Figure 7-28 Comparison of flow sensitivity results for the Optimised Option - Commons Road

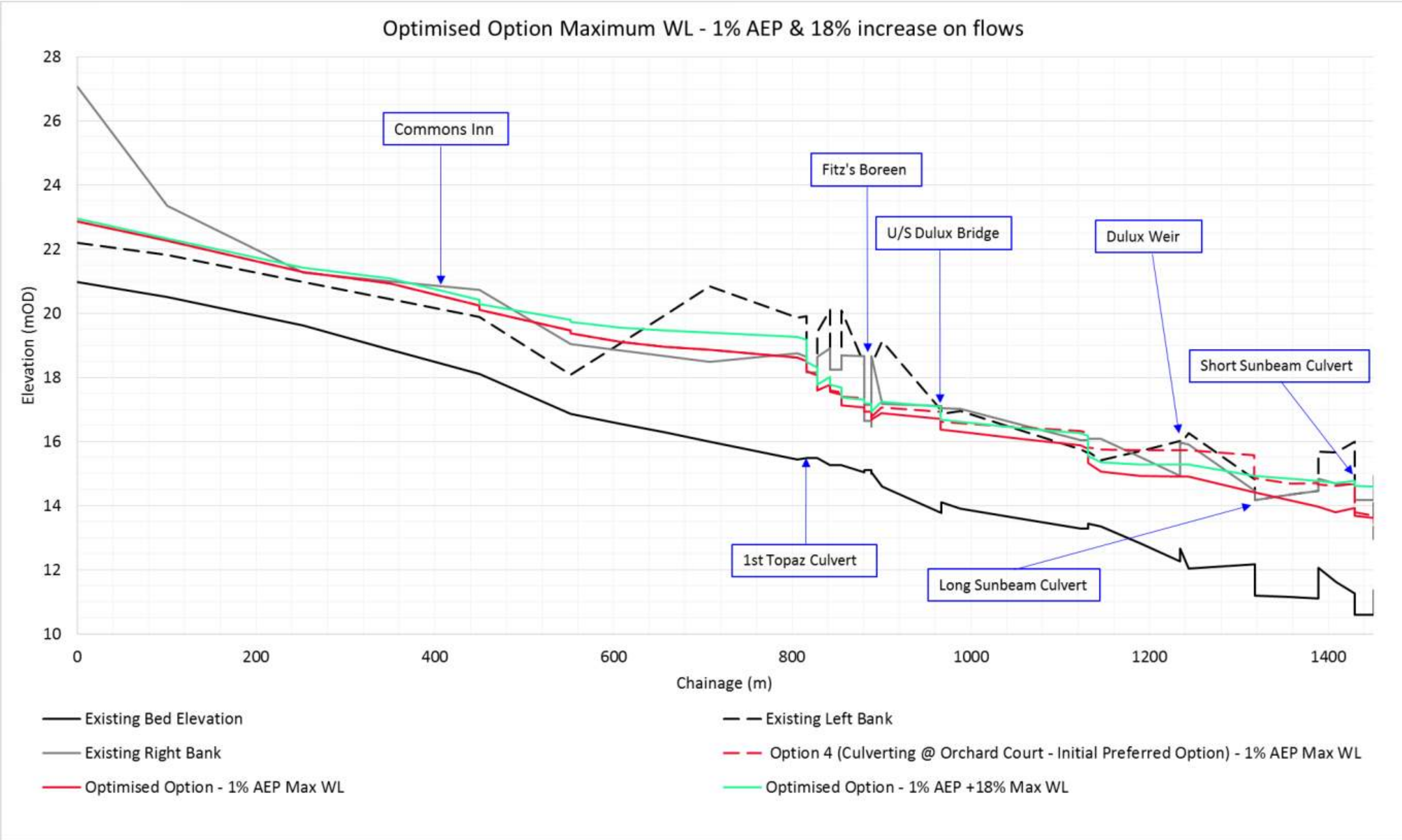


Figure 7-29 Comparison of flow sensitivity results for the Optimised Option - Blackpool

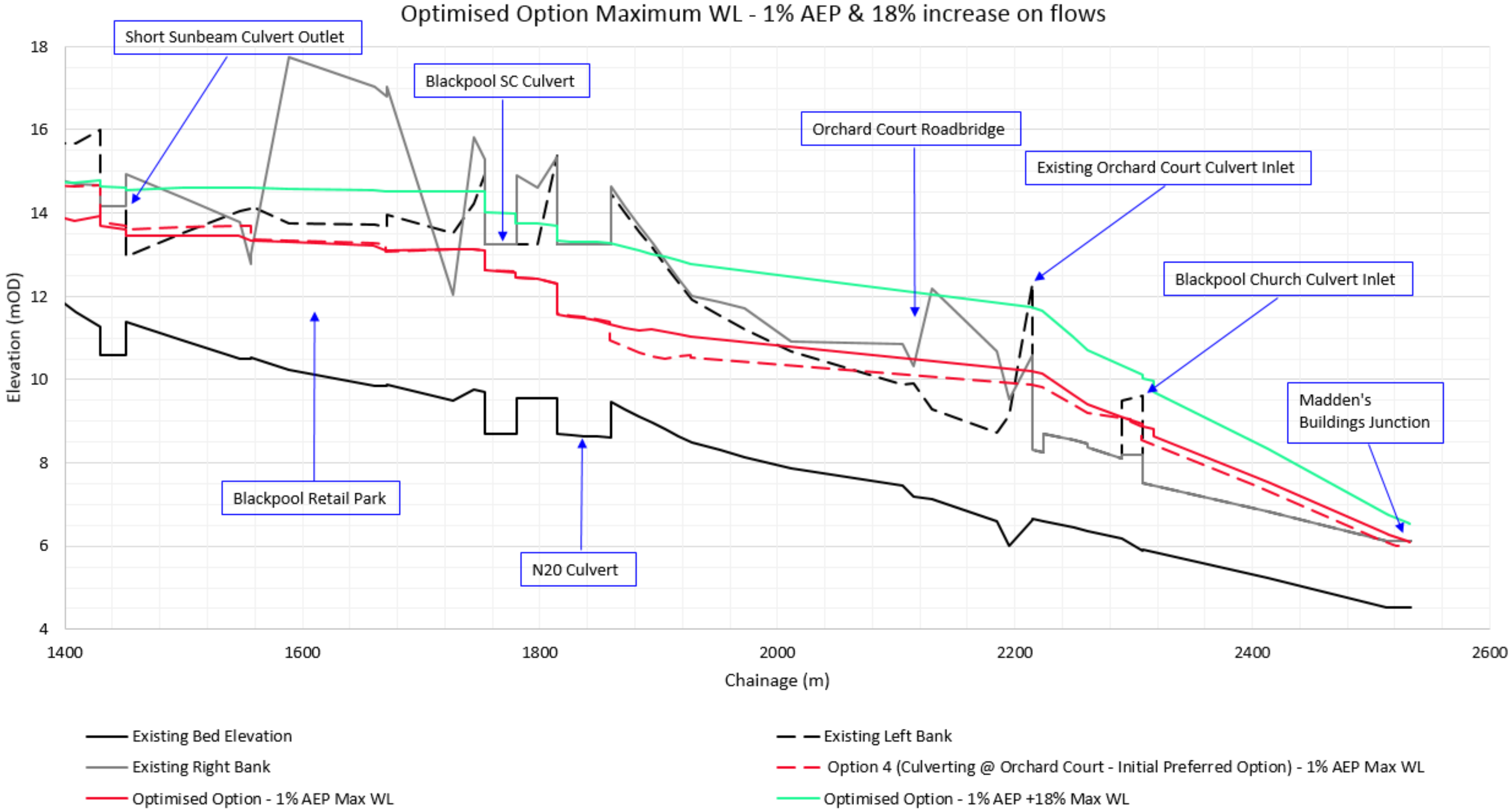


Figure 7-28 and Figure 7-29 show that the Optimised Scheme performs adequately when subjected to an increase of 18% on the model inflows. The maximum modelled water level for the 1% AEP+18% generally stays within the 600mm freeboard value, set above the 1% AEP water level. In this sensitivity test, it is not appropriate to adjust each individual HEP to the factored design flow. It is more appropriate to increase the inflows inputting to the model to generate the flow regime. In this way, hydraulic features of the scheme design which attenuate or accentuate the flow are also identified.

For example, the reach adjacent to Blackpool Retail Park has been identified as an extremely sensitive location. A small increase in flows along this reach can significantly elevate water levels due to the attenuating effect of the culvert at 7BRI_548; immediately downstream. Therefore, it has been decided to provide a greater standard of protection (approx. 1.35m above the modelled 1% AEP WL) here than the previously identified 600mm. This adds to the protection against uncertainty and recognises that there are areas on the watercourse system that will always be hydraulically sensitive.

As mentioned previously in Section 2.4, the sewer inflows in the Brewery Branch (calculated using the Modified Rational Method) were increased arbitrarily by 20% to test the sensitivity of the model for such an increase. It was found that that such an increase had no significant impact on water levels upstream in the culvert system and as a result, this sensitivity source was not considered further.

8 Conclusions

8.1 Summary of flood mechanisms and hydraulics in Blackpool at present

The hydraulic model has confirmed that there is a flooding issue in Blackpool village and along the Commons Road. The primary source of this risk is exceedance of channel capacity in the River Bride. A summary of the key flood mechanisms is provided below:

- Flooding at the North Point Business Park is caused by flow overtopping the left bank at return periods in excess of the 10% AEP event due to restrictions presented by a bridge and multiple culvert crossing. This occurs on the upstream faces of the Kilnap Glen access bridge and the North Point Business Park culvert. An overland flow route then develops and inundates the North Point Business Park. The capacity of the channel immediately upstream of the access bridge is approximately 14 m^3/s. The capacity reduces to 12.3 m^3/s at the upstream face of the North Point Business Park.
- Flooding on the Commons Road is caused by flow overtopping the right bank upstream of the Topaz garage. This is exacerbated by the restrictive nature of the Fitz's Boreen arch bridge downstream, which is regularly subject to significant blockage with debris. The capacity of the channel at this location is approximately 18 m^3/s.
- Flooding in the Dulux Paint factory is caused by a combination of sources; an overland flow route from the Commons Road and capacity of the channel being exceeded just downstream of an access bridge within the site. The capacity of the channel at this point is approximately 19.4 m^3/s. From here, flow continues overland and floods the Sunbeam Industrial Estate. This flow route occurs in events in excess of the 10% AEP.
- Blackpool Shopping Centre is not affected by flooding until the 0.5% AEP event. At this return period the Heron Gate building is inundated. In the 0.1% AEP MRFS and existing 0.1% AEP events, this flow route continues through the Blackpool Shopping Centre and car-park. From here, it travels down Thomas Davis St and joins further flooding from Orchard Court.
- Flooding at Orchard Court is caused by a lack of channel capacity and a hydraulically inefficient culvert system downstream. The threshold of flooding at Orchard Court is somewhere between the 20% and 10% AEP events. The flow at the Orchard Court culvert inlet when this overtopping occurs is approximately 20m^3/s. There is an approximate 300mm headloss across the Orchard Court roadbridge in the 1% AEP event, but it is not the primary cause of flooding in Blackpool village.
- The primary source of flood water in Blackpool village is an overland flow route through Wherland's Lane. It can be exacerbated by water escaping from the open channel section adjacent to Blackpool Church. The Blackpool Church culvert has a restrictive inlet and is undersized relative to the 1% AEP design flow.
- The current Blackpool Church inlet is inefficient in its design and is a source of headloss before flow can transfer into the culvert system. The combination of its configuration, the baffle system on the floor and the larger section size upstream at Blackpool Bridge slows river velocities and encourages a significant volume of sediment to drop out of suspension and collect on the culvert floors. Photographs in previous sections has shown the volume of sediment that can collect in the system under existing conditions. The collection of sediments in the culvert system further reduces capacity by reducing cross-sectional area and increasing friction losses. The collection of sediment can also affect the accuracy of watercourse monitoring as seen in the flow monitoring contract. Sediment can create localised standing waves, leading to 'false water levels'; as well as covering the probe itself.
- The bifurcation, as is currently configured, is not efficient in conveying flow downstream. A series of sharp turns and accumulation of debris slows velocities and elevates water levels upstream. The size of the junction, relative to the 1% AEP design flow, is also restrictive. The Brewery Branch culvert is an old, brick conduit and limited use should be made of it in any proposed alleviation option. The removal of the diversion block at the inlet to the Brewery Branch culvert, initially resulted in the majority (60-70%) of flow entering the Brewery conduit, as recorded in the flow monitoring survey. However, this percentage has since decreased (approximately 40%) due to debris and sediment

catching on the reinforcement bars left there after the block's removal The balance sweeps across the junction to the Phase 3 GBK culvert. This conduit must also take 100% of the flow coming from the Glen.

- It must also be noted that backing up of the culvert system in Blackpool village as a result of flow entering the Madden's Buildings junction from the Glen in the Phase 4 GBK conduit was not observed either in the flow monitoring survey or the hydraulic model. As previously stated, the headlosses recorded in the Madden's Buildings junction seem to suggest that much of the ineffiencies occur close to the Brewery inlet and the first channel turn. A larger event during the flow monitoring survey period would have confirmed this.
- However, the flow monitoring survey confirmed that there was sediment deposition in the middle of the bifurcation as a result of the inefficient system and slowing velocities. This sediment deposition has the potential to reduce flow capacity and raise water levels within the junction; potentially elevating water levels upstream at Blackpool village. The collection of sediment and debris at the Brewery inlet is testament to the potential for problems if the current junction configuration is retained.
- The largest event recorded during the monitoring period was the 13th/14th November 2014 event. The 21st November 2014 event was nearly identical in magnitude, with approximately 7.5 m^3/s draining to Blackpool Church. This flow rate is not particularly large when put in context with the study hydrology, as the Qmed value for Orchard Court has been estimated to be 13 m^3/s. Without a larger event on record, it is difficult to accurately calibrate the hydraulic model. However, whatever data that has been deemed useable has been used in the calibration process.
- Calibration of the hydraulic model was achieved using the flow monitoring survey data for the 21st November 2014 event. For the same recorded flow, the model parameters inside the junction and at Blackpool Church were adjusted until the modelled water levels agreed with the recorded data.
- The second hydraulic model, that was constructed to examine the June 2012 event, reinforced the causes of flooding within the system. It confirmed that the Orchard Court flow route is the major contributor to flooding in Blackpool village and that a satisfactory fit with observed extent and profile data could be achieved. It has confirmed that blockage of key culvert inlets and screens were major factors in the scale of the flooding in that event.

8.2 Preferred alleviation option

The preferred alleviation option was chosen by testing a number of different approaches and assessing their performance based on the following:

- Hydraulic profile i.e. reduction in modelled water level;
- Sensitivity to flow increases
- Adaptability to climate change

'Option 4' (i.e. construction of a new culvert to replace the open channel section adjacent to Orchard Court) has been chosen as the emerging preferred option. This option also includes structure replacement, junction improvements, provision of direct defences upstream and management of sediment.

As explained in previous sections, a point is reached at which increasing section size in the new culvert has little or no effect on modelled water levels as the primary control is the conduit system downstream.

Attention must also be paid to the role of the Brewery Branch culvert in the proposed scheme. If completely discounted, all flow will be forced through the Phase 3 GBK culvert and the cross-connection in the bifurcation. This will increase water levels further upstream. On the other hand, allowing too much flow down the Brewery Branch may compromise its structural integrity.

8.3 Optimisation of preferred option

Initial sensitivity testing concluded that flow was the major contributor to uncertainty in the model and would be the greatest influence on the provision of freeboard. The emerging preferred option, as initially designed, struggled with increases in the design event flow. Increasing the flow in the preferred option model identified further hydraulic pinch points; with water levels increasing downstream due to culvert pressurisation.

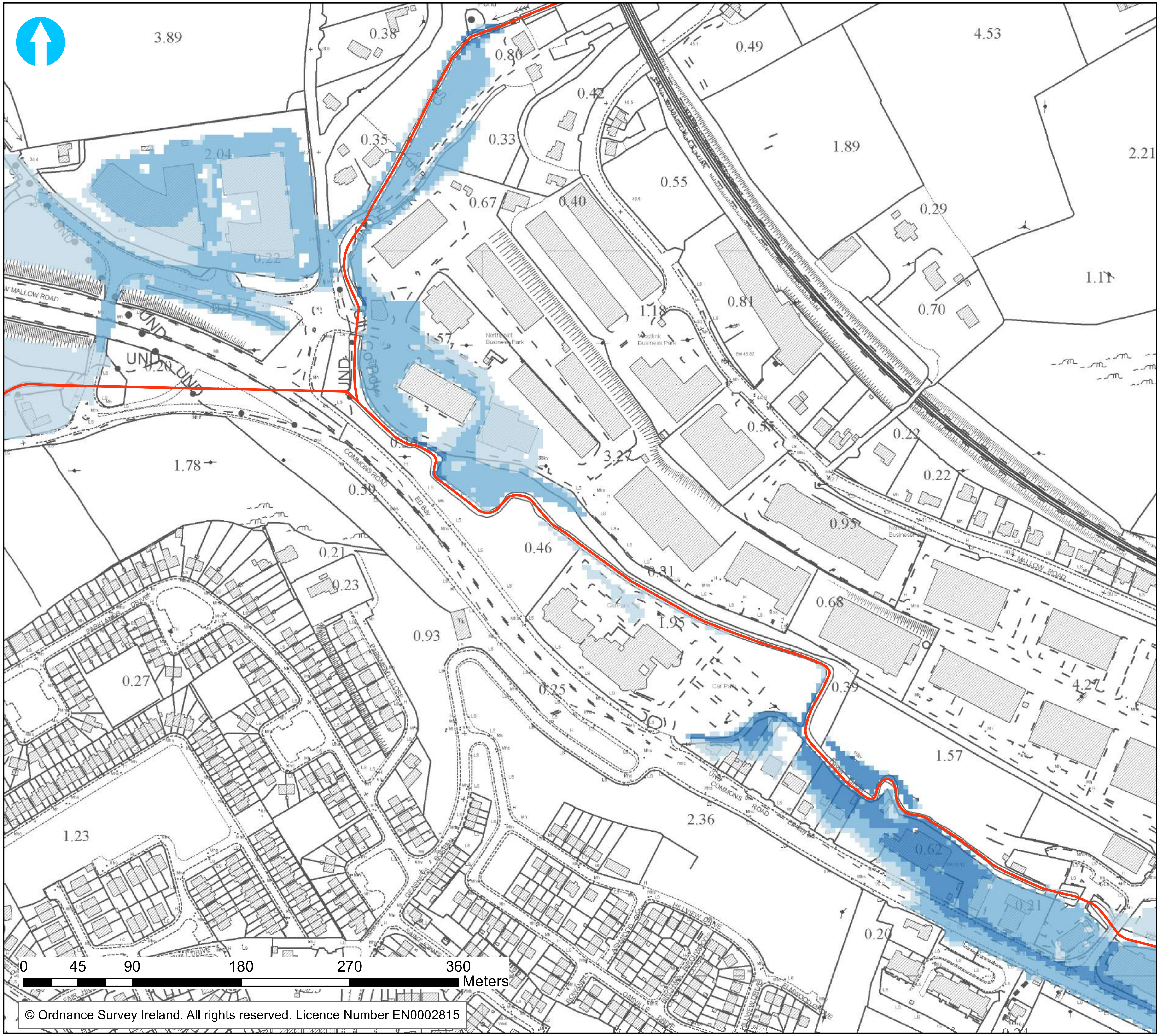
Therefore, further works were proposed that could help reduce water levels in flow sensitivity scenarios and decrease attenuation in the system. The full suite of proposed works, as implemented in the optimised option are shown below:

- Realignment of the Madden's Buildings junction to allow an easier transition from the Phase 5 GBK culvert to the Phase 3 GBK culvert.
- Limiting the inflow to the Brewery Branch culvert in the design 1% AEP event to 9.5 m^3/s; preventing surcharging of the conduit.
- Realignment of the existing Blackpool Church culvert inlet to allow an easier transition downstream.
- Culverting of the existing open channel at Blackpool Church to keep pressurised flows in the system.
- Culverting of the open channel adjacent to Orchard Court from the existing inlet to the outlet of the N20 culvert.
- Replacement and enlargement of the Short Sunbeam Culvert.
- Removal of the Long Sunbeam Culvert.
- Construction of a sedimentation area on the left bank at Sunbeam to manage sediment loads in the watercourse.
- Replacement of the Fitz's Boreen masonry bridge.
- Construction of a winter channel just downstream of the Commons Inn.
- Replacement of the North Point Business Park Culvert.
- Replacement of the Kilnap Glen House Access Bridge.
- Direct defences to be placed in Blackpool Retail Park, Dulux, Upstream of Topaz, Commons Inn and North Point Business Park.

Appendices

A Flood Extent Maps

A.1 Existing Scenario



Legend

- Modelled River Centreline
- 10% AEP Flood Extent
- 1% AEP Flood Extent
- 0.1% AEP Flood Extent

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Map: Lower Lee Flood Relief Scheme

Map Type: Fluvial Flood Extent

Scenario: Current

Drawn by: AB

Checked by: DF

Scale: 1:3000 A3

Project No: 2013s7174

Map No: BLK_EXT_CUR_001

Sheet: 1 of 3

Date: 16/Nov/2015

Status: Draft

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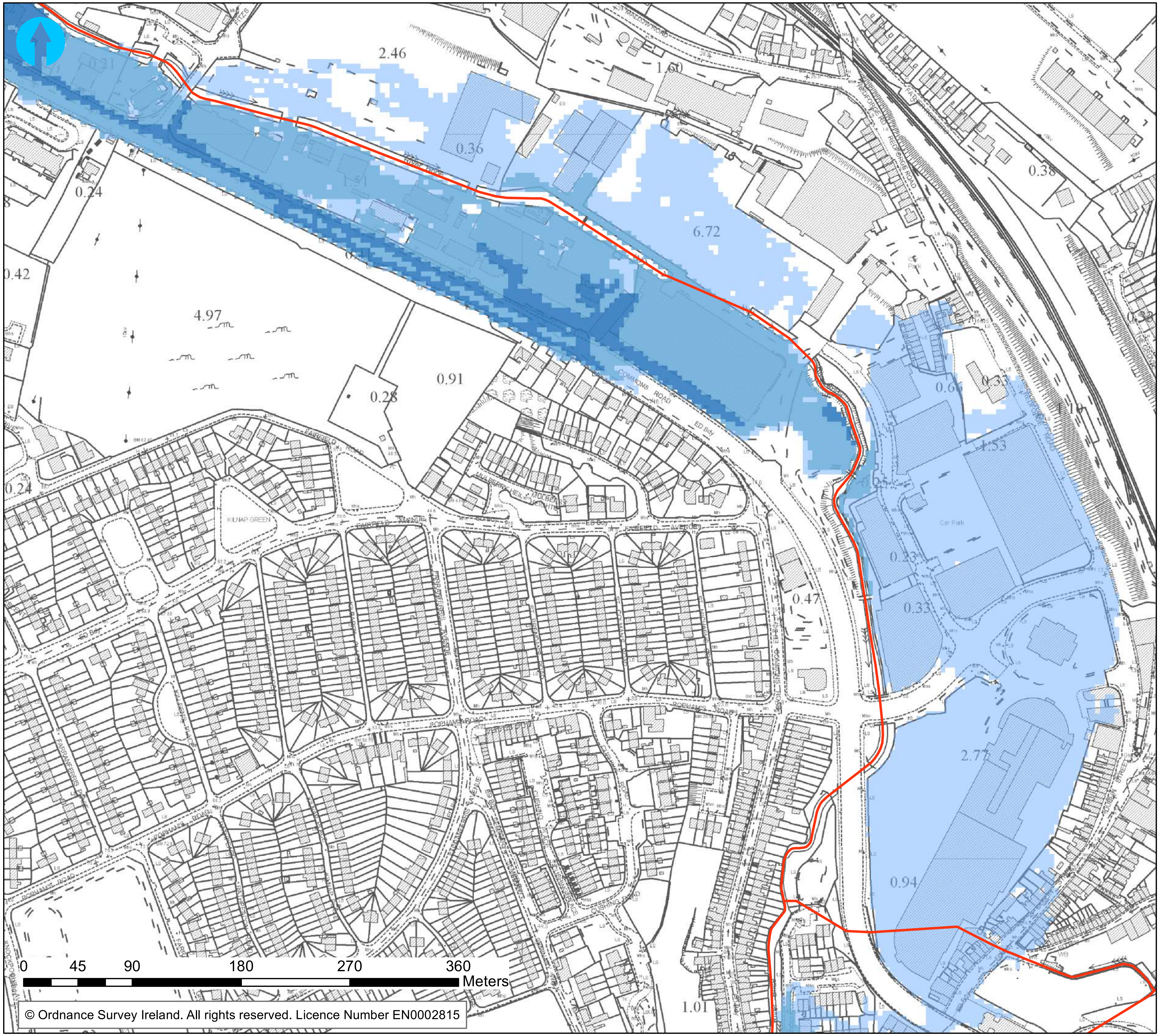

Legend

- Modelled River Centreline
- 10% AEP Flood Extent
- 1% AEP Flood Extent
- 0.1% AEP Flood Extent

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Map: Lower Lee Flood Relief Scheme	
Map Type: Fluvial Flood Extent	
Scenario: Current	**Scale:** 1:3000 A3
Drawn by: AB	
Checked by: DF	
Project No: 2013s7174	
Map No: BLK_EXT_CUR_002	
Sheet: 2 of 3	
Date: 18/Nov/2015	**Status** Draft

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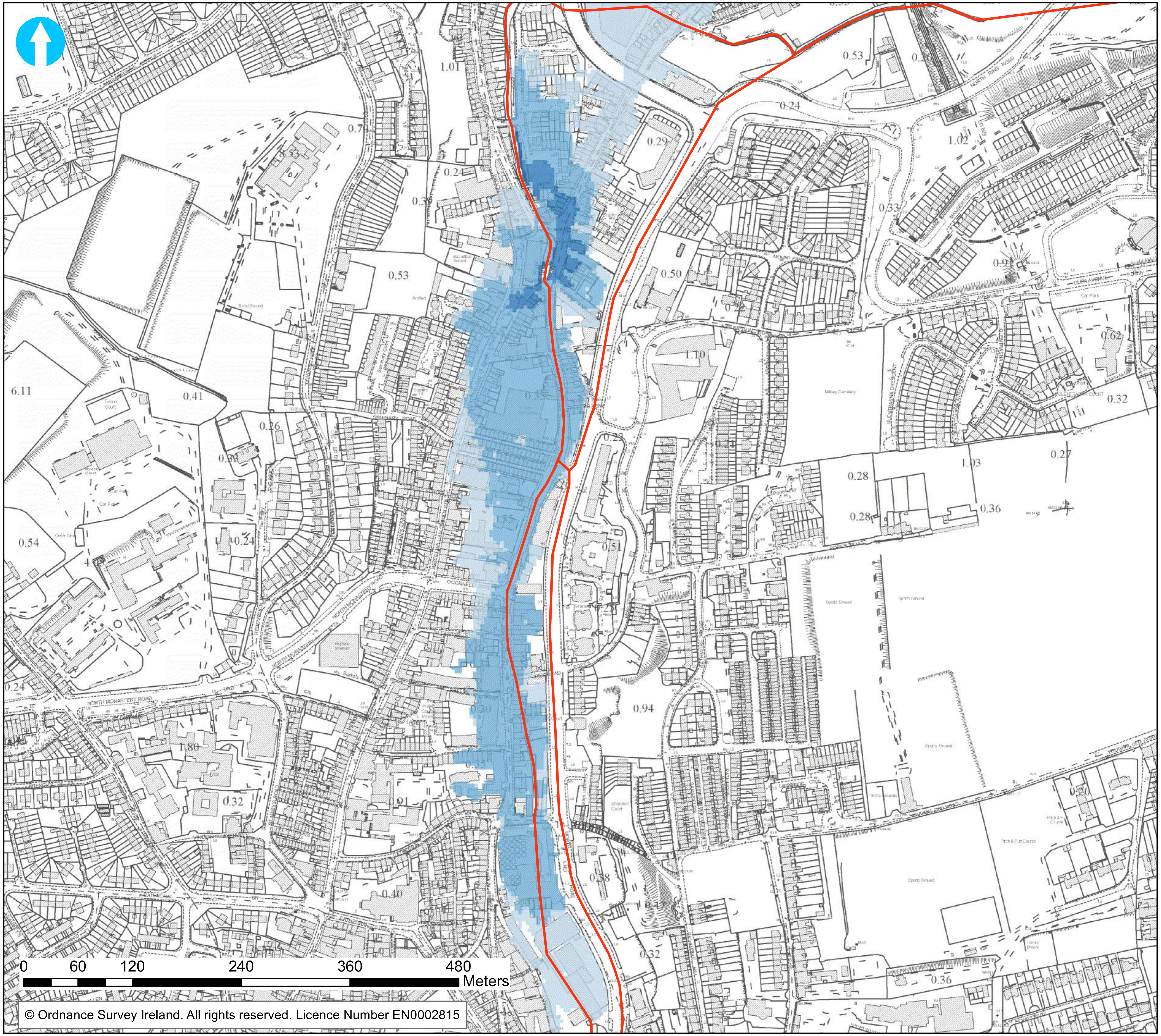

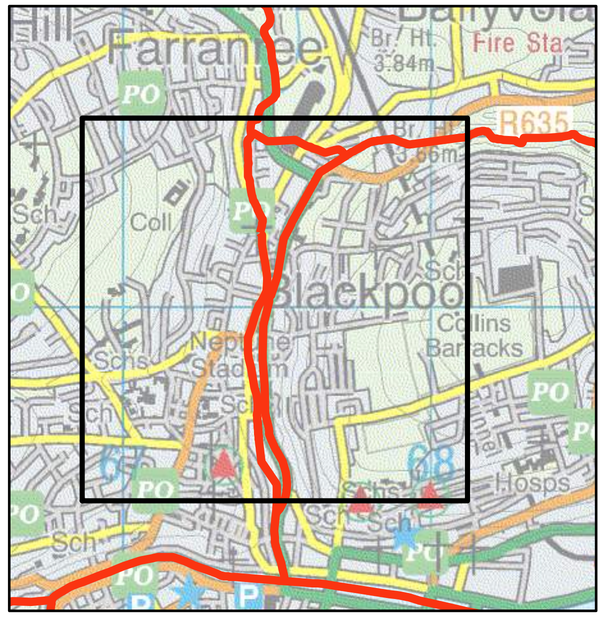

Legend

- Modelled River Centreline
- 10% AEP Flood Extent
- 1% AEP Flood Extent
- 0.1% AEP Flood Extent

Map: Lower Lee Flood Relief Scheme	
Map Type: Fluvial Flood Extent	
Scenario: Current	**Scale:** 1:4000 A3
Drawn by: AB	
Checked by: DF	
Project No: 2013s7174	
Map No: BLK_EXT_CUR_003	
Sheet: 3 of 3	
Date: 16/Nov/2015	**Status:** Draft

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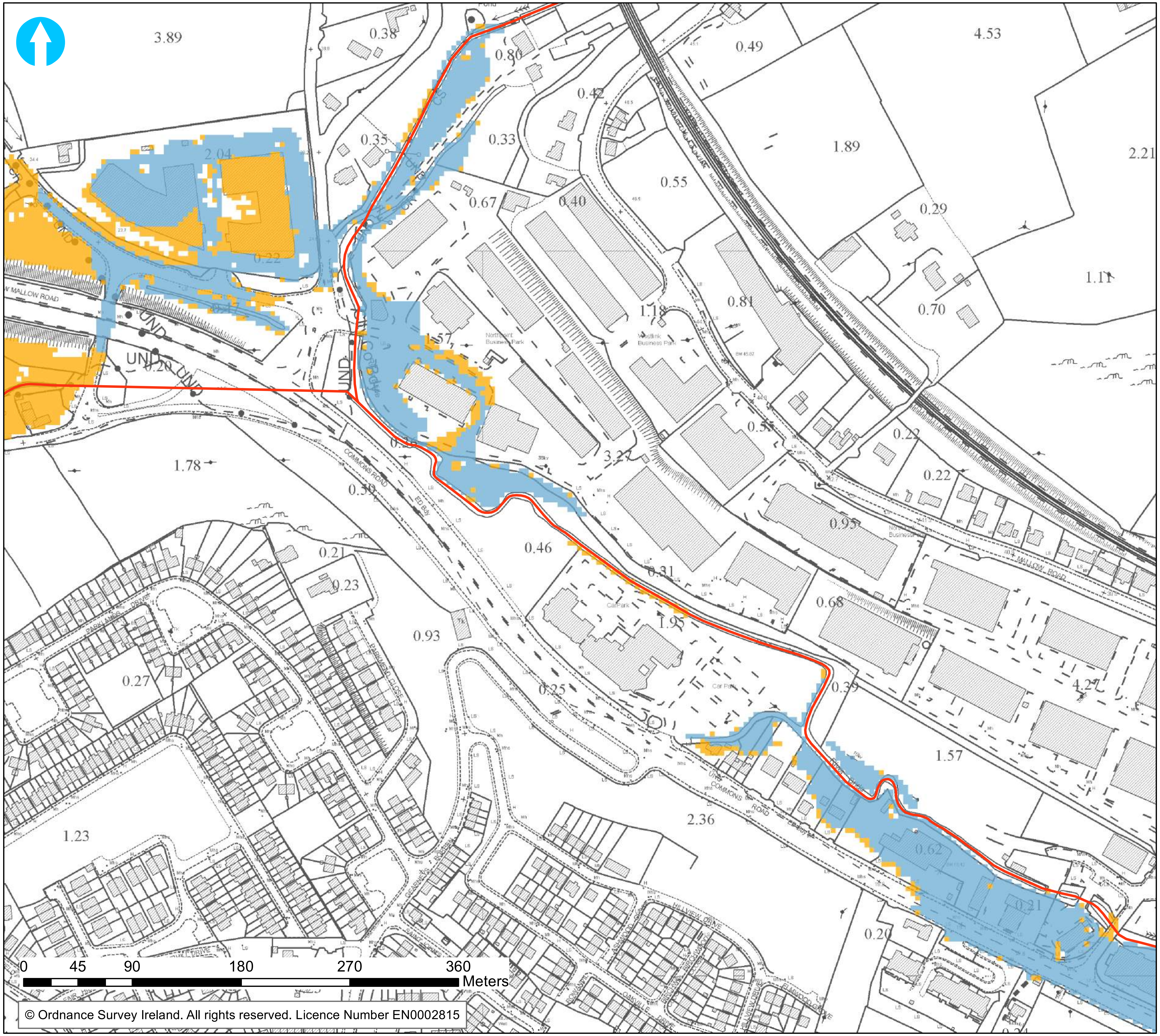
A.2 Climate Change



Legend

- Modelled River Centreline
- 1% AEP Flood Extent (Current)
- 1% AEP Flood Extent (MRFS)

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Map: Lower Lee Flood Relief Scheme	
Map Type: Fluvial Flood Extent	
Scenario: MRFS	**Scale:** 1:3000 A3
Drawn by: AB	
Checked by: DF	
Project No: 2013s7174	
Map No: BLK_EXT_MRFS_001	
Sheet: 1 of 3	
Date: 16/Nov/2015	**Status:** Draft

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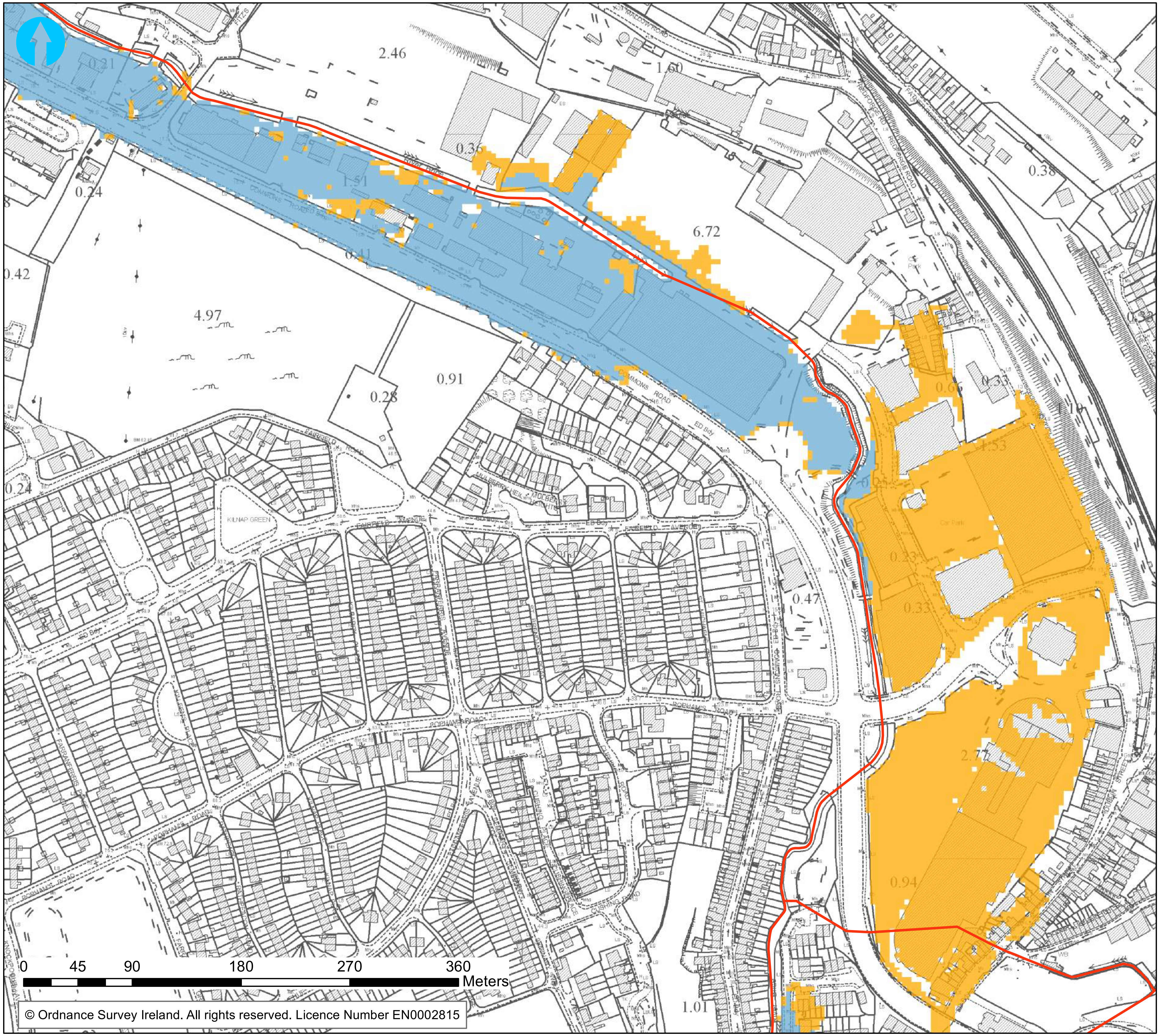

Legend

- Modelled River Centreline
- 1% AEP Flood Extent (Current)
- 1% AEP Flood Extent (MRFS)

Map: Lower Lee Flood Relief Scheme	
Map Type: Fluvial Flood Extent	
Scenario: MRFS	**Scale:** 1:3000 A3
Drawn by: AB	
Checked by: DF	
Project No: 2013s7174	
Map No: BLK_EXT_MRFS_002	
Sheet: 2 of 3	
Date: 16/Nov/2015	**Status** Draft

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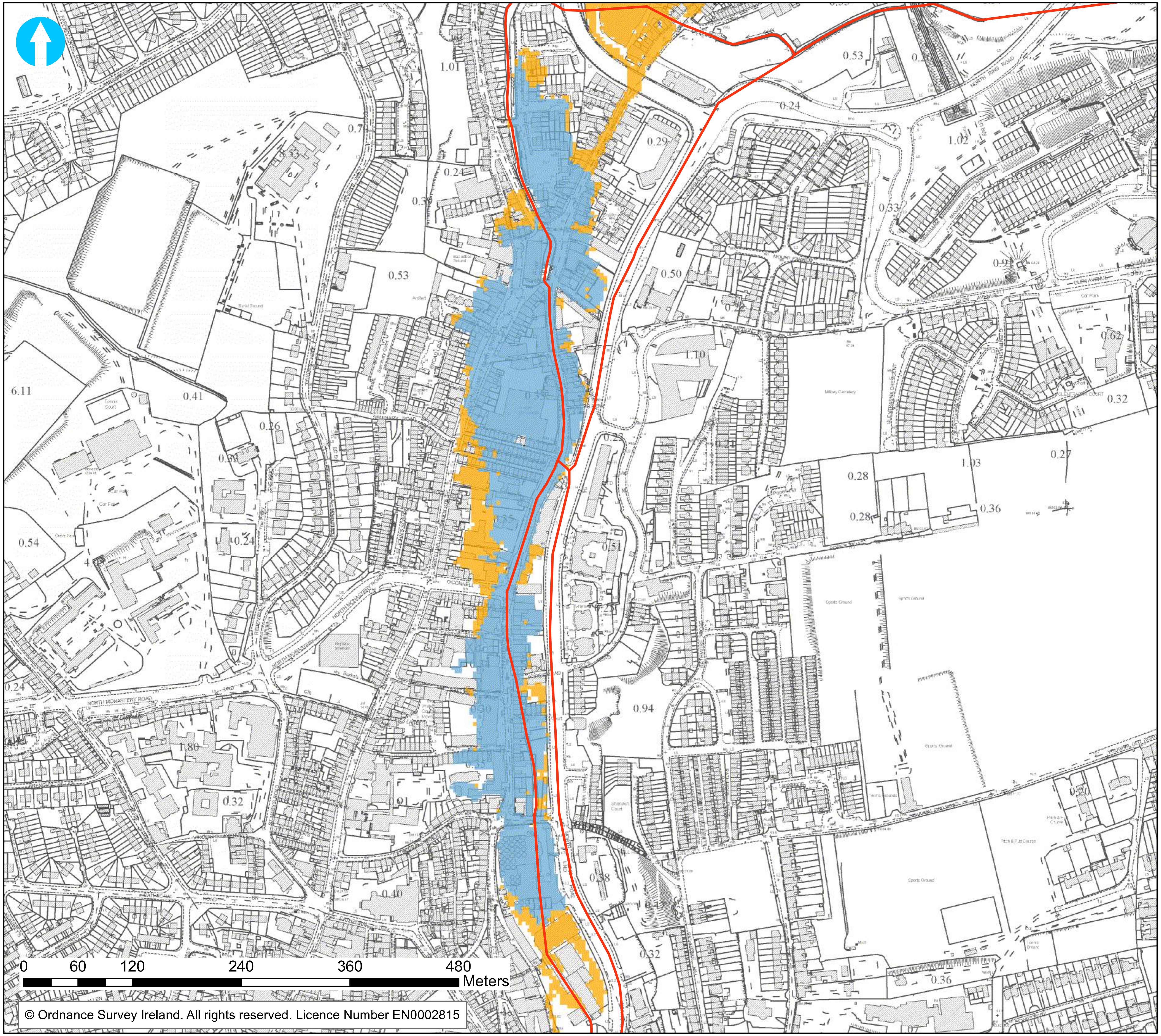

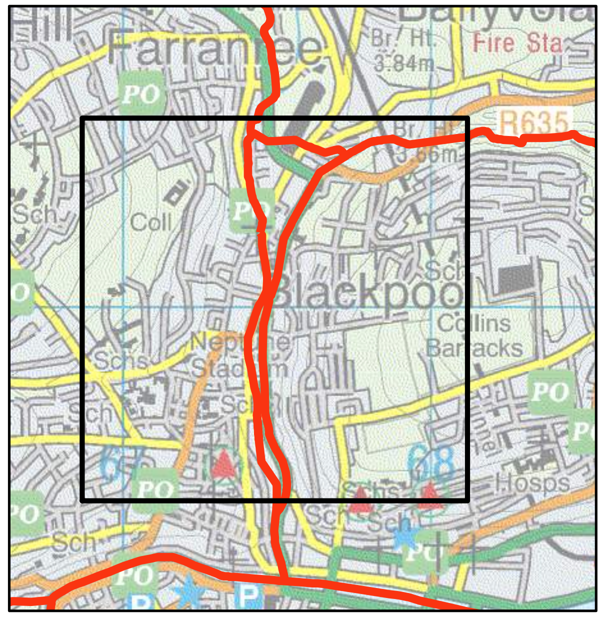

Legend

- Modelled River Centreline
- 1% AEP Flood Extent (Current)
- 1% AEP Flood Extent (MRFS)

Map: Lower Lee Flood Relief Scheme	
Map Type: Fluvial Flood Extent	
Scenario: MRFS	**Scale:** 1:4000 A3
Drawn by: AB	
Checked by: DF	
Project No: 2013s7174	
Map No: BLK_EXT_MRFS_003	
Sheet: 3 of 3	
Date: 16/Nov/2015	**Status:** Draft

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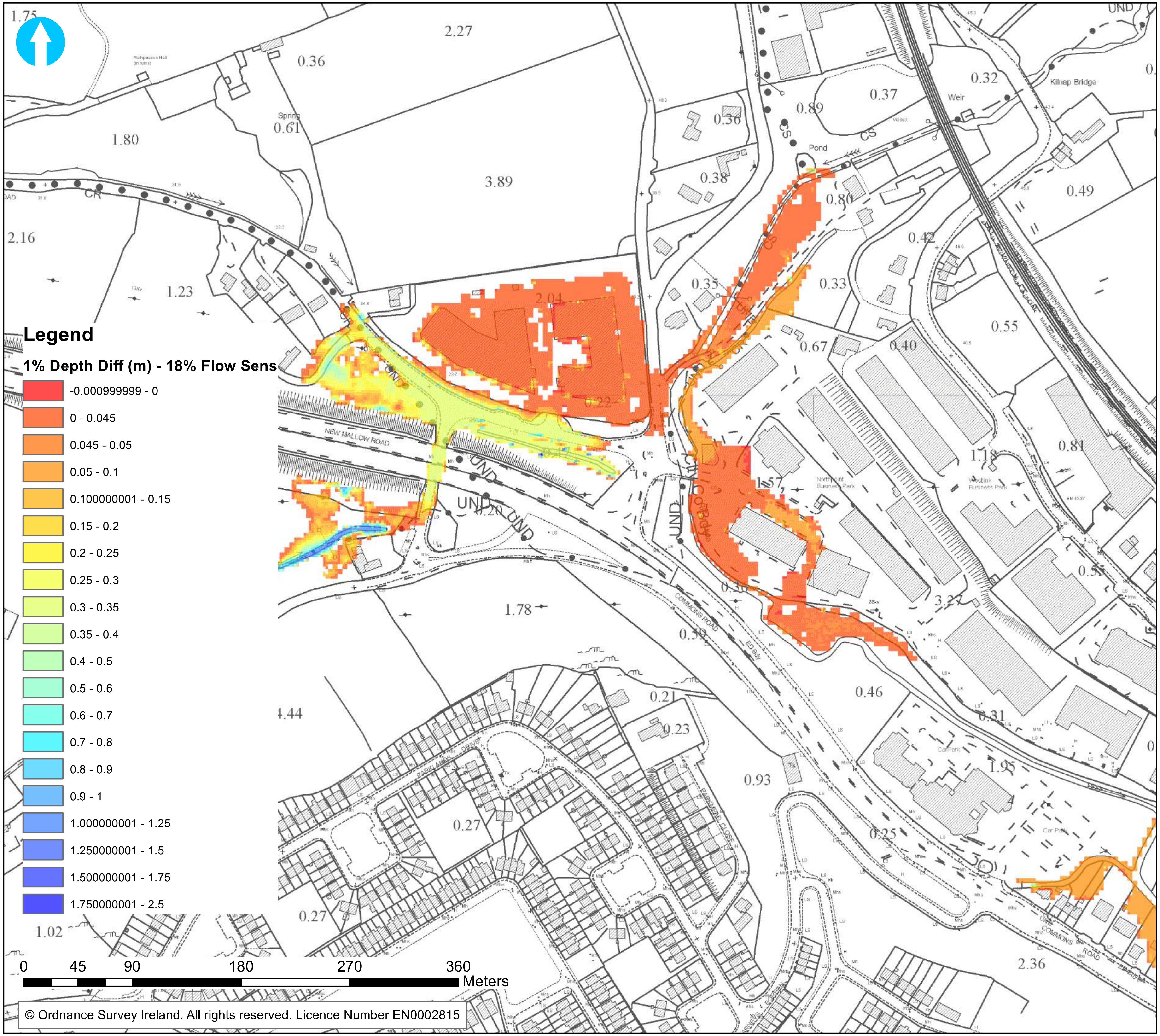
A.3 Sensitivity Testing

A.3.1 Peak Flow



Legend

1% Depth Diff (m) - 18% Flow Sens

- -0.000999999 - 0
- 0 - 0.045
- 0.045 - 0.05
- 0.05 - 0.1
- 0.100000001 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- 1.000000001 - 1.25
- 1.250000001 - 1.5
- 1.500000001 - 1.75
- 1.750000001 - 2.5

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Map: Lower Lee Flood Relief Scheme	
Map Type: 1% AEP - 18% Flow Sensitivity	
Scenario: Current	**Scale:** 1:3000 A3
Drawn by: AB	
Checked by: DF	
Project No: 2013s7174	
Map No: BLK_Flow_Sens_001	
Sheet: 1 of 4	
Date: 17/Nov/2015	**Status:** Draft

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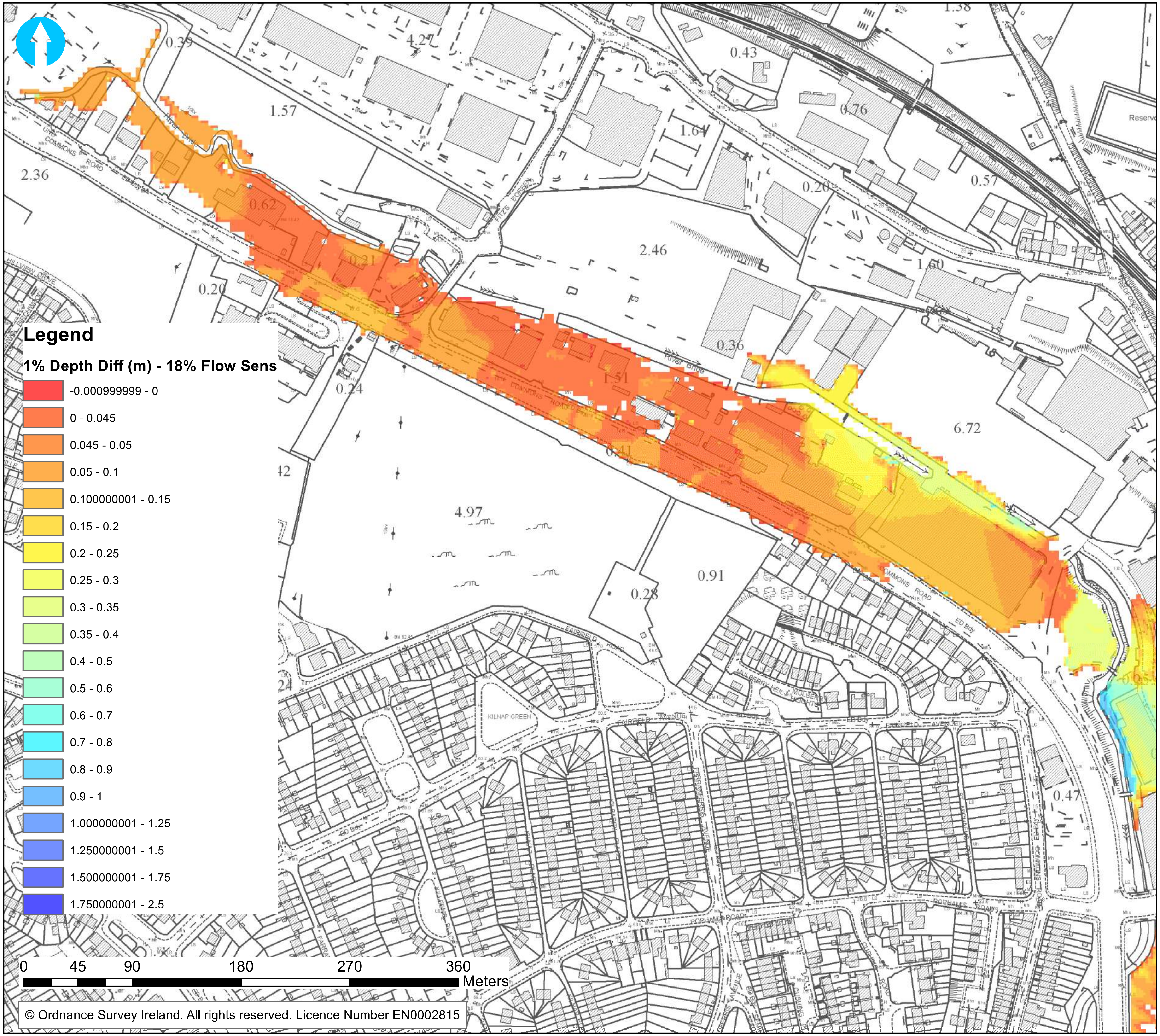

Map: Lower Lee Flood Relief Scheme

Map Type: 1% AEP - 18% Flow Sensitivity

Scenario: Current

Drawn by: AB

Checked by: DF

Scale: 1:3000 A3

Project No: 2013s7174

Map No: BLK_Flow_Sens_002

Sheet: 2 of 4

Date: 17/Nov/2015

Status: Draft

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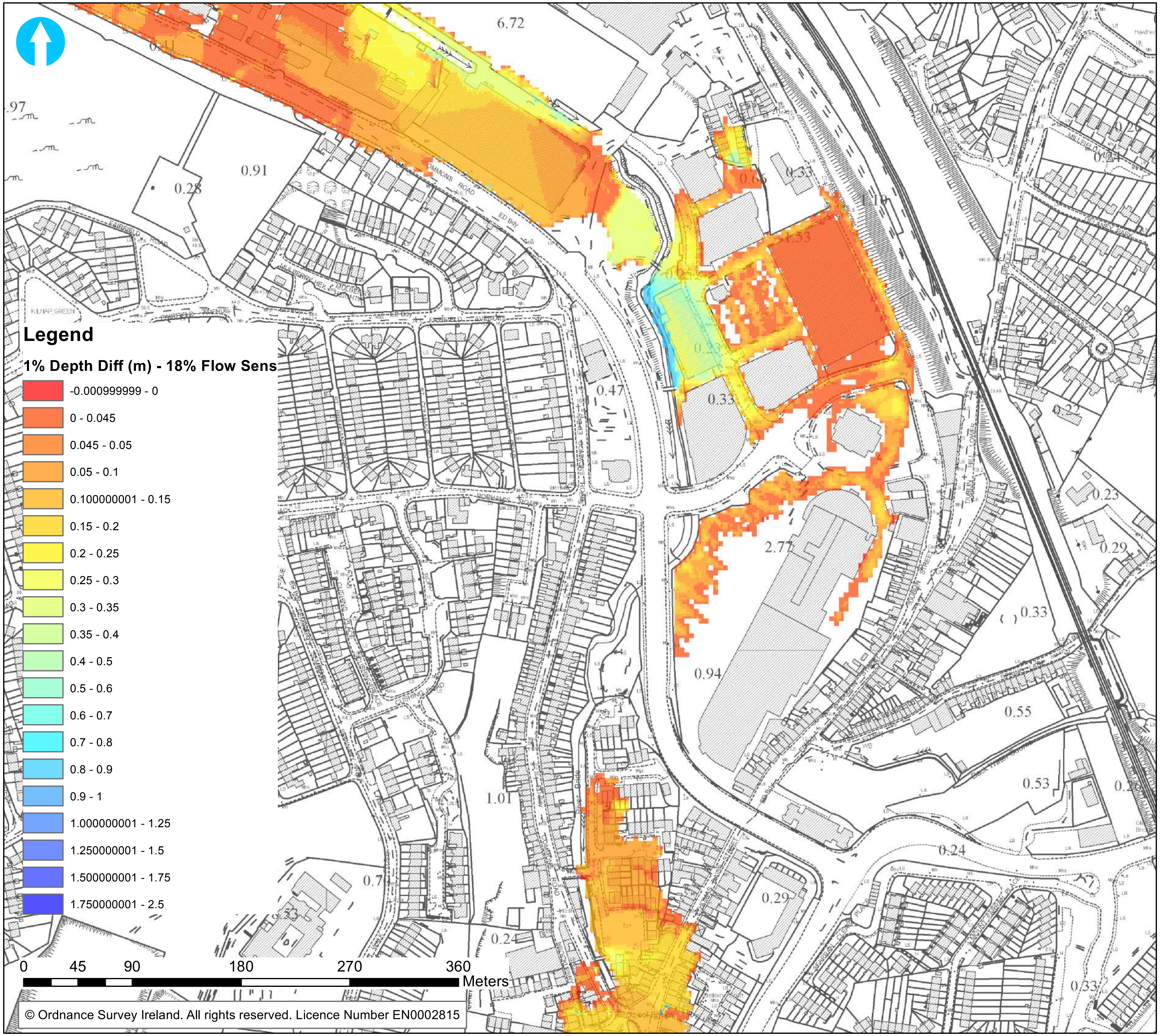

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Map: Lower Lee Flood Relief Scheme	
Map Type: 1% AEP - 18% Flow Sensitivity	
Scenario: Current	**Scale:** 1:3000 A3
Drawn by: AB	
Checked by: DF	
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Map No: BLK_Flow_Sens_003	
Sheet: 3 of 4	
Date: 17/Nov/2015	**Status:** Draft

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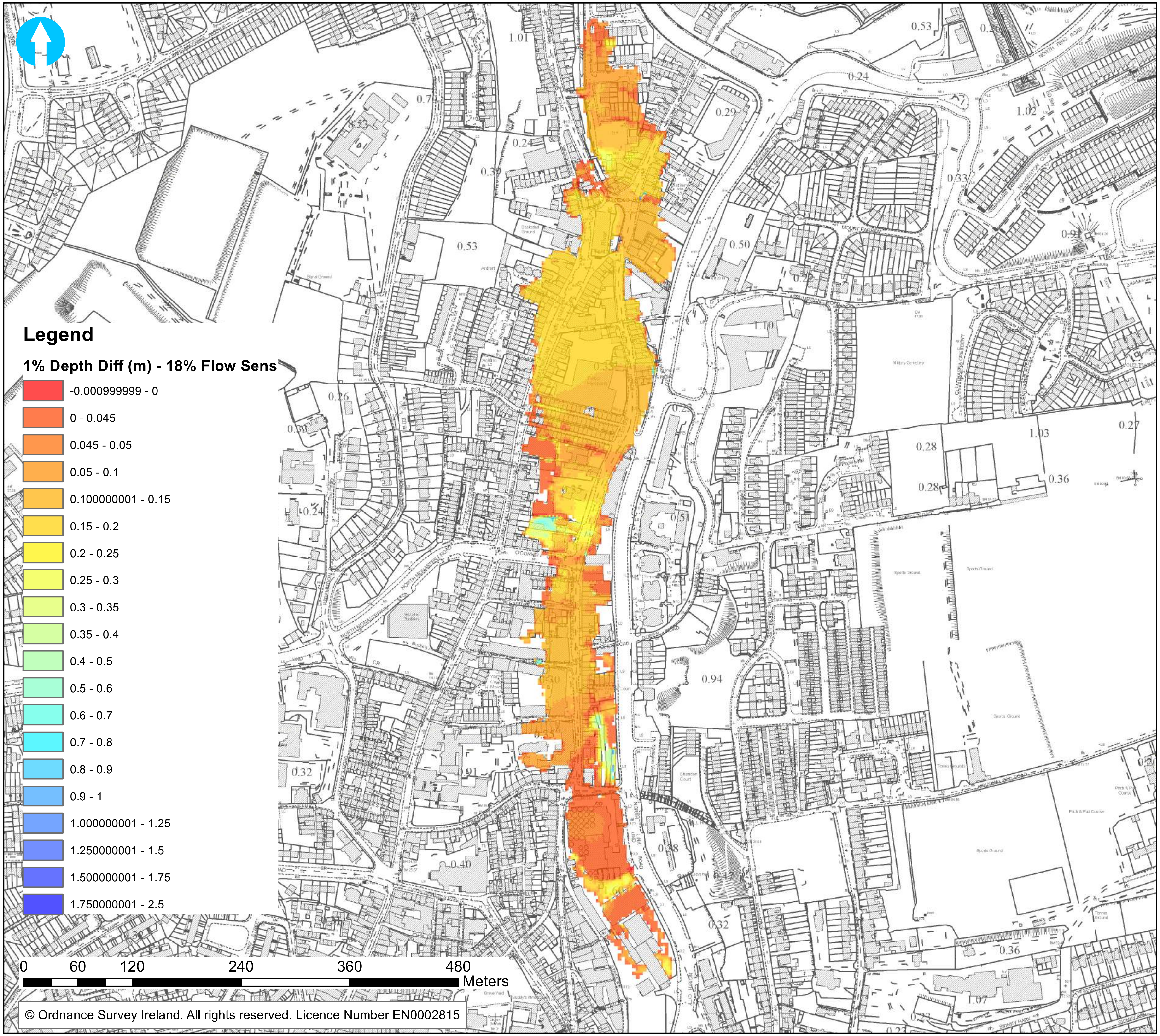

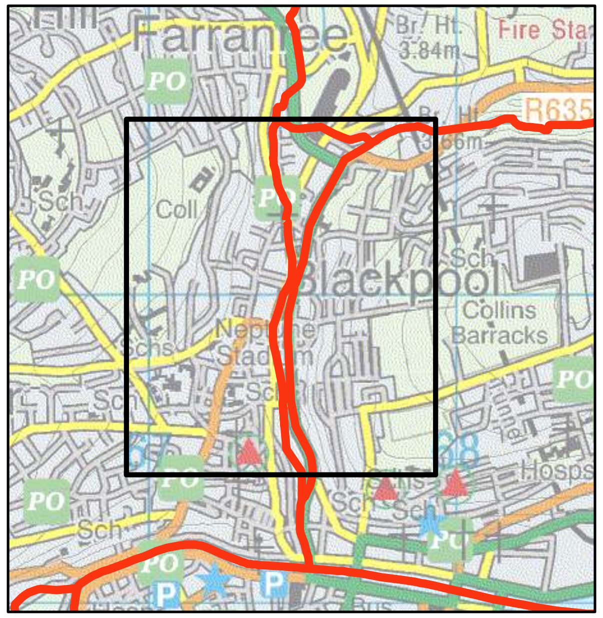

Map: Lower Lee Flood Relief Scheme

Map Type: 1% AEP - 18% Flow Sensitivity

Scenario: Current	**Scale:** 1:4000 A3
Drawn by: AB	
Checked by: DF	

Project No: 2013s7174

Map No: BLK_Flow_Sens_004

Sheet: 4 of 4

Date: 17/Nov/2015 **Status:** Draft

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A.3.2 Afflux at key structures