

# TOBIN

## Newtownmoyaghy Road Flood Risk Assessment



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## Document Control Sheet

|                    |                                 |
|--------------------|---------------------------------|
| Document Reference | Stage 3 – Flood Risk Assessment |
| Client:            | Meath County Council            |
| Project Reference  | 11434                           |

| Rev | Description | Author | Date       | Reviewer | Date       | Approval | Date       |
|-----|-------------|--------|------------|----------|------------|----------|------------|
| A   | Issue       | ST     | 18/09/2025 | DMcH     | 18/09/2025 | PC       | 18/09/2025 |
|     |             |        |            |          |            |          |            |
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## 1. INTRODUCTION

TOBIN Consulting Engineers carried out a Flood Risk Assessment (FRA) of the subject site in Newtownmoyaghy, Co. Meath.

Newtownmoyaghy Road L-6219 is a local secondary road situated to the northeast of Kilcock within the Meath County Council Local Authority Area (Figure 1-1). While it is a local secondary route, Newtownmoyaghy Road is used as a 'bypass' or 'rat run' for vehicles avoiding traffic congestion in Kilcock and Maynooth. Meath County Council has provided an estimated and Annual Average Daily Traffic (AADT) figure of approximately 2500.

The existing road edge and verge of Newtownmoyaghy Road has in discrete sections collapsed into the adjacent Newtownmoyaghy Stream due to erosion from stream flood events compounded by vehicles passing close to the road/stream interface. The length of road affected is 550m, which is subjected to flooding in extreme flood events. The present narrow road width increases the risk of vehicles travelling on and, on occasion, over the edge. Temporary non-retaining/non-structural edge barriers are currently in place to help prevent this acting more as a warning system.

This development proposes the provision of an open channel diversion to the east of and away from the existing road. The route of the diversion will pass-through privately-owned lands which will require a land acquisition. The existing roadside stream channel will be backfilled with suitable material including recovered material deemed suitable for reuse from the new channel excavation. This will provide the additional width required for a Type 3 Single (6.0m) Carriageway and widened grass verge.

An estimated 15m long box culvert will be required at the location where the proposed diversion will pass from the East side of the road to the West side before re-connecting into the existing stream and will be designed and approved appropriately through the Section 50 application process.

A full description of the proposed scheme is provided in Section 2.2 of the Planning and Environmental Consideration Report.

The landscape surrounding the Newtownmoyaghy Road is relatively flat and consisting of mainly agricultural fields.

The Newtownmoyaghy Stream flowing adjacent to Newtownmoyaghy Road, is a tributary of the Rye Water. The confluence with the Rye Water is located approximately 850m downstream of the subject site. The Newtownmoyaghy Stream flows under the two bridges near the ESB's Kilcock substation, before flowing parallel to the road for approximately 550m where it is crossed by another bridge which gives access for a neighbouring residential property. The stream then flows for another 1100m before out falling to the Rye Water.

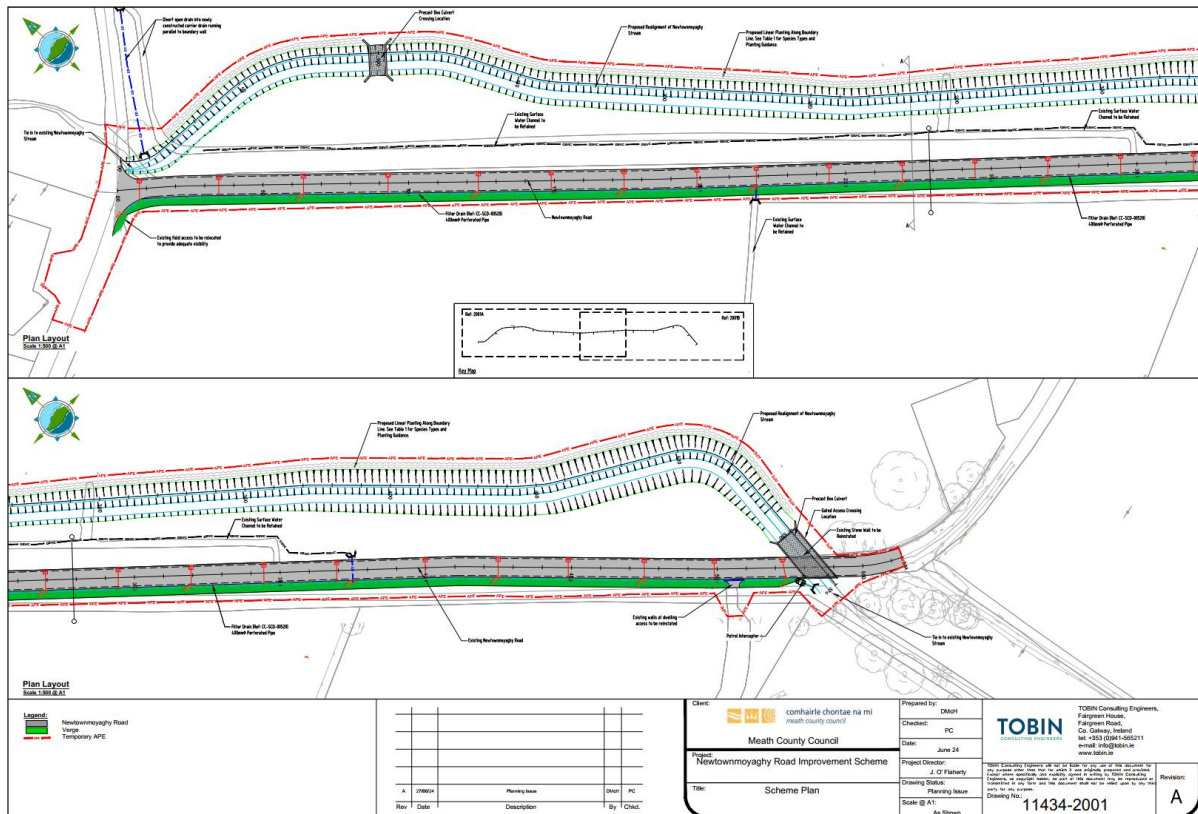


Figure 1-1: Scheme Plan

## 2. FLOOD RISK MANAGEMENT GUIDANCE

This Strategic Flood Risk Assessment was carried out in accordance with the following flood risk management guidance documents:

- The Planning System and Flood Risk Management Guidelines for Planning Authorities
- Flood Risk Management Climate Change Sectoral Adaptation Plan
- Meath County Development Plan 2021-2027

### 2.1 THE PLANNING SYSTEM AND FLOOD RISK MANAGEMENT GUIDELINES

The Planning System and Flood Risk Management Guidelines for Planning Authorities (PSFRM Guidelines) were published in 2009 by the Office of Public Works (OPW) and Department of the Environment, Heritage and Local Government (DoEHLG). Their aim is to ensure that flood risk is considered in development proposals and the assessment of planning applications.

### 2.2 FLOOD ZONES AND VULNERABILITY CLASSES

The PSFRM Guidelines discuss flood risk in terms of flood zones A, B, and C, which correspond to areas of high, medium, or low probability of flooding, respectively. The extents of each flood zone are based on the Annual Exceedance Probability (AEP) of various flood events.

The PSFRM Guidelines also categorise different types of development into three vulnerability classes based on their sensitivity to flooding. Table 2-1 shows a decision matrix that indicates which types of development are appropriate in each flood zone and when the Justification Test must be satisfied. The annual exceedance probabilities used to define each flood zone are also provided.

*Table 2-1: Decision Matrix for Determining the Appropriateness of a Development*

| Flood Zone<br>(Probability) | Annual Exceedance Probability<br>(AEP)                                            | Development Appropriateness |                       |                     |
|-----------------------------|-----------------------------------------------------------------------------------|-----------------------------|-----------------------|---------------------|
|                             |                                                                                   | Highly<br>Vulnerable        | Less<br>Vulnerable    | Water<br>Compatible |
| A (High)                    | <u>Fluvial &amp; Pluvial Flooding</u><br>More frequent than 1% AEP                | Justification<br>Test       | Justification<br>Test | Appropriate         |
|                             | <u>Coastal Flooding</u><br>More frequent than 0.5% AEP                            |                             |                       |                     |
| B (Medium)                  | <u>Fluvial &amp; Pluvial Flooding</u><br>0.1% to 1% AEP                           | Justification<br>Test       | Appropriate           | Appropriate         |
|                             | <u>Coastal Flooding</u><br>0.1% to 0.5% AEP                                       |                             |                       |                     |
| C (Low)                     | <u>Fluvial, Pluvial &amp; Coastal<br/>Flooding</u><br>Less frequent than 0.1% AEP | Appropriate                 | Appropriate           | Appropriate         |

“Local transport infrastructure” developments (such as the works proposed as part of this scheme) are considered “Less vulnerable” in terms of their sensitivity to flood risk (i.e., Appropriate in Flood Zone B, where the risk of flooding is less than a 1% Annual Exceedance Probability (AEP)).



## 2.3 THE FLOOD RISK MANAGEMENT CLIMATE CHANGE ADAPTATION PLAN

The Flood Risk Management Climate Change Sectoral Adaptation Plan was published in 2019 under the National Adaptation Framework and Climate Action Plan. This plan outlines the OPW's approach to climate change adaptation in terms of flood risk management.

This approach is based on a current understanding of the potential impacts of climate change on flooding and flood risk. Research has shown that climate change is likely to worsen flooding through more extreme rainfall patterns, more severe river flows, and rising mean sea levels.

To account for these changes, the Adaptation Plan presents two future flood risk scenarios to consider when assessing flood risk:

- Mid-Range Future Scenario (MRFS)
- High-End Future Scenario (HEFS)

Table 2-2 indicates the allowances that should be added to estimates of extreme rainfall depths, peak flood flows, and mean sea levels for the future scenarios.

*Table 2-2: Climate Change Adaptation Allowances for Future Flood Risk Scenarios*

| Parameter               | Mid-Range Future Scenario (MRFS) | High-End Future Scenario (HEFS) |
|-------------------------|----------------------------------|---------------------------------|
| Extreme Rainfall Depths | + 20%                            | + 30%                           |
| Peak River Flood Flows  | + 20%                            | + 30%                           |
| Mean Sea Level Rise     | + 0.5 m                          | + 1 m                           |

## 2.4 CURRENT MEATH COUNTY DEVELOPMENT PLAN 2021-2027 (EXTENDED)

The current Meath County Development Plan 2021-2027 was adopted on 22<sup>nd</sup> September 2021 and came into effect on 3<sup>rd</sup> November 2021. Chapter 9 outlines Meath County Council's strategy for Environmental Infrastructure.

Section 6.10.2 outlines Meath County Council's approach to flood risk management and sets out the following key policies:

- INF POL 18 To implement the "Planning System and Flood Risk Management –Guidelines for Planning Authorities" (DoEHLG/OPW, 2009) through the use of the sequential approach and application of Justification Tests for Development Management and Development Plans, during the period of this Plan.
- INF POL 19 To implement the findings and recommendations of the Strategic Flood Risk Assessment prepared in conjunction with the County Development Plan review, ensuring climate change is taken into account.
- INF POL 20 To require that a Flood Risk Assessment is carried out for any development proposal, where flood risk may be an issue in accordance with the "Planning System and Flood Risk Management –Guidelines for Planning Authorities" (DoEHLG/OPW, 2009). This assessment shall be appropriate to the scale and



nature of risk to and from the potential development and shall consider the impact of climate change.

- INF POL 21 To consult with the Office of Public Works in relation to proposed developments in the vicinity of drainage channels and rivers for which the OPW are responsible.
- INF POL 22 To retain a strip of 10 metres on either side of all channels/flood defence embankments where required, to facilitate access thereto.
- INF POL 23 To consult, where necessary, with Inland Fisheries Ireland, the National Parks and Wildlife Service and other relevant agencies in the provision of flood alleviation measures in the County.
- INF POL 24 To ensure that flood risk management is incorporated into the preparation of Local Area Plans in accordance with 'The Planning System and Flood Risk Management -Guidelines for Planning Authorities (2009)'.
  - INF POL 25 To have regard to the recommendations of the Fingal East Meath Flood Risk Assessment and Management Study (FEMFRAMS) and the Eastern Catchment Flood Risk Assessment and Management Study (CFRAMS).
- INF POL 26 To undertake a review of the 'Strategic Flood Risk Assessment for County Meath' in light of the completed flood mapping which has been developed as part of the Eastern Catchment Flood Risk Assessment and Management (CFRAM) Study.
- INF POL 27 To liaise with the Office of Public Works in relation to proposed developments in the vicinity of drainage channels and rivers for which the OPW are responsible, prior to the making of determinations/assumptions on surface water management proposals.
- INF POL 28 To consult with the Office of Public Works in relation to proposed developments which include the construction, replacement or alteration of a bridge or culvert and to require that the developers obtain consent from the OPW under Section 50 of the EU (Assessment and Management of Flood Risks) Regulations 2010 and Section 50 of the Arterial Drainage Act 1945, where appropriate.
- INF POL 29 To facilitate the provision of new, or the reinforcement of existing flood defences and protection measures where necessary and in particular to support the implementation of flood schemes being progressed through the planning process during the lifetime of the Plan. The provision of flood defences will be subject to the outcome of the Appropriate Assessment process. It is an objective of the Council.

### 3. INITIAL FLOOD RISK ASSESSMENT

#### 3.1 PAST FLOOD EVENTS

The OPW's National Flood Information Portal<sup>1</sup> provides past flood event mapping with records of flooding reports, meeting minutes, photos, and/or hydrometric data. Figure 3-1 summarizes recorded locations of recurring flood events noted in the vicinity of the subject site.



*Figure 3-1: OPW Flood Map of Past Flood Events*

There is one past flood event recorded within the subject site. The flood event (Flood ID-10480) occurred on the 8th of January 2005. The flood event is a fluvial flood event known as the Rye Water Newtown Prospect Kilcock, see Figure 3-2 below.

<sup>1</sup> floodinfo.ie



*Figure 3-2: Picture from 2005 Flood Event*



## 3.2 OPW PRELIMINARY FLOOD RISK ASSESSMENT (PFRA) STUDY

In 2009, the OPW produced a series of maps to assist in the development of a broad-scale FRA throughout Ireland. These maps were produced from several sources.

The OPW's National Preliminary Flood Risk Assessment (PFRA) Overview Report from March 2012 noted that *"the flood extents shown on these maps are based on broad-scale simple analysis and may not be accurate for a specific location"*<sup>2</sup>.

Limitations on potential sources of error associated with the PFRA maps include:

- Assumed channel capacity (due to absence of channel survey information)
- Absence of flood defences and other drainage improvements and channel structures (bridges, weirs, culverts)
- Local errors in the national Digital Terrain Model (DTM)

Figure 3-3 provides an overview of the fluvial, coastal, pluvial, and groundwater indicative flood extents in the vicinity of the subject site. The PFRA mapping shows that the subject site is susceptible to fluvial flooding during the 1 in 100-year flood event.

Figure 3-4 outlines the PFRA fluvial flood extents. These extents show that the subject site is susceptible to fluvial flooding during the 1 in 10, 100 and 1,000-year flood events.

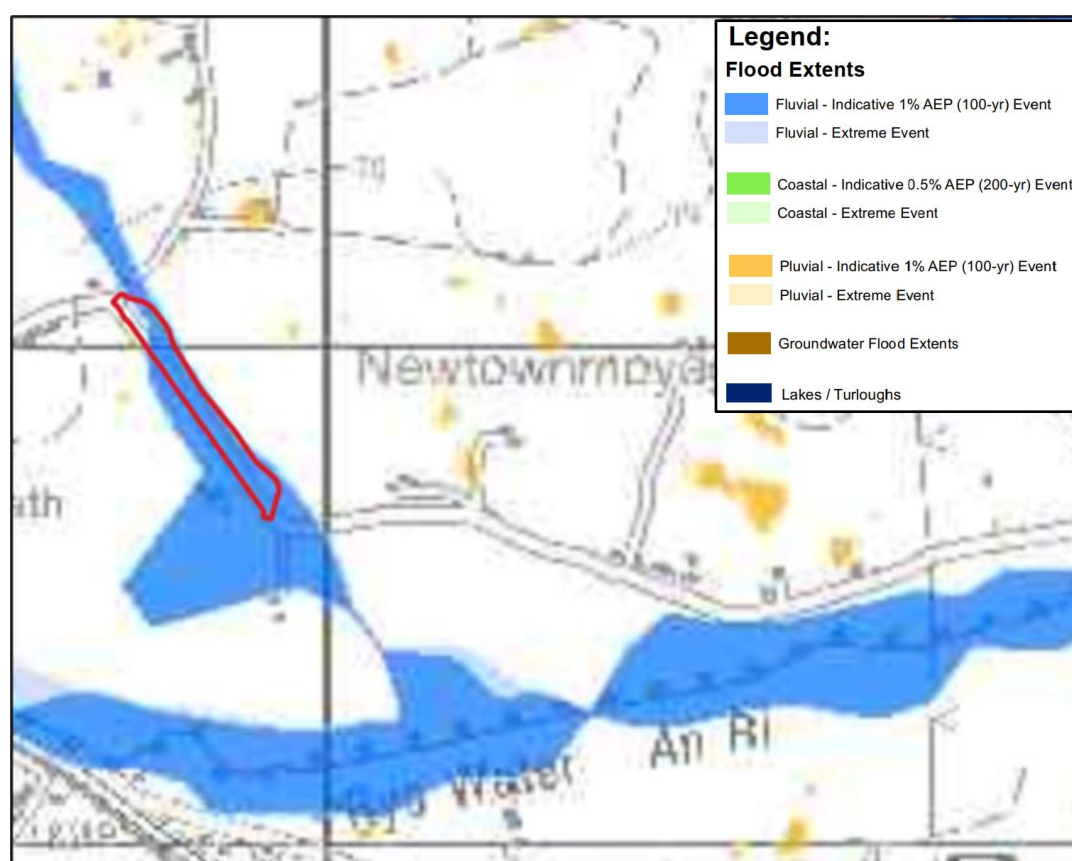


Figure 3-3: Indicative Flood Mapping [extract from PFRA Map 254 & 255]

<sup>2</sup> The National Preliminary Flood Risk Assessment (PFRA) Overview Report, OPW (March 2012)

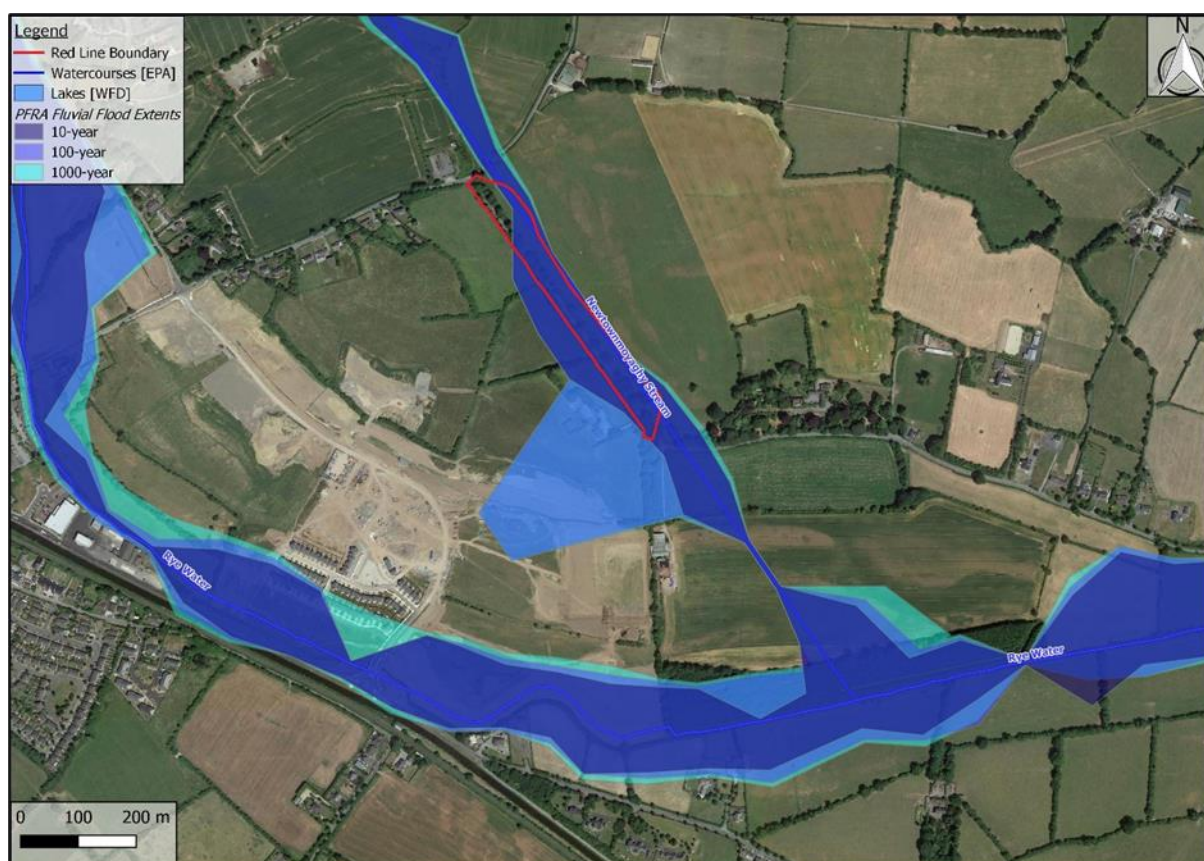


Figure 3-4: PFRA Flood Extents

### 3.3 CATCHMENT FLOOD RISK ASSESSMENT AND MANAGEMENT AREA (CFRAM)

In 2015, the OPW produced flood maps as part of the Catchment Flood Risk Assessment and Management (CFRAM) Study. The flood extents in these maps are based on detailed modelling of Areas for Further Assessment identified by the National Preliminary Flood Risk Assessment.

CFRAM mapping of existing fluvial flood extents, presented in Figure 3-5 indicates that significant portions of the subject site may be at risk of flooding from the Newtownmoyaghy Stream during the 10%, 1% and 0.1% AEP fluvial flood events. Accordingly, a majority of the site is located within Flood Zone A.

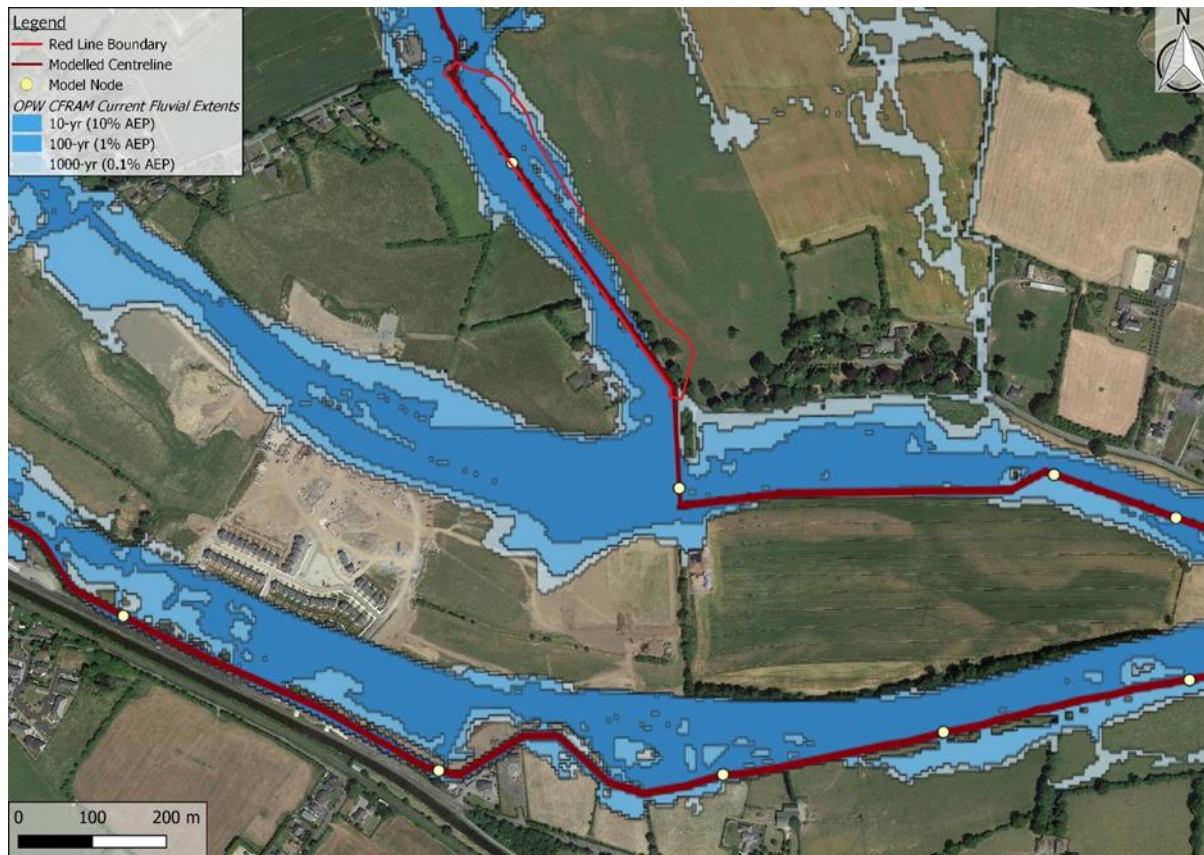
During the current 1 in 100-year event (without climate change) the CFRAM study estimates that water levels will vary in the vicinity of the site from **66.32mOD<sup>3</sup>** (CFRAM Node: 09DOLA00156) at the upstream portion of the subject site to approximately **64.22mOD** (CFRAM Node: 09DOLA00104) at the downstream extents of the subject site. With the road level at node 09DOLA00156 being circa **66.245mOD**, it is predicted that this portion of the Newtownmoyaghy Road will be inundated.

During the current 1 in 1,000-year event (without climate change) the CFRAM study estimates that water levels will vary in the vicinity of the site from **66.42mOD** (CFRAM Node:

<sup>3</sup> Eastern CFRAM Study Map No: E09KIK\_EXFCD\_F2\_07 (May 2017)



09DOLA00156) at the upstream portion of the subject site to approximately **64.40mOD** (CFRAM Node: 09DOLA00104) at the downstream extents of the subject site.



*Figure 3-5 CFRAM Current Extents*

The Eastern CFRAM study also included an assessment of the likely impact of climate change on flood risk in the area. The flood extents for a Mid-Range Future Scenario are shown in Figure 3-6, however no levels for this scenario were provided by the CFRAM.

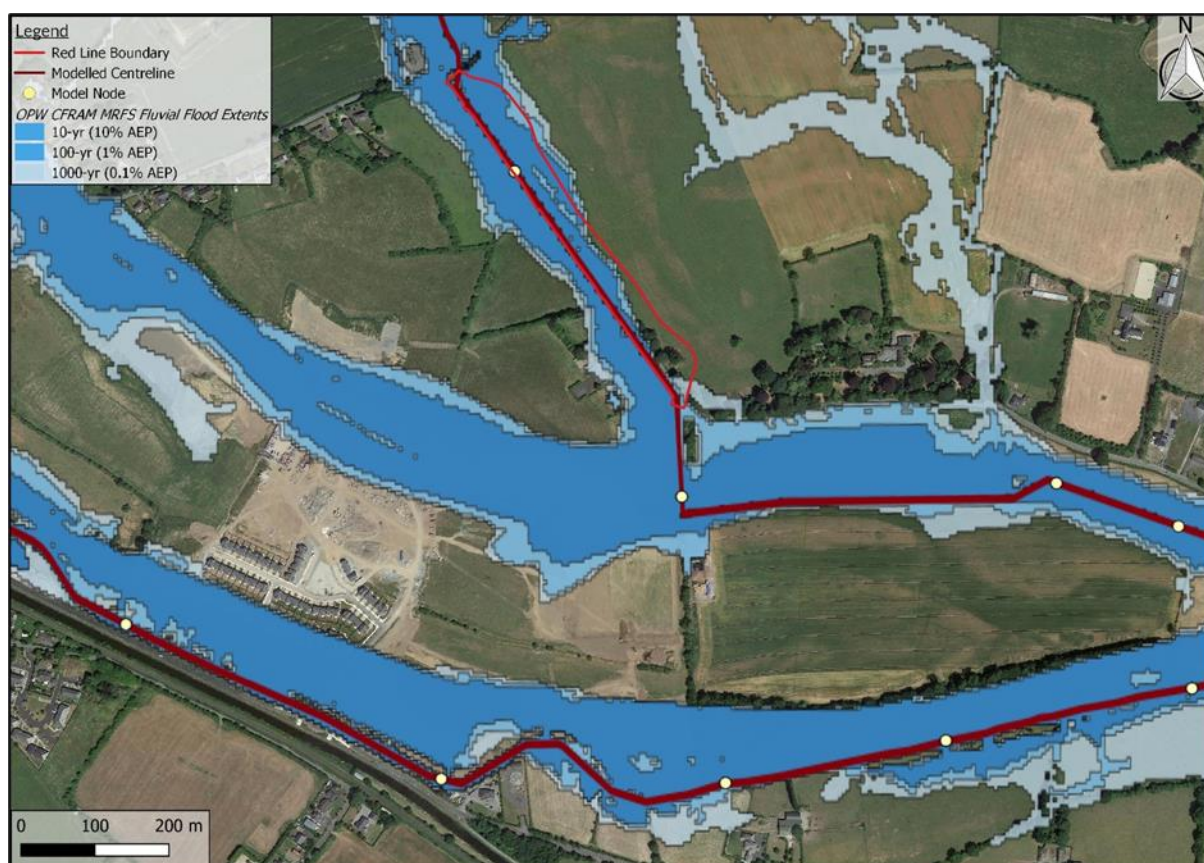


Figure 3-6 CFRAM MRFS Extents

### 3.4 GEOLOGICAL SURVEY IRELAND MAPPING

The Geological Survey Ireland (GSI) provides mapping<sup>10</sup> with data related to Ireland's subsurface. Based on the map shown in Figure 3-7, the closest Karst Feature to the subject site is a cave that is located approximately 7km south-east of the subject site. There are no karst features (caves, springs, turloughs, etc.) in the immediate vicinity of the subject site.

GSI surface water mapping shows that there is an area of surface water flooding located approximately 0.8km east of the subject site. This area of surface water flooding is located at the confluence between the Newtownmoyaghy Stream and the Rye Water.



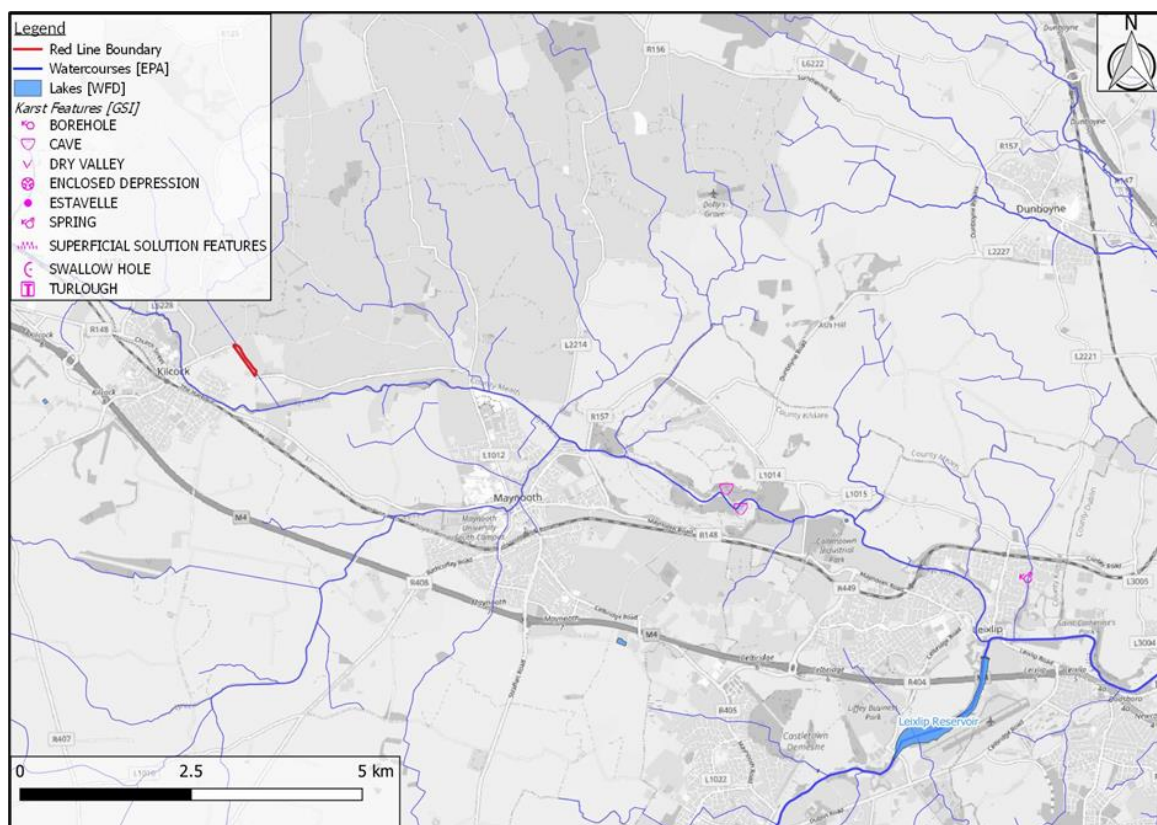


Figure 3-7: GSI Mapping of Karst Features



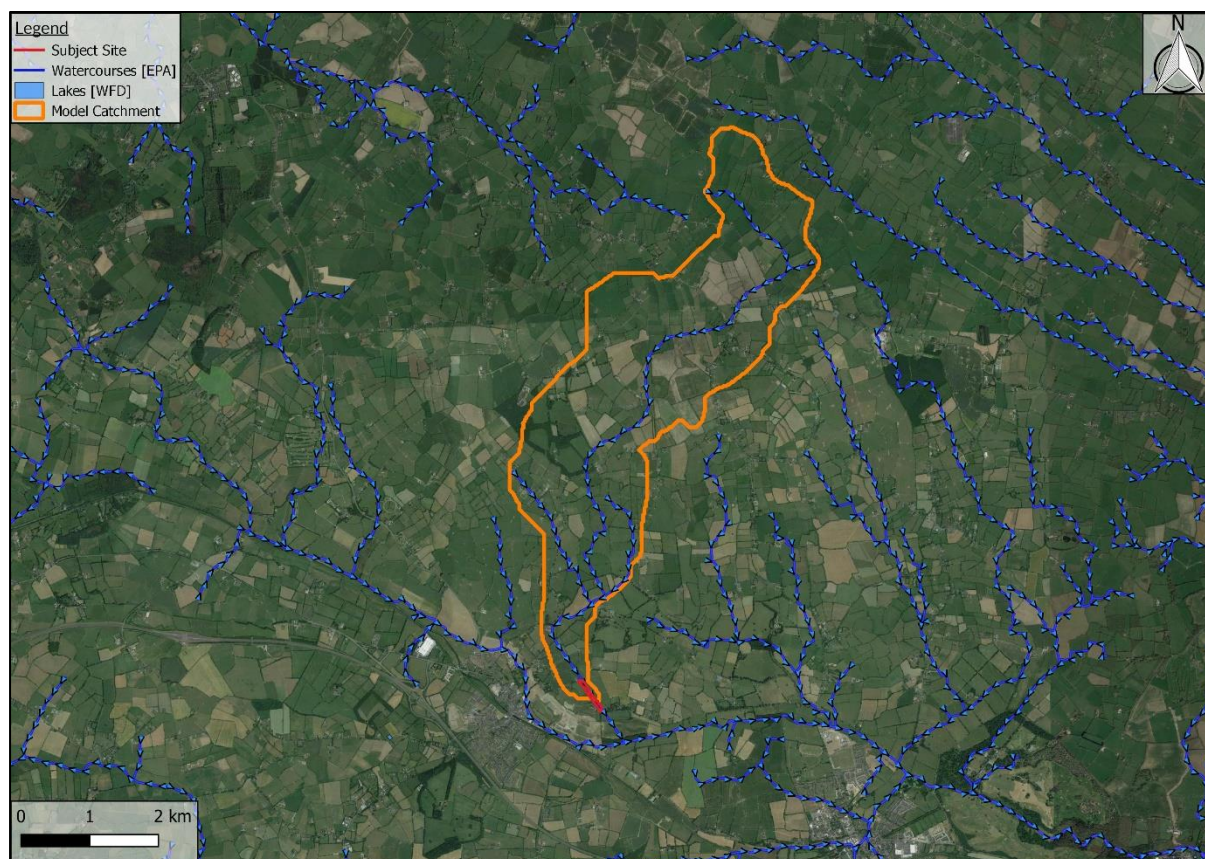
Figure 3-8: GSI 2015-2016 Surface Water Flood Mapping



## 4. SITE SPECIFIC HYDRAULIC ANALYSIS

### 4.1 FLOW ESTIMATION

The catchment area for the Newtownmoyaghy Stream at the subject site was estimated to be approximately 13.5km<sup>2</sup> based on the OPW's FSU dataset and the topography of the area; see Figure 4-1.



*Figure 4-1: Catchment Delineation*

Given the size of the Newtownmoyaghy Stream catchment, there are a number of flow estimation methodologies applicable:

- Flood Studies Update (FSU) Method
- Flood Estimation Handbook (FEH) Statistical Method
- Institute of Hydrology report no. 124 (IH124) Method

Extreme flows in the watercourse were estimated based on catchment descriptors, see Table 4-1.

Table 4-1 Summary of Catchment Descriptors

| Descriptor            | Units              | Value                        | Source    |
|-----------------------|--------------------|------------------------------|-----------|
| Watercourse           | -                  | <b>Newtownmoyaghy Stream</b> | EPA       |
| Catchment Area        | km <sup>2</sup>    | 13.473                       | FSU/TOBIN |
| Method Applicability  |                    |                              |           |
| FSU                   | -                  | YES                          | FSU       |
| FEH                   | -                  | YES                          | FEH       |
| IH124                 | -                  | YES                          | IH124     |
| Catchment Descriptors |                    |                              |           |
| BFI <sub>SOIL</sub>   | -                  | 0.467                        | FSU       |
| SAAR                  | mm                 | 817.660                      | FSU/MET   |
| FARL                  | -                  | 1.000                        | FSU/TOBIN |
| DRAIN2                | km/km <sup>2</sup> | 1.155                        | FSU       |
| S1085                 | m/km               | 4.498                        | FSU/DEM   |
| ARTDRAIN2             | -                  | 0.000                        | FSU       |
| URBEXT                | -                  | 0.000                        | FSU       |
| S2                    | -                  | 0.2                          | WRAP      |
| S5                    | -                  | 0.8                          | WRAP      |
| CWI                   | -                  | 118.0                        | graph     |
| URBAN                 | fraction           | 0.01                         | user      |

Generated GEV growth factors as defined by the FSU were applied to the estimation of  $Q_{bar}$  to predict the 10-, 100-, and 1000-year flows, respectively.

Table 4-2 Estimated and CFRAM Flows

| Return Period | Method              |                     |                       |       |
|---------------|---------------------|---------------------|-----------------------|-------|
|               | FSU Flow Estimation | FEH Flow Estimation | IH124 Flow Estimation | CFRAM |
| $Q_{MED}$     | 3.28                | 3.92                | 4.15                  | 4.96  |
| $Q_{10}$      | 5.96                | 7.14                | 7.56                  | 8.77  |
| $Q_{100}$     | 10.32               | 12.36               | 13.08                 | 15.94 |
| $Q_{1000}$    | 16.08               | 19.26               | 20.38                 | 27.98 |

A review of the Eastern CFRAM HA09 Hydrology Report was undertaken to review methods employed by the study to estimate the flow in the Newtownmoyaghy Stream. The findings of the hydrology report found that the IH124 methodology was the most applicable for the Newtownmoyaghy Stream catchment. The CFRAM calculated flows were higher than the flows TOBIN calculated using the IH124 approach. To be conservative, the CFRAM calculated flows were adopted for the hydraulic modelling.

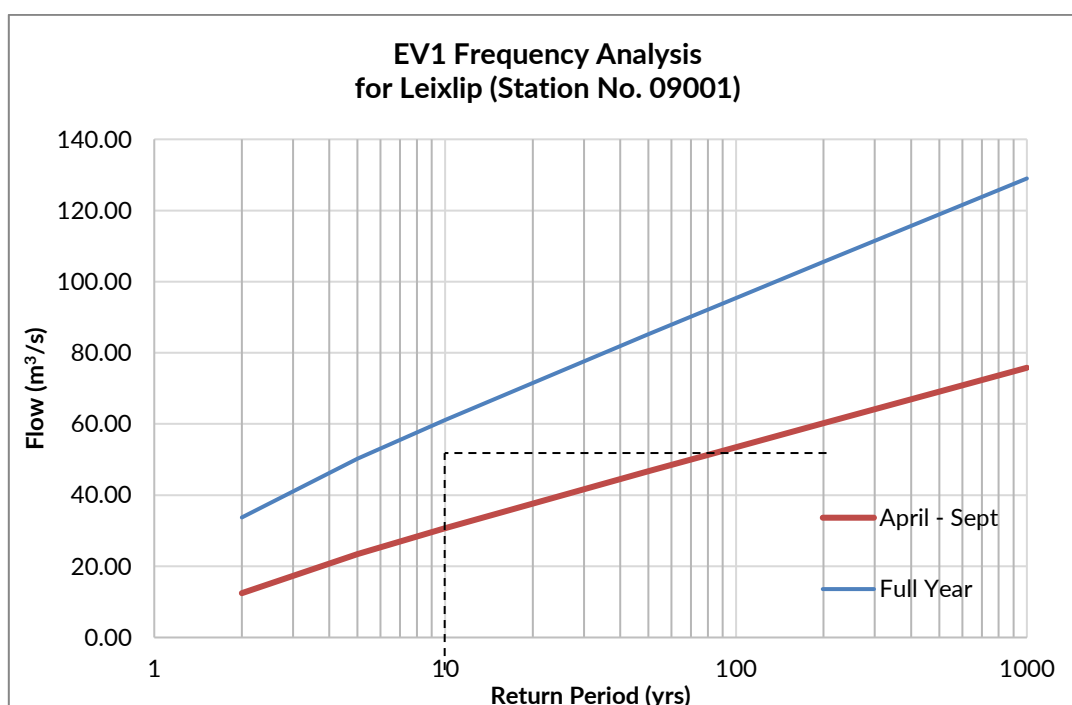
The Eastern CFRAM Hydraulics Report mentions flow spilling from the left bank of the Rye Water upstream of the Meath Bridge flows across the R125 and continues through a field, flowing roughly parallel to the main Rye Water channel. This flow eventually meets the

Newtownmoyaghy Stream. Peak flow values of approximately 1.4m<sup>3</sup>/s, 12.7m<sup>3</sup>/s and 23.4m<sup>3</sup>/s were found to occur in the 10%, 1% and 0.1% AEP design runs respectively for this overland flow (Table 4-3).

*Table 4-3 Summary of Flows for Newtownmoyaghy Stream*

| Return Period  | Units             | Newtownmoyaghy Stream | Lateral inflow |
|----------------|-------------------|-----------------------|----------------|
| 10-year Flow   | m <sup>3</sup> /s | 8.77                  | 1.40           |
| 50-year Flow   | m <sup>3</sup> /s | 13.40                 | 7.30           |
| 100-year Flow  | m <sup>3</sup> /s | 15.94                 | 12.70          |
| 1000-year Flow | m <sup>3</sup> /s | 27.98                 | 23.40          |

The new channel is proposed to be constructed between the months of April and September. Therefore, it is critical to ascertain the probability of an extreme event occurring during these months. Using Annual Maximum flow values from the downstream Leixlip Gauging Station (09001), an EV1 analysis was performed for extreme flow probability for an entire year, and separately for between the months April and September, see Figure 4-2. Based on the hydrological similarity between the catchment descriptors of the Rye Water in Leixlip and the Newtownmoyaghy Stream, it is assumed that the two catchments share similar flood seasonality patterns. Therefore from Figure 4-2, it can be denoted that there is 0.5% chance of a 10% AEP flood event occurring between the months of April and September of a given year (i.e., the 10-year 'annual' flood event  $\approx$  200-year 'summer' event).



*Figure 4-2 EV1 Frequency Analysis*

## 4.2 HYDRAULIC MODEL CONSTRUCTION

A 1D site-specific hydraulic model of the subject site was developed using the latest version (6.0) of Flood Modeller software. Flood Modeller is designed to perform one-dimensional and two-dimensional hydraulic calculations for a full network of natural and constructed channels. The three primary inputs into the Flood Modeller model are summarised below:



- Geometric Data: Cross-sectional survey of watercourse, bridges, and culverts
- Inflow Data: 10-, 50-, 100-, and 1000-year flows,
- Boundary Condition: Normal Depth downstream boundary
- Terrain Data: 2m OPW DTM

The cross-sectional survey was acquired from the OPW to provide baseline geometric data input for this hydraulic model. The Newtownmoyaghy Stream channel and floodplain were also surveyed by Murphy Geospatial in December 2022. The cross-sectional survey provided geometric data input for this hydraulic model.

This data was supplemented with high-resolution 2m Digital Terrain Model (DTM) LiDAR data to create a ground model of the watercourses and surrounding area.

Roughness values of 0.013, 0.03, 0.04, and 0.06 were applied to the road surface, floodplain, channel, and vegetation/brush respectively, based on published CFRAM values and a review of site photography and channel conditions.

Two hydraulic models were constructed for this project:

- existing channel adjacent to road
- proposed channel east of the road and with existing channel backfilled

See Appendix A for full drawing of modelled cross sections.

### **Existing Channel**

This hydraulic model included four No. bridge structures the details of which are ascertained from OPW cross-sectional data provided. The first bridge, located at cross-section no. 172 (Section 09DOLA00172), is a stone arch bridge that forms part of the Newtownmoyaghy Road. The deck, soffit and invert levels are 67.81mOD, 67.48mOD and 65.55mOD respectively. The bridge opening is approximately 3m wide. The second bridge, located at cross-section no. 170, forms part of the Newtownmoyaghy Road. It is a stone arch bridge with an opening of 1.74m. The deck, soffit and invert levels are 67.06mOD, 66.89mOD and 65.33mOD respectively. The third bridge on the Newtownmoyaghy Stream is located at cross section no. 122 (Section 09DOLA00122). The bridge provides access to a residential dwelling. This residential property is situated within the model boundaries located between sections 09DOLA00141 and 09DOLA00123.

The fourth bridge is located downstream of the study area at cross section 09DOLA00100 and was included in the model to assess any downstream impacts of the proposed scheme.

An overview of the hydraulic model for the existing channel is shown in Figure 4-3.

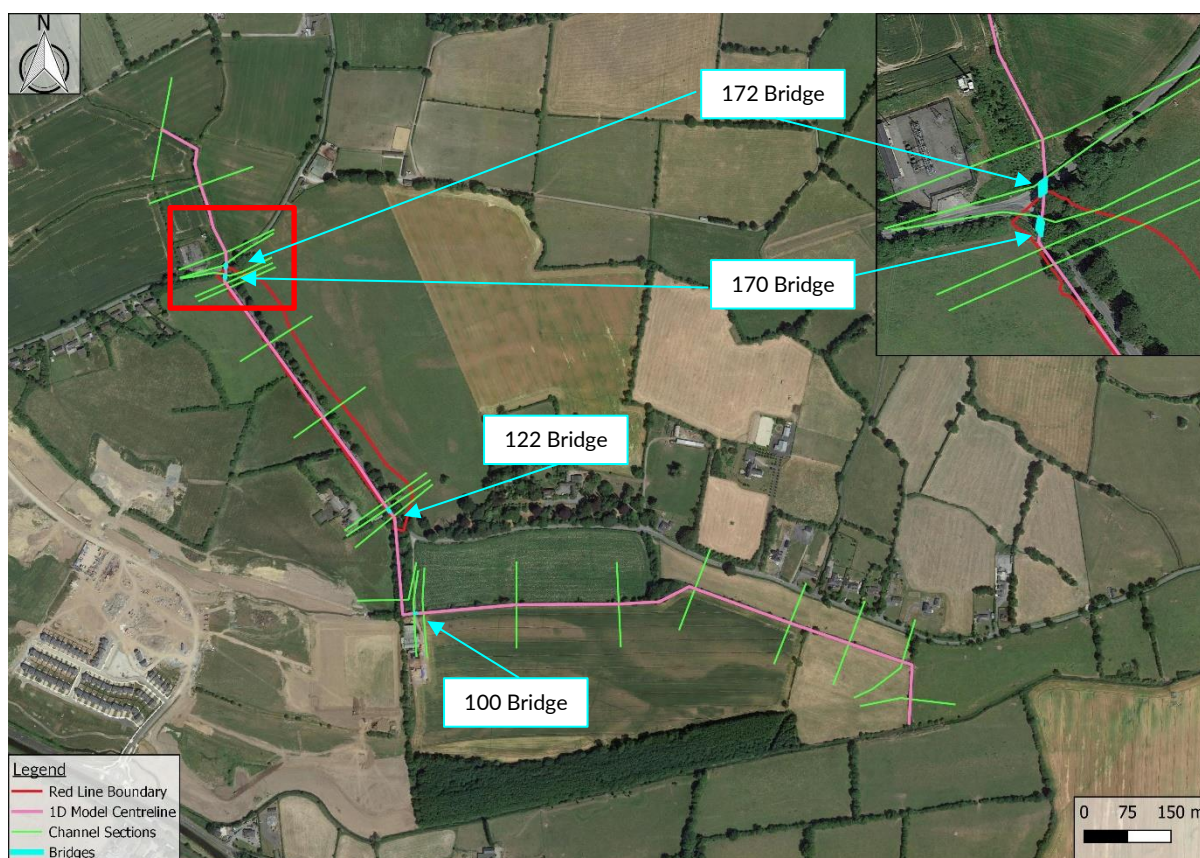


Figure 4-3 Flood Modeller Model Configuration for Existing Channel

### Proposed Channel

The new channel will bypass the bridge structure at cross section no.170 (CFRAM Section 09DOLA00170) and travel south to reconnect to the existing Newtownmoyaghy Stream channel via a bridge/box culvert connecting the stream from east to west. Infilling of the existing roadside Newtownmoyaghy Stream will include a conventional filter drain system containing a 400mm pipe to collect primarily surface water road runoff and local drainage on the west side of the road.

This hydraulic model included three No. bridge structures (there is also a proposed field crossing, which if required would be designed such as not to be an impediment to the hydraulic flow conditions). The first bridge is again located at cross-section no. 172 and will keep the same hydraulic properties as in the existing scenario. However, the existing bridge structure at cross-section no.170 no longer serves a primary hydraulic function, except for permitting overtopping overflow from north of the road to backflow to the two-stage channel, with the new channel intercepting the main flows east of the Newtownmoyaghy Road. The proposed channel is designed such that the existing hydraulic conditions are **maintained**, and stream levels are preserved. The new open channel section will operate as a two-stage channel to facilitate a depth of water at low flow. During high flow events, excess water will utilise a wider floodplain cross-sectional area at the higher flood flow elevations.

Arising from the replacement of the roadside stream with a localised filter drainage system and infilling of the bridge crossing at cross section no. 122 (Section 09DOLA00122) which provides access to a residential dwelling, this filter drain is rendered hydraulically redundant except for acting as a local carrier filter drain with 400mm pipe that drains the local area to the west of

the road and accommodating the road surface water run-off. In summary this bridge is removed from the model.

The model incorporates a small section of the existing channel as it will not be backfilled in its entirety. This allows overflow water to continue using the existing path over the road and discharge into the two-stage channel. In simpler terms, an opening near the second bridge will be kept enabling backflow into the two-stage channel. To further accommodate this, the road elevation adjacent to the entrance to the ESB substation will remain the same, and road levels will only gradually be raised (from the 172 bridge onwards) to continue to allow the spill at the right bank of the bridge structure at cross section 172 and over the road in extreme flood events. Doing this will prevent the creation of flood risk elsewhere and will not exacerbate flood risk at the adjacent substation.

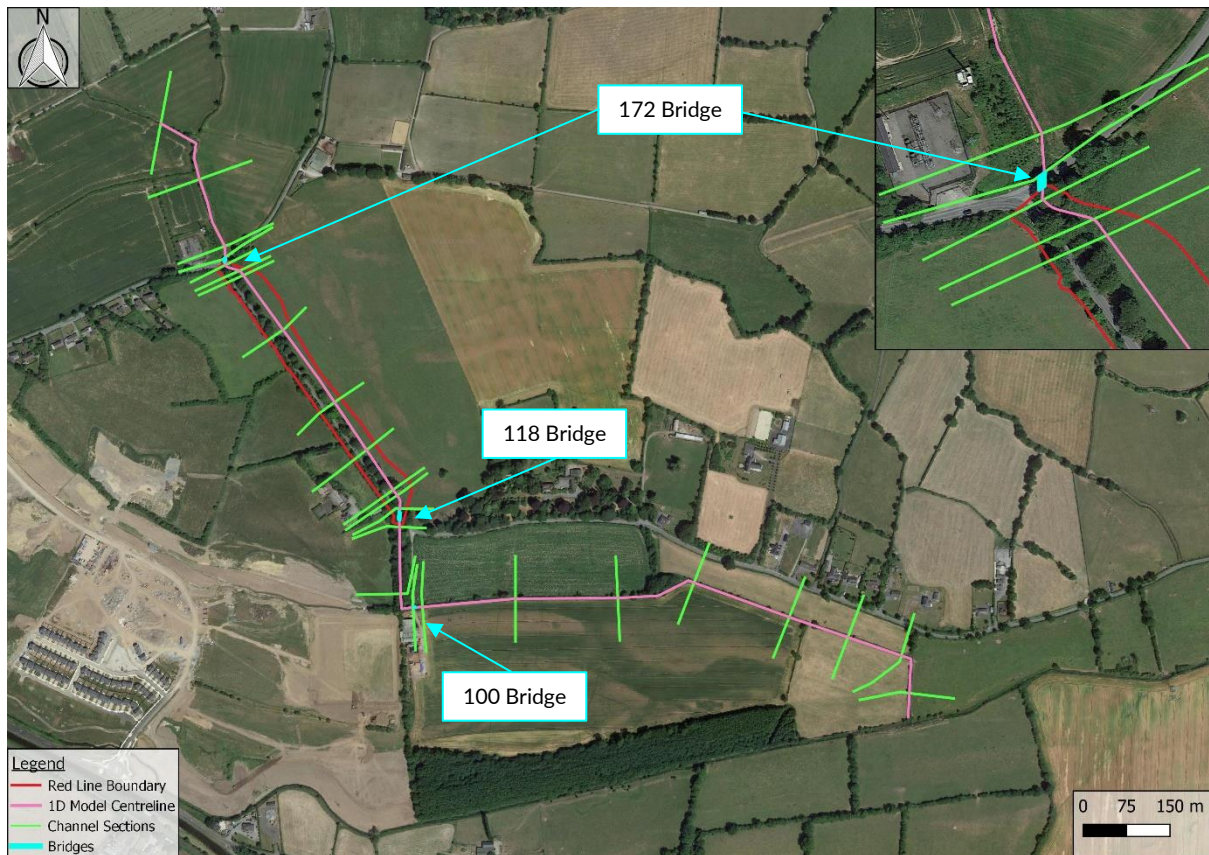
The alternative option of raising the road levels in front of the ESB substation, while potentially removing that section of road from the floodplain, could inadvertently exacerbate surcharging at Bridge 172. This may necessitate the subsequent upsizing of the bridge structure, a process requiring a Section 50 application due to potential downstream flood risk implications.

By maintaining road levels adjacent to the substation, no further flood risk is created elsewhere. However, this will maintain the designated overflow path across the road, discharging into the designated section of the existing channel. The proposed channel relocation to the east of the road necessitates a new bridge at the southeasterly end of the Newtownmoyaghy Road near cross-section 118. The proposed bridge structure will consist of multiple box culverts placed in parallel. Sufficient cover from the top of the box culvert to the road level is to be maintained at the road crossing. Again, the cross section will accommodate the two-stage channel design with low flow and high flow sections.

From anecdotal evidence and review of the available CFRAM mapping it is noted that in excess of 300mm of surface water is estimated to exist on sections of the existing road carriageway for the 1% AEP event. Therefore, for the proposed scenario the road has been modelled as being raised by 175mm to accommodate vehicles to pass in higher flood scenarios. Again, the road will be raised gradually at the northern end (near the bridge at Section 170) to continue to allow the spill at the right bank of the bridge structure at cross section 172 and over a short section of road in extreme flood events.

The bridge downstream of the study area at cross section 09DOLA00100 was again included in the model to assess any downstream impacts of the proposed scheme. An overview of the hydraulic model for the proposed channel is shown in Figure 4-4.





*Figure 4-4 Flood Modeller Model Configuration for Proposed Channel*

See Appendix A for full drawing of modelled cross sections.

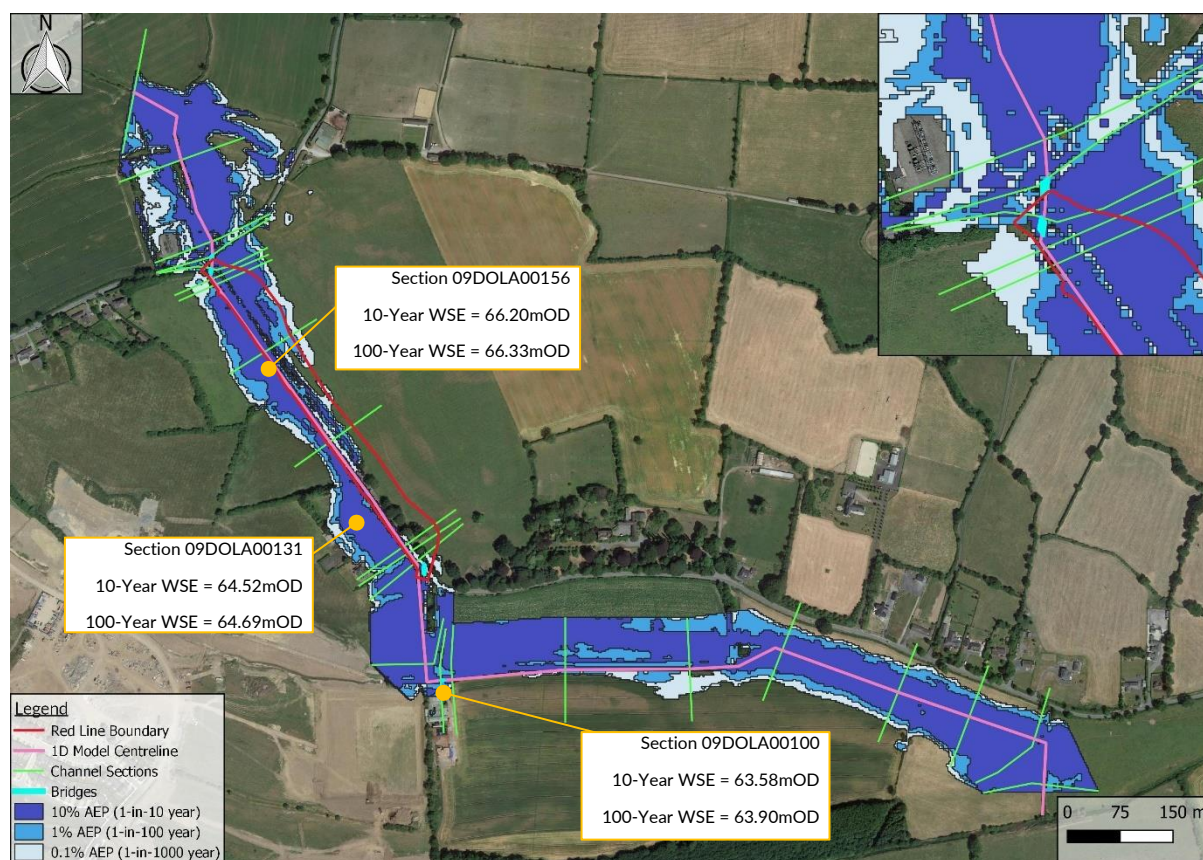


### 4.3 HYDRAULIC MODEL RESULTS

Full tabulated cross-sectional results are shown in Appendix B.

Figure 4-5 shows the predicted **10-,100-, and 1000-year** flood extents for the existing scenario in the vicinity of the subject site using the hydraulic model for the existing channel and utilising the CFRAM flows, corresponding to Flood Zones. This has been calibrated against the CFRAM Model.

Issues worth noting on this model scenario are that the Bridge at 122 acts as a hydraulic constraint in the higher flood scenario and the Residential property is at risk of flooding in the higher return period.



*Figure 4-5 Flood Extents for Existing Scenario [10-,100-, & 1000-Year]*

Figure 4-6 shows the 10- and 100-year flood extents estimated in the vicinity of the subject site using the hydraulic model for the proposed rerouted channel and the CFRAM Flows estimated as per Table 4-3.

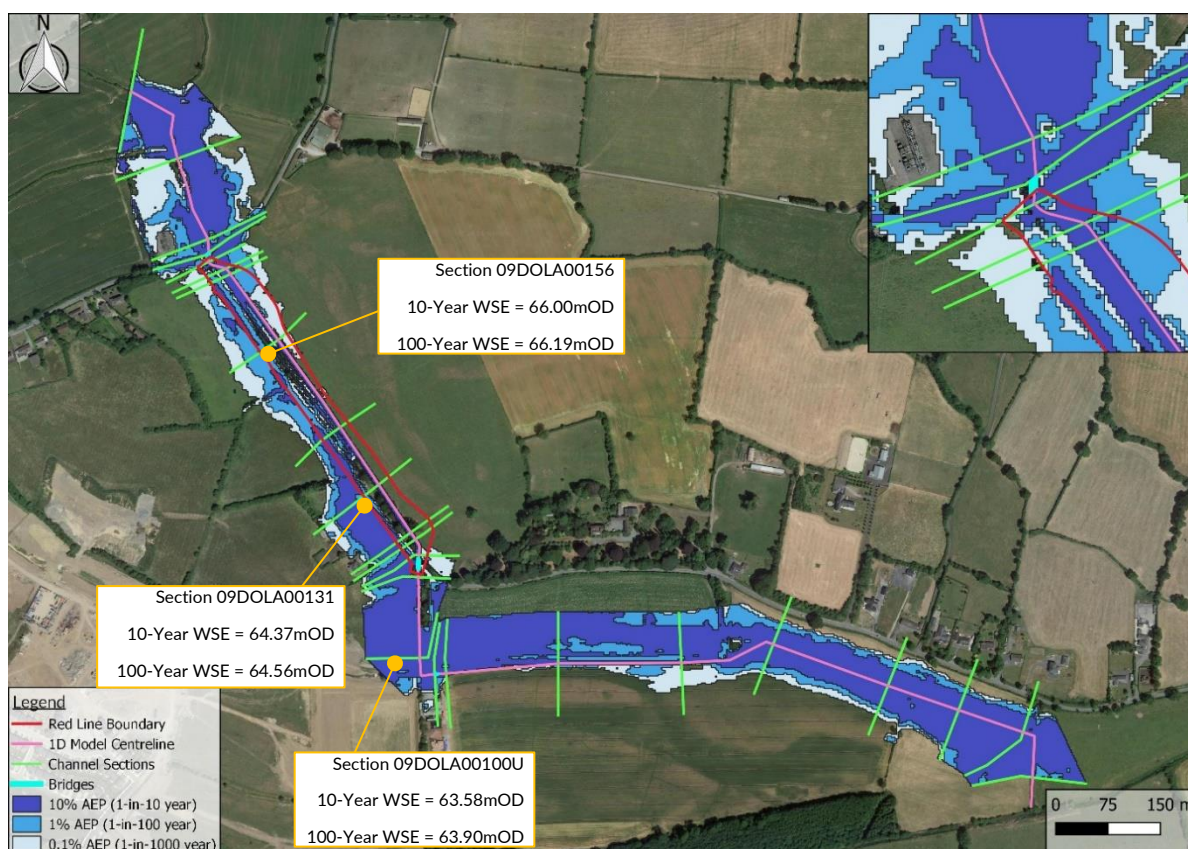


Figure 4-6 Flood Extents for Proposed Scenario [10-, 100-, & 1000-Year]

Table 4-4 and Table 4-5 show the inundation depths along the Newtownmoyaghy Road, for the 10-, 50-, 100-, and 1000-year events, in both the existing and proposed scenarios. The positive heights (highlighted in yellow) signify the inundation at a given cross section. The negative values show the amount of freeboard between the road and the predicted flood level.

In the existing scenario the Newtownmoyaghy road is estimated to be inundated at Section 09DOLA00156 in every modelled return period scenario, with the road elevation at approximately 0.39m below the flood level in the 0.1% AEP event (i.e., max flood depth of 0.39).

In the proposed scenario, flood depth at 09DOLA00156 is reduced to 0.08m in the 1000-year event. This is attributable to:

1. the road having been raised by 175mm.
2. additional hydraulic storage being provided in the 2-stage channel arrangement to account for the loss of hydraulic capacity where the road has been risen, and
3. the removal of a hydraulic constraint that was bridge No. 122

Table 4-4 Inundation along Newtownmoyaghy Road in existing scenario (metres)

| Node Label   | 10-yr | 50-yr | 100-yr | 1000-yr | Road Level (mOD) |
|--------------|-------|-------|--------|---------|------------------|
| 09DOLA001695 | -0.02 | 0.01  | 0.04   | 0.17    | 66.80            |
| 09DOLA00156  | 0.12  | 0.22  | 0.26   | 0.39    | 66.08            |
| 09DOLA00141  | -0.23 | -0.08 | -0.02  | 0.15    | 65.37            |
| 09DOLA00131  | -0.61 | -0.50 | -0.44  | -0.26   | 65.13            |
| 09DOLA00122  | -0.12 | 0.03  | 0.08   | 0.25    | 64.27            |

|                     |
|---------------------|
| Flooding on road    |
| No flooding on road |

Table 4-5 Inundation along Newtownmoyaghy Road in proposed scenario (metres)

| Node Label   | 10-yr | 50-yr | 100-yr | 1000-yr | Road Level (mOD) |
|--------------|-------|-------|--------|---------|------------------|
| 09DOLA001695 | -0.49 | -0.33 | -0.27  | -0.10   | 66.975           |
| 09DOLA00156  | -0.25 | -0.12 | -0.06  | 0.08    | 66.250           |
| 09DOLA00141  | -0.52 | -0.37 | -0.27  | -0.10   | 65.545           |
| 09DOLA00131  | -0.93 | -0.82 | -0.74  | -0.49   | 65.305           |
| 09DOLA00122  | -0.30 | -0.23 | -0.19  | -0.03   | 64.440           |

Flooding on road

No flooding on road

See Appendix B for full tabulated results at all of modelled cross sections.

## 4.4 DISCUSSION

As part of this FRA report indicative flood mitigation measures for the proposed scheme were investigated and assessed to quantify the impact on flood risk at the proposed scheme, and elsewhere.

The water level is predicted to drop at every cross section. The construction of the new channel will also render the bridge Section 122 (which provides access to the dwelling) hydraulically redundant, as it will no longer convey flow from the Newtownmoyaghy Stream. The **two-stage cross-section** of the new channel may introduce minor variations in water level. This is due to the differential filling rates between the lower channel and the upper floodplain section, which differs from the behaviour observed in the old channel.

Downstream of the proposed channel and road improvements (Model Nodes 09DOLA00104 to 09DOLA00003), model results show minimal impact to flood risk elsewhere with levels staying identical to pre scheme flood levels.

Table 4-6 Difference in flood levels for Existing and Proposed Scenarios

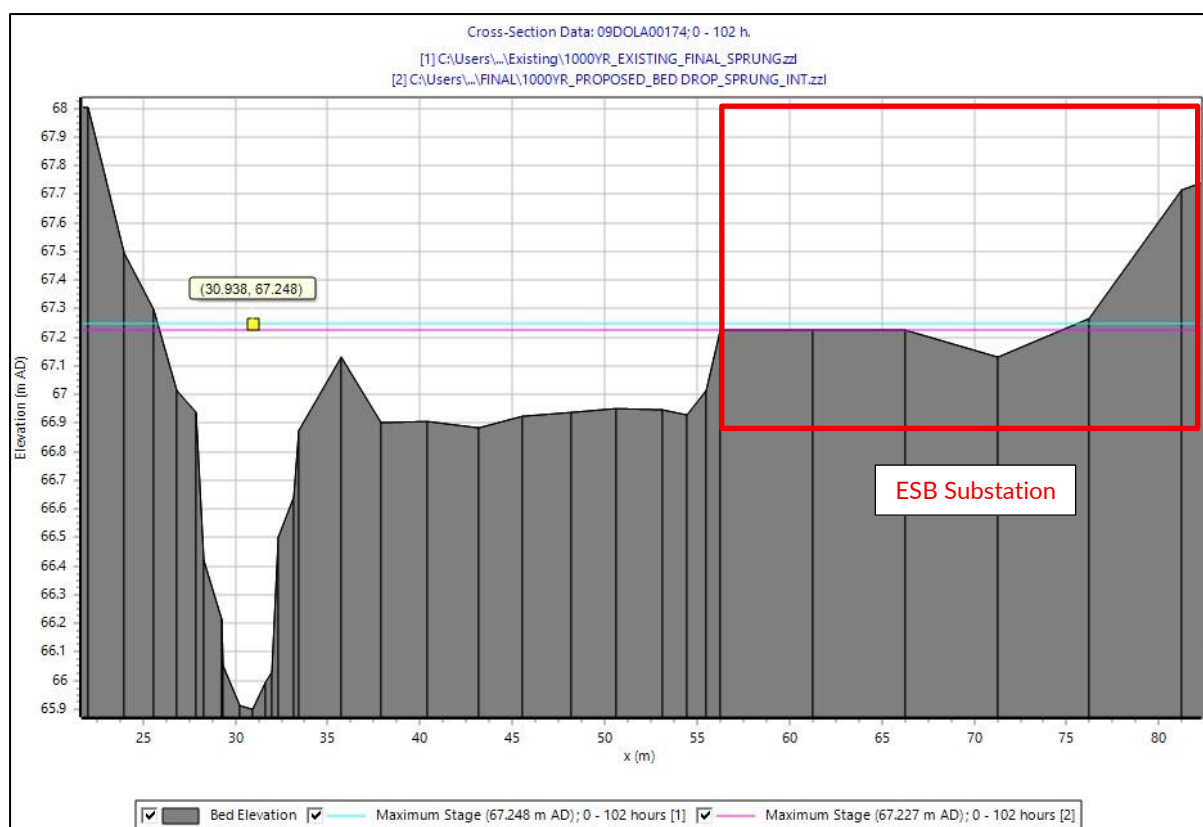
| Description            | Node Label   | 10-yr | 50-yr | 100-yr | 1000-yr |
|------------------------|--------------|-------|-------|--------|---------|
| Upstream of Study Area | 09DOLA00187  | -0.30 | -0.21 | -0.18  | -0.09   |
| ESB Substation         | 09DOLA00174  | -0.13 | -0.06 | -0.04  | -0.02   |
| Newtownmoyaghy Road    | 09DOLA00172U | -0.22 | -0.14 | -0.11  | -0.05   |
|                        | 09DOLA001695 | -0.30 | -0.17 | -0.14  | -0.10   |
|                        | 09DOLA00156  | -0.19 | -0.17 | -0.14  | -0.13   |
|                        | 09DOLA00141  | -0.11 | -0.11 | -0.07  | -0.07   |
|                        | 09DOLA00131  | -0.15 | -0.15 | -0.12  | -0.06   |
|                        | 09DOLA00122  | 0.00  | -0.08 | -0.09  | -0.11   |

Rise in water level

Drop in water level

An **ESB substation** is located at Section 09DOLA00174, with flood waters encroaching it from the 10-year event onwards. Water levels are predicted to remain relatively stable with the proposed scheme, with a predicted water level drop in the 10-, 50-, 100-, and 1000-year event of 0.13m, 0.06m, 0.04m, and 0.02m, respectively.





*Figure 4-7 1000-year pre and post works flood levels at ESB Substation*

The slight drop in water levels may be attributed to the greater capacity of the new proposed channel as well as the small area near the opening of the second bridge which will be kept enabling backflow into the two-stage channel. There is still a spill over the right bank of Bridge 172 which allows water to flow over the road (near the entrance to the ESB substation) and spill into the existing channel. Again, removing this flow path, could inadvertently exacerbate surcharging at Bridge 172, which would otherwise necessitate the subsequent upsizing of the bridge structure, a process requiring a Section 50 application due to potential downstream flood risk implications. By maintaining road levels adjacent to the substation, no further flood risk is created elsewhere. However, a designated overflow path will remain across the road, discharging into the designated section of the existing channel.

As a sensitivity test, the design flows were raised by **3.75%**. This adjustment reflects a similar increase applied to the CFRAM flows (the basis for design flows). This test considers the revised best estimate of  $17.60\text{m}^3/\text{s}$  for QMED at the Anne's Bridge gauging station. Even with the slightly increased flows, the difference in flood levels between the existing scenario and the proposed channel design for the 100-year event remained mostly unchanged. Again, there was no increase in flood level witnessed at any cross section. Flood levels at the ESB substation for the adjusted 100-year event were  $67.13\text{mOD}$  in the existing scenario and  $67.09\text{mOD}$  for the post scheme scenario, showing a  $0.04\text{m}$  drop in water levels. The residential property between sections 09DOLA00141 and 09DOLA00123 shows a water level drop in the range  $0.13\text{m}$  and  $0.40\text{m}$  across the length of the property.



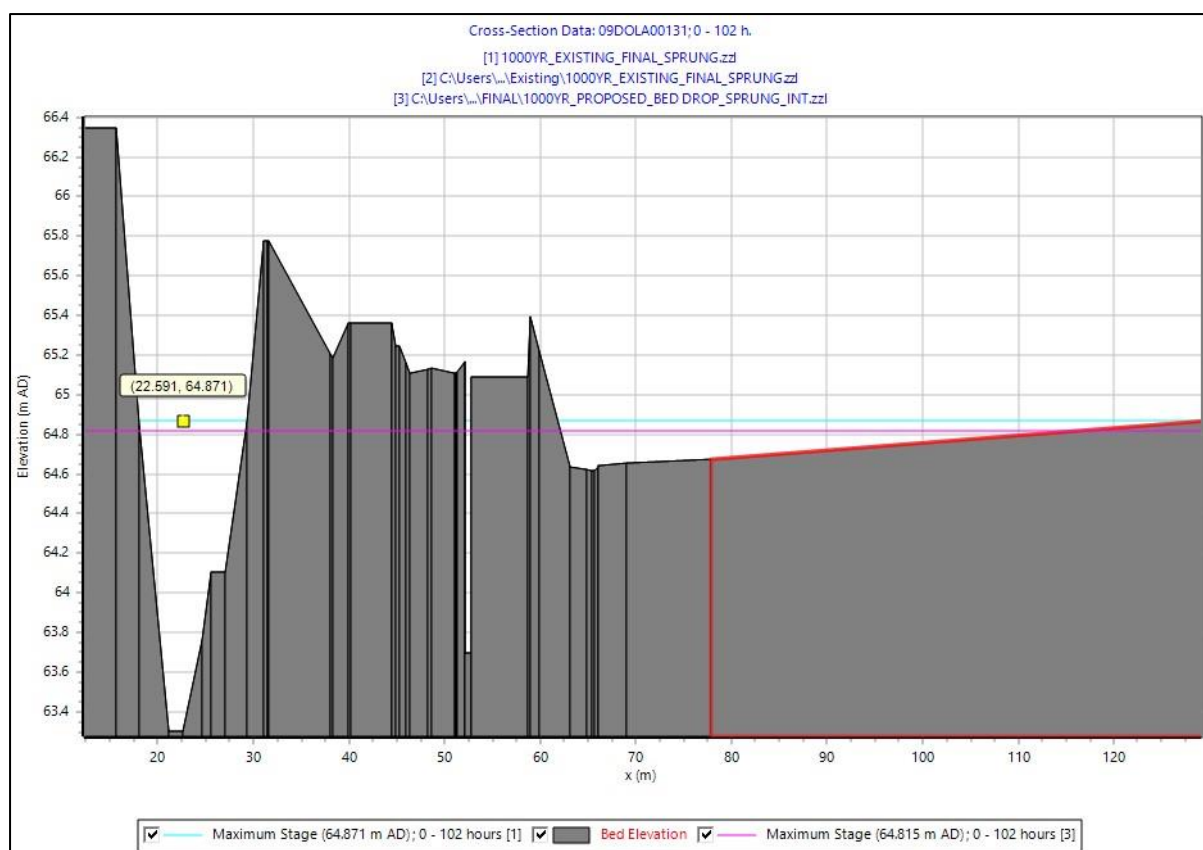


Figure 4-8 1000-year pre and post works flood levels at Residential Property (Note: Pre works flood level is superimposed on proposed cross section)

As another sensitivity test, the 1% AEP MRFS (1-in-100-year event + climate change) event was also simulated, with a 20% increase in peak flood flows. Again, there was no increase in flood level witnessed at any cross section. Flood levels at the ESB substation dropped by 0.03m for the post scheme scenario. The residential property between sections 09DOLA00141 and 09DOLA00123 shows a water level drop in the range 0.10m and 0.05m across the length of the property.

## 5. DETAILED FLOOD RISK ASSESSMENT

With reference to the PSFRM Guidelines, “Local transport infrastructure” (such as the works proposed as part of this scheme) are considered “Less vulnerable” in terms of their sensitivity to flood risk (i.e., Appropriate in Flood Zone B, where the risk of flooding is less than a 1% AEP).

### 5.1 EXISTING FLUVIAL FLOODING

Based on the results of OPW modelling (CFRAM), the majority of the subject site is located within the predicted 10%, 1%, and 0.1% AEP flood extents. During the current 1% AEP event (without climate change) the CFRAM study estimates that water levels at node 09DOLA00156 at the upstream portion of the subject site to be approximately 66.32mOD. With the road level at node 09DOLA00156 being circa 66.245mOD, it is predicted that this portion of the Newtownmoyaghy Road will be inundated. The levels here for the 0.1% AEP event without climate change are predicted to be 66.42mOD. No MRFS levels were provided by the CFRAM.

The TOBIN hydraulic model indicates that the Newtownmoyaghy Road will be inundated at Section 09DOLA00156 from the 10% AEP event onwards. The road lies 0.26m below the flood level in the 1% AEP event (design event for this scheme). Flooding is also evident at Section 09DOLA001695 from the 50-year event upwards.

### 5.2 FLUVIAL FLOODING POST WORKS

The proposed project and road improvements will involve changes in existing ground elevations and will optimise surface water drainage to make the area safer for road users within the developed area. The proposed channel is designed such that the existing hydraulic conditions are **maintained**, and stream levels are preserved. Two bridge structures within the existing channel will no longer be used for primary conveyance of flow from the Newtownmoyaghy Stream, however a box culvert is proposed to facilitate the road crossing at the southern eastern end of the site.

A summary of flood levels in the existing and proposed scenarios are shown in Table 7-8.

In the proposed scenario, flooding is relegated to just the 1000-year event at 09DOLA00156, where a flood depth of 0.08m is predicted. The revised channel location, situated further from the road and separated by an area of elevated ground, reduces the risk of flooding affecting the road in the proposed scenario. Additionally, the design of the new channel ensures that it can safely accommodate the flow associated with a 100-year event without breaching its banks. Furthermore, the infilling of the existing roadside Newtownmoyaghy Stream will include a conventional filter drain system and piped system to collect localised surface water road runoff.

Downstream of the proposed channel and road improvements (Model Nodes 09DOLA00104 to 09DOLA00003), model results show minimal impact to flood risk elsewhere.

The most upstream cross section (09DOLA00187), which typically experiences greater variations in water levels, is predicted to drop by up to 0.30 meters from existing water levels in all scenarios.

An **ESB substation** is located at Section 09DOLA00174, with flood waters encroaching it from the 10-year event onwards. Water levels are predicted to remain relatively stable with the

proposed scheme, with a predicted water level drop in the 10-, 50-, 100-, and 1000-year event of 0.13m, 0.06m, 0.04m, and 0.02m, respectively.

The slight drop in water levels may be attributed to the greater capacity of the new proposed channel as well as the small area near the opening of the second bridge which will be kept enabling backflow into the two-stage channel. There is still a spill over the right bank of Bridge 172 which allows water to flow over the road (near the entrance to the ESB substation) and spill into the existing channel. Again, removing this flow path, could inadvertently exacerbate surcharging at Bridge 172, which would necessitate the subsequent upsizing of the bridge structure, a process requiring a Section 50 application due to potential downstream flood risk implications. By maintaining road levels adjacent to the substation, no further flood risk is created elsewhere. However, a designated overflow path will remain across the road, discharging into the designated section of the existing channel. A residential property situated within the model boundaries is predicted to be at risk to flooding in the existing scenario and is located between sections 09DOLA00141 and 09DOLA00123. Water levels at 09DOLA00141 drop in all proposed scenarios. This drop is likely since construction of the new channel will render the bridge Section 122 (which provides access to the dwelling) hydraulically redundant, as it will no longer convey flow from the Newtownmoyaghy Stream. The **two-stage cross-section** of the new channel may introduce minor variations in water level. This is due to the differential filling rates between the lower channel and the upper floodplain section, which differs from the behaviour observed in the old channel. It is also worth noting that the new channel will be located east of the Newtownmoyaghy Stream and will no longer be on the same side of the road as the residential property. Additionally, any surface water that arises on the road will be collected by the introduction of a filter drain containing a 400mm pipe at the infilled channel.

Based on the hydraulic assessment above it is predicted that the proposed channel and road improvements will reduce the probability of flooding along the Newtownmoyaghy Road. This is against a backdrop of where a roadside stream is relocated away from a current location that directly interfaces with narrow roadside edge that has in places collapsed into the stream. The proposed channel is designed such that the existing hydraulic conditions are **maintained**, and stream levels are preserved.

It is also predicted that the proposed channel will not impact flow paths or exacerbate flood risk elsewhere in the area.

### 5.3 PLUVIAL FLOODING

Based on the indicative pluvial flood mapping presented in the OPW Preliminary Flood Risk Assessment, it is estimated that the subject site is not at risk from pluvial flooding during an extreme 0.1% AEP pluvial flood event. There is one area downstream of the subject site that is identified as being susceptible to surface water flooding by GSI mapping. This is located 0.8km east of the subject site and is located adjacent to the confluence between the Newtownmoyaghy Stream and Rye Water. Based on the topographical survey, it is indicated that ground levels tend to gently slope towards the Rye Water.

Therefore, it is estimated that risk of pluvial flooding associated with the proposed development is minimal.



## 5.4 GROUNDWATER FLOODING

There are no karst features located in the vicinity of the subject site. There is no record of historical groundwater flooding shown on GSI mapping. Older hydraulic modelling completed by HR Wallingford as part of the PFRA indicated no groundwater flooding in the vicinity of the subject site.

Therefore, it is estimated that risk of groundwater flooding associated with the proposed development is minimal.

## 5.5 COASTAL FLOODING

The proposed site in Newtownmoyaghy is located more than 30km inland, with minimum site elevations in the region of 63.84mOD. The nearest predicted 0.1% AEP MRFS coastal flood level at Dublin Port is estimated by the Irish Coastal Wave and Water Level Modelling Study (ICWWS) to be approximately 3.80mOD [reference node NE22]<sup>4</sup>. Therefore, it is estimated that the subject site is not at risk of coastal flooding.

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<sup>4</sup> Irish Coastal Protection Strategy Study—Phase III, Figure No: W / RA / EXT / MRFS / 10 (Dec 2012)



## 6. CONCLUSIONS

### Existing Fluvial Flooding:

Based on the results of OPW modelling (CFRAM), most of the subject site is located within the predicted 10%, 1% and 0.1% AEP flood extents. The TOBIN hydraulic model indicates that the Newtownmoyaghy Road will be inundated at Section 09DOLA00156 from the 10% AEP event onwards. The road lies 0.26m below the flood level in the 1% AEP event (design event for this scheme). Flooding is also evident at Section 09DOLA001695 from the 50-year event upwards.

### Fluvial Flooding Post Works

The stream channel and road improvements will involve changes in existing ground elevations and will optimise surface water drainage within the developed area. The proposed channel is designed such that the existing hydraulic conditions are **maintained**. Two bridge structures within the existing channel will no longer serve a primary hydraulic function, however a box culvert is proposed to facilitate a new road crossing at the southern eastern end of the site.

In the proposed scenario, flooding is relegated to just the 1000-year event at 09DOLA00156, where a flood depth of 0.08m is predicted. The revised channel location, situated further from the road and separated by an area of elevated ground, reduces the risk of flooding affecting the road in the proposed scenario. Additionally, the infilling of the existing roadside Newtownmoyaghy Stream will include a conventional filter drain system and piped system to collect surface water road runoff.

Downstream of the proposed channel and road improvements, model results show minimal impact to flood risk elsewhere (water level change of <0.01m).

Upstream of the site, section 09DOLA00187, the water level is predicted to drop by up to 0.30m from existing water levels in all return periods.

An **ESB substation** is located at Section 09DOLA00174, with flood waters encroaching it from the 10% AEP event onwards. Water levels are predicted to remain relatively stable with the proposed scheme, with a predicted water level drop in the 10-, 50-, 100-, and 1000-year event of 0.13m, 0.06m, 0.04m, and 0.02m, respectively.

There is still a spill over the right bank of Bridge 172 which allows water to flow over the road (near the entrance to the ESB substation) and spill into the existing channel. Again, removing this flow path, could inadvertently exacerbate surcharging at Bridge 172, which would necessitate the subsequent upsizing of the bridge structure, a process requiring a Section 50 application due to potential downstream flood risk implications. By maintaining road levels adjacent to the substation, no further flood risk is created elsewhere. However, a designated overflow path will remain across the road, discharging into the designated section of the existing channel.

A residential property situated within the model boundaries is predicted to be at risk to flooding in the existing scenario and is located between sections 09DOLA00141 and 09DOLA00123. Water levels at 09DOLA00141 drop in all proposed scenarios. This is likely since construction of the new channel will render the bridge Section 122 (which

provides access to the dwelling) hydraulically redundant, as it will no longer convey flow from the Newtownmoyaghy Stream.

The **two-stage cross-section** of the new channel may introduce minor variations in water level. This is due to the differential filling rates between the lower channel and the upper floodplain section, which differs from the behaviour observed in the old channel. It is also worth noting that the new channel will be located east of the Newtownmoyaghy Stream and will no longer be on the same side of the road as the residential property. Additionally, any localised surface water that arises on the road will be collected by the introduction of a filter drain containing a 400mm pipe at the infilled channel.

Based on the hydraulic assessment above it is predicted that the proposed channel and road improvements will reduce the probability of flooding along the Newtownmoyaghy Road. This is against a backdrop of where a roadside stream is relocated away from a current location that directly interfaces with narrow roadside edge that has in places collapsed into the stream. The proposed channel is designed such that the existing hydraulic conditions are **maintained**, and stream levels are preserved.

It is also predicted that the proposed channel will not impact flow paths or exacerbate flood risk elsewhere in the area. Again, it is worth noting that there will continue to be a spill over the right bank of Bridge 172 which allows water to flow over the road (near the entrance to the ESB substation) and spill into the existing channel. Removing this flow path, would otherwise have the potential to exacerbate flooding elsewhere, therefore this flow path must be maintained.

#### Pluvial Flooding:

Based on the indicative pluvial flood mapping presented in the OPW Preliminary Flood Risk Assessment, and seasonal flood mapping from the Geological Survey Ireland (GSI), it is estimated that the risk of pluvial flooding at the subject site is minimal.

Again, any surface water that arises on the road will be collected by the introduction of a filter drain containing a 400mm pipe at the infilled channel.

#### Groundwater Flooding:

Based on a review of GSI subsurface mapping of karst features, historic and predicted groundwater flooding in the area, and the PFRA study, the risk of groundwater flooding predicted at the proposed scheme location is minimal.

#### Coastal Flooding:

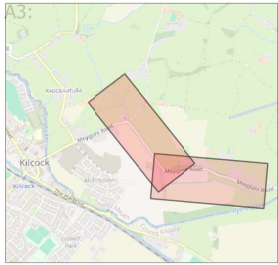
It is estimated that the lands are not at risk of coastal flooding due to their elevation.

## Appendix A MODELLED CROSS SECTION LOCATION





Site Overview:  
Scale @ 1:50,000



- Legend
- Diverted Channel
  - Existing Channel
  - Cross Sections
  - Crossings

|                                                                                                                                                                                                                                                                                                                                                                                                |                |                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------------|
| Client<br>Meath County Council                                                                                                                                                                                                                                                                                                                                                                 |                |                    |
| Project<br>Newtownmoyaghy Road,<br>Killock, Co. Meath                                                                                                                                                                                                                                                                                                                                          |                |                    |
| Title<br>Modelled Cross Sections                                                                                                                                                                                                                                                                                                                                                               |                |                    |
| Scale @ A3: As Shown on Map                                                                                                                                                                                                                                                                                                                                                                    |                |                    |
| Prepared by:<br>FOC                                                                                                                                                                                                                                                                                                                                                                            | Checked:<br>ST | Date:<br>Sept 2025 |
| Project Director                                                                                                                                                                                                                                                                                                                                                                               | PC             |                    |
| Drawing Status                                                                                                                                                                                                                                                                                                                                                                                 | Issue          |                    |
| TOBIN,<br>Fairgreen House, Fairgreen Road,<br>Galway, Ireland.<br>tel: +353-(0)91-565211<br>e-mail: galway@tobin.ie<br>www.tobin.ie                                                                                                                                                                                                                                                            |                |                    |
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| Drawing No.                                                                                                                                                                                                                                                                                                                                                                                    | 11434-M01      | A                  |

## Appendix B MODEL RESULTS



*Existing Scenario*

|              | <b>10</b> | <b>50</b> | <b>100</b> | <b>1000</b> |
|--------------|-----------|-----------|------------|-------------|
| 09DOLA00201  | 68.25     | 68.317    | 68.339     | 68.438      |
| 09DOLA00187  | 67.875    | 67.89     | 67.905     | 67.956      |
| 09DOLA00174  | 67.013    | 67.086    | 67.119     | 67.248      |
| 09DOLA00172U | 66.895    | 66.963    | 66.994     | 67.149      |
| CULIN        | 66.895    | 66.963    | 66.994     | 67.149      |
| CULOUT       | 66.884    | 66.94     | 66.976     | 67.112      |
| 172SPU       | 66.895    | 66.963    | 66.994     | 67.149      |
| 172SPD       | 66.884    | 66.94     | 66.976     | 67.112      |
| 09DOLA00172D | 66.884    | 66.94     | 66.976     | 67.112      |
| 09DOLA00170U | 66.857    | 66.912    | 66.949     | 67.076      |
| 170BRU       | 66.857    | 66.912    | 66.949     | 67.076      |
| 170BRD       | 66.819    | 66.865    | 66.899     | 67.024      |
| 170SPU       | 66.857    | 66.912    | 66.949     | 67.076      |
| 170SPD       | 66.819    | 66.865    | 66.899     | 67.024      |
| 09DOLA00170D | 66.819    | 66.865    | 66.899     | 67.024      |
| 09DOLA001695 | 66.777    | 66.812    | 66.844     | 66.969      |
| 09DOLA00156  | 66.197    | 66.294    | 66.334     | 66.461      |
| 09DOLA00141  | 65.141    | 65.286    | 65.346     | 65.519      |
| 09DOLA00131  | 64.519    | 64.634    | 64.686     | 64.871      |
| 09DOLA00123  | 64.175    | 64.314    | 64.365     | 64.536      |
| 09DOLA00122U | 64.143    | 64.291    | 64.345     | 64.52       |
| 122BRU       | 64.143    | 64.291    | 64.345     | 64.52       |
| 122BRD       | 64.002    | 64.091    | 64.135     | 64.3        |
| 122SPU       | 64.143    | 64.291    | 64.345     | 64.52       |
| 122SPD       | 64.002    | 64.091    | 64.135     | 64.3        |
| 09DOLA00122D | 64.002    | 64.091    | 64.135     | 64.3        |
| 09DOLA00118  | 63.921    | 64.02     | 64.079     | 64.251      |
| 09DOLA00104  | 63.701    | 63.867    | 63.957     | 64.166      |
| 09DOLA00100U | 63.582    | 63.806    | 63.895     | 64.092      |
| 100BRU       | 63.582    | 63.806    | 63.895     | 64.092      |
| 100BRD       | 63.169    | 63.526    | 63.616     | 63.762      |
| 100SPU       | 63.582    | 63.806    | 63.895     | 64.092      |
| 100SPD       | 63.169    | 63.526    | 63.616     | 63.762      |
| 09DOLA00100D | 63.169    | 63.526    | 63.616     | 63.762      |
| 09DOLA00098  | 63.182    | 63.341    | 63.43      | 63.626      |
| 09DOLA00081  | 62.809    | 62.996    | 63.085     | 63.279      |
| 09DOLA00066  | 62.389    | 62.591    | 62.685     | 62.887      |
| 09DOLA00051  | 62.068    | 62.26     | 62.349     | 62.546      |
| 09DOLA00033  | 61.523    | 61.681    | 61.761     | 61.939      |
| 09DOLA00022  | 61.252    | 61.378    | 61.446     | 61.604      |
| 09DOLA00013  | 61.068    | 61.18     | 61.23      | 61.345      |
| 09DOLA00003  | 60.769    | 60.891    | 60.937     | 61.036      |
| 104LAT       | -9999.99  | -9999.99  | -9999.99   | -9999.99    |
| 104LI        | 63.701    | 63.867    | 63.957     | 64.166      |

*Proposed Scenario*

|              | <b>10</b> | <b>50</b> | <b>100</b> | <b>1000</b> |
|--------------|-----------|-----------|------------|-------------|
| 09DOLA00201  | 68.276    | 68.345    | 68.368     | 68.467      |
| 09DOLA00187  | 67.58     | 67.684    | 67.724     | 67.863      |
| 185INT       | 67.386    | 67.487    | 67.529     | 67.664      |
| 180INT       | 67.229    | 67.331    | 67.36      | 67.48       |
| 175INT       | 67.125    | 67.256    | 67.294     | 67.386      |
| 09DOLA00174  | 66.885    | 67.029    | 67.077     | 67.227      |
| 09DOLA00172U | 66.675    | 66.823    | 66.882     | 67.1        |
| CULIN        | 66.675    | 66.823    | 66.882     | 67.1        |
| CULOUT       | 66.656    | 66.808    | 66.862     | 67.057      |
| 172SPU       | 66.675    | 66.823    | 66.882     | 67.1        |
| 172SPD       | 66.656    | 66.808    | 66.862     | 67.057      |
| 09DOLA00172D | 66.656    | 66.808    | 66.862     | 67.057      |
| Proposed599  | 66.534    | 66.735    | 66.795     | 66.965      |
| Proposed599A | 66.497    | 66.713    | 66.772     | 66.938      |
| Proposed599B | 66.535    | 66.744    | 66.8       | 66.968      |
| Proposed599C | 66.528    | 66.739    | 66.794     | 66.957      |
| Proposed599D | 66.483    | 66.673    | 66.733     | 66.88       |
| 09DOLA001695 | 66.481    | 66.64     | 66.706     | 66.87       |
| 09DOLA00156  | 66.004    | 66.128    | 66.19      | 66.327      |
| 09DOLA00141  | 65.029    | 65.175    | 65.275     | 65.449      |
| 09DOLA00131  | 64.371    | 64.48     | 64.563     | 64.815      |
| 09DOLA00122  | 64.14     | 64.214    | 64.251     | 64.406      |
| NewAli522.49 | 64.069    | 64.14     | 64.182     | 64.351      |
| NewAli549.94 | 63.917    | 64.041    | 64.104     | 64.29       |
| 09DOLA00118  | 63.919    | 64.049    | 64.111     | 64.303      |
| 118BRU       | 63.919    | 64.049    | 64.111     | 64.303      |
| 118BRD       | 63.905    | 64.015    | 64.076     | 64.256      |
| 118SPU       | 63.919    | 64.049    | 64.111     | 64.303      |
| 118SPD       | 63.905    | 64.015    | 64.076     | 64.256      |
| 09DOLA00118D | 63.905    | 64.015    | 64.076     | 64.256      |
| Proposed4.92 | 63.837    | 63.962    | 64.032     | 64.22       |
| 09DOLA00104  | 63.701    | 63.867    | 63.957     | 64.166      |
| 09DOLA00100U | 63.582    | 63.806    | 63.895     | 64.092      |
| 100BRU       | 63.582    | 63.806    | 63.895     | 64.092      |
| 100BRD       | 63.169    | 63.526    | 63.616     | 63.762      |
| 100SPU       | 63.582    | 63.806    | 63.895     | 64.092      |
| 100SPD       | 63.169    | 63.526    | 63.616     | 63.762      |
| 09DOLA00100D | 63.169    | 63.526    | 63.616     | 63.762      |
| 09DOLA00098  | 63.182    | 63.341    | 63.43      | 63.626      |
| 09DOLA00081  | 62.809    | 62.996    | 63.085     | 63.279      |
| 09DOLA00066  | 62.389    | 62.591    | 62.685     | 62.887      |
| 09DOLA00051  | 62.068    | 62.26     | 62.349     | 62.546      |
| 09DOLA00033  | 61.523    | 61.681    | 61.76      | 61.939      |
| 09DOLA00022  | 61.252    | 61.378    | 61.446     | 61.604      |
| 09DOLA00013  | 61.068    | 61.18     | 61.23      | 61.345      |
| 09DOLA00003  | 60.769    | 60.891    | 60.937     | 61.036      |
| 104LAT       | -9999.99  | -9999.99  | -9999.99   | -9999.99    |
| 104LI        | 63.701    | 63.867    | 63.957     | 64.166      |



Existing

|              | 10    | 50    | 100   | 1000  |
|--------------|-------|-------|-------|-------|
| 09DOLA00201  | 68.25 | 68.32 | 68.34 | 68.44 |
| 09DOLA00187  | 67.88 | 67.89 | 67.91 | 67.96 |
| 09DOLA00174  | 67.01 | 67.09 | 67.12 | 67.25 |
| 09DOLA00172U | 66.90 | 66.96 | 66.99 | 67.15 |
| 09DOLA001695 | 66.78 | 66.81 | 66.84 | 66.97 |
| 09DOLA00156  | 66.20 | 66.29 | 66.33 | 66.46 |
| 09DOLA00141  | 65.14 | 65.29 | 65.35 | 65.52 |
| 09DOLA00131  | 64.52 | 64.63 | 64.69 | 64.87 |
| 09DOLA00122  | 64.14 | 64.29 | 64.35 | 64.52 |
| 09DOLA00118  | 63.92 | 64.02 | 64.08 | 64.25 |

Proposed

|  | 10    | 50    | 100   | 1000  |
|--|-------|-------|-------|-------|
|  | 68.28 | 68.35 | 68.37 | 68.47 |
|  | 67.58 | 67.68 | 67.72 | 67.86 |
|  | 66.89 | 67.03 | 67.08 | 67.23 |
|  | 66.68 | 66.82 | 66.88 | 67.10 |
|  | 66.48 | 66.64 | 66.71 | 66.87 |
|  | 66.00 | 66.13 | 66.19 | 66.33 |
|  | 65.03 | 65.18 | 65.28 | 65.45 |
|  | 64.37 | 64.48 | 64.56 | 64.82 |
|  | 64.14 | 64.21 | 64.25 | 64.41 |
|  | 63.91 | 64.02 | 64.08 | 64.26 |

Difference

|  | 10    | 50    | 100   | 1000  |
|--|-------|-------|-------|-------|
|  | 0.03  | 0.03  | 0.03  | 0.03  |
|  | -0.30 | -0.21 | -0.18 | -0.09 |
|  | -0.13 | -0.06 | -0.04 | -0.02 |
|  | -0.22 | -0.14 | -0.11 | -0.05 |
|  | -0.30 | -0.17 | -0.14 | -0.10 |
|  | -0.19 | -0.17 | -0.14 | -0.13 |
|  | -0.11 | -0.11 | -0.07 | -0.07 |
|  | -0.15 | -0.15 | -0.12 | -0.06 |
|  | 0.00  | -0.08 | -0.09 | -0.11 |
|  | -0.02 | 0.00  | 0.00  | 0.00  |

