Appendix 15.3

Hydraulic Assessment of Sewers

Report No. HEL215601 v1.1

Arklow Sewerage Scheme

Hydraulic Assessment of Proposed Interceptor Sewer Pipe Encroachment of the River Avoca Channel at Arklow

On behalf of

Byrne Looby

August 2018

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Hydraulic Impact Assessment of proposed Interceptor Sewer Encroachment of the River Avoca Channel at Arklow

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Report No.:	**HEL0215601 v1.1**
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1. Introduction

Hydro Environmental Ltd have been engaged as sub-consultants by Byrne Looby to undertake a hydraulic impact assessment of the proposed Interceptor Sewer encroachment of the River Avoca as part of the Arklow Wastewater Treatment Plant Project. One proposed route for the Interceptor sewer pipe is along the south quay and an option being considered is the encroachment of the sewer pipe into the Avoca estuarine channel for a distance of 270m downstream of Arklow Bridge.

The proposed scheme is to run the proposed Interconnector Sewer under the existing bed of the first Arch at Arklow Bridge. The encroachment width from the existing quay walls downstream of the bridge is approximately 6m reducing the channel width from 96m to 90m at the downstream end of the encroachment, 117m to 111m at the mid-section and 132m to 126m towards the upstream section. This represents a reduction in channel area/width downstream of the bridge of 4.3% within the 270m reach section. The existing quay wall will be removed and replaced at a similar wall height along the edge of the encroachment both upstream and downstream of the bridge.

The proposal avoids direct obstruction of the Arklow Bridge arch at the existing bed levels but requires an upstream channel encroachment a short distance upstream of the arch for a manhole and access which potentially will interfere with the river flow entering the first bridge arch. The proposed alignment and channel encroachment is presented in Figure 1.

Figure 1: Proposed encroachment and new position of Quay Wall shown in Red

2. Methodology

2.1 Hydraulic modelling

A 2-D hydraulic model developed by Hydro Environmental Ltd. for the feasibility and engineering design of the Arklow Flood Relief Scheme was used to assess and quantify the hydraulic impact of the proposed Interceptor Sewer encroachment on flows and flood levels in the Avoca River at Arklow. This model uses the TELEMAC hydraulic software package, which is considered to be one of the leading hydraulic software packages internationally for such assessments.

The Telemac-2D model was revised to include a more recent river channel bathymetric survey carried out by Murphy Survey's Ltd. in March 2017 as part of this project. This new bathymetry data covered a reach distance of 575m upstream and 650m downstream of Arklow Bridge, including Arklow Bridge itself (refer to Figure 2) and replaces older survey data in the flood model.

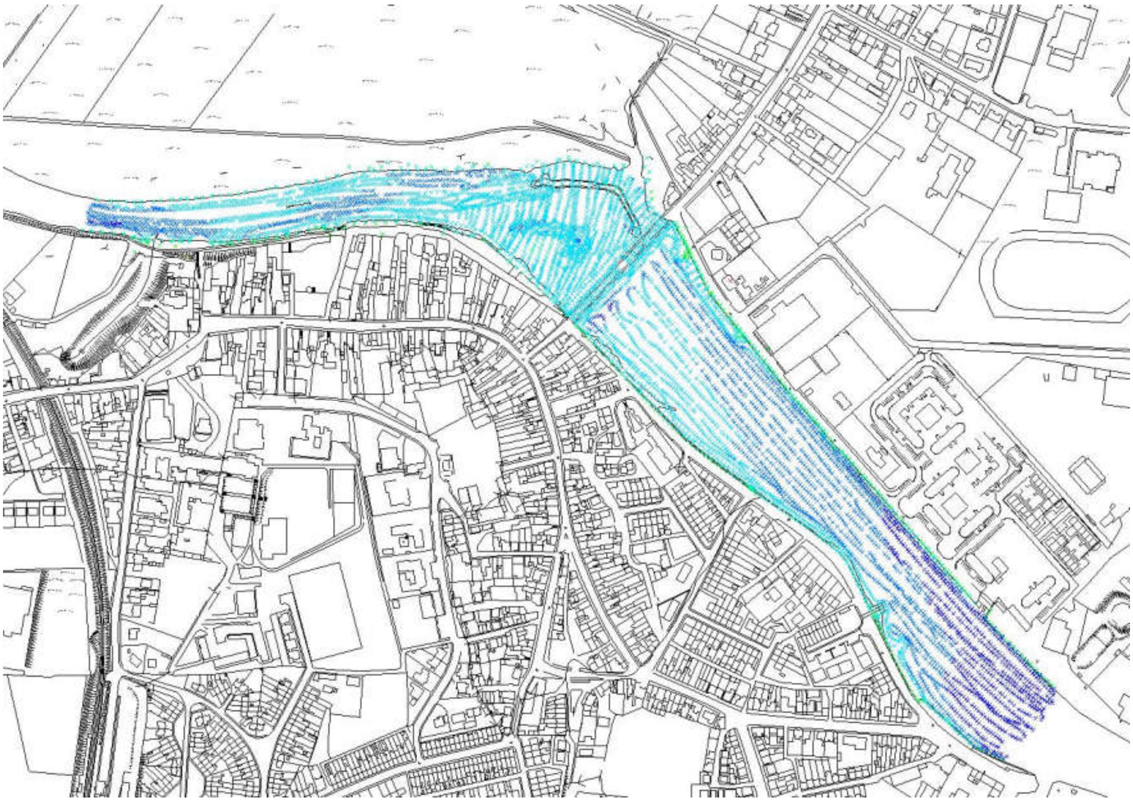

Figure 2: Extent of the March 2017 Murphy Survey of the Avoca near Arklow Br.

2.2 Design Flood Event

The design flood event for the impact assessment is the combined 200year event represented by the 100year river flood and the 0.35year tide (which is the critical combination of fluvial and tidal event). The design flow includes the OPW factors of safety in respect to factorial errors of the flood Study estimation method.

The design flood flows in the Avoca River at Arklow used in the Arklow Flood Relief Scheme Study were estimated using the FSR (Flood Study Report) ungauged catchment characteristic Index Flood Method. The catchment characteristics method gave a QBAR (mean annual maximum Flood Flow) of 247 m^3/s and 363 m^3/s, when multiplied by the Standard Factorial Error (SFE) of 1.47, i.e. a runoff rate of 0.557cumec/km^2. In designing bridges and flood relief schemes it is normal to include the statistical standard error of the estimation method as a safety factor against under predicting. The inclusion of the statistical standard error represents the upper 67-percentile confidence range and including twice the standard error represents the upper 95-percentile confidence interval.

The return period flood flows were derived by multiplying the QBAR estimate by a representative flood growth curve for the catchment. The lack of suitable recorded flood data from similar catchments located in the East / South East region of Ireland in respect to size and runoff, soil type precluded a detailed Pooled Group analysis for the Avoca River. As such, the growth curve for the Avoca River was approximated from combining the growth curves for the Slaney, Owenavorragh, Avonmore and Aughrim Rivers and the growth curve derived by Bruen et al. (2005) for the smaller gauged catchments in the Dublin area. This led to a proposed 100-year Growth Factor of 2.30. Including the SFE, the 100year flood flow estimate for the Avoca River at Arklow is 835m^3/s.

Table 1: Summary of design flood flows with and without climate change

Return Period	Design Flow m^3/s (no climate change allowance)	Design Flow m^3/s (with climate change allowance**)	Design Flow with SFE* m^3/s (no climate change allowance)
2	231	277	340
5	322	386	473
10	381	457	560
25	457	548	672
50	512	614	753
100	568	682	835
200	627	752	922
500	698	838	1026

*SFE is the standard factorial error of the regression equation used (SFE = 1.47)
** Climate Change Allowance – 20% increase in Flow Rate

The design flood hydrograph shape was derived using the Flood Study Report (FSR) hydrograph method and is specified at the upstream flow boundary of the model domain and the 0.35year design tidal curve of period 12.4hours with a highwater

0.83m OD at the downstream harbour open sea boundary. The design return period tidal levels were obtained from the Irish Costal Protection Strategy Study (ICPSS) Phase II Study (DCMNR, 2006) that was funded by the (then) Department of the Communications, Marine and Natural Resources.

Table 2: Combined 200year Fluvial Flow and Storm Tide Events

Fluvial Event (yrs)	***100***	***50***	***10***	***1.5***	***1***	***0.75***	***0.5***
Q_T (cumec)	835	753	560	307	255	217	164
Tide (highwater) event (yrs)	***0.35***	***0.75***	***3.5***	***10***	***50***	***100***	***200***
H_T (m OD Malin)	0.83	0.92	1.107	1.23	1.4	1.48	1.56

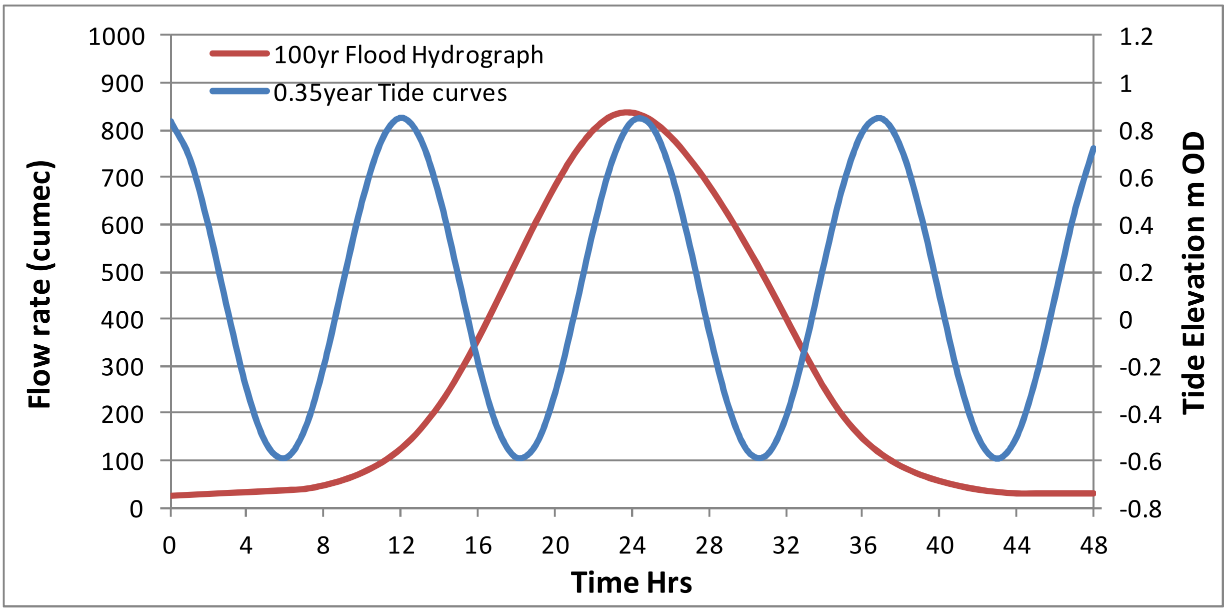

Figure 3: Combined 200year Flood Event (100year Fluvial Flood and 0.35year Tide)

3. Hydraulic Model simulations

3.1 Proposed Sewer Pipe Encroachment

The TELEMAC-2D Hydraulic model of the Avoca was run with and without the proposed Interceptor Sewer quay wall encroachment for the design flood event design flood of 835cumec and a corresponding tide with a highwater level of 0.83m. the shape and timing of the flood and tidal hydrographs were combined to ensure that the flood peaks coincided, refer to Figure 3. Six output locations identified as locations 1 to 6 in Figure 4 are used to compare computed river flood levels between the existing and the proposed encroachment case. The computed maximum flood levels at these reference points are presented in Table 3 for existing and proposed Interceptor Sewer case.

The effect of a c. 6m narrowing of a 270m length of Avoca estuarine channel immediately downstream of Arklow Bridge and the local encroachment immediately upstream of the Bridge produces a 0.033m rise in flood level immediately downstream of the bridge (location 3). The combined impact upstream of the encroachment including the upstream manhole encroachment produces a small rise of 0.017 to 0.019m at locations 4 to 6 respectively.

Table 3: Predicted peak flood elevations for existing case and the proposed Interceptor Sewer encroachment

Reference location Refer to Figure 4	Existing mOD	Proposed With Interceptor Encroachment m OD	Difference (m)
1	1.629	1.622	-0.007
2	1.977	1.970	-0.007
3	2.270	2.303	+0.033
4	3.236	3.253	+0.017
5	3.361	3.380	+0.019
6	3.409	3.427	+0.018

A rise of 3.3cm in predicted flood level caused by the Interceptor Sewer encroachment applies to a localised section of channel located immediately downstream of the bridge. The simulation shows that for much of the encroachment reach, the flow velocity increases which in turn limits or slightly reduces the peak flood levels in the narrowed channel section.

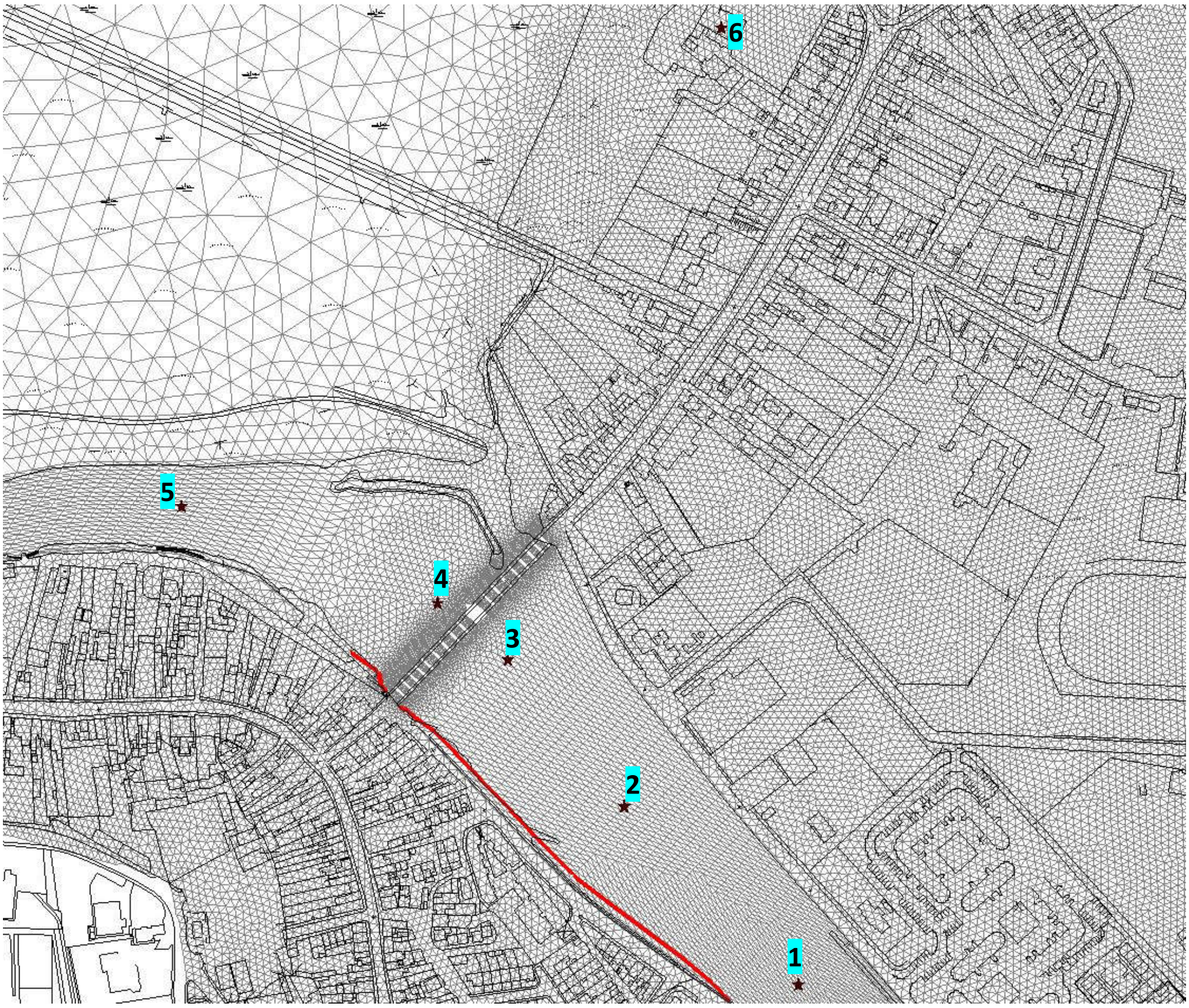

Figure 4: Reference Site locations within the Avoca River Channel for flood level impact prediction between existing and proposed Interceptor

A 1.9cm rise in upstream flood level is relatively minor and will not result in any significant impact on spill volumes discharging overbank on the north and south banks. The minor scale of impact of the encroachment on the design flood level in the river is represented in Figure 5 showing the predicted longitudinal Flood Profile for existing and proposed cases and also in Figure 8 showing the computed flood extent.

The computed flood flow velocities in the river channel for the existing and proposed cases are presented in Figures 6 and 7. The flow field plot shows increased velocities in the vicinity of the encroachment due to a reduction in flow width and area, refer to Figure 8 which presents change in flood velocity magnitude.

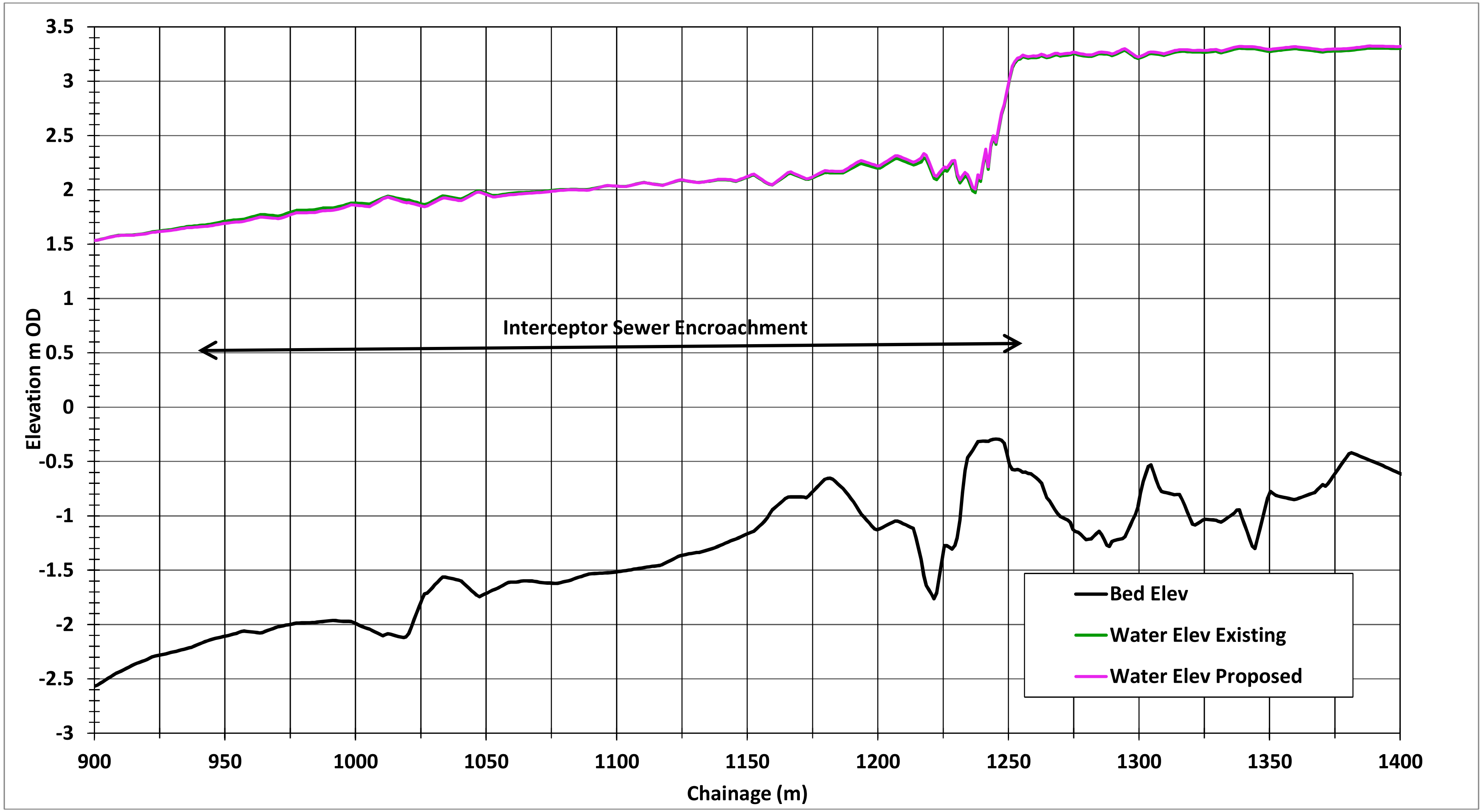

Figure 5: Computed Design Flood Profiles for the existing Case and proposed Sewer Encroachment Case

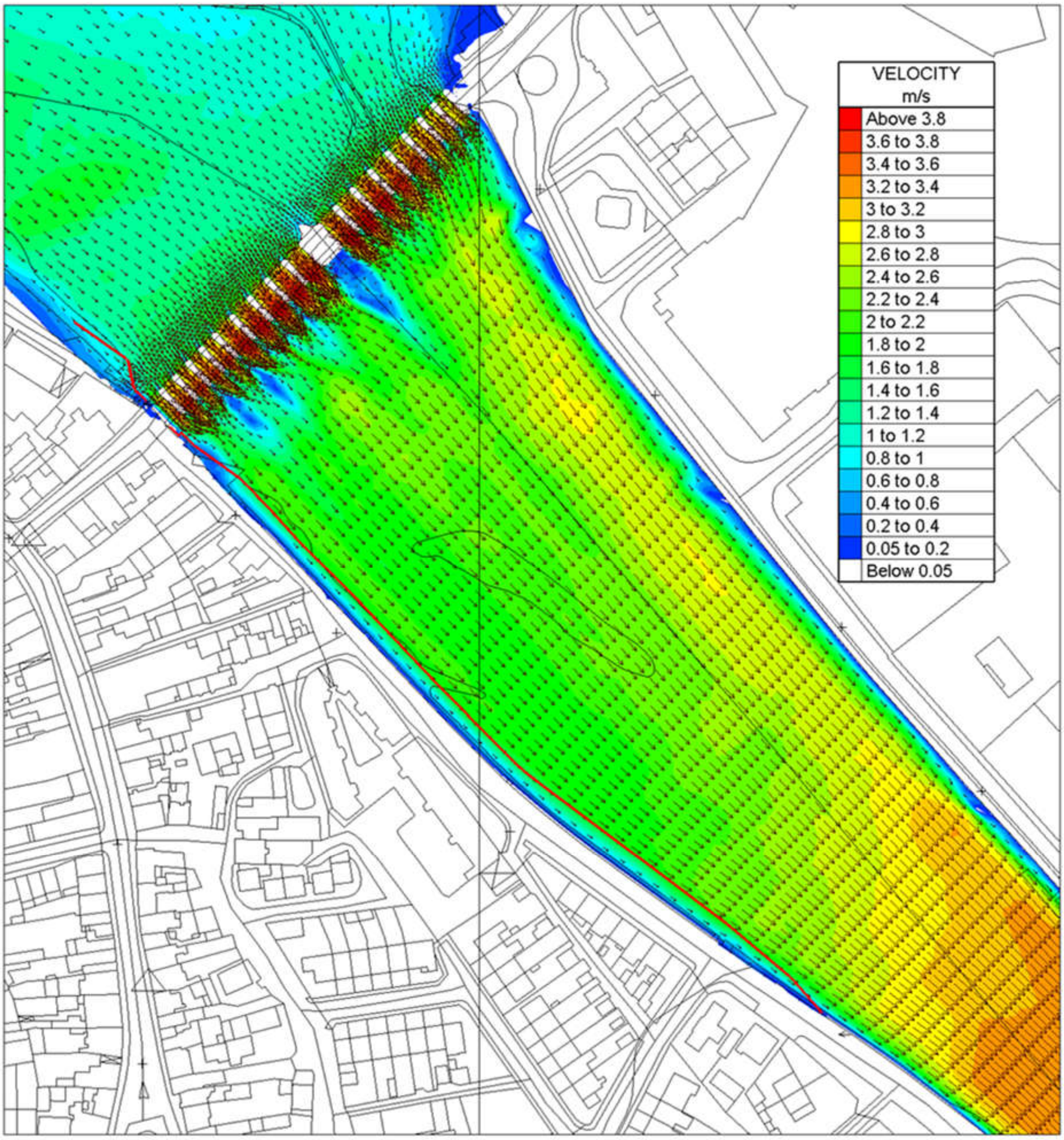

Figure 6: Flood flow velocities in river channel for Existing Case

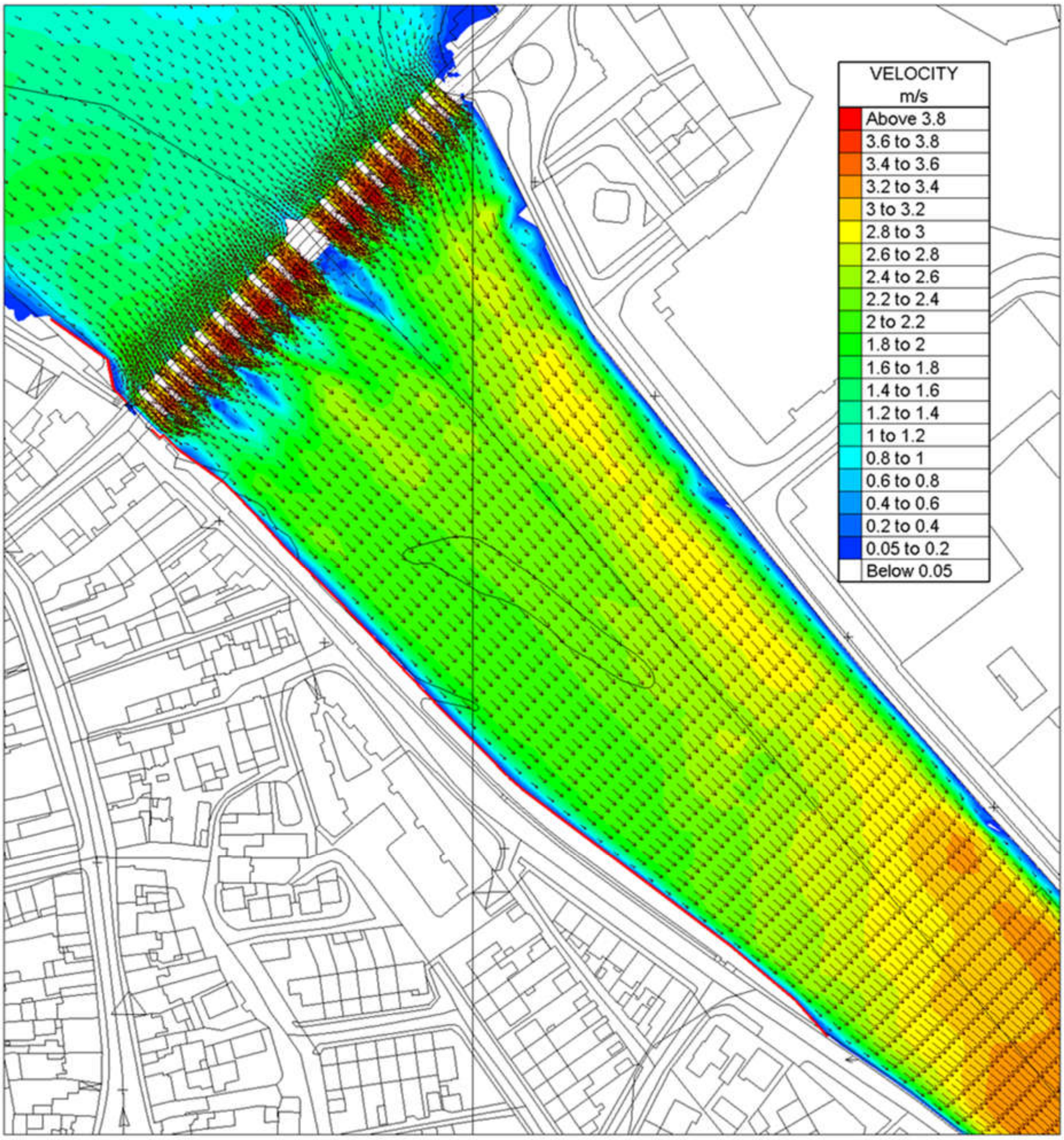

Figure 7: Flood flow velocities in river channel for proposed Interceptor Sewer encroachment

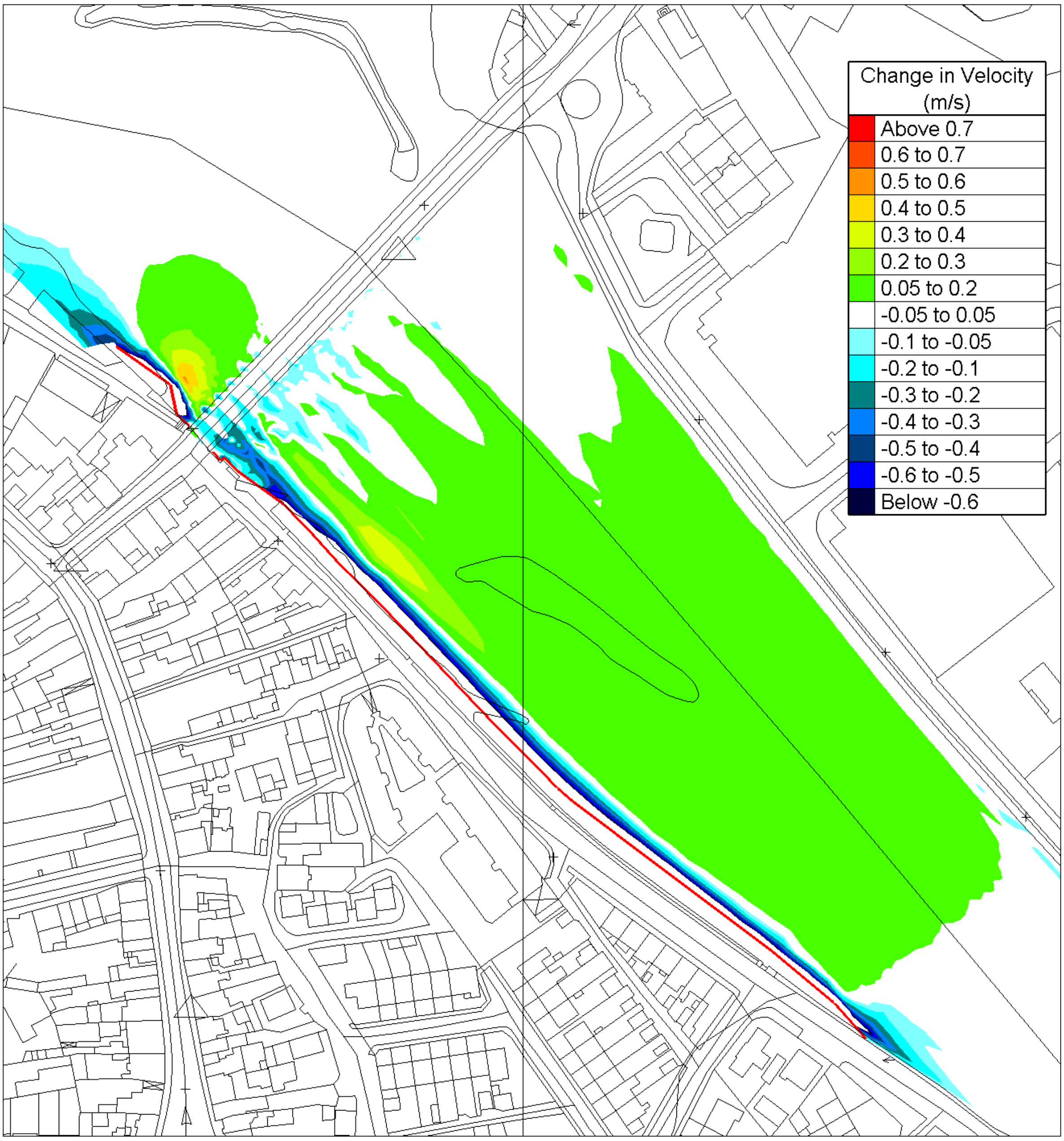

Figure 8: Change in flood flow velocity magnitude as a result of the proposed Interceptor Sewer encroachment

3.2 Flood Impact

The flooding of Arklow is principally caused by Arklow Bridge which under a design flood of 835cumec produces a significant bridge afflux of almost 1.2m (refer to Flood Profile presented in Figure 5). Such upstream flood levels cause flood waters to spill out of channel upstream of the Bridge on both north and south banks and flow as overbank flow downstream and returning to the downstream estuarine channel downstream of the Arklow Bridge. Therefore, increases in flood levels upstream of the bridge are critical as these could potentially worsen flooding in Arklow and where possible such impacts should be avoided or mitigated for.

The proposed Interceptor Sewer encroachment results in a small increase in the design flood level upstream of the Bridge of 0.019m, which in the context of the upstream flood level of c. 3.25 to 3.4m OD that produces overbank flood depths of 1 to 1.5m, is very minor and unlikely to impact significantly the flood risk in Arklow. The flood extents map presented in Figure 9 demonstrates limited effect that a 1.9cm upstream river level rise has on flooding in Arklow.

The development Management justification test in the Flood Risk Management Planning Guidelines (2009)[1] for developments that are located in floodplains or in moderate and high flood risk zones (A and B) require that such developments do not increase flood risk elsewhere and, if practicable, will reduce the overall flood risk, refer to Box 5.1 2. (i) in the flood risk management planning guidelines.

The local increase in downstream flood level of 3.3cm by the proposed Interceptor Sewer encroachment will not increase flooding as adjacent overbanks behind the quay walls will already have been flooded from floodwaters spilling out of bank upstream of the bridge and such flood waters returning to the estuarine reach further downstream. The predicted flood extents under the existing and proposed cases for the 100year design flood are presented in Figure 9, showing very slight expansion of the flood extents on the North side and no discernible change on the southside.

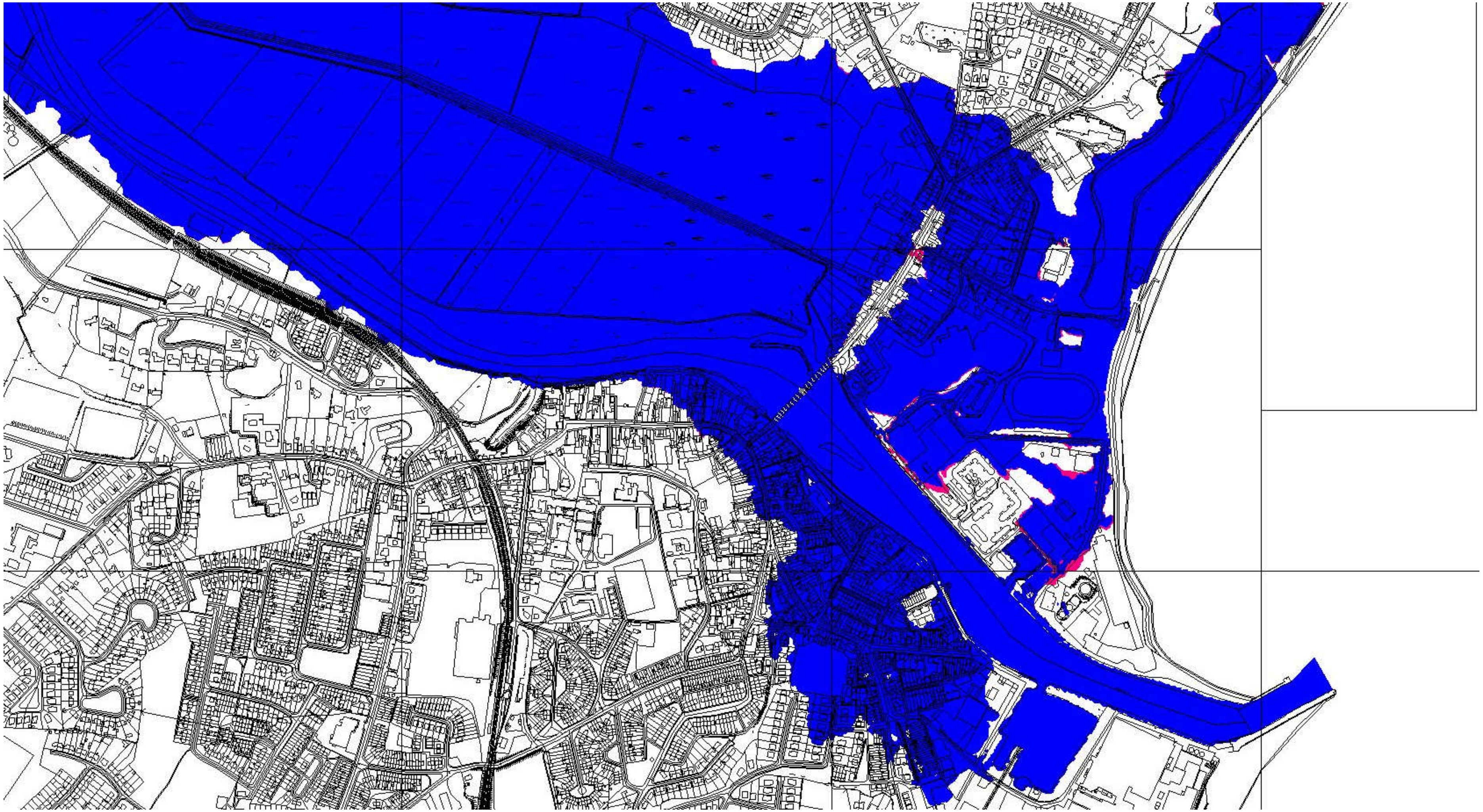

Figure 9: Predicted Flood Extents with and without Interceptor (Blue existing without interceptor and Magenta with interceptor)

3.3 Flood Mitigation

A proposed local mitigation measure that would mitigate and provide a small positive impact on upstream flood levels is the localised lowering of the bed in Arch 2 of Arklow Bridge. Arch 2 is the adjacent arch to the sewer pipe which is to be buried under the existing bed of Arch 1). The proposed lowering of the invert level is by 1m from c. -0.3m OD to -1.3mOD. To facilitate this lowering, dredging would extend 10m upstream and downstream of the arch to provide a suitable transition and met equivalent bed levels downstream. For scour protection the new bed at the bridge would have to be concrete lined or suitably sized rip-rap armour stone protection.

A simulation was carried out of this localised lowering which extended 10m upstream of the arch and 10m downstream. The predicted flood levels at the selected reference points for the proposed case and the mitigation measure are presented in Table 5 below.

This simulation shows that a slight reduction in upstream flood level can be achieved through this local mitigation measure, refer to Table 4 below.

Table 4: Predicted peak flood elevations under design flood conditions for existing baseline case and with proposed mitigation

Reference location Refer to Figure 4	Existing mOD	Proposed Interceptor Sewer and lowering of Arch 2 m OD	Difference (m)
1	1.629	1.623	-0.006
2	1.977	1.970	-0.007
3	2.270	2.303	+0.033
4	3.236	3.228	-0.008
5	3.361	3.356	-0.005
6	3.409	3.404	-0.005

The results of the simulation show a local increase in flood elevation of 3.3cm downstream of the bridge at locations 3 within the channel due to the Interceptor Sewer encroachment during the operation of the proposed sewer i.e. with underpinning of the arches and lowering of the 2nd Arch and temporary causeway fully removed. This 3.3cm increase in downstream flood level is shown not to be critical to the floodplain inundation and flood risk at Arklow for both north and south banks with an overall minor reduction in the flood extents which would be a slight beneficial impact.

The computed flood flow velocities in the river channel for the existing and proposed Interceptor Sewer with underpinning of first 2 arches and lowering of the 2nd Arch by 1m are presented in Figures 10 and 11. The flow field and plot shows increases in flow velocity upstream of 2nd Arch, reduction in the dredged area and increases in velocity in the downstream channel, particularly on the southern side. The higher velocities still remain on the northern side of the channel.

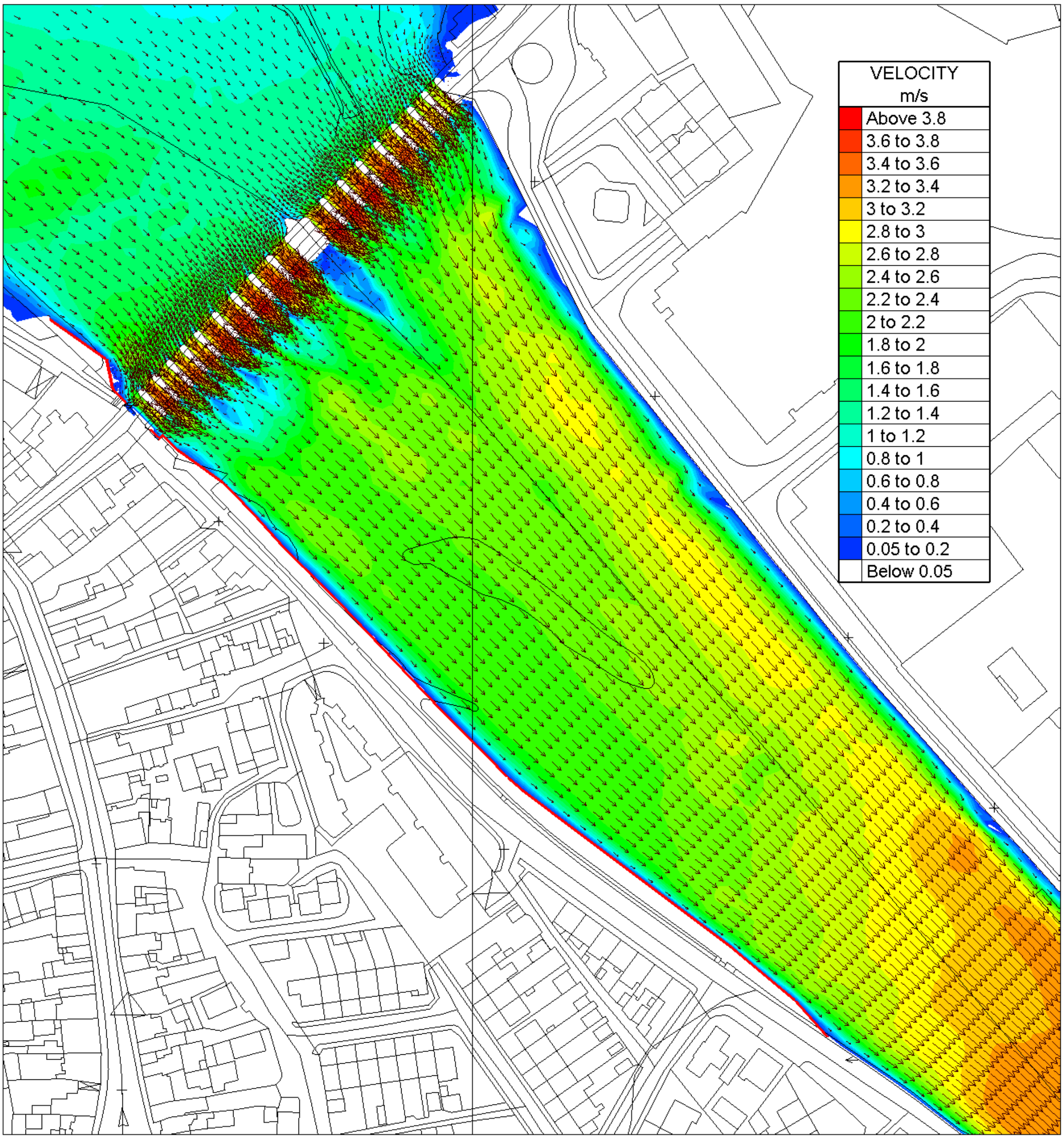

Figure 10 Computed Flood flow velocities for Interceptor sewer and localised deepening of Arch 2

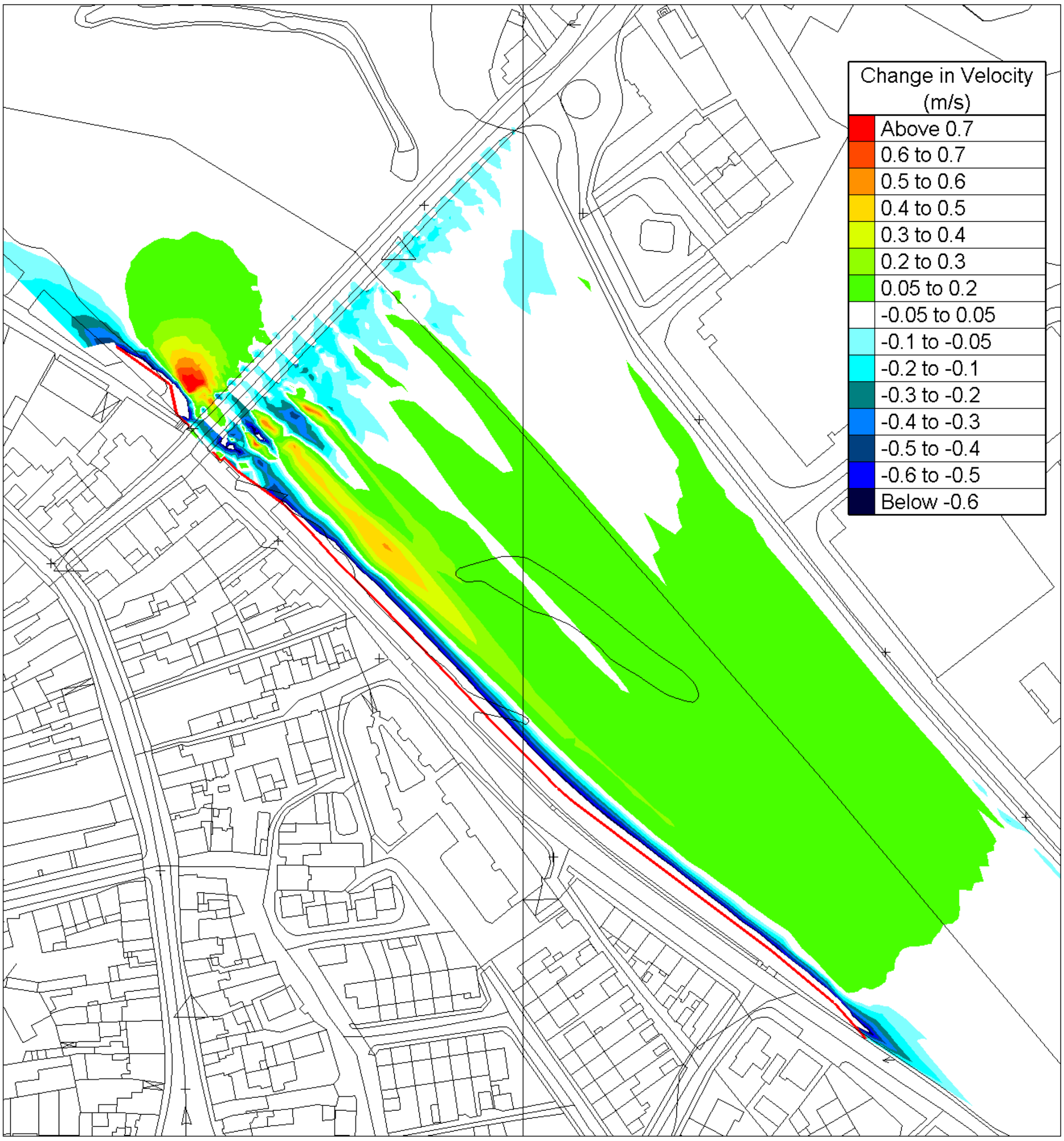

Figure 11 Computed change in Flood Flow Velocity magnitude as a result of Proposed Interceptor sewer and localised deepening of Arch 2

3.4 Proposed Construction Temporary Causeway Encroachment

A temporary causeway is required to facilitate construction of the Interceptor Sewer in the river channel. The temporary causeway would include a sufficient working area for installing manholes, the Interceptor Sewer and sheet pile walls. The causeway would also include provision for a c. 10m wide haul road for HGVs and larger construction plant required to allow excavated material to be removed from the working area, refer to Figure 13. This 10m width is inclusive of the 6m wide permanent encroachment required for the Interceptor Sewer.

The temporary causeway would be constructed from clean, suitable engineered fill granular material free from fines. The causeway would be contained on the river side to mitigate against siltation migration into the Avoca River. The two most likely methods to achieve this containment would either be an additional row of sheet piles on the river side of the causeway or alternatively a row of stone gabions wrapped in a geotextile membrane. Either method would require that the containing material (i.e. the sheet piles or the gabion walls) are extended (i.e. to a height above the surface of the causeway) to be effective.

The proposed elevation of the downstream causeway / haul road is 0.8m OD which includes for highwater mean spring tide of 0.5m OD plus 0.3m Freeboard.

To mitigate and minimise the potential flood impact caused by the construction causeway encroachment of the river channel the following sequence of works is proposed prior to construction of the approximately 270m long causeway downstream of the bridge:

- Proposed underpinning of the first 2 arches and lowering of the 2nd Arch by 1m at the bridge is completed
- Proposed in-stream works at and upstream of the bridge (i.e. the upstream Interceptor Sewer Manhole and the laying of the Interceptor Sewer beneath the bed of Bridge Arch 1).
- Installation of the proposed temporary causeway from downstream to upstream (i.e. from east to west direction).
- Following completion of construction of the Interceptor Sewer in the Avoca River (i.e. when the causeway is no longer required), the causeway would be removed in a similar sequential manner.
- Timely removal of sections of causeway should be a priority once works have been completed

The extent of this causeway is shown in Figure 12 and a cross-section through the causeway is presented in Figure 13.

Figure 12 Construction Infill Area that includes for the Temporary haul road

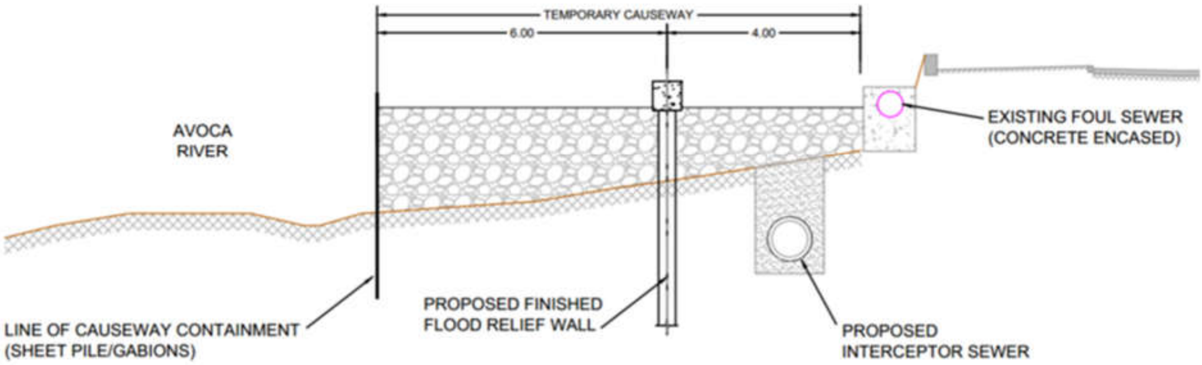

Figure 13 Cross Section through proposed temporary causeway

A flood simulation modelling the 100year design flood event was carried out to investigate the impact of the proposed temporary downstream causeway on design flood levels and flood risk. The simulation assumes that the upstream in-channel works have been completed and include the mitigation measure of deepening and underpinning bridge arch 2, the construction of the Interceptor Sewer manhole upstream of the bridge and all the in-stream works at the bridge (i.e. interceptor sewer through Arch 1 completed and arch reopened).

The computed maximum flood levels at the selected reference points (refer to Figure 4 for locations) are presented in Table 5 for existing and proposed construction causeway case. The simulation shows an overall very slight beneficial impact upstream of the bridge which is critical to mitigating flood impact of the downstream encroachment.

Table 5: Predicted peak flood elevations under design flood conditions for existing baseline case and with the infill for the construction haul road

Reference location Refer to Figure 4	Existing mOD	Proposed Construction Infill haul road m OD	Difference (m)
1	1.629	1.601	-0.028
2	1.977	1.996	+0.019
3	2.270	2.325	+0.055
4	3.236	3.234	-0.002
5	3.361	3.360	-0.001
6	3.409	3.408	-0.001

The simulation shows downstream of the bridge at locations 2 and 3 within the channel, an increase in flood elevation of 1.9 and 5.5cm respectively due to the causeway encroachment. These increases are shown not to be critical to the floodplain inundation and flood risk at Arklow for both north and south banks, which are flooded from upstream of the bridge, refer to Figure 16 showing an overall minor reduction in the flood extents- very slight beneficial impact.

The computed flood flow velocities and change in velocity magnitude for this simulation are presented in Figures 14 and 15.

Without the proposed mitigation of underpinning and phasing the in-stream bridge and upstream works first, the potential increase in upstream Flood Level under the design flood scenario is estimated to be c. 6 to 6.5cm.

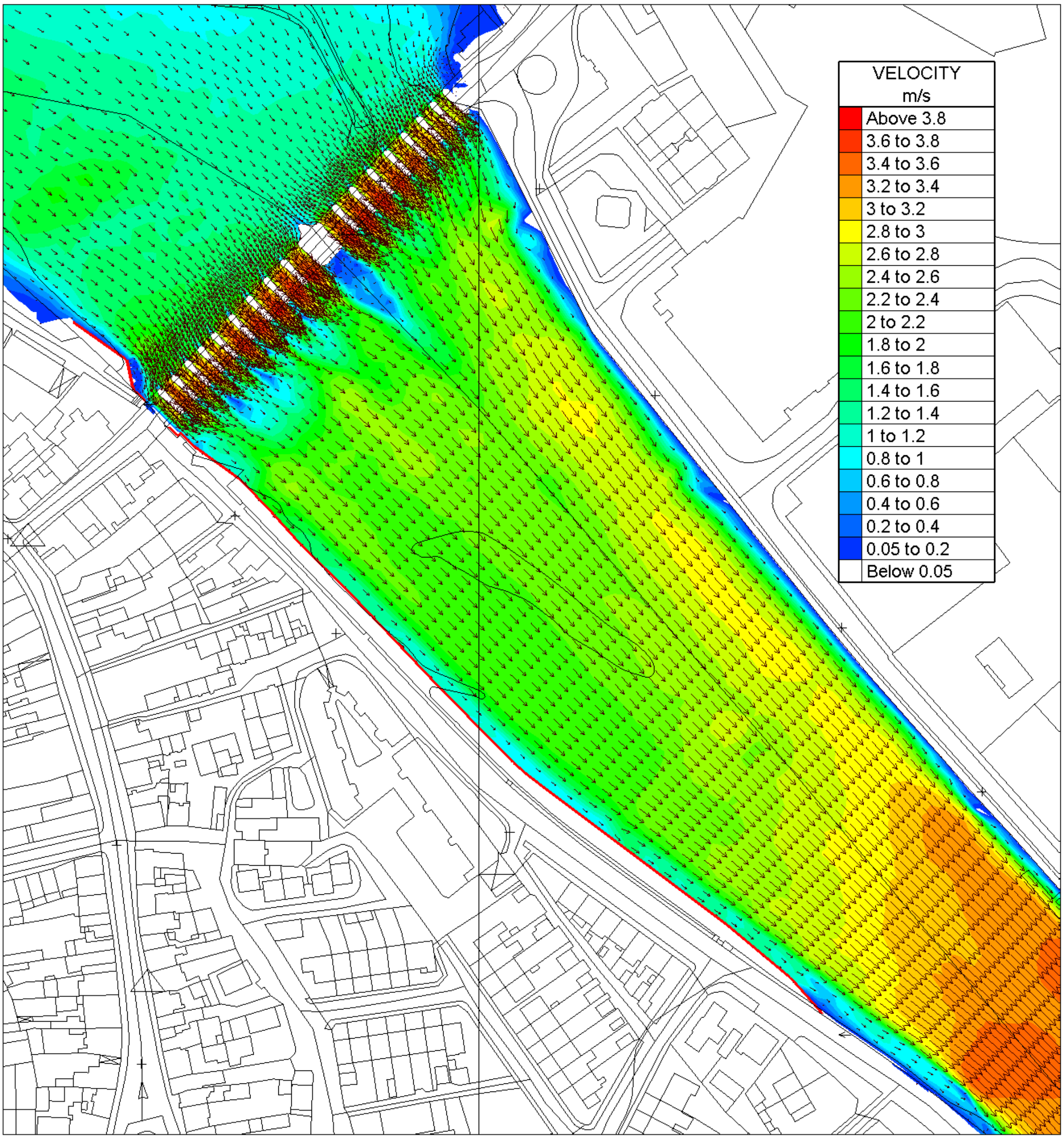

Figure 14: Flood flow velocities in river channel for construction infill and Haul Road

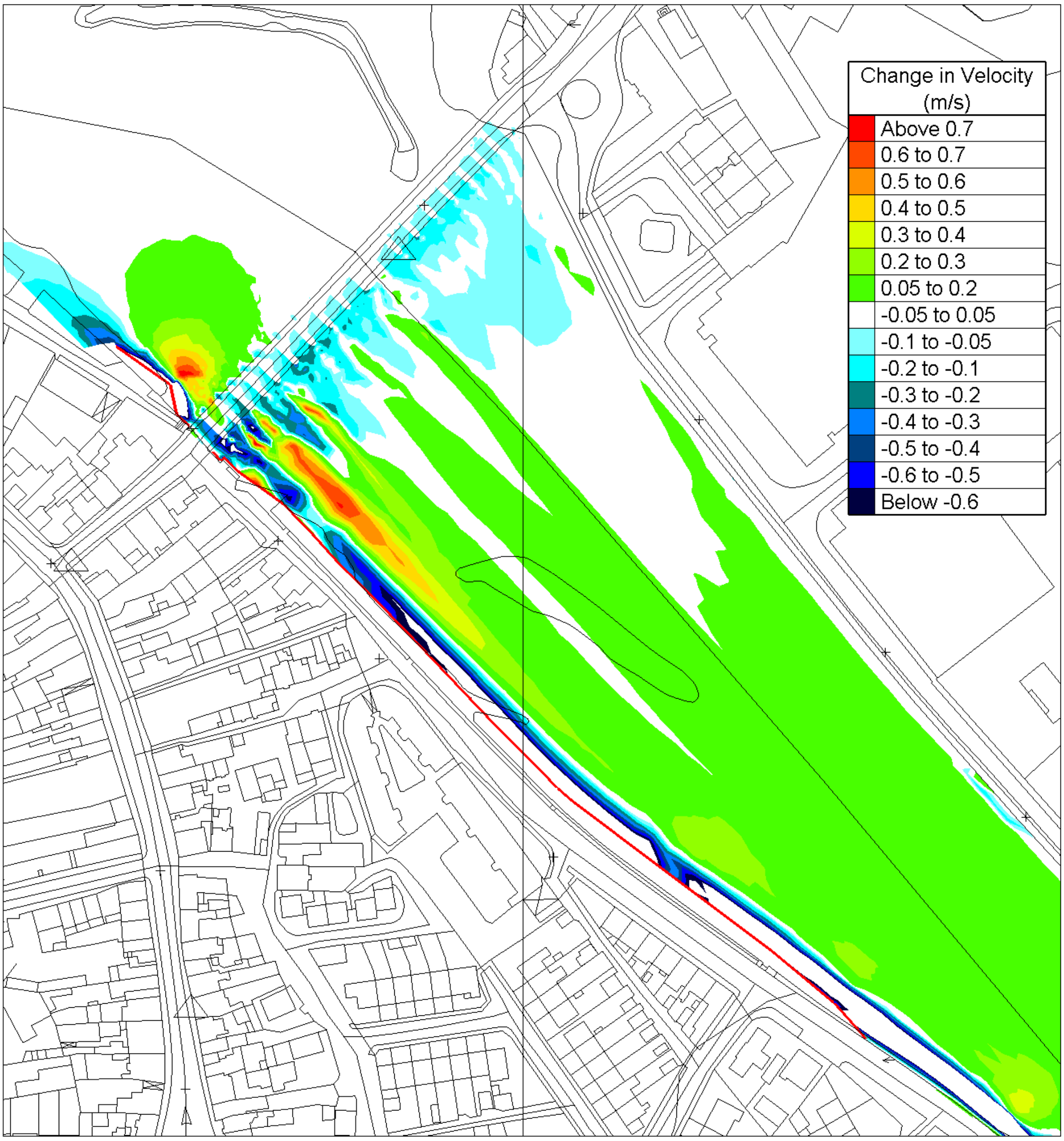

Figure 15: Change in flood flow velocity magnitude as a result of the proposed Construction Infill and Haul Road

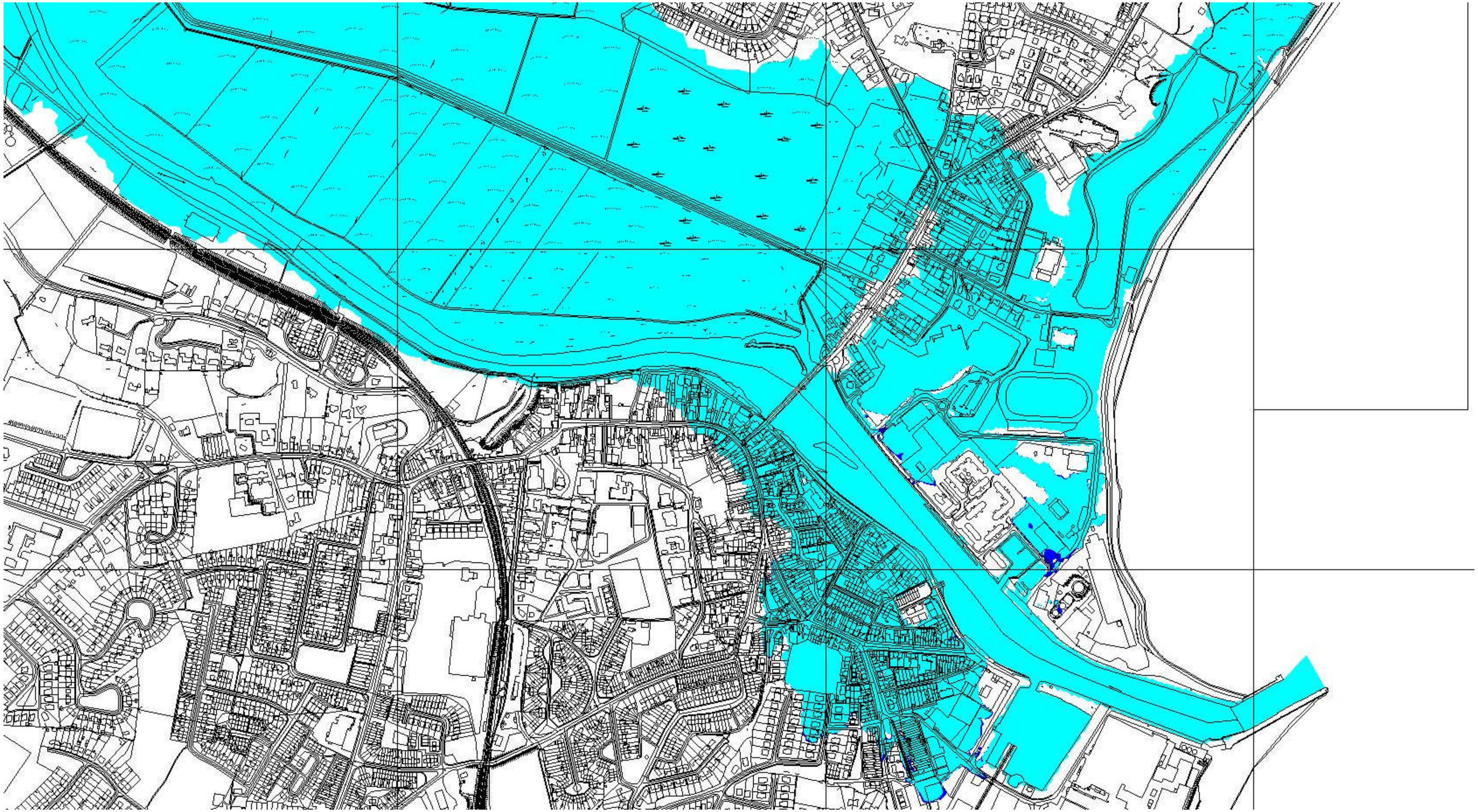

Figure 16: Predicted Flood Extents for existing and proposed temporary haul road downstream and Bridge arch underpinned and in-channel works completed at the bridge including upstream manhole encroachment. (Blue existing baseline and Cyan proposed construction) (overall minor reduction in the flood extents- very slight beneficial impact)

4. Conclusions

The flooding of Arklow is principally caused by Arklow Bridge which under a design flood of 835cumec produces a significant bridge afflux of almost 1.2m. Such upstream flood levels cause flood waters to spill out of channel upstream of the Bridge on both north and south banks and flow as overbank flow downstream causing significant flooding of Arklow before returning to the downstream estuarine channel reach downstream of the Arklow Bridge.

Any increase in flood level upstream of the bridge could potentially worsen flooding by generating a greater overbank spill volume in Arklow. Where possible such impacts should be avoided or mitigated against.

The hydraulic flood modelling, using detailed 2-D modelling of the proposed Interceptor Sewer encroachment shows a small increase in the design flood level of 0.019m upstream and 0.033m downstream of the Bridge. These increases in the context of the overall flood depths and overbank levels are very minor and unlikely to impact significantly the flood risk in Arklow. The computed flood extents indicate a very limited impact by the Proposed Interceptor Sewer encroachment.

The development Management justification test in the Flood Risk Management Planning Guidelines (2009)[1] for developments that are located in floodplains or in moderate and high flood risk zones (A and B) require that such developments do not increase flood risk elsewhere and, if practicable, will reduce the overall flood risk, refer to Box 5.1 2. (i) in the flood risk management planning guidelines.

A proposed local mitigation measure which assists both construction and operational phases is the localised lowering of the bed in Arch 2 of Arklow Bridge by 1m. The flood simulation shows that this measure achieves a slight reduction in upstream flood levels and no worsening of the existing Flood Risk areas in Arklow.

Flood simulations show an overall slight beneficial impact upstream of the bridge which is critical to mitigating flood impact in Arklow. The simulation shows downstream of the bridge flood elevation increases of 1.9 and 5.5cm respectively due to the causeway encroachment. These increases are shown not to be critical to the floodplain inundation and flood risk at Arklow with the computed flood extents presenting a slightly reduced flood area as a result of the slight reduction in upstream Flood level.

Key to the mitigating construction stage impacts on flooding is the phasing of works with the requirement for the bridge underpinning and upstream works to be fully completed before commencing construction of the 270m long causeway downstream of the bridge.

In conclusion the proposed 6m wide Interceptor Sewer pipe encroachment results in a small increase in out of channel flooding which can be fully mitigated by the proposed deepening and underpinning of Arch 2 at Arklow Bridge. The construction requirement of a 10m wide temporary causeway (inclusive of the permanent encroachment 6m width) can be phased and managed not to impact flood risk in Arklow.

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