highly permeable formations that would be able to drain quite high groundwater flows away. This tends to move the groundwater flooding problem down the catchment.

1.3 Consideration of groundwater flooding in planning applications

*1. **Pre-application stage and identification of flood risk***

It is critical that consideration of groundwater flooding risk is made early on in the planning processes to ensure that sufficient information is provided, appropriate assessment is made and mitigation measures incorporated into the design where considered necessary.

It is the responsibility of the applicant to gather relevant information to sufficiently identify and assess the risk of groundwater flooding and the impact of development proposals. The use of pre-application discussions is particularly important in identifying the number and scale of issues in relation to the development proposals and to allow all parties to establish the need for an appropriate groundwater flood risk assessment as part of the planning application process.

At the pre-application stage, development proposals should show the location, broad nature and extent of a proposed development. Northamptonshire County Council (NCC) does provide both a data provision and pre-application discussion service for a small charge. NCC can provide appropriate information on historical flooding incidents at this stage of the process.

The detail of the groundwater (GW) flood risk assessment will depend on the geological and hydro-geological setting, the level of risk and scale of development and the number of constraints being proposed. Therefore, small subject sites with low risk may be able to assess the risk in a summary manner but larger subject sites may require a more in depth assessment with more detailed calculations or potentially modelling.

2. Planning application submission

Having undertaken the initial screening exercise at the pre-application stage and identified the level of risk of groundwater flooding resulting from the proposals, the planning application should be accompanied, where necessary, by an appropriate site-specific groundwater flooding risk assessment – this can be incorporated into the flood risk assessment.

The complexity of this assessment will depend on the development proposals. The assessment should be proportional and must be cost effective.

3. Application process

When assessing development proposals in areas at risk of groundwater flooding, planning authorities will adopt a risk-based and balanced approach in producing recommendations. Applications with groundwater flood risk issues will be assessed by the LPA. Where these issues are complex in nature, the LPA may engage appropriate external advice or chargeable advice from NCC. They may also wish to seek the advice of the Environment Agencies Groundwater team on specific issues, where this is appropriate.

The LPA should ensure that the groundwater flood risk assessment demonstrates that the development proposed will not increase flood risk either on the site or elsewhere and, if practicable, will contribute to the reduction of overall flood risk in the catchment.

The development proposals should include mitigation measures (information provided at www.floodtoolkit.com) to ensure that residual risks to the surrounding area and/or subject site can be managed to an acceptable level.

4. Decision made

Where minor groundwater flood risk is established as being a potential issue, the planning authority may consider granting permission subject to conditions to ensure that mitigation is appropriate and can be applied.

Where the risk remains significant, even after mitigation measures, a precautionary approach will be applied. This will apply in such cases where groundwater flood issues have not been, or cannot be, addressed successfully and where unacceptable residual flood risks remain.

1.4 Site specific technical flood risk assessment

The use of a hierarchical risk-based approach to managing groundwater flood risk within a development is considered to be the most appropriate and effective management method. As such site specific assessment is crucial to understanding the risks and providing appropriate mitigation.

The methodology for evaluating the potential impact of development in areas susceptible to groundwater flooding is outlined below. Two levels of assessment are proposed.

- **Level 1 Screening Assessment** - defines the need for further assessment;
  - Outline the proposed development. This will normally be the proposed development in terms of the layout, proposed elevations, flood risk and drainage elements of the design.
  - Identify with the LPA the need for specific assessment based on the level of risk identified for the site on the groundwater flood risk maps produced by NCC.
  - If the groundwater flood risk is negligible, very low or low within the site boundary, then the developer will not be required to provide any additional information.

- **Level 2 – Detailed Assessment -** is related to specific identified constraints
  - Establish if sufficient data is available to either complete the conceptual ground model or if additional data collection must be undertaken prior to developing the site conceptual model. This could be through a desk top study, literature reviews, field data collection (such as boreholes and trial pits), or other methods. The scope and extent of the investigation will be specific to the proposed development, the areas of uncertainty and the risk.
  - Produce the most appropriate conceptual ground model proportional to the risk if considered necessary. Identify the potential mechanism(s) of groundwater flooding. Synthesise the best understanding into a conceptual model of the groundwater system. It is recommended that one or more sketch cross-sections and a plan are produced. Expert hydrogeological judgement will be required to develop a good representation of the conceptual model. The conceptual model will need to be updated if the scheme is modified.
  - If there is any uncertainty in the outcome of the modelling conduct a sensitivity study for the likely range of uncertainties in data and the conceptual models.
  - If there is a presence of surface water, watercourses, springs and ponds on site and within the vicinity of the site, then the potential for interaction between surface water and groundwater should be assessed.
  - The presence of historic or current land contamination in relation to groundwater should be assessed in terms of how this may impact development proposals.
  - Consideration should be given to whether the proposed development could increase groundwater recharge or move the recharge to an area of higher groundwater flood risk.
  - Changes to the site landform and the proposed elevations should be reviewed in relation to the potential groundwater levels.
  - Identify potential groundwater discharge locations and overland flow routes
  - Modifications in the behaviour of the groundwater system underlying the site should be assessed to ensure flood risk is not increased.
  - Assessment is recommended of the implications of groundwater flood risk on infiltration drainage systems, basements, slope stability, buried services and sewers.
  - Where uncertainty remains in the outcome of the assessment or where there is the potential for impacts then provision should be made to include post construction monitoring and verification.
  - The specific details of this will be determined on a site specific basis but could include:
    - Measurement of water levels and seasonal variation;

- Monitoring of basements and other subsurface structures for dampness and water ingress;
- On-going monitoring of water levels in retention and infiltration infrastructure to ensure that these are performing as expected;
- Maintenance of drainage structures to reduce groundwater and surface water flood risk and reduce the potential impact from introducing contamination directly to controlled waters.

Mitigation must incorporate all sources of flooding and an appropriate approach should be developed so as to alleviate any significant risk within the subject site and to adjacent properties and infrastructure.

The following stages are proposed:

- **Assessing and understanding the groundwater flood risk;**

  A sound understanding of the variation in flood risk across the site (and the surrounding area).

- **Avoiding the risk;**

  Having assessed and understood the risk of groundwater flooding, the next stage is to avoid the risk where possible. Wherever practicable, development should be avoided in areas that are susceptible to flooding or areas of development that will cause flooding on or adjacent to the subject site. This should become apparent from the assessment of risk. The modelling of the risk should help identify areas at risk and areas where development plans are acceptable.

- **Substitution/sequential approach;**

  Where groundwater flood risk cannot be avoided completely then the consequence of flooding within the subject site should be managed through substitution. This may include substituting land uses for ones that are less vulnerable to groundwater flooding, or orientating the development within the site so that more vulnerable uses are situated in areas that are least likely to flood or cause flooding elsewhere. The proposed land use should be commensurate with the likelihood, scale and severity of flooding in and around the subject site.

  The risk of pollution should be considered at the design stage of the development process, and where it is believed that there might be a risk of pollution, appropriate measures should be incorporated into the subject site to manage it

- **Incorporation of groundwater mitigation and management;**

  Where the groundwater flood risk cannot be avoided or substituted, appropriate mitigation and infrastructure should be incorporated within the site. Examples include; the appropriate use of SuDS which will not exacerbate, or be susceptible to, groundwater flooding. Below ground infrastructure can be designed to mitigate against the interruption or disturbance of groundwater flow paths; or the use of drainage infrastructure to mitigate for changes in groundwater levels or flow directions. Groundwater level control measures such as passive drainage blankets or active pumping methods could be considered where required. Care should be taken to ensure that groundwater and surface water flood alleviation defences complement each other in the mitigation of risk.

- **Resistant and resilient building techniques;**

  The risk of flooding should be mitigated by adopting resistant and/or resilient building techniques to minimise the damage and disruption that is caused by groundwater flooding.

Where groundwater flooding cannot be avoided, areas could be waterproofed to avoid the ingress of water and flood resistant building techniques adopted to minimise the damage sustained as a result of prolonged flooding.

The ground floor level should be raised above the predicted groundwater flood level. Where measures are proposed to raise the ground levels of the subject site, such measures should be demonstrated not to cause an increase in flood risk elsewhere.

The developer should establish that a commitment is in place for the long-term maintenance and safe operation of the groundwater flood risk management infrastructure in accordance with appropriate legislation and design codes.

- Produce report and outline mitigation measures proposed and submit the report with the planning application.

Table 2 Mapped groundwater flood risk categories

Risk category	Risk Definition	Recommended action
Very High	It is very likely that groundwater flooding will be experienced at, or near, this location with a return period of 1 in 100 years. Flooding may result in damage to property, road or rail closures but should not pose significant risk to life. Surface water flooding will be exacerbated when groundwater levels are high.	Further consideration of the level of risk and mitigation, by a suitably qualified professional, is recommended. A groundwater assessment should form part of the FRA (see section above)
High	It is likely that groundwater flooding will be experienced at, or near, this location with a return period of 1 in 100 years. Flooding may result in damage to property, road or rail closures but should not pose significant risk to life. Surface water flooding will be exacerbated when groundwater levels are high.	Further consideration of the level of risk and mitigation, by a suitably qualified professional, is recommended. A groundwater assessment should form part of the FRA (see section above)
Moderate	There is a possibility that groundwater flooding may be experienced at, or near, this location with a return period of 1 in 100 years. For sensitive land uses further consideration of site topography, drainage, and historical information on flooding in the local area should be undertaken by a suitably qualified professional. Where flooding occurs it is likely to be in the form of shallow pools or streams, there may be basement flooding, road or rail closures should not be needed. Surface water flooding may be exacerbated when groundwater levels are high.	Further consideration of the level of risk and mitigation, by a suitably qualified professional, is recommended. A groundwater assessment should form part of the FRA (see section above)
Low	There is a possibility that groundwater flooding may be experienced at, or near, this location with a return period of 1 in 100 years. Should there be any flooding it is likely to be limited to seepages and waterlogged ground, damage to basements and subsurface infrastructure.	No further investigation of risk is deemed necessary unless proposed site use is unusually sensitive.
Very Low	There is a remote possibility that groundwater flooding may be experienced at, or near, this location with a return period of 1 in 100 years. Should there be any flooding it is likely to be limited to seepages and waterlogged ground, damage to basements and subsurface infrastructure.	No further investigation of risk is deemed necessary unless proposed site use is unusually sensitive.
Negligible	The risk of groundwater flooding with a return period of 1 in 100 years is considered negligible at this location. Data may be lacking in some areas, so assessment as ‘negligible risk’ on the basis of the map does not rule out local flooding due to features not currently represented in the national datasets used to generate this version of the map.	No further investigation of risk is deemed necessary unless proposed site use is unusually sensitive.

1.5 Mitigation options appraisal for areas at risk of groundwater flooding

Mitigation is generally possible which can reduce the incidence and consequences of groundwater flooding, particularly at the design stage when it can often be provided at little or modest cost. Mitigating for groundwater flooding in existing property (retro-fitting) is more difficult and in some cases may be uneconomic. There are also differences between the target audience for mitigation between existing and proposed development.

Many of the measures developed to deal with river and surface water flooding can be used to counter groundwater flooding but not all will be feasible or effective in all situations. Some measures can be relatively cheap to install, particularly at the design stage, whereas some mitigation systems are ineffective or prohibitively expensive to retro-fit. Mitigation measures are presented in Table 3 below with an indication of possible costs for both new-build and retro-fits. An individual assessment of feasibility and costs should be made in each situation. Mitigation measures may often need to be combined to be successful. Barriers may only be partially successful for instance, and require a pump system to remove the water that seeps past.

The easiest way to mitigate for groundwater flooding is to avoid development in high risk areas. However, some sites may have to be developed for other reasons that may outweigh the risk, so consideration of mitigation may be necessary. The ESI Groundwater Flood Risk Map is a useful tool in identifying high risk areas and the supporting layer of Groundwater Flood Risk Source can help identify the flood mechanism causing the risk. The most appropriate mitigation will depend on the groundwater source. The appropriateness of each mitigation measure for proposed developments, depending on the different groundwater flood sources, is presented in Table 4.

Much, but not all, of the discussion for proposed developments is appropriate for retro-fitting in existing property but the practicality and economics of installation can be very different. One of the difficulties facing property owners is identification of the source of flooding and it may not even be apparent that groundwater is involved. Groundwater is usually clearer than river water, though this is not always the case. Checking the flood risk map, as well the supporting groundwater flood source map, to see if the property is in an area likely to be at risk is a first step as this may help determine what the likely source of flooding is. Table 5 provides information to help identify the source of flooding and recommended measures.

Table 3 Mitigation measures

Mitigation option	**Description**	**Indicative costs for new-build**	**Indicative costs for retrofit**
Avoidance	For new developments the best mitigation may be to avoid the area's most likely to be affected by groundwater flooding. In bedrock flooding a limited flow path in the bottom of a dry valley is often the highest risk and can be readily avoided. Development below a recognised spring line may also be at risk and should be carefully investigated before gaining approval. Avoidance is also possible within a site at the design stage by applying the 'sequential approach' to site layout planning.	Costs will depend on the economics of the site and possible other uses of land which is not developed: car parking or public open space may be feasible for instance, which frees up other parts of the site for building at no overall cost.	
Raise floor levels	Increasing the finished floor level on new property may be a cost-effective way to reduce groundwater flood risk except in the most severe bedrock flood areas. Other considerations, such as access, service connections and the effect of displacement or diversion on other nearby property must also be made. Floors can also be raised on existing property, although at greater cost. A new raised floor should be designed with a damp proof barrier integrated into the structure of the building. If a timber suspended floor is constructed it may also require a sump and pumping system to prevent permanently damp conditions below leading to rot.	Raising the floor level a small amount may not be an expensive proposition, though it may have consequences for roof line levels and restrict the type of building that is feasible on a site.	Likely to be a very expensive option and perhaps feasible only during property renovation.

Mitigation option	**Description**	**Indicative costs for new-build**	**Indicative costs for retrofit**
Install drainage to collect and dispose of water	Where an occasional flow from a spring line is identified then provision of an adequate drainage route may alleviate the problem. Drainage may also work where low levels of soil water excess occur, or where seepage occurs upslope of an affected property, and drainage around the property can safely collect and conduct the water away. Drainage provision might take the form of slotted plastic pipe in a gravel trench (a French drain) where volumes are low or the drainage route ill-defined. If only one property is affected by flow from a spring line then the flow route may be diverted around the property using a ditch, pipe, dwarf wall or embankment. Drainage is less likely to be successful where there is a large body of groundwater as the volumes will be too large. In flat areas it may also not be feasible to develop a suitable drainage route, and pumping may also be required to remove excess water. Permission to discharge collected water may be required and can only be done where the discharge will not cause further flooding elsewhere.	The costs of installing drainage depend on the type and scale of drainage required. Small drainage systems may be relatively cheap to install. A French drain around a single property for instance, may be below £5000 depending on the length required. Costs in a new build could be less if suitable equipment and manpower are already on site. A drainage system to protect a number of properties will be considerably more, and if a proper outfall structure is required then it may range up to £100 000 or more. Per property, however, a drainage system may still be a cost-effective way of dealing with some groundwater flooding sources.	
Physical flood barriers	A wide range of flood barriers for individual properties is available commercially. Physical barriers include flood gates across property entrances, covers for air bricks, non-return valves for surface and foul drains and low flood walls around individual properties. These systems have largely been developed to combat flooding from rivers and are therefore more effective when flooding occurs for a short period and they may require some warning to allow their installation. Groundwater flooding is likely to occur over a longer period, and thus can overcome many physical barriers, and may also enter the property from under the floor, by-passing the barrier entirely. Physical barriers may be effective for property in the path of flowing groundwater, particularly from spring lines where the flow is more likely to be short-lived.	New builds should not rely on these systems but provide permanent solutions, such as proper siting of property and provision of drainage routes which do not require the active participation of occupants.	Physical barriers can be a cost-effective way to retro-fit flood protection to an individual property. Flood barriers for doors and air bricks can be provided for a few hundred pounds which may be cost-effective for short lived occasional groundwater flow events but they do require some form of warning system so they can be deployed in good time.

<table>
<tr><th>Mitigation option</th><th>Description</th><th>Indicative costs for new-build</th><th>Indicative costs for retrofit</th></tr>
<tr><td>Tanking and water-proofing</td><td>Tanking systems provide a waterproof membrane on the floor and walls of a property and are particularly used in basements. They are best installed on the outside walls and therefore are more successful in a new build, but can be retro-fitted on the inside where flooding is occasional and water levels are modest. They should be designed and installed by a specialist company.</td><td>Tanking systems cost several thousand pounds to install. They may be cost-effective when installed in a new-build and where water levels are not constantly high.</td><td>Less likely to be cost-effective as a retro-fit unless groundwater flooding is a slight and rare occurrence.</td></tr>
<tr><td>Sump and pump system</td><td>These provide a collection area for groundwater and remove the excess by pumping to a suitable discharge route. They may be effective for seepages and small volumes of water, but less so where a large volume of groundwater occurs, such as in bedrock and permeable deposits. The sump can be outside of a property to reduce the groundwater level nearby, and will often require several sumps or a buried French drain system around the property to successfully lower the level over a large enough area. Alternatively, they may be installed inside under the floor or in a basement or cellar to keep water levels below the floor level.

Sump pumps are usually submersible and operated by automatic switches. These pumps are electric and consideration of a back-up generator may be required if power failure during floods is a possibility. Non-electric pumps (e.g. petrol or diesel) should not be used internally. Sumps may also be pumped out by externally sited pumps but these are generally less convenient and require more sophisticated switching systems.</td><td colspan="2">Sump and pump systems can be relatively cheap to install externally but are often used in conjunction with other mitigation measures. Installation inside a property is likely to require substantial building work and therefore be more expensive, but may still be cost effective particularly in a renovation project. Suitable pumps are relatively cheap – around £100 - £200 – but the installation costs may be several thousand pounds.</td></tr>
</table>

Table 4 Mitigation for proposed developments

Mitigation option	Best measure for	Potential measure for	Measure less likely to be successful for
Avoidance	Bedrock sources Springline sources PSD sources		
Raise floor levels	PSD sources	Bedrock sources Springline sources Flooding from excess soil water	
Install drainage to collect and dispose of water	Springline sources Flooding from excess soil water		Bedrock sources PSD sources
Physical flood barriers		Springline sources PSD sources Flooding from excess soil water	Bedrock sources
Tanking and waterproofing		Springline sources PSD sources Flooding from excess soil water	Bedrock sources
Sump and pump system		Flooding from excess soil water	Bedrock sources Springline sources (unless external to the property) PSD sources

Table 5 Mitigation for existing properties

Flooding experienced	Probable cause	Recommended action
Water coming up from under the floors every time it rains heavily	If this occurs every time it rains heavily, there is likely to be a problem with the local drainage. There may be a blocked or collapsed drainpipe near to or even under the property or perhaps something blocking a seepage route nearby.	A drainage survey will determine if this is the case. Restoring or replacing the drainage could provide the answer, or it may be necessary to provide a new drainage route around the property to lower the water level underneath it. If the property is near a watercourse check to see if the flooding corresponds to a high river level. Even if there is a flood barrier between the property and the watercourse water may be seeping underneath from the river or is being prevented from reaching the river by the barrier Providing a drain alongside the barrier to intercept this flow may help but it will be necessary to find a safe place to discharge the water and get landowner permissions to construct the drain. If this is not possible, then collecting the water in a sump under the floor or next to the property and then pumping it out could be feasible. Automatic submersible pumps can be effective in disposing of small quantities of water, which may then be discharged either into the watercourse or a drain (after receiving appropriate permissions) or across ground downhill from the property if doing so does not cause flooding elsewhere.
Water coming up from under the floors even in dry weather	Likely to be a leaking water main.	Contact the water authority for advice.
Water coming up from under the floors only after a very long wet period	It is possible that there is a spring under the property.	Provision of a pump set in a sump under the floor may assist in this case, but seek professional advice to ensure the correct type and size of pump is used. Only use electric pumps indoors to avoid safety issues with petrol or diesel fumes.
Water flowing in unusual places after heavy rain	This could just be a blocked drain but may also be from a spring source above the property, particularly if it flows for a few days.	The simplest mitigation may be a diversion channel or barrier wall that ensures the water flow goes around rather than through the property. This could be part of the landscaping around the property and quite unobtrusive. For small flows or seepages a slotted drain set within a gravel trench could also be effective. If there is no space for these, then physical barriers which can be used to cover doorways, airbricks and similar openings may help. These are readily available but usually require fitting before a flood occurs, which may not be feasible for this type of flooding if no warnings are available.
Persistent, flowing water after a long wet period	This is likely to be bedrock flooding – water coming directly from permeable rocks – particularly if it is flowing down a valley. If the property is flooded in this way after an exceptionally long wet period it is probably due to high groundwater tables and excess water will be draining from the rock.	Unfortunately this is very difficult to mitigate for as there is a large volume of water and it is likely to be around for an extended period. Barriers, from sandbags to thick walls are unlikely to resist flood water for an extended period unless very well engineered and accompanied by large pumps. This sort of flooding is very rare in Northamptonshire.
Flooding in basements and cellars	It is likely that waterproofing in the basement is either absent or has failed.	This can usually be remedied by specialist companies who can provide tanking of floors and walls which provides a new waterproof membrane. Pumping from a sump may also be necessary to relieve water pressure.

1.6 Further Information

Note that the map does not include localised flooding that occurs via a groundwater pathway that is initiated by another flood mechanism. Surface runoff, for example, may enter a property via a groundwater flow pathway. This could occur in any area of the map due to very local sub-surface features not picked up within the regional mapping, but which may be significant on a site-specific basis. For this reason the map should be interpreted as an initial indicative screening tool to help focus resources, but site specific assessment remains necessary where flooding impacts would lead to significant loss of asset or other harm to humans, the environment, or property.

It is important to note that in order to provide a consistent approach and in the light of data deficiencies, there are significant limitations in the assessment of likelihood. For example, groundwater flooding incidents in one location may correspond to a 1 in 50 year flood with the same event representing a 1 in 500 year event elsewhere. The 1 in 100 year return period should therefore be regarded as 'indicative'.

It is also important to note that, the evidence base for groundwater flooding is poor, and treating groundwater flood risk in isolation from other flooding sources imposes artificial constraints on our ability to represent real flooding incidence. Flooding occurs primarily as a result of the interaction of pluvial, fluvial, tidal, sewer, and groundwater flows, and the map is not an integrated model.

The map highlights areas where there is sufficient evidence to suggest that flooding could occur. However, given the various limitations of county wide-scale mapping and the available data, the map may represent 'false positives', where it suggests flooding risk which for local reasons or errors will not occur, and 'false negatives', where it suggests that flood risk is negligible when it may for similar reasons be significant.

The map represents the 'natural' groundwater flood mechanisms and flooding that can occur from anthropogenic influences, such as switching off a pumping station or alterations to the subsurface drainage patterns, are not taken into consideration.

1.7 References

ESI, 2016. Groundwater Flood Risk Study for Northamptonshire. Report for Northamptonshire Lead Local Flood Authority.

McKenzie A.A., Rutler H.K and Hulbert A.G., 2010. The use of elevation models to predict areas at risk of groundwater flooding. Geological Society, London, Special Publications 2010, v.345; p75-79.