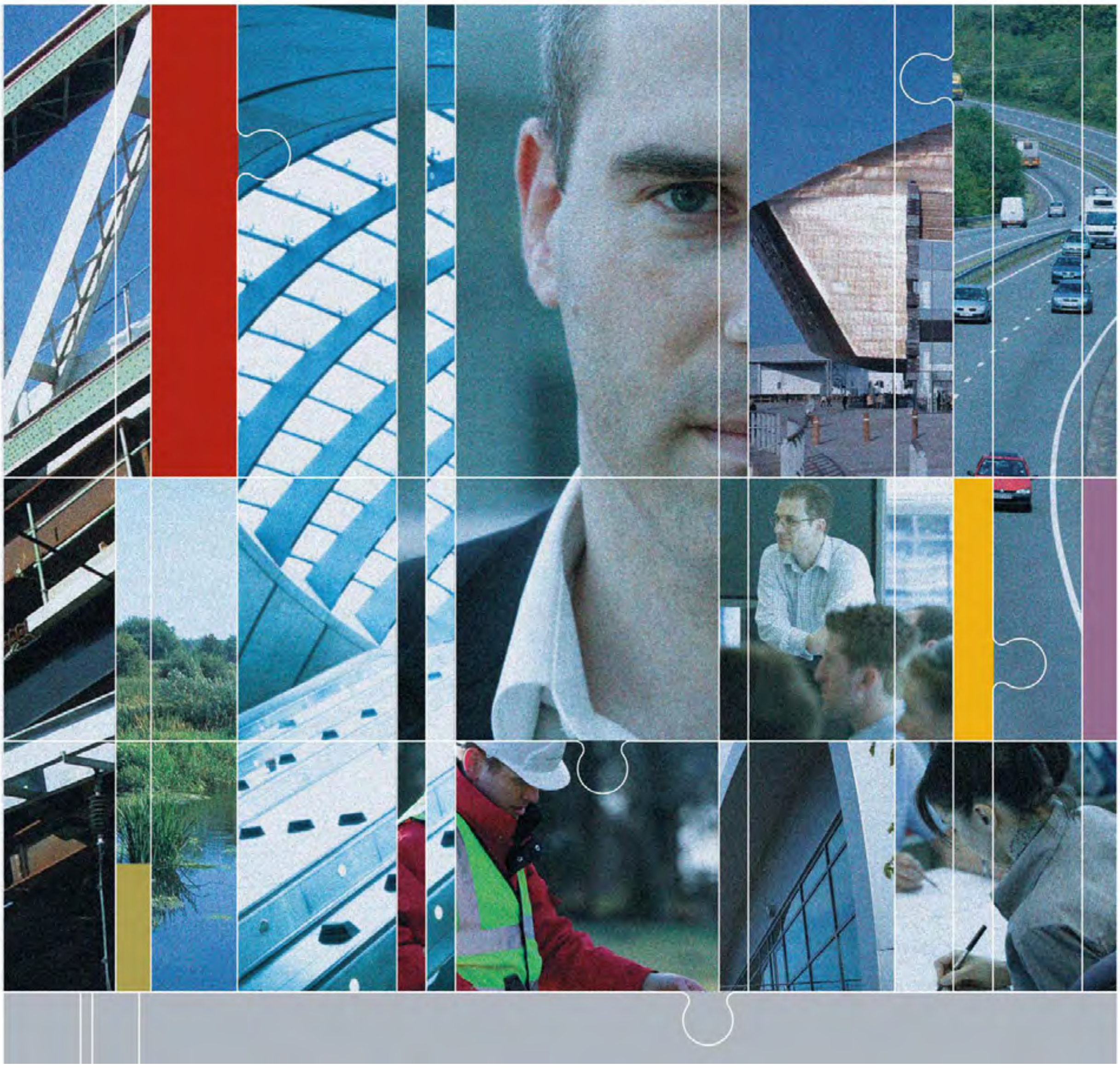

Southampton Surface Water Management Plan

Southampton City Council

Volume 1 Main Report (Rev. B) March 2011

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Glossary and Notation

30-year	Rainfall event with 1 in 30-year (or 'x'-year) return period
ABP	Associated British Ports
CC	Climate change (often applied with reference to rainfall event)
CHP	Combined Heat and Power
CLT	Cruise Liner Terminals
COW	Critical Ordinary Watercourse
DEFRA	Department for Environment, Food and Rural Affairs
DTM	Digital Terrain Model
EA	Environment Agency
FCERM-AG	Flood & Coastal Erosion Risk Management appraisal guidance
Flood Zones	Flood Zones as defined in PPS 25, Table D1
GIS	Geographical Information System/Geospatial Information System
LiDAR	Light Detection and Ranging (used to generate ground mapping for Southampton SWMP)
PPS 25	Planning Policy Statement Note 25: Development and Flood Risk (March 2010)
PUSH	Partnership for Urban South Hampshire
mAOD	Metres Above Ordnance Datum
Monte Carlo analysis	Class of computational algorithms that rely on repeated random sampling to compute
NR	Network Rail
OS	Ordnance Survey
SCC	Southampton City Council
SFRA	Strategic Flood Risk Assessment
SSSI	Site of Special Scientific Interest
SWMP	Surface Water Management Plan
WFD	Water Framework Directive

1. Introduction

1.1 Background

Southampton Surface Water Management Plan (SWMP) was commissioned by Southampton City Council in early 2010. The SWMP details the preferred surface water management strategy for the Southampton area based on an analysis of all the elements contributing to or having an effect on the surface water. The objective of the Southampton SWMP study is to determine the causes and effects of surface water flooding which affects the city and identify the most cost effective way of managing surface water flood risk for the long term.

Capita Symonds has been appointed to undertake the SWMP in consultation with key local partners responsible for surface water management. A partner can be defined as someone (a person or organisation) with responsibility for the management surface water and drainage systems.

The partners for the Southampton SWMP include:

- Southampton City Council (SCC)
- Associated British Ports (ABP)
- Environment Agency (EA)
- Network Rail (NR)
- Southern Water (SW)
- West Quay (WQ)

The Floods and Water Management Act 2010 establishes that unitary and county local authorities will lead local flood management activities (such as the SWMP) as the Lead Local Flood Authority. Southampton City Council (SCC) is designated as the lead partner/organisation for the SWMP. In this role, SCC shall lead its production and ensure the SWMP is periodically reviewed and updated.

1.2 Aims and Objectives

It is intended that the objectives for the SWMP are SMART (specific, measurable, achievable, realistic and timely) and programmed to a realistic timetable for delivery, which can be agreed between all partners. Setting out the aims and objectives of the study was first discussed at the Partners Start-up Meeting on 1st July 2010. The following objectives were proposed and accepted as appropriate elements at the meeting:

- To map current and potential surface water flood risk areas, and engage the community and all stakeholders to share this knowledge with them.
- To determine the extent and consequences of surface water flooding, so that we can establish our priorities and understand and compare the merits of different mitigation strategies.
- To identify effective, affordable, achievable and cost-beneficial measures to mitigate surface water flood risk.
- To develop a strategy which will contribute to the strategic planning of drainage provision in new developments.
- To develop an implementation plan showing how partners and stakeholders will be affected by the implementation of the preferred strategy.
- Review the issues raised by the Level 2 Strategic Flood Risk Assessment (SFRA2) which recommend they be further investigated within a SWMP study.

- To assess the current contribution of the pump stations within ABP land, the impact of climate change on the pump operation, residual risk from pump failure and (if appropriate) include indications on how new development could affect the reliance on pumping.

1.3 SWMP Technical Guidance

This study has been undertaken using the Surface Water Management Plan (SWMP) Technical Guidance published by DEFRA in March 2010, as the basis for the approach and methodology. The framework for undertaking the SWMP study is split into four principal phases: Preparation; Risk Assessment; Options; and Implementation and Review:

Figure 1.1: SWMP wheel diagram

1.4 Stages of SWMP

The following describes the various stages of the SWMP as shown on the wheel in Fig. 1.1:

1.4.1 Preparation

The first phase of a SWMP study focuses on preparing and scoping the requirements of the study. Initially, partners and stakeholders should identify the need to undertake a SWMP study. Once the need for a SWMP study has been identified a partnership should be established, (if one does not already exist), and partners should identify how they will work together to deliver the SWMP study.

The aims and objectives of the study should be established, and in parallel the partnership will also decide how they will engage with stakeholders throughout the SWMP study. An assessment should subsequently be undertaken to identify the availability of information. Based on the defined objectives, current knowledge of surface water flooding, and the availability of information, partners should agree the level of assessment at which the SWMP study should start.

1.4.2 Risk Assessment

The outputs from the preparation phase will identify which level of risk assessment will form the first stage of the SWMP study. The first stage is likely to be the strategic assessment where little is known about the local flood risks. The strategic assessment focuses on identifying areas more vulnerable to surface water flooding for further study. The intermediate assessment, where required, will identify flood hotspots in the chosen study area, and identify quick win mitigation measures, and scope out any requirements for a detailed assessment. A detailed assessment of surface water flood risk may be required to enhance the understanding of the probability and consequences of surface water flooding and to test potential mitigation measures in high risk locations. Guidance is provided on undertaking modelling to support a detailed assessment of surface water flood risk and mitigation measures.

The outputs from the strategic, intermediate and/or detailed assessment should be mapped and communicated by the Lead Partner to all stakeholders. These will include spatial planners, local resilience forums, and the public.

1.4.3 Options

In this phase a range of options has been identified, through stakeholder engagement, which seeks to alleviate the risk from surface water flooding in the study area. The options identified have been short-listed to eliminate those that were considered unfeasible. The remaining options have been developed and tested using a consideration of their relative effectiveness, benefits and costs. The purpose of this assessment is to identify the most appropriate mitigation measures which can be agreed and taken forward to the implementation phase.

1.4.4 Implementation and Review

Phase 4 is about preparing an implementation strategy (i.e. an action plan), delivering the agreed actions and monitoring implementation of these actions. The first step is to develop a coordinated delivery programme. Once the options have been implemented they should be monitored to assess the outcomes and benefits, and the SWMP should be periodically reviewed and updated, where required.

Whilst this phase will be delivered under this SWMP, it will not fall within the scope of this report. Consultation shall be required with the partners following the submission of the study report and prior to implementation and review.

2. Data Collection

2.1 Data Sharing Protocol

At the partners start-up meeting in July 2010, the matter of sharing confidential information between organisations was discussed. All parties agreed that a Data Sharing Protocol agreement should be drawn up to facilitate the transfer of information. The following terms were proposed:

- Data is shared on a 'best endeavours' basis, with no guarantee of absolute accuracy. Appropriateness of the data is to be assessed by the receiving party.
- Data is shared for the specific purpose of the study, and is not to be used by any party for any other purpose without the express consent of the data provider.
- Data is not to be released outside the steering group without the express consent of the data provider.
- Summary of data, or derived data, for publication in the final report must be approved by the data provider before publication.
- Data is to be 'time limited' – i.e. not to be used for any purpose beyond the completion of the final report, without the express consent of the data provider.
- Data of 'broad equivalence' is to be made available in exchange – e.g. highway drainage records for sewer records, overland model data for underground model etc. To be agreed on a case-by-case basis.

During the data collection phase, it became apparent that Capita Symonds (CS) was the main recipient of data issue from the partners. There was little or no requirement for data to be shared between partners, since the data processing was carried out by CS.

2.2 Availability of Information

A list of the data gathered (and record of the data quality) is provided in the Appendices. Data was primarily sourced from partners, who were able to provide information on historical flooding, asset data records and anecdotal evidence.

The SWMP programme indicated that the data gathering phase would be concluded by December 2010. It was thought that all stakeholders and partners would be able to supply relevant data by that time. Also should any information be received later than that it could impact on the study and the overall programme. However, further information has been received after this date from various sources and we have endeavoured to integrate any relevant information where possible, without compromising programme deadlines.

2.2.1 Network Rail

Information has been provided for the culverts through the city area, including location, culvert size and length. These features range from concrete pipe sections to bridges. It would appear this does not form an exhaustive list of pipes crossing NR land, but provides useful support to other asset record data.

A copy of a report titled 'Southampton City Highway & Storm Water Systems Stakeholder Meeting' (September 2008) was issued to Capita Symonds in February 2011. The report, prepared by Southampton City Council, reviewed the flooding incident which took place on 26th May 2008, affecting Southampton Central Station, A33 Millbrook Road West and West Quay area. It described the extent of flooding and the measures taken by stakeholders/partners during and after the event. This included records of emergency call-outs, culvert/ditch/watercourse ownership plans and pumping station operation times. The report and associated documents provide an understanding of the current flood response strategy which exists for the city.

Network Rail is working with DEFRA on a national scheme to facilitate the availability of data for schemes such as the SWMP. It is anticipated that DEFRA will be publishing further details on their Data Sharing Operational Guidance during 2011.

2.2.2 Associated British Ports (ABP)

An initial meeting was held with ABP in July 2010 to discuss their surface water infrastructure and to brief them on their involvement with the SWMP. Ownership and maintenance responsibilities were discussed.

Drawings were provided showing the surface water drainage system through ABP owned land. These included the routes of the main culverts/water courses draining a large percentage of the city into the River Test. Whilst the plans appear substantially complete, more recent dockside redevelopment has not been fully updated. Levels and dimensions on some older plans were shown in feet/inches to an arbitrary datum. A 'dock' or 'chart' datum was used, which required converting to AOD (above ordnance datum).

Details of the two pumping stations, located at Mayflower Park and King George V dry dock were received. Original record drawings were received and site visits made by Capita Symonds to the pumping stations. Due to the age of the pump infrastructure (c. 1930s), limited information was available on the pumping discharge capacities and operating times.

2.2.3 Capita Symonds (Southampton)

The Capita IT and Capita Symonds (Civil Engineering)/ SCC teams in Southampton have provided data on behalf of Southampton City Council. GIS information has been issued showing historical flooding incidents, parks and open spaces, gulley locations and public highways.

CS (Southampton) were able to provide LiDAR 2m-grid point coverage for the whole city, including 1m-grid point coverage for a smaller area towards the city centre.

2.2.4 Environment Agency (EA)

The EA issued their second generation flood maps in December 2010. These are an improvement on the first generation maps, taking into account obstructions and features affecting flow paths. The second generation project, titled 'Refining the Data Quality and the Methodology for Mapping Surface Water Flood Risk' incorporates improvements in four key areas:

- Identification of more representative critical rainfall durations for all rainfall probabilities modelled
- Representation of spatially variable infiltration and drainage system capacity using percentage runoff coefficients and Monte Carlo analysis of sewer capacity proxies respectively
- DEM quality and composition. New mapping will incorporate EA LiDAR data, where available and include buildings as solid, on floodable objects in the model grids
- Post-processing and formatting of final flood map deliverables

An EA scoping report for Tanners Brook was provided to CS by the EA in March 2011. Of particular relevance to the SWMP were the recommendations made within the report for improvements to the brook along the length of the water course between Lordswood and the outfall into the River Test. The conclusions are discussed later in the Options section of this report.

A condition report for Rolles Brook, including culverted sections up to (and under) Southampton Central Station was commissioned by the EA in February 2010. This document was received by CS for review in March 2011.

2.2.5 Southern Water

Southern Water have provided historical flooding records, listing foul, combined and surface water flooding incidents. These indicate the location and type of flooding that occurred. This information is shown in GIS format in the Appendices.

GIS data was also received, showing foul, surface and combined drainage systems. The network coverage across the city appears comprehensive, although only approximately 70% of cover levels, invert levels and pipe diameters are recorded. The interface between Southern Water and ABP records match for the main culverts; however, there are inconsistencies at outlet locations to the east of Cruise Line Terminals (CLTs).

Drainage model data was issued in Infoworks format and converted into the required format for use in MicroDrainage software. When the model was interrogated, it was discovered that the data sets supplied by SW were in fact the foul water network. It is understood there is no surface water network equivalent available.

2.2.6 Southampton City Council (SCC)

The Local Climate Impact Profile (LCLIP) was provided by SCC Planning, which contained relevant information on reported flooding events in and around Southampton.

SCC had identified 60 flooding problem areas, which have been programmed for action/review (see the Appendices). SCC Highways anticipate that 24 out of the 60 items will have been completed during 2011, which may alleviate (or relocate) some of the flooding hotspots identified later in this report.

Meetings were held with SCC's Emergency Planning and Parks/Open Spaces teams. Both provided valuable information regarding key locations, such as main transport routes, key infrastructure (utility substations, waste treatment plants, etc), SSSI sites and other areas of ecological importance. SCC Emergency Planning team also issued the Southampton Multi Agency Flood Response Plan, which describes the emergency response procedures presently in operation for the city area.

2.2.7 West Quay (WQ)

In February 2011, CAD drawings were provided showing the surface water and foul water networks in and around the West Quay shopping development. A summary of flooding incidents in 2008 and the actions taken to determine the source/mechanism was also included. It is acknowledged by WQ that the network data is incomplete and that further surveys will be required.

Due to the receipt of this information being after the programmed data gathering deadline, it has not been possible to interrogate (or include) this information within the Intermediate and Detailed Assessment phases. However, the flooding reports have been used to support other data sources in determining flooding hotspots.

2.2.8 *OTHER DATA RECEIVED*

In December 2007, Partnership for Urban South Hampshire (PUSH) issued a Level 1 Strategic Flood Risk Assessment (SFRA). The report provides information on flood risk (taking account of climate change) to provide a greater understanding of the risks to the sub-region and the local authority area.

In addition SCC have issued a Level 2 Strategic Flood Risk Assessment (SFRA2), which has been issued in August 2010 which looks at the flood risk within Southampton.

Several recommendations for further study within the scope of a SWMP have been made within the SFRA and SFRA2, including:

- Assess the capacity of the existing pump stations, the impact of climate change on the pump operation, residual risk from pump failure and (if appropriate) recommendations on how new development can reduce the reliance on pumping.

- Assess the effect of 'tide locking' on the surface water system and the increased risk it places on flooding within the city.

In November 2010, a meeting was held with Sarah Reghif (Hampshire County Council) to discuss the conclusions of a groundwater flooding report undertaken for the Hampshire area.

3. Catchment Characteristics

3.1 Topography

As described in the PUSH SFRA 'the topography of Southampton ranges from sea level to approximately 80 metres above ordnance datum (mAOD). The lowest areas are the docks frontage along Southampton Water and the Itchen Valley and Estuary [large areas of land historically reclaimed via dredging of Southampton Water]. The majority of the city lies on the higher ground to either side of the River Itchen.' [1]

3.2 Watercourses

The main watercourses in Southampton are the River Test which runs along the southern boundary of the city and the River Itchen which runs north to south through Southampton (see Appendices for figure of main watercourses).

There are several secondary watercourses which discharge into both the River Itchen and the River Test; a summary list is given below.

Primary Watercourses	Secondary Watercourses
River Test	Tanners Brook
	Holly Brook
	Bligmont Crescent Stream
	Rolles Brook
River Itchen	Monks Brook
	Lower Itchen
	Jurd's Lake

Table 3.1: EA Watercourses within Southampton

Both the River Test and the River Itchen are mostly tidal within Southampton.
The River Test and the River Itchen converge at the southern end of the city to form Southampton Water.

3.3 Bedrock Geology

The underlying Bedrock geology consists primarily of London Clay on the northern end of Southampton and Wittering Formation on the southern part of the city. Pockets of Whitecliff Sand Member and Portsmouth Sand Member are present in the northern half of city. There are bands of Earnley Sand, Marsh Farm and Selsey Sand Formations along the coast.

[1] PUSH SFRA for Southampton

Bedrock Type	Description	Permeability[2]
Wittering Formation	Sand, Silt and Clay	Moderate
London Clay Formation	Clay, Silt and Sand	Low
Whitecliff Sand Member	Sand	High
Portsmouth Sand Member	Sand	Moderate
Earnley Sand Formation	Sand, Silt and Clay	Moderate
Marsh Farm Formation	Clay, Silt and Sand	Low
Selsey Sand Formation	Sand, Silt and Clay	Moderate

Table 3.2: Bedrock Geology for Southampton

A map showing Bedrock Geology for Southampton is included as Figure GEN-013. see Appendices

3.4 Superficial Geology

Superficial geology consists of Tidal Flat Deposits in the areas adjacent to the rivers Test and Itchen. The higher ground areas away from the rivers are predominantly River Terrace deposits, with alluvium present in some of the smaller watercourses in the catchment.

A map showing superficial geology for Southampton is included as Figure GEN-012. See Appendices

3.5 Urbanisation

The city of Southampton has an administrative area of approximately 50km^2. Approximately 90% of Southampton is covered by existing development. Southampton Common, a Site of Special Scientific Interest (SSSI), along with other green areas and open spaces take up 10% of the city area.

Figure GEN-011 shows the location of Parks and Green Spaces within Southampton. See Appendices

[2] Permeability derived from PUSH Strategic Flood Risk Assessment (SFRA), December 2007

4. Type of Flooding

4.1 FLUVIAL (RIVER) FLOODING

Fluvial flooding occurs when water levels within watercourses rise beyond their bank level and flow across lower-lying areas (floodplains). The main mechanisms for fluvial flooding are:

- High runoff/overland flow from the catchment surrounding the watercourse, which can develop during extreme rainfall events. Inflow into the catchment exceeds watercourse capacity, leading to flooding
- Inflows from other sources, such as urban drainage systems. This can cause a different inflow hydrograph to surface runoff, since the urban areas are almost 100% impermeable and have shorter times of entry.
- Obstructions, which control or restrict flow within a watercourse. Relevant examples to Southampton include the multi-flaps to the culvert outlets in the Docks, culverted or channelled sections blocked by rubbish or waste.

4.2 TIDAL

DEFRA guidelines note that 'the normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters and a result of wet weather and tidal conditions'.[3] Outfall culverts which drain the Southampton city area to the west of the River Itchen are affected by tidal locking. Extension of these watercourses has taken place due to the reclamation of land that forms Southampton Docks. These outlets can be fully surcharged during high tide conditions.

Southampton is affected by a double high tide. The phenomenon occurs as a result of 'irregular depths and restrictions in width of the Channel between the Isle of Wight and the Cherbourg Peninsula result in a further four oscillations daily within an area bounded by Portland, Cherbourg, Littlehampton and Le Havre. Combined with the natural twice daily oscillations, this produces the 'Double High Water' curve as experienced in the Port of Southampton. In the shallower waters within the Isle of Wight and in the Port of Southampton up to thirty further oscillations of varying magnitude again vary the 'Double High Water' curve to produce the ultimate Southampton tidal curve embodying the local tidal features, namely, the short duration of the ebb tide, the 'young flood stand' and the pronounced fall between first and second High Water stands'.[4]

Whilst tidal flooding shall not be considered within the scope of a Surface Water Management Plan, it is known that Scott Wilson Ltd were appointed in July 2010 to develop the strategy for the coastline within Southampton , extending from Redbridge along the north bank of the River Test and the west bank of the River Itchen to Woodmill Lane.

4.3 PLUVIAL FLOODING

Pluvial flooding can be defined as 'flooding that results from rainfall-generated overland flow, before the runoff enters any watercourse or sewer. It is usually associated with high intensity rainfall events but can also occur with lower intensity rainfall or melting snow where the ground is saturated, frozen, developed or otherwise has low

[3] DEFRA (March 2010) SWMP Guidelines, Box 3

[4] http://www.bristolnomads.org.uk/stuff/double_tides.htm

permeability resulting in overland flow and ponding in depressions in the topography. Urban pluvial flooding arises from high intensity 'extreme' rainfall events. In such situations urban underground sewerage/drainage systems and surface watercourses may be completely overwhelmed.'[5]

4.4 Groundwater Flooding

Groundwater flooding is defined as flooding from sub-surface water. A report on Groundwater flooding was provided by Hampshire County Council in November 2010. After review of this document, it was concluded that no high-risk groundwater areas exist within the Southampton city area. Due to the limited probability of groundwater flooding[6] and data available, it has not been included within the modelling approach.

Further advice relating to the future groundwater flooding risk can be found in the SFRA2, Volume 2 (flooding from groundwater).

[5] http://waterworlds.wordpress.com/2008/01/03/13-pluvial-flooding/

[6] SCC Level 2 Strategic Flood Risk Assessment (SFRA2) August 2010, Volume 1 (section 1.77)

5. LiDAR

5.1 What is LiDAR

The LiDAR (Light Detection And Ranging) is a technology which uses remote sensing to measure distances. LiDAR operates in a similar way to radar in that it measures how long it takes for a wave to return to measure distances. LiDAR technology has application in such areas as geography, geology, geomorphology, seismology, remote sensing and atmospheric physics.

Commercial LiDAR typically uses a laser beam to measure distances. The LiDAR transmitter emits a laser (pulse or continuous wave) and measures how long it takes for the reflective energy to return to the transmitter. The time taken between the laser beam being transmitted and the reflective energy returning is used to determine distances.

The LiDAR dataset used for this project is supplied by the Environment Agency (EA) Geomatics Group to SCC. The EA Geomatics Group fly survey aircraft equipped with Optech Gemini LIDAR systems which send a laser to measure the distance between the aircraft and the ground surface to produce LIDAR datasets. The LIDAR ground level information used for this project has a vertical accuracy of ±150mm within the Southampton area.

Two types of Digital Elevation Models (DEM's) are produced from the LIDAR raw data:

- Digital Surface Model (DSM) – The DSM includes all surface objects.
- Digital Terrain Model (DTM) – Also known as a "bare earth" is a terrain model where surface objects such as vehicles, vegetation, street furniture, buildings, etc. have been removed. All objects except those that would impede the flow of water have been stripped from the DTMS.

The 2D hydraulic modelling in this project has used DTM data. The reason for this is that from the two datasets, it is the one that will best represent the flow of water within an urban catchment.

5.2 LiDAR Accuracy

The LiDAR data has been provided at 2m x 2m coverage for the whole city, including areas to the north. 1m x 1m LiDAR data also exists, covering a smaller area towards the city centre. The full extent of coverage is shown in Figure GEN-020. See Appendices

LiDAR is a recognised tool for analysing large areas that are impractical to survey using ground-based methods within normal timeframes. It is important to note that for studies such as the SWMP, the LiDAR data must be processed prior to use. Examples of features which may require resolution or removal include trees, hedge lines, vegetation and any features which may provide an inaccurate representation of the ground.

This may result in odd levels being produced which indicate a barrier to a water flow which may not exist and hence provide inaccurate results. Under these circumstances, it is important to check whether these anomalies are a true reflection of the topography at that point. However, these checks have only been undertaken when it is considered that the scale (and sensitivity) of modelling is likely to be adversely affected.

For the reasons mentioned above DTM has been used in preference to a DSM, in that we believe it offers a better representation of surface water flood flows. In addition checks on the data have been carried out when it has been considered that the scale (and sensitivity) of modelling is likely to be adversely affected.

5.3 Grid Size

The Southampton city covers approximately 50km², which translates to several million points of LiDAR data, on a 2m x 2m grid scale. When a city-wide DTM was built on this grid density, it became apparent that data processing on this scale was not feasible for large areas. To facilitate the processing through the assessment phases, the following approaches were adopted:

- Where modelling large catchment areas was more important than the density of point data (such as in the Intermediate Assessment phase), data was reduced to an 8m x 8m grid density.

- Where the survey detail was more important than the size of area to be modelled, 2m x 2m LiDAR 'squares' were trimmed to a manageable size (typically 2-3km²). This modelling approach was used during the Detailed Assessment phase.

- LiDAR data was 'optimised' within Windes using a 0.1m 'step' interval. This process removed large amounts of points where the areas in question were largely flat and had no significant impact on runoff patterns.

5.4 Use of LiDAR in Drainage Modelling

LiDAR was used to create DTMs for use within Windes software. Windes is a drainage modelling programme, which can create and utilise DTMs to model two-dimensional (2D) surface flows combined with a one-dimensional (1D) drainage model. Test DTMs were created in Windes to determine a balance between the size and density of LiDAR data against processing/modelling time. It was necessary to reduce the LiDAR data from its original coverage (using techniques explained in the previous section) to complete the modelling exercises.

6. Modelling Software

6.1 MicroDrainage (Windes)

Windes software (from MicroDrainage) was selected in this project for its ability to build, model and analyse complex urban drainage networks. For a large city area such as Southampton, this software was appropriate.

Windes can use a terrain profile to route the surface water together linked to pipe network to simulate the flow of water within a drainage system. Within the DEFRA SWMP guidance, this known as type 4b modelling (fully coupled 1D (underground) and 2D (above ground) model). This approach simulates surface water flow across the urban surface using an 'applied rainfall' method and re-enter the sewer network where there is an inlet and underground capacity. Further details on the different modelling approaches are shown in Table 6.1.

The modelling of surface water is split into two components, the above ground surface runoff which is modelled using a 2D model and the below ground pipe system which simulates water flows using a 1D model.

The modelling of overland flows is undertaken using Windes Floodflow module. Where a drainage network is available, Floodflow can simulate the drainage network (1D) and the surface water runoff routing (2D) elements of the modelling concurrently.

6.2 GIS Software

GIS software has been used throughout this project to manage, analyse and display key datasets.

GIS software has been used for the following key reasons:

- GIS is efficient and robust at dealing with large spatial datasets.
- GIS allows the use of semi-transparent layers, which enables for example to display flooding extents against background mapping.
- The hydraulic model output and the majority of the incoming datasets where primarily in a GIS format.

Industry standard software MapInfo and ArcGIS have been used on this project. MapInfo with Vertical Mapper has been used primarily for analysis of LIDAR terrain data and creation of point and level grids. ArcGIS has been used primarily for data analysis and creating figures. These GIS tools are compatible with Southampton City Council's GIS system.

6.3 DEFRA Modelling Approach

DEFRA's guidelines' identify the following modelling approaches, which have been referenced in this study:

Modelling Approach	Overview
1 — Rolling ball (or topographical analysis)	Surface water flow routes are identified by analysing the topography. This approach would normally be used as part of the strategic or intermediate assessment and is not easily used to quantify damages due to surface water.
2 — Direct rainfall	Rainfall is applied directly to a surface and is routed overland to predict flow pathways and locations where water will pond. The presence of underground drainage can be accounted for by adjusting rainfall profiles
3 — Drainage models (see 3a-3e for variations)	Based around models of the underground drainage network, with rainfall inputs routed directly to the underground network
3a — Store flood water	Users can choose to `store' flood water in a virtual above-ground structure which can be dimensioned to provide an approximation of flood depth as well as volume.
3b — Representing internal flooding	Internal flooding of properties (through direct connections to the drainage system) can be modelled by adding the detail of individual lateral sewer connections to each property.
3c — 1D modelling of overland flows	Where surface flood waters are known to flow away from the flooded manhole, 1D flow channels can be modelled on the surface diverting flows to remote storage areas and/or to other inlets to the underground system. This approach is unlikely to be suitable for hazard mapping of flow and depth.
3d — 2D modelling of overland flows	Flood hydrographs can be added, post simulation, to Digital Terrain Model or Digital Elevation Model flow models (as method 2) that route drainage exceedance flows through streets or in and around buildings. This is also known as an 'uncoupled' approach.
3e — 2D modelling of overland flows (coupled)	An advancement on method 3D is to use a fully 'coupled' 1D (underground) and 2D (above ground) model which permits surface water flow across the modelled urban surface and re-enter the sewer network where this is an inlet and underground capacity.
4a — Integrated urban drainage river model	Where there are interactions between urban drainage and watercourses (or main rivers) an integrated approach can be used. All components can be modelled in a single software package l or dynamically linked through simulation shells such as Open MI.
4b — Enhanced drainage modelling	Conventional drainage models (method 3) route runoff directly to the underground drainage network. Recent software developments mean it is now possible to apply rainfall directly to the 2D surface. Runoff is generated onto the 2D surface and either enters the underground drainage network at manholes or gullies, or continues to be routed on the 2D surface

Table 6.1: Overview of surface water modelling approaches

7. Catchments

7.1 Initial Plan

Three catchments were planned originally. The main reason for this was that the sewer record data obtained from Southern Water revolved around three catchments. These were Millbrook to the west, Portswood to the central north and Woolston to the east of the project area.

The network information was added to the plans and a preliminary simulation model run. The results from this were descriptive but inconclusive and verification of the data was undertaken.

7.2 Revised catchments

In view of the limited details from Southern Water and that a network model was not available it was decided to reduce the number of catchment areas to two and use the River Itchen as the natural break point for the two catchments.

8. Pumping Stations

8.1 Locations

Pumping Station locations are presented within the city of Southampton (Figure GEN-004 See Appendices). There are two main pumping stations, which are of particular interest to the scope of the SWMP study due to their location within the city:

8.1.1 Mayflower Park Pumping Station

This pumping station is located within ABP owned land, at the eastern end of the CLT in Southampton Docks (see Figure 8.1). The station comprises three pumps, originally installed in the 1930s, for the discharge of surface water drainage. All pumps are originals and we are led to believe are still in a good working order.

Figure 8.1: Mayflower Park Pumping Station

The pumping station operates on the line of the 2.1m-diameter storm water culvert, which drains the eastern section of the Millbrook catchment. The pumps operate when the culvert is full, drawing water from the surcharged opening above the soffit of the culvert (see Appendices). Drawings issued by ABP indicate there is a high level alarm within the pumping chamber. It is understood the pumps are manually operated by ABP staff.

The culvert inlet is protected from the tidal flows of the River Test by multi-flaps. It is understood that the pumping station is designed to be a tidal system such that the multi-flaps only close when the pumps are in operation.

CAPITA SYMONDS

The following information/records were unavailable for analysis:

- Pump discharge capacity: however enquiries with representatives of the original pump manufacturers estimate a maximum capacity of 2,500 litres per second per pump.
- Historical operational records of switch on/switch off times
- Survey records of pump condition

Records have been provided for pump operation times during the May 2008 flooding (see Appendices). These show that all three pumps were switched on when the initial flooding alarm was raised; however, pumps were alternated for short periods after this. Dialogue with ABP operational staff indicate that the pumps are always able to cope with surcharged culvert conditions and rarely have to run all three pumps in unison. Although pump condition reports were unavailable for analysis during this study, it was reported by ABP staff that all operating pumps are in good condition. The sump pump is currently out of operation.

8.1.2 Pumping Station No.7 (King George V Dry Dock)

This pumping station is located within ABP owned land, at the western end of the CLT in Southampton Docks. The station comprises seven pumps, originally installed in the 1930s. Four larger pumps are used to drain the King George V dock and three sump pumps, the sump pumps now being used as storm water pumps to drain the Millbrook culverts. ABP have advised that all three pumps are in good working order. The culvert backdrops into a pipe section, which pass under the dock and into the wet well (see Appendices). It is understood the pumps are manually operated by ABP staff.

Figure 8.2: Pumping Station No.7 (King George V dock)

During the May 2008 floods, one dry dock pump and two storm water pumps were used to drain the Millbrook culvert. The pumps were run together during the peak flooding, then run intermittently after this period had passed. No information was available with regard to the pumping capacity of dry dock or storm water pumps.

The culverts near Millbrook Station were surveyed in January 2008, prior to the floods[7], which recorded that at high tide, the water level surcharged to soffit level in some of the inspection chambers accessed.

At present, the Millbrook culvert is entirely reliant on this pumping station to drain this section of the storm water network. The 600mm-diameter gravity outlet previously in operation has been closed with stop logs. It is understood that the pumping station is designed to be a tidal system, such that the multi-flaps only close when the pumps are in operation.

[7] Network Rail (February 2008), Southern Region, Underwater Examination Report (Atkins, Bridgeway Consulting Limited)

9. Hydrology

9.1 Flood Estimation Handbook (FEH) approach

The Flood Estimation Handbook (FEH) was published in 2000. It is based on the percentage runoff equation:

$$PR = 0.829PIMP + 25SOIL + 0.078UCWI - 20.7$$

Where PR is percentage runoff, PIMP is percentage imperviousness of the catchment, SOIL is the soil index and UCWI is urban catchment wetness index.

The current national procedure for estimating rainfall and river flow in the UK is the Flood Estimation Handbook (FEH). FEH is a digitally-based methodology and has unique data values for a number of parameters.

The FEH approach was used within Windes to create rainfall profiles, which were used in the simulation process. FEH was implemented for intermediate and detailed modelling phases.

9.2 Climate Change

In line with PPS25 an allowance for climate change has been made. Flows have been increased by 30% to cater for increased rainfall intensities and runoffs in the higher return period event such as the 1:100 and the 1:200 year event. [8]

[8] UK Government (December 2006), Planning Policy Statement 25, Annex B, Table B2

10. Key Assumptions

10.1 Limitations of Data

Although a basic check will have been carried out on data received, in general it has been assumed that data provided by the partners is correct and fit for purpose. For example individual pipe diameters, manhole cover levels and pipe lengths from data received have been assumed as correct.

The conclusions and recommendations have been based upon modelling and analysis of the data provided to us during the course of this study by the partners and stakeholders. In particular, no surface water drainage model has been provided for the Southampton city area.

The data collection phase was concluded by the end of December 2010. Any information received after this date may not have been utilised within the study, or to have been considered in making conclusions and recommendations.

10.2 Uncertainties

Drainage infrastructure (pipes, manholes, gullies grills, etc) are in a clean, operational condition. No allowance has been made for blockages or broken/damaged sections which may compromise network capacity.

Watercourses and channels are assumed to be in a clean, operational condition. No allowance has been made for blockages or maintenance issues which may compromise pluvial/fluvial modelling.

10.3 Modelling Factors

Southampton has been divided into two catchments (east and west). Impermeability factors have been derived for each catchment based on mapping, existing land use and aerial photography; the following values have been derived:

Southampton East	–	Estimated overall impermeability of 90%
Southampton West	–	Estimated overall impermeability of 80%

No separate impermeability has been used for large green areas, such as Southampton Common and Lordsdale Greenway.

Consistent rainfall parameters have been implemented during the modelling phase for the whole Southampton catchment. This means that the same parameters been applied for the east and west catchments at the intermediate assessment phase and the hotspot locations during the detailed assessment phase.

Roof rainfall runoff is assumed to get to the ground surface immediately. In reality, the flow of rainwater will be delayed and attenuated as rainwater flows through rain water pipes to ground level. This has been ignored due to the complexity of modelling this accurately.

Tidal locking of the drainage systems has not been considered within the scope of the SWMP.

10.4 Sensitivity

It is accepted that LiDAR data is the most accurate representation of the ground surface for Southampton city. No guarantee can be made that all obstructions and features have been processed in the LiDAR dataset.

11. Intermediate Assessment

11.1 Process

The need for an Intermediate Assessment phase was discussed and proposed in the Preparation Phase report, issued in November 2010. The DEFRA Guidance states that the Intermediate Assessment is considered to be applicable at the town, city and London Borough scale. In this phase, detailed information is collected and assessed to improve the understanding of surface water flooding and to identify flooding hotspots.

The Intermediate Assessment was undertaken using the following processes of data analysis:

- Combining sources of flood evidence using a GIS-based approach to identify flood hotspots
- Using a pluvial (Type 1/Type 2) modelling approach
- Combining the sources of flood evidence using scoring techniques to identify flood hotspots (See Appendices).

11.1.1 Combining sources of evidence (GIS approach)

The following data was reviewed using GIS mapping:

- SCC Highways Maintenance regime (60 locations highlighting drainage problem areas)
- SCC Key/Critical Infrastructure (Figures GEN-008 and GEN-009 see Appendices)
- EA Second Generation Flood Maps (30-year and 200-year+CC maps)
- Southern Water historical flooding records (see Figure GEN-016 see Appendices)

11.1.2 Pluvial Modelling

The Floodflow application within Micro Drainage Windes' software was utilised to create a 2D surface water analysis. Two Floodflow methods were used:

- 'Fixed depth' analysis, applies a fixed depth of water over an imported DTM. The water flow paths are modelled across the surface over a specified period of time. Depths and velocities are analysed to determine where low spots exist and where the higher risk of surface runoff flooding is likely to occur. This method is similar to Type 1/Type 2 modelling approaches described within the DEFRA SWMP Guidelines. Water depths of 10mm, 30mm and 50mm were analysed over a period of 60mins. This is a recognized duration for this form of analysis. The results are shown in Figures FD-016, FD-017 and FD-018. see Appendices
- 'Rainfall profile' analysis approach provides a realistic, more sensitive analysis to surface runoff by implementing an applied rainfall approach. This allows runoff to be modelled across the DTM in 2D, using FEH rainfall profiles for the simulated storm event. The intention was to include the modeling of surface runoff within the drainage network, using the manholes as inflow positions. This was not however possible due to the lack of a surface water model network from Southern Water, as discussed in section 2.2.5
  The results are shown in Figures FD-001 to FD-015 (see Appendices).

Further details of modelling and analysis are discussed later in this chapter.

11.1.3 Combining sources of evidence (Scoring Technique approach)

The following data was used to identify flooding hotspot locations:

- SCC Highways Maintenance regime (60 locations highlighting localised flooding events which have been interpreted as drainage problem areas)
- SCC Level 2 Strategic Flood Risk Assessment
- SCC LCLIP (reported incidents of flooding by press)
- EA Second Generation Flood Maps (30-year and 200-year+CC maps)
  Shown in Figures GEN-016 and GEN 017. see Appendices
- Southern Water historical flooding records
- Type-1 modelling (Windes Floodflow fixed depth analysis)
- Type-2 modelling (Windes Floodflow rainfall profile analysis)

The likelihood (or probability) of flooding was scored, using a weighted system for these sources. The scoring system used is explained in the Appendices. The scores were banded into low, medium and high categories.

To determine flood risk impact (or severity) of these hotspots, a classification system was used similar in nature to the one within PPS 25. The impact was assessed using three criteria:

- Residential properties (assessed using aerial photography and OS mapping)
- Key/Critical Infrastructure (assessed using SCC's Critical Infrastructure dataset)
- SCC Key Development Sites (assessed using information presented within SFRA2)

An overall risk-rating was determined, using the **'risk= severity x likelihood' equation**. Using this approach, the most critical hotspots could be identified for further analysis under the Detailed Assessment phase.

11.2 Modelling and analysis

Several return periods and durations of interest across the DTM were modelled using the Floodflow 'rainfall analysis' approach according to design guidelines and standards. Using Sewers for Adoption (6th Edition), designed sewer systems shall not surcharge or flood under 1-year and 30-year storm events respectively. Within Planning Policy Statement (PPS) 25, Flood Zones 2 and 3 are defined by river flooding occurring greater than 100-year and 200-year events, with allowances for climate change.

Both east and west catchment models have been run for the intermediate assessment phase for 30-year, 100-year (plus climate change) and 200-year (plus climate change) events, at 15-minute, 120-minute and 360-minute durations. This yielded 9 rainfall events modelled per catchment.

11.3 Outputs

In total, 51 hotspots were identified within the local authority boundary. After these had been scored and risk ratings generated, 8 were identified as high-risk, 15 as medium-risk and 28 as low-risk. Within the scope of this SWMP study, the high-risk hotspots have been reviewed further in the Detailed Assessment phase, using appropriate modelling approaches for each location (see Appendices for hotspot locations).

As defined previously, the west and east sections of Southampton city either side of the River Itchen, have been modelled using type 1 and type 2 modelling approaches. The information has been converted into GIS layers and is presented within Figure HTS-001 see Appendices. A comprehensive set of GIS data has been issued to SCC (Capita IT).

12. Detailed Assessment

The DEFRA Technical Guidance states that a Detailed Assessment phase may be required if:

- The strategic or intermediate assessment have identified flood hotspots which require a more detailed assessment of surface water flooding
- Other studies have identified specific areas of greater surface water flood risk
- A recent flood event has occurred, or there are known locations that suffer from regular flooding with sufficient consequences to warrant action
- A detailed assessment of the potential mitigation measures is required.

The Intermediate Assessment phase identified 51 flooding hotspot locations within the Southampton city boundary. Eight of these have been scored as high risk, which have been reviewed in the detailed assessment phase. It is recognised that in hotspot areas, surface water flooding can be complex and therefore require a more detailed assessment to understand the mechanisms and consequences of flooding. It is also important to understand how mitigation measures can help to reduce the surface water flood risk.

Six of the hotspots are located within the Millbrook catchment and have been recorded as subject to flooding in the past. The last significant flooding event, in May 2008, caused the Southampton Central station and A33 Millbrook Road West to flood.

12.1 Methodology

The DEFRA Technical Guidance notes state that:

'choosing a method (or range of methods) is a difficult process and somewhat iterative. Choice will depend on the presence of existing data and tools, available funds, and an understanding of existing flood risks and likely plausible mitigation measures. There is no substitute for good judgement, pragmatism and experience when choosing an approach. Increasing the level of model detail does not necessarily correlate to improved surface water management mitigation measures.. it is important to record the quality of data and models that use them as this will inform how to interpret good model results'.[9]

The detailed assessment method, proposed originally at the outset of the SWMP, was intended to model a 'linked' 2D (above ground) and 1D (underground) integrated approach. This method allows the interaction between surface runoff and the surface water drainage network. Surface water flow is permitted to run across the urban surface and re-enter the sewer network at inlet points downstream.

No surface water network (or networks) has been modelled by Southern Water, or other bodies to our knowledge, for the Southampton city area. It is recognised that without this data, the original intention to model the Southampton city catchments using a type 4b modelling approach cannot be achieved without the data originally anticipated. Limitations of processing LiDAR data also restrict the size of area under assessment.

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

As a consequence, the type 2 and type 4b modelling approaches have been implemented for high-risk hotspots. It has been possible to use GIS records held by Southern Water to manually create 'skeleton' networks of the main sewers systems within Windes. The GIS records indicate that approximately 30% of invert levels and pipe diameters are recorded. Where possible, the upstream and downstream information has been interpolated to 'complete' the network (see 'Assumptions' chapter). ABP records have also been used to complete sections of the network where necessary.

It was decided that implementing a detailed modelling approach for some of the high-risk hotspots without a sewer network (Type 2) did not yield significantly reduced quality of results than using a type 4b approach. Type 2 modelling was implemented in predominantly 'green' hotspot locations, such as Monks Brook Greenway (FH-35) and Shoreburs Greenway (FH-51) where fluvial processes were judged to be more important than urban drainage-related processes.

12.2 High-Risk Hotspots

The following locations have been reviewed at the Detailed Assessment phase

Hotspot Ref.	Description	Modelling Approach
FH-16	A33 Millbrook Road West	Type 4b
FH-21	Southampton Central Station	Type 4b
FH-24	City Centre (St Andrews Terrace/Solent University Site)	Type 4b
FH-25	City Centre (Ocean Village/Queens Park)	Type 4b
FH-26	West Quay Retail Area	Type 4b
FH-35	Stoneham Way (junction with Wide Lane)	Type 2
FH-51	Shoreburs Greenway	Type 2

Table 12.1: Modelling analysis methods (detailed assessment phase)

12.2.1 Flooding Hotspot FH-15: Merging point of Tanners Brook/Holly Brook

Both Tanners Brook and Holly Brook are key watercourses which drain a significant area of the Millbrook catchment. The hotspot is located where the brooks meet in Lordswood Greenway, adjacent to the junction between Winchester Road, Romsey Road and Tebourba Way.

Tanners Brook runs north-south through the city, from Lordswood in the north, to Millbrook and the CLT (where it discharges into the River Test) in the south. In its upper reaches, Tanners Brook is an open watercourse, typically 2-3m in width. As the brook flows southward it is culverted, believed to be concrete/stonewall sections. At the hotspot location, the brook runs in a culvert approximately 1.5m wide (see Figure 13.1). The brooks merge and discharge into Romsey Road culvert, which passes under Winchester Road (A35).

Figure 12.1: Channelled section of Tanners Brook looking upstream, Lordsdale Greenway on right

Holly Brook flows in a south-westerly direction, from the golf course/Southampton Sports Centre to its merging point with Tanners Brook immediately downstream of Shirley Pond. Large sections are either culverted or in concrete channels It is important to note that flooding risk is classified as high from The Spire Hospital along Dale Valley Road, to Southampton Sports Centre, as well as at the hotspot point.

Whilst a majority of surface water would be contained within the lower reaches of Lordsdale Greenway during a significant rainfall event, flooding route analysis indicates that the Winchester Road junction with Romsey Road would be affected. Flooding has been reported at this location in the past, requiring the road to be temporarily closed. Tebourba Way and Winchester Road (A35) are identified by SCC Emergency Planning as key transport routes through Southampton.

12.2.2 Flooding Hotspot FH-16: A33 Millbrook Road West

This hotspot is located along the key transport route, which runs east-west through the Millbrook and Freemantle areas of Southampton. The areas covered include Millbrook Road West (A33) between the junctions with the M271 and Waterhouse Lane, and the main railway line running parallel to this road, including Millbrook Station. The land use is mainly residential to the north of the A33 and the container terminal is to the south (ABP land).

The lower reaches of Tanner's Brook pass through this hotspot and are fully culverted through this area. The culverted Luggy Creek joins with Tanner's Brook under the container terminal; this watercourse drains the western section of Southampton, to the north of the junction between A33/A35 (Millbrook Road West/Tebourba Way). It is understood these culverts are tidal, with no system of control in the downstream reaches.

To the east of the container port, two culverts pass under the A33 and main railway line, immediately to the west of Millbrook Station. These culverts drain into a ditch flowing westwards alongside the railway, which in turn discharges into another culvert, which then follows the branch rail line into the container terminal before reaching the quayside at King George V Dry Dock. The outfall arrangement is described in further detail in the Pumping Station Section.

In May 2008, Millbrook Road West flooded at the location of the petrol station, adjacent to the junction with Regents Park Road. Modelling of this area confirms Millbrook Road West as a high-risk flooding area. The culverts near Millbrook Station were surveyed in January 2008, prior to the floods[10] , which recorded that at high tide, the water level surcharged to soffit level in some of the inspection chambers accessed. Although surface water runoff conditions were unknown from this period, significant tidal locking is occurring within this section of the network.

12.2.3 Flooding Hotspot FH-21: Southampton Central Station

The hotspot is located in at Southampton Central Train Station and the adjacent Western Esplanade and Blechynden Terrace (see Figure 12.2). This area contains SCC key development site 1.

Figure 12.2: Southampton Central Station

This particular hotspot is significant in that it affects key transport links for Southampton. Any flooding has an impact on the passenger railway station, the main railway line crossing Southampton and the A3024 main road running along Western Esplanade. It is also in close proximity to the Coach Station, which is at risk of flooding

[10] Network Rail (February 2008), Southern Region, Underwater Examination Report (Atkins, Bridgeway Consulting Limited)

during extreme events. Detailed hydraulic modelling has confirmed that Central Station, the railway track, Western Esplanade, and the Coach Station are at risk of flooding.

There are historic records of flooding in this area. The most notable recent event has been the flooding which occurred on the 26th May 2008 where Southampton Central Station was closed for approximately 8 hours.

From Southern Water's records it has been established that there are currently three water conduits running beneath the railway tracks. The largest of the three is an egg shaped culvert with dimensions of 1500 x 1000. The other two being storm water sewers with diameters of 300mm and 225mm. Details of any dedicated Network Rail drainage in the area and/or connectivity into the public sewer network is not known. Nothing to indicate such is shown on the information obtained from NR. (see Data Collection chapter for details).

The watercourse Rolles Brook, the catchment of which covers a significant proportion of Southampton Common, flows into, what is indicated on the SW plans as a public surface water sewer, approximately 400m upstream of Central Station.

A CCTV condition survey has been undertaken on behalf of the EA by 365 Environmental Services, and includes the entire section between the sewer entrance 400m upstream of the Central Station to a manhole immediately south of the station. The CCTV survey was carried out in February 2010 and indicates various defects within the section immediately under the station, which include:

- Obstructions to the pipe (ranging from 10-50%)
- Multiple fractures
- Root ingress
- Sewer deformation
- Defective connections (including protruding connecting pipes)
- Infiltrations into pipe system

All of these defects will hinder the flow of water within the system and could affect the extent of flooding within the area drained by the public sewer.

12.2.4 *Flooding Hotspot FH-24: City Centre (St Andrews Road, Solent University Site)*

Hotspot FH-24 is located at the junctions between Charlotte Place to the north Britannia Road to the east, Lime Street to the south and Palmerston Road to the west.. Located adjacent to St Andrews Road is one of the Solent University campuses. The hotspot covers the A33 Kingsway and St Marys Place as far as the East Street Centre and the upper reaches of hotspot FH-25 (see Fig. 12.3).

Figure 12.3: St Mary' Place , looking north at junction with Houndswell Place (Hoglands Parkon left)

During 2008, widespread flooding was reported throughout the city centre, and both the intermediate and detailed assessment modelling has confirmed that risk of surface flooding is high in this area. Detailed analysis has been carried out using Type 4b modelling approach, although the surface water skeleton network modelled is limited to the A33 Kingsway section and areas further south.

Detailed assessment modelling shows that a much of the road network included within this area is not at significant risk. This has been determined from analysis using the 8m x 8m grid (intermediate assessment) scale. Areas with higher flood risk are located in lower areas at the sides of these roads, which include the south western section of the university campus. The road sections which remain at risk include A33 Evans Street, at the junction with A33 St Marys Place and Houndswell Street. Flooding, causing any form of road closure in this area could lead to significant traffic disruption to the city and commercial/residential areas nearby.

It is also indicated that the London-Southampton main line is at significant risk of flooding through this hotspot area. By using a 2m x 2m DTM, the railway cutting to the east of Palmerston Park was more clearly defined. The modelling results in Figure HTS-004 see Appendices, indicate that the affected section of main line extends eastwards, to the location of hotspot FH-23. No information has been obtained indicating any drainage within Network Rail land, which could potentially affect the depths of surface water runoff. Flooding in this area could lead to disruption to train services, as experienced when Southampton Central Station flooded. Train operations from the docks could also be compromised.

12.2.5 Flooding Hotspot FH-25: City Centre (Ocean Village, Queens Park)

The intermediate assessment indicated that there is a high risk of flooding around Queens Park in the city centre, to the north of Dock Gate 4. The area of interest extends northwards, to the southern end of Terminal Terrace. These roads form important links to the heart of the city, along the A33, from the north and west, and across the Itchen Toll Bridge, A3025, to the east (see Appendices).

Figure 12.4: Queens Park looking north-east

This hotspot has been modelled by building a skeleton sewer network through the area under a DTM based on the approximate sizes of the SW storm sewer shown on drawings. Drainage records indicate that two surface water sewers draining from the north, merge into one 600mm-diameter sewer under Queens Park, discharging southwards via an outlet in the vicinity of Town Quay docks. It is not known whether this outlet is below the high tide mark, and hence could be affected by tidal locking.

SCC Key Development Sites are located in the vicinity of FH-25, which include sites 3 and 7. Further development sites to the east and west are accessed using the key routes indicated above. SCC Highways have identified the surface water system as requiring gulley cleansing in Queens Terrace and a drainage scheme at the sewers connection points under Queens Park (details not available).

Flooding of the roads in this area could lead to significant disruption within the city centre, affecting commercial (town), industrial (port) and travel (ferry) activities. Therefore the impact of any flooding in this area could be particularly high.

Detailed modelling indicates that the roads bordering Queens Park are not liable to the flooding levels mapped in the intermediate assessment phase. The park area is lower than the adjacent roads and hence would flood, acting as a temporary attenuation area. It is assumed that this situation is currently occurring and site visits have confirmed this difference in levels. It is indicated that surface water flooding would affect Terminus Terrace, at the junction with Bernard Street and Captains Place, and Marsh Lane. Both locations form part of the A33 route into the city from the north. Modelling indicates that flooding would occur in 30-year and 100-year plus climate change events.

12.2.6 Flooding Hotspot FH-26: West Quay Retail Area (Western Esplanade, Harbour Parade)

This area is located south of Central Station and is immediately south of hotspot FH-21. For the purpose of this report this hotspot has considered the area south of the Western Esplanade dual carriageway, running parallel to the station. A significant part of SCC Key Development site 4 is included within this hotspot. This area contains SCC key development site 1 (See figure 12.5)

Figure 12.5: Western Esplanade with West Quay in background

During extreme rainfall events it is possible for some surface water runoff from the Central Station hotspot area to flow into the top end of the West Quay hotspot. As a consequence we believe hotspots FH-21 and FH-26 should be considered in conjunction, when reviewing surface water runoff in this location.

This hotspot lies within the area which was reclaimed from the sea at the beginning of the 20th century. The main activities for the area covered by this hotspot are retail, restaurants, leisure, an electricity substation and the Geothermal plus CHP district heating/cooling plant.

Historic records of flooding show this area was also affected by the intense rainfall event on the 26th May 2008, which caused major disruption to Southampton Central Station located immediately to the north. The Management of the West Quay shopping centre has confirmed that they suffered significant flooding during this particular event.

Southern Water records show there is a 2.1m diameter culvert which runs from the Western Esplanade, beside Central Station, along Harbour Parade and terminates at the Mayflower Park pumping station. Although ABP own and operate the Mayflower Park Pumping Station, the ownership and maintenance responsibility for 2.1m culvert remains unclear.

This culvert collects water from the 1.75m x 1.00m diameter culvert running under Central Station. In addition public sewer records indicate that there could potentially be surface water sewer connections into the 2.1m culvert at Pirelli Street, West Quay Road, Herbert Walker Avenue and Western Esplanade. At present we have insufficient information to determine how the surface water for the majority of the retail park currently drains. We have used the most accurate possible hydraulic model at this stage, a 4b 'enhanced drainage model'. However, to determine more accurately how the drainage network would respond during a flood event, more detail on levels and condition of the 2.1m culvert together with information on the connecting networks would be required.

With the information available the hydraulic modelling of the current flooding hotspot indicates that during extreme flooding events, typically the 30 and 100 year events, there would be significant flooding along the low points in sections of Western Esplanade, some areas adjacent to Harbour Parade and Pirelli Street. The main areas affected would be retail areas, car parks, the coach station and the Geothermal and CHP plant.

Flooding in this area is likely to result in the additional flooding of the A3024, which is one of the major links into Southampton and connects Southampton Docks and the M271 to the city centre. Blockage of this route could cause severe disruption to traffic approaching Southampton from the west and M271.

12.2.7 *FLOODING HOTSPOT FH-35: STONEHAM WAY (JUNCTION WITH WIDE LANE)*

The Stoneham Way hotspot is located on the northern outskirts of Southampton, approximately 4km from the city centre. Southampton is connected to the north by the A35, joining the M27 at junction 5. Hotspot FH-35 is located approximately 1km to the south of this junction. Monks Brook drains the area to the north of Southampton towards Eastleigh. Surface runoff/flows were not modelled beyond the M27 due to the extents of LiDAR data available, but also because this was outside the SCC boundary. Monks Brook runs adjacent the A35 Stoneham Way and London main line for a short distance, before passing under the railway and flowing south into the upper reaches of the River Itchen.

Figure 12.6: A35 Stoneham Way, looking north at junction with Wide Lane on the right

Southampton City Council manage and maintain Monks Brook Greenway, a wooded area surrounding the Monks Brook watercourse. The area extends 700m north towards the motorway. To the south the brook drains into Westfields Corner, also known as The Grange. This extended section of the Monks Brook Greenway is home to a range of wildlife, flora and fauna. Opportunities to improve the biodiversity within the area should not be overlooked in proposing flood mitigation measures.

Flood modelling indicates due to the proximity of Monks Brook to Stoneham Way, could lead to flooding on the dual carriageway at the junction with Wide Lane. Should flooding be significant this would potentially block one of the key arterial links in to Southampton. Ground levels indicate that the Southampton-London main railway line that is located on an embankment nearby would not be subject to flooding.

The SCC Highways maintenance/improvement work schedule included a requirement for a drainage scheme in the vicinity of Wide Lane/Monks Brook bridge. The schedule notes that work has taken place on Wide Lane, outside the Fleming Arms Pub. The pub is located on the western bank of Monks Brook.

A Type 2 modelling approach was used for this hotspot. The data gathered for the surface water network indicated that the contributing networks and flows were small in this location; highway drainage records were not shown within the datasets obtained, for the affected A35 section.

12.2.8 Flooding Hotspot FH-51: Shoreburs Greenway (Spring Road near Millers Pond)

This hotspot is located in Woolston catchment, in the vicinity of Millers Pond. A large area of the Woolston catchment, including Sholing and areas to the north, drain to this low point, where the local watercourses meet and are culverted under Portsmouth Road (A3025).

The railway line between Sholing and Netley runs on an embankment at this point, which acts as a barrier to overland runoff. Where Spring Road passes under the railway, there is the potential for surface water to be channelled under the bridge at this point (see Fig. 12.7). The junction between Spring Road and Portsmouth Road occurs immediately to the south of the rail embankment and at a natural low point in the area.

Figure 12.7: Spring Lane under bridge (A3025 Portsmouth Road in foreground)

Site visits to the area have confirmed there is minimal capacity within Millers Pond to accommodate additional surface water during significant rainfall events. An earth bund has been added at the interface between Spring Road and Millers Pond, which should act to prevent low levels of surface runoff being channelled onto Spring Road (see Fig. 12.8). There is evidence of water ponding on the north side of the rail embankment, adjacent to the bund.

Figure 12.8: Spring Road, under railway arches, bund and Millers Pond beyond lamp post

The impact of flooding in this area is likely to result in the flooding of the A3025. The road is one of two A roads, connecting Woolston and areas further east to Southampton. Blockage of this route could cause severe disruption to the surrounding residential areas and traffic approaching Southampton from the east. Local access to Sholing Station is also likely be restricted.

13. Map & Communicate Risks

13.1 Hazard Ratings

Flood hazard ratings have been derived using the EA/DEFRA guidance as set out in the "Flood Risks to People (FD2321/TR2)" guidance report. Flood hazard ratings are used to assess the risk to people caused by flooding.

The report identified three key factors for flood hazards

- Depth of flood water (m)
- Velocity of flood water (m/s)
- Debris factor (score)

$$Flood\ Hazard = Depth\ of\ water \times (Flood\ Water\ Velocity + 0.5) + \ Debris\ Factor$$

From the surface water runoff modelling analysis flood hazard maps have been produced for the 100-year plus climate change and 200-year plus climate change return periods. These maps have been included as Figures HR-001 and HR-002 in the Appendices.

Due to the mostly urban nature of the catchments within Southampton, for inundation depths greater than 0.25m a debris factor of 1 has been used.

Flood Hazard Rating	Degree of Flood Hazard	Description
<0.75	Low	Caution 'Flood zone with shallow flowing water or deep standing water'
0.75-1.25	Moderate	Dangerous for some, i.e. children 'Danger: Flood zone with deep or fast flowing water'
1.25-2.5	Significant	Dangerous for most people 'Danger: Flood zone with deep fast flowing water'
>2.5	Extreme	Dangerous for all 'Extreme danger: Flood zone with deep fast flowing water'

Table 13.1 – Flood Hazard Rating Types[11]

[11] Source: DEFRA/EA (March 2006) Flood and Coastal Defence R&D Programme - FD2321/TR1, Table 3.2s

14. Identify Measures

14.1 Identifying Measures

This section focuses upon the range of measures which should be considered to manage surface water flood risk within Southampton. Within this study, a measure is defined as a proposed individual action or procedure intended to minimise current and future surface water flood risk, or wholly or partially meet other agreed objectives.

The following measures have been identified in the various categories for further consideration:

14.1.1 Option 1: Do nothing

In line with the Flood & Coastal Erosion Risk Management Appraisal guidance (FCERM-AG) issued by DEFRA, the 'do nothing' option, no intervention and no maintenance, should be taken forward to the detailed options assessment.

14.1.2 Option 2: Do minimum

In line with the FCERM-AG issued by DEFRA, the 'do minimum' option, continuation of current practise, should be taken forward to the detailed options assessment.

14.1.3 Option 3: Maintenance/Repair of Existing Infrastructure

This option could include the following activities:

- Gulley and highway drainage maintenance regime (cleaning and jetting)
- Repair of leaking or damaged surface water elements
- Replacement of leaking or damaged surface water elements

14.1.4 Option 4: Additional, Extended or Enlarged Infrastructure

This option could include the following activities:

- Addition of gulleys within the highway
- Upsizing of leaking or damaged surface water elements
- Installing new surface water infrastructure, such as manholes, culverts, channels and pipes
- Linking of sewer networks via new pipe connections/overflows

14.1.5 Option 5: Flow Attenuation Measures in Sewers and/or Watercourses

This option could include the following activities:

- Underground storage (crates, concrete storage tanks, etc)
- Construction of large sewer pipes for attenuation

14.1.6 Option 6: ABP Outlet upgrade works

This option could include the following activities:

- Modification or improvements to existing pumping stations

- Installation of new multi-flaps at tidal outlet locations
- Construction of new pumping stations

14.1.7 *Option 7: On-line Controls and Features*

- In-channel features, such as baffles or riffles
- On-line controls (weirs, orifices, penstocks/gates)
- Vortex flow control devices

14.1.8 *Option 8: Sustainable Urban Drainage Schemes*

- De-culverting through green areas
- Two-stage watercourses
- Berms (increased width of channel)
- Meanders (increase extents of channel, modify water speed)
- Hollows with marginal vegetation (additional temporary storage)
- Off-line retention ponds
- On-line retention ponds
- Wetlands
- Scrapes
- Wet woodland areas
- Wet grassland areas
- Catchment trees (temporary storage and infiltration capacity)
- Cleaning and maintenance of watercourses

14.1.9 *Option 9: SUDS in Key Development Sites*

- Rainwater recycling/grey-water schemes
- Green Roofs
- Permeable Pavement used for storage

These measures have been selected with consideration to the nine key development sites identified by SCC. Potential funding streams and sources of investment for green infrastructure schemes have also been reviewed.

14.2 Shortlist Measures

Individual measures being considered have been scored against criteria and scores summed. At this stage, the objective is to rank individual measures to take forward a subset for more detailed appraisal. The table below sets out the short-listing criteria taken from the DEFRA SWMP technical Guidance:

<table>
<tr><th>Criteria</th><th>Description</th><th>Score</th></tr>
<tr><td>Technical (T)</td><td>Is the option technically feasible and buildable?</td><td rowspan="5">U (unacceptable) - measure eliminated from further consideration
-2: Severe negative outcome
-1: moderate negative outcome
+1: moderate positive outcome
+2: high positive outcome</td></tr>
<tr><td>Economic (Ec)</td><td>Will the expected benefits exceed the estimated costs?</td></tr>
<tr><td>Social (S)</td><td>Will the community benefit or suffer from implementation of the measure?</td></tr>
<tr><td>Environmental (En)</td><td>Will the environment benefit or suffer from implementation of the measure?</td></tr>
<tr><td>Objectives (O)</td><td>Will it help to achieve the objectives of the SWMP partnership?</td></tr>
</table>

Table 14.1: Short-listing criteria

14.3 Short-Listing Summary

The scoring and short-listing of the measures are summarised below:

Option.	Measure	Criteria					Score	Take further	Comments
		T	Ec	S	En	O			
1	Do nothing	2	-1	-2	0	-2	-3	Yes	Do nothing should be carried forward to option appraisal stage. (Under DEFRA guidelines)
2	Do minimum	1	-1	1	1	1	3	Yes	Do minimum should be carried forward to option appraisal stage. (Under DEFRA guidelines)
3	Maintenance/repair of existing infrastructure	2	-1	1	0	1	3	No	Can be technically achieved, although social disruption is likely through the city centre. Costs will be high whilst repairing a 'live' sewer network. Further information required prior to implementation of this option (see quick wins section).
4	Sewer network upgrade & expansion	1	1	0	0	2	4	No	Technically this measure can be implemented and is likely to be beneficial to society and the environment through reduced flooding and pollutions. However economically this is not feasible and is likely to have a poor cost benefit ratio.
5	Strategic SW storage	2	-1	0	0	2	3	No	This is technically feasible and will provide localised as well as strategic benefits. Locating these storage features will be socially disruptive and economically unfeasible.
6	Existing outfall works	1	-2	1	0	1	1	No	Constructing new infrastructure may be difficult in dockside land. Cost benefit ratio will be low due to high construction costs. The environmental impact is likely to be negative.
7	On-line controls and features	2	1	1	1	2	7	Yes	Controls and features are technically and economically feasible. There are many opportunities to create a positive impact on the environment from this option. This may cause slight disruption locally, but have a positive effect in the long term.
8	SUDS	2	1	1	2	2	8	Yes	Significant environmental benefits. Socially and economically, there will be long term gains. However, views to this approach may be mixed at first and funding streams require clarification.
9	SUDS in Key Development Sites	2	1	2	2	2	9	Yes	It is technically feasible to incorporate SUDS-based schemes within key development sites, with positive economic benefits. Inclusion of SUDS features will be welcomed by the community. SWMP objectives will be achieved through reducing runoff to the drainage network.

Table 14.2: Scoring of short-listed options

15. Assess options

15.1 Process for assessing options

The first step in the assessment process is to determine which benefits and costs are to be included in the analysis. DEFRA PAG guidance[12] states that multi-criteria techniques should be used to support decision making.

The following costing criteria has been used for the Southampton SWMP:

- Capital Costs: one-time costs associated with construction, purchase of assets, land or equipment
- Operational Costs: ongoing costs associated with maintenance of assets, land or equipment
- Carbon Costs
- Disruption to services: disruption to traffic or businesses during construction of infrastructure or maintenance
- Environmental Costs: where a proposed option could cause deterioration of the flow regime or physical habitat of a watercourse, compromising the ability to meet the WFD
- 'Do nothing' Costs (applicable only to the baseline 'do nothing' option)
- Opportunity Costs: costs associated with having to forego certain benefits. An example would be the loss of development value associated with land use planning restrictions (net of that from development which might be allowed in new, non-vulnerable areas). Opportunity costs may be particularly applicable to non-structural measures.

The following benefits criteria have been used for the Southampton SWMP:

- Reduced surface water flood risk to properties, businesses and critical infrastructure
- Reduced social and health impacts of flooding
- Reduced emergency costs of responding to flood incidents
- Reduced risk to life due to improvements in surface water flood risk management
- Contribution to meeting the requirements of the WFD through reducing pollution entering watercourses
- Contribution to meeting objectives of green infrastructure plans
- Contribution to creating or enhancing biodiversity or amenity
- Adaptability to climate change – the benefit could reduce use of carbon through the use of lower energy options and greater adaptability of an option to future climate change

The options have been assessed using a scored system based upon the above criteria. Costs have been considered as having a negative score, whilst benefits contribute a positive score. The elements have been summed together to give the overall score for further analysis and recommendation (as shown in Table 15.1).

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

Flooding Hotspot Ref	Catchment	Description	Severity (3=High, 1=Low)				Probability								Overall Risk Rating
			Properties	Key/Critical Infrastructure	SCC Key Dev Sites	Total Severity Score	SCC Hotspots	SFRA	Press Archive	EA 2nd Gen	SW Historical	Windes FF (R/B)	Windes FF (RA)	Total Probability Score	
FH-01	Millbrook	Lords Hill: Woburn Road (junction with Dunvegan Drive), including subway underpass	2	0	0	2	0	0	0	0	0	1	2	3	LOW
FH-02	Millbrook	Lords Hill: Lords Hill Way, at crossing point with Tanners Brook	1	0	0	1	0	0	0	2	0	1	2	5	LOW
FH-03	Millbrook	Lords Hill: Lords Hill District Centre on Lords Hill Centre West (junctions with Andromeda Road and Eastchurch Close)	3	0	0	3	0	1	0	2	2	1	0	6	LOW
FH-04	Millbrook	Maybush: Brownhill Way, adjacent to Tennis Centre and up to City boundary (to the west)	1	3	0	4	0	1	0	2	0	1	2	6	MEDIUM
FH-05	Millbrook	Redbridge: Redbridge Community College, Cuckmere Lane	2	0	0	2	0	0	0	2	0	1	2	5	LOW
FH-06	Millbrook	Wimpson: Evenlode Road (junction with Ingleton Road)	1	0	0	1	0	0	0	2	0	1	2	5	LOW
FH-07	Millbrook	Millbrook: Mason Moor Primary School, Shinewall Gardens	2	0	0	2	2	1	0	2	0	1	0	6	LOW
FH-08	Millbrook	Aldermoor: Conifer Road, Palm Road, Oliver Road, Coxford Road	1	0	0	1	0	1	0	2	2	1	0	6	LOW
FH-09	Millbrook	Aldermoor: Aldermoor Road (crossing point with Tanners Brook)	0	0	0	0	0	0	0	2	0	1	2	5	LOW
FH-10	Millbrook	Bassett: Golf Course Road, Greenbank Crescent, Holly Hill	1	1	0	2	0	0	0	0	0	1	2	3	LOW
FH-11	Millbrook	Lordswood: Dale Valley Road (junction with Lordswood Road), Lordswood Sports Centre, Redhill Close	1	0	0	1	0	0	0	2	0	1	2	5	LOW
FH-12	Millbrook	Lordswood: Dale Valley Road (between junctions with Dale Road and Lordswood Road)	1	1	0	2	2	1	0	2	2	1	2	10	MEDIUM
FH-13	Millbrook	Upper Shirley: Spire Southampton Hospital	0	3	0	3	0	0	1	2	0	1	2	6	LOW
FH-14	Millbrook	Shirley Warren: Southampton General Hospital, Princess Anne Hospital	0	3	0	3	0	1	0	2	2	1	2	8	MEDIUM
FH-15	Millbrook	Old Shirley: Old Mill Way (merging point of Tanners Brook and Holly Brook), Percy Road	1	3	0	4	2	1	1	2	2	1	2	11	HIGH
FH-16	Millbrook	Freemantle: Millbrook Road West (intersection with Paynes Road to roundabout with Teboura Way)	2	3	0	5	2	1	1	2	2	1	2	11	HIGH
FH-17	Millbrook	Shirley: Tauntons College, Wilton Gardens	2	1	0	3	0	1	0	2	2	1	0	6	LOW
FH-18	Millbrook	Freemantle: Firgrove Road/Park Road (junction with Pitt Road, Cawte Road)	1	1	0	2	2	1	0	2	2	1	2	10	MEDIUM
FH-19	Millbrook	Banister's Park: Archers Road (junction with Northlands Road to junction with Silverdale Road)	1	1	0	2	2	0	0	0	0	1	2	5	LOW
FH-20	Millbrook	The Polygon School	2	0	0	2	0	0	0	2	0	1	2	5	LOW
FH-21	Millbrook	Southampton Central Station	2	3	3	8	2	1	1	2	2	1	2	11	HIGH
FH-22	Millbrook	Bevois Valley: Imperial Road/Empress Road, Mount Pleasant Junior School	3	0	0	3	2	1	0	2	2	1	2	10	MEDIUM
FH-23	Millbrook	Near Golden Grove, between London/Southampton main line and park area	0	3	0	3	0	0	0	2	0	0	0	2	LOW
FH-24	Millbrook	Nichols Town: St Andrews Road, Southampton University	3	3	2	8	2	1	1	2	0	1	2	9	HIGH
FH-25	Millbrook	Ocean Village: area surrounding Queens Park, Terminal Terrace	1	3	2	6	2	1	0	0	2	1	2	8	HIGH
FH-26	Millbrook	Lansdowne Park: Western Esplanade leading into Harbour Parade	3	2	3	8	2	1	1	2	0	1	2	9	HIGH
FH-27	Portswood	Bitterne: Glenfield Avenue near and including Portswood Junior School, Beech Avenue (junction with Maybray King Way) crossing over to Chessel Crescent	2	0	0	2	0	0	0	2	2	1	2	7	LOW
FH-28	Portswood	Bitterne: Bitterne Rail Station, Macnachten Road	1	3	0	4	0	1	0	1	2	1	2	7	MEDIUM
FH-29	Portswood	Madanbury: Cleveland Road/Lytham Road at junction with Cleveland Court	1	0	0	1	0	0	0	2	0	1	2	5	LOW
FH-30	Portswood	Midanbury: Moorlands Primary School	2	0	0	2	0	0	0	2	2	1	0	5	LOW
FH-31	Portswood	Townhill Park: Meggeson Avenue (junction with Ozier Road) continuing into Forest Hills Drive	2	0	0	2	0	0	0	0	0	1	0	1	LOW
FH-32	Portswood	Townhill Park: River Walk	1	0	0	1	2	1	0	2	0	1	2	8	MEDIUM
FH-33	Portswood	Townhill Park: Dell Road/Woodmill Lane (at Bitterne Park School)	1	0	0	1	2	1	1	2	0	1	0	7	LOW
FH-34	Portswood	Townhill Park: Hillside Avenue (junction with Appleton Road)	1	0	0	1	0	0	0	2	0	1	0	3	LOW
FH-35	Portswood	Swaythling: A335/A27 Stoneham Way (junction with Wide Lane)	2	3	0	5	2	1	0	2	0	1	2	8	HIGH
FH-36	Portswood	Swaythling: A35 Stoneham Lane (junction with Carnation Road) leading on to junction with A335	2	3	0	5	2	0	0	2	2	1	0	7	MEDIUM
FH-37	Portswood	Portswood: Portswood Road (junction with Westridge Road, leading into Woodside Road	3	2	0	5	0	1	0	2	0	1	2	6	MEDIUM
FH-38	Portswood	Portswood: Belgrave Road, Thomas Lewis Way (adjacent to Sewage Treatment Works), Saltmead	1	3	0	4	0	1	0	2	1	1	2	7	MEDIUM
FH-39	Portswood	Portswood: London-Southampton railway line in vicinity of St Denys Road bridge (1km cutting section, north of St Denys Station)	0	3	0	3	0	0	0	2	0	1	2	5	LOW
FH-40	Woolston	Weston Common: Linacre Road	2	1	0	3	0	0	0	2	2	0	2	6	LOW
FH-41	Woolston	Thornhill: Hinkler Road (junction with Warburton Road), Proctor Close extending to Linacre Road	1	1	0	2	0	1	0	2	2	1	2	8	MEDIUM
FH-42	Woolston	Thornhill: Somerset Avenue (junction with Cheriton Avenue)	2	0	0	2	2	0	1	2	2	1	2	10	MEDIUM
FH-43	Woolston	Thornhill: Bitterne Road East (junction with Somerset Avenue), Sunningdale Gardens, Nursery Gardens	1	1	0	2	0	0	0	2	0	1	2	5	LOW
FH-44	Woolston	Merry Oak: Poplar Road, Spring Road	2	0	0	2	0	0	0	2	0	1	2	5	LOW
FH-45	Woolston	Itchen: Bridge Road (junction with Radstock Road)	2	1	0	3	0	1	1	2	2	1	2	9	MEDIUM
FH-46	Woolston	Itchen: Spring Road (junction with Rosoman Road)	1	1	0	2	0	0	0	2	2	1	0	5	LOW
FH-47	Woolston	Bitterne: Dean Road, Pound Street (junctions with Maybray King Way)	2	0	0	2	0	1	0	2	2	1	2	8	MEDIUM
FH-48	Woolston	Botany Bay: Botany Bay Road	1	0	0	1	2	0	0	2	2	1	2	9	MEDIUM
FH-49	Woolston	Woolston: Archery Road (Jurds Lake)	2	2	0	4	0	1	0	2	0	0	0	3	LOW
FH-50	Woolston	Merry Oak: Merridale Road, Peartree Road	2	1	0	3	0	0	0	2	0	1	2	5	LOW
FH-51	Woolston	Botany Bay: Spring Road near Millers Pond, A3025 (Portsmouth Road)	1	3	0	4	2	1	0	2	2	1	0	8	HIGH

Table 15.1 – Flooding Hotspots Risk Rating

This system adopts a combined monetised/non-monetised approach to scoring the criteria. Monetised assessment can provide a more comprehensive evaluation of costs and benefits. However, the quality of data and resulting modelling available for the SWMP study, has reduced the accuracy of the monetised decision-making approach.

Recommendations are made at the end of this study as to how modelling can be developed, which in turn would allow more comprehensive analysis.

15.2 Sub-Options for Assessment

Whilst a broad definition is given to the options listed in the previous chapter, it is important to relate these to the high-risk hotspots and expand upon the 'sub-options' suitable for implementation at each location. These sub-options are more clearly defined below.

15.2.1 Option 7a: Controls to Tanners Brook Channel (FH-16)

This option covers the open-channel section between Lordsdale Greenway and Millbrook Road West. At present the flow within the channel is generally laminar and uninterrupted, which allows water to be channelled more quickly to the lower sections of Tanners Brook owing to the continuous concrete cross section. Where connections are made with other culvert sections and the effects of tidal ingress are experienced, there is a greater risk of flooding in the vicinity of hotspot FH-16.

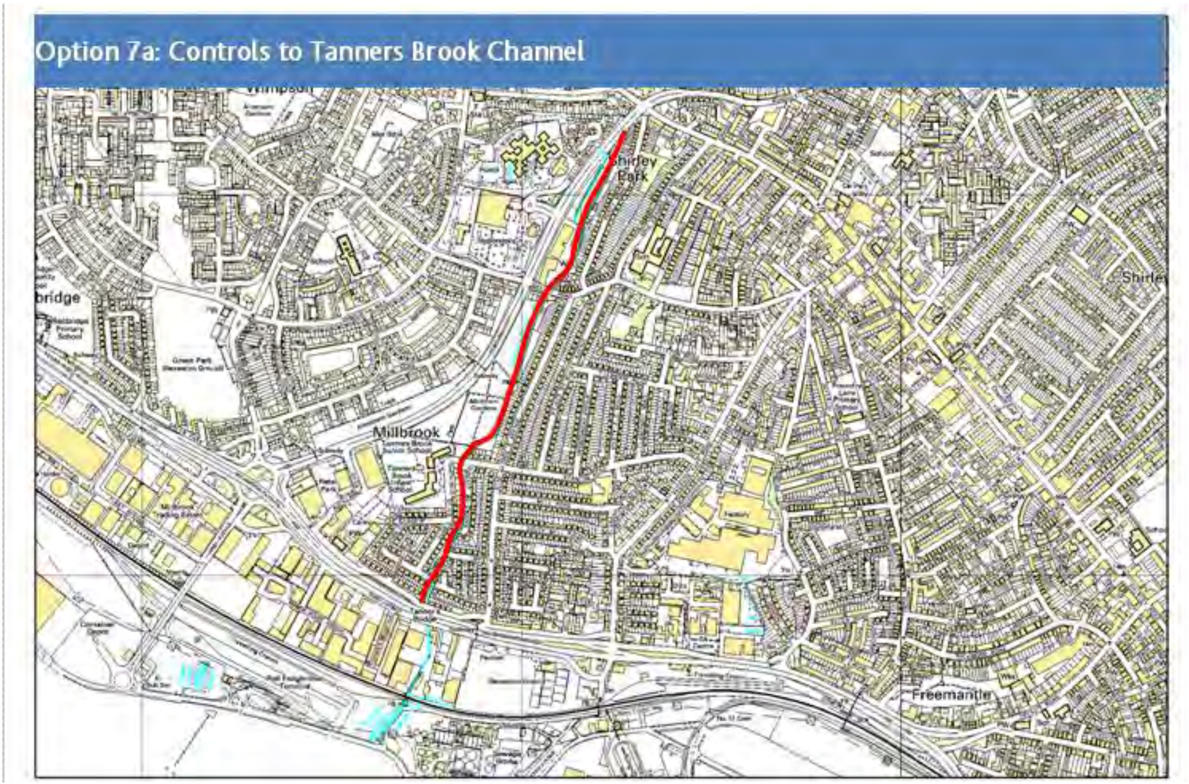

Figure 15.1: Option 7a location and extents

We are confident that if on-line controls are introduced within the watercourse, in order to restrict flows during significant storm events, the delay of discharges of water at the lower end of the catchment will consequently reduce the flood risk. This may be achieved through the use of:

- In-line baffles or riffles within the channel to slow and agitate flow, reducing the energy passed downstream.
- Weirs, with openings for regular flows during normal conditions, to allow water to be stored upstream of these features when necessary. Typically, this section of watercourse is greater than one metre in depth over the length of the channel, which would allow implementation of this method of flow restriction.
- Penstocks and gates: It may be possible to install these at appropriate intervals along the channel, where they can be easily accessed for manual control and maintenance (operating organisation to be identified). In a long term it may be feasible to automate the penstocks but this is not thought to appropriate during early stages of implementation of mitigation measures.

Such techniques are in line with the mitigation measures identified for Tanners Brook in accordance with the WFD.

15.2.2 *Option 7b: Controls to Holly Brook (FH-15)*

This option covers Holly Brook, from Southampton Sports Centre to its merging point with Tanners Brook. Opportunities exist to attenuate/retain water in green areas adjacent the brook during periods of heavy rainfall. Storing volumes of water in the upper reaches of the system and releasing them in a controlled manner over a longer duration will create additional capacity within the culverted sections downstream.

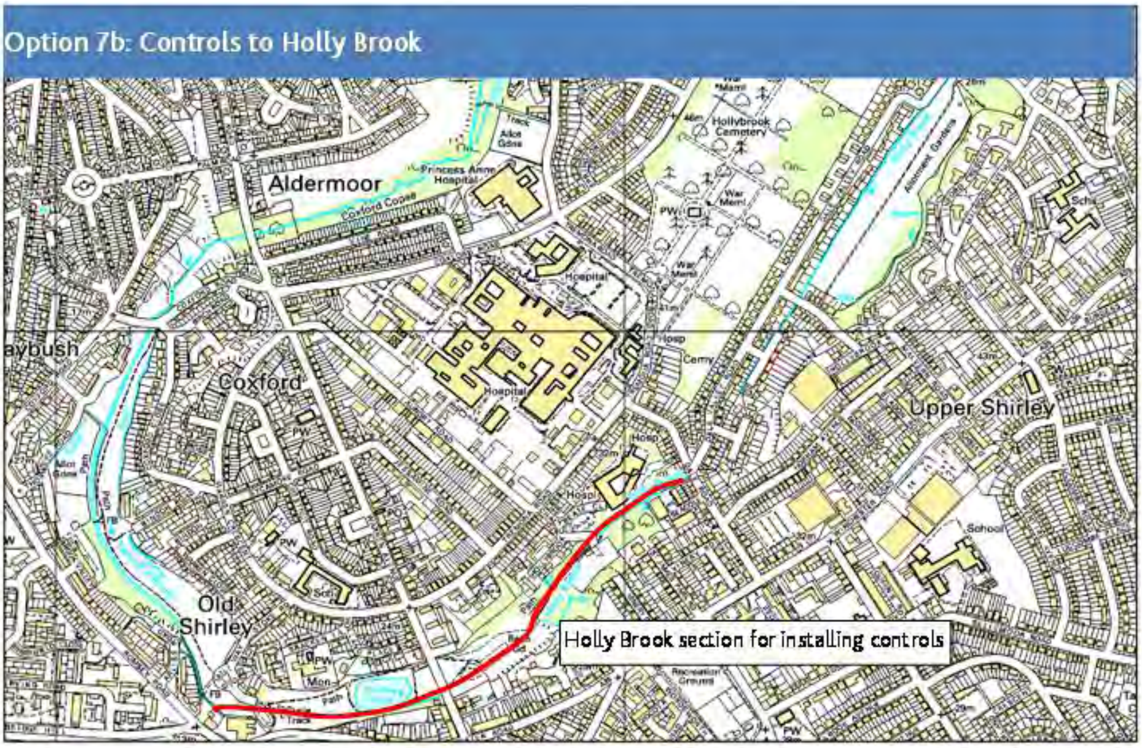

Figure 15.2: Option 7b location and extents

Such controls may be possible on existing structures, including the culvert inlet to the north of Shirley Ponds play area. Use of natural materials to create baffles or weirs through the Lordsdale Greenway area should be considered in undertaking these measures. Once detailed design has been undertaken it may be appropriate to include control features to the channel section of Holly Brook, alongside Dale Valley Road.

15.2.3 *Option 7c: Controls to Tanners Brook (FH-15)*

The Tanners Brook proposal includes the section from the Lords Hill Way underpass to its merging point with Tanners Brook. Opportunities exist to attenuate/retain water in the localised green areas around the brook during periods of heavy rainfall. Storing volumes of water in the upper reaches of the system and releasing them in a controlled manner over longer durations will create additional capacity within the culverted sections downstream.

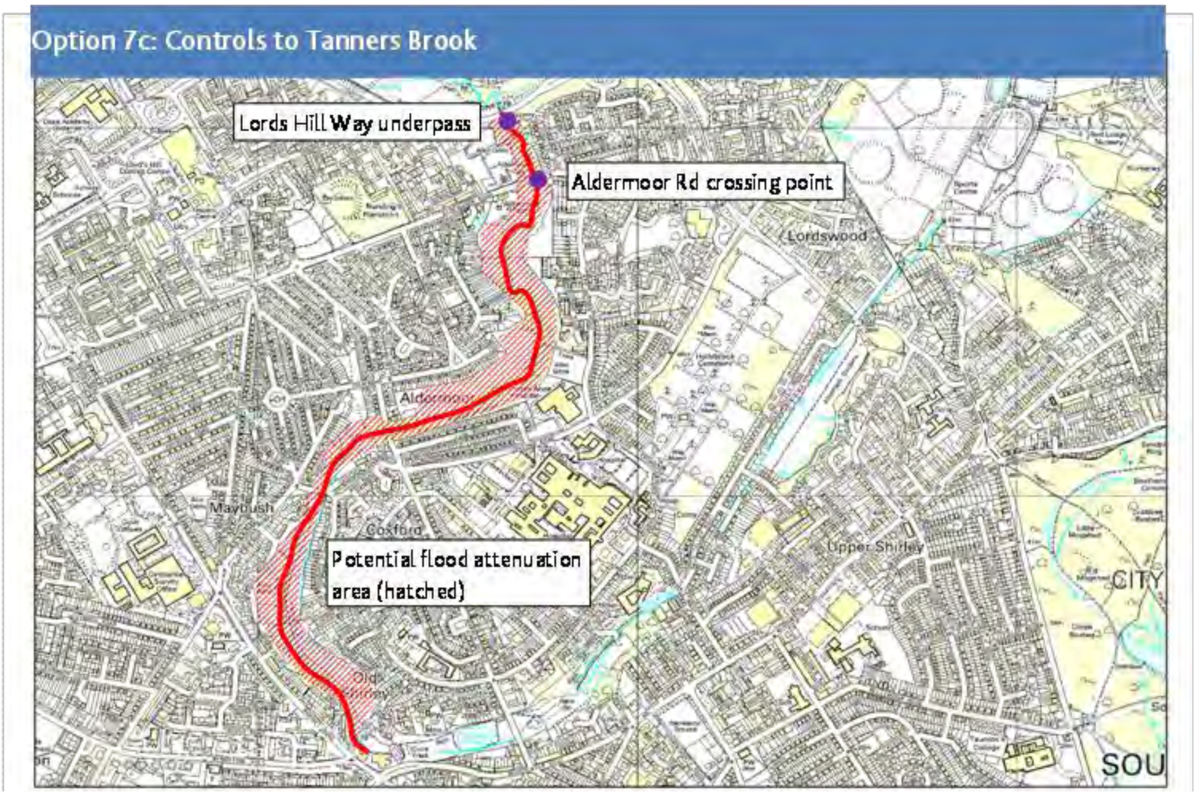

Figure 15.3: Option 7c location and extents

As suggested with Holly Brook, controls may be possible on some of the existing structures, including Aldermoor Road crossing and Lords Hill Way underpass. Once again the use of natural materials to create baffles or weirs through the Lordsdale Greenway area should be considered.

15.2.4 Option 7d: Controls to Rolles Brook (FH-21, FH-26)

The section of Rolles Brook watercourse, between the cemetery at Southampton Common, to West Hill Court immediately to the north of Southampton Central Station are included within this option. The brook drains into a culvert system which passes under the station and is a well known flooding location. The brook has recently been designated as a main river, due to concerns about its contribution to local flood risk[13]. It may be possible to utilise natural, un-culverted sections of the brook through the installation of on-line controls.

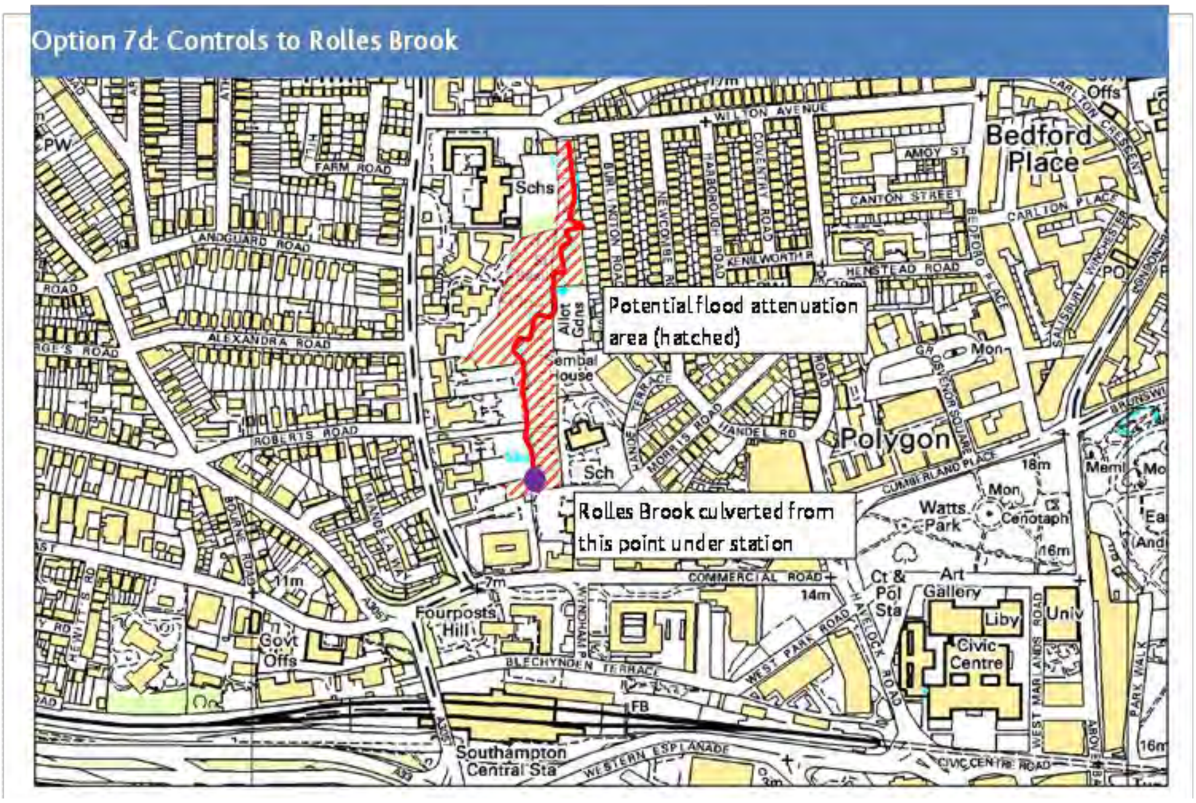

Figure 15.4: Option 7d location and extents

In March 2010, a report was published by the River Restoration Centre entitled ‘Opportunities for River Enhancement on the Rolles Brook, Southampton’. Whilst urban constraints are noted, the discovery of extensive stands of Japanese Knotweed along the watercourse will require major control prior to the implementation of any flood mitigation works.

[13] 365 Environmental Services(February 2010), Culvert Inspection: Survey and Condition Assessment Report – Rolles Brook (lower culverted section) on behalf of EA

15.2.5 OPTION 8A: SUDS SCHEME AT LORDSDALE GREENWAY (TANNERS BROOK SECTION) (FH-15)

The area considered appropriate for the introduction of a SUDS-based scheme under this option, includes the open space running alongside the channelled section of Tanners Brook in Lordsdale Greenway. There is major potential to introduce a variety of SUDS schemes, including:

- Re-routing of Tanners Brook through the green area, creating a potential meandering watercourse
- Overflow from Tanners Brook channel into off-line retention pond (controlled outfall back into channel further down)
- 'De-channelling' of Tanners Brook into two-stage watercourse, using stone filled cages.

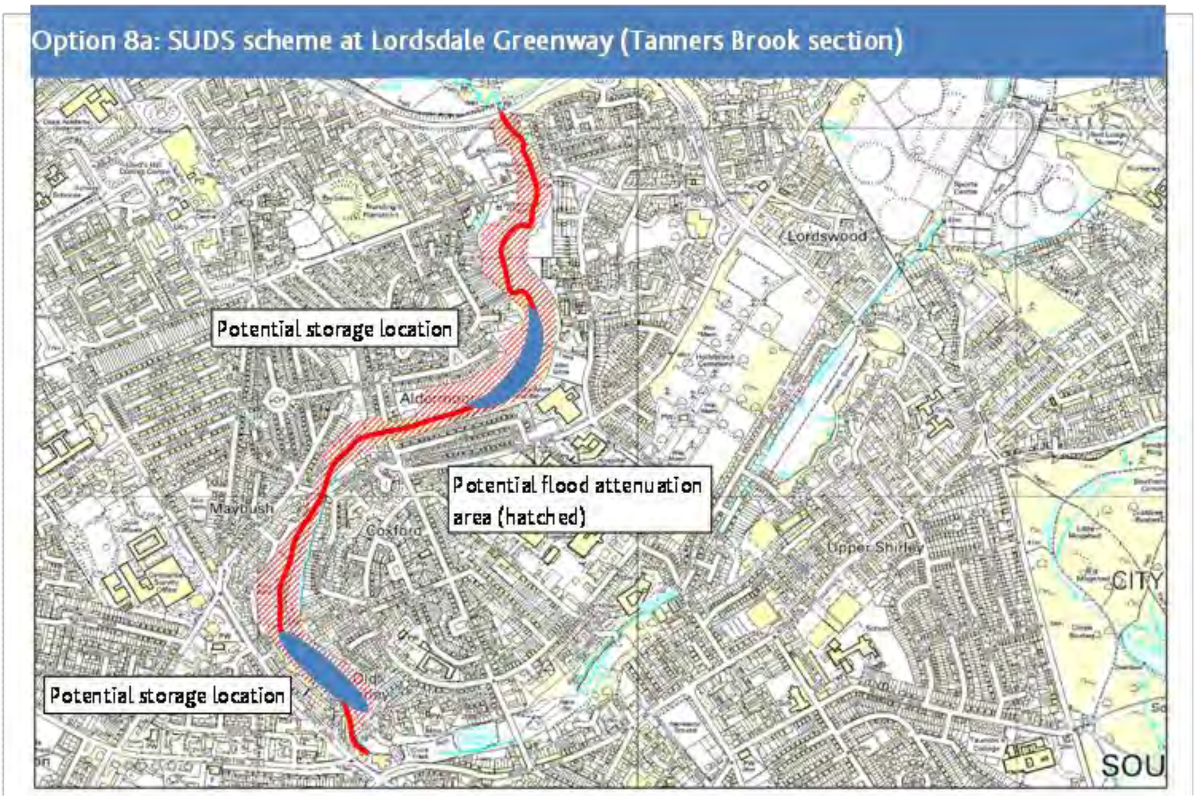

Figure 15.5: Option 8a location and extents

Such a scheme could enhance the biodiversity and increase the amenity value of the area through creating additional scope for and expanding upon the ecology already present within the Lordsdale Greenway. WFD objectives would be met though possible improved water quality and creation of physical habitat. The tracks/footways running through this area would be upgraded and incorporated within the SUDS scheme to improve access and movement to the public.

Whilst any additional benefits created by the mitigation works are to be welcomed it must be remembered that the primary function of these works is to provide attenuation, through the creation of additional upstream storage volume.

15.2.6 *Option 8b: SUDS scheme at Lordsdale Greenway (Holly Brook section) (FH-15)*

The scheme proposed here covers Holly Brook, between Shirley Pond and the junction with Tanners Brook downstream. It is proposed that this section, approximately 500m long, is de-culverted and the grassed field area to the west of Shirley Pond utilised for a retention pond. This SUDS approach is recommended to make the most of the available area, which is smaller than the Tanners Brook section proposed in Option 8a. Subsequent discharge from the retention pond would be controlled into Tanners Brook. This outlet could be either over a weir if it were decided to retain a wet area or through a small orifice level invert control structure to return the area to a dry state following a storm event.

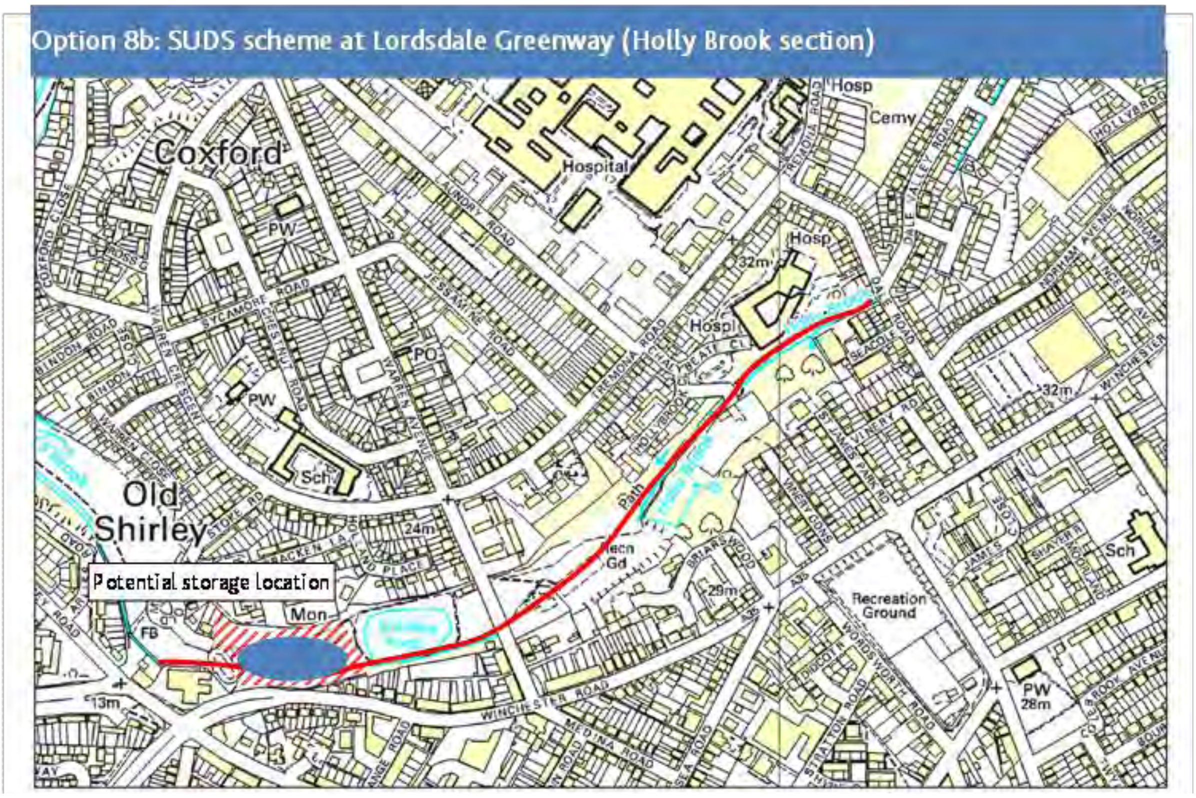

Figure 15.6: Option 8b: location and extents

The option creates an opportunity to expand upon the ecological habitats in the Shirley Park area and Greenway as a whole. Consideration of the benefits for ecological improvements should form part of the design process for this location.

Figure 15.7: Option 8b – SUDS scheme at Lordsdale Greenway, Holly Brook section (Shirley Pond in background)

15.2.7 *OPTION 8C: DE-CULVERTING THROUGH MILLERS POND PARK (FH-51)*

Millers Pond Park covers a area of open grassland, bordered on the south side by the railway line between Woolston and Netley, the line being on an embankment (see Fig. 15.8).

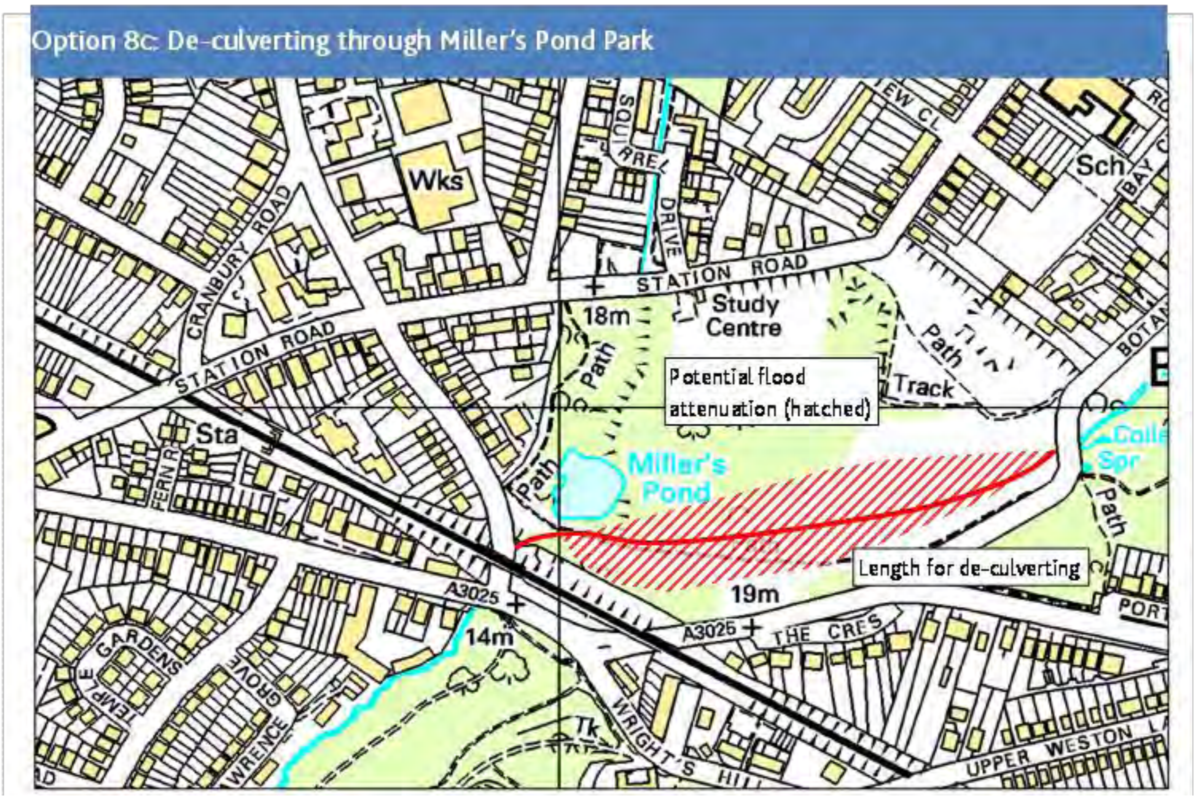

Figure 15.8: Option 8c location and extents

This option proposes the de-culverting of the surface water sewer running south-westwards between Spring Road and Botany Bay Road. Improvements could be made to the green area through the introduction of a two-stage, meandering watercourse.

Figure 15.9: Option 8c - De-culverting through Millers Pond Park (culvert manhole on right)

De-culverting together with a nominal meander would create longer channel length giving the opportunity for energy to be dissipated resulting in slower flows than currently experienced within the culvert. By changing the flow characteristics and creating localised flood storage, the capacity demand placed on the culvert under Portsmouth Road is reduced during significant storm events.

Immediately upstream and downstream of the culvert section are open watercourses running through woodland – the southern watercourse running adjacent to the Golden Jubilee Butterfly Walk. It is believed that ecological benefits could be achieved by linking the two systems, including the Miller's Pond area (and associated watercourse) to the north, as well as the primary objective of flood attenuation.

15.2.8 OPTION 8D: OFF-LINE DETENTION POND AT SOUTHAMPTON SPORTS CENTRE (FH-15)

Flood modelling indicates the residential area along Dale Valley Road is at significant risk of flooding from the channelled section of Holly Brook. The area indicated to be at risk extends southwards to include parts of The Spire hospital site. The area around this section of Holly Brook is heavily developed, with residential properties extending to the edge of the channel on both sides.

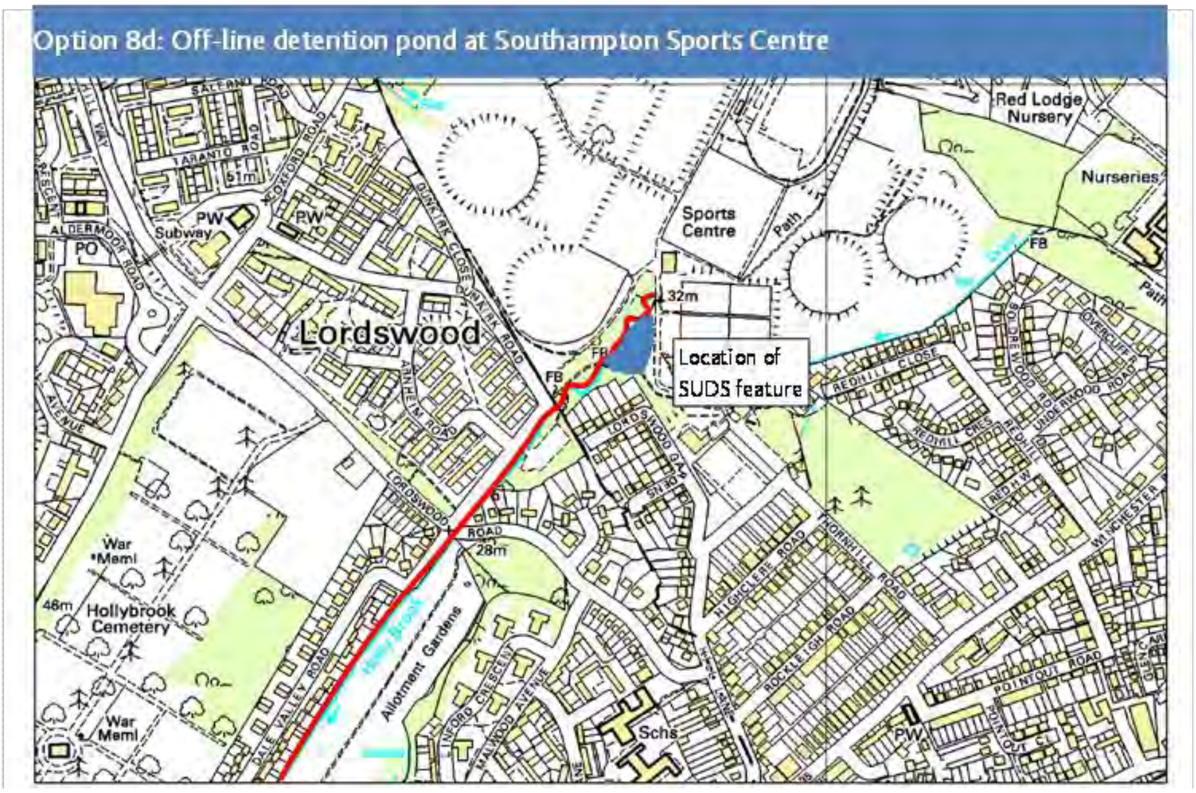

Figure 15.10: Option 8d location & extents

Immediately upstream of Dale Valley Road, there is an opportunity to create an off-line detention pond at Southampton Sports Centre (see Fig. 15.10). Surface water flows could thus be attenuated and controlled, reducing the flood risk locally downstream. Benefits of upstream storage include controlling of flows into Tanners Brook at hotspot FH-15.

Figure 15.11: Option 8d - Retention Pond at Southampton Sports Centre

15.2.9 *Option 8e: SUDS Scheme Within Southampton Common (FH-21, FH-26)*

Southampton Common is a large open space to the north of the city centre. The common consists of approximately 320 acres of woodland, parkland, rough grassland, ponds and wetlands. The common area drains into Rolles Brook watercourse, which is a key surface water flow path towards the hotspots identified at Southampton Central Station and West Quay.

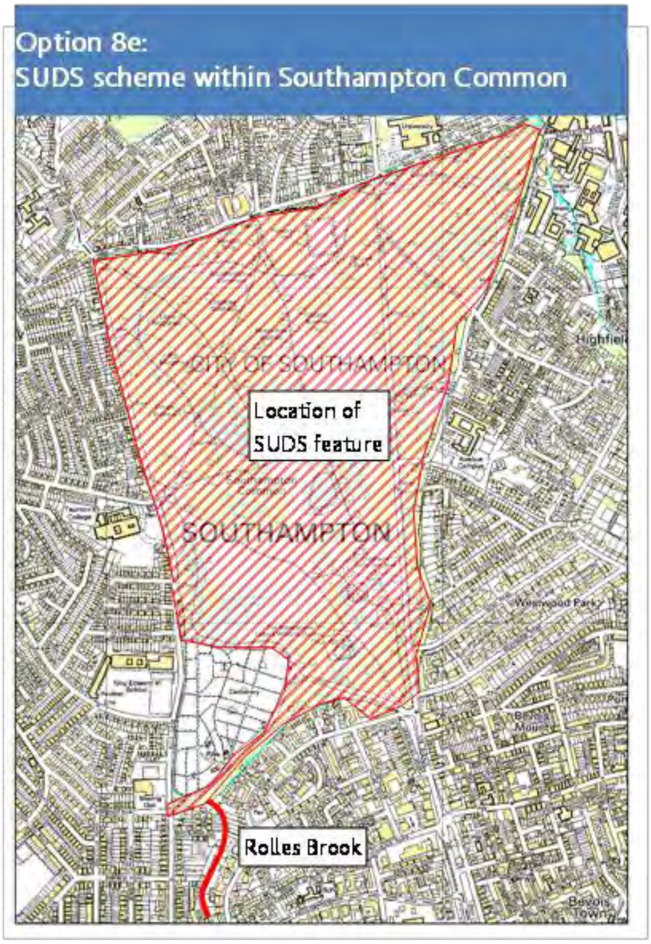

Figure 15.12: Option 8e location and extents

A large majority of the common is designated as a Site of Special Scientific Interest (SSSI) which would normally restrict any alterations to the area. However, initial consultation with SCC Parks and Open Spaces team suggest this may not necessarily prevent the implementation of a SUDS drainage-based scheme. This possibility would require detailed investigation and consultation with Natural England before the option could be taken further.

The detailed design of any option at this location would utilise suitable areas within the common to create additional flood attenuation ponds. In particular the area which lies outside of the SSSI, at the outlet to Rolles Brook, would be the primary location for a recommended scheme. It is proposed that a SUDS scheme incorporating a retention pond is developed, with a controlled outlet into Rolles Brook. By placing the pond at the lower (downstream) end of the common to the south, it is possible to attenuate a large percentage of surface water runoff generated on the common. Locating the attenuation pond elsewhere within the common may have limited benefits and requires more extensive connection into the existing drainage systems.

By controlling runoff/flows into Rolles Brook from Southampton Common and its associated catchment, it will be possible to reduce some of the flooding risk to Southampton Central Station, West Quay and key development sites further downstream. Less critical hotspots FH-19 and FH-20, which occur close to Rolles Brook should also benefit from these specific measures. Further consultation is required with the partners to establish the feasibility of developing a SUDS-based attenuation scheme within Southampton Common.

15.2.10 *OPTION 8F: SUDS SCHEME WITHIN ROLLES BROOK (FH-21, FH-26)*

Rolles Brook is a small watercourse which flows south from Southampton Common approximately 1km to a culvert around 400m north of the Southampton Central Station which then continues on under the station. Approximately 1 year ago, the brook was designated as a main river because of concern about its contribution to local flood risk[14].

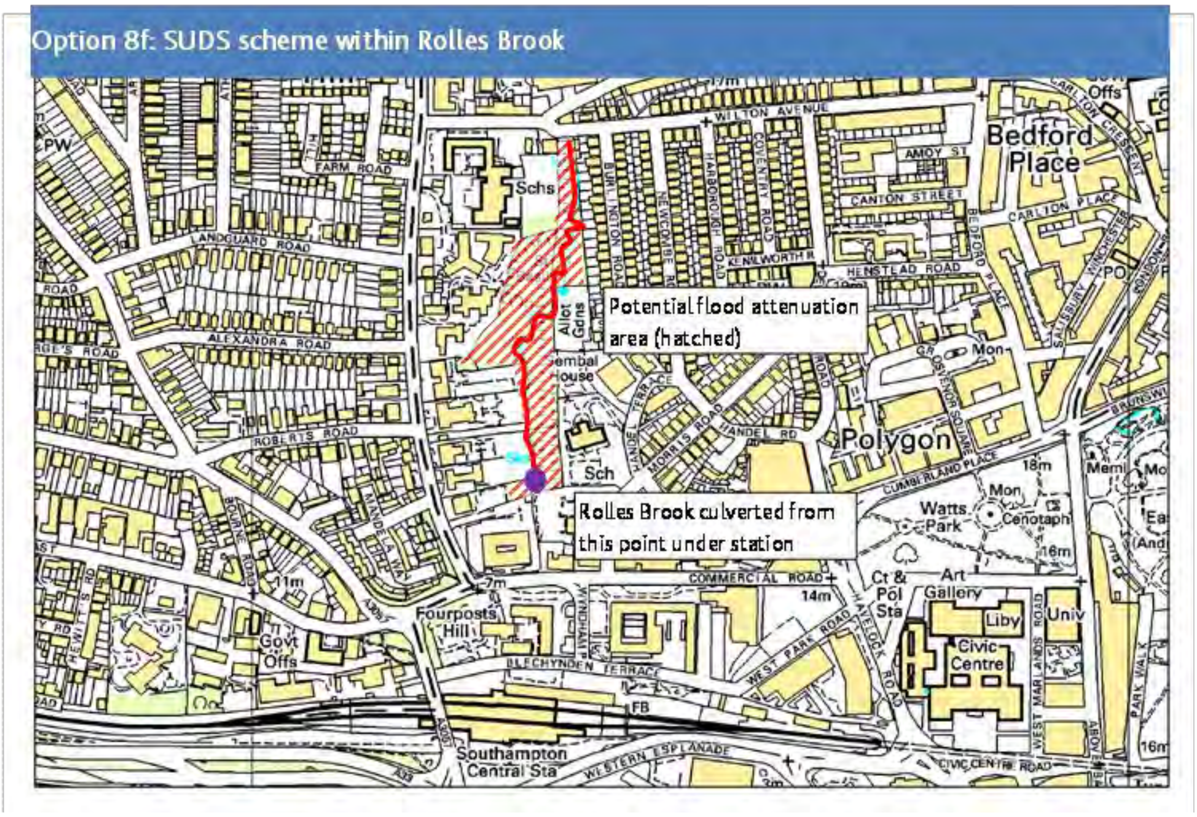

Figure 15.13: Option 8f Locations and Extents

It is proposed that the brook is developed to include a SUDS scheme encompassing a meandering flow if possible, with hollows for temporary attenuation. Alternatives which provide a similar variation to the flow characteristics/additional storage, such as two stages are also recommended. Before detail design is prepared it will be necessary to undertake major survey works along the course of the brook to determine the most appropriate design.

In March 2010, a report was published by the River Restoration Centre entitled 'Opportunities for River Enhancement on the Rolles Brook, Southampton'. Whilst urban constraints are noted, the strategic importance of the brook in respect to the high-risk hotspots justifies the inclusion of this measure within the options

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[14] 365 Environmental Services(February 2010), Culvert Inspection: Survey and Condition Assessment Report – Rolles Brook (lower culverted section) on behalf of EA

assessment. Implementation of this option may incur higher capital and maintenance costs due to the extensive stands of Japanese Knotweed along the watercourse, which will require major treatment and control.

15.2.11 *Option 9a: Implementation of Green Roof schemes*

Options for surface water control are essentially only appropriate within new greenfield or brownfield development. Green roofs can also provide a range of benefits, including:

- Reduce cooling loads on a building by fifty to ninety percent[15]
- Reduce stormwater run off
- Natural Habitat Creation
- Filter pollutants and carbon dioxide out of the air which has been indicated could assist in lowering disease rates such as asthma[16]
- Filter pollutants and heavy metals out of rainwater.
- Help to insulate a building for sound; the soil helps to block lower frequencies and the plants block higher frequencies.[17]

The use of green roofs is still in its infancy and there is often a reluctance to consider the use of such options. However, if considered more seriously for communal buildings where the onus of maintenance may not be directly the responsibility of residents, then acceptance of such methods should gain momentum.

As a consequence it is recommended that consideration of Green Roof schemes are included as an integral part of planning procedure for new developments, and particularly into the key development schemes currently identified by SCC. Many of these sites are located adjacent to the main surface water culverts draining Southampton. In particular, key development sites 1, 4 and 5 lie over the route of the 2.1m diameter culvert which outfalls to the Mayflower Park pumping station, and high-risk hotspots FH-21 and FH-26. The introduction of green roofs will help to reduce contributing flows from these developments and reducing peak stormwater runoff. The use of Green Roofs has been promoted within the SFRA2 as a valuable technique in the urban environment to reduce existing site runoff.[18]

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[15] Living Roofs designer http://www.roofgreening.ca/living_roofs.php

[16] http://www.roofgreening.ca/content/AirQuality_Final.pdf

[17] Green Roofs for Healthy Cities: About Green Roofs. www.greenroofs.org

[18] PUSH (August 2010), Level 2 Strategic Flood Risk Assessment, Volume 1, Section 4.29

15.2.12 *Option 9b: Implementation of rainwater recycling schemes*

Rainwater recycling systems, also known as rainwater harvesting or greywater recycling, is now a widely established method of intercepting surface water runoff for re-use within a variety of developments. Harvested/recycled water can be used for flushing toilets, irrigation and vehicle wash-down areas. If the water is treated after collection, the range of uses can be significantly increased.

It is recommended that the consideration of rainwater harvesting and greywater recycling is incorporated as an integral part of planning procedure for new developments. The key development sites currently identified by SCC should consider the use of rainwater recycling schemes in order to cut the surface water runoff into the sewer network. Several sites are located in proximity to high-risk flooding hotspot areas. Reducing the contributing flows to these sections of the surface water system will help to reduce the risk of flooding.

15.2.13 *Option 9c: Implementation of permeable pavements*

Permeable pavements are load-bearing constructions, surfaced with materials that allow surface water to enter the underlying construction. The surfacing material can itself be porous, or water can enter the sub-base through joints and spaces between impermeable blocks. By using permeable pavements, runoff is stored and conveyed through the sub-base construction. It also removes the need for conventional drainage infrastructure elements, such as gulley pots and manholes.

This option proposes the use of attenuating permeable pavements within key development sites, where possible. It is not advised that infiltration-based systems are adopted, due to potential leaching of pollutants over time and the recognition within the Southampton SFRA2 that infiltration based systems are not advised within the Southampton area .

15.3 Quick Wins

Quick wins are immediate actions which can be implemented to reduce surface water flooding without the need for further assessment, or the inexpensive location of points which require limited action to achieve a 'quick win'. The 'quick wins' indentified within the scope of the Southampton SWMP study are:

- CCTV surveying and inspection of the surface water network within high-risk (hotspot) or strategic areas. A CCTV drainage survey undertaken in February 2010 to the Central Station system demonstrates how the condition of a key drainage network could contribute towards or worsen the flooding. At present there is limited information relating to the condition of the surface water sewers in high-risk hotspot and strategic areas.
- Maintenance and clearing of the Millbrook ditch, running on the southern side of the London-Southampton main line. The ditch is of strategic importance, connecting culverts which drain the city from the north to the outlet at King George V dry dock.
- Prioritising planned maintenance works, currently scheduled by SCC Highways, that are linked to high-risk flooding hotspots, including maintenance and cleaning/jetting of gullies.
- Updating the flood response plan and other emergency planning functions using the modelling and conclusions of the SWMP study. For instance, the plan can be updated to include roads and rail transport infrastructure identified as being at highest risk of flooding.

- Category 1 responders, identified within the SCC Emergency Flood Response Plan, should be updated with the findings, datasets and conclusions reached within the SWMP, so this information can be reviewed and revised as part of the risk assessment process at local and county level.
- Information within the SWMP study should be used to support decision-making based upon known watercourse/surface water infrastructure locations within the city which are due for attention and may not be as effective as they might be.

16. Conclusions

Southampton's flooding risk hotspots are related to the major flow paths based on the overall topography of the area rather than on urbanisation. The urban development of the city has followed the general topography hence the hotspots are essentially related to topography. The interaction between the increased flows in watercourses together with the expansion of the city, have led to the progressive culverting and channelling of downstream sections.

Urbanisation heavily impacts upon the flow characteristics of watercourses and drainage systems through the city. Storm water flows faster, due to reduced friction from lined watercourses and in smooth bore pipes, and discharges to the lower reaches quicker. Flow is directed linearly between manholes, as opposed to meandering stretches which extended flow paths and reduce velocities. In many areas, urbanisation has encroached up to the edges of the watercourse and in culverted sections, over the top of them. Natural surface water attenuation areas have been removed, leading to flooding, effectively natural attenuation, occurring within the urban areas of the city during extreme rainfall events, resulting in transit disruption and access difficulties to the general population.

The problem of flooding is exacerbated through the flow restrictions at the outfalls, especially for the Millbrook and Portswood catchments, in the west. Several culverts are below the high tide level of the River Test and are thus affected by tidal locking. During high tide events culvert capacities are reduced, which throttle surface water flows. At Mayflower Pumping Station, the multi-flap outfall will hold back tidal waters, unless the surface water pressure head within the culvert exceeds tidal effects. In this case, the multi-flaps will open to allow the surface water to drain. At Pumping Station No.7 (King George V Docks), draining the Millbrook culvert, the discharge of surface water is entirely dependent upon the pumped outfall arrangement (see Section 8.1.2).

Not surprisingly, the flood risk is highest within Southampton when high tides and extreme rainfall events occur simultaneously. Surface water is channelled from the upper catchment reaches into gradually more charged drainage networks, which are affected at the outfalls by tidal locking. Surcharging then occurs within the immediate culvert networks, potentially leading to flooding incidents nearby, such as the Central Station, West Quay, A33 Millbrook Road West and city centre.

Although not conclusive, it is understood until further investigation, that the pumping stations have sufficient capacity to discharge surface water during extreme rainfall/tidal events. Operating records from the pumping stations during the 2008 floods together with discussions with the SWMP Partners, demonstrate that the pumps at Mayflower Park and Pumping Station No.7, are manually initiated but essentially operate individually, intermittently and generally for limited periods. The main drainage limitations at the outfalls are predominantly tidal and not linked to capacity restrictions associated with the pumping stations. However, it is relevant to note that Pumping Station No.7 is presently the only mechanism to drain the Millbrook culverts, making it a critical installation with regard to drainage in that area.

The eastern side of Southampton, covering the Woolston catchment, drains to the west. There are two watercourses within the area, although significantly the urbanisation has not encroached onto these to the same degree. This is evident through the natural woodland areas and allotments areas which surround the watercourses. Identified high-risk flood hotspots are limited. The outfall into Southampton Water is by gravity and the main watercourses have not been culverted or channelled. Fewer properties or key infrastructure is affected in the eastern catchment due to the green 'belts' lining the main watercourses.

In developing solutions to reduce flood risk in the western side, the key catchment characteristics of the eastern side should be considered where possible. These include:

- 'Natural' watercourses retained, limited culverting/channelling of surface water flows
- Green belts surrounding watercourses retained
- Outlet into tidal body of water is by gravity, with no tidal locking

Green areas in the western side of Southampton are limited and confined to the upper reaches of drainage networks, away from the city centre. However, the study concludes that these areas should be used to attenuate and control flows at source, by providing upstream storage areas in open spaces.

During the study, it became apparent there was some confusion relating to the ownership, responsibility and maintenance of critical culvert sections running under the Southampton docks, London-Southampton main line and the A33 Millbrook Road West. Ownership of this infrastructure will need to be defined to ensure appropriate future maintenance and repair which if left un-attended increase the risk of surface water flooding.

The Surface Water Management Plan creates an opportunity for the partners, both involved and affected by these drainage sections to *'work together to agree the most effective way of managing surface water flood risk through the process of working together as a partnership to encourage the development of innovating solutions and practises'*.[19] The recommendations are discussed in further detail in Preferred Options and Recommendations section of the report.

It is also possible to develop options to reinforce the downstream urban drainage networks. These are likely to be expensive and disruptive, with localised rather than wider-reaching benefits to the catchment. However, further investigation to determine connectivity and condition of these sewers is required before these options can be fully supported and implemented. These should not be overlooked as potential mid to long term measures.

The DEFRA guidelines recognise that:

'each organisation will inevitable be required to justify the necessary investment independently from the SWMP study. Once the outcome of investment decisions is known, and once partners have tried to secure funding to implement their element of the plan, there may be a requirement to revise the action plan. It is therefore important that partners continue to work together after the SWMP study has been completed.'

[19] PUSH (August 2010) Level 2 Strategic Flood Risk Assessment (Introduction)

17. Preferred Options & Recommendations

17.1 Summary

We believe it is clear from the report that in general any urban area has a limited potential for mitigation measures regarding to flooding. As a consequence the measures need to be heavily related to the drainage infrastructure and rate of discharge to drainage/sewerage networks.

As a consequence it is recommended that flooding in Southampton is managed by implementing options which seek to control and attenuate runoff from extreme rainfall events upstream of the city centre. No schemes are proposed to the urban drainage network at this stage due to the lack of available data necessary to inform and support decision-making.

The preferred options put forward for the implementation phase include:

- Installation of in-channel features (such as baffles and riffles) to Tanners Brook channel section between Winchester Road and Millbrook Road West (option 7a)
- Installation of on-line control features to Holly Brook watercourse section, through Lordsdale Greenway (option 7b).
- Installation of on-line control features to Rolles Brook watercourse section, between Southampton Common and West Hill Court (immediately north of Southampton Central Station)(option 7d).
- Implementation of a sustainable urban drainage scheme within the Lordsdale Greenway area, adjacent to Tanners Brook (option 8a)
- Implementation of a sustainable urban drainage scheme within the Lordsdale Greenway area, adjacent to Holly Brook (option 8b)
- Implementation of a sustainable urban drainage scheme within the Miller's Pond area to attenuate flood water runoff (option 8c).
- Implementation of a sustainable urban drainage scheme to attenuate flood water runoff in the green area identified at Southampton Sports Centre (option 8d)
- Implementation of a sustainable urban drainage scheme to attenuate flood water runoff in Southampton Common (option 8e)

These options are developed to mitigate flooding risk to high-risk hotspots. Options which encompass works to Tanners Brook and Holly Brook would benefit hotspots FH-15 (Lordsdale Greenway) and FH-16 (Millbrook Road West). Options which encompass works to Southampton Common and Rolles Brook will benefit hotspots FH-21 (Southampton Central Station) and FH-26 (West Quay).

17.2 Quick Wins and Long-Term Options

The quick-wins identified within this report should be implemented in conjunction with the preferred options. Hotspots FH-24, FH-25, both City Centre and FH-35, Stoneham Way, can benefit from quick-win solutions. Further investigations into the extents and condition of the urban drainage network are necessary to develop appropriate flood mitigation measures at these locations.

It is recommended that SCC key development sites incorporate where possible sustainable urban drainage systems which seek to reduce/control surface water runoff into the sewerage system. Where possible, developers should be encouraged to implement the use of green roofs (option 9a), greywater recycling schemes (option 9b) and permeable pavements (option 9c). Use of other SUDS schemes should be considered where feasible, including any new approaches/techniques which are developed in the interim period.

17.3 Cost Banding of Quick Wins And Preferred/Long Term Options

The table below provides an indication of the anticipated construction costs involved with each quick win, and preferred option. Long-term options are not considered, since their application within the key development sites needs to be determined. These values should not be considered to represent or incorporate other related flooding costs.

Quick win/preferred option	Cost Banding			
	0-£50k	£50k-£200k	£200k-£500k	£500k +
CCTV surveying & inspection	x			
Additional maintenance tasks	x			
Option 7a: Tanners Brook in-channel features		x		
Option 7b: Tanners Brook watercourse controls		x		
Option 7d: Holly Brook watercourse controls		x		
Option 8a: Tanners Brook SUDS			x	
Option 8b: Holly Brook SUDS		x		
Option 8d: Southampton Sports Centre SUDS		x		
Option 8e: Southampton Common SUDS			x	

Table 17.1: Cost banding of quick wins and preferred options

17.4 Recommendations

The following recommendations are made for further work beyond the implementation of this study:

- By introducing a comprehensive pipe system to the surface water modelling undertaken within the study, it would be possible to refine more comprehensively the flooding risk from the urban drainage system. For example, assess restriction points which cause surcharging and flooding in the areas immediately upstream. However, fundamental assumptions would still remain which could significantly affect the capacity and performance of the system being modelled. Examples of factors which could not be modelled include blocked gullies, blocked or damaged pipes/culverts and mis-recorded (or assumed) pipe sizes. The list of assumptions within this study has been recorded earlier.
- The liability of Mayflower Park and No.7 pumping stations of failure and the affect this would have on the surface water system should be investigated. This may conclude that increased resilience of power supply to pumping stations during large storm events is required.
- Investigating tidal effects by monitoring water levels in the large diameter pipes at the outlets.
- Modifications to LiDAR data (introduce buildings within city centre) – review flooding hotspot areas to determine whether anomalies are present.
- Engineering resilience schemes associated with the pumping stations should be developed to ensure that any failures or reduction in pumping capability is minimised.
- No evidence had been provided indicating that an emergency plan was in place for the operation of pumping stations during flood incidents/extreme rainfall and tidal events. This has been discussed and agreed with the SWMP partners. Conversations during the data gathering phase indicate both Pumping Station No.7 and Mayflower Park Pumping Station are manually operated. During the May 2008 floods, records indicate that the pumps were operated after flooding incidents were being reported. In the case of the Mayflower Park Pumping Station, the pumps were operated 4½ hours after the first signs of flooding were reported, although this was recorded as being outside normal working hours. An emergency plan needs to be implemented (or updated) to ensure that:
    - All parties are familiar with which areas of the city drain into which outlet/pump system. Reports of flooding can be forwarded to the appropriate pumping station contact if pump operation is required.
    - Key personnel are identified within partnership organisations for emergency response issues relating to the pumping stations. In particular, pumping station points of contact should be made available to these key personnel from the partners.
    - Communications are established between partners linking the 'real time' data which is available, to inform and make decisions. In particular, the monitoring of flooding incidents around the city, high tide levels/times and local forecasts should be communicated. Evidence exists from the 2008 floods which indicate that some decisions were taken based upon limited information.
- It is particularly important that partners are involved with decisions made at the preparation and implementation phase, after the issue of this report. Ownership and maintenance responsibilities should be clarified between partners to ensure critical sections of the drainage network do not become blocked or in a poor condition. It is understood that a Flood Board has been established for Southampton City, which meets on a regular schedule. This may represent a suitable forum for the discussion of SWMP matters by all SWMP Partners.

- Urban creep, essentially the increase of impermeable areas, should form part of the planning process, this would include paving of gardens, driveways and similar features. This element should be publicized
- High tide predictions and extreme rainfall events which are expected to occur simultaneously, should be issued as a combined warning, issued by the Environment Agency

18. References

- PUSH (August 2010), Level 2 Strategic Flood Risk Assessment
- DEFRA (March 2010), Surface Water Management Plan Technical Guidance
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