Flood Risk Exposure of Urban Drainage Systems

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Abstract
Urban drainage systems provide flood relief to urban areas. However, they are also vulnerable to flooding themselves. This paper discusses the potential flood risk to urban drainage system assets from fluvial, tidal and pluvial sources, following a project by Mott MacDonald to assess the risk to 292 Scottish Water assets. The modelling of flood risk is considered and some design considerations are identified that should be taken into account in the future design of urban drainage systems to reduce the flood risk exposure.

Flood risk exposure
Urban drainage systems, including surface water, sewer and combined systems are a network of infrastructure assets such as pipes (generally located underground) and non infrastructure assets such as wastewater treatment works and pumping stations (generally located above ground) and are generally designed to allow flows to be drained by gravity.

Above ground assets, such as pumping stations, are used to pump flows against gravity where the topography of the land does not provide the necessary gradient to drain the system naturally, either because it is too shallow or because it is up hill. As a consequence pumping stations are often located at low points in the system.

Waste Water Treatment Works treat waste water before it is safely discharged into the environment. They are located at the end of the system adjacent to watercourses or the sea where they can discharge the clean effluent.

Given their location these non-infrastructure assets can be vulnerable to fluvial, tidal and pluvial flooding and their failure can result in flooding, pollution and interruption to service. This was highlighted in the 2008 Pitt Review on the lessons learnt from the 2007 UK floods (Ref 1).

Whilst many of the non-infrastructure assets can cope with a certain amount of water, for example the wet well flooding of a submersible pump, there is a point at which the flooded asset will fail, such as when the level of the mains electrical connection is reached by flood waters.

Figure 1 below is a photo of a typical pumping station kiosk with the pump well in the foreground. Figure 2 shows the electrical equipment within the kiosk. If the pump well contains submersible pumps, these are likely to continue to operate if water levels are above the cover level. However, if flood water levels reach 350mm above the ground level the electrical equipment within the kiosk may fail, which may stop the pumps from operating and result in a fire.


Figure 1: Kiosk with wet well in foreground


Figure 2: Electrical equipment within kiosk

The pumping station asset in Figures 1 and 2 is located next to a river and is shown to be at flood risk by the fluvial flood risk map for the asset (Figure 3). Figure 4 shows a different asset, but illustrates the close proximity of many assets to flood sources such as watercourses.

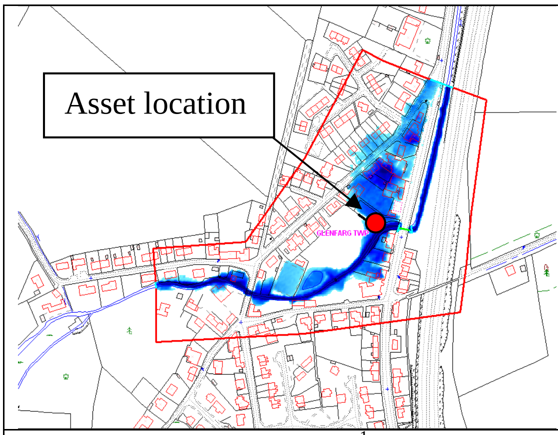

Figure 3: Fluvial flood risk map[1]

Figure 4: Kiosk and wet well next to a watercourse

Scottish Water's Asset Resilience Flood Risk Assessment Project

In 2010, as part of a UK initiative to improve resilience to extreme weather events, Scottish Water identified over 500 above ground water and waste water assets to be investigated for their vulnerability to flooding. These were widely distributed throughout Scotland, including many island locations as indicated in Figure 5. The scale of the project required an efficient method to be adopted to deliver value for money to Scottish Water and their customers. Mott MacDonald partnered with JBA for the project in order to pool resources and knowledge to develop an effective methodology for this challenging project.

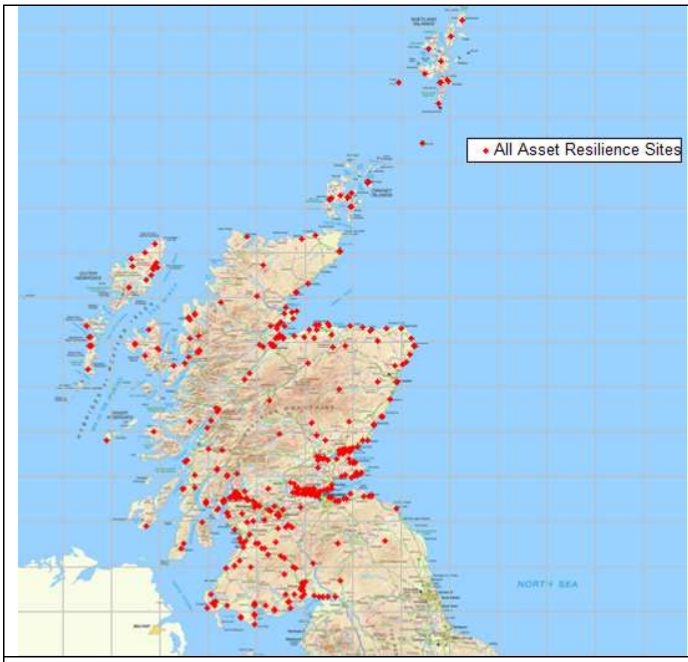

Figure 5: Locations of 500 urban drainage assets identified by Scottish Water as potentially at risk of flooding.

The four step process detailed below was developed to manage the assessment process in a cost effective manner:

- Step 1 – Identify assets potentially at risk

[1] Base mapping reproduced from OS Explorer data by permission of Ordnance Survey, on behalf of the Controller of Her Majesty's Stationery Office. Crown Copyright 2013. All rights reserved. Mott MacDonald Ltd licence number 100026791

- Step 2 – Assess hazard to assets
- Step 3 – Determine vulnerability
- Step 4 – Determine mitigation measures

Step 1 – Identify assets potentially at risk
During this step assets potentially at risk of flooding are identified. For the project, this process was undertaken by Scottish Water by using the Indicative River and Coastal Flood Maps produced by SEPA[2] (Ref 2) to identify assets lying within the 0.5% Annual Exceedance Probability (AEP) flood boundaries.

Step 2 – Assess hazard to assets
Given their scale and because of the information used to produce them, SEPA's indicative maps are not meant to be an accurate depiction of flood conditions at specific sites In addition, even when an asset is likely to be exposed to a flood event, it doesn't necessarily mean that it will stop operating. Therefore a second stage, more accurate, flood risk assessment has to be carried out for those assets identified as at risk. This assessment includes calculating predicted flood levels at the site to ascertain if the vulnerable parts of the asset in question could be affected by flood waters (Step 3).

A flood risk assessment for an individual site typically consists of a site visit, topographic survey, hydrological modelling and analysis.

To maximise efficiency on this project, LiDAR (aerial topographic survey) was identified as the most efficient method for gathering localised data around a large number of widely spaced assets. Aeroplanes could travel between the islands, removing travel and accommodation costs for surveyors.

The use of LiDAR required that the channel of the watercourses near the asset was suitably wide in order for it to be used to represent the channel. In other areas, or where the channel was too narrow for LiDAR to be used, additional traditional cross-section surveys were undertaken to inform the hydraulic model. This approach ensured that the accuracy of the overall assessment was not compromised.

The use of LiDAR resulted in good quality data in a grid format which provided a direct input into 2D hydraulic modelling packages. The 2D hydraulic modelling package TUFLOW was used to undertake the flood risk assessments at the assets where LiDAR was available. TUFLOW allows for the assessment of fluvial, tidal and pluvial surface water flood risk modelling as in Figure 3. Pipe networks can also be included to deliver a complete Integrated Catchment Model approach.

It is unusual for a direct 2D model to be used to model flood risk accurately when assessing watercourses. A more standard approach would have been to use a 1D model such as HEC-RAS for many of the assessments. However, to maximise the benefit of LiDAR, direct input into a hydraulic model was seen as an innovative advantage. Specific criteria were developed in order to ensure that a 2D model approach was suitable, such as selecting the cell size of the grid to contain at least 4 cells within the channel width.

Site visits to each asset at risk were required to inform the hydraulic model and to determine the vulnerability of the equipment at the asset. The use of LiDAR and available topographic survey data allowed the ground levels at the sites to be assessed prior to any site visit and an initial assessment of flood risk to be made. Through the use of this technique, some sites could be clearly determined not to be at risk of flooding due to ground levels being significantly above flood levels. These sites were not subject to a site visit. Where site visits were required, these were clustered so that a number of assets could be visited in a single day or couple of days. This approach improved the sustainability of the project through reduced travel, accommodation, time and costs.

Step 3 – Determine the vulnerability of the asset
This step of the assessment determined the vulnerability of each asset by comparing the level of the equipment critical to the operation of the site to predicted flood levels. The equipment levels were measured only for those assets identified as at risk in the previous step

[2] Scottish Environment Protection Agency

Only the relative height of equipment above floor level was required within buildings as the LiDAR data could be used to provide the building threshold level and so allow a direct conversion to a level. This minimised data collection requirements within buildings, reducing disruption to Scottish Water.

Whilst the level of each item of equipment identified whether it would be reached by flood waters,, it was important to understand the role of each item of apparatus in the overall operation of the asset, to enable Scottish Water to identify if the asset would stop functioning should the apparatus be affected. For example, some items of electrical equipment, such as power sockets, on their own are not critical to the operation of the asset. So the hazard of a power socket flooding is less than a critical item such as the main fuse box.

Therefore Mott MacDonald also assessed the process, mechanical and electrical requirement for each item of equipment to identify the critical components and determine the overall vulnerability of the asset to flooding. This assessment ensured that Scottish Water would only need to provide flood mitigation measures where critical items of equipment were vulnerable.

Step 4 – Determine mitigation measures
The final step identified mitigation measures for assets vulnerable to flooding. Potential measures included raising equipment, flood defences, improving resilience e.g. by waterproofing pumps. Examples of mitigation measures already employed by Scottish Water are shown in Figures 6 and 7. The development of these mitigation measures has led to the production of this paper which highlights a number of design considerations to ensure the flood risk of assets is appropriately taken into account when locating, refurbishing and constructing non infrastructure assets in flood risk areas.

	
Figure 6: Kiosk raised to reduce flood risk	Figure 7: Raised threshold to reduce flood risk

Design considerations
The project highlighted a number of design issues that if addressed could reduce the vulnerability of urban drainage systems. The following are design considerations that should be taken into account when designing or protecting existing urban drainage systems:

- The flood risk from all flood sources (especially pluvial, fluvial and coastal) should be assessed. When locating an asset, even if the asset is a long way from watercourse there is a potential flood risk. The use of integrated catchment models, to model all flood sources, can improve the assessment of the hazard.
- As it is not always possible to locate assets in areas that are not at risk of flooding, full consideration should be given to the location of equipment critical to the operation of the assets, such as kiosks containing electrical panels.
- Equipment can be designed to withstand flooding. Where necessary, the type of equipment should be selected to ensure the asset continues to operate, such as waterproof pumps.
- Urban drainage systems are generally designed to convey a 3%AEP flood event. Flood risk is generally assessed for a less frequent event and the location of the asset should be considered on the basis of the flood risk posed. For fluvial, pluvial and tidal flooding, a 0.5%AEP flood event is more usual. For critical infrastructure UK planning policy recommends a 0.1%AEP flood event.

Summary

This paper has highlighted the flood risk exposure to urban drainage systems and has identified a cost effective four step method to assess the flood risk to urban drainage systems for a large number of widely spaced assets. It is envisaged that other statutory bodies with a similarly large distribution of assets could adopt a similar cost effective approach to flood risk assessments to enable the vulnerability of their assets to be assessed. This paper also identifies design issues to be considered when undertaking urban drainage system design and/or refurbishment. These design considerations are seen as vital to reducing flood risk exposure and ensure that the system is resilient to flooding.

References

1. Pitt Review - Independent Government Review of summer 2007 floods - June 2008
2. SEPA flood map: http://www.sepa.org.uk/flooding/flood_extent_maps.aspx