


Strategic Flood Risk Assessment (Level 2) Plympton

Final Report

May 2010

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The Plympton Level 2 SFRA is a 'live' document. The current version has been developed using the best information and concepts available at the time. As new information and concepts become available the document will be updated and so it is the responsibility of the reader to be satisfied that they are using the most up-to-date information and that the SFRA accounts for this information. All revisions to this summary document are listed in the table.

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1 Introduction

1.1 Purpose of this report

In November 2009 Capita Symonds was commissioned by Plymouth City Council (PCC) to undertake a Level 2 Strategic Flood Risk Assessment (SFRA) for Plympton. A SFRA is a planning tool which can be used to inform the spatial planning process. The Plympton SFRA aims to provide a high level assessment of flood risk in Plympton and the Marsh Mills area to the west of Plympton, which can be used to understand the implications of land use planning and change and to inform decisions regarding the future allocation of development sites.

Planning Policy Statement 25 (PPS25) – Planning and Flood Risk states that the SFRA should provide sufficient data and information on all types of flood risk to enable the Local Planning Authority (LPA) to apply the Sequential Test when determining land use allocations and, where necessary, the Exception Test. More detailed information is required where there is deemed to be development pressure in areas that are at medium to high flood risk and there are no other suitable alternative areas for development after applying the Sequential Test.

The Plympton SFRA has been produced in consultation with PCC and the Environment Agency using data from existing sources. Sources of data / information used within the SFRA are:

- Level 1 SFRA and Plymouth Level 2 SFRA;
- Environment Agency Strategic Flood Risk Mapping (SFRM) studies;
- Environment Agency Development and Flood Risk Team;
- Plymouth City Council Planning Services team;
- South West Water.

The main objective of the SFRA is to provide an increased understanding of current and future flood risk across Plympton and Marsh Mills. It will primarily be used to inform the Council's planning policy but will have a wider application in the identification of required action to manage and reduce flood risk.

1.2 Links to other documents

Plymouth City Council has already completed a Level 2 SFRA for Plymouth[1]. This followed on from a Level 1 SFRA[2] undertaken for the whole of the City of Plymouth which identified the key areas that were selected for the Level 2 SFRA. The key areas assessed for the Plymouth Level 2 SFRA were East End, Sutton Harbour and Millbay development areas to the south of the city. These documents

[1] JBA Consulting / Plymouth City Council. January 2008. Plymouth Level 2 Strategic Flood Risk Assessment. Final Report.
[2] Pell Frischmann / Plymouth City Council. August 2006. Strategic Flood Risk Assessment. R02701R001 / A.

include guidance and policy recommendations on the implementation of PPS25; therefore this information has not been repeated within the current document.

Hydraulic modelling of the main watercourses (Tory Brook, Long Brook, and River Plym) within the study area has previously been undertaken by Capita Symonds for Environment Agency SFRM studies[3]; Section 3.1 includes summary of outputs from this work. The model results and datasets from these studies have been made available to PCC and have been used as the basis for the SFRA work.

1.3 Scope of assessment

The Level 1 SFRA identified that fluvial, tidal and surface water were the most important sources of flooding in the Plymouth area and required more detailed investigation. Specific to the Plympton area, the Level 1 report identified the Long Brook and Colebrook as problem drainage areas with inadequate culverts and limited capacity in surface water and combined sewers.

This SFRA provides detailed investigation of:

- The definition of the functional floodplain through Plympton and Marsh Mills.
- The impact of structure blockage on flood risk at two locations on the Tory Brook and two locations on the Long Brook.
- The tidal flood risk in Plympton and Marsh Mills.
- Broadscale surface water flood risk within Plympton and Marsh Mills.
- The type and condition of defences along the Tory Brook, Long Brook and River Plym.
- The impact on flood risk of a fluvial breach of the River Plym defences at May's Marsh.

General information regarding planning framework policy, strategic flood risk guidance and detailed flood risk assessments can be found in the Level 1 SFRA and Plymouth Level 2 SFRA documents.

1.4 Structure of the report

The reader requiring specific information is directed to the following sections:

- Section 2 – Study area
- Section 3 – Flooding from rivers (fluvial flooding)
- Section 4 – Flooding from the sea (tidal flooding)
- Section 5 – Flooding from land (surface water)
- Section 6 – Assessment of defences
- Section 7 – Summary

[3] Capita Symonds. May 2009. SW868: Plympton SFRM Final Report.
Capita Symonds. May 2009 & December 2009. SW872: River Plym SFRM Final Reports.

A discussion of the results and findings of each of the technical assessments can be found within the relevant sections. Section 7 summarises these results and findings, identifies locations susceptible to more than one source of flooding and the flood risk to key areas / vulnerable receptors in these locations. A discussion of the causes and mechanisms of flooding, its severity and issues that need to be addressed is provided.

The maps for each of the technical assessments can be found in Appendix A, as detailed in Table 1.1:

Table 1.1 – Map description

Map Identifier	Map description
Map O1	Overview of the study area
Map FF1 & FF2	Functional floodplain extent and areas for recreation of functional floodplain
Maps B1-B4 (a & c maps)	Flood depths for blockage locations
Maps B1-B4 (b & d maps)	Flood hazard for blockage locations
Maps T1-T3	Flood depths for tidal projection
Maps T4-T6	Current and future defence standard of protection
Map S1	Surface water flooding
Maps D1 & D2	Asset type and condition
Maps B5a & B5c	Flood depths for fluvial breach location
Maps B5b & B5d	Flood hazard for fluvial breach location

2 Study area

2.1 Definition

Plympton is an ancient stannary town located to the east of the city of Plymouth in Devon, just south of Dartmoor National Park, and is separated from the city by the River Plym. The A38 trunk road runs along the southern edge of Plympton. The study area incorporates the entire built-up area of Plympton including the Tory Brook and its associated tributaries and the Long Brook. Both the Tory Brook and Long Brook are tributaries of the River Plym. The study area also includes a short section of the River Plym and the land to the west of the Plym including the Marsh Mills area. Map O1 (Appendix A) provides an overview of the study area.

2.2 Area characteristics

Plympton is a reasonably large town with a population of approximately 35,000. There has been a settlement in this location for about 1,100 years. The oldest part of the town is Plympton St Maurice in the south-east. The town is primarily residential and acts as a commuter town for Plymouth. However there are also significant industrial and trading areas, in particular the industrial and trading estate along Valley Road in the west of the town, and Newnham Industrial Estate towards the north-east outskirts of the town. Langage Industrial Estate and Science Park is located on the eastern outskirts of the town.

It is anticipated that any future development within Plympton will be small-scale infill development and upgrade which will be designed to create a sustainable community. The site of the former cattle market off Market Road has been proposed for redevelopment for housing and a flood risk assessment submitted which proposes mitigation measures in order to satisfy the Exception Test. Work on this development has commenced on the ground. The PCC Strategic Housing Land Availability Assessment[4] provides details of other sites identified as suitable sites for housing within Plympton.

In terms of flood risk the main features in Plympton are the Tory Brook and Long Brook which flow east to west through the town centre to discharge to the River Plym. The River Plym flows south through the western part of the study area, separating Plympton from the eastern suburbs of Plymouth. The River Plym is tidally influenced in this area. Raised defences are present along the River Plym, Tory Brook and Long Brook to protect the town from fluvial and tidal flooding.

Plympton has expanded along the Tory Brook and Long Brook, with some development in the floodplain areas of these watercourses. The slopes rising from the floodplain are steep with fairly dense residential development. The geology of the Tory Brook catchment consists of Granite in the

[4] Plymouth City Council. September 2009. Strategic Housing Land Availability Assessment 2009. Final Report.

upper catchment and Slate in the middle and lower catchment, with alluvium and river gravel along the watercourses. The Long Brook catchment is underlain by Slate with alluvium along the watercourse. Soils within the study area are generally permeable and naturally well-drained. However, infiltration and storage of rainfall is limited on the steep slopes and where a large percentage of the land is covered by impermeable surfaces.

A small section of the River Plym floodplain is contained within the study area in Marsh Mills on the west bank of the River Plym. This area is important in terms of flood risk as it contains significant commercial and industrial development. The underlying geology of the upper Plym catchment is Granite with Sandstone, Slate and Shale in the lower catchment. The soils are generally slowly permeable with some seasonal waterlogging. The steep catchment will also reduce the opportunity for infiltration and storage within the soils. Burrator Reservoir, located in the upper catchment of the River Meavy, a tributary of the River Plym, may result in some attenuation of flood flows. However, it is thought that this effect is likely to be limited in the lower catchment and the area of interest to this SFRA.

In the headwaters of the Tory Brook and River Plym catchments there are historic China Clay workings. These workings are likely to lead to greater attenuation and storage within the catchment, especially at lower flows. It is not possible to quantify the full effect of the China Clay workings for a strategic study without detailed information on the extent of the workings and extensive gauged data. However, catchment gauged data has been used to improve the flow estimates used in the SFRA. The gauged data used in the hydrological assessment suggests that the effect of the China Clay workings is reflected in the recorded flows, and therefore in the SFRA flow estimates.

3 Flooding from rivers

3.1 Introduction

Flooding from rivers occurs when water levels rise higher than bank levels, causing flood water to spill across adjacent land (the floodplain). The main reasons that water levels can rise in rivers are:

- Intense or prolonged rainfall which causes runoff rates and flow to increase in rivers, exceeding the capacity of the channel. This can be exacerbated by wet antecedent conditions and where there are significant contributions to the watercourse from groundwater.
- Constrictions in the river channel.
- Blockage of structures or the river channel.
- High water levels and / or locked flood (tide) gates preventing discharge at the outlet of the watercourse.

The consequence of river flooding depends on how hazardous the flood waters are and what the receptor of flooding is. The hazard of river flood water is related to the depth and velocity. These parameters are dependent on:

- magnitude of flood flows;
- size, shape and slope of the river channel; and
- width and roughness of the floodplain.

Flood hazard can vary greatly throughout catchments and even across floodplain areas. The most hazardous flows generally occur in steep catchments and towards the bottom of large catchments. Hazardous river flows can pose a significant risk to exposed people, property and infrastructure. Whilst low hazard flows are of less risk to life, they can disrupt communities, require significant post-flood cleanup, and can cause superficial and possibly structural damage to property.

The Environment Agency SFRM studies looked at the predicted flooding from the Tory Brook, Long Brook and the River Plym for a defended scenario. Two of the Tory Brook tributaries were also modelled – the Chaddlewood Stream and Stoggy Lane Brook. Results were produced for a range of annual probability events from 50% to 0.1%; climate change results were also produced for all of these events. The flood extent for each event was mapped and depth, hazard and velocity results produced. Undefended model results were also produced for the 5%, 1% and 0.1% annual probability events. All structures were modelled as fully open (no blockages). No decision was made regarding the definition of the functional floodplain within the SFRM studies although the 5% annual probability event (often used as a starting point for defining the functional floodplain) was modelled. GIS datasets of the SFRM study results are provided as digital data in Appendix B. The Environment Agency Flood Map has so far been updated to incorporate the results from the Plympton SFRM study and is expected to be updated to incorporate the results of the River Plym SFRM study in the near future.

3.2 Flood Zone 3b

The functional floodplain (Flood Zone 3b – FZ3b) has been determined for this SFRA. PPS25 defines this zone as land where water has to flow or be stored in times of flood. The advice of the Environment Agency, in consultation with PCC, has been followed to define the functional floodplain for the SFRA.

3.2.1 Method

The functional floodplain has been based on the SFRM model results, Environment Agency Flood Zones and local knowledge, as detailed in this section. Two functional floodplain areas have been identified, as shown on Maps FF1 and FF2. These are:

- Map FF1 - Areas of land considered to be within the functional floodplain at present, and where appropriate policies relating to FZ3b should apply.
- Map FF2 - Areas of land where existing development means they are not currently part of the functional floodplain but where future development should seek to recreate the functional floodplain.

FZ3b has been digitised for the purposes of the SFRA based on the 5% annual probability event SFRM model results and information provided by the Environment Agency. Developed areas have generally not been identified as functional floodplain. The reason for this is that identification of the developed areas as FZ3a (rather than 3b) will encourage future development to improve the existing situation through appropriate redevelopment that would incorporate restoration of the functional floodplain. Buildings have typically been excluded from FZ3b.

In specific areas (as detailed in the bullet points below) judgement and local knowledge (Environment Agency / PCC) has been used to identify FZ3b. The outline has been drawn to provide a reasonably continuous and smoothed extent. It should be noted that where there are bridges across the watercourse the outline is indicative of the area beneath the bridge not the bridge itself.

- Plymouth Road, along the Tory Brook, is not included in FZ3b as the 5% annual probability event model results do not extend across the road and it has not been identified as a flow route. The FZ3b outline has been buffered slightly compared to the model results and taken to the road edge except where buildings are indicated on the map.
- Underwood Playing Field, adjacent to Long Brook, is not included in FZ3b as no flooding is indicated by the 5% annual probability event model results.
- For the Long Brook, adjacent to property gardens along Underwood Road, the outline has been adjusted to more closely match the 5% annual probability event model results with a slight buffer left across the gardens.
- Along the Long Brook culvert between Dark Street and Fore Street the model results indicate that flooding occurs during the 5% annual probability event however the area has not been included within the FZ3b outline due to the buildings which exist in the predicted flood area.

- To the south of Fore Street, along the Long Brook, the FZ3b outline is larger than the 5% annual probability event model results due to the presence of water features and the semi-rural nature of the area.
- FZ3b includes Longbrook Street (Long Brook) as this has been identified as a flow route.
- The area around Magdalen Gardens (Long Brook) has not been included in the FZ3b outline even though the 5% annual probability event model results show flooding as there are a number of buildings in the area. This is also applicable to the Station Road / Glen Road area around Tory Brook and Chaddlewood Stream (location of the Police Station and Fire Station).
- Boringdon Road, adjacent to the Tory Brook, is not included in the FZ3b outline as this is not shown flooded for the 5& annual probability event and has not been identified as a flow route.
- Part of Peacock Meadow Recreation Ground (Tory Brook) is included within FZ3b as there is some flooding shown to the south of the area (adjacent to Newnham Road) during the 0.1% annual probability event which comes from several different directions.
- Along Stoggy Lane Brook, Newnham Meadows is included within the FZ3b outline as this area may provide an opportunity to alleviate predicted flooding in the housing estate during the 0.1% annual probability event.

In the rural areas the 0.1% annual probability event model results have been used to define FZ3b. In general, a buffer has been included in addition to the modelled extent. Upstream of the modelled extent and for watercourses where no modelling has been undertaken the previous Environment Agency FZ3 outline has been used to define FZ3b.

The area for recreation of the functional floodplain is based on the Environment Agency FZ3. The definition of this area shows what could be aspired to in terms of recreating the functional floodplain. Areas which are unlikely to be redeveloped in the future have not been filtered from this outline. Therefore not all of the area shown necessarily has the potential for recreation of the functional floodplain.

3.3 Fluvial flooding

The Plympton SFRM and River Plym SFRM studies show the following areas predicted to be at risk during the 1% annual probability event:

- Area to the south of the railway line (Glen Road) – several buildings at risk including the Police Station and Fire Station.
- Significant out-of-bank flow from the Chaddlewood Stream – only a small number of properties at risk along Glen Road.
- Along the Long Brook a significant number of properties at risk from Burnstone Close to Magdalen Gardens.
- Fore Street culvert capacity is exceeded resulting in an overland flow path to Dark Street – residential properties at risk.

- Crash Care culvert capacity is exceeded leading to inundation of the former Cattle Market area – properties at risk.
- Upstream and downstream of the Cot Hill culvert – number of industrial and commercial units at risk.
- May's Marsh – commercial and residential property affected on both sides of the River Plym.

3.3.1 Structure blockage introduction

Structure blockage has been highlighted as potentially significant in terms of flood risk. The impact of structure blockage has therefore been assessed for the 1% annual probability event for the SFRA study. The Long Brook and Tory Brook contain a series of structures as they pass through Plympton. This section identifies which structures have been assessed to have the greatest potential risk and how the blockage of these structures may impact flooding in the local area.

3.3.2 Method

The ESTRY-TUFLOW model built for the Plympton SFRM commission was used to carry out the structure blockage analysis. Four structures have been selected for blockage analysis through consultation with PCC and the Environment Agency. Details of these structures are provided in Table 3.1. All four structures were completely blocked (100%) for the assessment. The blockage was modelled by restricting the flow through the structure using the in-built function within the modelling software.

Table 3.1 – Structures selected for blockage analysis

Name of blockage location	Structure type	Watercourse	Grid reference
Newnham Road	1 x Circular culvert	Tory Brook	254429 057094
Station Road	2 x Rectangular culverts	Tory Brook	254040 056632
Dark Street	1 x Circular culvert	Long Brook	254193 055948
Cot Hill	3 x Circular culverts	Long Brook	252635 056337

Two climate change scenarios were considered within the SFRA – 2050 and 2110. The 2006 Defra guidance referred to in Section 4.2 provides information regarding how flows will change over time. Fluvial flows in catchments that are not small or particularly urban are expected to increase by 10% for the period 1990-2025 and by 20% for the period 2025-2115.

The SFRM study applied a 20% increase to the fluvial flows used within the hydraulic model which showed a minimal increase in flood extent in most locations. As the two climate change scenarios requested for the SFRA fall within the 2025-2115 period the flows will be the same for both scenarios. The only difference between the two scenarios would be the tidal level applied at the downstream boundary of the model. Any change in the tidal boundary is only likely to affect model results in the Marsh Mills area where tidal flooding is the more dominant flooding mechanism. Therefore only one climate change scenario has been assessed, which is applicable to both 2050 and 2110. Two scenarios were simulated for each of the structure blockage locations:

- 1% annual probability
- 1% annual probability plus climate change (20% increase in flow).

3.3.3 Results

The hydraulic model has been used to estimate peak flood depths, hazard ratings and flood extent outlines for the four blockage locations. The hazard rating is based on the FD2320 methodology, and uses the following parameters:

- d = depth of flooding (m);
- v = velocity of floodwaters (m/s); and
- DF = debris factor (0, 0.5, or 1.0 dependent on the probability that debris will lead to a hazard).

The debris factor used within this assessment was 0.5 for flood depths up to 0.25m and 1.0 for greater flood depths.

The results from this assessment reflect the fluvial flood risk in the study area and not the risk from tidal inundation; this must be considered when interpreting the mapped outputs.

Maps B1-B4 (Appendix A) show the peak flood depths and hazard ratings for the four structure blockage scenarios. The flood hazard rating should be interpreted in line with the guidance in Table 3.2.

Table 3.2 - Flood hazard rating guidance

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 - Danger: flood zone with deep or fast flowing water.
1.25 – 2.0	Significant	Dangerous for most people - Danger: flood zone with deep fast flowing water.
> 2.0	Extreme	Dangerous for all - Extreme Danger: flood zone with deep fast flowing water.

Table 3.3 summarises the most significant results from the blockage modelling. The depth and hazard results from the baseline model used for the Plympton SFRM (defended) were compared to the blockage modelling results to assess the additional flood risk predicted by structure blockage.

Table 3.3 - Summary of structure blockage results

Scenario	General comments	Map	Depth / hazard comments
Newnham Road (1% AEP event)	Blockage predicts significant flooding between Colebrook and Torbridge road, extending south to the railway line. This contrasts greatly with the baseline SFRM model results where virtually all flow north of the railway was in bank	Map B1a	Most of the flood extent is <0.5m deep. In low-lying areas model results show ponding up to 3m in depth.
		Map B1b	Large proportion of new flood area is a "significant hazard".
Newnham Road (1% AEP event + CC)	Little change from 1% AEP event results.	Map B1c	As per 1% AEP event results.
		Map B1d	
Station Road (1% AEP event)	Blockage predicts significantly more flooding immediately north of the railway line than the baseline SFRM model results.	Map B2a	Most of the blockage-induced flood extent is 1 - 3m in depth.
		Map B2b	Almost all of the blockage-induced flood area is a "significant hazard". A small area by the railway line is an “extreme hazard”.
Station Road (1% AEP event + CC)	Little change from 1% AEP event results.	Map B2c	Most of the blockage-induced flood extent is 2 - 3m in depth.
		Map B2d	The blockage-induced flood area is predominantly "significant hazard" with a small area of "extreme hazard".
Dark Street (1% AEP event)	Blockage does not predict any change to the flood extent generated by the baseline SFRM model.	Map B3a	Blockage predicts insignificant changes in depth and hazard.
		Map B3b	
Dark Street (1% AEP event + CC)		Map B3c	
		Map B3d	
Cot Hill (1% AEP event)	Blockage predicts very little change to the outline of the flood extent generated by the baseline SFRM model.	Map B4a	The depth around Cot Hill is predominantly ~0.4m in depth. A small area north-east of the sewage works is 1-2m in depth.
		Map B4b	The flooding downstream of Cot Hill is largely a "moderate to significant hazard".
Cot Hill (1% AEP event + CC)		Map B4c	The depth around Cot Hill is predominantly ~0.6m in depth. A small area north-east of the sewage works is 1-3m in depth.
		Map B4d	The flooding downstream of Cot Hill is largely a "moderate to significant hazard".

The model results suggest that a blockage at the Newnham Road and Station Road structures would result in a significant increase in flood extent and risk compared to the existing 1% annual probability event flood extent. This increase in risk is largely due to the fact that if the structures are not blocked, virtually all flow is in bank. There are regions of low lying land to the east and west of the Tory Brook immediately north of the railway, such areas are vulnerable to flooding of up to 3m in depth if the structures at either Newnham Road or Station Road are blocked.

Blockage of the Dark Street structure has little impact on the flood extent and risk compared to the baseline SFRM model results. This is due to the fact that the water is almost entirely out of bank upstream of the structure in the baseline results and consequently does not flow to the culvert opening.

Little increase in flood extent is predicted when the Cot Hill structure is blocked, however, flood risk does increase compared to the baseline scenario. The strip of land 60m either side of the railway lies some 2m below the sewage works and the Industrial and Trading Estate; in this location the model shows depths of up to 3m.

Important infrastructure within the Plympton and Marsh Mills area have been identified as critical receptors, in terms of flood risk, for this study. Flooding of these receptors would have serious consequences in terms of emergency response and safe access / egress during a flood event, and could also have serious economic, environmental and social impacts. This definition of critical receptors is specific to the study area and differs from the classification used to identify flood risk vulnerability within PPS25. It should be noted that this selection of receptors does not represent a comprehensive statement of vulnerable / important infrastructure. The predicted depths and hazards for identified receptors due to blockage of structures are summarised in Table 3.4.

Table 3.4 – Predicted impacts on critical receptors

Receptor		Blockage location	Maximum hazard rating		Maximum flood depth	
Name	Approximate grid reference		1% event	1% event + CC	1% event (m)	1% event + CC (m)
Marsh Mills Roundabout	251750 056680	N/A	N/A	N/A	N/A	N/A
Railway Line	250840 055870 to 257190 056830	Cot Hill	Significant	Significant	0.5-1.0	1.0-1.5
		Station Road	Extreme	Extreme	1.5-2.0	1.5-2.0
		Newnham Road	Significant	Significant	1.0-1.5	1.0-1.5
Sewage Treatment Works	252310 056410	Cot Hill	Significant	Significant	1.0-1.5	1.0-1.5
Police Station	254007 056608	Station Road	Significant	Significant	0.5-1.0	1.0-1.5
Fire Station	254308 056668	Station Road	Moderate	Moderate	0.0-0.5	0.0-0.5
Plympton Hospital	253550 056100	N/A	N/A	N/A	N/A	N/A
B3416	251870 056767 to 256029 054976	Station Road	Significant	Significant	0.0-0.5	0.0-0.5
B3417	254531 056685 to 256090 058690	Newnham Road	Low	Low	0.0-0.5	0.0-0.5

Table 3.4 shows that if a blockage occurs at the Cot Hill, Station Road or Newnham Road structures, a number of critical receptors are potentially at risk. A blockage of the culvert at Dark Street is not likely to put any additional critical receptors at risk as it does not change the flood extent generated by the baseline SFRM model.

4 Flooding from the sea

4.1 Introduction

Tidal flooding occurs when water levels in the sea, estuaries and tidally influenced rivers rise above ground levels. This can occur during normal high tides, when there are extreme atmospheric effects, and when wind action causes sea water levels to rise. Tidal / fluvial flooding can also occur through 'tide locking', where high tide levels restrict discharge from rivers leading to flooding of areas further inland.

Current tide level information, from an Environment Agency extreme tide levels report[5], indicates that the defences along the River Plym provide a low standard of protection (SoP) from tidal flooding. The Environment Agency Flood Reconnaissance Information System (FRIS) database shows a number of flooding events which have been linked, at least in part, to tidal flooding. Consideration should be given to tidal flooding within Plympton, particularly in the Long Bridge (Speedway track) area where there is a low point in the tidal flood defence, and along the opposite bank of the River Plym in the May's Marsh area. Defence SoP has been investigated in Section 6.2.

The joint probability of tidal surge events in the River Plym estuary and fluvial flood events in the River Plym catchment was considered as part of the River Plym SFRM study. The results of the joint probability analysis indicated that there is no dependence between tidal surge events in the River Plym estuary and high flows in the River Plym. The Plympton SFRM study considered the impact of tide-locking on flooding from the Long Brook and Tory Brook. During normal tidal events flooding from the brooks is not particularly affected by tide-locking. Flooding due to overtopping of the River Plym defences during tidal flood events is considered to far outweigh the impact of tide-locking therefore no further consideration has been given to combined tidal and fluvial flooding within the SFRA.

As with river flooding, the consequence of flooding from the sea is dependent on how hazardous the flood waters are and what the receptor of flooding is. Flooding from the sea represents an extreme hazard as the onset of flooding can be extremely rapid and the water can be deep and fast-flowing. The severity of such flooding is dependent on a number of factors, often occurring in combination: the height of tides; weather systems; wind and wave conditions; topography; the effectiveness of drainage systems; and the condition of flood defences.

[5] Posford Haskoning. February 2003. South West Region. Report on Regional Extreme Tide Levels.

4.2 Assessing flood risk from the sea

The level of assessment required for the SFRA is broadscale. For this reason, existing datasets and tools have been used where possible to provide flood risk information.

4.2.1 Method

Tidal still water levels, from the extreme tide levels report, are available for Marsh Mills (NGR 251800 056500) on the River Plym and have been used for the SFRA assessment. The report contains tidal still water levels based on recorded data and projected tidal surges for a range of event probabilities. The levels provided do not account for any wave action however this is not important for Plympton as wave heights will be minimal[6].

Defra guidance[7] provides a method for estimating future tidal levels as shown in Table 4.1 for the South West. This method has been used to derive tidal flood levels for the current situation (2010) and for two future scenarios (2050 and 2110) for the annual probability events shown in Table 4.2.

Table 4.1 – South West net sea level rise allowances

Net sea level rise (mm/yr)			
1990-2025	**2025-2055**	**2055-2085**	**2085-2115**
3.5	8.0	11.5	14.5

Table 4.2 – Marsh Mills tidal still water levels (m)

Annual probability (%)	Return period (yrs)	Year			
		2002	**2010**	**2050**	**2110**
100	1	3.05	3.08	3.33	4.08
20	5	3.26	3.29	3.54	4.29
10	10	3.35	3.38	3.63	4.38
4	25	3.48	3.51	3.76	4.51
2	50	3.56	3.59	3.84	4.59
1	100	3.69	3.72	3.97	4.72
0.5	200	3.78	3.81	4.06	4.81
0.2	500	3.93	3.96	4.21	4.96
0.1	1000	4.06	4.09	4.34	5.09

Tidal projection maps have been generated for the 0.5% annual probability event for the current and two future scenarios. Flood depths across the study area were derived by determining the difference between the projected 0.5% annual probability event tidal levels and the ground levels defined by

[6] An update to the extreme tide level estimates was produced in 2008. This update has revised down the extreme tide level estimates for Plympton. The Environment Agency has advised that the new tide level estimates should only be used where a wave study is going to be undertaken. As this is not the case for the Plympton SFRA the 2003 report data has been used for the assessment.

[7] Defra. October 2006. Flood and Coastal Defence Appraisal Guidance. FCDPAG3 Economic Appraisal. Supplementary Note to Operating Authorities – Climate Change Impacts.

filtered LiDAR data. A visual check was carried out to remove areas for which a positive flood depth was shown but there was no flood pathway. The resulting depth grids have been banded to show the various depths of flooding and the results are shown in Maps T1-T3 (Appendix A). The SoP of the River Plym defence sections are shown spatially in Maps T4-T6 (Appendix A).

4.3 Results

An assessment of Maps T1-T3 shows the following areas predicted to be at risk of tidal flooding using the projection method:

- Sewage treatment works and industrial / commercial units to the west of Cot Hill. For the 2110 scenario the flood extent increases to include industrial / commercial units to the east of Cot Hill.
- Industrial area to the east of the River Plym (including the Park and Ride). The flood extent increases northwards for the future scenarios.
- Marsh Mills Retail Park / May's Marsh to the west of the River Plym. The flood extent increases for the future scenarios to include more buildings to the north-west.
- Crabtree – Superstore. The flood extent increases slightly to the north for the 2110 scenario.

There are a number of areas within the River Plym channel for which there is no predicted flood depth. These are areas for which there was no recorded ground elevation in the LiDAR used to derive the depths and will have a flood depth similar to immediately adjacent areas.

The main control on the flood extent appears to be roads. The predicted depths for the critical receptors identified in the previous section are summarised in Table 4.3.

Table 4.3 – Predicted impacts on critical receptors

Receptor		Maximum flood depth (m)		
Name	**Approximate grid reference**	**2010**	**2050**	**2110**
Marsh Mills Roundabout	251750 056680	0.5-1.0	1.0-1.5	2.5-3.0
Railway Line	250840 055870 to 257190 056830	0.5-1.0	1.0-1.5	>3.0
Sewage Treatment Works	252310 056410	>3.0	>3.0	>3.0
Police Station	254007 056608	N/A	N/A	N/A
Fire Station	254308 056668	N/A	N/A	N/A
Plympton Hospital	253550 056100	N/A	N/A	N/A
B3416	251870 056767 to 256029 054976	1.0-1.5	1.0-1.5	1.0-1.5
B3417	254531 056685 to 256090 058690	N/A	N/A	N/A

A review of Maps T1-T3 suggests that flooding of the A38 will occur as it passes over the railway line. This is because depth derivation has been based on filtered LiDAR data. The filtering process is intended to remove buildings and replace them with the ground level on which they are built, in order to yield a digital terrain model (DTM). This process also removes bridges and elevated roads and replaces them with the level of the underlying ground. As the A38 is elevated in this location it is not at risk of flooding.

The results of this assessment illustrate that for present day 0.5% annual probability event a number of the identified critical receptors are at risk from flooding. The predicted effect of climate change is to severely increase flood depths across these receptors. However, there is not a significant increase in the flood extent. It is important to appreciate that the predicted depths are based on a maximum tidal water level which will occur instantaneously in reality. This broadscale assessment is likely to slightly overestimate actual flood depths and provides a suitably conservative approach for the SFRA. More detailed modelling should be considered for site-specific flood risk assessments, especially for areas predicted to be at risk of flooding that are more distant from the River Plym channel.

The projection method does not allow for formal flood hazard mapping as detailed by Defra[8]. This is because velocity information is not generated for this methodology. However it is anticipated that the highest hazard and velocity areas would be those areas closest to the River Plym where the greatest depths are shown.

8 Udale-Clarke, H. *et al*. October 2005. Defra / Environment Agency Flood and Coastal Defence R&D Programme. R&D Technical Report FD2320/TR2. Flood Risk Assessment Guidance for New Development. Phase 2. Framework and Guidance for Assessing and Managing Flood Risk for New Development – Full Documentation and Tools. Defra, London.

5 Flooding from land (surface water)

5.1 Introduction

5.1.1 Description

Flooding from land, also known as surface water flooding, occurs when intense, often short duration rainfall is unable to soak into the ground or enter drainage systems. It is made worse when soils are saturated so that they cannot accept any more water. The excess water ponds in low points, overflows or concentrates in minor drainage lines that are usually dry. This type of flooding is usually short-lived and associated with heavy downpours of rain. Often there is limited warning before this type of localised flooding occurs.

Drainage basins or catchments vary in size and shape, which has a direct effect on the amount of surface runoff. The amount of runoff is also a function of geology, slope, climate, rainfall, saturation, soil type and vegetation. Geological considerations include rock and soil types and characteristics, as well as degree of weathering. Porous material (sand, gravel, and soluble rock) absorbs water more readily than fine-grained, dense clay or unfractured rock and has a lower runoff potential. Poorly drained material has a higher runoff potential and is more likely to cause flooding.

5.1.2 Causes and classifications

Water flowing over the ground surface that has not entered a natural channel or artificial drainage system is classified as surface water runoff or overland flow.

Flooding from land can occur in rural and urban areas, but usually causes more damage in the latter. Urban areas can be inundated by flow from adjacent farmland. Flood pathways include the land and water features over which flood water flows. These pathways include minor drainage lines, roads and even flood management infrastructure.

Developments that include significant areas of impermeable surfaces, such as roads and car parks, may increase the occurrence of surface water runoff.

Flooding can also occur when structures used to manage flooding fail. For example, flooding would be worse if a culvert were to collapse or block.

5.1.3 Impacts of surface water flooding

Surface water flooding can affect all forms of the built environment, including property, infrastructure, agriculture and the natural environment. It is usually short-lived and will tend to last as long as the rainfall event. However flooding may persist in low-lying areas where ponding occurs.

Flooding may cause increased erosion of agricultural land. This can result in 'muddy floods' where soil and other material are washed onto roads and properties, requiring extensive clean-up. Both rural and urban land use changes are likely to alter the amount of surface water in the future. Future development is also likely to change the position and numbers of people and / or developments exposed to flooding.

5.2 Assessment of flooding from land

Information held by the Environment Agency and local authorities regarding surface water flooding is limited and due to its nature it is difficult to accurately define all the areas at risk from this source of flooding. A variety of datasets have been used to gain an understanding of the possible surface water flooding mechanisms in Plympton, key infrastructure assets and areas more susceptible to flooding. The purpose of this assessment is to identify areas where more detailed assessment, including the preparation of Surface Water Management Plans (SWMPs), may be required.

Historic incidents of flooding recorded by the Environment Agency are included in its FRIS dataset. This dataset was used as a primary source of verification information in the assessment of flooding from land. In addition to this, historical flood incidents recorded by South West Water were evaluated. No additional information was available although it is likely that other stakeholders such as the highways authorities, fire brigade and the parish would hold records (in various formats and levels of detail).

The source of flooding was examined in the FRIS dataset to extract only those incidents related to surface water. In doing so, some of the FRIS incidents with a source labelled as 'unknown' have been reassigned a source of 'surface water', where it was judged that surface water was the most likely cause. These have been plotted on Map S1 in Appendix A.

No assessments of flooding from overland flow or surface water runoff appropriate to the scale of the SFRA were identified during consultation with PCC, the Environment Agency and South West Water.

The Environment Agency has supplied a map showing draft critical drainage areas for Plymouth. This covers the whole built-up area of Plympton. Critical drainage areas are identified as those areas where the drainage system is known to be close to or over its acceptable limit. Continued development and creation of impermeable surfaces, causing an increase in runoff to overloaded drainage paths, should be avoided in these areas.

PCC holds a surface water map derived from a simple model of surface water flooding and suitable for application at a national scale. PCC has provided the data for Plympton from this map and guidance[9] for its use within the SFRA. The map has been produced using a simplified method that excludes underground sewerage and drainage systems, and smaller over ground drainage systems, excludes buildings, and uses a single rainfall event. Therefore it only provides a general indication of areas which may be more likely to suffer from surface water flooding.

The map provides three bandings, indicating 'less' to 'more' susceptible to surface water flooding. It does not show the susceptibility of individual properties to surface water flooding. The 'more' band is useful to help identify areas which have a natural vulnerability to flood first, flood deepest, and / or flood for relatively frequent, less extreme events (when compared to the other bands). The susceptibility bandings have been applied nationally. Therefore even if a LPA has no 'more' susceptible areas within the national bandings applied, it does not mean that some parts of that LPA area will not be 'more susceptible' than others if a local assessment of relative susceptibility were applied. Representation of surface water flooding is better in steep catchments compared to areas with flat topography. Given the uncertainties in the data the guidance states that it should not be used with a more detailed base map scale than 1:50,000.

The Environment Agency supplied a pdf document indicating where properties are potentially at risk from surface water flooding. Based on areas susceptible to surface water flooding maps, the supplied document indicates where further investigation may be necessary and has not been used to identify individual properties at risk.

A broad scale assessment of flood risk from surface water was undertaken using the various datasets relating to surface water flooding and consideration of the physical characteristics of the study area.

5.3 Results

The soils within the study area are generally permeable and naturally well-drained and may allow for some infiltration of rainfall during a storm event. However, due to the highly urbanised nature of a large proportion of Plympton and the steep slopes the potential for infiltration will be limited and the volume and rate of surface water runoff increased. Surface water is likely to be channelled along roads and potentially through properties where this offers the path of least resistance to the runoff. The surface water will flow towards the floodplain areas of the Tory Brook and Long Brook. Therefore those areas most likely to be substantially affected by surface water flooding are the low-lying areas where water may pond and where surface water flooding may also occur in combination with fluvial flooding. Properties along the flow path of surface water runoff will be affected but this is likely to be only a short-term impact.

[9] Environment Agency. July 2009. Areas Susceptible to Surface Water Flooding. Guidance for Local Planning Authorities in ENGLAND for land use planning and other purposes (not emergency planning). V1. Environment Agency, Bristol.

There is a variety of surface water infrastructure within Plympton including sewers, outfalls, overflows, pumping stations, anti-flood valves and storage tanks. Outfalls and overflows may be locked by high water levels and unable to discharge, leading to backing-up of water within the system which may not have the capacity to store this water. If pumping stations and anti-flood valves fail this may also lead to backing-up of water and exceedance of the system storage capacity.

The various datasets were plotted together on a map. Where there was a concentration of evidence (records of historic flooding, South West Water infrastructure, areas 'more' susceptible to surface water flooding) that surface water could cause a risk of flooding broad areas were identified as potentially requiring more detailed assessment (for example, SWMPs). These areas are shown in Map S1 and include Plympton St Maurice, Colebrook, Underwood, and Marsh Mills / Long Bridge.

Marsh Mills / Long Bridge and Underwood are low-lying areas and thus are liable to long-term ponding of surface water. The southern area of Colebrook is also relatively vulnerable to ponding of surface water running off the nearby slopes of Colebrook and Woodford. A key flow route has been identified through Plympton St Maurice; there are steep slopes which are likely to create fast flowing surface water for a short duration.

In addition to the regions highlighted on Map S1, several flow paths have been identified where there may be fast flowing surface water runoff. These are predominantly in the north of Plympton draining down from Woodford and Colebrook; Larkham Lane, Dingle Road and Plymbridge Road are all thought to be potential flow paths.

There is no research covering the study area which specifically considers the impact of climate change on surface water flooding. Future climate change projections indicate that more frequent short duration, high intensity rainfall and more frequent periods of long duration rainfall are to be expected. These kinds of changes will have significant implications for flooding from land. Indirect impacts of climate change on land use and land management may also change future flood risk.

In the absence of certainty PPS25 advocates a precautionary approach. Sensitivity ranges are suggested for peak rainfall intensities over various time horizons. As our understanding of the impacts of climate change improves, these guidelines are likely to be revised. It is imperative that site specific flood risk assessments consider the impact of climate change on flooding from land.

The causes of surface water flooding are generally well understood. However it is difficult to predict the actual location, timing and extent of flooding, which are dependent on the characteristics of the site specific land use, local variations in topography, geology, soils and the hydrological conditions.

Furthermore, limited and variable measured datasets make it more difficult to determine an exact probability of flooding.

The analysis described above has attempted to determine areas more likely to be affected by this source of flooding. However the analysis has been undertaken on a very broad scale and should be used as a guide only. A detailed assessment of flooding from surface water should be undertaken for all proposed development sites, which assesses the potential impacts of climate change.

6 Assessment of defences

6.1 Introduction

Structures and defences are built to help reduce the occurrence, and therefore consequences of, flooding. These assets can be owned, operated and maintained by the Environment Agency, Local Authorities, private business and / or local residents.

The following assessments were undertaken as part of this SFRA:

- River Plym tidal defence SoP
- An appraisal of the current condition of flood defence infrastructure based on the Environment Agency National Flood and Coastal Defence Database (NFCDD).
- An appraisal of the probability (based on the NFCDD dataset) and consequences of overtopping or failure of flood risk management infrastructure, including an appropriate allowance for climate change:
    - modelling of a fluvial breach scenario in the River Plym defences; and
    - consideration of simplistic hazard mapping (FD2320 methodology) where defences are identified as having a poor condition.

These assessments are detailed in the following sections.

6.2 River Plym tidal defence standard of protection

An assessment of the approximate standard of protection (SoP) of the River Plym defences, both now and in the future, has been undertaken for the SFRA. This should be considered alongside the current SoP as reported in NFCDD and summarised in section 6.3.2.

Table 6.1 shows the maximum and minimum levels of defined sections of the River Plym defences.

Table 6.1 – Flood defences along the River Plym (Map T4)

Section number	Defence length (m)	Defence levels (mAOD)	
		Maximum	Minimum
1 (Left Bank)	240	3.56	3.13
2 (Left Bank)	225	4.62	4.09
3 (Left Bank)	154	5.50	4.70
4 (Left Bank)	235	3.54	2.29
5 (Left Bank)	568	4.02	3.61
6 (Right Bank)	145	4.76	4.47
7 (Right Bank)	460	4.60	4.10
8 (Right Bank)	120	6.55	4.60
9 (Right Bank)	139	5.70	3.19
10 (Right Bank)	215	4.77	2.97

The minimum defence levels have been compared to the current and predicted future tide levels (as shown in Table 4.2, section 4.2.1) to assign an approximate SoP to the defence sections. Table 6.2 shows this SoP; it can be seen that in many places the defences are relatively unimportant. For example, Section 5 adjacent to the sewage treatment works, currently has a minimum defence height approximately equal to the 2% annual probability (50 year return period) tidal event. This reduces to the 10% annual probability (10 year return period) event by 2050, and to less than the 100% annual probability (1 year return period) event by 2110.

Table 6.2 – Approximate standard of protection (SoP) of River Plym defences

Section number	Minimum defence level (m)	Approximate SoP					
		2010		2050		2110	
		AEP (%)	RP (yrs)	AEP (%)	RP (yrs)	AEP (%)	RP (yrs)
1 (Left Bank)	3.13	100	1	<100	<1	<100	<1
2 (Left Bank)	4.09	0.1	1000	0.5	200	100	1
3 (Left Bank)	4.70	>0.1	>1000	>0.1	>1000	2	50
4 (Left Bank)	2.29	<100	<1	<100	<1	<100	<1
5 (Left Bank)	3.61	2	50	20	5	<100	<1
6 (Right Bank)	4.47	>0.1	>1000	>0.1	>1000	10	10
7 (Right Bank)	4.10	0.1	1000	0.5	200	100	1
8 (Right Bank)	4.60	>0.1	>1000	>0.1	>1000	2	50
9 (Right Bank)	3.19	100	1	<100	<1	<100	<1
10 (Right Bank)	2.97	<100	<1	<100	<1	<100	<1

With the effects of climate change it is expected that the defences will provide even less protection in the future and that they may not be effective for even small events. It is expected that tidal flood levels within Plympton will be very similar to the peak tidal flood level in the River Plym, therefore tidal flood depths were estimated by projecting estimated tide levels across the digital terrain model (LiDAR).

6.3 Defence condition

6.3.1 Overview of defences and maintained channel

Several areas of Plympton are protected from flooding by raised defences. This section identifies these defences, assesses the condition of key defences, details current policy and considers the implications of failure.

The majority of the raised defences within Plympton are located on the River Plym, Tory Brook and Long Brook. Map D1 (Appendix A) shows the location of the fluvial and tidal defences within the study area as advised by the Environment Agency (from their NFCDD). It should be noted that there may be additional private defences that have not been included in NFCDD. Private walls may exist in the area but are not classed as 'flood defences'.

Within NFCDD there are 34km of linear asset in the Plympton study area, that are defined by their asset type as shown in Table 6.3.

Table 6.3 - Asset type and length

Asset type	Length (km)
Raised Defence	6.5
Maintained Channel	13.7
Natural Channel	10.4
Culvert	3.6
Total	**34.2**

Over 70% of the defences in the study area are classed as maintained channel or raised defences. There are approximately 6.5km of raised defences. The raised defences are on the River Plym (2.8km), Tory Brook (1.9km) and Long Brook (1.8km). No other 'defence' data was available for any other watercourses.

The most recent visual asset condition of linear defences is shown in Map D2 (Appendix A). Approximately 15% of the flood defence assets are Condition 1 or 2, approximately 85% Condition 3 and less than 1% Condition 4 or 5. The asset condition coding is provided in Table 6.4.

Table 6.4 - Asset condition coding

Condition	Asset description	Residual life (years)
1	**Very Good**. Cosmetic defects that will have no effect on performance.	>20
2	**Good**. Minor defects that will not reduce the overall performance of the asset.	11 - 20
3	**Fair**. Defects that could reduce performance of the asset.	6 - 10
4	**Poor**. Defects that would significantly reduce the performance of the asset. Further investigation needed.	1 - 5
5	**Very Poor**. Severe defects resulting in complete performance failure.	<1

Defences are designed to protect from flooding to a certain level – a standard of protection (SoP). The standard of protection is the maximum flood event that the defence can protect against before it is breached or overtopped. SoP data for defences along the River Plym, Tory Brook and Long Brook is available from the Environment Agency NFCDD. SoP analysis was also undertaken for the Plympton SFRM and River Plym SFRM studies. The NFCDD appears to contain the same information as that derived for the SFRM studies and therefore it is assumed that the NFCDD has been updated with the results of the SFRM studies. Currently the SoP provided by defences along the study area watercourses ranges from less than the 50% annual probability event to greater than the 0.1% annual probability event.

6.3.2 River Plym

Tidal flood protection is predominantly natural (from areas of high ground) although there are major raised defences in the areas around Marsh Mills and Crabtree on the River Plym. The tidal flood defences are raised earth embankments. The defences in this area, provided in NFCDD, are described as having a 'fair condition'.

The raised fluvial defences of the River Plym extend from the tidal limit at Mays Marsh up to Parkway Industrial Estate. The defences are in the form of earth embankment and concrete walls with sheet piled frontages. The condition of the raised defences is 'fair' or 'good'. Upstream of Parkway Industrial Estate in to Leighham the banks are not raised. The channel is defined as maintained channel, with earth banks, lining both sides of the Plym upstream as far as Mainstone Wood and the SFRA study area boundary.

According to NFCDD the SoP offered by the River Plym defences on both banks upstream of Parkway Industrial Estate is below the 50% annual probability event. Downstream of Parkway Industrial Estate the SoP on the left bank varies between the 2% and 0.1% annual probability event. The Crabtree area south of Marsh Mills has a SoP between the 10% and 5% annual probability event.

6.3.3 Tory Brook

The Tory Brook defences tie into the raised tidal defences of the River Plym at Long Bridge. The defences are described as concrete walls on both sides of the Tory Brook; gabions are used to provide erosion protection in some locations. The wall continues beyond the tidal limit in ad-hoc form for 1.5km up to Underwood Industrial Trading Estate and St Marys Bridge. From St Mary Bridge the channel is defined as 'maintained channel' with earth banks on both the left and right banks of the watercourse. The defences are in 'fair' condition with the exception of 36m of raised defence with a sheet piled revetment adjoining disused garages (Asset Reference 1140940320102R04) where the overall condition is 'poor'. The poor condition is likely to affect the standard of protection offered by the defence.

The NFCDD SoP for flood defence assets on the Tory Brook varies from less than the 50% annual probability event to the 0.1% annual probability event. The SoP of defences along the north bank of the Tory Brook close to Long Bridge is less than the 50% annual probability event. The remainder of assets on the Tory Brook are shown to have a SoP between a 0.2% annual probability and a 0.1% annual probability event. The asset with a poor condition described above is shown in NFCDD to have a SoP greater than the 0.1% annual probability event. This is likely to be due to the height of the land surrounding the asset and the predicted channel water levels.

6.3.4 Long Brook

The Long Brook is culverted for several sections as shown in Map D1. The culverts close to the sewage treatment works are described as twin circular pipes and have a 'fair condition'.

The Long Brook flows into the tidal River Plym via a culvert adjacent to the sewage treatment works. The brook does not have major continuous raised defences along its length. The channel defences are described as 'maintained channel' and NFCDD reports that maintenance work is carried out by the Environment Agency and private landowners.

Concrete raised defences have been constructed upstream of Underwood close to Plympton St Maurice. These defences are in 'good' or 'fair' condition.

The SoP of the Long Brook defences in NFCDD is reported to be between the 50% and 0.1% annual probability event. From the confluence with the River Plym up to Linketty Lane the SoP is reported to be between the 0.2% and 0.1% annual probability event. Upstream, towards Underwood, there are lengths of defence which are described as having less than a 50% annual probability event SoP. This includes defences on the southern bank of the Long Brook close to Plympton Hospital. The SoP of short lengths of defences in NFCDD is less than the 50% annual probability event further upstream in residential areas around Plympton St Maurice.

6.3.5 Condition assessment of key flood defences

The key defences in the SFRA study area are the raised defences around Marsh Mills / Long Bridge on the River Plym and Tory Brook. The asset conditions are shown on Map D2. The defences have an overall asset condition between 'good' and 'fair'. This indicates that the assets have a residual life of six to ten years ('fair') or 11 to 20 years ('good'), if remedial asset maintenance work is not carried out.

The SoP in NFCDD for key raised defences along the tidal boundary of the River Plym are described as being greater than the 0.5% annual probability event. The exception is the length of raised bank around Crabtree (Asset Ref: 1140930170103R01) where NFCDD describes the SoP as between the 10% and 5% annual probability event.

6.3.6 Current policy for flood defences and maintenance

Overall policy for flood management in the study area is set by the Environment Agency in the current Catchment Flood Management Plan (CFMP) for the Tamar Catchment. The plan sets how flood risks are to be managed into the future. There are six generic flood risk management policies which may be selected for a policy area. These are:

- **Policy 1** – Areas of little or no flood risk where we will continue to monitor and advise.
- **Policy 2** – Areas of low to moderate flood risk where we can generally reduce existing flood risk management actions.
- **Policy 3** – Areas of low to moderate flood risk where we are generally managing existing flood risk effectively.
- **Policy 4** – Areas of low, moderate or high flood risk where we are already managing the flood risk effectively but where we may need to take further actions to keep pace with climate change.
- **Policy 5** – Areas of moderate to high flood risk where we can generally take further action to reduce flood risk.
- **Policy 6** – Areas of low to moderate flood risk where we will take action with others to store water or manage runoff in locations that provide overall flood risk reduction or environmental benefits.

The most appropriate policy for an area has been identified within the CFMP by consideration of how social, economic and environmental objectives are affected by flood risk management activities under each policy option.

The Environment Agency advocates a strategic approach to flood risk management on a 'whole catchment' basis, and has adopted the Tamar CFMP. The need for defences within Plympton will increase in the future with increased fluvial flood risks, rising sea levels and a potential increase in storm surge frequency and magnitude. Plympton is included within the Tamar CFMP Sub-area 3 'Plymouth Area', which has been allocated Policy 5 as detailed below.

Areas of moderate to high flood risk where we can generally take further action to reduce flood risk. This policy will tend to be applied to those areas where the case for further action to reduce flood risk is most compelling, for example where there are many people at high risk, or where changes in the environment have already increased risk. Taking further action to reduce risk will require additional appraisal to assess whether there are socially and environmentally sustainable, technically viable and economically justified options.

To put this policy allocation for Plymouth Area into context with the rest of the Tamar CFMP area the allocated policies for the other sub-areas are detailed below:

- Sub-area 1 – Upper Tamar: **Policy 6**;
- Sub-area 2 – Tidal Central: **Policy 6**;

- Sub-area 4 – East Tamar: **Policy 4**;
- Sub-area 5 – Central Tamar: **Policy 3**; and
- Sub-area 6 – West Tamar: **Policy 3**.

It can therefore be seen that, within the Tamar CFMP area, Plymouth Area has the highest flood risk and is the area where most action is likely to be taken to reduce flood risk.

The vision for Policy 5 in this location is to support sustainability objectives by reducing future increase in flood risk to the urban environment whilst avoiding significant adverse impacts on the environment. The benefits will be most significant in relation to the economy of the urban centres. Objectives relating to geomorphology, biodiversity, and landscape may be met, but this is dependent on the response used to manage flood risk. However, it is envisaged that sensitive and appropriate approaches to managing flood risk (through incorporation of environmental constraints during detailed appraisal and design) could be developed that do not cause adverse impacts in the long term.

The proposed actions to implement the preferred policy in Plymouth Area, as detailed in the Tamar CFMP, are outlined below:

- Develop System Asset Management Plans to help reduce flood risk and investigate the need for, and where necessary implement, Surface Water Management Plans for problem areas in Plymouth and Plympton.
- Produce detailed studies for Plymouth, Plympton, Plymstock, Tamerton Foliot, Saltash and Turnchapel to review flow capacities, obstructions to high flows and to investigate upstream attenuation.
- Use programmes to raise and maintain awareness of flood risk and self-help measures.
- Ensure development conforms to PPS25 and identify opportunities through the implementation of PPS25 to work with developers to reduce flood risk elsewhere in Plymouth area.
- Investigate adaptation measures for the mainline railway and the A374 road against increased flooding due to climate change.
- Investigate opportunities to create green corridors alongside the rivers.
- Investigate opportunities for managed realignment to restore intertidal habitat along Plymouth waterfront and estuaries.
- Continue with work to identify rapid response catchments.
- Review urban drainage capacity within Plymouth, Plympton and other major urban areas. Implement findings and provide recommendations.
- Implement strategies for flood risk management of the mine site identified at Plympton to assess the potential pollution risk from flooding.

Based on this CFMP policy strategies to reduce flood risk in Plympton will be implemented by the partners identified in the CFMP document, one of which is Plymouth City Council.

In terms of defences the reduction in flood risk could be achieved by:

- More frequent maintenance and remedial work to existing defences and drainage systems.
- Implementation of flood defence improvement options.
- Adapting the operation of the current flood defence assets.

6.4 Probability and consequences of overtopping and failure

Within defended areas flood risk is primarily associated with overtopping and breach of defences. These risks are related to the likelihood (SoP and structural integrity of defences) and consequences of flooding (depth, speed and duration of flooding, velocity of floodwaters, and land use within the defended area). In general, a breach of a flood defence is most likely to occur where the defence is structurally weaker (poor condition) or more likely to be overtopped (low SoP). For a breach or overtopping to be a significant issue the ground level of the area adjacent to the potential breach location has to be low enough for the water to spread. When ground levels slope upwards in the direction from the potential breach location, the flow path for the flood water will be limited. However, high depths of water could be a significant issue.

One breach location has been modelled for the SFRA study. A breach or overtopping of defences could occur anywhere however they are more likely to occur when defences are in poor condition and / or have a low SoP. For other types of defence and assets (flaps and culverts) failure will be due to other factors. Blockage of culverts can lead to backing-up of water and increased flood risk, as detailed in Section 3.3. At the downstream extent of the Long Brook a flap acts to prevent water from the River Plym entering the Long Brook when water levels in the River Plym are high due to a large fluvial or tidal event. If this flap becomes stuck open the flood risk to Plympton will be increased.

Undefended fluvial models were constructed for the Plympton SFRM and River Plym SFRM studies. These did not show a substantial increase in flood extent compared to the defended models. The main areas where flood extent increased was on Linketty Lane, the Speedway track, and May's Marsh. Simulation of removal of the flap at the downstream extent of the Long Brook did not result in a difference in peak flood levels. From the results shown in Table 6.1, it is anticipated that a tidal breach would have limited impact due to the low SoP of the defences. Modelling a tidal breach would be unlikely to show any greater extent of flooding than would already be shown by a large tidal event as this would quickly overtop the defences. Due to this a fluvial breach, rather than a tidal breach, has been modelled for the SFRA.

6.5 Fluvial breach

There are a number of defences along the River Plym. The breach of a defence has the potential to cause significant changes in localised flooding. PCC and the Environment Agency identified a location on the River Plym where the likelihood and consequences of a breach of the defences are high and therefore warranted more detailed assessment for the SFRA. The location selected was the area of raised earth embankments upstream of Mays Marsh at (NGR 251740 057096).

6.5.1 Method

The TUFLOW model built for the River Plym SFRM was adapted for the breach scenario. Two scenarios were investigated:

- 1% annual probability event.
- 1% annual probability event plus climate change (20% increase in flow).

In line with current guidance[10] the breach was modelled as 40m wide and remained open for 56 hours (at which point it was assumed to be repaired). The breach was opened 14 hours into the flow hydrograph duration and remained open to the end of the event.

6.5.2 Results

The TUFLOW model was used to predict peak flood depths and hazard ratings for the breach scenario. These results were used to produce flood extent outlines. The results from this scenario only reflect the fluvial flood risk in the study area and not the risk from tidal inundation; this must be considered when interpreting the mapped outputs. It should be noted that an error was found in the DTM used for the SFRM study. This shows the A38 flyover to be an area of high ground and therefore does not allow water to flow across Marsh Mills roundabout. This has not been amended for the SFRA. However it is thought very likely that the hazard shown on the northern side of the roundabout would not change if the DTM was amended as the area into which water could flow is constrained by high ground on the southern side of the roundabout. Depth may decrease on the northern side but velocity is likely to increase.

Table 6.5 summarises the significant outcomes of the breach scenario modelling. The results from the baseline (defended) model (Appendix B) used for the River Plym SFRM were compared to the results of the breach analysis to assess the impact of the defence breach. The baseline model results for the 1% annual probability event do not show any flooding in the May’s Marsh area. When climate change is included the baseline model results show flooding of Marsh Close and the hotel.

Table 6.5 - Analysis of defence breach results

Scenario	General comments	Map	Depth / hazard comments
Breach at May's Marsh (1% AEP event)	The breach modelling predicts significant flooding from May's Marsh extending south to the B3416 and west to Marsh Mills Retail Park.	Map B5a	A significant proportion of the flood extent is 2-3m in depth.
		Map B5b	The majority of the breach-induced flood area is a "significant hazard".

[10] Worth, D and Cox, R (2000) Tidal Flood Risk Areas: Simply Credible. Environment Agency. South West Region

Breach at May's Marsh (1% AEP +CC)	As per the 1% AEP event comments.	Map B5c	A significant proportion of the flood extent is 2-3m in depth including a section of the B3416.
		Map B5d	The majority of the breach-induced flood area is a "significant hazard".

The model results suggest that a breach of the fluvial flood defence at May's Marsh would cause significant localised flooding during a 1% annual probability event, with further flooding occurring when climate change is included. It should be noted that the flooding shown to the east of the River Plym is due to overtopping and is not a result of the breach. Table 6.6 shows that if the May's Marsh defence breaches, two of the critical receptors previously identified are likely to be at risk.

Table 6.6 – Predicted impacts on critical receptors

Receptor		Maximum hazard rating		Maximum flood depth (m)	
Name	**Grid reference**	**1% event**	**1% event +CC**	**1% event**	**1% event +CC**
Marsh Mills Roundabout	251750 056680	Significant	Significant	1.0-1.5	1.0-1.5
Railway Line	250840 055870 to 257190 056830	N/A	N/A	N/A	N/A
Sewage Treatment Works	252310 056410	N/A	N/A	N/A	N/A
Police Station	254007 056608	N/A	N/A	N/A	N/A
Fire Station	254308 056668	N/A	N/A	N/A	N/A
Plympton Hospital	253550 056100	N/A	N/A	N/A	N/A
B3416	251870 056767 to 256029 054976	Significant	Significant	1.0-1.5	1.5-2.0
B3417	254531 056685 to 256090 058690	N/A	N/A	N/A	N/A

6.6 Simplistic hazard mapping

Where defences were identified which had a 'poor' condition classification simplistic hazard mapping was proposed to assess the risk behind the defence due to breaching and overtopping. This simplified approach does not consider the probability of one failure type compared to the other and therefore the precautionary approach is used to determine a composite categorisation for danger to people behind the defence based on the worst case. The method produces a series of concentric semi-circles radiating from the defence to assess flood depth and hazard.

As detailed in Section 6.3 and shown in Map D2, only one short section of defence in the study area is classified as poor condition. This defence is located on the right bank of the Tory Brook just downstream of Plympton St Mary Bridge. The defence was not included in the baseline (defended) Plympton SFRM model and the model results show that water stays in-bank for the 1% annual probability event. Therefore overtopping and breaching of the defence will not occur during this event, i.e. it is not acting as a defence for this event.

The simplistic hazard mapping method was considered for this defence for the 0.1% annual probability event to assess the potential impact for a larger magnitude event. Results showed that the defence would not be overtopped during this event and therefore the risk would only be from a breach of the defence. The extent of flooding was found to be very constrained due to the steep slopes in this area and depths were small. Consequently no further analysis using the simplistic hazard mapping approach was carried out as it was felt it would add no additional value to the SFRA.

7 Summary of flood risk

Sections 3 to 6 of this report have assessed the flood risk in Plympton from four sources of flooding:

- fluvial flooding from the Tory Brook and Long Brook;
- tidal flooding;
- surface water flooding; and
- failure of defence assets.

The following sections summarise the results of the assessment of the various sources of flooding and identify those locations within the study area which are susceptible to more than one source of flooding. Key areas with critical receptors are identified and discussed in terms of the causes / mechanisms of flooding, its severity and issues that should potentially be addressed through the LDF process.

7.1 Sources of flooding

7.1.1 Fluvial – Flood zone 3b

In urban areas the functional floodplain is generally restricted to the channel, gardens, and some roads which are known to act as flow paths or where the watercourse is culverted beneath them. The functional floodplain is wider in rural areas as there is no constraint from existing development.

Flood Zone 3 has been used to identify a broad aspirational area where future redevelopment should seek to recreate the functional floodplain. It is acknowledged that not all of this area will be available for future redevelopment.

7.1.2 Fluvial – Blockage

Blockage of structures at Newnham Road and Station Road results in a significant increase in flood extent and risk compared to predictions for the unblocked condition. At Dark Street blockage of the structure has little impact on flood extent and risk compared to results when the structure is not blocked. Blockage of the Cot Hill structure does not increase flood extent substantially but flood risk is increased compared to the unblocked scenario. It is recommended that a maintenance programme is established to ensure that these structures are checked and cleared regularly to reduce the likelihood of a blockage occurring.

7.1.3 Tidal - Projection

The assessment of tidal flooding, using a projection method, shows a number of areas close to the River Plym (Marsh Mills / Long Bridge, May's Marsh, Crabtree, and Coypool Road) which are predicted to be at risk from tidal flooding. Flood extent does not increase substantially for future scenarios compared to current predictions but depth does increase significantly. Therefore the consequences of flooding are likely to be greater in the future. SoP of defences in key areas could be assessed and improved. It is recommended that specific emergency flood plans are developed for these areas.

7.1.4 Surface water

There are a number of areas within Plympton where flood risk from surface water has been identified – Marsh Mills / Long Bridge, May's Marsh, Colebrook, Underwood and Plympton St Maurice. These are generally areas where there are steep slopes which will act as flow paths and low-lying areas where ponding of surface water will be an issue. Failure of surface water infrastructure is likely to increase the risk from this source of flooding. The production of surface water management plans (SWMPs) should be considered for these areas. Maintenance programmes for surface water infrastructure are also recommended.

7.1.5 Defences – Condition

The majority of defences have a 'good' or 'fair' condition classification however the SoP varies considerably from less than the 50% annual probability event (for example, the maintained channel upstream of the Parkway Industrial Estate) to greater than the 0.1% annual probability event (for example, parts of the Tory Brook raised defences). Undefended fluvial models constructed for the Plympton SFRM and River Plym SFRM studies indicate that failure of defences is unlikely to have a substantial impact on flood extent. These studies did not consider the impact of tidal events if defences fail as this is likely to show similar results to the tidal projection assessment due to the low SoP of the defences.

7.1.6 Defences – Fluvial breach

Results from this assessment show significant localised flooding in the May's Marsh area, with deep water and high hazard predicted close to the River Plym channel in particular.

7.2 Multiple flooding source locations

Several locations within the study area have been identified as being susceptible to more than one source of flooding:

- May's Marsh – tidal, surface water, fluvial (east bank), and fluvial breach.
- Marsh Mills / Long Bridge – tidal, surface water, and fluvial.
- Colebrook / Glen Road – surface water and fluvial blockage.
- Underwood – surface water, fluvial, and fluvial blockage.
- Plympton St Maurice – surface water and fluvial.

7.3 Key areas susceptible to flooding

Important infrastructure within the Plympton and Marsh Mills area has been identified as critical receptors in terms of flood risk. Flooding of these receptors would have serious consequences in terms of emergency response and safe access / egress during a flood event, and could also have serious economic, environmental and social impacts. This definition of critical receptors is specific to the study area and differs from the classification used to identify flood risk vulnerability within PPS25. It should be noted that this selection of receptors does not represent a comprehensive statement of vulnerable / important infrastructure.

7.3.1 May's Marsh / Marsh Mills

Critical receptors in this location are the Marsh Mills roundabout, the railway line and the B3416. There are also some residential properties at risk. Breach / overtopping of the River Plym defences and tidal flooding is the main flood risk and is significant in terms of flood depth and hazard, as shown by the results from the fluvial breach assessment and tidal projection analysis. Surface water ponding is likely to be an issue due to the low-lying nature of the area. The condition of the defences in this location is fair but the SoP could be improved. Production of a SWMP is recommended; this is likely to require consideration of upstream measures for reducing the flood risk from surface water.

7.3.2 Long Bridge

On the east bank of the River Plym in the Long Bridge area the critical receptors are the railway line, the B3416 and the sewage treatment works. Tidal flooding is likely to be the most important and significant source of flooding in this location and the tidal projection assessment shows water depths of >1m in some parts of the area. There is some risk of fluvial flooding from the Tory Brook and Long Brook across the area. Surface water flooding is a risk due to the low-lying nature of the land at the base of steep slopes.

The condition of the defences in this location is fair but the SoP could be improved. Continued maintenance of the flap at the downstream extent of the Long Brook is required as failure of this during a tidal event could potentially increase the flood risk. A SWMP is recommended for this location.

7.3.3 Colebrook / Glen Road

The Police Station, Fire Station, B3416, B3417 and the railway line are critical receptors in this location. Insufficient culvert and channel capacity at the confluence of the Tory Brook and Chaddlewood Stream is predicted to lead to substantial flooding. Blockage of structures at Station Road and Newnham Road is predicted to result in deep water and a high hazard classification in some parts. These are mainly confined to areas of industrial / commercial development but some residential property is affected as well as the emergency services (Police and Fire).

There are a number of sewer outfalls in the area and anti-flood valves. Locking of the outfalls by high water levels in the watercourse into which they discharge could lead to backing-up within the system and surcharging if there is insufficient storage capacity within the system. Failure of anti-flood valves could lead to increased flooding across the area. There are a number of flow paths for surface water, particularly to the north of Glen Road. The location of the emergency services and the industrial estate to the north is low-lying and is likely to be subject to ponding of surface water.

It is recommended that critical structures are regularly checked for blockages and cleaned when necessary. Maintenance and checks of the surface water infrastructure at regular intervals is also important. A SWMP should be undertaken for this location. It is recommended that opportunities to relocate the police and fire stations should be investigated.

7.3.4 Underwood

Critical receptors in this location are Plympton Hospital, the railway line and the B3416. Surface water flooding may be an issue as the area is low-lying, at the base of steep slopes, and subject to ponding. There are also a number of sewer outfalls and overflows in the area which could contribute to the flood risk. A number of residential and commercial properties are shown to be at risk of fluvial flooding. Culvert blockage is likely to significantly increase the risk of flooding to the southern end of Market Road.

Development of the former Cattle Market on Market Road is addressing flood risk by considering the removal of the 'Crash Care' culvert, providing a flow route through the development to allow fluvial and surface water back into the watercourse without affecting property, and increased channel storage capacity.

As for Colebrook / Glen Road structures should be regularly checked to ensure blockage does not occur and surface water infrastructure maintained on a frequent basis. It is recommended that a SWMP is carried out for this location.

7.3.5 Plympton St Maurice

There are no critical receptors at risk of flooding in this location although residential property is affected. Culvert capacity is limited along the watercourse and leads to flooding of property adjacent to the channel. Surface water flooding is a risk in the area due to the steep slopes and resultant fast-flowing surface runoff along flow paths. There are also a number of sewer outfalls and overflows which could exacerbate surface water flooding.

Improvements to the road culverts between Fore Street and Redvers Grove could be made to increase capacity and reduce flood risk. A SWMP should be considered for this location.

7.3.6 Summary

The flood risk from a fluvial breach of defences and tidal flooding is significant in the May's Marsh and Marsh Mills area, and particularly for transport infrastructure (Marsh Mills roundabout, the railway line and B3416). Tidal and fluvial flooding is also significant in the Long Bridge area with the railway line and sewage treatment works at risk. Surface water ponding is potentially important is all of these areas as they are low-lying.

The Colebrook / Glen Road area is susceptible to fluvial flooding particularly when structures along the watercourse become blocked. Fast-flowing surface water may be a risk down Boringdon Hill road with deep ponding likely in the industrial estate along Colebrook Road. This area is significant in terms of critical receptors as the Police and Fire Station are at risk as well as transport infrastructure (the railway line and B3416).

The Underwood and Plympton St Maurice areas are predominantly at risk from fluvial flooding, with culvert capacity being the main issue in Plympton St Maurice, and ponding of surface water. There are no critical receptors at risk in Plympton St Maurice; in Underwood Plympton Hospital may be at risk of flooding from ponding surface water.

In summary, Plympton faces flood risk issues from fluvial, tidal and surface water sources, which may be exacerbated by blockage of structures, failure of defences and the location of critical receptors. A number of locations have been identified where more than one source of flooding occurs and constitutes a combined flood risk.

8 Glossary and notation

Actual risk	The risk that has been estimated based on a qualitative assessment of the performance capability of the existing flood defences
AEP	Annual Exceedance Probability of a specific flood event
Breach or failure hazard	Hazards attributed to flooding caused by a breach or failure of flood defences or other infrastructure which is acting as a flood defence.
CFMP	Catchment Flood Management Plan
Defra	Department of Environment, Food and Rural Affairs
DPD	Development Plan Document
DTM	Digital Terrain Model, usually generated from SAR or LiDAR data
Flood defence	Natural or man-made infrastructure used to prevent flooding
Flood risk	*"Flood risk is a combination of two components: the chance (or probability) of a particular flood event and the impact (or consequence) that the event would cause if it occurred"* as per Environment Agency (2003) Flood Risk Management Strategy
FRA	Flood Risk Assessment
Flood risk management	*"Flood risk management can reduce the probability of occurrence through the management of land, river systems and flood defences, and reduce the impact through influencing development in flood risk areas, flood warning and emergency response"* as per Environment Agency (2003) Flood Risk Management Strategy
Flood Zones	This refers to the Flood Zones in accordance with Table D1 of PPS25. For the purpose of the SFRA, the definition of Flood Zones varies slightly from PPS25 in that it shows the extent of flooding ignoring the presence of flooding defences, 'except where the 'actual risk' extent is greater'
LDD	Local Development Documents
LDF	Local Development Framework
LiDAR	Light Detecting and Ranging. Technique used to capture topographic data from the air.
LPA	Local Planning Authority
m	metres (measure of distance)
m/s	metres per second (measure of velocity)
mAOD	metres above Ordnance Datum. Standard baseline used in all elevation data used in the SFRA
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
NFCDD	National Flood and Coastal Defence Database. Environment Agency database used to store and analyse flood defence structures and assets. Updated regularly and supplied to key stakeholders, including LPA.

NGR	National Grid Reference
OS	Ordnance survey
PCC	Plymouth City Council
PPS25	Planning Policy Statement 25: Development and Flood Risk. Current guidance explaining how flood risk should be considered at all stages of the planning and development process in order to reduce future damage to property and loss of life.
Precautionary principle	*''Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation*''. The precautionary principle was stated in the Rio Declaration in 1992. Its application in dealing with the hazard of flooding acknowledges the uncertainty inherent in flood estimation.
Residual risk	Flood risks resulting from an event more severe than for which particular flood defences have been designed to provide protection.
Return Period	The return period of a flood is the average interval between floods of that magnitude or greater.
RFRA	Regional Flood Risk Appraisal
RSS	Regional Spatial Strategy
Sequential risk-based assessment	Priority in allocating or permitting sites for development, in descending order to the Flood Zones set out in Table 1 of PPG25, including the sub divisions in Zone 3. Those responsible for land development plans or deciding applications for development would be expected to demonstrate that there are no reasonable options available in a lower-risk category (PPG25 paragraph 30).
SFRA	Strategic Flood Risk Assessment
SFRM	Strategic Flood Risk Management.
SoP	Standard of Protection
TUFLOW	A two-dimensional fully hydrodynamic modelling package developed by WBM Oceanics Australia. The TUFLOW model differs from the ISIS model in that it models the whole floodplain as 2D domains, providing a more complete description of flood behaviour where complex overland flows and backwater filling occur.
1D	1 dimensional
2D	2 dimensional

Appendix A

Appendix B