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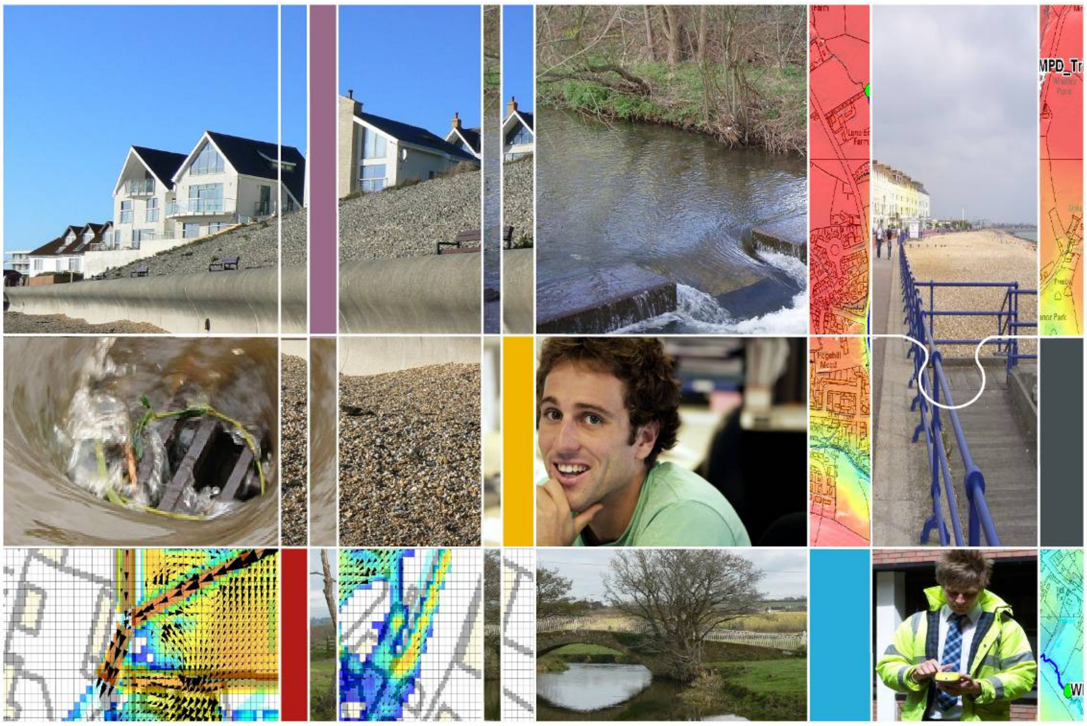

Medway Council Local Flood Risk Management Strategy

Technical Appendix 1: Pluvial Modelling Methodology (Final Report)

October 2013

CAPITA SYMONDS | URS
Flood Risk Management

Document overview

Capita Symonds with URS Infrastructure and Environment UK Ltd was commissioned by Medway Council in the preparation of their Local Flood Risk Management Strategy as required under the Flood and Water Management Act 2010.
This report details the methodology for the pluvial modelling carried out as part of this study.

Document history

Version	Status	Issue date	Prepared by	Reviewed by	Approved by
1	Draft	Aug 2012	Edward Byers Graduate Consultant Sarah Littlewood Assistant Consultant	Stephen Riley Principal Consultant Jon Robinson Technical Director	Jon Robinson Technical Director Scott Ferguson Technical Director
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1. Introduction

1.1 Project background

1.1.1 The Flood and Water Management Act[1] (FWMA) designates Medway Council as a Lead Local Flood Authority (LLFA) and requires Medway Council to develop, maintain and apply a Local Flood Risk Management Strategy (LFRMS) ("the Strategy") for its administrative area. Over time, Medway Council will use this Strategy to increase their understanding of local flooding issues (from surface water, groundwater and ordinary watercourses), and improve the management of local flood risk. Therefore, in order to inform the Strategy, it is necessary for Medway Council to undertake an assessment of the level of flood risk across the Council's administrative area.

1.1.2 In addition to this duty under the FWMA, one of the requirements of the Flood Risk Regulations 20092 (FRR 2009) is the preparation of flood risk and flood hazard maps for relevant sources of flooding by December 2013.

1.1.3 In light of these two requirements, direct rainfall modelling using TuFLOW software has been undertaken across the Council's administrative area in order to gain an improved understanding of the risk of flooding resulting from heavy rainfall and overland flow. This is also referred to as pluvial flooding.

1.1.4 This document provides a record of the approach and methodology that has been adopted for the pluvial modelling across Medway Council's administrative area. As such it forms a supporting document to Medway Council's LFRMS[3].

1.2 Study objectives

1.2.1 The aim of pluvial modelling is to determine the risk of pluvial flooding across the Council's administrative area. This will be achieved through the following objectives:

1) Apply rainfall events of known probability directly to the ground surface to provide an indication of potential flow path directions and velocities and areas where surface water will pond;

2) Undertake verification of pluvial modelling results based on historic flood records held by the Council, site visits and local knowledge;

[1] HMSO and the Queen's Printer of Acts of Parliament (2010) Flood and Water Management Act
[2] HMSO and the Queen's Printer of Acts of Parliament (2009) Flood Risk Regulations
[3] Capita Symonds / URS (August 2012) Medway Council Local Flood Risk Management Strategy (DRAFT)

3) Undertake sensitivity analysis to provide an indication of the level of confidence that can be placed in the model results;
4) Prepare maps to show the maximum flood depths for each modelled return period;
5) Prepare maps to show the corresponding flood hazard ratings (a function of both the depth and velocity of floodwater) for each modelled return period.

1.3 Previous studies

Environment Agency Flood Map for Surface Water

1.3.1 The Environment Agency (EA) have undertaken national surface water flood risk mapping and prepared the Flood Map for Surface Water (FMfSW) dataset. This dataset provides an indication of the broad areas likely to be at risk of surface water flooding during the 0.5% Annual Exceedance Probability (AEP) event and the 3.3% AEP event. For each event, the FMfSW identifies those areas that experience flooding greater than 0.1m, and those areas modelled to experience flooding of greater than 0.3m.

1.3.2 The TuFLOW pluvial modelling undertaken to support the LFRMS for Medway Council will build upon this the FMfSW national modelling and seeks to provide a model with an improved level of accuracy with assumptions based on the local conditions rather than national assumptions.

Medway Council Preliminary Flood Risk Assessment

1.3.3 In accordance with the requirements of the FRR 2009, Medway Council prepared a Preliminary Flood Risk Assessment[4] (PFRA) for their administrative area in 2011. The PFRA contains information regarding past and future (potential) floods from local sources of flooding, which principally includes surface water, groundwater and ordinary watercourses. Historic flood records held by the Council as well as those included within the PFRA report will be used to verify the pluvial modelling results.

4 Medway Council (2011) Preliminary Flood Risk Assessment Report

2. Model Build and Simulation

2.1 Modelling approach (choice of software)

2.1.1 TuFLOW software has been used to undertake the modelling assessment. TuFLOW is a modelling package for simulating depth averaged 2D free-surface flows and is in widespread use in the UK and elsewhere for direct rainfall modelling. All models have been run using TuFLOW build 2011-09-AF-iDP-w64.

2.1.2 Using this approach and software, rainfall events of known probability are applied directly to the ground surface and are routed overland to provide an indication of potential flow path directions and velocities and areas where surface water will pond.

2.2 Catchment characteristics and model extents

2.2.1 Medway is located in Kent, to the south of the Thames Estuary. The River Medway divides the administrative area in half, with the northern half comprising predominantly low lying rural marshland and scattered villages and the southern portion populated by the larger towns of Rochester, Chatham and Gillingham.

2.2.2 Due to the size of the study area ($260km^2$) it has not been possible to construct one model for the entire study area and retain a reasonable model resolution. As a result, five individual hydraulic models have been constructed to cover the administrative area of Medway Council. The extent of each of the models is based upon the natural catchments within Medway. Figure A.1 shows the boundaries of the models covering the Borough of Medway, along with the name of the model.

2.3 Model grid size

2.3.1 The five pluvial models have been constructed with a 5m grid size. This grid size was chosen as it represented a good balance between the degree of accuracy (i.e. ability to model overland flow paths along roads or around buildings) whilst maintaining reasonable model run ("simulation") times. For example, refining the grid size from a 5m grid to a 2m grid is likely to increase each model simulation time from 30 hours to approximately 11 days.

2.4 Topographic representation

2.4.1 Light Detecting and Ranging Data (LiDAR) was used as the base information for the model topography across the majority of the study area. LiDAR data is an airborne survey technique that uses a laser to measure the distance between an aircraft and the ground surface.

2.4.2 The EA LiDAR data covering the majority of the study area from their archive dataset that contains digital elevation data derived from surveys carried out since 1998. Some of the coverage has a resolution of 1m and the remainder, primarily to the north-west of the River Medway, 2m, and the vertical accuracy is typically +/-150mm. LiDAR data is provided in two formats:

- Digital Surface Model (DSM), which includes vegetation and buildings; and
- Digital Terrain Model (DTM), which is filtered to remove the majority of buildings, structures and vegetation.

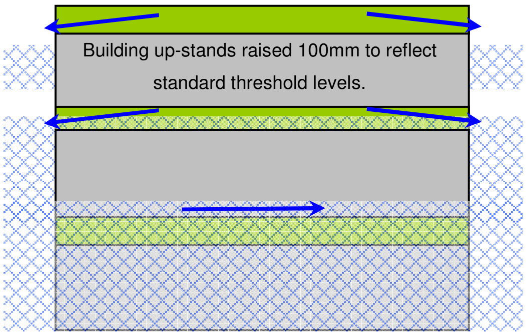
2.4.3 For the purpose of this study, the Digital Terrain Model (DTM) was used to represent the 'bare earth' elevation, with buildings, structures and vegetation removed. This is a conservative assumption as in reality these items would obstruct flood flows, thus potentially impacting on flood velocity and depth.

2.4.4 LiDAR data was not available for a small part of the study area. DTM data was purchased from GeoPerspectives for these areas which are identified on Figure A.1. This data has a resolution of 5m and the stated vertical accuracy is +/-1500mm.

2.4.5 Following initial model runs is was apparent that model instability occurred in a number of areas with sudden changes in topography such as the cliffs association with disused chalk pits in Frindsbury as well as Bores Hole near Cuxton, and the disused moat associated with Fort Amherst and Prince William's Bastion in Chatham. The ZSHP function in TuFLOW was used to smooth the changes in topography in these areas to improve the stability of the model. An example of the use of the ZSHP function for this purpose is shown in Figure A.2

2.5 Building representation

2.5.1 Building footprints have been represented in the model through the use of an 'up-stand' and higher roughness coefficients to mimic reduced conveyance through the footprints of the buildings. The 'up-stand' is derived based upon Ordnance Survey Master Mapping (OSMM) last revised in 2010, and is set at 100mm above the average ground level within each building footprint to represent the average threshold level of properties.



As the rainfall event begins, rainfall will fall onto the raised building pad and create flowpaths around the structure. The reduced Mannings (=0.015) is applied to the surface of the pad (only) to reduce any ponding occurring within the building pad itself and promote runoff from this area.

As the depth of flooding increased the Mannings of 0.015 is still being applied on the surface of the building pad until a depth of 30mm is attained.

As the depth of flooding increases, a high Manning's n value of 0.5 is then applied to the building to reflect the resistance to flow over the buildings pads surface (the low 0.015 is only applied the depths of flooding on the pad which are less than 30mm).

Building Pad Threshold = 100 mm
Area where variable Mannings roughness is applied = 30mm
Floodwater

Figure 2.1 Representation of buildings

2.6 Structures

2.6.1 In some parts of the model domain, it was necessary to modify the representation of the topography from that produced from the LiDAR data alone. Two approaches have been used to amend the topographic representation and to model structures in the model domain.

2.6.2 Structures within the study area which were modelled in the 2D domain include larger features such as rail or road overpasses, for example where roads pass underneath the rail line running from Chatham to Rochester, or where Claremont Way passes under New Road (A2) in Chatham. The structures were represented by using the ZLN or ZSHP function in TuFLOW which allows the user to specify the dimensions of the feature. Invert levels were determined by inspecting the LiDAR DTM. The widths of these features were either measured on site visits, from aerial photography, or from the LiDAR DTM.

2.6.3 The 2D domain has a grid size of 5m, and therefore it is not possible to accurately represent smaller structures and features using this approach. As a result, ESTRY has been used to represent these elements in a 1D domain linked to the 2D model domain. As opposed to a 2D representation of such structures, a 1D representation allows the width of the structure to be specified without being limited to grid size. Structures modelled in 1D using ESTRY include underpasses and culverts. For example in Gillingham, ESTRY was used to represent short sections of Pier Road and Medway Road where they pass under the rail line. ESTRY was also used for smaller structures, for example a pedestrian subway underneath Ito Way (A289), where it joins Sovereign Boulevard.

2.6.4 The dimensions of the structures were approximated from a review of aerial photography, observations made during the site walkover and interrogation of the DTM. Unlike structures modelled in 2D, rainfall is only allowed to enter the structure through the entrances of the structure and not from above.

2.6.5 Following the initial model simulations, a site walkover was undertaken for particular areas to verify the results. This identified further structures, such as culverts, that potentially have an influence on the propagation of surface water for inclusion within the models. The walkover informed the representation of structures already represented with the models.

2.7 Rainfall boundaries

2.7.1 The pluvial modelling is designed to analyse the impact of heavy rainfall events across Medway by assessing flow paths, velocities and catchment response.

2.7.2 In order to ensure that the worst case scenario is assessed and that the entire catchment is contributing to surface water runoff, the critical storm duration has been estimated.

2.7.3 In order to determine the rainfall profiles to be applied to the models, catchment descriptors for centre points of hydrological sub-catchments within each model area were exported from the Flood Estimation Handbook (FEH).

2.7.4 The Revitalised Flood Estimation Handbook (ReFH) method was used to carry out a high level investigation of critical storm duration for a number of distinct catchments within each model domain. Results indicated that critical storm duration varied greatly across model domains, even within a relatively small area. Ideally, model simulations would therefore be carried out applying a range of critical storm durations across the model domains.

2.7.5 However due to the large area to be modelled, approximately 267km^2, and the resultant long simulation times for 2D models, such an approach is not practical. Following the critical storm duration analysis, the decision was therefore taken to run all models with a single rainfall duration.

2.7.6 The range of critical storm durations for all models and sub-catchments was analysed and a single duration of 3 hours was selected, in order to represent a compromise between rainfall event duration and rainfall intensity across the modelled area.

2.7.7 The use of a 3 hour critical storm duration for all models also ensures consistency and comparability of model results across Medway District, and for practical purposes limits model run times to approximately 6 hours.

2.7.8 The Flood Map for Surface Water (FMfSW, 2010) and Areas Susceptible to Surface Water Flooding (SWtSWF, 2009) mapping applied critical storm durations of 1.1 hours and 6.5 hours respectively. The critical storm duration chosen for the Medway modelling therefore lies within the expected range for surface water modelling rainfall event durations, however it represents a different scenario to those modelled during previous studies.

2.7.9 Based on a critical storm duration of 3 hours (180 minutes), rainfall profiles (hyetographs) for the following rainfall events were generated:

- 3.3% AEP (1 in 30 year)
- 1% AEP (1 in 100 year) plus climate change (+30%)
- 0.5% AEP (1 in 200 year)

2.7.10 These were created by importing catchment descriptors and storm durations into the Rainfall Profile function of WinDes® software. The Rainfall Profile provides rainfall intensity (in mm/hr) for each minute of the storm. The Rainfall Profile function of WinDes® is unable to include an addition for climate change. Therefore, 30% (the figure provided within the Technical Guidance to the NPPF to account for climate change over the next 100 years) was added to the hyetograph.

2.7.11 Due to the decision to use a single critical storm duration across all model domains, sensitivity testing was carried out to provide an indication of the sensitivity of model output i.e. flood depths, to variation in the critical storm duration. This provides an indication of the influence of the choice of critical storm duration on model results. Further detail on the sensitivity testing carried out is provided in Section 2.12.

2.8 Runoff coefficients and drainage losses

2.8.1 Runoff coefficients have been applied to the rainfall profiles in order to represent the varying level of infiltration on different land use surfaces, therefore altering the input data directly. Table 2.1 shows the runoff coefficients that have been applied within the models based upon OSMM data land use categories.

2.8.2 In addition to variation in the rate of surface water runoff, the model also accounts for losses to the Southern Water surface water sewer network where it is present. Table 2.1 also includes details of the continuing losses to the drainage system, which is 12mm/hr based on best practice (EA FMfSW guidance doc).

Table 2.1 Runoff coefficients

OS Master Map Feature Code	Descriptive Group	Comment	Runoff Coefficient	Drainage - Continuous Loss (mm/hr)
10021	Building		0.9	12
10053	General Surface	Residential yards	0.5	12

OS Master Map Feature Code	Descriptive Group	Comment	Runoff Coefficient	Drainage - Continuous Loss (mm/hr)
10054	General Surface	Step	0.8	12
10056	General Surface	Grass, parkland	0.35	0
10062	Building	Glasshouse	0.95	12
10076	Land; Heritage And Antiquities		0.85	12
10089	Water	Inland	1	0
10111	Natural Environment (Coniferous/Non Coniferous Trees)	Heavy woodland and forest	0.2	0
10119	Roads Tracks And Paths	manmade	0.85	12
10123	Roads Tracks And Paths	tarmac or dirt tracks	0.75	12
10167	Rail		0.35	12
10172	Roads Tracks And Paths	Tarmac	0.85	12
10183	Roads Tracks And Paths (roadside)	Pavement	0.85	12
10185	Structures	Roadside structure	0.9	12
10187	Structures	Generally on top of buildings	0.9	12
10203	Water	foreshore	1	0
10210	Water	tidal water	1	0
10217	Land (unclassified)	Industrial Yards, Car Parks	0.85	12

2.9 Roughness coefficients

2.9.1 Given the shallow depths of flooding, in comparison to fluvial or tidal flooding, roughness values have an influence on the surface water flood flow paths and as such need to be represented accurately within pluvial models.

2.9.2 OSMM data has been used to specify varying Manning's roughness coefficients across the five models according to land use. The polygons contained in the Master Map dataset area were queried in MapInfo and the land uses have been split into groups, with a Manning's n roughness coefficient assigned to each land use category.

Table 2.2 Roughness coefficients

OS Master Map Feature Code	Descriptive Group	Comment	Manning's Roughness
10021	Building		0.015 (Depth <= 30mm) 0.500 (Depth > 30mm)
10053	General Surface	Residential yards	0.04
10054	General Surface	Step	0.025
10056	General Surface	Grass, parkland	0.03
10062	Building	Glasshouse	0.015 (Depth <= 30mm) 0.500 (Depth > 30mm)
10076	Land; Heritage And Antiquities		0.5
10089	Water	Inland	0.035
10111	Natural Environment (Coniferous/Non Coniferous Trees)	Heavy woodland and forest	0.1
10119	Roads Tracks And Paths	manmade	0.02
10123	Roads Tracks And Paths	tarmac or dirt tracks	0.025
10167	Rail		0.05
10172	Roads Tracks And Paths	Tarmac	0.02
10183	Roads Tracks And Paths (roadside)	Pavement	0.02
10185	Structures	Roadside structure	0.03
10187	Structures	Generally on top of buildings	0.5
10203	Water	foreshore	0.4
10210	Water	tidal water	0.035
10217	Land (unclassified)	Industrial Yards, Car Parks	0.035

2.10 Model scenarios and simulations

2.10.1 Table 2.3 sets out the model design runs that have been carried out for each of the five models as well as the suggested use for the outputs for each of the return periods. When considering climate change for rainfall events, a 30% increase has been applied. This is based upon information within the NPPF5 and PPS25 Practice Guide[6].

Table 2.3 Modelled scenarios and suggested use

Modelled Return Period	Suggested Use
3.3% AEP Probability of occurrence is 1 in 30 in any given year	Southern Water sewers are typically designed to accommodate rainfall event with a 3.3% AEP period or less. This GIS layer will help to identify areas that may be prone to regular flooding and could be used by highway teams to inform maintenance regimes.
1% AEP + climate change Probability of occurrence is 1 in 100 in any given year, plus a 30% allowance for climate change	The NPPF requires that the impact of climate change is fully assessed. Reference should be made to this flood outline by the spatial planning teams to assess the sustainability of future developments.
0.5% AEP Probability of occurrence is 1 in 200 in any given year	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding.

2.10.2 All models were initially run for six hours and then assessed to determine whether this duration was sufficient to allow full propagation of all surface water flow paths within each model. A six hour simulation time was considered appropriate for all five of the models.

2.11 Model stability

2.11.1 Assessing the stability of a model is a critical step in understanding the robustness of a model and its ability to simulate a flood event accurately. Stability in a TuFLOW model can be assessed by examining the cumulative error (or mass balance) of the model as well as the warnings outputted by the model during the simulation.

2.11.2 A review of the mass balance output files shows that the cumulative error of the models is largely within the recommended range of +/-5% for the majority of the simulation. High values

[5] CLG (March 2012) National Planning Policy Framework
[6] CLG (December 2009) Planning Policy Statement 25: Development and Flood Risk Practice Guide

are reported at the beginning of the rainfall event when the model cells first wet then settle down for the remainder of the simulation. The cause and location of the high cumulative errors was investigated by examining a number of other output files provided by TuFLOW. The high values were found to occur at isolated locations throughout the study area for a single timestep and were not found to persistently occur at a single cell. This suggests that the high cumulative error is a consequence of the initial wetting process at the start of the rainfall event. The high cumulative error values are therefore considered to have a negligible impact on the overall model results.

2.11.3 A number of warnings occur in all models. The warnings relate to areas of poor convergence, or in other words, where TuFLOW has had trouble finding a solution. The warnings were found to be spatially varied and non-persistent in time, which is a relatively common occurrence in these types of models. As the warnings were not found to repeatedly occur, these have a negligible impact on the overall model results and the model is considered fit for purpose.

2.12 Sensitivity analysis

2.12.1 Understanding the performance of a model is fundamental to the modelling process, as the fitness for purpose of a model must be demonstrated in order to apply confidence to the model results.

2.12.2 Calibration of the model is important to provide assurance that the model structure represents the study area appropriately. In the absence of suitable calibration data, greater emphasis should be placed on sensitivity testing of the model in order to gain understanding of the relationship between key input variables.

2.12.3 Uncertainties associated with numerical coefficients used to simulate ‘real life’ factors should be assessed in order to reinforce confidence in model outputs. If sensitivity testing shows that model outputs depend heavily on a particular factor, then further development of the model may be required to produce a more robust schematisation. Alternatively, the model outputs would require a caveat to make users of the results aware of the dependency on a particular factor.

2.12.4 In order to assess the magnitude of change arising from the sensitivity analysis, 30 points within the MED2 model domain have been selected and the change in depth arising from each test analysed. Placement of sensitivity testing points was based on location of flooding incidents recorded by Medway District Council between April 2001 and March 2011. Areas indicated as at risk from significant flooding by the baseline modelling were also deemed suitable testing points.

Storm Duration

2.12.5 Longer duration storms are generally characterised as featuring lower peak rainfall intensities in comparison to short duration storms within the same return period. Although a storm profile will feature a lower peak rainfall rate, sustained rainfall into a catchment area can highlight flooding mechanisms which would not come into force during a short duration event.

2.12.6 The variation of model outputs following changes to the critical storm duration, and therefore rainfall intensity, was examined. The 3 hour critical storm duration was chosen for the baseline modelling for all Medway models to ensure result consistency and comparability across the entire Medway district.

2.12.7 In order to determine the rainfall profile that should be applied to the MED2 model to test the sensitivity of the model outputs to critical storm duration, catchment descriptors for the centre point of the model area were exported from the Flood Estimation Handbook (FEH).

2.12.8 By importing the catchment descriptors into the Revitalised Flood Estimation Handbook (ReFH) a critical storm duration of 102 minutes (1.7 hours) was estimated for the MED2 model.

2.12.9 To examine the effect of storm duration on the model outputs sensitivity analysis was undertaken using the 1% AEP + CC storm event run with 3 and 1.7 hour rainfall profiles. The total rainfall depths applied for the 1.7hr and 3hr storm are 80.0mm and 88.9mm respectively. Figure 2.2 shows how the hyetograph for these different rainfall durations differs.

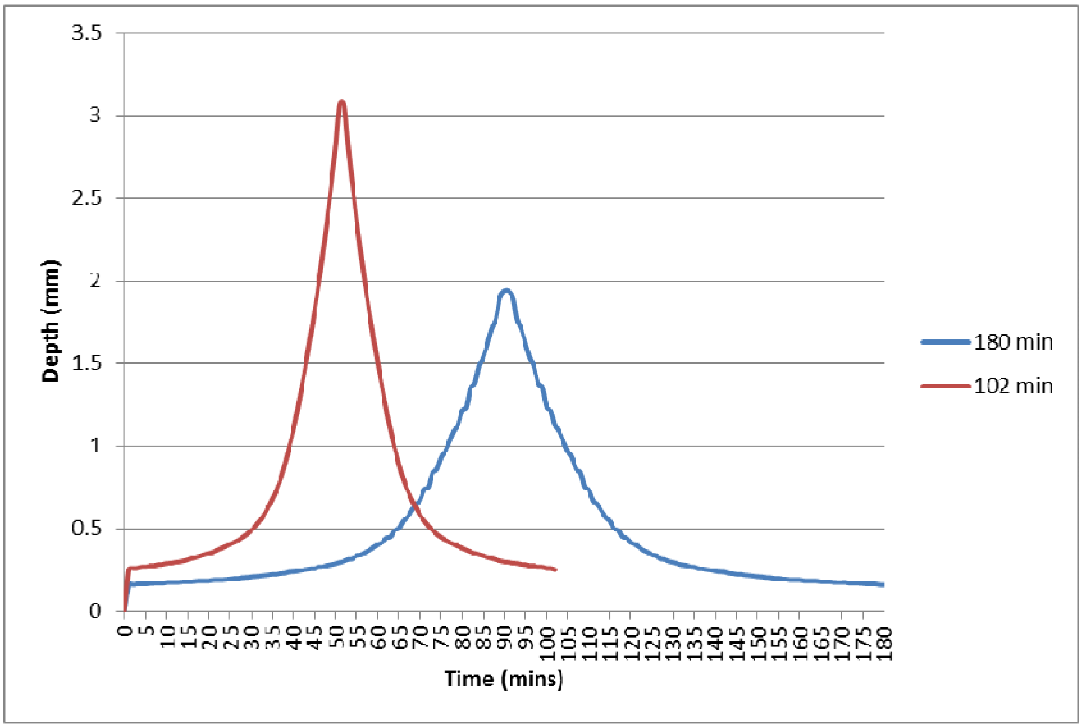


Figure 2.2: 100 year rainfall profiles (with an allowance for climate change) with varying storm duration

2.12.10 The flood extent and depth from the 1.7 hour rainfall event is generally greater than that of the 3 hour rainfall event. The assessment of the sensitivity testing locations shows a mean increase of peak flood depth of 0.03m (standard deviation 0.08). Of the 30 sensitivity testing locations, 5 experience a decrease in flood depths for the 1.7 hour rainfall event. Whilst the total rainfall depth applied to the model is greater for the 3 hour rainfall event, the rainfall intensity is far greater for the 1.7 hour event and therefore rainfall is input to the model more rapidly. The standard deviation of 0.08 indicates that the degree of change in flood depths does not vary significantly throughout the sensitivity testing locations.

Sensitivity Testing Conclusions

2.12.11 The sensitivity testing has highlighted that the model is relatively insensitive to changes in the critical storm duration. That is, changes in the rainfall profile result in minor variations in modelled flood depth. At 5 of the 30 sensitivity testing locations mean peak flood depth decreases for the shorter critical storm duration, indicating that the nature of changes in model outputs vary spatially throughout the model domain, though not to a great degree.

2.13 Calibration and verification data

2.13.1 The validity of each of the hydraulic models has been assessed using the following three sources of information:

- EA Flood Map for Surface Water Maps – A visual comparison of both data sets shows a good correlation between areas identified by the EA as being at greater risk of surface water flooding and pluvial modelling outputs
- Historic data provided by Medway Council representatives – Where available, historic flood records provided by the Councils have been plotted against pluvial modelling results
- Discussions with the Medway Council regarding pluvial modelling outputs

2.14 Model log

2.14.1 A completed Model Log and Quality Assurance form has been completed as part of the modelling process. The Model Log details the model build and the approach taken by the modeller, for example, details of the representation of specific structures and inclusion of specific boundaries within the models. The QA form documents URS' internal review of the models.

3. Model Results and Outputs

3.1 Maximum flood depth

3.1.1 The main output from the TuFLOW pluvial modelling is mapping of the maximum flood depth experienced across the study area. The maximum flood depth experienced at each cell across the model domain has been thematically mapped using the legend displayed in the following table. Maximum flood depth for the 3.3% AEP event has also been thematically mapped along with Medway District Council recorded flood incidents (Figure 3.1 of the main LFRMS report).

Table 3.1 Maximum Flood Depth Legend

	Maximum flood depth (m)
	< 0.1m
	0.1m to 0.25m
	0.25m to 0.5m
	0.5m to 1.0m
	1.0m to 1.5m
	> 1.5m

3.2 Flood hazard

3.2.1 Flood hazard is a function of both the flood depth and flow velocity at a particular location. The model outputs of flood depth and flow velocity (for each element in the model) were therefore used to determine flood hazard categories within the flood cell. Each grid cell within the TuFLOW model domain has been assigned one of four hazard categories: 'Extreme Hazard', 'Significant Hazard', 'Moderate Hazard', and 'Low Hazard'.

3.2.2 The derivation of these categories is based on Flood Risks to People FD2320[7], using the following equation:

$$\text{Flood Hazard Rating} = ((v+0.5)*D) + DF$$

(Where v = velocity (m/s), D = depth (m) and DF = debris factor)

3.2.3 The depth and velocity outputs from the 2D hydrodynamic modelling are used in this equation, along with a suitable debris factor. For this study, a precautionary approach has been adopted in line with FD2320; a debris factor of 0.5 has been used for depths less than and equal to 0.25m, and a debris factor of 1.0 has been used for depths greater than 0.25m.

[7] Defra, Environment Agency (2005) FD2320 Flood Risks to People

Table 3.2 Hazard categories based on FD2320, Defra & Environment Agency 2005

Hazard Rating		Description
HR < 0.75	**Low**	**Caution** – Flood zone with shallow flowing water or deep standing water
0.75 ≥ HR ≤ 1.25	**Moderate**	**Dangerous for some** (i.e. children) – Danger: flood zone with deep or fast flowing water
1.25 > HR ≤ 2.0	**Significant**	**Dangerous for most people** – Danger: flood zone with deep fast flowing water
HR > 2.0	**Extreme**	**Dangerous for all** – Extreme danger: flood zone with deep fast flowing water

3.3 Flood risk to properties

3.3.1 A count of the indicative number of properties shown to be at risk from the pluvial modelling has been undertaken.

3.3.2 OSMM data was used to create a dataset of all the buildings with an area greater than 25m2 within the modelled study area. GIS analysis was undertaken to determine the average flood depth within each building footprint during each of the modelled return periods. The EA National Receptor Dataset (NRD) was then queried against the buildings layer to determine the number of address points within each building footprint as well as the classification of the property based on MCM Codes (MCM Codes can be found in Appendix 3.1 of the Multi-Coloured Manual[8]).

3.3.3 This information was then used to provide counts for the following criteria during the 0.5% AEP (1 in 200 year) modelled flood event:

- No. of residential properties at risk of flooding to a depth equal to or greater than 0.1m
- No. of non-residential properties at risk of flooding to a depth equal to or greater than 0.1m
- No. of residential properties at risk of flooding to a depth equal to or greater than 0.5m
- No. of non-residential properties at risk of flooding to a depth equal to or greater than 0.5m

3.3.4 The results are presented in the following table.

[8] Flood Hazard Research Centre (2010) Multi-Coloured Manual

Table 3.3 Property and infrastructure at risk of pluvial flooding

Receptor	At risk of flooding to a depth of ≥ 0.1m during the 0.5% AEP modelled rainfall event	At risk of flooding to a depth of ≥ 0.3m during the 0.5% AEP modelled rainfall event
Residential	14,200	2,200
Commercial / Industrial	700	300
Infrastructure	100	0
Other	0	0
Unclassified	9,300	2
Total	24,300	4,500

Notes:

1. The EA National Receptor Database (NRD) has been used to identify receptors at risk of flooding. The type of receptor has been identified based on definitions (MCM Codes) within Appendix 3.1 of the Multi-Coloured Manual and divided into sub-categories.
2. Building thresholds have been represented in the modelling as 'up-stands', raised 100mm above the average ground level within the building footprint. A depth of >0.1m will result in a flood level of 0.1m above the property threshold.

3.4 Model uncertainty

3.4.1 Model validation can provide an indication of the uncertainty associated with modelled flood depths through comparison with previous modelled data, recorded flood incidents, and discussion with local stakeholders. Details of information used in the validation process are provided in Section 2.13.

3.4.2 Sensitivity testing allows analysis of the influence of model parameters on outputs.

3.4.3 Uncertainty in model outputs arises through the use of numerical coefficients used to simulate 'real life' factors. The selection of model parameters to represent such factors is necessary in the absence of appropriate data to inform aspects of the model.

3.4.4 Model parameters can potentially have a large impact on the model outputs, thereby impacting on confidence in model results. Sensitivity testing allows analysis of the impact of such parameters, through identification of the variation of model outputs as model parameters are varied one at a time. This analysis has been discussed in Section 2.12.

4. Conclusions and Recommendations

4.1.1 The pluvial modelling undertaken to inform the LFRMS for Medway Council represents a strategic approach to identify areas at risk of pluvial flooding. It represents a significant refinement on the previously available information on surface water flooding across the Medway Council administrative area. The models and their mapped results should only be used in conjunction with the information set out in this technical appendix. Recommendations for future improvements to the models include (but are not limited to) the following:

- Explicitly model the existing drainage network in key areas of risk, as opposed to a study area - wide assumption on drainage capacity
- Inclusion of survey data for critical structures
- Inclusion of river flows and channel capacity (where applicable)
- Reduction in model grid size in key areas of risk
- Further testing of different storm durations
- Inclusion of defacto defences outside of the scope of the current project (e.g. assets identified through the Asset Register process)
- The use of better quality or more up to date topographic information particularly in areas of recent development and where the most accurate LiDAR was not available.

Glossary

Annual Exceedance Probability (AEP)

The average probability of a rainfall event occurring in any given year.

Above Ordnance Datum (AOD)

The standard datum which topographic levels are quoted relative to throughout the study area.

Climate Change

When included as part of a flood event return period scenario, it means that that scenario includes the anticipated affects of climate change. For rainfall events, it incorporates a 30% increase. These climate change values are based upon information within the NPPF and PPS25 Practice Guide.

Culvert

A channel or pipe that carries water below the level of the ground.

Digital Terrain Model (DTM)

Digital representation of ground surface topography

ESTRY

ESTRY, which is a part of the TUFLOW software, is a 1D network dynamic flow software suitable for mathematically modelling floods and tides (and/or surges).

Flood and Water Management Act (FWMA)

Part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England.

Flood Hazard

The derivation of flood hazard is based on the methodology in Flood Risks to people FD2320 using and is a function of flood depth, flow velocity and a debris factor.

Flood Map for Surface Water (FMfSW)

National surface water flood risk mapping published by the EA. This dataset provides an indication of the broad areas likely to be at risk of surface water flooding during the 0.5% and 3.3% AEP rainfall events.

Flood Risk Regulations 2009 (FRR 2009)

Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically address flood risk by prescribing a common framework for its measurement and management.

Lead Local Flood Authority (LLFA)

Lead Local Flood Authority in relation to an area in England means the unitary authority for the area, or if there is no unitary authority, the county council for the area (as defined by the FWMA).

LiDAR

Light Detection and Ranging data is obtained from an airborne survey technique that uses a laser to measure the distance between an aircraft and the ground surface.

Local Flood Risk Management Strategy (LFRMS)

A strategy for the management of local flood risk (that from surface water, groundwater and ordinarywatercourses), to be developed, maintained, applied and monitored by the LLFA, as a duty under the FWMA.

National Receptor Database (NRD)

A collection of risk receptors produced by the Environment Agency.

Ordnance Survey Master Map (OSMM)

OS Master Map is highly detailed mapping including individual buildings, roads and areas of land according to land use categories. The data is presented in GIS as polygon and line data.

Pluvial modelling

Flooding from water flowing over the surface of the ground; often occurs when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with additional flow.

Preliminary Flood Risk Assessment (PFRA)

A report required under the FRR 2009 for each LLFA administrative area, detailing information on past and future (potential) floods, and identifying Flood Risk Areas. LLFAs are only required to undertake a PFRA for local sources of flooding, which principally includes surface water, groundwater and ordinary watercourses.

TuFLOW

TuFLOW is a modelling package for simulating depth averaged 2D free-surface flows and is in widespread use in the UK and elsewhere for 2D inundation modelling.

A. Appendix A – Study Area Mapping

B. Appendix B – Maximum Flood Depth Mapping

Figure B.1 Maximum flood depth – 3.3% AEP event

(Figures B.1.a – B.1.l provide 1:20,000 scale coverage of the study area).

Figure B.2 Maximum flood depth – 1% AEP event including 30% climate change allowance

(Figures B.2.a – B.2.l provide 1:20,000 scale coverage of the study area).

Figure B.3 Maximum flood depth – 0.5% AEP event

(Figures B.3.a – B.3.l provide 1:20,000 scale coverage of the study area).

C. Appendix C – Flood Hazard Mapping

Figure C.1 Flood hazard rating – 3.3% AEP event
(Figures C.1.a – C.1.l provide 1:20,000 scale coverage of the study area).

Figure C.2 Flood hazard rating – 1% AEP event including 30% climate change allowance
(Figures C.2.a – C.2.l provide 1:20,000 scale coverage of the study area).

Figure C.3 Flood hazard rating – 0.5% AEP event
(Figures C.3.a – C.3.l provide 1:20,000 scale coverage of the study area).

D. Appendix D – Sensitivity Analysis

Table D.1 – Sensitivity Analysis - 1.7 hour Critical Storm Duration 1% AEP event including 30% climate change allowance

(Figures D.1.a – D.1.l provide 1:20,000 scale coverage of the study area).

Figure D.1 – Sensitivity Analysis - 1.7 hour Critical Storm Duration 1% AEP event including 30% climate change allowance

Table D.1 Sensitivity Analysis. Comparison of 3 hour (baseline) and 1.7 hour (sensitivity test) storm duration, 1% AEP event including 30% climate change allowance.

Sensitivity Test Point	Maximum flood depth (m)		Difference (sensitivity test - baseline)	
	3hr rainfall event (baseline)	1.7hr rainfall event (sensitivity test)	(m)	%
ST_Location_01	1.86	1.92	0.06	3.2
ST_Location_02	1.24	1.30	0.06	4.8
ST_Location_03	1.86	1.89	0.03	1.6
ST_Location_04	1.73	1.71	-0.02	-1.2
ST_Location_05	0.55	0.67	0.12	21.8
ST_Location_06	0.13	0.15	0.02	15.4
ST_Location_07	1.77	1.96	0.19	10.7
ST_Location_08	1.12	1.30	0.18	16.1
ST_Location_09	1.76	1.78	0.02	1.1
ST_Location_10	2.09	1.92	-0.17	-8.1
ST_Location_11	0.09	0.09	0.00	0.0
ST_Location_12	0.01	0.01	0.00	0.0
ST_Location_13	0.17	0.28	0.11	64.7
ST_Location_14	0.03	0.05	0.02	66.7
ST_Location_15	0.06	0.05	-0.01	-16.7
ST_Location_16	0.11	0.07	-0.04	-36.4
ST_Location_17	0.01	0.02	0.01	100.0*
ST_Location_18	0.00	0.02	0.02	100.0*
ST_Location_19	0.00	0.01	0.01	100.0*
ST_Location_20	0.01	0.03	0.02	200.0*
ST_Location_21	0.04	0.04	0.00	0.0
ST_Location_22	0.02	0.02	0.00	0.0
ST_Location_23	0.16	0.16	0.00	0.0
ST_Location_24	1.65	1.86	0.21	12.7
ST_Location_25	1.83	1.70	-0.13	-7.1
ST_Location_26	0.66	0.69	0.03	4.6
ST_Location_27	0.01	0.01	0.00	0.0
ST_Location_28	0.74	0.81	0.07	9.5
ST_Location_29	0.16	0.19	0.03	18.8
ST_Location_30	0.84	0.90	0.06	7.1
Mean			**0.03**	
Maximum			**0.21**	
Minimum			**-0.17**	
SD			**0.08**	

% difference values unrealistically highly due to the very shallow depth of flooding encountered.