Surface water flood modelling for LLFAs: a reflection on advancements and lessons

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Introduction

Integrated urban drainage modelling is undertaken for many of purposes, for a range of clients. AECOM has been involved in a number of surface water feasibility studies on behalf of Lead Local Flood Authorities (LLFAs), the driver of which is often to consider the feasibility of mitigation measures aimed at reducing the risk of property flooding. These projects often involve integrated catchment modelling to refine the risk of surface water flooding and to identify baseline flood mechanisms that inform the selection of potential mitigation options. The benefit of integrated catchment modelling is the ability to identify and quantify the combined risk from overland flow, ordinary watercourses and sewers.

This paper provides the reader with an introduction to surface water flood modelling projects and discusses the enhancements of integrated 1D/2D surface water flood modelling process that are currently used by AECOM in InfoWorks ICM. With reference to recent case studies undertaken by AECOM, the paper considers two of the key modelling processes.

The paper also highlights the benefits of including an enhanced level of detail in the baseline modelling process when the project advances into the optioneering process. The paper concludes with a summary of the lessons learnt as part of recent AECOM modelling projects for LLFAs.

Context and Drivers

While the Environment Agency takes a strategic overview of managing the risk of flooding from all sources, Lead Local Flood Authorities (LLFAs) have responsibility within their county or unitary authority area for managing the risk of flooding from surface water, ordinary watercourses and groundwater[1]. Other Risk Management Authorities (RMAs) may include water and sewerage companies, Internal Drainage Boards, Highways Authority or District Councils. Flooding from surface water is defined in the Flood and Water Management Act (FWMA)[2] as:

> *"The flooding that takes place from the 'surface runoff' generated by rainwater (including snow and other precipitation) which: (a) is on the surface of the ground (whether or not it is moving), and (b) has not yet entered a watercourse, drainage system or public sewer."*

After the Environment Agency published online the national dataset identifying the Risk of Flooding from Surface Water (RoFSW)[3] in December 2013, which was previously named the updated Flood Map for Surface Water, there has been more awareness in the industry of the ability to quantify the risk of surface water flooding. In addition, a number

[1] Defra (2014), Flood risk management: information for flood risk management authorities, asset owners and local authorities. Last Accessed April 2017.
[2] Flood and Water Management Act (2010). Available online at http://www.legislation.gov.uk/ukpga/2010/29/contents .
[3] Available online at URL: https://flood-warning-information.service.gov.uk/long-term-flood-risk

of recent flood events across the country where the primary flood mechanism was not from fluvial or tidal sources, has increased public and institutional awareness of surface water flooding.

Hydraulic modelling to assess the risk of surface water flooding has been available for a number of years, through the use of various hydraulic modelling packages that have two-dimensional (2D) modelling capabilities. Surface Water Management Plans were undertaken in a number of authority areas and the majority included hydraulic modelling to quantify or refine the risk of surface water flooding.

LLFAs have the responsibility under Section 19 of the FWMA to investigate flood events within their area. Part of this responsibility is to identify the appropriate risk management authority and to publish the results of the investigation. The conclusions of a Section 19 flood investigation report may determine that further analysis is required to understand the conditions that led to flooding, including the need for more detailed hydraulic modelling. In addition, Surface Water Management Plans can identify the areas at greatest risk of surface water flooding and may recommend further hydraulic modelling.

The primary drivers for this detailed modelling are:

- **Improve confidence** in the predicted extent of surface water flood risk within an area through the refinement of model parameters and the representation of key flooding mechanisms; and,
- Consider the **feasibility of mitigation options** to manage the risk of flooding and reduce the probability of internal property flooding.

The results of such modelling studies will contribute towards a greater understanding of surface water flood risk and may lead to funding applications to implement solutions.

AECOM is undertaking an increasing number of surface water feasibility studies for LLFAs, predominantly utilising the 1D-2D linked capabilities of InfoWorks ICM (developed by Innovyze).

Flood Mechanisms and Data Requirements

The prediction of surface water flooding includes a number of mechanisms for the generation of rainfall runoff volumes, the removal of flood water from the ground surface and the routing of overland flow. These processes include:

- **Rainfall-runoff processes** – represented using appropriate runoff coefficients by land use type based on detailed Ordnance Survey (OS) MasterMap;
- **Physical ground modifications** – undertaken to represent obstructions to overland flow using OS MasterMap to raise or lower ground levels, accurately represent buildings, allocate ground roughness parameters and to include key topographic features;
- **Highway drainage losses** – provide link from ground surface to below-ground sewer network;
- **Sewer network capacity** – represent capacity of surface water/combined sewer network to accept surface water flows; and,
- **Soil infiltration losses** – dependent on underlying geology and applied where appropriate using infiltration surfaces.

Due to the complexities and inter-dependencies between these processes, as well as the availability of locally specific information, it is recommended that modelling strategies are tailored to site conditions and agreed with project stakeholders. Representing these processes requires a range of input datasets, some of which will be freely available as Open Data, whereas others will require bespoke requests from individual Risk Management Authorities.

Case Studies

The following two case studies present examples of projects where the modelling methodology has been tailored to the local flood mechanisms.

Soil Infiltration

AECOM was recently involved in a surface water feasibility study for a community in Redbourn on behalf of the LLFA, Hertfordshire County Council. Redbourn experienced surface water flooding in February 2014 following an extended period of rainfall. The affected community is at the edge of the urban extent and the upstream catchment is predominantly agricultural land. There is no permanent watercourse and there is a limited highway drainage network.

Early stakeholder consultation identified the importance of understanding the **sensitivity of flooding to the soil infiltration capacity** of the catchment as flooding occurred following an extended period of rainfall. Gauged rainfall and nearby monitored soil moisture content demonstrated that the soil moisture in February 2014 was saturated. The baseline hydraulic model was therefore built with infiltration surfaces using the Horton Infiltration methodology based on the expected underlying geology.

Both summer and winter storms were run, with an assumption of greater infiltration potential in summer months where geology permits and lower infiltration potential in winter months. Model results showed that although rainfall intensity is lower for a winter storm where there would be runoff from the agricultural fields, the number of flooded properties is equivalent to a higher intensity summer storm where there is minimal runoff from the surrounding agricultural land. There were consequently **two potential flood mechanisms** that had to be considered when developing mitigation options. In this case study, the upstream soil infiltration capacity and the seasonal storm profile became critical components of the modelling process to ensure that any recommended design protected properties in both summer and winter design storms.

Highway Drainage Gullies

In a separate surface water hydraulic modelling study on behalf of Medway Council in Kent, four hydraulic models were constructed in areas identified as having a higher risk of surface water flooding. Southern Water gave permission to incorporate aspects of its existing InfoWorks CS model into the surface water flood model. The assumptions regarding the **linkage between the 2D ground surface and the 1D surface water sewer network** became integral to ensuring the accurate representation of surface water flooding.

Sensitivity testing was undertaken to determine the influence on model results when the 1D-2D linkage was altered. Firstly, surface water sewer manholes were allocated a "2D" flood type, which allows for two-way transfer based on a discharge coefficient. This led to the removal of a considerable flood volume from the surface as there were limited restrictions on discharge to the sewer network. Secondly, the flood type at manholes was altered to be a "Gully 2D" relationship with a specified Head-Discharge relationship. An assumed three gullies and five gullies were tested at each manhole. This led to a more conservative estimate of the drainage potential of the highway gully network but it was found that the locations of manholes did not necessarily represent the location of highway drainage gullies.

During the process of the study, Medway Council had undertaken a survey to document the location of all highway drainage gullies in a **GIS dataset**. This information was used to update the model and **discretely represent the losses** from the ground surface to the surface water sewer network based on the assumption that each gully is connected to its closest surface water sewer manhole and that any restriction to flow is dictated by the head-discharge relationship. This model run altered the extent and distribution of flooding in a number of areas, resulting in an improved representation of surface water flood risk.

Options Modelling

The inclusion of the processes previously described, where applicable, can not only improve the representation of surface water flooding, but can also increase the potential options that can be modelled.

- The inclusion of **highway drainage gullies** in their specific locations enables the development of options to increase the number of drainage gullies and also allows for a reduced maintenance "Do Nothing" scenario to be modelled where gullies are assumed to become blocked;
- Representing **rainfall-runoff and infiltration processes** allows for checks to be undertaken during options modelling to determine whether options would be adequate during multiple flooding mechanisms;
- Including **surface water drainage infrastructure** allows for localised capacity increases where it is considered that restrictions in the drainage system exist.
- An accurate representation of the **surface topography** allows for options involving ground modification or to provide flood defence structures.

Lessons Learnt

The following list provides a summary of lessons learnt based on recent surface water flood modelling projects for LLFAs undertaken by AECOM.

1. Early **consultation** with all Risk Management Authorities and project stakeholders is important to identify key flood mechanisms and the availability of relevant data;
2. **Site visits** can be of utmost importance for surface water flood projects as the depth of flooding is generally shallow and can be significantly affected by changes in local topography.
3. Baseline modelling should represent as many processes as required based on the availability of data and the nature of the study catchment. Modelling strategies should be **tailored to the catchment** and the expected flood mechanisms.
4. **Model uncertainty** should be acknowledged and model results should be supported with suitable sensitivity tests.
5. Model construction should be undertaken with the likely options in mind to ensure that there is flexibility to accurately **represent proposed mitigation options**.
6. Stakeholder engagement and **public engagement** can be important in communicating flood risk to residents and Risk Management Authorities.
7. **Validation** based on gauged rainfall is encouraged, although the availability of accurate calibration data for surface flows or highway drainage discharges is limited.

Keywords

Integrated modelling, InfoWorks ICM, highway drainage, surface water flood risk, feasibility studies, LLFA