EU Interreg IVB FloodResilienCity Project

Draft Final Report – Dublin

Volume Four: Appendix A

Dublin South East Pilot Area

Detailed Modelling, Pluvial Flood Hazard and Risk Mapping for Pilot Areas
**Document control sheet**

Client: Dublin City Council  
Project: EU Interreg IVB Flood ResilienCity  
Project Job No: 32102500  
Document Title: Volume Four Appendix A – Dublin South East Pilot Area  
Detailed Modelling, Pluvial Flood Hazard and Risk Mapping for Pilot Areas

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## CONTENTS

**Volume Four – Appendix A: Dublin South East Pilot Area**

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>DETAILED MODELLING APPROACH</td>
<td>1</td>
</tr>
<tr>
<td>A1.1</td>
<td>Modelled Area</td>
<td>1</td>
</tr>
<tr>
<td>A1.2</td>
<td>Available Data Used for Dublin South East Pilot Area Type 2 Model</td>
<td>1</td>
</tr>
<tr>
<td>A1.3</td>
<td>Type 2 Dublin South East Pilot Area Hydraulic Model Schematisation</td>
<td>1</td>
</tr>
<tr>
<td>A1.4</td>
<td>Type 2 Dublin South East Pilot Area Model Verification</td>
<td>7</td>
</tr>
<tr>
<td>A2</td>
<td>BASELINE SCENARIO DETAILED PLUVIAL FLOOD HAZARD AND RISK MAPPING</td>
<td>10</td>
</tr>
<tr>
<td>A2.1</td>
<td>Pluvial Flood Depth and Hazard Rating Mapping</td>
<td>10</td>
</tr>
<tr>
<td>A2.2</td>
<td>‘Existing’ Pluvial Flood Risk Maps</td>
<td>18</td>
</tr>
<tr>
<td>A3</td>
<td>CORRECTIVE MITIGATION MEASURES APPRAISAL</td>
<td>22</td>
</tr>
<tr>
<td>A3.1</td>
<td>Overview of Key Problem Areas</td>
<td>22</td>
</tr>
<tr>
<td>A3.2</td>
<td>Options identification</td>
<td>23</td>
</tr>
<tr>
<td>A3.3</td>
<td>Appraisal of Options</td>
<td>23</td>
</tr>
<tr>
<td>A3.4</td>
<td>Preferred Mitigation Option</td>
<td>24</td>
</tr>
<tr>
<td>A3.5</td>
<td>‘With Scheme’ Pluvial Flood Risk Maps</td>
<td>30</td>
</tr>
<tr>
<td>A4</td>
<td>CONCLUSIONS AND RECOMMENDATIONS</td>
<td>33</td>
</tr>
<tr>
<td>A4.1</td>
<td>Conclusions</td>
<td>33</td>
</tr>
<tr>
<td>A4.2</td>
<td>Recommendations</td>
<td>34</td>
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A1 DETAILED MODELLING APPROACH

A1.1 Modelled Area

A Type 2 detailed model has been developed for the Dublin South East Pilot Area (Georges Quay & South Inner City) to simulate pluvial flooding over an area of approximately 2.8 km$^2$ comprising several locations at high risk of flooding.

The modelled area for the Dublin South East Pilot Area is shown on Figure A1.1 along with the combined and storm drainage networks. For orientation, a few locations have also been highlighted.

A1.2 Available Data Used for Dublin South East Pilot Area Type 2 Model

The datasets used to construct the Type 2 model within the Dublin South East Pilot Area are common to all Type 2 models constructed for this study. These are summarised in Section 2.1 of the Volume Four Main Report.

A1.3 Type 2 Dublin South East Pilot Area Hydraulic Model Schematisation

A1.3.1 2D Grid Schematisation

The Type 2 Dublin South East Pilot Area model grid was populated with ground elevation using filtered LiDAR covering the modelled area.

It should be noted that the filtered LiDAR dataset presented numerous ground elevation anomalies that were automatically created during the processing of the raw LiDAR data. The filtering process consists of removing high elevations associated with the buildings using an interpolation technique along the perimeter of each building. For the buildings where basements exist, the above technique tends to extrapolate the low ground elevations associated with the basement areas to the overall building footprint. Hence the numerous anomalies in the filtered LiDAR dataset affecting mostly the buildings fitted with basements, if not corrected, would result in a model grid unsuitable for pluvial flooding modelling.

To overcome these anomalies, extensive modifications to the model grid throughout the modelled area were required using interpolation techniques available with TUFLOW. Correction consisted of raising the low building footprints to the surrounding ground level. Corrected areas are shown on Figure A1.2 as ‘Grid Modifications’.

It should be noted that applying the corrections described above meant basement areas were not represented in the Type 2 Dublin South East Pilot Area model. During the course of the project, it was initially planned that the basement areas would be reinstated via further modifications to the corrected model grid. However this task was not pursued due to the lack of accurate basement data (location, depth and width) added to the fact that even with a 5m grid resolution the basement areas would be coarsely represented within the Type 2 model.
Other modifications to the model grid include:

- Road underpasses under the Dart line railway embankment were coarsely represented in the model using 1D elements\(^1\) to ensure flowpath continuity through these structures.
- A breakline\(^1\) was also used to improve the model grid definition along the Dart Line embankment.

### A1.3.2 Hydraulic Friction and Ground Infiltration (2D Domain)

The land use regions used to determine the appropriate Manning’s “n” values and ground infiltration losses required for the model grid are shown on Figure A1.2.

### A1.3.3 Boundary Conditions in the 2D Domain

Figure A1.2 shows the locations where ‘Inflow’ and ‘Free flow’ boundaries have been applied along the Dublin South East Pilot Area Type 2 model boundary.

### A1.3.4 Sub-surface Drainage Network Schematisation (1D Domain)

Manhole and pipe data were readily extracted from the existing Infoworks CS model of the City Centre / Docklands Drainage Area developed for the GDSDS study (2006)\(^2\) and assembled together to form the combined and storm drainage networks that include a total of 1502 pipes and 1435 manholes.

All the pipes are gravity drained in a general south to north direction. Part of the drainage system discharges into the River Liffey via several flapped outfalls lined along Georges Quay. There are no pumps or rising mains within the system.

Figure A1.3 shows the extent of the combined and storm drainage networks included in the Type 2 Dublin South East Pilot Area model. The blue arrow attached to each pipe represents the flow direction under normal conditions.

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1. Refer to Section 2.2.2 of the Volume Four Main Report for the definitions of breaklines and 1D elements.
Figure A1.1: 2D Modelled Area (black outline) and Combined & Storm Drainage Networks (blue lines)
Figure A1.2: Type 2 Dublin South East Pilot Area Model, 2D Domain Schematisation
A1.3.5 1D Boundary Conditions

Within the Pilot Area, tides on the River Liffey exert a significant tidal influence on the drainage system by impounding the discharges from the outfalls along Georges Quay. Although these outfalls are fitted with flap valves, it is known that tidal ingress still occurs into the drainage system.

For the purpose of this Pilot Area study (pluvial flood risk assessment), all flap valves have been assumed to perform correctly in the model. To represent the tide locking effect on the drainage system at high tide, a typical Spring Tide level hydrograph (MHWS is 1.7 mAOD³) has been applied as downstream condition to the modelled outfalls. This downstream condition applied is the same as that used in the GDSDS. Adopting a worst case approach, the timing of the level hydrograph was adjusted so that the tide locking period coincides with the peak of the pluvial event occurring in the drainage system.

Boundary types and boundary locations of the drainage system included in the Type 2 Dublin South East Pilot Area are shown on Figure A1.3.

A1.3.6 Rainfall Runoff Infiltration into the Drainage System (1D/2D link)

Figure A1.3 illustrates the locations of the 1D/2D links which were set up between the 2D domain to calculate the overland flow and the 1D drainage system where pluvial floodwater is conveyed underground.

³ Above ordnance datum (mAOD) is used to reference average sea levels (i.e. Spring) in meters
Figure A1.3: Type 2 Dublin South East Pilot Area Model, 1D Domain Schematisation
A1.4 Type 2 Dublin South East Pilot Area Model Verification

A1.4.1 Model Performance

Although no significant performance issues were identified, it should be noted that along the Dart line embankment crossing the modelled area, the 5m grid does not allow for a smooth representation of its steep slopes. Instead, it introduces step changes in the level between one cell and the adjacent one which result in the model overstating velocity and depth values along the toes of the embankment. Therefore depth, velocity and hazard rating values should be interpreted with caution in such locations.

A1.4.2 Verification against Historical Flood Events

Figures A1.4 and A1.5 show the maximum flood depths predicted by the Type 2 model and the flood incident locations for both August 2008 and July 2009 events.

It is difficult to draw direct conclusions from this comparison exercise as so few flood incident records are available (and the spatial accuracy of the incident reporting is not conclusive) to undertake a comprehensive verification of the model. In addition, some reported incidents are associated with blockages to the drainage system or occurred to the basements; the Type 2 model does not cater for both these cases. Nevertheless a reasonable correlation is apparent, particularly for the July 2009 event.

As noted in Volume Four Main Report, a further significant event occurred on 24 October 2011. However, as flood incident records were still being reviewed at the time of carrying out the Type 2 modelling, it was not possible to use this event for model verification. However, for information purposes, the recorded incidents from this event for the Dublin South East Pilot Area are displayed for the 2% AEP, 3 hour duration modelled event on Figures 3.4B and 3.4C of this Appendix.
Figure A1.4: Comparison between Reported Flood Incidents in August 2008 and Maximum Flood Depths Predicted by the Model
Figure A1.5: Comparison between Reported Flood Incidents in July 2009 and Maximum Flood Depths Predicted by the Model
A2 BASELINE SCENARIO DETAILED PLUVIAL FLOOD HAZARD AND RISK MAPPING

A2.1 Pluvial Flood Depth and Hazard Rating Mapping

A2.1.1 Examples of Maximum Flood Depth, Flow Velocity and Flood Hazard Rating Outputs

The following section provides examples of the Type 2 Dublin South East Pilot Area model outputs for the Do Minimum (existing conditions) and Do Nothing scenarios. Maximum flood depth, velocity and flood hazard rating (combined depth and velocity) predicted across the modelled area for a 2% AEP (1 in 50 annual chance) event are presented in Figures A2.1 and A2.2 overleaf.

Both Existing (Do Minimum) and Do Nothing scenarios show relatively similar results. However maximum flood depths and flood hazard rating are slightly exacerbated in the case of the Do Nothing scenario. This is expected as the Do Nothing scenario assumes 90% blockage to all inlets to the drainage system.

Flooding within Type 2 Dublin South East Pilot Area is characterised by localised flood cells spread across the modelled area and independent from each other.

Most of the predicted flood depths remain below 0.5m for the 2% AEP event with a few patches of deeply flooded cells, mostly consisting of low topographic spots situated at the end of an overland flowpath. Pluvial water conveyed by gravity in these areas ponds due to an obstacle across the flowpath (e.g. high ground or change in topographic slope). Examples of these areas are Pearse Square, Clarence Place Great, Stephen Street Lower, Hatch Place or Leeson Lane.

Maximum velocities across the modelled area are generally moderate (0 to 0.5m/s) with the exception of the Dart line embankment where very high velocities (>2 m/s) are predicted on either side of the embankment as pluvial water runs down its steep slopes. Areas where velocities are in the order of 0.5m/s correspond to streets and roads with a topographic gradient and acting as preferential flowpaths. Examples of these are immediately south of the Dart Line such as Sandwith Street Upper and Macken Street and also to the south-west of Trinity College such as Grafton Street and Dawson Street. There is a marked change in topography elevation following a line more or less parallel to the Dart Line running from Trinity College to the east to Grand Canal Street Lower. To the south of this line, ground elevations are 8-12m whilst to the north of this line, ground elevation drops down to 1.5m-3m. It is within the transition zone that overland flow is accelerated.

Flood hazard rating across the model area is mostly low to moderate with the exception of the deep flooded cells mentioned above where predicted flood depths are high enough to be calculated as a significant hazard. Examples of these areas are Pearse square, Clarence Place Great, Hatch Place or Leeson Lane.

Further detail on the areas at risk of flooding along with the flooding mechanisms is provided in the next section.

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4 Refer to Section 3.1 of Volume Two: City-wide Pluvial Flood risk Assessment Report for a comprehensive definition of flood hazard.
Figure A2.1: Examples of the Type 2 Pluvial Flood Depth, Velocity and Hazard Rating Mapping in the Existing Situation (Do Minimum scenario)
Figure A2.2: Examples of the Type 2 Pluvial Flood Depth, Velocity and Hazard Rating Mapping (Do Nothing scenario)
A2.1.2 Flooding Mechanisms within Dublin South East Pilot Area

This section discusses the likely flooding mechanisms which are apparent from the model outputs at key locations across the Dublin South East Area. Figure A2.3 shows the development of pluvial flooding through the 2% AEP (1 in 50 annual chance) 3 hour duration event under existing (Do – Minimum) conditions.

The model output shown for Figure A2.3 comprises three time-steps, as shown in parts A, B and C of Figure A2.3.

Event analysis

Due to the size of the South East Pilot Area and to ease discussion and analysis, the modelled area was divided into eight reporting areas which are discussed below.

Pearse Square

Pearse Square is a place known for frequent flooding issues to the basements of the properties sitting around the square. Although the Type 2 Dublin South East Model does not allow for the representation of the basements, the model outputs indicate there are two locations on Byrne’s Lane and on Hanover Street East where predicted pluvial flooding is likely to affect the back of the properties on Pearse Square.

On Byrne’s Lane, pluvial water would drain towards a low topographic spot located at the end of this narrow street. Velocity vectors indicate that part of the runoff on Pearse Street would be conveyed towards this point. Maximum flood depth predicted at this location is 0.7m and flood hazard rating is significant.

On Hanover Street East, pluvial water ponds in a low level spot located at the junction with Macken Street. Velocity maps indicate that this local flood cell is mainly fed by overland flow draining from the high ground on Misery Hill to the east of Macken Street. Maximum flood depth predicted at this location is 0.5m and flood hazard rating is moderate to significant.

Clarence Place Great / Macken Street

Severe flooding (up to 0.7m deep) is predicted in this area as a result of a combination of several factors:

- The area sits on lower ground (1m AOD) compared its surroundings (2m AOD on Pearse Street) which makes it prone to flooding from direct pluvial accumulation.
- The Dart Line embankment running to the south acts as an obstruction to the overland flow and prevents the accumulated flood water to drain further south.
- The area lies at the confluence of two important overland flowpaths draining via Macken Street: pluvial runoff on Pearse Street to the north and runoff on Lower Grand Canal Street to the south.

Flood hazard rating predicted in this area ranges from Moderate to Significant.
Figure A2.3A: Time Series showing Flood Depth, Velocity, Hazard Rating and State of the Drainage Network during a 2% AEP Three Hour Duration Event at t = 1hr
Volume Four – Appendix A: Dublin South East Pilot Area
Detailed Modelling, Pluvial Flood Hazard and Risk Mapping

Legend
- 2% AEP Depth Mapping
  - > 2.0
  - 1.0 - 2.0
  - 0.5 - 1.0
  - 0.3 - 0.5
  - 0.2 - 0.3
  - 0.1 - 0.2

Indicative Velocity Vectors
(Based on Magnitude)
- 1.75 (m/s)
- 0.1 (m/s)

Flood Depth and Velocity Vectors
3 hours into the event

Legend
- Manhole Location
- Manhole Location (Surcharged)
- Drainage Network
- Drainage Network (Surcharged)
Stephen’s Place / James Street East

These two locations present the same flood mechanisms where pluvial water accumulates (up to 0.4m to 0.6m respectively) on a low ground point located at the confluence of local flowpaths such as James Street East / James Place East on one hand and Stephen’s Place / Stephen’s Lane on the other. Velocity vectors and velocity maps show evidence of this. Significant flood hazard rating is predicted on James Street East after three hours into the event.

Wilton Terrace / Pembroke Row

A few properties on Wilton Terrace are predicted to be at risk of flooding (to a depth of 0.6m) due to incoming runoff conveyed via Lad Lane and Pembroke Row to a low topographic spot located at the back of Wilton Terrace. Pluvial water is trapped and flood depth builds up during the event to a maximum 0.6m. Significant flood hazard rating is predicted at this location.

Leeson Lane / Hatch Place / Cuffe Lane and Protestant Row

Significant flooding (>0.5m deep) is predicted to these areas which share the same flood mechanism. They are typical narrow streets sloping down to a low topographic point, which represent the end of a relatively long overland flood route that includes a large road where pluvial water is collected from.

The velocity vector maps show for example, runoff conveyed along Earlsfort Terrace (road) drains by gravity towards Leeson Lane; rain falling on Harcourt Terrace and Hatch Lane drains towards Hatch Place, pluvial water falling on Camden Street Lower Wexford Street will end up in Protestant Row. The same applies on Cuffe Lane receiving runoff from Cuffe Street and Harcourt Street (lower part).

In most of these areas, the accumulated flood depth results in a Moderate to Significant flood hazard rating.

Peter Place / Camden Court / Earlsfort Terrace / Stokes Place

Although distant from each other, these locations present the common feature of having a low ground level compared with their surroundings. During the modelled storm event, pluvial water simply accumulates as it cannot escape. Predicted flood depth after three hours into the event ranges from 0.3-0.4m and flood hazard rating is moderate.

Stephen Street Lower

Properties are at risk of flooding in this area because it is a low topographic spot situated at the confluence of three flood routes consisting of:

- Aungier Street and Upper Stephen Street to the west;
- William Street South to the north; and
- Lower Mercer Street to the south.
Predicted flood depth is up to 0.6 m deep and flood hazard rating is Moderate to Significant.

**Trinity College**

Trinity College is situated within a very low lying area, 2 to 3 m AD, compared to the level of the road (approximately 6m AD) running along its south perimeter. The built area is relatively flat and subject to pluvial flooding by accumulation in its lowest parts only, such as the Museum entrance. In addition, there are a few overland flowpaths that could contribute to the flooding of the area during a storm event. As highlighted by the velocity vectors and maps, pluvial water draining from Molesworth Street and Dawson Street would enter the College Grounds at the St Patrick’s entrance whilst runoff from Grafton Street and Dame Street would converge towards the west entrance of the site.

**Drainage System**

The drainage system seems to respond well to a 2% AEP (1 in 50 annual chance) 3 hour duration event as only a few manholes are predicted to surcharge. After three hours into the event, there is an apparent north and south divide in the response of the drainage system. To the south of a line approximately parallel to the Dart Line and running from Trinity College to Grand Canal Street Lower, the system mostly runs at less than capacity, with the exception of a few pipes (e.g. Lad Lane). To the north of the aforementioned line, the drainage system operates at full capacity and manhole surcharging occurs at various places such as City Quay, Hanover Street East, Lime Street, Cardinal Street and Macken Street. This is explained by the influence of the high tide in the River Liffey which impounds the outfalls on Georges Quay and City Quay. As a result, backing up occurs in the system and affects all the pipes located to the north of the divide line as the land above them is relatively flat. The tidal influence does not extend further south of the divide line because the ground level is much higher, as are the underlying drainage pipes.

**A2.2 ‘Existing’ Pluvial Flood Risk Maps**

The flood risk maps based on the existing situation are shown in Figures A2.4A, A2.4B and A2.4C.
A3 CORRECTIVE MITIGATION MEASURES APPRAISAL

A3.1 Overview of Key Problem Areas

As discussed in section A2.1 and as illustrated in Figure A2.3 the key flood mechanisms and characteristics of pluvial flooding and specific ‘Hot Spot’ or ‘problem areas’ within the Dublin South East Pilot Area (Georges Quay & South Inner City) can be summarised as follows:

- Basement property flooding: Although basements were not specifically represented in the model, pluvial flooding across the pilot area drains to the topographic low spots (e.g. Pearse Square, Macken Street) with these properties being at a significantly higher risk.
- In addition, within the Dublin South East Pilot Area, a large number of areas/properties (without basements) are located in topographic ‘low spots’ compared to the surrounding ground level making these areas particularly susceptible to pluvial accumulation.
- The Dart line, which runs through the north of the Dublin South East Pilot Area, acts as an obstruction to overland flow preventing accumulated flood water to drain south (e.g. Clarence Street, Macken Street).
- The existing road network plays an important role at conveying surface flow, specifically at low lying junctions which form the confluence of flow paths which feed surrounding low lying areas/properties (e.g. James Street and James Place).
- There is a north/south divide in the response from the drainage system during the observed events. To the south of a line approximately parallel to the Dart Line and running from Trinity College to Grand Canal Street Lower, the system mostly runs at less than capacity. To the north of the aforementioned line, the drainage system operates at full capacity and manhole surcharging occurs.
- High tide plays a key role in influencing water levels in the River Liffey which impounds the outfalls on Georges Quay and City Quay resulting in the backing up occurs in the system and affects all the pipes located to the north of the divide line as the land above them is relatively flat (compared to the higher ground levels to the south).

Therefore the mitigation measures considered for the Dublin South East Pilot Area have been specifically tailored to reduce the flooding to these areas, taking into account the key flooding mechanisms, while not increasing flood risk elsewhere in the immediate area or beyond.
A3.2 Options identification

In addition to the wider generic and good practice measures recommended in Section 4.3 of Volume Four Main Report, the following measures were identified as appropriate for further consideration to address the flood risk specifically in the Dublin South East Pilot Area:

- External Resistance Measures;
- SuDS storage and GreenWaterSpace storage;
- Aggregated Micro-storage;
- Underground storage;
- Surface Conveyance (Streets as Streams Roads as Rivers);
- Below Ground Conveyance;
- Basement Specific Measures;
- Access Protection;
- Rain Gardens; and
- BioSwales.

The flood risk management options developed based on the appropriate combinations of the above measures for the Dublin South East Pilot Area are as follows:

**Option A:** This option included storage areas where appropriate (bioswales, SuDs storage and underground storage) in the vicinity of Stephens Green Lower, Iveagh Garden, York Street, Stephen’s Place, Trinity College, Fenian Street, Lower Grand Canal Street, Pearse Square, Ely Place Upper and Pearse Grove. In addition, external resistance measures (flood walls, raised kerbing and access protection) and basement specific measures were applied to properties across the Dublin South East Pilot Area. Locations included Pearse Square, Macken Street, Stephen’s Place, Hatch Place, Cuffe Lane, Protestant Row, Leeson Lane, Molesworth Street, Stephens Green East, Merrion Square West and Trinity College. The existing green spaces at Merrion Square and adjacent to Stable Lane are used as storage areas.

**Option B:** This option consisted of the external resistance measure outlined in Option A with the removal of all storage areas. In addition basement specific measures were implemented at Pearse Square, Merrion Square North & South, Upper Mount Street, Herbert Street, Herbert Place, Fitzwilliam Square West and Ely Place.

**Option C:** This option included a combination of external resistance measures, storage areas, drainage enhancement (Pearse Square) and basement specific measures to the Pearse Square area only.

A3.3 Appraisal of Options

The total Present Value (PV) ‘Do Nothing’ damages for the Dublin South East Pilot Area is estimated to be €58,110,172.

Table A3.1 summarises the economic benefits for each of the flood risk management options, along with the estimated benefit / cost ratio.
Table A3.1 Summary of Economic Assessment

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<th>Do Minimum</th>
<th>Residual</th>
<th>Benefits</th>
<th>Estimated Costs</th>
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<td>€58,110,172</td>
<td>€42,093,356</td>
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Table A3.1 indicates that the total cost of each option is less than the benefit in terms of reduction in damages caused from flooding, i.e. the benefit/cost ratio is greater than 1 for all options.

Comparison of Options A, B and C indicates that Option C would have the greatest economic advantage. However model results indicated that the introduction of some elements of Option A could provide further benefit. This option was further evaluated using the model, and economic appraisal indicated an even higher benefit/cost ratio confirming this as the ‘preferred option’ (refer to Table A3.2). The various measures and elements which comprise the preferred option are discussed in the following section.

Table A3.2 Summary of Economic Assessment for Preferred Option

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<tr>
<th>Option</th>
<th>Do Nothing</th>
<th>Do Minimum</th>
<th>Residual</th>
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A3.4 Preferred Mitigation Option

The preferred option comprises the following set of mitigation measures. The main elements as indicated in the Schematic Plan in Figure A3.4A are:

- External Resistance Measures;
- SuDS storage (including underground storage);
- Surface Conveyance (Streets as Streams Roads as Rivers);
- Below Ground Conveyance;
- Basement Specific Measures;
- Access Protection;
- Aggregated Micro-storage; and
- Rain Gardens.

Table A3.3 provides a summary of the total estimated costs of this preferred option, including any uplifts applied compared with those costs estimated for Options A, B and C. Further details with regards the location, scope/extent as well as the estimated construction costs for each measure within the preferred option are outlined in Table A3.4.
Table A3.3 Summary of the Estimated Options Costs

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<tr>
<td>Design &amp; Survey</td>
<td>24%</td>
<td>€1,616,305</td>
<td>€1,731,034</td>
<td>€1,527,643</td>
<td>€1,451,326</td>
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<td>Planning &amp; Environmental</td>
<td>9%</td>
<td>€606,114</td>
<td>€649,138</td>
<td>€572,866</td>
<td>€544,247</td>
</tr>
<tr>
<td>Land &amp; Legal</td>
<td>2%</td>
<td>€101,019</td>
<td>€108,190</td>
<td>€95,478</td>
<td>€90,708</td>
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<tr>
<td>PM &amp; Site Supervision</td>
<td>7%</td>
<td>€471,422</td>
<td>€504,885</td>
<td>€445,562</td>
<td>€423,303</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td></td>
<td>€9,529,464</td>
<td>€10,205,891</td>
<td>€9,006,727</td>
<td>€8,556,774</td>
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<tr>
<td>Optimism Bias (30%)</td>
<td>30%</td>
<td>€2,858,839</td>
<td>€3,061,767</td>
<td>€2,702,018</td>
<td>€2,567,032</td>
</tr>
<tr>
<td>PV Future Maintenance</td>
<td></td>
<td>€689,655</td>
<td>€689,655</td>
<td>€689,655</td>
<td>€689,655</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td>€13,077,958</td>
<td>€13,957,313</td>
<td>€12,398,400</td>
<td>€11,813,461</td>
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</tbody>
</table>

The preferred option includes storage areas (SuDs and GreenWaterSpace storage, Aggregated Micro-storage and underground storage) in the vicinity of Stephen’s Green East, Iveagh Garden, York Street, Stephen’s Place, Trinity College, Fenian Street, Lower Grand Canal Street, Pearse Square, Ely Place Upper and Pearse Grove. Also, the existing green space adjacent to Stable Lane was included as a storage area.

In addition, External Resistance Measures (flood walls, raised kerbing and access protection) as well as basement specific measures are proposed to properties across the Dublin South East Pilot Area. Locations included Pearse Square, Macken Street, Stephen’s Place, Hatch Place, Cuffe Lane, Protestant Row, Leason Lane, Molesworth Street, Stephens Green Lower, Merrion Square West and Trinity College.

Figures A3.4B and A3.4C show the Existing Situation (Pre-Scheme) depth mapping and the With Scheme depth mapping for the Preferred Option.
## Table A3.4 Location, Scope / Extent and Estimated Construction Costs for Each Measure Within the Preferred Option

<table>
<thead>
<tr>
<th>Location</th>
<th>Generic Measure</th>
<th>Community Flood Resilience Measure</th>
<th>Site Specific Measure</th>
<th>Below Ground Conveyance</th>
<th>Underground storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>basement and</td>
<td>aggregated micro-storage</td>
<td>rain gardens</td>
<td>specific basement</td>
<td>SuDs Storage</td>
</tr>
<tr>
<td></td>
<td>ground level</td>
<td>measures</td>
<td></td>
<td>resistance measures</td>
<td>(SaS / RaR)</td>
</tr>
<tr>
<td></td>
<td>access</td>
<td></td>
<td></td>
<td></td>
<td>including</td>
</tr>
<tr>
<td></td>
<td>protection</td>
<td></td>
<td></td>
<td></td>
<td>raised kerbs</td>
</tr>
<tr>
<td></td>
<td>£50 per m</td>
<td>£50 per m³</td>
<td>£100 per m³</td>
<td>£4,400 per unit property</td>
<td>£100 per m³</td>
</tr>
<tr>
<td>Stephen's Street Lower</td>
<td>38</td>
<td>£1,800</td>
<td>54</td>
<td>£133,000</td>
<td>50</td>
</tr>
<tr>
<td>Mercer Street Upper</td>
<td>19</td>
<td>£950</td>
<td>69</td>
<td>£42,500</td>
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</tr>
<tr>
<td>Westford Street</td>
<td>17</td>
<td>£850</td>
<td>32</td>
<td>£144,000</td>
<td>320</td>
</tr>
<tr>
<td>Hardcourt Street/Stokes Place/Levegh Garden</td>
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<td>£850</td>
<td>11</td>
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<tr>
<td>Harcourt Road</td>
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<td>Peter Place</td>
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<tr>
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<tr>
<td>Earls Terrace</td>
<td>10</td>
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<td>660</td>
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<tr>
<td>St. Stephens Green East/Ely Place/Hume Street</td>
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<td>£61,600</td>
<td>13</td>
<td>£58,500</td>
<td>451</td>
</tr>
<tr>
<td>Fitzwilliam Square East/Pembroke Street</td>
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<tr>
<td>Fitzwilliam St Lower</td>
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<tr>
<td>Lad Lane</td>
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<td>3</td>
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<td>Wilton Terrace</td>
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<td>£70,800</td>
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</tr>
<tr>
<td>Clare Street/Merion Square North</td>
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<td>£1,500</td>
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<td>£54,000</td>
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</tr>
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<td>Stephen's Place</td>
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<tr>
<td>Trinity College</td>
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<td>£49,500</td>
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<td>Westland Row</td>
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<td>16</td>
<td>£72,000</td>
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<tr>
<td>Boyne Street/Sandwich Street Upper</td>
<td>9</td>
<td>£450</td>
<td>16</td>
<td>£72,000</td>
<td>363</td>
</tr>
<tr>
<td>Pearce Street/Clarence Place Great</td>
<td>60</td>
<td>£3,000</td>
<td>10</td>
<td>£44,000</td>
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</tr>
<tr>
<td>Pearce Square/Hanover Street East</td>
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<td>Moxews Street</td>
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<td>£202,000</td>
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<tr>
<td>Macken Street</td>
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<td>£700</td>
<td>553</td>
<td>£27,650</td>
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<tr>
<td>Railway Terrace/Macken Street (South of</td>
<td>68</td>
<td>£3,400</td>
<td>136</td>
<td>£812,000</td>
<td>5380</td>
</tr>
</tbody>
</table>

**Preferred Option Construction Cost Total:** €6,047,190
A3.5 ‘With Scheme’ Pluvial Flood Risk Maps

The ‘With Scheme’ Pluvial Flood Risk Maps are displayed in Figure A3.5 (A and B) and can be compared with the equivalent Existing Situation maps in Section A2.2.

Please note that a ‘With Scheme’ flood risk map is not included for the ‘Environment and Cultural Heritage’ receptor group as the predicted pluvial flood risk is unchanged by the preferred option modelled.

These maps illustrate the effectiveness of the Preferred Option in reducing flood risk to the ‘Hot spot’ areas identified in Section A3.1.
A4 CONCLUSIONS AND RECOMMENDATIONS

A4.1 Conclusions

The modelling approach has highlighted specific problem areas within the Dublin South East Pilot Area and provides an indication of local flood hazard and risk areas, which may be summarised as follows:

- Basement property flooding: Although basements were not specifically represented in the model, pluvial flooding across the pilot area drains to the topographic low spots (e.g. Pearse Square, Macken Street) with these properties being at a significantly higher risk.

- In addition within the Dublin South East Pilot Area, a large number of areas/properties (without basements) are located in topographic ‘low spots’ compared to the surrounding ground level making these areas particularly susceptible to pluvial accumulation.

- The Dart line which runs through the north of the Dublin South East Pilot Area acts as an obstruction to overland flow preventing accumulated flood water to drain south ( Clarence Street, Macken Street).

- The existing road network plays an important role at conveying surface flow, specifically at low lying junctions which form the confluence of flow paths which feed surrounding low lying areas/properties (e.g. James Street and James Place).

- There is a north/south divide in the response from the drainage system. To the south of a line approximately parallel to the Dart Line and running from Trinity College to Grand Canal Street Lower, the system mostly runs at less than capacity. To the north of the aforementioned line, the drainage system operates at full capacity and manhole surcharging occurs.

- High tide plays a key role in influencing water levels in the River Liffey which impounds the outfalls on Georges Quay and City Quay resulting in backing up in the system and affects all the pipes located to the north of the divide line as the land above them is relatively flat (compared to the higher ground levels to the south).

In general, pluvial flooding in the Dublin South East Pilot Area, north of the Dart line is influenced by the capacity of the drainage system in addition to surface runoff from upstream areas which reaches the low ponding areas and is obstructed by the Dart line.

The Type 2 Pluvial Flood Risk Assessment and Mapping indicates a high level of pluvial flood risk across the Pilot Area with a large proportion of properties contributing potentially significant damages.

The Present Value (PV) damages for the Do Nothing and Do Minimum (Existing Situation) options are €58.1M and €42.1M respectively based on a 50 year time frame and a 4% discount rate.
Three options (Options A, B and C) were considered, each comprising a range of specific measures to be implemented in combination. The preferred option from the economic appraisal was Option C, and this was then combined with some elements of Option A to provide further benefit. This preferred option comprises mainly External Resistance Measures including flood walls, raised kerbing and access protection (raised ramping) and redirection of flow. This option has estimated PV costs of around €11.8M and estimated PV benefits of around €25.6M giving a benefit/cost ratio of approximately 2.2.

The benefit/cost ratio of the Do Minimum option is 1.4. As this is greater than 1.0 further more detailed consideration of this option is justified.

**A4.2 Recommendations**

Recommendations for mitigating pluvial flood risk in the Dublin South East Pilot Area, through the implementation of the ‘Preferred Option’, include in broad terms:

- Access protection and external resistance measures;
- Use of existing green spaces as storage areas as well as other storage;
- Basement specific measures to be applied to residential properties; and
- Designated pathway measures including the re-profiling of road/embankment sections and kerb raising along designated flow routes.

As outlined within Section 4.3 of Volume Four Main Report, wider generic and good practice measures are also considered as an integral part of any scheme to reduce and manage pluvial flood risk in the area.

This study has confirmed there are a number of potentially viable flood risk management options for the Dublin South East Pilot Area. It is possible that Dublin City Council could consider progressing a Flood Risk Management Scheme through the standard appraisal process. This would start with a more detailed feasibility, or appraisal study to investigate the potential flood risk management options in more detail. The outline design of a preferred option, or combination of options, would be the deliverable from such a detailed appraisal study.

In the interim period, prior to any further measures being put in place, it is recommended that the ‘Do Minimum’ option is continued. This represents the existing situation and should include:

- Gulley maintenance/inspections;
- Maintenance of flap valves;
- Check after major storm events for blockages; and
- Clear out through autumn where leaves can be a particular blockage risk.

To support any future detailed appraisal study, the following immediate tasks are recommended:

- A topographic level survey to determine the property thresholds of all properties in the Dublin South East Pilot Area;
- Further public consultation with those who completed questionnaires made available as part of this project, thanking them for the information supplied, informing them of the project report, conclusions and anticipated way forward.
Much of the information collected, and tools developed, for this project could be used for any future detailed appraisal study. However, there are a number of recommendations made in this report that should be taken into consideration. These are as follows:

- A review of the TUFLOW 2D model is carried out to ensure it remains appropriate and fit for the purpose of a detailed appraisal study;
- A register of basements (location, use, floor level, drainage infrastructure and flooding history) to help identify properties currently at risk and potentially at future risk from new development and climate change effects (also identified by the GDSDS New Development Policy); and
- A more comprehensive costing associated with the recommended corrective mitigation measures to allow for a more accurate, site-specific cost analysis during the detailed appraisal.