A Data Register

B Hydrology Report

C Hydrogeology Report

D Hydraulic Model Check File

Contents

1 Introduction

This model check file has been prepared to document the model build process; it includes information on the modelling approach, details on the hydraulic structures included in the model and highlights assumptions made. This document has been prepared as an Appendix to the Carrigtohill Flood Risk Assessment Main Report.

2 Modelling Approach

2.1 Overview

The study area extends upstream beyond the extent of the original Lee CFRAMS model for Carrigtohill and also includes two reaches that were not modelled previously.

The approach taken was to first model these upper reaches as individual systems to carry out a preliminary assessment on flood risk at a number of key areas / structures. The 1D model systems for these individuals reaches (including those covered under Lee CFRAMS) were combined to form the basis for the overall 1D-2D linked model.

A 2D only model was also developed to assess the tidal risk along the coastal area of the study catchment, and not just at the downstream boundary of the fluvial reaches.

2.2 Available data

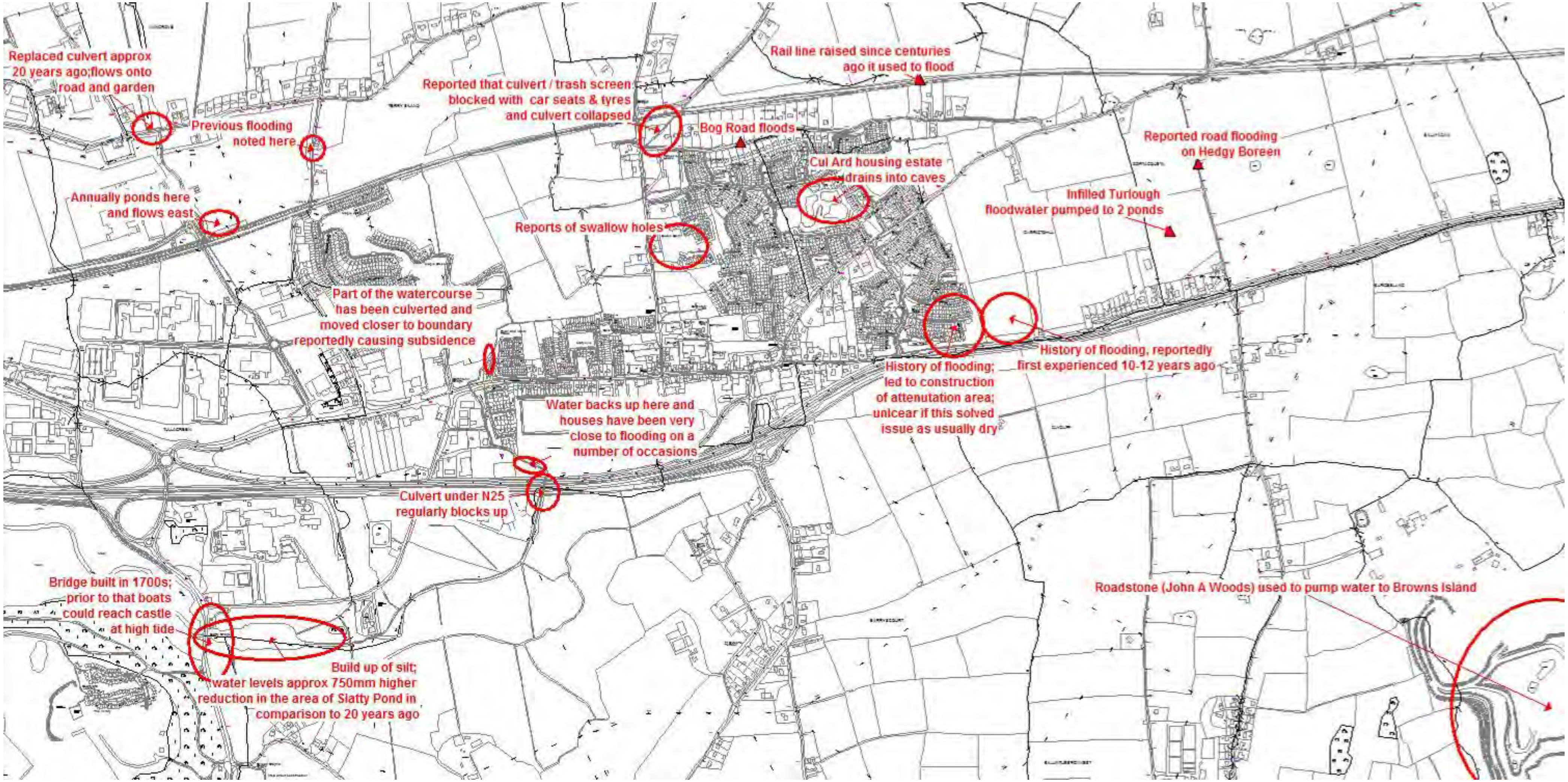
All available data was reviewed as part of the assessment. A public information day was held, where JBA met with the community chairman, landowners and local authority staff. Developers in the area, including IDA and Irish Rail were also consulted.

The information and datasets collated include the following:

- Original Lee CFRAMS Model and reports
- LIDAR
- Mapping and aerial photography
- Survey data
- Site visit photographs
- Drawings provided by developers – as-builts, topo and drainage design
- Carrigtohill Sewerage Scheme Preliminary Report, June 2008
- Slatty Pumps monthly reports
- Anecdotal evidence

Anecdotal evidence collected at the outset of the project is presented below in Figure 1.

Figure 1 Summary of Anecdotal Evidence



2.3 Model Basics

Model Construction - Summary	
Model Type(s) (and reasons)	Fluvial and some tidal runs – ISIS-TUFLOW Extreme Tidal Runs – TUFLOW only 4 river reaches surveyed and developed as separate ISIS models for inclusion / addition to the original Lee CFRAMS ISIS model. Linked 1D-2D (ISIS-TUFLOW) modelling was essential to model flood risk from fluvial overtopping but not for tidal (coastal) overtopping. To reduce the potential for instability arising from tidal inundation of narrow 1D watercourses, the ISIS channels were not considered to be an essential component of the tidal models and single domain TUFLOW only models were used to model the tidal flood risk.
Key Purpose(s) of model	Flood extent, depth and velocity mapping of Carrigtohill, in particular the land within the Special Local Area Plan (SLAP). There is a requirement to evaluate both the fluvial and tidal flood risk.
TUFLOW version used	TUFLOW.2012-05-AB-w64
ISIS version used	3.6
Key Model Directories	Carrigtohill ISIS-TUFLOW Fluvial Model Carrigtohill TUFLOW Tidal Model
Approach adopted	The linked fluvial model represents a physical extension upstream to the ISIS 1D model produced for the Lee CFRAMS and a link to 2D to represent floodplain flow. The model development consisted of: Creating a 1D-2D linked model for each river reach Extending each river reach upstream beyond the extent of the SLAP Including for groundwater based on detailed hydro geological study Including the pumping station at Slatty pond. Representing the flow split at the IDA estate where water passes under the rail line via siphons Including an extra river reach that was not part of the Lee CFRAMS Update of the Lee CFRAMS model based on new survey data. The tidal model is to assess the impact of varying tides along the coastal area of the Carrigtohill catchment. This assesses the impact based on the elevations of the shoreline / road embankment along the estuary.

2.4 Model Synopsis

Model Construction – 1D Domain (ISIS)	
Available Data	Channel survey for the lower reaches completed in June 2007 for the Lee CFRAMS project. Additional channel survey for the upper reaches in June 2012, with some sections re-surveyed within the original survey extent, where changes in the channel were observed or suspected or where access issue were an issue originally. LIDAR data collated for the Lee CFRAM project in 2007, 2m resolution DTM and DSM; the date this LIDAR was flown is unknown. OSi LIDAR data, 2m DTM, flown in March 2011.
General Schematisation	All watercourses are modelled with an upstream flow-time boundary and the downstream boundary is a tidal head-time boundary. Floodplain representation including reservoirs and floodplain sections in the original model were removed and spills were deactivated. Surveyed structures were included in the model and are detailed in Section 3.8.
Length of Model	
Total number of nodes	River units = 165 Interpolate river units = 67 Conduit units = 57 Total number ISIS units (including comments, junctions etc.) = 427
Labelling / numbering system	System aims to follow OPW naming convention as under national CFRAM programme however labelling has also been inherited from the original Lee CFRAMS model. Reach Codes are as follows: Kilacloyne Stream – KILA Tibbotstown Stream – TIBB (formerly 2CA1) Woodstock Stream – WOOD (formerly 2CA2) Poulaniska Stream – POUL (formerly 2CAR)

Model Construction – 2D Domain (TUFLOW)	
Choice of 2D domain	Fluvial 1D-2D model: An active domain of approx. 6.3km^2 was defined; this follows the line of high ground. Tidal 2D model: The active domain for the tidal 2D only model could be refined and measures approx 2.8km^2.
2D cell size	Fluival Model: 4m A relatively small cell size was necessary for the fluvial model as the watercourses are small. The 1D domain was defined to ensure at least 2 cell widths across the channel. Tidal Model: 10m A sensitivity check was carried out to test the impact of cell size.
Main 2D Topographic data source (s)	OSi 2m LIDAR flown in March 2011. Bank height survey collated in two river surveys, June 2007 and June 2012.
Problem with data quality	Some areas of NULL data in particular at Slatty Pond and along the watercourses.
Changes to model bathymetry	Fluvial Model: River banks were defined using elevation points at topographic river survey point location and interpolating between. Z lines were used to define road embankments and flow routes/channels. Local Z shapes stability patches were used to smooth the flood plain topography in troublesome areas. Tidal Model: Z lines were used to define the coastal boundary. Z shapes were used to fill in null data at Slatty Pond and tidal river reaches.
ESTRY components	ESTRY was used to define a number of floodplain culverts Fluvial Model: under the rail line. Tidal Model: under the rail line, N25 road embankment and at the model boundary

2.5 Model Folder Structure

The model folder structure used to save model files is shown below. The hydraulic model has been supplied to the client, Cork County Council in this format, as part of the deliverables of this project.

Fluvial Model

- CARRIGTOHILL FLUVIAL
  - check
    - DEF
    - UNDEF
  - model
    - GIS
    - isis
  - results
    - DEF_6.5HR
      - Q2_T2
      - Q2_T2_MRFS
      - Q5_T2
      - Q5_T2_MRFS
      - Q10_T2
      - Q10_T2_HEFS
      - Q10_T2_MRFS
      - Q25_T2
      - Q25_T2_MRFS
      - Q50_T2
      - Q50_T2_MRFS
      - Q100_T2
      - Q100_T2_HEFS
      - Q100_T2_MRFS
      - Q1000_T2
      - Q1000_T2_HEFS
      - Q1000_T2_MRFS
    - UNDEF_6.5HR
      - Q100_T2
      - Q100_T2_MRFS
      - Q1000_T2
      - Q1000_T2_MRFS
  - runs
    - batch
    - DEF_6.5HR
    - DEF_13HR
    - DEF_25HR
    - UNDEF_6.5HR
      - Q100_T2
      - Q100_T2_MRFS
      - Q1000_T2
      - Q1000_T2_MRFS

Tidal Model

- CARRIGTOHILL TIDAL
  - bc_dbase
  - check
    - 1d
  - model
    - GIS
  - results
    - Sensitivity
    - T2_HEFS
    - T2_MRFS
    - T5_MRFS
    - T10_HEFS
    - T10_MRFS
    - T25_MRFS
    - T50
    - T50_MRFS
    - T200
    - T200_HEFS
    - T200_MRFS
    - T1000
    - T1000_HEFS
    - T1000_MRFS
  - runs
    - batch

2.6 Summary of Model Files

ISIS - 1D Domain	
ISIS data file (s)	CARRIG_DEF_027.DAT CARRIG_UNDEF_030.DAT
ISIS event files	**6.5 HOUR DURATION** CARRIG_Q1000_6.5hr.IED CARRIG_Q100_6.5hr.IED CARRIG_Q50_6.5hr.IED CARRIG_Q25_6.5hr.IED CARRIG_Q10_6.5hr.IED CARRIG_Q5_6.5hr.IED CARRIG_Q2_6.5hr.IED LATERALS_Q1000_6.5hr.IED LATERALS _Q100_6.5hr.IED LATERALS _Q50_6.5hr.IED LATERALS _Q25_6.5hr.IED LATERALS _Q10_6.5hr.IED LATERALS _Q5_6.5hr.IED LATERALS _Q2_6.5hr.IED CARRIG_T2.IED CARRIG_T200.IED CARRIG_T1000.IED CARRIG_T2_HEFS.IED **13 HOUR DURATION** CARRIG_Q100_13hr.IED LATERALS _Q100_13hr.IED CARRIG_T2_13.IED CARRIG_T200_13.IED **25 HOUR DURATION** CARRIG_Q100_13hr.IED LATERALS_Q100_13hr.IED CARRIG_T2_25.IED CARRIG_T200_13.IED The fluvial inflows and tidal boundaries were stored in separate ied files to ensure maximum flexibility when modelling different fluvial/ tidal event combinations.
Hydraulic boundary conditions	Four QTBDY inflow units One HTBDY downstream boundary.
Initial conditions	From DAT File
ISIS results file location	See 2.5 of this Appendix for locating ISIS results files.

TUFLOW - 2D Domain	
TUFLOW Control (tcf / ecf) file(s)	Carrigtohill 1D-2D Fluvial Model DEF_6.5HR_Q1000_T2.tcf DEF_6.5HR_Q200_T2.tcf DEF_6.5HR_Q100_T2.tcf DEF_6.5HR_Q50_T2.tcf DEF_6.5HR_Q25_T2.tcf DEF_6.5HR_Q10_T2.tcf DEF_6.5HR_Q5_T2.tcf DEF_6.5HR_Q2_T2.tcf **Pump Off Scenario (undefended)** UNDEF_6.5HR_Q1000_T2.tcf UNDEF_6.5HR_Q100_T2.tcf **Carrigtohill 2D Tidal Model** Carrig_~e~.tcf Tidal_Events.tef All models make use of a common commands file: **Fluvial model:** Carrig_Common_Commands_007.trd **Tidal model:** Carrig_Common_Commands_tidal_012.trd
TUFLOW geometry (tgc) file(s)	**Fluvial model:** CARRIG_006.tgc **Tidal model:** CARRIG_tidal_012.tgc
TUFLOW boundary control (tbc) file(s)	**Fluvial model:** CARRIG_006.tbc **Tidal model:** CARRIG_Tidal_011.tbc
TUFLOW database and boundary file(s)	**Fluvial model:** 2d_bc_hxi_TIBB_001 2d_bc_hxi_KILA_003 2d_bc_hxi_2CA1_001 2d_bc_hxi_WOOD_001 2d_bc_hxi_2CA2_001 2d_bc_hxi_2CAR_001 2d_bc_hxi_POUL_001 2d_bc_hxi_RAIL_001 No TUFLOW database **Tidal model:** 2d_bc_tide_004 bc_dbase_TIDE_001.csv Tidal graph data for all events are stored in separate csv files: T50.csv T200.csv T1000.csv T2_MRFS.csv

TUFLOW - 2D Domain	
	T5_MRFS.csv T10_MRFS.csv T25_MRFS.csv T50_MRFS.csv T100_MRFS.csv T1000_MRFS.csv T2_HEFS.csv T5_HEFS.csv T10_HEFS.csv T25_HEFS.csv T50_HEFS.csv T100_HEFS.csv T1000_HEFS.csv
TUFLOW materials (tmf) file(s)	CARRIG_Roughness.tmf (common to both models)
Active/ Inactive model cells file(s)	**Fluvial model:** 2d_code_CARRIG_001.TAB - defines active 2D domain The following files define the inactive 2D domain: 2d_bc_cd_TIBB_001 2d_bc_cd_KILA_002 2d_bc_cd_POUL_001 2d_bc_cd_WOOD_001 2d_bc_cd_RAIL_001 2d_bc_cd_2CA1_001 2d_bc_cd_2CA2_001 2d_bc_cd_2CAR_001 **Tidal model:** 2d_code_tidal_003 - defines active 2D domain
Main topographic zpt (.MID) file(s)	Fluvial Model: 2d_zpt_CARRIG_003 (4m cell size) Due to the larger model domain and relatively small cell size the Write and Read Zpts command are used, as a TUFLOW error relating to memory was encountered when attempting the newer Read Grid Zpts command. Tidal Model: CARRIG_DTM_ASCII_GRD_ING.txt
Topographic changes to the basic model grid (i.e. z-line, z-shape, z-point layer(s))	**Fluvial model:** zlines to define the top of river banks: 2d_zline_banks_KILA_002 2d_zline_banks_TIBB_001 2d_zline_banks_2CA1_001 2d_zline_banks_WOOD_001 2d_zline_banks_RAIL_001 2d_zline_banks_2CA2_001 2d_zline_banks_2CAR_001 2d_zline_banks_POUL_001 Elevation assigned to the lake as this is a null area in the LIDAR: 2d_zsh_IDA_pond_001

TUFLOW - 2D Domain	
	Smooth over NULL LIDAR areas: 2d_zsh_null_patches_001.MIF Edit DEM to facilitate likely flow routes: 2d_zline_null_data_001 2d_zline_flow_routes_001 2d_zsh_DEM_adjustments_001.MIF **Tidal model:** To remove null data: 2d_zsh_KILA_estuary_001 2d_zsh_tidal_rivers_001 2d_z_Slatty_Water_001 To define elevations along the tidal boundary: 2d_zline_main_shore_001 2d_zline_south_shore_001
Roughness layer(s)	Materials layers defining roads and buildings common to both models: 2d_mat_roads_001.MIF 2d_mat_buildings_001.MIF
Boundary layer(s)	**Fluvial model:** 2d_bc_hxi_TIBB_001 2d_bc_hxi_KILA_002 2d_bc_hxi_2CA1_001 2d_bc_hxi_WOOD_001 2d_bc_hxi_2CA2_001 2d_bc_hxi_2CAR_001 2d_bc_hxi_POUL_001 2d_bc_floodplain_culverts_001 **Tidal model:** 2d_bc_tide_004
Initial Water Level(s)	Default (i.e. ground level).
1D model components(s)	**Fluvial model:** 1d_x1d_isis_nodes_KILA_002.MIF 1d_nwk_KILA_002.MIF 1d_WLL_KILA_002.mif 1d_x1d_isis_nodes_TIBB_001.MIF 1d_nwk_TIBB_001.MIF 1d_WLL_TIBB_001.mif 1d_x1d_isis_nodes_WOOD_002.MIF 1d_nwk_WOOD_001.MIF 1d_WLL_WOOD_001.MIF 1d_x1d_isis_nodes_POUL_001.MIF 1d_nwk_POUL_001.MIF 1d_WLL_POUL_001.MIF 1d_x1d_isis_nodes_2CA1_001.MIF

TUFLOW - 2D Domain	
	1d_nwk_2CA1_001.MIF 1d_WLL_2CA1_001.MIF 1d_x1d_isis_nodes_2CA2_001.MIF 1d_nwk_2CA2_001.MIF 1d_WLL_2CA2_001.MIF 1d_x1d_isis_nodes_2CAR_001.MIF 1d_nwk_2CAR_001.MIF 1d_WLL_2CAR_001.MIF 1d_x1d_isis_nodes_RAIL_001.MIF 1d_nwk_RAIL_001.MIF 1d_WLL_RAIL_001.MIF ESTRY floodplain culverts: 1d_nwk_floodplain_culverts_001 **Tidal model:** ESTRY floodplain culverts: 1d_nwk_tidal_fp_culverts_002 1d_nwk_SlattyBr_001 1d_nwk_Kila_Outfall_001
Other files (s)	2d_loc_CARRIG_001 (common to both models)
Check files enabled	Q100_T2 Defended and Undefended Scenarios
Output map format(s)	XMDF
Map save options	Output Data Types: d v h MB1 Map save interval = 25 mins (for both models)
Velocity map option	Maximum Velocity Cutoff Depth == 0.1 Records peak velocity at depths greater than 0.10m; otherwise, record velocity at peak stage
Hazard map option	Based on outcomes of the NTCG workshops, under the national CFRAM programme, the UK hazard formula without debris factor has been adopted. Therefore the following command is used as land use is not applicable: UK Hazard Land Use == NOT SET If land use is set this allows use of the UK hazard formula with depth varying debris factor.
Time series (PO) lines	2d_po_CARRIG_002 2d_po_Tidal_001
TUFLOW results location	See 2.5 of this Appendix for locating TUFLOW results files within the folder structure used.

2.7 Summary of Maps & Design Run Requirements

Purpose of model runs: To produce flood extent, depth, velocity and hazard maps for a number of scenarios and events.

Summary of Maps Required: The following lists the outputs required as per the brief, subsequently modified and agreed with the client, Cork County Council.

Type	Flood Map	Flood Extent	Flood Depth	Flood Velocity	Flood Hazard Function	Flood Zone
Current	50%	Y	Y	Y		
	20%	Y	Y	Y		
	10%	Y	Y	Y	Y	
	5%	Y	Y	Y		
	2%	Y	Y	Y		
	1%	Y	Y	Y	Y	Y
	0.5%	Y	Y	Y		
	0.1%	Y	Y	Y	Y	Y
MRFS	50%	Y				
	20%	Y				
	10%	Y	Y			
	5%	Y				
	2%	Y				
	1%	Y	Y			Y
	0.5%	Y				
	0.1%	Y	Y			Y
HEFS	10%	Y				
	1%	Y				
	0.1%	Y				
Total Number of GIS layers:			45			

Consideration of the interaction between a fluvial flood event and a tidal event is necessary.

Joint Probability – Tidal and Fluvial: The chance / probability of an extreme tide and an extreme fluvial event occurring at the same time is generally considered to be very low and a joint probability analysis can be carried out to assess this. For this situation to be worthy of detailed JP analysis, the outcome i.e. flooding must depend on the combined occurrence of these conditions and the dependence between the two conditions must be non-trivial i.e. neither independent nor fully dependent.

In this case, under a current scenario (i.e. existing defended) the flood risk generated from an extreme fluvial event is largely **independent** of the tide. The presence of tidal flap valves and the pump station mean that the tide does not have a significant influence. The tidal flap valves prevent the tide propagating up the fluvial channel and also prevent flow from the river discharging to the estuary when tides are high (higher that the outfall invert). Although the flow through the flap valves is restricted, flow discharges from the fluvial system through the pump station. The pumps operate on a minimum level in Slatty Pond (-0.9mAD) regardless of the tide. The flapped outfall soffit levels (ranging from-1.39 to 0.01mAD) are well below the 50% AEP tide (2.309mAD). Based on initial model run results, when gravity discharge is possible the max discharge is approx. 5.5m^3/s, meaning that during an extreme fluvial event the pumps operate to pump water out of the fluvial system into the estuary for all but for 2 to 3 hours at low tide.

Once tidal overtopping of the R624 road occurs during extreme or future events, tide levels will influence flood risk. Based on the survey and LIDAR levels limited overtopping will occur during a 0.5% AEP (200 year) tidal event. Such tidal inundation it is assumed that the pumps will fail and these extreme tidal events are modelled using a 2D only model.

Therefore, in summary, the catchment has both a fluvial and tidal influence. However, under the current scenario, with the Slatty pump station operating and the tidal flap valves functioning as normal, flood risk in the catchment is influenced by the magnitude of the fluvial event (provided that the tide does not overtop the N25 and R624 road). Once tidal inundation occurs, flood risk in the lower end of the catchment is likely to be dominated by the tide. With such tidal inundation, it is assumed that the pumps will fail. These extreme tidal scenarios are modelled using a 2D only model and map the predicted flood extent along the whole shoreline of the study catchment.

Summary of Design Runs:

The design runs required to produce these flood maps are summarised in the table below:

	Model	Tidal AEP	Fluvial AEP	Current	MRFS	HEFS	Current Undefended	MRFS Undefended
Fluvial Events	1D-2D	50%	50%	Y	Y			
	1D-2D	50%	20%	Y	Y			
	1D-2D	50%	10%	**Y**	Y	Y		
	1D-2D	50%	5%	Y	Y			
	1D-2D	50%	2%	Y	Y			
	1D-2D	50%	1%	**Y**	Y	Y	**Y**	**Y**
	1D-2D	50%	0.10%	**Y**	Y	Y	**Y**	**Y**
Tidal Events	2D	50%	-	-	Y	Y		
	2D	20%	-	-	Y			
	2D	10%	-	-	Y	Y		
	2D	5%	-	-	Y			
	2D	2%	-	**Y**	Y			
	2D	0.50%	-	**Y**	Y	Y	**Y**	**Y**
	2D	0.10%	-	**Y**	Y	Y	**Y**	**Y**

1D-2D model runs:	21
2D model runs:	17
Total Number Runs:	**38**

Fluvial Events: All fluvial events are modelled in a 1D-2D linked model, with a 50% AEP (2 year) downstream tidal boundary. The tidal data from the Lee CFRAMS was utilised directly in this study. A 50% AEP tide was used in the absence of available data for a mean high water spring tide (MHWS). A 50% AEP tide is considered to be more conservative than a MHWS tide.

Tidal Events: Lower return period tidal events are assessed using the 1D-2D model and as discussed above, more extreme tidal events that result in tidal inundation across the N25 and R624 roads, are assessed using a tidal only 2D model. The tidal model is run to assess flood risk from a 50% AEP tidal event and greater, when tidal water begins to overtop the road embankment at Slatty Bridge. The tidal model assesses the likelihood / impact of tidal waters along the entire coastal area of the Carrigtohill catchment (rather than just assessing levels at the mouth of the watercourses that flow into the estuary). The tidal events modelled include all climate change scenarios.

Defended / Undefended Scenarios: The current existing scenario is defended. The undefended scenario is required to map the Flood Zones as per The Planning System and Flood Risk Management Guidelines. For the undefended scenario the Pumps are OFF with the sluices are operating normally. (are stuck open. In the ISIS model, control rules for the pumps are set to manual and stopped and the sluices are set to manual and open. A sensitivity check with sluices closed was also completed.

Although the road embankment will provide a role in limiting the egress of flood water it is not considered a flood defence and is not modified or removed for the undefended scenario. Informal ineffective defences, in the form of earthen berms and stone walls, were noted near Slatty Bridge, however due to the discontinuity in the line of these features these are not considered effective flood defences.

3 Model Build

3.1.1 River Reaches and Model Domain

Item	Notes	Comments
What software & reason for choice:	ISIS-TUFLOW Linked 1D/2D Model.	Specified in the brief The original model was developed in ISIS and the purpose of this study is to build on the original model and data.
Grid size selection:	Outline the reasons behind selection of grid sizes for the 2D domain	**Fluvial Model (1d-2d linked model):** The relatively small watercourses require a fine grid size to be appropriately represented in the 2D domain. A cell size of 4m was selected as a compromise between model representation and computational time. **Tidal Model (2d only model):** A cell size of 10m was used to model the tidal inundation that could occur in an extreme tidal event.
Coefficients:	State documentary sources.	***Manning's***: Chow, 1965; USACE 1995; HR Wallingford & Barr D, 1994; JBA internal guidance ***Culvert coefficients:*** CIRIA Culvert Design and Operation Guide C689
Model Proving:	Outline the test to be applied with the reason, the target accuracy and method of calculation	Sensitivity: **Fluvial Model:** • Storm durations 6.5 hour, 13 hour, 25 hour • Manning's n roughness • Blockage – excessive silt cleaned out And climate change scenarios will indicate the effect of: • Model Inflows ±20%; • Downstream boundary +1.0m. **Tidal Model:** • Cell Size • Manning's roughness See Section 7 for more detail on sensitivity analysis.
Any limitations in the method of modelling used:	E.g. If model is used for other flow rates would it require modification?	ISIS can struggle with steep watercourses. Care is required when inputting pumps as automatic extrapolation of pump curves within the ISIS software can be incorrect. The tidal 2d model does not represent any storage that may be available in the watercourse channels. This is considered reasonable as the watercourse cross sectional area is relatively small, in comparison to the flow volumes achieved from tidal inundation in extreme events.

3.2 Model Boundaries

The model has an upstream inflow boundary based on the hydrological analysis of fluvial flows in the catchment. The analysis followed the methodology outlined in the Flood Studies Update (FSU) to estimate the fluvial peak flows and included a statistical analysis based on the FSU pooling group. The Rainfall Runoff method outlined in the Flood Studies Report (FSR) and Flood Studies Supplementary Reports (FSSR) was used to derive the runoff hydrograph shape for each in the hydraulic model.

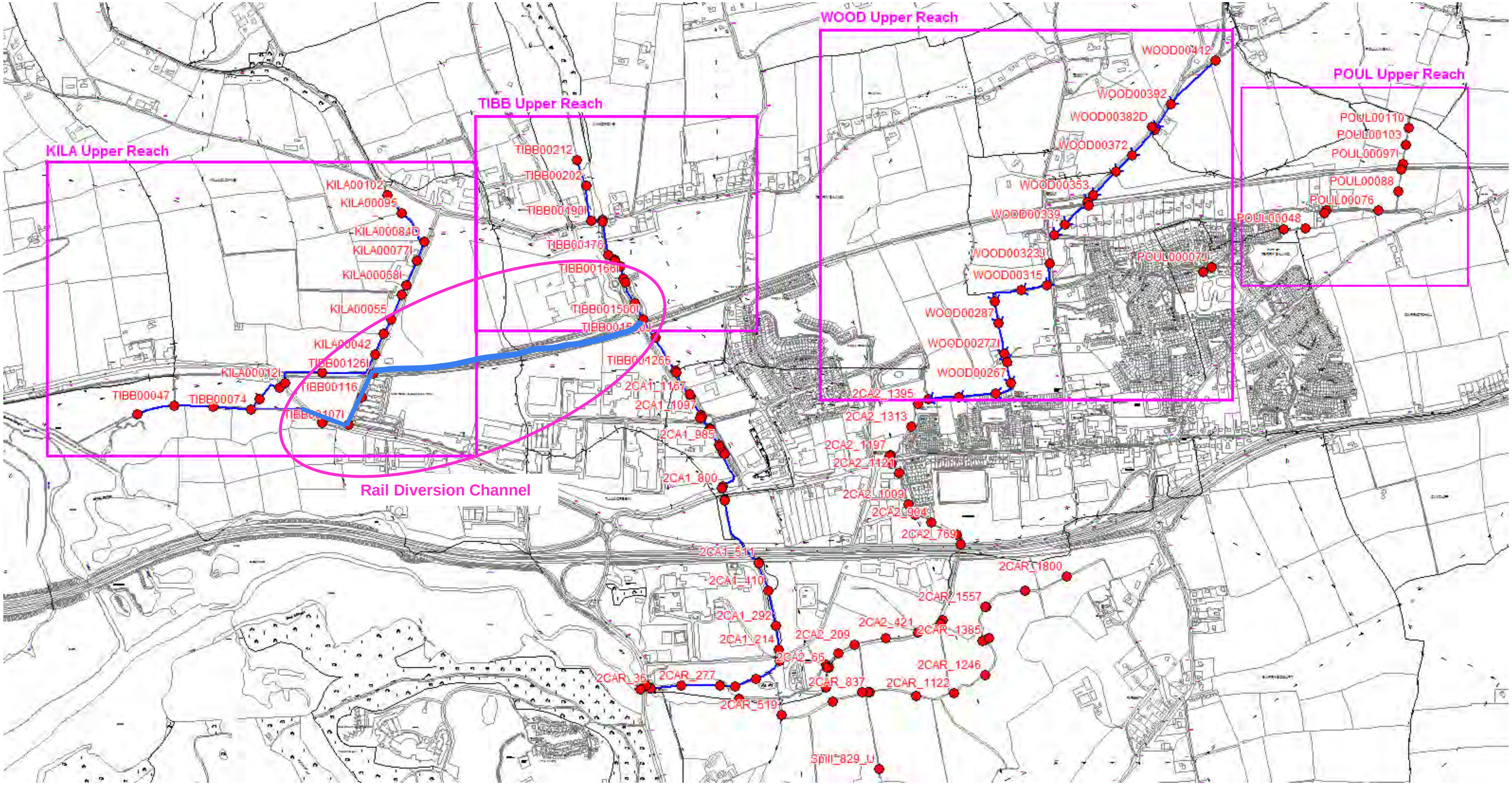
The downstream boundary is a tidal stage graph that is based on data used in the original Lee CFRAMS.

Model:	**Fluvial Model (1d-2d Linked Model)**
Upstream fluvial inflow boundary:	TIBB00212 WOOD00412 KILA00102 2CAR_1800
Lateral inflows:	760_FSU_inf 1187_FSU_inf 769_FSU_inf 1259_FSU_inf 188_FSU_inf 323_FSU_inf 167_FSU_inf Lat_2CAR Lat_2CAR2 Lat_KILA 2CAR_FSU_inf 323_RM_inf 1259_RM_inf 769_RM_inf
Tidal downstream boundary:	2CAR_-2 TIBB00035 Same tidal boundary used for Kilnacloyne and Tibbottstown Streams, which are located approx 2km apart. The time of the peak tide (in relation to the fluvial peaks) was tested in the sensitivity analysis runs with the tide shifted by =/- 3 hours.

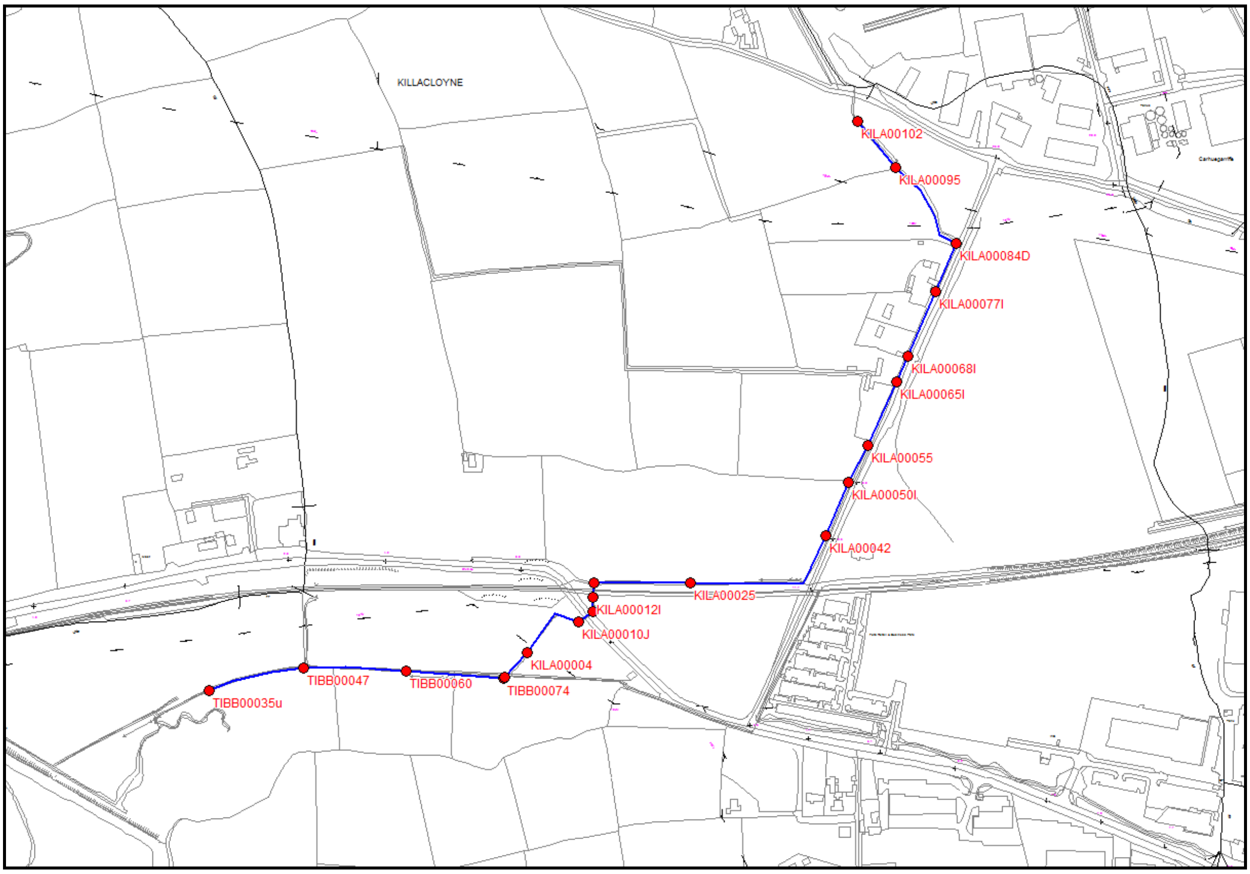
Model:	**Tidal Model (2d only model)**
Inflow boundary:	The same tidal boundary t is used as the hydraulic boundary for the 2D only model. This tidal stage graph is applied all along the shoreline of the Carrigtohill catchment.

3.3 1D-2D Model Schematic

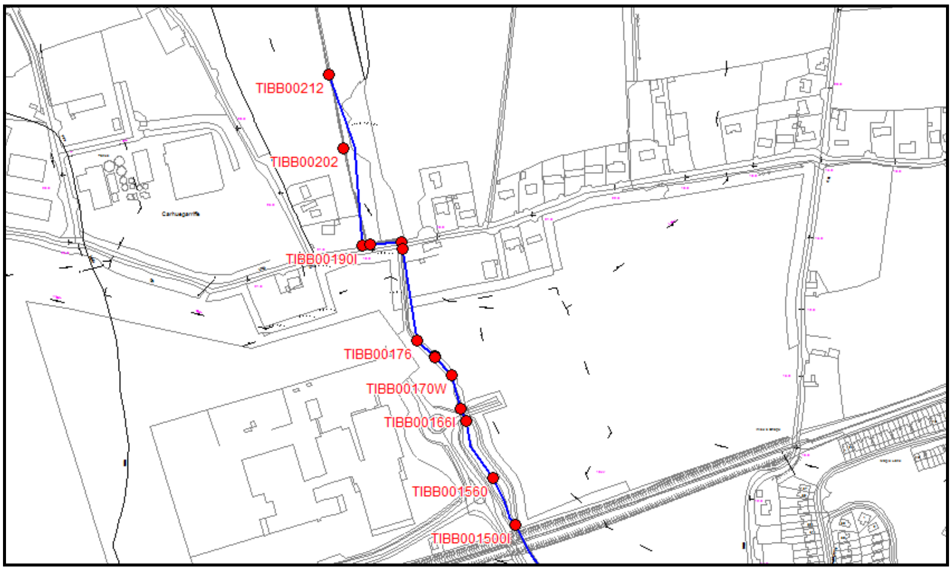
3.3.1 Overall Model Schematic



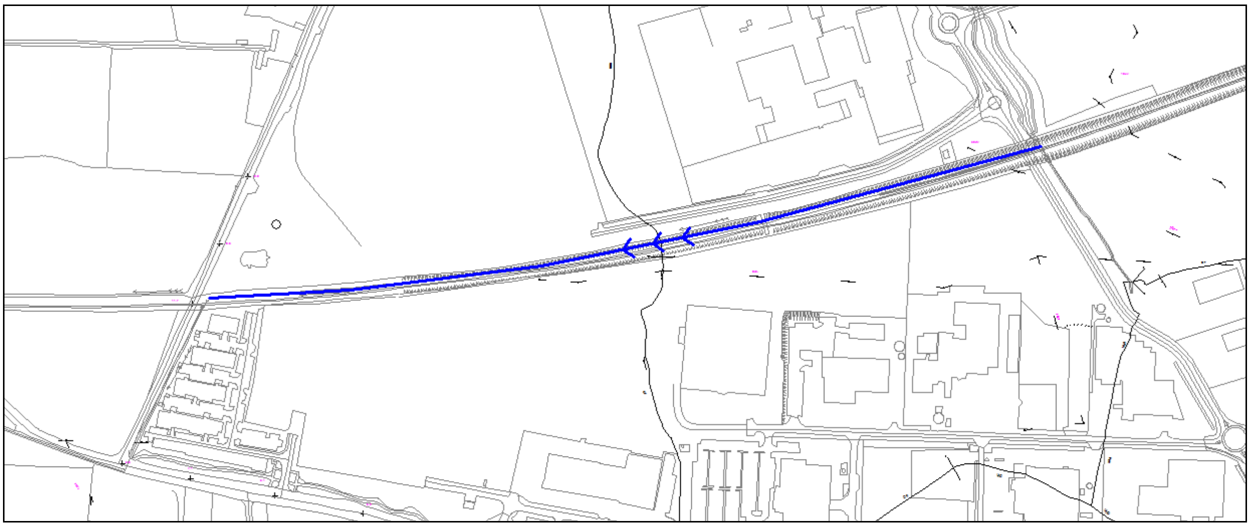
3.3.2 KILA Upper Reach Schematic



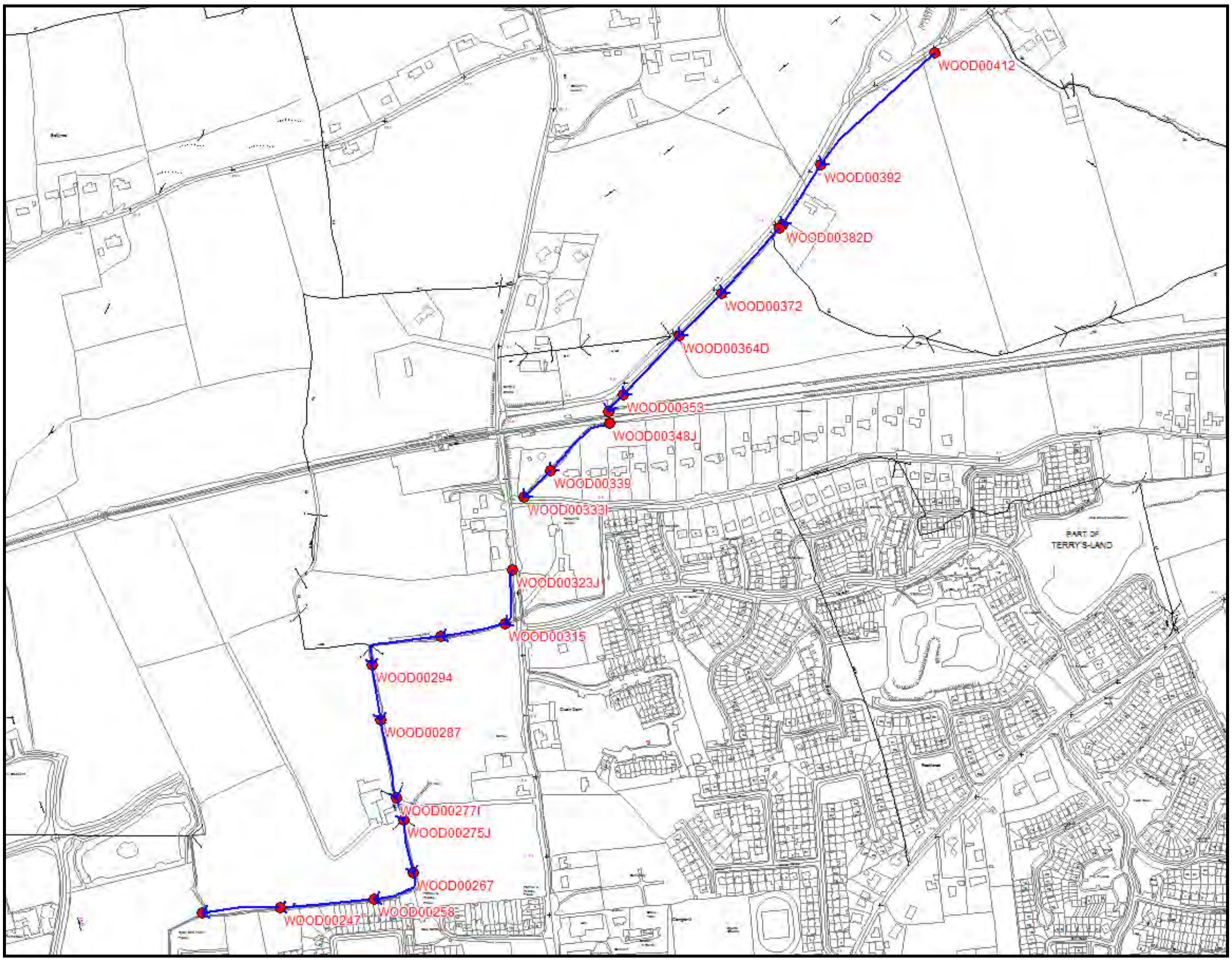
3.3.3 TIBB Upper Reach Schematic



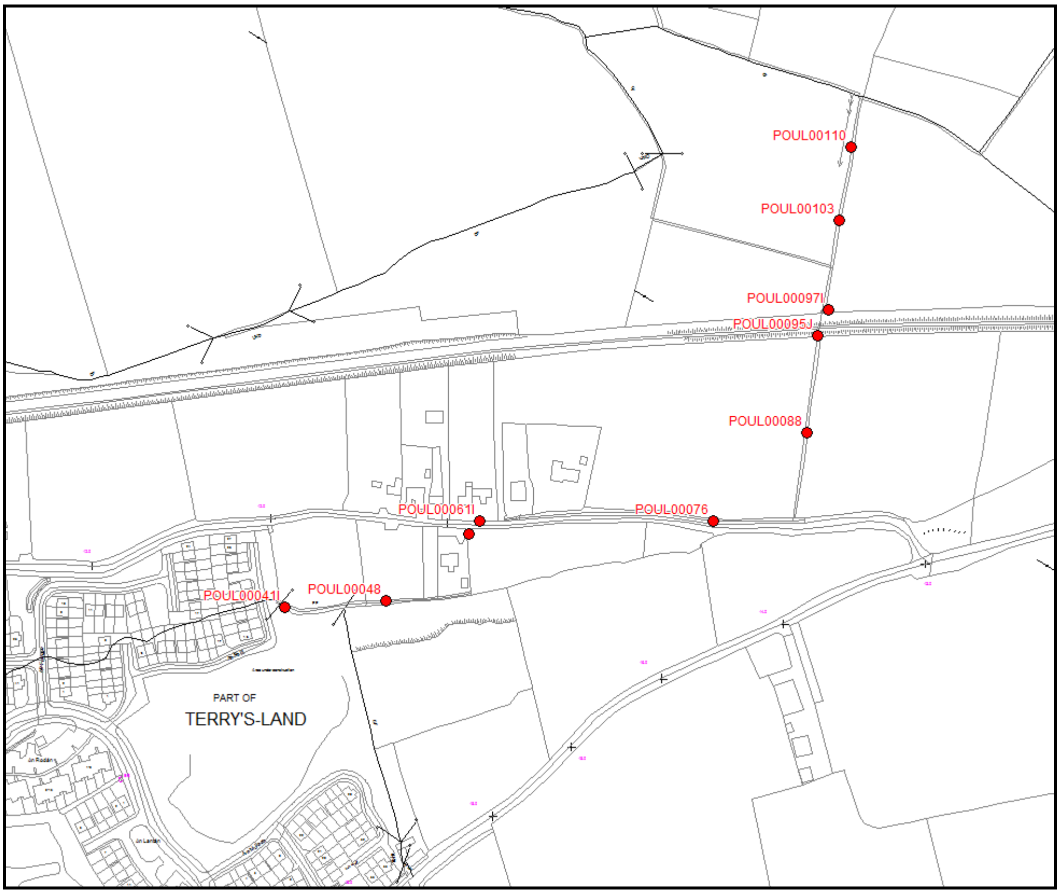
3.3.4 Rail Diversion Channel Schematic



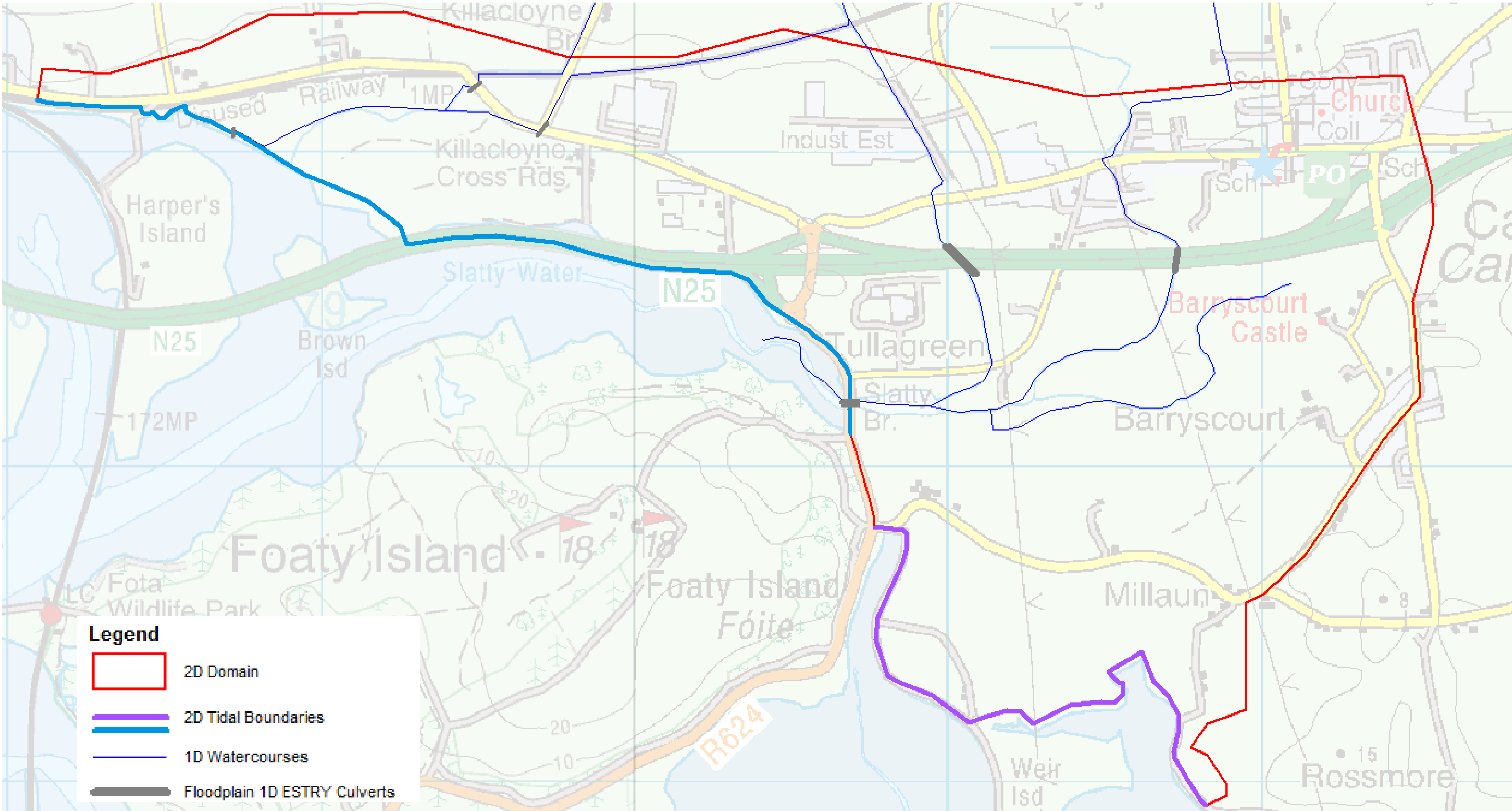
3.3.5 WOOD Upper Reach Schematic



3.3.6 POUL Upper Reach Schematic



3.4 2D Model Schematic



3.5 Bed and Floodplain Roughness

Manning's n roughness coefficients are required for 1D channels and culverts, and the 2D model domain. The choice of Manning's n roughness coefficients in the 1D and 2D model domains has differing effects and as such, Manning's n values are not directly transferable between 1D and 2D domains.

1D domains have increased sensitivity to Manning's n and hence a more significant impact on water levels. Consideration should be given to 2D grid sizes prior to selection of Manning's n for 2D domain areas.

3.5.1 1D Channel Roughness

1D channel Manning's n coefficients were based on survey photographs and observations made during site walkovers. Based on this evidence, the channel bed and banks were split into a number of different classifications each with different roughness characteristics. The approach that was taken in the original model was to apply a roughness value to the channel section within left and right bank markers and a roughness to the overbank section. A more complex approach has been adopted in key areas of the model where the selection of Manning's is considered more significant and a multiple panel approach has been adopted in these areas. The two approaches are illustrated in the figure below.

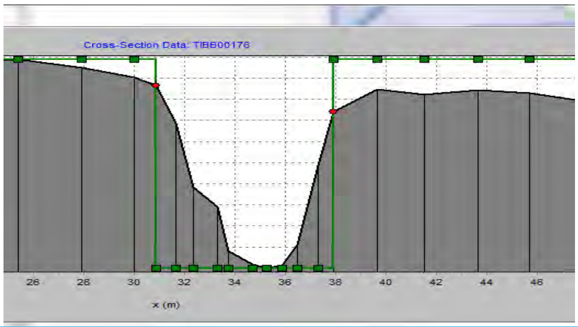
Channel Section (on Tibbotstown Stream)

Method 1:
Composite across channel (between bank) = 0.04

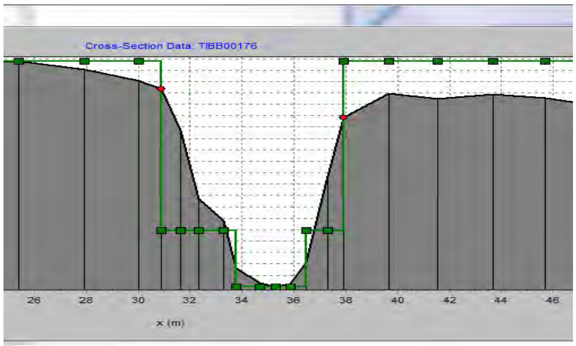
Method 2:
Section of channel under water = 0.035
Vegetated section in channel = 0.045

For both methods:
Overbank section = 0.06

Method 1



Method 2



For the limited overbank portion that remains in the 1D model domain the roughness value is set at 0.06. Based on the fact that the roughness of majority of the floodplain is categorised in the 2D model domain using a materials layers, this is considered a reasonable approach.

The roughness classifications and the Manning's n coefficient values selected for each of the zones identified in the modelled watercourses are outlined in the following table.

Hydraulic roughness values used in the 1D model

Material Code	1D Manning's n	Comment / Example
In – channel		
101	0.020	Concrete / rock lined channel
102	0.035	Silty mud channel, typical of tidal reaches
103	0.040	Natural stream which is clean, winding, some pools and shoals. Streambed consists of stones and cobbles.
Out of channel		
104	0.020	Road or paved area
105	0.060	Thickly vegetated banks consisting of scrub and weeds
106	0.040	Agricultural land; tillage and grazing
107	0.020	Concrete/rock walled bank

3.5.2 2D Floodplain Roughness

When assigning roughness values in 2D modelling it is important to have an appropriate contrast between roads and buildings to pick up the most likely flow paths.

Within the 2D domain a default value of 0.04 was applied for the Manning's n coefficient value across the entire area. Key floodplain features were then identified using Ordnance Survey (OSi) NTF data which categorises land cover into road, building and green space, including forestry. This provides a more physically reasonable representation of key floodplain features. 2D Manning's n roughness coefficients have been selected based on previous modelling experience and internal JBA guidance. The following table summarises the roughness values used in the 2D domain.

Hydraulic roughness values used in the 2D model

Material Code	2D Manning's n	Comment / Example
1	0.020	Roads from NTF Data
2	0.030	Railways lines from NTF Data
3	0.060	Scrub and rough grassland from NTF Data
4	0.040	Gardens or agricultural land from NTF Data
5	0.100	Buildings from NTF Data
6	0.070	Forestry from NTF Data
7	0.040	Inland Water
99	0.100	Stability patch

3.5.3 Roughness Values in the Model

The original Lee CFRAMS model assumed a manning roughness of 0.04 in channel and 0.06 for out of bank flow, across the whole model.

The following table categorises the channel type present in the catchment with reference to photos and gives information on the Mannings value assumed in the 1D and 2D components of the model.

The channel manning's values throughout the model, including the original Lee CFRAMS extents, have been updated based on observations on site and survey photos and to be in-line with those given in the following table.

Generally a value of 0.025 - 0.03 is used on the downstream silty or tidal reaches with 0.035 - 0.04 for upper gravel reaches. A lower value of 0.02 is used for concrete channels and structures. The following table gives an indication as to the range of Mannings selected for the model based on the channel characteristics.

Typical Channel Details and Assigned Roughness Values

Manning n value in channel	Photo and Description
Silty bed = 0.02	Silty / mud typical of tidal reaches  (typical of downstream reach of Kilacloyne Stream)
Silty bed = 0.02 Dense scrub in channel = 0.05 Averaged channel = 0.035	Silty bed heavily vegetated sides  (typical of Woodstock in vicinity of Carrigtohil bridge and N25)
Gravel bed = 0.035 Ferns & light scrub in channel = 0.045 Averaged channel = 0.04	Natural channel which is clean, winding, some pools and shoals. Streambed consists of stones and cobbles with some large stones / rocks  (typical of middle reaches of Tibbottstown Stream)

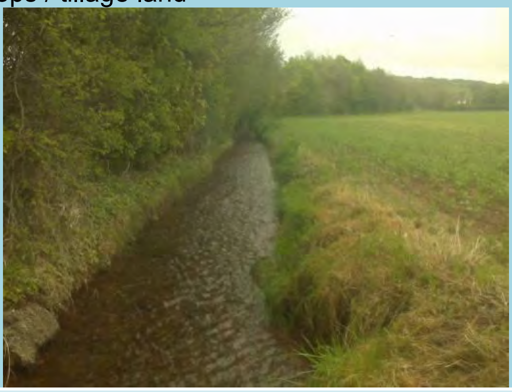
Manning n value in channel	Photo and Description
Gravel bed = 0.035 **Gravel sides in channel = 0.035** **Averaged channel = 0.035**	Clean gravel channel with sides clear of vegetation  (typical of upper reaches of Kilacloyne Stream)
Manmade channel with gravel and boulders = 0.023 **Averaged channel = 0.023**	Concrete lined channel with some boulders as part of channel design  (typical of rail diversion channel)
Gravel bed = 0.035 **Gabion sides = 0.03** **Averaged channel = 0.033**	Modified channel with gravel bed and gabion sides  (typical of modified channel downstream on rail diversion channel)

Manning n value in channel	Photo and Description
Gravel bed with silt = 0.02 **Walled side = 0.02 &** **vegetated side = 0.045** **Averaged channel = 0.025**	Gravel channel bed with walled side  (typical of lower reaches of Kilacloyne Stream adjacent to road)
Gravel bed = 0.035 **Vegetated section in channel = 0.045** **Averaged channel = 0.04**	Vegetated banks, with moderate to dense scrub and some trees 
Gravel bed = 0.02 **Grass edges in channel =0.045** **Averaged channel = 0.025**	Tidal reach with silty bed, grass banks with moderate levels of scrub 

Manning n value in channel	Photo and Description
Gravel bed = 0.035 **Light scrub in channel 0.045** **Averaged channel = 0.04**	Vegetated bank with grass, weeds and some large tress 
Standing water = 0.02	Wide open pond area with reeds etc.  (typical of Slatty Pond)

Typical Overbank Details and Assigned Roughness Values

As noted above the Manning's value used in the 1D ISIS model for the banks was set at 0.06; the remainder and majority of the floodplain is represented in the 2D TUFLOW domain. The following gives an indication to the range of values used in the model.

Manning n value overbank	Photos and Description
0.04 in 2D	Grazing land (generally shorter grass and not overgrown) 
0.04 in 2D	Crops / tillage land 
0.02 in 2D	Road / paved area 

3.6 Open Channel Sections on the Upper Reaches

The following gives information on the typical cross sections along each of the upper reaches of the extended section of the model.

3.6.1 Killacloyne Stream Typical Channel Sections

KILA00004_DOWN

KILA00025_UP

KILA00065I_UP

KILA00068J_DOWN

KILA00077I_UP

KILA00095_UP

3.6.2 Tibbotstown Stream Typical Channel Sections

TIBB00202_UP

TIBB00176_UP

TIBB00175X_DOWN

TIBB00175W_UP

TIBB00164J_DN

TIBB001501_UP

3.6.3 Woodstock Stream Typical Channel Sections


ANNA00392_DN


ANNA00382_UP

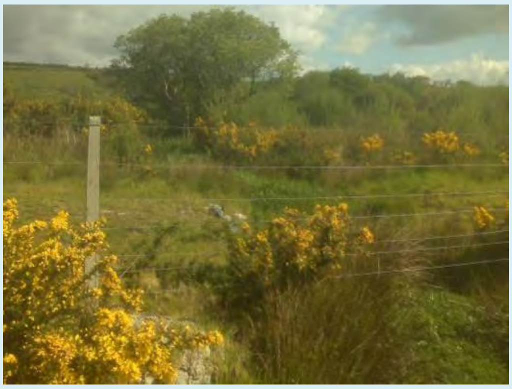

ANNA00372_UP


ANNA00364D_UP


ANNA00351UP


ANNA00307UP

3.6.4 Poulaniska Stream Typical Channel Sections


POUL00971I_UP


POUL0088_UP


POUL0076_UP


POUL0061I_UP


POUL0048_UP

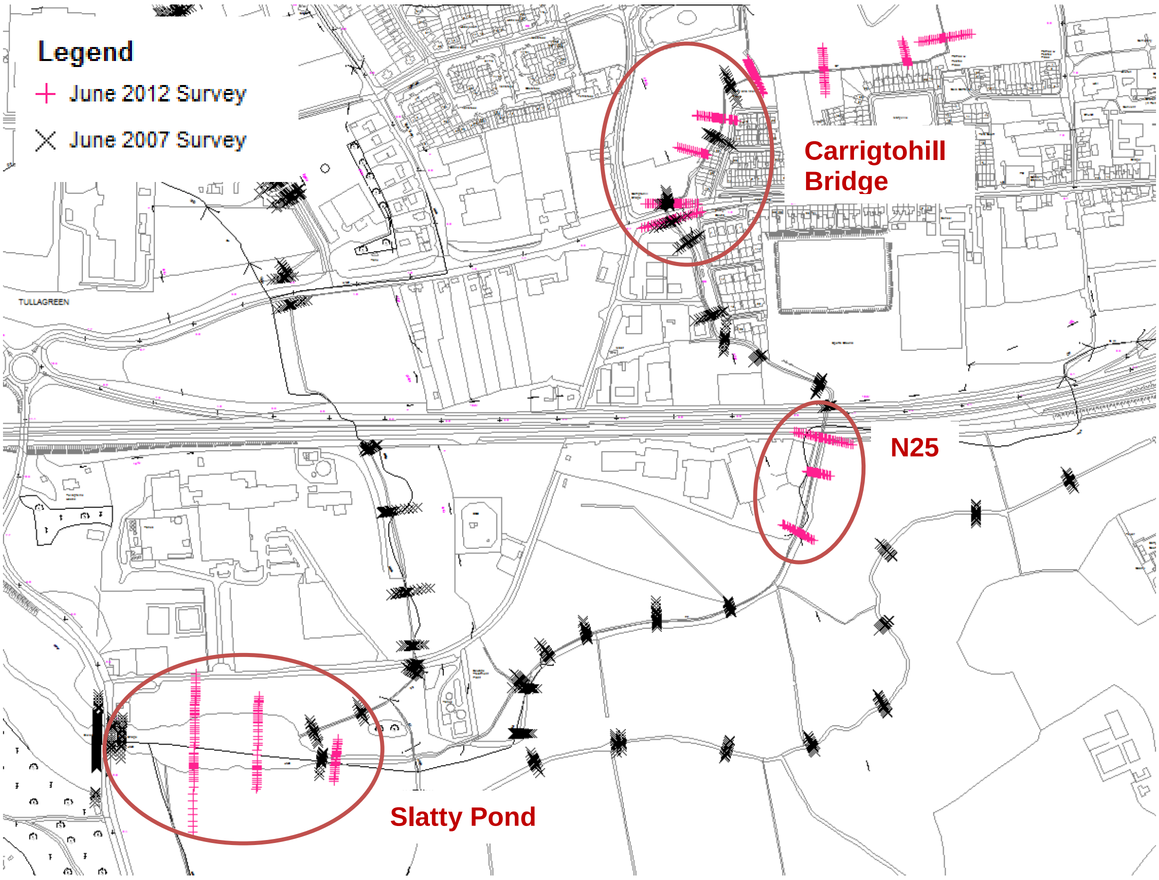

POUL0048_DN

3.7 Sections on the Lower Reaches

The lower reaches were included in the development of the Lee CFRAMS model. Due to significant development in recent years, a number of areas were identified where the topography is likely to have changed, since the survey was carried out in June 2007.

This section highlights the cross sections in the lower reaches that were included in the June 2012 survey and includes a comparison where the survey from 2007 and 2012 overlaps.

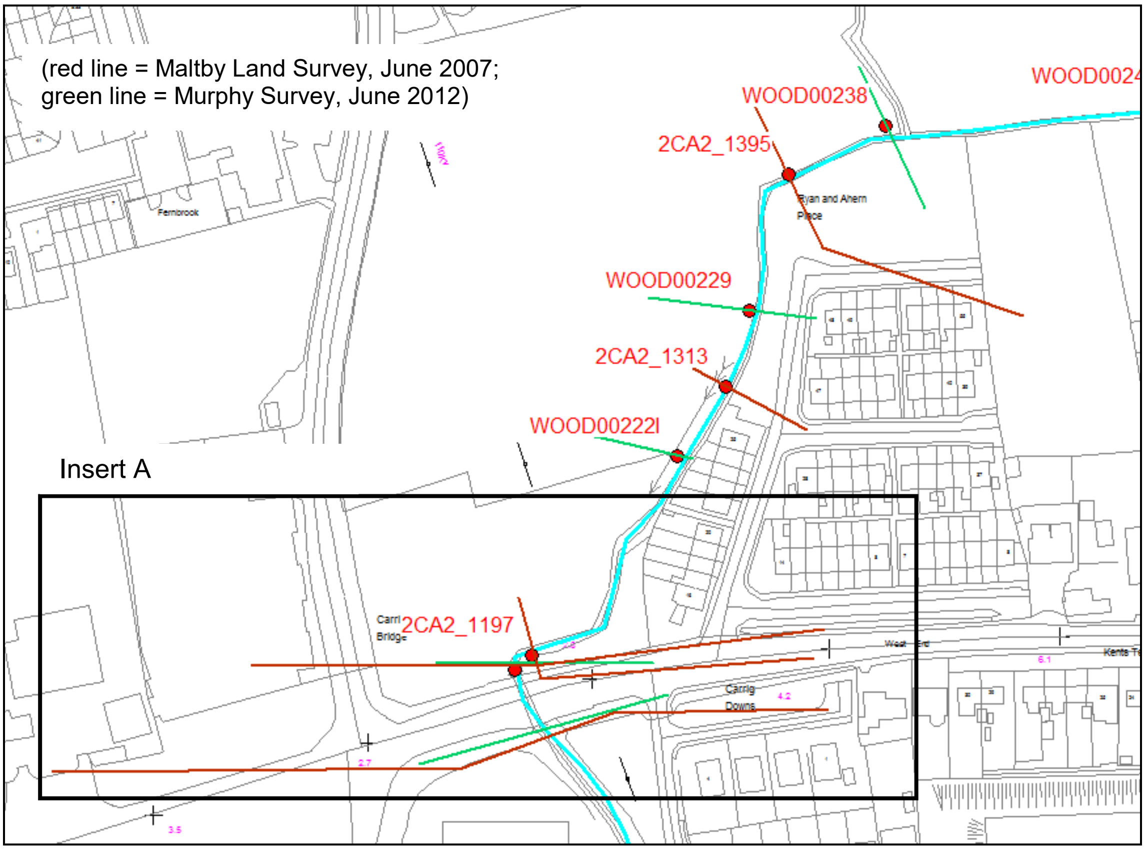
Where new more up-to-date survey data was available this was incorporated into the model, replacing estimated and interpolated cross sections.



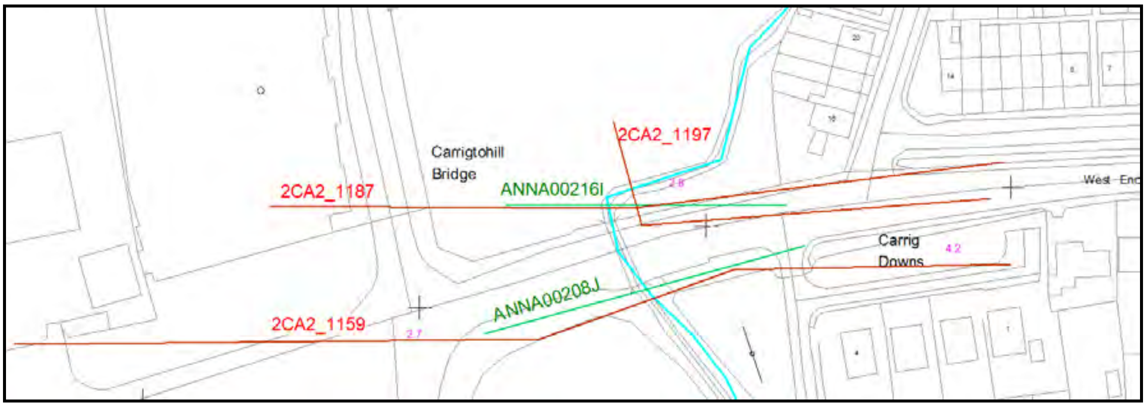
3.7.1 Upstream of Carrigtohill Bridge

As part of the June 2012 survey, cross sections were specified as far downstream as Carrigtohill Bridge with an overlap of approximately 200m on the June 2007 survey. Interpolated sections in the original Lee CFRAMS model were removed where surveyed sections were available. This applies to river sections 2CA2_1683I and 1313_I1 on reach 2CA2

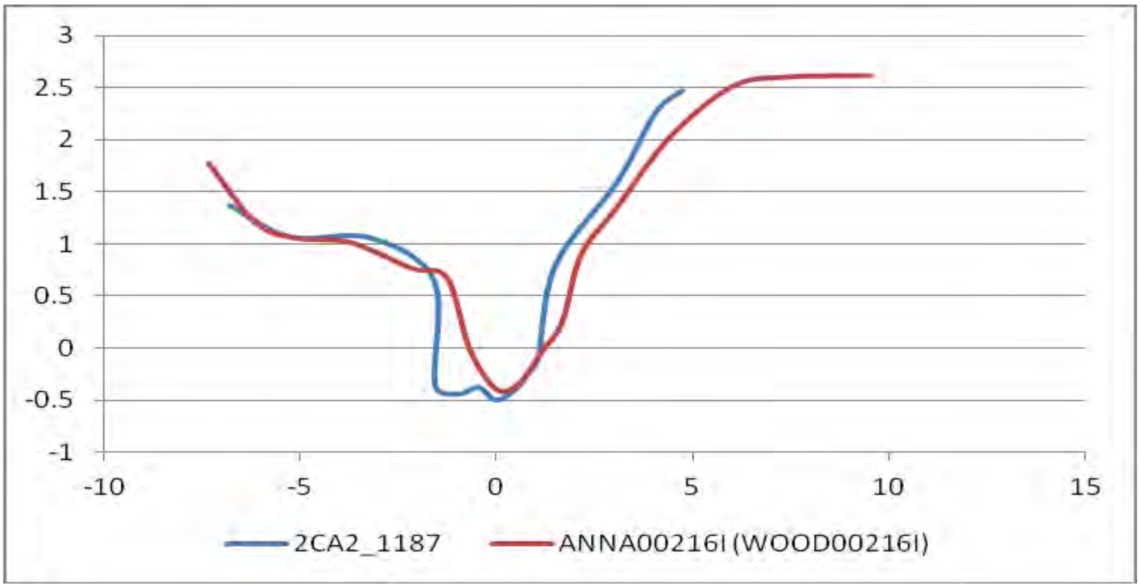
The sketch below indicates the location of all the surveyed cross sections.



Insert A – zoomed in map:



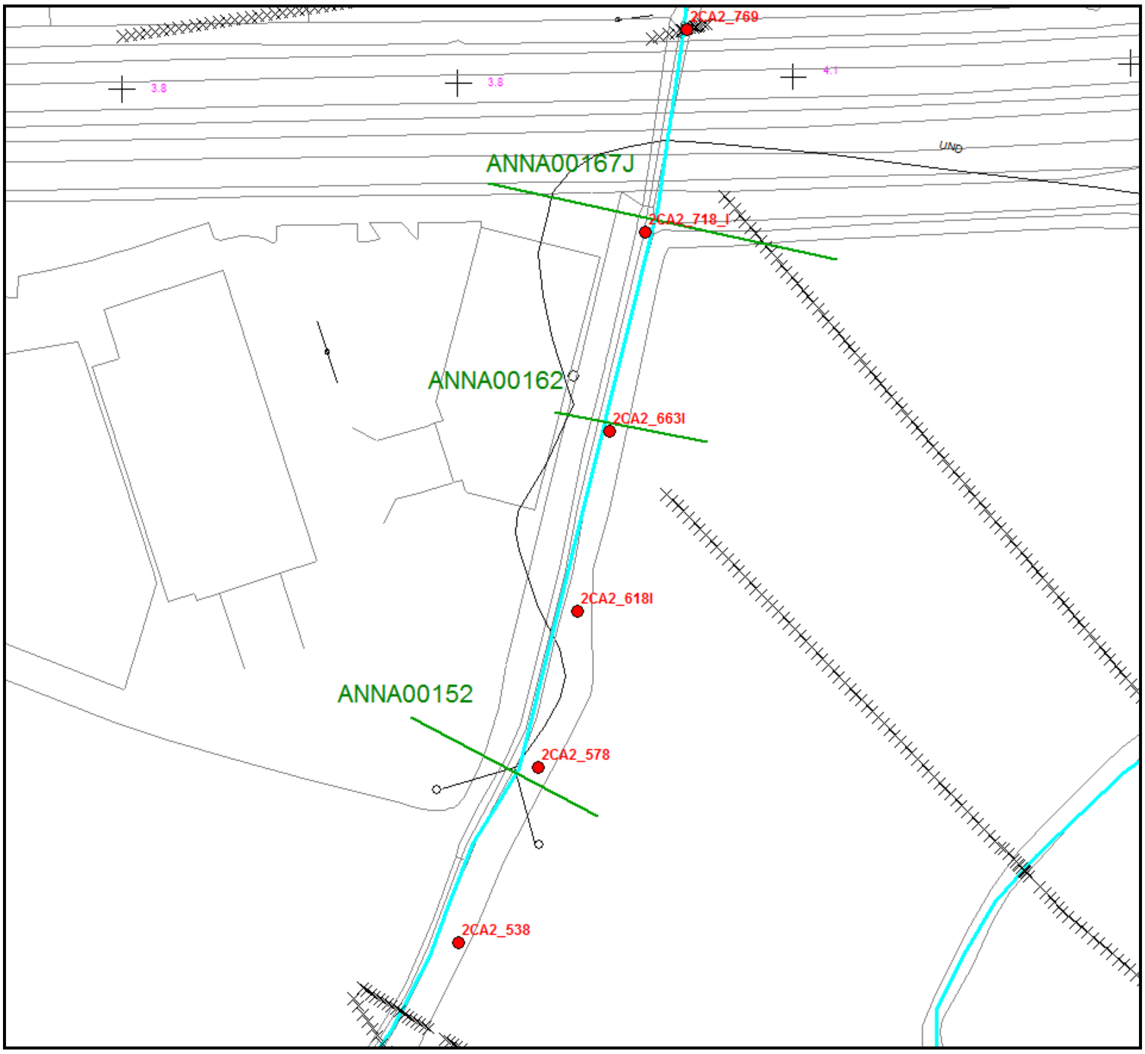
A comparison of survey data, gives a good indication of changes in the channel geometry in the last 5 years.



The relative bed invert levels are comparable but the more recent survey indicates a narrower width at bed invert level. This indicates that there may be sedimentation / siltation upstream of Carrigtohill Bridge. Observations made on visits to the site, confirmed that the channel is heavily vegetated and overgrown at this location. The June 2012 survey indicated that there is one pipe under the road however based on available data it has been concluded that there is two pipes at this location (as indicated in the June 2007 survey) with one pipe opening obscured due to silt and overgrowth.

For the purpose of the model, following agreement with Cork County Council, this culvert has been included in the model as a single pipe but equivalent to the twin pipes indicated on the June 2007 Survey. This is based on an agreement that regular maintenance will be carried out at this location to remove any blockage. Therefore the survey data of June 2007 remains in the model to represent the geometry of the channel at this location.

3.7.2 Downstream of N25 Road embankment



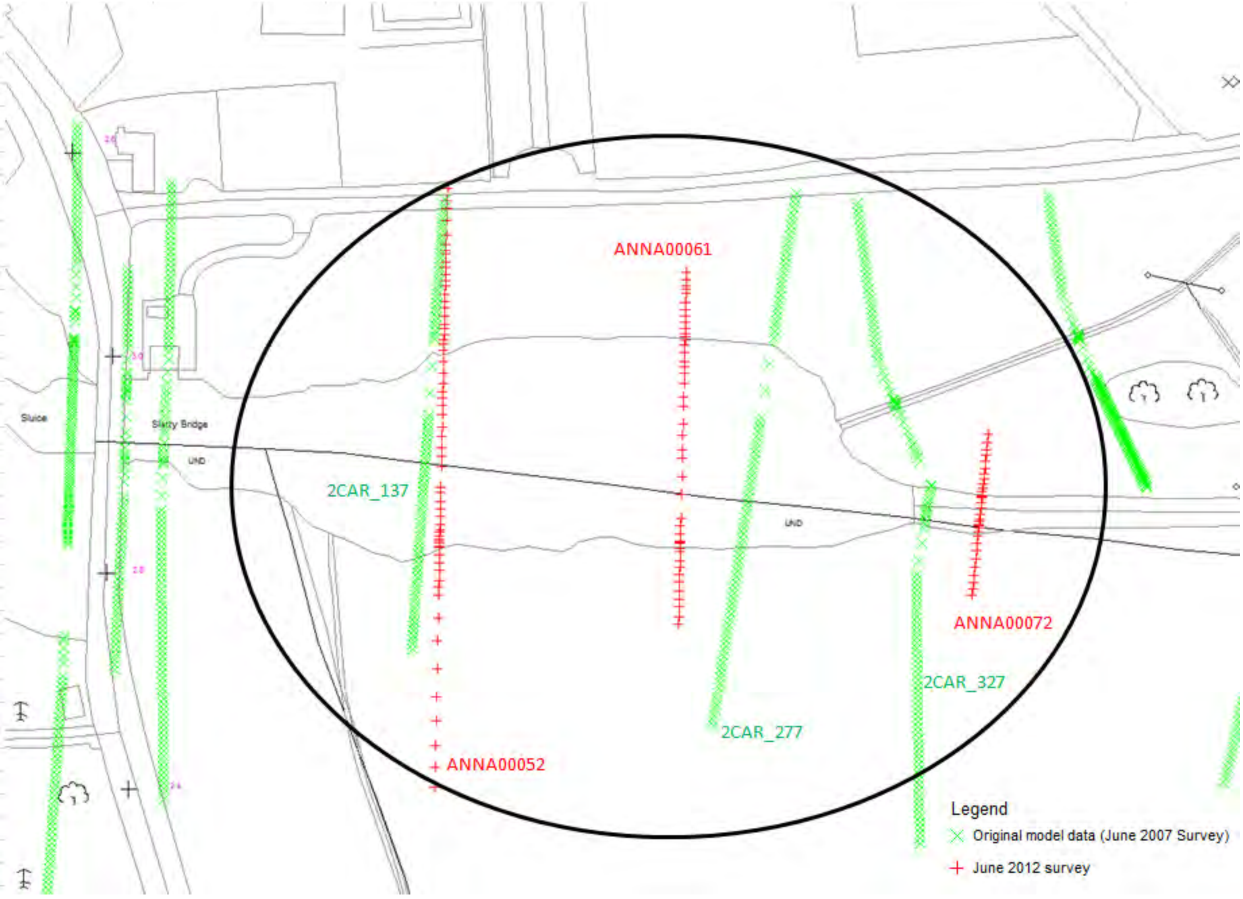
A length of watercourse, extending approximately 250m downstream of the N25, was inaccessible during the survey that was carried out in June 2007. However river sections were included in the original Lee CFRAMS model, possibly generated from DTM data. On closer inspection the elevations of the extended banks appear to be quite low in comparison to the 2m LIDAR information that was acquired under this study.

The estimated sections are replaced with river sections for which survey data has been collected on site as part of the more recent June 2012 survey.

3.7.3 Slatty Pond

Cross sections at Slatty Pond were included in the 2012 survey. Concerns were raised by locals about the potential of siltation to occur in the pond, reducing its storage capacity.

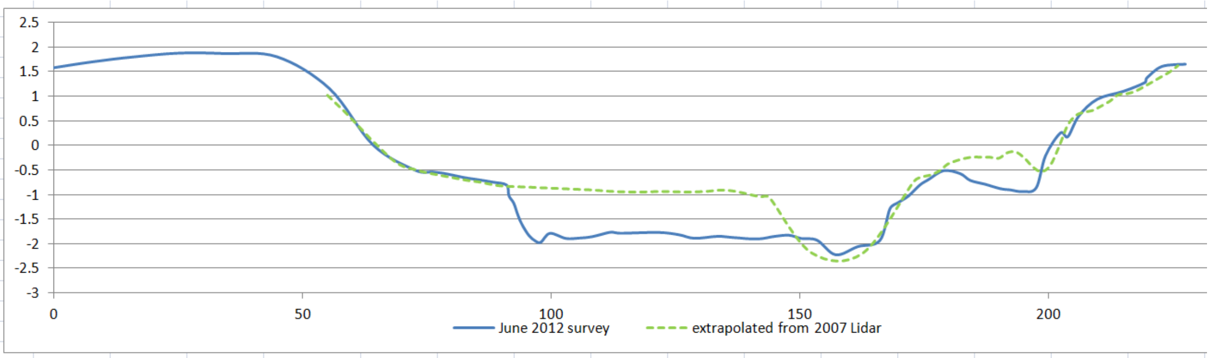
The surveyed cross sections were compared with sections from the original model. The following plan shows the location of these cross sections.



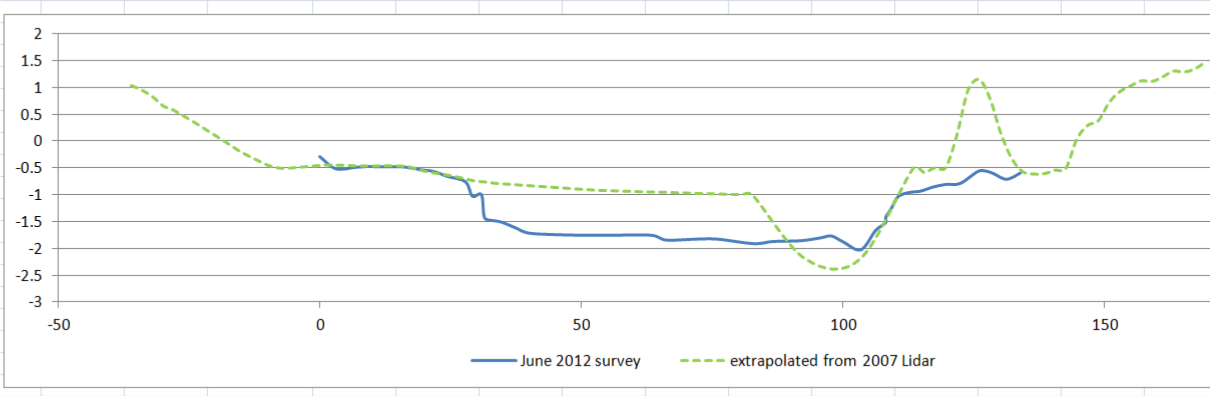
Based on comments included in the original model and the 2007 survey deliverables, it appears that the cross sections at 2CAR_137 and 2CAR_277 were inferred from LIDAR data. More detailed surveyed spot levels were collated at 2CAR_327.

The following cross sections plots indicate the difference between the two datasets.

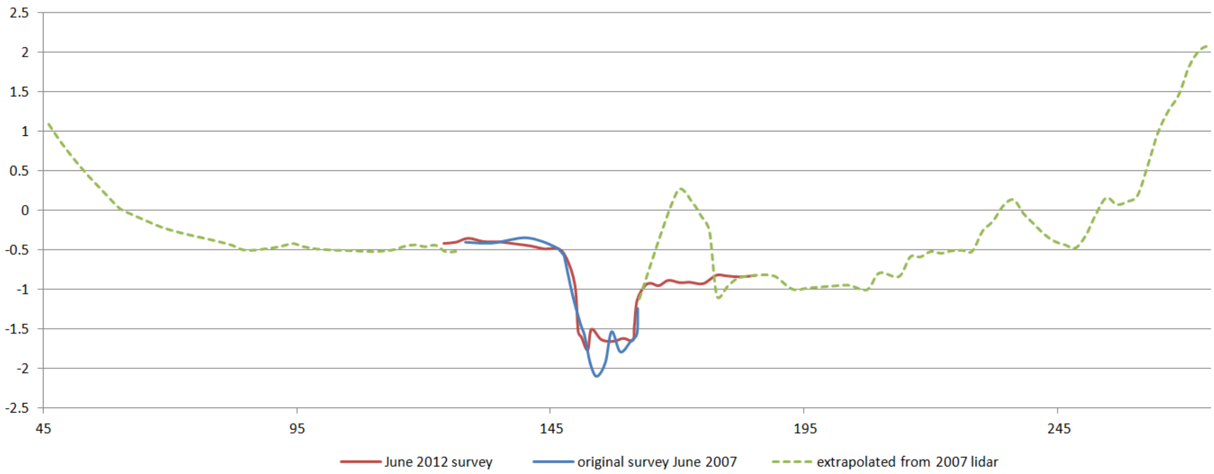
Cross section plot for 2CAR_137 and ANNA00052



Cross section plot for 2CAR_277 and ANNA00061



Cross section plot for 2CAR_327 and ANNA000721



The sections estimated from the 2007 DTM data indicate higher levels on the left bank. Surveyed points give more reliable and accurate data, the 2012 survey data has been added to the model in place of the old sections.

Surveyed spot levels are relatively comparable at section 2CAR_327 and ANNA00072 with the survey indicating that stream bed levels have risen by an average 300 to 400mm.

Due to a lack of surveyed sections from the 2007 survey, it is not possible to assess the degree of siltation that has occurred generally at Slatty Pond.

3.8 Structures

3.8.1 General procedures for all structures

This section deals with structures (bridge, culvert, weir, pump) within the study area. The following table includes all structures regardless of whether they have been directly included in the model or not. If a structure has not been directly represented in the model, a justification is provided.

For the upper reaches of the model (i.e. extended beyond original Lee CFRAMS model) the source of survey data is from survey undertaken by Murphys Surveys in June 2012. Survey for the original Lee CFRAMS model was undertaken by Maltby Land Surveys in June 2007.

Any assumptions made related to the modelling of structures in the extended portion of the model are recorded on the following pages.

3.8.2 Blockage

A geo-morphological assessment of the catchment was carried out as part of this study. This together with observations on site, indicate that there is a high occurrence of sedimentation at a number of structures in the catchment and this has the potential to reduce the flow capacity of structures. Where severe silting is evident, a reduced culvert size or effective height has been specified in the model geometry to represent this. This is detailed in this model check file and in the comment field of the ISIS model.

The percentage blockage at each culvert was assessed based on the survey information collected on site. Some work was undertaken, during the course of the study to clear silted culverts and remove debris. An assumption was made on the likelihood of blockage on a case by case basis, and is documented below.

Culverts that have trash screens were assumed to have a minimum 30% blockage unless observed at a higher value.

3.8.3 Inlet Loss Coefficients

The inlet loss coefficients for all structures in the model were updated to reflect the updated CIRIA guidance, Culvert Design and Operation Guide C689 April 2010.

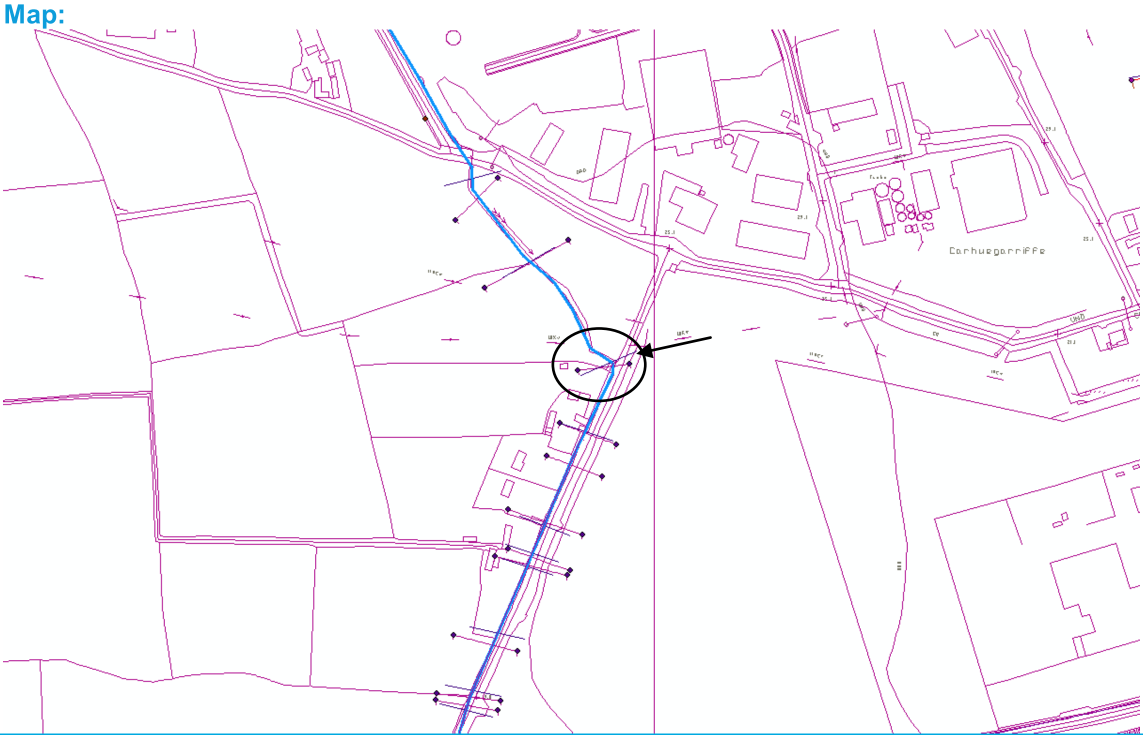
The following is a table showing the range of inlet coefficient used in this model. Values are taken from Table A.1.3 in the C689 report.

CIRIA Nr	CIRIA Description	Ki	K	M	c	Y
1	Circular concrete pipe, headwall, square edge	0.5	0.0098	2.0	0.0898	0.67
2	Circular concrete pipe, headwall, socket end	0.3	0.0078	2.0	0.0292	0.74
3	Circular concrete pipe projecting, socket end	0.3	0.0045	2.0	0.0317	0.69
6	Circular corrugated metal pipe, projecting	0.9	0.034	1.5	0.0553	0.54
16	Arch, corrugated metal, 90° Headwall	0.5	0.0083	2.0	0.0379	0.69
19	Rectangular concrete, 90° Headwall, 20mm chamfers	0.5	0.515	0.667	0.0375	0.69
23	Rectangular concrete, 30° flared wingwalls, top edge bevel 45°, single barrel	0.26	0.44	0.74	.04	0.48
24	Rectangular concrete, 30° flared wingwalls, top edge bevel 45°, single barrel, span to rise 2:1 to 4:1	0.2	0.48	0.65	0.041	0.57
30	Rectangular concrete, 0° flared wingwalls, top edge bevel 45°, multiple barrels (2, 3 or 4)	0.52	0.55	0.59	0.038	0.69
31	Rectangular concrete, 0° flared wingwalls, top edge bevel 45°, span to rise 2:1 to 4:1	0.37	0.61	0.57	0.041	0.67

3.9 Killacloyne (KILA) Reach Structures

Name of Structure / Survey Label:	Local private access bridge; KILA00084
Location (x, y):	179963 73678
Included in model (state reason if not):	No. This is a local land access and although reduces capacity in the channel it is not considered a significant structure in terms of flood risk.
Model Unit Label:	n/a
Type:	Simple bridge deck - concrete slab
Additional Information:	Opening 1.44m wide by ~0.6m high

Map:

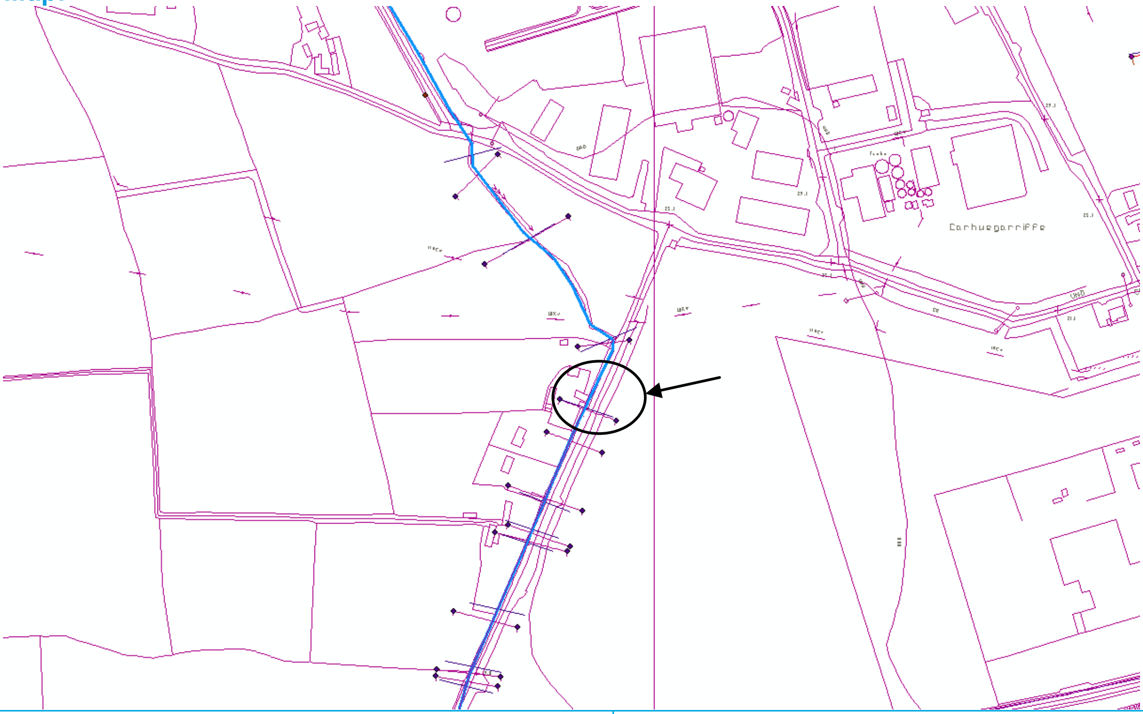


Photos:

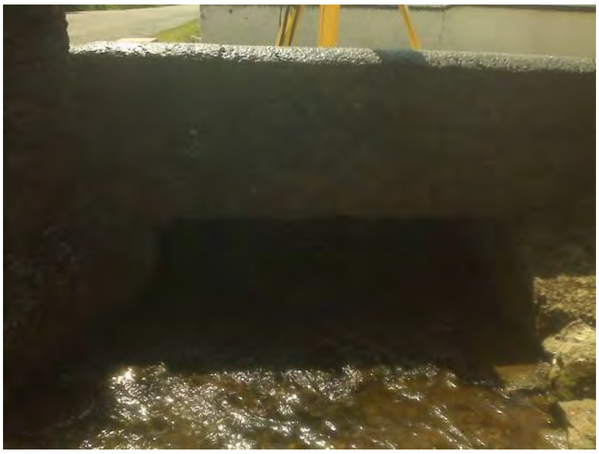
KILA00084 DS.jpg

Name of Structure / Survey Label:	Local private access bridge; KILA00077I
Location (x, y):	179937 73617
Included in model (state reason if not):	local land access
Model Unit Label:	n/a
Type:	Simple bridge deck
Additional Information:	Opening 1.48m wide by ~0.45m high

Map:



Photos:

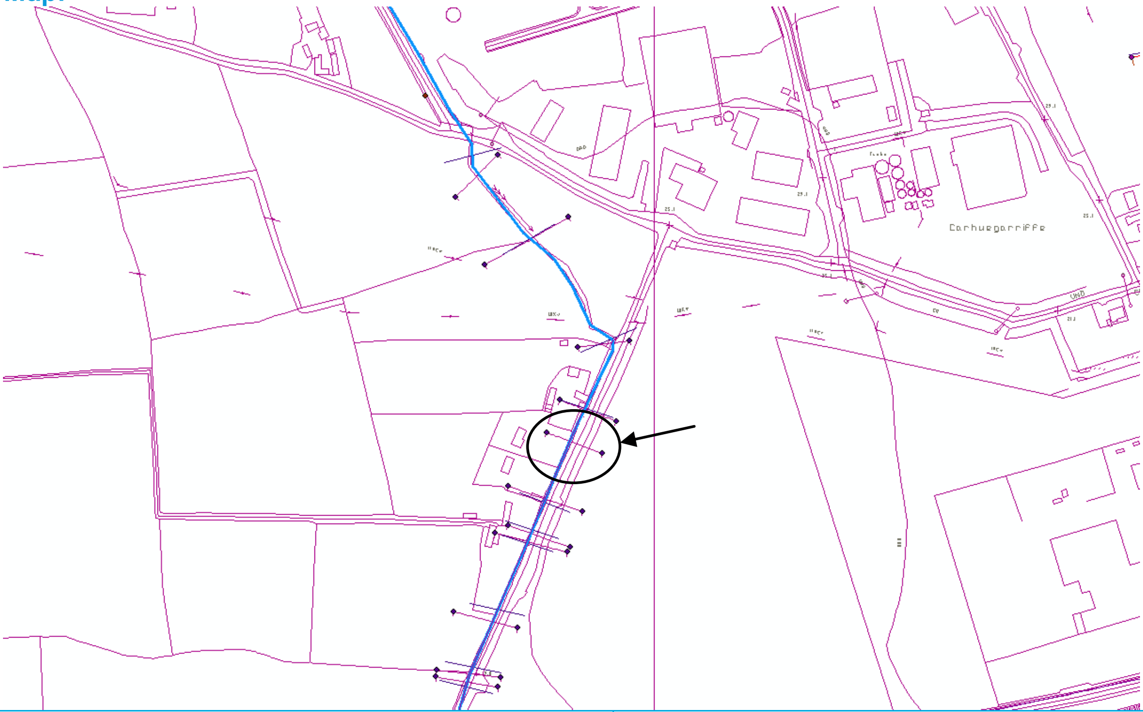


KILA000771_DN.jpg

KILA000771_UP.jpg

Name of Structure / Survey Label:	Local private access bridge; KILA00070
Location:	179926, 73590
Included in model (state reason if not):	Not surveyed; local land access. Similar but smaller structure downstream modelled that will represent restriction in channel.
Model Unit Label:	n/a
Type:	Triple barrel culvert
Additional Information:	3 x 500mm dia concrete pipes US ILs 14.66 / 14.60 / 14.65 DS ILs 14.44 / 14.37 / 14.41

Map:

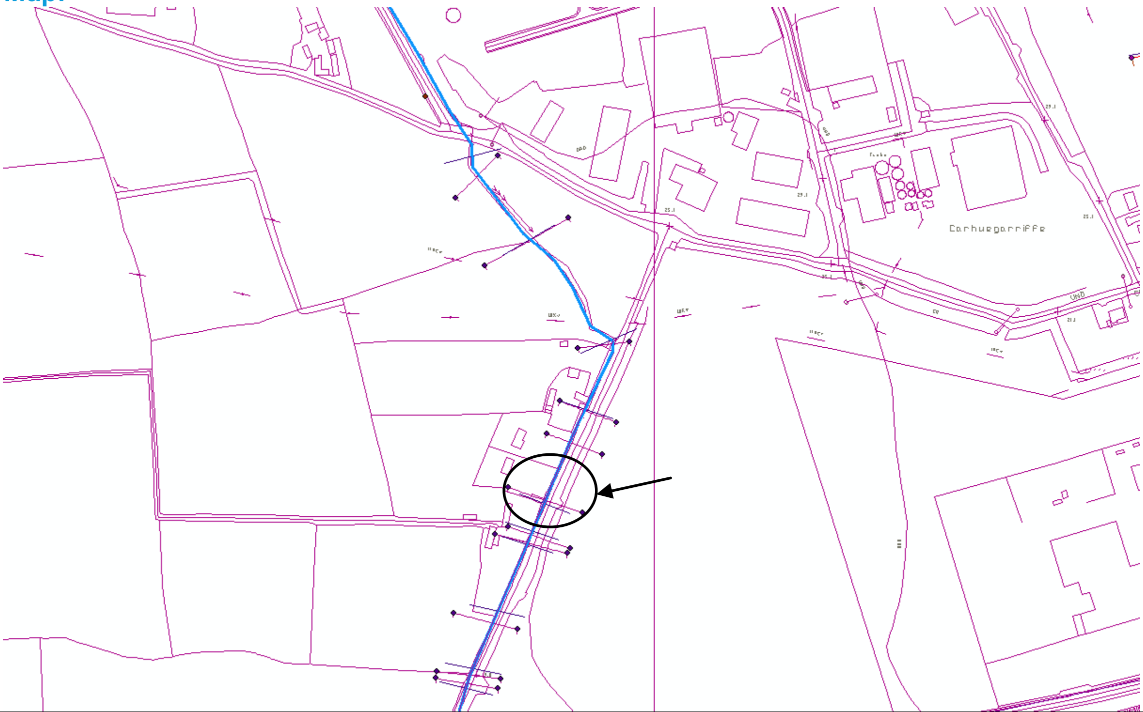


Photos:

No photos from survey

Name of Structure / Survey Label:	Local private access bridge; KILA00068
Location:	179902 73534
Included in model (state reason if not):	No; local land access. Similar but smaller structure downstream modelled that will represent restriction in channel.
Model Unit Label:	n/a
Type:	Triple barrel culvert, 550mm dia
Additional Information:	3 x 550mm dia concrete pipes US ILs 13.61 / 13.58 / 13.59 DS ILs 13.43 / 13.42 / 13.44

Map:

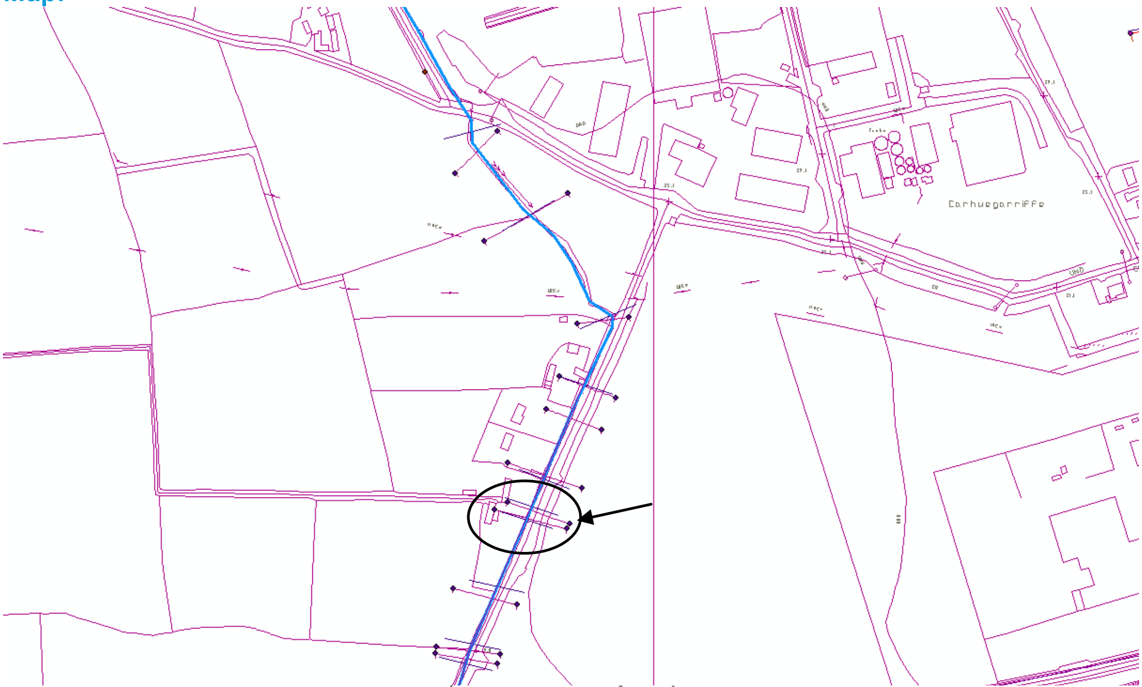


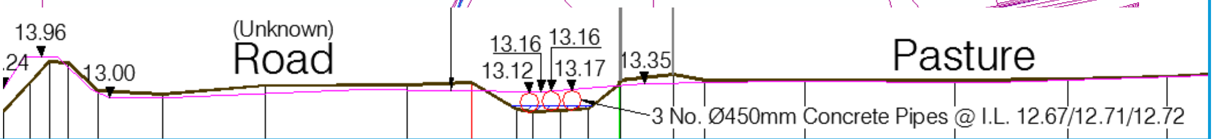
Photos:

KILA00068J_UP.jpg

Name of Structure / Survey Label:	Local private access bridge; KILA00065
Location:	179888 73503
Included in model (state reason if not):	No; local land access
Model Unit Label:	n/a
Type:	Triple barrel culvert, 450mm dia
Additional Information:	3 x 450mm dia concrete pipes US ILs 12.67 / 12.71 / 12.72 DS ILs 12.55 / 12.55 / 12.63

Map:



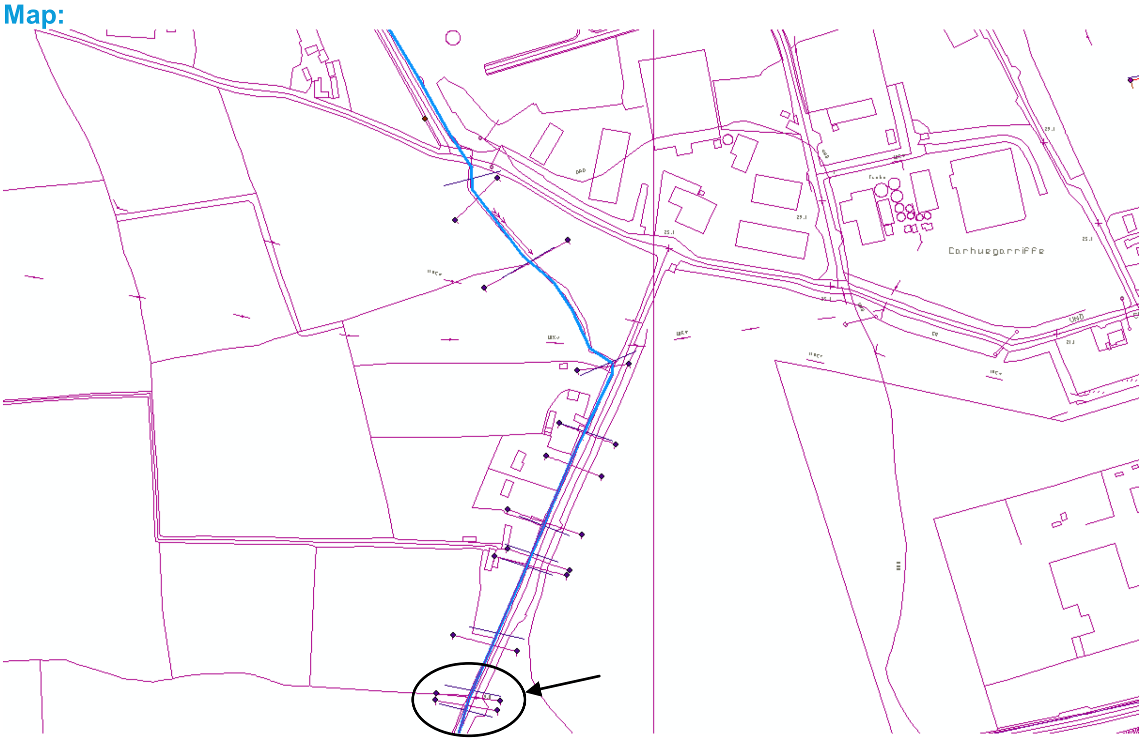


Photos:

KILA00065I DOWN.jpg

Name of Structure / Survey Label:	Local private access bridge; KILA00050I – 48J
Location:	179827 73375
Included in model (state reason if not):	No. Local land access, although will reduce capacity water is expected to re-enter channel just downstream.
Model Unit Label:	n/a
Type:	Twin barrel concrete culvert
Additional Information:	600mm dia plus 450mm dia US ILs 9.29 / 9.16 DS ILs 8.85 / 9.11

Map:

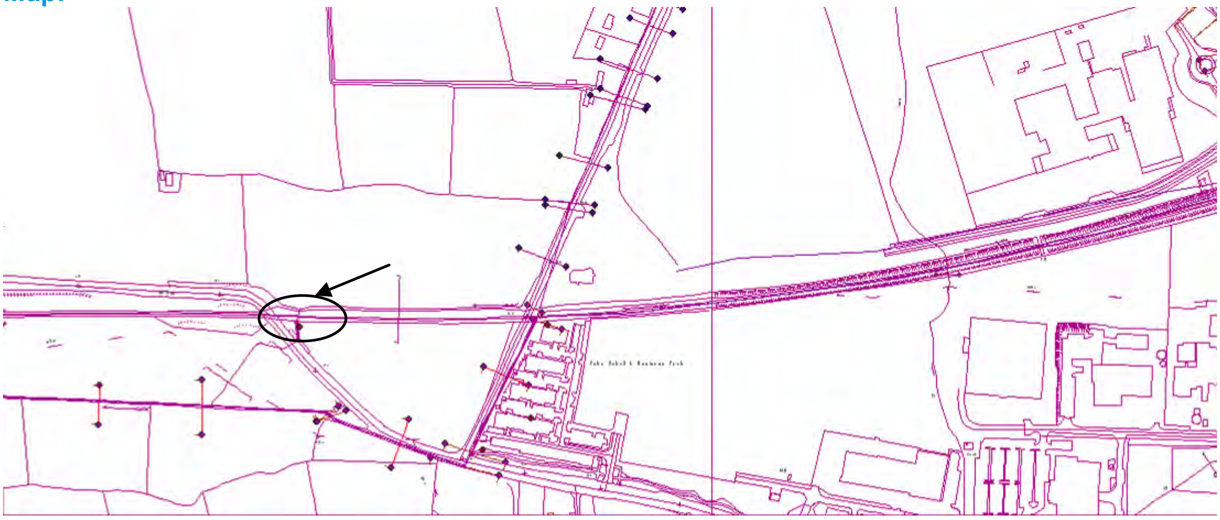


Photos:

KILA00050I_DN.jpg

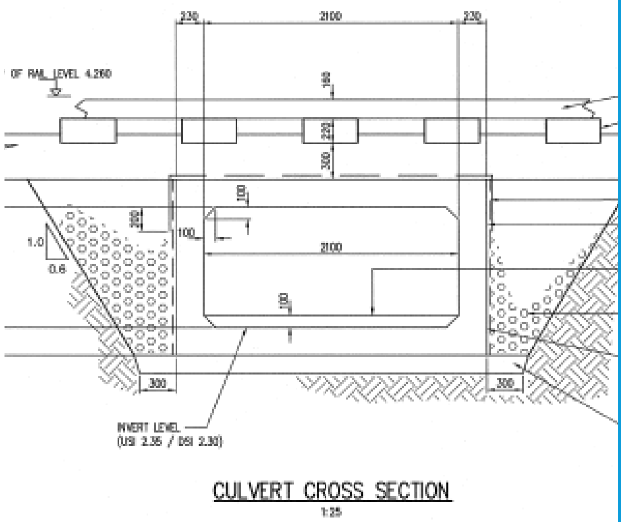
Name of Structure / Survey Label:	Irish Rail Culvert (C2)
Location:	179504 73247
Included in model (state reason if not):	Yes; key structure on rail line
Model Unit Label:	KILA0016I to KILA0014J
Type:	Culvert
Additional Information:	No access to survey; details from Irish Rail construction drawings Box culvert size 2.1x1.0 with 100mm gravel bed; Irish rail Section 50 indicates capacity of 3.3m^3/s US IL 2.45m; DS IL 2.40m (including 100mm gravel)

Map:



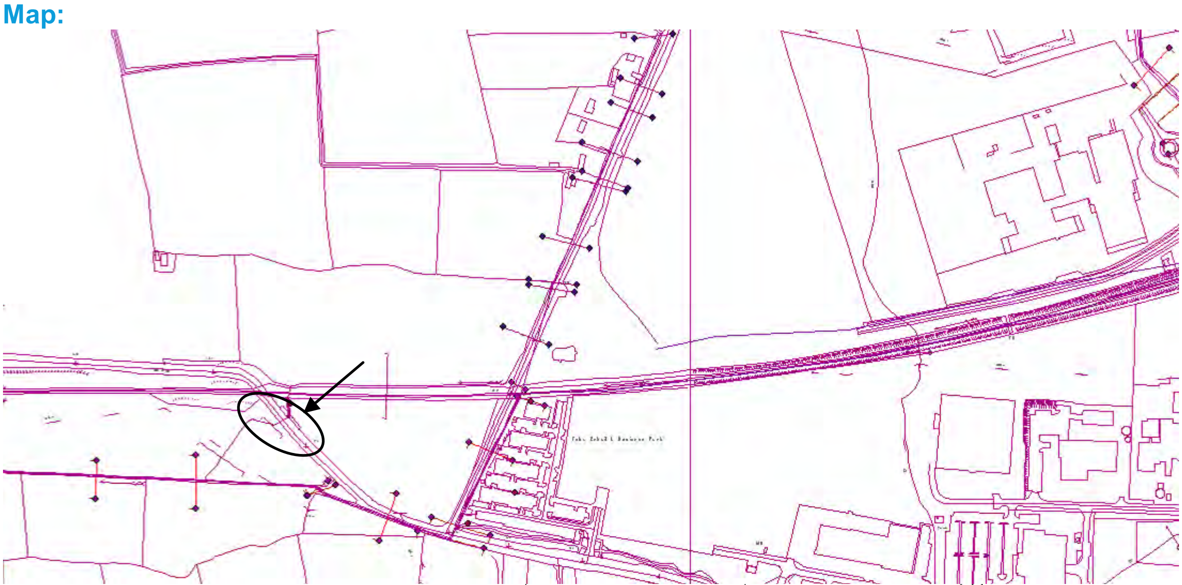
Photos:

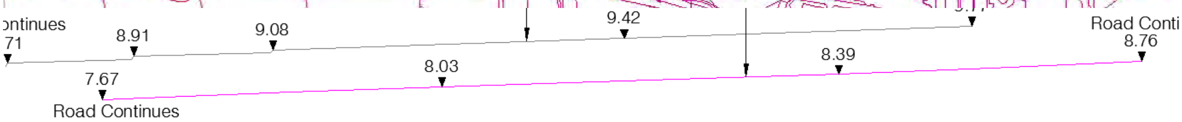
KILA00050I_DN.jpg

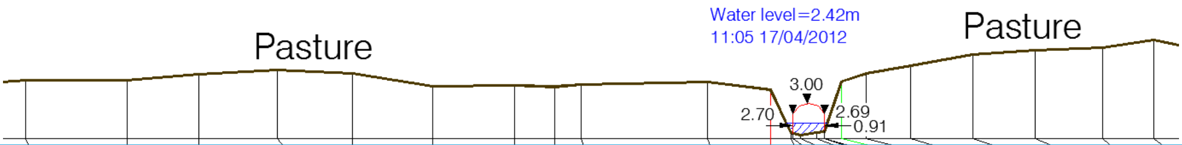


Name of Structure / Survey Label:	Road Bridge KILA00012I
Location:	179502 73229
Included in model (state reason if not):	Yes
Model Unit Label:	KILA00012I and KILA00010J
Type:	Arch Roof Culvert 900 x 900mm with arch roof
Additional Information:	High embankment / deck level above culvert Min bed US IL 2.09mAD; DS IL 1.87mAD

Map:







Photos:

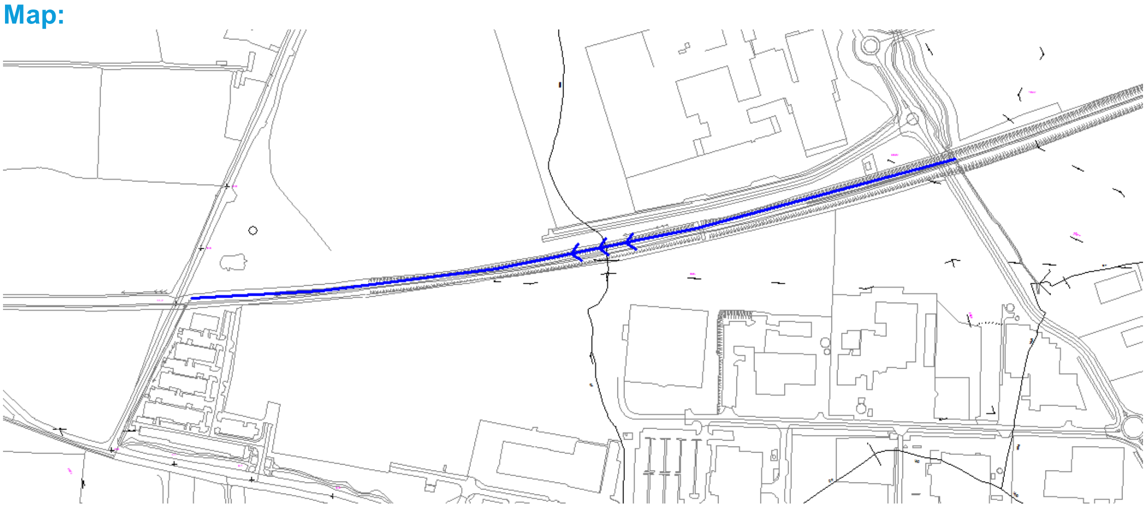
KILA00012I_DN.jpg

This reach enters tidal waters at its most downstream end. A tidal stage boundary is applied at the downstream end. There are no survey details available at the tidal outfall on the Kilacloyne Reach. An assumption has been made to model this outlet. It has been included in the model as a flapped 1m diameter outfall.

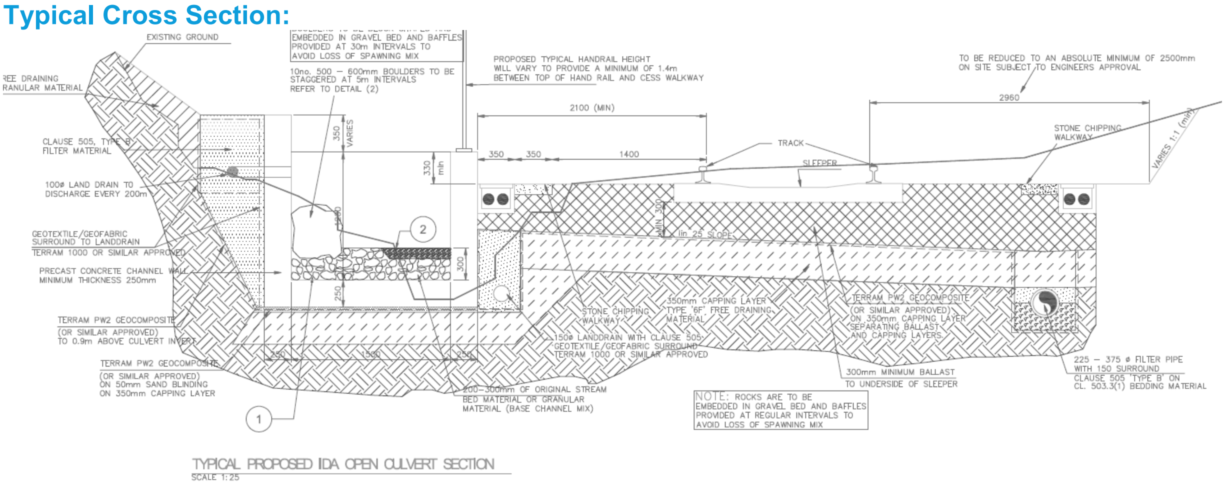
3.10 Rail Diversion Channel and Downstream

Name of Structure / Survey Label:	Rail Channel
Location:	180260 73300
Included in model (state reason if not):	Yes
Model Unit Label:	River units with RAIL reach code
Type:	River Unit
Additional Information:	Dimensions & levels taken from Irish Rail Drawings
How has structure been modelled?:	River Unit

Map:



Typical Cross Section:



(long section also available)

Photos:

Rail channel at upstream end (cascade)

Rail channel at downstream end

Name of Structure / Survey Label:	TIBB00126I (Irish Rail Culvert C3)
Location:	179793, 73244
Included in model (state reason if not):	Yes
Model Unit Label:	TIBB00126I
Type:	Twin concrete box culvert
Additional Information:	Irish Rail culvert survey indicates movement of silt/gravel.

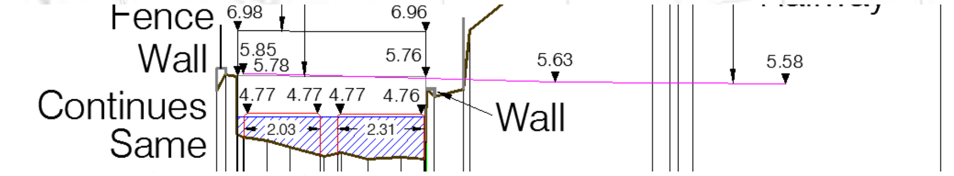
No. Barrels on site:	2	**Modelled as:**	1

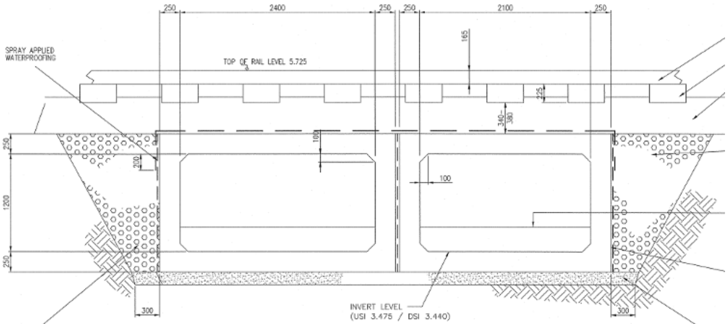
Inlet Type:	0° flared wingwalls, multiple barrels
Blockage?	Culvert design included 300mm gravel bed; surveyed soffit levels indicates little to no gradient in constructed culvert. Modelled as equivalent single barrel box; smaller height us due to silt; Manning's on invert set at 0.03 to indicate silt; 0.02 on walls.

Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a

Shape:	Box	**Height:**	(1.139m us)1.2m ds	**Width:**	4.34m
US invert:	3.631	**DS Invert:**	3.57	**Length:**	12m

Map:





Photos:

Upstream face - TIBB00126I_DN.jpg

Downstream face - TIBB00125J_UP.jpg

Name of Structure / Survey Label:	TIBB00107I
Location (x, y):	179711, 73075
Included in model (state reason if not):	Yes
Model Unit Label:	TIBB00107I
Type:	Concrete circular culvert
Additional Information:	900mm dia concrete pipe

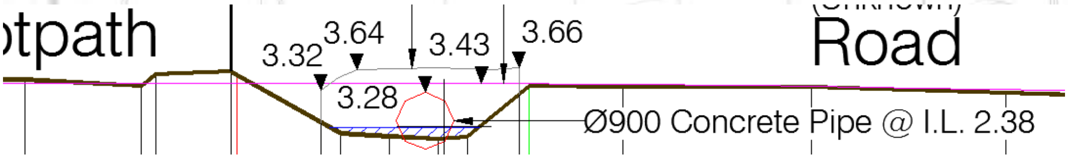
No. Barrels on site:	1	**Modelled as:**	1

Inlet Type:	Concrete circular projecting socket end pipe

Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a

Shape:	circle	**Height:**	0.9	**Width:**	0.9
US invert:	2.38	**DS Invert:**	2.25	**Length:**	18

Map:



Photos:

Upstream face - TIBB00107IDOWN.jpg

Downstream face - TIBB00105JUP.jpg

Name of Structure / Survey Label:	TIBB00087I
Location (x, y):	179543, 73118
Included in model (state reason if not):	No; not a critical structure; low level deck; tidal reach
Model Unit Label:	Open channel unit = TIBB00088I
Type:	circular culvert
Additional Information:	900mm dia steel pipe

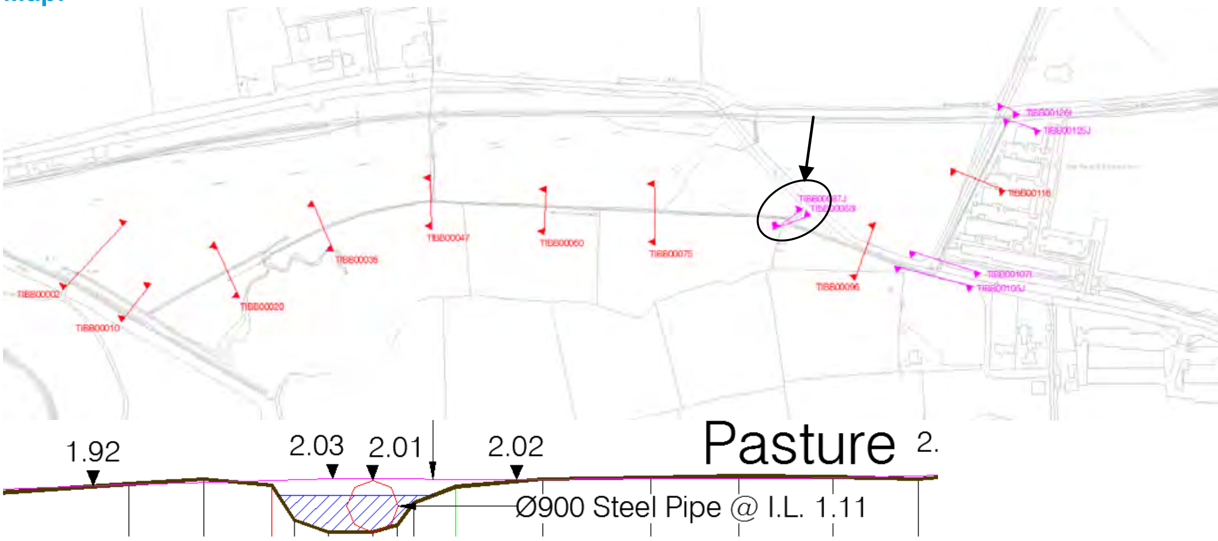
No. Barrels on site:	1	**Modelled as:**	n/a

Inlet Type:	Steel pipe projecting

Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a

Shape:	Circle	**Height:**	0.9	**Width:**	0.9
US invert:	1.11	**DS Invert:**	0.99	**Length:**	4.12

Map:



Photos:

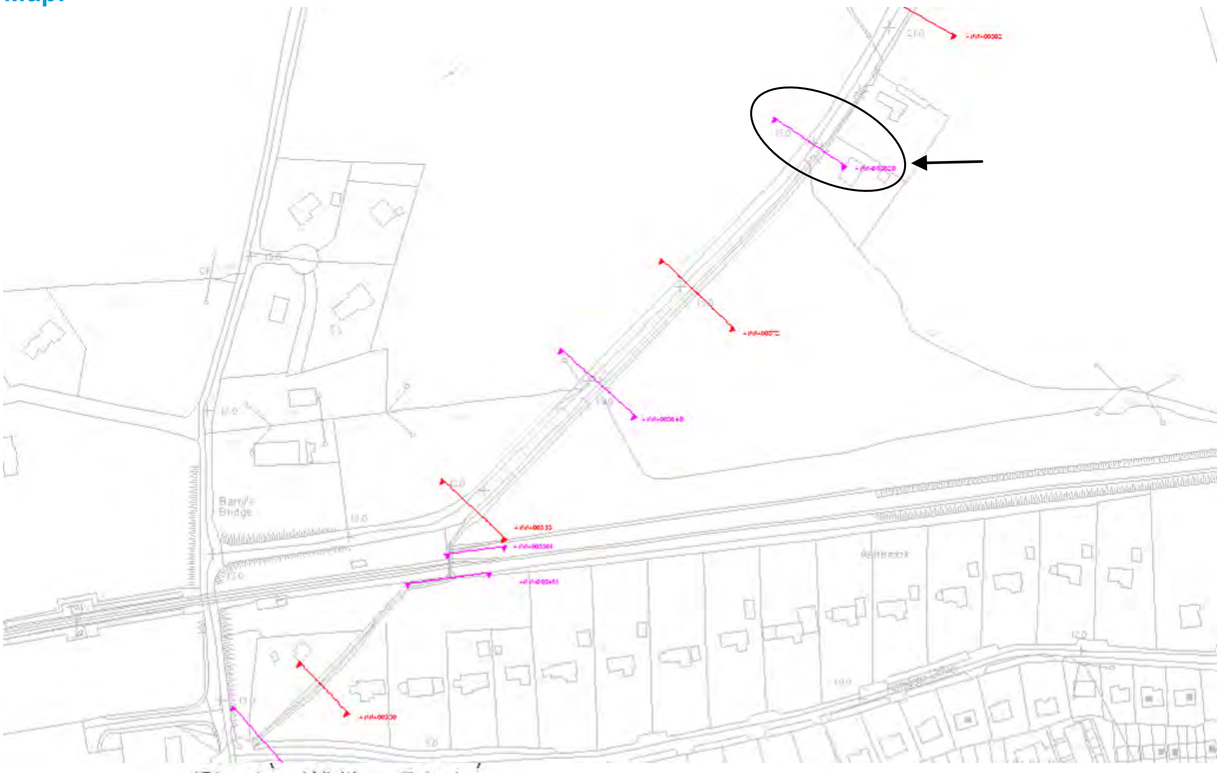
Upstream face - TIBB0088D_DN.jpg

3.11 Woodstock Stream (WOOD) Reach Structures

It was observed on site that the Woodstock Stream is culverted upstream of the modelled reach. This may have the effect of restricting flow in the modelled section of the Woodstock Stream. However, based on the topography of the ground in this area it is assumed that any out of bank flow is likely to re-enter the stream in the modelled reach.

Name of Structure / Survey Label:	Private Driveway; survey ID ANNA00382D						
Location (x, y):	182373, 74053						
Included in model (state reason if not):	Yes						
Model Unit Label:	WOOD00382D to WOOD00385E						
Type:	Concrete pipe						
Additional Information:	900mm dia; DS face similar but invert not surveyed; assumed slope similar to channel us						
No. Barrels on site:	1	**Modelled as:**	1				
Inlet Type:	Headwall with wingwalls						
Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a
Shape:	Circular	**Height:**	0.9m	**Width:**	0.9m		
US invert:	17.89mAD	**DS Invert:**	17.5mAD	**Length:**	7m		

Map:



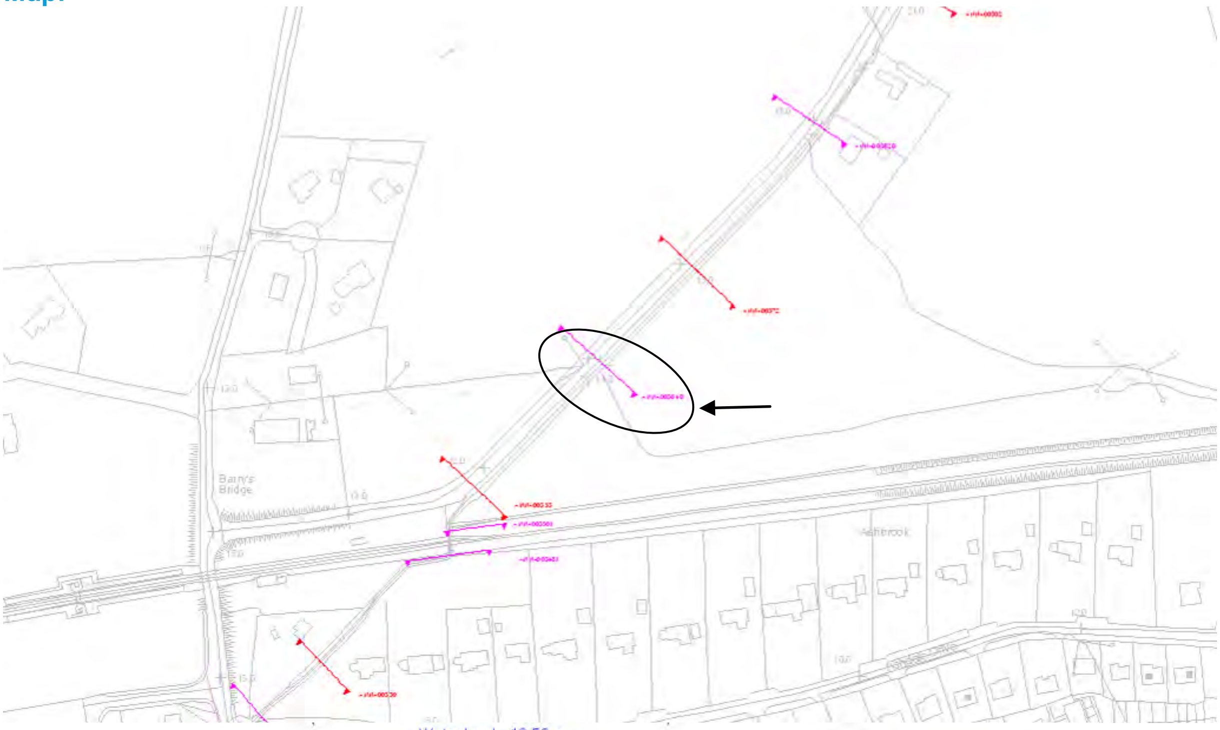
Photos:

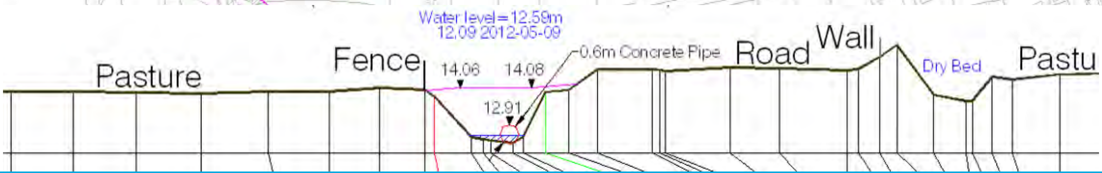
ANNA00382_DN.jpg

Note: The surveyed cross sections indicate two channels either side of the road. The stream that forms part of the model is the channel on the left side looking downstream.

Name of Structure / Survey Label:	Land drain; survey ID ANNA00364D
Location (x, y):	182240, 73909
Included in model (state reason if not):	No; small land drain and it is assumes that flow will not be blocked significantly.
Model Unit Label:	Not applicable
Type:	Concrete pipe
Additional Information:	600 dia concrete pipe; US IL 12.33mAD Downstream face similar; not surveyed

Map:





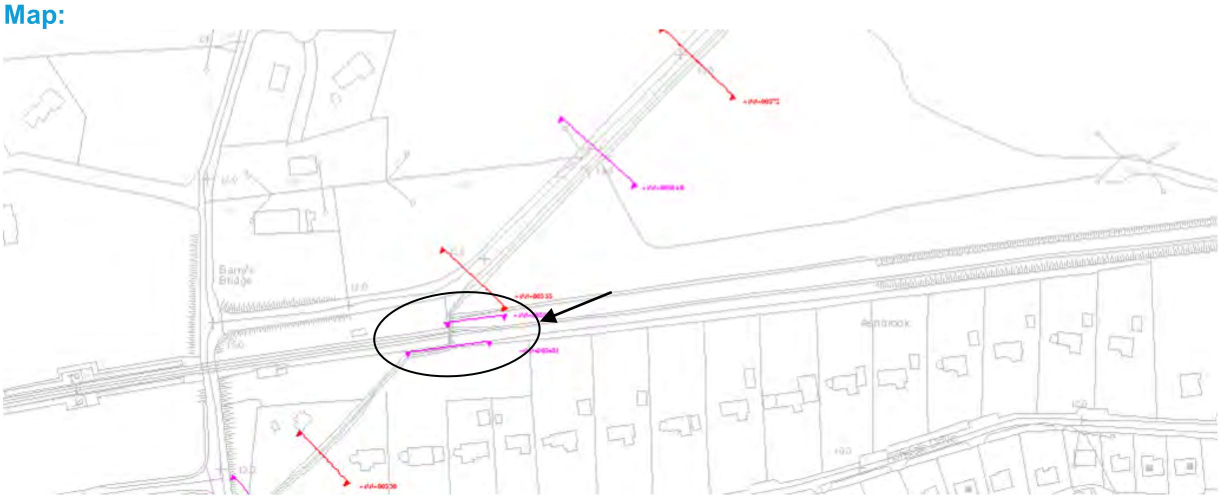
Photos:

ANNA00364D_DN.jpg

Name of Structure / Survey Label:	Irish Rail Culvert (C7); survey ID ANNA00350I
Location (x, y):	182148, 73811
Included in model (state reason if not):	Yes
Model Unit Label:	WOOD00350I to WOOD00350J
Type:	Concrete box culvert
Additional Information:	2.4m x 1m but partially blocked with silt build up

No. Barrels on site:	1	**Modelled as:**	1				
Inlet Type:	Headwall with wingwalls						
Trash Screen:	No	**Screen Width:**		**No. Bars:**		**% blockage:**	
Shape:	Box	**Height:**	0.81 us 0.36 ds	**Width:**	2.3		
US invert:	9.90mAD	**DS Invert:**	10.28mAD	**Length:**	14.350m		
How has structure been modelled?:	Site visit observations confirm that erosion and deposition issues are present at this structure. Concrete culvert (trowel finish) 0.02 on walls; 0.03 on invert to represent silt.						

Map:



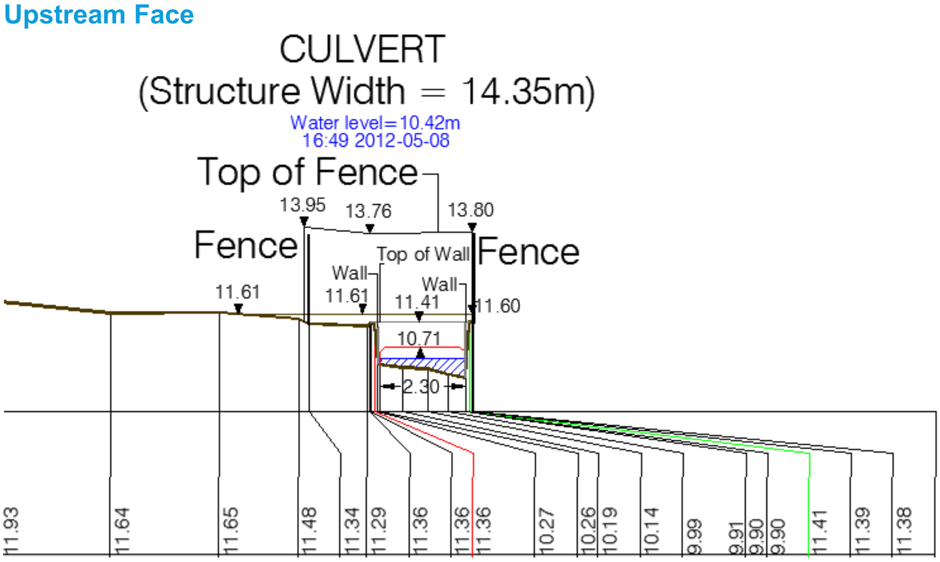
Photos:

No photos from survey available

US face

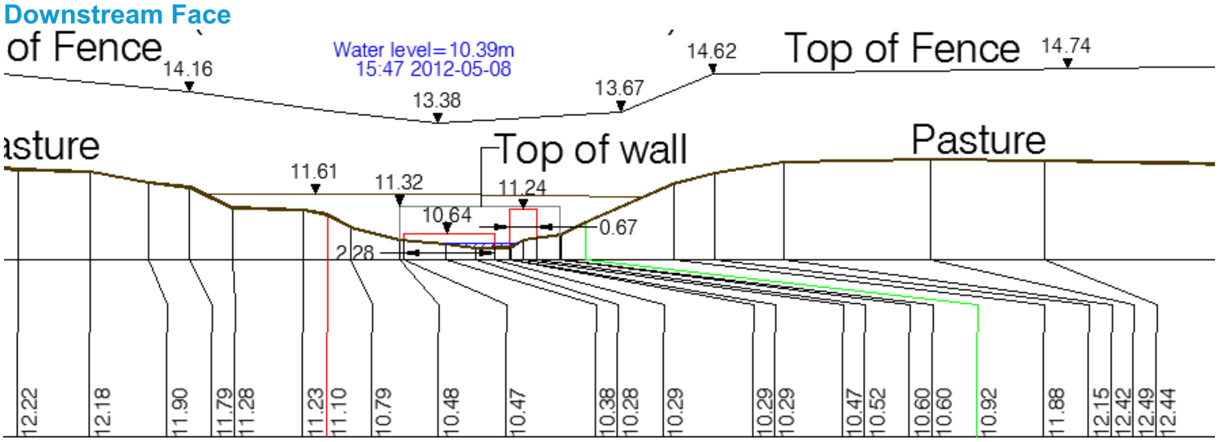
Erosion on left bank upstream

Upstream Face



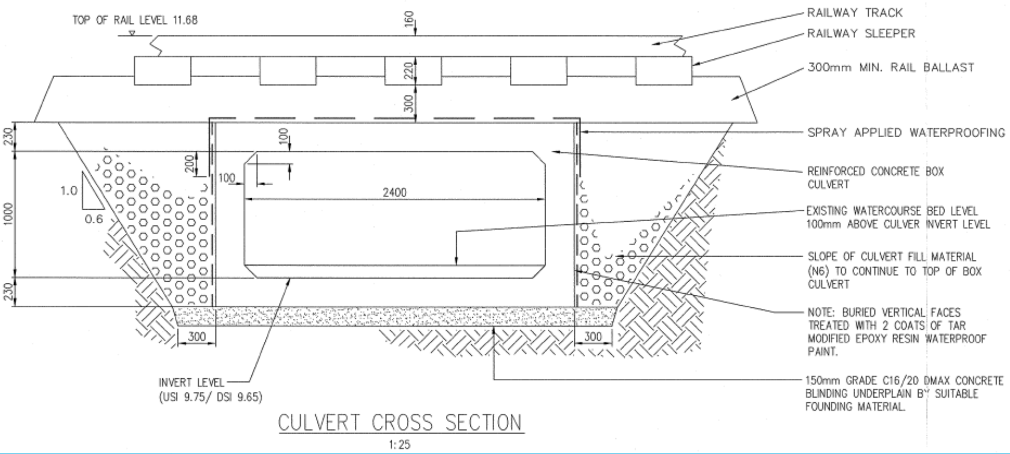
For model US invert taken as 9.9mAD
Soffit level is 10.71mAD
Effective Height = 0.81m

Downstream Face



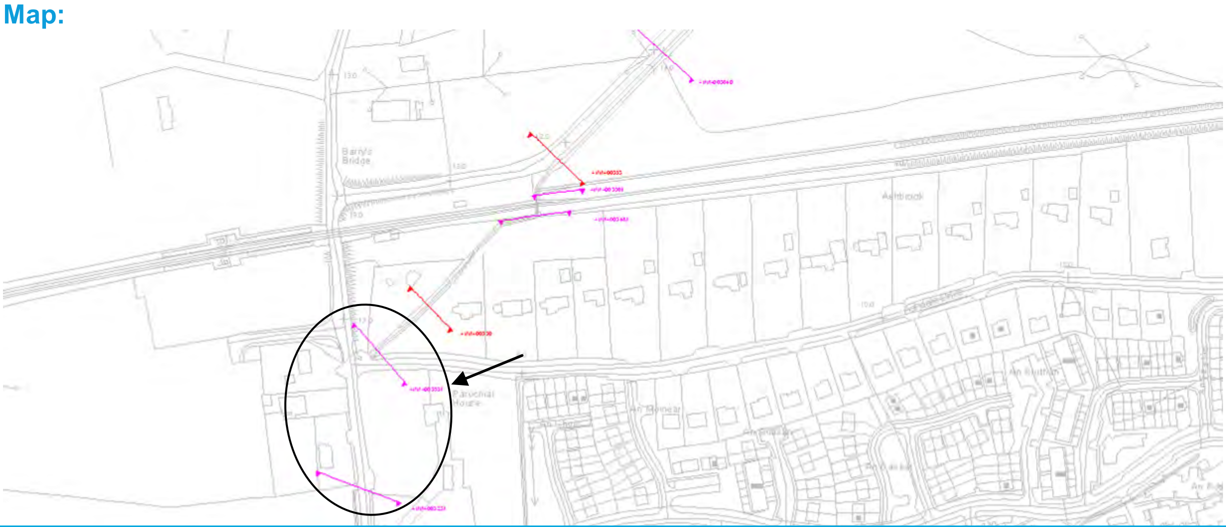
For model DS invert taken as 10.28mAD
Soffit Level is 10.64mAD
Effective Height = 0.36m

Irish Rail Drawing



Name of Structure / Survey Label:	ANNA00333I
Location (NGR):	182038, 73701
Included in model (state reason if not):	Yes
Model Unit Label:	WOOD0033I to WOOD00323J
Type:	Circular pipe and old stone arch culvert
Additional Information:	Surveyed circular pipe inlet 1.1m dia. This enters an old stone culvert under the main road, reported to be 900 x 900mm with arch roof. This old stone culvert collapsed during heavy rain in August 2012 and has been replaced with a 5m length of 1m diameter pipe (plus 4 inspection chambers). A trash screen was put in place at inlet.
How has structure been modelled?:	2 stage culvert - Culvert Inlet, circular conduit unit, rectangular conduit, Culvert Outlet.

Map:



Photos: No survey photos; photos from JBA site visit on 31/08/2012

Circular pipe inlet

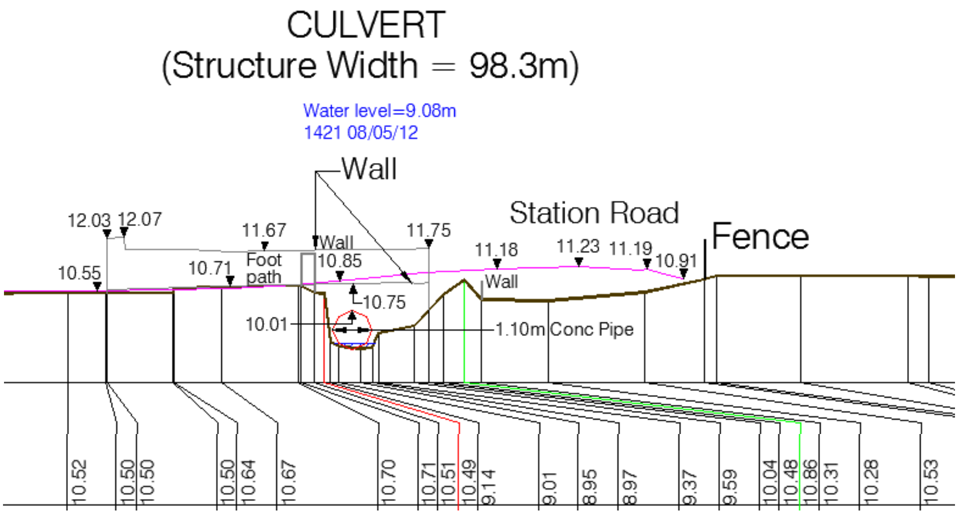
Old stone arch culvert (collapsed during flooding in Aug 2012)

Trash Screen

Dimensions for the trash screen on the bog road is as follows:

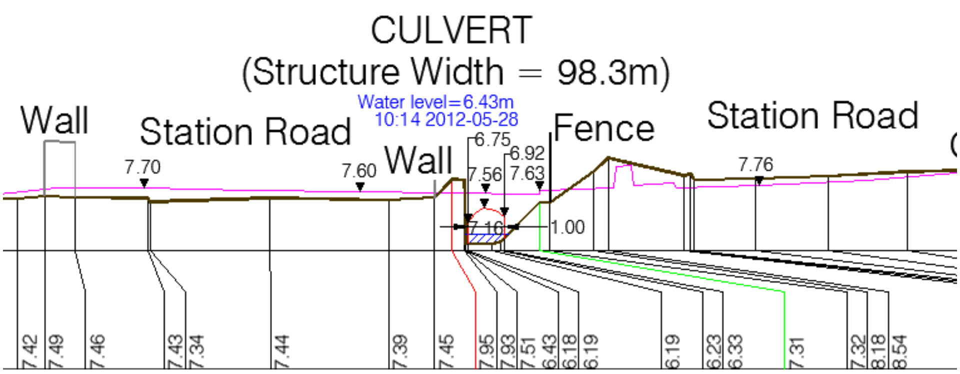
Width: 1.9m
Heights: 1.2m
Length from Concrete pipe: 1.2m
Spacing between bars is 150mm centres:
Diameter of Pipe internal is 1.2m
Trash screen fitted 300mm out from concrete pipe and 300mm above concrete pipe.

Upstream Face (note survey in June 2012 was carried out before installation of trash screen)



US IL 9.01mAD
During the study after the survey was carried out part of the old stone arch culvert collapsed and was replaced with a 5m length of 1m dia concrete pipe. This new pipe is represented in the model; (*US IL 8.43mAD; DS IL 8.285mAD).*

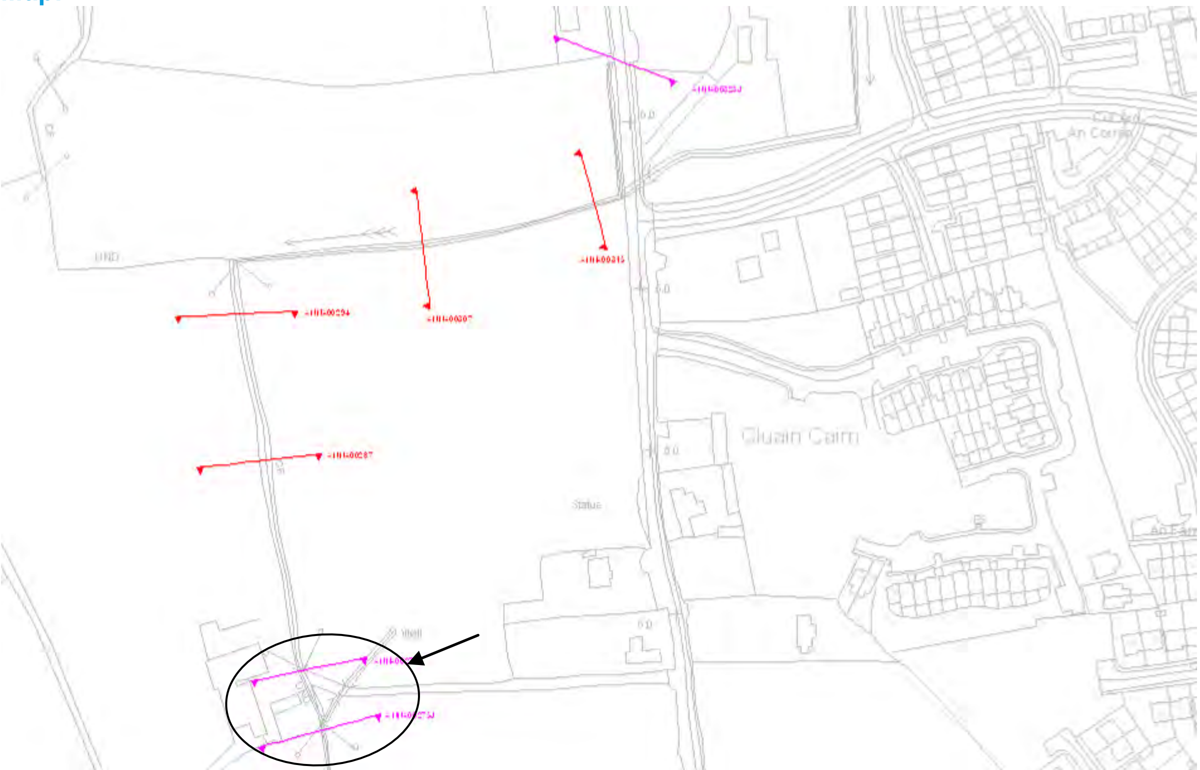
Downstream Face



DS IL 6.18mAD *(US IL 8.285mAD)*
Intermediate levels to represent the ds end of the circular pipe and us end of old stone arch are interpolated *(these are presented in italics above)*.

Name of Structure / Survey Label:	Private land access; ANNA00277I
Location (x, y):	181873, 73310
Included in model (state reason if not):	No; not considered a key element to flood risk, does not cause a backing up as water can flow over and around structure.
Model Unit Label:	Not applicable
Type:	Culvert
Additional Information:	Twin 600mm dia pipes; Min stream US IL 3.34mAD; DS IL 2.90mAD

Map:

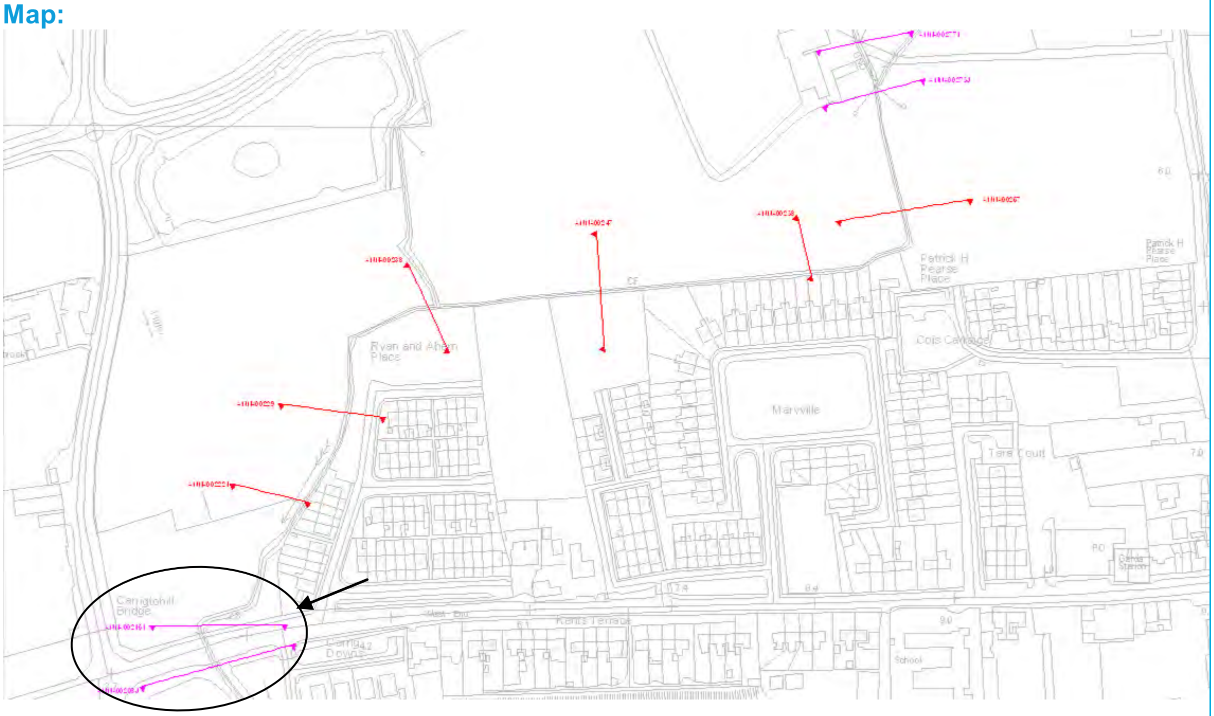


Photos:


ANNA00277IDOWN.jpg

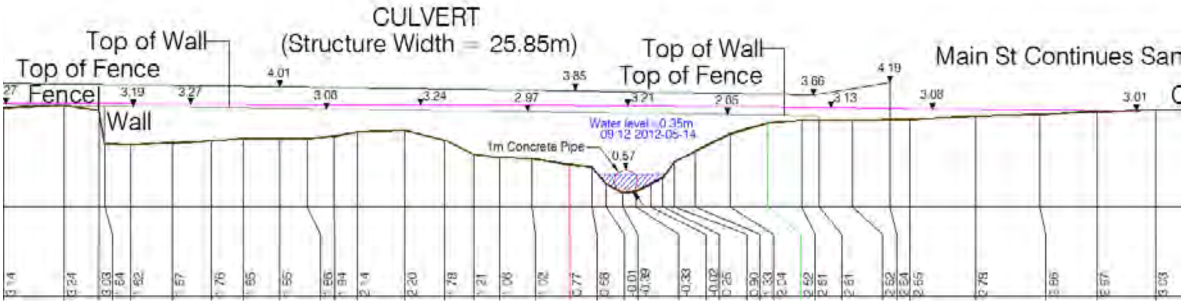

ANNA00275JUP

Name of Structure / Survey Label:	Carrigtohill Bridge; ANNA00216I – 208J						
Location (x, y):	181493, 72972						
Included in model (state reason if not):	Yes; this is a **KEY STRUCTURE**						
Model Unit Label:	2CA2_1187, 1187_Inlet, **Culvert 7**, 1187_Outlet						
Type:	Culvert						
Additional Information:	Maltby survey in 2007 indicated twin 700mm dia; Murphys survey in 2012 indicates single 1m dia; RPS report in 2009 indicated twin 900mm dia Site visit indicates heavily overgrown This structure is included in the Halcrow Lee CFRAM model (as an equivalent single dia of 1m). Previous flooding at Castlelake has been linked to insufficient capacity at this structure. Channel restriction due to temporary construction culverts was also cited as a problem in the 2009 flood event.						
How has structure been modelled?:	The 2012 survey, show only one culvert. Based on site visit it is considered likely that one of these culverts is blocked / overgrown with heavy vegetation. Based on an undertaking that this culvert would be regularly maintained the culvert was included in the model assuming full capacity. This structure has been modelled as a single pipe of an equivalent diameter of 1.4m in ISIS. The invert levels downstream are based on the Lee CFRAMS survey.						
No. Barrels on site:	2	**Modelled as:**	Equivalent single dia				
Inlet Type:	Projecting pipes						
Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a
Shape:	Circle	**Height:**	1.4	**Width:**	1.4		
US invert:	-0.39	**DS Invert:**	-0.258	**Length:**	25.226		
Map:							



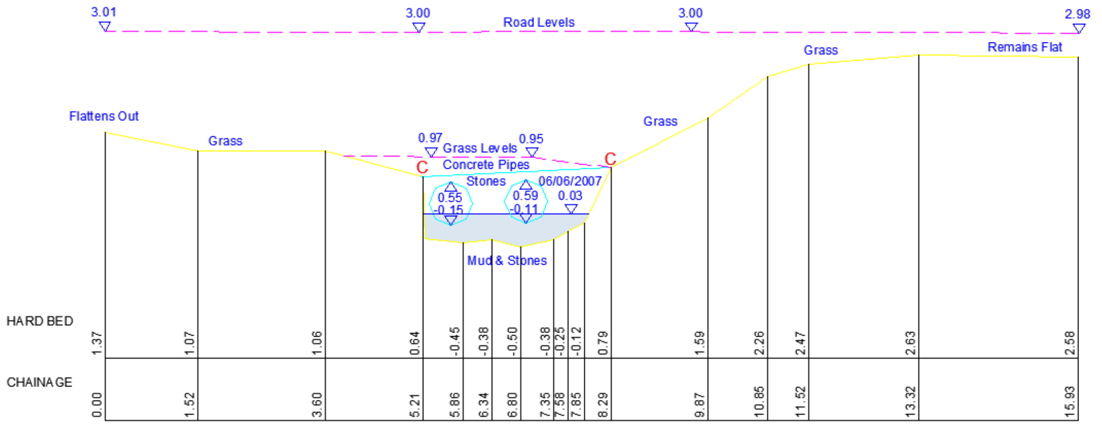
Upstream Face:

2012 Survey



From 2012 survey US IL -0.39mAD

2007 Survey



From 2007 survey pipes US IL -0.15 / -0.11mAD; Min stream IL -0.38mAD

Photos:

ANNA00216I_DN.jpg

ANNA00275JUP

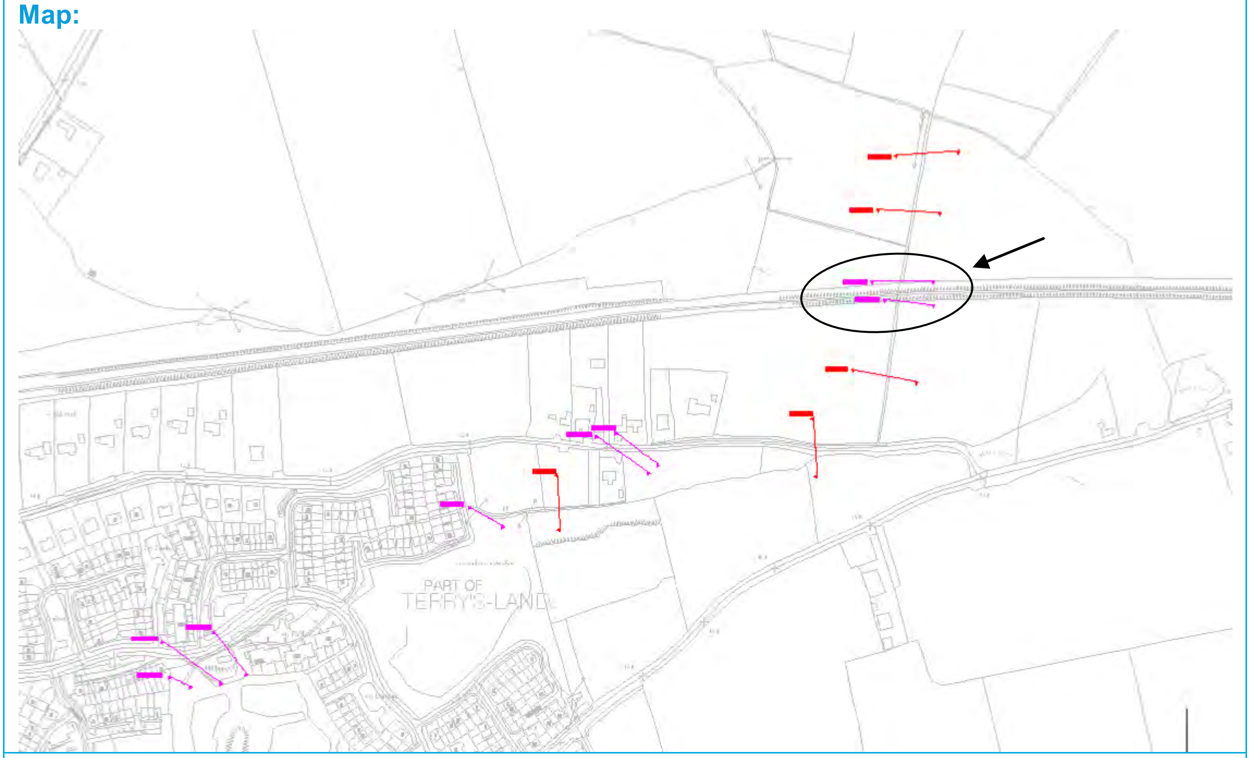
The remainder of the reach was surveyed and modelled under the Lee CFRAMS project, as reach code 2CA2 (see Section 3.14).

Some sections from the recent June 2012 survey overlap with that carried out in June 2012. These cross section have been compared and the best available data has been used in the model build. (see Section 3.7).

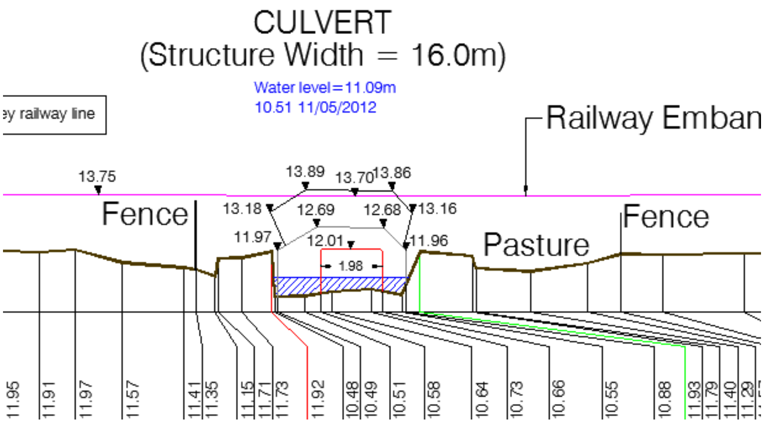
3.12 Poulaniska Reach (POUL) Structures

Name of Structure / Survey Label:	Railway Culvert (C9) POUL00097I
Location (x, y):	183186, 73934
Included in model (state reason if not):	Yes
Model Unit Label:	POUL00097I to POUL00095J
Type:	Concrete box culvert
Additional Information:	Design information taken from combination of Irish Rail construction drawings and survey data. (Drwg No. 011274-49-DR-1380) Irish Rail drawing indicates a 2.1 x 1.5m box culvert with 300mm gravel bed above culvert invert. The survey indicates this gravel layer has been eroded / washed away.

Map:

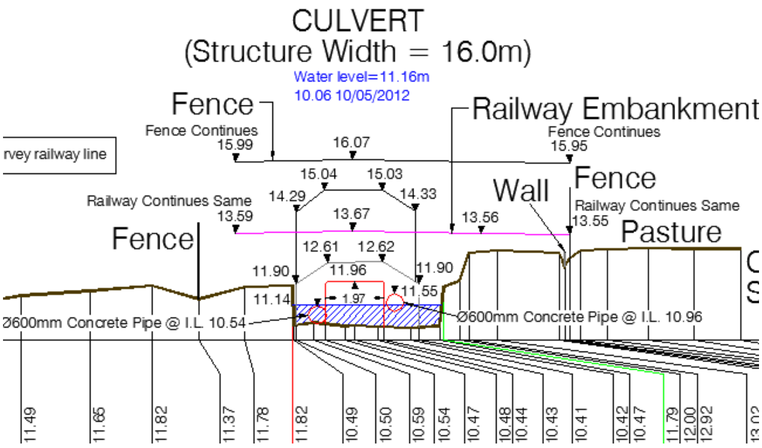


Upstream Face:



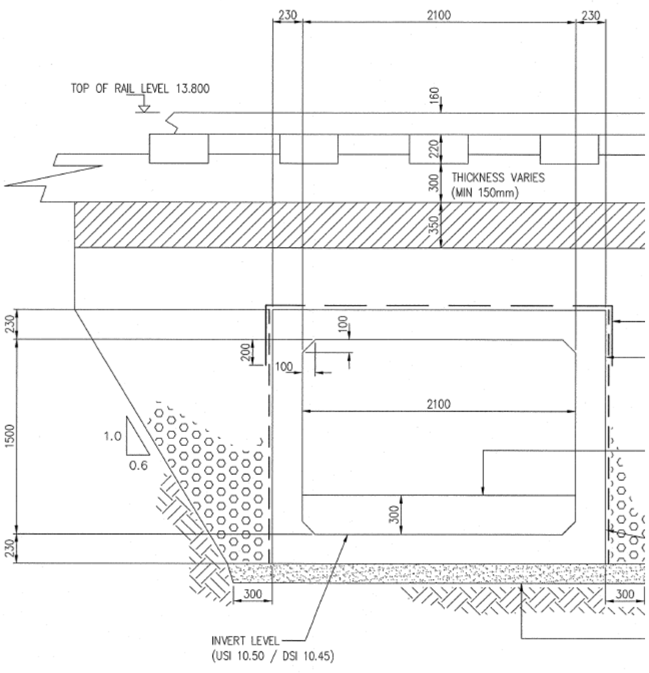
US IL 10.5mAD
Effective height 1.5m

Downstream Face:

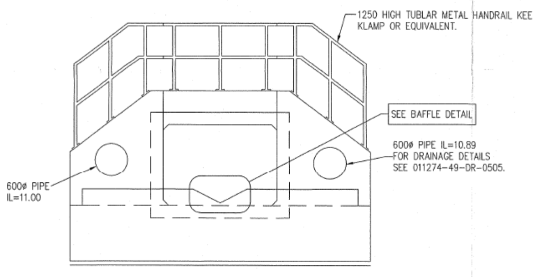


DS IL 10.45mAD
Effective height 1.5m

Irish Rail Drawing:



CULVERT CROSS SECTION



SECTION E–E
1:50

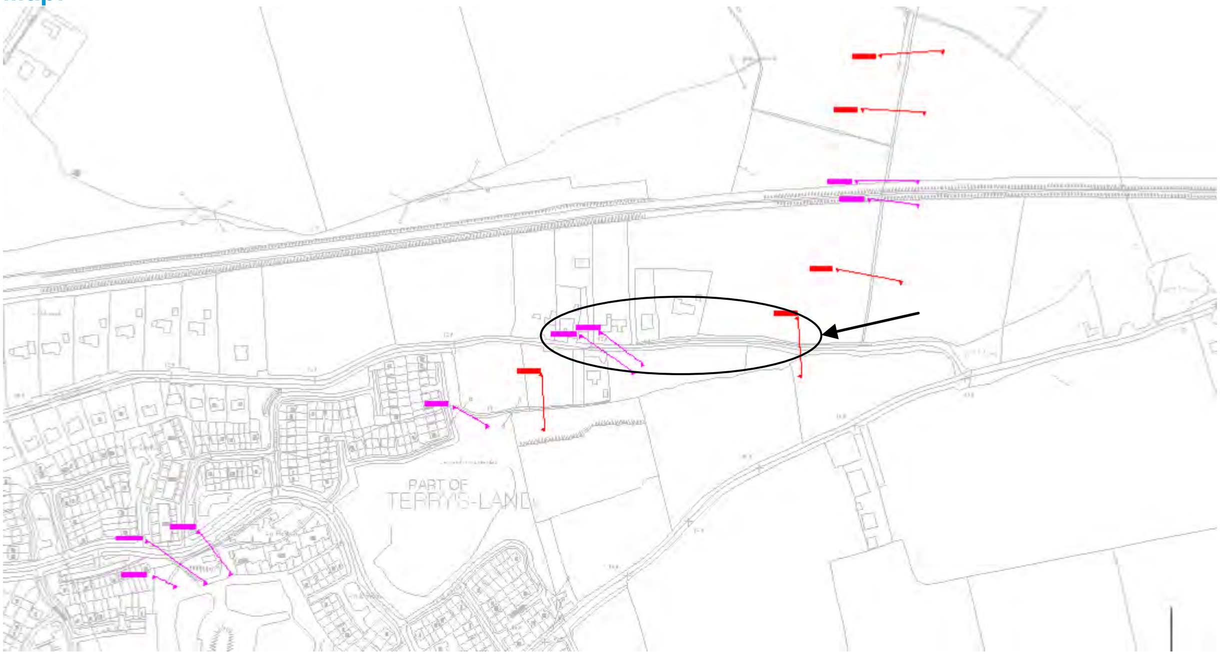
Photos:

POUL00097I_DN.jpg

POUL00095J_UP.jpg

Name of Structure / Survey Label:	Not surveyed
Location (x, y):	582900, 573840
Included in model (state reason if not):	No. Not surveyed. Beyond the scope of the model to include all small private structures unless they are considered particularly important in terms of flood risk.
Model Unit Label:	Not applicable
Type:	Small culverts
Additional Information:	Series of small structures, private driveways and footbridges to private dwellings.

Map:



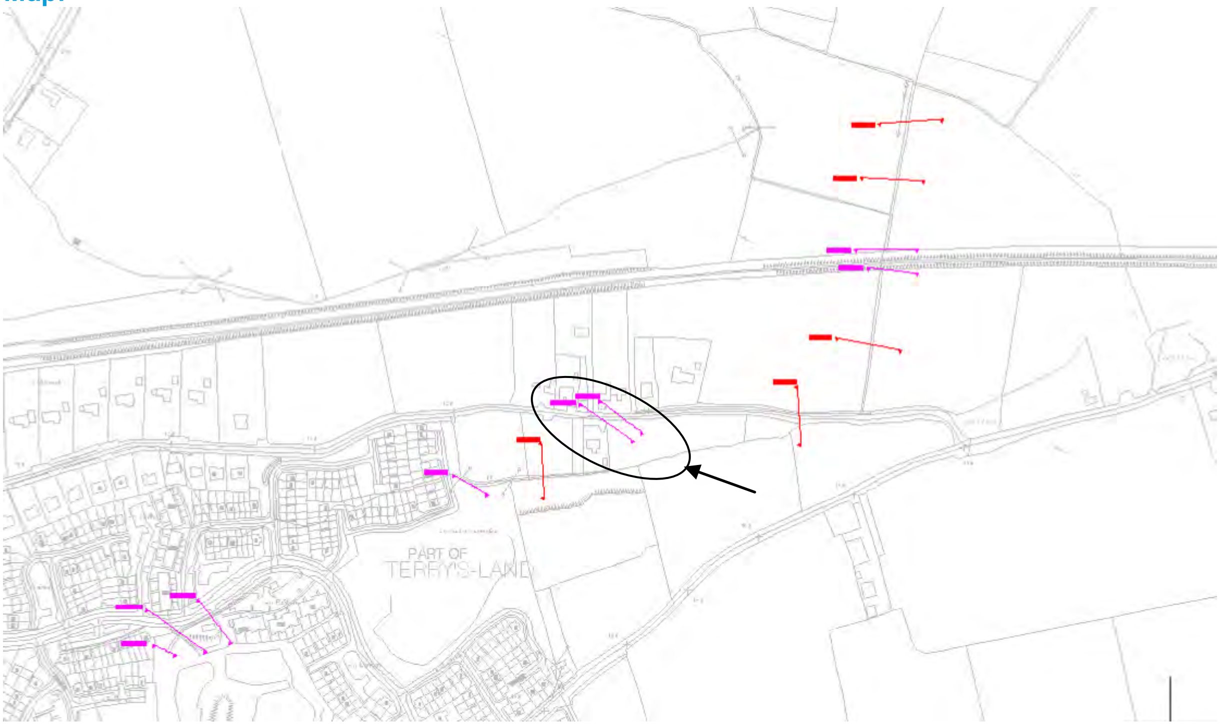
Photos:

POUL00063I_UP.jpg
Photos from surveyors but not surveyed

POUL00065I_DN.jpg

Name of Structure / Survey Label:	POUL00061I to 00054J
Location (x, y):	182935, 73782
Included in model (state reason if not):	Yes
Model Unit Label:	POUL00061a, 00061b
Type:	Corrugate plastic pipes
Additional Information:	Twin 600 dia; US IL 10.95 / 10.85mAD; DS IL 10.70 / 10.77mAD Modelled as equivalent single dia of 0.424m Manning's of 0.025 selected (similar for metal corrugated pipe)

Map:



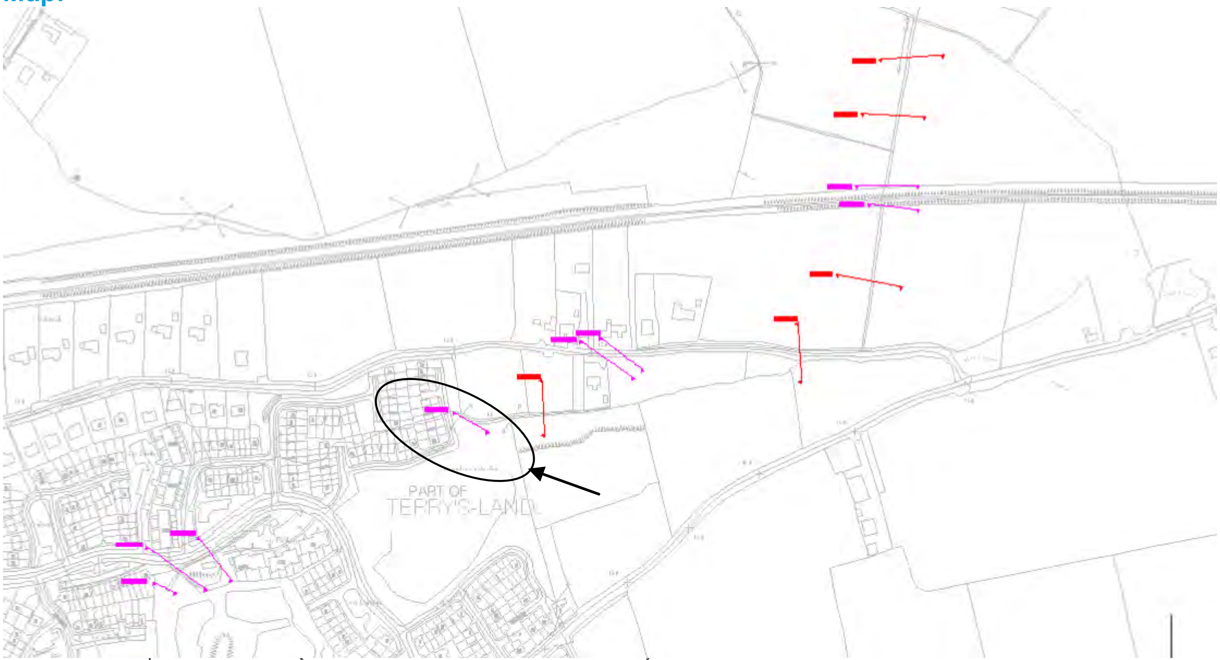
Photos:

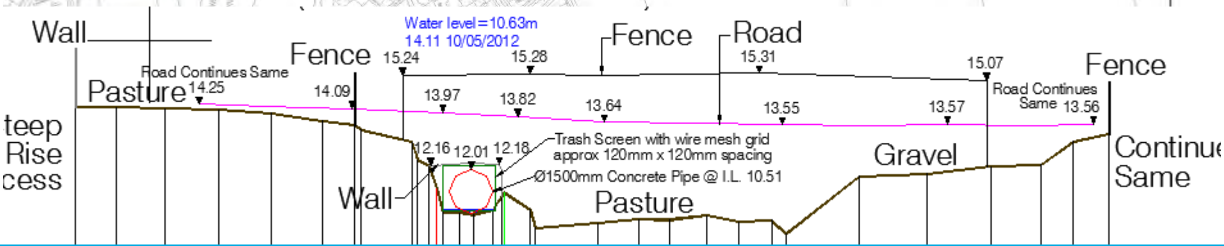
POUL00061I_DN.jpg

POUL000054J_UP.jpg

Name of Structure / Survey Label:	POUL00041I
Location (x, y):	182794, 73719
Included in model (state reason if not):	Yes
Model Unit Label:	POUL00041I
Type:	Culvert
Additional Information:	1500mm dia concrete pipe US IL 10.51mAD Trash screen with wire mesh 120 x 120mm spacing
How has structure been modelled?:	Circular culvert with inlet with trash screen and outlet unit. It is assumed that this trash screen will block up to a third of its height i.e. 500mm. This culvert outfalls into a reservoir unit representing the cave system.

Map:





Photos:

POUL00041I_DN.jpg

This reach enters a swallow hole / cave system at Cúl Ard and re-emerges further downstream near Slatty Pond.

The cave system is modelled as a reservoir unit that has a large capacity to store and attenuate the fluvial flows from the Poulaniska Stream. Based on the hydro-geological study carried for the area, it is assumed that the caves have the effect of introducing a lag time of 60 hours to the flow hydrograph in the stream. This results in a constant base flow of approx 0.26m^3/s.

In the model at the downstream end there is a reservoir unit representing the cave system and an abstraction unit is used to simulate flow from this storage area into the downstream reach of the model (2CAR).

The remainder of this reach (downstream of the cave system) was surveyed and modelled under the Lee CFRAMS, as reach code 2CAR (see Section 3.14).

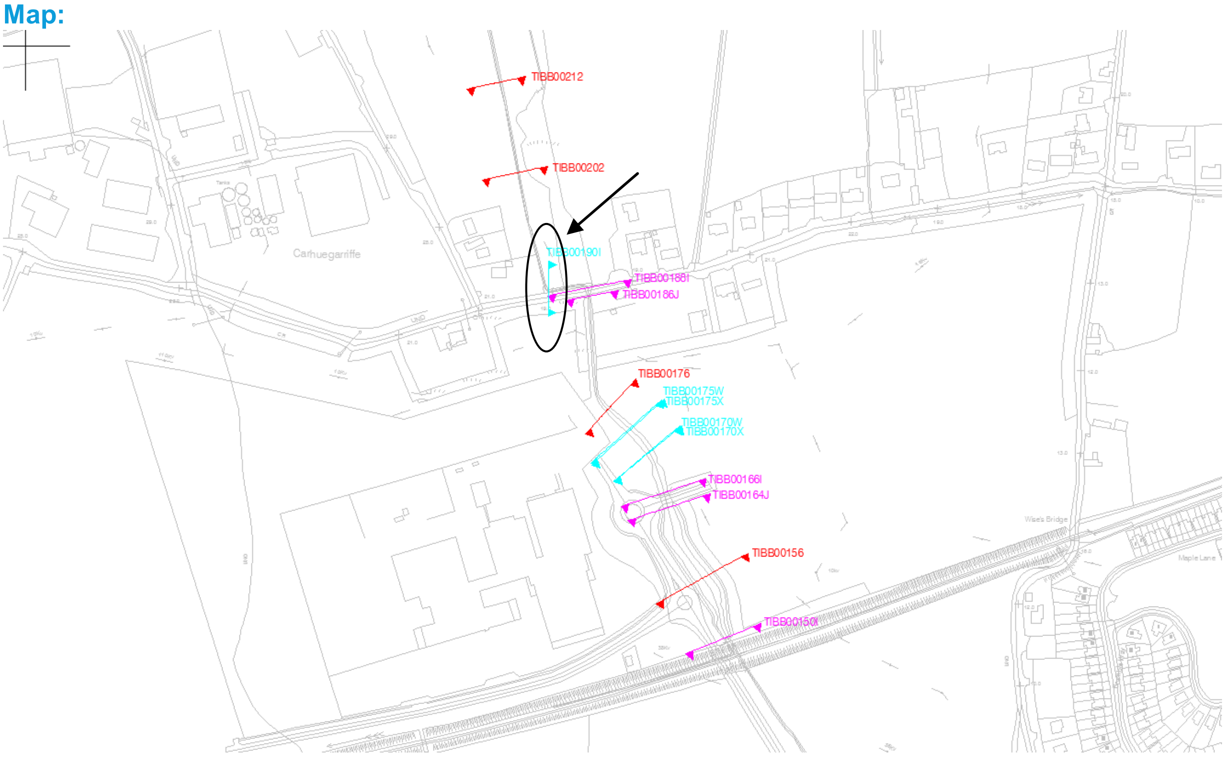
3.13 Tibbottstown Stream (TIBB) Reach Structures

Name of Structure / Survey Label:	TIBB00190I
Location (x, y):	180504, 73748
Included in model (state reason if not):	Yes; this is **KEY STRUCTURE**
Model Unit Label:	TIBB00190I to TIBB00190J
Type:	1000mm dia pipe
Additional Information:	Survey indicates silting of culvert to a depth of 0.33 to 0.38m (bed inverts 18.6, 18.65mAD) however the downstream end is not obstructed. The culvert is modelled as full circular bore; a Mannings of 0.03 on invert to represent silt along the culvert invert.
Inlet Type:	Projecting socket end of concrete pipe

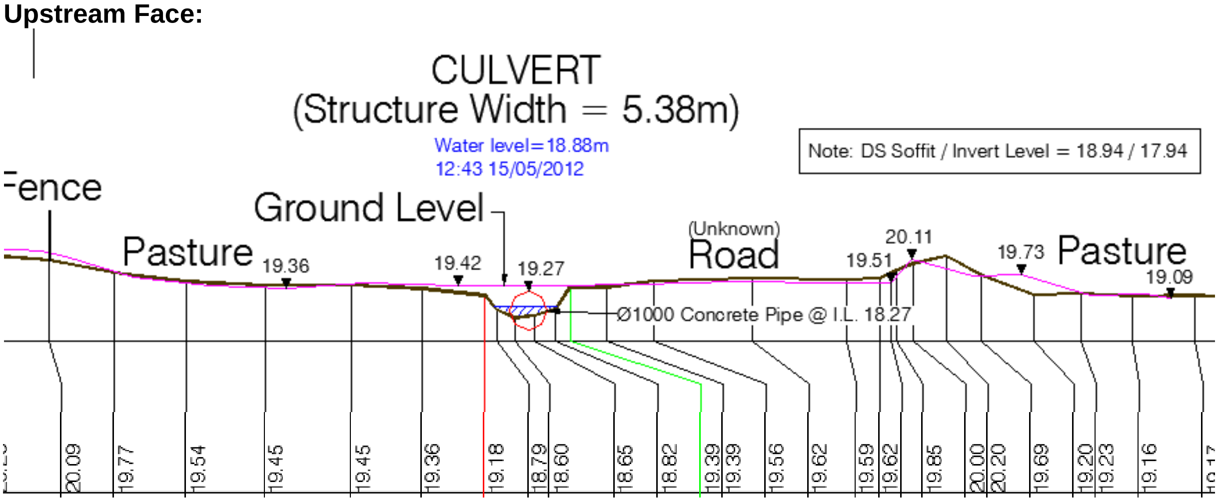
Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a

Shape:	Circular	**Height:**	1m	**Width:**	1m
US invert:	18.27mAD	**DS Invert:**	17.94mAD	**Length:**	5.38m

Map:



Upstream Face:



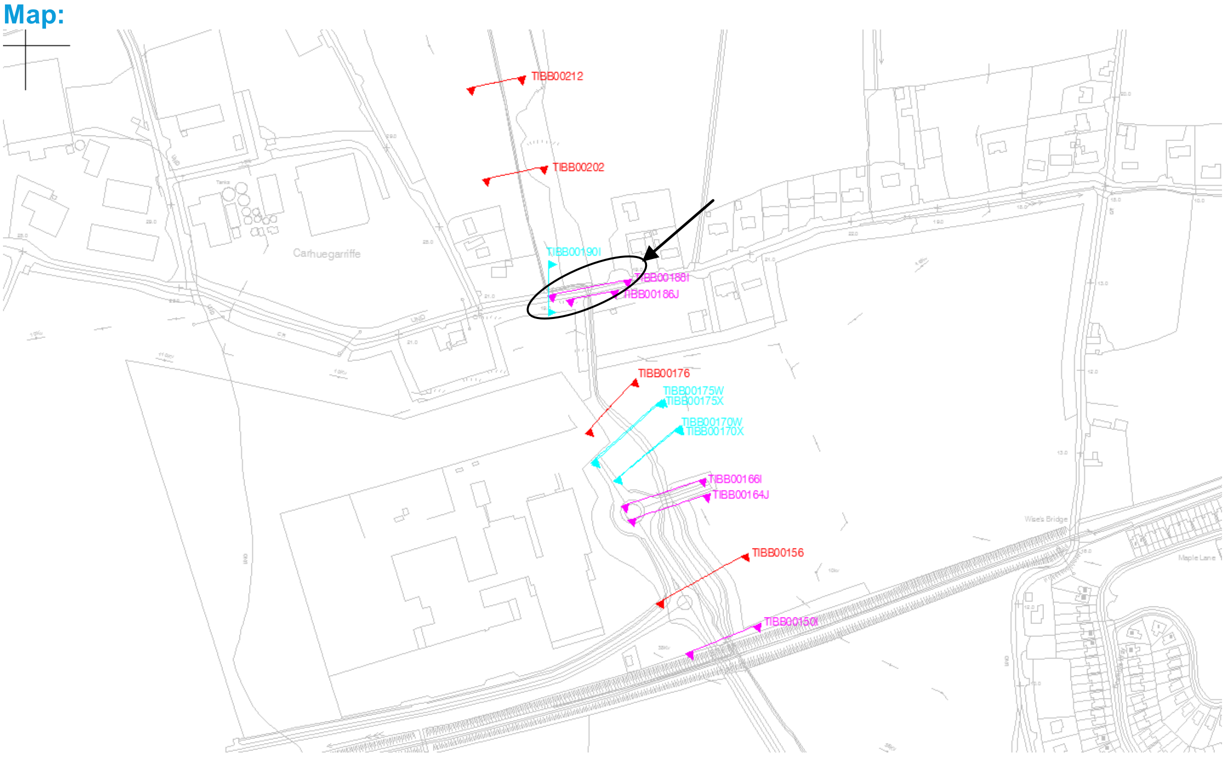
Photos:

TIBB001901_DN.jpg

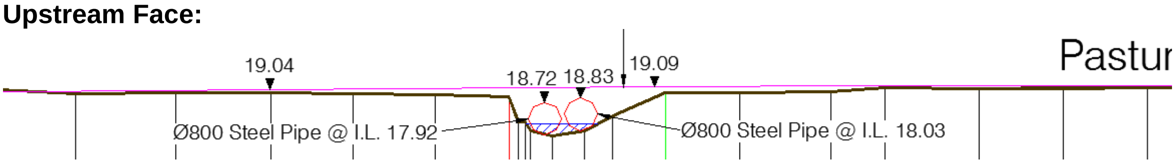
Model Parameters								
Inlet Type:	Projecting socket end of concrete pipe							
Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a	
Shape:	Circular	**Height:**	1m	**Width:**	1m			
US invert:	18.27mAD	**DS Invert:**	17.94mAD	**Length:**	5.38m			

Name of Structure / Survey Label:	TIBB00188I						
Location (x, y):	180549, 73752						
Included in model (state reason if not):	Yes; **KEY STRUCTURE**						
Model Unit Label:	TIBB00188I to TIBB00186J						
Type:	Twin 800mm dia steel pipe						
Additional Information:							
How has structure been modelled?:	Modelled as one equivalent diameter pipe (model input parameters for single pipe in brackets below)						
Inlet Type:	Corrugated metal pipe projecting						
Trash Screen:	No	**Screen Width:**	n/a	**No. Bars:**	n/a	**% blockage:**	n/a
Shape:	Circular	**Height:**	0.8 (1.13)	**Width:**	0.8 (1.13)		
US invert:	17.92mAD 18.03mAD (17.92mAD)	**DS Invert:**	17.61mAD 17.67mAD (17.67mAD)	**Length:**	7m		

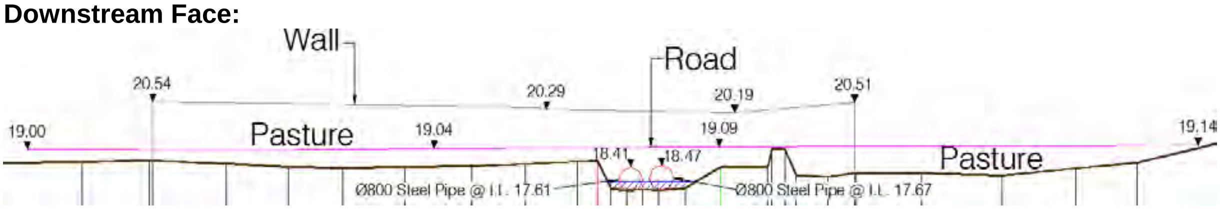
Map:



Upstream Face:



Downstream Face:

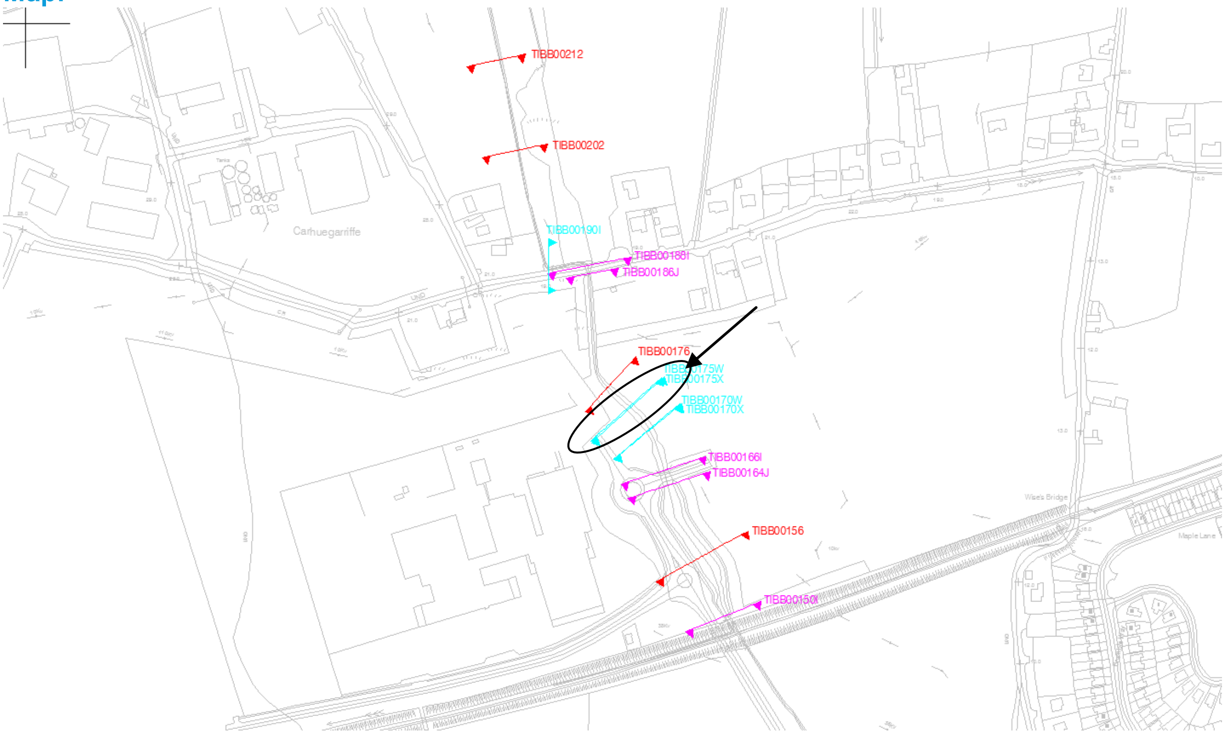


Photos:

 TIBB001881_DN.jpg	 TIBB001881_RB.jpg

Name of Structure / Survey Label:	TIBB00175W		
Location (x, y):	180588, 73619		
Included in model (state reason if not):	Yes		
Model Unit Label:	TIBB00175W		
Type:	Weir		
Additional Information:	This is modelled as a general purpose weir.		
Weir Crest Elevation:	16.39mAD	**Weir Width:**	3.3m

Map:

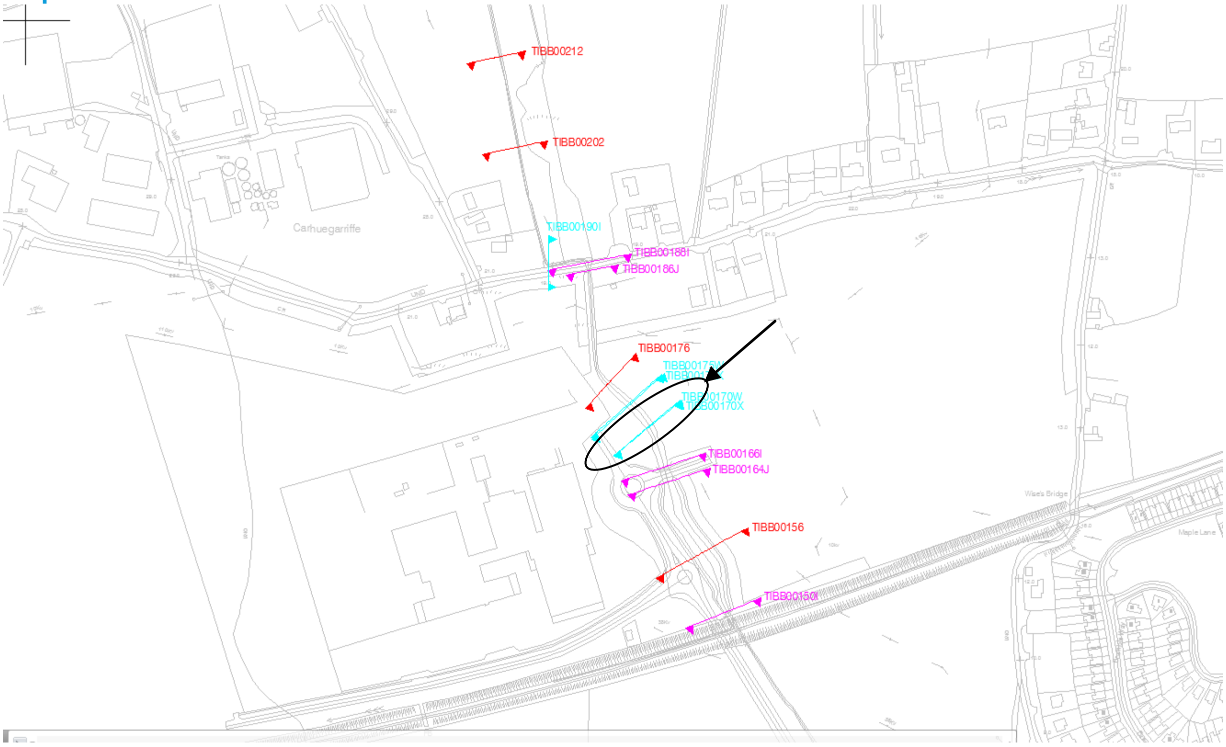


Photos:

TIBB00175X_UP.jpg

Name of Structure / Survey Label:		TIBB00170W	
Location (x, y):		180607, 73598	
Included in model (state reason if not):		Yes	
Model Unit Label:		TIBB00170W	
Type:		Weir	
Additional Information:		This is modelled as a general purpose weir.	
Weir Crest Elevation:	15.83mAD	**Weir Width:**	1.55m

Map:

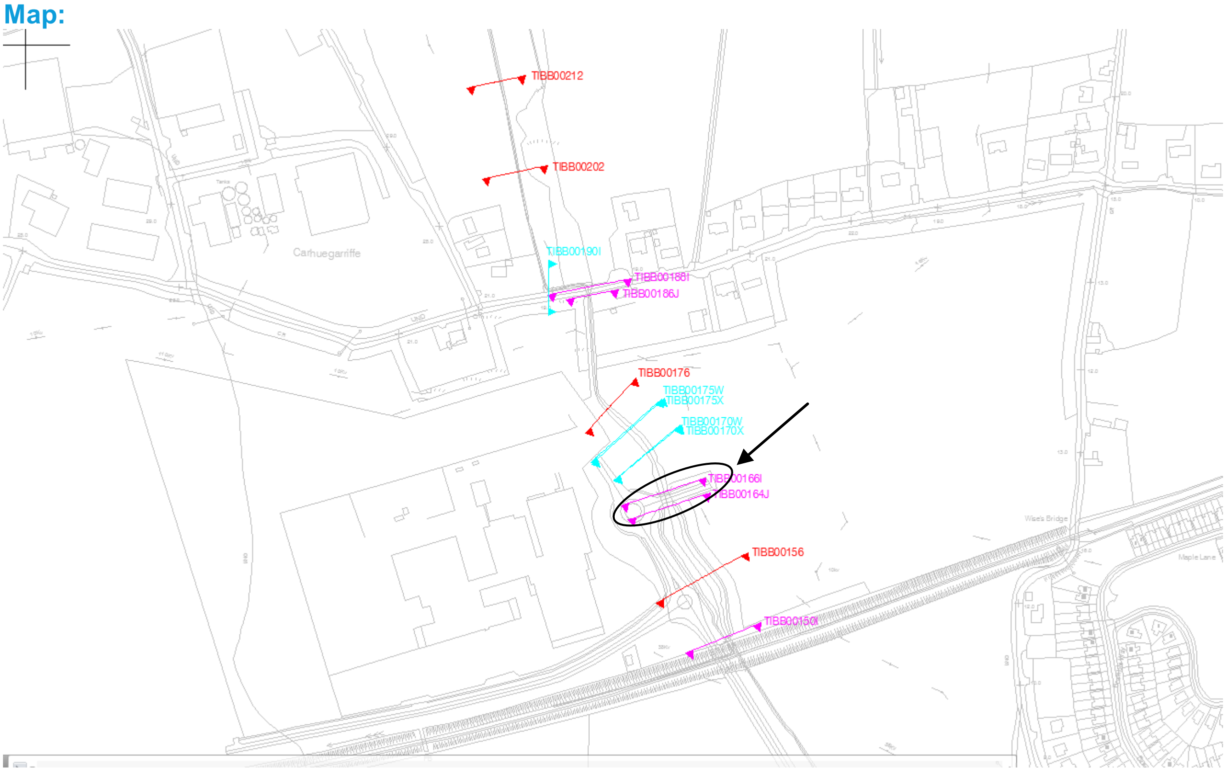


Photos:

TIBB00170X_UP.jpg

Name of Structure / Survey Label:	TIBB00166I
Location (x, y):	180618, 73557
Included in model (state reason if not):	Yes; this is a **KEY STRUCTURE**
Model Unit Label:	TIBB00166I to TIBB00166J
Type:	Box culvert
Additional Information:	Survey and observations on site visits indicate **severe siltation** at this structure. Reduced capacity represented in model structure unit.
How has structure been modelled?:	Due to silt us invert is higher than ds invert; mannings 0.03 to represent silt along invert;

Map:

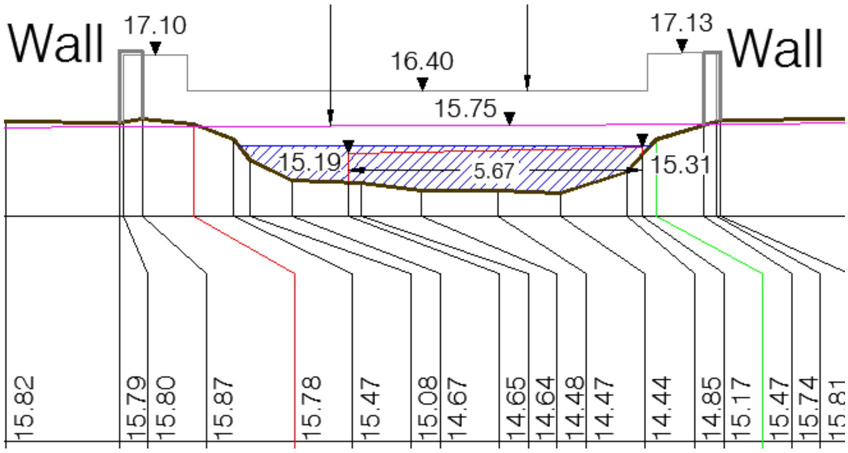


Photos:

TIBB001666I_DN.jpg

TIBB00164J_UP.jpg

Upstream Face:

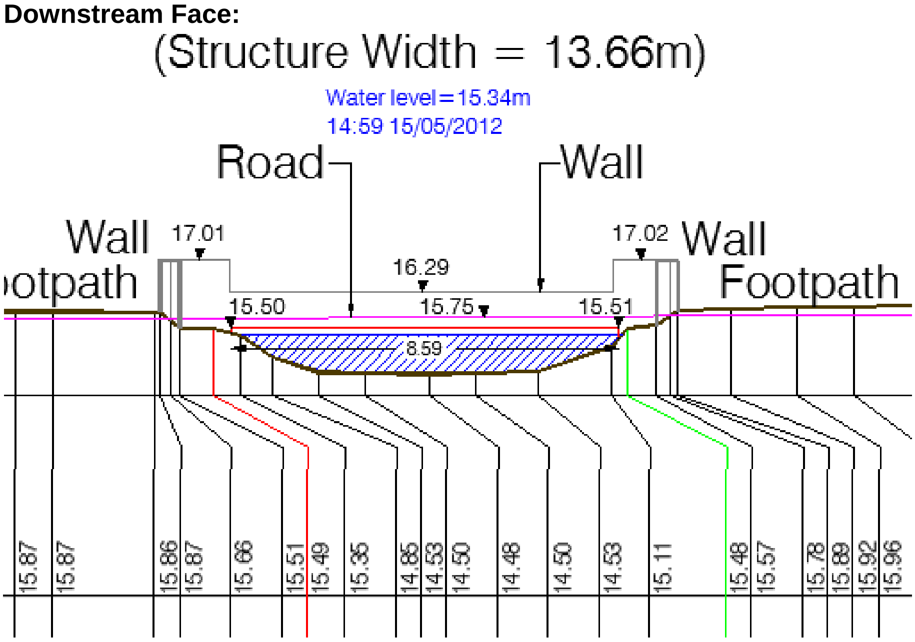


Assumed invert for model: 14.44mAD

Soffit Level: 15.2mAD

Width: 5.7m Effective Height: 0.76m

Downstream Face:



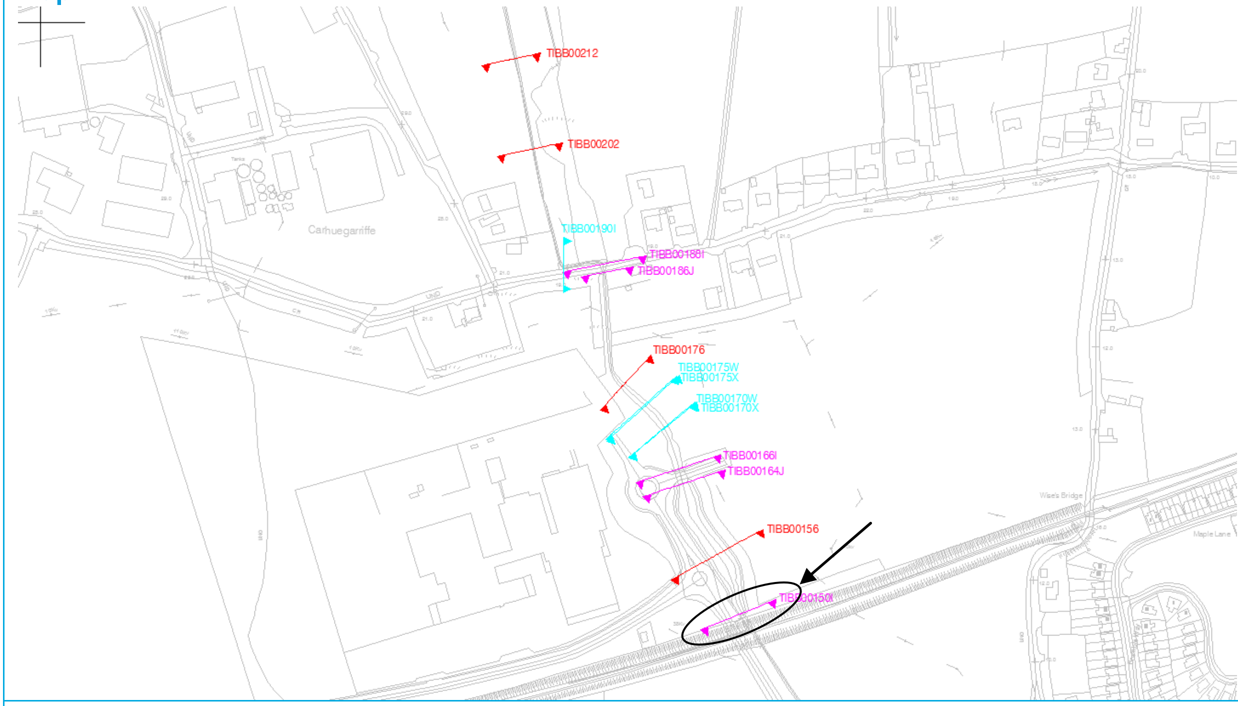
Assumed invert for model: 14.48mAD

Soffit Level: 15.5mAD

Width: 8.6m Effective Height: 1.02m

Name of Structure / Survey Label:	TIBB00150I
Location (NGR):	
Included in model (state reason if not):	Yes; this is a **KEY STRUCTURE**
Model Unit Label:	TIBB001500I to TIBB498C and TIBB001501S
Type:	Siphon
Additional Information:	Irish Rail siphon takes water from upstream under rail line to downstream side. Not accessible to survey and no design information on siphon. Info from Irish Rail on the rail line construction levels and associated diversion channel along with info from IDA used to establish reasonable assumptions on invert level for the siphon structure.
How has structure been modelled?:	Inverted siphon unit with culvert upstream representing the inlet.

Map:



Photos:

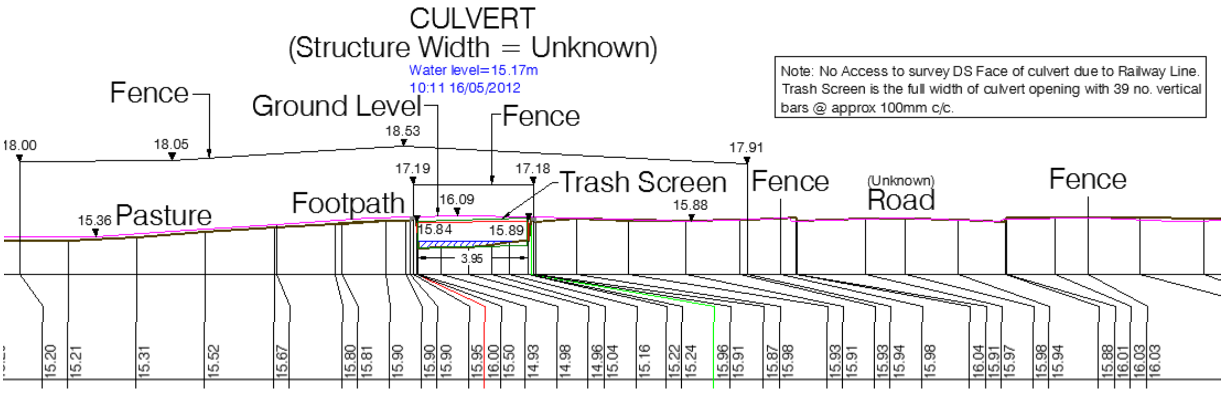
3 way split at TIBB00150I

Inlet to Irish Rail Siphon

Inlet to Cascade and Overflow Pipe to IDA Siphon

Cascade at downstream side

Upstream Face



Trash Screen

The trash screen is modelled by including an inlet following by a conduit. This is based on the dimension given in the survey drawings and a 30% blockage has been assumed at the trash screen. The conduit unit is followed by a junction which in turn directs flow into the siphon units.

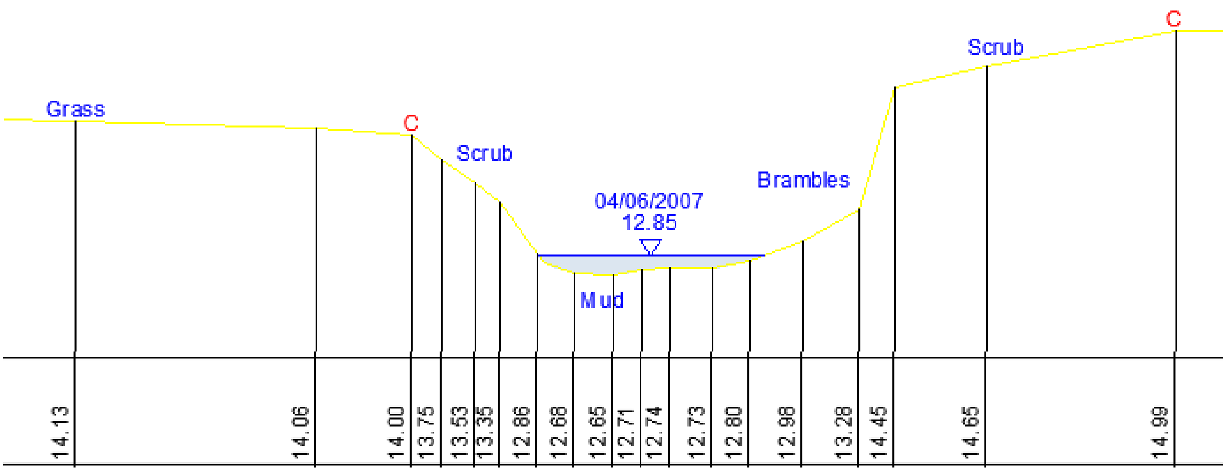
Inlet

The inlet is represented as a short conduit / culvert unit.
US invert: 14.93mAD DS invert: 14.93mAD
Width: 3.95m Height: 0.95
Length: 2m

Siphon Unit

A siphon unit has been used to represent the siphon taking flow under the rail line.
Survey at upstream face (outside trash screen) indicates an invert of 14.93mAD at TIBB00150I
Upstream sill level = 14.93mAD

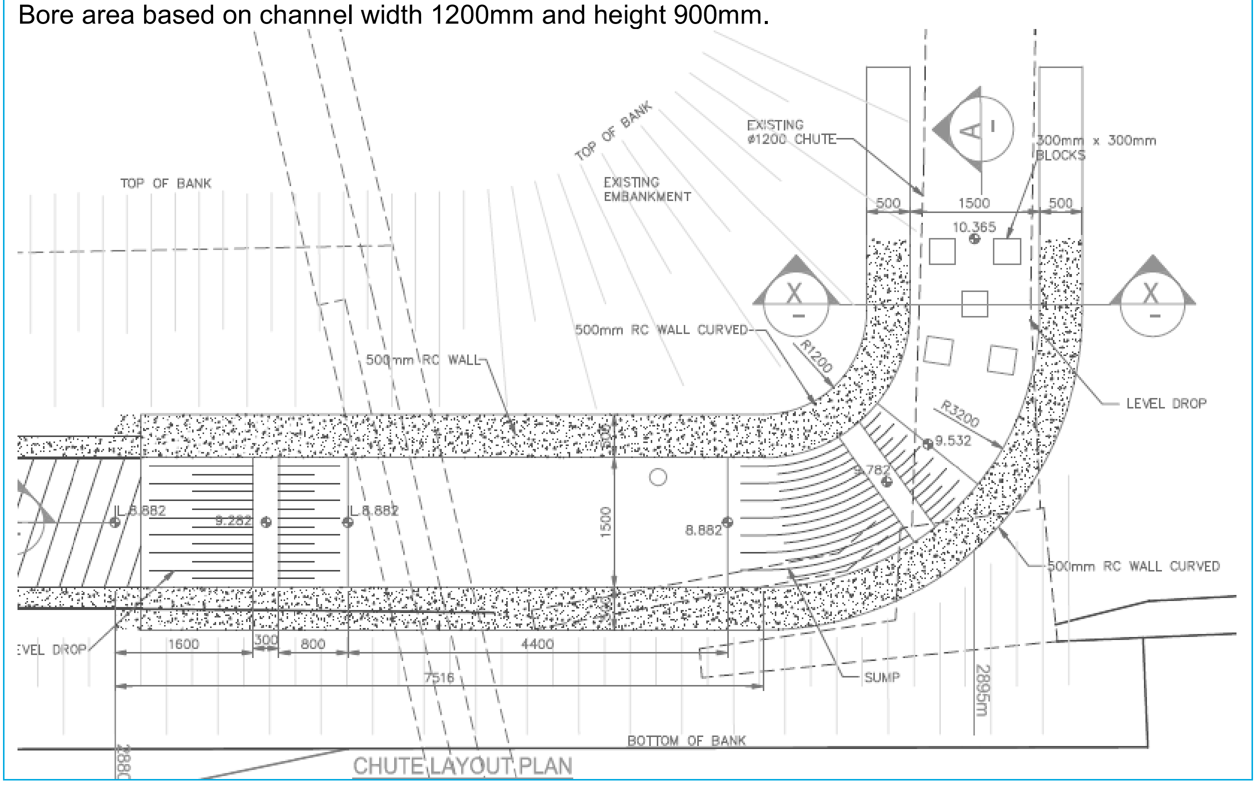
Survey at closest downstream section indicates invert = 12.655mAD at 2CA1_1395.8
Downstream sill level = 12.655mAD



The Irish Rail Drawings were also reviewed to consider the level of the rail line and the possible min level of the siphon pipe under the rail line. The rail level at this point is approx. 9.4mAD.

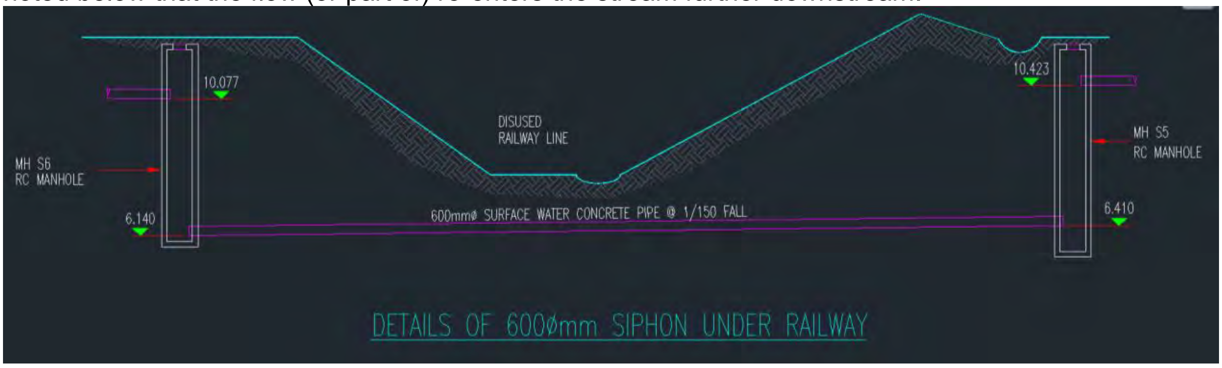
Input parameters for siphon TIBB001500S:
Upstream sill level = 14.93mAD
Siphon throat invert level = 7.7mAD
Throat soffit level = 8.15mAD
Bore Area = 0.16m^2 (450mm dia)
Downstream sill level = 12.655mAD (downstream river unit bed level)

Rail Channel
The inlet to the cascade (that feeds into the rail diversion channel) is modelled as a siphon due to steepness.
Assuming the invert level is 100mm above that of 450mm dia siphon (upstream sill level in model set at 15.13mAD, downstream sill level is 10.365mAD based on drawing from Irish Rail. With
Bore area based on channel width 1200mm and height 900mm.



Input parameters for siphon RAIL0900S:
Upstream sill level = 15.13mAD
Siphon throat invert level = 14mAD
Throat soffit level = 14.9mAD
Bore Area = 1.08m^2
Downstream sill level = 10.365mAD (downstream river unit bed level)

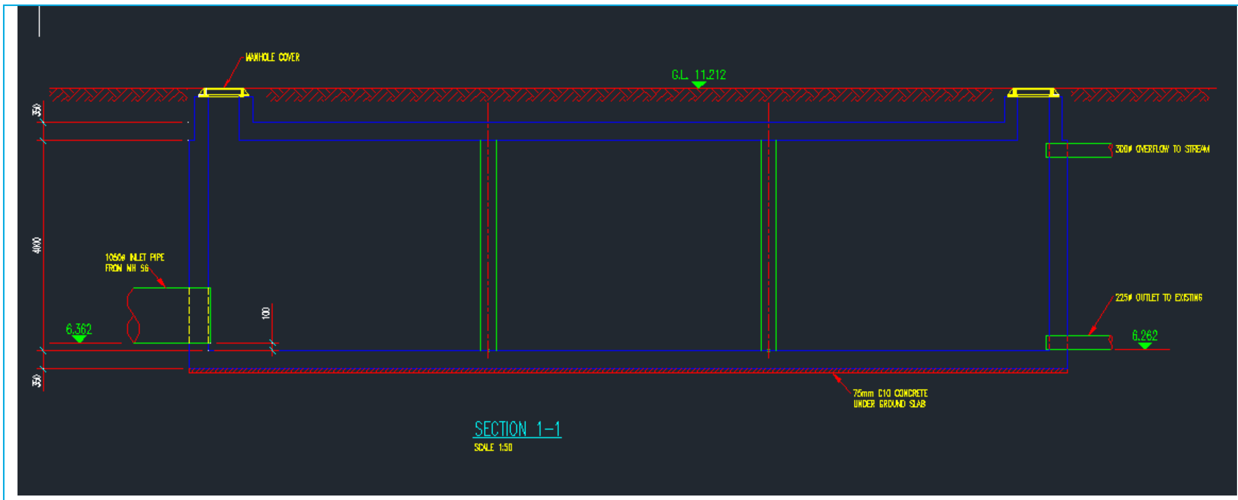
IDA Overflow Pipe
Siphon unit based on a 600mm diameter pipe. There is no survey data available for this pipe. It is noted below that the flow (or part of) re-enters the stream further downstream.



There are no survey or no drawings of pipe; Flow enters SW drainage network. After siphon flow enters 1050mm dia pipe then into balancing tank; inlet to tank at 6.362mAD, normal outfall to SW pipe network and high outfall to stream.
Discharge to the stream is limited by the size of the outlet which is twin 300mm diameter pipes at IL 10.262mAD; stream invert at this location is noted at of 7.959mAD. Tank size is 15x15x4m.
On site it was observed that this balancing tank system is flowing full and flow discharges into the stream.
Because the reservoir appears to be taking flow from the stream on a regular basis, it is not functioning as designed and it will almost always be full, therefore it has been assumed that there is no attenuation of the stream flow in the IDA siphon and subsequent pipe network.
The tank has not been included in the model and for the purpose of the modelling it is assumed that the flow through the IDA siphon discharges directly to the stream.

Input parameters for siphon IDA001: Assumed inlet 200mm higher than inlet to Rail Siphon therefore
Upstream sill level = 15.13mAD
Siphon throat invert level = 6.140mAD
Throat soffit level = 6.740mAD
Bore Area = 0.283m^2 (600mm dia)
Downstream sill level = 9.205mAD (downstream river unit bed level)

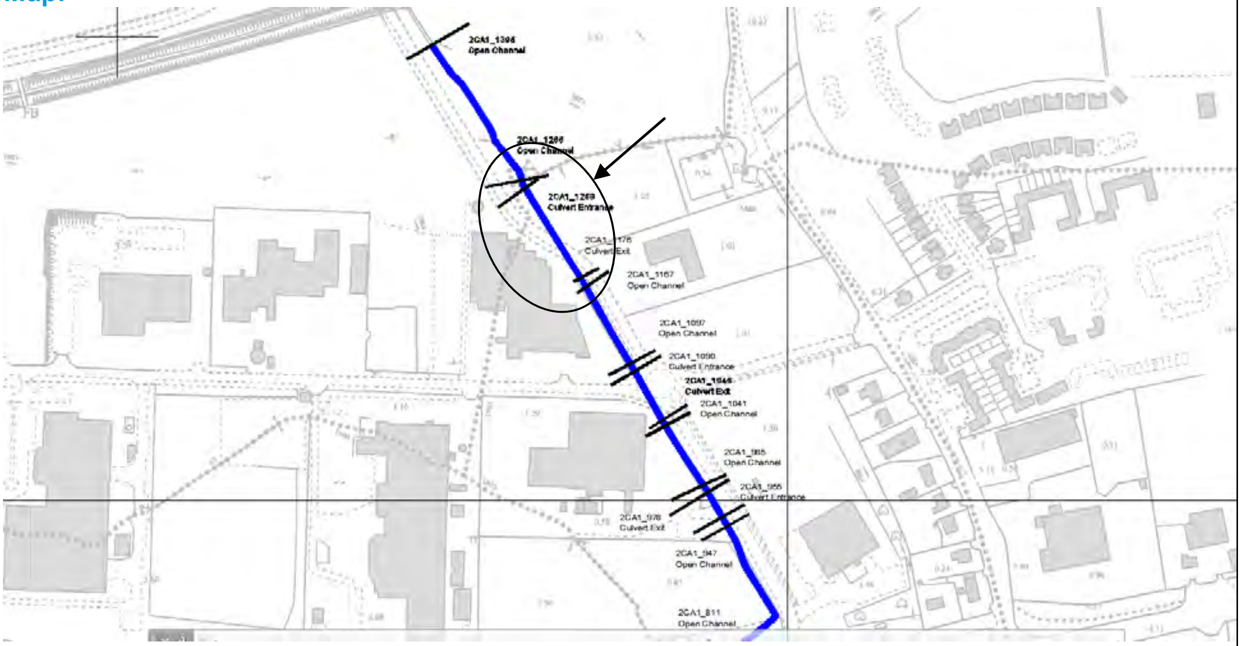
Reservoir: (not modelled)
Tank Invert = 6.262mAD
Plan area = 225m up to 10.262mAD



Outfall to stream: (not modelled)
Upstream sill level = 9.962mAD (invert level of pipe to stream)
Throat invert level = 9.832mAD (based on slope 1/100 for 13m length)
Throat soffit level = 10.132mAD (based on 300mm dia pipe)
Bore area = 0.138m^2 (based on twin 300mm dia)
Downstream sill level = 9.205mAD (stream bed invert at outfall)
Outfall is flapped to prevent high river levels causing flow from stream into tank.

Name of Structure / Survey Label:	2CA2_1259
Location (x, y):	180792, 73248
Included in model (state reason if not):	Yes
Model Unit Label:	TIBB001259I to TIBB001259J; with letter a, b, c to denote each of three pipes
Type:	Triple 450mm dia culvert:
Additional Information:	This structure was surveyed in 2006 for the Lee CFRAMS model, although was not included in the Lee CFRAMS model.
How has structure been modelled?:	Conduit units (no inlet and outlet units)

Map:



Photos:

2CA1_1258_Face.jpg – upstream face

2CA1_1176_US.jpg – downstream face

The remainder of the reach was surveyed and modelled under the Lee CFRAMS project, as 2CA1 (see Section 3.14).

3.14 Structures in Original Lee CFRAMS Model

The following are the details extracted from Appendix B of the Lee CFRAMS final draft Hydraulic Report.

3.14.1 Culverts

Name/model node label	2CA1_1090_in	**Culvert 2**	
Type of structure	Culvert		
Description	3 circular culverts under roundabout, with stone facing on upstream side.		
Survey reference	2CA1_1090.4		
Irish Grid reference(s)	180877 73102		
Included in model	Yes		
Photograph			
Dimensions and levels		Upstream	Downstream
	Invert Level	4.534 mOD	4.005 mOD
	Soffit Level	5.484 mOD	4.955 mOD
	Width	0.95m	0.95m
Manning's *n* roughness	0.011		
How modelled	Conduit Circular		
Headloss for 1% AEP flood	0.016m		

Note: 3 culverts modelled as equivalent single diameter culvert.

Name/model node label	Culvert_3_in	**Culvert 3**
Type of structure	Culvert	
Description	3 circular culverts under access road, concrete facing	
Survey reference	2CA1_978	
Irish Grid reference(s)	180935 73005	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	3.704mOD	3.628mOD
	Soffit Level	4.708mOD	4.632mOD
	Width	1.04m	1.04m

Manning's *n* roughness	0.011
How modelled	Conduit Circular
Headloss for 1% AEP flood	0.116m

Name/model node label	2CA1_800	**Culvert 4**
Type of structure	Culvert	
Description	Double circular culvert through bank, with trash screen on upstream side.	
Survey reference	2CA1_799.8	
Irish Grid reference(s)	180942 72867	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	2.586mOD	2.433mOD
	Soffit Level	3.434mOD	3.281mOD
	Width	0.848m	0.848m

Manning's *n* roughness	0.011
How modelled	Conduit Circular
Headloss for 1% AEP flood	0.453m

The conduit sections for this culvert are labelled as **Culvert 4**; surveyed as twin 600mm diameter pipes and modelled as an equivalent single diameter.

Name/model node label	2CA1_605_I	**Culvert 5**
Type of structure	Culvert	
Description	Double circular culverts, both of different sizes	
Survey reference	2CA1_510.6	
Irish Grid reference(s)	180951 72828	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	1.037mOD	0.189mOD
	Soffit Level	1.911mOD	1.063mOD
	Width	0.874m	0.874m

Manning's *n* roughness	0.011
How modelled	Conduit Circular
Headloss for 1% AEP flood	0.361m

The conduit sections for this culvert are labelled as **Culvert 5**; surveyed as 750 and 450mm diameter pipes and modelled as an equivalent single diameter.

Name/model node label	2CA1_186	**Culvert 6**
Type of structure	Culvert	
Description	Single concrete box culvert through bank.	
Survey reference	2CA1_186.2	
Irish Grid reference(s)	181133 72310	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	-1.109mOD	-1.169mOD
	Soffit Level	0.391mOD	0.331mOD
	Width	1.23m	1.23m

Manning's *n* roughness	0.012
How modelled	Conduit Rectangular
Headloss for 1% AEP flood	0.098m

Name/model node label	1187_Inlet	**Culvert 7**
Type of structure	Culvert	
Description	Double circular culvert in vegetated channel, behind house.	
Survey reference	2CA2_1187	
Irish Grid reference(s)	181494 72974	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	-0.504mOD	-0.258mOD
	Soffit Level	0.496mOD	0.742mOD
	Width	1m	1m

Manning's *n* roughness	0.011
How modelled	Conduit Circular
Headloss for 1% AEP flood	None

Name/model node label	809_Inlet	**Culvert 8**	
Type of structure	Culvert		
Description	Double circular culvert under dirt road, right side partially blocked.		
Survey reference	2CA2_808.8		
Irish Grid reference(s)	181717 72714		
Included in model	Yes		
Photograph			
Dimensions and levels		Upstream	Downstream
	Invert Level	-0.982mOD	-1.100mOD
	Soffit Level	0.715mOD	0.597mOD
	Width	1.697mOD	1.697mOD
Manning's *n* roughness	0.012		
How modelled	Conduit Circular		
Headloss for 1% AEP flood	None		

Note:

This was a temporary culvert put in place to allow access during the construction of a sewer system to serve development land to the east of Carrigtohill. This has since been removed. The model has been updated to reflect this.

Name/model node label	2CA2_769	**Culvert 9**

Type of structure	Culvert		
Description	Large rectangular concrete culvert with trash screen.		
Survey reference	2CA2_769.2		
Irish Grid reference(s)	181729 72683		
Included in model	Yes		
Photograph			
Dimensions and levels		Upstream	Downstream
	Invert Level	-1.387mOD	-1.587mOD
	Soffit Level	1.453mOD	1.253mOD
	Width	2.75m	2.75m
Manning's *n* roughness	0.012		
How modelled	Conduit Rectangular		
Headloss for 1% AEP flood	None		

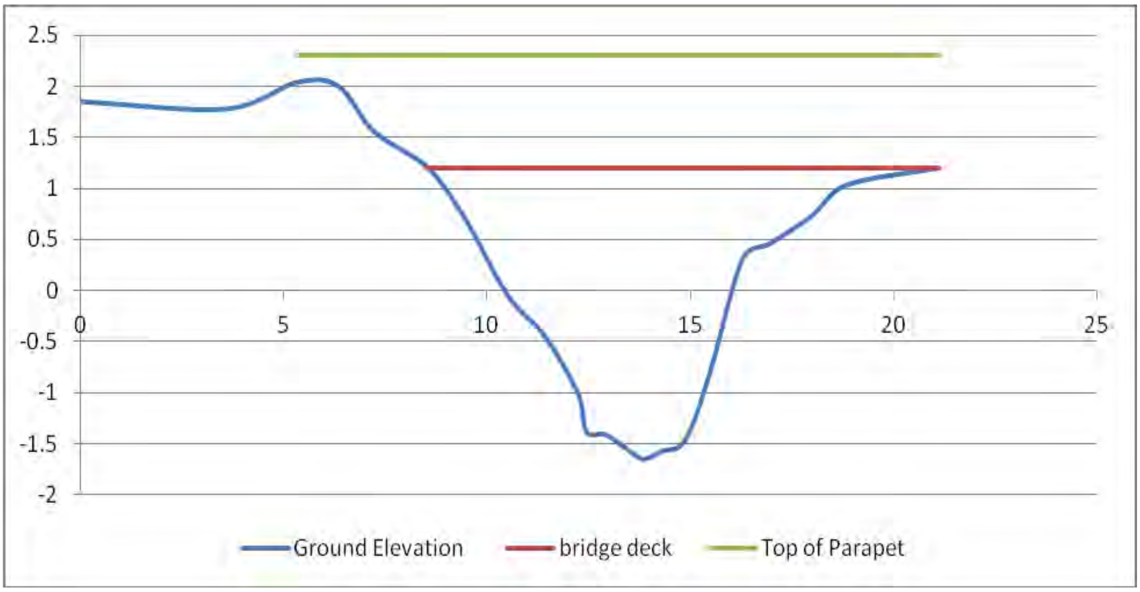
Box culvert surveyed as 2.8m wide by 3m high.

Note: *The Bar Proportion was entered as 0.01 in the original model. This is an error and has been corrected in this model to 0.1 based on the information available from the original survey and photos.*

Name/model node label	66_Inlet **Culvert 10**		
Type of structure	Culvert		
Description	Double circular culvert under building site access track.		
Survey reference	2CA2_66.5		
Irish Grid reference(s)	181294 72276		
Included in model	Yes		
Photograph			
Dimensions and levels		Upstream	Downstream
	Invert Level	1.653mOD	1.653mOD
	Soffit Level	3.333mOD	3.333mOD
	Width	1.68m	1.68m
Manning's *n* roughness	Upstream 0.012 Downstream 0.011		
How modelled	Conduit Circular		
Headloss for 1% AEP flood	None		

Note:

This was a temporary structure put in place during the construction of a sewer system to serve development land to the east of Carrigtohill. This is now replaced with a precast concrete bridge / slab unit as indicated below. The structure in the model has been modified to reflect this.



This bridge has been modelled as a single span bridge (US BPR). Based on the photo the bridge wall parapet has been estimated at 300mm higher than the embankment on the left bank.

Name/model node label	1385_Inlet	**Culvert 11**
Type of structure	Culvert	
Description	Single circular culvert linking two field drainage ditches	
Survey reference	2CAR_1384.9	
Irish Grid reference(s)	181811 72368	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	-1.660AOD	-1.660AOD
	Soffit Level	-0.710mOD	-0.710mOD
	Width	0.95m	0.95m

Manning's *n* roughness	Upstream 0.012 Downstream 0.011
How modelled	Conduit Circular
Headloss for 1% AEP flood	None

Name/model node label	829_Inlet	**Culvert 12**
Type of structure	Culvert	
Description	Single circular culvert linking two field drainage ditches.	
Survey reference	2CAR_828.6	
Irish Grid reference(s)	181422 72196	
Included in model	Yes	
Photograph		

Dimensions and levels		Upstream	Downstream
	Invert Level	-1.921mOD	-1.921mOD
	Soffit Level	-1.021mOD	-1.021mOD
	Width	0.9m	0.9m

Manning's *n* roughness	0.012
How modelled	Conduit Circular
Headloss for 1% AEP flood	None

Name/model node label	Sluice_1_US		
Type of structure	Culvert		
Description	Multiple stone culverts under road. Improvised trash screens on some inlets.		
Survey reference	2CAR_20.6		
Irish Grid reference(s)	180693 72217		
Included in model	Yes		
Photograph			
Dimensions and levels		Upstream	Downstream
	Invert Level	-2.160mOD	
	Soffit Level	AOD	
	Width	2.67m	
Manning's *n* roughness	Bed 0.04 Bank 0.06		
How modelled	Sluice Vertical		
Headloss for 1% AEP flood	None		

3.14.2 Weirs

Name/model node label	2CA1_1097	
Type of structure	Weir	
Description	Multiple small stone weirs across river, between road and buildings.	
Survey reference	2CA1_1097.3	
Irish Grid reference(s)	180874 73108	
Included in model	Yes	
Photograph		
Dimensions and levels	Elevation of crest	5.39mOD
	Length of crest	3.173m
	Breadth of crest	0.33m
Modular Limit	0.800	
Coefficient of velocity	1.000	
How modelled	General Purpose Weir	
Headloss for 1% AEP	0.567m	

3.14.3 Sluices

The Lee CFRAMS model included Vertical Sluice units to represent the flapped outfalls on Slatty Bridge, and the details of these as provided in the Appendix to the Lee CFRAMS Hydraulics Report is given below. Since completion of the Lee CFRAMS model 3 of the flap gates have been replaced with 1200mm diameter Tideflex valves. The "under gate" flow coefficients were adjusted to 0.4 to represent the greater headloss associated with the Tideflex valves. (This coefficient was adjusted to 0.7 for the remaining flapped outfalls to represent the headloss expected across these structures.)

Due to the lack of data on the works carried out here, an assumption was made that these tidelfex valves were installed to the three middle openings of the bridge i.e. Sluice_2.

Name/model node label	Sluice_1_US In Slatty Bridge	
Type of structure	Vertical sluice	
Description	Vertical sluice with one gate and small weir with opening set at -0.006m. Height of gates set at 10m.	
Survey reference	2CAR_20.6	
Irish Grid reference(s)	180693 72217	
Included in model	Yes	
Photograph		
Weir data	Elevation of weir crest	-2.16 mOD
	Breadth of weir crest	2.67 m
	Length of weir	12.54 m
Modular Limit	Weir Flow	0.7
	Under Gate Flow	0.7
	Over Gate Flow	0.7
Coefficient of velocity	Weir Flow	1.0
	Under Gate Flow	1.0
	Over Gate Flow	1.0
Headloss for 1% AEP	None	

Name/model node label	Sluice_2_US In Slatty Bridge	
Type of structure	Vertical sluice	
Description	Vertical sluice with three gate and a small weir with opening set at 0.394m. Height of gates set at 10m.	
Survey reference	2CAR_20.6	
Irish Grid reference(s)	180693 72217	
Included in model	Yes	
Photograph		
	Elevation of weir crest	-1.76 mOD
	Breadth of weir crest	1.00 m
	Length of weir	12.54 m
Modular Limit	Weir Flow	0.7
	Under Gate Flow	0.7
	Over Gate Flow	0.7
Coefficient of velocity	Weir Flow	1.0
	Under Gate Flow	1.0
	Over Gate Flow	1.0
Headloss for 1% AEP	None	

Name/model node label	Sluice_3_US In Slatty Bridge	
Type of structure	Vertical sluice	
Description	Vertical sluice with one gate and small weir with opening set at 0.944m. Height of gates set at 10m.	
Survey reference	2CAR_20.6	
Irish Grid reference(s)	180693 72217	
Included in model	Yes	
Photograph		
	Elevation of weir crest	-1.21 mOD
	Breadth of weir crest	1.22 m
	Length of weir	12.54 m
Modular Limit	Weir Flow	0.7
	Under Gate Flow	0.7
	Over Gate Flow	0.7
Coefficient of velocity	Weir Flow	1.0
	Under Gate Flow	1.0
	Over Gate Flow	1.0
Headloss for 1% AEP	None	

3.15 Pumps

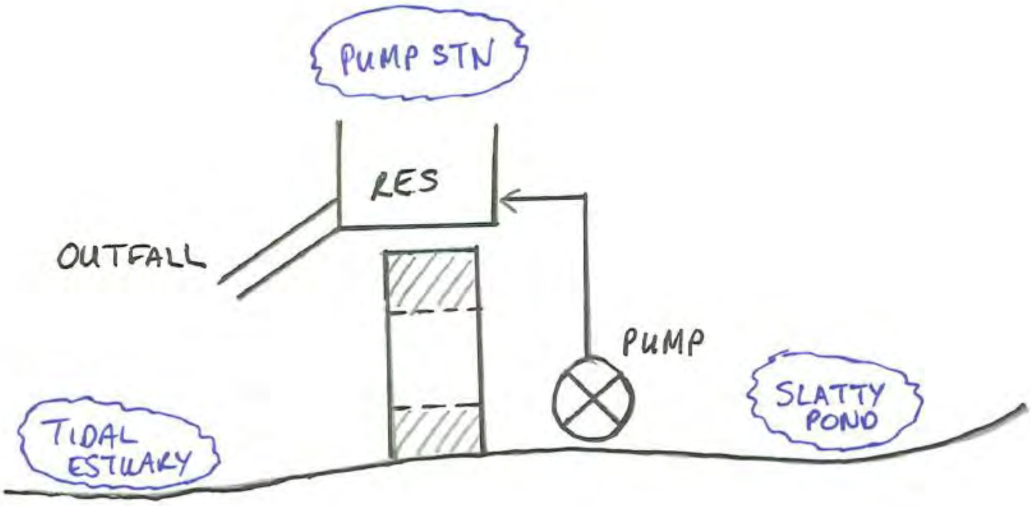
The construction of Slatty Pump Station was completed in 2009. The pump station consisted of 4 EMU Wilo submersible pump units, each with a capacity of 1000 l/s. The purpose of the pumps is to maintain levels in Slatty Pond at or below -0.9mAD.

The operating rules are summarised below:

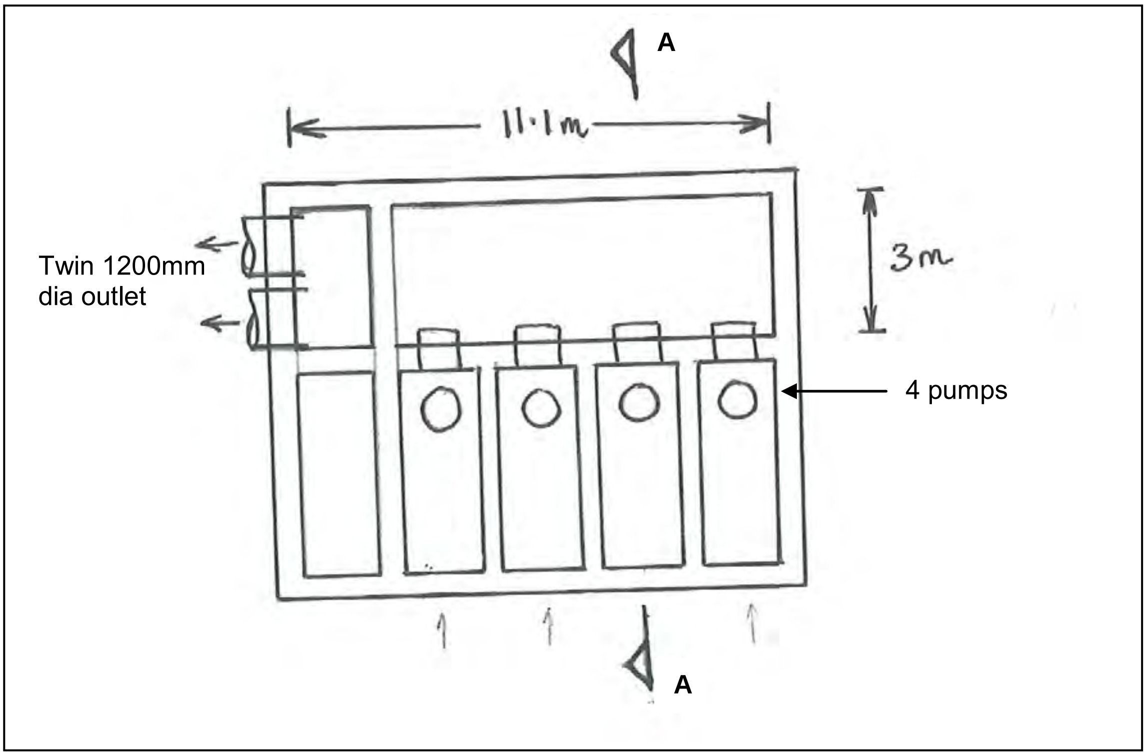
Level (mAD)	Pump 1	Pump 2	Pump 3	Pump 4
-0.75	ON	ON	ON	STARTS
-0.8	ON	ON	STARTS	STOPS
-0.85	ON	STARTS	STOPS	OFF
-0.9	STARTS	STOPS	OFF	OFF
-0.95	STOPS	OFF	OFF	OFF

Pumps units with logical rules have been used in ISIS to represent this. The pump units discharge into a reservoir unit that in turn outfalls into the estuary downstream of Slatty Bridge.

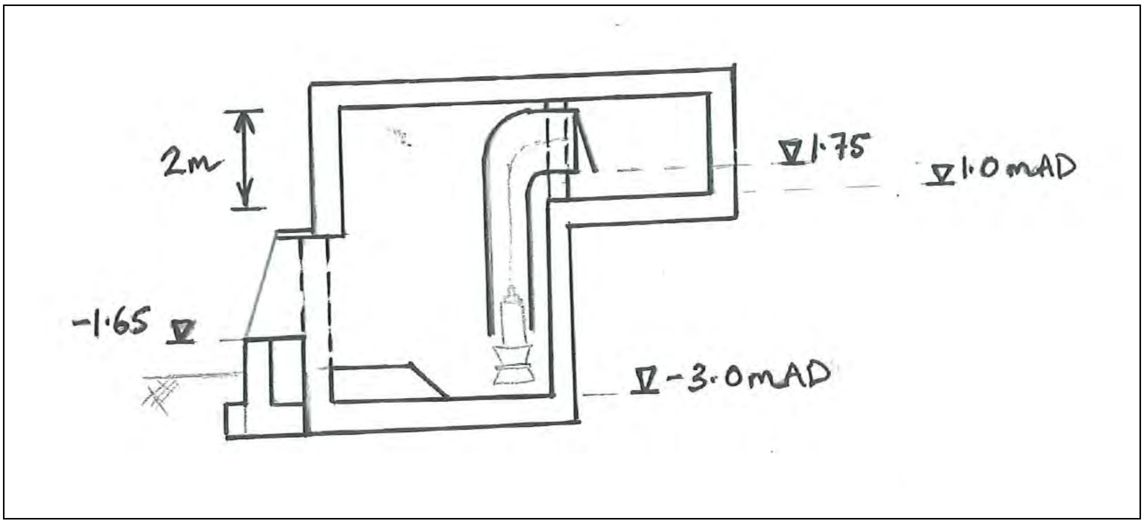
The following is a schematic of how the pumps are represented in ISIS.



The following figure shows the general arrangement of the pumps.



Plan



Section A-A

Based on an operating level of -0.9mAD the pump head is 2.65mAD.

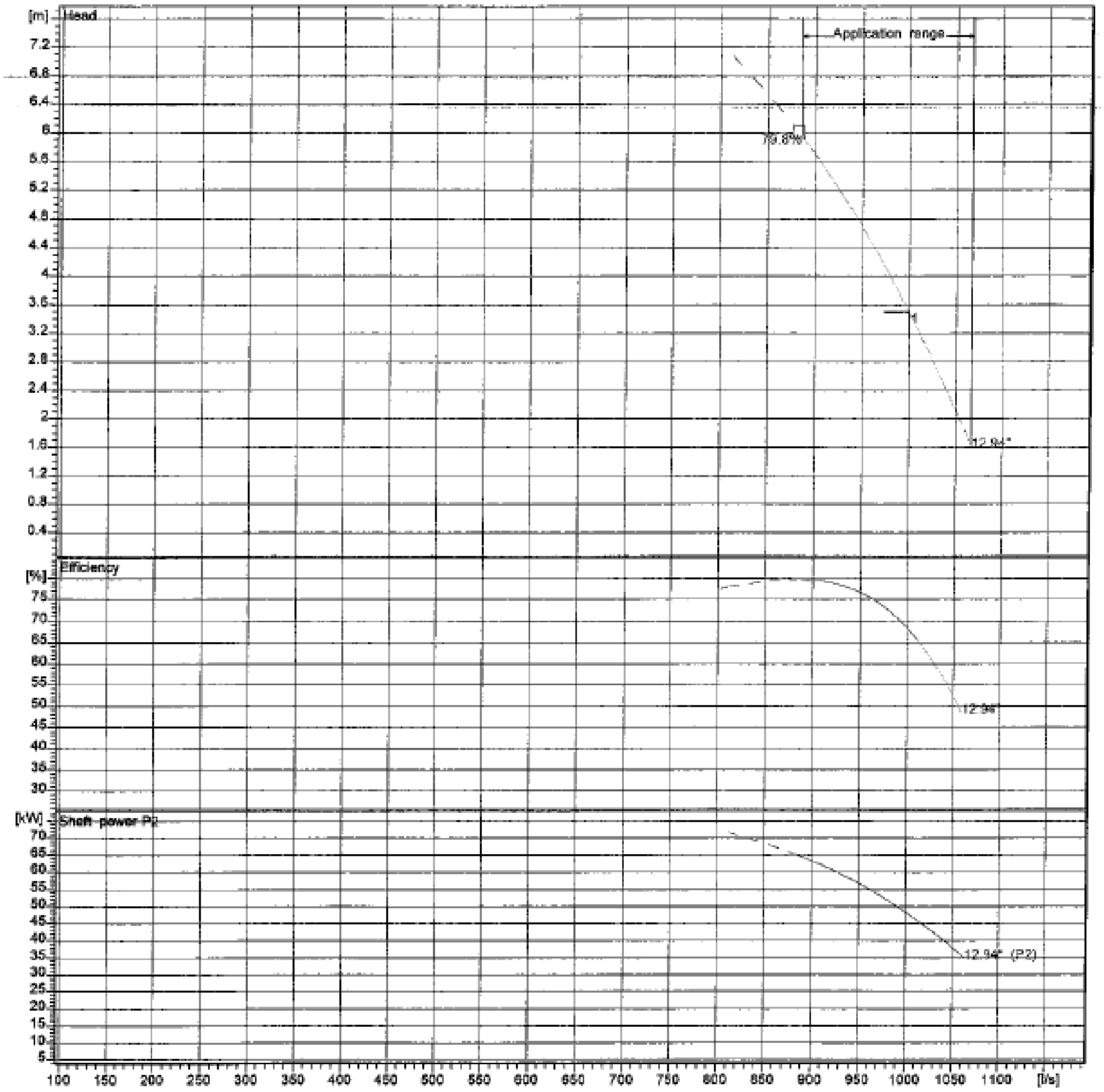
Performance curves

Project:	Slatty Pond	Created on:	2007-04-26
Project number:	alt1000l/s	Created by:	Jim Murphy

WILO EMU

Performance curves
Submersible propeller pump KPR 500 with motor T 34-6/41P

Power data referred to: Stomwater [100%] ; 20°C; 0.998kg/dm³; 1mm²/s
Tolerance as per ISO 9906 / Annex A.2

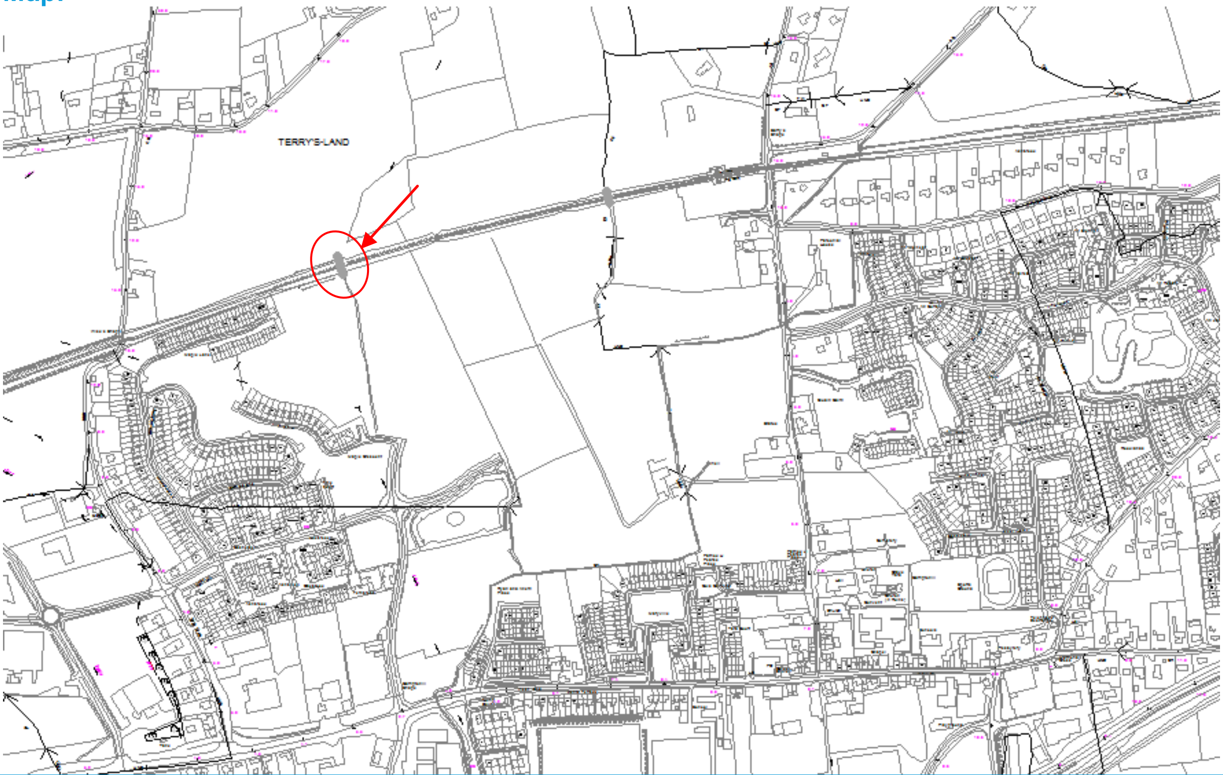


Pump			Duty point data			
Degree of propeller	13	°	Volume flow		1000	l/s
Nominal speed	950	1/min	Head		3.5	m
Frequency	50	Hz	Shaft power	P_2	48.5	kW
Impeller type	Propeller		Pump efficiency		68.6	%
Motor			Power input	P_1	53	kW
Rated power	65	kW	Required pump NPSH		9.3	m
Sel. explosion protection	--		Speed		974	1/min

3.16 Floodplain Culverts

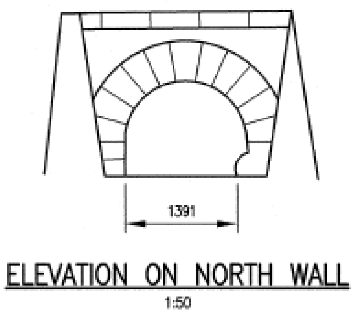
Name of Structure / Survey Label:	RAIL_C5
Location (NGR):	
Included in model (state reason if not):	Yes
Model Unit Label:	RAIL_C5
Type:	Old masonary arch
Additional Information:	Details on the structure size were taken from Irish Rail drawing and information from OPW area engineer. Irish rail works included cleaning out and regarding of channel.
How has structure been modelled?:	1d element in the 2D domain as a rectangular culvert 1.391 x 0.9m 1d_nwk_floodplain_culvert_ 2d_bc_floodplain_culverts_ Z line added to represent channel leading to culvert.

Map:



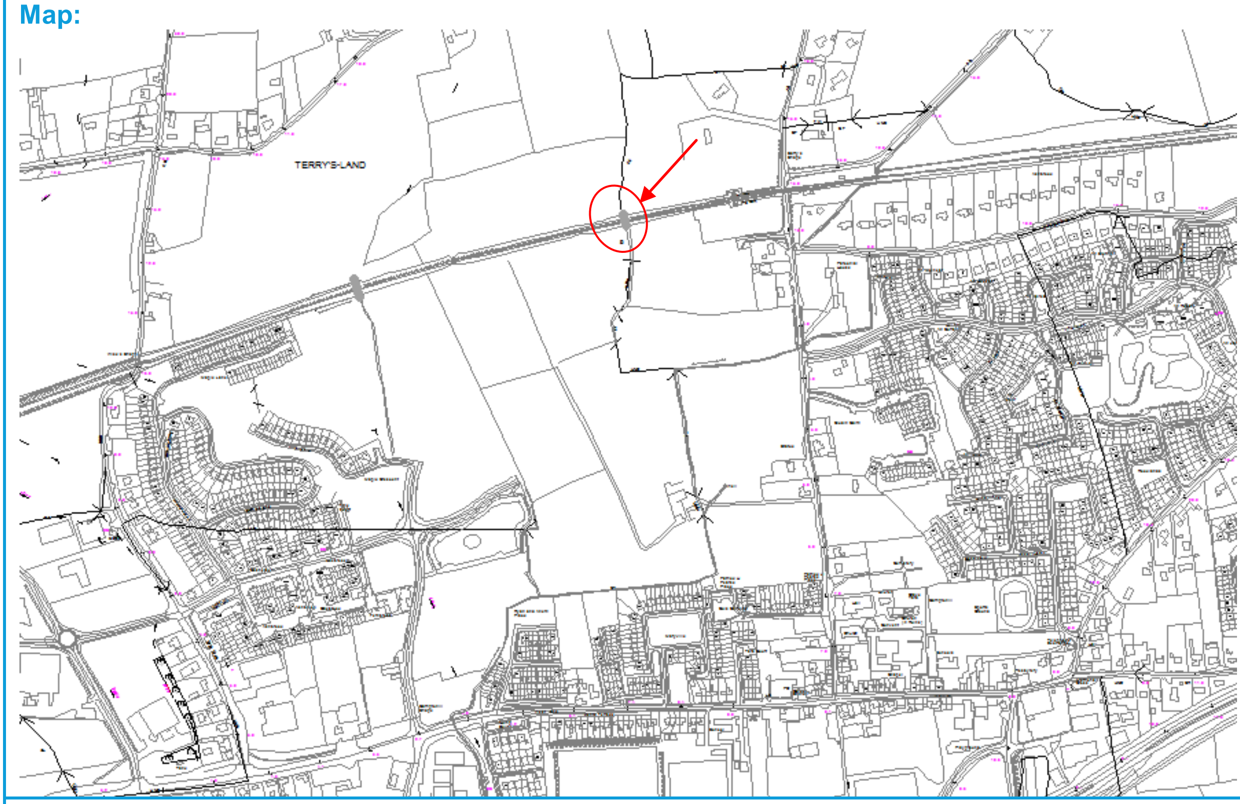
Photos:

Photo sourced from OPW.

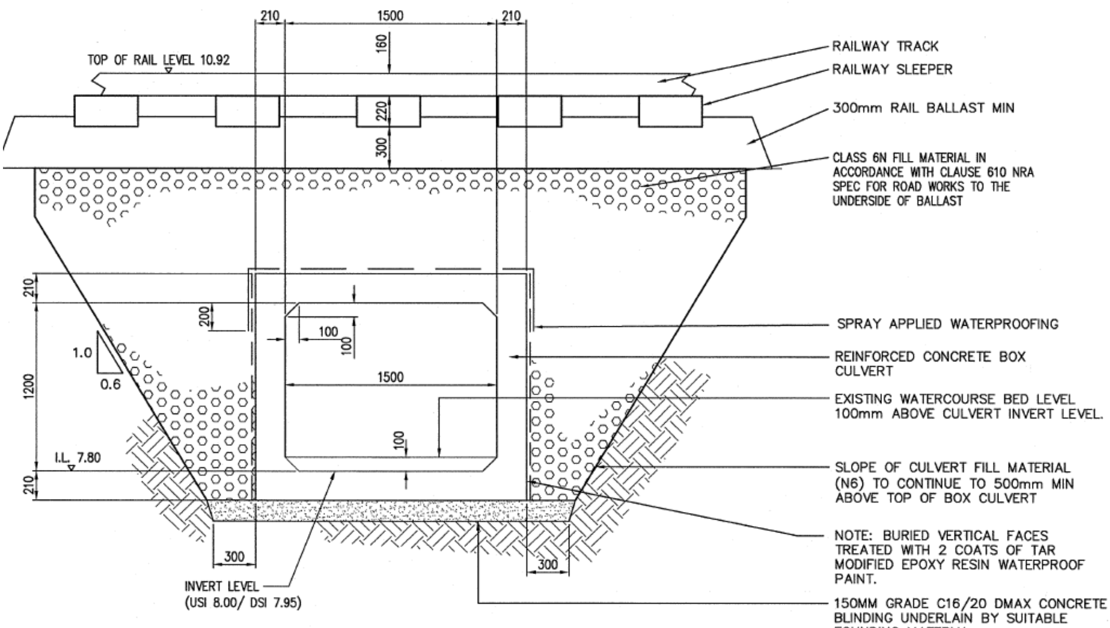


Name of Structure / Survey Label:	RAIL_C6
Location (NGR):	
Included in model (state reason if not):	Yes
Model Unit Label:	RAIL_C6
Type:	Concrete box culvert
Additional Information:	Details on the structure size were taken from Irish Rail drawing and information from OPW area engineer.
How has structure been modelled?:	1d element in the 2D domain as a rectangular culvert 1.5 x 1.1m 1d_nwk_floodplain_culvert_ 2d_bc_floodplain_culverts_

Map:



Drawing Details:



CULVERT CROSS SECTION

3.17 Floodplain Culverts in the 2D Tidal Model

Floodplain culverts in the 2D domain are represented using a 1d_nwk layer and a 2d_bc layer.

3.17.1 Lee_Culv_5

This information for this culvert is taken from the original Lee CFRAM model data. (See Section 3.14.)

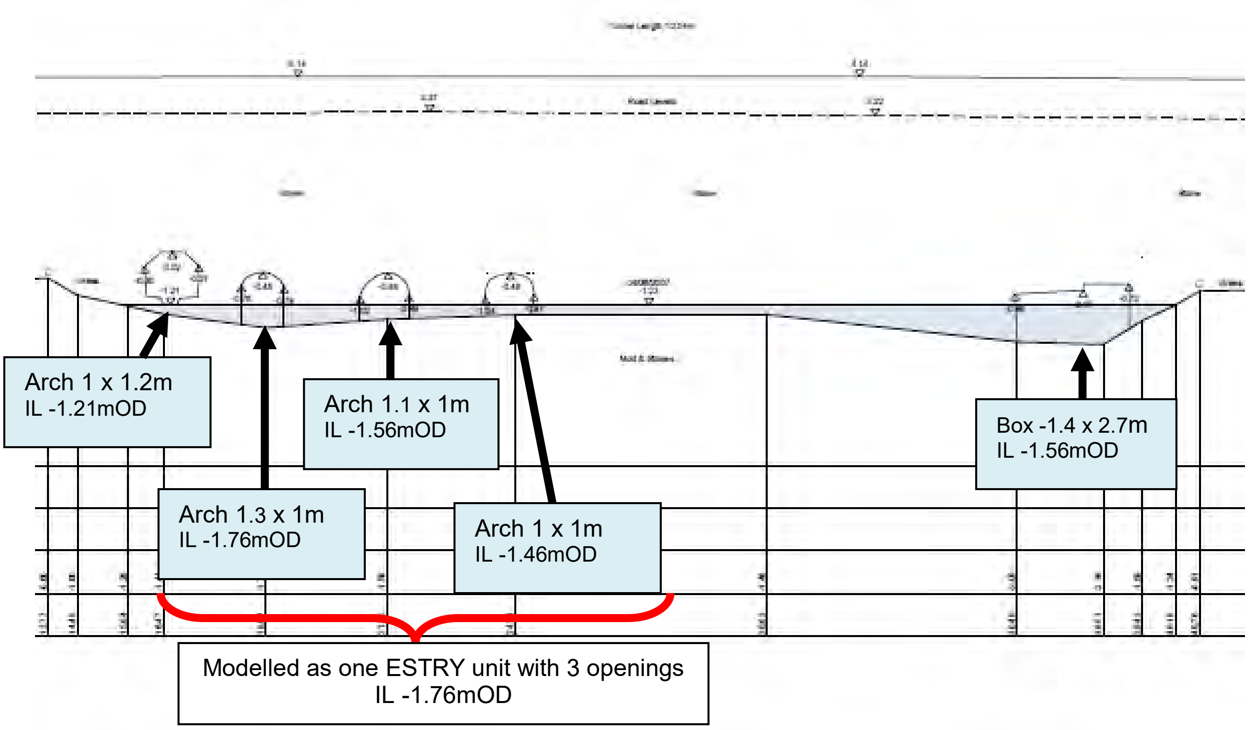
3.17.2 Lee_Culv_9

This information for this culvert is taken from the original Lee CFRAM model data. (See Section 3.14.)

3.17.3 Slatty Bridge

Slatty Bridge is represented in the TUFLOW 2D only model using 1d_nwk layer and a 2d_bc layer; 1d_nwk_SlattyBr_001; 2d_bc_SlattyBr_001

The opening size and invert levels are illustrated below.



3.17.4 Kila Tidal Outfall

The outfall at Kilacloyne is represented in the TUFLOW 2D only model using 1d_nwk layer and a 2d_bc layer; 1d_nwk_Kila_Outfall_001; 2d_bc_Kila_Outfall_001.

There is no survey data for this outfall. The outfall has been included in the model as a 1m diameter flapped culvert.

4 Model Flow Boundaries

For details on the hydrology of the catchment see the Hydrology Report (which forms one of the Appendices of the Carrigtohill FRA Main Report). The following gives a brief introduction to the flow and levels used in the model boundaries.

4.1 Fluvial

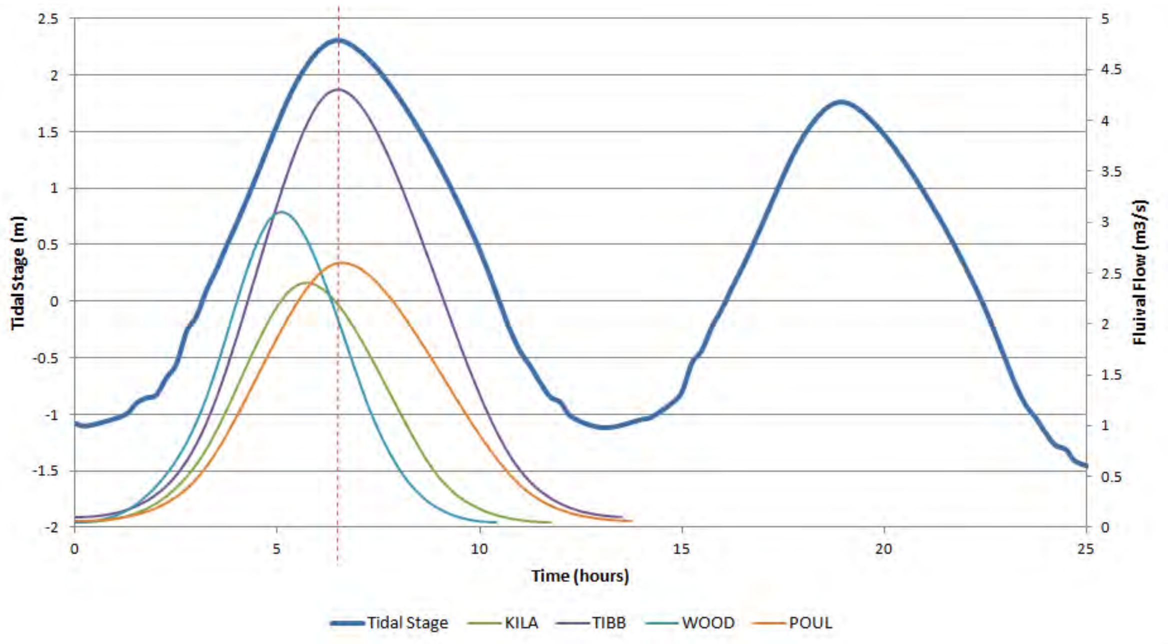
A hydrological analysis of the catchment has been carried out to determine the fluvial flows for a range of return periods at each of the modelled watercourses. A range of duration storms were considered and runoff flow hydrographs for a 6.5, 13 and 25 hour duration storm were developed. These hydrographs were used as flow boundaries to the modelled area. A sensitivity check was carried out to determine the critical storm in the context of the Carrigtohill catchment.

4.2 Tidal

A tidal analysis has not been carried out as part of this study. Extensive previous work carried out in the development of the Cork Harbour Model under the MODESTIS project by MarCon Computation International and the Lee CFRAMS has been drawn on to provide the tidal stage data that has been used as head time (stage) boundaries to the modelled area.

The model simulation runs for 25 hours covering two tidal cycles. The tidal boundary is applied so that the tidal peak coincides with the fluvial peak (at the upper end of the reach). The sensitivity of the model to the timing of the tide has been tested and is discussed in Section 7.

Tidal and Fluvial Inflow Boundaries (6.5 hour Storm Duration)



4.3 Surface water runoff

Surface water runoff from undeveloped site or permeable unpaved catchments is based on the flow estimation method adopted for the larger fluvial catchments, namely the Flood Studies Update (FSU). This method was also applied for developed sites that have provided attenuation as part of the surface water drainage design. The overland surface water runoff is included as lateral inflows to the appropriate length of the watercourse based on the topography of the land.

Surface water runoff from developed sites that is collected in a piped network and discharges to natural watercourses was determined based on the Rational Method. The design rainfall was extracted from Met Éireann DDF (depth duration frequency) data and a rainfall hyetograph was developed for a 6.5, 13 and 25 hour storm. Corresponding runoff hydrographs based on the impermeable area was calculated for each sub-catchment. Generally a 70:30 split for permeable and impermeable area was assumed. This calculation applies to un-attenuated flows into the modelled watercourses. The location of the surface water network outfalls were determined based on data collated from Cork County Council, TJ O'Connor (who completed the Carrigtohill Sewerage Improvement Scheme), local developers, survey data and site walkovers.

These surface water runoff flows were applied at various points along the modelled reaches in ISIS. The nodes used are listed below.

Inflow Name	flows into in ISIS
760_FSU_inf	2CA1_760
1187_FSU_inf	2CA2_1187
769_FSU_inf	2CA2_769
Lat_2CAR	2CAR_1380_I
Lat_2CAR2	ANNA00072
Lat_KILA	KILA00016I
1259_FSU_inf	TIBB001259
188_FSU_inf	TIBB00188
167_FSU_inf	WOOD00167
323_FSU_inf	WOOD00323

5 Model Run Settings

All 1D-2D linked models are run with the following settings:

- Version 3.6.0.156 ISIS and TUFLOW Build 2012-05-AE-iDP-w64
- A fixed 1D timestep of 1s is used in ISIS and a 2D timestep of 2s is applied in TUFLOW
- All model start with a single set of initial conditions that are saved in the individual .DAT files
- Two of the ISIS default advanced run parameters were modified; dflood is increased to 99 and maxitr is increased to 16
- The models were run for 25 hours to incorporate 2 full tidal cycles
- The models took around 3 to 4 hours to run on a Windows 7 quad core machine

All 2D TUFOW models were run with the following settings:

- TUFLOW Build 2012-05-AE-iDP-w64
- A fixed ESTRY (1D) timestep of 1s and a fixed TULFOW (2D) timestep of 2s
- The models were run for 40 hours to incorporate 3 full tidal cycles
- The models generally took 15 to 20 minutes to run

6 Model Stability

The information in this section of the Model Check File indicates the stability of the model in terms of hydraulic performance. The model results are discussed in the Main Report with reference to specific areas of interest i.e. IDA lands, existing developments, important infrastructure such as rail line etc.

6.1 Fluvial 1D-2D Model Design Runs

Model Event	No. TUFLOW warnings[1]	Max cumulative mass error[2] (%)	Final cumulative mass error[3] (%)	Run time[4] (hr:min)
Defended Scenario				
Q2_T2	0	0 to -8 (peak at t=0.25hrs)	-1.18	3:17
Q5_T2	0	0 to -8	-0.92	3:22
Q10_T2	0	0 to -8	-0.77	3:25
Q25_T2	0	0 to -8	-0.54	3:21
Q50_T2	0	0 to -8	-0.55	3:15
Q100_T2	0	0 to -8	-0.63	4:19
Q1000_T2	0	0.45 to -8	0.35	3:35
Q2_T2_MRFS	0	0 to -8	-0.86	3:12
Q5_T2_MRFS	0	0 to -8	-0.68	3:32
Q10_T2_MRFS	0	0 to -8	-0.5	3:20
Q25_T2_MRFS	0	0 to -8	-0.47	3:25
Q50_T2_MRFS	0	0 to -8	-0.56	3:15
Q100_T2_MRFS	0	0 to -8	-0.42	3:42
Q1000_T2_MRFS	0	0 to -8	-0.43	3:49
Q10_T2_HEFS	0	0 to -8	-0.27	3:35
Q100_T2_HEFS	0	0 to -8	-0.41	3:42
Q1000_T2_HEFS**	0	0 to -8	-1.01	0:50
Undefended Scenario				
UNDEF_Q100_T2	0	0 to -8	-0.42	3:21
UNDEF_Q1000_T2	0	0 to -8	0.05	3:29
UNDEF_Q100_T2_MRFS	0	0 to -8	0.07	3:54
UNDEF_Q1000_T2_MRFS	0	0.46 to -8	0.47	3:58

** The Q1000_T2_HEFS is an extreme scenario and in the 1D model, the model cannot cope with such an influx of tidal water from the tidal downstream boundary into the model domain. The model runs to a time 7h 40m which is beyond the peak of the event.

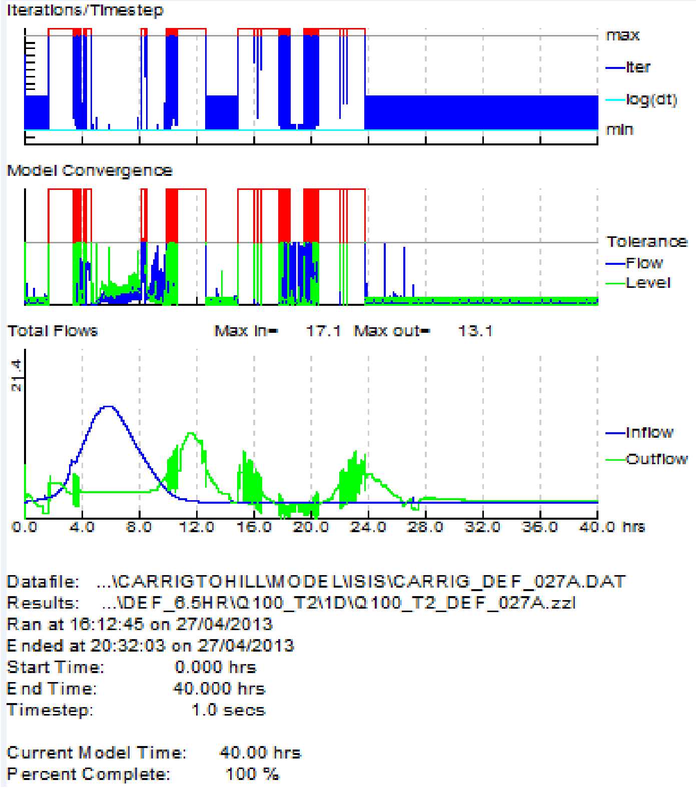
6.1.1 Comments on Fluvial 1D-2D Model Convergence and Stability

The following provide a commentary on the model convergence and stability.

[1] All recorded types of TUFLOW warnings should be checked and justified.
[2] This column records the maximum mass balance error during the model run as reported in the TUFLOW MB csv file.
[3] This column records the cumulative Mass Balance Error for the whole model run as reported in the TUFLOW tlf file.
[4] Note that run times should be viewed as approximate only. The majority of these models were run on a quad-core Windows 7 desktop PC but the reported times may include variations that arose due to models being run on different PCs and/or during periods of differing CPU pressures.

The results appear reasonable and realistic given the applied hydraulic boundaries (inflows and tide graphs). An evaluation of the model predictions against the limited historical flood data is given in Section 8.1.

The graphics below indicate model convergence plot and the cumulative mass error for the Q100_T2 design run.

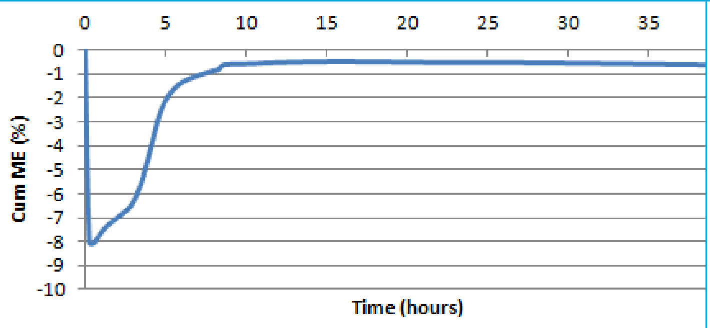


The convergence plot indcicates poor convergence throughout the model simulation.

The run settings, including timestep were modified to improve convergence in an iterative process.

The nature of the small steep watercourses, the inclusion of the pumps and the impact of the tidal downstream boundary increase the occurrence of instabilities in this model.

Minimum flows in each of the upstream fluvial boundaries are necessary to initialise the model.



The mass error peak of -8% is high and is beyond the generally accepted threshold of 1 to -1%. A closer inspection of the mass error throughout the model reveals that the peak mass error occurs at close to the start of the model at time of 0.25 hours. The mass error then tapers off to within +1 and -1% at approx 7.5hrs into the run. (It is also noted that the addition of WLLs increase the peak mass error from a general value of -3.3% at t=0.04hrs to -8% at t=3hrs.)

6.2 Tidal Model Design Runs

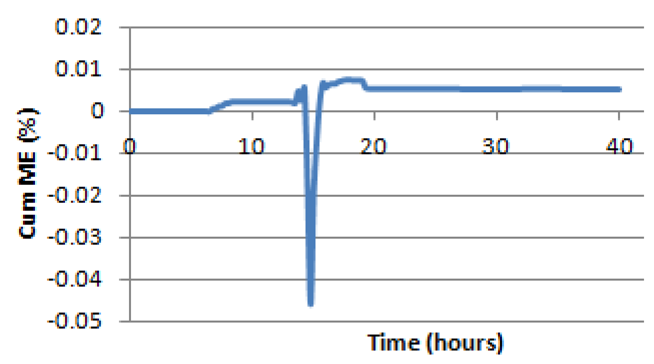
Model Event	**No. TUFLOW warnings[1] (during simulation)**	**Max cumulative mass error[2] (%)**	**Final cumulative mass error[3] (%)**	**Run time[4] (hr:min)**
T50	0	-0.022 to 0.005	-0.02	19
T200	0	-0.045 to 0.007	0.01	20
T1000	0	-0.169 to 0.236	0.05	20
T2_MRFS	0	-0.055 to 0.023	0.02	20
T5_MRFS	0	-0.058 to 0.075	0.07	21
T10_MRFS	0	-0.125 to 0.338	0.26	21
T25_MRFS	0	-0.061 to 0.807	0.65	23
T50_MRFS	0	-0.424 to 1.074	0.87	10
T200_MRFS	0	-0.667 to 1.145	1.05	29
T1000_MRFS	1	-0.037 to 1.399	1.23	31
T2_HEFS	0	-0.047 to 1.111	1.04	29
T10_HEFS	0	-0.048 to 1.173	1.13	33
T200_HEFS	1	-0.047 to 1.263	0.99	39
T1000_HEFS***	2	-0.169 to 0.236	0.59	40

6.2.1 Comments on Tidal 2D Model Stability

The results appear reasonable and realistic given the applied tidal boundary. The area flooded is low lying land close to Slatty Water. A review of maps indicates that a large proportion of this area has been reclaimed from the sea for agricultural purposes and this is supported by anecdotal evidence.

There are no warnings during the simulation for the majority of runs. Negative depth warnings are noted in the larger AEP events, with a tidal peak of 3.5mAD and greater (i.e. T1000_MRFS, T200_HEFS and T1000_HEFS). The maximum number of warnings in any individual run is 2 negative depth warnings associated with a T1000_HEFS, which is an extreme climate change scenario.

The graphic below shows the cumulative mass error for the T200 design run.



The cumulative mass error ranges from -0.05 to 0.007%; which is well within the acceptable bounds of +1 to -1%. A spike in the mass error occurs at approx 14.25hrs. This is the time that the tide begins to overtop the road embankment at Slatty and inundate the 2D floodplain.

7 Sensitivity Tests

Sensitivity tests for the following parameters were carried out for the final Carrigtohill models.

A discussion and presentation of the results for the fluvial model follows in Sections 8 and for the tidal model in Section 9.

7.1.1 Fluvial Model Sensitivity Tests

Hydraulic Parameter	Variation in Parameter	Scenario(s) Tested
Model Roughness	Manning's values adjusted by -10%	Q100_T2 _DEF
Critical Storm Duration	3 runoff hydrographs generated and used in the QT boundary based on a 6.5, 13 & 25 hours storm durations	Q100_T2_6.5HR_DEF Q100_T2_13HR_DEF Q100_T2_25HR_DEF
Blockage	Removal of silt at selected culvert	Q100_T2_6.5HR_DEF
Timing of the Tide	+/- 3hours shift in the HT boundary in relation to the peak fluvial inflow	Q100_T2_6.5HR_DEF
Downstream tidal boundary	0.5% AEP Tidal Event and other tidal events used to check sensitivity of HT boundary	Q100_T2_DEF Q100_T200_DEF

7.1.2 Tidal Model Sensitivity Tests

Hydraulic Parameter	Variation in Parameter	Scenario(s) Tested
2D Cell Size	Cell size decreased from 10m to 4m	T200_MRFS
Model Roughness	10% change in background roughness	T200_MRFS

8 Fluvial Model Sensitivity Results

8.1 1D Model Roughness

Manning's n was set to a global value of 0.04 for the channel and 0.06 in the original Halcrow Model. These values were refined in the updated model and a number of iterations were tested to reach the roughness values used in the final model. (See Section 3.5 for more detail on roughness).

Due to the complex nature of the model and the use of min flows in all reaches, a number of iterations were required to satisfy the initial conditions. For this reason it is important that the comparison of results between the baseline model and the sensitivity model considers the peak of the fluvial input only as the results may differ at the start and finish.

A comparison of the 1D results, which is presented below, indicates the sensitivity of the model to Manning's values. The maximum variance in stage occurs at the lower end of the reach, between N25 and Slatty Water.

A comparison of the 2D results does not reveal any notable difference in level or flow routes.

Mannings Sensitivity Result Comparison

Reach	Location	Difference in Stage (m) *	Diff (%)
TIBB / 2CA1	Slatty Water	0.014	9.5%
	N25 upstream	-0.107	11.2%
	Local rd to village upstream	0	0.0%
	3-way split upstream	-0.069	0.4%
WOOD / 2CA2	N25	0.198	33.8%
	Carrigothill Bridge upstream	0.054	4.4%
RAIL	Downstream end reach	0.096	8.1%
	Local rd upstream	0.069	1.9%
	Irish Rail Culvert at Fota Retail Park upstream	0.128	2.8%
KILA	Downstream end of reach	0.111	9.4%
	Irish Rail Culvert upstream	0.015	0.4%
POUL	Downstream end of reach	0.005	0.0%
	Local rd upstream	-0.003	0.0%
	Irish Rail Culvert	-0.006	0.0%
* minus indicates that the Sensitivity Run yielded a lower stage			

8.2 Critical Storm Duration

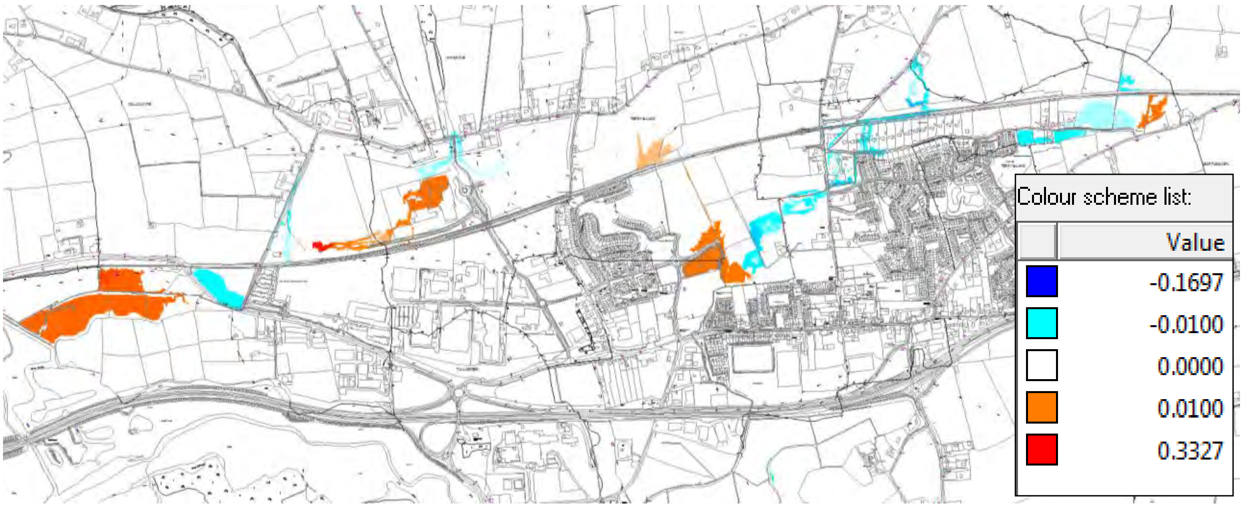
The fluvial model has been tested for storms of varying durations. Based on hydrological catchment descriptors the critical storm duration for peak flow is 6.5hours. However, due to the influence of Slatty Pond, tidal locking and the pump station, storms of longer duration but lower peak may be more critical in terms of flood risk. For this reason a sensitivity check was carried out to run the fluvial model with fluvial flows generated from a 6.5 hr, 13 hr and 25 hr storm (for 1% AEP fluvial).

The 25 hour storm results in a longer runoff hydrograph and this increased flood volume causes an increase in flood levels at the downstream end of the reach in the Slatty Pond area. Flooding in the upper reaches is less extensive in this model scenario (than the design 6.5Hr storm scenario).

The 13Hr storm results in lower flood levels in the Woodstock reach and slightly higher levels in the Tibbotstown reach than the design 6.5Hr storm scenario.

Difference in flood levels between 6.5Hr Storm and 25Hr storm

Difference in flood levels between 6.5Hr Storm and 13Hr storm



* Minus values indicate where flood levels in the longer duration scenario are lower.

Because the catchment area is relatively small it is not proposed to combine storms of different durations. The critical storm duration is assessed based on an overall worst case scenario in terms of flood risk. Consideration of a worst case flood risk scenario takes into account the location of receptors, and based on the demographics of the catchment the upper reaches are more vulnerable to flooding. The 6.5 hour storm corresponds to the critical duration for a worst case scenario in the upper reaches.

8.3 Blockage

Hydraulic modelling of blockage scenario is not required under the brief. However, JBA have included a brief assessment of blockage in the sensitivity analysis. As noted previously (see Section 3.7) a number of culverts have been identified on site that are currently silted or partially blocked. The sensitivity runs completed in the hydraulic modelling phase, test the impact of removing such blockage and allowing the full culvert capacity to convey flow. The results of the blockage runs are presented below.

Where severe siltation at a culvert was identified on site, and this was included in the design model for the current scenario, a sensitivity test was carried out to test the impact of cleaning out this silt. The blockage sensitivity check model was set up with the culverts units modified to represent a 'clean' culvert barrel. This test was completed for the Irish Rail Culvert on the Woodstock Stream.

When the culvert is cleaned out more water can flow through to the downstream end and causes additional flooding further downstream increasing flood depths by up to 40mm. The following illustrates the additional areas affected.

Difference in Flood Depths due to Blockage Sensitivity Test

* Minus values indicate where flood levels in the blockage scenario are lower.

Flood levels in the immediate vicinity of the culvert are lower (by up to 36mm) as the culvert has increased capacity. Flood levels further downstream are increased (by up to 44mm) because more flow reaches this area and is not stored in the floodplain further upstream.

8.4 Tide Timing

Outflow from the fluvial watercourse is restricted during high tide, therefore the timing of the tidal peak is an important factor to consider in the sensitivity analysis.

For the sensitivity test on the tide timing the tidal peak has been shifted 3 hours later and earlier relative to the fluvial peaks (at the upstream end of the model).

The 1D ISIS results are presented below and confirms that the largest difference in level occurs at the downstream end of the reach, between Slatty Water and the N25. The sensitivity runs show that moving the tidal peak (so that is does not coincide with the fluvial peak) reduces flood levels at the downstream end of the reach by up to 100mm. This is less conservative than the timing of peaks adopted in the design model runs. Elsewhere in the model the difference is negligible as the tide has less of an influence in the upper reaches.

Tidal peak occurs 3 hours later			
Reach	**Location**	**Difference in Stage (m) ***	**Diff (%)**
TIBB / 2CA1	Slatty Water	-0.099	40.2%
	N25 upstream	0.001	0.0%
	Local rd to village upstream	0.001	0.0%
	3-way split upstream	0	
WOOD / 2CA2	N25	0	0.0%
	Carrigtohill Bridge upstream	0.001	0.1%
	Irish Rail Culvert US	0	0.0%
RAIL	Downstream end reach	-0.011	0.9%
	Local rd upstream	-0.004	0.1%
	Irish Rail Culvert at Fota Retail Park upstream	-0.002	0.0%
KILA	Downstream end of reach	-0.011	0.9%
	Irish Rail Culvert upstream	0.002	0.1%
POUL	Downstream end of reach	0.002	0.0%
	Local rd upstream	0.001	0.0%
	Irish Rail Culvert	0.003	0.0%
* minus indicates that the Sensitivity Run yielded a lower stage			

Tidal Peak occurs 3 hours earlier			
Reach	**Location**	**Difference in Stage (m) ***	**Diff (%)**
TIBB / 2CA1	Slatty Water	-0.04	21.4%
	N25 upstream	-0.063	3.1%
	Local rd to village upstream	-0.023	0.6%
	3-way split upstream	-0.002	0.0%
WOOD / 2CA2	N25	-0.094	17.7%
	Carrigtohill Bridge upstream	-0.132	12.2%
	Irish Rail Culvert US	0	0.0%
RAIL	Downstream end reach	-0.016	1.4%

Tidal Peak occurs 3 hours earlier			
	Local rd upstream	0.002	0.1%
	Irish Rail Culvert at Fota Retail Park upstream	0	0.0%
KILA	Downstream end of reach	-0.016	1.4%
	Irish Rail Culvert upstream	-0.075	2.0%
POUL	Downstream end of reach	0.001	0.0%
	Local rd upstream	0.003	0.0%
	Irish Rail Culvert	0	0.0%
* minus indicates that the Sensitivity Run yielded a lower stage			

9 Tidal Model Sensitivity Results

9.1 2D Model Roughness

The sensitivity of the model to roughness was tested by simulating the T200_MRFS event with a lower general roughness value for the 2D domain. The following illustrates the results of that sensitivity check.

The different in flood level is a reduction in the Slatty Pond area of up to 0.09m with a general increase in levels up to 0.02m immediately upstream.

A more notable difference is shown in the Kilacloyne tidal area with a maximum increase of up to 0.244m in a localised area.

The flood map with a lower floodplain roughness allows floodwater to spread with slightly more ease and therefore results in a slightly larger extent in some localised areas by a cell size.

Overall, with consideration of the flood extent and location of the receptors, the change in model roughness has a negligible effect on predicted flood risk.

9.2 2D Model Cell Size

The model cell size was reduced from 10m to 6m to test the sensitivity of the model and check any impact on the mapped results. The model run time increased by an hour to 1hr 20mins. Flood levels in floodplain upstream of Slatty Pond increase by up to 0.58m.

In the Kilacloyne tidal area the difference in flood level is more pronounced closer to the model boundary with an increase in level by up to 0.3m, this increase drops to approx 0.36m further from the boundary.

The reduced model cell size allows the flood water to propagate across the DTM with topographic features more accurately defined. The model output for a reduced cell size results in larger flood extent by a cell width or two.

In terms of the predicted flood risk and the location of receptors this degree of sensitivity is manageable and the cell size used n the design model is appropriate for the tidal flood mapping exercise that is the purpose of this model.

10 Model Deliverables

A discussion on the design model results is presented in the Main Report. This also includes a section on the validation of the results based on available data and records of past flood events.

As per the brief model results in GIS format for all design scenarios are included as part of the delivery to the client. Following agreement with Cork County Council, print ready Flood Maps have been prepared in Geo-PDF format. This is an interactive map that allows the user to switch on and off GIS layer to interrogate and review the Flood Mapping. The following is a list of how the maps have been presented. The Flood Maps are included as an Appendix to the Main Report.

Summary of Geo-PDF (Print Ready) Maps

Geo Pdf Map No	Scenario / Map Title	Applicable Models	Map Layers
1	**Current Scenario (all AEPs)**	Fluvial Model: DEF_Qxxx_T2_027 Tidal: Txxx	Fluvial Flood Extent for 10%, 1% and 0.1% AEPs Tidal Flood Extent for 1% & 0.1% AEPs UMAP outlines Table of flow & levels at key model nodes 5kOSi Basemap 50k OSi Raster Map
2	**10% AEP Current Scenario** Fluvial: 10% AEP Fluvial plus 50% AEP Tidal	Fluvial: DEF_Q10_T2_027 Tidal: N/A	Fluvial Depth Fluvial Velocity Fluvial Hazard 5kOSi Basemap 50k OSi Raster Map
3	**1% (0.5%) AEP Current Scenario** Fluvial: 1% AEP Fluvial plus 50% AEP Tidal Tidal: 0.5% AEP Tidal	Fluvial: DEF_Q100_T2_027 Tidal: T200	Fluvial Depth Fluvial Velocity Fluvial Hazard Tidal Depth Tidal Velocity Tidal Hazard 5kOSi Basemap 50k OSi Raster Map
4	**0.1% AEP Current Scenario** Fluvial: 0.1% AEP Fluvial plus 50% AEP Tidal Tidal: 0.1% AEP Tidal	Fluvial: DEF_Q1000_T2_027 Tidal: T1000	Fluvial Depth Fluvial Velocity Fluvial Hazard Tidal Depth Tidal Velocity Tidal Hazard 5kOSi Basemap 50k OSi Raster Map
5	**Flood Zones**	Fluvial: UNDEF_Q100_T2_030; UNDEF_Q1000_T2_030 Tidal: T200, T1000	Flood Zone A Flood Zone B 5kOSi Basemap 50k OSi Raster Map