Appendix A : Detailed Modelling

The Kings Lynn and West Norfolk Settlements SWMP was completed in January 2012. The study assessed pluvial flood risk to 16 settlements across West Norfolk for a range of flood events. Due to project constraints, the flood risk associated with ordinary watercourses was not specifically assessed. Norfolk County Council have commissioned Capita to undertake a more detailed assessment of flood risk from ordinary watercourses within Kings Lynn and its interaction with surface water flooding.

A.1 Model Extent

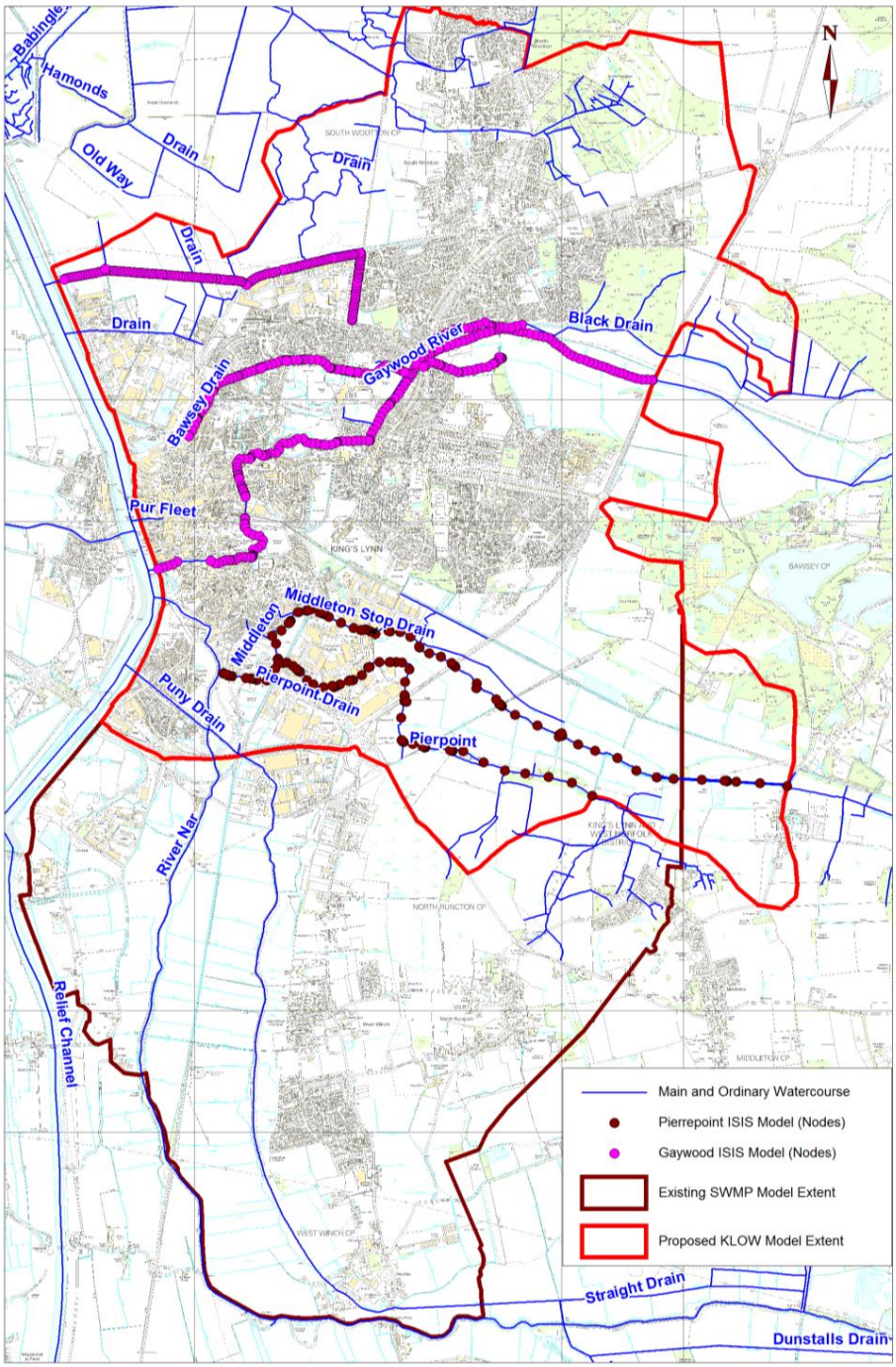
Four 2D TUFLOW hydraulic models were constructed by Capita to inform the SWMP study. The models named “Kings Lynn” covers the area of interest for this additional work and have been used to represent the 2D floodplain of a new combined model to be constructed for this study. Amendments and updates to certain model features are discussed in the subsequent sections of this appendix.

The existing extent of the 2D Kings Lynn SWMP TUFLOW model includes an area to the south that is not of interest as part of the Kings Lynn Ordinary Watercourse (KLOW) Study. This extent was trimmed as shown in Figure A-1 in order to reduce model simulation times. However the extent of the 2D model was extended further to the east to incorporate the upstream reach of the Middleton Stop Drain.

1D ISIS models, produced in 2004 and 2009, of a number of the ordinary watercourses within Kings Lynn were provided by. These models were constructed for River Gaywood Strategic Review and for the Pierrepoint District Strategic Review. Following a review of the existing ISIS models, the vertical datum was amended from “South Level Datum” to “Ordnance Datum Newyln” in order to make the 1D (ISIS) and 2D (TUFLOW) domains consistent. This was done by subtracting 100m from all model node elevations. The extent of the existing IDB’s ISIS models remains same as in the shown in the Figure A-1.

The new Kings Lynn Ordinary Watercourse (KLOW) Study model has been developed by combining the amended 1D ISIS models (from the IDBs) and the updated Kings Lynn 2D model.

Figure A-1: Model extents (existing SWMP and revised KLOW model boundaries)



A.2 Topography

The floodplain ground levels in the existing TUFLOW model have been based on 1m and 2m resolution LiDAR data flow in 2011. A check of the Environment Agency's Geomatics website[1] has shown that there have been no updates to this dataset since. The existing LiDAR data has therefore been retained for use in this study.

Following the review of ISIS models it was identified that the existing model (Gaywood River Model) did not include the more recent survey data, which was collected by Brandon surveys for the Bawsey Drain in 2013 and the right bank of the River Gaywood in July 2014.

A.3 Model updates

The following modifications and updates have been applied to the exiting ISIS and 2D model for the purposes of this study:

- Following a review of the existing ISIS models, the vertical datum was amended from "South Level Datum" to "Ordnance Datum Newyln" in order to make the 1D (ISIS) and 2D (TUFLOW) domains consistent. This was done by subtracting 100m from all model node elevations.

- Gaywood River model has been updated with cross section data from the Brandon surveys for Bawsey Drain in 2013

- The existing Railway Bridge on Middleton Stop Drain has been included in the model. The dimensions of the Railway Bridge were measured during the site visit

- 2d Zsh layers that raises watercourses to bankful in the existing SWMP model has been reviewed / checked and removed from the model for ordinary watercourses (as watercourses are modelled using ISIS)

- The representation of the left and right bank of the River Gaywood has been improved using July 2014 survey data.

- Improved representation of existing structures, where required. For example, in the existing IDB ISIS model the Broad Walk Bridge was modelled as two separate orifice units (9m apart) at BRU_0832 and BRU_0823 using the upstream and downstream openings of the bridge respectively. The Broad Walk Bridge has been represented in the KLOW model as an orifice unit at node BRU_0827,as per survey drawings using the dimension of the downstream face of the bridge since it has the minimum bore area. The node levels and distance between GWD_0832 to GWD_0804 also has been adjusted based on survey data.

- River channel cross sections were truncated, where required, as the floodplains have been represented within the 2D TUFLOW domain.

[1] https://www.geomatics-group.co.uk/GeoCMS/Homepage.aspx

- Removal of all reservoir units and associated spill units as the floodplains are now represented in the 2D domain.
- Interpolated sections were added, where required, in order to improve model stability.
- Panel markers were added to river channel sections, where required, in order to improve the conveyance calculations.

A.4 Structures

The majority of the structures located along the modelled sections of the watercourses were included in the existing ISIS models. The review of the existing ISIS models has identified that the Railway Bridge on Middleton Stop Drain (562939 319284) has not been included in the Pierrepoint ISIS model. This structure has been included in the ISIS model based on the site walkover survey.

A number of pipes (crossing the watercourses) have been deleted from the model where they were tending to create poor convergence, but there was no discernible change in head over the structures.

The Kings Lynn IDB are currently in the process of constructing a new attenuation pond at Queen Elizabeth Way as part of the 'Pierrepoint Scheme' (as detailed in the attached drawing reference C-205124/200 Rev P16). The attenuation pond is currently under construction and has been represented in the existing ISIS (1D) model. The attenuation pond has been represented in the 2D based on the construction drawings (C-205124/200-Rev-P16).

The review of the existing ISIS models also identified that flapped outfalls/gates from River Gaywood, Bawsey Drain and North Lynn Drain have been modelled using sluice gates, and the pumped outlet from the North Lynn Drain modelled as pump unit with automated operation with following operation rules:

The River Gaywood Sluice operating rules are defined to open the sluice gate to a height of 1.71m when the upstream water level is greater than the downstream water level.

The North Lynn Drain Sluice operating rules are defined to open the sluice gate to a height of 1.063m when the upstream water level is greater than the downstream water level.

The Bawsey Drain Sluice operating rules are defined to open the sluice gate to a height of 1.595m when the upstream water level is greater than the downstream water level.

Again for the Pierrepoint Model, the outfall to the River Nar from the watercourses has been modelled as three pumps in parallel, with data drawn from pump curves and IDB operation rules.

All above structure operation rules has been reviewed and modified/adjusted to fit with NewLyn Datum.

A.5 Model Software Version

The model has been simulated with the latest versions of both ISIS and TUFLOW (ISIS version 3. 7.0.110 and TUFLOW version 2013-12-AD-iDP) to make use of additional functionality and improved stability for direct rainfall models. Changes to the mathematical solver in TUFLOW will allow for the model time-step to be increased resulting in a significant reduction in model simulation time. Changes to default settings in either software package may result in changes to the model results.

A.6 Model Boundaries

A.6.1 *Model Inflow*

The hydrological report for the Gaywood River was reviewed and inflows for the Gaywood River, North Lynn, Bawsey and Black Drains generated.

No hydrology report or ISIS inflow boundaries were available for the Pierrepoint Model and the previous study recommended re-estimating flow boundaries using updated methods (since the FEH rainfall-runoff method has been superseded by the Revitalised Flood Hydrograph method) and data. Therefore, additional hydrological calculations have been carried out for the Pierrepoint and Middleton Stop Drains to derive inflows for the ISIS model.

A review of the direct rainfall from the SWMP model and inflows estimated from the ISIS models was carried out to ensure the flood risk is represented as accurately as possible and the fluvial flood risk is not over estimated and included from both approaches. The inflows applied to the model consisted of a combination of point inflows applied to the watercourses and rainfall hyetographs applied to the entirety of the 2D model extent. The point inflows represent runoff from the upper parts of the catchment that are not explicitly modelled.

The existing Kings Lynn SWMP model has been simulated with hydrological inflows based on a storm duration of 3.4hrs. The existing IDB's ISIS model has been simulated with hydrological inflows based on a storm duration of 26.1hrs. As agreed with the NCC, the fluvial and pluvial scenarios have been simulated separately (as the critical storm durations are so different) as shown below:

- Pluvial scenarios- with a critical storm duration of 3.4hrs
- Fluvial scenarios- with a critical storm duration of 26.1hrs

Further details on the hydrology changes can be found Appendix F – Flood Estimation Proforma.

A.6.2 *Downstream Boundaries*

The ordinary watercourses in the study area outfall to the tidally influenced River Great Ouse. The downstream boundary of the Gaywood ISIS model represents a spring tide estimated by extrapolating between known tidal curves at Hammonds Drain and Freebridge. The downstream boundary of the existing Pierrepoint ISIS model has been set as a constant level of River Nar. For this study the downstream boundaries remain the same as the existing IDB's ISIS model.

The tide curves were adjusted so that the peaks were synchronised.

A 2D tidal boundary is not required due to the presence of defences along the eastern boundary of the River Great Ouse.

A.7 Infiltration

The current SWMP model utilises runoff coefficients to represent the soils infiltration. Each land use is assigned a coefficient and the amount of rainfall applied to the model is adjusted according to the specified coefficient. Following the release of the 2012 version of TUFLOW, the Green-Ampt method was made available to represent soils infiltration. This method is more advanced than the use of runoff coefficients as it varies the rate of infiltration over time based on a number of soil characteristics.

The new KLOW 1D-2D model has included representation of soils infiltration using the Green-Ampt method. The classification of soils across the study area are based on data supplied by BGS as well as Cranfield University's Soils capes website. Infiltration has been applied across all permeable land uses in the study area only.

A.8 Representation of the Drainage Network

The TUFLOW models previously constructed for the SWMP study did not include an explicit representation of the drainage network. Instead a 3mm/hr loss was applied to impervious surfaces for some of the SWMP modelled area, to represent available storage within the drainage network. However, this loss was not included in the SWMP model for the Kings Lynn area to represent tide locking of the drainage network. This assumption was also retained for this KLOW study.