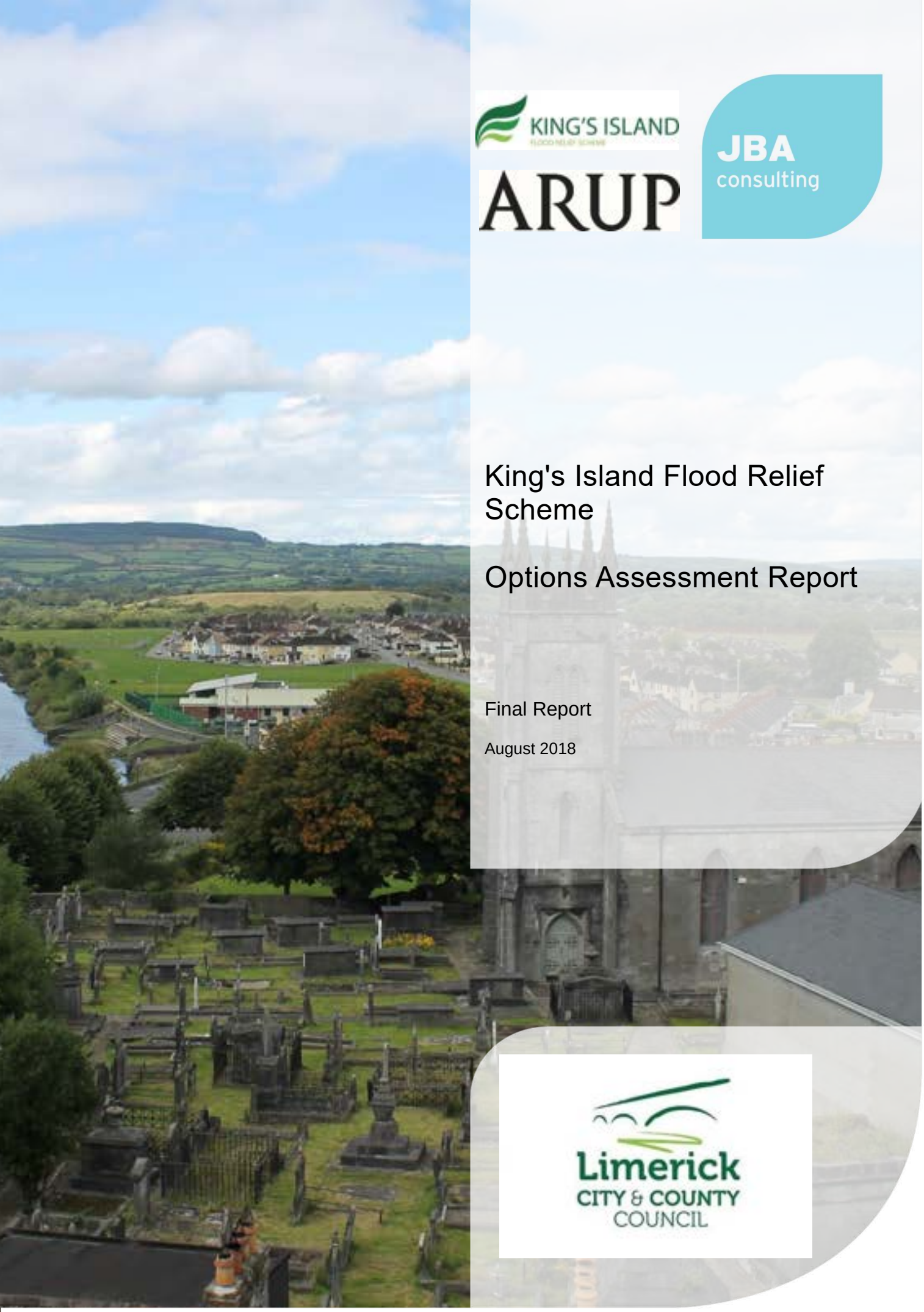

King's Island Flood Relief Scheme

Options Assessment Report

Final Report

August 2018

ARUP

JBA consulting

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
V1.0/ 13/03/2017	Initial draft issue	Limerick City & County Council
V2.0 09/11/2017	Reworking of measures, MCA and CBA	Limerick City & County Council
V3.0 16/11/2017	Figure and text updates prior to TAG	Technical Advisory Group
V4.0 26/02/2018	Damages updated to include additional commercial properties	Technical Advisory Group
V5.0 03/08/2018	Post PID updates	Technical Advisory Group
V6.0 08/05/2019	Minor amendments, but no material changes to the preferred scheme post-August 2018	Technical Advisory Group

Contract

This report describes work commissioned by Limerick City & County Council as part of Kings Island Flood Relief Scheme. Declan White, Elizabeth Russell, Declan Egan and Bernadette O'Connell of JBA Consulting carried out this work.

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Purpose

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Abbreviations

AEP	Annual Exceedance Probability
AMAX	Annual Maximum
CCTV	Closed Circuit Television
CFRAM	Catchment Flood Risk Assessment and Management
CFRAMS	Catchment-Based Flood Risk Assessment and Management Study
CSO	Combined Sewer Overflow
DECLG	Department of Environment, Community and Local Government
EPA	Environmental Protection Agency
ESB	Electricity Supply Board
FEH	Flood Estimation Handbook
GEV	General Extreme Value Distribution
GIS	Geographical Information System
GL	General Logistic Distribution
GSI	Geological Survey of Ireland
HEFS	High End Future Scenario
ICPSS	Irish Coastal Protection Strategy Study
LiDAR	Light Detection And Ranging
mOD	Meters above Ordnance Datum
MRFS	Medium Range Future Scenario
MSL	Mean sea level
NRA	National Roads Authority
OD	Ordnance Datum
OPW	Office of Public Works
RC	Reinforced Concrete
SAC	Special Area of Conservation, protected under the EU Habitats Directive
SPA	Special Protection Area for birds, protected under the EU Habitats Directive
WINFAP-FEH	Windows Frequency Analysis Package - FEH version
XS	Cross Section

1 Introduction

1.1 Context

King's Island lies in the heart of Limerick City and is surrounded by the waters of the River Shannon and the Abbey River. Both rivers are tidal at this location and the island is historically susceptible to both tidal and fluvial flood risk. King's Island and the surrounding area was badly flooded in early 2014 when there was an extremely high tide that overtopped the embankments around the Island and caused them to fail in one location. Further flooding was experienced in 2016 as a result of another storm surge event in the Shannon Estuary. This flooding was confined to Merchants Quay, as the sandbags around the Island contained the tidal surge.

A major improvement on the existing temporary flood defences is required to reduce the frequency of extreme events which inundate the island. Accordingly, following a public competition, JBA Consulting/Arup, were commissioned by Limerick City & County Council (LCCC) to provide engineering and environmental services for the King's Island Flood Relief Scheme (the Scheme). This scheme will be designed to provide protection to properties in the study area from the 1 in 200-year tidal flood event (0.5% AEP event).

There are five stages in the project:

- Stage I – Development of a number of flood defence options and the identification of a preferred Scheme.
- Stage II – Part 10 Planning & Detailed Design.
- Stage III & IV – Tender & Construction.
- Stage V – Project Close-Out (Handover to Client).

This Options Assessment Report is produced as part of Stage I of the project. It follows on from work carried out to date and the report should be read in conjunction with the earlier Constraints Study[1].

1.2 Scheme Objectives

The overarching objective of the project is to:

"*…to assess, develop and design an appropriate viable, cost-effective and sustainable flood relief scheme which aims to minimise risk to human beings, the existing community, social amenity, environment and landscape character.*"

The scheme is to be developed primarily to protect the affected areas against fluvial and tidal flooding. In addition, consideration will be given to the potential impact of any flood relief scheme on groundwater and pluvial flood risk. The target standard of protection (SOP) is the 0.5% AEP tidal event.

1.3 Scope of Report

The purpose of this report is to outline the development of possible flood relief options that could be implemented in King's Island and to describe the procedure for options assessment and selection of a preferred option.

The process is outlined as follows:

- An initial screening was carried out of an extensive list of possible flood risk management measures against a predetermined set of criteria, to determine their viability;
- A technical assessment of potentially viable flood risk management measures was undertaken;
- Potential flood relief options for all locations around the site were developed using combinations of those flood risk management measures which were determined to be technically viable. Each flood relief option was assessed from an environmental, engineering and economic perspective;

[1] Constraints Study for Flood Relief Scheme at King's Island, Limerick. V1 December 2015, JBA Consulting and Arup for Limerick City and County Council

- The flood relief options were then subjected to a multi-criteria assessment consisting of technical, economic and environmental criteria;
- The public were consulted on the options, including the emerging preferred option;
- The final solution was selected taking account of the following;
    - Multi Criteria Analysis;
    - Feedback from the Public and other stakeholders;
    - Cost benefit assessment;
    - Consideration of wider LCCC objectives for the area;
    - Professional judgement of the project steering group.
- Following identification of the emerging preferred scheme, Limerick City & County Council instructed Arup to engage the services of a landscape architect to further refine and develop the final scheme, taking account of the public feedback from the Public Information Day held on 23rd December 2017. Following a mini tender competition, Nicholas De Jong & Associates were engaged to fulfil this role.

This report does not provide an assessment of the King's Island Flood Relief Scheme Works at Verdant Place, which were advanced as a separate package, and are now complete.

However, for completeness, this report does include details of the benefits and costs of the Verdant Place elements of the scheme.

For the purposes of this report, King's Island has been divided into 2 separate flood cells, which are defined on the basis of the extent of the 0.5% AEP flood event. A map of the study area is shown in

Figure 1-1.

Flood Cell A - This is the more residential part of the island and currently has a level of flood protection primarily provided by embankments and temporary sandbags, although walls also contribute to the perimeter protection. One of the key constraints of this area is the Lower River Shannon Special Area of Conservation (SAC) and the proximity of its boundary to the proposed flood relief options. Flood Cell A includes the following sub-areas:

	Area	Start Chainage	End Chainage
A1	Thomond Bridge to Verdant Place (as constructed)	0	258
A2	Verdant Place steps and crèche	258	330
A3	North West Embankment	330	1250
A4	St. Mary's Park / SAC	1250	2100
A5	Star Rovers to Athlunkard Boat Club	2100	2400
A6	Athlunkard Boat Club	2400	2914
A7	Sir Harry's Mall	2914	3131
A8	Absolute Hotel Boardwalk	3131	3181
A9	South of Absolute Hotel Boardwalk to Abbey Bridge	3181	3221
A10	Abbey Bridge to Baal's Bridge	3221	3281

Flood Cell B- This is the more commercial part of the study area. Where there is flood protection, it is in the form of quay walls. However, there is no defence provision around the Potato Market and civic buildings on Merchant's Quay. Relating new flood management measures to the existing built environment is the key constraint in the south of the island. It includes the following sub-areas:

B1	George's Quay East	3281	3310
B2	George's Quay West	3310	3520
B3	Potato Market and Civic Buildings	3520	3963

B4	King John's Castle	3963	3777

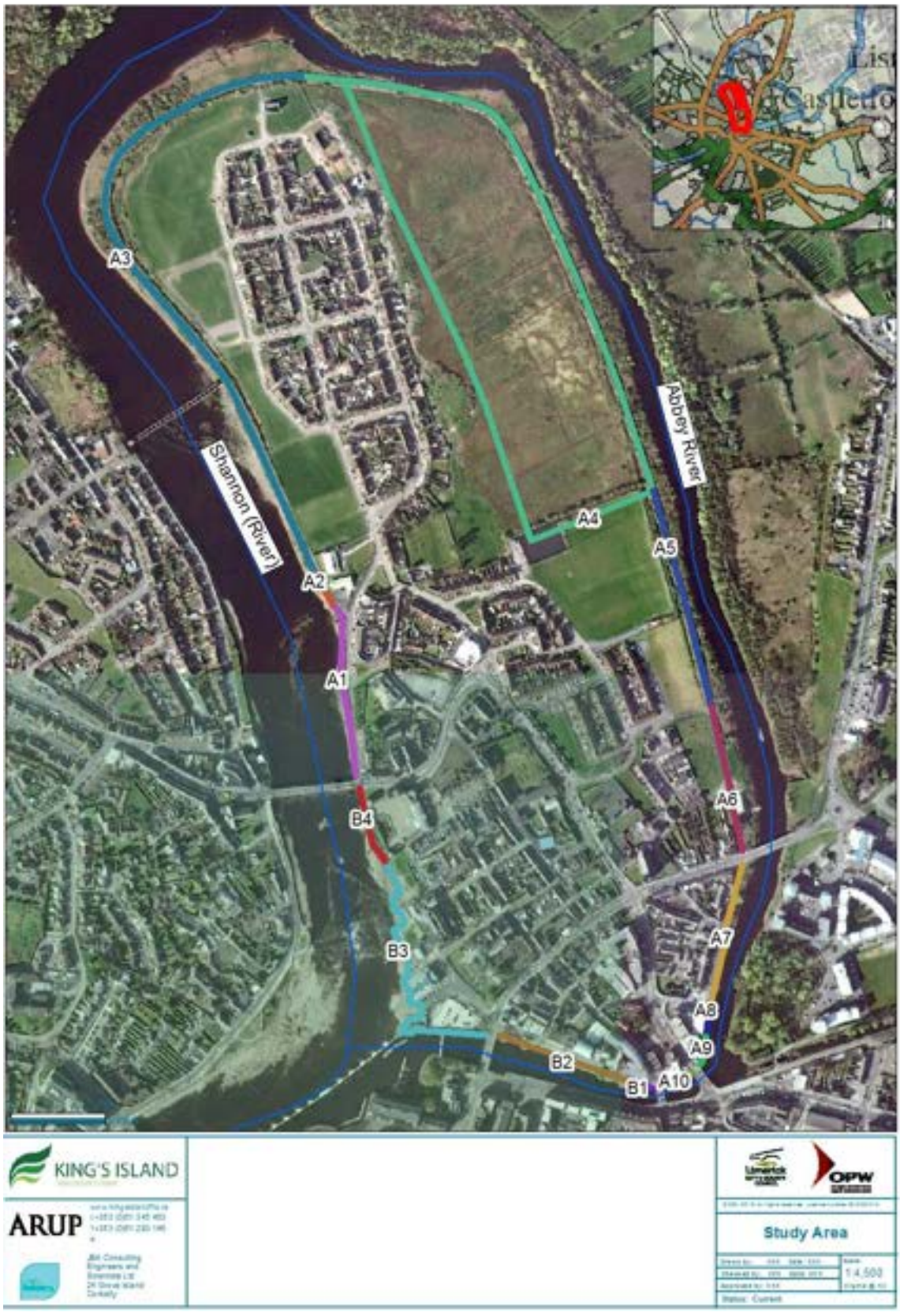

Figure 1-1: Defined Areas for Option Assessment

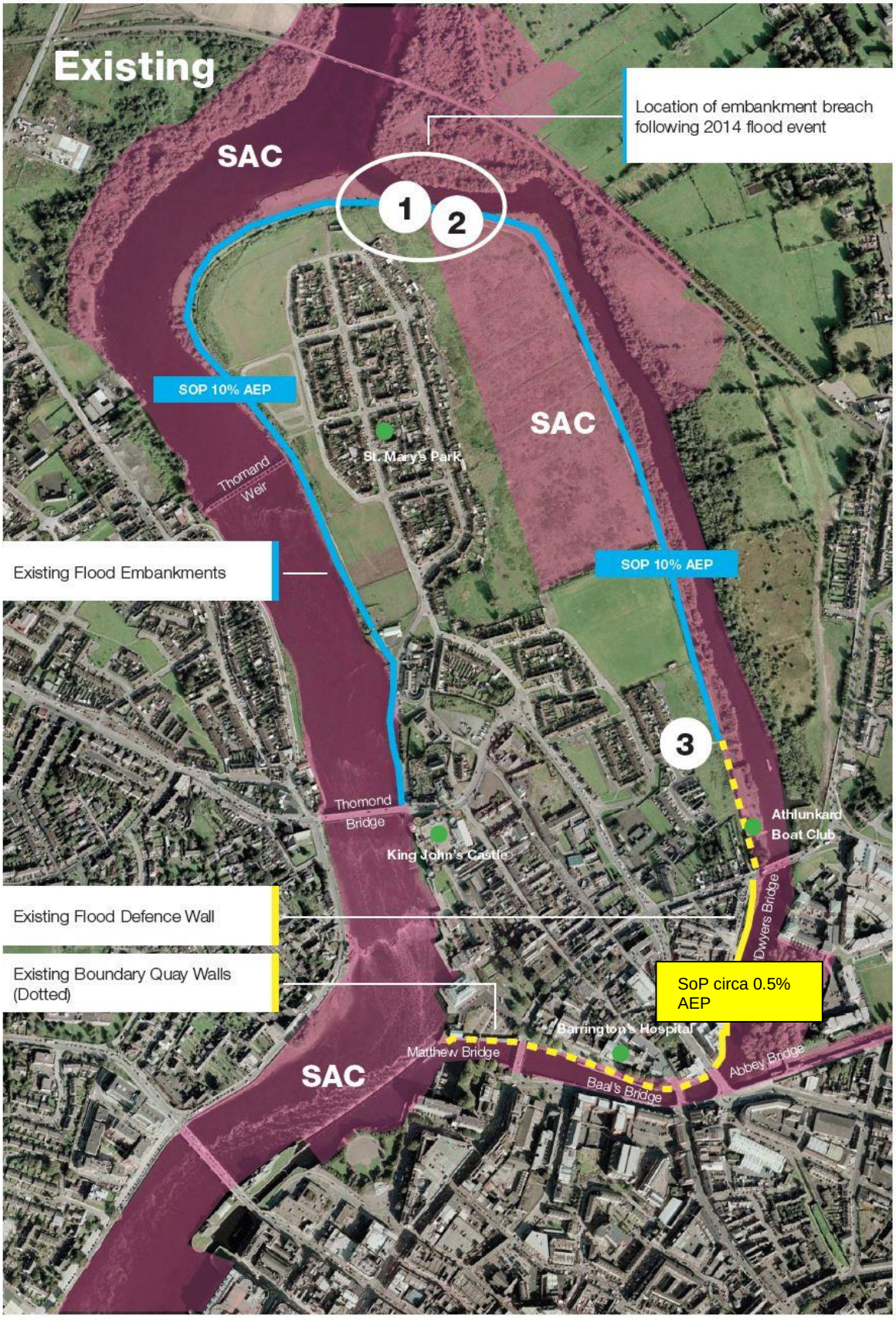

Figure 1-2: King's Island - Existing Situation

1.4 Study Area

The River Shannon is the largest river in Ireland, with a total catchment area covering approximately 15,700 km^2. The river rises in the Cuilcagh Mountains, at Shannon Pot, in Co. Cavan/Fermanagh. The river flows in a southerly direction, discharging in the Shannon Estuary. All of the River Shannon's flow drains to Limerick City, specifically around King's Island.

Approximately 1km upstream of King's Island, the main River Shannon meets the Ardnacrusha tailwaters at Parteen. At the north of King's Island, the Shannon splits into two distinct waterbodies; the Shannon and the Abbey River. The Abbey River is a smaller watercourse that flows along the eastern and southern boundaries of the island before re-joining the Shannon adjacent to Merchant's Quay and the Courthouse.

Much of the existing ground on the island is low-lying, particularly in the open spaces in the east of the island. The central spine of the island is generally quite elevated, with levels in the 'Englishtown' area (adjacent to the castle) being well in excess of the 0.5% AEP flood level (approx. 4.8mOD). Elevations on the island range from 1.85mOD to 11mOD.

As shown in Figure 1-2, the surrounding waterbodies and some eastern portions of the island are designated on ecological grounds as a Special Area of Conservation (SAC); as highlighted by the pink shading. The SAC applicable to King's Island is titled 'Lower River Shannon' (Site Code: 002165) and is of great ecological interest as it contains a high number of habitats and species listed on Annexes I and II of the E.U. Habitats Directive; the alluvial woodland that fringes the northern and eastern boundary of the island (Figure 1-3, taken from the King's Island Constraints Report, 2018) is a priority Annex I habitat and it is essential to maintain the integrity of the feature. The presence of the Lower River Shannon SAC means that any flood relief measures proposed would need to be carefully considered in terms of environmental impact and any proposal to construct in or directly adjacent to the river channel would need to be carefully considered and justified. This will be discussed in further detail in proceeding sections.

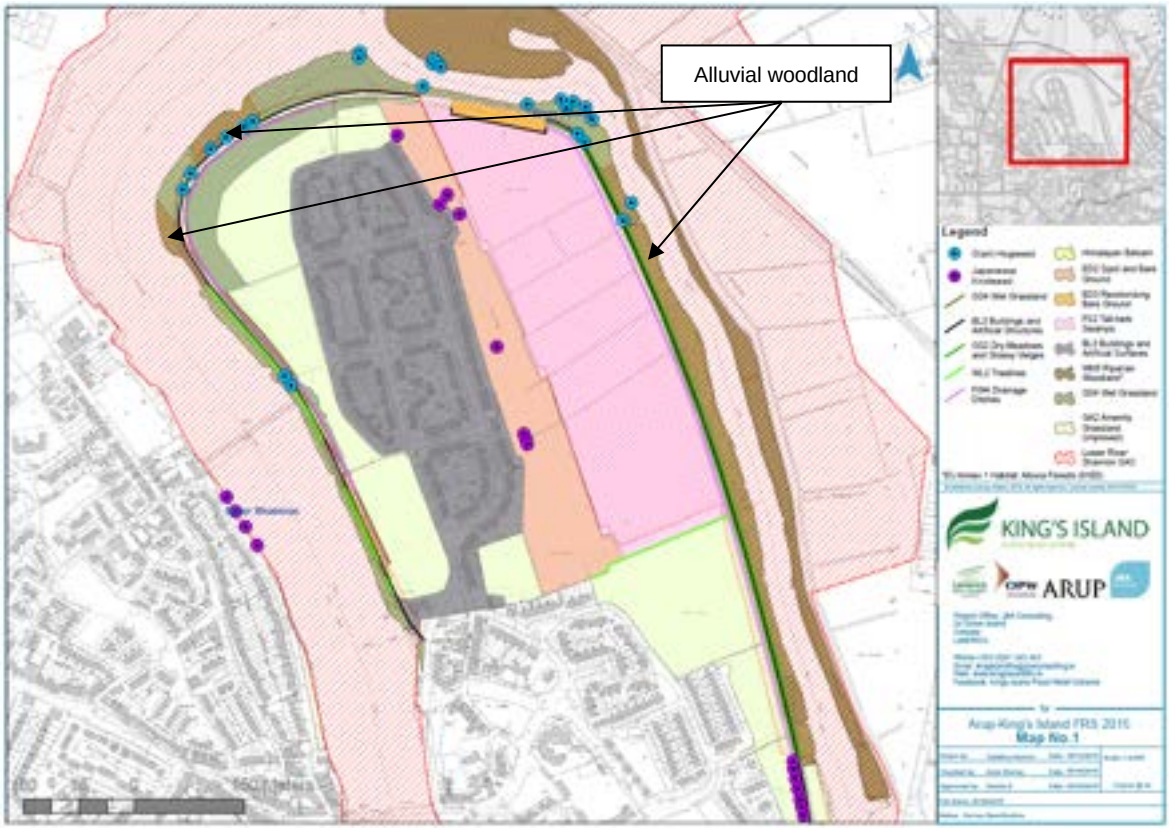

Figure 1-3: Habitat map

The existing embankment that runs along the northern boundary of the island currently provides a 10% AEP standard of protection (SOP) i.e. any flood event in excess of the 10-year tide would overtop the defences. Some of the quay walls in the south of the island, as shown in Figure 1-2 are constructed to approximately the 0.5% - 0.1% AEP level (i.e. the 200yr-1000yr tide).

However, these walls would not necessarily have been designed to the standard expected of contemporary flood defence structures and have no freeboard allowance for wave action, uncertainties in modelling etc.

Figure 1-2 also shows where the existing embankments failed and were breached in the January 2014 flood event. Flood levels in this event were estimated to be approximately 4.55mOD and were high enough to induce significant structural damage to the existing embankments and necessitated the installation of remedial sheet piling at the locations labelled ‘1’ & ‘2’.

The location of certain features of the proposed scheme is referred to by chainage, starting at the downstream end of Verdant Place and working in a clockwise direction around the island. Appendix A shows the chainage system around the island.

2 Stakeholder Input and Constraints

2.1 Constraints Study

The Constraints Study was the first step in the determining the key environmental constraints and drivers which would inform the development of potential flood relief options and will ultimately inform the preparation of an Environmental Impact Assessment Report (EIAR) for the final King's Island Flood Relief Scheme. The purpose of the Constraints Study was to determine what constraints (physical, procedural, legal, environmental etc.) exist that could affect the design of the scheme, might delay the progress of the scheme and could influence the cost of the scheme.

The scope of the Constraints Study has followed the headings prescribed in the Environmental Protection Agency's Guidelines 'Advice Notes on the Current Practice in the Preparation of Environmental Impact Statements', 2003, which was the relevant guidelines at the time of the study. The prescribed headings were as follows:

- Human Beings
- Air Quality
- Noise and Vibration
- Traffic
- Landscape
- Soils & Geology
- Archaeology & Cultural Heritage
- Water
- Ecology
- Material Assets

A summary of the key constraints identified for each of the headings above is provided in Section 4.2.4. Specific constraints relating to the study area have been detailed under the relevant sections of this report and are discussed in relation to the design of direct defences.

2.2 Consultation

Proactive consultation was a key requirement of the project. The purpose of the consultation is to obtain feedback on the proposals from all relevant affected stakeholders and landowners who might be impacted by the Scheme. Feedback throughout the project has been taken seriously, carefully considered, and where appropriate has influenced decisions on the final FRS. The goal is that this ensures the public's opinion is taken into consideration when developing the plan and that people are informed of the influence they had. The methods of consultation include but are not limited to Public Consultation Day (PCD), technical workshops, face-to-face meetings, emails, newsletters, and social media.

Detailed consultation planning for the project has been developed stage-by-stage, and is updated when necessary, in partnership with the Technical Advisory Group (TAG) and Stakeholder Advisory Group (SAG).

2.2.1 Ongoing Consultation

Comprehensive communication and engagement plans have been developed and adopted by the team, including the development, and maintenance of a project website, direct emails, newsletters, local media, and public consultation among other approaches as listed in Table 2-1 below.

Key elements of the project include the establishment of social media forums, such as a Facebook project page and a King's Island Scheme Twitter account. The purpose of the social media accounts is to maintain communication flow and provide updates for all interested stakeholders that have access to it; it can be a faster and more efficient way to keep the public informed of the progress of the project and is already established as a method of communication amongst community groups on the island.

During Stage 2 of the project, a Scoping Report will be prepared for the EIAR and Statutory Bodies, non-statutory bodies, and interested stakeholders will also be consulted with. Their views will be considered in the preparation of the EIAR.

Table 2-1: King's Island FRS Communication and Consultation Approaches

Communication Activity	Purpose
Project website	• To promote and provide information to stakeholders about the project. • The website will provide formal updates. • To provide a source of information that stakeholders and members of the public can download and review. • To provide a means of consultation and allow stakeholders to ask questions or submit information
Direct email	• Where stakeholders have supplied their contact details we will notify project updates, invitations to consultation events via email. • Names and addresses must be held securely in compliance with the Data Protection Act 1998.
Local authority / community publications such as parish newsletters	• Stories in local authority / community group newsletters are likely to reach a wide range of citizens. • King's Island newsletter is published quarterly by St Mary's Aid and has a wide circulation (hand delivered to all properties)
LCCC website	• News headlines, links to project website, publicise consultation events.
Local Media TV, radio, newspapers, magazine or publications	• Press releases are prepared in advance of public meetings and distributed to the media. Photo calls and media interviews can also be arranged. • Podcasts / webinars can provide an opportunity to reach a wider audience.
Paid for Advertising – in a media publication	• There are various options for advertising available – such as online, radio, television, outdoor, transport, press and more.
Public Consultation Days / workshops - held at a community venue.	• Consultation exhibitions / events offer a more extensive and open form of engagement on a personal basis. They provide opportunities for members of the public to express views on the consultation subject area, ask questions, take on board the information at their leisure, discuss any concerns, provide a view and receive feedback on the issues they raise. • The events will be geared to a specific issue, based on consultation stage of the project programme. • The consultation events can be held in community facilities – providing an environment conducive to actively seeking views in the relevant communities. • These events can combine the presentation of information, visual displays, verbal presentations, computer presentations (eg video loop) and other details whilst giving people the opportunity to provide views and opinions. Members of the design team and environmental team will be available on the day to answer any specific queries that may arise. • Events must be held in venues that are accessible for disabled users or users with special needs to maximize possible attendance. • One factor which can determine the success of a public event is how well it has been publicised.
Community groups and forums	• Community groups provide opportunities to reach a wider community. Meetings can be used as an opportunity to promote a project event. • Engagement through Stakeholder Advisory Group (SAG) will ensure the primary groups are involved / represented in the project.

Communication Activity	Purpose
Community centres	• Community centres can act as a focal point for the community and can be used to post information for citizens, e.g. Posters publicising consultation events. Community centres have notice boards, displays, reception areas and information points that can alert people to events.
Council meetings	• Council meetings are usually held on a monthly basis with agendas controlled by the clerk to the council. Can provide opportunities to promote the study and website via meetings and newsletters. • Key councillors are invited to the SAG so may already provide and outlet to the wide council body.
Social Media	• Twitter account are set up and linked to the project website and other relevant feeds. • Social media sites, such as Facebook Groups, may provide opportunities to promote messages and information about the Study.

2.2.2 Early Public Consultation Workshop

Shortly after commencement, when the project was at an early stage, the steering group and design team sought to take the opportunity to interact with the stakeholders that may be directly or indirectly affected by the FRS. The project team also sought the opportunity to listen to the views of those living or working in areas near the scheme. The goal of the workshop was to elicit these views and to start to build a relationship with members of the local community. The event was open to any and all interested parties, including political stakeholders.

The early public consultation workshop took place on October 7th, 2015 from 12pm to 7pm. It was carried out in the small exhibition room in City Hall (LCCC building) in Merchant's Quay, Limerick City. The event was set-up in a drop-in format, the exhibition room had information stands and posters, a registration table, one-to-one and small group discussions, and questionnaires to be completed or taken away for later submission.

The promotion of the public consultation workshop was carried out through various means such as posters, social media, traditional media (newspaper, radio), leaflet drop, pavement stands, word of mouth, meetings with local groups and publicity through the SAG (Stakeholder Advisory Group).

Five members of the JBA/Arup project team were present. The project team's local Resident Liaison Officer (RLO) was also present to welcome attendees, manage sign-ins, and to provide introductions to the project team. At the start of the project, the RLO introduced the project team to relevant user groups and stakeholders. This role was undertaken by an active member of the community, who facilitated a two-way flow of communication between the project team and local stakeholders, including residents.

The feedback provided on the day has very useful in the development of the FRS. There is a lot of genuine interest in the works and in particular the timeline of the construction. For the most part, attendees agreed that a solution was needed and although many expressed their concern in terms of potential visual impact, they understood that it was more important to provide flood protection in a timely manner. Where opportunities or constraints were highlighted by attendees, these have been detailed in the 'Design Constraints' sections of this report under the relevant Area headings.

2.2.3 Emerging Preferred Option - Public Information Day

A further Public Information Day was held on 20th December 2017. The aim of this PID was to present the emerging preferred option to attendees. The reasons behind the choice of option and alternatives considered were discussed. Constraints related to both preferred and alternative options were presented. The event was arranged as a split day, with the exhibition set up at City Hall from 11am to 3pm, before moving to King's Island Community Centre from 5pm to 8pm.

The same publicity mechanisms were used as for the 2015 workshop. In addition, there was local publicity by councillors, and emails were sent to stakeholders who had asked to be updated on the project. Five members of the project team were available to discuss the emerging option, as well as the LCCC project manager. The St Mary's Aid Estates Manager was also present at the community centre to welcome attendees, assist with signing in and to provide introductions to the project team.

The PID followed a meeting of the SAG on Friday 15th December, to which the councillors and other stakeholders had been invited. The emerging preferred option was presented to the SAG, with the aim of achieving sign-off. A number of comments were received from the TAG and were incorporated into the presentation at the PID.

The Workshop and PID Reports are both appended to the Constraints Report.

2.2.4 Meeting with community groups and businesses

As the project has progressed and the impacts on specific parts of the island have become clear, relevant user-groups / businesses have been consulted with. This has generally taken the form of short, informal meetings held either at the local JBA offices, or at a venue appropriate to the group. These meetings provided the opportunity to discuss the requirement for flood protection and present the possible options (where more than one exists) and elicit feedback. This feedback has directly informed the selection of measures and development of the preferred option. Groups who provided feedback in this way included:

- Athlunkard Rowing Club
- Star Rovers FC
- Athlunkard Villa FC
- Curragower Boat Club
- Court House
- Barrington's Hospital

2.3 Engagement of Landscape Architect

As a result of feedback received from the December 2017 PID and through discussion with community groups, Limerick City & County Council instructed Arup to engage the services of a landscape architect. Following a mini competition, Nicholas De Jong & Associates were commissioned to undertake this role. Nicholas De Jong & Associates has since worked closely as part of the multidisciplinary design team to address the comments received. The involvement of the landscape architect resulted in the refinement of the scheme in a number of areas. This includes items such as the softening of engineered embankment slopes, soft landscaping etc.

The emerging preferred scheme presented in Sections 5 to 11 is that which was presented at the December 2017 PID. The refinement of the scheme and evolution of the design since this PID is detailed in Section 12.

3 Design Assumptions and Constraints

3.1 Deriving Flood Defence Level

A review of the existing Shannon CFRAM hydrological and hydraulic modelling outputs was undertaken as part of this project. Various updates to the hydraulic model were made using recently commissioned infill survey and topographic data. The uncertainty in the hydraulic model methodology, as well as additional factors for wave action, have informed the calculation of the Scheme flood defence level (FDL). The assumptions that have been made with regard to the FDL are detailed in Appendix B and are summarised below.

3.1.1 Design flood level

The 0.5% AEP tide level at King's Island is generally consistent at circa 4.79mOD. There are some very slight differences in this level at various points around the island. As any variations in height are marginal, a blanket value of 4.8mOD has been adopted with a freeboard allowance added to account for local variation.

The extent of the predicted 0.5% AEP tidal flood extent is shown in Figure 3-1 and further details on the derivation of tide levels is provided in Appendix B.

Figure 3-1: Tidal 0.5% AEP flood extent

3.1.2 Freeboard analysis

Freeboard analysis has been carried out for the Shannon and Abbey Rivers. This has taken into account:

- Uncertainty in flow calculations
- Uncertainty in hydraulic model floodplain roughness
- Uncertainty in the calculation of the downstream tidal boundary
- Level increase due to standing waves (wave seiche)
- Level increase due to wind setup
- Type of defence being proposed (whether hard or soft).

Soft defences are vulnerable to long term consolidation of the earthworks (settlement), so are normally assigned a higher freeboard than hard defences, such as wall.

The Abbey River is a more constrained channel than the River Shannon, with a reduced wind setup and consequent lesser wave action. This has allowed a lower freeboard to be assigned to the hard defences on the Abbey River.

3.1.3 Final Flood Defence Levels

The Scheme FDL varies around the island, and is summarised as follows:

- Soft defences (embankments) - 5.5mOD
- Hard defences on River Shannon - 5.3mOD
- Hard defences on Abbey River - 5.1mOD

3.2 Design Constraints

In so as far as is practicable, flood defence proposals have considered the preliminary constraints identified in the preparation of the 'Constraints Study for Flood Relief Scheme at King's Island, Limerick'. A summary of the main design constraints are as follows:

- Flood defence solution shall align with the Limerick Regeneration 'Framework Implementation Plan', and specifically;
    - Explore the potential to upgrade Eel's (Thomond) Weir to provide a cycle and pedestrian link to the New Road and beyond.
    - Examine options to improve permeability and connections from St Mary's Park to its wider context at the northwest of St Mary's Park to the New Road, Thomond Park and beyond.
    - Retain and upgrade the Star Rovers Football Club to facilitate local sports club, Athlunkard Boat Club and the handball alley to the north of St. Mary's Park.
- Flood defence solution shall not interfere with the continuity of the public walkway around the Island.
- Flood defence solution shall ensure access to the River Shannon for fishing and boating
- Flood defence solution shall ensure that all parks and recreational areas are protected or flood risk not increased.
- An exclusion zone of one metre around existing buildings has been applied to account for their foundations.
- Timing constraints will apply to any in-channel work.
- Until such time as the demolition of the remaining houses on St. Munchin's Street is confirmed, the flood defence proposals shall continue to use the existing fence/wall to the rear of these residences as a design constraint.
- To avoid the need to re-excavate along the line of the new flood defence for the purpose of installing utilities, spare ducting will be laid along the length.
- A safe-guarding height of between 1.1m to 1.2m is to be provided on all walls; where this is substantially higher than the FDL would otherwise require. In many cases this will be achieved through the addition of railings atop the defence walls.
- LCCC have a wider objective to provide a high quality public realm in the Merchant's Quay area in the vicinity of the Court House and civil offices.

3.3 Environmental constraints

A summary of the main environmental constraints are listed below.

- The Special Area of Conservation (SAC) surrounding the Island is protected under European Law. Flood risk management options for the Island need to address the integrity of the SAC which contains priority annex 1 habitat (Alluvial Forests (91E0)) and wetland habitat present on the north east of the Island. The sources of water that maintain this wetland habitat have been investigated and it has been determined that the area is fed primarily by a combination of direct rainfall runoff and a direct connection through the 'Green Lady' (see Section 3.4). No loss or degradation of the alluvial forest habitat would be acceptable.
- This wetland habitat is also supporting habitat for birds of the River Shannon and River Fergus Estuaries Special Protection Area (SPA).

Therefore, the flood relief options must retain the integrity of this habitat for utilisation by the bird species identified as qualifying interests of the SPA. The operation of the flood relief options must also recognise the use of this area by SPA bird species, in particular by wintering bird species, and therefore not result in additional recreational disturbances in that area.

- The pre-treatment of Invasive species identified during the Constraints Study, is essential. An overlap between the 5-year treatment plan (now commenced) and the construction works is likely (see Section 3.4.3).
- Flood defences should be designed to minimise the impacts of the Scheme on the hydromorphology of the rivers on both sides of the Island.
- Protection of residential and civic views out to the river, river bank and open spaces within King's Island. Therefore, flood defences may include raised or ramped walkways and accesses in order to retain connection with the river where practicable. Glass panels may also be included in the design. For reasons of buildability and cost effectiveness, where glass panels are proposed, they shall be a minimum of 0.9m high.
- In-channel work or permanent modification to channel must not affect the aquatic vegetation.
- Avoidance of impacts on the setting and amenities of National Monuments in the ownership or guardianship of the State or local authority.
- It is the policy of LCCC to positively encourage and facilitate the careful refurbishment of Structures of Architectural Heritage merit and Protected Structures for sustainable and economically viable uses.

3.4 Environmental Aspects

3.4.1 Appropriate Assessment

The EU Habitats Directive requires an Appropriate Assessment to be carried out where a plan or project is likely to have a significant adverse effect on a Natura 2000 site. The Natura 2000 network of European sites in Ireland comprises Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

There are four steps to the Appropriate Assessment process as follows:

1. Screening for Appropriate Assessment,
2. Appropriate Assessment,
3. Alternative Solutions
4. Imperative Reasons of Overriding Public Interest (IROPI).

For those sites where potential adverse effects are identified, either alone or in combination with other plans or projects, further assessment is necessary to determine if the proposals will have an adverse impact on the integrity of a European designated site and therefore, must proceed to a more in-depth evaluation of the project, i.e. Appropriate Assessment.

In the selection of options, where adverse impacts on the integrity of Natura 2000 sites are identified, and mitigation to avoid or reduce such adverse impacts cannot be satisfactorily implemented, alternative ways of achieving the objectives of the Scheme, which avoid adverse impacts, need to be considered. If none can be found, the process proceeds to IROPI. Therefore, it is important at the options appraisal stage to consider the potential impacts of proposed options.

In the case of King's Island Flood Relief Scheme, potential adverse impacts are anticipated, given the proximity to Natura 2000 sites and the scale of the Scheme. The preferred option will have to undergo Appropriate Assessment and mitigation measures drawn up to ensure no significant impact is caused to a Natura 2000 site as a result of the Scheme.

3.4.2 SAC Boundary

Through the course of this study, a discrepancy in the legal boundary of the SAC and the delineation of habitats on the ground has been identified. This issue was raised by the Design team with National Parks and Wildlife Service (NPWS) Geographical Information Systems (GIS) unit.

NPWS has advised that the current SAC legal boundary for the Island is based on the boundary from the 6-inch mapping rather than the more commonly used 1:5000 Irish Transverse Mercator (ITM) Ordnance Survey Ireland (OSi) Map. This particularly impacts on the western area where the SAC legal boundary is on the landward side of the existing embankment. Habitats that exist on the landward side of the legal SAC boundary in this area include a man-made footpath, drainage ditch and amenity grassland, all of which are low value habitats in relation to the structure and function of the SAC. Following extensive ecological survey and assessment, it has been determined that the functional areas of the SAC are outside the embankment (i.e. on the river side) and that proposals for construction on the landward side of the existing embankment can be progressed, subject to Appropriate Assessment.

In contrast, to the east of the island in St. Mary's Park area, the SAC boundary and wetland habitat extends inland of the embankment and comprises a large portion of the north-east section of the island. The embankment and footpath fall within the SAC, but are bordered on both sides by alluvial woodland and wetland. Proposals for construction in this area may be progressed, subject to Appropriate Assessment, but it should be noted that if the construction footprint impinges on and/or causes permanent loss of the alluvial woodland and wetland SAC habitats then Stage 4 (IROPI) of the Appropriate Assessment is likely to be triggered. Provided there are other viable options which do not invoke IROPI, this would not be permissible.

With regard to the existing river walls, it has been assumed that the SAC legal boundary is on the river side only.

3.4.3 Invasive Species

Invasive plants such as Japanese Knotweed, Himalayan Balsam and Giant Hogweed are present at various locations on King's Island. These were identified during the preparation of the Constraints Report. The proposed flood defence works require that these plants be managed in accordance with the guidance that will be set out in the Environmental Impact Assessment Report (EIAR). Figure 3-2 shows a map of where these plants are located.

There is a stockpiled bund of Japanese knotweed to the rear of St. Munchin's Street and on land outside the SAC, that has been impounded following treatment/eradication works undertaken in 2016. Prior to undertaking any flood defence works which would impact on this bund, it will be necessary to either relocate part of the bund, excavate and remove the contaminated earth for treatment and potentially for offsite disposal or realign the flood defence around the area leaving the bund fenced off, isolated and undisturbed.

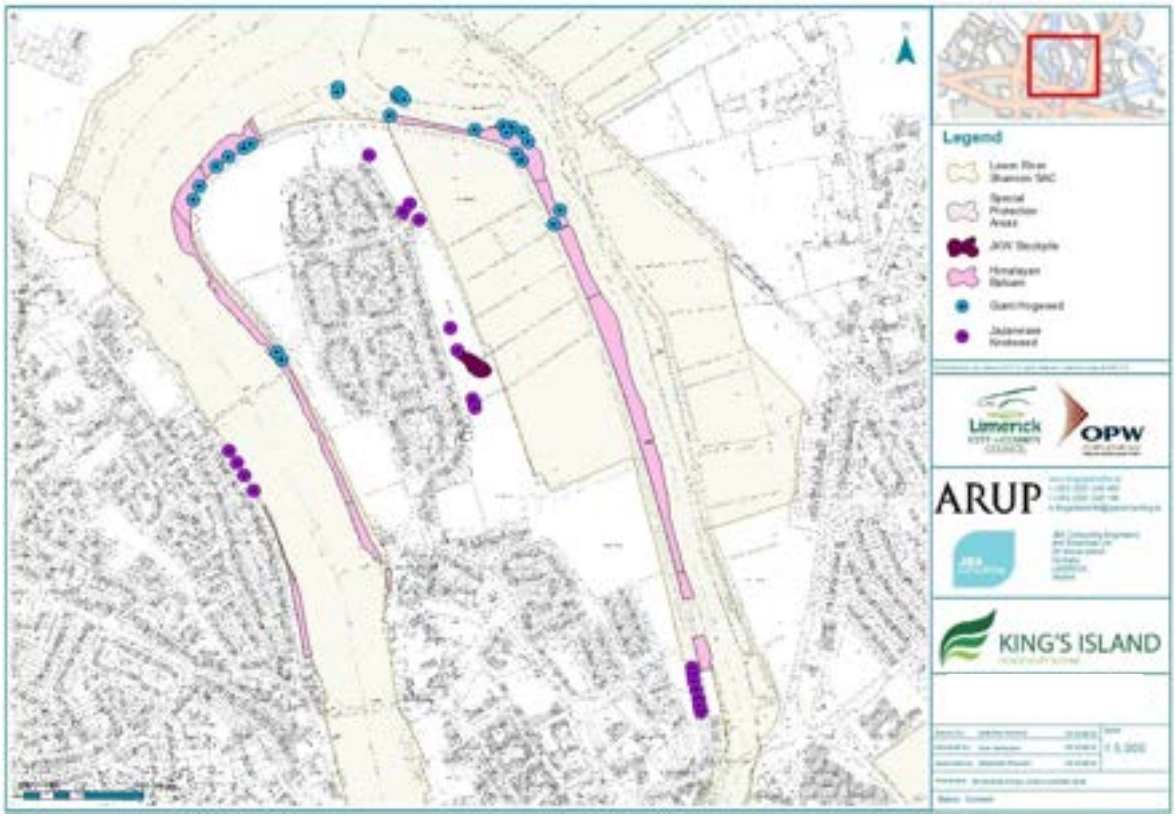

Figure 3-2: Invasive species location map

3.4.4 Archaeology

The Island is in an archaeologically sensitive area given its proximity to King John's Castle and historic city quay walls. The upper soil profile under the footprint of the proposed flood defences could be archaeologically significant and therefore, where possible, minimising the disruption to the in-situ soils on the Island has been considered as part of the development of options and will form part of the detailed design. Where disruption is likely, archaeological monitoring will be undertaken at an early stage in the process.

3.4.5 Contaminated Land

There is a history of dumping and burning waste around St. Mary's Park. The area to the east of St. Munchin's Street was a known illegal dumping site. Recently as part of the Regeneration Programme for King's Island, this area has been cleaned up. However, it is still considered a possible risk area for contaminated soil. This will influence the embankment foundation type in this area with its excavation being avoided where possible.

3.4.6 Hydrogeology and Groundwater

The design of the flood defence scheme shall consider the water flow regime into and out of the Island where the defences are being installed. The ground/tidal water interaction will heavily influence the construction methods used on site, particularly in relation to carrying out excavations. Alterations to groundwater flow could also impact the unregulated landfill and cause mobilisation of contaminates which may discharge to the SAC.

Groundwater dependent habitats may be impacted by the proposed flood defences through accidental contamination and alteration to base-flow to the SAC causing an area to dry out or flood out of season. The design of the proposed flood defences shall mitigate these impacts via a detailed understanding of the water flow though the Island and measures such as monitoring put in place to minimise impacts.

Based on the groundwater conceptual model and initial results of the groundwater monitoring it has been established that the SAC behind the current defences is primarily surface water fed, with additional contributions from the open drainage channels which discharge into the Abbey river. Possible longer-acting sub-surface hydrological processes would need further investigation to fully understand connectivity across the existing embankment.

3.5 Geotechnical

The findings of the site investigation indicate that the subsoil of King's Island generally comprise of estuarine/alluvial silts to the east and northwest, poorly drained mineral soils and peaty mineral soils further inland to the northwest of the Island and made ground elsewhere. Below this, the available site investigation data generally noted a layer of 1.5m to 3.5m thick beds of cobbles, boulders and weathered rock overlying strong light to dark grey limestone bedrock. Depth to weathered bedrock is generally approximately 3m to 11m below ground level across the Island, increasing in depth in a southwest to northeast direction.

The marine/estuarine soil deposits, present on the Island are soft compressible soils. The presence of such material restricts the type of equipment, construction techniques and engineering design that is appropriate for such soft ground conditions. During detailed design, the materials shall be profiled and its engineering properties established. This shall inform both the engineering design and appropriate construction techniques to be employed when building the flood defence for the Island.

The populated/urban areas of the Island are underlain by made ground comprising silty clay and clayey sand with loose ash, red brick, gravel, shells and occasional glass and wood. Depending on the proposed flood defence solution, the made ground which is uncompacted and highly variable may require to be excavated and replaced with suitable founding material. This material may also be a possible source of contamination. The material shall be screened, classified and appropriate measures specified for its excavation, storage and disposal during construction of the flood defences.

3.6 Climate Change Vulnerability and Risk Assessment

The purpose of this exercise is to inform the development of options for King's Island. The Climate Change Vulnerability and Risk Assessment has been carried out for the selected scenario, following the approach recommended in the *CFRAM Guidance Note 29 - Guidance Note 29 – Climate Change Adaptation Guidance Note (version 5)* and the *EU Non-Paper – Guidelines for Project managers: making vulnerable investments climate resilient*. The purpose of this is to determine what climate hazards the project needs to consider and then assess the risk to the project and its flood risk management objectives.

3.6.1 Identifying climate hazards

We have identified that the main climate hazards which could potentially affect a flood risk management project for Kings Island, Limerick are as follows:

- Change in average rainfall
- Extreme rainfall and intense storms
- Flooding
- Sea level rise
- Variations of temperature and freeze-thaw.

3.6.2 Vulnerability assessment

A vulnerability Assessment has been carried out to assess how vulnerable the project is to specific climate-related hazards and to enable prioritisation of hazards to identify which are most significant and should be taken forward for a more detailed location by location risk assessment.

Vulnerability is a function of the sensitivity of the project elements to climate hazards (irrespective of their proposed location) and the exposure of Kings Island to climate hazards.

- Sensitivity Assessment: Identifies climate hazards that would have a negative effect on the project if they occurred, considering construction, assets, infrastructure and operation.
- Exposure Assessment: Describes the level to which the area is currently affected by the identified climate hazards or could be in the future as a result of climate change. Exposure data is gathered for climate variables. The assessment has been carried out for the current and future exposure.

The exposure to climate change hazards is based upon:

- The National Climate Change Strategy 2007-2012
- EPA's Ireland's Climate Strategy to 2020 and Beyond

- EPA's Ireland's National Inventory Report 2016
- EPA's Ireland Greenhouse Gas Emissions to 2020
- DECLG Climate Action and Low Development Programme
- United Nations Framework Convention on Climate Chante (UNCCC): Paris Agreement
- EPA Research Programme 2014-2020: Ensemble of regional climate model projections for Ireland by Paul Nolan
- Met Eireann (2013) Ireland's Climate: the road ahead
- EPA Report 159: Ensemble of Regional Climate Model Projection for Ireland.

3.6.3 Risk Assessment Process

The key vulnerabilities (identified as a medium or high) of viable measures in current and future climate change scenarios progress to the more detailed risk assessment. This takes into consideration the specific location, construction, infrastructure, and operation of the viable flood risk management measures. The severity and likelihood of the risks from climate hazards are examined, considering in-built adaptation measures, the flexibility of the measure to adapt and the adaptation options available for each viable flood risk management measure. The residual risks to climate change hazards on both the proposed flood risk management structures and their ability to continue to provide flood risk management in the future is assessed. The assessment was undertaken for each area and is presented in tables in the relevant sections.

3.6.4 Climate Change Adaptability in the Scheme

For each potential measure, the potential for adaptability has been assessed. Where possible, and for all new walls and embankments, the structural design has included an allowance for climate change. This means it will be structurally viable, in the future, to raise walls and embankments by up to 0.5m to match the projected increases in sea levels for the Mid-Range Future Scenario. However, the direct defences are not being constructed to include this allowance. It should be noted that there are factors other than structural integrity which impact on the adaptation of the defence, such as aesthetics and land take, and it is these factors which were assessed as part of the option selection process.

Where an existing quay wall is to be raised under the proposed scheme, the structural stability has been assessed and confirmed that the raising required to meet the scheme FDL can be accommodated. Any further raising to allow for climate change has not been assessed and should be revisited at an appropriate time in the future.

4 Potentially Viable Measures

4.1 Initial Screening of Potentially Viable Measures

This section details all the flood risk management measures considered during the initial screening stage. These measures were assessed with regard to their viability in terms of the following criteria and are detailed in Table 4-1 below.

- Applicability to the area.
- Economic (potential benefits, impacts, likely costs etc.).
- Environmental (potential impacts and benefits).
- Social (impacts on people, society and the likely acceptability of the measure).
- Cultural (potential benefits and impacts upon heritage sites and resources).

The constraints detailed in Section 3 were also taken into account when screening the possible measures.

Table 4-1: Initial Screening of Measures

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Initial Screening Result	Comment
Non-Structural Measures							
Planning Control	N	Y	Y	N	Y	Not viable as stand-alone option	Long time to implement and would not reduce the flood risk to an acceptable level as a standalone measure but should be considered as a partial option.
Building Regulations	N	Y	Y	N	?	Not viable as stand-alone option	Long time to implement and would not reduce the flood risk to an acceptable level as a standalone measure but should be considered as a partial option.
Flood Forecasting & Flood Early Warning System	N	Y	Y	N	N	Not viable as stand-alone option	Flood forecasting would allow advanced warning for possible flood events. Would help in erection of demountables, however potential benefit would be limited as inundation in an event would be extensive. Limited warnings are received currently and will be sufficient to erect flood barriers and gates as part of an individual property protection solution.
Public Awareness	N	Y	Y	Y	Y	Not viable	Long time to implement and would not reduce the flood risk to an acceptable level.
Land Use Management	N	?	Y	?	N	Not viable	Long time to implement and limited area over which it could be applied. Would not reduce the flood risk to an acceptable level in the historic areas of the island.

Possible Flood Risk Management Measure	Applicability	Economic	Environmental	Social	Cultural	Initial Screening Result	Comment
Structural Measures							
Upstream Storage	?	?	N	N	N	Not viable as stand-alone option	Primary source of flood risk is tidal. There is minimal fluvial contribution to flood risk. Would work alongside a tidal barrier to manage tidal flows.
Tidal Barrier	?	N	N	Y	Y	Potentially viable as whole city, long term solution, but only in conjunction with upstream storage	Prohibitively high cost with environmental impacts but should be considered for climate change adaptation options and as a whole city approach. Would only work if fluvial flows could be managed through storage.
Barrier on upstream and downstream limits of Abbey River	Y	N	N	Y	Y	Not viable as high cost and high environmental impact	Would allow removal of defences on Abbey River, and provide some protection to Corbally. Would not negate the need for defences on the Shannon.
Direct Flood Defences	Y	Y	Y	Y	Y	Viable	Undertake technical assessment.
Diversion Channels or Culverts	Y	N	N	Y	y	Not viable	Would not be effective in tidal flood risk scenario
Relocation of Property Occupiers	N	Y	Y	N	N	Not viable	Large no. of properties to be re-located in flood risk area, included historic areas of the city. Partial re-location could be considered, but regeneration programme in force.
Individual Property Protection	Y	Y	Y	Y	Y	Viable (in places)	IPP may be feasible for a select number of properties, however would not be technically viable for the majority of locations. Requires a warning system to erect defences.
Pumping	N	N	N	N	N	Not viable	Prohibitively high cost, environmental and social impacts due to scale of Shannon watercourse.
Channel Widening	N	Y	N	?	?	Not viable	Primary flood risk is tidal. Channel widening would not be effective and would have severe environmental implications.
Bridge/Weir Modifications	N					Not viable	Structural constrictions do not add significantly to flood risk. Would not be effective.

4.2 Further Assessment of Potentially Viable Measures

Further to the initial screening, the following flood risk management measures were identified as potentially viable measures for King's Island and have been taken forward for further technical assessment in the following section. Those measures which are viable are then considered on an area by area basis in sections 5 and 6, taking into account the constraints faced on different parts of the island. The potentially viable measures consist of:

- Do nothing
- Do minimum
- Structural Measures
    - Direct defences
        - Reinforced Concrete (RC) Walls
        - Enhanced and raised quay walls
        - Engineered Earth Embankments
    - Individual Property Protection
    - Tidal barrier with upstream fluvial storage

4.2.1 Do Nothing

The 'Do Nothing' scenario is defined as the option involving no future expenditure on flood defences or maintenance of existing defences/channels. The implication is that the existing risk of flooding persists in the study area and possibly worsens over time, both as the condition of the banks reduces and climate change impacts are felt. This is not a sustainable option so it has not been considered.

4.2.2 Do Minimum

The "Do Minimum" measure consists predominantly of ongoing maintenance works. This is in order to maintain the existing standard of protection and would generally involve repairing and reinforcing existing walls and embankments now and as repairs are needed in the future.

It has been represented in the modelling as the current condition of walls and embankments, which have been modelled at their current height. It should be noted that the sandbags on the top of the embankment around the north of the island have been excluded from the model and openings in the quay walls have been represented as well as the resolution of the model will allow (the models vary between a 5m grid resolution for return periods less than the 1% AEP, and a 10m resolution for the 1% AEP and above.) As with the 'do nothing' scenario, the walls along George's Quay have been excluded from the model.

4.2.3 Structural Measures

4.2.3.1 Direct flood defences

This measure involves the construction of direct defences along the banks of the existing river to contain flood volumes and flows within the river channel and may take the form of embankments, reinforced concrete walls or sheet-piling.

The final choice of method, i.e. embankments or reinforced concrete / sheet piled walls, would be determined following further review of the detailed site investigation and subsequent detailed design. It is not appropriate to use the full Multi-criteria Analysis processes to choose between construction techniques within the various Areas. It is important that a realistic type of measure is used in discussion with stakeholders and in considering the relative environmental impacts of the various measures. In these situations, the lower environmental impact measure may be more expensive.

In general, it is considered that embankments will be more suited to the northern part of the island, where space allows; embankments are already part of the landscape and a more natural finish is required. In the southern, urban part of the island space is limited and there are already lengths of both formal and informal flood defence walls, so the likelihood is that these will be maintained and added to. Within each Area based discussion, the most appropriate form of direct defence is proposed as the direct defence measure, and the reason for this choice explained.

4.2.3.2 Individual property protection

This measure would protect properties on an individual basis. This typically consists of demountable barriers, which are effective to approximately 0.6m flood depth. Above this depth, the water pressure on the walls of typical domestic properties may cause structural damage. IPP would also include measures to seal or otherwise secure windows and vents and may involve tanking buildings above and below ground to resist ingress of water.

Individual property protection measures are not considered feasible as standalone measure due to the large number of properties at risk and the large predicted flood depths. However, there are some flood cells where smaller numbers of properties are at risk and IPP could be used in conjunction with existing or new structural measures, e.g. at the Courthouse.

Demountable barriers have the disadvantage of requiring a timely flood warning to ensure they are erected prior to the flood occurring. There is a warning system in use in Limerick, which allows for deployment of barriers along Clancy's Strand and O'Callaghan Strand. Risks associated with their use include failure to respond quickly enough or inconvenience caused by deployment without a flood occurring. However, they have the advantage of being relatively cheaper than lengths of flood wall and can be used to target specific 'at risk' buildings. They also provide a more discrete finish in areas of high visual or historical amenity value, or where views are to be protected.

It is important that a continuous and passive response to flood management is provided where possible. Because of the risks associated with the timely erection of the barrier, any measure involving IPP which places a significant number of people or properties behind demountable defences has been screened out as being non-technically viable. In localised situations, and where alternatives are either non-viable or non-cost beneficial, the use of IPP has been considered.

4.2.4 Tidal barrier and upstream storage

A tidal barrier to protect King's Island from tidal flooding would involve providing a tidal barrier downstream of Limerick City. It was found that the optimum location for the tidal barrier would be close to Coonagh West, just downstream of the tunnel, as illustrated in Figure 4-1. If the barrier was located further downstream, the channel width across which the barrier would have to span would be increased, thus increasing potential costs. As well as this, if the barrier was moved further downstream, contributions from other watercourses (e.g. River Maigue, River Owenagarney, River Fergus etc.) would have to be factored into the storage calculations for upstream of the barrier. This location would have the added benefit of providing protection from tidal flooding to the whole of Limerick city and other settlements in County Limerick and Clare.

In this location, the barrier would have an approximate length of 435m, from bank-top to bank-top. In summary, it was found that even with the tidal barrier in place, and defending against the peak 0.5% AEP tide level, the maximum water level upstream in Limerick City remains very similar for every configuration that was tested. This is due to insufficient capacity upstream of the tidal barrier and significant fluvial flows during the period of barrier closure. The maximum reduction realised in a given configuration was approximately 100mm. Significant defences would still be required at King's Island and the scale of works required as part of a tidal barrier could not be justified for such a small reduction in flood defence level. In addition, the works that would be required to span the estuary and provide the required upstream storage would be significant and are likely to pose numerous environmental challenges.

There is already considerable upstream storage provided through the ESB run Ardnacrusha Power Station and Parteen Weir, with extensive tracts of floodplain submerged during extreme floods.

Provision of sufficient additional storage, that does not impact on existing development was not found to be possible.

For these reasons, this measure was screened out at this stage.

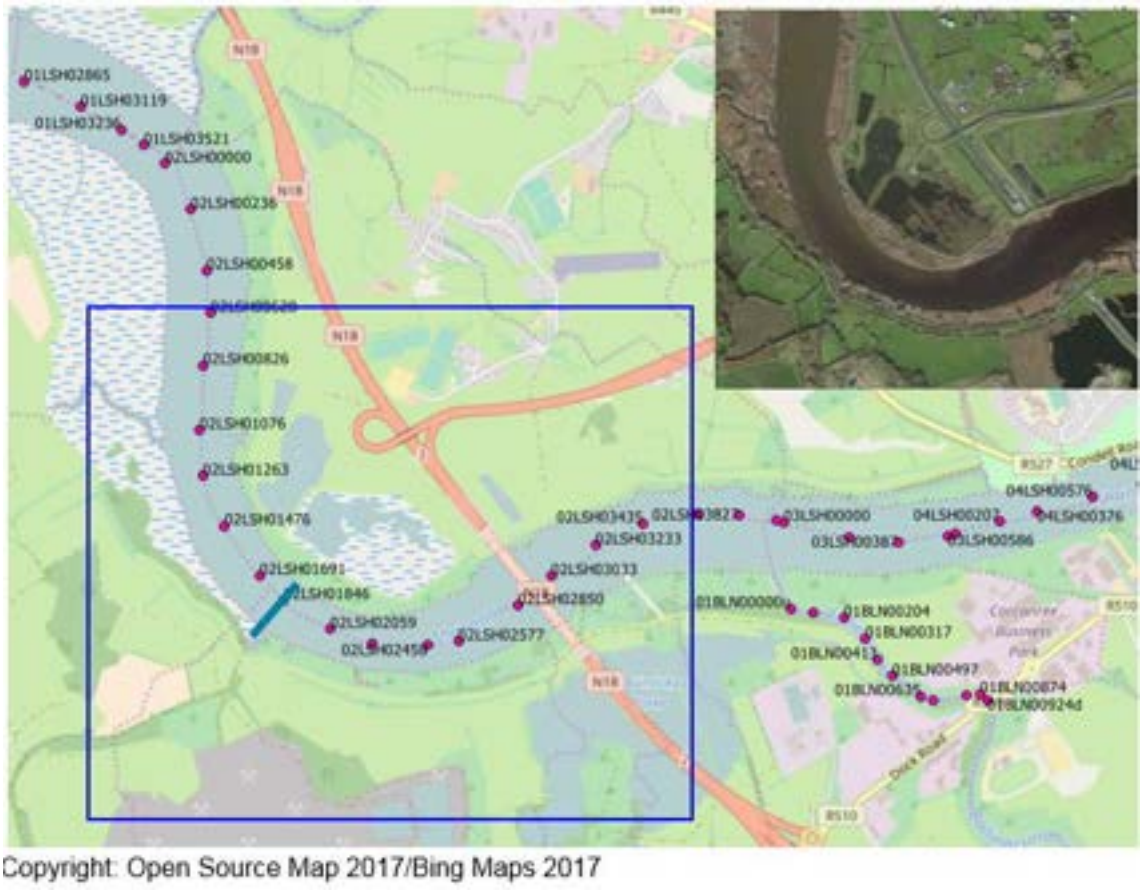

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Figure 4-1: Potential tidal barrier location

5 Review of Measures in Flood Cell A

5.1 Area A1 - Thomond Bridge to Verdant Place

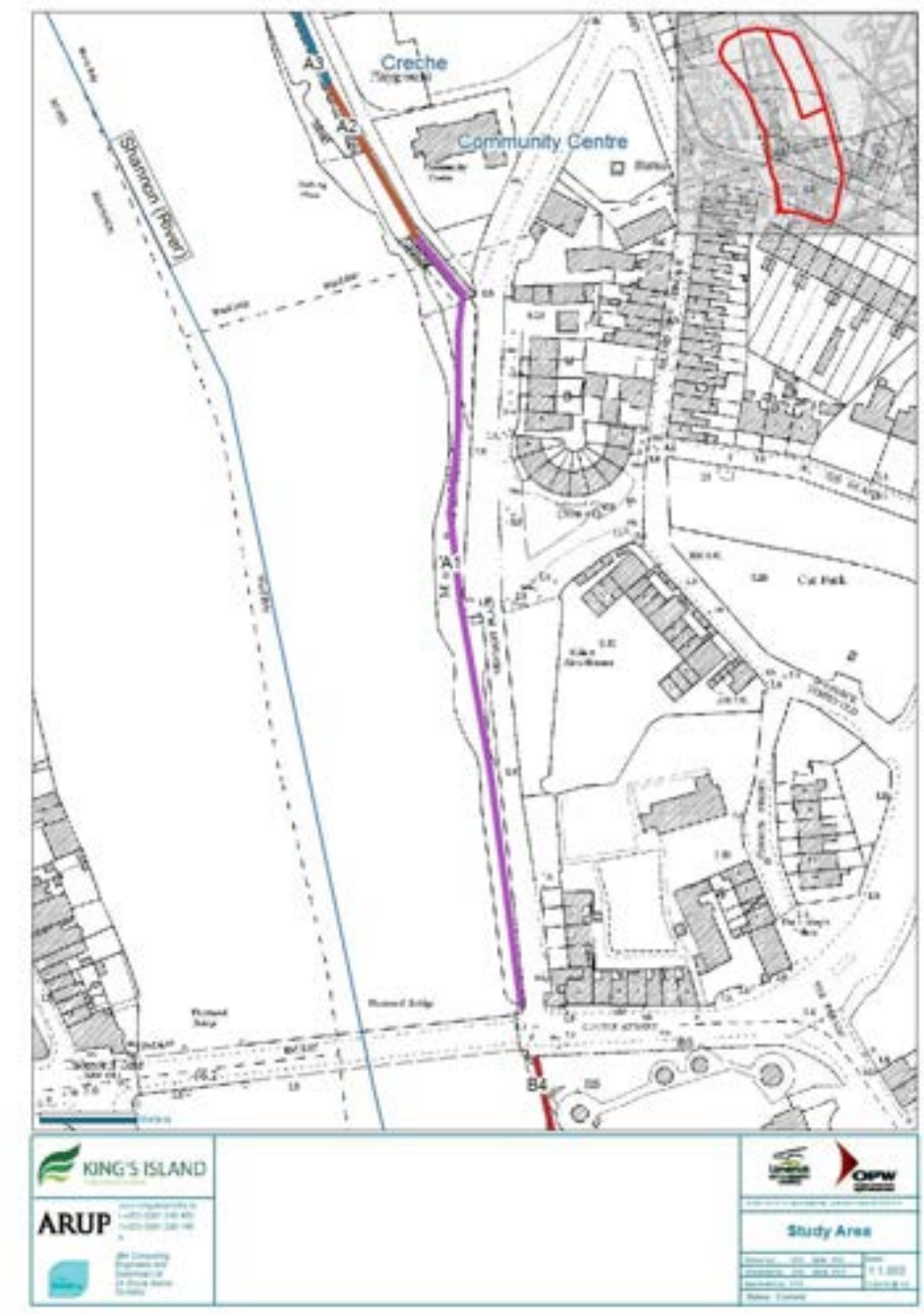

Figure 5-1: Overview of Areas A1 and A2

5.1.1 Current Situation (Engineering Chainage Ch. 0+000 to Ch. 0+258)

Limerick City and County Council advanced flood relief scheme works for Verdant Place, and construction of this length of wall was completed in August 2017 (see Figure 5-2). There is a length of existing wall immediately north of the bridge which provided a structural robust, and high enough level of protection. The new wall and incorporated access steps tie into the existing wall and run northwards for approximately 200m towards the crèche (see Figure 5-1).

As this length of wall has already been constructed, there is no further requirement to appraise the constraints or environmental and ecological impacts of its construction or operation.

Figure 5-2: Verdant Place before and after advanced works contract

5.1.2 Costs

The as-constructed costs for the Verdant Place works are €1.93 million. This sum is included in the overall cost estimate for the overall King's island Scheme.

5.2 Area A2 - Verdant Place Steps and Crèche

5.2.1 Current Situation (Engineering Chainage Ch. 0+258 to Ch.0+330)

This section of flood cell runs from the end of the completed Verdant Place Wall along the back of the crèche (see Figure 5-1). Currently there is temporary concrete barrier on the in-land side of the access steps, which ties into the current embankment arrangement immediately north of the access steps (see Figure 5-3).

Figure 5-3: Temporary concrete barrier (left) and embankment

5.2.2 Constraints

- There is a footpath/cycleway on the crest of the existing embankment that is regularly used by residents. It is a requirement of any proposed flood relief solution that this route is maintained. During construction, the existing footpath will be closed and access will be diverted to the east side of the creche along Verdant Place.
- The property ownership map indicates that the land area under consideration here is in the ownership of LCCC. However, it should be noted that the area of the crèche is leased to St Mary's Aid.
- There is limited space between the boundary of the crèche and the outer edge of the island.
- Access for fishing and boating at established points around the island.

5.2.3 Potential Measure(s)

5.2.3.1 Direct Defences

Due to space constraints between the river channel and the crèche, construction options are limited to a flood defence wall for this length. The wall will run for approximately 70m and will tie into the newly constructed wall and steps at Verdant Place to the south, and the embankment to the north, thus closing the flood cell. The temporary concrete barrier will be replaced with a permanent wall.

To allow views of the river to be retained, it is proposed that the footpath behind the wall be regraded and will result in a wall height of approximately 1.1 - 1.2m above proposed ground level, when standing on the path, i.e.at a safe guarding height.

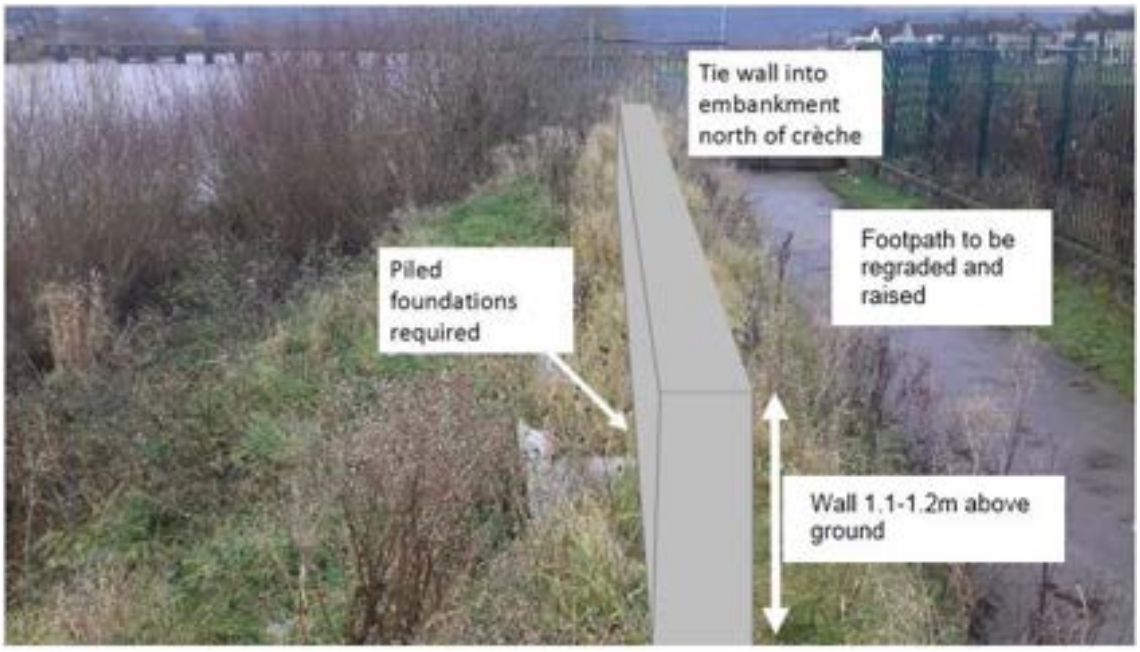

Figure 5-4: Proposed wall behind crèche

5.2.4 Environmental Issues

5.2.4.1 Ecological Considerations-Supporting the objective of the Habitats and Birds Directive

There is potential to impact on both the Lower River Shannon SAC and River Shannon and River Fergus SPA Natura 2000 sites through the temporary impacts of water pollution and sediments entering the adjacent River Abbey, River Shannon and the River Shannon estuary during construction. This may have a negative impact on water quality on which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter. A negative impact on water quality may also affect the habitats downstream of King's Island that support the designated bird species of the SPA. Disturbance to species of the Natura 2000 sites arising from construction noise and lighting is also a potential temporary negative impact. Species such as otter and SPA bird species that may migrate upstream to feed and shelter in the vicinity of King's Island may be disturbed and displaced by the construction works.

The main operational impact resulting from the proposed flood defence measures is the spread of invasive species, such as Japanese Knotweed, Himalayan Balsam and Giant Hogweed.

5.2.4.2 Avoid damages to, and where possible enhance the flora and fauna

There are a number of protected species that occur in the vicinity of King's Island including otter, eel, Atlantic salmon, brown trout, kingfisher, lamprey, dipper and bat species. All of these species and other locally important species and habitats could be potentially impacted by the proposed flood defences.

During the construction of the flood defence walls and embankments, riparian vegetation and trees may need to be removed, which will result in a loss of riparian habitat that could provide bird nesting and bat roosting potential. There is also potential for a negative impact on water quality and sediment release to the Shannon and Abbey Rivers, disturbance to species at a local level and the spread of invasive species, namely Japanese Knotweed, Himalayan Balsam and Giant Hogweed, during the course of the works.

5.2.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species.

The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.2.4.4 Construction Issues

The construction of the wall, will have to be carried out within a constrained corridor in-between the river channel /SAC boundary and the crèche. Due to the width constraints and proximity to the crèche there will be localised short-term effects on noise and air quality and disruption to the use of the public's open space. Long term the footway/cycleway and associated infrastructure will provide a local amenity and an environmental improvement.

5.2.5 Costs

The baseline construction costs for the direct defence measure in Area A2 is estimated at €344,501.

5.2.6 Climate Change Adaptability

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario. In the future, factors such as public amenity and visibility will need to inform the means of raising the wall.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-1.

Table 5-1. Area A2 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
RC Wall	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	High	Monitoring, inspection, maintenance.	Yes	Yes	RC Wall is set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.	Medium- the remaining risk includes potential spill over or overtopping under HEFS.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Only adaptable if in-built capacity measures (resilient foundation) included in original design which will allow for a raised wall crest. If raised once, it will no longer be adaptable for HEFS. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of raised defence crest is limited by sub-soil stability which is uncertain for potential foundation reinforcement.	Medium - limited ability to raise embankment crest and retain freeboard allowance. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall. Potential for construction of additional defence limited as minimal areas available and the sub-soil stability is uncertain for potential foundation reinforcement.	

5.3 Area A3 - North West Embankment

Figure 5-5: Overview of Area A3

5.3.1 Current Situation (Engineering Chainage Ch. 0+330 to Ch.1+250)

This area is the portion of King's Island from the north of the crèche to the handball alley. The length of defence required is approximately 1000m. Currently the area is surrounded by an embankment which serves as a combined flood embankment and raised walkway / cycle path. However, much of the embankment is in a poor state of repair, with the crest level temporarily formed of sandbags, many of which are damaged or missing. Without the sandbags, the embankment does not provide the required flood defence level.


Figure 5-6: Existing flood embankment with damaged sandbags

5.3.2 Constraints

- There is a footpath/cycleway on the crest of much of the existing embankment that is regularly used by local residents. It is a requirement of any proposed flood relief solution that this route is maintained.
- A 4m open-drain lies inside the line of the embankment that would have to be diverted post-development.
- The property ownership map indicates that the land area under consideration here is under the ownership of LCCC.
- The legal boundary of the adjacent SAC runs alongside the line of the proposed defence.
- Avoidance of the handball alley at the north of St. Mary's Park.
- Allowance for the proposed LCCC Thomond Weir Bridge upgrades.
- Access for fishing and boating at established points around the island.
- Minimising the loss of green space, including the running track and playing fields
- Although there are no recorded archaeological features in this area of the island, the presence of a Bastioned Fort (LI005-018) between St. Munchin's Street and Saint Ita's Street may mean that there are some unrecorded archaeological artefacts along the west side of the island.

5.3.3 Potential Measure(s)

5.3.3.1 Direct Defences

As the area is currently surrounded by an embankment, direct defence provision by embankment is the proposed form of defence.

An engineered embankment could be located approximately 4.5m inland from the line of sandbags on top of the existing embankment. At the southern end (near the crèche) it is proposed that the cycleway/walkway on this embankment be ramped to tie in with the proposed regrading of the existing access path to the west of the creche. Due to the presence of peat, a prolonged and staged construction approach may be required to allow a staged consolidation and settlement process to occur.

Along the length of the embankment, the top width will be 4m with side slopes of 1 in 3 on the wet side and 1 in 2 on the dry side, resulting in an overall width of circa 16m above ground. This will retain the current walking and cycling amenity and comply with health and safety best practice.

It is proposed to install intermittent steps and ramps down the embankment to facilitate pedestrians and fishermen, and localised areas for seating adjacent to the cycleway/footway (with local widening of the embankment as required). Separation bollards will be included along the top of the embankment at approximately 100m centres.

5.3.4 Environmental Issues

Key environmental issues were considered for each of the Engineering Alternative Options at this location. The Proposed Option i.e. embankment for the direct defence is the least environmentally constrained option and hence preferred from an environmental perspective. It does not disrupt the river side of the SAC where high value species are present and minimises risks during construction of accidental discharge of contaminants, impacting on the SAC. The key environmental issues at this location are discussed below.

The proposed top width of 4m will allow locals to continue to use the Island as a walking amenity, and access to the rivers for fishing will be maintained. Overall, this will support the local community in the area.

During construction, the contractor will be required to prepare a site-specific Construction Environmental Management Plan (CEMP). As a minimum, mitigation measures to prevent spillages of diesel/oils, capture of water containing suspended material, and an on-site waste management plan will be put in place. This will reduce/remedy any significant impacts on water quality during construction.

The geology along this side of the island comprises estuarine sediments with an overburden of between 3.4 m to 10 m in some places. The construction of the embankment will require 'keying in' the base of the embankment into the overburden. This operation will reduce the depth of overburden and consequently the level of protection to the underlying groundwater. The island is underlain by Visean limestones (undifferentiated). The Geological Survey of Ireland classifies the bedrock geology as locally important. The protection of soil and groundwater will be included in the CEMP during construction. The embankment when constructed will provide additional protection to the groundwater.

The construction of the embankment will require the importation of large volumes of suitable material. These will be transported to site in heavy good vehicles that will access the site via temporary haul routes along the route of the embankment. The truck movements will create temporary nuisance for the residents living close by.

5.3.4.1 Ecological Considerations -Supporting the objective of the Habitats and Birds Directive

As the construction of the proposed defences will be from the landward side, this will prevent potential impacts to the priority habitat Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) and water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation, which includes the plant species Triangular Club-rush (*Schoenoplectus triqueter*) that is located on the north-west of the island. However, the provision of access for fishing and boating at established points around the island has the potential to increase the footprint of the defence measures, depending on their design. Access points shall be designed so that there is no encroachment into the SAC on the river side of the existing embankment.

There is potential to impact on both the Lower River Shannon SAC and River Shannon and River Fergus SPA Natura 2000 sites through the temporary impacts of water pollution and sediments entering the adjacent River Abbey, River Shannon and the River Shannon estuary during construction. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter. A negative impact on water quality may also affect the habitats downstream of King's Island that support the designated bird species of the SPA. Disturbance to species of the Natura 2000 sites is also a potential temporary negative impact. Species such as otter and SPA bird species that may migrate upstream to feed and shelter in the vicinity of King's Island may be disturbed and displaced by the construction works.

The main operational impact resulting from the proposed flood defence measures is the spread of invasive species, such as Japanese Knotweed, Himalayan Balsam and Giant Hogweed. The loss of the ditch will also result in permanent loss of Opposite leaved pondweed (*Groenlandia densa*). This species is an element of the habitat watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation and therefore is a qualifying interest of the SAC. Translocation of this species will be required if the ditch is to be lost.

5.3.4.2 Avoid damages to, and where possible enhance the flora and fauna

There are a number of protected species that occur in the vicinity of King's Island including otter, eel, Atlantic salmon, brown trout, kingfisher, dipper and bat species. All of these species and other locally important species and habitats could be potentially impacted by the proposed flood defences. The construction of the proposed defences inside the line of the existing embankment will result in the potential loss of the aquatic habitat associated with the local drain.

During the construction of the flood defence walls and embankments, riparian vegetation and trees may need to be removed, which will result in a loss of riparian habitat that could provide bird nesting and bat roosting potential. There is also potential for a negative impact on water quality and sediment release to the Shannon and Abbey Rivers, disturbance to species at a local level and the spread of invasive species, namely Japanese Knotweed, Himalayan Balsam and Giant Hogweed, during the course of the works.

5.3.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.3.4.4 Construction Issues

The construction of the new embankment, will have to be carried out within a constrained corridor in-between the river channel /SAC boundary and the hedgerow. Due to the width constraints, there will be localised short-term effects on noise and air and disruption to the user of this walkway. Long term the footway/cycleway and associated infrastructure will be a local amenity and an environmental improvement.

5.3.5 Costs

The baseline construction costs for the direct defence measure in Area A3 is estimated at €1,270,950.

5.3.6 Climate Change Adaptability

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-2.

Table 5-2: Area A3 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Embankment	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.			Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			Only adaptable if in-built capacity measure (resilient foundation) included in original design which will allow for a raised crest of embankment. If embankment crest is raised once, it will no longer be adaptable for HEFS levels. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Further potential for an RC Wall or Sheet pile wall on the outer side of the proposed embankment.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	Moderate	Monitoring, inspection, maintenance.			Embankment set-back. Lower exposure to potential erosion. If required refurbishment or rebuild sections. Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise embankment crest or build another defences to increase level of protection i.e.: an RC Wall or Sheet pile wall on the outer side of the proposed embankment.	Low- If adaptation measure is in place the risk remaining is minimum.

5.4 Area A4 – St. Mary's Park / Special Area of Conservation (SAC)

Figure 5-7: Overview of Area A4

5.4.1 Current Situation

This area covers the north-east of the Island and includes the area of wetland which forms the land-based element of the SAC (see Figure 5-7). Currently the area is surrounded by a raised embankment which follows the perimeter of the island and continues from Area A3. In the 2014 flood, a section of the embankment to the north of the island was breached and undercut. Remedial works were carried out and consist of sheet piling. However, the impact of this is the long-term closure of the walkway at that location. As with Area A3, much of the embankment is in a poor state of repair, with the crest level temporarily formed of sandbags in places, many of which are damaged or missing. Without the sandbags, the embankment does not provide the required flood defence level.

Figure 5-8: Remedial sheet piles and view across wetland

5.4.2 Constraints

- Land under consideration here is under the ownership of LCCC. However, the sports pitch is leased to Star Rovers FC (northern pitches, including an astroturf pitch) and Athlunkard Villa FC (southern pitch).
- Consideration of the proximity of the residents to the embankment and the requirement to protect privacy.
- Avoidance of the SAC, or as a minimum ensuring impacts are avoided or reduced.
- Ensuring continued hydraulic connectivity between the Abbey River and the northeast portion of the SAC.
- Avoidance of Article 6(4) of the Habitats Directive, and the IROPI process and the resultant (unknown) impact that this would otherwise have on the design and construction programme.
- Prior to the demolition of residences to the east of St. Munchin's Street, the existing fence/wall to the rear of these residences is a design constraint.
- Avoidance, as far as possible, of the Star Rovers FC car park, pitch and changing rooms, and pitches of Athlunkard Villa FC.
- Stockpile of Japanese Knotweed to be managed by appropriate construction methods and environmental management.
- Historic landfill has been remediated, but there may be residual issues with land contamination.
- Incorporating the future cycleway/footway into the proposed embankment in the long term.

5.4.3 Potential Measure(s)

A direct defence in the form of an embankment, as a continuation of the embankment proposed in Area A3, is the proposed measure in this location. However, there are two potential embankment alignments. These will be considered as two alternative options as set out below.

5.4.3.1 Outer Alignment

The outer alignment would follow the route of the existing embankment around the eastern perimeter of the island. This would involve raising the crest level of the existing embankment by approximately 1.5m. To support this level of additional material, the embankment foundations will be widened and deepened, resulting in an increase in the footprint of the structure.

The design of the embankment, with sheet piling to the riverside face of the embankment and a steepened landward slope, will minimise encroachment into the SAC. However, there will be some loss of habitat on the landward side as a result of encroachment of the landward slope. In addition, during construction there will be temporary works involving haul roads and machinery platforms that would be within the SAC.

It is proposed to include areas for localised seating adjacent the cycleway/footway (with local widening of the embankment as required).

5.4.3.2 Inner Alignment

The inner alignment runs from the east of the handball alley, parallel to St. Munchin's Street and along the inner side of the SAC. It runs along the north side of the Star Rovers FC ground to return to the perimeter of the island. The defence line will be routed to avoid the Japanese Knotweed bund, or to minimise the extent of knotweed to be removed. It will also be routed to minimise disruption to the historic landfill. Where space is limited, such as alongside the Japanese Knotweed bund, as an alternative, a localised wall section could be constructed instead of an embankment.

Due to space constraints at Star Rovers FC, and to avoid works inside the SAC (including construction access), the required alignment of an embankment would require reconfiguration of the pitches and carparking area of the football club (see Figure 5-9). There would also be some impact on the pitch and club facilities, including the southern playing pitch, changing rooms and boundary fence and netting. Following liaison with the associated clubs, and direction from LCCC, a number of possible reconfigurations have been developed and assessed for this location. The main benefit of this option would be to provide continuity of defence line with an embankment around the full perimeter of the SAC.

Alternatively, approximately 100m of reinforced concrete wall could be run along the north side of the astro-turn pitch, thus avoiding the need to reconfigure the pitches. The wall would be tied into another length of embankment which will continue the line of defence to the north-eastern corner of the pitches. This wall would need to be piled and the construction approach will require a temporary working platform within the SAC. Breaking the line of the embankment with a section of narrow wall means the continuous, high level footpath would be lost, unless a boardwalk type solution were added. Access around the pitch and between the two lengths of embankment could be maintained through provision of such a cantilevered aerial walkway to continue access without impacting on ground level habitats and species and is the measure to be taken forward to planning and design.

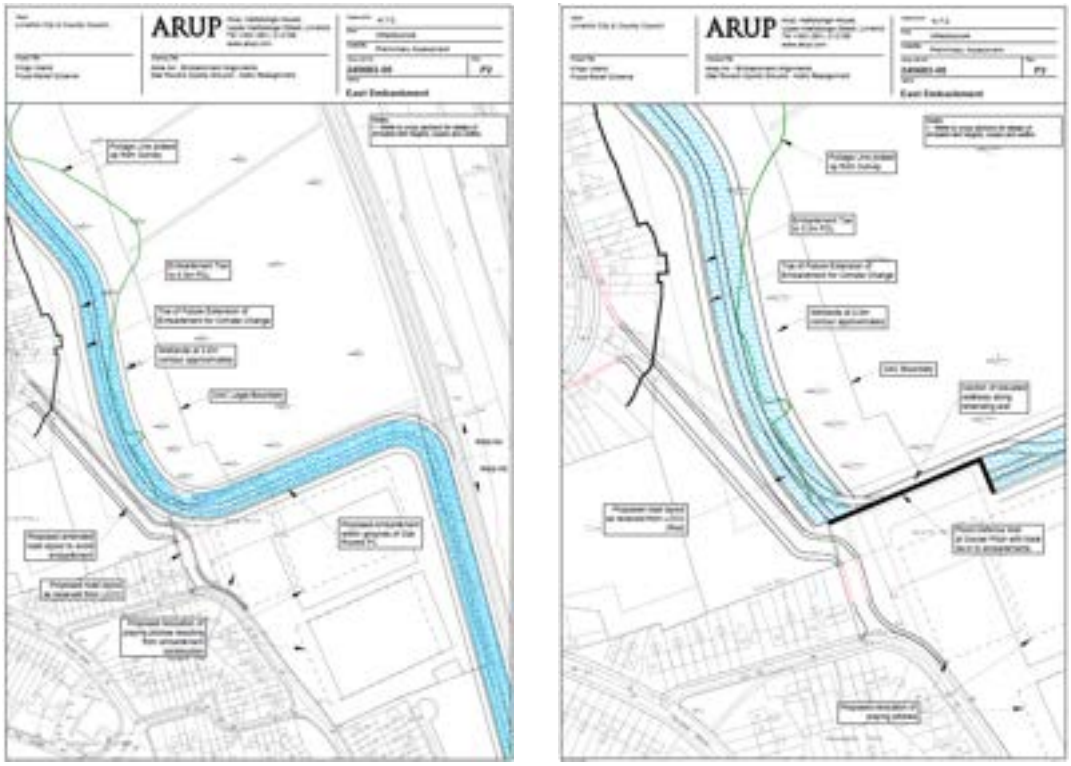

Figure 5-9: Proposed embankment and wall alignments at Star Rovers FC

It is proposed to include intermittent steps and ramps down the embankment to facilitate horse movement for grazing purposes, and areas for localised seating adjacent the cycleway/footway (with local widening of the embankment as required). Separation bollards will be included along the top of the embankment at approximately 100m centres. However, installation of public lighting (if included in the design) and movement alongside the edge of the SAC will need to be considered carefully in the ecological appraisal. Some modification of these access proposals may be required.

Under this measure, Limerick City and County Council could maintain the outer embankment as a walkway, but it will not be considered as a flood defence, and will not be maintained as such.

5.4.4 Environmental Issues

There are a number of environmental issues which are common to both alignments. For example, the completed embankment will enable the public to continue to use the island for amenity and walking purposes. However, a large volume of suitable material will be required to construct the embankment. This will require the importation of the material via road and site access routes to the working area and will have a temporary nuisance impact on the nearby residents.

Adopting an outer alignment would have the advantage of avoiding the Japanese Knotweed stockpile, and the historic landfill. It also ensures maximum separation to the properties on St. Munchin's Street, retaining the current (or very similar to current) visual and privacy impacts.

The biggest issue for the outer alignment is the potential ecological impact on the SAC. As well as encroachment within the SAC boundary, and resultant loss of habitat, the SAC is hydraulically connected to the Abbey River at a site known locally as the 'Green Lady'. Any measure which would affect this balance, would have a potential impact on the SAC and the species its supports, particularly the wintering birds. Protection of the alluvial woodland (the Priority Habitat) is required whether a wall or an embankment is chosen. As discussed in section 3.3, any loss of habitat or impact on the integrity of the SAC would trigger the IROPI planning process. It is unlikely that an IROPI process would be successful as a technically viable alternative (Inner Alignment) exists, which is less damaging to the affected European site and is located in the middle of the island.

The inner alignment has the advantage of being located outside the SAC boundary, but will be near the residences of St. Munchin's Street, potentially creating negative social amenity and visual impacts from obstruction of easterly views. It is likely that privacy may also be an issue.

The choice of alignment and construction methodology and management should be such as to minimise interference with the existing Japanese Knotweed stockpile and the historic landfill. However, the construction of a wall/embankment close to the Japanese Knotweed stockpile will need to be strictly controlled. Full Biosecurity Plans will be required particularly when excavating for foundations. The control measures that will be required will extend the period of construction in this area.

Construction close to the old landfill site at St. Munchin's Street may give rise to odours and odour control measures may need to be employed during construction. The inner alignment is very close to the Zone of Notification for the Bastioned Ford (LI005-018) (a Record of Monuments and Places). An on-site archaeologist will be required for this phase of the construction.

5.4.4.1 Ecological Considerations - Supporting the objective of the Habitats and Birds Directive

The main operational impact resulting from the proposed flood defence measures is the spread of invasive species, such as Japanese Knotweed, Himalayan Balsam and Giant Hogweed. Given the alignment of the proposed defence measures, the natural processes within the wetland will be unaltered due to the lack of requirement for drain diversions/drainage and encroachment into the SAC wetland area.

Many wintering birds of the SPA use the wetland area of the SAC and therefore there is potential for temporary disturbance and displacement during construction of the defences in these areas. Disturbance impacts to the SPA bird species during operation may occur due to increased recreational usage of the embankment, which is located immediately adjacent to the wetland area. The provision of lighting in this area (if required) could also potentially create a disturbance source to foraging and roosting wintering birds. Otter may also use the drainage ditches and wetland area of the SAC are for commuting and foraging and thus, potential disturbance of otter during construction may also be caused. Although these works are not immediately adjacent to the River Shannon and River Abbey, there is potential for negative impacts to water quality of these rivers due to the connectivity between the drainage ditches and the 'Green Lady', which provide surface water connectivity to the water bodies.

5.4.4.2 Avoid damages to, and where possible enhance the flora and fauna

During the construction of the flood defences, riparian vegetation and trees may need to be removed, which will result in a loss of riparian habitat that could provide bird nesting and bat roosting potential. The provision of lighting in this area has the potential to increase light pollution to the area and therefore disturb the activities of fauna that utilise the area e.g. nesting birds and bats. There is also potential for a negative impact on water quality and sediment release to the Shannon and Abbey Rivers, disturbance to species at a local level and the spread of invasive species, namely Japanese Knotweed, Himalayan Balsam and Giant Hogweed, during the course of the works.

5.4.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.4.4.4 Invasive Species

The large footprint of an embankment and wall will mean that avoidance of the old landfill site and the Japanese Knotweed dump site may be difficult. In which case, excavation of unsuitable material for foundations in these areas will cause a number of environmental issues. Excavation around or close to the Japanese Knotweed dump site will require special handling methods of the material and a Biosecurity Plan and Invasive Species Management Plan will be required. As a minimum, the Biosecurity Plan will require truck wash down, to avoid carry over of any Japanese Knotweed material to other part of the site along the travel route or onto public roads. Wash water will need to be stored and correct disposal methods put in place by a contractor. The section of embankment and reinforced wall to the west of the landfill site and the Japanese Knotweed dump as described above will be considered further from an engineering perspective at the next stage of the project.

5.4.4.5 Construction Issues

The construction of the embankment and a section of wall or sheet piles if viable, will have to be carried out within a constrained corridor in-between the residential properties on St Munchin's Street and the SAC boundary. Due to the width constraints and close proximity to the residential properties there will be localised short-term effects on noise and air for residents and disruption to the use of their rear garden space. Excavation around the old landfill site may create odours. Long term when these properties have been vacated and demolished the embankment with footway/cycleway and associated infrastructure will be a local amenity and an environmental improvement.

5.4.5 Costs

The baseline construction costs for the direct defence measure in Area A4 is estimated at:

- Inner alignment: €1,671,017
- Outer alignment: €2,727,059 (assumed sheet piling solution either side of existing walkway to avoid loss of SAC and Alluvial Woodland)

5.4.6 Climate Change Adaptation

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-3 and Table 5-4

Table 5-3: Area A4 Climate Change Adaptation: Inner Alignment

Options		Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options
Inner Alignment	Embankment	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.
		Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.			Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.
		Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			If embankment crest is raised once, it will no longer be adaptable for HEFS levels. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed . Further potential for an RC Wall or Sheet pile wall on the outer side of the proposed embankment possible for additional protection.
		Erosion Ground Stability	Moderate	Monitoring, inspection, maintenance.			Embankment set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.
		Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise embankment crest or build another defences to increase level of protection i.e.: an RC Wall or Sheet pile wall on the outer side of the proposed embankment.
	Sheet pile Wall	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.

Options		Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options
		Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			Only adaptable if in-built capacity measure (resilient foundation) included in original design which will allow for a raised crest of wall. There also further potential to build embankment on inside of proposed sheet piled wall to increase level of protection to MRFS or HEFS levels.
		Erosion Ground Stability	High	Monitoring, inspection, maintenance.			Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.
		Sea Level Rise	High	Resilient sheet pile wall foundation/base to ensure adaptability (increase wall height).			Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall or build embankment on side of proposed sheet pile.
	RC wall	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.
		Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.
		Erosion Ground Stability	High	Monitoring, inspection, maintenance.	Yes	Yes	RC Wall is set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.
		Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Only adaptable if in-built capacity measures (resilient foundation) included in original design which will allow for a raised wall crest. If raised once, it will no longer be adaptable for HEFS. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of raised defence crest is limited by sub-soil stability which is uncertain for potential foundation reinforcement.
		Sea Level Rise		Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall. Potential for construction of additional defence limited as minimal areas available and the sub-soil stability is uncertain for potential foundation reinforcement.

Table 5-4. Area A4 Climate Change Adaptation: Outer Alignment

Options		Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Outer Alignment	Embankment	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
		Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.			Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
		Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			If embankment crest is raised once, it will no longer be adaptable for HEFS levels. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of additional defence limited as minimal area available.	Low- If adaptation measure is in place the risk remaining is minimum.
		Erosion Ground Stability	Moderate	Monitoring, inspection, maintenance.			Embankment set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
		Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise embankment crest. Potential for construction of additional defence limited as minimal areas available.	Low- If adaptation measure is in place the risk remaining is minimum.

5.5 Area A5 - Star Rovers to Athlunkard Boat Club

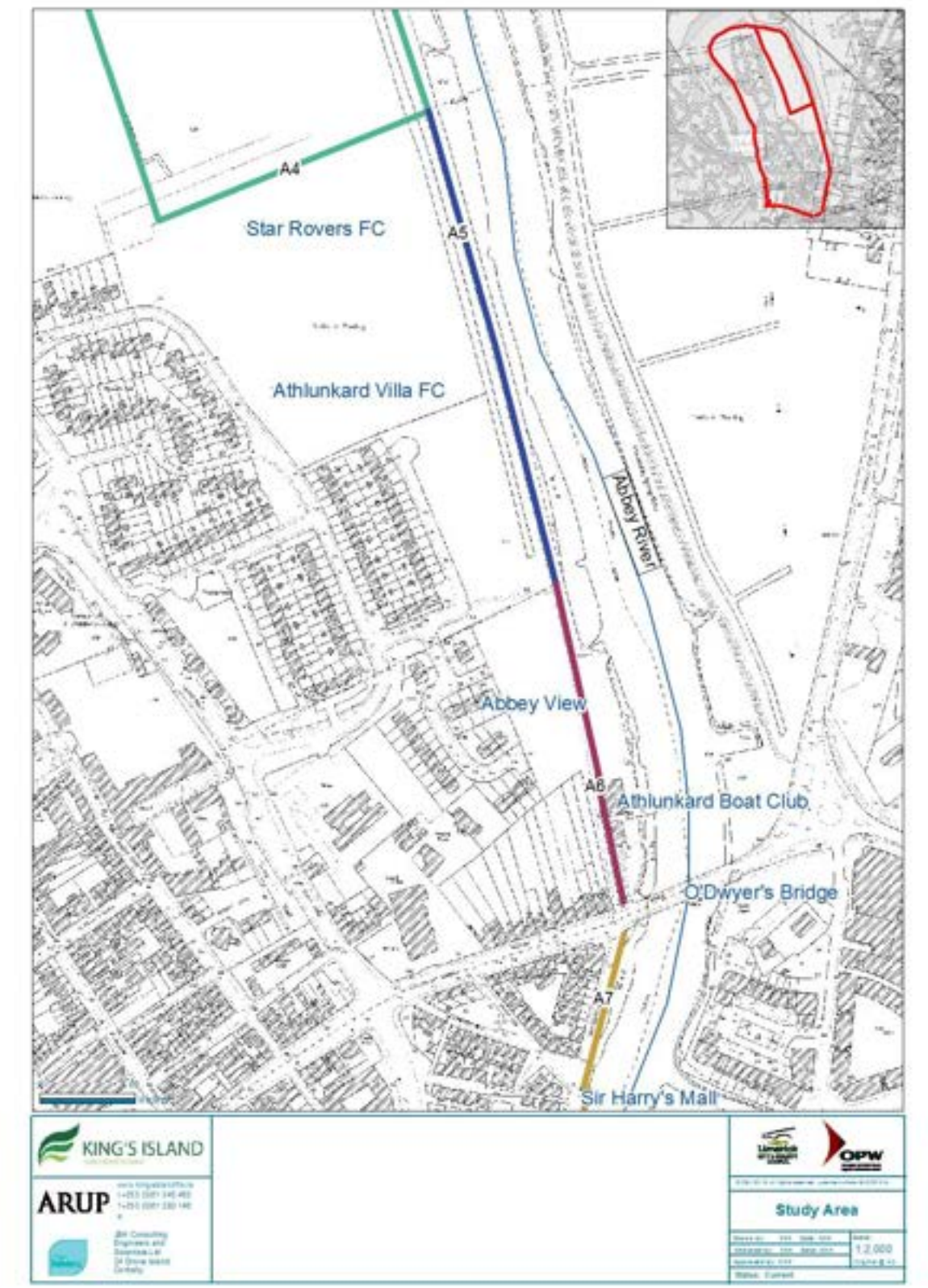

Figure 5-10: Overview of Areas A5 and A6

5.5.1 Current Situation (Engineering Chainage Ch. 2+100 to Ch.2+400)

The island perimeter in this area is bordered by a continuation of the embankment from Area A4 and runs from the northern corner of the Star Rovers FC pitches to the northern point of the Athlunkard Boat Club land holding (see Figure 5-10). The embankment runs along the eastern side of the Star Rovers FC and Athlunkard Villa FC grass pitches. Temporary sandbags line the riverside of the embankment. There is a drain on the landside of the embankment which runs from the Boat Club to the south-western corner of the pitches.

Figure 5-11: Looking along footpath in Area A5

5.5.2 Constraints

- Encroachment onto the SAC
- Land under consideration here is under the ownership of LCCC. However, the sports pitch is leased to Star Rovers FC (northern pitches, including astro-turf) and Athlunkard Villa FC (southern pitch)
- Avoidance, as far as possible, of the Star Rovers FC pitch and changing rooms, and if possible providing continuous access to the playing pitches during construction
- Incorporating the future cycleway/footway into the proposed embankment in the long term.

5.5.3 Potential Measure(s)

It is proposed to continue the line of direct defences from Area A4 (whether inner or outer alignment is selected) to provide flood defences to this section of the island through an embankment running alongside the eastern boundary of Star Rovers and Athlunkard Villa FC. The footprint of the embankment will encroach along the eastern perimeter of the Star Rovers FC sports grounds, including the training pitches. As this land is leased by Star Rovers FC and Athlunkard Villa FC from LCCC, discussions between the Landowner and Tenant are required at Compulsory Purchase Order (CPO) stage. The following should be noted:

- The container changing facilities may need to be relocated in consultation with Star Rovers FC during the construction phase; and
- The existing boundary fencing and netting at the eastern side of the playing fields will also need to be relocated.

5.5.4 Environmental Issues

The line of the defence encroaches onto the river side of the SAC between Chainage 2+100 and 2+400 and slightly encroaches into the Star Rovers football grounds. The key environmental issues and their significance at this location are discussed below.

Construction of the embankment may cause a temporary disruption to the users of the football pitch.

During the construction of the embankment, a large volume of suitable material will be required to construct the embankment. This will require the importation of the material via road and site access routes to the working area. This will have a temporary nuisance impact on the nearby residents.

5.5.4.1 Ecological Considerations -Supporting the objective of the Habitats and Birds Directive

The main operational impact resulting from the proposed embankment is the encroachment onto the SAC north of Athlunkard Boat Club.

However, the land within the SAC at this point is disturbed ground used for pedestrian access and of low habitat value. Subject to an Appropriate Assessment it is not envisaged that the encroachment at this area will result in a significant impact to the integrity of the SAC.

Other potential impacts from the direct defences at this location include the spread of invasive species, Himalayan Balsam has been identified as being present in this area. Given the alignment of the proposed defence measures, the natural processes within the wetland will be unaltered due to the lack of requirement for drain diversions/drainage and encroachment into the SAC wetland area.

Many wintering birds of the SPA use the wetland area of the SAC and therefore there is potential for temporary disturbance and displacement during construction of the defences in these areas. Otter may also use the drainage ditches and wetland area of the SAC are for commuting and foraging and thus, potential disturbance of otter during construction may also be caused. Although these works are not immediately adjacent to the River Shannon and River Abbey, there is potential for negative impacts to water quality of these rivers due to the connectivity between the drainage ditches and the 'Green Lady', which provide surface water connectivity to the water bodies. The proposed lighting will have an impact on the wintering birds and species in the area.

5.5.4.2 Avoid damages to, and where possible enhance the flora and fauna

During the construction of the flood defences, riparian vegetation and trees may need to be removed, which will result in a loss of riparian habitat that could provide bird nesting and bat roosting potential. There is also potential for a negative impact on water quality and sediment release to the Shannon and Abbey Rivers, disturbance to species at a local level and the spread of invasive species, during the course of the works.

5.5.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.5.4.4 Visual Amenity

Residents of Assumpta Park will experience visual impacts from the proposed embankment which will be raised by approximately 2m in height and cause an obstruction of easterly views towards the Abbey River and open space beyond.

5.5.4.5 Construction Issues

The construction of the embankment would have to be carried out within a constrained corridor in-between the Sports Ground and the river edge. Due to the width constraints and close proximity to the residential properties of Assumpta Park there will be localised short-term effects on noise and air for residents and disruption to the use of their rear garden space. Long term the embankment with footway/cycleway and associated infrastructure will be a local amenity and an environmental improvement.

5.5.5 Costs

The baseline construction costs for the direct defence measure in Area A5 is estimated at €610,740.

5.5.6 Climate Change Adaptability

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-5.

Table 5-5. Area A5 Climate Change Adaptation

Options	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Embankment	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.			Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			If embankment crest is raised once, it will no longer be adaptable for HEFS levels. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of additional defence limited as minimal area available.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	Moderate	Monitoring, inspection, maintenance.			Embankment set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Sea Level Rise	HIgh	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).			Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise embankment crest. Potential for construction of additional defence limited as minimal areas available.	Low- If adaptation measure is in place the risk remaining is minimum.

5.6 Area A6 – Athlunkard Boat Club

5.6.1 Current Situation (Engineering Chainage Ch.2+400 to 2+614)

Athlunkard Boat Club is located on the east side of King's Island, to the north of O'Dwyers Bridge (see Figure 5-10). Vehicular access is from the north, via Assumpta Park and pedestrian access is also available from Athlunkard Street. The FFL of the clubhouse is +4.92mOD, so lies above the 0.5% AEP tide level (without freeboard). The Boat Club has been consulted with in relation to the possible measures available in this location.

In Area A6, a FDL of 5.1mOD will be used for all hard defences, including walls and flood barriers, whilst 5.5mOD will be maintained as the FDL for embankments.

Figure 5-12: Rear wall of Athlunkard Boat Club and boat store and slip access to river

5.6.2 Constraints

- Avoidance of the SAC.
- Avoidance of Athlunkard Boat Club building which is a Recorded Structure (RPS 314); and any proposed changes that would affect this structure will be subject to certain conservation and heritage conditions.
- A 2m clearance to the existing buildings has been proposed to avoid conflict with existing foundations, which are unknown at present.
- The existing vehicle access from Assumpta Park to the Boat Club is maintained.
- The existing accesses from the back of the residences located on Athlunkard Street are maintained.
- Maintain flood cell protection through the use of passive defences.
- Incorporating the existing cycleway/footway.
- Consideration of the LCCC proposed housing regeneration project behind Athlunkard Street.
- Boat club lands are in private ownership. LCCC has taken ownership of lands within the regeneration parcel including 'Healy's Field'.

5.6.3 Potential Measure(s)

5.6.3.1 Direct Defence and IPP

Due to space constraints, it is proposed to construct a combination of wall, embankment and regraded ground profiles, all of which will tie in with the Area A5 embankment and run behind the Boat Club to link into the higher ground at O'Dwyer Bridge.

Under the LCCC proposed housing regeneration project behind Athlunkard Street, vehicular access will be created from Athlunkard Street and properties are to be constructed to the rear of No. 25 Athlunkard Street. LCCC propose that these properties will have a finished floor level of approximately 5.6mOD. Therefore, the area west of the new walkway/cycleway will be re-graded until such time as the housing scheme design is finalised.

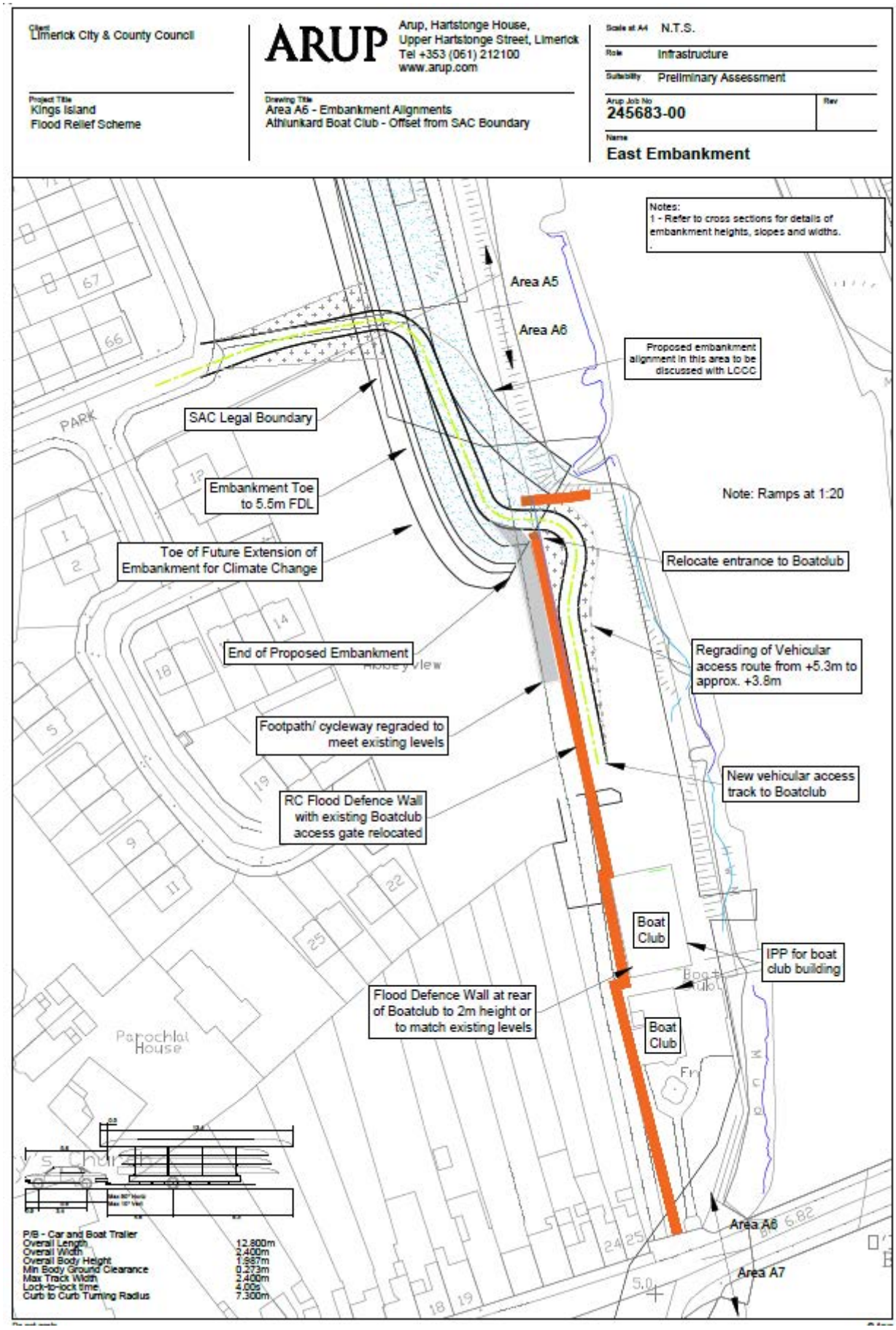

Figure 5-13: Direct defences at Area A6

This measure would include the following elements, which are also illustrated in Figure 5-13:

- The existing vehicle access track, that serves the Boat Club, would be re-routed along the top of the embankment and would be graded to allow access whilst retaining a passive solution for the flood cell.
- The cycleway/walkway on the embankment would be ramped to tie in with the existing cycleway/walkway to the north.
- The embankment would tie into the northern end of the wall, which would run adjacent to the Boat Club boundary i.e., on the east side of the cycleway/walkway.
- Installation of a new permanent wall along the wet-side slope of the embankment to replace the existing boundary wall.
- As the ground level would be raised to 5.1mOD outside the access gate, the existing access to the Boat Club would be relocated to the north and will be widened, with a new access gate and the entrance area re-graded within the Club's grounds.
- Access to rear gate at No. 24 Athlunkard Street to be maintained.
- IPP for the boat club gives the freeboard element of the design flood level.

Floor levels in the existing boat club buildings are at approximately 4.9mOD, which is above the design flood level of 4.8mOD, but does not include the recommended 300mm of freeboard. Therefore, IPP is proposed to provide flood defence to the 5.1mOD flood level. A site inspection has been carried out for the Boat Club buildings. The proposed IPP would include sealing of floor vents in the clubhouse building, which are below flood defence level, and the provision of replacement wall vents. In addition to this, demountable flood barriers are proposed for all doorways to a level of 5.1mOD.

5.6.4 Environmental Issues

5.6.4.1 Ecological Considerations -Supporting the objective of the Habitats and Birds Directive

The main operational impact resulting from the proposed embankment is the encroachment onto the SAC north of Athlunkard Boat Club. However, the land within the SAC at this point is disturbed ground used for pedestrian access and of low habitat value. Subject to an Appropriate Assessment it is not envisaged that the encroachment at this area will result in a significant impact to the integrity of the SAC.

Other potential impacts from the direct defences at this location include the spread of invasive species, such as Japanese Knotweed and Himalayan Balsam which are present in this area.

Although these works are not immediately adjacent to the River Shannon and River Abbey, there is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter.

5.6.4.2 Avoid damages to, and where possible enhance the flora and fauna

During the construction of the flood defences, riparian vegetation and trees may need to be removed, which will result in a loss of riparian habitat that could provide bird nesting and bat roosting potential. There is also potential for a negative impact on water quality and sediment release to the River Abbey, disturbance to species at a local level and the spread of invasive species, namely Japanese Knotweed, Himalayan Balsam and Giant Hogweed, during the course of the works.

5.6.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.6.4.4 Visual Amenity

Residents of Assumpta Park and one property on Athlunkard Street (No.25) will experience visual impacts from the proposed embankment and wall which will be raised by approximately 2m in height and cause an obstruction of easterly views towards River Abbey and open space beyond.

5.6.4.5 Archaeology & Cultural Heritage

Avoidance of Athlunkard Boat Club building which is a Recorded Structure (RPS 314); and any proposed changes that would affect this structure will be subject to certain conservation and heritage conditions to avoid disruption to the building and its foundations.

5.6.4.6 Construction Issues

The construction of the embankment and wall will have to be carried out within a constrained corridor. Due to the width constraints and close proximity to the residential properties of Abbey View and Athlunkard Street there will be localised short-term effects on noise and air for residents and disruption to the use of their rear garden space. Long term the embankment and wall with footway/cycleway and associated infrastructure will be a local amenity and an environmental improvement.

5.6.5 Costs

The baseline construction costs for the direct defence measure in Area A6 is estimated at €1,312,197.

5.6.6 Climate Change Adaptability

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-6.

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Table 5-6. Area A6 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Embankment	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	Moderate	Monitoring, inspection, maintenance.	Yes	Yes	Embankment set-back and so is less exposed to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).	Limited	Limited	Embankment crest can potentially be raised to MRFS; however space is limited and may present a constraint to achieving a crest level for the MRFS with 0.5m freeboard. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed.	Medium - limited ability to raise embankment crest and retain freeboard allowance. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height either as wall or embankment).	Limited	Limited		
RC Wall	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	HIgh	Monitoring, inspection, maintenance.	Yes	Yes	RC Wall is set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections. Bank protection can be introduced in the short, medium and long-term. It would be most effective if included in current design.	Medium- the remaining risk includes potential spill over or overtopping under HEFS.

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Only adaptable if in-built capacity measures (resilient foundation) included in original design which will allow for a raised wall crest. If raised once, it will no longer be adaptable for HEFS. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of raised defence crest is limited by sub-soil stability which is uncertain for potential foundation reinforcement.	Medium - limited ability to raise embankment crest and retain freeboard allowance. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall. Potential for construction of additional defence limited as minimal areas available and the sub-soil stability is uncertain for potential foundation reinforcement.	
Regrade ground profiles	Freeze-thaw damage	High	Drainage exceedance to be included in current design.	Limited	Limited	Drainage exceedance to be included in current design, however road drainage will be constrained by proximity to floodplain	Medium - limited potential for highway drainage to adapt.
	Flooding (coastal/fluvial)	High	No adaptable measures. Investment in IPP will not reduce future flood defence costs.	No	Limited	Limited. As the ground level will be raised to 5.1 OD Malin outside the access gate of the boat club. Significant works would be required to raise further to 5.6m OD Malin. Additional measures on top of raised ground could be considered at a significant future defence cost.	Medium - In the MRFS the freeboard is no longer present. Limited ability to raise ground level further, technically difficult and potentially not viable Additional measures possible at future defence cost. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High		No	Limited	Limited. As the ground level will be raised to 5.1 OD Malin outside the access gate of the boat club. Significant works would be required to raise further to 5.6m OD Malin to account 0.5m for sea level rise. Additional measures on top of raised ground could be considered at a significant future defence cost.	

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
IPP at Boat Club -Sealing off vents and replacement wall vents -Demountable Barriers	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	No adaptable measures. Investment in IPP will not contribute to or reduce future flood defence costs.	No	Limited	IPP can in some circumstances be adaptable to increased flood levels, however safety limits will apply, especially to occupied buildings and to be effective in the MRFS may require significant refurbishment to existing properties The sealing off floor vents and replacement of wall vents in Club house will provide some protection, but it will not be exhaustive as there remains vulnerability and risk. There still remains a level of adaptability in that new measures or IPP can be introduced at a future flood defence cost. The demountable flood barriers are proposed for all doorways of the boat club to a level of 5.1mOD. Increase to MRFS would be in the order of 0.5m.	Medium - In the MRFS the freeboard is no longer present. Limited ability to raise ground level further, technically difficult and potentially not viable Additional measures possible at future defence cost. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High		No	Limited		

5.7 Area A7 - Sir Harry's Mall

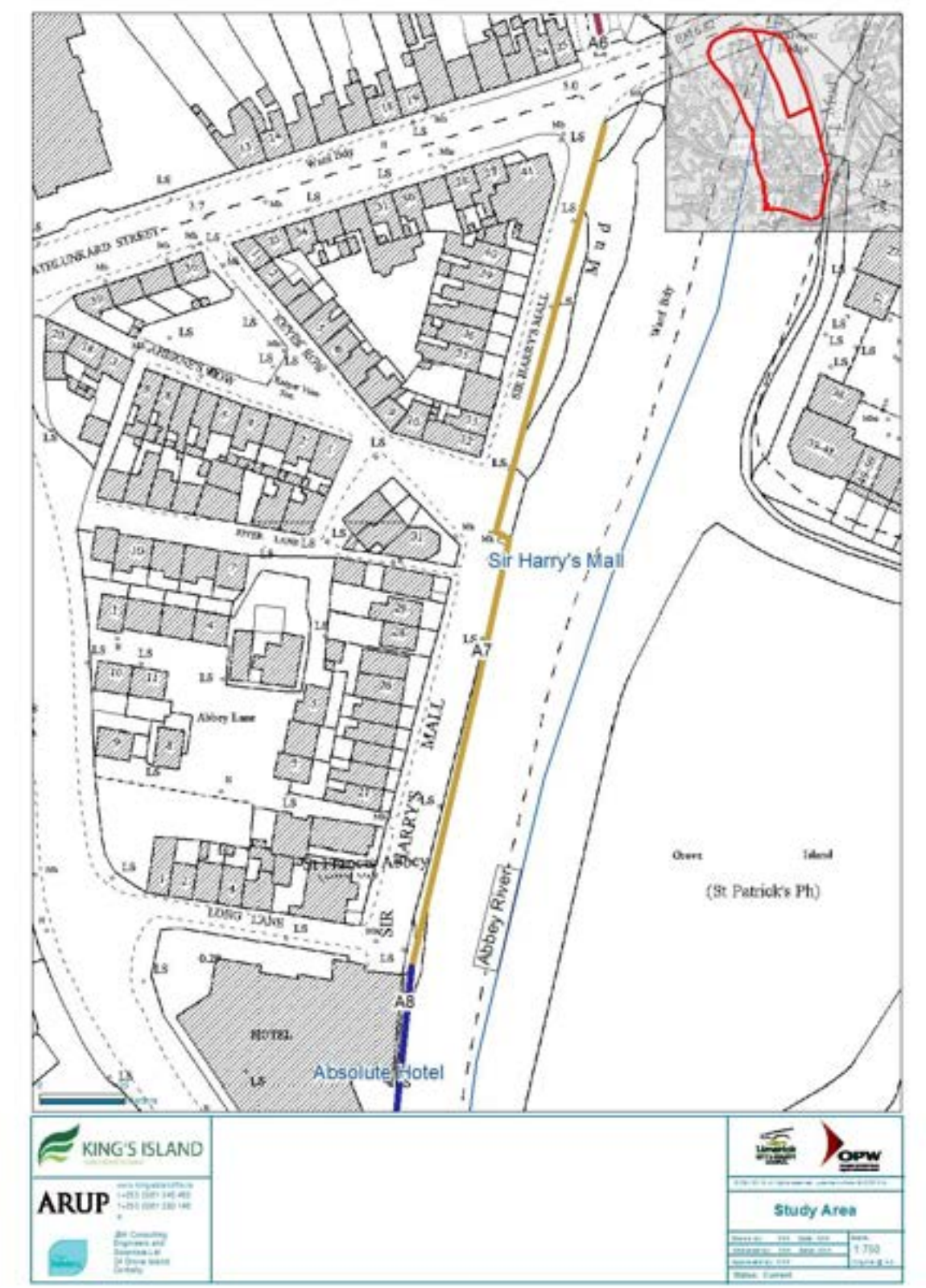


Figure 5-14: Overview of Area A7

5.7.1 Current Situation (Engineering Chainage Ch.2+614 to 2+830)

The area from O'Dwyer's Bridge to the Absolute Hotel forms part of the longer length of Harry's Mall but forms a discrete area due to the presence of an existing flood defence wall running between the hotel walkway and the bridge (see Figure 5-14). The wall was constructed approximately 15 years ago (see Figure 5-15). It varies in height from 4.68mOD up to approximately 6mOD at the bridge. Unfortunately, the majority of the length of wall does not provide the required FDL.

Figure 5-15: Looking southwards along Sir Harry's Mall

Although design drawings for the wall were provided by Limerick City Council, as-builts were not available. Accordingly, it became necessary to undertake intrusive investigations of the existing wall to confirm its construction form. This work was undertaken in August 2017, and the results confirmed that the wall, in its current form, could not be relied upon in an extreme flood event.

5.7.2 Constraints

- Avoidance of the SAC, which has been assumed to border the existing quay wall on the river side.
- Proximity to properties and restriction of river views, although it should be noted that views are currently limited by the height of the existing wall.
- Unknown design standard for the existing wall.
- The property ownership map indicates that the land area under consideration here is classified as unregistered public realm ownership.
- Presence of Japanese Knotweed on riverside of wall, which is being addressed through treatment cycle.
- The possible presence of archaeological features in this area.

5.7.3 Potential Measure(s)

5.7.3.1 Raising existing wall

To provide the FDL, the existing wall would need to be significantly remediated, including strengthening and raising by a maximum height of 0.42m. Along much of the length, this will result in a wall in excess of 1.25m above the existing road level. It is proposed to raise the existing footpath and widen to 2m, where it runs alongside the wall to the north of the Absolute Hotel, to maintain views to the river for pedestrians. A railing will provide protection from the road. Alternatively, a stepped access to/from Sir Harrys Mall can be provided given the one-way traffic system which will allow the road width adjacent to be reduced locally.

5.7.4 Environmental Issues

Key environmental issues were considered for each of the Engineering Alternative Options at this location. The Proposed Option i.e. raising the height of the wall is the least environmentally constrained option and hence preferred from an environmental perspective. The key environmental issues at this location are discussed below.

5.7.4.1 Ecological Considerations -Supporting the objective of the Habitats and Birds Directive

The main operational impact resulting from the proposed flood defence measure is the spread of invasive species, present along the river side of the existing wall.

There is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter.

5.7.4.2 Avoid damages to, and where possible enhance the flora and fauna

During the construction of the flood defence wall, riparian vegetation and trees may need to be removed, which will result in a loss of riparian habitat that could provide bird nesting and bat roosting potential. There is also potential for a negative impact on water quality and sediment release to the River Abbey, disturbance to species at a local level and the spread of invasive species, namely Japanese Knotweed, Himalayan Balsam, during the course of the works.

5.7.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.7.4.4 Visual Amenity

Residents of Sir Harry's Mall will experience slight visual impacts from the proposed raising of the wall which will be raised by approximately 0.42m in height and cause an obstruction of easterly views towards across Abbey River towards the tree covered area on the southwestern corner of Grove Island.

5.7.4.5 Archaeology & Cultural Heritage

The existing wall for proposed height extension is within an area referred to as a “zone of notification” which incorporates monuments that may be scheduled for inclusion in the next issue of the statutory “Record of Monuments and Places”. The zones do not define the exact extent of the monuments but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004). Consultation with National Monuments Service during the EIAR will be required for works in this area.

5.7.4.6 Construction Issues

The construction of the wall, will have to be carried out within a constrained corridor in-between the Sir Harry's Mall and the river edge. Due to the width constraints and close proximity to the residential properties Sir Harry's Mall there will be localised short-term effects on noise and air for residents. Increased traffic movements will be experienced by the local residents during construction of the wall.

5.7.5 Costs

The baseline construction costs for the direct defence measure in Area A7 is estimated at €441,304.

5.7.6 Climate Change Adaptability

While the existing wall is being raised to provide protection to the current scenario, it is unlikely that the ‘retro-fit’ solution proposed will allow for future raising to account for climate change as all technical analysis has shown that the existing wall cannot cater for the extra height, even with retro-fit works proposed. Providing a flood defence to a future level of +5.6mOD is likely to require full replacement of the wall. This is not being assessed any further under this contract.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-7.

Table 5-7: Area A7 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Wall raising work (RC Wall)	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase wall height).	No	No	The RC wall is to be to current level (+5.1mOD malin) raised using existing foundation. Foundation not designed to adapt to MRFS. Will need be re-examined at a future flood defence cost, new RC wall will likely be necessary.	High- the remaining risk is potential spill over or overtopping in the MRFS. Significant risk to life may be present in the area due to high velocity and depth of flooding. May require off areas and local evacuation plans for public buildings.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase wall height).	No	No		

5.8 Area A8 - Absolute Hotel and Boardwalk

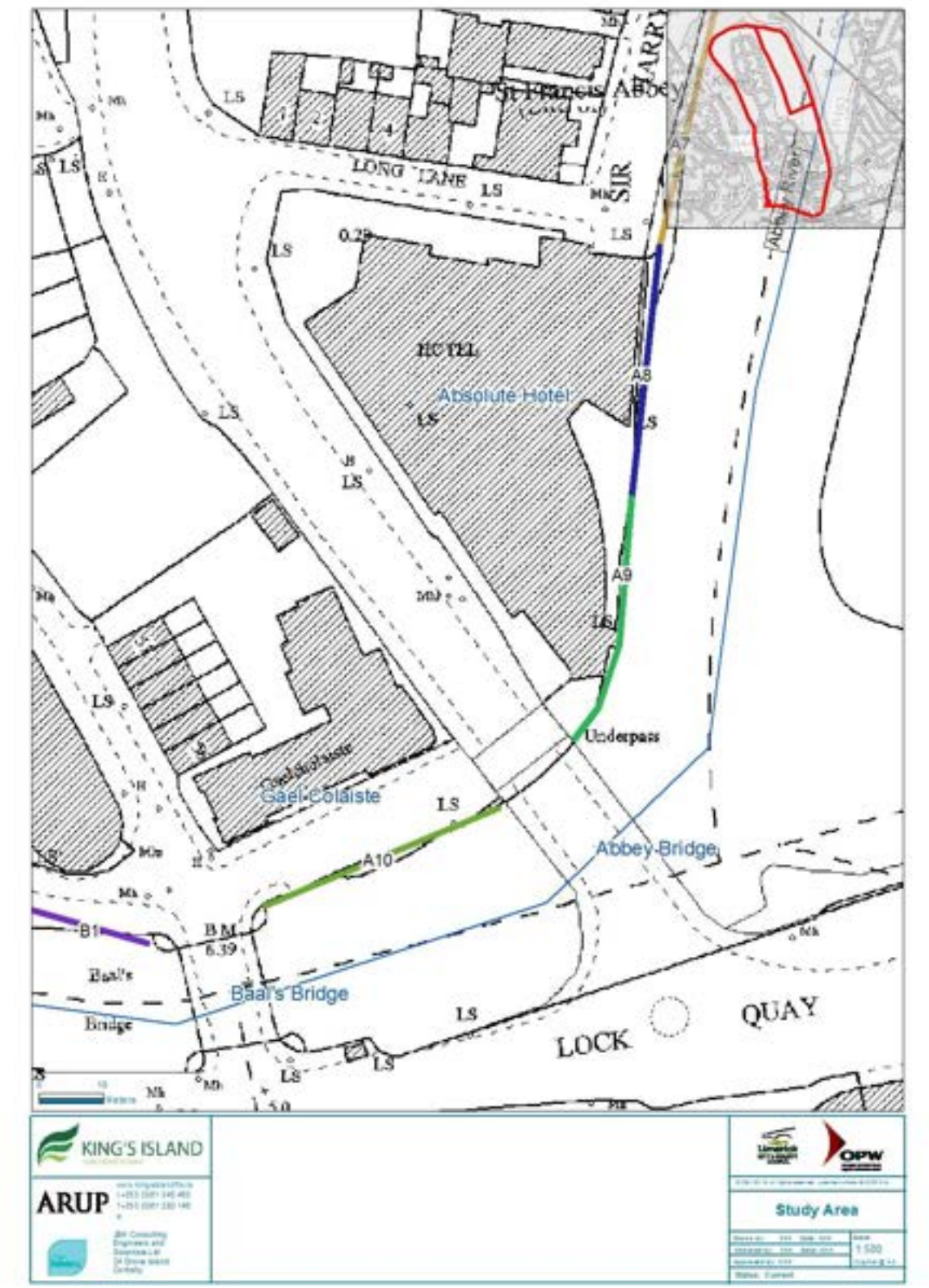


Figure 5-16: Overview of Areas A8, A9 and A10

5.8.1 Current Situation (Engineering Chainage Ch.2+830 to 2+880)

This area of Sir Harry's Mall consists of the length of river bank behind the Absolute Hotel (see Figure 5-16). The rear wall of the hotel forms the river bank and has a cantilevered boardwalk running across its length at a height of 5.1mOD. The boardwalk is connected to the pedestrian footpaths at either end by ramped accessways. To the north, the ramp also ties into the wall of Sir Harry's Mall and to the south the ramp slopes down to allow pedestrian access to the by-pass below Abbey Bridge.

The design finished floor level of the hotel is 3.58mOD at the lowest point, with most of the ground floor at 5.05mOD, as per the as built drawings provided by the hotel management. These drawings show 5 vents or windows on the river side adjacent to the boardwalk. The level of these opes is not indicated but a visual inspection suggests that all of them are above the design flood level and will not require remediation.

Figure 5-17: Boardwalk from opposite bank and looking downstream

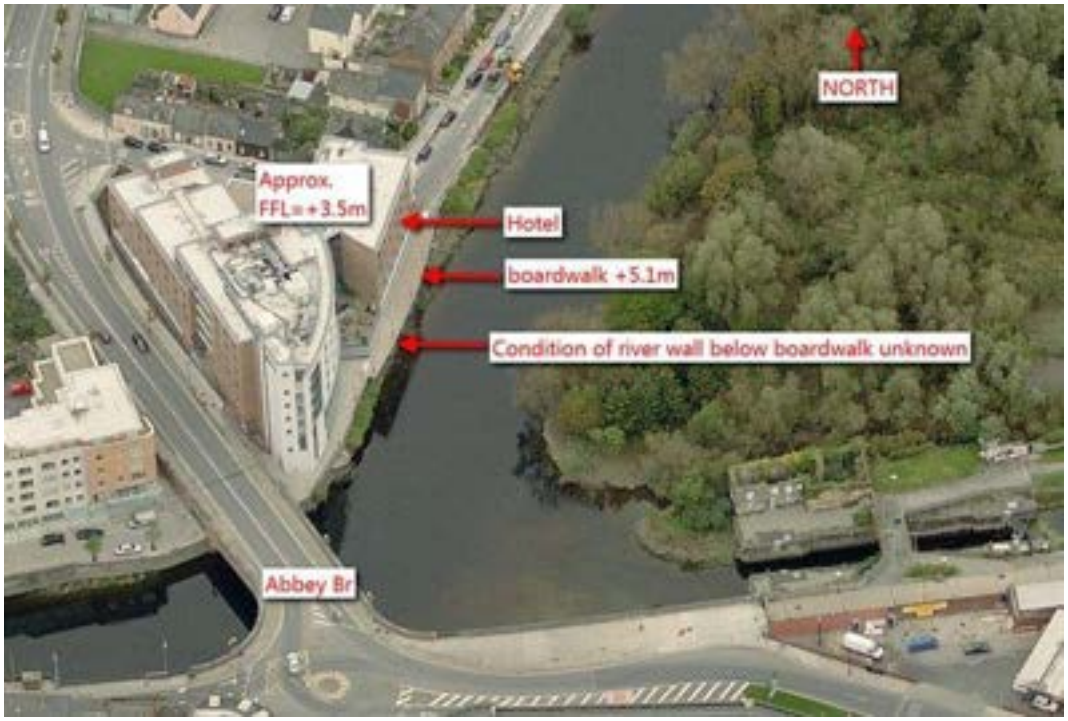


Figure 5-18: Absolute Hotel Location

5.8.2 Constraints

- Avoidance of the SAC which has been assumed to border the existing quay wall alignment;
- The property ownership map indicates that the hotel and boardwalk are classified as being in private ownership;

- The presence of archaeological features in this area. A number of features were uncovered during the construction of the hotel with an old burial ground (LI005-017177) close to the Abbey Bridge
- Invasive species are present on the river bank below the boardwalk.

5.8.3 Potential Measure(s)

5.8.3.1 "Do Nothing"

Currently the defence level provided by the access ramps and supporting walls is 5.1mOD, tying in with the boardwalk which meets the FDL on the Abbey river. Visual inspection and review of the as-built drawings indicates that no further works are required in this location.

There are no environmental or cost implications for a "do nothing" approach.

5.8.4 Climate Change Adaptability

The logistics of raising the ramps by a further 0.5m will require additional design considerations in relation to slope gradients and maintaining sufficient circulation space, and should be considered in the future.

Assessment for IPP has only been undertaken to the 5.1mOD level, so should be reassessed for climate change.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-8.

Table 5-8: Area A8 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Hotel Boardwalk IPP -Raising of Ramps	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase wall height).	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points.	Medium - limited potential for highway drainage to adapt.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase wall height).	No	Limited	Ramps raised at the two access points to the boardwalk to meet design flood defence level of +5.1mOD Malin. Significant works would be required to raise further to 5.6m OD Malin.at future flood defence cost. An additional flood defence measure and/or IPP (gate or demountable barrier) will be required to meet HEFS.	Medium - In the MRFS the freeboard is no longer present. Limited ability to raise ground level further, technically difficult and potentially not viable Additional measures possible at future defence cost. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Erosion Ground Stability	High	Monitoring, inspection, maintenance.	No	Limited		

5.9 Area A9 - South of Absolute Hotel Boardwalk to Abbey Bridge

5.9.1 Current Situation (Engineering Chainage Ch.2+880 to 2+920)

Area A9 spans the short length of wall between the end of the boardwalk and Abbey Bridge (see Figure 5-16). The area behind the wall is a semi-enclosed pedestrian walkway, with access from the fire exit of the Absolute Hotel, an underpass below the Abbey Bridge and stepped access down from Island Road. The wall crest is currently at approximately 4.75mOD, and the parapet is in a fair to poor state of repair, with open joints visible.

Figure 5-19: Looking from upstream from Abbey Bridge, and the underpass

5.9.2 Constraints

- Avoidance of the SAC which has been assumed to border the existing quay wall alignment.
- The property ownership map indicates that the land area under consideration here is classified as unregistered public realm ownership.
- Presence of Japanese Knotweed on riverside of wall, which is progressing through a treatment cycle.
- The presence of archaeological features in the area between the two bridges.

5.9.3 Proposed Measure(s)

5.9.3.1 Direct defences

As the existing wall is below the design flood defence level, and the condition of the parapet is only fair, with condition of the quay wall unknown, the proposed flood defence option consists of replacing the full length of the existing parapet wall with a reinforced concrete wall. Cleaning and repointing of the existing masonry river wall will also be carried out.

Due to the limited space available behind the river wall (approx. 2m between the existing wall and the hotel building at the nearest point), it is proposed to support the new RC wall on piled foundations through the existing wall (see Figure 5-20). The maximum wall height in this area will be 1.4m above ground level. Pavement re-grading works are not feasible due to the underpass. Therefore, it is proposed to accept the loss of view to the river in this short and discrete length.

It is likely that some in-channel works will be required at this location, either in the form of a barge or other form of work platform, which could be in the form of temporary rock fill causeway along the face of the existing quay wall. The latter would require lamprey surveys to assess the impact on habitat, assessment on the navigation passage through Baals Bridge and impacts on the wider SAC. There are significant issues with constructing a rockfill platform in the river and for costing purposes, it has been assumed that a piled platform is provided. The Contractor's plant could be placed via a crane located on the Abbey Bridge. This would be subject to the Contractor's proposed method of working being approved by the relevant authorities including Inland Fisheries Ireland, DAU and LCCC. The temporary causeway would have a crest width of approximately 4m, and side slopes of approx. 1V:2H. The causeway would be deconstructed on completion of the Works and the channel reinstated to its pre-construction condition.

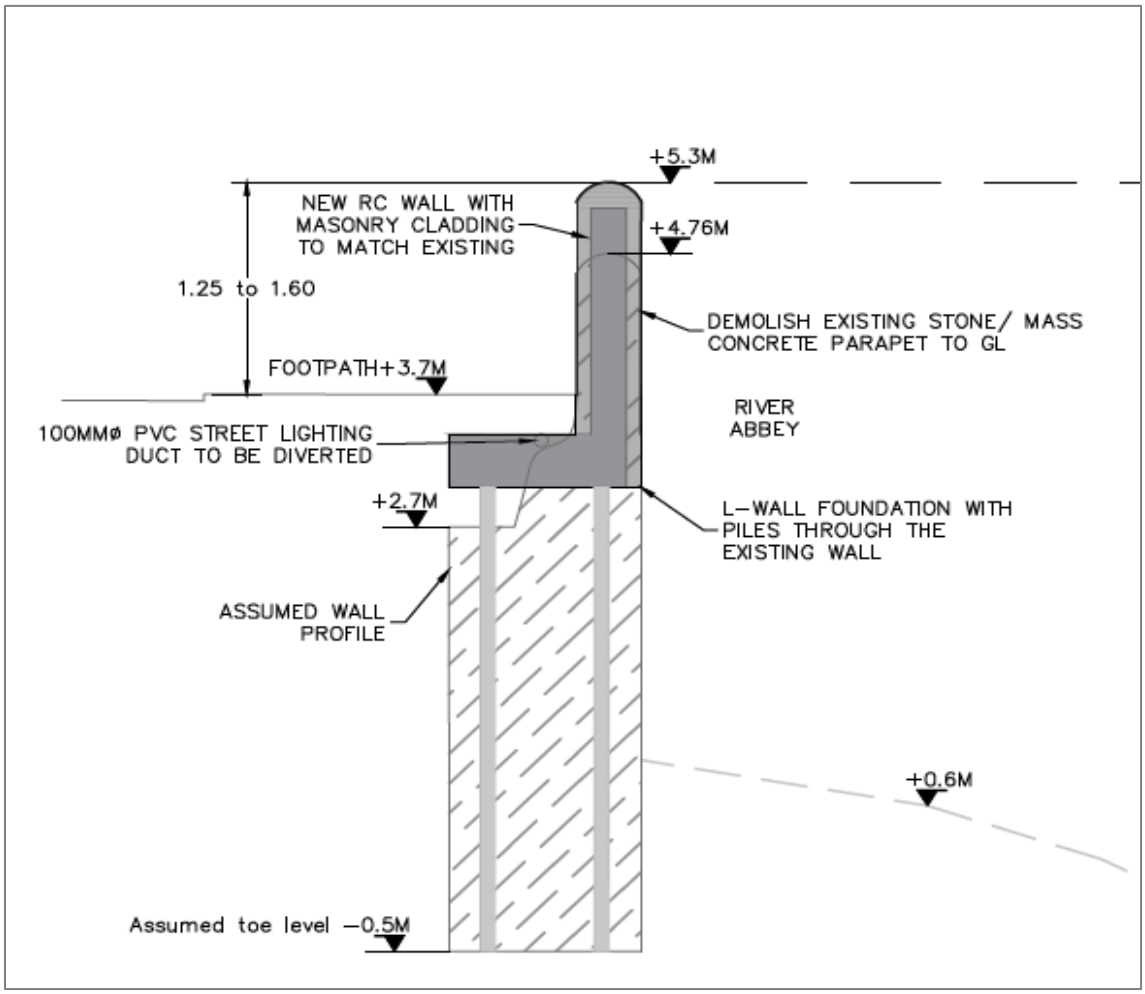


Figure 5-20 - Typical section through piled concrete wall

5.9.4 Environmental Issues

Key environmental issues were considered for each of the Engineering Alternative Options at this location. An Alternative option of a new RC wall set back from the existing parapet would be preferred from an environmental perspective however there is insufficient space for this option to be built. The Proposed Option i.e. replacing the full length of the existing parapet wall with a reinforced concrete wall will require instream works. The key environmental issues at this location are discussed below.

5.9.4.1 Ecological Considerations -Supporting the objective of the Habitats and Birds Directive

The main operational impact resulting from the proposed flood defence measure is the spread of invasive species, present along the river side of the existing wall, namely Japanese knotweed.

As instream works are anticipated in this area, there is potential for physical disturbance of the SAC and its qualifying interests. Instream works may result in disturbance to fisheries and loss of lamprey habitat, in particular the soft sediments at the channel margins. There is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter. The in-stream works will be restricted to between April to September inclusive and agreement will need to be sought from Inland Fisheries Ireland.

5.9.4.2 Avoid damages to, and where possible enhance the flora and fauna

There is the potential for a negative impact on water quality and sediment release to the River Abbey, disturbance to species at a local level and the spread of invasive species, namely Japanese Knotweed, during the works.

5.9.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. Instream works during the construction phase have the potential to negatively impact on fisheries and may result in the loss of lamprey habitat.

The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.9.4.4 Visual Amenity

Users of the river side walkway experience slight visual impacts from the proposed raising of the wall which will be raised by approximately 0.35m in height from 1.25m to 1.60m and cause an obstruction of easterly views towards across Abbey River towards the tree covered area on the southwestern corner of Grove Island and towards Canal Bridge.

5.9.4.5 Archaeology & Cultural Heritage

The existing wall to be raised, lies within an area referred to as a “zone of notification” which incorporates monuments that may be scheduled for inclusion in the next issue of the statutory “Record of Monuments and Places”. The zones do not define the exact extent of the monuments but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004). Consultation with National Monuments Service during the EIAR will be required for works in this area.

Navigation of sailing vessels through Baal's Bridge is particularly challenging due to the currents around the bend and the limited tidal window at the moment. Addition of temporary works in the river could result in the temporary closure of the Abbey River to navigation, which has caused a negative reaction from boat users previously.

5.9.4.6 Construction Issues

The construction of the wall, will have to be carried out within a constrained corridor in-between the Absolute Hotel and the river edge. Due to the width constraints and proximity to the hotel there will be localised short-term effects on noise and air for residents.

5.9.5 Costs

The baseline construction costs for the direct defence measure in Area A9 is estimated at €413,025.

5.9.6 Climate Change Adaptability

The defence option in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario. Further raising of the wall to 5.6mOD may be possible in the future, but the local scheme will need to tie in with protection provided at the Absolute Hotel.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-9.

Table 5-9: Area A9 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
RC Wall South of Boardwalk	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation to ensure adaptability	Yes	Yes	RC Wall foundation will be designed for the +5.6 OD Malin, which will allow for wall to be raised at a future date. Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertake. May require refurbishment or rebuilding of sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	High	Monitoring, inspection, maintenance.				
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability				

5.10 Area A10 - Abbey Bridge to Baal's Bridge

5.10.1 Current Situation (Engineering Chainage Ch.2+920 to 2+980)

The length of river bank from Abbey Bridge to Baal's Bridge (see Figure 5-16) has an existing quay wall along its length. Approximately half of this wall is in excess of the 5.1mOD FDL, whist the remaining length (approximately 24m) is below this level, at approximately 4.7mOD. None of the wall provides the recommended guarding height of between 1.1m and 1.2m from ground level and the site investigation indicates the wall and foundations are of insufficient strength to function as a flood defence. The Gael Colaiste is located on the landside of the road and has a finished floor level of approximately 4.7mOD.

Figure 5-21: Abbey Bridge and Gael Colaiste

5.10.2 Constraints

- Avoidance of the SAC which has been assumed to border the existing quay wall alignment.
- The property ownership map indicates that the land area under consideration here is classified as unregistered public realm ownership.
- The presence of archaeological features in the area between the two bridges.

5.10.3 Potential Measures

5.10.3.1 Direct defences

It is proposed to replace the entire length of existing masonry parapet with a new reinforced concrete wall to a maximum height of 1.6m above ground level, which will give the design flood standard of protection. This new parapet will be a maximum of 0.6m higher than the existing wall level. As a result, there will be some loss of visual amenity once the new wall is constructed. Since this length of wall is a cul-de-sac adjacent to the underpass, which is closed at night for security, and there is no defined footway on the river side of the road, it is proposed to accept the localised loss of view to the river in this area.

The new wall be supported by a mass concrete foundation. Cleaning and repointing of the existing masonry river wall will also be carried out.

5.10.4 Environmental Issues

Key environmental issues were considered for each of the Engineering Alternative Options at this location. The Proposed Option i.e. replacing the full length of the existing parapet wall with a reinforced concrete wall will not require instream works other than repointing of existing wall and is the preferred option from an environmental perspective. The key environmental issues at this location are discussed below.

5.10.4.1 Ecological Considerations --Supporting the objective of the Habitats and Birds Directive

It is presumed that these works will be conducted from the landward site of the quays and therefore, no physical disturbance of the SAC will take place. If works are to take place from the river side of the quays, there is potential for physical disturbance to the SAC, fisheries and lamprey habitat.

There is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter.

5.10.4.2 Avoid damages to, and where possible enhance the flora and fauna

There is the potential for a negative impact on water quality and sediment release to the River Abbey during the course of the works.

5.10.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. If works are to take place from the river side of the quays, there is potential for physical disturbance to fisheries and lamprey habitat. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

5.10.4.4 Visual Amenity

Users of the river side walkway experience slight visual impacts from the proposed raising of the wall which will be raised by approximately 0.35m in height from 1.25m to 1.60m and cause an obstruction of easterly views towards across Abbey River towards Loch Quay.

5.10.4.5 Archaeology & Cultural Heritage

The wall to be raised lies within an area referred to as a “zone of notification” which incorporates monuments that may be scheduled for inclusion in the next issue of the statutory “Record of Monuments and Places”. The zones do not define the exact extent of the monuments, but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004). Consultation with National Monuments Service during the EIAR will be required for works in this area.

5.10.4.6 Construction Issues

The construction of the wall, will have to be carried out within a constrained corridor in-between the Gael Coláiste and the river edge. Due to the width constraints and close proximity to the school, there will be localised short-term effects on noise and air for pupils and teachers. Traffic management will also be required and may involve closing the road to vehicles.

5.10.5 Costs

The baseline construction costs for the direct defence measures in Area A10 is estimated at €187,949.

5.10.6 Climate Change Adaptability

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 5-10.

Table 5-10: Area A10 Climate Change Adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
RC Wall	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase wall height).	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall. It should be noted that providing a flood defence to a future level of +5.6mOD Malin to account for climate change may require a replacement flood defence wall or alternative approach. Visual constraints to raised wall height may further limit viability of adaptation	Medium - limited ability to raise wall crest and retain freeboard allowance. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase wall height).	Limited	Limited		

6 Review of Measures for Flood Cell B

6.1 Area B1 - George's Quay East

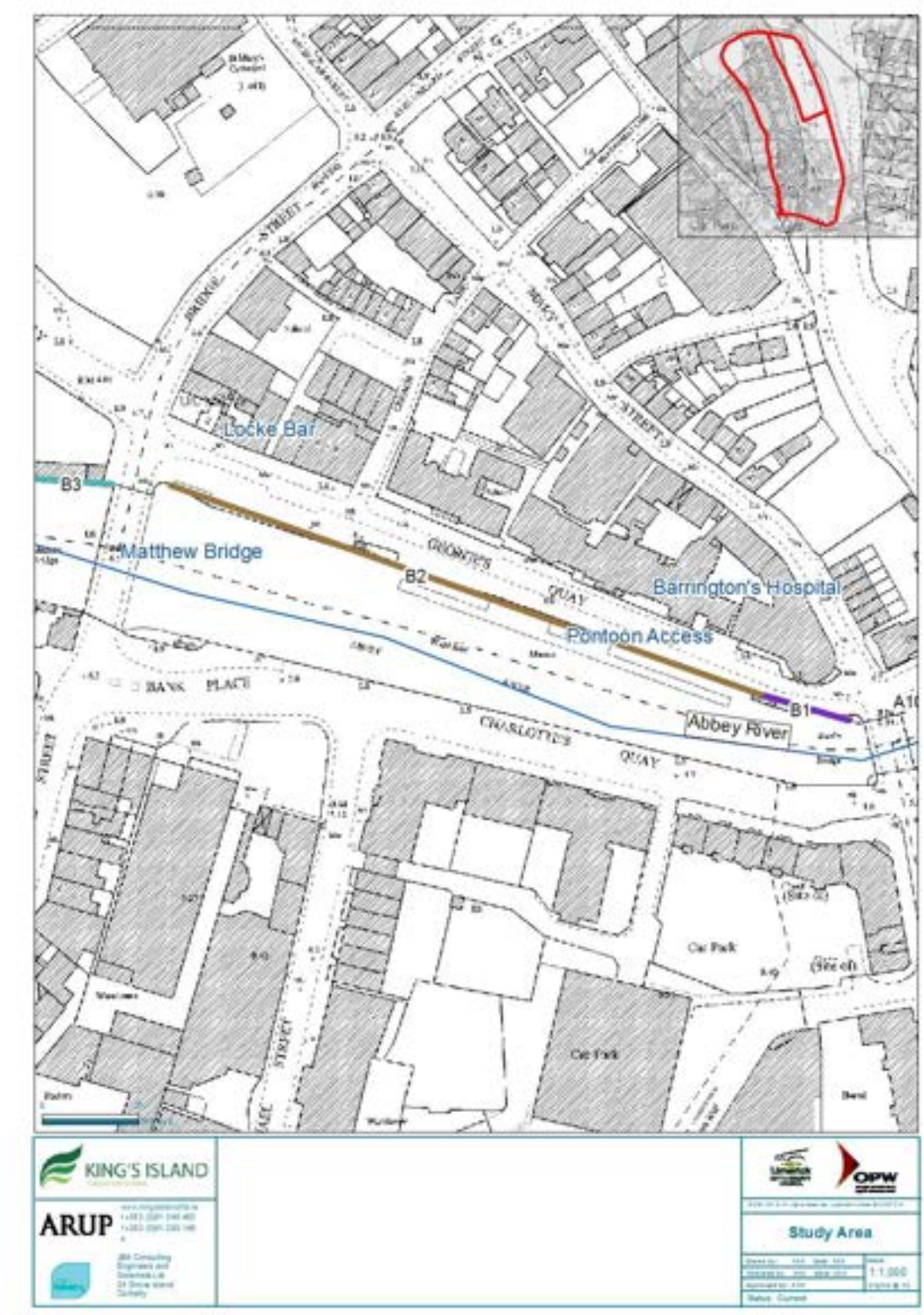
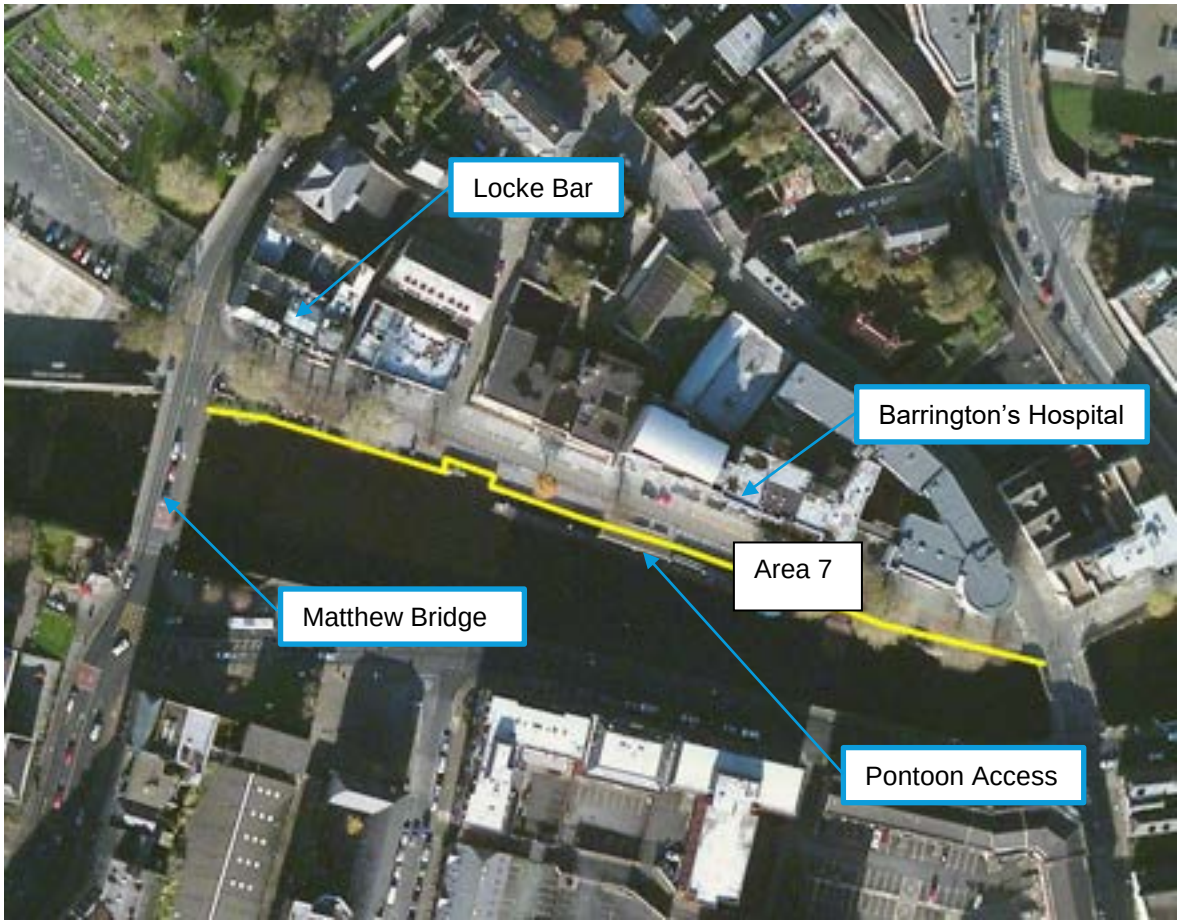


Figure 6-1: Overview of Areas B1 and B2

6.1.1 Current Situation (Engineering Chainage Ch.2+980 to 3+010)

This area is the eastern most portion of George's Quay and covers a distance of 24m from Baal's Bridge. The parapet wall in this location is above 5.3mOD (so includes the higher level of freeboard), but does not provide the recommended guarding height of between 1.1m and 1.2m above ground level.

Figure 6-2: Overview Map



6.1.2 Constraints

- The presence of an unclassified Mill (L1005-017069).
- The property ownership map indicates that the land area under consideration here is classified as unregistered public realm ownership.
- Avoidance of the SAC, which has been assumed to border the existing quay wall alignment;
- Maintaining the existing vehicle and pedestrian access along George's Quay, except for potential temporary closure during construction;
- Avoidance of utilities except at the pontoon access location.
- Maintaining visual amenity and public realm, including mature trees.

6.1.3 Potential Measure(s)

In Area B1, the existing wall meets the required flood defence level, so the only measure needed for this 24m length is raising the existing parapet by between 400 and 500mm to ensure a safe guarding height is provided (see Figure 6-4). The will be achieved by removing the existing rounded coping stone, building up the wall with stone to match the existing and replacing the coping stone. Cleaning and repointing of the existing masonry river wall will also be carried out.

6.1.4 Environmental Issues

The potential measure of raising the existing parapet wall will not require instream works other than repointing of existing wall and is the preferred option from an environmental perspective. The key environmental issues at this location are discussed below.

6.1.4.1 Ecological Considerations - Supporting the objective of the Habitats and Birds Directive

It is presumed that these works will be conducted from the landward site of the quays and therefore, no physical disturbance of the SAC will take place. If works are to take place from the river side of the quays, there is potential for physical disturbance to the SAC, fisheries and lamprey habitat.

There is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter.

6.1.4.2 Avoid damages to, and where possible enhance the flora and fauna

There is the potential for a negative impact on water quality and sediment release to the River Abbey during the course of the works.

6.1.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. If works are to take place from the river side of the quays, there is potential for physical disturbance to fisheries and lamprey habitat. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

6.1.4.4 Archaeology & Cultural Heritage

The wall to be raised lies within an area referred to as a “zone of notification” which incorporates monuments that may be scheduled for inclusion in the next issue of the statutory “Record of Monuments and Places”. The zones do not define the exact extent of the monuments but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004). Consultation with National Monuments Service during the EIAR will be required for works in this area.

6.1.4.5 Construction Issues

The construction of the wall, will have to be carried out within a constrained corridor in-between a footpath, an outdoor eating area with mature trees and the river edge. Due to the width constraints, there will be localised short-term effects on noise and air for pedestrians on the footpath.

6.1.4.6 Humans

The raising of the height of the wall will have a negative visual impact for the public.

6.1.5 Costs

The baseline construction cost for raising the existing direct defence in Area B1 is €20,000.

6.1.6 Climate Change Adaptability

The direct defences in this location will be designed and constructed to provide protection to the current scenario only. In the future, it will be necessary to look again at the design standard of the wall and defences before further raising is considered.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 6-1.

Table 6-1: Area B1 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Wall raising work (RC Wall)	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase wall height).	No	No	The RC wall is to be to current level (+5.1mOD Malin) raised using existing foundation. Foundation not designed to adapt to MRFS. Will need be re-examined at a future flood defence cost, new RC wall will likely be necessary.	High- the remaining risk includes no freeboard, potential spill over or overtopping in the MRFS. Significant risk to life may be present in the area due to high velocity and depth of flooding. May require off areas and local evacuation plans for public buildings.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase wall height).	No	No		

6.2 Area B2 - George's Quay West

6.2.1 Current Situation (Engineering Chainage 3+010 to Ch.3+220)

Running from the end of Area B1 to Matthews Bridge, this area is the most commercially sensitive of all areas at flood risk in the Scheme. It includes some key buildings such as the Locke bar, Barrington's Hospital, Azur Restaurant and LIT. The finished floor level at Barrington's Hospital is 4.1mOD, whilst the levels of the neighbouring buildings are higher (5.1mOD and 4.7mOD to downstream and upstream sides respectively). Although a proportion of the wall is above the design flood level of 5.1mOD, the full length of this parapet wall is of insufficient strength to withstand the design flood load.

Along this length of quay, there are three openings which provide viewing points from the Locke Bar and neighbouring buildings. A fourth opening through the wall on George's Quay provides access to the pontoon opposite Barrington's Hospital.

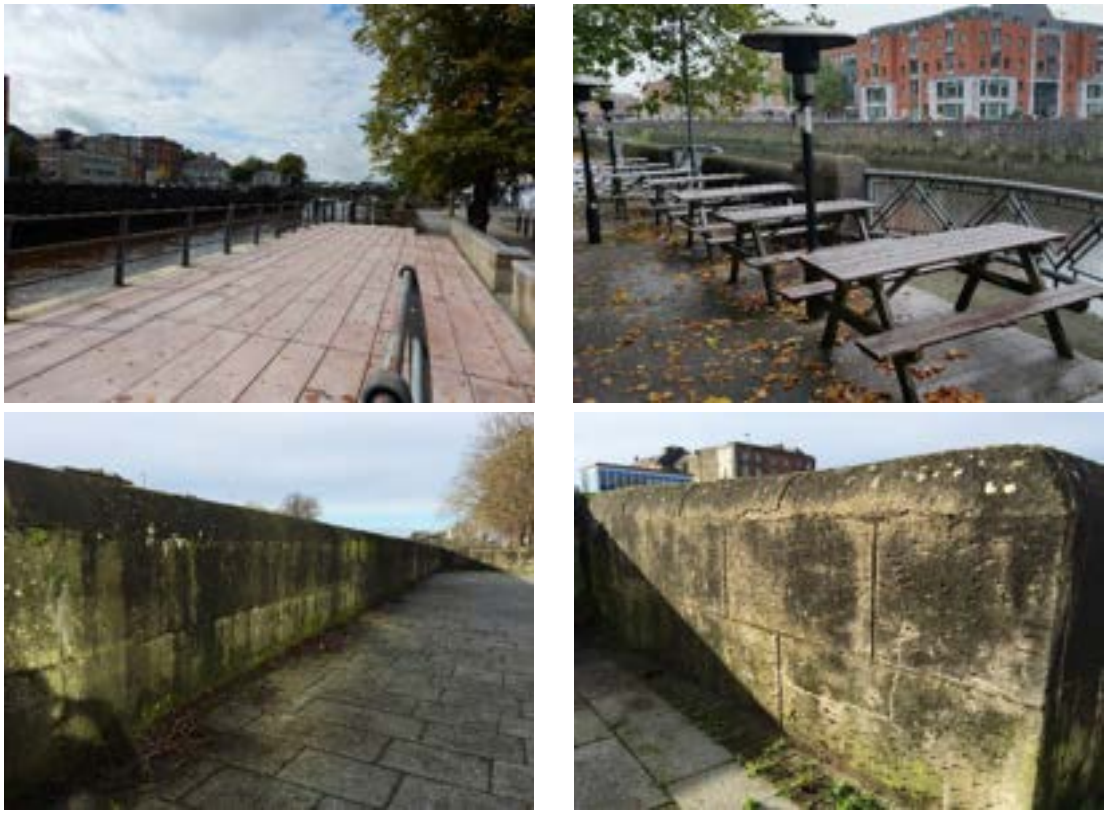


Figure 6-3: George's Quay pontoon, viewing points at Locke Bar and mass concrete wall

6.2.2 Constraints

- The presence of an unclassified Mill (L1005-017069).
- The property ownership map indicates that the land area under consideration here is classified as unregistered public realm ownership.
- Avoidance of the SAC which has been assumed to border the existing quay wall alignment;
- Maintaining the existing vehicle and pedestrian access along George's Quay, except for potential temporary closure during construction;
- Retaining connectivity to the river for pedestrians and boat users;
- Retain visual amenity and public realm.
- There are a number of utilities, including storm water outfalls, a watermain, sewer and electrical cables through or parallel to the wall.
- Maintaining the high townscape quality created by the presence of mature trees along river edge.

6.2.3 Potential Measure(s)

6.2.3.1 Direct defences

Following wall investigations work carried out in August 2017, it has been established that sections of the existing wall are of insufficient strength to function as a flood defence, regardless of current crest height. It is therefore proposed to replace the full length with a new reinforced concrete wall built on mass concrete foundations behind the existing wall. Providing safe guarding height of between 1.1m and 1.2m above ground level means the top of the wall will be up to 250mm higher than the existing wall. Cleaning and repointing of the existing masonry river wall will also be carried out.

In order to maintain, and as far as possible, improve connectivity with the river, it is proposed to alternate sections of glass panels with stone clad parapet walls at approximately 20m intervals, as shown in Figure 6-4. Pontoon access would be maintained through steps up and over the new wall, which would also incorporate glass panels.

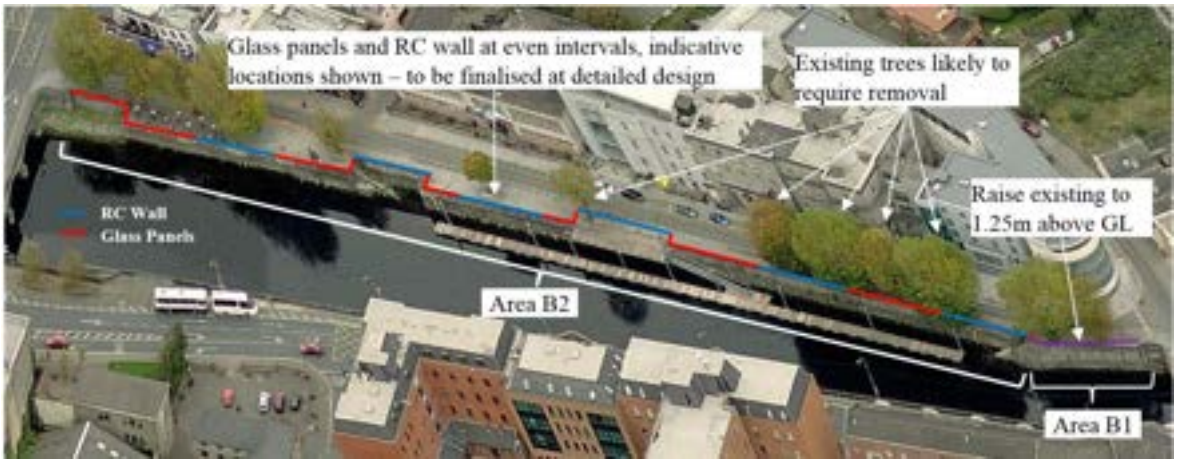


Figure 6-4: Direct defences at Area B1 and B2

6.2.4 Environmental Issues

The key environmental issues at this location are discussed below.

6.2.4.1 Ecological Considerations --Supporting the objective of the Habitats and Birds Directive

It is presumed that these works will be conducted from the landward site of the quays and therefore, no physical disturbance of the SAC will take place. If works are to take place from the river side of the quays, there is potential for physical disturbance to the SAC, fisheries and lamprey habitat.

There is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter.

6.2.4.2 Avoid damages to, and where possible enhance the flora and fauna

There is the potential for a negative impact on water quality and sediment release to the River Abbey during the course of the works.

6.2.4.3 Protect and where possibly enhance fisheries resource

The River Shannon and River Abbey are important rivers for fisheries. The proposed defences will not impact on river flows of the River Shannon or Abbey River or prevent the migration of fish species. If works are to take place from the river side of the quays, there is potential for physical disturbance to fisheries and lamprey habitat. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

6.2.4.4 Visual Amenity

The construction of the foundations for the new RC wall and intermittent glass panels along George's Quay will require removal of many of the existing trees within the footpath.

Five of these trees are mature i.e. in final third of life expectancy, and two are young i.e. in first third of life expectancy. A further eight mature trees at the western end of this area may also have to be removed subject to assessment of the extent of their tree roots in relation to space requirements for proposed wall foundations. The trees currently enhance the streetscape quality of this river edge corridor, they add to the biodiversity of the area and provide shade and shelter for the sitting out areas associated with the cafes at the western end of the Quay. The loss of the trees will result in negative impacts on the townscape quality of this area. Subject to the location of underground services replacement trees may be possible in other positions along the footpath of the Quay. However, the inclusion of glass panelling along the length of the wall will increase connectivity with the river for pedestrians and those in vehicles and is considered an environmental improvement to the area.

6.2.4.5 Archaeology & Cultural Heritage

The proposed glass walls are within an area referred to as a “zone of notification” which incorporates monuments that may be scheduled for inclusion in the next issue of the statutory “Record of Monuments and Places” including an unclassified Mill (L1005-017069). The zones do not define the exact extent of the monuments but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004). Consultation with National Monuments Service during the EIAR will be required for the construction works in this area.

6.2.4.6 Construction Issues

The construction of the walls will have to be carried out within a constrained corridor in-between a footpath, an outdoor eating area with mature trees and the river edge. Due to the width constraints, there will be localised short-term effects on noise and air for pedestrians on the footpath.

6.2.5 Costs

The baseline construction cost for raising the existing direct defence in Area B2 is €1,204,113.

6.2.6 Climate Change Adaptability

The direct defences in this location will be designed for the climate change scenario, but will be constructed to provide protection to the current scenario.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 6-2 .

Table 6-2. Area B2 Climate change adaptability

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
RC Wall	Freeze Thaw	Moderate	Monitoring, inspection, maintenance	Yes	Yes	If required refurbishment or rebuild sections.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	High	Monitoring, inspection, maintenance.	Yes	Yes	RC Wall is set-back. Lower exposure to potential erosion. If required refurbishment or rebuilding of sections.	Medium- the remaining risk includes potential spill over or overtopping under HEFS.
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Only adaptable if in-built capacity measures (resilient foundation) included in original design which will allow for a raised wall crest. The wall will be built to 5.1mODMalin but will be designed for future adaptability with a strong foundation that could withstand future increase of wall crest to 5.6mOD Malin Visual constraints to raised wall height may further limit viability of adaptation, however additional height could be made up of glass panelling in future. If raised once, it will no longer be adaptable for HEFS. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of raised defence crest is limited by sub-soil stability which is uncertain for potential foundation reinforcement.	Medium - limited ability to raise wall crest and retain freeboard allowance. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall. Potential for construction of additional defence limited as minimal areas available and the sub-soil stability is uncertain for potential foundation reinforcement.	

6.3 Area B3 - Potato Market and Civic Buildings

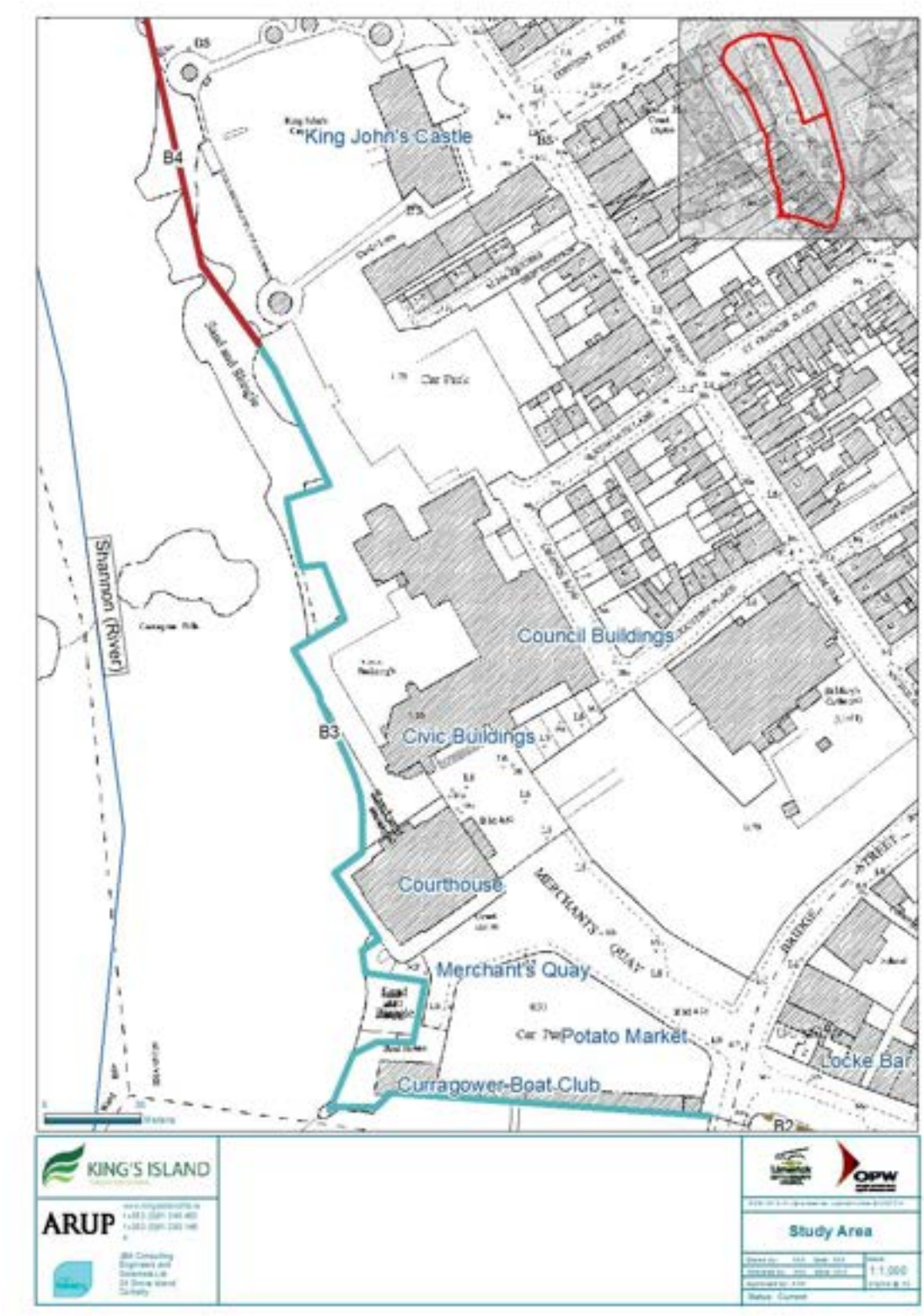


Figure 6-5: Overview of Areas B3 and B4

6.3.1 Current Situation (Engineering Chainage Ch.3+220 to Ch 3+663)

This area covers the Potato Market, access road to the courthouse and City Hall, the Court House, City Hall and civic buildings, Curragower Boat Club and the public amenity land as far north as King John's Castle (see Figure 6-5).

The Courthouse is constructed adjacent to the top of the quay wall and is bordered on the river side by a cantilevered pedestrian boardwalk which overhangs the river. The main entrance to the Courthouse is from the east along Augustine Place. Each of the four exterior walls have between six and nine windows, with sills that are close to the ground (see photograph in Figure 6-6). The Court House has been subject to shallow internal flooding twice in recent years. Predicted depths of flooding in a 0.5% AEP flood would be approximately 0.35m (based on FFL).

Access road to Merchants Quay

Potato Market

Rear of Civic Buildings

Stepped / ramped access to city hall

Court House with cantilevered walkway

Curragower Boat Club

Figure 6-6: Images of Merchants Quay

The City Hall and civic offices are located adjacent to the quay wall and to the north of the courthouse. Although forming one building, there are two distinct floor levels. The City Hall, to the front (landside) of the building is a level of between 5.3 and 5.5mOD, up to 1.5m above external ground levels. The civic buildings to the rear are at a level of approximately 4.1mOD.

The public realm adjacent to the river and surrounding the buildings is as low as 4.0mOD and floods on a regular basis. In a 0.5% AEP flood event, water depths of 0.7m would be expected. The buildings are used for emergency response operations when the city's emergency plan is enacted, so access in a flood situation is deemed to be essential by LCCC.

The Curragower Boat Club is located on the most westerly corner, where the Abbey and Shannon Rivers meet. The office and garage entrances are located on the north side of the building and are accessed from Merchant's Quay.

The Potato Market serves as a pay and display carpark. There is no associated building, but the walls of the market are of historic significance and not strong, or high enough to function as a flood defence. There is pedestrian access from the Potato Market across the mouth of the Abbey River via a footbridge, and also a viewing window out to the river. Vehicular access is from the north, via Bridge Street.

Floor levels of the buildings vary, and are summarised in Figure 6-7 and Table 6-3. In this area, the Design Flood Level is 5.3mOD as the quay is bounded by the Shannon.

Figure 6-7: Finished floor levels and ground levels at Merchant's Quay

Table 6-3: Floor levels at Merchant's Quay

Building	Finished Floor Level (mOD)	Comment
Court House	4.45	Below FDL. 0.5% AEP flood depth 0.35m
Civic Buildings	Approx. 4.19	Below FDL. 0.5% AEP flood depth 0.61m
City Hall	5.3-5.5	Above FDL
Curragower Boat Club	4.22	Below FDL. 0.5% AEP Flood depth 0.58m

6.3.2 Constraints

- Avoidance of the SAC which has been assumed to border the existing quay wall alignment;
- The existing vehicle and pedestrian access is maintained, including to boat club;
- Avoidance of utilities;
- Avoidance of works to the Potato Market (RPS 320) which is a protected structure and subject to conservation and heritage conditions;
- The property ownership map indicates that the road and access to the civic buildings, courthouse, etc. is classified as unregistered public realm ownership. The Potato Market is under a split of public and private ownership and Curragower Boat Club is privately owned. The remaining buildings are on a mixture of LCCC-owned land and public realm areas on LCCC land. The land associated with the Court House and walkway are owned by the OPW;

- The presence of a number of archaeological features in this area including the Quay (LI005-017073), a Battery (LI005-017073), a Medieval House (L1005-017169) and a Mill (L1005-017075);
- The City Hall and Courthouse are listed under the National Inventory of Architectural Heritage (NIAH).
- The masonry quay wall is assumed to be old city wall. There are several masonry arch culverts and service outfalls through the quay walls at various levels.
- Protection of residential and civic views out to the river and river bank. From the weir at Curragower Boat Club to King John's Castle there is no parapet wall, there are areas of single course blockwork;
- The long-term vision for the Potato Market is to create an open area of public realm, including space for open-air concerts. Any scheme must be compatible with this vision;
- The public realm around Merchant's Quay is subject to heavy traffic, both pedestrian and vehicular, so interruption to access during flood events should be minimised.

6.3.3 Potential Measures

There are two potential measures for this area. The first is to provide direct defences along the quayside, which is consistent with measures proposed around the island and ensures a passive flood defence is provided for the flood cell. As the area is a separate flood cell to George's Quay, an alternative measure is to provide IPP for those buildings that require it, accepting flooding of the external areas. Some localised road raising would also be required to provide freeboard against flooding in the George's Quay direction.

6.3.3.1 Direct Defences

The direct defence measures consist of a number of sub-measures which, when considered together, provide flood protection to Merchant's Quay. The sub-measures are illustrated in Figure 6-8 and are summarised as follows:

- Glass flood defence panels along the line of the existing river wall around the courthouse and along the edge of the public realm to the north, tying in to the castle wall. The glass parapet would have a minimum top level of 5.3mOD;
- Replacement of existing cantilevered walkway with a new boardwalk of similar width, designed to support the glass panels (see Figure 6-9);
- Ramp the access road to the Curragower Boat Club between the courthouse and the Potato Market Wall to a maximum height of 5.3mOD, and tie this in to ramped access to the boardwalk. Alternatively, in lieu of the ramped access, the provision of a self-closing flood barrier could be provided, thus minimising impact to the curtilage of the court house. However, this would leave a residual risk of failure and it would be advantageous to also consider road raising at Bridge Street to ensure any flooding would be confined to Merchants Quay in the event of a malfunction of the flood barrier.
- Re-routed pedestrian footpath from outside wall of Potato Market to boardwalk; Strengthen, raise and seal the existing wall around the western perimeter of the Potato Market for the length from the Abbey River to tie in with the ramp;
- Repair and repoint the riverside wall of the Potato Market;
- Remove the cantilevered viewing platform from the Potato Market wall and replace with a glass panel within the existing opening;
- Direct defence at the Sylvester O'Halloran pedestrian bridge via a flood wall, with access steps and raised ramp structure maintaining existing pedestrian movements.
- IPP to be provided to the Curragower Boat Club in the form of a demountable garage door and office door. The current FFL is 4.22mOD Malin, giving a depth of flooding against a barrier of 0.58m in the 0.5% AEP event.

As working space and access around the Courthouse will be limited, in-channel working in this area would be required.

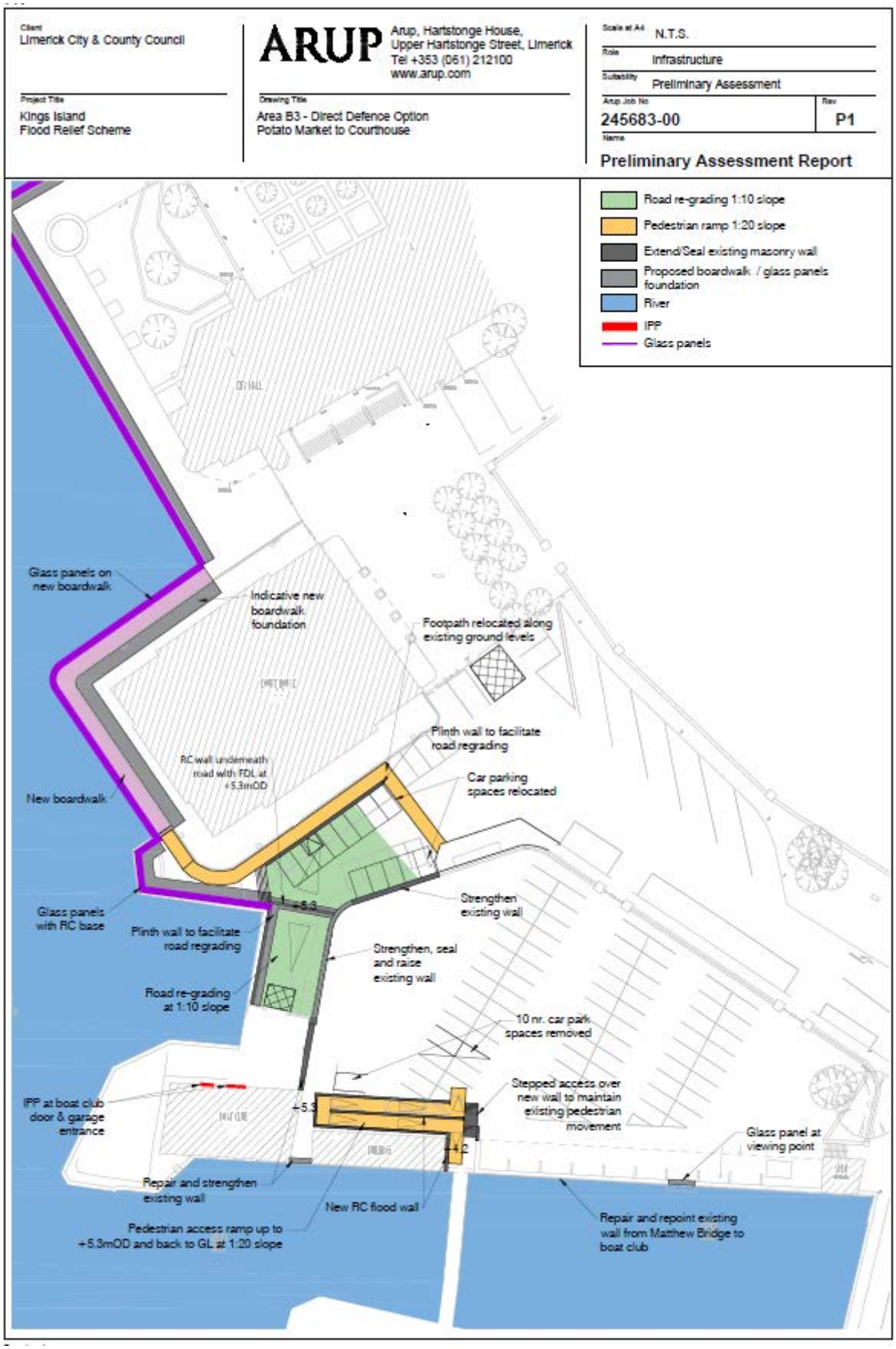


Figure 6-8: Direct defence measure for Area B3

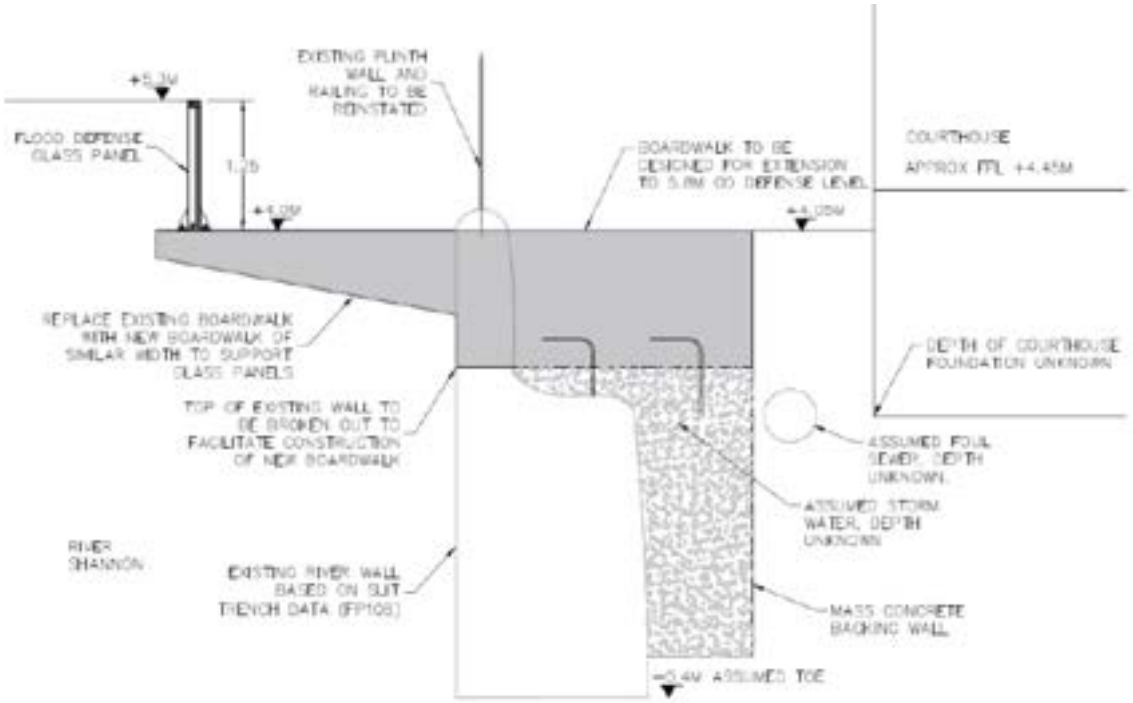


Figure 6-9: Typical section through defence around the Court House

6.3.3.2 Road Raising and Individual Property Protection

The alternative measure for this area is to raise the road levels on the Potato Market access road and parts of the car park west of Bridge Street to 5.3mOD Malin, thus preventing floodwater flowing from west to east (see Figure 6-10). This would ensure that Area B3 remains a discrete flood cell, with full freeboard, but would continue to allow the carpark and public realm around the civic buildings to flood.

Further works as part of this measure would include:

- On the north side of the access road, raising of the existing plinth wall and construction of a new RC wall to replace the existing bollards;
- Construction of a new RC wall within the car park to allow a transition in level within the car park and retain the same parking capacity;
- Sealing of the existing plinth and boundary walls;
- Construction of a plinth will around the tree located in the south-east corner of the car park so that the grading works can be completed.

In conjunction with the proposed road raising, it would be necessary to provide IPP to the Court House and the civic buildings up to a level of 5.3mOD. IPP would include demountable flood barriers, sealing of joints, tanking of walls, removal of vents on walls adjacent to the river and similar flood resistance measures.

As with the direct defence option, the Curragower Boat Club building would still require IPP, in the form of a demountable garage door and office door. The current FFL is 4.22mOD Malin, giving a depth of still water flooding against a barrier of 0.58m in the 0.5% AEP event. Construction of a higher barrier would provide freeboard, and added protection against wave runup, but it is generally not recommended to rely on a demountable barrier when depths of water are in-excess of 0.6m.

It would be necessary to develop an emergency plan for the area, which would provide actions to restrict access to the cantilevered walkway and the rear of the civic buildings and public realm to the north during a flood event. During this time, there would be no access to the Court House or boat club and access to the civic buildings and City Hall would be through the front (landward) doors only. This would require the closure of this access road on the receipt of a surge warning.

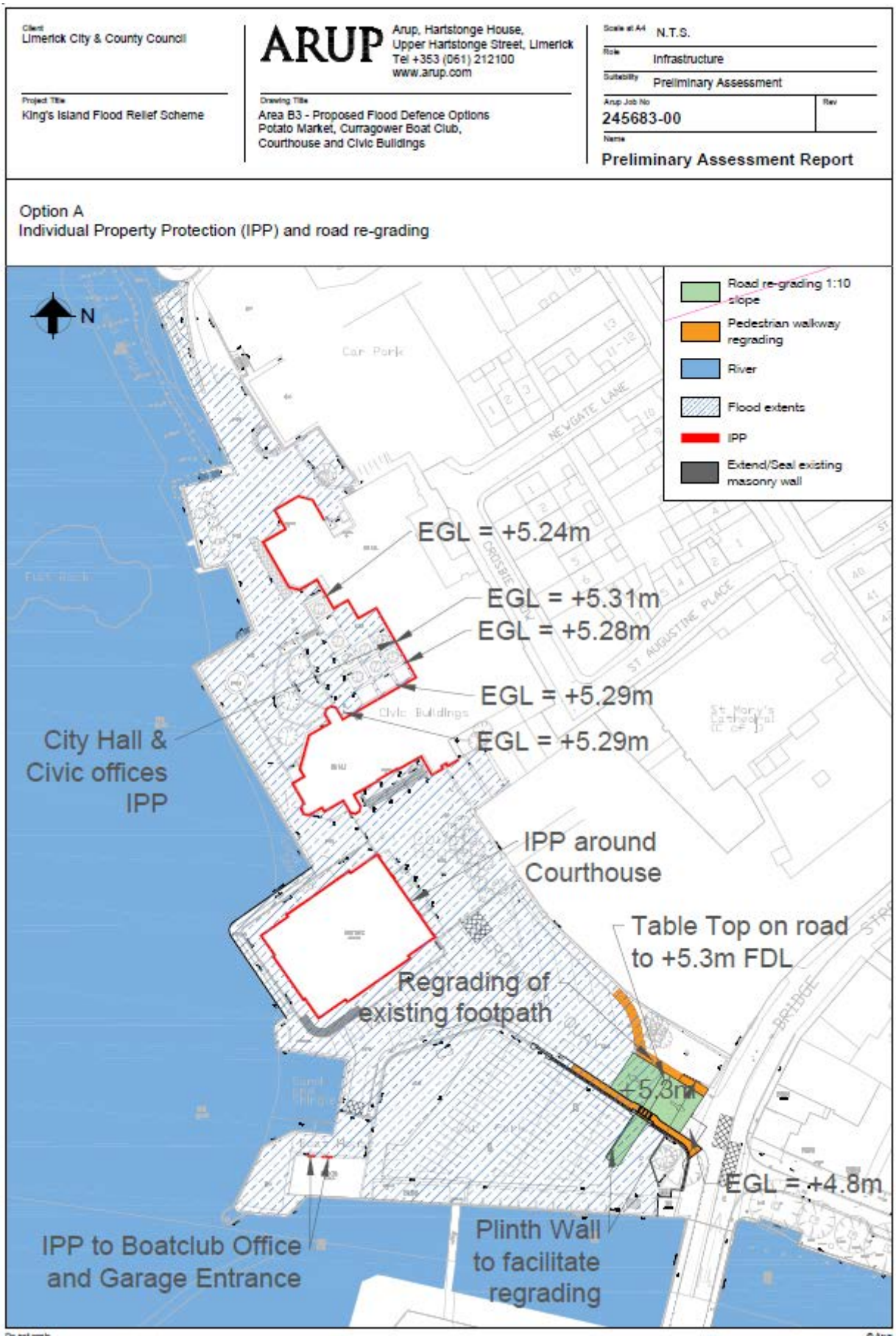


Figure 6-10: Road raising and IPP at Area B3

6.3.4 Environmental Issues

Key environmental issues were considered for each of the alternative measures at this location. Most elements of either measure i.e. Repair of existing walls, sections of new RC walls, individual property protection, glass panels and upgraded road surfaces are preferred measures from an environmental perspective as they do not require instream works. The key environmental issues at this location are discussed below.

6.3.4.1 Ecological Considerations --Supporting the objective of the Habitats and Birds Directive

It is presumed that, where possible, these works will be conducted from the landward site of the quays and therefore, no physical disturbance of the SAC will take place.

However, if direct defences are taken forward as the preferred option, in-channel working will be required around the Courthouse and there is potential for physical disturbance to the SAC, fisheries and lamprey habitat. It is likely that a Contractor will install a working platform within the river channel to undertake the required works to the boardwalk for demolition, strengthening, new walkway, etc. In order that the effect on the riverbed and existing channel species is mitigated, it is envisaged that an elevated platform via use of a jack up barge or stilts would be installed. Any platform to be installed would be subject to the Contractor's proposed method of working being approved by all relevant stakeholders, and following Appropriate Assessment.

With either measure, there is potential for negative impacts to water quality during construction, e.g. the accidental spillage of hydrocarbons. This may have a negative impact on water quality, which many water dependent species of the SAC are reliant, e.g. salmon, lamprey species and otter.

6.3.4.2 Avoid damages to, and where possible enhance the flora and fauna

There is the potential for a negative impact on water quality and sediment release to the River Shannon during the course of the works.

6.3.4.3 Protect and where possibly enhance fisheries resource

The River Shannon is an important river for fisheries. Once constructed, the proposed defences (either measure) will not impact on river flows of the River Shannon or prevent the migration of fish species. The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species through the sedimentation of river substrates and reduction in the diversity of macroinvertebrate communities.

As above, the construction of direct defences will require in-channel working and therefore has the potential for physical disturbance to fisheries and lamprey habitat.

6.3.4.4 Archaeology & Cultural Heritage

Works in this area, because of its high archaeological potential, will require advance archaeological surveys to be carried out. Licences for the Department may be required, and these should be considered in advance of any works. Additionally, the works are within an area referred to as a "zone of notification" which incorporates monuments that may be scheduled for inclusion in the next issue of the statutory "Record of Monuments and Places". The zones do not define the exact extent of the monuments but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004). Consultation with National Monuments Service during the EIAR will be required for works in this area.

6.3.4.5 Construction Issues

There will be localised short-term effects on noise and air for pedestrians and local workers. Whilst construction is ongoing there will also be temporary loss of carparking, disruption to the Potato Market and courthouse and the requirement for traffic management. With the direct defence measure there would also be the long-term loss of approximately 10 parking spaces from the Potato Market.

6.3.5 Costs

The baseline construction costs for the defence measures in Area B3 are:

- Direct defences: €2,550,528
- Road raising and IPP: €570,134

6.3.6 Climate Change Adaptability

6.3.6.1 Direct defences with road raising

The direct defences would be designed to be adaptable under climate change scenarios. Road raising and IPP are not adaptable, so in the long-term climate change will have to be managed through alternative land use and innovative building design. This may include:

- relocation of the boat club and abandonment of the jetty to allow a continuous direct defence to be provided to the south of the courthouse;
- further use to be made of the Potato Market wall as a defence;
- change of use of the Potato Market to development, which should be constructed to a higher level and will form part of the defence.

6.3.6.2 Road raising and IPP

As detailed above, road raising and IPP are not adaptable, so in the future an alternative means of defending against flooding would need to be designed and constructed.

The residual risks to climate change hazards on both the proposed flood risk management structure and its ability to continue to provide flood risk management in the future is assessed and is summarised in Table 6-4 and Table 6-5.

Table 6-4: Area B3 Climate Change Adaptability: IPP and Road Raising

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
IPP: Civic Buildings and Potato Market	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design.	Yes	Yes	Drainage exceedance to be included in current design.	Low- If adaptation measure is in place the risk remaining is minimum.
	Flooding (coastal/fluvial)	High	No adaptable measures. Investment in IPP will not contribute to or reduce future flood defence costs.	No	Limited	Currogower Boat Club: Proposed IPP in the form of demountable barriers to the garage door and office doors to a height of +5.3mOD. Increase to MRFS would be in the order of 0.5m. Civic Buildings: Proposed IPP in the form of demountable barriers to windows and office doors to a height of +5.3mOD. In addition to sealing joints, tanking of walls, removal of vents on walls adjacent to river. IPP can in some circumstances be adaptable to increased flood levels, however may safety limits will apply, especially to occupied buildings and to be effective in the MRFS may require significant refurbishment to existing properties.	Medium - In the MRFS the freeboard is no longer present. Limited ability to raise ground level further, technically difficult and potentially not viable Additional measures possible at future defence cost. Potential for future overtopping and flooding of properties. Significant risk to life may be present in the area due to high velocity and depth of flooding. May require cordoning off areas and local evacuation plans for public buildings.
	Sea Level Rise	High		No	Limited		
Road Raising of Potato Market access road and the car park west	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design.	Limited	Limited	Drainage exceedance to be included in current design, however road drainage will be constrained by proximity to floodplain.	Medium - limited potential for highway drainage to adapt.

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
of Bridge Street.	Flooding (coastal/fluvial)	High	No adaptable measures. Investment in IPP will not contribute to or reduce future flood defence costs.	No	Limited	None. The proposed level to raise the road at junction of Matthew's Bridge to +5.3mOD. Significant works would be required to raise further to 5.8mOD. There is potential for grading back further into the potato market access road where the road could be raised to 5.8mOD and introduce a gate to the road entrance, although it will come at future flood defence cost.	Medium - the remaining risk includes no freeboard, potential spill over or overtopping in the MRFS Limited ability to raise ground level further, technically difficult and potentially not viable Additional measures possible at future defence cost. Significant risk to life may be present in the area due to high velocity and depth of flooding. May require cordoning off areas and local evacuation plans for public buildings.
	Sea Level Rise	High		No	Limited		

Table 6-5. Area B3 Climate Change Adaptability for Road raising and IPP for Direct Defences and Road Raising

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
Direct Defence: Wall/Glass Panel	Flooding (pluvial, run-off, and drainage)	High	Drainage exceedance to be included in current design. Monitoring, inspection, maintenance.	Yes	Yes	Drainage exceedance to be included in current design, if not, option less flexible and less adaptable. New drainage would be costly.	Low- If adaptation measure is in place the risk remaining is minimum.
	Erosion Ground Stability	High		Limited	Limited	Wall will be directly adjacent to river, highly exposed.	Medium- the remaining risk includes potential spill over or overtopping under HEFS.

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
	Flooding (coastal/fluvial)	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Only adaptable if in-built capacity measures (resilient foundation) included in original design which will allow for a raised wall crest. If raised once, it will no longer be adaptable for HEFS. A stronger foundation would be needed to raise further otherwise an additional defence or replacement defence will be needed. Potential for construction of raised defence crest is limited by sub-soil stability which is uncertain for potential foundation reinforcement. Visual constraints of wall may limit viability of adaptation, however glass panel have been suggested for this section.	Medium - limited ability to raise wall crest and retain freeboard allowance. Potential for future overtopping and flooding of properties, however risk likely to be reduced with proposed defences in place.
	Sea Level Rise	High	Resilient foundation/base to ensure adaptability (increase crest height of wall)	Limited	Limited	Monitoring, inspection, maintenance with identified trigger points. If threshold reached, appropriate action to be undertaken must be identified such as raise crest of wall. Potential for construction of additional defence limited as minimal areas available and the sub-soil stability is uncertain for potential foundation reinforcement.	Medium - limited potential for highway drainage to adapt.
Road raising	Flooding (pluvial, run-off, and drainage)	Moderate	Drainage exceedance to be included in current design. No adaptable measures. Investment in IPP will not contribute to or reduce future flood defence costs.	Limited	Limited	Drainage exceedance to be included in current design, however road drainage will be constrained by proximity to floodplain.	Medium - limited potential for highway drainage to adapt.
	Flooding (coastal/fluvial)	High		No	Limited	None. The proposed level to raise the road at junction of Matthew's Bridge to +5.3OD Malin. Significant works would be required to raise further to 5.8m OD Malin. There is potential for grading back further into the potato market access road where the road could be raised to 5.8mOD Malin and introduce a gate to the road entrance, although it will come at future flood defence cost.	Medium - the remaining risk includes no freeboard, potential spill over or overtopping in the MRFS Limited ability to raise ground level further, technically difficult and potentially not viable Additional measures possible at future defence cost.
	Sea Level Rise	High		No	Limited		

Option	Climate change hazards	Vulnerability	In-built capacity measures	Flexible?	Adaptable?	Adaptation Options	Residual Risk
							Significant risk to life may be present in the area due to high velocity and depth of flooding. May require cordoning off areas and local evacuation plans for public buildings.

6.4 Area B4 - King John's Castle

6.4.1 Current Situation (Engineering Chainage Ch 3+663 to Ch.3+777)

King John's Castle is the remaining length of the island, running from the public amenity in Area B3 up to Thomond Bridge (see Figure 6-5).

The area around King John's Castle forms one of the iconic views within the City. The castle walls are several meters from the river bank top, and form a continuous barrier around the castle buildings (Figure 6-11).

Figure 6-11: King John's Castle on the banks of the River Shannon

6.4.2 Constraints

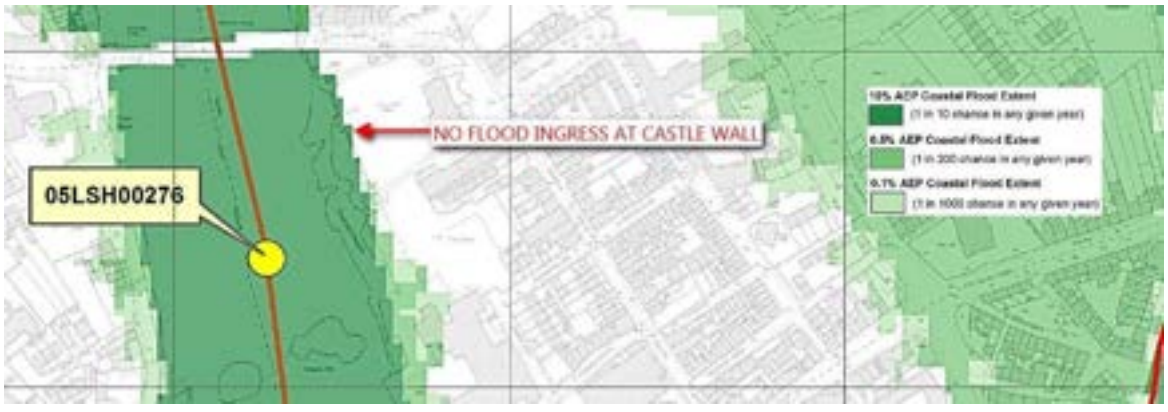
- Avoidance of works to King John's Castle which is listed as a protected structure;
- Avoidance of the SAC which has been assumed to border the existing quay wall alignment;
- Protection of residential and civic views out to the river and river bank.

6.4.3 Potential measures

The proposed flood defence option for this Area is to 'do nothing' as the Catchment Flood Risk Assessment and Management (CFRAMS) flood extent does not show ingress of flood waters in this Area, see Figure 6-12 below.

No alternative measures were considered for this Area and no specific environmental, ecological or economic assessment was undertaken.

Figure 6-12: Area 10 – Extract from Shannon CFRAM Map No. N16EXCCDD



6.4.4 Climate Change Adaptability

The 'do nothing' measure in Area 10 will be able withstand both MRFS and HEFS climate change projections.

7 Summary of Measures and Potential Flood Relief Options

7.1 Overview

Following the screening stage, a number of potentially viable measures have been identified to protect against flooding in the 1% AEP fluvial and 0.5% tidal event. This section further develops the potentially viable measures into options. Multi Criteria Assessment (MCA) for each flood cell will be carried out to aid in the selection of the preferred option. Table 7-1 provides a summary of potential measures for each area. From these measures, two potential options have been developed.

Table 7-1: Summary of potential measures

Area	Potential Measures
A1 - Thomond Bridge to Verdant Place	Advanced works completed
A2 - Verdant Place Steps and Crèche	Direct defences
A3 - North West Embankment	Direct defences
A4 - St Mary's Park / SAC	Direct defences - Inner alignment or Direct defences - Outer alignment
A5 - Star Rovers to Athlunkard Boat Club	Direct defences
A6 - Athlunkard Boat Club	Direct defences and IPP
A7 - Sir Harry's Mall	Direct defences - raise existing wall
A8 - Absolute Hotel Boardwalk	Regrade ramps
A9 - South of Absolute Hotel Boardwalk	Direct defences
A10 - Abbey Bridge to Baals Bridge	Direct defences
B1 - George's Quay East	Direct defences - raise existing wall
B2 - George's Quay West	Direct defences
B3 - Potato Market and Civic Buildings	Direct defences or Road raising and IPP
B4 - King John's Castle	Do nothing

7.2 Flood Relief Options

Measures which were progressed through the screening stage have been combined to create potential options which will manage the flood risk and achieve the objectives set by the study. As this scheme is predicated on providing a consistent standard across the whole island[2], a direct defence scheme is the preferred strategic solution. Analysis has been carried out for the two identified flood cells, on the basis that the choice of option in one flood cell will not impact on the choice in the other flood cell. Drawing on the potentially viable measures, two alternative options have been identified for each flood cell, as summarised in Table 7-2. These potential options show variation in only one area, with the remaining parts of the flood cell having only one potential measure.

Table 7-2: Potential Flood Relief Options

Flood Cell	Option	Description
A	1	Inner alignment at A4
	2	Outer alignment at A4
B	1	Direct defences at B3
	2	Road raising and IPP at B3

[2] Note, the constant standard includes variable freeboard, so defence heights vary around the island.

The design standard for this study is the 0.5% AEP event for tidal flood risk. The option achieving the design standard must also have provision for adaptability to future scenarios and climate change conditions.

However, when high end future scenarios are considered reliance on even higher direct defences is not realistic. A further combination of measures will be required, likely involving a tidal barrier type solution.

8 Costing of Options

8.1 Summary of Costs

A full build-up of costs for each option is included in Appendix E. Table 8-1, below summarises the total costs for each option, which do not include the costs for the construction of Verdant Place, but do include an allowance for the ongoing operation and maintenance of this part of the scheme within the costing for Flood Cell A.

These costs were as presented at the December 2017 Public Information Day and have not been updated to reflect the subsequent refinement of the preferred option following this PCD. Details of the refinement of the preferred option, and associated changes in cost are presented in Section 12.

Table 8-1: Summary of option costs (€)

Cost Item	Option A1 - Inner alignment	Option A2 - Outer alignment	Option B1 - Direct defences with road raising	Option B2 - Road raising with IPP
Measured Items	6,180,183	7,236,224	3,774,641	1,794,247
Unmeasured Items (10%)	618,018	723,622	377,464	179,425
Preliminaries (12%)	815,784	955,182	498,253	236,841
Sub-Total Costs	7,613,985	8,915,028	4,650,358	2,210,512
Archaeology & Env. Monitoring (10%)	618,018	723,622	377,464	179,425
Contingency / Optimism Bias (20%)	1,646,401	1,927,730	1,005,564	477,987
Total Construction Costs	**9,878,404**	**11,566,381**	**6,033,386**	**2,867,924**
Specialist Survey Costs incurred through Stages 1 and 2 *	341,793	341,793	146,483	146,483
Design and Supervision Costs (13%)	989,818	1,158,954	604,546	287,367
Land Purchase / Compensation	100,000	100,000	100,000	100,000
Art Cost *	44,800	44,800	19,200	19,200
Operation & Maintenance (1%)	2,412,081	2,774,659	740,402	740,402
Total Project Costs	**13,766,896**	**15,986,586**	**8,323,958**	**4,161,375**
Verdant Place completed costs		1,930,037		

* Fixed cost items have been divided between Flood Cell A and B on a 70:30 split

The possible options for the two flood cells have been combined to give total project costs for the options and as shown in the matrix in Table 8-2. The costs in this table include the final account cost of the Verdant Place Advanced Works element of the scheme.

Table 8-2: Total option costs

Options costs (€)	A1 - Inner alignment	A2 - Outer alignment
B1 - Direct defences and road raising	24,020,891	26,240,581
B2 - Road raising and IPP	19,858,308	22,077,998

9 Damages and Scheme Benefits

9.1 Baseline Scenario

The baseline scenario against which benefits of an option can be compared is the current situation or 'continue with existing practice'. Figure 9-1 shows that calculated benefits in the Current Scenario, for a range of design standards. The Baseline capped benefits for the 0.5% AEP SOP (Q200 in the graph) are calculated to be €23.56 Million. This confirms that the 0.5% standard, adopted by the OPW for tidal defences, is appropriate for the scheme.

This damage assessment scenario is based on the level to the top of the embankment at the northern end of the island (i.e. excluding the temporary sandbags), and the top of the quay walls / defence walls to the south of the island. It also assumes the defences, as included, do not breach or otherwise fail. See Appendix G for more details.

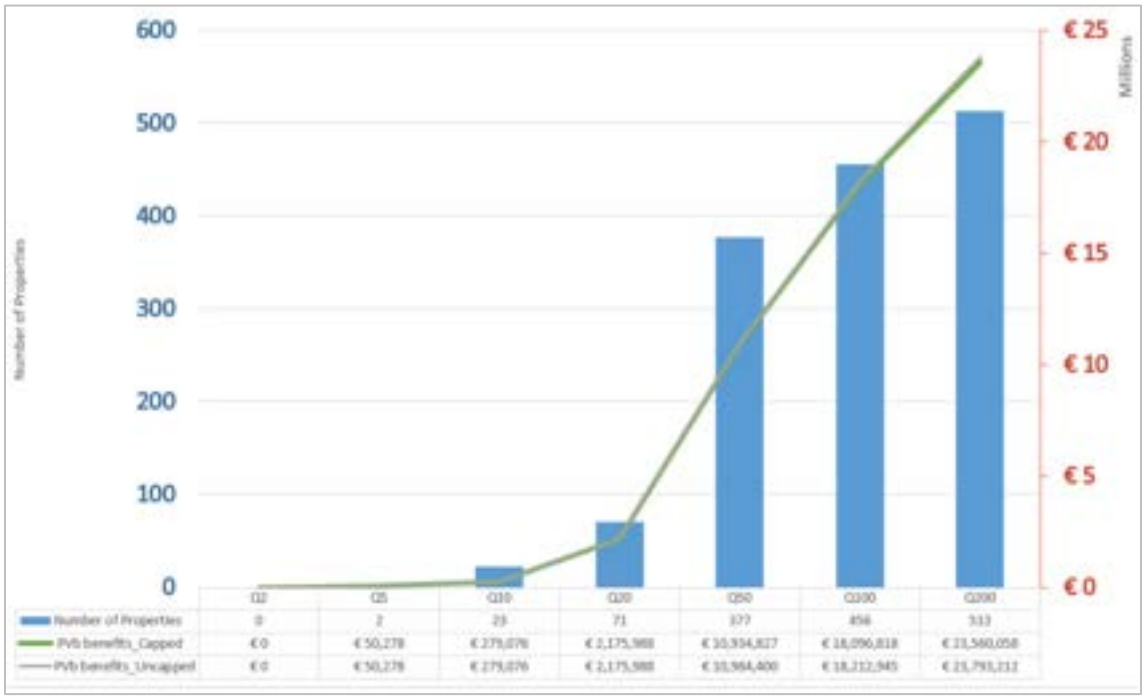


Figure 9-1: Total Present Value Damages (for a particular Design Standard) - Do Nothing (4% discounted)

9.2 Defence Breach Scenario

The baseline scenario provides a valid estimate of damage in most locations. However, the historic flood mechanisms on King's Island (i.e. defence breach), coupled with the generally poor condition of significant lengths of embankment, indicate that a more appropriate estimate of damages can be achieved by considering an embankment breach scenario.

Two alternative breach scenarios were considered; the first was a full breach in year 1, and the second draws upon the Environment Agency's Flood Risk and Coastal Erosion Management appraisal guidance. This results in an applied damage scenario of 50% breach after 10 years and full breach after 25 years. The latter assessment applies a reduced damage calculation based on both the probability of a breach over time and then discounting these values over the appraisal period. The raw baseline scenario benefits profile is shown in Figure 9-2.

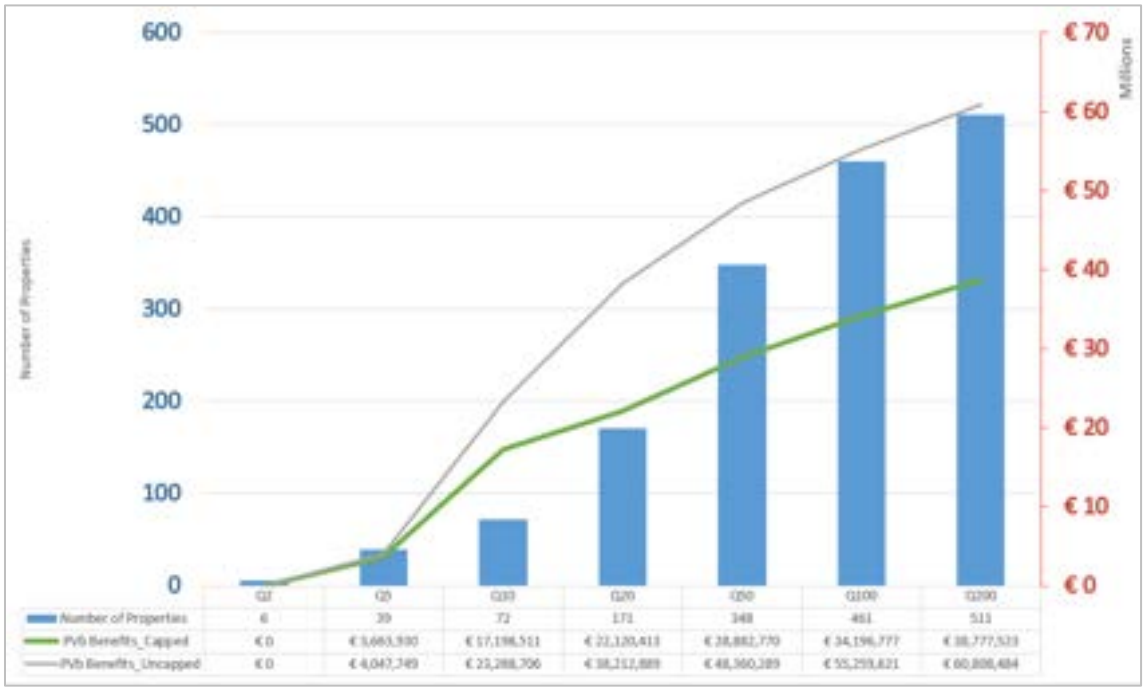


Figure 9-2: Total Present Value Damages (for each Design Standard) - Breach Scenario (4% discounted)

The resulting benefit figures are then based on a combination of the baseline benefits shown in Table 9-1, and the factored and discounted benefits arising from the breach run. Hence in Table 9.1, the probability factored breach accounts for €13.3m to the total scheme benefits. The maximum benefits, assuming a breach occurs on the next surge tide are above the combined breach and baseline damages, which confirms the proposed benefit assessment is realistic.

Table 9-1: Scheme Benefit figures

Scenario	PV Benefits (€)
Baseline	23.6m
Raw Breach Scenario	38.8m
Integrated breach assessment based on including the damages resulting from a breach scenario assuming a 50% likelihood breach after year 10 with full breach by year 25	36.9m

10 Multi-Criteria Analysis

10.1 MCA Scores

The effectiveness and attributes of the potential options has been assessed against the flood risk management objectives and the results are shown below. Table 10-1 shows the local weightings for both flood cells. The MCA scores for Flood Cell A (north) and Flood Cell B (south) are provided in Table 10-2 and Table 10-3 respectively. Further details on the MCA methodology are provided in Appendix D.

Table 10-1. MCA Local Weightings

Number	Criteria	Sub- objective	Local Weighting	Comments
1a	Technical	Ensure flood risk management options are operationally robust	5	Constant (no change permitted)
1b		Minimise health and safety risks associated with the construction and operation of flood risk management options	5	
1c		Ensure flood risk management options are adaptable to future flood risk	5	
2a	Economic	Minimise economic risk	5 (north), 0.54 (south)	Based upon AAD for the flood cell (€683,859 north, €40,484 south)
52b		Minimise risk to transport infrastructure	5 (north), 2.55 (south)	Based upon the probability of flooding to different road classifications
2c		Minimise risk to utility infrastructure	0	No utility infrastructure present
2d		Minimise risk to agriculture	0	No agriculture present
3a (i)	Social	Minimise risk to human health and life of residents	5 (north), 0.70 (south)	Based on number of residential properties at risk and probability of flooding
3a (ii)		Minimise risk to high vulnerability properties	1.04 (north), 5 (south)	St. Mary's Boys and Girls Schools in north, Barrington's Hospital in south
3b (i)		Minimise risk to social infrastructure and amenity	3.85 (north), 1.26 (south)	Based upon type of social infrastructure at risk and probability of flooding. Includes social amenity and open space, as well as social care, community centres, religious buildings, welfare office, etc.
3b (ii)		Minimise risk to local employment	0.04 (north), 0.02 (south)	Based on number and type of commercial properties at risk and probability of flooding
4a	Environmental	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives.	5	Constant (no change permitted)
4b		Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.	5	Set based on the presence of Natura 2000 sites and priority Annex 1 habitats.
4c		Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.	4	Set based on the presence of: Natural Heritage Areas (& proposed Natural Heritage Areas), Nature Reserves, Wildfowl Sanctuary, OSPAR and National Parks
4d		Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement	4	Waterbody supports substantial salmonid fisheries/shellfisheries and is of national value for fishing/angling

Number	Criteria	Sub- objective	Local Weighting	Comments
		of conditions that allow upstream migration for fish species.		
4e		Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor.	4	Landscape character type designated at a county level as highly sensitive and/or exceptional/high value and potentially affected
4f (i)		Avoid damage to or loss of features of architectural value and their setting.	2 (north), 4 (south)	A number of sites/features listed on the Record of Protected Structures and/or Recorded by NIAH are present and potentially affected with a moderate to low vulnerability. Nationally important feature(s) (e.g. Structures or sites that make a significant contribution to the architectural heritage of Ireland. These are structures and sites that are considered to be of great architectural heritage significance in an Irish context) present and potentially affected with a high to moderate vulnerability.
4f (ii)		Avoid damage to or loss of features of archaeological value and their setting.	4	Nationally important archaeological feature(s) (e.g. National Monument in State Care, sites on which Preservation Orders or Temporary Preservation Orders have been served) present and potentially affected

Table 10-2: Multi Criteria Analysis - Flood Cell A (North)

Number	Criteria	Sub- objective	Score Option A1 Inner alignment	Score Option A2 Outer alignment	Comments
1a	Technical	Ensure flood risk management options are operationally robust	400	400	Neither option scores maximum as both require IPP for Athlunkard Boat Club to maintain a freeboard over design flood levels.
1b		Minimise health and safety risks associated with the construction and operation of flood risk management options	300	300	Particular risks 1 and 5, as defined under the SAFETY, HEALTH AND WELFARE AT WORK (CONSTRUCTION) REGULATIONS 2013.
1c		Ensure flood risk management options are adaptable to future flood risk	400	400	All elements in northern flood cell can adapt to future climate change.
		TECHNICAL SCORE	1100	1100	
2a	Economic	Minimise economic risk	51	51	Same level of risk reduction for both options.
2b		Minimise risk to transport infrastructure	248	248	
2c		Minimise risk to utility infrastructure	0	0	
2d		Minimise risk to agriculture	0	0	
		ECONOMIC SCORE	299	299	
3a (i)	Social	Minimise risk to human health and life of residents	673	673	Same level of risk reduction for both options.
3a (ii)		Minimise risk to high vulnerability properties	84	84	
3b (i)		Minimise risk to social infrastructure and amenity	168	170	Inner alignment has slightly greater impact on amenity value of walkway around Kings Island.
3b (ii)		Minimise risk to local employment	1	1	
		SOCIAL SCORE	927	929	
4a	Environmental	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives.	-160	-160	Short-term construction phase impacts, can be mitigated. Instream works are proposed for which reduces score for both options.
4b		Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and stepping stones.	-50	-250	Significantly greater potential impacts for outer alignment as intrusion into SAC boundary. The option score the A1 is -1 for "*Any detrimental impact upon existing SAC or SPA site, including a delay in recovery of the site, but excluding impacts on the conservations objectives of the site, as a result of flood risk management measures, where suitable mitigation measures are technically feasible."* The option score for A2 is -5 for *"Any detrimental impact upon conservation objectives of existing*

Number	Criteria	Sub- objective	Score Option A1 Inner alignment	Score Option A2 Outer alignment	Comments
					SAC, SPA or Ramsar site, including a delay in recovery of the site, as a result of flood risk management measures, where suitable mitigation measures are technically feasible."
4c		Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.	-40	-20	Inner alignment has greater potential to disturb and spread Japanese Knotweed.
4d		Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species.	-52	-52	The potential for impaired water quality and the release of sediment to the river during the duration of the works may impact on fish species.
4e		Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor.	-64	-32	Properties to rear of St Munchin's Street impacted by proximity of inner alignment flood defence. Permanent impact, mitigation not yet designed. Less significant impacts from outer alignment.
4f (i)		Avoid damage to or loss of features of architectural value and their setting.	0	0	
4f (ii)		Avoid damage to or loss of features of archaeological value and their setting.	-16	-16	Works within a Zone of Notification at Sir Harry's Mall. No impact on Athlunkard Boat Club Protected Structure likely.
		ENVIRONMENTAL SCORE	-382	-530	

Table 10-3: Multi Criteria Analysis - Flood Cell B (South)

Number	Criteria	Sub- objective	Score Option B1 Direct defences with road raising	Score Option B2 Road raising and IPP	Comments
1a	Technical	Ensure flood risk management options are operationally robust	400	200	IPP required for Curragower Boat Club under Option B1. Sufficient lead time for installation of option B2, but fully reliant on IPP.
1b		Minimise health and safety risks associated with the construction and operation of flood risk management options	300	300	Particular risks 1 and 5, as defined under the SAFETY, HEALTH AND WELFARE AT WORK (CONSTRUCTION) REGULATIONS 2013
1c		Ensure flood risk management options are adaptable to future flood risk	200	0	Limited adaptive capacity off flood walls in option B1, and foundations designed to withstand increased loadings. IPP in option B2 is not adaptive. But does not preclude investment in an alternative solution in the future.
		TECHNICAL SCORE	900	500	
2a	Economic	Minimise economic risk	5	5	Same level of risk reduction for both options.
2b		Minimise risk to transport infrastructure	123	68	B2 reliant on forecasting to protect Merchant's Quay
2c		Minimise risk to utility infrastructure	0	0	
2d		Minimise risk to agriculture	0	0	
		ECONOMIC SCORE	128	70	
3a (i)	Social	Minimise risk to human health and life of residents	95	95	Same level of risk reduction for both options.
3a (ii)		Minimise risk to high vulnerability properties	404	404	
3b (i)		Minimise risk to social infrastructure and amenity	55	33	Social amenity walkway and part of courts buildings remain at risk of flooding in Option B3.
3b (ii)		Minimise risk to local employment	1	1	
		SOCIAL SCORE	554	532	
4a	Environmental	Provide no impediment to the achievement of water body objectives and, if possible, contribute to the achievement of water body objectives.	-80	-80	Short-term construction phase impacts. Instream works are proposed for Merchants Quay. Extremely localised construction phase impacts. No likely long term impacts.
4b		Avoid detrimental effects to, and where possible enhance, Natura 2000 network, protected species and their key habitats, recognising relevant landscape features and	-50	-50	Suitable mitigation measures likely to be achievable in mitigating potential impacts. No likely long term impacts.

Number	Criteria	Sub- objective	Score Option B1 Direct defences with road raising	Score Option B2 Road raising and IPP	Comments
		stepping stones.			
4c		Avoid damage to or loss of, and where possible enhance, nature conservation sites and protected species or other know species of conservation concern.	-20	-20	Potential localised loss or disturbance. No likely long term impacts.
4d		Maintain existing, and where possible create new, fisheries habitat including the maintenance or improvement of conditions that allow upstream migration for fish species.	-104	-52	Short term minor impacts to fisheries habitats during construction. Instream works in Option B1 increases potential risk.
4e		Protect, and where possible enhance, visual amenity, landscape protection zones and views into / from designated scenic areas within the river corridor.	-64	-64	Potential for permanent impact on local/moderate value landscape character and features in the zone of influence of the selected measure. Score reduced for sensitive design. Short term impact during construction on moderate sensitivity landscape character and features in the zone of visibility of the selected measure.
4f (i)		Avoid damage to or loss of features of architectural value and their setting.	32	32	Changes to the setting of architectural features (Record of Protected Structures and NIAH) such that it is clearly modified - adjusted for sensitive design. And, increase in the level of protection for a number of architectural features (Record of Protected Structures and NIAH) from extreme flooding, such that they are substantially less vulnerable to flood damage. Option B2 may potential have impact through installation of IPP on protected structures.
4f (ii)		Avoid damage to or loss of features of archaeological value and their setting.	16	16	Increase in the level of protection for a number of archaeological features (Recorded Monuments) from extreme flooding, such that they are substantially less vulnerable to flood damage. And, changes to the setting of archaeological features (Recorded Monuments) such that it is clearly modified.

Number	Criteria	Sub- objective	Score Option B1 Direct defences with road raising	Score Option B2 Road raising and IPP	Comments
		ENVIRONMENTAL SCORE	-270	-218	

10.2 MCA Outcomes

Following the completion of the multi criteria analysis the following outcomes are available:

Criteria Scores: The MCA produces a weighted score for each objective and the sum of these within each of the criteria classifications is the Criteria Score, Table 10-4.

- **MCA Benefit Score:** The sum of the scores for the economic, social and environmental criteria. It excludes the technical criteria score. This score represents the net benefits of the option.
- **Option Selection MCA Score:** The sum of the scores for all four of the criteria. This score compliments the MCA Benefit Score with the Technical Criteria Score, and hence includes all of the aspects that should be taken into account in considering the preferred option for a given location.

Table 10-4: Criteria Scores

Criteria	Option A1	Option A2	Option B1	Option B2
Technical	1100	1100	900	500
Economic	299	299	128	73
Social	927	929	554	532
Environmental	-382	-530	-270	-218
MCA Benefit Score	844	698	412	385
Options Selection Score	1944	1798	1312	885

When the MCA Benefit Score and Options Selection Score are considered, the highest scoring option for Flood Cell A is the inner alignment, and in Flood Cell B is direct defences with road raising. This is discussed further in Section 11.

11 Selection of Preferred Option

Having assessed the various measures and options in each flood cell, conclusions can be drawn to inform the development of the emerging preferred option. The merits of the alternative options will be summarised on the basis of: cost, MCA score, environmental and ecological impact, process and programme and climate change adaptability.

Whilst not being constructed to climate change levels, in considering the merits of the potential options, it is important that the current proposals are considered in the context of a longer term strategy which is flexible and adaptive to changes in the climate and its potential impact on flood risk.

Also taken into account in the selection of the preferred option was the combined professional judgement of the steering group members and consideration of the core messages which arose during the stakeholder consultation process.

11.1 Flood Cell A

The two options for consideration in flood cell A are the inner and outer alignment. The MCA scores for technical, economic and social criteria do not provide enough of a difference to allow a decision to be made as to which option is preferred. Construction techniques for each are reasonably similar, with the result that there is relatively little to distinguish them. The measured cost for the outer alignment is approximately 15% (€1 million) more expensive than the inner as a result of the substantial removal of the existing embankment, required sheet piling of the embankment on the wet-side and a highly restricted construction method. In addition to the measured costs, further specialist hydrogeological and ecological surveys would be required to demonstrate that the sheet piling would not impact on the integrity and functioning of the wetland.

There is a significant difference between the environmental and ecological impacts of the two options, reflected in the MCA scores of -382 and -530 for the inner and outer alignments respectively. Because the existing embankment and footpath fall within the SAC, and are bordered by alluvial woodland and wetland on the wet and dry sides respectively, proposals for construction in this area can only be progressed subject to Appropriate Assessment. The construction footprint of the outer alignment impinges on and/or may cause permanent loss of the alluvial woodland and wetland SAC habitats. If this option is selected then Stage 3 and Stage 4 (IROPI) of the Appropriate Assessment would be triggered. Provided there are other viable options which do not invoke IROPI, then this is not a permissible option. If there were no alternative options, the timeline for progressing through the IROPI route is untested in Ireland but likely to add a number of years to the delivery programme. However, as a viable alternative exists the IROPI process would not progress further than Stage 3, and a conclusion of the Inner Alignment as the preferred solution.

Both options are equally adaptable for climate change on a technical basis, although the visual impacts of the inner alignment will be greater, given the proximity of the route to the residential part of the island. The ecological impacts of raising the flood defences on the outer alignment, and encroaching further into the SAC, would give rise to additional Appropriate Assessment Screening and may not be permitted.

On the basis of the above, Option A1 (inner alignment) was progressed as the emerging preferred option and presented to the public as part of the Public Information Day.

11.2 Flood Cell B

The two alternative options considered in flood cell B are B1, direct defences coupled with road raising, and B2, road raising with IPP.

The key differentiating factors between these two options are cost, technical viability (in terms of the forecasting and manual erection of demountables needed in B2) and loss of access to the public realm and buildings while demountables are in place.

The measured construction costs for Option B1 is 450% more expensive than Option B2.

There is little to choose between the overall MCA scores, although direct defences score more highly in the technical criteria because the walls will form a passive system, where IPP relies on receipt of flood warning and a manual intervention.

The walls score lower on the environmental criteria, primarily because there will be some in-channel works required to construct the cantilevered walkway and defences around the courthouse. Further north, the walls can be constructed from the landside.

Operationally, the difference between the two options is linked to the public realm. If Option B2 is progressed, there will be periods when access to the Courthouse will be blocked, and the rear of the civic buildings and public walkway alongside the river will be flooded. At present, this is not a frequently occurring event although it will become more of a regular occurrence with climate change. However, for the majority of the time access to the buildings and through the public realm will not be impacted. It is noted that the civic buildings and city hall are used as the head-quarters for emergency planning, so a key element of working with Option B2 will be the development of a revised Major Emergency Plan, including designation of an alternative operation base, to be used in the event of flood warnings being issued. The other disadvantage of Option B2 is that it does not provide a passive flood defence for any of the buildings; protection is reliant on receipt of a flood warning and deployment of flood barriers. This may result in precautionary erection of flood barriers when no flood occurs, and, in the worst-case situation, non-erection of barriers and a flood event happening.

In contrast, provision of direct defences will allow permanent access to the buildings and public spaces, even in times of flood, and does not rely on the receipt of flood warnings. However, there will be an impact on architecture and heritage, including the protected structures, and some loss of visual amenity both for those in the Court house looking out and those viewing the south side of the courthouse from across the river.

The direct defences will be designed to be adaptable under climate change scenarios, although the nature of the glass panels means only one incremental increase in height is considered feasible. Road raising and IPP are not adaptable, so Option B2 is limited in time. Adapting Option B1 to climate change will require more innovative approaches, coupled with the raising of the glass walls, and may include alternative land use and building design.

When considering the cost benefit of the options, B2 would emerge as the option to carry forward. However, this option fails to meet the criteria and operational constraints detailed by Limerick City and County Council, which are full addressed by Option B1.

11.3 Emerging Preferred Option

On the basis of the information provided in this report, the emerging preferred option is A1-B1, Inner alignment in Area A4 and Direct Defences for Area B3. Such an option represents the combination which meets the council's brief for passive flood defences and will ensure the most sustainable, long-term use of the area around Merchant's Quay. It also provides advantages through MCA, including significant benefits in avoiding works within the SAC boundary at the north of the island.

12 Refinement of Preferred Option

12.1 Proposed Changes by Area

The emerging preferred option was presented at the Stakeholder Advisory Group (SAG) meeting and Public Information Day (PID) in December 2017. As discussed in Section 0, the feedback received from stakeholders prompted a review of the emerging preferred option and also resulted in LCCC deciding to engage the services of a landscape architect as part of the design team. Following a mini-tender competition, Nicholas de Jong Associates has been engaged to refine the design flood relief scheme around the island.

Changes arising as a result of feedback received from Stakeholders and input from the landscape architect are summarised in the following sections.

12.1.1 Area A1 - Thomond Bridge to Verdant Place (as constructed)

It is proposed to remove the temporary railing immediately north of Thomond Bridge which, whilst outside of the flood defence area, was provided as part of the Verdant Place contract to provide safe guarding height. In the permanent scenario, a new architecturally designed capping and railing is proposed for c.40m north of Thomond Bridge and as illustrated in Figure 12-1.

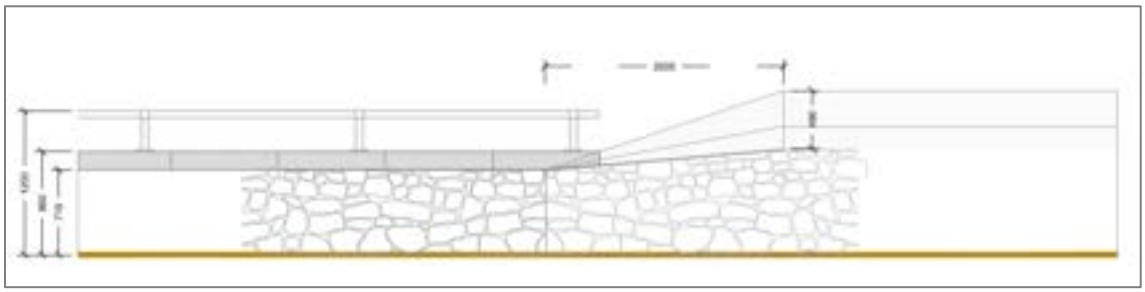


Figure 12-1: Replacement capping and railing at Verdant Place

12.1.2 Area A2 - Verdant Place steps and crèche

No changes proposed.

12.1.3 Area A3 - North West Embankment and Area A4 - St. Mary's Park / SAC

The embankment will be better integrated into the existing environment by adopting a considered design approach to the line and slope of the toe of the dryside slope (Figure 12-2). The width of the embankment will vary, with the toe meandering across the open space between the river and internal estate roads, creating a more sinuous appearance. This change results in a greater volume of sub-soil needing to be imported, and corresponding increase in truck movements, but provides a softer and more natural landscape. This softening is planned for all lengths of embankment, including at Abbeyview. The exception will at Star Rover's, where the embankment will be kept tight to allow maximum space for existing pitches.

A number of additional pedestrian access routes are also proposed to link the embankment level walkway to Oliver Plunket Street and St, Munchin's Street, providing seven formal access points in total; three from Oliver Plunket Street, two at the north of the island either side of the handball alley and two from St. Munchin's Street.

Figure 12-2 - Conceptual design showing softening of embankment slope and pedestrian access

A new open drain will be created along the inner toe of the north-west corner of the embankment and will be used to facilitate the reinstatement of the opposite leaved pond weed that exists in the existing open drain. A new outfall fitted with a non-return valve arrangement will connect the new open drain to the Shannon River. The existing, but unmaintained drain opposite St. Columcille Street will be closed off.

Measures for dealing with the Japanese Knotweed Bund were reviewed with a view to maintaining a contiguous embankment, rather than the previously proposed retaining wall around the existing bund. It is now proposed to relocate the northern portion of the bund locally. This will provide sufficient footprint for a continuation of the embankment past the bund, is less expensive than providing a localised retaining wall, and allows for management of the problem on-site. It should be noted that LCCC should still consider how best to address the existing bund given the risk of future growth and spread of invasive species.

12.1.4 Area A5 - Star Rovers to Athlunkard Boat Club

There was considerable discussion at the Stakeholder Advisory Group Meeting, and at the PCD in relation to the emerging option, of an embankment, and its impacts on the Star Rovers FC and Athlunkard Villa FC playing pitches and facilities. Several key points of objection were raised, most notably:

- Loss of training pitch and junior (undersized) pitches;
- Temporary loss of the astro-pitch;
- Loss of carparking and impact of relocated carparking on neighbouring residential properties.

Following the PCD, alternative measures were considered along with possible ways of maintaining or improving the facilities for Star Rovers and Athlunkard Villa FC. All of these alternatives were fully explored in relation to technical feasibility, environmental and ecological impacts and costs. They included:

- In conjunction with the embankment -
    - Moving and/or rotating the astro-pitch
    - Provision of a full size astro-pitch

- Moving the full-size grass pitches and relocating the carparking
- Also considered (but not costed) was the option of providing playing pitches elsewhere on King's Island.

- Revisiting the construction of the wall, rather than embankment. The alignment of the wall and inclusion of a cantilevered walkway minimise disruption to the football clubs and have no long-term encroachment into the pitches or training areas. There is also no necessity to relocate the carparking. To provide a more open feel to the boardwalk, the width of the walkway will be 4m and is 1m wider than the combined cycleway/footpath on the embankment.

Taking all the constraints into account, the Technical Advisory Group agreed to revert to an earlier option of a wall with cantilevered walkway with an increased width of 4m and as outlined in Figure 12-3.

Figure 12-3 - Embankment and wall alignment at Star Rovers FC and Athlunkard Villa FC

12.1.5 Area A6 - Athlunkard Boat Club

Access ramp positioning and alignment to be revised to tie in to the existing concrete path fronting the boat house.

12.1.6 Area A7 - Sir Harry's Mall

12.1.6.1 Sir Harry's Mall North

At the SAG meeting it was suggested that there would be benefits in providing a contiguous walkway around the island, including along Sir Harry's Mall.

A number of ways of achieving this were subsequently reviewed, including a cantilevered walkway running from the downstream face of O'Dwyer's Bridge for a length of approximately 100m on the outside of the defence wall on Sir Harry's Mall, refer Figure 12-4. The costs for this refinement were examined and found to be expensive (an additional construction cost of c.€450,000), with no additional benefit to flood management. LCCC therefore decided to adopt the option of raising the existing wall locally and to omit the cantilever boardwalk at this stage.

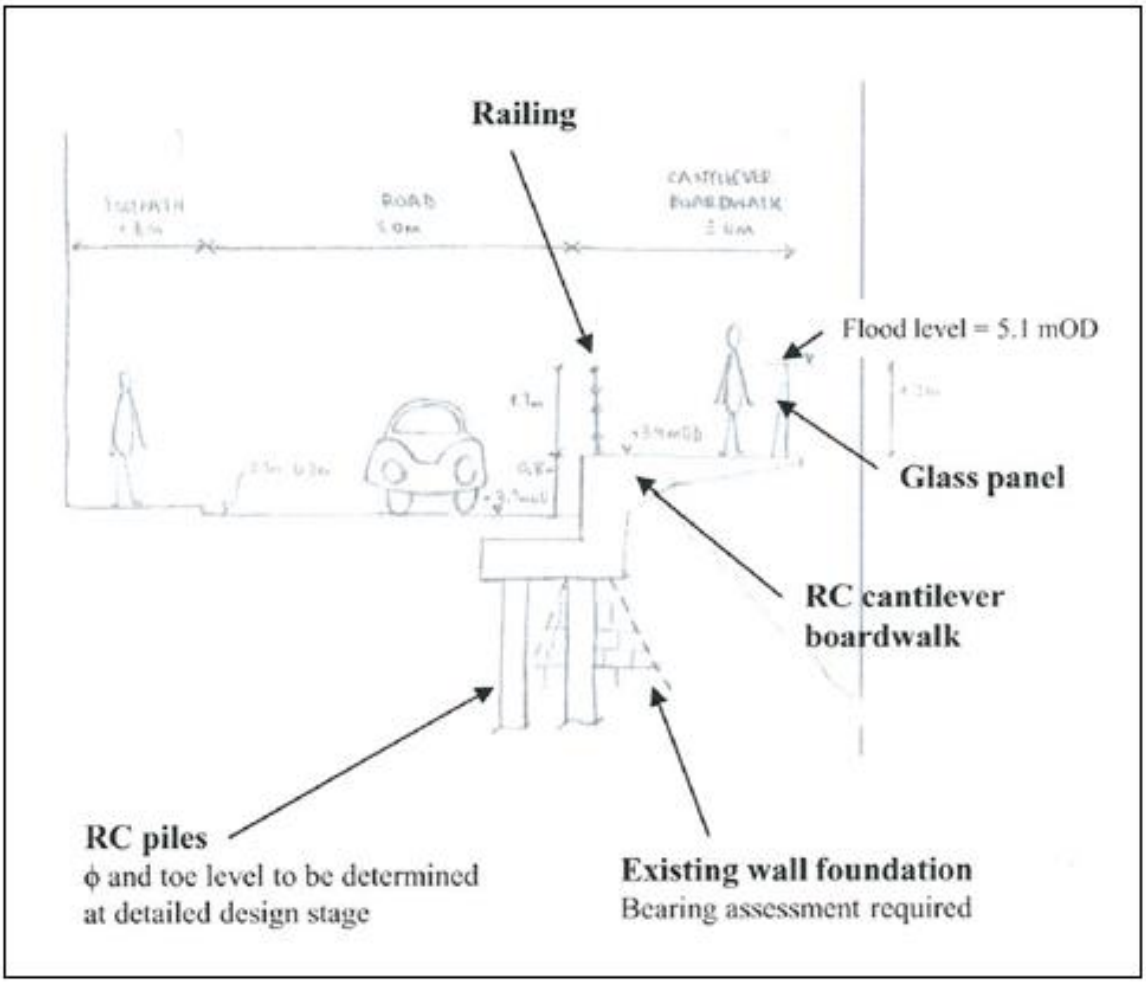


Figure 12-4: Proposed Cantilevered Boardwalk south of O'Dwyer Bridge

12.1.6.2 Sir Harry's Mall South

In lieu of a raised walkway with constrained access points at either end, an alternate detail would be a raised walkway with access steps to/from Sir Harrys Mall along its length with possible intermediate seating areas, refer Figure 12-5.

This would reduce the width of the road along Sir Harrys Mall immediately north of the Absolute Hotel but can be accommodated given the current one-way traffic system.

We await confirmation from Limerick City & County Council as to which detail is preferred in this area. Either approach will have limited impact on the overall costings contained in this report, and therefore a final decision can be made at planning stage.

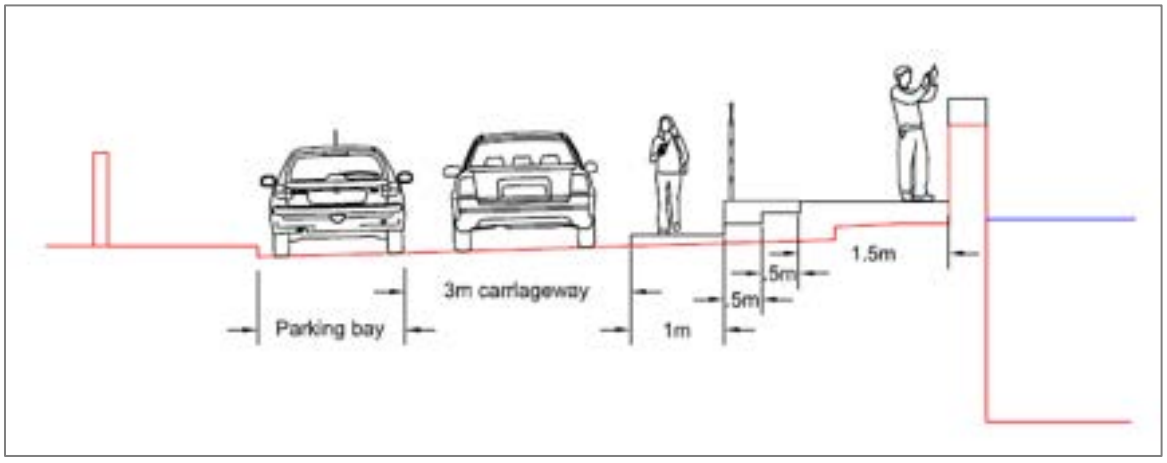


Figure 12-5: Typical section through the road, steps and wall at Sir Harry's Mall

12.1.7 Area A8 - Absolute Hotel Boardwalk

No changes proposed.

12.1.8 Area A9 - South of Absolute Hotel Boardwalk to Abbey Bridge

No changes proposed.

12.1.9 Area A10 - Abbey Bridge to Baal's Bridge

No changes proposed.

12.1.10 Area B1 - George's Quay East

No changes proposed.

12.1.11 Area B2 - George's Quay West

The original proposal for George's Quay West included a 50/50 split between glazed panels and stone facing to form the defence wall, with alternating panels being placed at typically 50m centres. The revised proposal has rationalised the location of the glass panels, taking into account the symmetry of surrounding buildings and viewpoints along the waterfront (see Figure 12-6).

Figure 12-6 - Proposed George's Quay Direct Defences

Consideration was also given to the inclusion of demountable flood defences at the access point to the pontoon, rather than a walled and stepped defence. However, this was discounted by the TAG as not providing a passive scheme throughout the city. At detailed design stage, the option of providing a demountable defence for the freeboard element only, may be reconsidered.

12.1.12 Area B3 - Potato Market and Civic Buildings

12.1.12.1 Access Ramp adjacent to the Courthouse

One of the most significant constraints to defending the Potato Market and other civic buildings related to the provision of a continuous line of defence around the Court House, across the access to Curragower Boat Club and tying into the Potato Market wall. The measure presented at the PCD involved ramped access to the boat club which would result in permanent loss of car-parking spaces and may be considered visually intrusive to the Court House. Discussions between LCCC and the Courthouse are on-going in this regard.

Should the raised access ramp not be acceptable, an alternative option is the use of a self-closing flood barrier, refer Figure 12-7.

Its design uses the approaching floodwaters to automatically raise the barrier. The automatic operation, along with its minimal footprint with no need for steps or ramps makes this type of defence more suitable for unmanned sites, where aesthetic considerations mean that a permanent barrier is not acceptable, or where there would be insufficient warning and manpower to use manually installed barriers.

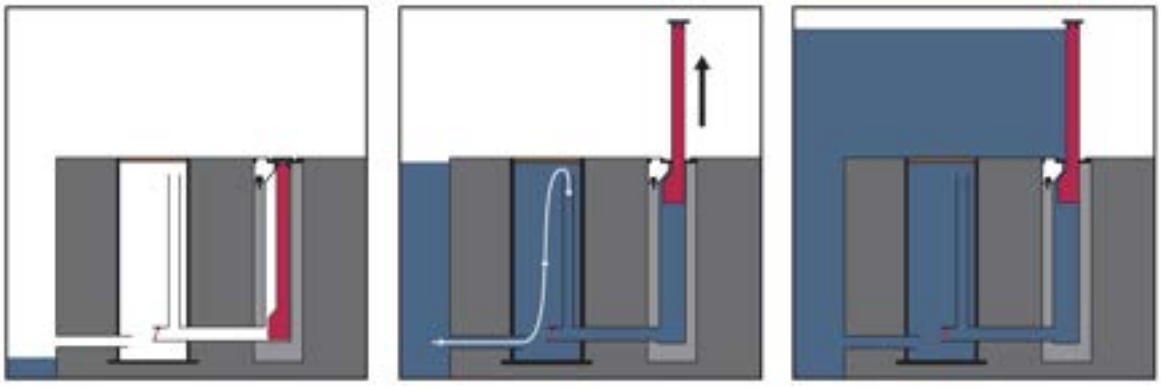


Figure 12-7: Self Closing Flood Barrier - Barriers rise as the floodwaters rise

Under non-flood conditions, the barrier is located below ground in a vertical position within a steel or concrete trough. When floodwater rises to a pre-determined level, the water spills into a service pit and then through a pipe into the trough and causes the barrier to float and raise fully. When the trough is filled, an angled support block locks the barrier into place, sealing it and making it watertight. The barrier is now fully effective and watertight to its full height.

As the floodwater recedes, the barrier lowers to its resting position again. The trough can be 'pumped out' also to lower the barrier before the adjacent groundwater levels recede fully.

In the event of defence failure (i.e. non-deployment of the barrier) the area around the Civic Buildings and Potato Market will be vulnerable to flooding. Therefore, it would be advantageous to also consider road raising at Bridge Street to ensure any flooding would be confined to Merchants Quay in the event of a malfunction of the flood barrier.

For the purposes of this options report, it is assumed that the cantilevered boardwalk and raised access ramp will form the direct defence in this location.

12.1.12.2 Public Walkway around Courthouse

In lieu of the cantilevered boardwalk around the courthouse as presented in Section 6.3.3 and Figure 6-9, a simpler and less expensive option is to omit the cantilever and construct the glass wall on top of the existing quay wall and as shown in Figure 12-8. However, this approach relies on agreement from the Courts Service to remove the railings which currently surround the building and to return this space to the public realm. This would also have the benefit of leaving the existing quay wall exposed. Discussions between LCCC and the Courthouse are also on-going in this regard.

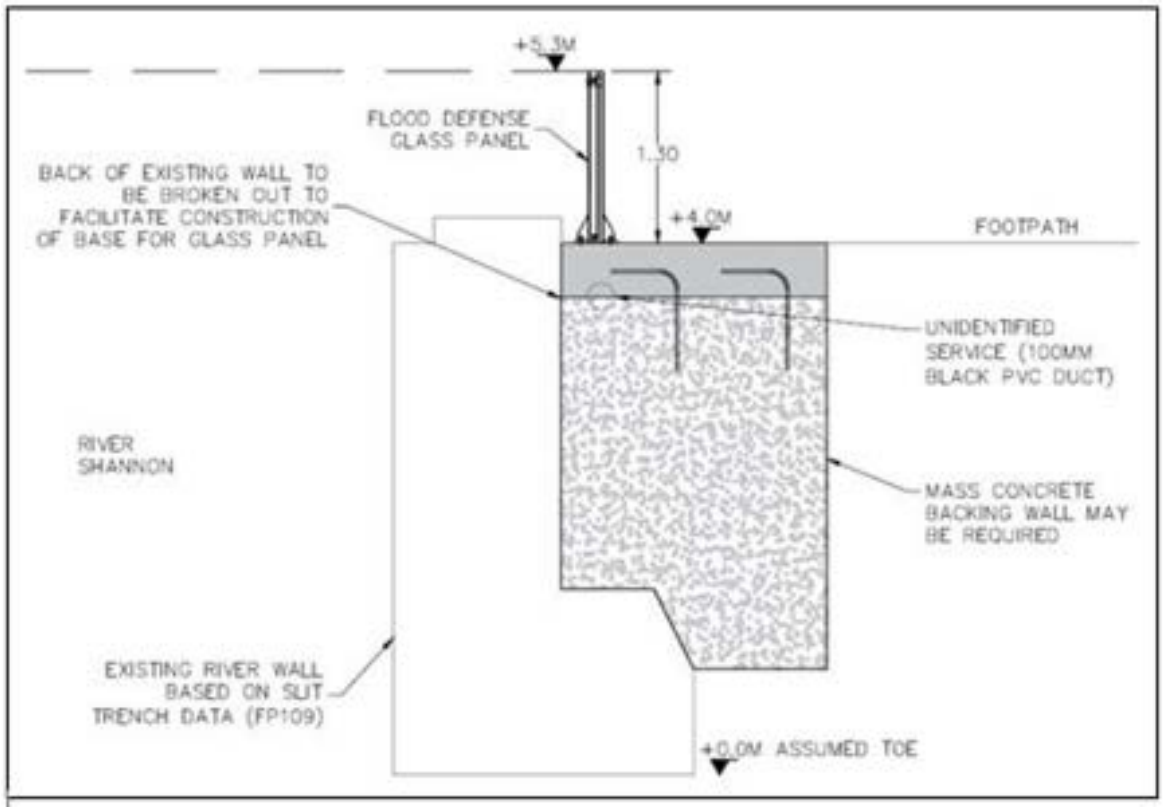


Figure 12-8 - Section through defence around Court House

12.1.13 Area B4 - King John's Castle

No changes proposed.

12.2 Costing the Refined Option

The various changes described above have been costed to establish a revised cost estimate for the preferred option to be taken forward to planning. This revised costing is presented in Table 12-1, and breakdown of the Refined Option baseline construction cost by sub-area is provided in Appendix E. The following points should also be noted:

- Area A1 - the cost of replacement capping at Verdant Place has been included in the costs for the main scheme. The completed costs for the Advanced Contract at Verdant Place as complete is itemised separately.
- Area A4 - there is a reduction in construction cost associated with the relocation of Japanese Knotweed bund compared to construction of the sheet piled wall, refer overleaf. The reduction in construction cost for this element of work is c.€200,000.
- Whilst a number of decisions remain to be finalised in terms of the proposed scheme to be taken forward to planning, it is considered that the cost implications of same are modest and will be catered for within the contingency sums allowed in the build-up. However, they need to be resolved by the steering group prior to completion of the EIAR.

Table 12-1: Cost summary of Refined Option

Cost Item	Emerging Preferred Option as presented at Dec 2017 PID	Refined Option developed post the PID
Verdant Place Advanced Contract		
Verdant Place Advanced Contract as completed	1,930,037	1,930,037
Main Scheme Works		
Measured Items	9,954,823	10,534,573 (for breakdown see Appendix E.3)
Unmeasured Items (10%)	995,482	1,053,457
Prelims (12%)	1,314,037	1,390,564
Sub-Total Costs	***12,264,342***	***12,978,594***
Archaeology & Environmental Monitoring (10%)	995,482	1,053,457
Contingency / Optimism Bias (20%)	2,651,965	2,806,410
Total Construction Costs	***15,911,790***	***16,838,462***
Specialist Survey Costs incurred to end of Stage 1	488,275	488,275
Design and Supervision Costs (13%)	1,594,365	1,687,217
Land Purchase / Compensation	200,000	200,000
Art Cost	64,000	64,000
Operation & Maintenance incl. Verdant Place (1%)	3,832,424	4,031,474
Total Project Costs	**24,020,891**	**25,239,465**

12.3 Potential Additional Items, not currently costed

In addition to the measured items which have been included in the costings for the options, there are a number of items which Limerick City and County Council may consider adding to the scheme through alternative funding mechanisms. These include:

- Railings on the embankments;
- Landscaping on the soft embankment, semi-mature trees and shrubbery, typically 2m centres;
- Landscaping / mature 4m high Irish Ash and / or Silver Birch tree provision at c.10m centres adjacent to Oliver Plunkett Street;
- CCTV cameras;
- Street furniture including benching and fitness pods;
- Treatment of Japanese Knotweed from the bund behind St. Munchin's Street given the risk of future growth and spread of invasive species;
- Wall finishes - it is assumed that all new and raised walls will be stone clad on river and land sides. Any alternative finish will require costing;

- Upgrade and ongoing maintenance of the outer embankment;
- Refurbishment of the wall at the bathing area, along with removal of diving board and stones from the river;
- Cleaning up area between Thomond Bridge and King John's Castle, including cleaning the steps;
- Continuous walkway at Sir Harry's Mall.

13 Conclusions

The extent and severity of the flood risk in the study area was established and defined through a detailed hydrology study, hydraulic modelling, flood mapping, largely undertaken through the Shannon CFRAM Study, but reviewed under this project.

The design standard of protection (SOP) for the Scheme is the 0.5% AEP tidal event, and includes a suitable level of freeboard, which varies between the River Shannon and the Abbey River, and also between the hard (wall) and soft (embankment) defences.

Initially, a long list of flood risk management measures was reviewed, and non-viable measures were screened out. Viable options were carried forward for more detailed investigation.

The development of the emerging preferred option was informed by a Constraints Study, Scoping Study and public consultation. Multi-criteria assessment, including an appraisal of environmental and climate change implications, was undertaken. The benefits of defending to the design standard of 0.5% AEP tidal was established to inform a detailed benefit analysis.

The emerging preferred option was presented to the Stakeholder Advisory Group and a at a Public Information Day in December 2017. As a result of feedback received, the option was further refined by both the engineering design team and with the inputs of a landscape architect.

The estimated whole life project cost of the refined scheme is €25,239,465.

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