Newry River and Tributaries

Submitted to
DfI Rivers Agency

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Newry River and Tributaries

Feasibility Report

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Rev No	Comments	Checked by	Approved by	Date
00	First Draft for Comment	JA	KMcC	03-10-16
01	Rivers Agency Comments Incorporated	JA	KMcC	09-01-17
02	Additional Rivers Agency Comments Incorporated	JA	KMcC	06-02-17

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1 Executive Summary

1.1 Introduction

AECOM was commissioned by the Department of Agriculture and Rural Development (DARD) Rivers Agency to appraise flood risk to residential properties, commercial properties and roads in the Newry area and to investigate options, including economic viability, to alleviate any potential flooding from a 1 in 100 year event.

1.2 History of Flooding

The Newry area has a long and well recorded history of flooding dating back to the mid 1800's across numerous parts of the city with the most recent flooding occurring in the Bridge Street area on 13th and 14th November 2014. Other recent incidents include flooding in the Greenan Road/Old Warrenpoint Road area on 22nd March 2013 which caused inundation of two residential properties and left the local road network impassable for a time.

A near miss incident occurred on 24th October 2011 where floodwater flowed from the Newry River into the Newry Canal overtopping the flood bank designed to prevent this occurrence and reduce flood risk downstream in Newry City Centre. No flooding occurred in the City Centre on this occasion however overtopping of the flood bank is a cause of concern.

It should be noted that a major flood protection scheme was undertaken in Newry during the 1990's which involved the construction of significant lengths of flood wall along the Newry River through the City Centre along with raising of the "Middle Bank" between Lock No. 3 and Clanrye Bridge.

1.3 River Modelling

A hydrodynamic one-dimensional hydraulic model of the watercourse integrated with a two-dimensional model of the surrounding topography created in InfoWorks ICM was provided by Rivers Agency to AECOM. This model was utilised to evaluate the impact of any proposed flood defence/alleviation options from a 1 in 100 year event. Climate change has been considered by undertaking sensitivity runs on the chosen options.

1.4 Flood Protection Options

A combination of options at various locations throughout the study area is proposed to help alleviate the threat of flooding to Newry. These include upstream storage on the Jerretspass and Clanrye Rivers, a flow control structure on the Newry Canal upstream of the City Centre, sealing of manholes on existing culverts, upgrading of existing culverts, provision of formal inlet structures and the construction of new flood walls and embankments along with extensions to existing flood defence infrastructure. No single option was found to provide an adequate solution to the flooding.

1.4.1 Option Assessment

The main source of flooding in the Newry study area is from a combination of the Newry River and the Newry Canal with the latter responsible for causing flooding of large sections of the City Centre. The canal has a limited capacity and due to the maintained water level being only approximately 0.5m below the quay wall level throughout the city it is unable to convey additional flows. To this end it is proposed to construct a flow control structure to limit the flows that can be experienced in the canal through the City Centre.

The introduction of a flow control structure will have the effect of forcing additional flow, which would have otherwise been conveyed via the canal, along the City Centre section of the Newry River. While existing flood walls are present on the river they are not constructed to a sufficient height to contain a Q100 return period flood event. It is proposed to provide upstream storage on the Jerretspass and Clanrye Rivers in the region of 1.1Mm^3 to attenuate the flows from a Q100 to a Q25 return period event. Some additional walls are required along the Newry River to contain a Q25 flow along with other works to the existing walls.

Tidal conditions can also have an influence in the Newry area due to water levels in the Newry River preventing discharge from the other minor tributaries along with backflow. This is particularly evident in areas where the watercourses are flat prior to their confluence with the Newry River. Works are also required on some of these tributaries to ensure that the flood risk from these is also alleviated. These works include culvert upgrades, sealing of manholes, flood walls and inlet structures.

1.5 Benefit Cost Analysis

The costs of damages for the Q5, Q10, Q25, Q50 and Q100 flood events were calculated based upon the Multi-Coloured Manual and discounted over a period of 100 years in order to determine the present value of benefits for each option. The benefit cost analysis found that the proposed combined options for the Newry study area are economically viable with a benefit cost ratio greater than 1 (approximately 16).

2 Terms of Reference

AECOM was commissioned by Department of Agriculture and Rural Development (DARD) Rivers Agency to appraise flood risk to residential properties, commercial properties and roads in the Newry area and to investigate options (including economic viability) to alleviate any potential flooding from a 1 in 100 year return period event.

2.1 Scope of the Brief

The main requirements of the brief were to:

- Utilise the supplied hydraulic model to evaluate the impact of any proposed flood defence / alleviation options (including upstream and downstream of the works location); and to run a model simulation for the recommended solution as appropriate

- Prepare a specification and procure a topographic survey to record the Finished Floor Levels of relevant properties at risk during the 1 in 100yr return period flood (305 residential and 700 commercial properties).

- Determine the hydraulic capacity of the existing channel and pertinent structures on the River and comment on their ability to contain the estimated flood flows.

- Consider the effects of development, as proposed in the latest Area Plan, on flows in the watercourses

- Investigate the performance of any back drainage systems and how they may contribute to the overall flooding mechanism. During option appraisal develop proposals for incorporating solutions to address any identified back-drainage issues in the overall flood alleviation options.

- Consider a range of options that would remove the threat of flooding up to and including the Q100 scenario. In developing options consideration should be given to the technical (buildability and construction issues), economic and environmental aspects of proposals.

- Identify and consider any interim measures that could readily be undertaken in order to alleviate flooding within the study area; make recommendations on the viability, effectiveness and appropriateness of such measures.

- Identify and quantify the flood damage to properties presently at risk of flooding in flood events up to the predicted Q100 event in accordance with the procedures outlined in the Flood Hazard Research Centre (FHRC) Multi-Coloured Manual.

- Consider the flood damage avoidance benefit for each of the options considered as part of the economic assessment, highlighting any residual flood risk.

- Lead and participate in value management exercises to review options on a Whole Life Costs basis.

- Lead and participate in risk management exercises to establish a Risk Register for the Works Project.

- Review and update Risk Register on at least a monthly basis for the duration of the Contract.

- Recommend the most cost effective solution for providing flood protection to the 1 in 100 year standard.

- Take into consideration the visual and environmental impact of proposed works and allow for consultation with Rivers Agency Environmental Advisors. Consultants will be required to contribute to the Environmental scoping exercise in conjunction with a Rivers Agency Conservation Officer.

- Consult any local or other authorities including Utility Providers; Newry, Mourne and Down District Council; NI Water, NIEA; Transport NI et al., about matters of principle in connection with the outline/recommended proposals for the Project.

- Undertake technical liaison with Rivers Agency staff as appropriate (including but not limited to Local Area, Asset Management, Hydrometric Section etc.), and other organisations such as Transport NI, District Councils, NI Water, NIEA et al.

- Undertake liaison with residents, landowners and developers as required to gain an understanding of the flooding history within the area and to assist the Consultant in producing a map illustrating all landowners potentially affected by the recommended solution and their known contact details.

2.2 Additions to the Scope

A number of additional items were added to the scope of the study as work was progressed. These included:

1) Extension of hydraulic model to Camlough Dam

2) Addition of Railway Drain culvert (in private ownership) to the hydraulic model provided to AECOM by Rivers Agency

3 Site Description

The Newry area consists of a complex network of open watercourses and culverts, including the Newry Canal, which drain into Carlingford Lough and is subject to a tidal cycle. Figure 3.1 below illustrates the location of the watercourses within the study area. A larger version of this can be found in Appendix A, drawing NWRY-ACM-XX-XX-DR-CE-01000-01.

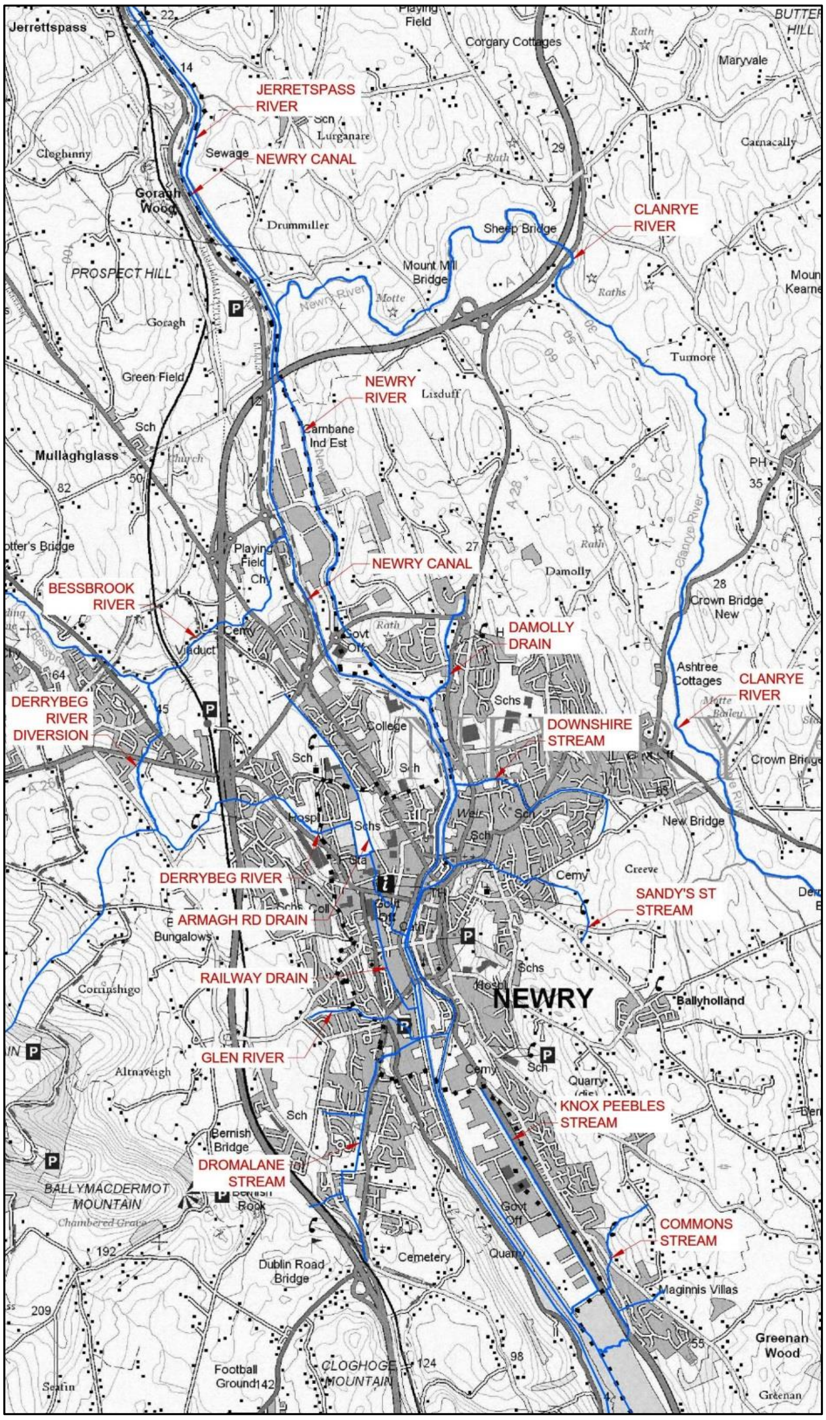

Figure 3.1 Site Location Map

3.1 Newry River

The Newry River is formed at the confluence of the Jerretspass River and the Clanrye River approximately 5.5km upstream of Newry City Centre. From the confluence point it continues through Newry City Centre where it becomes tidal downstream of Thompsons Weir. Downstream of the City Centre the river channel significantly widens before becoming Carlingford Lough.

The Newry River has other named tributaries including Damolly Drain, Downshire Stream, Sandy's Street Stream, Derrybeg River and its tributaries, Glen River and its tributaries, Knox Peebles Stream and the Commons Stream and its tributaries. The Bessbrook River can also be considered as a tributary however it discharges into the Newry Canal which in turn discharges via a side weir into the Newry River.

The entire Newry River catchment to its discharge to Carlingford Lough has a total catchment area of approximately 323km^2 and drains a large area of South East Down and South West Armagh.

3.2 Damolly Drain, Downshire Stream and Sandy's Street Stream

These three streams are located on the eastern side of the Newry River and have small, localised catchment areas.

The Damolly Drain rises to the north west of the A28 Belfast Road between the A27 Craigmore Way and A1 Newry Bypass. It has a mainly rural upstream catchment with the downstream reaches flowing through the lightly urbanised outskirts of Newry prior to its confluence with the Newry River in the Ardmore area. It has a total catchment area of approximately 1.86km^2.

The Downshire Stream flows through a densely populated part of Newry commencing near the Monks Hill Road. It is culverted for most of its length through the urban area and has a total catchment area of approximately 1.48km^2. The Downshire Stream joins the Newry River at Newry Hockey Club.

The Sandy's Street Stream, again, flows through a densely populated part of Newry in the lower reaches and commences near the village of Ballyholland. It is culverted for most of its length through the urban area and has a total catchment area of approximately 1.40km^2. It discharges to the Newry River in the vicinity of Newry Court House.

3.3 Derrybeg River and Tributaries

The Derrybeg River and its tributaries drain much of the western part of Newry and discharges to the Newry River via a syphon arrangement in the area of Cornmarket/O'Hagan Street. Large sections of the Derrybeg River are culverted through the low lying areas of the City Centre. Tributaries include the Armagh Road Drain and Railway Drain. The total catchment area is approximately 3.18km^2.

The river previously discharged via another syphon arrangement under the Newry Ship Canal on the downstream side of the Albert Basin. The designated line of the Derrybeg River still follows the old alignment however this now caters only for residual connections and acts as a storm drain with a much reduced pipe diameter (modelled as 450mm).

The former Derrybeg River culvert confluences with the Railway Drain at the front of the Quays Shopping Centre on Fathom Line and continues south to the syphons at the downstream end of the Albert Basin. Two separate syphons exist at the downstream side of the Albert Basin with the northern side catering for flows received from the Railway Drain and residual Derrybeg River. There is a manually controlled connection between the two syphons to allow for maintenance however this is normally closed with the two syphons operating independently.

A diversion watercourse is also present upstream of the city to divert flows from the upper catchment of the Derrybeg River to the Bessbrook River. This diversion removes approximately 1.51km^2 from the original Derrybeg River catchment area.

3.3.1 Armagh Road Drain

A major tributary of the Derrybeg River is the Armagh Road Drain which joins the Derrybeg River to the rear of the Translink Bus Depot on Upper Edward Street. The Armagh Road Drain commences to the north of the A27 Craigmore Way near McCanns Corner and follows the line of the former railway to the west of the A28 Armagh Road. A large proportion of the watercourse is culverted given the urban nature of the area through which it traverses.

3.3.2 Railway Drain

The Railway Drain is an un-adopted asset with unclear ownership. The culvert is not shown on Rivers Agency records and is annotated as "un-adopted" on NI Water records. It would appear that, for most part, the Railway Drain acts solely as a storm drain. The Railway Drain confluences with the former Derrybeg Culvert at the front of the Quays Shopping Centre on Fathom Line and continues south to the syphons at the downstream end of the Albert Basin.

3.4 Glen River and Tributaries

The Glen River and Dromalane Stream drain a sizeable area to the west of Newry totalling 6.37km^2. The upstream reaches of the catchment are rural and include the steep forested slopes of Camlough and Ballymacdermott Mountains to the west of the A1 Newry Bypass. The lower reaches become more urbanised and have a flatter gradient.

The Glen River crosses under the A2 Dublin Road at the junction with Dominic Street and Dromalane Road and continues as a culverted watercourse through the Quays Car Park to the twin syphons at the downstream end of the Albert Basin. As mentioned in Section 3.3, the two syphons normally operate independently with the southern syphon serving the Glen River and Dromalane Stream which confluence immediately upstream of the structure.

A former connection between the Glen River and the Railway Drain has recently been abandoned due to construction works for an extension of the Quays Shopping Complex.

3.5 Knox Peebles Stream

The Knox Peebles Stream has been heavily modified and forms a linear channel along the eastern boundary of the Greenbank Industrial Estate beside the A2 Warrenpoint Road. The upstream catchment is predominantly rural with some light urbanisation with the catchment area totalling approximately 2.04km^2.

The outlet of the Knox Peebles Stream is through the "Rampart" which is the south-east flood defence bank protecting the low-lying Greenbank area from the tidal influences of the Newry River. This outlet has a non-return valve which prevents backflow of tidal water. However this prevents the Knox Peebles stream from discharging during high tides and causes a build-up of water within the channel.

3.6 Commons Stream and Tributaries

The Commons Stream is located at the southern end of Newry and flows from the Commons area under the Warrenpoint Road, discharging to the intertidal mud flats at the downstream end of the Newry River. The upstream catchment is predominantly rural with some light urbanisation. The catchment area has quite steep gradients and a total area of approximately 2.80km^2.

3.7 Bessbrook River

The Bessbrook River is located to the north west of Newry and is the controlled outflow from Camlough Lake (which is also an impounding reservoir) and discharges into the Newry Canal in the Carnbane area. A side weir on the canal near Lock No.3 allows flows from the Bessbrook River to be transferred to the Newry River.

The river also receives flows from the upper catchment area of the Derrybeg River as described in Section 3.3 of this report. The catchment area prior to its discharge to the canal is approximately 38.4km^2.

3.8 Newry Canal

In brief, the Newry Canal was opened in 1742 to allow a connection through to the Upper Bann at Portadown and on to Lough Neagh. The canal was abandoned for commercial purposes in stages from 1949 to 1974. It is a designated watercourse and serves a drainage function in the rural area upstream of the City. The flow in the canal was previously restricted through the urban area by means of a 900mm inlet pipe which was installed in the 1970's in the vicinity of the WIN Business Park at Lock No.2. However this pipe was removed in June 2013 following the completion of works to the Middle Bank between Thompson's Weir and Lock No.3 as it was deemed to be redundant.

The level of the canal is controlled through the use of side weirs and also sluices at the Victoria Lock at its downstream termination point. The maintained water level of the Canal is 3.5m which is approximately 0.5m below the adjacent ground levels and so does not leave any scope to use the canal as a means of additional capacity in times of high flow in the river channel.

It is understood that an agreement is in place between Rivers Agency and Newry, Mourne and Down District Council to allow the canal to be lowered when warning is received of a potential flood event. The Victoria Lock is operated by the Council and the canal is lowered by opening sluices through the lock gates which allow flows to escape from the canal. In addition to this sluices at locks upstream of the City are closed to minimise the flow in the canal. Past instances of lowering the canal have taken in the region of 8hrs to achieve a level drop of approximately 150mm. It has also been reported during extreme high tide events that water from the river can overtop the side weir downstream of the Albert Basin and re-enter the canal.

3.9 Existing Flood Defences

Flood defences have existed throughout Newry City Centre for a significant period of time and include walls and embankments. An earlier feasibility study by WDR & RT Taggart (1991) examined the then existing flood defences. Recommendations from the 1991 report included:

1. New wall along left hand bank from Sugar Island Bridge to the former railway bridge at the downstream end of Kilmorey Street
2. Undertake diversions of local drainage connections to Water Service (now NI Water) networks in conjunction with sewerage improvements.
3. Construct new wall along Basin Quay
4. Raise part of existing flood bank at Greenbank and part of "Middle Bank" upstream of Clanrye Bridge to provide freeboard to estimated Q100 TWLs

This feasibility study was followed up by a construction scheme to address the issues highlighted. In particular, this addressed the structural condition of walls along the river in the City Centre and flooding associated with back flow through direct drainage connections. Drawings included with this earlier report also provide details on the finished level of the proposed flood walls and banks.

The report also makes mention that "On the non-tidal reaches a scheme, carried out by the Department in the mid 1970's, is found to provide 1 in 100 year protection to developed areas and no specific improvements are considered necessary." Other defences previously constructed include:

1. Raising of flood bank at Greenbank Industrial Estate
2. Localised repairs to walls following collapses
3. Cleaning river bed (River Street to St. Mary's Street)
4. Lowering tidal weir (Thompson's Weir)
5. Constriction of canal flow through installation of 900mm dia. pipe at Lock No. 2
6. Construction of wedge shaped flood bank from Lock No. 2 to Clanrye Bridge
7. Channel diversion at new Customs Station
8. Channel regrading and widening from Thompson's Weir to upstream of Carnbane Industrial Estate
9. Formation of bank along river at Carnbane Industrial Estate for additional flood protection

It is assumed that all existing flood defences have been included within the hydraulic model provided to AECOM by Rivers Agency.

4 Site Survey

4.1 Preliminary Survey

As AECOM were provided with the existing hydraulic model by Rivers Agency and no updates to this model were required under the scope of the study, no preliminary survey was undertaken.

4.2 Local Hydraulic Features

AECOM were provided with an existing hydraulic model by Rivers Agency which included 17 structures spanning across the Newry River in the section between the A1 Newry Bypass and last downstream bridge at the Dublin Road. The locations of these structures are illustrated on drawing NWRY-ACM-XX-XX-DR-CE-01002.

Other structures are present on the multiple tributaries of the Newry River and include significant lengths of culverted watercourse and bridges. These have been commented on individually if required later in this report during the analysis of the flood model. Within the model, no hydraulic structure within the study area has been modified unless it has been deemed to cause significant restriction to the flow. No survey information of the structures has been provided as part of the study.

The flood defences along the Newry River through the City Centre can also be considered as hydraulic structures. These are explained in more detail in Section 3.9.

4.3 Existing Services Infrastructure

AECOM undertook a service investigation for Newry using existing service information which includes the existing foul, storm and combined drainage that may have an impact upon the flood risk associated with Newry (See Drawing NWRY-ACM-XX-XX-DR-CE-01004 and 01005).

A network of existing water mains and trunk sewers was identified across the study area, as could be expected given the City Centre nature of the study. The majority of these services are under the ownership of NI Water however a number of sewers are in private ownership or have not yet been adopted by NIW. Given the flat nature of the City Centre there are also a number of NIW pumping stations which are seen as key infrastructure from a flood risk management perspective, however no additional information has been sought on these as their operation is deemed to be outside of the scope of this study.

It should also be noted that there is a significant network of culverts, both live and redundant, most of which are the responsibility of Rivers Agency throughout the study area. The majority of these are included within the hydraulic model provided to AECOM by Rivers Agency. The exception to this is the Railway Drain (private ownership); see Section 4.3.1.

NIE have also provided a network map of their services within the study area. The location of the underground and overhead cables has been identified as shown on drawing NWRY-ACM-XX-XX-DR-CE-01003. Note that the mV (medium voltage) network has been excluded from the assessment for clarity with only the 11kV network and above shown.

4.3.1 Railway Drain

During a review of the existing drainage infrastructure it was noted that a large diameter (900/1050mm) pipe was present in the western side of the city. This pipe was not within the existing hydraulic model and did not show up as the responsibility of Rivers Agency. NI Water records identified the pipe as “non-adopted” indicating that while they were aware of its existence they did not take responsibility for its maintenance.

AECOM was subsequently asked to add this asset to the flood model to assess if it has any impact on the flooding within the study area. Further commentary on this can be found within Section 6.13 of the accompanying modelling report.

4.4 Topographical Survey

AECOM were provided with an existing hydraulic model representative of the current conditions by Rivers Agency. A topographical survey of finished floor levels of properties in the flood affected area was obtained in order to assess the flood depth and therefore the damages arising from a range of flood events.

5 Consultations

AECOM consulted with a number of parties in relation to the flood risk investigation for the Newry area.

5.1 DARD Rivers Agency

AECOM consulted with DARD Rivers Agency Area Staff regarding the history of flooding in the Newry area. DARD Rivers Agency Area Staff were able to provide details of the extent of the flooding on 24th October 2011 caused by the overtopping of the Middlebank flood bank upstream of the City Centre and also on 22nd March 2013 in the Greenan Road/Old Warrenpoint Road area. Information was also gained on the flood event on 13th and 14th November 2014.

Pre-feasibility reports where provided for these flood events and supplemented with other additional data including:

- Newry Flood Defences Feasibility Study (Taggarts, 1991)
- Knox Peebles Feasibility Study (Taggarts, 2001)
- Newry Catchment Hydrology Report (RPS, 2012)
- Historical Flooding Review; Newry, Warrenpoint, Rostrevor, Newcastle, Ballygowan and Bangor (RPS, 2012)
- Newry Modelling and Flood Mapping Hydraulic Report (RPS, 2014)

These reports provided a significant volume of information on the past flooding problems that have occurred in Newry and what has been undertaken in an effort to address these issues. Information gained from these reports has been presented throughout this report to allow a fuller understanding of the issues to be gained. A selection of photos, below, have been extracted from the Rivers Agency reports and are included below to illustrate some of the problem areas:

Figure 5.1 Flow between Newry Canal and Newry River (October 2011)

Figure 5.2 Overtopping of Lock Gates at Lock No.3 (October 2011)

Figure 5.3 Flooding at properties on Forest Hill, Old Warrenpoint Road (March 2013)

Figure 5.4 Flooding on Greenan Road at No.34 (March 2013)

Figure 5.5 Flooding of Bridge Street (November 2014)

5.2 Ecology and Amenity

AECOM consulted with DARD Rivers Agency Environment Section in order to identify any ecological issues which may have to be considered during the options review in compliance with the Water Framework Directive (WFD) and Floods Directive.

Environmental Impact	Characteristics of Impact	Mitigation Measures
Human Beings	Accessibility requirement for houses and commercial buildings during proposed works	Traffic Control Measures required.
Flora	Loss of mature tree and shrub cover	Significant tree removal should be minimised where possible. Shrub removal may be required. Removal should take place outside nesting season (1st March to 31st August). Care should be taken to minimise root disturbance during removal.
Fauna	Potential impact on nesting birds and fisheries	Timing of works as above to ensure no disturbance of nesting birds. Channel works should aim to maximise the potential for local and migratory fish.
Water	Potential Water Quality Issue	Sediment trapping mechanisms should be considered if any work is carried out.

Table 5.1 Environmental Impacts

5.3 Local Residents

AECOM sent out letters to current occupiers/landowners of properties within the Newry area requesting any anecdotal information on previous flood events. While a minimal response was received, some information provided is included below.

5.3.1 PWS, Greenbank Industrial Estate

A number of photos were received from PWS, located in Greenbank Industrial Estate, of a flooding incident which took place on 13th November 2014. These are presented below however no additional information was provided in relation to loss or damage caused during this event.

Figure 5.6 Flooding at PWS, Greenbank Industrial Estate

Figure 5.7 Flooding at PWS, Greenbank Industrial Estate

5.3.2 35a Greenan Road

AECOM met with Mr and Mrs Donnelly, 35a Greenan Road, to gain a further understanding of a flooding event which took place at their property in January 2016. The source of water is believed to be from a stream which enters a culvert to the rear of 34 Greenan Road. The inlet structure on the culvert and the alignment of the watercourse are considered to be sub-standard which is likely to have been the major contributing factor.

Figure 5.8 Watercourse upstream of 34 Greenan Road

Figure 5.9 Culvert inlet to rear of 34 Greenan Road

Mr and Mrs Donnelly indicated that water was overtopping the culvert at the inlet structure and flowing down Greenan Road. As their property entrance was the first gap in the verge on the lower side of the road, floodwaters escaped from the road towards the front of their property. It then flowed around the northern side of their house via a pedestrian footpath and continued downhill causing flooding at a property 3 Greenan Court. The path of the floodwater was unknown beyond this location.

6 Desk Study Investigation

6.1 Planning Issues

The district development proposals for Newry form part of the Banbridge/Newry and Mourne Area Plan 2015. Newry is recognised both as a hub and as the South Eastern City gateway due to its proximity to the land border and the major port of Warrenpoint, which in itself is identified as a local hub.

Newry City functions as a major centre for housing, employment, retail and professional services, education and health care, and for cultural activities, including sport and leisure. A total of 27,433 persons representing 31% of the population of the district were living within the existing limit of development of the Newry Urban Area which includes the village of Bessbrook.

It is noted that the Banbridge/Newry and Mourne Area Plan includes significant areas for new development of greenfield lands within the catchment. Any new development should not increase flood risk elsewhere in line with Planning Policy Statement 15 – Planning and Flood Risk. In principle this means the storm water runoff rates and volumes of storm water discharged from urban developments should be approximate to the existing greenfield run off over a range of storm events. Therefore any future industrial and residential development within the study area should not have any adverse effects on the predicted flood events.

6.2 History of Flooding

The Newry area has a long and well recorded history of flooding dating back to the mid 1800's across numerous parts of the city with the most recent flooding occurring in the Bridge Street area on 13th and 14th November 2014. Other recent incidents include flooding in the Greenan Road/Old Warrenpoint Road area on 22nd March 2013 which caused inundation of two residential properties and left the local road network impassable for a time.

A near miss incident occurred on 24th October 2011 where floodwater flowed from the Newry River into the Newry Canal overtopping the flood bank designed to prevent this occurrence and reduce flood risk downstream in Newry City Centre. No flooding occurred in the City Centre on this occasion however overtopping of the flood bank is a cause of concern.

6.2.1 Flood Event on 13th and 14th November 2014

Minimal report information is currently available for the flood event which took place on 13th and 14th November 2014 however consultations with Rivers Agency Area staff and publicly available information on the Rivers Agency GIS website has provided an understanding of the incident.

A prolonged rainfall event took place over this period with the rainfall station at Glenanne No.2 recording 101.4mm over a four day period from 10th November. Flooding occurred across many areas of Northern Ireland during this period including Bridge Street in Newry and upstream of Newry in the village of Camlough from the Camlough Minor/Bessbrook River watercourse which is a tributary of the Newry River.

The flooding in Bridge Street has been attributed to a combination of surcharging of the NI Water storm drainage network, high flows in the Glen River culvert to which storm water is discharged and a high tide event in the Newry River preventing flow through the syphons at the downstream end of the Glen River Culvert.

Figure 6.1 Surcharge of NI Water storm sewer at Quays Car Park entry, Bridge Street (November 2014)

Figure 6.1 above shows surcharge occurring from a NI Water storm drainage manhole at the entrance to the Quays Car Park from Bridge Street. This is a pumped sewer from the NI Water Bridge Street Pumping Station and is a 900mm diameter pipe. It subsequently becomes a 1050mm diameter pipe downstream of this manhole and connects to the Glen River culvert in the Quays Car Park. Given the high flows experienced in the Glen River culvert and the high tide in the Newry River preventing flow through the syphons, this connection was unable to discharge and this led to flooding.

Rivers Agency Area staff also commented that the Railway Drain culvert was inspected during this flood event and was found to be conveying minimal flows. While two syphons exist at the downstream end of Albert Basin, these cater for flows from separate catchments with the northern syphon taking the residual Derrybeg Culvert and Railway Drain and the southern syphon catering for the Glen River and Dromalane Stream catchments. Suggestions have been made by Rivers Agency staff that NI Water should give consideration to redirecting the storm discharge from the Bridge Street Pumping Station to this system instead of the Glen River culvert as there is much greater available capacity during storm events.

6.2.2 Flood Event on 22nd March 2013

According to the Prefeasibility Report produced for the flood event on 22nd March 2013 by DARD Rivers Agency, flooding affected two residential properties and roads in the Greenan Road/Old Warrenpoint Road area of the city.

The flooding is believed to be primarily due to a lack of hydraulic capacity on an undesignated culvert which is a tributary of the Commons Stream. While no rainfall figures are available the weather was described as “heavy rain” and high flows were recorded in the watercourse. The catchment area is small at 0.57km^2 but is situated on a steep hillside with the area partially developed with housing. Siltation of the culvert outlet into Commons Stream is also believed to be causing some degree of flow restriction.

No previous history of flooding was recorded by Rivers Agency in this area however residents and Transport NI have reported regular flooding with sandbags placed to protect landowners.

6.2.3 Flood Event on 24th October 2011

The Prefeasibility Report produced for the flood event on 24th October 2011 by DARD Rivers Agency details how floodwater from the Newry River overtopped the flood bank between the Newry Canal and the river and also overtopped the gates at Lock No.3.

Flood defences where previously constructed between the river and the canal to reduce the flood risk to the City Centre region by preventing water from the river entering the canal. The maintained water level in the canal is approximately 500mm below the bank level and so any increase in the canal water level could have significant consequences in the City Centre area.

The weather conditions were stated as dry at the time of the incident but considerable rainfall had been received by the catchment in the days prior to its occurrence with flow conditions given as very high.

7 River Flow Assessment

AECOM reviewed the existing hydraulic model provided by Rivers Agency which included inflow files for the various tributaries associated with the Newry River. No calculations of flows were undertaken as part of this study.

The provided model also included a downstream tidal boundary condition which is stated as having a 2 year return period. No joint probability analysis on the effect of varying tidal conditions with different river flows was undertaken as part of this study.

7.1 1991 Feasibility Report

It is acknowledged that differences in flows exist between what is utilised in the current hydraulic model provided to AECOM by Rivers Agency and the design flows used in the 1991 report. The difference in flows is significant as shown in Table 7.1 below:

1991 Combined Q100 Design Flows (m^3/s)	2015 Combined Q100 Flows (m^3/s)	Increase (%)
86.0	138.5	61

Table 7.1 Flow Comparison

The 1991 report made use of gauged data from the Hydrometric Unit which provided 19 years of information for both the Clanrye and Jerretspass Rivers and 8 years of data for the Bessbrook River. Flows were calculated using the Hanna & Wilcock formula which is a modified version of the Flood Studies Report (FSR) equation to improve its appropriateness for Northern Ireland. It was found that the calculated flows had a reasonable agreement with the gauged flows. An additional gauging station was installed at the hockey pitch on the Belfast Road as part of the 1991 study however insufficient data had been gathered for use at the time of the publication of the report.

Hydrological assessment methods have advanced significantly over the past 25 years with the hydrology used in the current hydraulic model having been undertaken in significant detail by RPS in 2012. This used relevant industry standard software/techniques to predict design flows including the FEH (Flood Estimation Handbook) Statistical Method utilising WINFAP and the Revitalised FEH Rainfall Runoff Method (ReFH). The catchment characteristics influenced the method used for the calculation of flows.

It is difficult to compare the two methods used as the specific catchment characteristics required to calculate the flows are not contained within the reports supplied. It is likely that the changes in flow are as a result of updates of these characteristics. The greatest influence on the flow would be changes to the catchment area used in the calculations. This combined with the use of a greater number of characteristics used in updated methods, such as the inclusion of urban extent (URBEXT) and flood attenuation attributed to rivers and lakes (FARL), would lead to increased flows.

7.2 Future Development

The impact of future development relating to the Newry River catchment area was considered. The current Banbridge / Newry and Mourne Area Plan proposals show that there are many areas zoned for continual development and growth as discussed in Section 6.1 of this report.

Current Planning Policies, in particular Planning Policy Statement 15 – Planning and Flood Risk state that new development should not increase flood risk elsewhere. In principle this means the storm water runoff rates and volumes of storm water discharged from urban developments should be approximate to the existing greenfield run off over a range of storm events. Therefore any future industrial and residential development within the study area should not have any adverse effects on the predicted flood events.

8 Hydraulic Modelling of the Existing System

A hydrodynamic one-dimensional hydraulic model (dated July 2015) of the watercourse integrated with a two-dimensional model of the surrounding topography in InfoWorks ICM (version 6.0) was provided to AECOM by Rivers Agency.

The model provided was calibrated and verified before supply to AECOM. Details of the calibration and verification were also provided in an accompanying model report. Details on the flows used were again provided in an accompanying hydrology report.

8.1 Infoworks ICM Modelling

InfoWorks ICM operates by representing the modelled hydraulic network using a system of nodes and links to represent hydraulically significant features. Nodes utilised by the software may include, manholes, pipes, river cross sections, bridges, inflows and outflows etc. while links represent the river channel, closed conduits, spills etc. All of the nodes and links within the model require a series of parameters and coefficients to enable the hydraulic calculations to be completed.

The model can be modified to assess possible scenarios and run using the flows generated from a hydrological assessment to monitor the impact on the hydrologic regime of the watercourses.

The objective of the hydraulic modelling was detailed in the specification and stated:

- Utilise the model to evaluate the impact of any proposed flood defence / alleviation options (including upstream and downstream of the works location); and to run a model simulation for the recommended solution as appropriate.

The model provided was used as a base hydraulic model and utilised to estimate the 1 in 100 year flood event along with other events to allow the calculation of flood damages. Additional modelling was then conducted to assess the effectiveness of numerous flood alleviation options. The results generated were assessed and appraised for their effect on flooding within the study area, both as stand-alone options and then as a combined option.

8.2 Hydraulic Assessment of Existing System

Flows for the existing system were extracted and are available to view in Appendix F. The flood levels are relative to the ordnance datum and are for a range of cross sections along the Newry River and Canal over an array of flood events. Please note that the levels provided are based on a number of modelling assumptions, including but not limited to:

- All bridge openings are free from debris.
- Standard roughness values applied model wide for existing bridge openings, channel and terrain.
- Downstream level is tidal and varies with the tidal cycle (maximum tide level is based on T2 tidal event)

8.3 Model Calibration and Verification

As a completed and tested hydraulic model was provided to AECOM, no calibration and verification was undertaken. The detail of the calibration procedure was inspected and model checked to ensure it represented the results of the calibration process. A visual inspection of the flood extents was also conducted to ensure correlation between modelled and published flood extents.

8.4 Sensitivity Analysis

No sensitivity analysis was conducted on the existing model. The scope for this study detailed the use of the model to analyse options for alleviate flood risk.

The options simulations generated were subject to limited sensitivity testing. Each of the options was assessed for both the 100 year and 100 year climate change flows. These runs showed that a 100 year climate change flow was able to be conveyed through the City Centre within the freeboard allowance included in the design.

9 Assessment of Flood Risk

Modelling based on the assumptions outlined in the hydraulic assessment has shown that flooding occurs in multiple locations across the study area from different watercourses and at different times in the run. The nature of the flooding at these locations also varies.

The extent of the flooding in these areas is shown on the flood maps NWRY-ACM-XX-XX-DR-CE-01006 – NWRY-ACM-XX-XX-DR-CE-01015 for Q2 to Q1000 flood events and includes Q100 + climate change.

9.1 Areas at Risk

Flooding will occur at multiple areas throughout the study area and by multiple mechanisms. Screenshots from the hydraulic model during a Q100 model run of the present modelled conditions are included below as illustrations. Unless otherwise stated the extents shown are the maximum extents of flooding at these locations.

A summary of flood depths at properties for multiple return periods can be found in Appendix C.

9.1.1 Downshire Road Stream

Analysis of the model shows an early peak occurring within this tributary causing out of bank flooding upstream of the culvert which crosses under the A28 Downshire Road. This would appear to be caused by a lack of hydraulic capacity to vent the flow and leads to localised flooding including a number of commercial properties on the left hand bank.

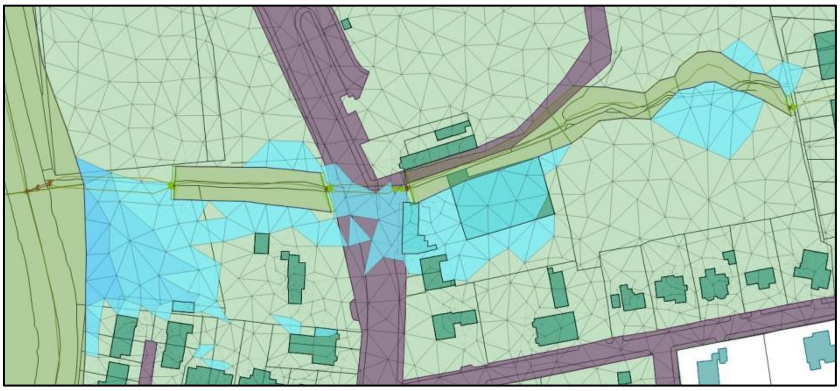

Figure 9.1 Downshire Stream Flooding

As the model run continues flow backs-up the lower reach of the watercourse downstream of Downshire Road from the Newry River and threatens flooding to a number of residential properties within Downshire Court.

9.1.2 Sandys Street

Flooding occurs from the Sandys Street Stream in the lower reaches close to its confluence with the Newry River. The stream is culverted over most of its length with the final section from Talbot St to Trevor Hill having a much shallower gradient than the upstream lengths.

It is believed that this flooding occurs as a result of the culvert outlet becoming “tide locked” due to it being lower than the extreme tide events which can occur on the Newry River. This causes backup of flow and surcharge of manholes due to the ground falling away from the edge of the river. Due to the topography of the area flood waters can flow north and east and cause inundation of properties in the area between Sandys St, Windsor Hill, Downshire Road and Church Avenue.

Figure 9.2 Sandys Street flooding at 10hrs model run time

Further flooding occurs later in the model run in this area as a result of overtopping of the Newry River left hand bank in the vicinity of the Downshire Road Car Park. Again, the topography causes flow away from the river to the east and the north with flood waters conveyed as far north as St. Patricks and St. Marys Hall on Downshire Road.

9.1.3 Toll House Park

It is believed that localised flooding occurs in this area as a result of a low point on the left hand bank of the Newry River. Flood damages are realised for approximately 20 residential properties within the development.

Figure 9.3 Flooding at Toll House Park

9.1.4 WIN Business Park

The area within the WIN Business Park appears to show flooding emanating from the Newry Canal from overtopping of the canal bank on the western side. The flow does not progress downstream from this location and appears to be limited to the area within the business park due to the topography of the area.

Figure 9.4 Flooding at WIN Business Park

9.1.5 Upper Edward Street and Vicinity

Upper Edward Street and adjacent streets suffer flooding at two stages during the model run. The first of these occurs earlier in the run and would appear to be due to a lack of capacity within the Derrybeg River culvert to convey the flows leading to overtopping of the channel and headwall near Upper Edward Street. Low areas of the channel bank may also be a contributing factor From this initial breach flood water flows along Railway Avenue to Monaghan Street and Lower Catherine Street causing inundation of properties.

Figure 9.5 Initial Flooding at Upper Edward Street (10hrs 45min model run time)

The second flooding is much more extensive and appears to be attributed to the Newry Canal overtopping along Merchants Quay causing flood water to spill away from the canal to the west due to the topography of the area. The flow then continues south through the western side of the City Centre inundating multiple properties before returning to the canal in the Albert Basin area.

9.1.6 Cornmarket

Flooding is initially experienced on Cornmarket due to backflow up the former Derrybeg River Culvert from the Newry River during the tidal event. This culvert passes under the Newry Ship Canal via a syphon at the southern end of the Albert Basin and runs parallel to the canal until the Cornmarket. Upstream of this point the Derrybeg River has been previously diverted under the canal to the Newry River so this smaller culvert has been retained to collect local storm drainage.

The culvert would appear to have a significant negative gradient within the Cornmarket area which also has an impact on the flows. Once surcharging occurs floodwaters are conveyed along Cornmarket and south onto Francis Street.

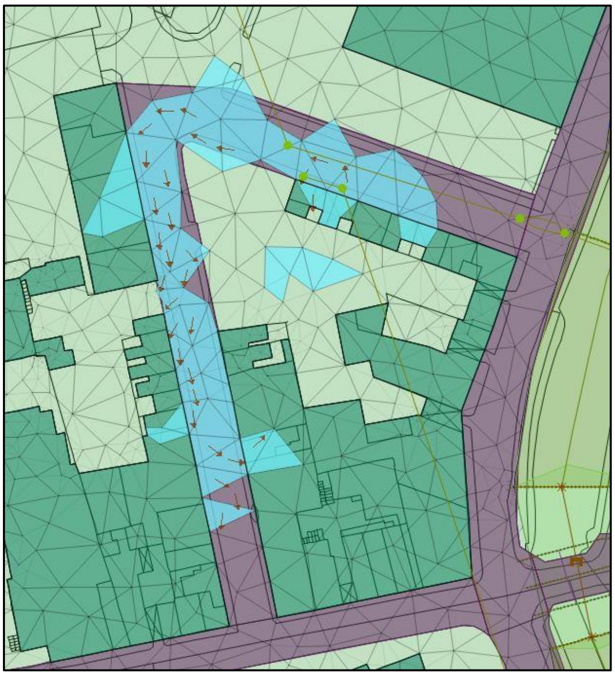

Figure 9.6 Initial Flooding at Cornmarket (3hrs model run time)

This area also suffers more significant flooding later in the model run and appears to be attributed to the Newry Canal overtopping along Merchants Quay causing flood water to spill away from the canal to the west due to the topography of the area. The flow then continues south through the western side of the City Centre inundating multiple properties before returning to the canal in the Albert Basin area.

9.1.7 Sugar Island

The Sugar Island area initially experiences flooding from overtopping of a low area of the existing flood wall to the rear of the war memorial on Bank Parade from the Newry River. The flood wall on the right hand bank is also breached upstream of this location as the run continues which allows inundation of the Sugar Island area.

Figure 9.7 Initial Flooding of Sugar Island (9hrs 30mins model run time)

As the model run continues the Newry Canal begins to overtop which allows flood waters to inundate Sugar Island from the western side. As there is no flood protection along the banks of the canal the flood waters rise and spread across a large area. They then cross the two road bridges from the eastern side of Sugar Island (Sugar Island Bridge and Bank Parade Bridge) upstream of the Town Hall and flow south along Hill Street and Kildare Street.

Given the topography of the city, when flood water overtops the canal and breaches these road bridges it cannot enter the river system again but is conveyed overland for large distances causing serious flooding on the eastern bank. The presence of flood walls along the Newry River throughout the City Centre also prevents flood waters being returned to the Newry River. The flood waters continue south and cross over the Dublin Road continuing along Kilmorey Street onto the Warrenpoint Road and enter the Greenbank area which is discussed in Section 9.1.9

Flow also occurs across the road bridge from Merchants Quay allowing flood waters into the western side of the city. This adds to overtopping of the canal along Merchants Quay which is discussed in Section 9.1.8.

9.1.8 Merchants Quay

Flooding to Merchants Quay initially occurs at the northern end in the vicinity of its junction with Edward Street due to overtopping of the canal bank. This is then added to by overland flow from Sugar Island and areas further upstream on the canal. Flood waters flow west along Edward Street and south along Merchants Quay towards the lower areas of the city on Lower Catherine Street and Monaghan Street. They also are conveyed between buildings.

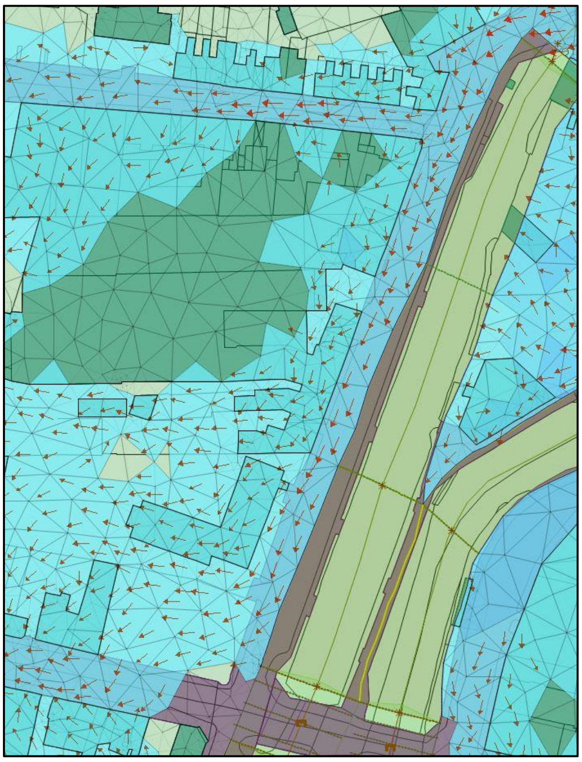

Figure 9.8 Flooding at Merchants Quay (northern end); 12hrs model run time

Further overtopping of the canal bank occurs in the area of Merchants Quay between Monaghan Street and Francis Street and again owing to the topography, flood waters flow west and south into the city inundating large areas.

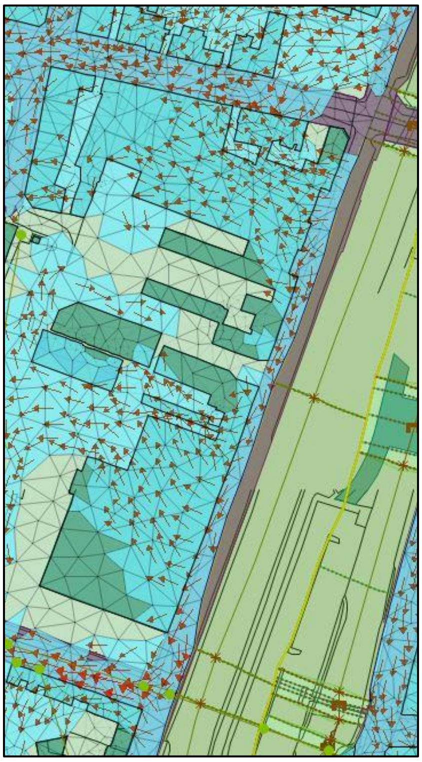

Figure 9.9 Flooding at Merchants Quay (southern end); 12hrs model run time

The flood waters continue south crossing Francis Street and through the Buttercrane Shopping Centre, crossing over Bridge Street and into the area surrounding The Quays Shopping Centre prior to re-entering the canal in the Albert Basin area. Some flow also re-enters the canal along Buttercrane Quay.

9.1.9 Greenbank Area

The Greenbank area has a significant history of flooding and much of this can be attributed to its low lying nature (primarily reclaimed land) protected from the Newry River by a flood embankment. The Knox Peebles Stream runs around the North Eastern and South Eastern perimeter of the area.

This stream would appear to have a number of low areas along its length which allow a flood to overtop the bank and flow out into the industrial estate, however this only leads to minor flooding with few properties affected. This stream can also become “tide-locked” which causes backing up of the flows and flooding at the downstream end.

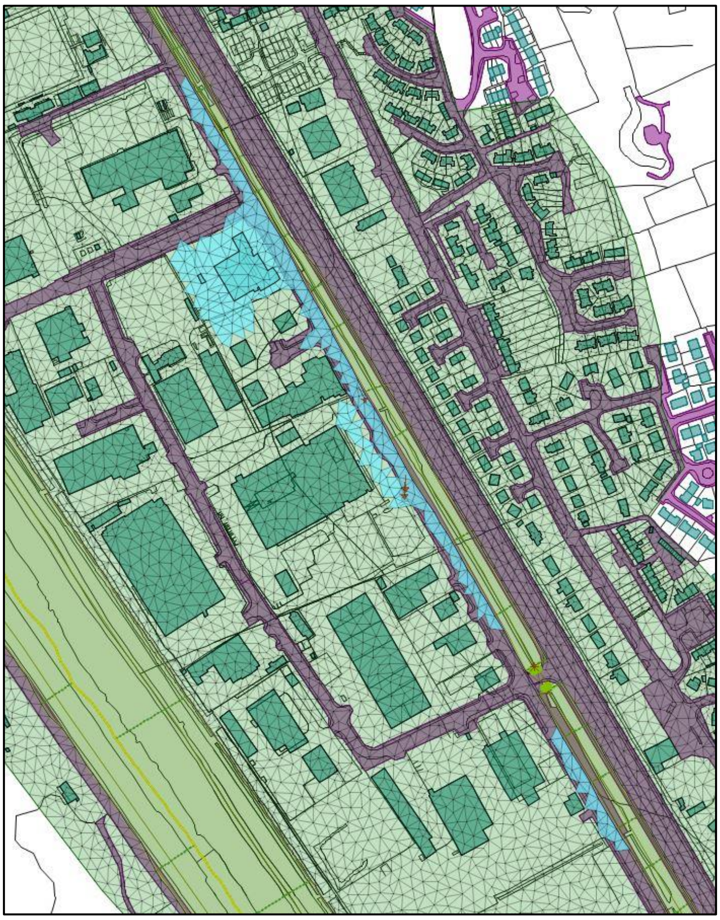

Figure 9.10 Flooding at Greenbank from Knox Peebles Stream (15hrs model run time)

A larger flood risk can be attributed to the overland flows from overtopping of the Canal and the Newry River as far upstream as Sugar Island which is 1.5km away. These flows are as described in Section 9.1.7 and become trapped in the Greenbank area due to the flood banks around the area to protect it from the River itself.

Flooding is also experienced along the A2 Warrenpoint Road Dual Carriageway and the Old Warrenpoint Road areas but again this can be contributed to the overland flows from further upstream.

9.1.10 Ballinlare Gardens

Flooding in the Ballinlare Gardens area including the Whitegates Community Centre and St. Patricks Primary School occurs early in the model run and appears to be caused by a lack of hydraulic capacity in the existing 900mm diameter culvert on the Armagh Road Drain. The flooding is quite localised and is caused by surcharge of the existing culvert.

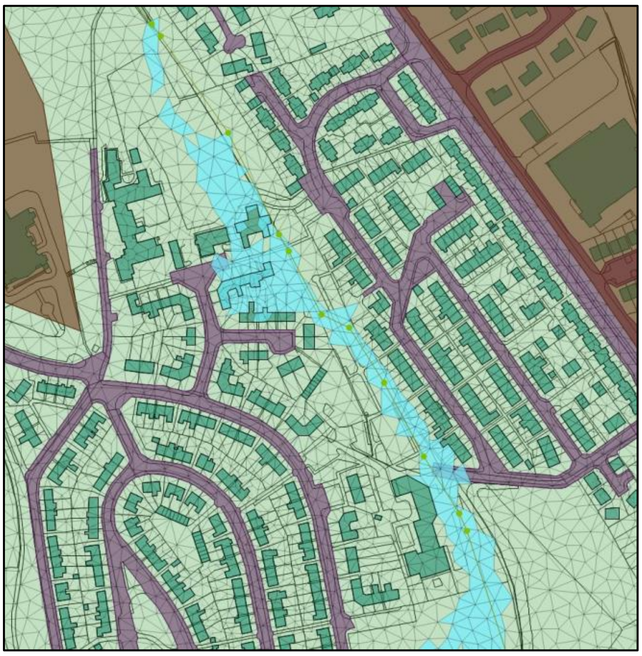

Figure 9.11 Flooding at Ballinlare Gardens and Whitegates Community Centre

9.1.11 A27 Tandragee Road at Carnbane Gardens

The area upstream of the Bessbrook River bridge at the A27 Tandragee Road suffers from flooding which appears to be due to overtopping of the banks of the river and a possible constriction caused by the bridge itself on the flow in the channel.

Minor flooding is shown to a number of properties in Carnbane Gardens adjacent to the river as it turns through 90° to parallel the Newry Canal.

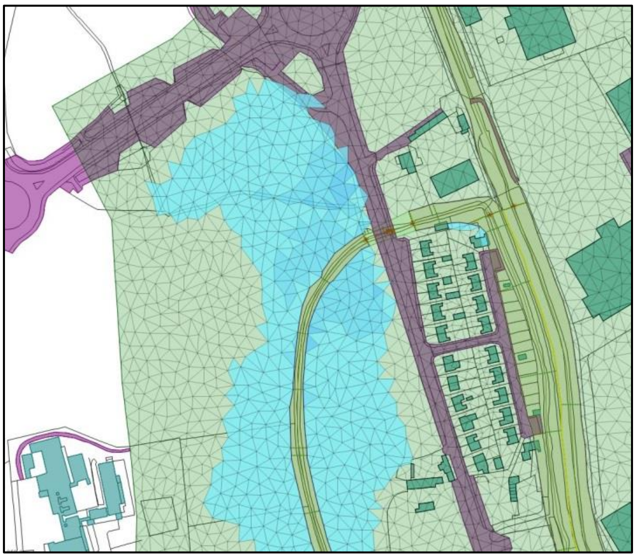

Figure 9.12 Flooding from Bessbrook River at A27

9.1.12 Carnbane Industrial Estate

Flooding occurs at a number of locations within the Carnbane Industrial Estate from both the Newry Canal and the Newry River. One of these is immediately upstream of the A28 Carnbane Way where flooding occurs due to water overtopping the left hand bank of the canal.

Figure 9.13 Flooding at Carnbane Industrial Estate

The second area is upstream of the Derryboy Road bridge and is also caused by overtopping but in this instance from the left hand bank of the Newry River.

9.1.13 Greenan Road/Old Warrenpoint Road

Flooding was not evident within the model provided by Rivers Agency however evidence from past events contradicts this with flooding having previously been experienced on at least two recorded occasions. This discrepancy would appear to arise from differences between the model and what is actually on the ground. An undesignated tributary of the Commons Stream which crosses the Greenan Road in the vicinity of No.34/No.35a appears to have hydraulic capacity issues which have led to past flooding.

Figure 9.14 Past flood event at Greenan Road from the undesignated tributary of Commons Stream

Evidence suggests that during periods of high flow the culvert inlet structure to the rear of No.34 Greenan Road overtops which sends floodwaters onto the Greenan Road. From here the waters are conveyed along the road and can escape at openings in the verge such as entrances to fields and private dwellings which are located on the lower side of the carriageway. Floodwaters then pond on the Old Warrenpoint Road due to the area being relatively flat and low and can leave the road impassable.

9.1.14 Chancellors Road

Out of bank flooding is occurring from the upstream side of Chancellors Road leading to conveyance of flows in a southerly direction along the road before returning to the channel approximately 100m further downstream and causing inundation to a small business.

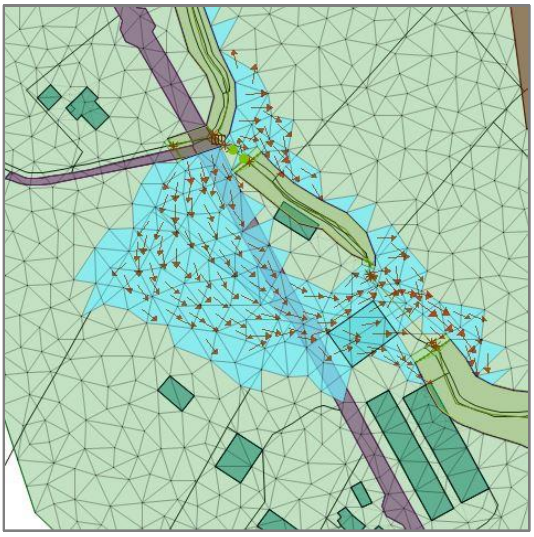

Figure 9.15 Flooding at Chancellors Road

This is possibly due to modelling inaccuracies at this location as there are no records of historical flooding in this location. The model provided to AECOM only extends a short distance upstream of the location from which the flooding is emanating.

A sharp 90° bend is present on the channel immediately downstream which may lead to backing up of flows and the culvert which would convey the Derrybeg River under Chancellors Road has been omitted. To ensure flow follows the existing regime it would be best to extend the model in the upstream direction as well as inserting the culvert. This would allow any existing channel capacity to be used and may reduce the estimated flooding from this location.

9.1.15 Railway Drain

AECOM carried out additional work to include the Railway Drain culvert within the hydraulic model. Full details on this can be found within the accompanying modelling report.

The additional of this culvert into the model showed that it was difficult to attribute any flooding directly to the Railway Drain culvert itself. The area through which the Railway Drain passes is subject to overland flooding from other sources including the Derrybeg River through surcharge of a culvert system and overtopping of banks and also the Newry Canal, again through overtopping of banks. Any storage which may be offered by this culvert is quickly taken up given that the syphons at the Albert Basin cannot discharge during extreme tidal events.

There are many historical instances of flooding in Newry however none have been found that relate directly to the Railway Drain culvert. This is likely due to the complex interdependence of events which lead to flooding in Newry (i.e. extreme rainfall coupled with extreme tidal events) from multiple sources.

9.2 Flood Risk Identification

The flood model was assessed to identify the consequences and risks of flooding on the following receptor groups taking account of a 1 in 100 year flood event.

9.2.1 Human Health

Consideration was given to any significant impact of flooding on human health including the risk of loss of life. This relates to the speed of flooding, the depth of flooding and local demographics. This is quantified within the Economic Appraisal. It is also possible to assess the economic effects of loss of life, stress etc. caused by flooding

9.2.2 Environment

The environmental impacts of flooding include effects on the natural environment from floodwater intrusion and the impacts of associated pollution on important habitats and biodiversity. This includes any landscape, recreation or conservation areas within the Newry area.

9.2.3 Economy

Economic impacts comprise all impacts which have an economic element, including environmental impacts and indirect effects such as stress if the impacts can be quantified in financial terms.

9.2.4 Key Infrastructure

The study identified any vulnerable buildings, which may be at risk from flooding, e.g. Schools, Police stations, government offices, NI Water Pumping Stations, NIE Sub Stations, BT telephone exchange etc. Consideration was given to the road and transport network in the area.

9.3 Risk to Receptor Groups

The impact upon the receptor groups was considered for the Newry River Study Area taking into account a 1 in 100 year flood event

9.3.1 Human Health

There is a high risk to human life given the depth and speed of water associated with the flood event and the number of properties affected during the 1 in 100 year flood event. The urban nature of the primary flooded area also increases the risk.

9.3.2 Environment

As detailed in Section 3 of this report the Newry River catchment area is predominantly rural but has a large urban area including industrial estates in the downstream reaches. Hence during extreme flooding events the amount of pollutants (i.e. fuel and oils) entering the Newry River and tributaries via increased run-off from hard standing areas may have a significant impact.

9.3.3 Economy

Flooding would potentially result in residential and commercial properties in the vicinity of the Newry River being inundated during a 1 in 100 year flood event, resulting in large economic impact from flood damages.

9.3.4 Key Infrastructure

The infrastructure affected by flooding along the Newry River and tributaries includes strategic and local roads with the City Centre cut-off and the city severed. The local roads affected include many roads in the City Centre as well as access to residential and commercial properties. Flooding will result in road closures causing temporary diversions that will impact upon local businesses, residents within the area and anyone travelling through Newry.

A number of NIE substation locations and NIW pumping stations will also be impacted by the flooding including the sewage treatment works in the Greenbank area. The BT telephone exchange which serves the city will also suffer flooding which may lead to communication problems.

10 Summary of Causes of Flooding

The flooding in the Newry area can be attributed to a combination of factors including:

- Overtopping of banks and walls,
- Surcharging of culverts and manholes,
- Influence of a high tide with storm surge,
- Topography of the City Centre.

These factors have been expanded on below.

10.1 Capacity of System

The InfoWorks Model identified a number of capacity issues within the model which then led to overtopping of banks and walls and surcharging of culverts and manholes.

The single biggest contributing factor is the control of this overtopping between the Newry River and the Newry Canal. The banks and quay walls of the canal are significantly lower than the flood walls which have been constructed along the banks of the river through the City Centre, therefore a small increase in flow in the canal leads to major overtopping of its banks causing severe flooding.

10.2 Blocked Openings

The InfoWorks ICM model was constructed on the assumption that all culvert inlets and manholes would be free from debris.

10.3 Overland Flow

It is considered that overland flow as a result of an extreme rainfall event is also a contributing factor to the flooding of the roads and properties within the Newry area.

10.4 Influence of Tides

The lower reaches of the Newry River including the reach through the City Centre are tidal. When an extreme tidal event is experienced on the river this significantly reduces the capacity leading to backing up of fluvial flows. This then causes overtopping of the river and additional flow into the canal leading to flooding.

An extreme tide event also “tide locks” a number of culverts which discharge to the river in the tidal region including the Derrybeg River, Glen River, Sandy’s Street Stream and Knox Peebles Stream. This again leads to backing up of fluvial flows and surcharge of the culverts and associated manholes.

10.5 Topography of the City Centre

The Newry River and Canal do not traverse the City Centre at its lowest point. This increases the flooding extents because when water escapes from the river or canal it is not contained and flows away from the system.

On the western side of the city it follows the line of the old Derrybeg River and re-enters the canal at the Albert Basin. On the eastern side, flood waters are conveyed for approximately 2km downstream through the City Centre as far as the Greenbank area. Here, it is prevented from entering the river due to the large flood embankments built around the area which are designed to keep the river at bay, and it simply ponds with depths of up to 1.6m experienced in the 1 in 100yr event.

11 Flood Protection Options

Given the complex network of watercourses that exist throughout the study area and also the extent of the flooding likely to be experienced there are multiple options proposed at different locations. Some of these options require to be combined to produce the desired level of protection. For ease of identification of the options, each watercourse has been given a reference as listed in the table below:

Watercourse Name	AECOM Reference
Newry River/Newry Canal (including Jerretspass River and Clanrye River)	A
Downshire Stream	B
Sandys Street Stream	C
Knox Peebles Stream	D
Tributary of Commons Stream (Greenan Road)	E
Bessbrook River	F
Derrybeg River	G
Armagh Road Drain	H

Table 11.1 Watercourse Reference System for Options

There is no predicted flood risk which affects properties from the following watercourses within the study area from the model provided by Rivers Agency and therefore no flood protection options are proposed:

- Damolly Drain
- Commons Stream
- Derrybeg River Diversion
- Glen River
- Dromalane Stream

The factors influencing the choice of options include:

- Ability to provide flood protection against a 1 in 100 year flood event
- Impact on any proposed developments
- Environmental Impact
- Ground Conditions
- Aesthetics
- Cost

The proposals and the viability of each option are considered in the following sections. It is believed that in some areas items such as flap valves and sealed manholes already exist however these are not currently included within the model and so have been examined as potential options. The scope of this study specifically excludes updating the provided hydraulic model with corrections to reflect reality.

11.1 Consideration of Flood Alleviation Options

11.1.1 Newry River/Newry Canal (A)

A substantial proportion of the flooding experienced within the study area can be attributed to the Newry River and more so the Newry Canal. A number of potential options have been considered to reduce and control this problem.

11.1.1.1 Option A-1; Upstream Storage

Capturing flow in the upper reaches of the watercourse, either using online or designated offline storage areas adjacent to the river would provide attenuation within the system. This would have the effect of reducing the flow in the main channel of the Newry River during a Q100 return period event and therefore preventing overtopping of the river and subsequent flooding.

AECOM have undertaken analysis of the model in an attempt to determine what flow can be passed through the City Centre to gain an understanding of how much attenuation would be required. Estimates suggest that a flow corresponding to a Q25 return period event could be conveyed by the existing channel with only minor additional works. This gives an estimated storage requirement of approximately $1.1Mm^3$ to attenuate a Q100 event to a Q25 event.

A number of potential sites have been identified on both the Jerretspass and Clanrye branches of the Newry River however some of these already experience flooding and therefore are of limited usage. The potential storage sites are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01020 to NWRY-ACM-XX-XX-DR-CE-01022. Some of these areas are beyond the extents of the current ICM hydraulic model and therefore to allow a full assessment of these the model would need to be extended. There would also be significant agricultural land take required to deliver these flood storage areas and agreement with landowners on items such as compensation etc. These issues are outside the remit of this feasibility study but would require to be addressed before upstream storage proposals could be taken forward.

A storage area has been identified on the Bessbrook River but again this area is already subject to some flooding. When analysed it was found that this storage area provided little benefit due to the non-coincidence of the peaks in the Bessbrook River and the Newry River.

A small storage area was also identified on the Newry River in the vicinity of Lock 3. While the available storage in this area is small it has been included at this stage as a potential area. Further design works may lead to the elimination of this area as it is thought that is can provide limited benefit.

A fuller analysis of the potential upstream storage areas including the derivation of the required volumes etc. can be found in Appendix D.

11.1.1.2 Option A-2; Downstream Storage

An option to introduce storage downstream of the city by means of a tidal barrage with movable gates at the mouth of the estuary was considered. It is envisaged that such a barrage would be operated by Rivers Agency. When personnel become aware of an extreme weather event, the gates would be raised at low tide with the resulting effect of turning the estuary upstream of the barrage into a storage area. This option is illustrated on drawing NWRY-ACM-XX-XX-DR-CE-01023.

Such a barrage could help protect the city from tidal surge events however the location would have to be carefully considered. The barrage would be required to be constructed far enough downstream to provide sufficient storage but the width of the barrage should be minimised to reduce the construction cost associated with it.

A model run was undertaken with the downstream tidal boundary removed and this had little effect on the flood extents experienced during a Q100 event. This is due to the constriction placed on the Newry River as it flows through the City Centre. For a downstream storage option to be successful in reducing the flood risk in the City Centre, other significant works would be required to allow a Q100 event to be conveyed through it. With this in mind the option of providing downstream storage has been discounted as it cannot deliver significant benefit against the associated cost of construction of a tidal barrage and the other required works.

11.1.1.3 Option A-3; Flow Diversion

The route of the Clanrye River follows an “S” shape from its source near Rathfriland; initially flowing in a south/south-westerly direction the river undertakes a 180° turn in the vicinity of Derryleckagh to flow north approximately 2km east of the City Centre and then loops round to flow westward at Sheepbridge. It subsequently joins with the Jerretspass River north of the A1 Newry Bypass before flowing in a generally southerly direction through the City Centre.

Two potential flow diversion options, as shown on drawing NWRY-ACM-XX-XX-DR-CE-01024, have been considered. Option 1 (magenta) is an 8.0km diversion through an area of low ground with a maximum depth of culvert of approximately 15m which would divert flows in a southerly direction from downstream of Derryleckagh Bridge to the Newry River in the vicinity of Narrow Water.

Option 2 (red) is a much shorter route of approximately 2.7km but traverses a much higher area of ground with maximum depths approximately 60m. The interception location is similar to option 1 and would proceed in a south westerly direction. It is anticipated that this route would potentially encounter rock, perhaps granite, which would leave tunnelling works very expensive. The option 2 route would discharge to the Newry River at the southern edge of the City Centre just upstream of Greenbank Industrial Estate and so the downstream section would involve tunnelling beneath a residential area.

It is envisaged that any diversion option would only be utilised during periods of high flow so having a reduced environmental impact on the river downstream. Basic calculations have indicated that the diversion would have to convey flows in the region of $15m^3/s$ at its peak with approximately 80% of the Clanrye catchment upstream of the proposed interception location. This would require a culvert/tunnel in the region of 2500mm diameter depending on gradients.

The option of the diversion of the Clanrye has been discounted on both technical and environmental grounds. The construction of a diversion tunnel will have an impact on the area in which it traverses and could potentially permanently alter the ground water level in the area by providing a preferential route for flows. Given that there are bodies of water in close proximity to the Option 1 route this could cause reductions in water levels or at worst draining of the loughs. Construction of a tunnel through rock is particularly difficult and would be complicated further by the depths at which the Option 2 route is required to take.

Other options such as online and offline flood storage would be much easier to construct and cheaper, with a lesser impact on the environment and so should be considered prior to such a diversion.

11.1.1.4 Option A-4; Flood Walls/Embankments

Option A-4 considers introducing additional flood walls and embankments along the banks of the river and canal. Embankments and flood walls are seen as a solution for addressing areas were localised low points in the bank are allowing flow to escape from the channel and cause flooding. Quite a few areas throughout the study area can benefit from their construction however they are not seen as a standalone solution and are included here as a partial solution which requires to be combined with other proposed options to create a solution which has the best outcome.

Flood walls/embankments are proposed at the following locations along the Newry River/Newry Canal. Note that all finished levels (FLs) include a freeboard allowance of 600mm above the design Q100 return period water level. For further details on the required height of flood walls/embankments and comparison with existing conditions please refer to Appendix E. Also, constraining the flow to the river channel also causes an increase in the Q100 level from that which is currently experienced.

The locations of flood walls are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01025 to NWRY-ACM-XX-XX-DR-CE-01027.

Location	Proposed Defence	Existing Defence Height and Difference	Comments
Toll House Park	Wall 140m length FL: 7.00m	N/A No existing defence Ex GL = 4.80m	Flooding from Newry River by overtopping of left hand bank affecting multiple residential properties. Embankment height to match existing ground level at hockey club immediately downstream.
Downshire Court	Wall 225m length FL: 6.80m	N/A No existing defence Ex GL = 5.00m	Backflow from Newry River along Downshire Stream causing overtopping of left hand bank affecting multiple residential properties.
Canal Flow Control structure to Thompsons Weir along Middle Bank Flood Wedge	Wall 330m length FL: 6.70m reducing to 6.60m	Embankment Level Varies, 4.70 to 5.30m Difference = 1.40 to 1.90m	Overtopping of existing flood bank from Newry River causing additional flow into Newry Canal. Causes canal to overtop further downstream and affects large area of City Centre. Wall ties in with Canal Flow Control structure.
Thompsons Weir to Clanrye Bridge along Middle Bank Flood Wedge	Wall 285m length FL: 6.60m	Embankment Level Varies, 3.80 to 4.70m Difference = 2.80 to 1.90m	Overtopping of existing flood bank from Newry River causing additional flow into Newry Canal. Causes canal to overtop further downstream and affects large area of City Centre.
Thompsons Weir to Clanrye Bridge, Left Hand Bank, Newry River	Wall 250m length FL: 6.60m	N/A No existing defence Ex GL = 3.60 to 4.20m	Overtopping of left hand bank causing flooding to Downshire Car Park with flows continuing south and east leading to flooding of property in the area bounded by Sandys Street, Downshire Road, Church Avenue and Windsor Hill. Properties affected include BT telephone exchange, Newry Court House, Windsor Hill Primary School and two churches.
Clanrye Bridge to Sugar Island Bridge, Both Banks, Newry River	Wall 450m length FL: 6.50m	Wall Level Varies, 4.90 to 5.90m Difference = 0.60 to 1.60m Ex GL = 3.90 to 5.00m	Overtopping of existing flood walls causing flooding to Sugar Island leading to additional flow into canal. Severe flooding of low lying areas of City Centre occurring from this location.
Sugar Island Bridge, Upstream Parapet Wall	Wall 30m length FL: 6.50m	Wall Level = 4.90m Difference = 1.60m	Overtopping of existing parapet walls causing flooding to Sugar Island leading to additional flow into canal. Severe flooding of low lying areas of City Centre occurring from this location.
Sugar Island Bridge, Downstream Parapet Wall	Wall 25m length FL: 6.20m	Wall Level = 4.70m Difference = 1.50m	Overtopping of existing parapet walls causing flooding to Sugar Island leading to additional flow into canal. Severe flooding of low lying areas of City Centre occurring from this location.

Location	Proposed Defence	Existing Defence Height and Difference	Comments
Sugar Island Bridge to Town Hall, Both Banks, Newry River	Wall 100m length FL: 6.20m	Wall Level Varies, 4.30 to 4.70m Difference = 1.50 to 1.90m Ex GL = 3.60 to 4.00m	Overtopping of existing flood walls causing flooding to Sugar Island leading to additional flow into canal. Severe flooding of low lying areas of City Centre occurring from this location.
Town Hall Bridge, Upstream Parapet Wall	Wall 25m length FL: 6.20m	Wall Level = 4.70m Difference = 1.50m	Overtopping of existing parapet walls causing flooding to Sugar Island leading to additional flow into canal. Severe flooding of low lying areas of City Centre occurring from this location.
Town Hall Bridge, Downstream Parapet Wall	Wall 25m length FL: 5.60m	Wall Level = 4.60m Difference = 1.00m	Overtopping of existing parapet walls causing flooding to Sugar Island leading to additional flow into canal. Severe flooding of low lying areas of City Centre occurring from this location.
Town Hall Bridge to Needham Bridge, Both Banks, Newry River	Wall 255m length FL: 5.60m	Wall Level = 4.60m Difference = 1.00m Ex GL = 3.40m	Proposed flow control structure on canal leads to additional flow in river. Causes overtopping of existing flood walls and flooding of eastern side of City Centre.
Needham Bridge, Upstream Parapet Wall	Wall 20m length FL: 5.60m	Wall Level = 4.60m Difference = 1.00m	Proposed flow control structure on canal leads to additional flow in river. Causes overtopping of existing flood walls and flooding of eastern side of City Centre.
Needham Bridge, Downstream Parapet Wall	Wall 20m length FL: 5.20m	Wall Level = 4.50m Difference = 0.70m	Proposed flow control structure on canal leads to additional flow in river. Causes overtopping of existing flood walls and flooding of eastern side of City Centre.
Needham Bridge to Ballybot Bridge, Both Banks, Newry River	Wall 610m length FL: 5.20m	Wall Level = 4.50m Difference = 0.70m Ex GL = 3.20m	Proposed flow control structure on canal leads to additional flow in river. Causes overtopping of existing flood walls and flooding of eastern side of City Centre.
Ballybot Bridge, Upstream Parapet Wall	Wall 20m length FL: 5.20m	Wall Level = 4.50m Difference = 0.70m	Proposed flow control structure on canal leads to additional flow in river. Causes overtopping of existing flood walls and flooding of eastern side of City Centre.

Table 11.2 Wall and Embankment Locations on Newry River/Canal

It should be noted that there are extensive walls along the Newry River as it traverses the City Centre. The current finished level of these should be verified as part of outline design works. No structural assessment has been undertaken as part of this study and this should also be undertaken at later design stages to determine if it is possible to extend existing walls or if replacement walls are required.

During meetings with Rivers Agency Area personnel concerns were raised over the structural condition of some walls. Concerns were also raised over the height of some of the proposed walls in the City Centre and the impact which they may have on the surroundings. While the construction details of the walls will be dependent on the local situation, consideration should be given to the use of composite construction methods such as concrete for 0-1.5m high and glass panels with steel supports above this to lessen the visual impact.

11.1.1.5 Option A-5; Flow Control Structure on Canal

From analysis of the model it is apparent that during peak flows there is a significant interaction of flows between the Newry River and the Newry Canal in the area between Sugar Island and Carnbane Industrial Estate. In this area the river and the canal are parallel with a flood embankment constructed between them as an attempt to prevent any transfer of flows.

As the canal water level is maintained approximately 0.5m below bank/wall level there is very little additional capacity available within the canal through the City Centre. When flow transfers from the river then the capacity of the canal is exceeded which causes significant flooding. In order to prevent flows greater than what can be accommodated it is proposed to construct a flow control device within the canal in the form of a 1800mm diameter pipe and associated embankment, with a finished level of 6.70m, to prevent overtopping. This is illustrated on drawing NWRY-ACM-XX-XX-DR-CE-01028. Additional information on the choice of throttle pipe size can be found in Appendix E.

An additional requirement of Option A-5 is to raise the flood bank in a downstream direction from the flow control structure to Clanrye Bridge to prevent flow entering the canal from the river over this reach. It would also be necessary to raise the level of the existing flood walls on the Newry River from the control structure as far down as Ballybot Bridge. This is necessary to contain the additional flow which would have otherwise been conveyed by the canal. The details of the proposed flood walls and embankments are given in Option A-4 under section 11.1.1.4.

While this option suggests the use of a throttle pipe for flow control other options of flow constriction may be possible including sluice gates. It is understood that the previous flow control structure was removed with agreement of multiple parties including Inland Waterways who saw the pipe as an obstruction to the use of the canal for recreation. A special set of extended lock gates with adjoining walls may offer suitable flexibility for the canal to remain useable but with gates that could be closed to prevent flooding during times of high flow.

11.1.1.6 Option A-6; Use Canal for Storage

Given that the canal level is controlled at the downstream end by sluices at the Victoria Lock it is possible to reduce the water level in the canal. It is understood that these gates allow a flow in the region of $1m^3/s$ to leave the canal. This is based on past lowering events when a drop of approximately 150mm was achieved in 8hrs through opening of the Victoria Lock sluices.

Basic calculations, as summarised in Table 11.3 below, illustrate the possible storage capacity that could be obtained along the canal between Lock No. 2 and the Victoria Lock through lowering of the water level. The current top water level of the canal has been taken as 3.5m.

Level Difference (m)	Cumulative Storage Volume Gained (m^3)
-0.25	43,200
-0.50	85,300
-0.75	126,500
-1.00	166,800

Table 11.3 Canal draw down capacity

To enable draw down in a more efficient manner and in a shorter time it is envisaged that a new controllable side weir would be required along the canal downstream of the Albert Basin. This would consist of a series of gates which would be adjustable to drop the water level in the canal prior to an expected storm event.

This proposal however has a significant number of variables which introduce a high degree of risk. As the river is tidal, there is a limited window of time available for draw down to occur. The gates would be lowered on the downward limb of the tidal cycle but would subsequently have to be raised and draw down suspended as the tide begins to rise to prevent backflow. Given that the canal would still have a base flow, the storage volume available would be eroded when the gates are in their closed position.

A significant warning of a storm event is required; currently Met Office data provides approximately 48 hours warning prior to an occurrence and if this does not coincide positively with the tidal cycle, it may lead to a delay in commencement of draw down.

Draw down of the canal level would also have environmental impacts. The stability of the canal banks and quay walls is also unknown and thought to be poor in places therefore draw down has to be undertaken in a slow and controlled manner to reduce the risk of damage occurring. This may mean that sufficient storage cannot be created in the time window available. Loughs Agency have previously expressed their concern at the impact on fisheries by the lowering of the canal under the current arrangement between Rivers Agency and Newry, Mourne and Down District Council.

Finally, there is always the risk of mechanical malfunction given that operation of the structure would only be occasional. AECOM have therefore ruled out this option given the amount of variables associated with it and the limited amount of benefit that would be gained from such a relatively small volume of storage. It is believed that other options would provide a more robust solution with a lower degree of risk.

11.1.2 Downshire Stream (B)

The Downshire Stream exhibits some flooding in the lower sections close to where it crosses Downshire Road. Two options as detailed below have been examined in an attempt to alleviate flooding. Option B-1 and B-2 are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01029 and NWRY-ACM-XX-XX-DR-CE-01030 respectively.

It is noted that the downstream end of Downshire Stream is also subject to flooding from the Newry River however options for resolving this are detailed in Section 11.1.1. This section deals specifically with flooding emanating from the Downshire Stream only.

11.1.2.1 Option B-1; Culvert Upgrade at Downshire Road

The current arrangement consists of twin 900mm diameter concrete culverts beneath Downshire Road which gives a combined capacity of approximately 2m^3/s. The peak flow experienced in this watercourse is 3.33m3/s for a Q100 return period event. It is proposed to upgrade this culvert to a twin concrete box culvert, 2.0m high by 1.0m deep providing approximately 4m^3/s.

Modelling of the upsized culverts showed that it had little impact on flooding emanating from Downshire Stream. This is attributed to a lack of capacity within the channel upstream of the culverts causing out of bank flooding prior to reaching the culverts. Also, increasing the capacity of the culverts may lead to more flooding at this location as it would allow back flow from the Newry River which is currently restricted due to the culvert size.

This option has therefore been discounted and will not be considered further as upgrading the culvert capacity does not have any significant impact on the flood extents in this vicinity.

11.1.2.2 Option B-2; Flood Walls upstream of Downshire Road

As mentioned in Section 11.1.2.1, out of bank flooding occurs from the left hand bank upstream of the Downshire Road culverts due to a lack of capacity within the channel to convey flow. Given the urban nature and constraints of existing development around the watercourse, the only feasible solution to increase the capacity is to provide flood walls along the stream to contain the flow and prevent flooding. The existing right hand bank is of sufficient height to prevent overtopping.

Modelling has shown that a wall should be constructed to a level of 10.30m which is based on a Q100 return period flood level of 9.70m and a 600mm freeboard allowance. The wall should be constructed from reinforced concrete and may be required to have a decorative finish applied to the exposed outer faces to improve its aesthetics. The total length of wall required is 75m.

It is noted that there is an existing wall at this location. It is assumed that this wall was not included in the model as it is not constructed as a flood wall. The wall should be assessed structurally to see if the application of tanking to the existing wall would provide a more appropriate solution other than its demolition and rebuilding.

11.1.3 Sandys Street Stream (C)

The Sandys Street Stream exhibits flooding in the lower reaches from its confluence with the Newry River back to the Talbot Street area where the ground begins to rise. Analysis of the model suggests that flooding is experienced in this area from a combination of "flood locking" and back flow from the Newry River along the culvert which leads to surcharge of the system and flow escaping to the surrounding area through manholes.

Two options as detailed below have been examined in an attempt to alleviate flooding. Options C-1 and C-2 are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01031 and NWRY-ACM-XX-XX-DR-CE-01032 respectively.

It is noted that this area is also subject to out of bank flooding from the Newry River, however options for resolving this are detailed in Section 11.1.1. This section deals specifically with flooding emanating from the Sandys Street Stream only.

11.1.3.1 Option C-1; Flap Valve at Outfall

Option C-1 considers the installation of a flap valve or similar non-return feature on the outlet of the Sandys Street culvert before its outfall to the Newry River. Such a feature would prevent backflow from the Newry River.

The model showed that adding a flap valve at the outlet proved to be ineffective due to the downstream end of the watercourse being submerged throughout the model run. The flap valve therefore retained all flow within the culvert network which still resulted in surcharging of manholes. This option has therefore been discounted and should not be considered further.

11.1.3.2 Option C-2; Sealing of Manholes

Option C-2 considers sealing the manholes along the culvert network which currently surcharge to prevent flow from escaping through them. When modelled, this worked successfully with all flows retained within the culvert network preventing surcharge to street level and preventing flooding.

It is noted that given the tide levels experienced in the Newry River that this area should currently flood on a regular basis as it is at a lower elevation. It is therefore suspected that the manholes along Sandys Street are already sealed to prevent back flow.

Also, the modelling report which accompanied the ICM model received from Rivers Agency stated that "in order to represent interaction between overland flows and culverted watercourses, manholes have been modelled as 2D gullies. This allows a head-discharge relationship to be defined at the manholes, allowing water to flow between the 1D culverts and 2D domain. This represents the effect of gullies draining water into the subsurface network."

Further investigation of the manholes and any possible connections to the culvert should be undertaken to establish if there is a risk of surcharge occurring through any associated manholes, gullies or drains. Any connections to the culvert should be fitted with non-return devices to prevent backflow. If manholes are found to be "un-sealed" then sealing should take place along the culvert from the Newry River back along Sandys Street to its junction with Talbot Street.

11.1.4 Knox Peebles Stream (D)

The Knox Peebles Stream shows flooding from two locations along its length. It is thought that this is a result of areas of low bank allowing flows to escape from the channel. Only one option is proposed as illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01033 and NWRY-ACM-XX-XX-DR-CE-01034.

It is noted that this area is also subject to flooding from the Newry River however options for resolving this are detailed in Section 11.1.1. This section deals specifically with flooding emanating from the Knox Peebles Stream only. Conversations with Rivers Agency personnel suggest that the Knox Peebles Stream is sensitive to the tide and in particular neap tides (i.e. a low high tide and a high low tide) which prevents discharge for a prolonged period. This can cause major problems if coincident with a rainfall event, however a combined probability assessment is deemed outside of the scope of this study and has not be undertaken.

11.1.4.1 Option D-1; Flood Wall/Embankment

Analysis of the flood model has shown that flow overtops the right hand bank of the stream at two locations onto Ballinacraig Way. To address this issue it is proposed to construct either a flood wall or flood embankment at these locations to contain the flow within the channel and prevent flooding.

The maximum water level experienced in the stream prior to the influence of the Newry River is 1.2m and therefore the proposed wall/embankment should be constructed to a level of 1.8m including a 0.6m allowance of freeboard. The choice of wall or embankment should be determined at a later design stage depending on the available space in the area. The total length of defence required at location 1 is 450m with 200m length required at location 2.

It is recommended that the levels of the existing banks along the Knox Peebles Stream are verified to ensure that they meet a required minimum level of 1.8m to give consistency to the level of protection provided along its length.

11.1.5 Tributary of Commons Stream (Greenan Road) (E)

The undesignated tributary of the Commons Stream which crosses the Greenan Road in the vicinity of No.34/No.35a did not show any flooding within the model provided by Rivers Agency however evidence from past events contradicts this with flooding having previously been experienced on at least two recorded occasions and detailed in earlier sections of this report. This discrepancy would appear to arise from differences between the model and what is actually on the ground. The proposed option is based on historic flooding rather than the model output and is illustrated on drawing NWRY-ACM-XX-XX-DR-CE-01035.

11.1.5.1 Option E-1; Construction of Inlet Structure and Culvert Upgrade/Maintenance

Given that the flooding is associated with hydraulic capacity issues it is proposed to construct a suitable headwall inlet structure within the channel to the rear of No.34 Greenan Road and improve the orientation of the culvert through the removal of a 90° bend that is currently present downstream of the existing inlet. A direction change of 45° maximum would significantly reduce the headlosses and improve flow through the culvert. Any new section of culvert between the proposed inlet structure and the existing 900mm dia. PVC culvert should be constructed using a 900mm dia. concrete pipe.

Further downstream it is proposed to culvert the remaining section of open watercourse with a 900mm dia. concrete pipe before connecting into the existing 750mm dia. section. It is noted from the documents provided by Rivers Agency that the structural condition of the existing 750mm dia. culvert is questionable. To ensure future serviceability of the culvert it is proposed that this section is re-surveyed prior to undertaking repairs on the detected defects. Repairs may also include the construction of manholes at locations as determined from the survey.

Also, the existing backdrop manholes on the lower section of the culvert should be inspected with maintenance undertaken as deemed necessary. Consideration should also be given to undertaking de-silting works in the lower reaches to restore the culvert to its full capacity. Rivers Agency may also wish to consider designation of this watercourse under the Drainage Order so that an annual inspection can be undertaken to ensure that an optimal condition is preserved.

11.1.6 Bessbrook River (F)

While flooding is experienced upstream of the A27 Tandragee Road it does not cause damage to any properties. However flooding is experienced in a localised area of Carnbane Gardens on the downstream side of the A27 where the Bessbrook River turns through 90° to flow parallel to the Newry Canal.

Investigation into the use of the area upstream of the A27 bridge for flood storage as part of the wider Newry River solution was conducted. This option is described in Section 11.1.1.1.

11.1.6.1 Option F-1; Flood Wall

Water levels in the Bessbrook River exceed that of the right hand bank in the vicinity of Carnbane Gardens. It is proposed to construct a flood wall with a crest level of 10.9m to provide protection to these properties and prevent flooding. This includes for a freeboard allowance of 600mm above an estimated Q100 return period flood level of 10.3m and is illustrated on drawing NWRY-ACM-XX-XX-DR-CE-01036. The total length of wall required is 95m.

11.1.7 Derrybeg River (G)

Flooding is experienced at a number of locations along the Derrybeg River including in the upstream reach prior to the branch to the Derrybeg River Diversion, on Upper Edward Street near the bus depot and at Merchants Quay.

Five options as detailed below have been examined in an attempt to alleviate flooding. Options G-1 to G-5 are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01037 to NWRY-ACM-XX-XX-DR-CE-01041 respectively.

It is noted that areas are also subject to flooding from the Newry River/Newry Canal however options for resolving this are detailed in Section 11.1.1. This section deals specifically with flooding emanating from the Derrybeg River only.

11.1.7.1 Option G-1; Flood Wall at Chancellors Road

Out of bank flooding is occurring from the upstream side of Chancellors Road leading to conveyance of flows in a southerly direction along the road before returning to the channel approximately 150m further downstream and causing inundation to a small business.

Option G-1 considers the construction of flood walls to contain the flow within the channel and prevent overtopping of the channel banks. It is proposed to construct flood walls to a finished top level of 87.0m which allows for a 600mm freeboard above an estimated flood level of 86.4m. The total length of wall required is 50m.

The flooding at the upstream reach may be attributed to model inaccuracies. The model provided to AECOM only extends a short distance upstream of the location from which the flooding is emanating. A sharp 90° bend is present on the channel immediately downstream which may lead to backing up of flows and the culvert which would convey the Derrybeg River under Chancellors Road has been omitted. To ensure flow follows the existing regime it would be best to extend the model in the upstream direction as well as inserting the culvert. This would allow any existing channel capacity to be used and may reduce flooding from this location.

11.1.7.2 Option G-2; Culvert Upgrade at Chancellors Road

Option G-2 is to upgrade the culvert to a size capable of passing the Q100 flows with a freeboard allowance. Out of bank flooding would suggest that the culvert beneath Chancellors Road is unable to vent the Q100 flow and hence should be upgraded to allow flows to pass. However on examination of the model it is apparent that the culvert which conveys the flows under Chancellors Road has been omitted from the model and therefore an assessment of its capacity was unable to be undertaken.

11.1.7.3 Option G-3; Flood Wall at Upper Edward Street

Option G-3 considers the construction of flood walls along the open channel section of the Derrybeg River in the vicinity of the bus depot. Flooding in this area is caused by the channel overtopping its banks. This is a result of high water levels in the lower reaches of the Derrybeg River, which is culverted and has a very flat gradient and is therefore influenced by the water level in the Newry River.

The wall should be reinforced concrete with a minimum finished level of 4.6m which includes a freeboard allowance of 0.6m. The total length of wall required is 330m.

11.1.7.4 Option G-4; Flood Wall at Upper Edward Street and Non-Return Device

Option G-4 considers the installation of a non-return device such as a flap valve on the downstream culvert outlet to the Newry River to assist with prevention of backflow up the culvert, along with the construction of flood walls in the vicinity of the bus depot as described in Section 11.1.7.3.

The model showed that adding a flap valve at the outlet proved to be ineffective due to the downstream end of the watercourse being submerged throughout the model run. The flap valve therefore retained all flow within the culvert network and resulted in flooding still occurring from the section of open watercourse at the bus depot. This option has therefore been discounted and should not be considered further as the construction of flood walls on their own is seen as being as effective.

It is noted that there may already be an existing flap valve on the outfall of the Derrybeg River culvert to the Newry River however this is not included within the model supplied by Rivers Agency to AECOM.

11.1.7.5 Option G-5; Seal Manholes at Cornmarket

Two manholes on the old line of the Derrybeg River culvert are shown to surcharge in the Cornmarket vicinity. This is due to backflow in the culvert from the Newry River. When modelled as sealed, this successfully retained flows within the culvert network preventing surcharge to street level and prevented flooding.

It is noted that given the tide levels experienced in the Newry River this area should currently flood on a regular basis, as it is at a lower elevation. It is therefore suspected that these manholes are already sealed to prevent back flow.

Also, the modelling report which accompanied the ICM model received from Rivers Agency stated that “in order to represent interaction between overland flows and culverted watercourses, manholes have been modelled as 2D gullies. This allows a head-discharge relationship to be defined at the manholes, allowing water to flow between the 1D culverts and 2D domain. This represents the effect of gullies draining water into the subsurface network.”

Further investigation of the manholes and any possible connections to the culvert should be undertaken to establish if there is a risk of surcharge occurring through any associated manholes, gullies or drains. Any connections to the culvert should be fitted with non-return devices to prevent backflow. If manholes are found to be “un-sealed” then sealing should take place along the culvert from the Newry River back to Cornmarket.

11.1.8 Armagh Road Drain (H)

Flooding is experienced at two locations along the Armagh Road Drain; upstream of the A27 Craigmore Way at Craigmore Road and more extensively in the vicinity of Ballinlare Gardens, the Whitegates Community Centre and St. Patricks Primary School.

Four options as detailed below have been examined in an attempt to alleviate flooding. Options H-1 to H-4 are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01042 to NWRY-ACM-XX-XX-DR-CE-01045 respectively.

It is noted that the downstream reaches of the Armagh Road Drain are also subject to flooding from the Newry River/Newry Canal, however options for resolving this are detailed in Section 11.1.1. This section deals specifically with flooding emanating from the Armagh Road Drain only.

11.1.8.1 Option H-1; Embankment at Craigmore Road

Flooding originates from both banks of the watercourse at this location but it is flows from the left hand bank adjacent to the property that is resulting in flooding to it. To alleviate this issue it is proposed to construct a flood embankment along the left hand bank with a finished height of 16.95m which includes for a freeboard allowance of 600mm above the Q100 flood level. The embankment should retain flow within the watercourse and prevent flooding with a required length of 30m.

It is also noted that images of this section of watercourse show that the open channel appears to be significantly overgrown which may be impacting on the hydraulic performance of the channel. It is recommended that channel maintenance is undertaken to help reduce the risk of flooding from this location.

11.1.8.2 Option H-2; Seal Manholes Downstream of Primary School

Option H-2 considers the sealing of manholes along the majority of the length of the culverted section of the Armagh Road Drain downstream of St. Patricks Primary School. This would total 18No. manholes along an approximately length of 970m. When this was modelled it successfully alleviated the flooding without causing any adverse effects on other areas.

Also, the modelling report which accompanied the ICM model received from Rivers Agency stated that "in order to represent interaction between overland flows and culverted watercourses, manholes have been modelled as 2D gullies. This allows a head-discharge relationship to be defined at the manholes, allowing water to flow between the 1D culverts and 2D domain. This represents the effect of gullies draining water into the subsurface network."

Further investigation of the manholes and any possible connections to the culvert should be undertaken to establish if there is a risk of surcharge occurring through any associated manholes, gullies or drains. Any connections to the culvert should be fitted with non-return devices to prevent backflow. If manholes are found to be "un-sealed" then sealing should take place along the length of the culvert.

It is noted that there are large areas of land zoned for both residential (14.6ha) and economic (11.3ha) development within the catchment associated with the Armagh Road Drain. These developments should be required to employ SuDS techniques to ensure there is no increase in surface water runoff rates. This cannot be ignored and has the potential to put significant pressure on the existing culvert which has insufficient hydraulic capacity. This option is therefore seen as a short term measure but should not be considered as a long term fix to the flooding associated from this watercourse.

11.1.8.3 Option H-3; Upgrade Culvert Downstream of Primary School

Option H-3 considers upgrading the existing culvert over a 970m length from St. Patricks Primary School to the downstream confluence point with the Derrybeg River. Analysis of the existing culvert suggests that the current 900mm dia. concrete pipe has a capacity of approximately 0.9m^3/s but the peak flow experienced in this watercourse is approximately 1.73m^3/s.

It is therefore proposed to use a 1350mm dia. concrete pipe which gives a capacity of approximately 2.0m^3/s. This would allow free flow of water throughout the network without causing surcharge to any manholes on the system.

11.1.8.4 Option H-4; Storage Area at Killeavey Road

Option H-4 considered the construction of offline storage in playing fields adjacent to the watercourse to provide attenuation of flows. Given the locations available and their current use as public spaces it was viewed that changing this into a flood storage area could present a significant health and safety risk as the area is urban in nature.

It has therefore been disregarded as other potential solutions are available which provide alleviation of the flooding.

11.2 Option Assessment

Given the number of options presented and the amount of watercourses requiring works to provide alleviation from flooding it has been assessed that the combination of the following options will provide suitable protection throughout the Newry study area.

Watercourse Name	Option
Newry River/Newry Canal (including Jerretspass River and Clanrye River)	A-1; Upstream Storage A-4; Flood Walls/Embankments A-5; Flow Control Structure on Canal
Downshire Stream	B-2; Flood Walls upstream of Downshire Road
Sandys Street Stream	C-2; Sealing of Manholes
Knox Peebles Stream	D-1; Flood Wall/Embankment
Tributary of Commons Stream (Greenan Road)	E-1; Construction of Inlet Structure and Culvert Upgrade/Maintenance
Derrybeg River	G-1; Flood Wall at Chancellors Road G-3; Flood Wall at Upper Edward Street G-5; Seal Manholes at Cornmarket
Armagh Road Drain	H-1; Embankment at Craigmore Road H-3; Upgrade Culvert downstream of Primary School

Table 11.4 Chosen Options Summary

The main source of flooding in the Newry study area is from a combination of the Newry River and the Newry Canal with the latter responsible for causing flooding of large sections of the City Centre. The canal has a limited capacity and due to the maintained water level being only approximately 0.5m below the quay wall level throughout the city it is generally unable to convey additional flows. To this end it is proposed to construct a flow control structure as described in section 11.1.1.5 to limit the flows that can be experienced in the canal through the City Centre.

The introduction of a flow control structure has had the effect of forcing additional flow, which would have otherwise been conveyed via the canal, along the City Centre section of the Newry River. While existing flood walls are present on the river they are not constructed to a sufficient height to contain a Q100 return period flood event. It is realised that extending the existing flood walls through the City Centre, while not impossible, is limited by the visual impact which such walls would have. It is also recognised that there is a limit to how high flood walls can be constructed, particularly in such urban areas. Extensions using glass walls and steel posts are suggested but it is also proposed to introduce upstream storage into the Jerretspass and Clanrye catchments to attenuate the flow leading to a reduction in the peak experienced through the City Centre.

AECOM recommend the construction of approximately 1.1Mm^3 of flood storage within the wider Newry River catchment with identified areas on the Jerretspass River comprising of 500,000m^3 and the remaining 600,000m^3 stored on the Clanrye River. This would allow attenuation of the flows to approximately a Q25 event and therefore only require modest increases in the height of the existing flood walls throughout the City Centre. The details of the proposed and extended flood walls can be found in section 11.1.1.4.

The use of flood storage within the catchment to provide attenuation reduces the flow significantly so as to alleviate the flooding experienced at Carnbane Industrial Estate (9.1.12) and at Carnbane Gardens on the A27 Tandragee Road (9.1.11). Therefore, Option F-1 (11.1.6.1) proposed for Carnbane Gardens is no longer required and no flood alleviation options are proposed at Carnbane Industrial Estate.

Most of the minor tributaries within the study area have minimal options due to the physical and technical constraints that exist and therefore there are limited solutions available for these. AECOM recommend that the works required on the minor tributaries are carried out in conjunction with the works on the main river and channel in order to realise the maximum benefit potential of the scheme. It should be noted that some of the tributaries may experience a degree of worsening of flooding following the works to the main river and channel due to the re-distribution of flows across the watercourses.

12 Cost Estimation

12.1 Flood Alleviation Options and Cost Estimates

The flood risk assessment identified that there is the potential for major flooding in the Newry area including large parts of the City Centre with approximately 600 residential and 900 commercial properties at risk during a Q100 return period flood event. Properties within the City Centre include buildings with a range of uses and purposes including residential, commercial, industrial, educational and community. Flooding will also impact the road network and other key infrastructure including NIW pumping stations, NIE sub-stations and the BT telephone exchange.

Table 12.1 shows a summary of the costs for the options considered for the Newry Area. As described in section 11.2, the combination of multiple options is required to provide flood protection during a 100yr return period event. The costs have been estimated using tendered rates for similar schemes within Northern Ireland (costs in brackets include for optimism bias at 37.8% – refer to Economic Appraisal). For a detailed breakdown of the costs for each option refer to Appendix B.

Watercourse Name	Option	Option Cost (£)
Newry River/Newry Canal (including Jerretspass River and Clanrye River)	A-1; Upstream Storage	5,366,655.00 (7,395,250.59)
	A-4; Flood Walls/Embankments	3,090,150.00 (4,258,226.70)
	A-5; Flow Control Structure on Canal	51,030.00 (70,319.34)
Downshire Stream	B-2; Flood Walls upstream of Downshire Road	85,050.00 (117,198.90)
Sandys Street Stream	C-2; Sealing of Manholes	3,572.10 (4,922.35)
Knox Peebles Stream	D-1; Flood Wall/Embankment	589,680.00 (812,579.04)
Tributary of Commons Stream (Greenan Road)	E-1; Construction of Inlet Structure and Culvert Upgrade/Maintenance	29,892.24 (41,191.51)
Derrybeg River	G-1; Flood Wall at Chancellors Road	45,360.00 (62,506.08)
	G-3; Flood Wall at Upper Edward Street	299,376.00 (412,540.13)
	G-5; Seal Manholes at Cornmarket	1,020.60 (1,406.39)
Armagh Road Drain	H-1; Embankment at Craigmore Road	5,613.30 (7,735.13)
	H-3; Upgrade Culvert downstream of Primary School	779,851.80 (1,074,635.78)
	Total Combined Cost	**10,347,251.04 (14,258,511.93)**

Table 12.1 Option Cost Estimate Breakdown

12.2 Temporary Defences

For means of comparison and given that the majority of the watercourses in the study area are designated, a “do minimum” option of placement of sandbags at properties at risk of flooding coupled with temporary pumping was considered as a possible base scenario. This measure would only be deployed when necessary and would be undertaken primarily by Rivers Agency staff and supported as required by the fire service, other drainage authorities and local council employees if a more urgent and wider deployment is required.

Costing the deployment of temporary pumps and sandbags is very difficult to undertake as it varies widely depending on what flood event occurs, where flooding is experienced and the duration of the flood event. During discussions with Rivers Agency Area personnel, enquires were made as to what sort of cost was associated with such a deployment. A previous recent deployment of pumps to the Knox Peebles Stream in Greenbank Industrial Estate cost in the region of £45,000; this was for a duration of 2-3 weeks and for 2 to 4 pumps in operation. No additional information was available on flood damages avoided by undertaking this action.

The deployment of sandbags as and when required is not seen as a continued long term resolution given that the level of protection provided is minimal and will only protect to depths of approximately 0.5m before backflow will occur through sewers into properties via ground floor toilets etc. Some of the properties which are at risk of inundation in the City Centre area experience flood depths much greater than this.

12.3 Newry River and Tributaries Benefit Analysis

The benefits were calculated in accordance with the method described in ‘Flood Coastal Erosion Risk Management Appraisal Guidance’ (FCERM-AG). The 2011 revision of ‘The Green Book – Appraisal and Evaluation in Central Government’ recommends the discount rate of 3.5% for years 0 – 30, 3% for years 31 – 75, and 2.5% for years 76 – 100.

The assessment indicates that the annual benefit for providing flood protection against a 1 in 100 year return period amounts to:

- Total Annual Benefit = £7,526,426.79

The net present value of annual benefits has been calculated using a test discount rate and amounts to:

- Present Value of Annual Benefits = £224,764,418.02

These figures indicate that combined options would provide benefits of flood damage avoidance of approximately £224,764,418.02.

12.4 Summary

The benefit cost analysis shows that the proposed combined options for the Newry study area is greater than 1 (15.76) and therefore can be considered to be economically viable.

13 Conclusion

Analysis of the hydraulic model provided to AECOM by Rivers Agency has shown that the main source of flooding in the Newry study area is from a combination of the Newry River and the Newry Canal with the latter responsible for causing flooding of large sections of the City Centre. The canal has a limited capacity and due to the maintained water level being only approximately 0.5m below the quay wall level throughout the city it is generally unable to convey additional flows. Some areas of localised flooding can be attributed to the multiple tributaries of the Newry River within the study area.

A combination of options at various locations throughout the study area is proposed to help alleviate the threat of flooding to Newry. These include upstream storage on the Jerretspass and Clanrye Rivers, flow control structure on the Newry Canal upstream of the City Centre, sealing of manholes on existing culverts, upgrading of existing culverts, provision of formal inlet structures and the construction of new flood walls and embankments along with extensions to existing flood defence infrastructure. No single option was found to provide an adequate solution to the flooding.

Given the limit of the model information provided it has not been possible to include the proposed upstream storage areas within the hydraulic model. AECOM would recommend that the current hydraulic model is extended to include a greater amount of the upstream catchment of both the Jerretspass and Clanrye Rivers and allow the proposed storage areas to be represented. It is known that a recent public realm scheme in the City Centre raised the quay level of the canal along Merchants Quay and Buttercrane Quay. Therefore AECOM would also recommend that an updated survey of all the watercourses within the City Centre area would be beneficial to ensure the accuracy of the model and to capture any recent changes. Such increases in quay level along the canal would allow it to convey additional flow and could lead to a reduction in the required wall heights proposed through the City Centre area.

As there is a large urban area within the model, AECOM consider that it would prove useful to include the interactions between the NI Water storm drainage network, Transport NI road drainage network and Rivers Agency assets. It is not known how many interconnections exist between these networks however they all contribute to the removal of surface water from the city. Some areas will have direct connections to the watercourses without any means of backflow protection. While it is acknowledged that, strictly speaking, it is outside of the scope of this study, it is an important factor in providing a total solution to the flooding problems faced in the Newry area.

The cost of damages for the Q5, Q10, Q25, Q50 and Q100 flood events were calculated based upon the Multi-Coloured Manual and discounted over a period of 100 years in order to determine the present value of benefits for each option. The benefit cost analysis found that the proposed combined options for the Newry study area are economically viable with a benefit cost ratio greater than 1 (approximately 16).

Going forward, it is recognised that the protection of Newry City from flooding is difficult to achieve with current measures limited to the deployment of temporary defences such as sandbags and pumps. While there is already significant temporary measures available AECOM would recommend that these along with their condition are reviewed and if deemed necessary that additional pumps and temporary defence measures be purchased by Rivers Agency for protection in the interim. It is noted that the alert system downstream of the Bus Station also plays a key role and is seen as critical in providing Rivers Agency with a warning to provide a response to an impending flood event.

Appendix A Drawings

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Drawing Number	Drawing Title
NWRY-ACM-XX-XX-DR-CE-01000	Site Location Plan
NWRY-ACM-XX-XX-DR-CE-01000-01	Tributary Key Plan
NWRY-ACM-XX-XX-DR-CE-01001	Catchment Map
NWRY-ACM-XX-XX-DR-CE-01002	Hydraulic Structures Location Plan
NWRY-ACM-XX-XX-DR-CE-01003	NIE Apparatus Location Plan
NWRY-ACM-XX-XX-DR-CE-01004	Watermains and Sewer Locations Sheet 1 of 2
NWRY-ACM-XX-XX-DR-CE-01005	Watermains and Sewer Locations Sheet 1 of 3
NWRY-ACM-XX-XX-DR-CE-01006	1 in 2yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01007	1 in 5yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01008	1 in 10yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01009	1 in 25yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01010	1 in 50yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01011	1 in 75yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01012	1 in 100yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01013	1 in 100yr +CC Flood Extents
NWRY-ACM-XX-XX-DR-CE-01014	1 in 200yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01015	1 in 1000yr Flood Extents
NWRY-ACM-XX-XX-DR-CE-01016	Cross Section Location Plan; Sheet 1 of 3
NWRY-ACM-XX-XX-DR-CE-01017	Cross Section Location Plan; Sheet 2 of 3
NWRY-ACM-XX-XX-DR-CE-01018	Cross Section Location Plan; Sheet 3 of 3
NWRY-ACM-XX-XX-DR-CE-01019	Options Location Plan
NWRY-ACM-XX-XX-DR-CE-01020	Option A-1; Upstream Storage - Jerretspass River
NWRY-ACM-XX-XX-DR-CE-01021	Option A-1; Upstream Storage - Clanrye River
NWRY-ACM-XX-XX-DR-CE-01022	Option A-1; Upstream Storage - Bessbrook & Newry Rivers
NWRY-ACM-XX-XX-DR-CE-01023	Option A-2; Downstream Storage
NWRY-ACM-XX-XX-DR-CE-01024	Option A-3; Flow Diversion
NWRY-ACM-XX-XX-DR-CE-01025	Option A-4; Flood Walls and Embankments; Sheet Layout Plan
NWRY-ACM-XX-XX-DR-CE-01026	Option A-4; Flood Walls and Embankments; Sheet 1 of 2
NWRY-ACM-XX-XX-DR-CE-01027	Option A-4; Flood Walls and Embankments; Sheet 2 of 2
NWRY-ACM-XX-XX-DR-CE-01028	Option A-5; Canal Flow Control Structure
NWRY-ACM-XX-XX-DR-CE-01029	Option B-1; Culvert Upgrade at Downshire Stream
NWRY-ACM-XX-XX-DR-CE-01030	Option B-2; Flood Walls upstream of Downshire Road
NWRY-ACM-XX-XX-DR-CE-01031	Option C-1; Flap Valve at Outfall, Sandys Street Stream
NWRY-ACM-XX-XX-DR-CE-01032	Option C-2; Seal Manholes, Sandys Street Stream
NWRY-ACM-XX-XX-DR-CE-01033	Option D-1; Flood Wall on Knox Peebles Stream; Sheet 1 of 2
NWRY-ACM-XX-XX-DR-CE-01034	Option D-1; Flood Wall on Knox Peebles Stream; Sheet 2 of 2
NWRY-ACM-XX-XX-DR-CE-01035	Option E-1; Inlet, Culvert Upgrade and Culvert Maintenance; Undesignated Tributary of Commons Stream (Greenan Road)
NWRY-ACM-XX-XX-DR-CE-01036	Option F-1; Flood Wall at Carnbane Gardens; Bessbrook River
NWRY-ACM-XX-XX-DR-CE-01037	Option G-1; Flood Wall at Chancellors Road; Derrybeg River
NWRY-ACM-XX-XX-DR-CE-01038	Option G-2; Culvert Upgrade at Chancellors Road; Derrybeg River
NWRY-ACM-XX-XX-DR-CE-01039	Option G-3; Flood Wall at Upper Edward Street; Derrybeg River

Drawing Number	Drawing Title
NWRY-ACM-XX-XX-DR-CE-01040	Option G-4; Flood Wall at Upper Edward Street and Non-Return Device; Derrybeg River
NWRY-ACM-XX-XX-DR-CE-01041	Option G-5; Seal Manholes at Cornmarket; Derrybeg River
NWRY-ACM-XX-XX-DR-CE-01042	Option H-1; Flood Wall at Craigmore Road; Armagh Road Drain
NWRY-ACM-XX-XX-DR-CE-01043	Option H-2; Seal Manholes Downstream of Primary School; Armagh Road Drain
NWRY-ACM-XX-XX-DR-CE-01044	Option H-3; Culvert Upgrade Downstream of Primary School; Armagh Road Drain
NWRY-ACM-XX-XX-DR-CE-01045	Option H-4; Storage Area at Killeavy Road; Armagh Road Drain

Appendix B Option Costs

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Appendix C Flood Depths

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Appendix D Upstream Storage Areas

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Appendix E Flood Walls/Embankments

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Appendix F Cross Section Flood Levels

Note: Drawings NWRY-ACM-XX-XX-DR-CE-01016 to NWRY-ACM-XX-XX-DR-CE-01018 illustrates the cross section locations.

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Maximum Flood Levels for Newry River

Cross Section No:	Q2	Q5	Q10	Q25	Q50	Q75	Q100	Q200	Q1000	Q100+CC
	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)
NEWR_01692	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
NEWR_02493	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76
NEWR_02996	2.77	2.77	2.76	2.76	2.76	2.77	2.77	2.77	2.77	2.77
NEWR_03518	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.78	2.78
NEWR_04056	2.78	2.78	2.77	2.77	2.78	2.78	2.78	2.78	2.79	2.79
NEWR_04125	2.78	2.78	2.78	2.77	2.78	2.78	2.78	2.79	2.79	2.79
NEWR_04540	2.78	2.78	2.78	2.78	2.78	2.79	2.79	2.80	2.81	2.80
NEWR_04592	2.78	2.78	2.78	2.78	2.78	2.79	2.79	2.79	2.80	2.80
NEWR_04815	2.79	2.79	2.79	2.80	2.80	2.81	2.81	2.83	2.85	2.83
NEWR_05016	2.79	2.80	2.80	2.80	2.81	2.82	2.83	2.84	2.86	2.84
NEWR_05241	2.80	2.80	2.80	2.81	2.82	2.84	2.84	2.86	2.89	2.86
NEWR_05640	2.80	2.81	2.81	2.83	2.83	2.85	2.86	2.88	2.92	2.89
NEWR_06106	2.81	2.82	2.83	2.86	2.86	2.90	2.91	2.94	2.99	2.95
NEWR_06345	2.82	2.83	2.84	2.87	2.87	2.91	2.93	2.96	3.02	2.97
NEWR_06569	2.83	2.84	2.86	2.90	2.91	2.96	2.98	3.02	3.20	3.03
NEWR_06773	2.83	2.86	2.88	2.93	2.95	3.01	3.04	3.08	3.36	3.09
NEWR_06982	2.84	2.87	2.90	2.96	2.98	3.05	3.08	3.12	3.49	3.13
NEWR_07148	2.85	2.88	2.91	2.98	3.00	3.08	3.11	3.15	3.58	3.17
NEWR_07206	2.85	2.89	2.92	2.99	3.01	3.09	3.12	3.16	3.61	3.18
NEWR_07433	2.86	2.90	2.94	3.01	3.04	3.11	3.14	3.19	3.67	3.20
NEWR_07646	2.88	2.93	2.98	3.05	3.08	3.15	3.18	3.22	3.74	3.24
NEWR_07697	2.90	2.97	3.04	3.12	3.15	3.22	3.25	3.29	3.94	3.31

Cross Section No:	Q2	Q5	Q10	Q25	Q50	Q75	Q100	Q200	Q1000	Q100+CC
	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)
NEWR_07730	2.89	2.97	3.03	3.11	3.13	3.21	3.23	3.28	3.91	3.30
NEWR_07749	2.90	2.98	3.04	3.12	3.15	3.22	3.24	3.29	3.93	3.31
NEWR_07812	2.91	3.00	3.08	3.15	3.18	3.25	3.27	3.32	4.00	3.33
NEWR_07865	2.93	3.04	3.12	3.19	3.22	3.28	3.30	3.35	4.09	3.37
NEWR_07913	2.98	3.14	3.24	3.32	3.34	3.40	3.42	3.46	4.25	3.54
NEWR_07956	3.02	3.22	3.33	3.41	3.44	3.49	3.51	3.55	4.36	3.67
NEWR_07984	3.03	3.25	3.36	3.44	3.46	3.51	3.53	3.58	4.41	3.70
NEWR_08030	3.08	3.32	3.43	3.50	3.53	3.57	3.59	3.66	4.51	3.79
NEWR_08030u	3.17	3.47	3.59	3.66	3.68	3.72	3.74	3.85	4.66	3.97
NEWR_08045	3.21	3.54	3.65	3.72	3.74	3.79	3.80	3.92	4.74	4.05
NEWR_08056	3.22	3.54	3.66	3.73	3.75	3.79	3.81	3.93	4.74	4.06
NEWR_08104	3.22	3.55	3.67	3.74	3.76	3.80	3.81	3.94	4.79	4.07
NEWR_08160	3.21	3.53	3.64	3.70	3.73	3.77	3.78	3.91	4.82	4.03
NEWR_08193	3.38	3.78	3.88	3.94	3.96	4.00	4.03	4.16	4.92	4.28
NEWR_08231	3.62	4.05	4.12	4.18	4.20	4.24	4.27	4.40	4.99	4.51
NEWR_08293	3.74	4.18	4.25	4.31	4.33	4.37	4.41	4.53	5.02	4.63
NEWR_08315	3.85	4.37	4.45	4.50	4.51	4.57	4.61	4.73	5.14	4.80
NEWR_08378	3.89	4.40	4.48	4.53	4.54	4.60	4.64	4.75	5.16	4.82
NEWR_08438	3.93	4.44	4.51	4.56	4.58	4.63	4.67	4.78	5.18	4.84
NEWR_08489	4.11	4.73	4.82	4.87	4.88	4.97	5.02	5.15	5.56	5.22
NEWR_08533	4.12	4.74	4.83	4.87	4.89	4.97	5.02	5.15	5.55	5.21
NEWR_08554	4.22	4.92	5.02	5.07	5.09	5.19	5.25	5.42	5.96	5.51
NEWR_08638	4.21	4.90	5.00	5.04	5.06	5.16	5.23	5.40	5.94	5.50

Cross Section No:	Q2	Q5	Q10	Q25	Q50	Q75	Q100	Q200	Q1000	Q100+CC
	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)
NEWR_08650	4.22	4.91	5.01	5.05	5.07	5.17	5.24	5.41	5.96	5.51
NEWR_08759	4.32	4.99	5.10	5.14	5.16	5.26	5.32	5.47	6.00	5.57
NEWR_08790	4.34	5.03	5.14	5.18	5.21	5.31	5.38	5.54	6.12	5.65
NEWR_08857	4.37	5.08	5.19	5.24	5.26	5.37	5.44	5.60	6.19	5.71
NEWR_09030	4.45	5.12	5.23	5.27	5.30	5.42	5.49	5.66	6.23	5.78
NEWR_09043	4.48	5.14	5.25	5.30	5.32	5.44	5.51	5.68	6.26	5.80
NEWR_09335	4.64	5.23	5.35	5.40	5.43	5.54	5.61	5.78	6.34	5.89
NEWR_09587	5.02	5.49	5.62	5.69	5.73	5.81	5.85	6.00	6.54	6.12
NEWR_09688	5.21	5.66	5.79	5.86	5.91	5.98	6.01	6.16	6.70	6.27
NEWR_09792	5.41	5.85	5.98	6.06	6.11	6.17	6.21	6.30	6.84	6.41
NEWR_10008	5.69	6.10	6.24	6.34	6.41	6.49	6.52	6.61	7.05	6.67
NEWR_10043	5.69	6.10	6.24	6.34	6.41	6.49	6.52	6.61	7.05	6.67
NEWR_10095	5.79	6.19	6.34	6.45	6.52	6.61	6.65	6.74	7.16	6.80
NEWR_10197	5.87	6.25	6.41	6.53	6.61	6.71	6.74	6.86	7.24	6.91
NEWR_10393	6.05	6.39	6.56	6.70	6.79	6.89	6.94	7.04	7.47	7.11
NEWR_10590	6.25	6.55	6.71	6.86	6.98	7.10	7.14	7.27	7.67	7.34
NEWR_10661	6.39	6.71	6.88	7.06	7.21	7.35	7.41	7.56	8.00	7.66
NEWR_10679	6.42	6.74	6.92	7.11	7.27	7.42	7.49	7.67	8.17	7.77
NEWR_10730	6.47	6.79	6.97	7.16	7.33	7.48	7.56	7.74	8.26	7.84
NEWR_10807	6.58	6.92	7.10	7.31	7.48	7.64	7.72	7.92	8.46	8.03
NEWR_10860	6.65	6.99	7.19	7.40	7.58	7.75	7.83	8.02	8.50	8.12
NEWR_10900	6.69	7.03	7.24	7.47	7.68	7.87	7.97	8.20	8.79	8.32
NEWR_10977	6.81	7.15	7.36	7.60	7.80	7.99	8.09	8.31	8.87	8.42

Cross Section No:	Q2	Q5	Q10	Q25	Q50	Q75	Q100	Q200	Q1000	Q100+CC
	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)
NEWR_11025	6.85	7.19	7.40	7.63	7.83	8.01	8.11	8.33	8.85	8.43
NEWR_11053	6.89	7.24	7.46	7.71	7.92	8.12	8.22	8.47	9.09	8.59
NEWR_11053	6.89	7.24	7.46	7.71	7.92	8.12	8.22	8.47	9.09	8.59
NEWR_11113	6.96	7.31	7.53	7.78	8.00	8.20	8.30	8.55	9.16	8.67
NEWR_11262	7.08	7.44	7.66	7.92	8.14	8.34	8.44	8.69	9.31	8.82
NEWR_11489	7.26	7.62	7.83	8.08	8.30	8.49	8.59	8.83	9.43	8.95
NEWR_11506	7.31	7.67	7.89	8.14	8.36	8.54	8.64	8.89	9.50	9.01
NEWR_11634	7.41	7.77	7.99	8.24	8.45	8.63	8.73	8.97	9.58	9.09
NEWR_11828	7.67	8.03	8.24	8.48	8.69	8.86	8.96	9.19	9.80	9.31
NEWR_11876	7.75	8.11	8.32	8.57	8.78	8.95	9.04	9.28	9.89	9.39
NEWR_11901	7.77	8.14	8.36	8.62	8.84	9.02	9.13	9.38	10.07	9.50
NEWR_11957	7.83	8.19	8.41	8.66	8.89	9.07	9.17	9.42	10.13	9.54
NEWR_12044	7.95	8.32	8.54	8.80	9.03	9.21	9.31	9.56	10.28	9.69
NEWR_12252	8.34	8.69	8.91	9.15	9.36	9.53	9.63	9.85	10.46	9.96
NEWR_12465	8.63	8.97	9.19	9.41	9.61	9.75	9.83	10.03	10.61	10.14
NEWR_12643	8.86	9.21	9.42	9.65	9.83	9.96	10.04	10.25	10.82	10.34
NEWR_12709	8.97	9.32	9.53	9.76	9.94	10.06	10.14	10.32	10.89	10.42
NEWR_12728	9.04	9.40	9.61	9.84	10.03	10.15	10.23	10.41	10.97	10.51
NEWR_12728	9.04	9.40	9.61	9.84	10.03	10.15	10.23	10.41	10.97	10.51
NEWR_12808	9.22	9.56	9.78	10.02	10.23	10.36	10.44	10.65	11.14	10.75
NEWR_12865	9.34	9.67	9.87	10.11	10.31	10.42	10.50	10.70	11.17	10.79
NEWR_12925	9.50	9.83	10.02	10.24	10.43	10.54	10.61	10.80	11.26	10.89

Maximum Flood Levels for Newry Canal

Cross Section No:	Q2 Max Flood Level (mAOD)	Q5 Max Flood Level (mAOD)	Q10 Max Flood Level (mAOD)	Q25 Max Flood Level (mAOD)	Q50 Max Flood Level (mAOD)	Q75 Max Flood Level (mAOD)	Q100 Max Flood Level (mAOD)	Q200 Max Flood Level (mAOD)	Q1000 Max Flood Level (mAOD)	Q100+CC Max Flood Level (mAOD)
NCAN_00799	2.84	2.84	2.83	2.83	2.84	2.83	2.83	2.85	2.86	2.85
NCAN_00997	2.83	2.83	2.83	2.83	2.84	2.83	2.83	2.85	2.86	2.85
NCAN_01197	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.85	2.86	2.85
NCAN_01397	2.83	2.83	2.83	2.83	2.83	2.82	2.83	2.85	2.86	2.85
NCAN_01597	2.82	2.82	2.82	2.82	2.83	2.82	2.83	2.85	2.86	2.85
NCAN_01797	2.82	2.82	2.82	2.82	2.82	2.82	2.83	2.85	2.86	2.85
NCAN_01997	2.81	2.82	2.82	2.82	2.82	2.82	2.83	2.84	2.86	2.85
NCAN_02199	2.81	2.81	2.81	2.81	2.82	2.82	2.83	2.84	2.86	2.85
NCAN_02399	2.80	2.81	2.81	2.81	2.81	2.82	2.83	2.84	2.86	2.85
NCAN_02600	2.80	2.80	2.80	2.81	2.81	2.82	2.83	2.84	2.86	2.84
NCAN_02799	2.79	2.79	2.79	2.80	2.80	2.82	2.82	2.84	2.86	2.84
NCAN_03006	2.79	2.79	2.79	2.80	2.80	2.82	2.82	2.83	2.86	2.84
NCAN_03416	2.79	2.79	2.80	2.80	2.80	2.82	2.82	2.84	2.86	2.84
NCAN_03813	2.80	2.80	2.81	2.82	2.82	2.84	2.85	2.87	2.90	2.87
NCAN_04013	2.80	2.81	2.81	2.83	2.83	2.86	2.87	2.89	2.93	2.90
NCAN_04213	2.81	2.82	2.82	2.84	2.85	2.88	2.89	2.92	2.96	2.92
NCAN_04413	2.81	2.82	2.83	2.86	2.86	2.91	2.92	2.95	3.00	2.96
NCAN_04613	2.82	2.83	2.84	2.88	2.89	2.94	2.96	2.99	3.08	3.00
NCAN_04812	2.82	2.84	2.85	2.90	2.91	2.98	3.00	3.04	3.21	3.05
NCAN_05011	2.83	2.85	2.87	2.92	2.94	3.02	3.05	3.09	3.33	3.10
NCAN_05211	2.83	2.86	2.88	2.95	2.98	3.07	3.10	3.14	3.47	3.16
NCAN_05452	2.84	2.87	2.89	3.08	3.17	3.23	3.28	3.36	3.63	3.39

Cross Section No:	Q2 Max Flood Level (mAOD)	Q5 Max Flood Level (mAOD)	Q10 Max Flood Level (mAOD)	Q25 Max Flood Level (mAOD)	Q50 Max Flood Level (mAOD)	Q75 Max Flood Level (mAOD)	Q100 Max Flood Level (mAOD)	Q200 Max Flood Level (mAOD)	Q1000 Max Flood Level (mAOD)	Q100+CC Max Flood Level (mAOD)
NCAN_05480	2.84	2.87	2.89	3.10	3.20	3.27	3.32	3.41	3.69	3.44
NCAN_05620	2.84	2.87	2.89	3.11	3.21	3.28	3.33	3.42	3.71	3.45
NCAN_05808	2.84	2.87	2.89	3.03	3.11	3.16	3.20	3.28	3.55	3.31
NCAN_05847	2.84	2.87	2.89	3.12	3.22	3.29	3.36	3.47	3.78	3.51
NCAN_05883	2.84	2.87	2.89	3.21	3.34	3.43	3.50	3.63	3.95	3.67
NCAN_05925	2.84	2.87	2.89	3.32	3.46	3.57	3.66	3.79	4.12	3.84
NCAN_05956	2.84	2.87	2.89	3.37	3.52	3.65	3.74	3.88	4.21	3.93
NCAN_05988	2.84	2.87	2.91	3.43	3.59	3.72	3.81	3.95	4.26	4.00
NCAN_06140	2.85	2.87	2.98	3.50	3.66	3.81	3.93	4.09	4.47	4.15
NCAN_06179	2.85	2.87	3.09	3.66	3.84	3.99	4.10	4.27	4.67	4.33
NCAN_06296	2.85	2.87	3.24	3.89	4.10	4.26	4.37	4.52	4.90	4.58
NCAN_06387	2.85	2.88	3.26	3.92	4.14	4.29	4.39	4.55	4.91	4.60
NCAN_06502	2.85	2.88	3.31	3.98	4.20	4.34	4.44	4.59	5.03	4.65
NCAN_06529	2.85	2.88	3.33	4.03	4.27	4.41	4.51	4.67	5.12	4.73
NCAN_06593	2.85	2.88	3.38	4.12	4.37	4.51	4.59	4.75	5.16	4.81
NCAN_06660	2.85	2.88	3.42	4.16	4.42	4.58	4.65	4.82	5.26	4.89
NCAN_06733	2.85	2.88	3.41	4.16	4.44	4.61	4.67	4.85	5.27	4.92
NCAN_06780	2.86	2.89	3.56	4.56	4.95	5.20	5.30	5.51	6.16	5.63
NCAN_06880	2.86	2.89	3.69	4.63	4.96	5.19	5.27	5.46	6.03	5.57
NCAN_06917	2.86	2.89	3.73	4.72	5.09	5.36	5.43	5.61	6.16	5.71
NCAN_07031	2.87	2.90	3.80	4.76	5.13	5.38	5.46	5.64	6.21	5.74
NCAN_07203	2.89	2.91	3.89	4.81	5.18	5.43	5.51	5.68	6.26	5.79
NCAN_07360	2.91	2.94	3.95	4.86	5.23	5.49	5.56	5.74	6.33	5.84

Cross Section No:	Q2	Q5	Q10	Q25	Q50	Q75	Q100	Q200	Q1000	Q100+CC
	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)	Max Flood Level (mAOD)
NCAN_07459	2.95	2.97	3.98	4.88	5.24	5.52	5.60	5.78	6.36	5.87
NCAN_07650	3.30	3.39	4.14	4.97	5.34	5.65	5.75	5.93	6.50	6.03
NCAN_07801	3.50	3.59	4.32	5.10	5.47	5.83	5.96	6.15	6.73	6.26
NCAN_07960	3.60	3.69	4.41	5.18	5.55	5.93	6.06	6.31	6.91	6.42
NCAN_08121	3.74	3.81	4.48	5.23	5.60	5.98	6.12	6.37	7.02	6.50
NCAN_08150	3.77	3.83	4.48	5.24	5.60	5.99	6.12	6.38	7.03	6.50
NCAN_08153	6.58	6.69	6.74	6.81	6.77	6.86	6.89	6.97	7.31	7.01
NCAN_08204	6.58	6.68	6.74	6.80	6.76	6.85	6.88	6.94	7.19	6.98
NCAN_08247	6.58	6.69	6.75	6.81	6.77	6.86	6.89	6.96	7.24	6.99
NCAN_08390	6.58	6.68	6.73	6.79	6.75	6.85	6.88	6.97	7.40	7.02
NCAN_08505	6.60	6.72	6.78	6.86	6.80	6.92	6.95	7.05	7.55	7.11
NCAN_08799	6.74	6.92	7.02	7.16	7.04	7.25	7.28	7.41	8.04	7.47
NCAN_08886	6.75	6.92	7.03	7.16	7.07	7.26	7.30	7.43	8.07	7.49
NCAN_08968	6.75	6.92	7.03	7.17	7.09	7.27	7.32	7.46	8.11	7.53
NCAN_08968	6.75	6.92	7.03	7.17	7.09	7.27	7.32	7.46	8.11	7.53
NCAN_09294	6.75	6.93	7.21	7.39	7.48	7.59	7.64	7.77	8.47	7.83
NCAN_09699	6.89	7.51	7.84	8.04	8.18	8.26	8.31	8.46	9.00	8.52
NCAN_09875	7.56	8.01	8.29	8.47	8.60	8.67	8.73	8.86	9.35	8.93
NCAN_09875	7.56	8.01	8.29	8.47	8.60	8.67	8.73	8.86	9.35	8.93
NCAN_10090	8.62	9.05	9.30	9.46	9.59	9.65	9.70	9.83	10.25	9.89
NCAN_10489	8.92	9.56	9.89	10.10	10.27	10.34	10.40	10.55	10.91	10.62
NCAN_10889	9.01	9.72	10.08	10.31	10.49	10.57	10.63	10.79	11.19	10.87

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About AECOM

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Upstream Storage Area Analysis

1.1 Introduction

In order to calculate the required storage volume upstream of the City Centre, analysis and modelling was undertaken to determine what return period flow could be safely passed with minimum modifications to the existing flood protection arrangements.

It is known that the Newry Canal causes the highest risk of flooding to the City Centre due to the minimal freeboard available within the canal banks and quay walls as it traverses the Centre. When flow in the Newry River exceeds a Q25 return period event then it starts to overtop the existing flood bank between Carnbane and Sugar Island which increases the flow in the canal. This increase in flow in the canal then leads to out-of-bank flooding along the canal in the City Centre.

When AECOM introduced a flow control structure to the canal as an attempt to limit the flow to an acceptable volume this prevented the river flow from reducing and led to flooding from the Newry River through the City Centre, i.e. the flooding problem transferred to the river instead of the canal and still caused inundation of large areas of the City Centre.

AECOM then increased the height of the walls and embankments along the river as an attempt to contain this flow however the height of the wall required to protect from flooding is, in places, in excess of 3.0m above the existing ground level. This has therefore been discounted as being a viable option due to the height and the impact which these would have, however it is acknowledged that lower height walls will be required as part of the overall solution. A further analysis of the proposed walls and embankments can be found in Appendix E of this report.

Given that the total flow upstream of the city was greater than that which could be conveyed through the Centre it was decided that a means of reducing this flow would be required. The only feasible option is the construction of upstream storage areas to provide attenuation of flow. A diversion of the Clanrye River was considered but has been discounted on technical grounds (see Section 11.1.1.3 for details).

The volume of storage required to attenuate the flows at various return periods is explained in section 1.2 below. Note that identification of storage areas has been undertaken using OSNI Height Data information and/or LiDAR information of the study area where this was available. Topographic analysis was used to identify approximate extents of storage areas with a proposed stored depth of water limited to 1.5m maximum.

It is recommended that the hydraulic models provided are extended to beyond the proposed storage areas to allow these to be appropriately modelled and their impact fully assessed. AECOM have based this analysis on reduction of inflows to the watercourses to which attenuation is proposed as a means of representing the proposed storage areas.

1.2 Estimation of Storage Volume

Hydrographs were extracted from the model at cross section NEWR_09335.1 which was selected as it includes all of the upstream point inflows and lateral inflows for the Newry River. The difference in volume between smaller return periods and the Q100 calculated is presented in Figure 1 below.

Storing from	Storing to	Estimated Volume of Storage Required (m³)
Q5	Q100	2,555,000
Q10		1,872,000
Q25		1,080,000
Q50		876,000

Figure 1 Estimated Storage Volumes

The hydrograph extracted from the model is presented in Figure 2 below:

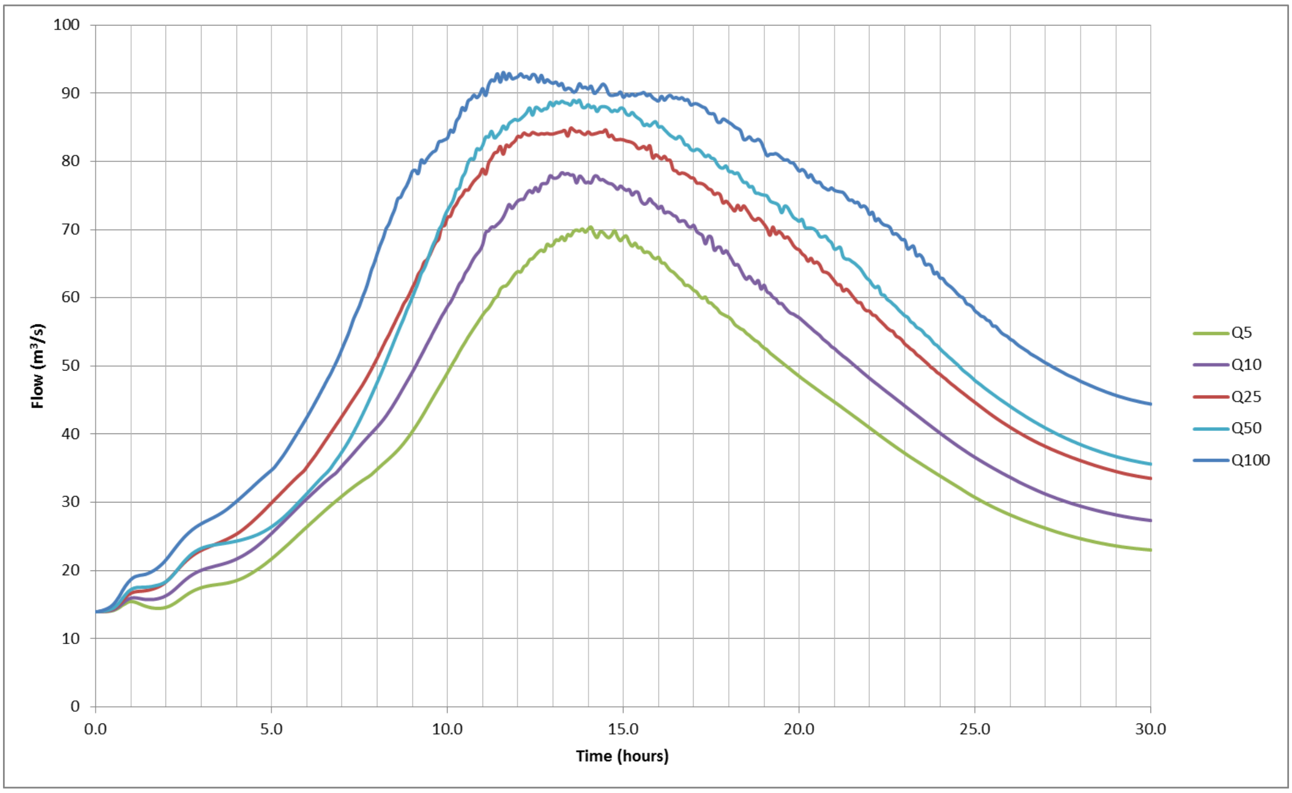

Figure 2 Hydrograph for flows at cross section NEWR_09335.1

The volume required to store flows from the Q5 to Q100 is too large when the upstream catchment is considered along with flooding already experienced on the Jerretspass River & Clanrye River. The Q50 to Q100 is also not considered as the amount of flooding experienced in the City is too large. The main focus will be storing flows from the Q25 to Q100 and the Q10 to Q100.

Analysis of the flows on the contributing rivers shows that approximately 50% of the flow is conveyed by the Jerretspass River with 40% conveyed by the Clanrye River and the remaining 10% of the flows coming from the Bessbrook River. Therefore in an attempt to balance the attenuation provided across the catchment it is proposed to try and identify the following volume of storage as shown in Figure 3 below:

Catchment	Storage Volume (m^3)	
	Q10 to Q100	Q25 to Q100
Jerrettspass	936,000	540,000
Clanyre	748,800	432,000
Bessbrook	187,200	108,000

Figure 3 Storage Volume per Catchment

1.3 Available Storage on the Jerretspass River

Four potential locations have been identified as shown in Figure 4 below and also illustrated on drawing NWRY-ACM-XX-XX-DR-CE-01020.

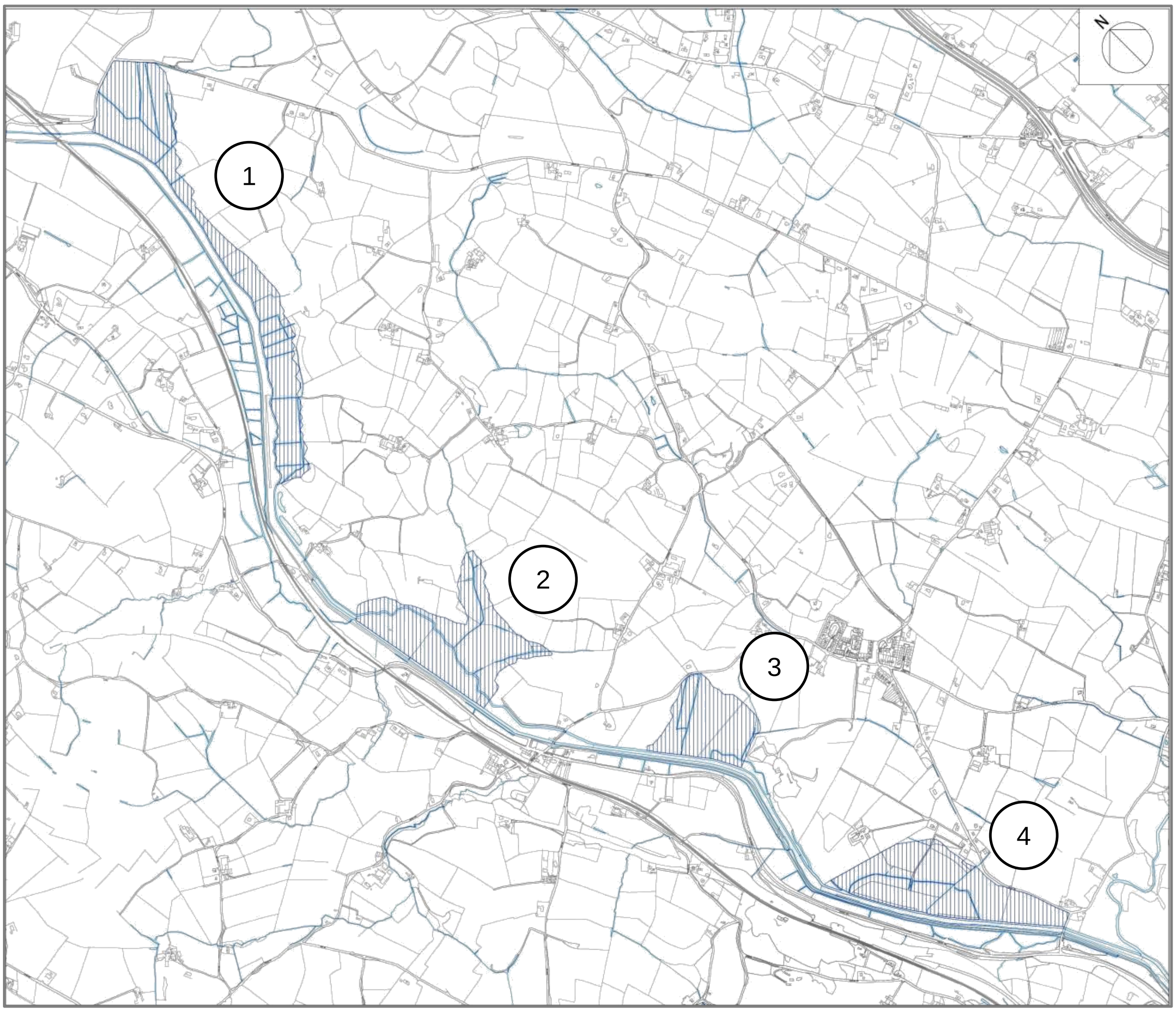

Figure 4 Jerretspass River Identified Storage Locations

River	Location	Approximate Volume (m³)
Jerretspass River	1	250,000
	2	200,000
	3	100,000
	4	200,000
	Total	750,000

The total volume in the four sites is in excess of the volume required to be retained during a Q25 flood event with excess volume available if required however it falls short of the volume required to attenuate the flows to a Q10 event.

The model was inspected and it was noted that storage areas 3 and 4 on the Jerretspass River were within the model extents. Analysis of the model for the Q100 simulation showed that there was already out of bank flooding and inundation at these locations. This value should be deducted from the available volume as a portion of the storage area already contains flow.

In Location 3 the available volume was estimated at 100,000m³. This area is noted to be flooded in the model during the Q100 simulation as shown here:

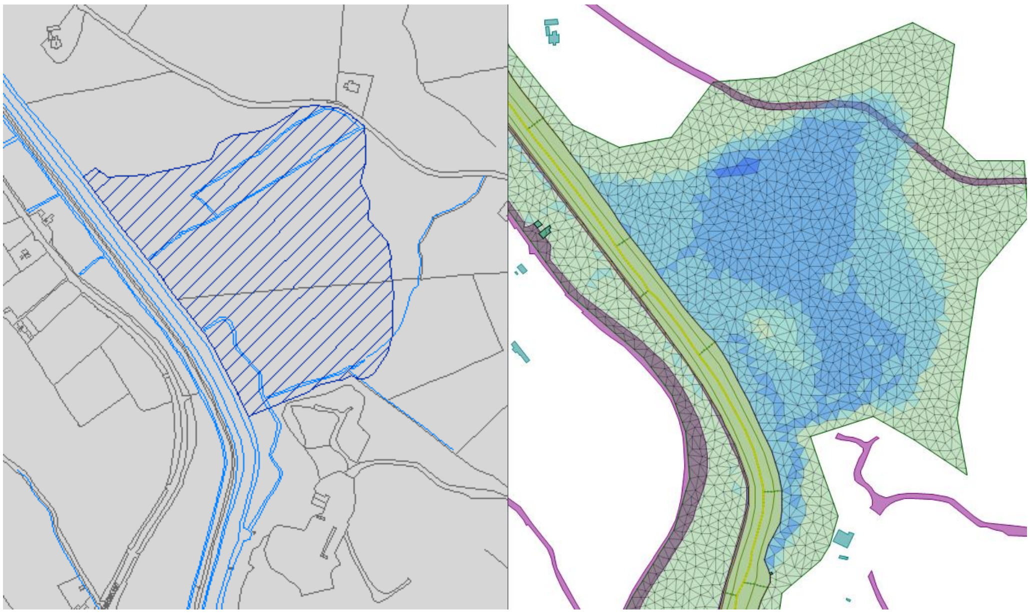

Figure 5 Jerretspass River Storage Location 3

The storage volume used in the model is estimated at 162,000m³ which is in excess of the estimated 100,000m³ leaving this storage area unavailable.

In Location 4 the available volume was estimated at 200,000m³. This area is noted to be flooded in the model during the Q100 simulation as shown here:

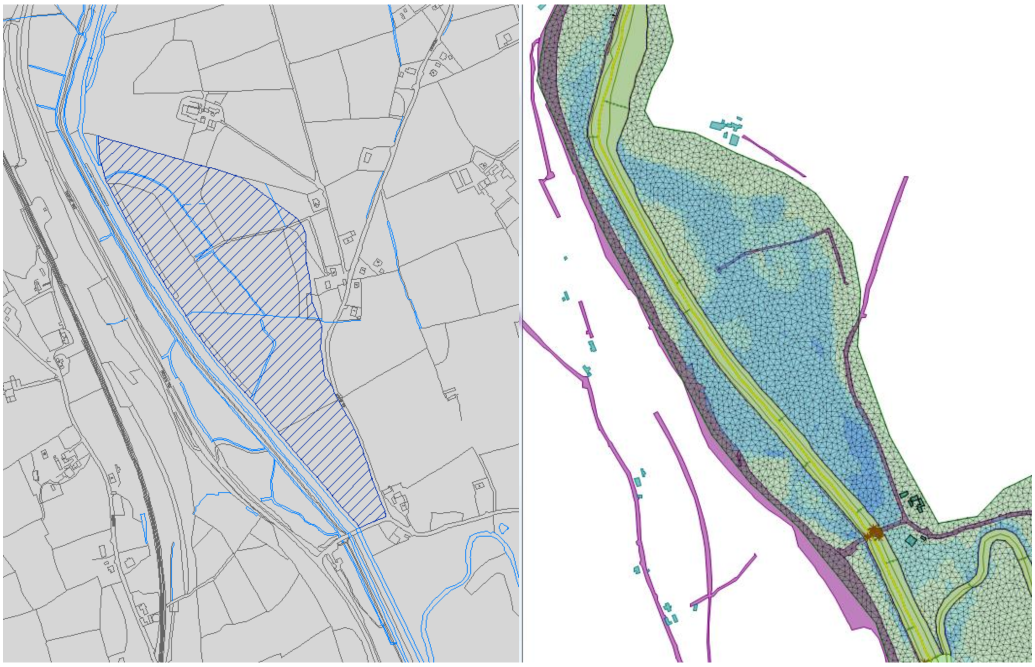

Figure 6 Jerretspass River Storage Location 4

The storage volume used in the model is estimated at 163,000m³ leaving an estimated 37,000m³ of available storage.

Storage locations 1 & 2 are further upstream outside the extent of the current hydraulic model however it is assumed that some of this may flood during a Q100 return period. This would reduce the volume of additional storage available however given the absence of a model and flood extents this cannot be confirmed. At this stage in the development of options it has been deemed appropriate that identification of potential flood storage areas and a total volume requiring storage is sufficient.

Therefore the total available storage identified on the Jerretspass River equates to 487,000m^3. This means that unequal levels of attenuation will be required to reduce flow in the Newry River to a Q25 return period as insufficient storage volumes are available on the Jerretspass portion of the catchment area.

1.4 Available Storage on the Clanrye River

Two potential locations have been identified:

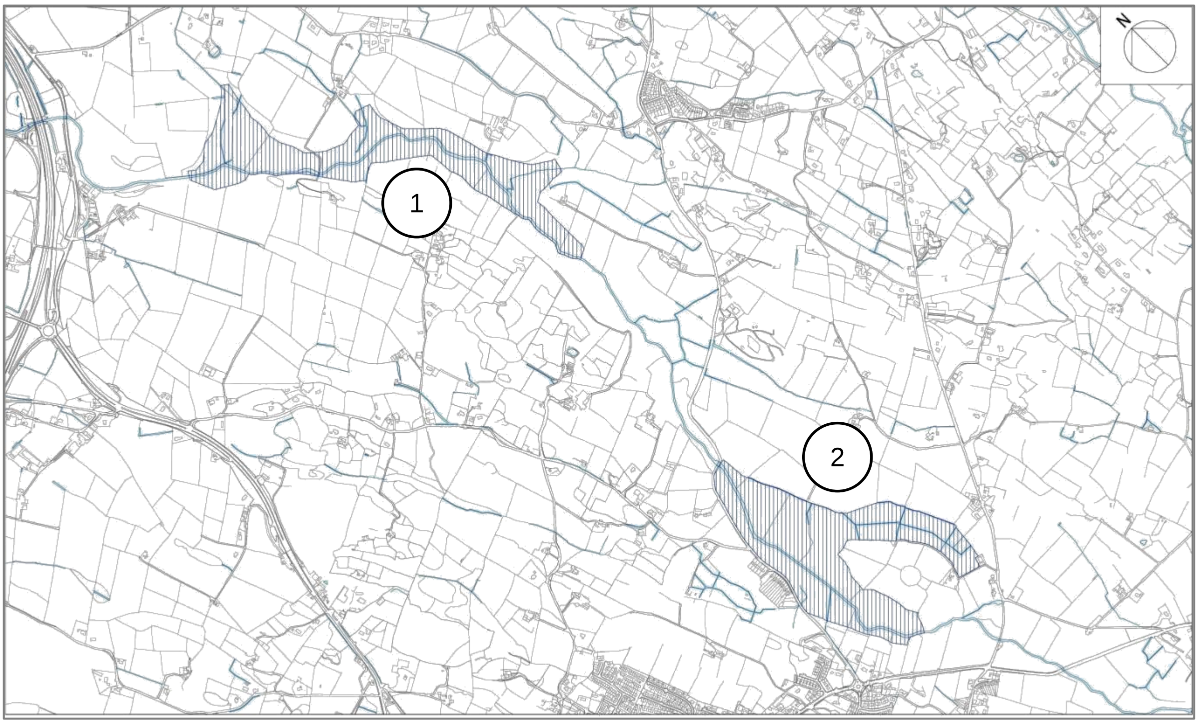

Figure 7 Clanrye River Identified Storage Locations

River	Location	Approximate Volume (m³)
Clanrye River	1	300,000
	2	300,000
	Total	600,000

The total volume in the two sites is in excess of the volume required to be retained during a Q25 flood event with excess volume available if required however it falls short of the volume required to attenuate the flows to a Q10 event.

Storage locations 1 & 2 are outside the extent of the current hydraulic model however it is assumed that some of this may flood during a Q100 return period. This would reduce the volume of additional storage available however given the absence of a model and flood extents this cannot be confirmed. At this stage in the development of options it has been deemed appropriate that identification of potential flood storage areas and a total volume requiring storage is sufficient.

Therefore the total available storage identified on the Clanrye River equates to 600,000m^3. This means that unequal levels of attenuation can be applied to reduce flow in the Newry River to a Q25 return period by utilising additional storage on the Clanrye River.

1.5 Available Storage on the Bessbrook River

One location has been identified with an available volume estimated at 125,000m³.

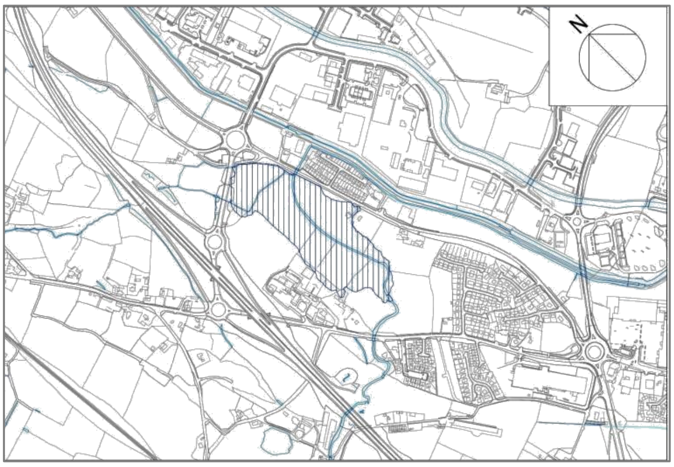

Figure 8 Bessbrook River Identified Storage Location

The model was inspected and it was noted that the storage area on the Bessbrook River was within the model extents. Analysis of the model for the Q100 simulation showed that there was already out of bank flooding at this location. This value should be deducted from the available volume as a portion of the storage area already contains flow.

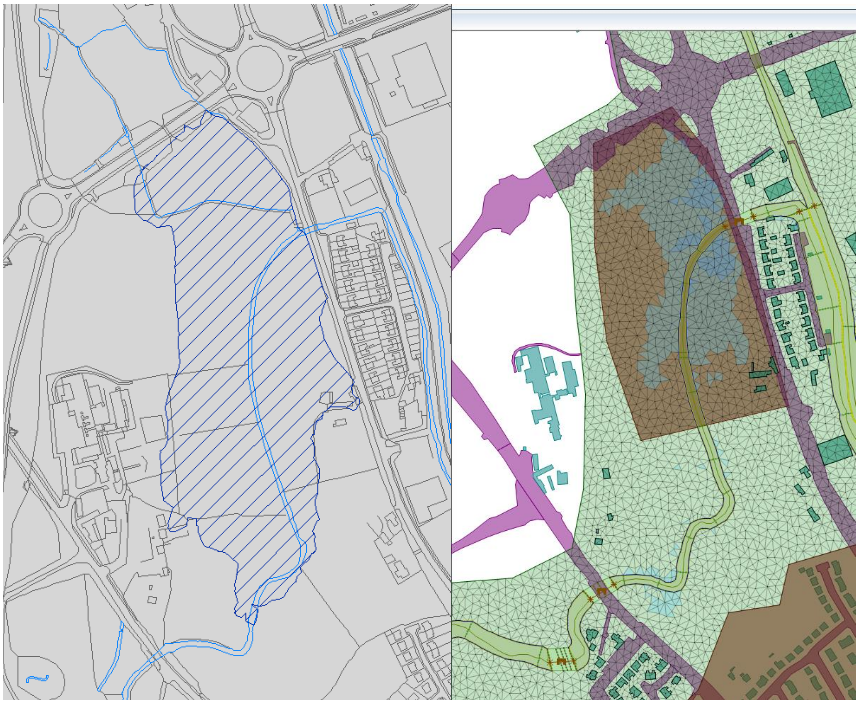

Figure 9 Bessbrook River Storage Location

The storage volume used in the model is estimated at 20,000m³ leaving approximately 105,000m³ of storage available.

On analysis of results from model runs which included this storage area it became apparent that its utilisation did not provide any benefit and did not result in any reduction in flooding. This was due to non-coincident peak flows in the Newry River and the Bessbrook River (the Bessbrook River peak occurring much sooner). The use of this storage area has therefore been ruled out as it does not provide any benefit.

1.6 Available Storage on the Newry River

One location has been identified with an available volume estimated at 65,000m³.

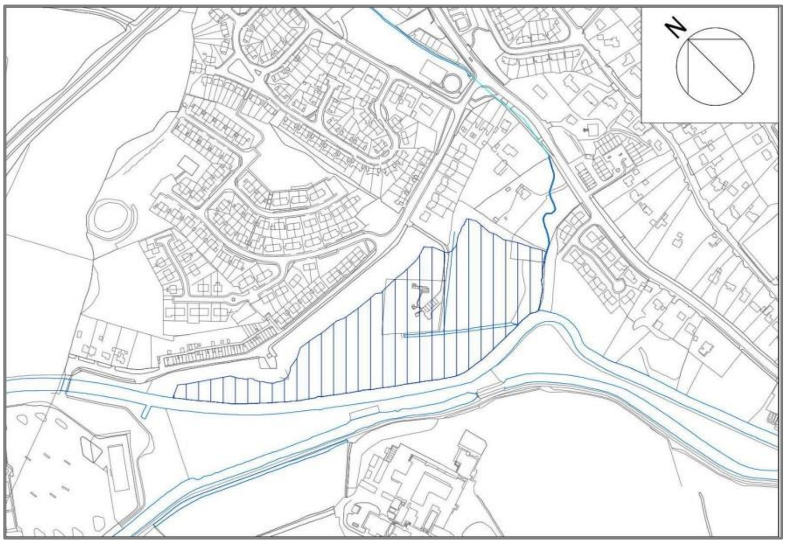

Figure 10 Newry River Identified Storage Location

The model was inspected and it was noted that the storage area on the Newry River was within the model extents. Analysis of the model for the Q100 simulation showed that there was already out of bank flooding at this location. This value should be deducted from the available volume as a portion of the storage area already contains flow.

Figure 11 Newry River Storage Location

The storage volume used in the model is estimated at 29,035m³. The volume available is estimated at 65,000m³ providing approximately 36,000m³ of extra storage at this location, a minimal volume in comparison with the total volume required. This volume should be considered further in future studies.

1.7 Conclusion

Following identification and analysis of potential flood storage areas upstream of Newry City Centre it would appear possible to provide attenuation for flows to reduce a Q100 return period peak to that of a Q25 return period peak. Provision of upstream storage is seen as a key element in the development of flood alleviation options for the wider Newry area.

The following storage has been identified:

- Jerretspass River
  - 3No. Feasible Areas
  - Total Storage Volume = 487,000m^3
- Clanrye River
  - 2No. Feasible Areas
  - Total Storage Volume = 600,000m^3
- Bessbrook River
  - No beneficial areas
- Newry River
  - 1No. Feasible Area
  - Total Storage Volume = 36,000m^3

Identification of storage areas has been undertaken using topographic analysis to determine approximate extents of storage areas with a proposed stored depth of water limited to 1.5m maximum. No consideration has been given to land availability within the identified study areas.

It is recommended that the hydraulic models provided are extended to beyond the proposed storage areas to allow these to be appropriately modelled and their impact fully assessed. AECOM have based this analysis on reduction of inflows to the watercourses to which attenuation is proposed as a means of representing the proposed storage areas.

Flood Wall and Embankment Analysis

1.1 Introduction

A combination of upstream storage and flow control on the canal is proposed along with walls/embankments. The construction of additional flood walls/embankments and the extension of existing such structures are seen as a key part of the overall solution to address the flooding experienced in the Newry Study area. It should be noted that walls/embankments on their own do not resolve the issues.

Analysis of the available upstream storage areas was conducted, with the results presented in Appendix E of this report, and concluded that it would be feasible to provide storage to attenuate a Q100 return period event to that of a Q25 within the Jerretpass and Clanrye River catchments. In an attempt to optimise the works required throughout the City Centre a number of scenarios have been assessed at different return periods. This allows a better understanding to be gained of the required increase in wall height should the required amount of flood storage not be achievable.

It is also appreciated that there is an implied limit as to how high flood walls can be built within an urban environment given their visual impact and intrusive nature. Flood walls already exist along the Newry River from Clanrye Bridge downstream and so providing additional wall height is likely to require the use of glass to reduce the impact. No walls are present along the canal quays through the City Centre and, where possible, AECOM have avoided proposals for walls along it, again due to the impact these would have.

1.2 Canal Flow Control Structure

In order to keep the wall heights to a minimum it is proposed to allow as much water as possible to be conveyed by the canal without causing overtopping of the quay walls throughout the city. AECOM conducted model runs of multiple throttle pipe sizes ranging from a 1050mm diameter pipe up to a 2100mm diameter pipe.

Model runs using the smallest diameter pipe (1050mm) caused a large increase in the flow conveyed by the river. To accommodate this flow, wall heights would have been required to be significant and much greater than what would be acceptable and this was therefore ruled out. AECOM then changed focus to larger diameter throttle pipes to allow more flow through the canal but not too much so as to cause flooding from the canal.

1.3 Maximum Wall Heights

The maximum wall heights, as given in Table 1 below, were applied to the model from the proposed throttle pipe structure to Ballybot Bridge if required by the model run. The maximum wall heights are based on an analysis of the existing ground level adjacent to the River/Canal with no wall greater than 2.5m above the adjacent ground. Walls with a height greater than 1.5m should consider using materials such as glass for the upper sections which would help to reduce their visual impact if this is deemed necessary.

The general wall locations are illustrated on drawings NWRY-ACM-XX-XX-DR-CE-01025 to NWRY-ACM-XX-XX-DR-CE-01027.

Wall Location		Max. Height (mAOD)
Newry Canal	Throttle pipe embankment	7.00
	Upstream of Clanrye Bridge	4.50
	Clanrye Bridge to Sugar Island Bridge	4.50
	Sugar Island Bridge to Needham Bridge	4.20
Newry River	Thompsons Weir to Clanrye Bridge	6.60
	Clanrye Bridge to Sugar Island Bridge	6.50
	Sugar Island Bridge to Town Hall	6.50
	Town Hall to Needham Bridge	5.50
	Needham Bridge To Ballybot Bridge	5.20

Table 1 Maximum Applied Wall Heights

1.4 1800mm dia. Throttle Pipe

The model run with an 1800mm diameter throttle pipe resulted in water levels as illustrated in Table 2 for the range of return periods shown. Note that figures **in red** indicate overtopping of the wall in the model and are therefore not indicative of possible flow level.

Reach	Wall Location	Section	Flow Level per Return Period (mAOD)			
			Q25	Q50	Q75	Q100
Newry Canal	Throttle pipe embankment	NCAN_07650-NCAN_07459	6.197	6.587	6.863	6.890
Newry River	Thompsons Weir to Clanrye Bridge	NEWR_08857	5.979	6.397	**6.660**	**6.660**
	Clanrye Bridge to Sugar Island Bridge	NEWR_08650	5.846	6.268	**6.525**	**6.555**
	Sugar Island Bridge to Town Hall	NEWR_08489	5.541	5.879	6.080	6.104
	Town Hall to Needham Bridge	NEWR_08378	4.989	5.176	5.278	5.290
	Needham Bridge To Ballybot Bridge	NEWR_08231	4.565	4.738	4.836	4.847

Table 2 1800mm Throttle Pipe – Water Levels

The levels shown in the table above are flood levels and do not include for the required freeboard of 600mm. Table 3 below shows the required wall level for the Q25 & Q50 return periods. Note that with the exception of the embankment associated with the canal flow control structure, there are no other walls required on the canal.

Reach	Wall Location	Required Flood Wall Level including Freeboard (mAOD)	
		Q25	Q50
Newry Canal	Throttle pipe embankment	6.80	7.20
Newry River	Thompsons Weir to Clanrye Bridge	6.60	7.00
	Clanrye Bridge to Sugar Island Bridge	6.50	6.90
	Sugar Island Bridge to Town Hall	6.20	6.50
	Town Hall to Needham Bridge	5.60	5.80
	Needham Bridge To Ballybot Bridge	5.20	5.40

Table 3 Required Flood Wall Levels for 1800mm Throttle Pipe

1.5 2100mm dia. Throttle Pipe

The model run with a 2100mm diameter throttle pipe resulted in water levels as illustrated in Table 4 for the range of return periods shown. Note that figures **in red** indicate overtopping of the wall in the model and are therefore not indicative of possible flow level.

Reach	Wall Location	Section	Flow Level per Return Period (mAOD)			
			Q25	Q50	Q75	Q100
Newry Canal	Throttle pipe embankment	NCAN_07650-NCAN_07459	6.072	6.462	6.777	6.862
	Upstream of Clanrye Bridge	NCAN_07031	3.727	3.958	4.306	**4.601**
	Clanrye Bridge to Sugar Island Bridge	NCAN_06780	3.496	3.763	4.128	4.418
	Sugar Island Bridge to Needham Bridge	NCAN_06660	3.374	3.639	3.956	4.153
Newry River	Thompsons Weir to Clanrye Bridge	NEWR_08857	5.856	6.277	**6.603**	**6.641**
	Clanrye Bridge to Sugar Island Bridge	NEWR_08650	5.724	6.145	6.474	**6.536**
	Sugar Island Bridge to Town Hall	NEWR_08489	5.442	5.785	6.040	6.087
	Town Hall to Needham Bridge	NEWR_08378	4.926	5.127	5.257	5.282
	Needham Bridge To Ballybot Bridge	NEWR_08231	4.507	4.689	4.814	4.838

Table 4 2100mm Throttle Pipe – Water Levels

The levels shown in the table above are flood levels and do not include for the required freeboard of 600mm. Table 5 below shows the required wall level for the Q25 & Q50 return periods.

Reach	Wall Location	Required Flood Wall Level including Freeboard (mAOD)	
		Q25	Q50
Newry Canal	Throttle pipe embankment	6.50	6.80
	Upstream of Clanrye Bridge	4.00	4.40
	Clanrye Bridge to Sugar Island Bridge	3.80	4.20
	Sugar Island Bridge to Needham Bridge	3.70	4.00
Newry River	Thompsons Weir to Clanrye Bridge	6.30	6.70
	Clanrye Bridge to Sugar Island Bridge	6.20	6.50
	Sugar Island Bridge to Town Hall	5.80	6.10
	Town Hall to Needham Bridge	5.20	5.30
	Needham Bridge To Ballybot Bridge	4.70	4.90

Table 5 Required Flood Wall Levels for 2100mm Throttle Pipe

1.6 Comparison of Wall Levels

As could be expected, the greater the volume of flow allowed to pass down the canal the smaller the flow in the river which results in lower flood walls along the river. However, the use of a 2100 diameter pipe does cause some small overtopping of canal quay walls in the vicinity of Sugar Island but this can be addressed through the introduction of low height additions in this area.

The Q50 return period wall levels demonstrate that an increase in the region of 200-500mm would be required if the attenuation provided by the proposed upstream storage was unable to reduce flows from a Q100 to a Q25.

Reach	Wall Location	Q25 Return Period, Required Flood Wall Level including Freeboard (mAOD)		Q50 Return Period, Required Flood Wall Level including Freeboard (mAOD)	
		1800Ø	2100Ø	1800Ø	2100Ø
Newry Canal	Throttle pipe embankment	6.80	6.50	7.20	6.80
	Upstream of Clanrye Bridge	N/A	4.00	N/A	4.40
	Clanrye Bridge to Sugar Island Bridge	N/A	3.80	N/A	4.20
	Sugar Island Bridge to Needham Bridge	N/A	3.70	N/A	4.00
Newry River	Thompsons Weir to Clanrye Bridge	6.60	6.30	7.00	6.70
	Clanrye Bridge to Sugar Island Bridge	6.50	6.20	6.90	6.50
	Sugar Island Bridge to Town Hall	6.20	5.80	6.50	6.10
	Town Hall to Needham Bridge	5.60	5.20	5.80	5.30
	Needham Bridge To Ballybot Bridge	5.20	4.70	5.40	4.90

Table 6 Comparison of Wall Levels

Analysis shows that with the provision of walls to a maximum height, as given in Table 1, overtopping will occur of certain walls during return periods greater than a Q50 and therefore it is deemed essential that as a minimum upstream storage is provided and can reduce peak flows to at least a Q50 return period flow.

1.7 Conclusion

Following analysis of the multiple model runs it is clear that provision of a flow control structure on the canal is successful at limiting the flooding within the City Centre but has the effect of forcing additional flow to the river. To contain the additional flow it is required to construct new flood walls and extend additional flood walls.

The results show that limiting flow using an 1800 diameter pipe will only require works to walls along the Newry River with no works to the canal which is seen as preferable given the impact which walls along the canal may have. The use of a 2100 diameter pipe, while reducing the overall height of the walls required, would require flood walls to be constructed on the canal in the vicinity of Sugar Island to contain the flows.

In order to limit the height of the wall required it would be necessary to introduce upstream storage within the Jerretspass and Clanrye catchments and to ideally provide a sufficient volume to attenuate flows from a Q100 to a Q25 flow. An analysis of the available flood storage areas can be found in Appendix D of this report. It is also noted that overtopping will occur of certain walls during return periods greater than a Q50 and therefore it is deemed essential that as a minimum upstream storage is provided and can reduce peak flows to at least a Q50 return period flow.