

Cathy Carleton

From: Mike Amiel Mekell <mamekell@mkoireland.ie>
Sent: Tuesday 28 October 2025 16:30
To: Appeals2
Cc: Alan Clancy; Eoin McCarthy; Micheal Cahill
Subject: RE: 230502-h Briskalagh Renewable Energy Development - Response to Further Information - ACP Ref. 322154-25 (Email 5 of 5)
Attachments: RFI Appendix 9 - Detailed Site Specific Hydraulic Modelling.pdf

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Is mise le meas,
Mike.

Mike Amiel Mekell BA, MSc, RTPI Licentiate
Planner

MKO

Tuam Road, Galway, H91 VW84

Offices in Galway and Dublin
mkoireland.ie | +353 (0)91 735 611



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Sent: Tuesday 28 October 2025 16:29
To: 'Appeals2' <appeals@pleanala.ie>
Cc: Alan Clancy <aclancy@mkoireland.ie>; Eoin McCarthy <emccarthy@mkoireland.ie>; Micheal Cahill <mcahill@mkoireland.ie>
Subject: RE: 230502-h Briskalagh Renewable Energy Development - Response to Further Information - ACP Ref. 322154-25 (Email 4 of 5)

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Mike.



APPENDIX 9

DETAILED SITE-SPECIFIC HYDRAULIC MODELLING



Briskalagh Renewable Energy Development Detailed Site-Specific Hydraulic Modelling



September 2025

Project:		Briskalagh Renewable Energy Development		
Site:		Briskalagh		
Client:		Briskalagh Ltd. Lissarda Industrial Estate, Lissarda, Co. Cork Ireland		
Job title:		Briskalagh Wind Farm		
Job ID:		IE-2025.05-ENC		
Document title:		IE-2025.05-ENC-FA-BriskalaghWF-DetailedSSHdraulicModellingAssessment.pdf		
Date:		26/09/2025		
Revision	Date			
Draft	08-Sep-25	Filename:	IE-2025.05-ENC-FA- BriskalaghWF-DetailedSSHdraulicModelling-draft.pdf	
			Prepared by	Checked / Approved by
		Name	IK, EMcK	EMcK
		Signature	 Dr. Igor Kerin, CEng. MIEI.	 Dr. Eamon McKeogh BSc. PhD. MBA. CEng. MIEI.
Final	02-Oct-25	Filename:	IE-2025.05-ENC-FA- BriskalaghWF-DetailedSSHdraulicModelling.pdf	
			Prepared by	Checked / Approved by
		Name	IK, EMcK	EMcK
		Signature	 Dr. Igor Kerin, CEng. MIEI.	 Dr. Eamon McKeogh BSc. PhD. MBA. CEng. MIEI.

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1 Introduction and Location

1.1 INTRODUCTION

1.1.1 General

Fluvio R&D Ltd. was commissioned by Briskalagh Ltd. to carry out a Flood Assessment (FA) for the Proposed Wind Farm development at Briskalagh, Co. Kilkenny, Ireland (Figure 1).

The Proposed Wind Farm is located adjacent to the Tullaroan Stream and its tributaries, with a smaller portion of the catchment on the east located close to the Breaghagh stream (Figure 1). Indicative flood maps (Figure 2) produced by the OPW are available for the Tullaroan Stream and show flooding potential only around the existing site access road (see red arrow). The remaining areas of the development are fully outside of flood zone A and B. OPW maps did not include three relevant streams (Oldtownhill, Briskalagh and Knockeenglass) as shown in Figure 1 and Figure 2 (marked with red letters). It was considered that a more detailed Flood Risk Assessment would be required for the development. This was confirmed by the Planning authority with the following comments:

"It is noted that the crossing of the Tullaroan Stream and some access roads are proposed to be located within a flood zone (National Indicative Fluvial Mapping). In addition, there is a history of flood events immediately downstream of the site within the village of Kilmanagh. In this regard, you are required to submit an updated Flood Risk Assessment (FRA) which includes detailed site-specific hydraulic modelling of the Tullaroan Stream which should examine the potential impact on the existing floodplain or on flood risk elsewhere downstream. The updated FRA shall also have regard to the alterations that have been undertaken to the Tullaroan Stream within the boundaries of the site."

This Detailed Site-Specific Hydraulic Modelling Assessment focusses on two main hydrological/hydraulic aspects of the development:

1. The impact of the Proposed Wind Farm infrastructure viz. internal wind farm road network, new stream crossings, hardstands and turbines on the hydrology of the Tullaroan stream catchment and Breaghagh Tributary catchment at this location
2. The study also assesses the flood risk both upstream and downstream of the Proposed Wind Farm (attention is given to Kilmanagh area also) by comparing existing and design water levels and flow rates.

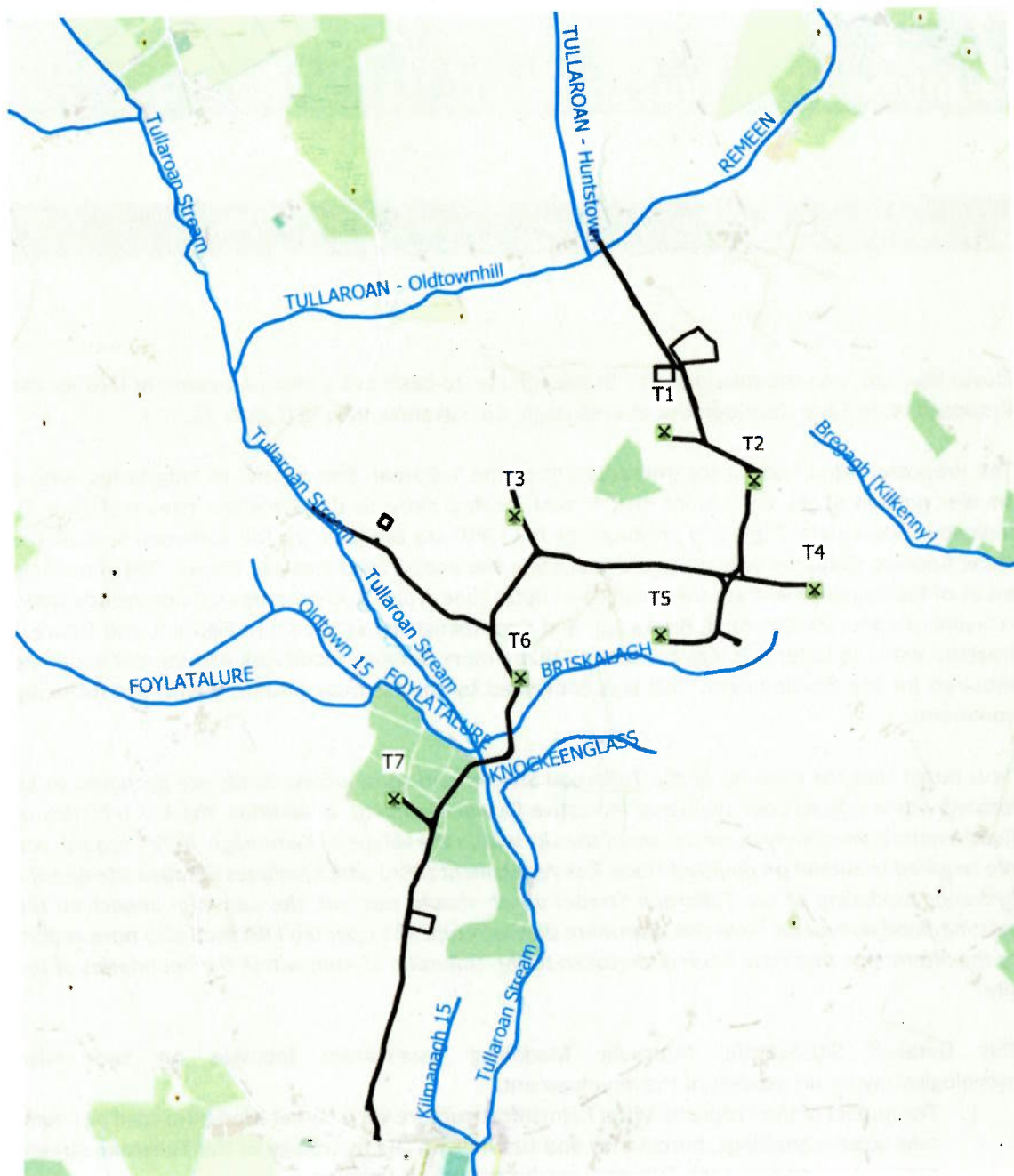


Figure 1. Proposed Wind Farm development with river network.

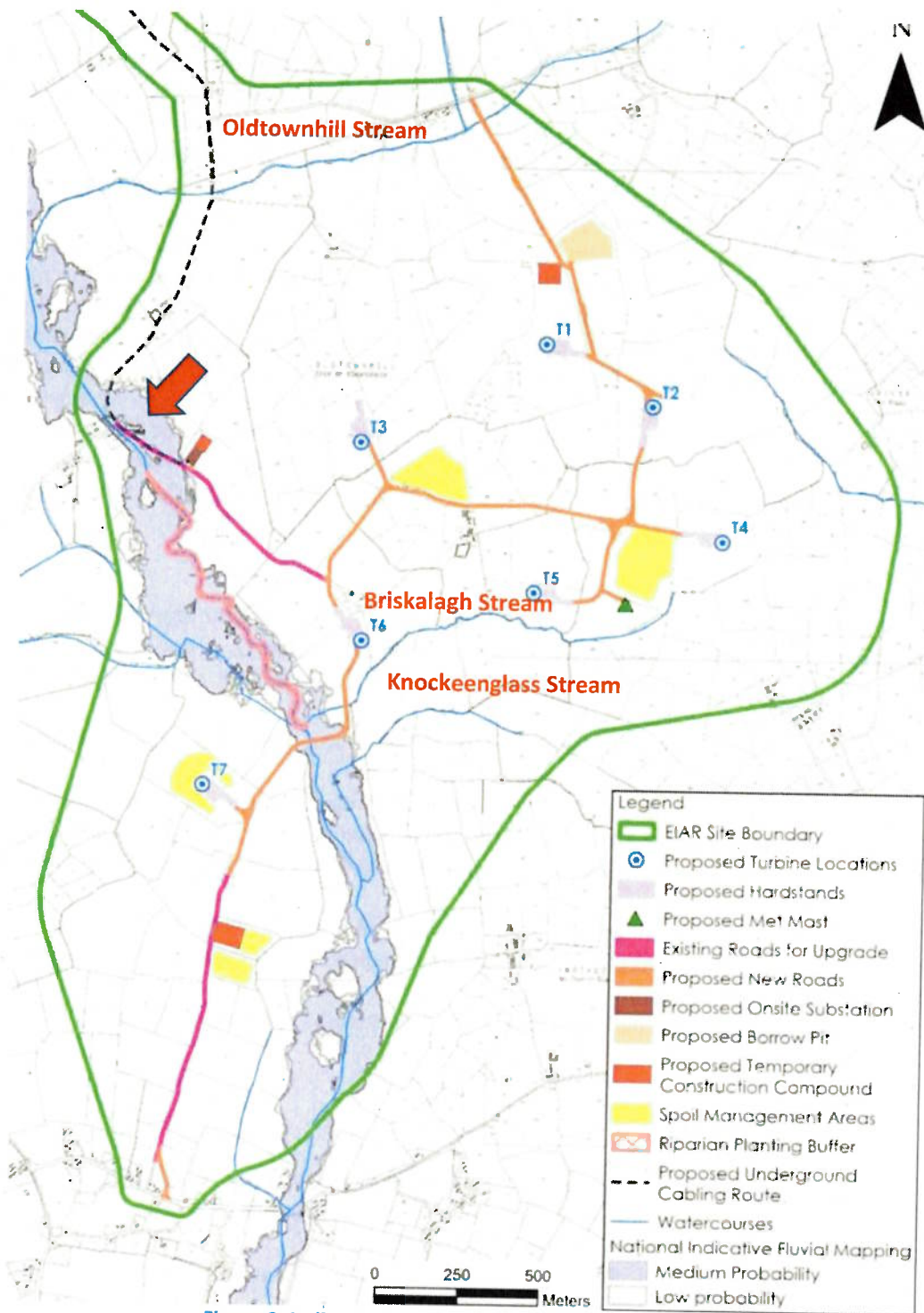


Figure 2. Indicative flood maps (floodinfo.ie and MKO)

1.1.2 Methodology

The FRA involves a detailed hydrological analysis to determine a 'design flood' flow; this is normally a flood event which has the probability of occurring once in one hundred years with an additional increase to take into account the effects of Climate Change (20% increase for Mid Range Future Scenario is used). The design flood hydrograph is then used in an unsteady flow computer model simulation to determine the water levels in the river along the entire river reach within the zone of influence of the Proposed Wind Farm. The model includes the full extents of the flood plains of the river and tributaries and this enables the simulation to identify the limits to which the water level in the river extends on the flood plains. This is plotted on the detailed topographical site map to give a Flood Extents Map. The flood mapping gives not only the flooding extents and but also the variation in flood water depth throughout the flooded area. Using a 2D, unsteady flow, computer model simulation enabled the effects of storage on the flood plain to be determined for the existing green field site and for the site, post construction. This technical approach allows for an assessment of the impact (if any) of the Proposed Wind Farm infrastructure on the flood flow rate at the downstream end of the development and hence any impact on flooding in the village of Kilmanagh and environs. HEC-RAS 2-D computer software v6.6. [6-9] is used for the development of the computer model.

The assessment involved the following:

1. A hydrological analysis appropriate for this catchment area viz. the standard FSU method [10] to determine the magnitude of the mean annual flood Q_{med} , and the 100-year and 1000-year flood for the Tullaroan stream with tributaries, and also a tributary of the Breagagh stream on the east part of the site.
2. Site visits and river survey to determine the extent of the river reach to be modelled based on detailed river and flood plain survey data.
3. The collection of additional flood plain survey data (LIDAR) to develop a detailed topographical DEM of selected river reach and all tributaries and drainage channels.
4. Computer model simulations to determine existing flood levels at the site for the design flow for the existing river and flood plain.
5. Computer simulations of modifications to Proposed Wind Farm layout.
6. Evaluation of results in terms of hydrology and implications for the eventual Proposed Wind Farm planning application.
7. Identification of the locations of any new culvert requirements or upgrading of existing culverts.

1.1.3 Objectives

The general objectives of this report are to determine fluvial flood risk downstream of the development and flood risk for the Proposed Wind Farm. The report will provide:

- Hydrological calculations for design flood flows,
- Produce flood maps for: MRFS, e.g. Q100cc (Flood Zone A), and up to Q1000cc (Flood Zone B),
- Assess the impact that the proposed development has on flood risk in adjacent lands and downstream.
- Mitigate flood risks, if any, for the development.

1.1.3.1 Flood zone concept

There are three types or levels of flood zones in accordance with the guidelines published by the OPW and DHELG in November 2009 "The Planning System and Flood Risk Management – Guidelines for Planning Authorities" [1].



Indicative flood zone map

1.1.3.1.1 Flood Zone A

Is the zone where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding).

1.1.3.1.2 Flood Zone B

Is the zone where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding);

1.1.3.1.3 Flood Zone C

Flood zone C is where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

1.1.3.2 Flood zone concept in relation wind farm development

A wind farm development can be classified as an industrial development and does not come into the category of highly vulnerable development which is normally restricted to Zone C. It is appropriate therefore to consider wind farm infrastructure to be developed in Zones A&B provided that there are no flood risk implications for adjacent properties and no change to the downstream flood hydrograph flows. This FRA study will pay particular attention to these factors and the hydrological and DEM modelling in particular will be sufficiently detailed so as to give high resolution Flood Extents Maps and the Unsteady Flow Model gives conservative estimates of flood hydrographs through the site and downstream of the site.

1.2 DESCRIPTION OF THE SITE

1.2.1 Location of the site and hydrology features

The site is located just west from Kilkenny, e.g. north from the townland of Kilmanagh and south from Tullaroan in Co. Kilkenny as shown in Figure 2. On the west boundary of the site, Tullaroan stream flows from North to South direction. There are three significant tributaries (Oltownhill stream, Briskalagh and Knockeenglass) flowing into the Tullaroan stream from east to west. The stream network is shown in Figure 1 and Figure 2.



Figure 3. Site map.

1.3 HYDROLOGICAL FEATURES

Topographical and bathymetric survey was carried out in September 2025. The survey established the pattern of existing drainage and recorded existing hydrology features. The site has a gentle slope in a north – south direction. Site visit has shown that Toullaroan Stream was in most of reach dry. The surface runoff percolates underground upstream of confluence with Oldtownhill stream due to soil configuration, e.g. layers. Photos associated with the site walkover are provided in Annex A. Location of identified hydrological features (bridges and culverts) are shown in Figure 4 and are listed in Table 1.

In total 12 stream/river crossings have been identified within the site and adjacent to the site boundary, these are marked in Figure 4 below. Property access culverts/bridges are marked from '1' to '12'. As Bridges. Crossings characteristics are provided in Table 1.

Table 1. Culvert details

No	Type	Detail
BR01	Bridge	Private dwelling access bridge. Box culvert 1.5m x 2.0m River: Oldtownhill stream
BR02	Culvert	Road bridge 2x900mm pipes. Locals noted that the bridge and road floods. Site visit showed that pipes were partially blocked on the u/s elevation. River: Oldtownhill stream
BR03	Bridge	Single span (3m wide) arch stone road bridge under Oldtown road. River: Oldtownhill stream
BR04	Culvert	Culvert 2x750mm pipes River: Huntstown stream
BR05	Bridge	Single span (11.84m x 1.85m) RC road bridge under Oldtown road. River: Tullaroan stream. Scour noted at downstream left abutment.
BR06	Bridge	Four span arch stone bridge under R695/L1009 road in Kilmanagh town. River: Tullaroan stream.
BR07	Culvert	Single pipe 600mm culvert. River: Kilmanagh 15 stream
BR08	Bridge	600mm pipe. Briskalagh Stream.
BR09	Bridge	750mm pipe. Briskalagh Stream.
BR10	Bridge	750mm Pipe on the Upstream elevation, 1.5m x1.5m Box culvert on the downstream elevation
BR11	Culvert	300mm pipe. Breagagh Stream.
BR12	Culvert	300mm pipe. Breagagh Stream.

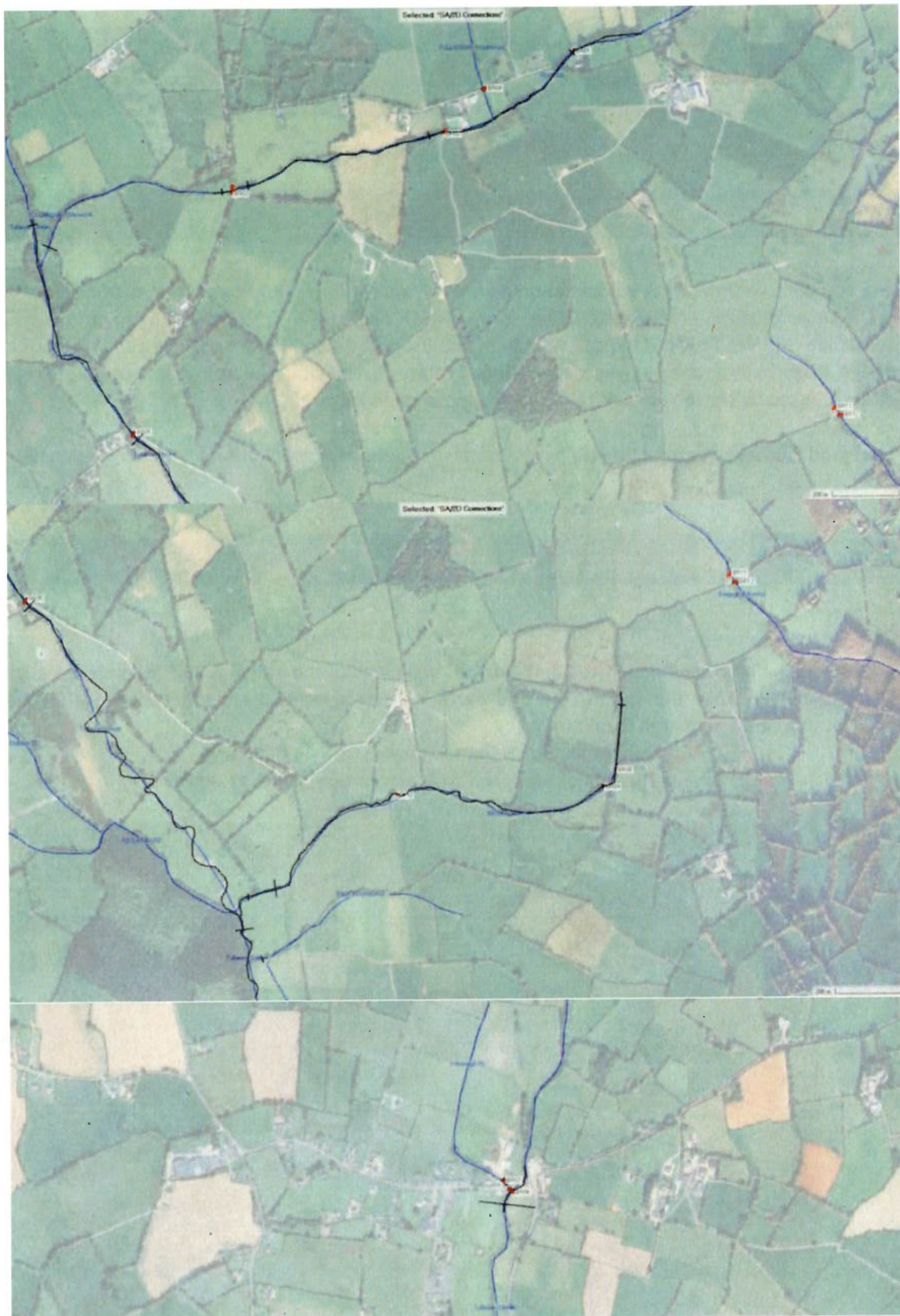


Figure 4. Hydrological Features

2 Hydrology

2.1 INTRODUCTION

In accordance with the OPW guidelines on hydrology, appropriate hydrological methods were used in the determination of the design peak flow which reflected the size of the catchment and the availability of river flow data in the vicinity of the Proposed Wind Farm site. The generation of a design flood hydrograph was necessary since we are investigating hydrological system storage effects caused by the infrastructure of the Proposed Wind Farm.

The Flood Studies Update – FSU [10] hydrological methods were used for calculation of design flow rates.

2.2 CATCHMENT AREA AND HEP'S

2.2.1 Area

The total delineated catchment area at the downstream end of the model is 40.979km², see Figure 5 and Table 2. Since the Proposed Wind Farm extends over two catchments, the effective contributing catchment area is split into:

Catchment area of Tullaroan stream, $A = 40.067\text{km}^2$.

Catchment area of Breaghagh stream tributary, $A = 0.913\text{km}^2$.

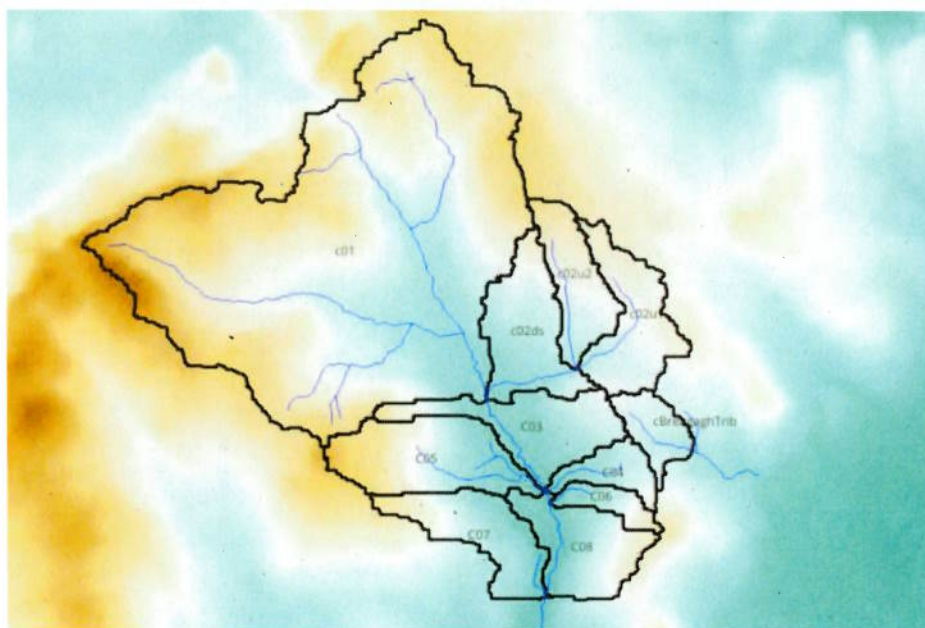


Figure 5. Catchment area delineation for all HEPs.

Table 2. Delineated catchment areas.

Subbasin ID	AREA [km ²]
c01	22.968681
c02u1	2.231497
c02u2	1.716804
c02ds	2.395880
C03	2.372595
C04	0.867785
C05	2.825428
C06	0.608180
C07	1.996914
C08	2.083102
Total Tullaroan Stream in Kilmanagh:	40.066866
cBreagaghTrib	0.912617
Total (Tullaroan+Breagagh)	40.979483

2.2.2 HEPs

For the hydraulic model development, the site specific FRA requires a high resolution hydrological analysis. The hydrological model for the Proposed Wind Farm site therefore, is complex involving the combination of a number of tributaries and drainage channels.

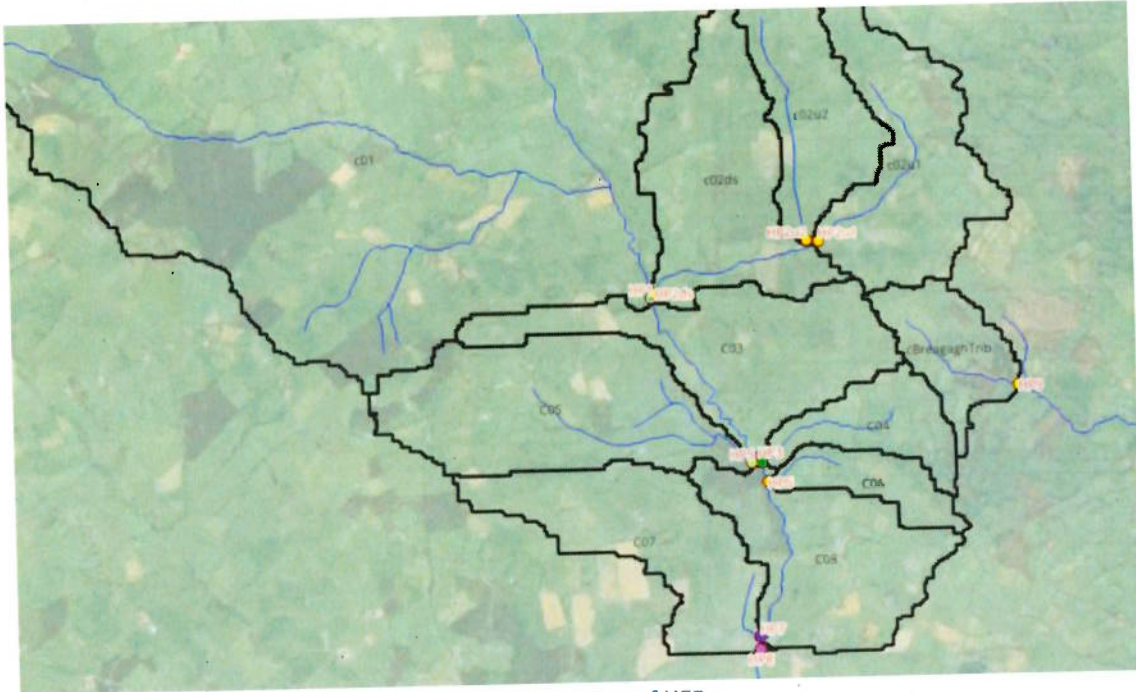


Figure 6. Location of HEPs.

Each of the tributaries is assessed separately hydrologically and the runoff is calculated for a set of Hydrological Estimation Points. The location of Hydrological Estimation Points (HEPs, e.g. "H") is shown in 5 above. The breakdown of contributing catchment areas for each HEP is given in the Table 3 below.

Table 3. Contributing (incremental) catchment area for each HEP

Return Period [years]	HP1	HP2ds	HP2u1	HP2u2	HP3	HP4	HP5	HP6	HP7	HP8	HP9
Incremental catchment area [km ²]	8.089	1.097	0.984	0.898	0.923	0.464	1.282	0.257	0.751	0.781	0.478
Total catchment area [km ²]	22.969	6.344	2.231	1.717	2.373	0.868	2.825	0.608	1.997	40.067	0.913

2.3 DESIGN FLOW RATES

2.3.1 Flood Study Update

The FSU Catchment characteristic approach was used to determine Q_{med} values. The OPW offline tools were used to determine BFISOIL, SAAR, FARL, DRAIN2, ARTDRAIN2 and URBEXT, see table below and [Annex D](#).

The catchment of the selected subject site has an area of more than 40.979km², but its sub-catchments have much lower catchment area (Figure 5 and Table 2) which is below the FSU minimum threshold for using FSU 7-parameter equation. Therefore, the Q_{med} was calculated using the small catchment (5-parameter) equation

$$Q_{med} = 0.000020951 \times AREA^{0.9245} BFISOIL^{-0.903} SAAR^{1.2695} FARL^{2.3163} S1085^{0.2513} \quad (2.1)$$

In order to satisfy OPW Mid Range Future Scenario (MRFS) a Climate Change factor of 1.20 is applied to the Q_{100} and Q_{1000} . MRFS 1% AEP and 0.1% AEP flows have naming convention of Q_{100cc} and Q_{1000cc} respectively.

Table 4. FSU Input parameters.

Hydrological Point	HP1	HP2ds	HP2u1	HP2u2	HP3	HP4	HP5	HP6	HP7	HP8	HP9
OPW Node I.D.	15_1622_3	15_1619_4	15_1728_3	15_1648_1	15_1649_4	15_1626_2	15_1573_2	15_1729_1	15_645_1	15_1729_4	15_1748_1
Incremental catchment area [km ²]	8.089	1.097	0.984	0.898	0.923	0.464	1.282	0.257	0.751	0.781	0.478
Total catchment area at HP [km ²]	22.969	6.344	2.231	1.717	2.373	0.868	2.825	0.608	1.997	40.067	0.913
BFIsoils (index)	0.589	0.528	0.565	0.512	0.590	0.531	0.582	0.590	0.590	0.591	0.532
SAAR (mm)	883.480	846.360	846.600	842.220	875.470	848.900	883.410	874.890	873.540	873.610	848.900
FARL (index)	1	1	1	1	1	1	1	1	1	1	1
DRAIND (km/km ²)	0.832	1.244	0.878	1.529	0.849	1.081	1.378	0.913	0.892	0.881	1.289
S1085 (m/km)	19.485	23.598	25.310	33.256	15.503	32.365	27.326	14.330	12.983	12.983	30.365
ARTDRAIN2 (prop)	0	0	0	0	0	0	0	0	0	0	0
URBEXT (%)	0	0	0	0	0	0	0	0	0	0	0
ALLUV	0.0412	0.0112	0.0179	0	0.0458	0.0075	0.0173	0.0437	0.0459	0.0462	0.0081
ARTDRAIN	0	0	0	0	0	0	0	0	0	0	0
FOREST	0.082	0.000	0.000	0.000	0.061	0.000	0.037	0.055	0.051	0.052	0.015
Q _{med} [m ³ /s]	8.089	1.097	0.984	0.898	0.923	0.464	1.282	0.257	0.751	0.781	0.478

The Pivotal site adjustment factor was not used as the flows without adjustment are more conservative. The most conservative distribution was adopted for each sub-catchment and yielded the Growth factors as shown in Table 5 below.

Table 5. Growth factors from FSU analysis.

Return Period [years]	HP1	HP2ds	HP2u1	HP2u2	HP3	HP4	HP5	HP6	HP7	HP8	HP9
Adopted distribution	GLO	GEV	LN2	LN2	GLO	LN2	LN2	LN2	LN2	LN2	LN2
1.3	0.792	0.588	0.616	0.628	0.790	0.628	0.628	0.617	0.616	0.616	0.628
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.301	1.632	1.740	1.703	1.301	1.703	1.703	1.736	1.740	1.740	1.703
10	1.514	2.055	2.324	2.250	1.513	2.249	2.250	2.315	2.324	2.324	2.249
20	1.739	2.466	2.952	2.831	1.736	2.830	2.831	2.937	2.952	2.952	2.830
25	1.815	2.597	3.165	3.027	1.812	3.026	3.027	3.148	3.165	3.165	3.026
30	1.880	2.704	3.343	3.190	1.876	3.190	3.190	3.325	3.343	3.343	3.190
35	1.935	2.794	3.496	3.331	1.931	3.331	3.331	3.477	3.496	3.496	3.331
50	2.069	3.003	3.863	3.667	2.063	3.666	3.667	3.840	3.863	3.863	3.666
100	2.353	3.410	4.622	4.357	2.342	4.356	4.357	4.590	4.622	4.622	4.356
200	2.671	3.820	5.447	5.101	2.655	5.100	5.101	5.405	5.447	5.447	5.100
500	3.153	4.367	6.645	6.177	3.127	6.175	6.177	6.589	6.645	6.645	6.175
1000	3.573	4.785	7.641	7.064	3.535	7.061	7.064	7.572	7.641	7.641	7.061

The FSU Method was applied to the HEPs as shown in Table 6 below:

Table 6. FSU design flows.

Return Period [years]	HP1	HP2ds	HP2u1	HP2u2	HP3	HP4	HP5	HP6	HP7	HP8	HP9
Incremental catchment area [km ²]	8.089	1.097	0.984	0.898	0.923	0.464	1.282	0.257	0.751	0.781	0.478
Total catchment area [km ²]	22.969	6.344	2.231	1.717	2.373	0.868	2.825	0.608	1.997	40.067	0.913
1.3	6.404	1.815	0.606	0.564	0.730	0.291	0.804	0.159	0.462	11.146	0.300
2	8.089	2.979	0.984	0.898	0.923	0.464	1.282	0.257	0.751	15.526	0.478
5	10.524	5.031	1.712	1.530	1.201	0.790	2.183	0.446	1.306	22.840	0.814
10	12.247	6.562	2.286	2.021	1.397	1.044	2.884	0.595	1.745	28.287	1.075
20	14.066	8.151	2.904	2.543	1.603	1.313	3.629	0.755	2.216	34.037	1.353
25	14.685	8.681	3.113	2.720	1.673	1.404	3.880	0.809	2.376	35.978	1.446
30	15.205	9.120	3.289	2.867	1.732	1.480	4.090	0.854	2.509	37.600	1.524
35	15.656	9.497	3.440	2.993	1.783	1.546	4.270	0.893	2.625	38.999	1.592
50	16.740	10.388	3.801	3.294	1.905	1.701	4.700	0.987	2.900	42.337	1.752
100	19.033	12.202	4.547	3.914	2.163	2.021	5.584	1.179	3.470	49.261	2.081
100cc	22.840	14.642	5.457	4.697	2.595	2.426	6.701	1.415	4.164	59.113	2.498
200	21.605	14.132	5.359	4.584	2.451	2.367	6.539	1.389	4.089	56.823	2.437
500	25.508	16.877	6.538	5.550	2.887	2.866	7.917	1.693	4.989	67.924	2.951
1000	28.899	19.111	7.517	6.346	3.264	3.277	9.054	1.945	5.736	77.251	3.374
1000cc	34.679	22.933	9.021	7.616	3.917	3.932	10.865	2.335	6.883	92.702	4.049

These flows were further processed for suitable form for hydraulic model input (see Table 7).

2.4 HYDROLOGY – SUMMARY

The total catchment area was calculated to be c40km².

There are no gauges at Tullaroan stream or its tributaries; the same applies for the Breagagh tributary.

The FSU approach was used to determine Q_{med} , Q_{100} , Q_{100cc} and Q_{1000} flood flows.

The design flows are shown in Table 6.

During low flows, Tullaroan stream is completely dry as flow is conveyed underground due to soil properties that consist of lower layers of gravel and sand.



Figure 7. Soil Layers.

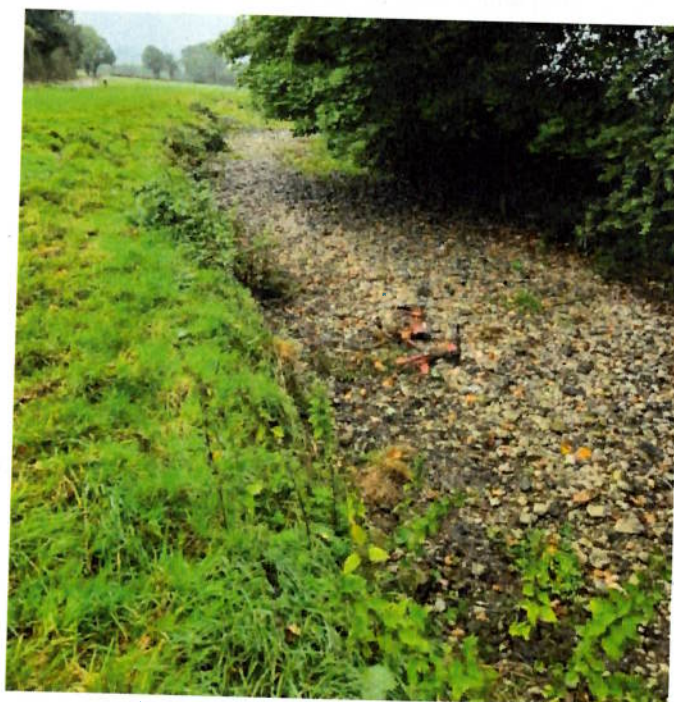


Figure 8. Tullaroan stream dry riverbed.

3 Hydraulic design

3.1 MODEL DESCRIPTION

The methodology described in Section 1.2.2 above requires the development of a 2-D HEC-RAS computer model for varying flood flows to provide:

1. Simulations for the existing pre-development on the Tullaroan Stream with tributaries, Breaghagh stream and flood plain site which give a benchmark for post-development impacts.
2. Hydrological simulations to determine if there are any hydrological impacts adjacent to or downstream of the site.
3. Hydrological/hydraulic simulations of the final Proposed Wind Farm layout to obtain all relevant impact data relating to the Proposed Wind Farm design and planning application.

The computer model is based on detailed river and tributary channels combined with detailed topographical maps of the surrounding flood plains which combined, provide the 2-D component of the full 2D HEC-RAS computer model. In addition to this, estimates of the river channel and flood plain roughness (Manning's-n values) are required as input parameters and these were determined during a site inspection.

Models were developed for three River Systems:

- The Existing River System which uses the geometry of the natural river channel and flood plains.
- The Design River System 1 that includes the geometry of the Proposed Wind Farm.

In addition to the assessment of flood risks for the development, adjacent lands and downstream reaches the simulations provided the following information:

- Identification of locations where new or upgraded culverts would be required.
- Identification of capacity of existing culverts and the role they play in providing storage in the hydrological system.

The 2-D model element of the overall HEC-RAS model covers an area of 7.8km², and includes 14 bridges/culverts (Existing River System model contains 10 bridges). The layout of the HEC-RAS cross-section locations and DTM are shown in Figure 9.

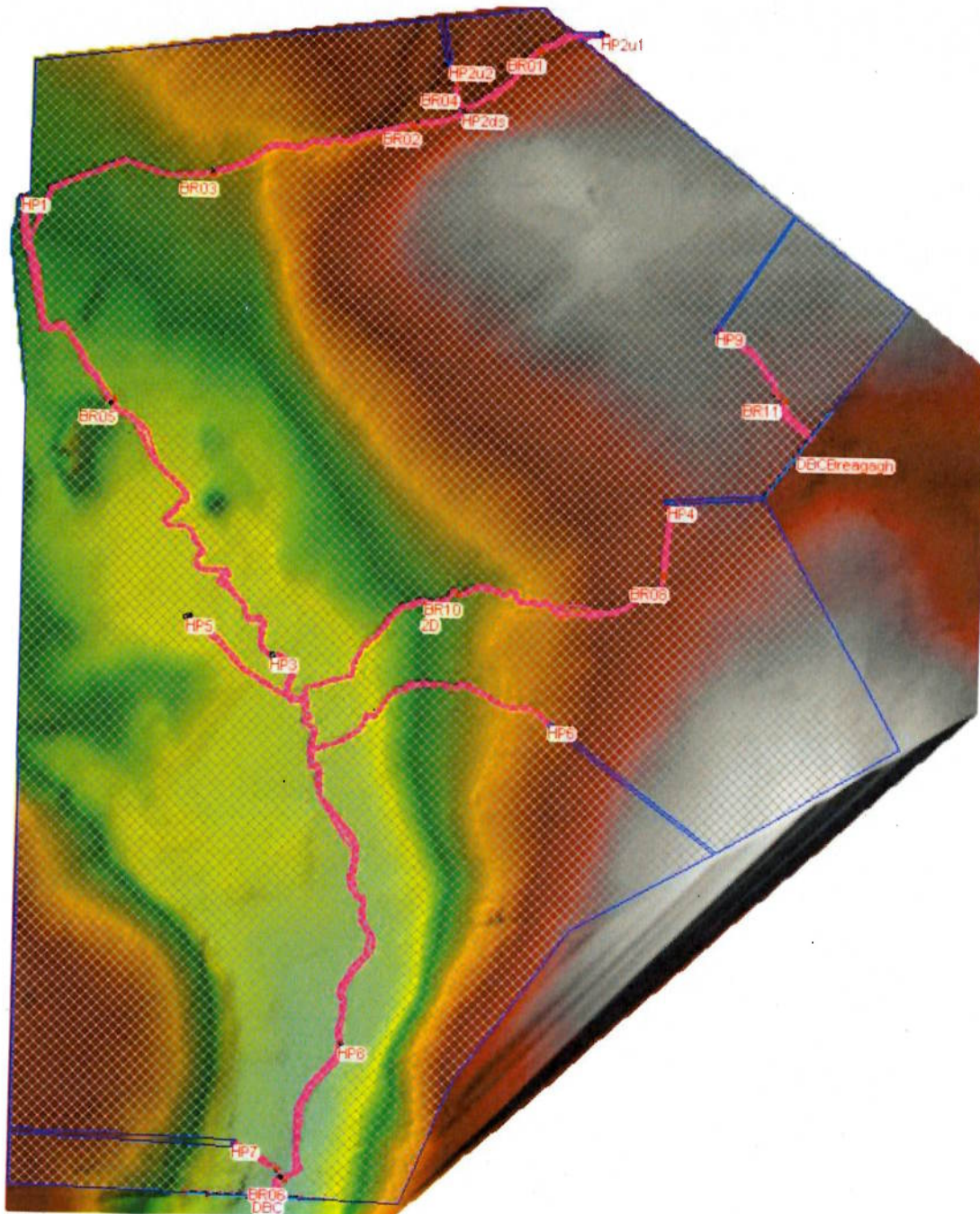


Figure 9. Layout of HEC-RAS model.

3.2 MODEL INPUT DATA

3.2.1 Geometry - Survey of river bed and flood plains

A survey of the river bathymetry was carried out between 8th and 11th September 2025 by KU217 Ltd. The survey included river banks, river channel, including existing channels changes within the WF site and flood plains, (see Figure 10). The extensive area of the flood plains was surveyed using a LIDAR/RGB Drone surveying which was conducted by © Bluesky International Ltd. The survey data covered an area of approximately 800ha and included a river length of c. 10km. The survey data were processed using a GIS toolset and a Digital Terrain Model (DTM) was created. Two DTM's were created. The first one describes the Existing River System (including flood plains) (Figure 11) and second one describes the Design River System with added new crossings, wind turbine hardstands elevated above flood water levels and a road network which follows the existing terrain (Figure 12).

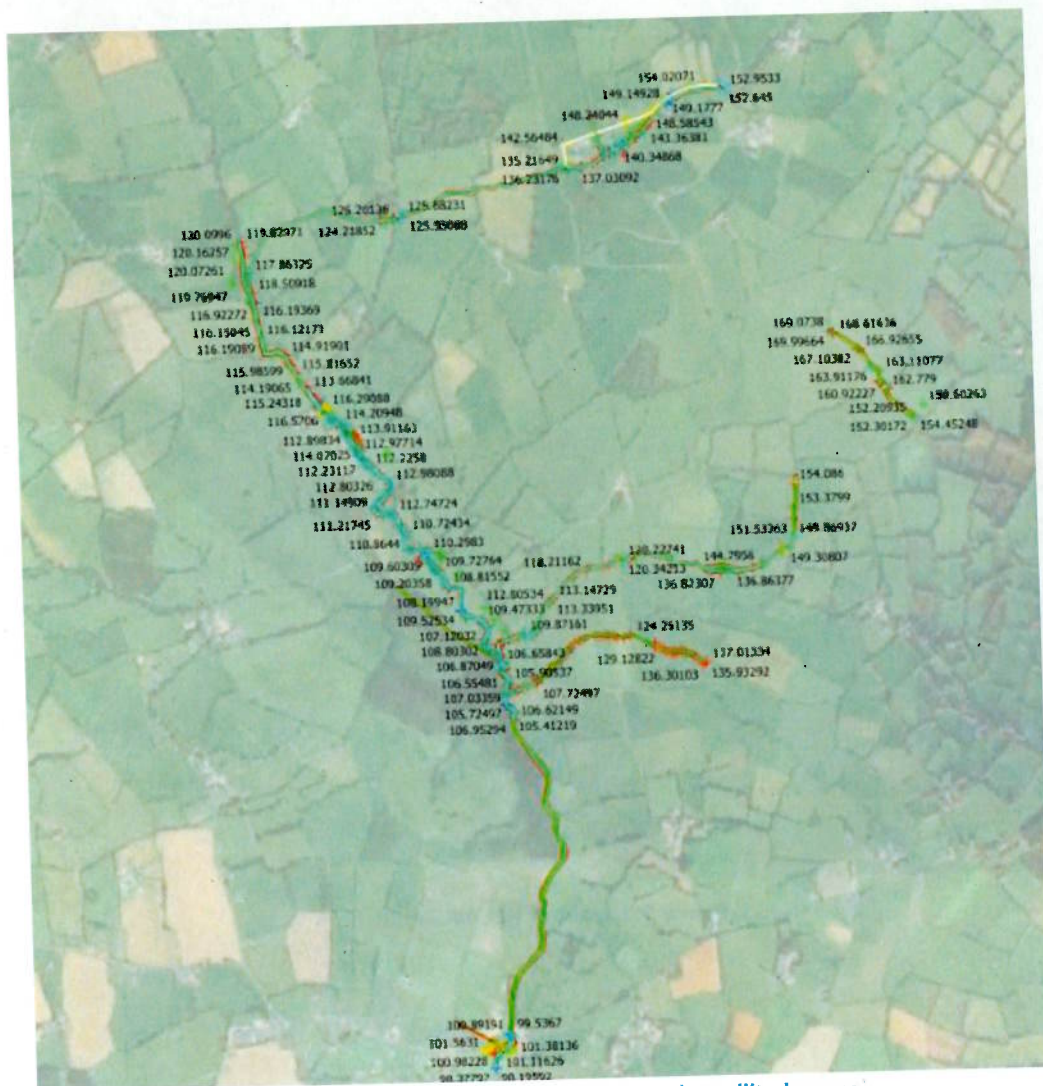


Figure 10. Overlay of the Survey points and satellite images.

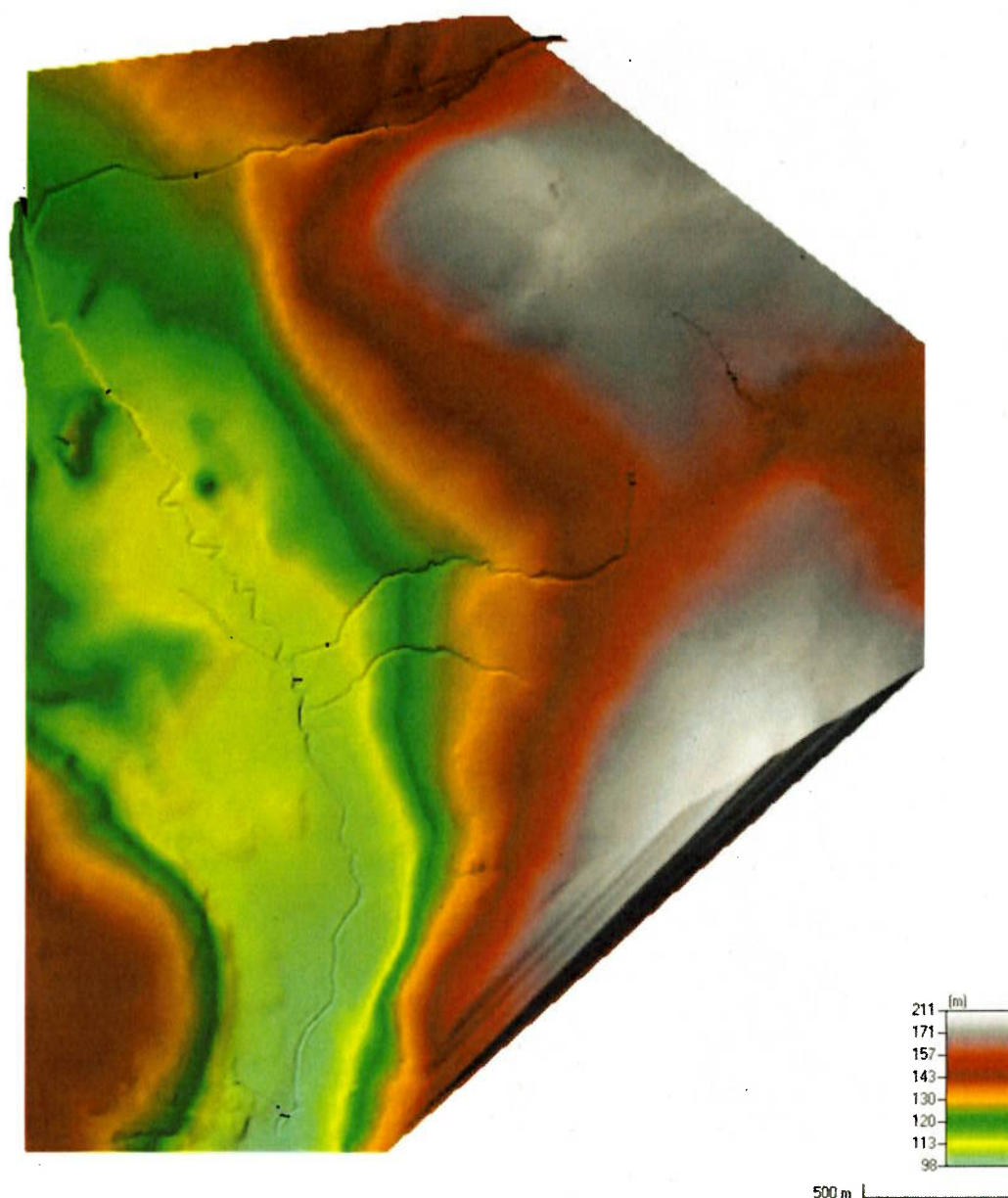


Figure 11. Digital Terrain Model of the existing model area.

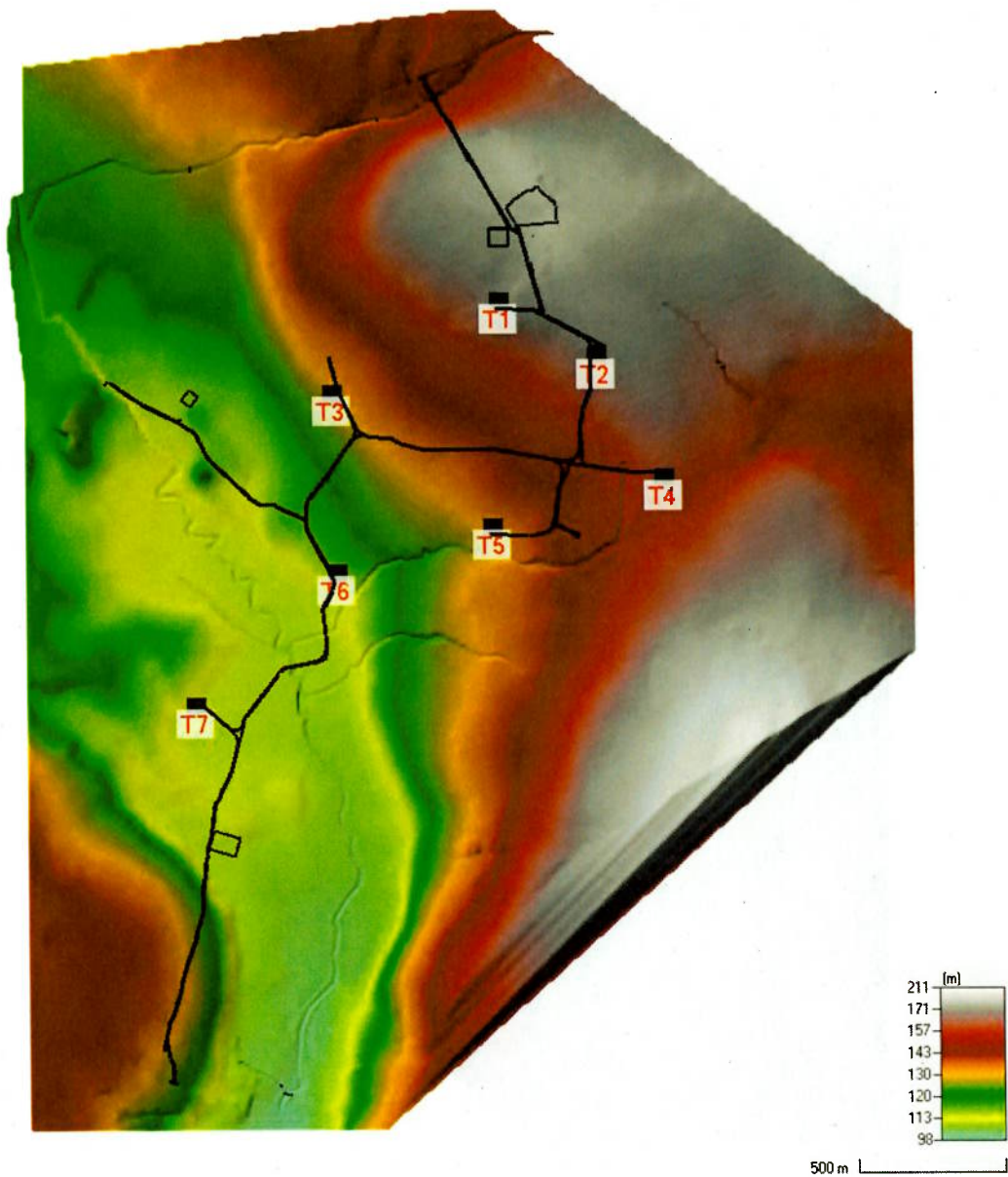


Figure 12. Digital Terrain Model of the design model area.

3.2.2 Upstream Boundary condition

The upstream boundary condition is defined with hydrographs calculated using OPW approach (see Figure 13 and Figure 14). A total of 11 upstream boundary conditions were defined and are listed in Table 7.

Table 7. Input design flows for the hydraulic model.

HEPs	HEC-RAS			Peak Flow [m ³ /s]		
	No	River	Contributing catchment area A [km ²]	Q _{med}	Q _{100cc}	Q _{1000cc}
HP1	1	Tullaroan Stream - upstream	8.089	8.089	22.84	34.679
HP2ds	2	Tullaroan Olddownhill	1.097	1.097	14.642	22.933
HP2u1	3	Remeen	0.984	0.984	5.457	9.021
HP2u2	4	Tullaroan Huntstown	0.898	0.898	4.697	7.616
HP3	5	Tullaroan Stream - middle	0.923	0.923	2.595	3.917
HP4	6	Briskalagh	0.464	0.464	2.426	3.932
HP5	7	Foylatalure	1.282	1.282	6.701	10.865
HP6	8	Knockeenglass	0.257	0.257	1.415	2.335
HP7	9	Killmanagh 15	0.751	0.751	4.164	6.883
HP8	10	Tullaroan Stream - middle	0.781	0.781	59.113	92.702
HP9	11	Breaghagh (Kilkenny)	0.478	0.478	2.498	4.049

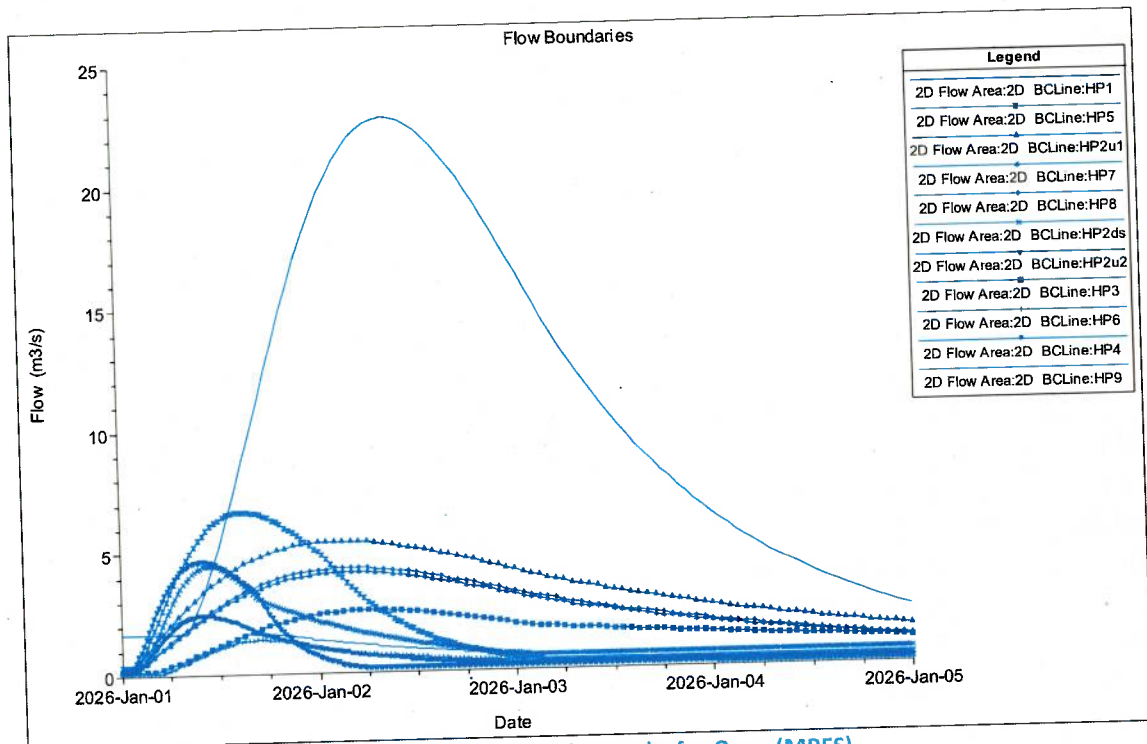


Figure 13. Resulting hydrographs for Q_{100cc} (MRFS).

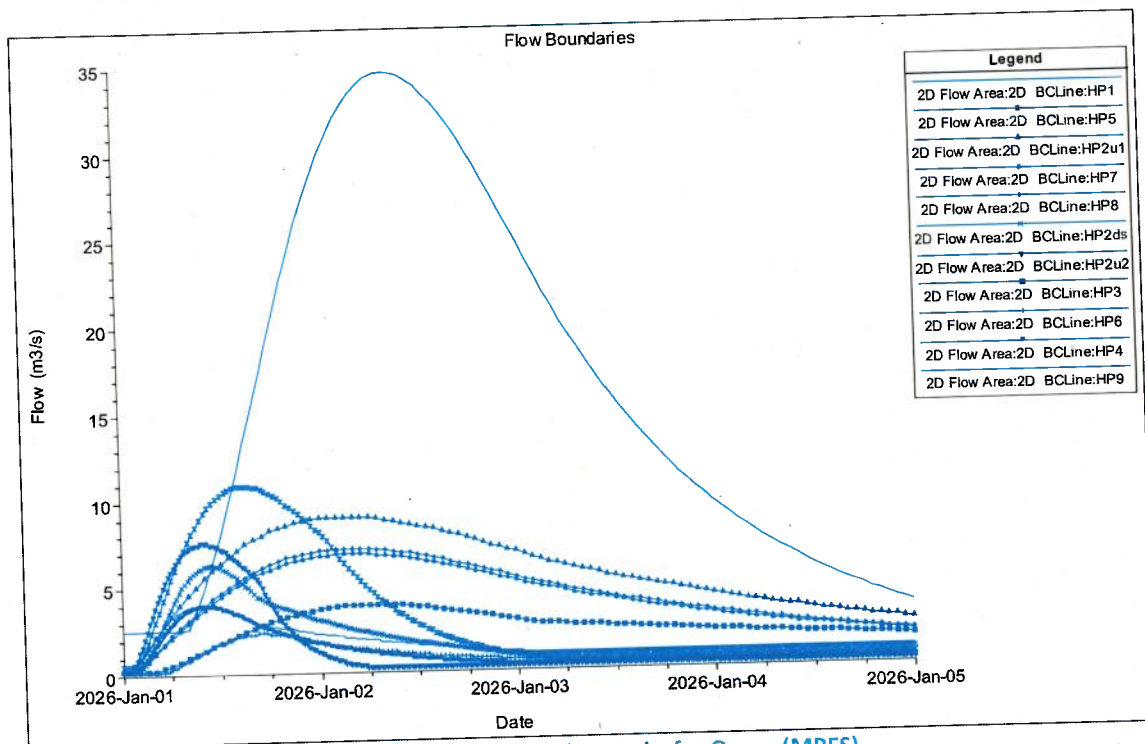


Figure 14. Resulting hydrographs for Q_{1000cc} (MRFS).

3.2.3 Downstream Boundary condition

The downstream boundary conditions are defined as the normal depth, d_n , with a defined energy slope of 0.00595m/m for Tullaroan Stream and 0.05447m/m for Breaghagh Stream.

3.2.4 Calibration results

According to inspected site conditions, roughness values for river channel have a Manning coefficient of $n=0.035 \text{ s/m}^{1/3}$. Roughness factor of $n=0.045 \text{ s/m}^{1/3}$ was used for the flood plains, $n=0.150 \text{ s/m}^{1/3}$ was used for the forests and $n=0.120 \text{ s/m}^{1/3}$ was used for developed areas. Distribution shown in Figure 15 below.

Recommended values of Manning roughness values for channels and flood plains are shown in [Annex B - Table E4.3](#).

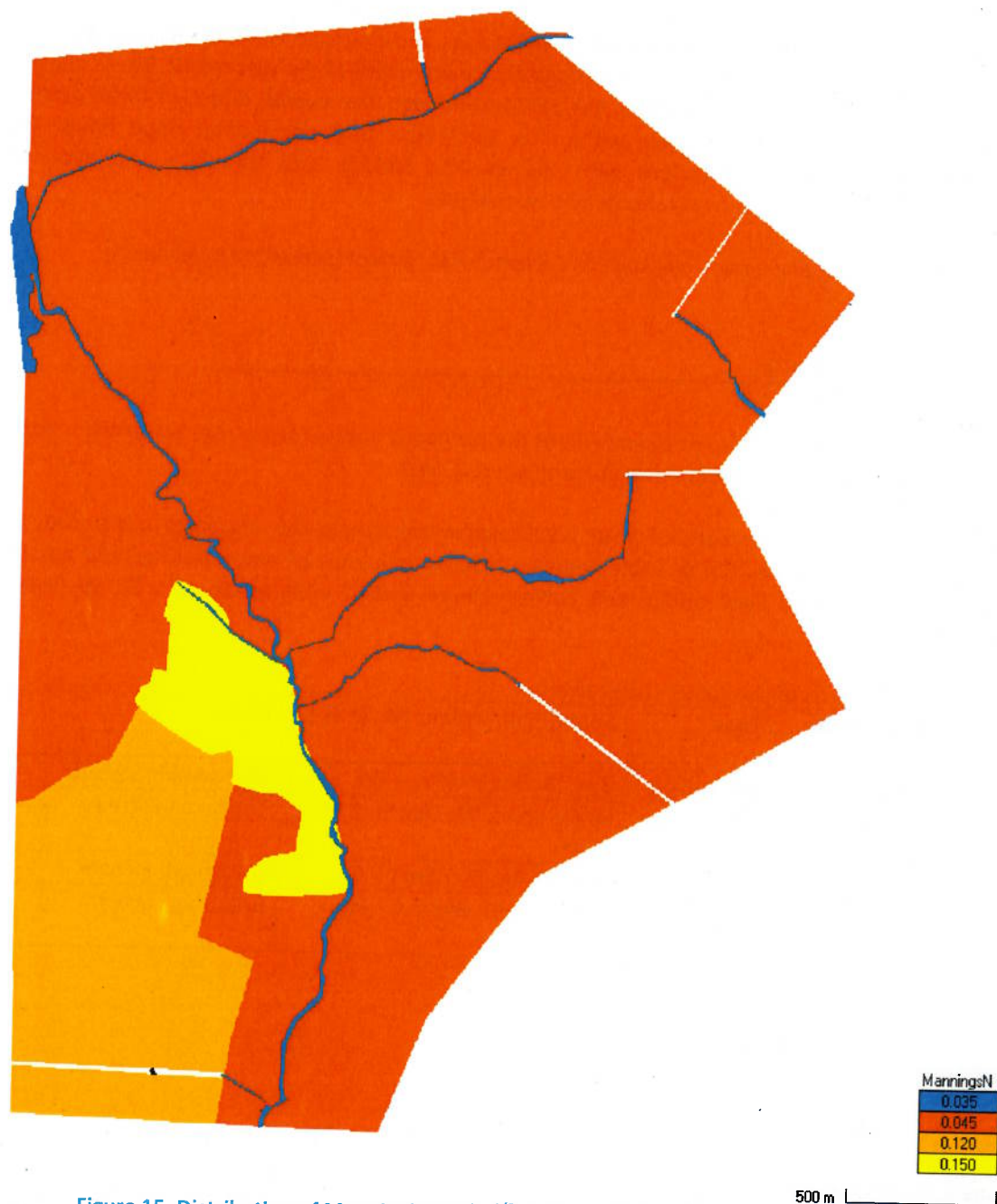


Figure 15. Distribution of Manning's $n \text{ [s/m}^{1/3}\text{]}$ values within hydraulic model domain.

3.3 HYDRAULIC MODEL RESULTS

3.3.1 Culvert requirements

3.3.1.1 Existing Culverts

Existing culverts with location are shown in Annex A below.

The existing river system of main channels, tributaries and drainage channels has a number of existing culverts which influence the hydrological characteristics of the catchment. These culverts have been modelled accurately within the HEC-RAS model. The overall effect of these existing culverts is to increase the storage within the catchment thus attenuating flood flows. The development should not interfere with the existing storage and therefore the hydraulic characteristics of existing culverts should not be changed.

During the site visit and survey blockage of Culvert 2 was evident (see photo in Annex A).

3.3.1.2 New Culverts

New culverts will be required at points where the proposed access roads cross waterways. Figure 16 identifies the locations where new culverts are required.

Note that the bridge openings and water level calculations around new crossings in this study are reasonably conservative. The possible negative residual influence of new crossings and possible blockage was tested. Final bridge and culvert design should undergo Section 50 application procedure.

Table 8. Specification of new Bridges and culverts.

No.	Crossing ID	Type	Shape: Dimensions (W, D, H, L)	Notes
1	New Br1	Box culvert	Box: W=3m H=4m L = 6m	Oldtownhill Stream
2	New Br2	Single span bridge	Single span: W=18m H=2.2m L = 6m	Toullaroan Stream
3	New Br3	Culvert	Box: W=4m H=1.5m L = 6m	Briskalagh Stream
4	New Br4	Singke span bridge	Box: W=10m H=3m L = 6m	Briskalagh Stream

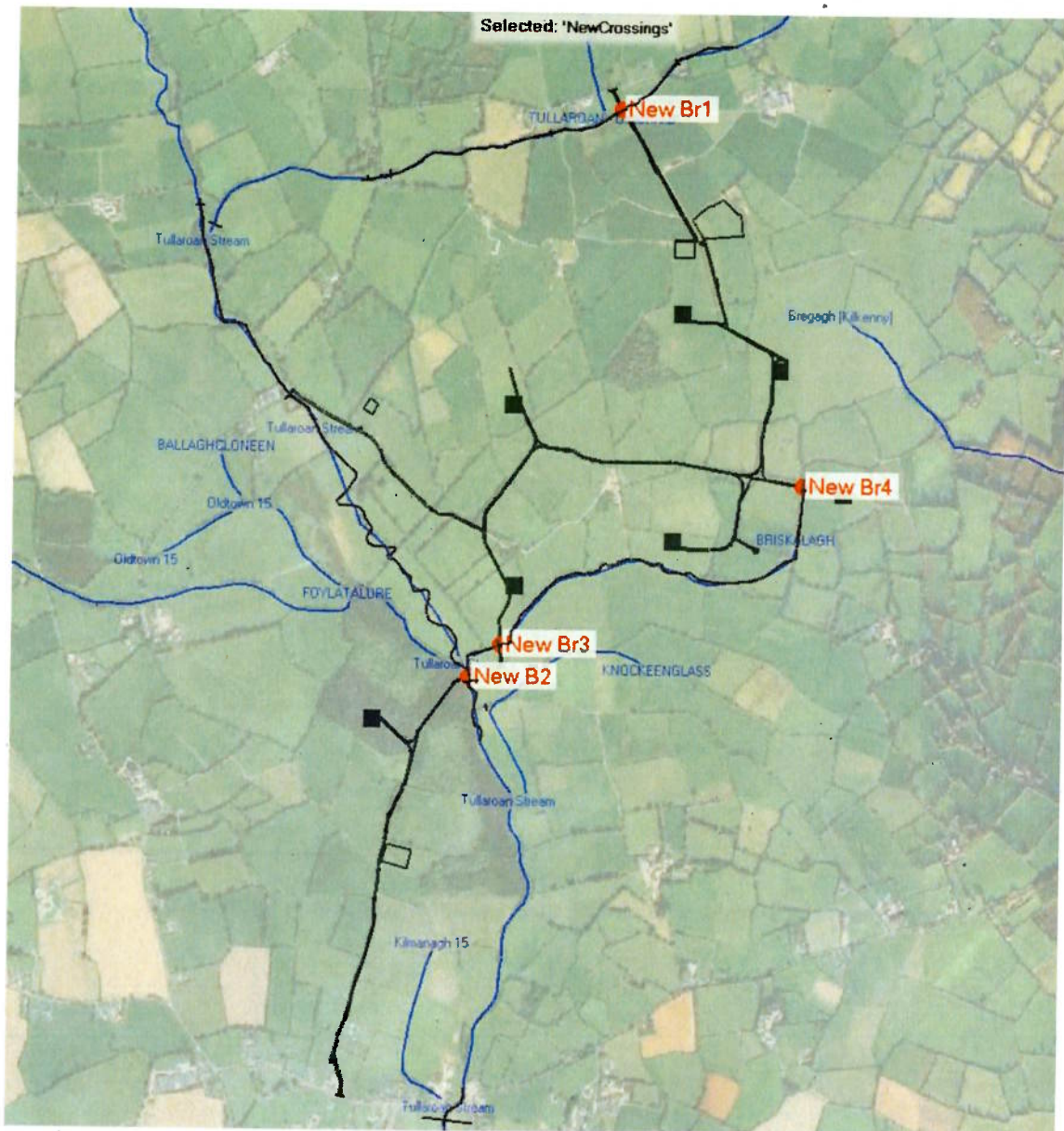
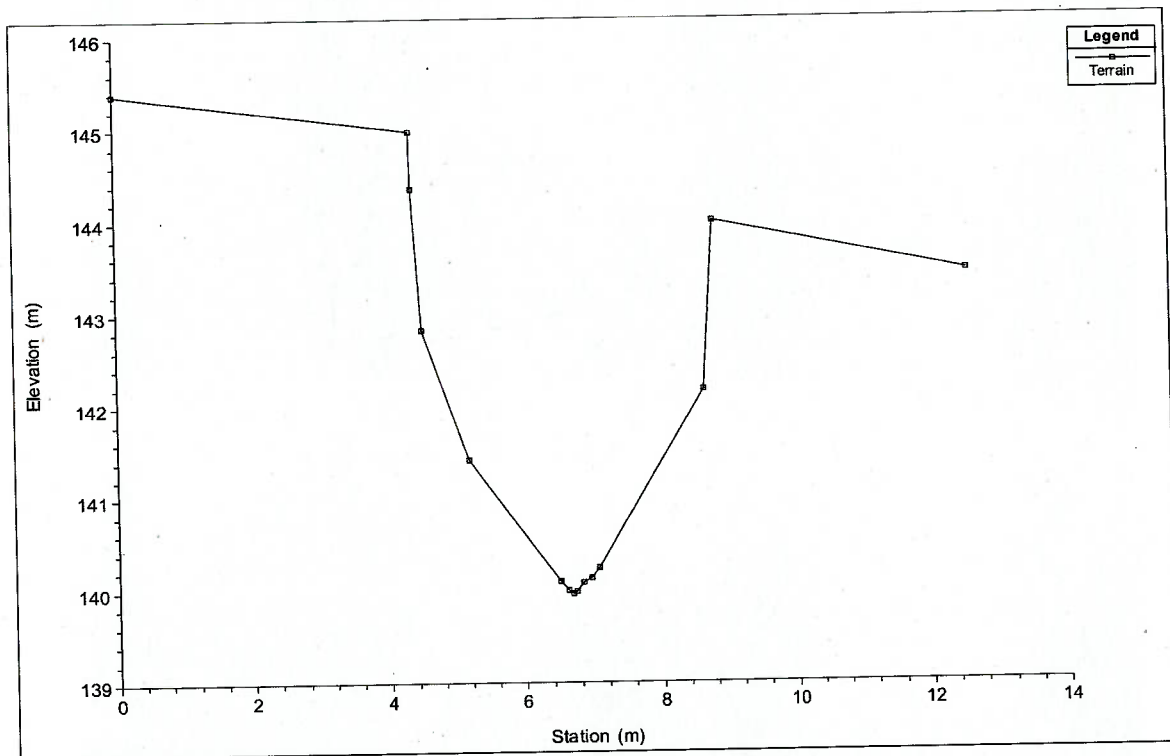


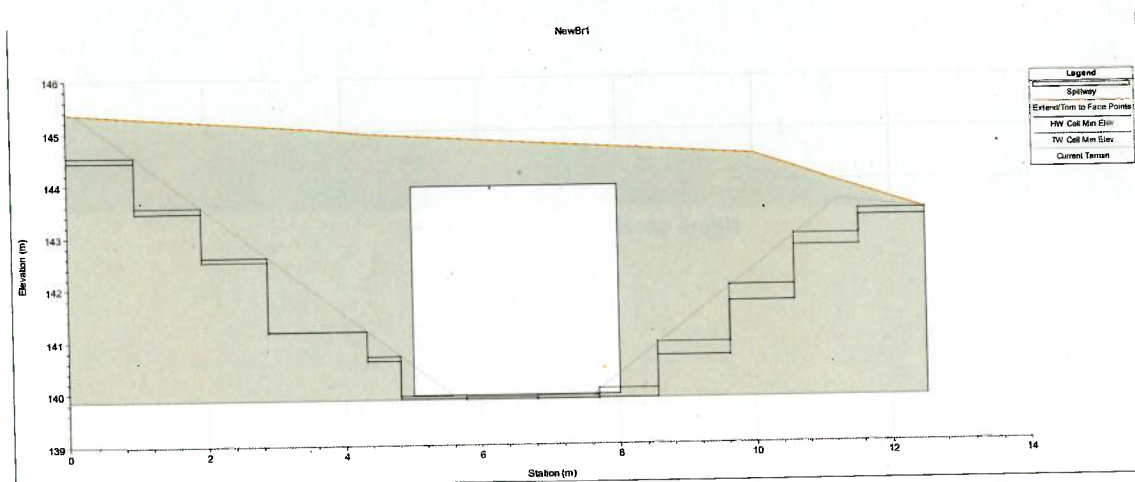
Figure 16. New culvert locations.

3.3.1.2.1 New Bridge 1 (3x4m)

Figure below shows typical cross section at the location of the bridge. The channel depth is 5m at the left bank and 4m at the right bank.

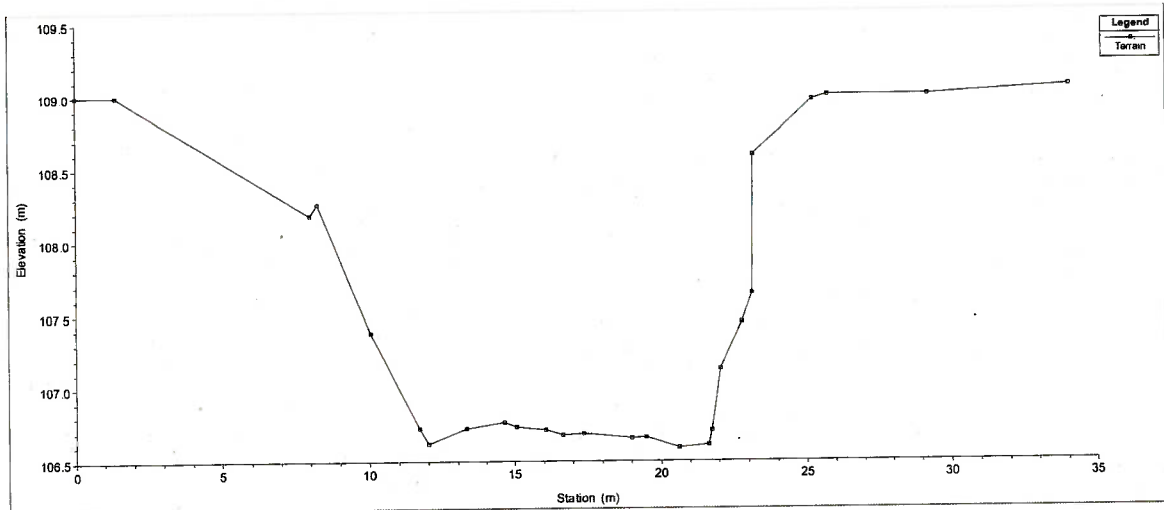


Brige elevation (opening 6x4m) and widening of the channel is shown in figure below.

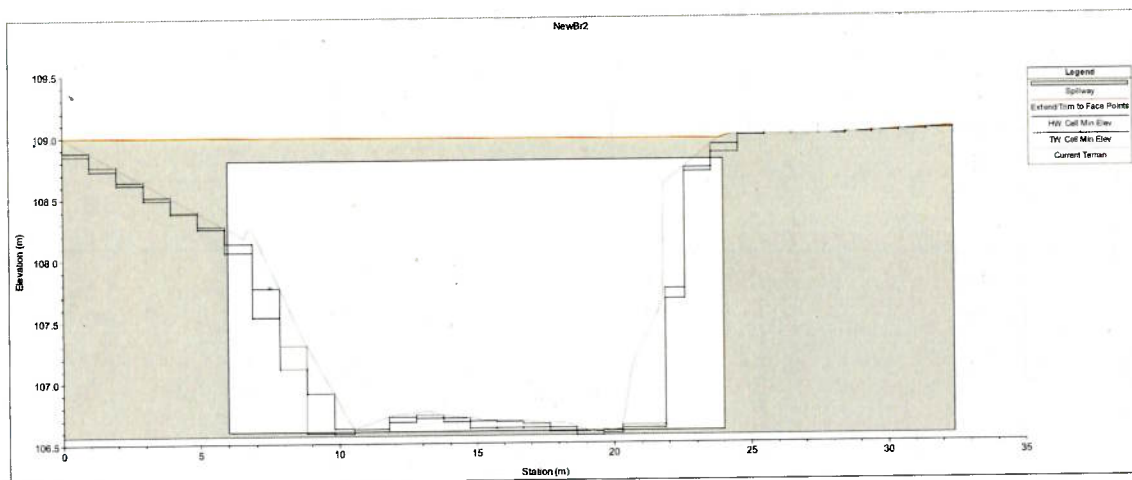


3.3.1.2.2 New Bridge 2 (18m x 2.2m)

The figure below shows typical cross section at the location of the bridge. The channel depth at the location of the bridge is c. 4.8m.

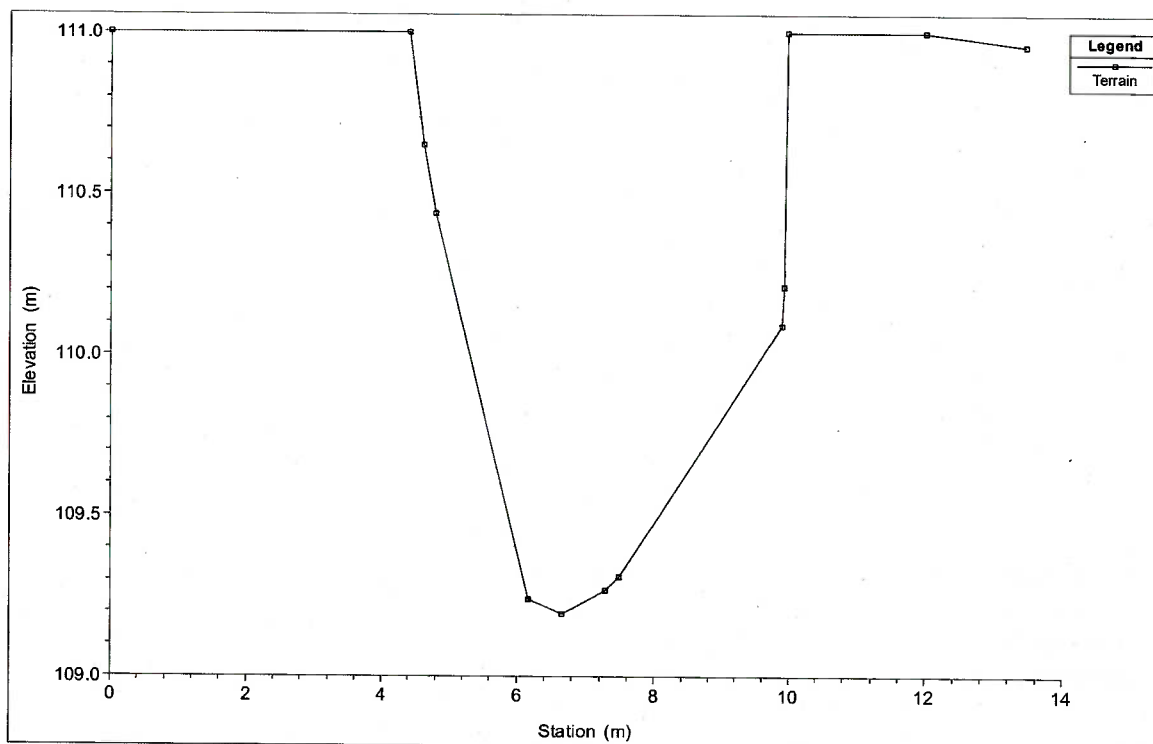


Bridge elevation is shown in figure below. Note that during simulation runs of the Design River System, a bridge opening between 10m and 20m was tested. Finally, an 18m span was applied. However, it is recommended that this should be further investigated during a Section 50 application and design.

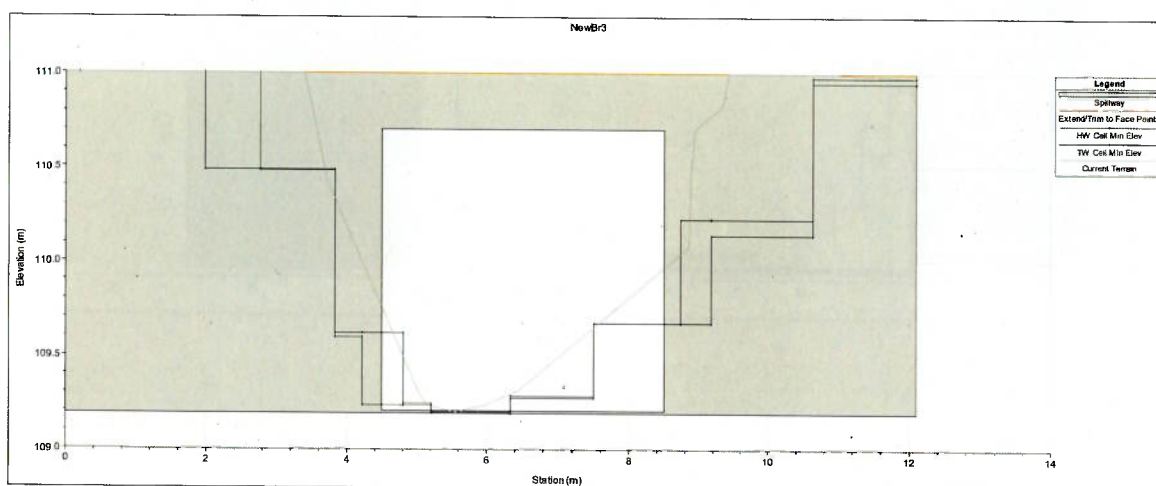


3.3.1.2.3 New Bridge 3 (4m x 1.5m)

The figure below shows a typical cross section at the location of the bridge. The channel depth at the location of the bridge is c. 1.8m.

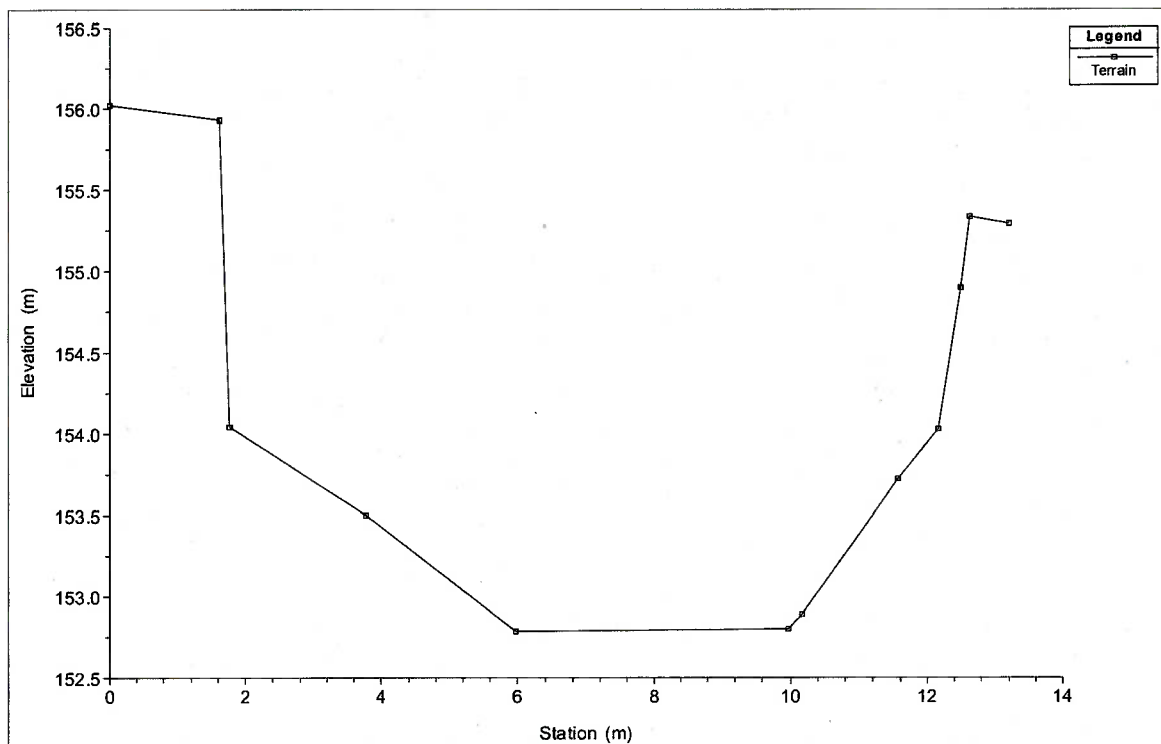


Bridge elevation is shown in figure below.

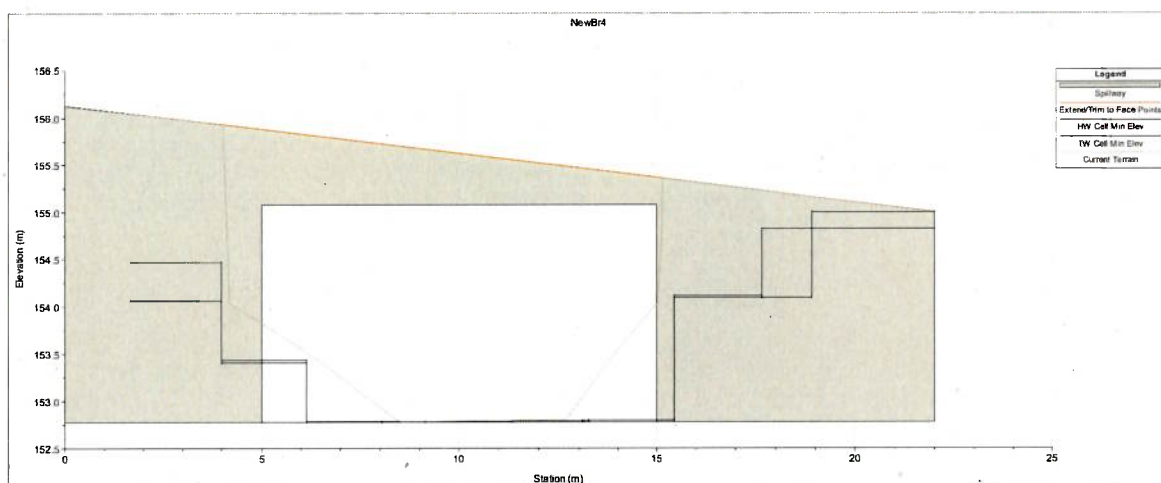


3.3.1.2.4 New Bridge 4

The figure below shows a typical cross section at the location of Bridge 4. The channel depth at the location of the bridge is c. 2.5m.



The bridge elevation is shown in the figure below. For the purpose of the HEC-RAS Design River System simulations, a 10m span bridge is used. This could be potentially downsized in a more detailed Section 50 design.



3.3.2 Longitudinal Profiles

3.3.2.1 Q_{100cc} MRFS Longitudinal profiles

The results are shown for Existing and Design River Systems for Q_{100cc} (MRFS) year flow as follows:

- Q_{100cc} MRFS Longitudinal profiles for Tullaroan stream main channel showing water levels for Existing and Design river systems (Figure 17).

Longitudinal profiles are coincident indicating no change in water level between Existing river System and Design River System

- Q_{100cc} MRFS Longitudinal profiles for Tullaroan stream main channel at the downstream end of the model in Kilmanagh town showing water levels for Existing and Design river systems (Figure 18).

Longitudinal profiles are coincident indicating no change in water level between Existing river System and Design River System

- Q_{100cc} MRFS Longitudinal profiles for Oldtownhill stream main channel showing water levels for Existing and Design river systems (Figure 19).

There are some changes in water surface profiles at the bridge location shown in red box. However these are not considered to be significant.

- Q_{100cc} MRFS Longitudinal profiles around the 4 new bridges/culverts as part of WF road network showing water levels for Existing and Design river systems for new Bridges 1-4 as shown in Figure 19 to Figure 23.

These impact of changes in water level upstream are assessed using the flood extents maps in Figure 20(b) to Figure 23(b). The flood extents maps shown in Figure 20(b) to Figure 23(b) shown very little perceptible change in flood pan for Existing and Design River Systems. (changes would be highlighted in red).

Water Surface Elevation on 'Longitudinal - Tullaroan Stream'

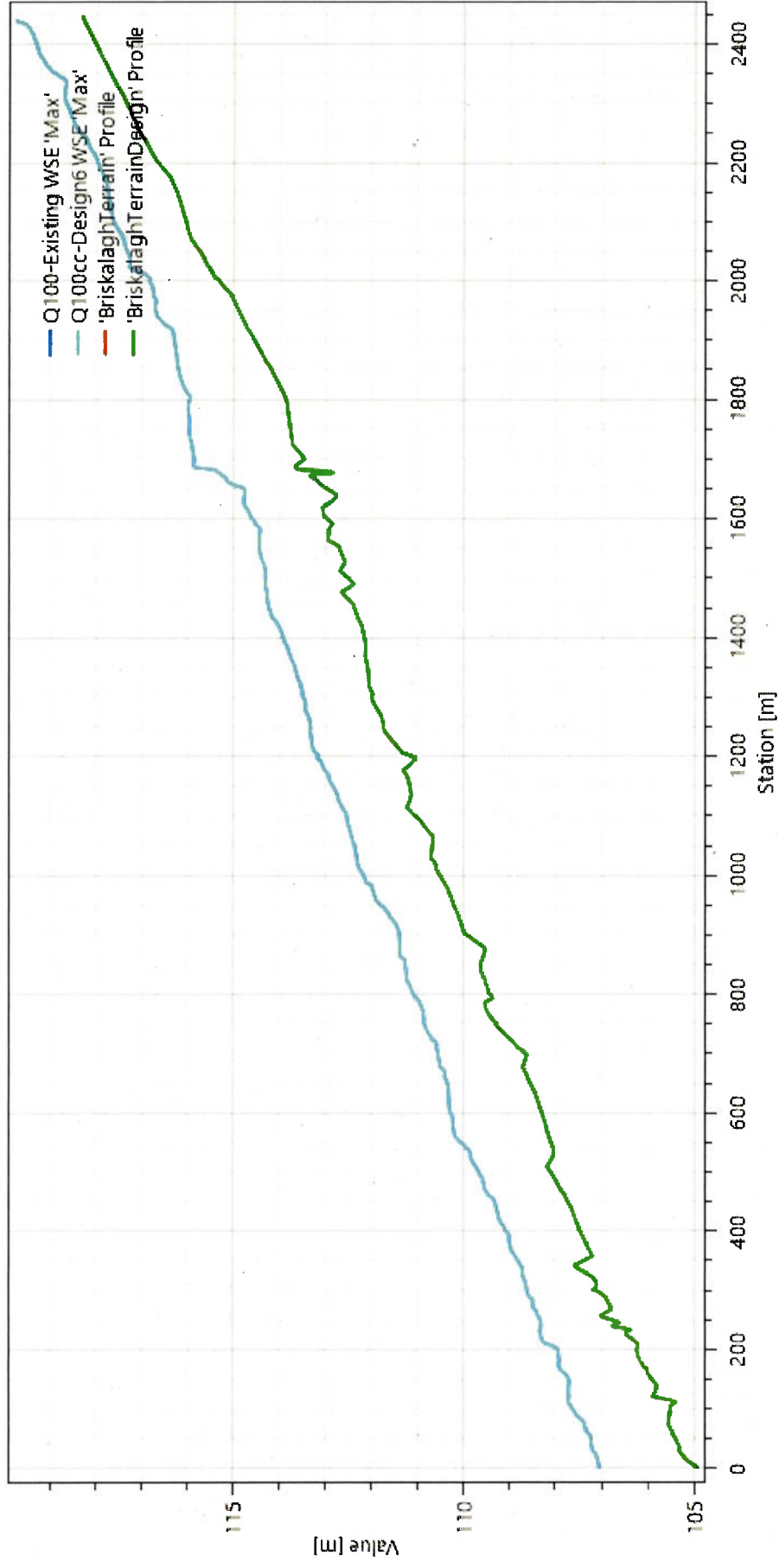


Figure 17. Tullaroan Stream longitudinal profile showing water levels in the river channel for Existing and Design River System for Q_{100cc} .

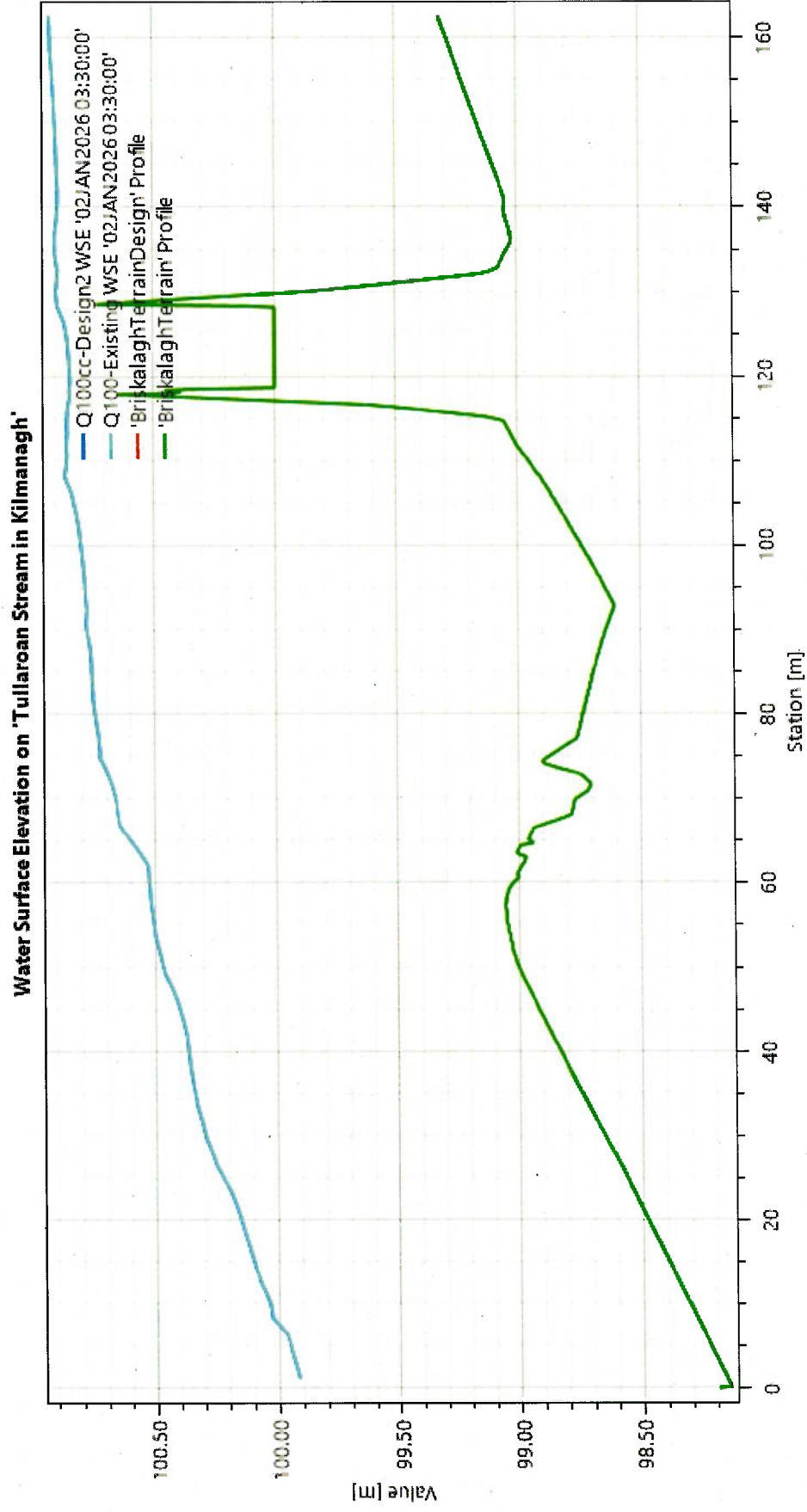


Figure 18. Tullaroan Stream in Kilmanagh town longitudinal profile showing water levels in the river channel for Existing and Design River System for Q_{100cc} .

Water Surface Elevation on 'Longitudinal - OldtownhillStream'

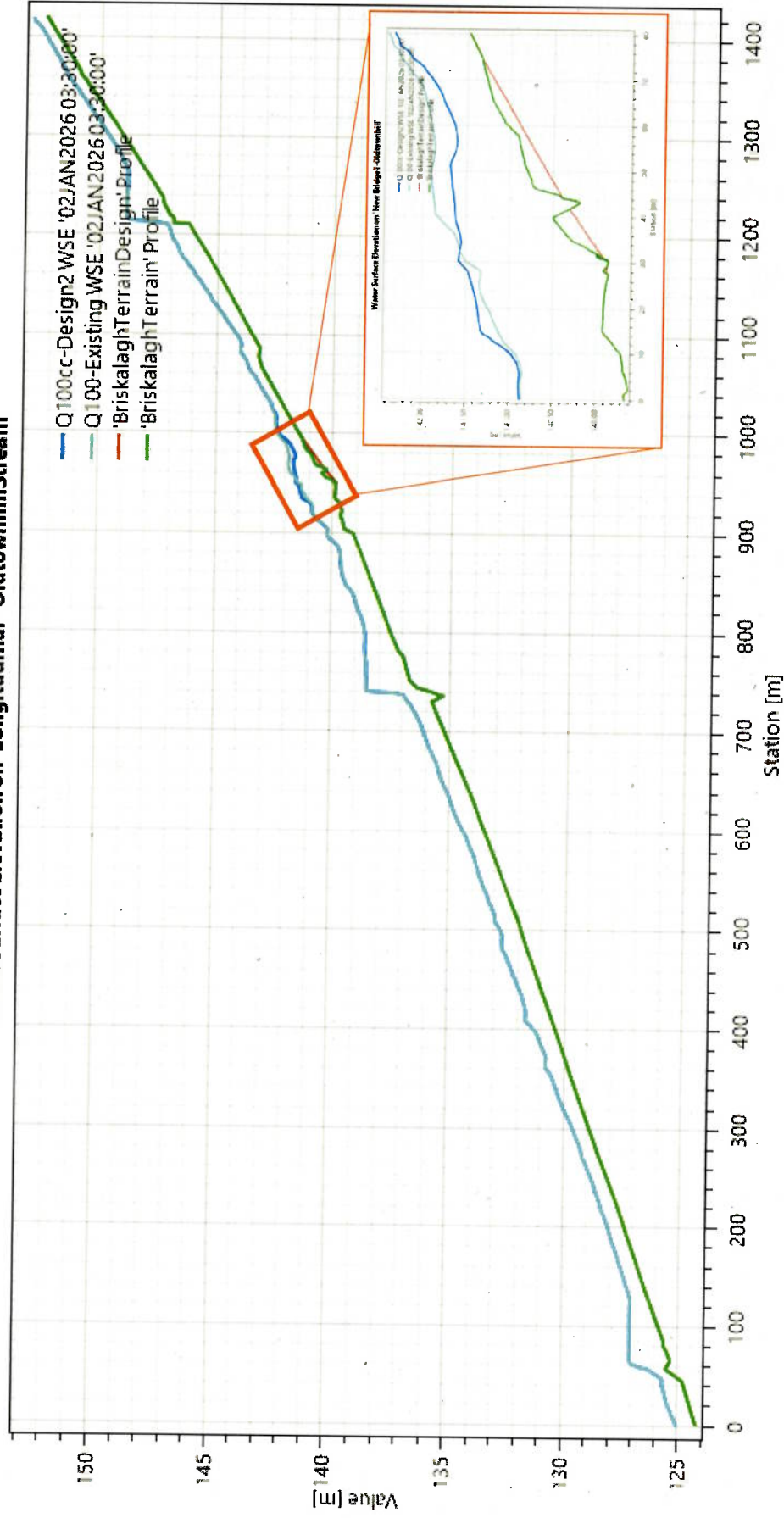


Figure 19: Oldtownhill Stream Longitudinal profile showing water levels in the river channel for Existing and Design River System for Q_{100cc}.

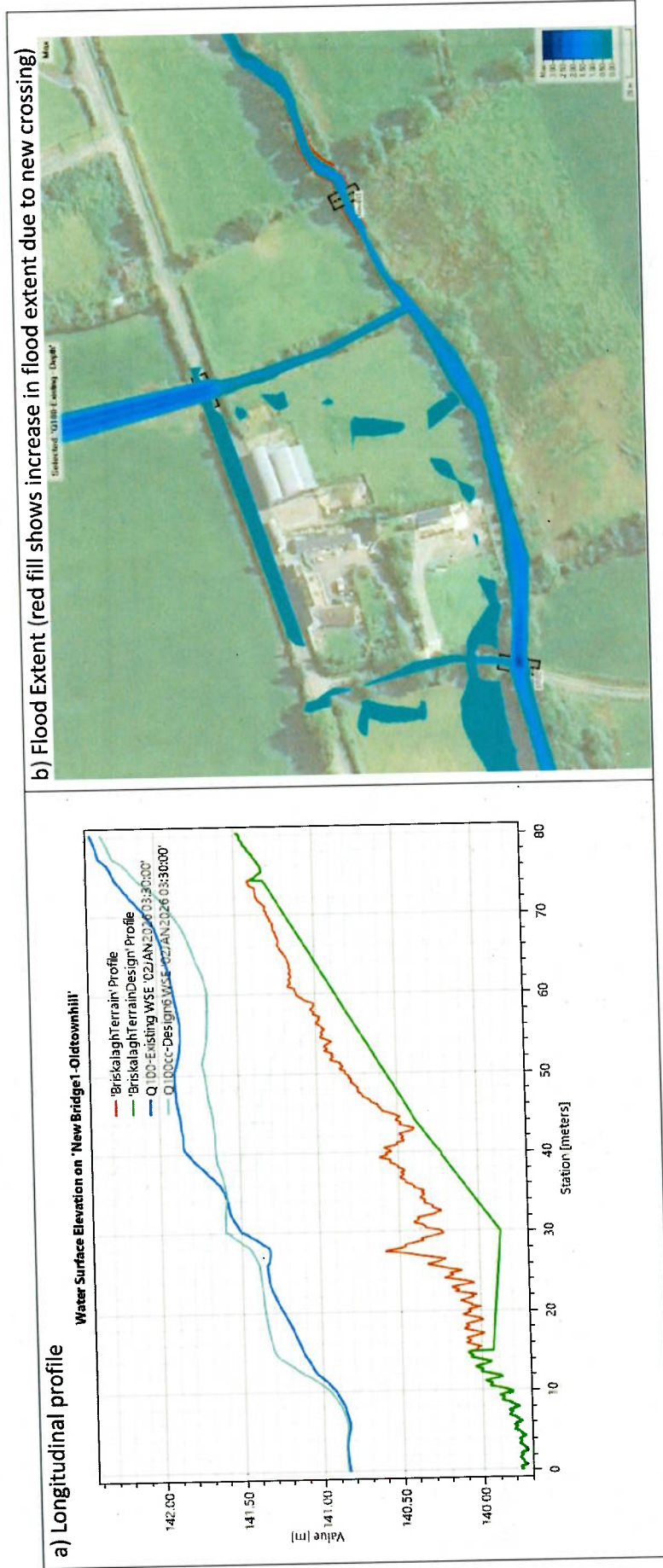


Figure 20. Oldtownhill Stream Longitudinal profile and flood extent around New Bridge 1 showing water levels in the river channel for Existing and Design River System for Q_{100cc} .

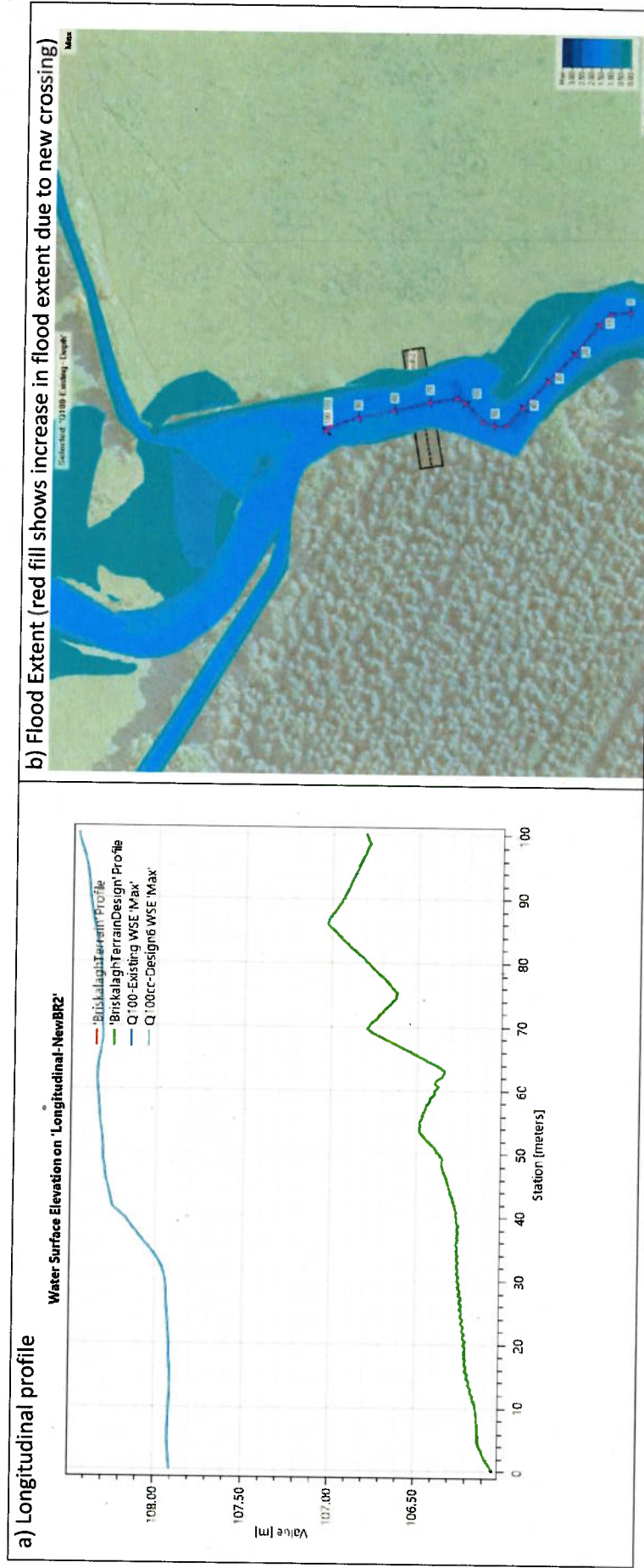


Figure 21. Tullaroan Stream Longitudinal profile and flood extent around New Bridge 2 showing water levels in the river channel for Existing and Design River System for Q_{100cc} .

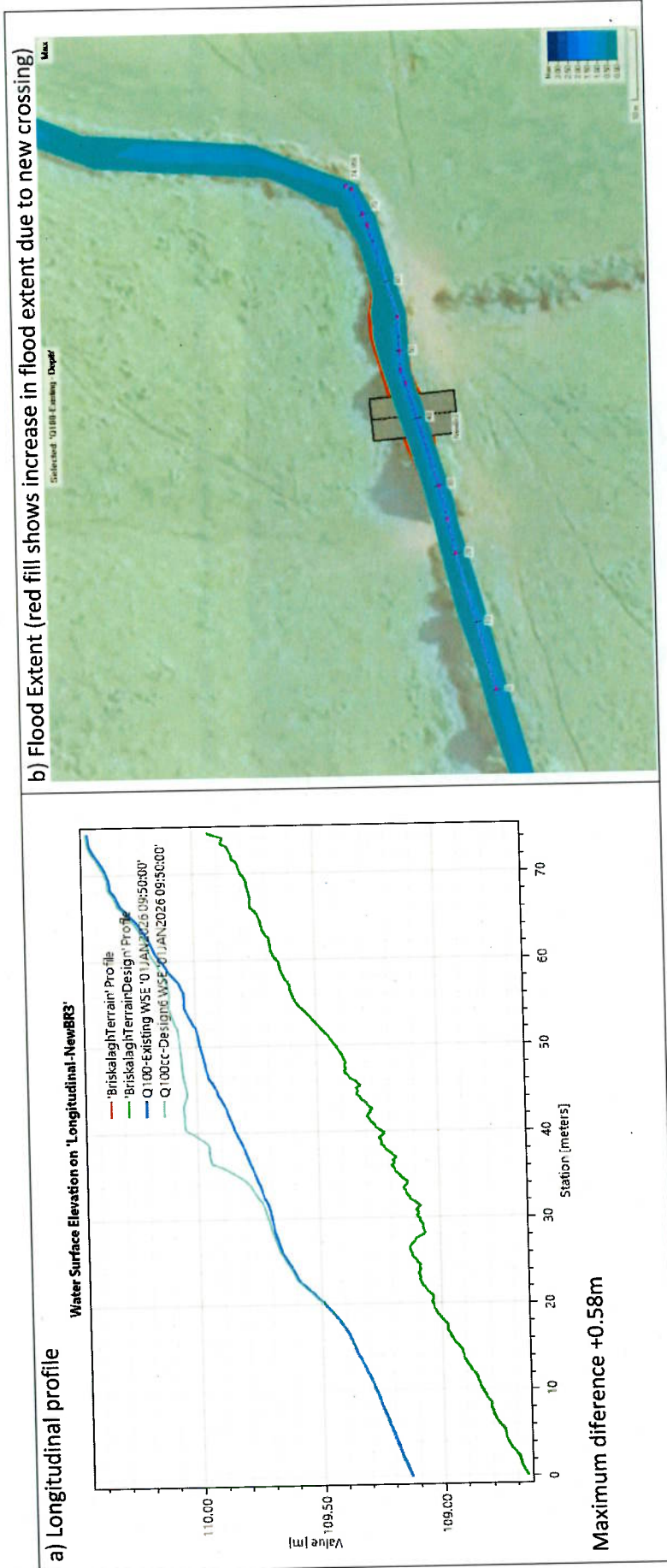


Figure 22. Briskalagh Stream Longitudinal profile around New Bridge 3 showing water levels in the river channel for Existing and Design River System for Q_{100cc} .

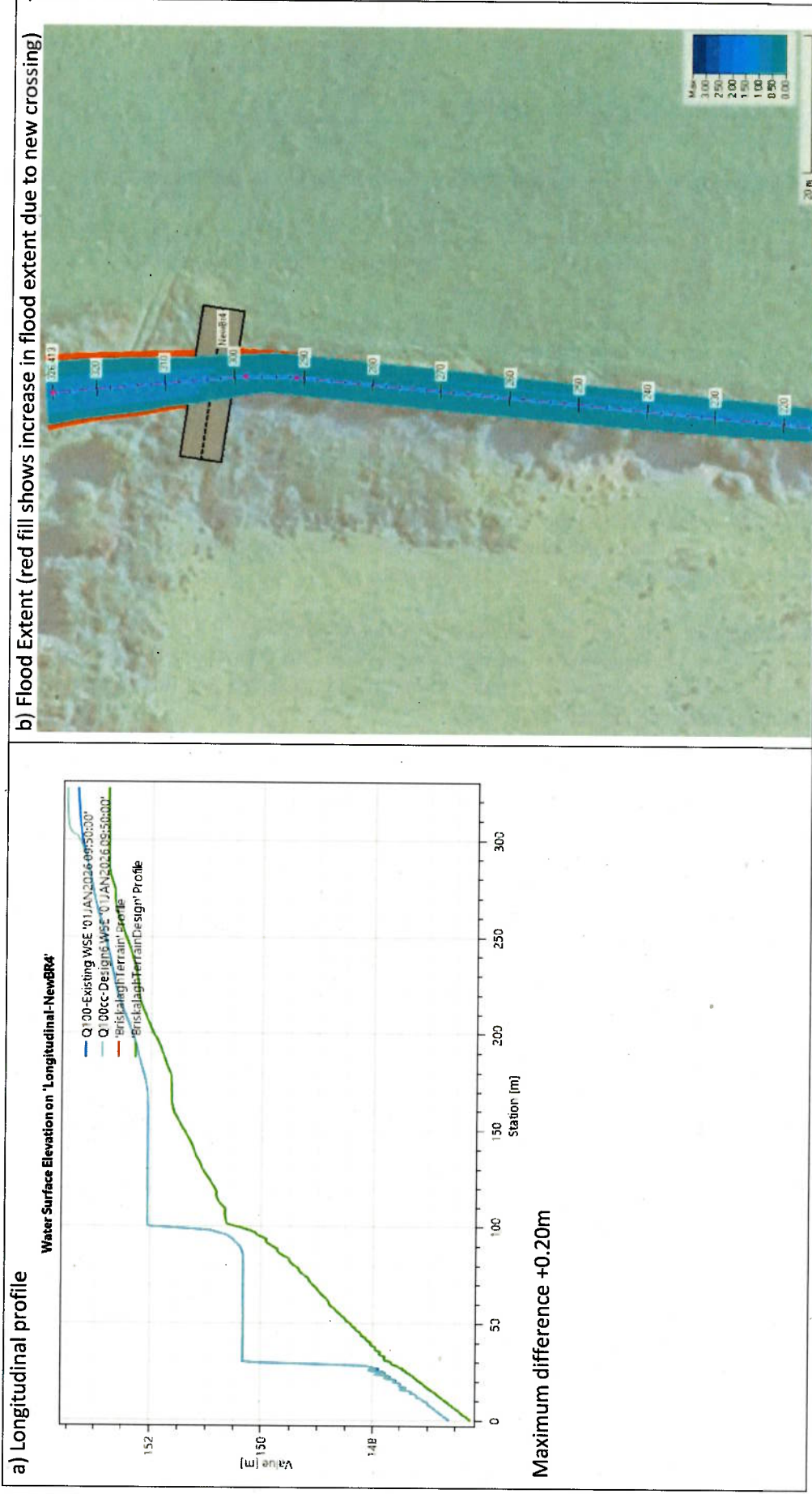


Figure 23. Briskalagh Stream Longitudinal profile around New Bridge 4 showing water levels in the river channel for Existing and Design River System for Q_{100cc} .

3.3.2.2 Q_{1000cc} MRFS Longitudinal profiles

The results are shown for Existing and Design River Systems for Q_{1000cc} (MRFS) year flow as follows:

- Q_{1000cc} MRFS Longitudinal profiles for Tullaroan stream main channel showing water levels for Existing and Design river systems (Figure 24).
- Q_{1000cc} MRFS Longitudinal profiles for Tullaroan stream main channel at the downstream end of the model in Kilmanagh town showing water levels for Existing and Design river systems (Figure 25).
- Q_{1000cc} MRFS Longitudinal profiles for Oldtownhill stream main channel showing water levels for Existing and Design river systems (Figure 26).
- Q_{1000cc} MRFS Longitudinal profiles around new bridges/culverts as part of WF road network showing water levels for Existing and Design river systems for new Bridge 1-4 (Figure 27-Figure 30).

The impact of changes in water level upstream are assessed using the flood extents maps in Figure 27(b) to Figure 30(b). The flood extents maps shown in Figure 27(b) to Figure 30(b) shown very little perceptible change in flood pam for Existing and Design River Systems. (changes would be highlighted in red).

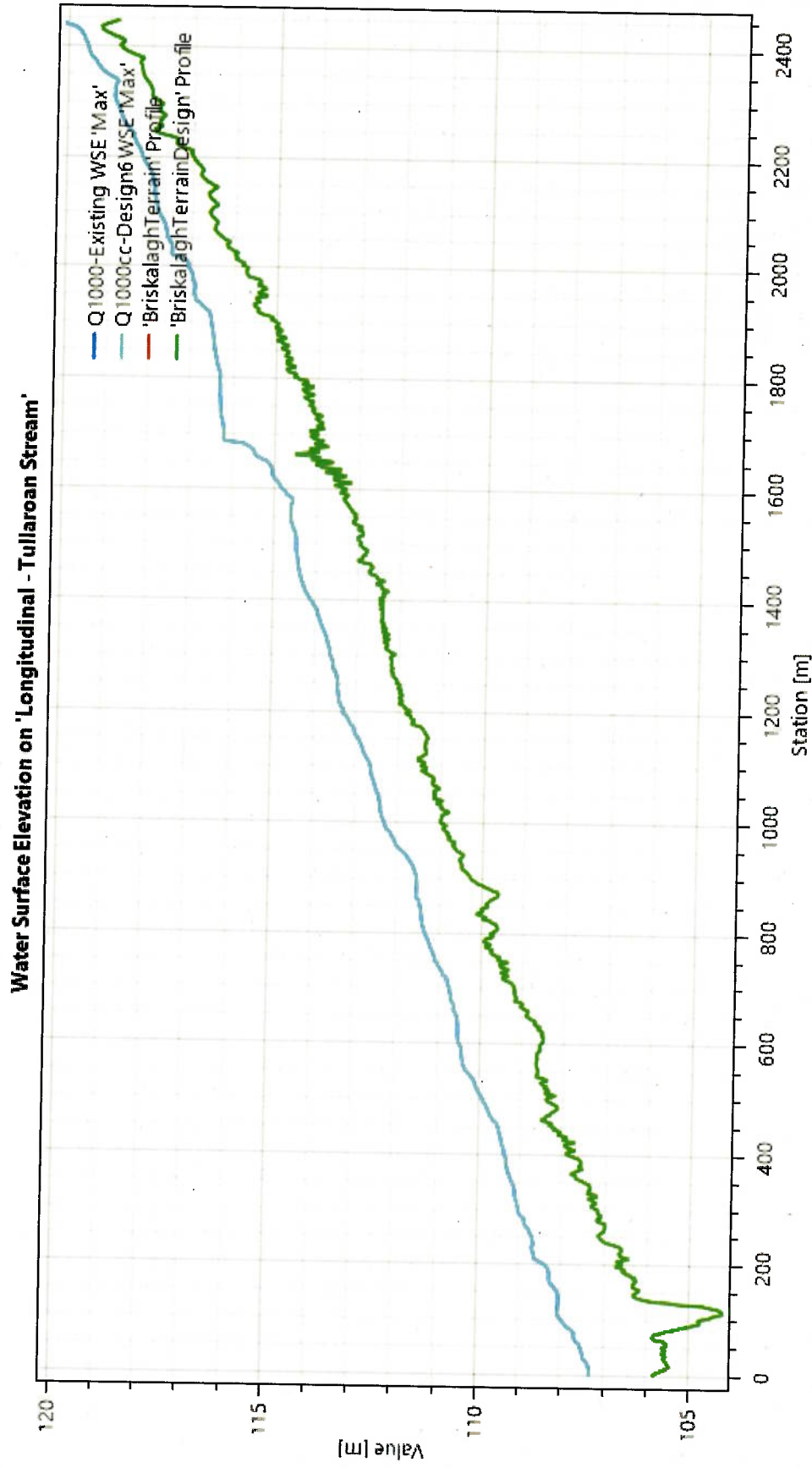


Figure 24. Tullaroan Stream longitudinal profile showing water levels in the river channel for Existing and Design River System for Q_{1000cc} .

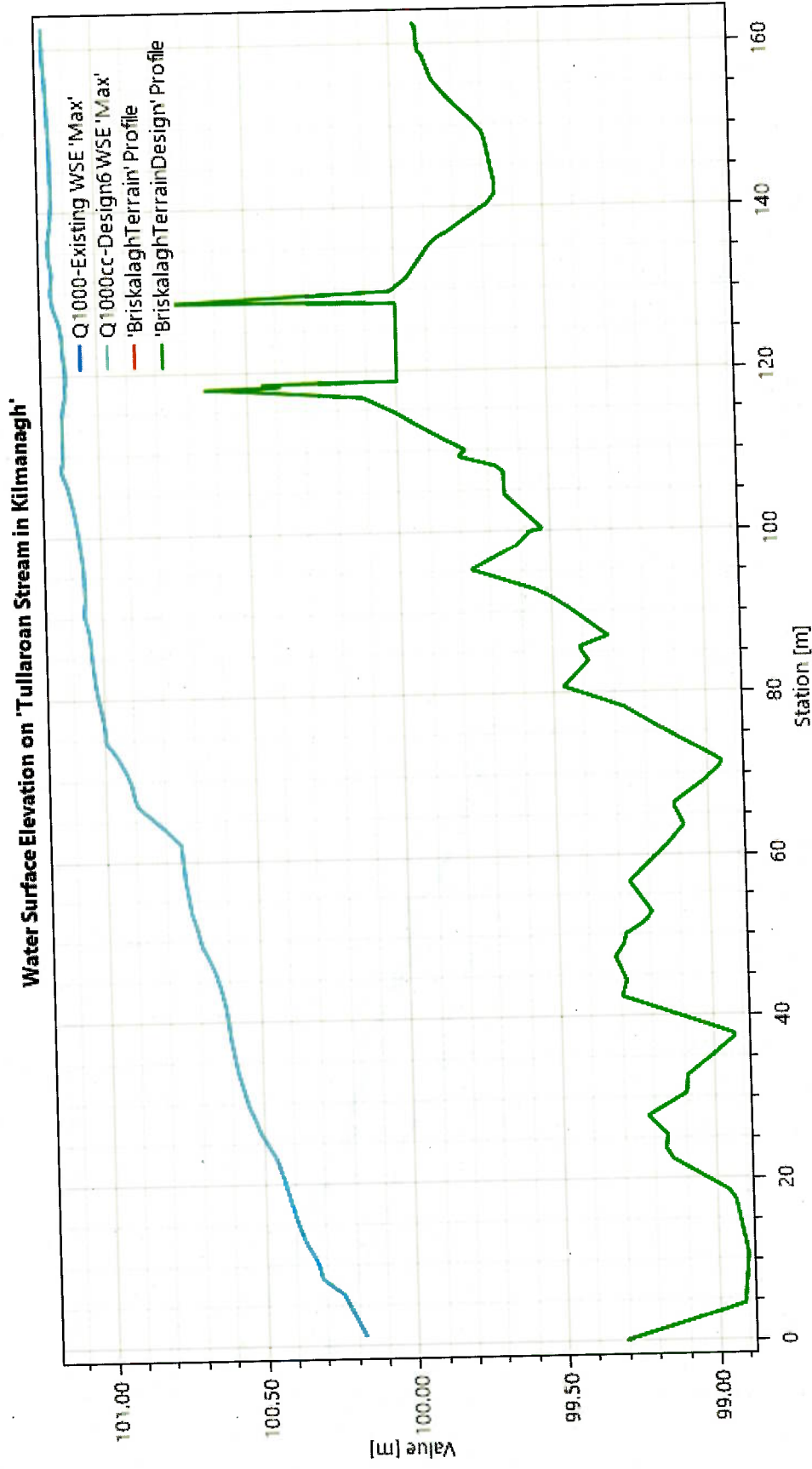


Figure 25. Tullaroan Stream in Kilmanagh town longitudinal profile showing water levels in the river channel for Existing and Design River System for Q_{1000cc} .

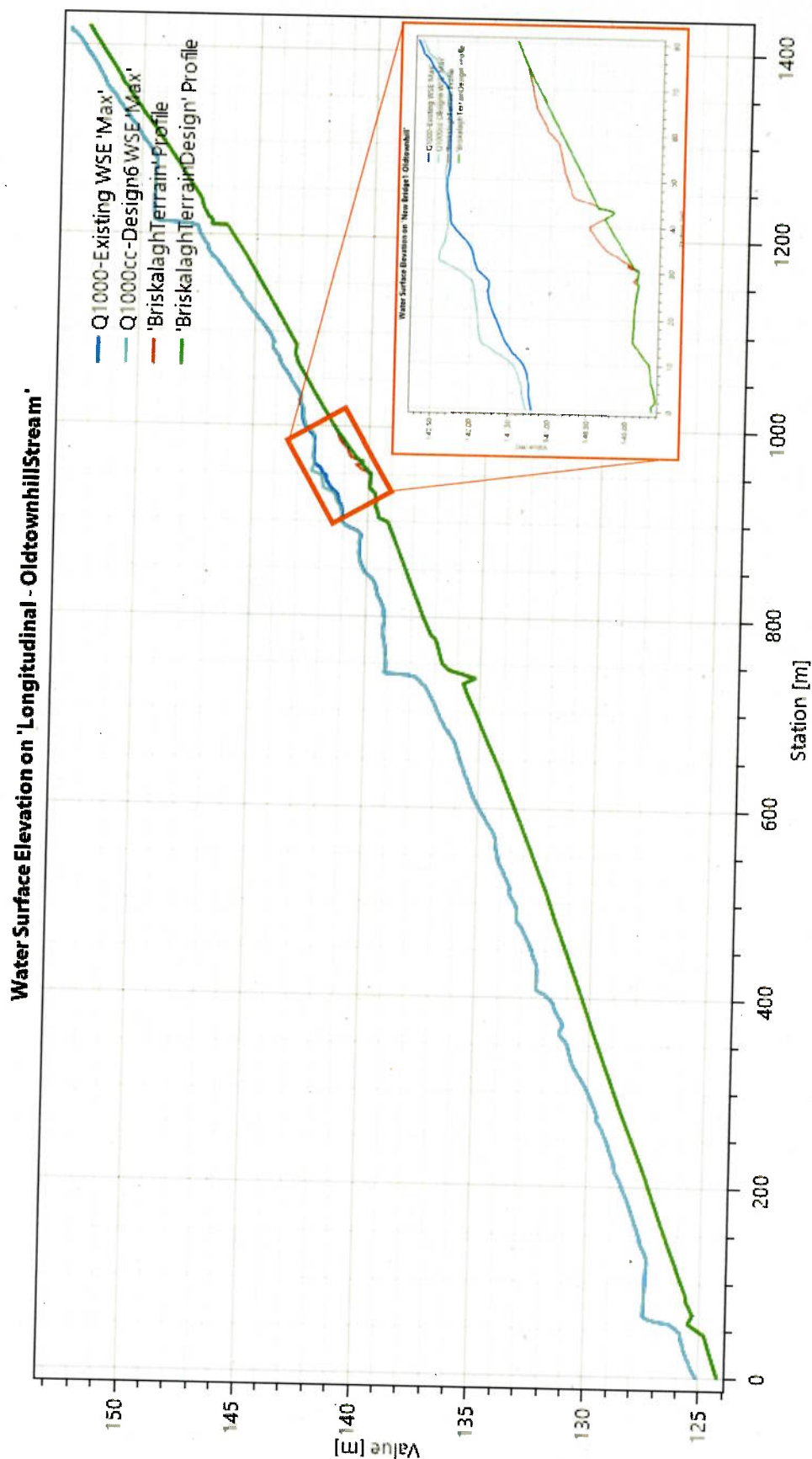


Figure 26. Oldtownhill Stream Longitudinal profile showing water levels in the river channel for Existing and Design River System for Q_{1000cc} .

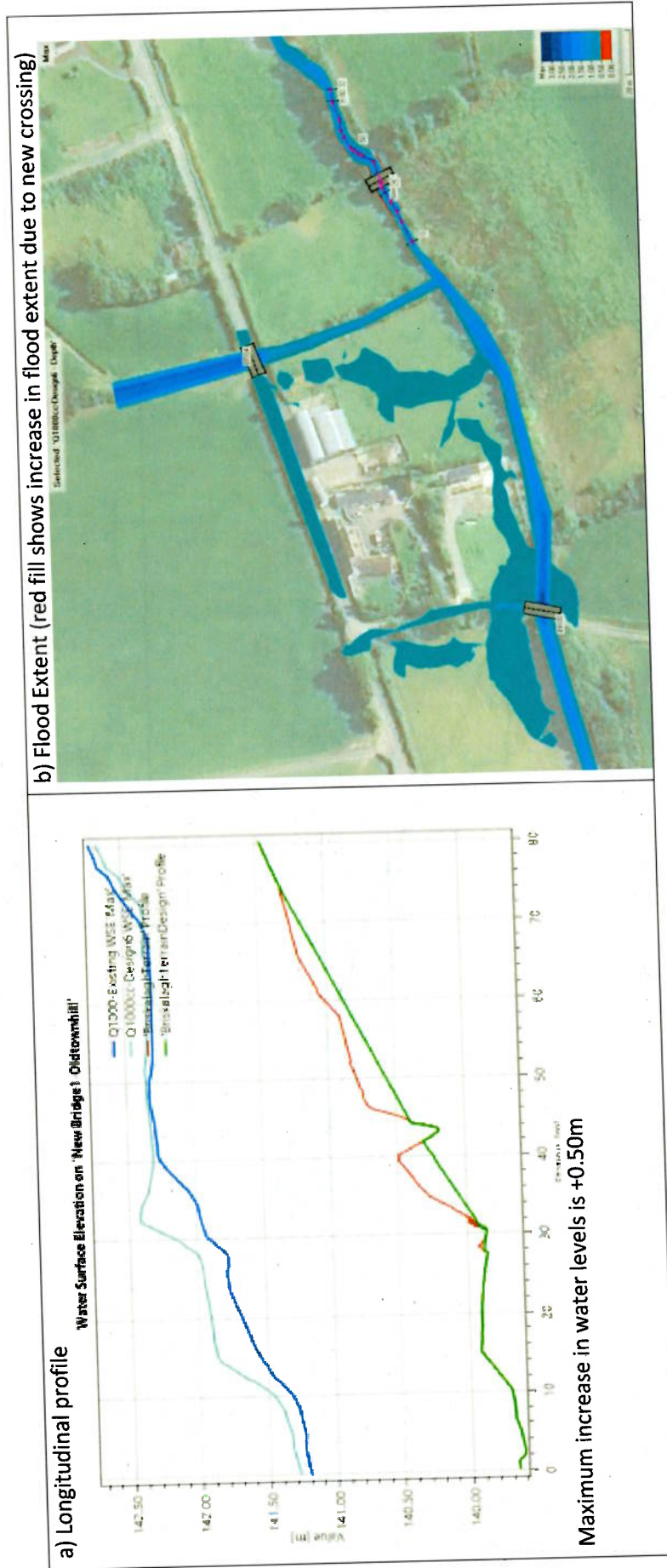


Figure 27. Oldtownhill Stream Longitudinal profile and flood extent around New Bridge 1 showing water levels in the river channel for Existing and Design River System for $Q_{10000cc}$.

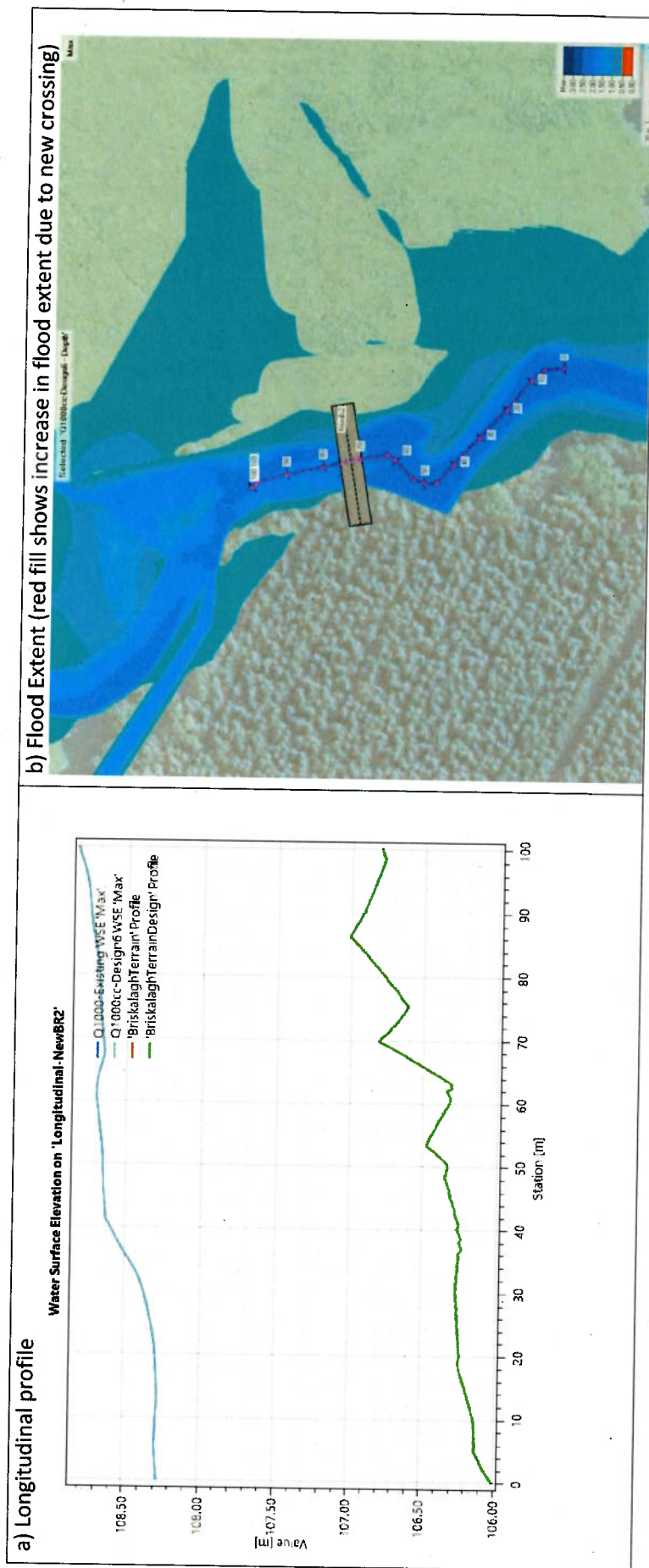


Figure 28. Tullaroan Stream Longitudinal profile and flood extent around New Bridge 2 showing water levels in the river channel for Existing and Design River System for Q_{1000cc} .

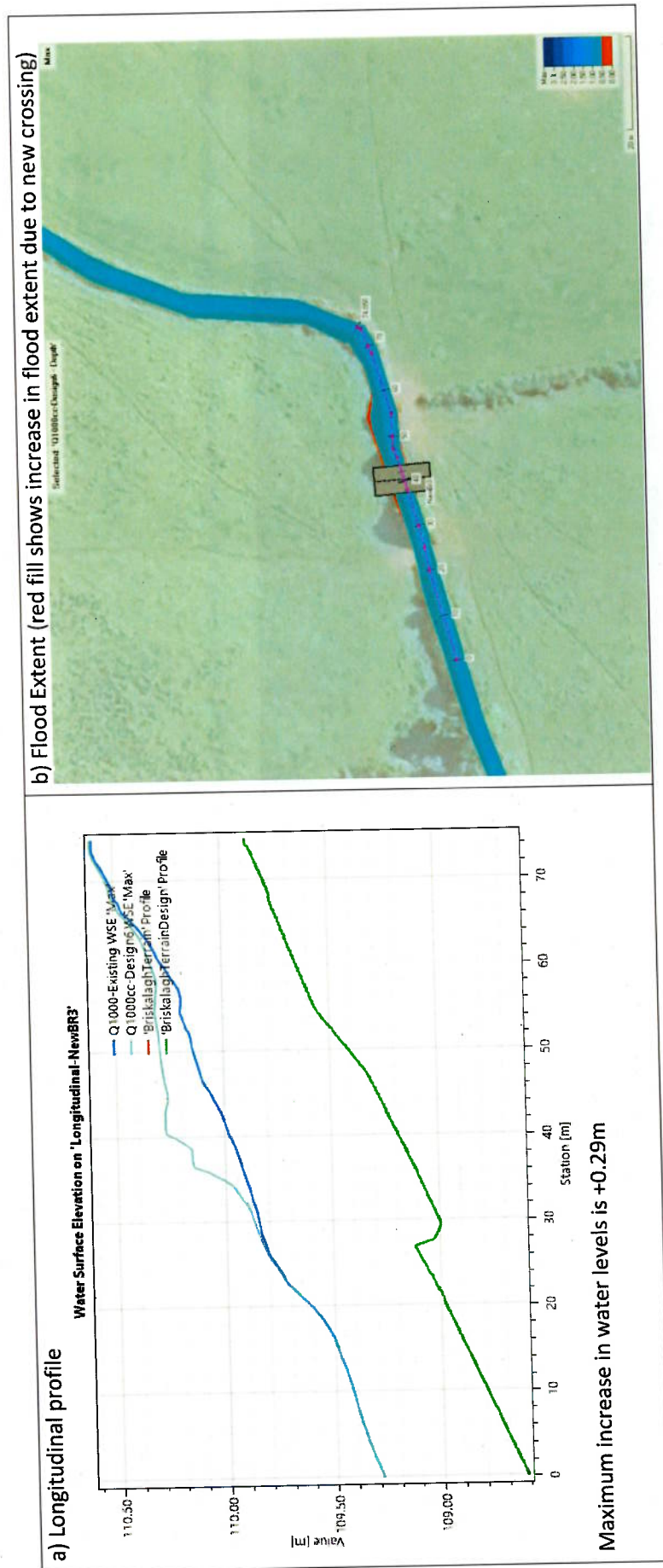


Figure 29. Briskalagh Stream Longitudinal profile around New Bridge 3 showing water levels in the river channel for Existing and Design River System for Q_{1000cc} .

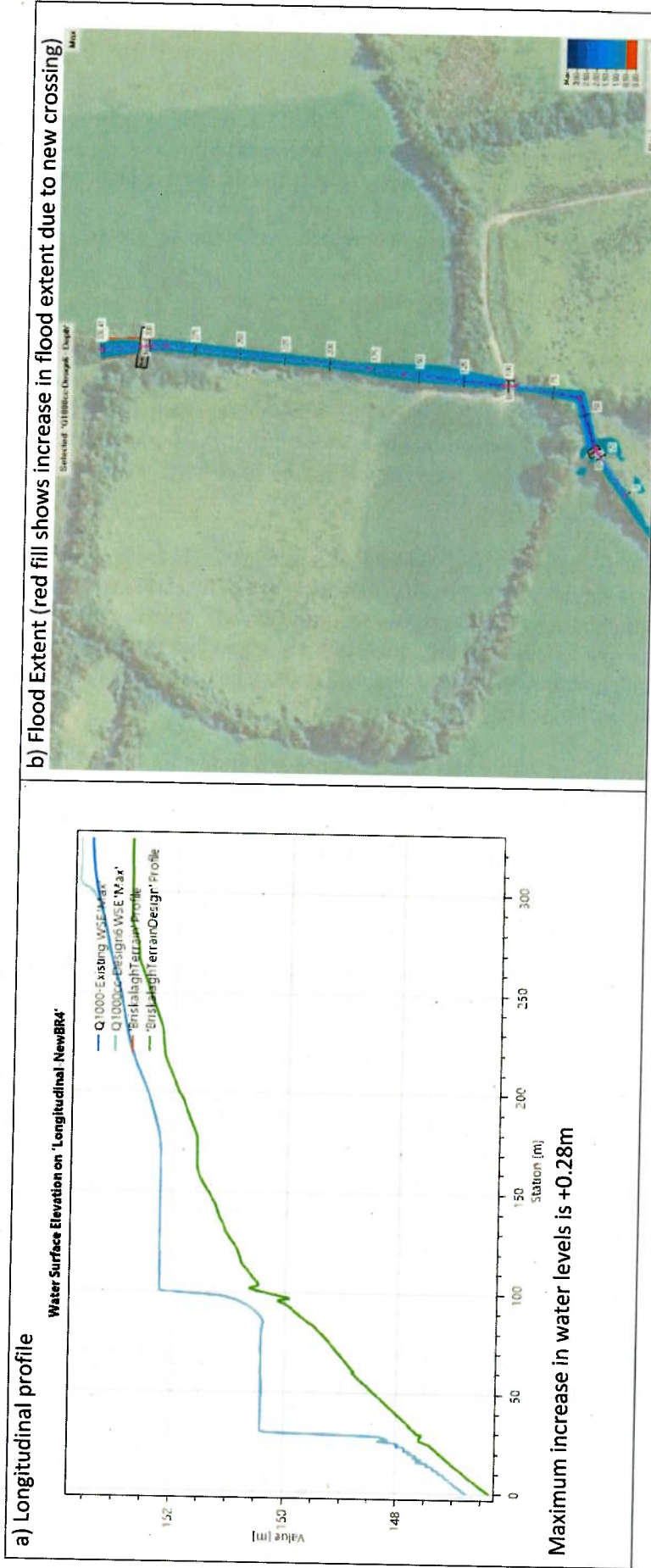


Figure 30. Briskalagh Stream Longitudinal profile around New Bridge 4 showing water levels in the river channel for Existing and Design River System for Q_{10000} .

Flood Levels in Kilmanagh

Special attention was given to flood levels in Kilmanagh town with focus on:

- Kilmanagh hurling pitch located on the right floodplain (West) downstream of Kilmanagh Bridge
- Industrial areas upstream of Kilmanagh Bridge (Left Floodplain – East)
- Farmers facilities/buildings upstream of Kilmanagh Bridge (Right Floodplain – West)
- Road levels at Kilmanagh Bridge
- Left floodplain (East) downstream of Kilmanagh Bridge

Figure 31 shows longitudinal profile with Q_{100cc} water levels at Kilmanagh. Levels of the hurling pitch are marked with green dashed line (100.71mOD). Also locations of two cross sections A-A and B-B are marked on the longitudinal section. Two cross sections showing river channel and Q_{100cc} water levels are shown below the longitudinal section. Analysis showed that the hurling pitch does not flood on during Q_{100cc} flood flows since water levels bounding the pitch vary between 99.95mOD and 100.51mOD.

Figure 32 shows longitudinal profile with Q_{1000cc} water levels at Kilmanagh. Levels of the hurling pitch are marked with green dashed line (100.71mOD). Also locations of two cross sections A-A and B-B are marked on the longitudinal section. Two cross sections showing river channel and Q_{1000cc} water levels are shown below the longitudinal section. Analysis showed that the hurling pitch is at higher risk of flooding for Q_{1000cc} as the levels are marginal reaching just 100.70mOD immediately upstream of the hurling pitch, however the hurling pitch does not flood.

Figure 33 and Figure 34 show layout with water levels (depths are shown in Annex C Maps 5&6) around Kilmanagh bridge for Q_{100cc} and Q_{1000cc} . Small triangles in the figures show Survey levels. The analysis concluded that:

- The hurling pitch, e.g. downstream right floodplain does not flood for Q_{100cc} and Q_{1000cc} .
- Downstream left floodplain is subject to flooding as it falls within flood Zone A and B with levels varying between 100.71mOD and 100.47mOD for Q_{100cc} , e.g. 100.97mOD and 100.63mOD for Q_{1000cc} .
- Some flooding at the farmer facilities on the upstream right floodplain (in respect to bridge) is possible as the road levels are at 100.83mOD. For Q_{100cc} only minor flooding occurs with depths <0.10m since flood levels vary between 100.75mOD and 100.83mOD. For Q_{1000cc} flood is more extensive with depths less than <0.28m since flood levels vary between 100.88mOD and 101.11mOD.
- Some flooding in industrial zone (left floodplain u/s of the bridge) has parking lot/road levels at 100.38mOD, and flood levels are between 100.75mOD (upstream of the bridge) and 101.17mOD (upstream of the industrial zone) for Q_{100cc} . For Q_{1000cc} these levels are 101.00mOD (upstream of the bridge) and 101.46mOD (upstream of the industrial zone).
- Road at the yield between R695 and R691 Knockeebaun road (east of the bridge) has levels between 100.65mOD and 100.41mOD and is prone to flooding. Downstream pastures (South from the yield) adjacent to road are also prone to flooding.

All above applies for Existing and Design flood levels since there is no significant change in water levels between Existing and Design flows and water levels, e.g. water depths.

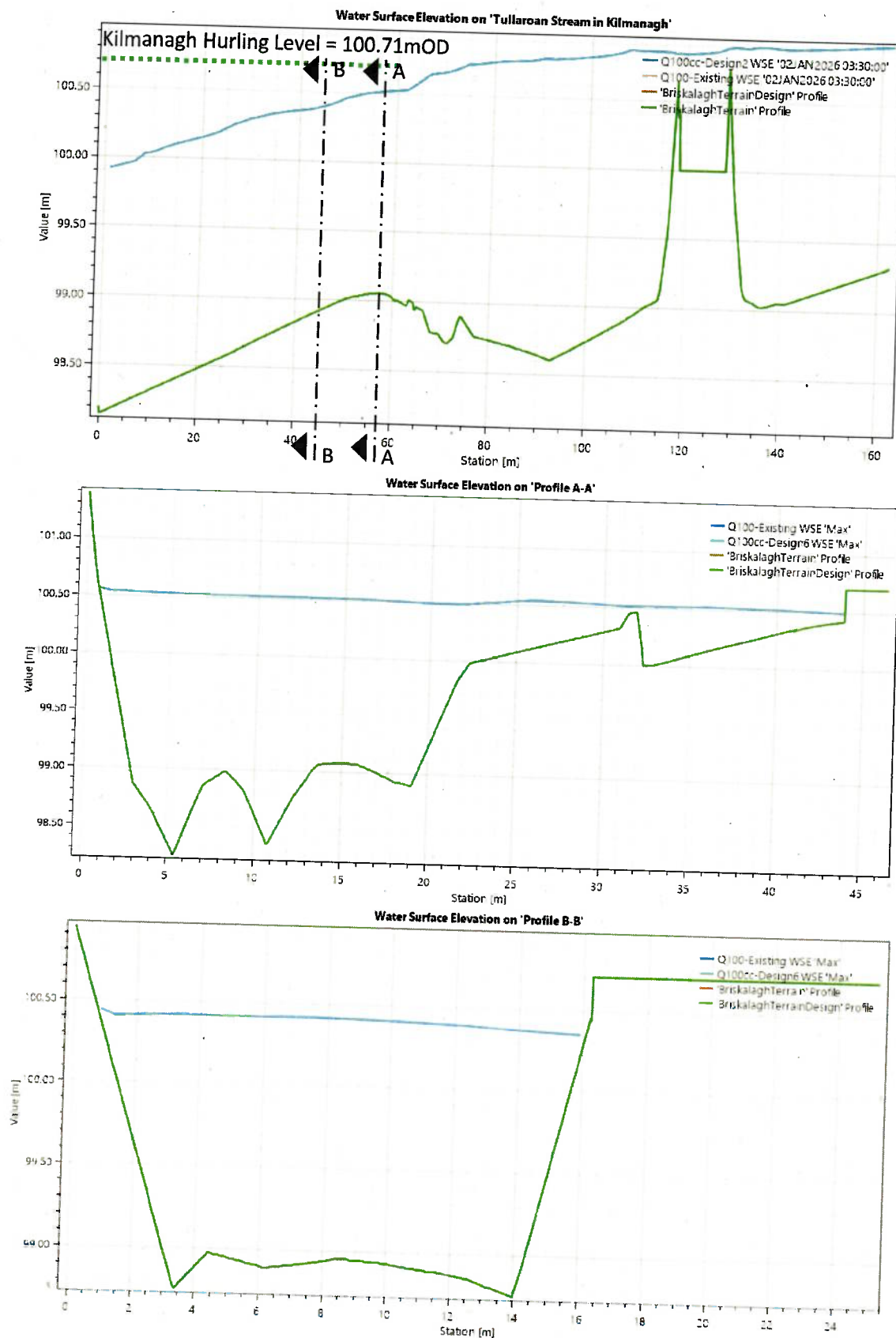
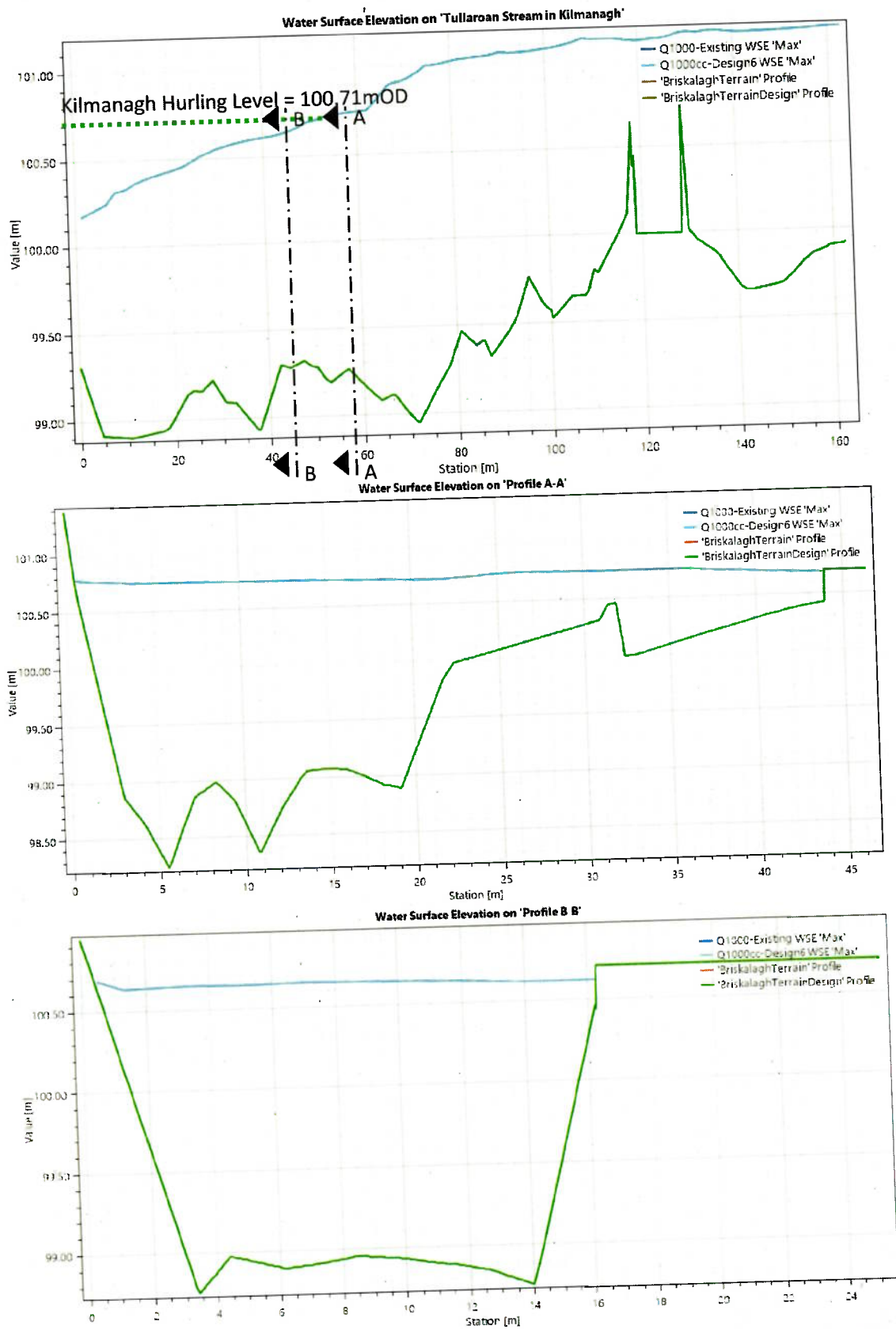


Figure 31. Kilmanagh town Tullaroan Stream longitudinal profile and two cross sections showing water levels in the river channel for Existing and Design River System for Q_{100cc} .







3.3.3 Flood Maps

Figure 35 gives the Flood Map for the Q_{100cc} (MRFS) flood event which has the probability of occurring approximately every 100 years, and includes an increase of 20% in flow to account for Climate Change. The map shows that, in general, there is minor flooding of the access road at the Oldtown road with water depths less than $<0.10\text{m}$. Turbines, hardstands and sub-station are outside flood Zones A.

Figure 36 gives the flood map for the extreme 1000-year flood with Climate Change factored in (Q_{1000cc}). The main access roads affected are in the vicinity of turbines T7, T8 and T9 where there is significant flooding with relatively high water depths. It is important that the turbine hardstands at these locations should be elevated constructions with ground levels 0.5m higher than the extreme flood level. The access roads to these elevated hardstands should be ramped at a suitable gradient. The Design model used in the hydrological/hydraulic simulations has accounted for elevated hardstands and ramped approach roads.

Figure 37 and Figure 38 give a comparison of the flood extents maps for the Existing and Design systems for Q_{100cc} and Q_{1000cc} respectively. The flood extent comparison confirms that change is minimal, almost imperceptible. More detailed figures of these affected areas are shown in 20b-3b for Q_{100cc} and Figure 27b-Figure 30b for Q_{1000cc} .

Hi-Resolution flood maps are shown in Annex C.

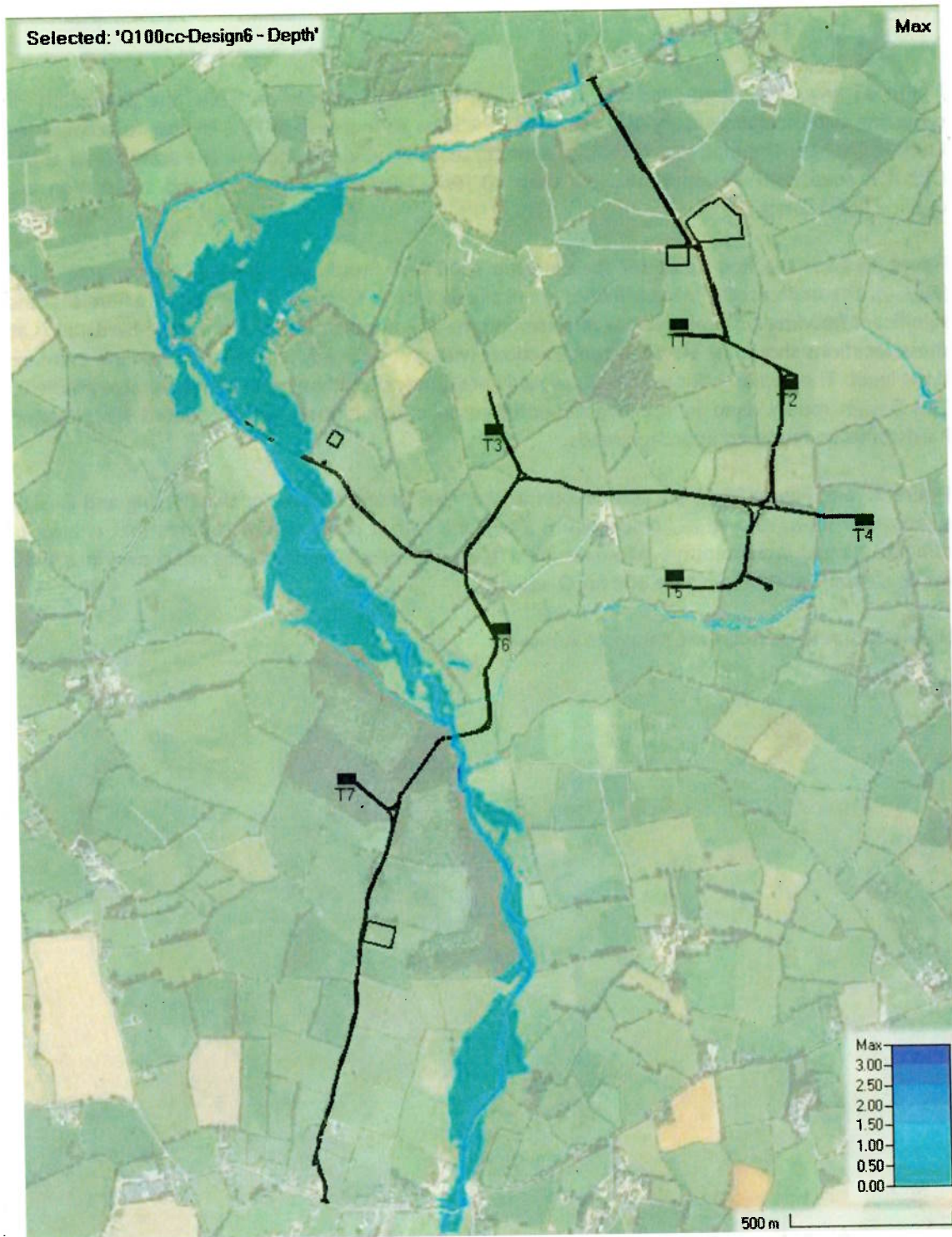


Figure 35. Flood map with water depths for Design River System and Q_{100cc} design flow.

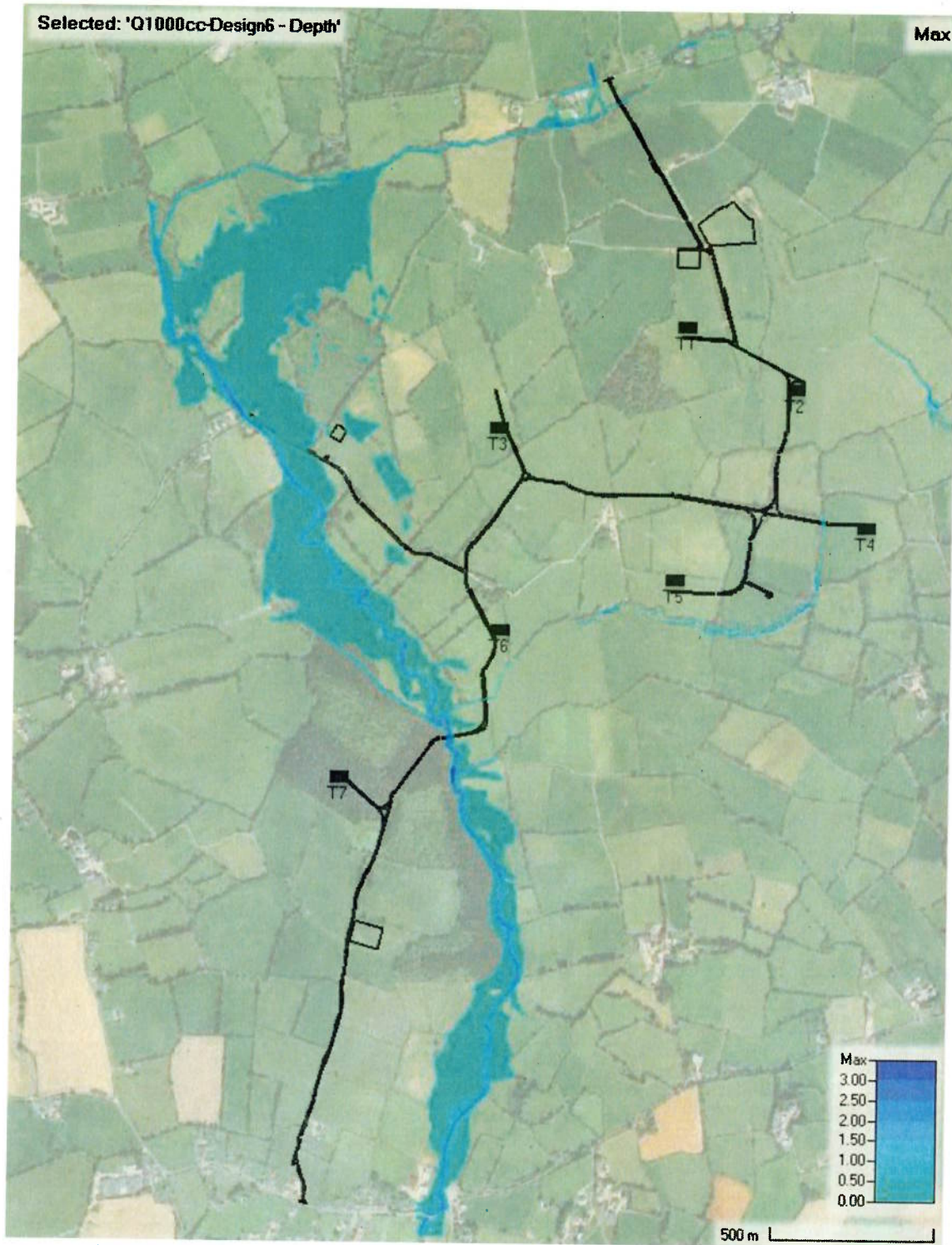


Figure 36. Flood map with water depths for Design River System and Q_{1000cc} design flow.

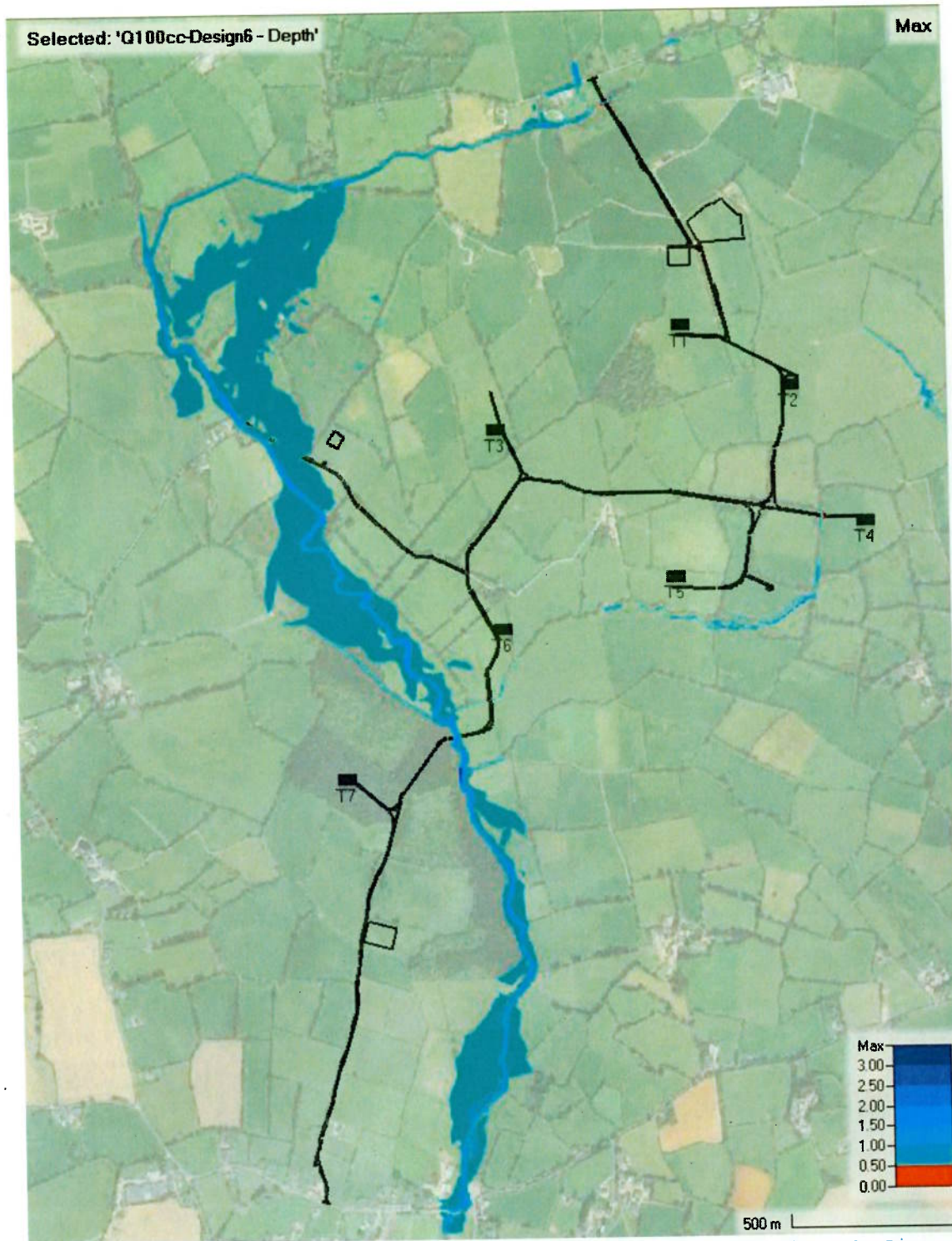


Figure 37. Comparison of Existing and Design River System flood extent (Flood extent for Design System is shown in red fill) for Q_{100cc} design flow.

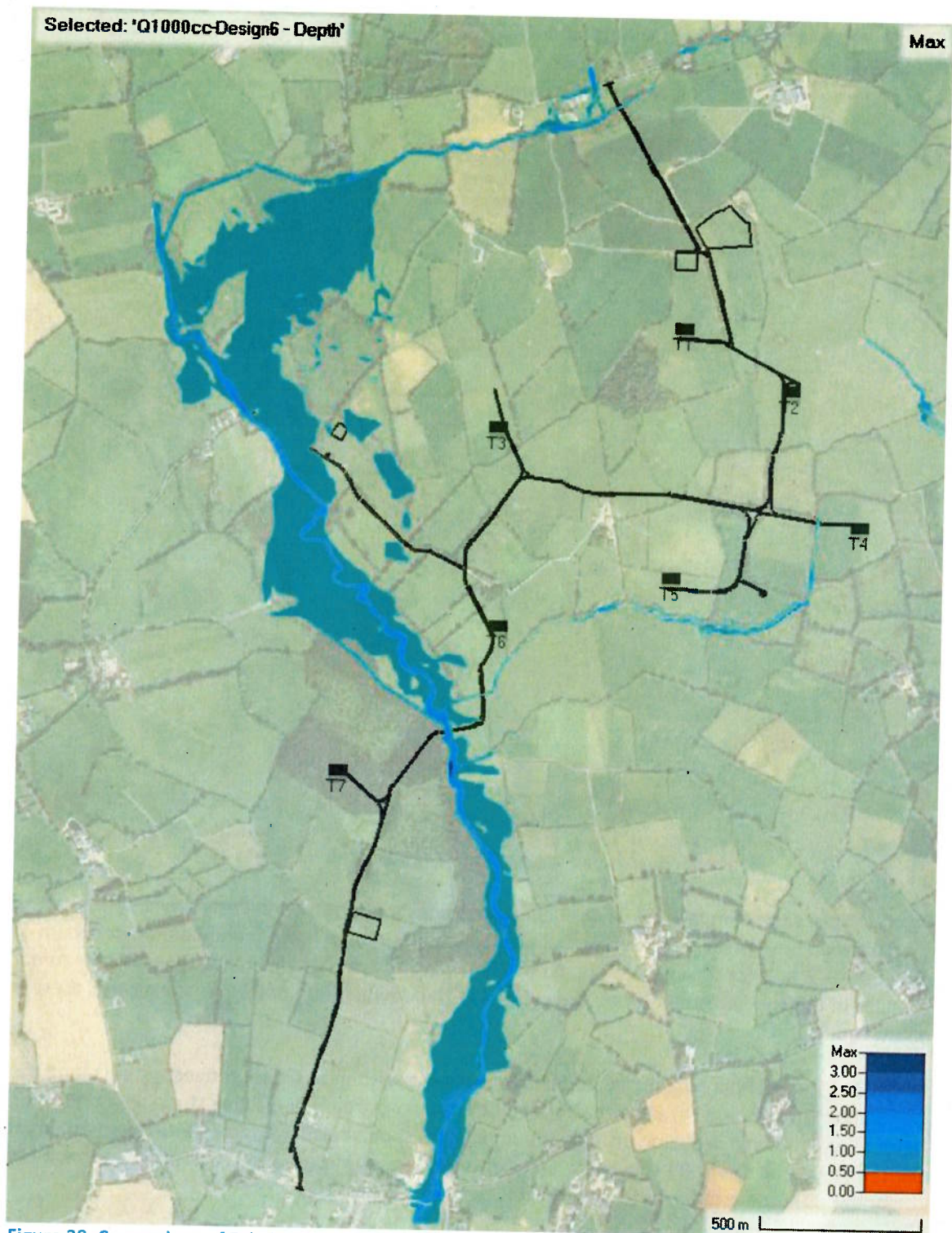


Figure 38. Comparison of Existing and Design River System flood extent (Flood extent for Design System is shown in red fill) for Q_{1000cc} design flow.

3.3.4 Hydrograph comparisons

The hydrographs for the existing river system were compared to the hydrograph for the design River system at a number of locations as shown in Figure 39 below.

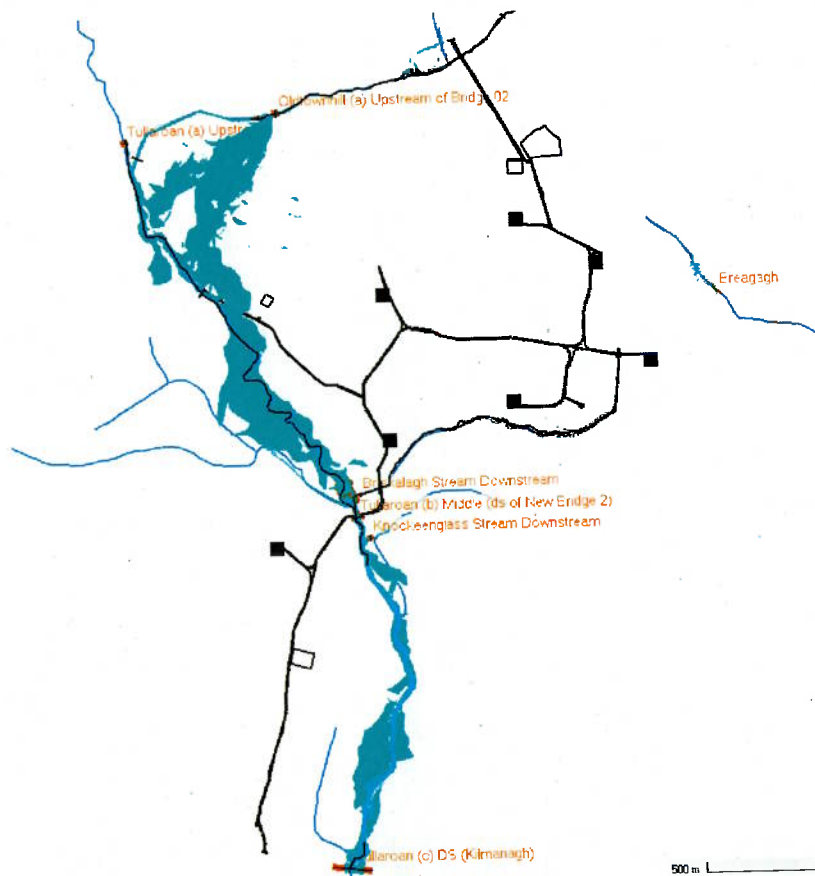


Figure 39. Hydrograph comparison locations for Q_{100cc} design flow.

Figure 40 gives the comparisons of calculated flow rates for existing and design river system along the Tullaroan Stream (a) Upstream end of the stream, (b) middle reach immediate downstream of new bridge 2 and (c) downstream reach at Kilmanagh town. It is clear that there is only minor changes in the sub-catchment flood flow values at the downstream points (in some cases there is a flow reduction).

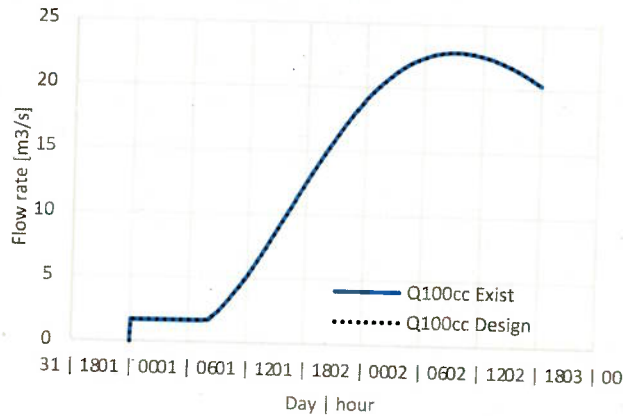
Figure 41 gives comparison of calculated flow rates for existing and design river system along the Oldtownhill Stream, e.g. (a) shows calculated flow rates upstream of existing stone arch bridge 02, before the flood flow diversion onto the floodplain, (b) shows calculated flow rates downstream of the bridge 02 and figure (c) shows the amount of flow rate that (due to reach of flow capacity of the bridge 02) is diverted over the floodplain.

Figure 42 shows comparison of calculated flow rates for existing and design river system for (a) Briskalagh Stream, (b) Knockeenglass Stream and (c) Breagagh Stream.

It is clear that there is only minor changes in the sub-catchment flood flow values at the downstream points (in some cases there is a flow reduction). The highest flow increase of +0.05 m^3/s is evident at Briskalagh Stream due to construction of two new crossings, e.g. local increase of

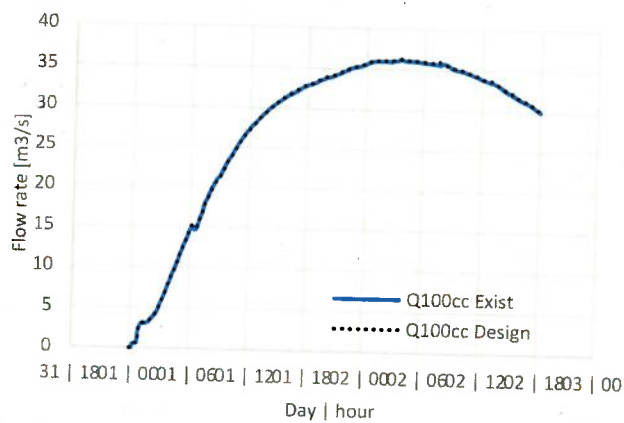
roughness. This can be mitigated in Section 50 applications and the final by ensuring culvert bottom roughness similar to gravel bed as in the natural channel.

(a) Location A – Tullaroan Stream Upstream



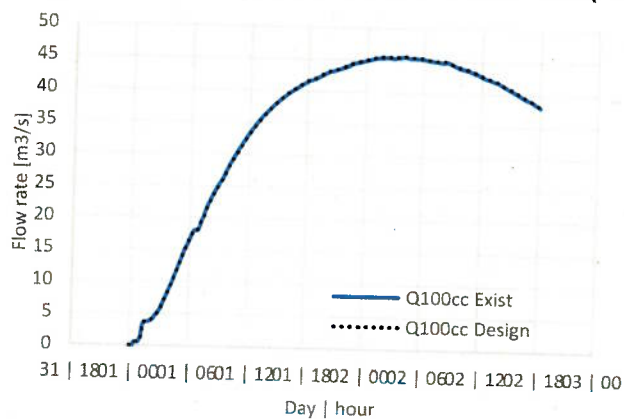
Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
22.84	22.84	0.00	0.00%

(b) Location B - Tullaroan Stream Middle



Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
36.22	36.31	0.09	0.26%

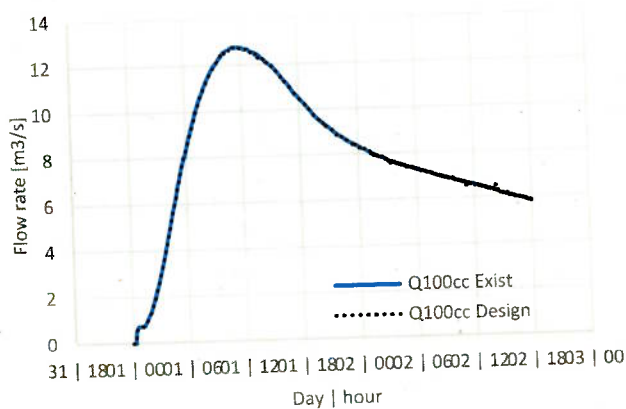
(c) Location C - Tullaroan Stream Downstream (Kilmanagh)



Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
45.56	45.66	0.10	0.22%

Figure 40. Hydrograph comparisons along the Tullaroan Stream for Q_{100cc} design flow.

(a) Location A – Oldtownhill Stream Upstream of Bridge 02



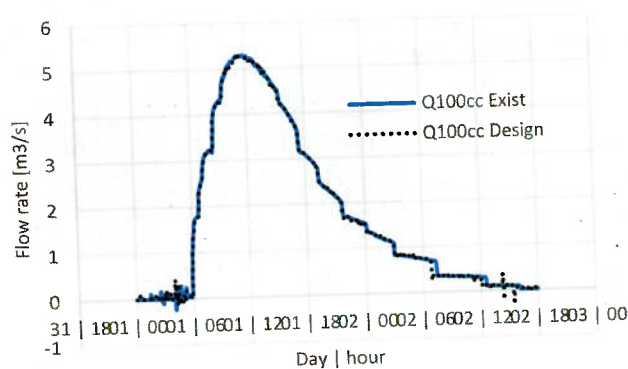
Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
12.80	12.81	0.00	0.03%

(b) Location B - Oldtownhill Stream Downstream of Bridge 02



Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
8.18	8.12	-0.06	-0.73%

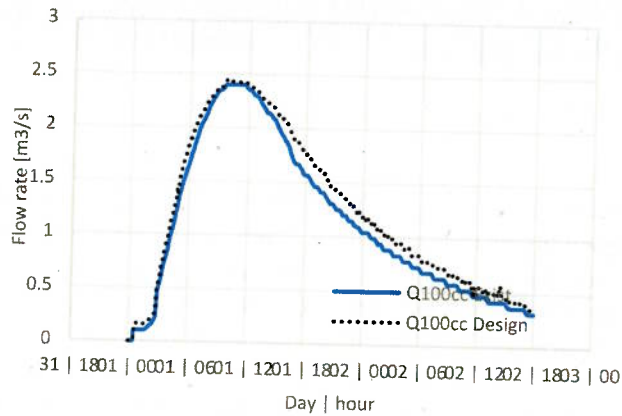
(c) Location C - Oldtownhill Stream difference and overland flow diverted u/s of Bridge 02



Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
5.30	5.30	0.00	0.02%

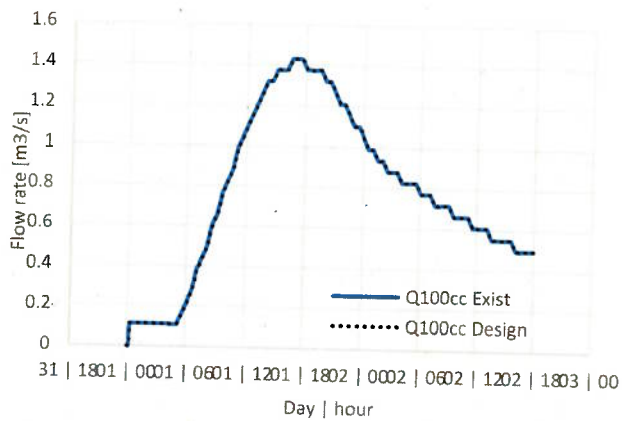
Figure 41. Hydrograph comparisons along the Oldtownhill Stream for Q_{100cc} design flow.

(a) Briskalagh Stream downstream



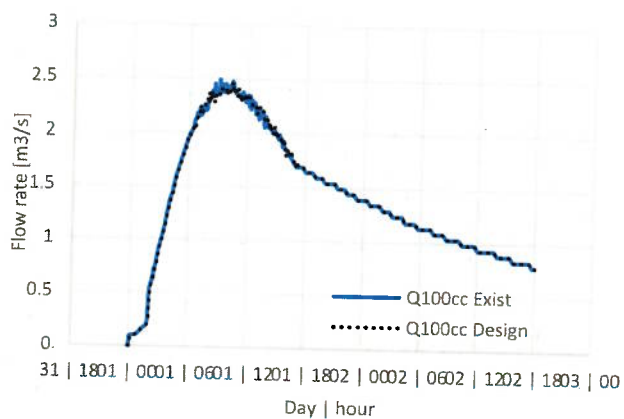
Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
2.41	2.45	0.05	1.95%

(b) Knockeenglass Stream downstream



Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
1.43	1.43	0.00	0.00%

(a) Breagagh Stream downstream



Q_{100cc} Exist [m ³ /s]	Q_{100cc} Design [m ³ /s]	ΔQ [m ³ /s]	ΔQ [%]
2.49	2.49	0.00	0.00%

Figure 42. Hydrograph comparisons along the Oldtownhill Stream for Q_{100cc} design flow.

4 Conclusions

1. The extensive area of the flood plains was surveyed using a LIDAR/RGB Drone surveying which was conducted by © Bluesky International Ltd. In order to capture channel bathymetry, check road levels and address existing channels changes within the WF site detailed topographical and bathymetric survey of the stream(s) bank and bed levels was carried out in September 2025 (see Figure 10).
2. A hydrological analysis for the total catchment draining to the Proposed Wind Farm site gave Q_{100cc} 'Design Flows' and Q_{100cc} (including a climate change factor of 1.2) obtained from FSU methodology for 11 Hydrological Estimation Points (HEPs) as shown below:

HEPs	HEC-RAS			Peak Flow [m^3/s]		
	No	River	Contributing catchment area A [km^2]	Q_{med}	Q_{100cc}	Q_{1000cc}
HP1	1	Tullaroan Stream - upstream	8.089	8.089	22.84	34.679
HP2ds	2	Tullaroan Olddownhill	1.097	1.097	14.642	22.933
HP2u1	3	Remeen	0.984	0.984	5.457	9.021
HP2u2	4	Tullaroan Huntstown	0.898	0.898	4.697	7.616
HP3	5	Tullaroan Stream - middle	0.923	0.923	2.595	3.917
HP4	6	Briskalagh	0.464	0.464	2.426	3.932
HP5	7	Foylatalure	1.282	1.282	6.701	10.865
HP6	8	Knockeenglass	0.257	0.257	1.415	2.335
HP7	9	Killmanagh 15	0.751	0.751	4.164	6.883
HP8	10	Tullaroan Stream - middle	0.781	0.781	59.113	92.702
HP9	11	Breagagh (Kilkenny)	0.478	0.478	2.498	4.049

3. An unsteady flow analysis was required for the FRA to assess the development impact on storage and consequently a number of hydrographs for each of the constituent rivers, streams and channels were developed as shown in Figure 13 and Figure 14.
4. A number of simulations using Q_{100cc} were carried out as follows:
 - a. Existing river system for Q_{100cc} .
 - b. Proposed Wind Farm layout with Q_{100cc}
5. The results from the simulations showed that in general there is no significant change on the longitudinal profile water levels of the Q_{100cc} floods for Existing and Design River Systems. This is confirmed in Figure 17 to Figure 20.

6. There are some changes in water surface profiles adjacent to of the proposed bridges as shown in Figure 20 and Figure 22. However the changes in water surface profile does not impact the flood extents maps at these locations as shown in Figure 20(b) and Figure 22(b).
7. Special attention (section 0 and) was given to flood levels in Kilmanagh town with focus on:
 - a. Kilmanagh hurling pitch
 - During the Survey in September 2025, levels of the Kilmanagh hurling pitch were taken. Surveyed levels are 100.71mOD.
 - The flood levels for Q_{100cc} vary between 99.95mOD and 100.51mOD. This means that Hurling pitch is outside flood zone A not flooded during Q_{100cc} floods with freeboard of 0.20m
 - The flood levels for Q_{1000cc} reach 100.70mOD upstream of Hurling pitch is not flooded, but there is no freeboard
 - b. Industrial areas upstream of Kilmanagh Bridge (Left bank – East)
 - During the Survey in September 2025, levels of the industrial lot, e.g. open space were taken. Surveyed levels are 100.38mOD.
 - This means that the portions of industrial areas, e.g. parking lots are located in Zone A and B and are prone to flooding.
 - c. Farmer facilities/buildings upstream of Kilmanagh Bridge (Right bank – West)
 - During the Survey in September 2025, levels of the private farm road around Bridge/culvert 7 were taken. Surveyed levels are 100.83mOD.
 - This means that some flooding at the farmer facilities is possible and that portions of farm lands are located in Zone A (with water depths <0.10m) and Zone B (with water depths <0.28m).
 - d. Road levels at Kilmanagh Bridge
 - Number of road level points are taken along the Kilmanagh Bridge R695/L1009 road.
 - L1009/R695 road levels at the bridge and west of the bridge are higher than Q_{100cc} and Q_{1000cc} flood levels.
 - As the road levels drop below 100.7mOD east from the bridge, the R695road becomes prone to flooding and falls within flood zone A and B.
 - Road at the yield between R695 and R691 Knockeebaun road (east of the bridge) has levels between 100.65mOD and 100.41mOD and is prone to flooding. Downstream pastures (South from the yield) adjacent to road are also prone to flooding.
 - e. Areas downstream of Kilmanagh Bridge
 - Whole left floodplain (east) is prone to flooding and falls within Zone A and B in both existing and design river system.
 - Kilmanagh hurling pitch is outside flood Zone(s) A and B.

All above applies for Existing and Design flood levels since there is no significant change in water levels between Existing and Design flows and water levels, e.g. water depths.

8. A comparison of flood extents maps in Figure 35 and Figure 37 confirms that there is no significant change in the flood extents for the Q_{100cc} flood event, which means that there is no change in flood risk to adjacent properties.
9. A comparison of flood extents maps in Figure 36 and Figure 38 confirms that there is no significant change in the flood extents for the Q_{1000cc} flood event, which means that there is no change in flood risk to adjacent properties.

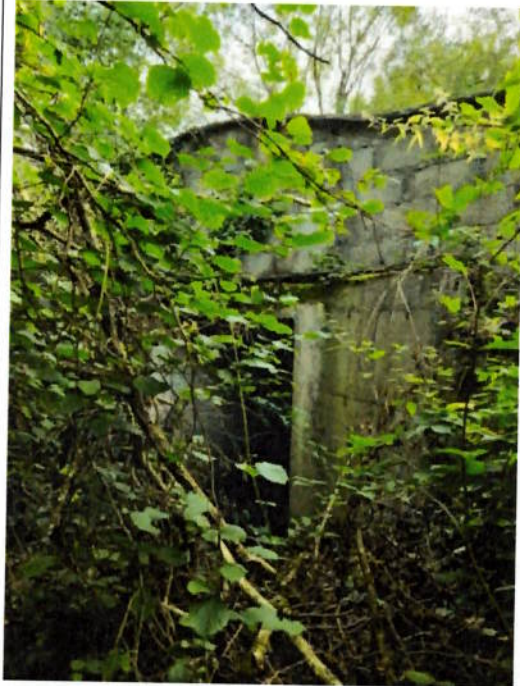
10. The impact of the development of the storage capacity of the Proposed Wind Farm site was assessed and was demonstrated to be minor by comparing the hydrographs for existing and design river systems at a number of locations of the site as shown in Figure 40, Figure 41 and Figure 42. The hydraulic model results suggest that there is no significant change in the flow rate downstream of the WF site and this confirms that downstream flooding will not be impacted. Total catchment area upstream of Kilmanagh is c. 40km², and the proposed development footprint is ~0.087km², ~0.22%, so the ability of the proposed development to effect downstream flows is very small. Furthermore, a 0.22% increase in flow at Kilmanagh Bridge is not a significant change as this very small predicted increase is offset by the conservative nature of the modelling approach (which includes 20% increase in flows to account for potential climate change and does not account for other mitigation measures at the WF site). The proposed mitigation also includes for attenuation of drainage from the development WF footprint to greenfield runoff rates, so after mitigation is included the net effect is “no change” in flow rates.

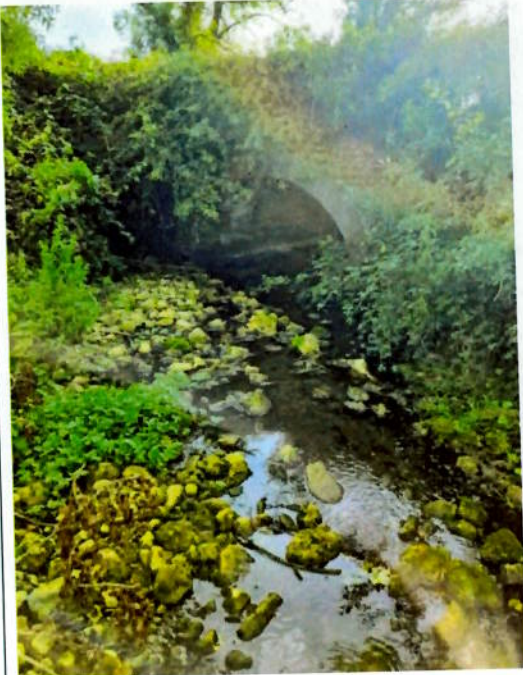
5 References

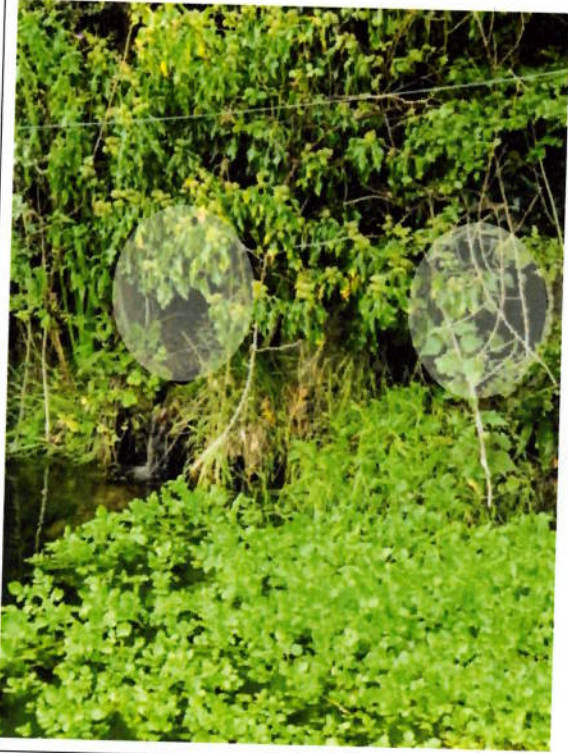
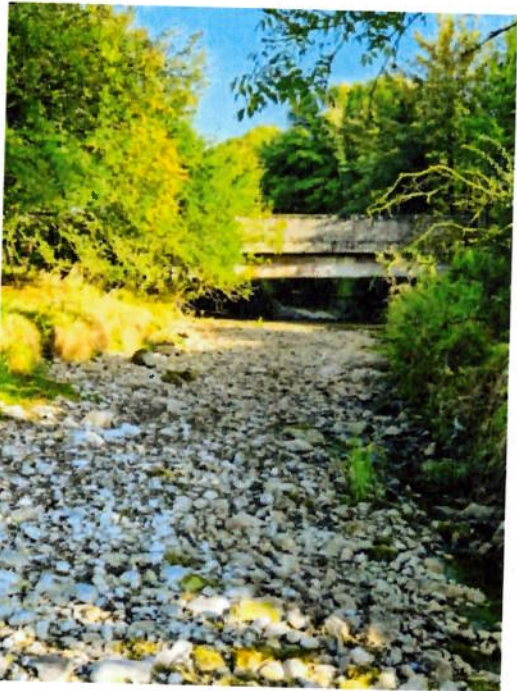
- [1] The Planning System and Flood Risk Management - Guidelines for Planning Authorities, OPW and the Department of the Environment, Heritage and Local Government, November 2009.
- [2] OPW Planning and Development Flood Policy, published on www.flooding.ie.
- [3] Arterial Drainage Act, 1945.
- [4] Arterial Drainage (Amendment) Act, 1995.
- [5] OPW Flood Hazard Mapping, www.floodmaps.ie
- [6] U.S. Army Corps of Engineers, HEC-RAS Hydraulic Reference Manual, <https://www.hec.usace.army.mil/software/hec-ras/download.aspx>
- [7] U.S. Army Corps of Engineers, HEC-RAS 2D User's Manual, <https://www.hec.usace.army.mil/confluence/rasdocs/r2dum/latest>
- [8] U.S. Army Corps of Engineers, HEC-RAS User's Manual, <https://www.hec.usace.army.mil/confluence/rasdocs/rasum/latest>
- [9] U.S. Army Corps of Engineers, Benchmarking of the HEC-RAS Two-Dimensional Hydraulic Modeling Capabilities, April 2020.
- [10] OPW, Flood Studies Update, Volume II Flood Frequency Estimation, , 2014.

Annex A - Photos of hydrological features



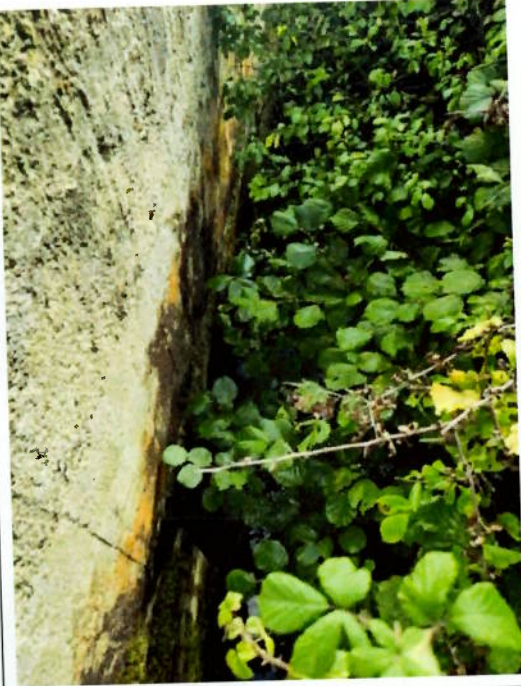
Type of structure	Detail	
Bridge 01 Box W=1.5m H=1.8m	u/s elevation	d/s elevation
		
	Looking upstream	Looking downstream
		

Type of structure	Detail	
Bridge 02	Local road culvert 2x900mm pipes. Culvert was partially blocked due to debris accumulation on the upstream elevation. Locals report that bridge is often overtopped and road flooded. River: Oldtownhill stream.	
	Upstream elevation 	Downstream elevation 
Bridge 03 Road stone arch bridge	Upstream elevation 	Downstream elevation 

Type of structure	Detail
Bridge 04 2x750mm pipes	Road crossing – Huntstown/Oldtownhill road 
Bridge 05	Single span RC road bridge. Oldtown road. River: Tullaroan stream Upstream elevation  Downstream elevation 

Type of structure	Detail
	Four span arch stone bridge under R695/L1009 road in Kilmanagh town. River: Tullaroan stream. U/s elevation 
Bridge 06	D/s elevation 

Type of structure	Detail	
Bridge 07	Single pipe 600mm culvert. River: Kilmanagh 15 stream, Located at dwelling in Kilmanagh town.	
	U/s elevation 	D/s elevation 
Bridge 08	600mm pipe. Briskalagh Stream. No photo	
Bridge 09	750mm pipe. Briskalagh Stream.	
	 D/s elevation	

Type of structure	Detail	
Bridge 10	750mm Pipe on the Upstream elevation, 1.5m x1.5m Box culvert on the downstream elevation	
	U/s elevation 	D/s elevation 
Bridge 11 Breagagh stream 300mm pipe	 D/s elevation	

Type of structure	Detail	
Bridge 12 Breagagh stream	U/s elevation 	D/s elevation 

Annex B – Tables with various coefficients

5.1.1 Manning n values

Table E4.1. Manning's "n" for Closed Conduits Flowing Partially Full

Type of Channel and Description	Minimum	Normal	Maximum
Brass, smooth:	0.009	0.010	0.013
Steel:			
Lockbar and welded	0.010	0.012	0.014
Riveted and spiral	0.013	0.016	0.017
Cast Iron:			
Coated	0.010	0.013	0.014
Uncoated	0.011	0.014	0.016
Wrought Iron:			
Black	0.012	0.014	0.015
Galvanized	0.013	0.016	0.017
Corrugated Metal:			
Subdrain	0.017	0.019	0.021
Storm Drain	0.021	0.024	0.030
Lucite:			
Glass:	0.008	0.009	0.010
Cement:	0.009	0.010	0.013
Neat, surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
Concrete:			
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016
Unfinished, rough wood form	0.015	0.017	0.020
Wood:			
Stave	0.010	0.012	0.014
Laminated, treated	0.015	0.017	0.020
Clay:			
Common drainage tile	0.011	0.013	0.017
Vitrified sewer	0.011	0.014	0.017
Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
Vitrified Subdrain with open joint	0.014	0.016	0.018
Brickwork:			
Glazed	0.011	0.013	0.015
Lined with cement mortar	0.012	0.015	0.017
Sanitary sewers coated with sewage slime with bends and connections	0.012	0.013	0.016
Paved invert, sewer, smooth bottom	0.016	0.019	0.020
Rubble masonry, cemented	0.018	0.025	0.030

[Chow, 1959]

Table E4.2. Manning's "n" for Corrugated Metal Pipe

Type of Pipe and Diameter	Unpaved	25% Paved	Fully Paved
Annular 2.67 x 2 in. (all diameters) Helical 1.50 x 1/4 in.:	0.024	0.021	0.021
8 inch diameter	0.012		
10 inch diameter	0.014		
Helical 2.67 x 2 in.:			
12 inch diameter	0.011		
18 inch diameter	0.014		
24 inch diameter	0.016	0.015	0.012
36 inch diameter	0.019	0.017	0.012
48 inch diameter	0.020	0.020	0.012
60 inch diameter	0.021	0.019	0.012
Annular 3 x 1 in. (all diameters)	0.027	0.023	0.012
Helical 3 x 1 in.:			
48 inch diameter	0.023	0.020	0.012
54 inch diameter	0.023	0.020	0.012
60 inch diameter	0.024	0.021	0.012
66 inch diameter	0.025	0.022	0.012
72 inch diameter	0.026	0.022	0.012
78 inch & larger	0.027	0.023	0.012
Corrugations 6 x 2 in.:			
60 inch diameter	0.033	0.028	
72 inch diameter	0.032	0.027	
120 inch diameter	0.030	0.026	
150 inch diameter	0.028	0.024	

[AISI, 1980]

Table E4.3. Manning's "n" for channels and flood plains

Type of Channel and Description		Minimum	Normal	Maximum
A. Natural Streams				
1. Main Channels				
a	Clean, straight, full, no rifts or deep pools			
b	Same as above, but more stones and weeds	0.025	0.030	0.033
c	Clean, winding, some pools and shoals	0.030	0.035	0.040
d	Same as above, but some weeds and stones	0.033	0.040	0.045
e	Same as above, lower stages, more ineffective slopes and sections	0.035	0.045	0.050
f	Same as "d" but more stones	0.040	0.048	0.055
g	Sluggish reaches, weedy, deep pools	0.045	0.050	0.060
h	Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.050	0.070	0.080
		0.070	0.100	0.150
2. Flood Plains				
a	Pasture no brush			
1	Short grass	0.025	0.030	0.035
2	High grass	0.030	0.035	0.050
b	Cultivated areas			
1	No crop	0.020	0.030	0.040
2	Mature row crops	0.025	0.035	0.045
3	Mature field crops	0.030	0.040	0.050
c	Brush			
1	Scattered brush, heavy weeds	0.035	0.050	0.070
2	Light brush and trees, in winter	0.035	0.050	0.060
3	Light brush and trees, in summer	0.040	0.060	0.080
4	Medium to dense brush, in winter	0.045	0.070	0.110
5	Medium to dense brush, in summer	0.070	0.100	0.160
d	Trees			
1	Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2	Same as above, but heavy sprouts	0.050	0.060	0.080
3	Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
4	Same as above, but with flow into branches	0.100	0.120	0.160
5	Dense willows, summer, straight	0.110	0.150	0.200
3. Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged				
a	Bottom gravels, cobbles, and few boulders			
b	Bottom cobbles with large boulders	0.030	0.040	0.050
		0.040	0.050	0.070

Continue below (source HEC-RAS Hydraulic Reference Manual v4.1, 2010)

Type of Channel and Description	Minimum	Normal	Maximum
B. Lined or Built Up Channels			
1. Concrete	0.011	0.013	0.015
a. Trowel finish	0.013	0.015	0.016
b. Float Finish	0.015	0.017	0.020
c. Finished, with gravel bottom	0.014	0.017	0.020
d. Unfinished	0.016	0.019	0.023
e. Gunite, good section	0.018	0.022	0.025
f. Gunite, wavy section	0.017	0.020	
g. On good excavated rock	0.022	0.027	
h. On irregular excavated rock			
2. Concrete bottom float finished with sides of:	0.015	0.017	0.020
a. Dressed stone in mortar	0.017	0.020	0.024
b. Random stone in mortar	0.016	0.020	0.024
c. Cement rubble masonry, plastered	0.020	0.025	0.030
d. Cement rubble masonry	0.020	0.030	0.035
e. Dry rubble on riprap			
3. Gravel bottom with sides of:	0.017	0.020	0.025
a. Formed concrete	0.020	0.023	0.026
b. Random stone in mortar	0.023	0.033	0.036
c. Dry rubble or riprap			
4. Brick	0.011	0.013	0.015
a. Glazed	0.012	0.015	0.018
b. In cement mortar			
5. Metal	0.011	0.012	0.014
a. Smooth steel surfaces	0.021	0.025	0.030
b. Corrugated metal			
6. Asphalt	0.013	0.013	
a. Smooth	0.016	0.016	
b. Rough			
7. Vegetal lining	0.030		0.500

Type of Channel and Description	Minimum	Normal	Maximum
C. Excavated or Dredged Channels			
1. Earth, straight and uniform	0.016	0.018	0.020
a. Clean, recently completed	0.018	0.022	0.025
b. Clean, after weathering	0.022	0.025	0.030
c. Gravel, uniform section, clean	0.022	0.027	0.033
d. With short grass, few weeds			
2. Earth, winding and sluggish	0.023	0.025	0.030
a. No vegetation	0.025	0.030	0.033
b. Grass, some weeds	0.030	0.035	0.040
c. Dense weeds or aquatic plants in deep channels	0.028	0.030	0.035
d. Earth bottom and rubble side	0.025	0.035	0.040
e. Stony bottom and weedy banks	0.030	0.040	0.050
f. Cobble bottom and clean sides			
3. Dragline excavated or dredged	0.025	0.028	0.033
a. No vegetation	0.035	0.050	0.060
b. Light brush on banks			
4. Rock cuts	0.025	0.035	0.040
a. Smooth and uniform	0.035	0.040	0.050
b. Jagged and irregular			
5. Channels not maintained, weeds and brush	0.040	0.050	0.080
a. Clean bottom, brush on sides	0.045	0.070	0.110
b. Same as above, highest stage of flow	0.050	0.080	0.120
c. Dense weeds, high as flow depth	0.080	0.100	0.140
d. Dense brush, high stage			

5.1.2 Entrance coefficients

Table E5.1. Entrance Loss Coefficient for Pipe Culverts

Type of Structure and Design of Entrance	Coefficient, k_{en}
Concrete Pipe Projecting from Fill (no headwall):	
Socket end of pipe	0.2
Square cut end of pipe	0.5
Concrete Pipe with Headwall or Headwall and Wingwalls:	
Socket end of pipe (grooved end)	0.2
Square cut end of pipe	0.5
Rounded entrance with rounding radius = 1/12 of diameter	0.2
Concrete Pipe:	
Mitered to conform to fill slope	0.7
End section conformed to fill slope	0.5
Beveled edges, 33.7 or 45 degree bevels	0.2
Side slope tapered inlet	0.2
Corrugated Metal Pipe or Pipe-Arch:	
Projected from fill (no headwall)	0.9
Headwall or headwall and wingwalls square edge	0.5
Mitered to conform to fill slope	0.7
End section conformed to fill slope	0.5
Beveled edges, 33.7 or 45 degree bevels	0.2
Side slope tapered inlet	0.2

Table E5.2. Entrance Loss Coefficient for Reinforced Concrete Box Culverts

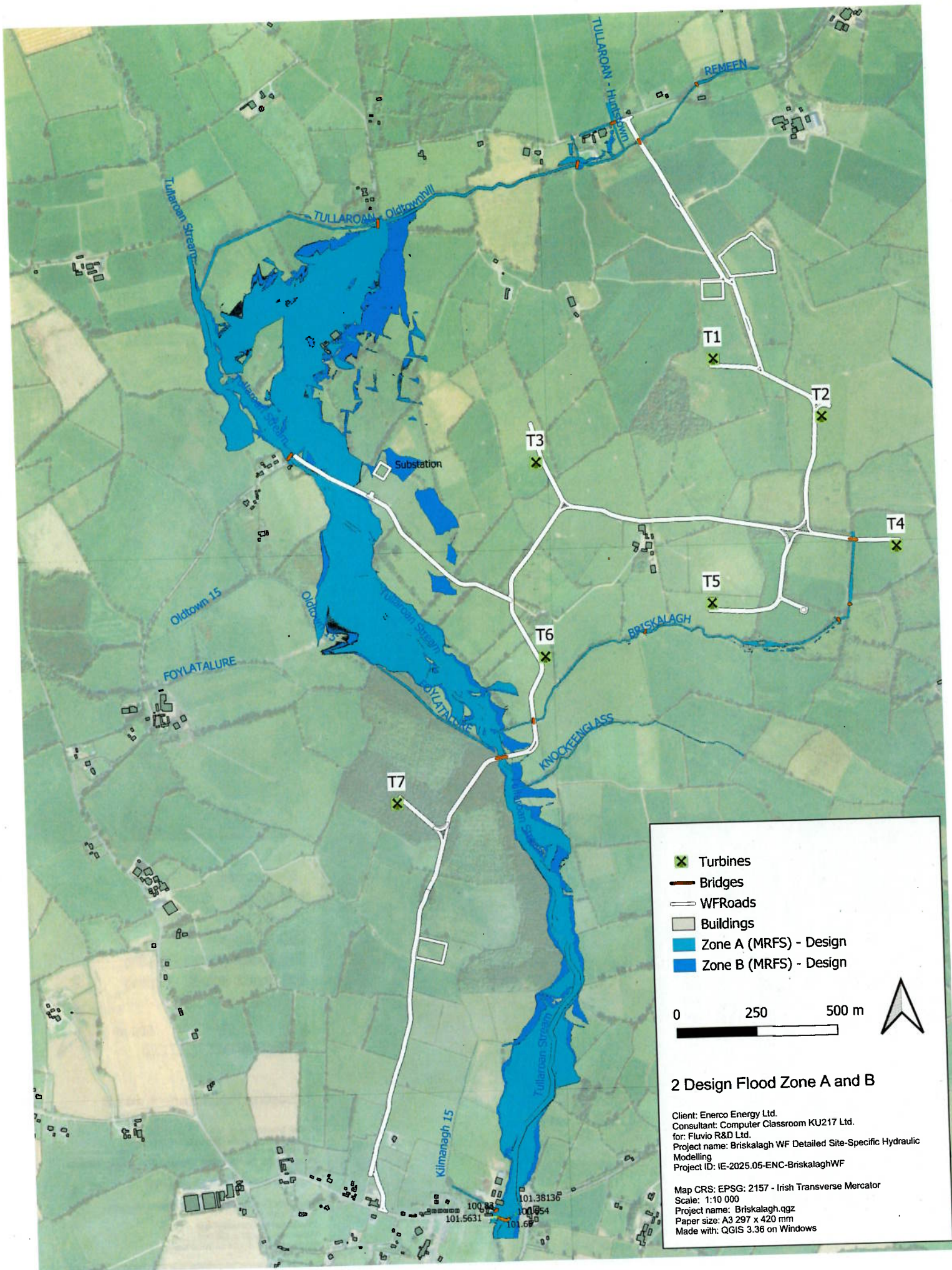
Type of Structure and Design of Entrance	Coefficient, k_{en}
Headwall Parallel to Embankment (no wingwalls):	
Square-edged on three edges	0.5
Three edges rounded to radius of 1/12 barrel dimension	0.2
Wingwalls at 30 to 75 degrees to Barrel:	
Square edge at crown	0.4
Top corner rounded to radius of 1/12 barrel dimension	0.2
Wingwalls at 10 to 25 degrees to Barrel:	
Square-edge at crown	0.5
Wingwalls parallel (extension of sides):	
Square-edge at crown	0.7
Side or slope tapered inlet	0.2

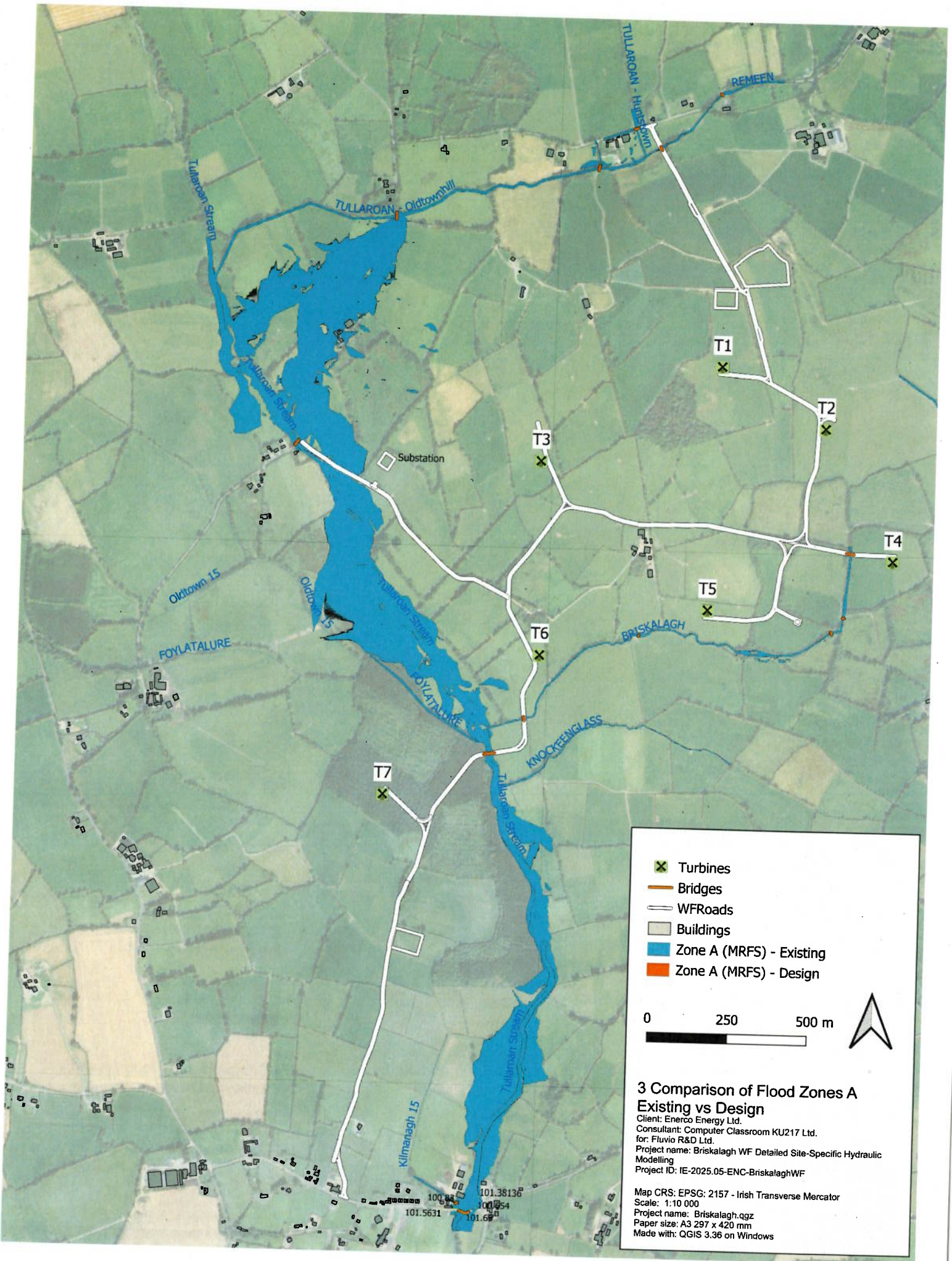
Table E5.3. Entrance Loss Coefficient for ConSpan Culverts

Type of Entrance	Coefficient, k_{en}
Extended wingwalls 0 degrees	0.5
45 degree wingwalls	0.3
Straight Headwall	0.4

Source: HEC-RAS Hydraulic Reference Manual

Annex C – Flood Maps





- ✕ Turbines
- Bridges
- WFRoads
- Buildings
- Zone A (MRFS) - Existing
- Zone A (MRFS) - Design

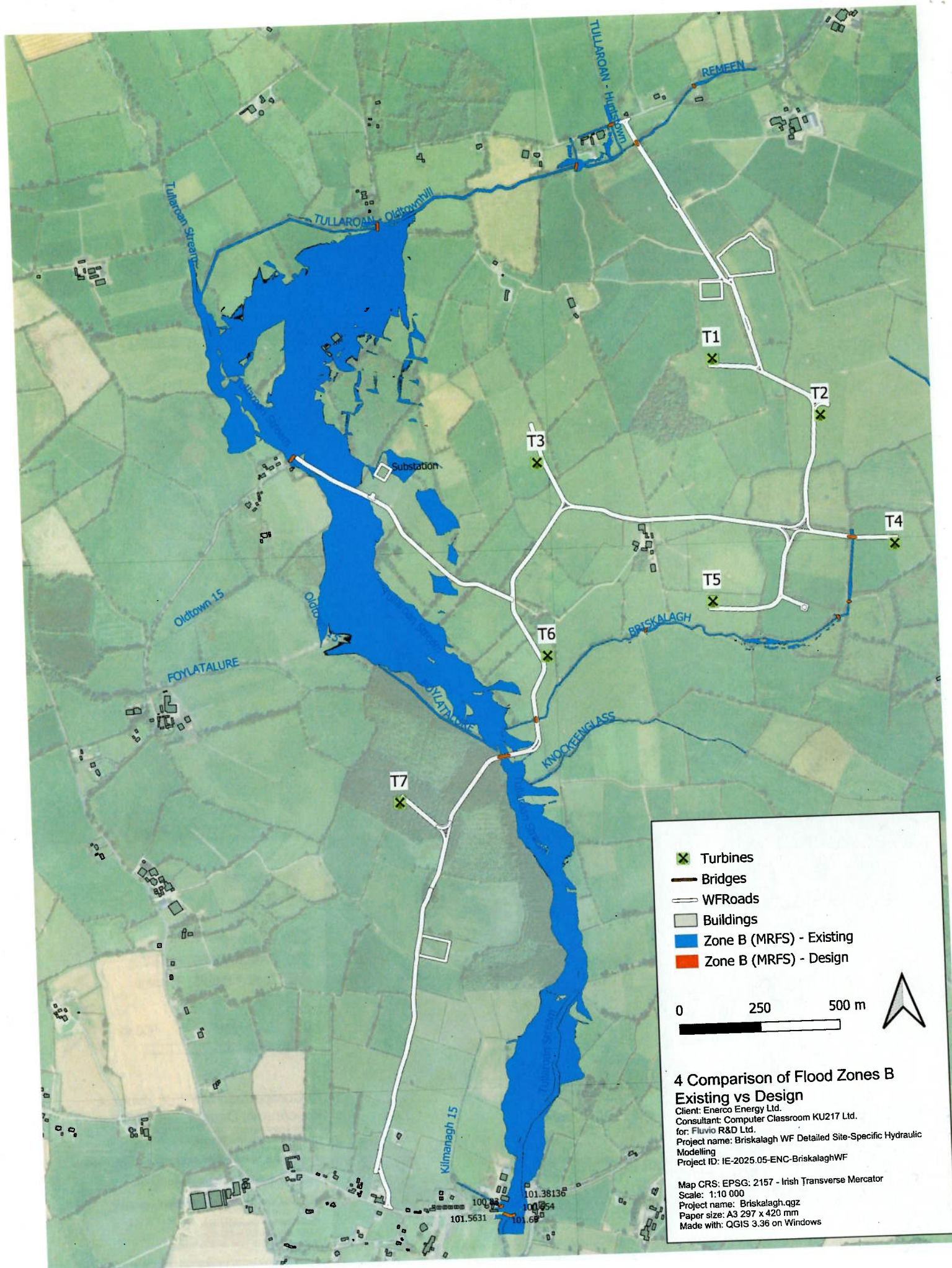
0 250 500 m



3 Comparison of Flood Zones A Existing vs Design

Client: Enerco Energy Ltd.
Consultant: Computer Classroom KU217 Ltd.
for: Fluvio R&D Ltd.
Project name: Briskalagh WF Detailed Site-Specific Hydraulic
Modelling
Project ID: IE-2025.05-ENC-BriskalaghWF

Map CRS: EPSG: 2157 - Irish Transverse Mercator
Scale: 1:10 000
Project name: Briskalagh.qgz
Paper size: A3 297 x 420 mm
Made with: QGIS 3.36 on Windows

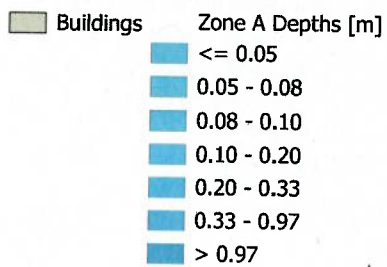


- Turbines
- Bridges
- WFRoads
- Buildings
- Zone B (MRFS) - Existing
- Zone B (MRFS) - Design



**4 Comparison of Flood Zones B
Existing vs Design**
Client: Enerco Energy Ltd.
Consultant: Computer Classroom KU217 Ltd.
for: Fluvio R&D Ltd.
Project name: Briskalagh WF Detailed Site-Specific Hydraulic
Modelling
Project ID: IE-2025.05-ENC-BriskalaghWF

Map CRS: EPSG: 2157 - Irish Transverse Mercator
Scale: 1:10 000
Project name: Briskalagh.gqz
Paper size: A3 297 x 420 mm
Made with: QGIS 3.36 on Windows



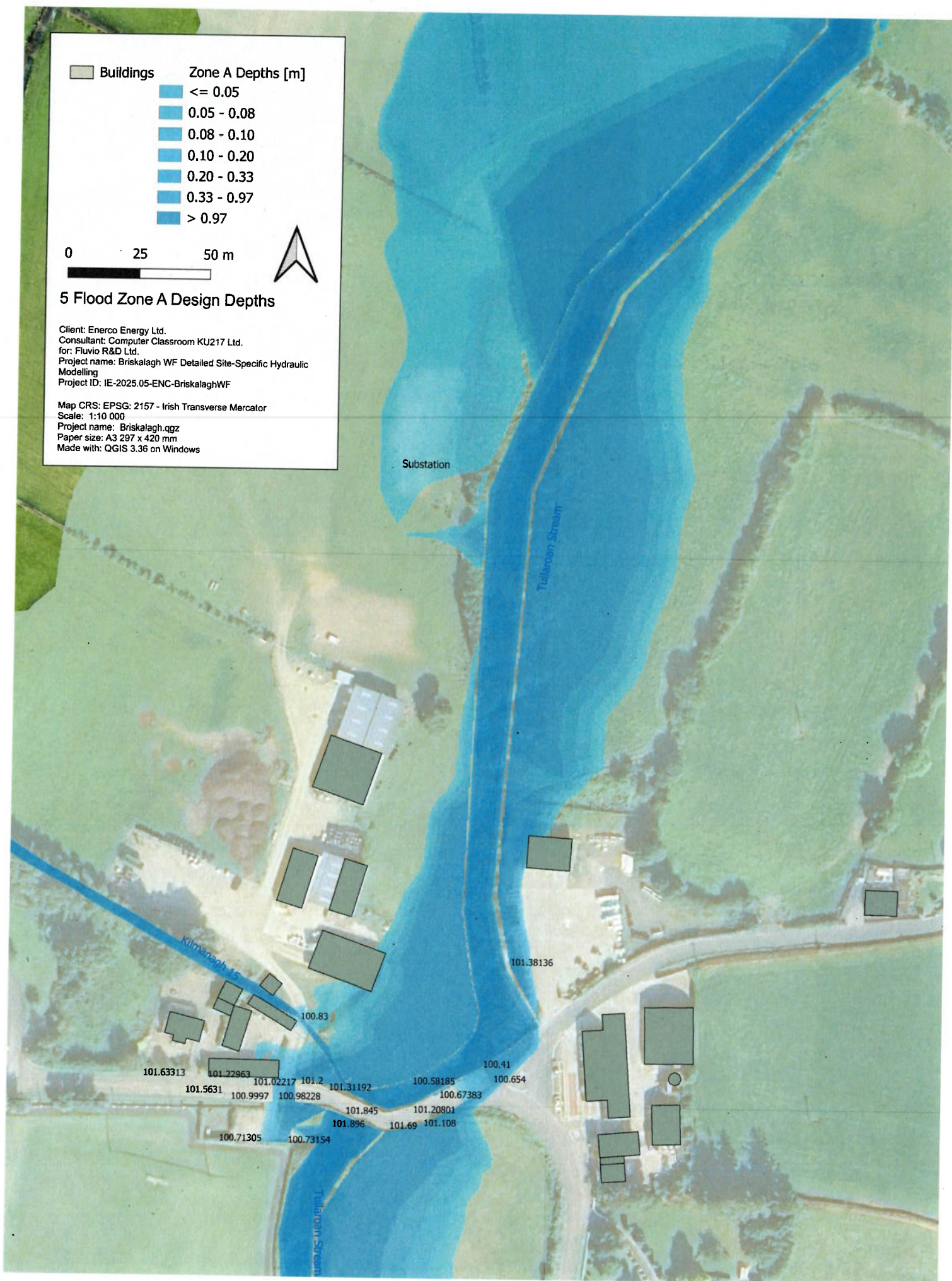
0 25 50 m



5 Flood Zone A Design Depths

Client: Enerco Energy Ltd.
 Consultant: Computer Classroom KU217 Ltd.
 for: Fluvio R&D Ltd.
 Project name: Briskalagh WF Detailed Site-Specific Hydraulic
 Modelling
 Project ID: IE-2025.05-ENC-BriskalaghWF

Map CRS: EPSG: 2157 - Irish Transverse Mercator
 Scale: 1:10 000
 Project name: Briskalagh.qgz
 Paper size: A3 297 x 420 mm
 Made with: QGIS 3.36 on Windows



Buildings

Zone B Depths [m]

- <= 0.05
- 0.05 - 0.08
- 0.08 - 0.10
- 0.10 - 0.20
- 0.20 - 0.33
- 0.33 - 0.97
- > 0.97

0 25 50 m



6 Flood Zone B Design Depths

Client: Enerco Energy Ltd.
Consultant: Computer Classroom KU217 Ltd.
for: Fluvio R&D Ltd.
Project name: Briskalagh WF Detailed Site-Specific Hydraulic
Modelling
Project ID: IE-2025.05-ENC-BriskalaghWF

Map CRS: EPSG: 2157 - Irish Transverse Mercator
Scale: 1:10 000
Project name: Briskalagh.qgz
Paper size: A3 297 x 420 mm
Made with: QGIS 3.36 on Windows

Substation

Tullaghan Stream

Kilmanagh R

101.63313

101.22963

101.02217

101.2

101.31192

100.58185

100.67383

101.5631

100.9997

100.98228

101.845

101.20801

100.71305

100.73154

101.896

101.69

101.108

100.41

100.654

101.38136

Tullaghan Stream

Annex D – FSU Q_{med} and Flood Frequency Analysis

 OPW FEMI Flood Estimation Report	CLIENT: Briskalagh Ltd.		
	PROJECT: Briskalagh Renewable Energy Development		
	DOC. TITLE: Qmed and Peak Flow Calculations for HP01ds		
	REFERENCE: IE 25 05		
	SUBJECT: CALCULATION OF QMED & PEAK DESIGN FLOWS IN UNGAUGED CATCHMENTS		
Checked: IK Approved: EMcK			

A Selection of the Subject Site

- A1 Ungauged Node ID
 A2 Ungauged Node Catchment Descriptors:

15_1622_3

Physical Catchment Descriptors

AREA (km ²)	22.97	Node East	238517
BFIsoils (index)	0.589	Node North	155319
SAAR (mm)	883.48	Centroid East	235860
FARL (index)	1.000	Centroid North	157710
DRAIN (km/km ²)	0.832	ALLUV	0.0412
S1085 (m/km)	19.485	ARTDRAIN	0.0000
ARTDRAIN2 (prop)	0.000	FOREST	0.0819
URBEXT (%)	0.0000		

B Module 1: Estimation of the Index Flood (QMED)

B.1. Estimation of QMED without the use of a pivotal site	4.18
B.2. Estimation of QMED by using one pivotal site: 30004	3.05
B.3. Estimation of QMED using three pivotal sites: 14057, 14014, 13001	5.08
B.4. Final chosen QMED estimate: Using the small catchment equation	8.09

C Module 2: Estimation of the flood growth factors and design flood magnitudes

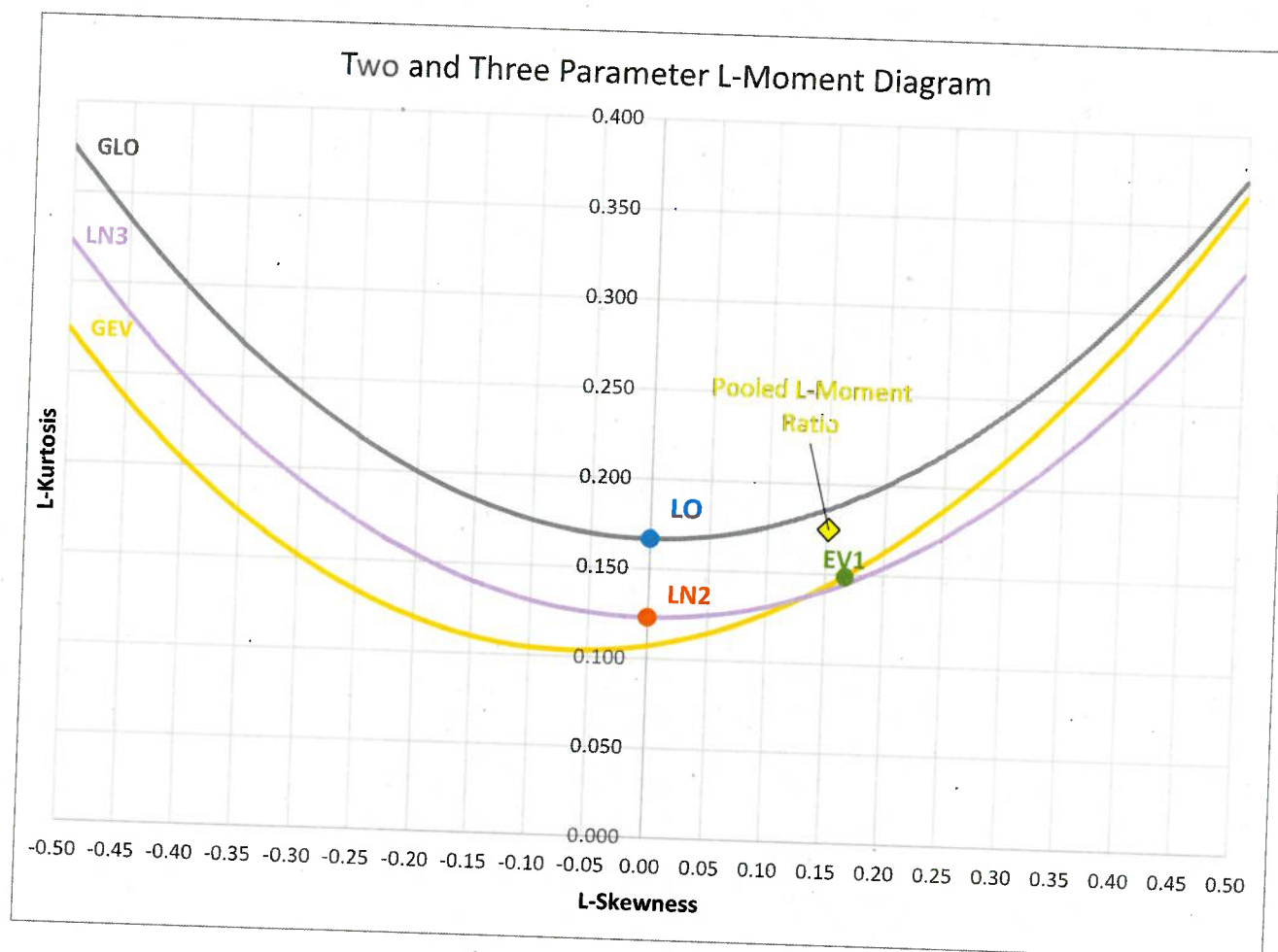
C.1. Selection of Pooling Group for flood frequency analysis

station no.	Location	similarity measure	No. of Yrs of data	t2 L-CV	t3 L-Skewness	t4 L-Kurtosis
16051	CLOBANNA	0.33	32	0.219	0.267	0.196
6033	CONEYBURROW BR	0.86	47	0.232	0.093	0.137
16001	ATHLUMMON	1.02	51	0.129	0.000	0.108
14009	CUSHINA	1.03	43	0.144	0.064	0.166
36031	LISDARN	1.04	25	0.151	0.291	0.215
10021	COMMON'S ROAD	1.15	41	0.244	0.244	0.126
25040	ROSCREA	1.26	37	0.154	0.120	0.081

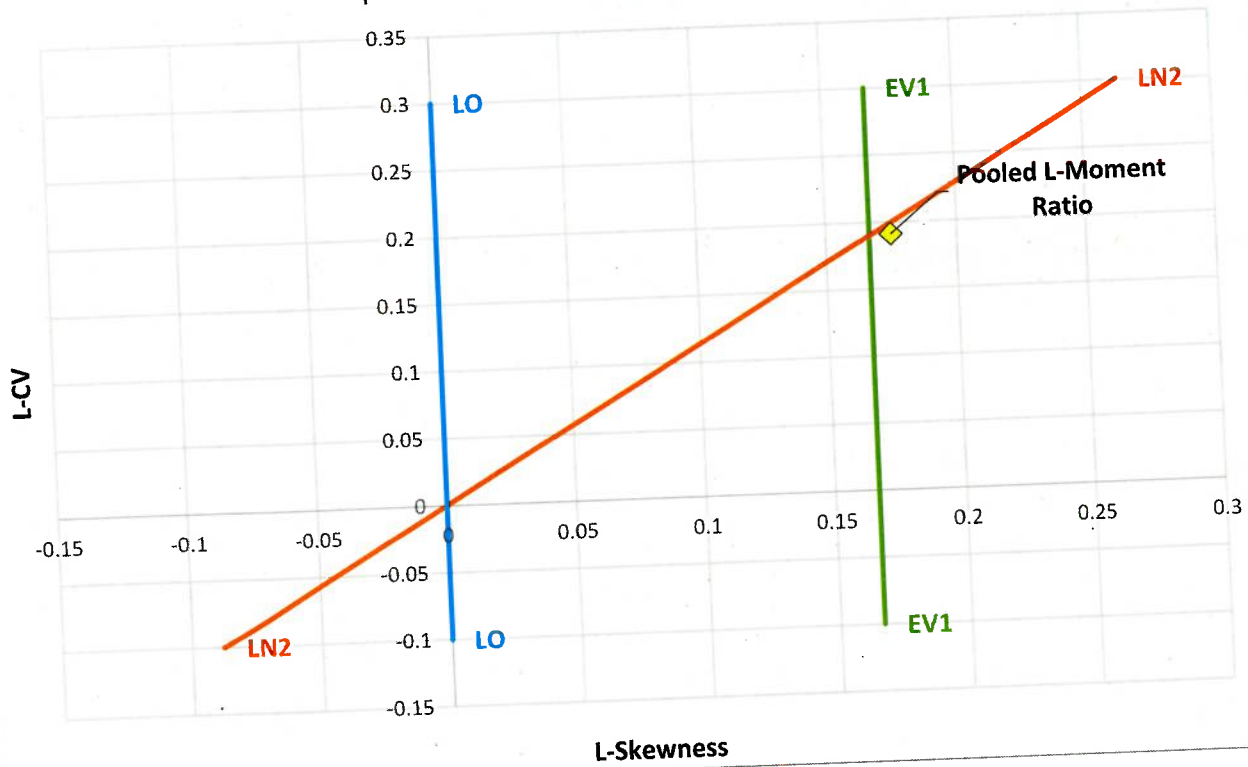
36018	ASHFIELD	1.30	68	0.156	0.216	0.194
9037	BOTANIC GARDENS	1.32	24	0.342	0.305	0.100
6014	TALLANSTOWN	1.34	48	0.143	0.231	0.197
9001	LEIXLIP	1.36	66	0.245	0.207	0.139

C.2. Selection of the best fit flood frequency distribution to the pooled data

L-Moment Ratio Diagrams:



2- parameter L-Moment Ratio Diagram



Final Growth Factors and Design Flows:

GLO		
Return Period (T)	Growth Factors	Design Flows
1.3	0.792	6.404
2	1.000	8.089
5	1.301	10.524
10	1.514	12.247
20	1.739	14.066
25	1.815	14.685
30	1.880	15.205
35	1.935	15.656
50	2.069	16.740
100	2.353	19.033
200	2.671	21.605
500	3.153	25.508
1000	3.573	28.899

Custom Return Period

100	2.353	19.033

D Module 3: Generation of Design Hydrograph Shape Parameters

D.1. Generation of Initial Design Hydrograph Shape Parameters

Catchment Wetness Indicator (CWI)

123

Baseflow:

0.60

m³/s

n	Tr (hours)	C (hours)
4.90	20.43	49.06

D.2. Selection of most hydrologically similar catchments

	Station No.	Dij similarity measure	n	Tr	C
1st most similar	30004	0.187	5.300	59.440	46.420
2nd most similar	25021	0.195	3.335	31.739	281.315
3rd most similar	16004	0.239	3.236	62.757	76.105

D.2. Option 1: Adjusted parameters using most hydrologically similar catchment, 30004

n	Tr	C
4.901	36.343	40.089

D.2. Option 2: Adjusted Shape parameters using 3 no. Pivotal Sites, 30004, 25021, 16004

n	Tr	C
3.493	25.735	139.403

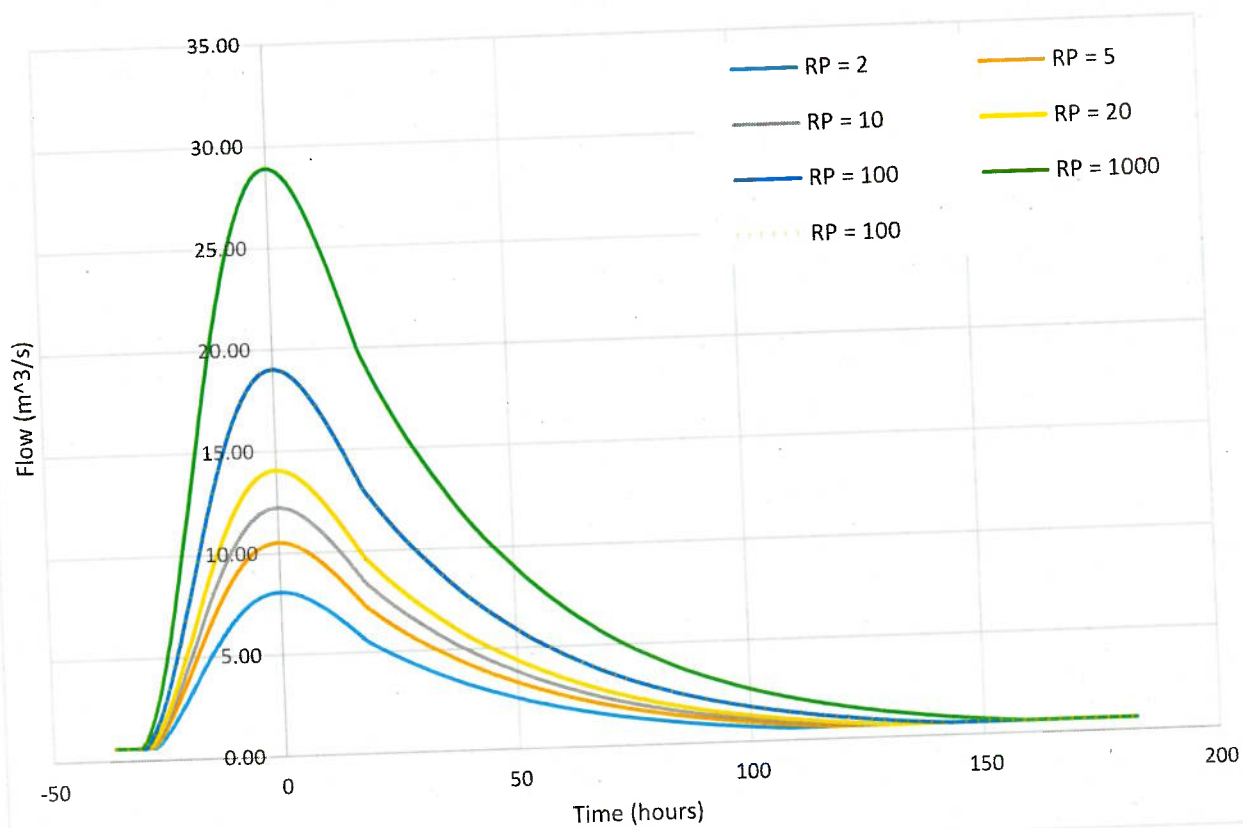
Chosen parameter selection method:

Adjusted parameters using most hydrologically similar catchment, 30004

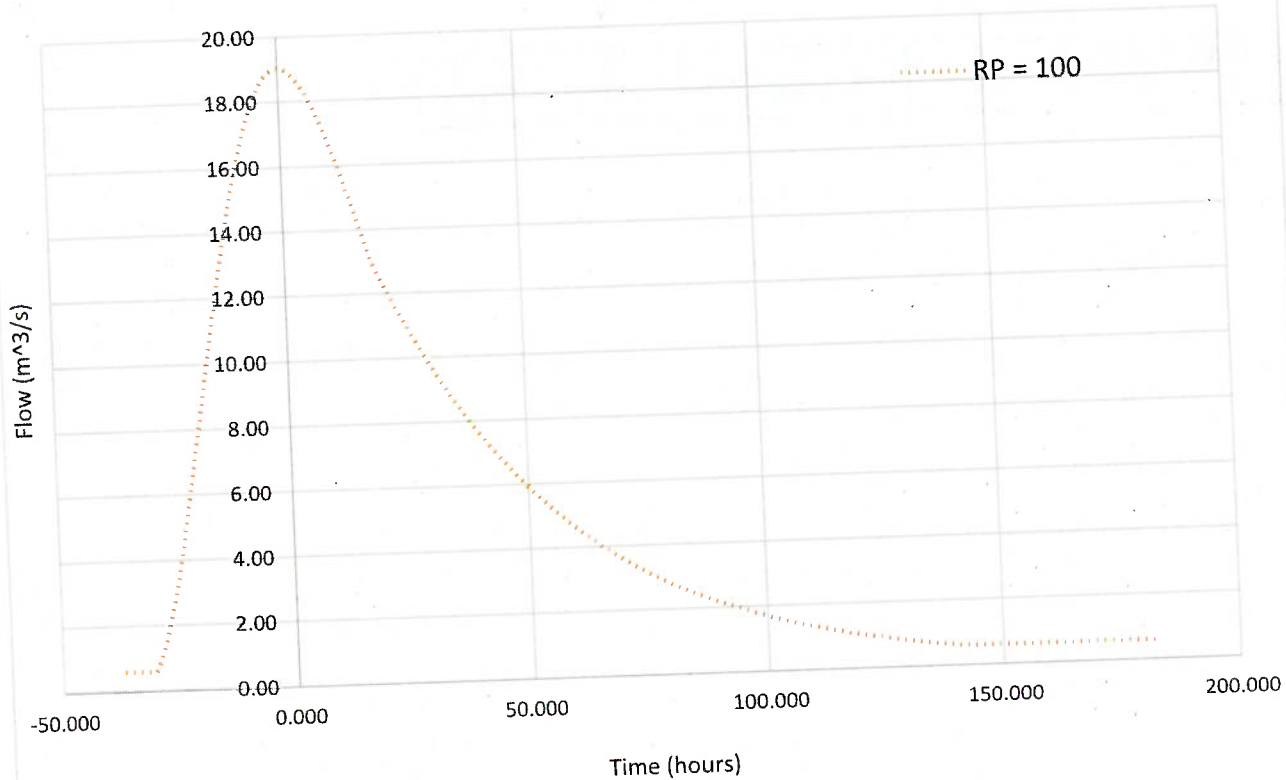
D.3. Final Hydrograph Parameters:

n	Tr	C
4.901	36.343	40.089

All Design Hydrographs



RP = 100



Hydrograph Plot Data:

Time (Hours)	RP = 2	RP = 5	RP = 10	RP = 20	RP = 100	RP = 1000	Custom RP
-36.343	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-35.248	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-34.153	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-33.059	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-31.964	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-30.869	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-29.774	0.598	0.598	0.598	0.598	0.598	0.598	0.598
-28.679	0.598	0.598	0.614	0.705	0.598	0.892	0.598
-27.584	0.607	0.789	0.918	1.055	0.954	1.448	0.954
-26.489	0.854	1.111	1.293	1.485	1.427	2.167	1.427
-25.395	1.145	1.490	1.734	1.992	2.009	3.051	2.009
-24.300	1.477	1.922	2.236	2.568	2.695	4.092	2.695
-23.205	1.844	2.399	2.792	3.206	3.475	5.277	3.475
-22.110	2.241	2.915	3.392	3.896	4.339	6.588	4.339
-21.015	2.660	3.461	4.027	4.625	5.272	8.004	5.272
-19.920	3.096	4.027	4.686	5.382	6.259	9.503	6.259
-18.825	3.540	4.606	5.360	6.156	7.283	11.059	7.283
-17.731	3.988	5.188	6.037	6.934	8.330	12.648	8.330
-16.636	4.431	5.765	6.709	7.705	9.382	14.246	9.382
-15.541	4.865	6.329	7.365	8.459	10.426	15.831	10.426
-14.446	5.284	6.874	8.000	9.188	11.447	17.381	11.447
-13.351	5.683	7.394	8.604	9.882	12.432	18.877	12.432
-12.256	6.058	7.882	9.172	10.534	13.371	20.303	13.371
-11.161	6.407	8.335	9.699	11.140	14.255	21.644	14.255
-10.067	6.725	8.749	10.182	11.693	15.074	22.888	15.074
-8.972	7.012	9.122	10.615	12.192	15.823	24.026	15.823
-7.877	7.265	9.452	10.999	12.632	16.498	25.049	16.498
-6.782	7.484	9.737	11.331	13.013	17.093	25.954	17.093
-5.687	7.669	9.977	11.610	13.334	17.609	26.737	17.609
-4.592	7.819	10.172	11.837	13.595	18.043	27.396	18.043
-3.497	7.935	10.323	12.013	13.797	18.396	27.932	18.396
-2.403	8.017	10.431	12.138	13.941	18.669	28.346	18.669
-1.308	8.068	10.497	12.215	14.029	18.864	28.643	18.864
-0.213	8.089	10.523	12.246	14.065	18.984	28.825	18.984
0.882	8.080	10.512	12.233	14.050	19.032	28.897	19.032
1.977	8.044	10.466	12.179	13.987	19.012	28.867	19.012
3.072	7.983	10.386	12.086	13.881	18.927	28.739	18.927
4.167	7.899	10.276	11.958	13.734	18.784	28.520	18.784
5.261	7.793	10.139	11.798	13.550	18.585	28.219	18.585
6.356	7.668	9.976	11.609	13.333	18.336	27.841	18.336
7.451	7.525	9.790	11.393	13.085	18.041	27.393	18.041
8.546	7.367	9.585	11.154	12.810	17.706	26.884	17.706
9.641	7.196	9.362	10.895	12.513	17.335	26.321	17.335
10.736	7.013	9.124	10.618	12.195	16.932	25.709	16.932
11.831	6.821	8.874	10.327	11.860	16.502	25.056	16.502
12.925	6.620	8.613	10.023	11.511	16.049	24.368	16.049
14.020	6.413	8.343	9.709	11.151	15.577	23.651	15.577
15.115	6.201	8.067	9.388	10.782	15.089	22.911	15.089
					14.590	22.153	14.590

16.210	5.985	7.787	9.062	10.407	14.083	21.383	14.083
17.305	5.767	7.503	8.732	10.028	13.570	20.605	13.570
18.400	5.548	7.218	8.400	9.648	13.055	19.822	13.055
20.042	5.326	6.929	8.063	9.260	12.531	19.026	12.531
21.684	5.112	6.651	7.739	8.889	12.028	18.263	12.028
23.327	4.907	6.384	7.429	8.532	11.545	17.530	11.545
24.969	4.710	6.127	7.131	8.189	11.082	16.826	11.082
26.611	4.521	5.882	6.844	7.861	10.637	16.151	10.637
28.253	4.339	5.645	6.570	7.545	10.210	15.503	10.210
29.896	4.165	5.419	6.306	7.242	9.800	14.880	9.800
31.538	3.998	5.201	6.053	6.952	9.407	14.283	9.407
33.180	3.838	4.993	5.810	6.673	9.029	13.710	9.029
34.823	3.684	4.792	5.577	6.405	8.667	13.159	8.667
36.465	3.536	4.600	5.353	6.148	8.319	12.631	8.319
38.107	3.394	4.415	5.138	5.901	7.985	12.124	7.985
39.749	3.258	4.238	4.932	5.664	7.665	11.638	7.665
41.392	3.127	4.068	4.734	5.437	7.357	11.171	7.357
43.034	3.001	3.905	4.544	5.219	7.062	10.722	7.062
44.676	2.881	3.748	4.361	5.009	6.778	10.292	6.778
46.319	2.765	3.597	4.186	4.808	6.506	9.879	6.506
47.961	2.654	3.453	4.018	4.615	6.245	9.482	6.245
49.603	2.548	3.314	3.857	4.430	5.994	9.102	5.994
51.245	2.445	3.181	3.702	4.252	5.754	8.736	5.754
52.888	2.347	3.054	3.554	4.081	5.523	8.386	5.523
54.530	2.253	2.931	3.411	3.918	5.301	8.049	5.301
56.172	2.163	2.814	3.274	3.760	5.088	7.726	5.088
57.815	2.076	2.701	3.143	3.609	4.884	7.416	4.884
59.457	1.992	2.592	3.017	3.465	4.688	7.118	4.688
61.099	1.913	2.488	2.895	3.325	4.500	6.832	4.500
62.741	1.836	2.388	2.779	3.192	4.319	6.558	4.319
64.384	1.762	2.292	2.668	3.064	4.146	6.295	4.146
66.026	1.691	2.200	2.561	2.941	3.979	6.042	3.979
67.668	1.623	2.112	2.458	2.823	3.820	5.800	3.820
69.311	1.558	2.027	2.359	2.710	3.666	5.567	3.666
70.953	1.496	1.946	2.264	2.601	3.519	5.344	3.519
72.595	1.436	1.868	2.174	2.496	3.378	5.129	3.378
74.237	1.378	1.793	2.086	2.396	3.242	4.923	3.242
75.880	1.323	1.721	2.003	2.300	3.112	4.726	3.112
77.522	1.270	1.652	1.922	2.208	2.987	4.536	2.987
79.164	1.219	1.586	1.845	2.119	2.867	4.354	2.867
80.807	1.170	1.522	1.771	2.034	2.752	4.179	2.752
82.449	1.123	1.461	1.700	1.952	2.642	4.011	2.642
84.091	1.078	1.402	1.632	1.874	2.536	3.850	2.536
85.733	1.035	1.346	1.566	1.799	2.434	3.696	2.434
87.376	0.993	1.292	1.503	1.727	2.336	3.547	2.336
89.018	0.953	1.240	1.443	1.657	2.243	3.405	2.243
90.660	0.915	1.190	1.385	1.591	2.153	3.268	2.153
92.303	0.878	1.142	1.329	1.527	2.066	3.137	2.066
93.945	0.843	1.097	1.276	1.466	1.983	3.011	1.983
95.587	0.809	1.053	1.225	1.407	1.904	2.890	1.904
97.230	0.777	1.010	1.176	1.350	1.827	2.774	1.827
98.872	0.745	0.970	1.129	1.296	1.754	2.663	1.754

100.514	0.716	0.931	1.083	1.244	1.684	2.556	1.684
102.156	0.687	0.894	1.040	1.194	1.616	2.454	1.616
103.799	0.659	0.858	0.998	1.146	1.551	2.355	1.551
105.441	0.633	0.823	0.958	1.100	1.489	2.261	1.489
107.083	0.607	0.790	0.920	1.056	1.429	2.170	1.429
108.726	0.598	0.758	0.883	1.014	1.372	2.083	1.372
110.368	0.598	0.728	0.847	0.973	1.317	1.999	1.317
112.010	0.598	0.699	0.813	0.934	1.264	1.919	1.264
113.652	0.598	0.671	0.781	0.896	1.213	1.842	1.213
115.295	0.598	0.644	0.749	0.860	1.164	1.768	1.164
116.937	0.598	0.618	0.719	0.826	1.118	1.697	1.118
118.579	0.598	0.598	0.690	0.793	1.073	1.629	1.073
120.222	0.598	0.598	0.663	0.761	1.030	1.563	1.030
121.864	0.598	0.598	0.636	0.730	0.988	1.501	0.988
123.506	0.598	0.598	0.610	0.701	0.949	1.441	0.949
125.148	0.598	0.598	0.598	0.673	0.911	1.383	0.911
126.791	0.598	0.598	0.598	0.646	0.874	1.327	0.874
128.433	0.598	0.598	0.598	0.620	0.839	1.274	0.839
130.075	0.598	0.598	0.598	0.598	0.805	1.223	0.805
131.718	0.598	0.598	0.598	0.598	0.773	1.174	0.773
133.360	0.598	0.598	0.598	0.598	0.742	1.127	0.742
135.002	0.598	0.598	0.598	0.598	0.712	1.081	0.712
136.644	0.598	0.598	0.598	0.598	0.684	1.038	0.684
138.287	0.598	0.598	0.598	0.598	0.656	0.996	0.656
139.929	0.598	0.598	0.598	0.598	0.630	0.956	0.630
141.571	0.598	0.598	0.598	0.598	0.605	0.918	0.605
143.214	0.598	0.598	0.598	0.598	0.598	0.881	0.598
144.856	0.598	0.598	0.598	0.598	0.598	0.846	0.598
146.498	0.598	0.598	0.598	0.598	0.598	0.812	0.598
148.140	0.598	0.598	0.598	0.598	0.598	0.779	0.598
149.783	0.598	0.598	0.598	0.598	0.598	0.748	0.598
151.425	0.598	0.598	0.598	0.598	0.598	0.718	0.598
153.067	0.598	0.598	0.598	0.598	0.598	0.689	0.598
154.710	0.598	0.598	0.598	0.598	0.598	0.661	0.598
156.352	0.598	0.598	0.598	0.598	0.598	0.635	0.598
157.994	0.598	0.598	0.598	0.598	0.598	0.609	0.598
159.636	0.598	0.598	0.598	0.598	0.598	0.598	0.598
161.279	0.598	0.598	0.598	0.598	0.598	0.598	0.598
162.921	0.598	0.598	0.598	0.598	0.598	0.598	0.598
164.563	0.598	0.598	0.598	0.598	0.598	0.598	0.598
166.206	0.598	0.598	0.598	0.598	0.598	0.598	0.598
167.848	0.598	0.598	0.598	0.598	0.598	0.598	0.598
169.490	0.598	0.598	0.598	0.598	0.598	0.598	0.598
171.132	0.598	0.598	0.598	0.598	0.598	0.598	0.598
172.775	0.598	0.598	0.598	0.598	0.598	0.598	0.598
174.417	0.598	0.598	0.598	0.598	0.598	0.598	0.598
176.059	0.598	0.598	0.598	0.598	0.598	0.598	0.598
177.702	0.598	0.598	0.598	0.598	0.598	0.598	0.598
179.344	0.598	0.598	0.598	0.598	0.598	0.598	0.598
180.986	0.598	0.598	0.598	0.598	0.598	0.598	0.598
182.628	0.598	0.598	0.598	0.598	0.598	0.598	0.598
182.628	0.598	0.598	0.598	0.598	0.598	0.598	0.598

 OPW FEMI Flood Estimation Report	CLIENT: Briskalagh Ltd.		
	PROJECT: Briskalagh Renewable Energy Development		
	DOC. TITLE Qmed and Peak Flow Calculations for HP02u1		
	REFERENCE:	IE	25 05
Checked: IK	SUBJECT: CALCULATION OF QMED & PEAK DESIGN FLOWS IN UNGAUGED CATCHMENTS		
Approved: EMcK			

A Selection of the Subject Site

- A1 Ungauged Node ID
A2 Ungauged Node Catchment Descriptors:

15_1728_3

Physical Catchment Descriptors

AREA (km ²)	2.23	Node East	239895
BFIsols (index)	0.565	Node North	155624
SAAR (mm)	846.60	Centroid East	240710
FARL (index)	1.000	Centroid North	156590
DRAIND (km/km ²)	0.878	ALLUV	0.0179
S1085 (m/km)	25.310	ARTDRAIN	0.0000
ARTDRAIN2 (prop)	0.000	FOREST	0.0000
URBEXT (%)	0.0000		

B Module 1: Estimation of the Index Flood (QMED)

B.1. Estimation of QMED without the use of a pivotal site	0.37
B.2. Estimation of QMED by using one pivotal site: 30004	0.27
B.3. Estimation of QMED using three pivotal sites: 14057, 25040, 10021	0.46
B.4. Final chosen QMED estimate: Using the small catchment equation	0.98

C Module 2: Estimation of the flood growth factors and design flood magnitudes

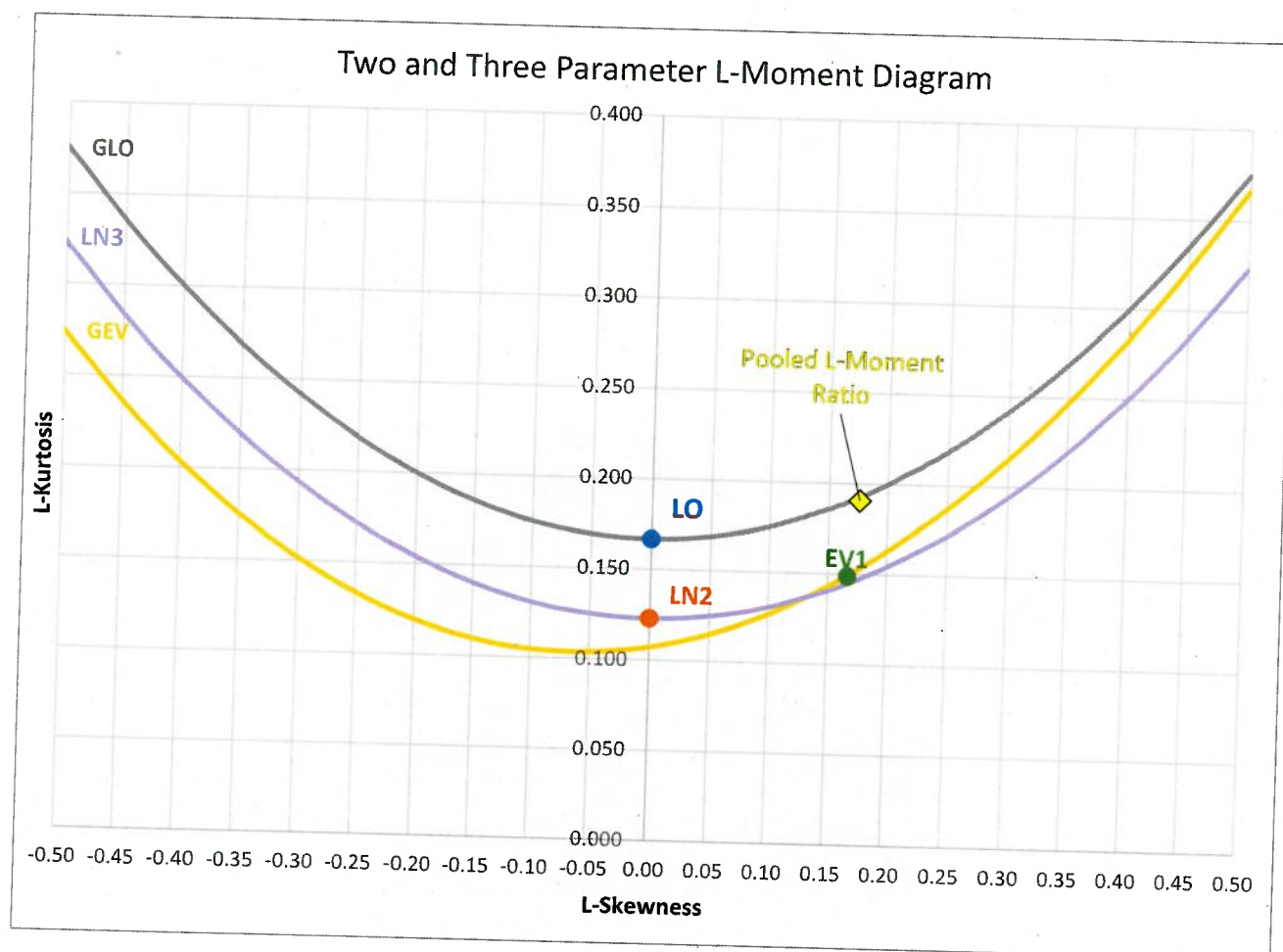
C.1. Selection of Pooling Group for flood frequency analysis

station no.	Location	similarity measure	No. of Yrs of data	t2 L-CV	t3 L-Skewness	t4 L-Kurtosis
16051	CLOBANNA	1.48	32	0.219	0.267	0.196
10021	COMMON'S ROAD	1.67	41	0.244	0.244	0.126
6033	CONEYBURROW BR	1.78	47	0.232	0.093	0.137
25040	ROSCREA	1.86	37	0.154	0.120	0.081
36031	LISDARN	1.96	25	0.151	0.291	0.215
14009	CUSHINA	2.04	43	0.144	0.064	0.166
16001	ATHLUMMON	2.22	51	0.129	0.000	0.108

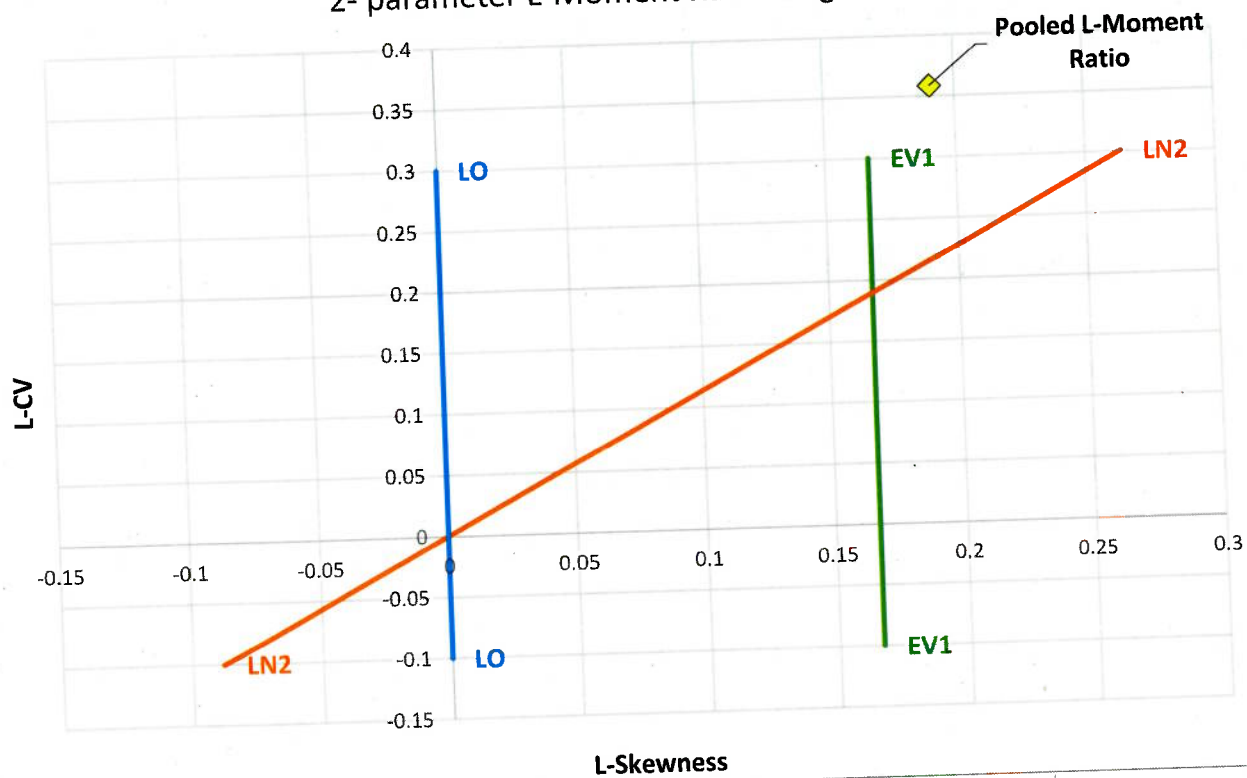
9037	BOTANIC GARDENS	2.27	24	0.342	0.305	0.100
11001	BOLEANY	2.42	51	0.150	0.185	0.240
9001	LEIXLIP	2.45	66	0.245	0.207	0.139
24005	ATHLACCA	2.50	35	2.670	0.471	0.447
36018	ASHFIELD	2.52	68	0.156	0.216	0.194

C.2. Selection of the best fit flood frequency distribution to the pooled data

L-Moment Ratio Diagrams:



2- parameter L-Moment Ratio Diagram



Final Growth Factors and Design Flows:

LN2		
Return Period (T)	Growth Factors	Design Flows
1.3	0.616	0.606
2	1.000	0.984
5	1.740	1.712
10	2.324	2.286
20	2.952	2.904
25	3.165	3.113
30	3.343	3.289
35	3.496	3.440
50	3.863	3.801
100	4.622	4.547
200	5.447	5.359
500	6.645	6.538
1000	7.641	7.517

Custom Return Period

100	4.622	4.547
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D Module 3: Generation of Design Hydrograph Shape Parameters

D.1. Generation of Initial Design Hydrograph Shape Parameters

Catchment Wetness Indicator (CWI)

Baseflow:

122
0.05 m ³ /s

n	Tr (hours)	C (hours)
4.43	17.54	41.54

D.2. Selection of most hydrologically similar catchments

	Station No.	Dij similarity measure	n	Tr	C
1st most similar	16004	0.138	3.236	62.757	76.105
2nd most similar	30005	0.250	5.270	67.750	30.299
3rd most similar	26019	0.279	3.122	64.848	73.906

D.2. Option 1: Adjusted parameters using most hydrologically similar catchment, 16004

n	Tr	C
2.340	24.712	69.128

D.2. Option 2: Adjusted Shape parameters using 3 no. Pivotal Sites, 16004, 30005, 26019

n	Tr	C
2.863	27.680	62.560

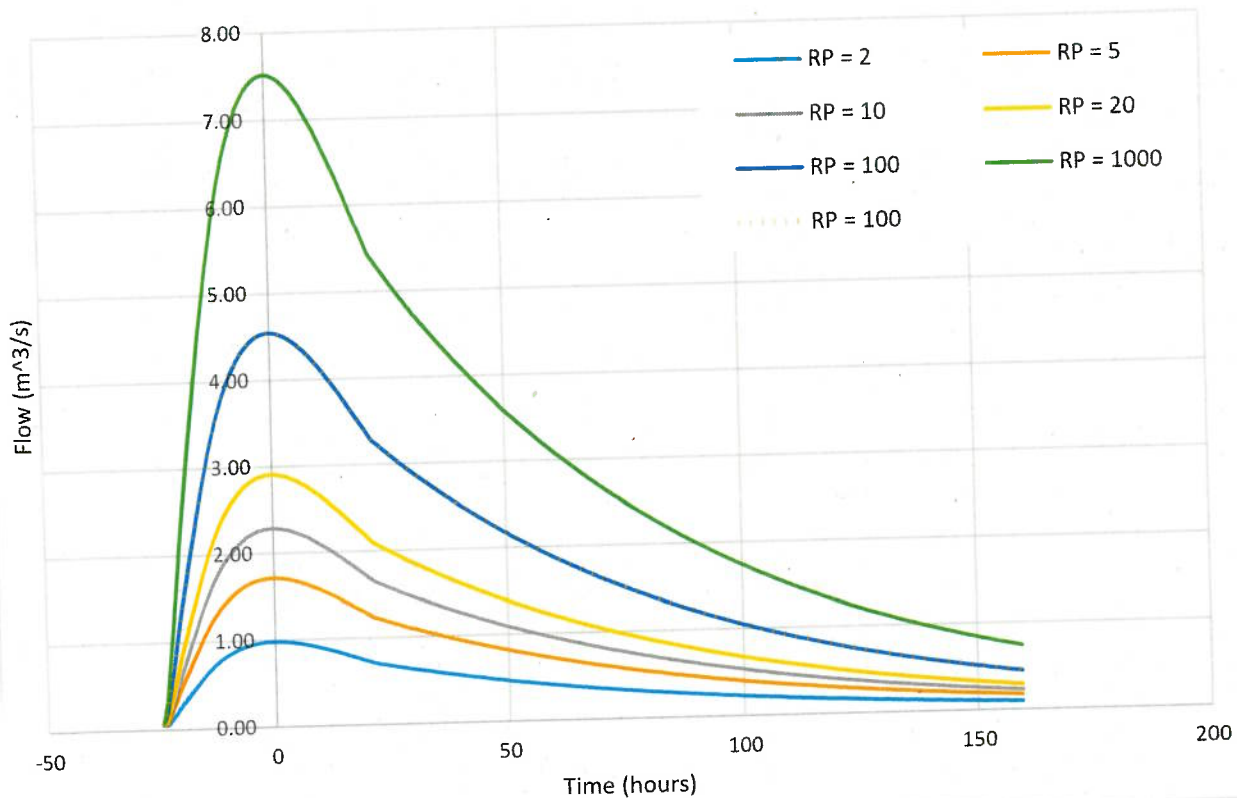
Chosen parameter selection method:

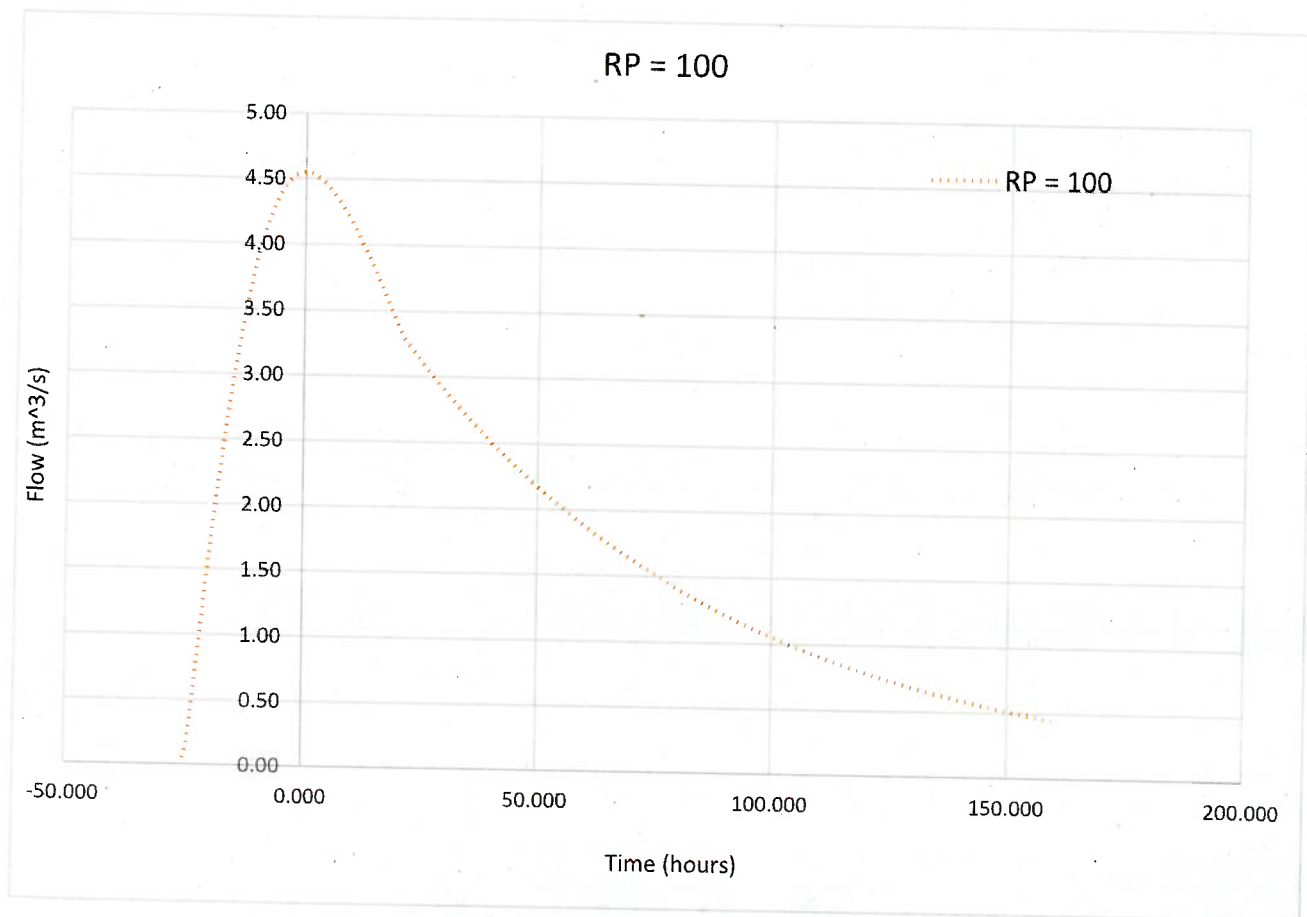
Adjusted parameters using most hydrologically similar catchment, 16004

D.3. Final Hydrograph Parameters:

n	Tr	C
2.340	24.712	69.128

All Design Hydrographs





Hydrograph Plot Data:

Time (Hours)	RP = 2	RP = 5	RP = 10	RP = 20	RP = 100	RP = 1000	Custom RP
-24.712	0.054	0.054	0.054	0.054	0.054	0.054	0.054
-23.791	0.054	0.076	0.101	0.129	0.201	0.333	0.201
-22.870	0.105	0.182	0.244	0.310	0.485	0.801	0.485
-21.948	0.172	0.299	0.399	0.507	0.794	1.312	0.794
-21.027	0.240	0.418	0.558	0.709	1.110	1.836	1.110
-20.106	0.308	0.536	0.716	0.910	1.424	2.355	1.424
-19.185	0.374	0.651	0.870	1.105	1.730	2.860	1.730
-18.264	0.438	0.762	1.017	1.292	2.023	3.345	2.023
-17.342	0.498	0.866	1.157	1.470	2.302	3.805	2.302
-16.421	0.555	0.965	1.289	1.637	2.564	4.239	2.564
-15.500	0.608	1.057	1.412	1.794	2.809	4.643	2.809
-14.579	0.657	1.143	1.527	1.939	3.036	5.019	3.036
-13.657	0.702	1.222	1.632	2.072	3.245	5.365	3.245
-12.736	0.744	1.294	1.728	2.195	3.437	5.681	3.437
-11.815	0.781	1.359	1.815	2.306	3.610	5.968	3.610
-10.894	0.815	1.418	1.894	2.406	3.767	6.228	3.767
-9.973	0.845	1.471	1.965	2.495	3.907	6.459	3.907
-9.051	0.872	1.518	2.027	2.575	4.031	6.664	4.031
-8.130	0.896	1.559	2.082	2.644	4.140	6.844	4.140
-7.209	0.916	1.594	2.129	2.704	4.234	7.000	4.234