APPENDIX C

Surface Water Flood Hazard Mapping

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Introduction

Surface water or pluvial flooding can be defined as flooding which results from rainfall generated overland flow *before* the runoff enters any watercourse or sewer. It is usually associated with high intensity rainfall events (typically >30mm/hr). However, it can also occur with lower intensity rainfall (as was the case in e.g. East Riding of Yorkshire in June 2007) or melting snow where the ground is saturated, frozen, developed or otherwise has low permeability resulting in overland flow and ponding in depressions in the topography. During pluvial flooding, urban underground sewerage/drainage systems and surface watercourses may be completely overwhelmed.

Selection of Mapping Technique

Following the widespread pluvial flooding in June and July 2007 and the subsequent Pitt Review (2008), initial attempts are being made to identify areas which may be at risk of future surface water flooding. Prior to the summer 2007 floods, Jacobs developed the Pluvial Extreme Event Planning (PEEP) methodology in order to identify areas most susceptible to pluvial flooding and, subsequently, develop contingency measures. The methodology could involve the following key elements:

- **Screening:** Initial rapid screening to identify potential risk areas through GIS techniques to identify topographic depressions and surface flow paths.
- **Inspection:** Site inspection of identified areas (following desktop review of the screened data) to determine any existing drainage outlets and level of hazard.
- **Mitigation:** Evaluation and possible implementation of any measures to mitigate impacts e.g. improvement of relief pathways.
- **Contingency Planning:** Information to raise awareness on potential risk from pluvial flooding (including foul sewage contamination) and consideration of contingency measures.
- **Refinement and Review:** Further refinement and more detailed assessment of hydraulics where justified. Plans should be kept under continuous review to incorporate refinements, new techniques or observations from real events.

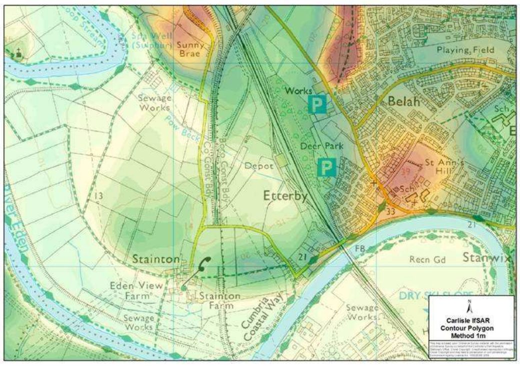
The potential risk areas, or hotspots, are identified through an initial screening process using GIS techniques to identify depressions in the topography and critical surface flowpaths. It is envisaged that PEEP maps of areas most susceptible to pluvial flooding could be developed and used in conjunction with similar existing maps and plans (e.g. Surface Water Management Plans and Community Risk Registers), including those for other sources of flooding.

From studies already undertaken for the Environment Agency, Kent County Council's Highway Services and the Rivers Agency (Northern Ireland), we have assessed a number of different methods to rapidly screen topographic data for potential hotspots, including the Contour Polygon Screening (CPS) technique. When used with an IfSAR Digital Terrain Model (DTM), the CPS technique has been found to be highly effective (80-90%) in clearly identifying hazardous depressions in all types of land use (e.g. rural and urban). However, for the most heavily urbanised areas, the technique is generally between 90-100% effective when used with a higher resolution LiDAR DTM. Encouraging results have also been obtained with a GIS screening technique used to identify critical flowpaths. In some cases these flowpaths follow existing watercourses but they can also be remote from any watercourse location and can include important traffic routes and pass through new developments.

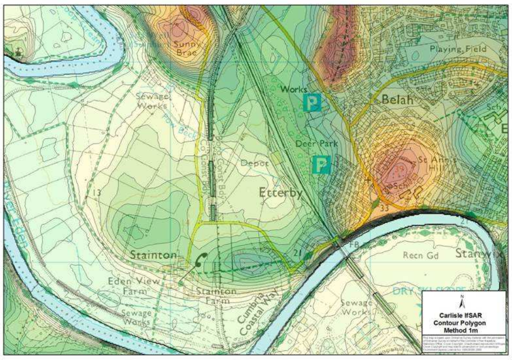
Description of Methodology

For a study area the size of the East Riding of Yorkshire, the most feasible topographic dataset to use was the NextMap IfSAR data which has a horizontal resolution of 5m and a vertical accuracy of around ±1m. This was provided in both bare-earth DTM, as well as the Digital Surface Model (DSM) which contains all the surface features (e.g. buildings, embankments etc). To efficiently process such a large dataset, the data were divided into catchment areas which ensures that flowpaths will not be required to cross boundaries within the data which could introduce error.

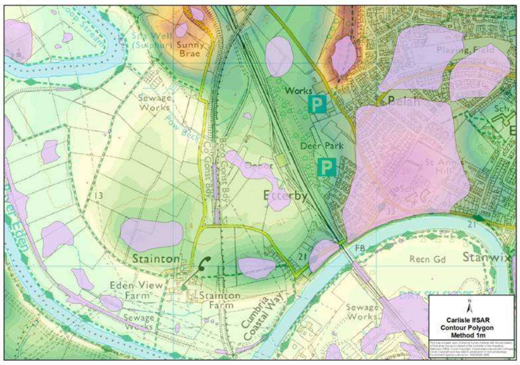
Using the 'bare-earth' DTM, the rapid GIS-based CPS technique proceeds (Figure 1) to contour the topographic data at 0.5m intervals and identify areas of closed contours which represent depressions where surface water could pond. The outermost closed contour of a group is taken as the boundary of the depression which is converted to a polygon. Only polygons with a surface area greater than $100m^2$ are considered to present a hazard. By dividing the volume of the depression by its surface area, the average depth of the depression can be determined. Through site verification visits, this depth estimation has been found to be highly effective and only those depressions with an average depth greater than 0.2m are considered.



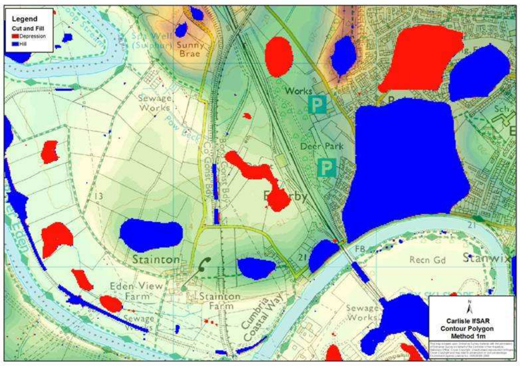
(a) DTM data is obtained



(b) The DTM is contoured at 0.5m



(c) Contours are converted to closed polygons



(d) Polygons are classified as depressions (red) or hills (blue)

Figure 1: Example identification of topographic depressions using the Contour Polygon Screening method

In parallel, using the DSM which contains the surface features around which flood waters could travel, the surface water flowpaths are identified using another rapid GIS technique. By identifying areas greater than 1 hectare ($0.01km^2$) where rainfall could accumulate and begin to flow downhill, the technique determines flow direction and linkage of streams to produce a flowpath network. These flowpaths represent existing watercourses but also proceed down roads and across fields, for example, as the topography and surface features dictate.

In order to highlight those depressions which could pose a severe pluvial flood hazard, the following factors should be considered:

- **Depth** of the depression: depths are categorised into four groups:
    - 0.2m – 0.5m indicating low pluvial hazard
    - 0.5 – 1.0m indicating moderate pluvial hazard
    - 1.0m – 2.0m indicating high pluvial hazard
    - >2.0m indicating severe pluvial hazard
- Presence of a **flowpath** that transects the depression and drains an upstream catchment area

These factors, the depth of the depression and the presence of one or more flowpaths can be used to assess the likely severity of flooding in the depression. In order to assess the severity, the depth bands indicated above have been combined with information on the presence of a flowpath as per the matrix presented in Table 1. This results in depressions being categorised as either Low, Medium or High severity.

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		Potential Depth of Flooding (m)		
		<0.5m	0.5m to 1.0m	>1.0m
Presence of flowpath	Yes	Low	Medium	High
	No	Low	Low	Medium

Table 1: Potential severity of flooding

Discussion of Results

The rapid GIS screening methodology has identified 20120 distinct areas which could be at risk of pluvial flooding in the East Riding of Yorkshire area. Of these, application of the severity matrix (Table 1) suggests that in 320, the severity of flooding could be high, in 786 the severity could be medium and in the remainder (19014) the severity is likely to be low.

The next step in the PEEPs methodology outlined above would be to further refine the list of the 320 highest severity depressions by considering their current and/or future landuse. In other words, to determine the sensitivity of the area to flooding: whether there are significant infrastructure or other buildings in the vicinity that would be particularly vulnerable to pluvial flooding. This filtering would leave a manageable number identified as posing the highest risk which should be visited, to determine, as a minimum, the following:

- Does the depression exist? For example the coarse resolution of the IfSAR data can sometimes mean that trees and other dense surface features appear to form the wall of a depression.
- Does the depression have an average depth as calculated?
- Is there an obvious surface flowpath route, as identified, whereby surface water could enter the depression? The coarse resolution of the IfSAR data could mean slight displacement of the flowpaths.
- What is the land use within the hazard area? Does it include any critical infrastructure? This allows for a more refined classification of risk than from the desk study.
- Is there an obvious outlet present which could easily block and which should perhaps be added to a maintenance schedule?
- What mitigating actions could be considered?
- What should the initial hazard rating be based on all the above information?

Comparison with Other Surface Water Flooding Data

Whilst site verification visits were not possible, good records of surface water flooding were available from the Independent Review Body Investigation into the June 2007 flooding in Hull (Coulthard et al., 2007). In addition, the Hull City Council SFRA report contains other modelling undertaken to identify locations at risk of surface water flooding. These two datasets are compared here with the results presented from the PEEPs analysis.

Comparison with June 2007 Flooding in Hull

Figure 3.1 in Coulthard et al. (2007) shows roads and properties flooded during June 2007. There are three main areas where surface water flooding appears to have been concentrated; 2 areas around Cottingham in west and north west Hull and Bransholme in north Hull.

Due to the high average depth of the depression and the presence of many flowpaths flowing north west into the River Hull, the PEEPs analysis clearly shows a large depression covering the majority of Bransholme which has been given an initial severity rating of High. This would clearly be an area at risk which should be followed up by site investigation to determine potential mitigation measures.

Around Cottingham, the depressions identified in the PEEPs analysis appear to be generally more shallow and smaller in area so that the areas known to flood in June 2007 are not picked out as clearly. This is particularly true for the area of Cottingham to the north, towards Dunswell. However, more to the south west near Willerby, there are depressions identified (e.g. centred on the Education Centre) which were recorded as flooded in June 2007.

Relatively flat areas such as Hull will always present a major challenge methods of analysis which rely heavily on interpretation of the topography. Indeed, site verification visits to Hull undertaken as part of the RF5 project identified this problem with the coarser IfSAR data and achieved clearer identification of areas at risk with the more accurate LiDAR data. Unfortunately, analysis of the entire East Riding Authority area using LiDAR data was impractical within the timescales of this study.

However, analysis of the surface water flowpaths for Cottingham clearly shows those locations flooded during June 2007 identified as potential risk areas. In the area of Cottingham to the north (towards Dunswell), surface water accumulate over a significant area from the west, south and east and will flow north through the urbanised region. In the area of Cottingham to the west, water will accumulate over the substantial areas to the west and north and flow southwards into the urbanised region.

This analysis underlines the necessity of considering both surface flowpaths and topographic depressions in any analysis of areas at risk from surface water flooding.

Comparison with the Hull SFRA Surface Water Flood Risk Zones

Figure 7.19 of the SFRA report shows, for the 0.5% flood event, zones at risk of surface water flooding categorised as either low, medium or high risk according to the predicted depth of flooding. In general, the SFRA map shows many more smaller areas to be at risk than the PEEPs analysis, which has been designed to reduce the amount of ‘clutter’ shown on a map and provide clear identification of those areas which are likely to pose the greatest hazard. However, the two maps broadly identify the same areas to be either at risk or not at risk, despite large differences in the approach used. For example, similar to the discussion above for the two areas around Cottingham known to have flooded in June 2007, the SFRA map shows areas at risk of flooding in the west of Hull, but no substantial areas at risk in the north west towards Dunswell. Perhaps importantly, however, only small isolated areas of Bransholme are indicated to be at risk in the SFRA maps whereas the PEEPs analysis indicates a large hazard area.

Recommended Further Work

The next step in the PEEPs methodology outlined above would be to further refine the list of the 320 highest severity depressions by considering their current and/or future landuse. In other words, to determine the sensitivity of the area to flooding: whether there are significant infrastructure or other buildings in the vicinity that would be particularly vulnerable to pluvial flooding. This filtering would leave a manageable number identified as posing the highest risk which should be visited.

In addition to the site investigations, it is recommended that an extension of the above technique is applied whereby the severity of a flowpath passing through a depression can be quantified based on its steepness and the area of land drained. This will enable a refinement of the severity matrix shown in Table 1 and potentially more focussed site investigations.