Developing a local flood risk management strategy
Annex 5: A rational GIS based approach to preliminary flood component analysis

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These notes are based on the shared knowledge and experience of the partners of the Interreg IVB projects FloodResilienCity (FRC), Managing Adaptive Responses to Changing Flood Risk (MARE) and Skills Integration and New Technology (SKINT)

They are written in a way that they can be easily understood by the majority of Europeans, whose first language is not English. A bye product of this is that they can be easily translated and that they should also be easy to understand by non specialists. Hopefully, this should make them more relevant to those for whom flood risk management is relevant, but who are not water engineers.

The notes describe how to carry out a preliminary flood component analysis which contributes to the first phase of developing strategies for the management of flood risk and flood risk management plans. **They describe what can be done, but the authors recognise that this is an ideal and that because this is a preliminary assessment some of the later Steps may be considered not to be sufficiently beneficial to use.**

Please feel free to use any part of these notes, but a reference to FRC, MARE and SKINT would be appreciated.

If you have any comments and suggestions about these notes, please email John Blanksby at j.blanksby@sheffield.ac.uk and we shall take them on board in subsequent versions.

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Contents

1 Introduction:

1.1 Flood component analysis – a framework for identifying causes and attributing responsibility for flooding

Flood component analysis was developed by David Wilson of Scottish Water as a means of illustrating responsibilities for flooding to the different partners involved in the Glasgow Strategic Drainage Plan. In its initial form the flood component analysis used different modelling techniques to estimate the volume of different sources of flooding. Figures 1 – 4 provide examples of the relative importance of different flood components (and hence stakeholders) in three case studies and a general impression of the flood cluster resulting from a significant event in Glasgow in July 2002.

Figure 5 shows the main flood components, with an indication of the impacts of future drivers (climate change and urbanisation) and an example of how the main components may be further sub divided

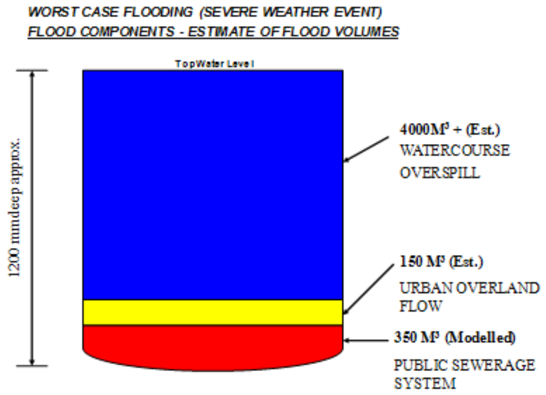

Figure 1: Flood component analysis, Example 1, Glasgow 30th July 2002, (Scottish Water)

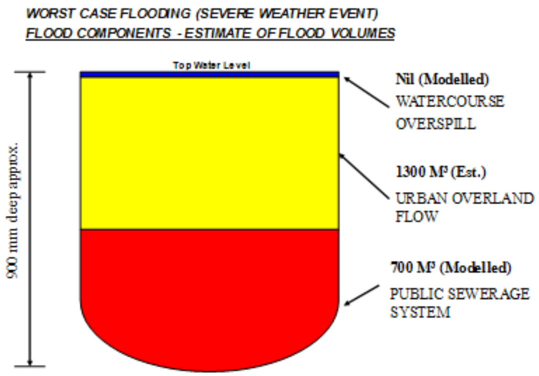

Figure 2: Flood component analysis, Example 2, Glasgow 30th July 2002, (Scottish Water)

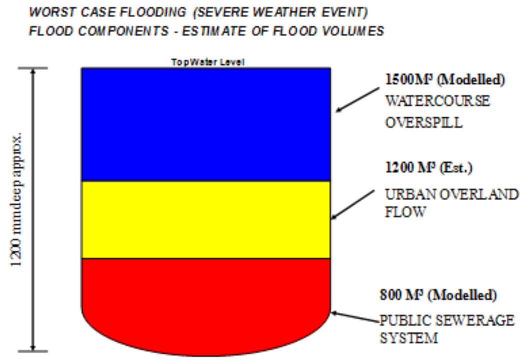

Figure 3: Flood component analysis, Example 3, Glasgow 30th July 2002 (Scottish Water)

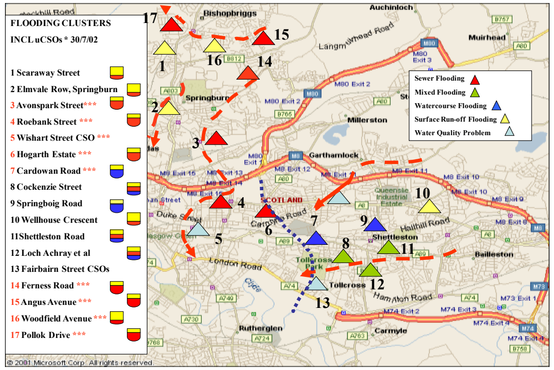

Figure 4: Main Flood Clusters 30th July 2002 with Dominant Cause highlighted (Scottish Water)

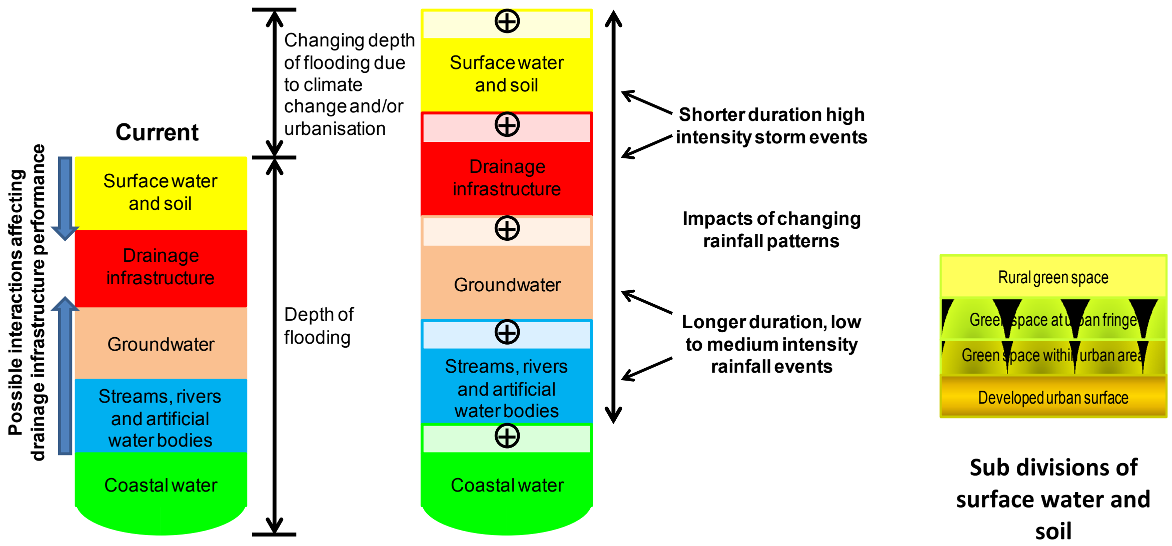

Figure 5: Flood component analysis and the impact of future drivers

1.2 The need for a preliminary flood component analysis

There are benefits in carrying out an assessment to identify the potential causes of flooding prior to embarking on detailed diagnostic studies. The results of the assessment will help to identify:

- The different sources of flood risk associated with a particular problem
- The stakeholders who should be involved
- Appropriate modelling techniques
- Data collection needs
- Resource requirements
- Costs and their likely distribution amongst atkeholders.

The proposed approach may be used as part of the investigation of specific flood incidents or as a general approach to the assessment of flood risk in potential development sites or of high vulnerability infrastructure and buildings.

2 Rationale

The approach should be simple and should be capable of automation and should use readily available data

2.1 Data requirements

The analysis requires the following information as a minimum:

- A digital elevation model
- Digital maps with layers identifying different types of surfaces
- Digital flood hazard, probability, risk and extent maps for coastal and river flooding

In addition information on the distribution of depth, duration and frequency of local rainfall will provide enhanced outputs, as will basic information of the hydraulic performance of drainage infrastructure. In the absence of the latter, the analysis will enable a preliminary assessment of drainage infrastructure performance to be made where knowledge of the rainfall causing flooding exists.

3 Aim

To identify how the following flood components may contribute to flooding

- Water bodies
    - Coastal
    - Rivers
    - Streams
- Drainage infrastructure
- Surface types
    - Rural green space
    - Green space at the urban fringe
    - Urban Green space
    - Developed urban surfaces
        - Highways
        - Buildings and structures

4 Comments on digital elevation models

The quality of a digital elevation models is by and large inversely proportional to the resolution of the model and the method by which it is created. The higher the resolution, the more the detail that is picked up, including walls and mounds around buildings, low kerbs etc. Because these can affect flow pathways, inaccuracies are more likely to happen the lower the resolution of the model. This is particularly the case where there are convex surfaces.

Human actions during flood events such as the use of sandbags also alter flow paths.

Steps have to be taken to ensure accurate representation of flows under bridges and it is necessary to check that airborne remote sensing surveys have penetrated narrow gaps between buildings etc.

In these notes it is assumed that the resolution of the DEM is sufficient for the purpose for which it is used. Guidance on the fitness for purpose of digital elevation models is provided elsewhere

5 Comments on digital maps

Digital maps contain many layers of data and there may be inconsistencies.

The layers included within a digital map may not be quite ideal for the use to which they are being put, but providing that deficiencies are recognised, there should be no need to go to great lengths to create additional layers for what is a preliminary assessment. However, the effort taken to enhance the layer for the detailed diagnostic study can be identified and included within the cost of that study.

Further information on the management of digital map layers is provided elsewhere

6 The preliminary flood component analysis process

The process has 11 steps as follows:

1) Define the boundary of the study area
2) Identify all pathways and sinks
3) Identify pathways and sinks associated with surface water
4) Identify pathways, sinks and flood extents associated with water bodies
    a) Coastal, rivers and large streams
    b) Small streams
5) Identify contribution from developed urban surfaces
    a) Highways
    b) Buildings, structures and associated ground surfaces
6) Identify contribution from green space
    a) Urban Green space
    b) Green space at the urban fringe
    c) Rural green space
7) Assess drainage system capacity
8) Assess decay rates for surface water flooding along developed urban surface
9) Assess decay rates for flooding from small streams along developed urban surface
10) Assess joint probabilities
11) Finalise flood component analysis

6.1 Step 1 – Define the boundary of the study area.

This Step identifies the natural drainage boundary of the study area. It requires GIS competencies for application and drainage competencies for review.

6.1.1 Aim

To identify the downstream and upstream drainage boundaries of the area under investigation.

6.1.2 Method

The starting point is to identify the downstream drainage boundary. This is achieved by identifying locations downstream that could be adversely affected by actions taken in the area under investigation. The downstream boundary can then be identified as a "Pour Point" in a GIS layer

The next step is to identify the upstream boundary. Using an appropriate resolution DEM and the layer defining the downstream boundary the appropriate GIS tools can be used to determine the upper catchment boundary (the watershed).

The downstream and upstream boundaries should then be reviewed together with other relevant information such as sewer utility drainage area boundaries and other potentially linked study areas to finalise the boundary of the study area.

6.2 Step 2 - Identify all pathways and sinks

This element requires GIS competencies.

Within each surface water management zone the best available resolution DEM (say 1 metre horizontal) should be used to:

- Identify sinks
- Fill sinks
- Determine slopes
- Determine pathways (by means of an accumulation of contributing cells)

This layer will contain all sinks and pathways including those associated with:

- Surface water
- Small streams, large streams, rivers and associated water bodies
- Coastal waters

6.3 Step 3 - Identify pathways and sinks associated with surface water

This Step eliminates the pathways and sinks associated with small streams, large streams, rivers, associated water bodies and coastal waters, leaving the pathways associated with surface water. It requires GIS competencies

To do this the map layers for these features should be used to create "Black Holes" in the DEM.

The process described in Step 2 is then used to identify the pathways and sinks associated with surface water

6.4 Step 4 - Identify pathways, sinks and flood extents associated with water bodies

This Step requires GIS competencies.

6.4.1 Coastal, rivers and large streams

The pathways, sinks and flood extents are defined by the national or regional flood extent mapping

6.4.2 Small streams

For the pathways, the accumulations from Step 3 are subtracted from those from Step 2 to produce the accumulations occurring where a culvert collapses or its capacity is exceeded

The same process is used, but with the depth of cells within sinks used to identify those sinks associated with the collapse or lack of capacity in small stream culverts.

Note on progress

At this stage it will be possible to define those areas subject to flooding from:

- Coastal water
- Rivers
- Large streams
- Small streams
- Surface water

It will also be possible to identify those areas where there are joint probabilities of flooding and in the case of surface water and small streams identify their relative contribution. The next Steps will differentiate between the different types of surface water

6.5 Step 5 - Identify contribution from developed urban surfaces

This Step requires drainage competencies to help define the boundaries and GIS competencies for application.

6.5.1 Highways

Using the routines described, define the highway boundaries and determine the accumulations within the pathways emanating from them

6.5.2 Buildings, structures and associated ground surfaces

Using the routines described, define the buildings, structures and associated ground surface boundaries and determine the accumulations within the pathways emanating from them

6.6 Step 6 - Identify contributions from green space

This Step requires drainage competencies to help define the boundaries and GIS competencies for application.

6.6.1 Urban Green space

Urban green space is defined as green space which receives flows from and discharges flows to developed urban surfaces.

Define the boundaries and determine the accumulations within the pathways emanating from them

6.6.2 Green space at the urban fringe

Fringe urban green space is defined as green space which has the potential to EITHER receives flows from OR discharge flows to developed urban surfaces. If runoff from green space enters a stream or river before entering the urban area then that green space is defined as rural

Define the boundaries and determine the accumulations within the pathways emanating from them

6.6.3 Rural green space

This covers all other areas of green space where flows enter water bodies before entering the urban area

Define the boundaries and determine the accumulations within the pathways (and water bodies) emanating from them.

6.7 Step 7 - Assess drainage system capacity

This Step requires GIS and drainage competencies.

The drainage infrastructure that may be considered includes:

- Sewers (combined and surface water)/(private and public)
- Suds
- Piped drains
- Open drains

6.7.1 Availability of models

Hydrodynamic simulation models of core network and hydraulically important peripheral sewers may be available for combined sewer systems and some surface water sewer systems. Some of these may have been built for flood risk assessments, but others may have been for water quality assessments and may not have been verified to the required standard. The age of the model is also a factor.

Other models may be available through the development and building control processes, but these may be hydrological rather than hydrodynamic simulation models.

If no models exist it is possible to assess capacity by means of the rational method using basic pipe information (dimensions and gradient) providing that this information is available. However this is only possible for relatively small and simple networks.

A combination of DEM, map and rainfall data will provide the basis for any necessary hydrological modelling

6.7.2 Standards for comparison

Ideally, the drainage system performance should be assessed using agreed local, regional or national standards. Where hydrodynamic models are available the standard should be that for the system to be full and surcharged to the ground surface. For hydrological models the standard should be for the system to be full but without surcharge. In the absence of local, regional or national standards, guidance may be found in EN 752[1]. Tables 2 and 3 of EN 752 are summarised below:

[1] EN752 2008. Drain and sewer systems outside buildings. European Committee for Standardisation, Management Centre: rue de Stassart, 36 B-1050 Brussels.

Location	Simple, hydrological methods		Complex, hydrodynamic methods	
	Return period (1 in "n" years)	Probability of exceeding in any 1 year	Return period (1 in "n" years)	Probability of exceeding in any 1 year
Rural area	1 in 1	100%	1 in 10	10%
Residential areas	1 in 2	50%	1 in 20	5%
City centres, industrial and commercial areas.	1 in 5	20%	1 in 30	3%
Underground railway and underpasses.	1 in 10	10%	1 in 50	2%

The event probability causing failure of the actual system can be divided by the event probability of the standard to give a ratio that may be less than or greater than 1. This indicates whether or not the drainage system under performs and contributes to flooding.

Note on progress

At this stage it is possible to identify the potential contributions from small streams and different surface types by comparing the accumulations at any point. As a first pass this may seem fine, but there is a problem as there is as yet no account taken of the capacity within the different urban drainage systems to accept and transport surface water. In order to do this, a basic approach using the rational method is described.

This approach may be used to develop a rate of decay for flooding emanating from green space and blocked streams as it flows along pathways in developed urban areas, and into drainage systems through gullies, providing that the capacity of the drainage systems serving those areas are not exceeded.

This provides a method of determining the extent of the impact of runoff from green space saturated by long duration, heavy, (but not intense) cyclonic rainfall, which is the cause of the majority of flooding incidents in and around urban areas

6.8 Step 8 - Assess decay rates for surface water flooding along developed urban surface

An appropriate approach is described using a worked example in Appendix 5 the SKINT project report "Gulley Optimosation" which can be downloaded at:

http://kvina.niva.no/skint/ArticleView/tabid/61/ArticleId/73/Gulley-optimisation.aspx

Users should use local information, judgement and sensitivity analysis to determine the runoff and decay rate in their own locality. **This Step requires GIS and drainage competencies.**

6.9 Step 9 - Assess decay rates for flooding from small streams along developed urban surface

The exceedance flow from small streams/stream culverts may be determined by subtracting the channel/culvert capacity from the calculated discharge within the stream at that point.

The discharge may be calculated using appropriate hydrological approaches and may be enhanced using the Conveyance and Afflux Estimation System which is available at:

http://www.river-conveyance.net/

As with the runoff from green space the spare capacity within the drainage system can be calculated and the downstream extent of the stream flooding determined. **This Step requires GIS and drainage competencies.**

6.10 Step 10 - Assess potential for joint probabilities

The approach to this step will be agreed with key stakeholders based on local circumstances

6.11 Step 11 - Finalise flood component analysis

The approach to this step will be agreed with key stakeholders based on local circumstances