APPENDIX A Modelling Memo

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South Tyneside SWMP

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South Tyneside SWMP

Detailed Modelling Technical Note

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1. Introduction

The purpose of this Detailed Modelling Technical Note is to document the processes used throughout the "Detailed Modelling" phase, following on from the "Intermediate Modelling" phase and to report on the results of the modelling leading on to the identification of alleviation options and the determination of an Action Plan.

2. Detailed Modelling

Phase 1 identified 10 areas as potential locations that could be taken further to detailed modelling. Of these, 4 were deemed to be unsuitable as options due to either the potential cost benefit ratio being too low at the site, or schemes already being promoted in the area (such as in the Hebburn area).

After discussions with South Tyneside Council and Northumbria Water, it was decided that the areas to be carried forwards were Fellgate, two locations in Cleadon (focusing on Cleadon Lea and West Drive, and the area to the east around Sunderland and Whitburn Road), King George Road and Lindisfarne Roundabout (which was identified by South Tyneside Council as a key transport link and hence had a high importance). Subsequent to the initial decision to model King George Road, it was brought to the attention of South Tyneside Council that a scheme was already in progress in the area to address the issues. It was then decided to replace King George Road with a detailed model of the area around Newmarket Walk.

These locations were selected due to the intermediate modelling results indicating that a substantial flooding incident could occur at these locations, as well as there being known historic flooding in the vicinity within the last two years. This in turn gave these areas the potential for a reasonably high cost/benefit ratio. There were also no current schemes in place or underway in order to alleviate these issues, ensuring the issues were not being addressed unnecessarily.

These locations were then focussed on individually in order to achieve a greater detail in the modelling. However, both the locations in Cleadon were modelled as one detailed zone due to the fact the sewer model for the area could not be easily split into two sections as no appropriate hydraulic break point could be identified between them. The benefit to splitting the South Tyneside model into the smaller detailed models was that the simulation runs would complete quicker, and the smaller areas meant that the mesh element size could be reduced, thus giving a finer resolution to the representation of the overland flow (since there is a maximum number of triangles that can be generated in a mesh zone).

The 2D zone that the rainfall was applied to was then drawn onto the geoplan. The extents of this zone were directly influenced by the flow paths simulated in the intermediate runs. By ensuring that the 2D zone was as small as possible whilst not removing any area that contributed to the flows in the mesh area, the maximum element size was able to be reduced. This yielded a finer mesh that could pick up more features of the DTM whilst simultaneously giving more accurate results at areas of interest. The buildings were then cut out of the DTM as voids which meant that flow paths between buildings could be observed, as well as seeing how deep the water may have got against a structure.

Below in Figure 1 to Figure 5, the five areas carried forward to detailed modelling can be seen.

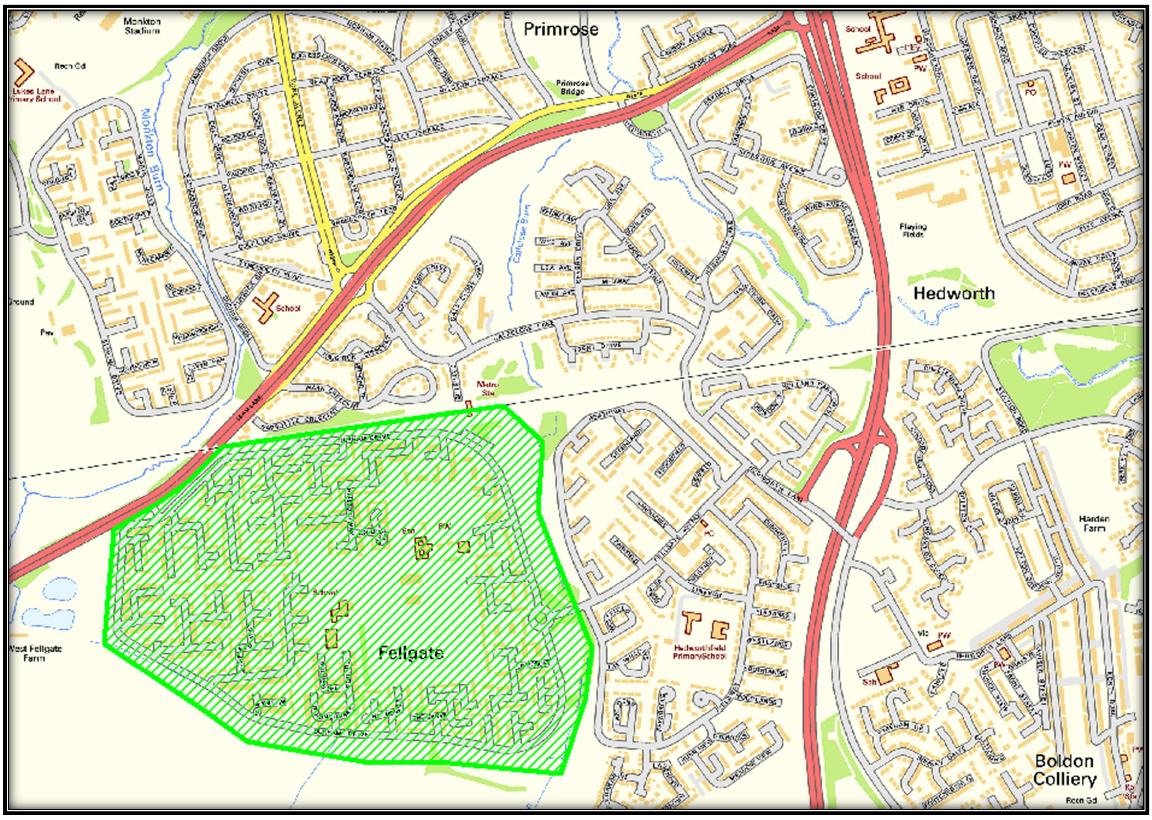

Figure 1 - The detailed area of Fellgate covers the area surrounded by the A194 and the A19

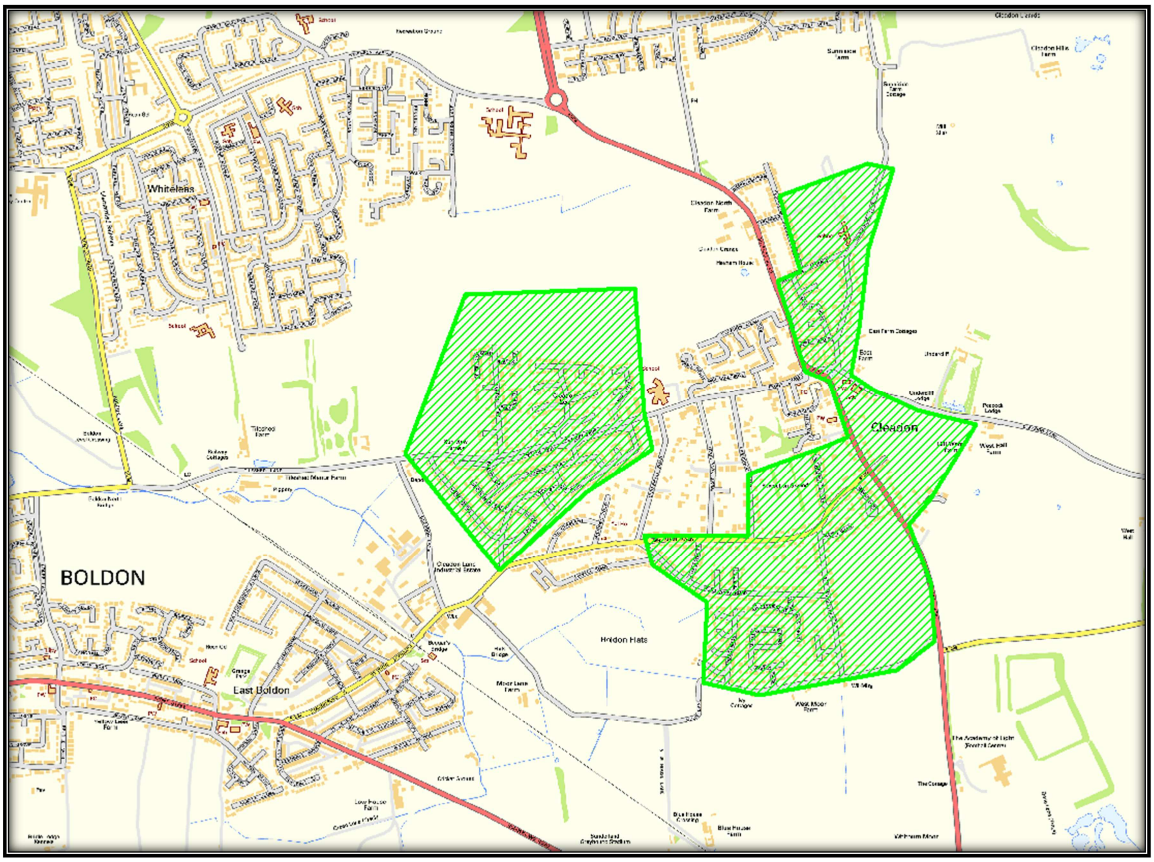

Figure 2 - Both the detailed modelling locations in Cleadon (the left had area encapsulates Cleadon Lea and West Drive, while the right hand zone surrounds Sunderland and Whitburn Road)

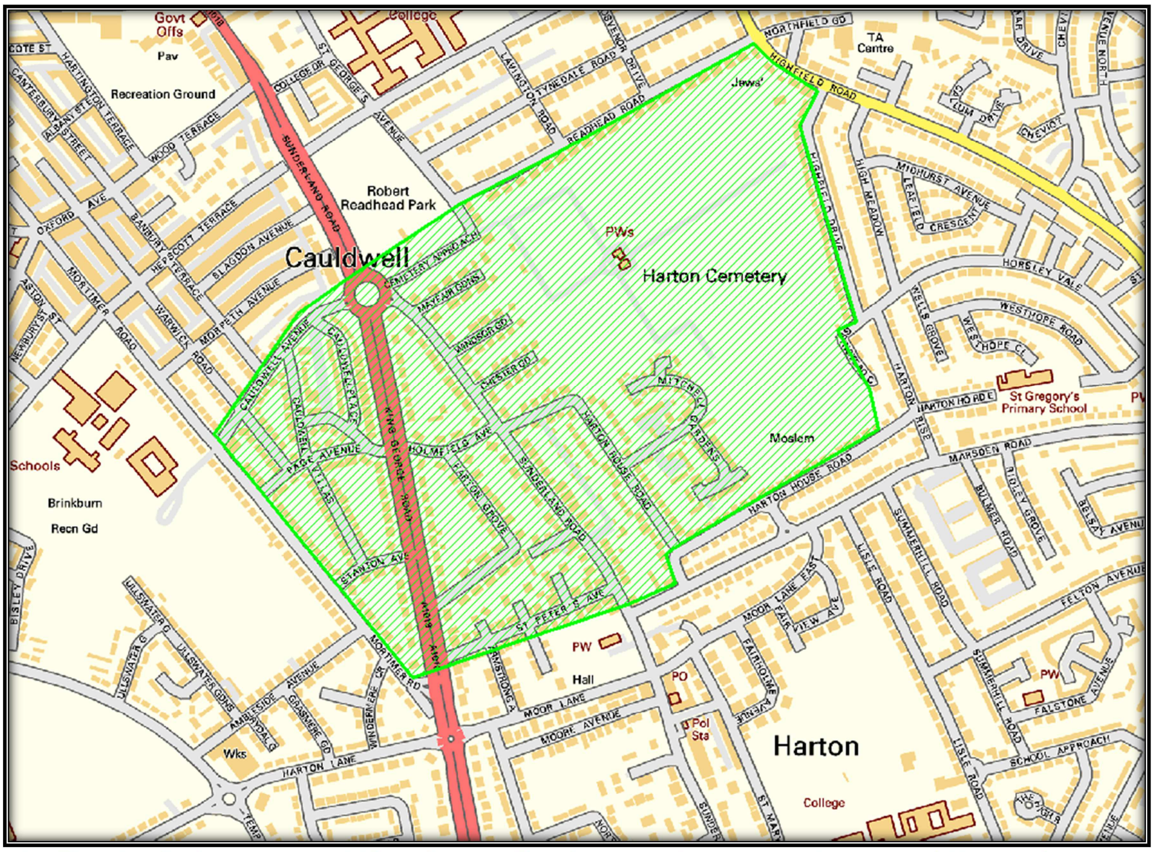

Figure 3 - The detailed area around King George Road covers the area to the west of Harton Cemetery in the Harton area of South Tyneside – this was subsequently removed from being an area of interest

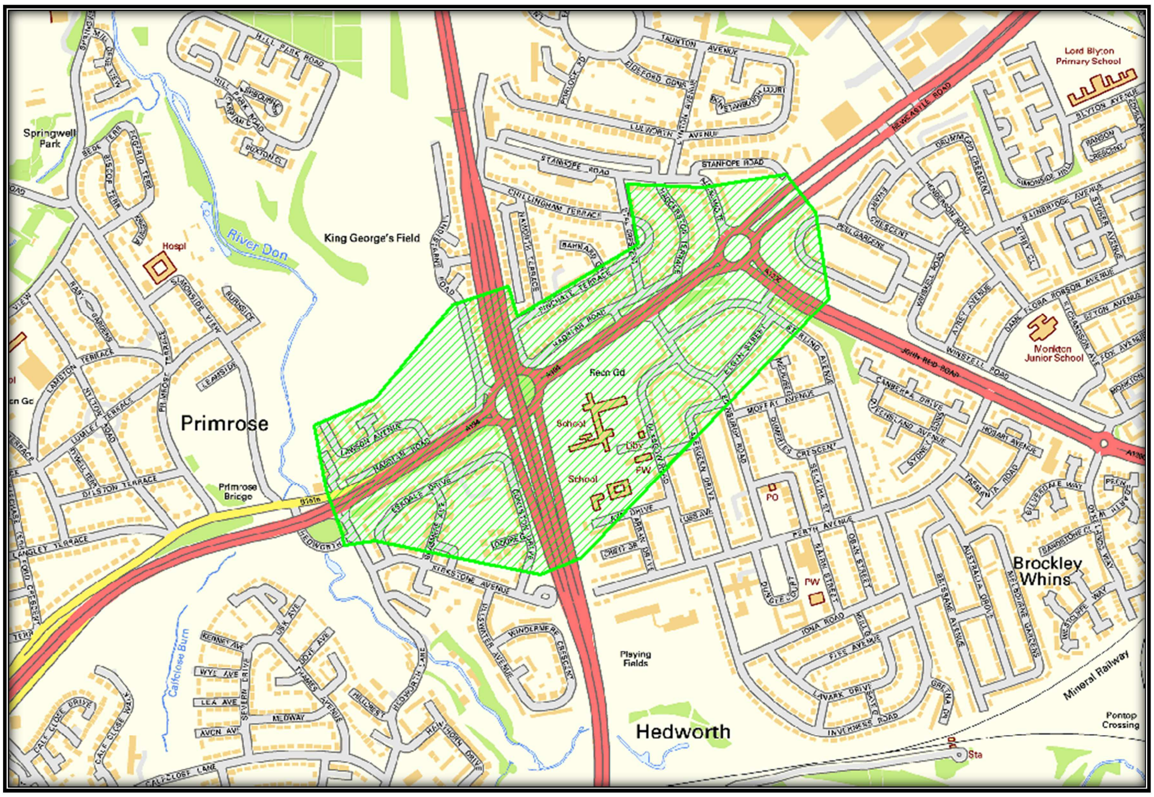

Figure 4 - The detailed area of Lindisfarne Roundabout, which was identified as a key transport link by South Tyneside Council

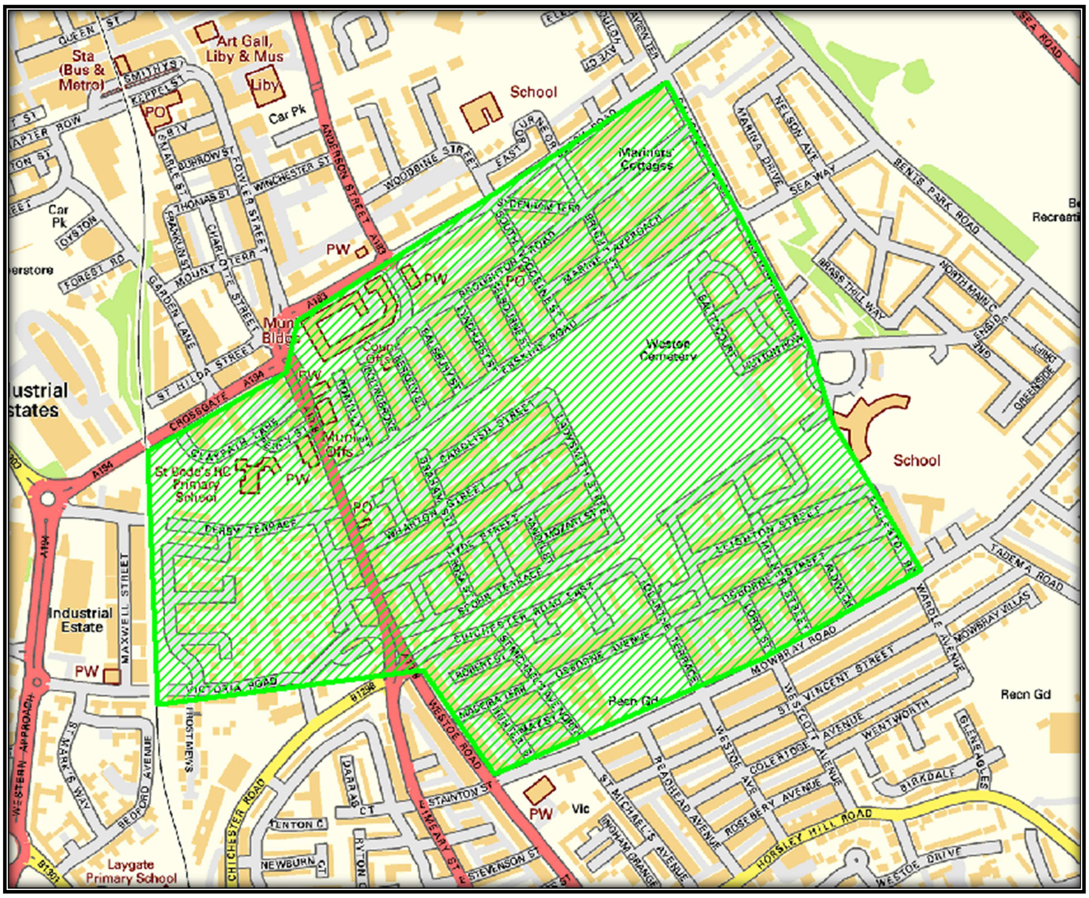

Figure 5 - Newmarket Walk area taken forward to detailed modelling in place of the disregarded King George Road

Mesh Zones

In order to begin detailed modelling and be able to simulate pluvial runoff, the first step was to create a 2D zone that covered the entire area of interest, and its catchment. This gave the model a zone where overland flow could be represented.

In all of the areas within the detailed zones, it was considered very important to model the kerb lines due to the fact that the roads were the main way the overland flow was conveyed around the developed areas in the catchment. This is highlighted by the fact that photos of the flooding in 2012 clearly show this as the main mechanism of movement of the water in certain areas (see Figure 6).

Figure 6 - Photos highlighting the flow paths and how the roads convey the flow

This was achieved in ICM by converting the regions in the Mastermap data that represented the roads and paths into 'mesh zones'. When importing these roads into ICM, the mesh zones were lowered by 125mm (setting it into the DTM [digital terrain model]), creating the channel. The triangles in the mesh zone were usually given a finer resolution with maximum element area of $4m^2$, and a minimum of $1m^2$, which allowed an accurate representation of the flow down the roads. This worked very well as can be seen in Figure 7 overleaf, which represents the same location as the bottom and right hand photographs in Figure 6.

Any manhole that was found within the lowered mesh zone had its cover level adjusted accordingly, by reducing it by 125mm too. This ensured that the cover level matched that of the road, and that flows could enter the sewers as appropriate.

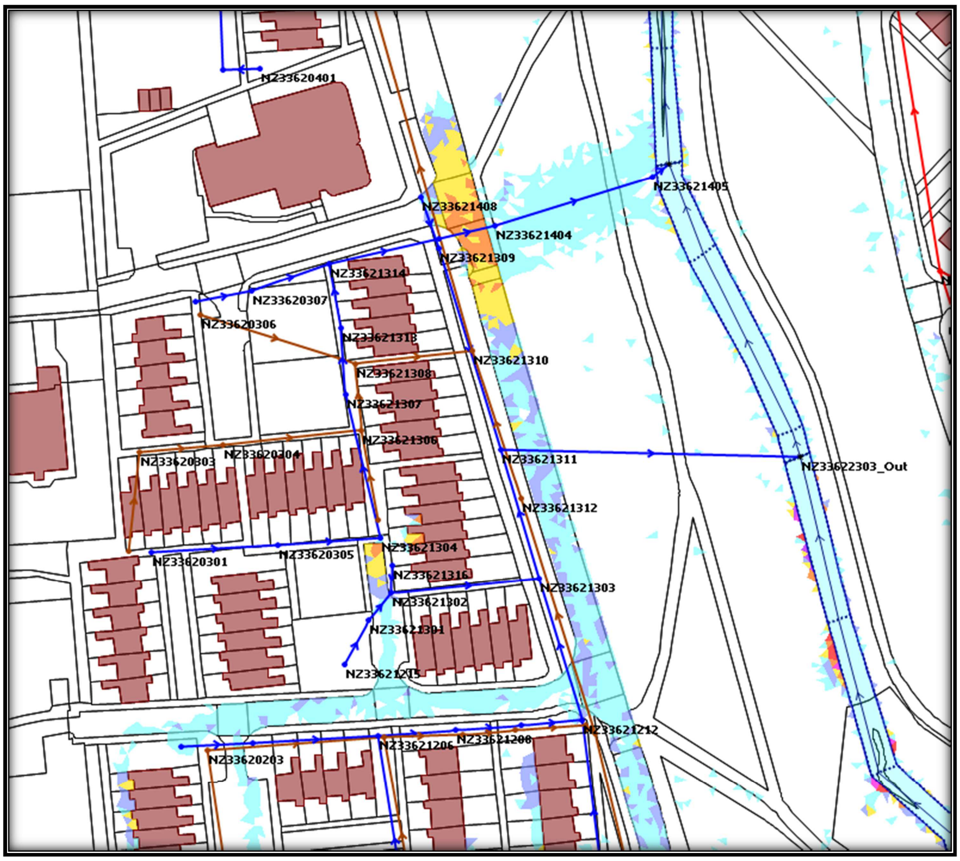

Figure 7 - Simulation results for the detailed Fellgate model along Durham Drive showing that the 'mesh zones' have encouraged the flow along the roads.

Walls

Another very important aspect of the detailed modelling is the use of walls and fences to divert flows around properties or buildings as they would in reality. Since in most cases the DTM would not have picked up small walls and fences (or if they were they may have been removed when the DSM [digital surface model] was converted into a DTM – this process uses algorithms to effectively remove all items such as houses, trees and walls), these elements needed to be put back into the model where the intermediate runs predicted a flow path. This could (in some cases) prevent the flooding of a property that was predicted to flood in the intermediate runs (or vice versa as the flows were redirected towards other properties). It allowed a much more accurate representation of the true flow paths. These features were put in from both the knowledge gained during the site visit, photos supplied and tools such as 'Google Maps'. When they were input into the model, they were assigned a height, which if the depth of flow exceeds, can be over topped by the water. In Figure 8, the walls in the model (the red lines) represent gravel boards at the bottoms of fences. These were given a height of 0.125m, and as can be seen they have been overtopped (on the right hand side of the image). Until the depth exceeded the height of the wall, no flow crossed it.

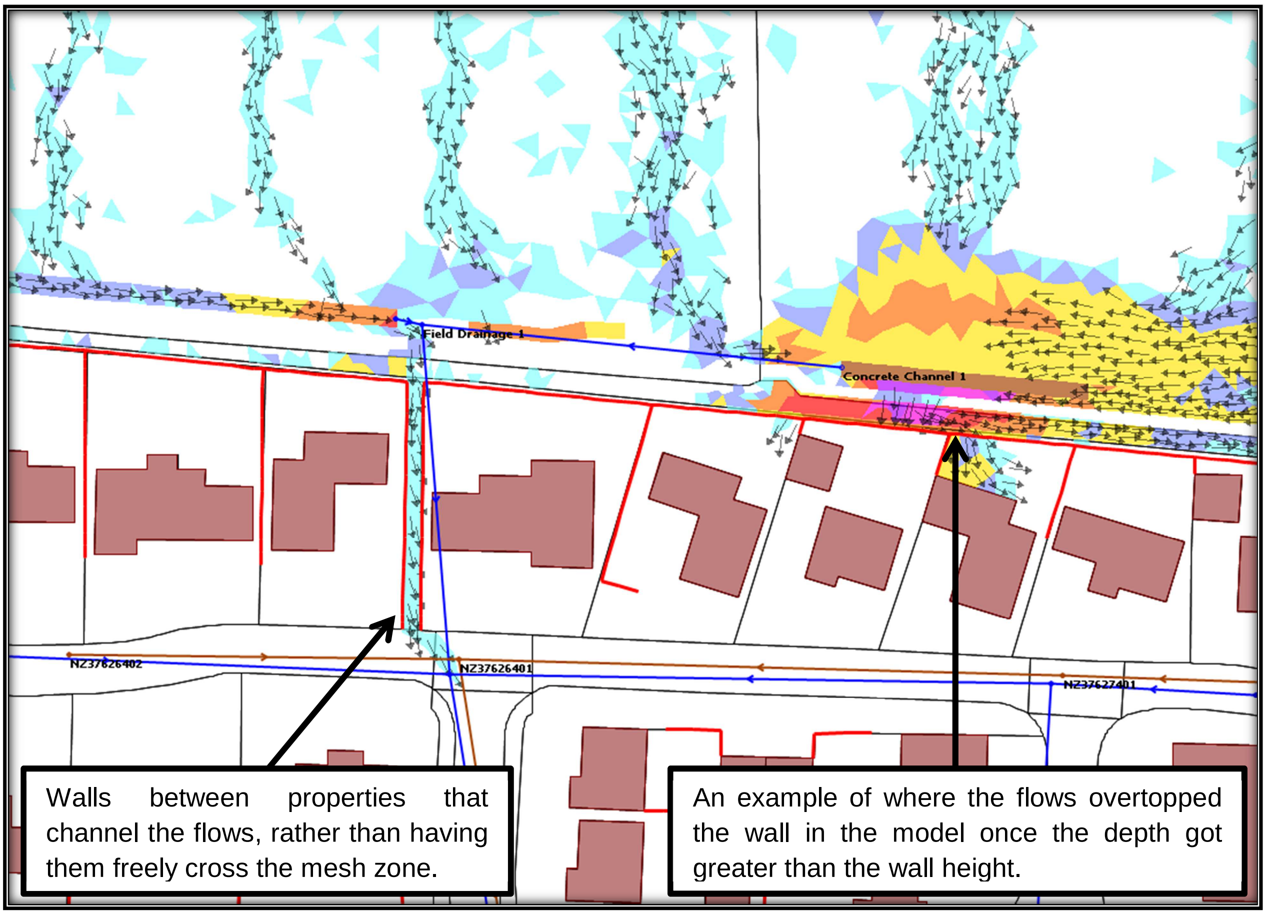

Figure 8 - Simulation results around Cleadon Lea which clearly shows how the walls can channel the flows direction, rather than allowing them to flow freely across the mesh (the walls are show in red).

Gullies

In locations that had shown significant flow along the roads, RAA were requested to model the gullies along the flow paths in order to get a better representation of how the flows enter the sewers. After discussion with STC regarding the areas selected for the modelling of gullies, Cleadon (Sunderland Road), and Lindisfarne Roundabout were selected as areas to take forwards. Where these gullies were added into the model, the head/discharge relationship of the gulley was altered between the 'Do Nothing' scenario and the 'Do Minimum' scenarios. In essence, this allowed the modelling of a clear and blocked gulley (when the gulley was 'blocked', the discharge limit was set to 0.1 l/s to replicate some flow passing through the blockage). Where gullies were added, the manholes were changed to 'Gulley 2D' as well. The head discharge relationship for these manholes was set according to the paper 'Modelling Road Gullies' by RAA, which allowed only small amounts of flow into the manhole, but would allow much more out when the sewer surcharged. An image of the gullies added into the model can be seen in Figure 9 overleaf.

Figure 9 - Image of the gullies added into the model

The head discharge relationship for each of the gullies was set according to the type of gulley that was present at the site. For the most part, the gulley type was assumed to be a Type ‘S’ gulley. This was due to the fact they are a relatively standard design gulley. Finally, an assessment was made from the DTM to identify the slopes of the roads present, as different slope combinations require different head discharge characteristics.

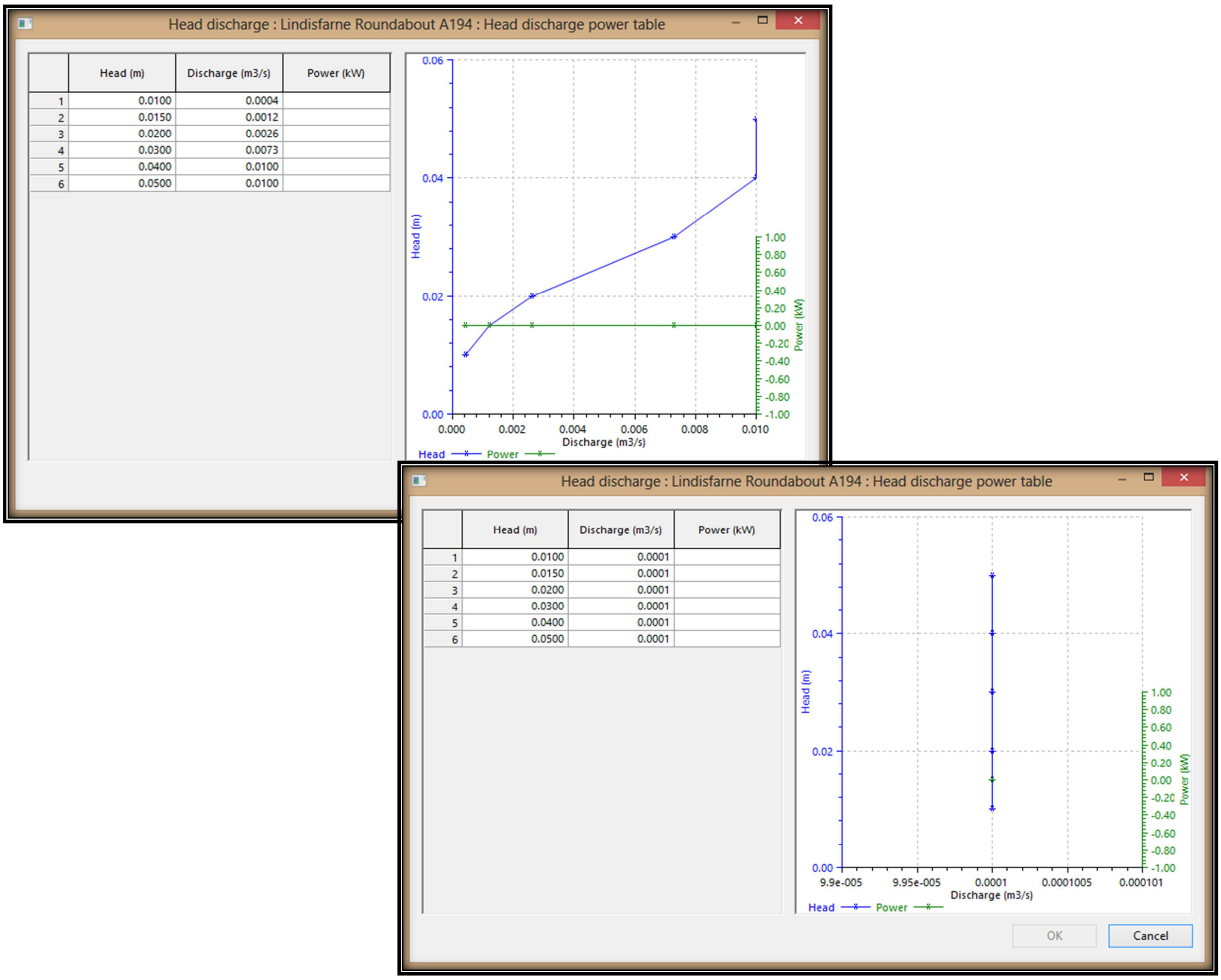

Figure 10 - Generalised head discharge relationship curve for flows into a gulley (left) for a maintained gulley, and (right) a blocked gulley

Hydrology

The hydrology used in the detailed model was different to that used in the intermediate model. The 2D zones that covered the pluvial runoff areas for each of the detailed zones were drawn ensuring that all the catchment contributing runoff to the area of interest was included as this prevented underestimation of the volume of flows entering the area. The rainfall parameters in each of the detailed zones were then selected to more accurately reflect the historical data in the area. This information was obtained from FEH for the catchment area for each of the detailed locations and supplied information such as runoff percentage.

In some cases (such as in Cleadon), there was not a risk of fluvial flooding from the local watercourse, and hence the watercourses were not modelled. Where a local watercourse was present (such as in Fellgate), the inflow hydrograph data that was applied to the head of the watercourse was selected from FEH. Since the models were of a more focussed area than for the intermediate modelling, it was not necessary to model the full length of the watercourse. Instead, where the watercourse was 'cut', a level file was applied. The information on the water level at a given break point came from the intermediate runs. This level file created the hydraulic boundary condition of the watercourse downstream.

Similarly, since the water level in the watercourse can directly affect the conditions of the sewers (through river ingress), where outfalls that were not connected to the watercourse were located, level files were applied. This meant that if the water level at a given time submerged the outfall, the flow out of the sewers could be stopped (or reduced), backing up the system. This ensured that the hydraulic boundary conditions of these outfalls were representative of reality, and flows were not just free to leave the system. Sensitivity testing was carried out on some of these locations to determine how much of an affect a downstream boundary condition had on the result. In locations such as Lindisfarne Roundabout, the model was not sensitive to the level at the break point of the model.

If a watercourse was present in the detailed model, the simulation runs were set to give results for a significant length of time (10 hours or more). This was because although the storm could finish within several hours, the effect of the rainfall on the watercourse occurred for much longer.

Sewer Model

The detailed modelling stage made use of the most up to date and accurate model of each of the areas, which in some cases were supplied subsequent to the intermediate modelling being completed. These models were more representative as they had been verified (by Northumbrian Water) and were comprised of information with a higher confidence level. Much (but not all) of the intermediate model was made from assumed invert level data since there was no detailed information at the time of the model build. The sewer models used at the detailed modelling stage were therefore far more accurate.

Each of the detailed models was coupled with the DTM for South Tyneside. The level the DTM gave for the cover level for each manhole was compared to that from the sewer records. Where the difference between the two was greater than 0.2m, the cover level was changed to match the DTM. Where this happened the invert levels for both the upstream and downstream pipes were amended to ensure that the depth to invert (from cover level) was maintained. A manual check was carried out to ensure that this routine did not change the longitudinal profiles of any pipes. No pipe diameters or manhole locations were changed however.

In some cases, the sewer model was cut at a hydraulic break point in order to minimise the simulation time. Where it was cut, an outfall was created and a level hydrograph file applied to give a boundary condition.

Unfortunately, no detailed sewer model was available for Newmarket Walk, and therefore the intermediate stage model was used. Although this model was not verified and did not contain any subcatchments it was considered to be satisfactory. As there were no subcatchments to contribute flows, all of the flows in the model were generated as pluvial runoff. This required the buildings to be kept in the model (rather than cut out as voids) and therefore each building in the area was raised up by 300mm in order to create 'stubby buildings'. An infiltration zone was then applied to the same building footprint with a runoff percentage of 100%. This ensured that where the rainfall fell on the buildings, all of the rainfall could contribute to the mesh – this process was also conducted for the roads and any other impermeable surfaces in the area. Locations outside of the area of interest were altered so that more rainfall was applied to the surface, and was able to fill the sewer more realistically, ensuring the hydraulic conditions were more representative.

Design Storms

The rainfall parameters for each of the detailed zones were tailored to the specific catchment that the detailed zone fell into. This approach was a more accurate and focussed approach than was used for the intermediate model, and was possible as the rainfall parameters no longer needed to be representative of the whole of the South Tyneside catchment. The FEH program was used in identifying the rainfall parameters for each of the individual catchments, and the catchment specific details from the program were entered into the rainfall files. This increased the confidence in the model for each specific area.

The model was run with storms of 30, 75, 100 and 200 year return periods, and durations of 60, 120, 180 and 240 minutes. 300 minute duration events were also run for the models that contained a river reach which could influence the sewers in the area of interest. This is because shorter events have a greater effect on the sewer system, and as such, a 300 minute event would not be as critical as it could be in areas where water courses are present.

Furthermore, each of these events was run with allowances made for climate change (see Section 4).

3. Model Verification

Since the detailed modelling used 4 smaller, separate models with a higher level of detail than the intermediate modelling stage, it was deemed necessary that verification of each of the sub-models should be undertaken. Since there were flooding issues reported during June and August 2012 and survey sheets and photographs had been supplied to the residents, it was decided that the responses and photos supplied to the Council would form the basis of the verification.

Since the rainfall data for the exact events that caused the flooding was not avaialble (other than the fact it was thought that the events were approximately 1 in 80-85 year events), the model was run for both 75 and 100 year events. Since there was no information on the duration of the events, a 2 hour duration was selected. This was because there was existing knowledge of a large event in the local area that happened around the end of June which had a duration of 2 hours. Once these events had been run on the models, the simulation results were compared to the photos and information supplied by residents to see if an appropriate match was achieved.

Furthermore, photos from the site visit depict many of the homes in certain areas having sandbags or makeshift flood defences outside the property. This clue gave a strong indication that flooding had been observed in the local area, and as such, the simulation results were scrutinised to identify if the areas that had the makeshift defences in them experienced flooding in the simulation. In most cases and areas the model very closely matched the knowledge gained from the site visit.

Unfortunately there were no photos supplied for either the Lindisfarne Roundabout model or the Newmarket Walk model.

Once the models were deemed verified, the model was run for events outlines in Section 2 – Design Storms.

4. Climate Change Modelling

In order to include the effects of climate change, the rainfall files were amended to include a 1.2 multiplying factor to the rainfall in order to allow for the predicted future increase in rainfall intensity. Furthermore, where level files and inflow files were needed, the data was taken from the climate change runs on the intermediate model, ensuring that they had the additional contribution of the climate change.

5. Detailed Modelling Results

Once the model simulations had been run and the results obtained, the data was exported from InfoWorks ICM and converted into into .asc files which were sent to Royal Haskoning DHV. The model run results allowed potential flood alleviation schemes to be modelled in order to address the effectiveness of each scheme.

The results of the runs can be seen within the main SWMP report.

6. Conclusions

During the detailed modelling phase of the project, 5 ‘hotspots’ were identified and accurately modelled to represent the flooding within the area. This process has been very successful and shown a close agreement between the simulation results and the reported and recorded flooding in the catchment (where applicable). This verification was achieved through the matching of events to photos and information received through the local residents.