Urban Flood Routing……… The Next Step

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SYNOPSIS

Following the WaPUG/FWR workshop on Urban Flood Routing, Haswell has been looking into an interim method of predicting and mapping flood paths. Starting from basic information using manhole cover levels and benchmarks to produce digital terrain models, we have investigated the use of contour data, digital imagery and LIDAR data to obtain more accurate digital terrain maps. These data have then been used to initially produce simplified flood paths using engineering judgement. Then the data was run through a spatial analysis software package to determine flow paths within a catchment automatically. This technology and the data are relatively inexpensive and can be used for functions across the water industry where potential flood paths are part of the planning process.

INTRODUCTION

On the 26th September 2002, WaPUG and the Foundation for Water Research (FWR) held a workshop on “Urban Flood Route Prediction – Can We Do It?” Recommendations that came from this workshop encouraged further development of ways and means to model and predict overland flow routes. At this discussion various methods of micro-up routing were discussed e.g. packages using simple contours to predict where flood water from a manhole may go.

Although the concept of complete flow routing is still a very complicated issue, the belief that a partial solution is better than no solution has led Haswell to research a ‘next step’ in the evolution of a complete solution – Potential Flood Path Mapping (PFPM). This is a process which is undertaken on a macro down scale to determine catchment wide flow properties.

DATA TYPE AND SOURCES

The essential base data for the determination of flood path is geo-referenced elevation data which is entered into an elevation model. These models, dependant on data type follow the terminology outlined below:

DTM – Digital Terrain Model

This essentially is an elevation data set that does not include elevation data for any buildings, trees and other unnatural features, so it represents the ground surface only. This is the most common for of elevation model

DEM – Digital Elevation Model

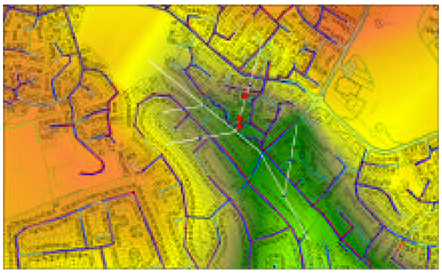
This model includes all elevation data recorded, so will include representations of buildings etc where elevation data has been recorded.

Other terminology includes DSM (Digital Surface Model) and DHM (Digital Height Model). These are less common, but are used to describe the same data sets as DTM and DEM respectively.

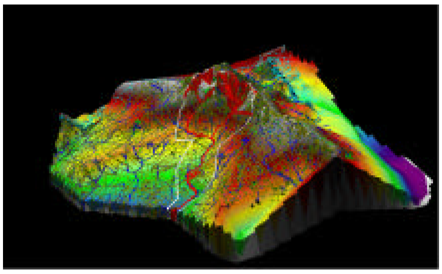
The elevation model can come in many forms, from topographic surveys, sewer records and Radar and Laser scanned digital data. These data can be interrogated to provide flood path information on differing levels of accuracy and quality. This paper discusses how the various data sources have evolved over recent years, identifying benefits of data sources and there use in DTM/DEM generation and finally the use of this data in the production of a Potential Flood Path Map.

Land Survey is the oldest and most widely used method of obtaining topographical data for a specific site. It is the most accurate form of data collection with accuracy up to ± 1 cm. The process remains fairly laborious even with the recent introduction of Total Station GPS and as such makes the cost prohibitive on a large scale. The main advantage of land survey is the ability to identify specific features such as channel beds which may not be picked up on a larger scale data set.

Sewer records normally include some form of manhole geo-referencing and a relative over/ground level. These data, in simplest form can be used to produce an initial catchment DTM using thematic mapping capabilities within GIS packages such as Mapinfo. The DTM can be produced showing coloured bands at set height ranges. These data can also be taken one step further by the use of 3D mapping tools. This provides the user with a better visual representation of the catchment.



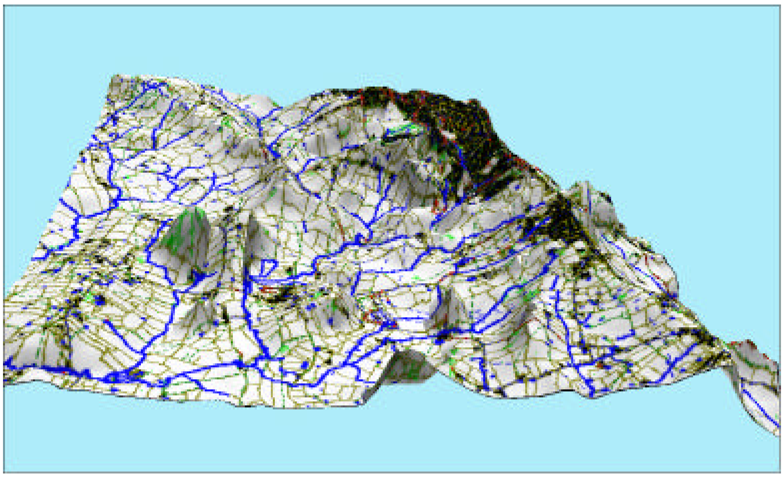
GIS Thematic Map using Cover Levels



GIS 3-D mapping

The Main problems with the data are resolution and quality. At best, these data will give a broad brush idea of what exists topographically where manholes are present, with no data for surrounding areas, which are equally important in terms of flow paths. Additional information (e.g. benchmarks) can be added to the data which can often help fill in some gaps in the cover level data.

The **Ordnance Survey** holds ‘contour’ data in grid form. This data used to be supplied as a 1:50,000 DHM with a 50m grid (**Panorama**) This information was very coarse. Panorama was withdrawn from sale in 2002, however may still be available through companies which hold the data. An updated data set is currently available called **Profile**. The data set improved on the resolution of the Panorama data, providing a 10m grid with vertical accuracy of ±2.5-5 m (dependant on vertical interval). However the main issue again with this data set is quality and vertical accuracy for the purposes of a PFPM.



Sample of DTM taken from Ordnance Survey Panorama Data

Photogrammetry involves the automatic generation of a DTM from existing aerial photography. As a process this has been around for a period of time using stereoscopic viewers to hand determine elevations. The more up to data procedure involves the use of automated pixel correlation techniques to generate a DTM/DEM at 1m resolution. As the automatic process only correlates pixels, not pictures, a degree of manual editing is necessary to differentiate between terrain and the tops of trees or buildings. This is a more time consuming process, but will generate a reasonably accurate terrain model for use with PFPM.

Synthetic Aperture Radar (SAR) is a process that uses an electromagnetic imaging sensor which has often been used in remote sensing applications. The SAR sensor is mounted on an aircraft or a satellite, and is used to make a high-resolution image of the earth's surface as well as being used to determine elevations. This initially produces a DEM but can be processed to give a 'bare earth' DTM.

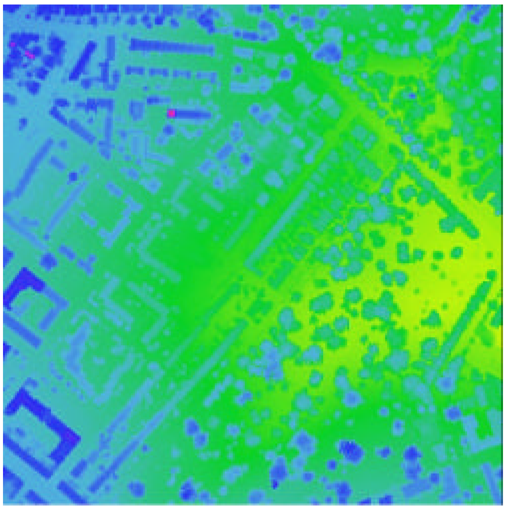
The radar unit has a ground swath of 3-10 km, enabling large areas to be covered quickly. The radar is side looking so there is a reduced ground view and problems can be encountered in determining reflections from buildings, so some manual checking is required. The elevation data has an accuracy of ± 2.0 m (95 %ile DTM) at a 5m grid.

Light Distance and Ranging (LIDAR) data has become available in recent years. The process involves the use of an aeroplane mounted laserscanner which emits a series of pulses which are returned by objects on the ground. These objects could be terrain, vegetation or man made structures. LIDAR data is available in the UK primarily from Infoterra at varying resolutions. The Environment Agency also holds some LIDAR data but it is older data set and only available for limited areas.

The laser beam is scanned across a swath beneath the aircraft using and oscillating mirror. The Infoterra laserscanner is capable of capturing up to 33,000 pieces of elevation data every second across a swath width of 1454m. As such it is a very efficient data collection system.

All this information is combined with GPS locations and altitudes to provide an accurate DEM. From this the 'clutter' (buildings, trees etc) can be removed to produce a DTM of the same catchment.

Vertical accuracy is dependant on aeroplane altitude and equipment used. At 900m the accuracy can be as good as ±0.15 m.



LIDAR DEM Data courtesy of Infoterra

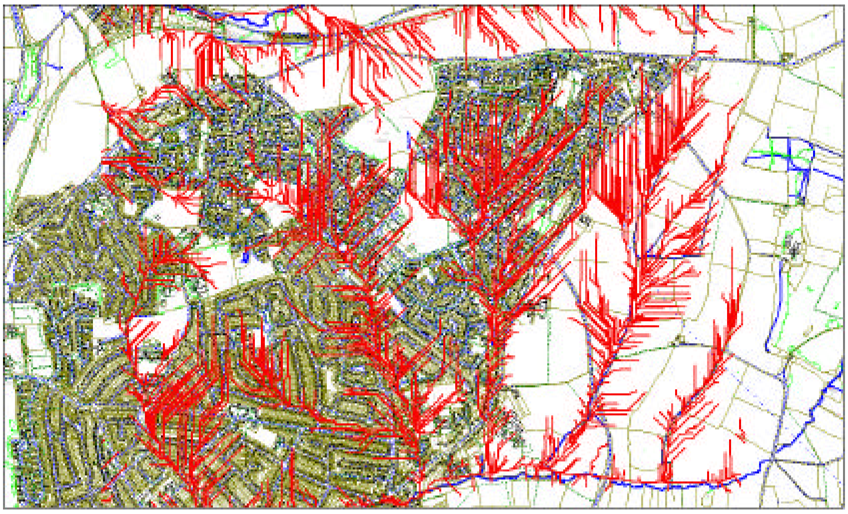
USING DTM DATA

First Principles

The simplest flood path generation can be performed using a DTM generated from any data set, for example manhole cover levels. The data can be manipulated in GIS packages to produce a thematic map and simplified flood paths can be determined using engineering judgement. This can be used as a first step to identify properties that could be at risk. This method is however time consuming and labour intensive if it is to be undertaken on a large scale and will only provide limited accuracy depending on the base data used.

GIS Plug-ins

Additional plug-ins are available for Mapinfo which go some way to automating the process of flood path determination. As long as the DTM grid can be brought into Mapinfo, it can be manipulated to determine vector flood routes. These simplified routing packages use a directionally limited routing method allowing only 8 possible directional paths (Think of the points on a compass: N, NE, E, SE etc). This gives an unrealistic overall flood path.



Flow Path Generation using GIS Plug-in Software

This software can be used to give an overall idea of catchment flow paths and is certainly simple to use in relation with base GIS data and packages, but is limited in its directional flow path determination.

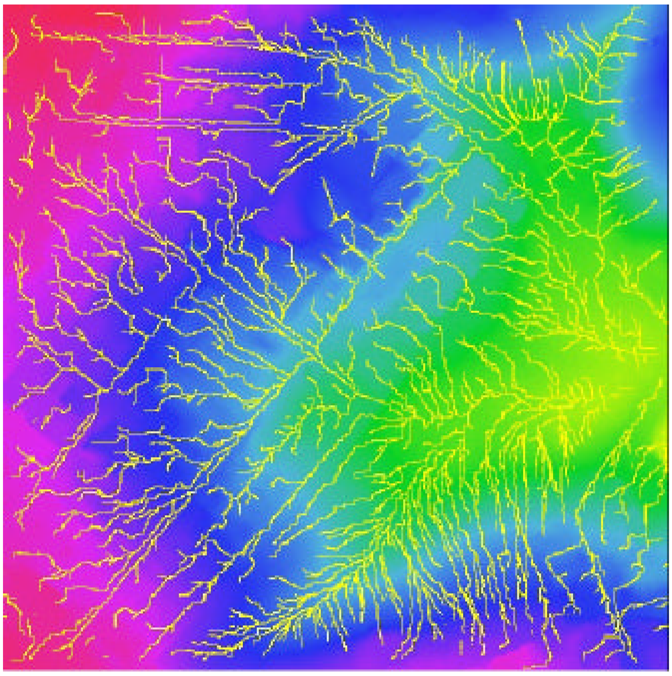
Flood Path Mapping – Spatial Analysis

Haswells are currently using spatial analysis software to produce a more accurate flood path map using various data sources. The software uses a series of algorithms in pre-processing to condition the data.

The first of these involves the identification of "Flats and Pits" within the DTM. When the flood routing algorithm is run, if it comes across a flat section or small depression, it doesn't know which route to take. The pre processing algorithms will interrogate the surrounding elevation data and determine which route would be the primary route and 'fills' small depressions and will give some slope to flat sections to allow a flow path to be completed. In the case of major depressions within the terrain, this process is not performed and the flow path will terminate at the depression.

Once the data has undergone pre-processing, the flow routing algorithm uses a 'rolling ball' style methodology to determine flow paths. It uses primary and secondary flow vectors to determine the probable flow path across the data grid. This routing is not limited to the 8 direction routing previously mentioned so gives a more accurate flow path generation. This can be used to generate flow paths for the full DTM, paths draining to a specific area or the flow path from a specific site e.g. a manhole.

One major point that has been identified is the difference in flow paths generated from a DTM and a DEM of the same area. The DEM shows routing influenced by the buildings and as such does identify major flow paths down roads, it may give an inaccurate representation of which buildings may be impacted upon by flood waters. A comparison of the two data sets would be very useful in determining areas where problems may arise.



Catchment Wide Potential Flood Path Mapping

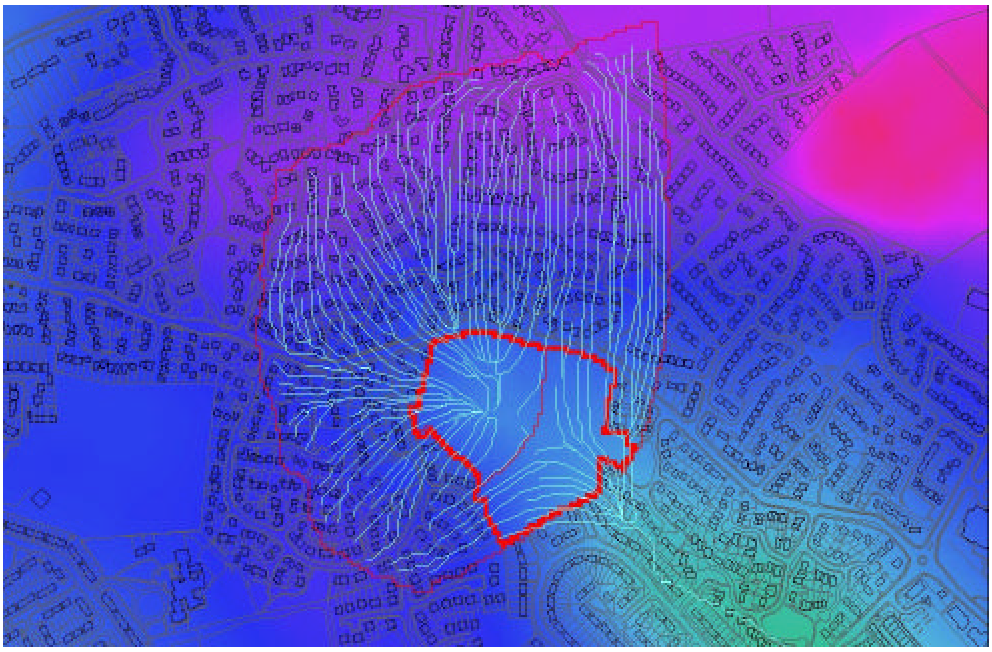
DTM Courtesy of Infoterra

APPLICATIONS

The uses of Potential Flood Path Mapping are wide ranging. It can be used as a catchment wide tool identifying areas which may be at risk and to help understand the potential implications of extreme rainfall for the specified catchment.

Potential Flood Path Mapping within a Specific Catchment

There are also major obligations on developers and councils as well as the EA in determining the flood routing associated with new developments and identifying potential flow paths both to and from a proposed development.



Flood paths relating to a hypothetical development site

The data could also be used to provide additional data for flood risk assessment in determining potential additional contributing areas to watercourses under extreme conditions.

CONCLUSIONS

In conclusion, following the obstacles outlined at the FWR/WaPUG workshop on Urban Flood routing, Haswell have developed a next step in the quest to achieve a solution, the Potential Flood Path Map. This can be produced from a DTM generated by various sources of data which are now readily available.

THE FUTURE

Potential Flood Path Mapping has given us some idea of what directions flood waters may take and can give some idea of routing, but development of full flood route modelling to quantify flood depths and volumes may still be some way off.