Shannon Catchment-based Flood Risk Assessment and Management (CFRAM) Study

Hydraulics Report
Unit of Management 23

Final Report

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Glossary

AEP	Annual Exceedance Probability	The probability that a certain flow value will be exceeded in any one year. For example the flow associated with the 1% AEP event at a particularly location has a 1 in 100 chance of being exceeded in any year. A 5% AEP event has a 1 in 20 chance of being exceeded in any year.
AFA	Area for Further Assessment	An area that is considered to be at potentially significant risk of flooding, thereby justifying its inclusion for further assessment. Note that the term AFA is a replacement term for what was previously referred to as an APSR (Area of Potential Significant Risk). AFAs include cities, towns, villages, and individual risk receptors (IRR)
CFRAM Study	Catchment-based Flood Risk Assessment and Management Study	The five year study covering the whole River Shannon catchment area which gives a picture of past flooding and areas at risk of future flooding, and sets out a prioritised set of specific measures for reducing and managing flood risk.
HEP	Hydrological Estimation Point	A location along a watercourse (MPW and HPW) at which flood flows are estimated for a range of flood events of different frequencies.
HEFS	High-End Future Scenario	Potential future scenario representing climate change impacts not significantly outside the range of accepted predictions available, and with the allowances for increased flow, sea level rise etc. at the upper bounds of widely accepted projections
HPW	High Priority Watercourse	Watercourses that could give rise to existing or potential future fluvial or estuarine flooding within an AFA
IRR	Individual Risk Receptor	A receptor that warrants consideration of flood risk in its own right (rather than within an AFA), typically major infrastructure. Note that an IRR is a specific type of AFA
Manning's 'n'	Manning's 'n'	An empirical value used widely in hydraulic modelling to describe the hydraulic roughness of an area along (or over) which water flows. Higher values

		indicate a “rougher” surface.
MPW	Medium Priority Watercourse	Watercourses that could give rise to existing or potential future fluvial or estuarine flooding outside of AFAs. River reaches between AFAs, or between an AFA and the sea are also defined as MPWs.
MRFS	Mid-Range Future Scenario	Represent a ‘likely‘ future scenario based on the wide range of predictions available and with the allowances for increased flow, sea level rise, etc. within the bounds of widely accepted projections
OSi	Ordnance Survey Ireland	The base mapping (ortho aerial imagery, vector data and raster data) used throughout the study and this report is owned by Ordnance Survey Ireland and is reproduced under a licence agreement.
RBD	River Basin District	The natural geographical and hydrological units for water management, as defined during the implementation of the Water Framework Directive.
UoM	Unit of Management	The division of the study area into major catchments and their associated coastal areas.
1D domain	1D domain	The part of a hydraulic model which is defined by flow in 1 dimension. This is used for flow that is within the banks of a watercourse as the flow is essentially in one direction.
2D domain	2D domain	The part of a hydraulic model which is defined by flow in 2 dimensions. This is used for flow that is out of bank, spreading across a floodplain or other area. The flow is characterised by flood water spreading in two dimensions (in plan view) once it overtops the banks of a watercourse. Tidal flooding is also typically in 2 dimensions.

1 Introduction

1.1 Shannon CFRAM Study Area

The Shannon (the "Study Area") is the largest River Basin District (RBD) in Ireland, covering approximately 17,800km^2 and more than 20% of the island of Ireland. The RBD includes the entire catchment of the River Shannon and its estuary as well as some catchments in North Kerry and West Clare that discharge directly to the Atlantic.

The Shannon River rises in the Cuilcagh Mountains, at a location known as the Shannon Pot in the counties of Cavan and Fermanagh. The river flows in a southerly direction before turning west and discharging through the Shannon Estuary to the Atlantic Ocean between counties Clare and Limerick. Whilst the River Shannon is 260km long from its source to the head of the Shannon Estuary in Limerick City, over its course the river falls less than 200m in elevation. The Shannon RBD is characterised as an 'International RBD' as it extends into Northern Ireland. However, there are no areas identified as being at significant flood risk in the Shannon RBD within Northern Ireland, and no significant cross-border issues.

Significant tributaries of the Shannon include the Inny, Suck and Brosna. There are several lakes in the RBD, including Lough Ree, Lough Derg and Lough Allen.

Other important rivers within the RBD include the Maigue, Deel and Feale discharging into the Shannon Estuary from the south, and the Fergus, Owenogarney (or Ratty) and Cloon discharging into the estuary from the north.

The RBD includes parts of 17 counties: Limerick, Clare, Tipperary, Offaly, Westmeath, Longford, Roscommon, Kerry, Galway, Leitrim, Cavan, Sligo, Mayo, Cork, Laois, Meath and Fermanagh. While much of the settlement in the RBD is rural there are six significant urban centres within the RBD - Limerick City, Ennis, Tralee, Mullingar, Athlone and Tullamore.

As defined under the Water Framework Directive (WFD) a RBD is divided further into Units of Management (UoM). The UoM constitute major catchments or river basins (typically greater than 1000km^2) and their associated coastal areas, or conglomerations of smaller river basins and their associated coastal areas. The Shannon RBD (and by definition the Shannon CFRAM Study Area) and the UoM within the Shannon RBD are shown in Figure 1.1. There are five UoMs within the Study Area, as marked on Figure 1.1:

- Tralee Bay – Feale (Hydrometric Area 23 – 'HA23') – UoM 23
- Shannon Estuary South - (Hydrometric Area 24 – 'HA24') – UoM 24
- Shannon Upper and Lower (Hydrometric Area 25 & 26 – 'HA25 & 26') – UoM 25/26
- Shannon Estuary North (Hydrometric Area 27 – 'HA27') – UoM 27
- Mal Bay (Hydrometric Area 28 – 'HA-28') – UoM 28

1.2 Hydraulics Report Scope

The specification for the Hydraulics Report is set out in Section 7 of the Catchment – based Flood Risk Assessment and Management (CFRAM) Studies Stage 1 Project Brief (June 2010) and elements of Sections 2.21 to 2.23 of the Shannon CFRAM Study Stage II Project Brief (October 2010). Relevant extracts are included in Appendix A. It should be noted that programme dates noted in Appendix A are superseded.

The scope requires a single Hydraulics Report for each UoM. Each Hydraulics Report is required to cover both fluvial hydraulic models and coastal flooding models where applicable.

There are no hydraulic models or coastal flooding models required for UoM 28 under the scope of works for the Study Area, so therefore no associated Hydraulics Report for this UoM is required. There are therefore four Hydraulics Reports for the Shannon CFRAM Study Area, one for each UoM in which at least one fluvial hydraulic model or coastal flooding model exists.

1.2.1 Fluvial & Coastal Hydraulic Models

The Shannon CFRAM Study Area is comprised of 38 fluvial and / or coastal hydraulic models, split between the UoM. The model numbers and AFA/IRR names are a unique identifier enabling easy identification of the relevant model covering a particular AFA of interest. The prefix "N" refers to the "North" part of the Shannon RBD which is all models covering UoM 25/26, while the prefix "S" refers to the "South" part of the Shannon RBD covering UoM 23, 24, and 27. The North and South identifiers do not represent any formal administrative or regional boundaries; they are used for convenience within this study due to the study's large geographic area.

There are two IRRs within the Shannon RBD (Tarbert Power Station and Shannon Airport) which are at risk of flooding from tidal and wave conditions only and therefore are being appraised as standalone coastal flooding models. Table 1.1 summarises the 62 AFAs and 4 IRRs being represented across the 38 hydraulic models.

Table 1.1 List of Hydraulic Fluvial & Coastal Models by UoM

UoM	Model Ref	AFA/IRR names	Fluvial (F) or Coastal (C) models
UoM 23	S14-a	Abbeyfeale, Listowel	F
	S14-b	Moneycashen	F / C
	S14-c	Athea	F
	S15	Abbeydorney	F
	S16	Tralee	F / C
	S17	Banna	F / C

UoM	Model Ref	AFA/IRR names	Fluvial (F) or Coastal (C) models
UoM 24	S05	Ballylongford	F / C
	S06	Adare, Clarina	F / C
	S07	Croom	F
	S08	Kilmallock, Charleville	F
	S09	Foynes	F / C
	S10	Rathkeale, Askeaton	F / C
	S11	Newcastle West	F
	S12	Dromcolliher, Milford	F
	IRR4	Tarbert Power Station (IRR4)	C
UoM 25/26	N01	Boyle, Drumshanbo, Leitrim, Carrick-on-Shannon	F
	N02	Mohill, Dromod, Longford, Cloondara	F
	N03	Edgworthstown, Abbeyshrule, Ballymahon	F
	N04	Roscommon	F
	N05	Mullingar	F
	N06	Kilbeggan, Clara, Pollagh	F
	N07	Clonaslee, Rahan	F
	N08	Castlerea, Athleague	F
	N09	Ahascragh, Ballinasloe	F
	N10	Lanesborough Power Station (IRR1), Athlone, Shannonbridge Power Station (IRR2), Shannon Harbour	F
	N11	Roscrea, Birr	F
	N12	Portumna, Killaloe / Ballina, O'Brien's Bridge, Casteconnell, Springfield	F
	N13	Borrisokane	F
	N14	Nenagh	F
	N15	Cappamore, Newport	F
	N16	Limerick City and Environs	F / C
UoM 27	S01	Ennis	F / C
	S02	Quin	F
	S03	Bunratty, Sixmilebridge	F / C
	S04	Shannon,	F / C
	IRR3	Shannon Airport (IRR3)	C.
	S18	Kilrush	F / C
	S19	Kilkee	F / C

1.3 Context for Hydraulics Report under the EU Floods Directive

The four Shannon CFRAM Study Hydraulics Reports, representing each of the UoM, have all been produced to support the OPW in its legislative role to report flood hazard and develop a management plan for all significant flood risk areas across Ireland. This is required under the EU "Directive on the assessment and management of flood risks" (2007/60/EC), commonly referred to as the "Floods Directive".

1.4 Structure of this Report

1.4.1 Main Report

This Hydraulics Report covers all hydraulic modelling and mapping aspects relating to this UoM 23. The "Main Report" i.e. this document excluding appendices, is structured to reflect the specific reporting requirements of the CFRAM Studies Project Brief as follows:

Section 1 Provides an introduction to the Hydraulics Report and sets the context and scope of this activity within the Shannon RBD.

Section 2 Provides a description of the Hydrometric and Hydrological Information used in the Fluvial Hydraulic Modelling and Coastal Flooding Modelling.

Section 3 Describes, in general terms, the approach to Fluvial Hydraulic Model construction and calibration.

Section 4 Describes, in general terms, the approach to Coastal Flooding Model construction and calibration

Section 5 Presents the approach to flood hazard and flood risk mapping.

With specific reference to the detailed requirements of the Hydraulics Report, as set out in the CFRAM Studies Project Brief, Table 1.2 shows how these requirements are met within the structure of this report.

Table 1.2 Project Brief Requirements and Links to this Report

Brief Requirement	Hydraulics Report Section and Description
Surveys	*Section 3.3 - Survey Data and Base Mapping* This section describes the flood defences, the channels, the structures and the floodplain survey data that was collected for the development of the hydraulic models.
Development of Fluvial Hydraulic Models	*Section 3 – Hydraulic Model – Summary of Methodology* This section details the methodology followed in the development of the fluvial hydraulic models.

Model Calibration	*Section 3.5 - Hydraulic Model Calibration and Sensitivity Model Runs* This section details the process involved in the calibration of the hydraulic models. The purpose of the calibration process is to test the confidence of the results and to ultimately identify flood outlines, flood depths, and flood hazards.
Development of Coastal Flooding Models	*Section 4 - Coastal Flooding Model Construction* This section addresses the coastal flooding model construction process in general terms.
Development of Flood Hazard Mapping	*Section 5 – Flood Hazard Mapping* This section describes the methodology behind development of the flood hazard maps.

1.4.2 Report Appendices

A series of appendices to this Hydraulics Report are relevant to summarising our adopted modelling approach. These are:

Appendix A Relevant extracts from CFRAM Studies Project Stages I and II defining the scope of the Hydraulics Report.

Appendices B Fluvial Hydraulic Model Appendices. Each hydraulic model with a fluvial only component has an individual Appendix section numbered B1, B2, B3, B4 etc, covering specified elements of the models for UoM 23.

Appendices C Fluvial/Coastal Hydraulic Model Appendices. Each hydraulic model with coastal only or coastal and fluvial components has an individual Appendix section numbered C1, C2, C3, C4 etc, covering specified elements of the models for UoM 23.

Appendix D Shannon CFRAMS Design Tidal Hydrographs

Appendix E National Technical Co-ordination Group (NTCG) Guidance Note no. 23 (GN23)

Appendix F National Technical Co-ordination Group (NTCG) Guidance Note no. 22 (GN22)

Appendices B and C provide specific information for each respective model. This enables different stakeholders to easily identify the models that may be of interest to them, allowing them to view the **relevant model Appendix section**. Table 1.3 summarises the Appendix section reference for each model and the relevant AFA for UoM 23.

Table 1.3 Fluvial Hydraulic Model and Fluvial/Coastal Model Appendices for UoM 23

Appendix Section	Hydraulic Model Reference	AFA	County
Appendix B1	S14-a	Abbeyfeale	Limerick
		Listowel	Kerry
Appendix B2	S14-c	Athea	Limerick
Appendix B3	S15	Abbeydorney	Kerry
Appendix C1	S14-b	Moneycashen	Kerry
Appendix C2	S16	Tralee	Kerry
Appendix C3	S17	Banna	Kerry

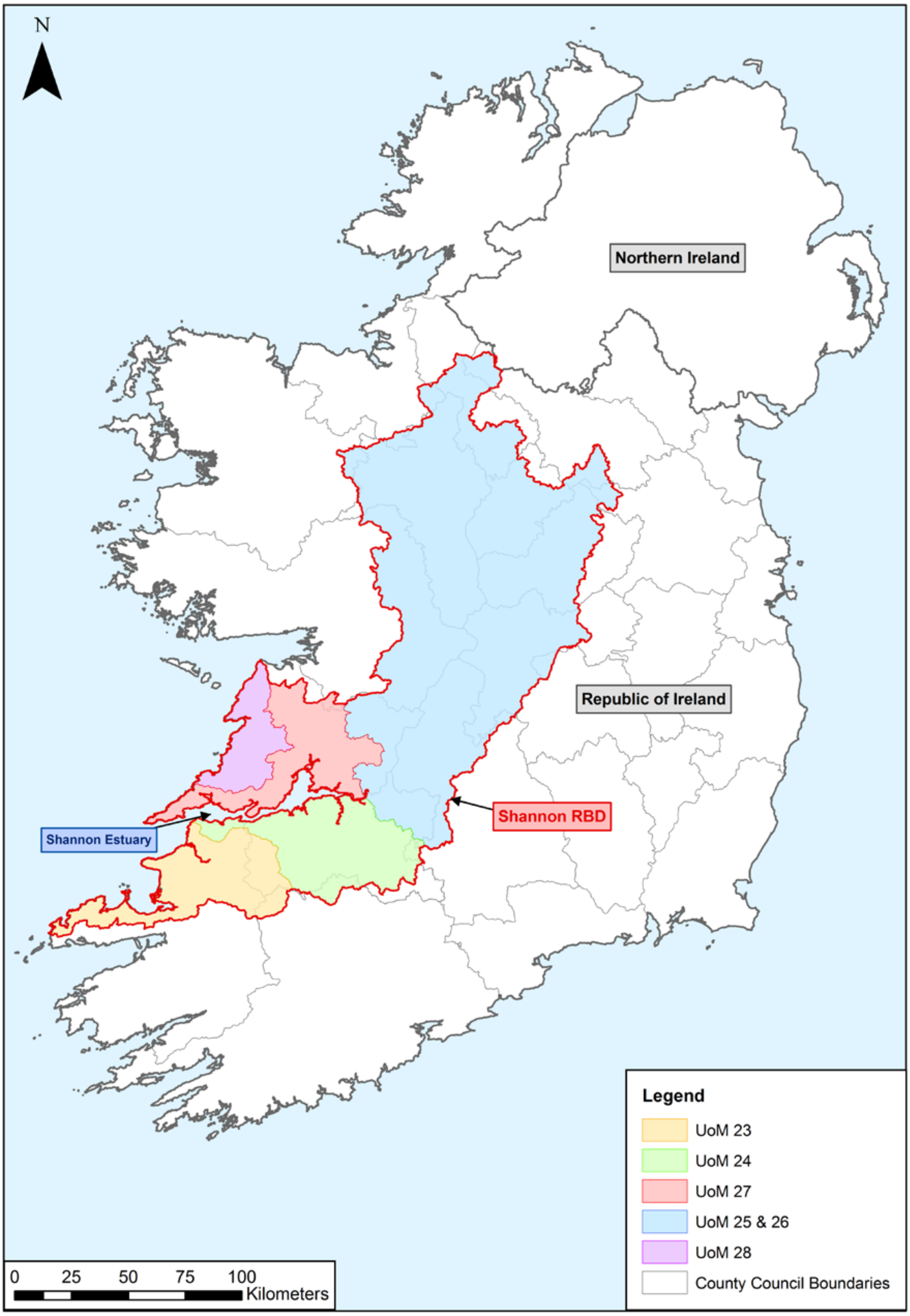

Figure 1.1 Shannon RBD and its Units of Management

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2 Hydrological and Hydrometric Information

2.1 Catchment Description

The Tralee Bay - Feale Unit of Management (or UoM 23) is shown in its wider context within the Shannon RBD in Figure 1.1, and in more detail in Figure 2.1. It encompasses areas of three counties; Kerry, Limerick and Cork. It is bounded on the northwest by the mouth of the Shannon Estuary and on the east and southeast by the Mulllaghareirk Mountains, forming the catchment divide between UoM 23 and 24 (Figure 2.1). Along the southern boundary from east to west are the Glanaruddery Mountains and the Slieve Mish Mountains which extend into the Dingle Peninsula. The total area of UoM 23 is approximately 1800 km^2.

The unit of management is dominated by the Feale catchment in the central and eastern area. The River Feale drains into Cashen Bay in its lower reaches where it becomes tidally influenced. This catchment, with a total area to the mouth of the Cashen of 1155 km^2 makes up around 65% of the total area of UoM 23.

Major tributaries to the Feale catchment include the Shannow, Brick, Galey, Smearlagh, Allaghaun, and Oolagh rivers. These typically drain the upland areas to the east and south of the area, with the exception of the Brick which predominantly drains a lowland area towards the west.

The southern and southwestern area is dominated by mountainous and upland areas with many steep and flashy watercourses, notably around the Dingle Peninsula and Tralee. The Slieve Mish mountains are to the south and southwest of Tralee, with Stack's Mountains to the east and northeast of Tralee. The main rivers in this area are the River Lee and Big River, both flowing into Tralee.

The western area along the Atlantic coast (Ballyheige Bay) is a mainly low lying area with small catchments draining to the west coast. This area is protected by an extensive coastal dune system. There are important drainage schemes in this area behind the dune system, notably the Akeragh Drainage System which discharges to the Atlantic approximately 3km south of Ballyheige.

The northwest coast, with the exception of the Cashen which also discharges here, is characterised by small rivers and streams discharging to the Atlantic Ocean

Table 2.1 below indicates the main sub-catchments and watercourses modelled in this unit of management.

Table 2.1 Sub-catchment and models within UoM 23

Sub-catchments	Main Watercourses	AFAs	Model Reference
Feale	Allaghaun (River) Oolagh (River) Feale (River)	Abbeyfeale Listowel	S14-a
	Cashen (River) Feale (River)	Moneycashen	S14-b
	Galey (River)	Athea	S14-c
	Brick (River)	Abbeydorney	S15

Lee	Lee (River)	Tralee	S16
Big	Big (River)	Tralee	S16
Tyshe	Tyshe (River)	Banna	S17

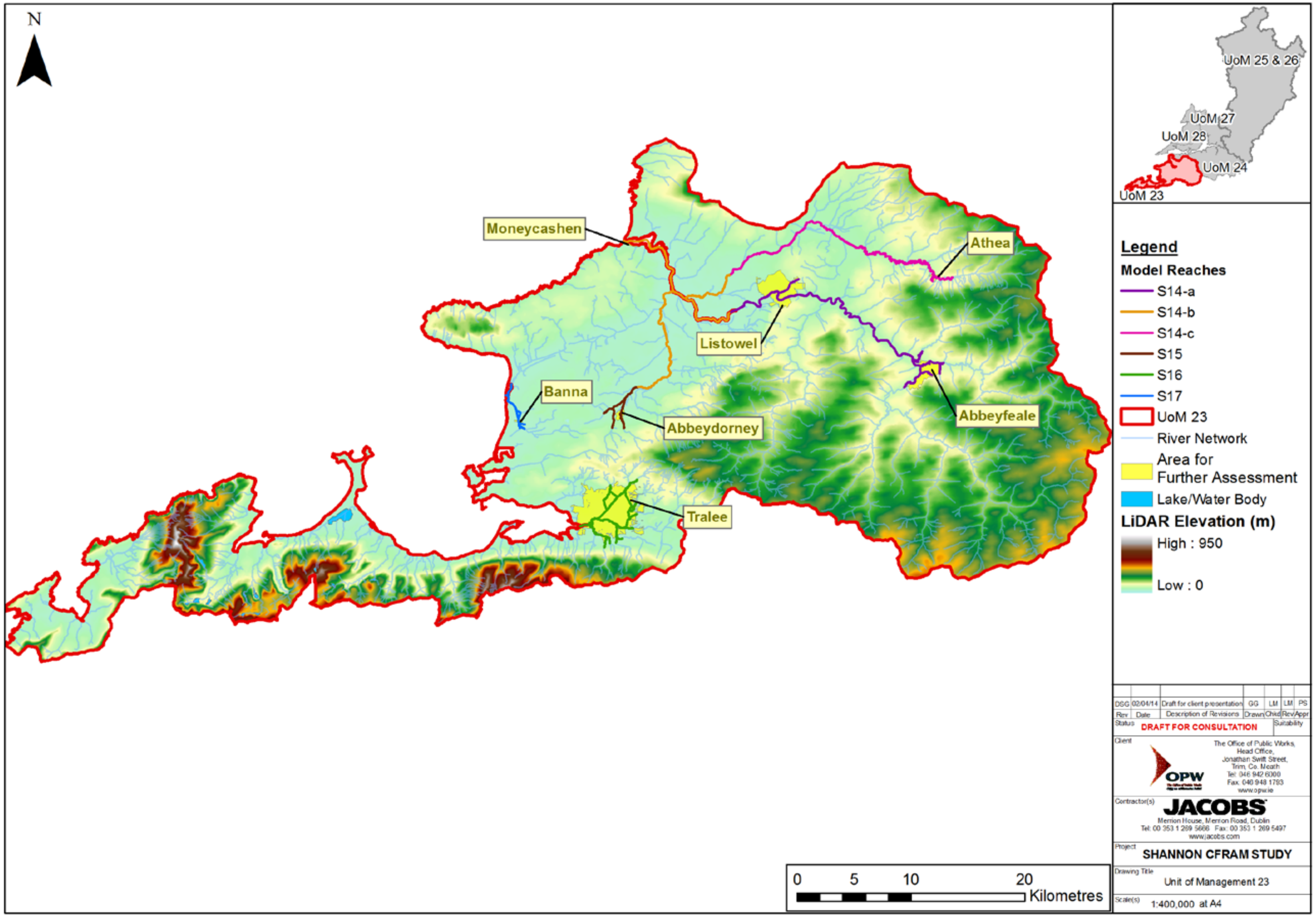

Figure 2.1 UoM 23 Study Area and hydraulic models

2.2 Hydrometric Data

Details of the hydrometric data used in the study, and the relevance to each UoM within the Shannon RBD, are discussed in the Preliminary Hydrological Assessment and Method Statement, produced as part of the **Inception Report** in 2012.

There is also a **Hydrology Report** associated with each UoM prepared in conjunction with this Hydraulics Report, which provides significant information with regard to the hydrometric data used.

Details of the Hydrology Report are not repeated within this Hydraulics Report, although the key aspects are noted.

The focus for the use of hydrometric data within the Shannon RBD is on river gauging stations where there are time series records of both water level and flow. As noted in the Inception Report, there is limited sub-daily rainfall data available within the Shannon RBD, and therefore rainfall-runoff modelling has not been used. The derivation of flow estimates for input to the hydraulic models is therefore based on the statistical analysis of flows across the catchment. This is the case for all UoM's within the Shannon RBD.

Table 2.2 summarises the split of gauging station reviews across each of the UoM, with a full list of the gauging station reviews undertaken for UoM 23 presented as Table 2.3.

Table 2.2 Hydrometric Gauging Stations for review across the Shannon RBD

Unit of Management	Number of GS for rating Review
UoM 23	3
UoM 24	11
UoM 25/26	28
UoM 27	2
UoM 28	0

2.3 Historic Data

In addition to the hydrometric data, historic flood information has also been used where possible, to inform the development of the hydraulic models and to check the validity of the model against historic events.

In principle, this requires recorded water levels and flows at a defined location and time. This can then be verified with flow estimates derived from gauging station data, enabling the accuracy of the hydraulic model to be verified.

Appendix F of the Hydrology Report for UoM 23 contains the relevant historic data available and used for each respective hydraulic model within UoM 23.

Table 2.3 Gauging Stations with a Rating Review within UoM 23

Hydrometric Gauging Station No.	Name of Station	River	UoM 23 sub-catchment
23012	Ballymullen	Lee	Lee
23014	Athea	Galey	Feale
23021	Shannow Bridge	Shannow	Feale

2.4 Design Flows

Taking account of the gauging station reviews, historic flood information and the use of appropriate hydrological methods, design flows have been developed across the RBD at specified Hydrological Estimation Points (HEPs). These HEPs are typically at 5km spacing along watercourses, at the confluence of watercourses, and at the upstream and downstream AFA boundaries where the watercourse flows into and out of the AFA.

The design flows for each hydraulic model are provided in the relevant model Appendix section, with further information provided in the Hydrology Report.

2.5 Coastal Aspects of the Catchment

2.5.1 Sites for coastal flooding assessment

Table 2.4 lists the AFAs within UoM 23 selected by the OPW for being at risk of flooding from coastal sources either through a combination of high tide and surge and/or due to wave overtopping. These areas are shown on Figure 2.3. For completeness, Table 2.4 also shows whether these areas are also at risk of fluvial flooding.

Table 2.4 Sites for coastal flooding assessment within UoM 23

Model reference	Name of AFA	Source of flood risk		
		Tide +Surge	Wave overtopping	Fluvial
S14-b	Moneycashen	Yes	No	No
S16	Tralee	Yes	Yes	Yes
S17	Banna	Yes	No	Yes

2.5.2 Coastal data

OPW have provided the results from the Irish Coastal Protection Strategy Study (ICPSS)[1]. This gives extreme tidal peak levels for the following annual probabilities: 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.1% for the south western coast and the Shannon Estuary. These peak levels along with tidal gauge level data (2003-2007)

[1] Irish Coastal Protection Strategy Study Phase 4 – South West Coast, December 2013 - RPS

collected from the Shannon Foynes Port Company at Carrigaholt were used to produce design tidal hydrographs. This process is fully explained in Section 4.3 and Appendix D of this report. The design tidal hydrographs were used to inform downstream boundary conditions for the following hydraulic models: S14-b, S16 and S17.

OPW has also provided results from the ICWWS (Irish Coastal Wave & Water Level Modelling Study)[2] screening analysis which highlight coastal locations potentially vulnerable to wave overtopping for the south western coast and the Shannon Estuary.

For these locations, detailed wave and still water level model outputs are available in the form of shoreline prediction points and their associated predicted water level and wave climate (wave height H_{mo}, period T_p and mean direction) combinations for a range of annual probabilities (50%, 20%,10%, 5%, 2%, 1%, 0.5% and 0.1%). These outputs include both the current condition and two future scenarios (Mid Range Future Scenario [MRFS] and High End Future Scenario [HEFS]).

S16 is the only model within UoM23 for which wave overtopping simulations have been undertaken because it is the only location in the Shannon CFRAM Study which is within UoM23 that the ICWWS has highlighted as a location that is potentially vulnerable. The methodology adopted to carry out wave overtopping modelling is fully explained in Section 5.5 of this report.

[2] Irish Coastal Wave & Water Level Modelling Study – Coastal Areas Potentially Vulnerable to Wave Overtopping, RPS, November 2012

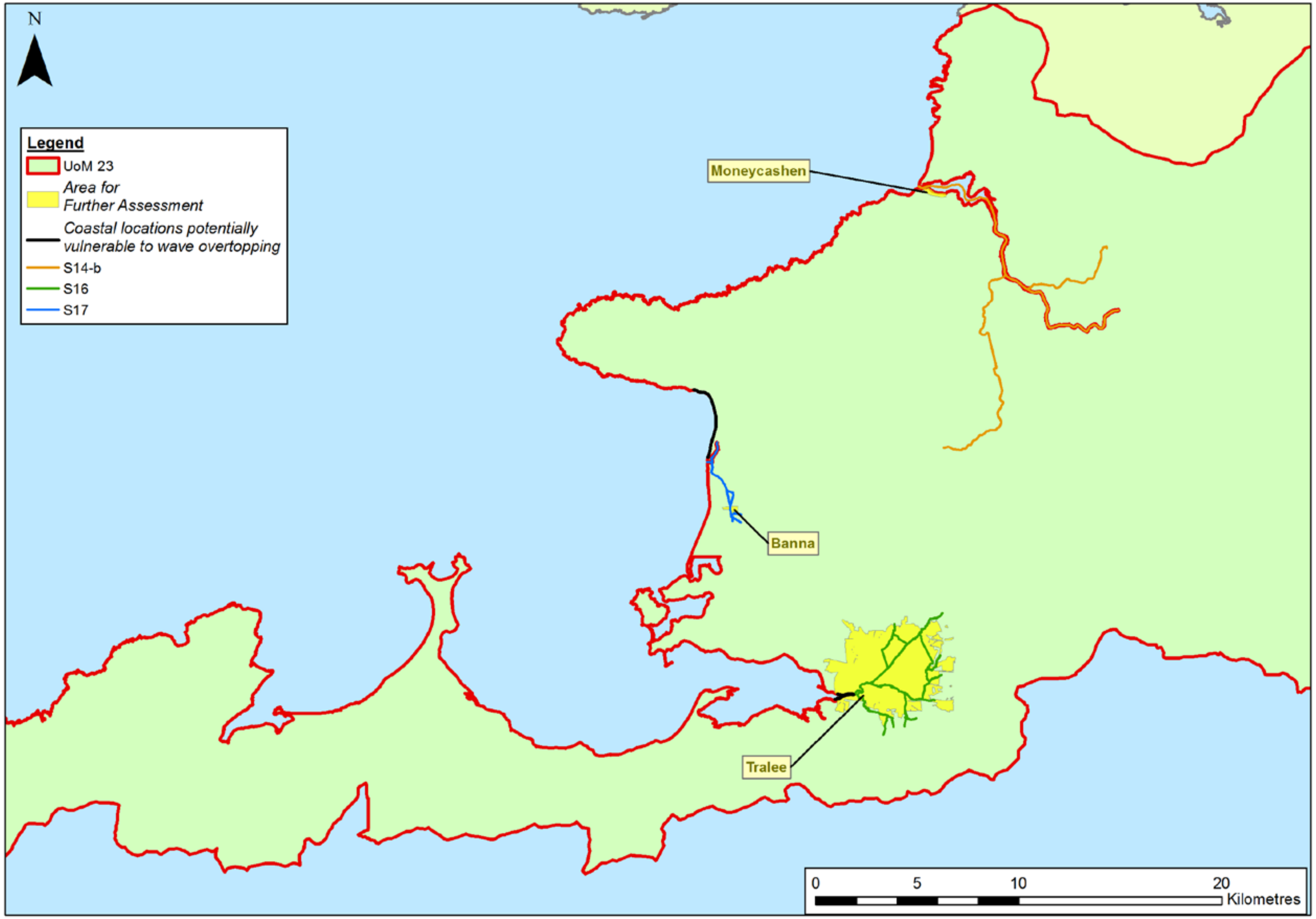

Figure 2.3 – AFAs and Models within UoM 23 for coastal flooding assessment

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3 Fluvial Hydraulic Model – Summary of Methodology

3.1 Introduction

All hydraulic models within UoM 23 have been developed for HPWs and MPWs to estimate fluvial design and potential future flood levels, depths, velocities and extents. Where possible the models have been calibrated and verified against observed flood events. The models have been run for fluvial design flood events with the following range of annual exceedance probabilities (AEPs):

- 50%, 20%, 10%, 4%, 2%, 1%, 0.5% and 0.1% for existing conditions and for the Mid-Range Future Scenario (MRFS)
- 10%, 1% and 0.1% for the High End Future Scenario (HEFS)

This section of the Hydraulics Report provides an overview of the model construction method, common to all the Shannon CFRAM fluvial hydraulic models with the exception of the S16 model for which different software has been used (See Section 4).

Further detail on each hydraulic model is then included in the relevant model Appendix section (Appendix B and C), covering specific information on the following elements:

- Basic Model Information
- Survey Data and Base Mapping
- Hydraulic Model Construction and Schematisation
- Hydraulic Model Calibration and Sensitivity
- Model Files and Naming Convention
- Key Model Assumptions

The following sections provide the overview of the relevant data and approach taken with regard to these elements.

3.2 Base Model Information

The base model information provided for each model covers:

- Model ID
- Unit of Management
- AFAs included within the model
- Primary watercourses and water bodies included within the model domain

3.3 Survey Data and Base Mapping

The base data required for the hydraulic model build is as follows:

- Mapping data in suitable formats to provide base mapping for the models
- Survey data for floodplain areas derived from LiDAR survey
- Topographic survey defining key ground levels, channel cross-sections
- Longitudinal sections, and levels and dimensions of critical structures

- Flood defence information[3]: type, extents and crest levels

3.3.1 Base Mapping

The base mapping used throughout is standard OSi mapping at a scale of 1:50,000 provided in raster format. Within each relevant model Appendix section, the relevant 1:50,000 OSi tile reference(s) are noted for the area covered by the model.

To aid with the presentation of the flood mapping, this is supplemented by OSi NTF[4] vector mapping at scales of 1:5,000, 1:2,500 and 1:1,000 covering the entire Shannon RBD. There is no overlap between these mapping files; the scale at which mapping is available depends on the nature of the area. For example, rural areas are typically at 1:5,000 while town centres are typically covered by 1:1,000 map tiles.

3.3.2 Digital Terrain Model for 2D Model domain

For the development of the two dimensional (2D) model domain, for those models that are constructed using a 1D-2D (ISIS-TUFLOW) approach, a Digital Terrain Model (DTM) is required for the 2D domain.

The data used for the 2D domain is a combination of high resolution LiDAR data covering the AFAs and the HPW reaches, combined with lower resolution IFSAR data for the areas outside of the AFAs and along MPW reaches.

The LiDAR data has a 2m horizontal resolution and a 200mm vertical accuracy. The IFSAR data has a 5m horizontal resolution and an approximate 500mm-1000mm vertical accuracy.

Due to the method by which the LiDAR data has been gathered (by flying defined flight lines over the area for which LiDAR data is to be captured) there is often LiDAR available for reaches outside the defined AFA boundary. Where this higher accuracy LiDAR data is available outside AFAs, it has been incorporated into the hydraulic models in preference to the IFSAR.

3.3.3 River Channel / Structures Survey

The topographic survey of the watercourse channels, estuaries and associated structures for UoM 23 has been undertaken by Blom and Murphy Surveys. The survey was procured by Jacobs from August 2012 to July 2013.

The channel and structure survey includes:

- **Channel cross-sections.** This includes the bank profile extending a short distance into the floodplain, the channel bed profile, the water level at the time of the survey, and an indicative location of the “top of bank”.

- **Longitudinal sections.** This includes sections along both river banks, picking up key features of the river bed profile such as weirs and along the river banks, such as high points, low points, start / end of flood defences walls etc.

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[3] The Flood Defence Asset Database is provided as a separate deliverable to this report.
[4] NTF is a vector mapping format provided by OSi. It can be translated into a Mapinfo/ArcGIS compatible format.

- **Structure surveys.** This includes a section at the upstream and downstream faces of all identified structures. It also includes details of the structure and any flood relief features such as shapes, width, height, length, pier details, soffit level, deck level, springing levels.

- **Flood defence surveys.** Long section spot levels along the crest and the toe of formal flood defences.

The survey information has been provided in AutoCad, ArcGIS and ISIS format for the river cross-sections. Full details of survey outputs for each model are provided in the topographic survey deliverables submitted separately to this report.

3.4 Fluvial Hydraulic Model Construction and Schematisation

The model build process includes the following:

- Modelling approach and Software used for the 1D and 2D domains
- Model area covering the modelled reaches and the 2D domain
- River reaches defined within the model, covering both MPW and HPW
- Structures included in the model that have a hydraulic impact
- Floodplain schematisation
- Schematisation of the 2D domain (for 1D-2D models) including 1D elements and breaklines within the 2D domain
- Hydraulic roughness for in bank and out of bank flows
- Model boundaries – Inflows and Downstream conditions

3.4.1 Modelling Approach and Software

The software used and the modelling approach developed can vary, depending principally on the hydraulic complexity and scale of the river system network.

The vast majority of models developed on the Shannon CFRAM Study are dynamically linked 1D-2D models, where:

- 1D approach is adopted for the modelling of in-bank (channel) fluvial reaches for HPWs and for in-bank and out-of-bank (floodplain) modelling for MPWs.
- 2D approach is used for out-of-bank modelling for HPWs.

However in some instances, there are exceptions to these principles where a 1D approach is deemed appropriate for out-of-bank modelling of HPWs. Conversely there are also some examples where a 2D approach is used to undertake the out-of-bank modelling for MPWs.

The modelling approach used for each fluvial hydraulic model within UoM 23 is indicated within the relevant model Appendix section.

The 1D-2D models are constructed using the ISIS-TUFLOW[5] link based on the combination of the one dimensional (1D) river modelling package ISIS (by

[5] As mentioned in Section 3.1, model S16 in UoM23 uses a different approach and software. Further details are provided in Section 6.

CH2MHILL Software) and the two dimensional (2D) modelling software TUFLOW (by BMT WBM).

The methodology adopted for the hydraulic modelling of the river systems is based on the approaches described by the TUFLOW modelling manual. The user sets up a model as a combination of 1D network domain representing the river channel, dynamically linked to a 2D domain representing the adjacent floodplain, using the hydrodynamic programme to form a single model.

The 1D and 2D domains can be linked by three separate methods which are as follows:

- Replace part of a 1D model by nesting a 2D domain inside a broader scale 1D model
- Insert 1D networks underneath a 2D domain or through an embankment
- Replace or carve a 1D channel through a 2D domain

The general approach applied within this study is the latter, in which a 1D ISIS model of the river / watercourse system is "carved" through the 2D TUFLOW model of the floodplain as shown schematically in Figure 3.1.

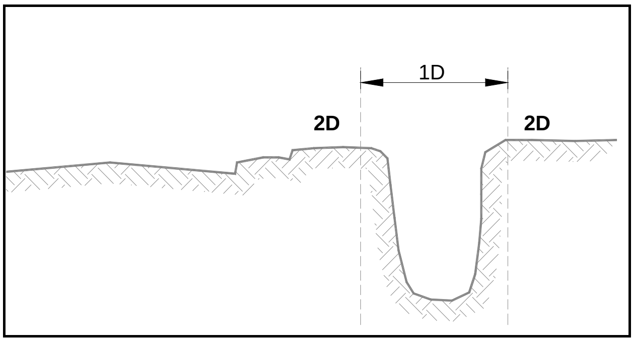

Figure 3.1 Modelling a river channel in one dimension and the floodplain in two dimensions (TUFLOW Manual, 2010)

In addition to this 1D-2D approach, there are also specific 1D elements which can be added within the 2D domain using ESTRY, which is a 1D software embedded within TUFLOW. This may be used, for example, if there is a culvert through a road or railway embankment that may be crossing a 2D represented floodplain. This allows the two sides of the floodplain to be linked via the culvert which is effectively a 1D flow path. This is outlined further under Section 3.4.9.

The specific model software versions used for each model are included within the relevant model Appendix section.

3.4.2 Model Area and Extent

The model area and the extent of both the 1D reaches and the 2D domain are included as an Annex to each relevant model Appendix section. These are in the form of a series of plans as follows:

- **Model extent plans** – These show the full modelled reaches, names of primary watercourses and the AFA boundaries.

- **Model schematic plans** – These show a series of maps at a larger scale than the model extent plan, detailing critical parts of the model schematisation. They include the AFA boundaries, MPW and HPW reaches, the 2D domain extent, cross-section locations and their model reference number, presence of spill units, reservoir units, flood defences, parallel channels, and other model details pertinent to the specific location.

3.4.3 Model Reaches

Each model is comprised of a series of model reaches. The reaches defined in the model are included in the relevant model Appendix section and are identified by the watercourse name, the reach identification number and the upstream and downstream model nodes.

3.4.4 ISIS river cross-sections

As already mentioned, topographic survey cross-sections across the river reaches have been provided in ISIS format and therefore are directly imported into the ISIS software.

Where required, interpolated cross-sections are added between the topographic survey sections to ensure model convergence where significant change occurs in the water level profile.

Panel markers are set at the top of bank to mark the change between channel and floodplain. Additional panel markers are also used to mark changes in roughness values across the floodplain for extended cross-sections.

Deactivation markers are used to deactivate out-of-bank areas within the cross-sections deemed to be hydraulically inactive in the ISIS model. These are, for example, widely applied across the reaches where out-of-bank areas are modelled in 2D.

3.4.5 Model Structures

The structures surveyed are typically bridges, culverts, weirs, sluices and gates. Not all surveyed structures have been included within the hydraulic model. Those structures not included in the model do not influence water levels during high flow events. For example, a low weir in the river channel becoming drowned out before out of bank flow occurs would not be included in the model unless deemed hydraulically necessary (e.g. part of the in-bank model calibration process).

For each model a structure schedule has been prepared and includes:

- topographic survey reference
- ISIS node reference
- type of structure
- modelling approach
- whether the structure is included in the model

The structure schedule(s) are included in an Annex to each relevant model Appendix section.

3.4.6 Floodplain Schematisation

The schematisation of the floodplain depends on the modelling approach adopted to model a particular reach and its adjacent floodplain. As mentioned previously, 1D approach is generally adopted for the modelling of in-bank (channel) fluvial reaches for HPWs and for in-bank and out-of-bank (floodplain) modelling for MPWs whilst 2D approach is used for out-of-bank modelling for HPWs.

Transition between 1D only and 1D-2D domains are therefore located near MPW/HPW interfaces; more precisely they are set up according to the local topography depicted by the LiDAR data preferably where the flood flow stays confined to the river channel or where the floodplain flow is well defined and run parallel to the river channel.

For the 1D (ISIS) only reaches, out-of-bank flow areas have been modelled by extending the river channel cross-sections or using reservoir units, spill units or parallel channels within the model.

With regard to the cross-section extension, this is done by using and extending the available cross-section survey using LiDAR or IFSAR, in a direction perpendicular to the 1D floodplain flow. Thus, the final cross-section is a combination of topographically derived ground levels and LiDAR / IFSAR. Where necessary, the LiDAR / IFSAR is adjusted by ground truthing to take account of the lower vertical accuracy of the LiDAR and IFSAR compared to the ground survey. Where such adjustment is made, a comment has been left in the ISIS main model file at the relevant cross-section.

Reservoir units (flood storage areas) or parallel channels are used in combination with spill units where the floodplain ground levels are below the river bank top level (e.g. flood defended reach). In such a situation it is not always appropriate to use extended cross-sections to represent floodplain flooding processes. Reservoir units across the floodplain are interlinked using either spill units or ISIS floodplain sections.

Where the floodplain is represented using a 2D approach, the 2D domain is based on a regular grid comprising individual square cells of a defined size. Each cell is given characteristics relating to the topography such as ground elevation, hydraulic roughness (see Section 3.4.10) and initial water level. For some models there may be more than one 2D domain defined.

On either side of the modelled watercourses, boundary lines define the bank crests. At these locations, there are 2D open flow boundary cells to represent the dynamic links between the 1D network and the 2D TUFLOW domain. 2D cells falling within the 1D network domain are ignored by the model and considered as inactive.

At each 1D ISIS model node, the corresponding river cross-sections are either trimmed or the floodplain area within the cross-sections deactivated at bank top level to match the 2D domain topography. The 1D model nodes are then connected to the 1D-2D boundary cells, allowing flood water to spill to and from the 2D domain when the calculated water level exceeds the banks' crest elevation.

3.4.7 2D Domain Grid Size

For the 1D-2D models, multiple 2D domains can be defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. The domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the floodplain flow.

Within each relevant model Appendix section, the number of 2D domains, the grid size and area covered by each domain is given.

3.4.8 Model Breaklines/Z-shape polygons in the 2D Domain

Breaklines are used in the 2D grid to accurately represent any geographical features that could have a significant impact on the propagation of the flood wave across the floodplain. It is particularly useful where the TUFLOW fixed grid discretisation does not guarantee that the crest along, for example, a wall, is picked up from the DTM. Breaklines are also used to incorporate surveyed features into the 2D model grid such as formal flood defences, surveyed bank tops, bridge parapets etc.

In a similar manner Z-shape polygons are used to correct any LiDAR anomalies picked up by the model grid or add additional features such as bridge decks that are often missing in the LiDAR data.

The features represented by breaklines/Z-shape polygons in each model are referenced in Section 3.7 of each Hydraulic Modelling Report..

3.4.9 Floodplain Structures in the 2D Domain

As noted under Section 3.4.1, 1D elements can be included in the 2D model using ESTRY software to represent structures permitting hydraulic connectivity across the floodplain. These can include a variety of features including: culverts under roads or railways, pedestrian subways, highway underpasses, a road under a railway bridge / viaduct (although these may also be represented as 2D features).

Specific 1D elements included in each model are listed in the relevant model Appendix section.

3.4.10 Hydraulic Roughness

Hydraulic roughness, or friction, is represented by Manning's coefficient "n" in the hydraulic models. The value of 'n' accounts for a range of factors that influence overall roughness either in the channel or across the floodplain. Factors included within the overall evaluation of Manning's 'n' include bed materials and size, vegetation, surface irregularities, channel bed forms, erosional and depositional features, channel sinuosity, and obstructions, all of which influence channel and floodplain conveyance.

Manning's 'n' is a semi-empirical parameter and cannot be directly measured; however a number of established reference literatures such as Chow[6] and UK

[6] Chow, V.T., Open Channel Hydraulics, 1984, McGraw Hill, Singapore

Environment Agency guidance[7] give advice on the selection of the roughness coefficients for channels and floodplains.

The values adopted in the models are highly variable but are generally in the range 0.025 for a relatively smooth, even, un-vegetated channel, up to 0.090 for out of bank flows across woodland. However, these are not strictly defined limits.

Floodplain Roughness

To represent the friction within the floodplain, Manning's 'n' has been defined based on the EPA Land Use classification for the floodplain areas where a 1D approach has been considered. This classification is provided as a GIS file, and for each different land use identified, a value for n has been assigned. Example areas are listed in Table 3.1. The incorporation of this GIS data into the ISIS software allows Manning's 'n' to be specified automatically for every cross-section data set across the floodplain.

Table 3.1 Example of Roughness definition within 1D floodplain areas based on EPA Land Use Classification

Land Use classification Level 3 Code	Manning's "n" value	Land Use description
231	0.035	Pastures
243	0.045	Heterogeneous agricultural land
122	0.025	Roads
111	0.100	Buildings
324	0.060	Transitional Woodland scrub
313	0.090	Forests
141	0.035	Green urban areas

[7] Fisher K., Dawson H., Roughness Review, Project W5A-057, July 2003 DEFRA/Environment Agency

To represent the friction within the floodplain areas represented in 2D, Manning's 'n' has been defined based on the more refined OSi NTF vector mapping classification. This classification is also provided as a GIS file, and for each different land use identified, a value for n has been assigned, as listed in Table 3.2. The incorporation of this GIS data into the 2D model DTM allows Manning's 'n' to be specified automatically for every grid cell within the 2D domain.

Table 3.2 Example of Roughness definition within 2D models based on OSi NTF Land Use Classification

NTF Land Use classification	Manning's "n" value	Land Use description
618	0.045	General Rural land
557	0.025	Roads
600	0.100	Buildings
611	0.060	General Urban
527	0.080	Woodland / Dense vegetation
583	0.035	Parkland / Sport grounds

It should be noted that the use of filtered LiDAR data to inform the 2D model DTM means that buildings are not inherently represented in the grid. Given the fact that any building is an obstruction to the flow and would have a major impact on the overland flow routes, a very high roughness value (0.100) has been attributed to each building/house within the study area to model the effect of the obstruction to flow. This is not a "true" Manning's 'n' value for a building, but is a technique that allows the obstruction from the building to be adequately factored in.

Channel Roughness

Channel roughness is defined for HPWs and MPWs reaches. Each reach is split into sections as appropriate depending on bed material, bank side vegetation and channel sinuosity and irregularities.

For each section of reach, a single Manning's 'n' value is set from left bank to right bank in each ISIS cross-section. This is a compound value which is estimated from photos, survey information and using the previously referenced UK Environment Agency roughness guidance.

For each MPW and HPW reaches within a model a channel roughness schedule is prepared, which includes details of Manning's 'n' values determined for each section of reach as described above.

3.4.11 Model Boundaries - Inflows

For each model, a detailed hydrological analysis of the river system catchment is carried out in order to produce hydrological inflows to the hydraulic model. This analysis is fully discussed in the UoM 23 Hydrology Report. The hydrological assessment also defines how to distribute the catchment flows within the hydraulic model i.e. flow boundaries are generally set at the upstream extents of a model and

also distributed laterally at appropriate HEP locations. The flows are reconciled with hydraulic influences during the HEP calibration process described in Section 3.5.2.

The Critical Duration is established intrinsically by virtue of the hydrological methodology employed (taking the maximum levels from the main and tributary flows) and is not established through hydraulic routing. The method is explained in the UoM 23 Hydrology Report.

The peak inflow values used for each modelled design event are included in the relevant model Appendix section, along with the HEP reference name and the model node at which the inflow hydrographs are applied.

3.4.12 Model Boundaries – Downstream Conditions (fluvial model)

The downstream boundary condition selected for the fluvial models within UoM 23 (i.e. model S14a, S14c and S15) is a free flow boundary set at the downstream limit in the 1D ISIS model. This equates to the flow being at "normal depth" for the channel slope at the downstream limit of the model. Checks have been made to ensure the normal depth assumption is reasonable and flood flows "leaving" the model are not in reality subject to a backing up effect from tidal influence, hydraulic structure or other floodplain features located downstream.

3.5 Hydraulic Model Calibration and Sensitivity Model Runs

Calibration of hydraulic models and the associated sensitivity analysis to test the confidence of the results based on uncertainty in the model input parameters is a critical part of hydraulic model development.

The following aspects are integral to the approach, as described in the following sections:

- Model Calibration and Verification taking account of relevant gauging stations and historical events
- Calibration to Hydrological Estimation Points (HEP)
- Sensitivity of modelled water level to key parameters – roughness, inflow, influence of structures, downstream boundary condition

3.5.1 Model Calibration and Verification to Historical Events

The approach to model calibration is described in National Technical Co-ordination Group (NTCG) Guidance Note no. 23 (GN23). This is included for reference in Appendix D. The fundamental points to note, with regard to achieving the best model calibration, are that the following data must be known:

- **Flow** at the point of interest
- **Water level** at the point of interest
- **Channel / hydraulic controls influencing the water level** at the location of interest so that the model is representative of the situation

Where there is uncertainty in any of these three variables, the accuracy of the calibration is reduced. As some catchments are gauged and some are ungauged, there is more flood history with reliable flow and water level data in some AFAs than others; and local hydraulic features have more of an influence in some locations than others; the reliability of each model's calibration is varied.

Wherever possible, a range of in-bank and out-of-bank events are used for calibration and verification. However, as noted in GN23, the lack of data in some locations makes calibration of the model unfeasible. Under these circumstances, a reality check against known flooding events (or events that caused flooding elsewhere but are known not to have caused flooding at the location of interest) is a useful part of a qualitative assessment to increase confidence in the model output in the absence of reliable quantitative data.

The use of photographs and anecdotal evidence of past events has also been used to validate flood extents modelled.

For each model, an analysis of available flood event data and high flow data for possible consideration as calibration and verification events has been carried out. Results of these analyses are covered in the Hydrology report.

Within each relevant model Appendix section, a summary of the calibration and verification events along with associated model calibration results is provided.

3.5.2 Verification to HEP

Hydrological Estimation Points (HEPs) are independently derived hydrological values, the details of which are provided within the Hydrology Report. Verification of the hydraulic models to the HEPs is carried out for the 10%, 1% and 0.1% AEP design events simulated.

The timing of the inflow hydrographs is adjusted to account for the travel time in the modelled reaches. This is done through an iterative process whereby the model is firstly run with the main river upstream inflow, then, at each iteration, the next downstream lateral inflow is added with its peak flow time adjusted to coincide with the peak time of the propagating flood wave as it is routed down the main river. This process is repeated until the most downstream lateral inflow is added. In this manner, the design hydrograph peaks and shapes are preserved within a reasonable degree of accuracy throughout the models. Total peak flows predicted by the hydraulic models at HEPs are then compared to the HEP predictions. Where necessary, hydrological inflows to the hydraulic model are scaled up or down to ensure that the modelled total peak flows remain within ±10% of the HEP predictions.

3.5.3 Model Sensitivity

Sensitivity tests are carried out on the hydraulic models in order to assess the sensitivity of the modelled systems to alterations in a number of key hydraulic parameters.

The results of the sensitivity analysis give an indication of the confidence levels that can be placed in the results being generated by the respective model.

For each model within UoM23, the sensitivity runs are carried out for the 1% AEP fluvial event. The following sensitivity tests have been carried out:

- Sensitivity to hydraulic roughness: Manning's 'n' values are both increased and decreased by 20%
- Sensitivity to hydrological inflows. All hydrological inflows are both increased and decreased by 20%

- Sensitivity to afflux parameters at key structures within an AFA. Afflux parameters are varied to reduce or increase the head loss during a 1% AEP flood event at key structures susceptible to having an impact on the flood extents
- Sensitivity to the downstream conditions. Depending on the type of the downstream boundary conditions chosen for a specific model, changes are made to assess how far upstream the design water levels are affected

Within each relevant model Appendix section, the results of the sensitivity tests for Manning's n and inflows are compared to the base case scenario and processed to determine the average peak water level difference and where the maximum water level difference occurs throughout the models; for other changes, the distance the effect is noticed in the water level results up and downstream of the changed parameter (e.g. downstream boundary conditions) is reported. An assessment is then made of the significance of the change on flood risk. The sensitivity results also inform the Uncertainty mapping, which shows the maximum impact of the sensitivity runs.

3.6 Model files and naming convention

The hydraulic model files associated with each model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. Within each relevant model Appendix section, there are details (names and purpose) on the model files included.

A generic convention is adopted to keep a consistent approach to the naming of the main ISIS (.dat) and where applicable TUFLOW (.tcf) files.

Model naming is as follows:

ModelNumber_QXXX_Source_Scenario_RunType_StatusVersion

Where:

- Model Number is a unique model ID (e.g. S15)
- QXXX is the flood frequency of the event simulated expressed in return period (e.g. Q100 for the 1% AEP event)
- Source is the source of flooding using either Flu for fluvial, Co for coastal, Mi for mixed (fluvial and tidal) and Wa for wave overtopping
- Scenario uses either C for current, M for MRFS and H for HEFS
- Run Type uses either Des for Design runs, Cal for calibration runs, Val for validation runs and Sen for sensitivity testing.
- StatusVersion uses IssV# for any model version that is delivered to the OPW.

Of a particular note, where joint probability runs are simulated, the Source element in the file name uses "FluMi" for fluvially-dominated event and "CoMi" for tidally-dominated event; this for a given flood frequency.

In each ISIS model, the 12-character node labels also follow a naming convention, which is described in Table 3.3.

Table 3.3 ISIS node label naming convention

Character	Description
1 2	**Model Reach Number** *Model reaches are specific to a watercourse. They are numbered from downstream to upstream. Model reach number is incremented at every confluence with a tributary and also at each model boundary for the watercourses whose full extent is covered by several hydraulic models (e.g. River Shannon).* Example: "01"
3 4 5	**Watercourse Reference Name** *Watercourse reference is unique across the entire UoM.except for small bifurcations off a main river (cut, loop) where the letter"X" replaces the last letter of the watercourse reference.* Example: River Brosna = "BRA", branch off the Brosna = "BRX"
6 7 8 9 10	**Cross-section chainage (m)** *Cross-section chainage starts at zero at the downstream end of each model reach* Example: "15010"
11 12	**Structure reference:** *Two letters are usually used to indicate the structure type (bridge, weir, culverts) and the upstream or downstream node* Example for a bridge: "bu" for the upstream node and "bd"for the downstream node.

3.7 Key Model Assumptions

Model specific assumptions are described in Section 6 of the relevant model Appendix section. In addition, there are generic assumptions which are summarised below.

3.7.1 Structures

Bridges

- USBPR and Arch Bridge units are used to represent bridges. In both units, the orifice mode is activated to allow for orifice flow when a structure becomes surcharged. For short bridges with a low soffit (e.g. farm or driveway access bridge), orifice units are preferably used as the structure is likely to become rapidly surcharged when the flow increases.
- Each bridge is associated with a spill unit to allow for spilling over the bridge under extreme conditions. When using the extended cross-section approach to model the floodplain area, the spill unit is also extended over a longer distance than the bridge itself to represent flow paths on either side of the structure. Where a 1D-2D approach is adopted, the spill extends up to the 2D domain or is removed if the deck area is large enough to be represented in the 2D domain.

- The calibration coefficient in bridge units is usually set to the default value of 1.0. This value is only changed if supported by observed water level data during the calibration process.

Weirs

- Available ISIS units (e.g. round nose broad crested weir, labyrinth weir, sharp crested weirs etc) are used to represent weirs with a regular crest profile.
- Unless changed during the calibration phase, default weir and velocity coefficients are used.
- For irregular shaped weirs and large steps (>500mm) in the river slope profile, spill units are used.

Culverts

- Long culverts (length > 5m) are modelled using appropriate conduit, inlet and outlet units. Whilst short culverts are modelled as orifice units.
- Roughness coefficients used for the culvert barrel are selected based on the material of construction from the survey photographs, plus reference to publications[8].
- If the inlet and outlet are very different in shape, the first half of the structure is represented using conduit units representative of the inlet and the second half using conduit units representative of the outlet, i.e. the change in section is assumed to occur halfway through the culvert.

3.7.2 Spills

- Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain).
- Spill profile geometry is defined using topographic survey data and LiDAR/IFSAR.
- Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can also be found to account for lateral spilling perpendicular to the main direction of flow.

3.7.3 Confluences

- ISIS junction units are used at confluences allowing water levels to be considered at each river section connected to a junction.
- If no survey section data is available at the junctions, river sections are determined from the nearest upstream and downstream surveyed sections. Chainage correction and changes in river bed elevation when copying these sections are implemented so that the bed level at all junction sections are identical, i.e. no sudden drop in bed level.

[8] HR Wallingford and D.I.H. Barr, Tables for the hydraulic design of pipes, sewers and channels, 6th edition, Volume II, 1994

3.8 Quality Assurance

Modelling work carried out as part of the CFRAM study follows the Jacobs Quality Management procedures whereby any work is checked, reviewed and verified before being approved for release to the OPW.

Throughout the hydraulic modelling process, quality checks are being undertaken by the modeller and a senior modeller as checker and reviewer respectively, to ensure that the models accurately represent the river and coastal systems.

Table 3.4 shows the key stages throughout the modelling process when Quality Assurance (QA) audits are carried out.

Table 3.4 Stages at which Quality Assurance Audits are carried out throughout the modelling process

Stage	Purpose
Data Collection	Ensure all data required to carry out the modelling is collected and suitable for use in the models.
Model Input Statement	Defines in detail the modelling approach for each model extent.
Model construction	Ensure each model is built to industry standard, is sufficiently robust and stable, has suitable mass balance conservation and that the schematisation meets the Project brief requirements.
Calibration to historical flood events	Ensure calibration of the hydraulic model to historical events is correctly undertaken and compliant with the Project Brief.
Calibration to HEPs	Ensure calibration of the hydraulic model to HEPs is correctly undertaken and compliant with the Project Brief.
Upon completion of the design runs for each scenario: existing, sensitivity tests, optioneering etc	Ensure model results are appropriate with regards to model performance (i.e. stability, mass balance conservation), consistency between events of different severity and "ground truthing" of the outputs.
Flood Mapping	Ensure flood maps are consistent with model results and compliant with the Project Brief.

Each of these quality checks are documented through a series of check list forms populated by the modeller, checker and reviewer to allow for a detailed level of checking whilst providing an audit trail at different stages of a model development.

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4 S16 ICM Hydraulic Model – Summary of Methodology

4.1 Introduction

As mentioned in Section 3.1, a different modelling software has been used for model S16 in Tralee AFA. It was considered more appropriate to use Infoworks ICM software by Innovyze to represent HPW reaches and their adjacent floodplain areas for the following reasons:

- In Tralee the HPW reaches are significantly culverted with multiple, long culverts and also very steep gradients. Infoworks ICM is known to provide a much more stable modelling platform than ISIS to model flow through such structures.

- Tralee AFA is the largest AFA area to be modelled in UoM23. All reaches in model S16 are classified as HPWs and warrant a 2D modelling approach to represent flood flows in the floodplain. Therefore the 2D modelled area anticipated is large (approximately 17.5 km^2). Infoworks ICM software allows for a representation of 2D areas using irregular triangles (of varying size which make up individual elements within the mesh). This has the benefit of enabling greater detailing of the 2D surface in urban areas, thus increasing the model detail at certain locations while allowing a coarser representation in rural areas, where the same level of detail is not required. This prevents long model run times associated with a high level of detail applied across the whole AFA.

The following sections provide an overview of the methodology used for the schematisation of the Infoworks ICM S16 model.

4.2 Data used

The S16 Infoworks ICM model uses the same input data as for the other hydraulic models in UoM 23. A full description has already been provided in Section 3.3 of this report.

4.3 ICM model schematisation

4.3.1 Modelling Approach and Software

The modelling approach adopted for model S16 using the Infoworks ICM software is similar to other models developed using ISIS-TUFLOW where the user sets up a model as a combination of 1D reaches representing the river channel, dynamically linked to a 2D zone representing the adjacent floodplain, using the hydrodynamic programme to form a single model (see explanation and Figure 3.1 in Section 3).

In addition to this 1D-2D approach, there are also specific 1D elements which can be added within the 2D zone to allow for example two sides of the floodplain to be linked via culvert under an embankment.

Infoworks ICM software version 4.0 is used for the S16 model.

4.3.2 Model Reaches and hydraulic structures

In-bank model reaches represented in the Infoworks ICM model are built in a similar way when using the ISIS software. Cross-section data collected from topographic survey can be readily imported into the Infoworks ICM software. River reaches are formed and can then automatically be linked to the 2D zone at the bank top interface (see Figure 4.1).

Hydraulic structures across the river reaches are represented using structure survey data and appropriate ICM structure units such as conduit, orifice, weir, bridges and sluices.

The HPWs reaches defined in the S16 model are included in the S16 model Appendix section and are identified by the watercourse name, the reach identification number and the upstream and downstream model nodes.

Similarly, a structure schedule has been prepared and includes:

- topographic survey reference
- ICM node reference
- type of structure
- modelling approach
- whether the structure is included in the model

Channel roughness in the Infoworks ICM model is defined in a similar way as in the ISIS models. Each reach is split into sections as appropriate depending on bed material, bank side vegetation and channel sinuosity and irregularities. For each section of a reach, a single Manning's 'n' value is set from left bank to right bank in each ICM cross-section.

Roughness values adopted for the channel reaches in the S16 model are included in the S16 model Appendix section.

4.3.3 Floodplain Schematisation

The floodplain representation in the Infoworks ICM is based on a 2D zone[9] as a boundary polygon defining the 2D domain of the model and used to generate the mesh.

Infoworks ICM uses a 2D mesh to represent the modelled surface and is generated using the ground model [10] and relevant polygons representing the different roughness zones. These features define the ground levels, roughness and initial water level values in each element within the mesh.

[9] Also referred to as 2D Model Boundary.

[10] The ground model used as part of the model build was developed based on the available LiDAR data.

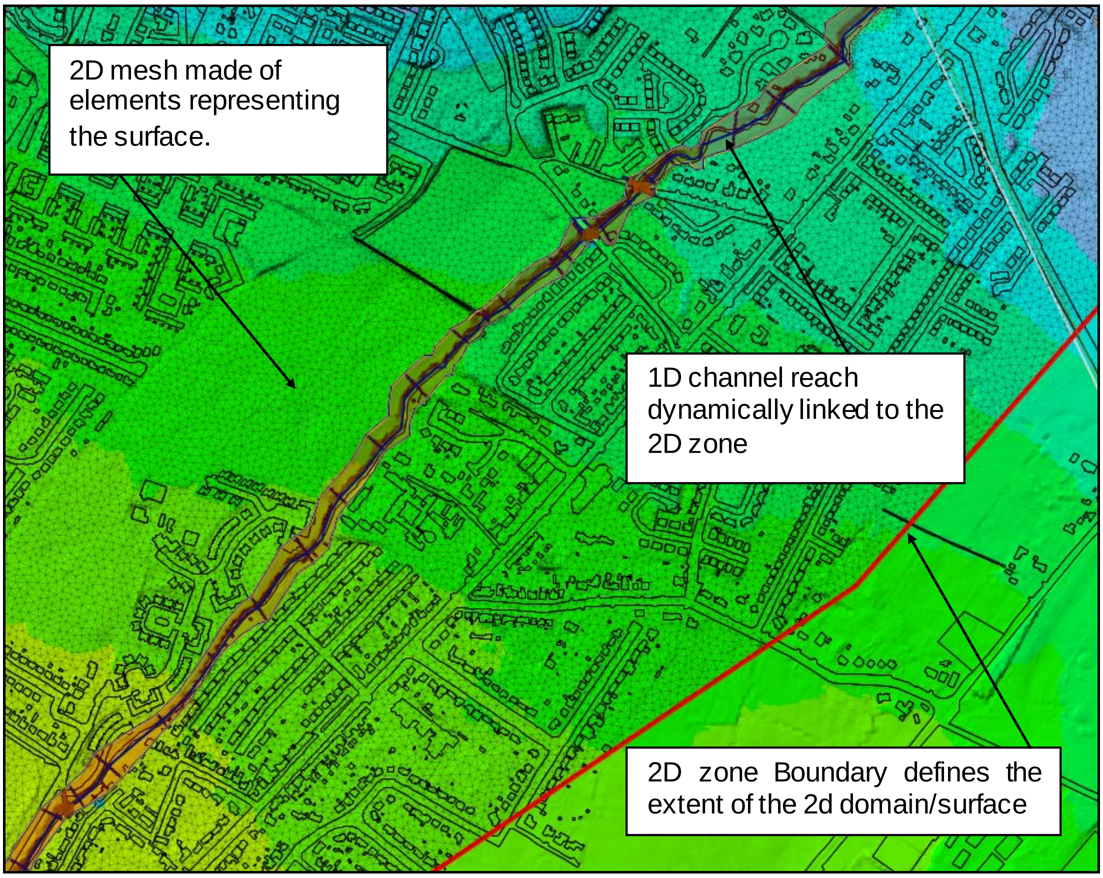


Figure 4.1 View of the S16 model 2D Mesh

The area of each triangle in the mesh is variable (based on the defined values during the meshing of the 2D zone). As a result, the 2D mesh resolution (element size) differs where there are more breakline features (i.e. such as buildings and road boundaries). This can potentially provide greater detail in the urban areas, whilst the wider catchment (i.e. rural areas and fields) is typically represented by larger triangles and mesh elements. To enhance this, the meshing parameters are set so that the minimum element size is 2m² and maximum mesh triangle area is set to 100 m². In addition, terrain sensitive meshing is enabled (the threshold was set to 1m) to allow elements to represent more subtle changes in topographic elevation across the 2D zone.

Breaklines are used in the 2D domain to define key geographical features that could otherwise be inadequately represented by the mesh, to ensure that the mesh picks up the ground level from the LiDAR at these locations. In addition, roughness zones, derived from the NTF basemapping data for key landuse groups as defined in Table 3.2, are used as breakline features to aid the refinement of the mesh.

Each roughness zone is assigned a Manning's roughness coefficient 'n' as per Table 3.2 and is used to inform each 2D mesh element across the 2D zone with a roughness coefficient.

Figure 4.2 below shows how the 2D mesh elements are informed by the underlying features.

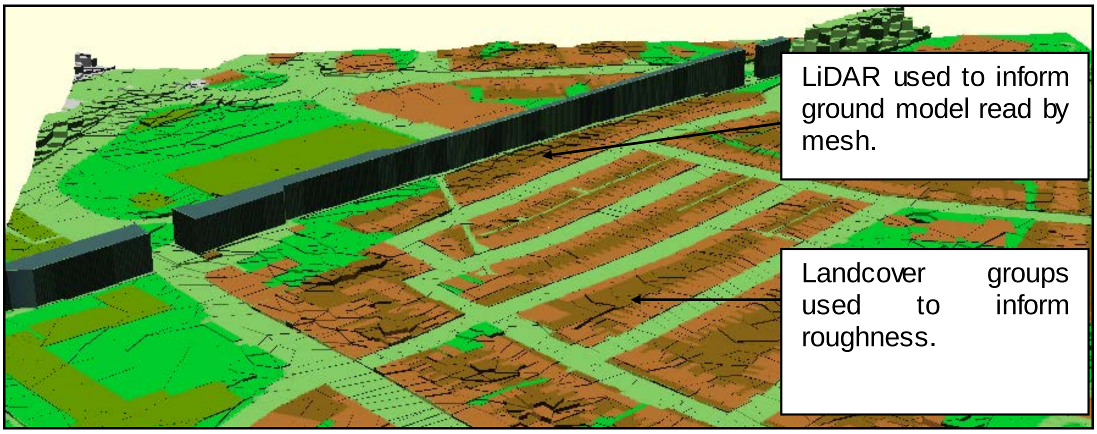


Figure 4.2 2D zone features view in 3D

4.3.4 Infoworks ICM Model Boundaries

The principles described in Section 3.4.11 regarding the integration of hydrological inflows to the ISIS-Tuflow models also apply to the Infoworks ICM model and are therefore not repeated here.

Downstream conditions for the Infoworks ICM S16 model are governed by tidal and wave conditions in Tralee Bay. Further information is provided in Section 5.2.6 on how these were derived.

4.4 Hydraulic Model Calibration and Sensitivity Model Runs

Details of calibration of the Infoworks ICM S16 model and sensitivity testing undertaken are provided in the S16 model appendix. It follows the principles set out in Section 3.5.

4.5 Infoworks ICM model files and naming convention

The naming convention adopted of the Infoworks ICM S16 model files follows as much as possible the convention adopted for the ISIS-Tuflow models. However some changes are expected due to different data management rules operating under the Infoworks ICM software. Model files provided and names adopted are fully described in S16 model appendix.

4.6 Key Infoworks ICM model assumptions

S16 Model specific assumptions are described in Section 6 of the relevant model Appendix section.

4.7 Quality Assurance

The quality assurance audits carried out on the development and utilisation of the Infoworks ICM model follow the same step process described in Section 3.8. It is therefore not repeated here.

5 Coastal Flooding Model Construction

5.1 Introduction

For consistency across the entire Shannon RBD, for those Units of Management for which coastal flooding models have been developed (UoM 23, 24 and 27), this section reports the coastal flooding model construction process in general terms.

In UoM23, S14-b, S16 and S17 hydraulic models encompass estuarine reaches subject to both tidal and fluvial influences. Therefore these models have been developed to simulate coastal flooding as well as fluvial flooding. As already mentioned, the following sections focus only on the coastal modelling aspects of these models.

5.2 Coastal hydraulic model construction and schematisation

The coastal model build process includes the following:

- Modelling approach and Software used for the coastal floodplain areas
- Model area covering the coastal floodplain
- Coastal Floodplain schematisation
- Hydraulic roughness
- Model boundaries – Tidal and wave conditions

5.2.1 Modelling Approach and Software

As specified in Section 7.3.1 of the CFRAM Studies Project Brief Stage 1, a two dimensional approach is adopted to simulate the propagation of coastal floodwaters inland using TUFLOW modelling software produced by BMT WBM for model S14-b and S17 whilst Infoworks ICM by Innovyze has been used for model S16. A 1D approach is used to represent small structures (e.g. culverts under road or railway embankment) across the coastal floodplain.

The specific model software versions used for each model are included within the relevant model Appendix section.

5.2.2 Model Area and Extent

The extent of the 2D coastal domain is determined to accommodate the largest expected flood extent using LiDAR data and ICPSS extreme tidal peak levels. Consideration of the AFA boundary is also given to ensure the model area encompasses the AFA areas subject to coastal flooding.

Model area and extent are included as an Annex to each relevant model Appendix section.

5.2.3 Coastal floodplain Schematisation (TUFLOW)

The 2D coastal domain is based on a regular grid comprising individual square cells of a defined size. Each cell is given characteristics relating to the topography such as ground elevation, hydraulic roughness (see Section 5.2.5) and an initial water level if required.

The data used to inform the 2D grid with ground elevation is a combination of high resolution LiDAR data covering the AFAs, combined with lower resolution IFSAR data for the areas outside of the AFAs.

Due to the method by which the LiDAR data has been gathered (by flying defined flight lines over the area for which LiDAR data is to be captured) there is often LiDAR available for areas outside the defined AFA boundary. Where this higher accuracy LiDAR data is available outside AFAs, it has been incorporated into the hydraulic models in preference to the IFSAR.

As for the fluvial models, the domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the coastal floodwater flows. For the models sharing a fluvial component the orientation of the grid is according to the fluvial floodplain flows.

As for the fluvial models, breaklines/Z-shape polygons and 1D elements are used in the 2D coastal domains in a similar fashion described in Section 3.4.8 and 3.4.9 respectively. In particular breaklines are used to incorporate into the model grid surveyed crest levels of formal coastal flood defences.

Within each relevant model Appendix section, 2D coastal domain area, grid size, breaklines/Z-shape polygons and 1D elements included in each model are given.

5.2.4 Coastal floodplain Schematisation (ICM)

Section 4.3.3 gives an overview of the floodplain schematisation adopted for the Infoworks ICM S16 model. A single 2D zone has been set up that encompasses both fluvial and coastal floodplain areas.

5.2.5 Hydraulic Roughness in the coastal floodplains

To represent the hydraulic friction within the coastal floodplains, Manning's 'n' has been defined based on the OSi NTF vector mapping classification which covers all AFA areas subject to coastal flooding. This classification is the same as used in the fluvial model. Refer to Section 3.4.10 and Table 3.2 of this report for a full description.

For coastal floodplain areas outside the AFA boundaries where OSi NTF data is not available, Manning's 'n' has been defined based on the EPA Land Use classification as described in Section 3.4.10 and Table 3.1 of this report.

5.2.6 Coastal Model Boundaries Conditions

As already mentioned, the coastal models are developed to simulate flooding from coastal sources either through a combination of high tide and surge and/or due to wave overtopping. Therefore two types of boundary conditions are possible:

- Where coastal flooding arising from the combination of high tide and a meteorological surge is to be simulated, a variable water level (Stage vs.Time) mimicking the sea level motion is applied. Section 5.3 and Appendix D provide a comprehensive description on how such tidal hydrographs are derived. The boundary condition is set along the coastal fringe of the modelled area including the estuarine section for the models with a fluvial component.

- Where coastal flooding arising from wave overtopping is to be simulated, a flow hydrograph associated with the wave overtopping rate of discharge is applied. Section 5.5 provides a full description on how such flow hydrographs are derived. The boundary condition is set only along the coastlines prone to wave overtopping as identified in the Irish Coastal Wave & Water Level Modelling Study.

Within each relevant model Appendix section, the type of boundary condition and its location are indicated.

5.3 Production of design tidal hydrographs to inform boundary conditions of coastal models

The approach taken to define the tidal boundary conditions in the current situation for the Shannon CFRAMS hydraulic models along the Shannon Estuary and the Atlantic west coast is fully provided in Appendix D of this report. A summary of the approach specific to UoM23 is provided in this section.

5.3.1 Data used

The following available datasets are used to produce the design tidal surge hydrographs as boundary conditions for the models shown on Figure 2.3.

- ICPSS Predicted Extreme Water Levels (Tide and Surge) for the following design events: 50%AEP, 20%AEP, 10%AEP, 5%AEP, 2%AEP, 1%AEP, 0.5%AEP and 0.1%AEP at appropriate locations in Tralee Bay and the Shannon Estuary.
- Carrigaholt Tidal gauge records (2003-2007) obtained from Shannon – Foynes Port Company
- Admiralty Tide Tables information for Carrigaholt and Fenit Pier[11]
- OSi Conversion Graphs (Poolbeg-Malin head datum) including levelling information for Carrigaholt and Fenit Pier.

5.3.2 Methodology

A four-stage approach is followed to develop the downstream tidal hydrographs assigned to each model.

Stage 1: Production of mean Spring tidal cycles at key ports

Tidal records collected at Carrigaholt have been used to extract typical Spring tidal profiles (i.e. level hydrograph shapes). These have been scaled to generate mean Spring tide profiles ranging from Mean High Water Spring (MHWS) to Mean Low

[11] Admiralty Tide Tables, United Kingdom and Ireland, Vol 1 NP 201-06, (2006)

Water Spring (MLWS) levels using information from the Admiralty Tide Tables for Carrigaholt and Fenit Pier classified as secondary ports. These two port locations are shown in Figure 5.1 along with other key ports locations within the Shannon Estuary. Details of the calculations carried out to determine MHWS and MLWS levels to Malin Head datum are provided in Appendix D.

Figure 5.1 Key ports listed in the Admiralty Tide Tables for which MHWS and MLWS information is available

Stage 2: Association of ICPSS prediction points with mean Spring tidal cycles at key ports

Each ICPSS prediction point[12] for which extreme water levels, combining tide and surge, have been estimated are shown on Figure 5.2. These have been associated with a mean Spring tidal cycle for the key ports mentioned above. This allocation is based on the nearest port location.

Table 5.1 below describes the association of the ICPSS prediction points relevant to UoM23 with the mean Spring profiles at the key ports.

Table 5.1 Allocation of prediction points to ports

Port/Spring profile	ICPSS (Prediction Point Reference) relevant to UoM23
Carrigaholt	S2
Fenit Pier	SW37
Fenit Pier	SW39

[12] Prediction point references used in Figure 4.2 and Table 4.1 are the IPCSS Prediction point references used in the ICPSS report.

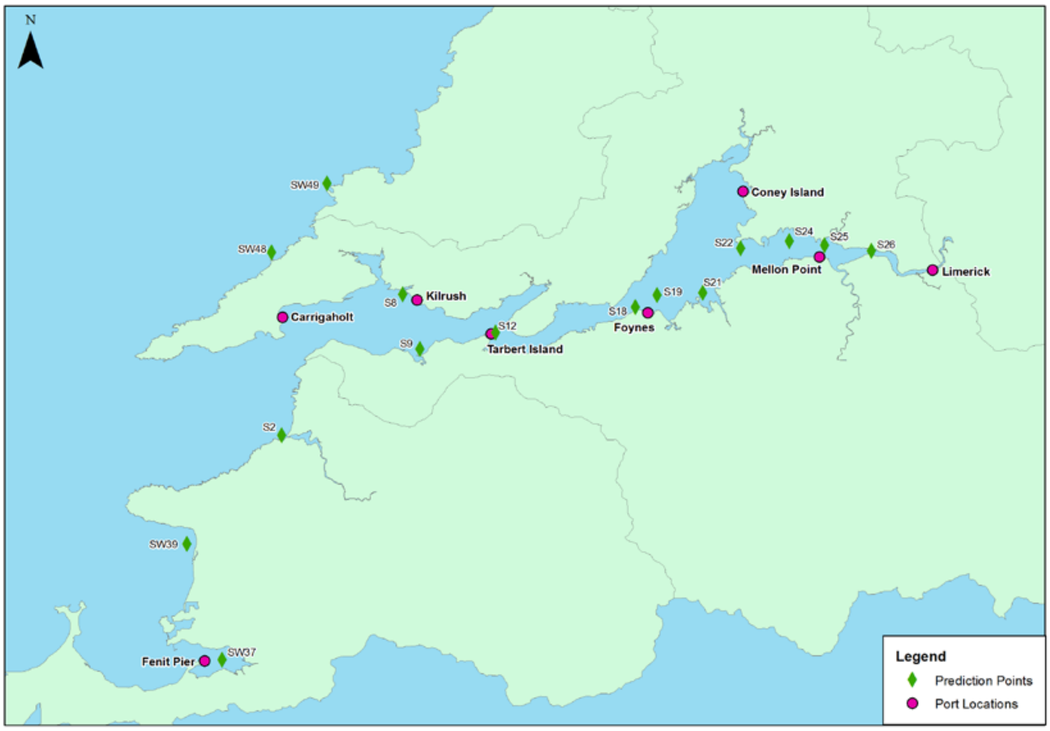


Figure 5.2 ICPSS prediction point and key port locations

Stage 3: Production of design hydrographs at the ICPSS prediction points

Using the spring profiles and the available ICPSS extreme water levels for a range of annual probabilities, a series of design tidal hydrographs have been produced at each prediction point. The tidal hydrographs represent the effect of 30hr meteorological surges of increasing intensity on the mean Spring profile associated with each ICPSS prediction point. The 30hr surge duration means that 3 tide cycles are affected. The surge effect is centred such that middle high tide level matches with the extreme water levels taken from the ICPSS data.

This process is illustrated on Figure 5.3.

It is acknowledged that a 30hr meteorological surge duration is a key, though considered realistic, assumption to the production of the design tidal hydrographs. Sensitivity tests as described in Section 4.6 are carried out with the hydraulic model to assess the effect on predicted flood risk of varying surge duration in the tidal boundaries.

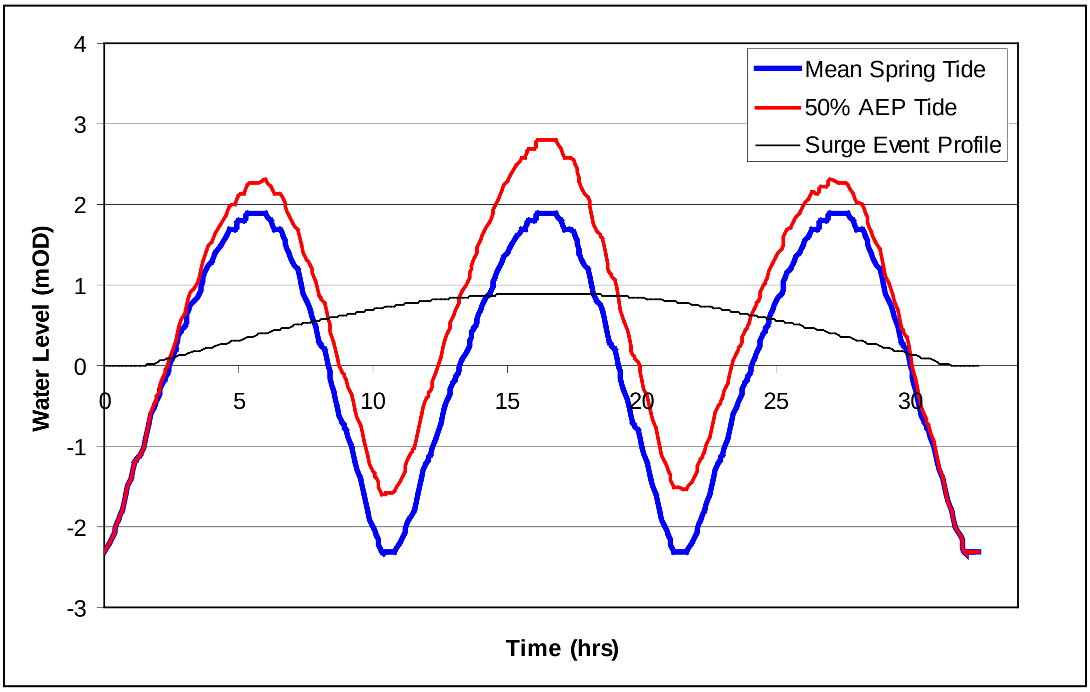


Figure 5.3 Example showing how a design tide hydrograph is produced

Stage 4: Allocation of design tidal hydrographs to the hydraulic model

In a final step, the different model downstream boundaries have been assigned to the closest prediction points and their associated design tidal hydrographs. For all models in UoM 23, direct allocation is deemed appropriate.

Table 5.2 below lists the prediction points assigned to each model downstream boundary

Table 5.2 Allocation of ICPSS prediction points to model coastal boundary in UoM23

ICPSS (Prediction Point Reference)	AFAs – Model No
S2	Moneycashen – Model S14-b
SW37	Tralee – Model S16
SW39	Banna - Model S17

Within each relevant model Appendix section, coastal boundary location and associated design tidal hydrographs are indicated.

5.3.3 Changes made to the design tidal hydrographs for future scenario (MRFS and HEFS)

Changes have been made to the design tidal hydrographs for the design events under the MRFS and HEFS scenarios. They consist of a simple increase of the overall hydrograph according to the mean sea level rise and land movement

allowances defined in Table F.1 of Appendix F in Shannon CFRAM Study Stage I Project Brief.

These allowances are summarised in Table 5.3 below.

Table 5.3 Future scenario allowances

	MRFS	HEFS
Mean Sea Level Rise (to 2100)	+500 mm	+1000 mm
Land Movement	-50 mm	-50 mm
Total change made to the tidal hydrographs	+450mm	+950mm

5.4 Joint probability analysis for fluvially- and tidally-influenced models

A joint probability analysis of the coincidence of fluvial flood flows and coastal flood levels in the Shannon Estuary has been carried out. Methodology and outcomes of this analysis are detailed in the Hydrology Report for UoM 24. These results have been applied for the UoM 23 models subject to both tidal and fluvial influences.

Table 5.4 below is the main output of the joint probability analysis. It presents the combinations of design fluvial flood events and design tidal flood events that are used for the modelling of design events in areas of both fluvial and tidal influence. As required by the Project brief, in these areas two set of design runs are required to determine on one hand fluvially-dominated flood risk (odd number scenarios in Table 5.4) and on the other hand tidally-dominated flood risk (even number scenarios in Table 5.4).

Table 5.5 lists the hydraulic models in UoM23 for which such runs are carried out

Table 5.4 Combinations of fluvial and tidal events adopted for modelling in areas of both fluvial and tidal influence.

	Joint Probability Design Event (AEP)	Combinations suggested by the joint probability analysis (AEP)		Combinations adopted for modelling (AEP)	
Scenario	**Overall AEP**	**Fluvial**	**Tidal**	**Fluvial**	**Tidal**
1	50%	50%	500%	50%	500%
2	50%	**500%**	50%	50%	50%
3	20%	20%	500%	20%	500%
4	20%	**500%**	20%	50%	20%
5	10%	10%	200%	10%	200%
6	10%	**200%**	10%	50%	10%
7	5%	5%	100%	5%	100%
8	5%	**100%**	5%	50%	5%
9	2%	2%	50%	2%	50%
10	2%	50%	2%	50%	2%
11	1%	1%	20%	1%	20%
12	1%	20%	1%	20%	1%
13	0.5%	0.5%	10%	0.5%	10%
14	0.5%	10%	0.5%	10%	0.5%
15	0.1%	0.1%	2%	0.1%	2%
16	0.1%	2%	0.1%	2%	0.1%

Remarks on the adopted scenarios for modelling:

- For fluvial events of a lower magnitude than that for a 50% AEP event as highlighted in bold in column 3 of Table 5.4, design event data is not available. Therefore the tidally-dominated scenarios 2, 4, 6 and 8 have been run with a 50% AEP fluvial flow as indicated in column 5.

- Peak tidal levels associated with the design tidal events of lower magnitude than a 50% AEP event are not readily available from the ICPSS data. However they have been generated using extrapolation techniques for the relevant prediction point as shown on Figure 5.5 below.

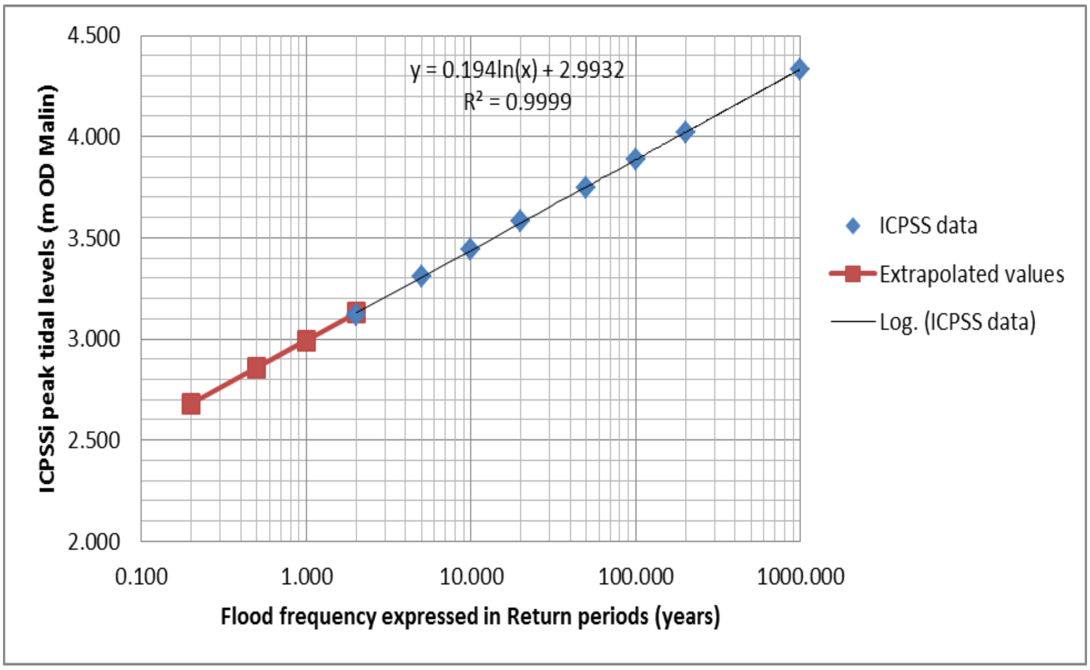


Figure 5.5 Extrapolation of ICPSS data fro high frequency tidal events

Table 5.5 Hydraulic models in UoM23 for which joint probability runs are required

Model No	AFAs affected
S14-b	Moneycashen
S16	Tralee
S17	Banna

5.5 Production of design wave overtopping discharge hydrographs to inform boundary conditions of coastal models

ICWWS data supplied by OPW shows areas potentially vulnerable to wave overtopping (see Section 2.5.2 and Figure 2.3). Foynes (Model S09) and Tarbert Power Station (IRR4) are the two locations within UoM24 where modelling is required to simulate flooding arising from wave overtopping of coastal defences.

To generate suitable boundary conditions to the hydraulic models, ICWWS data has been used following a four-step approach described below.

5.5.1 Step 1: Selection of coastal defence reaches

At each site, coastal defences vary in height, type and orientation relative to the mean direction of the incident waves. Therefore coastal defences prone to wave overtopping are divided in discrete reaches of similar characteristics (height, type and orientation) and allocated a wave prediction point according to its geographic proximity and the mean direction of the incident waves.

5.5.2 Step 2: Wave characteristics selection for the selected reaches of coastal defence:

For each flood event annual probability, ICWWS data consists of six combinations of extreme coastal water levels with predicted significant wave heights ('Hmo'), peak wave period ('Tp') and mean wave direction. For each combination, the mean overtopping discharge (in m3/s per m of coastal defence length) associated with the wave characteristics and the type of flood defence (sea dikes, embankments and vertical wall) involved will be calculated. This calculation is to be carried out using the Neural Network method.

It should be noted that for the case when, for a given annual probability event, the water levels provided exceed the average elevation of the coastal defence reach overtopping will no longer occur and there will be tidal flooding. Is this case the tidal flooding from wave overtopping will be considered along with the tidal flood risk.

5.5.3 Step 3: Generating a wave overtopping discharge hydrograph for the selected reaches of coastal defences

As quoted from the overtopping manual, "in reality there is no constant discharge over the crest of a defence during overtopping. The process of wave overtopping is very random in time and volume". A simplified approach is followed here to generate a wave overtopping discharge hydrograph (Flow vs. Time) which is input in the hydraulic models at the landward side of the defences.

A wave overtopping discharge hydrograph is to be generated assuming 12 hour storm surge duration. Overtopping is to be assumed to occur for the full 12 hour storm surge duration. As the rate of overtopping varies with freeboard, the height of the crest of the defence above still water level, overtopping discharge rates are to be calculated at 30 points along the tidal curve. These discharge rates will be used to create the inflow hydrographs. The duration of overtopping is to be typically limited to the hours where the tidal water levels are at their peak.

5.5.4 Step 4: Simulating flooding arising from wave overtopping

Once the wave overtopping discharge hydrographs are generated for all the reaches of coastal defences under consideration at a particular site; these flow inputs will be applied directly to the hydraulic model using a flow versus time boundary along the landward side of the flood defences.

Within each relevant model Appendix section, wave overtopping boundary locations and associated discharge hydrographs will be indicated.

The wave overtopping models will be run for the full range of probabilities specified in Section 6.5.1 of the Project Brief for existing conditions and for the MFRS, and for the 10%, 0.5% and 0.1% AEP design events for the HEFS.

5.6 Hydraulic Model Calibration and Sensitivity Model Runs

5.6.1 Model Calibration and Verification to Historical Events

The approach to model calibration for the coastal models is described in Section 3.2.4 of the National Technical Co-ordination Group (NTCG) Guidance Note no. 23 (GN23) in Appendix D. The fundamental points to note, with regard to achieving the best model calibration, are that the following data must be known:

- **Tidal hydrograph and wave conditions** – as the driving force leading to coastal flooding
- **Water levels** recorded on the coastal floodplain and/or within the estuarine reaches
- **Coastal floodplain conditions – any topographic feature influencing the water level** across the floodplain at the time/date when the coastal flooding occurred.

For each model, an analysis of available flood event data for possible consideration as calibration/"reality checking" has been carried out. Results of these analyses are covered in the Hydrology report.

In UoM23 the availability of usable information is very limited and S14-b is the only model for which partial calibration to one tidal event has been possible. However, for some of the other models, some form of verification has been possible through "reality checks" carried out on the flood extents obtained and cross referenced with anecdotal evidence of flooding arising from tidal inundation and/or wave overtopping, if it exists.

Within each relevant model Appendix section, a summary of the calibration/"reality checking" process along with associated results is provided.

5.6.2 Model Sensitivity

Sensitivity tests are carried out on the hydraulic models in order to assess the sensitivity of the modelled systems to alterations in a number of key hydraulic parameters.

The results of the sensitivity analysis give an indication of the confidence levels that can be placed in the results being generated by the respective model.

For each coastal model within UoM23, the sensitivity runs are carried out for the 0.5% AEP tidal event. The following sensitivity tests have been carried out:

- Sensitivity to hydraulic roughness: Manning's 'n' values have both been increased and decreased by 20%
- Sensitivity to hydrological inflows. All hydrological inflows have both been increased and decreased by 20%
- Sensitivity to afflux parameters at key structures across the estuarine reaches. Afflux parameters have been varied to reduce or increase the head

loss during a 0.5% AEP flood event at key structures susceptible to having an impact on the tidally dominated flood extents
- Sensitivity to the downstream conditions. Changes are made to the tidal boundaries by varying by +/-50% the surge duration component in the design tidal hydrographs to assess how the coastal flood outlines are affected.

Within each relevant model Appendix section, the results of the sensitivity tests are compared to the base case scenario and processed to determine the significance of the change in flood risk.

5.7 Model files and naming convention

The hydraulic model files associated with each coastal model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. Details (names and purpose) on the model files are included within each relevant model Appendix section.

The same model naming convention previously described in Section 3.6 is adopted for the coastal models.

5.8 Key Model Assumptions

Model specific assumptions are described in Section 6 of the relevant model Appendix section. In addition, there are generic assumptions which are summarised below.

As already mentioned in Section 5.3, the design tidal hydrographs used as downstream conditions are based on estimated ICPSS extreme water levels and hydrograph shapes derived using a mean Spring profile from the nearest port location and assuming a meteorological surge of 30hr duration.

For the hydraulic model with both fluvial and tidal components, the timing of the tidal hydrograph as downstream condition is adjusted so that the time of the highest tidal level coincides with the time of the maximum water levels within the estuarine reach for fluvial dominated event. This is a conservative approach that allows for a worst case scenario.

5.9 Quality Assurance

The same level of quality checking as previously described in Section 3.8 of this report is carried out on the development of coastal hydraulic models.

6 Flood Hazard Mapping

The following section describes the development of the flood hazard maps for the Shannon CFRAM study. The flood map type, information and format are provided, along with details relating to the associated processes.

6.1 Flood Map Type

The maps produced fall into one of the following five types:

- **Flood extent:** These maps show the extents of flooding associated with a design flood event for a given annual probability. Additional information such as tabulated peak flows and water levels are also shown (see Section 6.3).
- **Flood zone:** These maps show flood zones A, B and C, to facilitate implementation of the Guidelines on the Planning System and Flood Risk Management (DoEHLG & OPW, November 2009).
- **Flood depth:** These maps show the depths of flooding associated with a design flood event for a given annual probability.
- **Flood velocity:** These maps show the velocities of floodplain flows associated with a design flood event for a given annual probability.
- **Flood hazard:** These maps show the hazard (or 'risk to life') associated with a design flood event for a given annual probability as a function of the depth and velocity (see Section 6.7).

6.2 Flood Map Format

The flood maps are produced in both digital (GIS) and print ready (PDF) format, as follows:

- **GIS Format:** Geographical Information System (GIS) format refers to the display and representation of data produced by the models (and subsequently displayed on the print ready format maps) in digital format with both spatial and not spatial attributes defined. These files can be interrogated by users on their own GIS platforms and software.
- **Print Ready:** This format refers to the printable versions of the maps. This format allows for a wide range of users to access and view a complete standalone map including title block and legend in a single PDF.

Table 6.1A and B sets out the type of maps produced for each of the scenarios (current only) for the design flood event probabilities simulated with the hydraulic model.

Table 6.1 A - Shannon CFRAM Study “Print Ready” flood map outputs

	Current								MRFS								HEFS							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
Flood Extent Maps			✓			✓		✓			✓			✓		✓								
Flood Zone Maps						✓		✓																
Flood Depth Maps			✓			✓		✓																
Flood Velocity Maps			✓			✓		✓																
Flood Hazard Function Maps			✓			✓		✓																

Grey cells indicate that no map is required

Table 6.1 B Shannon CFRAM Study “GIS” format flood map outputs

	Current								MRFS								HEFS							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
Flood Extent Maps	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓			✓		✓
Flood Zone Maps						✓		✓						✓		✓								
Flood Depth Maps	✓	✓	✓	✓	✓	✓	✓	✓			✓			✓		✓								
Flood Velocity Maps	✓	✓	✓	✓	✓	✓	✓	✓																
Flood Hazard Function Maps			✓			✓		✓																

Grey cells indicate that no map is required

6.3 Flood Extent Maps

The flood extent maps are the extents of flooding along the modelled reach. The production technique for these maps differs depending on the model type used (i.e. whether 1D or 2D) and the processing requirements of the results. The procedure for each of model types is provided below.

- **1D Model Results:** First, the peak water levels at each node are extracted from the 1D ISIS model. Then a water surface profile is generated, based on a triangulated interpolation of model results (peak water levels) and model geometry information at each cross-section. The water surface profile is then subtracted from the LiDAR/IFSAR elevation grid at the corresponding location. This results in a 1D flood depth grid being created. This grid is processed into an extent polygon.

- **2D Model Results:** Flood extents are generated by processing the depth grid produced across the 2D domain by the model. In a 1D-2D linked models the 1D and 2D flood depth grids are combined. There is no particular flood depth threshold under which flooding is not reported**.** The combined flood depth grid is then converted into an extent.

In both instances described above, the results require post processing to ensure "Dry" and "Wet" islands are removed. These refer to holes or small areas separated hydraulically from the extents. A clean-up process is carried out to remove polygon islands or small holes (<100m²).

Ponding will occur where fluvial flow paths convey water into topographic depressions in the floodplain. As a result areas of ponding will not be removed. Wet islands which are disconnected from the fluvial contributions (which related to the 1D result processing) have been removed.

With regards to format of the print ready maps, the key requirements of these are provide below:

- **Map scale:** Maps are produced at 1:5,000 scale for AFAs and at 1:25,000 with background mapping at 1:50,000 for areas outside the AFAs, with the mapping in greyscale.
- **Map layers shown:** Fluvial flood events are shown for 10%, 1% and 0.1% AEPs, and are coloured using a transparent fill from dark blue to light blue. Also shown are points along the river centreline, with a table on the map showing the flow for 10%, 1% and 0.1% AEP (at selected locations) and water level at each point for 10%, 1% and 0.1% AEP. Areas benefiting from defences are shown by a grey hatched area.

6.3.1 Flood mapping in tidally- and fluvially-influenced areas

Tidal flood maps are produced for the 10%, 0.5% and 0.1% AEP events using the same methodology described above.

In areas where flooding is subject to both tidal and fluvial influence additional sets of flood maps are produced as defined in Section 7.5.2.1 of the project brief Stage I with an annotation text box showing the tidal/fluvial influence boundary.

6.3.2 Mapping uncertainty

Uncertainty is presented as per the Guidance Note 22 v5.5 (please see Appendix F), relating to sensitivity and uncertainty but is limited to the 1% AEP flood extent (0.5% AEP for coastal model). This is because the sensitivity analysis (described in Sections 3.5.3 and 5.6.2 and compliant with the mandatory suggested sensitivity runs) has been carried out for the 1% AEP event only (0.5% AEP for coastal models).

The sensitivity results have been used to generate outlines which have then been merged to create a single "worst case" outline. This is then compared to the 1% AEP design event on maps in addition to the flood extent maps listed in Table 6.1 A.

6.4 Flood Zone Maps

Flood zone maps show three zones: within the 1% AEP, between the 1% (or 0.5% AEP for coastal areas) and 0.1% AEP and outside the 0.1% AEP. The maps have been developed following the publication of the Guidelines on Planning and Flood Risk Management (Guidance note 33) and are based on the undefended scenario runs for the flood events mentioned above. The flood zone maps are generated using the outer flood extents associated with the undefended runs undertaken.

6.5 Flood Depth Maps

Flood depth maps show where the water would flow and the resulting peak depths that would be achieved for a specified annual exceedence probability. The maps are useful in planning and design to understand the depth of flooding in an area and they allow emergency responders to determine rescue areas, evacuation areas and potential evacuation routes. Flood depths also form the basis for the economic assessment.

The map borders, features and general components of the hardcopy depth maps are the same as the flood extent maps. The key features particular to the depth maps are:

- The 10%, 1% and 0.1% are shown on individual maps
- Depth information is only required for the current situation
- Flood depths are shown on the map in six graduated classes, coloured light blue to purple for low to high depths respectively.

6.6 Velocity Mapping

Flood velocity maps are only required for AFAs and not for MPW reaches.

The 2D models output velocity to the 2D grid which has a cell resolution of typically 5-20m (see Section 3.4.7). The 2D velocity output is therefore readily extracted to generate velocity maps. For the channel and floodplain represented in 1D, velocity distribution map is created using the predicted maximum velocity at each model node and GIS interpolation. For reservoir units represented in 1D, no velocity will be calculated as by definition the floodplain areas represented by reservoir units are non-conveyance zones and the velocity equals zero.

The key features particular to the velocity maps are:

- The 10%, 1% and 0.1% are shown on individual maps
- Velocity information is only required for the current situation and HPW reaches
- Flood velocities are shown on the map in five graduated classes, coloured yellow to red for low to high velocities respectively.

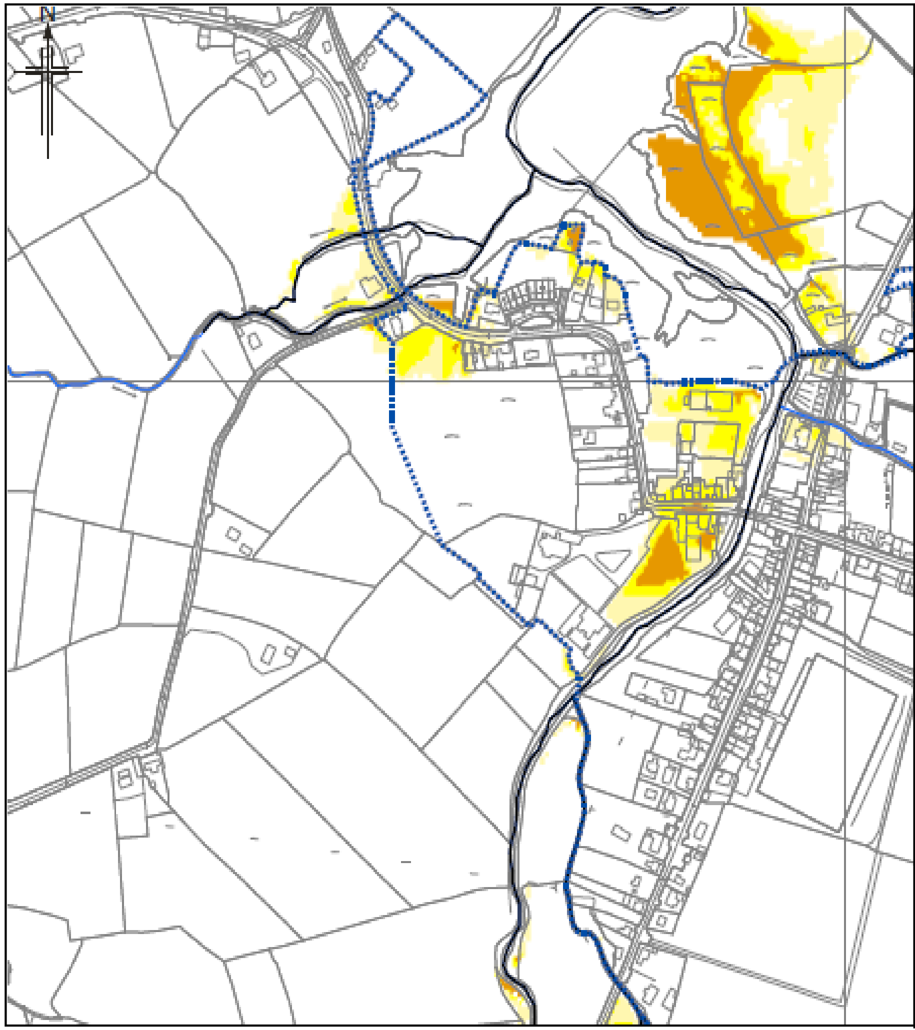
6.7 Flood Hazard Function Mapping

Flood hazard function maps show the risk to life which may be experienced for a particular flood event. This is calculated as a function of the depth and velocity of the flood waters. The Shannon CFRAM Study uses the methodology and concept set out in the Defra / EA guidance Flood Risks to People Phase 2 Study[15] to calculate flood hazard without a debris factor. The flood hazard function maps are created by calculating the hazard from the depth and velocity grids, as follows:

$$\text{Hazard} = d \times (0.5 + v)$$

The classifications of the degree of flood hazard are shown in Figure 6.1 along with the graduated colours used to display the flood hazard on the maps. An example of a flood hazard map is also shown in Figure 6.1.

[15] DEFRA 2006, Flood Risks to People, Phase 2, FD2321/TR1, The Flood Risks to People Methodology



Flood Hazard

- Low (< 0.75)
- Moderate (0.75 - 1.25)
- Significant (1.25 - 2.0)
- Extreme (> 2.0)

Thresholds for Flood Hazard Rating H = d x (v+ 0.5)	Degree of Flood Hazard	Description
< 0.75	Low	Caution - " Flood zone with shallow flowing water or deep standing water"
0.75 - 1.25	Moderate	Dangerous for some (i.e children)-" Danger : Flood zone with deep or fast flowing water"
1.25 - 2.0	Significant	Dangerous for most people - " Danger : Flood zone with deep fast flowing water"
> 2.0	Extreme	Dangerous for all- " Extreme Danger : Flood zone with deep and/or fast flowing water"

Figure 6.1 Flood hazard map classifications

7 Conclusions

7.1 Conclusions

Calibration and verification was only possible for the S14b model using the information gathered up to Summer 2012, the date the topographic survey was completed. The S14b model was calibrated to within the specified tolerances. High level verification was possible for a blockage version of the S14c Model using photographs of recent flood events. It was not possible to complete historical calibration for the other models within this UoM due to a lack of historical data.

The resulting flood maps form a representation of the predicted existing risk using all data made available up to the Summer of 2012 and were displayed at Public Consultation Days (PCD's) held in each AFA. Table 6.1 below provides information on the dates of the PCD and numbers of people attending. Further this these consultation days a national consultation exercise on the Draft Flood Maps was launched in November 2015 where objections could be made on the maps. There were no objections received on the UoM 23 maps.

Table 6.1 - Shannon CFRAM Study UoM 23 Public Consultation Days

AFA	County	Date of Public Consultation	Venue	Number of Attendees
Tralee	Co. Kerry	24/03/2015	Tralee Library	25
Banna	Co. Kerry	24/03/2015	Banna Leisure Centre	19
Abbeyfeale	Co Limerick	25/09/2014	Abbeyfeale Library	24
Athea,	Co Limerick	25/09/2014	Athea Hall	45
Abbeydorney	Co. Kerry	24/09/2014	Shannow Family Resource Centre	28
Moneycashen	Co. Kerry	24/09/2014	Ballyduff Family Resrouce Centre	16
Listowel	Co. Kerry	24/09/2014	Listowel Library	9

The conclusion from this PCD exercise is that no amendments to the flood outlines were justified as a result.

7.2 Recommendations

In some AFAs, the lack of gauge data resulted in higher degree of uncertainty in the resulting predicted flood risk particularly the AFA of;

- Tralee
- Banna
- Abbeydorney

Recommendations have been made for additional gauge stations in these AFAs.

Anecdotal evidence from flood events in September and November/December 2015 suggest there are areas of Tralee at risk of flooding that are not represented on the Shannon CFRAM predicted flood maps. As the CFRAMs hydrological study and flood maps are effectively 'date stamped' to Summer 2012, the reasons for the

difference with the 2015 flood events has not been investigated. It is therefore a recommendation of this study that the 2015 flood events are appraised to determine the source of flooding, their annual exceedance probability and then, if necessary, updated calibration of the CFRAMs hydraulic model for Tralee to reflect this new information

It is also recommended that on future iterations of the flood model and maps for all AFAs, are verified against flood events which have occurred post Summer 2012.

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Extract from Section 7 of the CFRAM Studies Stage I Project Brief (June 2010)

7.8. HYDRAULICS REPORT

The Consultant shall submit to the OPW detailed, technical Hydraulics Reports that shall set out the work and analysis undertaken in relation to, and the findings and conclusions of, the surveys as defined within Section 5 and the hydraulic analysis as defined within Section 7, except for the work defined in Section 7.6 and 7.7, which shall be reported upon in the Preliminary Options Reports.

The Consultant shall supply the following as part of, or as an accompaniment to, the Draft and Final Hydraulics Reports:

- All survey data, including digital data files, as detailed in Section 5.
- Digital hydraulic model files, including, but not necessarily limited to, calibration, verification, design run and sensitivity analysis model and results files, for the work detailed in Section 7, excluding Section 7.6 and 7.7.
- A copy of the defence asset database with all flood defence asset geometric and condition survey completed and accurately entered, including the defence asset survey deliverables, as detailed in Section 5.1 and 5.2 and Appendices C and D
- Digital copies of the GIS-Format and Print-Ready Format Flood hazard maps, as detailed in Section 7.5

The OPW, assisted by the Steering Group and other experts as deemed necessary by the OPW, shall review the Draft Hydraulics Reports and submit observations to the Consultant within six (6) weeks of receipt.

The Consultant shall review the observations submitted by the OPW, and prepare and submit to the OPW a Draft Final Hydraulics Reports that suitably addresses the observations of the OPW within four (4) weeks of receipt of the observations from the OPW.

The OPW, assisted by the Steering Group and other experts as deemed necessary by the OPW, shall, within four (4) weeks of receipt, review the Draft Final Hydraulics Reports to ensure that all observations have been appropriately addressed. In the event that the OPW does not consider that all observations have been appropriately addressed, the OPW shall submit further observations to the Consultant to be addressed by the Consultant as set out above. In the event that the OPW is satisfied that all observations have been appropriately addressed, the Consultant shall re-submit the Draft Final Hydraulics Reports as the Final Hydraulics Reports.

The Consultant shall prepare and submit separate Draft, Draft Final and Final Hydraulics Reports for each Unit of Management within the Study Area.

The Consultant shall provide a number, as identified in the tender documentation for the Specific Tender Stage (Stage II), of bound sets of printed hardcopies of each set of Draft and of Final flood hazard maps as set out in Section 7.5 and above.

Extract of Sections 2.21 to 2.23 of the Stage II Project Brief (October 2010)

2.21 Section 7.3.1 – Coastal Flooding Model Development

For the APSRs where the OPW shall provide the Consultant with wave data (see Section 2.19 herein, amending Section 6.5.4 of the Generic Specification), the Consultant shall develop the coastal flooding models such that they will be able to simulate flooding from wave overtopping of defences as well as from tide and surge events.

2.22 Section 7.3.3 – Coastal Flooding Model Design Runs

For the APSRs where the OPW shall provide the Consultant with wave data (see Section 2.19 herein, amending Section 6.5.4 of the Generic Specification), the Consultant shall run the coastal flooding models to simulate flooding for the design flood events to determine flood levels, extents and other parameters for flooding that would be projected to arise from wave overtopping [as well as such runs for tide and surge events (i.e., based on data provided as set out in Sections 6.5.4 and 7.3 and Appendix E of the Generic Specification)], for the full range of probabilities specified in Section 6.5.1 of the Generic Specification for existing conditions and for the MRFS, and for the 10%, 0.5% and 0.1% AEP design events for the HEFS. The Consultant shall produce flood mapping for the flooding that would be projected to arise from wave overtopping as set out in Sections 7.5 and 8.3 of the Generic Specification [as well as such mapping for tide and surge events].

2.23 Section 7.8 – Hydraulics Report

The fourth bullet point under the second paragraph of Section 7.8 of the Generic Specification (starting 'Digital copies of the GIS-Format …') is deleted in its entirety and replaced with:

- Digital copies of the GIS-Format and Print-Ready Format flood hazard maps and flood risk maps, as detailed in Section 7.5 and 8.3

The Consultant shall supply as an accompaniment to the Draft and, amended as necessary, Final Hydraulics Report a set of GIS files and summary report for each Unit of Management, providing the information set out in Appendix V.

The fourth paragraph of Section 7.8 of the Generic Specification (starting 'The Consultant shall review the observations submitted …') is deleted in its entirety and replaced with:

> The Consultant shall review the observations submitted by the OPW, and prepare and submit to the OPW a second Draft Final Hydraulics Reports that suitably addresses the observations of the OPW within four (4) weeks of receipt of the observations from the OPW.

The fifth paragraph of Section 7.8 of the Generic Specification (starting 'The OPW, assisted by the Steering Group and other experts as deemed necessary by the OPW, shall, within four (4) weeks of receipt, review the Draft Final Hydraulics Reports …') is deleted in its entirety and replaced with:

> The OPW, assisted by the Steering Group and other experts as deemed necessary by the OPW, shall, within three (3) weeks of receipt, review the second Draft Final Hydraulics Reports to ensure that all observations have been appropriately addressed. In the event that the OPW does not consider that all observations have been appropriately addressed, the OPW shall submit further observations to the Consultant to be addressed by the Consultant as set out above. In the event that the OPW is satisfied that all observations have been appropriately addressed, the Consultant shall re-submit the second Draft Final Hydraulics Reports, and accompanying flood hazard and risk maps, as the Draft Final Hydraulics Reports and the Draft Final Flood Maps.

The Consultant shall provide twenty-five (25) bound and printed hardcopies of the Draft Hydraulics Report.

The Consultant shall provide twenty-five (25) bound and printed hardcopies of the Draft Final Flood Maps.

The Draft Final Flood Maps (including the hazard and risk maps, as set out in Sections 7.5 and 8.3 of the Generic Specification) shall be put out to public and stakeholder consultation for a period of three (3) months.

The Consultant shall review all submissions made during the three (3) month public and stakeholder consultation period, that should close no later than 30/09/2013, and shall provide written appropriate responses to each and all submissions to the OPW within one (1) month (i.e., by 31/10/2013) for review and, subject to clarification of any queries on the response by the Consultant, issue to the submitter.

The Consultant shall submit, no later than 31/10/2013, the first version of the Final Hydraulics Reports and Flood Maps that shall be amended revisions the Draft Final Hydraulics Reports (and all components thereof) and Draft Final Flood Maps that address the submissions and comments raised during the public and stakeholder consultation period, subject to discussions with the OPW and Steering Group.

The OPW, assisted by the Steering Group and other experts as deemed necessary by the OPW, shall, within two (2) weeks of receipt, review the first version of the Final Hydraulics Reports and Flood Maps. In the event that the OPW does not consider that all observations have been appropriately addressed, the OPW shall submit further observations to the Consultant to be addressed by the Consultant, after which the Consultant shall submit a revised version of the Final Hydraulics Reports and Flood Maps within two (2) weeks. In the event that the OPW is satisfied that all observations have been appropriately addressed, the Consultant shall re-submit the Reports and Maps as the final versions of the Final Hydraulics Reports and Final Flood Maps

The Consultant shall provide twenty-five (25) bound and printed hardcopies of the Final Hydraulics Report.

The Consultant shall provide twenty-five (25) bound and printed hardcopies of the Final Flood Maps.

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Appendix B Fluvial Hydraulic Model Appendices

Fluvial Hydraulic Modelling Report

1. Basic Model Information

1.1 General Information	
Model ID:	S14a
Unit of Management	23
AFAs included in the Model	Listowel Abbeyfeale
Primary Watercourses / Water Bodies	River Feale Allaghaun River Allaghaun Tributary Oolagh River
1.2 Reference to other Relevant Reports	
Catchment Description	Hydrology Report Unit of Management 23 – Appendix A1.1
Model Location	Hydraulics Report Unit of Management 23 – Section 3.4.2
HEP Schematisation	Hydrology Report Unit of Management 23 – Appendix B1 – Figure B1.1

2. Survey Data and Base Mapping

2.1 Base Mapping:	OSi data base mapping at scale 1:50k Reference: OS0812_D, OS1012_D
2.2 DTM for 2D Model Domain:	**Within AFAs:** LiDAR data with 2m horizontal resolution and approximately 200mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain areas included in the AFA boundaries.
	Outside AFAs: IFSAR data with 5m horizontal resolution and approximately 500mm-1000mm vertical accuracy has been used to inform the ground elevation of the floodplain within the hydraulic model for areas outside the AFA boundaries. **Note:** In general there is overlap between the AFA areas and areas outside the AFAs with regard to the availability of LiDAR data. Therefore some areas outside the AFAs are covered by LiDAR to the same resolution as that for the AFAs.
2.3 River Channel/Structures Survey	General information on the topographic survey of the river channel and structures are included in the main Hydraulics Report. Full details of the survey outputs are provided in the topographic survey deliverables, as required under Section 5.2 of the Stage I Project Brief. Number of cross-sections included in this model: 305.

2.4 Defence Asset Survey Data	The defence asset database has been completed for this Model Area. This comprises (1) Raised embankments on the right bank of the River Feale in Listowel between the N69 Road crossing and the Race Course Footbridge. (2) Raised embankments on the left bank of the River Feale in Listowel between the N69 Road crossing and the Race Pavillion (3) There are four raised flood defence extents on the River Feale MPW reach downstream of the Listowel AFA. All defences have been included in the model schematisation as shown on the maps presented in Annex A.
2.5 Survey interaction	The Lidar, SAR and topographic survey were checked for anomalies, and to ensure that interactions between were within expected tolerances. No issues were identified in this model. Although no issues were found, the LiDAR data has a 2m horizontal resolution and a 200mm vertical accuracy, while the IFSAR data has a 5m horizontal resolution and an approximate 500mm-1000mm vertical accuracy which result in anomalies in the mapping outputs at the LiDAR IFSAR interface.

3. Hydraulic Model Construction and Schematisation

3.1 Software:	**1D domain:**	ISIS Version 3.6.0.156 (32 bit - Single Precision)
	2D domain(s):	TUFLOW Version: 2012-05-AE-iSP-w32
3.2 Model Area / Extent:	The areal extent of the model and its schematisation are shown in Annex A.	

The mapping details for the model extent included in Annex A are as follows:

1. **Full modelled area showing**:
   - River centre lines, HPW/MPW extents, names of watercourses
   - 2D domain area
   - AFA boundaries

2. **Maps showing a detailed model schematic of the HPW/MPW reaches are also included**

3.3 Model Reaches: The following model reaches as shown on the maps referred above have been defined in the model:

Watercourse Name	Reach	Upstream Model Node	Downstream Model Node
River Feale	06FEL	06FEL02265	06FEL00000
	05FEL	05FEL00690	06FEL00000
	04FEL	04FEL01095	04FEL00000
	03FEL	03FEL18134	03FEL00000
	02FEL	03FEL05611	02FEL00000
Oolagh River	01OLG	01OLG02290	01OLG00000
Allaghaun River	02ALL	02ALL00384	02ALL00000
	01ALL	06ALL02261	01ALL00000
Un-named Tributary of Allaghaun River	01EST	01EST001073	01EST00000

Total model HPW length (km):	16.4	**Total model MPW length (km):**	17.3

3.4 Model Structures: A full schedule of structures included in the model is provided in Schedule A in Annex B. A summary of the structures included is given below

Culverts:	☒	How many?	5
Bridges:	☒	How many?	8
Fixed crest weirs:	☒	How many?	1
Adjustable crest weirs:	☐	How many?	0
Sluice / Gate structures:	☐	How many?	0
Locks:	☐	How many?	0
Dams:	☐	How many?	0
Other (describe):			

3.5 Floodplain Schematisation

Out-of-bank areas for MPW reaches have been modelled using a 1D approach in the ISIS model by either extending the river channel cross-sections or using lateral spills connected to reservoir units.

Out-of-bank areas for HPW reaches in Abbeyfeale and Listowel AFAs have been modelled using a 2D approach and the TUFLOW software.

Out-of-bank areas for HPW reaches of the Feale, the Allaghaun and its tributary upstream of the Listowel AFA were modelled using a 1D approach

	in the ISIS model using extended river channel cross-sections. Extended 1D sections are considered appropriate for HPW extents where floodplain flow paths are simple (e.g., parallel to river flow). 1D-2D modelling is required where HPWs flow through urban areas and out-of-bank flows will form complex flow paths. An overview of the floodplain schematisation is available in the maps shown in Annex A.		
3.6 2D Domain Grid Size:	The number of 2D domains defined and the grid sizes of each 2D model domain are as follows:		
	Number of 2D domains: 2		
	Domain 1: Abbeyfeale	Grid cell size: 5m	Area: 10.8 km^2
	Domain 2: Listowel	Grid cell size: 5m	Area: 2.5 km^2
	2D domains are defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. The domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the floodplain flow.		
3.7 Model Breaklines in the 2D Domain:	Bank tops and bridge parapets are represented as breaklines in the 2D domain. Details on the use of breaklines and the method used to alter DTM is provided in Section 3.4.8 of the Hydraulics Report for Unit of Management 23.		
3.8 Floodplain Structures in the 2D Domain	1D elements have been included in the Listowel 2D domain to represent the hydraulic structures along the Millstream channel. A single road alignment within Abbeyfeale is included in the 2D domain as a gully line. This is relevant to the 0.1%AEP flood extent only. This structure was not surveyed therefore the dimensions have been estimated based on LiDAR and best engineering judgement.		
3.9 Hydraulic Roughness	Hydraulic roughness (Manning's 'n') has been defined in accordance with the approaches described in the main report. Details of the values adopted for this model are included in Schedule B in Annex B. A summary of Manning's 'n' for the model as a whole is as follows:		
MPW In-bank	Minimum 'n' value:	0.035	
	Maximum 'n' value:	0.060	
HPW In-bank	Minimum 'n' value:	0.035	
	Maximum 'n' value:	0.060	
Floodplain (ISIS Model)	Manning's n for out of bank areas represented in the ISIS model are as defined by EPA land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in ISIS are as follows:		
	Land Use	**Manning's 'n' Value**	
	Pastures	0.035	
	Woodland	0.060	

Floodplain (TUFLOW Model)	Manning's 'n' for out of bank areas represented in the TUFLOW model are as defined by OSi NTF land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in TUFLOW are as follows:

Land Use	Manning's 'n' Value
Buildings	0.100
Short grass, parks	0.035
General Urban	0.060
General Rural	0.045
Pastures	0.035
Dense Vegetation	0.080
Roads	0.025
Railways	0.050
Water bodies	0.020

3.10 Spill Units	• Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain, flows spilling over structures). • Spill profile geometry is defined using topographic survey data and LiDAR/IfSAR. • Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can be also found to account for lateral spilling perpendicular to the main direction of flow.
3.11 Model Boundaries - Inflows	Hydrological flow hydrographs were input to the model at key model locations as indicated in the tables below. The production of peak flow estimates and flow hydrograph shapes is fully explained in the Hydrology Report relevant to Unit of Management 23. Peak inflows (m^3/s) are summarised in the tables below for the current situation and the design event simulated. These are the final inflows as obtained following calibration to HEPs (see Section 4.2).
(a) Current Situation (Main Stream)	

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_2388_4	06FEL02265	207.9	281.3	324.3	365.5	419.0	459.0	498.9	591.2
23_001_1	05FEL00690	2.4	3.2	3.7	4.2	4.8	5.3	5.7	6.8
23_121_3	04FEL01095	47.5	64.2	74.0	83.4	95.6	104.7	113.8	134.9
23_120_2	03FEL17646	5.0	6.8	7.8	8.8	10.1	11.1	12.1	14.3
23_2546_1	03FEL12940	7.5	10.2	11.7	13.2	15.2	16.6	18.1	21.4
23_374_4	03FEL05837	78.4	106.1	122.3	137.9	158.0	173.1	188.2	223.0
23_2557_1	02FEL05611	0.4	0.6	0.7	0.8	0.9	1.0	1.0	1.2
23_2557_0	02FEL05611	1.5	2.1	2.4	2.7	3.1	3.4	3.7	4.4
23_114_6	01OLG02290	23.7	32.0	36.9	41.6	47.6	52.2	56.7	67.2

(a) Current Situation (Tributaries)	

<table>
<tr><th rowspan="2">HEP Reference Name</th><th rowspan="2">Input Node in the Hydraulic Model</th><th colspan="8">Annual Exceedance Probability</th></tr>
<tr><th>50%</th><th>20%</th><th>10%</th><th>5%</th><th>2%</th><th>1%</th><th>0.5%</th><th>0.1%</th></tr>
<tr><td>23_1973_2</td><td>01EST01073</td><td>3.1</td><td>4.2</td><td>4.9</td><td>5.5</td><td>6.3</td><td>6.9</td><td>7.5</td><td>8.9</td></tr>
<tr><td>23_1739_2</td><td>02ALL00384</td><td>61.7</td><td>83.4</td><td>96.2</td><td>108.4</td><td>124.3</td><td>136.1</td><td>148.0</td><td>175.4</td></tr>
</table>

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for both the MRFS and the HEFS. These events are selected as these are the MRFS and HEFS that are to be mapped.

<table>
<tr><th rowspan="3">HEP Reference Name</th><th rowspan="3">Input Node in the Hydraulic Model</th><th colspan="8">Annual Exceedance Probability</th></tr>
<tr><th colspan="8">MRFS</th></tr>
<tr><th>50%</th><th>20%</th><th>10%</th><th>5%</th><th>2%</th><th>1%</th><th>0.5%</th><th>0.1%</th></tr>
<tr><td>23_2388_4</td><td>06FEL02265</td><td>249.5</td><td>337.5</td><td>389.1</td><td>438.7</td><td>502.7</td><td>550.8</td><td>598.6</td><td>709.5</td></tr>
<tr><td>23_001_1</td><td>05FEL00690</td><td>2.9</td><td>3.9</td><td>4.5</td><td>5.0</td><td>5.8</td><td>6.3</td><td>6.8</td><td>8.1</td></tr>
<tr><td>23_121_3</td><td>04FEL01095</td><td>56.9</td><td>77.0</td><td>88.8</td><td>100.1</td><td>114.7</td><td>125.7</td><td>136.6</td><td>161.9</td></tr>
<tr><td>23_120_2</td><td>03FEL17646</td><td>6.0</td><td>8.2</td><td>9.4</td><td>10.6</td><td>12.2</td><td>13.3</td><td>14.5</td><td>17.1</td></tr>
<tr><td>23_2546_1</td><td>03FEL12940</td><td>9.0</td><td>12.2</td><td>14.1</td><td>15.9</td><td>18.2</td><td>19.9</td><td>21.7</td><td>25.7</td></tr>
<tr><td>23_374_4</td><td>03FEL05837</td><td>94.1</td><td>127.3</td><td>146.8</td><td>165.4</td><td>189.6</td><td>207.7</td><td>225.8</td><td>267.6</td></tr>
<tr><td>23_2557_1</td><td>02FEL05611</td><td>0.5</td><td>0.7</td><td>0.8</td><td>0.9</td><td>1.0</td><td>1.1</td><td>1.2</td><td>1.5</td></tr>
<tr><td>23_2557_0</td><td>02FEL05611</td><td>1.8</td><td>2.5</td><td>2.9</td><td>3.2</td><td>3.7</td><td>4.1</td><td>4.4</td><td>5.2</td></tr>
<tr><td>23_114_6</td><td>01OLG02290</td><td>28.4</td><td>38.4</td><td>44.3</td><td>49.9</td><td>57.2</td><td>62.6</td><td>68.1</td><td>80.7</td></tr>
<tr><td>23_1973_2</td><td>01EST01073</td><td>3.7</td><td>5.1</td><td>5.8</td><td>6.6</td><td>7.6</td><td>8.3</td><td>9.0</td><td>10.7</td></tr>
<tr><td>23_1739_2</td><td>02ALL00384</td><td>74.0</td><td>100.1</td><td>115.4</td><td>130.1</td><td>149.1</td><td>163.4</td><td>177.6</td><td>210.4</td></tr>
</table>

<table>
<tr><th rowspan="3">HEP Reference Name</th><th rowspan="3">Input Node in the Hydraulic Model</th><th colspan="3">Annual Exceedance Probability</th></tr>
<tr><th colspan="3">HEFS</th></tr>
<tr><th>10%</th><th>1%</th><th>0.1%</th></tr>
<tr><td>23_2388_4</td><td>06FEL02265</td><td>421.6</td><td>596.7</td><td>768.6</td></tr>
<tr><td>23_001_1</td><td>05FEL00690</td><td>4.8</td><td>6.8</td><td>8.8</td></tr>
<tr><td>23_121_3</td><td>04FEL01095</td><td>96.2</td><td>136.1</td><td>175.4</td></tr>
<tr><td>23_120_2</td><td>03FEL17646</td><td>10.2</td><td>14.4</td><td>18.6</td></tr>
<tr><td>23_2546_1</td><td>03FEL12940</td><td>15.3</td><td>21.6</td><td>27.8</td></tr>
<tr><td>23_374_4</td><td>03FEL05837</td><td>159.0</td><td>225.1</td><td>289.9</td></tr>
<tr><td>23_2557_1</td><td>02FEL05611</td><td>0.9</td><td>1.2</td><td>1.6</td></tr>
<tr><td>23_2557_0</td><td>02FEL05611</td><td>3.1</td><td>4.4</td><td>5.7</td></tr>
<tr><td>23_114_6</td><td>01OLG02290</td><td>47.9</td><td>67.9</td><td>87.4</td></tr>
<tr><td>23_1973_2</td><td>01EST01073</td><td>6.3</td><td>9.0</td><td>11.5</td></tr>
<tr><td>23_1739_2</td><td>02ALL00384</td><td>125.0</td><td>177.0</td><td>228.0</td></tr>
</table>

3.12 Model Boundaries – Downstream Conditions	Downstream boundary conditions adopted in the model are as follows:
	A normal depth boundary was chosen to provide a free flow condition at the downstream end of the model. Checks have been made to ensure the

	normal depth assumption is reasonable and flood flows “leaving” the model are not in reality subject to a backing up effect from hydraulic structures or other floodplain features located downstream. The slope parameter was taken from the local river bed slope. Sensitivity to this assumption is discussed in the relevant section below.

4. Hydraulic Model Calibration and Sensitivity

<table>
<tr><td rowspan="1">4.1 Model Calibration and Verification to Historical Events</td><td colspan="5">The approach to model calibration is documented in the Main Report.
The analysis of available flood event data and high flow data for possible consideration as calibration and verification events is covered in detail in the Hydrology Report for UoM23 (Appendix F).
A summary of the calibration and verification events along with associated model calibration results is as follows:
No flooding information was available to allow calibration.</td></tr>
<tr><td>Catchment Gauging</td><td colspan="5">Is modelled catchment: Gauged ☐ Ungauged ☒ check one box only</td></tr>
<tr><td rowspan="3">Gauging Stations used for Calibration</td><td colspan="5">NA</td></tr>
<tr><td>Station Number</td><td>Watercourse</td><td>Location</td><td colspan="2">ISIS Node Reference</td></tr>
<tr><td>NA</td><td>NA</td><td>NA</td><td colspan="2">NA</td></tr>
<tr><td rowspan="2">Calibration Events</td><td rowspan="2">Event Date</td><td rowspan="2">Station Number</td><td rowspan="2">Difference between Modelled and Observed Water Level (m)</td><td colspan="2">Root Mean Square Error</td></tr>
<tr><td>HPW</td><td>MPW</td></tr>
<tr><td>Event</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Summary of Findings</td><td colspan="5">NA</td></tr>
<tr><td>4.2 Calibration to HEP</td><td colspan="5">Calibration of the hydraulic model to the HEP target flows has been carried out for all design events simulated (10%, 1% and 0.1% AEP). Section 2.7.2 of the Hydrology Report for UoM 23provides a summary of the calibration to HEP process.

Preliminary inflow hydrographs derived from the hydrological analysis and input to the model were adjusted in time so that their respective peak flows coincide with the peak time of the propagating flood wave as it is routed down the model. Total peak flows predicted by the hydraulic model at HEP locations were then compared to the HEP target flows estimated during the hydrological analysis. Where required, inflows to the hydraulic model were scaled up/down to ensure that the modelled total peak flows remain within ±10% of the HEP target flows. This ±10% target allows for good agreement between the hydrological estimates and the hydraulic results without the addition/removal of unrealistic volumes of flow from the model. The robustness of this has been verified by the agreement of the design flood maps.
The table below shows the percentage difference between the modelled and target flows at each HEP location. The average percentage differences for the HEP nodes for the “Main river” are as follows: 2.2%, 1.5% and 1.4% for the 10%, 1% and 0.1% AEP events respectively. The average percentage differences for the HEP nodes for the “Tributary runs” are as follows: 1.3%, 1.1% and 0.7% for the 10%, 1% and 0.1% AEP events respectively.</td></tr>
</table>

	At HEP location 23_114_10, no comparison has been made between the modelled flows and the target flows as these two points are located next to the confluence between the Oolagh River and the River Feale. At this location floodplain flow patterns are complex involving some re-circulation of flow across the floodplain area between the two watercourses. It is therefore not possible to quantify the total flows that should be attributed to each of the HEP nodes.

HEP Reference Name	Node in the Hydraulic Model	Annual Exceedance Probability							
		Percentage Difference (%)							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_2388_4	06FEL02265	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23_132_2	06FEL01555	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
23_121_2	06FEL00130	0.4	0.4	0.4	0.4	0.2	0.1	0.0	0.0
23_121_3	05FEL00357	-0.3	-0.3	-0.4	-0.4	-0.5	-0.5	-0.5	-0.5
23_122_2	04FEL00741	-4.9	-3.6	-3.2	-2.9	-2.8	-2.7	-2.6	-2.6
23_123_2	04FEL00174	-3.9	-1.8	-0.9	-0.3	0.3	0.8	0.6	1.3
23_120_2	03FEL17646	-2.7	-1.3	-0.9	-0.5	-0.2	0.1	-0.4	0.6
23_2546_1	03FEL12740	-3.4	-2.1	-1.6	-1.2	-0.9	-0.7	-1.1	-0.1
23_154_2	03FEL10168	-6.1	-4.8	-4.4	-3.9	-3.7	-3.4	-3.8	-2.8
23_374_4	03FEL06424	-7.4	-6.1	-5.7	-5.2	-4.9	-4.5	-4.8	-4.0
23_2551_2	03FEL04739	-4.7	-3.5	-3.0	-2.5	-2.3	-1.6	-2.1	-1.3
23_2554_2	03FEL02852	-4.7	-3.5	-3.1	-2.6	-2.5	-2.0	-2.5	-1.5
23_2548_2	03FEL02333	-4.7	-4.2	-4.6	-4.1	-4.3	-4.0	-4.0	-2.7
23_2555_3	03FEL01331u	-4.7	-3.6	-3.2	-2.9	-2.5	-2.0	-2.5	-1.6
23_2555_5	03FEL00528	-4.7	-3.6	-3.2	-3.0	-3.9	-2.2	-2.6	-1.8
23_2556_2	03FEL00000	-4.7	-3.6	-3.2	-3.1	-4.1	-2.4	-2.9	-2.5
23_2288_2	02FEL05140	-4.4	-3.3	-2.8	-3.2	-4.7	-2.7	-3.0	-2.1
23_2288_3	02FEL03982	-4.5	-3.8	-3.0	-2.9	-3.8	-2.0	-2.5	-2.2
23_2823_3	02FEL03567	-4.5	-3.8	-3.9	-3.0	-3.9	-2.2	-2.7	-3.2
23_2941_3	02FEL01963	-4.6	-3.3	-4.8	-2.9	-3.1	-1.3	-2.1	-2.2
23_2941_3	02FEL00000	-4.6	-3.3	-4.8	-2.9	-3.1	-1.3	-2.1	-2.2
23_114_6	01OLG02290	1.1	1.1	1.1	1.1	1.1	1.1	-7.0	1.1
23_114_7	01OLG01800	0.2	1.1	2.0	1.4	0.2	-0.7	-8.6	-1.9
23_114_8	01OLG01079bu	-3.4	-0.1	0.3	-0.5	-1.3	-1.7	-9.5	-1.5
23_1739_2	02ALL00384	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
23_1733_2	01ALL01756	2.0	3.3	3.9	3.9	3.7	3.3	2.9	2.0
23_1733_5	01ALL00129	2.3	2.7	2.3	2.1	1.9	1.7	1.6	1.2
23_1973_2	01EST01073	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23_1973_3	01EST00521	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.3 Model Sensitivity	Sensitivity tests have been carried out in order to assess the sensitivity of the predicted peak water levels to alterations in roughness (Manning's 'n'), fluvial flow, afflux at key structures and downstream conditions. In each case the sensitivity run was carried out for the 1% AEP fluvial event. Uncertainty maps illustrating the results of the sensitivity analysis will be delivered as part of the final stage of this work. Sensitivity test results are provided in the following tables:			
+20% Manning's 'n'	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section / Reach where the Maximum Difference occurs**
	06FEL	0.15	0.20	06FEL00238
	05FEL	0.15	0.18	05FEL00291
	04FEL	0.17	0.20	04FEL00048
	03FEL	0.21	0.45	03FEL02852
	02FEL	0.21	0.34	02FEL04721
	01OLG	0.07	0.17	01OLG00000
	02ALL	0.12	0.14	06ALL00384
	01ALL	0.13	0.26	01ALL00039
	01EST	0.05	0.12	06FEL00238
-20% Manning's 'n'	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	06FEL	-0.17	-0.23	06FEL00238
	05FEL	-0.18	-0.23	05FEL00143
	04FEL	-0.20	-0.27	04FEL00048
	03FEL	-0.27	-0.80	03FEL03046
	02FEL	-0.33	-0.61	02FEL04721
	01OLG	-0.08	-0.22	01OLG00000
	02ALL	-0.14	-0.19	02ALL00384
	01ALL	-0.15	-0.37	01ALL00039
	01EST	-0.06	-0.16	01EST00020

+20% inflows	Watercourse	Average Water Level Difference	Maximum Water Level Difference	Cross-section where the Maximum Difference occurs
	06FEL	0.15	0.21	06FEL00000
	05FEL	0.18	0.22	05FEL00505
	04FEL	0.18	0.22	04FEL00917
	03FEL	0.25	0.53	06FEL03046
	02FEL	0.23	0.36	06FEL04721
	01OLG	0.10	0.23	00OLG01090
	02ALL	0.13	0.14	02ALL00310
	01ALL	0.13	0.22	01ALL02152
	01EST	0.09	0.25	01EST00533
-20% inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	06FEL	-0.17	-0.24	06FEL00011
	05FEL	-0.21	-0.25	05FEL00532
	04FEL	-0.21	-0.28	04FEL00929
	03FEL	-0.31	-0.73	06FEL03046
	02FEL	-0.38	-0.55	06FEL04801d
	01OLG	-0.10	-0.25	00OLG01090
	02ALL	-0.16	-0.18	02ALL00310
	01ALL	-0.19	-0.37	01ALL00182
	01EST	-0.10	-0.27	01EST00533
Afflux at Key Structure Calibration coefficient increased by 20%	Two structures (Race Course Stand Footbridge and the Race Course / Castle Footbridge) on the River Feale in the Listowel AFA, produced significant (>400mm) head loss during the 1% AEP flood event and were selected for the sensitivity analysis. A further two structures within the Abbeyfeale AFA (N21 crossing on the Allaghaun Tributary and R524 crossing of the Allaghaun River) produced significant head losses and were also selected for the sensitivity analysis. At Listowel Race Course Stand Footbridge 116mm reduction in maximum stage occurs in response to the 20% increase in the Bridge Orifice Discharge Coefficient. The floodplain here is relatively constrained and an insignificant reduction in flood extent occurs. At Listowel Race Course / Castle Footbridge less than 10mm reduction in maximum stage occurs in response to the 20% increase in the Bridge Orifice Discharge Coefficient. There is no effect on the modelled flood extent. At the N21 crossing on the Allaghaun Tributary 114mm increase in maximum stage occurs in response to the 20% increase of the Inlet Head Loss Coefficient however in both design model and sensitivity test the watercourse remains in bank and there is no change to flood extent.			

	At R524 crossing of the Allaghaun River an 18mm increase in maximum stage occurs in response to the 20% increase of the Inlet Head Loss Coefficient and no significant change to the modelled flood extent occurs.
Afflux at Key Structure Calibration coefficient decreased by 20%	At Listowel Race Course Stand Footbridge 106mm increase in maximum stage occurs in response to the 20% decrease in the Bridge Orifice Discharge Coefficient. The floodplain here is relatively constrained and an insignificant reduction in flood extent occurs. At Listowel Race Course / Castle Footbridge less than 10mm increase in maximum stage occurs in response to the 20% increase in the Bridge Orifice Discharge Coefficient. There is no effect on the modelled flood extent. At the N21 crossing on the Allaghaun Tributary 116mm decrease in maximum stage occurs in response to the 20% decrease of the Inlet Head Loss Coefficient however in both design model and sensitivity test the watercourse remains in bank and there is no change to flood extent. At R524 crossing of the Allaghaun River a 28mm decrease in maximum stage occurs in response to the 20% decrease of the Inlet Head Loss Coefficient and no significant change to the modelled flood extent occurs.
Downstream Conditions Normal Depth downstream boundary slope doubled	The change to the downstream boundary condition has resulted in a decrease in maximum water level of 0.7m at the downstream boundary (ISIS node 02FEL00000). The diminishing effect can be seen for approximately 2km upstream of the boundary and therefore has no impact on water levels in Listowel AFA.
Downstream Conditions Normal Depth downstream boundary slope halved	The change to the downstream boundary condition has resulted in an increase in maximum water level of 0.42m at the downstream boundary (ISIS node 02FEL00000). The diminishing effect can be seen for 2 km upstream of the boundary and therefore has no impact on water levels in Listowel AFA.
4.4 Model Files	The hydraulic model files associated with this model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. The model files included are detailed in Annex D.

5. Hydraulic Model Outputs

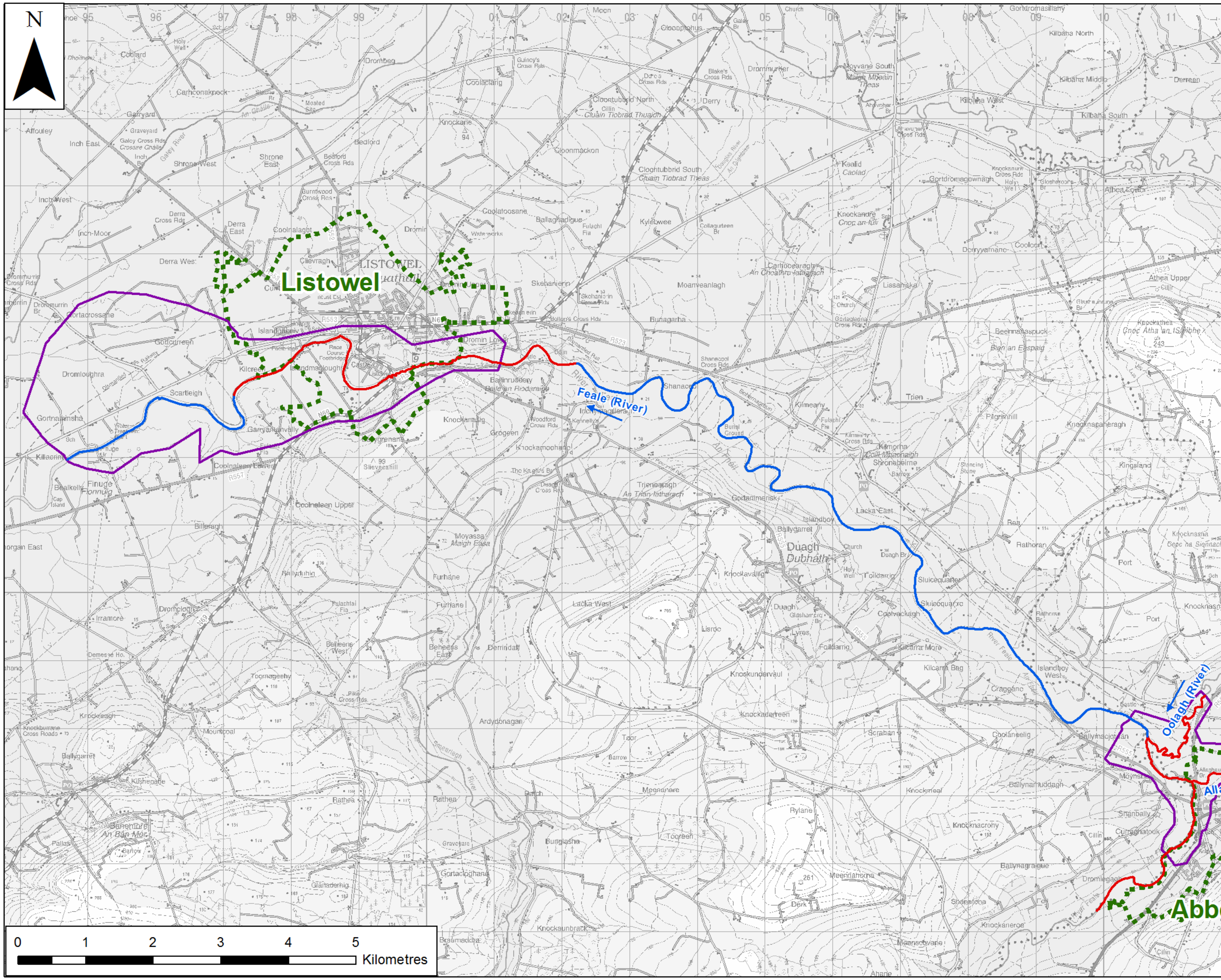
5.1 Mapping	The model outputs were processed to produce a series of flood maps according to the requirements stated in the Stage I Project Brief under Section 7.5.2. This includes mapping outputs covering: • Flood extents • Flood depth and velocity • Flood hazard All of the maps contain the maximum extent, depth, velocity and flood hazard for the combined main stream inflows and the tributaries inflows. An explanation for the main stream inflows and the tributaries inflows is provided in Section 6. Mapping outputs corresponding to the **defended**, **current** scenario for the 10%, 1% and 0.1% AEP flood events are shown in Annex E for flood extent and depth only.

6. Key Model Assumptions and Limitations

- As detailed in the Hydrology Report, the hydrological approach to the study catchment requires the main river and its tributaries to be treated separately in order to produce flood extents for the design events considered in this study. The River Feale and the Oolagh River were classified as main stream, whilst the Allaghaun River and its (2^{nd} Order) tributary were considered as tributaries. Inflow hydrographs were produced for both the main stream and tributaries. Two runs were conducted; the first containing only the main stream inflows and then the second contained the tributaries inflows. Both Main Stream and Tributary models share exactly the same geometry (structures and topography). The model outputs for all three runs were then merged together to pick up the maximum flood depths and extents to create the flood maps.
- For the reaches where a 1D schematisation of the floodplain has been adopted, the flood depth maps were generated using modelled peak water levels and LiDAR (where available)/IFSAR data for ground level information. Although no issues were found, the LiDAR data has a 2m horizontal resolution and a 200mm vertical accuracy, while the IFSAR data has a 5m horizontal resolution and an approximate 500mm-1000mm vertical accuracy which result in anomalies in the mapping outputs at the LiDAR IFSAR interface.
- There is approximately 8 km of formal flood defences within the model extent. These formal flood defences comprise earth embankments and are located on the left and right bank of the River Feale, within and downstream of the Listowel AFA, shown in Annex A. The defences have been represented in the model therefore the model and outputs presented in this report represent a defended scenario.

Annex A – Model Extent and Schematisation Maps

Annex A1 – Model Extent



Legend

2D Model Boundary

AFA Boundary

Model Reaches

HPW

MPW

Model:

S14a

Figure ref:

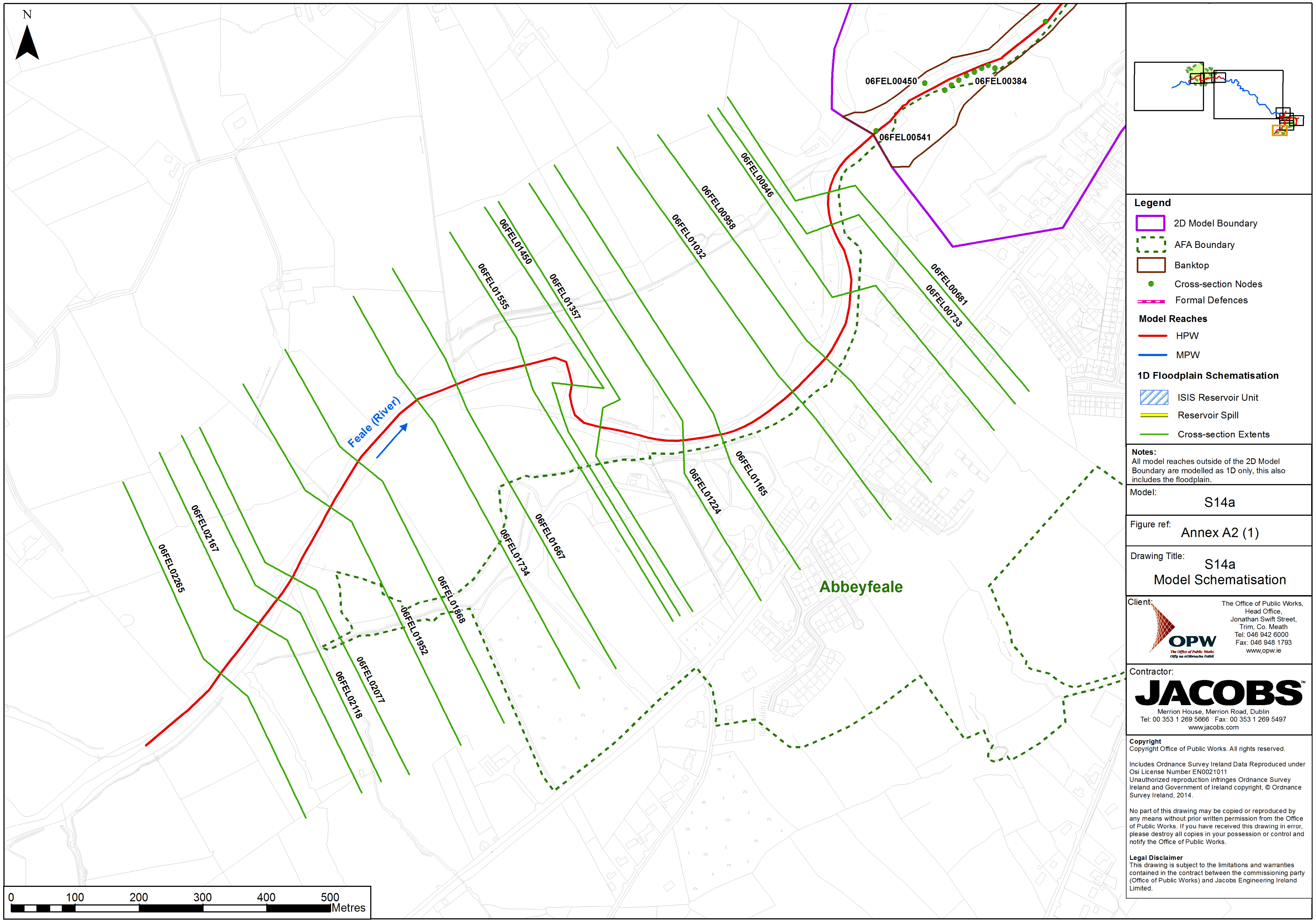
Annex A1

Drawing Title:

S14a
Model Extent

JACOBS

Annex A2 – Schematisation Maps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06FEL00846
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06FEL01357
06FEL00681
06FEL00733
Feale (River)
06FEL01224
06FEL01165
06FEL01667
06FEL01734
06FEL02167
06FEL02265
06FEL01868
06FEL01952
06FEL02077
06FEL02118
Abbeyfeale
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Reservoir Spill
Cross-section Extents
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14a
Figure ref:
Annex A2 (1)
Drawing Title:
S14a
Model Schematisation
Client:
The Office of Public Works, Head Office, Jonathan Swift Street, Trim, Co. Meath
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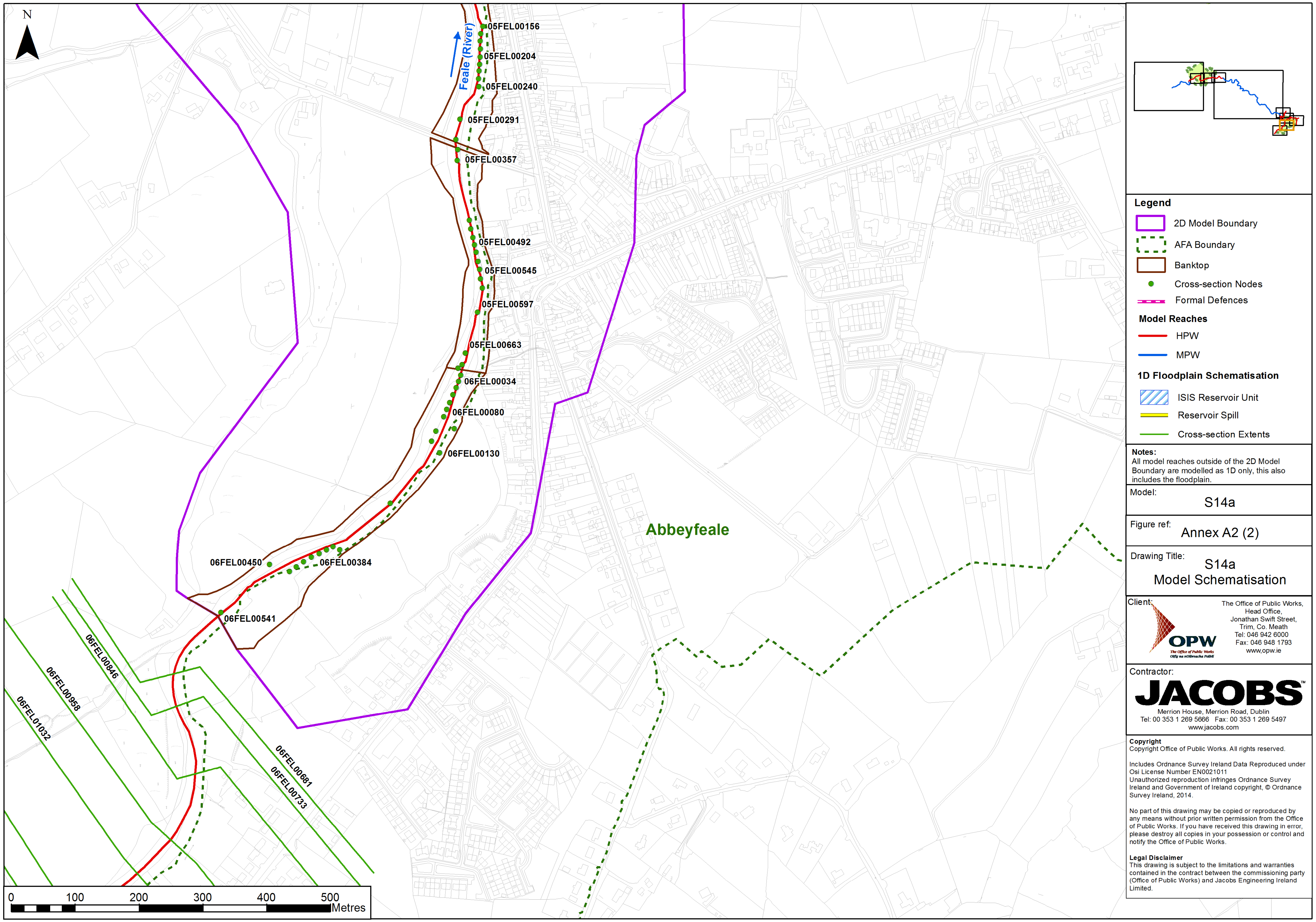
N
Feale (River)
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06FEL00384
06FEL00541
06FEL00846
06FEL00958
06FEL01032
06FEL00681
06FEL00733
Abbeyfeale
0
100
200
300
400
500
Metres
Legend
2D Model Boundary
AFA Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Reservoir Spill
Cross-section Extents
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14a
Figure ref:
Annex A2 (2)
Drawing Title:
S14a
Model Schematisation
Client:
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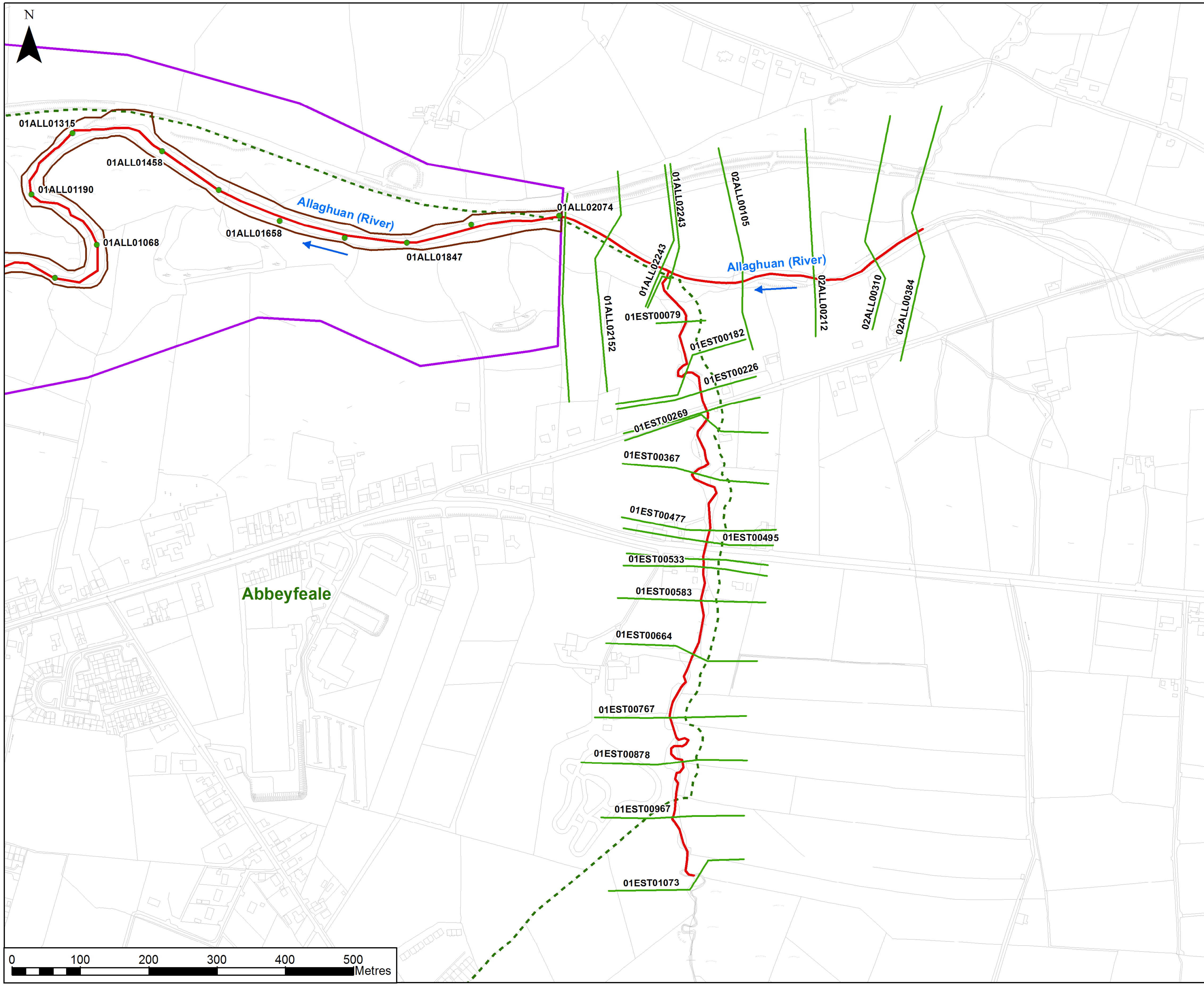

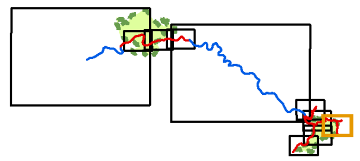

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14a

Figure ref: Annex A2 (3)

Drawing Title: S14a Model Schematisation

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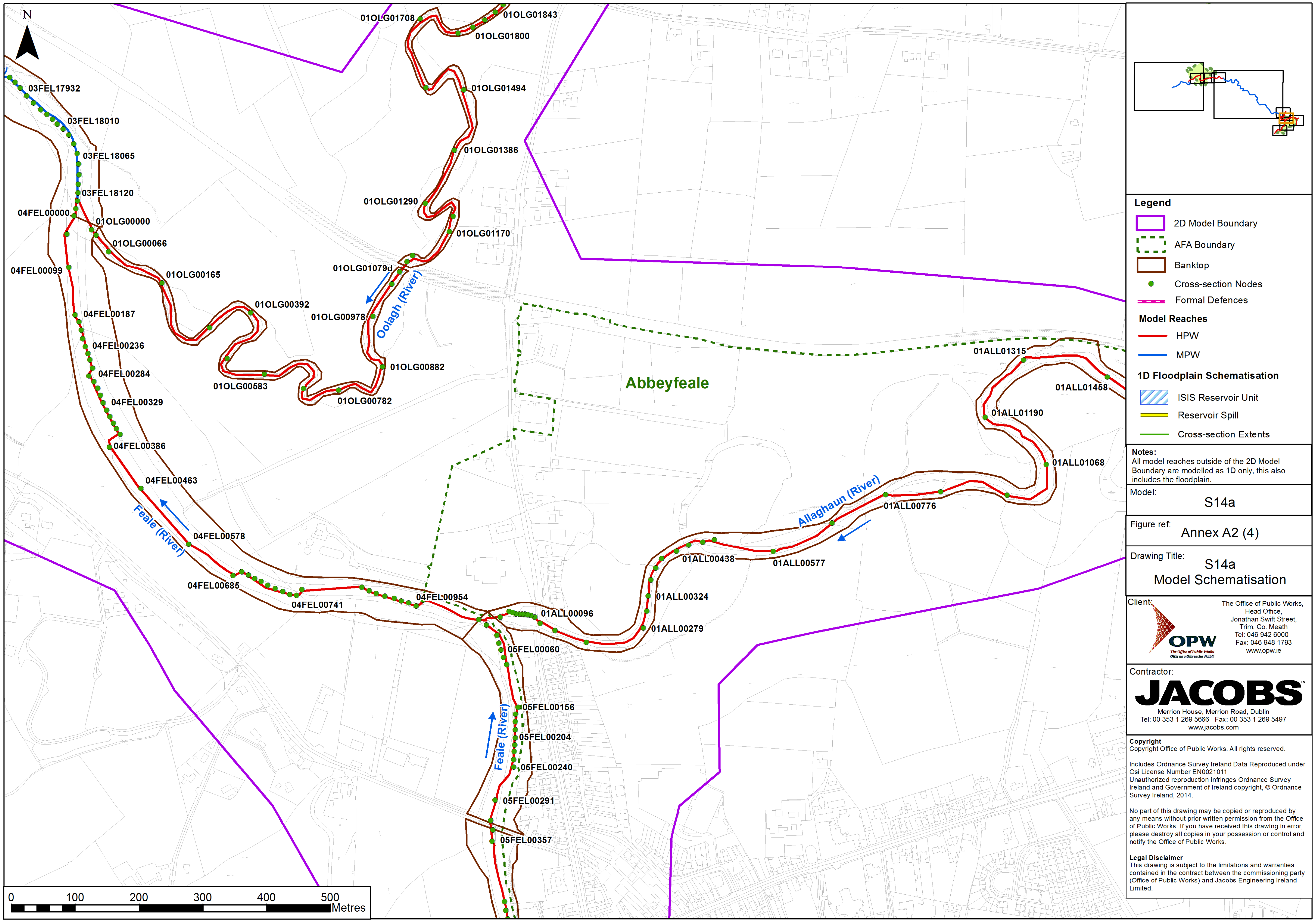
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01OLG01494
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01OLG01290
01OLG01170
01OLG01079d
Oolagh (River)
01OLG00978
01OLG00882
01OLG00782
01OLG00583
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03FEL18120
04FEL00000
04FEL00099
04FEL00187
04FEL00236
04FEL00284
04FEL00329
04FEL00386
04FEL00463
Feale (River)
04FEL00578
04FEL00685
04FEL00741
04FEL00954
01ALL00096
01ALL00279
01ALL00324
01ALL00438
01ALL00577
Allaghaun (River)
01ALL00776
01ALL01068
01ALL01190
01ALL01458
01ALL01315
Abbeyfeale
05FEL00060
05FEL00156
05FEL00204
05FEL00240
05FEL00291
05FEL00357
Feale (River)
0
100
200
300
400
500
Metres
Legend
2D Model Boundary
AFA Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Reservoir Spill
Cross-section Extents
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14a
Figure ref:
Annex A2 (4)
Drawing Title:
S14a
Model Schematisation
Client:
The Office of Public Works,
Head Office,
Jonathan Swift Street,
Trim, Co. Meath
Tel: 046 942 6000
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Contractor:
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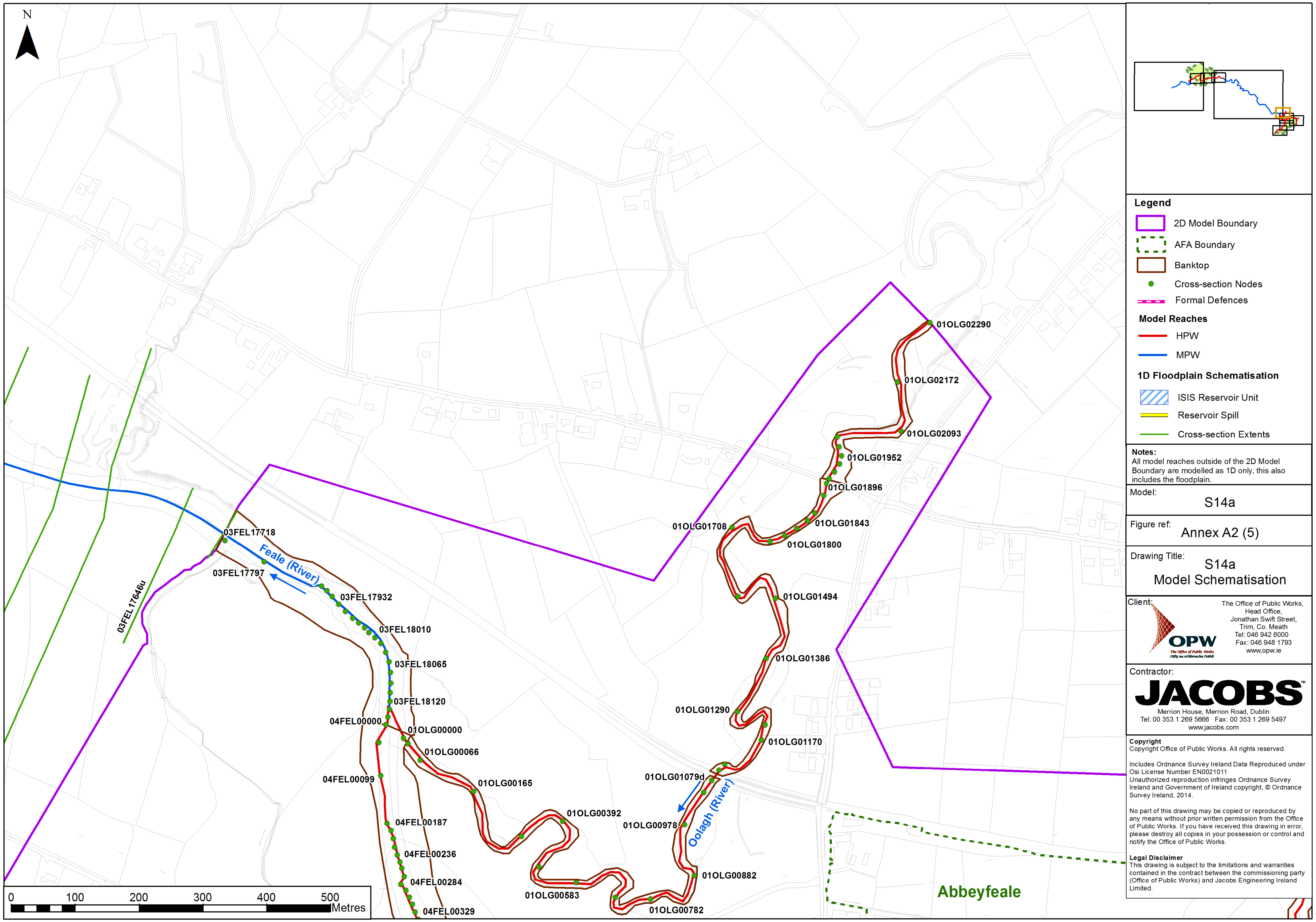
N
03FEL17718
Feale (River)
03FEL17797
03FEL17646u
03FEL17932
03FEL18010
03FEL18065
03FEL18120
04FEL00000
01OLG00000
01OLG00066
04FEL00099
01OLG00165
04FEL00187
04FEL00236
04FEL00284
04FEL00329
01OLG00392
01OLG00583
01OLG00782
01OLG00882
01OLG00978
Oolagh (River)
01OLG01079d
01OLG01170
01OLG01290
01OLG01386
01OLG01494
01OLG01708
01OLG01800
01OLG01843
01OLG01896
01OLG01952
01OLG02093
01OLG02172
01OLG02290
Abbeyfeale
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Reservoir Spill
Cross-section Extents
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14a
Figure ref:
Annex A2 (5)
Drawing Title:
S14a
Model Schematisation
Client:
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N
03FEL03624
03FEL03966
03FEL04739
03FEL05239
03FEL06202
03FEL07170
03FEL08202
03FEL08670
03FEL09197
03FEL09683
03FEL10661
03FEL11197
03FEL11696
03FEL12165
03FEL13202
03FEL13701
03FEL14197
03FEL14686
03FEL15183
03FEL15696
03FEL16178
0 0.5 1 1.5 2
Kilometers
Legend
2D Model Boundary
AFA Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Reservoir Spill
Cross-section Extents
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14a
Figure ref:
Annex A2 (6)
Drawing Title:
S14a
Model Schematisation
Client:
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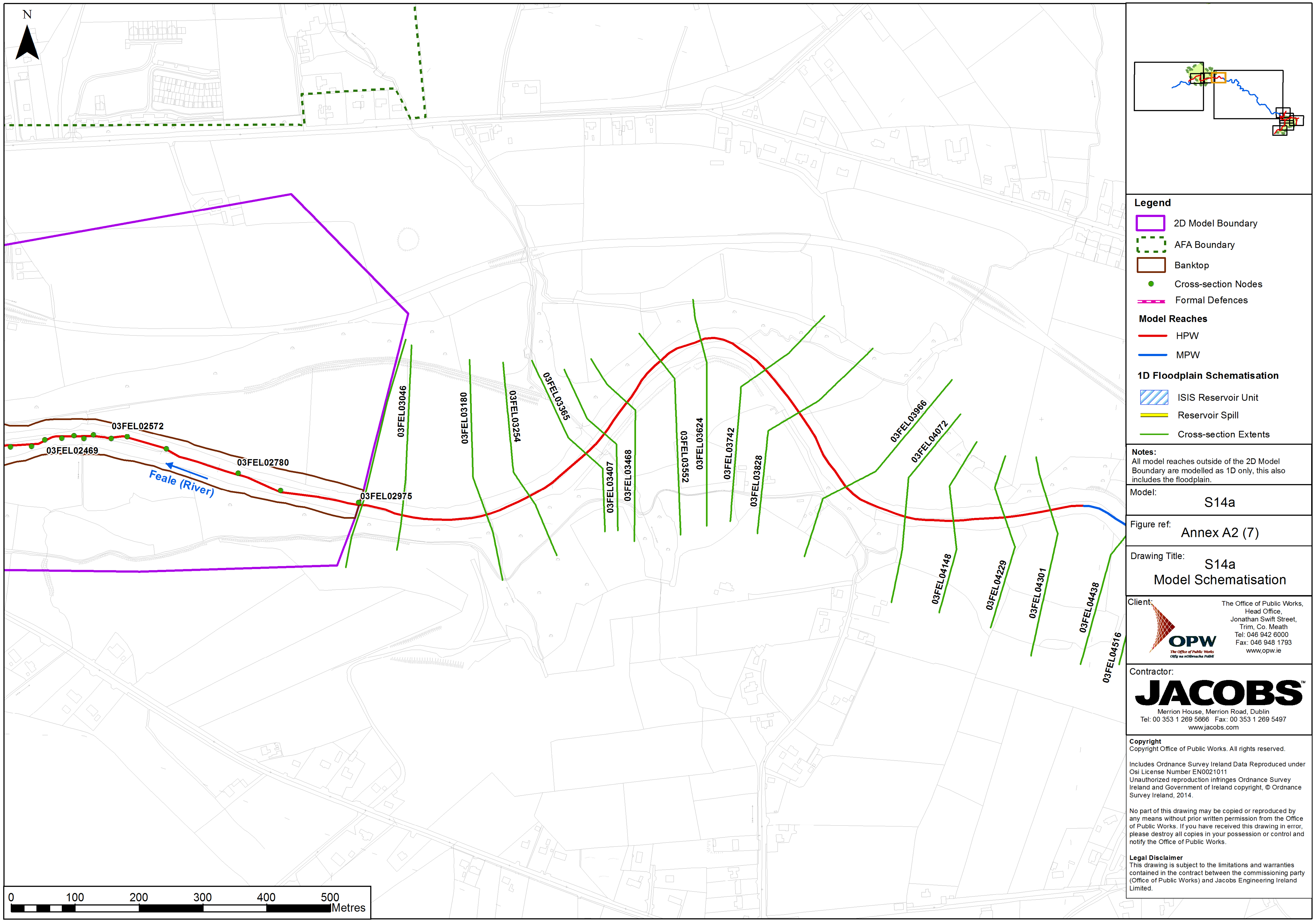
N
03FEL02572
03FEL02469
03FEL02780
03FEL02975
Feale (River)
03FEL03046
03FEL03180
03FEL03254
03FEL03365
03FEL03407
03FEL03468
03FEL03552
03FEL03624
03FEL03742
03FEL03828
03FEL03966
03FEL04072
03FEL04148
03FEL04229
03FEL04301
03FEL04438
03FEL04516
0 100 200 300 400 500 Metres
Legend
2D Model Boundary
AFA Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Reservoir Spill
Cross-section Extents
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model: S14a
Figure ref: Annex A2 (7)
Drawing Title: S14a Model Schematisation
Client: The Office of Public Works, Head Office, Jonathan Swift Street, Trim, Co. Meath Tel: 046 942 6000 Fax: 046 948 1793 www.opw.ie
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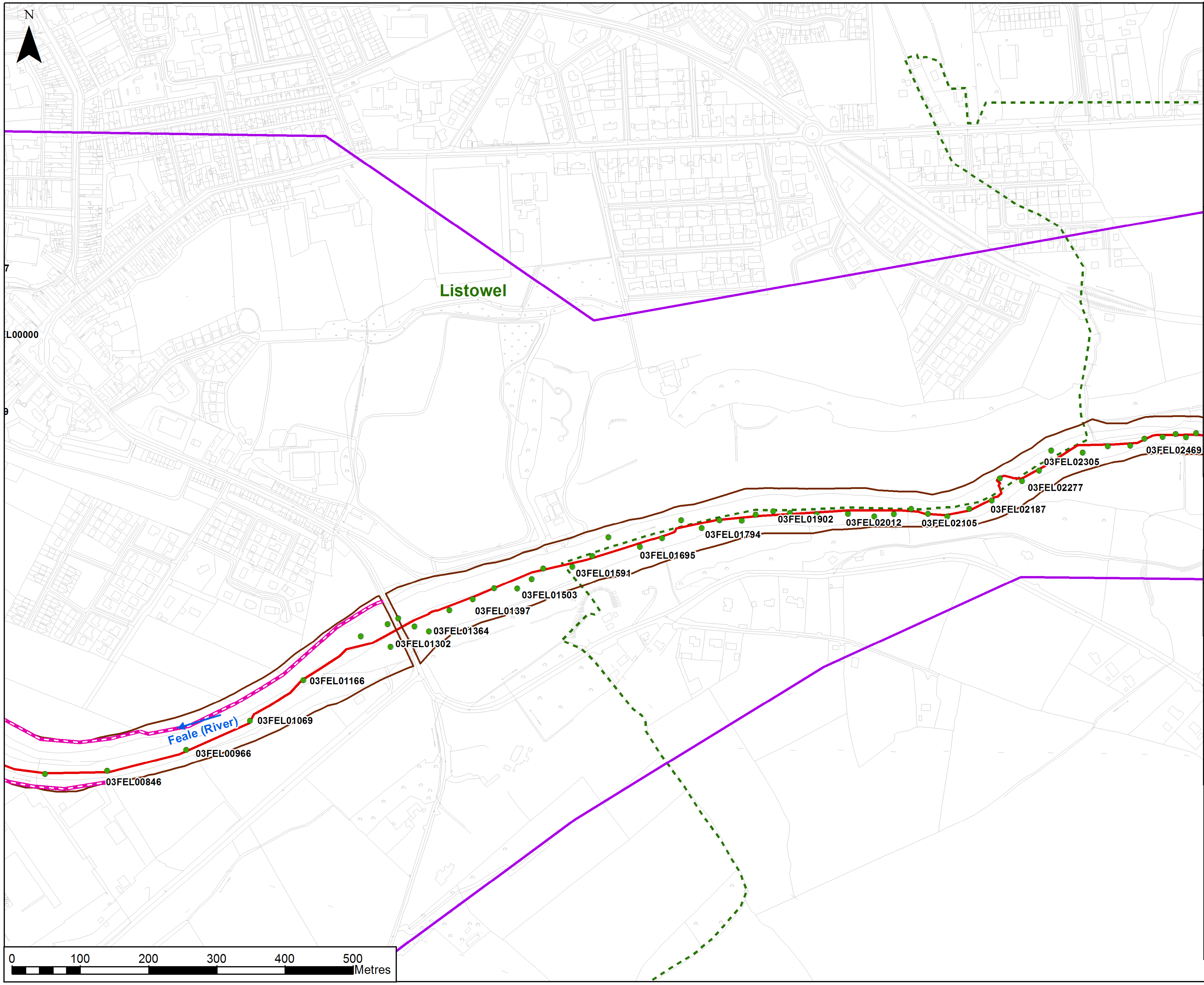

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14a

Figure ref: Annex A2 (8)

Drawing Title: S14a Model Schematisation

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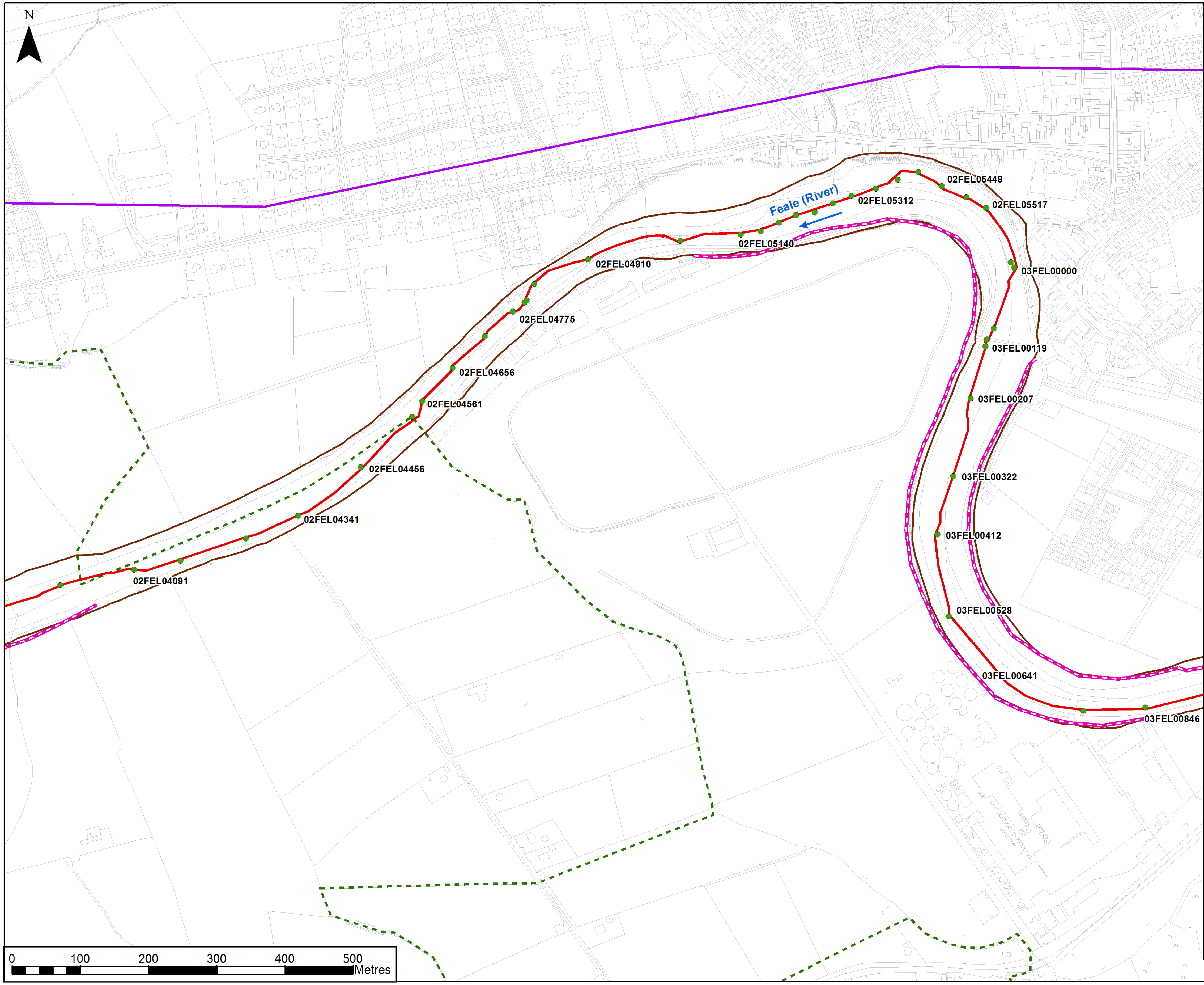

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14a

Figure ref: Annex A2 (9)

Drawing Title: S14a Model Schematisation

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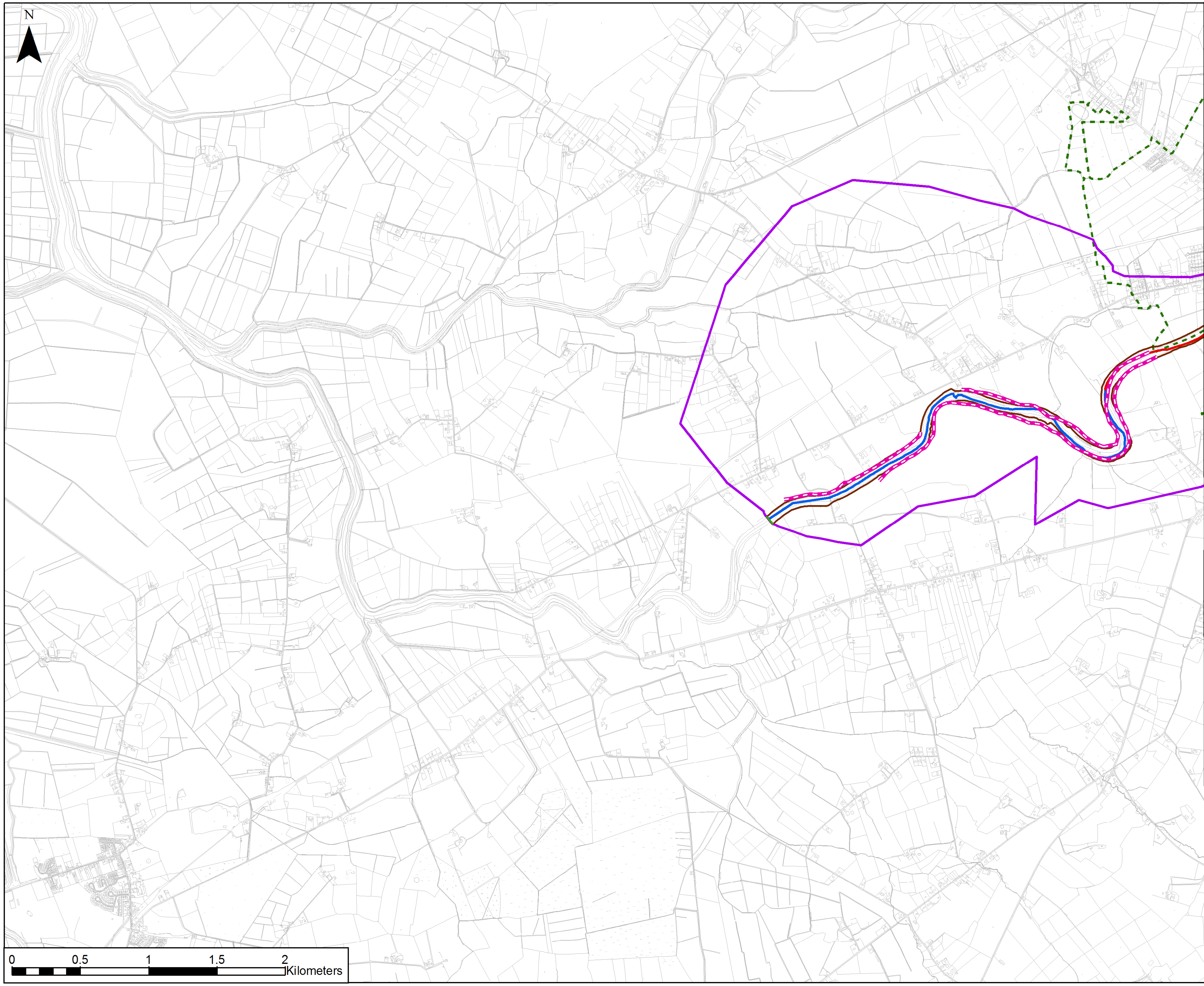

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14a

Figure ref: Annex A2 (10)

Drawing Title: S14a
Model Schematisation

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Annex B – Structure and Hydraulic Roughness Schedules

Schedule A.1 - Structure Schedule for the River Feale

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23FEAL03617D	05FEL00339	R555 Bridge of 9.5 m length	USBPR Bridge + Spill	Y
23FEAL02933D	03FEL12710	Bridge of 6.30 m length	USBPR Bridge + Spill	Y
23FEAL01795D	03FEL01331	N69 Bridge of 8.56 m length	USBPR Bridge + Spill	Y
23FEAL01673D	03FEL00108	Bridge of 3.62 m length	USBPR Bridge + Spill	Y
23FEAL01581D	02FEL04801	Bridge of 3.98 m length	USBPR Bridge + Spill	Y
23FEAL01276W, 23FEAL01275W 23FEAL01275X	02FEL01750	Weir	Broad Crested Weir	Y
23FEAL01151D	02FEL00496	Bridge of 3.98 m length	Arch Bridge + Spill	Y

Schedule A.2 - Structure Schedule for the Oolagh River

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23OOLA00195D	01OLG01925	L1327 Road Bridge of 6.96 m length	Arch bridge + Spill	Y
23OOLA00110D	01OLG01079	Footbridge of 1.99 m length	Arch Bridge + Spill	Y

Schedule A.3 - Structure Schedule for the Allaghaun River

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23ALLB00052I and 23ALLB00052J	01EST00521	N21 Culvert of 26.12 m length	Circular Culverts + Spill	Y
23ALLAB00026D	01EST00255	Bridge of 9.80 m length.	Sprung Arch Culvert + Spill	Y
23ALLA00009D	01ALL00103	Allaghaun(R524 Road) bridge of 7.29 m wide	Sprung Arch Culvert with 3 openings + Spill	Y

Schedule B.1 – Manning's 'n' for HPW Network

River Name	ISIS Node Reference	Estimated In-bank Roughness	Estimated Floodplain Roughness
River Feale	06FEL02265 to 03FEL18023	0.050	2D domain : based on OSi NTF land use polygons 1D domain: Land use EPA data has been used for assigning the floodplain roughness.
	03FEL18023 to 03FEL18120	0.060	
	03FEL04301 to 03FEL03046	0.050	
	03FEL02975 to 03FEL03567	0.040	
Oolagh River	01OLG02290 to 01OLG00000	0.050	
Allaghaun River	02ALL00384 to 01ALL00000	0.050	

Schedule B.2 – Manning's 'n' for MPW Network

River Name	ISIS Node Reference	Estimated In-bank Roughness	Estimated Floodplain Roughness
River Feale	03FEL18120 to 03FEL04438	0.06	Land use EPA data has been used for assigning the floodplain roughness.
	02FEL03462 to 02FEL00000	0.05	

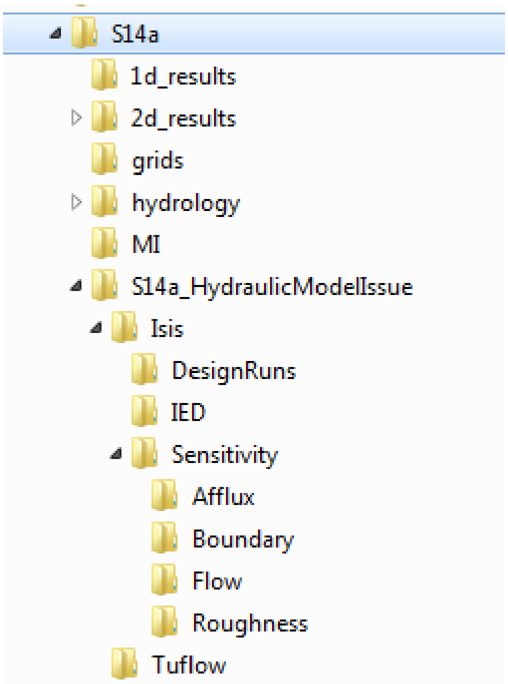
Annex C – Model Verification Summary Note

Unused as no calibration to historic events was possible.

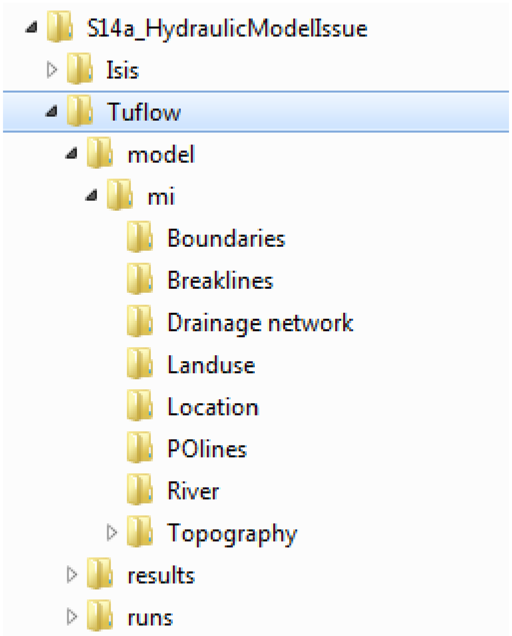
Annex D - Hydraulic Model Files

Model Files Folders Structure

ISIS



TUFLOW



ISIS Files

Model Geometry (.dat) and Associated Files (e.g.: .ief, .zzl, .zzd, .zzu,.zzx)	**Design Runs – Defended Current Scenario:** **Main Stream Model** S14a_Q2_Flu_C_Des_Main_IssV2.dat S14a_Q5_Flu_C_Des_Main_IssV2.dat S14a_Q10_Flu_C_Des_Main_IssV2.dat S14a_Q20_Flu_C_Des_Main_IssV2.dat S14a_Q50_Flu_C_Des_Main_IssV2.dat S14a_Q100_Flu_C_Des_Main_IssV2.dat

	S14a_Q200_Flu_C_Des_Main_IssV2.dat S14a_Q1000_Flu_C_Des_Main_IssV2.dat **Tributary Models** S14a_Q2_Flu_C_Des_Trib_IssV2.dat S14a_Q5_Flu_C_Des_Trib_IssV2.dat S14a_Q10_Flu_C_Des_Trib_IssV2.dat S14a_Q20_Flu_C_Des_Trib_IssV2.dat S14a_Q50_Flu_C_Des_Trib_IssV2.dat S14a_Q100_Flu_C_Des_Trib_IssV2.dat S14a_Q200_Flu_C_Des_Trib_IssV2.dat S14a_Q1000_Flu_C_Des_Trib_IssV2.dat **Sensitivity Runs – Defended Current Scenario:** **Main Stream Model** S14a_Q100_Flu_C_Sen_Main_AfDe.dat S14a_Q100_Flu_C_Sen_Main_AfIn.dat S14a_Q100_Flu_C_Sen_Main_BoDe.dat S14a_Q100_Flu_C_Sen_Main_BoIn.dat S14a_Q100_Flu_C_Sen_Main_FlDe.dat S14a_Q100_Flu_C_Sen_Main_FlIn.dat S14a_Q100_Flu_C_Sen_Main_RoDe.dat S14a_Q100_Flu_C_Sen_Main_RoIn.dat **Tributary Models** S14a_Q100_Flu_C_Sen_Trib_AfDe.dat S14a_Q100_Flu_C_Sen_Trib_AfIn.dat S14a_Q100_Flu_C_Sen_Trib_BoDe.dat S14a_Q100_Flu_C_Sen_Trib_BoIn.dat S14a_Q100_Flu_C_Sen_Trib_FlDe.dat S14a_Q100_Flu_C_Sen_Trib_FlIn.dat S14a_Q100_Flu_C_Sen_Trib_RoDe.dat S14a_Q100_Flu_C_Sen_Trib_RoIn.dat

Hydrological Inflow Files	**Design Runs – Current Scenario:** **Main Stream Model** S14a_Q2_Flu_C_Des_Main_IssV2.ied S14a_Q5_Flu_C_Des_Main_IssV2.ied S14a_Q10_Flu_C_Des_Main_IssV2.ied S14a_Q20_Flu_C_Des_Main_IssV2.ied S14a_Q50_Flu_C_Des_Main_IssV2.ied S14a_Q100_Flu_C_Des_Main_IssV2.ied S14a_Q200_Flu_C_Des_Main_IssV2.ied S14a_Q1000_Flu_C_Des_Main_IssV2.ied **Tributary Models** S14a_Q2_Flu_C_Des_Trib_IssV2.ied S14a_Q5_Flu_C_Des_Trib_IssV2.ied S14a_Q10_Flu_C_Des_Trib_IssV2.ied S14a_Q20_Flu_C_Des_Trib_IssV2.ied S14a_Q50_Flu_C_Des_Trib_IssV2.ied S14a_Q100_Flu_C_Des_Trib_IssV2.ied S14a_Q200_Flu_C_Des_Trib_IssV2.ied S14a_Q1000_Flu_C_Des_Trib_IssV2.ied **Sensitivity Runs – Current Scenario:** **Main Stream Model** S14a_Q100_Flu_C_Sen_Main_FlDe.ied S14a_Q100_Flu_C_Sen_Main_FlIn.ied **Tributary Models** S14a_Q100_Flu_C_Sen_Trib_FlDe.ied S14a_Q100_Flu_C_Sen_Trib_FlIn.ied
TUFLOW files	
TUFLOW Control Files (.tcf) and Associated Files (e.g.: ecf, tgc, tbc)	**Design Runs – Current Scenario:** **Main Stream Model** S14a_Q2_Flu_C_Des_Main_IssV2.tcf S14a_Q5_Flu_C_Des_Main_IssV2.tcf S14a_Q10_Flu_C_Des_Main_IssV2.tcf S14a_Q20_Flu_C_Des_Main_IssV2.tcf S14a_Q50_Flu_C_Des_Main_IssV2.tcf S14a_Q100_Flu_C_Des_Main_IssV2.tcf S14a_Q200_Flu_C_Des_Main_IssV2.tcf S14a_Q1000_Flu_C_Des_Main_IssV2.tcf } 2d_5m_S14a_Abbeyfeale.tbc 2d_5m_S14a_Abbeyfeale.tgc 2d_5m_S14a_Listowel.tbc 2d_5m_S14a_Listowel.tgc S14a_landuse.tmf

	Tributary Models S14a_Q2_Flu_C_Des_Trib_IssV2.tcf S14a_Q5_Flu_C_Des_Trib_IssV2.tcf S14a_Q10_Flu_C_Des_Trib_IssV2.tcf S14a_Q20_Flu_C_Des_Trib_IssV2.tcf S14a_Q50_Flu_C_Des_Trib_IssV2.tcf S14a_Q100_Flu_C_Des_Trib_IssV2.tcf S14a_Q200_Flu_C_Des_Trib_IssV2.tcf S14a_Q1000_Flu_C_Des_Trib_IssV2.tcf 2d_5m_S14a_Abbeyfeale.tbc 2d_5m_S14a_Abbeyfeale.tgc S14a_landuse.tmf **Sensitivity Runs – Current Scenario:** **Main Stream Model** S14a_Q100_Flu_C_Sen_Main_AfDe.tcf S14a_Q100_Flu_C_Sen_Main_AfIn.tcf S14a_Q100_Flu_C_Sen_Main_BoDe.tcf S14a_Q100_Flu_C_Sen_Main_BoIn.tcf S14a_Q100_Flu_C_Sen_Main_FlDe.tcf S14a_Q100_Flu_C_Sen_Main_FlIn.tcf S14a_Q100_Flu_C_Sen_Main_RoDe.tcf S14a_Q100_Flu_C_Sen_Main_RoIn.tcf 2d_5m_S14a_Abbeyfeale.tbc 2d_5m_S14a_Abbeyfeale.tgc 2d_5m_S14a_Listowel.tbc 2d_5m_S14a_Listowel.tgc S14a_landuse.tmf S14a_landuse_RoDe.tmf S14a_landuse_RoIn.tmf **Tributary Models** S14a_Q100_Flu_C_Sen_Trib_AfDe.tcf S14a_Q100_Flu_C_Sen_Trib_AfIn.tcf S14a_Q100_Flu_C_Sen_Trib_BoDe.tcf S14a_Q100_Flu_C_Sen_Trib_BoIn.tcf S14a_Q100_Flu_C_Sen_Trib_FlDe.tcf S14a_Q100_Flu_C_Sen_Trib_FlIn.tcf S14a_Q100_Flu_C_Sen_Trib_RoDe.tcf S14a_Q100_Flu_C_Sen_Trib_RoIn.tcf 2d_5m_S14a_Abbeyfeale.tbc 2d_5m_S14a_Abbeyfeale.tgc S14a_landuse.tmf S14a_landuse_RoDe.tmf S14a_landuse_RoIn.tmf
Grid Orientation File	2d_loc_S14a_abbe.MIF 2d_loc_S14a_list.MIF
Material Files	2d_mat_others_S14a.MIF 2d_mat_urban_S14a.MIF
Zpt Files, Model DTM (.asc)	abbeyfe2m_dtm.asc ListoLidar_sar.asc 2d_zshp_LidarSmooth.MIF
Breaklines Files	2d_zln_Banktops_S14a_abbe_v2.MIF 2d_zln_Banktops_S14a_list_v2.MIF 2d_zln_Deck_S14a_abbe.MIF 2d_zln_Drain_S14a_list.MIF 2d_zln_gully_S14a_abbe.MIF

	2d_zln_Parapet_S14a_abbe.MIF 2d_zln_wall_list.MIF
Boundary Files	2d_bc_hxe_S14a_abbe.MIF 2d_bc_hxe_S14a_list.MIF 2d_bc_hxi_S14a_abbe_v2.MIF 2d_bc_hxi_S14a_list_v2.MIF 2d_bc_hq_S14a_list.MIF 2d_bc_sx_S14a_list.MIF
Flow/Head Files in bc_dbase	NA
Initial Water Level Files	NA
Time Series Files	2d_po_List_AtoB.MIF 2d_po_S14a.MIF 2d_po_S14a_Abbe.MIF
One Dimensional Network Files	1d_ISIS_nodes_5m_S14a_Abbe_v2.MIF 1d_ISIS_nodes_5m_S14a_List_v2.MIF 2d_nwk_Culvert_S14a_list.MIF

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
Design Runs						
1	S14a_Q2_Flu_C_Des_Main_IssV22.DAT S14a_Q2_Flu_C_Des_Main_IssV22.tcf	0	26	1 sec 1D 1 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
2	S14a_Q5_Flu_C_Des_Main_IssV2.DAT S14a_Q5_Flu_C_Des_Main_IssV2.tcf	0	26	1 sec 1D 1 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
3	S14a_Q10_Flu_C_Des_Main_IssV2.DAT S14a_Q10_Flu_C_Des_Main_IssV2.tcf	0	26	1 sec 1D 1 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
4	S14a_Q20_Flu_C_Des_Main_IssV2.DAT S14a_Q20_Flu_C_Des_Main_IssV2.tcf	0	26	1 sec 1D 1 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
5	S14a_Q50_Flu_C_Des_Main_IssV2.DAT S14a_Q50_Flu_C_Des_Main_IssV2.tcf	0	26	1 sec 1D 1 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
6	S14a_Q100_Flu_C_Des_Main_IssV2.DAT S14a_Q100_Flu_C_Des_Main_IssV2.tcf	0	26	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
7	S14a_Q200_Flu_C_Des_Main_IssV2.DAT S14a_Q200_Flu_C_Des_Main_IssV2.tcf	0	26	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
8	S14a_Q1000_Flu_C_Des_Main_IssV2.DAT S14a_Q1000_Flu_C_Des_Main_IssV2.tcf	0	21	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
9	S14a_Q2_Flu_C_Des_Trib_IssV2.DAT S14a_Q2_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
10	S14a_Q5_Flu_C_Des_Trib_IssV2.DAT S14a_Q5_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
11	S14a_Q10_Flu_C_Des_Trib_IssV2.DAT S14a_Q10_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
12	S14a_Q20_Flu_C_Des_Trib_IssV2.DAT S14a_Q20_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
13	S14a_Q50_Flu_C_Des_Trib_IssV2.DAT S14a_Q50_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
14	S14a_Q100_Flu_C_Des_Trib_IssV2.DAT S14a_Q100_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
15	S14a_Q200_Flu_C_Des_Trib_IssV2.DAT S14a_Q200_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6
16	S14a_Q1000_Flu_C_Des_Trib_IssV2.DAT S14a_Q1000_Flu_C_Des_Trib_IssV2.tcf	0	18	2 sec 1D 4 sec 2D	"Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 6 and "maxitr" value is set to 29, ISIS Matrix Dummy Coefficient set to 0.0001	Convergence within acceptable tolerance, see Section 6

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
Sensitivity Analysis						
17	S14A_Q100_FLU_C_SEN_MAIN_FLDE.DAT S14A_Q100_FLU_C_SEN_MAIN_FLDE.tcf	0	20	1 sec 1D 1 sec 2D	The flow in Main stream has been decreased by 20%	Convergence within acceptable tolerance, see Section 6
18	S14A_Q100_FLU_C_SEN_MAIN_FLIN.DAT S14A_Q100_FLU_C_SEN_MAIN_FLIN.tcf	0	20	1 sec 1D 1 sec 2D	The flow in Main stream has been increased by 20%	Convergence within acceptable tolerance, see Section 6
19	S14A_Q100_FLU_C_SEN_MAIN_RODE.DAT S14A_Q100_FLU_C_SEN_MAIN_RODE.tcf	0	20	1 sec 1D 1 sec 2D	The roughness has been decreased by 20% in 1D and 2D model	Convergence within acceptable tolerance, see Section 6
20	S14A_Q100_FLU_C_SEN_MAIN_ROIN.DAT S14A_Q100_FLU_C_SEN_MAIN_ROIN.tcf	0	20	1 sec 1D 1 sec 2D	The roughness has been increased by 20% in 1D and 2D model	Convergence within acceptable tolerance, see Section 6
21	S14A_Q100_FLU_C_SEN_TRIB_FLDE.DAT S14A_Q100_FLU_C_SEN_TRIB_FLDE.tcf	0	16	1 sec 1D 1 sec 2D	The flow in the Allaghaun River and Allaghaun Tributary has been decreased by 20%	Convergence within acceptable tolerance, see Section 6
22	S14A_Q100_FLU_C_SEN_TRIB_FLIN.DAT S14A_Q100_FLU_C_SEN_TRIB_FLIN.tcf	0	16	1 sec 1D 1 sec 2D	The flow in the Allaghaun River and Allaghaun Tributary has been increased by 20%	Convergence within acceptable tolerance, see Section 6
23	S14A_Q100_FLU_C_SEN_TRIB_RODE.DAT S14A_Q100_FLU_C_SEN_TRIB_RODE.tcf	0	16	1 sec 1D 1 sec 2D	The roughness has been decreased by 20% in 1D and 2D model	Poor convergence noted in 1d domain. To be addressed at later stage if required.
24	S14A_Q100_FLU_C_SEN_TRIB_ROIN.DAT S14A_Q100_FLU_C_SEN_TRIB_ROIN.tcf	0	16	1 sec 1D 1 sec 2D	The roughness has been increased by 20% in 1D and 2D model	Convergence within acceptable tolerance, see Section 6
25	S14A_Q100_FLU_C_SEN_MAIN_BODE.DAT S14A_Q100_FLU_C_SEN_MAIN_BODE.tcf	0	20	2 sec 1D 4 sec 2D	The slope in the downstream boundary is doubled	Convergence within acceptable tolerance, see Section 6

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
26	S14A_Q100_FLU_C_SEN_MAIN_BOIN.DAT S14A_Q100_FLU_C_SEN_MAIN_BOIN.tcf	0	20	2 sec 1D 4 sec 2D	The slope in the downstream boundary is halved	Convergence within acceptable tolerance, see Section 6
27	S14A_Q100_FLU_C_SEN_MAIN_AFIN.DAT S14A_Q100_FLU_C_SEN_MAIN_AFIN.tcf	0	20	1 sec 1D 1 sec 2D	Calibration Coefficient increased by 20% for key structures	Convergence within acceptable tolerance, see Section 6
28	S14A_Q100_FLU_C_SEN_TRIB_AFIN.DAT S14A_Q100_FLU_C_SEN_TRIB_AFIN.tcf	0	16	1 sec 1D 1 sec 2D	Calibration Coefficient increased by 20% for key structures	Convergence within acceptable tolerance, see Section 6
29	S14A_Q100_FLU_C_SEN_MAIN_AFDE.DAT S14A_Q100_FLU_C_SEN_MAIN_AFDE.tcf	0	20	1 sec 1D 1 sec 2D	Calibration Coefficient decreased by 20% for key structures	Convergence within acceptable tolerance, see Section 6
30	S14A_Q100_FLU_C_SEN_TRIB_AFDE.DAT S14A_Q100_FLU_C_SEN_TRIB_AFDE.tcf	0	16	1 sec 1D 1 sec 2D	Calibration Coefficient decreased by 20% for key structures	Convergence within acceptable tolerance, see Section 6

Parameters changed from Default	Justification
Automated Preismann slot for River Sections turned on.	Automated Preismann slot are a standard parameter used to aid model stability particularly in low flows. These Preismann slots have negligible to no impact on the water levels during flood events.
Minitr	Increased to 6 to improve model stability.*
Maxitr	Increased to 29 to improve model stability.*
Matrix Dummy Coefficient set to 0.0001	Set to 0.0001 to solve IFAG error. *

*Stage and Flow profiles at all cross sections have been checked to ensure results are sensible and to ensure any changes to the default model run parameters has not impacted on the model results.

Annex E - Flood Mapping

Flood Maps are available through the OPW flood mapping website; http://maps.opw.ie/fhrm/

Fluvial Hydraulic Modelling Report

1. Basic Model Information

1.1 General Information	
Model ID:	S14-c
Unit of Management	23
AFA included in the Model	Athea
Primary Watercourses / Water Bodies	River Galey Two unnamed tributaries
1.2 Reference to other Relevant Reports	
Catchment Description	Hydrology Report Unit of Management 23 – Appendix A1.1
Model Location	Hydraulics Report Unit of Management 23 – Section 3.4.2
HEP Schematisation	Hydrology Report Unit of Management 23 – Appendix B3 – Figure B3.1

2. Survey Data and Base Mapping

2.1 Base Mapping:	OSi data base mapping at scale 1:50k Reference: OS0812_D, OS1012_D
2.2 DTM for 2D Model Domains:	**Within AFA:** LiDAR data with 2m horizontal resolution and approximately 200mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain areas included in the AFA boundary.
	Outside AFA: IFSAR data with 5m horizontal resolution and approximately 500mm-1000mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain areas outside the AFA boundary. **Note:** In general, there is overlap between the AFA area and area outside the AFA with regard to the availability of LIDAR data. Therefore, some areas outside the AFA are covered by LIDAR to the same resolution as that for the AFA.
2.3 River Channel/Structures Survey	General information on the topographic survey of the river channel and structures are included in the main Hydraulics Report. Full details of the survey outputs are provided in the topographic survey deliverables, as required under Section 5.2 of the Stage I Project Brief. Number of cross-sections included in this model: 299.
2.4 Defence Asset Survey Data	The defence asset database has been completed for this model area and is provided as a separate deliverable to this report. The defence asset database indicates that there are approximately 6 km of formal defences in the model area, and provides further details on these defences. All defences have been included in the model schematisation as shown on the maps presented in Annex A.
2.5 Survey interaction	The Lidar, and topographic survey were checked for anomalies, and to ensure that interactions between were within expected tolerances. No issues were identified in this model.

	The Lidar and IFSAR were also checked for anomalies in elevation. Although no issues were found, the LiDAR data has a 2m horizontal resolution and a 200mm vertical accuracy, while the IFSAR data has a 5m horizontal resolution and an approximate 500mm-1000mm vertical accuracy which result in anomalies in the mapping outputs at the LiDAR IFSAR interface.

3. Hydraulic Model Construction and Schematisation

3.1 Software:	**1D Domain:**	ISIS Version 3.6.0.156 (32 bit - Double Precision)
	2D Domain(s):	TUFLOW Version: 2012-05-AE-iDP-w32
3.2 Model Area / Extent:	The extent of the model and its schematisation are shown in Annex A.	

The mapping details for the model extent included in Annex A are as follows:

1. **Full modelled area showing**:
   - River centre lines, HPW/MPW extents, names of watercourses
   - 2D domain area
   - AFA boundary

2. **Maps showing a detailed model schematic of the HPW/MPW reaches are also included**

3.3 Model Reaches: The following model reaches as shown on the maps referred above have been defined in the model:

WatercourseName	Reach	Upstream Model Node	Downstream Model Node
River Galey	04GAL	04GAL02614	04GAL00000
	03GAL	03GAL13209	03GAL00000
	02GAL	02GAL09447	02GAL00000
	01GAL	01GAL11379	01GAL05410
Unnamed tributary (east branch)	01GGR	01GGR00593	01GGR00000u
Unnamed tributary (west branch)	01GGR	01GGR00321	01GGR00000cd

Total model HPW length (km):	4.5	**Total model MPW length (km):**	27.8

3.4 Model Structures: A full schedule of structures included in the model is provided in Schedule A in Annex B. A summary of the structures included is given below

Culverts:	☒	How many?	02
Bridges:	☒	How many?	07
Fixed crest weirs:	☐	How many?	0
Adjustable crest weirs:	☐	How many?	0
Sluice / Gate structures:	☐	How many?	0
Locks:	☐	How many?	0
Dams:	☐	How many?	0
Other (describe):			

3.5 Floodplain Schematisation

Out-of-bank areas for MPW reaches have been modelled adopting a 1D approach using the ISIS software by either: extending the river channel cross-sections or using lateral spills and reservoir units.

In Athea, out-of-bank areas for HPW reaches have been modelled adopting a 2D approach using the TUFLOW software.

Extended 1D sections are considered appropriate for HPW extents where floodplain flow paths are simple (e.g., parallel to river flow). 1D-2D

<table>
<tr><td rowspan="1"></td><td colspan="3">modelling is required where HPWs flow through urban areas and out-of-bank flows will form complex flow paths.
An overview of the floodplain schematisation is available in the maps shown in Annex A.</td></tr>
<tr><td rowspan="4">3.6 2D domain Grid Size:</td><td colspan="3">The number of 2D domains defined and the grid sizes of each 2D model domain are as follows:</td></tr>
<tr><td colspan="3">Number of 2D domains: 1</td></tr>
<tr><td>Domain 1: Athea</td><td>Grid cell size: 6 m</td><td>Area: 0.61 km^2</td></tr>
<tr><td colspan="3">2D domains are defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. The domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the floodplain flow.</td></tr>
<tr><td>3.7 Model Breaklines in the 2D Domain:</td><td colspan="3">Bank tops and boundary walls along R523 road in the vicinity of Athea Bridge have been represented as breaklines in the 2D domain.</td></tr>
<tr><td>3.8 Floodplain Structures in the 2D Domain</td><td colspan="3">No floodplain structure was included in the 2D domain.</td></tr>
<tr><td>3.9 Hydraulic Roughness</td><td colspan="3">Hydraulic roughness (Manning's 'n') has been defined in accordance with the approaches described in the main report. Details of the values adopted for this model are included in Schedule B in Annex B. A summary of Manning's 'n' for the model as a whole is as follows:</td></tr>
<tr><td rowspan="2">MPW In-bank</td><td>Minimum 'n' value:</td><td colspan="2">0.047</td></tr>
<tr><td>Maximum 'n' value:</td><td colspan="2">0.053</td></tr>
<tr><td rowspan="2">HPW In-bank</td><td>Minimum 'n' value:</td><td colspan="2">0.040</td></tr>
<tr><td>Maximum 'n' value:</td><td colspan="2">0.055</td></tr>
<tr><td rowspan="6">Floodplain (ISIS Model)</td><td colspan="3">Manning's 'n' for out-of-bank areas represented in the ISIS model are as defined by EPA land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in ISIS are as follows:</td></tr>
<tr><td>Land use</td><td colspan="2">Manning's 'n' value</td></tr>
<tr><td>Pastures</td><td colspan="2">0.035</td></tr>
<tr><td>Dense Vegetation</td><td colspan="2">0.080</td></tr>
<tr><td>Road Network</td><td colspan="2">0.025</td></tr>
<tr><td>Buildings</td><td colspan="2">0.100</td></tr>
<tr><td rowspan="7">Floodplain (TUFLOW Model)</td><td colspan="3">Manning's 'n' for out-of-bank areas represented in the TUFLOW model are as defined by OSi NTF land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in TUFLOW are as follows:</td></tr>
<tr><td>Land use</td><td colspan="2">Manning's 'n' value</td></tr>
<tr><td>Buildings</td><td colspan="2">0.100</td></tr>
<tr><td>Short grass, parks</td><td colspan="2">0.035</td></tr>
<tr><td>General Urban</td><td colspan="2">0.060</td></tr>
<tr><td>General Rural</td><td colspan="2">0.045</td></tr>
<tr><td>Dense Vegetation</td><td colspan="2">0.080</td></tr>
</table>

	Roads	0.025
	Railways	0.050
	Water bodies	0.020

3.10 Spill Units	• Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain, flows spilling over structures). • Spill profile geometry is defined using topographic survey data and LiDAR/IfSAR. • Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can be also found to account for lateral spilling perpendicular to the main direction of flow.
3.11 Model Boundaries - Inflows	Hydrological flow hydrographs were input to the model at key model locations as indicated in the tables below. The production of peak flow estimates and flow hydrograph shapes is fully explained in the Hydrology Report relevant to Unit of Management 23. Peak inflows (m3/s) are summarised in the tables below for the current situation and the design event simulated. These are the final inflows as obtained following calibration to HEPs (see Section 4.2)
(a) Current Situation	

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		50%	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1%**
(a) Main Model									
23_1853_1	04GAL02614	27.5	37.9	44.4	50.7	58.7	64.8	70.8	84.8
23_1920_2	04GAL00979	2.4	3.4	3.9	4.5	5.2	5.7	6.3	7.5
23_2579_3	03GAL12594	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.3
23_2580_2	03GAL12048	1.0	1.3	1.6	1.8	2.1	2.3	2.5	3.0
23_2514_2	03GAL11524	13.9	19.2	22.4	25.6	29.7	32.7	35.8	42.8
23_1756_1	03GAL07078	6.2	8.5	9.9	11.3	13.1	14.5	15.8	19
23_2517_2	03GAL06087	3.4	4.7	5.5	6.3	7.3	8.0	8.8	10.5
23_2954_2	03GAL02001	0.8	1.1	1.3	1.4	1.7	1.8	2.0	2.4
23_1755_3	03GAL00000	7.4	10.2	12.0	13.6	15.8	17.4	19.1	22.8
23_2650_2	02GAL08855	1.3	1.8	2.2	2.5	2.9	3.2	3.5	4.1
23_2650_5	02GAL07752	7.8	10.7	12.5	14.3	16.6	18.3	20.0	23.9
23_2696_1	02GAL07213	1.8	2.4	2.8	3.2	3.7	4.1	4.5	5.4
23_2567_2	02GAL05514	15.3	22.5	29.6	35.1	40.6	46.1	53.2	60.3
23_1852_3	02GAL04013	6.4	10.9	15.3	18.5	21.8	25.0	28.9	32.7
23_2558_2	02GAL03511	5.2	16.8	28.3	36.3	44.2	52.2	60.2	68.2
23_2371_2	01GAL10909	2.0	2.7	3.2	3.7	4.2	4.7	5.1	6.1
(a) Tributary									
23_2579_00a	01GGR00321	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6
23_2579_00b	01GGR00593	0.6	0.9	1.0	1.2	1.3	1.5	1.6	1.9

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for all return periods for the MRFS.

	These events are selected as these are the MRFS that are to be mapped.								
HEP Reference Name	**Input Node in the Hydraulic Model**	**MRFS Annual Exceedance Probability**							
		50%	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1%**
(b) Main Model									
23_1853_1	04GAL02614	33.0	45.5	53.3	60.8	70.4	77.8	85.0	101.8
23_1920_2	04GAL00979	2.9	4.1	4.7	5.4	6.2	6.8	7.6	9.0
23_2579_3	03GAL12594	0.5	0.7	0.8	1.0	1.1	1.2	1.3	1.6
23_2580_2	03GAL12048	1.2	1.6	1.9	2.2	2.5	2.8	3.0	3.6
23_2514_2	03GAL11524	16.7	23.0	26.9	30.7	35.6	39.2	43.0	51.4
23_1756_1	03GAL07078	7.4	10.2	11.9	13.6	15.7	17.4	19.0	22.8
23_2517_2	03GAL06087	4.1	5.6	6.6	7.6	8.8	9.6	10.6	12.6
23_2954_2	03GAL02001	1.0	1.3	1.6	1.7	2.0	2.2	2.4	2.9
23_1755_3	03GAL00000	8.9	12.2	14.4	16.3	19.0	20.9	22.9	27.4
23_2650_2	02GAL08855	1.6	2.2	2.6	3.0	3.5	3.8	4.2	4.9
23_2650_5	02GAL07752	9.4	12.8	15.0	17.2	19.9	22.0	24.0	28.7
23_2696_1	02GAL07213	2.2	2.9	3.4	3.8	4.4	4.9	5.4	6.5
23_2567_2	02GAL05514	18.4	27.0	35.5	42.1	48.7	55.3	63.8	72.4
23_1852_3	02GAL04013	7.7	13.1	18.4	22.2	26.2	30.0	34.7	39.2
23_2558_2	02GAL03511	6.2	20.2	34.0	43.6	53.0	62.6	72.2	81.8
23_2371_2	01GAL10909	2.4	3.2	3.8	4.4	5.0	5.6	6.1	7.3
(b) Tributary									
23_2579_00a	01GGR00321	0.2	0.4	0.4	0.4	0.5	0.5	0.6	0.7
23_2579_00b	01GGR00593	0.7	1.1	1.2	1.4	1.6	1.8	1.9	2.3

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for 10%, 1% and 0.1% events for the HEFS. These events are selected as these are the HEFS that are to be mapped.			
HEP Reference Name	**Input Node in the Hydraulic Model**	**HEFS Annual Exceedance Probability**		
		10%	1%	0.1%
(b) Main Model				
23_1853_1	04GAL02614	57.7	84.2	110.2
23_1920_2	04GAL00979	5.1	7.4	9.8
23_2579_3	03GAL12594	0.9	1.3	1.7
23_2580_2	03GAL12048	2.1	3.0	3.9
23_2514_2	03GAL11524	29.1	42.5	55.6
23_1756_1	03GAL07078	12.9	18.9	24.7
23_2517_2	03GAL06087	7.2	10.4	13.7
23_2954_2	03GAL02001	1.7	2.3	3.1
23_1755_3	03GAL00000	15.6	22.6	29.6
23_2650_2	02GAL08855	2.9	4.2	5.3

23_2650_5	02GAL07752	16.3	23.8	31.1
23_2696_1	02GAL07213	3.6	5.3	7.0
23_2567_2	02GAL05514	38.5	59.9	78.4
23_1852_3	02GAL04013	19.9	32.5	42.5
23_2558_2	02GAL03511	36.8	67.9	88.7
23_2371_2	01GAL10909	4.2	6.1	7.9
(b) Tributary				
23_2579_00a	01GGR00321	0.4	0.5	0.8
23_2579_00b	01GGR00593	1.3	2.0	2.5

3.12 Model Boundaries – Downstream Conditions	Downstream boundary conditions adopted in the model are as follows:
	A normal depth boundary was chosen to provide a free flow condition at the downstream end of the model. The slope parameter was taken from the local river bed slope. Sensitivity to this assumption is discussed in the relevant section below.

4. Hydraulic Model Calibration and Sensitivity	
4.1 Model Calibration and Verification to Historical Events	The approach to model calibration is documented in the Main Report. The analysis of available flood event data and high flow data for possible consideration as calibration and verification events is covered in detail in the Hydrology Report for UoM23 (Appendix F). The results of this analysis concluded that no calibration of S14c model could be performed along the entire modelled reaches due to insufficient hydrometric data. However, a very high level verification has been carried out in Athea AFA by comparing the predicted flood outlines of the model for a 0.1% AEP (1 in 1000 years) flood event against observed reported evidences of the 31st July and 6th August 2008 historical flood events, estimated as a 0.15% AEP (1 in 650 years) event. There are reports that prior to these event the channel was substantially blocked by overgrown vegetation, debris and the build-up of sediment at the bridge. Therefore to carry out a verification for this event a blockage assessment was carried out. A full account of the blockage assessment and model verification is provided in Annex C.
Catchment Gauging	Is modelled catchment: Gauged ☒ Ungauged ☐
Gauging Stations	If the modelled part of the catchment is gauged, list gauging stations:

Station Number	Watercourse	Location	ISIS Node Reference
23001	River Galey (MPW)	Inch Bridge	01GAL07238

Conclusion	The verification analysis is documented in Appendix C.
4.2 Calibration to HEP	Calibration of the hydraulic model to the HEP target flows has been carried out for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP design event. Section 2.7.2 of the hydrology report for UoM23 provides a summary of the calibration to HEP process. Preliminary inflow hydrographs derived from the hydrological analysis and input to the model were adjusted in time so that their respective peak flows coincide with the peak time of the propagating flood wave as it is routed down the model. Total peak flows predicted by the hydraulic model at HEP locations were then compared to the HEP target flows estimated during the hydrological analysis. Where required, inflows to the hydraulic model were scaled up/down to ensure that the modelled total peak flows remain within ±10% of the HEP target flows. The flows at the following HEP nodes were increased by varying amounts: 23_2567_2, 23_1852_3 and 23_2558_2. This ±10% target allows for good agreement between the hydrological estimates and the hydraulic results without the addition/removal of unrealistic volumes of flow from the model. The robustness of this has been verified by the agreement of the design flood maps. The table below shows the percentage difference between the modelled and target flows at each HEP location. The average percentage differences for all of the HEP nodes are as follows: 1.5%, 2.1%, and 0.9% for the 10%, 1% and 0.1% AEP events respectively. Notes:

	HEP points: 23_2650_5, 23_2696_1, 23_2567_2, 23_1852_2, 23_1852_3, 23_2558_2 are located along a reach of the River Galey for which out-of-bank flows have been modelled using reservoir units. Therefore at these HEP points it is not possible to quantify precisely the out-of-bank flows. Upstream of these reservoir units, agreement between the HEP target flows and the model flows is within the 10% criterion. Along and downstream of these reservoir units, flood attenuation provided by the storage of flood water overbank reduces peak discharge. Thus along and downstream of the reservoir units flows were increased to ensure that the modelled total peak flows remain within ±10% of the HEP target flows especially at HEP node corresponding to the gauging station no 23001, at Inch Bridge.

HEP Reference Name	Node in the Hydraulic Model	Annual Exceedance Probability							
		Percentage Difference (%)							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_1915_1	04GAL01718	4.5	4.5	0.0	4.5	4.5	0.0	4.5	0.0
23_1920_2	04GAL00979	0.1	0.1	0.4	0.0	0.1	1.0	0.1	1.1
23_1919_2	04GAL00333	0.0	0.3	0.9	1.0	1.2	0.5	1.2	0.6
23_2579_1	04GAL00323	0.5	0.8	0.9	0.9	0.8	0.5	0.5	0.6
23_2579_2	03GAL13097	0.5	0.8	3.5	0.9	0.8	3.1	0.5	3.5
23_2579_3	03GAL12594	2.9	3.2	4.0	3.1	3.2	3.1	3.1	3.5
23_2580_2	03GAL12048	3.2	3.6	2.3	3.3	3.4	1.0	3.2	0.2
23_2514_2	03GAL11524	0.5	2.2	2.1	1.6	1.5	0.9	5.5	0.2
23_1894_2	03GAL10586	0.4	2.2	1.7	1.6	1.4	0.8	1.7	0.3
23_1756_1	03GAL07078	0.7	1.8	1.0	1.5	1.2	0.4	0.9	-0.2
23_2517_2	03GAL06087	0.1	1.9	0.8	0.7	0.7	0.3	0.2	-0.2
23_2954_2	03GAL02001	-0.1	1.3	0.7	0.4	0.6	0.2	0.2	-0.3
23_1755_3	03GAL00000u	-0.3	1.0	0.6	0.3	0.4	0.1	0.1	-0.4
23_2650_2	02GAL08855u	-0.4	0.9	0.5	0.3	0.3	0.0	-0.1	-0.4
23_2650_5	02GAL07752u	-0.7	0.6	-0.3	0.0	0.1	-0.2	-0.1	-0.6
23_2696_1	02GAL07213u	-0.7	0.0	-0.9	0.3	0.0	-0.3	-0.1	-0.7
23_2567_2	02GAL05514u	-1.1	-0.6	-6.4	0.0	-0.1	-3.1	-0.2	-3.0
23_1852_2	02GAL04515	-3.3	-2.8	-2.0	-3.8	-2.4	-6.5	-2.0	-0.3
23_1852_3	02GAL04013u	-3.1	-1.4	-2.0	-5.0	-11.0	-6.5	-1.3	-0.3
23_2558_2	02GAL03511u	-3.2	-1.4	1.4	-4.9	-11.2	-9.6	-1.3	-2.4
23_2371_2	01GAL10909	-3.0	0.2	0.4	-0.5	-6.8	-4.5	-11.1	-0.7
23_2929_1	01GAL07361	-3.3	2.8	0.2	3.8	-0.5	-4.5	-3.6	-0.9

4.3 Model Sensitivity

Sensitivity tests have been carried out in order to assess the sensitivity of the predicted peak water levels to alterations in roughness (Manning's 'n'), fluvial flow, afflux at key structures and downstream conditions. In each case the sensitivity run was carried out for the 1% AEP fluvial event. Sensitivity test results are provided in the following tables:

+20% Manning's 'n'

Watercourse	Average Water Level Difference (m)	Maximum Water Level Difference (m)	Cross-section / Reach where the Maximum Difference occurs
River Galey at Athea AFA	0.12	0.32	03GAL12958
River Galey (downstream of Athea AFA)	0.15	0.26	01GAL06884u
Unnamed tributary (east branch)	0.05	0.10	01GGR00042

	Unnamed tributary (west branch)	0.03	0.05	01GGR00054
-20% Manning's 'n'	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section where the Maximum Difference occurs**
	River Galey at Athea AFA	-0.13	-0.24	03GAL12958
	River Galey (downstream of Athea AFA)	-0.1	-0.18	01GAL06884u
	Unnamed tributary (east branch)	-0.07	-0.17	01GGR00042
	Unnamed tributary (west branch)	-0.02	-0.04	01GGR00054
+20% inflows	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section where the Maximum Difference occurs**
	River Galey at Athea AFA	0.14	0.22	04GAL00180u
	River Galey (downstream of Athea AFA)	0.25	0.96	01GAL07238u
	Unnamed tributary (east branch)	0.05	0.31	01GGR00393u
	Unnamed tributary (west branch)	0.05	0.08	01GGR00044u
-20% inflows	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section where the Maximum Difference occurs**
	River Galey at Athea AFA	-0.16	-0.25	04GAL00180u
	River Galey (downstream of Athea AFA)	-0.13	-0.78	01GAL09717u
	Unnamed tributary (east branch)	-0.06	-0.25	01GGR00393u
	Unnamed tributary (west branch)	-0.05	-0.08	01GGR00044u
Afflux at Key Structure Calibration coefficient	There are two structures within the model which have a significant head loss during a 1% AEP flood event due to surcharging. These are the bridges located at 03GAL08514u and 03GAL01427u. For both structures the bridge			

increased by 20%	calibration coefficient was increased by 20% and resulted in a negligible increase of maximum water level immediately upstream of the bridge and no impact on the predicted flood risk in this area.
Afflux at Key Structure Calibration coefficient decreased by 20%	For both structures the calibration coefficient was decreased by 20% and resulted in a negligible decrease of maximum water level immediately upstream of the bridge and no impact on the predicted flood risk in this area.
Downstream Conditions Normal Depth downstream boundary slope doubled	The change to the downstream boundary condition has resulted in a decrease in maximum water level by 682 mm at the downstream limit of the model (ISIS node 01GAL05410). The diminishing effects can be seen up to 0.6 km upstream of the downstream extent. The change in the downstream boundary condition has no impact on the predicted flood levels within Athea AFA.
Downstream Conditions Normal Depth downstream boundary slope halved	The change to the downstream boundary condition has resulted in an increase in maximum water level by 588 mm at the downstream model limit (ISIS node 01GAL05410). The increasing effects can be seen up to 0.8 km upstream of the downstream extent. The change in the downstream boundary condition has no impact on the predicted flood levels within Athea AFA.
4.4 Model Files	The hydraulic model files associated with this model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. The model files included are detailed in Annex D.

5. Hydraulic Model Outputs

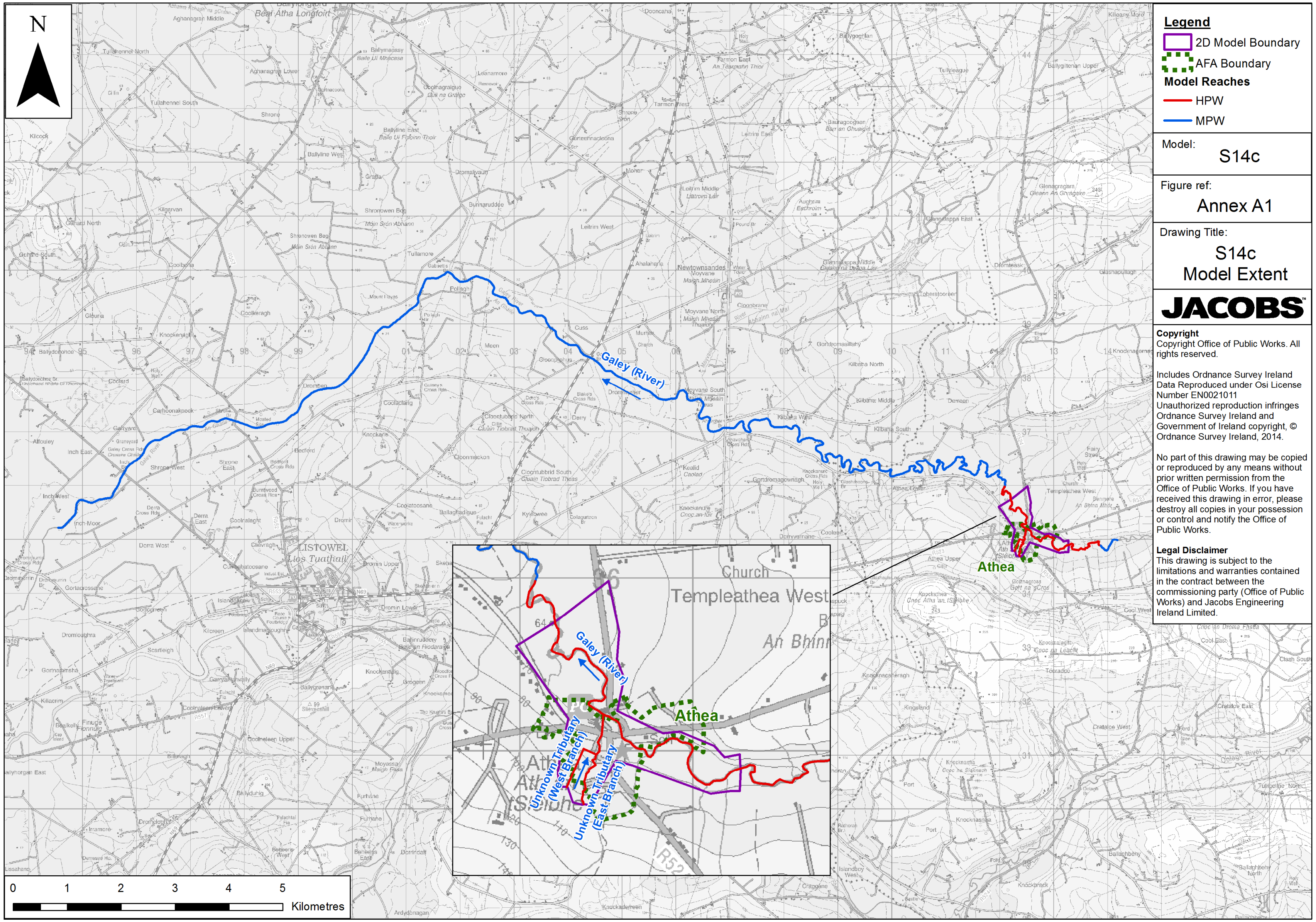
5.1 Mapping	Model outputs were processed to produce a series of flood maps according to the requirements stated in the Stage I Project Brief under Section 7.5.2. This includes mapping outputs covering: • Flood extents • Flood depth and velocity • Flood hazard All of the maps contain the maximum extent, depth, velocity and flood hazard for the combined main stream inflows and the tributaries inflows. An explanation for the main stream inflows and the tributaries inflows is provided in Section 6. Mapping outputs corresponding to the **defended**, **current** scenario for the 10%, 1% and 0.1% AEP flood events are shown in Annex E for flood extent and depth only.

6. Key Model Assumption and Limitations

- As detailed in the Hydrology Report, Model S14-c comprises the main branch of the River Galey and a tributary of two branches which flow through the settlement of Athea AFA. One model run is sufficient for modelling the critical events in both the main stream and tributary branches.
- There is approximately 6 km of formal flood defences within the model extent. These formal flood defences comprise earth embankments and are located on the left and right bank of the River Galey shown in Annex A. Further details on the standard of protection afforded by these defences is contained in the flood extent maps, with the defence asset register detailing the condition of the defences. The defences have been represented in the model therefore the model and outputs presented in this report represent a defended scenario.
- The model represents the study area in its current situation (at the time of the survey). From the provided photos and sections survey no blockage has been deemed necessary to be added to structures. For that reason, historical observed flood mechanisms due to structure failure or sediment built-up may not be predicted by the model. This is in particular the case at Athea Bridge where photographs of the bridge after the 2008 flood event show significant blockage of the bridge due to sediment build-up. Following this event, channel and bank clearance in the area of Athea have been carried out. As verification, a blockage sensitivity analysis due to sediment build-up at the Athea Bridge has been carried out (see Annex C).
- For the reaches where a 1D schematisation of the floodplain has been adopted, the flood depth maps were generated using modelled peak water levels and LiDAR (where available)/SAR data for ground level information. At the locations where the LiDAR and SAR datasets meet there are some unavoidable discrepancies in the ground levels which can result in anomalies in the mapping outputs presented in this report.

Annex A – Model Extent and Schematisation Maps

Annex A1 – Model Extent


N
Legend
2D Model Boundary
AFA Boundary
Model Reaches
HPW
MPW
Model:
S14c
Figure ref:
Annex A1
Drawing Title:
S14c
Model Extent
JACOBS
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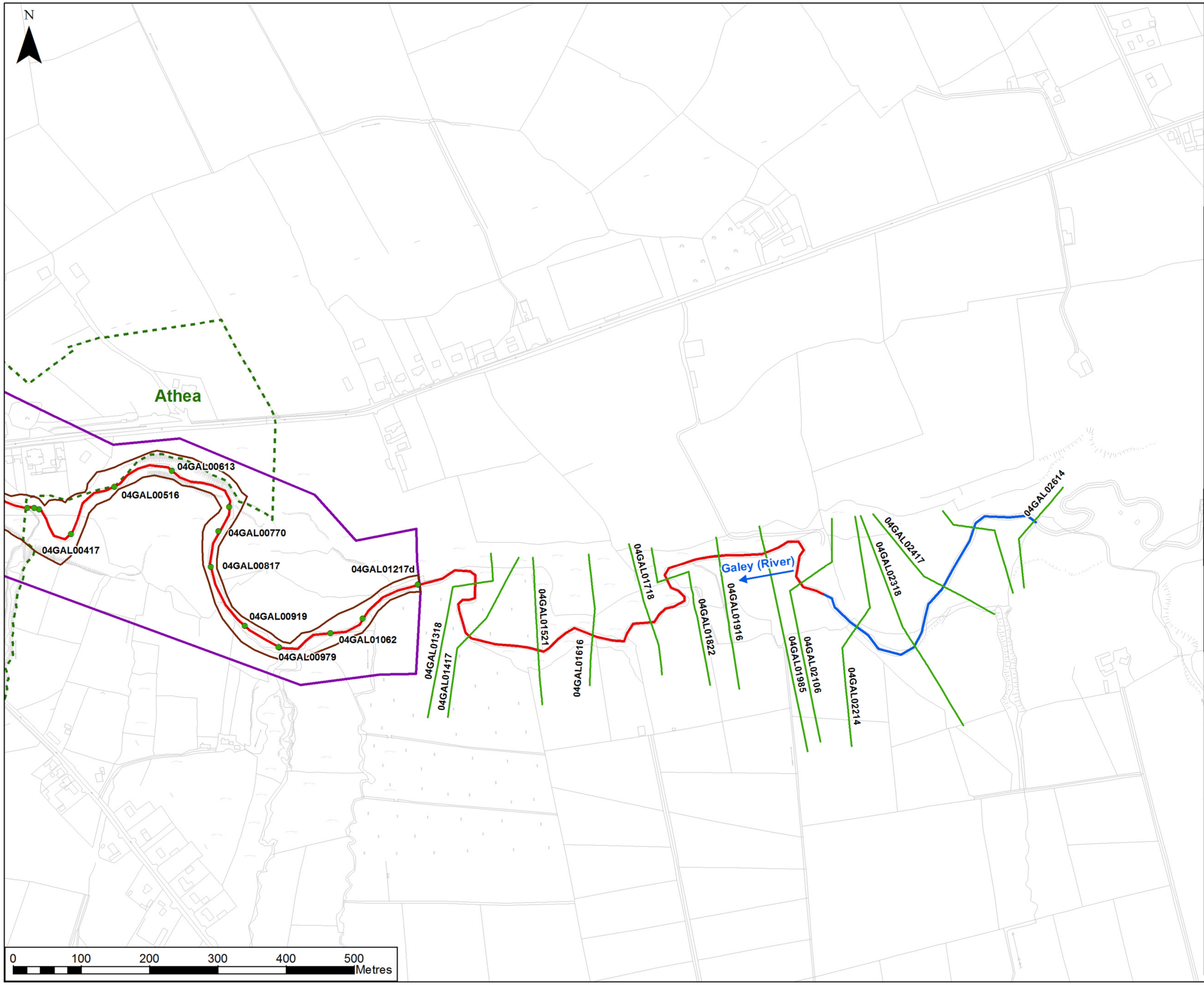
Galey (River)
Athea
LISTOWEL
Lios Tuathail
Templeathea West
An Bhinn
Church
Unknown Tributary (West Branch)
Unknown Tributary (East Branch)
0
1
2
3
4
5
Kilometres

Annex A2 – Schematisation Maps



Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14c

Figure ref: Annex A2 (1)

Drawing Title: S14c Model Schematisation

Client: The Office of Public Works, Head Office, Jonathan Swift Street, Trim, Co. Meath
Tel: 046 942 6000
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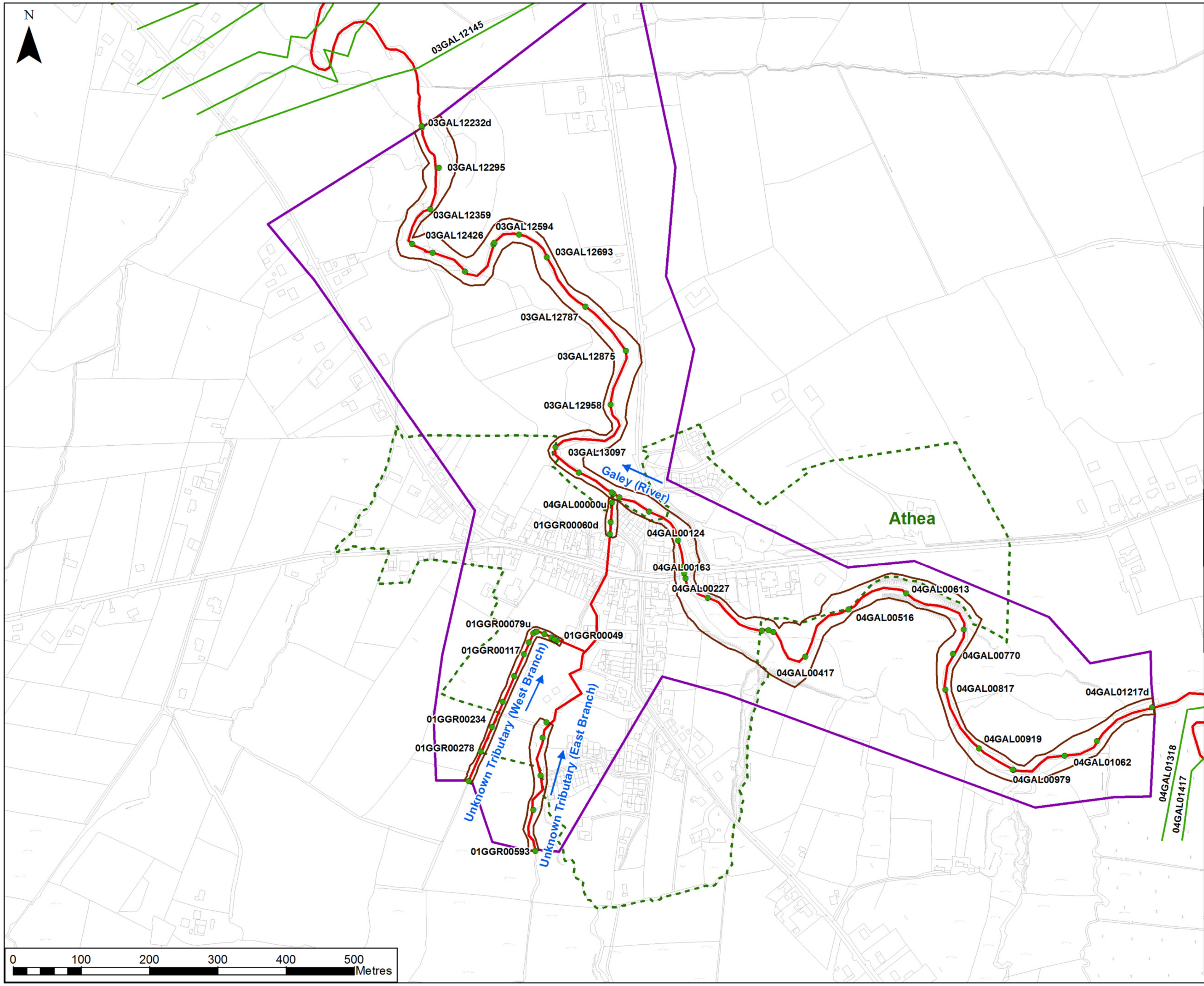

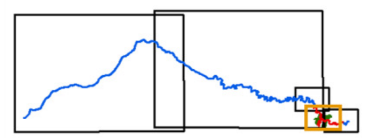

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14c

Figure ref: Annex A2 (2)

Drawing Title: S14c Model Schematisation

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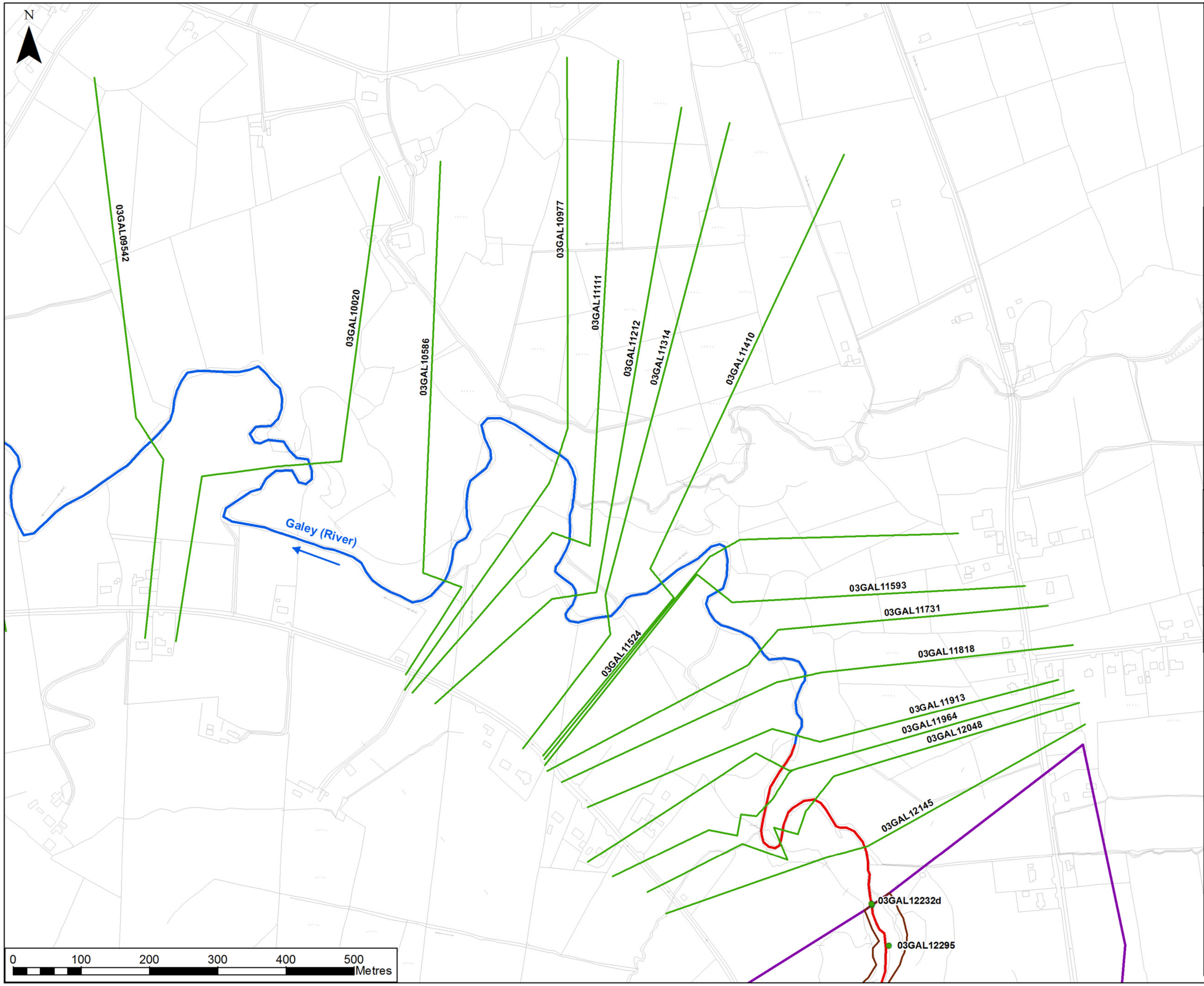

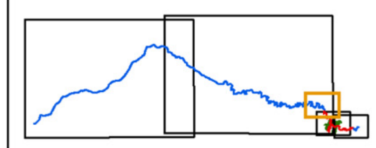

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14c

Figure ref: Annex A2 (3)

Drawing Title: S14c Model Schematisation

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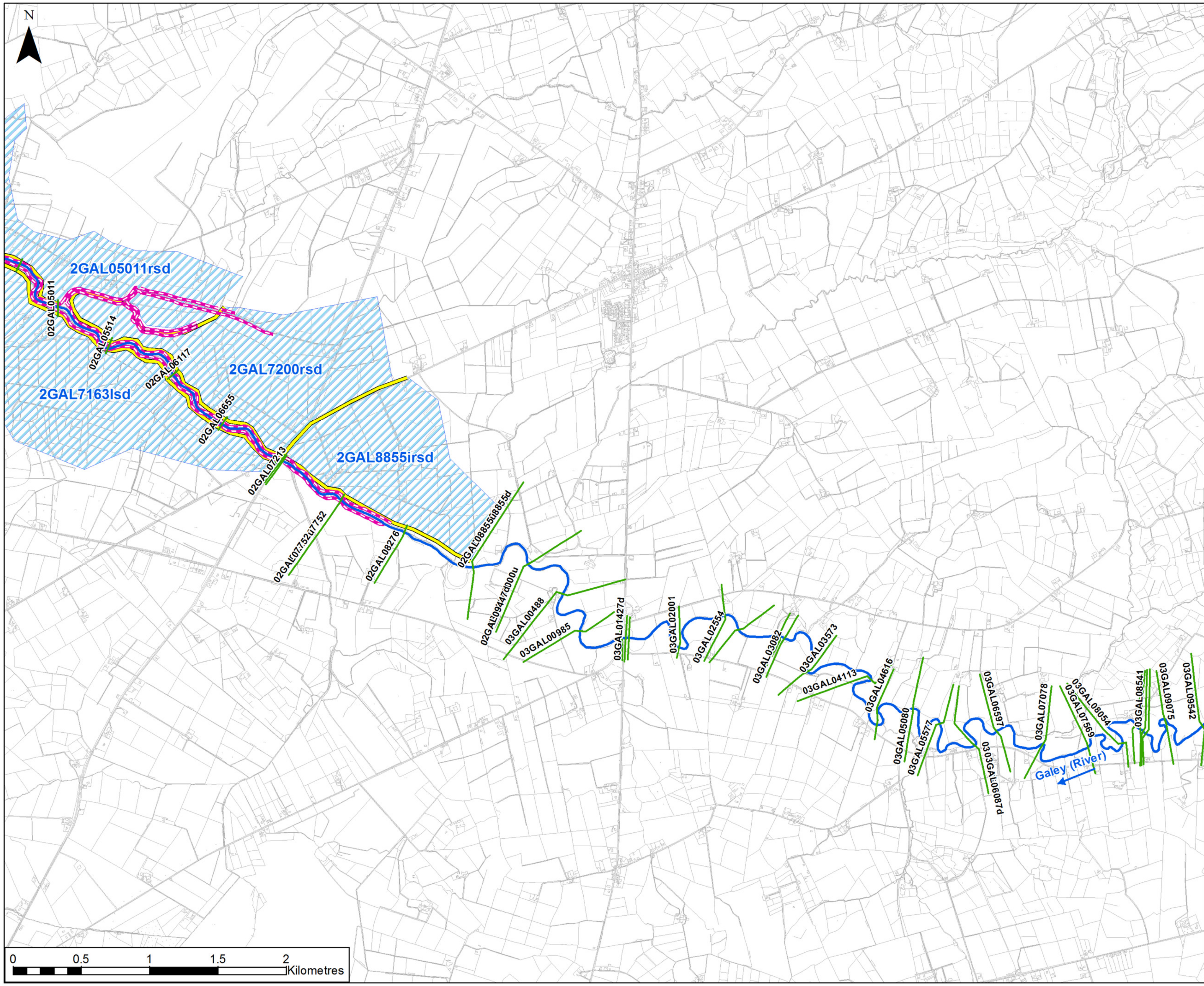

Legend

- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14c

Figure ref: Annex A2 (4)

Drawing Title: S14c Model Schematisation

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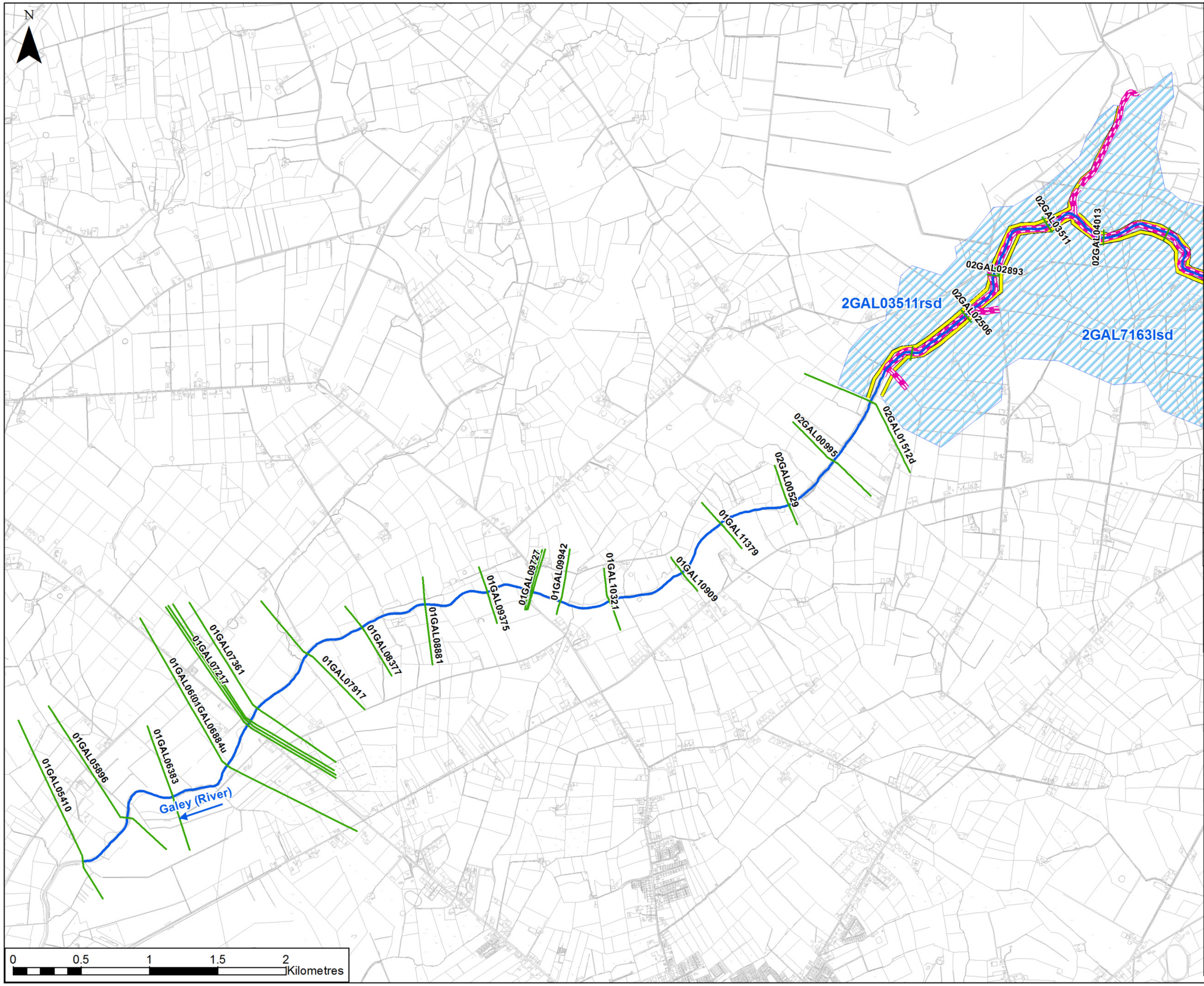

Legend
- 2D Model Boundary
- AFA Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches
- HPW
- MPW

1D Floodplain Schematisation
- ISIS Reservoir Unit
- Reservoir Spill
- Cross-section Extents

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14c

Figure ref: Annex A2 (5)

Drawing Title: S14c Model Schematisation

Client:
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Annex B – Structure and Hydraulic Roughness Schedules

Schedule A.1 - Structure Schedule for River Galey

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23GALE03449D	04GAL00180u	Bridge of 6.71 m wide	Arch bridge + Spill	Y
23GALE02944D	03GAL08514u	Bridge of 6.43 m wide	Arch bridge + Spill	Y
23GALE02236D	03GAL01427u	Bridge of 6.43 m wide	Arch bridge + Spill	Y
23GALE01868D	02GAL07200u	Bridge of 10.68 m wide	Arch bridge + Spill	Y
23GALE01441D	02GAL02927u	Bridge of 6.94 m wide	Arch bridge + Spill	Y
23GALE00982D	01GAL09717u	Bridge of 7.37m wide	Arch bridge + Spill	Y
23GALE00734D	01GAL07238u	Bridge of 10.82m wide	Arch bridge + Spill	Y

Schedule A.2 - Structure Schedule for Unnamed Tributary at Athea (East Branch)

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23GALF00042I	01GGR00393u	Culvert of 333m wide	Circular culvert then rectangular culvert after junction with other culverted west branch (Spill represented in 2D domain)	Y

Schedule A.3 - Structure Schedule for Unnamed Tributary at Athea (West Branch)

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23GALG00003I	01GGR00044u	Culvert of 44m wide	Circular culvert (Spill represented in 2D domain)	Y

Schedule B.1 – Manning's 'n' for HPW Network

River Name	ISIS Node Reference	In-bank Roughness*	Estimated Floodplain Roughness
River Galey	04GAL02106 to 04GAL00516	0.047	2D Domain : based on OSi NTF land use polygons 1D Domain: Land use EPA data has been used for assigning the floodplain roughness.
River Galey	04GAL00417 to 03GAL13097	0.050	
River Galey	03GAL12958 to 03GAL12594	0.040	
River Galey	03GAL12515 to 03GAL12145	0.050	
River Galey	03GAL12048 to 03GAL11964	0.045	
Unnamed tributary (east branch)	01GGR00593 to 01GGR00000u	0.040	
Unnamed tributary (west branch)	01GGR00321 to 01GGR00044u	0.055	

*In some cross-sections a different bed roughness coefficient may have been used to represent specific bed material (e.g. engineered concrete sections).

Schedule B.2 – Manning's 'n' for MPW Network

River Name	ISIS Node Reference	In-bank Roughness*	Estimated Floodplain Roughness
River Galey	04GAL02614 to 04GAL02214	0.048	Land use EPA data has been used for assigning the floodplain roughness.
River Galey	03GAL11913 to 02GAL04013	0.053	
River Galey	02GAL03511u to 01GAL05410	0.047	

Annex C - Model Verification and Blockage Summary Note

The aim of this note is to describe the verification methodology applied to the S14-c model and report on the results.

Verification and blockage assessment of the model using anecdotal evidence collected during the summer 2008 historical event in Athea:

A very high level verification of the model results was possible in Athea AFA by comparing the predicted flood outlines of the model for a 0.1% AEP (1 in 1000 years) flood event, against reported evidence of flooding during the 31st July and 6th August 2008 historical flood events, estimated as a 0.15% AEP (1 in 650 years) flood event. The 6th August flood event was less severe than the 31st July event, but due to channel restrictions caused by sediment and debris deposition flood extent and flood mechanism were similar.

A report[1] was commissioned by Limerick County Council in the wake of these two significant flood events in Athea. It is reported that during the 31st July event, flooding of the River Galey occurred at Athea, where the channel was substantially blocked by overgrown vegetation, debris and the build-up of sediment. The report identified roots causes of the flooding and flow routes.

The report includes photographs of Athea Bridge and river bed after the 2008 flood events. At the Athea Bridge, flow was reportedly impeded by a substantial build-up of sediment in the channel and beneath the bridge arches. Local residents observed that the central bridge arch was partially blocked by gravel about 1.5m deep, and that the right arch was substantially blocked by sediment. At the peak of the flood, the water level was reported to be about 300 mm below the soffit of the central arch of the bridge.

The model in its current scenario, run for a 0.1% AEP (Q1000) flood event, reproduces well the observed flood extent downstream of Athea Bridge. However, upstream of the bridge, the flood extent and all the flood mechanisms reported are not predicted by the model, neither the maximum observed water level at the Athea Bridge (300mm below soffit level). An explanation of this difference is that the model represents the state of the River Galey at the time of the survey and not the state of the channel at the peak of flooding during the 2008 summer event.

A blockage test has been carried out in order to assess the sensitivity of the predicted peak water levels to blockage by sediment build-up at Athea Bridge. The blockage run was carried out for the 0.5% AEP (Q200) and 0.1% AEP (Q1000) event as the estimated return period of the 2008 summer event is 650 years (0.15% EAP).

The river section at Athea Bridge has been modified to account for the important sediment deposit observed, in an attempt to reproduce flood mechanisms observed during the 2008 event and get model results more in line with the observed level at the bridge. Bed level under the central and right bridge arches has been raised by 1.5m while the left bank has been raised by 0.5m see figure 1.

[1] **Athea Flood Severity and Impact Report, 31st July and 6th August 2008, Limerick County Council, JBA Consulting.**

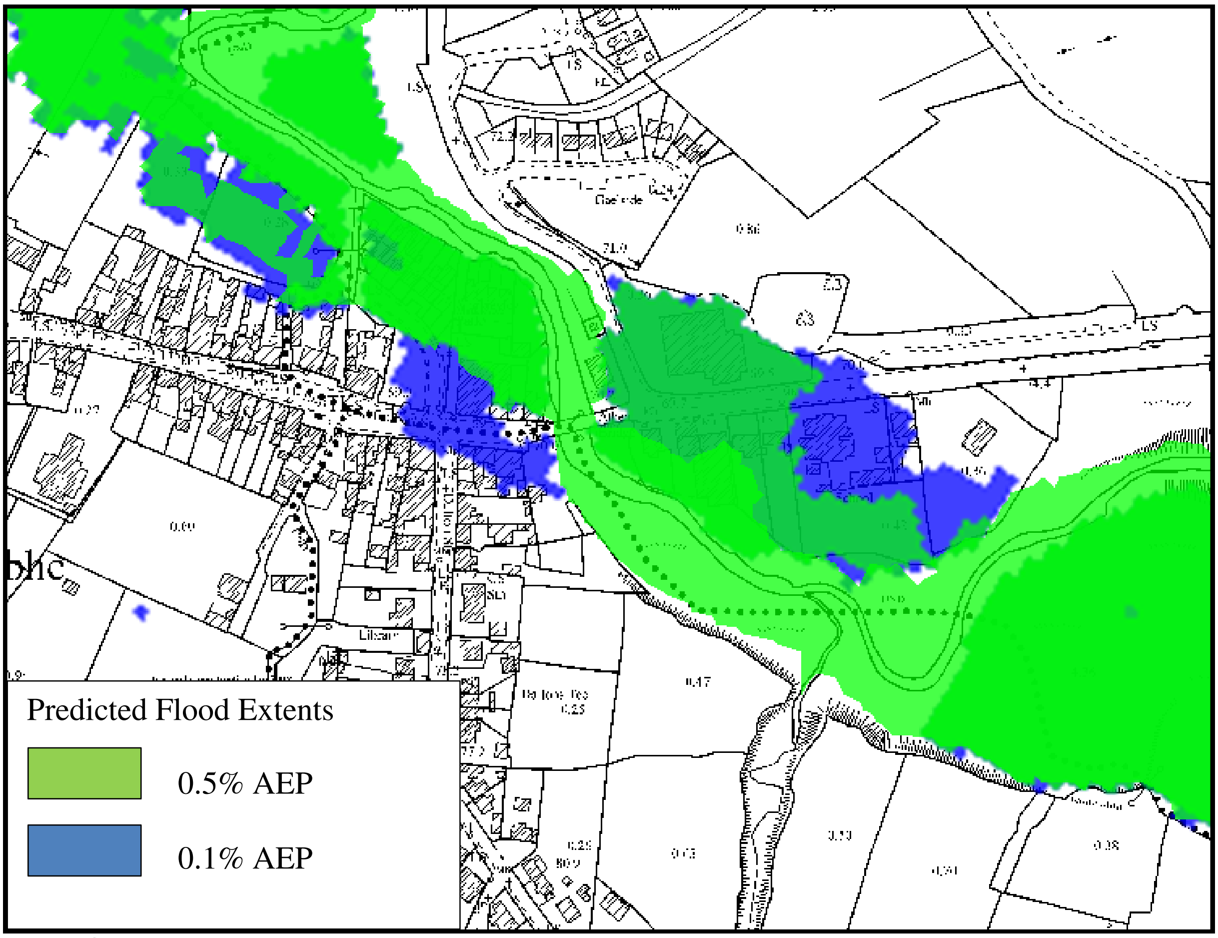
Figure C.1 – Sediment build up at Athea Bridge

The results of the blockage assessment are reported in Table 1 and indicate that the predicted maximum stage, at Athea Bridge for the 0.5% AEP event with blockage, are comparable to the observed stage from the 2008 event, with no difference in water level. The flood extent and flood mechanisms described in the report (see Figure 2) are comparable to the ones predicted by the model (see Figure 1): houses downstream of the school flooded, floodwater by-passed the bridge on both sides flowing northwards and crossed the R523 road.

Table C.1: Historical Flood Events at Athea Bridge

Historical Flood Event	Blockage Model maximum stage 0.5% AEP (m OD*)	Blockage Model maximum stage 0.1% AEP (m OD*)	Estimated observed maximum stage (m OD*)
Summer 2008	70.24	70.70	70.24

(* Datum is taken for Malin Head)



FigureC. 2 – Predicted Flood Extents Blockage Model

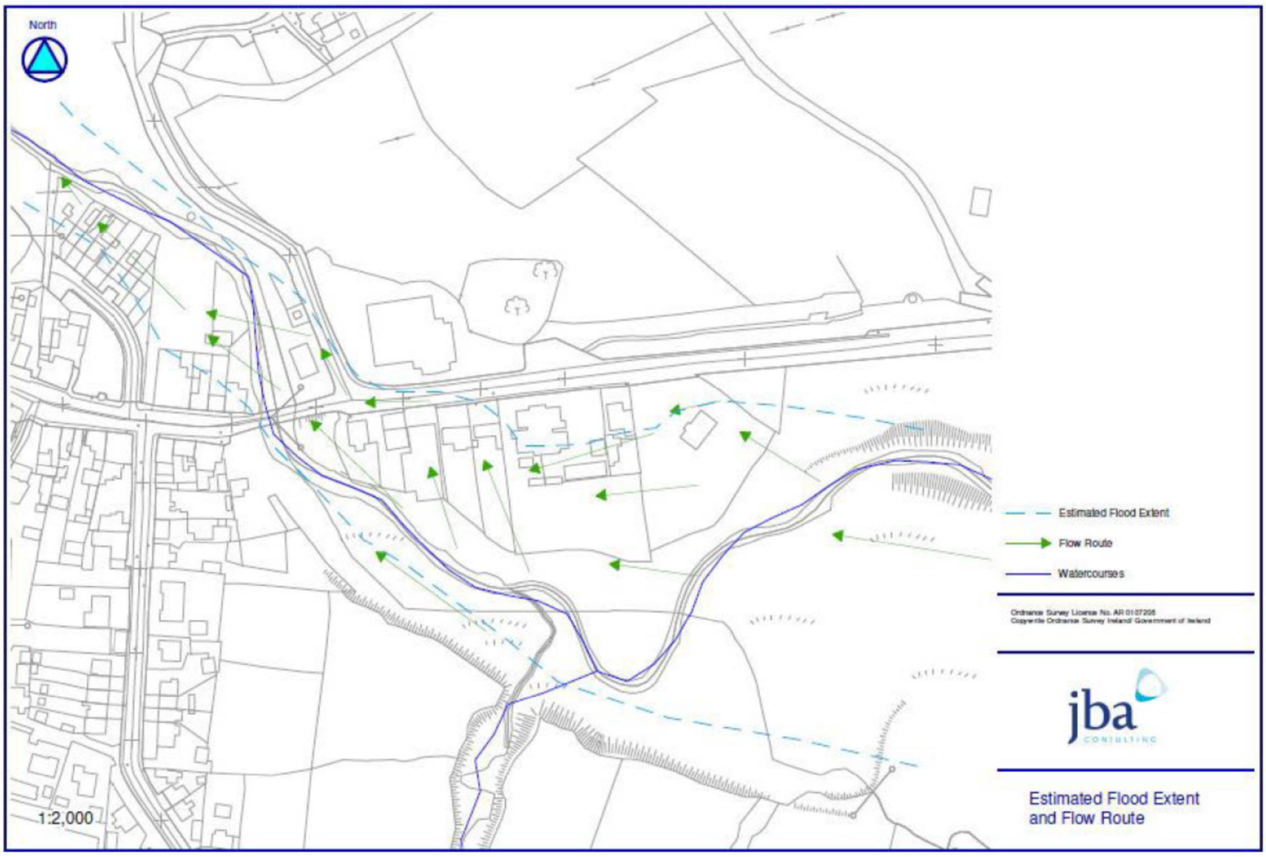


Figure C.3 - Estimated Flood Extent and Flow route (31st July 2008).

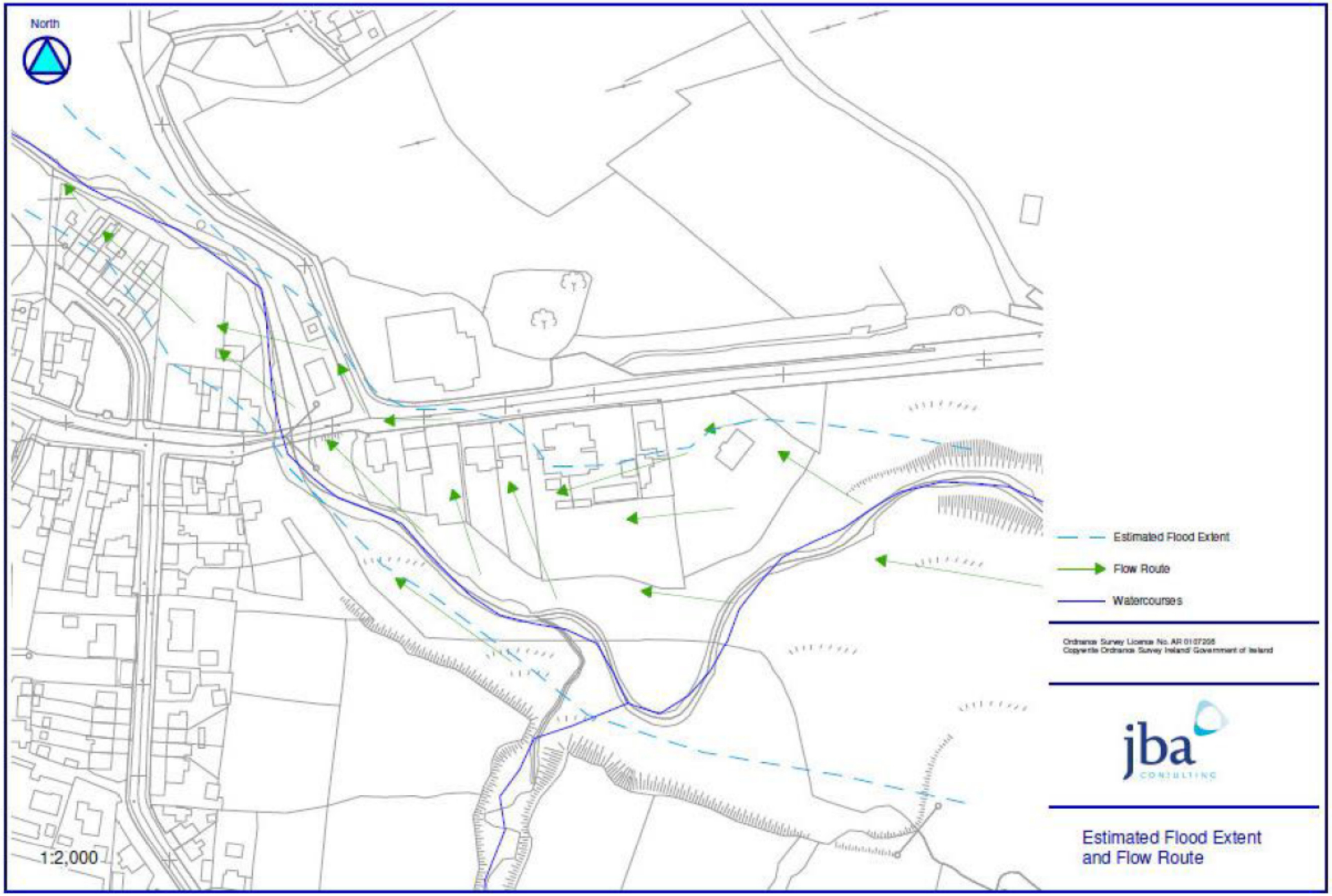


Figure C.3: Estimated Flood Extent and Flow route (31st July 2008).
Source: Athea Flood Severity and Impact Report, Limerick County Council, JBA Consulting.

Annex D - Hydraulic Model Files

Model Files Folders Structure	
ISIS	Model S14c Hydrology ISIS Calibration Design Runs IED Sensitivity Analysis Afflux Blockage Boundary Condition Flow Roughness
TUFLOW	Model S14c Hydrology ISIS QA Tuflow bc_dbase Checks model bg cs mi Boundaries Breaklines empty Landuse Location POlines River Topography xs results runs

ISIS Files	
Model Geometry (.dat) and Associated Files (e.g.: .ief, .zzl, .zzd, .zzu,.zzx)	**Design Runs – Current Scenario:** S14-c_Q10_FLU_C_DES_ISSV1.DAT S14-c_Q100_FLU_C_DES_ISSV1.DAT S14-c_Q1000_FLU_C_DES_ISSV1.DAT

	Sensitivity Runs – Current Scenario S14-c_Q100_FLU_C_Sen_20AfDe_ISSV1.DAT S14-c_Q100_FLU_C_Sen_20AfIn_ISSV1.DAT S14-c_Q100_FLU_C_Sen_20FlDe_ISSV1.DAT S14-c_Q100_FLU_C_Sen_20FlIn_ISSV1.DAT S14-c_Q100_FLU_C_Sen_20RoDe_ISSV1.DAT S14-c_Q100_FLU_C_Sen_20RoIn_ISSV1.DAT S14-c_Q100_FLU_C_Sen_BdyDe_ISSV1.DAT S14-c_Q100_FLU_C_Sen_BdyIn_ISSV1.DAT **Verification Run** S14-c_Q1000_FLU_C_Sen_Bloc_ISSV1.DAT
Hydrological Inflow Files	**Design Runs – Current Scenario:** Q10_DesignR.ied Q100_DesignR.ied Q1000_DesignR.ied **Sensitivity Runs – Current Scenario** Q100_Sen_De.ied Q100_Sen_In.ied

TUFLOW files	
TUFLOW Control Files (.tcf) and Associated Files (e.g.: ecf, tgc, tbc)	**Design Runs – Current Scenario:** S14-c_Q10_FLU_C_DES_ISSV1.tcf S14-c_Q100_FLU_C_DES_ISSV1.tcf S14-c_Q1000_FLU_C_DES_ISSV1.tcf } S14c_6m_Athea_v1.tbc S14c_6m_Athea_v1.tgc S14c_Athea_Landuse.tmf **Sensitivity Runs – Current Scenario** S14-c_Q100_FLU_C_Sen_20AfDe_ISSV1.tcf S14-c_Q100_FLU_C_Sen_20AfIn_ISSV1.tcf S14-c_Q100_FLU_C_Sen_20FlDe_ISSV1.tcf S14-c_Q100_FLU_C_Sen_20FlIn_ISSV1.tcf S14-c_Q100_FLU_C_Sen_20RoDe_ISSV1.tcf S14-c_Q100_FLU_C_Sen_20RoIn_ISSV1.tcf S14-c_Q100_FLU_C_Sen_BdyDe_ISSV1.tcf S14-c_Q100_FLU_C_Sen_BdyIn_ISSV1.tcf } S14c_6m_Athea_v1.tbc S14c_6m_Athea_v1.tgc S14c_Athea_Landuse.tmf S14c_Athea_Landuse_20RoDe.tmf S14c_Athea_Landuse_20RoIn.tmf **Verification Run** S14-c_Q1000_FLU_C_Sen_Bloc_ISSV1.tcf } S14c_6m_Athea_v1.tbc S14c_6m_Athea_v1.tgc S14c_Athea_Landuse.tmf
Grid Orientation File	2d_loc_S14c_Athea.MIF
Material Files	**Design runs – Current scenario:** S14c_Athea_Landuse.tmf **Sensitivity runs – Current scenario** S14c_Athea_Landuse_20RoDe.tmf S14c_Athea_Landuse_20RoIn.tmf 2d_mat_Athea.MIF 2d_mat_Buildings_S14c_Athea.MIF 2d_mat_Athea_high_roughness_patches.MIF
Zpt Files, Model DTM (.asc)	S14C_Athea_DTM_2m_LIDAR.asc
Breaklines Files	2d_zln_Banktop_Unsurv_Athea.MIF 2d_zln_Thin_walls_S14c_Athea.MIF 2d_zln_Thick_walls_S14c_Athea.MIF
Boundary Files	2d_bc_hxe_S14c_Athea.MIF 2d_bc_hxi_S14c_Athea_v2.MIF
Flow/Head Files in bc_dbase	No Flow/Head boundaries provided in 2D domain.

Initial Water Level Files	No IWL files provided in 2D domain
Time Series Files	No time series files provided to the 2D domain.
One Dimensional Network Files	1d_ISIS_nodes_S14c_Athea.MIF
Available 2D Result Files	Depth, stage, hazard and velocity 2D results in ASCII file format for all available design return periods.

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
Verification run						
1	S14-c_Q1000_FLU_C_Sen_Bloc_ISSV1	0	45	1 sec 1D 2 sec 2D	Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 2, "maxitr" value is set to 29 and "dflood" value is set to 6.	Convergence within manufacturer tolerance.
Design Runs – Current Scenario						
2	S14-c_Q10_FLU_C_DES_ISSV1	0	45	1 sec 1D 1 sec 2D	Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 2, "maxitr" value is set to 29 and "dflood" value is set to 6.	Cumulative mass balance error superior to 1% due to low flow in the 2D domain. Deemed to not affect the accuracy of model results. Convergence within manufacturer tolerance.
3	S14-c_Q100_FLU_C_DES_ISSV1	0	45	1 sec 1D 2 sec 2D	Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 2, "maxitr" value is set to 29 and "dflood" value is set to 6.	Convergence within manufacturer tolerance.
4	S14-c_Q1000_FLU_C_DES_ISSV1	0	45	1 sec 1D 2 sec 2D	Automated Preissmann Slot for River Sections" is checked, "minitr" value is set to 2, "maxitr" value is set to 29 and "dflood" value is set to 6.	Convergence within manufacturer tolerance.

Sensitivity Analysis						
5	S14-c_Q100_FLU_C_Sen_20AfDe_ISSV1	0	45	1 sec 1D 2 sec 2D	The calibration coefficient of the bridge units were reduced by 20%.	Convergence within manufacturer tolerance.
6	S14-c_Q100_FLU_C_Sen_20AfIn_ISSV1	0	45	1 sec 1D 2 sec 2D	The calibration coefficient of the bridge units were increased by 20%.	Convergence within manufacturer tolerance.
7	S14-c_Q100_FLU_C_Sen_20FlDe_ISSV1	0	45	1 sec 1D 2 sec 2D	The inflows have been decreased by 20%	Convergence within manufacturer tolerance.
8	S14-c_Q100_FLU_C_Sen_20FlIn_ISSV1	0	45	1 sec 1D 2 sec 2D	The inflows have been increased by 20%	Convergence within manufacturer tolerance.
9	S14-c_Q100_FLU_C_Sen_20RoDe_ISSV1	0	45	1 sec 1D 2 sec 2D	The roughness has been decreased by 20% in 1D and 2D model	Convergence within manufacturer tolerance.
10	S14-c_Q100_FLU_C_Sen_20RoIn_ISSV1	0	45	1 sec 1D 2 sec 2D	The roughness has been increased by 20% in 1D and 2D model	Convergence within manufacturer tolerance.
11	S14-c_Q100_FLU_C_Sen_BdyDe_ISSV1	0	45	1 sec 1D 2 sec 2D	The slope of the normal depth has been halved	Convergence within manufacturer tolerance.
12	S14-c_Q100_FLU_C_Sen_BdyIn_ISSV1	0	45	1 sec 1D 2 sec 2D	The slope of the normal depth has been doubled	Convergence within manufacturer tolerance.

Parameters changed from Default	Justification
Automated Preismann slot for River Sections turned on.	Automated Preismann slot are a standard parameter used to aid model stability particularly in low flows. These Preismann slots have negligible to no impact on the water levels during flood events.
Maxitr	Increased to 29 to improve model stability.*
Dflood	Increased to 6 to improve model stability.*

*Stage and Flow profiles at all cross sections have been checked to ensure results are sensible and to ensure any changes to the default model run parameters has not impacted on the model result.

Annex E - Flood Mapping

Flood Maps are available through the OPW flood mapping website; http://maps.opw.ie/fhrm/

Fluvial Hydraulic Modelling Report

1. Basic Model Information

1.1 General Information	
Model ID:	S15
Unit of Management	23
AFAs included in the Model	Abbeydorney
Primary Watercourses / Water Bodies	Milltown House Stream River Ballybroman River Boherroe
1.2 Reference to other Relevant Reports	
Catchment Description	Hydrology Report Unit of Management 23 – Appendix A1.1
Model Location	Hydraulics Report Unit of Management 23 – Section 3.4.2
HEP Schematisation	Hydrology Report Unit of Management 23 – Appendix B4 – Figure B4.1

2. Survey Data and Base Mapping

2.1 Base Mapping:	OSi data base mapping at scale 1:50k Reference: OS0812_D OS1014_D
2.2 DTM for 2D Model Domain:	**Within AFAs:** LiDAR data with 2m horizontal resolution and approximately 200mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain areas included in the AFA boundary.
	Outside AFAs: Partial coverage of LiDAR data with 2m horizontal resolution and approximately 200mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain areas included in the AFA boundary. Full coverage of IFSAR data with 5m horizontal resolution and approximately 500mm-1000mm vertical accuracy has been used to inform the ground elevation of the floodplain within the hydraulic model for areas outside the AFA boundary.
2.3 River Channel/Structures Survey	General information on the topographic survey of the river channel and structures are included in the main Hydraulics Report. Full details of the survey outputs are provided in the topographic survey deliverables, as required under Section 5.2 of the Stage I Project Brief. Number of cross-sections included in this model: 148.

2.4 Defence Asset Survey Data	The defence asset database has been completed for this Model Area, and is provided as a separate deliverable to this report. This comprises (1) Raised embankments on both banks of the Milltown House Stream downstream of the confluence with the River Boherroe. (2) Raised embankments on both banks of the Cahernead tributary of the Milltown House Stream that runs from Cahernead village, and joins left bank of the Milltown House Stream.
2.5 Survey interaction	The Lidar, IFSAR and topographic survey were checked for anomalies, and to ensure that interactions between were within expected tolerances. No issues were identified in this model.

3. Hydraulic Model Construction and Schematisation

3.1 Software:	**1D domain:**	ISIS Version 3.6.0.156 (32 bit - Single Precision)
	2D domain(s):	TUFLOW Version: 2012-05-AE-iSP-w32
3.2 Model Area / Extent:	The areal extent of the model and its schematisation are shown in Annex A.	

The mapping details for the model extent included in Annex A are as follows:

1. **Full modelled area showing**:
   - River centre lines, HPW/MPW extents, names of watercourses
   - 2D domain area
   - AFA boundary
2. **Maps showing a detailed model schematic of the HPW/MPW reaches are also included**

3.3 Model Reaches:	The following model reaches as shown on the maps referred above have been defined in the model:

Watercourse Name	**Reach**	**Upstream Model Node**	**Downstream Model Node**
River Ballybroman	04BRK	04BRK01027	04BRK00000
Milltown House Stream (upper)	01KCK	01KCK01882	01KCK00000
River Boherroe	01ABD	01ABD02979	01ABD00000
Milltown House Stream (lower)	03BRK - 02BRK	03BRK01445	02BRK00000

Total model HPW length (km):	7.2	**Total model MPW length (km):**	2.5

3.4 Model Structures:

A full schedule of structures included in the model is provided in Schedule A in Annex B. A summary of the structures included is given below

Culverts:	☒	How many?	3
Bridges:	☒	How many?	8
Fixed crest weirs:	☐	How many?	0
Adjustable crest weirs:	☐	How many?	0
Sluice / Gate structures:	☐	How many?	-
Locks:	☐	How many?	0
Dams:	☐	How many?	0

Other (describe):

5 No. parallel culvert pipes modelled in a lumped fashion using a single orifice unit.

3.5 Floodplain Schematisation

Out-of-bank areas downstream of the confluence between the Milltown House Stream and the River Boherroe have been modelled using a 1D approach in the ISIS model using lateral spill units and reservoir units.

Out-of-bank areas upstream of this confluence, including the

reach have been modelled using a 2D approach as set in the TUFLOW model.

Extended 1D sections are considered appropriate for HPW extents where floodplain flow paths are simple (e.g., parallel to river flow). 1D-2D

	modelling is required where HPWs flow through urban areas and out-of-bank flows will form complex flow paths. An overview of the floodplain schematisation is available in the maps shown in Annex A.
3.6 2D Domain Grid Size:	The number of 2D domains defined and the grid sizes of each 2D model domain are as follows:
	Number of 2D domains: 1, Abbeydorney
	Domain 1: Grid cell size (m) 5 — Area (km^2) 3.64
	2D domains are defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. The domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the floodplain flow.
3.7 Model Breaklines in the 2D Domain:	Bank tops and bridge parapets are represented as breaklines in the 2D domain. Breaklines have also been used to represent the R556, R557 Road alignments and a disused Railway embankment. Details on the use of breaklines and the method used to alter DTM is provided in Section 3.4.8 of the main hydraulic report.
3.8 Floodplain Structures in the 2D Domain	NA
3.9 Hydraulic Roughness	Hydraulic roughness (Manning's n) has been defined in accordance with the approaches described in Section 3.4.10 of the main report. Details of the values adopted for this model are included in Schedule B in Annex B. A summary of Manning's n for the model as a whole is as follows:

MPW In-bank	Minimum 'n' value:	0.050
	Maximum 'n' value:	0.065
HPW In-bank	Minimum 'n' value:	0.050
	Maximum 'n' value:	0.065

Floodplain (ISIS model)	As mentioned in Section 3.5, out of bank areas represented in the ISIS model are represented with lateral spills and reservoir units only, therefore no Manning's n values were required for this part of the model.
Floodplain (TUFLOW Model)	Manning's n for out of bank areas represented in the TUFLOW model are as defined by OSi NTF land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in TUFLOW are as follows:

Land use	Manning's 'n' value
Buildings	0.100
Short grass, parks	0.035
General Urban	0.060
General Rural	0.045
Pastures	0.035
Dense Vegetation	0.080
Roads	0.025

	Railways	0.050
	Water bodies	0.020

3.10 Spill Units	• Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain). • Spill profile geometry is defined using topographic survey data and LiDAR/IfSAR. • Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can be also found to account for lateral spilling perpendicular to the main direction of flow.
3.11 Model Boundaries - Inflows	Hydrological flow hydrographs were input to the model at key model locations as indicated in the tables below. The production of peak flow estimates and flow hydrograph shapes is fully explained in the hydrology report relevant to Unit of Management 23.
(a) Current Situation	Peak inflows (m^3/s) are summarised in the tables below for the current situation and the design event simulated. These are the final inflows as obtained following calibration to HEPs (see Section 4.2)

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_195_1	04BRK01027	1.5	2.1	2.5	2.9	3.4	3.7	4.1	5.0
23_435_2	04BRK00000	2.4	3.3	4.0	4.6	5.4	6.0	6.6	8.0
23_436_1	01KCK01882	5.2	7.3	8.8	10.1	11.9	13.2	14.6	17.6
23_436_3	01KCK00932	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.3
23_988_4	01ABD02979	4.2	5.9	7.1	8.2	9.6	10.7	11.8	14.3
23_988_5	01ABD02484	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
23_988_8	01ABD00975	0.7	1.0	1.2	1.4	1.7	1.8	2.0	2.5
23_758_1	02BRK02338	1.4	2.0	2.4	2.7	3.2	3.6	3.9	4.8
23_197_3*	02BRK01195	4.2	10.2	12.0	13.5	14.3	13.0	13.9	13.8
23_806_2*	02BRK00686	1.5	2.2	2.7	3.4	5.0	7.3	8.8	18.2

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for all return periods for the MRFS. These events are selected as these are the MRFS that are to be mapped.

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_195_1	04BRK01027	1.7	2.5	3.0	3.4	4.0	4.5	4.9	6.0
23_435_2	04BRK00000	2.8	4.0	4.8	5.5	6.5	7.2	7.9	9.6
23_436_1	01KCK01882	6.2	8.8	10.5	12.1	14.3	15.9	17.5	21.1
23_436_3	01KCK00932	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.5
23_988_4	01ABD02979	5.0	7.1	8.5	9.8	11.6	12.8	14.1	17.1
23_988_5	01ABD02484	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.8
23_988_8	01ABD00975	0.9	1.2	1.5	1.7	2.0	2.2	2.4	3.0
23_758_1	02BRK02338	1.7	2.4	2.8	3.3	3.9	4.3	4.7	5.7

23_197_3*	02BRK01195	5.1	12.3	14.4	16.2	17.1	15.6	16.7	16.6
23_806_2*	02BRK00686	1.8	2.6	3.3	4.1	6.0	8.7	10.5	21.8

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for 10%, 1% and 0.1% events for both the MRFS and the HEFS. These events are selected as these are the MRFS and HEFS that are to be mapped. Note: Future Scenarios will be assessed during a future project stage.

HEP Reference Name	Input Node in the Hydraulic Model	HEFS Annual Exceedance Probability		
		10%	**1%**	**0.1%**
23_195_1	04BRK01027	3.2	4.8	6.4
23_435_2	04BRK00000	5.2	7.8	10.4
23_436_1	01KCK01882	11.4	17.2	22.9
23_436_3	01KCK00932	0.8	1.3	1.7
23_988_4	01ABD02979	9.2	13.9	18.5
23_988_5	01ABD02484	0.4	0.6	0.8
23_988_8	01ABD00975	1.6	2.4	3.2
23_758_1	02BRK02338	3.1	4.6	6.2
23_197_3*	02BRK01195	15.6	16.9	17.9
23_806_2*	02BRK00686	3.6	9.4	23.7

*flows modified during HEP calibration

3.12 Model Boundaries – Downstream Conditions	Downstream boundary conditions adopted in the model are as follows:
	The outflows at the downstream end of the model extent are modelled using a normal depth boundary type with gradient of 0.00176 m/m based on the upstream bed profile. Sensitivity to this assumption is discussed in the relevant section below.

4. Hydraulic Model Calibration and Sensitivity	
4.1 Model Calibration and Verification to Historical Events	The analysis of available flood event data and high flow data for possible consideration as calibration and verification events is covered in detail in the Hydrology Report for UoM23 (Appendix F). The results of this analysis concluded that no calibration or verification could be performed in the Abbeydorney AFA or the upper reaches of the Milltown House Stream, Balleybroman and Boherroe rivers as no past flood event has been reported in sufficient detail. Additionally, no hydrometric station is present along the entire extent of the S15 model.. Although four 'water level only' stations namely 23030, 23033, 23034 and 23036 are present downstream of the model extent; these are of little use due to the absence of any station upstream to provide quality inflow data. Calibration and verification between stations on the S15 model is therefore not possible.
4.2 Calibration to HEP	Calibration of the hydraulic model to the HEP target flows has been carried out for all design events simulated. Section 2.7.2 of the Hydrology Report for UoM23 provides a summary of the calibration to HEP process. Preliminary inflow hydrographs derived from the hydrological analysis and input to the model were adjusted in time so that their respective peak flows coincide with the peak time of the propagating flood wave as it is routed down the model. Total peak flows predicted by the hydraulic model at HEP locations were then compared to the HEP target flows estimated during the hydrological analysis. Where required, inflows to the hydraulic model were scaled up/down to ensure that the modelled total peak flows remain within ±10% of the HEP target flows. The flows at the HEP nodes: 23_197_3, 23_806_2 were increased by varying amounts. This ±10% target allows for good agreement between the hydrological estimates and the hydraulic results without the addition/removal of unrealistic volumes of flow from the model. The robustness of this has been verified by the agreement of the design flood maps. The table below shows the percentage difference between the modelled and target flows at each HEP location. The average percentage differences for all of the HEP nodes are as follows: 3.8%, 3.9% 4.3% for the 10%, 1% and 0.1% AEP events respectively. The following points should be noted: • The hydraulic model predicts significant overland flows emanating from Milltown House Stream (upper) and flowing in back in channel on the River Boherroed. Consequently at HEP point 23_988_8, downstream of where the flows get back in the River Boherroe, there is an increase in flow and a poor agreement with the required target flows (overprediction of the model). To reconcile predicted flows and HEP target flows, the overland peak flows were quantified and taken away from the peak flows at this HEP point. Conversely at HEP points 23_436_5 and 23_759_2 on the Milltown House Stream downstream of the bypassing flows, modelled flows underpredict the target flows. To reconcile HEP target flows and predicted flows the overland peak flows mentioned above were added to the modelled flows at these HEP points. The percentage difference at HEP point 23_759_2 is 11% but due to the method of flow calculation at this HEP point it was felt no further modification

	to the flows should be carried out. • At HEP nodes 23_759_3 and 23_757_2 no comparison have been made between the modelled flows and the target flows as these two points are located next to the confluence between the Milltown House Stream and the River Boherroe. At this location floodplain flow patterns are complex involving some re-circulation of flow across the floodplain area between the two watercourses. It is therefore not possible to quantify the total flows that should be attributed to each of the HEP nodes. • Calibration at HEP point 23_758_1 for the 50% AEP was not possible due to the water retained in the floodplain. No further modifications was required

HEP Reference Name	Node in the Hydraulic Model	Annual Exceedance Probability							
		Percentage Difference (%)							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_195_2	04BRK00508	-1	-5	-4	-8	-7	-7	-6	-9
23_435_2	04BRK00000	1	3	3	2	3	5	7	8
23_436_3	01KCK00932	0	1	-1	-1	-1	-1	-2	-2
23_436_5	01KCK00070ds	-4	-4	-3	-4	-4	-4	-5	-4
23_759_2	03BRK01016c	10	10	10	8	7	7	6	7
23_759_3	03BRK00448ds	NA	NA	NA	NA	NA	NA	NA	NA
23_988_5	01ABD02484	0	1	0	0	0	-1	-1	1
23_988_7	01ABD01460c	3	5	4	3	2	1	0	-2
23_988_8	01ABD00975	-4	-1	-1	-2	-2	-3	-5	-8
23_757_2	01ABD00000	NA	NA	NA	NA	NA	NA	NA	NA
23_758_1	02BRK02338	-19	-5	-6	-6	-3	-4	-4	-1
23_197_3	02BRK01195	-3	-6	-4	-5	-1	1	6	10
23_806_2	02BRK00686ds	-4	-6	-5	-4	-2	-5	-8	-4
23_806_3	02BRK00000	-5	-7	-5	-5	-3	-5	-8	-1

4.3 Model Sensitivity	Sensitivity tests have been carried out in order to assess the sensitivity of the predicted peak water levels to alterations in roughness (Manning's n), fluvial flow, afflux at key structures and downstream conditions. In each case the sensitivity run was carried out for the 1% AEP fluvial event. Uncertainty maps illustrating the results of the sensitivity analysis will be delivered as part of the final stage of this work. Sensitivity test results are provided in the following tables:

+20% Manning's n	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section / Reach where the Maximum Difference occurs**
	River Ballybroman	+0.066	+0.080	04BRK00807
	Milltown House Stream (upper)	+0.060	+0.155	01KCK01660
	Milltown House Stream	+0.050	+0.174	02BRK00000

	(lower)			
	River Boherroe	+0.058	+0.137	01ABD02979
-20% Manning's n	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Ballybroman	-0.076	-0.082	04BRK00438
	Milltown House Stream (upper)	-0.108	-0.398	01KCK01345
	Milltown House Stream (lower)	-0.084	-0.255	02BRK00000
	River Boherroe	-0.065	-0.199	01ABD02789
+20% inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Ballybroman	+0.073	+0.089	04BRK00066
	Milltown House Stream (upper)	+0.089	+0.329	01KCK01022u
	Milltown House Stream (lower)	+0.065	+0.155	02BRK00000
	River Boherroe	+0.067	+0.199	01ABD02829u
-20% inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Ballybroman	-0.079	-0.086	04BRK00438 04BRK00344
	Milltown House Stream (upper)	-0.120	-0.395	01KCK01345
	Milltown House Stream (lower)	-0.133	-0.373	02BRK00795u
	River Boherroe	-0.072	-0.213	01ABD02829u

Afflux at Key Structure Orifice discharge coefficient increased by 20%	There is only one structure in the Abbeydorney AFA which has a significant head loss during a 1% AEP flood event. It is at ISIS node 01ABD01599bu the R557 “Bridge Road” Crossing. The orifice discharge coefficient was adjusted by plus 20% (to a value of 1.2). This resulted in a small decrease of 53mm to the maximum water level immediately upstream of the structure. The change in stage caused a small effect on the predicted flood extent in the immediate vicinity of the bridge. The minimal response is further explained as the bridge structure is bypassed on both the left and right banks during flood conditions.
Afflux at Key Structure Orifice discharge coefficient decreased by 20%	The orifice discharge coefficient was decreased by 20% (to a value of 0.8) and resulted in an increase of 116 mm to the maximum water level immediately upstream of the weir. Similarly to the case above, the increase in stage resulted in a minor increase to the predicted flood extent in the immediate vicinity of the bridge.
Downstream Conditions The Gradient in the ND boundary is reduced by 50%	Reducing the gradient on the downstream boundary results in an increase in maximum stage at the downstream model extent of approximately 500mm. The effect diminishing upstream can be seen for 1.2km upstream of the downstream boundary, but has no significant impact on the water levels and predicted flood extents in Abbeydorney AFA.
Downstream Conditions The Gradient in the ND boundary is increased by 100%	Increasing the gradient on the downstream boundary results in a reduction in maximum stage at the downstream model extent of approximately 490mm. The effect diminishing upstream can be seen for 1.2km upstream of the downstream boundary, but has no significant impact on the water levels and predicted flood extents in Abbeydorney AFA.
4.4 Model Files	The hydraulic model files associated with this model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. The model files included are detailed in Annex C.

5. Hydraulic Model Outputs

5.1 Mapping	The model outputs were processed to produce a series of flood maps according to the requirements stated in the Stage I Project Brief under Section 7.5.2. This includes mapping outputs covering: • Flood extents • Flood depth and velocity • Flood hazard All of the maps contain the maximum extent, depth, velocity and flood hazard for the combined main stream inflows and the tributaries inflows. An explanation for the main stream inflows and the tributaries inflows is provided in Section 6. Mapping outputs corresponding to the **defended**, **current** scenario for the 10%, 1% and 0.1% AEP flood events are shown in Annex E for flood extent and depth only.

6. Key Model Assumption and Limitations

- At model node 02BRK01195 an unmodelled watercourse, the Cahernead, joins the Milltown House Stream. Upstream of the confluence this tributary is defended on its right bank by an embankment which forms the left boundary of Reservoir “Resr03” in the model. As shown on the maps in Annex A, Resr03 in the model accounts for the floodplain area between the Milltown House Stream (left bank) and the Cahernead (right bank). The reservoir is connected to a spill representing the Cahernead right bank embankment and the spill is directly connected to node 02BRK01195 assuming the Cahernead in-bank channel has sufficient capacity to convey any excess flow from the reservoir overtopping the right bank embankment. This assumption has been validated. The model results show water levels in Resr03 are high enough for the Cahernead right bank embankment to be overtopped up to a maximum of 18 m^3/s for 0.1% AEP event whilst the Cahernead bank full capacity was estimated at 39 m^3/s, using survey data available and the Manning’s n equation.
- Linkage from 2D to 1D domains at model node SP_Hdummy utilises a simplified spill profile in order to ensure suitable model convergence. It has been checked that this modification does not have any effect on the predicted flood outlines.
- For the reaches where a 1D schematisation of the floodplain has been adopted, the flood depth maps were generated using modelled peak water levels and LiDAR (where available)/SAR data for ground level information. At the locations where the LiDAR and SAR data sets meet there are some unavoidable discrepancies in the ground levels which can result in anomalies in the mapping outputs presented in this report.

Annex A – Model Extent and Schematisation Maps

Annex A1 – Model Extent

Legend

2D Model Boundary

AFA Boundary

Model Reaches

HPW

MPW

Model:

S15

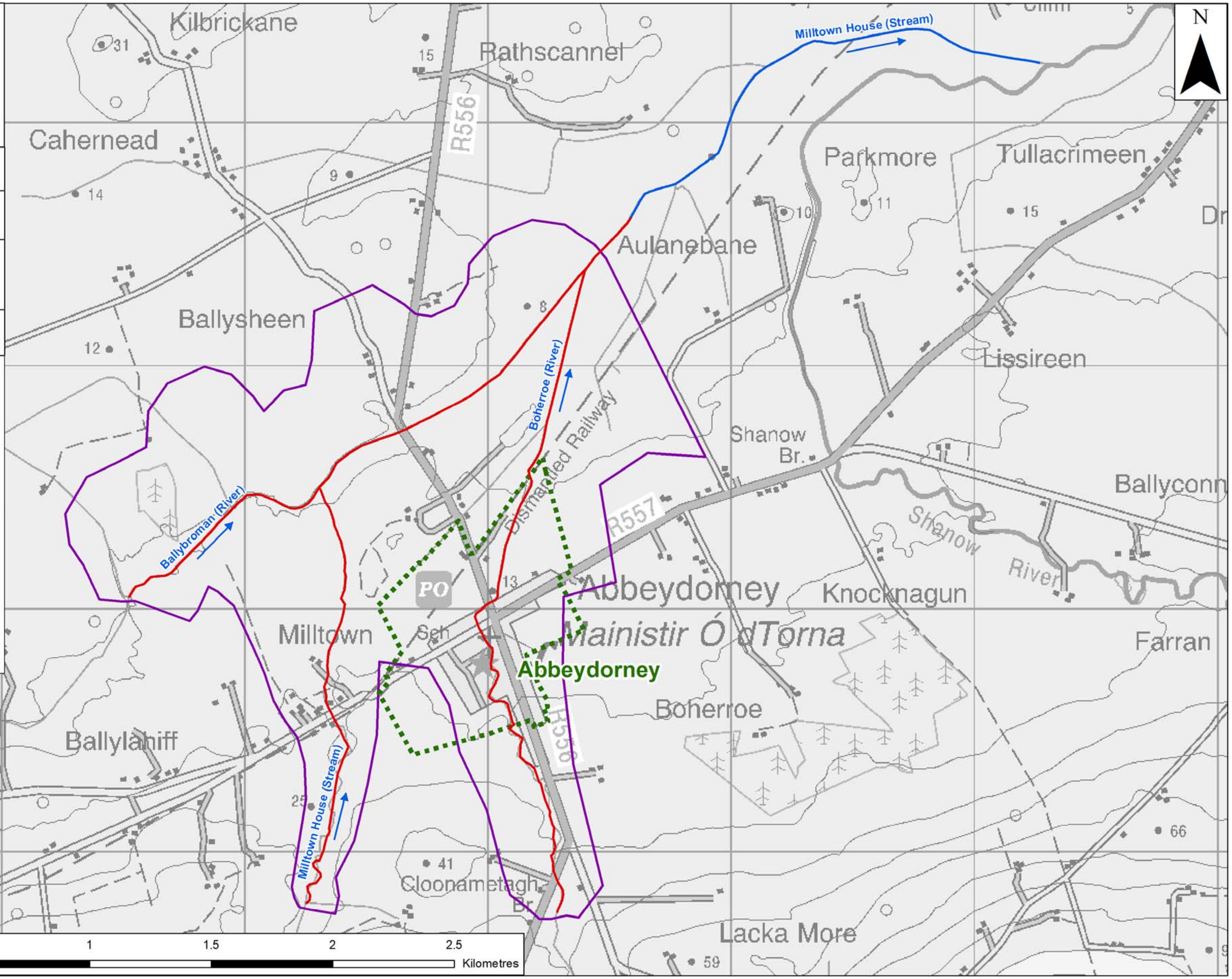
Figure ref:

Annex A1

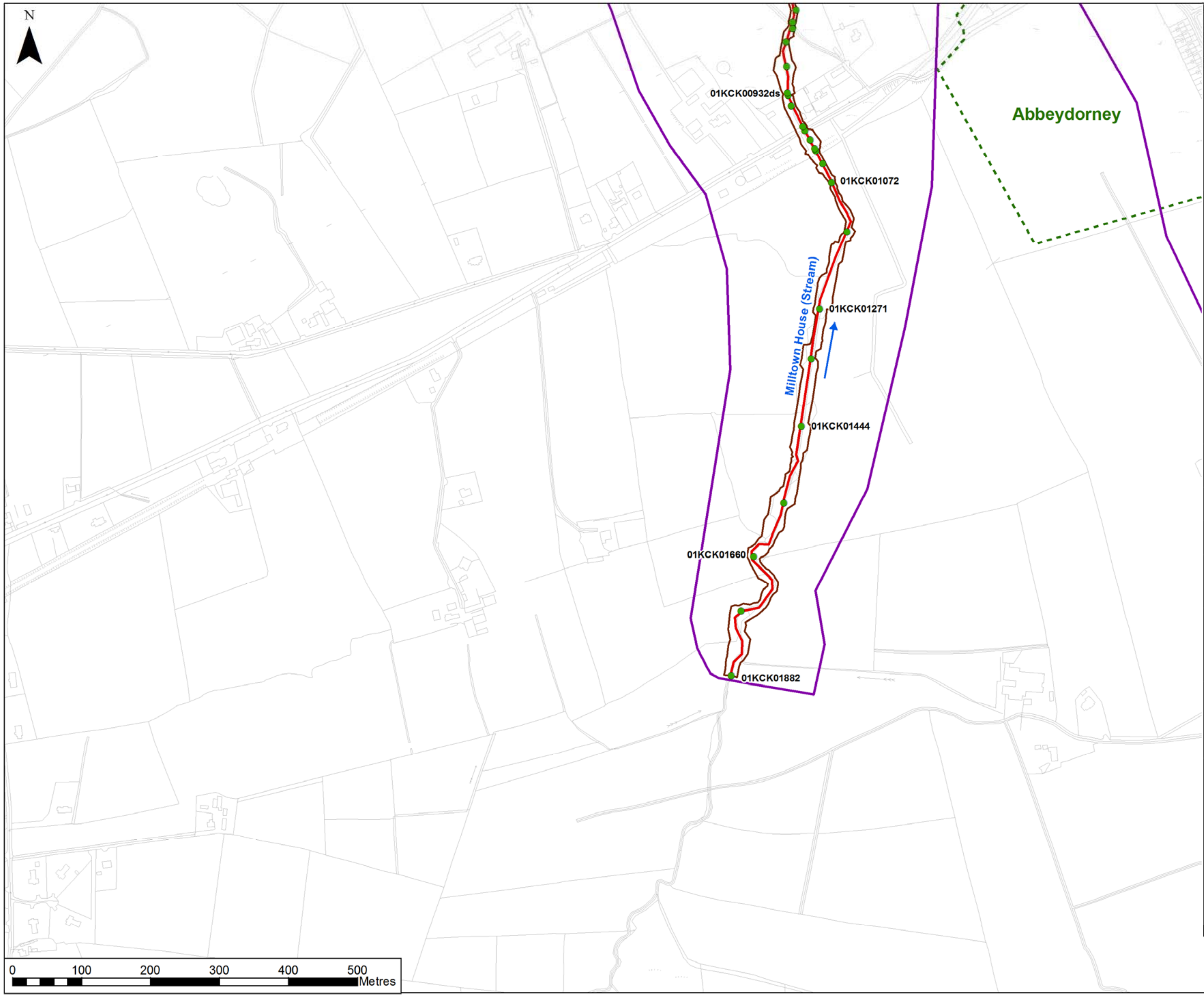
Drawing Title:

S15
Model Extent

JACOBS



Annex A2 – Schematisation Maps



Legend

- AFA Boundary
- 2D Model Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Cross-section Extents
- Reservoir Spill

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S15

Figure ref: Annex A2 (1)

Drawing Title: S15 Model Schematisation

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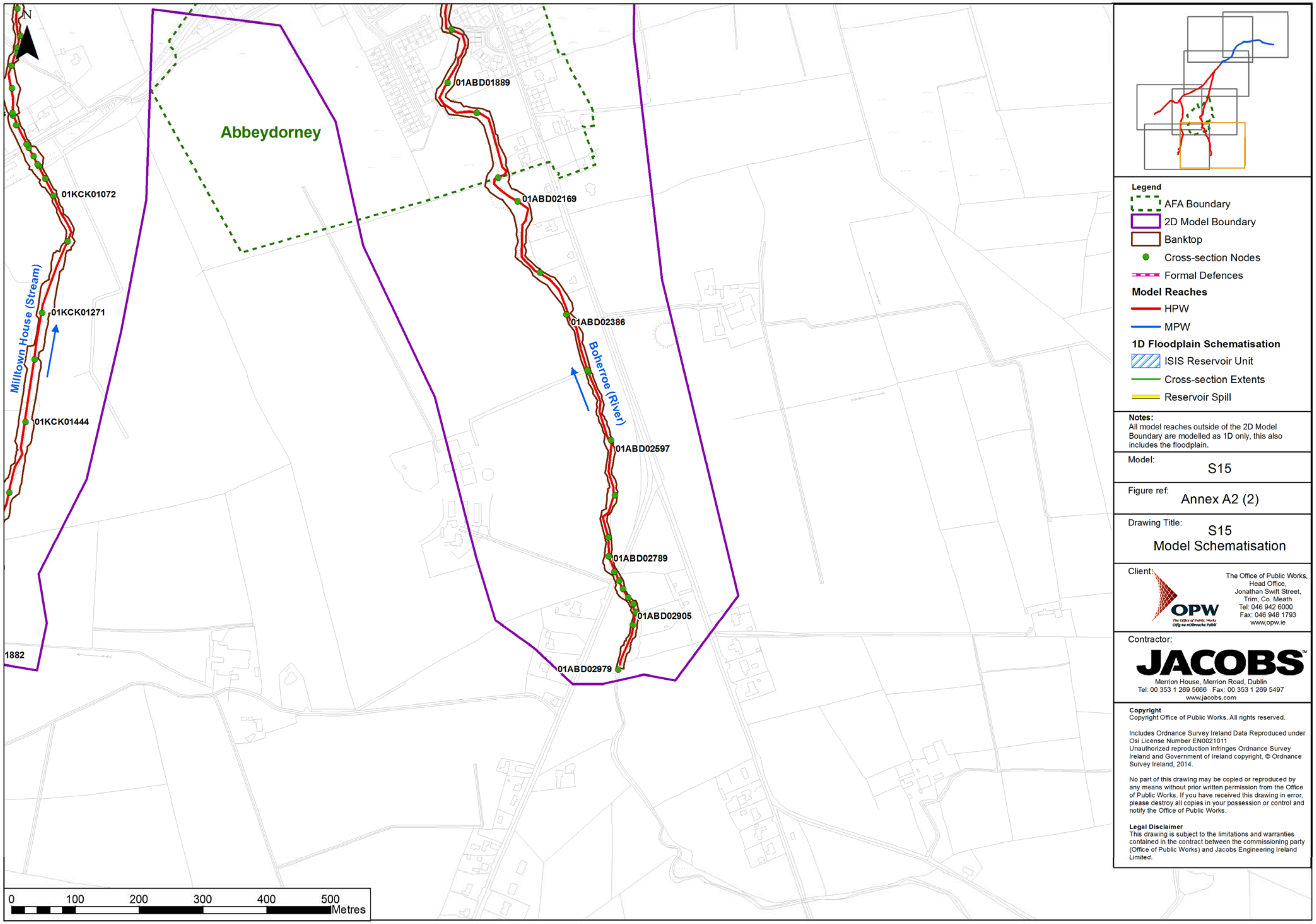
N
Abbeydorney
01ABD01889
01ABD02169
01ABD02386
Boherroe (River)
01ABD02597
01ABD02789
01ABD02905
01ABD02979
01KCK01072
01KCK01271
Milltown House (Stream)
01KCK01444
1882
0
100
200
300
400
500
Metres
Legend
AFA Boundary
2D Model Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Cross-section Extents
Reservoir Spill
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S15
Figure ref:
Annex A2 (2)
Drawing Title:
S15
Model Schematisation
Client:
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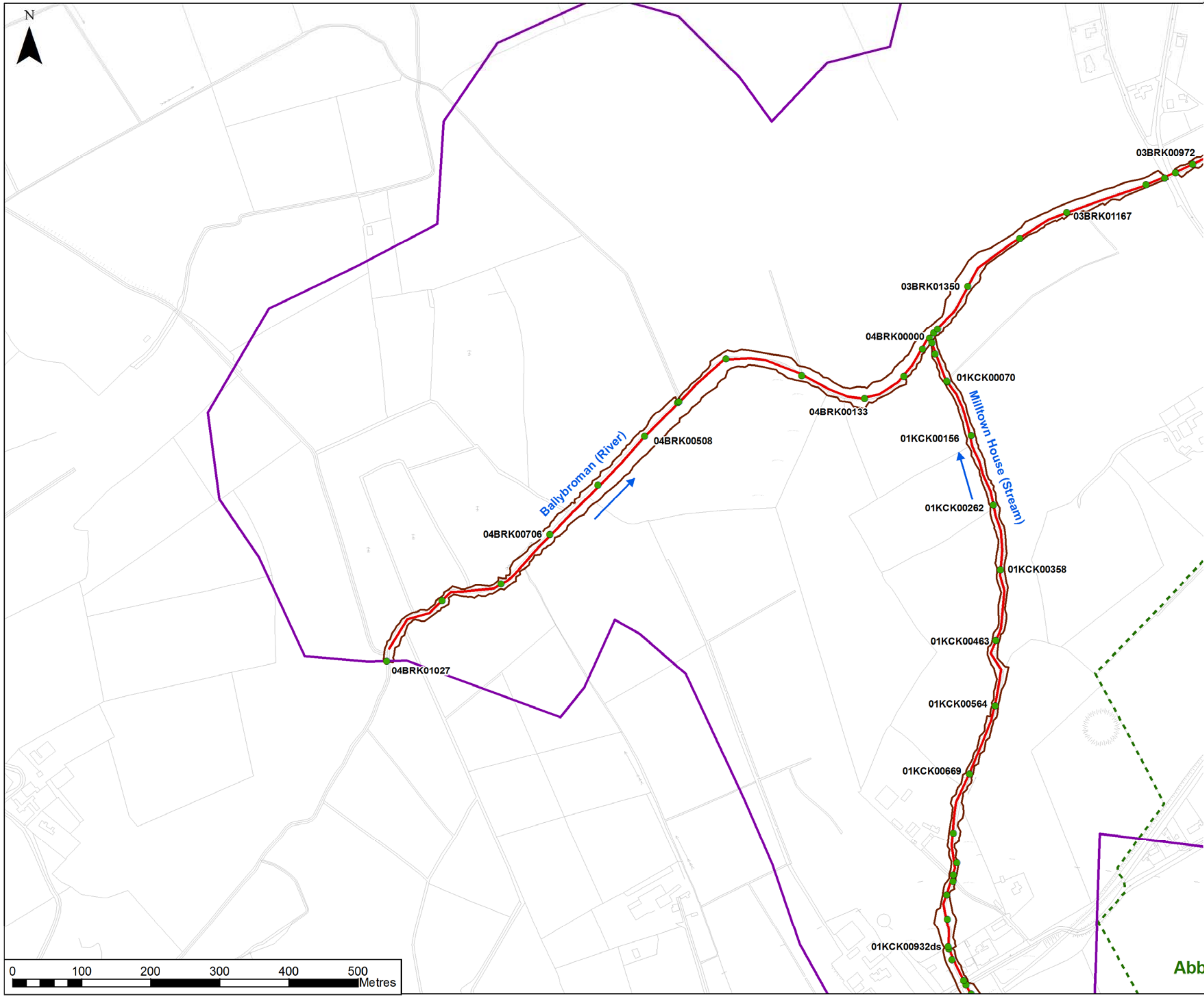

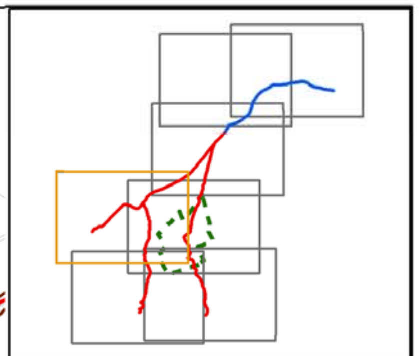

Legend

- AFA Boundary
- 2D Model Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Cross-section Extents
- Reservoir Spill

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S15

Figure ref: Annex A2 (3)

Drawing Title: S15
Model Schematisation

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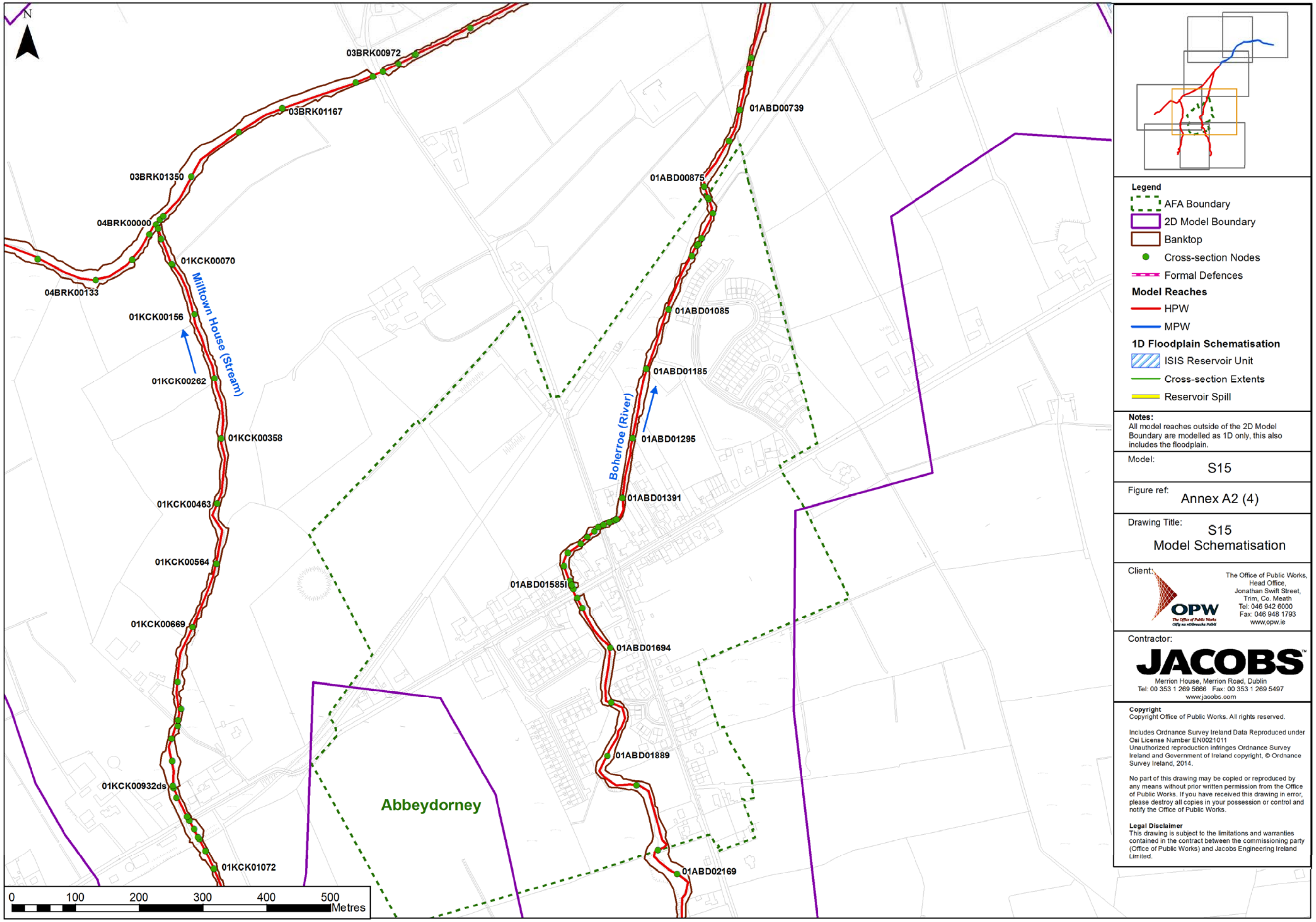
N
03BRK00972
03BRK01167
03BRK01350
04BRK00000
04BRK00133
01KCK00070
Milltown House (Stream)
01KCK00156
01KCK00262
01KCK00358
01KCK00463
01KCK00564
01KCK00669
01KCK00932ds
01KCK01072
01ABD00739
01ABD00875
01ABD01085
01ABD01185
Boherroe (River)
01ABD01295
01ABD01391
01ABD01585
01ABD01694
01ABD01889
01ABD02169
Abbeydorney
0
100
200
300
400
500
Metres
Legend
AFA Boundary
2D Model Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Cross-section Extents
Reservoir Spill
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S15
Figure ref:
Annex A2 (4)
Drawing Title:
S15
Model Schematisation
Client:
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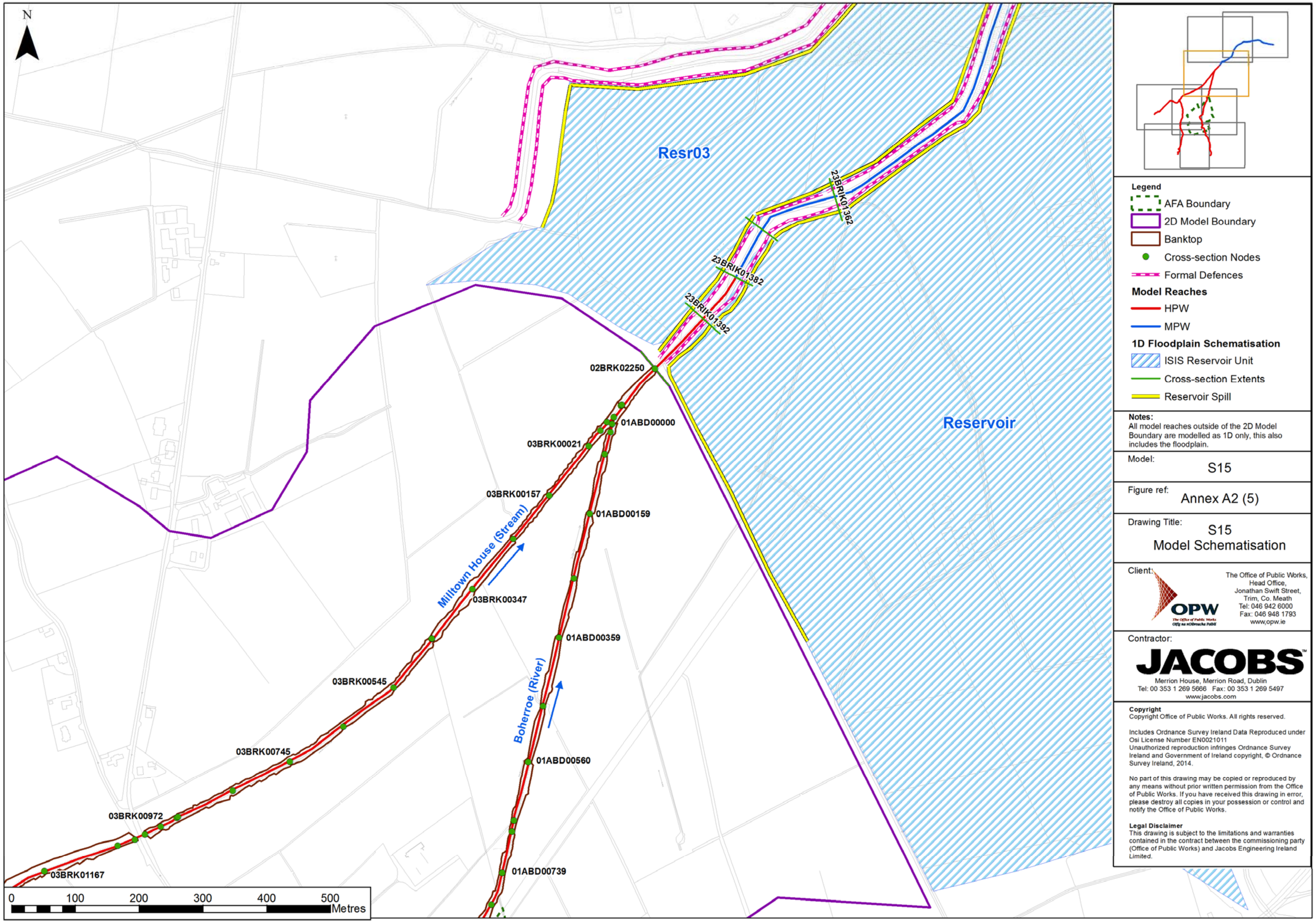
N
Resr03
Reservoir
23BRIK01362
23BRIK01382
23BRIK01392
02BRK02250
01ABD00000
03BRK00021
03BRK00157
01ABD00159
Milltown House (Stream)
03BRK00347
01ABD00359
03BRK00545
Boherroe (River)
03BRK00745
01ABD00560
03BRK00972
03BRK01167
01ABD00739
0 100 200 300 400 500
Metres
Legend
AFA Boundary
2D Model Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Cross-section Extents
Reservoir Spill
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S15
Figure ref:
Annex A2 (5)
Drawing Title:
S15
Model Schematisation
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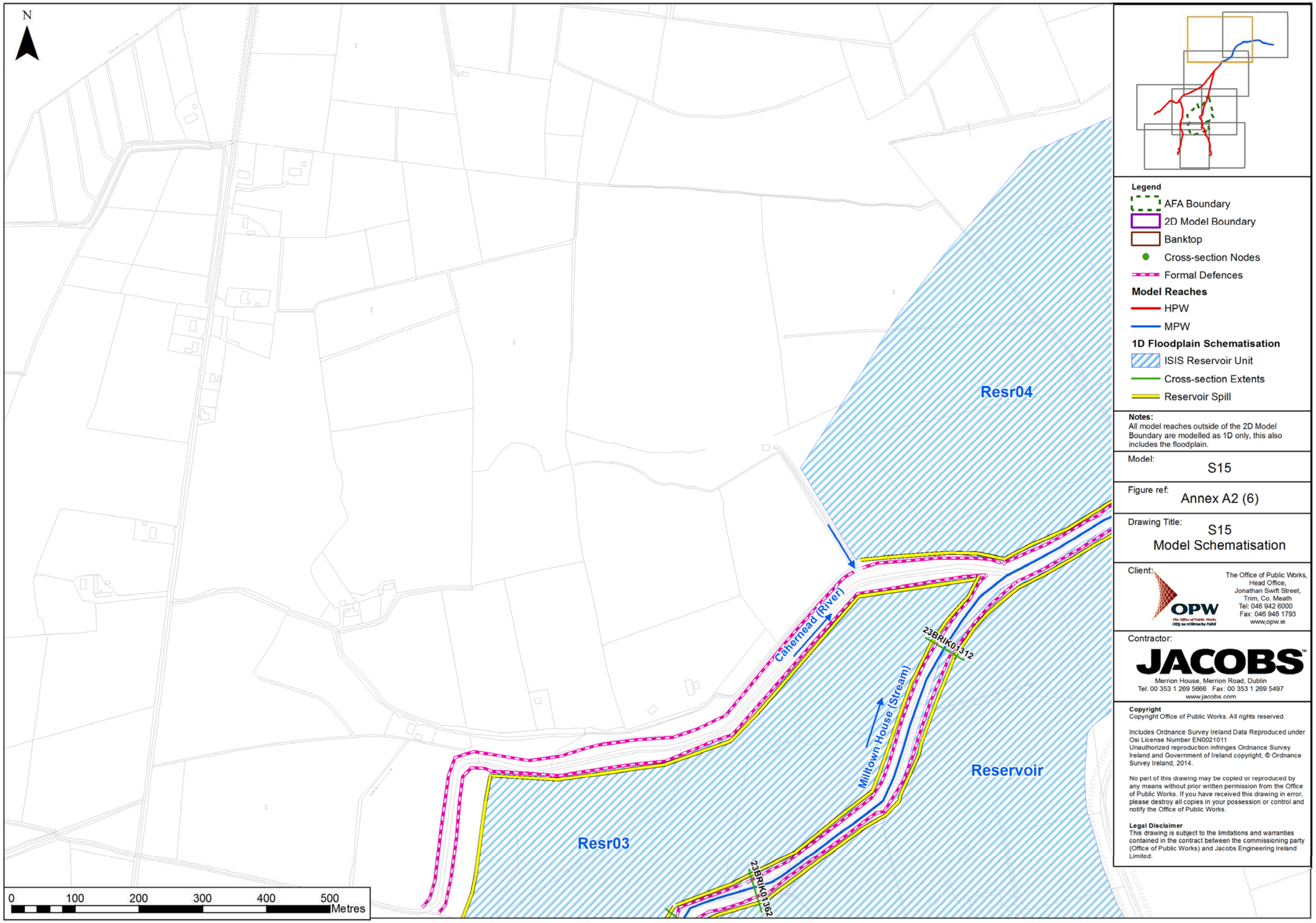

N
Resr04
Resr03
Reservoir
Cahernead (River)
Milltown House (Stream)
23BRIK01312
23BRIK01362
0
100
200
300
400
500
Metres
Legend
AFA Boundary
2D Model Boundary
Banktop
Cross-section Nodes
Formal Defences
Model Reaches
HPW
MPW
1D Floodplain Schematisation
ISIS Reservoir Unit
Cross-section Extents
Reservoir Spill
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S15
Figure ref:
Annex A2 (6)
Drawing Title:
S15
Model Schematisation
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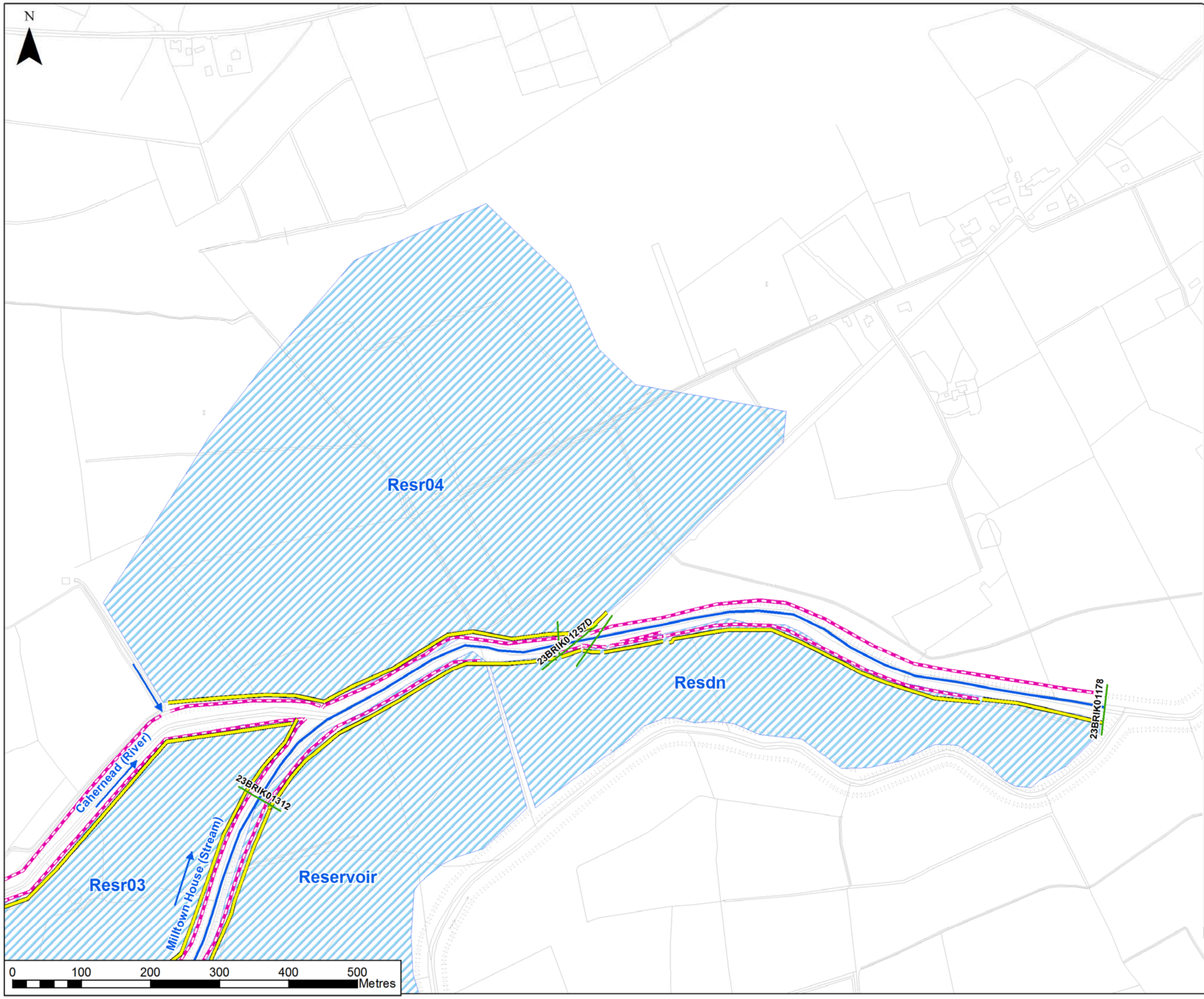

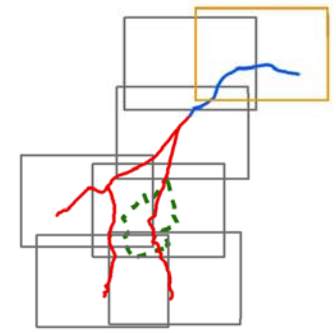

Legend

- AFA Boundary
- 2D Model Boundary
- Banktop
- Cross-section Nodes
- Formal Defences

Model Reaches

- HPW
- MPW

1D Floodplain Schematisation

- ISIS Reservoir Unit
- Cross-section Extents
- Reservoir Spill

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S15

Figure ref: Annex A2 (7)

Drawing Title: S15 Model Schematisation

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Annex B – Structure and Hydraulic Roughness schedules

Schedule A.1 - Structure Schedule for the Milltown House (upper)

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23BRIK01514D	03BRK01016u	15 m wide Bridge	Rectangular culvert	Y
23BRIK01257D	02BRK00795bu	2.70 m wide Bridge	Arch bridge + Spill	Y

Schedule A.2 - Structure Schedule for the Milltown House (lower)

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23BRIC00102D	01KCK01022bu	5.0 m wide Bridge	Arch bridge + Spill	Y
23BRIC00098D	01KCK00990bu	6.0 m wide R557 Bridge	Arch bridge + Spill	Y
23BRIC00082D	01KCK00828bu	3.0 m wide Bridge	Arch bridge + Spill	Y

Schedule A.3 - Structure Schedule for the River Boherroe

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23BRIA00289I	01ABD02888ou	2.37 m wide Bridge	Orifice + Spill	Y
23BRIA00283E	01ABD02829ci	14.51 m wide Bridge	Rectangular Culvert	Y
23BRIA00159D	01ABD01599bu	14.0 m wide Bridge with three openings	Three arch culvert	Y
23BRIA00149D	01ABD01460ci	7.0 m wide Bridge	Arch Culvert + Spill	Y
23BRIA00146D	01ABD01429bu	2.98 m wide Bridge	Arch bridge + Spill	Y
23BRIA00098E	01ABD00975Bu	3.5 m wide Bridge	Arch bridge + Spill	Y
23BRIA00090D	01ABD00896Bu	4.0 m wide Bridge	Arch bridge + Spill	Y

Schedule B.1 – In-bank Manning's n for HPW Network

River Name	Cross Sections	In-bank Roughness
River Ballybroman	23BRIK01658 to 23BRIK01382	0.060
Milltown House	23BRIC00187 to 23BRIC00117	0.060
	23BRIC00107 to 23BRIC00001	0.060
River Boherroe	23BRIA00299 to 23BRIA00179	0.065
	23BRIA00169 to 23BRIA00129	0.055
	23BRIA00129 to 23BRIA0046	0.050
	23BRIA00046 to 23BRIA00002	0.060

Schedule B.2 – Manning's n for MPW Network

River Name	Cross Sections	In-bank Roughness
Milltown House	23BRIK01372 to 23BRIK01178	0.050

.

Annex C – Model Calibration

Not used as calibration to historical events was not possible.

Annex D - Hydraulic Model Files

Model Files Folders Structure	

ISIS	S15_Hydraulic_Model
	  ISIS
	    Design Runs
	    Sensitivity
	      Afflux
	      Boundary Condition
	      Flow
	      Roughness
	  Tuflow

TUFLOW	S15_Hydraulic_Model
	  ISIS
	  Tuflow
	    model
	      mi
	        Boundaries
	        Breaklines
	        Empty
	        Landuse
	        Location
	        POlines
	        River
	        Topography
	    results
	    runs

ISIS Files	
Model Geometry (.dat) and Associated Files (e.g.: .ief, .zzl, .zzd, .zzu,.zzx)	**Design Runs – Defended Current Scenario:** S15_ISIS_10yr_Design7c.DAT S15_ISIS_100yr_Design3c.DAT S15_ISIS_1000yr_Design2c.DAT **Sensitivity Runs – Defended Current Scenario:** S15_ISIS_100yr_Design3c_KSminus20%.DAT S15_ISIS_100yr_Design3c_KSplus20%.DAT S15_ISIS_100yr_Design3c_DSminus.DAT S15_ISIS_100yr_Design3c_DSplus.DAT S15_ISIS_100yr_Design3c_Qminus20%.DAT S15_ISIS_100yr_Design3c_Qplus20%.DAT S15_ISIS_100yr_Design3c_Nminus20%.DAT S15_ISIS_100yr_Design3c_Nplus20%.DAT

TUFLOW files	
TUFLOW Control Files (.tcf) and Associated Files (e.g.: ecf, tgc, tbc)	**Design Runs – Current Scenario:** S15_10yr_Des7c.tcf S15_100yr_Des3c.tcf S15_1000yr_Des2c.tcf } 2d_5m_grid_S15_abby_V27.tgc 2d_5m_grid_S15_abby_V28.tbc landuse.tmf **Sensitivity Runs – Current Scenario:** S15_100yr_Des3c_MinusDS.tcf S15_100yr_Des3c_PlusDS.tcf S15_100yr_Des3c_MinusKS.tcf S15_100yr_Des3c_PlusKS.tcf S15_100yr_Des3c_MinusN.tcf S15_100yr_Des3c_PlusN.tcf S15_100yr_Des3c_MinusQ.tcf S15_100yr_Des3c_PlusQ.tcf } 2d_5m_grid_S15_abby_V27.tgc 2d_5m_grid_S15_abby_V28.tbc landuse.tmf
Grid Orientation File	2d_loc_S15_abby.MIF
Material Files	landuse.mif landuse.tmf landuse_Minus.tmf landuse_Plus.tmf
Zpt Files, Model DTM (.asc)	80000_120000_dtm_5m_ing.asc abbeydo2m_dtm.asc
Breaklines Files	2d_z_Polygon_Bank.MIF 2d_zln_Bank_Adjust.MIF 2d_zln_Banktop_12Feb.MIF 2d_zln_Rail_Under_Road.MIF 2d_zln_Railway_P1_V2.MIF 2d_zln_Railway_P2.MIF 2d_zln_Railway_P3.MIF 2d_zln_Road_556.MIF 2d_zln_Road_557.MIF 2d_zln_Wall_Arti.MIF 2d_zsh_Bridge_Deck.MIF 2d_zsh_Parapet_Wall.MIF
Boundary Files	2d_bc_hxe_S15_abby_V2.MIF 2d_bc_hxi_17FEB.MIF 2d_bc_SX_14Mar.MIF
Flow/Head Files in bc_dbase	NA
Initial Water Level Files	NA
Time Series Files	NA
One Dimensional Network Files	NA

Available 2D Result Files	Depth, stage, hazard and velocity 2d results in ASCII file format for all available design return periods.

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
Design Runs						
1	S15_ISIS_10yr_Design7c.DAT	0	35	1 sec 1D 2 sec 2D	“Automated Preissmann Slot for River Sections” is checked, “maxitr” value is set to 17, and “perform corrective 1d timestep” is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
2	S15_ISIS_100yr_Design3c.DAT	0	35	1 sec 1D 2 sec 2D	“Automated Preissmann Slot for River Sections” is checked, “maxitr” value is set to 17, and “perform corrective 1d timestep” is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
3	S15_ISIS_1000yr_Design2c.DAT	0	35	1 sec 1D 2 sec 2D	“Automated Preissmann Slot for River Sections” is checked, “maxitr” value is set to 17, and “perform corrective 1d timestep” is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
Sensitivity Analysis						
1	S15_ISIS_100yr_Design3c_KSminus20%.DAT	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. Bridge 01ABD01599bu orifice coefficient decreased to 0.8	Convergence within manufacturer tolerance.
2	S15_ISIS_100yr_Design3c_KSplus20%.DAT	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. Bridge 01ABD01599bu orifice coefficient increased to 1.2	Convergence within manufacturer tolerance.
3	S15_ISIS_100yr_Design3c_DSminus.DAT	0	35	1 sec 1D 2 sec	Run parameters as Design Runs above. Normal Depth Boundary gradient reduced by 50%	Convergence within manufacturer tolerance.

				2D		
4	S15_ISIS_100yr_Design3c_DSplus.DAT	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. Normal Depth Boundary gradient increased by 100%	Convergence within manufacturer tolerance.
5	S15_ISIS_100yr_Design3c_Qminus20%.DAT	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. Model inflows have been decreased by 20%	Convergence within manufacturer tolerance.
6	S15_ISIS_100yr_Design3c_Qplus20%.DAT	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. Model inflows have been increased by 20% in 1D and 2D model	Convergence within manufacturer tolerance.
7	S15_ISIS_100yr_Design3c_Nminus20%.DAT	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. The roughness has been increased by 20% in 1D and 2D model	Convergence within manufacturer tolerance.
8	S15_ISIS_100yr_Design3c_Nplus20%.DATN08_Q10	0	35	1 sec 1D 2 sec 2D	Run parameters as Design Runs above. The roughness has been decreased by 20% in 1D and 2D model	Convergence within manufacturer tolerance.

Parameters changed from Default	Justification
Automated Preismann slot for River Sections turned on.	Automated Preismann slot are a standard parameter used to aid model stability particularly in low flows. These Preismann slots have negligible to no impact on the water levels during flood events.
Maxitr	Increased to 17 to improve model stability.*
Perform Corrective 1D Timestep	Used to improve model stability.*

*Stage and Flow profiles at all cross sections have been checked to ensure results are sensible and to ensure any changes to the default model run parameters has not impacted on the model results.

Annex E - Flood Mapping

Flood Maps are available through the OPW flood mapping website; http://maps.opw.ie/fhrm/

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Appendix C Fluvial/Coastal Hydraulic Model Appendices

Fluvial and Coastal Hydraulic Modelling Report

1. Basic Model Information

1.1 General Information	
Model ID:	S14b
Unit of Management	23
AFAs included in the Model	Moneycashen
Primary Watercourses / Water Bodies	River Cashen, River Feale, River Galey, River Brick
1.2 Reference to other Relevant Reports	
Catchment Description	Hydrology Report Unit of Management 23 – Appendix A1.1
Model Location	Hydraulics Report Unit of Management 23 – Section 3.4.2
HEP Schematisation	Hydrology Report Unit of Management 23 – Appendix B2 – Figure B2.1

2. Survey Data and Base Mapping

2.1 Base Mapping:	OSi data base mapping at scale 1:50k Reference: OS0812_D OS0612_D
2.2 DTM for 2D Model Domain:	**Within AFA** LiDAR data with 2m horizontal resolution and approximately 200mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain within the AFA boundary.
	Outside AFA IFSAR data with 5m horizontal resolution and approximately 500mm-1000mm vertical accuracy has been used to inform the ground elevation of the floodplain within the hydraulic model for areas outside the AFA boundaries.
2.3 River Channel/Structures Survey	General information on the topographic survey of the river channel and structures are included in the main Hydraulics Report. Full details of the survey outputs are provided in the topographic survey deliverables, as required under Section 5.2 of the Stage I Project Brief. Number of cross-sections included in this model: 120.
2.4 Defence Asset Survey Data	The defence asset database has been completed for this model area and is provided as a separate deliverable to this report. Formal flood defences have been surveyed and included into the model. The locations of the flood defences are shown in the model schematisations provided in Annex A. They consist of: 1. Sea wall running along Cashen road between the settlement and the estuary 2. Extensive raised embankment defences throughout the modelled reach of the River Feale and its tributaries Further details of these defences is contained in the defence asset database.
2.5 Survey interaction	The Lidar, IFSAR and topographic survey were checked for anomalies, and to ensure that interactions between were within expected tolerances. No issues were identified in this model.

3. Hydraulic Model Construction and Schematisation

3.1 Software:	**1D domain:** ISIS Version 3.7.0.233 (64 bit - double Precision)
	2D domain(s): TUFLOW Version: 2012-05-AE-iDP-w64
3.2 Model Area / Extent:	The areal extent of the model and its schematisation are shown in Annex A.

The mapping details for the model extent included in Annex A are as follows:

1. **Full modelled area showing**:
   - River centre lines, HPW/MPW extents, names of watercourses
   - 2D domain area including coastal and fluvial floodplains
   - AFA boundary
2. **Maps showing a detailed model schematic of the HPW/MPW reaches are also included.**

3.3 Model Reaches:	The following model reaches as shown on the maps referred to above have been defined in the model:

Watercourse Name	Reach	Upstream Model Node	Downstream Model Node
River Cashen	01	03CHA01270	03CHA00000
River Cashen	02	02CHA03266	02CHA00111
River Cashen	03	01CHA05782	01CHA00000
River Feale	01	01FEL06455	01FEL00000
River Galey	01	01GAL05410	01GAL00000
River Brick	01	01BRK12401	01BRK00000

A schematic of the modelled river reach is available in the .IXY file provided in conjunction with each ISIS .DAT file (see Annex C)

Total model HPW length (km):	1.7	**Total model MPW length (km):**	3296

3.4 Model Structures:

A full schedule of structures included in the model is provided in Schedule A in Annex B. A summary of the structures included is given below

Culverts:	☐	How many?	0
Bridges:	☒	How many?	8
Fixed crest weirs:	☐	How many?	0
Adjustable crest weirs:	☐	How many?	0
Sluice / Gate structures:	☐	How many?	0
Locks:	☐	How many?	0
Dams:	☐	How many?	0
Other (describe):			

3.5 Floodplain Schematisation

Out-of-bank areas across the entire floodplain of the River Feale system were modelled using a 2D approach using TUFLOW.

The same 2D approach and 2D domain have been used to represent the coastal floodplain.

Extended 1D sections are considered appropriate for HPW extents where floodplain flow paths are simple (e.g., parallel to river flow). 1D-2D modelling is required where HPWs flow through urban areas and out-of-bank flows will form complex flow paths.

An overview of the floodplain schematisation is available in the maps shown in Annex A.

3.6 2D Domain Grid Size: The number of 2D domains defined and the grid sizes of each 2D model

	domain are as follows:
	Number of 2D domains: one domain encompassing both fluvial and coastal floodplains
	Domain 1: Grid cell size 20m Area 98.8 km^2
	2D domains are defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. The domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the floodplain flow.
3.7 Model Breaklines in the 2D Domain:	Bank tops and flood defences are represented as breaklines in the 2D domain. Bridge parapets are represented as spill units in the 1D model. Details on the use of breaklines and the method used to alter DTM is provided in Section 3.4.8 of the main hydraulics report.
3.8 Floodplain Structures in the 2D Domain	There are no floodplain structures present in the 2D domain. Information on how buildings were included in the 2D domain is included in Section 3.4.10 of the main Hydraulics Report.
3.9 Hydraulic Roughness	Hydraulic roughness (Manning's 'n') has been defined in accordance with the approaches described in the main report. Details of the values adopted for this model are included in Schedule B in Annex B. A summary of Manning's 'n' for the model as a whole is as follows:
MPW in-bank	Minimum 'n' value: 0.030
	Maximum 'n' value: 0.040
HPW in-bank	Minimum 'n' value: 0.030
	Maximum 'n' value: 0.040
Floodplain (TUFLOW Model)	Manning's 'n' for the coastal and fluvial floodplain areas represented in the TUFLOW model are as defined by OSi NTF land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in TUFLOW are as follows:

Land Use	Manning's 'n' Value
Buildings	0.100
Short grass, parks	0.035
General Rural	0.045
Pastures, Short Grass	0.035
Dense Vegetation	0.080
Roads	0.025
Flat Rock	0.025
Water bodies	0.020

3.10 Spill Units	Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain).nSpill profile geometry is defined using topographic survey data and LiDAR/IfSAR. Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can be also found to account for lateral spilling perpendicular to the main direction of flow.

3.11 Model Boundaries – Fluvial Inflows	Hydrological flow hydrographs were input to the model at key model locations as indicated in the tables below. The production of peak flow estimates and flow hydrograph shapes is fully explained in the Hydrology Report relevant to Unit of Management 27.
(a) Current Situation	Peak fluvial inflows (m^3/s) are summarised in the tables below for the current situation and the design event simulated. These peak inflows did not change following calibration to HEPs (as explained in Section 4.2).

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_2941_3	01FEL06455	366.1	495.2	570.9	643.5	737.6	808.0	878.2	1040.9
23_2929_5	01GAL05410	107.6	148.3	173.7	198.0	229.6	253.2	276.7	331.3
23_806_2	01BRK12401	17.6	24.9	29.7	34.4	40.4	44.9	49.4	59.7
23_806_3	01BRK11636	18.7	26.5	31.7	36.6	43.0	47.8	52.5	63.6
23_443_2	01BRK10990	4.6	6.5	7.8	9.0	10.6	11.8	13.0	15.7
23_2631_2	01BRK09001	8.6	12.1	14.5	16.7	19.7	21.8	24.0	29.1
23_2682_2	01BRK08031	3.6	5.1	6.1	7.1	8.3	9.2	10.2	12.3
23_2820_3	01BRK06500	7.1	10.0	12.0	13.8	16.3	18.1	19.9	24.1
23_2155_2	01BRK05502	9.7	13.8	16.4	19.0	22.3	24.8	27.3	33.0
23_204_4	01BRK02503	4.8	6.8	8.2	9.4	11.1	12.3	13.6	16.4
23_2153_2	01BRK02000	2.0	2.9	3.4	4.0	4.7	5.2	5.7	6.9

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below events for both the MRFS and the HEFS.

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		MRFS							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_2941_3	01FEL06455	439.3	594.2	685.1	772.2	885.1	969.6	1053.9	1249.1
23_2929_5	01GAL05410	129.2	177.9	208.4	237.6	275.5	303.8	332.1	397.5
23_806_2	01BRK12401	21.1	29.9	35.7	41.2	48.4	53.8	59.2	71.7
23_806_3	01BRK11636	22.5	31.8	38.0	43.9	51.6	57.3	63.0	76.3
23_443_2	01BRK10990	5.5	7.8	9.4	10.8	12.7	14.1	15.6	18.8
23_2631_2	01BRK09001	10.3	14.5	17.4	20.1	23.6	26.2	28.8	34.9
23_2682_2	01BRK08031	4.3	6.1	7.3	8.5	10.0	11.1	12.2	14.7
23_2820_3	01BRK06500	8.5	12.0	14.4	16.6	19.5	21.7	23.8	28.9
23_2155_2	01BRK05502	11.7	16.5	19.7	22.8	26.7	29.7	32.7	39.6
23_204_4	01BRK02503	5.8	8.2	9.8	11.3	13.3	14.8	16.3	19.7
23_2153_2	01BRK02000	2.4	3.5	4.1	4.8	5.6	6.2	6.9	8.3

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability
		HEFS

		10%	1%	0.1%
23_2941_3	01FEL06455	742.2	1050.5	1353.1
23_2929_5	01GAL05410	225.7	329.1	430.7
23_806_2	01BRK12401	38.6	58.3	77.7
23_806_3	01BRK11636	41.1	62.1	82.7
23_443_2	01BRK10990	10.2	15.3	20.4
23_2631_2	01BRK09001	18.8	28.4	37.8
23_2682_2	01BRK08031	8.0	12.0	16.0
23_2820_3	01BRK06500	15.6	23.5	31.3
23_2155_2	01BRK05502	21.3	32.2	42.9
23_204_4	01BRK02503	10.6	16.0	21.3
23_2153_2	01BRK02000	4.5	6.7	9.0

3.12 Model Boundaries – Downstream Conditions	Downstream boundary conditions adopted in the model are as follows: Tidal level hydrographs at the outlet of the Cashen Estuary were produced for a series of design events using the Irish Coastal Protection Strategy Study (ICPSS) extreme tidal peak levels data. The time series were set up as boundary conditions for the hydraulic model along the coastal boundary of the hydraulic model (see maps in Annex A). Full details on how these tidal level hydrographs were derived are provided in Appendix D of the main report. Peak tidal levels are summarised in the table below for the current and future situations.

	Annual Exceedance Probability										
Peak Tidal Levels (m OD)	**500%**	**200%**	**100%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1%**
	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.1	3.1	3.2	3.4
	MRFS Annual Exceedance Probability										
Peak tidal levels (m OD)	500%	200%	100%	50%	20%	10%	5%	2%	1%	0.5%	0.1%
	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.7	3.7	3.8	4.0
	HEFS Annual Exceedance Probability										
Peak tidal levels (m OD)	500%	200%	100%	50%	20%	10%	5%	2%	1%	0.5%	0.1%
	3.5	3.6	3.7	3.8	3.9	4.0	4.0	4.2	4.2	4.3	4.5

4. Hydraulic Model Calibration and Sensitivity

4.1 Model Calibration and Verification to Historical Events

The analysis of available flood event data and high flow data for possible consideration as calibration and verification events is covered in detail in the Hydrology report for UoM23 (Appendix F). The results of this analysis concluded that:

- One event was available suitable for tidal calibration; Feb 2002
- One event was available suitable for fluvial calibration; Jan 2005
- One event was available suitable for model verification; Nov 2009

- One further event; Feb 1995, was potentially suitable for model verification, dependent on availability of level gauge data. No data was forthcoming so use of this event was discontinued.

Details of the calibration are provided in Annex C.

4.2 Calibration to HEP

Calibration of the hydraulic model to the HEP target flows has been carried out for all AEP fluvial events. Section 2.7.2 of the hydrology report for UoM23 provides a summary of the calibration to HEP process.

Preliminary inflow hydrographs derived from the hydrological analysis and input to the model were adjusted in time so that their respective peak flows coincide with the peak time of the propagating flood wave as it is routed down the model. Total peak flows predicted by the hydraulic model at HEP locations were then compared to the HEP target flows estimated during the hydrological analysis. Modelled total peak flows at all HEP locations on the main rivers were found to be within ±10% of the HEP target flows for the 10%, 1% and 0.1% AEP events. Therefore no inflow scaling was deemed necessary.

This ±10% target allows for good agreement between the hydrological estimates and the hydraulic results without the addition/removal of unrealistic volumes of flow from the model.

The robustness of this has been verified by the agreement of the design flood maps.

The lower half of the River Brick was shown to be unsuitable for HEP calibration due to extreme floodplain storage and also due to the occurrence of backflow because of high water levels on the River Feale downstream. A number of HEP points on the upper Brick River were also unsuitable for HEP calibration due to flow complexity in the adjacent floodplain.

HEP Reference Name	Node in the Hydraulic Model	Annual Exceedance Probability – Percentage Difference (%)							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_806_2	01BRK12401	9.4	1.5	0.4	0.3	0.3	0.4	0.5	0.4
23_806_3	01BRK11827i	-8.9	-2.7	2.4	6.4	10.8	13.5	8.3	-0.7
23_443_2	01BRK11038i	47.1	12.4	-0.5	-9.3	-17.5	-22.2	-14.4	-0.7
23_2631_2	01BRK09001u	59.7	27.7	16.0	8.4	1.2	-2.8	1.0	7.8
23_2682_2	01BRK08125i	20.5	1.1	-5.2	-9.2	-12.9	-14.9	-18.6	-24.9
23_2820_3	01BRK07029u	-21.8	-14.3	-9.0	-4.5	0.1	2.8	1.3	-1.4
23_2155_2	01BRK05969u	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23_204_4	01BRK02593i	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

23_2153_2	01BRK02220i	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23_2945_3	01BRK00685i	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23_2945_4	01BRK00000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23_2929_5	01GAL05410	13.2	4.2	3.1	2.9	3.0	3.1	3.1	3.1
23_2929_9	01GAL04032i	12.1	1.7	-0.1	-0.9	-1.5	-1.7	-1.2	-0.3
23_2941_3	01FEL06455	10.9	0.9	0.0	-0.2	-0.2	-0.1	-0.1	0.0

4.3 Fluvial and Tidal Events Simulated

The River Feale is influenced by the tidal levels of the Atlantic Ocean. As such, a joint probability analysis of the coincidence of fluvial flood flows and coastal flood levels was carried out to determine the appropriate combinations of flows and sea levels to be used for the design probability events, as required under Section 6.5.6 of the Stage I Project Brief.

The methodology and outcomes of this analysis are detailed in the main Hydraulic Report and in the Hydrology Report. A summary of the joint probability of fluvial and tidal conditions used for the hydraulic modelling in the Moneycashen AFA is reported in the table below.

Combination of Fluvial and Tidal Events

	Joint Probability Design Event	AEP adopted for Fluvial Flows and Tidal Levels	
Scenario	**Overall AEP**	**Fluvial**	**Tidal**
1	50%	50%	500%
2	50%	50%	50%
3	20%	20%	500%
4	20%	50%	20%
5	10%	10%	200%
6	10%	50%	10%
7	5%	5%	100%
8	5%	50%	5%
9	2%	2%	50%
10	2%	50%	2%
11	1%	1%	20%
12	1%	20%	1%
13	0.5%	0.5%	10%
14	0.5%	10%	0.5%
15	0.1%	0.1%	2%
16	0.1%	2%	0.1%

4.4 Model Sensitivity	Sensitivity tests have been carried out in order to assess the sensitivity of the predicted peak water levels to alterations in roughness (Manning's 'n'), fluvial flow, afflux at key structures and downstream conditions. In each case the sensitivity run was carried out for the 1% AEP fluvial event. Sensitivity test results are provided in the following tables. Uncertainty maps illustrating the results of the sensitivity analysis will be delivered as part of the final stage of this work.			
+20% Manning's 'n'	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section / Reach where the Maximum Difference occurs**
	River Brick	0.054	0.112	01BRK00000
	River Galey	0.115	0.209	01GAL04739i
	River Feale	0.178	0.336	01FEL06455
	River Cashen	0.043	0.194	03CHA00985
-20% Manning's 'n'	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Brick	-0.061	-0.132	01BRK02264
	River Galey	-0.067	-0.172	01GAL04351d
	River Feale	-0.623	-0.641	01FEL04480u
	River Cashen	-0.000	-0.037	02CHA01868
+20% inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Brick	0.129	0.258	01BRK01411i
	River Galey	0.142	0.280	01GAL04351u
	River Feale	0.217	0.332	01FEL04494
	River Cashen	0.111	0.309	03CHA01270
-20% inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Brick	-0.094	-0.181	01BRK05502u
	River Galey	-0.081	-0.163	01GAL04556i
	River Feale	-0.272	-0.605	01FEL04494
	River Cashen	-0.013	-0.055	02CHA01696i
Afflux at Key Structure Bridge calibration coefficient increased by 20%	Not applicable. No structures are present within the AFA			
Afflux at Key Structure Bridge calibration coefficient decreased by 20%	Not applicable. No structures are present within the AFA			
Downstream Conditions Duration of surge component of tidal boundary is increased by 100% (i.e. 60 hours)	The change to the downstream boundary condition results in no change to the maximum water level at the downstream boundary (ISIS node 01CHA00000). There is a minor, general increase in the modelled flood outline across the entire model system resulting from the larger tidal flood water volumes associated with the increased surge duration.			
Downstream Conditions Duration of surge component of tidal boundary is decreased by 50% (i.e. 15 hours)	The change to the downstream boundary condition results in no change to the maximum water level at the downstream boundary (ISIS node 01CHA00000). There is a minor, general decrease in the modelled flood outline across the entire model system resulting from the lower tidal flood water volumes associated with the increased surge duration.			

4.5 Model Files	The hydraulic model files associated with this model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. The model files included are detailed in Annex D.

5. Hydraulic Model Outputs

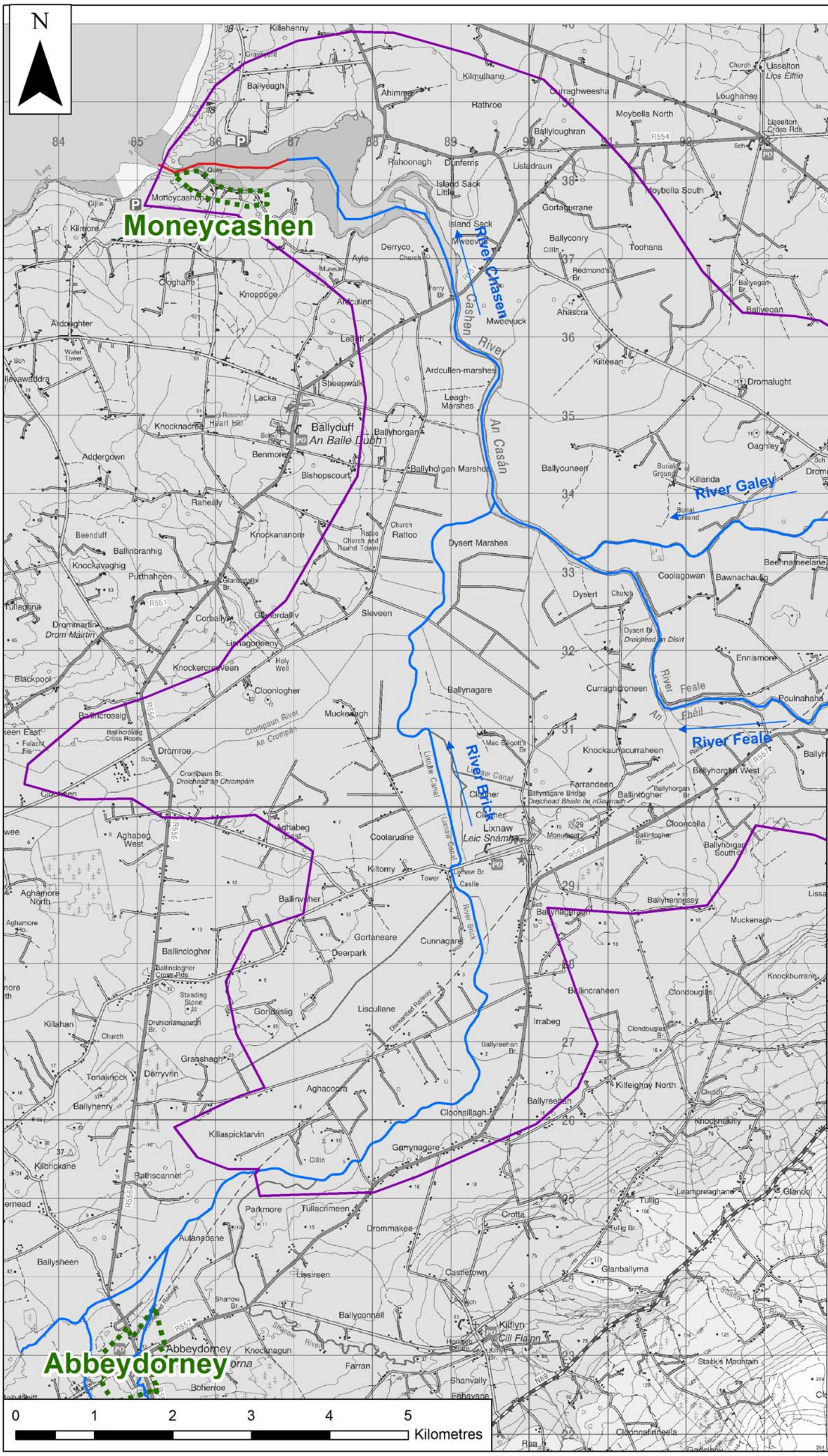
5.1 Mapping	The model outputs were processed to produce a series of flood maps according to the requirements stated in the Stage I Project Brief under Section 7.5.2 and, more specifically, under Section 7.5.2.1, Moneycashen being an area where flooding is subject to both tidal and fluvial influence. This includes mapping outputs covering: • Flood extents • Flood depth and velocity • Flood hazard Flood mapping outputs corresponding to the **defended** current scenario for the 10%, 1% and 0.1% AEP fluvial dominated flood events with the corresponding tidal boundary conditions and to the **defended** current scenario for the 10%, 0.5% and 0.1% AEP tidal dominated events with the corresponding fluvial events are shown in Annex E for flood extent and depth only.

6. Key Model Assumption and Limitations

- Tidal level hydrographs at the downstream boundary of the model have been adjusted in time so that the highest tidal level coincides with the fluvial peak flow upstream of the Cashen Estuary (conservative approach).
- The formal flood defences listed in Section 2.4 are included in the model schematisation. Therefore the model and outputs presented in this report represent a defended scenario.
- A number of raised bank tops are un-surveyed. Best engineering judgement has been applied along with the use of LiDAR and IFSAR topographic data, river cross section survey, as well as site visit photos and available aerial photography, in order to estimate the bank top crest top level.

Annex A – Model Extent and Schematisation Maps

Annex A1 – Model Extent



Model: S14b

Figure ref: Annex A1

Drawing Title: S14b Model Extent

JACOBS

Annex A2 – Schematisation Maps

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S14b

Figure ref: Annex A2 (3)

Drawing Title: S14b Model Schematisation

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Merrion House, Merrion Road, Dublin
Tel: 00 353 1 269 5666 Fax: 00 353 1 269 5497
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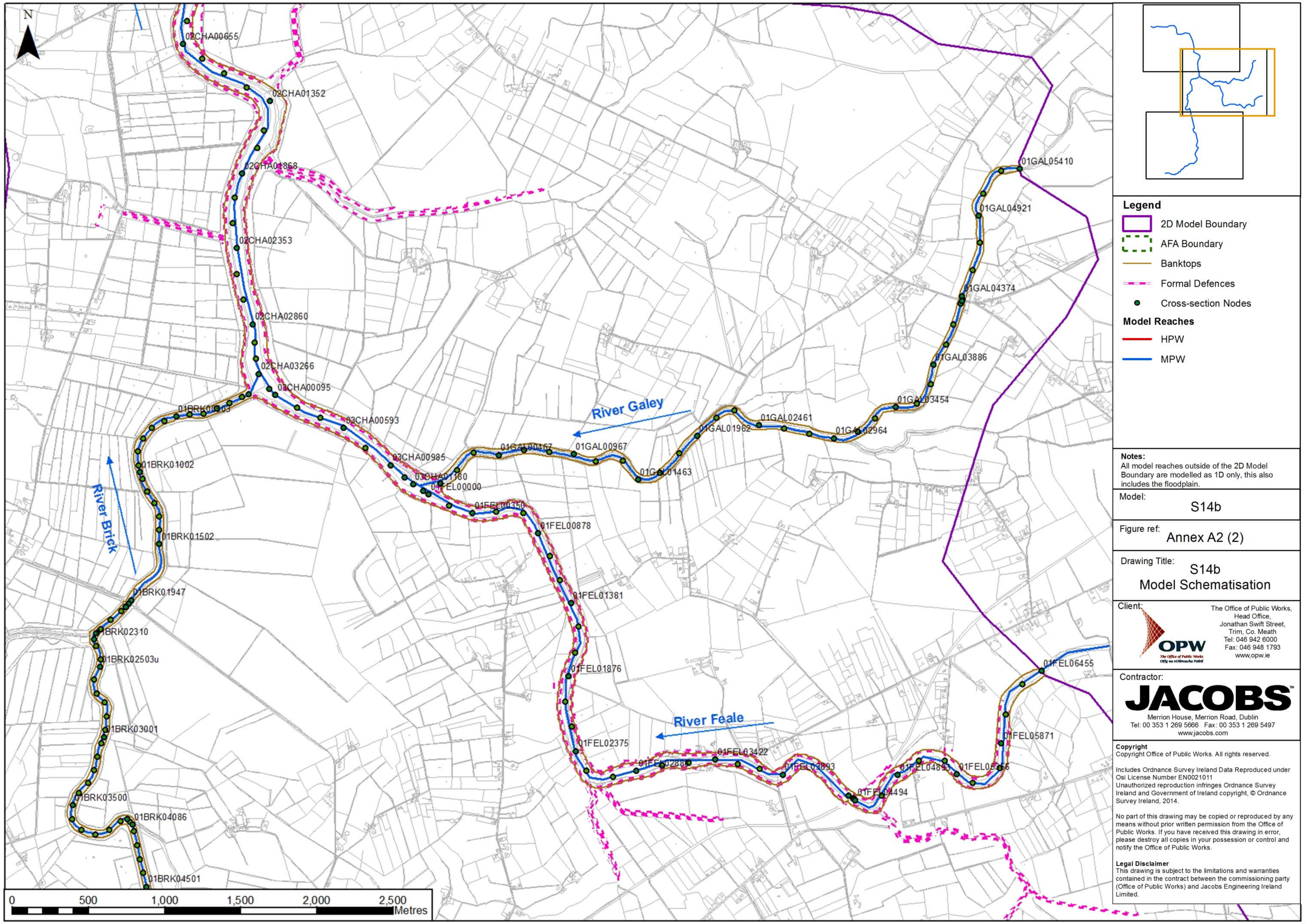

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02CHA03266
03CHA00095
03CHA00593
03CHA00985
03CHA01180
01FEL00000
01FEL00350
01FEL00878
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01FEL04494
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01FEL05871
01FEL06455
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01BRK01947
01BRK02310
01BRK02503u
01BRK03001
01BRK03500
01BRK04086
01BRK04501
River Galey
River Brick
River Feale
0
500
1,000
1,500
2,000
2,500
Metres
Legend
2D Model Boundary
AFA Boundary
Banktops
Formal Defences
Cross-section Nodes
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14b
Figure ref:
Annex A2 (2)
Drawing Title:
S14b
Model Schematisation
Client:
The Office of Public Works, Head Office, Jonathan Swift Street, Trim, Co. Meath
Tel: 046 942 6000
Fax: 046 948 1793
www.opw.ie
Contractor:
JACOBS
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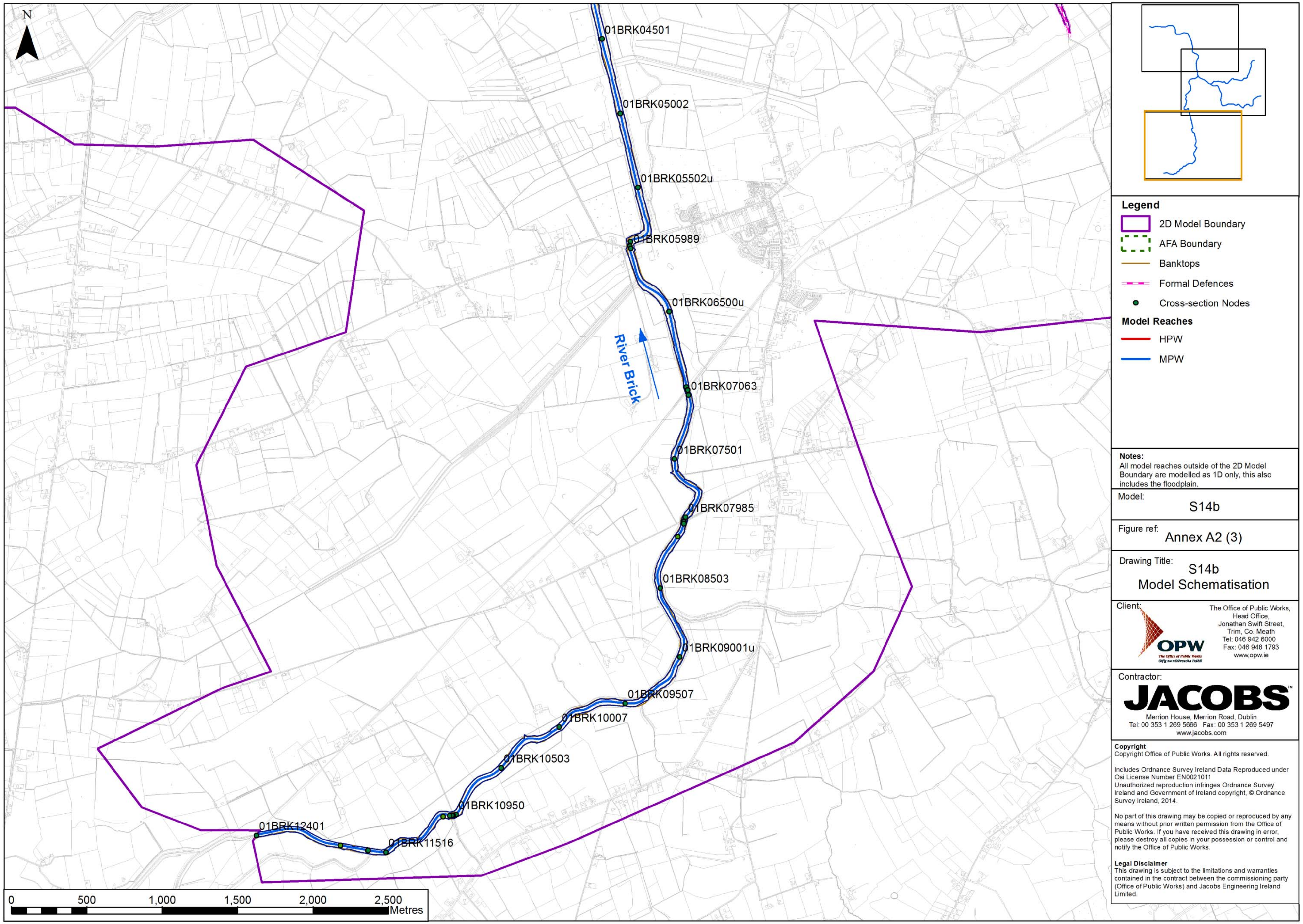
N
01BRK04501
01BRK05002
01BRK05502u
01BRK05989
01BRK06500u
River Brick
01BRK07063
01BRK07501
01BRK07985
01BRK08503
01BRK09001u
01BRK09507
01BRK10007
01BRK10503
01BRK10950
01BRK12401
01BRK11516
0
500
1,000
1,500
2,000
2,500
Metres
Legend
2D Model Boundary
AFA Boundary
Banktops
Formal Defences
Cross-section Nodes
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S14b
Figure ref:
Annex A2 (3)
Drawing Title:
S14b
Model Schematisation
Client:
The Office of Public Works,
Head Office,
Jonathan Swift Street,
Trim, Co. Meath
Tel: 046 942 6000
Fax: 046 948 1793
www,opw.ie
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Merrion House, Merrion Road, Dublin
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Annex B – Structure and Hydraulic Roughness Schedules

Schedule A.1 - Structure Schedule

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23FEAL00902D	01FEL04480	Bridge 5.70 m wide	USBPR bridge + Spill	Y
23FEAL00021D	02CHA00140	Bridge 8.31 m wide.	USBPR bridge + Spill	Y
23BRIK01111D	01BRK10972	4.24 m wide Bridge	Arch bridge with modified width	Y
23BRIK00815D	01BRK08017	3.63 m wide Bridge	Arch bridge + Spill	Y
23BRIK00716D	01BRK07029	4.5 m wide Bridge	Arch bridge + Spill	Y
23BRIK00611E	01BRK05969	6.0 m wide Bridge	Arch bridge + Spill	Y
23BRIK00211D	01BRK01977	7.0 m wide Bridge	USBPR bridge + Spill	Y
23GALE00447D	01GAL04351	9.4 m wide Bridge	Arch bridge + Spill	Y

Schedule B.1 – In-bank Manning's 'n' for HPW Network

River Name	Cross Sections	In-bank Roughness
River Cashen	01CHA02245 to 01CHA00000	0.030

Schedule B.2 – In-bank Manning's 'n' for MPW Network

River Name	Cross Sections	In-bank Roughness
River Galey	01GAL05410 to 01GAL00000	0.040
River Feale	01FEL06455 to 01FEL00000	0.035
River Cashen	03CHA01270 to 02CHA00111	0.035
River Cashen	01CHA05782 to 01CHA02245	0.030

Annex C - Model Calibration Summary Note

The aim of this technical note is to describe the calibration methodology applied to the S14b model and report on the results.

Calibration Methodology:

Hydrometric data recorded at two gauging stations on the River Cashen (Poulnahaha, station no. 23061) and the River Feale (Cashen Estuary, station no. 23068) has been used to calibrate the model. The entire modelled watercourse is classified as MPW.

Four historical events were found to be suitable for calibrating the S14b model for the sections of the model shown in Figure C.1. Of these, one event, February 1995 was not used due to water level data being unavailable. The model has therefore been calibrated using two out-of-bank events (January 2005 and Feb 2002). The model has been verified using an out-of bank-event that occurred in November 2009.

The S14a model was also used to generate flows for the calibration process and was truncated to cover the River Feale reach from station 23002 to its original downstream limit.

Peak water levels predicted by the hydraulic model were then compared against the observed water levels at gauging stations 23031 and 23061.

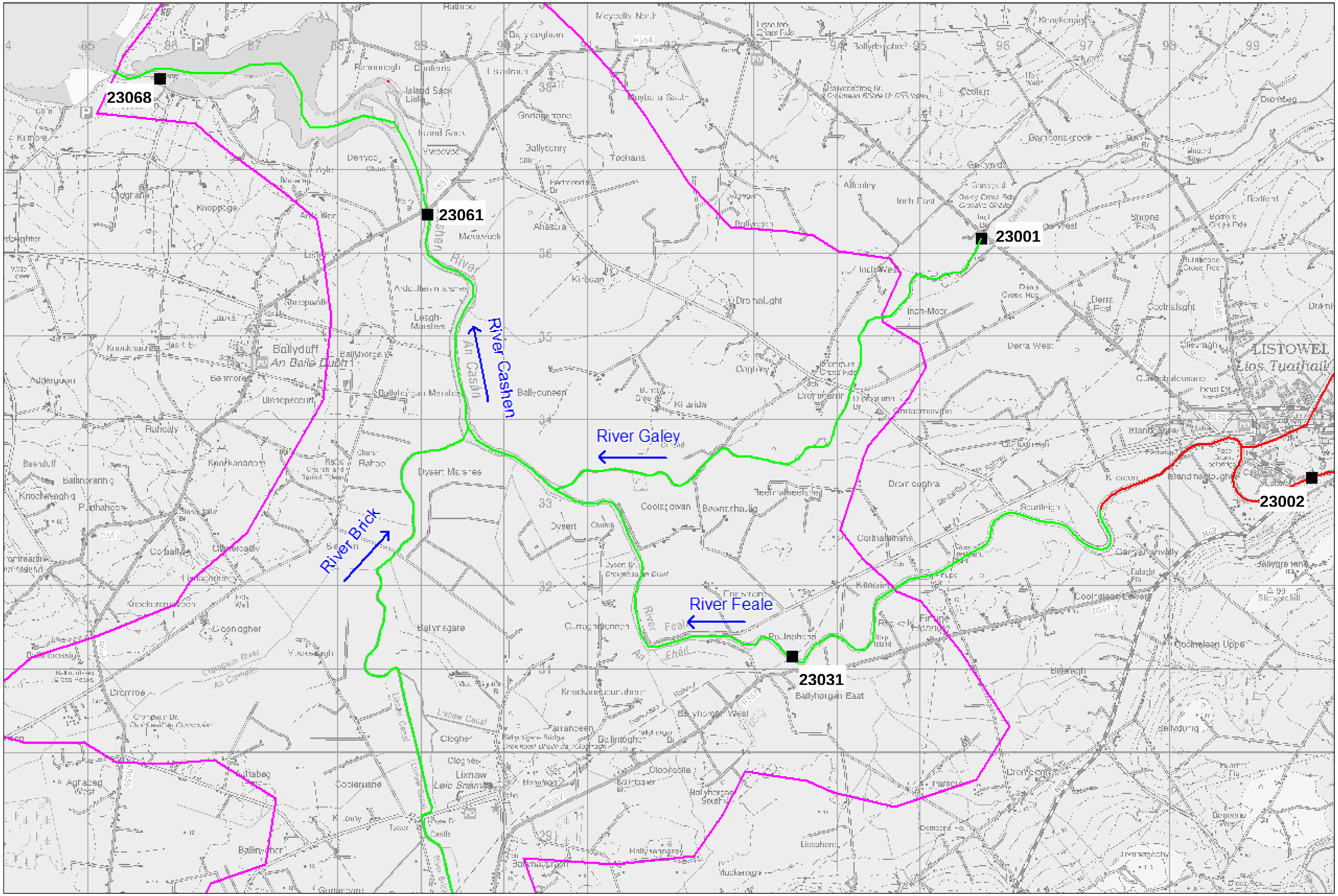


Figure C.1: S14b – Calibration map

Calibration of the Model

The model was calibrated to two out of bank historic events that occurred in January 2005 and February 2002.

Recorded flow data from Gauges 23002 and 23001 were used to inform model inflows on the River Feale and River Galey respectively. As there are no recorded flows available on the River Brick model, inflows for the calibration were estimated using the available design hydrology. A comparison of the recorded flows on the River Feale and Galey with the design event growth curve for each location, was used to allocate the return period event for use on the River Brick as follows:

- Feb 2002 = 50%AEP
- Jan 2005 = 10% AEP
- Nov 2009 = 10% AEP

Historic tidal levels from gauge 23068 were utilised as a downstream boundary for all events simulated.

In order to assess the model calibration for the January 2005 fluvial event observed water levels at gauge 23031 were compared to the modelled stage hydrograph (Table C.1). For the February 2005 tidal event observed water levels at gauge 23061 were compared to the modelled stage hydrograph (Table C.2).

Table C.1: Historical Fluvial Flood Event at Gauging Station 23031 (Poulnahaha)

Event	Historical Flood Event	Model Maximum Stage (m OD*)	Observed Maximum Stage (m OD*)	Difference (mm)
Out-of-bank	January 2005	4.11	4.16	-50

(* Datum relates to Malin Head)

Table C.2: Historical Tidal Flood Event at Gauging Station 23061 (Cashen Estuary)

Event	Historical Flood Event	Model Maximum Stage (m OD*)	Observed Maximum Stage (m OD*)	Difference (mm)
Out-of-bank	01 Feb 2002 08:00	3.16	3.19	-30
Out-of-bank	01 Feb 2002 19:45	2.79	2.71	+80
Out-of-bank	02 Feb 2002 08:30	2.76	2.76	0

(* Datum relates to Malin Head)

The stage results in Table C.1 and C.2 show that the modelled peak water levels accurately predict the observed water levels for both the fluvial and the tidal event. The Manning's 'n' values in the hydraulic model were adjusted to achieve this calibration.

From the stage hydrographs in Figures C.3 and C.4 below it can be seen that the model accurately simulates the time to peak for all events. Considering this, and the fact that the calibration was within required tolerances, no further changes were made to the hydraulic model.

Anecdotal evidence (UoM_23 Flood History and Key Environmental issues document) for the February 2002 event states that the Moneycashen Tidal wall overtopped and 3 to 4 houses plus the coast road received flooding. This situation is replicated by the model simulation which shows minor overtopping of the tidal wall as described (see Figure C.5)

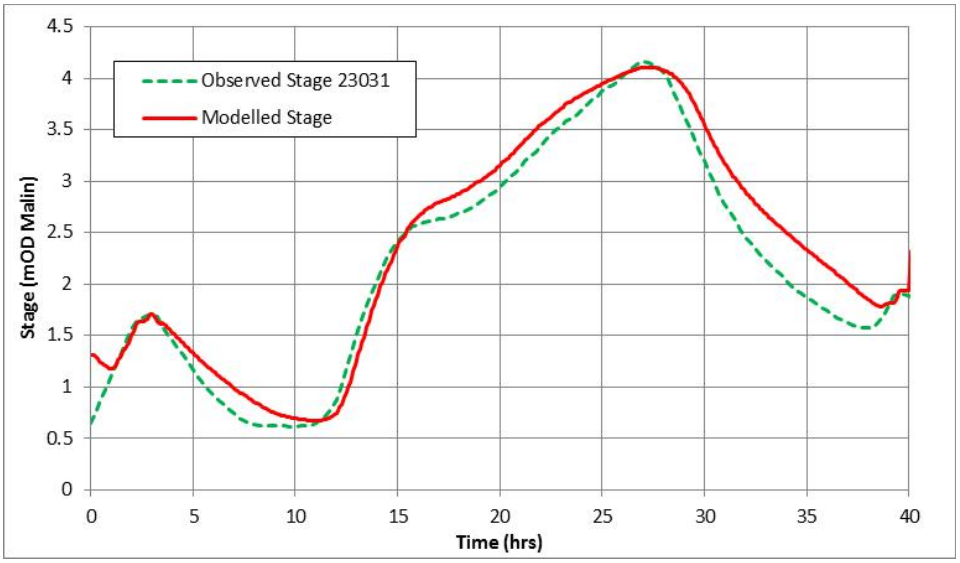


Figure C.3 - Modelled and observed water levels at Poulnahaha GS for the Jan 2005 event.

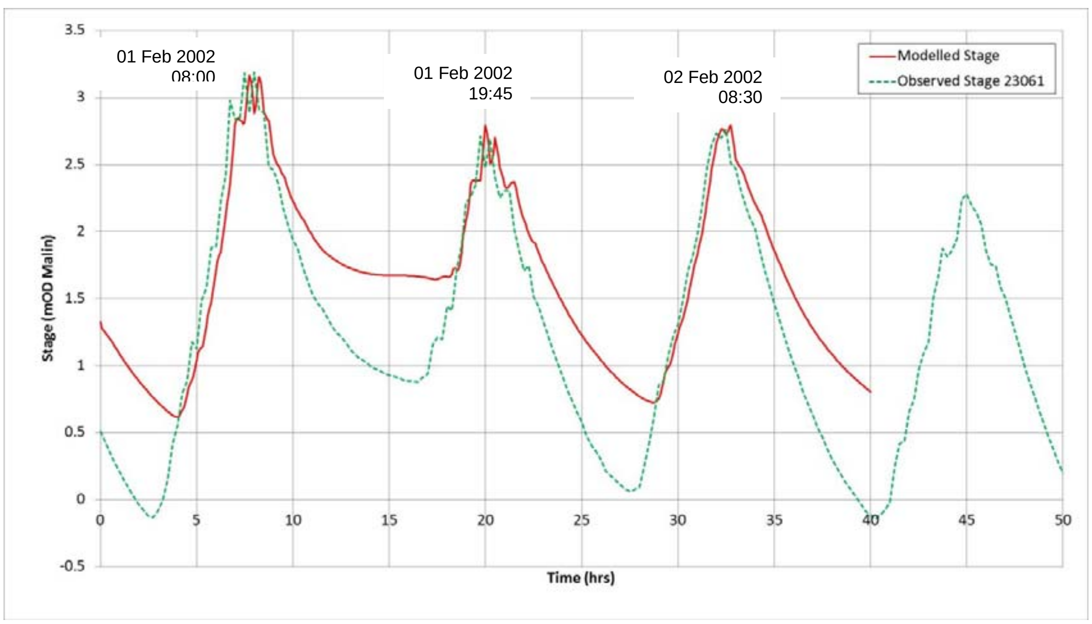


Figure C.4 - Modelled and observed water levels at Cashen Estuary GS for the February 2002 event.

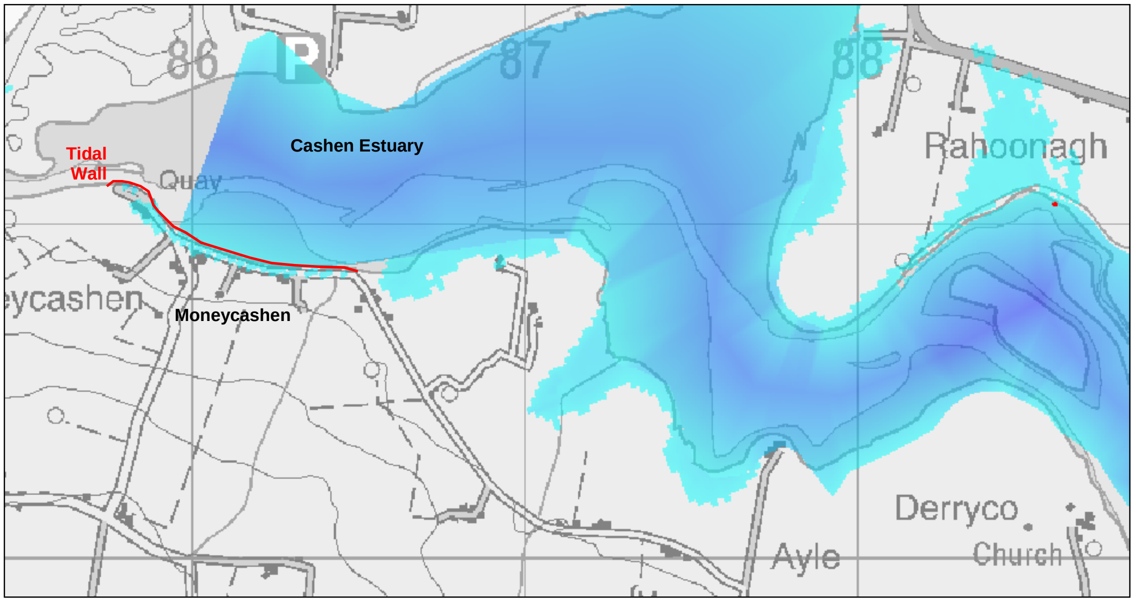


Figure C.5 – Modelled flood outline for the February 2002 Tidal Flood event at Moneycashen.

Verification of the Model

An out of bank event that occurred in November 2009 was used to verify the model. The methodology used for the verification is the same as for the calibration events.

The modelled and observed water levels for the November 2009 event are reported in Table C.3.The result suggests that the model replicates the November 2009 flood event successfully with the difference between modelled stage and observed stage of approximately 80mm and 20mm for the two main tidal peaks. Difference between the time of peak is +2hrs. The middle tidal peak is over-predicted by around 130mm. Overall, the model is verified satisfactorily to the 2009 event.

Table C.3: Verification Tidal Flood Event at Gauging Station 23061

Event	Historical Flood Event	Model Maximum Stage (m AOD*)	Observed Maximum Stage (m AOD*)	Difference (mm)
Out-of-bank	19 Nov 2009 02:30	2.55	2.53	+20
Out-of-bank	19 Nov 2009 15:30	2.74	2.61	+130
Out-of-bank	20 Nov 2009 03:15	2.34	2.26	+80

(*Datum is taken from Malin Head)

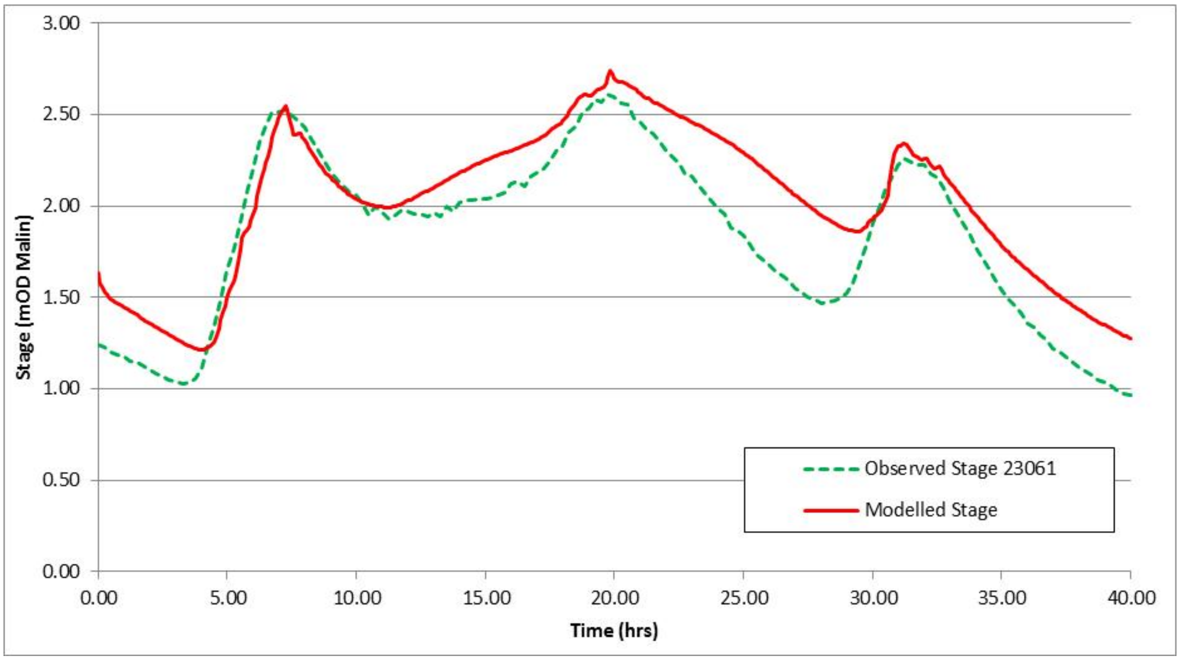


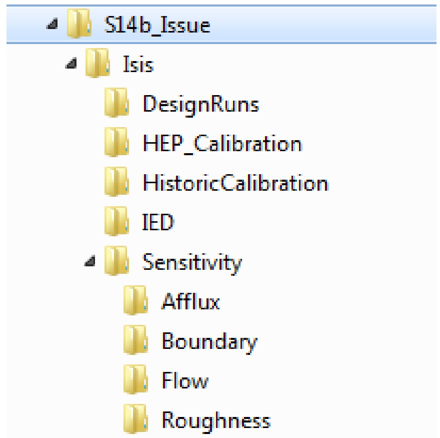
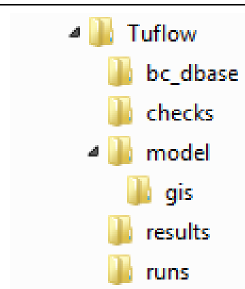
Figure C.6 - Modelled and observed water levels at Cashen Estuary GS for the November 2009 event.

Conclusions

It was possible to calibrate the model, for two out-of-bank historical events and one fluvial and one tidal, and to verify the model, for one tidal event out-of-bank event, along the MPW reaches of the River Cashen and River Feale.

The results suggest that the model calibrates well for both tidal and fluvial events with the modelled peak water levels over predicting the observed water levels within the acceptable range of +/-0.4m for a MPW for all events considered. The verification was also satisfactory.

Annex D - Hydraulic Model Files

Model Files Folders Structure	
ISIS	
TUFLOW	

ISIS Files	
Model Geometry (.dat) and Associated Files (e.g.: .ief, .zzl, .zzd, .zzu,.zzx)	**Design Runs – Fluvial Scenarios:** S14b_Moneycashen_Q2_FluMi_C_Des_ISS2.dat S14b_Moneycashen_Q5_FluMi_C_Des_ISS2.dat S14b_Moneycashen_Q10_FluMi_C_Des_ISS1.dat S14b_Moneycashen_Q20_FluMi_C_Des_ISS2.dat S14b_Moneycashen_Q50_FluMi_C_Des_ISS2.dat S14b_Moneycashen_Q100_FluMi_C_Des_ISS1.dat S14b_Moneycashen_Q200_FluMi_C_Des_ISS2.dat S14b_Moneycashen_Q1000_FluMi_C_Des_ISS1.dat **Design Runs – Tidal Scenarios:** S14b_Moneycashen_Q2_CoMi_C_Des_ISS2.dat S14b_Moneycashen_Q5_CoMi_C_Des_ISS2.dat S14b_Moneycashen_Q10_CoMi_C_Des_ISS1.dat S14b_Moneycashen_Q20_CoMi_C_Des_ISS2.dat S14b_Moneycashen_Q50_CoMi_C_Des_ISS2.dat S14b_Moneycashen_Q100_CoMi_C_Des_ISS1.dat S14b_Moneycashen_Q200_CoMi_C_Des_ISS2.dat S14b_Moneycashen_Q1000_CoMi_C_Des_ISS1.dat **Sensitivity Runs – Defended Current Scenario:** S14b_Q200_ CoMi_C_Sen_ SuDe_ISS1.dat

	S14b_Q200_ CoMi _C_Sen_ SuIn_ISS1.dat S14b_Q100_ FluMi _C_Sen_ FlDe_ISS1.dat S14b_Q100_ FluMi _C_Sen_ FlIn_ISS1.dat S14b_Q100_ FluMi_C_Sen_ RoDe_ISS1.dat S14b_Q100_ FluMi_C_Sen_ RoIn_ISS1.dat
Hydrological Inflow Files	**Current Fluvial Scenarios:** S14b_Q2_FluMi.IED S14b_Q5_FluMi.IED S14b_Q10_FluMi.IED S14b_Q20_FluMi.IED S14b_Q50_FluMi.IED S14b_Q100_FluMi.IED S14b_Q200_FluMi.IED S14b_Q1000_FluMi.IED **Current Tidal Scenarios:** S14b_Q2_CoMi.IED S14b_Q5_CoMi.IED S14b_Q10_CoMi.IED S14b_Q20_CoMi.IED S14b_Q50_CoMi.IED S14b_Q100_CoMi.IED S14b_Q200_CoMi.IED S14b_Q1000_CoMi.IED **Sensitivity Scenarios:** S14b_Q100_FluMi_Sen_FlDe.IED S14b_Q100_FluMi_Sen_FlIn.IED S14b_Q200_CoMi_Sen_SuDe.IED S14b_Q200_CoMi_Sen_SuIn.IED

TUFLOW files	
TUFLOW Control Files (.tcf) and Associated Files (e.g.: ecf, tgc, tbc)	**Design runs – Fluvial scenarios:** S14b_Moneycashen_Q2_FluMi_C_Des_ISS2.tcf S14b_Moneycashen_Q5_FluMi_C_Des_ISS2.tcf S14b_Moneycashen_Q10_FluMi_C_Des_ISS1.tcf S14b_Moneycashen_Q20_FluMi_C_Des_ISS2.tcf S14b_Moneycashen_Q50_FluMi_C_Des_ISS2.tcf S14b_Moneycashen_Q100_FluMi_C_Des_ISS1.tcf S14b_Moneycashen_Q200_FluMi_C_Des_ISS2.tcf S14b_Moneycashen_Q1000_FluMi_C_Des_ISS1.tcf **Design runs – Tidal scenarios:** S14b_Moneycashen_Q2_CoMi_C_Des_ISS2.tcf S14b_Moneycashen_Q5_CoMi_C_Des_ISS2.tcf S14b_Moneycashen_Q10_CoMi_C_Des_ISS1.tcf S14b_Moneycashen_Q20_CoMi_C_Des_ISS2.tcf S14b_Moneycashen_Q50_CoMi_C_Des_ISS2.tcf S14b_Moneycashen_Q100_CoMi_C_Des_ISS1.tcf S14b_Moneycashen_Q200_CoMi_C_Des_ISS2.tcf S14b_Moneycashen_Q1000_CoMi_C_Des_ISS1.tcf

	Sensitivity Runs – Defended Current Scenario: S14b_Q200_ CoMi_C_Sen_ SuDe_ISS1.tcf S14b_Q200_ CoMi _C_Sen_ SuIn_ISS1.tcf S14b_Q100_ FluMi _C_Sen_ FlDe_ISS1.tcf S14b_Q100_ FluMi _C_Sen_ FlIn_ISS1.tcf S14b_Q100_ FluMi_C_Sen_ RoDe_ISS1.tcf S14b_Q100_ FluMi_C_Sen_ RoIn_ISS1.tcf
Grid Orientation File	2d_loc_S14-b_0-01.TAB
Material Files	2d_mat_S14-b_0-02.TAB S14-b_landuse.tmf S14-b_landuse_RoDe.tmf S14-b_landuse_RoIn.tmf
Zpt Files, Model DTM (.asc)	S14_b_MPW_SAR.asc moneyca2m_dtm.asc S15_SAR.asc
Breaklines Files	2d_zlr_S14_b_banktopsfromLiDAR_0-01.MIF 2d_zlr_S14-b_banktopsfromSAR_0-02.MIF 2d_zlr_S14-b_defencesfromSAR_0-01.MIF 2d_zlr_S14-b_defencesfromxs_0-03.MIF 2d_zlr_S14-b_defences_0-05.MIF 2d_zlr_S14-b_mc_defences_0-01.MIF
Boundary Files	2d_code_S14-b_0-02.MIF 2d_bc_hxi_S14-b_int_0-05.TAB 2d_bc_HT_4m_S18_Kilr.MIF 2d_bc_HQ_4m_S18_Kilr.MIF
One Dimensional Network Files	1d_nwk_S14-b_0-02.MIF
Available 2D Result Files	Depth, stage, hazard and velocity 2d results in ASCII file format for all available design return periods.

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
Design Runs						
1	S14b_Moneycashen_Q2_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Large mass balance error when the Qi starts but is deemed acceptable
2	S14b_Moneycashen_Q5_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
3	S14b_Moneycashen_Q10_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
4	S14b_Moneycashen_Q20_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
5	S14b_Moneycashen_Q50_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
6	S14b_Moneycashen_Q100_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
7	S14b_Moneycashen_Q200_FluMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
8	S14b_Moneycashen_Q1000_FluMi_C_Des_ISS2	0	55	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
Design Runs						
9	S14b_Moneycashen_Q2_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Large mass balance error when the Qi starts but is deemed acceptable
10	S14b_Moneycashen_Q5_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
11	S14b_Moneycashen_Q10_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
12	S14b_Moneycashen_Q20_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
13	S14b_Moneycashen_Q50_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
14	S14b_Moneycashen_Q100_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
15	S14b_Moneycashen_Q200_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	
16	S14b_Moneycashen_Q1000_CoMi_C_Des_ISS2	0	45	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	

Sr.	Model File Name	Start	End	Time	Advanced Options /Other Information	Comments on Model

No.		Time	Time	step		Stability
			Calibration			
17	S14-b_Feb02_Cal_v3.DAT	0	40	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
18	S14-b_Jan05_Cal_v2.DAT	0	40	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
19	S14-b_Nov09_Cal_v2.DAT	0	55	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
			Sensitivity Analysis			
	S14b_Q200_ CoMi_C_Sen_ SuDe_ISS1.dat	0	50	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
	S14b_Q200_ CoMi _C_Sen_ SuIn_ISS1.dat	-6	55	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
	S14b_Q100_ FluMi _C_Sen_ FlDe_ISS1.dat	0	50	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
	S14b_Q100_ FluMi _C_Sen_ FlIn_ISS1.dat	0	50	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
	S14b_Q100_ FluMi_C_Sen_ RoDe_ISS1.dat	0	50	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.
	S14b_Q100_ FluMi_C_Sen_ RoIn_ISS1.dat	0	50	2 sec 1D 5 sec 2D	"perform corrective 1d timestep" is checked. All other run parameters = default.	Convergence within manufacturer tolerance.

Parameters changed from Default	Justification
Perform Corrective 1D Timestep	Used to improve model stability.*

*Stage and Flow profiles at all cross sections have been checked to ensure results are sensible and to ensure any changes to the default model run parameters has not impacted on the model results.

Annex E - Flood Mapping

Flood Maps are available through the OPW flood mapping website; http://maps.opw.ie/fhrm/

Fluvial and Coastal Hydraulic Modelling Report

1. Basic Model Information

1.1 General Information	
Model ID:	S16
Unit of Management	23
AFAs included in the Model	Tralee
Primary Watercourses / Water Bodies	River Big River Lee Ballynabrennagh Cloghers Caherweesheen Ballyvelly Hospital Tralee Tralee Ratass Ballydunlea

1.2 Reference to other Relevant Reports	
Catchment Description	Hydrology Report Unit of Management 23 – Appendix A2.1
Model Location	Hydraulics Report Unit of Management 23 – Section 3.4.2
HEP Schematisation	Hydrology Report Unit of Management 23 – Appendix B5 – Figure B5.1

2. Survey Data and Base Mapping

2.1 Base Mapping:	OSi data base mapping at scale 1:50k Reference: OS5521_b, OS5521_d, OS5522_a, OS5522_b, OS5522_c, OS5522_d, OS5587_a, OS5587_b, OS5587_c, OS5587_d, , OS5588_a, OS5588_b, OS5588_c, OS5588_d, , OS5657_b, OS5658_a,	
2.2 DTM for 2D Model Domain:	**Within AFAs:** LiDAR data with 2m horizontal resolution and approximately 200mm vertical accuracy has been used to inform the hydraulic model with ground elevation in the floodplain areas included in the AFA boundary	
	Outside AFAs: The above LIDAR data also provided coverage outside of the AFA boundary.	
2.3 River Channel/Structures Survey	General information on the topographic survey of the river channel and structures are included in the main Hydraulics Report. Full details of the survey outputs are provided in the topographic survey deliverables, as required under Section 5.2 of the Stage I Project Brief. Number of cross-sections included in this model: 556	

Location **2.4 Defence Asset Survey Data**	The defence asset database has been completed for this model and defences are present on the right bank of the river Lee from R551 to downstream of the River Lee near Blennerville town and on the left bank of the River Lee near the Steam Railway Area. The defences are shown on the figures in Annex A2. Various details from the defence asset database (for example, defence level crest heights) have been incorporated into the hydraulic model where appropriate. It should be noted that some HPW reaches have no defence assets. The defence asset database is provided as a separate deliverable to this report, and contains further details on the defences identified.
2.5 Survey interaction	The Lidar, IFSAR and topographic survey were checked for anomalies, and to ensure that interactions between were within expected tolerances. No issues were identified in this model.

3. Hydraulic Model Construction and Schematisation

3.1 Software:	**1D domain:**	InfoWorks ICM 4.5
	2D domain(s):	InfoWorks ICM 4.5
3.2 Model Area / Extent:	The areal extent of the model and its schematisation are shown in Annex A.	

The mapping details for the model extent included in Annex A are as follows:

1. **Full modelled area showing**:
   - River centre lines, HPW extents, names of watercourses
   - 2D domain area
   - AFA boundary
2. **Maps showing a detailed model schematic of the HPW reaches are also included**

3.3 Model Reaches: The following model reaches as shown on the maps referred above have been defined in the model:

Watercourse Name	Reach	Upstream Model Node	Downstream Model Node
River Lee	05LEE	05LEE00647	05LEE00000
	04LEE	04LEE01199	04LEE00000
	03LEE	03LEE01898	03LEE00000
	02LEE	02LEE01191	02LEE00000
	01LEE	01LEE00900	01LEE00000
River Big	02BIG	02BIG05264	02BIG00000
River Big	01BIG	01BIG00228	01BIG00000
Ballynabrennagh	02BNR	02BNR00746	02BNR00000
Ballynabrennagh	01BNR	01BNR01019	01BNR00000
Cloghers	02CGH	02CGH00489	02CGH00000
Cloghers	01CGH	01CGH01266	01CGH00000
Caherweesheen	01CWS	01CWS00499	01CWS00000
Ballyvelly	02BLV	02BLV00702	02BLV00000
Ballyvelly	02BLV	01BLV02604	01BLV00000
Hospital Tralee	01HPT	01HPT01216	01HPT00000
Tralee	02TLE	02TLE01135	02TLE00000
Tralee	01TLE	02TLE00736	02TLE00000
Ratass	01RTS	01RTS02052	01RTS00000
Ballydunlea	01BLD	01BLD01034	01BLD00000
Total model HPW length (km):		21.17	

3.4 Model Structures:	A full schedule of structures included in the model is provided in Schedule A in Annex B. A summary of the structures included is given below: **Culverts:** ☒ How many? 21 **Bridges:** ☒ How many? 34 **Fixed crest weirs:** ☒ How many? 6 **Adjustable crest weirs:** ☐ How many? 0 **Sluice / Gate structures:** ☐ How many? 0 **Locks:** ☐ How many? 0 **Dams:** ☐ How many? 0 **Other (describe):** ☐ How many? 0 **Vertical trash screen** ☒ How many? 3
3.5 Floodplain Schematisation	Out-of-bank areas for HPW reaches have been modelled using a 2D approach as set in the InfoWorks ICM model. The general lines "2D zone extension" and "2D Zone Ext2"were drawn to aid limiting the extent of the 2D Zone. They do not play any role or affect the hydraulic model results. An overview of the floodplain schematisation is available in the maps shown in Annex A.
3.6 2D Domain Grid Size:	The number of 2D domains defined and the grid sizes of each 2D model domain are as follows: **Number of 2D domains: 1** **Domain 1:** Maximum grid cell size (m2) 100 | Area (ha) 1790 2D domains are defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. Tralee has been modelled with terrain-sensitive flexible meshing. The minimum element area is $2m^2$ and maximum element area of 100 m^2. The smaller element sizes are used in very urbanised areas where there are multiple features that could not be suitably represented with a larger grid.
3.7 Model Breaklines in the 2D Domain:	Only the ‘effective’ defences were modelled as the embankments adjacent to watercourses and other similar defence levels were picked up by the DTM and the model mesh.
3.8 Floodplain Structures in the 2D Domain	No 1D elements have currently been included in the 2D model to represent structures or underpasses. Information on how buildings were included in the 2D domain is included in Section 3.4.10 of the main Hydraulics Report.
3.9 Hydraulic Roughness	Hydraulic roughness (Manning’s ‘n’) has been defined in accordance with the approaches described in Section 3.4.10 of the main Hydraulics Report. Details of the values adopted for this model are included in Schedule B in Annex B. The Manning's values have been applied using vector mapping data. A summary of Manning’s ‘n’ for the model as a whole is as follows:
HPW in-bank	Minimum ‘n’ value: 0.030 Maximum ‘n’ value: 0.050
Floodplain (ICM Model - 1D River Reach)	Manning’s ‘n’ for out of bank areas represented in the ICM model are as defined by EPA land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in the 1D River Reach in ICM are as follows:

	Land use	**Manning's 'n' value**
	Pastures	0.035
	Dense Vegetation	0.080
	Road Network	0.020
	Buildings	0.100
Floodplain (ICM Model - 2D Zone)	Manning's 'n' for out of bank areas represented in the ICM model are as defined by OSi NTF land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in the 2D zone are as follows:	
	Land use	**Manning's 'n' value**
	Buildings	0.100
	Short grass, parks	0.030
	General Urban	0.060
	General Rural	0.045
	Pastures	0.035
	Dense Vegetation	0.080
	Roads	0.025
	Railways	0.050
	Water bodies	0.020
3.10 Spill Units	• Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain). • Spill profile geometry is defined using topographic survey data and LiDAR/IfSAR. • Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can be also found to account for lateral spilling perpendicular to the main direction of flow.	
3.11 Model Boundaries - Inflows	Full details of the flow estimates and flow hydrographs are provided in the Hydrology Report. Summary details are included within this section.	
(a) Current Situation	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for the current situation.	

HEP Reference Name	**Input Node in the Hydraulic Model**	**Annual Exceedence Probability**							
		50%	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1%**
23_1521_1	05LEE00647	16.1	19.9	22.4	24.8	27.9	30.3	32.6	37.9
23_1521_2	05LEE00099	6.7	8.2	9.3	10.3	11.6	12.5	13.5	15.7
23_1520_1	04LEE01083	6.0	7.4	8.4	9.3	10.4	11.3	12.2	14.2
23_1556_2	02TLE01135	6.1	7.6	8.6	9.6	10.8	11.8	12.7	14.8
23_1556_3	02TLE00635	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0
23_2649_0	01RTS00462	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
23_2649_1	01RTS00012	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3
23_2649_2	01TLE00267	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5
23_2698_5	02BNR00746	3.2	4.0	4.5	5.0	5.7	6.1	6.6	7.7

23_2728_5	02CGH00489	4.5	5.7	6.5	7.2	8.2	8.9	9.6	11.2
23_2728_6	01CGH01250	3.7	4.7	5.3	5.9	6.7	7.3	7.9	9.2
23_1551_3	01CWS00499	6.1	7.7	8.7	9.7	11.0	11.9	12.9	15.1
23_2349_2	02BIG05264	3.3	4.2	4.8	5.3	6.0	6.6	7.1	8.3
23_2349_3	02BIG04972	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9
23_2349_4	02BIG04405	4.7	5.9	6.7	7.5	8.4	9.2	9.9	11.6
23_2727_2	02BIG03817	2.7	3.4	3.9	4.3	4.9	5.3	5.7	6.7
23_2612_2	01BIG00137	2.9	3.7	4.2	4.6	5.2	5.7	6.2	7.2
23_2612_3	01BIG00028	4.3	5.4	6.1	6.8	7.7	8.4	9.0	10.5
23_2922_1	03LEE00461	32.1	39.6	44.6	49.4	55.6	60.2	64.8	75.5
23_2647_2	02LEE00608	0.7	0.9	1.0	1.1	1.3	1.4	1.5	1.7
23_2375_1	01HPT01216	1.6	2.0	2.3	2.6	2.9	3.2	3.4	4.0
23_2375_2	01HPT00834	2.0	2.5	2.9	3.2	3.6	3.9	4.2	5.0
23_673_1	02BLV00702	1.8	2.3	2.6	2.9	3.3	3.6	3.9	4.6
23_587_3	01CWS00499	8.8	11.1	12.6	14.1	16.0	17.4	18.8	22.1
23_2409_1	01BLV02467	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7
23_2409_2	01BLV02053	0.3	0.4	0.4	0.5	53.0	0.6	0.6	0.7
23_2409_3	01BLV01566	4.6	5.8	6.6	7.4	8.4	9.1	9.9	11.6

(b) Future Scenarios

The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for all return periods for the MRFS. These events are selected as these are the MRFS that are to be mapped

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		MRFS							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_1521_1	05LEE00647	19.3	23.9	26.9	29.8	33.5	36.3	39.1	45.5
23_1521_2	05LEE00099	8.0	9.9	11.1	12.3	13.9	15.0	16.2	18.8
23_1520_1	04LEE01083	7.2	8.9	10.0	11.1	12.5	13.6	14.6	17.0
23_1556_2	02TLE01135	7.4	9.2	10.4	11.5	13.0	14.1	15.2	17.8
23_1556_3	02TLE00635	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
23_2649_0	01RTS00462	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7
23_2649_1	01RTS00012	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3
23_2649_2	01TLE00267	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5
23_2698_5	02BNR00746	3.8	4.8	5.4	6.0	6.8	7.4	7.9	9.3
23_2728_5	02CGH00489	5.5	6.9	7.8	8.7	9.8	10.7	11.5	13.5
23_2728_6	01CGH01250	4.5	5.6	6.4	7.1	8.0	8.7	9.4	11.0
23_1551_3	01CWS00499	7.3	9.2	10.4	11.6	13.1	14.3	15.4	18.1
23_2349_2	02BIG05264	4.0	5.0	5.7	6.4	7.2	7.9	8.5	10.0
23_2349_3	02BIG04972	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1
23_2349_4	02BIG04405	5.6	7.1	8.0	8.9	10.1	11.0	11.9	14.0

23_2727_2	02BIG03817	3.2	4.1	4.6	5.2	5.8	6.4	6.9	8.1
23_2612_2	01BIG00137	3.5	4.4	5.0	5.5	6.3	6.8	7.4	8.7
23_2612_3	01BIG00028	5.1	6.4	7.3	8.1	9.2	10.0	10.8	12.6
23_2922_1	03LEE00461	38.5	47.5	53.5	59.2	66.7	72.3	77.8	90.6
23_2647_2	02LEE00608	0.9	1.1	1.2	1.3	1.5	1.6	1.8	2.1
23_2375_1	01HPT01216	1.9	2.4	2.8	3.1	3.5	3.8	4.1	4.8
23_2375_2	01HPT00834	2.4	3.0	3.4	3.8	4.3	4.7	5.1	5.9
23_673_1	02BLV00702	2.2	2.8	3.1	3.5	4.0	4.3	4.7	5.5
23_587_3	01CWS00499	10.5	13.3	15.1	16.9	19.1	20.8	22.5	26.5
23_2409_1	01BLV02467	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.8
23_2409_2	01BLV02053	0.4	0.4	0.5	0.6	63.6	0.7	0.7	0.9
23_2409_3	01BLV01566	5.5	7.0	7.9	8.9	10.1	10.9	11.8	13.9

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for 10%, 1% and 0.1% events for the HEFS. These events are selected as these are the HEFS that are to be mapped.

HEP Reference Name	Input Node in the Hydraulic Model	HEFS Annual Exceedance Probability		
		10%	**1%**	**0.1%**
23_1521_1	05LEE00647	29.1	39.3	49.3
23_1521_2	05LEE00099	12.1	16.3	20.4
23_1520_1	04LEE01083	10.9	14.7	18.4
23_1556_2	02TLE01135	11.2	15.3	19.2
23_1556_3	02TLE00635	0.8	1.1	1.3
23_2649_0	01RTS00462	0.4	0.6	0.8
23_2649_1	01RTS00012	0.2	0.3	0.4
23_2649_2	01TLE00267	0.3	0.5	0.6
23_2698_5	02BNR00746	5.9	8.0	10.0
23_2728_5	02CGH00489	8.4	11.5	14.6
23_2728_6	01CGH01250	6.9	9.5	12.0
23_1551_3	01CWS00499	11.3	15.5	19.6
23_2349_2	02BIG05264	6.2	8.5	10.8
23_2349_3	02BIG04972	0.7	1.0	1.2
23_2349_4	02BIG04405	8.7	11.9	15.1
23_2727_2	02BIG03817	5.0	6.9	8.7
23_2612_2	01BIG00137	5.4	7.4	9.4
23_2612_3	01BIG00028	7.9	10.9	13.7
23_2922_1	03LEE00461	58.0	78.3	98.2
23_2647_2	02LEE00608	1.3	1.8	2.2

23_2375_1	01HPT01216	3.0	4.1	5.2
23_2375_2	01HPT00834	3.7	5.1	6.4
23_673_1	02BLV00702	3.4	4.7	6.0
23_587_3	01CWS00499	16.4	22.6	28.7
23_2409_1	01BLV02467	0.5	0.7	0.9
23_2409_2	01BLV02053	0.5	0.7	0.9
23_2409_3	01BLV01566	8.6	11.9	15.1

3.12 Model Boundaries – Downstream Conditions	Downstream boundary conditions adopted in the model are as follows:
	Tidal level hydrographs for Tralee were produced for a series of design events using ICPSS extreme tidal peak levels data. The time series were set up as boundary conditions for the hydraulic model along the coastal boundary of the hydraulic model. This was applied to both the 1D river reach and the 2D zone boundary. In the wider 2D zone normal conditions were applied to allow for free flow out of the floodplain. Full details on how these tidal level hydrographs were derived are provided in Appendix D of the main Hydraulics Report. Peak tidal levels are summarised in the table below for the current and future situations. For the wave overtopping model, wave overtopping hydrographs have been applied directly to the hydraulic model using a flow versus time boundary along the landward side of the flood defences. The hydrographs vary for different points along the defence as shown in Annex F. Full details on how these tidal level hydrographs were derived are provided in section 4.4 of the main Hydraulics Report. The tidal hydrographs applied for wave overtopping are available in Annex F of this report.

	Current Annual Exceedance Probability							
Peak tidal levels (m OD)	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1%**
	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.6
	MRFS Annual Exceedance Probability							
Peak tidal levels (m OD)	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1%**
	3.4	3.5	3.6	3.7	3.8	3.8	3.9	4.1
	HEFS Annual Exceedance Probability							
Peak tidal levels (m OD)	**10%**	**0.5%**	**0.1%**					
	4.1	4.4	4.6					

4. Hydraulic Model Calibration and Sensitivity

4.1 Model Calibration and Verification to Historical Events	The approach to model calibration is documented in the Main Report. The analysis of available flood event data and high flow data for possible consideration as calibration and verification events is covered in detail in the Hydrology report. A summary of the calibration and verification events along with associated model calibration results is as follows: Due to the lack of calibration data, a calibration of the model was not carried out. A verification of the results was carried out against reported flood locations for the 2008 and 2011 flood events. This verification although limited to a comparison of locations of historic flooding compared to the modelled outputs, the areas reported were also shown as flooded.
Catchment Gauging	Is modelled catchment: Gauged ☒ Ungauged ☐ *check one box only*
4.2 Calibration to HEP	Calibration of the hydraulic model to the HEP has been carried out for the design events simulated. Total peak flows predicted by the hydraulic model at appropriate locations were compared to the HEP predictions. The Caherweesheen reach was the only reach were HEP calibration was possible. Reaches in the north of Lee and Lee itself have hydrology impacted by the hydraulics and subsequently they cannot be HEP calibrated. Flow estimates are for natural catchments whereas the rivers in these reaches are highly modified. In addition to these issues, Reach 5 is tidally dominated and thus could not be HEP calibrated. The calibration of Reach 3 shows perfect calibration for all return periods as the modelled reach is very short and there is no attenuation or loss.
4.3 Model Sensitivity	Sensitivity tests have been carried out in order to assess the sensitivity of the predicted peak water levels to alterations in roughness (Manning's 'n'), fluvial flow, afflux at key structures and downstream conditions. The sensitivity runs were carried out for the 1% AEP fluvial dominated event with the corresponding tidal event from the joint probability study in all cases with the only exception of the tests on the downstream boundary conditions, which were carried out for the 0.5% AEP tidal dominated events with the corresponding fluvial event. Sensitivity test results are provided in the following tables. Uncertainty maps illustrating the results of the sensitivity analysis will be delivered as part of the final stage of this work.

	Watercourse	Average Water Level Difference (m)	Maximum Water Level Difference (m)	Cross-section / Reach where the Maximum Difference occurs
+20% Manning's 'n'	River Ballydunlea	0.06	0.10	01BLD00126
	River Ballynabrennagh	0.09	0.20	01BNR00312
	River Ballyvelly	0.02	0.14	01BLV02604
	River Big	0.04	0.13	02BIG04693
	River Caherweesheen	0.09	0.10	01CWS00012
	River Cloghers	0.17	0.22	01CGH00446
	River Mackies	0.05	0.10	01HPT00834
	River Lee	0.09	0.29	04LEE00806
	River Ratass	0.03	0.16	01RTS00370
	River Tralee	0.04	0.18	02TLE00941

-20% Manning's 'n'	Watercourse	Average Water Level Difference	Maximum Water Level Difference	Cross-section where the Maximum Difference occurs
	River Ballydunlea	-0.07	-0.11	01BLD00126
	River Ballynabrennagh	-0.19	-0.33	01BNR00610D
	River Ballyvelly	-0.01	-0.18	01BLV02604
	River Big	-0.04	-0.18	02BIG04693
	River Caherweesheen	-0.11	-0.15	01CWS00409
	River Cloghers	-0.15	-0.23	01CGH00032D
	River Mackies	-0.06	-0.13	01HPT00980
	River Lee	-0.11	-0.34	04LEE01083
	River Ratass	-0.11	-0.17	01RTS000370
	River Tralee	-0.15	-0.31	01TLE00086U
+20% Inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Ballydunlea	0.08	0.11	01BLD00808U
	River Ballynabrennagh	0.05	0.18	01BNR00312
	River Ballyvelly	0.04	0.15	01BLV02467
	River Big	0.15	0.50	02BIG01178I
	River Caherweesheen	0.10	0.11	01CWS00012
	River Cloghers	0.16	0.21	01CGH00591
	River Mackies	0.14	0.96	01HPT00577I
	River Lee	0.08	0.35	05LEE00171
	River Ratass	0.02	0.07	01RTS00493
	River Tralee	0.03	0.18	02TLE00941
-20% Inflows	**Watercourse**	**Average Water Level Difference**	**Maximum Water Level Difference**	**Cross-section where the Maximum Difference occurs**
	River Ballydunlea	-0.08	-0.12	01BLD00808U
	River Ballynabrennagh	-0.37	-0.48	02BNR00070
	River Ballyvelly	-0.04	-0.16	01BLV02467
	River Big	-0.21	-1.46	02BIG01113D
	River Caherweesheen	-0.09	-0.14	01CWS00409
	River Cloghers	-0.14	-0.24	02CGH00096
	River Mackies	-0.14	-0.66	01HPT00577I
	River Lee	-0.13	-0.44	05LEE00171
	River Ratass	-0.31	-0.49	01RTS00012
	River Tralee	-0.27	-0.63	01TLE00086U
Afflux at Key Structure	No structures were identified with significant afflux within the AFA.			
Downstream Conditions Duration of the surge component of tidal boundary is increased by 100%	The change to the downstream conditions causes a maximum increase in peak stage of 0.013m at the downstream end of the River Lee. This is considered to be a negligible increase.			

Downstream Conditions Duration of the surge component of tidal boundary is decreased by 50%	The change to the downstream conditions causes a maximum decrease in peak stage of -0.007m at the downstream end of the River Lee. This is considered to be a negligible increase.
4.4 Model Files	The hydraulic model files associated with this model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. The model files included are detailed in Annex D. The model provided will contain multiple result files (relating to a single model "scenario"/or Build). The results files included in the database will follow the naming convention provided in the model run log(as with the associated tidal, Flu etc) but the specific return period and details associated with the overall model/database file name need to be either generalised or removed (as all of the above information will be contained within it).

5. Hydraulic Model Outputs

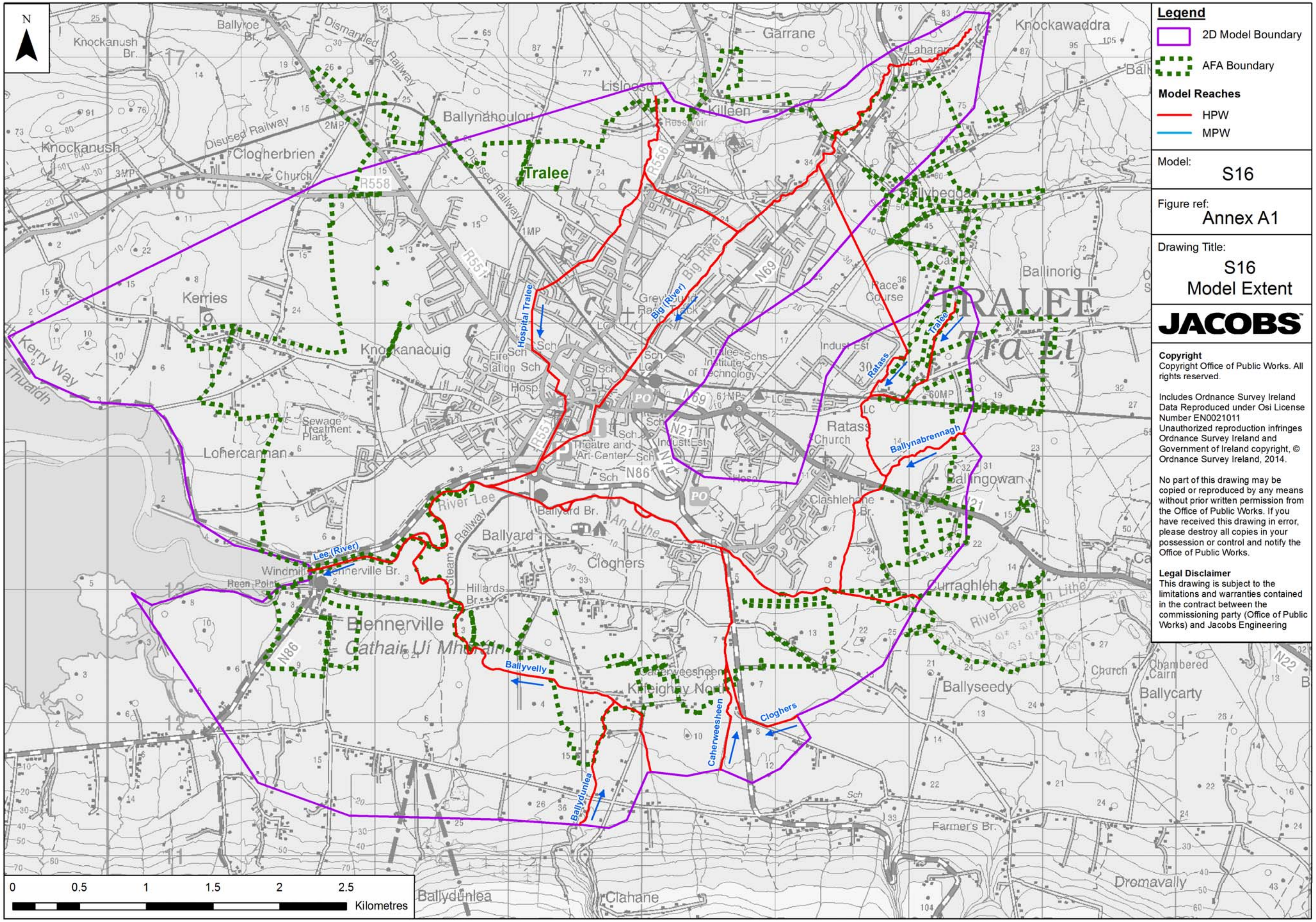
5.1 Mapping	Model outputs were processed to produce a series of flood maps according to the requirements stated in the Stage I Project Brief under Section 7.5.2. This includes mapping outputs covering: • Flood extents • Flood depth and velocity • Flood hazard • Wave overtopping Mapping outputs corresponding to the 10%, 1% and 0.1% AEP flood events are shown in Annex E for flood extent and depth.

6. Key Model Assumption and Limitations

- Informal, inefficient features such as parapets, stub walls and 1D structures in the flood plain have not been included in the S16 model.
- Historical information was used for verification purposes only and the model was not calibrated. This was due to the limited historical calibration information available in Tralee. As mentioned in Section 4, the conclusions from the verification were that there was a good match with the modelled flood extents and the reported historical flood locations. Due to the lack of historical data, this model was not calibrated and should additional information become available, further assessment should be carried out.

Annex A – Model Extent and Schematisation Maps

Annex A1 – Model Extent


Legend
2D Model Boundary
AFA Boundary
Model Reaches
HPW
MPW
Model:
S16
Figure ref:
Annex A1
Drawing Title:
S16
Model Extent
JACOBS
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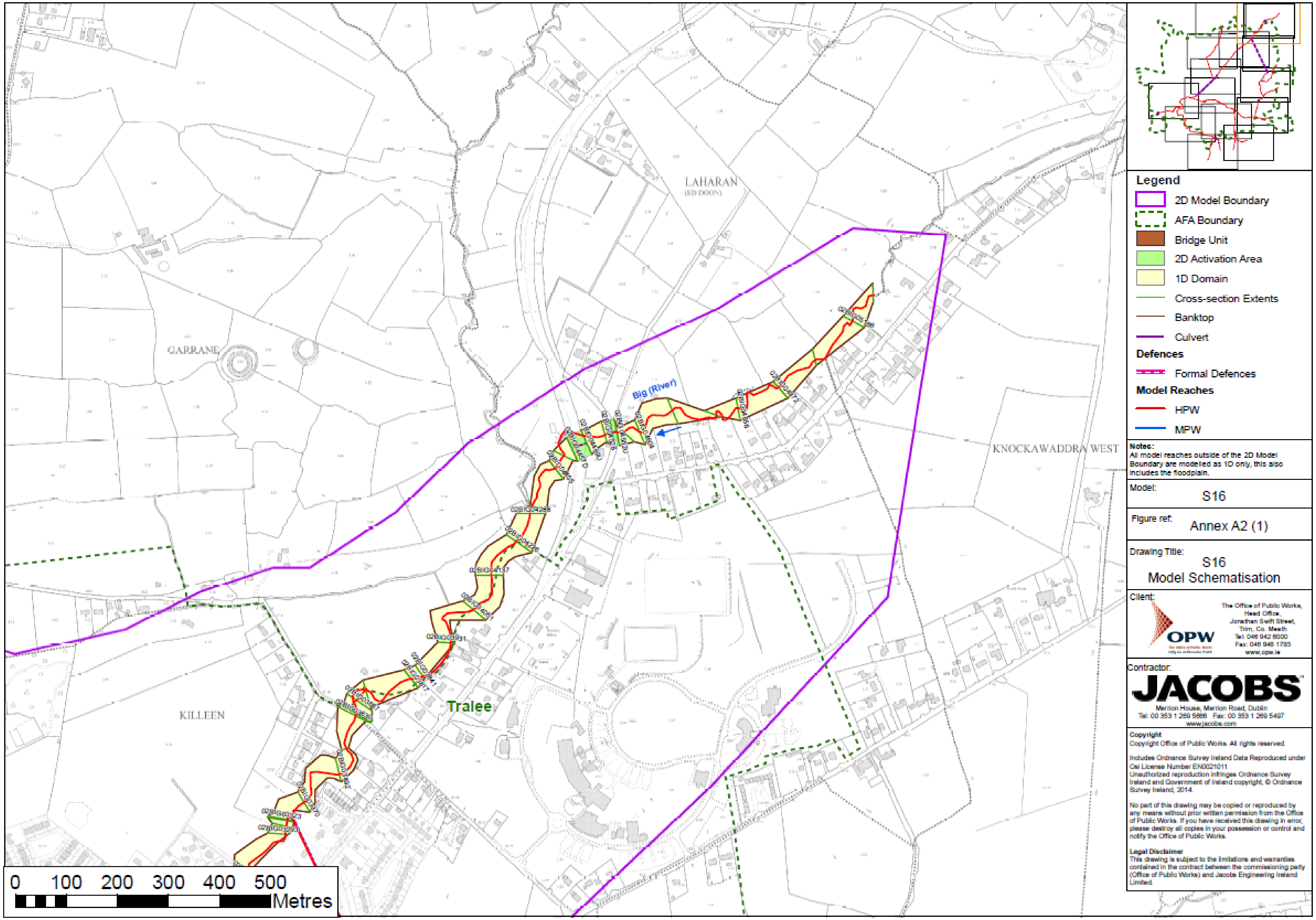
0 0.5 1 1.5 2 2.5
Kilometres
Tralee
Hospital Tralee
Big (River)
Tralee
Ratass
Ballynabrennagh
Lee (River)
Ballyvelly
Ballydunlea
Caherweesheen
Cloghers

Annex A2 – Schematisation Maps

Further details of the defences in the schematisation maps will be contained in the defence asset database. The profile of the embankment which the railway line runs on along the canal is included in the model topography.



LAHARAN
GARRANE
KNOCKAWADDRA WEST
KILLEEN
Tralee
Big (River)
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Bridge Unit
2D Activation Area
1D Domain
Cross-section Extents
Banktop
Culvert
Defences
Formal Defences
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model: S16
Figure ref: Annex A2 (1)
Drawing Title: S16 Model Schematisation
Client:
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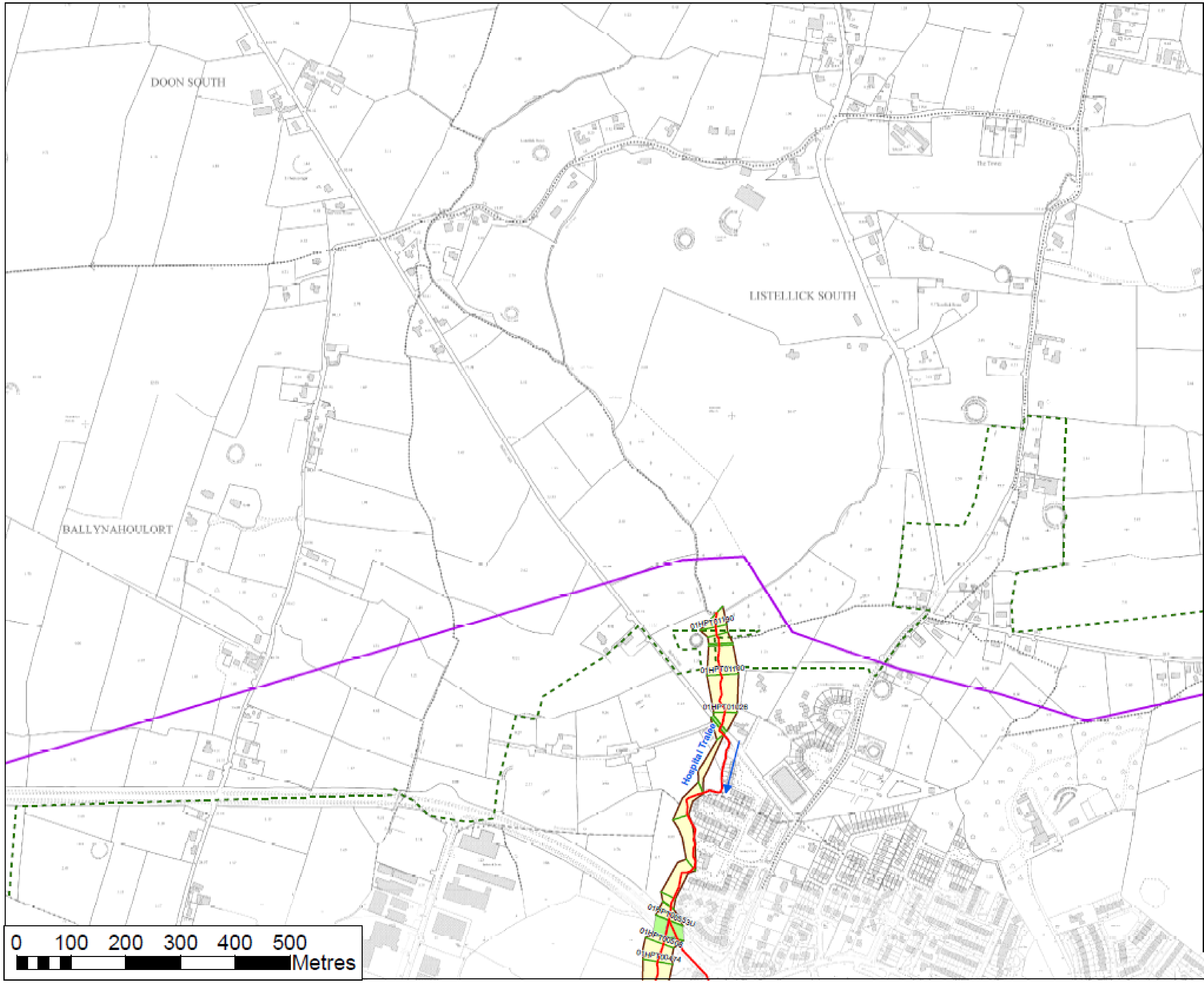

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes:
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Model: S16

Figure ref: Annex A2 (2)

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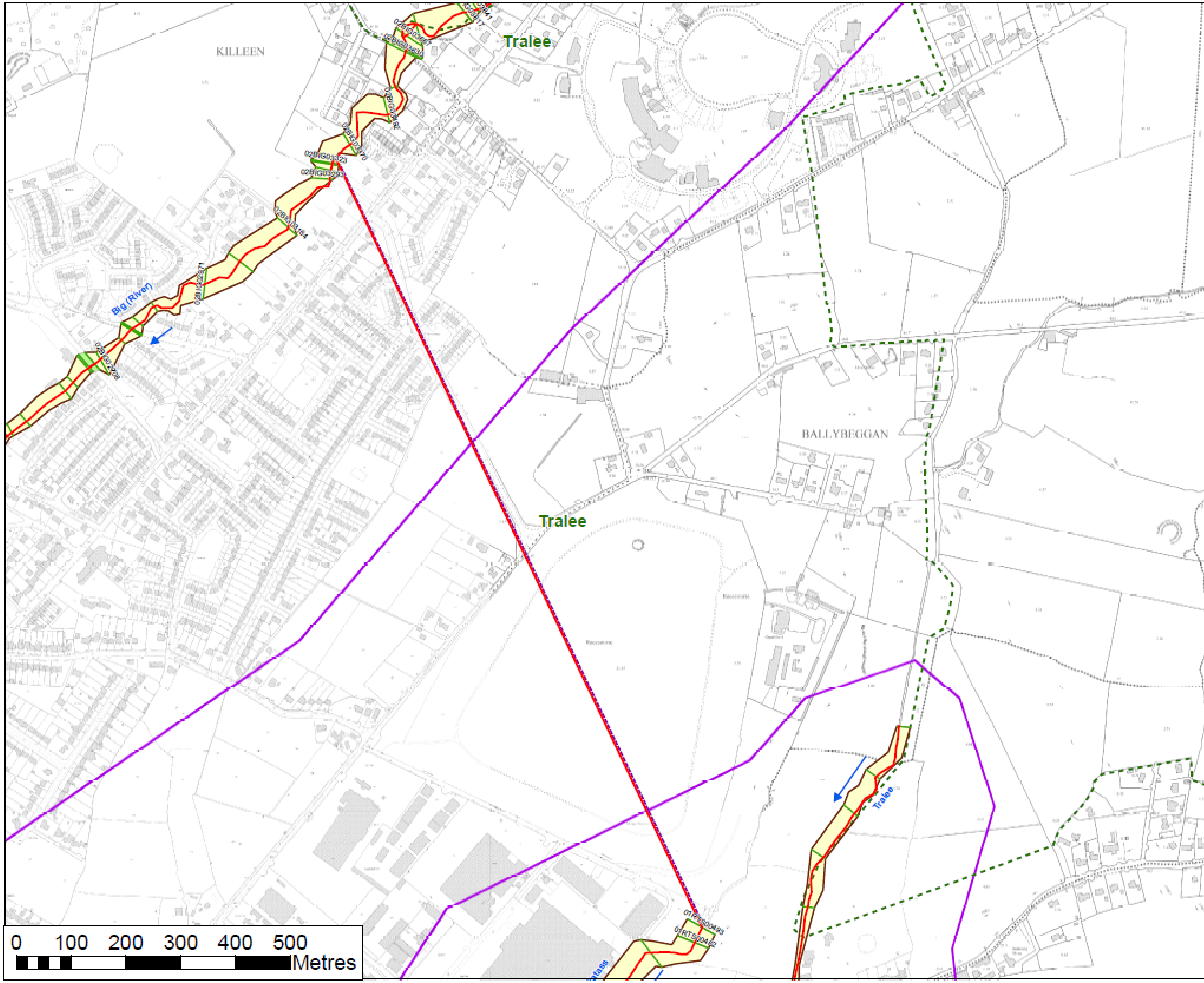

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S16

Figure ref: Annex A2 (3)

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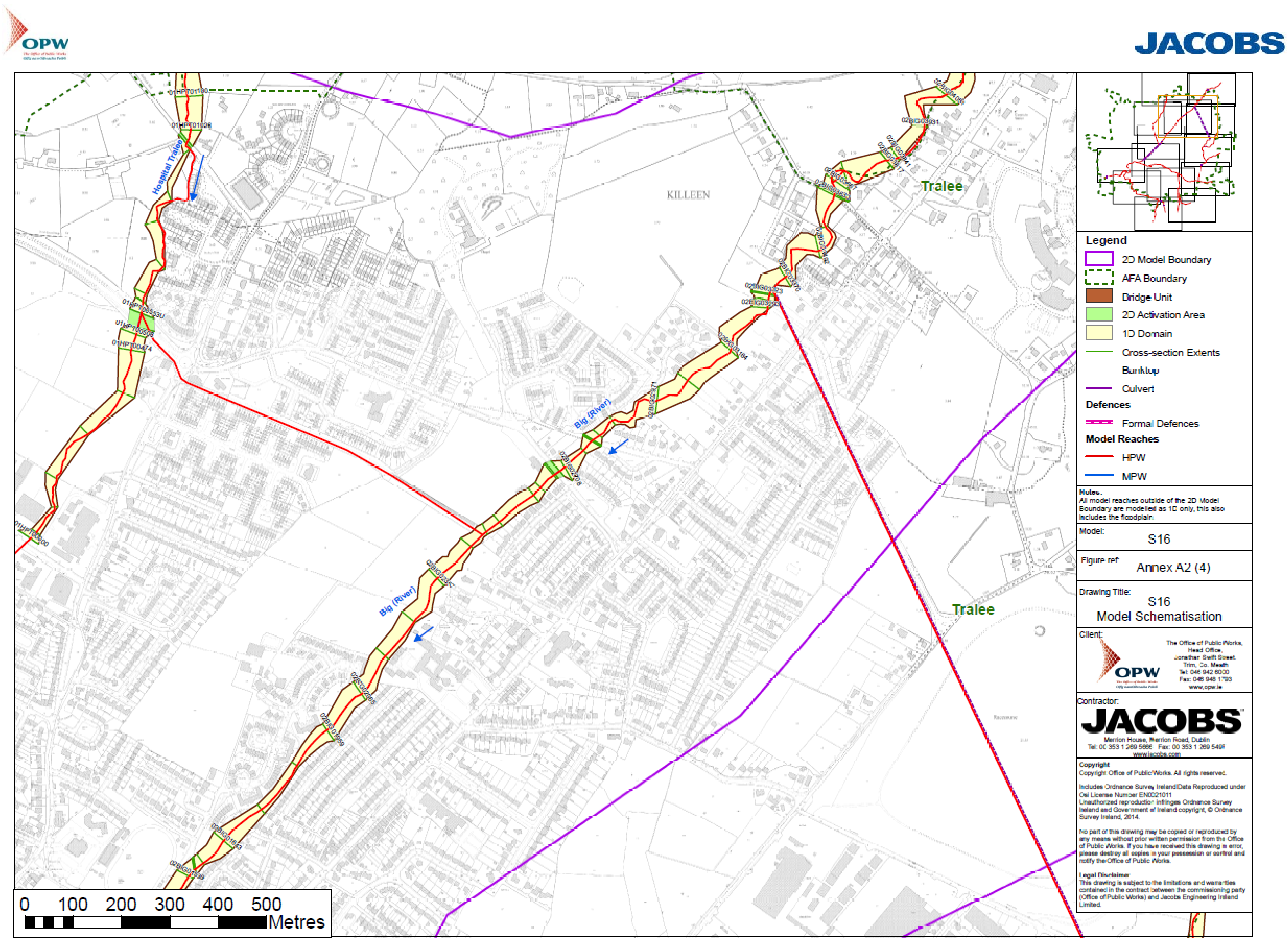

OPW
JACOBS
KILLEEN
Tralee
Tralee
Big (River)
Big (River)
Hospital Tralee
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Bridge Unit
2D Activation Area
1D Domain
Cross-section Extents
Banktop
Culvert
Defences
Formal Defences
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S16
Figure ref:
Annex A2 (4)
Drawing Title:
S16
Model Schematisation
Client:
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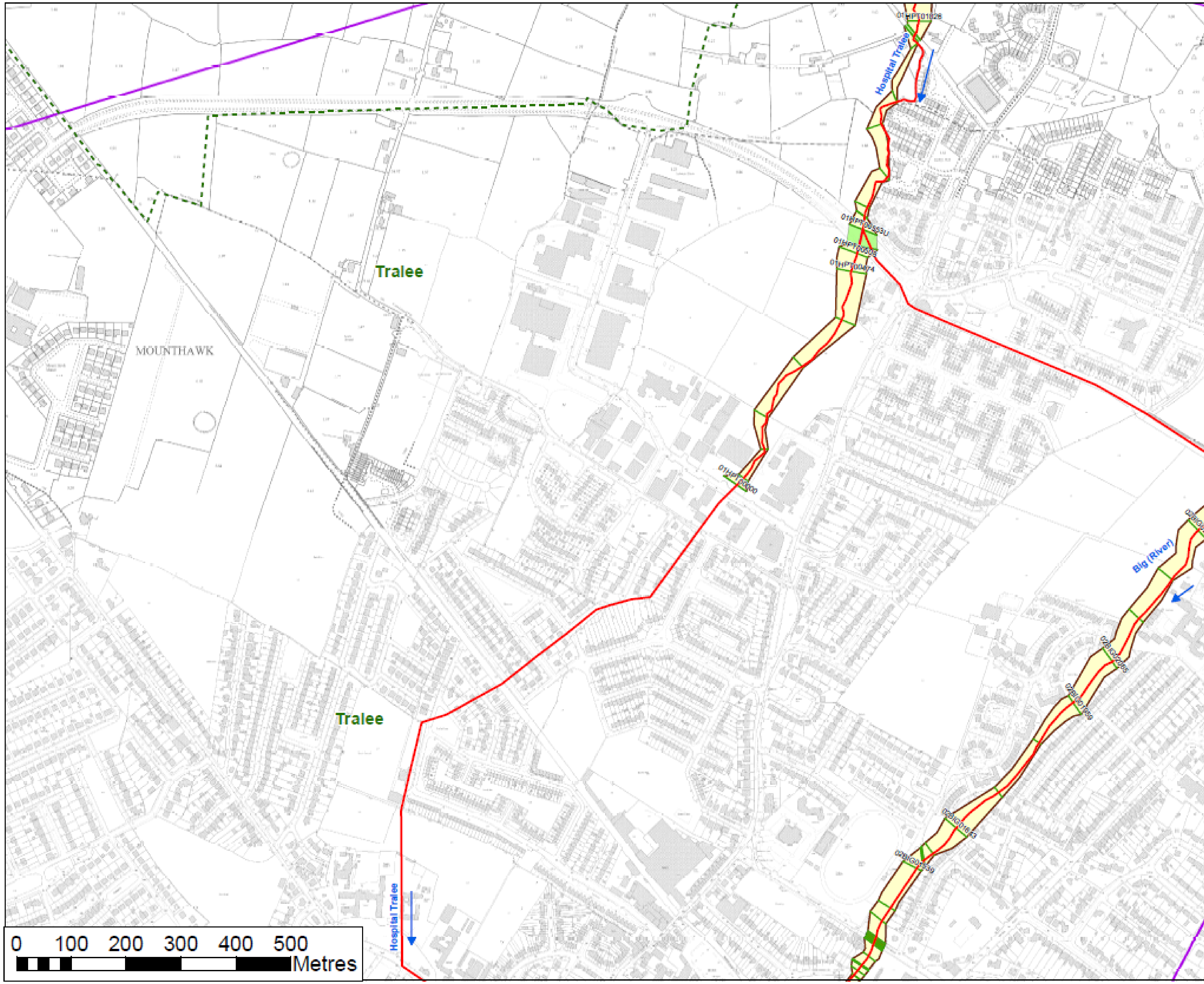

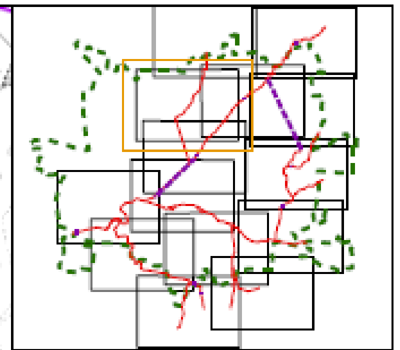

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S16

Figure ref: Annex A2 (5)

Drawing Title: S16 Model Schematisation

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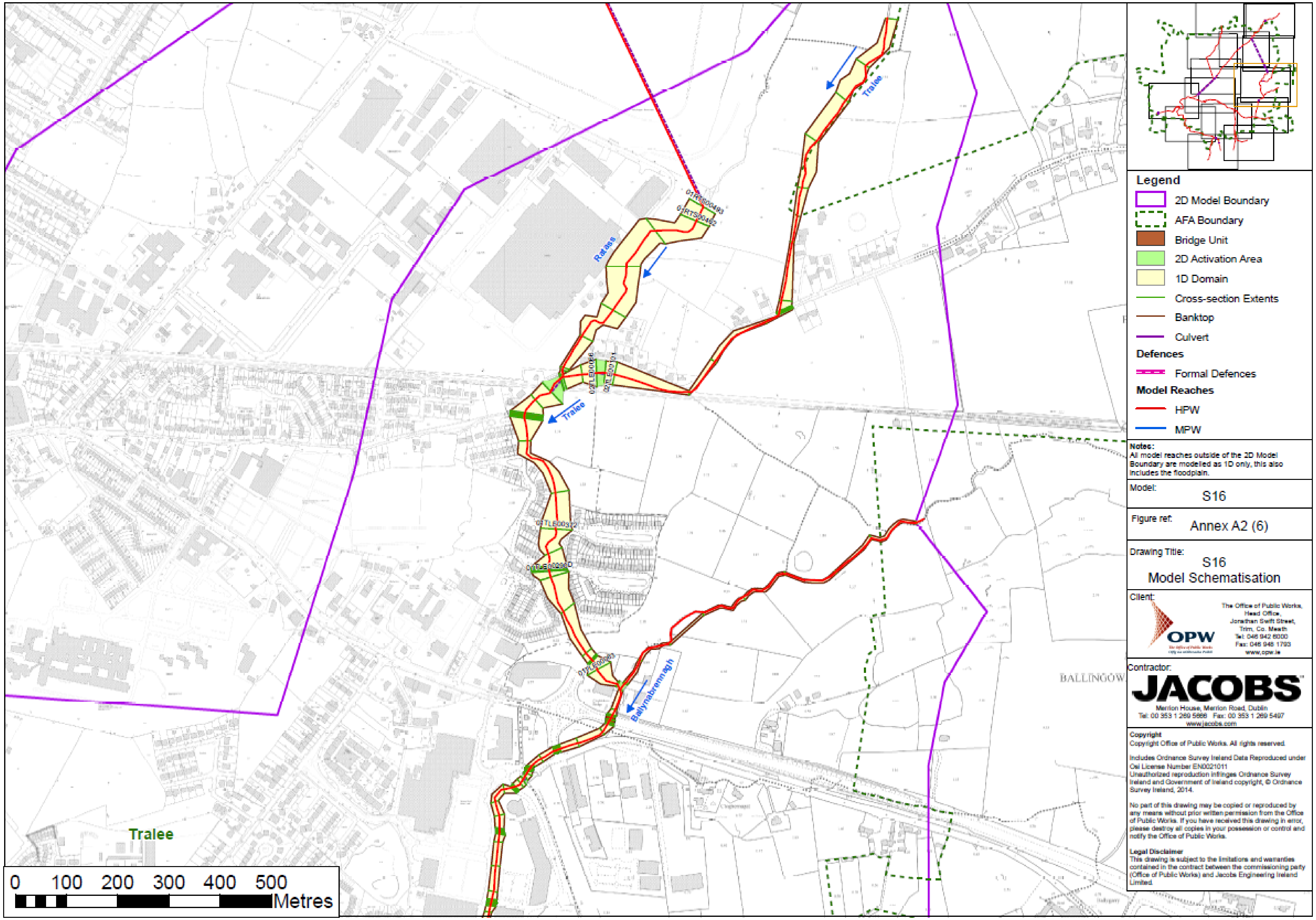
Legend
2D Model Boundary
AFA Boundary
Bridge Unit
2D Activation Area
1D Domain
Cross-section Extents
Banktop
Culvert
Defences
Formal Defences
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S16
Figure ref:
Annex A2 (6)
Drawing Title:
S16
Model Schematisation
Client:
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Trim, Co. Meath
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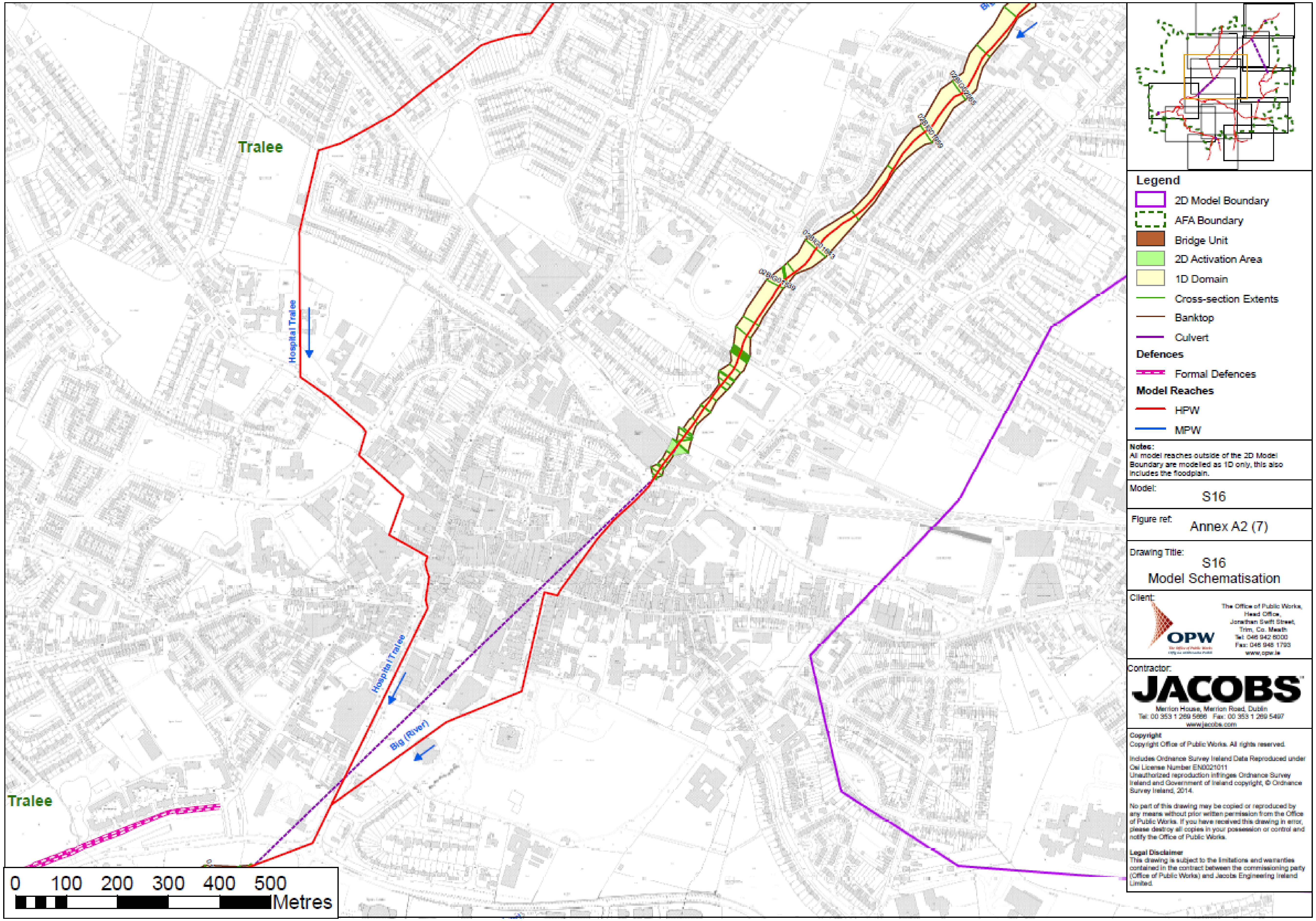
Tralee
Rattass
Ballynabrennagh
BALLINGOW
0 100 200 300 400 500
Metres


Tralee
Hospital Tralee
Hospital Tralee
Big (River)
Tralee
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Bridge Unit
2D Activation Area
1D Domain
Cross-section Extents
Banktop
Culvert
Defences
Formal Defences
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S16
Figure ref:
Annex A2 (7)
Drawing Title:
S16
Model Schematisation
Client:
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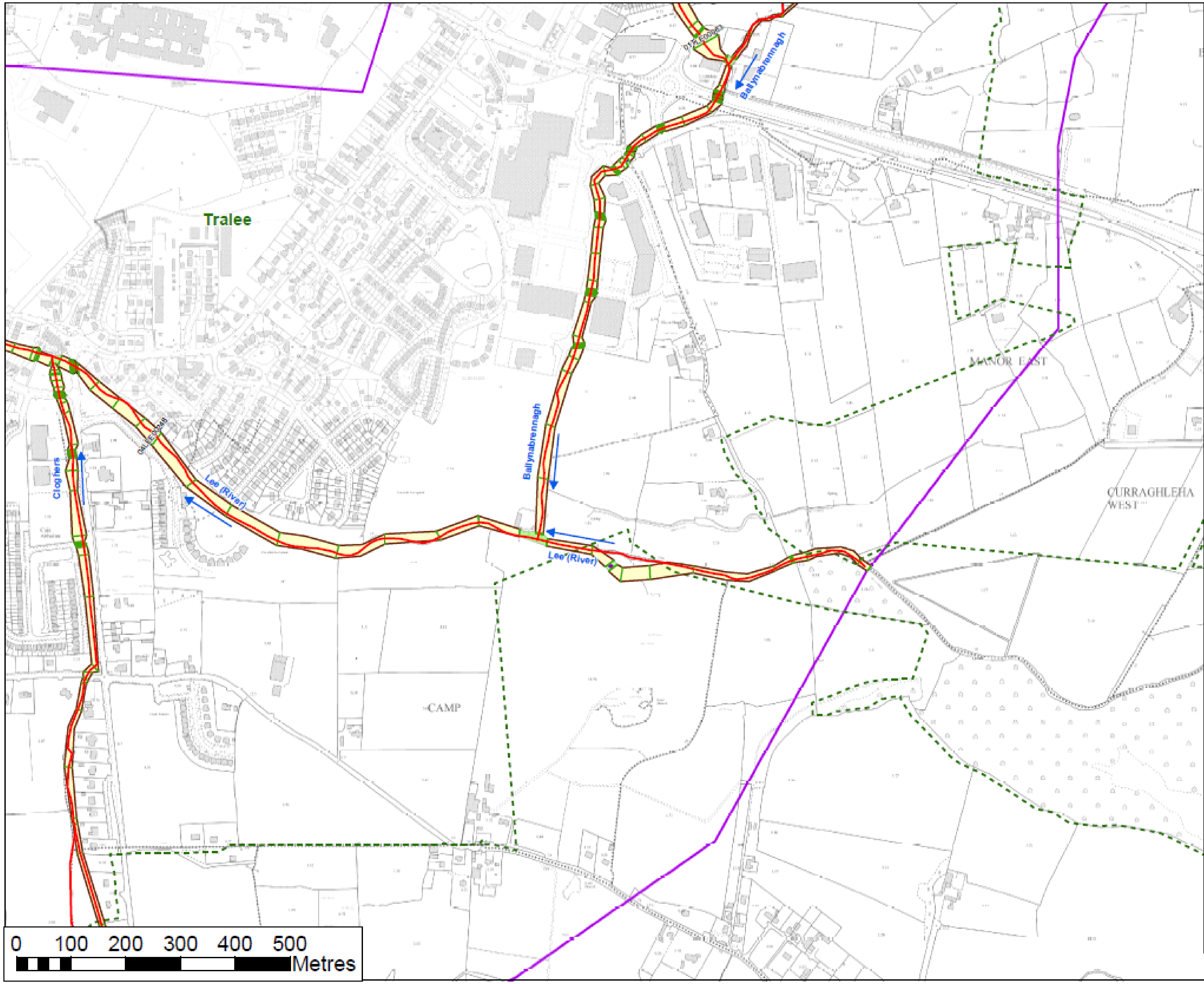

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes: All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S16

Figure ref: Annex A2 (8)

Drawing Title: S16 Model Schematisation

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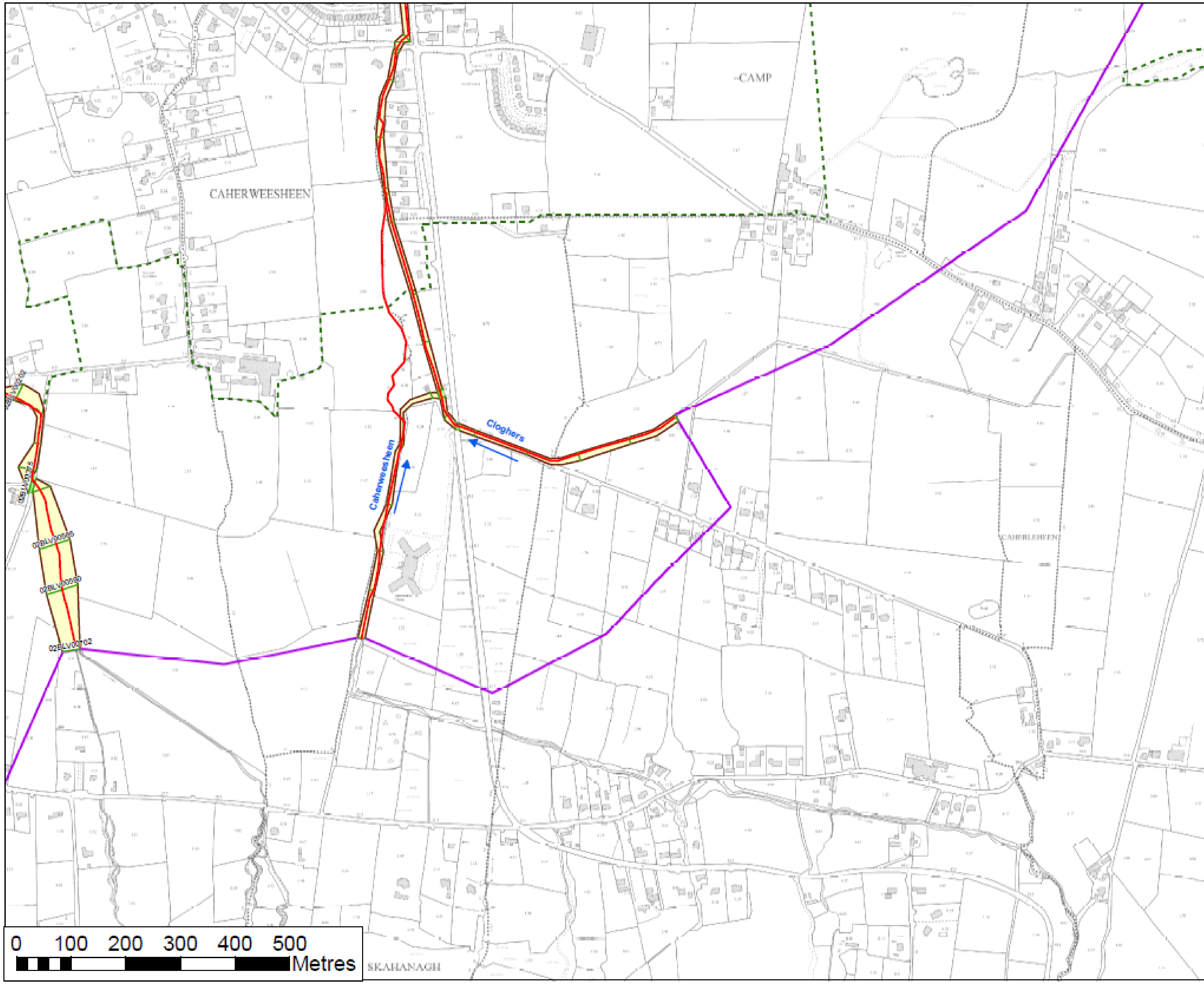

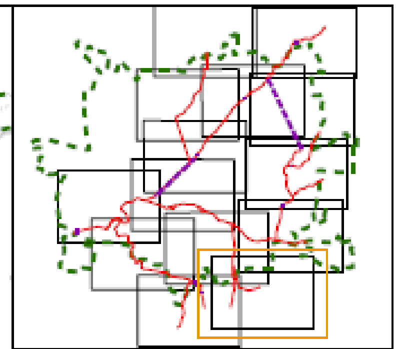

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S16

Figure ref: Annex A2 (9)

Drawing Title: S16 Model Schematisation

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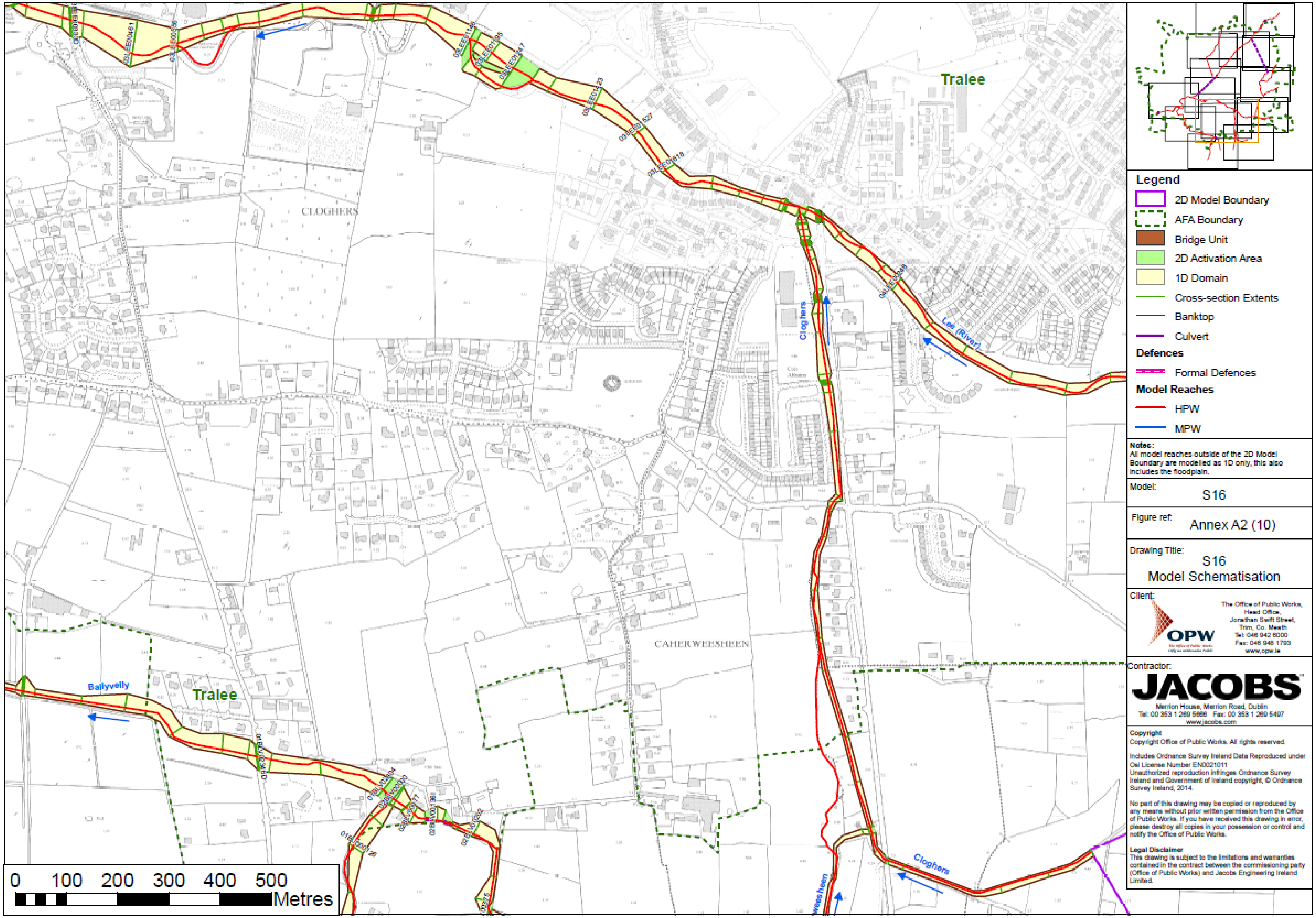
Tralee
CLOGHERS
Cloghers
Lee (River)
CAHERWEESHEEN
Ballyvelly
Tralee
Cloghers
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Bridge Unit
2D Activation Area
1D Domain
Cross-section Extents
Banktop
Culvert
Defences
Formal Defences
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model: S16
Figure ref: Annex A2 (10)
Drawing Title: S16 Model Schematisation
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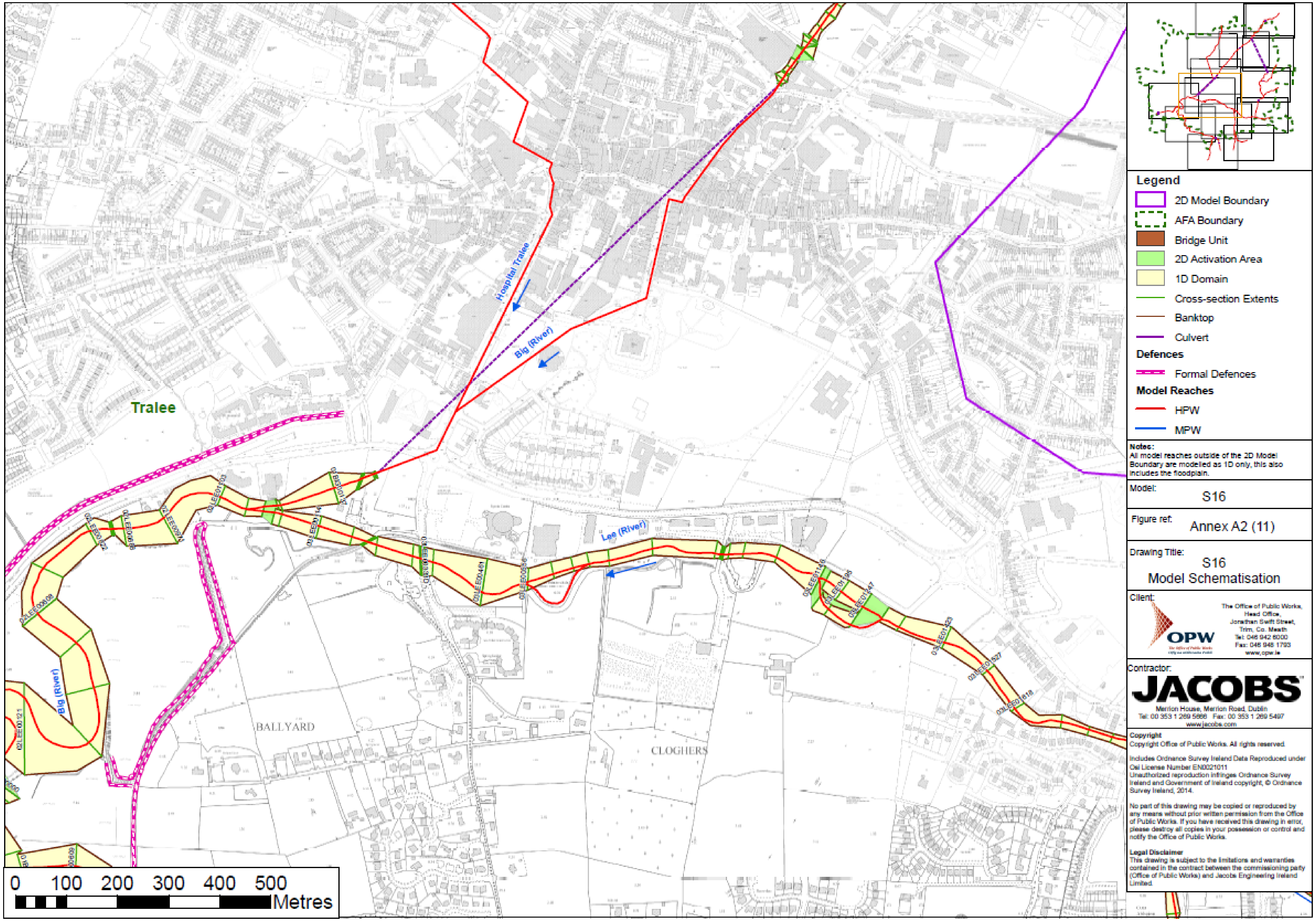

Tralee
Hospital Tralee
Big (River)
Lee (River)
BALLYARD
CLOGHERS
0 100 200 300 400 500
Metres
Legend
2D Model Boundary
AFA Boundary
Bridge Unit
2D Activation Area
1D Domain
Cross-section Extents
Banktop
Culvert
Defences
Formal Defences
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S16
Figure ref:
Annex A2 (11)
Drawing Title:
S16
Model Schematisation
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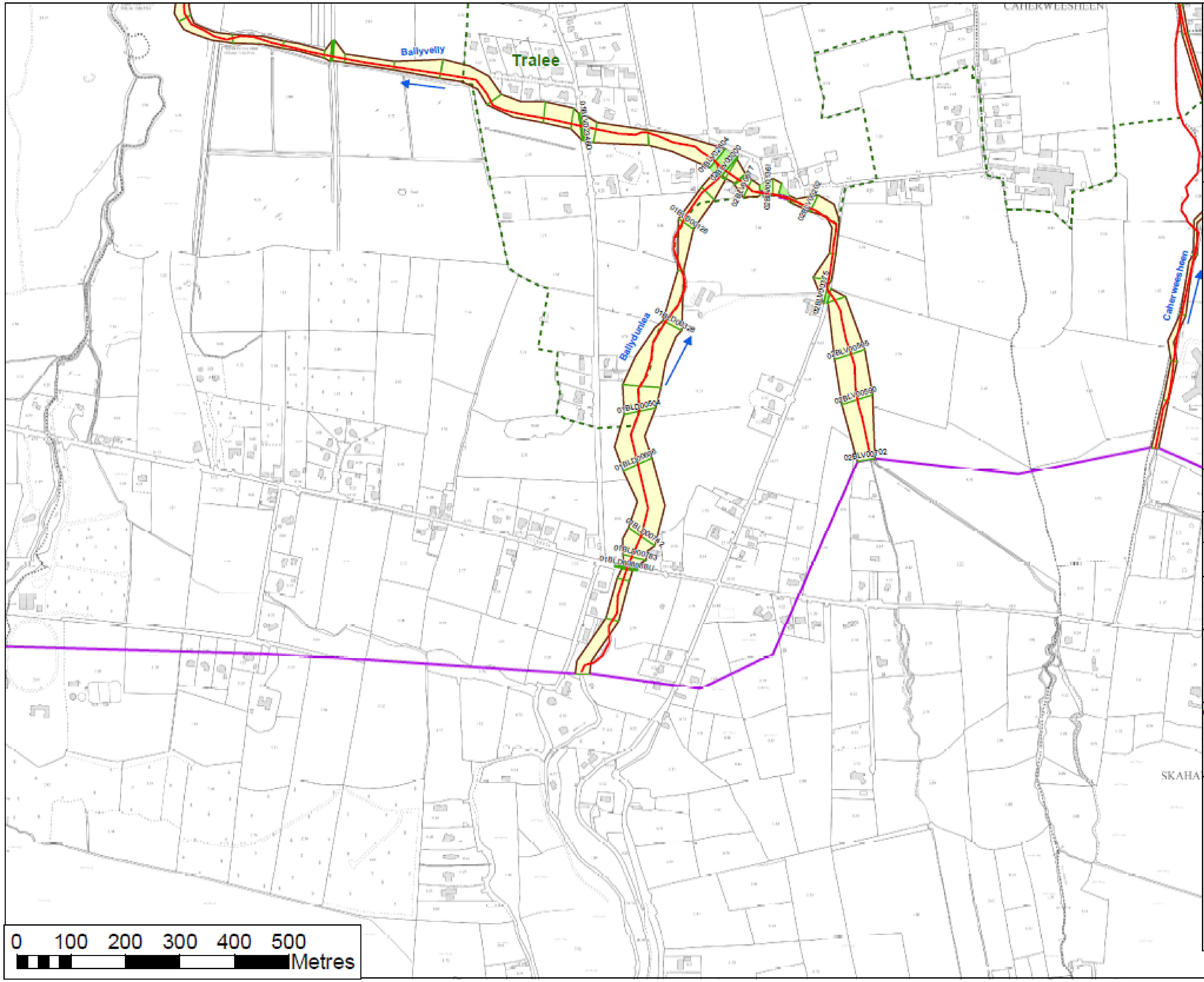

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S16

Figure ref: Annex A2 (12)

Drawing Title: S16 Model Schematisation

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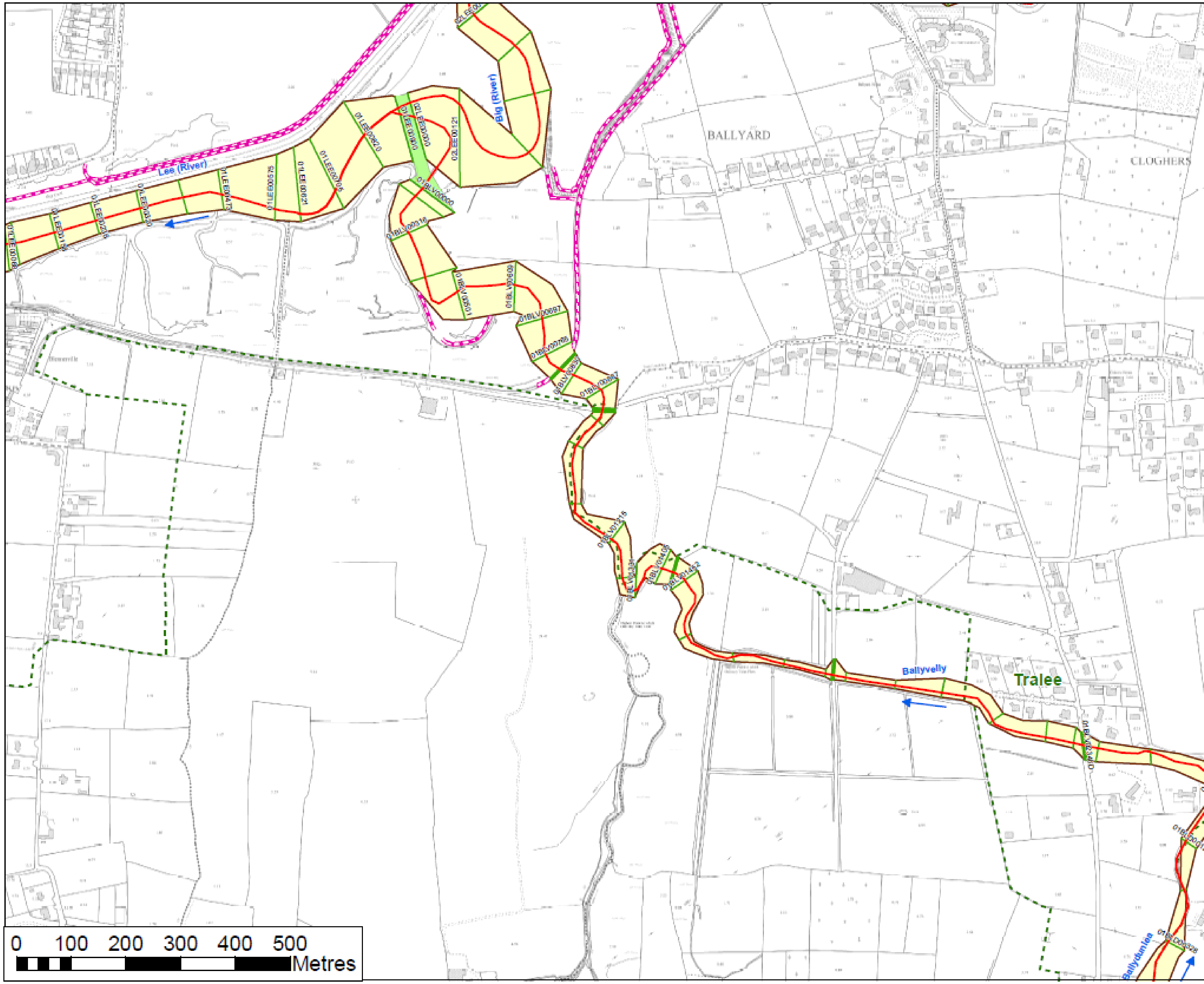

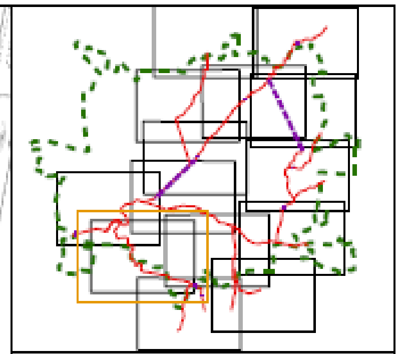

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.

Model: S16

Figure ref: Annex A2 (13)

Drawing Title: S16 Model Schematisation

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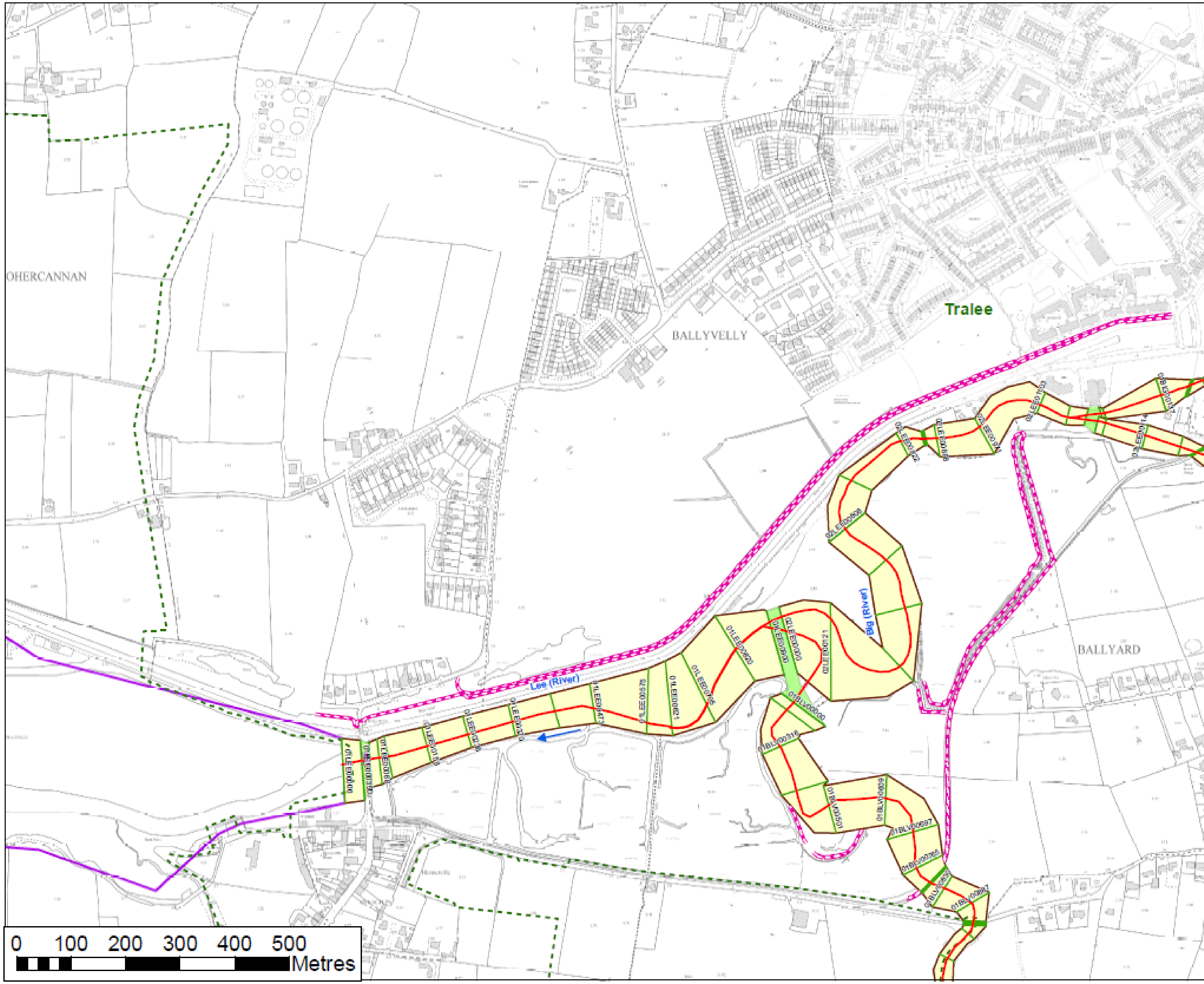

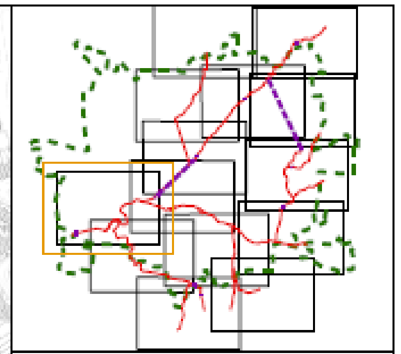

Legend

- 2D Model Boundary
- AFA Boundary
- Bridge Unit
- 2D Activation Area
- 1D Domain
- Cross-section Extents
- Banktop
- Culvert

Defences

- Formal Defences

Model Reaches

- HPW
- MPW

Notes:
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Model: S16

Figure ref: Annex A2 (14)

Drawing Title: S16 Model Schematisation

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Annex B – Structure and Hydraulic Roughness Schedules

Schedule A.1 - Structure Schedule for River Lee

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23RLEE00555D	05LEE00496U	Bridge 4.85m wide	Arch Bridge single rectangular opening + Spill	Y
23RLEE00520I	05LEE00152U	Culvert 10.37m wide	5 X Circular Culverts + Spill	Y
23RLEE00407D and 23RLEE00406E	04LEE00050U	Bridge 16.18m wide	Arch Bridge with rectangular opening + Spill	Y
23RLEE00401D and 23RLEE00401E	03LEE01874U	Bridge 3.11m wide	Sprung arch Bridge + Spill	Y
23RLEE00309D	03LEE00949U	Bridge 5.86m wide	Arch Bridge with rectangular opening+ Spill	Y
23RLEE00246D	03LEE00333U	R556 Bridge 12.60m wide	Arch Bridge with rectangular opening+ Spill	Y
23RLEE00234D	03LEE00215U	Bridge 4.34m wide	Arch Bridge with rectangular opening+ Spill	Y
23RLEE00180D	02LEE00869U	Bridge 5.09m wide	Sprung arch Bridge + Spill	Y
23RLEE00008D and 23RLEE00006E	01LEE00050U	N86 Bridge 14.94m wide	6 X Sprung Arch Culvert +Spills	Y

Schedule A.2 - Structure Schedule for River Big

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23BIGR00486D	02BIG04552U	Bridge 8.77 m wide	Sprung Arch Culvert + Spill	Y
23BIGR00478I and 23BIGR00475J	02BIG04489U	N69 Culvert of 31.41 m wide	Sprung Arch Culvert + Spill	Y
23BIGR00390D	02BIG03638U	Bridge of 3.64 m wide	Arch Bridge + Spill	Y
23BIGR00357	02BIG03323	Trash Screen	Screen	Y
23BIGR00305D	02BIG02789U	Bridge of 3.14 m wide	Arch Bridge with two rectangular openings+ Spill	Y
23BIGR00294E	02BIG02683U	Bridge of 11.70 m wide	Sprung Arch Culvert +Spill	Y
23BIGR00182D	02BIG01559U	Bridge of 3.27 m wide	Arch Bridge with two	Y

			rectangular openings + Spill	
23BIGR00165D	02BIG01393U	Bridge of 14.23 m wide	Arch SPRUNG Bridge +Spill	Y
23BIGR00160D	02BIG01335U	Bridge of 1.95 m wide	Screen	Y
23BIGR00158W and 23BIGR00158X	02BIG01312U	Weir	General Purpose Weir	Y
23BIGR00153W and 23BIGR00153X	02BIG01258U	Weir	General Purpose Weir	Y
23BIGR00146W and 23BIGR00146X	02BIG01201U	Weir	Round Nose Weir	Y
23BIGR00144W and 23BIGR00144X	02BIG01179U	Weir	General Purpose Weir with Screen	Y
23BIGR00142D and 23BIGR00142E	02BIG01171U	Bridge of 24.31 m wide	Culvert Inlet with Rectangular opening and Culvert Outlet with Sprung arch opening +Spill	Y
23BIGR00138W and 23BIGR00138X	02BIG01116U	Weir	Round Nose Weir	Y
23BIGR00136W and 23BIGR00136X	02BIG01094U	Weir	Round Nose Weir	Y
23BIGR00135I and 23BIGR00024J	02BIG01089U	R556 Culvert of 1088.93 m wide	Sprung Arch Culvert +Spill	Y
23BIGR00023D	01BIG00198U	Bridge of 4.02 m wide	Arch Bridge + Spill	Y

Schedule A.3 - Structure Schedule for Ballynabreneagh Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23LEEA00096D	01BNR00966U	N21 Bridge of 21.87 m wide	Arch Bridge with rectangular opening + Spill	Y
23LEEA00083D	01BNR00838U	Bridge of 13.50 m wide.	Arch Bridge with rectangular opening + Spill	Y
23LEEA00077D and 23LEEA00076E	01BNR00772U	Bridge of 14.15 m wide.	Arch Bridge with rectangular opening + Spill	Y
23LEEA00074I and 23LEEA00073J	01BNR00749	Culvert of 8.14 m wide.	Rectangular Culvert + Spill	Y

23LEEA00072D	01BNR00719U	Bridge of 8.72 m wide.	Arch Bridge with rectangular opening + Spill	Y
23LEEA00061D	01BNR00610U	Bridge of 11.23 m wide.	Arch Bridge with rectangular opening + Spill	Y
23LEEA00046E	01BNR00457U	Bridge of 13.07 m wide.	Arch Bridge with rectangular opening + Spill	Y
23LEEA00037D and 23LEEA00036E	01BNR00367U	Bridge of 9.20 m wide.	Arch Bridge with rectangular opening + Spill	Y

Schedule A.4 - Structure Schedule for Tralee Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23LEEB00124D	02TLE00498U	Bridge of 6.40 m wide	Arch Bridge with 1 rectangular opening + 2 Sprung Arch openings+ Spill	Y
23LEEB00083D and 23LEEB00080E	02TLE00082	Bridge of 16.52 m wide	Sprung Arch Culvert + Spill	Y
23LEEB00074I and 23LEEB00070J	01TLE00736	Culvert of 38.69 m wide	Rectangular Culvert	Y
23LEEB00060D	01TLE00628U	Bridge of 11.00 m wide	Bridge with rectangular opening+ Spill	Y
23LEEB00029D	01TLE00290U	Bridge of 10.72 m wide	Bridge with rectangular opening+ Spill	Y
23LEEB00008D	01TLE00086U	Bridge of 3.97 m wide	Arch Bridge with rectangular opening + Spill	Y

Schedule A.5- Structure Schedule for Ratass Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23LEEC00205I and 23LEEC00049J	01RTS00493	Culvert of 1544.86 m wide	Rectangular Culvert	Y
23LEEC00001I	01RTS00000	Culvert of 12.33 m wide	Rectangular Culvert + Spill	Y

Schedule A.6 - Structure Schedule for Cloghers Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23LEEF00133D	02CGH00065U	N70 Bridge 8.91m wide	Rectangular Culvert + Spill	Y
23LEEF00035D	01CGH00355U	Bridge of 6.0 m wide	Arch Bridge with rectangular opening + Spill	Y
23LEEF00018D	0 01CGH00191U	Bridge of 14.66 m wide	Arch Bridge with rectangular opening + Spill	Y
23LEEF00008D and 23LEEF00007E	01CGH00078U	Bridge of 12.74 m wide	Arch bridge with rectangular opening + Spill	Y
23LEEF00004D and 23LEEF00004E	01CGH00034U	Bridge of 2.53 m wide	Arch Bridge + Spill	Y

Schedule A.7 - Structure Schedule for Ballyvelly Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23LEEH00300I & 23LEEH00300J	02BLV00385	Culvert of 9.93 m wide	3 x Rectangular conduits + Spill	Y
23LEEH00278I & 23LEEH0276J	02BLV00157U	Culvert of 21.25 m wide	3 x Circular conduits + Spill	Y
23LEEH00274I & 23LEEH0273J	02BLV00116U	Culvert of 15.52 m wide	2 x Circular conduits + Spill	Y
23LEEH00269D	02BLV00057U	Bridge of 1.34 m wide	Sprung Arch bridge with rectangular opening + Spill	Y
23LEEH00236D	01BLV02346U	Bridge of 5.18 m wide	Sprung Arch bridge with two openings + Spill	Y
23LEEH00187D	01BLV01854U	Bridge of 4.24 m wide	Sprung Arch bridge with two openings + Spill	Y
23LEEH00144D	01BLV01429U	Bridge of3.53 m wide	Arch bridge with rectangular opening + Spill	Y
23LEEH00094D	01BLV00930U	Bridge of 7.46 m wide	Sprung Arch bridge + Spill	Y
23LEEH00081D	01BLV00805U	Bridge of 3.12 m wide	Arch bridge with rectangular opening + Spill	Y

Schedule A.8- Structure Schedule for Ratass Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23LEEJ00081D	01BLD00808U	Bridge of 5.86 m wide	Sprung Arch bridge + Spill	Y

Schedule A.9- Structure Schedule for Hospital Tralee Tributary

Survey Reference	InfoWorks ICM Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23BIGA00250D	01HPT01158 U	Bridge 3.62 m wide	Orifice + Spill	Y
23BIGA00234D	01HPT01001 U	Bridge of 7.87 m wide	Rectangular Culvert + Spill	Y
23BIGA00193I and 23BIGA00193J	01HPT00578 U	Culvert of 0.57 m wide	Circular Culvert + Spill	Y
23BIGA00188I and 23BIGA00186J	01HPT00553 U	Culvert of 30.92 m wide	Circular Culvert + Spill	Y
23BIGA00134I And 02BIG00000	01HPT00000	Culvert of Unknown Extent	Circular Culvert + Spill	Y

Schedule B.1 – Manning's 'n' for the Network

River Name	InfoWorks ICM Node Reference	Bed Roughness*	Estimated Bank Side Roughness	Estimated Floodplain Roughness
River LEE	05LEE00647 to 03LEE00932	0.040	Determined on a case by case basis using photos, videos and survey drawing 2D domain : based on OSi NTF land use polygons	1D domain: Land use EPA data has been used for assigning the floodplain roughness.
	03LEE00808 to 01LEE00000	0.035		
River BIG	02BIG05264 to 02BIG03323	0.045		
	02BIG03309 to 02BIG01424	0.040		
	02BIG01393 to 02BIG01094	0.035		
	02BIG01090 to 01BIG00000	0.030		
BAALYNAB RENNAGH	02BNR00746 to 01BNR00000	0.045		

TRALEE	02TLE01135 to 01TLE00000	0.045		
RATASS	01RTS02052 to 01RTS00000	0.050		
CLOGHERS	02CGH00489 to 01CGH00000	0.045		
CAHERWEESHEEN	01CWS00499 to 01CWS00000	0.045		
BALLYVELLY	02BLV00702 to 01BLV01967	0.045		
	01BLV01875 to 01BLV00000	0.040		
BALLYDUNLEA	01BLD01034 to 01BLD00000	0.050		
HOSPITAL TRALE	01HPT01216 to 01HPT00000	0.050		

*In some cross-sections a different bed roughness coefficient may have been used to represent specific bed material (e.g. engineered concrete sections). All of the altered cross sections are within the roughness bounds defined in Section 3.6.

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Annex C - Model Calibration Summary Note

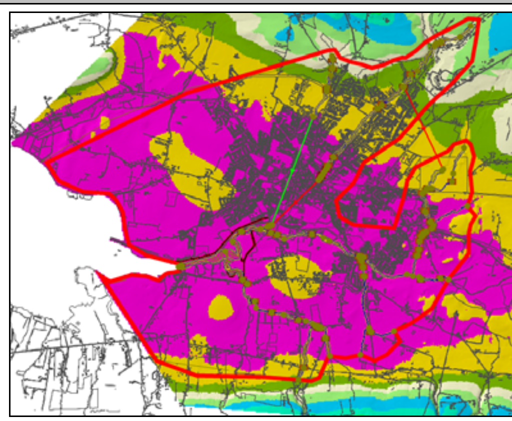
Unused as no calibration to historic events was possible.

Annex D - Hydraulic Model Files

Model files folders structure

Infoworks ICM	Master Database s16_test s16_dtm S16 S16 Tralee (Base)
Result Files	S16_baseline_10yr_V0 (Fluvial) DWF S16_baseline_200yr_V0 (Tidal) DWF

Network files

Model Network	 S16_Tralee_ICM_Model_Network.icmt
Hydrological Inflow Files	**Design Runs – Current Scenario:** S16_100yr_v1 S16_10yr_v1 S16_1000yr_v1 S16_200yr_v1 S16_2yr_v1 (50% aep) S16_50yr_v1 (2% aep) 2D_Level_ (1% aep) 2D_Level_ (10% aep) 2D_Level_ (0.1% aep) 2D_Level_ (0.5% aep) 2D_Level_ (20% aep) 2D_Level_ (2% aep) 2D_Level_ (200% aep)

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
			Design Runs			
1	S16_baseline_10yr_V0 (Fluvial)	0.00	25hrs	1 sec 1d 1 sec 2d	Final Model has been used to simulate the flows for 10 yr Fluvial event.	Convergence within manufacturer tolerance.
2	S16_baseline_100yr_V0 (Fluvial)	0.00	25hrs	1 sec 1d 1 sec 2d	Final Model has been used to simulate the flows for 100 yr Fluvial event.	Convergence within manufacturer tolerance.
3	S16_baseline_1000yr_V0 (Fluvial)	0.00	25hrs	1 sec 1d 1 sec 2d	Final Model has been used to simulate the flows for 1000 yr Fluvial event.	Convergence within manufacturer tolerance.
4	S16_baseline_10yr_V0 (Tidal)	0.00	25hrs	1 sec 1d 1 sec 2d	Final Model has been used to simulate the flows for 10 yr Tidal event.	Convergence within manufacturer tolerance.
5	S16_baseline_200yr_V0 (Tidal)	0.00	25hrs	1 sec 1d 1 sec 2d	Final Model has been used to simulate the flows for 200 yr Tidal event.	Convergence within manufacturer tolerance.
6	S16_baseline_1000yr_V0 (Tidal)	0.00	25hrs	1 sec 1d 1 sec 2d	Final Model has been used to simulate the flows for 1000 yr Tidal event.	Convergence within manufacturer tolerance.

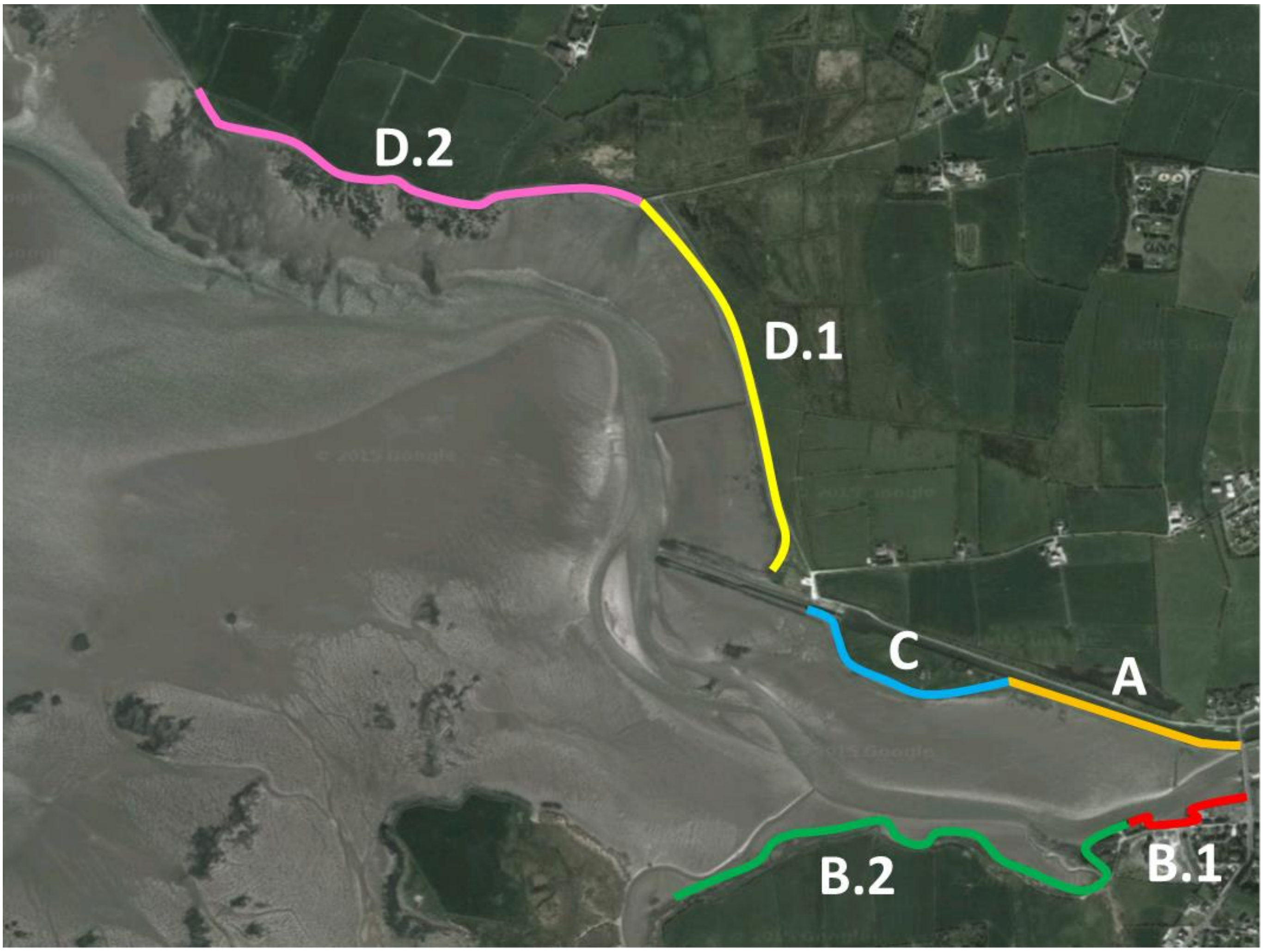
Annex E - Flood Mapping

Flood Maps are available through the OPW flood mapping website; http://maps.opw.ie/fhrm/

Annex F – Wave Overtopping

ICWWS CAPO Tralee
Prediction Locations

North



Location A

Current Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.000	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300
11.167	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300	-		-2.300
11.333	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400
11.500	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400	-		-2.400
11.667	-		-2.351	-		-2.346	-		-2.342	-		-2.339	-		-2.334	-		-2.331	-		-2.328	-		-2.328
11.833	-		-2.302	-		-2.292	-		-2.285	-		-2.278	-		-2.268	-		-2.261	-		-2.255	-		-2.255
12.000	-		-2.153	-		-2.138	-		-2.128	-		-2.117	-		-2.103	-		-2.092	-		-2.083	-		-2.083
12.167	-		-2.104	-		-2.085	-		-2.071	-		-2.057	-		-2.038	-		-2.024	-		-2.012	-		-2.012
12.333	-		-2.055	-		-2.032	-		-2.014	-		-1.997	-		-1.973	-		-1.956	-		-1.941	-		-1.941
12.500	-		-1.908	-		-1.879	-		-1.858	-		-1.838	-		-1.809	-		-1.788	-		-1.770	-		-1.770
12.667	-		-1.760	-		-1.727	-		-1.703	-		-1.679	-		-1.646	-		-1.622	-		-1.601	-		-1.601
12.833	-		-1.614	-		-1.576	-		-1.549	-		-1.521	-		-1.484	-		-1.456	-		-1.432	-		-1.432
13.000	-		-1.468	-		-1.425	-		-1.395	-		-1.364	-		-1.322	-		-1.292	-		-1.265	-		-1.265
13.167	-		-1.322	-		-1.276	-		-1.242	-		-1.208	-		-1.162	-		-1.128	-		-1.098	-		-1.098
13.333	-		-1.178	-		-1.127	-		-1.090	-		-1.054	-		-1.003	-		-0.966	-		-0.934	-		-0.934
13.500	-		-1.035	-		-0.980	-		-0.940	-		-0.900	-		-0.845	-		-0.805	-		-0.770	-		-0.770
13.667	-		-0.893	-		-0.834	-		-0.791	-		-0.748	-		-0.689	-		-0.646	-		-0.608	-		-0.608
13.833	-		-0.752	-		-0.689	-		-0.643	-		-0.597	-		-0.534	-		-0.488	-		-0.448	-		-0.448
14.000	-		-0.512	-		-0.445	-		-0.396	-		-0.348	-		-0.281	-		-0.232	-		-0.189	-		-0.189
14.167	-		-0.274	-		-0.203	-		-0.152	-		-0.100	-		-0.029	-		0.022	-		0.067	-		0.067
14.333	-		-0.137	-		-0.062	-		-0.008	-		0.046	-		0.120	-		0.174	-		0.221	-		0.221
14.500	-		-0.001	-		0.077	-		0.133	-		0.190	-		0.268	-		0.324	-		0.374	-		0.374
14.667	-		0.233	-		0.314	-		0.373	-		0.432	-		0.513	-		0.572	-		0.624	-		0.624
14.833	-		0.466	-		0.550	-		0.611	-		0.672	-		0.757	-		0.818	-		0.872	-		0.872
15.000	0.000	0.000	0.596	0.000	0.000	0.684	0.000	0.000	0.747	0.000	0.000	0.811	0.000	0.000	0.898	0.000	0.000	0.961	0.000	0.000	1.017	0.000	0.000	1.017
15.167	0.000	0.000	0.826	0.000	0.000	0.916	0.000	0.000	0.981	0.000	0.000	1.047	0.000	0.000	1.137	0.000	0.000	1.202	0.000	0.000	1.260	0.000	0.000	1.260
15.333	0.000	0.000	1.053	0.000	0.000	1.146	0.000	0.000	1.213	0.000	0.000	1.281	0.000	0.000	1.374	0.000	0.000	1.441	0.000	0.000	1.500	0.000	0.000	1.500
15.500	0.000	0.000	1.279	0.000	0.000	1.374	0.000	0.000	1.443	0.000	0.000	1.512	0.000	0.000	1.608	0.000	0.000	1.677	0.000	0.000	1.738	0.000	0.000	1.738
15.667	0.000	0.000	1.502	0.000	0.000	1.600	0.000	0.000	1.671	0.000	0.000	1.742	0.000	0.000	1.839	0.001	0.000	1.910	0.001	0.001	1.972	0.011	0.006	1.972
15.833	0.000	0.000	1.624	0.000	0.000	1.724	0.000	0.000	1.796	0.000	0.000	1.869	0.001	0.000	1.969	0.001	0.001	2.041	0.003	0.001	2.104	0.027	0.013	2.104
16.000	0.000	0.000	1.844	0.000	0.000	1.946	0.000	0.000	2.020	0.001	0.000	2.093	0.002	0.001	2.195	0.006	0.003	2.269	0.015	0.008	2.334	0.123	0.063	2.334
16.167	0.000	0.000	1.962	0.000	0.000	2.065	0.001	0.000	2.140	0.001	0.001	2.216	0.005	0.003	2.319	0.015	0.008	2.394	0.040	0.020	2.460	0.320	0.162	2.460
16.333	0.000	0.000	2.178	0.001	0.000	2.283	0.002	0.001	2.359	0.006	0.003	2.435	0.031	0.016	2.540	0.117	0.059	2.616	0.381	0.194	2.683	1.813	0.920	2.683
16.500	0.001	0.000	2.391	0.003	0.002	2.498	0.013	0.007	2.575	0.054	0.028	2.652	0.406	0.206	2.759	1.274	0.647	2.836	2.979	1.512	2.903	13.810	7.009	2.903
16.667	0.004	0.002	2.603	0.037	0.019	2.711	0.194	0.098	2.789	0.792	0.402	2.867	3.264	1.657	2.974	7.436	3.774	3.052	13.750	6.979	3.121	0.000	0.000	3.121
16.833	0.016	0.008	2.713	0.173	0.088	2.821	0.781	0.397	2.900	2.448	1.242	2.979	8.058	4.090	3.087	0.000	0.000	3.166	0.000	0.000	3.235	0.000	0.000	3.235
17.000	0.017	0.009	2.720	0.197	0.100	2.829	0.867	0.440	2.909	2.662	1.351	2.988	8.681	4.406	3.097	0.000	0.000	3.176	0.000	0.000	3.246	0.000	0.000	3.246
17.167	0.019	0.009	2.726	0.211	0.107	2.835	0.928	0.471	2.915	2.843	1.443	2.995	9.142	4.640	3.104	0.000	0.000	3.184	0.000	0.000	3.254	0.000	0.000	3.254
17.333	0.081	0.041	2.829	0.849	0.431	2.939	2.770	1.406	3.019	7.007	3.556	3.099	0.000	0.000	3.209	0.000	0.000	3.288	0.000	0.000	3.358	0.000	0.000	3.358
17.500	0.082	0.042	2.830	0.860	0.436	2.940	2.796	1.419	3.020	7.061	3.584	3.100	0.000	0.000	3.210	0.000	0.000	3.290	0.000	0.000	3.360	0.000	0.000	3.360
17.667	0.081	0.041	2.829	0.849	0.431	2.939	2.770	1.406	3.019	7.007	3.556	3.099	0.000	0.000	3.209	0.000	0.000	3.288	0.000	0.000	3.358	0.000	0.000	3.358
17.833	0.077	0.039	2.826	0.808	0.410	2.935	2.662	1.351	3.015	6.781	3.442	3.095	0.000	0.000	3.204	0.000	0.000	3.284	0.000	0.000	3.354	0.000	0.000	3.354
18.000	0.017	0.009	2.720	0.197	0.100	2.829	0.867	0.440	2.909	2.662	1.351	2.988	8.681	4.406	3.097	0.000	0.000	3.176	0.000	0.000	3.246	0.000	0.000	3.246
18.167	0.016	0.008	2.713	0.173	0.088	2.821	0.781	0.397	2.900	2.448	1.242	2.979	8.058	4.090	3.087	0.000	0.000	3.166	0.000	0.000	3.235	0.000	0.000	3.235
18.333	0.004	0.002	2.603	0.037	0.019	2.711	0.194	0.098	2.789	0.792	0.402	2.867	3.264	1.657	2.974	7.436	3.774	3.052	13.750	6.979	3.121	0.000	0.000	3.121
18.500	0.002	0.001	2.491	0.009	0.005	2.598	0.042	0.021	2.675	0.201	0.102	2.752	1.153	0.585	2.859	3.035	1.540	2.936	6.312	3.204	3.003	13.810	7.009	3.003
18.667	0.001	0.000	2.378	0.003	0.002	2.483	0.011	0.006	2.559	0.044	0.022	2.635	0.324	0.165	2.740	1.068	0.542	2.816	2.515	1.276	2.883	6.911	3.508	2.883
18.833	0.000	0.000	2.262	0.001	0.001	2.365	0.004	0.002	2.440	0.012	0.006	2.516	0.073	0.037	2.619	0.289	0.147	2.694	0.849	0.431	2.760	3.124	1.586	2.760
19.000	0.000	0.000	2.044	0.000	0.000	2.146	0.001	0.000	2.220	0.002	0.001	2.293	0.009	0.005	2.395	0.027	0.014	2.469	0.077	0.039	2.534	0.575	0.292	2.534
19.167	0.000	0.000	1.924	0.000	0.000	2.024	0.001	0.000	2.096	0.001	0.001	2.169	0.003	0.002	2.269	0.010	0.005	2.341	0.026	0.013	2.404	0.209	0.106	2.404
19.333	0.000	0.000	1.702	0.000	0.000	1.800	0.000	0.000	1.871	0.000	0.000	1.942	0.001	0.000	2.039	0.002	0.001	2.110	0.004	0.002	2.172	0.042	0.021	2.172
19.500	0.000	0.000	1.479	0.000	0.000	1.574	0.000	0.000	1.643	0.000	0.000	1.712	0.000	0.000	1.808	0.001	0.000	1.877	0.001	0.001	1.938	0.009	0.005	1.938
19.667	0.000	0.000	1.353	0.000	0.000	1.446	0.000	0.000	1.513	0.000	0.000	1.581	0.000	0.000	1.674	0.000	0.000	1.741	0.001	0.000	1.800	0.004	0.002	1.800
19.833	0.000	0.000	1.126	0.000	0.000	1.216	0.000	0.000	1.281	0.000	0.000	1.347	0.000	0.000	1.437	0.000	0.000	1.502	0.000	0.000	1.560	0.000	0.000	1.560
20.000	0.000	0.000	0.896	0.000	0.000	0.984	0.000	0.000	1.047	0.000	0.000	1.111	0.000	0.000	1.198	0.000	0.000	1.261	0.000	0.000	1.317	0.000	0.000	1.317
20.167	-		0.766	-		0.850	-		0.911	-		0.972	-		1.057	-		1.118	-		1.172	-		1.172
20.333	-		0.533	-		0.614	-		0.673	-		0.732	-		0.813	-		0.872	-		0.924	-		0.924
20.500	-		0.299	-		0.377	-		0.433	-		0.490	-		0.568	-		0.624	-		0.674	-		0.674
20.667	-		0.163	-		0.238	-		0.292	-		0.346	-		0.420	-		0.474	-		0.521	-		0.521
20.833	-		-0.074	-		-0.003	-		0.048	-		0.100	-		0.171	-		0.222	-		0.267	-		0.267
21.000	-		-0.312	-		-0.245	-		-0.196	-		-0.148	-		-0.081	-		-0.032	-		0.011	-		0.011
21.167	-		-0.552	-		-0.489	-		-0.443	-		-0.397	-		-0.334	-		-0.288	-		-0.248	-		-0.248
21.333	-		-0.693	-		-0.634	-		-0.591	-		-0.548	-		-0.489	-		-0.446	-		-0.408	-		-0.408
21.500	-		-0.935	-		-0.880	-		-0.840	-		-0.800	-		-0.745	-		-0.705	-		-0.670	-		-0.670
21.667	-		-1.178	-		-1.127	-		-1.090	-		-1.054	-		-1.003	-		-0.966	-		-0.934	-		-0.934
21.833	-		-1.322	-		-1.276	-		-1.242	-		-1.208	-		-1.162	-		-1.128	-		-1.098	-		-1.098
22.000	-		-1.568	-		-1.525	-		-1.495	-		-1.464	-		-1.422	-		-1.392	-		-1.365	-		-1.365
22.167	-		-1.814	-		-1.776	-		-1.749	-		-1.721	-		-1.684	-		-1.656	-		-1.632	-		-1.632
22.333	-		-1.960	-		-1.927	-		-1.903	-		-1.879	-		-1.846	-		-1.822	-		-1.801	-		-1.801
22.500	-		-2.008	-		-1.979	-		-1.958	-		-1.938	-		-1.909	-		-1.888	-		-1.870	-		-1.870
22.667	-		-2.155	-		-2.132	-		-2.114	-		-2.097	-		-2.073	-		-2.056	-		-2.041	-		-2.041
22.833	-		-2.204	-		-2.185	-		-2.171	-		-2.157	-		-2.138	-		-2.124	-		-2.112	-		-2.112
23.000	-		-2.253	-		-2.238	-		-2.228	-		-2.217	-		-2.203	-		-2.192	-		-2.183	-		-2.183

Mid -Range Future Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.833	-		-2.300	-		-2.300	-	0.000	-2.300	-		-2.300	-		-2.300	-		-2.300	-	0.000	-2.300	-	0.000	-2.300
12.000	-		-2.300	-		-2.300	-		-2.117	-		-2.300	-		-2.300	-		-2.300	-		-2.083	-		-2.087
12.167	-		-2.400	-		-2.400	-		-2.057	-		-2.400	-		-2.400	-		-2.400	-		-2.012	-		-2.017
12.333	-		-2.400	-		-2.400	-		-1.997	-		-2.400	-		-2.400	-		-2.400	-		-1.941	-		-1.947
12.500	-		-2.329	-		-2.324	-		-1.838	-		-2.317	-		-2.312	-		-2.309	-		-1.770	-		-1.778
12.667	-		-2.258	-		-2.248	-		-1.679	-		-2.234	-		-2.225	-		-2.218	-		-1.601	-		-1.610
12.833	-		-2.087	-		-2.073	-		-1.521	-		-2.052	-		-2.038	-		-2.027	-		-1.432	-		-1.443
13.000	-		-2.017	-		-1.998	-		-1.364	-		-1.970	-		-1.951	-		-1.937	-		-1.265	-		-1.276
13.167	-		-1.947	-		-1.923	-		-1.208	-		-1.889	-		-1.865	-		-1.848	-		-1.098	-		-1.111
13.333	-		-1.778	-		-1.750	-		-1.054	-		-1.708	-		-1.680	-		-1.659	-		-0.934	-		-0.947
13.500	-		-1.610	-		-1.577	-		-0.900	-		-1.529	-		-1.496	-		-1.472	-		-0.770	-		-0.785
13.667	-		-1.443	-		-1.405	-		-0.748	-		-1.350	-		-1.313	-		-1.285	-		-0.608	-		-0.624
13.833	-		-1.276	-		-1.234	-		-0.597	-		-1.173	-		-1.131	-		-1.100	-		-0.448	-		-0.465
14.000	-		-1.111	-		-1.065	-		-0.348	-		-0.997	-		-0.951	-		-0.917	-		-0.189	-		-0.208
14.167	-		-0.947	-		-0.897	-		-0.100	-		-0.823	-		-0.772	-		-0.735	-		0.067	-		0.048
14.333	-		-0.785	-		-0.730	-		0.046	-		-0.650	-		-0.595	-		-0.555	-		0.221	-		0.201
14.500	-		-0.624	-		-0.565	-		0.190	-		-0.479	-		-0.420	-		-0.377	-		0.374	-		0.353
14.667	-		-0.465	-		-0.402	-		0.432	-		-0.310	-		-0.247	-		-0.201	-		0.624	-		0.602
14.833	-		-0.208	-		-0.141	-		0.672	-		-0.043	-		0.024	-		0.072	-		0.872	-		0.849
15.000	-		0.048	-		0.118	-		0.811	-		0.221	-		0.292	-		0.343	-		1.017	-		0.993
15.167	-		0.201	-		0.276	-		1.047	-		0.384	-		0.458	-		0.512	-		1.260	-		1.235
15.333	-		0.353	-		0.430	-		1.281	-		0.544	-		0.621	-		0.678	-		1.500	-		1.475
15.500	-		0.602	-		0.683	-		1.512	-		0.801	-		0.882	-		0.941	-		1.738	-		1.712
15.667	-		0.849	-		0.933	-		1.742	-		1.055	-		1.140	-		1.201	0.011		1.972	-		1.946
15.833	0.000	0.000	0.993	0.000	0.000	1.080	0.000	0.000	0.747	0.000	0.000	1.207	0.000	0.000	1.295	0.000	0.000	1.358	0.000	0.000	1.017	0.000	0.000	1.017
16.000	0.000	0.000	1.235	0.000	0.000	1.325	0.000	0.000	0.981	0.000	0.000	1.456	0.000	0.000	1.546	0.000	0.000	1.612	0.000	0.000	1.260	0.000	0.000	1.260
16.167	0.000	0.000	1.475	0.000	0.000	1.567	0.000	0.000	1.213	0.000	0.000	1.702	0.000	0.000	1.795	0.001	0.001	1.863	0.000	0.000	1.500	0.000	0.000	1.500
16.333	0.000	0.000	1.712	0.000	0.000	1.807	0.000	0.000	1.443	0.001	0.000	1.945	0.002	0.001	2.041	0.004	0.002	2.110	0.000	0.000	1.738	0.000	0.000	1.738
16.500	0.000	0.000	1.946	0.001	0.000	2.043	0.000	0.000	1.671	0.002	0.001	2.185	0.009	0.004	2.283	0.024	0.012	2.354	0.001	0.001	1.972	0.011	0.006	1.972
16.667	0.000	0.000	2.077	0.001	0.000	2.177	0.000	0.000	1.796	0.006	0.003	2.322	0.027	0.014	2.422	0.079	0.040	2.494	0.003	0.001	2.104	0.027	0.013	2.104
16.833	0.001	0.001	2.306	0.004	0.002	2.408	0.000	0.000	2.020	0.046	0.023	2.555	0.275	0.139	2.657	0.867	0.440	2.731	0.015	0.008	2.334	0.123	0.063	2.334
17.000	0.002	0.001	2.432	0.013	0.007	2.535	0.001	0.000	2.140	0.209	0.106	2.685	1.083	0.550	2.789	2.683	1.362	2.864	0.040	0.020	2.460	0.320	0.162	2.460
17.167	0.022	0.011	2.655	0.197	0.100	2.759	0.002	0.001	2.359	2.131	1.082	2.912	6.629	3.365	3.017	12.740	6.466	3.093	0.381	0.194	2.683	1.813	0.920	2.683
17.333	0.429	0.218	2.874	2.314	1.174	2.981	0.013	0.007	2.575	11.920	6.050	3.135	0.000	0.000	3.242	0.000	0.000	3.319	2.979	1.512	2.903	13.810	7.009	2.903
17.500	4.734	2.403	3.091	0.000	0.000	3.199	0.194	0.098	2.789	0.000	0.000	3.355	0.000	0.000	3.462	0.000	0.000	3.540	13.750	6.979	3.121	0.000	0.000	3.121
17.667	0.000	0.000	3.205	0.000	0.000	3.314	0.781	0.397	2.900	0.000	0.000	3.471	0.000	0.000	3.579	0.000	0.000	3.658	0.000	0.000	3.235	0.000	0.000	3.235
17.833	0.000	0.000	3.216	0.000	0.000	3.325	0.867	0.440	2.909	0.000	0.000	3.484	0.000	0.000	3.593	0.000	0.000	3.672	0.000	0.000	3.246	0.000	0.000	3.246
18.000	0.000	0.000	3.224	0.000	0.000	3.333	0.928	0.471	2.915	0.000	0.000	3.493	0.000	0.000	3.602	0.000	0.000	3.682	0.000	0.000	3.254	0.000	0.000	3.254
18.167	0.000	0.000	3.328	0.000	0.000	3.438	2.770	1.406	3.019	0.000	0.000	3.598	0.000	0.000	3.708	0.000	0.000	3.788	0.000	0.000	3.358	0.000	0.000	3.358
18.333	0.000	0.000	3.330	0.000	0.000	3.440	2.796	1.419	3.020	0.000	0.000	3.600	0.000	0.000	3.710	0.000	0.000	3.790	0.000	0.000	3.360	0.000	0.000	3.360
18.500	0.000	0.000	3.328	0.000	0.000	3.438	2.770	1.406	3.019	0.000	0.000	3.598	0.000	0.000	3.708	0.000	0.000	3.788	0.000	0.000	3.358	0.000	0.000	3.358
18.667	0.000	0.000	3.324	0.000	0.000	3.433	2.662	1.351	3.015	0.000	0.000	3.593	0.000	0.000	3.702	0.000	0.000	3.782	0.000	0.000	3.354	0.000	0.000	3.354
18.833	0.000	0.000	3.216	0.000	0.000	3.325	0.867	0.440	2.909	0.000	0.000	3.484	0.000	0.000	3.593	0.000	0.000	3.672	0.000	0.000	3.246	0.000	0.000	3.246
19.000	0.000	0.000	3.205	0.000	0.000	3.314	0.781	0.397	2.900	0.000	0.000	3.471	0.000	0.000	3.579	0.000	0.000	3.658	0.000	0.000	3.235	0.000	0.000	3.235
19.167	4.734	2.403	3.091	0.000	0.000	3.199	0.194	0.098	2.789	0.000	0.000	3.355	0.000	0.000	3.462	0.000	0.000	3.540	13.750	6.979	3.121	0.000	0.000	3.121
19.333	1.446	0.734	2.974	5.647	2.866	3.081	0.042	0.021	2.675	0.000	0.000	3.235	0.000	0.000	3.342	0.000	0.000	3.419	6.312	3.204	3.003	13.810	7.009	3.003
19.500	0.329	0.167	2.855	1.890	0.959	2.959	0.011	0.006	2.559	10.160	5.157	3.112	0.000	0.000	3.217	0.000	0.000	3.293	2.515	1.276	2.883	6.911	3.508	2.883
19.667	0.060	0.030	2.732	0.501	0.254	2.835	0.004	0.002	2.440	3.956	2.008	2.985	10.750	5.456	3.089	0.000	0.000	3.164	0.849	0.431	2.760	3.124	1.586	2.760
19.833	0.004	0.002	2.506	0.028	0.014	2.608	0.001	0.000	2.220	0.477	0.242	2.755	1.952	0.991	2.857	4.412	2.239	2.931	0.077	0.039	2.534	0.575	0.292	2.534
20.000	0.002	0.001	2.377	0.008	0.004	2.477	0.001	0.000	2.096	0.096	0.049	2.622	0.562	0.285	2.722	1.522	0.772	2.794	0.026	0.013	2.404	0.209	0.106	2.404
20.167	0.001	0.000	2.146	0.001	0.001	2.243	0.000	0.000	1.871	0.010	0.005	2.385	0.045	0.023	2.483	0.141	0.071	2.554	0.004	0.002	2.172	0.042	0.021	2.172
20.333	0.000	0.000	1.912	0.000	0.000	2.007	0.000	0.000	1.643	0.002	0.001	2.145	0.006	0.003	2.241	0.017	0.009	2.310	0.001	0.001	1.938	0.009	0.005	1.938
20.500	0.000	0.000	1.775	0.000	0.000	1.867	0.000	0.000	1.513	0.001	0.000	2.002	0.002	0.001	2.095	0.005	0.003	2.163	0.001	0.000	1.800	0.004	0.002	1.800
20.667	0.000	0.000	1.535	0.000	0.000	1.625	0.000	0.000	1.281	0.000	0.000	1.756	0.001	0.000	1.846	0.001	0.001	1.912	0.000	0.000	1.560	0.000	0.000	1.560
20.833	0.000	0.000	1.293	0.000	0.000	1.380	0.000	0.000	1.047	0.000	0.000	1.507	0.000	0.000	1.595	0.000	0.000	1.658	0.000	0.000	1.317	0.000	0.000	1.317
21.000	-		1.149	-		1.233	-		-0.148	-		1.355	-		1.440	-		1.501	-		0.011	-		-0.008
21.167	-		0.902	-		0.983	-		-0.397	-		1.101	-		1.182	-		1.241	-		-0.248	-		-0.265
21.333	-		0.653	-		0.730	-		-0.548	-		0.844	-		0.921	-		0.978	-		-0.408	-		-0.424
21.500	-		0.501	-		0.576	-		-0.800	-		0.684	-		0.758	-		0.812	-		-0.670	-		-0.685
21.667	-		0.248	-		0.318	-		-1.054	-		0.421	-		0.492	-		0.543	-		-0.934	-		-0.947
21.833	-		-0.008	-		0.059	-		-1.208	-		0.157	-		0.224	-		0.272	-		-1.098	-		-1.111
22.000	-		-0.265	-		-0.202	-		-1.464	-		-0.110	-		-0.047	-		-0.001	-		-1.365	-		-1.376
22.167	-		-0.424	-		-0.365	-		-1.721	-		-0.279	-		-0.220	-		-0.177	-		-1.632	-		-1.643
22.333	-		-0.685	-		-0.630	-		-1.879	-		-0.550	-		-0.495	-		-0.455	-		-1.801	-		-1.810
22.500	-		-0.947	-		-0.897	-		-1.938	-		-0.823	-		-0.772	-		-0.735	-		-1.870	-		-1.878
22.667	-		-1.111	-		-1.065	-		-2.097	-		-0.997	-		-0.951	-		-0.917	-		-2.041	-		-2.047
22.833	-		-1.376	-		-1.334	-		-2.157	-		-1.273	-		-1.231	-		-1.200	-		-2.112	-		-2.117
23.000	-		-1.643	-		-1.605	-		-2.217	-		-1.550	-		-1.513	-		-1.485	-		-2.183	-		-2.187
11.000	-		-1.810	-		-1.777	-		-2.300	-		-1.729	-		-1.696	-		-1.672	-		-2.300	-		-2.300
11.167	-		-1.878	-		-1.850	-		-2.300	-		-1.808	-		-1.780	-		-1.759	-		-2.300	-		-2.300
11.333	-		-2.047	-		-2.023	-		-2.400	-		-1.989	-		-1.965	-		-1.948	-		-2.400	-		-2.400
11.500	-		-2.117	-		-2.098	-		-2.400	-		-2.070	-		-2.051	-		-2.037	-		-2.400	-		-2.400
11.667	-		-2.187	-		-2.173	-		-2.334	-		-2.152	-		-2.138	-		-2.127	-		-2.329	-		-2.324

High End Future Scenario

	10%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
12.667	-		-2.300	-		-2.300	-		-2.300
12.833	-		-2.300	-		-2.300	-		-2.300
13.000	-		-2.400	-		-2.400	-		-2.400
13.167	-		-2.400	-		-2.400	-		-2.400
13.333	-		-2.299	-		-2.284	-		-2.284
13.500	-		-2.198	-		-2.168	-		-2.168
13.667	-		-1.997	-		-1.953	-		-1.953
13.833	-		-1.897	-		-1.838	-		-1.838
14.000	-		-1.798	-		-1.724	-		-1.724
14.167	-		-1.600	-		-1.512	-		-1.512
14.333	-		-1.402	-		-1.300	-		-1.300
14.500	-		-1.207	-		-1.090	-		-1.090
14.667	-		-1.012	-		-0.882	-		-0.882
14.833	-		-0.820	-		-0.676	-		-0.676
15.000	-		-0.629	-		-0.472	-		-0.472
15.167	-		-0.440	-		-0.270	-		-0.270
15.333	-		-0.253	-		-0.071	-		-0.071
15.500	-		-0.069	-		0.126	-		0.126
15.667	-		0.212	-		0.419	-		0.419
15.833	-		0.491	-		0.710	-		0.710
16.000	-		0.667	-		0.897	-		0.897
16.167	-		0.840	-		1.081	-		1.081
16.333	-		1.110	-		1.361	-		1.361
16.500	-		1.377	-		1.638	-		1.638
16.667	0.000	0.000	1.541	0.002	0.001	1.810	0.000	0.000	1.810
16.833	0.000	0.000	1.800	0.008	0.004	2.079	0.079	0.040	2.079
17.000	0.001	0.001	2.057	0.066	0.033	2.343	0.480	0.244	2.343
17.167	0.007	0.003	2.309	0.659	0.335	2.604	2.970	1.507	2.604
17.333	0.062	0.032	2.558	4.673	2.372	2.859	11.700	5.938	2.859
17.500	0.327	0.166	2.703	11.440	5.806	3.011	22.960	11.653	3.011
17.667	3.158	1.603	2.943	0.000	0.000	3.258	0.000	0.000	3.258
17.833	8.667	4.399	3.080	0.000	0.000	3.400	0.000	0.000	3.400
18.000	0.000	0.000	3.313	0.000	0.000	3.637	0.000	0.000	3.637
18.167	0.000	0.000	3.541	0.000	0.000	3.869	0.000	0.000	3.869
18.333	0.000	0.000	3.765	0.000	0.000	4.097	0.000	0.000	4.097
18.500	0.000	0.000	3.885	0.000	0.000	4.220	0.000	0.000	4.220
18.667	0.000	0.000	3.900	0.000	0.000	4.237	0.000	0.000	4.237
18.833	0.000	0.000	3.911	0.000	0.000	4.250	0.000	0.000	4.250
19.000	0.000	0.000	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.167	0.000	0.000	4.020	0.000	0.000	4.360	0.000	0.000	4.360
19.333	0.000	0.000	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.500	0.000	0.000	4.011	0.000	0.000	4.350	0.000	0.000	4.350
19.667	0.000	0.000	3.900	0.000	0.000	4.237	0.000	0.000	4.237
19.833	0.000	0.000	3.885	0.000	0.000	4.220	0.000	0.000	4.220
20.000	0.000	0.000	3.765	0.000	0.000	4.097	0.000	0.000	4.097
20.167	0.000	0.000	3.641	0.000	0.000	3.969	0.000	0.000	3.969
20.333	0.000	0.000	3.513	0.000	0.000	3.837	0.000	0.000	3.837
20.500	0.000	0.000	3.380	0.000	0.000	3.700	0.000	0.000	3.700
20.667	13.340	6.771	3.143	0.000	0.000	3.458	0.000	0.000	3.458
20.833	4.990	2.533	3.003	0.000	0.000	3.311	0.000	0.000	3.311
21.000	0.602	0.306	2.758	14.860	7.542	3.059	0.000	0.000	3.059
21.167	0.038	0.019	2.509	3.220	1.634	2.804	8.880	4.507	2.804
21.333	0.010	0.005	2.357	0.940	0.477	2.643	3.768	1.912	2.643
21.500	0.002	0.001	2.100	0.088	0.044	2.379	0.622	0.315	2.379
21.667	0.000	0.000	1.841	0.010	0.005	2.110	0.096	0.049	2.110
21.833	-		1.677	0.003	0.002	1.938	0.032	0.016	1.938
22.000	-		1.410	-		1.661	-		1.661
22.167	-		1.140	-		1.381	-		1.381
22.333	-		0.967	-		1.197	-		1.197
22.500	-		0.691	-		0.910	-		0.910
22.667	-		0.412	-		0.619	-		0.619
22.833	-		0.131	-		0.326	-		0.326
23.000	-		-0.053	-		0.129	-		0.129
11.000	-		-0.340	-		-0.170	-		-0.170
11.167	-		-0.629	-		-0.472	-		-0.472
11.333	-		-0.820	-		-0.676	-		-0.676
11.500	-		-1.112	-		-0.982	-		-0.982
11.667	-		-1.407	-		-1.290	-		-1.290
11.833	-		-1.602	-		-1.500	-		-1.500
12.000	-		-1.700	-		-1.612	-		-1.612
12.167	-		-1.898	-		-1.824	-		-1.824
12.333	-		-1.997	-		-1.938	-		-1.938
12.500	-		-1.788						

Location B.1

Current Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.000							-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.167							-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.333							-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.500							-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.667							-	0.000	-2.351	-	0.000	-2.351	-	0.000	-2.351	-	0.000	-2.351	-	0.000	-2.342	-	0.000	-2.339
11.833							-	0.000	-2.302	-	0.000	-2.302	-	0.000	-2.302	-	0.000	-2.302	-	0.000	-2.285	-	0.000	-2.278
12.000							-	0.000	-2.153	-	0.000	-2.153	-	0.000	-2.153	-	0.000	-2.153	-	0.000	-2.128	-	0.000	-2.117
12.167							-	0.000	-2.104	-	0.000	-2.104	-	0.000	-2.104	-	0.000	-2.104	-	0.000	-2.071	-	0.000	-2.057
12.333							-	0.000	-2.055	-	0.000	-2.055	-	0.000	-2.055	-	0.000	-2.055	-	0.000	-2.014	-	0.000	-1.997
12.500							-	0.000	-1.908	-	0.000	-1.908	-	0.000	-1.908	-	0.000	-1.908	-	0.000	-1.858	-	0.000	-1.838
12.667							-	0.000	-1.760	-	0.000	-1.760	-	0.000	-1.760	-	0.000	-1.760	-	0.000	-1.703	-	0.000	-1.679
12.833							-	0.000	-1.614	-	0.000	-1.614	-	0.000	-1.614	-	0.000	-1.614	-	0.000	-1.549	-	0.000	-1.521
13.000							-	0.000	-1.468	-	0.000	-1.468	-	0.000	-1.468	-	0.000	-1.468	-	0.000	-1.395	-	0.000	-1.364
13.167							-	0.000	-1.322	-	0.000	-1.322	-	0.000	-1.322	-	0.000	-1.322	-	0.000	-1.242	-	0.000	-1.208
13.333							-	0.000	-1.178	-	0.000	-1.178	-	0.000	-1.178	-	0.000	-1.178	-	0.000	-1.090	-	0.000	-1.054
13.500							-	0.000	-1.035	-	0.000	-1.035	-	0.000	-1.035	-	0.000	-1.035	-	0.000	-0.940	-	0.000	-0.900
13.667							-	0.000	-0.893	-	0.000	-0.893	-	0.000	-0.893	-	0.000	-0.893	-	0.000	-0.791	-	0.000	-0.748
13.833							-	0.000	-0.752	-	0.000	-0.752	-	0.000	-0.752	-	0.000	-0.752	-	0.000	-0.643	-	0.000	-0.597
14.000							-	0.000	-0.512	-	0.000	-0.512	-	0.000	-0.512	-	0.000	-0.512	-	0.000	-0.396	-	0.000	-0.348
14.167							-	0.000	-0.274	-	0.000	-0.274	-	0.000	-0.274	-	0.000	-0.274	-	0.000	-0.152	-	0.000	-0.100
14.333							-	0.000	-0.137	-	0.000	-0.137	-	0.000	-0.137	-	0.000	-0.137	-	0.000	-0.008	-	0.000	0.046
14.500							-	0.000	-0.001	-	0.000	-0.001	-	0.000	-0.001	-	0.000	-0.001	-	0.000	0.133	-	0.000	0.190
14.667							-	0.000	0.233	-	0.000	0.233	-	0.000	0.233	-	0.000	0.233	-	0.000	0.373	-	0.000	0.432
14.833							-	0.000	0.466	-	0.000	0.466	-	0.000	0.466	-	0.000	0.466	-	0.000	0.611	-	0.000	0.672
15.000							0.000	0.000	0.596	0.000	0.000	0.596	0.000	0.000	0.596	0.000	0.000	0.596	0.000	0.000	0.747	0.000	0.000	0.811
15.167							0.000	0.000	0.826	0.000	0.000	0.826	0.000	0.000	0.826	0.000	0.000	0.826	0.000	0.000	0.981	0.000	0.000	1.047
15.333							0.000	0.000	1.053	0.000	0.000	1.053	0.000	0.000	1.053	0.000	0.000	1.053	0.000	0.000	1.213	0.000	0.000	1.281
15.500							0.000	0.000	1.279	0.000	0.000	1.279	0.000	0.000	1.279	0.000	0.000	1.279	0.000	0.000	1.443	0.000	0.000	1.512
15.667							0.000	0.000	1.502	0.000	0.000	1.502	0.000	0.000	1.502	0.000	0.000	1.502	0.000	0.000	1.671	0.000	0.000	1.742
15.833							0.000	0.000	1.624	0.000	0.000	1.624	0.000	0.000	1.624	0.000	0.000	1.624	0.000	0.000	1.796	0.000	0.000	1.869
16.000							0.000	0.000	1.844	0.000	0.000	1.844	0.000	0.000	1.844	0.000	0.000	1.844	0.000	0.000	2.020	0.000	0.000	2.093
16.167							0.000	0.000	1.962	0.000	0.000	1.962	0.000	0.000	1.962	0.000	0.000	1.962	0.000	0.000	2.140	0.000	0.000	2.216
16.333							0.000	0.000	2.178	0.000	0.000	2.178	0.025	0.008	2.178	0.037	0.012	2.178	0.071	0.023	2.359	0.215	0.070	2.435
16.500							0.000	0.000	2.391	0.000	0.000	2.391	0.042	0.014	2.391	0.063	0.020	2.391	0.124	0.040	2.575	0.343	0.111	2.652
16.667							0.000	0.000	2.603	0.038	0.012	2.603	0.072	0.023	2.603	0.108	0.035	2.603	0.181	0.059	2.789	0.436	0.142	2.867
16.833							0.027	0.009	2.713	0.048	0.016	2.713	0.090	0.029	2.713	0.133	0.043	2.713	0.207	0.067	2.900	0.464	0.151	2.979
17.000							0.027	0.009	2.720	0.049	0.016	2.720	0.092	0.030	2.720	0.135	0.044	2.720	0.208	0.068	2.909	0.466	0.151	2.988
17.167							0.028	0.009	2.726	0.050	0.016	2.726	0.092	0.030	2.726	0.136	0.044	2.726	0.210	0.068	2.915	0.468	0.152	2.995
17.333							0.034	0.011	2.829	0.059	0.019	2.829	0.107	0.035	2.829	0.157	0.051	2.829	0.234	0.076	3.019	0.502	0.163	3.099
17.500							0.034	0.011	2.830	0.059	0.019	2.830	0.107	0.035	2.830	0.157	0.051	2.830	0.235	0.076	3.020	0.503	0.163	3.100
17.667							0.034	0.011	2.829	0.059	0.019	2.829	0.107	0.035	2.829	0.157	0.051	2.829	0.234	0.076	3.019	0.502	0.163	3.099
17.833							0.033	0.011	2.826	0.059	0.019	2.826	0.106	0.035	2.826	0.156	0.051	2.826	0.233	0.076	3.015	0.500	0.162	3.095
18.000							0.027	0.009	2.720	0.049	0.016	2.720	0.092	0.030	2.720	0.135	0.044	2.720	0.208	0.068	2.909	0.466	0.151	2.988
18.167							0.027	0.009	2.713	0.048	0.016	2.713	0.090	0.029	2.713	0.133	0.043	2.713	0.207	0.067	2.900	0.464	0.151	2.979
18.333							0.000	0.000	2.603	0.038	0.012	2.603	0.072	0.023	2.603	0.108	0.035	2.603	0.181	0.059	2.789	0.436	0.142	2.867
18.500							0.000	0.000	2.491	0.029	0.009	2.491	0.054	0.017	2.491	0.082	0.027	2.491	0.153	0.050	2.675	0.395	0.128	2.752
18.667							0.000	0.000	2.378	0.000	0.000	2.378	0.041	0.013	2.378	0.061	0.020	2.378	0.120	0.039	2.559	0.333	0.108	2.635
18.833							0.000	0.000	2.262	0.000	0.000	2.262	0.031	0.010	2.262	0.045	0.015	2.262	0.088	0.029	2.440	0.261	0.085	2.516
19.000							0.000	0.000	2.044	0.000	0.000	2.044	0.000	0.000	2.044	0.000	0.000	2.044	0.050	0.016	2.220	0.148	0.048	2.293
19.167							0.000	0.000	1.924	0.000	0.000	1.924	0.000	0.000	1.924	0.000	0.000	1.924	0.000	0.000	2.096	0.000	0.000	2.169
19.333							0.000	0.000	1.702	0.000	0.000	1.702	0.000	0.000	1.702	0.000	0.000	1.702	0.000	0.000	1.871	0.000	0.000	1.942
19.500							0.000	0.000	1.479	0.000	0.000	1.479	0.000	0.000	1.479	0.000	0.000	1.479	0.000	0.000	1.643	0.000	0.000	1.712
19.667							0.000	0.000	1.353	0.000	0.000	1.353	0.000	0.000	1.353	0.000	0.000	1.353	0.000	0.000	1.513	0.000	0.000	1.581
19.833							0.000	0.000	1.126	0.000	0.000	1.126	0.000	0.000	1.126	0.000	0.000	1.126	0.000	0.000	1.281	0.000	0.000	1.347
20.000							0.000	0.000	0.896	0.000	0.000	0.896	0.000	0.000	0.896	0.000	0.000	0.896	0.000	0.000	1.047	0.000	0.000	1.111
20.167							-	0.000	0.766	-	0.000	0.766	-	0.000	0.766	-	0.000	0.766	-	0.000	0.911	-	0.000	0.972
20.333							-	0.000	0.533	-	0.000	0.533	-	0.000	0.533	-	0.000	0.533	-	0.000	0.673	-	0.000	0.732
20.500							-	0.000	0.299	-	0.000	0.299	-	0.000	0.299	-	0.000	0.299	-	0.000	0.433	-	0.000	0.490
20.667							-	0.000	0.163	-	0.000	0.163	-	0.000	0.163	-	0.000	0.163	-	0.000	0.292	-	0.000	0.346
20.833							-	0.000	-0.074	-	0.000	-0.074	-	0.000	-0.074	-	0.000	-0.074	-	0.000	0.048	-	0.000	0.100
21.000							-	0.000	-0.312	-	0.000	-0.312	-	0.000	-0.312	-	0.000	-0.312	-	0.000	-0.196	-	0.000	-0.148
21.167							-	0.000	-0.552	-	0.000	-0.552	-	0.000	-0.552	-	0.000	-0.552	-	0.000	-0.443	-	0.000	-0.397
21.333							-	0.000	-0.693	-	0.000	-0.693	-	0.000	-0.693	-	0.000	-0.693	-	0.000	-0.591	-	0.000	-0.548
21.500							-	0.000	-0.935	-	0.000	-0.935	-	0.000	-0.935	-	0.000	-0.935	-	0.000	-0.840	-	0.000	-0.800
21.667							-	0.000	-1.178	-	0.000	-1.178	-	0.000	-1.178	-	0.000	-1.178	-	0.000	-1.090	-	0.000	-1.054
21.833							-	0.000	-1.322	-	0.000	-1.322	-	0.000	-1.322	-	0.000	-1.322	-	0.000	-1.242	-	0.000	-1.208
22.000							-	0.000	-1.568	-	0.000	-1.568	-	0.000	-1.568	-	0.000	-1.568	-	0.000	-1.495	-	0.000	-1.464
22.167							-	0.000	-1.814	-	0.000	-1.814	-	0.000	-1.814	-	0.000	-1.814	-	0.000	-1.749	-	0.000	-1.721
22.333							-	0.000	-1.960	-	0.000	-1.960	-	0.000	-1.960	-	0.000	-1.960	-	0.000	-1.903	-	0.000	-1.879
22.500							-	0.000	-2.008	-	0.000	-2.008	-	0.000	-2.008	-	0.000	-2.008	-	0.000	-1.958	-	0.000	-1.938
22.667							-	0.000	-2.155	-	0.000	-2.155	-	0.000	-2.155	-	0.000	-2.155	-	0.000	-2.114	-	0.000	-2.097
22.833							-	0.000	-2.204	-	0.000	-2.204	-	0.000	-2.204	-	0.000	-2.204	-	0.000	-2.171	-	0.000	-2.157
23.000							-	0.000	-2.253	-	0.000	-2.253	-	0.000	-2.253	-	0.000	-2.253	-	0.000	-2.228	-	0.000	-2.217

Mid -Range Future Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.000	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.333	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.500	-	0.000	-2.350	-	0.000	-2.347	-	0.000	-2.321	-	0.000	-2.317	-	0.000	-2.312	-	0.000	-2.309	-	0.000	-2.306	-	0.000	-2.306
12.667	-	0.000	-2.301	-	0.000	-2.294	-	0.000	-2.241	-	0.000	-2.234	-	0.000	-2.225	-	0.000	-2.218	-	0.000	-2.212	-	0.000	-2.212
12.833	-	0.000	-2.151	-	0.000	-2.141	-	0.000	-2.062	-	0.000	-2.052	-	0.000	-2.038	-	0.000	-2.027	-	0.000	-2.018	-	0.000	-2.018
13.000	-	0.000	-2.102	-	0.000	-2.088	-	0.000	-1.984	-	0.000	-1.970	-	0.000	-1.951	-	0.000	-1.937	-	0.000	-1.925	-	0.000	-1.925
13.167	-	0.000	-2.053	-	0.000	-2.036	-	0.000	-1.906	-	0.000	-1.889	-	0.000	-1.865	-	0.000	-1.848	-	0.000	-1.832	-	0.000	-1.832
13.333	-	0.000	-1.905	-	0.000	-1.884	-	0.000	-1.729	-	0.000	-1.708	-	0.000	-1.680	-	0.000	-1.659	-	0.000	-1.641	-	0.000	-1.641
13.500	-	0.000	-1.757	-	0.000	-1.733	-	0.000	-1.553	-	0.000	-1.529	-	0.000	-1.496	-	0.000	-1.472	-	0.000	-1.450	-	0.000	-1.450
13.667	-	0.000	-1.610	-	0.000	-1.583	-	0.000	-1.378	-	0.000	-1.350	-	0.000	-1.313	-	0.000	-1.285	-	0.000	-1.261	-	0.000	-1.261
13.833	-	0.000	-1.464	-	0.000	-1.433	-	0.000	-1.204	-	0.000	-1.173	-	0.000	-1.131	-	0.000	-1.100	-	0.000	-1.073	-	0.000	-1.073
14.000	-	0.000	-1.318	-	0.000	-1.284	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
14.167	-	0.000	-1.174	-	0.000	-1.137	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
14.333	-	0.000	-1.030	-	0.000	-0.990	-	0.000	-0.690	-	0.000	-0.650	-	0.000	-0.595	-	0.000	-0.555	-	0.000	-0.520	-	0.000	-0.520
14.500	-	0.000	-0.887	-	0.000	-0.844	-	0.000	-0.522	-	0.000	-0.479	-	0.000	-0.420	-	0.000	-0.377	-	0.000	-0.339	-	0.000	-0.339
14.667	-	0.000	-0.746	-	0.000	-0.700	-	0.000	-0.356	-	0.000	-0.310	-	0.000	-0.247	-	0.000	-0.201	-	0.000	-0.161	-	0.000	-0.161
14.833	-	0.000	-0.506	-	0.000	-0.457	-	0.000	-0.092	-	0.000	-0.043	-	0.000	0.024	-	0.000	0.072	-	0.000	0.115	-	0.000	0.115
15.000	-	0.000	-0.267	-	0.000	-0.216	-	0.000	0.170	-	0.000	0.221	-	0.000	0.292	-	0.000	0.343	-	0.000	0.388	-	0.000	0.388
15.167	-	0.000	-0.130	-	0.000	-0.076	-	0.000	0.330	-	0.000	0.384	-	0.000	0.458	-	0.000	0.512	-	0.000	0.559	-	0.000	0.559
15.333	-	0.000	0.006	-	0.000	0.063	-	0.000	0.487	-	0.000	0.544	-	0.000	0.621	-	0.000	0.678	-	0.000	0.727	-	0.000	0.727
15.500	-	0.000	0.240	-	0.000	0.299	-	0.000	0.742	-	0.000	0.801	-	0.000	0.882	-	0.000	0.941	-	0.000	0.993	-	0.000	0.993
15.667	-	0.000	0.473	-	0.000	0.535	-	0.000	0.994	-	0.000	1.055	-	0.000	1.140	-	0.000	1.201	-	0.000	1.255	-	0.000	1.255
15.833	0.000	0.000	0.604	0.000	0.000	0.668	0.000	0.000	1.144	0.000	0.000	1.207	0.000	0.000	1.295	0.000	0.000	1.358	0.000	0.000	1.414	0.000	0.000	1.414
16.000	0.000	0.000	0.834	0.000	0.000	0.899	0.000	0.000	1.391	0.000	0.000	1.456	0.000	0.000	1.546	0.000	0.000	1.612	0.000	0.000	1.669	0.000	0.000	1.669
16.167	0.000	0.000	1.061	0.000	0.000	1.129	0.000	0.000	1.635	0.000	0.000	1.702	0.000	0.000	1.795	0.000	0.000	1.863	0.000	0.000	1.922	0.000	0.000	1.922
16.333	0.000	0.000	1.287	0.000	0.000	1.357	0.000	0.000	1.876	0.000	0.000	1.945	0.000	0.000	2.041	0.000	0.000	2.110	0.000	0.000	2.171	0.000	0.000	2.171
16.500	0.000	0.000	1.511	0.000	0.000	1.582	0.000	0.000	2.114	0.000	0.000	2.185	0.000	0.000	2.283	0.030	0.010	2.354	0.047	0.015	2.416	0.204	0.066	2.416
16.667	0.000	0.000	1.633	0.000	0.000	1.706	0.000	0.000	2.249	0.000	0.000	2.322	0.000	0.000	2.422	0.043	0.014	2.494	0.067	0.022	2.558	0.284	0.092	2.558
16.833	0.000	0.000	1.853	0.000	0.000	1.927	0.000	0.000	2.481	0.000	0.000	2.555	0.048	0.016	2.657	0.075	0.024	2.731	0.106	0.034	2.796	0.405	0.132	2.796
17.000	0.000	0.000	1.971	0.000	0.000	2.046	0.000	0.000	2.610	0.035	0.011	2.685	0.062	0.020	2.789	0.087	0.028	2.864	0.114	0.037	2.930	0.430	0.140	2.930
17.167	0.000	0.000	2.187	0.000	0.000	2.264	0.034	0.011	2.836	0.051	0.016	2.912	0.073	0.024	3.017	0.097	0.032	3.093	0.136	0.044	3.160	0.477	0.155	3.160
17.333	0.000	0.000	2.401	0.049	0.016	2.478	0.043	0.014	3.058	0.057	0.018	3.135	0.089	0.029	3.242	0.141	0.046	3.319	0.217	0.071	3.386	0.799	0.260	3.386
17.500	0.043	0.014	2.613	0.082	0.027	2.691	0.049	0.016	3.277	0.082	0.027	3.355	0.175	0.057	3.462	0.324	0.105	3.540	0.544	0.177	3.609	1.609	0.523	3.609
17.667	0.055	0.018	2.723	0.096	0.031	2.801	0.068	0.022	3.392	0.130	0.042	3.471	0.313	0.102	3.579	0.573	0.186	3.658	0.948	0.308	3.727	2.515	0.817	3.727
17.833	0.056	0.018	2.730	0.097	0.032	2.810	0.071	0.023	3.404	0.138	0.045	3.484	0.336	0.109	3.593	0.614	0.199	3.672	1.017	0.330	3.742	2.663	0.865	3.742
18.000	0.057	0.018	2.736	0.098	0.032	2.815	0.073	0.024	3.413	0.144	0.047	3.493	0.354	0.115	3.602	0.645	0.210	3.682	1.070	0.348	3.752	2.774	0.901	3.752
18.167	0.066	0.022	2.839	0.101	0.033	2.919	0.124	0.040	3.518	0.264	0.086	3.598	0.625	0.203	3.708	1.123	0.365	3.788	1.890	0.614	3.858	4.437	1.441	3.858
18.333	0.066	0.022	2.840	0.101	0.033	2.920	0.126	0.041	3.520	0.267	0.087	3.600	0.632	0.205	3.710	1.135	0.369	3.790	1.910	0.620	3.860	4.478	1.455	3.860
18.500	0.066	0.022	2.839	0.101	0.033	2.919	0.124	0.040	3.518	0.264	0.086	3.598	0.625	0.203	3.708	1.123	0.365	3.788	1.890	0.614	3.858	4.437	1.441	3.858
18.667	0.066	0.021	2.836	0.101	0.033	2.915	0.121	0.039	3.513	0.255	0.083	3.593	0.606	0.197	3.702	1.087	0.353	3.782	1.819	0.591	3.852	4.297	1.396	3.852
18.833	0.056	0.018	2.730	0.097	0.032	2.810	0.071	0.023	3.404	0.138	0.045	3.484	0.336	0.109	3.593	0.614	0.199	3.672	1.017	0.330	3.742	2.663	0.865	3.742
19.000	0.055	0.018	2.723	0.096	0.031	2.801	0.068	0.022	3.392	0.130	0.042	3.471	0.313	0.102	3.579	0.573	0.186	3.658	0.948	0.308	3.727	2.515	0.817	3.727
19.167	0.043	0.014	2.613	0.082	0.027	2.691	0.049	0.016	3.277	0.082	0.027	3.355	0.175	0.057	3.462	0.324	0.105	3.540	0.544	0.177	3.609	1.609	0.523	3.609
19.333	0.033	0.011	2.501	0.064	0.021	2.578	0.045	0.015	3.158	0.062	0.020	3.235	0.114	0.037	3.342	0.190	0.062	3.419	0.319	0.103	3.486	1.087	0.353	3.486
19.500	0.000	0.000	2.387	0.047	0.015	2.464	0.043	0.014	3.036	0.056	0.018	3.112	0.085	0.028	3.217	0.133	0.043	3.293	0.201	0.065	3.360	0.739	0.240	3.360
19.667	0.000	0.000	2.271	0.035	0.011	2.346	0.038	0.012	2.910	0.054	0.017	2.985	0.075	0.024	3.089	0.104	0.034	3.164	0.151	0.049	3.230	0.531	0.172	3.230
19.833	0.000	0.000	2.053	0.000	0.000	2.127	0.025	0.008	2.681	0.041	0.013	2.755	0.067	0.022	2.857	0.090	0.029	2.931	0.117	0.038	2.996	0.436	0.142	2.996
20.000	0.000	0.000	1.933	0.000	0.000	2.006	0.000	0.000	2.549	0.030	0.010	2.622	0.055	0.018	2.722	0.082	0.027	2.794	0.111	0.036	2.858	0.421	0.137	2.858
20.167	0.000	0.000	1.711	0.000	0.000	1.782	0.000	0.000	2.314	0.000	0.000	2.385	0.031	0.010	2.483	0.050	0.016	2.554	0.078	0.025	2.616	0.320	0.104	2.616
20.333	0.000	0.000	1.487	0.000	0.000	1.557	0.000	0.000	2.076	0.000	0.000	2.145	0.000	0.000	2.241	0.000	0.000	2.310	0.041	0.013	2.371	0.181	0.059	2.371
20.500	0.000	0.000	1.361	0.000	0.000	1.429	0.000	0.000	1.935	0.000	0.000	2.002	0.000	0.000	2.095	0.000	0.000	2.163	0.029	0.009	2.222	0.120	0.039	2.222
20.667	0.000	0.000	1.134	0.000	0.000	1.199	0.000	0.000	1.691	0.000	0.000	1.756	0.000	0.000	1.846	0.000	0.000	1.912	0.000	0.000	1.969	0.000	0.000	1.969
20.833	0.000	0.000	0.904	0.000	0.000	0.968	0.000	0.000	1.444	0.000	0.000	1.507	0.000	0.000	1.595	0.000	0.000	1.658	0.000	0.000	1.714	0.000	0.000	1.714
21.000	-	0.000	0.773	-	0.000	0.835	-	0.000	1.294	-	0.000	1.355	-	0.000	1.440	-	0.000	1.501	-	0.000	1.555	-	0.000	1.555
21.167	-	0.000	0.540	-	0.000	0.599	-	0.000	1.042	-	0.000	1.101	-	0.000	1.182	-	0.000	1.241	-	0.000	1.293	-	0.000	1.293
21.333	-	0.000	0.306	-	0.000	0.363	-	0.000	0.787	-	0.000	0.844	-	0.000	0.921	-	0.000	0.978	-	0.000	1.027	-	0.000	1.027
21.500	-	0.000	0.170	-	0.000	0.224	-	0.000	0.630	-	0.000	0.684	-	0.000	0.758	-	0.000	0.812	-	0.000	0.859	-	0.000	0.859
21.667	-	0.000	-0.067	-	0.000	-0.016	-	0.000	0.370	-	0.000	0.421	-	0.000	0.492	-	0.000	0.543	-	0.000	0.588	-	0.000	0.588
21.833	-	0.000	-0.306	-	0.000	-0.257	-	0.000	0.108	-	0.000	0.157	-	0.000	0.224	-	0.000	0.272	-	0.000	0.315	-	0.000	0.315
22.000	-	0.000	-0.546	-	0.000	-0.500	-	0.000	-0.156	-	0.000	-0.110	-	0.000	-0.047	-	0.000	-0.001	-	0.000	0.039	-	0.000	0.039
22.167	-	0.000	-0.687	-	0.000	-0.644	-	0.000	-0.322	-	0.000	-0.279	-	0.000	-0.220	-	0.000	-0.177	-	0.000	-0.139	-	0.000	-0.139
22.333	-	0.000	-0.930	-	0.000	-0.890	-	0.000	-0.590	-	0.000	-0.550	-	0.000	-0.495	-	0.000	-0.455	-	0.000	-0.420	-	0.000	-0.420
22.500	-	0.000	-1.174	-	0.000	-1.137	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
22.667	-	0.000	-1.318	-	0.000	-1.284	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
22.833	-	0.000	-1.564	-	0.000	-1.533	-	0.000	-1.304	-	0.000	-1.273	-	0.000	-1.231	-	0.000	-1.200	-	0.000	-1.173	-	0.000	-1.173
23.000	-	0.000	-1.810	-	0.000	-1.783	-	0.000	-1.578	-	0.000	-1.550	-	0.000	-1.513	-	0.000	-1.485	-	0.000	-1.461	-	0.000	-1.461
11.000	-	0.000	-1.957	-	0.000	-1.933	-	0.000	-1.753	-	0.000	-1.729	-	0.000	-1.696	-	0.000	-1.672	-	0.000	-1.650	-	0.000	-1.650
11.167	-	0.000	-2.005	-	0.000	-1.984	-	0.000	-1.829	-	0.000	-1.808	-	0.000	-1.780	-	0.000	-1.759	-	0.000	-1.741	-	0.000	-1.741
11.333	-	0.000	-2.153	-	0.000	-2.136	-	0.000	-2.006	-	0.000	-1.989	-	0.000	-1.965	-	0.000	-1.948	-	0.000	-1.932	-	0.000	-1.932
11.500	-	0.000	-2.202	-	0.000	-2.188	-	0.000	-2.084	-	0.000	-2.070	-	0.000	-2.051	-	0.000	-2.037	-	0.000	-2.025	-	0.000	-2.025
11.667	-	0.000	-2.251	-	0.000	-2.241	-	0.000	-2.162	-	0.000	-2.152	-	0.000	-2.138	-	0.000	-2.127	-	0.000	-2.118	-	0.000	-2.118

High End Future Scenario

	10%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
12.667	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
13.000	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.333	-	0.000	-2.299	-	0.000	-2.284	-	0.000	-2.284
13.500	-	0.000	-2.198	-	0.000	-2.168	-	0.000	-2.168
13.667	-	0.000	-1.997	-	0.000	-1.953	-	0.000	-1.953
13.833	-	0.000	-1.897	-	0.000	-1.838	-	0.000	-1.838
14.000	-	0.000	-1.798	-	0.000	-1.724	-	0.000	-1.724
14.167	-	0.000	-1.600	-	0.000	-1.512	-	0.000	-1.512
14.333	-	0.000	-1.402	-	0.000	-1.300	-	0.000	-1.300
14.500	-	0.000	-1.207	-	0.000	-1.090	-	0.000	-1.090
14.667	-	0.000	-1.012	-	0.000	-0.882	-	0.000	-0.882
14.833	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
15.000	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
15.167	-	0.000	-0.440	-	0.000	-0.270	-	0.000	-0.270
15.333	-	0.000	-0.253	-	0.000	-0.071	-	0.000	-0.071
15.500	-	0.000	-0.069	-	0.000	0.126	-	0.000	0.126
15.667	-	0.000	0.212	-	0.000	0.419	-	0.000	0.419
15.833	-	0.000	0.491	-	0.000	0.710	-	0.000	0.710
16.000	-	0.000	0.667	-	0.000	0.897	-	0.000	0.897
16.167	-	0.000	0.840	-	0.000	1.081	-	0.000	1.081
16.333	-	0.000	1.110	-	0.000	1.361	-	0.000	1.361
16.500	-	0.000	1.377	-	0.000	1.638	-	0.000	1.638
16.667	0.000	0.000	1.541	0.000	0.000	1.810	0.000	0.000	1.810
16.833	0.000	0.000	1.800	0.000	0.000	2.079	0.000	0.000	2.079
17.000	0.000	0.000	2.057	0.062	0.020	2.343	0.289	0.094	2.343
17.167	0.000	0.000	2.309	0.121	0.039	2.604	0.516	0.167	2.604
17.333	0.033	0.011	2.558	0.167	0.054	2.859	0.628	0.204	2.859
17.500	0.046	0.015	2.703	0.179	0.058	3.011	0.619	0.201	3.011
17.667	0.063	0.020	2.943	0.228	0.074	3.258	0.838	0.272	3.258
17.833	0.065	0.021	3.080	0.326	0.106	3.400	1.206	0.392	3.400
18.000	0.088	0.029	3.313	0.810	0.263	3.637	2.462	0.800	3.637
18.167	0.221	0.072	3.541	2.478	0.805	3.869	6.216	2.019	3.869
18.333	0.783	0.254	3.765	0.000	0.000	4.097	0.000	0.000	4.097
18.500	1.571	0.510	3.885	0.000	0.000	4.220	0.000	0.000	4.220
18.667	1.725	0.560	3.900	0.000	0.000	4.237	0.000	0.000	4.237
18.833	1.841	0.598	3.911	0.000	0.000	4.250	0.000	0.000	4.250
19.000	3.470	1.127	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.167	3.533	1.148	4.020	0.000	0.000	4.360	0.000	0.000	4.360
19.333	3.470	1.127	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.500	3.346	1.087	4.011	0.000	0.000	4.350	0.000	0.000	4.350
19.667	1.725	0.560	3.900	0.000	0.000	4.237	0.000	0.000	4.237
19.833	1.571	0.510	3.885	0.000	0.000	4.220	0.000	0.000	4.220
20.000	0.783	0.254	3.765	0.000	0.000	4.097	0.000	0.000	4.097
20.167	0.389	0.126	3.641	4.282	1.391	3.969	9.668	3.140	3.969
20.333	0.190	0.062	3.513	2.081	0.676	3.837	5.390	1.751	3.837
20.500	0.108	0.035	3.380	1.065	0.346	3.700	3.098	1.006	3.700
20.667	0.067	0.022	3.143	0.403	0.131	3.458	1.415	0.460	3.458
20.833	0.064	0.021	3.003	0.253	0.082	3.311	0.954	0.310	3.311
21.000	0.051	0.017	2.758	0.184	0.060	3.059	0.627	0.204	3.059
21.167	0.029	0.009	2.509	0.162	0.052	2.804	0.625	0.203	2.804
21.333	0.000	0.000	2.357	0.131	0.043	2.643	0.549	0.178	2.643
21.500	0.000	0.000	2.100	0.068	0.022	2.379	0.317	0.103	2.379
21.667	0.000	0.000	1.841	0.000	0.000	2.110	0.000	0.000	2.110
21.833	0.000	0.000	1.677	0.000	0.000	1.938	0.000	0.000	1.938
22.000	-	0.000	1.410	-	0.000	1.661	-	0.000	1.661
22.167	-	0.000	1.140	-	0.000	1.381	-	0.000	1.381
22.333	-	0.000	0.967	-	0.000	1.197	-	0.000	1.197
22.500	-	0.000	0.691	-	0.000	0.910	-	0.000	0.910
22.667	-	0.000	0.412	-	0.000	0.619	-	0.000	0.619
22.833	-	0.000	0.131	-	0.000	0.326	-	0.000	0.326
23.000	-	0.000	-0.053	-	0.000	0.129	-	0.000	0.129
11.000	-	0.000	-0.340	-	0.000	-0.170	-	0.000	-0.170
11.167	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
11.333	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
11.500	-	0.000	-1.112	-	0.000	-0.982	-	0.000	-0.982
11.667	-	0.000	-1.407	-	0.000	-1.290	-	0.000	-1.290
11.833	-	0.000	-1.602	-	0.000	-1.500	-	0.000	-1.500
12.000	-	0.000	-1.700	-	0.000	-1.612	-	0.000	-1.612
12.167	-	0.000	-1.898	-	0.000	-1.824	-	0.000	-1.824
12.333	-	0.000	-1.997	-	0.000	-1.938	-	0.000	-1.938
12.500	-	0.000	-2.097	-	0.000	-2.053	-	0.000	-2.053

Location B.2

Current Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.000	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.167	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.333	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.500	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.667	-	0.000	-2.351	-	0.000	-2.346	-	0.000	-2.342	-	0.000	-2.339	-	0.000	-2.334	-	0.000	-2.331	-	0.000	-2.328	-	0.000	-2.328
11.833	-	0.000	-2.302	-	0.000	-2.292	-	0.000	-2.285	-	0.000	-2.278	-	0.000	-2.268	-	0.000	-2.261	-	0.000	-2.255	-	0.000	-2.255
12.000	-	0.000	-2.153	-	0.000	-2.138	-	0.000	-2.128	-	0.000	-2.117	-	0.000	-2.103	-	0.000	-2.092	-	0.000	-2.083	-	0.000	-2.083
12.167	-	0.000	-2.104	-	0.000	-2.085	-	0.000	-2.071	-	0.000	-2.057	-	0.000	-2.038	-	0.000	-2.024	-	0.000	-2.012	-	0.000	-2.012
12.333	-	0.000	-2.055	-	0.000	-2.032	-	0.000	-2.014	-	0.000	-1.997	-	0.000	-1.973	-	0.000	-1.956	-	0.000	-1.941	-	0.000	-1.941
12.500	-	0.000	-1.908	-	0.000	-1.879	-	0.000	-1.858	-	0.000	-1.838	-	0.000	-1.809	-	0.000	-1.788	-	0.000	-1.770	-	0.000	-1.770
12.667	-	0.000	-1.760	-	0.000	-1.727	-	0.000	-1.703	-	0.000	-1.679	-	0.000	-1.646	-	0.000	-1.622	-	0.000	-1.601	-	0.000	-1.601
12.833	-	0.000	-1.614	-	0.000	-1.576	-	0.000	-1.549	-	0.000	-1.521	-	0.000	-1.484	-	0.000	-1.456	-	0.000	-1.432	-	0.000	-1.432
13.000	-	0.000	-1.468	-	0.000	-1.425	-	0.000	-1.395	-	0.000	-1.364	-	0.000	-1.322	-	0.000	-1.292	-	0.000	-1.265	-	0.000	-1.265
13.167	-	0.000	-1.322	-	0.000	-1.276	-	0.000	-1.242	-	0.000	-1.208	-	0.000	-1.162	-	0.000	-1.128	-	0.000	-1.098	-	0.000	-1.098
13.333	-	0.000	-1.178	-	0.000	-1.127	-	0.000	-1.090	-	0.000	-1.054	-	0.000	-1.003	-	0.000	-0.966	-	0.000	-0.934	-	0.000	-0.934
13.500	-	0.000	-1.035	-	0.000	-0.980	-	0.000	-0.940	-	0.000	-0.900	-	0.000	-0.845	-	0.000	-0.805	-	0.000	-0.770	-	0.000	-0.770
13.667	-	0.000	-0.893	-	0.000	-0.834	-	0.000	-0.791	-	0.000	-0.748	-	0.000	-0.689	-	0.000	-0.646	-	0.000	-0.608	-	0.000	-0.608
13.833	-	0.000	-0.752	-	0.000	-0.689	-	0.000	-0.643	-	0.000	-0.597	-	0.000	-0.534	-	0.000	-0.488	-	0.000	-0.448	-	0.000	-0.448
14.000	-	0.000	-0.512	-	0.000	-0.445	-	0.000	-0.396	-	0.000	-0.348	-	0.000	-0.281	-	0.000	-0.232	-	0.000	-0.189	-	0.000	-0.189
14.167	-	0.000	-0.274	-	0.000	-0.203	-	0.000	-0.152	-	0.000	-0.100	-	0.000	-0.029	-	0.000	0.022	-	0.000	0.067	-	0.000	0.067
14.333	-	0.000	-0.137	-	0.000	-0.062	-	0.000	-0.008	-	0.000	0.046	-	0.000	0.120	-	0.000	0.174	-	0.000	0.221	-	0.000	0.221
14.500	-	0.000	-0.001	-	0.000	0.077	-	0.000	0.133	-	0.000	0.190	-	0.000	0.268	-	0.000	0.324	-	0.000	0.374	-	0.000	0.374
14.667	-	0.000	0.233	-	0.000	0.314	-	0.000	0.373	-	0.000	0.432	-	0.000	0.513	-	0.000	0.572	-	0.000	0.624	-	0.000	0.624
14.833	-	0.000	0.466	-	0.000	0.550	-	0.000	0.611	-	0.000	0.672	-	0.000	0.757	-	0.000	0.818	-	0.000	0.872	-	0.000	0.872
15.000	0.000	0.000	0.596	0.000	0.000	0.684	0.000	0.000	0.747	0.000	0.000	0.811	0.000	0.000	0.898	0.000	0.000	0.961	0.000	0.000	1.017	0.000	0.000	1.017
15.167	0.000	0.000	0.826	0.000	0.000	0.916	0.000	0.000	0.981	0.000	0.000	1.047	0.000	0.000	1.137	0.000	0.000	1.202	0.000	0.000	1.260	0.000	0.000	1.260
15.333	0.000	0.000	1.053	0.000	0.000	1.146	0.000	0.000	1.213	0.000	0.000	1.281	0.000	0.000	1.374	0.000	0.000	1.441	0.000	0.000	1.500	0.000	0.000	1.500
15.500	0.000	0.000	1.279	0.000	0.000	1.374	0.000	0.000	1.443	0.000	0.000	1.512	0.000	0.000	1.608	0.000	0.000	1.677	0.000	0.000	1.738	0.000	0.000	1.738
15.667	0.000	0.000	1.502	0.000	0.000	1.600	0.000	0.000	1.671	0.000	0.000	1.742	0.000	0.000	1.839	0.000	0.000	1.910	0.000	0.000	1.972	0.000	0.000	1.972
15.833	0.000	0.000	1.624	0.000	0.000	1.724	0.000	0.000	1.796	0.000	0.000	1.869	0.000	0.000	1.969	0.000	0.000	2.041	0.020	0.021	2.104	0.000	0.000	2.104
16.000	0.000	0.000	1.844	0.000	0.000	1.946	0.002	0.002	2.020	0.005	0.005	2.093	0.015	0.015	2.195	0.052	0.053	2.269	0.209	0.214	2.334	2.117	2.170	2.334
16.167	0.000	0.000	1.962	0.002	0.002	2.065	0.004	0.004	2.140	0.009	0.009	2.216	0.048	0.049	2.319	0.247	0.253	2.394	0.963	0.987	2.460	5.231	5.362	2.460
16.333	0.002	0.002	2.178	0.006	0.006	2.283	0.017	0.017	2.359	0.091	0.093	2.435	0.868	0.889	2.540	2.641	2.707	2.616	5.429	5.565	2.683	15.090	15.469	2.683
16.500	0.006	0.007	2.391	0.054	0.055	2.498	0.332	0.340	2.575	1.348	1.382	2.652	4.592	4.707	2.759	8.658	8.876	2.836	14.470	14.834	2.903	32.970	33.799	2.903
16.667	0.090	0.092	2.603	0.829	0.850	2.711	2.491	2.554	2.789	5.620	5.761	2.867	13.590	13.932	2.974	24.190	24.798	3.052	0.000	0.000	3.121	0.000	0.000	3.121
16.833	0.369	0.378	2.713	2.146	2.200	2.821	5.029	5.155	2.900	10.600	10.866	2.979	24.540	25.157	3.087	0.000	0.000	3.166	0.000	0.000	3.235	0.000	0.000	3.235
17.000	0.400	0.410	2.720	2.295	2.353	2.829	5.317	5.451	2.909	11.160	11.441	2.988	25.840	26.489	3.097	0.000	0.000	3.176	0.000	0.000	3.246	0.000	0.000	3.246
17.167	0.428	0.439	2.726	2.378	2.438	2.835	5.519	5.658	2.915	11.610	11.902	2.995	26.780	27.453	3.104	0.000	0.000	3.184	0.000	0.000	3.254	0.000	0.000	3.254
17.333	1.249	1.280	2.829	4.885	5.008	2.939	10.600	10.866	3.019	21.260	21.794	3.099	0.000	0.000	3.209	0.000	0.000	3.288	0.000	0.000	3.358	0.000	0.000	3.358
17.500	1.260	1.292	2.830	4.919	5.043	2.940	10.670	10.938	3.020	21.380	21.917	3.100	0.000	0.000	3.210	0.000	0.000	3.290	0.000	0.000	3.360	0.000	0.000	3.360
17.667	1.249	1.280	2.829	4.885	5.008	2.939	10.600	10.866	3.019	21.260	21.794	3.099	0.000	0.000	3.209	0.000	0.000	3.288	0.000	0.000	3.358	0.000	0.000	3.358
17.833	1.214	1.245	2.826	4.750	4.869	2.935	10.330	10.590	3.015	20.770	21.292	3.095	0.000	0.000	3.204	0.000	0.000	3.284	0.000	0.000	3.354	0.000	0.000	3.354
18.000	0.400	0.410	2.720	2.295	2.353	2.829	5.317	5.451	2.909	11.160	11.441	2.988	25.840	26.489	3.097	0.000	0.000	3.176	0.000	0.000	3.246	0.000	0.000	3.246
18.167	0.369	0.378	2.713	2.146	2.200	2.821	5.029	5.155	2.900	10.600	10.866	2.979	24.540	25.157	3.087	0.000	0.000	3.166	0.000	0.000	3.235	0.000	0.000	3.235
18.333	0.090	0.092	2.603	0.829	0.850	2.711	2.491	2.554	2.789	5.620	5.761	2.867	13.590	13.932	2.974	24.190	24.798	3.052	0.000	0.000	3.121	0.000	0.000	3.121
18.500	0.019	0.020	2.491	0.232	0.237	2.598	0.984	1.008	2.675	2.877	2.949	2.752	7.565	7.755	2.859	13.820	14.167	2.936	22.630	23.199	3.003	47.110	48.294	3.003
18.667	0.006	0.006	2.378	0.043	0.044	2.483	0.267	0.274	2.559	1.164	1.193	2.635	4.137	4.241	2.740	7.947	8.147	2.816	13.180	13.511	2.883	30.540	31.308	2.883
18.833	0.003	0.003	2.262	0.010	0.011	2.365	0.046	0.048	2.440	0.300	0.307	2.516	1.812	1.858	2.619	4.350	4.459	2.694	7.794	7.990	2.760	19.680	20.175	2.760
19.000	0.000	0.000	2.044	0.003	0.003	2.146	0.006	0.006	2.220	0.017	0.017	2.293	0.128	0.131	2.395	0.651	0.667	2.469	1.970	2.020	2.534	8.070	8.273	2.534
19.167	0.000	0.000	1.924	0.002	0.002	2.024	0.003	0.003	2.096	0.007	0.007	2.169	0.028	0.029	2.269	0.123	0.126	2.341	0.510	0.522	2.404	3.601	3.692	2.404
19.333	0.000	0.000	1.702	0.000	0.000	1.800	0.000	0.000	1.871	0.000	0.000	1.942	0.006	0.006	2.039	0.013	0.014	2.110	0.035	0.036	2.172	0.000	0.000	2.172
19.500	0.000	0.000	1.479	0.000	0.000	1.574	0.000	0.000	1.643	0.000	0.000	1.712	0.000	0.000	1.808	0.000	0.000	1.877	0.000	0.000	1.938	0.000	0.000	1.938
19.667	0.000	0.000	1.353	0.000	0.000	1.446	0.000	0.000	1.513	0.000	0.000	1.581	0.000	0.000	1.674	0.000	0.000	1.741	0.000	0.000	1.800	0.000	0.000	1.800
19.833	0.000	0.000	1.126	0.000	0.000	1.216	0.000	0.000	1.281	0.000	0.000	1.347	0.000	0.000	1.437	0.000	0.000	1.502	0.000	0.000	1.560	0.000	0.000	1.560
20.000	0.000	0.000	0.896	0.000	0.000	0.984	0.000	0.000	1.047	0.000	0.000	1.111	0.000	0.000	1.198	0.000	0.000	1.261	0.000	0.000	1.317	0.000	0.000	1.317
20.167	-	0.000	0.766	-	0.000	0.850	-	0.000	0.911	-	0.000	0.972	-	0.000	1.057	-	0.000	1.118	-	0.000	1.172	-	0.000	1.172
20.333	-	0.000	0.533	-	0.000	0.614	-	0.000	0.673	-	0.000	0.732	-	0.000	0.813	-	0.000	0.872	-	0.000	0.924	-	0.000	0.924
20.500	-	0.000	0.299	-	0.000	0.377	-	0.000	0.433	-	0.000	0.490	-	0.000	0.568	-	0.000	0.624	-	0.000	0.674	-	0.000	0.674
20.667	-	0.000	0.163	-	0.000	0.238	-	0.000	0.292	-	0.000	0.346	-	0.000	0.420	-	0.000	0.474	-	0.000	0.521	-	0.000	0.521
20.833	-	0.000	-0.074	-	0.000	-0.003	-	0.000	0.048	-	0.000	0.100	-	0.000	0.171	-	0.000	0.222	-	0.000	0.267	-	0.000	0.267
21.000	-	0.000	-0.312	-	0.000	-0.245	-	0.000	-0.196	-	0.000	-0.148	-	0.000	-0.081	-	0.000	-0.032	-	0.000	0.011	-	0.000	0.011
21.167	-	0.000	-0.552	-	0.000	-0.489	-	0.000	-0.443	-	0.000	-0.397	-	0.000	-0.334	-	0.000	-0.288	-	0.000	-0.248	-	0.000	-0.248
21.333	-	0.000	-0.693	-	0.000	-0.634	-	0.000	-0.591	-	0.000	-0.548	-	0.000	-0.489	-	0.000	-0.446	-	0.000	-0.408	-	0.000	-0.408
21.500	-	0.000	-0.935	-	0.000	-0.880	-	0.000	-0.840	-	0.000	-0.800	-	0.000	-0.745	-	0.000	-0.705	-	0.000	-0.670	-	0.000	-0.670
21.667	-	0.000	-1.178	-	0.000	-1.127	-	0.000	-1.090	-	0.000	-1.054	-	0.000	-1.003	-	0.000	-0.966	-	0.000	-0.934	-	0.000	-0.934
21.833	-	0.000	-1.322	-	0.000	-1.276	-	0.000	-1.242	-	0.000	-1.208	-	0.000	-1.162	-	0.000	-1.128	-	0.000	-1.098	-	0.000	-1.098
22.000	-	0.000	-1.568	-	0.000	-1.525	-	0.000	-1.495	-	0.000	-1.464	-	0.000	-1.422	-	0.000	-1.392	-	0.000	-1.365	-	0.000	-1.365
22.167	-	0.000	-1.814	-	0.000	-1.776	-	0.000	-1.749	-	0.000	-1.721	-	0.000	-1.684	-	0.000	-1.656	-	0.000	-1.632	-	0.000	-1.632
22.333	-	0.000	-1.960	-	0.000	-1.927	-	0.000	-1.903	-	0.000	-1.879	-	0.000	-1.846	-	0.000	-1.822	-	0.000	-1.801	-	0.000	-1.801
22.500	-	0.000	-2.008	-	0.000	-1.979	-	0.000	-1.958	-	0.000	-1.938	-	0.000	-1.909	-	0.000	-1.888	-	0.000	-1.870	-	0.000	-1.870
22.667	-	0.000	-2.155	-	0.000	-2.132	-	0.000	-2.114	-	0.000	-2.097	-	0.000	-2.073	-	0.000	-2.056	-	0.000	-2.041	-	0.000	-2.041
22.833	-	0.000	-2.204	-	0.000	-2.185	-	0.000	-2.171	-	0.000	-2.157	-	0.000	-2.138	-	0.000	-2.124	-	0.000	-2.112	-	0.000	-2.112
23.000	-	0.000	-2.253	-	0.000	-2.238	-	0.000	-2.228	-	0.000	-2.217	-	0.000	-2.203	-	0.000	-2.192	-	0.000	-2.183	-	0.000	-2.183

Mid -Range Future Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.000	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.333	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.500	-	0.000	-2.329	-	0.000	-2.324	-	0.000	-2.321	-	0.000	-2.317	-	0.000	-2.312	-	0.000	-2.309	-	0.000	-2.306	-	0.000	-2.306
12.667	-	0.000	-2.258	-	0.000	-2.248	-	0.000	-2.241	-	0.000	-2.234	-	0.000	-2.225	-	0.000	-2.218	-	0.000	-2.212	-	0.000	-2.212
12.833	-	0.000	-2.087	-	0.000	-2.073	-	0.000	-2.062	-	0.000	-2.052	-	0.000	-2.038	-	0.000	-2.027	-	0.000	-2.018	-	0.000	-2.018
13.000	-	0.000	-2.017	-	0.000	-1.998	-	0.000	-1.984	-	0.000	-1.970	-	0.000	-1.951	-	0.000	-1.937	-	0.000	-1.925	-	0.000	-1.925
13.167	-	0.000	-1.947	-	0.000	-1.923	-	0.000	-1.906	-	0.000	-1.889	-	0.000	-1.865	-	0.000	-1.848	-	0.000	-1.832	-	0.000	-1.832
13.333	-	0.000	-1.778	-	0.000	-1.750	-	0.000	-1.729	-	0.000	-1.708	-	0.000	-1.680	-	0.000	-1.659	-	0.000	-1.641	-	0.000	-1.641
13.500	-	0.000	-1.610	-	0.000	-1.577	-	0.000	-1.553	-	0.000	-1.529	-	0.000	-1.496	-	0.000	-1.472	-	0.000	-1.450	-	0.000	-1.450
13.667	-	0.000	-1.443	-	0.000	-1.405	-	0.000	-1.378	-	0.000	-1.350	-	0.000	-1.313	-	0.000	-1.285	-	0.000	-1.261	-	0.000	-1.261
13.833	-	0.000	-1.276	-	0.000	-1.234	-	0.000	-1.204	-	0.000	-1.173	-	0.000	-1.131	-	0.000	-1.100	-	0.000	-1.073	-	0.000	-1.073
14.000	-	0.000	-1.111	-	0.000	-1.065	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
14.167	-	0.000	-0.947	-	0.000	-0.897	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
14.333	-	0.000	-0.785	-	0.000	-0.730	-	0.000	-0.690	-	0.000	-0.650	-	0.000	-0.595	-	0.000	-0.555	-	0.000	-0.520	-	0.000	-0.520
14.500	-	0.000	-0.624	-	0.000	-0.565	-	0.000	-0.522	-	0.000	-0.479	-	0.000	-0.420	-	0.000	-0.377	-	0.000	-0.339	-	0.000	-0.339
14.667	-	0.000	-0.465	-	0.000	-0.402	-	0.000	-0.356	-	0.000	-0.310	-	0.000	-0.247	-	0.000	-0.201	-	0.000	-0.161	-	0.000	-0.161
14.833	-	0.000	-0.208	-	0.000	-0.141	-	0.000	-0.092	-	0.000	-0.043	-	0.000	0.024	-	0.000	0.072	-	0.000	0.115	-	0.000	0.115
15.000	-	0.000	0.048	-	0.000	0.118	-	0.000	0.170	-	0.000	0.221	-	0.000	0.292	-	0.000	0.343	-	0.000	0.388	-	0.000	0.388
15.167	-	0.000	0.201	-	0.000	0.276	-	0.000	0.330	-	0.000	0.384	-	0.000	0.458	-	0.000	0.512	-	0.000	0.559	-	0.000	0.559
15.333	-	0.000	0.353	-	0.000	0.430	-	0.000	0.487	-	0.000	0.544	-	0.000	0.621	-	0.000	0.678	-	0.000	0.727	-	0.000	0.727
15.500	-	0.000	0.602	-	0.000	0.683	-	0.000	0.742	-	0.000	0.801	-	0.000	0.882	-	0.000	0.941	-	0.000	0.993	-	0.000	0.993
15.667	-	0.000	0.849	-	0.000	0.933	-	0.000	0.994	-	0.000	1.055	-	0.000	1.140	-	0.000	1.201	-	0.000	1.255	-	0.000	1.255
15.833	0.000	0.000	0.993	0.000	0.000	1.080	0.000	0.000	1.144	0.000	0.000	1.207	0.000	0.000	1.295	0.000	0.000	1.358	0.000	0.000	1.414	0.000	0.000	1.414
16.000	0.000	0.000	1.235	0.000	0.000	1.325	0.000	0.000	1.391	0.000	0.000	1.456	0.000	0.000	1.546	0.000	0.000	1.612	0.000	0.000	1.669	0.000	0.000	1.669
16.167	0.000	0.000	1.475	0.000	0.000	1.567	0.000	0.000	1.635	0.000	0.000	1.702	0.000	0.000	1.795	0.000	0.000	1.863	0.000	0.000	1.922	0.000	0.000	1.922
16.333	0.000	0.000	1.712	0.000	0.000	1.807	0.000	0.000	1.876	0.000	0.000	1.945	0.000	0.000	2.041	0.032	0.033	2.110	0.098	0.000	2.171	0.000	0.000	2.171
16.500	0.000	0.000	1.946	0.003	0.004	2.043	0.007	0.007	2.114	0.018	0.019	2.185	0.104	0.106	2.283	0.458	0.470	2.354	1.450	0.000	2.416	7.328	0.000	2.416
16.667	0.002	0.002	2.077	0.007	0.007	2.177	0.018	0.018	2.249	0.075	0.077	2.322	0.606	0.621	2.422	2.045	2.096	2.494	4.640	0.000	2.558	14.800	0.000	2.558
16.833	0.009	0.009	2.306	0.061	0.062	2.408	0.341	0.349	2.481	1.459	1.496	2.555	4.838	4.960	2.657	8.797	9.018	2.731	13.690	0.000	2.796	31.820	0.000	2.796
17.000	0.033	0.034	2.432	0.399	0.409	2.535	1.509	1.547	2.610	3.899	3.997	2.685	8.867	9.090	2.789	14.690	15.059	2.864	22.650	0.000	2.930	48.380	0.000	2.930
17.167	0.722	0.740	2.655	3.100	3.178	2.759	6.150	6.305	2.836	11.390	11.676	2.912	23.300	23.886	3.017	0.000	0.000	3.093	0.000	0.000	3.160	0.000	0.000	3.160
17.333	3.917	4.015	2.874	10.470	10.733	2.981	19.200	19.683	3.058	0.000	0.000	3.135	0.000	0.000	3.242	0.000	0.000	3.319	0.000	0.000	3.386	0.000	0.000	3.386
17.500	15.460	15.849	3.091	0.000	0.000	3.199	0.000	0.000	3.277	0.000	0.000	3.355	0.000	0.000	3.462	0.000	0.000	3.540	0.000	0.000	3.609	0.000	0.000	3.609
17.667	0.000	0.000	3.205	0.000	0.000	3.314	0.000	0.000	3.392	0.000	0.000	3.471	0.000	0.000	3.579	0.000	0.000	3.658	0.000	0.000	3.727	0.000	0.000	3.727
17.833	0.000	0.000	3.216	0.000	0.000	3.325	0.000	0.000	3.404	0.000	0.000	3.484	0.000	0.000	3.593	0.000	0.000	3.672	0.000	0.000	3.742	0.000	0.000	3.742
18.000	0.000	0.000	3.224	0.000	0.000	3.333	0.000	0.000	3.413	0.000	0.000	3.493	0.000	0.000	3.602	0.000	0.000	3.682	0.000	0.000	3.752	0.000	0.000	3.752
18.167	0.000	0.000	3.328	0.000	0.000	3.438	0.000	0.000	3.518	0.000	0.000	3.598	0.000	0.000	3.708	0.000	0.000	3.788	0.000	0.000	3.858	0.000	0.000	3.858
18.333	0.000	0.000	3.330	0.000	0.000	3.440	0.000	0.000	3.520	0.000	0.000	3.600	0.000	0.000	3.710	0.000	0.000	3.790	0.000	0.000	3.860	0.000	0.000	3.860
18.500	0.000	0.000	3.328	0.000	0.000	3.438	0.000	0.000	3.518	0.000	0.000	3.598	0.000	0.000	3.708	0.000	0.000	3.788	0.000	0.000	3.858	0.000	0.000	3.858
18.667	0.000	0.000	3.324	0.000	0.000	3.433	0.000	0.000	3.513	0.000	0.000	3.593	0.000	0.000	3.702	0.000	0.000	3.782	0.000	0.000	3.852	0.000	0.000	3.852
18.833	0.000	0.000	3.216	0.000	0.000	3.325	0.000	0.000	3.404	0.000	0.000	3.484	0.000	0.000	3.593	0.000	0.000	3.672	0.000	0.000	3.742	0.000	0.000	3.742
19.000	0.000	0.000	3.205	0.000	0.000	3.314	0.000	0.000	3.392	0.000	0.000	3.471	0.000	0.000	3.579	0.000	0.000	3.658	0.000	0.000	3.727	0.000	0.000	3.727
19.167	15.460	15.849	3.091	0.000	0.000	3.199	0.000	0.000	3.277	0.000	0.000	3.355	0.000	0.000	3.462	0.000	0.000	3.540	0.000	0.000	3.609	0.000	0.000	3.609
19.333	7.318	7.502	2.974	18.520	18.986	3.081	0.000	0.000	3.158	0.000	0.000	3.235	0.000	0.000	3.342	0.000	0.000	3.419	0.000	0.000	3.486	0.000	0.000	3.486
19.500	3.462	3.549	2.855	9.323	9.557	2.959	17.080	17.509	3.036	29.870	30.621	3.112	0.000	0.000	3.217	0.000	0.000	3.293	0.000	0.000	3.360	0.000	0.000	3.360
19.667	1.445	1.481	2.732	4.718	4.837	2.835	8.873	9.096	2.910	16.180	16.587	2.985	32.080	32.886	3.089	0.000	0.000	3.164	0.000	0.000	3.230	0.000	0.000	3.230
19.833	0.100	0.103	2.506	0.955	0.979	2.608	2.624	2.690	2.681	5.633	5.775	2.755	11.670	11.963	2.857	19.230	19.713	2.931	29.190	0.000	2.996	59.190	0.000	2.996
20.000	0.017	0.017	2.377	0.169	0.173	2.477	0.826	0.847	2.549	2.545	2.609	2.622	6.704	6.873	2.722	11.220	11.502	2.794	17.200	0.000	2.858	38.600	0.000	2.858
20.167	0.003	0.003	2.146	0.011	0.011	2.243	0.035	0.035	2.314	0.172	0.176	2.385	1.216	1.247	2.483	3.345	3.429	2.554	6.579	0.000	2.616	18.330	0.000	2.616
20.333	0.000	0.000	1.912	0.003	0.003	2.007	0.006	0.006	2.076	0.014	0.014	2.145	0.064	0.066	2.241	0.268	0.274	2.310	0.916	0.000	2.371	5.547	0.000	2.371
20.500	0.000	0.000	1.775	0.000	0.000	1.867	0.000	0.000	1.935	0.000	0.000	2.002	0.017	0.018	2.095	0.052	0.053	2.163	0.170	0.000	2.222	1.960	0.000	2.222
20.667	0.000	0.000	1.535	0.000	0.000	1.625	0.000	0.000	1.691	0.000	0.000	1.756	0.000	0.000	1.846	0.000	0.000	1.912	0.000	0.000	1.969	0.000	0.000	1.969
20.833	0.000	0.000	1.293	0.000	0.000	1.380	0.000	0.000	1.444	0.000	0.000	1.507	0.000	0.000	1.595	0.000	0.000	1.658	0.000	0.000	1.714	0.000	0.000	1.714
21.000	-	0.000	1.149	-	0.000	1.233	-	0.000	1.294	-	0.000	1.355	-	0.000	1.440	-	0.000	1.501	-	0.000	1.555	-	0.000	1.555
21.167	-	0.000	0.902	-	0.000	0.983	-	0.000	1.042	-	0.000	1.101	-	0.000	1.182	-	0.000	1.241	-	0.000	1.293	-	0.000	1.293
21.333	-	0.000	0.653	-	0.000	0.730	-	0.000	0.787	-	0.000	0.844	-	0.000	0.921	-	0.000	0.978	-	0.000	1.027	-	0.000	1.027
21.500	-	0.000	0.501	-	0.000	0.576	-	0.000	0.630	-	0.000	0.684	-	0.000	0.758	-	0.000	0.812	-	0.000	0.859	-	0.000	0.859
21.667	-	0.000	0.248	-	0.000	0.318	-	0.000	0.370	-	0.000	0.421	-	0.000	0.492	-	0.000	0.543	-	0.000	0.588	-	0.000	0.588
21.833	-	0.000	-0.008	-	0.000	0.059	-	0.000	0.108	-	0.000	0.157	-	0.000	0.224	-	0.000	0.272	-	0.000	0.315	-	0.000	0.315
22.000	-	0.000	-0.265	-	0.000	-0.202	-	0.000	-0.156	-	0.000	-0.110	-	0.000	-0.047	-	0.000	-0.001	-	0.000	0.039	-	0.000	0.039
22.167	-	0.000	-0.424	-	0.000	-0.365	-	0.000	-0.322	-	0.000	-0.279	-	0.000	-0.220	-	0.000	-0.177	-	0.000	-0.139	-	0.000	-0.139
22.333	-	0.000	-0.685	-	0.000	-0.630	-	0.000	-0.590	-	0.000	-0.550	-	0.000	-0.495	-	0.000	-0.455	-	0.000	-0.420	-	0.000	-0.420
22.500	-	0.000	-0.947	-	0.000	-0.897	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
22.667	-	0.000	-1.111	-	0.000	-1.065	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
22.833	-	0.000	-1.376	-	0.000	-1.334	-	0.000	-1.304	-	0.000	-1.273	-	0.000	-1.231	-	0.000	-1.200	-	0.000	-1.173	-	0.000	-1.173
23.000	-	0.000	-1.643	-	0.000	-1.605	-	0.000	-1.578	-	0.000	-1.550	-	0.000	-1.513	-	0.000	-1.485	-	0.000	-1.461	-	0.000	-1.461
11.000	-	0.000	-1.810	-	0.000	-1.777	-	0.000	-1.753	-	0.000	-1.729	-	0.000	-1.696	-	0.000	-1.672	-	0.000	-1.650	-	0.000	-1.650
11.167	-	0.000	-1.878	-	0.000	-1.850	-	0.000	-1.829	-	0.000	-1.808	-	0.000	-1.780	-	0.000	-1.759	-	0.000	-1.741	-	0.000	-1.741
11.333	-	0.000	-2.047	-	0.000	-2.023	-	0.000	-2.006	-	0.000	-1.989	-	0.000	-1.965	-	0.000	-1.948	-	0.000	-1.932	-	0.000	-1.932
11.500	-	0.000	-2.117	-	0.000	-2.098	-	0.000	-2.084	-	0.000	-2.070	-	0.000	-2.051	-	0.000	-2.037	-	0.000	-2.025	-	0.000	-2.025
11.667	-	0.000	-2.187	-	0.000	-2.173	-	0.000	-2.162	-	0.000	-2.152	-	0.000	-2.138	-	0.000	-2.127	-	0.000	-2.118	-	0.000	-2.118

High End Future Scenario

	10%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
12.667	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
13.000	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.333	-	0.000	-2.299	-	0.000	-2.284	-	0.000	-2.284
13.500	-	0.000	-2.198	-	0.000	-2.168	-	0.000	-2.168
13.667	-	0.000	-1.997	-	0.000	-1.953	-	0.000	-1.953
13.833	-	0.000	-1.897	-	0.000	-1.838	-	0.000	-1.838
14.000	-	0.000	-1.798	-	0.000	-1.724	-	0.000	-1.724
14.167	-	0.000	-1.600	-	0.000	-1.512	-	0.000	-1.512
14.333	-	0.000	-1.402	-	0.000	-1.300	-	0.000	-1.300
14.500	-	0.000	-1.207	-	0.000	-1.090	-	0.000	-1.090
14.667	-	0.000	-1.012	-	0.000	-0.882	-	0.000	-0.882
14.833	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
15.000	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
15.167	-	0.000	-0.440	-	0.000	-0.270	-	0.000	-0.270
15.333	-	0.000	-0.253	-	0.000	-0.071	-	0.000	-0.071
15.500	-	0.000	-0.069	-	0.000	0.126	-	0.000	0.126
15.667	-	0.000	0.212	-	0.000	0.419	-	0.000	0.419
15.833	-	0.000	0.491	-	0.000	0.710	-	0.000	0.710
16.000	-	0.000	0.667	-	0.000	0.897	-	0.000	0.897
16.167	-	0.000	0.840	-	0.000	1.081	-	0.000	1.081
16.333	-	0.000	1.110	-	0.000	1.361	-	0.000	1.361
16.500	-	0.000	1.377	-	0.000	1.638	-	0.000	1.638
16.667	0.000	0.000	1.541	0.000	0.000	1.810	0.000	0.000	1.810
16.833	0.000	0.000	1.800	0.000	0.000	2.079	0.000	0.000	2.079
17.000	0.011	0.011	2.057	1.435	1.471	2.343	7.816	8.012	2.343
17.167	0.104	0.107	2.309	9.324	9.558	2.604	24.500	25.116	2.604
17.333	2.108	2.161	2.558	23.010	23.588	2.859	49.850	51.103	2.859
17.500	5.572	5.712	2.703	38.720	39.693	3.011	0.000	0.000	3.011
17.667	15.380	15.767	2.943	0.000	0.000	3.258	0.000	0.000	3.258
17.833	28.290	29.001	3.080	0.000	0.000	3.400	0.000	0.000	3.400
18.000	0.000	0.000	3.313	0.000	0.000	3.637	0.000	0.000	3.637
18.167	0.000	0.000	3.541	0.000	0.000	3.869	0.000	0.000	3.869
18.333	0.000	0.000	3.765	0.000	0.000	4.097	0.000	0.000	4.097
18.500	0.000	0.000	3.885	0.000	0.000	4.220	0.000	0.000	4.220
18.667	0.000	0.000	3.900	0.000	0.000	4.237	0.000	0.000	4.237
18.833	0.000	0.000	3.911	0.000	0.000	4.250	0.000	0.000	4.250
19.000	0.000	0.000	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.167	0.000	0.000	4.020	0.000	0.000	4.360	0.000	0.000	4.360
19.333	0.000	0.000	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.500	0.000	0.000	4.011	0.000	0.000	4.350	0.000	0.000	4.350
19.667	0.000	0.000	3.900	0.000	0.000	4.237	0.000	0.000	4.237
19.833	0.000	0.000	3.885	0.000	0.000	4.220	0.000	0.000	4.220
20.000	0.000	0.000	3.765	0.000	0.000	4.097	0.000	0.000	4.097
20.167	0.000	0.000	3.641	0.000	0.000	3.969	0.000	0.000	3.969
20.333	0.000	0.000	3.513	0.000	0.000	3.837	0.000	0.000	3.837
20.500	0.000	0.000	3.380	0.000	0.000	3.700	0.000	0.000	3.700
20.667	0.000	0.000	3.143	0.000	0.000	3.458	0.000	0.000	3.458
20.833	19.950	20.451	3.003	0.000	0.000	3.311	0.000	0.000	3.311
21.000	7.116	7.295	2.758	45.730	46.879	3.059	0.000	0.000	3.059
21.167	1.316	1.349	2.509	19.070	19.549	2.804	42.720	43.794	2.804
21.333	0.194	0.199	2.357	11.080	11.358	2.643	27.630	28.324	2.643
21.500	0.014	0.014	2.100	1.975	2.025	2.379	9.525	9.764	2.379
21.667	0.000	0.000	1.841	0.000	0.000	2.110	0.000	0.000	2.110
21.833	0.000	0.000	1.677	0.000	0.000	1.938	0.000	0.000	1.938
22.000	-	0.000	1.410	-	0.000	1.661	-	0.000	1.661
22.167	-	0.000	1.140	-	0.000	1.381	-	0.000	1.381
22.333	-	0.000	0.967	-	0.000	1.197	-	0.000	1.197
22.500	-	0.000	0.691	-	0.000	0.910	-	0.000	0.910
22.667	-	0.000	0.412	-	0.000	0.619	-	0.000	0.619
22.833	-	0.000	0.131	-	0.000	0.326	-	0.000	0.326
23.000	-	0.000	-0.053	-	0.000	0.129	-	0.000	0.129
11.000	-	0.000	-0.340	-	0.000	-0.170	-	0.000	-0.170
11.167	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
11.333	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
11.500	-	0.000	-1.112	-	0.000	-0.982	-	0.000	-0.982
11.667	-	0.000	-1.407	-	0.000	-1.290	-	0.000	-1.290
11.833	-	0.000	-1.602	-	0.000	-1.500	-	0.000	-1.500
12.000	-	0.000	-1.700	-	0.000	-1.612	-	0.000	-1.612
12.167	-	0.000	-1.898	-	0.000	-1.824	-	0.000	-1.824
12.333	-	0.000	-1.997	-	0.000	-1.938	-	0.000	-1.938
12.500	-	0.000	-2.097	-	0.000	-2.053	-	0.000	-2.053

Location C

Current Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.000													-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.167													-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.333													-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.500													-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.667													-	0.000	-2.351	-	0.000	-2.342	-	0.000	-2.328	-	0.000	-2.328
11.833													-	0.000	-2.302	-	0.000	-2.285	-	0.000	-2.255	-	0.000	-2.255
12.000													-	0.000	-2.153	-	0.000	-2.128	-	0.000	-2.083	-	0.000	-2.083
12.167													-	0.000	-2.104	-	0.000	-2.071	-	0.000	-2.012	-	0.000	-2.012
12.333													-	0.000	-2.055	-	0.000	-2.014	-	0.000	-1.941	-	0.000	-1.941
12.500													-	0.000	-1.908	-	0.000	-1.858	-	0.000	-1.770	-	0.000	-1.770
12.667													-	0.000	-1.760	-	0.000	-1.703	-	0.000	-1.601	-	0.000	-1.601
12.833													-	0.000	-1.614	-	0.000	-1.549	-	0.000	-1.432	-	0.000	-1.432
13.000													-	0.000	-1.468	-	0.000	-1.395	-	0.000	-1.265	-	0.000	-1.265
13.167													-	0.000	-1.322	-	0.000	-1.242	-	0.000	-1.098	-	0.000	-1.098
13.333													-	0.000	-1.178	-	0.000	-1.090	-	0.000	-0.934	-	0.000	-0.934
13.500													-	0.000	-1.035	-	0.000	-0.940	-	0.000	-0.770	-	0.000	-0.770
13.667													-	0.000	-0.893	-	0.000	-0.791	-	0.000	-0.608	-	0.000	-0.608
13.833													-	0.000	-0.752	-	0.000	-0.643	-	0.000	-0.448	-	0.000	-0.448
14.000													-	0.000	-0.512	-	0.000	-0.396	-	0.000	-0.189	-	0.000	-0.189
14.167													-	0.000	-0.274	-	0.000	-0.152	-	0.000	0.067	-	0.000	0.067
14.333													-	0.000	-0.137	-	0.000	-0.008	-	0.000	0.221	-	0.000	0.221
14.500													-	0.000	-0.001	-	0.000	0.133	-	0.000	0.374	-	0.000	0.374
14.667													-	0.000	0.233	-	0.000	0.373	-	0.000	0.624	-	0.000	0.624
14.833													-	0.000	0.466	-	0.000	0.611	-	0.000	0.872	-	0.000	0.872
15.000													0.000	0.000	0.596	0.000	0.000	0.747	0.000	0.000	1.017	0.000	0.000	1.017
15.167													0.000	0.000	0.826	0.000	0.000	0.981	0.000	0.000	1.260	0.000	0.000	1.260
15.333													0.000	0.000	1.053	0.000	0.000	1.213	0.000	0.000	1.500	0.000	0.000	1.500
15.500													0.000	0.000	1.279	0.000	0.000	1.443	0.000	0.000	1.738	0.000	0.000	1.738
15.667													0.000	0.000	1.502	0.000	0.000	1.671	0.000	0.000	1.972	0.000	0.000	1.972
15.833													0.000	0.000	1.624	0.000	0.000	1.796	0.001	0.001	2.104	0.006	0.003	2.104
16.000													0.000	0.000	1.844	0.002	0.001	2.020	0.002	0.001	2.334	0.012	0.006	2.334
16.167													0.000	0.000	1.962	0.003	0.002	2.140	0.003	0.001	2.460	0.018	0.009	2.460
16.333													0.004	0.002	2.178	0.006	0.003	2.359	0.006	0.003	2.683	0.039	0.019	2.683
16.500													0.008	0.004	2.391	0.012	0.006	2.575	0.014	0.007	2.903	0.087	0.042	2.903
16.667													0.016	0.008	2.603	0.025	0.012	2.789	0.032	0.016	3.121	0.228	0.111	3.121
16.833													0.023	0.011	2.713	0.037	0.018	2.900	0.061	0.029	3.235	0.422	0.205	3.235
17.000													0.024	0.012	2.720	0.038	0.019	2.909	0.065	0.032	3.246	0.449	0.218	3.246
17.167													0.024	0.012	2.726	0.039	0.019	2.915	0.068	0.033	3.254	0.468	0.227	3.254
17.333													0.034	0.017	2.829	0.059	0.028	3.019	0.150	0.073	3.358	0.867	0.421	3.358
17.500													0.034	0.017	2.830	0.059	0.029	3.020	0.152	0.074	3.360	0.878	0.426	3.360
17.667													0.034	0.017	2.829	0.059	0.028	3.019	0.150	0.073	3.358	0.867	0.421	3.358
17.833													0.034	0.016	2.826	0.058	0.028	3.015	0.144	0.070	3.354	0.842	0.409	3.354
18.000													0.024	0.012	2.720	0.038	0.019	2.909	0.065	0.032	3.246	0.449	0.218	3.246
18.167													0.023	0.011	2.713	0.037	0.018	2.900	0.061	0.029	3.235	0.422	0.205	3.235
18.333													0.016	0.008	2.603	0.025	0.012	2.789	0.032	0.016	3.121	0.228	0.111	3.121
18.500													0.011	0.005	2.491	0.017	0.008	2.675	0.020	0.010	3.003	0.131	0.064	3.003
18.667													0.008	0.004	2.378	0.011	0.006	2.559	0.013	0.006	2.883	0.080	0.039	2.883
18.833													0.005	0.003	2.262	0.008	0.004	2.440	0.008	0.004	2.760	0.051	0.025	2.760
19.000													0.003	0.001	2.044	0.004	0.002	2.220	0.004	0.002	2.534	0.023	0.011	2.534
19.167													0.000	0.000	1.924	0.003	0.001	2.096	0.002	0.001	2.404	0.015	0.007	2.404
19.333													0.000	0.000	1.702	0.000	0.000	1.871	0.001	0.001	2.172	0.007	0.003	2.172
19.500													0.000	0.000	1.479	0.000	0.000	1.643	0.000	0.000	1.938	0.000	0.000	1.938
19.667													0.000	0.000	1.353	0.000	0.000	1.513	0.000	0.000	1.800	0.000	0.000	1.800
19.833													0.000	0.000	1.126	0.000	0.000	1.281	0.000	0.000	1.560	0.000	0.000	1.560
20.000													0.000	0.000	0.896	0.000	0.000	1.047	0.000	0.000	1.317	0.000	0.000	1.317
20.167													-	0.000	0.766	-	0.000	0.911	-	0.000	1.172	-	0.000	1.172
20.333													-	0.000	0.533	-	0.000	0.673	-	0.000	0.924	-	0.000	0.924
20.500													-	0.000	0.299	-	0.000	0.433	-	0.000	0.674	-	0.000	0.674
20.667													-	0.000	0.163	-	0.000	0.292	-	0.000	0.521	-	0.000	0.521
20.833													-	0.000	-0.074	-	0.000	0.048	-	0.000	0.267	-	0.000	0.267
21.000													-	0.000	-0.312	-	0.000	-0.196	-	0.000	0.011	-	0.000	0.011
21.167													-	0.000	-0.552	-	0.000	-0.443	-	0.000	-0.248	-	0.000	-0.248
21.333													-	0.000	-0.693	-	0.000	-0.591	-	0.000	-0.408	-	0.000	-0.408
21.500													-	0.000	-0.935	-	0.000	-0.840	-	0.000	-0.670	-	0.000	-0.670
21.667													-	0.000	-1.178	-	0.000	-1.090	-	0.000	-0.934	-	0.000	-0.934
21.833													-	0.000	-1.322	-	0.000	-1.242	-	0.000	-1.098	-	0.000	-1.098
22.000													-	0.000	-1.568	-	0.000	-1.495	-	0.000	-1.365	-	0.000	-1.365
22.167													-	0.000	-1.814	-	0.000	-1.749	-	0.000	-1.632	-	0.000	-1.632
22.333													-	0.000	-1.960	-	0.000	-1.903	-	0.000	-1.801	-	0.000	-1.801
22.500													-	0.000	-2.008	-	0.000	-1.958	-	0.000	-1.870	-	0.000	-1.870
22.667													-	0.000	-2.155	-	0.000	-2.114	-	0.000	-2.041	-	0.000	-2.041
22.833													-	0.000	-2.204	-	0.000	-2.171	-	0.000	-2.112	-	0.000	-2.112
23.000													-	0.000	-2.253	-	0.000	-2.228	-	0.000	-2.183	-	0.000	-2.183

Mid -Range Future Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.833				-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.000				-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.167				-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.333				-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.500				-	0.000	-2.324	-	0.000	-2.321	-	0.000	-2.317	-	0.000	-2.312	-	0.000	-2.309	-	0.000	-2.306	-	0.000	-2.306
12.667				-	0.000	-2.248	-	0.000	-2.241	-	0.000	-2.234	-	0.000	-2.225	-	0.000	-2.218	-	0.000	-2.212	-	0.000	-2.212
12.833				-	0.000	-2.073	-	0.000	-2.062	-	0.000	-2.052	-	0.000	-2.038	-	0.000	-2.027	-	0.000	-2.018	-	0.000	-2.018
13.000				-	0.000	-1.998	-	0.000	-1.984	-	0.000	-1.970	-	0.000	-1.951	-	0.000	-1.937	-	0.000	-1.925	-	0.000	-1.925
13.167				-	0.000	-1.923	-	0.000	-1.906	-	0.000	-1.889	-	0.000	-1.865	-	0.000	-1.848	-	0.000	-1.832	-	0.000	-1.832
13.333				-	0.000	-1.750	-	0.000	-1.729	-	0.000	-1.708	-	0.000	-1.680	-	0.000	-1.659	-	0.000	-1.641	-	0.000	-1.641
13.500				-	0.000	-1.577	-	0.000	-1.553	-	0.000	-1.529	-	0.000	-1.496	-	0.000	-1.472	-	0.000	-1.450	-	0.000	-1.450
13.667				-	0.000	-1.405	-	0.000	-1.378	-	0.000	-1.350	-	0.000	-1.313	-	0.000	-1.285	-	0.000	-1.261	-	0.000	-1.261
13.833				-	0.000	-1.234	-	0.000	-1.204	-	0.000	-1.173	-	0.000	-1.131	-	0.000	-1.100	-	0.000	-1.073	-	0.000	-1.073
14.000				-	0.000	-1.065	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
14.167				-	0.000	-0.897	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
14.333				-	0.000	-0.730	-	0.000	-0.690	-	0.000	-0.650	-	0.000	-0.595	-	0.000	-0.555	-	0.000	-0.520	-	0.000	-0.520
14.500				-	0.000	-0.565	-	0.000	-0.522	-	0.000	-0.479	-	0.000	-0.420	-	0.000	-0.377	-	0.000	-0.339	-	0.000	-0.339
14.667				-	0.000	-0.402	-	0.000	-0.356	-	0.000	-0.310	-	0.000	-0.247	-	0.000	-0.201	-	0.000	-0.161	-	0.000	-0.161
14.833				-	0.000	-0.141	-	0.000	-0.092	-	0.000	-0.043	-	0.000	0.024	-	0.000	0.072	-	0.000	0.115	-	0.000	0.115
15.000				-	0.000	0.118	-	0.000	0.170	-	0.000	0.221	-	0.000	0.292	-	0.000	0.343	-	0.000	0.388	-	0.000	0.388
15.167				-	0.000	0.276	-	0.000	0.330	-	0.000	0.384	-	0.000	0.458	-	0.000	0.512	-	0.000	0.559	-	0.000	0.559
15.333				-	0.000	0.430	-	0.000	0.487	-	0.000	0.544	-	0.000	0.621	-	0.000	0.678	-	0.000	0.727	-	0.000	0.727
15.500				-	0.000	0.683	-	0.000	0.742	-	0.000	0.801	-	0.000	0.882	-	0.000	0.941	-	0.000	0.993	-	0.000	0.993
15.667				-	0.000	0.933	-	0.000	0.994	-	0.000	1.055	-	0.000	1.140	-	0.000	1.201	-	0.000	1.255	-	0.000	1.255
15.833				0.000	0.000	1.080	0.000	0.000	1.144	0.000	0.000	1.207	0.000	0.000	1.295	0.000	0.000	1.358	0.000	0.000	1.414	0.000	0.000	1.414
16.000				0.000	0.000	1.325	0.000	0.000	1.391	0.000	0.000	1.456	0.000	0.000	1.546	0.000	0.000	1.612	0.000	0.000	1.669	0.000	0.000	1.669
16.167				0.000	0.000	1.567	0.000	0.000	1.635	0.000	0.000	1.702	0.000	0.000	1.795	0.000	0.000	1.863	0.000	0.000	1.922	0.000	0.000	1.922
16.333				0.000	0.000	1.807	0.000	0.000	1.876	0.000	0.000	1.945	0.000	0.000	2.041	0.001	0.001	2.110	0.002	0.001	2.171	0.012	0.006	2.171
16.500				0.000	0.000	2.043	0.000	0.000	2.114	0.000	0.000	2.185	0.002	0.001	2.283	0.002	0.001	2.354	0.004	0.002	2.416	0.028	0.013	2.416
16.667				0.000	0.000	2.177	0.000	0.000	2.249	0.001	0.001	2.322	0.002	0.001	2.422	0.004	0.002	2.494	0.007	0.003	2.558	0.046	0.022	2.558
16.833				0.000	0.000	2.408	0.001	0.001	2.481	0.002	0.001	2.555	0.005	0.002	2.657	0.009	0.004	2.731	0.017	0.008	2.796	0.108	0.052	2.796
17.000				0.001	0.001	2.535	0.002	0.001	2.610	0.003	0.002	2.685	0.008	0.004	2.789	0.015	0.007	2.864	0.028	0.013	2.930	0.188	0.091	2.930
17.167				0.002	0.001	2.759	0.004	0.002	2.836	0.007	0.004	2.912	0.018	0.009	3.017	0.037	0.018	3.093	0.077	0.037	3.160	0.554	0.269	3.160
17.333				0.004	0.002	2.981	0.008	0.004	3.058	0.018	0.009	3.135	0.055	0.027	3.242	0.148	0.072	3.319	0.365	0.177	3.386	1.813	0.879	3.386
17.500				0.011	0.005	3.199	0.026	0.012	3.277	0.074	0.036	3.355	0.323	0.157	3.462	0.873	0.423	3.540	1.883	0.913	3.609	5.661	2.746	3.609
17.667				0.021	0.010	3.314	0.063	0.030	3.392	0.208	0.101	3.471	0.857	0.416	3.579	2.035	0.987	3.658	3.993	1.937	3.727	9.901	4.803	3.727
17.833				0.023	0.011	3.325	0.070	0.034	3.404	0.235	0.114	3.484	0.956	0.464	3.593	2.237	1.085	3.672	4.344	2.107	3.742	10.550	5.118	3.742
18.000				0.025	0.012	3.333	0.076	0.037	3.413	0.256	0.124	3.493	1.024	0.497	3.602	2.391	1.160	3.682	4.639	2.250	3.752	11.080	5.375	3.752
18.167				0.059	0.029	3.438	0.205	0.099	3.518	0.655	0.318	3.598	2.200	1.067	3.708	4.691	2.276	3.788	8.443	4.096	3.858	17.410	8.446	3.858
18.333				0.060	0.029	3.440	0.209	0.101	3.520	0.666	0.323	3.600	2.231	1.082	3.710	4.748	2.303	3.790	8.533	4.139	3.860	17.550	8.513	3.860
18.500				0.059	0.029	3.438	0.205	0.099	3.518	0.655	0.318	3.598	2.200	1.067	3.708	4.691	2.276	3.788	8.443	4.096	3.858	17.410	8.446	3.858
18.667				0.057	0.027	3.433	0.195	0.095	3.513	0.628	0.305	3.593	2.112	1.025	3.702	4.522	2.194	3.782	8.174	3.965	3.852	16.990	8.242	3.852
18.833				0.023	0.011	3.325	0.070	0.034	3.404	0.235	0.114	3.484	0.956	0.464	3.593	2.237	1.085	3.672	4.344	2.107	3.742	10.550	5.118	3.742
19.000				0.021	0.010	3.314	0.063	0.030	3.392	0.208	0.101	3.471	0.857	0.416	3.579	2.035	0.987	3.658	3.993	1.937	3.727	9.901	4.803	3.727
19.167				0.011	0.005	3.199	0.026	0.012	3.277	0.074	0.036	3.355	0.323	0.157	3.462	0.873	0.423	3.540	1.883	0.913	3.609	5.661	2.746	3.609
19.333				0.006	0.003	3.081	0.013	0.006	3.158	0.031	0.015	3.235	0.115	0.056	3.342	0.331	0.160	3.419	0.788	0.382	3.486	3.053	1.481	3.486
19.500				0.004	0.002	2.959	0.008	0.004	3.036	0.016	0.008	3.112	0.047	0.023	3.217	0.122	0.059	3.293	0.298	0.145	3.360	1.580	0.766	3.360
19.667				0.003	0.001	2.835	0.005	0.002	2.910	0.010	0.005	2.985	0.024	0.012	3.089	0.053	0.026	3.164	0.118	0.057	3.230	0.796	0.386	3.230
19.833				0.001	0.001	2.608	0.002	0.001	2.681	0.004	0.002	2.755	0.010	0.005	2.857	0.019	0.009	2.931	0.036	0.017	2.996	0.251	0.122	2.996
20.000				0.001	0.000	2.477	0.002	0.001	2.549	0.003	0.001	2.622	0.006	0.003	2.722	0.011	0.006	2.794	0.021	0.010	2.858	0.138	0.067	2.858
20.167				0.000	0.000	2.243	0.000	0.000	2.314	0.001	0.001	2.385	0.003	0.001	2.483	0.005	0.002	2.554	0.008	0.004	2.616	0.056	0.027	2.616
20.333				0.000	0.000	2.007	0.000	0.000	2.076	0.000	0.000	2.145	0.001	0.001	2.241	0.002	0.001	2.310	0.004	0.002	2.371	0.024	0.011	2.371
20.500				0.000	0.000	1.867	0.000	0.000	1.935	0.000	0.000	2.002	0.000	0.000	2.095	0.002	0.001	2.163	0.002	0.001	2.222	0.014	0.007	2.222
20.667				0.000	0.000	1.625	0.000	0.000	1.691	0.000	0.000	1.756	0.000	0.000	1.846	0.000	0.000	1.912	0.001	0.001	1.969	0.000	0.000	1.969
20.833				0.000	0.000	1.380	0.000	0.000	1.444	0.000	0.000	1.507	0.000	0.000	1.595	0.000	0.000	1.658	0.000	0.000	1.714	0.000	0.000	1.714
21.000				-	0.000	1.233	-	0.000	1.294	-	0.000	1.355	-	0.000	1.440	-	0.000	1.501	-	0.000	1.555	-	0.000	1.555
21.167				-	0.000	0.983	-	0.000	1.042	-	0.000	1.101	-	0.000	1.182	-	0.000	1.241	-	0.000	1.293	-	0.000	1.293
21.333				-	0.000	0.730	-	0.000	0.787	-	0.000	0.844	-	0.000	0.921	-	0.000	0.978	-	0.000	1.027	-	0.000	1.027
21.500				-	0.000	0.576	-	0.000	0.630	-	0.000	0.684	-	0.000	0.758	-	0.000	0.812	-	0.000	0.859	-	0.000	0.859
21.667				-	0.000	0.318	-	0.000	0.370	-	0.000	0.421	-	0.000	0.492	-	0.000	0.543	-	0.000	0.588	-	0.000	0.588
21.833				-	0.000	0.059	-	0.000	0.108	-	0.000	0.157	-	0.000	0.224	-	0.000	0.272	-	0.000	0.315	-	0.000	0.315
22.000				-	0.000	-0.202	-	0.000	-0.156	-	0.000	-0.110	-	0.000	-0.047	-	0.000	-0.001	-	0.000	0.039	-	0.000	0.039
22.167				-	0.000	-0.365	-	0.000	-0.322	-	0.000	-0.279	-	0.000	-0.220	-	0.000	-0.177	-	0.000	-0.139	-	0.000	-0.139
22.333				-	0.000	-0.630	-	0.000	-0.590	-	0.000	-0.550	-	0.000	-0.495	-	0.000	-0.455	-	0.000	-0.420	-	0.000	-0.420
22.500				-	0.000	-0.897	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
22.667				-	0.000	-1.065	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
22.833				-	0.000	-1.334	-	0.000	-1.304	-	0.000	-1.273	-	0.000	-1.231	-	0.000	-1.200	-	0.000	-1.173	-	0.000	-1.173
23.000				-	0.000	-1.605	-	0.000	-1.578	-	0.000	-1.550	-	0.000	-1.513	-	0.000	-1.485	-	0.000	-1.461	-	0.000	-1.461
11.000				-	0.000	-1.777	-	0.000	-1.753	-	0.000	-1.729	-	0.000	-1.696	-	0.000	-1.672	-	0.000	-1.650	-	0.000	-1.650
11.167				-	0.000	-1.850	-	0.000	-1.829	-	0.000	-1.808	-	0.000	-1.780	-	0.000	-1.759	-	0.000	-1.741	-	0.000	-1.741
11.333				-	0.000	-2.023	-	0.000	-2.006	-	0.000	-1.989	-	0.000	-1.965	-	0.000	-1.948	-	0.000	-1.932	-	0.000	-1.932
11.500				-	0.000	-2.098	-	0.000	-2.084	-	0.000	-2.070	-	0.000	-2.051	-	0.000	-2.037	-	0.000	-2.025	-	0.000	-2.025
11.667				-	0.000	-2.173	-	0.000	-2.162	-	0.000	-2.152	-	0.000	-2.138	-	0.000	-2.127	-	0.000	-2.118	-	0.000	-2.118

High End Future Scenario

	10%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
12.667	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
13.000	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.333	-	0.000	-2.299	-	0.000	-2.284	-	0.000	-2.284
13.500	-	0.000	-2.198	-	0.000	-2.168	-	0.000	-2.168
13.667	-	0.000	-1.997	-	0.000	-1.953	-	0.000	-1.953
13.833	-	0.000	-1.897	-	0.000	-1.838	-	0.000	-1.838
14.000	-	0.000	-1.798	-	0.000	-1.724	-	0.000	-1.724
14.167	-	0.000	-1.600	-	0.000	-1.512	-	0.000	-1.512
14.333	-	0.000	-1.402	-	0.000	-1.300	-	0.000	-1.300
14.500	-	0.000	-1.207	-	0.000	-1.090	-	0.000	-1.090
14.667	-	0.000	-1.012	-	0.000	-0.882	-	0.000	-0.882
14.833	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
15.000	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
15.167	-	0.000	-0.440	-	0.000	-0.270	-	0.000	-0.270
15.333	-	0.000	-0.253	-	0.000	-0.071	-	0.000	-0.071
15.500	-	0.000	-0.069	-	0.000	0.126	-	0.000	0.126
15.667	-	0.000	0.212	-	0.000	0.419	-	0.000	0.419
15.833	-	0.000	0.491	-	0.000	0.710	-	0.000	0.710
16.000	-	0.000	0.667	-	0.000	0.897	-	0.000	0.897
16.167	-	0.000	0.840	-	0.000	1.081	-	0.000	1.081
16.333	-	0.000	1.110	-	0.000	1.361	-	0.000	1.361
16.500	-	0.000	1.377	-	0.000	1.638	-	0.000	1.638
16.667	0.000	0.000	1.541	0.000	0.000	1.810	0.000	0.000	1.810
16.833	0.000	0.000	1.800	0.002	0.001	2.079	0.000	0.000	2.079
17.000	0.000	0.000	2.057	0.005	0.002	2.343	0.035	0.017	2.343
17.167	0.001	0.001	2.309	0.013	0.006	2.604	0.089	0.043	2.604
17.333	0.002	0.001	2.558	0.035	0.017	2.859	0.241	0.117	2.859
17.500	0.004	0.002	2.703	0.066	0.032	3.011	0.472	0.229	3.011
17.667	0.010	0.005	2.943	0.255	0.124	3.258	1.520	0.737	3.258
17.833	0.017	0.008	3.080	0.688	0.334	3.400	3.000	1.455	3.400
18.000	0.066	0.032	3.313	3.283	1.593	3.637	8.858	4.297	3.637
18.167	0.490	0.238	3.541	11.490	5.574	3.869	22.530	10.929	3.869
18.333	2.704	1.312	3.765	0.000	0.000	4.097	0.000	0.000	4.097
18.500	5.900	2.862	3.885	0.000	0.000	4.220	0.000	0.000	4.220
18.667	6.469	3.138	3.900	0.000	0.000	4.237	0.000	0.000	4.237
18.833	6.914	3.354	3.911	0.000	0.000	4.250	0.000	0.000	4.250
19.000	12.710	6.166	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.167	12.850	6.233	4.020	0.000	0.000	4.360	0.000	0.000	4.360
19.333	12.710	6.166	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.500	12.240	5.938	4.011	0.000	0.000	4.350	0.000	0.000	4.350
19.667	6.469	3.138	3.900	0.000	0.000	4.237	0.000	0.000	4.237
19.833	5.900	2.862	3.885	0.000	0.000	4.220	0.000	0.000	4.220
20.000	2.704	1.312	3.765	0.000	0.000	4.097	0.000	0.000	4.097
20.167	1.109	0.538	3.641	18.140	8.800	3.969	0.000	0.000	3.969
20.333	0.379	0.184	3.513	9.819	4.763	3.837	20.030	9.716	3.837
20.500	0.116	0.056	3.380	4.705	2.282	3.700	11.550	5.603	3.700
20.667	0.023	0.011	3.143	1.032	0.501	3.458	3.938	1.910	3.458
20.833	0.013	0.006	3.003	0.368	0.179	3.311	1.970	0.956	3.311
21.000	0.005	0.002	2.758	0.083	0.040	3.059	0.589	0.286	3.059
21.167	0.002	0.001	2.509	0.029	0.014	2.804	0.191	0.093	2.804
21.333	0.001	0.001	2.357	0.015	0.007	2.643	0.103	0.050	2.643
21.500	0.000	0.000	2.100	0.006	0.003	2.379	0.040	0.019	2.379
21.667	0.000	0.000	1.841	0.003	0.001	2.110	0.016	0.008	2.110
21.833	0.000	0.000	1.677	0.002	0.001	1.938	0.000	0.000	1.938
22.000	-	0.000	1.410	-	0.000	1.661	-	0.000	1.661
22.167	-	0.000	1.140	-	0.000	1.381	-	0.000	1.381
22.333	-	0.000	0.967	-	0.000	1.197	-	0.000	1.197
22.500	-	0.000	0.691	-	0.000	0.910	-	0.000	0.910
22.667	-	0.000	0.412	-	0.000	0.619	-	0.000	0.619
22.833	-	0.000	0.131	-	0.000	0.326	-	0.000	0.326
23.000	-	0.000	-0.053	-	0.000	0.129	-	0.000	0.129
11.000	-	0.000	-0.340	-	0.000	-0.170	-	0.000	-0.170
11.167	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
11.333	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
11.500	-	0.000	-1.112	-	0.000	-0.982	-	0.000	-0.982
11.667	-	0.000	-1.407	-	0.000	-1.290	-	0.000	-1.290
11.833	-	0.000	-1.602	-	0.000	-1.500	-	0.000	-1.500
12.000	-	0.000	-1.700	-	0.000	-1.612	-	0.000	-1.612
12.167	-	0.000	-1.898	-	0.000	-1.824	-	0.000	-1.824
12.333	-	0.000	-1.997	-	0.000	-1.938	-	0.000	-1.938
12.500	-	0.000	-2.097	-	0.000	-2.053	-	0.000	-2.053

Location D.1

Current Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.000										-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.167										-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.333										-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.500										-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.667										-	0.000	-2.351	-	0.000	-2.346	-	0.000	-2.342	-	0.000	-2.342	-	0.000	-2.328
11.833										-	0.000	-2.302	-	0.000	-2.292	-	0.000	-2.285	-	0.000	-2.285	-	0.000	-2.255
12.000										-	0.000	-2.153	-	0.000	-2.138	-	0.000	-2.128	-	0.000	-2.128	-	0.000	-2.083
12.167										-	0.000	-2.104	-	0.000	-2.085	-	0.000	-2.071	-	0.000	-2.071	-	0.000	-2.012
12.333										-	0.000	-2.055	-	0.000	-2.032	-	0.000	-2.014	-	0.000	-2.014	-	0.000	-1.941
12.500										-	0.000	-1.908	-	0.000	-1.879	-	0.000	-1.858	-	0.000	-1.858	-	0.000	-1.770
12.667										-	0.000	-1.760	-	0.000	-1.727	-	0.000	-1.703	-	0.000	-1.703	-	0.000	-1.601
12.833										-	0.000	-1.614	-	0.000	-1.576	-	0.000	-1.549	-	0.000	-1.549	-	0.000	-1.432
13.000										-	0.000	-1.468	-	0.000	-1.425	-	0.000	-1.395	-	0.000	-1.395	-	0.000	-1.265
13.167										-	0.000	-1.322	-	0.000	-1.276	-	0.000	-1.242	-	0.000	-1.242	-	0.000	-1.098
13.333										-	0.000	-1.178	-	0.000	-1.127	-	0.000	-1.090	-	0.000	-1.090	-	0.000	-0.934
13.500										-	0.000	-1.035	-	0.000	-0.980	-	0.000	-0.940	-	0.000	-0.940	-	0.000	-0.770
13.667										-	0.000	-0.893	-	0.000	-0.834	-	0.000	-0.791	-	0.000	-0.791	-	0.000	-0.608
13.833										-	0.000	-0.752	-	0.000	-0.689	-	0.000	-0.643	-	0.000	-0.643	-	0.000	-0.448
14.000										-	0.000	-0.512	-	0.000	-0.445	-	0.000	-0.396	-	0.000	-0.396	-	0.000	-0.189
14.167										-	0.000	-0.274	-	0.000	-0.203	-	0.000	-0.152	-	0.000	-0.152	-	0.000	0.067
14.333										-	0.000	-0.137	-	0.000	-0.062	-	0.000	-0.008	-	0.000	-0.008	-	0.000	0.221
14.500										-	0.000	-0.001	-	0.000	0.077	-	0.000	0.133	-	0.000	0.133	-	0.000	0.374
14.667										-	0.000	0.233	-	0.000	0.314	-	0.000	0.373	-	0.000	0.373	-	0.000	0.624
14.833										-	0.000	0.466	-	0.000	0.550	-	0.000	0.611	-	0.000	0.611	-	0.000	0.872
15.000										0.000	0.000	0.596	0.000	0.000	0.684	0.000	0.000	0.747	0.000	0.000	0.747	0.000	0.000	1.017
15.167										0.000	0.000	0.826	0.000	0.000	0.916	0.000	0.000	0.981	0.000	0.000	0.981	0.000	0.000	1.260
15.333										0.000	0.000	1.053	0.000	0.000	1.146	0.000	0.000	1.213	0.000	0.000	1.213	0.000	0.000	1.500
15.500										0.000	0.000	1.279	0.000	0.000	1.374	0.000	0.000	1.443	0.000	0.000	1.443	0.000	0.000	1.738
15.667										0.000	0.000	1.502	0.000	0.000	1.600	0.000	0.000	1.671	0.000	0.000	1.671	0.000	0.000	1.972
15.833										0.000	0.000	1.624	0.000	0.000	1.724	0.000	0.000	1.796	0.000	0.000	1.796	0.000	0.000	2.104
16.000										0.000	0.000	1.844	0.000	0.000	1.946	0.000	0.000	2.020	0.000	0.000	2.020	0.000	0.000	2.334
16.167										0.000	0.000	1.962	0.000	0.000	2.065	0.000	0.000	2.140	0.000	0.000	2.140	0.085	0.072	2.460
16.333										0.000	0.000	2.178	0.020	0.017	2.283	0.033	0.028	2.359	0.000	0.000	2.359	0.165	0.140	2.683
16.500										0.016	0.014	2.391	0.032	0.027	2.498	0.057	0.048	2.575	0.105	0.089	2.575	0.352	0.298	2.903
16.667										0.027	0.023	2.603	0.056	0.048	2.711	0.109	0.092	2.789	0.207	0.175	2.789	0.793	0.672	3.121
16.833										0.036	0.030	2.713	0.080	0.068	2.821	0.160	0.136	2.900	0.306	0.259	2.900	1.217	1.031	3.235
17.000										0.036	0.031	2.720	0.082	0.069	2.829	0.165	0.140	2.909	0.315	0.267	2.909	1.267	1.073	3.246
17.167										0.037	0.031	2.726	0.083	0.071	2.835	0.169	0.143	2.915	0.323	0.274	2.915	1.305	1.106	3.254
17.333										0.050	0.043	2.829	0.120	0.101	2.939	0.248	0.210	3.019	0.472	0.400	3.019	1.895	1.605	3.358
17.500										0.050	0.043	2.830	0.120	0.102	2.940	0.250	0.212	3.020	0.476	0.403	3.020	1.909	1.617	3.360
17.667										0.050	0.043	2.829	0.120	0.101	2.939	0.248	0.210	3.019	0.472	0.400	3.019	1.895	1.605	3.358
17.833										0.050	0.042	2.826	0.118	0.100	2.935	0.246	0.208	3.015	0.467	0.396	3.015	1.862	1.577	3.354
18.000										0.036	0.031	2.720	0.082	0.069	2.829	0.165	0.140	2.909	0.315	0.267	2.909	1.267	1.073	3.246
18.167										0.036	0.030	2.713	0.080	0.068	2.821	0.160	0.136	2.900	0.306	0.259	2.900	1.217	1.031	3.235
18.333										0.027	0.023	2.603	0.056	0.048	2.711	0.109	0.092	2.789	0.207	0.175	2.789	0.793	0.672	3.121
18.500										0.021	0.017	2.491	0.041	0.035	2.598	0.076	0.064	2.675	0.142	0.121	2.675	0.509	0.431	3.003
18.667										0.016	0.014	2.378	0.031	0.026	2.483	0.054	0.046	2.559	0.100	0.085	2.559	0.328	0.278	2.883
18.833										0.012	0.011	2.262	0.023	0.020	2.365	0.040	0.034	2.440	0.072	0.061	2.440	0.213	0.181	2.760
19.000										0.000	0.000	2.044	0.000	0.000	2.146	0.000	0.000	2.220	0.000	0.000	2.220	0.104	0.088	2.534
19.167										0.000	0.000	1.924	0.000	0.000	2.024	0.000	0.000	2.096	0.000	0.000	2.096	0.073	0.062	2.404
19.333										0.000	0.000	1.702	0.000	0.000	1.800	0.000	0.000	1.871	0.000	0.000	1.871	0.000	0.000	2.172
19.500										0.000	0.000	1.479	0.000	0.000	1.574	0.000	0.000	1.643	0.000	0.000	1.643	0.000	0.000	1.938
19.667										0.000	0.000	1.353	0.000	0.000	1.446	0.000	0.000	1.513	0.000	0.000	1.513	0.000	0.000	1.800
19.833										0.000	0.000	1.126	0.000	0.000	1.216	0.000	0.000	1.281	0.000	0.000	1.281	0.000	0.000	1.560
20.000										0.000	0.000	0.896	0.000	0.000	0.984	0.000	0.000	1.047	0.000	0.000	1.047	0.000	0.000	1.317
20.167										-	0.000	0.766	-	0.000	0.850	-	0.000	0.911	-	0.000	0.911	-	0.000	1.172
20.333										-	0.000	0.533	-	0.000	0.614	-	0.000	0.673	-	0.000	0.673	-	0.000	0.924
20.500										-	0.000	0.299	-	0.000	0.377	-	0.000	0.433	-	0.000	0.433	-	0.000	0.674
20.667										-	0.000	0.163	-	0.000	0.238	-	0.000	0.292	-	0.000	0.292	-	0.000	0.521
20.833										-	0.000	-0.074	-	0.000	-0.003	-	0.000	0.048	-	0.000	0.048	-	0.000	0.267
21.000										-	0.000	-0.312	-	0.000	-0.245	-	0.000	-0.196	-	0.000	-0.196	-	0.000	0.011
21.167										-	0.000	-0.552	-	0.000	-0.489	-	0.000	-0.443	-	0.000	-0.443	-	0.000	-0.248
21.333										-	0.000	-0.693	-	0.000	-0.634	-	0.000	-0.591	-	0.000	-0.591	-	0.000	-0.408
21.500										-	0.000	-0.935	-	0.000	-0.880	-	0.000	-0.840	-	0.000	-0.840	-	0.000	-0.670
21.667										-	0.000	-1.178	-	0.000	-1.127	-	0.000	-1.090	-	0.000	-1.090	-	0.000	-0.934
21.833										-	0.000	-1.322	-	0.000	-1.276	-	0.000	-1.242	-	0.000	-1.242	-	0.000	-1.098
22.000										-	0.000	-1.568	-	0.000	-1.525	-	0.000	-1.495	-	0.000	-1.495	-	0.000	-1.365
22.167										-	0.000	-1.814	-	0.000	-1.776	-	0.000	-1.749	-	0.000	-1.749	-	0.000	-1.632
22.333										-	0.000	-1.960	-	0.000	-1.927	-	0.000	-1.903	-	0.000	-1.903	-	0.000	-1.801
22.500										-	0.000	-2.008	-	0.000	-1.979	-	0.000	-1.958	-	0.000	-1.958	-	0.000	-1.870
22.667										-	0.000	-2.155	-	0.000	-2.132	-	0.000	-2.114	-	0.000	-2.114	-	0.000	-2.041
22.833										-	0.000	-2.204	-	0.000	-2.185	-	0.000	-2.171	-	0.000	-2.171	-	0.000	-2.112
23.000										-	0.000	-2.253	-	0.000	-2.238	-	0.000	-2.228	-	0.000	-2.228	-	0.000	-2.183

Mid -Range Future Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.000	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.333	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.500	-	0.000	-2.342	-	0.000	-2.337	-	0.000	-2.329	-	0.000	-2.324	-	0.000	-2.312	-	0.000	-2.309	-	0.000	-2.306	-	0.000	-2.306
12.667	-	0.000	-2.285	-	0.000	-2.275	-	0.000	-2.258	-	0.000	-2.248	-	0.000	-2.225	-	0.000	-2.218	-	0.000	-2.212	-	0.000	-2.212
12.833	-	0.000	-2.128	-	0.000	-2.112	-	0.000	-2.087	-	0.000	-2.073	-	0.000	-2.038	-	0.000	-2.027	-	0.000	-2.018	-	0.000	-2.018
13.000	-	0.000	-2.071	-	0.000	-2.050	-	0.000	-2.017	-	0.000	-1.998	-	0.000	-1.951	-	0.000	-1.937	-	0.000	-1.925	-	0.000	-1.925
13.167	-	0.000	-2.014	-	0.000	-1.988	-	0.000	-1.947	-	0.000	-1.923	-	0.000	-1.865	-	0.000	-1.848	-	0.000	-1.832	-	0.000	-1.832
13.333	-	0.000	-1.858	-	0.000	-1.827	-	0.000	-1.778	-	0.000	-1.750	-	0.000	-1.680	-	0.000	-1.659	-	0.000	-1.641	-	0.000	-1.641
13.500	-	0.000	-1.703	-	0.000	-1.667	-	0.000	-1.610	-	0.000	-1.577	-	0.000	-1.496	-	0.000	-1.472	-	0.000	-1.450	-	0.000	-1.450
13.667	-	0.000	-1.549	-	0.000	-1.507	-	0.000	-1.443	-	0.000	-1.405	-	0.000	-1.313	-	0.000	-1.285	-	0.000	-1.261	-	0.000	-1.261
13.833	-	0.000	-1.395	-	0.000	-1.349	-	0.000	-1.276	-	0.000	-1.234	-	0.000	-1.131	-	0.000	-1.100	-	0.000	-1.073	-	0.000	-1.073
14.000	-	0.000	-1.242	-	0.000	-1.191	-	0.000	-1.111	-	0.000	-1.065	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
14.167	-	0.000	-1.090	-	0.000	-1.035	-	0.000	-0.947	-	0.000	-0.897	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
14.333	-	0.000	-0.940	-	0.000	-0.880	-	0.000	-0.785	-	0.000	-0.730	-	0.000	-0.595	-	0.000	-0.555	-	0.000	-0.520	-	0.000	-0.520
14.500	-	0.000	-0.791	-	0.000	-0.726	-	0.000	-0.624	-	0.000	-0.565	-	0.000	-0.420	-	0.000	-0.377	-	0.000	-0.339	-	0.000	-0.339
14.667	-	0.000	-0.643	-	0.000	-0.574	-	0.000	-0.465	-	0.000	-0.402	-	0.000	-0.247	-	0.000	-0.201	-	0.000	-0.161	-	0.000	-0.161
14.833	-	0.000	-0.396	-	0.000	-0.323	-	0.000	-0.208	-	0.000	-0.141	-	0.000	0.024	-	0.000	0.072	-	0.000	0.115	-	0.000	0.115
15.000	-	0.000	-0.152	-	0.000	-0.074	-	0.000	0.048	-	0.000	0.118	-	0.000	0.292	-	0.000	0.343	-	0.000	0.388	-	0.000	0.388
15.167	-	0.000	-0.008	-	0.000	0.073	-	0.000	0.201	-	0.000	0.276	-	0.000	0.458	-	0.000	0.512	-	0.000	0.559	-	0.000	0.559
15.333	-	0.000	0.133	-	0.000	0.218	-	0.000	0.353	-	0.000	0.430	-	0.000	0.621	-	0.000	0.678	-	0.000	0.727	-	0.000	0.727
15.500	-	0.000	0.373	-	0.000	0.462	-	0.000	0.602	-	0.000	0.683	-	0.000	0.882	-	0.000	0.941	-	0.000	0.993	-	0.000	0.993
15.667	-	0.000	0.611	-	0.000	0.703	-	0.000	0.849	-	0.000	0.933	-	0.000	1.140	-	0.000	1.201	-	0.000	1.255	-	0.000	1.255
15.833	0.000	0.000	0.747	0.000	0.000	0.842	0.000	0.000	0.993	0.000	0.000	1.080	0.000	0.000	1.295	0.000	0.000	1.358	0.000	0.000	1.414	0.000	0.000	1.414
16.000	0.000	0.000	0.981	0.000	0.000	1.080	0.000	0.000	1.235	0.000	0.000	1.325	0.000	0.000	1.546	0.000	0.000	1.612	0.000	0.000	1.669	0.000	0.000	1.669
16.167	0.000	0.000	1.213	0.000	0.000	1.314	0.000	0.000	1.475	0.000	0.000	1.567	0.000	0.000	1.795	0.000	0.000	1.863	0.000	0.000	1.922	0.000	0.000	1.922
16.333	0.000	0.000	1.443	0.000	0.000	1.547	0.000	0.000	1.712	0.000	0.000	1.807	0.000	0.000	2.041	0.000	0.000	2.110	0.000	0.000	2.171	0.000	0.000	2.171
16.500	0.000	0.000	1.671	0.000	0.000	1.777	0.000	0.000	1.946	0.000	0.000	2.043	0.009	0.008	2.283	0.015	0.013	2.354	0.023	0.019	2.416	0.000	0.000	2.416
16.667	0.000	0.000	1.796	0.000	0.000	1.905	0.000	0.000	2.077	0.000	0.000	2.177	0.013	0.011	2.422	0.020	0.017	2.494	0.032	0.027	2.558	0.182	0.154	2.558
16.833	0.000	0.000	2.020	0.000	0.000	2.130	0.013	0.011	2.306	0.019	0.016	2.408	0.022	0.019	2.657	0.038	0.032	2.731	0.064	0.054	2.796	0.397	0.336	2.796
17.000	0.000	0.000	2.140	0.012	0.010	2.253	0.017	0.014	2.432	0.026	0.022	2.535	0.032	0.027	2.789	0.057	0.048	2.864	0.101	0.085	2.930	0.638	0.540	2.930
17.167	0.009	0.008	2.359	0.019	0.016	2.473	0.029	0.025	2.655	0.048	0.041	2.759	0.067	0.057	3.017	0.132	0.112	3.093	0.253	0.214	3.160	1.474	1.249	3.160
17.333	0.015	0.013	2.575	0.033	0.028	2.691	0.055	0.047	2.874	0.100	0.085	2.981	0.168	0.143	3.242	0.358	0.304	3.319	0.699	0.592	3.386	3.135	2.656	3.386
17.500	0.026	0.022	2.789	0.063	0.054	2.906	0.122	0.103	3.091	0.244	0.206	3.199	0.508	0.431	3.462	1.053	0.892	3.540	1.929	1.634	3.609	6.297	5.334	3.609
17.667	0.036	0.030	2.900	0.094	0.080	3.018	0.197	0.167	3.205	0.411	0.348	3.314	0.949	0.804	3.579	1.915	1.622	3.658	3.389	2.871	3.727	9.153	7.754	3.727
17.833	0.036	0.031	2.909	0.098	0.083	3.028	0.207	0.175	3.216	0.434	0.368	3.325	1.019	0.863	3.593	2.057	1.743	3.672	3.624	3.070	3.742	9.565	8.103	3.742
18.000	0.037	0.032	2.915	0.100	0.085	3.035	0.213	0.181	3.224	0.451	0.382	3.333	1.077	0.912	3.602	2.165	1.834	3.682	3.802	3.221	3.752	9.871	8.362	3.752
18.167	0.052	0.044	3.019	0.152	0.129	3.139	0.348	0.294	3.328	0.735	0.623	3.438	1.943	1.646	3.708	3.752	3.178	3.788	6.360	5.388	3.858	13.810	11.699	3.858
18.333	0.053	0.045	3.020	0.153	0.130	3.140	0.351	0.297	3.330	0.742	0.629	3.440	1.965	1.665	3.710	3.791	3.211	3.790	6.421	5.439	3.860	13.900	11.775	3.860
18.500	0.052	0.044	3.019	0.152	0.129	3.139	0.348	0.294	3.328	0.735	0.623	3.438	1.943	1.646	3.708	3.752	3.178	3.788	6.360	5.388	3.858	13.810	11.699	3.858
18.667	0.052	0.044	3.015	0.150	0.127	3.135	0.339	0.287	3.324	0.718	0.609	3.433	1.879	1.592	3.702	3.636	3.080	3.782	6.152	5.212	3.852	13.510	11.445	3.852
18.833	0.036	0.031	2.909	0.098	0.083	3.028	0.207	0.175	3.216	0.434	0.368	3.325	1.019	0.863	3.593	2.057	1.743	3.672	3.624	3.070	3.742	9.565	8.103	3.742
19.000	0.036	0.030	2.900	0.094	0.080	3.018	0.197	0.167	3.205	0.411	0.348	3.314	0.949	0.804	3.579	1.915	1.622	3.658	3.389	2.871	3.727	9.153	7.754	3.727
19.167	0.026	0.022	2.789	0.063	0.054	2.906	0.122	0.103	3.091	0.244	0.206	3.199	0.508	0.431	3.462	1.053	0.892	3.540	1.929	1.634	3.609	6.297	5.334	3.609
19.333	0.019	0.016	2.675	0.044	0.037	2.791	0.078	0.066	2.974	0.148	0.125	3.081	0.272	0.231	3.342	0.581	0.492	3.419	1.097	0.929	3.486	4.305	3.647	3.486
19.500	0.015	0.012	2.559	0.031	0.027	2.673	0.052	0.044	2.855	0.093	0.079	2.959	0.151	0.128	3.217	0.318	0.270	3.293	0.621	0.526	3.360	2.884	2.443	3.360
19.667	0.011	0.009	2.440	0.023	0.020	2.553	0.036	0.030	2.732	0.061	0.051	2.835	0.088	0.074	3.089	0.178	0.150	3.164	0.342	0.290	3.230	1.872	1.586	3.230
19.833	0.007	0.006	2.220	0.014	0.012	2.330	0.020	0.017	2.506	0.031	0.026	2.608	0.039	0.033	2.857	0.071	0.060	2.931	0.129	0.109	2.996	0.810	0.686	2.996
20.000	0.000	0.000	2.096	0.011	0.009	2.205	0.015	0.013	2.377	0.023	0.019	2.477	0.027	0.022	2.722	0.046	0.039	2.794	0.078	0.066	2.858	0.493	0.418	2.858
20.167	0.000	0.000	1.871	0.000	0.000	1.977	0.000	0.000	2.146	0.013	0.011	2.243	0.015	0.013	2.483	0.024	0.020	2.554	0.038	0.032	2.616	0.219	0.186	2.616
20.333	0.000	0.000	1.643	0.000	0.000	1.747	0.000	0.000	1.912	0.000	0.000	2.007	0.009	0.007	2.241	0.013	0.011	2.310	0.021	0.017	2.371	0.000	0.000	2.371
20.500	0.000	0.000	1.513	0.000	0.000	1.614	0.000	0.000	1.775	0.000	0.000	1.867	0.000	0.000	2.095	0.000	0.000	2.163	0.000	0.000	2.222	0.000	0.000	2.222
20.667	0.000	0.000	1.281	0.000	0.000	1.380	0.000	0.000	1.535	0.000	0.000	1.625	0.000	0.000	1.846	0.000	0.000	1.912	0.000	0.000	1.969	0.000	0.000	1.969
20.833	0.000	0.000	1.047	0.000	0.000	1.142	0.000	0.000	1.293	0.000	0.000	1.380	0.000	0.000	1.595	0.000	0.000	1.658	0.000	0.000	1.714	0.000	0.000	1.714
21.000	-	0.000	0.911	-	0.000	1.003	-	0.000	1.149	-	0.000	1.233	-	0.000	1.440	-	0.000	1.501	-	0.000	1.555	-	0.000	1.555
21.167	-	0.000	0.673	-	0.000	0.762	-	0.000	0.902	-	0.000	0.983	-	0.000	1.182	-	0.000	1.241	-	0.000	1.293	-	0.000	1.293
21.333	-	0.000	0.433	-	0.000	0.518	-	0.000	0.653	-	0.000	0.730	-	0.000	0.921	-	0.000	0.978	-	0.000	1.027	-	0.000	1.027
21.500	-	0.000	0.292	-	0.000	0.373	-	0.000	0.501	-	0.000	0.576	-	0.000	0.758	-	0.000	0.812	-	0.000	0.859	-	0.000	0.859
21.667	-	0.000	0.048	-	0.000	0.126	-	0.000	0.248	-	0.000	0.318	-	0.000	0.492	-	0.000	0.543	-	0.000	0.588	-	0.000	0.588
21.833	-	0.000	-0.196	-	0.000	-0.123	-	0.000	-0.008	-	0.000	0.059	-	0.000	0.224	-	0.000	0.272	-	0.000	0.315	-	0.000	0.315
22.000	-	0.000	-0.443	-	0.000	-0.374	-	0.000	-0.265	-	0.000	-0.202	-	0.000	-0.047	-	0.000	-0.001	-	0.000	0.039	-	0.000	0.039
22.167	-	0.000	-0.591	-	0.000	-0.526	-	0.000	-0.424	-	0.000	-0.365	-	0.000	-0.220	-	0.000	-0.177	-	0.000	-0.139	-	0.000	-0.139
22.333	-	0.000	-0.840	-	0.000	-0.780	-	0.000	-0.685	-	0.000	-0.630	-	0.000	-0.495	-	0.000	-0.455	-	0.000	-0.420	-	0.000	-0.420
22.500	-	0.000	-1.090	-	0.000	-1.035	-	0.000	-0.947	-	0.000	-0.897	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
22.667	-	0.000	-1.242	-	0.000	-1.191	-	0.000	-1.111	-	0.000	-1.065	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
22.833	-	0.000	-1.495	-	0.000	-1.449	-	0.000	-1.376	-	0.000	-1.334	-	0.000	-1.231	-	0.000	-1.200	-	0.000	-1.173	-	0.000	-1.173
23.000	-	0.000	-1.749	-	0.000	-1.707	-	0.000	-1.643	-	0.000	-1.605	-	0.000	-1.513	-	0.000	-1.485	-	0.000	-1.461	-	0.000	-1.461
11.000	-	0.000	-1.903	-	0.000	-1.867	-	0.000	-1.810	-	0.000	-1.777	-	0.000	-1.696	-	0.000	-1.672	-	0.000	-1.650	-	0.000	-1.650
11.167	-	0.000	-1.958	-	0.000	-1.927	-	0.000	-1.878	-	0.000	-1.850	-	0.000	-1.780	-	0.000	-1.759	-	0.000	-1.741	-	0.000	-1.741
11.333	-	0.000	-2.114	-	0.000	-2.088	-	0.000	-2.047	-	0.000	-2.023	-	0.000	-1.965	-	0.000	-1.948	-	0.000	-1.932	-	0.000	-1.932
11.500	-	0.000	-2.171	-	0.000	-2.150	-	0.000	-2.117	-	0.000	-2.098	-	0.000	-2.051	-	0.000	-2.037	-	0.000	-2.025	-	0.000	-2.025
11.667	-	0.000	-2.228	-	0.000	-2.212	-	0.000	-2.187	-	0.000	-2.173	-	0.000	-2.138	-	0.000	-2.127	-	0.000	-2.118	-	0.000	-2.118

High End Future Scenario

	10%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
12.667	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
13.000	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.333	-	0.000	-2.299	-	0.000	-2.284	-	0.000	-2.284
13.500	-	0.000	-2.198	-	0.000	-2.168	-	0.000	-2.168
13.667	-	0.000	-1.997	-	0.000	-1.953	-	0.000	-1.953
13.833	-	0.000	-1.897	-	0.000	-1.838	-	0.000	-1.838
14.000	-	0.000	-1.798	-	0.000	-1.724	-	0.000	-1.724
14.167	-	0.000	-1.600	-	0.000	-1.512	-	0.000	-1.512
14.333	-	0.000	-1.402	-	0.000	-1.300	-	0.000	-1.300
14.500	-	0.000	-1.207	-	0.000	-1.090	-	0.000	-1.090
14.667	-	0.000	-1.012	-	0.000	-0.882	-	0.000	-0.882
14.833	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
15.000	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
15.167	-	0.000	-0.440	-	0.000	-0.270	-	0.000	-0.270
15.333	-	0.000	-0.253	-	0.000	-0.071	-	0.000	-0.071
15.500	-	0.000	-0.069	-	0.000	0.126	-	0.000	0.126
15.667	-	0.000	0.212	-	0.000	0.419	-	0.000	0.419
15.833	-	0.000	0.491	-	0.000	0.710	-	0.000	0.710
16.000	-	0.000	0.667	-	0.000	0.897	-	0.000	0.897
16.167	-	0.000	0.840	-	0.000	1.081	-	0.000	1.081
16.333	-	0.000	1.110	-	0.000	1.361	-	0.000	1.361
16.500	-	0.000	1.377	-	0.000	1.638	-	0.000	1.638
16.667	0.000	0.000	1.541	0.000	0.000	1.810	0.000	0.000	1.810
16.833	0.000	0.000	1.800	0.000	0.000	2.079	0.000	0.000	2.079
17.000	0.000	0.000	2.057	0.028	0.024	2.343	0.000	0.000	2.343
17.167	0.007	0.006	2.309	0.054	0.046	2.604	0.324	0.274	2.604
17.333	0.013	0.011	2.558	0.124	0.105	2.859	0.762	0.645	2.859
17.500	0.018	0.015	2.703	0.219	0.185	3.011	1.293	1.095	3.011
17.667	0.035	0.030	2.943	0.617	0.523	3.258	2.944	2.494	3.258
17.833	0.057	0.048	3.080	1.131	0.958	3.400	4.535	3.842	3.400
18.000	0.155	0.131	3.313	3.079	2.608	3.637	9.038	7.656	3.637
18.167	0.551	0.467	3.541	8.414	7.128	3.869	0.000	0.000	3.869
18.333	2.171	1.839	3.765	0.000	0.000	4.097	0.000	0.000	4.097
18.500	4.516	3.826	3.885	0.000	0.000	4.220	0.000	0.000	4.220
18.667	4.965	4.206	3.900	0.000	0.000	4.237	0.000	0.000	4.237
18.833	5.294	4.485	3.911	0.000	0.000	4.250	0.000	0.000	4.250
19.000	9.485	8.035	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.167	9.632	8.160	4.020	0.000	0.000	4.360	0.000	0.000	4.360
19.333	9.485	8.035	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.500	9.194	7.789	4.011	0.000	0.000	4.350	0.000	0.000	4.350
19.667	4.965	4.206	3.900	0.000	0.000	4.237	0.000	0.000	4.237
19.833	4.516	3.826	3.885	0.000	0.000	4.220	0.000	0.000	4.220
20.000	2.171	1.839	3.765	0.000	0.000	4.097	0.000	0.000	4.097
20.167	1.008	0.854	3.641	12.760	10.809	3.969	0.000	0.000	3.969
20.333	0.465	0.394	3.513	7.331	6.210	3.837	16.060	13.605	3.837
20.500	0.220	0.187	3.380	4.016	3.402	3.700	10.810	9.158	3.700
20.667	0.072	0.061	3.143	1.440	1.220	3.458	5.380	4.558	3.458
20.833	0.043	0.036	3.003	0.776	0.657	3.311	3.466	2.936	3.311
21.000	0.021	0.018	2.758	0.266	0.226	3.059	1.534	1.300	3.059
21.167	0.011	0.010	2.509	0.102	0.086	2.804	0.628	0.532	2.804
21.333	0.008	0.007	2.357	0.061	0.052	2.643	0.368	0.312	2.643
21.500	0.000	0.000	2.100	0.030	0.026	2.379	0.000	0.000	2.379
21.667	0.000	0.000	1.841	0.000	0.000	2.110	0.000	0.000	2.110
21.833	0.000	0.000	1.677	0.000	0.000	1.938	0.000	0.000	1.938
22.000	-	0.000	1.410	-	0.000	1.661	-	0.000	1.661
22.167	-	0.000	1.140	-	0.000	1.381	-	0.000	1.381
22.333	-	0.000	0.967	-	0.000	1.197	-	0.000	1.197
22.500	-	0.000	0.691	-	0.000	0.910	-	0.000	0.910
22.667	-	0.000	0.412	-	0.000	0.619	-	0.000	0.619
22.833	-	0.000	0.131	-	0.000	0.326	-	0.000	0.326
23.000	-	0.000	-0.053	-	0.000	0.129	-	0.000	0.129
11.000	-	0.000	-0.340	-	0.000	-0.170	-	0.000	-0.170
11.167	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
11.333	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
11.500	-	0.000	-1.112	-	0.000	-0.982	-	0.000	-0.982
11.667	-	0.000	-1.407	-	0.000	-1.290	-	0.000	-1.290
11.833	-	0.000	-1.602	-	0.000	-1.500	-	0.000	-1.500
12.000	-	0.000	-1.700	-	0.000	-1.612	-	0.000	-1.612
12.167	-	0.000	-1.898	-	0.000	-1.824	-	0.000	-1.824
12.333	-	0.000	-1.997	-	0.000	-1.938	-	0.000	-1.938
12.500	-	0.000	-2.097	-	0.000	-2.053	-	0.000	-2.053

Location D.2

Current Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.000	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.167	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
11.333	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.500	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
11.667	-	0.000	-2.351	-	0.000	-2.346	-	0.000	-2.342	-	0.000	-2.339	-	0.000	-2.334	-	0.000	-2.339	-	0.000	-2.328	-	0.000	-2.328
11.833	-	0.000	-2.302	-	0.000	-2.292	-	0.000	-2.285	-	0.000	-2.278	-	0.000	-2.268	-	0.000	-2.278	-	0.000	-2.255	-	0.000	-2.255
12.000	-	0.000	-2.153	-	0.000	-2.138	-	0.000	-2.128	-	0.000	-2.117	-	0.000	-2.103	-	0.000	-2.117	-	0.000	-2.083	-	0.000	-2.083
12.167	-	0.000	-2.104	-	0.000	-2.085	-	0.000	-2.071	-	0.000	-2.057	-	0.000	-2.038	-	0.000	-2.057	-	0.000	-2.012	-	0.000	-2.012
12.333	-	0.000	-2.055	-	0.000	-2.032	-	0.000	-2.014	-	0.000	-1.997	-	0.000	-1.973	-	0.000	-1.997	-	0.000	-1.941	-	0.000	-1.941
12.500	-	0.000	-1.908	-	0.000	-1.879	-	0.000	-1.858	-	0.000	-1.838	-	0.000	-1.809	-	0.000	-1.838	-	0.000	-1.770	-	0.000	-1.770
12.667	-	0.000	-1.760	-	0.000	-1.727	-	0.000	-1.703	-	0.000	-1.679	-	0.000	-1.646	-	0.000	-1.679	-	0.000	-1.601	-	0.000	-1.601
12.833	-	0.000	-1.614	-	0.000	-1.576	-	0.000	-1.549	-	0.000	-1.521	-	0.000	-1.484	-	0.000	-1.521	-	0.000	-1.432	-	0.000	-1.432
13.000	-	0.000	-1.468	-	0.000	-1.425	-	0.000	-1.395	-	0.000	-1.364	-	0.000	-1.322	-	0.000	-1.364	-	0.000	-1.265	-	0.000	-1.265
13.167	-	0.000	-1.322	-	0.000	-1.276	-	0.000	-1.242	-	0.000	-1.208	-	0.000	-1.162	-	0.000	-1.208	-	0.000	-1.098	-	0.000	-1.098
13.333	-	0.000	-1.178	-	0.000	-1.127	-	0.000	-1.090	-	0.000	-1.054	-	0.000	-1.003	-	0.000	-1.054	-	0.000	-0.934	-	0.000	-0.934
13.500	-	0.000	-1.035	-	0.000	-0.980	-	0.000	-0.940	-	0.000	-0.900	-	0.000	-0.845	-	0.000	-0.900	-	0.000	-0.770	-	0.000	-0.770
13.667	-	0.000	-0.893	-	0.000	-0.834	-	0.000	-0.791	-	0.000	-0.748	-	0.000	-0.689	-	0.000	-0.748	-	0.000	-0.608	-	0.000	-0.608
13.833	-	0.000	-0.752	-	0.000	-0.689	-	0.000	-0.643	-	0.000	-0.597	-	0.000	-0.534	-	0.000	-0.597	-	0.000	-0.448	-	0.000	-0.448
14.000	-	0.000	-0.512	-	0.000	-0.445	-	0.000	-0.396	-	0.000	-0.348	-	0.000	-0.281	-	0.000	-0.348	-	0.000	-0.189	-	0.000	-0.189
14.167	-	0.000	-0.274	-	0.000	-0.203	-	0.000	-0.152	-	0.000	-0.100	-	0.000	-0.029	-	0.000	-0.100	-	0.000	0.067	-	0.000	0.067
14.333	-	0.000	-0.137	-	0.000	-0.062	-	0.000	-0.008	-	0.000	0.046	-	0.000	0.120	-	0.000	0.046	-	0.000	0.221	-	0.000	0.221
14.500	-	0.000	-0.001	-	0.000	0.077	-	0.000	0.133	-	0.000	0.190	-	0.000	0.268	-	0.000	0.190	-	0.000	0.374	-	0.000	0.374
14.667	-	0.000	0.233	-	0.000	0.314	-	0.000	0.373	-	0.000	0.432	-	0.000	0.513	-	0.000	0.432	-	0.000	0.624	-	0.000	0.624
14.833	-	0.000	0.466	-	0.000	0.550	-	0.000	0.611	-	0.000	0.672	-	0.000	0.757	-	0.000	0.672	-	0.000	0.872	-	0.000	0.872
15.000	0.000	0.000	0.596	0.000	0.000	0.684	0.000	0.000	0.747	0.000	0.000	0.811	0.000	0.000	0.898	0.000	0.000	0.811	0.000	0.000	1.017	0.000	0.000	1.017
15.167	0.000	0.000	0.826	0.000	0.000	0.916	0.000	0.000	0.981	0.000	0.000	1.047	0.000	0.000	1.137	0.000	0.000	1.047	0.000	0.000	1.260	0.000	0.000	1.260
15.333	0.000	0.000	1.053	0.000	0.000	1.146	0.000	0.000	1.213	0.000	0.000	1.281	0.000	0.000	1.374	0.000	0.000	1.281	0.000	0.000	1.500	0.000	0.000	1.500
15.500	0.000	0.000	1.279	0.000	0.000	1.374	0.000	0.000	1.443	0.000	0.000	1.512	0.000	0.000	1.608	0.000	0.000	1.512	0.000	0.000	1.738	0.000	0.000	1.738
15.667	0.000	0.000	1.502	0.000	0.000	1.600	0.000	0.000	1.671	0.000	0.000	1.742	0.000	0.000	1.839	0.000	0.000	1.742	0.000	0.000	1.972	0.000	0.000	1.972
15.833	0.000	0.000	1.624	0.000	0.000	1.724	0.000	0.000	1.796	0.000	0.000	1.869	0.573	0.597	1.969	1.090	1.136	1.869	1.868	1.947	2.104	0.000	0.000	2.104
16.000	0.057	0.060	1.844	0.162	0.169	1.946	0.344	0.358	2.020	0.710	0.740	2.093	1.718	1.791	2.195	3.099	3.230	2.093	4.966	5.177	2.334	11.630	12.123	2.334
16.167	0.101	0.105	1.962	0.306	0.319	2.065	0.656	0.684	2.140	1.338	1.395	2.216	3.083	3.214	2.319	5.319	5.545	2.216	8.145	8.490	2.460	0.000	0.000	2.460
16.333	0.340	0.355	2.178	1.046	1.090	2.283	2.122	2.212	2.359	3.974	4.142	2.435	7.956	8.293	2.540	0.000	0.000	2.435	0.000	0.000	2.683	0.000	0.000	2.683
16.500	1.248	1.301	2.391	3.346	3.488	2.498	5.996	6.250	2.575	0.000	0.000	2.652	0.000	0.000	2.759	0.000	0.000	2.652	0.000	0.000	2.903	0.000	0.000	2.903
16.667	4.010	4.180	2.603	0.000	0.000	2.711	0.000	0.000	2.789	0.000	0.000	2.867	0.000	0.000	2.974	0.000	0.000	2.867	0.000	0.000	3.121	0.000	0.000	3.121
16.833	0.000	0.000	2.713	0.000	0.000	2.821	0.000	0.000	2.900	0.000	0.000	2.979	0.000	0.000	3.087	0.000	0.000	2.979	0.000	0.000	3.235	0.000	0.000	3.235
17.000	0.000	0.000	2.720	0.000	0.000	2.829	0.000	0.000	2.909	0.000	0.000	2.988	0.000	0.000	3.097	0.000	0.000	2.988	0.000	0.000	3.246	0.000	0.000	3.246
17.167	0.000	0.000	2.726	0.000	0.000	2.835	0.000	0.000	2.915	0.000	0.000	2.995	0.000	0.000	3.104	0.000	0.000	2.995	0.000	0.000	3.254	0.000	0.000	3.254
17.333	0.000	0.000	2.829	0.000	0.000	2.939	0.000	0.000	3.019	0.000	0.000	3.099	0.000	0.000	3.209	0.000	0.000	3.099	0.000	0.000	3.358	0.000	0.000	3.358
17.500	0.000	0.000	2.830	0.000	0.000	2.940	0.000	0.000	3.020	0.000	0.000	3.100	0.000	0.000	3.210	0.000	0.000	3.100	0.000	0.000	3.360	0.000	0.000	3.360
17.667	0.000	0.000	2.829	0.000	0.000	2.939	0.000	0.000	3.019	0.000	0.000	3.099	0.000	0.000	3.209	0.000	0.000	3.099	0.000	0.000	3.358	0.000	0.000	3.358
17.833	0.000	0.000	2.826	0.000	0.000	2.935	0.000	0.000	3.015	0.000	0.000	3.095	0.000	0.000	3.204	0.000	0.000	3.095	0.000	0.000	3.354	0.000	0.000	3.354
18.000	0.000	0.000	2.720	0.000	0.000	2.829	0.000	0.000	2.909	0.000	0.000	2.988	0.000	0.000	3.097	0.000	0.000	2.988	0.000	0.000	3.246	0.000	0.000	3.246
18.167	0.000	0.000	2.713	0.000	0.000	2.821	0.000	0.000	2.900	0.000	0.000	2.979	0.000	0.000	3.087	0.000	0.000	2.979	0.000	0.000	3.235	0.000	0.000	3.235
18.333	4.010	4.180	2.603	0.000	0.000	2.711	0.000	0.000	2.789	0.000	0.000	2.867	0.000	0.000	2.974	0.000	0.000	2.867	0.000	0.000	3.121	0.000	0.000	3.121
18.500	2.220	2.314	2.491	5.390	5.619	2.598	0.000	0.000	2.675	0.000	0.000	2.752	0.000	0.000	2.859	0.000	0.000	2.752	0.000	0.000	3.003	0.000	0.000	3.003
18.667	1.149	1.198	2.378	3.100	3.231	2.483	5.594	5.831	2.559	0.000	0.000	2.635	0.000	0.000	2.740	0.000	0.000	2.635	0.000	0.000	2.883	0.000	0.000	2.883
18.833	0.568	0.592	2.262	1.664	1.735	2.365	3.220	3.357	2.440	5.690	5.931	2.516	0.000	0.000	2.619	0.000	0.000	2.516	0.000	0.000	2.760	0.000	0.000	2.760
19.000	0.156	0.163	2.044	0.478	0.498	2.146	1.011	1.054	2.220	1.990	2.074	2.293	4.353	4.538	2.395	7.205	7.510	2.293	0.000	0.000	2.534	0.000	0.000	2.534
19.167	0.084	0.087	1.924	0.243	0.254	2.024	0.517	0.539	2.096	1.049	1.093	2.169	2.443	2.547	2.269	4.246	4.426	2.169	6.604	6.884	2.404	0.000	0.000	2.404
19.333	0.000	0.000	1.702	0.000	0.000	1.800	0.164	0.171	1.871	0.329	0.343	1.942	0.806	0.841	2.039	1.513	1.577	1.942	2.516	2.623	2.172	0.000	0.000	2.172
19.500	0.000	0.000	1.479	0.000	0.000	1.574	0.000	0.000	1.643	0.000	0.000	1.712	0.000	0.000	1.808	0.000	0.000	1.712	0.000	0.000	1.938	0.000	0.000	1.938
19.667	0.000	0.000	1.353	0.000	0.000	1.446	0.000	0.000	1.513	0.000	0.000	1.581	0.000	0.000	1.674	0.000	0.000	1.581	0.000	0.000	1.800	0.000	0.000	1.800
19.833	0.000	0.000	1.126	0.000	0.000	1.216	0.000	0.000	1.281	0.000	0.000	1.347	0.000	0.000	1.437	0.000	0.000	1.347	0.000	0.000	1.560	0.000	0.000	1.560
20.000	0.000	0.000	0.896	0.000	0.000	0.984	0.000	0.000	1.047	0.000	0.000	1.111	0.000	0.000	1.198	0.000	0.000	1.111	0.000	0.000	1.317	0.000	0.000	1.317
20.167	-	0.000	0.766	-	0.000	0.850	-	0.000	0.911	-	0.000	0.972	-	0.000	1.057	-	0.000	0.972	-	0.000	1.172	-	0.000	1.172
20.333	-	0.000	0.533	-	0.000	0.614	-	0.000	0.673	-	0.000	0.732	-	0.000	0.813	-	0.000	0.732	-	0.000	0.924	-	0.000	0.924
20.500	-	0.000	0.299	-	0.000	0.377	-	0.000	0.433	-	0.000	0.490	-	0.000	0.568	-	0.000	0.490	-	0.000	0.674	-	0.000	0.674
20.667	-	0.000	0.163	-	0.000	0.238	-	0.000	0.292	-	0.000	0.346	-	0.000	0.420	-	0.000	0.346	-	0.000	0.521	-	0.000	0.521
20.833	-	0.000	-0.074	-	0.000	-0.003	-	0.000	0.048	-	0.000	0.100	-	0.000	0.171	-	0.000	0.100	-	0.000	0.267	-	0.000	0.267
21.000	-	0.000	-0.312	-	0.000	-0.245	-	0.000	-0.196	-	0.000	-0.148	-	0.000	-0.081	-	0.000	-0.148	-	0.000	0.011	-	0.000	0.011
21.167	-	0.000	-0.552	-	0.000	-0.489	-	0.000	-0.443	-	0.000	-0.397	-	0.000	-0.334	-	0.000	-0.397	-	0.000	-0.248	-	0.000	-0.248
21.333	-	0.000	-0.693	-	0.000	-0.634	-	0.000	-0.591	-	0.000	-0.548	-	0.000	-0.489	-	0.000	-0.548	-	0.000	-0.408	-	0.000	-0.408
21.500	-	0.000	-0.935	-	0.000	-0.880	-	0.000	-0.840	-	0.000	-0.800	-	0.000	-0.745	-	0.000	-0.800	-	0.000	-0.670	-	0.000	-0.670
21.667	-	0.000	-1.178	-	0.000	-1.127	-	0.000	-1.090	-	0.000	-1.054	-	0.000	-1.003	-	0.000	-1.054	-	0.000	-0.934	-	0.000	-0.934
21.833	-	0.000	-1.322	-	0.000	-1.276	-	0.000	-1.242	-	0.000	-1.208	-	0.000	-1.162	-	0.000	-1.208	-	0.000	-1.098	-	0.000	-1.098
22.000	-	0.000	-1.568	-	0.000	-1.525	-	0.000	-1.495	-	0.000	-1.464	-	0.000	-1.422	-	0.000	-1.464	-	0.000	-1.365	-	0.000	-1.365
22.167	-	0.000	-1.814	-	0.000	-1.776	-	0.000	-1.749	-	0.000	-1.721	-	0.000	-1.684	-	0.000	-1.721	-	0.000	-1.632	-	0.000	-1.632
22.333	-	0.000	-1.960	-	0.000	-1.927	-	0.000	-1.903	-	0.000	-1.879	-	0.000	-1.846	-	0.000	-1.879	-	0.000	-1.801	-	0.000	-1.801
22.500	-	0.000	-2.008	-	0.000	-1.979	-	0.000	-1.958	-	0.000	-1.938	-	0.000	-1.909	-	0.000	-1.938	-	0.000	-1.870	-	0.000	-1.870
22.667	-	0.000	-2.155	-	0.000	-2.132	-	0.000	-2.114	-	0.000	-2.097	-	0.000	-2.073	-	0.000	-2.097	-	0.000	-2.041	-	0.000	-2.041
22.833	-	0.000	-2.204	-	0.000	-2.185	-	0.000	-2.171	-	0.000	-2.157	-	0.000	-2.138	-	0.000	-2.157	-	0.000	-2.112	-	0.000	-2.112
23.000	-	0.000	-2.253	-	0.000	-2.238	-	0.000	-2.228	-	0.000	-2.217	-	0.000	-2.203	-	0.000	-2.217	-	0.000	-2.183	-	0.000	-2.183

Mid -Range Future Scenario

	50%			20%			10%			5%			2%			1%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
11.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.000	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.333	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
12.500	-	0.000	-2.329	-	0.000	-2.324	-	0.000	-2.321	-	0.000	-2.317	-	0.000	-2.312	-	0.000	-2.309	-	0.000	-2.306	-	0.000	-2.306
12.667	-	0.000	-2.258	-	0.000	-2.248	-	0.000	-2.241	-	0.000	-2.234	-	0.000	-2.225	-	0.000	-2.218	-	0.000	-2.212	-	0.000	-2.212
12.833	-	0.000	-2.087	-	0.000	-2.073	-	0.000	-2.062	-	0.000	-2.052	-	0.000	-2.038	-	0.000	-2.027	-	0.000	-2.018	-	0.000	-2.018
13.000	-	0.000	-2.017	-	0.000	-1.998	-	0.000	-1.984	-	0.000	-1.970	-	0.000	-1.951	-	0.000	-1.937	-	0.000	-1.925	-	0.000	-1.925
13.167	-	0.000	-1.947	-	0.000	-1.923	-	0.000	-1.906	-	0.000	-1.889	-	0.000	-1.865	-	0.000	-1.848	-	0.000	-1.832	-	0.000	-1.832
13.333	-	0.000	-1.778	-	0.000	-1.750	-	0.000	-1.729	-	0.000	-1.708	-	0.000	-1.680	-	0.000	-1.659	-	0.000	-1.641	-	0.000	-1.641
13.500	-	0.000	-1.610	-	0.000	-1.577	-	0.000	-1.553	-	0.000	-1.529	-	0.000	-1.496	-	0.000	-1.472	-	0.000	-1.450	-	0.000	-1.450
13.667	-	0.000	-1.443	-	0.000	-1.405	-	0.000	-1.378	-	0.000	-1.350	-	0.000	-1.313	-	0.000	-1.285	-	0.000	-1.261	-	0.000	-1.261
13.833	-	0.000	-1.276	-	0.000	-1.234	-	0.000	-1.204	-	0.000	-1.173	-	0.000	-1.131	-	0.000	-1.100	-	0.000	-1.073	-	0.000	-1.073
14.000	-	0.000	-1.111	-	0.000	-1.065	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
14.167	-	0.000	-0.947	-	0.000	-0.897	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
14.333	-	0.000	-0.785	-	0.000	-0.730	-	0.000	-0.690	-	0.000	-0.650	-	0.000	-0.595	-	0.000	-0.555	-	0.000	-0.520	-	0.000	-0.520
14.500	-	0.000	-0.624	-	0.000	-0.565	-	0.000	-0.522	-	0.000	-0.479	-	0.000	-0.420	-	0.000	-0.377	-	0.000	-0.339	-	0.000	-0.339
14.667	-	0.000	-0.465	-	0.000	-0.402	-	0.000	-0.356	-	0.000	-0.310	-	0.000	-0.247	-	0.000	-0.201	-	0.000	-0.161	-	0.000	-0.161
14.833	-	0.000	-0.208	-	0.000	-0.141	-	0.000	-0.092	-	0.000	-0.043	-	0.000	0.024	-	0.000	0.072	-	0.000	0.115	-	0.000	0.115
15.000	-	0.000	0.048	-	0.000	0.118	-	0.000	0.170	-	0.000	0.221	-	0.000	0.292	-	0.000	0.343	-	0.000	0.388	-	0.000	0.388
15.167	-	0.000	0.201	-	0.000	0.276	-	0.000	0.330	-	0.000	0.384	-	0.000	0.458	-	0.000	0.512	-	0.000	0.559	-	0.000	0.559
15.333	-	0.000	0.353	-	0.000	0.430	-	0.000	0.487	-	0.000	0.544	-	0.000	0.621	-	0.000	0.678	-	0.000	0.727	-	0.000	0.727
15.500	-	0.000	0.602	-	0.000	0.683	-	0.000	0.742	-	0.000	0.801	-	0.000	0.882	-	0.000	0.941	-	0.000	0.993	-	0.000	0.993
15.667	-	0.000	0.849	-	0.000	0.933	-	0.000	0.994	-	0.000	1.055	-	0.000	1.140	-	0.000	1.201	-	0.000	1.255	-	0.000	1.255
15.833	0.000	0.000	0.993	0.000	0.000	1.080	0.000	0.000	1.144	0.000	0.000	1.207	0.000	0.000	1.295	0.000	0.000	1.358	0.000	0.000	1.414	0.000	0.000	1.414
16.000	0.000	0.000	1.235	0.000	0.000	1.325	0.000	0.000	1.391	0.000	0.000	1.456	0.000	0.000	1.546	0.000	0.000	1.612	0.000	0.000	1.669	0.000	0.000	1.669
16.167	0.000	0.000	1.475	0.000	0.000	1.567	0.000	0.000	1.635	0.000	0.000	1.702	0.000	0.000	1.795	0.000	0.000	1.863	0.000	0.000	1.922	0.000	0.000	1.922
16.333	0.000	0.000	1.712	0.000	0.000	1.807	0.000	0.000	1.876	0.533	0.555	1.945	1.228	1.280	2.041	2.159	2.251	2.110	3.466	3.613	2.171	0.000	0.000	2.171
16.500	0.164	0.171	1.946	0.450	0.469	2.043	0.903	0.941	2.114	1.713	1.786	2.185	3.655	3.810	2.283	5.973	6.226	2.354	8.897	9.274	2.416	0.000	0.000	2.416
16.667	0.332	0.346	2.077	0.916	0.955	2.177	1.800	1.876	2.249	3.255	3.393	2.322	6.555	6.833	2.422	10.140	10.570	2.494	0.000	0.000	2.558	0.000	0.000	2.558
16.833	1.221	1.273	2.306	3.068	3.198	2.408	5.439	5.670	2.481	0.000	0.000	2.555	0.000	0.000	2.657	0.000	0.000	2.731	0.000	0.000	2.796	0.000	0.000	2.796
17.000	2.443	2.547	2.432	5.591	5.828	2.535	0.000	0.000	2.610	0.000	0.000	2.685	0.000	0.000	2.789	0.000	0.000	2.864	0.000	0.000	2.930	0.000	0.000	2.930
17.167	0.000	0.000	2.655	0.000	0.000	2.759	0.000	0.000	2.836	0.000	0.000	2.912	0.000	0.000	3.017	0.000	0.000	3.093	0.000	0.000	3.160	0.000	0.000	3.160
17.333	0.000	0.000	2.874	0.000	0.000	2.981	0.000	0.000	3.058	0.000	0.000	3.135	0.000	0.000	3.242	0.000	0.000	3.319	0.000	0.000	3.386	0.000	0.000	3.386
17.500	0.000	0.000	3.091	0.000	0.000	3.199	0.000	0.000	3.277	0.000	0.000	3.355	0.000	0.000	3.462	0.000	0.000	3.540	0.000	0.000	3.609	0.000	0.000	3.609
17.667	0.000	0.000	3.205	0.000	0.000	3.314	0.000	0.000	3.392	0.000	0.000	3.471	0.000	0.000	3.579	0.000	0.000	3.658	0.000	0.000	3.727	0.000	0.000	3.727
17.833	0.000	0.000	3.216	0.000	0.000	3.325	0.000	0.000	3.404	0.000	0.000	3.484	0.000	0.000	3.593	0.000	0.000	3.672	0.000	0.000	3.742	0.000	0.000	3.742
18.000	0.000	0.000	3.224	0.000	0.000	3.333	0.000	0.000	3.413	0.000	0.000	3.493	0.000	0.000	3.602	0.000	0.000	3.682	0.000	0.000	3.752	0.000	0.000	3.752
18.167	0.000	0.000	3.328	0.000	0.000	3.438	0.000	0.000	3.518	0.000	0.000	3.598	0.000	0.000	3.708	0.000	0.000	3.788	0.000	0.000	3.858	0.000	0.000	3.858
18.333	0.000	0.000	3.330	0.000	0.000	3.440	0.000	0.000	3.520	0.000	0.000	3.600	0.000	0.000	3.710	0.000	0.000	3.790	0.000	0.000	3.860	0.000	0.000	3.860
18.500	0.000	0.000	3.328	0.000	0.000	3.438	0.000	0.000	3.518	0.000	0.000	3.598	0.000	0.000	3.708	0.000	0.000	3.788	0.000	0.000	3.858	0.000	0.000	3.858
18.667	0.000	0.000	3.324	0.000	0.000	3.433	0.000	0.000	3.513	0.000	0.000	3.593	0.000	0.000	3.702	0.000	0.000	3.782	0.000	0.000	3.852	0.000	0.000	3.852
18.833	0.000	0.000	3.216	0.000	0.000	3.325	0.000	0.000	3.404	0.000	0.000	3.484	0.000	0.000	3.593	0.000	0.000	3.672	0.000	0.000	3.742	0.000	0.000	3.742
19.000	0.000	0.000	3.205	0.000	0.000	3.314	0.000	0.000	3.392	0.000	0.000	3.471	0.000	0.000	3.579	0.000	0.000	3.658	0.000	0.000	3.727	0.000	0.000	3.727
19.167	0.000	0.000	3.091	0.000	0.000	3.199	0.000	0.000	3.277	0.000	0.000	3.355	0.000	0.000	3.462	0.000	0.000	3.540	0.000	0.000	3.609	0.000	0.000	3.609
19.333	0.000	0.000	2.974	0.000	0.000	3.081	0.000	0.000	3.158	0.000	0.000	3.235	0.000	0.000	3.342	0.000	0.000	3.419	0.000	0.000	3.486	0.000	0.000	3.486
19.500	0.000	0.000	2.855	0.000	0.000	2.959	0.000	0.000	3.036	0.000	0.000	3.112	0.000	0.000	3.217	0.000	0.000	3.293	0.000	0.000	3.360	0.000	0.000	3.360
19.667	0.000	0.000	2.732	0.000	0.000	2.835	0.000	0.000	2.910	0.000	0.000	2.985	0.000	0.000	3.089	0.000	0.000	3.164	0.000	0.000	3.230	0.000	0.000	3.230
19.833	3.591	3.743	2.506	0.000	0.000	2.608	0.000	0.000	2.681	0.000	0.000	2.755	0.000	0.000	2.857	0.000	0.000	2.931	0.000	0.000	2.996	0.000	0.000	2.996
20.000	1.825	1.902	2.377	4.290	4.472	2.477	7.242	7.549	2.549	0.000	0.000	2.622	0.000	0.000	2.722	0.000	0.000	2.794	0.000	0.000	2.858	0.000	0.000	2.858
20.167	0.487	0.508	2.146	1.314	1.370	2.243	2.486	2.591	2.314	4.356	4.541	2.385	8.309	8.661	2.483	0.000	0.000	2.554	0.000	0.000	2.616	0.000	0.000	2.616
20.333	0.139	0.145	1.912	0.371	0.386	2.007	0.743	0.775	2.076	1.410	1.470	2.145	3.042	3.171	2.241	5.005	5.217	2.310	7.553	7.873	2.371	0.000	0.000	2.371
20.500	0.000	0.000	1.775	0.187	0.195	1.867	0.365	0.381	1.935	0.700	0.729	2.002	1.584	1.651	2.095	2.713	2.828	2.163	4.253	4.433	2.222	0.000	0.000	2.222
20.667	0.000	0.000	1.535	0.000	0.000	1.625	0.000	0.000	1.691	0.000	0.000	1.756	0.000	0.000	1.846	0.000	0.000	1.912	0.000	0.000	1.969	0.000	0.000	1.969
20.833	0.000	0.000	1.293	0.000	0.000	1.380	0.000	0.000	1.444	0.000	0.000	1.507	0.000	0.000	1.595	0.000	0.000	1.658	0.000	0.000	1.714	0.000	0.000	1.714
21.000	-	0.000	1.149	-	0.000	1.233	-	0.000	1.294	-	0.000	1.355	-	0.000	1.440	-	0.000	1.501	-	0.000	1.555	-	0.000	1.555
21.167	-	0.000	0.902	-	0.000	0.983	-	0.000	1.042	-	0.000	1.101	-	0.000	1.182	-	0.000	1.241	-	0.000	1.293	-	0.000	1.293
21.333	-	0.000	0.653	-	0.000	0.730	-	0.000	0.787	-	0.000	0.844	-	0.000	0.921	-	0.000	0.978	-	0.000	1.027	-	0.000	1.027
21.500	-	0.000	0.501	-	0.000	0.576	-	0.000	0.630	-	0.000	0.684	-	0.000	0.758	-	0.000	0.812	-	0.000	0.859	-	0.000	0.859
21.667	-	0.000	0.248	-	0.000	0.318	-	0.000	0.370	-	0.000	0.421	-	0.000	0.492	-	0.000	0.543	-	0.000	0.588	-	0.000	0.588
21.833	-	0.000	-0.008	-	0.000	0.059	-	0.000	0.108	-	0.000	0.157	-	0.000	0.224	-	0.000	0.272	-	0.000	0.315	-	0.000	0.315
22.000	-	0.000	-0.265	-	0.000	-0.202	-	0.000	-0.156	-	0.000	-0.110	-	0.000	-0.047	-	0.000	-0.001	-	0.000	0.039	-	0.000	0.039
22.167	-	0.000	-0.424	-	0.000	-0.365	-	0.000	-0.322	-	0.000	-0.279	-	0.000	-0.220	-	0.000	-0.177	-	0.000	-0.139	-	0.000	-0.139
22.333	-	0.000	-0.685	-	0.000	-0.630	-	0.000	-0.590	-	0.000	-0.550	-	0.000	-0.495	-	0.000	-0.455	-	0.000	-0.420	-	0.000	-0.420
22.500	-	0.000	-0.947	-	0.000	-0.897	-	0.000	-0.860	-	0.000	-0.823	-	0.000	-0.772	-	0.000	-0.735	-	0.000	-0.703	-	0.000	-0.703
22.667	-	0.000	-1.111	-	0.000	-1.065	-	0.000	-1.031	-	0.000	-0.997	-	0.000	-0.951	-	0.000	-0.917	-	0.000	-0.887	-	0.000	-0.887
22.833	-	0.000	-1.376	-	0.000	-1.334	-	0.000	-1.304	-	0.000	-1.273	-	0.000	-1.231	-	0.000	-1.200	-	0.000	-1.173	-	0.000	-1.173
23.000	-	0.000	-1.643	-	0.000	-1.605	-	0.000	-1.578	-	0.000	-1.550	-	0.000	-1.513	-	0.000	-1.485	-	0.000	-1.461	-	0.000	-1.461
11.000	-	0.000	-1.810	-	0.000	-1.777	-	0.000	-1.753	-	0.000	-1.729	-	0.000	-1.696	-	0.000	-1.672	-	0.000	-1.650	-	0.000	-1.650
11.167	-	0.000	-1.878	-	0.000	-1.850	-	0.000	-1.829	-	0.000	-1.808	-	0.000	-1.780	-	0.000	-1.759	-	0.000	-1.741	-	0.000	-1.741
11.333	-	0.000	-2.047	-	0.000	-2.023	-	0.000	-2.006	-	0.000	-1.989	-	0.000	-1.965	-	0.000	-1.948	-	0.000	-1.932	-	0.000	-1.932
11.500	-	0.000	-2.117	-	0.000	-2.098	-	0.000	-2.084	-	0.000	-2.070	-	0.000	-2.051	-	0.000	-2.037	-	0.000	-2.025	-	0.000	-2.025
11.667	-	0.000	-2.187	-	0.000	-2.173	-	0.000	-2.162	-	0.000	-2.152	-	0.000	-2.138	-	0.000	-2.127	-	0.000	-2.118	-	0.000	-2.118

High End Future Scenario

	10%			0.50%			0.10%		
Time	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)	q (l/m/s)	q (m^3/s)	Water Level (mAOD)
12.667	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
12.833	-	0.000	-2.300	-	0.000	-2.300	-	0.000	-2.300
13.000	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.167	-	0.000	-2.400	-	0.000	-2.400	-	0.000	-2.400
13.333	-	0.000	-2.299	-	0.000	-2.284	-	0.000	-2.284
13.500	-	0.000	-2.198	-	0.000	-2.168	-	0.000	-2.168
13.667	-	0.000	-1.997	-	0.000	-1.953	-	0.000	-1.953
13.833	-	0.000	-1.897	-	0.000	-1.838	-	0.000	-1.838
14.000	-	0.000	-1.798	-	0.000	-1.724	-	0.000	-1.724
14.167	-	0.000	-1.600	-	0.000	-1.512	-	0.000	-1.512
14.333	-	0.000	-1.402	-	0.000	-1.300	-	0.000	-1.300
14.500	-	0.000	-1.207	-	0.000	-1.090	-	0.000	-1.090
14.667	-	0.000	-1.012	-	0.000	-0.882	-	0.000	-0.882
14.833	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
15.000	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
15.167	-	0.000	-0.440	-	0.000	-0.270	-	0.000	-0.270
15.333	-	0.000	-0.253	-	0.000	-0.071	-	0.000	-0.071
15.500	-	0.000	-0.069	-	0.000	0.126	-	0.000	0.126
15.667	-	0.000	0.212	-	0.000	0.419	-	0.000	0.419
15.833	-	0.000	0.491	-	0.000	0.710	-	0.000	0.710
16.000	-	0.000	0.667	-	0.000	0.897	-	0.000	0.897
16.167	-	0.000	0.840	-	0.000	1.081	-	0.000	1.081
16.333	-	0.000	1.110	-	0.000	1.361	-	0.000	1.361
16.500	-	0.000	1.377	-	0.000	1.638	-	0.000	1.638
16.667	0.000	0.000	1.541	0.000	0.000	1.810	0.000	0.000	1.810
16.833	0.000	0.000	1.800	3.177	3.312	2.079	0.000	0.000	2.079
17.000	0.993	1.035	2.057	8.539	8.901	2.343	0.000	0.000	2.343
17.167	3.321	3.462	2.309	0.000	0.000	2.604	0.000	0.000	2.604
17.333	0.000	0.000	2.558	0.000	0.000	2.859	0.000	0.000	2.859
17.500	0.000	0.000	2.703	0.000	0.000	3.011	0.000	0.000	3.011
17.667	0.000	0.000	2.943	0.000	0.000	3.258	0.000	0.000	3.258
17.833	0.000	0.000	3.080	0.000	0.000	3.400	0.000	0.000	3.400
18.000	0.000	0.000	3.313	0.000	0.000	3.637	0.000	0.000	3.637
18.167	0.000	0.000	3.541	0.000	0.000	3.869	0.000	0.000	3.869
18.333	0.000	0.000	3.765	0.000	0.000	4.097	0.000	0.000	4.097
18.500	0.000	0.000	3.885	0.000	0.000	4.220	0.000	0.000	4.220
18.667	0.000	0.000	3.900	0.000	0.000	4.237	0.000	0.000	4.237
18.833	0.000	0.000	3.911	0.000	0.000	4.250	0.000	0.000	4.250
19.000	0.000	0.000	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.167	0.000	0.000	4.020	0.000	0.000	4.360	0.000	0.000	4.360
19.333	0.000	0.000	4.018	0.000	0.000	4.357	0.000	0.000	4.357
19.500	0.000	0.000	4.011	0.000	0.000	4.350	0.000	0.000	4.350
19.667	0.000	0.000	3.900	0.000	0.000	4.237	0.000	0.000	4.237
19.833	0.000	0.000	3.885	0.000	0.000	4.220	0.000	0.000	4.220
20.000	0.000	0.000	3.765	0.000	0.000	4.097	0.000	0.000	4.097
20.167	0.000	0.000	3.641	0.000	0.000	3.969	0.000	0.000	3.969
20.333	0.000	0.000	3.513	0.000	0.000	3.837	0.000	0.000	3.837
20.500	0.000	0.000	3.380	0.000	0.000	3.700	0.000	0.000	3.700
20.667	0.000	0.000	3.143	0.000	0.000	3.458	0.000	0.000	3.458
20.833	0.000	0.000	3.003	0.000	0.000	3.311	0.000	0.000	3.311
21.000	0.000	0.000	2.758	0.000	0.000	3.059	0.000	0.000	3.059
21.167	7.867	8.201	2.509	0.000	0.000	2.804	0.000	0.000	2.804
21.333	4.109	4.283	2.357	0.000	0.000	2.643	0.000	0.000	2.643
21.500	1.231	1.283	2.100	9.641	10.050	2.379	0.000	0.000	2.379
21.667	0.000	0.000	1.841	3.598	3.751	2.110	0.000	0.000	2.110
21.833	0.000	0.000	1.677	0.000	0.000	1.938	0.000	0.000	1.938
22.000	-	0.000	1.410	-	0.000	1.661	-	0.000	1.661
22.167	-	0.000	1.140	-	0.000	1.381	-	0.000	1.381
22.333	-	0.000	0.967	-	0.000	1.197	-	0.000	1.197
22.500	-	0.000	0.691	-	0.000	0.910	-	0.000	0.910
22.667	-	0.000	0.412	-	0.000	0.619	-	0.000	0.619
22.833	-	0.000	0.131	-	0.000	0.326	-	0.000	0.326
23.000	-	0.000	-0.053	-	0.000	0.129	-	0.000	0.129
11.000	-	0.000	-0.340	-	0.000	-0.170	-	0.000	-0.170
11.167	-	0.000	-0.629	-	0.000	-0.472	-	0.000	-0.472
11.333	-	0.000	-0.820	-	0.000	-0.676	-	0.000	-0.676
11.500	-	0.000	-1.112	-	0.000	-0.982	-	0.000	-0.982
11.667	-	0.000	-1.407	-	0.000	-1.290	-	0.000	-1.290
11.833	-	0.000	-1.602	-	0.000	-1.500	-	0.000	-1.500
12.000	-	0.000	-1.700	-	0.000	-1.612	-	0.000	-1.612
12.167	-	0.000	-1.898	-	0.000	-1.824	-	0.000	-1.824
12.333	-	0.000	-1.997	-	0.000	-1.938	-	0.000	-1.938
12.500	-	0.000	-2.097	-	0.000	-2.053	-	0.000	-2.053

Fluvial and Coastal Hydraulic Modelling Report

1. Basic Model Information

1.1 General Information	
Model ID:	S17
Unit of Management	23
AFAs included in the Model	Banna
Primary Watercourses / Water Bodies	Ballynoe Tyshe River and unnamed tributary Banna Mountain Carrahane
1.2 Reference to other Relevant Reports	
Catchment Description	Hydrology Report Unit of Management 23 – Appendix A3.1
Model Location	Hydraulics Report Unit of Management 23 – Section 3.4.2
HEP Schematisation	Hydrology Report Unit of Management 23 – Appendix B6 – Figure B6.1

2. Survey Data and Base Mapping

2.1 Base Mapping:	OSi data base mapping at scale 1:50k Reference: OS0610_D_BW, OS0612_D_BW, OS0810_D_BW, OS0812_D_BW
2.2 DTM for 2D Model Domain:	**Within AFAs:** LiDAR with 2m resolution (horizontal) and 200mm accuracy (vertical) has been used for the 2D domain of the hydraulic model.
	Outside AFAs: The supplied LiDAR data covers the area to be modelled outside the AFA. Therefore this has been used instead of IFSAR, given the much greater accuracy.
2.3 River Channel/Structures Survey	General information on the topographic survey of the river channel and structures are included in the main Hydraulics Report. Full details of the survey outputs are provided in the topographic survey deliverables, as required under Section 5.2 of the Stage I Project Brief. Number of cross-sections included in this model: 119
2.4 Defence Asset Survey Data	There are no formal defences within the Banna catchment. There are penstocks and a tidal exclusion sluice gate on the Tyshe River. The surveyor confirmed that access was problematic in the area and therefore both structures have been surveyed along one face. Using the information provided by the surveyor we are content that key hydraulic conditions are represented in the model and the accuracy of the study is not compromised by the missing data. It does mean however that assumptions had to be made with regard to the maximum and minimum opening for each structure. These are detailed in Annex B. Control rules have been assumed for both structures. These are also detailed in Section 6.

2.5 Survey interaction	The Lidar, IFSAR and topographic survey were checked for anomalies, and to ensure that interactions between were within expected tolerances. No issues were identified in this model.

3. Hydraulic Model Construction and Schematisation

3.1 Software:	**1D domain : ISIS v3.7.0.223**
	2D domain(s): TUFLOW Build 2013-12-AB-iDP-w64
3.2 Model Area / Extent:	

The mapping details for the model extent included in Annex A are as follows:

1. **Full modelled area showing**:
   - River centre lines, HPW/MPW extents, names of watercourses
   - 2D domain area
   - AFA boundary
2. **Maps showing a detailed model schematic of the HPW/MPW reaches are also included**

3.3 Model Reaches: The following model reaches as shown on the maps referred above have been defined in the model:

Watercourse name	Reach	Upstream model node	Downstream model node
Tyshe River	05TYS	05TYS00523	05TYS00000
Tyshe River	04TYS	04TYS00190	04TYS00000
Tyshe River	03TYS	03TYS01427	03TYS00000
Tyshe River	02TYS	02TYS01636	02TYS00000
Ballynoe	01BYN	01BYN00127	01BYN00000
Banna Mountain	01BNM	01BNM00554	01BNM00000
Carrahane	01CHN	01CHN00177	01CHN00000
Tyshe	01BAN	01BAN00855	01BAN00000
Total model HPW length (km):	4.26	**Total model MPW length (km):**	2.41

3.4 Model Structures: A full schedule of structures included in the model is provided in Schedule A in Annex B. A summary of the structures included is given below

Structure	Included		Number
Culverts:	☒	How many?	3
Bridges:	☒	How many?	10
Fixed crest weirs:	☐	How many?	0
Adjustable crest weirs:	☐	How many?	0
Sluice / Gate structures:	☒	How many?	2
Locks:	☐	How many?	0
Dams:	☐	How many?	0
Other (describe):	**Flapped Outfall x1**		

3.5 Floodplain Schematisation

The 2D domain covers some of the MPW, as shown in Annex A. The 2D domain out-of-bank areas have been modelled using TUFLOW.

The 1D domain out of bank areas have been modelled using extended cross-sections, extended to be above the 1000 year peak tidal level.

Extended 1D sections are considered appropriate for HPW extents where floodplain flow paths are simple (e.g., parallel to river flow). 1D-2D modelling is required where HPWs flow through urban areas and out-of-bank flows will form complex flow paths.

An overview of the floodplain schematisation is available in the maps shown

	in Annex A.		
3.6 2D Domain Grid Size:	The number of 2D domains defined and the grid sizes of each 2D model domain are as follows:		
	Number of 2D domains: 1		
	Domain 1:	Grid cell size (m) 5	Area (km^2) 6.393
	2D domains are defined depending on the level of detail required to pick up the appropriate features in the 2D domain that will impact on the local hydraulics. The domain grid square size is typically in the range 5m to 20m, with the smaller grid sizes used in very urbanised areas where there are multiple features that could not be suitably represented in, say, a 10m grid. The model grid is orientated in the main direction of the floodplain flow.		
3.7 Model Breaklines in the 2D Domain:	None		
3.8 Floodplain Structures in the 2D Domain	There are no structures modelled in the 2D domain; all are left in the 1D domain including spills over structures. Information on how buildings were included in the 2D domain is included in Section 3.4.10 of the main Hydraulics Report.		
3.9 Hydraulic Roughness	Hydraulic roughness (Manning's 'n') has been defined in accordance with the approaches described in the main report. Details of the values adopted for this model are included in Schedule B in Annex B. A summary of Manning's 'n' for the model as a whole is as follows:		
MPW In-bank	Minimum 'n' value:	0.04	
	Maximum 'n' value:	0.04	
HPW In-bank	Minimum 'n' value:	0.04	
	Maximum 'n' value:	0.05	
Floodplain (ISIS Model)	Manning's 'n' for out of bank areas represented in the ISIS model are as defined by EPA land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in ISIS are as follows:		
	Land use	**Manning's 'n' value**	
	Pastures	0.035	
	Dense Vegetation	0.08	
	Road Network	0.025	
	Buildings	0.1	
Floodplain (TUFLOW Model)	Manning's 'n' for out of bank areas represented in the TUFLOW model are as defined by OSi NTF land use characteristics, as described in the main report. Floodplain land uses and adopted roughness values in TUFLOW are as follows:		
	Land use	**Manning's 'n' value**	
	Buildings	0.1	
	Short grass, parks	0.035	
	General Urban	0.06	
	General Rural	0.045	
	Pastures	0.035	
	Dense Vegetation	0.08	
	Roads	0.025	

	Water bodies	0.02
3.10 Spill Units	Spill units are used for a number of different purposes (e.g. irregular weir, lateral spilling in the floodplain). Spill profile geometry is defined using topographic survey data and LiDAR/IFSAR. Spill coefficients used generally vary between 0.9 and 1.5 depending on the type of ground conditions (e.g. rough vegetated, smooth concrete) over which flood flows are spilling. Lower coefficients (<1.0) can be also found to account for lateral spilling perpendicular to the main direction of flow.	
3.11 Model Boundaries – Inflows	Full details of the flow estimates and flow hydrographs are provided in the Hydrology Report. Summary details are included within this section.	
(a) Current Situation	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for the current situation.	

HEP Reference Name	Input Node in the Hydraulic Model	Annual Exceedance Probability							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_428_1	05TYS00523	3.0	3.9	4.5	5.1	5.8	6.4	6.9	8.2
23_428_2	05TYS00000	3.0	3.9	4.5	5.0	5.8	6.3	6.9	8.2
23_497_1	04TYS00190	3.2	4.1	4.8	5.4	6.2	6.8	7.3	8.7
23_497_2	03TYS01316	3.2	4.1	4.8	5.4	6.2	6.8	7.3	8.7
23_2732_2	03TYS01100i	0.2	0.4	0.4	0.5	0.5	0.6	0.6	0.7
23_2732_3	01BAN00029i	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
23_2925_2	02TYS01095	3.6	4.7	5.5	6.2	7.1	7.7	8.4	10.0
23_2925_5	02TYS00010	3.6	4.7	5.5	6.2	7.1	7.7	8.4	10.0
23_224_1	01CHN00177	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5
23_524_4.1	01BNM00004	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
23_2743_4	03TYS00000	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for all return periods for the MRFS. These events are selected as these are the MRFS that are to be mapped

HEP Reference Name	Input Node in the Hydraulic Model	MRFS Annual Exceedance Probability							
		50%	20%	10%	5%	2%	1%	0.5%	0.1%
23_428_1	05TYS00523	3.6	4.7	5.4	6.1	7.0	7.7	8.3	9.8
23_428_2	05TYS00000	3.6	4.7	5.4	6.0	7.0	7.6	8.3	9.8
23_497_1	04TYS00190	3.8	4.9	5.8	6.5	7.4	8.2	8.8	10.4
23_497_2	03TYS01316	3.8	4.9	5.8	6.5	7.4	8.2	8.8	10.4
23_2732_2	03TYS01100i	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.9
23_2732_3	01BAN00029i	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3
23_2925_2	02TYS01095	4.3	5.6	6.6	7.4	8.5	9.2	10.1	12.0
23_2925_5	02TYS00010	4.3	5.6	6.6	7.4	8.5	9.2	10.1	12.0
23_224_1	01CHN00177	0.2	0.2	0.4	0.4	0.5	0.5	0.5	0.6
23_524_4.1	01BNM00004	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
23_2743_4	03TYS00000	0.1	0.2	0.2	0.2	0.2	0.4	0.4	0.4

(b) Future Scenarios	The peak inflows (m^3/s) used as inputs to the model at key model locations are summarised in the table below for 10%, 1% and 0.1% events for the HEFS. These events are selected as these are the HEFS that are to be mapped.			
HEP Reference Name	**Input Node in the Hydraulic Model**	**HEFS Annual Exceedance Probability**		
		10%	**1%**	**0.1%**
23_428_1	05TYS00523	5.9	8.3	10.7
23_428_2	05TYS00000	5.9	8.2	10.7
23_497_1	04TYS00190	6.2	8.8	11.3
23_497_2	03TYS01316	6.2	8.8	11.3
23_2732_2	03TYS01100i	0.5	0.7	0.9
23_2732_3	01BAN00029i	0.2	0.2	0.3
23_2925_2	02TYS01095	7.2	10.0	13.0
23_2925_5	02TYS00010	7.2	10.0	13.0
23_224_1	01CHN00177	0.4	0.5	0.7
23_524_4.1	01BNM00004	0.1	0.1	0.1
23_2743_4	03TYS00000	0.3	0.4	0.4

3.12 Model Boundaries – Downstream Conditions	Downstream boundary conditions adopted in the model are as follows: **A static tidal boundary was used for the HEP calibration. All other models have tidal HTBDY curves as boundary units.** The time series were set up as boundary conditions for the hydraulic model along the coastal boundary of the hydraulic model. Full details on how these tidal level hydrographs were derived are provided in Appendix D of the main Hydraulics Report. Peak tidal levels are summarised in the table below for the current and future situations. Tidal level hydrographs at the outlet of the Tyshe River were produced for a series of design events. The time series were set up as boundary conditions for the hydraulic model along the coastal boundary of the hydraulic model (see maps in Annex A). Full details on how these tidal level hydrographs were derived are provided in the main report. Peak tidal levels are summarised in the table below for the current situation.

	Annual Exceedance Probability										
Peak Tidal Levels (m OD)	**500%**	**200%**	**100%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.1 %**
	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.3
	MRFS Annual Exceedance Probability										
Peak tidal levels (m OD)	500%	200%	100%	50%	20%	10%	5%	2%	1%	0.5%	0.1 %
	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.6	3.7	3.9
	HEFS Annual Exceedance Probability										
Peak tidal levels (m OD)	500%	200%	100%	50%	20%	10%	5%	2%	1%	0.5%	0.1 %
	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.1	4.2	4.4

4. Hydraulic Model Calibration and Sensitivity

4.1 Model Calibration and Verification to Historical Events	The approach to model calibration is documented in the Main Report. The analysis of available flood event data and high flow data for possible consideration as calibration and verification events is covered in detail in the Hydrology Report. No historical model calibration has been carried out.
Catchment Gauging	Is modelled catchment: Gauged ☐ Ungauged ☒ check one box only
4.2 Calibration to HEP	Calibration of the hydraulic model to the HEP target flows was attempted for all fluvial events. Due to the nature of the catchment topping up of flows resulted in additional flow in the floodplain rather than increased flows downstream. Therefore topping up the flows in order to satisfy the 10% criteria would have resulted in unrealistic flooding in the floodplain, and hence the calibration was deemed inappropriate.
4.3 Fluvial and Tidal Events Simulated	The River Tyshe is influenced by the tidal levels along the Shannon Estuary. As such, a joint probability analysis of the coincidence of fluvial flood flows and coastal flood levels was carried out to determine the appropriate combinations of flows and sea levels to be used for the design probability events, as required under Section 6.5.6 of the Stage I Project Brief. Methodology and outcomes of this analysis are detailed in the main Hydraulic Report and in the Hydrology Report. A summary of the joint probability of fluvial and tidal conditions used for the hydraulic modelling in the Banna AFA is reported in the table below.

Combination of Fluvial and Tidal Events

	Joint Probability Design Event	AEP adopted for Fluvial Flows and Tidal Levels	
Scenario	**Overall AEP**	**Fluvial**	**Tidal**
1	50%	50%	500%
2	50%	50%	50%
3	20%	20%	500%
4	20%	50%	20%
5	10%	10%	200%
6	10%	50%	10%
7	5%	5%	100%
8	5%	50%	5%
9	2%	2%	50%
10	2%	50%	2%
11	1%	1%	20%
12	1%	20%	1%
13	0.5%	0.5%	10%
14	0.5%	10%	0.5%
15	0.1%	0.1%	2%
16	0.1%	2%	0.1%

4.4 Model Sensitivity

Sensitivity tests have been carried out in order to assess the sensitivity of the predicted peak water levels to alterations in roughness (Manning's 'n'), fluvial flow, afflux at key structures and downstream conditions. The sensitivity runs were carried out for the 1% AEP fluvial dominated event with the corresponding tidal event from the joint probability study in all cases with the only exception of the tests on the downstream boundary conditions, which were carried out for the 0.5% AEP tidal dominated events with the corresponding fluvial event (see Section 4.3).
Sensitivity test results are provided in the following tables. Uncertainty maps illustrating the results of the sensitivity analysis will be delivered as part of the final stage of this work.

+20% Manning's 'n'	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section / Reach where the Maximum Difference occurs**
	Tyshe River u/s of CHN	+0.015	+0.015	Full reach
	Tyshe River u/s of BNM	+0.014	+0.014	Full reach
	CHN	+0.014	+0.014	Full reach
	BNM	+0.014	+0.014	Full reach
	BAN	+0.009	+0.009	Full reach
	Tyshe River u/s of BAN	+0.004	+0.009	03TYS01077
	Tyshe River d/s of BAN	+0.003	+0.015	02TYS01609d

-20% Manning's 'n'	**Watercourse**	**Average Water level difference (m)**	**Maximum water level difference (m)**	**Cross-section where the Maximum Difference occurs**
	Tyshe River u/s of CHN	-0.006	-0.019	05TYS00117
	Tyshe River u/s of BNM	-0.020	-0.020	Full reach
	CHN	-0.010	-0.021	01CHN00007
	BNM	-0.006	-0.031	01BNM00554
	BAN	-0.008	-0.008	Full reach
	Tyshe River u/s of BAN	-0.006	-0.019	03TYS01316
	Tyshe River d/s of BAN	-0.004	-0.016	02TYS01609d

+20% inflows	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section where the Maximum Difference occurs**
	Tyshe River u/s of CHN	+0.022	+0.057	05TYS00537
	Tyshe River u/s of BNM	+0.062	+0.062	Full reach
	CHN	+0.062	+0.062	Full reach
	BNM	+0.055	+0.055	Full reach
	BAN	+0.076	+0.076	Full reach
	Tyshe River u/s of BAN	+0.006	+0.035	03TYS01016
	Tyshe River d/s of BAN	0.000	0.000	N/A
-20% inflows	**Watercourse**	**Average Water Level Difference (m)**	**Maximum Water Level Difference (m)**	**Cross-section where the Maximum Difference occurs**
	Tyshe River u/s of CHN	-0.069	-0.069	Full reach
	Tyshe River u/s of BNM	-0.071	-0.071	Full reach
	CHN	-0.070	-0.070	Full reach
	BNM	-0.066	-0.073	01BNM00274
	BAN	-0.070	-0.070	Full reach
	Tyshe River u/s of BAN	-0.070	-0.009	03TYS01316
	Tyshe River d/s of BAN	0.000	0.000	N/A
Afflux at Key Structure	Structures within the AFA do not surcharge, and therefore this has not been carried out.			
Downstream Conditions	To test the effect of the duration of high tide levels for a given upstream flood flow condition, the duration of the surge component of the 0.5% AEP tidal boundary was increased by 100% (i.e. 60 hours). The increase in the downstream boundary condition resulted in no increase in maximum water level at the downstream limit of the model but resulted in increases in water level on 01BAN and 03TYS of 244mm and 111mm respectively. Its effect extended to the upstream extent of 01BAN and to the upstream extent of the model. However despite the large increases in the level, there were no noticeable effects on the flood extents, due to increases in accumulation on the floodplain at the upstream extent, along the old course of the channel between 01BAN and 03TYS, and on the left bank of 01BAN. The absence of a significant increase in the flood extent is as a result of the deep topographical depression filling upwards rather than outwards.			
Blockage Analysis	The River Tyshe flows through the AFA of Banna and discharges to the sea at Black Rock, via a tidal sluice outfall. This outfall is vulnerable to blockage from the build-up of sand / seaweed. This material is excavated, and the outfall maintained, at least once every two weeks but this can be daily in the			

	winter months. The sluice gates close on high tides to prevent tide flowing up the Tyshe River, typically closed once every few weeks. These maintenance works have the effect of reducing flood risk to the AFA of Banna and land downstream of Banna. A blockage anaylsis was carried out to determine the flood risk to the Banna AFA if the excavation of sand and seaweed from the channel entrance was to cease and the sand and seaweed at the outlet would level reach the level of the beach on the right and left bank of 2m OD. As a result of abandoning the existing regime there is increased risk to the properties within the AFA for both fluvial and coastal scenarios. Annex E includes a set of flood extent maps illustrating the results of the blockage scenario.
4.5 Model Files	The hydraulic model files associated with this model are provided as a separate deliverable under the contract, as required under Sections 7.8 and 13 of the Stage I Project Brief. The model files included are detailed in Annex D.

5. Hydraulic Model Outputs

5.1 Mapping	Model outputs were processed to produce a series of flood maps according to the requirements stated in the Stage I Project Brief under Section 7.5.2. These include mapping outputs covering: • Flood extent • Flood depth and velocity • Flood hazard Mapping outputs corresponding to the **defended**, **current** scenario for the 10%, 1% and 0.1% AEP flood events are shown in Annex E for flood extent and depth only. Outputs are also provided for the blockage scenario.

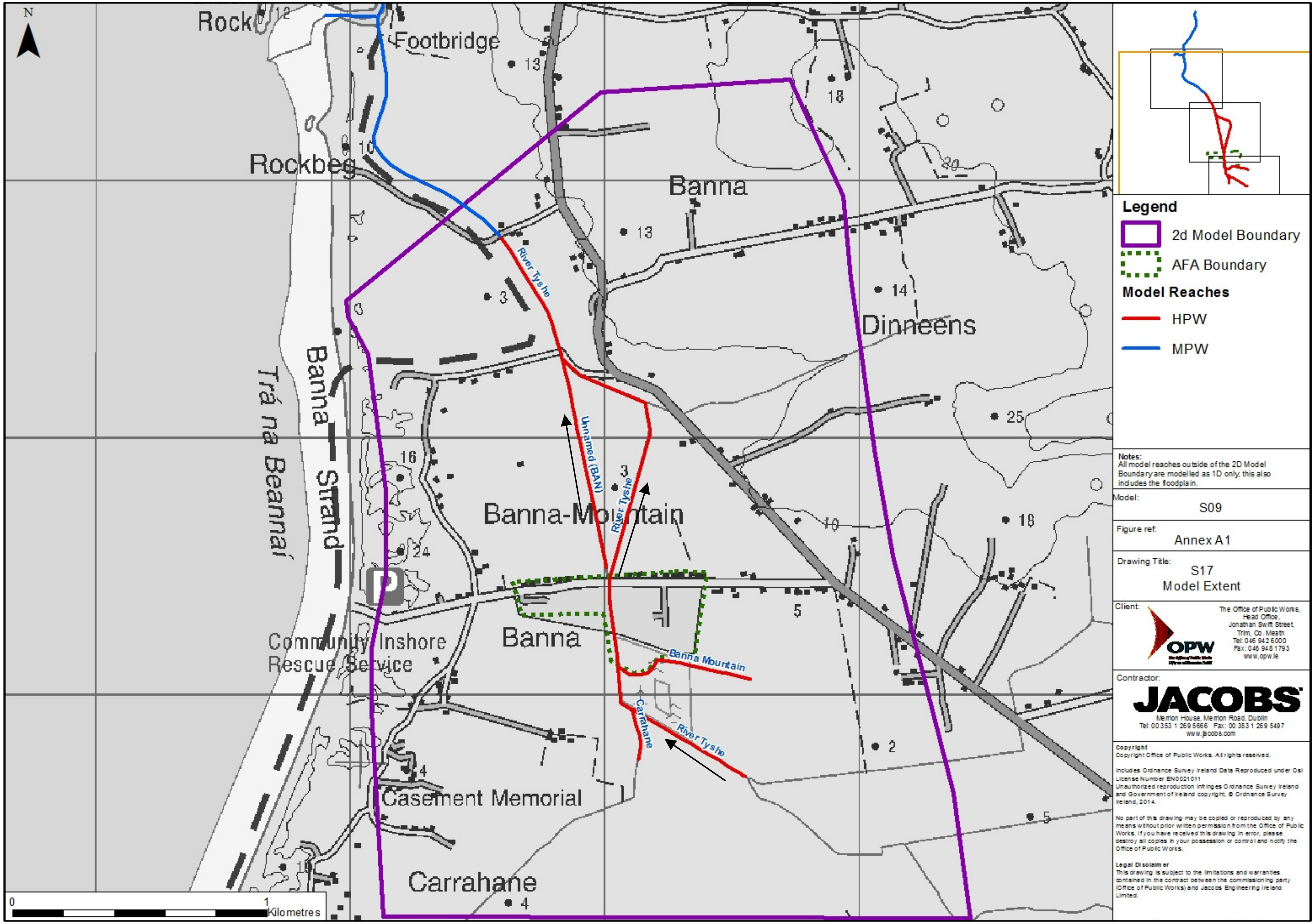
6. Key Model Assumption and Limitations

Control rules have had to be assumed for the two key structures; the penstocks and tidal exclusion sluice gates, on the downstream Tyshe River. These have been developed as a basic comparison between upstream and downstream levels resulting in the operation of the sluice gates. When the upstream water level exceeds the downstream, both gates open, and when the downstream exceeds the upstream, they close. The first set of sluice gates has been modelled to close to restrict tidal flow upstream of the sluice gates. This is based on information provided to us from the OPW and LA. The second set of sluice gates has been modelled as flapped sluice gates based on survey information and site photographs.

The main limitation for the S17 Banna Model is that the hydrological calibration had to be discontinued due to the inability to reach target flows, as is reported in Annex C, and this is therefore an un-calibrated model. Due to the nature of the catchment topping up of flows resulted in additional flow in the floodplain rather than increased flows downstream, Therefore, topping up flows in order to satisfy the 10% criteria would have resulted in unrealistic flooding in the floodplain.

Limitations of the topographic survey prevented full addition of details of land drains within the catchment.

Annex A – Model Extent and Schematisation Maps
Annex A1 – Model Extent



N
Rock
12
Footbridge
13
18
Rockbeg
10
Banna
13
3
14
Dinneens
River Tyshe
Banna Strand
Trá na Beannaí
Unnamed (BAN)
River Tyshe
25
16
3
Banna-Mountain
10
18
24
5
Banna
Community Inshore
Rescue Service
Banna Mountain
Carrahane
River Tyshe
2
4
Casement Memorial
5
Carrahane
4
0
1
Kilometres
Legend
2d Model Boundary
AFA Boundary
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S09
Figure ref:
Annex A1
Drawing Title:
S17
Model Extent
Client:
The Office of Public Works,
Head Office,
Jonathan Swift Street,
Trim, Co. Meath
Tel: 046 942 6000
Fax: 046 948 1793
www,opw.ie
Contractor:
JACOBS
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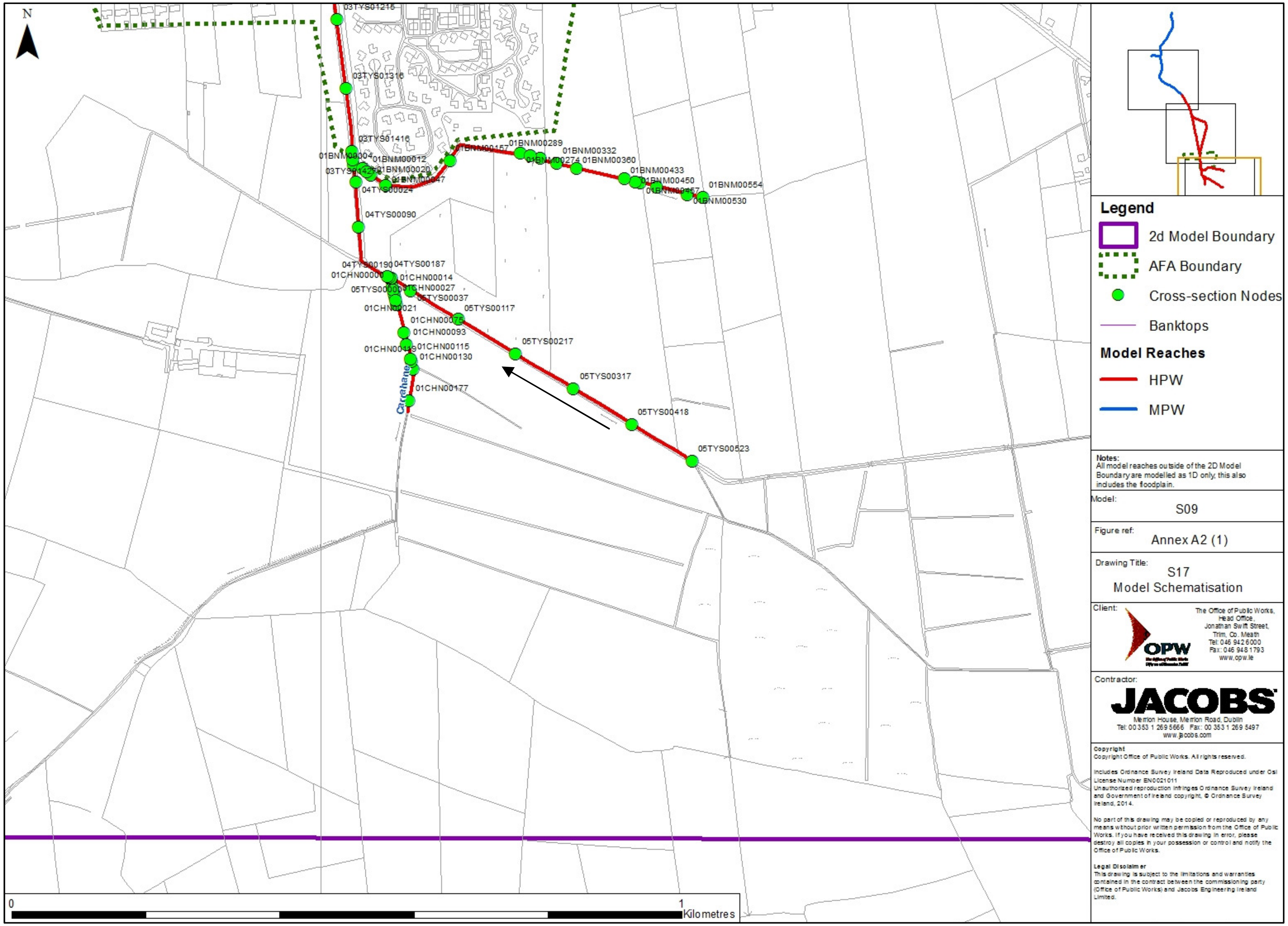
Annex A2 – Schematisation Maps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05TYS00523
0
1
Kilometres
Legend
2d Model Boundary
AFA Boundary
Cross-section Nodes
Banktops
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S09
Figure ref:
Annex A2 (1)
Drawing Title:
S17
Model Schematisation
Client:
The Office of Public Works, Head Office, Jonathan Swift Street, Trim, Co. Meath
Tel: 046 942 6000
Fax: 046 948 1793
www.opw.ie
Contractor:
Merrion House, Merrion Road, Dublin
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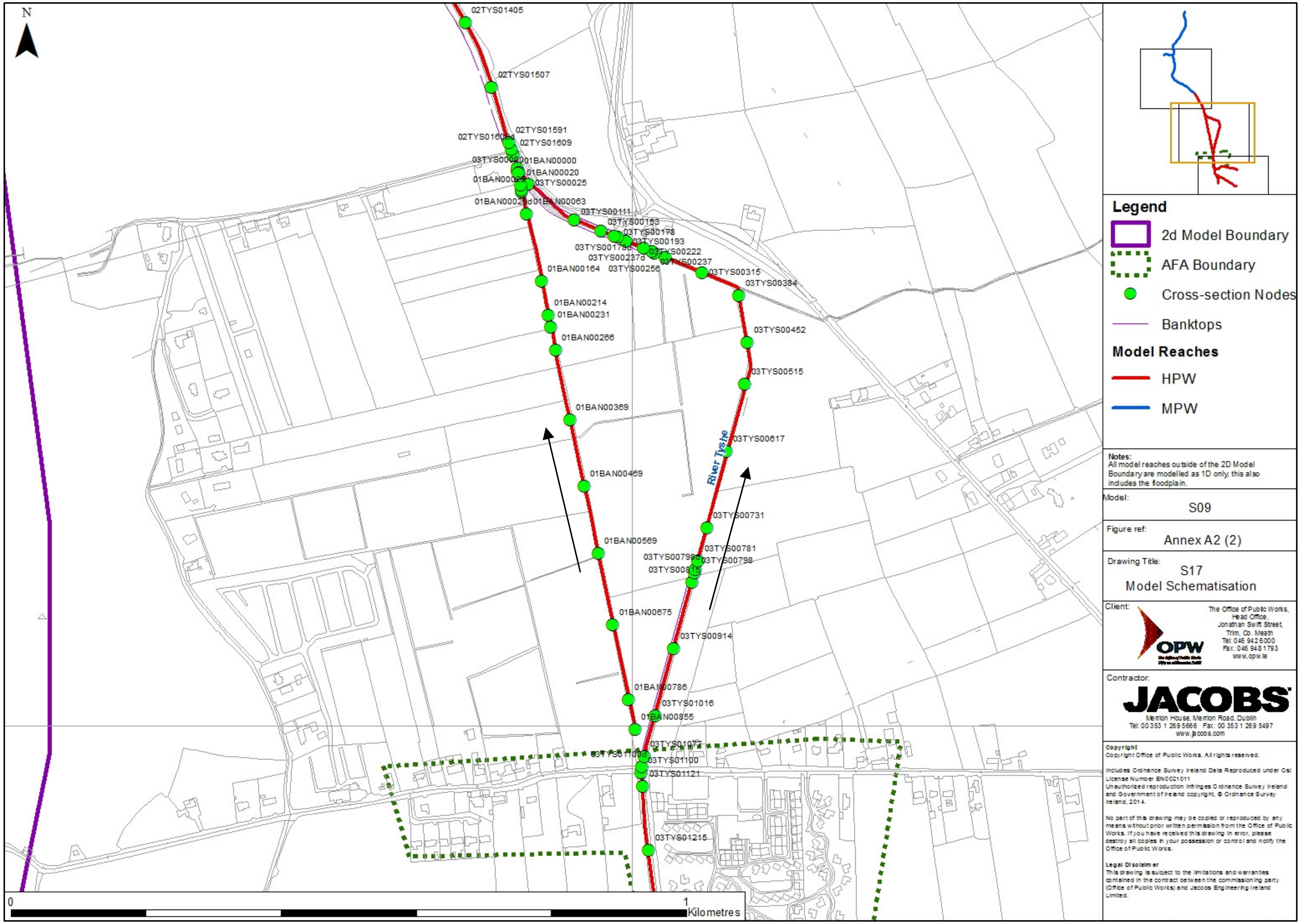
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01BAN00369
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River Tyshe
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Kilometres
Legend
2d Model Boundary
AFA Boundary
Cross-section Nodes
Banktops
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S09
Figure ref:
Annex A2 (2)
Drawing Title:
S17
Model Schematisation
Client:
The Office of Public Works, Head Office, Jonathan Swift Street, Trim, Co. Meath
Tel: 046 942 6000
Fax: 046 948 1793
www.opw.ie
Contractor:
Merrion House, Merrion Road, Dublin
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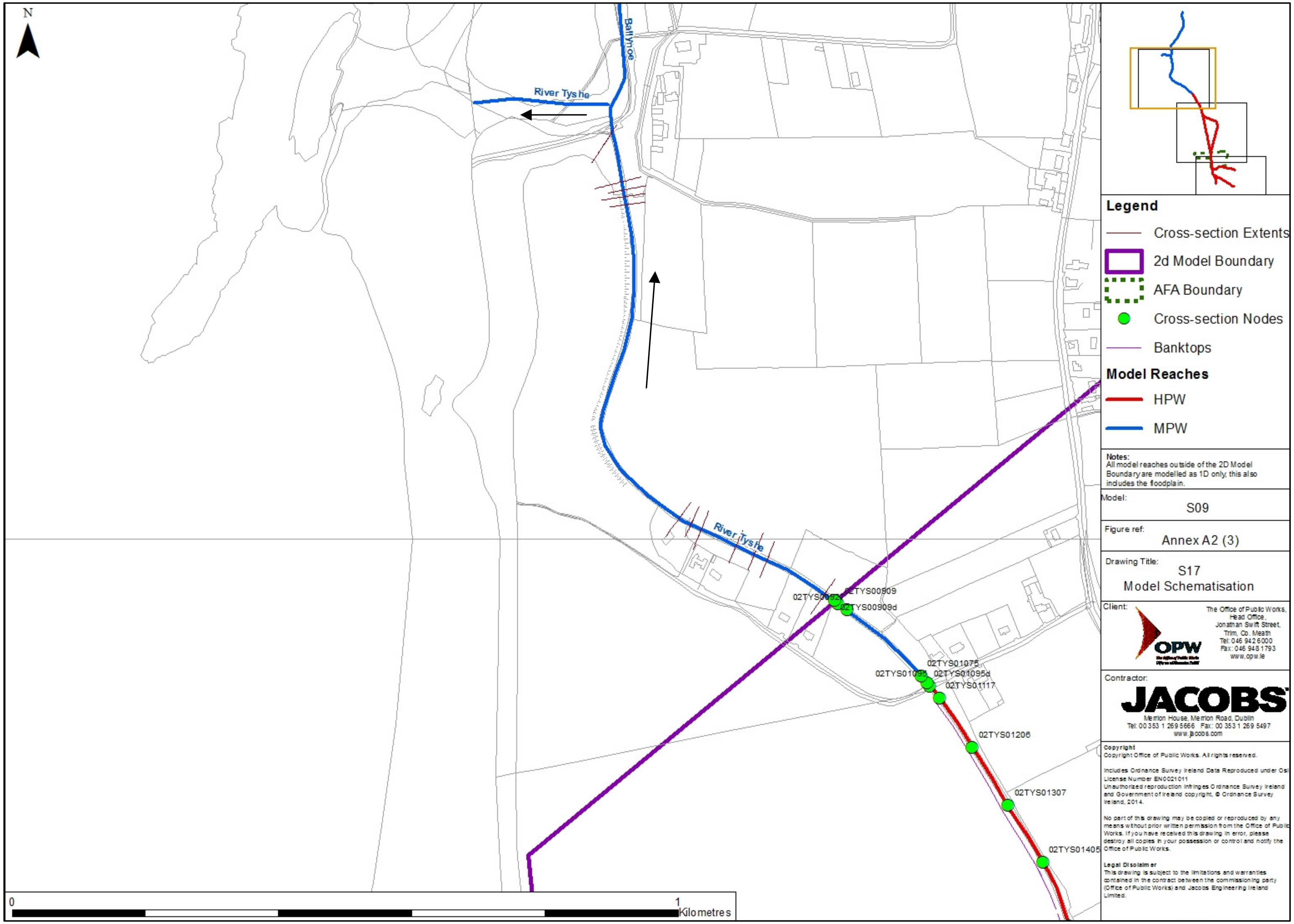
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Ballyhoe
River Tyshe
River Tyshe
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02TYS00909d
02TYS01075
02TYS01095
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02TYS01206
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Kilometres
Legend
Cross-section Extents
2d Model Boundary
AFA Boundary
Cross-section Nodes
Banktops
Model Reaches
HPW
MPW
Notes:
All model reaches outside of the 2D Model Boundary are modelled as 1D only, this also includes the floodplain.
Model:
S09
Figure ref:
Annex A2 (3)
Drawing Title:
S17
Model Schematisation
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Annex B – Structure and Hydraulic Roughness Schedules

Schedule A.1 - Structure Schedule for Tyshe River

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23TYSB00276D	03TYS01100bu	Bridge of 3 m wide	Arch Bridge and spill	Y
23TYSB00246D	03TYS00798bu	Bridge of 3.88 m wide	USBPR and spill	Y
23TYSB00190D	03TYS00237bu	Bridge of 3.5 m wide	USBPR and spill	Y
23TYSB00184D	03TYS00178bu	Bridge of 3.69 m wide	USBPR and spill	Y
23TYSB00164D	02TYS01609bu	Bridge of 2.8 m wide	Arch Bridge and spill	Y
23TYSB00112D	02TYS01095bu	Bridge of 2.9 m wide	Arch Bridge and spill	Y
23TYSB00094D	02TYS00909bu	Bridge of 10.44 m wide	USBPR and spill	Y
23TYSB00079D	02TYS00764pu	3 Sluice gates of 1.58 m wide	Sluice x 1 and all three gate areas combined into 1 unit.	Y
23TYSB00069D	02TYS00659bu	Bridge of 3.6 m wide	Arch Bridge and spill	Y
23TYSB00013D	02TYS00107bu	Bridge of 4.99 m wide	Arch Bridge and spill	Y
23TYSB00013E	02TYS00097a	2 Sluice gates of 1.6 m wide	1 Sluice gate, areas combined into 1 unit.	Y

Schedule A.2 - Structure Schedule for Ballynoe

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23TYSA00031D	01BYN00111	Flat Deck Bridge – 1 pier	N/A	N*

Schedule A.3 - Structure Schedule for Carrahane

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23TYSI00012J	01CHN00119	Culvert of 0.60 m wide	Orifice unit for stability purposes, with spill	Y
23TYSI00003D	01CHN00021u	Culvert of 0.76 m wide	Orifice unit due to small size with spill	Y

Schedule A.4 - Structure Schedule for Banna Mountain

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23TYSG00047I	01BNM00457	Culvert of 0.50 m wide	Orifice for stability purposes with a spill over.	Y

23TYSG00001I	01BNM00004	2 Culverts of 0.90 m wide	Orifice with double bore area and a spill.	Y

Schedule A.5 Structure Schedule for Tyshe Trib (BAN)

Survey Reference	ISIS Node Reference	Type of Structure	Modelling Approach	Structure included in Model (Y/N)
23TYSF00005D	01BAN00029u	Culvert of 1.03 m wide	Flapped orifice and spill	Y
23TYSF00026D	01BAN00231	Flat Deck Bridge	N/A	N*

*Structure is not hydraulically significant during peak flood flows.

Schedule B.1 – Manning's 'n' for HPW Network

River Name	ISIS Node Reference	Bed Roughness*	Estimated Bank Side Roughness	Estimated Floodplain Roughness
Tyshe	05TYS00523 to 02TYS00659	0.04	Determined on a case by case basis using photos, videos and survey drawing	Based on OSi NTF land use polygons
Carrahane	01CHN00177 to 01CHN00021	0.045		
	01CHN00021d to 1CHN00000	0.04		
Banna Mountain	01BNM00554 to 01BNM00004	0.05		
Tyshe Trib (BAN)	01BAN00855 to 01BAN00000	0.04		

*In some cross-sections a different bed roughness coefficient may have been used to represent specific bed material (e.g. engineered concrete sections). All of the altered cross sections are within the roughness bounds defined in Section 3.6.

Schedule B.2 – Manning's 'n' for MPW Network

River Name	ISIS Node Reference	Bed Roughness	Estimated Bank Side Roughness	Estimated Floodplain Roughness
Tyshe	03TYS00659d to 02TYS00000	0.04	Determined on a case by case basis using photos, videos and survey drawing	2D: Based on OSi NTF land use polygons Land use EPA data has been used for assigning the floodplain roughness.
Ballynoe	01BYN00127 to 01BYN00000	0.04		

*In some cross-sections a different bed roughness coefficient may have been used to represent specific bed material (e.g. engineered concrete sections). All of the altered cross sections are within the roughness bounds defined in Section 3.6.

Annex C - Model Calibration Summary Note

No historical calibration has been carried out for the AFA.

Annex D - Hydraulic Model Files

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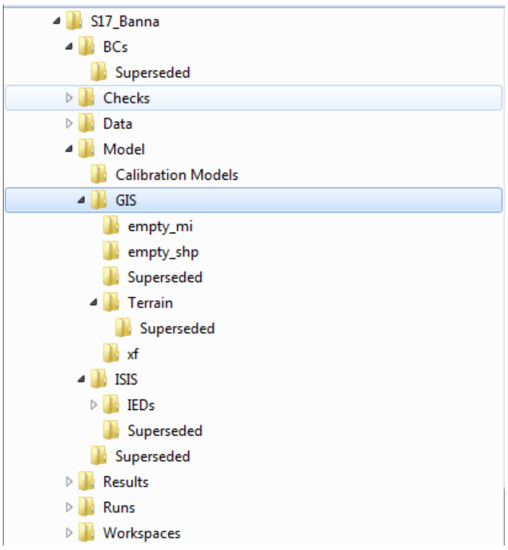
<tr><th colspan="2">Model Files Folders Structure</th></tr>
<tr><td>ISIS</td><td>


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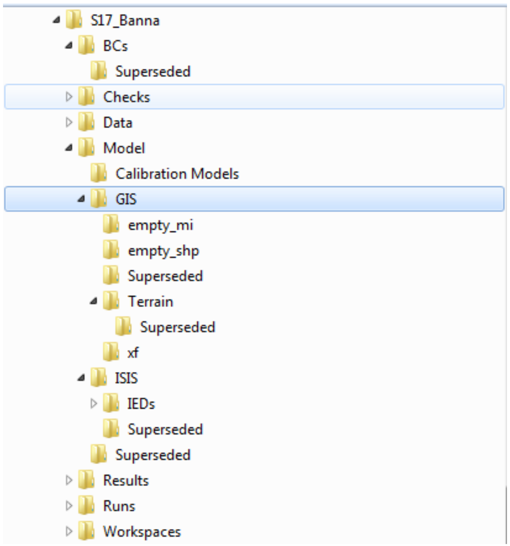
<tr><td>TUFLOW</td><td>


</td></tr>
</table>

ISIS Files	
Model Geometry (.dat) and Associated Files (e.g.: .ief, .zzl, .zzd, .zzu,.zzx)	**Calibration Runs** S17_Banna_Mi_C_v8 - .dat, .zzl, .zzd, .zzu F10_Static_Tide.ied S17_Banna_v01_f10_Cal.ief F100_Static_Tide.ied S17_Banna_v01_f100_Cal.ief F100_Static_Tide_double.ied S17_Banna_v01_f100_Cal_double.ief F1000_Static_Tide.ied S17_Banna_v01_f1000_Cal.ief

	Design Runs – Current scenario S17_Banna_Mi_C_v10 - .dat, .zzl, .zzd, .zzu S17_Q10_CoMi_C_Des_ISS1.IEF S17_Q10_FluMi_C_Des_ISS1.IEF S17_Q200_CoMi_C_Des_ISS1.IEF S17_Q1000_CoMi_C_Des_ISS1.IEF S17_Q100_FluMi_C_Des_ISS1.IEF S17_Q1000_FluMi_C_Des_ISS1.IEF **Sensitivity Runs – Current Scenario** S17_Banna_Mi_S_N+20 - .dat, .zzl, .zzd, .zzu S17_Q100_FluMi_C_Sen_N+20.IEF S17_Banna_Mi_S_N-20 - .dat, .zzl, .zzd, .zzu S17_Q100_FluMi_C_Sen_N-20.IEF
Hydrological Inflow Files	**Design Runs – Current Scenari** S17_Q10_CoMi_C_Des_ISS1.IED S17_Q10_FluMi_C_Des_ISS1.IED S17_Q200_CoMi_C_Des_ISS1.IED S17_Q1000_CoMi_C_Des_ISS1.IED S17_Q100_FluMi_C_Des_ISS1.IED S17_Q1000_FluMi_C_Des_ISS1.IED **Sensitivity Runs – Current Scenario** S17_Q100_FluMi_C_Sen_I+20.IED, .IEF S17_Q100_FluMi_C_Sen_I-20.IED, .IEF

TUFLOW files	
TUFLOW Control Files (.tcf) and Associated Files (e.g.: ecf, tgc, tbc)	**Design Runs – Current Scenario:** S17_Q10_CoMi_C_Des_ISS1.TCF S17_Q10_FluMi_C_Des_ISS1.TCF S17_Q200_CoMi_C_Des_ISS1.TCF S17_Q1000_CoMi_C_Des_ISS1.TCF S17_Q100_FluMi_C_Des_ISS1.TCF S17_Q1000_FluMi_C_Des_ISS1.TCF **Sensitivity Runs – Current Scenario** S17_Q100_FluMi_C_Sen_I+20.TCF S17_Q100_FluMi_C_Sen_I-20.TCF

	S17_Q100_FluMi_C_Sen_N-20.TCF S17_Q100_FluMi_C_Sen_N+20.TCF
Grid Orientation File	2d_loc_Banna.shp
Material Files	**Design runs – Current scenario:** 2d_mat_S17_Banna_Final.shp S17_Banna_MAT.tmf **Sensitivity runs – Current scenario** S17_Banna_MAT-20.tmf S17_Banna_MAT+20.tmf
Zpt Files, Model DTM (.asc)	S17_2m_dtm.asc
Breaklines Files	2d_hxi_banktops_S17_L_v2.shp 2d_hxi_banktops_S17_P_v2.shp
Boundary Files	2d_bc_S17_banna_v3.shp
Flow/Head Files in bc_dbase	NoFlow/Head Boundaries
Initial Water Level Files	No files provided
Time Series Files	No files provided
One Dimensional Network Files	1d_x1d_ISISNodes_S17_V02.SHP
Available 2D Result Files	Depth, stage, hazard and velocity 2d results in ASCII file format for all available design return periods.

Model Run Log

Sr. No.	Model File Name	Start Time	End Time	Time step	Advanced Options /Other Information	Comments on Model Stability
1	10 yr Verification: S17_Banna_Mi_C_v4.DAT	0	35	0.5 sec 1d 1 sec 2d	Run with a static tidal IED (F10_Static_Tide.IED)	Convergence within manufacturer tolerance.
2	100 yr Verification: S17_Banna_Mi_C_v4.DAT	0	35	0.5 sec 1d 1 sec 2d	Run with a static tidal IED (F100_Static_Tide.IED)	Convergence within manufacturer tolerance.
3	1000 yr Verification: S17_Banna_Mi_C_v4.DAT	0	35	0.5 sec 1d 1 sec 2d	Run with a static tidal IED (F1000_Static_Tide.IED)	Convergence within manufacturer tolerance.
				Design Runs		
1	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F50_T1000_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
2	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F1000_T50_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
3	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F100_T5_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
4	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F10_T200_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
5	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F2_T10_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
6	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F10_T05_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
				Sensitivity Analysis		
7	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F100_T5_Mi_SenI+20.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.
8	S17_Banna_Mi_C_v10.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F100_T5_Mi_SenI-20.ied	Minor 1D instability on third tidal cycle, and some on second tidal cycle, this does affect the peak slightly.
9	S17_Banna_Mi_S_N-20.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F100_T5_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, and some on second tidal cycle, this does affect the peak slightly.
10	S17_Banna_Mi_S_N+20.DAT	0	35	0.5 sec 1d 1 sec 2d	S17_F100_T5_Mi_C_Des.ied	Minor 1D instability on third tidal cycle, this does not affect the peak.

Annex E - Flood Mapping

Flood Maps are available through the OPW flood mapping website; http://maps.opw.ie/fhrm/

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Appendix D Shannon CFRAMS Design Tidal Hydrographs

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Shannon CFRAMS Design Tidal Hydrographs – Technical Note

1 Background and Aims

Following the definition of the model extents in the Shannon RBD (as part of the Shannon CFRAMs Study) several hydraulic models have been identified for which downstream tidal boundary conditions will have to be defined to pilot the downstream levels during the required design event simulations. This note details the approach taken to define the downstream boundary conditions at the model extents (see Figure 1) along the Shannon Estuary using the ICPSS (Irish Coastal Protection Strategy Study) extreme water levels associated with combined tide and surge information provided by the OPW.

2 Data Used

The following available datasets were used to produce the design tidal surge hydrographs as boundary conditions for the models shown on Figure 1. (All the information associated with these files is contained in the annexes of this technical note):

- Predicted Extreme Water Levels (Tide and Surge) [16] for the following design events: 50%AEP, 20%AEP, 10%AEP, 5%AEP, 2%AEP, 1%AEP, 0.5%AEP and 0.1%AEP
- Foynes, Carrigaholt and Limerick Tidal gauge level data (2003-2007) [17]
- Admiralty Tide Tables information for port locations along the Shannon Estuary[18]
- OSi Conversion Graphs (Poolbeg-Malin head) including levelling information for port locations
- Shannon CFRAMS Model Extents for the downstream tidal models

[16] OPW - RPS Irish Coastal Protection Strategy Study Phase IV South West Coast
[17] Shannon – Foynes Port Company
[18] Admiralty Tide Tables, United Kingdom and Ireland, Vol 1 NP 201-06, (2006)

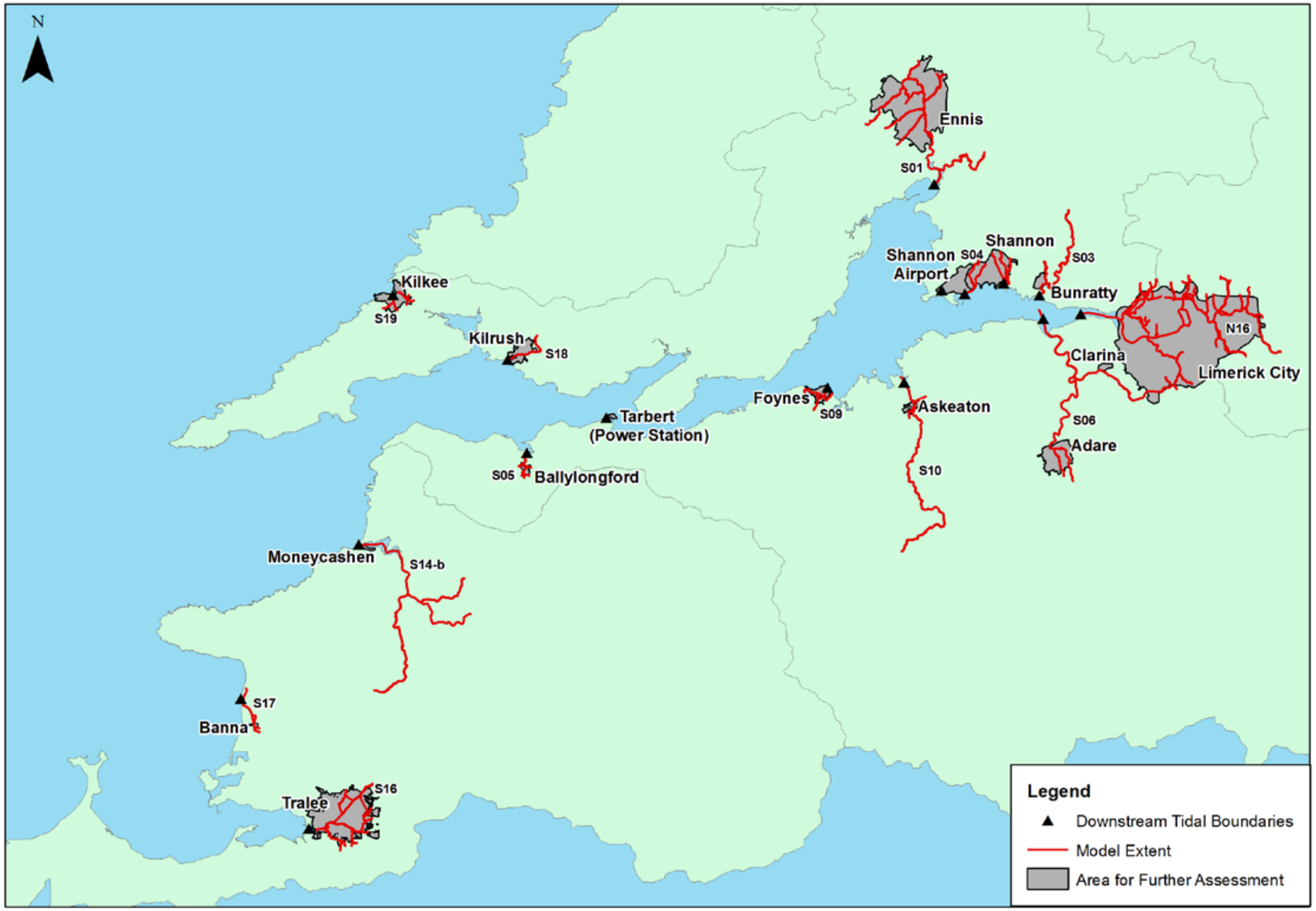


Figure 1: Shannon CFRAM models where tidal boundary conditions are required

3 Methodology

The following section details the different stages followed to develop the downstream tidal hydrographs assigned to each model.

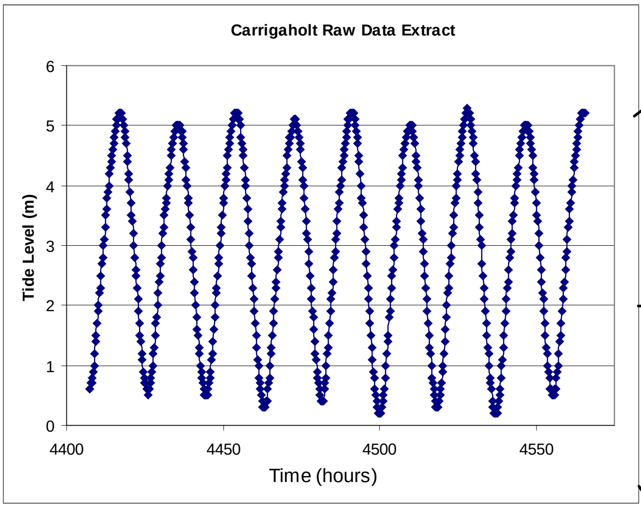
Stage 1

Following a data collection exercise tidal records at port locations: Carrigaholt, Limerick and Foynes (see Figure 2 below) were collated (Please refer to appendix A). These were used to extract tidal profiles which have been subsequently used and scaled to generate mean Spring tide profile ranging from Mean High Water Spring (MHWS) to Mean Low Water Spring (MLWS) levels at the nine port locations (see Figure 3) listed in the Admiralty Tide Tables as standard and secondary ports and located within the Shannon Estuary and Tralee Bay. These locations are Tarbert Island (Standard port), Carrigaholt, Kilrush, Foynes Island, Mellon Point, Limerick Dock, Coney Island and Fenit Pier (Tralee Bay). Details of the calculations carried out to determine MHWS and MLWS levels are provided in Annex B.

Figure 2: Shannon Estuary

Figure 3: Port locations as listed in the Admiralty Tide Tables

Figure 4 below is an example of how the raw data collected from the tidal gauges at Carrigaholt, Limerick and Foynes have been scaled to produce tidal data for the ports outlined above with the exception of Tarbert Island. The scaling factors that have been used for each port are detailed in Annex B of this Appendix. The raw data was extracted to define the shape of the hydrograph and scaled based on the MHWS/MLWS levels at each port location. For the case of Tarbert Island, as it is a standard port, a typical Spring tide curve is available in the Admiralty Tide Tables and was therefore used.



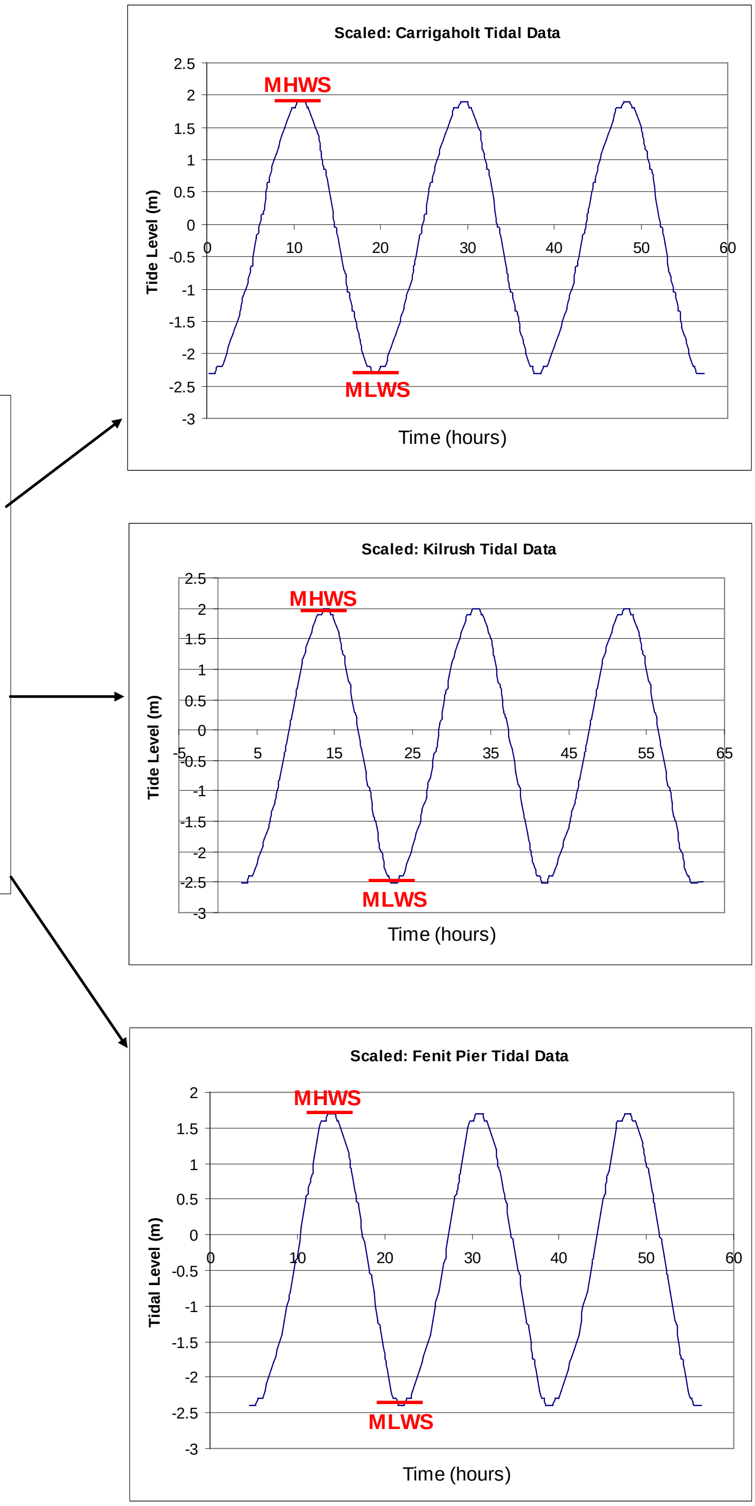


Figure 4: Example of Scaling of Raw Data

Stage 2

One of the outputs of the Irish Coastal Protection Strategy Study (ICPSS) was a series of prediction points for which extreme water levels combining tide and surge have been estimated. Each of the prediction points[19], as shown on Figure 5, has been allocated one of the mean spring profiles described above. This allocation was based on the nearest port location and tidal hydrodynamics within the Shannon Estuary.

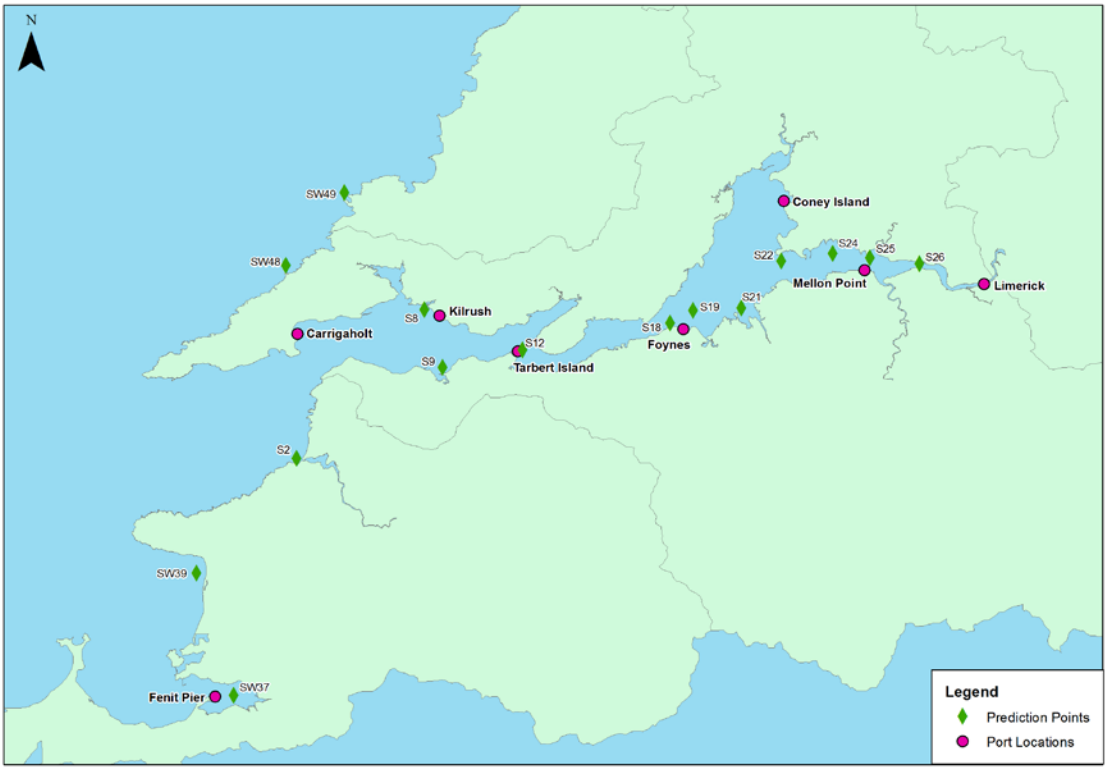


Figure 5: Prediction Point Locations

Table 1 below describes the allocation of the prediction points to each of the associated ports.

Table 1: Allocated of Prediction Points to Ports

Port	ICPSS (Prediction Point Reference)
Mellon Point	S25
	S24
Coney Island	S22
Kilrush	S9
	S8

Table 1: Allocated of Prediction Points to Ports

Port	ICPSS (Prediction Point Reference)
Limerick	S26
Foynes	S18
	S19
	S21
Carrigaholt	S2
	SW48-SW49
Fenit Pier	SW37
	SW39
Tarbert	S12

[19] Prediction point references used in Figure 5 and Table 1 are the ICPSS Prediction point references

Stage 3

Using the spring profiles and the available ICPSS extreme water levels for a range of annual probabilities, a series of design tidal hydrographs have been produced at each prediction point. The tidal hydrographs represent the effect of 30hr meteorological surges of increasing intensity on the mean Spring profile associated with each ICPSS prediction point. The 30hr surge duration means that 3 tide cycles are affected. The surge effect is centred such that middle high tide level matches with the extreme water levels taken from the ICPSS data.

This process is illustrated on Figure 6 below

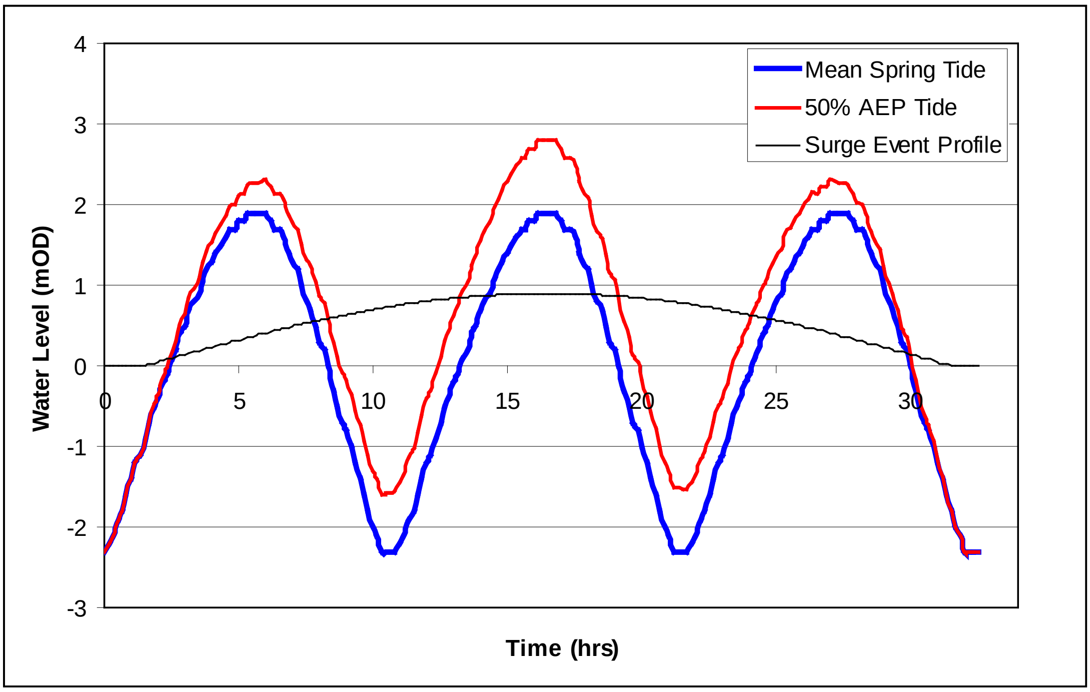


Figure 6: Example showing how an extreme event tide hydrograph has been produced

Stage 4

In the final step, the different model downstream boundaries were assigned to the closest prediction points and their associated design tidal hydrographs. For most of the models direct allocation was deemed appropriate except for the model S19 (AFA Kilkee) and S09 (AFA Foynes) where linear interpolation between two prediction points was carried out. An example of this is shown in Figure 7 below.

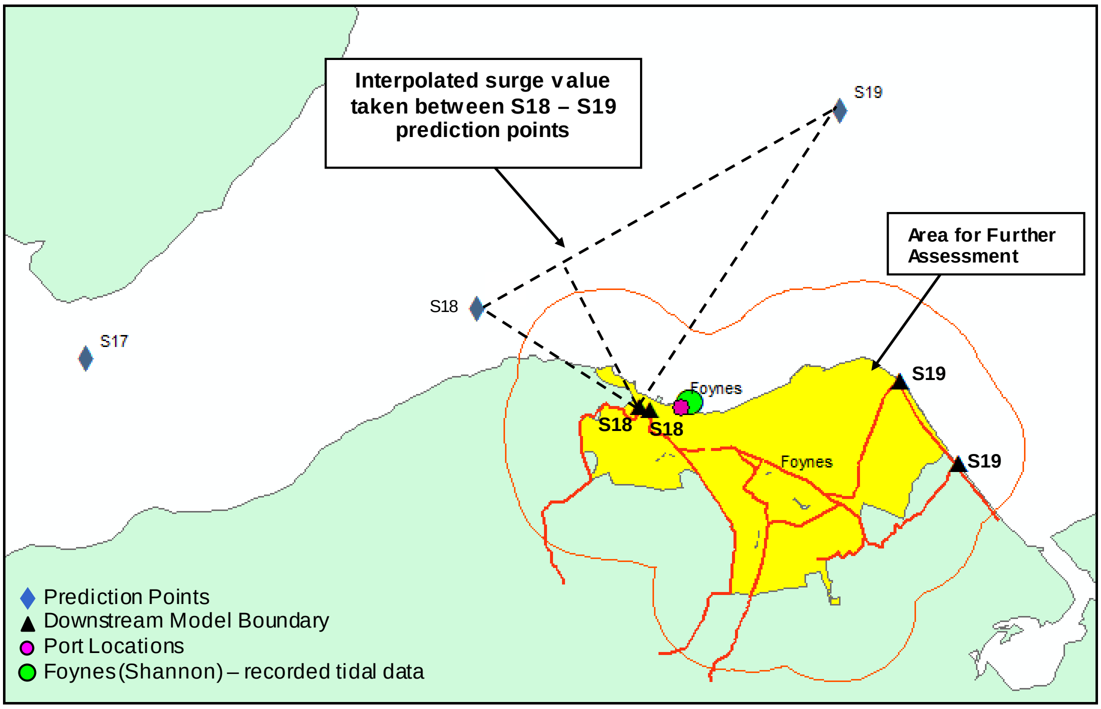


Figure 7: Model downstream boundary assignment for Foynes AFA (model S09)

Table 2 below lists the prediction points assigned to each model downstream boundary

Table 2: Allocation of Prediction Points to Model Downstream Boundaries	
ICPSS (Prediction Point Reference)	**AFAs – Model No**
S25	Adare / Clarina - Model S06
	Bunratty – Model S03
S24	Shannon Airport – IRR3
	Shannon - Model S04
S22	Ennis Model S01[20]

Table 2: Allocation of Prediction Points to Model Downstream Boundaries	
ICPSS (Prediction Point Reference)	**AFAs – Model No**
S9	Ballylongford – S05
S8	Kilrush – S18
S26	Limerick – Model N16
S18 - S19	Foynes - Model S09
S21	Askeaton – Model S10
S2	Moneycashen – Model S14b
SW48-SW49	Kilkee – Model S19
SW37	Tralee – Model S16
SW39	Banna – Model S17
S12	Tarbert – IRR4

Figure 8 shows the predictions points, the model extents and the area affected by the tidal conditions

[20] For the S01 model, the obtained design tidal boundary will be reviewed against the one used in the Ennis Main Drainage and Flood Study, Ennis urban District Council, 2001

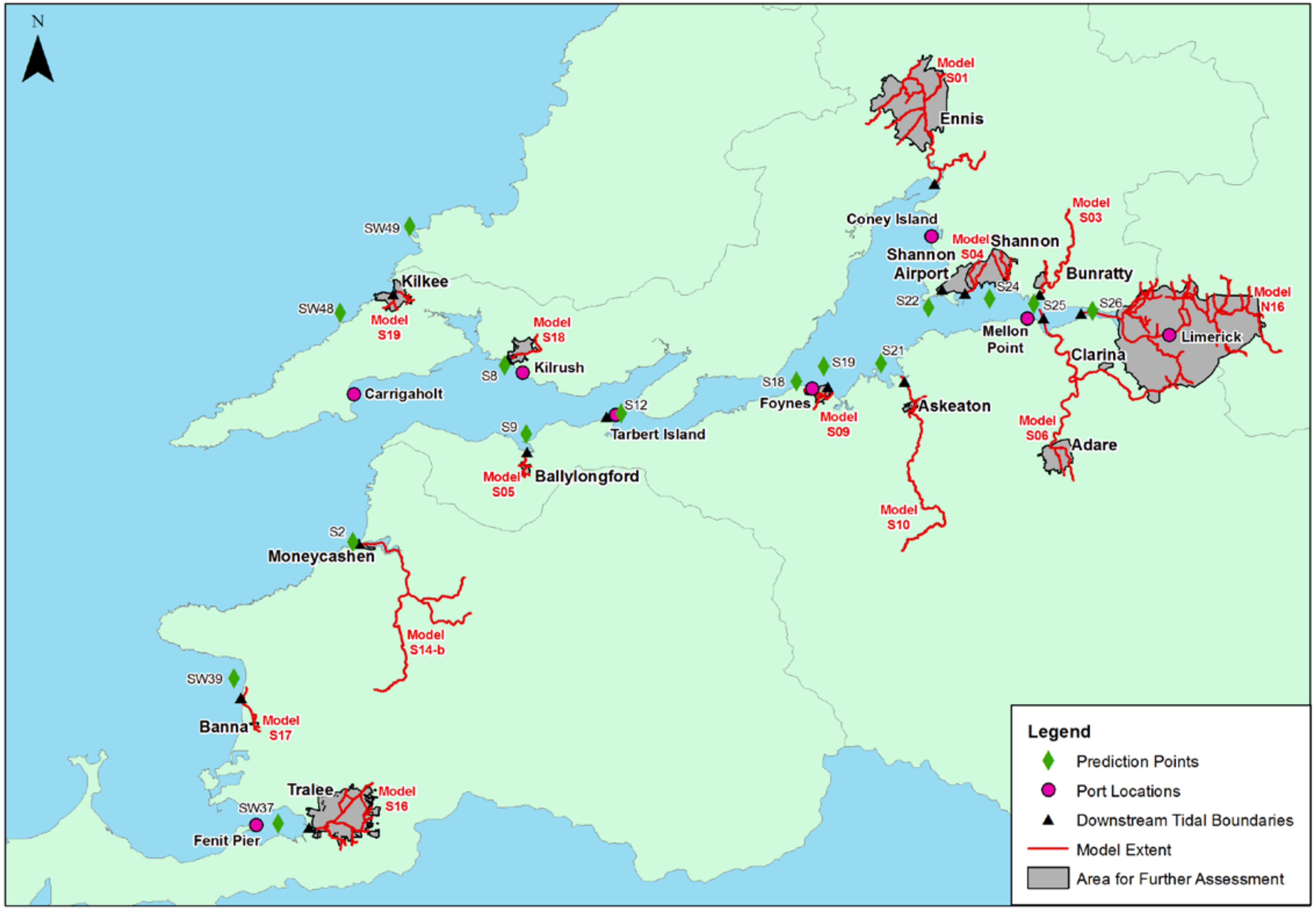


Figure 8 – Prediction point, model extents and AFAs

4 Conclusion

A summary of the methodology described in detail above is shown as a flow chart on Figure 9 below. For each model, a summary table of the assigned prediction point along with the data used to derive the downstream boundary tide profiles is also available in Annex C.

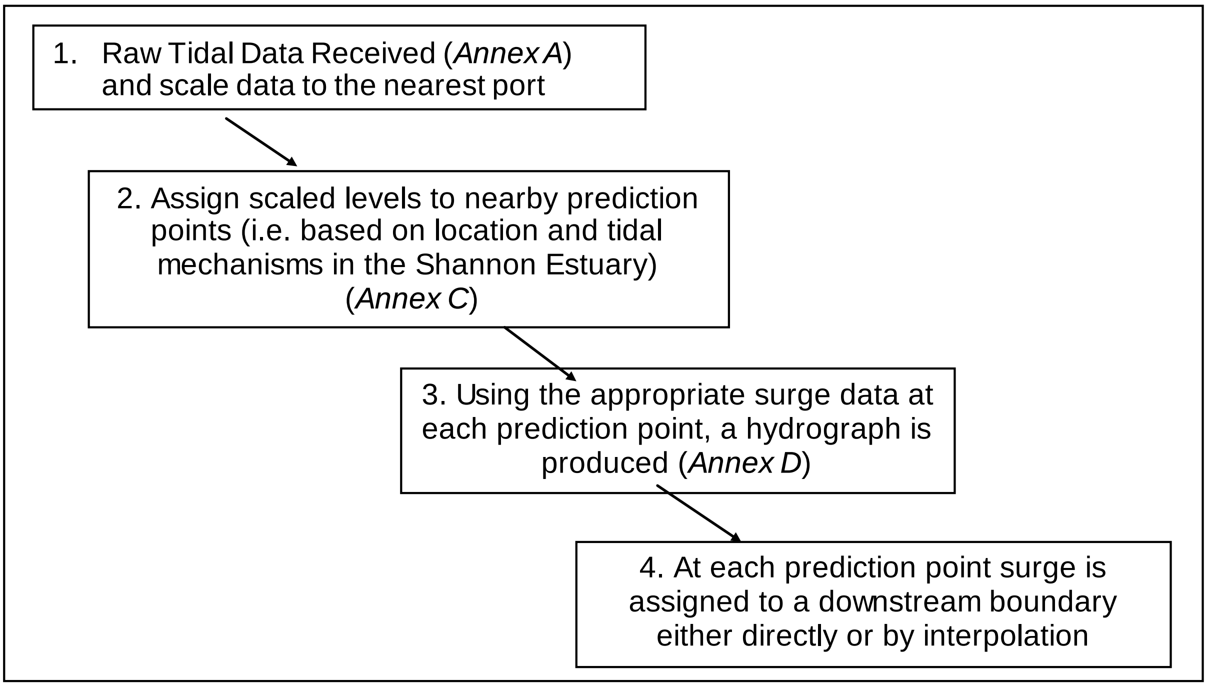
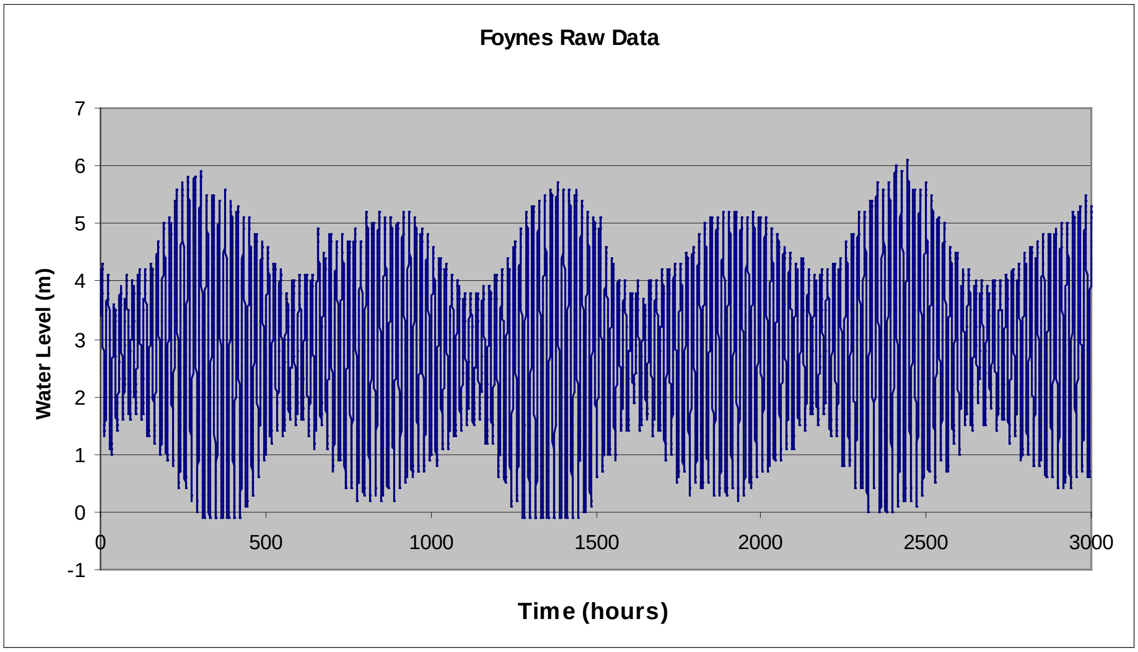
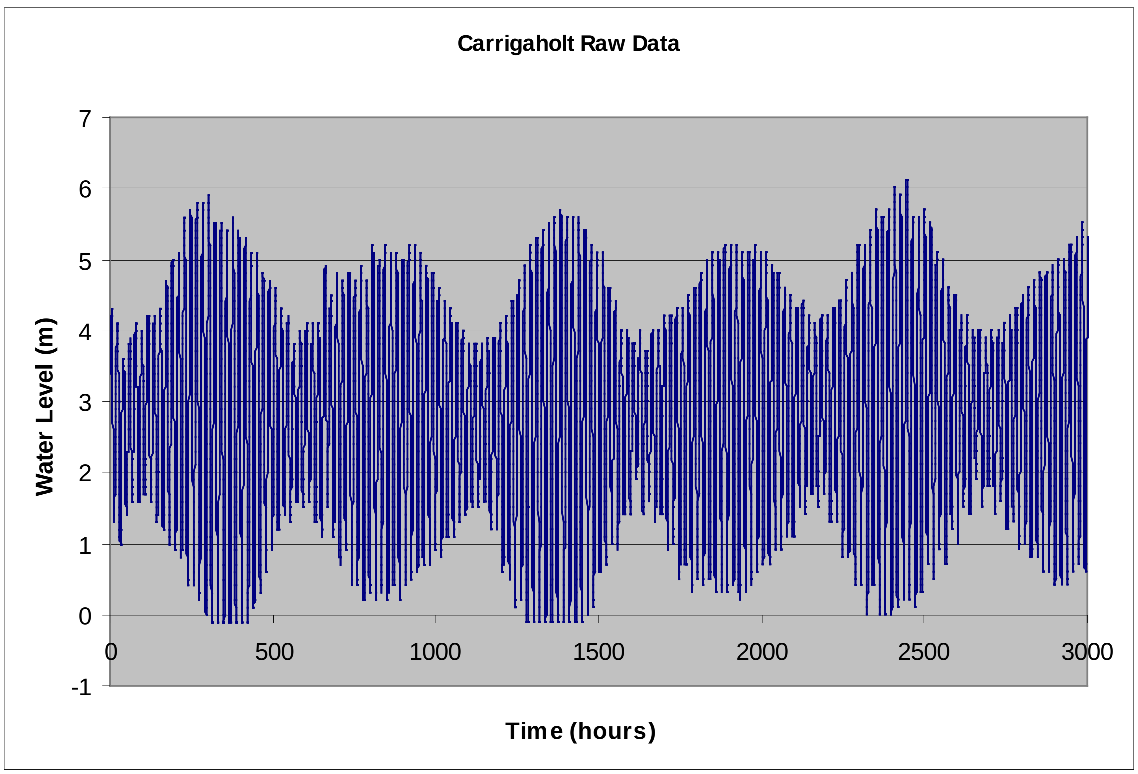
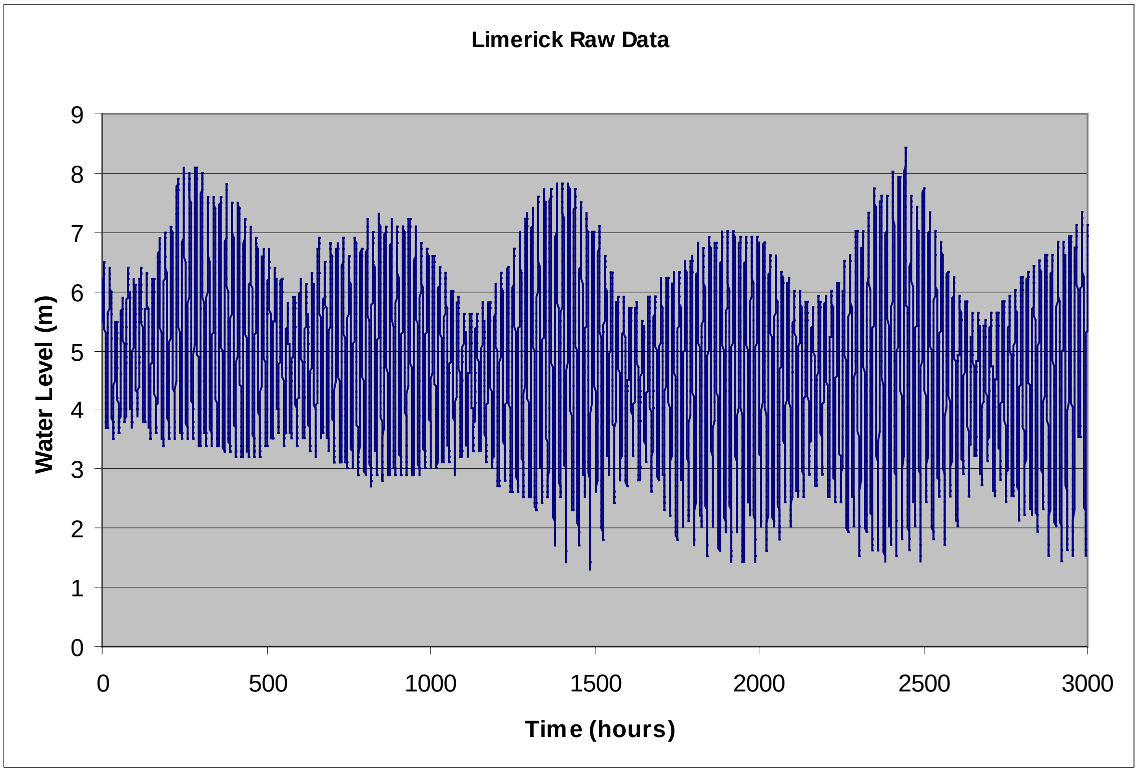


Figure 9: Flow Diagram of the Methodology

Annex A – Raw Tidal Data Extract






Limerick Raw Data
Water Level (m)
0
1
2
3
4
5
6
7
8
9
0
500
1000
1500
2000
2500
3000
Time (hours)

Annex B – MHWS/MHWL (Port Scaling Table)

Tidal record used to derive tidal hydrograph		Height difference in meters MHWS	MHWN	MLWN	MLWS	ML (m)	Water level in meters (Chart Datum Local) MHWS	MHWN	MLWN	MLWS	ML (m)	Water level in meters (Malin Head) MHWS	MHWN	MLWN	MLWS	ML (m)
(Foynes)	**Tarbert Island (Standard Port)**	5.00	3.80	1.70	0.50	2.77	5.00	3.80	1.70	0.50	2.77	1.995	0.795	-1.305	-2.505	-0.235
(Carrigaholt)	Carrigaholt	-0.10	-0.10	0.20	0.20		4.90	3.70	1.90	0.70	2.73	1.895	0.695	-1.105	-2.305	-0.275
(Carrigaholt)	Kilrush	0.00	-0.10	0.00	0.00		5.00	3.70	1.70	0.50	2.64	1.995	0.695	-1.305	-2.505	-0.365
(Foynes)	Foynes Island	0.20	0.20	0.10	-0.20		5.20	4.00	1.80	0.30		2.195	0.995	-1.205	-2.705	
(Foynes)	Mellon Point	0.90	0.70	0.20	-0.10		5.90	4.50	1.90	0.40		2.895	1.495	-1.105	-2.605	
(Limerick)	Limerick Dock	1.10	0.80	-0.50	-0.10		6.10	4.60	1.20	0.40		2.977	1.477	-1.923	-2.723	
(Foynes)	River Fergus (Coney Island)	0.20	0.10				5.20	3.90				2.195	0.895			

	Height difference in meters MHWS	MHWN	MLWN	MLWS	ML (m)	Water level in meters MHWS	MHWN	MLWN	MLWS	ML (m)	Water level in meters (Malin Head) MHWS	MH WN	MLWN	MLWS	ML (m)
COBH (Standard Port)	4.10	3.20	1.30	0.40	2.25	4.10	3.20	1.30	0.40	2.25					
Fenit Pier - Tralee Bay	0.50	0.20	0.30	0.10		4.60	3.40	1.60	0.50	2.53	1.70	0.50	-1.30	-2.40	-0.38
	4.6	3.4	1.6	0.5	2.525						-2.90				

	Land Leveling (Height in Meters)	
Tarbert Island	-0.30	
Carrigaholt	-0.30	
Kilrush	-0.30	
Foyes Island	-0.30	
Limerick Dock	-0.46	-2.663
Fenit Pier	-0.21	-2.693

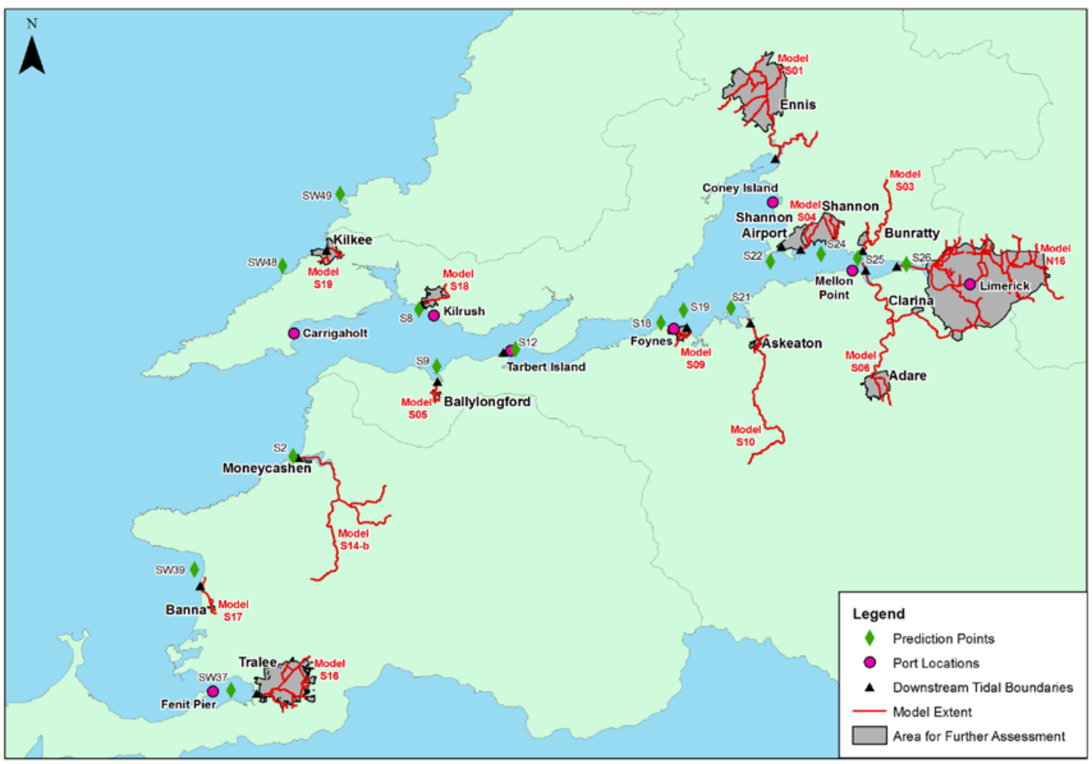
Poolbeg (Datum) - Malin Head Conversion

Poolbeg (Datum) - Malin Head Conversion	
-2.705	(Futher refinement Based on OSi data/sheets)

Note: The above table denotes the ports allocated the scaled recorded tidal data to produce the MHWS (Mean High Water Spring) and MLWS (Mean Low water Spring). The spring tides are highlighted in yellow as these are key in determining flood risk.
The tables below the MHWS and MLWS denotes the Land Levelling used.

Annex C – Prediction Point Assignment

AFA Applicable to	ICPSS (Prediction Point Reference)	Method	Port	Tidal_Data
Adare / Clarina	S25	Direct Assignment	Mellon Point	Foynes
Bunratty	S25	Direct Assignment	Mellon Point	Foynes
Shannon Airport	S24	Direct Assignment	Mellon Point	Foynes
Shannon	S24	Direct Assignment	Mellon Point	Foynes
Ennis	S22	Direct Assignment	Coney Island	Foynes
Ballylongford	S9	Direct Assignment	Kilrush	Carrigaholt
Kilrush	S8	Direct Assignment	Kilrush	Carrigaholt
Limerick	S26	Direct Assignment	Limerick	Limerick
Foynes	S18-S19	Interpolated	Foynes	Foynes
Foynes	S19	Direct Assignment	Foynes	Foynes
Askeaton	S21	Direct Assignment	Foynes	Foynes
Moneycashen	S2	Direct Assignment	Carrigaholt	Carrigaholt
Kilkee	SW48-49	Interpolated	Carrigaholt	Carrigaholt
Tralee	SW37	Direct Assignment	Fenit Pier	Carrigaholt
Banna	SW39	Direct Assignment	Fenit Pier	Carrigaholt
Tarbert	S12	Direct Assignment	Tarbert	Foynes



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Annex D – ICPSS Predicted Extreme Water Levels Associated with Combined Tide and Surge

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ICPSS PHASE IV - SOUTH WEST COAST

Predicted Extreme Water Levels Associated with Combined Tide and Surge

PREDICTION POINT ID	ANNUAL EXCEEDENCE PROBABILITY (AEP) 50%	20%	10%	5%	2%	1%	0.5%	0.1%	COORDINATES OF PREDICTION POINTS EASTINGS	NORTHINGS
SW27	2.32	2.42	2.49	2.56	2.65	2.71	2.78	2.93	30635	104299
SW28	2.38	2.48	2.56	2.63	2.73	2.80	2.87	3.04	36361	109676
SW29	2.42	2.53	2.61	2.68	2.78	2.85	2.92	3.09	41593	112847
SW30	2.47	2.58	2.66	2.74	2.84	2.91	2.98	3.15	48882	116516
SW31	2.52	2.63	2.70	2.77	2.86	2.93	3.00	3.16	54279	114238
SW32	2.53	2.64	2.71	2.78	2.87	2.94	3.00	3.16	59207	115106
SW33	2.56	2.67	2.75	2.82	2.92	3.00	3.08	3.25	60950	120616
SW34	2.68	2.79	2.86	2.93	3.01	3.08	3.15	3.30	64289	115512
SW35	2.69	2.79	2.86	2.94	3.03	3.10	3.17	3.33	68777	112162
SW36	2.72	2.83	2.91	2.98	3.08	3.15	3.22	3.39	73381	113155
SW37	2.83	2.94	3.02	3.10	3.21	3.29	3.36	3.55	78171	113613
SW38	2.63	2.74	2.81	2.89	2.98	3.05	3.12	3.29	72867	119737
SW39	2.63	2.74	2.82	2.90	3.00	3.08	3.16	3.33	74265	126382
SW40	2.59	2.71	2.79	2.86	2.97	3.04	3.12	3.29	67371	131016
SW41	2.63	2.74	2.82	2.90	3.00	3.07	3.15	3.32	74926	133602
SW42	2.67	2.79	2.87	2.96	3.07	3.15	3.23	3.42	84187	139720
SW43	2.64	2.77	2.86	2.95	3.07	3.16	3.25	3.45	86181	149471
SW44	2.62	2.75	2.83	2.92	3.03	3.12	3.20	3.40	74602	147527
SW45	2.57	2.69	2.78	2.86	2.97	3.06	3.14	3.33	67807	147150
SW46	2.59	2.71	2.79	2.88	2.98	3.07	3.15	3.33	73800	151815
SW47	2.60	2.72	2.80	2.88	2.99	3.07	3.15	3.34	78108	154787
SW48	2.61	2.73	2.82	2.90	3.01	3.10	3.18	3.37	83599	158464
SW49	2.62	2.74	2.83	2.92	3.03	3.12	3.20	3.40	89719	166059
SW50	2.64	2.77	2.86	2.95	3.06	3.15	3.24	3.44	97955	167774
SW51	2.65	2.78	2.87	2.96	3.08	3.17	3.26	3.46	98414	173525
SW52	2.66	2.79	2.88	2.97	3.08	3.17	3.26	3.46	101090	178980
SW53	2.70	2.83	2.93	3.02	3.15	3.24	3.33	3.55	107926	187640
SW54	2.69	2.82	2.92	3.01	3.13	3.22	3.31	3.52	100223	189240
SW55	2.72	2.85	2.95	3.04	3.16	3.24	3.33	3.54	104725	195829
SW56	2.82	2.97	3.07	3.17	3.30	3.39	3.49	3.72	112752	208923

Notes

All water levels shown are in metres and referenced to Ordnance Datum Malin
Prediction Point Coordinates are referenced to Irish Grid TM65

ICPSS PHASE IV - SOUTH WEST COAST

Predicted Extreme Water Levels Associated with Combined Tide and Surge

PREDICTION POINT ID	ANNUAL EXCEEDENCE PROBABILITY (AEP)								COORDINATES OF PREDICTION POINTS	
	50%	20%	10%	5%	2%	1%	0.5%	0.1%	EASTINGS	NORTHINGS
S1	2.64	2.76	2.85	2.94	3.06	3.15	3.23	3.43	82688	148391
S2	2.71	2.82	2.91	2.99	3.10	3.18	3.26	3.44	84845	138260
S3	2.73	2.85	2.93	3.02	3.13	3.22	3.30	3.49	85474	144422
S4	2.71	2.83	2.92	3.01	3.12	3.21	3.30	3.50	86013	151950
S5	2.72	2.84	2.92	3.01	3.12	3.20	3.29	3.48	88695	148419
S6	2.74	2.86	2.95	3.03	3.15	3.24	3.32	3.52	91646	152584
S7	2.77	2.89	2.98	3.07	3.18	3.27	3.35	3.55	95785	147777
S8	2.76	2.89	2.98	3.07	3.19	3.28	3.37	3.58	98052	153862
S9	2.79	2.91	3.00	3.09	3.20	3.29	3.37	3.57	99936	147831
S10	2.75	2.87	2.96	3.05	3.17	3.26	3.35	3.55	103931	150900
S11	2.77	2.89	2.99	3.08	3.20	3.29	3.38	3.59	106638	150798
S12	2.72	2.84	2.93	3.02	3.13	3.21	3.29	3.48	108294	149661
S13	2.70	2.83	2.92	3.01	3.12	3.21	3.30	3.50	109699	148606
S14	2.72	2.85	2.94	3.03	3.15	3.24	3.33	3.53	112483	148567
S15	2.72	2.86	2.96	3.06	3.20	3.30	3.40	3.63	115609	151987
S16	2.75	2.89	3.00	3.10	3.24	3.34	3.45	3.69	118265	150532
S17	2.78	2.93	3.04	3.16	3.30	3.42	3.53	3.79	121126	152131
S18	2.83	2.99	3.11	3.22	3.38	3.50	3.62	3.89	123686	152457
S19	2.89	3.04	3.17	3.29	3.45	3.57	3.69	3.97	126062	153757
S20	2.93	3.09	3.22	3.34	3.51	3.63	3.76	4.05	127363	157071
S21	3.03	3.20	3.32	3.45	3.61	3.74	3.86	4.15	131090	154017
S22	3.12	3.31	3.44	3.58	3.75	3.89	4.02	4.33	135251	158930
S23	3.18	3.37	3.52	3.66	3.86	4.00	4.15	4.48	138731	157900
S24	3.22	3.42	3.57	3.72	3.92	4.07	4.21	4.56	140612	159730
S25	3.29	3.50	3.66	3.81	4.02	4.17	4.33	4.68	144515	159263
S26	3.40	3.64	3.82	4.00	4.24	4.41	4.59	5.00	149662	158626

Notes

All water levels shown are in metres and referenced to Ordnance Datum Malin
Prediction Point Coordinates are referenced to Irish Grid TM65

Annex E – Ordnance Survey Conversion Tables (Poolbeg-Malin Head)

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POOLBEG:MALIN HEAD DIFFS COUNTRYWIDE

AREA	DIFF (MEAN)	AREA	DIFF (MEAN)
ARTHURSTOWN (WEX)	2.578 mts	DUNDALK	2.640 mts
ATHLONE	2.766 mts	DUNGARVAN	2.697 mts
BALLINA	2.810 mts	DUN LAOGHAIRE	2.722 mts
BALLINACOLLIG	2.739 mts	DUNMORE EAST	2.610 mts
BALLINROBE	2.773 mts	EDENDERRY	2.670 mts
BALLYBOFEY	2.747 mts	EDGEWORTHSTOW1	2.780 mts
BALLYBUNION	2.704 mts	ENNISCORTHY	2.645 mts
BALLYHAUNIS	2.759 mts	FERBANE	2.717 mts
BALLYSADARE (SLIGO)	2.792 mts	GALWAY	2.732 mts
BALLYSHANNON	2.744 mts	GEASHILL	2.784 mts
BANTRY	2.756 mts	GORMANSTOWN-ST	2.716 mts
BLANCHARDSTOWN	2.744 mts	GREENHILLS RD. (D	2.722 mts
BOYLE	2.797 mts	KILKENNY	2.674 mts
CAHIR	2.705 mts	KILLARNEY	2.686 mts
CARLOW	2.713 mts	KINSALE	2.704 mts
CARRICKMACROSS	2.647 mts	LETTERKENNY	2.719 mts
CARRICK-ON-SUIR	2.665 mts	LIMERICK	2.663 mts
CARRIGTOHILL	2.701 mts	LISTOWEL	2.737 mts
CASTLEBAR	2.840 mts	LONGFORD	2.760 mts
CASTLEBLANEY	2.744 mts	LUCAN-LEIXLIP	2.719 mts
CASTLEISLAND	2.689 mts	MACROOM	2.762 mts
CHARLEVILLE	2.669 mts	MALIN HEAD	2.598 mts
CLARA	2.698 mts	MANORHAMILTON	2.781 mts
CLAREMORRIS	2.764 mts	MAYNOOTH	2.746 mts
CLONAKILTY	2.719 mts	MOATE	2.782 mts
CLONEE	2.763 mts	MONASTEBOICE (L(	2.689 mts
CLONES	2.775 mts	MONASTERVIN	2.682 mts
CLONMEL	2.714 mts	MULLINGAR	2.777 mts
COBH	2.690 mts	NAAS	2.685 mts
CORK	2.701 mts	NAVAN	2.732 mts
DONEGAL TOWN	2.700 mts	NENAGH	2.644 mts
DROGHEDA	2.680 mts	NEWCASTLEWEST	2.699 mts

AREA	DIFF (MEAN)
NEW ROSS	2.573 mts
PORT LAOISE	2.703 mts
RATHKEALE	2.695 mts
SHANNON	2.705 mts
SLIGO	2.790 mts
SKERRIES	2.700 mts
SKIBBEREEN	2.737 mts
SWINFORD	2.839 mts
SWORDS	2.694 mts
TEMPLEMORE	2.726 mts
TRALEE	2.693 mts
TRAMORE	2.643 mts
TULLAMORE (CLARA ROAD)	2.701 mts
WATERFORD	2.702 mts
WESTPORT	2.818 mts
WEXFORD TOWN	2.662 mts

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Appendix E National Technical Co-ordination Group (NTCG) Guidance Note no. 23 (GN23)

Technical Note

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Date	**17th June 2013**
To	John Martin, Office of Public Works
From	Peter Smyth, Jacobs
Project	**Shannon CFRAM Study**
Subject	NTCG Guidance Note No.23 (GN23) - Hydraulic Model Calibration
Reference	32103000/TD_HYDO_0330_V2_0_JAC_GN23_Model_Calib_130617

1.0 Introduction

This Guidance Note (GN23) outlines Jacobs' proposed approach for calibrating the fluvial hydraulic models and the tidal inundation models, and the reasoning behind the approach to be adopted. Throughout the Guidance Note any references to "we" implies that it is Jacobs' approach on the Shannon CFRAM Study.

This note only covers calibration of the main hydraulic model deliverables. It excludes the calibration of the hydraulic models required for the Gauging Station Rating Reviews: which are to be calibrated using the recorded check gaugings (spot flows) as deemed reliable, up to the maximum gauged flows.

This Guidance Note has been produced for circulation amongst all CFRAM Study Consultants for information. The approaches outlined in this Guidance Note apply specifically to the Shannon CFRAM Study, although each CFRAM Study Consultant may adopt the approach where the methodology lends itself suitably to application elsewhere. However, it is emphasised that differences in approach, such as the possible application of rainfall-runoff modelling in other CFRAM Studies, will require additional consideration by other CFRAM Study consultants.

2.0 Summary of Stage I Tender Documents

Stage I Tender Documents: Project Brief states:

6. HYDROLOGICAL ANALYSIS

6.1. LEVEL OF DETAIL

The hydrological analysis of the whole Study Area should be comprehensive and taken to a high level of detail, such that no further hydrological analysis should be required after completion of the Project (other than to confirm findings of the Project, assess minor design variations or update the analysis after a number of years or the occurrence of an extreme event) for the OPW or other authorities to have justifiable confidence in the implementation of the strategy and specific measures identified through the Project to manage the flood risk within the APSRs. The hydrological analysis should place particular emphasis on flood flow estimation for the APSRs and HPWs in terms of, for example, statistical flood frequency estimation and the calibration of hydrological models.

6.5. ESTIMATION OF DESIGN FLOOD PARAMETERS

6.5.5. Hydrological Calibration and Validation

The Consultant shall calibrate and validate the estimates of the design flood parameters (other than extreme peak sea levels) to recorded data as far as reasonably possible, based on historic or recorded flood event data.

7. HYDRAULIC ANALYSIS

7.1. LEVEL OF DETAIL

The level of detail of the hydraulic analysis to be undertaken under this Project should be sufficient to enable the Consultant to fully meet the requirements and objectives of the flood mapping, flood risk assessment, development and appraisal of flood risk management actions and measures (and associated assessments) and the preparation of a Flood Risk Management Plan, as set out herein.

Within APSRs, the hydraulic analysis should be comprehensive and taken to a high level of detail, such that no further hydraulic analysis should be required after completion of the Project (other than to confirm findings of the Project, assess minor design variations or for validation and / or re-calibration after the occurrence of an extreme event) for the OPW or other authorities to have justifiable confidence in the implementation of the strategy and specific measures identified through the Project to manage the flood risk within the APSRs. The level of detail of the hydraulic analysis for MPWs does not need to be as high as that required for the APSRs, but nonetheless should be the best achievable within the constraints of the survey specification and available calibration data for MPWs to enable reasonable estimates of flood hazard and risk.

7.2. DEVELOPMENT OF FLUVIAL HYDRAULIC MODELS

7.2.1. Fluvial Model Development

The Consultant shall develop dynamic hydraulic models for the HPWs and MPWs and their associated floodplains, based on the definitions of HPWs and MPWs set out herein, and the APSRs associated with fluvial flood risk, as identified in the tender documentation of the Specific Tender Stage (Stage II), to analyse historic flood events and estimate design and potential future flood levels, depths, velocities and extents.

The Consultant shall develop models to a high level of detail for the HPWs, but to a lower level of detail for MPWs, making full and best use of the survey, calibration and other information captured, provided or developed as specified herein……

7.2.2. Fluvial Model Calibration

The Consultant shall appropriately ensure that the flood flows within the hydraulic models along HPW and MPW reaches are calibrated to the flood flow estimates at the Hydrological Estimation Points to ensure hydrological continuity (taking account of flood attenuation explicitly simulated within the hydraulic modelling) and that the design flood flows for each AEP are maintained along all lengths of relevant watercourses. Such adjustment might, for example, be by the provision of appropriate lateral inflows and ensuring appropriate inflow from tributaries, or by running the hydraulic models for individual reaches.

The Consultant shall calibrate and verify the fluvial hydraulic models against a number of suitable past flood events (not less than four (4) events for each APSR if relevant data is

available). The calibration and verification of the models shall make use of the best available data including, but not limited to, hydrometric data, photographs, videos, press articles and anecdotal information provided by local authority staff and other Stakeholders. The models should be verified to vertical accuracies of not less than 0.2m and 0.4m for HPWs and MPWs respectively, subject to the availability of suitable calibration data.

7.3. DEVELOPMENT OF COASTAL FLOODING MODELS

7.3.1. Coastal Flooding Model Development

The Consultant shall develop models for the APSRs associated with risk of flooding from coastal sources, as identified in the tender documentation of the Specific Tender Stage (Stage II), to analyse the inland propagation of coastal or estuarine flood waters and to analyse historic flood events and estimate design and potential future flood levels, depths, velocities and extents. It is reiterated that the Consultant shall not be required to develop hydrodynamic storm surge models, or off-shore models, under this Project and shall instead use the peak design extreme coastal water levels provided by the OPW as the basis for the inland (overland) propagation modelling of flood waters.

The Consultant shall develop models to a high level of detail making full and best use of the survey and other information captured, provided or developed as specified herein. The modelling shall be undertaken using 2-dimensional modelling or other equivalent types of flood spreading modelling capable of accurately simulating the propagation of coastal floodwaters over tidal cycles and storm surge events inland.

The hydraulic models shall be developed using one of the following modelling software packages:

- *ISIS-2D / Tuflow*
- *Mike 21, Mike Flood*
- *JFlow*

Hydraulic modelling software packages other than those listed above may not be used in undertaking this element of the Project.

7.3.2. Coastal Flooding Model Calibration

The Consultant shall calibrate and verify the coastal flooding models against a number of suitable past flood events (not less than four (4) events for each APSR if relevant data is available). The calibration and verification of the models shall make use of the best available data including, but not limited to, hydrometric data, photographs, videos, press articles and anecdotal information provided by local authority staff and other Stakeholders. The models should be verified to vertical accuracies of not less than 0.2m, subject to the availability of suitable calibration data.

3.0 Proposed Approach

3.1 Technical Requirements for Calibration

Calibration of the hydrological and hydraulic models is required to give confidence in the results of the models.

The calibration and verification of the models will make appropriate use of the available data including, but not necessarily limited to, hydrometric data, photographs, videos, press articles and anecdotal information provided by local authority staff and other Stakeholders. Reliable calibration can only be achieved within the constraints of the available data, taking account of both its relevance and reliability.

The hydraulic models need to be calibrated and verified against a number of suitable past flood events representing both in-bank and out-of-bank events (not less than two of each for each AFA if relevant data is available).

The hydraulic models should be verified to vertical accuracies of 0.2m and 0.4m or less for High Priority Watercourses (HPWs) and Medium Priority Watercourses (MPWs) respectively, subject to the availability of suitable calibration data. This calibration accuracy will be measured based on the RMSE compared to observed levels along HPWs associated with a given AFA, or along a reach of MPW. A degree of flexibility and pragmatism is required with this approach taking account of the reliability of data provided at various locations along a reach. The focus will be on achieving a better calibration against the more reliable data sources, rather than allowing less reliable data points to unreasonably influence the calibration.

In considering the above requirements, the following data must be known in order to give a reliable model calibration:

- **Flow** at the point of interest;
- **Water level** at the point of interest;
- **Channel / hydraulic controls** influencing the water level at the location of interest so that the model is representative of the situation.

Where there is uncertainty in any of these three variables, the accuracy of the calibration is reduced.

3.2 Methodology

3.2.1 General

The dearth of sub-daily rainfall records for the Shannon RBD Study area in particular severely limits the application and accuracy of traditional rainfall-runoff techniques to simulate historical events. The uncertainty arising in the calibration of such models and the subsequent need to adjust the model flood flow predictions, to align with the flood frequencies derived from local flow gauge records, renders rainfall-runoff modelling ineffective. Rainfall-runoff modelling of historical events has therefore been discounted. It is noted that the contract recognises this eventuality and does not require the use of rainfall-runoff modelling for historic events.

Hence a combination of Hydrological Estimation Point calibration and hydraulic calibration is proposed as detailed in the sections below.

3.2.2 Hydrological Estimation Point (HEP) Calibration

Within the broader context of hydraulic model calibration, there is the need consistency and continuity moving downstream through the catchments with regard to flows and flow frequency. This means that, for example, the 2% AEP event at one location as given in the hydraulic model, should be cross-checked against the 2% AEP event derived from the hydrological analysis at the same location, and there should be only a small discrepancy between the estimates. This is explicitly covered in Step 8 below, but is of fundamental importance with regard to the model output – the flood maps themselves.

A sequence of tasks proposed to undertake the HEP calibration is provided below. It is emphasised that this is the proposed approach in the absence of any rainfall-runoff modelling.

1) Undertake gauging station rating reviews to provide increased confidence in high flows gauged at specific gauging stations in the catchment. These gauging station reviews are critical in providing reliable information to be used as pivotal sites for hydrological adjustments to flood estimates at ungauged sites.

2) Rework the annual maxima series of flood flows as required following Step 1 at reviewed gauging stations.

3) Estimate Qmed for key gauging stations (ideally ones that have been subject to a rating review) in or near the model domain from the gauged annual maxima at the site and compare this to the outcome of the FSU regression equation at the gauging station. If no suitable "pivotal" site can be found in or near the model domain, then FSU Guidance on the approach to choosing appropriate pivotal sites based on hydrological similarity (Area, BFI and SAAR) should be followed. Divide the two Qmed estimates at these stations to obtain an adjustment factor ($Qmed_{observed}$/ $Qmed_{synthetic}$)

4) Estimate Qmed at all HEPs using the FSU regression equation and adjust these using the adjustment factor found in Step 3 for the key gauging station in the vicinity of the HEPs. This is done in line with implementation guidance on the FSU with respect to pivotal sites, with the determination of adjustment factors for any model length being guided by the number, quality and similarity of the gauging stations available for selection as pivotal sites.

5) Produce flood frequency estimates at the key gauging stations. This is done by pooling group analysis and single site analysis. The results of these two methods are then compared and a view is taken on the best choice of distribution. Generally the selected distribution will be one of two distributions which come out of the pooling group analysis as the best fits to the pooled data. Pooled analysis is favoured over single site analysis for higher return period (e.g. 100 year) because the single site analysis is not normally based on a sufficiently long record. If the single site analysis is based on sufficiently reliable data (with a relatively long record and a few extreme floods), the pooled distribution which matches closest with the single site growth curve will be favoured as the latter is based on local flood data. The comparison of single site analysis with pooling group analysis allows a check on the validity of the design floods. A combined approach may also be appropriate in some instances, in which a composite growth curve is developed that takes account of both the pooling group and single site growth curves. In the unlikely event that further adjustments to the pooled (or combined) growth factors are deemed appropriate Steps 5 to 7 could be repeated.

6) Estimate hydrograph shape for the watercourse from gauged data or analogue sites.

7) Combine output from Steps 4, 5 and 6 above to estimate design flood hydrographs at each HEP.

8) Run hydraulic models (with appropriate amendments to the models where required) to give consistency of design flows between the hydrological and hydraulic estimates, within a reasonable degree of accuracy.

9) Once calibrated, the timings of the downstream tidal boundary will be adjusted such that the flood peak at the downstream end of the model coincides with the tidal peak, taking account of the Guidance Note on Joint Probability Analysis (GN20).

3.2.3 Hydraulic Model Calibration

As there is insufficient sub-daily raingauge coverage within the Shannon RBD, it will not be possible to reliably calibrate a rainfall-runoff model to supply flood flows to the hydraulic models and run calibration events through the model.

The approach taken will therefore depend on the level of data availability, and its quality. Fundamentally, the critical information required to calibrate a model is:

- **Flow**
- **Level** – this may come from a gauging station record (where available) or a reliable recorded water level at a specific location.
- **Hydraulic controls** – a knowledge of the conditions in the channel at the time / date of the recorded flow and level.

The approach taken for different locations and situations is described below based on four categories.

Category 1 - Gauged locations within AFAs or immediately u/s or d/s of the AFA

Where a flow gauge is located at a suitable location upstream or downstream of an AFA and suitable historic flood data exists, we will select not less than two in-bank events and not less than two out of bank events, obtain the relevant flow hydrographs from the gauging station and apply it to the hydraulic model to allow the gauged reach through (or very close to) the AFA to be calibrated and verified. Intervening ungauged catchments contributing to the watercourse through the AFA will be scaled according to the ratio of the peaks of the gauged calibration event and design event at the gauged location. Clearly, the closer the gauge is to the AFA and the fewer the number of ungauged contributing catchments between the gauge and the AFA, the more successful the calibration is likely to be.

The focus of the calibration must be on locations within the AFAs where there is a reliable estimate of flow, level and hydraulic controls.

- **Flow** – this will come from the gauging station record (using the rating curves as recommended from the rating review or existing rating elsewhere)
- **Level** – this will come from a suitable gauging station record and (where available) a reliable recorded water level at specific locations in the AFA that can be linked to a location on the modelled reach. The water level results from a hydraulic model which uses the direct gauged flow from a given gauging station as input inflow, should not in

turn be directly calibrated against gauged water levels from that gauging station as this would constitute circular calibration.

- **Hydraulic controls** – these will be as constructed in the model to represent conditions in the channel as at present (based on the channel survey). Where specific, reliable information is available with regard to issues such as blocked culverts, blockage at bridges, and changes to hydraulic controls between the event date and conditions now, this will be taken into account. However, it is noted that the availability of such information is likely to be extremely limited.

Where reaches that are suitable for calibration are tidally influenced, and suitable historic tidal hydrographs exist, we will apply these to the models as part of the calibration process. However, this introduces another level of uncertainty to the calibration.

It should also be noted that the accuracy of the information relating to these three factors can be influenced by the size of the river (and its responsiveness) at the gauging station.

Category 2 - Gauged locations significantly outside of the AFA i.e. on MPWs

Where suitable historic flood flow and level data exists on MPWs, i.e. at a gauging station, we will follow the same method outlined for the AFAs (Category 1). The primary difference between the level of information available on these reaches is that there is unlikely to be any reliable information on flood history in the vicinity, or reliable observed levels away from the gauge location.

As for gauged locations within the AFAs, where reaches that are suitable for calibration are tidally influenced, and suitable historic tidal hydrographs exist, we will apply these to the models as part of the calibration process. As noted above, this introduces another level of uncertainty to the calibration.

Category 3 - Ungauged locations within an AFA

Where the gauge is too far removed from an AFA to enable reliable calibration, or in the case of tidally affected reaches where the tidal hydrograph data is unsuitable, we will compare anecdotal and historical flood information (if suitably reliable information is available) to the flood outlines derived from the design events. This can serve as a reality check and help determine whether the frequency of flooding experienced in the past is replicated by the model. It is emphasised that the calibration at these locations is reliant on the same three factors identified for gauged locations, namely: (1) flow, (2) water level, and (3) knowledge of the channel conditions that led to the particular water level at the point of interest. Typically, reliable information of this nature is rare, and by definition, flow is not measured at these locations so at best it can only ever be a "best estimate".

It should also be noted that calibration based on observed flood frequency is highly variable and can only ever be treated as indicative. For example, if there is a reliable flood history over 50 years, and there have been 7 reliably recorded flood events at a specific location e.g. a level on a wall of a house, it is **likely** that the threshold event for flooding at that location is in the range 20% to 10% AEP event (5 year to 10 year return period). It is statistically very unlikely that Qmed would flood the property, and equally, it is very unlikely that the threshold event would be as high as the 5% AEP event (20 year return period). Linking this to the flood mapping, it would be anticipated that the Qmed flood outline would not show the property as being flooded and that the 5% AEP event outline would show it as flooded. Both the 20% and 10% AEP could, not unreasonably, potentially show the property as either flooded or not flooded. Hence this high level assessment does not constitute a calibration –

it is merely a high level indicator of what may be considered reasonable. An alternative example would be a location with a long known history with very few flood events recorded. These can be even more difficult to assign threshold events for flooding, giving a greater range of what might be considered reasonable in terms of the flood outline that shows a location to be flooded.

Category 4 - Ungauged locations outside of the AFA i.e. on MPWs

The approach here is similar in principle to the ungauged locations within an AFA. However, there is likely to be even less usable information on known levels in known events, and hence use of the term "calibration" in these areas would generally be misleading. Consideration of the question "is it believable?" is most appropriate as a reality check (see Section 3.2.5).

Summary of Approaches Considered

The above sections outline what can be considered for each type of location. This is summarised in terms of the focus for hydraulic model calibration in Table 1, and the approach likely to be adopted for different situations.

With regard to data gathering for use within the model calibration exercise, the focus is to draw on data included within www.floodmaps.ie where this provides sufficient information, supplemented with additional data provided by Local Authorities where details are known. To facilitate the data collection and provide an indication of when flooding may have occurred, the dates of the AMAX data for specific gauges have been used as a guide to possible (or likely) high flows within particular AFAs. Clearly, this depends on the size of the catchment and proximity to the AFA and it is quite possible that the dates of the highest ranked AMAX events at nearby gauges do not correspond to flood events. However, it can provide a useful pointer for the Local Authorities as to when there may have been flood events, particularly when coupled with data included from events recorded in the floodmaps.ie database.

Technical Note

1		2	3	4	5	6	7	8
Location description		**Likely accuracy of Flow estimate**	**Likely accuracy of Gauged Level estimate**	**Known hydraulic conditions [(1)]**	**Supplement-ary known, useful flood levels[(2)]**	**Reliable flood history (levels, locations, dates) [(3)]**	**Indicative calibration score (sum of columns 2-6)**	**Calibration comment**
Category 1	Large gauged river within an AFA (HPW)	3	3	2 - 3	2	2	12 - 13	Calibrate main channel to large events on the river. E.g Croom using Station 24001 (Maigue @ Croom)
	Small gauged river within an AFA (HPW)	2	3	2	1	1	9	Calibrate main channel to large events on the river. E.g Dromcolliher using Station 24015 (Ahavarragh @ Dromcolliher). Take note of uncertainties due to channel blockages etc.
Category 3	Large ungauged river within an AFA (HPW)	1 - 2	0	2	2	2	7 - 8	Calibrate main channel to best estimate of flow with known level in AFA (if available). If no dates / levels, then modelled outline to reflect "reasonable" historic flood frequency (if available). Otherwise not calibrated – use reasonable hydraulic parameters.
	Small ungauged river within an AFA (HPW)	0 - 1	0	1 - 2	1	1	3 - 5	Modelled outline to reflect "reasonable" historic flood frequency (if available). Otherwise not calibrated – use reasonable hydraulic parameters
Category 2	Gauged MPW	3	3	2 - 3	0	0	8 – 9	Calibrate main channel to large events on the river – this will have been done for the gauging station review (for those stations included for review).
Category 4	Ungauged MPW	0 - 2	0	0 - 2	0	0	0 - 4	Reach uncalibrated – use reasonable hydraulic parameters. Reliant on better calibration at u/s and d/s AFAs, and other gauged MPW reaches.

Scores for columns 2 to 6: 0 = Not available; 1 = Poor / Unlikely; 2 = Fair / Possible; 3 = Good / Likely. Total score in column 7 provides an overall indicative guide as to how good the calibration may be, based on the data quality for columns 2 to 6.

Notes:

(1) Hydraulic conditions relates to hydraulic controls influencing water level during a flood e.g. level of blockage at a bridge, culvert trashscreen blockage; any new works since flood event. It is a statement regarding whether the conditions in the flood can be accurately reflected in the hydraulic model.

(2) Flood levels – these are levels during a known flood NOT at the gauged location that represent the true flood level at that location e.g. they must not be due to a very localised hydraulic issue such as flow around a building.

(3) Flood history – for this information to be useful it must include a date, precise location and level as per note (2).

3.2.4 Tidal Inundation Model Calibration

In the event that a suitable tidal hydrograph for a past flood event (and associated details of the resultant flood consequences) exists, we would carry out at least 4 event runs to calibrate and verify the model. However, we would note that to date, we have not found sufficient information relating to a tidal inundation event that could be used as a true calibration event, although sources such as ICPSS or Proudman Oceanographic Laboratory may yield some data.

Where a suitable tidal hydrograph does not exist – which we consider will be the norm for the tidal inundation modelling - we will compare any suitable flood data with the design flood outlines, in a similar way to the fluvial model calibration methodology, outlined in Section 3.2.3 for Categories 3 and 4 – i.e. in an ungauged location. This will serve as a reality check and help determine whether the frequency of flooding experienced in the past is replicated by the model.

It should be noted that all tidal inundation model calibration requires the following fundamental information:

- Tidal hydrograph – as the driving force leading to the tidal inundation
- Water levels – peak flood level recorded on the tidal flood plain
- Tidal flood plain conditions – the ground profile in the model must replicate the situation for the time / date when the tidal inundation occurred.

Given these requirements we anticipate that (as for Category 4 in the fluvial model calibration) the availability of usable information is likely to be very limited and hence the term "calibration" in these areas would generally be misleading. Consideration of the question "is it believable?" is therefore likely to be the level of detail for the calibration, as a reality check against known tidal flooding.

The accuracy of the tidal flooding inundation is likely to be best at locations where the threshold event for inundation is low e.g. events up to around the 20% AEP event tide level, assuming this relatively frequent level of flooding is observed.

3.2.5 Reality Checking of Mapping as and Aid to Calibration

We note that within the Stage I Tender Documents Sections 7.2.2 and 7.3.2 state:

'The calibration and verification of the models shall make use of the best available data including, but not limited to, hydrometric data, photographs, videos, press articles and anecdotal information provided by local authority staff and other Stakeholders.'

Our approach outlined above will do this. However, we do anticipate based on the lack of calibration data available to date through many AFAs, along MPW reaches, and in tidal locations, that a reality check on the flood mapping could add value to the process prior to the formal public consultation on the draft flood mapping. Those with the best local knowledge within the Local Authorities and OPW Regional Staff could be engaged in the process. Typical questions to address will include:

- Are there areas that you (LA and OPW) know flood (i.e. have flooded once or more in the past), which are not shown by the design event extents?
- Are there areas shown as flooded, that you believe are highly unlikely to ever flood? If so, why do you believe they are highly unlikely to ever flood?
- Is there evidence of the range of design event flood profile levels having been met or exceeded? If so, how often?

This type of local review providing a reality check on the mapping could be usefully facilitated through a flood-mapping workshop (or series of workshops) focused on different groupings of AFAs. For example, there could be a mapping workshop for each Local Authority or each UoM. Although these Local Authority / Regional OPW flood mapping workshops are not identified as an activity within the Stage I or Stage II tender documents, the Progress and Steering / Advisory Group meetings may be suitable fora for such workshops, noting that additional workshops with individual Local Authorities, OPW Regional Staff and/or other Stakeholders may need to be considered as well. These meetings / workshops within the context of the Progress and Steering / Advisory Group meetings do not replace the formal requirement for stakeholder workshops for flood mapping.

Appendix F National Technical Co-ordination Group (NTCG) Guidance Note no. 22 (GN22)

GUIDANCE NOTE 22 V5.0

JBA Project Code	2011s5232
Contract	Western CFRAM
Client	OPW
Day, Date and Time	17 February 2014
Author	Sam Willis
Subject	Guidance Note 22 – Sensitivity Analysis and Uncertainty Mapping Guidance Note

1 Overview

This note updates Guidance Note 22 on Sensitivity Analysis and Uncertainty and supersedes all previous guidance notes issued on these topics. The revised Guidance Note 22 now includes alternative recommendations for the representation of uncertainty in the flood maps.

The objective of the proposed approach to representing uncertainty is to incorporate the best available knowledge of the modelling limitations into the analysis without requiring significant additional input from the CFRAM consultants. To do this the approach will use the understanding provided by the sensitivity analyses to determine the level of uncertainty. The proposed approach is an alternative option only and consultants are free to continue to use the approach outlined in the project brief if preferred.

The proposed representation of uncertainty will be through a second flood extent developed for the 10%, and 1% flood extents only. These extents will not be presented on the standard flood maps but will only be provided online as separate uncertainty maps with the relevant best estimate flood extent. There would therefore be no requirements to include the alternative line-type around the design extents as currently outlined in the project brief. This should simplify the presentation of the flood maps whilst allowing uncertainty maps to be made available as required.

The development of the uncertainty bounds will utilise only the results from those sensitivity tests that are found to produce the largest increase in the predicted flood extent. Where two sensitivity tests are producing a comparable increase in the predicted flood extent in an area of interest then further consideration of the appropriate uncertainty bound as described below in Section 3 is required.

The key steps are as follows:

1. Prepare screening assessment from knowledge of model build and its calibration
2. Undertake sensitivity tests on hydrological parameters
3. Undertake sensitivity tests on core hydraulic parameters
4. Undertake additional hydraulic testing where it is scoped in
5. Assess which test or combination is to be displayed on the maps

To minimise the work load associated with the alternative approach it has been agreed to represent uncertainty on the medium priority flood extents using the alternative line-type approach and classify the full medium priority reach as highly uncertain. Similarly it has been agreed that uncertainty mapping will not be required for the Flood Zone maps as there is no guarantee that this information would be utilised if made available.

This note first discusses the required approach to completing the sensitivity analysis before highlighting how the results from this analysis can be incorporated into the uncertainty mapping.

2 Sensitivity Analysis

Section 7.4 of the project brief states that:

The Consultant shall undertake sensitivity tests for each and all forms of modelling as described above as appropriate to determine the robustness and sensitivity of the models and the design flood levels, extents, etc. estimated using the models. Such tests should include, but not necessarily be limited to, variations in roughness parameters, flow values, boundary conditions and (within APSRs) afflux parameters at hydraulically-significant structures.

The nature of the sensitivity analysis and the model parameters assessed means that any analysis will be based on engineering judgement only, however by maximising the hydraulic modellers knowledge of the site, sensitivity assessments can be representative of the limitations of the data availability for the site.

It is not appropriate to adopt a generic approach to the sensitivity analysis, rather a screening judgement should be made as to those tests that are applicable and required for a given AFA. Once decided, analyses should be AFA specific and utilise knowledge of the site. Decisions and justification will need to

be recorded as part of the hydraulics reporting.

Typically, sensitivity analyses will be run for the 1% AEP event, however to support the development of uncertainty bounds described in Section 3 it will also be necessary to run the 10% AEP event. In some instances this will require a variation to the sensitivity tests applied for the 1% AEP event.

The following sections discuss the range of the sensitivity tests required and provide examples of how parameters should be adjusted to reflect known uncertainties. In all cases it is important to consider the sensitivity tests as a sensible shift within the bounds of reasonableness. Therefore, if through the calibration/validation process, parameters have been increased towards the upper limits of reasonableness for a given parameter then the additional shift for a review of sensitivity will be less than if no calibration/validation process has been carried out and default parameters have been applied. Increased confidence in model results will be directly linked to the calibration classifications discussed in Guidance Note 23 and reference to these classifications will support and guide the level of sensitivity tests required.

The following sensitivity tests are outlined for consideration:

Table 2-1: Sensitivity tests for consideration

Mandatory	Optional tests following Screening Assessment
Flow (1% AEP Event)	Building representation (1% and 10% AEP Event)
Roughness (1% AEP Event)	Flow volume (1% and 10% AEP Event)
Water level boundaries (1% AEP Event)	Afflux/head loss at key structures (1% and 10% AEP Event)
	Timing of tributaries (1% and 10% AEP Event)
	Flow, roughness and water level boundaries (10% AEP Event)

This list is not exhaustive and where predicted flood risk is dependent on additional parameters or modelling assumptions, these should be highlighted in the model report and investigated through further sensitivity tests.

Sensitivity tests to flow, roughness and water level boundaries should be carried out on all models for the 1% AEP event. Sensitivity tests to building representation, flow volume, afflux at key structures and timing of tributaries for the 1% AEP event and for all tests listed in Table 2-1 for the 10% AEP event should be carried out where a screening exercise has identified that there remains significant uncertainty and models may be underestimating flood risk.

2.1 Flow

As flow is probably the most critical of all the sensitivity tests it will be important to consider the quality of data available in the derivation of the design flows.

Table 2-2 provides a scoring mechanism through which each watercourse is attributed a score from each row of the table reflecting the level of confidence in the hydrology. The resulting scores are summed to provide an overall indication of uncertainty and used to look up in Table 2-3 the uncertainty weighting to apply.

The uncertainty in QMED can be assessed using the equations for SE and FSE provided in the FSU WP2.2 report. These are provided for estimates derived from catchment descriptors, which will give a scaling factor of 1.37, and can be calculated at gauge sites which have been typically found to be around 1.06. Site with donor adjustments will be in between these values and it is recommended an adjustment factor of 1.2 is applied.

This QMED adjustment factor reflects the uncertainty in the index flood but does not reflect the uncertainty in the growth curve, for this reason an additional adjustment factor is included for the 1% AEP

event. A review of single site analyses with greater than 40 years of data produced an uncertainty adjustment factor for the growth curve of approximately 1.2. Use of pooling groups would reduce this uncertainty suggesting an adjustment factor of 1.1 is appropriate. Uncertainty at the upper end is harder to quantify and consultants should review the adjustment factors produced using this scoring system to confirm they are appropriate.

Table 2-2: Flow sensitivity scoring system

Scoring Parameter	Score of 1	Score of 3	Score of 5	Score of 7
Is there a local recording gauge/s that have been used as a donor for the hydrology or to provide confidence in the hydrology by other means?	Within 5km of the AFA and on the same watercourse with no significant other inflows between the gauge and the AFA OR Upstream and downstream of the AFA with no significant other inflows between and routing of flows supports the hydrology	Within 5km of the AFA but not on the same watercourse or with significant other inflows between the gauge and the AFA	Beyond 5km or with significant other inflows between the gauge and the AFA	No useable gauge
What is the length of record of the local gauge?	Greater than 40 years	Between 20 and 40 years	Between 2 and 20 years.	No useable gauge
What quality is the record from the gauge?	Rating review carried out, high confidence	Rating review carried out, moderate confidence or no rating review carried out but gauge is FSU class A	All other sites.	N/A.
What unusual features are there in the catchment hydrology?	None – a rural catchment typical of many in the gauged datasets	Some lakes (0.99>FARL>0.9) or urbanisation (0.05<URBEXT< 0.15)	Some karst or extensive lakes (FARL<0.9) or urbanisation (URBEXT>0.15) or arterial drainage	N/A
What is the size of the catchment	N/A	N/A	<25km	N/A

Table 2-3: Flow sensitivity adjustment factors

	Summed Scores			
Return Period of Event	**Score up to 6**	**Score of between 7 and 14**	**Score of between 15 and 22**	**Score above 23**
10%	No sensitivity test required.	Use QMED uncertainty	Use QMED uncertainty	Use QMED uncertainty
1%*	Use QMED uncertainty then apply adjustment factor of 1.1	Use QMED uncertainty then apply adjustment factor of 1.2	Use QMED uncertainty then apply adjustment factor of 1.3	Use QMED uncertainty then apply adjustment factor of 1.5.
***** Where extensive areas of karst with connections to the surface water system is present then use QMED uncertainty then multiply flows by 2.0 to reflect the uncertainty in the 1% event flow.				

2.2 Roughness

As part of the hydraulic modelling work completed it is expected that channels will have been assessed for typical vegetation cover. Using these descriptions and an understanding of the maintenance regime carried out by the local authorities and OPW it should be possible to determine high and low end roughness values for each channel. The hydraulic modeller should justify the variations to this parameter based on the known conditions on site.

If one or more large events have been observed and sufficient data is available with which to calibrate the roughness within the channel then it will not be necessary to vary Manning's n to the full extent suggested in the tables below. It is also noted that in large events with greater depths the influence of channel roughness will often reduce. Again in these instances a variation to the maximum upper bound may not be applicable.

The following tables provide typical roughness values and upper and lower bounds for various surfaces. These can be used as a guide or, if preferred, alternative data sources can be referenced and applied when determining appropriate sensitivity tests. It is not proposed that upper values are applied with no consideration of local factors as discussed above.

Table 2-4: Typical roughness bounds for river channels

Channel Substrate	**Roughness Values (Manning's n)**		
	Typical Value	**Lower Bound Value**	**Upper Bound Value**
Bedrock	0.025	0.023	0.028
Cobbles (64-256mm)	0.055	0.04	0.07
Coarse Gravel	0.035	0.022	0.04
Gravel (2-64mm)	0.03	0.028	0.035
Sands	0.025	0.023	0.032
Silt	0.022	0.02	0.025
Clay	0.02	0.018	0.023
Concrete	0.02	0.018	0.022

Simplified version of Table 10 from Reducing Uncertainty in River Flood Conveyance. Roughness Review. By Karen Fisher and Hugh Dawson. DEFRA / Environment Agency Flood and Coastal Defence R&D Programme, Project W5A-057. July 2003.

Table 2-5: Typical roughness bounds for river banks

Bank Material	Roughness Values (Manning's n)		
	Typical Value	**Lower Bound Value**	**Upper Bound Value**
Scrub/Long Grass	0.04		
Bushes	0.06		
Trees – flood level not reaching branches	0.07	0.05	0.13
Trees – flood level reaching branches	0.15	0.1	0.2

Simplified version of Table 16 and 23 from Reducing Uncertainty in River Flood Conveyance. Roughness Review. By Karen Fisher and Hugh Dawson. DEFRA / Environment Agency Flood and Coastal Defence R&D Programme, Project W5A-057. July 2003.

Table 2-6: Typical roughness bounds for rivers to flood stage

General Channel	Roughness Values (Manning's n)		
	Typical Value	**Lower Bound Value**	**Upper Bound Value**
Clean, straight, full stage, no rifts or deep pools	0.030	0.025	0.033
As above but more stones and weeds	0.035	0.030	0.040
Clean, winding, some pools and riffles	0.040	0.033	0.045
As above but some weeds and stones	0.045	0.035	0.050
As above but lower stages, more ineffective slopes and sections	0.048	0.040	0.055
As above but more stones	0.050	0.045	0.060
Sluggish reaches. Weedy deep pools	0.070	0.050	0.080
Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.100	0.075	0.150
Mountainous streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high water levels. Bed: gravels, cobbles and a few boulders.	0.040	0.030	0.050
Mountainous streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high water levels. Bed: cobbles and with large boulders.	0.050	0.040	0.070

Simplified version of Table A1.1 from Culvert design and operation guide, CIRIA C689, 2010.

Floodplain Manning's n values should be adjusted in the same roughness sensitivity test. Digital data on floodplain surface types is generally limited however a suggested range of typical floodplain roughness values are provided below.

Table 2-7: Typical Roughness Values in the Floodplain

Floodplain Material	Roughness Values (Manning's n)		
	Typical Value	**Lower Bound Value**	**Upper Bound Value**
General Natural Surfaces	0.040	0.030	0.050
Buildings	0.300	0.100	1.000
Inland Water	0.035	0.025	0.045
Roads, Tracks and Paths	0.015	0.013	0.017
Non-coniferous Woodland	0.070	0.060	0.100
Coniferous Trees	0.100	0.080	0.120
General Manmade Surfaces	0.017	0.015	0.020
Glasshouses	0.200	0.100	0.300
Rock	0.050	0.040	0.070
Mixed Vegetation	0.080	0.060	0.110

2.3 Building Representation

Buildings in the floodplain can dictate flow paths and some consideration of how the preferred representation of buildings influences the flood extent is required.

The preferred methods for floodplain and building representation appear to be AFA specific. For example, a major conurbation could utilise a generic roughness approach whereas a small AFA outline could be heavily influenced by an individual riverside or floodplain building and hence a bespoke method may be appropriate.

The key aim of the sensitivity tests is to ascertain whether the selected approach is appropriate and whether by changing the level to which buildings dictate flow routes, alternative routes are identified. For example if a generic roughness approach is used full storage within buildings is available from ground level, raising thresholds in the sensitivity would divert low flows around buildings and reduce the storage available in the floodplain and potentially cause flooding elsewhere; modelling buildings as voids would be an extreme example of this where there is no floodplain storage within buildings.

Building representation will be different for different CFRAMs and different AFAs within each CFRAM but the essential approach to this sensitivity should be to;

- increase the influence of buildings where they have a low influence, (i.e. have been modelled as reduced hydraulic conveyance only with full floodplain storage allowed), either by increasing thresholds or modelling buildings as voids in the active floodplain,
- or reduce the influence where they have a high influence (i.e. have been modelled with raised thresholds or as voids) by modelling a bare earth scenario where the influence of buildings is represented by reduced hydraulic conveyance only.

The results of the sensitivity test will determine if the alternate approach needs to be adopted for all model runs for the AFA or if it can remain as a demonstration of sensitivity only.

2.4 Water Level Boundaries

The effect of rising sea levels is being investigated through the climate change scenarios and it is recommended that the change quoted for the MRFS is used to test sensitivity to sea levels.

Requiring further consideration may be the initial conditions in lakes within hydraulic models. Where long term level data from gauges on the lake, or historic data is available, this should be reviewed to determine

levels in a typical year and in an extreme year during winter months. Where no long term or historic data is available an estimate of appropriate changes in water levels is required; an increase in lake levels of 1m is proposed.

Where the water level boundary is situated on a river, the potential implications associated with changes to this boundary should be considered given Section 1.2.2.4 of the project brief requires HPWs to extend a sufficient distance downstream of an AFA to minimise the risk of any downstream boundary uncertainty. For this reason sensitivity tests for downstream boundaries on watercourses will not generally be required. Where there is potential for downstream water levels to impact sites within an AFA (typically on large flat watercourses), then MPW models should be used in conjunction with the flow sensitivity test to determine potential increases in water levels. Where tributaries join larger watercourses, increases in levels can be extracted from these models however care should be taken not to apply unrealistic joint probability events, i.e. coinciding a 1% AEP peak flow on a small tributary with the same event on a larger watercourse.

2.5 Flow Volume

Hydrograph durations will have in some cases been developed from observed data. Where this data consists of multiple hydrographs in excess of the 10% AEP event it is considered a reasonable approximation of the flood duration has been made and a significant increase in flow volume will not be required.

In other cases flood durations may have been developed from single events or from catchment descriptors only, in these cases there will be much more uncertainty in the flood duration applied. Because of the different approaches being used to develop hydrographs across the CFRAM it is not possible to be prescriptive for this sensitivity test. Instead it is assumed that some analysis will have been done comparing hydrographs generated from catchment descriptors at gauge sites and indicative scaling factors can be extracted from this analysis

Table 2-8: Adjustment Factors for Flood Duration

Description of Site	Sensitivity Adjustment Factor applied to Flood Duration
Flood duration has been developed from a single observed event data or multiple events below the 10% AEP.	1.2
Flood duration has been developed from catchment descriptors and there are few or no lakes in the upstream catchment (FARL>0.9)	Adjustment factors to be developed by CFRAM consultants reflecting preferred approach for hydrograph generation.
Flood duration has been developed from catchment descriptors and there are extensive lakes in the upstream catchment (FARL<0.9)	

2.6 Afflux/Head loss at Key Structures

General modelling units and parameters can often not fully represent the head loss that can occur at atypical or complex structures. Whilst it is not realistic to model these structures exactly as observed on site it is feasible to investigate if additional flooding could result from variability in head loss away from the standard representation included in the modelling software. This sensitivity test will review the potential implications of additional head losses at a structure above those predicted through normal modelling methods.

It is recommended that this analysis is completed for those structures that are likely to have an impact on either the scale of flood risk or future flood risk management measures only.

Head losses at a given structure are related to the velocity head and as a preliminary screening

assessment, local flow velocities can be reviewed to determine if the head losses required to cause additional flooding can be realistically achieved.

Where additional flooding appears to be a risk, a review of the maximum potential head loss at peak velocity needs to be completed. Published head loss coefficients describe losses associated with the expansion and contraction of flows at structures. It is therefore proposed that the structure be remodelled using a conservative estimate of head loss based on published values, either as a series of loss units or by adjusting calibration coefficients in the model to reflect the expected head loss calculated using this method.

For example losses across a bridge could be calculated using the typical bridge expansion and contraction coefficients detailed below and then, if these are greater than currently predicted, should be re- modelled by adjusting calibration parameters to deliver this loss at peak velocity. Alternatively losses at an inlet controlled culvert could be calculated using the culvert contraction loss and compared to the modelled representation of the culvert inlet.

Where there are additional complexities within the structure additional losses associated with further contractions and expansions of flows would need to be incorporated.

Table 2-9: Typical Head Loss Coefficents

	K Value
Calculated expansion loss	$K = (1 - \frac{W1}{W2})$ where W1 and W1 are the upstream and downstream widths
Typical bridge expansion	K = 0.5
Culvert contraction	K = 0.44
Abrupt expansion	K = 0.8
Square edged contraction	K = 0.3 (lower bound 0.23, upper bound 0.35)
Round edged contraction	K = 0.15 (lower bound 0.1, upper bound 0.2)
Typical bridge contraction	K = 0.3
Abrupt contraction	K = 0.6

Based on Table 5-2 in the HEC-RAS manual

Note: expansion losses are applied to upstream velocities and contraction losses are applied to downstream velocities.

2.7 Timing of Tributaries

Design events assume a consistent storm falls across a river basin and allow the response and size of each catchment to determine the occurrence of peak flows in the watercourse. Understanding this response is particularly important at the confluence of tributaries where downstream flows are the product of the combined response of two upstream catchments. This sensitivity test aims to understand the potential implications of a different catchment response resulting in higher peak flows downstream of a confluence, i.e. the peak flows on two contributing watercourses occur closer together.

It is not considered realistic to simply adjust inflow hydrographs from separate watercourses so that peak flows coincide, effectively making downstream flows the sum of the maximum flow on each tributary. Instead the timing of the inflow hydrograph peak of the smaller watercourse will be moved closer to peak of the larger watercourse by up to 10% of the overall duration of the smaller watercourse hydrograph. This will prevent moving smaller tributary inflows to 'sit' on the peak of a larger watercourse.

Flows at all confluences should be screened however it will not be necessary to complete this sensitivity test if the increase in flows resulting from the adjusting the timing of tributaries is less than the increase in flows being assessed in the flow sensitivity test.

3 Presentation of uncertainty

3.1 Scope

The objective of any alternative methodology is to deliver more representative uncertainty bounds than are currently produced using the RPS/Halcrow methodology whilst not increasing the work load required to produce these bounds.

This approach is applicable for the representation of uncertainty on flood maps. In determining uncertainty and freeboard in scheme investigations a more detailed site specific analysis will be required.

3.2 Data

The proposed approach will utilise readily available information developed as part of the sensitivity analyses discussed above, thereby limiting the additional work to be completed. Confidence in how these sensitivity assessments are undertaken is therefore an important consideration in the expected accuracy of the confidence bounds. The process requires thought and justification on the part of the hydraulic modeller for the variation in modelling parameters but the reporting of this should provide an auditable trail for the basis of the resulting flood maps.

It is noted that a similar justification would be required for the development of the data quality/confidence parameters that are fed into the RPS/Halcrow tool without the benefit of visualising the implications of any decisions.

3.3 Methodology

In developing an uncertainty bound from the sensitivity tests it is proposed that the sensitivity test resulting in the greatest flood extent for a given location be used as the uncertainty bound in all cases. The final uncertainty bound will therefore be the result of all sensitivity tests overlain using a GIS package to produce a final merged uncertainty bound. This suits the 2d modelling packages being used on the CFRAMs, and avoids extending a random ΔH across cross sections to form an outer outline.

This approach, which applies the single most sensitive parameter adjustment in all locations, is different from a typical sum of squares approach which applies a proportional allowance for each source of uncertainty.

It is noted that in the majority of cases the hydrology sensitivity test will produce the greatest uncertainty extents, reflecting the fact that hydrology is usually the greatest source of uncertainty in modelling. However, in the particular locations where multiple uncertainties are present to equivalent extents, a review should be undertaken, and if necessary an additional model run completed to incorporate a greater worst case scenario by modelling a combination of uncertainties for that specific location.

The approach for combining uncertainties has been developed in response to the unlikely eventuality that multiple sensitivity tests are producing similarly large increases in flood extents. Combinations will not be required where sensitivity test extents are close to the baseline. Only those combinations the consultant considers appropriate will need to be assessed and these can all be included in a single model run if desired. Therefore whilst there are a large number of possible combinations the consultant should attempt to minimise additional runs where possible.

The following points highlight examples where it may be possible to scope out combinations of uncertainties:

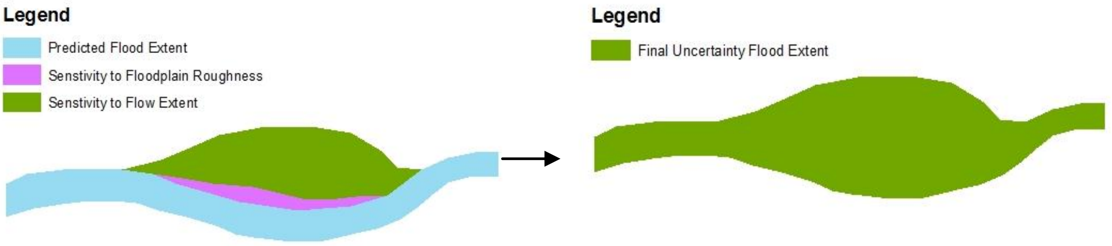
- The sensitivity tests for flow, water level boundary within lakes and timing of tributaries will all have the effect of increasing downstream flows. As such it is likely only the worst of these will be required in any combination event unless the sensitivity tests demonstrate that increases in downstream flows from these are of equivalent magnitude, in which case some combination event will need to be considered.
- Where the combination of flow and tidal boundaries is reviewed in depth in the joint probability analysis this test will not be required.
- Building representation is reviewed to determine the most appropriate method for representing buildings in a given AFA, however if significant variation is apparent between methods and there is cause to justify either approach then a combination of the alternative method with the most significant sensitivity test will likely be required. In this example the uncertainty bound could vary significantly from the best estimate of the extent.

The critical joint sensitivity tests will therefore likely be an increase in flow of one form or another in conjunction with an increase in flow volume and additional losses at structures. If each of these are found to produce similarly large extents in one location it is recommended a worst case combination event is run to provide a conservative uncertainty bound.

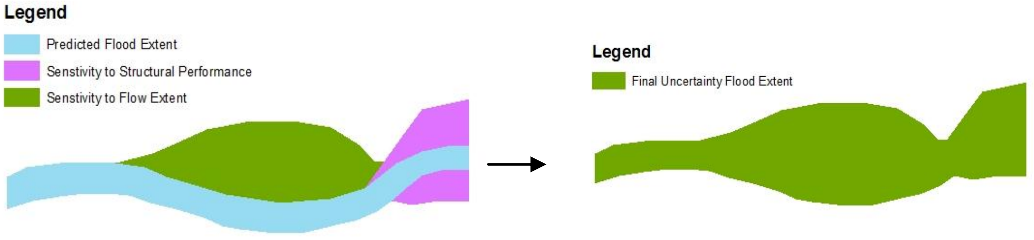
In summary the approach is as follows:

1. Complete hydraulic modeller led sensitivity assessments and document findings
2. Map 2D model results and review extents to identify where multiple sensitivity tests produce similarly extreme outlines.
3. Run extreme sensitivity model run if required.
4. Overlay and merge in GIS to develop a final uncertainty bound.

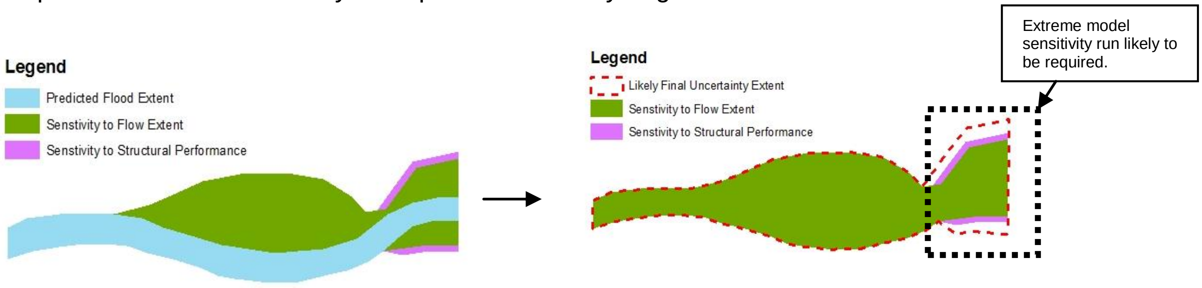
Example 1 – A single sensitivity test produces the greatest bound



Example 2 – Different locations are sensitive to different sensitivity tests



Example 3 – Different sensitivity tests produce similarly large extents in critical areas



3.4 Discussion

The benefits of this approach are as follows:

- The use of the hydraulic modelling outputs effectively allows uncertainty to be assessed in detail at all locations rather than on a reach scale. This is the benefit of the application of 2D modelling in HPW reaches.
- The production of the uncertainty map by building on the sensitivity tests allows modellers/reviewers to see 'behind' the uncertainty bounds in the final map to understand where there are large changes in the extent and why. This compares to the original approach as indicated in the CFRAM Generic Specification that develops an increase in water levels based on an empirical formula derived from a limited number of watercourses.
- Hydraulic modeller input into the sensitivity analysis and the process of the sensitivity testing allows the implications of changes to model assumptions to be better understood and reduces the risk of unwanted outcomes from the current approach, for example a large uncertainty bound where hydraulic modellers feel there is good certainty in the output.
- Less work associated with splitting the watercourse into uncertainty reaches.

The disadvantages of this approach are as follows:

- Potential for inconsistent application between CFRAMS as it relies on professional judgement for suitable parameter shifts. This guidance note attempts to mitigate this risk but it remains a reasonable caveat that different watercourses will be sensitive to different assumptions. This will always be a challenge.
- More work associated with model runs for the Q10 design event where the need for these sensitivity tests have been identified as required as part of the screening assessment.