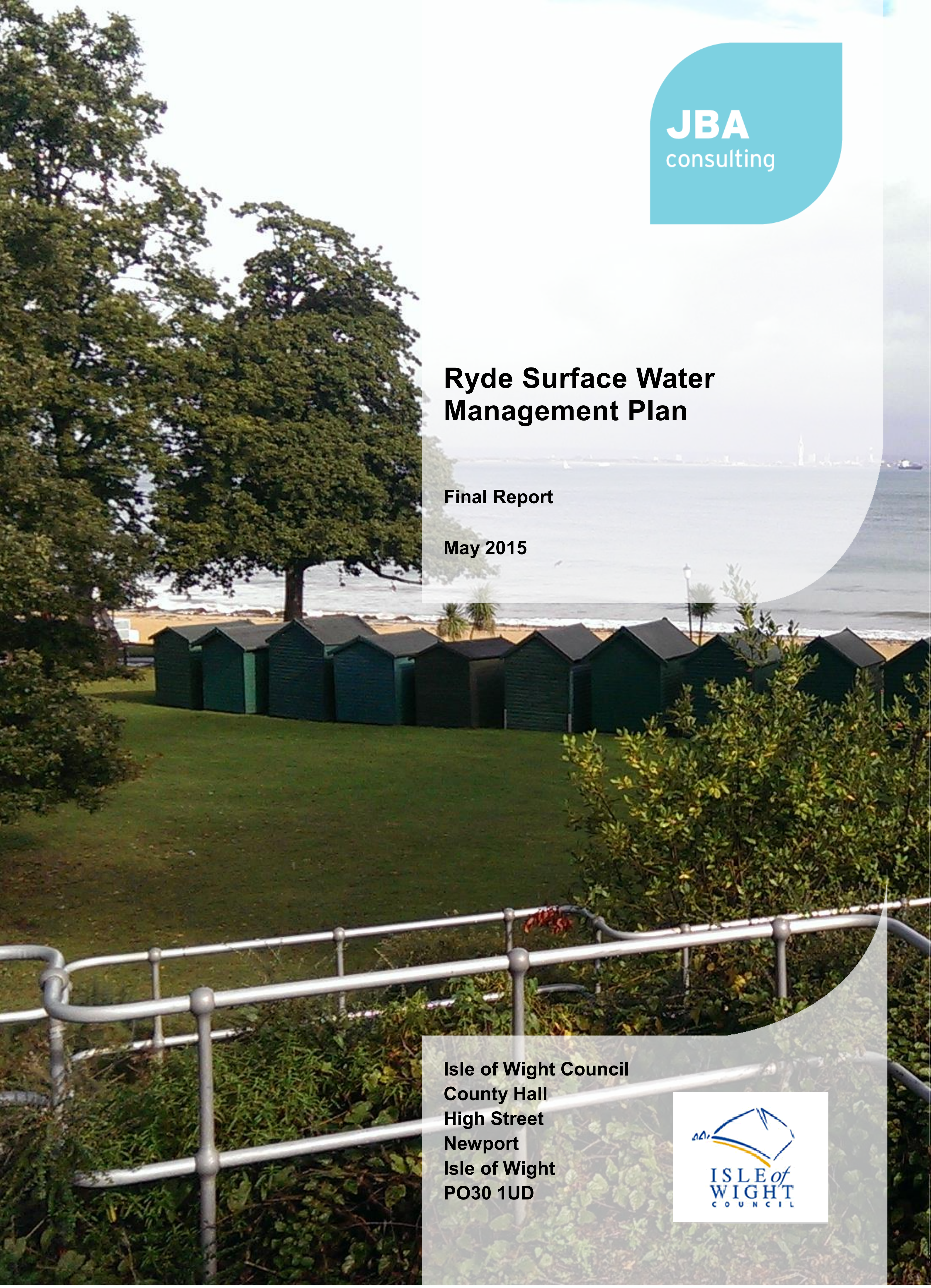

Ryde Surface Water Management Plan

Final Report

May 2015

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Contract

This report describes work commissioned by Wendy Perera on behalf of the Isle of Wight Council, under the Environment Agency's Water and Environment (WEM) Framework, by a letter dated 26th September 2014. Isle of Wight Council's representative for the contract was Wendy Perera. Alistair Clark, Elizabeth Gorton and Paul Eccleston of JBA Consulting carried out this work.

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Purpose

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JBA Consulting has no liability regarding the use of this report except to Isle of Wight Council.

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Abbreviations and Glossary of Terms

Term	Definition
CFMP	Catchment Flood Management Plan- A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
CIL	Community Infrastructure Levy
CIRIA	Construction Industry Research and Information Association
CSO	Combined Sewer Overflow
Defra	Department for Environment, Food & Rural Affairs
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EA	Environment Agency
EU	European Union
FAG	Flood Action Group. Groups of residents concerned about flooding in their area.
FCERM-AG	Environment Agency Flood and Coastal Erosion Risk Management Appraisal Guidance
FDGiA	Flood Defence Grant in Aid
Flood defence	Infrastructure used to protect an area against floods as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Flood Risk Area	An area determined as having a significant risk of flooding in accordance with guidance published by Defra and WAG (Welsh Assembly Government).
Flood Risk Regulations	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.
Floods and Water Management Act	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.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a main river
FMfSW	Flood Map for Surface Water. It has subsequently been replaced by the uFMfSW.
IDB	Internal Drainage Board
InfoWorks CS	Hydraulic and hydrologic modelling software produced by Innovyze. Used for modelling drainage systems.
InfoWorks ICM	Hydraulic and hydrologic modelling software produced by Innovyze. Capable of modelling integrated drainage systems including rivers, surface runoff, sewers and highway drainage.
IoWC	Isle of Wight Council
IR	Island Roads
ISIS-TUFLOW	A hydrodynamic model combining a one-dimensional (ISIS) model of river channels and structures with a two-dimensional (TUFLOW) model of floodplains.
JBA	Jeremy Benn Associates
LLFA	Lead Local Flood Authority - Local Authority responsible for taking the lead on local flood risk management
Main River	A watercourse shown as such on the Main River Map, and for which the Environment Agency has responsibilities and powers
NPPF	National Planning Policy Framework
NRD	National Receptor Dataset – a collection of risk receptors produced by the Environment Agency
Ordinary Watercourse	All watercourses that are not designated Main River. Local Authorities or, where they exist, IDBs have similar permissive powers as the Environment Agency in relation to flood defence work. However, the riparian owner has the responsibility of maintenance.
PAR	Project Appraisal Report
Pathway	The mechanism or method flood waters are directed to a location/ receptor.
PFRA	Preliminary Flood Risk Assessment
Receptor	The area at risk from receiving flood water

Term	Definition
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, and the consequence of the flood.
RMA	Risk Management Authorities
SAB	SuDS Approving Body - responsible for approving, adopting and maintaining drainage plans and SuDS schemes that meet the National Standards for sustainable drainage.
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
SFRA	Strategic Flood Risk Assessment
SHLAA	Strategic Housing Land Availability Assessment - The Strategic Housing Land Availability Assessment (SHLAA) is a technical piece of evidence to support the Core Strategy and Sites & Policies Development Plan Documents (DPDs). Its purpose is to demonstrate that there is a supply of housing land in the District which is suitable and deliverable.
Source	Source of flooding i.e. heavy rainfall
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.
SuDS	Sustainable Drainage Systems - Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques
Surface water flooding	Flooding as a result of surface water runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity, thus causing what is known as pluvial flooding.
SW	Southern Water
SWMP	Surface Water Management Plan - The SWMP plan should outline the preferred surface water management strategy and identify the actions, timescales and responsibilities of each partner. It is the principal output from the SWMP study.
uFMfSW	Updated Flood Map for Surface Water. An update of the Environment Agency's previous national scale surface water flood map (FMfSW) with local information and knowledge on surface water from LLFA's.
WwPS	Wastewater Pumping Station
WwTW	Wastewater Treatment Works

1 Introduction

1.1 What is a Surface Water Management Plan?

A Surface Water Management Plan (SWMP) is a study to understand the flood risk that arises from local flooding, which is defined by the Flood and Water Management Act 2010 as flooding from surface runoff, groundwater, and ordinary watercourses[1].

SWMPs are led by a partnership of flood risk management authorities who each have risk management roles for aspects of flooding, including the LA Authority (LA), the Local Planning Authority (LPA), Environment Agency, Sewerage Undertaker and other relevant authorities.

The purpose of a SWMP is to identify what the local flood risk issues are, what options there may be to manage them or the damage they cause and who should take these options forward. This is presented in an Action Plan that the partners agree.

1.2 Previous studies

As Lead Local Flood Authority (LLFA), the Isle of Wight Council (IoWC), commissioned a Preliminary Flood Risk Assessment (PFRA) for the Isle of Wight which was carried out by AMEC in November 2011. The aim of the PFRA was to address flood risks from all sources other than those for which the Environment Agency (EA) has permissive powers over (i.e. tidal and Main River flooding). The PFRA determined there was significant flood risk within the Ryde area, with a history of flooding from ordinary watercourses and overloaded combined drainage system.

In June 2014 the IoWC undertook a Flood Investigation Report, as within their role as LLFA they have a duty to investigate significant flood events as defined under the Flood and Water Management Act 2010. The report was triggered by flooding incidents on the 23rd and 24th December 2013 within the Binstead and Ryde area, particularly the area around Cemetery Road, Binstead and The Strand area, Ryde. These areas are both residential and the report aimed to investigate the impact of flooding to people, property and infrastructure as well as review the roles and responsibilities of all the risk management authorities which have a responsibility for flooding at the identified sites. The report identified the need for a more in depth local flood risk management investigation for the Ryde area. As a result the Council commissioned this SWMP for Ryde.

1.3 SWMP drivers

The preparation of a SWMP was driven in response to the following considerations:

- The need to build on the understanding of high risk areas highlighted within the Flood Investigation Report and to develop feasible options for improving local flood risk within known hot spot areas.
- To investigate actions proposed within the Flood Investigation Report, including the installation of an attenuation tank within Binstead and the Canoe Lake outfall project.
- To investigate options for longer term solutions and accompanying sources of funding. This includes options such as removing properties from the combined system, removing highway drainage from the combined system and increasing storage capacity in the wider catchment.
- The need for a long term strategy for all the agencies involved in the water management within Ryde to manage the local flood risk.

1.4 SWMP objectives

The Ryde SWMP has the following objectives:

- Establish a local partnership group between those who are responsible for the management of surface water within Ryde

[1] All watercourses that are not designated Main River. Local Authorities or, where they exist, IDBs have similar permissive powers as the Environment Agency in relation to flood defence work. However, the riparian owner has the responsibility of maintenance.

- Create a hydrodynamic flood model which can model the interaction between surface water sewers, combined sewers, ordinary watercourses, tides and overland flow to predict flooding for a variety of storm durations.
- Use the model outputs to determine areas at risk of flooding; identify the causes of flooding and/or any constraints to drainage; estimate the economic impact of flooding to Ryde and assess mitigation options for the flood risks identified.
- Produce an Action Plan for further work.
- Use public engagement to present the findings of the SWMP and proposed Action Plan to the partners and public.

1.5 Study area

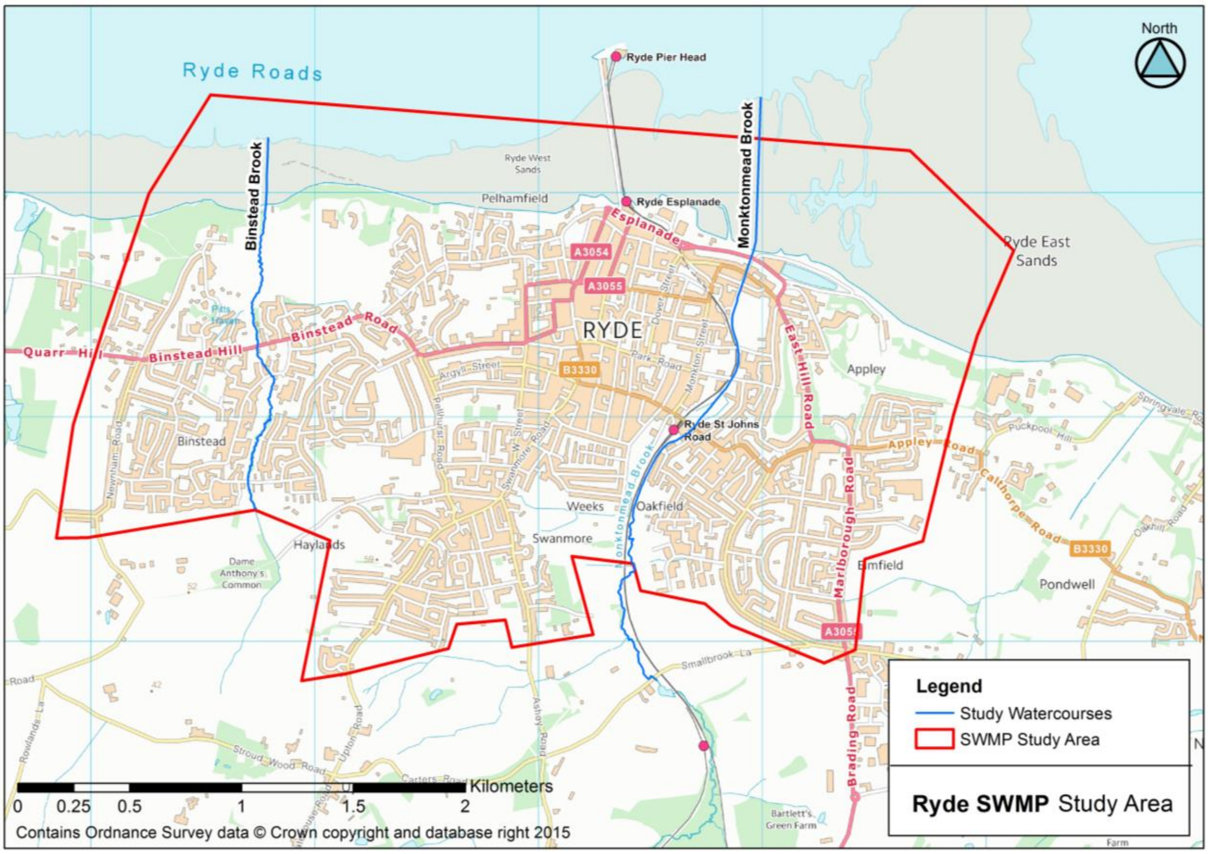
The study area consists of the town of Ryde. The hills to the south of Ryde and Binstead drain north and therefore these catchment areas were included within the hydraulic model. The study area is shown in Figure 1-1.

The study area is predominately residential with some commercial uses, predominately related to tourism. There are a number of school sites with playing fields and public open spaces particularly along the Monktonmead Brook, for example the Simeon Street recreation ground. The railway line runs alongside the Monktonmead Brook before diverging opposite the Simeon Street recreation ground where it goes into a tunnel below sea level re-emerging above-ground immediately to the north of the A3055. The area is bounded to the north by the coastline, which has been classified as at medium risk of wave exposure.

The topography of Ryde is steep with a pronounced hill which slopes northeast to the inlet formed by the Monktonmead Brook. The older Victorian town is built along the coast and the sides of the river valley. The streets are generally narrow, steep and with limited permeable areas. These slopes encourage runoff as water moves on the surface under gravity quicker than the rate of infiltration.

To assess the risk of flooding within Ryde the study considers the entire Monktonmead Brook and Binstead Brook catchment inflows, the tidal influence on the outfall of the Monktonmead Brook and the combined and separate sewerage systems of Ryde draining to the Sandown Wastewater Treatment Works.

Figure 1-1: SWMP study area



1.6 Using this report

Table 1-1 displays the information contained within each section of the report.

Table 1-1: Report Layout

Section	Description of contents
1. Introduction	This section defines the objectives of the SWMP, describes the background of the study area.
2. Partnership and Communications	This section provides a summary of the key partners and the consultation and engagement that accompanied the development of the SWMP.
3. Risk Assessment	Briefly describes the process followed to assess flood risk, and identifies the risk at hotspots within the study area.
4. Options	Describes the assessment of options to manage and reduce flood risk.
5. SWMP Action Plan	Provides details of the catchment wide and the location specific Action Plan and potential funding opportunities.

2 Partnership and Communications

2.1 Partnership Approach

Surface water cannot be managed by a single authority, organisation or partner; all the key organisations and decision-makers must work together to plan and act to manage surface water across Ryde. Many organisations have rights and responsibilities for management of surface water. Although the Isle of Wight Council has commissioned this project, the key partners have been consulted with throughout the study.

Working in partnership encourages co-operation between different agencies and enables all parties to make informed decisions and agree the most cost effective way of managing surface water flood risk across Ryde over the long term. The partnership process is also designed to encourage the development of innovative solutions and practices; and improve understanding of surface water flooding.

2.2 Key partners

Partners are defined as organisations with responsibility for the decision or actions that need to be taken to manage surface water flooding. The key partners involved in this project are:

- Isle of Wight Council
- Environment Agency
- Southern Water
- Island Roads
- Ryde Flood Action Group
- Binstead Flood Action Group

Ryde and Binstead Flood Action Groups were groups of residents concerned about the ongoing flooding issues in their area.

Figure 2-1: Key partners and stakeholders

2.3 Partnership meetings and engagement events

Table 2-1: Partnership meetings and engagement events

Meeting	Date	Purpose	Attendees
Start up meeting	08/10/2014	Purpose of the meeting was to meet all the partners, agree the scope of the SWMP and agree data provision from the partners.	IoWC, EA, SW, RFAG
Site visit	08/10/2014	A walk through of the main flooding locations within the catchment.	RFAG
Progress and model amendment meeting	12/11/2014	A technical review of the integrated model to ensure all partners agreed with the work undertaken.	IoWC, EA, SW, RFAG
Progress and options meeting	18/12/2014	The partners reviewed the draft integrated model, Critical Duration Testing and draft modelled risk areas. Catchment wide and local options were discussed.	IoWC, EA, IR, SW, RFAG
Public engagement event	22/01/2015	Public event for residents of Ryde and Binstead. Presented and sought views on areas at risk of flooding and on proposed measures.	Residents and representatives from IoWC, EA, IR, SW, RFAG, BFAG

3 Risk Assessment

3.1 Level of assessment

The Flood Investigation Report[2] identified the Ryde area as being at significant risk of flooding, with a history of flooding from various sources. Therefore, in line with the DEFRA guidance[3] a **detailed assessment** has been undertaken for this SWMP. This level of assessment aims to provide a detailed understanding of the causes and consequences of surface water flooding, and to test the benefits and costs of mitigation measures. This will be achieved through the modelling of surface and sub-surface drainage systems. The results of the detailed analyses have then been used to prepare an action plan.

The risk assessment carried out used the Source > Pathway > Receptor approach:

- **Sources** refers to the sources of flooding - in this case flooding from pluvial (intense rainfall), sewers and watercourses has been quantified using a hydraulic model
- **Pathways** of flooding are how the flood waters get from the source to the receptor. In this study, overland pathways from all modelled sources have been considered using the 2-dimensional model described in section 3.2.
- **Receptors** refer to anything which can be impacted by flooding, including people, households, community facilities, infrastructure and land. This is discussed further in section 3.2.

Having applied the Source-Pathway-Receptor model it is possible to mitigate the flood risk by addressing the source (often very difficult), block or alter the pathway and even remove the receptor e.g. steer development away.

3.2 Modelling the catchment

An integrated modelling approach was taken, which included the Monktonmead Brook and all of the drainage systems. A limited amount of highways drainage where there was information available was included but no private sewerage was included (due to lack of information available).

A detailed integrated approach was justified by the requirement of the model to assess the flood risk from a variety of flooding sources and to test a range of flood risk management measures in Ryde. The model needed to consider the capacity of the local drainage system, the capacity of the Monktonmead Brook open channel and culverted channels, the specific runoff from the rural and urban areas as well as the tide locking on the Monktonmead brook outfall.

InfoWorks ICM was chosen as the most appropriate modelling software as it can represent direct rainfall and overland flows, river networks and sewer networks simultaneously within one modelling platform. Most importantly, it also accounts for the interactions between these systems.

In brief, a surface water flood risk model was built and run using the hydraulic modelling software InfoWorks ICM. Full technical details are provided in the Model Operation Manual in Appendix C. The following points describe the modelling:

- InfoWorks ICM was selected principally for its ability to model river networks, sewer networks and surface water flow routes in one software package
- The model utilised data provided by Environment Agency, Southern Water and Island Roads. A full list of supplied data is provided in Appendix C.
- The Monktonmead Brook had previously been modelled in 1D by the Environment Agency using ISIS. This model was transferred into InfoWorks ICM to represent the river channels and structures.
- Southern Water provided an InfoWorks CS model of the foul, combined and surface water sewerage systems which was imported into the InfoWorks ICM model. Two CS models were provided, one representing the present (2014) network and one with the proposed scheme to increase capacity of the system in The Strand area (2015). The

[2] Ryde/Binstead Flood Investigation Report (Isle of Wight Council, June 2014)

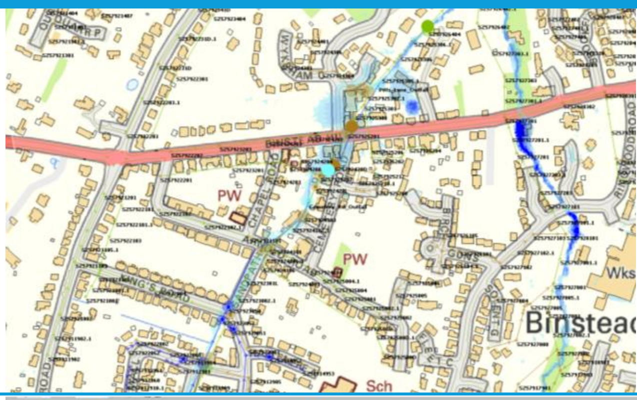
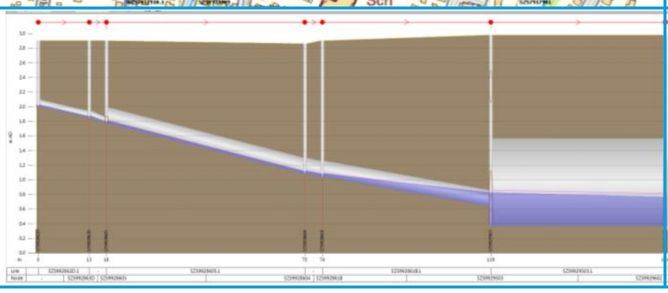
[3] Surface Water Management Plan Technical Guidance (DEFRA, March 2010)

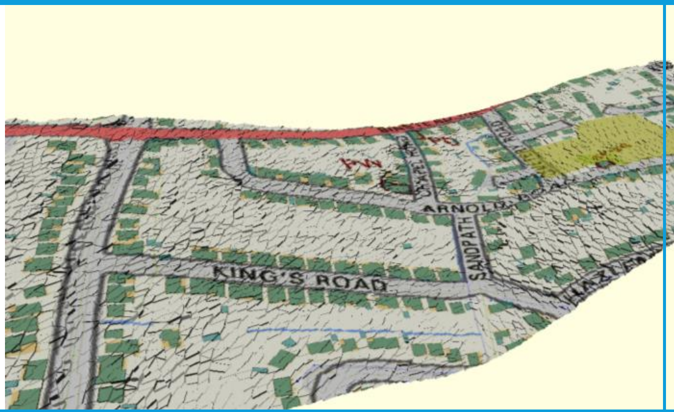
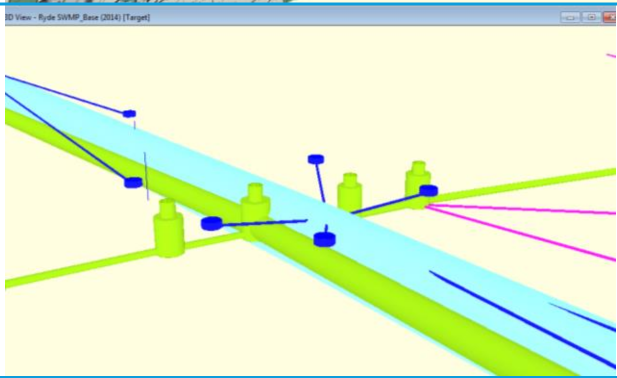
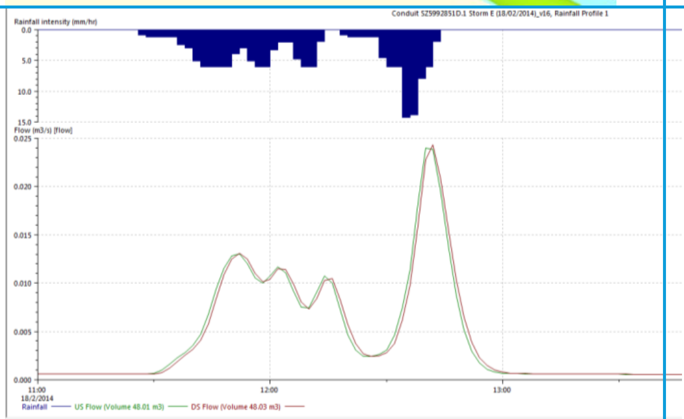
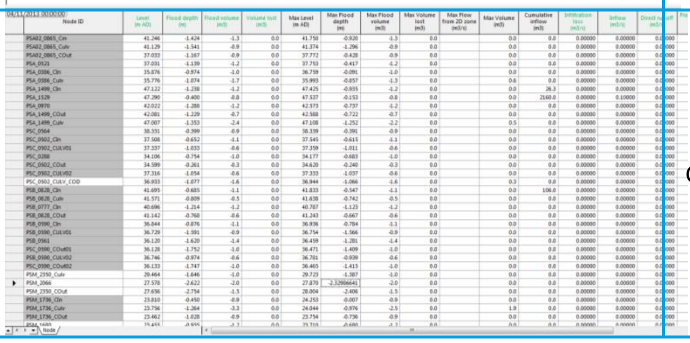
scheme is currently under construction, therefore version of the model has been used as the baseline model against which options have been tested.

- The sewer network has been directly connected to the river reaches where applicable to represent the discharges from outfalls from the surface water system and overflows from the combined sewer system into the watercourses.
- Additional highways gullies and associated surface water subcatchments were included around The Strand and the Canoe Lake areas based on information from the Southern water Impermeable Area Survey and Island Roads plans. The surface water subcatchments in the Strand and Canoe Lake areas were connected directly to the culverted Monktonmead Brook under Simeon Street and the Canoe Lake outfalls respectively. Basements were included in the Strand area as dummy nodes to allow for basement flooding to be modelled where possible.
- Surface water subcatchments were created for the upper southwest region of Binstead to assess the capacity of the surface water system in that area.
- The model of the catchment surface includes representation of features which play an important role in directing, diverting and storing surface water, including buildings, railway embankments/walls and small ditches.
- Runoff and flows into the model represent runoff from rural subcatchments to the south of the town, urban surfaces connected directly to the sewer system and from other open spaces within the study area.
- The model has been run using 1 in 2, 5, 10, 30, 75, 100 and 200 year rainfall return periods, plus the 1 in 100 year with a 20% increase to account for the possible impacts of climate change
- The model was also tested using summer and winter design storms of a range of durations (lengths of time); 15, 30, 60, 120, 180, 360 and 720 minutes. The critical duration (that which leads to the greatest risk of flooding) varies across the catchment, but the catchment is primarily most vulnerable to relatively short, intense rainfall events. This is typical for a relatively compact catchment with moderate to steep topography. The 120 minute Summer event was selected for the baseline risk assessment.

The model can provide results in a variety of formats and provides a powerful tool for understanding and communicating flood risk within the study area. The range of results formats are displayed in Table 3-1.

Table 3-1: Model results formats

Results format / Description	Appearance	Export formats
Map / plan view. Results from the 2D model including depth, velocity and hazard (a combination of depth and velocity which indicates the danger to people due by flooding) can be displayed.		GIS (SHP, TAB)
Long-section. These show a section along part of the drainage network (rivers and pipes), with the water level shown. They are useful for identifying pinch-points (restrictions) within the system and how they impact on upstream flooding.		BMP, WMF

Results format / Description	Appearance	Export formats
3D plan view. Adds the vertical dimension to the map / plan view, allowing the influence of catchment topography on flooding to be better understood.		BMP
3D node view. Allows the connectivity below ground to be viewed. Particularly useful to understand complex structures such as the pumping stations or storage tanks.		BMP
Graphs. Enable better understanding of the catchment hydraulics e.g. depth vs. velocity, and viewing results at different locations.		BMP, WMF
Tabular views and exports. Enable results to be exported to spreadsheets etc. for further analysis.		CSV

3.3 Assessing the risk

After producing the modelled results in the form of a map showing the predicted depth, velocity and hazard to people, the next step was to estimate the receptors at risk of flooding at different return periods. This involved a count of properties at risk as well as an assessment of the damage costs based on depth of flooding and the plan area of the property.

Receptors are people, buildings, infrastructure or areas of land which can be impacted adversely by flooding. The principal source of information on receptors used for this study was the National Receptor Database (NRD) maintained and supplied by the EA. This is a geographically referenced database of all homes, public buildings and services, commercial premises, above-ground utility services and environmentally designated areas. Housing units are classified by their lowest level (basement, ground floor, first floor etc.) to assist the quantification of risk to people and property.

3.4 Validating the risk assessment

A number of approaches have been taken to validate the risk assessment which are discussed in the following sections.

3.4.1 Project partner meetings

The progress and option meeting involved a presentation of the model build and the initial results to all the project partners. The results for the five main areas at risk (The Strand, West Hill Road and East Hill Road, St. Thomas' Street, Queen's Road and Binstead) following the initial model runs were discussed enabling additional feedback about the flood history at each location to be captured. The principle feedback from this meeting was that:

- Queen's Road was identified in the model and the uFMfSW however none of the partners had any records of flooding there with the exception of a Southern water flood record at Arthur's Street. It is known that gullies in Westwood Road and Queen's Road have been blocked / surcharged in the past but without causing any flooding.
- Wastewater pump station was known to be critical to the function of the network in the St Thomas' Street area.

3.4.2 Comparison with historic flood events

Appendix B shows a comparison of historic flooding and modelled risk for hotspots across the modelled area, the results used in this comparison are from the 2014 version of the model as discussed above. The historic flooding evidence available is insufficient to undertake full modelling of the historic events however it provides a good assessment for the modelling outputs.

A summary of the results of the comparison of the reported historic flooding and modelled flood risk are summarised below in Table 3-2.

Table 3-2: Summary of model performance against historic flooding

Location	Model performance	Conclusion
The Strand	The model predicts surcharge from gullies on The Strand and Simeon Street. Ponding occurs in the roads and against properties. Surface water ponding is also modelled on East Street and Monkton Street.	The uFMfSW flooding is more extensive than the modelled flooding as it does not take account of the Monktonmead Brook. The modelled flooding of basements and roads is consistent with the historical flooding.
West Hill and East Hill Road	The model predicts combined surface water and sewer discharge along West Hill Road and ponding at the north of West Hill Road.	This is consistent with historical flood records in the area.
St Thomas Street	The model simulates surface water flooding at the north of St Thomas Street, with some combined system surcharging.	The combined sewer flooding is consistent with the Southern Water records.
Queen's Road	The model shows a surface water flow path flowing south to north, with ponding predicted in the low spots. The model predicts, combined, foul and surface water manholes to surcharge.	The modelled flow path is consistent with the uFMfSW. However there are no records of flooding in the area with the exception of a SW flood record on Arthur's Street.
Binstead	The model predicts a surface water flow path down Greenway with ponding at junction with The Mall. Flow is expected out of bank when the overland channel on Cemetery Road makes a sharp turn. Ponding is predicted on Cemetery Road and a flow path is shown to continue northeast over Binstead Hill.	The modelled flow path down Greenway is not as extensive as the uFMfSW because of the surface water drains within the model. The flow path and locations of flooding are generally consistent with the historic records however the predicted flooding extent as a result of water coming out of the overland channel banks has limited accuracy

Location	Model performance	Conclusion
		as there was limited data on the channel dimensions, culvert inlet and outlet details and the wall/structure to prevent the water carrying straight on.

3.4.3 Stakeholder input to the risk assessment

The views of internal and external stakeholders on the risk assessment were gathered at the public event held on the 22nd January 2015 for people who live or work within Ryde. Feedback took the form of:

- A flooding questionnaire given out to all those who attended the public event
- At the public event, attendees were invited to mark on a risk assessment map locations where flooding had been observed

Table 3-3 summarises the responses to the flooding questionnaire. Locations where internal and basement flooding was reported was clustered around The Strand, Monkton Street and Simeon Street. Flooding on roads was reported on Binstead Road, Quarr Road, the Esplanade, Newport Street and The Strand`.

Table 3-3: Summary results of questionnaire from Ryde public event

Result	Total number
Questionnaires returned	9
Personal experience of flooding	4
No personal experience of flooding	1
No answer	4
Reported flooding locations	
Internal ground floor	4
Inhabited basement / cellar	5
Uninhabited basement / cellar	1
Road / public highway	2

'Personal' experience of flooding was defined as having had your property affected by flooding in the past either internally, in the garden or on the street directly outside.

3.5 Results

3.5.1 Flood risk mapping

Flood risk mapping has been produced for the 1 in 2, 5, 10, 30, 75, 100 and 200 year rainfall events plus the 1 in 100 year plus climate change event, see Appendix A. Maps show the depth of flooding and maps show the hazard to people rating, which uses a combination of depth and velocity flow to assess health and safety hazards to people.

It is important to note that the risk mapping shows the flood depth and flood hazard specifically as a result of an extreme rainfall event in Ryde. It has been assumed that the flow in the river is $3m^3/s$, which is sufficient to limit any discharge from the sewer system, but not to cause extensive fluvial flooding. This approach has been taken to isolate the surface water drainage problems in the town.

3.5.2 Flood risk metrics

The results of the modelling have been used in conjunction with the historical flooding data to identify surface water flooding hotspots, which have been outlined in Section 3.4.2 and discussed further in Appendix B. An assessment has been made of the identified hotspots and the damages to the receptors have been assessed using the methodology in the 2010 Multi-Coloured Manual[4]. The damages have been calculated based on the data in the 2013 update to the Multi-Coloured Manual. Further details of the damage cost appraisal is included in Appendix D.

[4] Penning-Rowsell E, Viavattene C, Pardoe J, Chatterton J, Parker D and Morris J (2010) The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques (Multi-Coloured Manual). Flood Hazard Research Centre, London

It should be noted that the damage estimates included in this study aim to provide a means of identifying the areas at greatest risk and comparing the potential benefits derived from the different options. The damage values are not intended to be used in a cost-benefit analysis as this would require a more detailed site specific assessment.

A summary of the estimated damages for the study area as a whole for a range of return periods is shown in Table 3-4 and Table 3-5 below. It should be noted that the property counts shown below include all properties that are affected by flooding that runs across the land surface and does not include properties that may be affected by internal flooding from the sewer network.

Table 3-4: Summary of Flood Damages for the 2014 Scenario

Return Period	Area Flooded / m^2	Number of Properties flooded to a depth of 0.1m	Total damages / £
1 in 2	28950	93	1,357,000
1 in 10	45575	237	4,631,000
1 in 30	59150	347	6,935,000
1 in 100	83725	617	10,979,000

Table 3-5: Summary of Flood Damages for the 2015 Scenario (post SW scheme)

Return Period	Area Flooded / m^2	Number of Properties flooded to a depth of 0.1m	Total damages / £
1 in 2	28850	91	1,320,000
1 in 10	45725	235	4,613,000
1 in 30	59950	342	6,906,000
1 in 100	85625	604	10,796,000

The reduction in the total number of properties flooded can be attributed to the installation of the Southern Water FAS at The Strand.

Table 3-6 presents a summary of the flood damages for the hotspots identified above for the 1 in 100 year storm.

Table 3-6: Summary of Flood Damages for 1 in 100 year storm (2015 Scenario)

Location	Area Flooded / m^2	Number of Properties flooded to a depth of 0.1m	Total damages / £
Binstead	14353	114	1,871,000
The Strand	1191	21	255,000
West Hill Road	1609	69	586,000
Queens Road	2200	24	474,000

The flood damages shown above highlight the Binstead area as having the highest flood risk resulting from surface water. This is consistent with the reported flooding in the area. It is noted that the modelled flood damages in The Strand area are reduced in the 2015 model simulation as a result of the installation of the Southern Water FAS in this area. This value is also lower than expected compared with the historical evidence because the surface water flood damages assessment does not take into consideration internal flooding resulting from surcharge in the sewer network.

3.6 Water quality assessment

3.6.1 Coastal and bathing waters

Ryde has a designated bathing water to the north of Ryde town centre. The town esplanade with swimming pool and Canoe Lake allow easy access to the long straight sandy beach which is an important asset to the town's tourism economy. According to the Environment Agency's Bathing Water Quality website[5], the Monktonmead Brook, crossing the beach to the west of the designated sampling point, is often contaminated with bacterial pollution.

In recent years the bathing water quality results have varied between the 'Higher' and 'Minimum' standard[6]. Historic data show reduced water quality associated with rainfall and high levels of contamination occasionally found soon after high tide[7]. The EA have undertaken tidal and catchment surveys, largely focussed on the Monktonmead Brook. The stream receives several storm overflow inputs from the urban area and results from surveys often show elevated levels of bacteria in the urban area of the catchment. Bathing water surveys show that after high tide water flushing from the outfall can affect bathing water quality. The stream is also subject to diffuse agricultural inputs in the upper catchment.

Southern Water have made improvements in the past including improving numerous Combined Storm Overflows in the Ryde catchment under Asset Management Plans 2 & 3 (1995 to 2005); flows from Ryde long sea outfall were diverted to Sandown wastewater treatment works prior to the 2001 bathing season and an investigation of the performance and impact of their storm overflows was carried out between 2005 and 2007. All storm overflows meet operational requirements.

3.6.2 Surface waters

The Monktonmead Brook and Binstead Stream have been assessed as having Moderate overall status in the Environment Agency's Water Framework Directive assessment of surface waters[8]. Both are designated as Heavily Modified Watercourses with an overall objective of Good Potential by 2027.

5 EA Bathing Water Quality (accessed 1/05/2015):
http://environment.data.gov.uk/bwq/profiles/profile.html?_search=isle%20of%20wight&site=ukj3400-17900

[6] Bathing water quality compliance classification for use during transition to the Revised Bathing Water Directive - rBWD (2006/7/EC). For annual assessments, "Higher" means that the bathing water meets the criteria for the stricter guideline standards of the cBWD Directive (76/0160/EEC). Sample limits used are: "Higher" EC: ≤100; IE: ≤100. "Minimum" EC: ≤2000 "Fail" EC: >2000 EC = Escherichia coli, IE = Intestinal enterococci. All numeric limits are cfu/100ml

[7] Environment Agency (2015) http://environment.data.gov.uk/bwq/explorer/info.html?site=ukj3400-17900

[8] Environment Agency (2015) http://data.gov.uk/dataset/wfd-surface-water-classification-status-and-objectives

4 Options

4.1 Objectives

The objective of the options assessment process was to identify, shortlist and assess measures for mitigating surface water flooding within Ryde and agree the preferred options. The preferred options were then carried forward to the Action Plan.

4.2 Options meeting

At the options meeting the partners reviewed flood risk at all the hotspots identified by the risk assessment to identify where and what type of solutions should be considered and to select a short list of options to investigate in greater detail. Since the EA and SW were both working on schemes (see Section 4.3) to improve the Monktonmead Brook outfall and increase capacity of the network in The Strand region respectively, the partnership agreed that the Ryde SWMP would focus on:

- Catchment wide options - which would focus on planning policy and community engagement
- Investigating local opportunities including:
  - using the Canoe Lake as additional storage
  - using West Hill Road roadway for conveyance of surface water flows to the river
  - installation of a storage tank in Binstead
  - opportunity for rain gardens / SuDS retrofit in Greenway, Binstead
  - Property Level Protection
- Development opportunities - this was considered limited by the partners however the area at Pennyfeathers could be used to provide some attenuation.
- Options should seek to protect or preferably enhance the water quality of the Monktonmead Brook and the Ryde bathing beach.

4.3 Planned schemes

Whilst the Ryde SWMP was being undertaken both the EA and Southern Water are undertaking work to reduce the flood risk in the Ryde area. While the work does not relate directly to the reduction of surface water, changes to the capacity of the existing drainage system will have an impact on surface water flood risk.

In addition to the work being undertaken by the EA and Southern Water, Island Roads have a programme of works in place to improve the road drainage and ordinary watercourse Binstead with the aim of reducing flood risk, particularly in the area around Cemetery Road.

4.3.1 Environment Agency

The Monktonmead outfall has frequently been subject to its flaps being locked either open or closed by the movement of sand on the beach which reduces the effectiveness of the Flood Alleviation Scheme built to reduce flooding within Ryde. The EA undertook a clearance operation at the end of 2014 to remove a large amount of sand from around the outfall and create a channel from the outfall out to sea. The outfall pipe was also jetted. At the December 2014 meeting the EA described the flaps on the outfall to be cleared once a week with extra clearing to be completed in the event of heavy rain alerts.

Given the significant sediment transport in the area is a reoccurring problem the EA has initiated a separate study looking into the longer term improvements to the Flood Alleviation Scheme including the relocation of the outfall to allow for free gravity discharge. Modelling had been undertaken and shows that the original proposal, to modify the outfall to prevent the build up of sand, may not reduce the risk of flooding as much as had been expected. This is because the new model shows that the culvert between Marymead Close and the pumping station may not be big enough to carry all the extra water in the brook to the sea. Any improvements to the culvert are likely to be very expensive and the scheme is not considered cost effective at the time of writing.

The partners had concern over the scheme's timescales and uncertainty over future funding, which is controlled by central government. It was therefore decided that the SWMP options should be based on the existing fluvial model information.

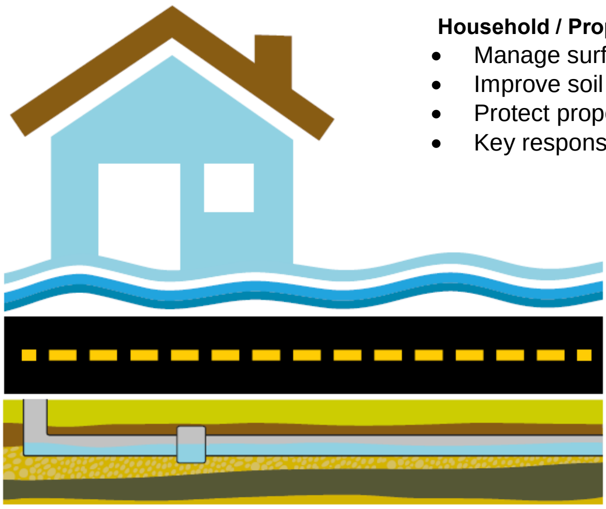
4.3.2 Southern Water

Southern Water are undertaking improvements to the sewer network around The Strand area to increase capacity and reduce the risk of surcharge from the sewer network at the western end of Simeon Street, The Strand and East Street. The scheme includes deeper oversized sewer with rider sewer for regular flows and an off-line storage tank at the eastern end of The Strand. Work commenced in January 2015 and is due for completion in the summer of 2015. As the Southern Water scheme is currently under construction the details have been included in the SWMP model to ensure any further schemes that are recommended take into consideration the changes made.

4.4 Options assessment concept

The options assessment for Ryde and Binstead was based around the concept of a three-tiered approach for improving surface water management. This included property level (recognising that a large proportion of impermeable surfaces are private roofs and driveways), street level (seeking to slow runoff from roads), town level (putting in place planning polices and making the most of new developments) and below ground (recognising the need to improve sewerage system performance). This approach is illustrated in Figure 4-1 and the options described in the following sections.

Figure 4-1: Tiered approach to options assessment



Household / Property Level

- Manage surface water better at the household level
- Improve soil wetness and store water for use during dry spells
- Protect properties against the entry of surface water
- Key responsibilities: Property owners, IWDC (planning)

Street Level

- Reduce rapid runoff into sewers and watercourses
- Trap highway pollutants to protect rivers and beaches
- Improve the street scene and local biodiversity
- Key responsibilities: Island Roads, Isle of Wight

Town Level

- Introduce policies to reduce runoff from brownfield sites when they are redeveloped and manage surface water on greenfield sites so flood risk is not increased
- Key responsibilities: Isle of Wight Council

Below Ground

- Maximise the capacity of the sewerage system
- Target maintenance where it has the most benefit
- Increase capacity only where above ground management of surface water cannot sufficiently reduce the flood risk.
- Key responsibilities: Southern Water

4.5 Property Level

4.5.1 Option 1 - Property Level Protection

This option accepts that even with mitigation options there may be a residual risk from surface water flooding. Property Level Protection (PLP) may be the best solution to protecting a home or business for some specific surface water issues and locations, such as Queen's Road, Argyl Street and Arthur Street PLP measures can be categorised as flood resistant measures, which can form a barrier to flood water to keep it out of the property, or flood resilience measures such as replacing carpets with waterproof tiling and raising electricity sockets in order to reduce the impact of any floodwater that does enter the property and aid in the recovery process.

Homes and business owners would be responsible for PLP with the support of Isle of Wight Council.

Modelling

No additional modelling. This option is represented by the base case.

4.5.2 Option 2 - Management of surface water at property level

This option considers the additional benefit that could be attained by the application of SuDS retrofit measures in the East Hill Road and West Hill Road area. The measure considered was the replacement of all impermeable road and pavements within the area with permeable surfaces.

This measure represents a scenario in which Isle of Wight Council and residents work together to address flood risk.

Modelling

The option was modelled by adding the roads and pavements land use area to the permeable land use and reducing the land use area of roads and pavements to zero, effectively modelling their disconnection from the combined sewerage system.

4.6 Street Level

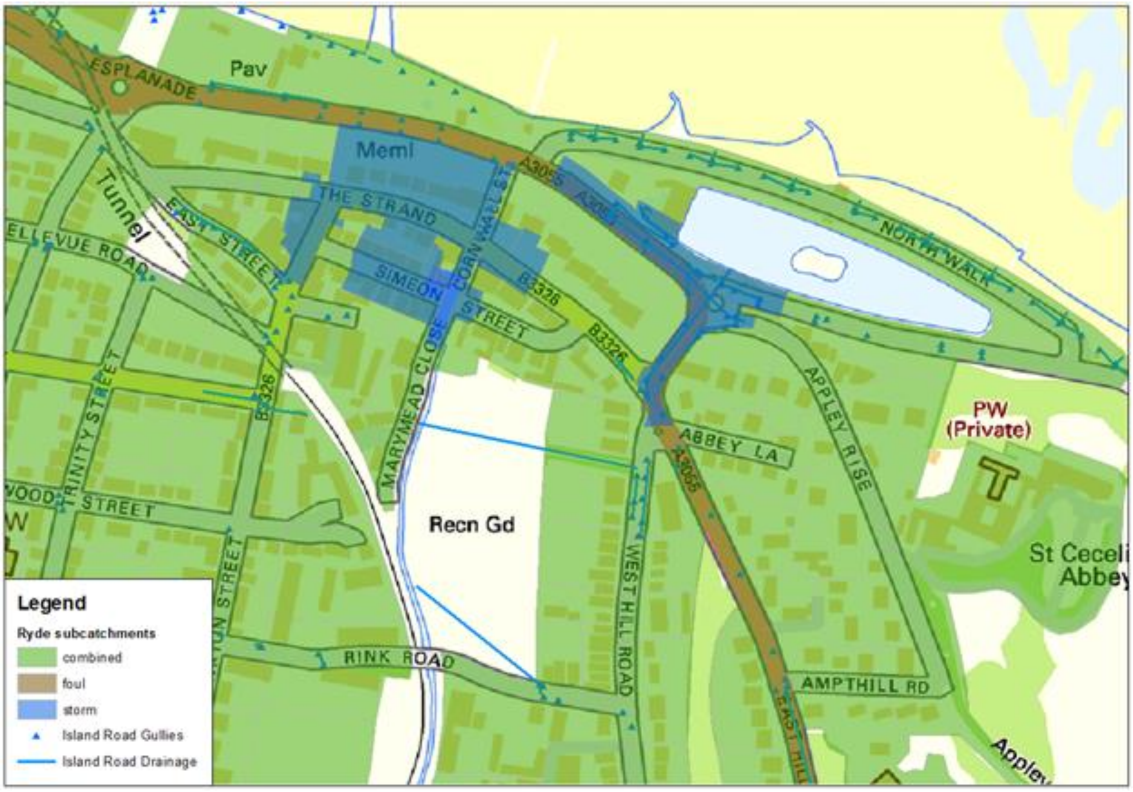
4.6.1 Option 3 - Canoe Lake

There may be scope to increase the amount of highways drainage which discharges directly into the Canoe Lake to make use of its additional storage capacity. The area around East Hill and West Hill Road has potential as it is not far from the lake and is at risk from surface water flooding. This option would be limited by the pumped outfall from the lake and there may also be risks, but also opportunities, with regards to the water quality of the Canoe Lake.

This measure would require Isle of Wight Council, Southern Water and Island Roads to work together to address flood risk.

Further investigation of the highway drainage in this area has shown that the invert levels of the highway drainage network in this area are below the existing water level in the lake, which may limit the potential discharge. Due to the general water level in the lake there is limited scope to change this.

Figure 4-2: Current known surface water subcatchments discharging directly to the Canoe Lake



Modelling

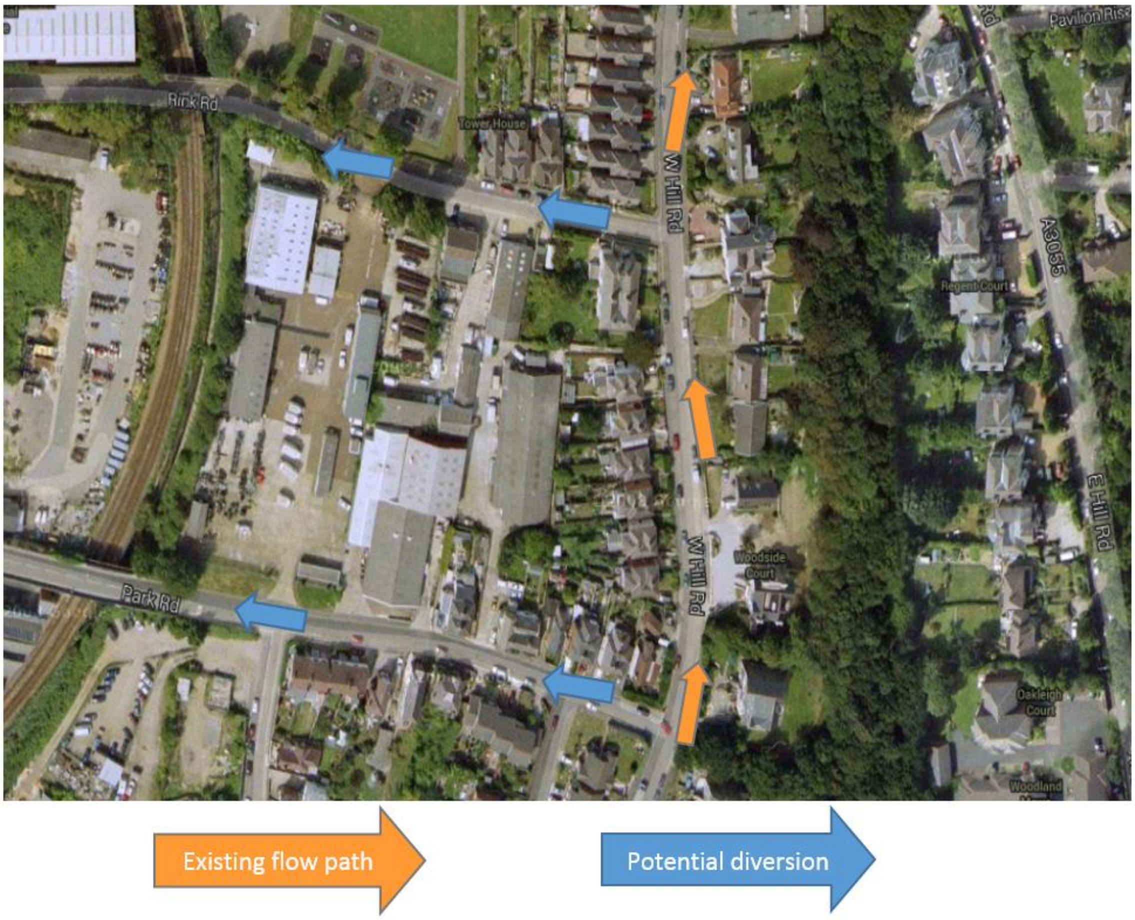
No additional modelling has been undertaken for this option.

4.6.2 Option 4 - Divert flows

Along West Hill Road there are many locations of large driveways and impermeable areas on the upstream (east) side of the road. The houses on the opposing side of the road are located below ground level and given the strong camber of the road and low kerbs they are at risk from surface runoff from the roads. West Hill Road also acts as a flow path and ponding is prevalent at the downhill (north) of the road.

This option considers the use of roadways for conveyance of overland flows towards the Monktonmead Brook. The benefit of installing kerbs on the downstream side of West Hill Road and speed bumps at the junctions with Park and Rink roads was considered to assess improvements in the amount of surface water ponding at northern end of West Hill Road and against properties on the downhill (west) side of the road.

Figure 4-3: West Hill Road existing and potential overland flow paths



Imagery ©2015 DigitalGlobe, Getmapping plc, Infoterra Ltd & Bluesky. The GeoInformation Group. Map data ©2015 Google.

Modelling

Permeable walls on the downhill side of West Hill Road, Rink Road and Park Road were used to represent raised kerbs. Speed bumps at the downhill of road junctions were modelled using mesh zones which raised the 2D surface. The permeable walls and speed bumps were modelled as 0.5m high so there was no chance of flow overtopping and the necessary height they would need to be could be investigated. Island Roads gully nodes on Rink Road were connected to the Monktonmead Brook.

4.6.3 Option 5 - Manage highway drainage

Greenway in Binstead was identified as a potential location for retrofitting of SuDS measures because of it is a quiet street with wide pavements and open grass regions between the road and pavements, and because it conveys a large amount of surface water along its length to the Mall in a storm event.

As well as the street rain gardens along the length of Greenway, the design considers a lowered channel at the junction between the Mall and Greenway. The use of rain gardens provides the additional benefits in terms of enhancing the appearance of the streetscape and some improvements in biodiversity. However, engagement with residents would be required to gauge their opinion on the impact of the streetscape. A recent retrofit of rain gardens has been undertaken in Nottingham. The CIRIA website contains a case study including photographs of the installed rain gardens and information on resident feedback[9].

This option would require Isle of Wight Council, Island Roads and the residents to work together.

[9] CIRIA (2014) http://www.susdrain.org/case-studies/case_studies/nottingham_green_streets_retrofit_rain_garden_project.html

Modelling

The rain gardens were represented in the model using infiltration polygons (to provide a fixed seepage into the ground at 10mm/hr) and mesh zones to represent the porosity (void space) within the 0.25m deep rain garden. The rain gardens were modelled as 2m wide strips running parallel to the road. The rain gardens work by intercepting runoff from the road surface. Where their capacity is exceeded they would overflow into new gully nodes at the downstream of the rain gardens which were connected to the nearest storm manhole. The channel at the junction between Greenway and the Mall was modelled using a mesh zone to lower the level in the 2D zone, and with 2 gully nodes connected to the nearest storm manhole.

4.7 Town Level

4.7.1 Option 6 - Developments

The main combined sewer which runs along Cornwall Street has a large catchment area. Within this catchment there are a number of SHLAA sites and a few other development sites. This causes both risks and opportunities with regards to surface water flooding. To ensure that the flood risk does not increase there is the potential to impose conditions on these sites such that greenfield sites should achieve a betterment and redevelopment of brownfield sites runoffs return to greenfield runoff rates.

Imposing these policies would be the responsibility of the planning authorities and subsequently the developer's responsibility to follow through with the policies.

Modelling

To test the benefit of reduced runoff from greenfield SHLAA sites they were represented in the model as infiltration zones. The infiltration zones were set as a fixed infiltration surface with the fixed runoff coefficient reduced from the default of 0.3 to 0.2. 30% percentage runoff represents permeable land whilst 20% runoff is a lower runoff than expected from greenfield and therefore represents some attenuation within the SHLAA sites.

4.8 Below ground

4.8.1 Option 7 - Binstead attenuation tank

This option considers the benefit of Island Roads' plan to install a storage tank beneath the footpath between The Mall and the King's Road to alleviate flows at the Binstead Hill - Cemetery Road junction. The size of the storage tank required at different return periods depending on whether the storage tank has been connected to the manhole at the upstream or downstream end of the footpath has been considered.

This measure would be carried out by Island Roads.

Modelling

This option has been modelled by connecting a weir between an offline 1D outfall node and either the storm manhole at either the upstream (7) or downstream (7a) of the footpath. The weir level was set to 0.4m above the node chamber floor. An orifice unit was added to the downstream of the manhole node with a limiting discharge of 0.425m^3/s to restrict flows downstream. Greater storage capacity was require if the tank was connected at the downstream of the footpath because an additional branch of surface water network joins there, but this enabled a greater reduction in the flooding downstream.

4.8.2 Option 8 - Upgrade pipes

Island Roads are considering upgrading the pipes which run between Newnham Road and The Mall.

Modelling

No additional modelling has been undertaken for this option.

4.9 Catchment scale and non-structural measures

4.9.1 Surface water disconnection measures

The catchment offers a very limited number of potential opportunities to disconnect surface water drainage from large roofed and paved areas from discharging to the sewerage system or watercourses. They fall into two categories:

- The potential to disconnect surface water sewers connected to the combined sewer system. These are areas of the catchment where development has installed separate sewers, but these then join together to discharge to the combined sewer system.

  These areas are limited within Ryde however there are some small areas of surface water system at the upstream of the large catchment which eventually drains into the combined sewer which runs along Cornwall Street (Figure 4-4). Disconnecting these is unlikely to have a significant impact downstream given how small the areas are, however they warrant investigation as part of a programme of incremental change to reduce surface water runoff into the combined sewerage system. .
- The potential to disconnect large roofs and car parks within the catchment. These would be opportunities best considered during redevelopment or refurbishment.

Figure 4-4: Ryde separate surface water networks

4.9.2 Spatial planning measures

There are a number of sites considered in the IoWC Strategic Housing Land Availability Assessment (SHLAA) which may potentially be selected for development. The following are measures specific to spatial planning which could offer benefit to flood risk management in the longer term.

Recommendation: Restrict runoff from brownfield sites

The Isle of Wight Strategic Flood Risk Assessment (SFRA)[10] specifies that the run-off rates and volumes from brownfield sites should be reduced from their current values:

[10] Isle of Wight Strategic Flood Risk Assessment (Entec, June 2010)

"the Isle of Wight Council have an aspiration to see run-off rates and run-off volumes reduced from the current condition on previously developed sites."

"the Council require that planning applications for all new developments on sites over 0.25 hectares in Flood Zone 1 should be accompanied by a Drainage Strategy."… "For previously developed sites the Drainage Strategy should describe how the development reduces surface water run-off rates and volumes. In flood Zones 2 and 3, where FRA's are required for any proposed development, there again must be no increase in run-off rates or volumes post development and there should be a reduction in run-off rates and volumes from previously developed sites."

The specifications within the IoWC SFRA are in line with the draft SuDS National Standards[11], which recommend attenuation of surface water flows from brownfield sites but do not impose this where it is not reasonably practical.

Recommendation: Presumption against culverting

The Flood and Water Management Act 2010 amended the Land Drainage Act 1991 so that flood risk from ordinary watercourses is now considered and managed at the local level. IoWC is the drainage board and works that are likely to alter or impact the flow or storage of water, or the erection of a culvert requires consent from the board. The IoWC's current ordinary watercourse policy currently discourages against culverting of watercourses.

It is recommended that this policy would apply within the existing urban areas as well as to new developments. Wherever possible, existing watercourses and drainage channels should remain above-ground, offering risk management authorities' benefits in terms of maintenance, future upgrading, increased biodiversity and pollution prevention. The CIRIA (2010) Culvert Design and Operation Guide provides guidance in this area. The policy would need to be managed and applied by IoWC and EA when reviewing planning applications and Land Drainage consents.

Recommendation: Raise awareness and enforcement of paving front gardens

Much of Ryde has experienced the loss of front gardens to hard standing parking. Incremental increases of impermeable areas (known as 'urban creep') have been demonstrated to increase the risk of flooding. As this is a difficult area to enforce the preferred approach is to raise a greater awareness of the issue within Ryde and provide guidance to households. Further policy and guidance in this area to consider:

- Raise awareness of the restrictions on paving of front gardens and provide best practice advice to contractors who undertake the work on behalf of residents
- Education on the issue of household drainage and misconnections and developments carried out under permitted development rights
- Advice with the respect to drainage of small developments
- Identify how Development Control can implement this policy without creating large amounts of additional activity

Recommendation: Drainage of new developments / SuDS

The Isle of Wight Strategic Flood Risk Assessment (SFRA) recognises the need for discharge patterns from new developments to reflect the discharge pattern of the undeveloped greenfield site. It states that, "*The design and implementation of sustainable drainage solutions should be factored into the design of any new development"* and as a requirement of PPS25, "*that the new development do not result in an increase in surface water run-off rates post development."*

Although new developments should not increase the risk flooding on the site or elsewhere, there is no requirement for them to reduce the risk where surface water flooding issues are currently identified. This could only be achieved by reducing the runoff from development sites below greenfield runoff levels.

Recommendation: Incorporate SWMP findings into SFRA

The SFRA does not contain the Flood Zones for the Binstead watercourse and predates the EA's national scale surface water mapping as well as the detailed surface water flood risk mapping undertaken for this SWMP. Consequently surface water flood risk may not be accurately

[11] National Standards for sustainable drainage systems. (DEFRA, Draft December 2011)

considered within Flood Risk Assessments in that area. The SFRA needs to be updated, either as an addendum or a full fresh SFRA.

4.10 Assessment of options

The modelled options have been assessed by comparing the number of properties affected by flooding and the total mean flood damages. The results for the different options have been assessed for the areas that they are expected to influence. To this end, Options 2 and 4 have been compared for the West Hill and East Hill Road and The Strand areas, Options 5 and 7 have been assessed for the Binstead area and Option 6 has been assessed for all areas. The tables below show the change in modelled surface water flood risk for the options.

Table 4-1: Change in modelled flood damages for Options 2 and 4

Option	Location	Return Period	Number of Properties flooded to a depth of 0.1m	Change in Number of Properties flooded to a depth of 0.1m	Change in total damages / £
Option 2 - management of surface water at property level	The Strand	5 year	0	0	0
		30 year	11	0	-3,500
		100 year	21	0	-500
	West Hill and East Hill Road	5 year	39	0	0
		30 year	51	0	-500
		100 year	68	-1	-16,500
Option 4 - flow diversions	The Strand	5 year	0	0	0
		30 year	11	0	-4,000
		100 year	34	13	218,000
	West Hill and East Hill Road	5 year	47	8	15,000
		30 year	61	10	29,000
		100 year	63	-6	-119,000

The result in Table 4-1 show a very limited benefit resulting from an increase in the area drained to permeable surfaces. Following discussions with the project partners it was confirmed that the local geology would also make this option difficult and it can therefore be discounted. Re-directing flows towards the Monktonmead Brook resulted in increased damages in both the lower order events for West Hill and East Hill Roads and in the higher order events around The Strand, therefore it was not felt that this option should be taken forward.

Table 4-2: Change in modelled flood damages for Options 5, 7 and 7a

Option	Location	Return Period	Number of Properties flooded to a depth of 0.1m	Change in Number of Properties flooded to a depth of 0.1m	Change in total damages / £
Option 5 - Manage highway drainage	Binstead	2 year	58	-1	6,500
		5 year	64	-1	-9,500
		30 year	74	-1	-20,500
		100 year	93	0	-6,000
Option 7 - Binstead storage (U/S connection)	Binstead	2 year	58	-1	-37,500
		5 year	63	-2	-85,500
		30 year	71	-4	-83,500
		100 year	82	-11	-208,500
Option 7a - Binstead storage (D/S connection)	Binstead	2 year	32	-27	-305,000
		5 year	38	-27	-350,500
		30 year	70	-5	-155,000
		100 year	80	-13	-237,500

The results for the Binstead area options show a limited reduction in the number of properties flooded; however due to a reduction in the flood volume and therefore depth of flooding as a result of the modelled storage. It is noted that by locating the flood storage at the downstream end of Sandpath there is significant increase in the benefit of approximately £265k in the lower order events (1 in 2 and 1 in 5 year); however in the higher order events the increase in benefit is reduced to between £29k and £72k.

Table 4-3: Change in modelled flood damages for Option 6

Option	Return Period	Location	Number of Properties flooded to a depth of 0.1m	Change in Number of Properties flooded to a depth of 0.1m	Change in total damages / £
Option 6 - Greenfield runoff at development sites	5 year	Binstead	64	-1	-14,000
		The Strand	0	0	0
		West Hill and East Hill Road	39	0	0
		Queens Road	4	0	0
	30 year	Binstead	77	-3	-49,500
		The Strand	11	0	-1,500
		West Hill and East Hill Road	51	0	0
		Queens Road	15	0	2,000
	100 year	Binstead	112	-2	-55,000
		The Strand	21	0	0
		West Hill and East Hill Road	69	0	0
		Queens Road	24	0	-500

A reduction in the runoff from the SHLAA sites around Ryde shows limited benefit in the hotspots within Ryde, however there is a reduction in the mean damages in the Binstead area. This reduction is likely due to the number of sites located around the southern edge of the existing developed area of Binstead and suggest that ensuring that DM14 of the Core Strategy is adopted will provide a benefit in the area.

An initial economic appraisal of the options has not been made of the cost-benefit of the options assessed and this should be completed following any additional investigation into the options that may be taken forward.

4.11 Stakeholder input to options assessment

The views of the internal and external stakeholders on potential solutions were gathered at the partnership options meeting and the public event for residents of Ryde.

4.11.1 Partners input

The options meeting was held during the initial stages of options testing using the integrated model. The meeting was intended to update the partners on progress, discuss the initial model outputs and the implications for the areas of concern, and gain views from all attending on the proposed options. Outcomes from this meeting were used to inform the draft Action Plan and the public event.

Those present at the meeting included:

- representatives of all project partners (Isle of Wight Council, Southern Water, Island Roads, the Environment Agency);
- Ryde Town Councillor;
- Ryde Flood Action Group
- Binstead Flood Action Group and
- JBA Consulting (the appointed project consultants).

Comments and concerns were raised about a number of options including the following:

- Option 2 - the local geology limits infiltration in this area. This is further evident in the limited benefit that has been shown from this option in the modelled results.
- Option 3 - there were concerns over the water quality of the runoff from the urban area entering the Canoe Lake and whether any bio-filtration may be required prior to discharge from the lake. It was noted that the pump capacity of the outfall from the lake

is limited and this may reduce the potential storage capacity of the lake for flood risk benefits. In addition a concern was raised about the possible conflict between the flood risk benefits and amenity use of the lake.

- Option 4 - the possible increase in the flow to the Monktonmead Brook would need to be mitigated. The results of the modelling outlined above suggest that additional attenuation would be required if this option was to be explored further.
- Option 5 - it is understood that services may exist along the verges in the Greenway, which may make the installation of raingardens difficult; however if used in conjunction with the storage modelled in Option 7 this could provide some benefit to the properties on Cemetery Road.
- Option 7 - there is limited space at this location, however the potential benefit is such that further investigation of this option is of interest.

4.11.2 Public event

The public event was held on the 22nd January 2015 at the George Street Centre, Ryde. The public event presented the areas known to be most at risk from surface water flooding and an outline of potential options for alleviating flooding in these key areas.

Attendees were asked their experience of flooding and their views on the proposed actions. The following question was asked:

In principle, do you support the types of actions being taken in the SWMP to tackle flooding?

Results

Of the nine questionnaire responses, six said 'yes', none said 'no' or 'unsure', and three did not answer the question.

Comments

The general reaction to the actions being taken by the SWMP were positive although there was worry the actions needed to be faster. There were a number of concerns regarding directing additional flows to the Monktonmead Brook as it is often full and also concerns over how the additional housing developments and climate change would affect the current drainage network.

There was demand for further communication between residents and drainage authorities, including a process where residents could report flooding incidents so that a map could be built up over time.

In addition there was concern about how additional development within the town may impact on the existing flood risk.

5 SWMP Action Plan

5.1 Introduction

The Flood Investigation Report identified a number of recommendations and future actions for the reduction of flood risk across the Ryde SWMP study area. The Action Plan collates all the information undertaken and collected as part of this SWMP study and:

- Outlines the actions required and where and how they should be undertaken;
- Sets out with partner or stakeholder is responsible for implementing the actions and who will support them;
- Provides indicative costs; and
- Identifies priorities.

This section restates the actions within the Flood Investigation Report and identifies new actions for the study area identifies by this SWMP.

5.2 Catchment wide Action Plan

Table 5-1 describes the catchment wide actions to be applied throughout the study area of Ryde and Binstead.

Key: Flood Investigation Report action completed, Flood Investigation Report action in progress, Flood Investigation Report action remaining, SWMP new action.

Table 5-1: Catchment wide Action Plan

Ref	Action/Option (What?)	Priority Actions (How?)	Lead Action Owner	Supporting Action Owner(s)	Priority (When?)*	Indicative Relative Cost
1	Commission a surface water management plan for the Ryde area to inform the longer term project development for all agencies involved in water management in the area.	N/A	IoWC	EA, SW & IR	Quick win	Low
2	All local agencies to provide an update to both the Binstead Flood Action Group and the Ryde Flood Action Group on a quarterly basis.	FAG meetings, phone conversations, site visits, newsletters, public events.	IoWC	EA, SW & IR	Short - Long Term	Low
3	IoWC, EA and SW to continue to investigate options for longer-term solutions and accompanying sources of funding. This will include the outfall project as well as options for removing properties from the combined system, removing highway drainage from the combined system and increasing storage capacity in the wider catchment.	Options and possible solutions have been included within the SWMP (except outfall project). Further investigation of specific options should be undertaken	IoWC, SW & EA	IR	Short - Long Term	Low
		Monktonmead outfall project is currently ongoing by the EA. Modelling of different options has been undertaken.	EA	IoWC	Short - Long Term	Low
4	IoWC and Island Roads should agree a programme of cleaning the critical gullies.	Develop and initiate a strategy for the maintenance and clearing of the critical gullies	IoWC & IR		Short - Long Term	Medium
5	Raise the awareness of Property Level Protection (PLP) for homeowners and businesses with a residual risk of flooding.	Identify properties and businesses which would benefit from PLP.	IoWC	EA	Quick win	Low
6	In line with the council's Core Strategy DM14 developments are required to reduce overall and local flood risk, to this end it is recommended that, where possible developers aim to disconnect surface water drainage from large roofed and paved areas from discharging to the combined sewerage system or watercourses when there are redevelopment or refurbishment opportunities.	Identify large roofed or paved areas within the catchment.	IoWC	SW	Long Term	Medium
7	Raise awareness of urban creep. Further policy and guidance	Review need for and methods of	IoWC		Long Term	Low

Ref	Action/Option (What?)	Priority Actions (How?)	Lead Action Owner	Supporting Action Owner(s)	Priority (When?)*	Indicative Relative Cost
	in this area might consider: 1. Raise public awareness of the restrictions on paving of front gardens. 2. Raise awareness of the restrictions on paving of front gardens and provide best practice advice to contractors who undertake the work on behalf of residents 3. Education on the issue of household drainage and misconnections. 4. Advice with respect to drainage of small developments. 5. Identify how Development Control can implement this policy without creating large amounts of additional activity	awareness raising				
8	Ensure SWMP findings are available to users of the SFRA. This could take the form of an addendum or assisting with the updating of the SFRA	Include findings from the SWMP in the ongoing update to the SFRA	IoWC		Short Term	Low
9	Maintain regular communications within the SWMP partnership and monitor progress of actions.	Initially a meeting or quarterly teleconference	IoWC	EA, SW & IR	Short - Long Term	Low
10	Maintain regular (quarterly) communications with residents and other stakeholders to update on progress. Could involve a variety of methods including IoWC website, Ryde Flood Action Group and Binstead Flood Action Group meetings, mailshot, drop-in meetings.	Agree a long term communications plan.	IoWC		Short - Medium Term	Low

***Priority: Quick win = within 12 months. Short Term = up to 2 years. Medium Term = up to 5 years. Long Term = open ended/indefinite.**

5.3 Location Specific Action Plan

Table 5-2Table 5-1 describes the location specific actions to be applied throughout the study area of Ryde and Binstead.

Key:

Flood Investigation Report action completed, Flood Investigation Report action in progress, Flood Investigation Report action remaining, SWMP new action, project undertaken independently by a partner.

Table 5-2: Location specific actions

Area of benefit	Location of action	Action/Option	Benefits	Next Steps	Action Owner	Supporter(s)	Priority *	Indicative Cost (£)
Binstead	Binstead Cemetery	Undertake works arising from the DARES drainage investigation at the Cemetery, Binstead.	Maintain drainage network	Review maintenance schedule	IoWC	EA, IR & SW	Quick win	
	The Mall to King's Road footpath	Investigate the potential for installation of an attenuation tank at Cemetery Road/Binstead Hill in order to slow down the flow of water.	Reduce flood risk at Cemetery Road/Binstead Hill	Modelling / site check	IR	IoWC & SW	Medium Term	£50-70k
	Cemetery Road	Liaise with landowners on Cemetery Road to discuss improvements to the culverted stream.	Improve flow of water through culvert. Reduce flood risk Cemetery Road/Binstead Hill	Communicate with residents.	IoWC	EA & SW	Medium Term	
	Cemetery Road	IoWC, EA and SW to continue to work together to maintain flow through the culvert and prevent blockages. Including, identifying and securing capital funding for Partnership Funding.	Improve flow of water through culvert. Reduce flood risk Cemetery Road/Binstead Hill	Review maintenance schedule	IoWC,	EA & SW	Medium Term	
	Greenway	Investigate the potential of using rain gardens along Greenway to reduce the flow path down Greenway and reduce surface water flooding in Binstead.	Reduce flows within surface water network, reduce flooding at Cemetery Road/Binstead Hill and The Mall. Enhance appearance of streetscape.	Gauge residents' opinion and on site review of potential for SuDS retrofit.	IoWC	SW, EA & IR	Medium Term	
	Newham Road	Island Roads are considering upgrading the pipes which run between Newham Road and The Mall.	Increased capacity of network, reduced flood risk on Newham Road		IR		Quick win	

Area of benefit	Location of action	Action/Option	Benefits	Next Steps	Action Owner	Supporter(s)	Priority *	Indicative Cost (£)
Canoe Lake		Deliver the Canoe Lake outfall project	Increase capacity with Canoe Lake		IoWC (parks and recreation)		Short Term	£110k
The Strand	The Strand area	SW scheme to increase capacity of combined sewer system. Scheme includes deeper oversized sewer with rider sewer for regular flows, and off-line storage at the eastern end of the Strand. Project to be completed by the summer of 2015.	Increase capacity of combined sewer systems and reduce surcharge at western end of Simeon Street, The Strand and East Street.	Complete project build.	SW	IoWC	Quick win	
	Haylands	Investigate the options for surface water disconnection from the combined system in the area around Pound Mead, Node Close, Partlands Close and Leighwood Close has potential for reducing flood risk.	Reduce flows in the combined system which flows through Cornwall Street.	On-site review of potential for disconnection.	IoWC	SW	Medium Term	
West Hill Road	West Hill and East Hill Road	Increase highways drainage area which discharges directly into the Canoe Lake.	Reduce flood risk at East Hill and West Hill Rd.		IoWC	SW, IR & EA	Quick win	
	West Hill and East Hill Road	Manage surface water better at a household level through by retrofitting SuDS.	Reduce flood risk at East Hill and West Hill Rd.	Gauge residents' opinion and on site review of potential for SuDS retrofit.	IoWC	SW & EA	Medium Term	

***Priority: Quick win = within 12 months. Short Term = up to 2 years. Medium Term = up to 5 years. Long Term = open ended/indefinite.**

5.4 Timeframe and responsibilities

The project partners have reviewed and commented on the actions at the draft report stage.

High priority and quick win actions identified the 'Action Plan' are likely to be those addressed first. However this report only considers the relative priorities within Ryde and Binstead. Some of the partner organisations, Southern Water and the Environment Agency have flood risk management responsibilities beyond the SWMP study area, and therefore the priority of actions within Ryde will have to be assessed against the priority of actions in other areas.

Within the Isle of Wight Preliminary Flood Risk Assessment[12] Ryde was ranked third in Locally Significant Flood Risk Areas ranked by number of people at risk, and first if ranked by critical services. The PFRA considered flood risk from ordinary watercourses, surface water and groundwater.

It is recommended that an annual review of the High and Medium priority actions is undertaken to allow for forward financial planning in line with internal and external partners budget allocations. Low priority actions should be reviewed on a three year cycle.

5.5 Sources of funding

Funding for local flood risk management may come from a wide range of sources. In Ryde these may include:

- Defra (Flood Defence Grant in Aid)
- Isle of Wight Council
- Island Roads (highways)
- Southern Water
- Network Rail
- Industrial estate owners and businesses
- New developments (directly through the developer or through CIL)
- Local communities

It is likely that schemes in Ryde will not have sufficient cost-benefit ratio to attract 100% funding from Defra Flood Defence Grant in Aid (FDGiA) and therefore require funding to be developed from a number of sources to support the Defra funding. These other funding sources could also have other objectives such as improving highways, public open spaces or biodiversity.

The EA secured FDGiA funding (2014/15) to investigate measures that could be implemented to improve flood risk in Ryde. In February 2014 they gained approval to assess the favoured options and their associated costs resulting in a Project Appraisal Report (PAR). Construction of the preferred option is planned for 2015 with the final project potentially eligible for FDGiA, but will need to be matched by Partnership Funding (local investment partners) from other sources.

5.6 Ongoing monitoring

The partnership established as part of the SWMP process should continue beyond the completion of the SWMP in order to discuss the implementation of the actions and review opportunities and legislation changes.

The Defra SWMP technical guidance recommends that the SWMP Action Plan should be reviewed and updated once every six years as a minimum. However there may be circumstances that initiate a review and/or update of the action plan in the interim period, for example:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, which may alter the understanding of flood risk within the study area;
- Investment decision by partner(s) is different to the preferred option within the action plan, which may require a revision of the action plan, and;

[12] Isle of Wight Preliminary Flood Risk Assessment (AMEC, November 2011)

- Additional (major) development or other changes in the catchment which may affect the surface water flood risk.

The action plan should act as a live document that is updated and amended on a regular basis, e.g. on an annual basis. As a minimum the action plan should be agreed in the Isle of Wight Local Flood Risk Management Strategy, although individual partners may wish to review their actions more regularly.

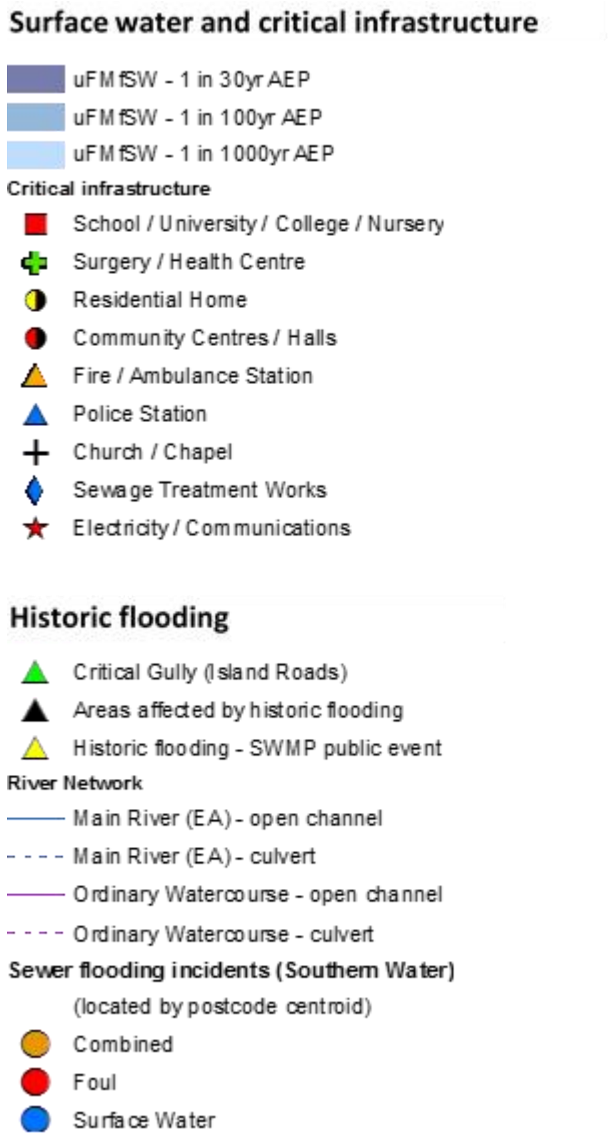
Appendices

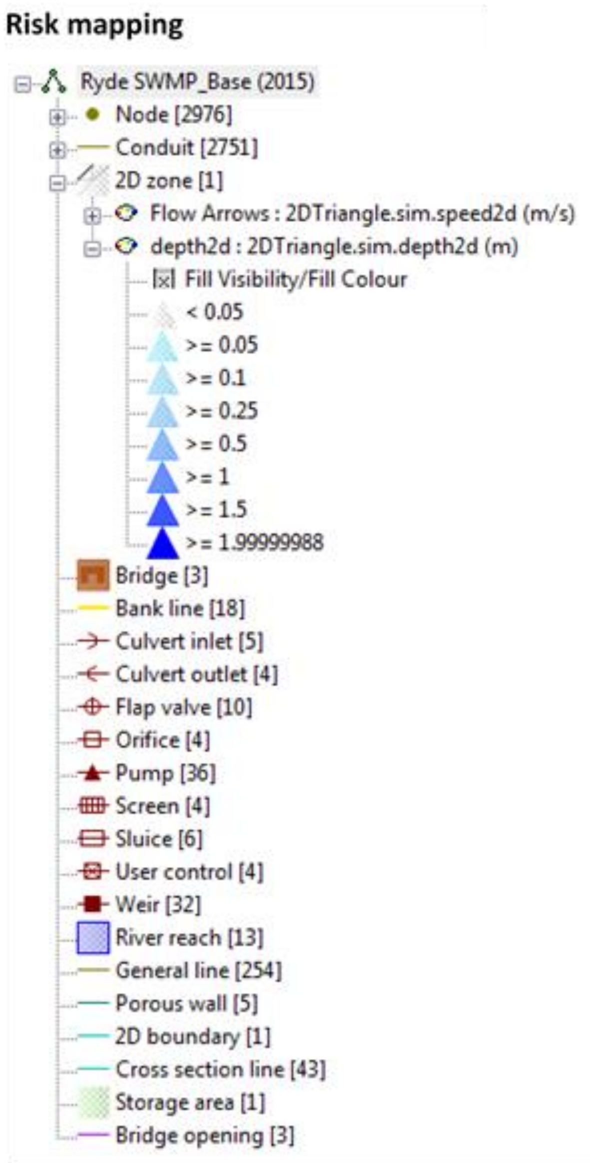
A Maps

Map	Title
1	Study area and topography
2	Watercourses and drainage systems
3	Land use and development
4	Historic flooding
5	Flooding receptors
6	Fluvial Flood Zones
7	Flood Map for Surface Water: 1 in 30 AEP 2015
8	Flood Map for Surface Water: 1 in 100 AEP 2015
9	Flood Map for Surface Water: 1 in 1000 AEP 2015
10	Modelled watercourses and drainage systems
11	Model results - Depth - 1 in 2 AEP 2015, 120 minute storm duration
12	Model results - Depth - 1 in 5 AEP 2015, 120 minute storm duration
13	Model results - Depth - 1 in 10 AEP 2015, 120 minute storm duration
14	Model results - Depth - 1 in 30 AEP 2015, 120 minute storm duration
15	Model results - Depth - 1 in 75 AEP 2015, 120 minute storm duration
16	Model results - Depth - 1 in 100 AEP 2015, 120 minute storm duration
17	Model results - Depth - 1 in 100 AEP plus Climate Change, 120 minute storm duration
18	Model results - Depth - 1 in 200 AEP 2015, 120 minute storm duration
19	Model results - Depth - 1 in 2 AEP 2014, 120 minute storm duration
20	Model results - Depth - 1 in 10 AEP 2014, 120 minute storm duration
21	Model results - Depth - 1 in 30 AEP 2014, 120 minute storm duration
22	Model results - Depth - 1 in 100 AEP 2014, 120 minute storm duration
23	Model results - Hazard - 1 in 2 AEP 2015, 120 minute storm duration
24	Model results - Hazard - 1 in 5 AEP 2015, 120 minute storm duration
25	Model results - Hazard - 1 in 10 AEP 2015, 120 minute storm duration
26	Model results - Hazard - 1 in 30 AEP 2015, 120 minute storm duration
27	Model results - Hazard - 1 in 75 AEP 2015, 120 minute storm duration
28	Model results - Hazard - 1 in 100 AEP 2015, 120 minute storm duration
29	Model results - Hazard - 1 in 100 AEP plus Climate Change, 120 minute storm duration
30	Model results - Hazard - 1 in 200 AEP 2015, 120 minute storm duration
31	Model results - Hazard - 1 in 2 AEP 2014, 120 minute storm duration
32	Model results - Hazard - 1 in 10 AEP 2014, 120 minute storm duration
33	Model results - Hazard - 1 in 30 AEP 2014, 120 minute storm duration
34	Model results - Hazard - 1 in 100 AEP 2014, 120 minute storm duration

B Flood risk assessment

B.1 Key to maps

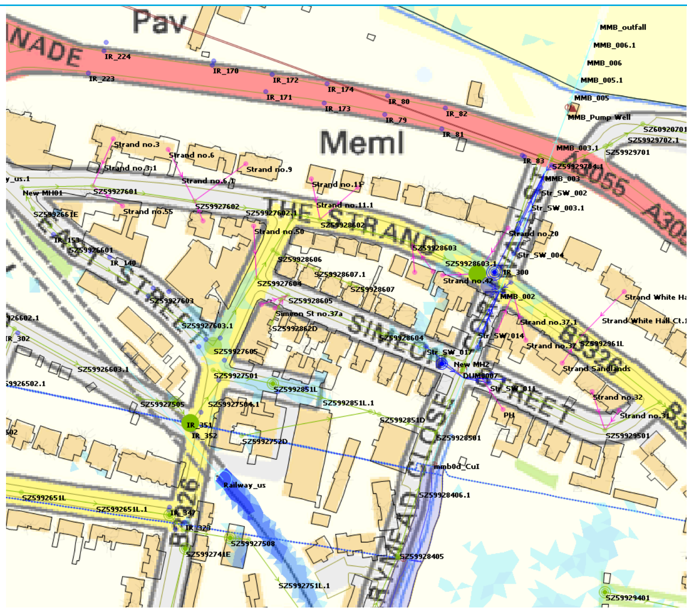




B.2 The Strand

uFMfSW and critical infrastructure

SWMP model results (M100-120)



Historic flooding

Model performance:

The model shows the gullies on Simeon Street and The Strand to surcharge and ponding is occurs near to these gullies on The Strand and Simeon Street. Not all the flooding is contained within the roads.

Further significant surface water ponding is modelled at the junction of East Street and Monkton Street.

The uFMfSW shows a large amount of flooding in this region however much of this flow within the combined model is contained within the Monktonmead Brook.

The modelled results are consistent with the high number of historic flood events located in the area, particularly basement flooding on The Strand and a number of Southern Water sewer flooding incidents.

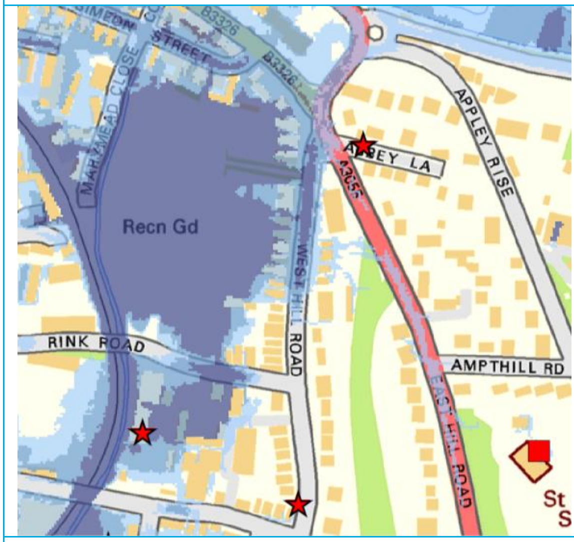
Assessment of flood mechanisms and risk:

The main source of flooding on The Strand and Simeon Street is from surcharging surface water gullies connected to the culverted Monktonmead Brook. Combined sewers also surcharge. The surcharged water ponds in the roads and flows into the basements of the properties.

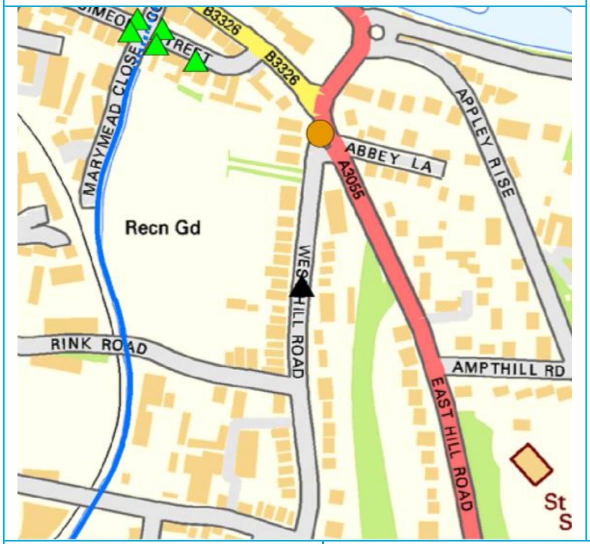
The flooding on East Street and Monkton Street is a result of surface water ponding and is of shallow depth.

B.3 West Hill Road and East Hill Road

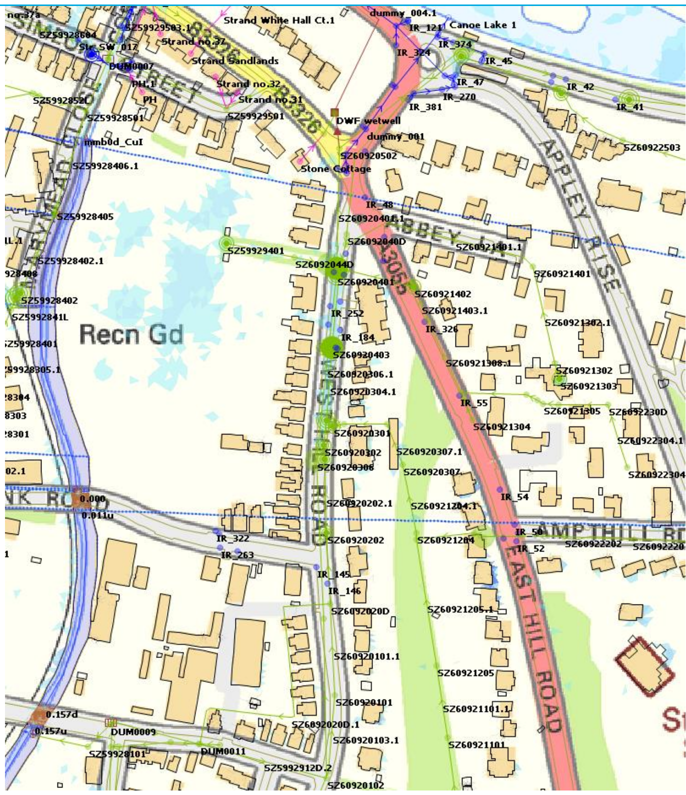
uFMfSW and critical infrastructure



Historic flooding



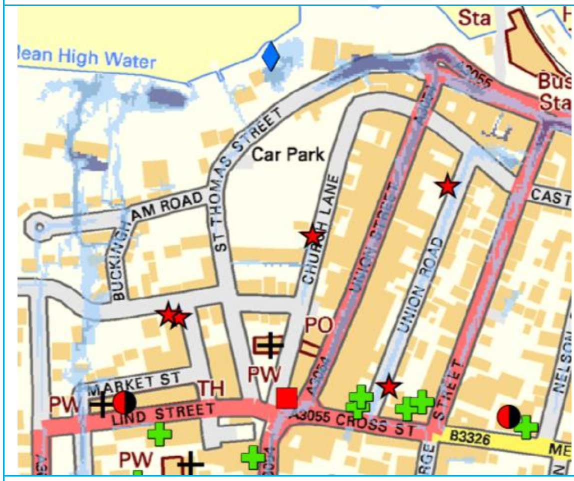
SWMP model results (M100-120)



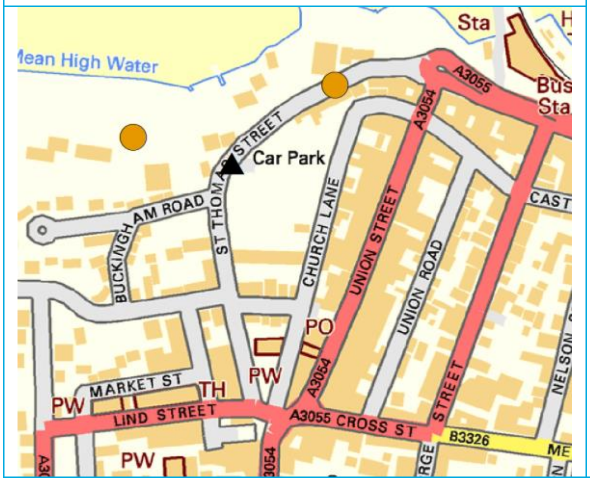
Model performance:	The model is simulating flooding at the bottom of West Hill Road and ponding on the uphill sides of properties. The model shows combined surface water and sewer surcharge along West Hill Road. This is consistent with the historic flooding events.
Assessment of flood mechanisms and risk:	Surcharging from combined system on West Hill Road along with surface water runoff causes flooding at the bottom of West Hill Road. Ponding at properties is a result of runoff on the steep topography.

B.4 St Thomas' Street

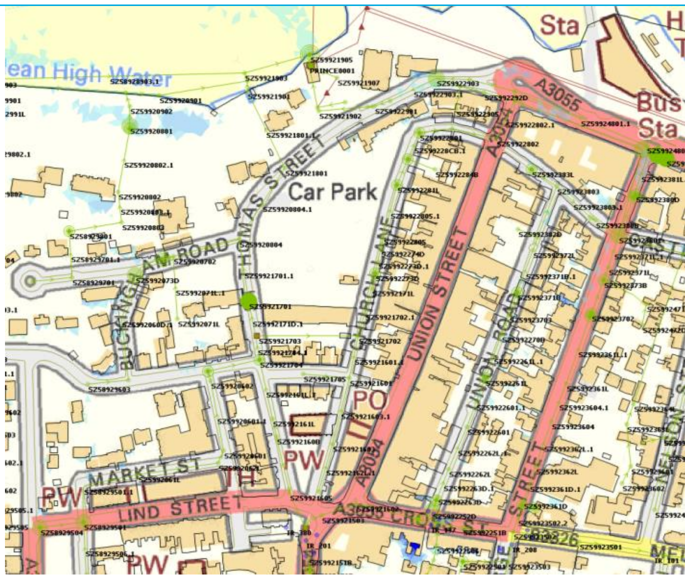
uFMfSW and critical infrastructure



Historic flooding



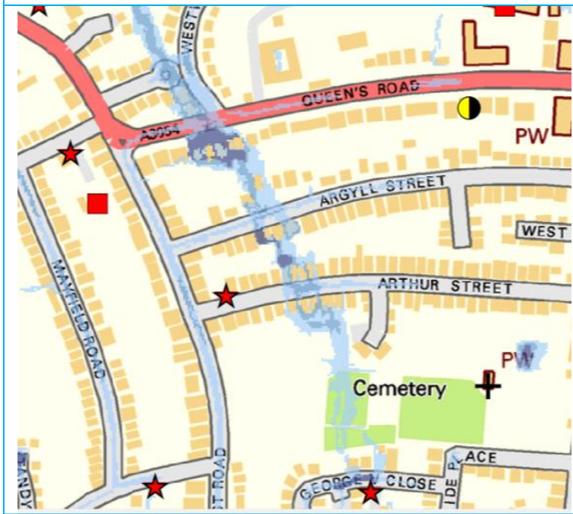
SWMP model results (M100-120)



Model performance:	The model is simulating surface water flooding on the northern section of St Thomas Street, with some surcharge from the combined system. The model does not simulate the flow path down Union Street within the uFMfSW. The model results reflect the known historic flooding incidents.
Assessment of flood mechanisms and risk:	Surface water flooding is modelled at the north of St Thomas Street and is mostly the result of the combined sewer system surcharging. The sewer pump station is crucial to the function of the network in this area.

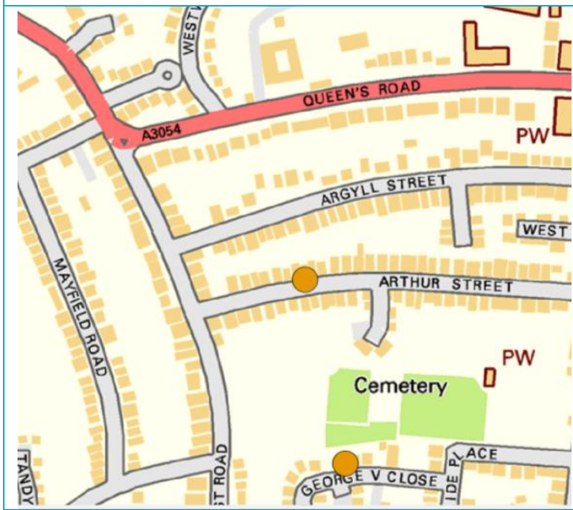
B.5 Queen's Road

uFMfSW and critical infrastructure



SWMP model results (M100-120)

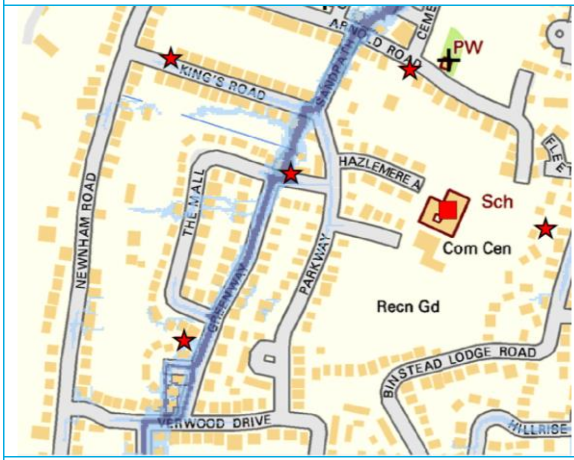
Historic flooding



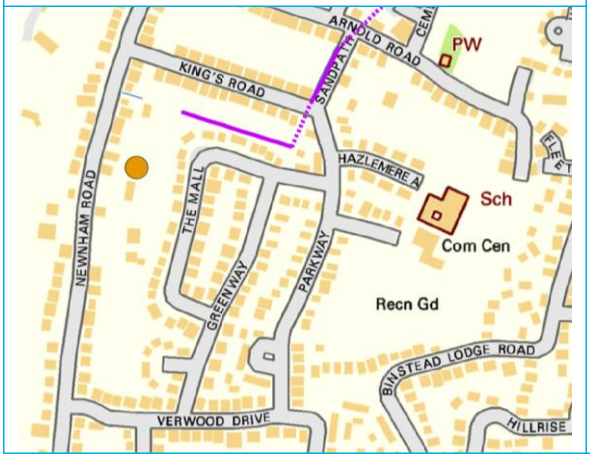
Model performance:	A flow path running south to north is identified within the model results and uFMfSW. Larger ponding occurs in a topographical low spot south of the Queen's Road. The model shows combined, foul and surface water sewers surcharging. There are no records of flooding within this area with the exception of SW sewer flood records at Arthur Street and George V Close.
Assessment of flood mechanisms and risk:	Mainly surface water flooding from the south of the area flowing to the north west, following the topography. Ponding in the low spots. Some sewer flooding is modelled.

B.6 Binstead - Greenway

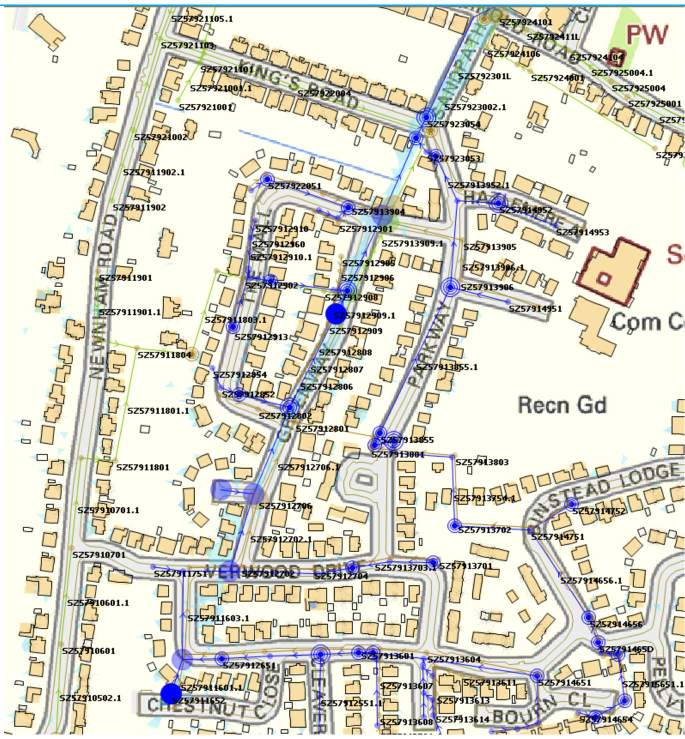
uFMfSW and critical infrastructure



Historic flooding

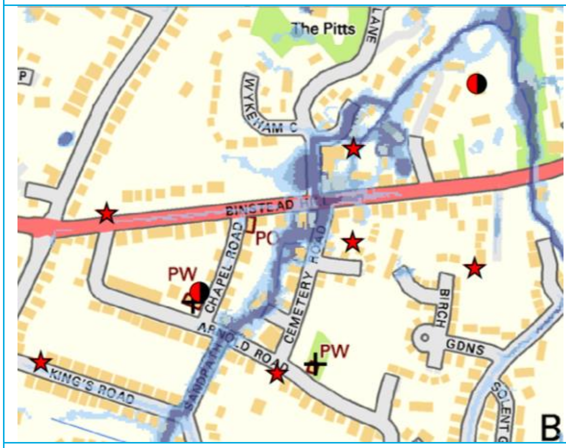
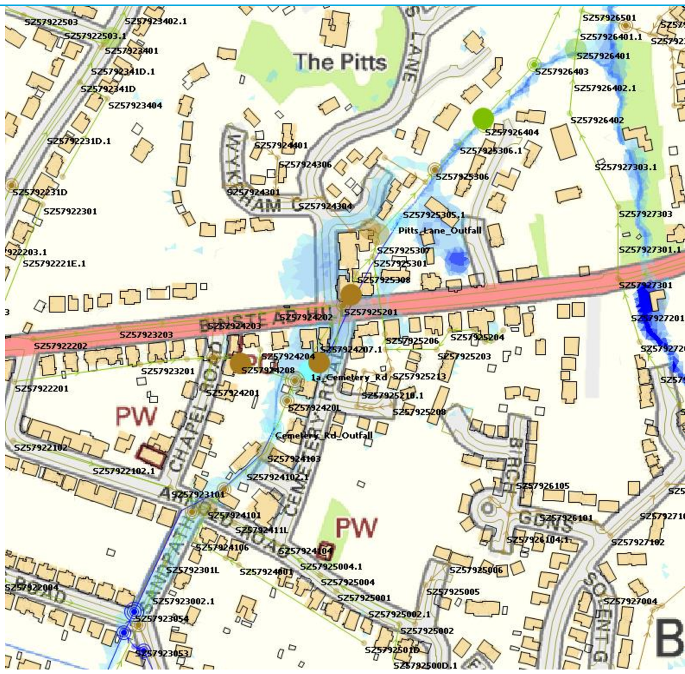
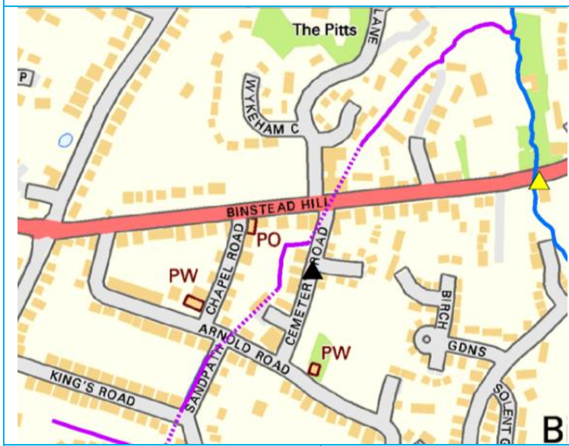


SWMP model results (M100-120)



Model performance:	Model shows ponding against houses and in the road, but flow path from uFMfSW not replicated within model as the surface water drains into the sewer network. Greatest ponding is modelled at the road junction between Greenway and The Mall.
Assessment of flood mechanisms and risk:	Surface water flooding that travels from the south of Greenway to the north and ponds at the road junction as this is the lowest point. Most of flooding is retained within the road.

B.7 Binstead - Binstead Hill / Cemetery Road

uFMfSW and critical infrastructure	SWMP model results (M100-120)
	
Historic flooding	
	

Model performance:	The model shows a surface water flow path which follows the open channel/culverted ordinary watercourse running from the southwest to the north east. This flow path is consistent with the uFMfSW. Flooding is a result of the surface water flow path and the model shows water coming out of bank when the overland channel makes a sharp 90 degree turn behind the houses on Cemetery Road. The model shows the greatest ponding to occur in the northern region of Cemetery Road, across Binstead Hill and to the south of Binstead Hill. Flooding is known to have occurred in the grounds of properties on Cemetery Road as a result of the sharp turn, and across the Binstead Hill Road which is consistent with the modelled results.
Assessment of flood mechanisms and risk:	Flooding is a results of surface water which travels from the southwest to the northeast. The surface water sewer comes out of culvert behind the houses on Cemetery Road and the overland channel takes a 90 degree turn before going back into culvert. There has been a history of problems here due to the sharp turn. The overtopping water continues to flow northeast over the Binstead Hill Road and ponds in the grounds of the properties to the south and north of Binstead Hill.

C Model Operation Manual

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft Model Report v1.0	-	Wendy Perera (Isle of Wight Council)
Final Model Report v2.0		Wendy Perera (Isle of Wight Council)

Contract

This report describes work commissioned by Wendy Perera, on behalf of the Isle of Wight Council under the Environment Agency's Water and Environment (WEM) Framework. Isle of Wight Council's representative for the contract was Wendy Perera.

Prepared by ....Elizabeth Gorton BA

Assistant Analyst

Reviewed by ....Alistair Clark BSc MSc

Senior Analyst

Purpose

This report provides a detailed record of the information required to operate the hydraulic model updated and developed for the Ryde Surface Water Management Plan. It provides a technical overview of the network and river model complementing the more general and non-technical information within the main report.

Acknowledgements

Thanks to Wendy Perera of the Isle of Wight Council; Ian Tripp and Rob Sheehan of the Environment Agency; Keith Herbert, Mike Tomlinson and Marc Barton of Southern Water and Garry Stretch from Island Roads for the provision of information and assistance during the project. Thanks also to Barry Arnold of the Ryde Flood Action Group.

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Appendices I

A. Hydraulic Model Check File II

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A. Hydraulic Model Check File II II

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1. Introduction

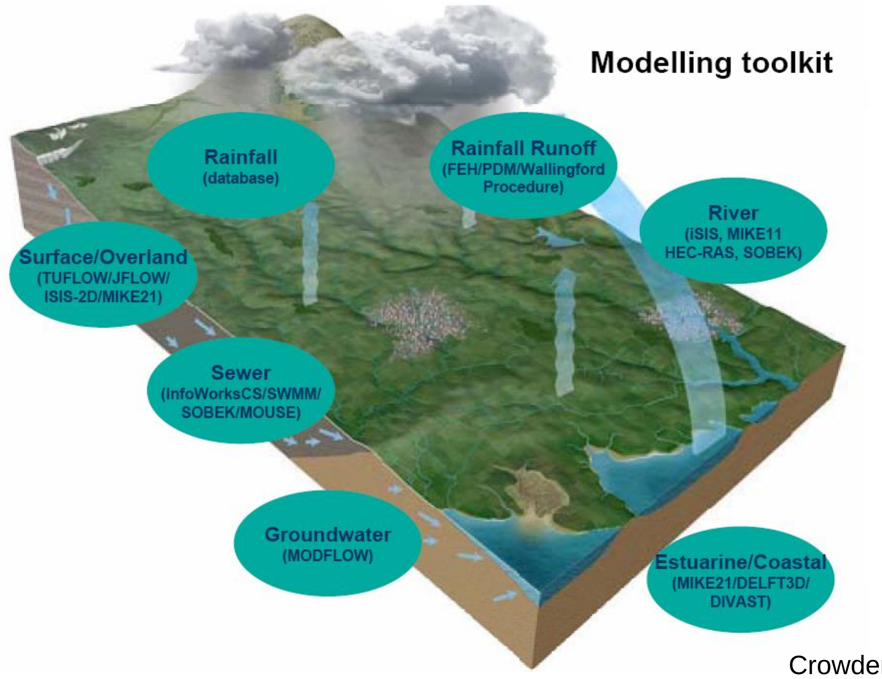
In September 2014 JBA Consulting were commissioned by Isle of Wight Council, as Lead Local Flood Authority, to undertake a Surface Water Management Plan (SWMP) for Ryde on the Isle of Wight. This study considers the interaction of the combined drainage system within Ryde with the Monktonmead Brook which flows through the centre of Ryde on its route to the sea. There is also a combined flood risk from the tide locking of the Monktonmead Brook outfall.

Ryde lies on the north east coast of the Island and the study area covers the main Ryde and Binstead towns. The study area is composed of both residential and commercial buildings with some public open spaces and recreation grounds.

The Ryde SWMP requires a modelling approach to understand the flood risk mechanisms and to test potential solutions to reduce the risks identified. The model must simulate the response to a rainfall event and the interactions of the full drainage network as a result. Historically the different aspects of the urban drainage system have been treated in isolation however relatively new techniques have allowed the interaction between the river, coastal, above ground and below ground urban drainage environments to be considered together. This type of approach is referred to as Integrated Urban Drainage (IUD) modelling. The development of IUD techniques have in part been a response to the floods of 2007 and a number of consultations including "Making Space for Water", "Foresight Future Flooding", and the "Pitt Review".

Figure 1-1**Error! Reference source not found.** below shows some of the modelling platforms and techniques that are commonly used in the UK for hydrologic and hydraulic investigations / engineering design.

Figure 1-1: Integrated Urban Drainage modelling approaches



Crowder, 2006

There are a number of modelling software packages that could be used for IUD modelling. In this case InfoWorks ICM was preferred as it is the most suitable software to represent direct rainfall and overland flows, river networks and sewer networks simultaneously within one modelling platform. Importantly, it also accounts for the interactions between these systems.

The Ryde SWMP InfoWorks ICM model has principally been developed from a Southern Water InfoWorks CS model and the Monktonmead Brook Flood Risk Mapping (2005) ISIS model.

This Model Operation Manual notes the more major changes made during the InfoWorks ICM build process as well as the final network models and the results of sensitivity and validation checks.

2. Technical Summary

Item	Comments
What software & reason for choice:	InfoWorks ICM v5.0.4 InfoWorks ICM was used as it is the most capable software package available for modelling surface water, sewerage networks, river channels and 2D surface flood modelling. Version 5.0.4 was used as this was the latest release of InfoWorks ICM at project commencement.
General Schematisation:	The hydrology within the study area uses a mixture of rainfall-runoff and direct rainfall. The runoff has been routed through sewer sub-catchments, surface water sub-catchments and infiltration zones. The river network has been imported from an existing ISIS model provided by the Environment Agency. The structures have been reproduced in InfoWorks ICM. The original ISIS model contained a number of ReFH inflows. Only the upstream inflow has been retained since the lateral inflows have been replaced by the direct rainfall in the 2D domain.
Design Events	The following pluvial design events have been run: 1 in 2 year, 5 year, 10 year, 30 year, 75 year, 100 year and 200 year. In addition the 1 in 100 year plus climate change event has been run. The climate change allowance is +20% as recommended for the 2080s change factor or 2050s upper end estimate. Critical duration analysis has been completed using both a 1 in 30 year and 1 in 100 year summer storm event. The following durations were tested: 15, 30, 60, 120, 180, 360 and 720 minutes. The results were compared for each of the areas of interest and showed that the greatest risk was the 120 minute storm duration.
Rainfall Runoff	The model uses a mixture of sewer and surface water sub-catchments and infiltration zones to route the flows within the 2D domain. The infiltration zones represent open spaces and parks within the urban area. The runoff can be varied individually for each infiltration zone to test different types of development within each zone. A default value of 30% has also been applied for the 2D zone for any area not covered by sub-catchments or infiltration zones. A 30% rainfall runoff value represents permeable land and therefore is a reasonable runoff percentage.
Coefficients:	Standard Manning's n and Colebrook White roughness coefficients are used to represent hydraulic roughness in the open watercourse and surface and waste water drainage network. The channel roughness values and structure roughness and coefficients within the fluvial model have been exported from the ISIS model. These were originally informed by survey and photographs. A standard 2D roughness value of 0.0125 is used across the 2D urban domain. A standard Colebrook-White value of 3.00 for the bottom roughness and 0.60 for the top roughness has been used throughout the network model. This has been retained from the Southern Water InfoWorks CS model.
Structures	There are a number of structures on the Monktonmead Brook. Details on their representation and coefficients are within Appendix A.3.
Model Proving:	The network model was previously verified by Southern Water. Following updates to the model the same storm events used to verify the model were rerun and the results compared against the verified model. The results compared well and no significant differences were noted. The fluvial model was verified as part of the Monktonmead Brook Flood Risk Mapping study. It should be noted that although the cross sections and structures were imported from the ISIS model it is not possible to schematise the structures is identically. Further, the ISIS model was 1D only with extended cross sections. These have been trimmed in InfoWorks.

	The integrated model has been further verified through internal audit and the draft results reviewed by representatives from the Isle of Wight Council, Southern Water and the Environment Agency.
Modelling assumptions and limitations	The model has been built to understand the interaction between rainfall, above ground flows, Monktonmead Brook and the drainage networks. The model would require additional sensitivity testing before it could be considered suitable for uses other than surface water mapping. Assumptions: - 30% percentage runoff is representative of the natural land surfaces in Ryde - Sewer condition is generally good and there are no blockages (Bottom roughness, Colebrook-White = 3.0 and top roughness, Colebrook-White = 0.6) - Houses drain to the combined system within Ryde (apart from the Strand area where an Impermeable Area Survey was completed) and the surface water system within Binstead rather than a soak away - A Manning's n value of 0.0125 is representative of Ryde considering the presence of buildings and road features that obstruct and route flow within the 2D domain
Strengths, Weaknesses and future development	The fluvial model has been built based on the ISIS model schematisation. The original survey used to inform the ISIS model was not available, nor any other channel / structure survey. The fluvial inflows to the model have been imported from the upstream ReFH inflow within the ISIS model. Additional lateral ReFH inflows within the ISIS have been replaced by the direct rainfall in the 2D domain. Due to the original fluvial model being 1D and the integrated nature of the model it is difficult to directly compare the fluvial flooding. The ground model was based on the most recent 1m filtered LIDAR available. The Southern Water sewer model had been verified for a number of storm events. Additional gully data and surface water catchments has been built in from Island Roads gully data and the Southern Water Impermeable Area Survey of the Strand. Surface water sub-catchments were built in the south east corner of Binstead.
Model Convergence and Instability	Some model non-convergence is recorded in the model run however this is not unexpected for an integrated model and checks indicate that it does not significantly impact upon model results.

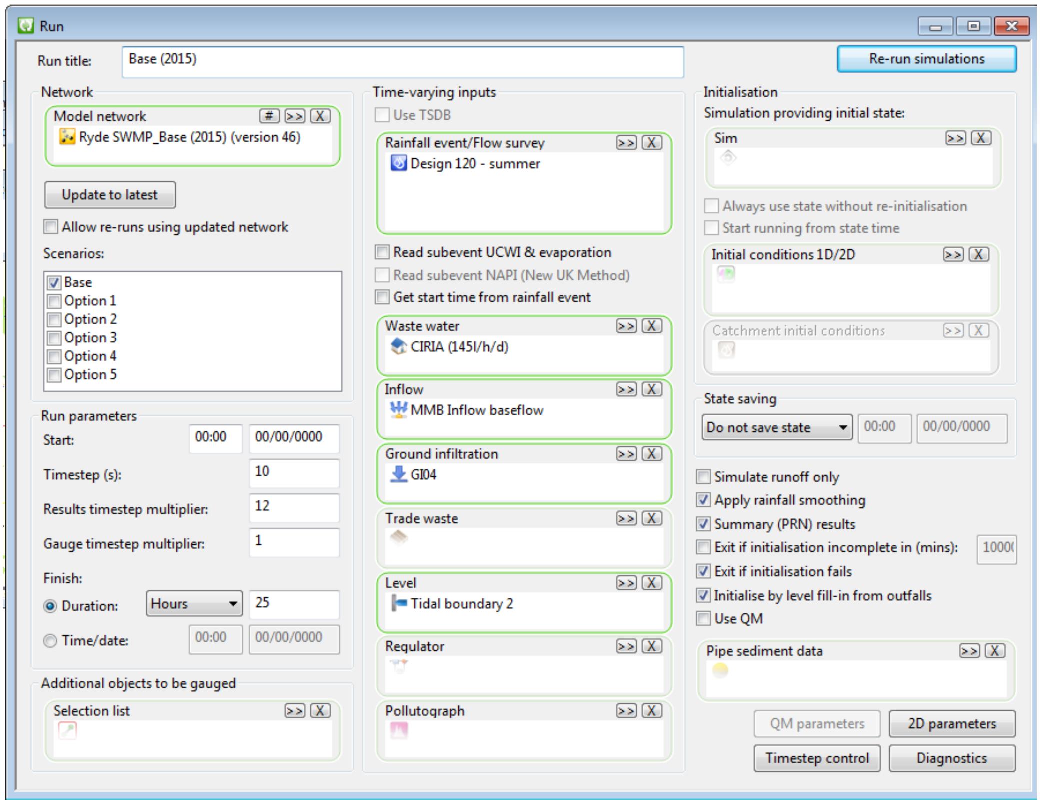
3. Data Structure and File Names

Table 3-1: Ryde SWMP ICM modelling master database

Folder	Sub Folder	Description
Networks	Ryde SWMP_Base (2014)	*Ryde SWMP model without the Southern Water 2015 updates*
	Ryde SWMP_Base (2015)	*Ryde SWMP model with the Southern Water 2015 updates. It includes the following modelled scenarios;* *- Base* *- Option 1 – Retain flows within West Hill Road and divert to river* *- Option 2 – Land use adjustment on West Hill and East Hill Road* *- Option 3 – SHLAA site runoff*
	Ryde SWMP_Base (2015)_Binstead_Options	*Cut down of Ryde SWMP 2015 model for Binstead. It includes the following modelled scenarios;* *- Base* *- Option 4 – Attenuation tank at upstream of footpath* *- Option 4a – Attenuation tank at downstream of footpath* *- Option 5 – Rain gardens*
RYDE – Appley Park Ryde\RYDE – Wastewater Group	CIRIA (145l/h/d)	*Dry weather inflows to the foul sewer network*
Rainfall	Critical Duration Testing: CDT – summer and CDT M100 - summer	*Critical duration testing for summer storms. The M30 and M100 event was used for the following storm durations: 15, 30, 60, 120, 180, 360 and 720*
	Design Events: Design 120 – summer and Design_Climate Change_120 - summer	*ReFH design rainfall for 120 minute storm. Includes the following return periods; M2, M5, M10, M30, M75, M100 and M200.* *Also includes climate change rainfall for M100-60 at 1.2 multiplier*
MMB Boundaries	MMB Inflow baseflow	*Monktonmead Brook constant 3 cumec fluvial inflow*
	Tidal boundary 2	*Monktonmead Brook mean high water spring tide downstream boundary*
Runs	Critical Duration testing: CDTM30 and CDT M100	*Critical duration testing runs*
	Design Runs: Base (2015), Base (2014) and Base (2015)_Climate Change	*Design runs for all return periods*
	Options testing: Options (2015) and Binstead Options (2015)	*Options testing for all return periods*
DTM	Ryde SWMP DTM (full)	*LIDAR at a 1m grid size*
Themes	GeoPlan Base	*A colour coding theme used during model build*
	Flood Theme	*A colour coding theme used for displaying results.*
	2D Flood Theme	*A colour coding theme used for displaying 2D results.*

4. Model Operation

Run purpose	Urban Flood Risk Mapping
Operation and model running instructions	1. It is important that the correct version of InfoWorks ICM is installed (version 5.0.4.10022). If running an updated version of ICM the software will prompt the user to allow it to update the models compatibility with the latest version. Note once this is done you cannot revert to running the model with earlier versions. 2. Import the transportable database into InfoWorks ICM. All necessary files to complete reruns of the model and results are contained within these files. 3. Ideally the InfoWorks root directory should be set to"C:\Infoworks_local_root" to maintain continuity of the original project. 4. Open a new run group; select the network; set the run parameters; set the time-varying inputs and hit 'Run Simulations'
InfoWorks ICM	
Master database	Ryde SWMP.icmm All model files are contained within the model database or its equivalent transportable database.
Network	Detailed model
Network version	Ryde SWMP_Base (2014) – version 44 Ryde SWMP_Base (2015) – version 46 Ryde SWMP_Base (2015)_Binstead_Options – version 47
Scenario	Ryde SWMP_Base (2014): - Base Ryde SWMP_Base (2015): - Base - Option 1 – Retain flows within West Hill Road and divert to river - Option 2 – Land use adjustment on West Hill and East Hill Road - Option 3 – SHLAA site runoff Ryde SWMP_Base (2015)_Binstead_Options - Base - Option 4 – Attenuation tank at upstream of footpath - Option 4a – Attenuation tank at downstream of footpath - Option 5 – Rain gardens
Rainfall Events	M2-120 M5-120 M10-120 M30-120 M75-120 M100-120 M200-120 M100+CC-120
Fluvial Event	Steady inflow into Monktonmead Brook of 3 m^3/s
Run Settings - Design Runs	



Run Parameters			
Model start time (hrs)	00:00 00/00/0000	**Model end time (hrs)**	25
Time Step (s)	10	**Results Timestep Multiplier**	12

2D parameters	
Tolerance	Default
Advanced	Link 1D and 2D calculations at minor timestep has been ticked
GPU	Use GPU card for 2D calculations if suitable card is available
Steady State	Default

Timestep Control Options			
Rainfall	Default	**Outflows**	Default
Sub-catchments	Default	**RTC**	Default
Control	Default	**Levels**	Default
Nodes	Default	**Rainfall**	Default
Diagnostics	The following options have been selected: Timestep Log Output RTC State Log RTC Rule Changes		

Comments		
Run Time	M2-120 = 11.8 hours	M5-120 = 15.7 hours
	M10-120 =1.3 hours	M30-120 = 1.3 hours

	M75-120 = 1.4 hours	M100-120 = 1.3
	M200-120 = 2.4 hours	M100+CC-120 = 4.2 hours
Comments on results	A full discussion of the results in found in the main report.	

5. Model Parameters

5.1 Hydrology

Monktonmead Brook

The fluvial inflow to the model have been imported from the upstream ReFH inflow from the ISIS model. Lateral ReFH inflows within the ISIS have been replaced by the direct rainfall in the 2D domain.

To assess the accuracy of the inflows from the ISIS model a separate ReFH calculation was carried out for the Monktonmead Brook catchment. There was little difference between the flood peaks for each return period and therefore the ISIS inflows were taken forward.

Table 5-1 shows the inflows used from the ISIS model. They were extracted from the design runs with the pumps operational (Design_###yr_Op).

Table 5-1: Monktonmead Brook peak flows

Fluvial return period (in years)	Flood Peak (m^3/s)
2	4.12
5	5.89
10	7.16
25	8.94
50	10.46
100	12.18
100 + climate change	14.67

Rainfall

The design rainfalls used in the modelling were generated within InfoWorks ICM using the FEH DDF rainfall model. Catchment parameters were extracted from the FEH CD-ROM v3 for the whole catchment. The parameters were then loaded into the InfoWorks FEH rainfall generator from which InfoWorks is able to produce a hyetograph for a series of return periods and durations.

The critical storm duration can vary due to the topography, land use, size of the upstream catchment and nature of the drainage systems. It is therefore important to model a range of storm durations in order to assess the one which has the greatest effect on the catchment.

Sensitivity testing was carried out on the surface water network to determine the 'worst case' storm duration. A range of storm durations, ranging from 15 minutes up to 12 hours, were modelled for both the 30 year and 100 year rainfall events. Generally the 120 minute storm proved to be the 'worst-case' for most of the nodes in the sewer model and was therefore used for the remainder of the design runs and options testing.

As the key areas of interest within the study area are urban summer rainfall profiles were used for the critical duration testing. The rainfall event parameters for the model runs were set as shown in

Table 5-2 below

Table 5-2: Rainfall Initial Conditions

Catchment Parameter	Summer	Winter
Antecedent Depth (mm)	5	12
Evaporation (mm/day)	3	1
UCWI	90	135
NEW PR API30 – Soil type 4	10.3	13.6
ReFH Cini (mm)	0	0
ReFH BF0 (m3/s)	0	0

Sub-catchments

The surface water and combined sewer catchments were split into a number of sub catchments in order to route flows into the surface water or combined network respectively. Each of the sub-catchments has a defined unit hydrograph with defined Tp and Tb values. Open areas such as parks and recreational areas within the 2D zone but outside of the drainage network were modelled as infiltration zones. This was considered the most suitable approach for these areas.

The catchment rainfall hydrograph is split among the sub-catchments and routed into the sewer system according to the runoff factors representing likely areas of surface water flooding.

Runoff Surfaces

The study area is contained within soil type 4 and therefore each sub-catchment was assigned the same land use ID of 1. Within the land use ID different runoff surfaces were specified (see

Table 5-3).

Table 5-3: Land use ID runoff zones

	Runoff surface 1	Runoff surface 2	Runoff surface 3	Runoff surface 4
Runoff ID	1	2	1	3

The runoff surface ID correspond to the following land uses:

- Runoff ID 1 - Roads and Pavements
- Runoff ID 2 - Buildings
- Runoff ID 3 - Impermeable areas

The runoff surfaces within each of the sub-catchments were defined using the MasterMap land use types which were used to calculate the absolute areas of runoff within each sub-catchment. The critical parameters for each of the runoff zones are displayed below in .

Table 5-4.

Table 5-4: Runoff zone parameters

Runoff Surface ID	Runoff Routing Value	Runoff Volume Type	Surface Type	Initial Loss Type	Routing Model	Runoff Coefficient	New UK Depth
1	1	Fixed	Impervious	Slope	Wallingford	0.85	-
2	1	Fixed	Impervious	Slope	Wallingford	0.75	-
3	30	New UK	Pervious	Slope	Wallingford	-	0.2
25	1	ReFH	Pervious	Slope	ReFH	-	-

The ReFH runoff zone was used for the area directly to the south west of Binstead and Ryde where no LIDAR data was available to model the inflow by direct rainfall on the 2D zone. The region slopes north east providing overland inflows to Binstead and small tributaries to the Monktonmead Brook.

5.2 Drainage System

The Southern Water InfoWorks CS model of Ryde forms the basis of the network model and was assumed to be the best available data of the sewer system of the study area. The CS model was converted to an ICM model and checked. Ryde is principally composed of a combined sewer system, whilst Binstead is predominately a separate sewer system although only the foul system was included within the CS model.

Once the sewer model had been imported into InfoWorks the surface water, foul and combined network manholes within the 2D zone were converted to 2D manhole units allowing surcharged water to enter the 2D zone and represent the overland flow/flood pathways.

No additional survey was undertaken for this project although additional surface water network information was available from Southern Water in the form of an impermeable area survey around the Strand area and highways drainage data received from Island Roads. The impermeable area survey showed which regions of the Strand connected directly to the Monktonmead Brook and therefore surface water catchments were created to model this inflow into the stream.

Gully nodes were connected to the closest downstream node of the culverted brook. Pipe upstream invert dimensions were assumed to be 0.3m below ground level and the downstream inverts to be 0.6m below ground level.

Similarly the sub-catchments where Appley Rise, North Walk and the A3055 meet were divided up using OS MasterMap data such that the roads formed surface water sub-catchments and the remaining areas combined sub-catchments. Island Roads gully and pipe data showed this region discharged into the Canoe Lake.

Gully data from Island Roads contained invert locations and some pipe dimensions. The gully inverts were assumed to be 0.3m below road level with 100mm pipe joining it to the nearest suitable node.

After project commencement Southern Water had undertaken updates to their InfoWorks CS model. Of greatest significance was increasing the capacity of the system along Simeon Street and introducing a new underground storage tank to reduce the risk of surcharge from the sewer network. The original model provided by Southern Water at project commencement is the Ryde SWMP_Base (2014) model, whilst the Southern Water updates were incorporated to produce the Ryde SWMP_Base (2015) model. Although the scheme in the Strand had not been completed it was considered the base model for options testing.

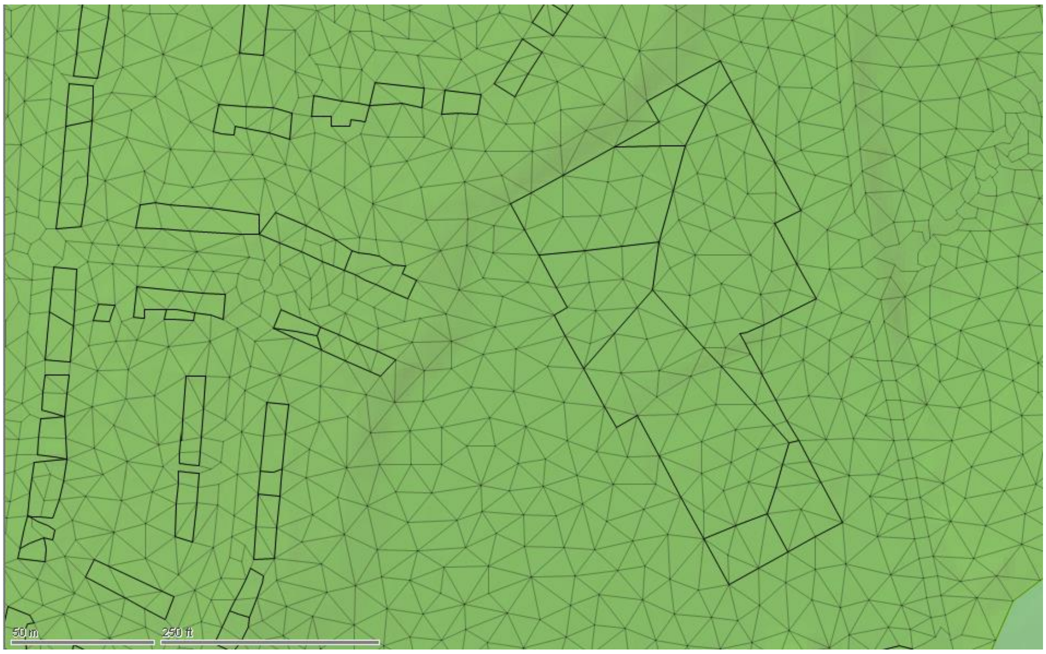
5.3 2D Representation

The 2D zone consists of an irregular triangular mesh, which represents the ground topography. The ground levels of this mesh were based on the most recent Environment Agency LIDAR data available at the start of the project (September 2014) with Bluesky data filling a small gap in the Environment Agency coverage.

Mesh Definition

The 2D Mesh is built to represent the local topography and features such as drainage channels and embankments which can have significant impacts on the flow of surface water, and hence on flood risk. Meshing parameters were set to provide the most detail possible and are documented in the model overview sections.

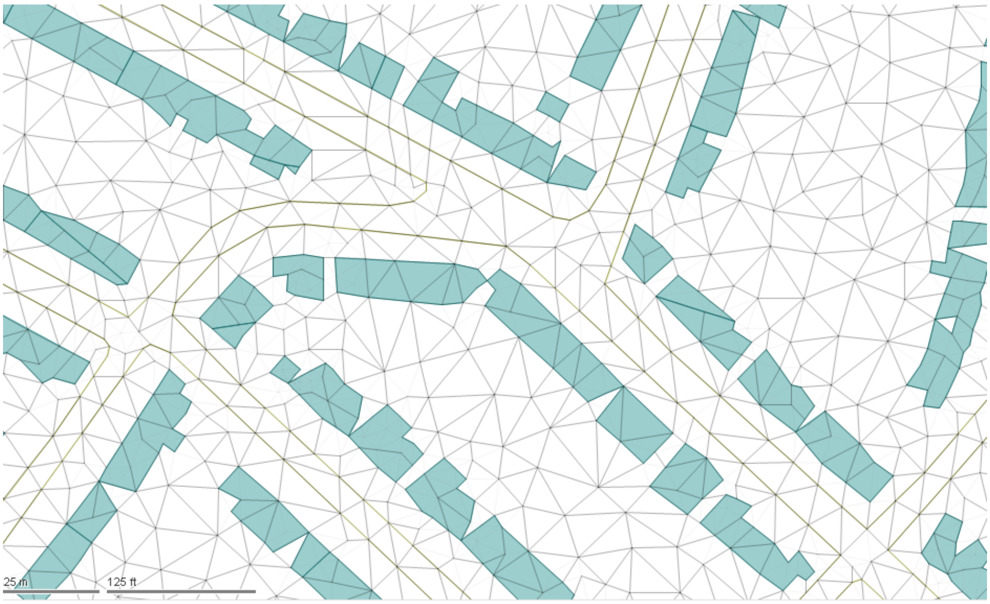
Figure 5-1: Illustration of the Triangular Mesh using Mesh polygons



Buildings

InfoWorks ICM allows buildings to be modelled either as permeable walls or as mesh polygons representing the footprint of the building. For this model the buildings were represented as porous polygons using a porosity of 0.05 (5%), representing the small areas where water can infiltrate into buildings (e.g. doors and airbricks). Representing the buildings as porous polygons also means that the ground model tin is meshed to the outlines.

Figure 5-2: Illustration of buildings as porous polygons used in a Triangular Mesh



Flow Paths within the 2D Domain

During modelling it was found that the LIDAR was not showing the small open channel section behind the houses on Cemetery Road, Binstead. A mesh zone was created to lower the LIDAR by 0.5m to represent this significant flow path within the mesh.

No other flow paths potentially affected by LIDAR filtering were identified within the 2D domain and therefore no other amendments were necessary.

2D Domain

The surface roughness within the 2D domain was simply represented as a blanket 0.0125 Manning's n value. The level of roughness detail within the 2D model domain was kept simple primarily to minimize InfoWorks meshing and run times (instability when using variable roughness is a known issue with InfoWorks ICM) and because previous experience has shown that correctly representing buildings and breaklines within the model mesh has a far greater impact on the flow paths than roughness zones.

Pipe Roughness

Roughness values in the pipe network were left with their original values from the Southern Water InfoWorks CS model. These were predominately set to a standard Colebrook-White value of 0.6mm for the top roughness and 3.0mm for the bottom roughness which are the default values for a relatively clean surface water with no silting. Any surface water pipes added to the network were assigned the same default values.

6. Sensitivity Testing

Sensitivity testing of the baseline model was undertaken to assess the impact of variations in flow on the surface water and combined networks and the overland flow.

6.1 Extreme Rainfall

Sensitivity to extreme rainfall was tested by increasing the 100-year model inflows by 20%, which also allowed for the impacts of climate change to be assessed. The increase follows guidance issued by the Environment Agency (2011)[1] on adapting to climate change for Flood Risk Management Authorities (FRMAs), which includes Local Authorities and Sewerage Companies (WaSCs). It replaces DEFRA's previous guidance[2] which was based on UKCIP02. The new guidance is based on UKCP09 and recommends a single "change factor" for change to extreme rainfall, including upper and lower end estimates of uplift values for the 2020s, 2050s and 2080s for events less frequent than 1 in 5 year chance of occurrence.

Table 6-1: Change to extreme rainfall intensity compared to a 1961-90 baseline

Applies across all of England	Total potential change anticipated for the 2020s	Total potential change anticipated for the 2050s	Total potential change anticipated for the 2080s
Upper end estimate	10%	20%	40%
Change factor	5%	10%	20%
Lower end estimate	0	5%	10%

Using an increase of 20% to the 100-year model inflow investigates the potential change anticipated by 2080 and the upper end estimate of the change anticipated by 2050. Increasing the size of the rainfall event increased the overall flood envelope and flood depths as is to be expected however the model is not overly sensitive to rainfall.

6.2 Storm Duration

The model was tested for a range of storm durations for the 30 year and 100 year storm events in order to test the impact of this on the network, the durations were modelled:

- 15 minute
- 30 minute
- 60 minute
- 120 minute
- 180 minute
- 360 minute
- 720 minute

The storm duration results were compared at key locations including: the CSO on the Monktonmead Brook (at mmb1); the Strand; the Canoe Lake; West Hill and East Hill Roads; Queen's Hill Road; St Thomas' Street and Binstead.

Comparison of the critical storm duration results showed little difference between the shorter duration storms which, as expected, created the most extensive flooding. At each of the key locations the critical duration was between 30 minutes and 120 minutes.

1 Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities. (Environment Agency, September 2011). http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0711btzu-e-e.pdf
2 Supplementary Note to Operating Authorities – Climate Change Impacts. (DEFRA, October 2006).

The 120 minute storm duration was selected as the critical event for design runs and options testing as this generally caused the most extensive flooding for Ryde and Binstead.

6.3 Storm Profile

Both summer and winter storm profiles were tested. The summer profiles show larger flood envelopes and depths than the winter profiles which is as expected given the urban nature of the catchment. Therefore the summer profiles were taken forward for all design and options runs.

6.4 Assumptions, Limitations and Uncertainty

The representation of any complex system within a hydraulic model requires a number of assumptions to be made. These assumptions within the hydraulic model include:

- Network model provided by Southern Water is accurate
- ISIS model provided by the Environment Agency is accurate
- Model parameters are reasonable
- Design inflows accurately represent the flows for a given return period
- The units used to represent the hydraulic structures within the model represent the situation accurately
- A stable numerical solution can be achieved

Whilst the accuracy of a hydraulic model depends largely on the accuracy of the hydrological, topographical and structural data some assumptions and uncertainty can be introduced as part of the modelling process. Whilst every effort has been made to reduce these uncertainties, they can never be certain. Assumptions introduced during the modelling process include:

- Estimates of model parameters such as roughness, structure coefficients and percentage runoffs are representative of Ryde
- Inflows to Monktonmead ISIS model
- Geometry of cross sections and schematisation of structures remains as Monktonmead 2005 survey
- Topographic errors in LIDAR and the filtering algorithm used
- Decisions made during model proving

Efforts have been made to reduce the levels of uncertainty within the modelling process. For example: LIDAR data was checked for null data; consideration was given to the roughness values and coefficients used within the original Southern Water network model and EA ISIS model; the ReFH Monktonmead inflows were compared against separate ReFH flow estimates; and cross sections and structures were compared against LIDAR data, satellite imagery and photographs taken during site visits.

There was no suitable monitoring within the study area to calibrate the model against however the network model was previously verified by Southern Water and following updates to the model the same storm events used to verify the model were rerun and the results compared against the verified model. The results compared well and no significant differences were noted. The fluvial model was verified as part of the Monktonmead Brook Flood Risk Mapping study however due to the original fluvial model being 1D and the integrated nature of the model it is difficult to directly compare the fluvial flooding with the previous results.

As part of the validation process sensitivity analysis was carried out and the hydraulic model results were reviewed by representatives from the Environment Agency, Isle of Wight Council, Southern Water and local residents at the Ryde SWMP public event.

7. Options Testing

7.1 Ryde Options

These options were tested from the Ryde SWMP_Base (2015) model.

7.1.1 Option 1: Divert flow

Permeable walls on the downhill side of West Hill Road, Park Road and Rink Road were used to represent raised kerbs. They were digitised to follow the MasterMap road lines and raised 0.5m so there was no chance of overland flow paths overtopping and the height the kerbs would need to be raised could be investigated. Speed bumps were modelled using mesh zones raised by 0.5m and placed on West Hill Road downhill of the road junctions with Park Road and Rink Road. These were to divert flow paths down Park Road and Rink Road. Island Road gully nodes on Rink Road were connected to Monktonmead Brook at the downstream of the Rink Road bridge.

7.1.2 Option 2: Land use

To test the benefit of removing flows from impermeable areas getting directly into the combined network, the area assigned to roads and pavement for the subcatchments around East Hill and West Hill roads was reduced to zero and the area was added to the permeable land use category.

7.1.3 Option 3: SHLAA site runoff

SHLAA sites were represented in the model as infiltration zones. The infiltration zones were set as a fixed infiltration surface with the fixed runoff coefficient reduced from the default of 0.3 to 0.2. 30% percentage runoff represents permeable land whilst 20% runoff is a lower runoff than expected from Greenfield and therefore represents some attenuation within the SHLAA sites.

7.2 Binstead Options

These options were tested from the Ryde SWMP_Base (2015)_Binstead_Options model.

7.2.1 Option 4: Attenuation tank

Island Roads are considering putting in an attenuation tank beneath the footpath which links the Mall with the King's Road. The amount of storage required if the tank was connected to the storm network at the upstream of the footpath for different rainfall return periods was tested by using a weir to connect to an offline 1D outfall. The weir level was 0.4m above the node chamber floor level. An orifice was added to the downstream of the storm network with a limiting discharge of 0.425m^3/s to restrict flows downstream.

7.2.2 Option 4a: Attenuation tank

An additional branch of storm network joins at the downstream of the footpath and therefore the effect of connecting the storage tank to the network at the downstream of the footpath was considered. For direct comparison with option 4 the weir level remained 0.4m above the upstream node chamber floor and the orifice had a limiting discharge of 0.425m^3/s.

7.2.3 Option 5: Rain gardens

Greenway was identified as a potential location for rain gardens. They were represented in the model as 2m wide mesh zones running parallel to the road and lowered by 0.25m in order to represent the small amount of storage they provide. Infiltration zones were imposed on top of the mesh zones with a constant infiltration of 10mm/hour. Gully nodes were added at the downstream of each of the rain gardens and connected to the nearest storm manhole. At the junction between Greenway and The Mall a narrow mesh zone was used to lower the mesh by 0.25m with additional gully nodes removing the water to the nearest manhole.

Appendices

A. Hydraulic Model Check File

Contents

A. Hydraulic Model Check File II

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A.3 Monktonmead Brook Structures VIII

A.1 Modelling Approach

A.1.1 Available Data

Item	Comments
Models	The InfoWorks ICM models were developed from the following existing models: • Ryde InfoWorks CS network model – Southern Water • Monktonmead ISIS model from the Monktonmead Brook Flood Risk Mapping (2005) project - EA
Survey data	No new survey of assets or river channel sections were undertaken for this project. Any additional information used to update the InfoWorks CS model and ISIS river model are documented below.
Other Network Data	All partners of the SWMP agreed to provide data to support the project. The network and survey information collated and used within the study consisted of: • The Strand Impermeable Area Survey IAS and Level survey – Southern Water • Simeon Street CCTV Survey - Southern Water • The Strand sewer flow survey – Southern Water • Highway drainage and gully locations – Island Roads
LIDAR & other Topographic Data	1m filtered LIDAR data
Map Data	OS MasterMap, OS 1:10000 and OS Open Data
Gauging station flows / levels	None received although the Monktonmead Brook is gauged at the location it goes into culvert, Marymead Close.
Gauging station rating curves	None available.

A.1.2 Data Flags

The following data flags were used within the InfoWorks ICM model.

Name	Description
#A	Asset Data
#D	System Default
#G	Data From GeoPlan
#I	Model Import

#S	System Calculated
#V	CSV Import
AS	ASSUMED - Data assumed by Modeller based on Engineering judgement
DW	DRAWINGS - data based on drawings
EA	Data imported directly from EA ISIS model
IA	VERIFICATION - Impermeable area study data
IAS	Data from Southern Water Impermeable Area Survey
IF	INFERRED - Data Inferred by Infoworks automated process
IN	INFERRED - Data interpolated/extrapolated by Modeller
IR	Data from Island Roads highways data
IT	INFERRED - Level Data inferred from a Terrain Model
JBA	JBA Updates for Ryde SWMP
M2	Yr4 DG5 - Model Update
MM	Yr3 DAP - Model Update
OP	OPTIONEERING
SC	SURVEYED - Data Obtained from CCTV Survey
SL	SURVEYED - Data Obtained from Level Survey
SM	SURVEYED - Data Obtained from Manhole Survey
SO	SURVEYED - Data Obtained from Overflow Survey
SP	SURVEYED - Data Obtained from Pumping Station Survey
ST	STABILTY - Alteration made to improve model stability
SW	SPECIFICATION - Southern Water standard
TA	TEMPORARY - Temporary assumption made pending survey or other process
UC	UPDATED - Data altered by reference to As Constructed Drawings
V2	VERIFICATION - Data altered based on verification alone during Year 4 DG5 study
VN	VERIFICATION - Data altered based on verification alone

A.2 Model Overview

This section provides a detailed summary of what is contained within the Ryde and Binstead models. It provides a detailed overview of the models, the structures and the methods by which they have been represented.

A.2.1 Model Summary

Following summary is for the Ryde SWMP_Base (2015) model. The Ryde SWMP_Base (2014) differs slightly in terms of number of nodes, and Ryde SWMP_Base (2015)_Binstead_Options represents a cut down model of Ryde SWMP_Base (2015) to test options within Binstead with faster run times.

River	Model Description		
	Channel	Floodplain	Length
Monktonmead Brook	ICM model: 1D sim engine to calculate in channel flows	ICM model: 2D sim engine to calculate floodplain flows	2.3km

Sewers	Model Description		
	Nodes	Pipes	
Combined and separate system	2930 manholes or outfalls modelled Flood Type: 2D for manholes within the 2D Zone, Sealed for manholes outside the 2D zone	2751 sewers modelled 1D sim engine	101.2 km

Surface	Model Description		
	Buildings	Roads	Green Space
Land cover	8039 porous polygons modelled Porosity = 0.05	0 roughness polygons modelled	33 infiltration zones modelled Infiltration type = Fixed Runoff coefficient = 0.30

A.2.2 Network Model schematic

Figure 7-1: Ryde SWMP_Base (2015) Network Model Schematic

A.2.3 Overview of Fluvial Model

General Schematisation:	The Monktonmead Brook has been modelled in 1D. The 1D river reaches in InfoWorks ICM solve the Saint-Venant equations using a 4-point implicit Preissmann scheme. The channel cross sections have been truncated at the join with the bank lines within the river reach where they have been linked to the 2D domain. Bank lines link the channel system to the overland flow environment (2D domain). A modular limit of 0.90 and a coefficient of discharge of 0.90 have been used. These were selected to broadly represent the ability of flow to leave the channels and are based on the recommendations provided within InfoWorks ICM help, as well as through the use of the basic weir equation. The river model was developed from the Monktonmead Brook Flood Risk Mapping (2005) ISIS river model. The original cross section and structure survey data was not available.
Upstream Boundaries	Upstream of Smallbrook Lane Road bridge. MMB_US.
Lateral Catchments	Lateral inflow occurs throughout the length of the river model as direct rainfall can flow under gravity into the river network. Point inflows occur at surface water / combined sewer outfalls where rain water channelled by the sewer network is discharged.
Downstream Boundaries	An outfall node, MMB_Outfall, has been used at the downstream end of the culvert which discharges into the sea. The mean high water spring tidal stage-time boundary has been applied at the downstream end (obtained from the Monktonmead Brook Flood Risk Mapping (2005) ISIS river model).
Length of Model (km):	2.3km of the Monktonmead Brook has been modelled.
Total Number structures:	Bridges: 3 Culverts: 5 Weirs: 2 Rotary pumps: 2 Flap valve: 1
Labelling/ Numbering System Used:	Labelling of the cross sections remain as per the 2005 ISIS model. The cross sections decrease from 1.843, at the upstream of the model, to 0.000. Sections mmb3 to mmb0 had been included within the ISIS model from a previous model.
Hydraulic roughness values used	Channel roughness values have been imported from the ISIS model. This model used Manning's 'n' for the open channel sections and for the culverted sections. It is assumed that the culverts are in a good state of repair.
Amendments to existing model	The original InfoWorks CS model contained a fluvial model. This was replaced by the imported ISIS model.

A.2.4 Overview of Sewer Model

Sewer Network:	The sewer network has been imported from Southern Water's InfoWorks CS Ryde model. The model Southern Water provided at project commencement forms the basis of the Ryde SWMP_Base (2014) model, whilst the Ryde SWMP_Base (2015) model includes the update Southern water made after project commencement. The biggest difference between the two models is the increased the capacity of the system along Simeon Street and introducing a new underground storage tank to reduce the risk of surcharge from the sewer network within the 2015 base model. The same updates were made to both of the base models, including additional sections of the surface water network have been added in the Strand, Canoe Lake and Esplanade areas from the Southern Water impermeable area survey and Island Roads highway drainage data.

	The majority of the network within Ryde is designated as combined. The localised areas of surface water networks drain into the combined system, directly into the watercourse or onto the beach. There are a number of combined sewer overflows into the Monktonmead Brook. Within Binstead the majority of the sewer network is separate foul and surface water systems. The foul and surface water systems drain into combined systems and finally into the Binstead Brook. No surface water network was modelled within the original InfoWorks CS model. InfoWorks ICM calculates in-sewer flows by solving the Saint-Venant equations using a 4-point Preissmann scheme.
Inflows:	Inflows to the network model are generated using sub-catchments. Infiltration Zones have been created to improve the representation of the rainfall response in these areas and to cover the full extent of the urban area within the model. The area contributed from roads, buildings and permeable areas was calculated using the InfoWorks routine called Area Take Off. Soil type was taken from the FSR soil maps for England and Wales. Losses were accounted for using the Wallingford routing model. Manholes in the 2D zone were coupled to the surface. Therefore, additional inflow could be made if surface water ran over a node.
Pipe Inverts:	Pipe inverts have been taken from the original Southern Water model. Inverts for the Island Roads pipes added contained values within the data or inverts were inferred from the upstream or downstream connection.
Pipe Dimensions:	Pipe dimensions have been taken from the original Southern Water model. Dimensions for the Island Roads pipes added contained values within the data or they were inferred from the upstream or downstream connection.
Length of Model (km):	101.2km
Total Number of nodes and structures:	Manholes: 2905 Outfalls: 25
Labelling/ Numbering System Used:	As per Southern Water's model: node ID = National Grid reference Nodes added from Southern Water impermeable area survey: node ID = Str_SW_## Nodes added from Island Roads highways data: node ID = IR##
Hydraulic roughness values used	No CCTV data was available to calibrate roughness specifically for this catchment. Colebrook-White values remained as per the Southern Water CS model. Bottom roughness Colebrook-White value = 3.0mm Top roughness Colebrook-White value = 0.6mm
Amendments to existing model	The flood type of the nodes was changed from stored to 2D where the manholes fell within the 2D zone. Additional surface water network has been added based on the Southern Water IAS and Island Roads highways data. Surface water sub-catchments were created within Binstead.

A.2.5 Overview of 2D Model

Triangular mesh:	The 2D domain has been constructed internally within InfoWorks ICM using the Delaunay Triangulation Algorithm. This creates a triangular mesh of ground elevation.
Overland flow:	The 2D domain solves the Shallow Water Equations (SWEs) across the triangular mesh.
Area of 2D domain:	725 Ha (reduced to 153 Ha for Ryde SWMP_Base (2015)_Binstead_Options)

Boundary condition:	The boundary condition of the 2D Zone is set to be 'vertical wall'. It is considered to be an impermeable infinitely high barrier such that water cannot flow out of, or into, the 2D Zone.		
DTM data source:	filtered LIDAR	**DTM resolution:**	1m
Mesh Modifications			
Roads	No modifications made.		
Buildings	The buildings have been represented as porous polygons. A porosity of 0.05 has been assigned representing a restriction to flow but allowing a small amount of water to infiltrate. A value of 0.05 is assumed to be the likely percentage of the building where water could enter, for example doors or airbricks. Representing the buildings as porous polygons also means the ground model tin is meshed to the outlines.		
The Strand	In the Strand area of the model where the Impermeable Area Survey was undertaken, and there has been known flooding problems, the original combined sub-catchments have been replaced with smaller sub-catchments. The IAS survey data has been used to divide the area into foul / combined sub-catchments and surface water sub-catchments. This provides a better representation of the flows directly into the combined system.		
Canoe Lake	The Island Roads highways data showed that most of the gullies where Appley Rise, North Walk and the A3055 meet discharged into the Canoe Lake. The sub-catchments in this area were divided up using OS MasterMap data such that the roads formed surface water sub-catchments and the remaining areas combined sub-catchments.		

	Mesh Parameters
Maximum triangle size (m^2):	25
Minimum triangle size (m^2):	4
Terrain sensitive meshing:	Yes
Maximum height variation (m):	1
Minimum angle (degrees):	25
Roughness (Manning's n)	0.0125

A.3 Monktonmead Brook Structures

This section provides details of the schematisation of each of structures along the Monktonmead Brook study reach.

Note that no survey of the structures were available. Photographs have been included where they are available. The structures were modelled as they were in the original ISIS model (Mon113a_10hrs.DAT from the Monktonmead Flood Risk Mapping Report 2005). The ISIS model was built from survey commissioned by Atkins and undertaken by Maltby Land Surveys specifically for the 2005 project. Three channel sections located adjacent to the recreation ground and upstream of the culvert and outfall were from a topographic survey undertaken in 1999 by Merrett Survey Partnership to assist in a previous study undertaken by Bullens in 2000.

Roughness values of culverts, the modular limit and weir coefficient of bridge decks remain the same as the ISIS model.

Structure 1

Structure name	Smallbrook Lane road bridge
Included in model	Yes
Model label	1.843
Type	In line sprung arch culvert
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Inlet and outlet structures modelled with inlet and outlet links respectively. Sprung arch culvert modelled as 2070mm width, 2330mm height, 1530mm springing height and 22.9m length
Structure photo	Not available

Structure 2

Structure name	Rosemary Lane bridge
Included in model	Yes
Model label	1.424
Type	In line sprung arch culvert
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Inlet and outlet structures modelled with inlet and outlet links respectively. Sprung arch culvert modelled as 1600mm width, 1900mm height, 1110mm springing height and 7.3m length.
Structure photo	Not available

Structure 3

Structure name	Railway crossing
Included in model	Yes
Model label	1.274
Type	In line sprung arch culvert
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Inlet and outlet structures modelled with inlet and outlet links respectively. Sprung arch culvert modelled as 2100mm width, 2250mm height, 1280mm springing height and 10.9m length.

Structure photo	Not available

Structure 4

Structure name	Bridge upstream of St John's road bridge
Included in model	Yes
Model label	0.449
Type	Concrete access bridge with railings
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Structure modelled as a bridge. Deck level Modular Limit = 0.90, Weir Coefficient = 1.70 as in ISIS model. The bridge opening has been modelled based on the ISIS schematisation which was informed by survey data.
Structure photo	Not available

Structure 5

Structure name	Weir
Included in model	Yes
Model label	0.441
Type	Concrete access bridge with railings
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	In line round nosed broad-crested weir. Modelled with crest = 2.65 mAOD, width = 3.768m and length 0.98m.
Structure photo	Not available

Structure 6

Structure name	St John's road bridge
Included in model	Yes
Model label	0.438
Type	Road bridge
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Structure modelled with two in line sprung arch culverts with a round nosed broad-crested weir in the middle. Inlet and outlet structures modelled with a culvert inlet and outlet links respectively. Sprung arch culverts modelled as 4670mm width, 3650mm height, 2560mm springing height and 4m length each. Round nosed broad crested weir modelled with crest = 2.07 mAOD, width = 4.67m and length 1.56m.
Structure photo	Not available

Structure 7

Structure name	Park Road bridge
Included in model	Yes
Model label	0.157
Type	Road bridge

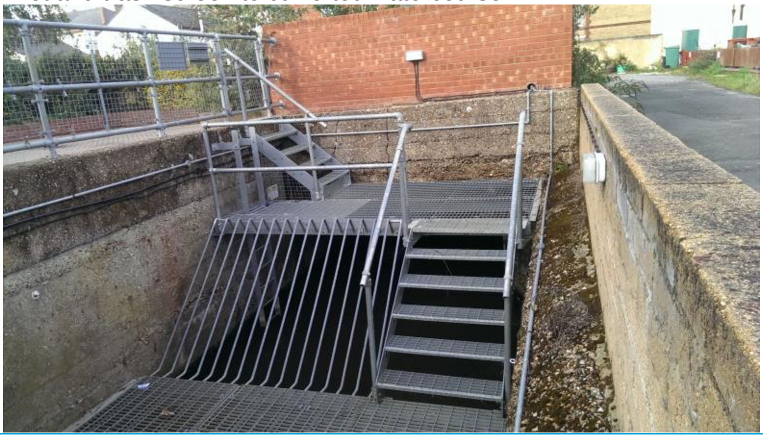
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Structure modelled as a bridge. Deck level Modular Limit = 0.90, Weir Coefficient = 1.70 as in ISIS model. The bridge opening has been modelled based on the ISIS schematisation which was informed by survey data.
Structure photo	Not available

Structure 8

Structure name	Rink Road bridge
Included in model	Yes
Model label	0.011
Type	Road bridge
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Structure modelled as a bridge. Deck level Modular Limit = 0.90, Weir Coefficient = 1.70 as in ISIS model. The bridge opening has been modelled based on the ISIS schematisation which was informed by survey data. The railway line on the left bank was excluded from the structure and modelled within the 2D. However bank level on left bank raised 1m to account for wall between stream and railway line which was not picked up in cross section survey data. Bank level raised on left bank between Park Road Bridge (0.157) and Rink Road Bridge (0.011), and between Rink Road Bridge and location where railway track and stream diverges. Drop in bed level modelled as weir after bridge unit.
Structure photo	Photo of bridge structure not available. View from Rink Road bridge looking downstream showing wall:  View from Rink Road bridge looking upstream showing wall:

Structure 9

Structure name	Culverted watercourse to pumps
Included in model	Yes
Model label	mmb0d
Type	Culvert screen and culverted watercourse
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Structure modelled with three in line sprung arch culverts and a rectangular culvert. Inlet structure modelled as culvert inlet unit. Sprung arch culverts modelled as 3210mm width, 2570mm height and 1758mm springing height. 117m length. Rectangular culverts 3000mm width and 1800mm height. 85.7m total length with pumps (Structure 10) 65.7m before outfall.
Structure photo	Inlet and trash screen to culverted watercourse. 

Structure 10

Structure name	Pumps
Included in model	Yes
Model label	MMB_Pump Well and MMB_Discharge Well
Type	Two rotary pumps and a flap valve.
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)

How has this structure been modelled?	Pumps modelled as flap valve allowing free outfall when tides and fluvial level allows and two rotary pumps. Invert level of flap valve is 0.05 mAOD, diameter is 3.028m. Rotary pump 1: Switch on level is 1.00 mAOD, switch off level is 0.5 mAOD. Rotary pump 2: Switch on level is 1.20 mAOD, switch off level is 0.7 mAOD. Operations of pumps and head discharge table modelled as in the ISIS model.
Structure photo	Not available

Structure 11

Structure name	Outfall
Included in model	Yes
Model label	MMB_Outfall
Type	2D Outfall
Survey drawing ref & job number	No survey available – modelled as in Monktonmead ISIS model (2005)
How has this structure been modelled?	Outfall modelled as outfall unit with flood level equal to ground level (-0.25 mAOD).
Structure photo	 

D Economic Appraisal

D.1 Approach

The 2010 Multi Coloured Manual provides standard flood depth/direct damage datasets for a range of property types, both residential and commercial. This standard depth/damage data for direct and indirect damages has been utilised in this study to assess the potential damages that could occur under each of the options. Flood depths within each property have been provided by the 2D hydraulic modelling results.

A mean, minimum and maximum flood depth is derived by JBA's in-house FRISM tool based on the range of flood depths within the building footprint. The mean flood damages have been presented in this analysis.

A key assumption with the flood damage calculations is that bare earth ground levels are assumed for the flood damage calculations. Flood depth thresholds of 0.01 and 0.1m have been tested to represent flood levels that may be able to enter properties. This is a significant assumption; the site visit confirmed that where some properties are below the road levels this is generally not unreasonable, but there are properties with lower and higher thresholds.

The following assumptions, presented in Table D-1 were used to generate direct flood damage estimates.

Table D-1: Direct flood damage assumptions

Data type	Data and any assumptions used
Depth Damage data	Standard 2013 Multi-Coloured Manual used.
Flood depths	Mean flood depths for each property extracted for the 2, 5, 10, 30, 75, 100 and 200 year return periods.
Threshold level	No building threshold values used – depth threshold of 0.1m has been tested to assess the impact of flood depth
Residential property types	Defined by property types (Detached, Semi-Detached, Terraced, Flat, Bungalow).
Upper floor flats	Due to the nature of the residential properties in the study area, with the majority of properties being single dwellings the upper floor flats have been retained in the NRD; however the damages have been excluded in the FRISM software.
Non residential property types	MCM property types defined using national receptor dataset.
Property areas	Defined by OS MasterMap data.
Capping of property damages	Property market values have not been used for capping.
Flood duration	Assumed to be less than 12 hours.
Updating of MCM damage data	Uses 2013 damage data

Data errors and inconsistencies

The approach to estimation of flood damages relies on the input of 2D modelling and the overlay of property boundaries to define average depths at each property. Filtered LIDAR data has been used in the model build and this forms the basis of the flood depths within each property boundary. In some locations, due to the filtering process and the averaging of flood depths within large property boundaries, flood depths are not always consistent (i.e. they do not increase with increasing return periods). A more thorough analysis using property threshold levels would help to correct these inconsistencies in the future.

Indirect damages

The multi coloured manual provides guidance on the assessment of indirect damages. It recommends that a value equal to 5.6% of the direct property damages is used to represent emergency costs. These include the response and recovery costs incurred by organisations such as the emergency services, local authorities and the Environment Agency.

Guidance and standard costs are also provided in the multi coloured manual for the assessment of additional costs incurred by property owners as a result of flooding. These include rental costs for alternative accommodation, additional heating and electricity costs required to dry out a flooded property. These have not been included in the analysis at this stage.

Intangibles

Current guidance indicates that the value of avoiding health impacts of fluvial flooding is of the order of £200 per year per household. This value is equivalent to the reduction in damages associated with moving from a do-nothing option to an option with an annual flood probability of 1% (100 year standard). A risk reduction matrix has been used to calculate the value of benefits for different pre-scheme standards and designed scheme protection standards.

D.2 Damages calculation methodology

D.2.1 Summary

Property counts and damage estimates have been calculated using FRISM, JBA's in-house flood metrics software.

D.2.2 Flooding Data

The FRISM calculation was run for the following return periods; 2, 5, 10, 30, 75, 100 and 200 year. These results were annualised assuming a first flood with a return period of 1 year to obtain average annual damages.

All the return periods were queried for depths greater than 0.1m. The depth threshold was used to generate a flood outline from the model depth grid. The outline was then used for property counts. Damages were only calculated for properties which were within the flood outline.

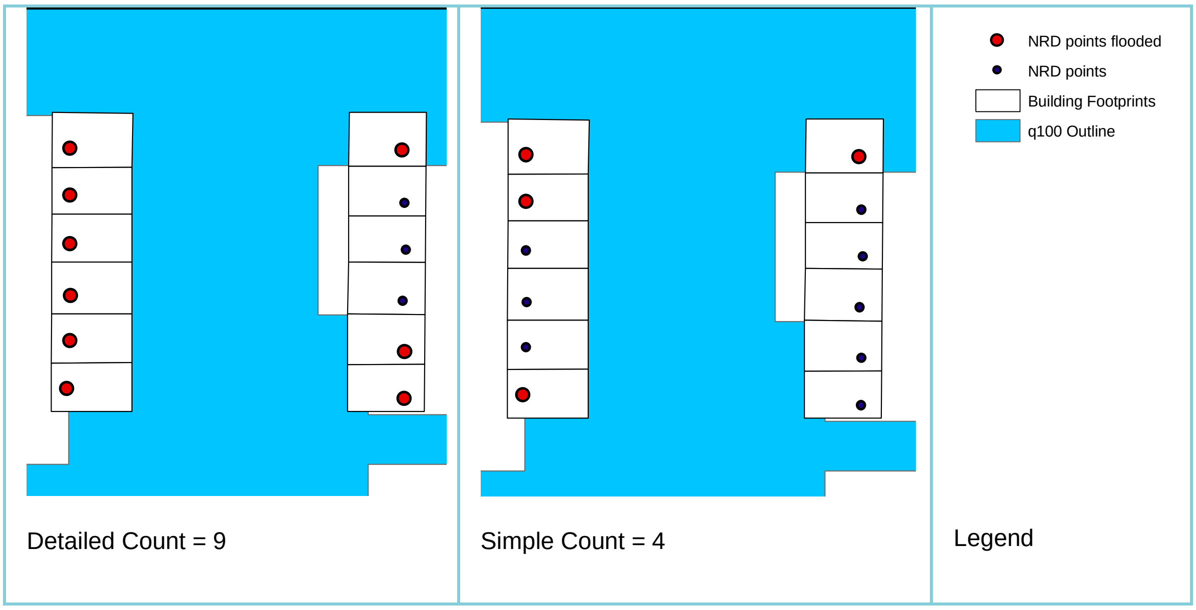
D.2.3 Receptor Data

The receptor datasets used for the calculations were the NRD property points layer together with Master Map building polygons. The full NRD data was used in the assessment of damages. This includes some receptor points that were retained, but did not have a building footprint in Master Map. These receptors include features such as public telephones and electricity sub stations and have been retained to ensure that the value of lost services is included in the damage counts.

D.2.4 Property counts

Property counts were undertaken using the detailed counting method. This method utilises the Master Map building footprints in conjunction with the NRD property points. A property point is counted as flooded if its corresponding building footprint is within the flood outline, even if the property point itself may not fall within the flood outline, this is illustrated in Figure D-1. Where the additional points without footprints have been retained a single depth value is taken at the point in question.

Figure D-1: Counting method



D.2.5 Depths

Each flooded property point is attributed with a min, max and mean depth value these values correspond to the minimum, maximum and mean value of the depth grid within the property footprint. If the property footprint contains less than half a depth grid cell then it will not receive any depth values, although the property will count as flooded.

D.2.6 Damages

Each flooded property point is attributed with a min, max and mean damage value these values correspond to the damage value for the minimum, maximum and mean depth within the property footprint.

The damage value is in pounds and is worked out by obtaining a unit damage value (£/m2) using the depth damage curves from the Multi Coloured Manual 2013 (Flood Hazards Research Centre 2013). The unit damage value depends on the depth at the property and the property type. This damage value is then multiplied by the value in the floorarea field of the NRD to obtain an absolute damage value.

Damages have not been calculated for properties whose floorlevel is ‘pU’. These are potential uppers which are generally upper floors in flats, however properties with a floor level of ‘pU’ have been included within the property counts. This is because the damage occurred by an upper floor flat is likely to be null however the residents of the property will still be affected by the flooding.

- The values of damages to each property have not been capped

D.2.7 Reporting Units

Properly counts and damages were summarised on a reporting unit level. The reporting units used for this study were the areas outlined in the previous Flood Study report and Section 3.4.2 of this report. For each model scenario each reporting units is attributed with a count according to the number of each receptor type flooded within the reporting unit. The max, min and mean depth of individual receptors within the reporting unit is also recorded as well as the max, min and mean damage of individual receptors. Damages are also summed within each reporting unit. There are 3 damages sums for each reporting unit as the minimum, maximum, and mean damage of each individual receptor is summed giving a min, max and mean sum. Table D-5 defines the fieldnames used in the reporting unit feature classes and the excel spreadsheet.

Table D-5: FRISM Field definitions

Field Name Prefix	Field Name Suffix	Definition
Area Flooded		
nrd_ppl_Full.shp	Detailed Count	Property Count within the reporting unit according to the metric definition
nrd_ppl_Full.shp	Detailed Count Depth Min	The minimum depth at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Depth Mean	The mean depth at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Depth Max	The maximum depth at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Damage Min	The minimum damages at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Damage Mean	The mean damages at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Damage Max	The maximum damages at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Damage Min Sum	The sum of minimum damages at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Damage Mean Sum	The sum of mean damages at an individual property within the reporting unit
nrd_ppl_Full.shp	Detailed Count Damage Max Sum	The sum of maximum damages at an individual property within the reporting unit

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