Appendix 10.2: Floor Risk and Drainage Assessment

Flood Risk & Drainage Assessment

Mullaghclogher Wind Farm

M01616-26_DG03 | October 2024

WATER & ENVIRONMENTAL CONSULTANTS

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1 INTRODUCTION

1.1 Terms of Reference

This Flood Risk and Drainage Assessment has been commissioned by RES, to support a planning application for the proposed Mullaghclogher Wind Farm development located near Plumbridge, in Northern Ireland, hereafter referred to as the 'Proposed Development'.

The purpose of this assessment is to address Revised Planning Policy Statement 15 (PPS15). The assessment will therefore determine potential sources of flooding at the site and their associated risk to life and property; and shall discuss the site suitability for development and outline proposed design and mitigation measures where appropriate.

1.2 Statement of Authority

This report and assessment have been prepared and reviewed by qualified professional civil engineers, specialising in the fields of hydrology, drainage and flood risk as required by DfI Rivers. The key staff members involved in this project are as follows:

- Andrew Snowling – Environmental Technician with expectance in flood risk assessments, environmental assessments, and surface water environments.
- Iain Muir MSc CEnv MIEnvSc – Senior Consultant and Chartered Environmentalist specialising in environmental assessment and applied hydrology, and particular experience in fluvial flood hydrology and modelling.
- Kyle Somerville BEng (Hons) CEng MIEI – Director and Chartered Engineer specialising in the fields of flood risk assessment; flood modelling, drainage, and surface water management design.

1.3 Approach to the Assessment

Consideration has been given to the sources and extent of fluvial and tidal flooding at the site, as well as flooding of the site from pluvial sources, infrastructure failure, overland flow, and ponding of localised rainfall within the site. The assessment is intended to be proportionate to the scale and nature of the development and the perceived risk to it.

For the purposes of this study the following have been considered:

- Available information on historical flooding in the area;
- Site level information based on a high-resolution digital terrain model.
- Detailed assessment of potential flooding from rivers, including fluvial flood modelling.
- Assessment of potential flooding to the site from overland sources.
- Assessment of potential flood risk to adjacent lands caused by development at the site; and
- Determination of the availability of safe discharge of surface water from the site.

In the absence of a local development plan strategy, the relevant planning policy is retained PPS 15 (Revised) which has the same policy direction as the SPPS and is generally more prescriptive. Further guidance is also provided in:

- CIRIA Research Project 624 "Development and Flood Risk: Guidance for the Construction Industry"; and
- Technical Flood Risk Guidance in relation to Allowances for Climate Change in Northern Ireland.

1.4 Application Site

The development and application site (referred to as the 'Planning Application Boundary') lies within a surveyed site comprising a wider landholding (lands under applicant control) referred to as 'the Site' within which the ‘Planning Application Boundary’ lies. The site is located on elevated land north-east of Plumbridge.

Site context and location are shown on the drawings submitted in support of the application.

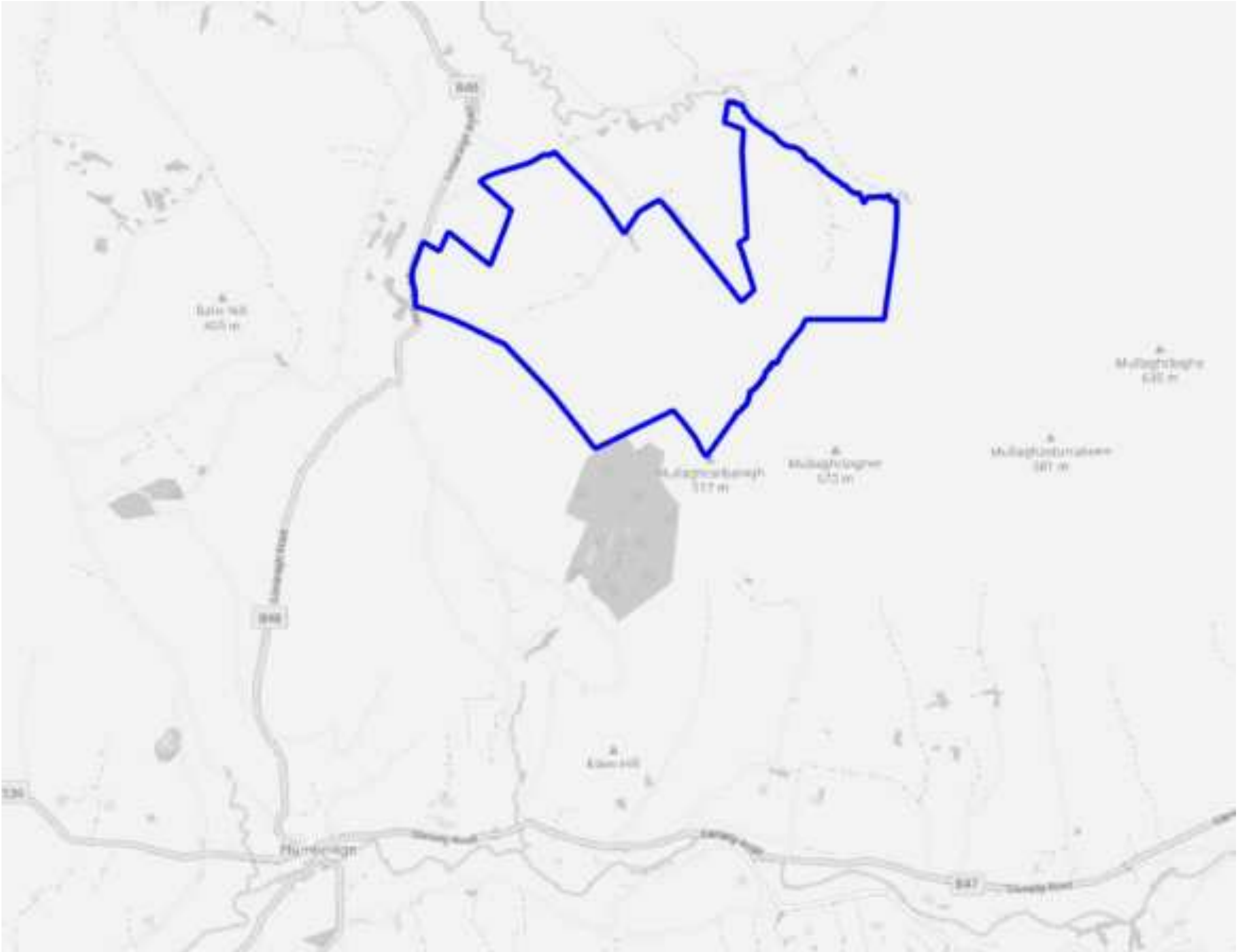


Figure 1-1 Site Location

1.4.1 Existing Land Use

The surveyed site comprises undeveloped land used for agricultural grazing. The site is accessed from Lisnaragh Road (B48) to the west.

1.4.2 Proposed Development

The proposed development involves the construction of 12 no. wind turbines with associated permanent unbound gravel track for access and egress, associated site infrastructure including a control building / substation, and permanent drainage features.

The proposed development footprint within the site is shown on the following figure.

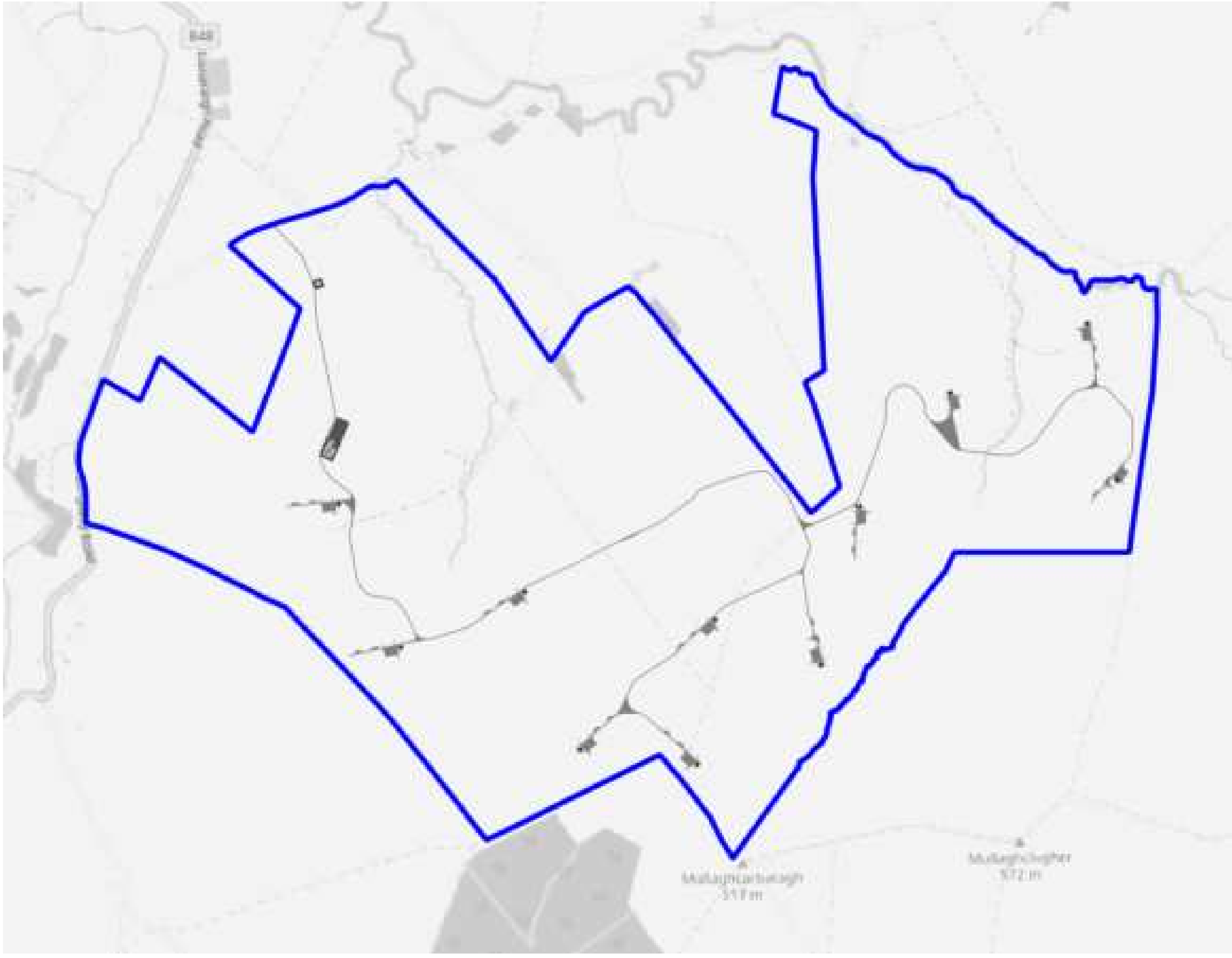


Figure 1-2 Proposed Site Layout

1.5 Site Characteristics

Site characteristics are more fully described within the Geology and Water Environment chapter within the Environmental Statement that this assessment is intended to support. Those aspects pertinent to flood risk and drainage are highlighted in the following sections.

1.5.1 Topography

Topography derived from the OSNI NI 10m DTM merged with a 2m DTM generated from survey data is shown on the following figure.

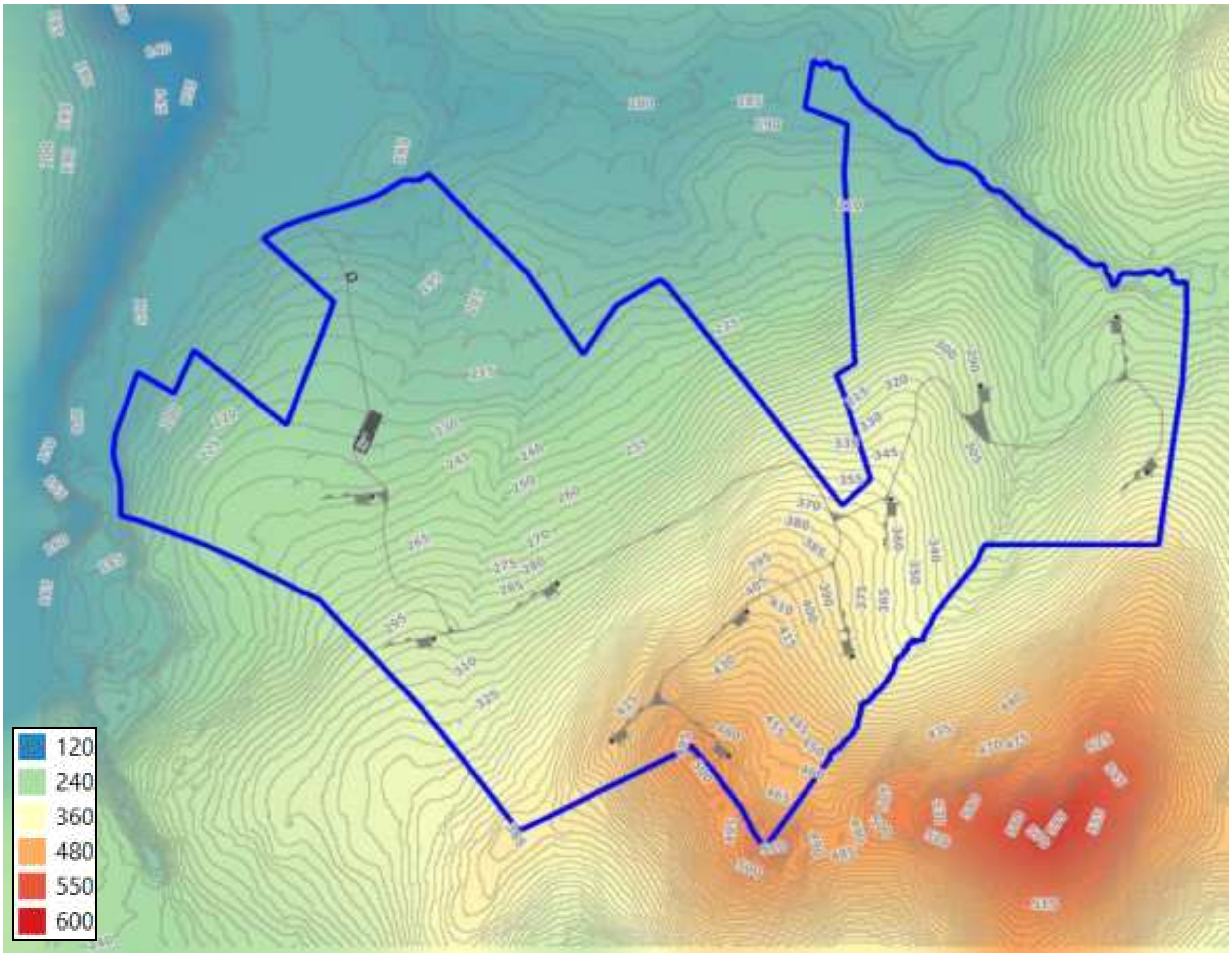


Figure 1-3 Site location and Topography

1.5.2 Hydrology and Watercourses

There is 1 no. watercourse designated under the Drainage Order within the site which runs along the northeastern boundary and is designated as “Craig River” wc no. MW1104.

Undesignated / minor drainage has been mapped to inform the Environmental Statement.

The hydrology in the areas where development is proposed falls across one primary drainage basin defined by the Water Framework Directive. The site drains west and north to the “Burn Dennet River (Ballynamallaght)”.

Watercourses, peat / land drainage and field boundary drainage, have been mapped as part of the wider hydrological assessment. Main water features on and adjacent to the site are shown on Figure 1-4. A detailed hydrology map is included at Appendix A (which is a duplicate of EIAR Figure 10.1).

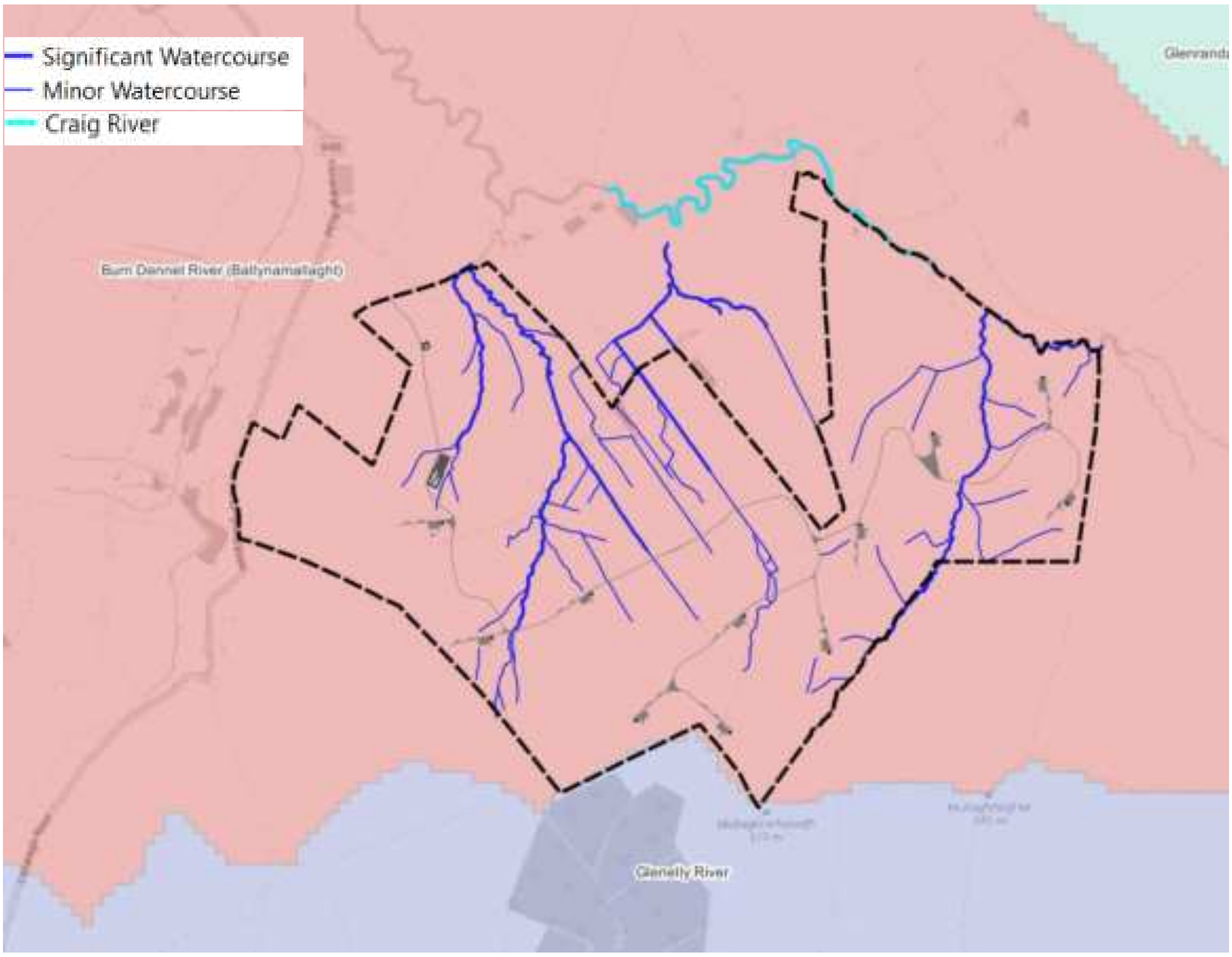


Figure 1-4 Site Hydrology

1.5.3 Geology

A review of GSNI geology data[1] has been undertaken to inform this assessment. Underlying superficial site geology based on GSNI 10k mapping is shown on the following figure. A refined description of ground cover is contained in the Environmental Statement.

[1] Department for the Economy. GSNI GeoIndex. Available from: https://mapapps2.bgs.ac.uk/GSNI_Geoindex/home.html. [Accessed: 28/1/2020].

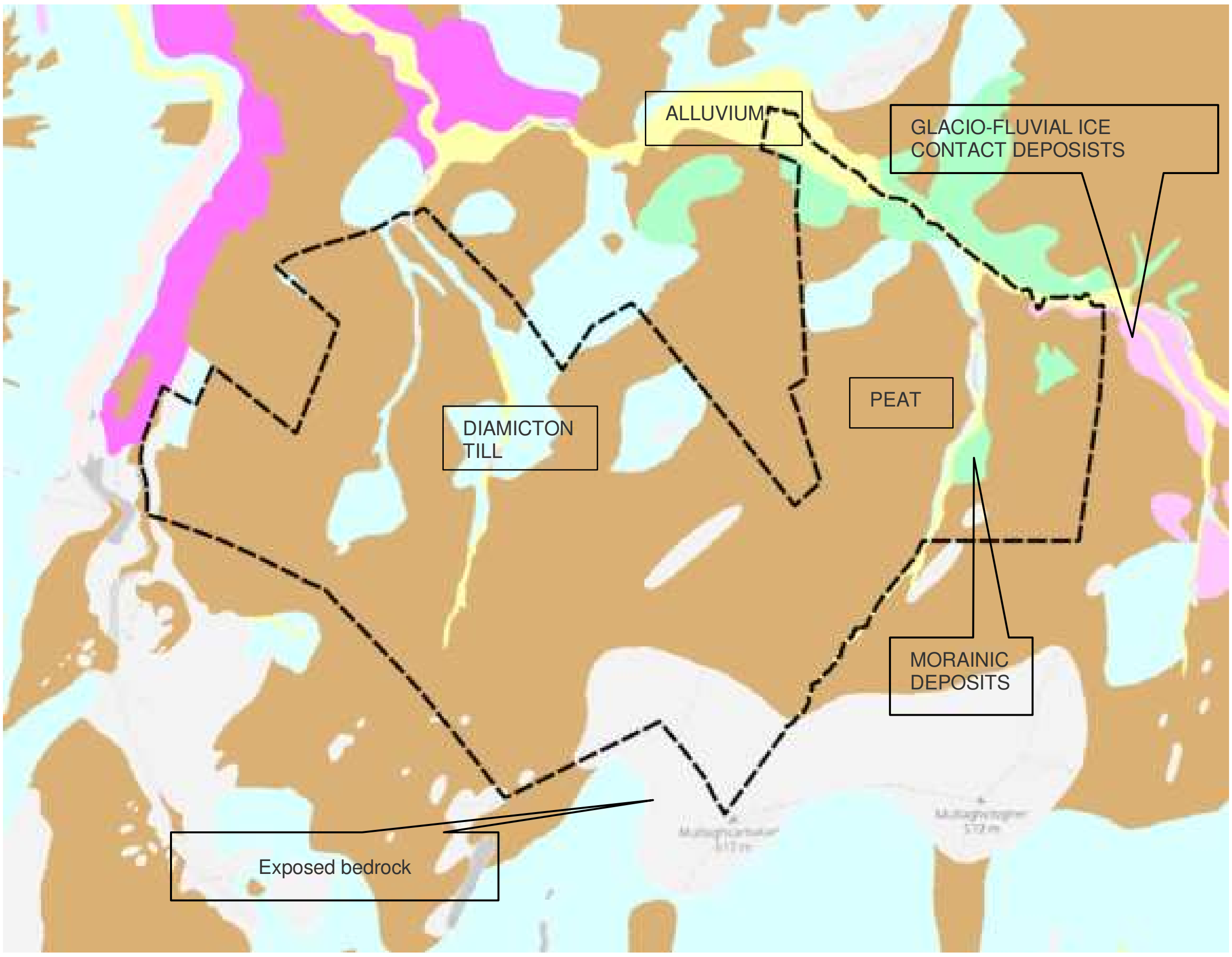


Figure 1-5 GSNI 1:10K Superficial Cover

2 BACKGROUND INFORMATION REVIEW

As part of the data collection phase, several sources of information were investigated to develop an understanding of the potential site flood risk. The following review highlights the findings of the anecdotal evidence collection exercise.

2.1 Internet/Media/Background Search

Preliminary consultation with online media sources indicates that there are no recorded flood incidents which have affected the site.

2.2 Northern Ireland Water

Review of asset information confirms that there are no NIW water supply or drainage assets within or proximal to the site and no further consideration has been given to flooding from such artificial sources.

2.3 DfI Rivers

2.3.1 Flood Maps NI

The extent of development was reviewed with reference to Flood Maps (NI). DfI Rivers in consultation will recommend that climate change is a material consideration, and therefore reference to flood maps is to climate change datasets. Information obtained from flood maps is summarised as follows:

- There is no record of historic flooding within or in proximity of the proposed development.
- DfI Rivers indicative fluvial flood maps indicates that a reach coinciding with a headwater of the Craig River (referred to as 'Glengarrow' Burn in ES Chapter 10) is affected by the indicatively modelled 1% AEP fluvial flood extents. Tributaries of the Burn Dennet River, located in the north-western section of the site, are also affected by the indicatively modelled 1% AEP fluvial flood extents.
- DfI Rivers indicative surface water flood maps – present day indicates that parts of the site are affected by the indicatively modelled 0.5% AEP surface water flood extent. Flooding generally coincides with the routes of watercourse.
- The DfI Reservoir inundation maps confirms that the site is unaffected by the inundation zone of any controlled reservoir.

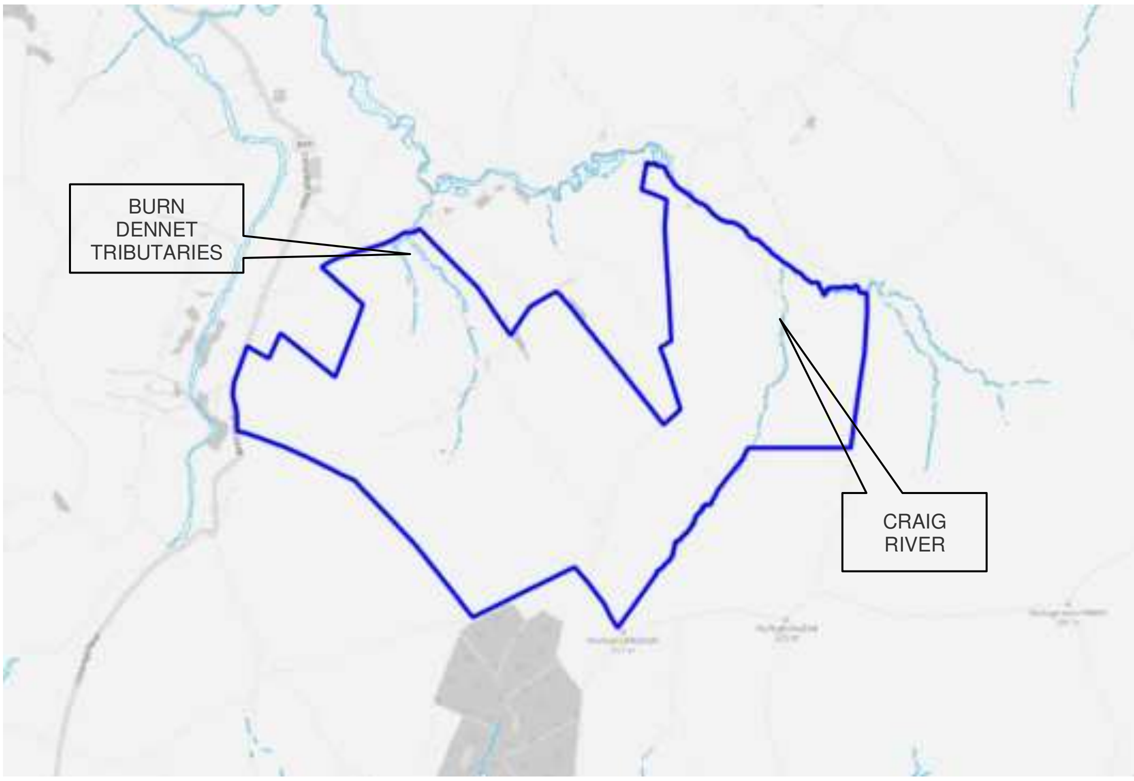


Figure 2-1 Extract from Flood Maps NI – Indicative 1% AEP Fluvial Flood Extent

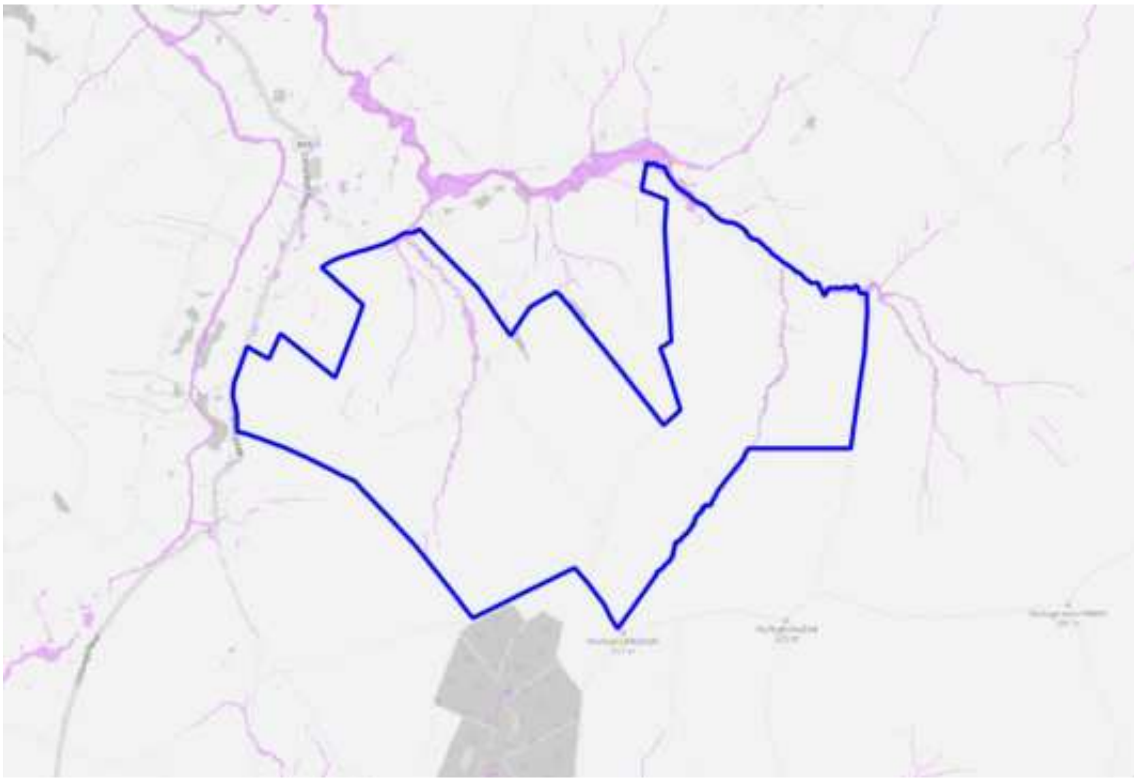


Figure 2-2 Extract from Flood Maps NI – Indicative 0.5% AEP Surface Water Flood Extent

3 FLOOD RISK ASSESSMENT

3.1 Initial Assessment

The following flood mechanism and policy screening is undertaken based on the initial information obtained and in the absence of any pre-application DfI Rivers Planning Advisory consultation response.

Table 3-1 Potential Flood Mechanism and Policy Screening

Policy	Flood Mechanism	Initial Assessment	Policy Applies?	Assess further?
FLD 1 - Development in Fluvial & Coastal Flood Plains	Fluvial Flooding	The site is affected by fluvial flooding shown on FMNI. Locations where development is proposed coincide with proposed watercourse crossing at access tracks.	Yes	Yes
	Coastal Flooding	The site is unaffected by coastal flooding shown on FMNI.	No	
	Flood Defence / Failure	The site does not lie in a defended area.	No	
FLD 2 - Protection of Flood Defence & Drainage Infrastructure	Development near drainage or flood defence assets	The proposed development is located adjacent to and crosses several watercourses and minor drains.	Yes	Yes
FLD 3 – Development and Pluvial Flood Risk Outside Flood Plains	Surface water flooding	Predicted surface water flooding shown on FMNI coincides with watercourses and is more appropriately assessed as fluvial.	No	Yes
	Surface water discharge	The development would potentially modify surface water run-off characteristics onsite/offsite. The scale and nature of the proposal triggers the need for a drainage assessment; development is required to demonstrate that safe discharge of surface water is feasible.	Yes	
	Culvert Blockage	No existing culverted watercourses have potential to affect the site in areas that would be of concern in relation to flood damage to the proposal.	No	
	Urban Drainage / Local Drainage Failure	No record of local drainage failures.	No	
	Groundwater	Not for consideration due to underlying geology and soil types.	No	
FLD 4 – Artificial Modification of Watercourses	Development affecting watercourses	The development shall involve several crossings of undesignated watercourses and field drains to permit access.	Yes	Yes
FLD 5 - Development in Proximity to Reservoirs	Reservoir Flooding	The site is not located within a reservoir inundation zone.	No	No

3.2 Fluvial Flooding

3.2.1 Background – Indicative Floodplains

Review of Flood Maps (NI) indicates that the designated "Craig River" watercourse has been indicatively modelled within and proximal to the Planning Application Boundary. The flooding affects an area where an access track is proposed to cross the watercourse and floodplain. No development is planned in affected areas other than one watercourse crossing where the track is required for access.

A more robust site-specific river model, suitable to the scale and nature of the Proposed Development, has been prepared using high resolution DTM to allow design and evaluation of crossing options given spate upland rivers can characteristically spread over a broad valley floor from a small base channel. Flood mapping produced is intended to supersede the indicative model predictions within the Planning Application Boundary.

3.2.2 Existing 1% AEP Flood Extent

Site-specific hydraulic modelling of the Craig River (See Appendix D for methodology and detail) indicates 1% AEP flooding broadly consistent with that shown on Flood Maps NI.

Due to expected climate change impacts, the application of the precautionary approach requires any assessment of flood risk to incorporate the necessary allowances for increased rainfall, storminess and sea level rise (where appropriate) specified in current UK research and guidance. As per DfI guidance[2], a climate change has been derived through modelling an increase of current design flows by 20%.

The effect of climate change is included in the flood levels and flood mapping shown on all subsequent figures. The 1% AEP flood extents applicable to policy FLD 1 is shown in Figure 3-1.

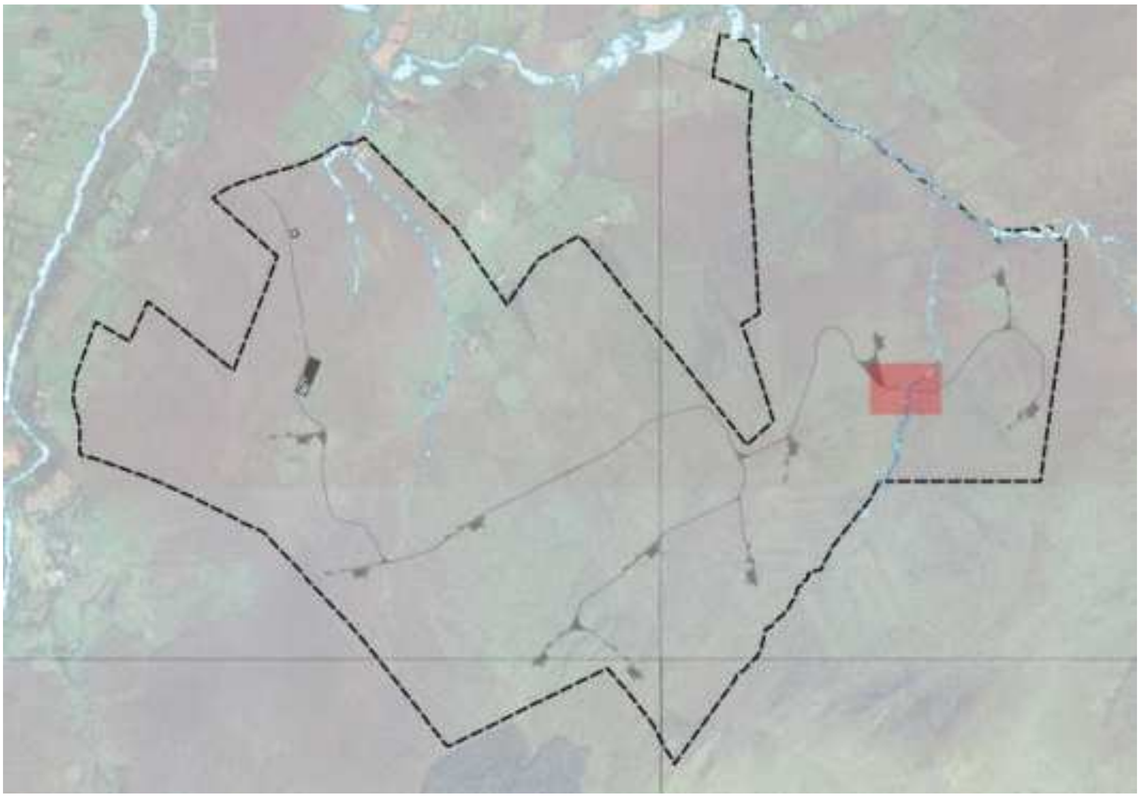


Figure 3-1 1% AEP Flood Extent – Existing Scenario for Context

[2] DfI. (2019). Technical Flood Risk Guidance in relation to Allowances for Climate Change in Northern Ireland. Available from: link.

Figure 3-2 1% AEP Flood Extent – Craig River

Detailed flood extents mapping is provided in Appendix G. Mitigation of risk to the development adjacent to or crossing the floodplain is stated in Section 4.2.

3.2.3 Effect of the Development

The proposed access tracks must cross the undesignated watercourse to permit access to the eastern extent of the Site. The number of crossings has been minimised and have sought to avoid complex meandering reaches which would cause a complex extended culvert or need for a diversion / realignment of the watercourse.

There are 14 no. proposed culverts / crossings of which one is located on an undesignated water feature where fluvial flood mapping is shown on Flood Maps NI. Other watercourse crossings are not significant in flood risk and planning terms and cannot have a significant effect on flood risk, and their design is deferred post-planning consent subject to normal requirements for DfI Rivers authorisation.

Due to the larger scale of the significant crossing to the Craig River , the effect of the Proposed Development (track geometry and proposed culvert opening) has been assessed by incorporating the track alignment as raised embankments within the model geometry and testing river culvert dimensions until a satisfactory outcome was resolved that complies with normal culvert design and flood protection standards.

The proposal has targeted the following standard:

- Main channel culvert / bridge sized to accommodate the in-channel 1% AEP + Climate Change flow with min. 0.3m freeboard between inlet top water level to culvert soffit, per CIRIA C689 Culvert Design and Evaluation Guide. The culvert span is informed primarily by environmental protection standards which seek to maintain the stream banks and bed intact on a precautionary basis due to potential for good fishery habitat.
- While causing no change to upstream water levels is not viable without bridging the whole floodplain, then the proposal has sought to cause an upstream effect not greater than approximately +0.3m, the effect of which is contained entirely within lands under control of the applicant.

The outcome of the analysis and design is scheduled in the following table. Pre-/post-development flood extent mapping is included at Appendix G.

Upstream 1% AEP + CC Flood Level		Effect (m)	Proposed Solution
Pre-Development	Post Development		
276.186	276.270	0.084	Bottomless culvert with span 3.0m, height 1.8m and soffit not less than 276.57 m OD.

Modelling confirms no significant effect on flooding elsewhere, with any localised effect contained immediately proximal to the proposed infrastructure and within lands under control of the applicant. No further mitigation (in the form of floodplain reprofiling) is necessary to mitigate any effect elsewhere.

3.2.4 Risk to the Development

All development other than unavoidable watercourse crossings is sited outside of floodplains and away from watercourses.

All development adjacent to floodplains and proposed track crest levels and any other proposed infrastructure adjacent to watercourse crossings shall be sited at a level greater than the adjacent 1% AEP Climate Change flood level (per mapping shown at Appendix G, ideally including 0.6m freeboard, and as such will have an appropriate standard of flood protection.

3.3 Surface Water

3.3.1 Effect of the Development

The proposed development shall lead to an increase in the impermeable area of the site. Therefore, the risk of flooding from surface water run-off from the site shall be greater relative to the existing scenario without appropriate mitigation.

An estimate of the unmitigated post-development run-off for the footprint of the proposed development has been made as part of this assessment. A comparison of existing and proposed run-off rates in litres per second (lps) are provided in Table 3-2.

Table 3-2 Comparison of surface water run-off rates (Peak [1hr] Runoff rates)

Return Period	Existing Site (l/s)	Proposed Site (l/s)	Increase (l/s)
1 in 2 year	122	198	*76*
1 in 30 year	212	565	*354*
1 in 100 year	252	767	*515*

3.3.1.1 Potential for Overland Flooding

The site setting is rural, and the proposal is unlikely to cause any significant direct risk of surface water flooding to any receptor downgradient.

Routing of overland flooding from the site has been determined based on a “rolling ball” hydrological analysis, the outcome of which (showing key overland flow routes) is shown on Figure 3-3. That analysis tends to confirm that all runoff from the site will be intercepted by the watercourse network prior to causing any effect of adjacent land.

Mitigation of surface water flood risk to adjacent lands shall be by provision of an adequate drainage system, see Section 4.2.3.

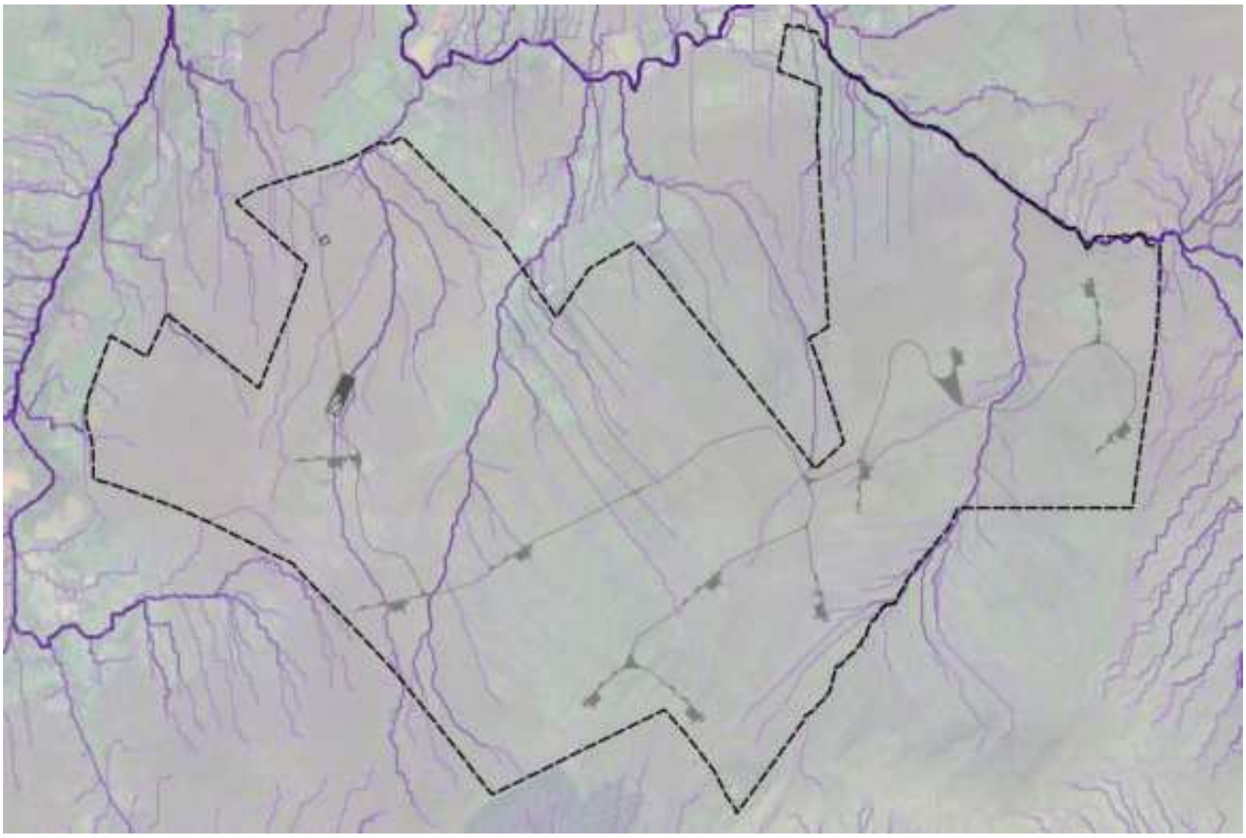


Figure 3-3 Indicative Overland Flow Paths

3.3.1.2 Effect on Downstream Watercourses

All runoff from the site will drain to downstream watercourses lands under control of the applicant.

The effect of the development has been assessed as causing an increased rate and volume of run-off. To mitigate this effect, it is proposed to use a rural SuDS approach to encourage dispersal of runoff over the site and discourage point discharges to watercourses; and to limit run-off from direct discharges to watercourses to a greenfield equivalent pre-development run-off rate.

Point discharges to watercourses will be attenuated to the DfI Rivers greenfield rate up to the 1% AEP + Climate Change. DfI Rivers consent for point discharges has been sought in parallel with submission of the planning application – Rivers application reference IN1-24-9698. A copy of the consent will be supplied separately when available.

Requirements for the attenuation and discharge of surface water based on the proposals at the site are discussed in Section 4.2.

4 SUMMARY OF FINDINGS AND RECOMMENDATIONS

4.1 Summary of Findings

Parts of the site are affected by the 1% AEP fluvial flood extents which are associated with out of bank flooding from an undesignated watercourse comprising the upper reaches of the Craig River.

An assessment of fluvial flooding undertaken. No development is sited within the fluvial floodplain other than a proposed track watercourse crossing required to permit access. The Proposed Development has been assessed and determined to cause no adverse effect outside lands under control of the applicant. No other significant flood risk has been identified after mitigation.

The Proposed Development causes an increase in peak rate and volume of runoff from the site. Mitigation of surface water flood risk to the development, by providing an adequate drainage system, is discussed below.

4.2 Design Measures

This section details measures which have been incorporated into the proposal submitted in support of the planning application, and to be further developed in any detailed design or variation post-determination of the planning application.

4.2.1 Track Levels

Finished track levels adjacent to watercourse crossings where fluvial flooding has been assessed in detail shall be sited at a minimum level of the adjacent 1% AEP Climate Change flood level + 0.6m freeboard, to comply with DfI Rivers standard recommendations. Adjacent flood levels are shown on maps at Appendix G.

All other infrastructure is sited sufficiently remotely from watercourses that no minimum design levels apply.

4.2.2 Watercourse Crossings

The development shall involve the installation of piped crossings for thirteen features locations across the site to permit access, comprising of 1 no. significant watercourses (i.e. catchment areas >0.25 km^2) and 13 no. minor watercourses. Watercourses vary from headwater channels to substantial upland streams with bed widths >2m.

The nature of the crossing proposed (i.e. closed culvert or clear span) is dictated by other overriding environmental factors (fisheries and habitats requirements) and the need to avoid in-stream works where applicable.

A detailed schedule of culvert crossings and the watercourses affected is included at Appendix H.

4.2.2.1 Culvert Crossings

Where no requirement for fish passage has been identified within the site-specific fisheries assessment included in the Environmental Statement, piped crossings on these 13 no. watercourses shall be designed as to mitigate potential for flooding of infrastructure. Culverts shall be designed to have free inlet conditions for an appropriate flood design standard, nominally 1% AEP / 1-in 100 years with climate change allowance or as may otherwise be required by DfI Rivers in consultation.

Any crossings required shall be designed to accommodate track crossings whilst limiting the length of the channel affected.

Hydraulic design of crossings shall be undertaken as per the guidance and requirements provided in CIRIA C689 "Culvert Design and Operation Guide" (or other standard as may be required by DfI Rivers in post-consent consultation), with primary parameters likely to include:

- Width of the crossing will be greater than the width of the active drainage channel.

- Alignment of the crossing will suit the alignment of the drainage channel i.e. preserve the existing direction of flow.
- The slope of the crossing will not exceed the slope of the bed of the existing channel.

Proposed culverts shall be subject to future approval from DfI Rivers through a Schedule 6 application, under the Drainage Order (NI) 1973. The locations affected are not located in any floodplain and are of a conventional nature and there is no significant potential for the culverts in themselves to cause a new flood risk requiring consideration as part of this flood risk assessment. Consent has been sought in parallel with the planning application, DfI reference IN1-24-9701, and consent will be forwarded when available if required.

4.2.2.2 Clear Span Crossing

The crossing over the Craig River is sited on a floodplain and as such its effects are of material consideration in terms of this flood risk assessment, and so have been considered and assessed in further detail.

The proposed structure, which complies with and exceed the minimum standards stated in Section 4.2.2.1 for minor watercourse crossings, is shown on drawings included in Appendix B. There is sufficient information in this FRA to allow the conclusion that the proposed structure is satisfactory from a flood risk point of view and that the planning application can be determined without DfI Rivers Schedule 6 consent in place. Consent has been sought in parallel with the planning application, DfI reference IN1-24-9701, and consent will be forwarded when available if required.

The culvert shall be formed from precast portal frame sections or similar. The section heights shall be dictated by the structural and foundation / formation design and the minimum soffit height determined by this assessment.

4.2.3 Drainage Design

Drainage is to meet or exceed the hydraulic standards stated as follows:

• The drainage network / site layout ensures containment and control of the 100-year (1% AEP) return period storm within the site to ensure no offsite effect elsewhere. • The drainage network allows for a **20%** allowance for climate change for the flood protection standard.	To suit DfI Rivers flood protection standards.

Due to the nature of the development, a formalised conventional drainage system is not considered feasible or practical at the site. The design principles in summary are as follows:

- Runoff from the access track shall be collected via open swales. Run-off shall be attenuated with the use of check dams to reduce the peak rate of run-off and to encourage infiltration of surface water.
- Settlement/attenuation basins will be provided where drainage from significant areas of hardstanding discharge directly to streams and watercourses.
- If feasible at detailed design, run-off should be encouraged to discharge overland, rather than accumulate concentrated peak flows to discharge to watercourses.

The drainage networks should also allow for a 20% allowance for climate change at all the above listed return periods. SuDS features shall be designed in accordance with best practice guidance in The SuDS Manual (Document ref: C753; CIRIA).

4.2.3.1 Discharge Rate and Location

To demonstrate that the safe discharge of surface water from the proposed wind farm site is feasible, a preliminary drainage design has been prepared and is included in Appendix B. The proposal involves surface water from the proposed development discharging directly to the existing on-site watercourses and field drains, at the 9 no. locations indicated on the drainage design.

Point discharges to watercourses will be attenuated to the DfI Rivers greenfield rate up to the 1% AEP + Climate Change event. DfI Rivers consent for point discharges has been sought in parallel with submission of the planning application – Rivers application reference IN1-24-9698. A copy of the consent will be supplied separately when available.

Surface water run-off shall be limited as closely as feasible to the greenfield run-off rate of 10l/s/ha for the developed site area.

4.2.3.2 Attenuation Requirement

The indicative drainage design shown intends surface water from the site to discharge into 16 no. attenuation basins at locations adjacent watercourses and field drains. Flows controls shall be installed at the pond outflow points to ensure that flows are discharging to watercourses as per Table 4-1.

The storage calculation has not included the storage provided within the drainage conveyance system i.e. by check dams in swales, and loss of water by overland dispersal. The attenuation sizes required are therefore considered highly conservative. Attenuation calculations demonstrate that attenuation as scheduled on Table 4-1 (overleaf pg. 17) is required.

The attenuation volume stated is based on preliminary information; drainage catchments are subject to change dependent on the finalised layout of any drainage layout and finished ground levels. Volumes stated are dependent on the type and efficiency of the flow control method used. Ultimately the final design (to be completed and agreed post-consent) must comply with the limiting discharge rate (per hectare) applied to the drained development area.

The location of attenuation basins / configuration can be viewed in drawings included in Appendix B.

Table 4-1 Attenuation Requirements

Catchment	Comment	Drainage area (m2)	Attenuation storage required (m3)	Allowable run-off rate (l/s)
1	Discharge to watercourse / drain	4558	123	4.6
2	Discharge to watercourse / drain	5022	135	5
3	Discharge to watercourse / drain	1276	34	1.3
4	Discharge to watercourse / drain	8643	233	8.6
5	Discharge to watercourse / drain	4001	108	4
6	Discharge to watercourse / drain	4900	132	4.9
7	Discharge to watercourse / drain	436	12	0.4
8	Discharge to watercourse / drain	698	19	0.7
9	Discharge to watercourse / drain	4843	131	4.8
10	Discharge to watercourse / drain	1122	30	1.1
11	Discharge to watercourse / drain	1410	38	1.4
12	Discharge overland over heath	10476	282	10.5
13	Discharge to watercourse / drain	1001	27	1
14	Discharge to watercourse / drain	6452	174	6.5
15	Discharge to watercourse / drain	2650	71	2.7
16	Discharge to watercourse / drain	2152	58	2.2
17	Discharge to watercourse / drain	4903	132	4.9
18	Discharge to watercourse / drain	6032	163	6
19	Discharge to watercourse / drain	2751	74	2.8
20	Discharge to watercourse / drain	11131	300	11.1
21	Discharge to watercourse / drain	608	16	0.6
22	Discharge to watercourse / drain	1123	30	1.1
23	Discharge to watercourse / drain	4380	118	4.4
24	Discharge to watercourse / drain	7351	198	7.4
TOTAL		**97919 SQ M**	**2638 CU. M**	**98 lps (equivalent to 10 lps/Ha)**

4.2.3.3 Exceedance

In the event of an unprecedented flood, any attenuation pond is expected to overtop and drain overland.

It has been demonstrated that flows from the site up to the flood protection design standard (1 in 100 year/1% AEP) can be safely contained within the system without flooding. Runoff in the event of other exceedance (i.e. blockage or other failure) will tend to follow flow routes tending towards the south/south west of the site as per the present day scenario (refer to Figure 3-3.)

Mitigation of such exceedance shall be by robust maintenance of the drainage network described subsequently.

4.2.4 Protection of Watercourses

The proposal includes measures that prevent development within 10m of minor watercourses and 50m of hydrologically significant water features, which ensure that the requirements of policy FLD2 are met. The nature of the proposal causes no built development of a type that would impede riparian maintenance of watercourses, and as such meets the normal requirements stated in policy FLD2 in relation to watercourse maintenance.

4.3 Maintenance Requirements

4.3.1 Drainage System Maintenance

The developer/site operator is to ensure that the maintenance of the drainage system is included within the overall management plan for the site. Detailed drainage layouts for the site shall ensure that key features requiring maintenance (e.g. flow control devices) are in accessible locations.

Maintenance plans for SuDS are to include (where applicable):

- Cyclical (min. annual, or after significant storm event) check of any flow control device for damage, debris, or blockage.
- Seasonal maintenance of any surface water feature e.g. swales/ponds – nominally to include management of vegetation, clearing of obstructions, etc.

4.3.2 Drainage Feature Maintenance

The operator is reminded of their statutory obligations set out in the Drainage (Northern Ireland) Order 1973 in relation to their role as a riparian landowner to the watercourses and field drains located on site.

4.4 Flood Risk & Planning Policy Summary

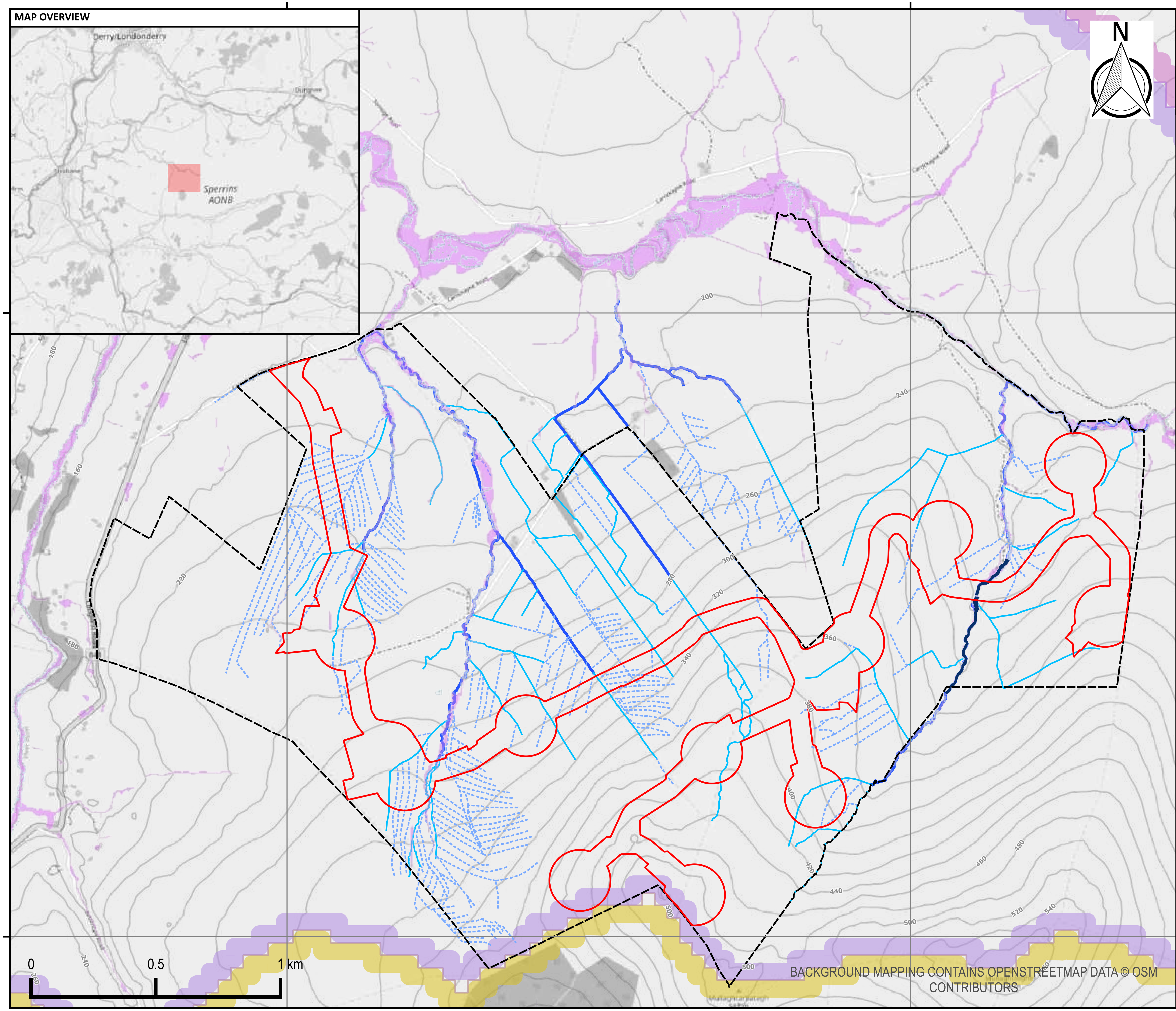
The following table summarises the findings, mitigation, and policy context of those flood mechanisms and policies deemed to be required to be investigated further by the initial assessment.

Table 4-2 PPS15 Policy Summary

Policy	Assessment / Mitigation
FLD 1 - Development in Fluvial & Coastal Flood Plains	No development in floodplains is proposed other than where a proposed access track crosses a watercourse with an adjacent floodplain. Development adjacent to floodplains is resilient to flooding including freeboard to climate change flood levels. Proposed watercourse crossings have been assessed to have no effect elsewhere and no additional mitigation is required.
FLD 2 - Protection of Flood Defence & Drainage Infrastructure	The proposals shall not impede riparian maintenance of watercourses. The proposal therefore complies with FLD2.
FLD 3 – Development and Pluvial Flood Risk Outside Flood Plains	Site drainage shall ensure that the site is adequately drained and flood resilient. Drainage design shall adopt suitable hydraulic standards in relation to standards of flood protection to the site and downstream watercourses. Surface water can be safely disposed of to existing field drains and watercourses subject to pending DfI Rivers consent. The proposal will comply with FLD3.
FLD 4 – Artificial Modification of Watercourses	The proposed development shall involve the construction of crossings to existing watercourses and field drains. The crossings shall be constructed to facilitate access only and are a permissible exception to policy FLD4. Crossing designs ensure flood risk outside the site / outside lands under control of the applicant is unaffected.
FLD 5 - Development in Proximity to Reservoirs	Does not apply (see Section 3.1)

Appendix A

Site Hydrology Map



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MULLAGHCLOGHER WIND FARM

M01616-26 CHAPTER 10
EIAR_FIG_10.1

SITE HYDROLOGY

The Site
Lands Under Applicant Control - as Site Boundary
Planning Application Boundary

Hydrology
Significant Watercourse (>0.25 km2)
Minor Watercourse (<0.25 km2)
Other Watercourse

Flooding
Site-Specific Model 1% CC AEP Flood Extent

Flood Maps NI
FMNI Indicative 1% AEP Fluvial Flooding (Beyond Site-Specific Model Extents)
FMNI Indicative 0.5% AEP Surface Water

Height Data [OSNI 10m DTM)
20m Major Contour

River Basin Context Map
Burn Dennet River (Ballynamallaght)
Glenelly River

M01616-26_FIG_10.1

SCALE - AS SHOWN

ENVIRONMENTAL STATEMENT

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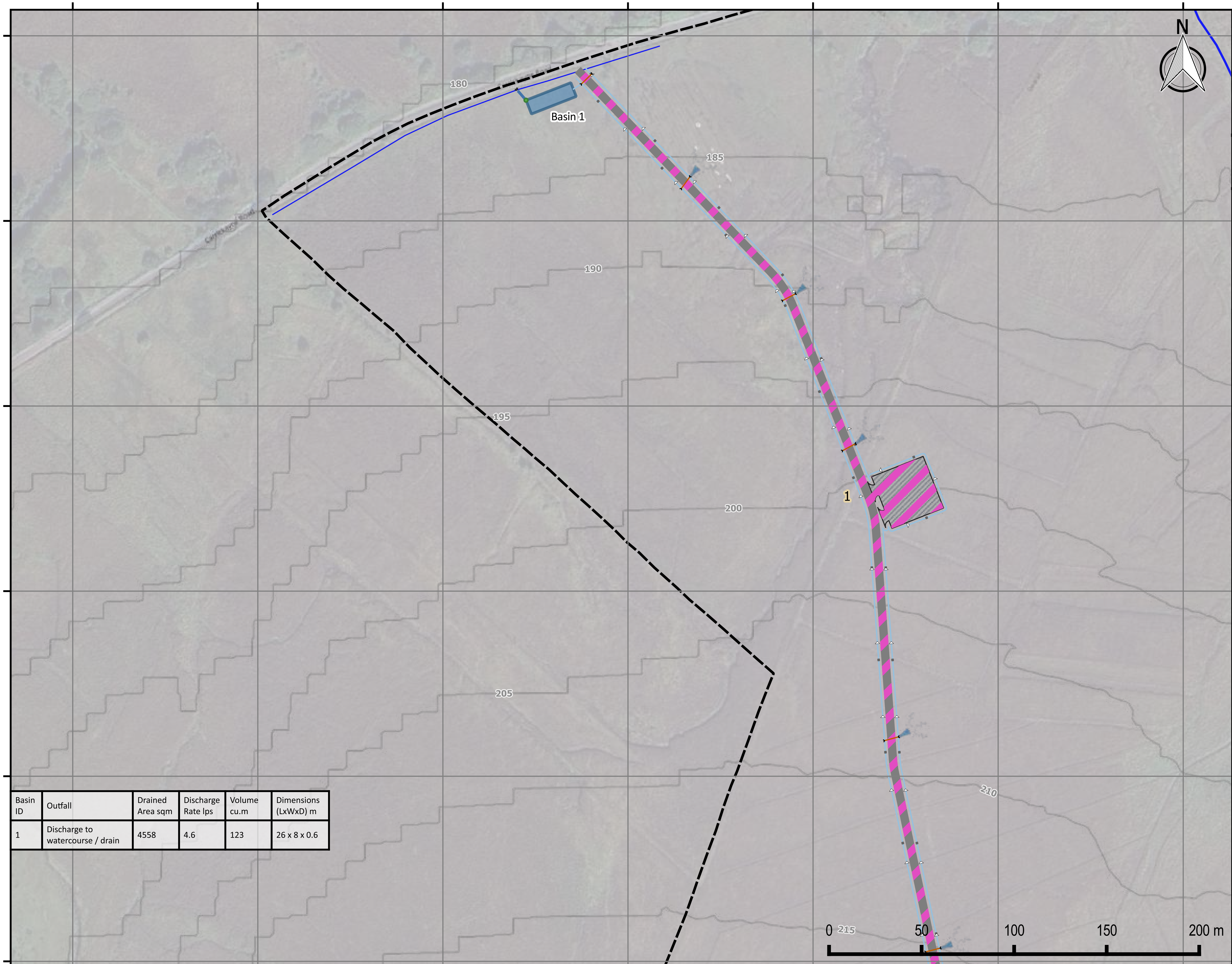
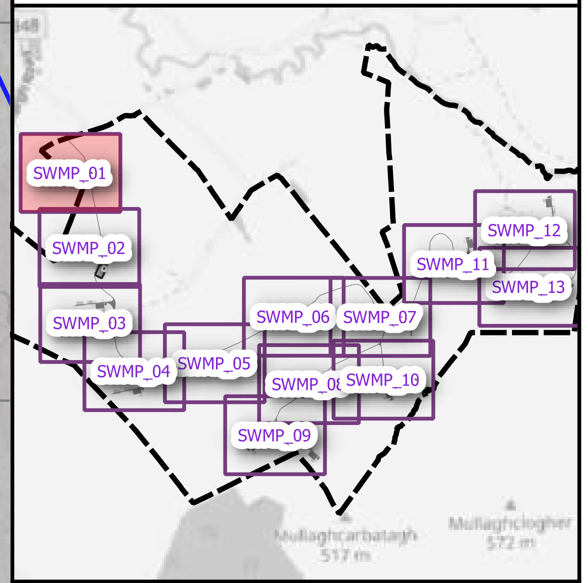
Appendix B

Drainage Layouts



Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
1	Discharge to watercourse / drain	4558	4.6	123	26 x 8 x 0.6

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse
- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments
- 1

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DESCRIPTION
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 1

PROJECT / FIGURE NO.
M01616-26_DC_01

DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

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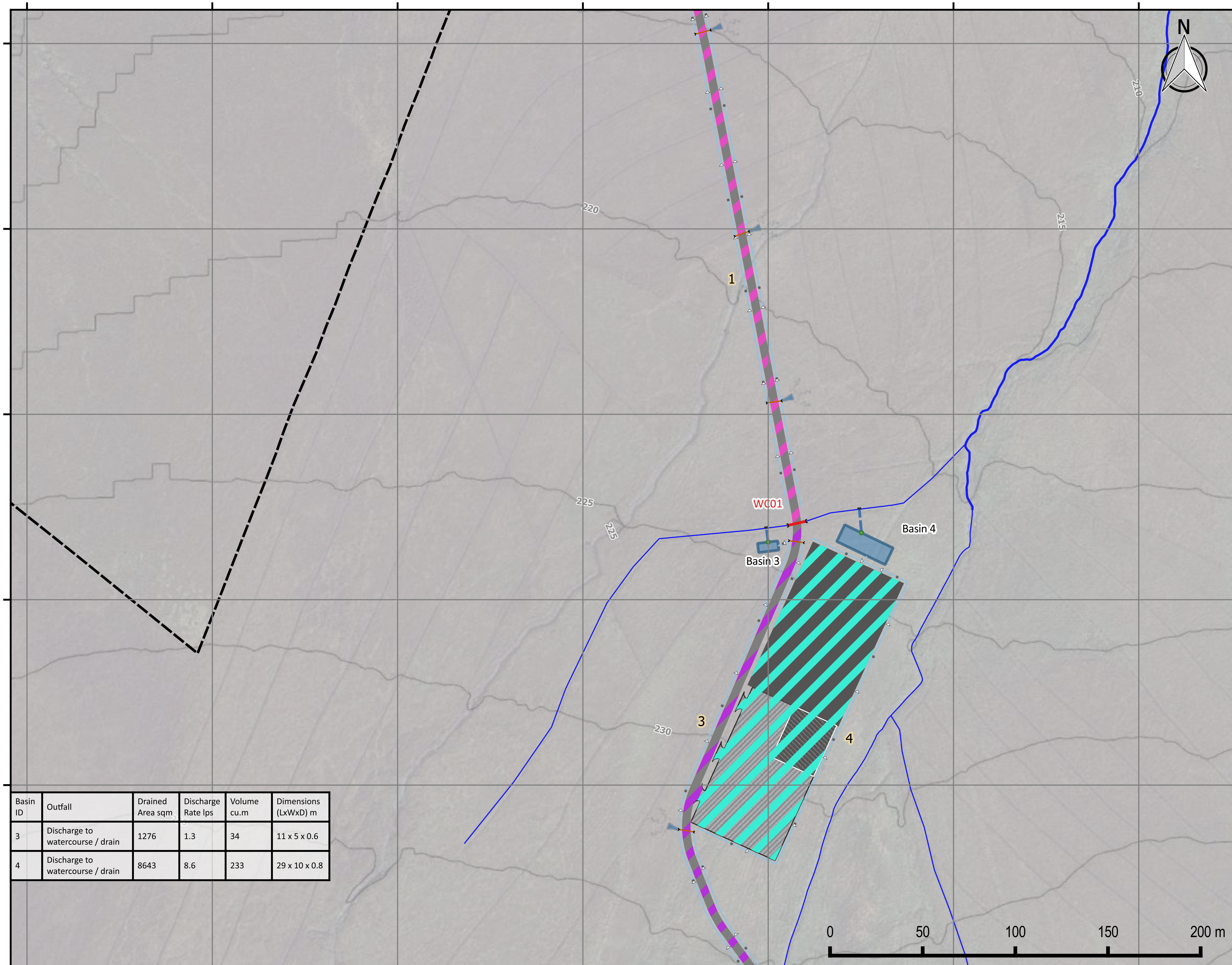
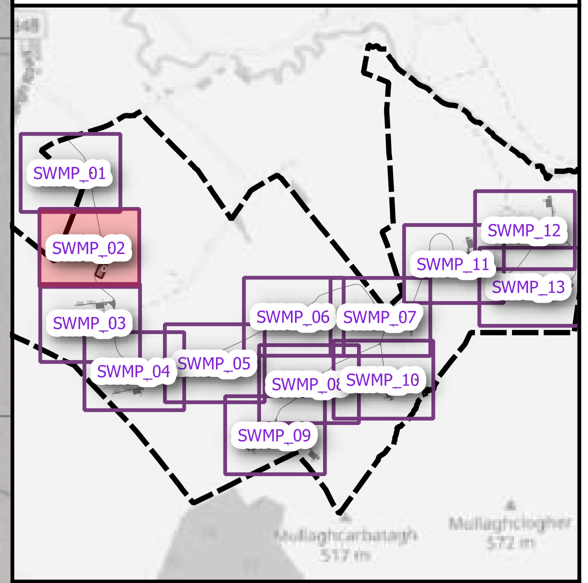


Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
3	Discharge to watercourse / drain	1276	1.3	34	11 x 5 x 0.6
4	Discharge to watercourse / drain	8643	8.6	233	29 x 10 x 0.8

KEY PLAN



LEGEND

The Development

Survey Boundary

Proposed Infrastructure

PERMENT CRANEPADS, SITE TRACKS

TEMPORARY WTG HARDSTANDING

TEMPORARY HARDSTANDING

SUBSTATION/CONTROL BUILDING

BESS

Hydrology Constraints

Significant Watercourse

Minor Watercourse

New Diversion

Abandoned

1% CC Flood Extent

New Drainage Features

Watercourse Crossing

Trackside Drain & Checkdam

Dirty Track Drainage Pipe

Outfall, Flow Control

Track Drainage Breakout

Attenuation Basin

Drainage Subcatchments

1 3 4

REF	WATERCOURSE CROSSING DESC.
WC01	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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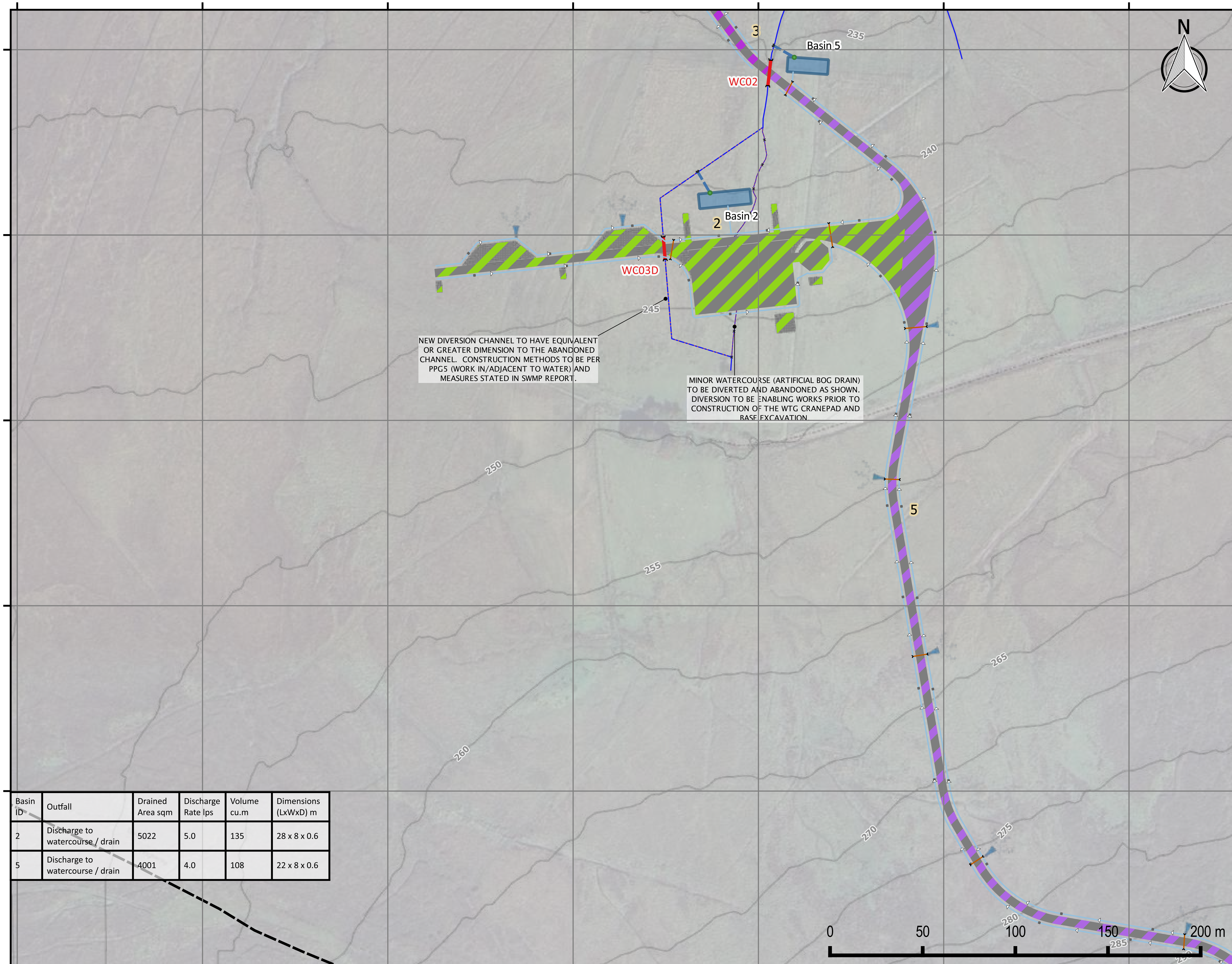
DESCRIPTION

MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 2

PROJECT / FIGURE NO.

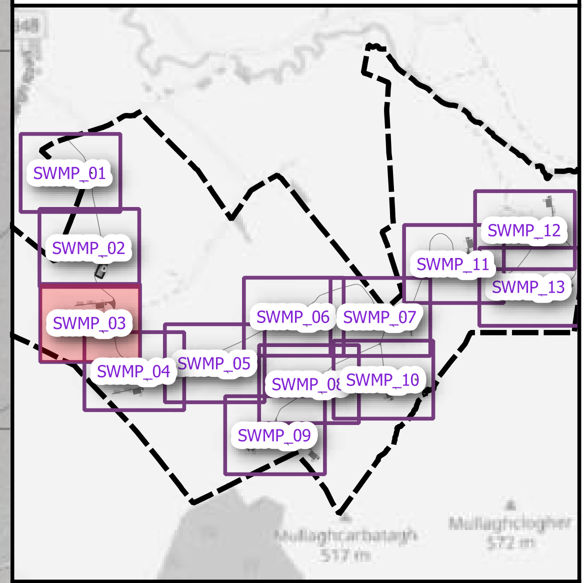
M01616-26_DC_02

DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024



Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
2	Discharge to watercourse / drain	5022	5.0	135	28 x 8 x 0.6
5	Discharge to watercourse / drain	4001	4.0	108	22 x 8 x 0.6

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments

2 3 5

REF	WATERCOURSE CROSSING DESC.
WC02	NEW MIN. 0.9 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC03D	NEW MIN. 0.9 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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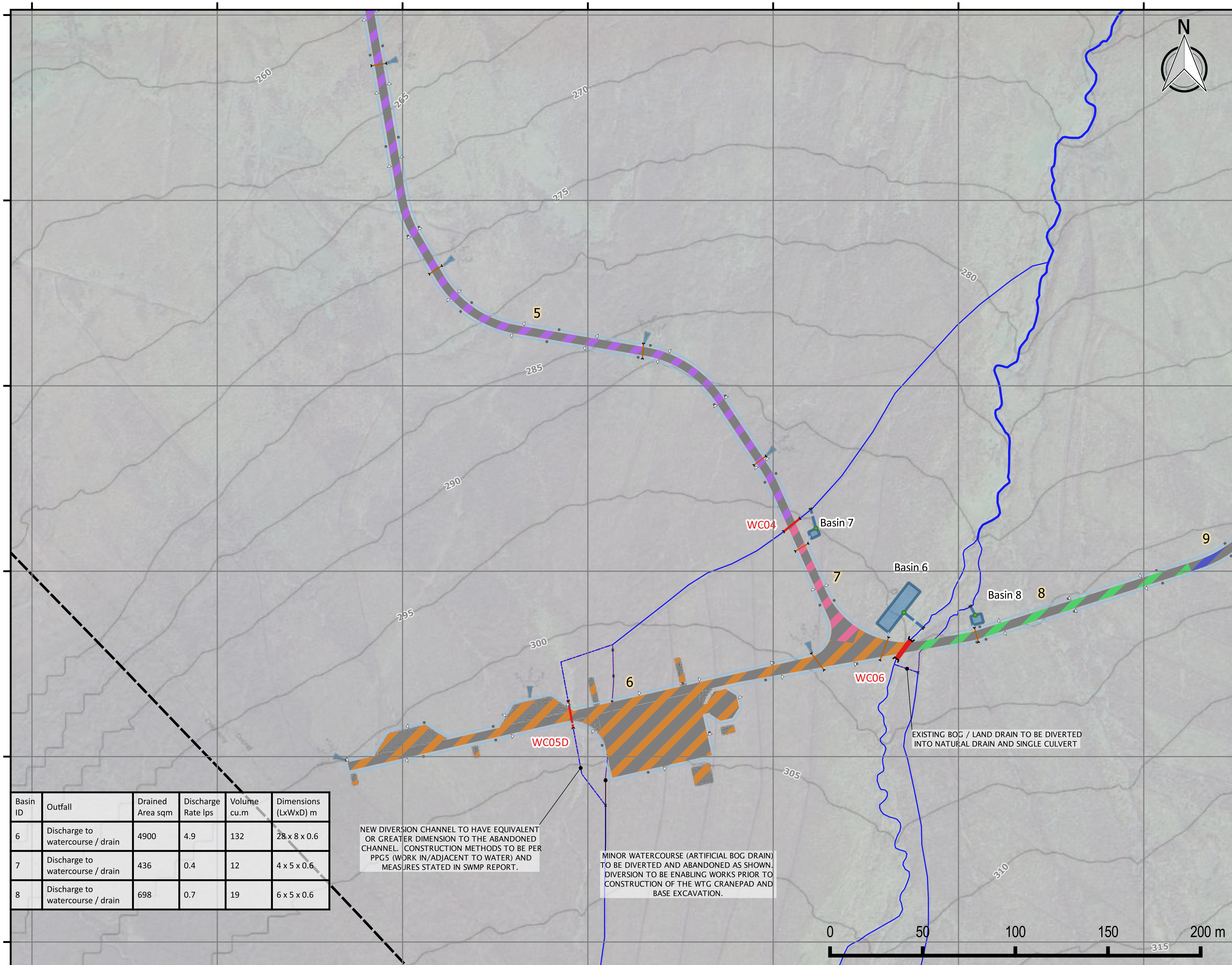
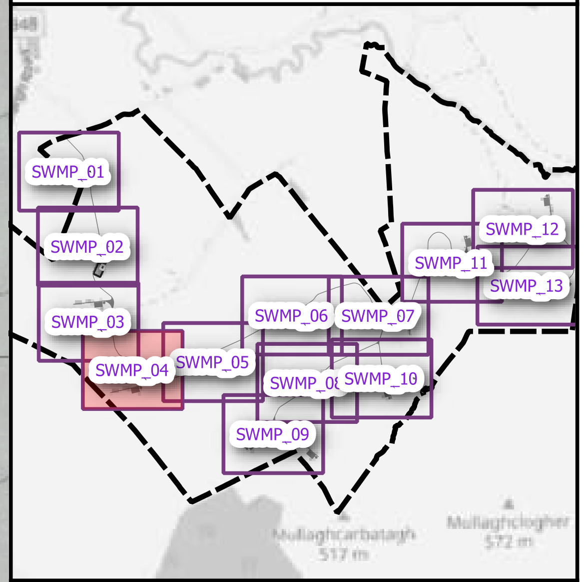
DESCRIPTION			
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 3			
PROJECT / FIGURE NO.			
M01616-26_DC_03			
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024



Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
6	Discharge to watercourse / drain	4900	4.9	132	28 x 8 x 0.6
7	Discharge to watercourse / drain	436	0.4	12	4 x 5 x 0.6
8	Discharge to watercourse / drain	698	0.7	19	6 x 5 x 0.6

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments

5 6 7 8 9

REF	WATERCOURSE CROSSING DESC.
WC04	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC05D	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC06	NEW MIN. 1.35 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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DESCRIPTION
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 4

PROJECT / FIGURE NO.
M01616-26_DC_04

DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

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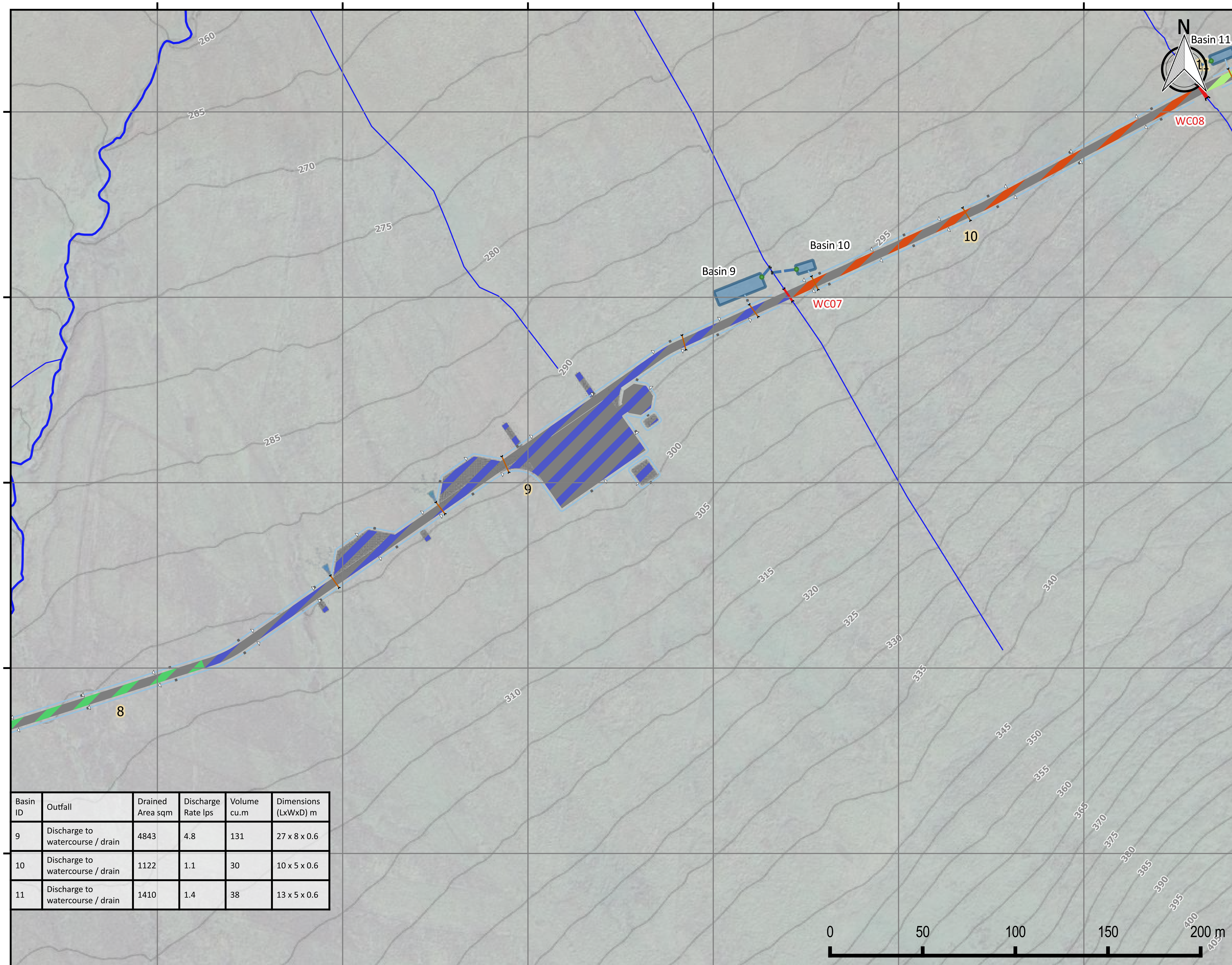
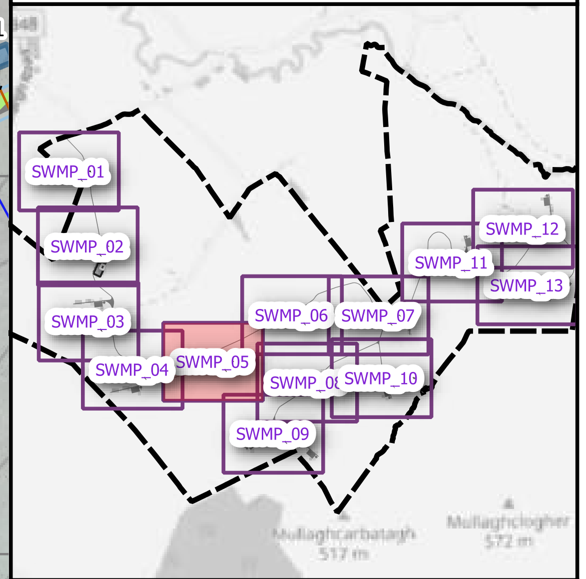


Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
9	Discharge to watercourse / drain	4843	4.8	131	27 x 8 x 0.6
10	Discharge to watercourse / drain	1122	1.1	30	10 x 5 x 0.6
11	Discharge to watercourse / drain	1410	1.4	38	13 x 5 x 0.6

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments

8 9 10 11

REF	WATERCOURSE CROSSING DESC.
WC07	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC08	NEW MIN. 1.05 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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DESCRIPTION			
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 5			
PROJECT / FIGURE NO.			
M01616-26_DC_05			
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

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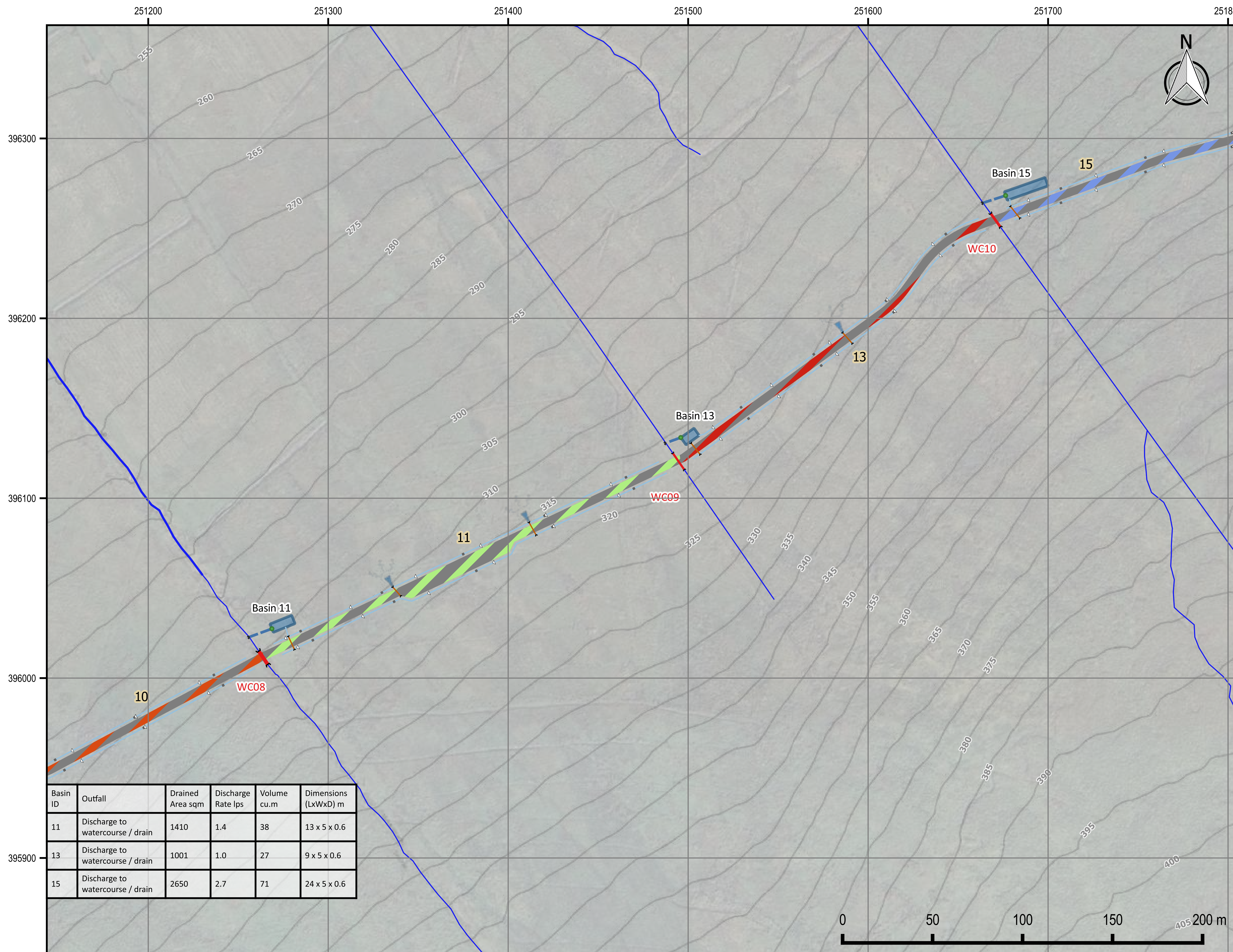
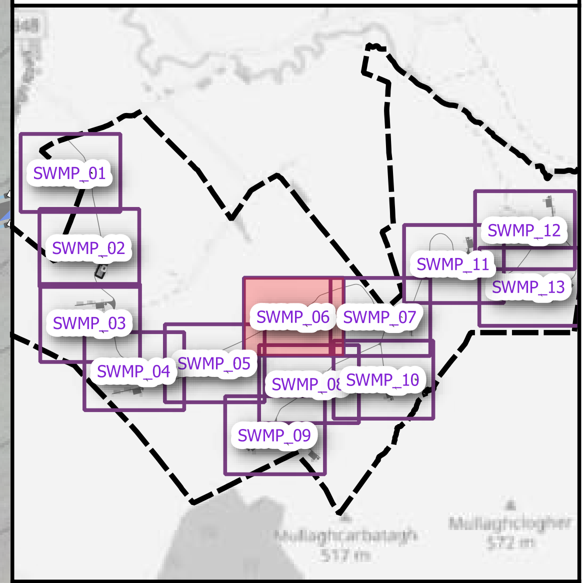


Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
11	Discharge to watercourse / drain	1410	1.4	38	13 x 5 x 0.6
13	Discharge to watercourse / drain	1001	1.0	27	9 x 5 x 0.6
15	Discharge to watercourse / drain	2650	2.7	71	24 x 5 x 0.6

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments

10 11 13 15

REF	WATERCOURSE CROSSING DESC.
WC08	NEW MIN. 1.05 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC09	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC10	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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DESCRIPTION			
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 6			
PROJECT / FIGURE NO.			
M01616-26_DC_06			
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

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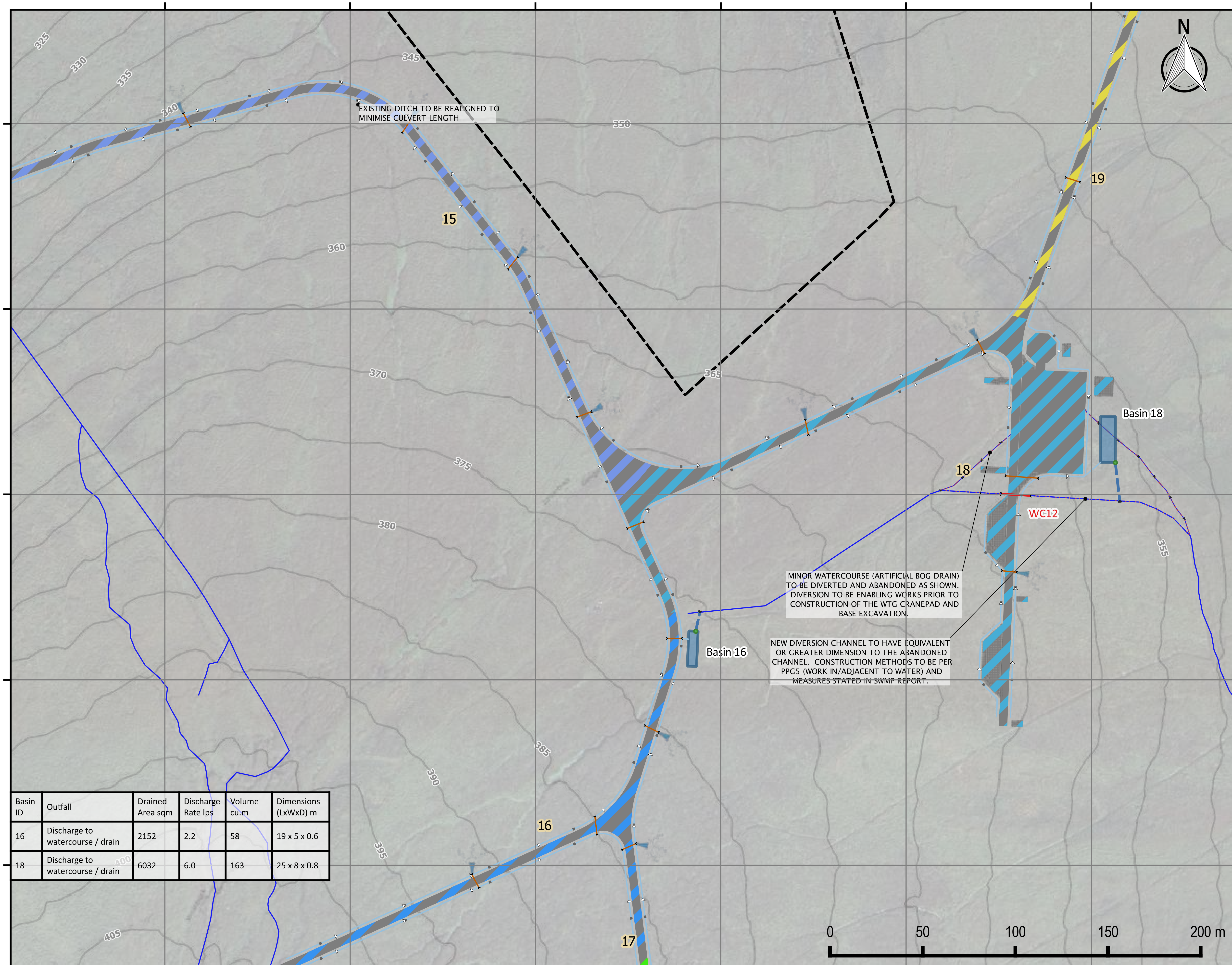
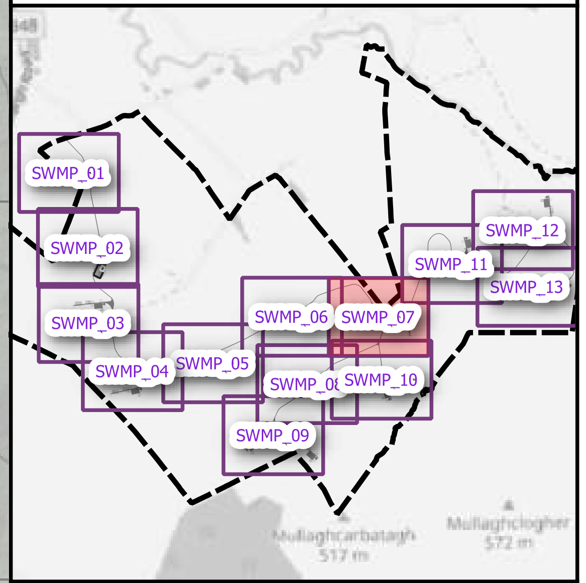


Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
16	Discharge to watercourse / drain	2152	2.2	58	19 x 5 x 0.6
18	Discharge to watercourse / drain	6032	6.0	163	25 x 8 x 0.8

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments

15 16 17 18 19

REF	WATERCOURSE CROSSING DESC.
WC12	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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DESCRIPTION			
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 7			
PROJECT / FIGURE NO.			
M01616-26_DC_07			
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

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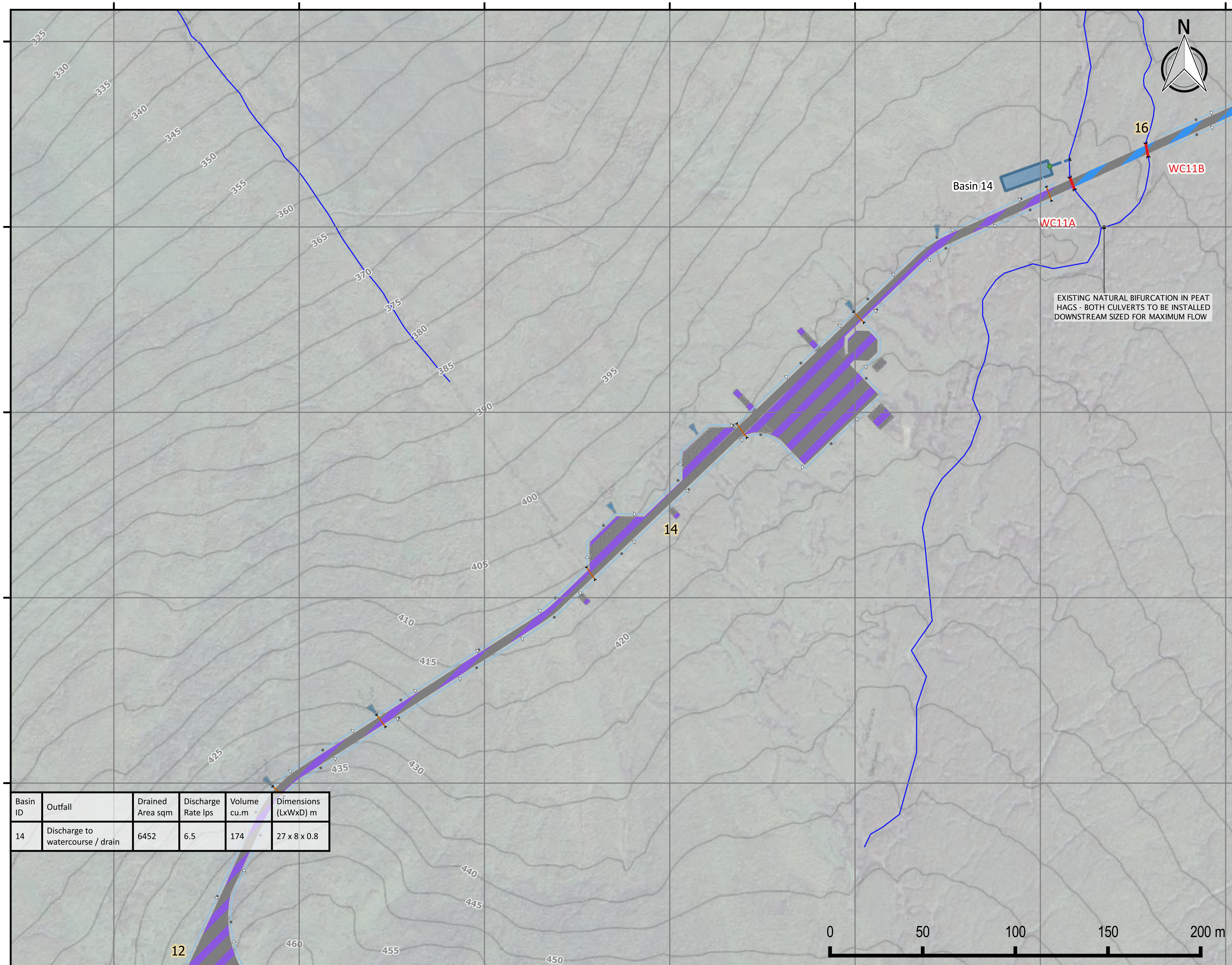
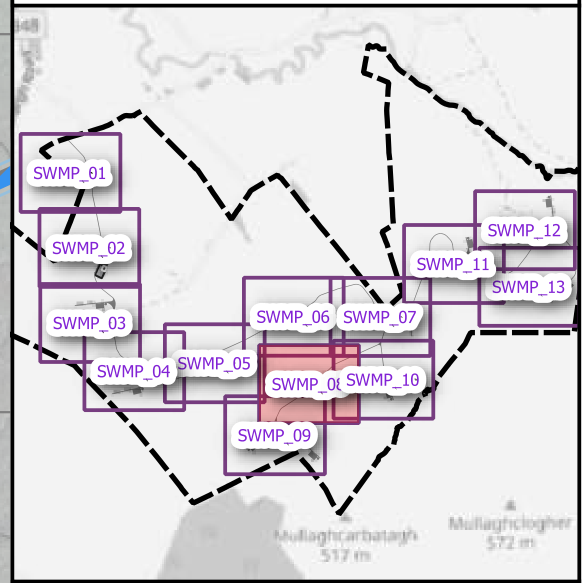


Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
14	Discharge to watercourse / drain	6452	6.5	174	27 x 8 x 0.8

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments

12 14 16

REF	WATERCOURSE CROSSING DESC.
WC11A	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC11B	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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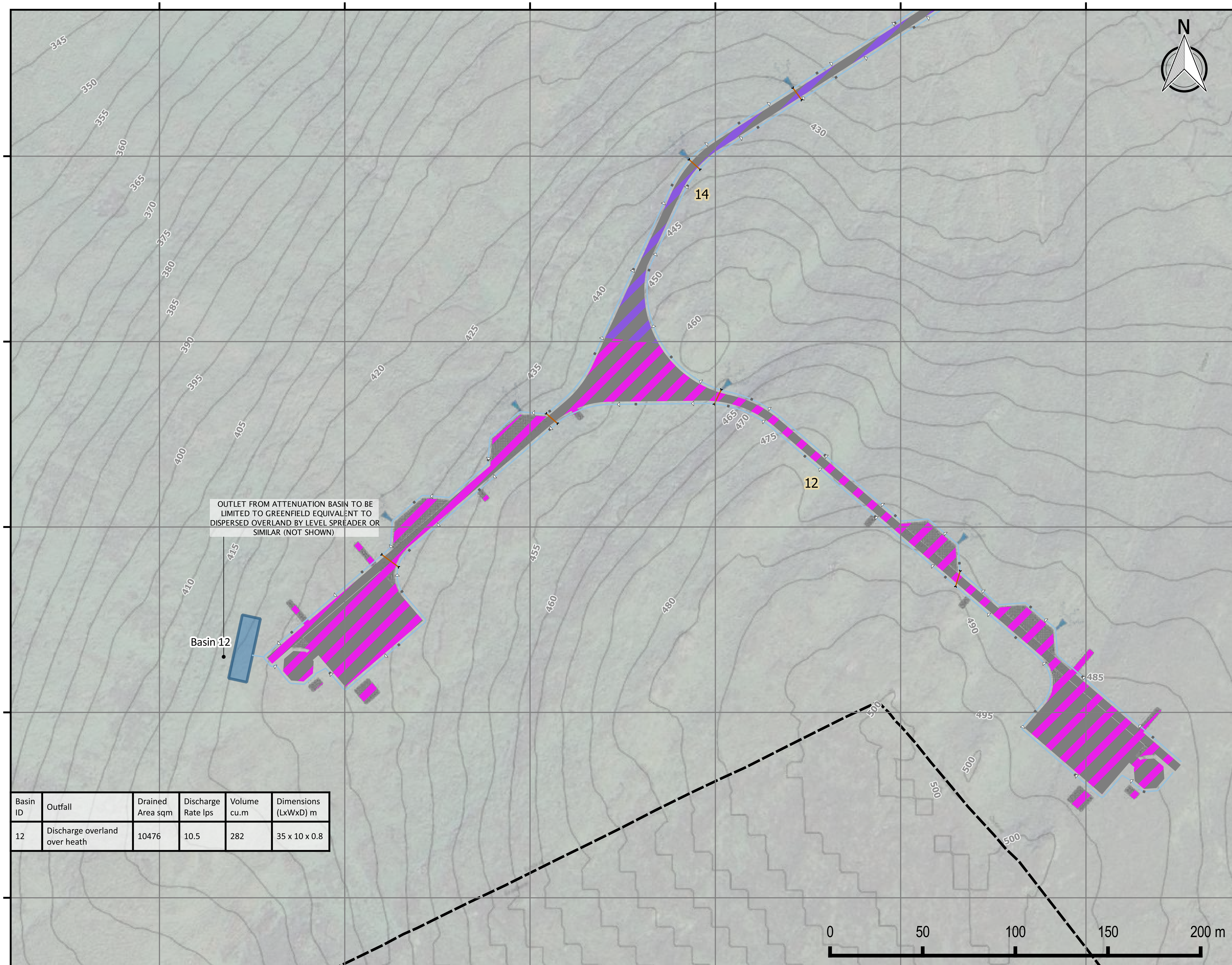
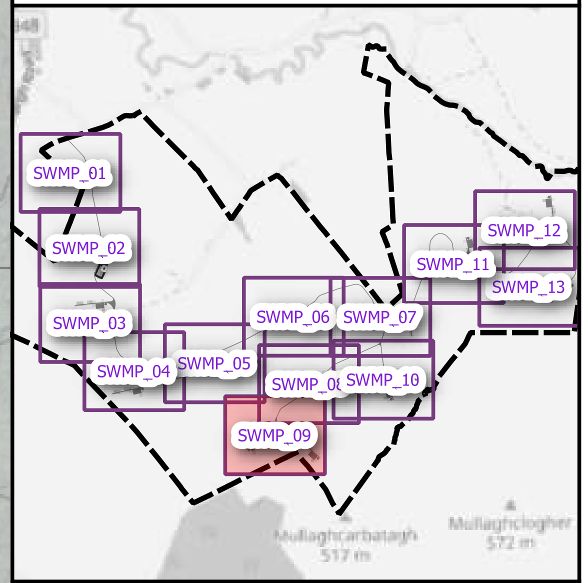
DESCRIPTION			
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 8			
PROJECT / FIGURE NO.			
M01616-26_DC_08			
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024



Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
12	Discharge overland over heath	10476	10.5	282	35 x 10 x 0.8

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse

- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments
- 12
- 14

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DESCRIPTION
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 9

PROJECT / FIGURE NO.
M01616-26_DC_09

DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

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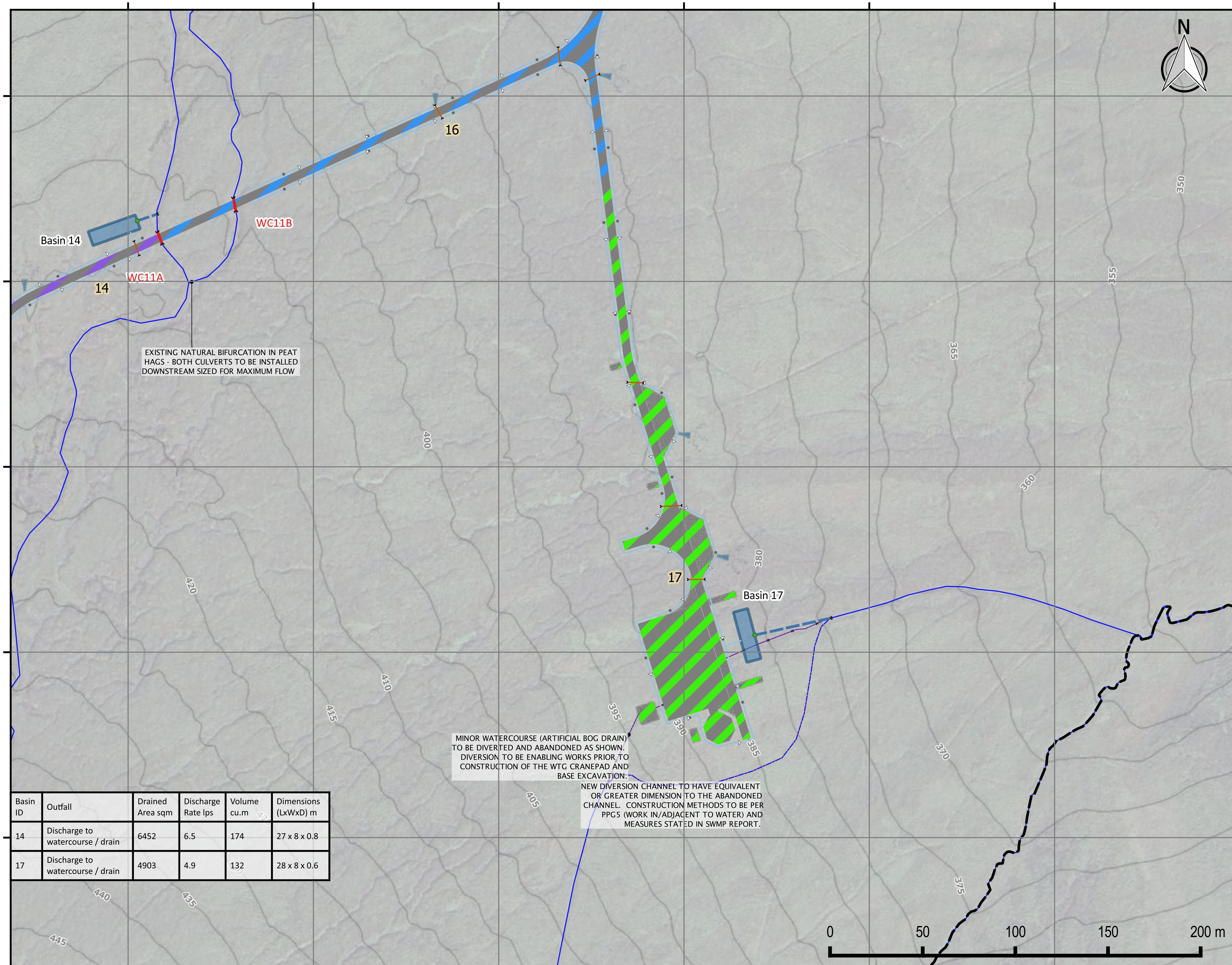
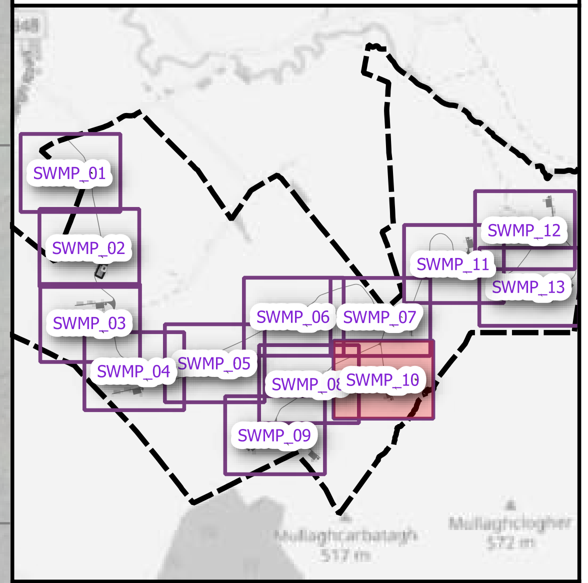


Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
14	Discharge to watercourse / drain	6452	6.5	174	27 x 8 x 0.8
17	Discharge to watercourse / drain	4903	4.9	132	28 x 8 x 0.6

KEY PLAN



LEGEND

The Development
Survey Boundary

Proposed Infrastructure
PERMENT CRANEPADS, SITE TRACKS
TEMPORARY WTG HARDSTANDING
TEMPORARY HARDSTANDING
SUBSTATION/CONTROL BUILDING
BESS

Hydrology Constraints
Significant Watercourse
Minor Watercourse

New Diversion
Abandoned
1% CC Flood Extent

New Drainage Features
Watercourse Crossing
Trackside Drain & Checkdam
Dirty Track Drainage Pipe
Outfall, Flow Control
Track Drainage Breakout
Attenuation Basin

Drainage Subcatchments
14 16 17

REF	WATERCOURSE CROSSING DESC.
WC11A	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).
WC11B	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT).

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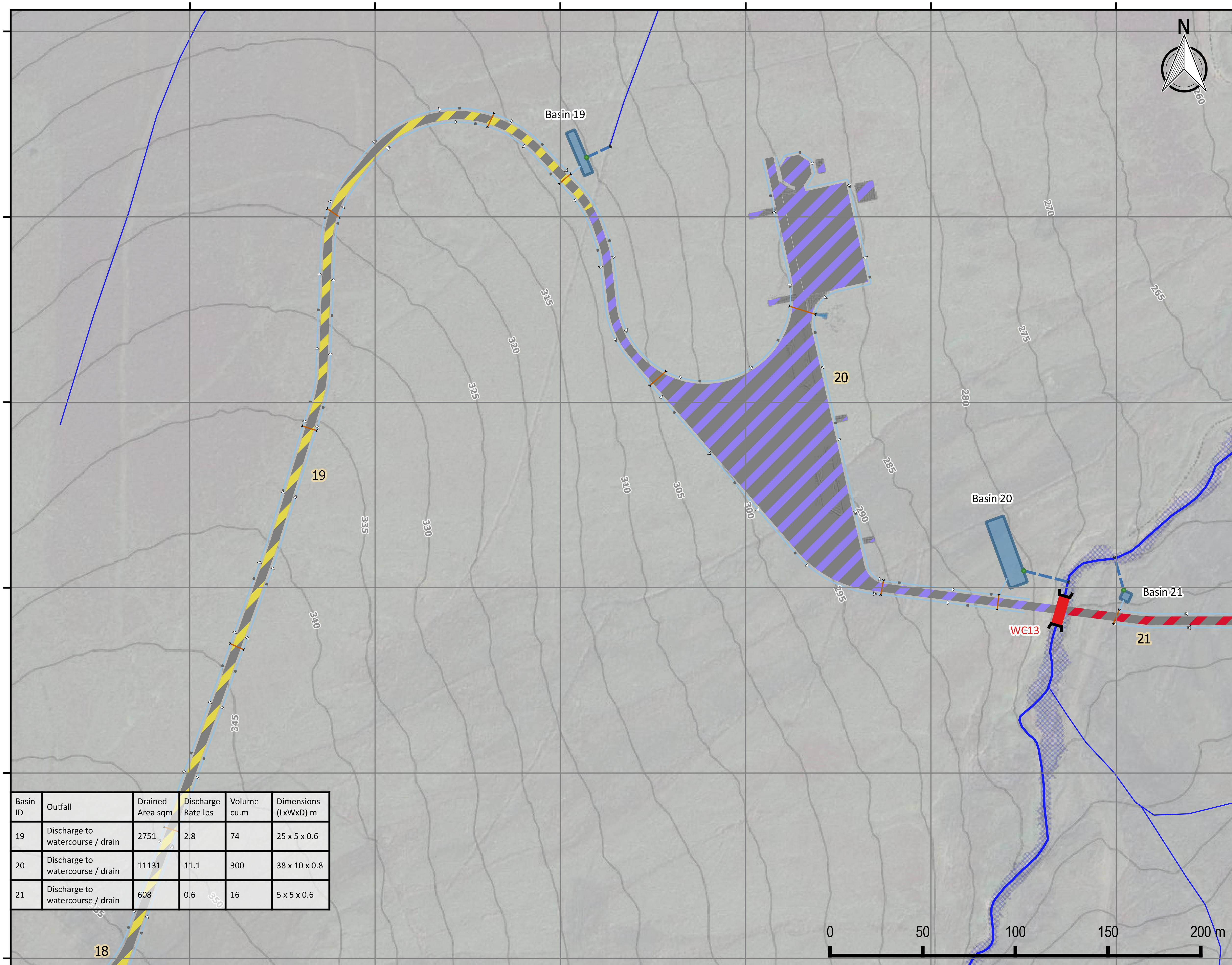
DESCRIPTION
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 10

PROJECT / FIGURE NO.
M01616-26_DC_10

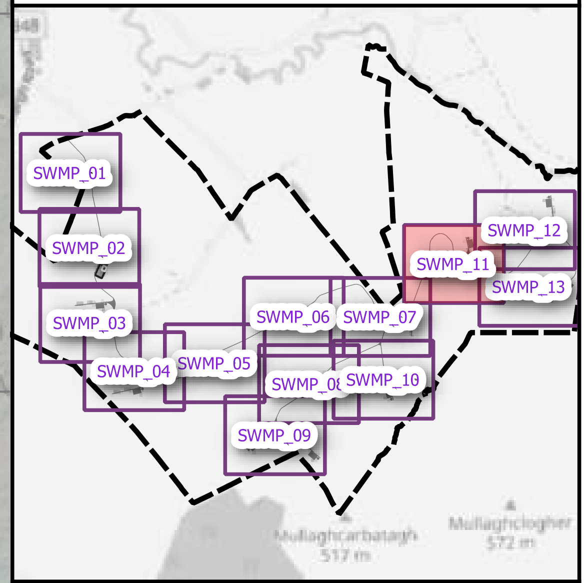
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

res



Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
19	Discharge to watercourse / drain	2751	2.8	74	25 x 5 x 0.6
20	Discharge to watercourse / drain	11131	11.1	300	38 x 10 x 0.8
21	Discharge to watercourse / drain	608	0.6	16	5 x 5 x 0.6

KEY PLAN



LEGEND

The Development

Survey Boundary

Proposed Infrastructure

PERMENT CRANEPADS, SITE TRACKS

TEMPORARY WTG HARDSTANDING

TEMPORARY HARDSTANDING

SUBSTATION/CONTROL BUILDING

BESS

Hydrology Constraints

Significant Watercourse

Minor Watercourse

New Diversion

Abandoned

1% CC Flood Extent

New Drainage Features

Watercourse Crossing

Trackside Drain & Checkdam

Dirty Track Drainage Pipe

Outfall, Flow Control

Track Drainage Breakout

Attenuation Basin

Drainage Subcatchments

18 19 20 21

REF	WATERCOURSE CROSSING DESC.
WC13	NEW MIN. 3m x 1.8m (SPAN X HEIGHT) CLEAR SPAN BOTTOMLESS CULVERT, SOFFIT MIN. 276.57 mOD. CLEAR SPAN TO AVOID DISRUPTION TO RIVER BED TO SUIT FISHERIES REQUIREMENTS.

PRELIMINARY

McCloy Consulting

Mossley Mill,
Lower Ground (West),
Carnmoney Road North,
Newtownabbey BT36 5QA
T: 028 9084 8694
E: info@mccloyconsulting.com
w: www.mccloyconsulting.com

DESCRIPTION			
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 11			
PROJECT / FIGURE NO.			
M01616-26_DC_11			
DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

res

Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
20	Discharge to watercourse / drain	11131	11.1	300	38 x 10 x 0.8
22	Discharge to watercourse / drain	1123	1.1	30	10 x 5 x 0.6
23	Discharge to watercourse / drain	4380	4.4	118	25 x 8 x 0.6
24	Discharge to watercourse / drain	7351	7.4	198	31 x 8 x 0.8

PRELIMINARY

McCloy Consulting
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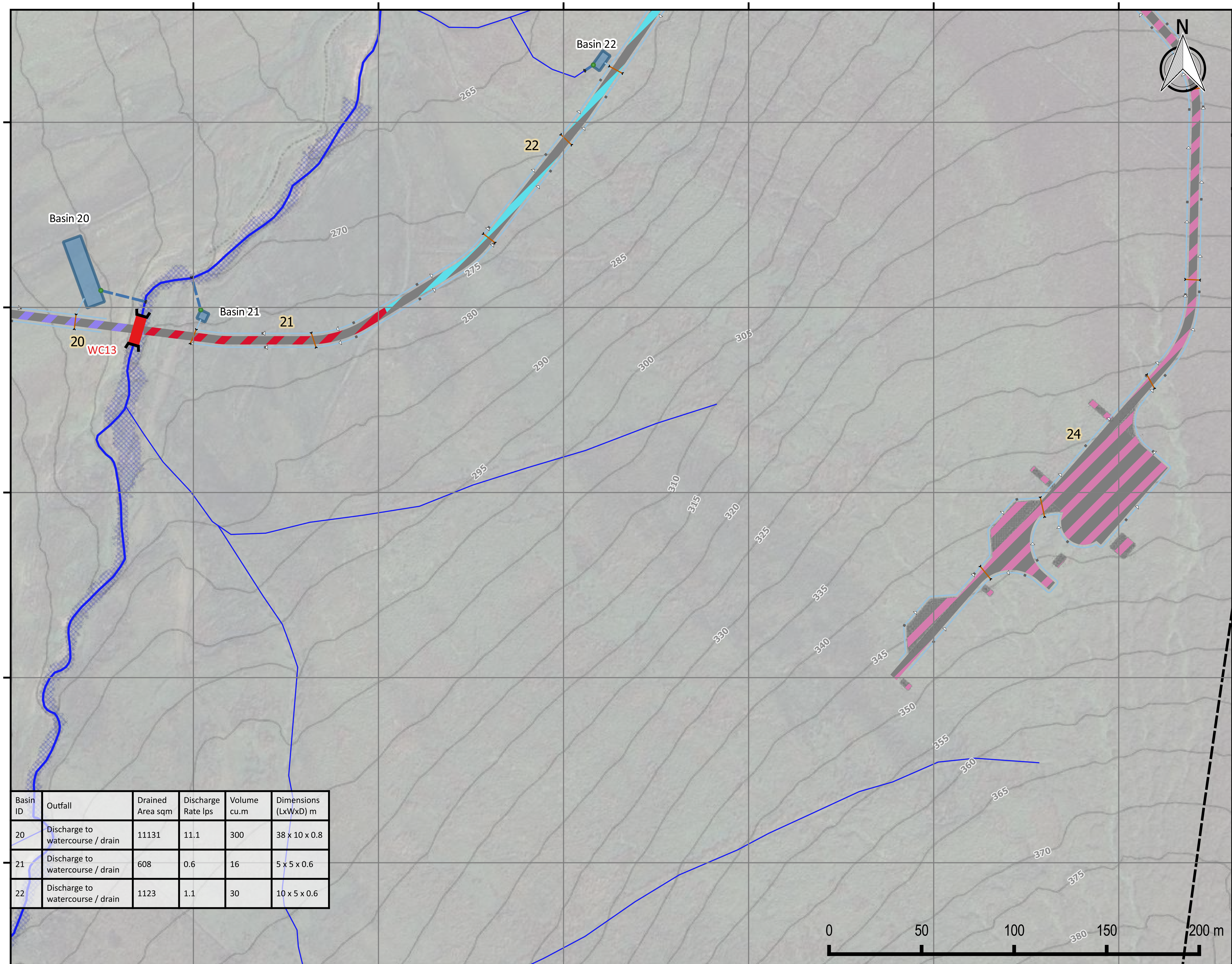
w: www.mccloyconsulting.com

DESCRIPTION
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 12

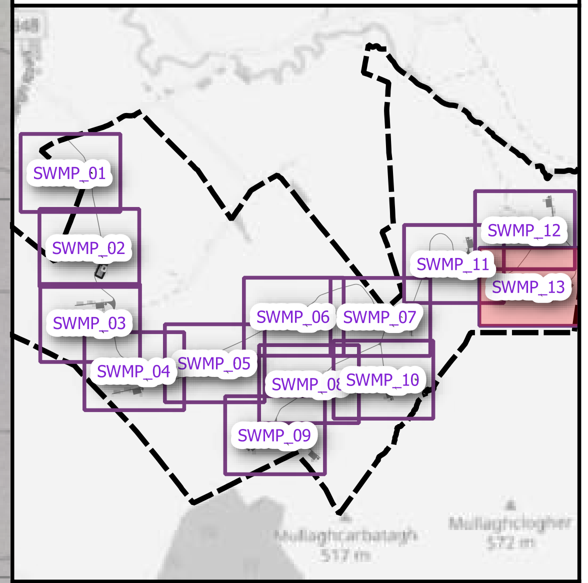
PROJECT / FIGURE NO.
M01616-26_DC_12

DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024



Basin ID	Outfall	Drained Area sqm	Discharge Rate lps	Volume cu.m	Dimensions (LxWxD) m
20	Discharge to watercourse / drain	11131	11.1	300	38 x 10 x 0.8
21	Discharge to watercourse / drain	608	0.6	16	5 x 5 x 0.6
22	Discharge to watercourse / drain	1123	1.1	30	10 x 5 x 0.6

KEY PLAN



LEGEND

The Development
- Survey Boundary

Proposed Infrastructure
- PERMENT CRANEPADS, SITE TRACKS
- TEMPORARY WTG HARDSTANDING
- TEMPORARY HARDSTANDING
- SUBSTATION/CONTROL BUILDING
- BESS

Hydrology Constraints
- Significant Watercourse
- Minor Watercourse
- New Diversion
- Abandoned
- 1% CC Flood Extent

New Drainage Features
- Watercourse Crossing
- Trackside Drain & Checkdam
- Dirty Track Drainage Pipe
- Outfall, Flow Control
- Track Drainage Breakout
- Attenuation Basin

Drainage Subcatchments
20 21 22 24

REF	WATERCOURSE CROSSING DESC.
WC13	NEW MIN. 3m x 1.8m (SPAN X HEIGHT) CLEAR SPAN BOTTOMLESS CULVERT, SOFFIT MIN. 276.57 mOD. CLEAR SPAN TO AVOID DISRUPTION TO RIVER BED TO SUIT FISHERIES REQUIREMENTS.

PRELIMINARY

McCloy Consulting
Mossley Mill,
Lower Ground (West),
Carnmoney Road North,
Newtownabbey BT36 5QA
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E: info@mccloyconsulting.com
w: www.mccloyconsulting.com

DESCRIPTION
MULLAGHCLOGHER WIND FARM - SCHEDULE 6 LAYOUT SHEET 13

PROJECT / FIGURE NO.
M01616-26_DC_13

DRAWN BY	SCALE	REVISION	DATE
DKS	1:2000	0	27/05/2024

res

Appendix C

Correspondence

DfI Rivers Omagh

Ian Muir
McCloy Consulting
Mossley Mill
Carnmoney Road North
Newtownabbey
Co. Antrim
BT36 5QA

Department for Infrastructure
An Roinn Bonneagair
Depairtment fur Infrastructure
www.infrastructure-ni.gov.uk

3A St Julian's Road
OMAGH
Co. Tyrone
BT79 7HQ

Rivers.omagh@infrastructure-ni.gov.uk

Telephone: 028 8225 4900

Your reference:M01616-26
Our reference:IN1-22-13133

06 September 2022

Dear Mr. Muir

PROPOSED DEVELOPMENT INFORMATION REQUEST FOR A WIND FARM NORTH OF PLUMBRIDGE.

Thank you for your correspondence dated 22 August 2022 regarding the proposed development information request for a wind farm North of Plumbridge.

The Department would like to inform you that your proposals affect several watercourses which are undesignated under the terms of the Drainage (Northern Ireland) Order 1973, with maintenance responsibilities resting with riparian landowners. You should note that the Department does not hold any information on undesignated watercourses.

The area identified within your correspondence also affects a watercourse which is designated within the meaning of the Drainage (Northern Ireland) Order 1973 and known to the Department as the Craig River, watercourse number MW1104.

Floodplain extents can be viewed on Flood Map (NI) by accessing the DfI Rivers web site at https://www.infrastructure-ni.gov.uk/topics/rivers-and-flooding/flood-maps-ni

Pertaining to the area highlighted within your correspondence; Strategic Flood Map for Northern Ireland suggests that a portion of this site falls within or adjacent the predicted 1 in 100 year floodplain. The Department also notes that parts of this site are adjacent to an area identified to have historic flooding and there may also be localised flooding the Department is unaware of.

Flood Map NI is the best information at the Department present disposal, however at this location it is indicative only and of insufficient accuracy to determine site specific flood risk; a more precise Flood Risk Assessment would be required to define the exact extents of the floodplain and flood levels.

Please note, the Department makes every effort to maintain and improve the quality of data through the use of quality control procedures; however no responsibility is accepted for any loss or damage, costs or claims arising directly or indirectly from data use.

A Schedule 6 application is required for any watercourse works e.g. Discharge storm water to a watercourse/ Construct a bridge across or culvert a watercourse/ Divert a watercourse/ Other works adjacent to or affecting a watercourse. Your application should take into consideration the following; discharge rate, discharge location, backwater effect during flood conditions and details of any outfall structure to the receiving watercourse.

Schedule 6 applications are available at: https://www.infrastructure-ni.gov.uk/publications/schedule-6-application-consent-undertake-works-watercourse

In addition to the above, it is noteworthy that the Department interest is from a drainage and flood risk aspect only, therefore it is the responsibility of the developer/applicant to acquire authorisation/consent from other parties/statutory bodies who may have any interest in your proposals.

The applicant should also fully satisfy themselves that any permanent works will not increase flood risk within the catchment.

Your application should include detailed drawings/calculations and be forwarded to this office for consideration, taking into account the foregoing comments, prior to commencement of any works.

I trust you find the foregoing to be helpful, however if you require any further information or clarification please contact the Department at rivers.omagh@infrastructure-ni.gov.uk quoting the reference number above.

Yours faithfully.

S BUCHANAN
Assistant Engineer

Appendix D

Flood Model Summary

MODEL PARAMETERS

Introduction

As no existing modelled data was available for the undesignated watercourse at the site, a coarse hydraulic model suitable to the scale and nature of the proposed development and associated risk, was developed for the site. An Infoworks ICM linked 1D-2D model has been developed for the site, allowing more accurate determination of flood levels and extents at the site.

HYDROLOGICAL ASSESSMENT

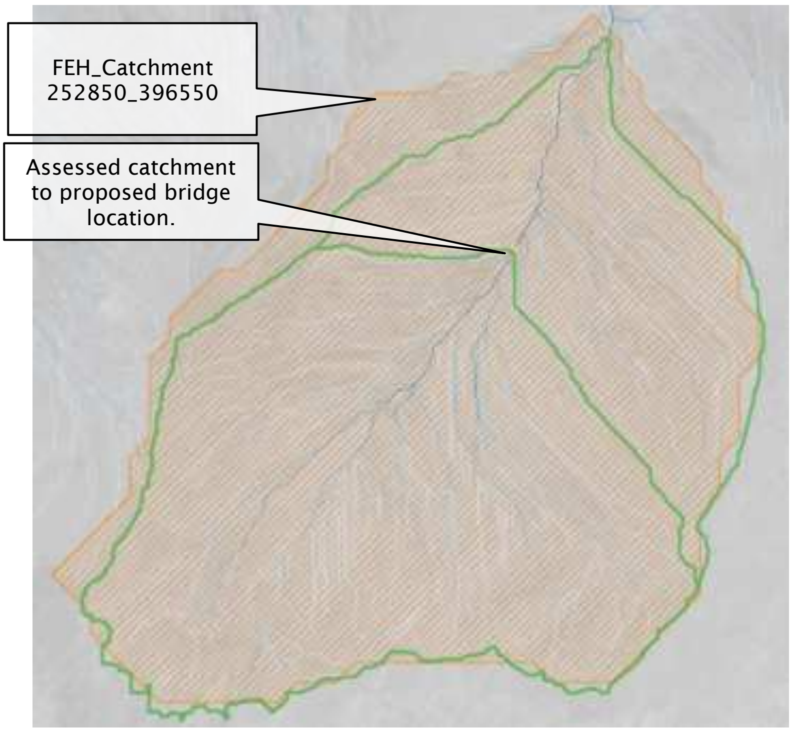
The estimation of peak flow for the required design annual probability has been necessary to determine the peak inflow and hydrograph for input to an unsteady state hydraulic model.

The derivation of the 1% AEP peak flow and hydrograph for the undesignated watercourse was assessed using the FEH Revitalised Flood Hydrograph (ReFH) Method. The method is deemed appropriate where best practice guidance directs practitioners to FEH-based methods in all instances, and where catchments investigated are small and there is little useful local or comparable data to inform a Statistical analysis.

Site-specific flow-accumulation raster analysis based on site survey and the OSNI Northern Ireland 10m DTM was used to determine a conservative estimate of the catchments draining to the areas of interest, and the ReFH2 flow for the FEH catchment scaled pro-rata by areal extent.

As per DfI guidance[3], an effect of climate change has been derived by applying an uplift of +20% to the estimated flow.

Hydrological Catchment



Hydrology Summary

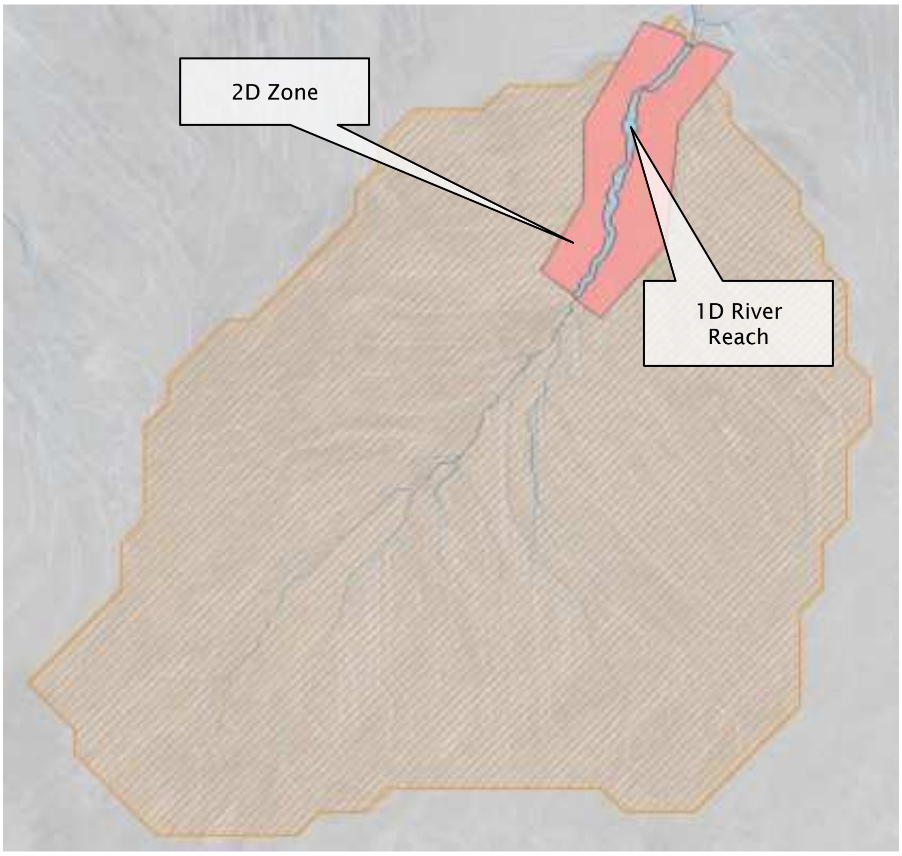
[3] DfI. (2019). Technical Flood Risk Guidance in relation to Allowances for Climate Change in Northern Ireland. Available from: https://www.infrastructure-ni.gov.uk/sites/default/files/publications/infrastructure/technical-flood-risk-guidance-in-allowances-for-climate-change-6feb19.PDF. [Accessed: 15/04/2022].

Analysis Method	1% AEP Design Flow (m3/sec)
FEH ReFH2 Method	4.068

Detailed calculations for the determination of the flows are contained within Appendix E.

MODEL GEOMETRY

Model Extents



2-Dimensional Surface Model Areas

Topography

Model topography was based on a detailed site-specific LiDAR survey. The survey was cleaned to a "bare earth" digital terrain model (DTM) and exported for use at a 0.5m grid resolution.

The use of LiDAR survey data is likely to underrepresent channel capacity and overestimate flooding due to it underestimating below-water ground levels and levels under vegetation, and as such is precautionary and suitable for planning purposes.

2D Zone

The terrain model was loaded into InfoWorks ICM as a ground model, and subsequently converted into 2D mesh elements (the surface used to simulate flows across the topography within the model). The 2D zone has a maximum triangle area of 10m^2, minimum area of 2m^2.

Boundary Conditions

The boundary condition for 1D and 2D elements is set as the normal depth of flow for the element gradient at that location. The downstream boundary is sited at an elevation >10m lower than the area of interest in order to ensure that variance in the boundary condition could have no backwater effect that would affect prediction of water levels at the bridge location.

Surface Roughness

A Manning's n Roughness value of 0.07 has been conservatively applied to the whole 2D zone to represent the area over which water would flow which comprises a combination of rough grass.

Surface Infiltration

It is noted that no infiltration has been included in the model in keeping with the approach used in similar DfI Rivers SFRA detailed models. The absence of infiltration in the model is likely to present conservative results.

1-Dimensional Model Elements

Cross sections

The river reach is derived from discrete cross sections sampled from the DTM formed from height data described previously.

Channel Roughness

An in-channel roughness Manning's n of 0.06 is adopted as representative of the observed channel conditions.

Structures

No structures are represented in the present-day scenario.

Proposed Scenario

The proposed scenario is represented by inclusion of an embankment at the crossing location imposed on the 2D zone as a mesh level zone. Conservative crest heights in excess of actual heights likely required have been adopted to provide conservative upstream peak flood levels.

The main river culvert is included as a conduit on the river reach with roughness 0.06 (representative of stream substrate) and upper roughness of 0.016 (representative of precast concrete). Inlet losses are represented by the FHWA methodology per industry norms.

Assumptions and Limitations of Modelling

The representation of any complex system by a model requires a number of assumptions to be made. In the case of the hydraulic model developed for the purposes of the study it is assumed that:

- The terrain model sufficiently accurately represents the surface topography and associated flow paths.
- The design flows are an accurate representation of flows of a given return period.
- Roughness does not vary with time.

The primary limitations of the study are noted as follows:

- No allowance for infiltration has been made within the model.
- The model does not represent any topographic features smaller than the minimum resolution of the underlying terrain model derived for the site.

MODEL SENSITIVITY

Model roughness is intentionally precautionary and at the higher end of permissible Manning's N roughness values for the conditions observed. Sensitivity testing for further increases in roughness would be an unreasonable requirement.

Flows are conservative and include uplifts for climate change for the default scenario and are taken for a flow extraction point downstream of the area of interest and so are likely to represent a sufficiently precautionary estimate without need for further stress testing.

The model boundary condition is sited >10m downgradient of the site and so further stress testing of boundary condition on the area of interest can be discounted.

The model can therefore be deemed reliable / conservative and is and fit for its intended purpose of a precautionary evaluation of flood risk and culvert opening sizes at the site.

Appendix E

Hydrology Calculation Summaries

UK Design Flood Estimation

Generated on 19 September 2023 15:51:07 by terminal
Printed from the ReFH2 Flood Modelling software package, version 4.0.8560.23190

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details Checksum: 93EF-CADA

Site name: FEH_Catchment_Descriptors_252850_396550_v5_0_1

Easting: 252850

Northing: 396550

Country: England, Wales or Northern Ireland

Catchment Area (km²): 2.05

Using plot scale calculations: No

Model: 2.3

Site description: None

Model run: 100 year

Summary of results

Rainfall - FEH22 (mm):	50.28	Total runoff (ML):	60.96
Total Rainfall (mm):	38.89	Total flow (ML):	79.51
Peak Rainfall (mm):	4.07	Peak flow (m³/s):	8.19

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH22)

Name	Value	User-defined?
Duration (hh:mm:ss)	02:30:00	No
Timestep (hh:mm:ss)	00:06:00	No
SCF (Seasonal correction factor)	0.8	No
ARF (Areal reduction factor)	0.96	No
Seasonality	Winter	No

Loss model parameters

Name	Value	User-defined?
Cini (mm)	128.62	No
Cmax (mm)	193.15	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m^3/s)	0.18	No
BL (hr)	17.86	No
BR	0.3	No

Urbanisation parameters

Name	Value	User-defined?
Sewer capacity (m^3/s)	0	No
Exporting drained area (km^2)	0	No
Urban area (km^2)	0	No
Urbext 2000	0	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No

Time series data

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (m^3/s)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
00:00:00	0.322	0.000	0.215	0.000	0.178	0.178
00:06:00	0.405	0.000	0.270	0.004	0.177	0.181
00:12:00	0.508	0.000	0.341	0.017	0.176	0.193
00:18:00	0.637	0.000	0.429	0.041	0.175	0.217
00:24:00	0.798	0.000	0.541	0.080	0.175	0.254
00:30:00	0.999	0.000	0.681	0.136	0.174	0.310
00:36:00	1.248	0.000	0.859	0.215	0.173	0.388
00:42:00	1.557	0.000	1.083	0.322	0.173	0.495
00:48:00	1.939	0.000	1.366	0.465	0.172	0.638
00:54:00	2.405	0.000	1.722	0.654	0.172	0.826
01:00:00	2.969	0.000	2.166	0.899	0.173	1.072
01:06:00	3.623	0.000	2.705	1.210	0.173	1.383
01:12:00	4.068	0.000	3.118	1.597	0.175	1.771
01:18:00	3.623	0.000	2.850	2.073	0.177	2.250
01:24:00	2.969	0.000	2.386	2.637	0.180	2.817
01:30:00	2.405	0.000	1.966	3.269	0.184	3.453
01:36:00	1.939	0.000	1.607	3.946	0.189	4.135
01:42:00	1.557	0.000	1.305	4.643	0.195	4.839
01:48:00	1.248	0.000	1.055	5.338	0.203	5.541
01:54:00	0.999	0.000	0.850	6.004	0.211	6.215
02:00:00	0.798	0.000	0.683	6.615	0.221	6.836
02:06:00	0.637	0.000	0.547	7.142	0.231	7.374
02:12:00	0.508	0.000	0.438	7.553	0.243	7.795
02:18:00	0.405	0.000	0.350	7.814	0.254	8.068
02:24:00	0.322	0.000	0.279	7.920	0.266	8.186
02:30:00	0.000	0.000	0.000	7.890	0.278	8.169
02:36:00	0.000	0.000	0.000	7.746	0.290	8.036
02:42:00	0.000	0.000	0.000	7.506	0.301	7.807
02:48:00	0.000	0.000	0.000	7.192	0.312	7.504
02:54:00	0.000	0.000	0.000	6.825	0.322	7.147
03:00:00	0.000	0.000	0.000	6.420	0.332	6.751
03:06:00	0.000	0.000	0.000	5.993	0.340	6.333
03:12:00	0.000	0.000	0.000	5.560	0.348	5.908
03:18:00	0.000	0.000	0.000	5.133	0.355	5.488
03:24:00	0.000	0.000	0.000	4.718	0.362	5.080

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (m^3/s)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
03:30:00	0.000	0.000	0.000	4.317	0.368	4.685
03:36:00	0.000	0.000	0.000	3.934	0.372	4.306
03:42:00	0.000	0.000	0.000	3.573	0.377	3.950
03:48:00	0.000	0.000	0.000	3.232	0.380	3.613
03:54:00	0.000	0.000	0.000	2.908	0.384	3.292
04:00:00	0.000	0.000	0.000	2.600	0.386	2.986
04:06:00	0.000	0.000	0.000	2.305	0.388	2.693
04:12:00	0.000	0.000	0.000	2.024	0.390	2.413
04:18:00	0.000	0.000	0.000	1.756	0.391	2.146
04:24:00	0.000	0.000	0.000	1.502	0.391	1.893
04:30:00	0.000	0.000	0.000	1.263	0.391	1.655
04:36:00	0.000	0.000	0.000	1.042	0.391	1.433
04:42:00	0.000	0.000	0.000	0.839	0.391	1.230
04:48:00	0.000	0.000	0.000	0.660	0.390	1.049
04:54:00	0.000	0.000	0.000	0.509	0.388	0.897
05:00:00	0.000	0.000	0.000	0.386	0.387	0.773
05:06:00	0.000	0.000	0.000	0.288	0.385	0.674
05:12:00	0.000	0.000	0.000	0.211	0.384	0.595
05:18:00	0.000	0.000	0.000	0.151	0.382	0.533
05:24:00	0.000	0.000	0.000	0.105	0.380	0.485
05:30:00	0.000	0.000	0.000	0.070	0.378	0.448
05:36:00	0.000	0.000	0.000	0.045	0.376	0.421
05:42:00	0.000	0.000	0.000	0.026	0.374	0.400
05:48:00	0.000	0.000	0.000	0.013	0.372	0.385
05:54:00	0.000	0.000	0.000	0.005	0.370	0.375
06:00:00	0.000	0.000	0.000	0.001	0.368	0.369
06:06:00	0.000	0.000	0.000	0.000	0.366	0.366
06:12:00	0.000	0.000	0.000	0.000	0.364	0.364
06:18:00	0.000	0.000	0.000	0.000	0.362	0.362
06:24:00	0.000	0.000	0.000	0.000	0.360	0.360
06:30:00	0.000	0.000	0.000	0.000	0.358	0.358
06:36:00	0.000	0.000	0.000	0.000	0.356	0.356
06:42:00	0.000	0.000	0.000	0.000	0.354	0.354
06:48:00	0.000	0.000	0.000	0.000	0.352	0.352
06:54:00	0.000	0.000	0.000	0.000	0.350	0.350
07:00:00	0.000	0.000	0.000	0.000	0.348	0.348

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (m^3/s)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
07:06:00	0.000	0.000	0.000	0.000	0.346	0.346
07:12:00	0.000	0.000	0.000	0.000	0.344	0.344
07:18:00	0.000	0.000	0.000	0.000	0.342	0.342
07:24:00	0.000	0.000	0.000	0.000	0.340	0.340
07:30:00	0.000	0.000	0.000	0.000	0.338	0.338
07:36:00	0.000	0.000	0.000	0.000	0.336	0.336
07:42:00	0.000	0.000	0.000	0.000	0.334	0.334
07:48:00	0.000	0.000	0.000	0.000	0.333	0.333
07:54:00	0.000	0.000	0.000	0.000	0.331	0.331
08:00:00	0.000	0.000	0.000	0.000	0.329	0.329
08:06:00	0.000	0.000	0.000	0.000	0.327	0.327
08:12:00	0.000	0.000	0.000	0.000	0.325	0.325
08:18:00	0.000	0.000	0.000	0.000	0.323	0.323
08:24:00	0.000	0.000	0.000	0.000	0.322	0.322
08:30:00	0.000	0.000	0.000	0.000	0.320	0.320
08:36:00	0.000	0.000	0.000	0.000	0.318	0.318
08:42:00	0.000	0.000	0.000	0.000	0.316	0.316
08:48:00	0.000	0.000	0.000	0.000	0.314	0.314
08:54:00	0.000	0.000	0.000	0.000	0.313	0.313
09:00:00	0.000	0.000	0.000	0.000	0.311	0.311
09:06:00	0.000	0.000	0.000	0.000	0.309	0.309
09:12:00	0.000	0.000	0.000	0.000	0.307	0.307
09:18:00	0.000	0.000	0.000	0.000	0.306	0.306
09:24:00	0.000	0.000	0.000	0.000	0.304	0.304
09:30:00	0.000	0.000	0.000	0.000	0.302	0.302
09:36:00	0.000	0.000	0.000	0.000	0.301	0.301
09:42:00	0.000	0.000	0.000	0.000	0.299	0.299
09:48:00	0.000	0.000	0.000	0.000	0.297	0.297
09:54:00	0.000	0.000	0.000	0.000	0.296	0.296
10:00:00	0.000	0.000	0.000	0.000	0.294	0.294
10:06:00	0.000	0.000	0.000	0.000	0.292	0.292
10:12:00	0.000	0.000	0.000	0.000	0.291	0.291
10:18:00	0.000	0.000	0.000	0.000	0.289	0.289
10:24:00	0.000	0.000	0.000	0.000	0.287	0.287
10:30:00	0.000	0.000	0.000	0.000	0.286	0.286
10:36:00	0.000	0.000	0.000	0.000	0.284	0.284

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (m^3/s)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
10:42:00	0.000	0.000	0.000	0.000	0.283	0.283
10:48:00	0.000	0.000	0.000	0.000	0.281	0.281
10:54:00	0.000	0.000	0.000	0.000	0.280	0.280
11:00:00	0.000	0.000	0.000	0.000	0.278	0.278
11:06:00	0.000	0.000	0.000	0.000	0.276	0.276
11:12:00	0.000	0.000	0.000	0.000	0.275	0.275
11:18:00	0.000	0.000	0.000	0.000	0.273	0.273
11:24:00	0.000	0.000	0.000	0.000	0.272	0.272
11:30:00	0.000	0.000	0.000	0.000	0.270	0.270
11:36:00	0.000	0.000	0.000	0.000	0.269	0.269
11:42:00	0.000	0.000	0.000	0.000	0.267	0.267
11:48:00	0.000	0.000	0.000	0.000	0.266	0.266
11:54:00	0.000	0.000	0.000	0.000	0.264	0.264
12:00:00	0.000	0.000	0.000	0.000	0.263	0.263
12:06:00	0.000	0.000	0.000	0.000	0.261	0.261
12:12:00	0.000	0.000	0.000	0.000	0.260	0.260
12:18:00	0.000	0.000	0.000	0.000	0.258	0.258
12:24:00	0.000	0.000	0.000	0.000	0.257	0.257
12:30:00	0.000	0.000	0.000	0.000	0.256	0.256
12:36:00	0.000	0.000	0.000	0.000	0.254	0.254
12:42:00	0.000	0.000	0.000	0.000	0.253	0.253
12:48:00	0.000	0.000	0.000	0.000	0.251	0.251
12:54:00	0.000	0.000	0.000	0.000	0.250	0.250
13:00:00	0.000	0.000	0.000	0.000	0.249	0.249
13:06:00	0.000	0.000	0.000	0.000	0.247	0.247
13:12:00	0.000	0.000	0.000	0.000	0.246	0.246
13:18:00	0.000	0.000	0.000	0.000	0.244	0.244
13:24:00	0.000	0.000	0.000	0.000	0.243	0.243
13:30:00	0.000	0.000	0.000	0.000	0.242	0.242
13:36:00	0.000	0.000	0.000	0.000	0.240	0.240
13:42:00	0.000	0.000	0.000	0.000	0.239	0.239
13:48:00	0.000	0.000	0.000	0.000	0.238	0.238
13:54:00	0.000	0.000	0.000	0.000	0.236	0.236
14:00:00	0.000	0.000	0.000	0.000	0.235	0.235
14:06:00	0.000	0.000	0.000	0.000	0.234	0.234
14:12:00	0.000	0.000	0.000	0.000	0.232	0.232

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (m^3/s)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
14:18:00	0.000	0.000	0.000	0.000	0.231	0.231
14:24:00	0.000	0.000	0.000	0.000	0.230	0.230
14:30:00	0.000	0.000	0.000	0.000	0.229	0.229
14:36:00	0.000	0.000	0.000	0.000	0.227	0.227
14:42:00	0.000	0.000	0.000	0.000	0.226	0.226
14:48:00	0.000	0.000	0.000	0.000	0.225	0.225
14:54:00	0.000	0.000	0.000	0.000	0.223	0.223
15:00:00	0.000	0.000	0.000	0.000	0.222	0.222
15:06:00	0.000	0.000	0.000	0.000	0.221	0.221
15:12:00	0.000	0.000	0.000	0.000	0.220	0.220
15:18:00	0.000	0.000	0.000	0.000	0.219	0.219
15:24:00	0.000	0.000	0.000	0.000	0.217	0.217
15:30:00	0.000	0.000	0.000	0.000	0.216	0.216
15:36:00	0.000	0.000	0.000	0.000	0.215	0.215
15:42:00	0.000	0.000	0.000	0.000	0.214	0.214
15:48:00	0.000	0.000	0.000	0.000	0.212	0.212
15:54:00	0.000	0.000	0.000	0.000	0.211	0.211
16:00:00	0.000	0.000	0.000	0.000	0.210	0.210
16:06:00	0.000	0.000	0.000	0.000	0.209	0.209
16:12:00	0.000	0.000	0.000	0.000	0.208	0.208
16:18:00	0.000	0.000	0.000	0.000	0.207	0.207
16:24:00	0.000	0.000	0.000	0.000	0.205	0.205
16:30:00	0.000	0.000	0.000	0.000	0.204	0.204
16:36:00	0.000	0.000	0.000	0.000	0.203	0.203
16:42:00	0.000	0.000	0.000	0.000	0.202	0.202
16:48:00	0.000	0.000	0.000	0.000	0.201	0.201
16:54:00	0.000	0.000	0.000	0.000	0.200	0.200
17:00:00	0.000	0.000	0.000	0.000	0.199	0.199
17:06:00	0.000	0.000	0.000	0.000	0.198	0.198
17:12:00	0.000	0.000	0.000	0.000	0.196	0.196
17:18:00	0.000	0.000	0.000	0.000	0.195	0.195
17:24:00	0.000	0.000	0.000	0.000	0.194	0.194
17:30:00	0.000	0.000	0.000	0.000	0.193	0.193
17:36:00	0.000	0.000	0.000	0.000	0.192	0.192
17:42:00	0.000	0.000	0.000	0.000	0.191	0.191
17:48:00	0.000	0.000	0.000	0.000	0.190	0.190

Time (hh:mm:ss)	Rain (mm)	Sewer Loss (m^3/s)	Net Rain (mm)	Runoff (m^3/s)	Baseflow (m^3/s)	Total Flow (m^3/s)
17:54:00	0.000	0.000	0.000	0.000	0.189	0.189
18:00:00	0.000	0.000	0.000	0.000	0.188	0.188
18:06:00	0.000	0.000	0.000	0.000	0.187	0.187
18:12:00	0.000	0.000	0.000	0.000	0.186	0.186
18:18:00	0.000	0.000	0.000	0.000	0.185	0.185
18:24:00	0.000	0.000	0.000	0.000	0.184	0.184
18:30:00	0.000	0.000	0.000	0.000	0.183	0.183
18:36:00	0.000	0.000	0.000	0.000	0.182	0.182
18:42:00	0.000	0.000	0.000	0.000	0.181	0.181
18:48:00	0.000	0.000	0.000	0.000	0.180	0.180

Appendix

Catchment descriptors

Name	Value	User-defined value used?
Area (km^2)	2.05	No
ALTBAR	410	No
ASPBAR	11	No
ASPVAR	0.66	No
BFIHOST	0.25	No
BFIHOST19	0.26	No
DPLBAR (km)	1.27	No
DPSBAR (mkm^{-1})	187	No
FARL	1	No
LDP	2.22	No
PROPWET	0.64	No
RMED1H	9	No
RMED1D	37.5	No
RMED2D	51.9	No
SAAR (mm)	1484	No
SAAR4170 (mm)	1470	No
SPRHOST	58.74	No
Urbext2000	0	No
Urbext1990	0	No
URBCONC	0	No
URBLOC	0	No
DDF parameter C	-0.03	No
DDF parameter D1	0.45	No
DDF parameter D2	0.46	No
DDF parameter D3	0.35	No
DDF parameter E	0.29	No
DDF parameter F	2.28	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.48	No
DDF parameter D2 (1km grid value)	0.45	No
DDF parameter D3 (1km grid value)	0.37	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.29	No

Appendix F

Drainage Calculations

CRM Stormflow Stormwater Management Software

Client:	RES
Project:	M01616-26
Location:	Mullaghclogher Wind Farm
Catchment:	Whole Drained Area

Catchment Details:

Buildings	0	m^2	x 95 %
Dense surfacing	97919	m^2	x 60 %
Effective Area	58751.4	m^2	

Storage Details:

Volume	2640	Cu.m
Porosity	100	%
Area Increase	0	%

Rainfall Details - FEH Method:

Return Period	100	years	
Climate Change Factor	20	%	
c	-0.029	d1	0.45402
d2	0.45619	d3	0.34706
e	0.2886	f	2.27691

	mm	mm/h	storage (m^3)
30 min	35.3	70.7	1899.194
45 min	40.2	53.6	2099.207
60 min	44.1	44.1	2239.469
2 hours	55.1	27.5	2532.060
6 hours	78.4	13.1	2489.062
24 hours	122.4	5.1	0.000

Outflow Details:

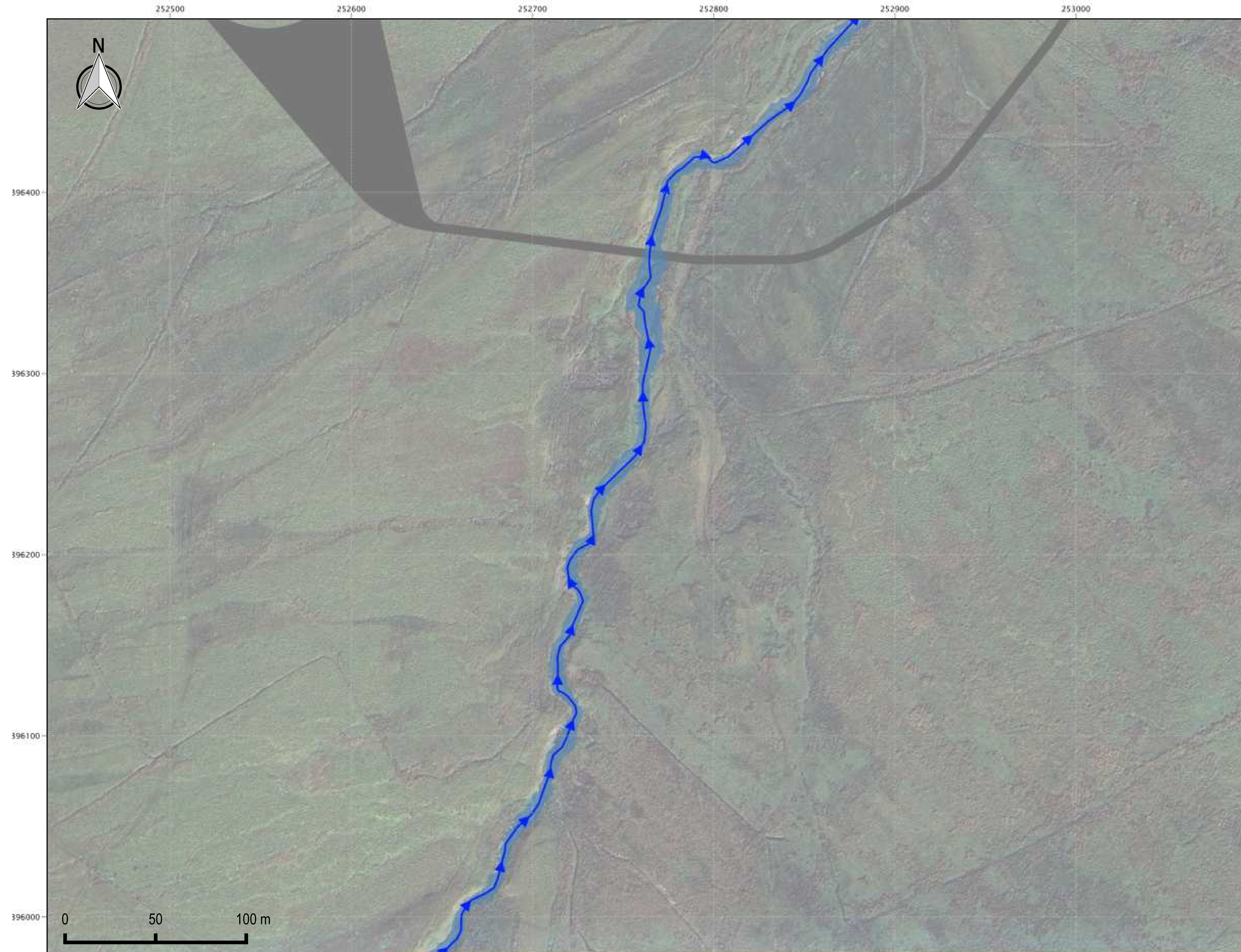
Infiltration rate	0	m/hr
Attenuation Control	Fixed Outflow	
Control Diameter	-	mm
Discharge rate	97.9	l/s

Results:

Outcome:	Pass
Critical Storm Duration	3.55 hrs
Hmax	1 m
Time to half empty	3.7 hrs

Appendix G

Flood Mapping



MODEL OVERVIEW

LEGEND

- Devlopment boundary
- River reach

Hydrology

- Pre-Development 1% AEP +CC Flood Extent

Structure

- Proposed Infastructure

McCloy Consulting

Mossley Mill,
Lower Ground (West),
Carnmoney Road North,
Newtownabbey, BT36 5QA

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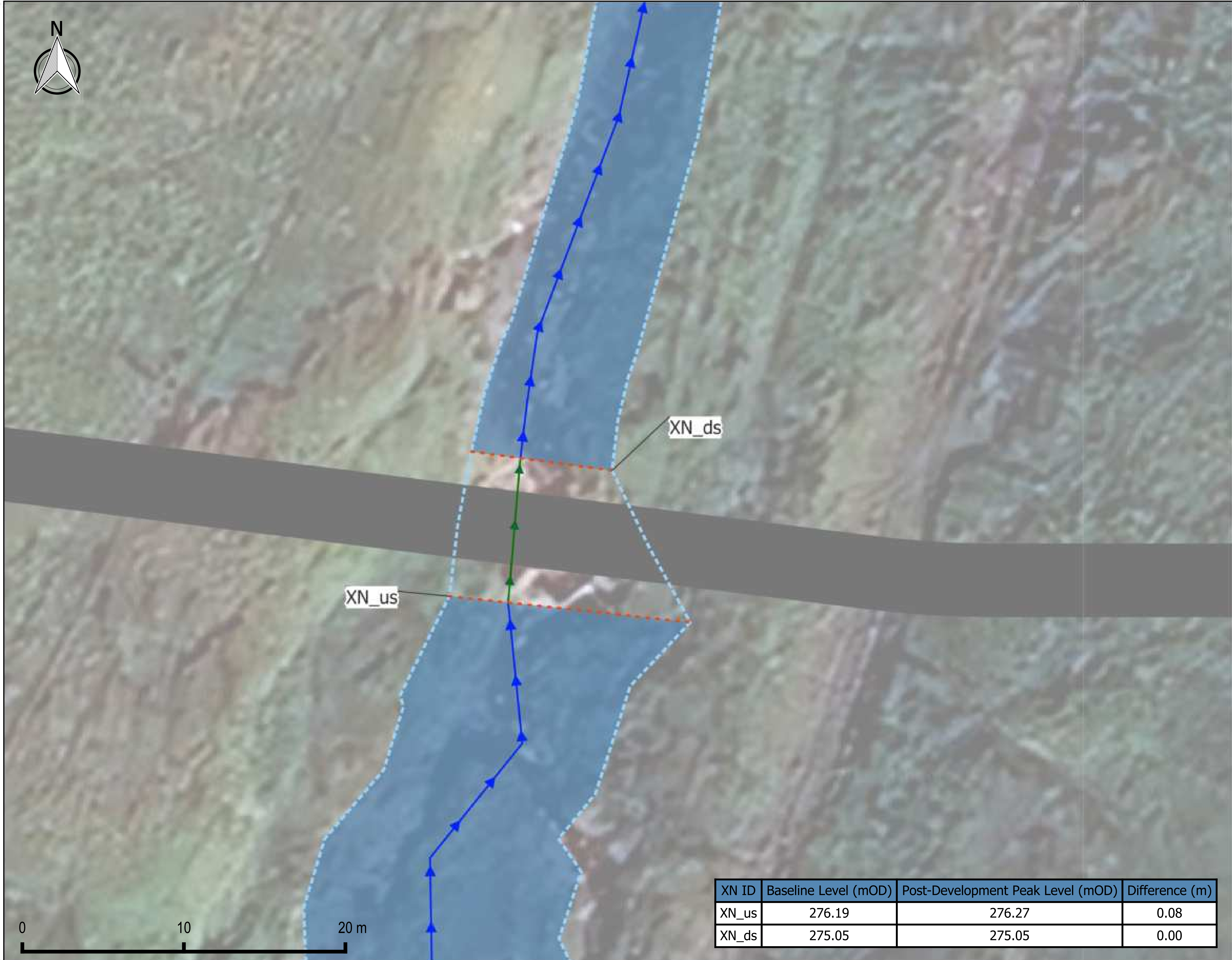
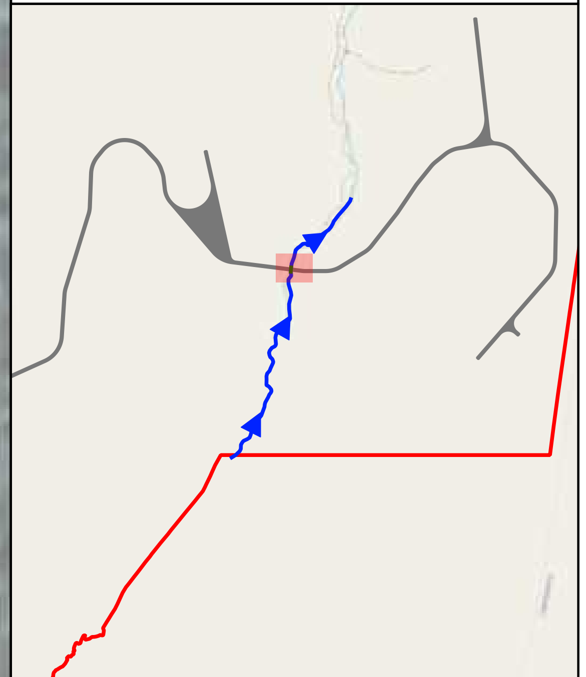
W: www.mccloyconsulting.com

PROJECT		HYDROLOGY SCENARIO	SCALE	ORIGINAL SIZE
MULLAGHCLOGHER WIND FARM		CLIMATE CHANGE	1:2000	A3
MAP TYPE		GEOMETRY SCENARIO	DRAWN BY	APPROVED BY
FLOOD EXTENT		PRE-DEVELOPMENT	DL	DKS
SOURCE	FLOOD EVENT	FIGURE NUMBER	REVISION	DATE
FLUVIAL	1% AEP	M01616-26_FIG_FL101	01	03/10/2023



XN ID	Baseline Level (mOD)	Post-Development Peak Level (mOD)	Difference (m)
XN_us	276.19	276.27	0.08
XN_ds	275.05	275.05	0.00

MODEL OVERVIEW



LEGEND

- Devlopment boundary
- River reach
- Modelled Cross Section Location

Hydrology

- Post-Development 1%+CC AEP Flood Extent
- Pre-Development 1% AEP +CC Flood Extent

Structure

- Proposed Infastructure
- Proposed Culvert

McCloy Consulting
Mossley Mill,
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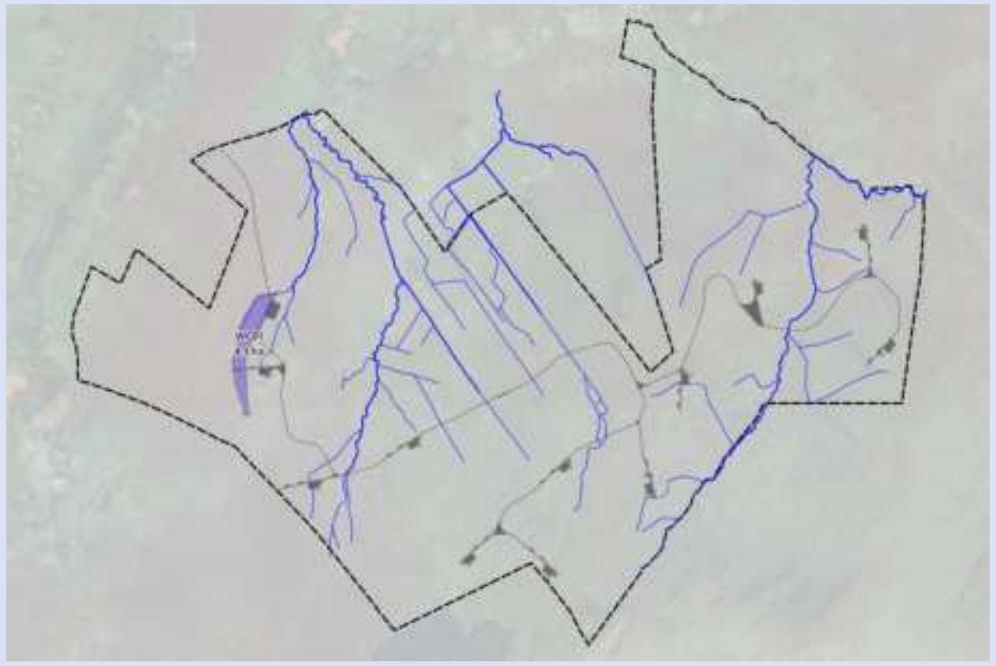
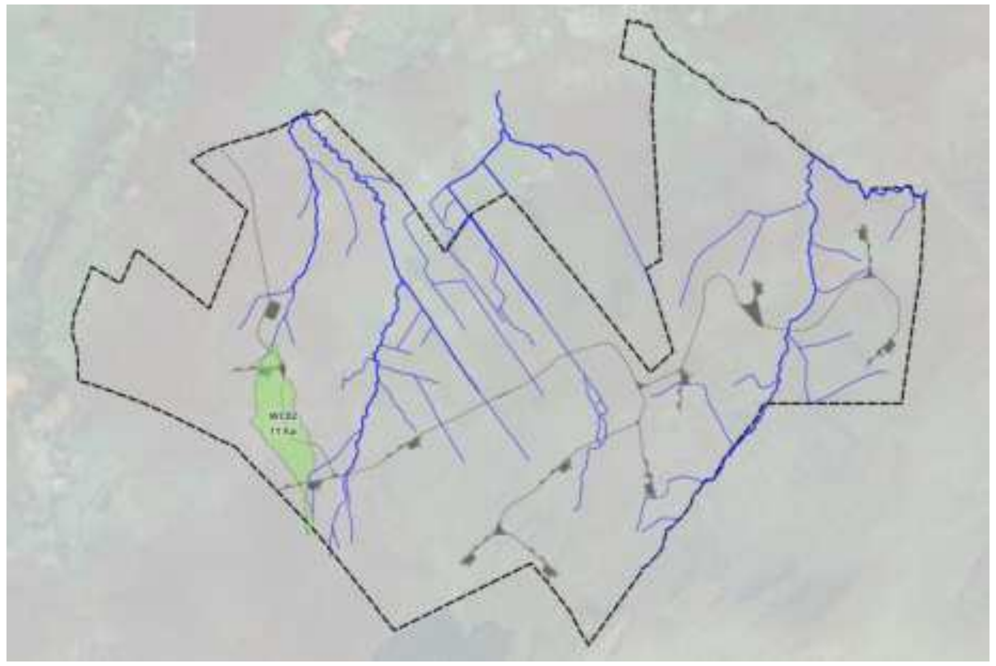
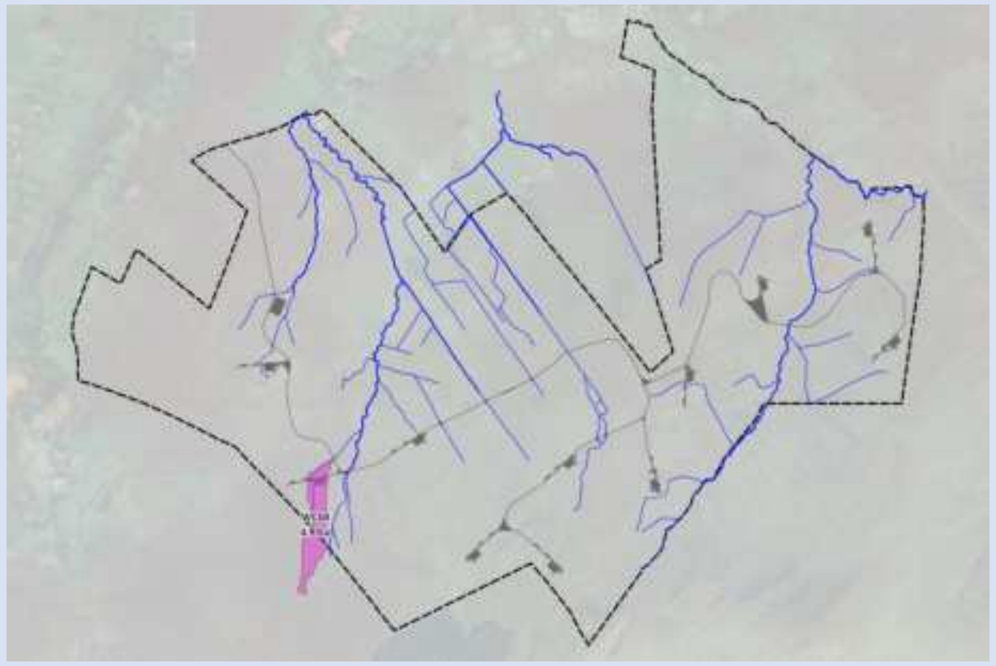
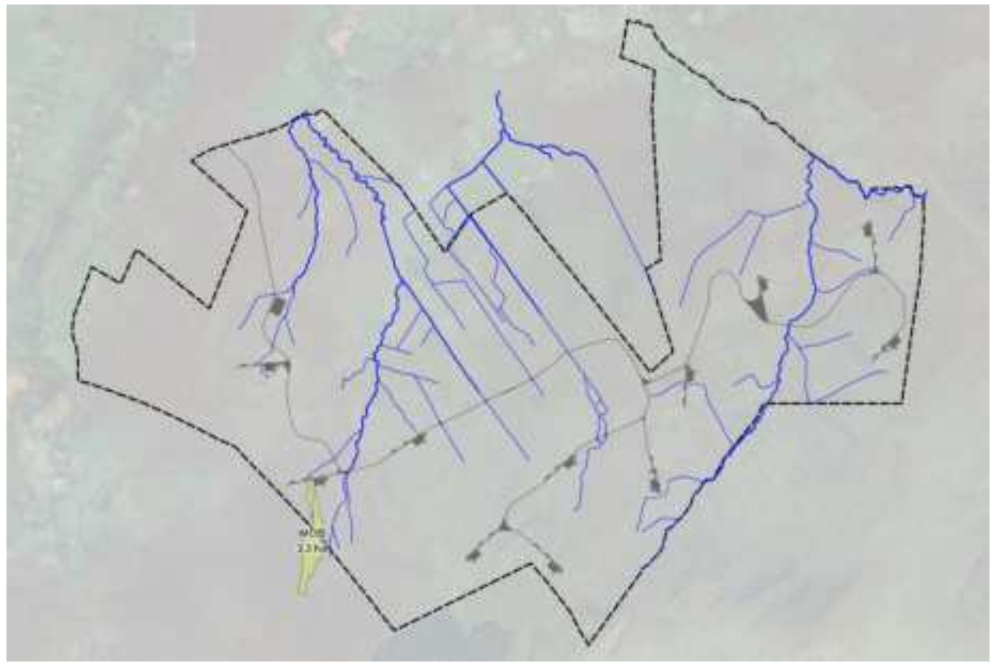
W: www.mccloyconsulting.com

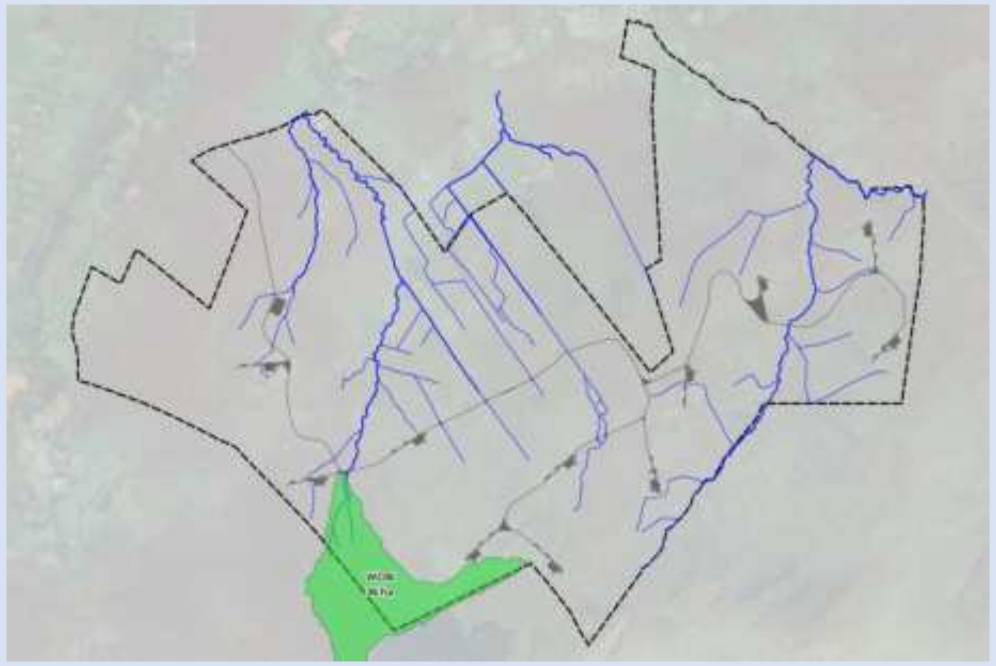
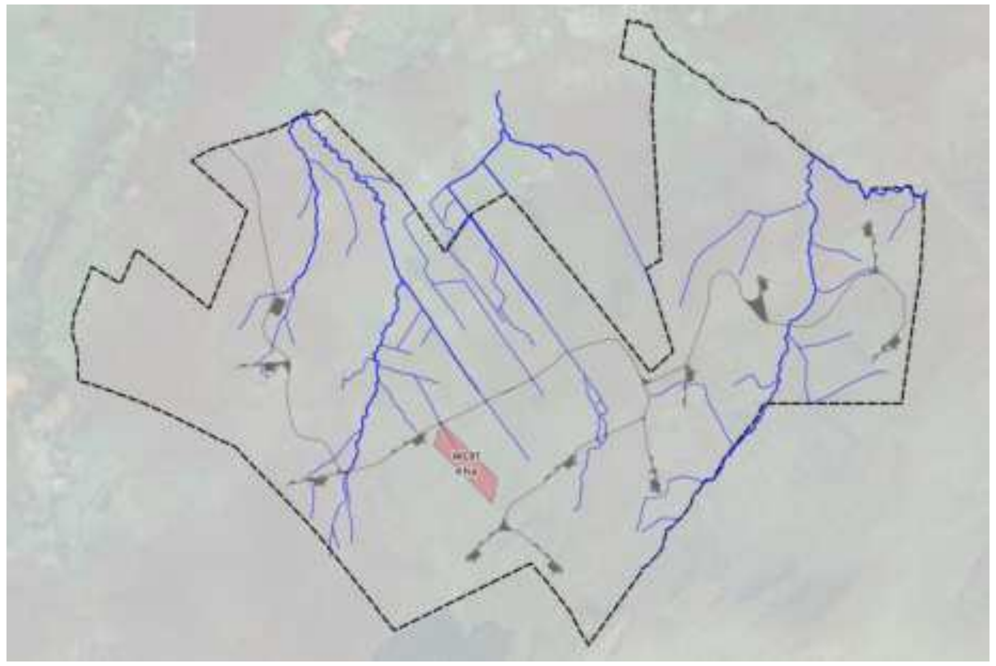
PROJECT: MULLAGHCLOGHER WIND FARM	HYDROLOGY SCENARIO: CLIMATE CHANGE	SCALE: AS SHOWN	ORIGINAL SIZE: A3
MAP TYPE: FLOOD EXTENT	GEOMETRY SCENARIO: POST-DEVELOPMENT	DRAWN BY: DL	APPROVED BY: DKS
SOURCE: FLUVIAL / FLOOD EVENT: 1% AEP +CC	FIGURE NUMBER: M01616-26_FIG_FL102	REVISION: 01	DATE: 03/10/2023

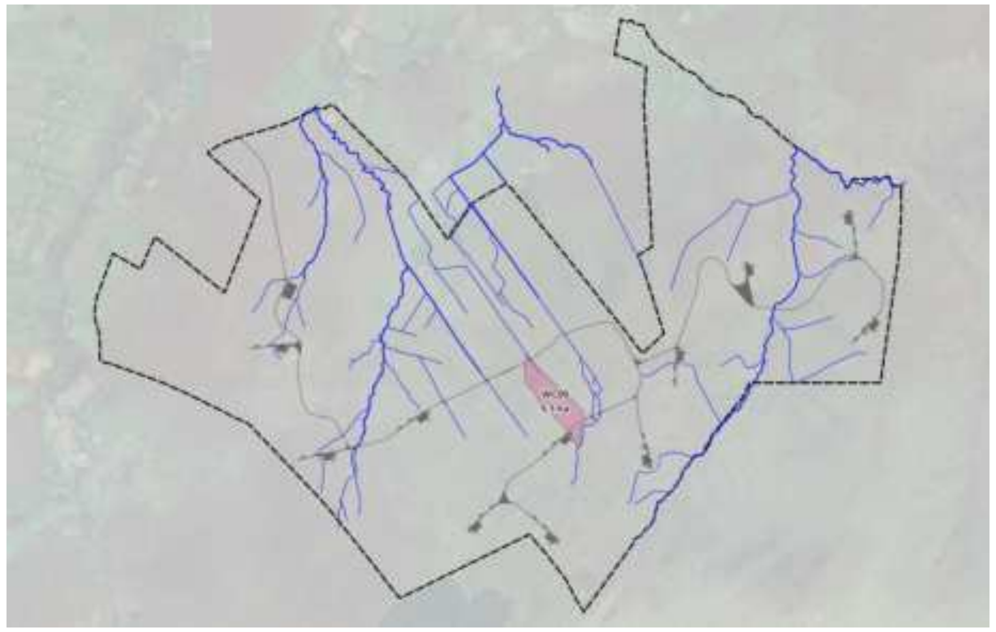
Appendix H

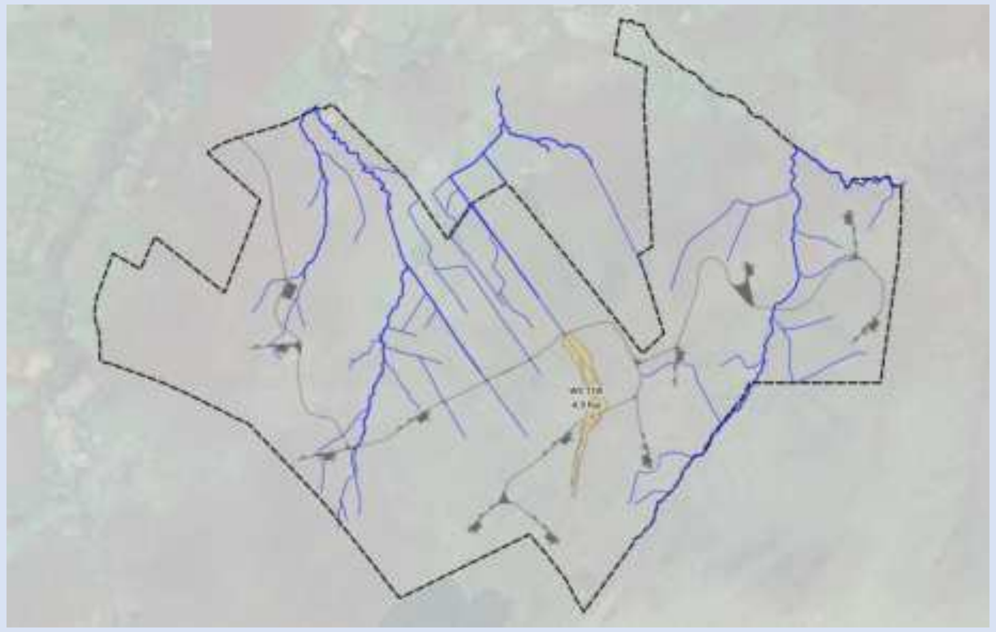
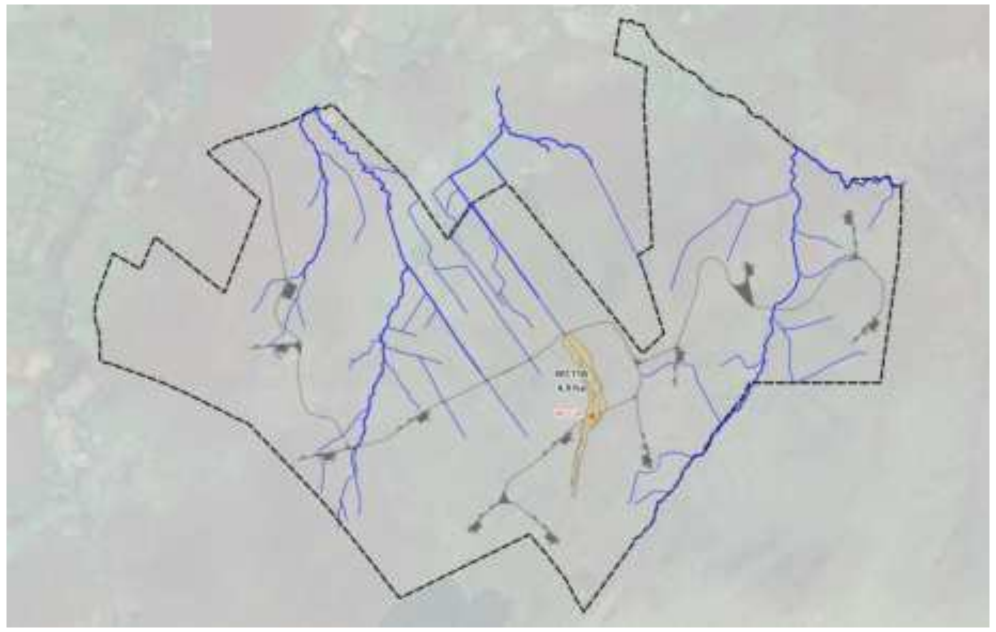
Watercourse Crossing Schedule

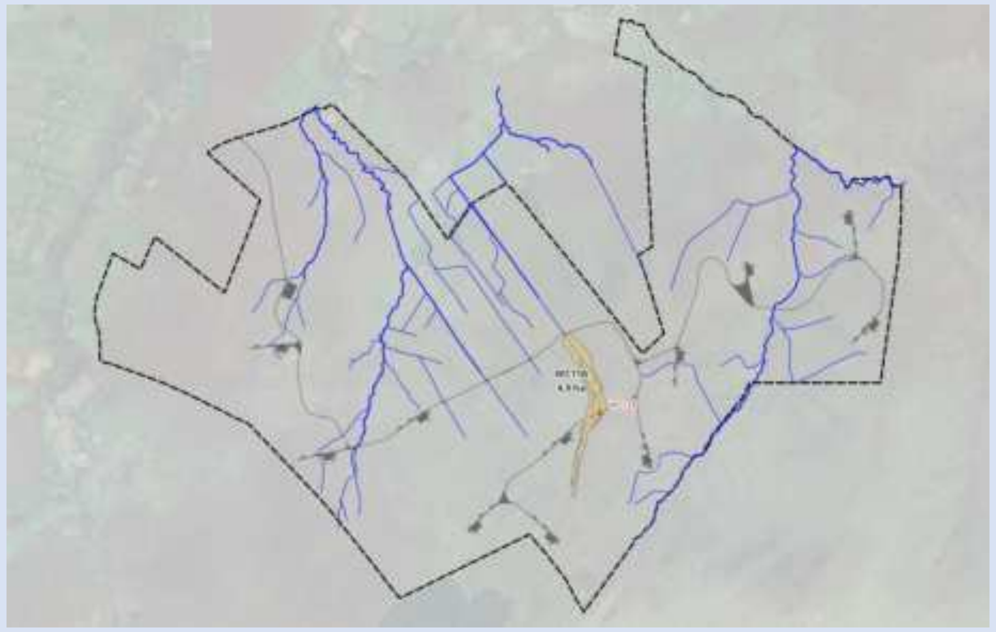
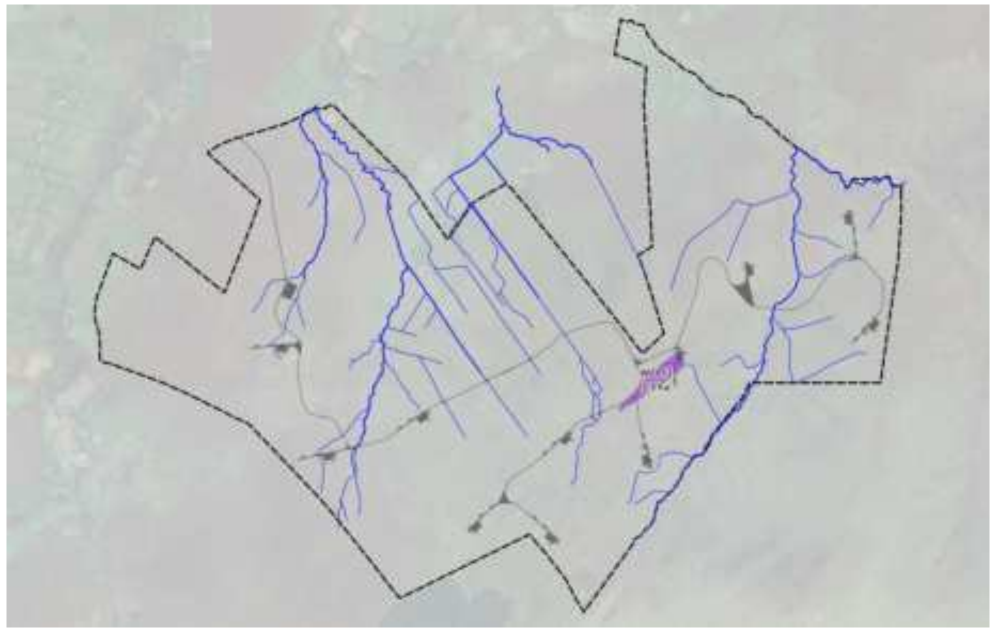
WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC01	250216	396541	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		
WC02 / WC03D	250206	396288	NEW MIN. 0.9 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY; DUE TO PROXIMITY SAME HYDROLOGY ADOPTED FOR BOTH CULVERTS WC03 ON REALIGNED CHANNEL; CHANNEL TO HAVE EWUIVALENT OR GREATER DIMENSIONS THAN THE REPLACED CHANNEL		

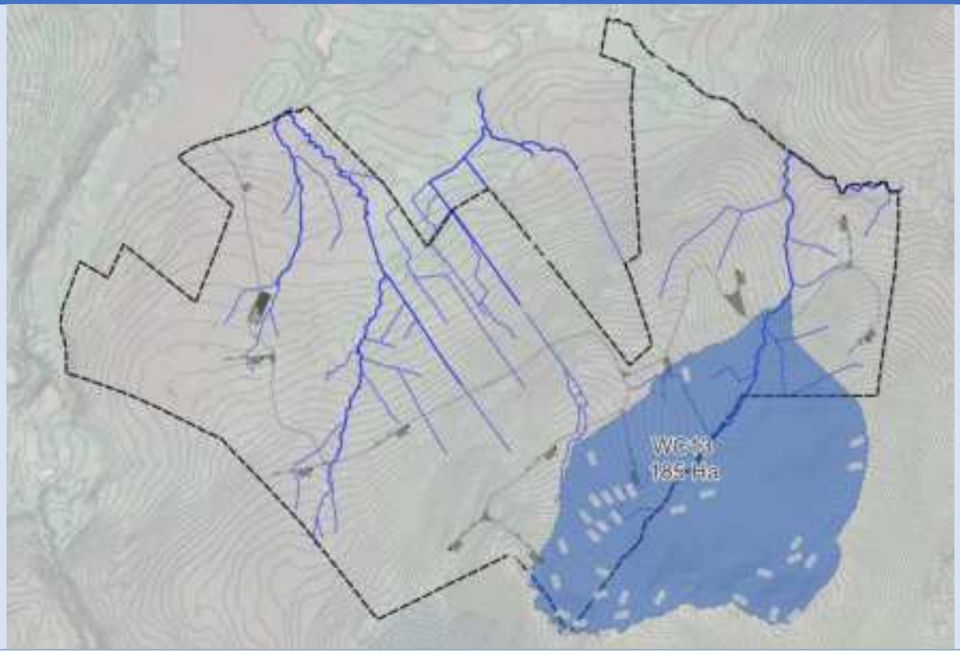
WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC04	250510	395725	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		
WC05D	250391	395623	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE. CULVERT PROPOSED ON REALIGNED CHANNEL; CHANNEL TO HAVE EWUIVALENT OR GREATER DIMENSIONS THAN THE REPLACED CHANNEL		

WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC06	250570	395658	NEW MIN. 1.35 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		
WC07	251040	395901	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		

WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC08	251264	396011	NEW MIN. 1.05 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. INCISED CHANNEL. GRAVEL SUBSTRATE MAY BE FROM EROSION / HIGH VELOCITIES UNDER FLOW CONDITIONS. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		
WC09	251495	396121	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL FIND BOUNDARY DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		

WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC10	251671	396255	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		
WC11A	251817	395824	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. DOWNSTREAM CULVERT CATCHMENT (WC10) ADOPTED TO ENSURE PRECAUTIONARY ANALYSIS; NO ALLOWANCE MADE FOR FLOW SPLIT BETWEEN WC10 A & B DUE TO UNCERTAINTY AROUND FLOOD FLOW DIRCTIONS. PEAT SUBSTRATE IN ERODED BOG HAG. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE / PEAT EXTRACTION. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		

WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC11B	251857	395842	NEW MIN. 0.75 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. DOWNSTREAM CULVERT CATCHMENT (WC10) ADOPTED TO ENSURE PRECAUTIONARY ANALYSIS; NO ALLOWANCE MADE FOR FLOW SPLIT BETWEEN WC10 A & B DUE TO UNCERTAINTY AROUND FLOOD FLOW DIRCTIONS. PEAT SUBSTRATE IN ERODED BOG HAG. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE / PEAT EXTRACTION. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		
WC12	252259	396100	NEW MIN. 0.6 M DIA CIRCULAR CULVERT (CLASS 120 CONCRETE OR EQUIVALENT). DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY & HYDRAULIC ASSESSMENT IN ANNEX A & B RESPECTIVELY. PEAT SUBSTRATE. CHARACTERISTIC OF ARTIFICAL HISTORIC BOG DRAINAGE. FISHERIES ASSESSMENT CONCLUDED CLOSED CULVERT IS SUITABLE.		

WXREF	EASTING	NORTHING	DESCRIPTION	PHOTO	CATCHMENT MAP
WC13	252770	396388	BOTTOMLESS CULVERT WITH SPAN 3.0M, HEIGHT 1.8M AND SOFFIT NOT LESS THAN 276.57 M OD. DESIGNED FOR FREE INLET CONDITIONS 1% AEP + CLIMATE CHANGE. HYDROLOGY AND HYDRAULICS DESCRIBED IN THE FLOOD RISK ASSESSMENT. FISHERIES ASSESSMENT REQUIRES BOTTOMLESS STRUCTURE TO ENSURE FISH PASSAGE / MINIMISE IN-STREAM WORKS AFFECTING WATER QUALITY.		

ANNEX A – HYDROLOGY / FLOW ESTIMATON SUMMARY

Calculation Record - Flood Hydrology

Purpose

To estimate design floods at culvert locations. Culvert catchments are insufficient to be represented in FEH dataset. Approach adopts estimation of discharge at closest downstream point in FEH dataset by REFH2.3 methodology. REFH flow scaled pro-rata by area to respective culvert catchments

Donor Catchment

Hydrological estimation point	252850_396550		
Catchment Area	2.05	sq km	from FEH dataset
1% AEP Present Day (cumecs)	8.19	from REFH2.3	refer to separate REFH calculation output
Specific Discharge	4.00	cumecs/Sq.km	

Culvert Catchment / Flow Estimation

CulvertID	AreaSQM	Area Sq KM	1% AEP Present Day (cumecs)	**1% AEP Climate Change (cumecs)**
WC01	40951	0.041	0.16	**0.20**
WC02	115930	0.116	0.46	**0.56**
WC03D	115930	0.116	0.46	**0.56**
WC04	49781	0.050	0.20	**0.24**
WC05D	33582	0.034	0.13	**0.16**
WC06	364557	0.365	1.46	**1.75**
WC07	40750	0.041	0.16	**0.20**
WC08	206557	0.207	0.83	**0.99**
WC09	51478	0.051	0.21	**0.25**
WC10	49416	0.049	0.20	**0.24**
WC11A	49416	0.049	0.20	**0.24**
WC11B	49416	0.049	0.20	**0.24**
WC12	23777	0.024	0.09	**0.11**
WC13	**Refer to Flood Risk & Drainage Assessment Appendix D - assessed by flood modelling**			

UK Design Flood Estimation

Generated on 19 September 2023 15:51:07 by terminal
Printed from the ReFH2 Flood Modelling software package, version 4.0.8560.23190

Summary of estimate using the Flood Estimation Handbook revitalised flood hydrograph method (ReFH2)

Site details

Checksum: 93EF-CADA

Site name: FEH_Catchment_Descriptors_252850_396550_v5_0_1

Easting: 252850

Northing: 396550

Country: England, Wales or Northern Ireland

Catchment Area (km²): 2.05

Using plot scale calculations: No

Model: 2.3

Site description: None

Model run: 100 year

Summary of results

Rainfall - FEH22 (mm):	50.28	Total runoff (ML):	60.96
Total Rainfall (mm):	38.89	Total flow (ML):	79.51
Peak Rainfall (mm):	4.07	Peak flow (m³/s):	8.19

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.
** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH22)

Name	Value	User-defined?
Duration (hh:mm:ss)	02:30:00	No
Timestep (hh:mm:ss)	00:06:00	No
SCF (Seasonal correction factor)	0.8	No
ARF (Areal reduction factor)	0.96	No
Seasonality	Winter	No

Loss model parameters

Name	Value	User-defined?
Cini (mm)	128.62	No
Cmax (mm)	193.15	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	1	No
Up	0.65	No
Uk	0.8	No

Baseflow model parameters

Name	Value	User-defined?
BF0 (m^3/s)	0.18	No
BL (hr)	17.86	No
BR	0.3	No

Urbanisation parameters

Name	Value	User-defined?
Sewer capacity (m^3/s)	0	No
Exporting drained area (km^2)	0	No
Urban area (km^2)	0	No
Urbext 2000	0	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.4	No
Tp scaling factor	0.75	No
Depression storage depth (mm)	0.5	No

Appendix

Catchment descriptors

Name	Value	User-defined value used?
Area (km^2)	2.05	No
ALTBAR	410	No
ASPBAR	11	No
ASPVAR	0.66	No
BFIHOST	0.25	No
BFIHOST19	0.26	No
DPLBAR (km)	1.27	No
DPSBAR (mkm^{-1})	187	No
FARL	1	No
LDP	2.22	No
PROPWET	0.64	No
RMED1H	9	No
RMED1D	37.5	No
RMED2D	51.9	No
SAAR (mm)	1484	No
SAAR4170 (mm)	1470	No
SPRHOST	58.74	No
Urbext2000	0	No
Urbext1990	0	No
URBCONC	0	No
URBLOC	0	No
DDF parameter C	-0.03	No
DDF parameter D1	0.45	No
DDF parameter D2	0.46	No
DDF parameter D3	0.35	No
DDF parameter E	0.29	No
DDF parameter F	2.28	No
DDF parameter C (1km grid value)	-0.03	No
DDF parameter D1 (1km grid value)	0.48	No
DDF parameter D2 (1km grid value)	0.45	No
DDF parameter D3 (1km grid value)	0.37	No
DDF parameter E (1km grid value)	0.29	No
DDF parameter F (1km grid value)	2.29	No

ANNEX B - HYDRAULICS – CULVERT SIZING

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	18/10/2023

McCloy Consulting

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC01		
Coordinates (E/N)		250149	396193	
Function / Description		Track crossing		
Design Discharge Q		***0.2***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		223.9	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		223.5	m AOD	From Survey
Culvert Length		15	m	From Survey
Elevation of Stream bed upstream of Culvert		224.7	m AOD	From Survey
Distance upstream of Culvert		45	m	From Survey
Elevation of Stream bed downstream of Culvert		222	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		227	m AOD	From Survey
Average channel invert width		0.5	m	From Survey
Average channel top of bank width		0.7	m	From Survey
Average Channel Depth to Bank		0.6	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		224.9	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		224.9	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	56.25	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	26.67	-	Calculated
Bedslope across Culvert 1 in S3	S3	37.50	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	37.04	-	Calculated
Channel Side Slopes 1 in X	X =	0.17	-	Calculated
Upstream Left Over- Bank Slope	Y =	12.50	-	Calculated
Upstream Right Over- Bank Slope	Z =	12.50	-	Calculated

Calculate Tailwater Depth and Level:

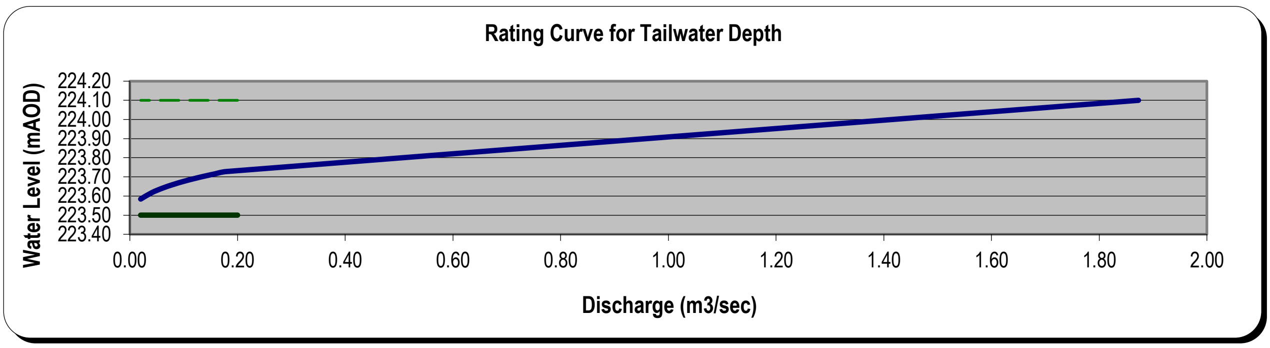
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Discharge Contained in Channel, Depth of Normal Flow Considered

Depth of water in channel is	y_{dc}	0.60	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	224.10	mAOD	Calculated
	V_{dc}	0.76	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	224.13	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		2.46	m2
Top Width (B)		7.70	m
Hydraulic mean depth (A per unit B)	d_m	0.32	m
Froude Number	Fr	0.43	*Subcritical*
Critical depth in channel	h_c	0.51	m
Critical Velocity	v_c	1.77	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.60	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.75	m	Calculated
where freeboard depth is:	F	0.07	m	Calculated
Area required as per tailwater fllow calculation:	A_t	2.46	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		4.10	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.75*	*m*	Calculated
	B_i	*4.10*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.75	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.19	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*223.85*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*223.90*	*mAOD*
Upstream Soffit Elevation		*224.60*	*mAOD*
Downstream Pipe Invert Elevation		*223.45*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*223.50*	*mAOD*
Downstream Soffit Elevation		*224.20*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.2	m3/s
Depth / Diameter of barrell	D	0.70	m
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2
Discharge Coefficient	qi	1.26	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where	Discharge	Q	0.2	m3/s	
	Depth / Diameter of barrell	D	0.7	m	
	Unsubmerged analysis constant	k	0.0078		Table A1.3
	Unsubmerged analysis constant	M	2		Table A1.3
	Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2	
	Culvert Slope	So	0.03	m/m	1 in 37.5
$\frac{Q^2 W}{gA^3} = 1$	Critical depth calculated as:	y_c	0.238	m	
	Specific Energy at Critical Depth	E_{sc}	0.36	m	
$E_{sc} = \frac{3}{2}y_c$	Therefore Specific Energy of Headwater	E_{sh}	0.36	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

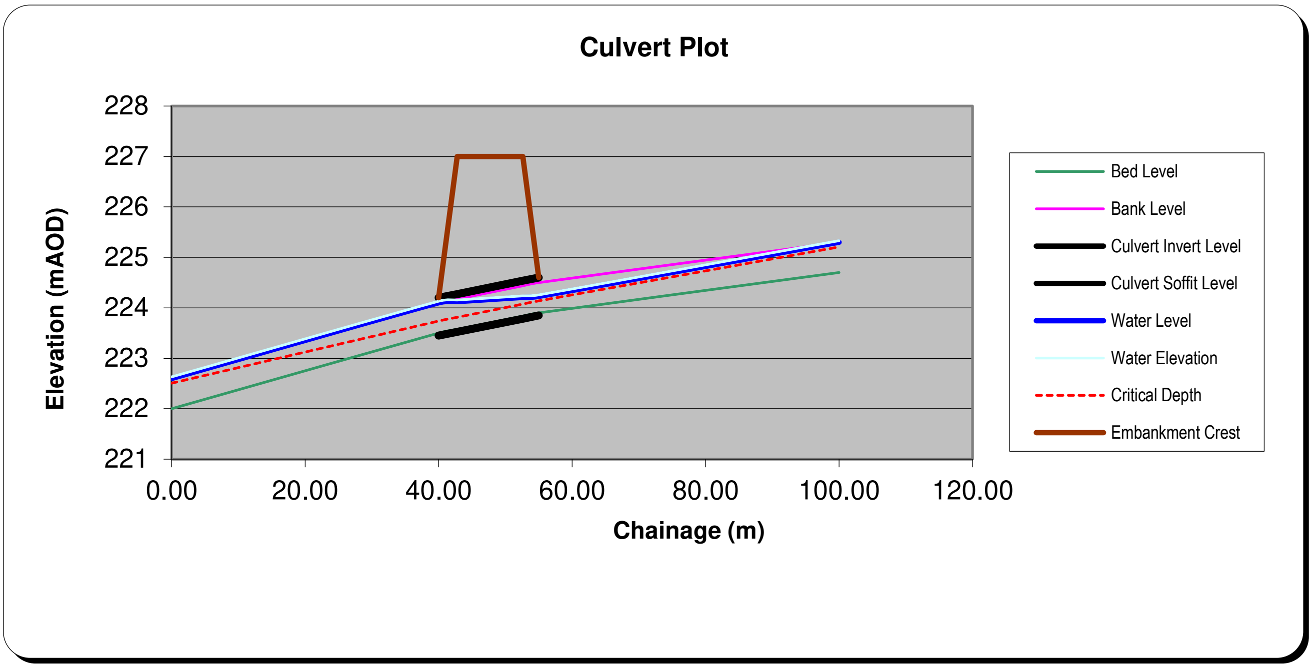
Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	223.90	mAOD
Specific Energy of Headwater	E_{sh}	0.36	m
Therefore Headwater Elevation:	H_{hic}	224.26	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	224.26	mAOD
Velocity in Upstream Channel	V_{uc}	0.76	m/s
Therefore Water Level at Inlet:	WL_{hic}	224.23	mAOD

Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.75 m**

By	Checked	Revision	Date
KS	KS	Original	18/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC010		
Coordinates (E/N)		251671	396255	
Function / Description		Track crossing		
Design Discharge Q		***0.24***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		331	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		327.9	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		342.5	m AOD	From Survey
Distance upstream of Culvert		40	m	From Survey
Elevation of Stream bed downstream of Culvert		317.7	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		333	m AOD	From Survey
Average channel invert width		0.4	m	From Survey
Average channel top of bank width		0.4	m	From Survey
Average Channel Depth to Bank		0.2	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		331.4	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		332.1	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	3.48	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	3.92	-	Calculated
Bedslope across Culvert 1 in S3	S3	3.23	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	3.63	-	Calculated
Channel Side Slopes 1 in X	X =	0.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	25.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	5.56	-	Calculated

Calculate Tailwater Depth and Level:

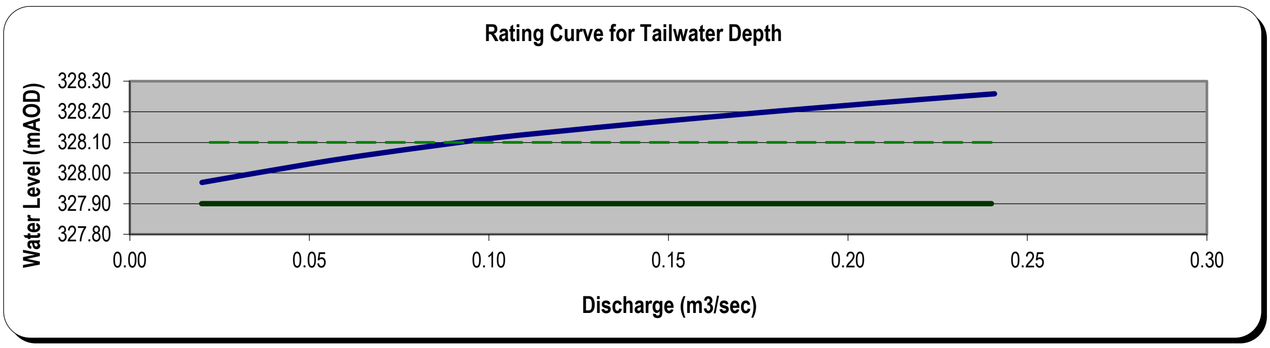
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.36	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	328.26	mAOD	Calculated
	V_{dc}	1.65	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	328.41	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.15	m2	
Top Width (B)		5.25	m	
Hydraulic mean depth (A per unit B)	d_m	0.03	m	
Froude Number	Fr	3.15	*Supercritical*	
Critical depth in channel	h_c	0.26	m	
Critical Velocity	v_c	0.52	m/s	

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.36	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.45	m	Calculated
where freeboard depth is:	F	0.04	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.15	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.41	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.45*	*m*	Calculated
	B_i	*0.41*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.75	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.19	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*330.95*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*331.00*	*mAOD*
Upstream Soffit Elevation		*331.70*	*mAOD*
Downstream Pipe Invert Elevation		*327.85*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*327.90*	*mAOD*
Downstream Soffit Elevation		*328.60*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.24	m3/s
Depth / Diameter of barrell	D	0.70	m
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2
Discharge Coefficient	qi	1.52	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where Discharge	Q	0.24	m3/s	
Depth / Diameter of barrell	D	0.7	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2	
Culvert Slope	So	0.31	m/m	1 in 3.23
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.265	m	
Specific Energy at Critical Depth	E_{sc}	0.40	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.30	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	331.00	mAOD
Specific Energy of Headwater	E_{sh}	0.30	m
Therefore Headwater Elevation:	H_{hic}	331.30	mAOD

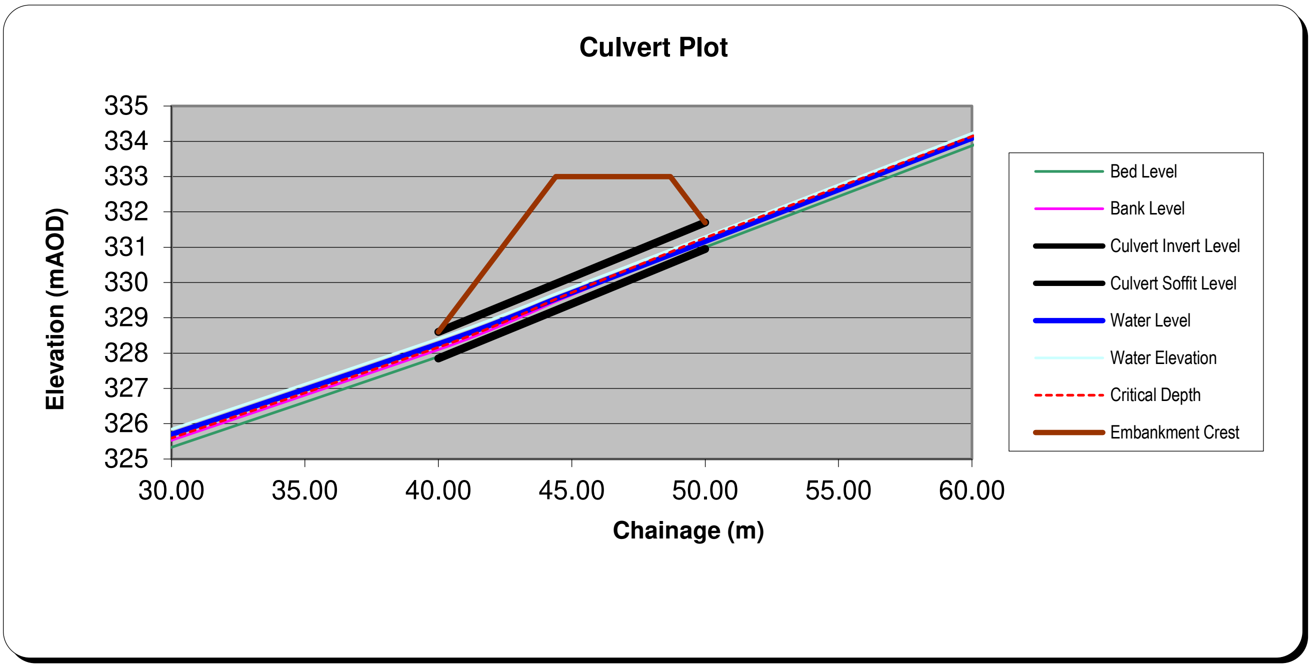
Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	331.30	mAOD
Velocity in Upstream Channel	V_{uc}	1.65	m/s
Therefore Water Level at Inlet:	WL_{hic}	331.16	mAOD

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	19/10/2023

Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.75 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC011A		
Coordinates (E/N)		251817	395824	
Function / Description		Track crossing		
Design Discharge Q		***0.24***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		407.9	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		407.3	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		408.2	m AOD	From Survey
Distance upstream of Culvert		20	m	From Survey
Elevation of Stream bed downstream of Culvert		405	m AOD	From Survey
Distance downstream of Culvert		20	m	From Survey
Elevation of Proposed Embankment Crest		409.9	m AOD	From Survey
Average channel invert width		0.5	m	From Survey
Average channel top of bank width		1	m	From Survey
Average Channel Depth to Bank		0.8	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		408.5	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		408.3	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	66.67	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	8.70	-	Calculated
Bedslope across Culvert 1 in S3	S3	16.67	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	15.63	-	Calculated
Channel Side Slopes 1 in X	X =	0.31	-	Calculated
Upstream Left Over- Bank Slope	Y =	-25.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	-12.50	-	Calculated

Calculate Tailwater Depth and Level:

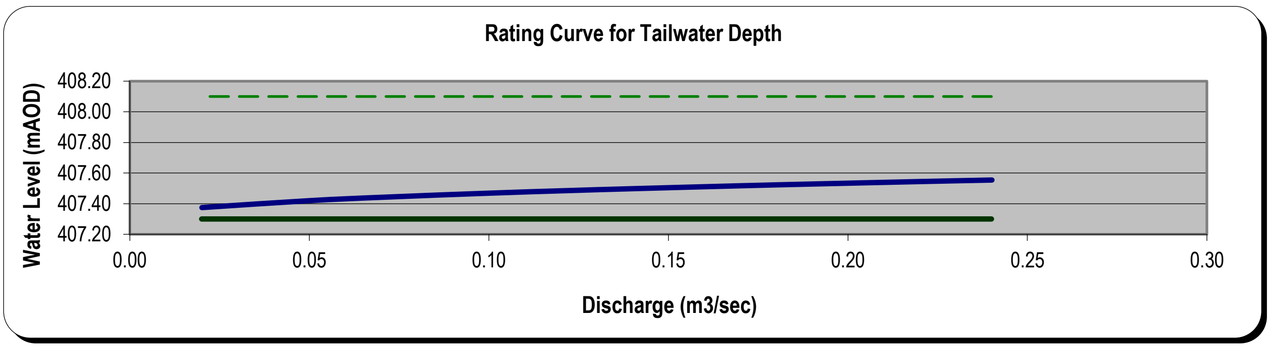
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Discharge Contained in Channel, Depth of Normal Flow Considered

Depth of water in channel is	y_{dc}	0.25	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	407.55	mAOD	Calculated
	V_{dc}	0.72	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	407.58	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.33	m2
Top Width (B)		2.13	m
Hydraulic mean depth (A per unit B)	d_m	0.16	m
Froude Number	Fr	0.58	*Subcritical*
Critical depth in channel	h_c	0.17	m
Critical Velocity	v_c	1.24	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.25	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.32	m	Calculated
where freeboard depth is:	F	0.03	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.33	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		1.31	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.32*	*m*	Calculated
	B_i	*1.31*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.75	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.19	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*407.85*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*407.90*	*mAOD*
Upstream Soffit Elevation		*408.60*	*mAOD*
Downstream Pipe Invert Elevation		*407.25*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*407.30*	*mAOD*
Downstream Soffit Elevation		*408.00*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.24	m3/s
Depth / Diameter of barrell	D	0.70	m
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2
Discharge Coefficient	qi	1.52	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where Discharge	Q	0.24	m3/s	
Depth / Diameter of barrell	D	0.7	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2	
Culvert Slope	So	0.06	m/m	1 in 16.67
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.265	m	
Specific Energy at Critical Depth	E_{sc}	0.40	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.39	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	407.90	mAOD
Specific Energy of Headwater	E_{sh}	0.39	m
Therefore Headwater Elevation:	H_{hic}	408.29	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	408.3	mAOD
Velocity in Upstream Channel	V_{uc}	0.72	m/s
Therefore Water Level at Inlet:	WL_{hic}	408.3	mAOD

Project	Mullaghclogher Wind Farm
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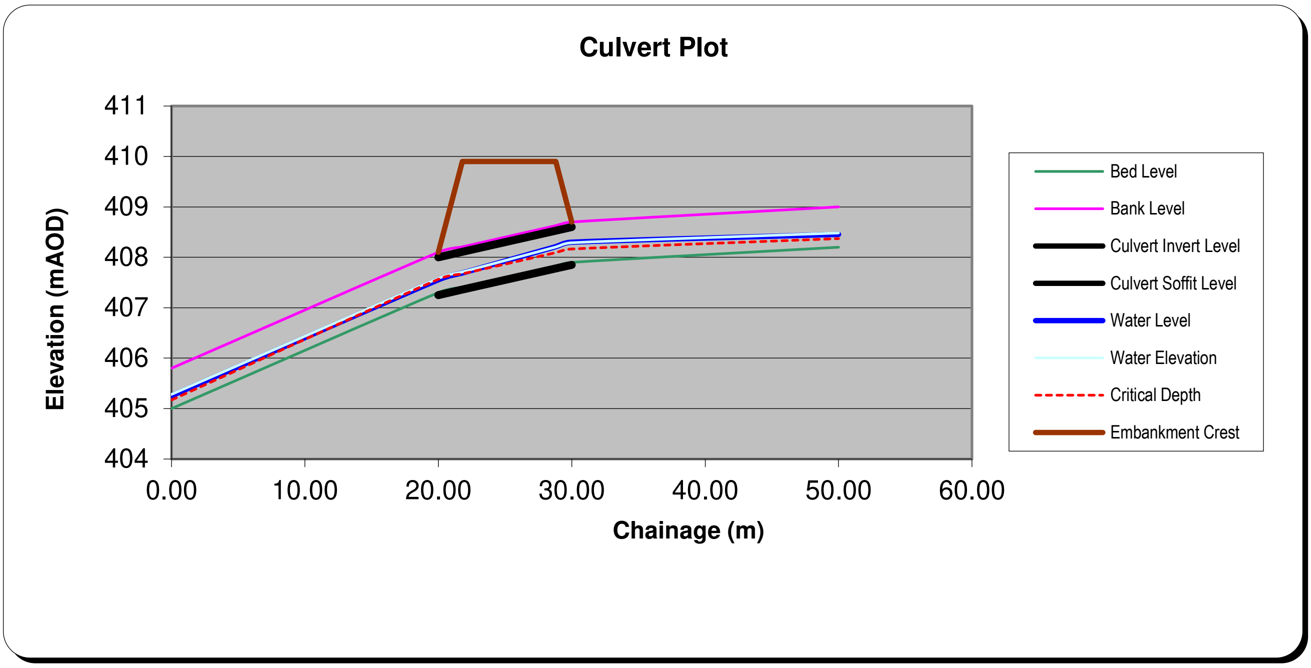
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: 1 nr Diameter 0.75 m

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	19/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC011A		
Coordinates (E/N)		251857	395842	
Function / Description		Track crossing		
Design Discharge Q		***0.24***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		403.8	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		402.7	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		404.3	m AOD	From Survey
Distance upstream of Culvert		20	m	From Survey
Elevation of Stream bed downstream of Culvert		402	m AOD	From Survey
Distance downstream of Culvert		20	m	From Survey
Elevation of Proposed Embankment Crest		405.8	m AOD	From Survey
Average channel invert width		4	m	From Survey
Average channel top of bank width		5	m	From Survey
Average Channel Depth to Bank		1	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		405	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		404.5	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	40.00	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	28.57	-	Calculated
Bedslope across Culvert 1 in S3	S3	9.09	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	21.74	-	Calculated
Channel Side Slopes 1 in X	X =	0.50	-	Calculated
Upstream Left Over- Bank Slope	Y =	25.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	-16.67	-	Calculated

Calculate Tailwater Depth and Level:

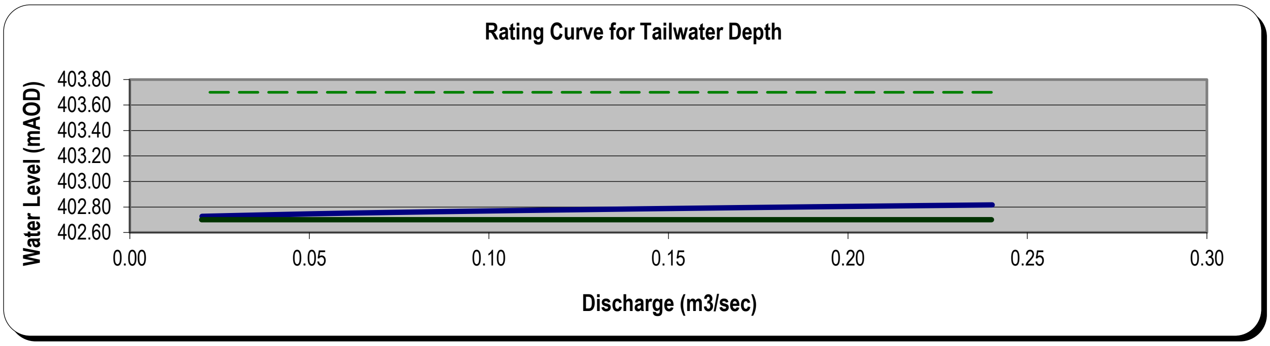
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Discharge Contained in Channel, Depth of Normal Flow Considered

Depth of water in channel is	y_{dc}	0.12	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	402.82	mAOD	Calculated
	V_{dc}	0.49	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	402.83	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.49	m2
Top Width (B)		4.46	m
Hydraulic mean depth (A per unit B)	d_m	0.11	m
Froude Number	Fr	0.47	*Subcritical*
Critical depth in channel	h_c	0.07	m
Critical Velocity	v_c	1.04	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.12	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.15	m	Calculated
where freeboard depth is:	F	0.01	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.49	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		4.23	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.15*	*m*	Calculated
	B_i	*4.23*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.75	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.19	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*403.75*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*403.80*	*mAOD*
Upstream Soffit Elevation		*404.50*	*mAOD*
Downstream Pipe Invert Elevation		*402.65*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*402.70*	*mAOD*
Downstream Soffit Elevation		*403.40*	*mAOD*

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Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where

Discharge	Q	0.24	m3/s
Depth / Diameter of barrell	D	0.70	m
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2
Discharge Coefficient	qi	1.52	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a

i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where

Discharge	Q	0.24	m3/s	
Depth / Diameter of barrell	D	0.7	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.34	m2	
Culvert Slope	So	0.11	m/m	1 in 9.09
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.265	m	
Specific Energy at Critical Depth	E_{sc}	0.40	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.37	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where

Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	403.80	mAOD
Specific Energy of Headwater	E_{sh}	0.37	m
Therefore Headwater Elevation:	H_{hic}	404.17	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where

Headwater Elevation:	H_{hic}	404.17	mAOD
Velocity in Upstream Channel	V_{uc}	0.49	m/s
Therefore Water Level at Inlet:	WL_{hic}	404.16	mAOD

Project	Mullaghclogher Wind Farm
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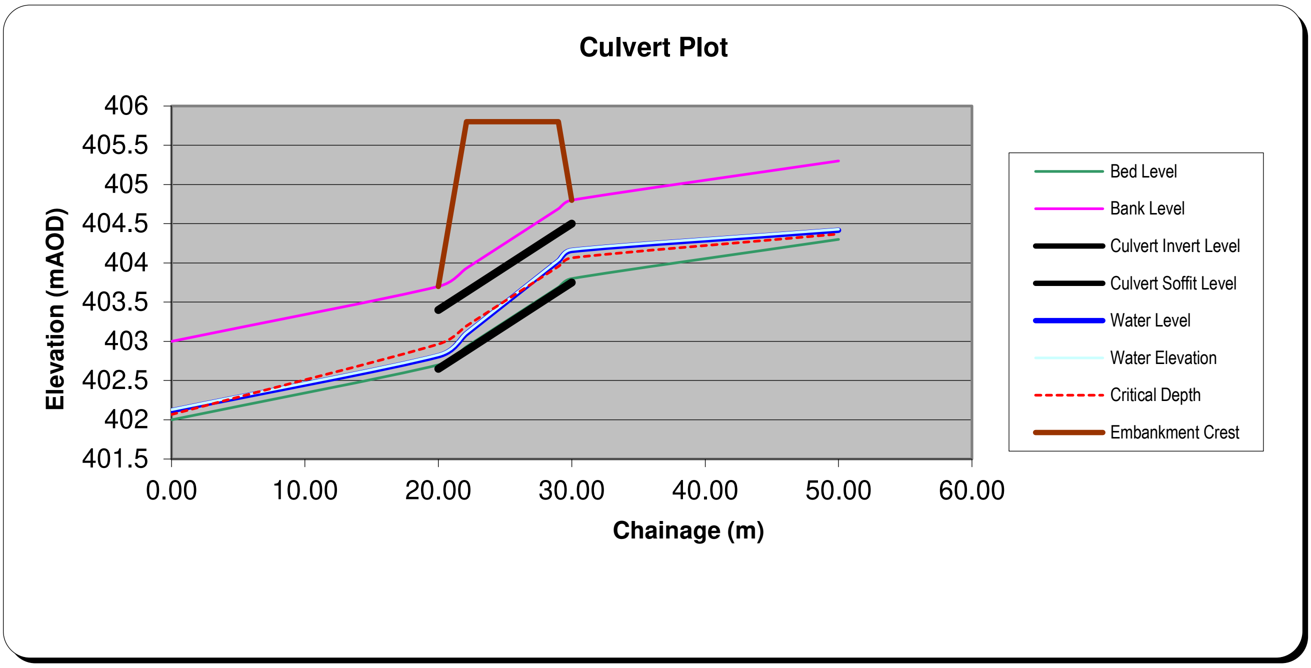
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.75 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	20/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC012		
Coordinates (E/N)		252259	396100	
Function / Description		Track crossing		
Design Discharge Q		***0.11***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		362.8	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		361.4	m AOD	From Survey
Culvert Length		15	m	From Survey
Elevation of Stream bed upstream of Culvert		364	m AOD	From Survey
Distance upstream of Culvert		20	m	From Survey
Elevation of Stream bed downstream of Culvert		360.1	m AOD	From Survey
Distance downstream of Culvert		20	m	From Survey
Elevation of Proposed Embankment Crest		364.8	m AOD	From Survey
Average channel invert width		0.5	m	From Survey
Average channel top of bank width		1	m	From Survey
Average Channel Depth to Bank		0.2	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		362.7	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		363.1	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	16.67	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	15.38	-	Calculated
Bedslope across Culvert 1 in S3	S3	10.71	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	14.10	-	Calculated
Channel Side Slopes 1 in X	X =	1.25	-	Calculated
Upstream Left Over- Bank Slope	Y =	-16.67	-	Calculated
Upstream Right Over- Bank Slope	Z =	50.00	-	Calculated

Calculate Tailwater Depth and Level:

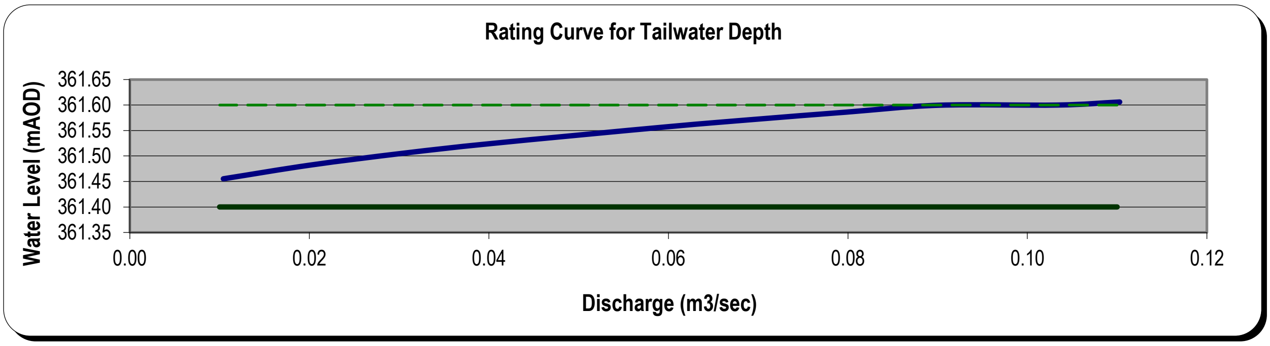
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.21	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	361.61	mAOD	Calculated
	V_{dc}	0.71	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



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Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	361.63	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.16	m2
Top Width (B)		1.20	m
Hydraulic mean depth (A per unit B)	d_m	0.13	m
Froude Number	Fr	0.63	*Subcritical*
Critical depth in channel	h_c	0.13	m
Critical Velocity	v_c	1.13	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.21	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.26	m	Calculated
where freeboard depth is:	F	0.03	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.16	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.76	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.26*	*m*	Calculated
	B_i	*0.76*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.60	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.15	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*362.75*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*362.80*	*mAOD*
Upstream Soffit Elevation		*363.35*	*mAOD*
Downstream Pipe Invert Elevation		*361.35*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*361.40*	*mAOD*
Downstream Soffit Elevation		*361.95*	*mAOD*

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	20/10/2023

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Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.11	m3/s
Depth / Diameter of barrell	D	0.55	m
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2
Discharge Coefficient	qi	1.24	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a

i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where				
Discharge	Q	0.11	m3/s	
Depth / Diameter of barrell	D	0.55	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2	
Culvert Slope	So	0.09	m/m	1 in 10.71
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.182	m	
Specific Energy at Critical Depth	E_{sc}	0.27	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.25	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	362.80	mAOD
Specific Energy of Headwater	E_{sh}	0.25	m
Therefore Headwater Elevation:	H_{hic}	363.05	mAOD

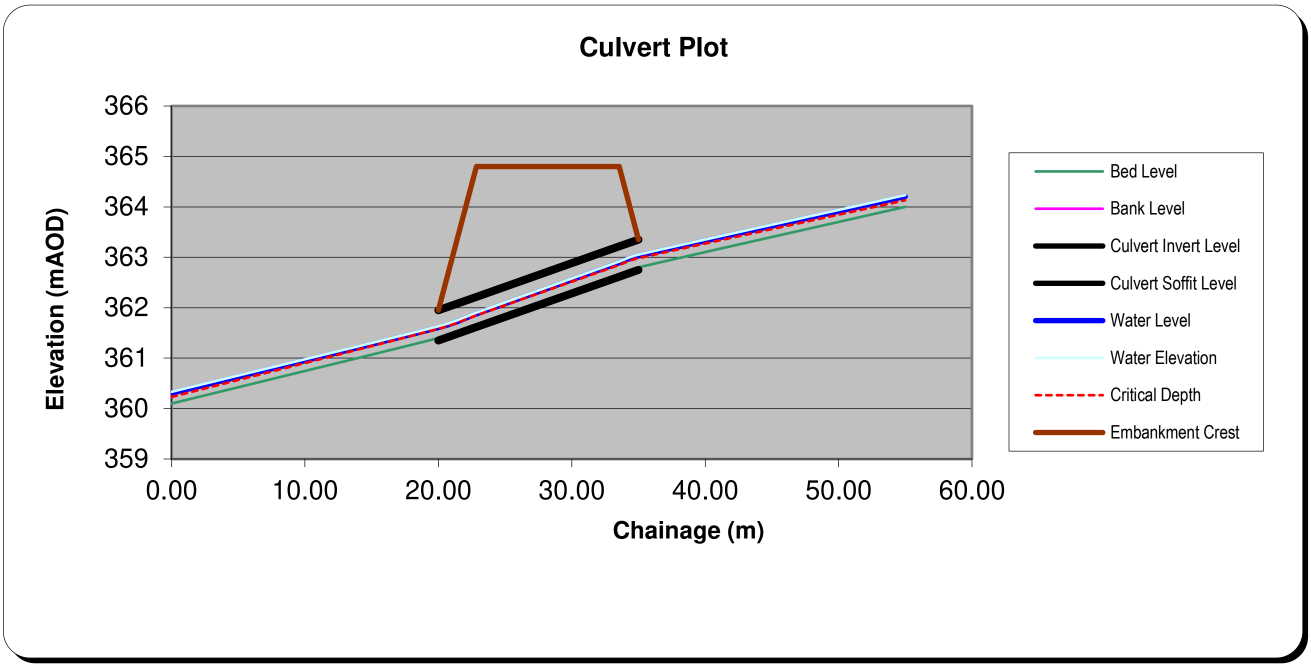
Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	363.05	mAOD
Velocity in Upstream Channel	V_{uc}	0.71	m/s
Therefore Water Level at Inlet:	WL_{hic}	363.03	mAOD

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	20/10/2023

Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.60 m**

By	Checked	Revision	Date
KS	KS	Original	20/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	18/10/2023

McCloy Consulting

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC02		
Coordinates (E/N)		250206	396288	
Function / Description		Track crossing		
Design Discharge Q		***0.56***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		235.8	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		234.8	m AOD	From Survey
Culvert Length		15	m	From Survey
Elevation of Stream bed upstream of Culvert		237.16	m AOD	From Survey
Distance upstream of Culvert		20	m	From Survey
Elevation of Stream bed downstream of Culvert		233.9	m AOD	From Survey
Distance downstream of Culvert		20	m	From Survey
Elevation of Proposed Embankment Crest		237.8	m AOD	From Survey
Average channel invert width		1	m	From Survey
Average channel top of bank width		1	m	From Survey
Average Channel Depth to Bank		0.2	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		236.2	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		236.1	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	14.71	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	22.22	-	Calculated
Bedslope across Culvert 1 in S3	S3	15.00	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	16.87	-	Calculated
Channel Side Slopes 1 in X	X =	0.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	25.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	50.00	-	Calculated

Calculate Tailwater Depth and Level:

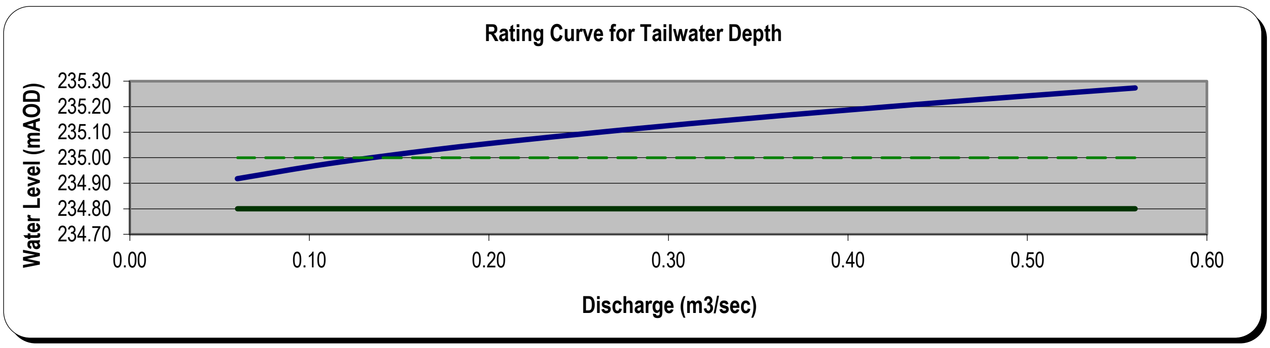
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.47	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	235.27	mAOD	Calculated
	V_{dc}	1.18	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V^2_{dc}}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	235.35	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.48	m2	
Top Width (B)		21.52	m	
Hydraulic mean depth (A per unit B)	d_m	0.02	m	
Froude Number	Fr	2.53	*Supercritical*	
Critical depth in channel	h_c	0.28	m	
Critical Velocity	v_c	0.47	m/s	

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.47	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.59	m	Calculated
where freeboard depth is:	F	0.06	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.48	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		1.00	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.59*	*m*	Calculated
	B_i	*1.00*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.90	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.23	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*235.75*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*235.80*	*mAOD*
Upstream Soffit Elevation		*236.65*	*mAOD*
Downstream Pipe Invert Elevation		*234.75*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*234.80*	*mAOD*
Downstream Soffit Elevation		*235.65*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where

Discharge	Q	0.56	m3/s
Depth / Diameter of barrell	D	0.85	m
Culvert cross section area excl. freeboard + siltation	Ab	0.50	m2
Discharge Coefficient	qi	2.21	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where

Discharge	Q	0.56	m3/s	
Depth / Diameter of barrell	D	0.85	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.50	m2	
Culvert Slope	So	0.07	m/m	1 in 15
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.403	m	
Specific Energy at Critical Depth	E_{sc}	0.60	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.61	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where

Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	235.80	mAOD
Specific Energy of Headwater	E_{sh}	0.61	m
Therefore Headwater Elevation:	H_{hic}	236.41	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where

Headwater Elevation:	H_{hic}	236.41	mAOD
Velocity in Upstream Channel	V_{uc}	1.18	m/s
Therefore Water Level at Inlet:	WL_{hic}	236.34	mAOD

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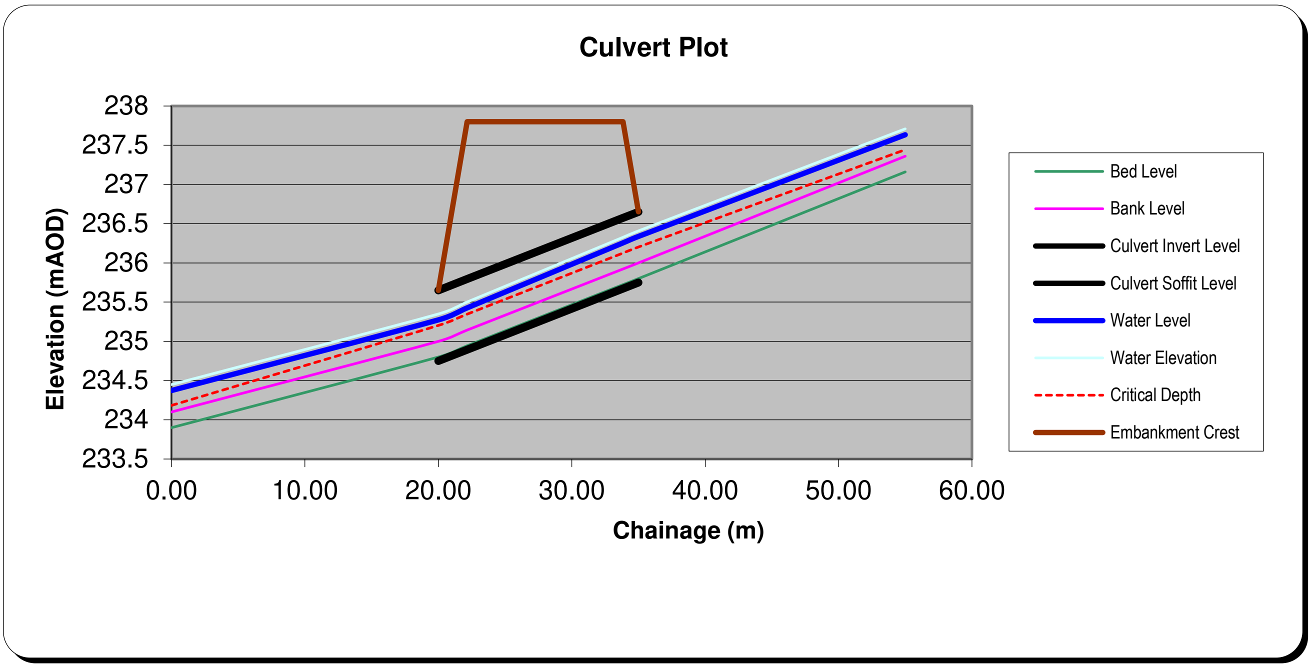
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.90 m**

By	Checked	Revision	Date
KS	KS	Original	18/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC03D		
Coordinates (E/N)		250149 396193		
Function / Description		Track crossing (on realigned channel)		
Design Discharge Q		***0.56***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		242.9	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		241.9	m AOD	From Survey
Culvert Length		15	m	From Survey
Elevation of Stream bed upstream of Culvert		243.5	m AOD	From Survey
Distance upstream of Culvert		20	m	From Survey
Elevation of Stream bed downstream of Culvert		240.4	m AOD	From Survey
Distance downstream of Culvert		20	m	From Survey
Elevation of Proposed Embankment Crest		244.9	m AOD	From Survey
Average channel invert width		0.6	m	From Survey
Average channel top of bank width		0.8	m	From Survey
Average Channel Depth to Bank		0.5	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		244	m AOD	From Survey
Distance from bank		10	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		244	m AOD	From Survey
Distance from bank		10	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	33.33	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	13.33	-	Calculated
Bedslope across Culvert 1 in S3	S3	15.00	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	17.74	-	Calculated
Channel Side Slopes 1 in X	X =	0.20	-	Calculated
Upstream Left Over- Bank Slope	Y =	16.67	-	Calculated
Upstream Right Over- Bank Slope	Z =	16.67	-	Calculated

Calculate Tailwater Depth and Level:

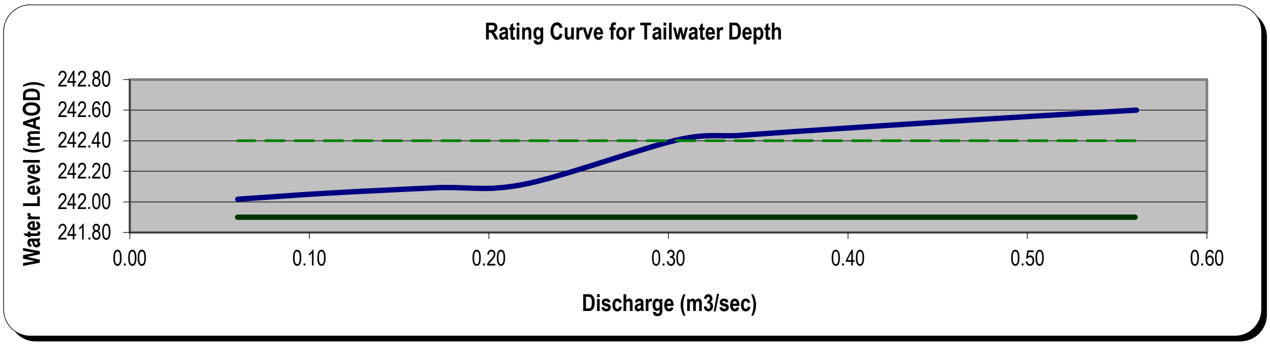
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.70	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	242.60	mAOD	Calculated
	V_{dc}	1.09	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	242.67	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.51	m2	
Top Width (B)		7.47	m	
Hydraulic mean depth (A per unit B)	d_m	0.07	m	
Froude Number	Fr	1.33	*Supercritical*	
Critical depth in channel	h_c	0.38	m	
Critical Velocity	v_c	0.82	m/s	

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.70	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.88	m	Calculated
where freeboard depth is:	F	0.09	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.51	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.73	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.88*	*m*	Calculated
	B_i	*0.73*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.90	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.23	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*242.85*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*242.90*	*mAOD*
Upstream Soffit Elevation		*243.75*	*mAOD*
Downstream Pipe Invert Elevation		*241.85*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*241.90*	*mAOD*
Downstream Soffit Elevation		*242.75*	*mAOD*

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Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.56	m3/s
Depth / Diameter of barrell	D	0.85	m
Culvert cross section area excl. freeboard + siltation	Ab	0.50	m2
Discharge Coefficient	qi	2.21	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a

i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where	Discharge	Q	0.56	m3/s	
	Depth / Diameter of barrell	D	0.85	m	
	Unsubmerged analysis constant	k	0.0078		Table A1.3
	Unsubmerged analysis constant	M	2		Table A1.3
	Culvert cross section area excl. freeboard + siltation	Ab	0.50	m2	
	Culvert Slope	So	0.07	m/m	1 in 15
$\frac{Q^2 W}{gA^3} = 1$	Critical depth calculated as:	y_c	0.403	m	
	Specific Energy at Critical Depth	E_{sc}	0.60	m	
$E_{sc} = \frac{3}{2} y_c$	Therefore Specific Energy of Headwater	E_{sh}	0.61	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	242.90	mAOD
Specific Energy of Headwater	E_{sh}	0.61	m
Therefore Headwater Elevation:	H_{hic}	243.51	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	243.51	mAOD
Velocity in Upstream Channel	V_{uc}	1.09	m/s
Therefore Water Level at Inlet:	WL_{hic}	243.45	mAOD

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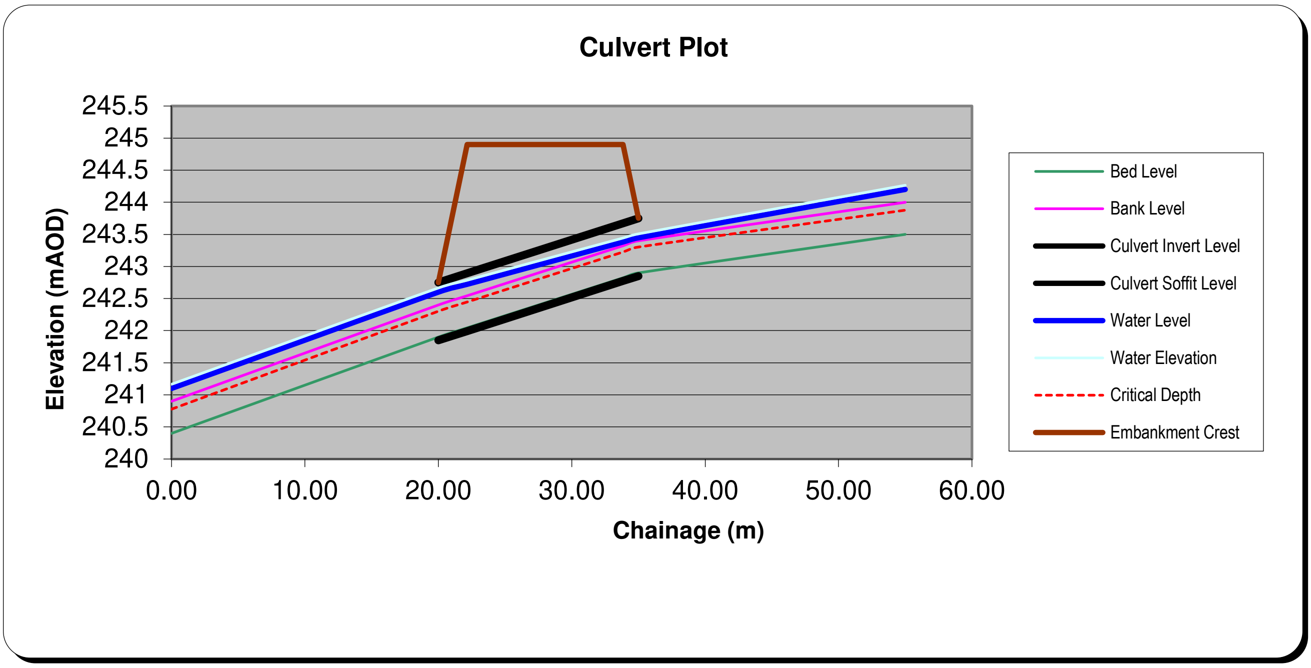
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: 1 nr Diameter 0.90 m

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
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Date	19/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC04		
Coordinates (E/N)		250510	395725	
Function / Description		Track crossing		
Design Discharge Q		***0.24***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		294.9	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		294.1	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		296.7	m AOD	From Survey
Distance upstream of Culvert		40	m	From Survey
Elevation of Stream bed downstream of Culvert		290.9	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		297.9	m AOD	From Survey
Average channel invert width		0.5	m	From Survey
Average channel top of bank width		0.5	m	From Survey
Average Channel Depth to Bank		0.2	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		296	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		296	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	22.22	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	12.50	-	Calculated
Bedslope across Culvert 1 in S3	S3	12.50	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	15.52	-	Calculated
Channel Side Slopes 1 in X	X =	0.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	5.56	-	Calculated
Upstream Right Over- Bank Slope	Z =	5.56	-	Calculated

Calculate Tailwater Depth and Level:

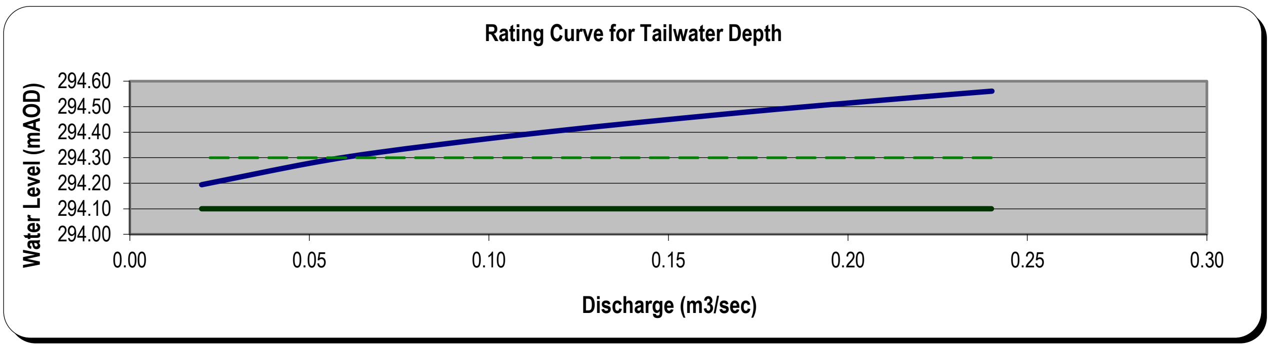
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.46	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	294.56	mAOD	Calculated
	V_{dc}	0.99	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V^2_{dc}}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	294.61	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.24	m2	
Top Width (B)		3.40	m	
Hydraulic mean depth (A per unit B)	d_m	0.07	m	
Froude Number	Fr	1.18	*Supercritical*	
Critical depth in channel	h_c	0.28	m	
Critical Velocity	v_c	0.84	m/s	

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.46	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.58	m	Calculated
where freeboard depth is:	F	0.06	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.24	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.53	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.58*	*m*	Calculated
	B_i	*0.53*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.60	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.15	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*294.85*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*294.90*	*mAOD*
Upstream Soffit Elevation		*295.45*	*mAOD*
Downstream Pipe Invert Elevation		*294.05*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*294.10*	*mAOD*
Downstream Soffit Elevation		*294.65*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.24	m3/s
Depth / Diameter of barrell	D	0.55	m
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2
Discharge Coefficient	qi	2.71	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a

i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where Discharge	Q	0.24	m3/s	
Depth / Diameter of barrell	D	0.55	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2	
Culvert Slope	So	0.08	m/m	1 in 12.5
$\frac{Q^2 W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.286	m	
Specific Energy at Critical Depth	E_{sc}	0.43	m	
$E_{sc} = \frac{3}{2} y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.44	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	294.90	mAOD
Specific Energy of Headwater	E_{sh}	0.44	m
Therefore Headwater Elevation:	H_{hic}	295.34	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	295.34	mAOD
Velocity in Upstream Channel	V_{uc}	0.99	m/s
Therefore Water Level at Inlet:	WL_{hic}	295.29	mAOD

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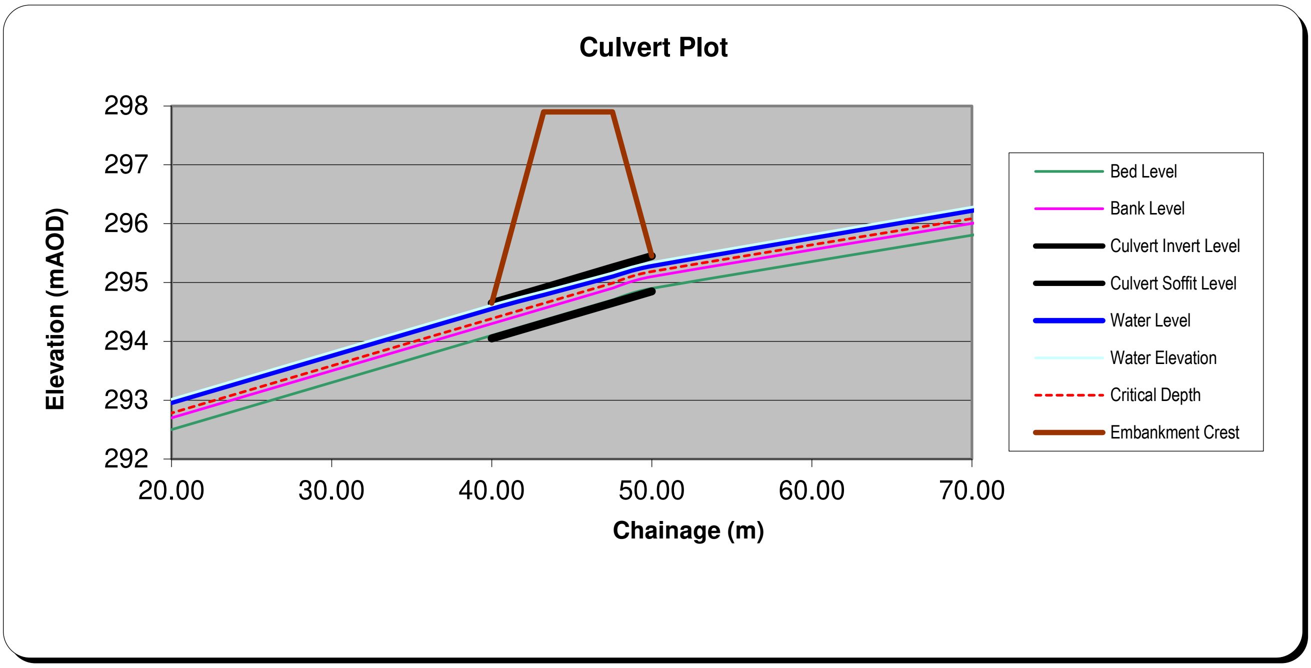
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.60 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	19/10/2023

McCloy Consulting

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC05D		
Coordinates (E/N)		250149	396193	
Function / Description		Track crossing		
Design Discharge Q		***0.16***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		302.6	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		301.9	m AOD	From Survey
Culvert Length		15	m	From Survey
Elevation of Stream bed upstream of Culvert		305	m AOD	From Survey
Distance upstream of Culvert		20	m	From Survey
Elevation of Stream bed downstream of Culvert		301.1	m AOD	From Survey
Distance downstream of Culvert		20	m	From Survey
Elevation of Proposed Embankment Crest		304.6	m AOD	From Survey
Average channel invert width		0.5	m	From Survey
Average channel top of bank width		0.5	m	From Survey
Average Channel Depth to Bank		0.2	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		302.9	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		302.7	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	8.33	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	25.00	-	Calculated
Bedslope across Culvert 1 in S3	S3	21.43	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	14.10	-	Calculated
Channel Side Slopes 1 in X	X =	0.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	50.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	-50.00	-	Calculated

Calculate Tailwater Depth and Level:

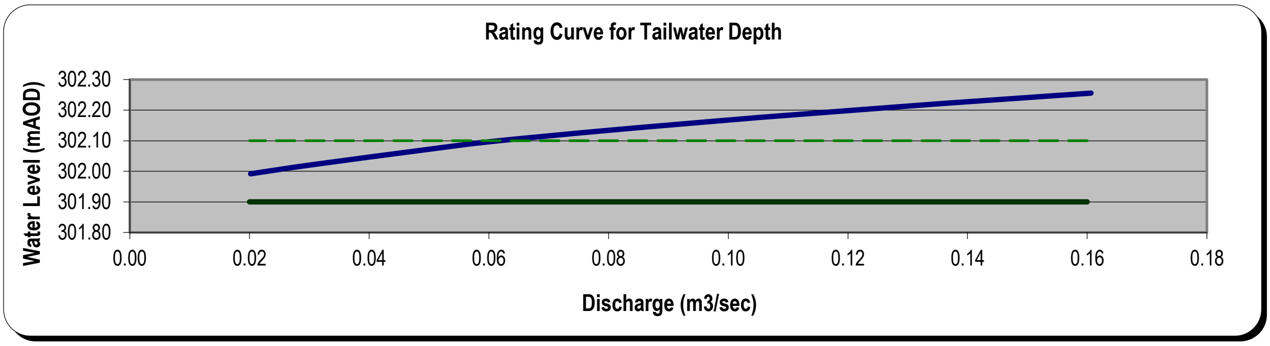
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.36	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	302.26	mAOD	Calculated
	V_{dc}	0.90	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



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Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	302.30	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.18	m2
Top Width (B)		0.50	m
Hydraulic mean depth (A per unit B)	d_m	0.36	m
Froude Number	Fr	0.48	*Subcritical*
Critical depth in channel	h_c	0.21	m
Critical Velocity	v_c	1.87	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.36	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.44	m	Calculated
where freeboard depth is:	F	0.04	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.18	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.50	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.44*	*m*	Calculated
	B_i	*0.50*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.60	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.15	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*302.55*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*302.60*	*mAOD*
Upstream Soffit Elevation		*303.15*	*mAOD*
Downstream Pipe Invert Elevation		*301.85*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*301.90*	*mAOD*
Downstream Soffit Elevation		*302.45*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where

Discharge	Q	0.16	m3/s
Depth / Diameter of barrell	D	0.55	m
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2
Discharge Coefficient	qi	1.81	n/a
Discharge intensity classification is:	Free Flow Inlet Control		

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where

Discharge	Q	0.16	m3/s	
Depth / Diameter of barrell	D	0.55	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2	
Culvert Slope	So	0.05	m/m	1 in 21.43
$\frac{Q^2 W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.226	m	
Specific Energy at Critical Depth	E_{sc}	0.34	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.34	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where

Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	302.60	mAOD
Specific Energy of Headwater	E_{sh}	0.34	m
Therefore Headwater Elevation:	H_{hic}	302.94	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where

Headwater Elevation:	H_{hic}	302.94	mAOD
Velocity in Upstream Channel	V_{uc}	0.90	m/s
Therefore Water Level at Inlet:	WL_{hic}	302.90	mAOD

Project	Mullaghclogher Wind Farm
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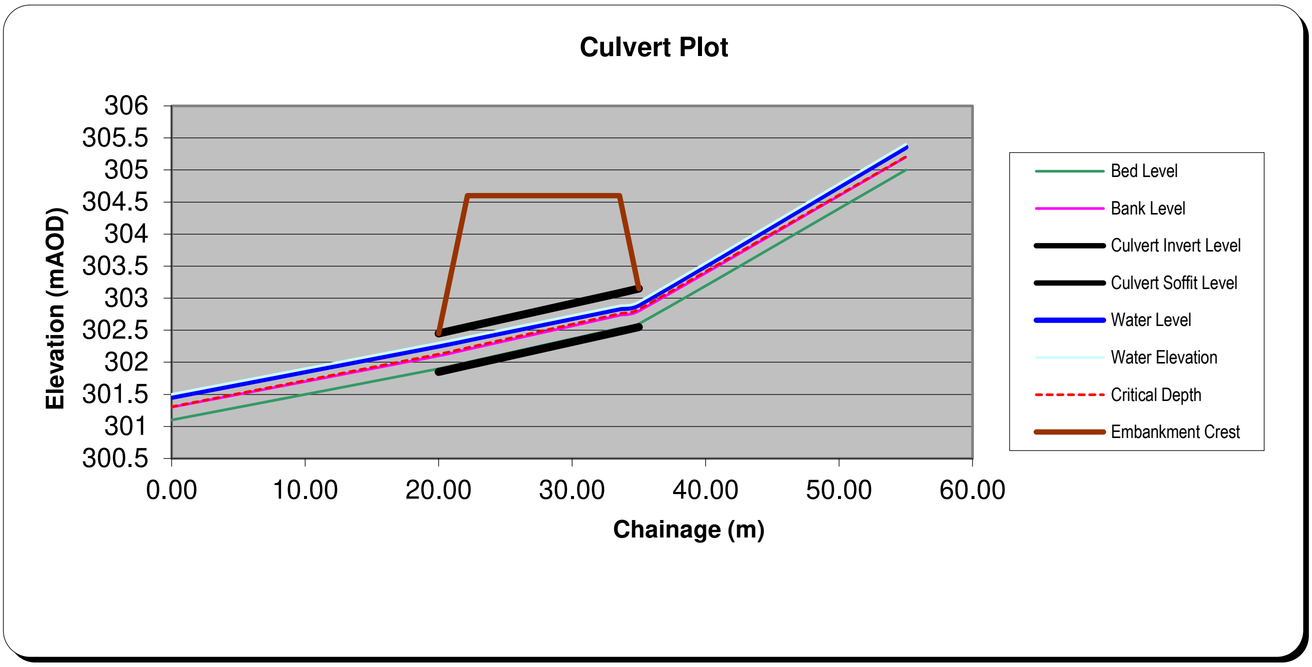
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.60 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	19/10/2023

McCloy Consulting

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC06		
Coordinates (E/N)		250570	395658	
Function / Description		Track crossing		
Design Discharge Q		***1.75***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		295.8	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		294.5	m AOD	From Survey
Culvert Length		15	m	From Survey
Elevation of Stream bed upstream of Culvert		299.3	m AOD	From Survey
Distance upstream of Culvert		40	m	From Survey
Elevation of Stream bed downstream of Culvert		291.8	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		297.8	m AOD	From Survey
Average channel invert width		1.6	m	From Survey
Average channel top of bank width		2	m	From Survey
Average Channel Depth to Bank		0.4	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		296.3	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		296.4	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	11.43	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	14.81	-	Calculated
Bedslope across Culvert 1 in S3	S3	11.54	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	12.67	-	Calculated
Channel Side Slopes 1 in X	X =	0.50	-	Calculated
Upstream Left Over- Bank Slope	Y =	50.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	25.00	-	Calculated

Calculate Tailwater Depth and Level:

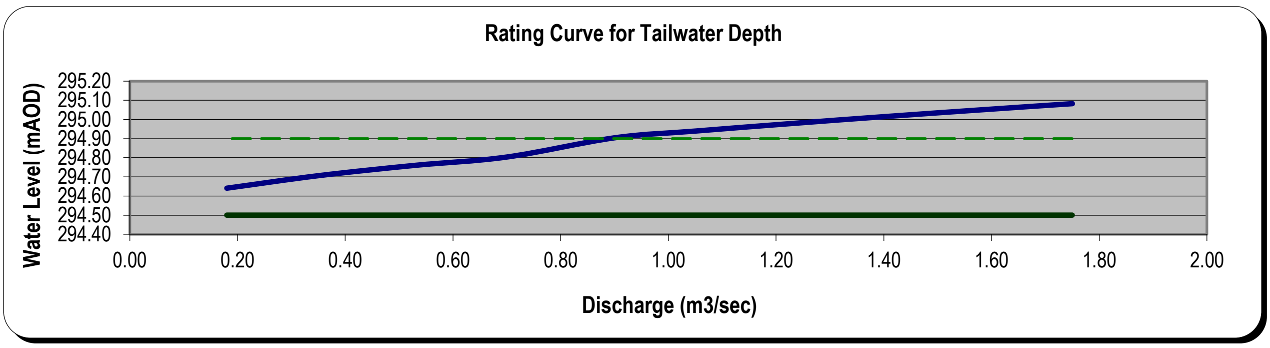
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.58	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	295.08	mAOD	Calculated
	V_{dc}	1.61	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	295.22	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		1.09	m2
Top Width (B)		15.69	m
Hydraulic mean depth (A per unit B)	d_m	0.07	m
Froude Number	Fr	1.96	*Supercritical*
Critical depth in channel	h_c	0.37	m
Critical Velocity	v_c	0.82	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.58	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.73	m	Calculated
where freeboard depth is:	F	0.07	m	Calculated
Area required as per tailwater fllow calculation:	A_t	1.09	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		1.86	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.73*	*m*	Calculated
	B_i	*1.86*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	1.35	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.30	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*295.75*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*295.80*	*mAOD*
Upstream Soffit Elevation		*297.10*	*mAOD*
Downstream Pipe Invert Elevation		*294.45*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*294.50*	*mAOD*
Downstream Soffit Elevation		*295.80*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	1.75	m3/s
Depth / Diameter of barrell	D	1.30	m
Culvert cross section area excl. freeboard + siltation	Ab	1.18	m2
Discharge Coefficient	qi	2.36	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where Discharge	Q	1.75	m3/s	
Depth / Diameter of barrell	D	1.3	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	1.18	m2	
Culvert Slope	So	0.09	m/m	1 in 11.54
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.663	m	
Specific Energy at Critical Depth	E_{sc}	0.99	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	1.00	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	295.80	mAOD
Specific Energy of Headwater	E_{sh}	1.00	m
Therefore Headwater Elevation:	H_{hic}	296.80	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	296.80	mAOD
Velocity in Upstream Channel	V_{uc}	1.61	m/s
Therefore Water Level at Inlet:	WL_{hic}	296.66	mAOD

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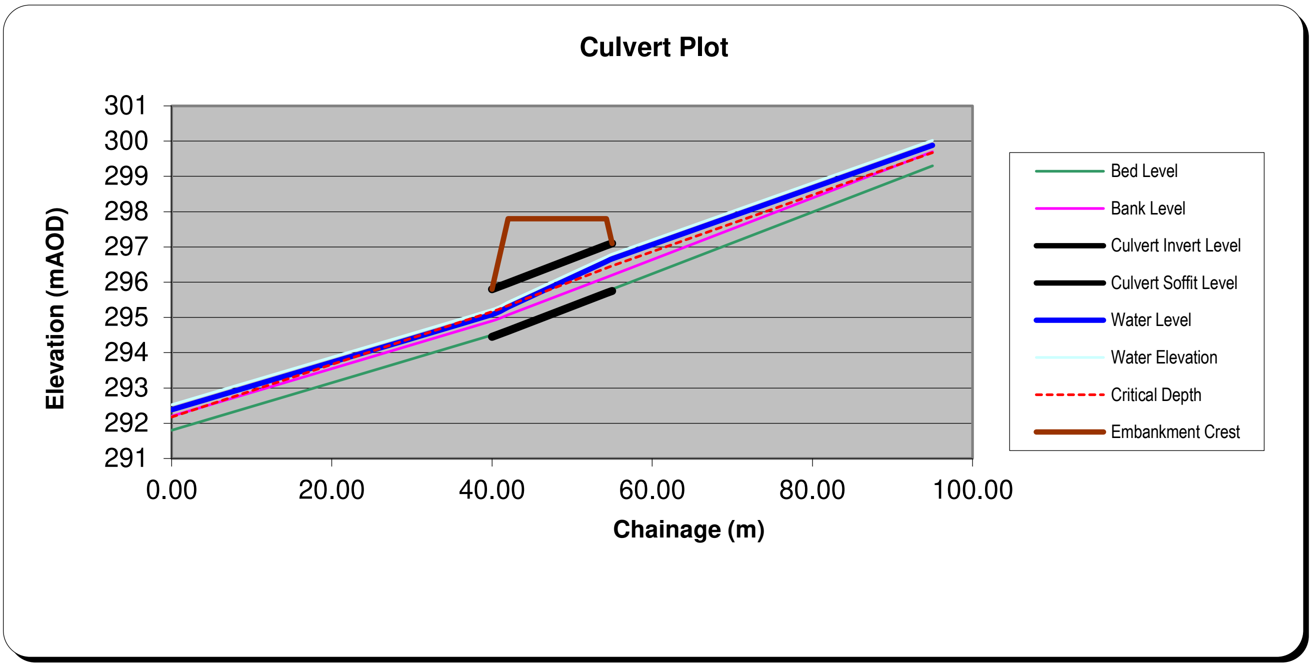
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **1.35 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	19/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC07		
Coordinates (E/N)		251040	395901	
Function / Description		Track crossing		
Design Discharge Q		***0.2***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		294.7	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		293.2	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		301.8	m AOD	From Survey
Distance upstream of Culvert		40	m	From Survey
Elevation of Stream bed downstream of Culvert		287.4	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		296.7	m AOD	From Survey
Average channel invert width		0.5	m	From Survey
Average channel top of bank width		0.5	m	From Survey
Average Channel Depth to Bank		0.3	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		295.4	m AOD	From Survey
Distance from bank		5	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		294.6	m AOD	From Survey
Distance from bank		5	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	5.63	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	6.90	-	Calculated
Bedslope across Culvert 1 in S3	S3	6.67	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	6.25	-	Calculated
Channel Side Slopes 1 in X	X =	0.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	12.50	-	Calculated
Upstream Right Over- Bank Slope	Z =	-12.50	-	Calculated

Calculate Tailwater Depth and Level:

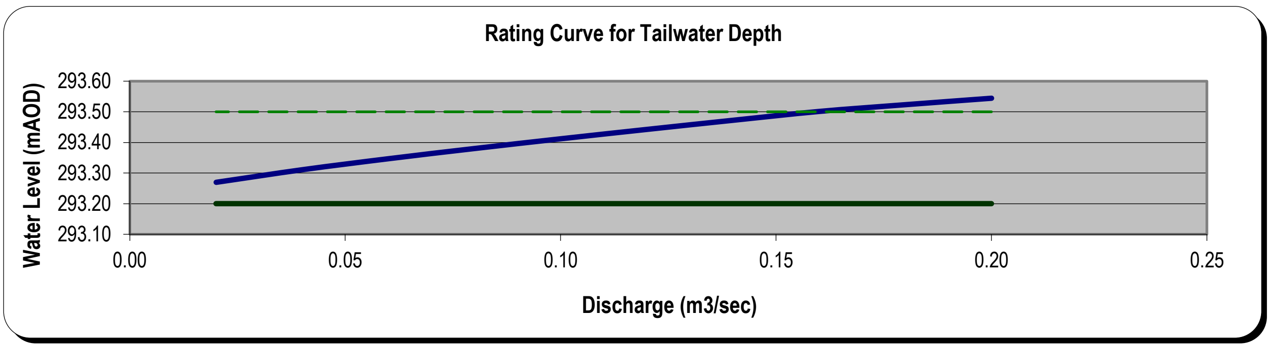
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.34	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	293.54	mAOD	Calculated
	V_{dc}	1.16	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	293.62	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.17	m2
Top Width (B)		0.50	m
Hydraulic mean depth (A per unit B)	d_m	0.34	m
Froude Number	Fr	0.63	*Subcritical*
Critical depth in channel	h_c	0.21	m
Critical Velocity	v_c	1.84	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.34	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.43	m	Calculated
where freeboard depth is:	F	0.04	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.17	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.50	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.43*	*m*	Calculated
	B_i	*0.50*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.60	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.15	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*294.65*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*294.70*	*mAOD*
Upstream Soffit Elevation		*295.25*	*mAOD*
Downstream Pipe Invert Elevation		*293.15*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*293.20*	*mAOD*
Downstream Soffit Elevation		*293.75*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.2	m3/s
Depth / Diameter of barrell	D	0.55	m
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2
Discharge Coefficient	qi	2.26	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where				
Discharge	Q	0.2	m3/s	
Depth / Diameter of barrell	D	0.55	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2	
Culvert Slope	So	0.15	m/m	1 in 6.67
$\frac{Q^2 W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.258	m	
Specific Energy at Critical Depth	E_{sc}	0.39	m	
$E_{sc} = \frac{3}{2} y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.37	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	294.70	mAOD
Specific Energy of Headwater	E_{sh}	0.37	m
Therefore Headwater Elevation:	H_{hic}	295.07	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	295.07	mAOD
Velocity in Upstream Channel	V_{uc}	1.16	m/s
Therefore Water Level at Inlet:	WL_{hic}	295.00	mAOD

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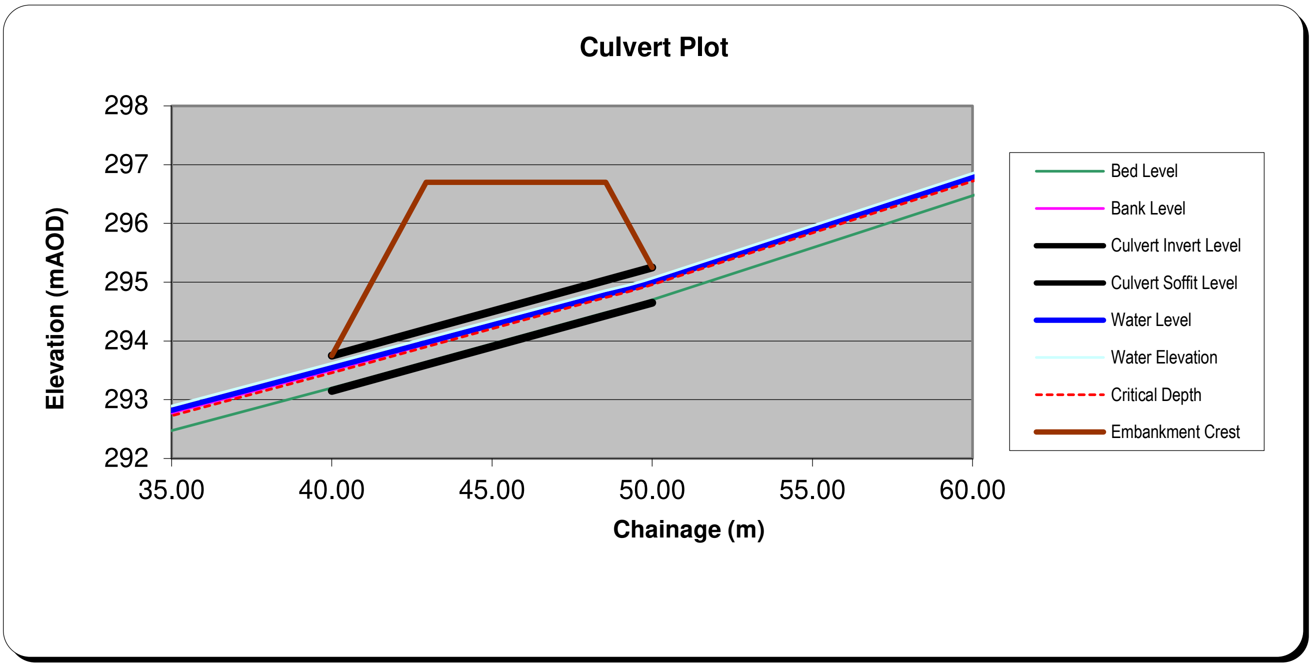
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.60 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm	
Ref	M01616-26	
Date	19/10/2023	

McCloy Consulting

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC08		
Coordinates (E/N)		251264	396011	
Function / Description		Track crossing		
Design Discharge Q		***0.99***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		306.8	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		304.4	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		315.8	m AOD	From Survey
Distance upstream of Culvert		40	m	From Survey
Elevation of Stream bed downstream of Culvert		293.9	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		308.8	m AOD	From Survey
Average channel invert width		5	m	From Survey
Average channel top of bank width		6	m	From Survey
Average Channel Depth to Bank		0.5	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		308	m AOD	From Survey
Distance from bank		10	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		308	m AOD	From Survey
Distance from bank		10	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	4.44	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	3.81	-	Calculated
Bedslope across Culvert 1 in S3	S3	4.17	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	4.11	-	Calculated
Channel Side Slopes 1 in X	X =	1.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	14.29	-	Calculated
Upstream Right Over- Bank Slope	Z =	14.29	-	Calculated

Calculate Tailwater Depth and Level:

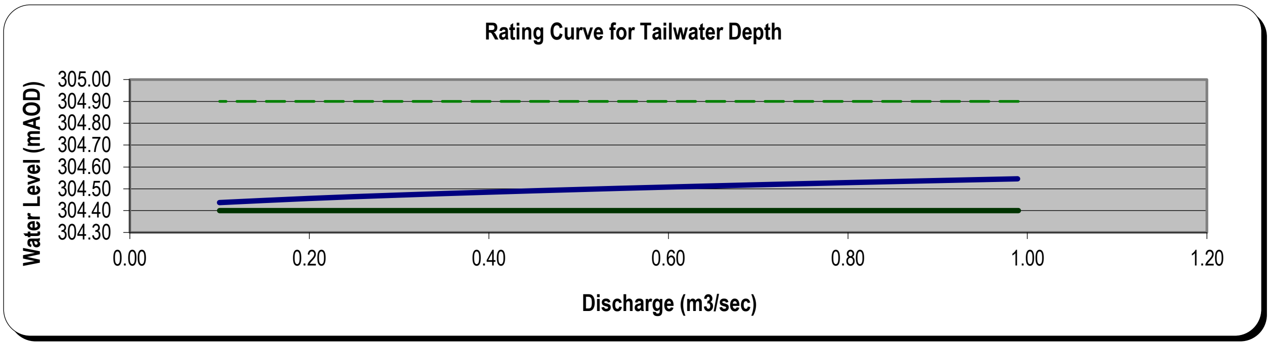
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Discharge Contained in Channel, Depth of Normal Flow Considered

Depth of water in channel is	y_{dc}	0.15	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	304.55	mAOD	Calculated
	V_{dc}	1.32	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	304.64	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.75	m2
Top Width (B)		5.29	m
Hydraulic mean depth (A per unit B)	d_m	0.14	m
Froude Number	Fr	1.12	*Supercritical*
Critical depth in channel	h_c	0.12	m
Critical Velocity	v_c	1.18	m/s

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.15	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.18	m	Calculated
where freeboard depth is:	F	0.02	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.75	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		5.15	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.18*	*m*	Calculated
	B_i	*5.15*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	1.05	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.18	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*306.75*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*306.80*	*mAOD*
Upstream Soffit Elevation		*307.80*	*mAOD*
Downstream Pipe Invert Elevation		*304.35*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*304.40*	*mAOD*
Downstream Soffit Elevation		*305.40*	*mAOD*

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.99	m3/s
Depth / Diameter of barrell	D	1.00	m
Culvert cross section area excl. freeboard + siltation	Ab	0.76	m2
Discharge Coefficient	qi	2.37	n/a
Discharge intensity classification is:		Free Flow Inlet Control	

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is Nr 2 n/a
i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where Discharge	Q	0.99	m3/s	
Depth / Diameter of barrell	D	1	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.76	m2	
Culvert Slope	So	0.24	m/m	1 in 4.17
$\frac{Q^2 W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.526	m	
Specific Energy at Critical Depth	E_{sc}	0.79	m	
$E_{sc} = \frac{3}{2} y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.71	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	306.80	mAOD
Specific Energy of Headwater	E_{sh}	0.71	m
Therefore Headwater Elevation:	H_{hic}	307.51	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	307.51	mAOD
Velocity in Upstream Channel	V_{uc}	1.32	m/s
Therefore Water Level at Inlet:	WL_{hic}	307.42	mAOD

Project Mullaghclogher Wind Farm
Ref M01616-26
Date 19/10/2023

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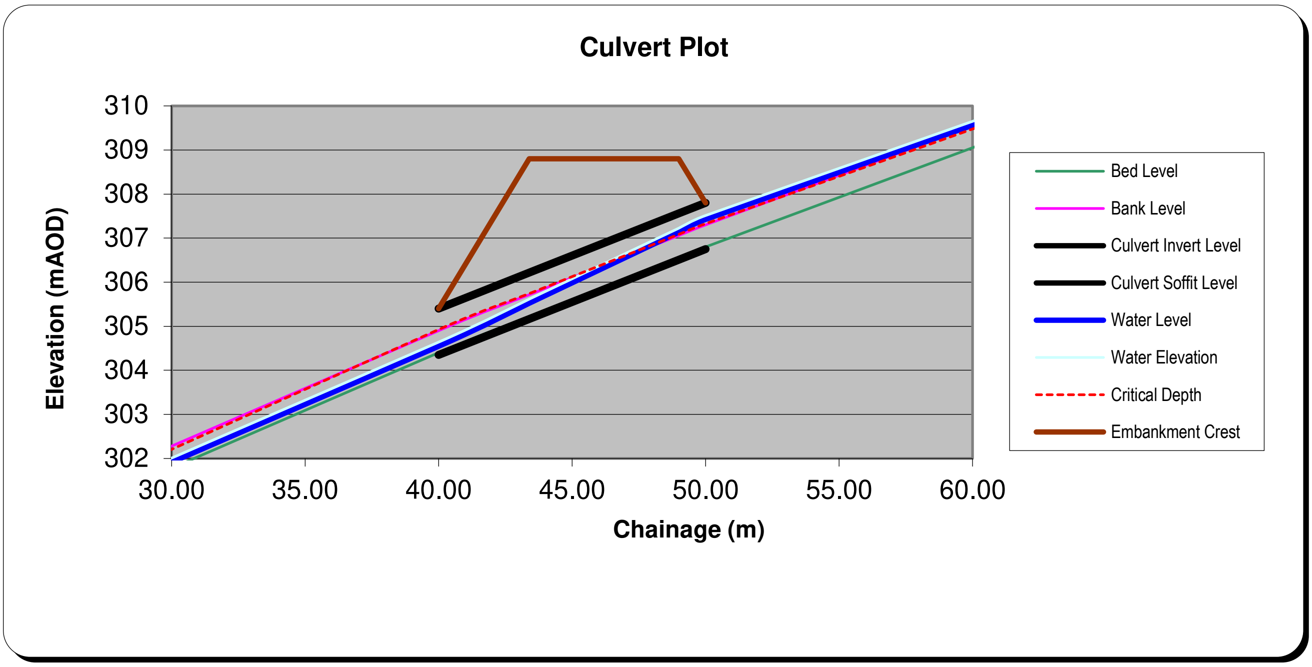
Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **1.05 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023

Project	Mullaghclogher Wind Farm
Ref	M01616-26
Date	19/10/2023

Purpose

To determine the adequacy of hydraulic capacity for culverts in accordance with the requirements of CIRIA C689

Input Data:

Culvert Ref:		WC09		
Coordinates (E/N)		251495	396121	
Function / Description		Track crossing		
Design Discharge Q		***0.25***	***m3/sec***	As per Hydrological Analysis
Design Return Period		*100+CC*	*Yrs*	As per LA requirement
Elevation of Stream Bed @ Culvert Inlet		318.5	m AOD	From Survey
Elevation of Stream Bed @ Culvert Outlet		316.42	m AOD	From Survey
Culvert Length		10	m	From Survey
Elevation of Stream bed upstream of Culvert		325.7	m AOD	From Survey
Distance upstream of Culvert		40	m	From Survey
Elevation of Stream bed downstream of Culvert		309.6	m AOD	From Survey
Distance downstream of Culvert		40	m	From Survey
Elevation of Proposed Embankment Crest		320.5	m AOD	From Survey
Average channel invert width		0.4	m	From Survey
Average channel top of bank width		0.4	m	From Survey
Average Channel Depth to Bank		0.2	m	From Survey
Left Over-Bank Ground Level (Floodplain) (Culvert Inlet)		318.6	m AOD	From Survey
Distance from bank		10	m	From Survey
Right Over-Bank Ground Level (Floodplain) (Culvert Inlet)		318.8	m AOD	From Survey
Distance from bank		10	m	From Survey
Mannings n - Channel		0.1		From C689 Table A1.1
Mannings n - Overbanks		0.06		From C689 Table A1.1
Bedslope upstream of Culvert 1 in S1	S1	5.56	-	Calculated
Bedslope downstream of Culvert 1 in S2	S2	5.87	-	Calculated
Bedslope across Culvert 1 in S3	S3	4.81	-	Calculated
Bedslope across whole reach considered 1 in S4	S4	5.59	-	Calculated
Channel Side Slopes 1 in X	X =	0.00	-	Calculated
Upstream Left Over- Bank Slope	Y =	-100.00	-	Calculated
Upstream Right Over- Bank Slope	Z =	100.00	-	Calculated

Calculate Tailwater Depth and Level:

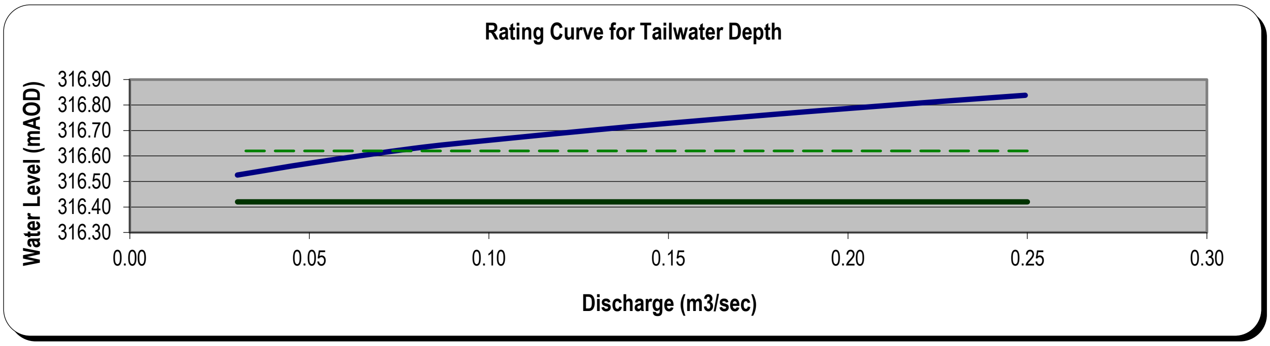
Mannings Equation:

$$Q = VA = \left(\frac{1.00}{n}\right) A R^{\frac{2}{3}} \sqrt{S} \quad [SI] \qquad R_h = \frac{A}{P}$$

Channel Capacity < Discharge, Out of Bank Flooding Considered

Depth of water in channel is	y_{dc}	0.42	m	Calculated
Therefore water level at downstream extent of culvert i	WL_t	316.84	mAOD	Calculated
	V_{dc}	1.49	m/s	Calculated

Rating Curve for Tailwater Channel Discharge



Calculate Tailwater Elevation (Total Head) Ht:

$$H_t = Z_{bo} + y_{dc} + \frac{V_{dc}^2}{2g}$$

Where: Z_{bo} Elevation @ Culvert Outlet
y_{dc} Water depth in downstream channel
V_{dc} Velocity in downstream channel

Tailwater Elevation:	H_t	316.96	mAOD	Calculated

Calculate Froude No.

Cross Sectional Area (A)		0.17	m2	
Top Width (B)		0.40	m	
Hydraulic mean depth (A per unit B)	d_m	0.42	m	
Froude Number	Fr	0.74	*Subcritical*	
Critical depth in channel	h_c	0.27	m	
Critical Velocity	v_c	2.03	m/s	

Initial Design

Initial Estimate of required culvert cross sectional area required. Analysis is based on new culvert, therefore design should allow for freeflow conditions. Applicable method is Flow Area Method

Flow Area Method - refer to C689 Section 6.7.1

Depth; Min. Tailwater depth	D	0.42	m	Calculated
Assume 20% Initial loss of culvert height due to Freeboard / S		0.52	m	Calculated
where freeboard depth is:	F	0.05	m	Calculated
Area required as per tailwater fllow calculation:	A_t	0.17	m2	Calculated
Nominal width (Area / Depth (not inc. freeboard):		0.40	m	Calculated
Therefore prelim culvert dimensions (incl freeboard + si	D_i	*0.52*	*m*	Calculated
	B_i	*0.40*	*m*	Calculated

Detailed Design

Try Culvert dimensions...

Based on previous Initial Design

Height / Diameter	D	0.60	m	
Breadth (BLANK IF CIRCULAR)	B		m	
Number of Culverts	nr	1	n/a	
Shape		CIRCULAR		
Freeboard		0.15	m	As per CIRIA Guidance
Siltation / Depth lowered below ex. stream invert		0.05	m	Manually Entered Value

Therefore:

Upstream Pipe Invert		*318.45*	*mAOD*
Upstream Pipe Base (w/Silt)Elevation	Z_i	*318.50*	*mAOD*
Upstream Soffit Elevation		*319.05*	*mAOD*
Downstream Pipe Invert Elevation		*316.37*	*mAOD*
Downstream Pipe Base (w/ Silt) Elevation	Z_o	*316.42*	*mAOD*
Downstream Soffit Elevation		*316.97*	*mAOD*

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McCloy Consulting

Calculation of Discharge Intensity

$$q_i = \frac{1.811Q}{A_b D^{0.5}}$$

Where			
Discharge	Q	0.25	m3/s
Depth / Diameter of barrell	D	0.55	m
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2
Discharge Coefficient	qi	2.83	n/a
Discharge intensity classification is:	Free Flow Inlet Control		

Calculation of headwater depth for free flow inlet control

Based on Table A1.3, Culvert type is	Nr	2	n/a

i.e, Circular concrete pipe; Headwall, socket end of pipe

$$\frac{E_{sh}}{D} = \frac{E_{sc}}{D} + k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M - 0.5S_0$$ Eqn 6.23

$$\frac{E_{sh}}{D} = k\left[\frac{1.811Q}{A_b D^{0.5}}\right]^M$$ Eqn 6.25

Therefore applicable CIRIA C689 equation reference: Equation 6.23

Where Discharge	Q	0.25	m3/s	
Depth / Diameter of barrell	D	0.55	m	
Unsubmerged analysis constant	k	0.0078		Table A1.3
Unsubmerged analysis constant	M	2		Table A1.3
Culvert cross section area excl. freeboard + siltation	Ab	0.22	m2	
Culvert Slope	So	0.21	m/m	1 in 4.81
$\frac{Q^2W}{gA^3} = 1$ Critical depth calculated as:	y_c	0.293	m	
Specific Energy at Critical Depth	E_{sc}	0.44	m	
$E_{sc} = \frac{3}{2}y_c$ Therefore Specific Energy of Headwater	E_{sh}	0.42	m	

Calculation of headwater elevation for inlet control

Headwater Elevation H_{hic} determined by:

$$H_{hic} = Z_i + E_{sh} + h_s$$

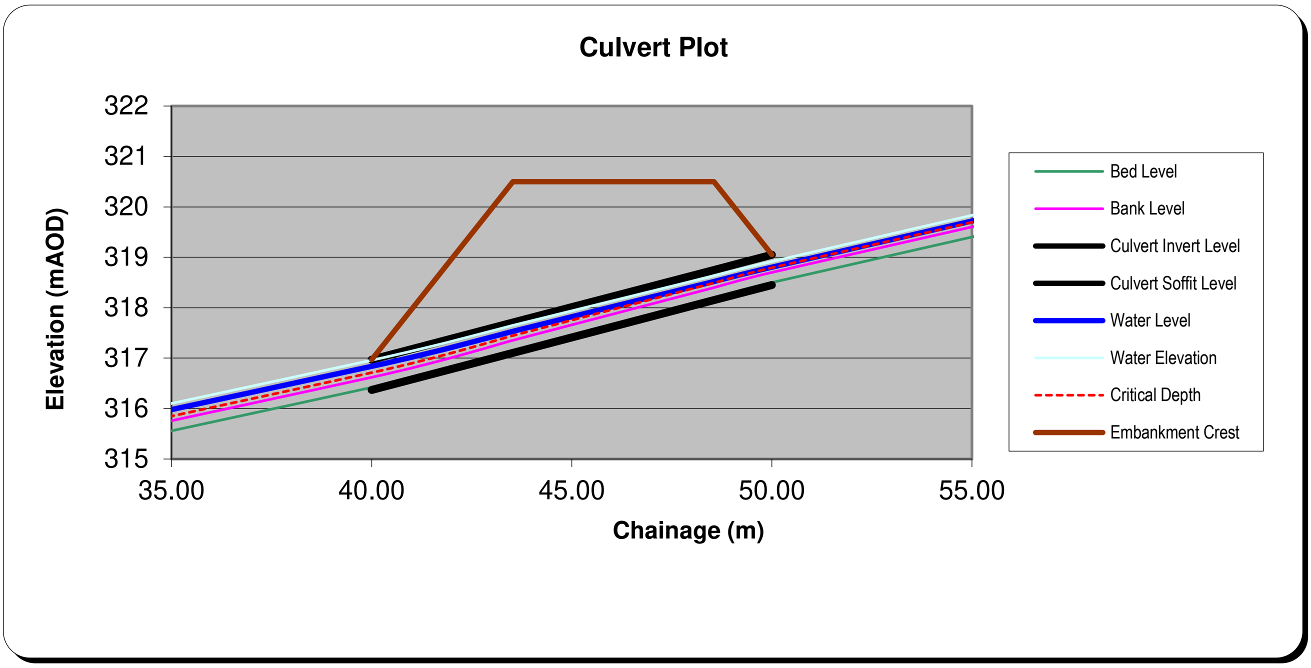
Where			
Headloss due to inlet screen	h_s	N/A	(No Screen Proposed)
Stream Elevation at Inlet	Z_i	318.50	mAOD
Specific Energy of Headwater	E_{sh}	0.42	m
Therefore Headwater Elevation:	H_{hic}	318.92	mAOD

Water Level at the headwater for inlet control WL_{hic} determined by:

$$WL_{hic} = H_{hic} - \frac{V_{uc}^2}{2g}$$

Where			
Headwater Elevation:	H_{hic}	318.92	mAOD
Velocity in Upstream Channel	V_{uc}	1.49	m/s
Therefore Water Level at Inlet:	WL_{hic}	318.80	mAOD

Culvert Profile



Summary

	Complies	Fails	Comment
Culvert Inlet Soffit Elevation > Headwater Elevation for Inlet C	X		
Adequate Freeboard provided to water level?	X		

Therefore proposed culvert dimensions: **1 nr** **Diameter** **0.60 m**

By	Checked	Revision	Date
KS	KS	Original	19/10/2023