Appendix 3-2

Surface Water Management Plan

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Carrownagowan Wind Farm

Surface Water Management Plan (SWMP)

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1 Introduction

This Surface Water Management Plan (SWMP) describes the designed drainage and the control measures for the construction phase of the proposed wind farm development. In particular, the SWMP relates to the wind farm site. During the construction phase of the Carrownagowan Wind Farm, the storm water runoff from the works areas can potentially cause sediment pollution of the downstream watercourses. The purpose of the Surface Water Management Plan (SWMP) is to set out the procedures and control mechanisms that need to be put in place in order to prevent such pollution.

The plan forms part of the drainage design for the wind farm proposal and should be read in conjunction with **Planning Drawings 19107-5013 to 5019** and **Planning Drawings 1907-5024 to 5026**.

2 Site Description

The proposed wind farm is located in east County Clare on the north-western slopes of Slieve Bernagh, approximately 4km north-east of the village of Broadford, 7km north-west of Killaloe and 2.5km south of the village of Bodyke, at its closest point. Lough Derg lies approximately 4km to the east of the proposed development area (Figure 2-1). The proposed lands include lands under Coillte ownership along with additional private lands.

The site is situated in an upland area (approx. 200-420m OD), on the north-western slopes of the Slieve Bearnagh mountains. The site covers an area of approx. 853 hectares, which principally consists of conifer plantation (of different age profiles). Sections of bogland (raised/upland blanket bog), cutover bogland, and a number of field areas of wet grassland occur, reverting back from improvement for agriculture. The forestry operations have impacted the overall site.

The site is drained by a number of first and second order streams, in the upper reaches of the catchment area. The site is drained largely by the Owengarney River. The eastern extent of the proposed wind farm development site is drained by the Annacarriga River. The proposed grid connection route lies mainly within the Broadford and Blackwater River catchments. The forest operations have impacted the overall drainage regime at the site and habitats occurring at the site.

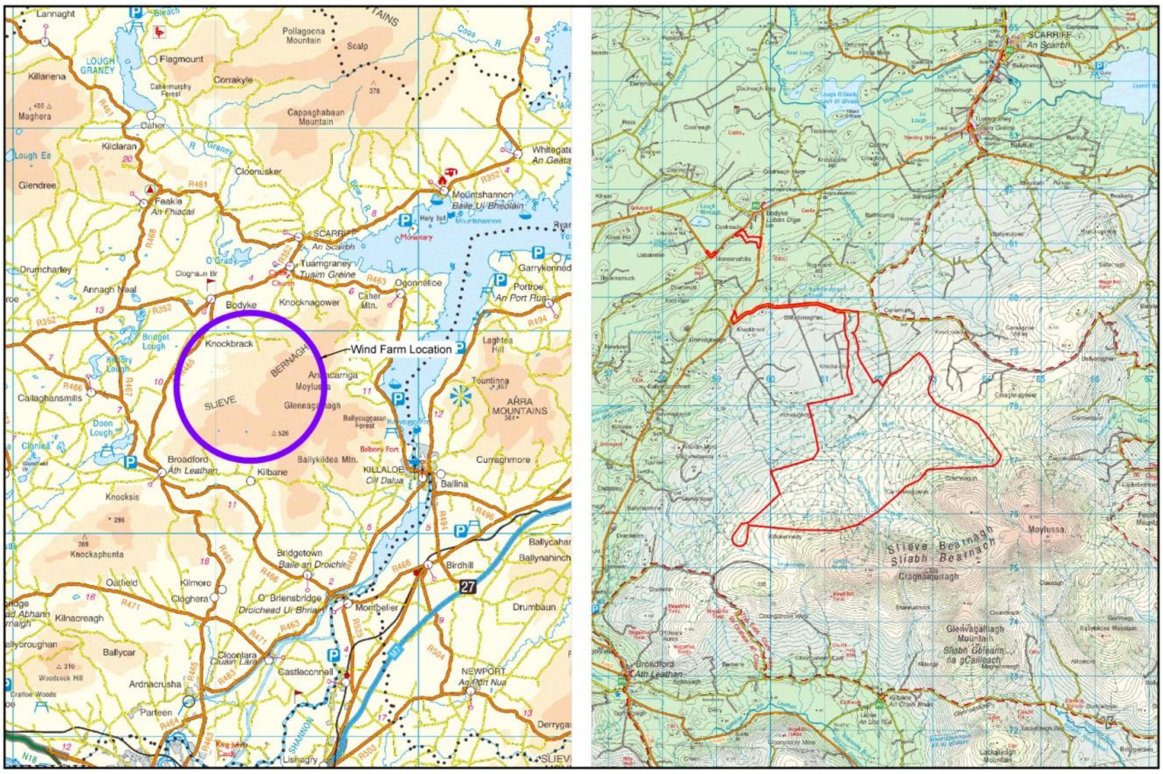

Figure 2-1 – Proposed site location

3 Site Drainage Proposals

3.1 Design Principles

The proposed wind farm site drainage system was designed as a measure to ensure that the proposal will not change the existing flow regime across the site, will not deteriorate water quality and will safeguard existing water quality status of the catchment from wind farm related sediment runoff.

A fundamental principle of the drainage design is that clean water flowing in the upstream catchment, including overland flow and flow in existing drains, is allowed to bypass the works areas without being contaminated by silt from the works. This will be achieved by intercepting the clean water and conveying it to the downstream side of the works areas either by piping it or diverting it by means of new drains or earth mounds.

This process will cause the normally dispersed flow to be concentrated at specific discharge points downstream of the works. Predominantly intercepted runoff will be diverted to the nearest existing drain or stream. Where existing drains are not available, dispersed outflow will be used. In order to disperse this flow, each such clean water drain will be terminated in a discharge channel running parallel to the ground contours that will function as a weir to disperse the flow over a wider area of vegetation. An alternative method is to allow the water to discharge through perforated pipes running parallel to the ground contours. Both of these methods will prevent erosion of the ground surface and will attenuate the flow rate to the downstream receiving waters. The specific drainage measures to be used at each location are shown on the drainage drawings included with the planning application.

Separating the clean and dirty water will minimise the volume of water requiring treatment. The dirty water from the works areas will be collected in a separate drainage system and treated by removing the suspended solids before exiting the site. Dirty water drains will be provided on both sides of the access roads and along the periphery of the turbines, crane hardstands, substation compound, Met mast and the temporary site construction compounds. See Figure 3-1.

The treatment system will consist of a series of settlement ponds at designated locations throughout the site. The outflow from the treatment system will be dispersed over vegetation in the same manner as the clean water dispersion and will become diluted through contact with the clean water runoff in the buffer areas before eventually entering the downstream watercourses.

An extract from the drainage drawings is illustrated in Figure 3-2. The clean water interceptor drains or earth mounds are all positioned upslope to prevent any mixing of the clean and dirty water. The outflow from these drains is then piped under the road at suitable intervals and at low points depending on the site topography. In the illustration 'dirty water' drains collect all incident rainwater that falls on the infrastructure. This water then drains to settlement ponds for removal of sediment before it is discharged via overland dispersal to the downstream watercourse.

The site drainage layout is presented in **Planning Drawings 19107-5013**. Settlement pond details and typical water crossing details are shown on **Planning Drawings 19107-5024** respectively. The drainage layout is overlaid on background OSI mapping on the A1 drawings that accompany the planning application.

Figure 3-1 – Separation of clean and dirty water drainage on a wind farm site

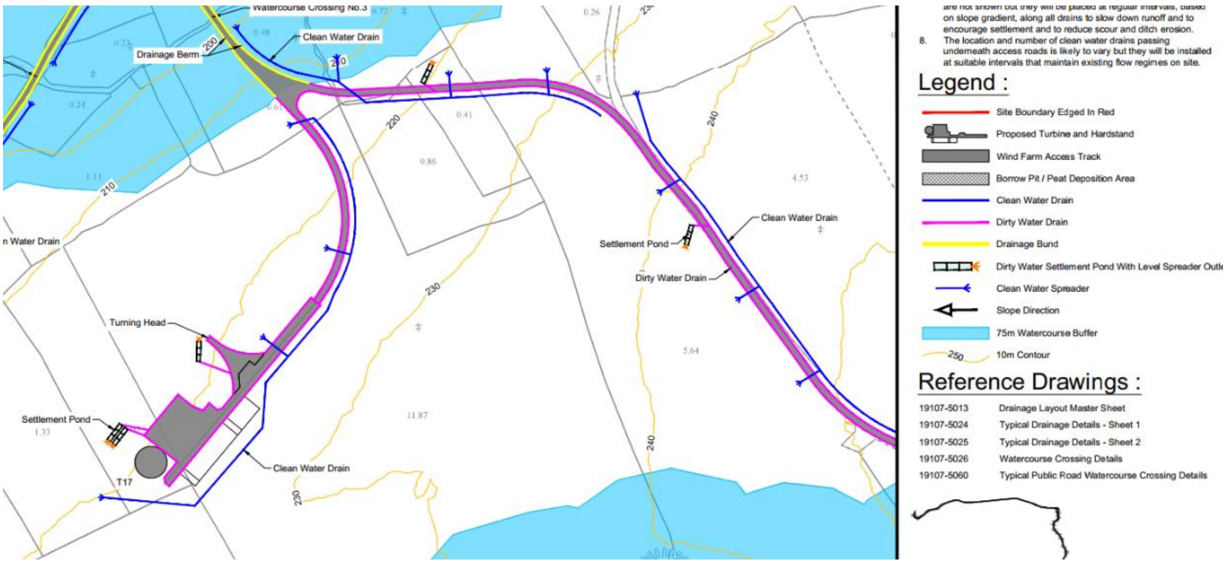

Figure 3-2 – Extract from drainage drawing

3.2 Treatment of water from the work areas

3.2.1 Constructions Works Areas

Runoff from the internal roadways, hardstands and other wind farm infrastructure will be isolated from the clean catchment runoff by means of a series of open drains that will be constructed within the works areas. These drains will be directed to settlement ponds that will be constructed throughout the site, downhill from the works areas. Each drain will incorporate a series of check dams that will attenuate the flow and provide storage for the increased runoff from exceptional rainfall events. The ponds have been designed to a modular size to cater for a single turbine and hardstand area or a 1,200m^2 area of internal access road.

Dewatering of turbine base excavations can result in significant flow rates to the drainage and settlement system if high capacity pumps are used. In order to avoid the need for pumping it is proposed to provide drainage channels from the excavations so as to prevent a build up of water. Where this is not feasible, temporary storage will be provided within the excavations and dewatering carried out at a flow rate that is within the capacity of the settlement ponds.

3.2.2 Watercourse Crossings

Where the crossing of an existing natural or artificial drainage channel cannot be avoided, suitable crossings have been designed. The crossings have been designed for a rainfall event with a 0.5% exceedance probability (1/200 year storm event). The crossing and widening proposed in this application are in accordance with Inland Fisheries Ireland (IFI) recommendations.

On the proposed site, a number of watercourse crossings will be required, detailed as follows:

- 7 new natural river / stream crossings;
- 6 existing natural stream / drain crossings to be widened or upgraded;

The design and management of the watercourse crossings is discussed in more detail in Section 4.3.9. Refer to **Planning Drawings 19107-5013** for locations and details.

3.3 Flood attenuation

The creation of impermeable areas within a development site has the effect of increasing rates of runoff into the downstream drainage system and this may increase flood risk and flood severity downstream. This applies particularly to urban areas that drain to closed pipe systems which do not have the capacity to cater for increased hydraulic loads. The Carrownagowan Wind Farm development is located within a large rural catchment with an open drainage system. The footprint of the impermeable areas and the associated increase in runoff rate is very small in the context of the catchment size and therefore represents a negligible increase in downstream flood risk. However, it is proposed to provide some attenuation in order to limit the flow rate into the construction stage settlement ponds during high intensity storm events so that they do not become overloaded. This will also attenuate the flow during the operational phase .

The volume of water requiring attenuation relates to direct precipitation on the roads and other infrastructure footprint only. The developed surfaces have some permeability and this reduces the attenuation requirement. Conventional attenuation systems use proprietary flow control units but these can become blocked with debris and vegetation and require regular maintenance. They are, therefore, not appropriate for use within a forest environment or where long-term routine maintenance would not be practical.

It is proposed to provide the temporary storage within the drainage channels by creating stone dams within them at regular intervals. The spacing of the dams is typically 100 metres but depends on the channel slope, with steeper channels requiring shorter intervals. The dams, which are constructed with small sized aggregate held in place by large aggregate, also reduce the flow rate through the drainage system and are an effective means of providing flow control. Silt fences will also provide storage and flow control.

Figure 3-3 – Stone check dam with large aggregate on downstream side

All runoff from the infrastructure areas will be routed through settlement ponds downstream. The outflow from the settlement ponds will be released in a controlled and diffuse manner onto the vegetation or forestry floor where selected forestry rills may be blocked to further promote diffusion of runoff. Therefore, the proposal will not increase the magnitude of the hydrograph peak and will not increase flood levels downstream.

4 Water quality management

4.1 General

Sediment such as peat, clay, or silt can cause significant pollution during the construction phase of a civil engineering project due to the erosion of exposed soil by surface water runoff. The water quality management system has been prepared in order to control erosion and prevent sediment runoff during the construction phase of the Carrownagowan Wind Farm. The implementation of sediment and erosion control measures is essential in preventing sediment pollution. The proposed drainage system was designed having regard to:

- Knowledge of the site's environmental conditions;
- Previous construction experience of wind farm developments in similar peat environments;
- Previous experience of environmental constraints and issues from construction of wind farms in similar environmental conditions;
- Technical guidance and best management practice manuals (See References).

The following site specific information was used in the design of the drainage and treatment system:

- High resolution aerial photography;
- LiDAR ground surface information;
- Wind farm infrastructure layout (turbines, service roads and ancillary development);
- Hydrology maps (watercourses and buffer zones);
- Soil and land use maps;
- Field Work, Site Surveys and Baseline water quality assessments; and
- Met Éireann extreme rainfall data.

The settlement ponds and check dams described in the previous section provide the essential mechanism for the removal of silt from construction related runoff and the controlled return of the treated runoff to the downstream watercourses. Additional infrastructure and control methodologies as described in Section 4.3 are also required in order to minimise the sediment load from the runoff and to prevent contamination by other potential pollutants.

The drainage and treatment system will ensure that the construction and post-construction phases of Carrownagowan Wind Farm will not create adverse effects on the aquatic environment

4.2 Treatment process

Sediment loaded runoff could be generated on the site access roads and hardstands and is mainly due to excavation for the infrastructure or movement of delivery vehicles and on-site traffic. Drains carrying construction site runoff will be diverted into settlement ponds that reduce flow velocities, allowing silt to settle and reducing the sediment loading. A modular approach has been adopted for the design of the settlement ponds which have been sized to cater for a 1,200 m^2 works area. This is equivalent to a road length of 240 metres or the area of a typical turbine base and crane hardstand.

The settlement ponds have been designed as a three stage tiered system and this has been proven to work effectively on wind farm construction sites. The three stage system also facilitates effective cleaning with minimal contamination of water exiting the pond.

The settlement ponds have been designed with regard to the following:

- Met Éireann Point Rainfall Frequency data (statistical rainfall intensity / duration table)
- Runoff flow rate for the modular catchment area
- Character of the impermeable areas (runoff coefficients)
- Design particle size and density

The treatment process consists of primary, secondary and tertiary treatment as follows:

- The *primary treatment* consists of a three stage settlement pond with an over-topping weir at each stage. The first chamber will remove most of the sediment load, while the remaining two chambers will remove most of the remaining load.
- Before the water is released onto the existing ground surface, it passes through a *secondary treatment* system in the form of a graded gravel filter bed.
- The outflow from each interceptor is dispersed across a wide area of vegetation so that the velocity is minimised and the vegetation can filter out the residual sediment. This is the final or *tertiary* stage of the treatment process. Existing forest mound and collector drains within the tertiary treatment area are blocked off to prevent concentration of the flow.

Each sediment treatment unit has been micro-sited using the contour maps and aerial photos to avail of any locally level areas and to ensure that the outflow is spread over as much vegetation as possible before entering an aquatic buffer zone.

Settlement ponds will require regular inspection and cleaning when necessary as sediment builds up. This will be carried out under low or zero flow conditions so as not to contaminate the clean effluent from the pond. The water level would first be lowered to a minimum level by pumping without disturbing the settled sediment. The sediment would then be removed by mechanical excavator and disposed of in areas designated for deposition of spoil. Settlement ponds will require perimeter fencing and signage to ensure that there are no health and safety risks.

Figure 4-1 shows a well constructed and maintained tiered settlement pond. This example is located in an upland environment with significant ground surface slope and operates efficiently provided that it is well maintained. The design has been developed in conjunction with Inland Fisheries Ireland personnel and local authority engineers.

Figure 4-1 – Multi tiered settlement pond with stone filter

The design of the settlement pond system for the Carrownagowan site is detailed in the **Planning Drawing 19107-5024.** The hydraulic design of the settlement ponds is outlined in Section 4.4.

The effluent from each settlement pond will discharge to an open channel, 8 to 10 metres in length, running parallel to the ground contours. This will form a weir that will overflow on its downhill side and disperse the flow across the existing vegetation. A minimum buffer width of 20m is specified between the overflow weir and downstream watercourses. Buffer widths are designed in line with *Forests and Water, UK Forestry Standard Guidelines (Forestry Commission, 2011)* on protection of watercourses during forestry operations and management. This method buffers the larger volumes of run-off discharging from the drainage system during periods of high precipitation, further reducing suspended sediment load to surface watercourses. , The outflow weirs will not be located on slopes steeper than 3:1 or in areas of high instability risk. Existing forest mound and drains within the dispersion zone will be blocked off where necessary to prevent concentration of the flow.

4.3 Water quality control measures

Additional infrastructure and measures used to control water quality are described in the following sub-sections.

4.3.1 Minimise exposed areas

The area of exposed ground will be kept to a minimum by maintaining where possible existing vegetation that would otherwise be subject to erosion in the vicinity of the internal wind farm roads and other infrastructure. The clearing of topsoil will be delayed until just before construction begins rather than stripping the entire site months in advance particularly during road construction.

4.3.2 Establish vegetation

Best practice for excavation in peat is that the acrotelm (top 50cm of peat), which contains the seed bank, is stored and maintained separately from the catotelm (i.e. peat below the acrotelm layer). Wherever good quality acrotelm is identified, it will be stored for re-use in accordance with best practice. Once works are complete, the acrotelm can be used to cover exposed areas of peat. Exposed areas of the site that are slow to re-vegetate may need to be replanted with suitable vegetation. This can be by natural regeneration or by reseeding. Natural regeneration relies on colonisation of bare ground by native species from adjacent habitats. For this method, a roughened surface will be provided that can trap seeds and soil to provide initial regeneration areas.

4.3.3 Road construction and maintenance

On-site experience in wind farm construction and forestry development across the country has shown that the single most effective method of reducing the volume of sediment created by construction is the surfacing of all service roads with high quality, hard wearing crushed aggregate such as basalt, granite or limestone laid to a transverse grade. When storm water drains transverse across a road constructed from hard wearing aggregate, as opposed to low class aggregate, the level of suspended solids is reduced significantly. This design measure is fundamental to effective water quality management and will form part of the Construction civil Contract.

The road surface can become contaminated with clay or other silty material during construction. Road cleaning will, therefore, need to be undertaken regularly during wet weather to reduce the volume of sediment runoff to the treatment system. This is normally achieved by scraping the road surface with the front bucket of an excavator and disposing of the material at designated locations within the site.

4.3.4 Engineered deposition areas

Temporary engineered deposition areas will be designated where necessary at the turbine and hardstand locations to hold temporary stockpiles. These will be located away from drains and watercourses. Stockpiles that are at risk of erosion will be protected by a silt trapping apparatus such as a geo-textile silt fence to prevent contamination of runoff.

4.3.5 Wheel washes

Wheel washes will be provided for heavy vehicles exiting the site to ensure that roads outside of the site boundary are clean. These can take the form of dry or wet wheel wash facilities. In the case of a wet wheel wash it is recommended that a designated bunded and impermeable wheel wash area is provided and that the resultant waste water is diverted to a settlement pond for settling out of suspended solids.

4.3.6 Check dams

Check dams will be placed at regular intervals, based on gradient, along all drains to provide flow attenuation, slow down runoff to promote settlement and to reduce scour and ditch erosion. Check dams are relatively small and constructed with gravel, straw bales or other suitable material. They will be placed at appropriate intervals and heights, depending on the drain gradient, to allow small pools to develop behind them. Examples of check dams or swales are shown below in Figure 4-2.

Figure 4-2 – Example of check dams along roadside drainage channels

4.3.7 Silt fences

Silt fences placed along drains are an alternative method of reducing the volume of suspended sediment. They will be placed at the end of any locally steep section of drain. They have the double benefit of effectively producing a localised swale to reduce scour effects and also attenuating and filtering the discharge. An example of a typical silt fence installation is shown in Figure 4-3.

Figure 4-3 – Silt fence used in conjunction with check dams along roadside drainage channels

4.3.8 Tree felling

Felling of commercial conifer forestry is required within and around wind farm infrastructure to accommodate the construction of foundations, hardstands and access roads as well as to facilitate assembly of turbines. It is proposed to fell to a distance of 86m around turbines and 5m on either side of roads.

All tree felling will be undertaken in accordance with a tree felling licence, using good working practices as outlined by the Forest Service in their '*Standards for Felling & Reforestation 2019*. All conditions associated with a felling licence will be complied with.

4.3.9 Work in and near watercourses

No work will take place within 75m buffer zones of watercourses identified in the Water Chapter of the EIAR except for clear span culverts and associated road construction. Working near watercourses during or after intense or prolonged rainfall events will be avoided and work will cease entirely near watercourses when it is evident that there is a risk that pollution could occur. All construction method statements will be developed in consultation with Inland Fisheries Ireland and in accordance with the details in the CEMP accompanying this application.

4.3.9.1 Drainage / Stream Channel Crossings

Where the crossing of an existing natural or artificial drainage / stream channel is unavoidable, a suitable crossing will be designed. Typically this will be in the form of precast concrete or HDPE pipes. All crossings will be designed for a minimum 1 in 200 year return rainfall event. The invert of the pipe is submerged approx $^{1}/_{4}$ of its diameter below the original drainage bed. Where natural gradients allow, a nominal back fall in the pipe will be incorporated to prevent scour and promote the settling of natural material along the invert of the pipe. An example of a permanent drain crossing is illustrated in Figure 4-4. New turbine service roads will be required to cross several minor drains / streams within the site. All construction method statements for watercourse crossings will be in consultation with Inland Fisheries Ireland.

Figure 4-4 – Typical drainage channel crossing

Figure 4-5 shows a typical measure to be put in place at drainage and watercourse crossings in order to ensure dirty water does not enter clean watercourses. For Carrownagowan Wind Farm, the intention is to use vegetated soil bunds to divert dirty water generated on the section of road over the crossings to the dirty water system. Alternatively silt curtains, as shown in Figure 4-6 will be placed along the existing roads within the 75m buffer zone. These silt curtains can run longitudinal to watercourses with a layer of stone placed along the bottom to prevent any seepage if there is a risk of silted runoff.

Figure 4-5 – Dirty water containment at watercourse crossing

Figure 4-6 – Silt curtain containment along existing roads near watercourses

4.3.9.2 Watercourse Crossings

On Carrownagowan Wind Farm is it proposed that 4 no. Major watercourses will be crossed using clear span pre-cast concrete culvert crossings such as a bottomless arch or bottomless box culvert. In general the major watercourses within the wind farm site, such as the Carrownagowan, Coumnagun and Inchalughoge rivers, are cut into relatively deep channels. These channels would require significant upfill to maintain vertical alignment criteria for turbine deliveries along access roads. Clear span pre-cast concrete culverts are advantageous in several manners for this type of installation. As spans increase the height can increase accordingly allowing significant light penetration under the culvert. The increase in height is complimentary to the vertical alignment requirements for access road design. Refer to **Planning Drawing 19107-5026** for further details.

The selection criteria for crossing natural streams and rivers within the site were:

I. Avoid crossing streams or rivers at acute angles;
II. Avoid meanders at the crossing location;
III. Cross where foundations could be constructed without excess excavation;
IV. Consider vertical alignment requirements;

The design of a clear span pre-cast concrete culvert crossings will ensure that:

- The existing channel profile within the watercourse is maintained;
- Gradients within the watercourse are not altered;
- There is unrestricted passage for all size classes of fish by retaining the natural watercourse stream / river bed;

- There are no blockages within the watercourse. The large size of a clear span culvert allows for the passage of debris in the event of flood flow conditions;
- The watercourse velocity is not changed;
- The clear span of a culvert will ensure that the existing stream / river bank is maintained during construction which will in turn avoid the occurrence of in-stream works;

Construction of the four clear span crossings will be supervised by the Construction Manager, a suitably qualified engineer, the project manager and the Environmental Manager in accordance with Inland Fisheries Ireland *"Guidelines on Protection of Fisheries During Construction Works in and Adjacent to Waters, 2016"* and Office of Public Works *"Construction, Replacement or Alteration of Bridges and Culverts, 2013"*.

Typically the proposed installation works for a clear span pre-cast concrete culvert will comprise the following:

I. Prior to the commencement of works the design of the culvert proposed in this application will be submitted for approval to the Office of Public Works (OPW) under Section 50 of the Arterial Drainage Act, 1945 and to Inland Fisheries Ireland (IFI);
II. Upon design approval the extent of the excavations required for the culvert foundations at either side of the watercourse will be marked out. The foundations are to be set to an agreed minimum distance by IFI from the existing watercourse so as not to impact on the riparian habitat. Health and safety measures such as lifebuoys on stakes will be installed and where appropriate life jackets will be provided to persons working near the watercourse;
III. Appropriate environmental control measures such as silt curtains, silt traps, mats etc. will be erected on both sides of the watercourse. These environmental control measures will reduce the potential for sedimentation of the watercourse;
IV. Excavators will begin to excavate the foundations to formation level where all excavations will be battered back to a safe angle of repose (minimum slope angle of 45°) and comply with the final Construction and Environmental Management Plan (CEMP) . All excavation works will stop in the event of heavy rainfall.
V. All excavated material will be transported to the on-site deposition areas located outside of the 75m hydrology buffer zone at the proposed borrow pits. Some of the excavated material will subsequently be reused as backfill around the culvert abutments and structure upon installation. Bare ground will be minimised.
VI. Once formation is reached at suitable ground conditions; steel reinforcement and shuttering will be installed. The culvert abutments will be prepared for the pouring of concrete by dewatering standing water within the excavations, which is likely to contain suspended solids, via a pump to an adequately sized settlement pond located outside of the 75m hydrology buffer zone. The standing water will be treated through the settlement pond and clean filtration stone prior to outfall over vegetation away from the watercourse;
VII. Ready-mix concrete will be delivered to the culvert abutments by ready-mix concrete trucks and placed into each abutment by means of excavators. During the concreting works the watercourse will be temporary covered over with a tarpaulin so as to protect the watercourse from concrete spills. Upon completion the abutments will be covered and allowed to cure;
VIII. Following curing, the shuttering around the abutments will be struck and removed. A small temporary hardstand will be constructed so that a lifting crane, which will install the pre-cast concrete culvert components onto the abutments, can be set up;

IX. Deliveries of the pre-cast concrete culvert components will arrive to site. These components will be individually fitted and manoeuvred into position by the lifting crane onto the concrete abutments. The components will be inspected to ensure that each unit is level and secure;

X. Backfilling on either side of the culvert will commence in accordance with the culvert supplier's specifications using excavated material;

XI. The access road surface will be laid over the culvert structure using site won stone aggregate and compacted in maximum 250mm layers with the use of 10-20 Ton rollers. An internal cable trench will be installed within the carriageway of the culvert so that it can cross over the watercourse;

XII. Vegetated soil bunds, or silt fencing as per Figure 4-5, will be installed to divert dirty water generated on the section of road over the culvert crossing into the dirty water system. This will ensure that dirty water will not enter the clean watercourse;

XIII. Steel parapet railings and timber post and rail fencing will be installed at the sides and on the approaches to the culvert. This will prevent persons or vehicles falling into the watercourse while travelling across the culvert;

Figure 4-7 – Typical clear span pre-cast concrete units in place over an existing watercourse

Figure 4-8 – Completed clear span pre-cast concrete culvert crossing over an existing watercourse

4.3.10 Inspection and maintenance

The drainage and treatment system for the proposed wind farm must be managed and monitored at all times and particularly after heavy rainfall events during the construction phase. The drainage and treatment system will be regularly inspected and maintained to ensure that any failures are quickly identified and repaired so as to prevent water pollution. A programme of inspection and maintenance will be designed and dedicated construction personnel assigned to manage this programme. A checklist of the inspection and maintenance control measures will be developed and records kept of inspections and maintenance works. These drainage controls will be kept in place during the operational phase of the wind farm until the vegetation is re-established.

4.3.11 Weather monitoring

Weather monitoring is a key input to the successful management of the drainage and treatment system during the construction of the wind farm. This, at a minimum, will involve 24-hour advance meteorological forecasting (Met Éireann download) and on site rain guage linked to a trigger-response system. When a pre-determined rainfall trigger level is exceeded (e.g. 1 in 5 year storm event), planned responses will be undertaken. These responses will involve control measures including the cessation of construction until the storm event has passed over and flood flows have subsided. Dedicated construction personnel will be assigned to monitor weather.

4.3.12 Water quality monitoring

A programme for water monitoring will be prepared in consultation with Inland Fisheries Ireland (IFI) prior to the commencement of the construction of the wind farm. The plan will include monitoring of water during the pre-, throughout and post construction phases.

Further baseline water quality monitoring of all streams near the development site will be undertaken prior to construction to confirm existing conditions at the time of construction. This baseline data will include the main components of a full hydrograph for the streams including both high spate flow and base flow where possible.

During the construction phase of the project, water quality in the streams and outflow from the drainage and attenuation system will be monitored, field-tested and laboratory tested on a regular basis during different weather conditions. This monitoring together with the visual monitoring will help to ensure that the mitigation measures that are in place to protect water quality are working effectively.

During the construction phase of the project, the development areas will be monitored regularly for evidence of groundwater seepage, water ponding and wetting of previously dry spots, and visual monitoring of the effectiveness of the constructed drainage and attenuation system to ensure it does not become blocked, eroded or damaged during the construction process.

4.3.12.1 Surface Water Quality and Cementitious Material

It is important to prevent raw cement from entering waterways within and in close proximity to the Carrownagowan Wind Farm site.

Cement is required as a constituent for concrete. Concrete will be used for construction of the 19 no. turbine bases, the substation buildings, culvert crossings and a small quantity will be needed for the meteorological mast foundation.

The primary method of reducing the potential impact from cementitious material on the hydrology of the Carrownagowan Wind Farm site is the selection of ready-mixed concrete as opposed to site batching of concrete. Site batching requires the delivery and storage on site of significant quantities of raw cement. The chemical reactivity of cement is at its most vigorous in the early stages of its activation by water (Hydolysis, typically in the first 15 minutes). In the batching plant water is added to the cement at the correct water/cement ratio to fully activate the cement hydration process.

By removing cement in its raw state from the site the potential for a significant impact from Hydrolysis of cement in the surrounding watercourses is eliminated.

When ready-mixed concrete is used the Hydrolysis stage of the cement process has already been completed during the batching process and the chemical reaction undergoes a dormancy period during which it enters a plastic state. During this period the concrete is delivered and placed.

After approx 3 hours the cement in the concrete enters a third stage of the chemical process where it hardens, primarily due to the hydration of tricalcium silicate. This process increases in activity for approx 12 hours and then decreases over the following 20 hours. After approx 36 hours the concrete is considered to have set.

As part of the curing process the top exposed surface of poured concrete is covered in a curing blanket which eliminates the effect of rain washing down uncured cement from the top surface.

Concrete placement for a truck load is typically complete within 3 hours of batching. It is normal for the truck operator to wash out the drum and chutes of the truck on site. This typically requires approx 250 litres of water to complete. This concrete washout contains cement that has not fully completed the hydration process and as a result can have an elevated pH level (higher alkalinity).

Concrete truck washouts for Carrownagowan will be limited to washing down chutes only, reducing water volume to an absolute minimum of approx 25 litres. The chute wash down area, which will retain the washout water, will be located within the construction compounds and there will be no other chute wash down activity on any other part of the wind farm site.

Washout of concrete truck drums will be carried out at the source quarry.

There will be no on-site batching of concrete; concrete requirements will be met by ready-mix suppliers.

The environmental manager will monitor the pH of the water in the chute wash out bund and can dose with CO_2 or acidic water from the drains until the wash out water achieves neutrality before discharge. Any overflow of water will be collected in the site compound drainage system which will be connected to a settlement pond for treatment prior to discharge to the external drainage system

The concrete sediment in the construction compound washout area will be removed at regular intervals.

4.4 Settlement pond design

4.4.1 Pond surface area (roads and hardstands)

Generally, high intensity rainfall events have a short duration and lower intensity rainfall events tend to have a longer duration. The Met Éireann Extreme Rainfall Data for the area (Table 2 and Table 3) demonstrate that the chance of occurrence of a storm event of a given duration decreases (higher return period) as intensity increases. Table 2 shows the Point Rainfall Frequency which shows the total rainfall for each duration and return period in millimetres. Table 3 shows the same data converted to a rainfall rate in mm/hour. For a given return period the total depth of rainfall increases with storm duration but the actual rainfall rate over that period of time decreases.

For the operation of the settlement ponds it is the rate of flow rather than the total rainfall that is relevant. The return period is a measure of the likelihood that a storm of a particular intensity will occur in a given year. However, it is important to note that the chances of occurrence of a storm event with a particular return period are the same in each year but should on average occur once in that time period. For instance, a storm event with an intensity of 170 mm/hour and 5-minute duration would be expected to occur once in a 100-year period (first row of Table 3). This is more appropriately expressed as an annual exceedance probability (AEP) of 1%; that is, it has a 1% chance of being equalled or exceeded in any year.

The runoff control measures for the wind farm site have been designed in the context of storm events of varying duration and intensity. The settlement ponds have been designed to cater for a maximum continuous flow rate associated with a medium-intensity rainfall event. Higher intensity runoff will be attenuated by the open drain collection system which provides temporary storage and limits the rate at which it enters the settlement ponds. This is achieved by the use of check dams within the open drains as described elsewhere in this document. Longer duration storms of 24 hours or more generally have very low intensity and are not critical in terms of the runoff rates that they generate. Since the design is for the construction phase only, no additional allowance has been made for a possible increase in rainfall intensity due to climate change in the future. Where exceptional rainful is expected, where the design related rainfall events and returns periods may be breached, works will be stopped by the appointed contractor. While the design parameters remain the same in the context of climate change, should extreme rainfall events occur more frequently, then the works will accordingly be stopped more frequently.

The modular settlement ponds are designed to operate effectively for the runoff rate associated with a continuous high rainfall rate of 20 mm/hour. This is equivalent to a 60-minute duration storm event with a 10-year return period (M10-60) or a 30 minute duration storm event with a 2-year return (M2-30). These rates are taken from the Met Éireann Point Rainfall Frequency table for the site location.

The design runoff rate is calculated using the formula:

$Q = c\,i\,A$

where c is the runoff coefficient,

i is the rainfall intensity in m/sec, and

A is the catchment surface area in m^2.

A runoff coefficient of 0.70 is assumed for the hardcore surface. For a rainfall intensity of 20mm/hour and an area of 1,200m^2 the runoff rate is:

$$Q = 0.70 \times (0.02/3600) \times 1{,}200 \text{ m}^3/\text{sec}$$

$$= 0.0047 \text{ m}^3/\text{sec (4.70 litres/sec)}$$

The main design parameter for the settlement pond is the water surface area. The required surface area is the design flow rate in m^3/sec divided by the particle settlement velocity (V_s) in m/sec (Area = Q/V_s m^2).

The particle settlement velocity is determined using the formula derived by Stokes in 1851 as follows:

$$V_s = 2 r^2 (D_p - D_f) / (9 n)$$

where V_s is the particle settlement velocity (m/sec),

r is the radius of the particle (metres),

D_p is the density of the particles (kg/m^3),

D_f is the density of the fluid (kg/m^3), and

n is the viscosity of the fluid (0.000133 kg sec/m^2 @ 10°C).

For a particle density of 2,400kg/m^3, water density of 1,000kg/m^3 and particle diameter of 20 microns (radius 10^{-5} metres) the settlement velocity, V_s, is:

$$V_s = 2 \times (10^{-5})^2 \times (2{,}400 - 1{,}000) / (9 \times 0.000133)$$

$$= 2 \times 10^{-10} \times 1{,}400 / 0.001197$$

$$= 0.000234 \text{ m/sec.}$$

The required settlement pond surface area is

$$A_p = Q/V_s$$

$$= 0.0047/0.000234$$

$$= 19.95\text{m}^2$$

Theoretically the pond depth is not relevant but in practice a minimum depth is required to ensure laminar flow and to allow temporary storage of settled silt. The modular settlement pond has been designed with a surface area of 24m^2 (12m x 2m) and a depth of 1m. This is divided into three chambers of equal length and in practice it has been found that most of the settlement occurs in the first chamber with very low turbidity levels being achieved in the final effluent. The design is conservative and therefore has sufficient redundancy to cater for occasional higher runoff rates or sediment loads.

For practical reasons it may be necessary to increase the area directed to a settlement pond in which case the pond surface area will be increased pro rata.

4.4.2 Attenuation Design

For rainfall intensities above the design value of 20mm/hour the excess runoff needs to be temporarily stored. The storage will be provided in the drainage channels by installing check dams at intervals along the channel as described below.

The storage volumes required for 10-year storm events of various durations are shown in Table 1 below. The volumes are based on a catchment area of 1,200m^2 and a runoff coefficient of 0.70. The maximum storage volume required is 6.52m^3 for 15 minutes storm duration. This is equivalent to 25 minutes of flow through the settlement pond at the design through flow rate of 4.70 litres/second. The stored water will drain off gradually as runoff from the works area subsides. The storage volume represents an average depth of 0.05m in a 218m long, 0.60m wide open drain and can therefore be easily accommodated in the drainage system.

Storm Event	Duration (minutes)	Rainfall rate (mm/hour)	Excess (mm/hour)	Runoff Coefficient	Storage Volume (m^3)
M10-60min	60	20.00	0.00	0.70	0.00
M10-30min	30	32.00	12.00	0.70	4.92
M10-15min	15	51.20	31.20	0.70	**6.52**
M10-10min	10	64.80	44.80	0.70	6.25
M10-5min	5	93.60	73.60	0.70	5.14

Table 1 Calculated storage volumes

The ability to limit flow rates is fundamental to the control of sediment during extreme storm events. It is not proposed to use any proprietary mechanical devices for this purpose but instead to rely on the check dams to effectively limit flow rates to the required values. The check dams will be constructed with gravel or other suitable material and will be of sufficient length and height to provide the required attenuation rates. The number of dams will vary depending on the gradient of the drainage channel with higher gradients requiring a greater number of dams with larger dimensions. Their ability to retain water and release it slowly can be confirmed visually.

Storm Duration	Return Period (years)							
	0.5	1	2	5	10	20	50	100
5 min	2.80	3.90	4.50	6.30	7.80	9.40	11.90	14.20
10 min	3.90	5.40	6.20	8.80	10.80	13.10	16.60	19.80
15 min	4.60	6.40	7.30	10.40	12.80	15.40	19.50	23.30
30 min	6.20	8.40	9.50	13.20	16.00	19.00	23.80	28.10
60 min	8.20	10.90	12.30	16.70	20.00	23.60	29.00	33.90
2 hours	11.00	14.30	16.00	21.20	25.00	29.20	35.40	40.80
4 hours	14.70	18.70	20.70	26.90	31.30	36.10	43.10	49.20
6 hours	17.40	21.90	24.20	30.90	35.80	40.90	48.40	54.90
12 hours	23.30	28.70	31.30	39.20	44.80	50.60	59.00	66.10
24 hours	31.00	37.50	40.60	49.80	56.10	62.60	71.90	79.70
48 hours	39.70	47.30	51.00	61.50	68.60	76.00	86.40	95.00

Table 2 Met Éireann point rainfall frequency table (rainfall depth in mm)

Storm Duration	Return Period (years)							
	0.5	1	2	5	10	20	50	100
5 min	33.60	46.80	54.00	75.60	93.60	112.80	142.80	170.40
10 min	23.40	32.40	37.20	52.80	64.80	78.60	99.60	118.80
15 min	18.40	25.60	29.20	41.60	51.20	61.60	78.00	93.20
30 min	12.40	16.80	19.00	26.40	32.00	38.00	47.60	56.20
60 min	8.20	10.90	12.30	16.70	20.00	23.60	29.00	33.90
2 hours	5.50	7.15	8.00	10.60	12.50	14.60	17.70	20.40
4 hours	3.67	4.67	5.17	6.72	7.82	9.02	10.77	12.30
6 hours	2.89	3.64	4.03	5.14	5.96	6.81	8.06	9.14
12 hours	1.94	2.39	2.60	3.26	3.73	4.21	4.91	5.50
24 hours	1.29	1.56	1.69	2.07	2.33	2.60	2.99	3.32
48 hours	0.82	0.98	1.06	1.28	1.42	1.58	1.79	1.97

Table 3 Met Éireann point rainfall frequency table (rainfall rate in mm per hour)

5 Conclusions

This Surface Water Management Plan as designed will ensure that all contaminated water will be collected and treated before being dispersed overland to the downstream watercourses. The attenuation system will ensure that there will be no increase in flow rates downstream and consequently there will be no increase in flood risk downstream of the site as a result of the development.

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