Noel Frisby Construction Ltd

Site Specific Flood Risk Assessment Addendum

LRD 2023/1

Cork Road, Waterford, Co. Waterford

February 2024

IE CONSULTING
WATER-ENVIRONMENTAL-CIVIL

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Client: Noel Frisby Construction Ltd

Location: Cork Road, Waterford, Co Waterford

Date: 02nd February 2024

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Contents

Appendices

1. Introduction

IE Consulting was requested by Noel Frisby Construction Ltd to undertake a Site Specific Flood Risk Assessment (SSFRA) in support of a LRD planning application (reference LRD 2023/1) for a proposed development at Cork Road, Waterford City, Co. Waterford. The development as proposed comprises of the construction of a student accommodation facility and all associated works at the site.

The details and information presented herein are presented as an Addendum to the previously submitted Site Specific Flood Risk Assessment prepared in support of this LRD application and which has previously been submitted to Waterford City & County Council.

In particular this Site Specific Flood Risk Assessment Addendum has been prepared in response to 'Point 2 – Culverts at Existing Watercourse' and 'Point 3 – Flood Risk Assessment' of the LRD Opinion (reference LRD 2023/1) issued by Waterford City & County Council on 13th December 2023.

In this regard a meeting was held between IE Consulting, Malone O'Regan Consulting Engineers and the Waterford City & County Council Area Engineer on 08th January 2024 with respect to the additional works required in response to Point 2 and Point 3 of the LRD Opinion. The details presented herein are in accordance with the scope of works presented during this meeting.

This Site Specific Flood Risk Assessment Addendum has been undertaken in consideration of the following guidance document:-

'The Planning System and Flood Risk Management – Guidelines for Planning Authorities' DOEHLG 2009.'

2. Point 2 – Culverts at Existing Watercourse

As presented on the drawings and associated details provided by Malone O'Regan Consulting Engineers, it is proposed to culvert a section of the watercourse channel adjacent to the northern boundary of the site and a section of the watercourse channel adjacent to the south-eastern boundary of the site. For the purposes of this Site Specific Flood Risk Assessment Addendum, and as presented in the previously submitted Site Specific Flood Risk Assessment, this watercourse is referred to as the Lisduggan Stream (also known locally as the John's River). The proposed culverting adjacent to the northern boundary of the site is referred to as the 'Cork Road Culvert' and the proposed culverting adjacent to the south-eastern boundary of the site is referred to as the 'Lacken Road Culvert'.

As presented below, a hydrological assessment has been undertaken in order to provide an estimation of extreme fluvial flood volumes in the Lisduggan Stream watercourse at the location of the proposed development site. A hydraulic analysis has also been undertaken in order to assess the hydraulic conveyance capacity of the proposed culverts in consideration of extreme fluvial flood volumes.

2.1. Prediction of Peak Flows in Lisduggan Stream Watercourse

No suitable historical flow data, hydrometric gauging station data or anecdotal information is available from the OPW, EPA or local authority for the Lisduggan Stream catchment area from which an estimation of design flood flows can be extrapolated or correlated.

As illustrated in *Figure 1* below, the catchment area of the Lisduggan Stream to the location of the Cork Road culvert and the Lacken Road culvert were delineated and estimated to be 4.368 km^2 and 4.430 km^2 respectively.

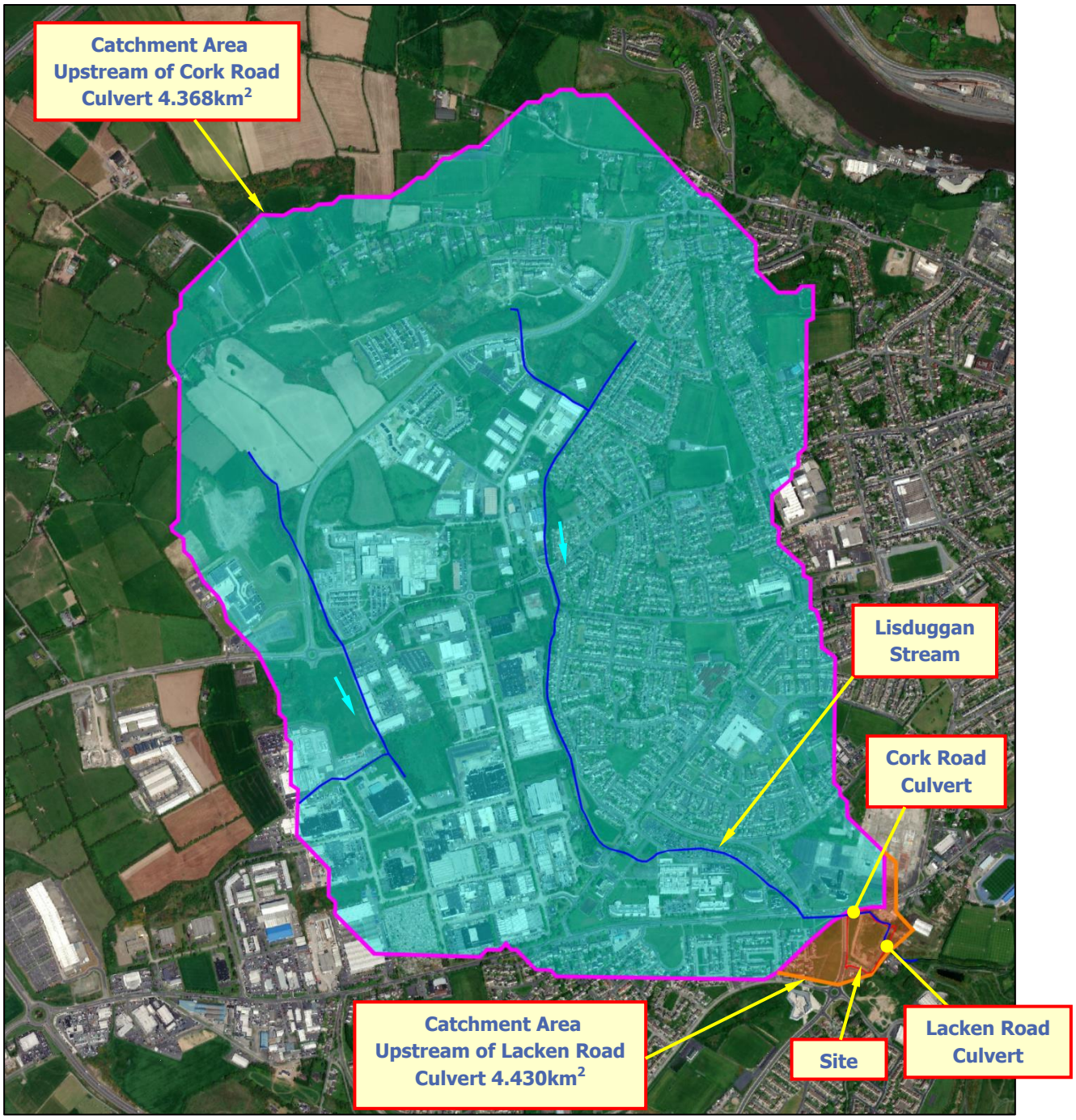


Figure 1 – Lisduggan Stream Catchment Area

2.1.1. Peak Flow Estimation – Mean Annual Flood Methodology for Small Catchment

Given the small size of the catchment area of the Lisduggan Stream, the FSU portal software is not considered appropriate to estimate the median or mean flood volume. The mean annual flood , Q_{BAR} *(m^3/s)*, is therefore estimated by utilising any of the two multiple parameter regression equations detailed in the Flood Studies Report (FSR) and Flood Studies Supplementary Reports (FSSR) and the Institute of Hydrology Report (IH) No. 124 'Flood Estimation for Small Catchments' regression equation. These equations are listed below:-

$Qbar\ Rural = 0.00066 \times Area^{0.92} \times SAAR^{1.22} \times SOIL^{2.0}$ *EQN 1.5 (FSSR)*

$Qbar\ Rural = 0.0288 \times Area^{0.90} \times RSMD^{1.23} \times SOIL^{1.77} \times STMFRQ^{0.23}$ *EQN 1.6 (FSR)*

$Qbar\ Rural = 0.00108 \times Area^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$ *EQN 7.1 (IH124)*

where:

AREA = the topographic catchment area

Area *Cork Road Culvert Upstream* ***= 4.368 Km²***

Area *Lacken Road Culvert Upstream* ***= 4.430 Km²***

SAAR = Standard Annual Average Rainfall

SAAR = 992.56 mm (*from Met Éireann data)*

STMFRQ = the stream frequency of the catchment, which is equal to the number of channel junctions within the catchment divided by the catchment area. STMFRQ = (J/ A) = 1/4.368

STMFRQ *Cork Road Culvert Upstream* ***= 0.229***

STMFRQ *Lacken Road Culvert Upstream* ***= 0.226***

RSMD = the 5 year, 1 day rainfall excess (mm) for the catchment and is estimated using the following equation or can be directly derived from *Figure 2* below:

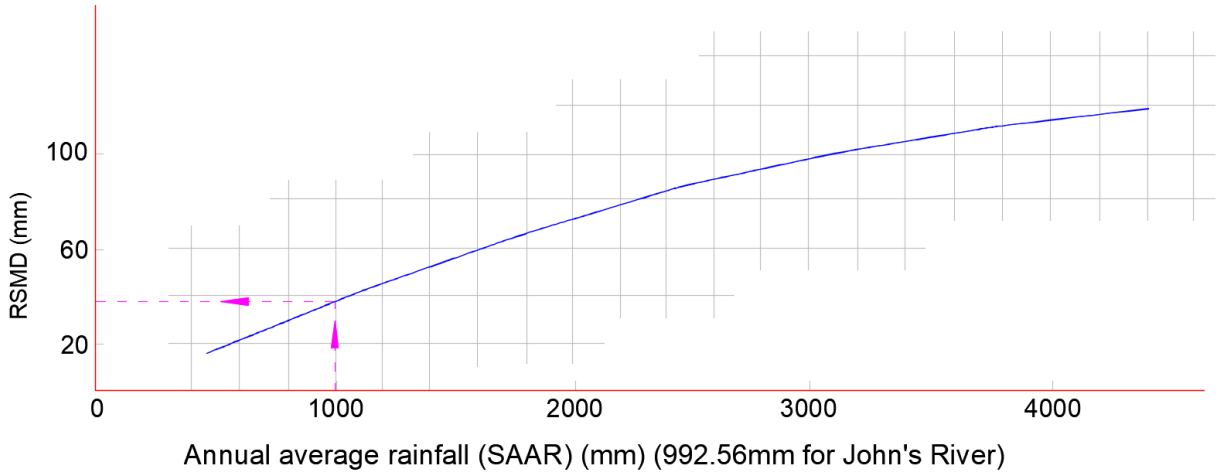


Figure 2 – Plot of 5 year, 1 day rainfall excess. RSMD, against mean annual rainfall, SAAR

RSMD = 38.1, *for SAAR value of 992.56mm.*

SOIL = A number depending on the soil type and relating to the winter rain acceptance potential of the soils in the catchment. Values for SOIL are obtained from *Figure 3* and *Figure 4* below, which are replicated from map I. 4.18 (I) in the FSR.

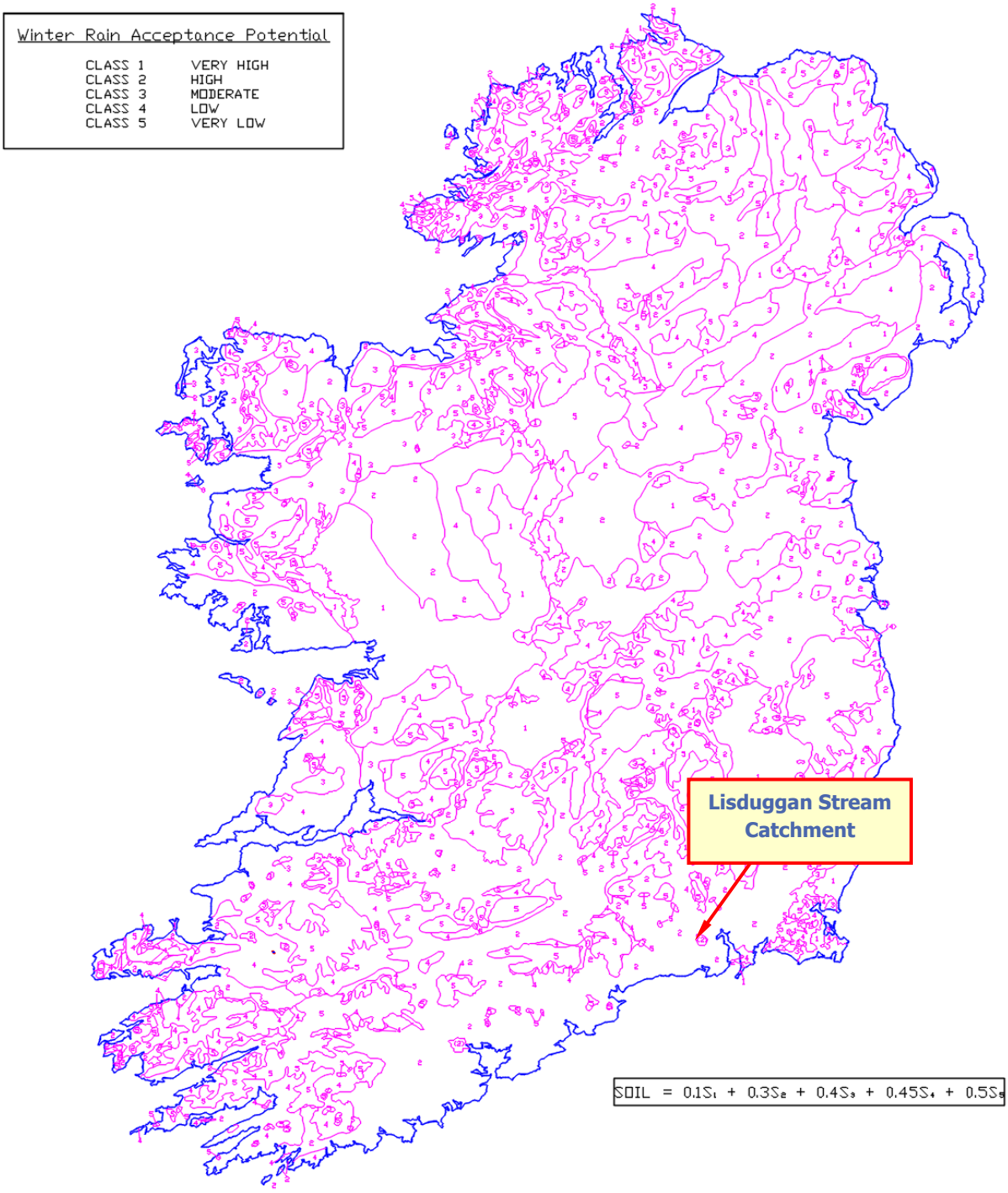


Figure 3 – Winter Rainfall Acceptance Potential

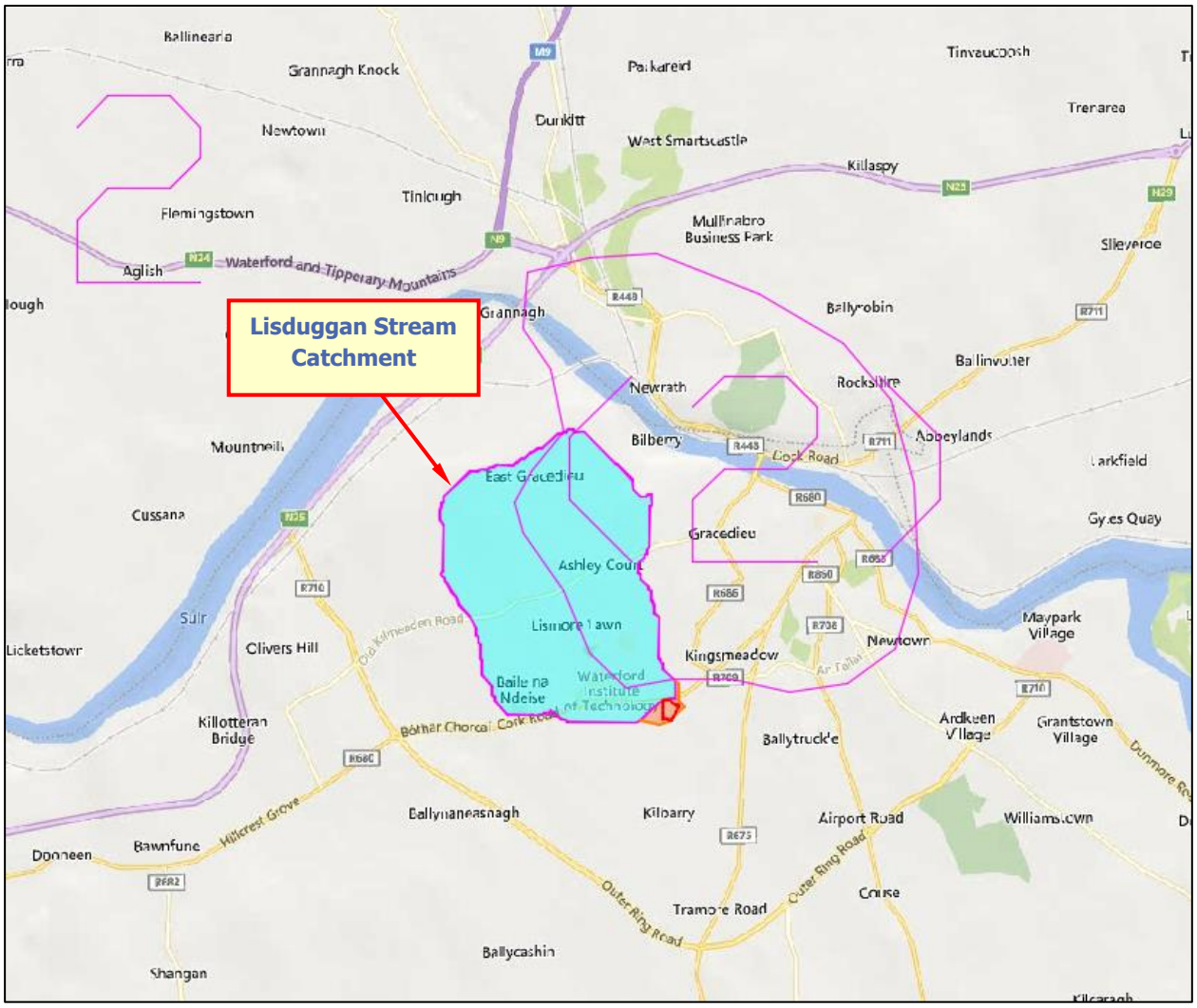


Figure 4 – Winter Rainfall Acceptance Potential

From *Figure 3* and *Figure 4* above (not to scale) the Lisduggan Stream catchment area comprises 100% SOIL Type 2.

Therefore:

SOIL = 0.15(S1) + 0.3(S2) + 0.40(S3) + 0.45(S4) + 0.5(S5)

SOIL = 0.15(0) + 0.3(1) + 0.40(0) + 0.45(0) + 0.5(0)

SOIL = 0.3

Therefore:

Qbar Rural = 0.00066 x Area$^{0.92}$ x SAAR$^{1.22}$ x SOIL$^{2.0}$ *EQN 1.5(FSSR)*

Qbar Rural $_{Cork\ Road\ Culvert\ Upstream}$ = 0.00066 x 4.368$^{0.92}$ x 992.56$^{1.22}$ x 0.3$^{2.0}$ = ***1.044 m^3/s***

Qbar Rural $_{Lacken\ Road\ Culvert\ Upstream}$ = 0.00066 x 4.43$^{0.92}$ x 992.56$^{1.22}$ x 0.3$^{2.0}$ = ***1.058 m^3/s***

Qbar Rural = 0.0288 x Area$^{0.90}$ x RSMD$^{1.23}$ x SOIL$^{1.77}$ x STMFRQ$^{0.23}$ *EQN 1.6 (FSR)*

Qbar Rural $_{Cork\ Road\ Culvert\ Upstream}$ = 0.0288 x 4.368$^{0.90}$ x 38.1$^{1.23}$ x 0.3$^{1.77}$ x 0.229$^{0.23}$ ***= 0.809 m^3/s***

Qbar Rural $_{Lacken\ Road\ Culvert\ Upstream}$ = 0.0288 x 4.43$^{0.90}$ x 38.1$^{1.23}$ x 0.3$^{1.77}$ x 0.226$^{0.23}$ ***= 0.817 m^3/s***

Qbar Rural = 0.00108 x Area$^{0.89}$ x SAAR$^{1.17}$ x SOIL$^{2.17}$ *EQN 7.1 (IH124)*

Qbar Rural $_{Cork\ Road\ Culvert\ Upstream}$ = 0.00108 x 16.602$^{0.89}$ x 800.85$^{1.17}$ x 0.3$^{2.17}$ ***= 0.944 m^3/s***

Qbar Rural $_{Lacken\ Road\ Culvert\ Upstream}$ = 0.00108 x 16.602$^{0.89}$ x 800.85$^{1.17}$ x 0.3$^{2.17}$ ***= 0.956 m^3/s***

For the purposes of this Site Specific Flood Risk Assessment, the more conservative FSSR Q_{BAR} estimates of ***1.044 m^3/s*** and ***1.058 m^3/s*** are utilised for the Lisduggan Stream at the location of the Cork Road Culvert and the Lacken Road Culvert respectively.

The FSSR equation has a standard factorial error of 1.58, therefore the design ***Q_{BAR} Rural*** estimates are:

Qbar Rural $_{Cork\ Road\ Culvert\ Upstream}$ = 1.044 m^3/s x 1.58 ***= 1.65 m^3/s***

Qbar Rural $_{Lacken\ Road\ Culvert\ Upstream}$ = 1.058 m^3/s x 1.58 ***= 1.672 m^3/s***

2.1.2. Urbanisation

As illustrated in *Figure 1* above, the catchment area of the Lisduggan Stream upstream of the Cork Road Culvert and Lacken Road Culvert contains a significant urban fraction. The effects of urbanisation can have a significant impact on flood events. An increase in urbanisation tends to result in a corresponding increase in peak surface runoff volumes due to more impervious surfaces and an increase in surface water runoff response times. To account for this urbanisation an Urban Adjustment Factor was calculated utilising the methodology presented in the Institute of Hydrology Report No. 124 'Flood Estimation for Small Catchments' as listed below:-

QbarUrban/QbarRural = (1+Urban%)2NC x (1+Urban%((21/CIND)-0.3) *EQN 7.4*

A detailed measure of urbanisation within the upstream catchment area was undertaken as follows:

Urban% $_{Cork\ Road\ Culvert\ Upstream}$ = percentage of catchment that is urbanised

*= **Urban% = 2.590 km^2 = 0.593** (decimal %)*

Urban% $_{Lacken\ Road\ Culvert\ Upstream}$ = percentage of catchment that is urbanised

*= **Urban% = 2.569 km^2 = 0.580** (Decimal %)*

NC = Rainfall Continentality Factor

NC = 0.92 – 0.00024 x SAAR (for 500 $\leq$ SAAR $\leq$ 1100mm)

NC = 0.74 – 0.000082 x SAAR (for 1100 $\leq$ SAAR $\leq$ 3000mm)

*$\Rightarrow$ NC = 0.92 – 0.00024 x 992.56 = **0.682***

CIND = Catchment Index

CIND = 102.4 x SOIL + 0.28 x (CWI – 125)

CWI = the catchment wetness index for the catchment and is estimated from Figure 5 below (reproduced from FSR):

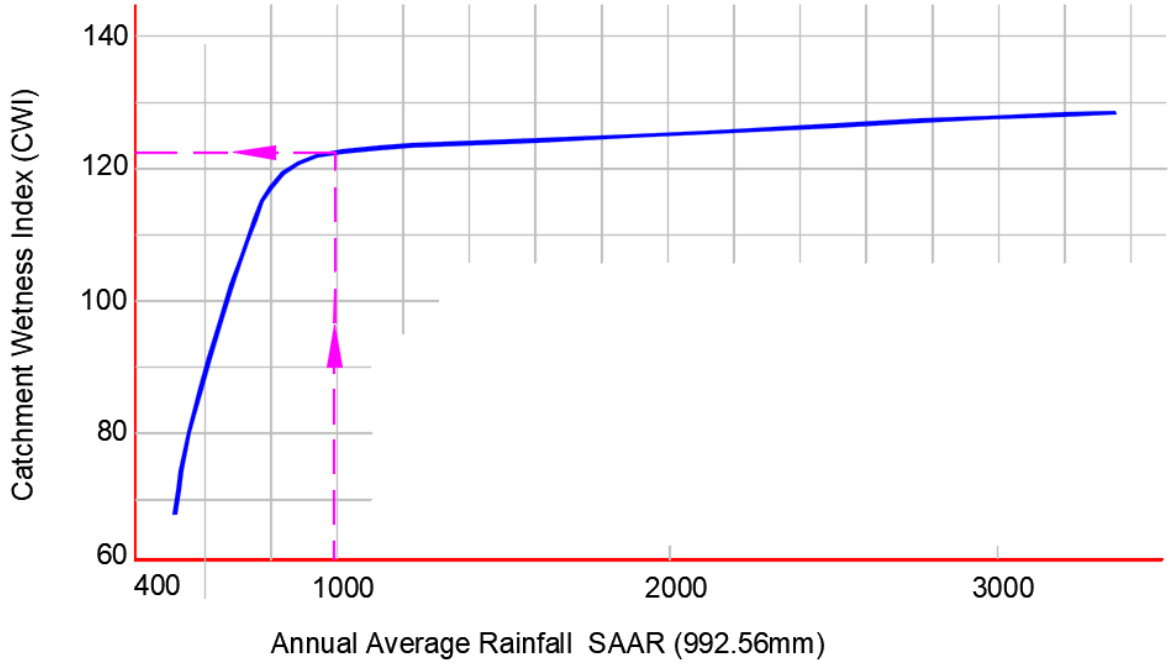


Figure 5 – Plot of Catchment Wetness Index, CWI, against mean annual rainfall, SAAR

from Met Éireann data SAAR = 992.56mm, therefore from Figure 5 above ***CWI = 122.46mm***

Therefore:

$\Rightarrow$ *CIND = 102.4 x 0.30 + 0.28 x (122.46 – 125)=* ***30.01***

$Q_{BAR\ Urban}/Q_{BAR\ Rural} = (1+Urban\%)^{2NC}$ *x (1+Urban%((21/CIND)-0.3)* *EQN 7.4*

$Q_{BAR\ Urban}/Q_{BAR\ Cork\ Road\ Culvert\ Upstream}$ *= ((1+0.593)^2 x 0.682) x (1+0.593((21/30.01)-0.3) =* ***2.402***

$Q_{BAR\ Urban}/Q_{BAR\ Lacken\ Road\ Culvert\ Upstream}$ *= ((1+0.580)^2 x 0.682) x (1+0.580((21/30.01)-0.3) =* ***2.379***

Therefore:

$Q_{BAR\ Urban} = Q_{BAR\ Rural}$ *x* $Q_{BAR\ Urban}/Q_{BAR\ Rural}$

$Q_{BAR\ Urban\ Cork\ Road\ Culvert\ Upstream}$ *= 1.65 x 2.402 =* ***3.96 m³/s***

$Q_{BAR\ Urban\ Lacken\ Road\ Culvert\ Upstream}$ *= 1.672 x 2.379 =* ***3.98 m³/s***

2.2. Estimated Flows for Different Return Periods

The return period flows 'QT' are estimated using the index flood method and multiplying the annual maximum flow by the appropriate growth factor 'XT' using the FSR national growth curve for Ireland, as shown in *Figure 6* below: -

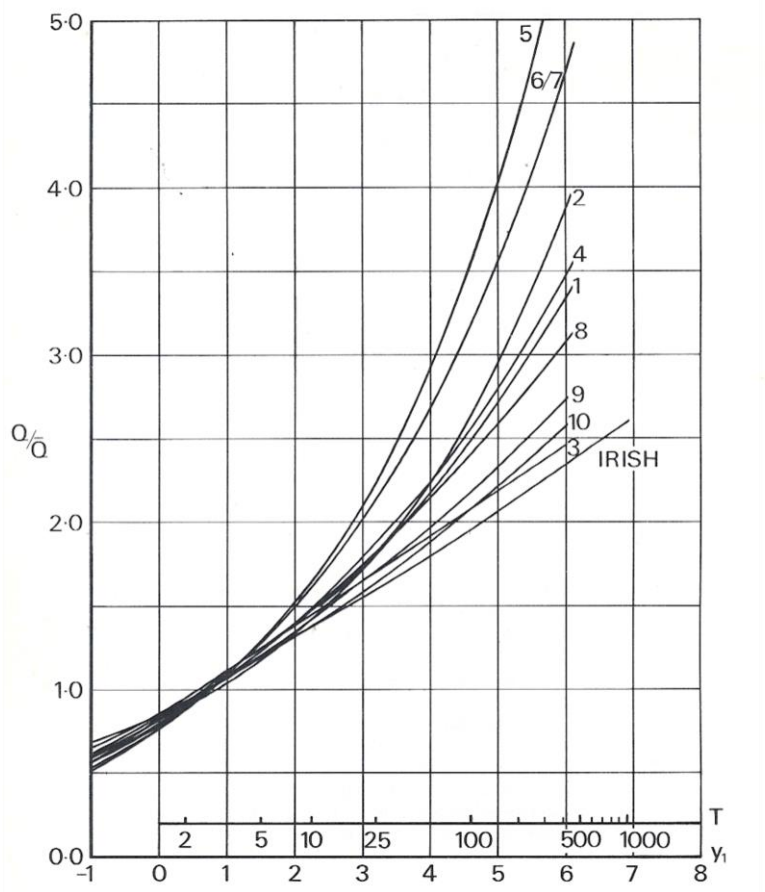


Figure 6 – Regional Growth Factors

For flood return periods 1 in 2, 1 in 5, 1 in 10, 1 in 20, 1 in 50, 1 in 100 and 1 in 1000 years the growth factors determined from *Figure 6* above are listed in *Table 1* below: -

Flood Return Period (Yrs)	2	5	10	20	50	100	1000
Growth Curve Factor (Q_T/Q_{BAR})	0.95	1.20	1.37	1.54	1.77	1.96	2.59

Table 1 – Growth Factors Applied to Irish Catchments for Q_{BAR} Discharge Prediction

Table 2 below lists the estimated peak flood flows in the Lisduggan Stream watercourse at the points of interest for different return periods: -

Flood Return Period (Yrs)	2	5	10	20	50	100	1000
Lisduggan Stream (Cork Road Culvert) Estimated Peak Flow (m^3/s)	3.76	4.75	5.43	6.10	7.00	7.76	10.25
Lisduggan Stream (Lacken Road) Estimated Peak Flow (m^3/s)	3.78	4.77	5.45	6.13	7.04	7.80	10.31

Table 2 – Estimated Peak Flows for Various Return Periods

The estimated 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) flood flows for the Lisduggan Stream watercourse at the location of the Cork Road Culvert and Lacken Road Culvert is therefore:-

$Q_{50\ Cork\ Road\ Culvert}$ = 7.00 m^3/s

$Q_{100\ Cork\ Road\ Culvert}$ = 7.76 m^3/s

$Q_{1000\ Cork\ Road\ Culvert}$ = 10.25 m^3/s

$Q_{50\ Cork\ Road\ Culvert}$ = 7.04 m^3/s

$Q_{100\ Lacken\ Road\ Culvert}$ = 7.80 m^3/s

$Q_{1000\ Lacken\ Road\ Culvert}$ = 10.31 m^3/s

2.3. Culvert Hydraulic Analysis

As presented on the drawings and associated details provided by Malone O'Regan Consulting Engineers, the proposed 'Cork Road Culvert' and the proposed 'Lacken Road Culvert' shall comprise a **3.2m wide x 1.2m** high precast concrete box structure.

The hydraulic conveyance capacity of the proposed Cork Road Culvert and proposed Lacken Road Culvert was analysis utilising the Autodesk Hydraflow culvert analysis software package. The hydraulic conveyance capacity of the proposed culverts was analysis in consideration of the 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) fluvial flood volumes in the Lisduggan Stream watercourse as presented in *Section 2.2* above.

2.3.1. Cork Road Culvert

Figure 7 below illustrates the output of the hydraulic analysis of the proposed Cork Road Culvert in consideration of the 2% AEP (1 in 50 year) flood volume in the Lisduggan Stream watercourse. A full copy of the culvert hydraulic analysis output is presented in *Appendix A*.

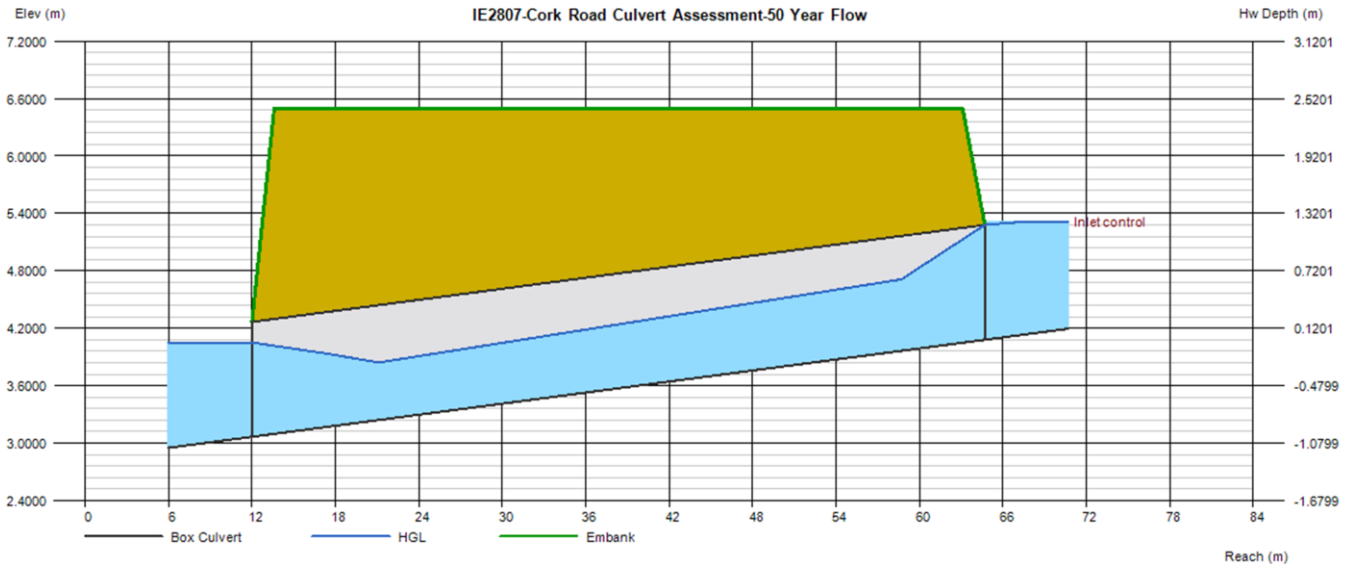


Figure 7 – Proposed Cork Road Culvert – 2% AEP (1 in 50 year) Flood Volume

Figure 8 below illustrates the output of the hydraulic analysis of the proposed Cork Road Culvert in consideration of the 1% AEP (1 in 100 year) flood volume in the Lisduggan Stream watercourse. A full copy of the culvert hydraulic analysis output is presented in *Appendix A*.

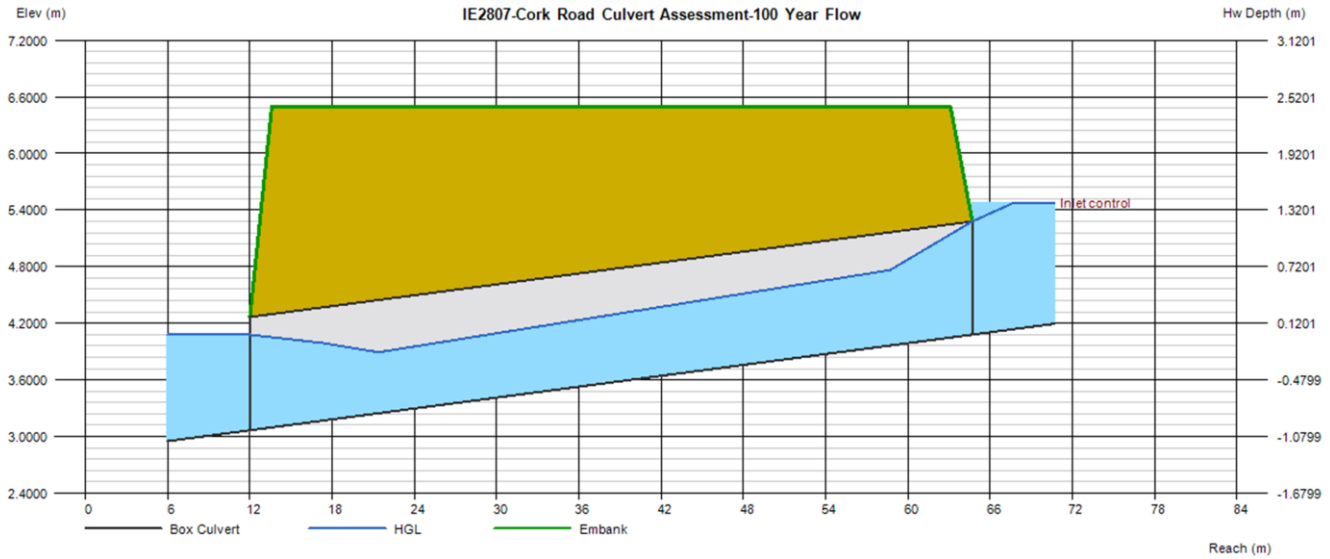


Figure 8 – Proposed Cork Road Culvert – 1% AEP (1 in 100 year) Flood Volume

Figure 9 below illustrates the output of the hydraulic analysis of the proposed Cork Road Culvert in consideration of the 0.1% AEP (1 in 1000 year) flood volume in the Lisduggan Stream watercourse. A full copy of the culvert hydraulic analysis output is presented in *Appendix A*.

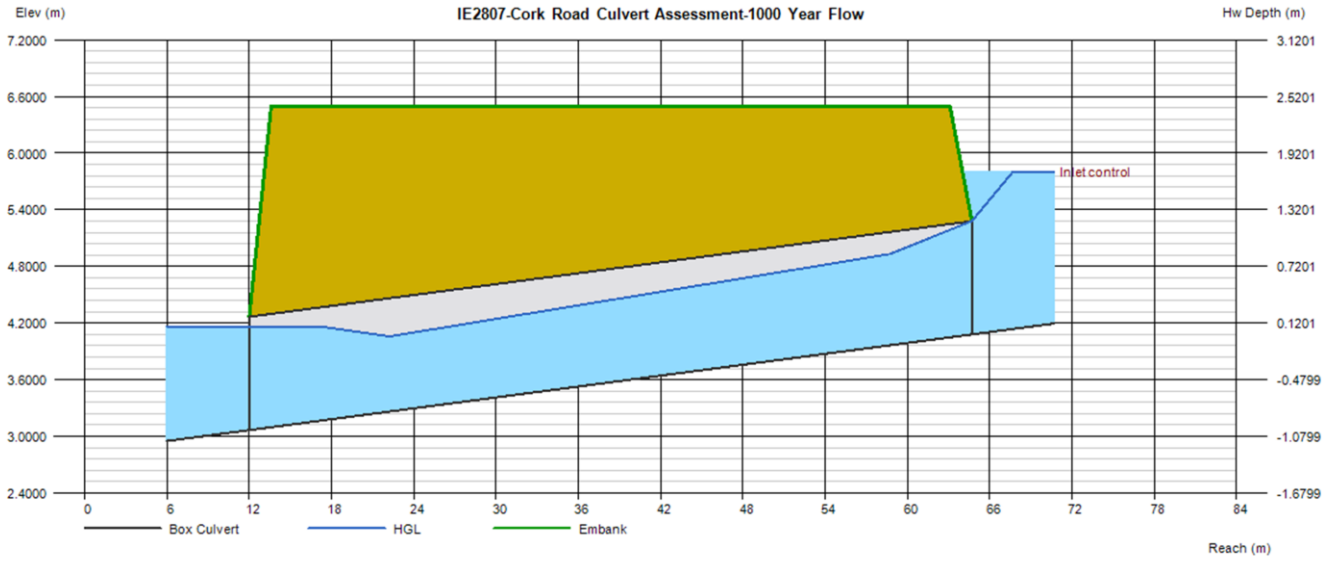


Figure 9 – Proposed Cork Road Culvert – 0.1% AEP (1 in 1000 year) Flood Volume

The hydraulic analysis presented in *Figure 7*, *Figure 8* and *Figure 9* above indicates that the proposed **3.2m wide x 1.2m high** Cork Road culvert has adequate hydraulic capacity to convey the 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) fluvial flood volumes in the Lisduggan Stream watercourse at this location.

Some surcharging at the culvert inlet is predicted in consideration of the 0.1% AEP (1 in 1000 year) fluvial flood volume, however no overtopping of the culvert or channel exceedence is predicted in consideration of the 0.1% AEP (1 in 1000 year) fluvial flood volume.

Overall, the proposed Cork Road culvert is not predicted to result in an adverse impact to the existing hydrological regime of the area or to increase flood risk to the proposed development site or elsewhere.

2.3.2. Lacken Road Culvert

Figure 10 below illustrates the output of the hydraulic analysis of the proposed Lacken Road Culvert in consideration of the 2% AEP (1 in 50 year) flood volume in the Lisduggan Stream watercourse. A full copy of the culvert hydraulic analysis output is presented in *Appendix B*.

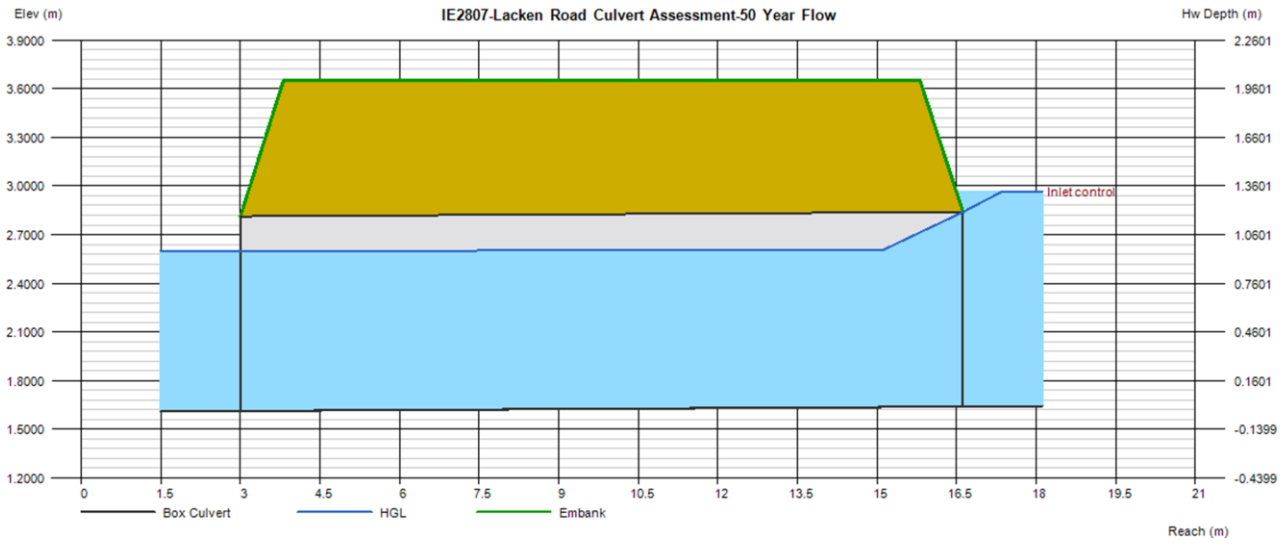


Figure 10 – Proposed Lacken Road Culvert – 2% AEP (1 in 50 year) Flood Volume

Figure 11 below illustrates the output of the hydraulic analysis of the proposed Lacken Road Culvert in consideration of the 1% AEP (1 in 100 year) flood volume in the Lisduggan Stream watercourse. A full copy of the culvert hydraulic analysis output is presented in *Appendix B*.

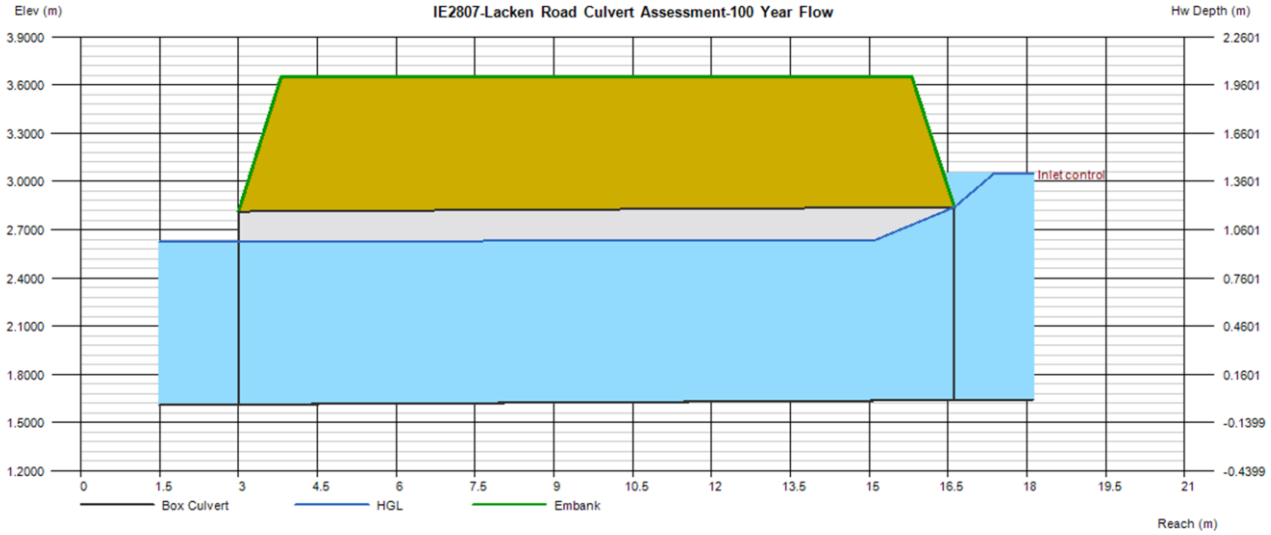


Figure 11 – Proposed Lacken Road Culvert – 1% AEP (1 in 100 year) Flood Volume

Figure 12 below illustrates the output of the hydraulic analysis of the proposed Lacken Road Culvert in consideration of the 0.1% AEP (1 in 1000 year) flood volume in the Lisduggan Stream watercourse. A full copy of the culvert hydraulic analysis output is presented in *Appendix B*.

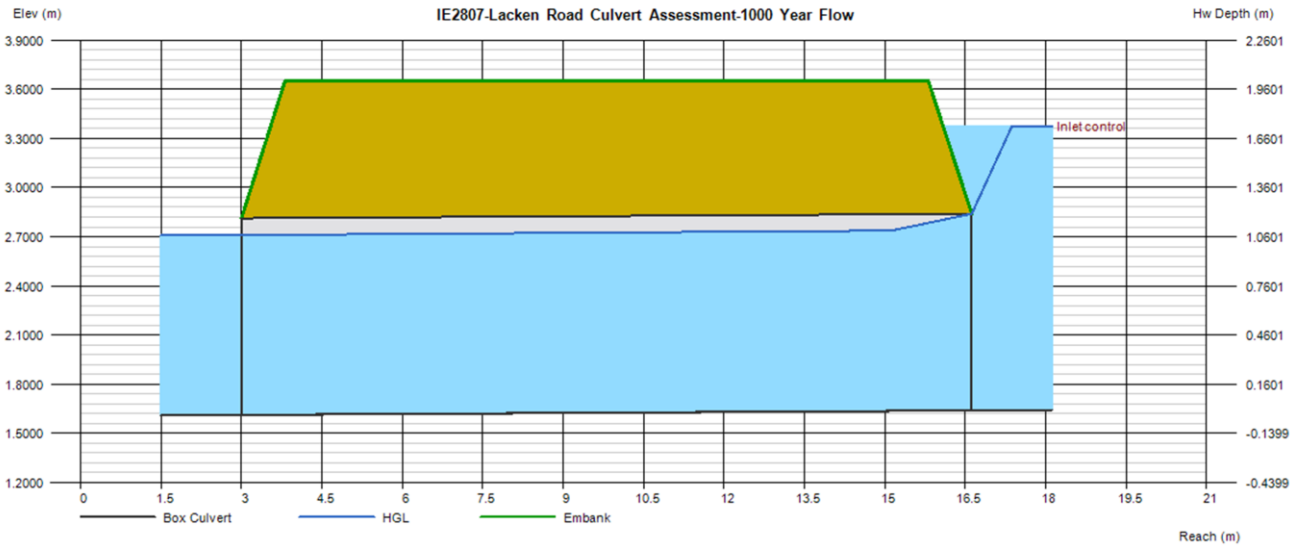


Figure 12 – Proposed Lacken Road Culvert – 0.1% AEP (1 in 1000 year) Flood Volume

The hydraulic analysis presented in *Figure 10, Figure 11* and *Figure 12* above indicates that the proposed **3.2m wide x 1.2m high** Lacken Road culvert has adequate hydraulic capacity to convey the 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) fluvial flood volumes in the Lisduggan Stream watercourse at this location.

Some surcharging at the culvert inlet is predicted in consideration of the 0.1% AEP (1 in 1000 year) fluvial flood volume, however no overtopping of the culvert or channel exceedence is predicted in consideration of the 0.1% AEP (1 in 1000 year) fluvial flood volume.

Overall, the proposed Lacken Road culvert is not predicted to result in an adverse impact to the existing hydrological regime of the area or to increase flood risk to the proposed development site or elsewhere.

3. Point 3 – Flood Risk Assessment

The LRD Opinion response states that the Site Specific Flood Risk Assessment should primarily be undertaken in consideration of the flood zone extent mapping as per the Waterford City & County Development Plan 2022-2028 flood maps as opposed to the OPW CFRAMS mapping for this location.

However, it should be noted that the Waterford City & County Development Plan flood maps at the location of this site are based on the 2011 OPW PFRA indicative flood maps. These maps are not based on the results of any detailed hydrological assessment or hydraulic modelling undertaken along the reach length of the Lisduggan watercourse at this location are intended to be indicative only and are not intended to be used to assess potential flood risk at the site specific scale.

The OPW CFRAMS maps are based on the results of a hydraulic modelling exercise of the Lisduggan watercourse at this location, therefore these maps provide a significantly more accurate and up to date representation of potential flood risk at this location in comparison to the OPW PFRA (and hence Development Plan) flood maps at this location. The OPW CFRAMS flood maps are intended to supersede the OPW PFRA flood maps.

Figure 13 below illustrates the Waterford City & County Development Plan flood map at the location of the proposed development site.

Figure 14 below illustrates the OPW PFRA indicative flood map at the location of the proposed development site.

As illustrated, the flood zone extents (Flood Zone 'A' & Flood Zone 'B') illustrated on the Waterford City & County Development Plan flood map are exactly the same as the flood zone extents (Flood Zone 'A' & Flood Zone 'B' illustrated on the OPW PRFA indicative flood map.

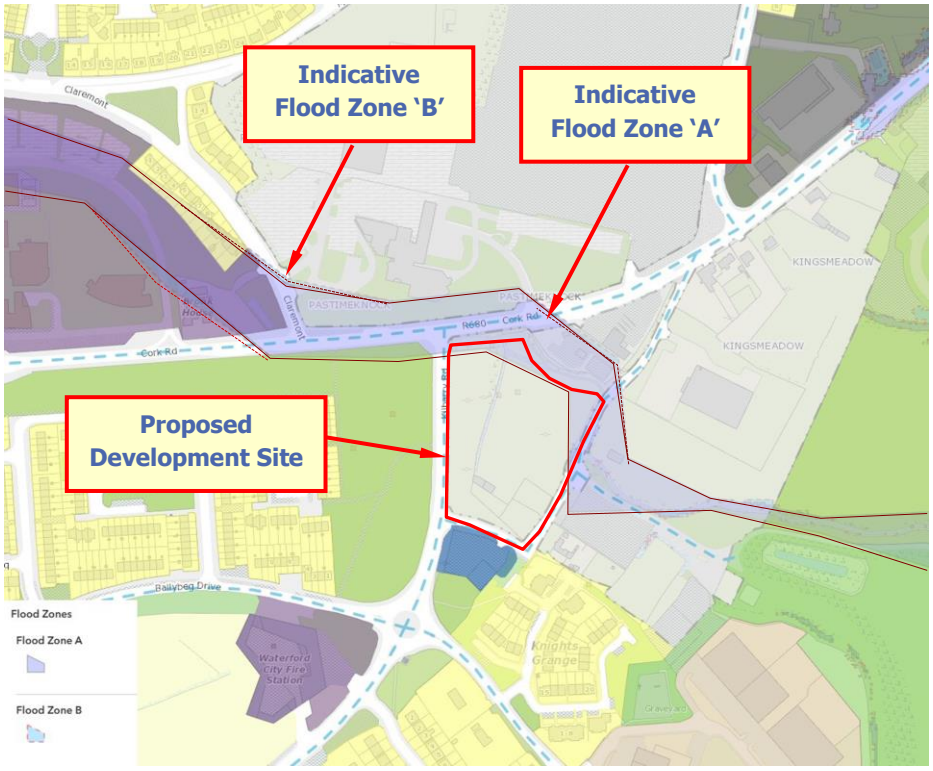


Figure 13 – Waterford City & County Development Plan 2022-2028 Flood Map

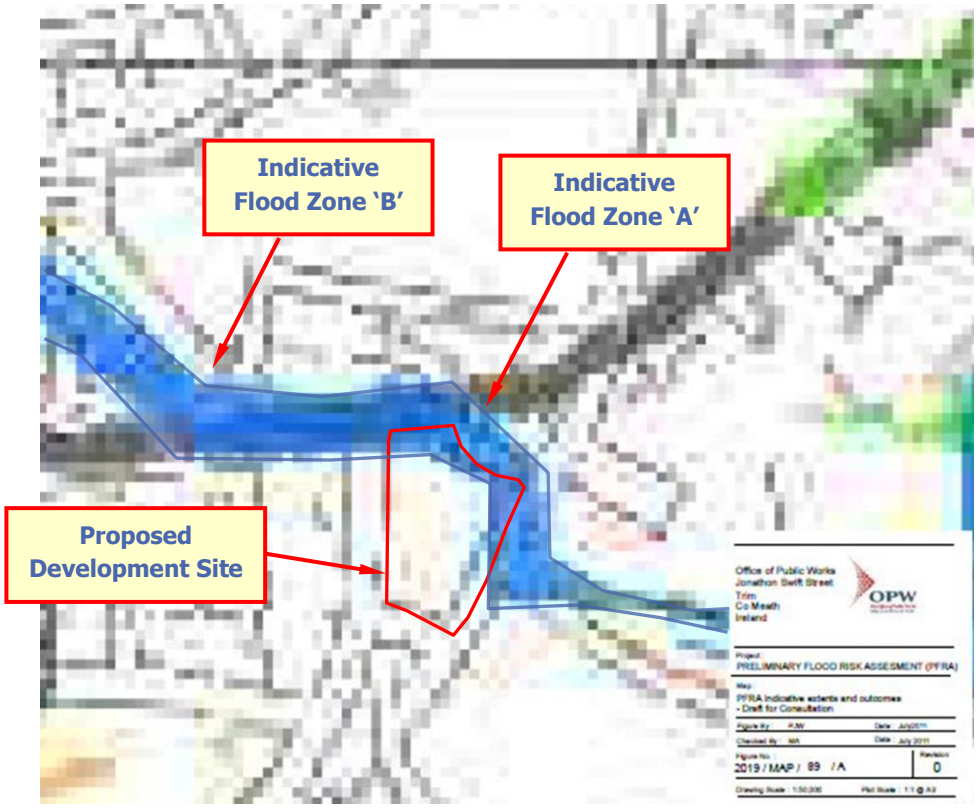


Figure 14 – OPW PFRA Indicative Flood Map

Figure 15 below illustrates an extract from OPW CFRAMS fluvial flood extent map reference 016wtd_exmcd_fo_12.

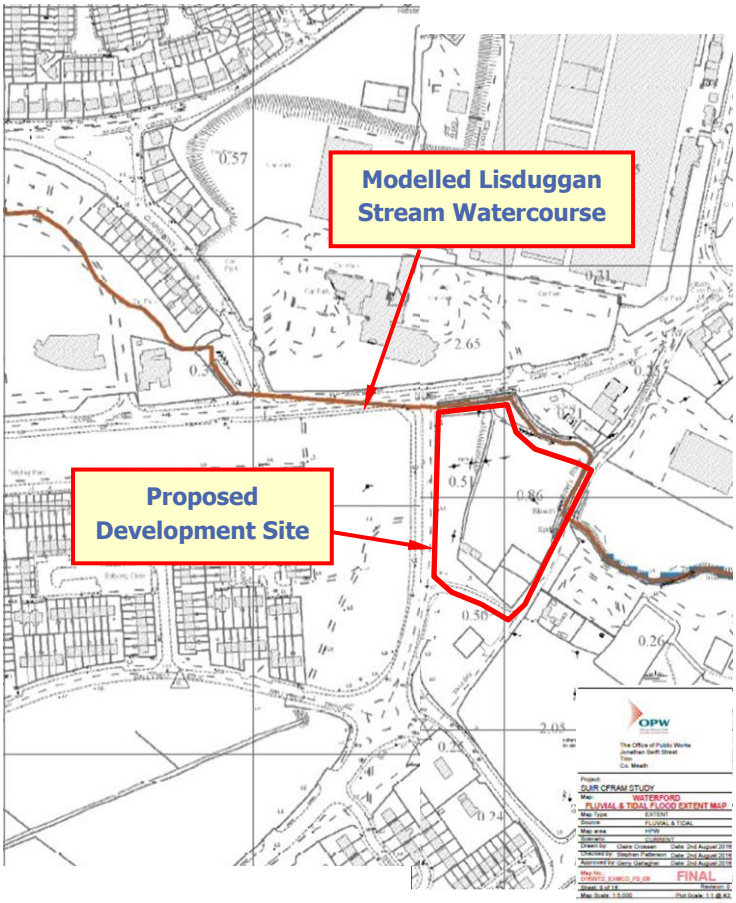


Figure 15 – OPW CFRAMS Predictive Flood Map

As illustrated in *Figure 15* above, as part of the OPW CFRAM study, the Lisduggan Stream watercourse has been hydraulically modelled upstream, downstream and at the location of the proposed development site.

As illustrated in *Figure 15*, and as presented in the previously submitted Site Specification Flood Risk Assessment, the proposed development site does not fall within a predictive Flood Zone 'A' or Flood Zone 'B'.

The OPW CFRAMS maps are based on the results of a detailed hydraulic modelling exercise of the Lisduggan watercourse at this location. The OPW PFRA flood maps, and hence the Waterford City & County Development Plan flood map at this location, are not based on any detailed hydraulic modelling exercise.

As presented in the previously submitted Site Specific Flood Risk Assessment the proposed development site does not fall within a predictive fluvial Flood Zone 'A' or Flood Zone 'B'. In this regard the

development as proposed is not subject to the Justification Test as per The Planning System & Flood Risk Management Guidelines.

It is also presented in Point 3 of the LRD opinion that the proposed development site is partially located with a National Coastal Flood Hazard Mapping (NCFHM) High End Future Climate Change Scenario 0.1% AEP (1 in 1000 year) coastal flood zone.

It is noted that the digital terrain model (DTM) used to generate the OPW NCFHM coastal flood extents at this location are based on ground surface data capture from 2006. In recent years the area of the proposed development site has been significantly infilled and ground levels have been raised, therefore in consideration of the existing topography of the site, the site does not partially fall within a (NCFHM) High End Future Climate Change Scenario 0.1% AEP (1 in 1000 year) coastal flood zone.

4. Summary Conclusions

In consideration of the findings of this Site Specific Flood Risk Assessment Addendum the following conclusions are made:

- The hydrological assessment and hydraulic analysis presented above indicates that the proposed **3.2m wide x 1.2m high** Cork Road culvert has adequate hydraulic capacity to convey the 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) fluvial flood volumes in the Lisduggan Stream watercourse at this location.

- The proposed Cork Road culvert is not predicted to result in an adverse impact to the existing hydrological regime of the area or to increase flood risk to the proposed development site or elsewhere.

- The hydrological assessment and hydraulic analysis presented above indicates that the proposed **3.2m wide x 1.2m high** Lacken Road culvert has adequate hydraulic capacity to convey the 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.1% AEP (1 in 1000 year) fluvial flood volumes in the Lisduggan Stream watercourse at this location.

- The proposed Lacken Road culvert is not predicted to result in an adverse impact to the existing hydrological regime of the area or to increase flood risk to the proposed development site or elsewhere.

- In consideration of the existing topography of the site, the site does not partially fall within a (NCFHM) High End Future Climate Change Scenario 0.1% AEP (1 in 1000 year) coastal flood zone.

Appendices

Appendix A. Cork Road Culvert Hydraulic Analysis

- 2% AEP (1 in 50 Year Culvert Analysis)
- 1% AEP (1 in 100 Year Culvert Analysis)
- 0.1% AEP (1 in 1000 Year Culvert Analysis)

Culvert Hydraulic Analysis Report

IE2807-Cork Road Culvert Assessment-1 in 50 Year Volume

Invert Elev Dn (m)	=	3.0665
Pipe Length (m)	=	52.7000
Slope (%)	=	1.9230
Invert Elev Up (m)	=	4.0799
Rise (mm)	=	1200.0
Shape	=	Box
Span (mm)	=	3200.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

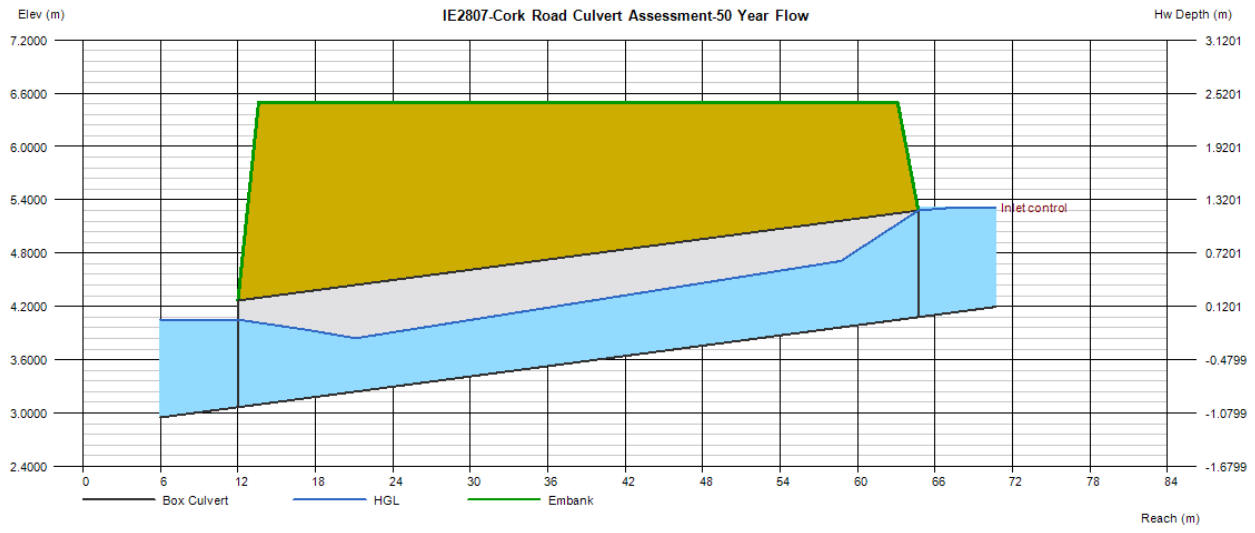
Top Elevation (m)	=	6.5000
Top Width (m)	=	49.5000
Crest Width (m)	=	4.0000

Calculations

Qmin (cms)	=	6.9900
Qmax (cms)	=	7.0000
Tailwater Elev (m)	=	(dc+D)/2

Highlighted

Qtotal (cms)	=	6.7800
Qpipe (cms)	=	6.7800
Qovertop (cms)	=	0.0000
Veloc Dn (m/s)	=	2.1509
Veloc Up (m/s)	=	2.7513
HGL Dn (m)	=	4.0515
HGL Up (m)	=	4.8500
Hw Elev (m)	=	5.3156
Hw/D (m)	=	1.0298
Flow Regime	=	Inlet Control



Culvert Hydraulic Analysis Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Thursday, Feb 8 2024

IE2807-Cork Road Culvert Assessment-1 in 100 Year Volume

Invert Elev Dn (m)	=	3.0665
Pipe Length (m)	=	52.7000
Slope (%)	=	1.9230
Invert Elev Up (m)	=	4.0799
Rise (mm)	=	1200.0
Shape	=	Box
Span (mm)	=	3200.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

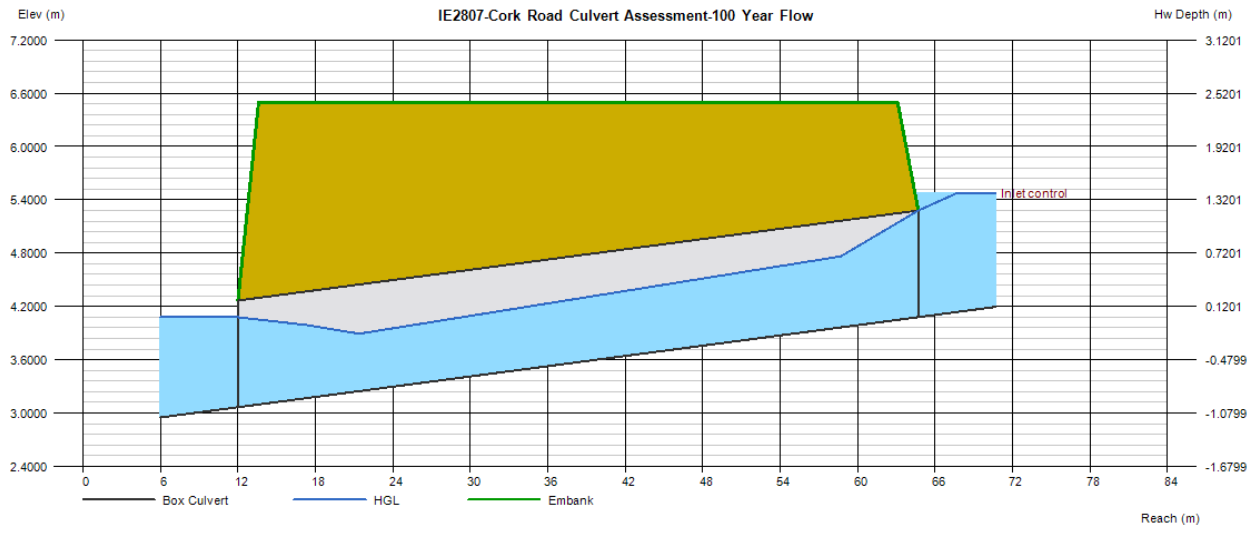
Top Elevation (m)	=	6.5000
Top Width (m)	=	49.5000
Crest Width (m)	=	4.0000

Calculations

Qmin (cms)	=	7.7520
Qmax (cms)	=	7.7600
Tailwater Elev (m)	=	(dc+D)/2

Highlighted

Qtotal (cms)	=	7.5070
Qpipe (cms)	=	7.5070
Qovertop (cms)	=	0.0000
Veloc Dn (m/s)	=	2.3179
Veloc Up (m/s)	=	2.8465
HGL Dn (m)	=	4.0786
HGL Up (m)	=	4.9040
Hw Elev (m)	=	5.4755
Hw/D (m)	=	1.1630
Flow Regime	=	Inlet Control



Culvert Hydraulic Analysis Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Thursday, Feb 8 2024

IE2807-Cork Road Culvert Assessment-1 in 1000 Year Volume

Invert Elev Dn (m)	=	3.0665
Pipe Length (m)	=	52.7000
Slope (%)	=	1.9230
Invert Elev Up (m)	=	4.0799
Rise (mm)	=	1200.0
Shape	=	Box
Span (mm)	=	3200.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

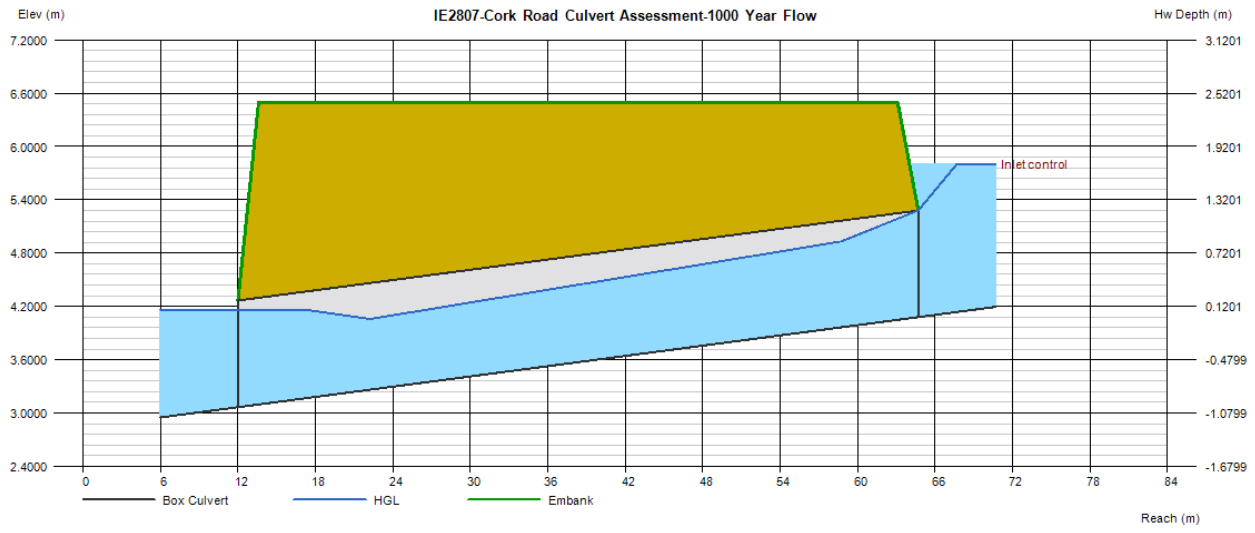
Top Elevation (m)	=	6.5000
Top Width (m)	=	49.5000
Crest Width (m)	=	4.0000

Calculations

Qmin (cms)	=	9.9510
Qmax (cms)	=	10.2500
Tailwater Elev (m)	=	(dc+D)/2

Highlighted

Qtotal (cms)	=	9.9520
Qpipe (cms)	=	9.9520
Qovertop (cms)	=	0.0000
Veloc Dn (m/s)	=	2.8345
Veloc Up (m/s)	=	3.1276
HGL Dn (m)	=	4.1637
HGL Up (m)	=	5.0743
Hw Elev (m)	=	5.8050
Hw/D (m)	=	1.4376
Flow Regime	=	Inlet Control



Appendix B. Lacken Road Culvert Hydraulic Analysis

- 2% AEP (1 in 50 Year Culvert Analysis)
- 1% AEP (1 in 100 Year Culvert Analysis)
- 0.1% AEP (1 in 1000 Year Culvert Analysis)

Culvert Hydraulic Analysis Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Tuesday, Jan 30 2024

IE2807-Lacken Road Culvert Assessment-1 in 50 Year Volume

Invert Elev Dn (m)	=	1.6127
Pipe Length (m)	=	13.6215
Slope (%)	=	0.1997
Invert Elev Up (m)	=	1.6399
Rise (mm)	=	1200.0
Shape	=	Box
Span (mm)	=	3200.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

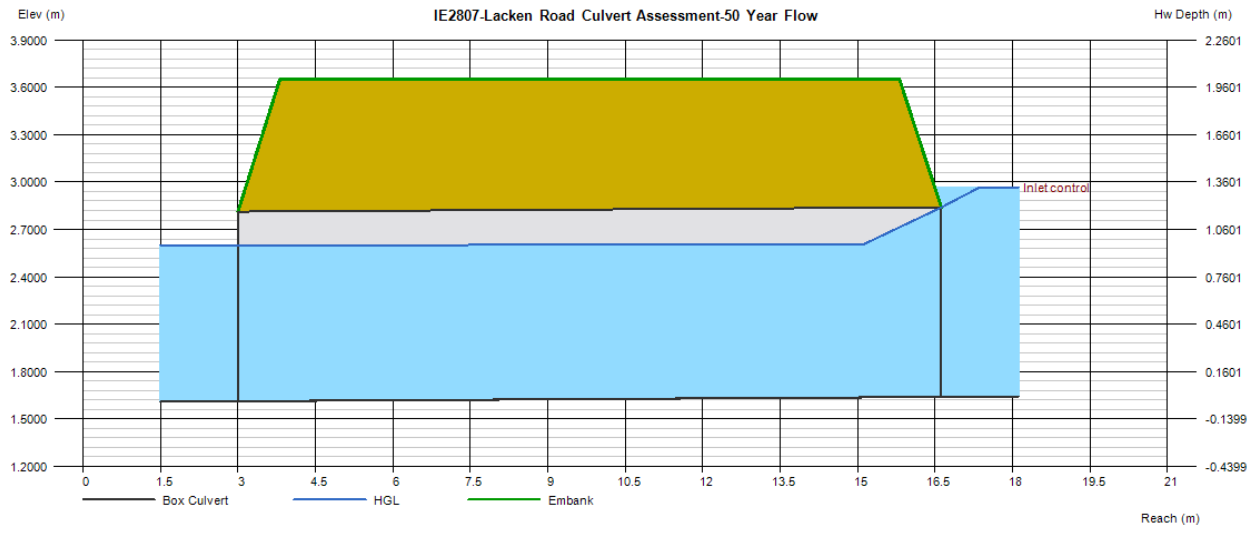
Top Elevation (m)	=	3.6500
Top Width (m)	=	12.0000
Crest Width (m)	=	4.0000

Calculations

Qmin (cms)	=	6.9570
Qmax (cms)	=	7.0400
Tailwater Elev (m)	=	(dc+D)/2

Highlighted

Qtotal (cms)	=	6.8010
Qpipe (cms)	=	6.8010
Qovertop (cms)	=	0.0000
Veloc Dn (m/s)	=	2.1558
Veloc Up (m/s)	=	2.1954
HGL Dn (m)	=	2.5985
HGL Up (m)	=	2.6080
Hw Elev (m)	=	2.9678
Hw/D (m)	=	1.1066
Flow Regime	=	Inlet Control



Culvert Hydraulic Analysis Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Monday, Jan 29 2024

IE2807-Lacken Road Culvert Assessment-1 in 100 Year Flow

Invert Elev Dn (m)	=	1.6127
Pipe Length (m)	=	13.6215
Slope (%)	=	0.1997
Invert Elev Up (m)	=	1.6399
Rise (mm)	=	1200.0
Shape	=	Box
Span (mm)	=	3200.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

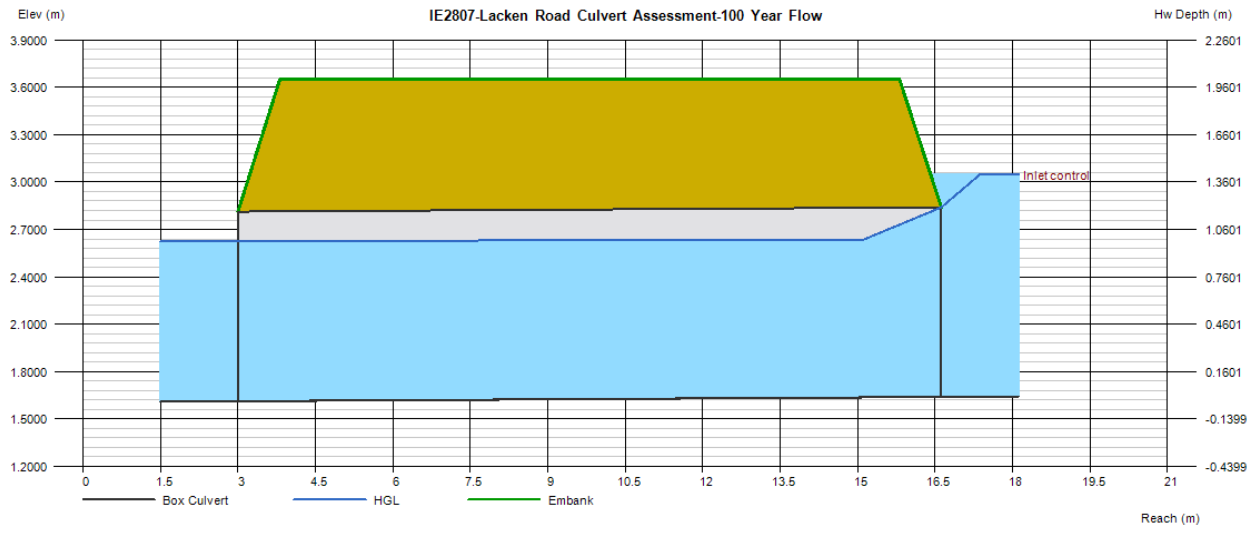
Top Elevation (m)	=	3.6500
Top Width (m)	=	12.0000
Crest Width (m)	=	4.0000

Calculations

Qmin (cms)	=	7.7910
Qmax (cms)	=	7.8000
Tailwater Elev (m)	=	(dc+D)/2

Highlighted

Qtotal (cms)	=	7.5310
Qpipe (cms)	=	7.5310
Qovertop (cms)	=	0.0000
Veloc Dn (m/s)	=	2.3233
Veloc Up (m/s)	=	2.3576
HGL Dn (m)	=	2.6256
HGL Up (m)	=	2.6381
Hw Elev (m)	=	3.0486
Hw/D (m)	=	1.1739
Flow Regime	=	Inlet Control



Culvert Hydraulic Analysis Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Monday, Jan 29 2024

IE2807-Lacken Road Culvert Assessment-1 in 1000 Year Flow

Invert Elev Dn (m)	=	1.6127
Pipe Length (m)	=	13.6215
Slope (%)	=	0.1997
Invert Elev Up (m)	=	1.6399
Rise (mm)	=	1200.0
Shape	=	Box
Span (mm)	=	3200.0
No. Barrels	=	1
n-Value	=	0.012
Culvert Type	=	Flared Wingwalls
Culvert Entrance	=	30D to 75D wingwall flares
Coeff. K,M,c,Y,k	=	0.026, 1, 0.0347, 0.81, 0.4

Embankment

Top Elevation (m)	=	3.6500
Top Width (m)	=	12.0000
Crest Width (m)	=	4.0000

Calculations

Qmin (cms)	=	9.9681
Qmax (cms)	=	10.3100
Tailwater Elev (m)	=	(dc+D)/2

Highlighted

Qtotal (cms)	=	9.9520
Qpipe (cms)	=	9.9520
Qovertop (cms)	=	0.0000
Veloc Dn (m/s)	=	2.8345
Veloc Up (m/s)	=	2.8253
HGL Dn (m)	=	2.7099
HGL Up (m)	=	2.7407
Hw Elev (m)	=	3.3754
Hw/D (m)	=	1.4462
Flow Regime	=	Inlet Control