Surface Water model updates

Final Report

June 2023

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Revision History

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February 2023	Draft Report	Oran Balazs (Dorset Council)
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Contract

This report describes work commissioned by Oran Balazs, on behalf of Dorset Council, by an email from Chris Osbourne on the 13 December 2021. Dorset Council's representative for the contract was Oran Balazs. Emily Jones and Ed Hartwell of JBA Consulting carried out this work.

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Purpose

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

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Abbreviations

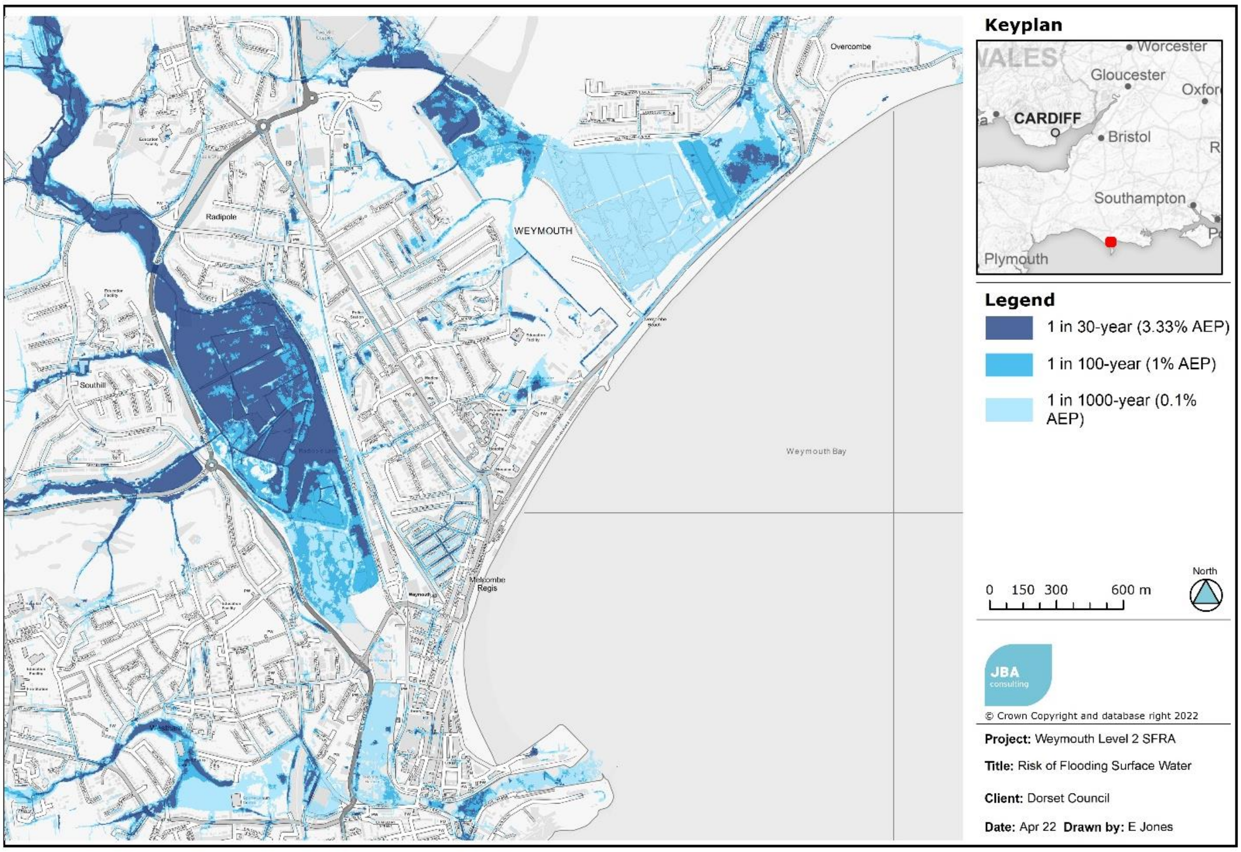
1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AEP	Annual Exceedance Probability
CC	Climate Change
DTM	Digital Terrain model
EA	Environment Agency
FEH	Flood Estimation Handbook
HOST	Hydrology Of Soil Types
InfoWorks ICM	1D-2D hydraulic modelling software
JBA	JBA Consulting
LIDAR	Light Detection and Ranging
RoFSW	Risk Of Flooding from Surface Water (mapping)
ReFH	Revitalised Flood Hydrograph method
SFRA	Strategic Flood Risk Assessment
SPRHOST	Standard percentage runoff associated with each HOST soil class

1 Introduction

JBA Consulting have been commissioned by Dorset Council to undertake an update to the surface water flood risk mapping across Weymouth. The updated surface water modelling will support the Level 2 SFRA, which requires analysis of all sources of flood risk, including surface water.

The EA RoFSW mapping shows that large areas are at risk, shown in Figure 1-1. However, the RoFSW mapping does not explicitly include specific pipe networks or tidal and fluvial boundary conditions, and therefore is potentially over/under-estimating flood risk across the area. This modelling study takes the Wessex Water 1D InfoWorks ICM model, including all sewer information, and integrates it with 2D rainfall modelling, for an improved understanding of surface water flood risk.

Figure 1-1: EA RoFSW mapping for Weymouth



2 Available data

The following datasets have been used in the development of the Weymouth surface water model.

Table 2-1: Data used for model development

Data Type	Data used	Coverage	Source of data
Topographic data	Environment Agency 1m resolution LiDAR data	Entire study area	Data.gov.uk
Land-use data	Ordnance Survey MasterMap	Entire study area	Data.gov.uk
Existing sewer models	InfoWorks ICM sewer model	Entire study area	Wessex Water
Tidal / fluvial boundary conditions	Model outputs from the Weymouth Coastal Model, developed for the Environment Agency and updated as part of the Level 2 SFRA.	Weymouth coastline, Weymouth Harbour and Radipol Lake	Environment Agency
Fluvial / tidal defences - present day	Defence data from Weymouth Coastal Model	Weymouth coastline and Weymouth Harbour	Environment Agency
Fluvial / tidal defences - future	Weymouth Harbour & Esplanade Flood and Coastal Risk Management Strategy (2020)	Weymouth coastline and Weymouth Harbour	Dorset Council
Rainfall hyetographs	FEH13 Rainfall	Entire study area	FEH web service

3 Application of hydrology

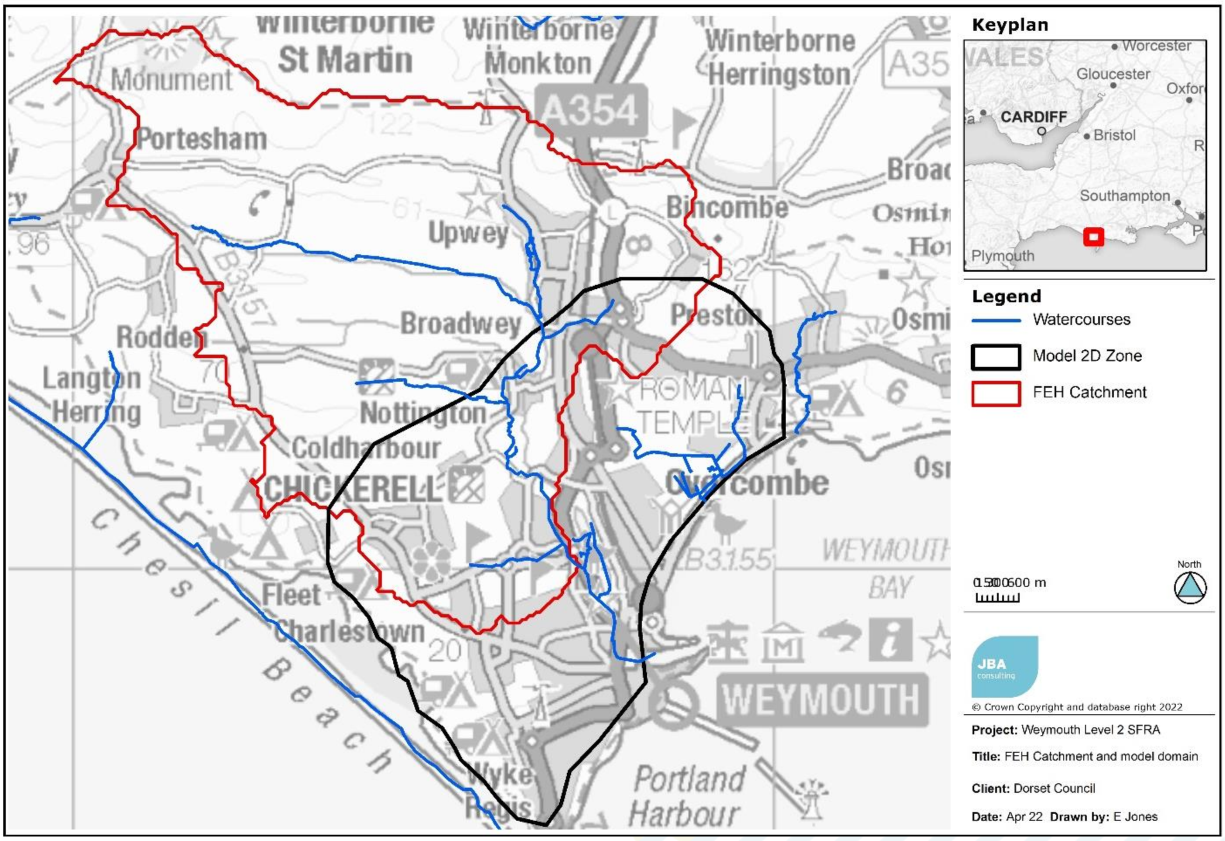
FEH13 (Flood Estimation Handbook) rainfall was generated and applied across the entire study area to generate surface water runoff, using a direct rainfall modelling approach.

Flood Estimation Handbook (FEH13) design rainfall was generated using catchment descriptors, available from the FEH web service. The catchment descriptors are shown in Table 3-1 and the catchment in Figure 3-1.

Table 3-1: Catchment descriptors for FEH catchment

Area	BFIHOST19	DPLBAR	DPSBAR	FARL	PROPWET	SPRHOST	URBEXT2000
41.59	0.517	6.83	80.1	0.999	0.38	35.44	0.0491

Figure 3-1: FEH catchment used for hydrology inputs to the model



3.1 Hyetograph generation

Revitalised Flood Hydrograph 2 (ReFH2) software was used to produce the design rainfall hyetographs for the Weymouth model. Urban hyetographs were applied.

A summer rainfall profile was used in ReFH2, as this generated the greatest rainfall intensities, reflecting the influence of rainfall-runoff mechanisms in contributing to flooding in Weymouth.

3.2 Storm durations

Several storm durations were tested to determine the critical duration for the model. The following durations were tested: 1-, 3-, 6-, 9- and 12-hours. The 1-hour storm was found to be the critical duration in the urban areas, producing more flow paths, in comparison to the 3-hour or longer duration storms.

4 Application of downstream boundary

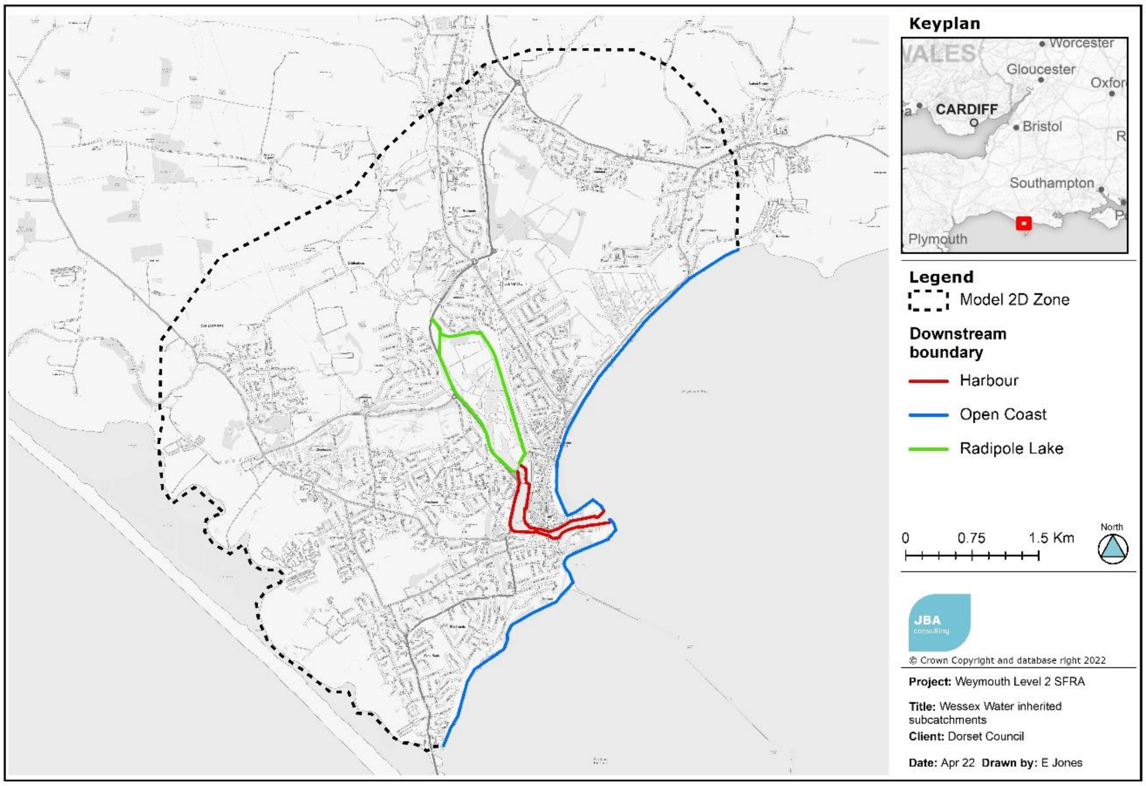
Within the model, boundary lines were used to apply a downstream boundary to the harbour, Radipole Lake and the coastline. Figure 4-1 shows the extent of each boundary. Elsewhere, the model boundary was set to a ‘normal’ condition, which allows floodwater accumulating in the floodplain to flow off the edge of the model.

The downstream boundary applied was dependent on the AEP of the model run. Table 4-1 shows the modelled return periods and the corresponding downstream boundaries.

Table 4-1: Model run AEP and associated tidal curve application

Model AEP	Tidal curve
3.33%	T2 (2-year)
3.33% + CC	T2_2138 (2-year + climate change)
1%	T2 (2-year)
1% + CC	T2_2138 (2-year + climate change)
0.1%	T20 (20-year)
0.1% + CC	T20_2138 (20-year + climate change)

Figure 4-1: Extent of downstream boundary



The downstream boundary was also applied to 1D outfalls, based on their location.

Two downstream boundary scenarios were applied; tidally dominant and fluvially dominant. Figure 4-2 and Figure 4-3 show the water level applied at each boundary/outfall.

To assess the worst-case of flooding, the peaks were shifted to align with the peaks in the sewer network.

Figure 4-2: 50% AEP fluvially dominant defended downstream boundary

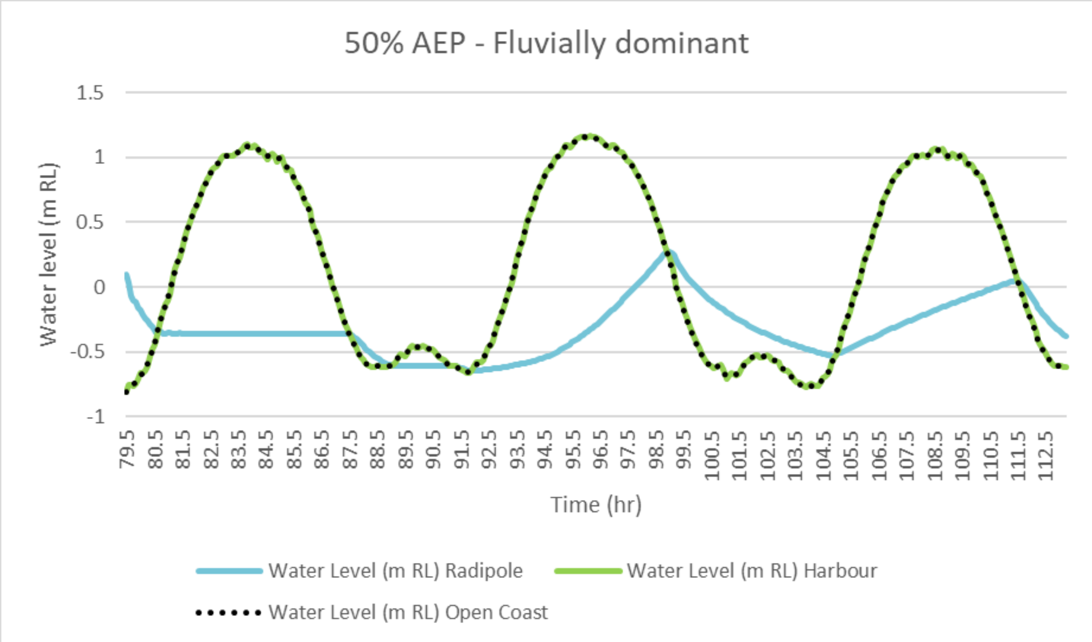
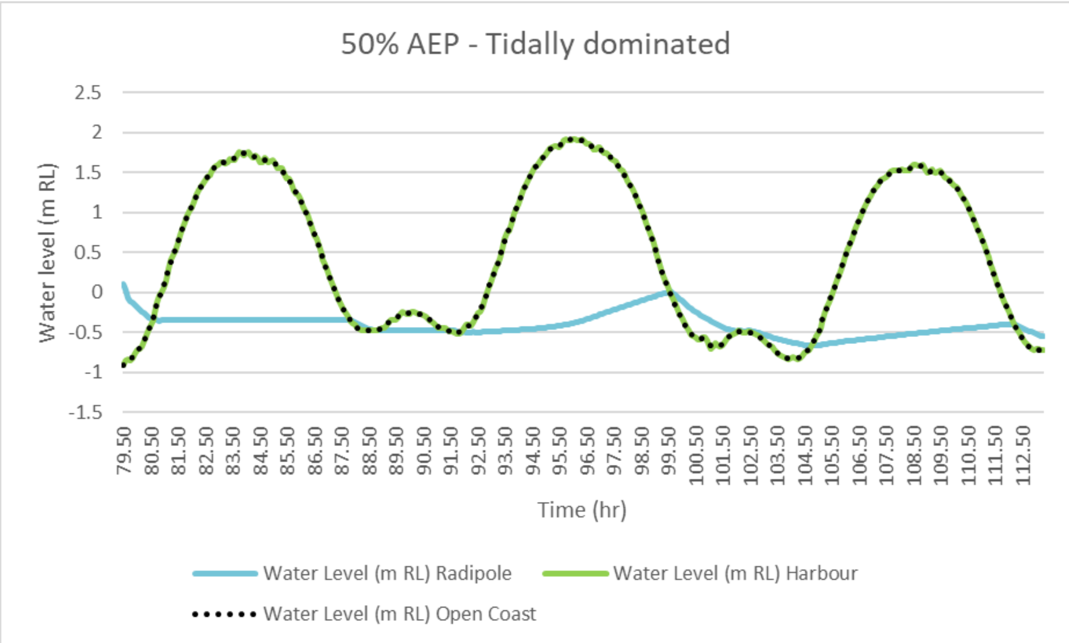


Figure 4-3: 50% AEP tidally dominant defended downstream boundary



5 Hydraulic model schematisation

5.1 Modelling software and version

InfoWorks ICM is the modelling software used for this study. InfoWorks ICM is the most suitable software in this case as it can represent the interactions between direct rainfall, overland flows and sewer networks as part of an integrated model. Additionally, this software was also used in the Wessex Water model, which is used for the sewer networks. The software version was InfoWorks ICM 2021.2, which was released in February 2021. The model version was latterly updated from v2021.2 to v2023.1 in January 2023 at the request of Dorset Council.

5.2 1D model overview

The sewer network was derived from a Wessex Water model.

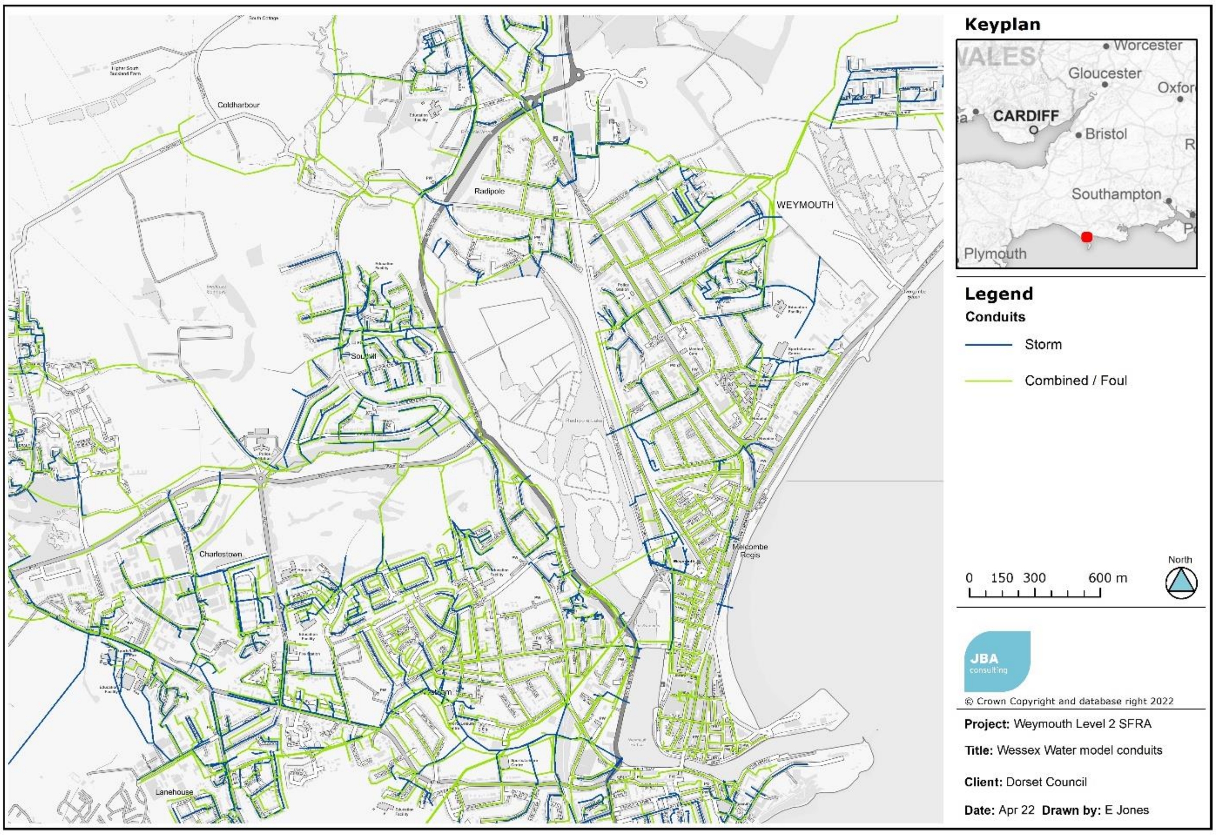
The 1D surface water, combined and foul sewers are linked to the 2D domain at manholes (for details of how these were linked see section 5.4). Surface water sewers which discharge to watercourses are linked via sewer outfalls.

The extent of the sewer network is shown in Figure 5-1.

The Wessex Water model was incorporated into the Weymouth model in its entirety. This approach was used to ensure all sewer flows across catchments were represented in the model, and to maintain the verification achieved on the existing model.

The contributing subcatchments from the surface water, combined and foul sewer networks were also inherited from the Wessex Water model. Further detail is provided in Section 5.2.1.

Figure 5-1: Strom and combined/foul conduits, derived from Wessex Water model



5.2.1 Sewer inflows

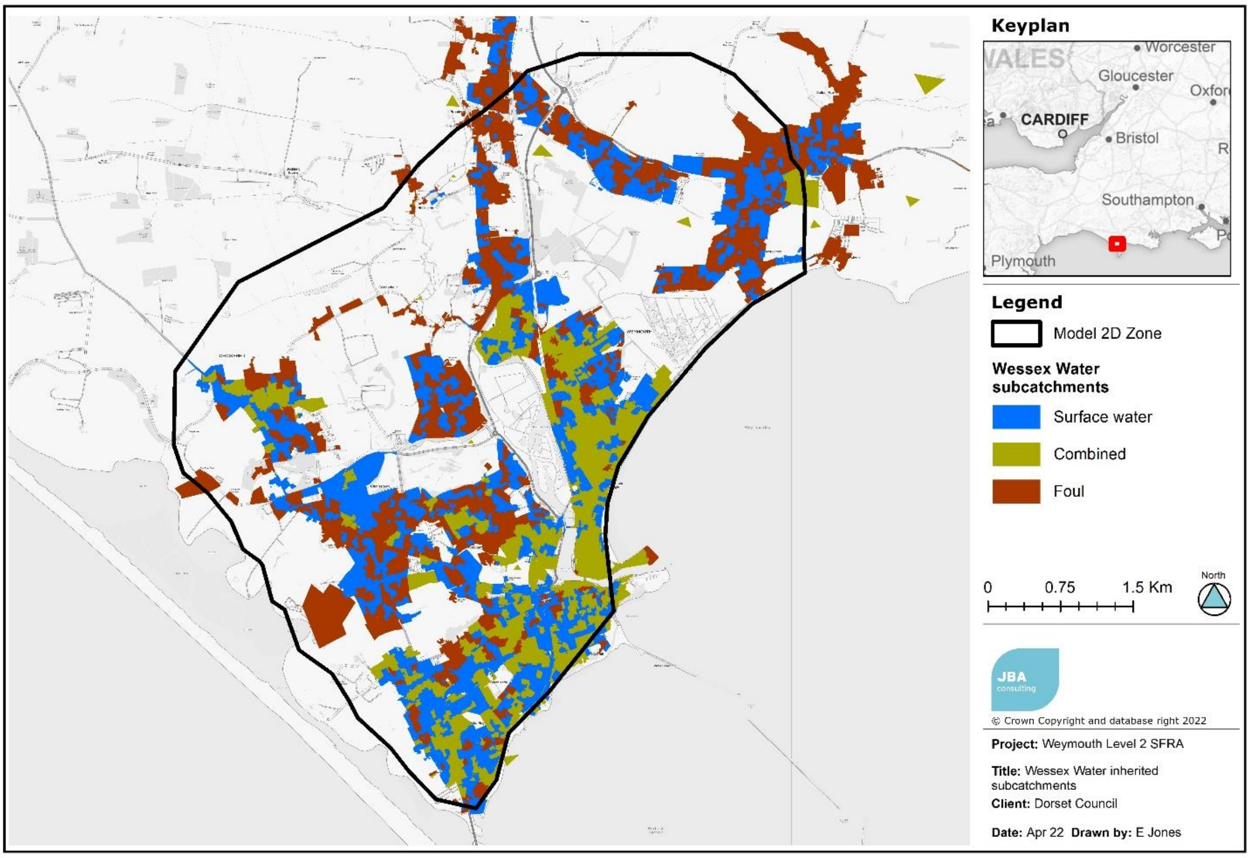
Within InfoWorks, rainfall is applied to a 1D sewer model via subcatchments. Subcatchments are polygon areas that cover the area expected to drain to the modelled sewer. Typically, a subcatchment is divided into three types of surface: roofs, roads and unpaved areas. The rate of runoff is defined for each surface type. In the UK, one standard approach is to use the Fixed runoff model from roofs and roads and the NewUK runoff model for unpaved areas.

The fixed runoff percentage from roads and roofs can vary according to modeller preference. Typically, a value greater than or equal to 70% (0.7 fixed runoff coefficient) is used. The remaining proportion of rainfall (30% or less) is not considered to drain to the sewer system. This acts to approximate the mechanisms of drainage capacity exceedance, evapotranspiration and interception storage.

Surface water, foul and combined sewer system subcatchments (shown in Figure 5-2) were inherited from the Wessex Water model. The inherited subcatchments apply seven different land uses:

- 31 New UK – RRV 4 (Soil 1)
- 31 New UK – RRV4 (Soil 3)
- 31 New UK – RRV 4 (Soil 4)
- 32 New UK – RRV 8 (Soil 3)
- 32 New UK Fixed + Slow008
- 33 New UK – RRV 25 (Soil 3)
- 33 New UK Fixed + Slow025

Figure 5-2: Surface water, combined and foul subcatchment coverage



Each land use contains a combination roofs, hardstanding and permeable surfaces. All use the same runoff surface for roads and roofs. The surfaces have a fixed runoff volume type, and runoff coefficients of 0.8 and 0.75, respectively. The varying factor, in each land use, is the permeable runoff surface.

It is assumed that the Wessex Water model has been verified against short-term flow survey data. Part of this process would have included calibrating the area of roofs, hardstanding and permeable surfaces connected to the sewer system. To retain this calibration, the contribution of runoff from roads and areas of hardstanding was retained within the Weymouth model. However, areas of permeable surface draining to sewer (represented by NewUK runoff volume types) were removed from the subcatchments, by setting a contributing area of 0Ha for permeable surface types. These permeable surface types were removed from the subcatchments because during high return period events, which are the focus of this study, permeable surfaces are more likely to generate overland flow, rather than draining directly into the sewer network. Instead, the routing of rainfall across permeable surfaces has been represented in greater spatial detail within the 2D model domain, though the use of roughness zones and infiltration zones, as detailed in Section 5.3.2.

In the existing 1D-only Wessex Water model subcatchments, 75% - 80% of runoff from impermeable areas is drained directly to sewer, with the remaining 15 – 20% not entering the sewer, and being 'lost' to exceedance. As exceedance from the sewer can be routed overland in areas covered by the 2D domain of the Weymouth model, infiltration zones were added within the existing subcatchments to capture the 'lost' element of runoff from the subcatchments as overland flows.

To avoid double counting of runoff, the inverse fixed runoff rate of the subcatchments was applied within the infiltration zones. The approach was applied across the model in areas where the 1D and 2D domains are linked (i.e. within the 2D Zone), with more details provided in Section 5.3.2

5.3 2D model overview

The 2D domain extends to approximately 4km west Weymouth Bay. This catchment is large enough to account for the for the interaction between surface water and the tide. It was not necessary to include a large proportion of the River Wey catchment, as this study is not focussed on the interaction between fluvial and tidal risk and fluvial flows from the River Wey into Radipole Lake have been modelled as a time varying water level (see section 4).

Table 5-1: Summary of 2D components

Area of 2D domain	28.33km^2
Resolution of triangular mesh	Minimum element size: 1m^2 Maximum element size: 25m^2
DTM data source	Open-source LiDAR (data.gov.uk)
DTM resolution	1m

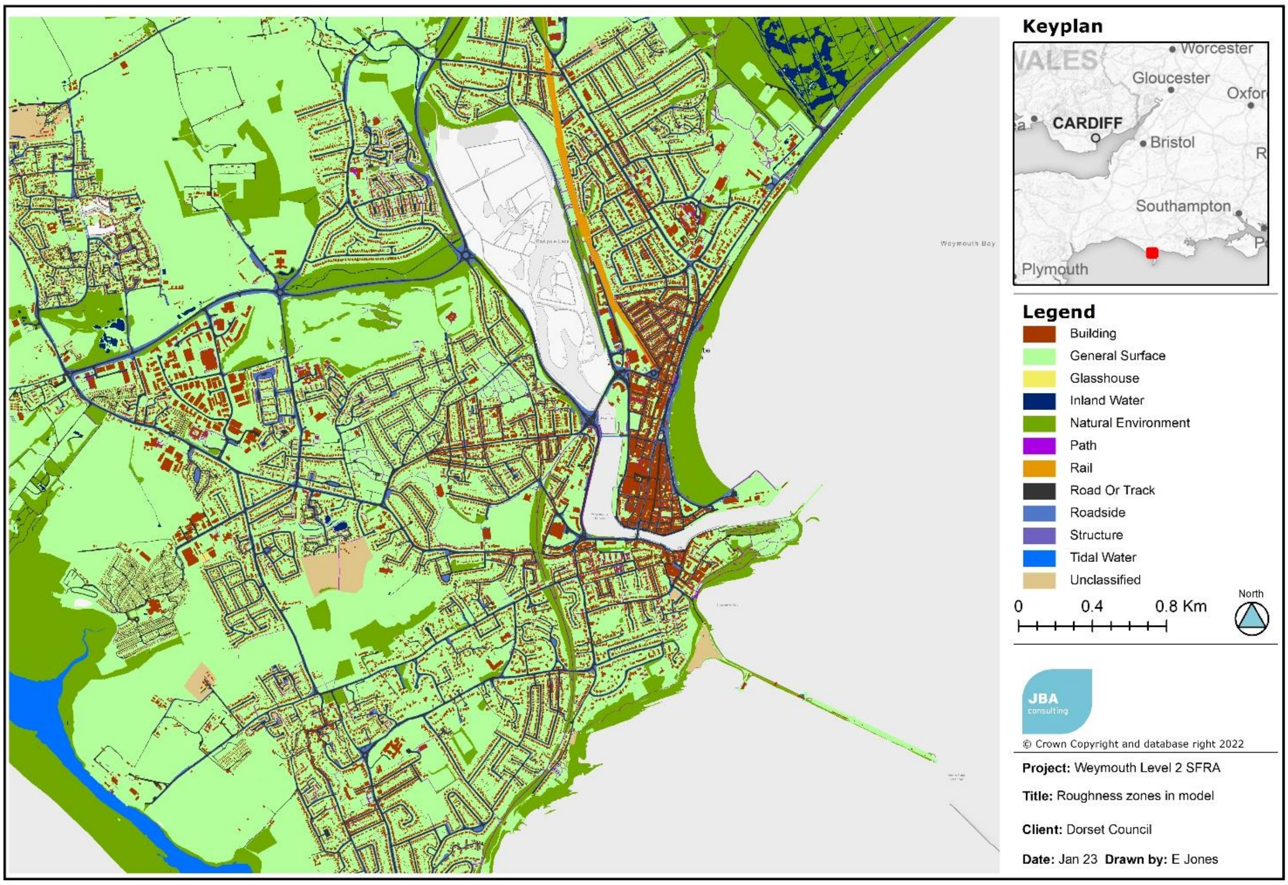
5.3.1 2D hydraulic roughness

Manning's *n* values have been used to represent hydraulic roughness in the 2D domain. The roughness values recorded in Table 5-2 (where present) were used in the model and are based on land cover types recorded in the Ordnance Survey MasterMap Topographic Area layer dataset. Coverage of land uses is shown in Figure 5-3.

Table 5-2: 2D hydraulic roughness values

Land cover	Manning's *n*
Building	0.300
General surface - multi surface	0.050
General surface - step	0.050
General surface	0.060
Glasshouse	0.200
Inland water	0.045
Natural environment	0.090
Path - step	0.050
Path	0.035
Rail	0.045
Road or track	0.035
Roadside	0.050
Structure	0.300

Figure 5-3: Roughness zone coverage in model



5.3.2 2D infiltration

Infiltration has been used within the model, in conjunction with subcatchments, to ensure that there is no double counting or underestimating of rainfall runoff.

In the 1D sewer component of the model, rainfall is applied to subcatchments that cover the areas expected to drain to sewer. These are divided into roads, roofs and unpaved areas of which a specific runoff rate is defined for each. A fixed runoff is typically applied to roads and roofs, and the remaining rainfall is not considered to be directly connected to sewers.

In the 2D component of the model, direct rainfall is applied directly to the mesh surface, and is routed across the topography. Rainfall losses are applied within the model, using infiltration zones. These zones control the percentage of rainfall which is lost to infiltration and evapotranspiration and a fixed runoff value is applied.

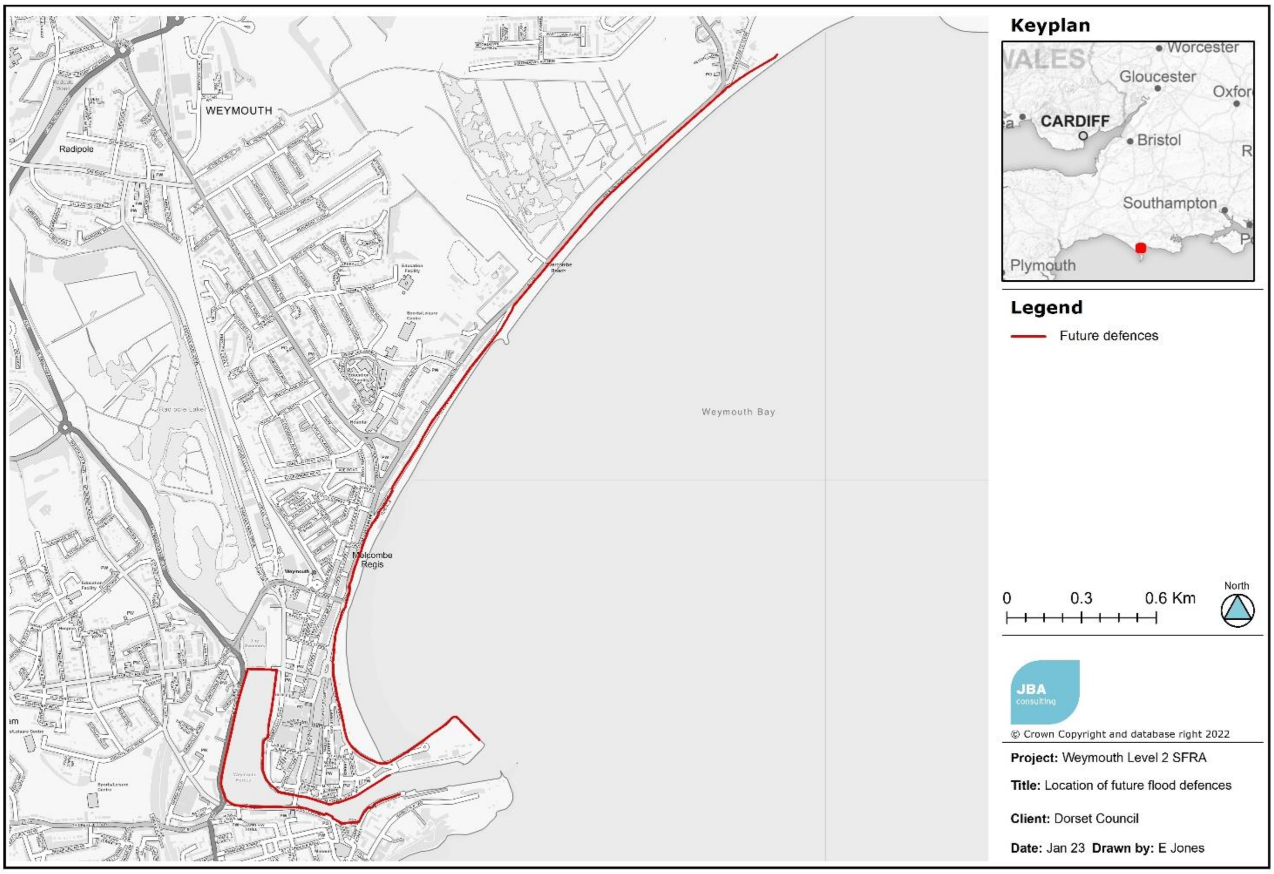
In the Weymouth model, an infiltration surface was applied to the 2D domain with a fixed runoff coefficient of 0.35, which is derived from the SPRHOST value. This represents the percentage runoff from permeable surfaces based on the HOST soils type.

Section 5.2.1 outlines the 1D subcatchments present within the model, including details of those inherited from the Wessex Water model. In summary, the subcatchments direct 80% and 75% of runoff to the sewer, from roads and roofs, respectively. Infiltration zones were therefore applied to these areas with runoff coefficients of 20% and 25%, to account for the remaining runoff.

5.3.3 Flood defences

Existing and future flood defences have been included in the baseline model. These include the defences along the promenade and around the harbour. Flood defences have been included in the model as 2D base linear structures. Proposed future defences have been included in the future scenario and used with all climate change simulations. Figure 5-4 shows the location of these defences.

Figure 5-4: Defences included in the future model



*Note – the location of the defences is largely similar in the baseline model, but the height may have changed.

5.4 1D-2D linking

The standard approach to linking 1D-2D models in InfoWorks ICM is adopted throughout this model. For the surface water and combined sewer networks, manholes within the 2D zone have been set to a '2D' flood type, which allows flood water to both enter and leave the 1D system and 2D domain, via the manholes. Head-discharge relationships have been applied to all 2D nodes to represent the presence of manhole covers where there were either no road gullies present (for surface water system nodes) or where a surface water system was present (for combined system nodes). Elsewhere (i.e. where road gullies were believed to be connected to the sewer system) a road gully head discharge curve has been used. These allow the restriction of flow into and out of the sewer system to be controlled based on the presence of manhole covers or road gullies.

6 Model results

The model was run for the following AEPs; 3.33%, 1%, 0.1%, 3.33% + CC and 1% + CC and 0.1% + CC. Each AEP was run with the following boundary conditions; no boundary applied, tidally dominant boundary and fluvial-dominant boundary. In total, 15 runs were completed.

Climate change allowances were applied based on the uplifts provided in the Environment Agency climate change allowances guidance1.

For the Dorset River Basin District peak rainfall intensity uplifts of 40% for the 3.3% AEP event and 45% for the 1% AEP event are recommended for the Upper End climate change allowance during the 2080's epoch. In the absence of other information, the 45% uplift has also been applied to the 0.1% AEP event.

The model results are summarised in the Level 2 SFRA summary sheets.

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1 https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

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