Surface water flooding summary: Methodology and mapping

1. Introduction

The Flood Risk Management (Scotland) Act 2009 (FRM Act) introduced a co-ordinated and partnership approach to how we tackle flood risk in Scotland in a sustainable manner. To fulfil this we are considering all sources of flooding and whole river catchments when making flood risk management decisions.

A key milestone of the FRM Act is the production of flood hazard and flood risk maps for Scotland. These maps will provide the most comprehensive national source of data on flood hazard and risk and include information on different likelihoods of flooding:

Likelihood of flooding	Return period
High	10 year
Medium	200 year
Low	200 year plus climate change

To produce a flood hazard map for each source of flooding SEPA has developed new datasets and methodologies for coastal, river and surface water flooding. These create flood maps for Scotland and supersede the current Indicative River and Coastal Flood Map.

This summary provides information on how we developed our surface water flood map and how to interpret this data. The primary purpose of this summary is to support Scottish Government, local authorities and Scottish Water in their understanding of how the maps were developed and support internal/external briefings and enquiries. This in turn will help to increase public awareness and understanding of flood risk. This summary assumes previous knowledge of flood maps and their development.

This summary will also be shared with the Loch Lomond and Trossachs National Park, Cairngorms National Park Authority and the Forestry Commission Scotland as responsible authorities from 21 December.

2. Development and review

The surface water map combines information on pluvial (rainfall) and sewer model outputs. Whilst these flood sources are shown on the same map they have been considered independently of one another and therefore the map does not show their interaction.

2.1 Improvements from the Indicative River and Coastal Flood Map (Scotland)

The production of this surface water flood map has improved our understanding of surface water flooding. In particular improvements relate to:

- The first national surface water flooding map for Scotland

- Flood extents and depth outputs developed for a greater range of return periods
- Flood velocity for areas identified at 'significant' risk of surface water flooding

2.2 Future review and development

The mapping of flood hazard is a dynamic process and the flood extent map will be subject to review and change as we develop our input data, methodologies and techniques. SEPA will work with responsible authorities and partner organisations to improve our confidence in representing surface water flood hazard across Scotland.

Ongoing developments that SEPA is working towards include:

- Improved input data:
    - For example, use new LiDAR information that extends our coverage of higher resolution ground models
    - Variations in rainfall and storm duration to reflect local contexts
- Investigate how to effectively apply more detailed hydraulic modelling methods

The flood maps, as made publicly available on 15 January 2014, reflect the knowledge and data we have available at that time and were able to incorporate into our national methodologies.

3. Methodology and data

3.1 Approach

A nationally applied methodology has been used to produce the surface water flood map for Scotland. The map provides indicative flood hazard information and identifies communities at risk from surface water flooding. The approach develops the surface water flooding data derived as part of the National Flood Risk Assessment (NFRA) and provides higher resolution outputs and sewer flooding information where possible.

3.2 Data

The data used to produce the coastal flood map is listed in table 1(Appendix A, page 9), alongside a description of the data, how it was used and the quality review process.

3.3 Methodology

The surface water flood map incorporates data from three separate studies:

- National surface water study developed for, and extended from the National Flood Risk Assessment (NFRA)
- Regional surface water study with increased resolution from the national study for selected areas
- Scottish Water sewer flooding assessment

The surface water flood map provides:

- Flood extents and depths for seven return periods, including a climate change scenario, for the entire country
- Velocity and hazard outputs for seven return periods in those areas covered by the regional studies

Table 2 (Appendix A, page 11) shows the return periods for which surface water flood extents, velocities and depth grids were derived.

3.3.1 National Dataset from the NFRA

This was the first national assessment of surface water flooding with the aim of identifying areas at the greatest risk to its impacts. A simplified rapid flood spreading model was used for the national surface water output. Rainfall is spread across the ground model, flooding depressions in the land surface. Where the depression fills up and spills over, the neighbouring depression is filled. Due to the simplified nature of the rapid flood spreading model, this output does not account for flow pathways or velocities, only depths and extents are derived. Models were run for sub-catchment-units (SCU's) across the country, producing approximately 4000 models.

NEXTmap data was used for the digital terrain model (DTM) as it was the only nationally available DTM. Ground levels were dropped by 0.1m in roads, and raised by 0.3m at buildings to account for the 5m resolution of the DTM used and better represent these features.

Rainfall inputs to the model were provided by the Centre for Ecology and Hydrology (CEH). Rainfall events for all 7 return periods were routed into the model, with rainfall losses due to drainage networks and runoff applied depending on whether the area was urban or rural as shown in Table 2 (below)

Table 2

	Urban Environment	Rural Environment
Storm Duration	1 hour	3 hour
Percentage Runoff	70%	55%
Losses to drainage	12mm/hr	0mm/hr

3.3.2 High resolution regional dataset

73 of the catchments at the greatest risk from surface water flooding identified in the NFRA were put forward for higher resolution modelling, forming the regional surface water dataset. This dataset predominantly focuses on urban centres, with models being run for 5km tiles A 2D hydraulic model was used for the regional dataset, which improves on the national dataset by considering flow pathways and producing velocity and hazard rating outputs as well as depths and extents.

LiDAR data constituted the majority of the DTM used, however some small areas of catchments are not covered by LiDAR and therefore NEXTmap data was used in these areas. Ground levels were raised by 0.3m at buildings to represent the threshold at which flooding of buildings could occur, however unlike the national model ground levels were not dropped at roads due to the improved DTM resolution and the consideration of flow pathways in the model. The use of LiDAR data has improved the quality of the ground model from that used in the national study.

Similar to the national dataset, rainfall inputs to the model were provided by the Centre for Ecology and Hydrology (CEH) and rainfall losses applied to account for differences in drainage and runoff between urban and rural areas as shown in table 3 (below).

Roughness values (a measure of resistance to flood flows required for 2D models) were derived for the modelled catchments using the Land Cover Map 2007.

Table 3

	Urban Environment	**Rural Environment**
Storm Duration	1 hour & 3 hour	1 hour & 3 hour
Percentage Runoff	70%	55%
Losses to drainage	equivalent to 5 year rainfall event for catchment	0mm/hr

3.3.3 Scottish Water sewer flooding assessment

Under the FRM Act, Scottish Water is responsible for assessing the impacts of sewerage flooding in consultation with SEPA. In April 2012 SEPA consulted with responsible authorities on the assessment of flood risk from sewerage systems as required by section 16 of the FRM Act. This consultation contributed to Scottish Water's sewer flooding assessment. Through dialogue and agreement with SEPA, Scottish Water has carried out an assessment on 64 catchments to date and will ultimately assess 206 catchments in total following a period of inspection and survey work on their infrastructure. Rainfall inputs were provided by Scottish Water having been derived using industry standard methods.

1D sewer models were used to determine the locations of where a flood is likely to originate from a sewer system and the volumes of sewerage / water which released from the sewer system in the event of a flood. Once the volumes were estimated, they were spread across the ground surface from the locations determined by the 1D model using a 2D model. The DTM used for the regional dataset was used for the sewer flooding assessment with the addition of NEXTmap data in those areas not covered by the regional output.

Only depths and extents were provided for the sewer flooding assessment, in line with the requirements of Section 16 of the FRM Act.

3.3.4 Climate change

The estimation of future changes in convective rainfall events (localised, high intensity events known to cause most surface water flooding) is difficult at a regional or local scale and therefore a national increase in rainfall of 20% was applied to account for climate change. This is in line with 2006 DEFRA guidance. The uplift was applied to selected scenarios including the 200 year return periods (medium likelihood).

3.3.5 Flood defences and structures

Defended and undefended model runs are not considered in the surface water map as defences in SFDAD are not formally built for surface water flood events. Defences that have been picked up in the DTM's will influence flood extents and modelling strategies developed.

False blockages were identified and removed from the DTMs by cross referencing structures datasets prior to model runs and by looking at the flood extent for the 200 year event once models had been run.

3.3.6 Combining outputs

For each return period the national, regional and sewer assessments were combined to provide a single surface water flood map. The 3hr event was used in all instances of data combination to provide consistency with NFRA and Appraisal work.

The higher resolution regional dataset has been shown where available and the national dataset shown outwith these areas. The Scottish Water sewer assessment was then merged with these datasets, however it should be noted that these sources are considered independently of one another and the maps do not reflect an interaction of the drainage systems.

Velocity data is only shown in those areas covered by the higher resolution regional dataset.

Areas with flood depths of less than 0.1m were removed due to the relatively low risk these depths pose, and the underlying accuracy of the DTM.

4. Validation and quality review

A robust validation and review process was undertaken for the surface water flood map data.

- **Peer contribution –** The Scottish Advisory and Implementation Forum for Flooding Modelling Appraisal Strategy Group (MASt) provided peer contribution to the approach for the surface water flood map. This group includes representation from industry, academia, the Society of Chief Officers of Transportation in Scotland (SCOTS), Scottish Water and Scottish Government.

- **Internal review –** Checks of the datasets used as inputs are referenced in Table 1 (Appendix A, page 8). Checks on the surface water flood map were carried out on extents, depths and velocities:
    - Manual reviews were undertaken on model outputs on aspects such as extreme depths and velocities to ensure they were within acceptable modelling error bands, roughness values and DTM changes were correct, outputs seemed logical in comparison to existing surface water models and reports and that depths, velocities and extents seemed reasonable.
    - An automated review was undertaken to ensure that flood extents, depths and velocities increased with return period and to identify any extreme depths.
    - A review of public records was carried out to identify areas with a history of surface water flooding and these compared to mapped outputs as a sense-check .

- **Local authority review** - Local authorities reviewed flood extents for low, medium and high likelihood events. SEPA hosted workshops and drop-in sessions to review the maps in partnership with local authorities and has acted on the comments and feedback received where there is data available to do so.

5. Interpretation

The surface water flood map has been developed using a nationally applied methodology. It is a tool to support flood risk management decisions, land-use planning and to help raise public awareness and understanding of flood risk.

The map is of a strategic nature to support flood risk management planning at a community level. It is not appropriate for property level assessment. This is due to necessary assumptions and inherent uncertainty in the application of a nationally consistent methodology to provide Scotland-wide surface water flood mapping. We have set appropriate controls on the zoom on the map, hosted on the website to support the intended use of the maps at a community level. Similarly we would advise that when data is hosted on your internal servers, that going beyond the recommended level of zoom will lead to increased uncertainty in the application of the map and be beyond the scope of the various assessments.

As the national source of flood hazard in Scotland, the map forms a key basis for flood risk management planning. This will go on to become a key element of Flood Risk Management Strategies and Local Flood Risk Management Plans.

The map is not licensed for commercial use and all users must agree to terms and conditions before viewing the map.

5.1 Confidence

Flood hazard mapping and the assessment of the sources and impacts of flooding is a complex process. Due to assumptions that are necessary to allow us to reflect complex natural processes, there are uncertainties associated with developing any assessment or modelling methodology.

Assumptions may be applied at each stage of the process and from a range of sources. For example, sources of uncertainty in flood hazard mapping include:

- The data going into the assessment such as design rainfall
- The resolution of topographical information
- The method or model used
- Future changes e.g. climate change and land use changes

The consideration of model/map confidence enables us to make informed decisions by providing understanding the confidence in the data and the final mapped outputs. It also identifies where resources can be focused for further development.

5.2 Limitations

The surface water flood map has been produced at the national scale using national datasets and standard methodologies. This map is a strategic product to support Flood Risk Management Planning at a community level.

5.2.1 Method limitations

The key limitations of the strategic modelling approach taken for surface water mapping are as follows:

- Rainfall inputs are based on defined durations of 1 hour and 3 hours, rather than the most intense or critical storm duration.
- Ground models are varied in their resolution between national and regional investigation and each contain inherent limitations such as landscape artifacts and historic changes in ground levels due to development.
- Roughness values for land cover in the regional study are based on broad land-use categories from Land Cover Map (LCM) 2007 so may not represent variability of all local environments.
- The actual volumes of rainfall lost to drainage systems or simple runoff is highly locally variable and is dependent on infrastructure capacity and management practices. Applying national or regionalised loss values may under or over-estimate reality.
- Antecedent conditions (such as initial catchment wetness) and other local effects on infiltration are not directly considered (other than through the use of nationally applicable percentage runoff values for urban and rural land-use).
- The national study does not identify flow pathways and therefore surface water flooding associated with pathway flooding may not be represented.
- Velocities are only provided for those areas covered by the regional study.

5.2.2 Caveats

- The map is not licensed for commercial use and all users must agree to terms and conditions before viewing the map.
- The surface water map does not consider the interaction of pluvial and sewerage flood sources. These sources are considered independently.

Appendix A

Table 1: Data as an input to surface water flood map

Data	Description	How the data was used	Quality check
National Study Digital Terrain Model (DTM)	Intermap's NEXTMap DTM with a horizontal resolution of 5m was used in the national study.	• To develop the national surface water flood model.	• Manual quality checks to ensure blockages were removed from river channels, such as bridges and vegetation. • Manual check of the 200 year flood extent to identify any remaining false
Regional Study DTM	The DTM used in the regional study comprises LiDAR and Intermap's NEXTMap DTM with a horizontal resolution of 5m or 2m depending on the catchment being modelled.	• To develop the regional surface water flood model.	• Manual quality checks to ensure blockages were removed from river channels, such as bridges and vegetation. • Manual check of the 200 year flood extent to identify any remaining false blockages • Checks were also undertaken at the boundary of NEXTmap and LiDAR data to ensure there were no jumps in ground level.
Sewer Modelling DTM	The regional study DTM with NEXTmap data added in to those areas not covered by the regional study for which sewer modelling is required.	• To develop the sewer flood model.	• Manual quality checks to ensure blockages were removed from river channels, such as bridges and vegetation. • Manual check of the 200 year flood extent to identify any remaining false blockages • Checks were also undertaken at the boundary of NEXTmap

			and LiDAR data to ensure there were no jumps in ground level.
OS Mastermap layers	Dataset containing geographic features such as roads, properties and topography.	• Used to identify possible false blockages in the DTMs • Used to identify buildings for the regional output in order to raise DTM heights by 0.3m • Used to determine urban/rural areas for alterations to model inflows in the regional study	• This is a published dataset from Ordnance Survey and therefore checks on this were not undertaken.
OS Vectormap Layers	Dataset containing geographic features such as roads, properties and topography.	• Used to identify buildings for the national output in order to raise DTM heights by 0.3m	• This is a published dataset from Ordnance Survey and therefore checks on this were not undertaken.
Scottish Government Urban/Rural Classification	Dataset identifying urban and rural areas based on population and accessibility.	• Used to determine urban/rural areas for alterations to model inflows in the national study	• This is a published dataset and therefore checks on this were not undertaken.
National & Regional Rainfall values	$1km^2$ tiles holding rainfall inputs for the 7 return periods being modelled Alterations were made to these tiles to account for losses to drains and losses to runoff.	• To develop the national and regional models.	• Rainfall values were provided by the Centre for Ecology and Hydrology (CEH) this is commercially available software and therefore checks on this were not undertaken.
Land Cover Map 2007	LCM2007 has been derived from satellite images and digital cartography and gives land cover information for the entire UK on a 25m grid. Land cover classes are based on UK Biodiversity Action Plan Broad Habitats, for example coniferous forest or saltmarsh. LCM2007 is produced by the	• Used to define roughness values (a measure of resistance to flood flow) for areas in the regional study	• This is a published dataset and therefore checks on this were not undertaken.

	Centre for Ecology and Hydrology (CEH) (http://www.ceh.ac.uk/landcovermap2007.html).		

Table 2: Return periods for which surface water outputs were derived

Return Period	Extents, Depths, velocities and hazard rating derived
10	✓
30	✓
30 + climate	✓
50	✓
100	✓
200	✓
200 + climate	✓