Figure 11 - Cross Section Locations: Kil1 & Kil2

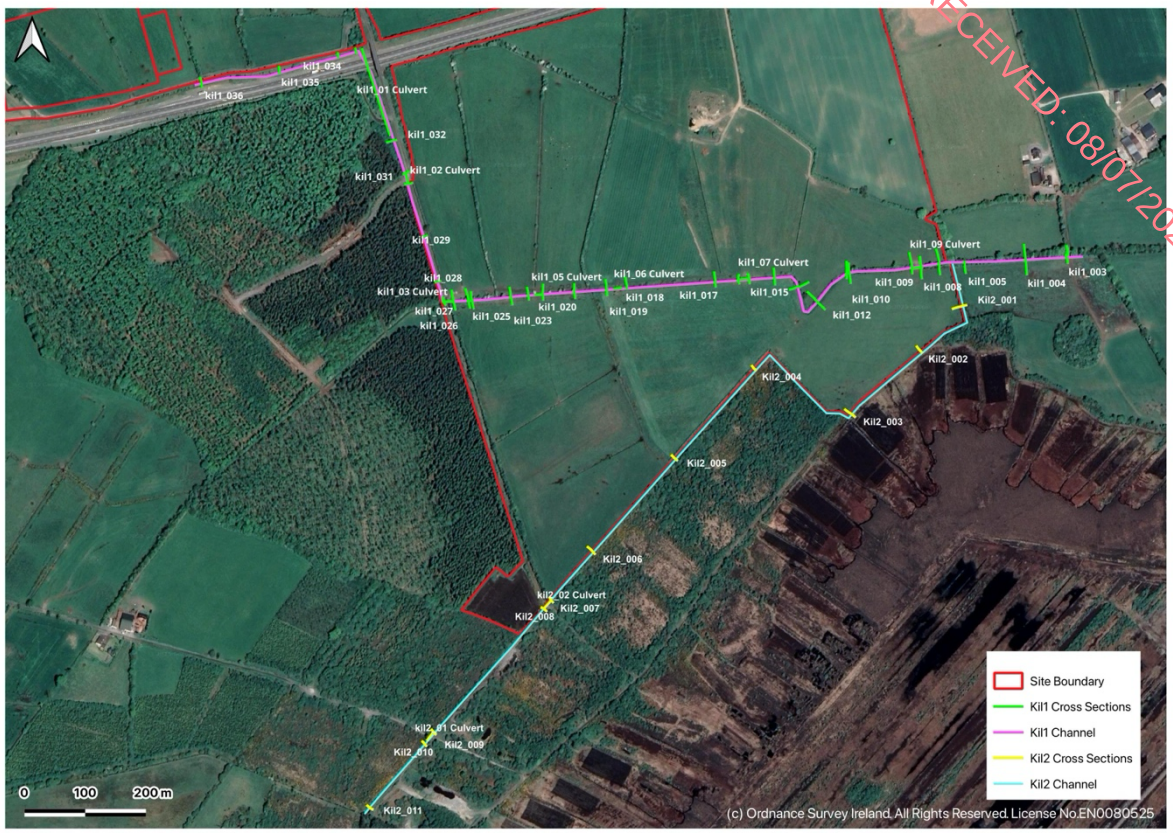
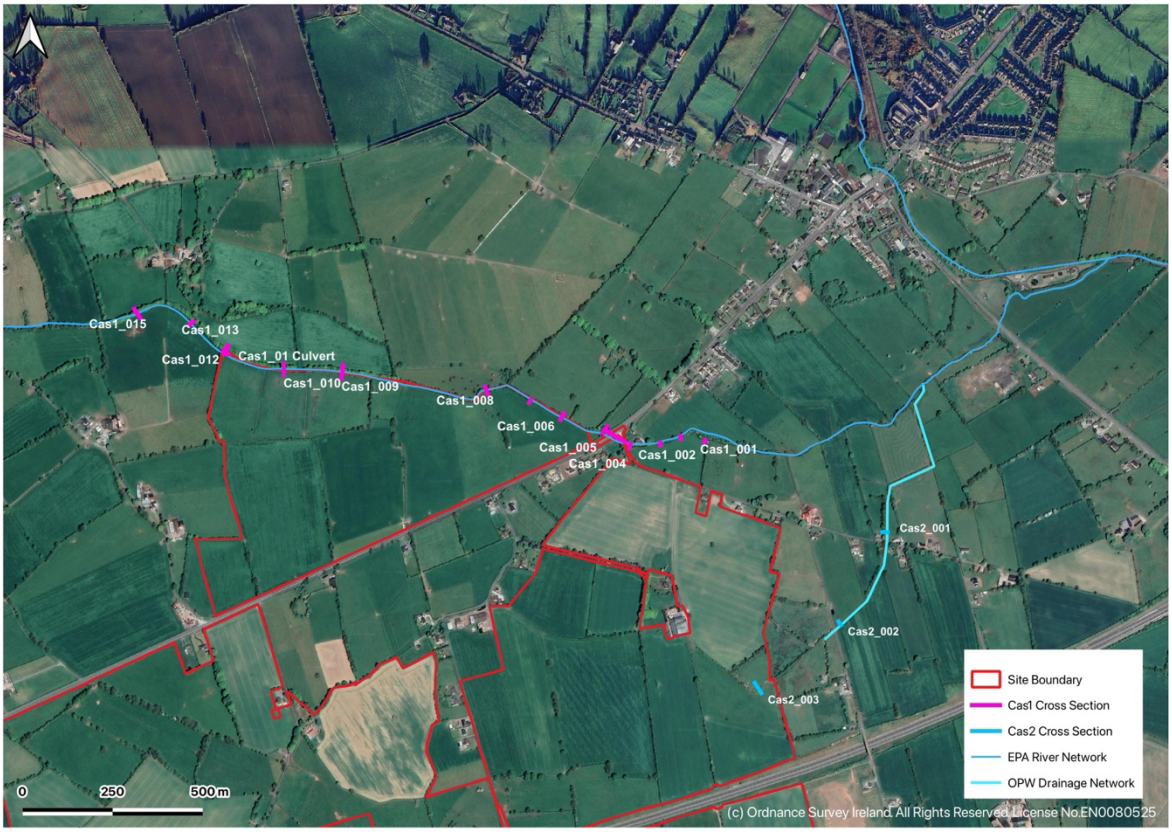


Figure 12 - Cross Section Locations: Cas1 & Cas2



5.2.2 Flow Boundaries

The Q_{100+cc} and Q_{1000} flow rates calculated above using Modified IH124 method were selected as the design flood flows through each channel. For catchments Kil2, Cas1 and Cas2 these flow rates apply to the catchment area at the downstream site boundary. In taking a conservative approach these flows were introduced as the upstream flow boundary, i.e. the start of the modelled reach.

Only in the case of Kil1 was this flow split to better represent flow gains through the catchment. Upstream of the motorway, the catchment which feeds into the culvert Kil1_01US represents 27% of the overall catchment area, resulting in Q_{100+cc} and Q_{1000} flow values of 0.79 m^3/s and 0.87 m^3/s respectively. The remainder was introduced at the culvert outlet (Kil1_01DS) resulting in a combined flow of 2.94 m^3/s and 3.24 m^3/s throughout the remainder of the modelled reach.

5.2.3 Roughness Coefficients & Channel Geometry

A Manning's roughness coefficient of 0.03 was applied to open river channel bed sections (noted as silty/gravelly) and a value of 0.04 applied to riverbanks. The Kil1, Kil2 and Cas1 channels are noted on the OPW drainage network database as being maintained as part of the Boyne arterial drainage district. It was observed during the site visit that the channel profiles generally have steep banks and channel beds with a low-gradient.

5.2.4 Existing Structures

Specifications of the key hydraulic structures on each of the surveyed watercourses are summarised below in Table 14.

Table 14 – Summary Details of Existing Hydraulic Structures

Culvert Ref	Location	Culvert Invert U/S mOD	Culvert Crown U/S mOD	Culvert Invert D/S (mOD)	Culvert Crown D/S (mOD)	Culvert Diameter (mm)	Culvert Length (m)
Kil1_01	TII M6 Motorway	90.56	91.09	86.37	87.27	530 U/S 900 D/S	160
Kil1_02	Forest Access Road	85.96	85.87	85.78	86.68	900	18.5
Kil1_03	Forest Access Road	83.94	84.94	83.93	84.93	1000	4.5
Kil1_04	Field Culvert	83.64	84.64	83.62	84.62	1000	4.5
Kil1_05	Field Culvert	83.26	84.26	83.26	84.26	1000	4.5
Kil1_06	Field Culvert	82.99	83.99	82.97	83.97	1000	7
Kil1_07	Field Culvert	82.31	83.61	82.29	83.59	1300	16.5
Kil1_08	Field Box Culvert	82.2	83.7	82.2	83.70	1500 x1500	3.5

Kil1_09	Field Culvert	81.82	83.42	81.79	83.39	1600	15.5
Kil2_01	Forest Access Road	82.518	83.518	82.51	83.51	1000	6
Kil2_02	Forest Access Road	82.113	83.113	82.05	83.05	1000	4.5
Cas1_01	Field Culvert	97.9	98.9	97.7	98.70	1000	5.5
Cas1_02	R446 Culvert	92.5	93.5	92.294	93.294	1000	60

5.3 SIMULATION: FLOOD FLOWS & FLOOD EXTENTS

The conveyance capacity of all surveyed cross sections along the existing stream were assessed for suitability to transmit Q_{100} and $Q_{1000+cc}$ flood flows. The design flows are presented in Table 15.

Table 15 – Modelled Q_{100} and $Q_{1000+cc}$ flood flows for each channel

Channel	Q_{100+cc} Flow (m^3/s)	Q_{1000} Flow (m^3/s)
Kil1 (036 – 032)	0.88	1.30
Kil1 (032-003)	2.94	3.24
Kil2	2.24	2.47
Cas1	2.26	2.99
Cas2	0.50	0.55

5.3.1 Simulation Results: Kil1

The predicted peak surface water elevations from the Flood Modeller 1D simulation during unsteady-state conditions are presented in Table 16.

Table 16 - Predicted surface water elevations for Q_{100} and $Q_{1000+cc}$ flood flows: Kil1

Cross Section	Kil1			
	Q_{100+cc} Flow (m^3/s)	Q_{100+cc} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
Kil1_036	0.79	92.95	0.87	93.00
Kil1_035	0.79	92.51	0.87	92.91
Kil1_034	0.79	92.50	0.87	92.91
Kil1_033	0.79	92.50	0.87	92.91
Kil1_01US	0.79	91.00	0.87	91.00
Kil1_01DS	0.79	87.31	0.87	87.49
Kil1_032	2.94	87.37	3.24	87.39
Kil1_031	2.94	87.30	3.24	87.32

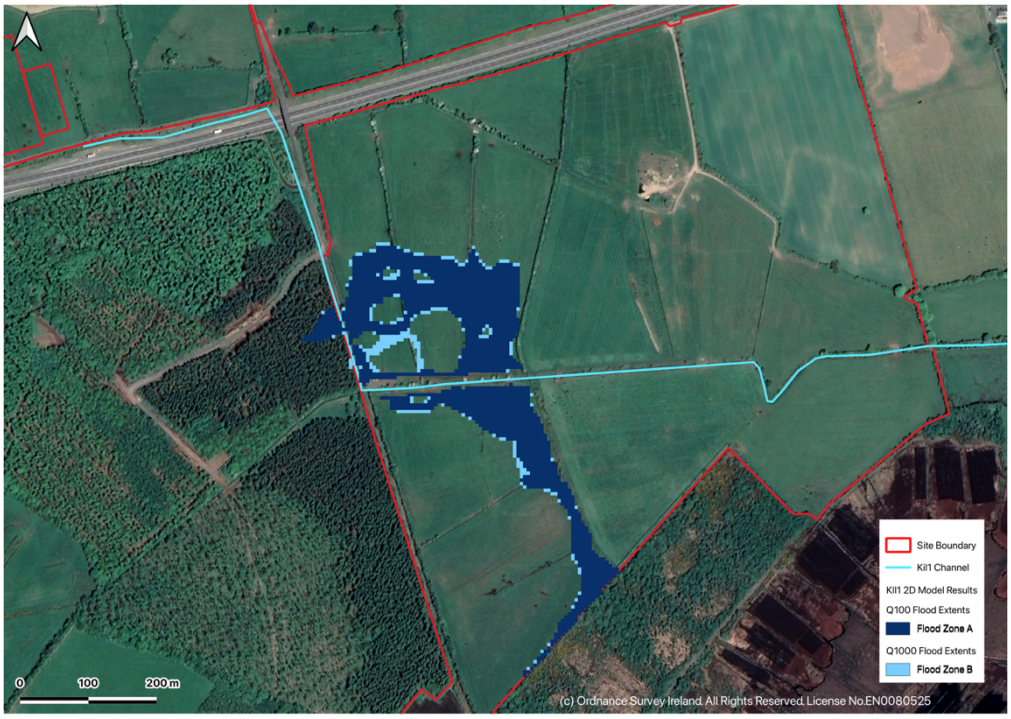
Cross Section	Kil1			
	Q_{100+cc} Flow (m^3/s)	Q_{100+cc} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
Kil1_02US	2.94	86.97	3.24	87.09
Kil1_02DS	2.94	86.88	3.24	87.00
Kil1_030	2.94	86.61	3.24	86.71
Kil1_029	2.94	86.45	3.24	86.62
Kil1_028	2.94	86.40	3.24	86.55
Kil1_027	2.94	86.38	3.24	86.53
Kil1_03US	2.94	86.15	3.24	86.30
Kil1_03DS	2.94	86.12	3.24	86.26
Kil1_026	2.94	85.67	3.24	85.81
Kil1_025	2.94	85.66	3.24	85.80
Kil1_04US	2.94	85.51	3.24	85.70
Kil1_04DS	2.94	85.49	3.24	85.68
Kil1_024	2.94	85.18	3.24	85.49
Kil1_023	2.94	85.18	3.24	85.49
Kil1_022	2.94	85.18	3.24	85.48
Kil1_05US	2.94	85.10	3.24	85.39
Kil1_05DS	2.94	85.09	3.24	85.38
Kil1_021	2.94	84.93	3.24	85.19
Kil1_020	2.94	84.93	3.24	85.18
Kil1_019	2.94	84.92	3.24	85.18
Kil1_06US	2.94	84.13	3.24	84.60
Kil1_06DS	2.94	84.08	3.24	84.54
Kil1_018	2.94	83.67	3.24	83.98
Kil1_017	2.94	83.64	3.24	83.97
Kil1_016	2.94	83.62	3.24	83.95
Kil1_07US	2.94	83.61	3.24	83.94
Kil1_07DS	2.94	83.58	3.24	83.89
Kil1_015	2.94	83.466	3.24	83.65
Kil1_014	2.94	83.38	3.24	83.60
Kil1_013	2.94	83.34	3.24	83.56
Kil1_012	2.94	83.31	3.24	83.54
Kil1_011	2.94	83.27	3.24	83.50
Kil1_08US	2.94	83.19	3.24	83.41
Kil1_08DS	2.94	83.18	3.24	83.40
Kil1_010	2.94	83.08	3.24	83.29

Cross Section	Kil1			
	Q_{100+cc} Flow (m^3/s)	Q_{100+cc} fluvial flood levels (mOD)	Q_{1000} Flow (m^3/s)	Q_{1000} fluvial flood levels (mOD)
Kil1_009	2.94	82.97	3.24	83.20
Kil1_09US	2.94	82.66	3.24	82.83
Kil1_09DS	2.94	82.62	3.24	82.79
Kil1_008	2.94	82.41	3.24	82.55
Kil1_007	2.94	82.38	3.24	82.53
Kil1_006	2.94	82.35	3.24	82.51
Kil1_005	2.94	82.06	3.24	82.19
Kil1_004	2.94	81.72	3.24	81.84

The results show that there is surcharging upstream of the culvert Kil1_02 (southwest of the southern site boundary and outside the application site) and upstream of Kil1_04 resulting in out of bank flooding.

The fate of surcharged flood waters was examined with a combined 1D-2D model. The 2D model confirms floodwaters overtop the left bank of Kil1_02 and across the southern portion of the application site in a southerly direction. Floodwaters flow back into the Kil1 channel at various points. Floodwaters at Kil1_04 exceed both banks. On the right bank, floodwaters flow in a southerly direction across the southern portion of the application site. The floodwaters continue to flow across the southern portion of the application site, along a field drain, before re-entering Kil2, in the vicinity of Kil2_006. The flood extents as generated by the 1D-2D model have been mapped in Figure 13. The maximum depth of flooding is 0.61 m in the southeast corner of the site, as floodwaters enter Kil2.

Figure 13 – Flood Extents emanating from Kil1



5.3.2 Simulation Results: Kil2

The predicted peak surface water elevations from the 1D unsteady state simulation for Kil2 are presented in Table 17. The results showed that there is surcharging upstream of the culverts Kil2_01 (southwest of the southern site boundary and outside the application site) and Kil2_02 (beneath the end of the laneway at the southwestern end of the southern portion of the application site), resulting in out of bank flooding.

The fate of surcharged flood waters was examined with a combined 1D-2D model. The 2D model confirms minor flooding upstream of Kil2_01, with these waters being outside the application site. The surcharge upstream of Kil2_02 was also minor, resulting in a floodplain of only 126 m^2, to maximum depths of 0.19 m and 0.42 m for the Q_{100} and $Q_{1000+cc}$ simulations, respectively (Figure 14).

Progressing downstream of these culverts, flood waters are maintained within the remainder of the channel, as shown in the Longitudinal Profile: Kil2 (see Appendix A).

Table 17 – Predicted surface water elevations for Q_{100} and $Q_{1000+cc}$ flood flows: Kil2

Cross Section	2.24 m^3/s	2.27 m^3/s
	Q_{100+cc} fluvial flood levels (mOD)	Q_{1000} fluvial flood levels (mOD)
Kil2_011	84.60	84.93
Kil2_010	84.58	84.91
Kil2_01US	84.37	84.66
Kil2_01DS	84.33	84.65
Kil2_009	83.93	84.13
Kil2_008	83.84	84.06
Kil2_02US	83.58	83.73
Kil2_02DS	83.55	83.70
Kil2_007	83.16	83.22
Kil2_006	83.06	83.12
Kil2_005	82.93	82.99
Kil2_004	82.72	82.76
Kil2_003	82.37	82.44
Kil2_002	82.16	82.21
Kil2_001	81.96	82.01

Figure 14 – Surcharging and Flood Zones adjacent to Kil2 Channel

5.3.3 Simulation Results: Cas1

The predicted surface water elevations from the 1D unsteady state simulation for Cas1 are presented in Table 18. The results showed that there is surcharging upstream of the culvert Cas1_02 (crossing under R446 at northeastern site corner), in both the Q_{100+cc} and Q_{1000} flood scenarios. However, this only occurs during the Q_{1000} flood scenario. The fate of these surcharge flood waters was examined with a combined 1D-2D model. The 2D model confirms that surcharged waters do not encroach on any part of the site boundary. They do however, spillover the R446, where the road has an elevation of 94.70 mOD. The flood waters continue south-east through a field and re-enter the Cas1 channel (Figure 15). Flood depths as the waters cross the R446 do not exceed a depth of 0.09 m (Table 18). Flood extents and depths were identical for the Q_{1000} simulation. Further downstream of this culvert, flood waters are maintained within the channel (Longitudinal Profile: Cas1; see Appendix A).

Table 18 – Predicted surface water elevations for Q_{100+cc} and Q_{1000} flood flows: Cas1

Cross Section	2.26 m^3/s	2.99 m^3/s
	Q_{100+cc} fluvial flood levels (mOD)	Q_{1000} fluvial flood levels (mOD)
Cas1_015	100.12	100.248
Cas1_014	99.93	100.072
Cas1_013	99.70	99.85
Cas1_012	99.63	99.78
Cas1_01US	98.68	98.81
Cas1_01DS	98.65	98.78
Cas1_011	98.32	98.40
Cas1_010	98.06	98.06
Cas1_009	98.07	98.07
Cas1_008	95.43	95.50
Cas1_007	94.65	95.09
Cas1_006	94.34	95.06
Cas1_005	94.25	95.05
Cas1_02US	93.69	94.37
Cas1_02DS	93.31	93.71
Cas1_004	92.94	93.03
Cas1_003	92.38	92.50
Cas1_002	92.16	92.30
Cas1_001	91.67	91.79

Figure 15 – Predicted Q_{1000} Flood Extents & Depths adjacent to Cas1 Channel

5.3.4 Simulation Results: Cas2

The predicted surface water elevations from the 1D unsteady state simulation for Cas2 are presented in Table 19. The results showed that there is no out of bank flooding. The associated longitudinal profile is illustrated in Appendix A).

Table 19 - Predicted surface water elevations for Q_{100+cc} and Q_{1000} flood flows: Cas2

Cross Section	0.50	0.55
	Q_{100+cc} fluvial flood levels (mOD)	Q_{1000} fluvial flood levels (mOD)
Cas2_003	90.60	90.61
Cas2_002	87.26	87.29
Cas2_001	86.85	86.88

5.4 PROPOSED BRIDGE CROSSINGS

Two new bridges are proposed to facilitate new internal access roads; these are to be installed along the Kil1 channel at locations as shown in Figure 16.

For new river crossing structures OPW guidelines (2013) advise that:

- *A bridge or culvert must be capable of passing a fluvial flood flow with a 1% annual exceedance probability (AEP) or 1 in 100-year flow without significantly changing the hydraulic characteristics of the watercourse.*
- *A bridge must be capable of operating under the above design conditions while maintaining a freeboard of at least 300 mm.*
- *A culvert diameter, height and width must not be less than 900 mm to facilitate maintenance access and reduce the likelihood of debris blockage.*

Envirologic have sized the proposed bridge crossings to ensure conveyance of Q_{100} flood flows, as calculated using the IH124 method. In addition, a further 20% allowance has been made for climate change. As per OPW Section 50 requirements a drainage factor of 1.6 has also been applied given the Kil1 channel is part of an OPW maintained arterial drainage scheme. The OPW requirements are satisfied as follows:

- Design flood flow as per OPW requirements = 3.72 m^3/s x 1.6 = 5.95 m^3/s

Each bridge structure shall consist of a precast concrete deck. Stone gabions will act as a foundation to the concrete base of the deck level, which will be set back approximately 1m from the top of the channel bank. There will be a minimum clearance of 400 mm from the top of the channel bank to the bridge soffit. A schematic of the bridge crossing design is illustration in Plate 6.

5.4.1 Br1

- Coordinates = 645,902 m Easting / 738,458 Northing;
- Design flood level = 85.35 mOD;
- Channel bank elevation = 86.79 mOD (left), 85.96 mOD (right);
- Soffit elevation = 87.20 mOD;
- Spring elevation = 86.79 mOD = left bank ground elevation;
- Bridge deck level = 87.70 mOD;
- Bridge Width = 6 m;
- Bridge Span = 28 m;
- Freeboard = 1.85 m;
    - OPW criteria for culvert design satisfied

5.4.2 Br2

- Coordinates = 646,259 m Easting / 738,439 m Northing;
- Design flood level = 84.09 mOD;
- Channel bank elevation = 84.46 mOD (left), 85.92 mOD (right);
- Soffit elevation = 86.32 mOD;
- Spring elevation = 84.46 mOD = left bank ground elevation;
- Bridge deck level = 86.82 mOD;
- Bridge Width = 6 m;
- Bridge Span = 23 m;
- Freeboard = 2.23 m;
    - OPW criteria for culvert design satisfied

Figure 16 - Location of Proposed Bridges