Appendix 10.5: Groundwater Dependent Terrestrial Ecosystems (GWDTE) Assessment

Executive Summary

This document provides a summary of the Groundwater Dependent Terrestrial Ecosystems (GWDTE) in the context of the Garn Fach wind farm development. The high annual rainfall of the Cambrian Mountains, combined with the relatively impermeable bedrock, results in significant surface water run-off within river catchments. As such the bedrock aquifer designation across the proposed development area is Secondary B, characterised by predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

A number of GWDTE habitats are located within the site, including habitats of both low and moderate dependence on groundwater. It was found that the low dependency habitats are not reliant on groundwater resources, identified through the hydrogeological conceptual model and site characteristics. The low dependency habitats require drainage for the surrounding infrastructure which ensures the hydraulic continuity of surface water to these habitats which they may partly rely upon. For the moderate dependency habitats, it has been concluded that they could be partially reliant on the groundwater of superficial deposits, whilst also being supported by rainfall and surface water.

Mitigation measures for moderate dependency habitats include embedded drainage around turbine bases and borrow pits, cross track drainage in access tracks and demarcation of the most sensitive habitats to avoid construction damage.

Contents

1 Introduction

This technical appendix provides a summary of the Groundwater Dependent Terrestrial Ecosystems (GWDTE) in the context of the Garn Fach wind farm development. A desk-based study into the baseline geology, hydrogeology, soil and topography has been completed to inform the assessment. All the relevant GWDTE's have been identified in relation to the site's infrastructure development with their likely groundwater dependence level; high or moderate, given the ecohydrological conditions of each locality. The potential reduction of availability of groundwater was then assessed for each habitat including embedded mitigation measures, as well as the need for further mitigation, for each habitats Zone of Contribution (ZoC).

Excavation of soil and bedrock during construction within the vicinity of a GWDTE may cause localised disruption and interruption to groundwater flow, with associated dewatering potentially causing a large change to the quantity of groundwater supply. Where GWDTE are present, interrupting groundwater flow may reduce the proportion of the ZoC available to such ecosystems, by changing the quantity of surface water runoff and groundwater supplying the GWDTE. The ZoC is defined for each habitat as the area up hydraulic gradient of the GWDTE, based upon the geology and topographic information of the site. Contamination of groundwater or surface water may cause physical or chemical contamination to the GWDTE.

Detailed guidance has been developed for the assessment of wind farm infrastructure on GWDTE in Scotland by SEPA[1]. Although for Scotland primarily, this guidance is relevant for this assessment in Wales. This guidance states that GWDTEs within 100m from roads, tracks and trenches or within 250m from borrow pits and turbine foundations should be identified, with details provided as to how these sensitive receptors will be protected. 100m and 250m buffers have been defined around the relevant infrastructure as presented in Figures 1-7 All GWDTEs that fall within these buffer zones have been examined. Additional habitats further from the proposed infrastructure will also benefit from the mitigation measures introduced.

1.1 Legislation

This GWDTE assessment has been undertaken in accordance with the following legislation:

- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017
- The Pollution Prevention and Control (England and Wales) Regulations 2000
- The Town and Country Planning (Environmental Impact Assessment) (Wales) Regulations 2017, as amended

1.2 Guidance

This GWDTE assessment has been carried out in accordance with the principles outlined in the following documents:

- SEPA (2017). Land Use Planning System, SEPA Guidance Note 4: Planning advice on wind farm developments. Version 8.
- CIEEM (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland.
- Scottish Renewables, SNH, SEPA, Forestry Commission Scotland, Historic Environment Scotland, Marine Scotland Science, AEECoW, 4th Edition (2019). Good Practice during Wind Farm Construction.
- Pollution Prevention Guidelines (PPG) 1. (2013) General guide to the prevention of water pollution.
- Guidance for Pollution Prevention (GPP) 5. (2018) Works and maintenance in or near water.
- PPG06. (2015) Working at construction and demolition sites.
- Scottish Natural Heritage (2015). Constructed tracks in the Scottish Uplands.
- UKTAG (2009) Guidance 5 ab Annex 1: NVC plant communities and dependency on groundwater,

[1]SEPA (2017). Land Use Planning System, SEPA Guidance Note 4: Planning advice on wind farm developments. Version 8, https://www.sepa.org.uk/media/136117/planning-guidance-on-on-shore-windfarms-developments.pdf
[2] Ordnance Survey (2020) OS Terrain 50 https://www.ordnancesurvey.co.uk/business-government/products/terrain-50
[3] Ordnance Survey (2020) 1:12500 Scale Colour Raster https://www.ordnancesurvey.co.uk/business-government/products/25k-raster

2 Baseline

In order to assess the level of dependency of the GWDTE on groundwater in this locality, baseline environmental information was collected. This allowed the examination of the hydroecological regime and the relationship between the habitats recorded and groundwater at the site. Table 2-1 outlines the sources of information used for this baseline study.

Table 2-1: Information sources for baseline study

Topic	Source of Information
Topography	OS Terrain 50 contour mapping[2]
Local Mapped Features	OS 1:25000 raster mapping[3]
Hydrogeology – Bedrock, Superficial Deposits & Aquifers	British Geological Survey (BGS) 1:50,000 Web Map Services online mapping[4]
Borehole data	BGS Geology of Britain Viewer[5]
Hydrogeology - Soils	Cranfield Soil and Agrifood Institute Soilscapes map[6]
Presence of GWDTE	Phase 1 habitat survey

2.1 Bedrock

The BGS online mapping service indicates that the proposed development area is underlain by two bedrock geologies. The majority of the site is underlain by sandstone and mudstone of the Penstrowed Grits formation, with the geology along the eastern margins of the site underlain by mudstone and siltstone of the Nantglyn Flags formation.

2.2 Superficial deposits

No superficial deposits have been recorded across large parts of the proposed development area, however where superficial deposits are recorded, they are shown to be Till of the Devensian- Diamicton type, formed in the Quartenary period and glacigenic in origin. These are present in the upper part of the catchments along the eastern edge of the site.

2.3 Soils

In terms of soils, the Landis Soilscapes Map was used to assess these on a strategic scale. Most of the proposed development area is comprised of peaty soils, specifically either slowly permeable wet very acid upland soils with a peaty surface or very acid loamy upland soils with wet peaty surface. In total they encompass approximately 75% of the proposed development area.

Some other soil classes are also present including a region of freely draining acid loamy soils which runs across the central site area and through the west of the southern site area. A small area of slowly permeable seasonally wet acid loamy and clayey soils is also present in the north of the central site area.

2.4 Aquifers

The high annual rainfall of the Cambrian Mountains, combined with the relatively impermeable bedrock, results in significant surface water run-off within river catchments. As such the bedrock aquifer designation across the proposed development area is Secondary B, characterised by predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. There are no principal bedrock aquifers in the vicinity of the site.

There is no aquifer designation for Superficial Drift, thought to be due to the limited extent of drift across both the proposed development area and surrounding areas. There are small areas of GWDTE habitat which

[4] British Geological Survey (2020) Geology 1:50,000 Web Map Services (WMS https://www.bgs.ac.uk/data/services/digmap50wms.html
[5] British Geological Survey (2021) Geology of Britain Viewer, https://www.bgs.ac.uk/map-viewers/geology-of-britain-viewer/
[6] Cranfield Soil and Agrifood Institute Soilscapes (2020) Soilscapes map http://www.landis.org.uk/soilscapes/

are underlain by Devensian Till made up of unsorted sediment and gravel with a fine mud matrix. There is potential that shallow groundwater exists in these deposits and could contribute to GWDTE's water supply.

2.4.1 Hydrogeological Conceptual Site Model

The area is underlain by a succession of Late Ordovician (Ashgill) to Silurian sedimentary rocks, over 5 km thick, deposited between 450 and 420 million years ago in the Early Palaeozoic Welsh Basin[7]. There is an offset vertical fracture trending north to south dividing the two main geological formations underlying the site; Penstrowed Grits and Nantglyn Flags. The examination of all available boreholes in proximity to the site has been completed to develop this model, see Appendix Figure 7 and table 2-2. In all of the formations where boreholes were present the water strike was found at depth. The boreholes with water rest level data available all proved that the groundwater was confined below an impermeable rock strata for the Nantglyn Flags, Glanyrafon and Penstrowed Grits formations. The borehole with BGS ID SO07NE2 was drilled within the Penstrowed Grits formation approximately 1.2km from the site. This aquifer was found to be confined which indicates this same formation underlying the majority of the site is also confined. As a result, the potential GWDTE's within the boundary of the site are not considered to have hydraulic continuity with the bedrock aquifers underlying the site. Therefore, the source of water for these habitats is considered to be from surface water inflow to the near surface soils.

2.5 NVC habitat classification

The areas of GWDTE habitat have been identified within the site boundary which are shown in Figures 1-3. The classification of vegetation can be seen in Table 3-1 below, the national vegetation classification (NVC) and the respective codes are used throughout the table. The habitat number allows cross-reference with the figures appended to this report. The broad national classification of groundwater dependency is recorded as the potential groundwater dependency, with the likely dependency column taking into account the local groundwater conditions of the site. It is with this more accurate classification that the assessment of the impact of the construction and operation techniques is based.

2.6 Additional Local Mapped Features

Peat and rough grassland characterise the majority of the proposed development area. There are some isolated areas of coniferous forest also present, although it is most prevalent between the three development areas.

One mapped spring has been identified within the site boundary, located in the central site area at NGR: 304024, 280619 and is thought to be the source of a tributary to the Custogion Brook lying in the River Ithon catchment.

1 [7] Earthwise BGS (2021) Geology of the Llanidloes area: Introduction http://earthwise.bgs.ac.uk/index.php/Geology_of_the_Llanidloes_area:_Introduction

Borehole NGR and date	BGS reference	Water strike [m depth]	Geological Formation	Proximity to site	Potentiometric level (+/- 10m AOD)
306808 282070 Drilled 2015	SO08SE65 — OLD CHAPEL FARM LLAITHDDU	38m, Within shale, rest level 3m	Nantglyn Flags	3km east of the site, elevation at surface approx. 360mAOD, bottom of valley location	357
307051 281677 Drilled 2016	SO08SE66 — PENCWM FARM LLAITHDDU	43m, within mudstone, no rest level specified.	Nantglyn Flags	Approx. 2.5km east of the site, elevation 350mAOD at surface, bottom of valley	
306458 277874 Drilled 2015	SO07NE2 — WAUN FARM LAITHDDU	26m in shale, rest level 9 m	Penstow Grits	Approx 1.4km east of site, 416mAOD elevation at surface, valley location	407
300701 283234 Drilled 2017	SO08SW41 — TY'N-Y-PWLL DOLWEN LLANIDLOES POWYS	60m, within mudstone, rest level 15m	Glanyrafon	Approx 3km west of the site, 240mAOD surface elevation, mid way up a hillside.	225
306712 279492 Drilled 2018	SO07NE4 — LLAITHDDU POWYS LD1 6YS	15m, in mudstone, rest level 3m	Nantglyn Flags	Approx 2.2km east of site, 340mAOD surface elevation, in valley	337
300200 280100 Drilled 2012	SO08SW40 — FELIN GUTRHOS LLYDIARTYWAEN	26m, within purple gritstone, no rest level	Dolgau mudstones	Approx 4km west of the site, surface elevation 310mAOD, in valley	
299542 280144 Drilled 2018	SN98SE38 — BRYNHESGLYWN LLIDIARTYWAEN LLANIDLOES	24m, within mudstone, rest level 9m	Glanyrafon	Approx 5km west of site, surface elevation 390mAOD, near summit of hill	381
300300 284817 Drilled 2019	SO08SW42 — UPPER CAERAU DOLWEN LLANIDLOES	18m, within mudstone, rest level 3m	Glanyrafon	Approx 3.5km North-west of the site, elevation 250mAOD, half way up hillside	247
307508 280830, Drilled 2016	SO08SE67 — HAFOD FARM LLAITHDDU	45m, within mudstone, no rest level	Nantglyn Flags	Approx 3km east of the site, elevation 360mAOD, on hill.	
308066 282215 Drilled 2014	SO08SE64 — ESGAIR DRAEN LLWYN LLAITHDDU	9m, within shale, no rest level	Nantglyn Flags	Approx 4km east of the site, elevation 380mAOD, half-way up hillside	

Table 2-2: Borehole Information

3 Potential impacts on Groundwater Dependant Terrestrial Ecosystems

3.1 Construction

Excavation of soil and bedrock during construction within the vicinity of a GWDTE (including peat) may cause localised disruption and interruption to groundwater flow, with associated dewatering potentially causing a large change to the quantity of groundwater supply. Where GWDTE are present, interrupting groundwater flow may reduce the proportion of the ZoC available to such ecosystems, by changing the quantity of surface water runoff and groundwater supplying the GWDTE. The ZoC is defined for each habitat as the area up hydraulic gradient of the GWDTE, based upon the geology and topographic information of the site. Contamination of groundwater or surface water may cause physical or chemical contamination to the GWDTE.

The habitats are differentiated between those which are potentially highly and moderately groundwater dependent. Table 3-1 presents each of the identified potential highly and moderately dependent ecosystems within the buffer zones. Their likely dependence on groundwater based on the topographic and geological location is discussed. There is a range of dependencies across the site resulting from the variety of elevations and substrata typologies. There are no areas of highly dependent GWDTE when taking into account the baseline characteristics of the locality, however moderate and low dependency habitats are present. There are numerous locations where infrastructure is proposed that will result in direct GWDTE habitat loss, which is considered in the ecology chapter. Where access tracks are proposed appropriate drainage would ensure runoff is not diverted away from the habitats. Those habitats located down hydraulic gradient of the infrastructure, which could be dewatered during construction, such as turbine foundations are potentially at risk from a change in groundwater quantity and quality.

Table 3-1: Assessment of the GWDTE's areas of the Garn Fach site

GWDTE (NVC Community)	Habitat area number	Potential Groundwater Dependency	Likely Groundwater Dependency	Potential Reduction in GWDTE ZoC with Embedded Mitigation
Rush-Pasture – M23 Centred on 304610, 279940	14	Highly dependent, moderate in some hydroecological conditions.	Moderate:. High rainfall, surface water and shallow groundwater within the till superficial deposits are likely to support this habitat.	The access track crosses this habitat, parallel to the slope direction, therefore track drainage should not reduce groundwater availability. However, there will be direct habitat loss, which is assessed in the ecology chapter. A borrow pit is located in this habitat, further increasing habitat loss. T13 is within 250m of the southern edge of this habitat, although out of its ZoC. T12 and its crane pad is within its ZoC, however it is 360m away. Additional mitigation around the borrow pit will be used in the form of parallel to contour drainage. See Appendix 10.7 - Water Management Plan – Section 3.1.2.
Rush-Pasture – M23 Acid Grassland – U6 & U5 Centred on 303467, 281206	12	Highly dependent, moderate in some hydroecological conditions.	Low: impermeable bedrock underlays this area. Likely rainfall and surface water runoff supports this habitat.	T8 and its crane pad are located in this habitat, and the track crosses it. This will lead to some direct habitat loss, which is assessed in the ecology chapter. Embedded cross track drainage will be included to ensure hydraulic continuity.
Rush - Pasture – M23 Mire – M25 Centred on 303606, 281611	11	Highly and moderately dependent respectively.	Low: impermeable bedrock underlays this area. Likely rainfall and surface water runoff supports this habitat.	T7 and its crane pad are located in this habitat, and the access track crosses it. This will lead to direct habitat loss, which is assessed in the ecology chapter. Embedded cross track drainage will be included to ensure surface water hydraulic continuity.
Rush - Pasture – MG10 Centred on 304168, 280962	10	Moderate dependency	Low: impermeable bedrock underlays this area. Likely rainfall and surface water runoff supports this habitat.	This habitat is within 250m of T9 and T10 and crane pads. The access track is within 100m and crosses this habitat. This infrastructure is within the ZoC, however T10 is down slope and will not have an effect on water availability to this habitat. T9 and the upslope access track could impact water availability of throughflow and surface flow. Embedded cross track drainage will be included here.
Rush - Pasture – MG10 Centred on 304676, 280693	9	Moderate dependency	Low: Underlain by impermeable bedrock, wet and slowly permeable soil type, resulting in low dependency on groundwater. Likely dependent on surface water runoff.	T11 is within 250m but it is downslope of the habitat. The access track crosses the habitat, loss will occur, see Ecology chapter for assessment.
Rush - Pasture – MG10 Centred on 305095, 280385	8	Moderate dependency	Low: Underlain by impermeable bedrock, and partly by Till, seasonally wet and slowly permeable soil type and low elevation could likely mean moderate dependency on shallow groundwater.	The habitat is within 100m of the access track buffer and is in the ZoC. Embedded cross track drainage will be included to the west, to ensure hydraulic continuity to the habitat.
Rush - Pasture – MG10 Centred on 304044, 279678	7	Moderate dependency	Low: Underlain by impermeable bedrock, freely draining soil and high elevation. Likely lowdependency, as rainfall and surface water would support this habitat.	It is within 250m of T12 and 100m of the crane pad and track, which are upslope in the ZoC. Due to the likely low dependency, additional mitigation of parallel to contour drainage around T12 will ensure hydraulic continuity of surface water to this habitat.
Festuca ovina grassland – U6 Rush – Pasture M23 Centred on 303854, 279217	1	M23 highly dependent, U6 moderately dependent (high in some ecohydrological conditions)	Low: Low permeability bedrock, wet peaty soil indicates low dependency on groundwater.	Habitat is within 250m of T12 and T13, and associated crane pads, it is within 100m of the access track. However T13 and infrastructure is out of its ZoC, being downslope. Embedded cross track drainage and additional mitigation of parallel to contour drainage around T12 will be used to ensure hydraulic continuity of surface water to this habitat.

GWDTE (NVC Community)	Habitat area number	Potential Groundwater Dependency	Likely Groundwater Dependency	Potential Reduction in GWDTE ZoC with Embedded Mitigation
Mire – M25 Rush – Pasture M23 Centred on 304328, 279100	2	M23 highly dependent, M25 moderately dependent (high in some ecohydrological conditions)	Moderate: Lies across the boundary of bedrock and superficial till deposit, with the lower half of habitat over Till, could indicate dependency on shallow groundwater. Likely moderate dependency.	Habitat is within 250m of T14, crane pad and the associated access track. This is within the ZoC of the lower elevation parts of the habitat. Embedded cross track drainage and additional mitigation in the form of drainage parallel to contours around T14 will be used, to prevent impact to shallow groundwater resources. See Appendix 10.7 - Water Management Plan.
Mire – M25 Rush - Pasture – MG10 Centred on 304697, 279140	3	M25 moderately dependent, MG10 moderately dependent	Moderate: Entire habitat over superficial till deposit, with slowly permeable soil, indicates moderate dependency on shallow ground water.	Habitat is within 250m of T13, T15 & T16 and their infrastructure, with T14 sited in the habitat. The access track is within 100m. These are all in the ZoC, with the habitat downslope of the infrastructure. Alongside T13 there is an auxiliary infrastructure. Dewatering during construction may have short term impacts on shallow groundwater resources. Embedded cross track drainage and additional mitigation in the form of drainage parallel to contours around T14 and T16 will be used. ,See Appendix 10.7 - Water Management Plan.
Rush Pasture – MG10 Centred on 304579, 278646	4	Moderate dependency	Moderate: Almost the entire habitat over superficial till deposit, with slowly permeable soil, indicates potential moderate dependency on shallow ground water.	This habitat is within 250m of T15, T16 & T17, 100m of the access tracks linking them and 250m from an auxiliary infrastructure adjacent to T15. T17 is out of the ZoC, however T16 and T15 and access tracks are within the ZoC. It is 70m from a borrow pit, to the west. Dewatering during construction may have short term impacts on shallow groundwater resources. Embedded cross track drainage and additional mitigation in the form of drainage parallel to contours around T15, T16, the borrow pit and the auxiliary infrastructure will be used to mitigate losses of surface and shallow groundwater. See Appendix 10.7 - Water Management Plan.
Rush – Pasture M23 Centred on 304797, 277983	5	Highly dependent	Moderate: Entire habitat over superficial till deposit, likely moderate dependency on shallow groundwater.	These rush pastures are within 250m of T17 and its infrastructure. They are downslope and within the ZoC. Embedded drainage around T17, its infrastructure and track will be used to prevent reduction of available groundwater resources to this moderately dependent habitat.
Rush Pasture – MG10 Rush – Pasture M23 Mire – M25 Centred on 304674, 277571	6	M23 highly dependent, M25 & MG10 moderately dependent.	Moderate: Majority of habitat overlying till with slowly permeable soil, indicates likely moderate dependency on shallow ground water.	Only MG10 vegetation within 100m of the access track, but the track doesn't fall within the ZoC here.
Rush pasture - M23 Centred on 303632, 282053	13	Highly dependent	Low: Underlain by impermeable bedrock, and high elevation indicate that this habitat is supported by rainfall and surface water run-off predominantly. Resulting in a likely low dependency.	This habitat is within 250m of T7, T5 & T6. T7 & T5 are outside of the ZoC. Embedded drainage parallel to contours around T6 will be used to limit the impact on groundwater resources for this habitat during turbine construction. Embedded cross track drainage will be required here.
Mire – M6 Centred on 303997, 282377	15	Moderate, can be high in some ecohydrological conditions.	Moderate: The southern portion of this habitat is underlain by till, alluvium and head superficial deposit. It has a wet peaty soil and is at a lower elevation. This indicates a likely moderate dependence on shallow groundwater within superficial deposits.	The habitat is within 100m of the track and 250m of T4. Both are within the ZoC and there is potential that during construction of T4, dewatering could cause groundwater levels to become reduced for this habitat. Embedded cross track drainage and additional mitigation in the form of parallel to contour drainage around T4 will be included. There will also be direct habitat loss as the track crosses the habitat, see the ecology chapter for assessment.

GWDTE (NVC Community)	Habitat area number	Potential Groundwater Dependency	Likely Groundwater Dependency	Potential Reduction in GWDTE ZoC with Embedded Mitigation
Rush Pasture – MG10 Centred on 304125, 282590	16	Moderate – high in some ecohydrological conditions.	Low: Underlaid by impermeable bedrock, and high elevation indicate that this habitat is supported by rainfall and surface water run-off predominantly. Resulting in a likely low dependency.	T4 and its infrastructure will be built over the northern portion of this habitat, therefore direct habitat loss will occur here, see ecology chapter for assessment. Embedded drainage around T4 will likely allow surface runoff to reach the remaining southern portion of the habitat. The access track runs around the north and east of this habitat. Embedded cross track drainage will allow the continued hydraulic continuity across the track for this habitat.
Festuca ovina grassland - U6 Mire - M6 Rush pasture U23 Centred on 303567, 282436	17	High and moderate	Low: Slowly permeable wet soil, underlain by impermeable bedrock would indicate that this habitat has low dependency on groundwater, supported by rainfall and surface runoff.	T3 & T5 are within 250m of parts of this habitat, with the access track within 100m. All of this infrastructure is within the ZoC. Surface water connection to the habitats will be maintained via embedded drainage around the turbines and cross track drainage.
Festuca ovina grassland - U6 Rush pasture U23 Centred on 303401, 282691	18	High and moderate	Low: Slowly permeable wet soil, underlain by impermeable bedrock would indicate that this habitat has low dependency on groundwater, supported by rainfall and surface runoff.	T3 is sited within this habitat, leading to habitat loss. The access track is within 100m of the habitat. These features are within the ZoC, however as we would expect low groundwater dependency here, embedded drainage around the turbine and cross track drainage, will be sufficient to mitigate impacts on this habitat.
Rush pasture - M23 estuca ovina grassland - U6 Centred on 304065, 282947	19	High and moderate.	Low: Slowly permeable wet soil, underlain by impermeable bedrock would indicate that this habitat has low dependency on groundwater, supported by rainfall and surface runoff.	T1 is sited within this habitat on the upslope side, leading to direct habitat loss (see ecology chapter). The access tracks are within 100m. The auxiliary infrastructure is downslope of the habitat, so would be out of its ZoC. Low groundwater dependency would be expected here, embedded drainage around the turbine and cross track drainage, will be used to fully mitigate impacts on this habitat.
M15 – Wet Heath M25 - Mire U6 Festuca ovina grassland - Mire - M6 Centred on 303684, 283108	20	Moderate	Low: Slowly permeable wet soil, underlain by impermeable bedrock and being located at the top of the ridge would indicate that this habitat has low dependency on groundwater, supported by rainfall and surface runoff.	T2 is sited within this habitat, leading to direct habitat loss (see ecology chapter). The majority is within the buffer zone of T2 and the access track, which are within its ZoC. T1 is within 250m, however it is downslope of this habitat. An auxiliary infrastructure located to the North within 250m. It is unlikely that this habitat is supported by groundwater, therefore only the embedded drainage around T2 and the auxiliary infrastructure and cross track drainage would need to be used here.
Rush pasture - M23 Centred on 303551, 283391	21	High dependency	Low: Slowly permeable wet soil, underlain by impermeable bedrock and being located at the top of the ridge would indicate that this habitat has low dependency on groundwater, supported by rainfall and surface runoff.	Within 250m of T2, which is in the ZoC. However, it is unlikely to be groundwater dependent so embedded drainage around T2 and cross track drainage would be used to fully mitigate the impact on this habitat.

3.2 Operational

During the operational phase of the wind farm there is the potential that cross track flow will be reduced, both on the surface and through subsurface throughflow. This could lead to water logging of areas upslope of tracks and drying on the downslope side. A change in the hydrological regime could restrict the GWDTE habitats water source and lead to degradation and habitat loss.

4 Proposed Mitigation and residual effects

Through the assessment of GWDTE's in Table 3-1, mostly low and some moderately dependent habitats have been identified within range of the site infrastructure. It was found that the low dependency habitats are not reliant on groundwater resources, identified through the hydrogeological conceptual model and site characteristics. The low dependency habitats require drainage for the surrounding infrastructure which ensures the hydraulic continuity of surface water to these habitats which they may partly rely upon. For the moderate dependency habitats, we have concluded they could be partially reliant on the groundwater of superficial deposits, whilst also being supported by rainfall and surface water. Therefore, additional mitigation techniques must be employed to protect them from potential changes to these localised groundwater resources. A summary of proposed mitigation techniques is provided below, followed by any residual effects expected.

4.1 Low dependency

- Avoiding siting infrastructure within GWDTE habitats where possible.
- Include embedded cross track drainage in the drainage design to maintain hydraulic continuity of surface water to the habitat areas it supports.
  Where infrastructure other than tracks are within the zone of contribution maintain the flow paths/redistribute water when it is diverted.

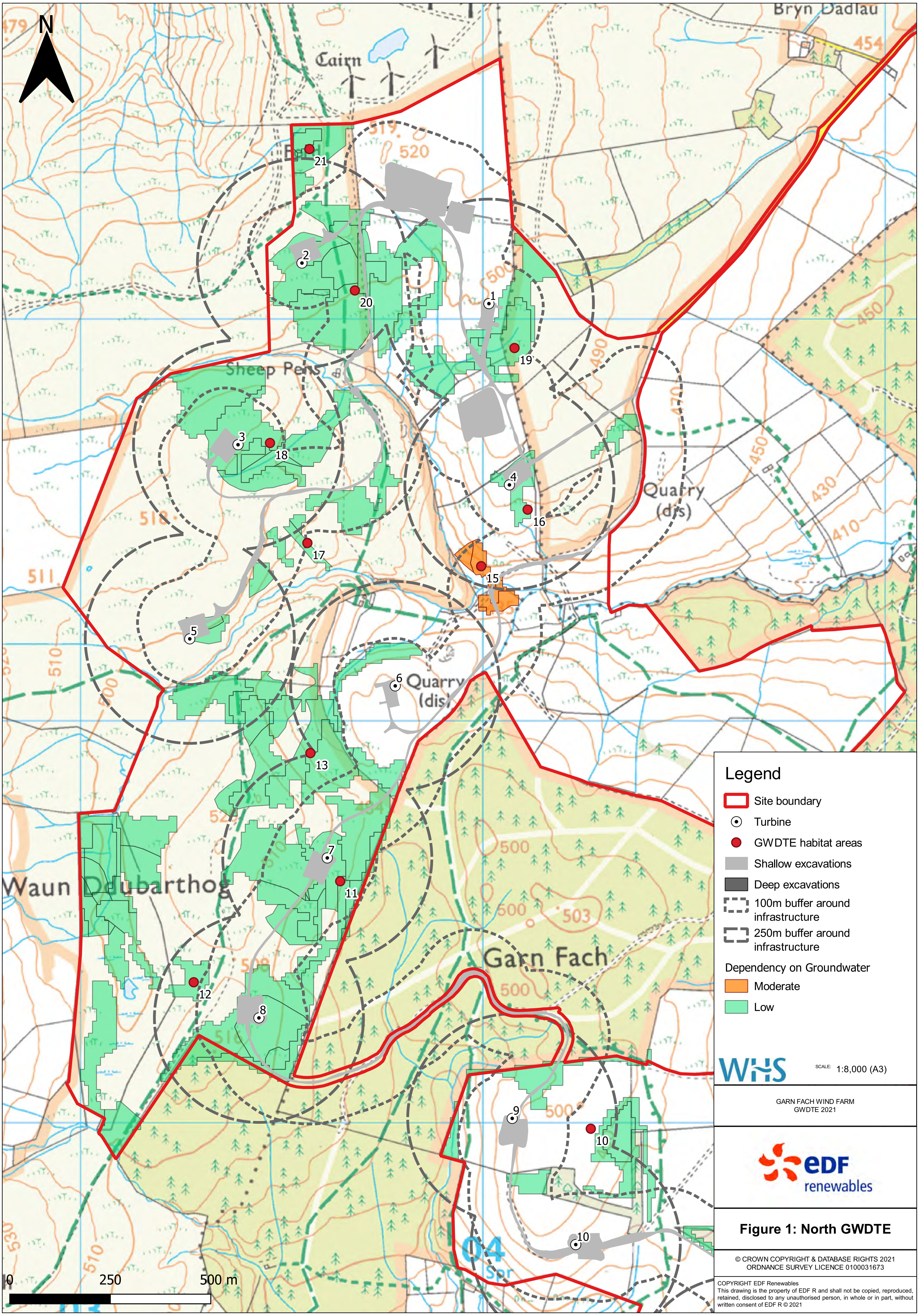
4.2 Moderate Dependency

- Appropriate embedded drainage around turbine bases, with a path that is parallel to the site contours would ensure that the ZoC of the habitats would not be significantly reduced. This would allow an opportunity for water to re-infiltrate and recover the groundwater levels in areas with moderate groundwater dependency.
- Appropriate embedded drainage around borrow pits.
- Include embedded cross track drainage in the drainage design to maintain hydraulic continuity of surface water that supplies shallow groundwater areas.
- Demarcation of the most sensitive areas and monitoring of works in close proximity by the Environmental Clerk of the Works.
- Avoiding siting infrastructure within GWDTE habitats where possible.

Due to the likely low to moderate dependency on groundwater of the habitats identified in the site, the appropriate mitigation techniques outlined here must be employed to not lead to any residual effects on the GWDTE of the site. There will be some direct loss of habitat where infrastructure is proposed within GWDTE habitats, this is assessed with the Ecology chapter of the ES.

5 Summary/Conclusion

- Turbines T12 T14, T16, T6, T15, T17, T4 and both borrow pits – must have parallel to contour drainage to increase infiltration where shallow groundwater could be lost by dewatering during the construction phase.
- There are many areas of access track that will require cross track drainage associated with locations of GWDTE habitats to maintain the surface water hydraulic connectivity.
- There are areas where direct GWDTE habitat loss will occur with the current infrastructure placements.


N
Cairn
Bryn Dadlau
Sheep Pens
Quarry (dis)
Waun Ddubarthog
Garn Fach
Legend
Site boundary
Turbine
GWDTE habitat areas
Shallow excavations
Deep excavations
100m buffer around infrastructure
250m buffer around infrastructure
Dependency on Groundwater
Moderate
Low
WHS
SCALE: 1:8,000 (A3)
GARN FACH WIND FARM
GWDTE 2021
eDF renewables
Figure 1: North GWDTE
© CROWN COPYRIGHT & DATABASE RIGHTS 2021
ORDNANCE SURVEY LICENCE 0100031673
COPYRIGHT EDF Renewables
This drawing is the property of EDF R and shall not be copied, reproduced, retained, disclosed to any unauthorised person, in whole or in part, without written consent of EDF R © 2021
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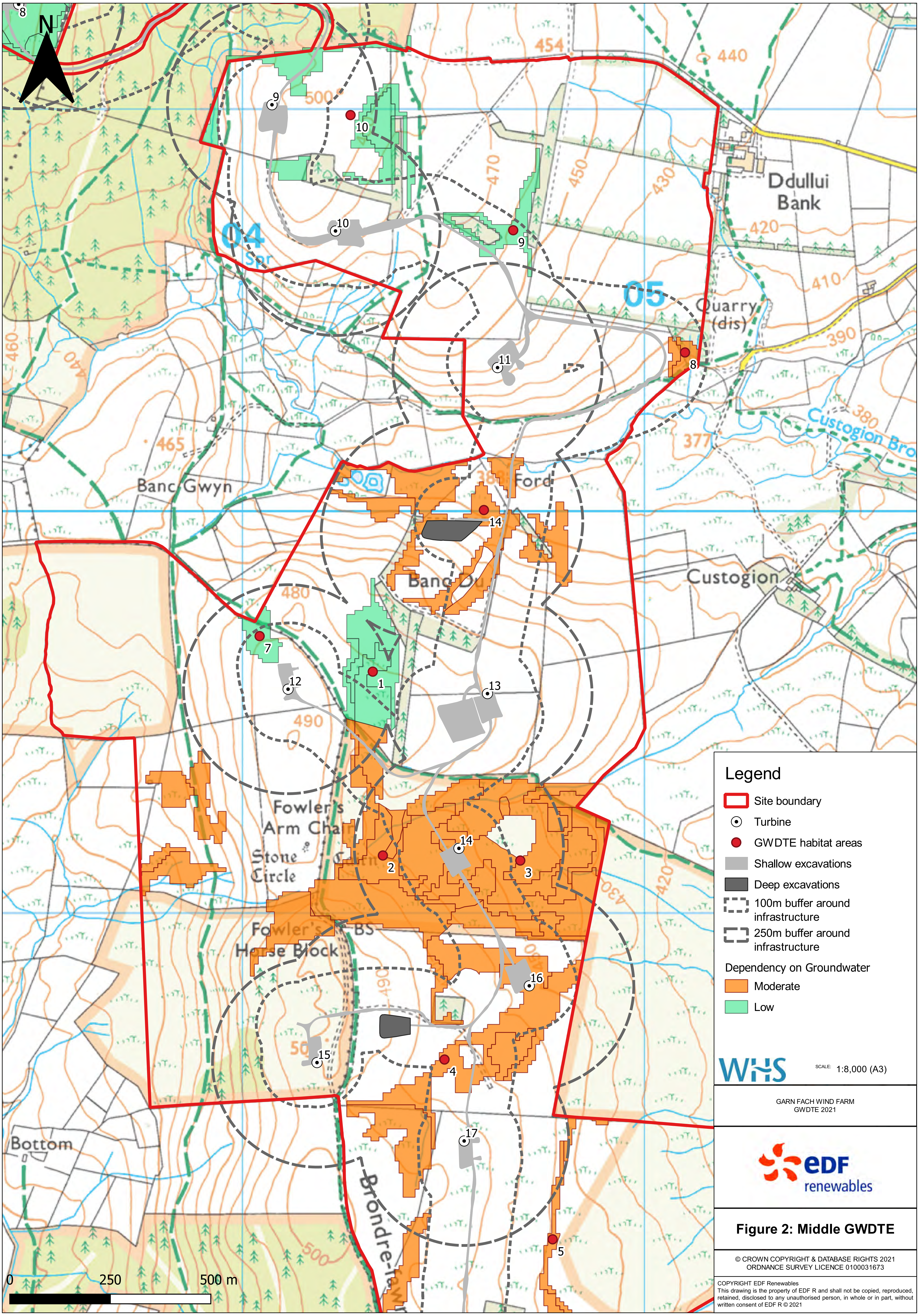
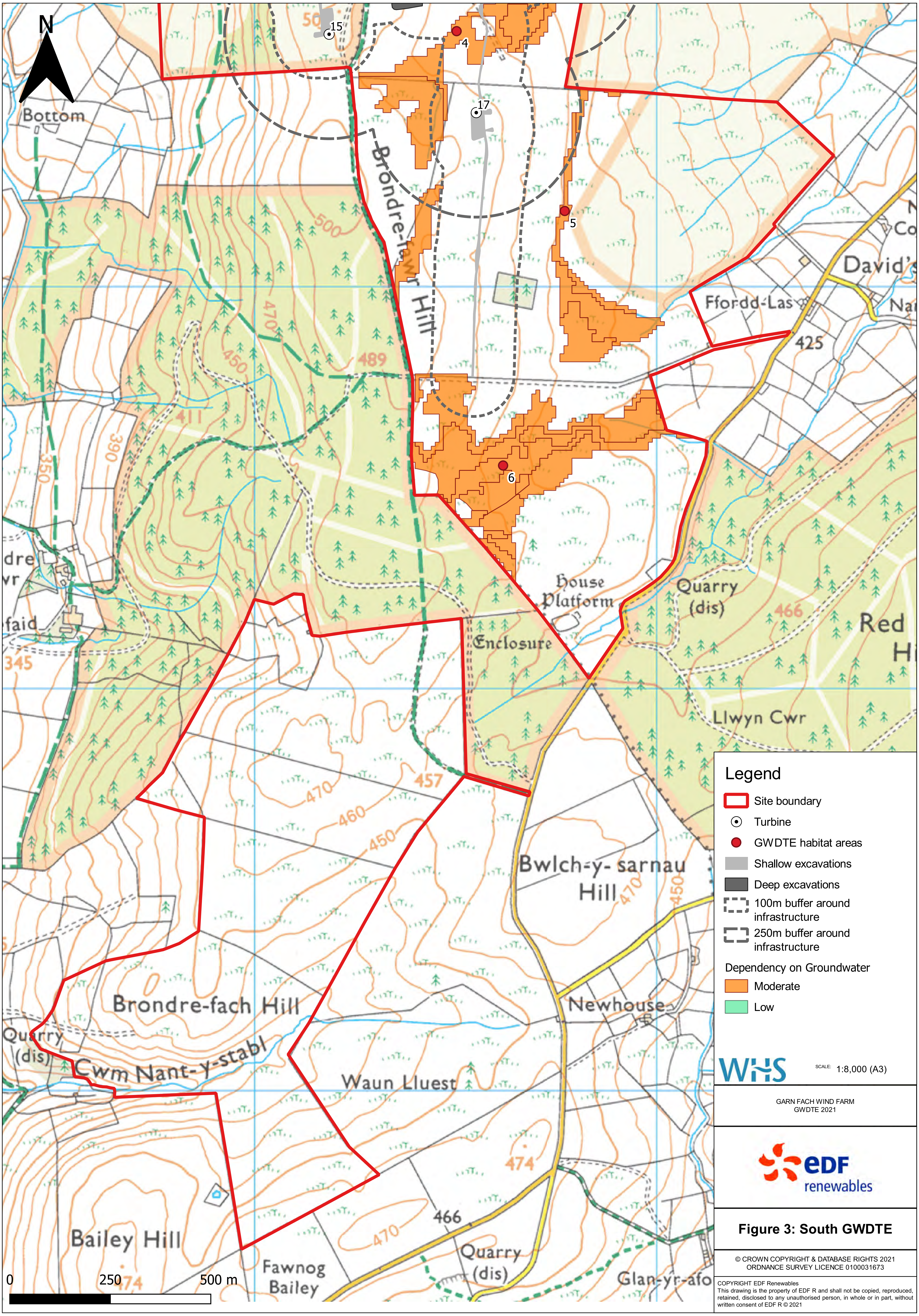


Figure 2: Middle GWDTE



N
Bottom
Brondre-fawr Hill
Ffordd-Las
David's
425
489
500
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411
390
350
345
House Platform
Enclosure
Quarry (dis)
466
Red Hi
Llwyn Cwr
457
470
460
450
Bwlch-y- sarnau Hill
Newhouse
Brondre-fach Hill
Cwm Nant-y-stabl
Waun Lluest
474
Bailey Hill
Fawnog Bailey
Quarry (dis)
Glan-yr-afo
0
250
500 m
Legend
Site boundary
Turbine
GWDTE habitat areas
Shallow excavations
Deep excavations
100m buffer around infrastructure
250m buffer around infrastructure
Dependency on Groundwater
Moderate
Low
WHS
SCALE: 1:8,000 (A3)
GARN FACH WIND FARM
GWDTE 2021
EDF renewables
Figure 3: South GWDTE
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ORDNANCE SURVEY LICENCE 0100031673
COPYRIGHT EDF Renewables
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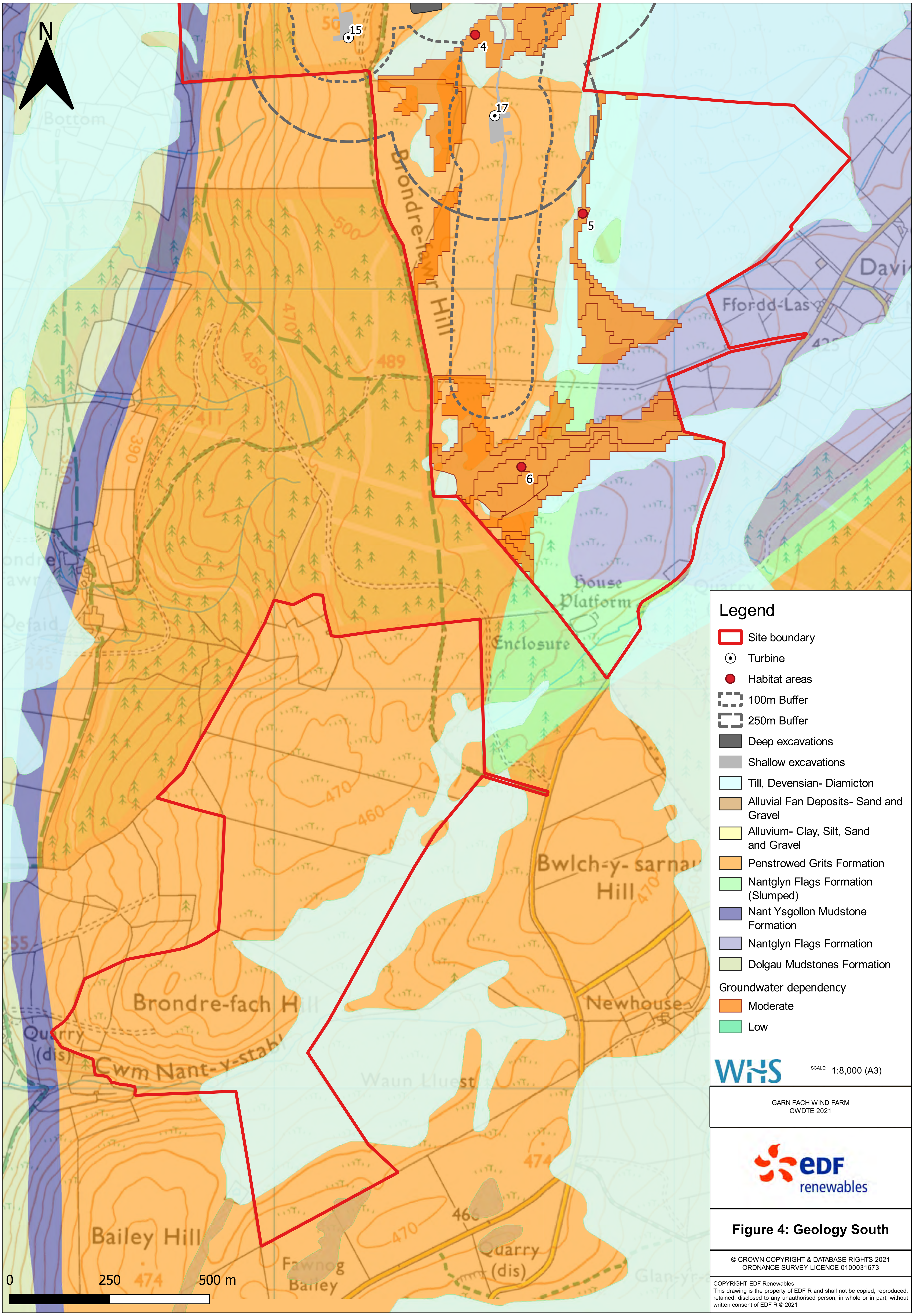
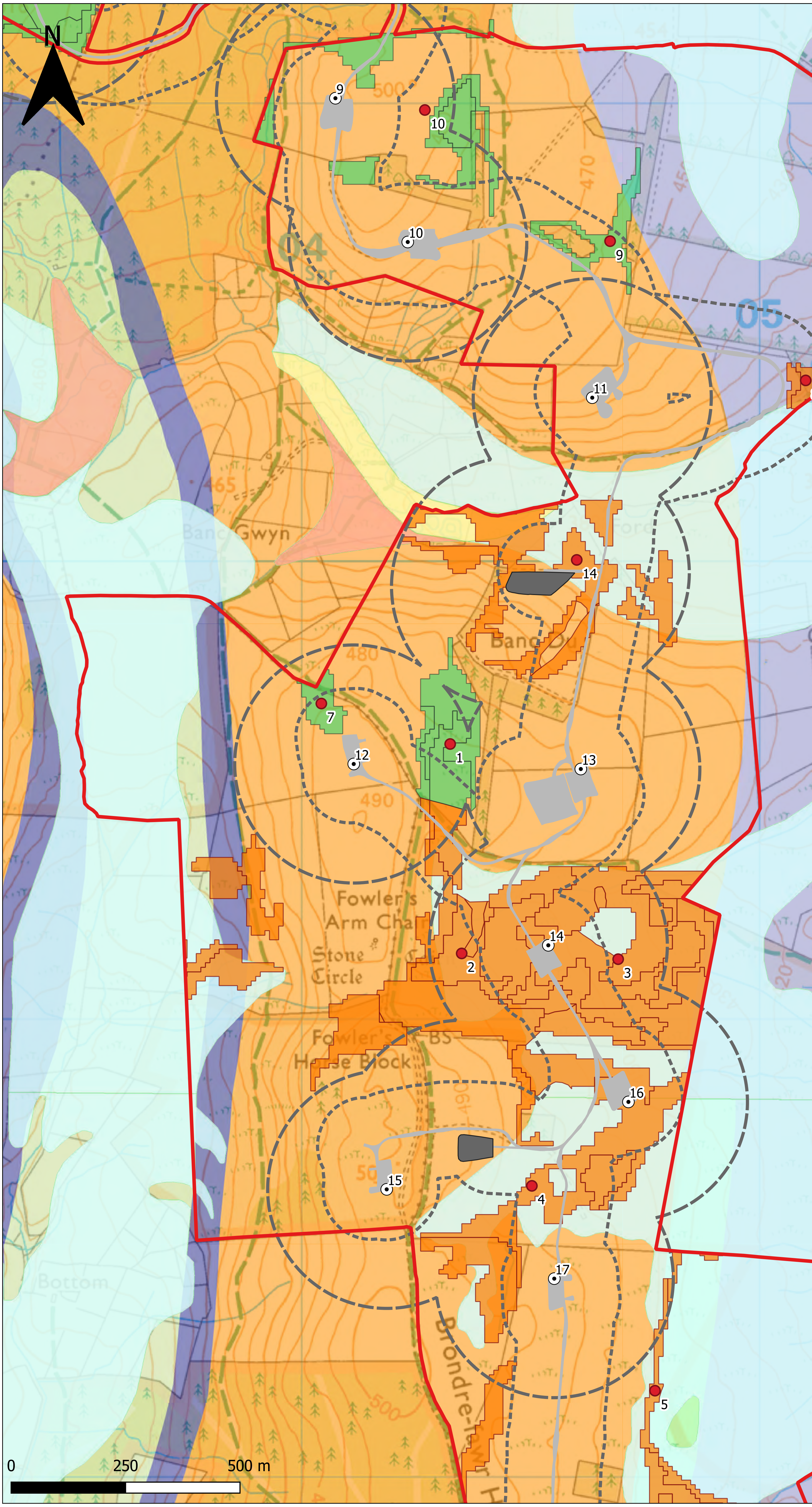


Figure 4: Geology South



Legend

- Site boundary
- Turbine
- Habitat areas
- 100m Buffer
- 250m Buffer
- Deep excavations
- Shallow excavations
- Till, Devensian- Diamicton
- Alluvial Fan Deposits- Sand and Gravel
- Alluvium- Clay, Silt, Sand and Gravel
- Penstrowed Grits Formation
- Nantglyn Flags Formation (Slumped)
- Nant Ysgollon Mudstone Formation
- Nantglyn Flags Formation
- Dolgau Mudstones Formation

Groundwater dependency

- Moderate
- Low

WHS SCALE: 1:8,000 (A3)

GARN FACH WIND FARM
GWDTE 2021

edf renewables

Figure 5: Geology Middle

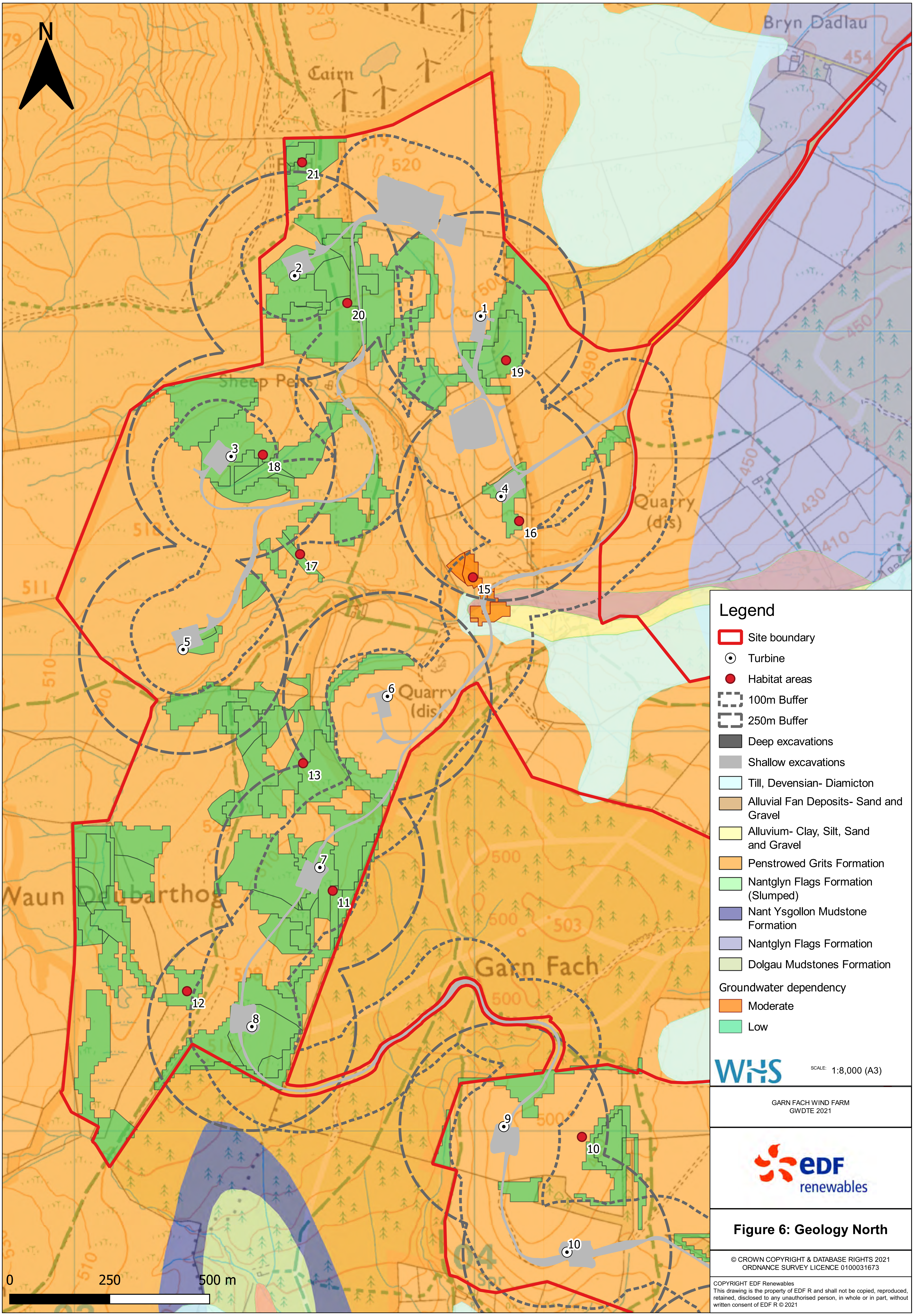


Figure 6: Geology North

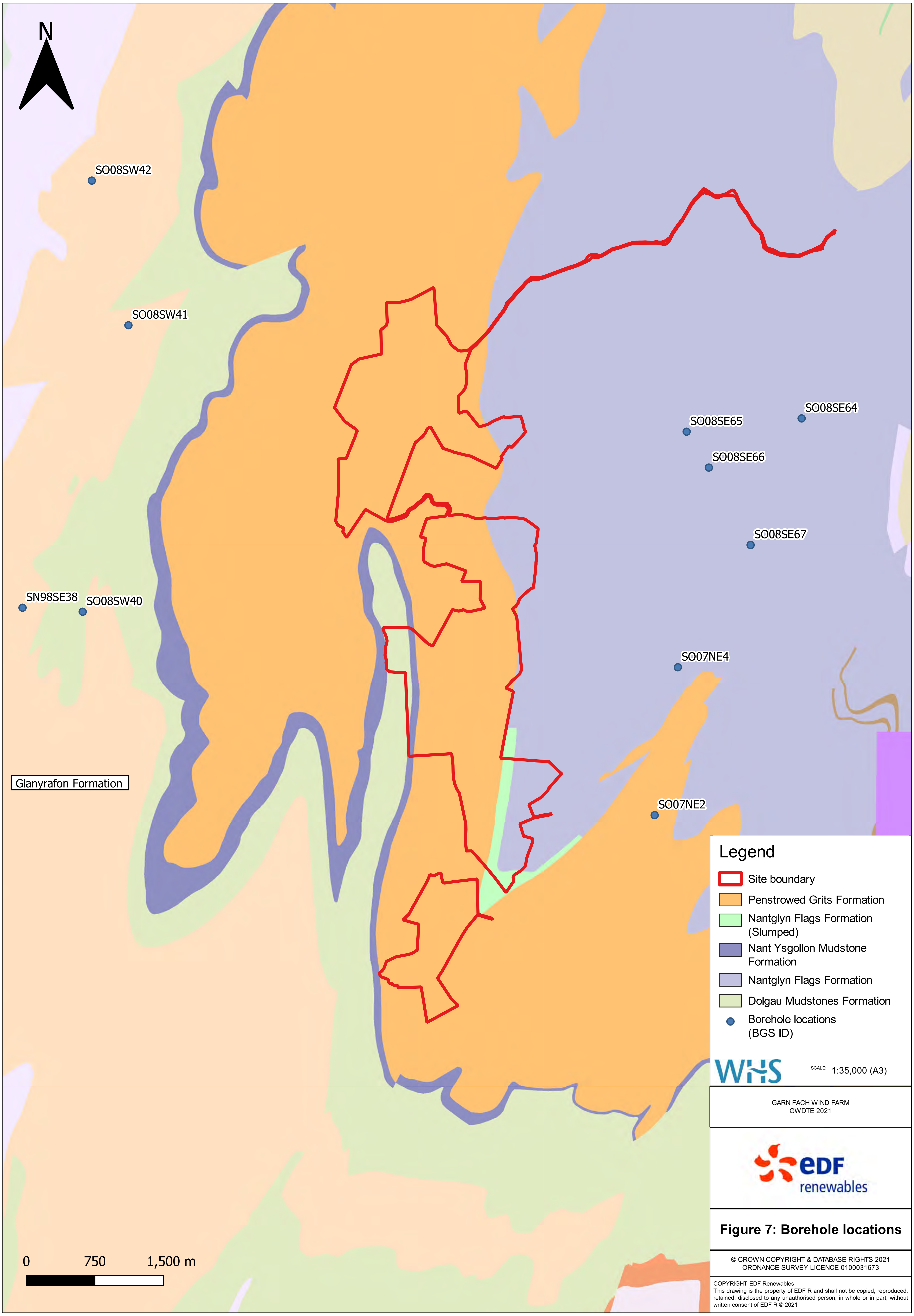


Figure 7: Borehole locations

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Appendix 10.6- Garn Fach Wind Farm Private Water Supply Risk Assessment

Executive Summary

This document forms the private water supply risk assessment for the Garn Fach wind farm. The EIA Report desk-study and preliminary consultation with Powys County Council (PCC) revealed that, although there are no properties located within the Site, there are a number of properties served by a Private Water Supply (PWS) within the draining sub-catchments. Of the PWS identified, 20 drain the proposed development site. Mitigation such as exclusion zones, Sustainable Drainage Systems, pollution control measures and the implementation of a Pollution Prevention, Water Quality Monitoring and an Emergency Response Plan will be implemented to protect these supplies. As a result, no significant effects are considered likely.

Contents

1 Introduction

This private water supply risk assessment (PWSRA) report is submitted in support of a planning application made by EDF Renewables for the proposed Garn Fach wind farm (the Proposed Development). Located south of Newtown, Powys, NGR: SO 03413 81467, the Site is situated approximately 10 km south of Newtown and 7 km east of Llanidloes.

The hydrological assessment in Chapter 10 of the Environmental Statement (ES), undertaken by Wallingford HydroSolutions Ltd (WHS), details the impacts of the Proposed Development upon the hydrological environment. The Site is illustrated in Chapter 10, Figure 10.1. The EIA Report desk-study and preliminary consultation with Powys County Council (PCC) revealed that, although there are no properties located within the Site, there are a number of properties served by a Private Water Supply (PWS) within the draining sub-catchments; thus necessitating a Private Water Supply Risk Assessment (PWSRA). PWSs are defined as any water supply that is not provided by a statutory water undertaker; the responsibility for its maintenance lies with the owner, or person who uses the supply. These supplies may be drawn from a variety of surface and groundwater sources. The PWS sources are recognised as a potential key sensitive feature that are required to be considered as part of the hydrological assessment of a wind farm.

Those properties requiring further assessment are detailed in Section 2. For these properties, a PWSRA was conducted to confirm the details of the water supply with the property residents. Section 3 presents the details of the PWS and the confirmed abstraction locations.

The risks associated with the construction and operation of the Proposed Development, are assessed on a source-by-source basis within Section 0. This has been achieved through a review of the proposed design to determine if the activities associated with the construction and operation of the Proposed Development are likely to affect each source. Where necessary, mitigation measures are proposed to protect those water supplies that could be at risk from the construction and/or operation, within Section 5. Finally, the residual impacts are presented in Section 6. Chapter 10 of the ES details the assessment methodology to determine the significance of impacts upon the hydrological baseline. The same assessment methodology has been used within the PWSRA.

2 Identification of Water Supplies and the requirement for a PWSRA

PCC were contacted on 9 September 2020 to confirm the location and type of any properties served by a PWS within the sub-catchments draining the Site. There are no properties within the Site. PCC identified 16 properties on a PWS within close proximity of the Proposed Development.

It is notoriously difficult to identify all PWSs in any area, particularly one as rural as the Garn Fach Site. For example, records usually identify the property rather than the location and type of the PWS source. In addition, the sources can be small springs that are obscure and hard to locate without detailed local knowledge. Furthermore, it is not compulsory for abstractors of private water for domestic use to notify Local Council Environmental Standards departments. 17 additional potential PWS properties within the drainage pathways of the Site were also identified during the desk-study. Although these 17 properties are not listed by PCC, they may use a PWS and therefore have been investigated further. A total of 34 properties have therefore been identified as potentially being served by a PWS.

Table 2-1 lists all 34 properties identified within the desk-study and consultation with the PCC, and their requirement for additional information. Those requiring additional information on their water supply form part of this PWSRA, where the use of a PWS is confirmed. The dependency of a property requiring a PWSRA is determined by the property PWS being located within the drainage pathways of the Site. Of the 34 properties identified, 31 properties warranted a detailed risk assessment based upon their location and topography with respect to the Site, as presented in Figures 1 and 2, and Table 2-1.

Not all of the properties served by a PWS were taken forward into the PWSRA, for the following reasons:

- Property deemed either distant enough from, or outside of, the Site drainage pathways so as not to be hydrologically connected to the Site; and/or

- Property located such that the likely zone of contribution of the PWS would not be at risk from any potential wind farm activity.

Letters and questionnaires notifying resident of the PWSRA were issued in October 2020 and properties identified as requiring further information were visited in December 2020. The questionnaire asked residents for details of their water supply, and if on a PWS, the source, type, treatment, location (to mark on accompanying map), number of people the supply serves and source history (including issues associated with the quantity and quality).

Of the questionnaires issued, 13 were not returned. These properties were visited in December 2020, whereupon four further responses were collected. One further response was then collected in April 2021, pertaining to Nanthir (Lower) and Rock House. It is noted as a limitation of this assessment, that the Coronavirus pandemic limited the opportunity for face-to-face discussions with residents, such that beyond the information enclosed within survey responses, no significant additional detail was gathered from the site visit undertaken. Where confirmation of PWS' could not be confirmed we have conservatively assessed the properties as using a PWS.

Table 2-1 Properties identified within the desk-study and consultation with PCC, with their requirement for additional information and use of PWS confirmed

Property	Property NGR	Further information required?	Use of PWS confirmed
Ashdale	303323, 276134	Yes	Yes
Beilibog	303301, 275305	No	Yes (No further assessment required)
Brondrefach	303323, 276134	Yes	Yes
Brondrefawr	303513, 277296	Yes	Yes
Bryn Heulog	307360, 281410	Yes	Yes
Bwthyn Penygareg	306405, 282342	Yes	Yes
Custogion	305358, 279829	Yes	Yes
Cwmderw	303059, 278760	Yes	Yes
Ddulley Bank Farm	305202, 280903	Yes	Yes
Fwnog	304806, 281359	Yes	Yes
Glan Ithon Lodge	306928, 280353	Yes	Unconfirmed
Glanyrafon	307060, 281619	Yes	Yes
Gorsty	307325, 281281	Yes	Yes (shared)
Great Meadows	305913, 278491	Yes	Yes
Green Meadow	306048, 278423	Yes	Yes
Maens Cottage	305560, 280560	Yes	Yes
Nanthir (Lower)	305533, 277982	Yes	Yes
Old House- Blue Lins River Cottage	306680, 282169	Yes	Unconfirmed
Old School	306904, 280029	Yes	Unconfirmed
Pabyllwyd	305361, 282589	Yes	No (defunct supply)
Pabyllwyd Barn	305358, 282587	Yes	Yes
Pen Ithon Hall	307546, 281438	Yes	Yes
Pen Ithon Lodge	307572, 281162	Yes	Yes
Pencwm	307264, 280782	Yes	Unconfirmed
Pencwm Cottage	307242, 281118	Yes	Yes
Penygarreg	306379, 282374	Yes	Yes
Rock House	305762, 278305	Yes	Yes
School House	306930, 280391	Yes	Unconfirmed
Stables	307394, 281374	Yes	Yes
Upper Llaithddu	306550, 279369	Yes	Yes
Upper Maens	305824, 280711	Yes	Yes
Upper Nanthir	305722, 277863	Yes	Unconfirmed
Waun Cottage	306457, 278067	No	Yes (No further assessment required)
Wuan Llydan	306372, 277950	No	Yes (No further assessment required)

3 Private Water Supply Details

3.1 Confirmed Private Water Supplies

24 different private water supplies were identified through consultation with the property residents. A number of these supplies provide drinking water to more than one property. Throughout the risk assessment, the supplies are referred to as follows:

- The **Ashdale** supply services the house and is shared by **Brondefach**. The supply consists of a spring and well located upslope of the properties along an access track near the forestry.
- The **Brondrefawr Supply** is taken from natural watercourses from the forestry land.
- The **Bryn Heulog Supply** services the house and farm only. Consists of a spring which is located some half a kilometre from the property in open fields.
- The **Bwthyn Penygareg Supply** services the house, garden and three polytunnels. The supply consists of a spring located 300m north of the property, which is the source of a minor watercourse.
- The **Custogion Supply** services the house. The supply consists of a well located 1km west of the property, within the wind farm site.
- The **Cwmderw Supply** is marked by the property owner as not currently being used. The supply consists of a well located 0.5km west of the property.
- The **Ddulley Bank Farm Supply** services the property and Farm, as well as **Maens Cottage**. The supply consists of a spring and two separate boreholes. The spring is located 500m west of the Ddulley farm building in open fields. The two boreholes are located across the access road from the farm, to the north and east respectively.
- The **Fwnog Supply** services the property only. The supply consists of a borehole 60m north of the property on the edge of the Garn Fach forestry.
- The **Glanyrafon Supply** services the house and gardens. The supply consists of both two springs and a borehole. The springs are located 200m northeast of the property, and the borehole immediately to the southwest across the access road. It is indicated by the resident that the springs were used until 2006/7 at which point they temporarily dried -up necessitating the digging of a borehole, which now services the property (the springs only being used for the garden at present).
- The **Great Meadows Supply** services the house. The supply consists of a borehole located immediately adjacent to the property.
- The **Green Meadow Supply** services the house. The supply consists of a borehole 40m to the east of the property, within open fields, whilst there is also a spring, located to the west, adjacent to a minor watercourse.
- The **Nanthir (Lower) Supply** services the farm and holiday let. The supply consists of a borehole within the property grounds.
- The **Pabyllwyd Barn Supply** services the house. The supply consists of a well, located 4m from the Blue Lins Brook.

- The **Pen Ithon Hall Supply** services a large holiday let property at Pen Ithon Hall, as well as **Gorsty** and **Pen Ithon Lodge**. The supply consists of a borehole located immediately north of the property within the gardens, a spring 250m to the west and well 200m west, both in open fields.
- The **Pencwm Cottage Supply** services the house. The supply consists of a borehole located immediately adjacent to the property.
- The **Penygarreg Supply** services the house. The supply consists of a well located 300m to the north of the property in open fields.
- The **Rock House Supply** services the house. Details of this supply were provided by the resident at Nanthir (Lower) though are not substantiated by the property owner at Rock House. The supply is indicated as consisting of a spring/well of which the exact location is unknown- though is likely upgradient of the property near a stream of the Llaithddy Brook.
- The **Stables Supply** services the house. The supply consists of a well located 100m to the north of the property within open fields.
- The **Upper Llaithddu Supply** services the house and farm (specified as approximately 6000ltr/day usage). The supply consists of a borehole located 300m west of the property within open fields.
- The **Upper Maens Supply** services the house. The supply consists of a borehole within fields adjacent to the property

The source locations for the above supplies are displayed in Figures 3 and 4. The details for each property using these supplies are presented in **Error! Reference source not found.**.

3.2 Properties requiring further information

The resident of **Glan Ithon Lodge** did not respond to the letter sent and no one was present when the property was visited in December 2020. Glan Ithon Lodge is not listed by the PCC as being served by a PWS and was identified during the desk-study as an Additional Potential PWS. A worst-case scenario is that Glan Ithon is served by a PWS abstracting surface water from the tributary of the Llaithddy Brook. The risk associated with this is addressed in Section 0.

The resident of **Old House (School House)** did not respond to the letter sent and no one was present when the property was visited in December 2020. Old House (School House) is not listed by the PCC as being served by a PWS and was identified during the desk-study as an Additional Potential PWS. A worst-case scenario is that Old House (School House) is served by a PWS abstracting surface water from the Blue Lins Brook. The risk associated with this is addressed in Section 0.

The resident of **Old School** did not respond to the letter sent - it was found when visiting the property address, that 'The Old School' was wrongly titled. The letter was instead delivered to a property called the School House at the same location when visited in December 2020. No response has since been received, however. Old School is not listed by PCC as being served by a PWS and was identified during the desk-study as an Additional Potential PWS. A worst-case scenario is that Old School is served by a PWS abstracting surface water from the Llaithddy Brook. The risk associated with this is addressed in Section 0.

The **Pabyllwyd** Supply is currently defunct as it was destroyed when the forestry was felled 20-30 years ago, as informed by the resident by phone call. It used to be from one of the small streams to the south east of the property (unnamed), therefore not draining the site. There is a planned borehole at the property, though this is not currently installed.

The resident of **Pencwm** did not respond to the letter sent and no one was present when the property was visited in December 2020. Pencwm is not listed by PCC as being served by a PWS and was identified during the desk-study as an Additional Potential PWS. A worst-case scenario is that Pencwm is served by a PWS abstracting surface water from a minor tributary of the Blue Lins Brook. The risk associated with this is addressed in Section 0.

The resident of **School House** did not respond to the letter sent and no one was present when the property was visited in December 2020. School House is not listed by PCC as being served by a PWS and was identified during the desk-study as an Additional Potential PWS. Similarly to Glan Ithon Lodge, a worst-case scenario is that the School House is served by a PWS abstracting surface water from the tributary of the Llaithddy Brook. The risk associated with this is addressed in Section 0.

The resident of **Upper Nanthir** did not respond to the letter sent. When visited in December 2020, the resident said they did not want to respond to the survey issued. Upper Nanthir is listed by PCC as being served by a single borehole PWS, though this has not been confirmed by the owner. A worst-case scenario is that Upper Nanthir is served by a PWS borehole within the property grounds. The risk associated with this is addressed in Section 0.

Table 3-1 Details of the water supplies for properties confirmed as using a private supply

Water Supply	Properties Supplied	Supply Type	Abstraction NGR	Supply protection	Supply Land Use	Quantity used	Water Quality Issues	Water Supply Issues	Treatment
Ashdale	Ashdale, Brondrefach	Spring/well	303610, 276458	Fenced	Grazing Livestock	1 adult at property	None	None	Filter, UV
Brondrefawr	Brondrefawr	Surface water abstraction	-	-	Grazing Livestock	Not Known (variable)	None	None	Untreated
Bryn Heulog	Bryn Heulog	Spring	307344, 281593	Yes (unspecified)	Sheep and cattle	5 adults at property	None	None	Unknown
Bwthyn Penygareg	Bwthyn Penygareg	Spring	306600, 282600	None	Grazing Sheep	2 adults at property, 3 polytunnels and garden	None	None	Untreated
Custogion	Custogion	Well	304344, 279325	Fenced	Grazing	2 adults at property	None	Yes, during the summer	Filter
Cwmderw	Cwmderw	Well	302655, 278995	Covered	Grazing	None	None	None	Untreated
Ddulley Bank Farm	Ddulley Bank Farm, Maens Cottage	Spring and Borehole	304680, 280984	Fenced	Unknown	4 adults at property	None	None	Chlorination
Fwnog	Fwnog	Borehole	304835, 281412	Fenced	Unknown	2 adults at property	None	None	Untreated
Glanyrafon	Glanyrafon	Borehole and Spring	307232, 281842 307240, 281774	None	Unknown	2 adults at property	Originally E-coli on spring, now used for garden	Yes spring dried up in 2006/2007 hence borehole	Have a UV filter but it is not currently being used
Great Meadows	Great Meadows	Borehole	305913, 278489	Pump house	Unknown	2 adults at property	High sulphur content	None	Filter, UV
Green Meadow	Green Meadow	Spring and Borehole	305973, 278449	Yes fenced	Farmers field	2 adults at property	None	None	Filter, UV
Nanthir (Lower)	Nanthir (Lower)	Borehole	305537, 277972	Within property grounds	Farming and holiday let		None	None	Filter, UV
Pabyllwyd Barn	Pabyllwyd Barn	Well	305338, 282546	Well has frame and cover	Garden	2 adults at property, normal domestic use	None	None	Filter
Pen Ithon Hall	Pen Ithon Hall, Gorsty and Pen Ithon Lodge	Well and Borehole	307437, 281592	Fenced	Farm	Holiday Let - max 32 people	None	None	Chlorination and UV
Pen Ithon Lodge	Pen Ithon Lodge, Gorsty and Pen Ithon Hall	Bore Hole	307503, 281422 307503, 281422	Steel tanks	Sheep or nothing	Not Known (variable)	None	yes- pump issues (energy supply)	UV
Pencwm Cottage	Pencwm Cottage	borehole	On property	Manhole Cover	Agriculture	Not Known (variable)	None	None	Untreated
Penygarreg	Penygarreg (named Penygarreg farm)	Spring/Well	306528, 282660	None	Grazed	2 adults at property	None	None	Chlorination
Rock House	Rock House	Spring/Well	Near 305635, 78501	Unknown	Unknown	Not known	None	None	Unknown
Stables	Stables	Well	307400, 281500	Yes (unspecified)	Cattle and Sheep	2 adults at property	Occasionally with heavy rain	None	Untreated
Upper Llaithddu	Upper Llaithddu	Borehole	306266, 279401	Fenced	Grazing Sheep	Estimated 6000ltr/day	None	None	Chlorination, Filter
Upper Maens	Upper Maens	Borehole, 290ft deep	305806, 280743	Manhole Cover	Grass Grazing	2 adults at property	None	None	Untreated

4 Risk Assessment

The potential risks to the water quality and quantity within the Site and draining sub-catchments from the construction and operation of the proposed development are summarised within this section and described in full within Chapter 10 of the EIA Report. During construction, the primary impacts are the temporary potential for reductions in water quality through sedimentation and changes to in-stream hydrochemistry. These arise from necessary ground disturbance resulting in increased sediment supply and the potential mobilisation of disturbed sediment into the stream network and subsequent increased in-stream concentrations. The potential temporary impacts also include the potential for the pollution of watercourses and groundwater as a consequence of accidental spillage of chemicals, hydrocarbons and other construction materials. This is also a potential risk during the operation of the proposed development. The long-term changes to the site drainage could occur through increased impermeable areas and the introduction of a drainage system for the proposed infrastructure, tracks and cable trenches.

The information collated within the baseline assessment studies, site visit, consultation and PWSRA were used to identify hydrologically sensitive areas of the Site. Subsequently, a map of constraints was developed around the proposed development infrastructure layout (Chapter 10: Figure 10.7). These layout constraints include an exclusion zone in the vicinity of a river or wetland (mapped on OS 1:10,000 scale) in accordance with PPG5 (1), which has been conservatively defined as 50 m. No development will occur within the exclusion zones without additional mitigation.

The sources of private water supplies may come from surface water (watercourses or lakes) or groundwater (springs, boreholes or wells). For the risk assessment and protection of groundwater abstractions during wind farm construction, relevant UK regulatory guidance (2) states that abstractions within 100 m from roads, tracks and trenches, and 250 m from foundations or borrow pits, should be identified within a hydrological assessment. This assessment requires the zone of contribution to be defined and a quantitative hydrogeological assessment of the potential impacts made. These zones identify all surface water runoff, superficial groundwater and bedrock fracture flow areas which are up hydraulic gradient of the abstraction point (i.e. the areas draining to the abstraction point).

A 250 m exclusion zone has been defined for all PWS within 250 m of the Site boundary. For each of these PWS, an indicative zone of contribution has been defined and presented in Figures 3 and 4. Small springs, such as those supplying a PWS tend to have localised catchments, with discharges sourced by surface runoff and shallow groundwater flow. Therefore, these indicative zones of contribution have been defined on the basis of topography using a digital terrain model and OS 10m contours.

The following sections assess the potential risks to each of the private water supplies identified.

4.1 Supplies Potentially Receiving Drainage from the Site

The indicative zones of contribution for the following supplies are located within the Site. Without appropriate mitigation, the water supplies would be considered potentially at risk from any construction within the zone of contribution.

4.1.1 Ashdale and Brondrefach

The Ashdale supply is shared with Brondrefach and services both properties. The supply consists of a spring and well, situated on steep open ground, near an existing track. The supply is from groundwater contributions of which the contributing catchment overlaps with the southernmost Site area of the proposed windfarm. There are no significant superficial deposits mapped either near the source or contributing catchment, which is underlain by a sandstone bedrock. The bedrock is designated as a medium vulnerability secondary aquifer.

Although the spring is located outside the Site, a 250 m exclusion zone has been applied at the location of the source, as displayed in Figure 3. Due to the well and spring's location, the water supply is hydrologically connected to the Site. No development is currently planned within the southern area of the Site, thus it should not be significantly affected by Site construction or operation. The Ashdale/Brondrefach supply is therefore not considered to be at risk and does not need to be considered further.

4.1.2 Brondrefawr

The Brondrefawr supply services the property. The supply is noted as being a surface water abstraction, which is taken from an unnamed watercourse (tributary of the Afon Marteg) which is fed from forestry land. The natural catchment of this watercourse extends through forestry land up to the boundary of the windfarm. No development is however currently planned within the catchment of the watercourse, with the nearest feature being an access track planned over 260m to the north of the catchment (draining to the north), thus it should not be significantly affected by Site construction or operation. The Brondrefawr supply is therefore not considered to be at risk and does not need to be considered further.

4.1.3 Custogion

The Custogion supply services the property. The supply consists of a well situated on steep open ground, near the source of a minor watercourse (tributary of the Llaithddy Brook). It is thought the majority of the supply is from groundwater contributions. Little information is known about the depth or age of the well, other than that the resource has been fenced off. Superficial till deposits of diamicton (unsorted sediment with gravel in a mud matrix) overlay the well's location, which are designated a secondary aquifer. The bedrock is sandstone and mudstone, which is designated a secondary aquifer of medium vulnerability.

A 250 m exclusion zone has been applied at the location of the source, as displayed in Figure 3. The well's location is within the Site. Without appropriate mitigation, the water supply would be considered at risk from a reduction in water supply, hydrochemical changes or accidental spillage/loss of chemicals and materials during the construction and operation of the Proposed Development. The Custogion supply may receive drainage from Turbine 12, which is 280m northwest of the supply and is also located in close proximity to the proposed access track (30m to the north of the PWS). Turbine 13 and 14 are both slightly downstream of the source, though are both within 350m of the well, with turbine 14 located within the same formation of superficial deposits. The Custogion supply is considered further in sections 5 and 6.

4.1.4 Ddulley Bank Farm and Maens Cottage

The Ddulley Bank Farm supply services the Ddulley Bank property and Maens Cottage. The supply consists of a spring located within the Site area and two boreholes located outside. It is thought the majority of the supply is from groundwater contributions. Superficial till deposits of diamicton (unsorted sediment with gravel in a mud matrix) overlay the contributing catchments for the two borehole supplies. The bedrock is sandstone, siltstone and mudstone, which is designated a secondary aquifer of medium vulnerability.

Although the boreholes are located outside the Site, a 250 m exclusion zone has been applied at the location of the borehole located nearest the Site boundary, as displayed Figure 4. The contributing catchments for the two boreholes run along the perimeter of the Site boundary, however the catchment for the spring is located within the Site boundary. The spring is within 600m of turbine 9, however it is located the other side of the ridge line from this feature and therefore the spring is not likely to be affected by groundwater flow from this area. The Ddulley Bank Farm and Maens Cottage supplies are considered further in sections 5 and 6.

4.1.5 Fwnog

The Fwnog supply services the property. The supply consists of a borehole situated on steep open ground, adjacent to the Garn Fach forest and near the source of a minor watercourse (tributary of the Blue Lins Brook). The supply is from groundwater contributions. Little information is known about the depth or age of the well, other than that the resource has been fenced off. Superficial till deposits of diamicton (unsorted sediment with gravel in a mud matrix) overlay the borehole location, which are designated a secondary aquifer. This is underlain by sedimentary bedrock (siltstone, sandstone and mudstone), which is a secondary

(1) Guidance for Pollution Prevention (GPP) 5. (2018) Works and maintenance in or near water

(2) SEPA (2017). Land Use Planning System, SEPA Guidance Note 4: Planning advice on wind farm developments. Version 8.

aquifer. The contributing catchment skirts the northern boundary of the Proposed Development Site and is within 850m of turbine 9. It is noted however that this turbine is located the other side of the ridgeline to the supply and so there is not likely to be any hydraulic connection between the two locations. It is therefore considered to be not at risk and not considered further.

4.1.6 Glan Ithon Lodge

No information has been supplied for the Glan Ithon Lodge, either through PCC or from a survey response. A worst-case scenario has thus been assumed for this property, that the property abstracts from the minor watercourse adjacent to the house, which is a tributary of the Llaithddy Brook. The topographic catchment for this watercourse makes it unlikely that any surface water runoff from the Site would enter this watercourse, however it is possible that groundwater contributions may travel from the Site to this location. The bedrock is labelled as a secondary aquifer at this location, with medium vulnerability. Given the topography and distance (over 2km) between the property and nearest infrastructure, it is considered to be not at risk and not considered further.

4.1.7 Glanyrafon

Glanyrafon is serviced by two springs and a borehole. The two springs are located across the Blue Lins valley from the wind farm and draw water from the east of this location, therefore are not considered at risk from Site operations or construction. The borehole servicing this property, is however on the western side of the Blue Lins valley and within 75m of the Blue Lins Brook, which has a large proportion of the northern Site within its catchment. The catchment does not have significant superficial deposits, though has a sandstone and mudstone bedrock, designated a secondary aquifer of medium vulnerability. Given the distance between the borehole and the brook it is considered highly unlikely that any potential impact on the water quality of the Blue Lins Brook would impact the water quality within the borehole. Therefore it is considered to be not at risk and not considered further.

4.1.8 Great Meadows

The Great Meadows supply services the property. The supply consists of a borehole situated at the property, between the Llaithddy Brook and road. Superficial till deposits of diamicton (unsorted sediment with gravel in a mud matrix) overlay the borehole location, which are designated a secondary aquifer. This is underlain by sedimentary bedrock, which is a secondary aquifer. Any surface or near surface flow would be intercepted by the Llaithddy Brook and tributaries, thus would not reach the borehole location. The groundwater catchment extends to the middle Site area, overlapping with the southern land of this area. Given the topography and distance between the borehole and nearest infrastructure, it is considered to be not at risk from reduced groundwater quality and not considered further.

4.1.9 Green Meadows

The Green Meadows supply services the property. The supply consists of a borehole and spring. The borehole is located the opposite side of the Llaithddy Brook to the Site, and the catchment drains from land to the east, which is far removed from the Site boundary, therefore not considered to be at risk. The Spring is also located on the eastern bank of the Llaithddy Brook, however it is located very close to the watercourse, such that hydraulic connection between the two features cannot be discounted. For a worst-case scenario, the Llaithddy Brook catchment is considered as potentially interacting with the spring supply at this location, which drains the middle and southern land parcels of the Site. There is no infrastructure located within the area of the site draining to the Llaithddy Brook upstream of this location, therefore this supply is considered to be not at risk and not considered further.

4.1.10 Nanthir (Lower)

Nanthir (Lower) consists of a borehole which supplies the property. The borehole currently services this property and farm, located within the grounds of the property. The wind farm Site would be located within the groundwater catchment for this feature and it is also likely runoff from the site would reach this location. There are generally no superficial deposits within the contributing catchment, or at the location of the borehole according to BGS mapping, whilst the bedrock is sedimentary mudstone, designated a secondary aquifer of medium vulnerability. No turbines are located in or near the catchment outlined for this feature, with turbine 17 located over 1km to the northeast, with runoff from this location captured by the Llaithddy Brook downstream of the supply. It is therefore considered to be not at risk and not considered further.

4.1.11 Old House

Old House was not listed by PCC nor was a survey response received to provide information on the water supply. A worst-case scenario is thus assumed, whereby abstraction is either taken from the Blue Lins Brook, or from a borehole within the property grounds. The Blue Lins Brook has a large proportion of the northern and middle Site within its catchment, including turbines 1-8. The catchment does not have significant superficial deposits, though has a sandstone and mudstone bedrock underlaying, which is designated as a secondary aquifer of medium vulnerability. Without appropriate mitigation, the water supply would be considered at risk from a reduction in water supply, hydrochemical changes or accidental spillage/loss of chemicals and materials during the construction and operation of the Proposed Wind Farm Development. The Old House supply is considered further in sections 5 and 6.

4.1.12 Old School

Old School was listed by PCC as having a PWS which supplied the property; however no survey response was received to confirm this information. A worst-case scenario is thus assumed, whereby abstraction is taken from the Llaithddy Brook, or from a borehole within the property grounds. The property is downstream of the Custogion Brook confluence and so the watercourse catchment at this location drains both the middle and southern area of the Site, which drains turbines 10, 11, 12, 14, 16 and 17. Without appropriate mitigation, the water supply would be considered at risk from a reduction in water supply, hydrochemical changes or accidental spillage/loss of chemicals and materials during the construction and operation of the Proposed Wind Farm Development. The Old School supply is considered further in sections 5 and 6.

4.1.13 Pabyllwyd Barn

Pabyllwyd Barn is serviced by a well, located 4m from the Blue Lins Brook. It is therefore assumed that the area drained to this supply includes the catchment of the Blue Lins Brook, which encompasses the majority of the northern and middle wind farm Site area, including turbines 1-8. The catchment does not have significant superficial deposits, though has a sandstone and mudstone bedrock, designated a secondary aquifer of medium vulnerability. Without appropriate mitigation, the water supply would be considered at risk from a reduction in water supply, hydrochemical changes or accidental spillage/loss of chemicals and materials during the construction and operation of the Proposed Wind Farm Development. The Pabyllwyd Barn supply is considered further in sections 5 and 6.

4.1.14 Pabyllwyd

There is a planned borehole at property, though this is not currently installed. Any future PWS planned for the Pabllwyd property, would likely share the same risks as Pabyllwyd Barn. As a worst case-scenario, the borehole would share the catchment of the Blue Lins Brook, which encompasses the majority of the northern and middle wind farm Site area, including turbines 1-8. The catchment does not have significant superficial deposits, though has a sandstone and mudstone bedrock, designated a secondary aquifer of medium vulnerability. Without appropriate mitigation, the water supply would be considered at risk from a reduction in water supply, hydrochemical changes or accidental spillage/loss of chemicals and materials during the construction and operation of the Proposed Wind Farm Development. The potential new Pabyllwyd supply is considered further in sections 5 and 6.

4.1.15 Pencwm

Pencwm was not listed by PCC nor was a survey response received to provide information on the water supply to the property. A worst-case scenario is thus assumed, whereby abstraction is either taken from the tributary of the Blue Lins Brook, or from a borehole within the property grounds. There are no significant superficial deposits within the catchment, whilst sandstone and mudstone bedrock underlay area, designated a secondary aquifer of medium vulnerability. Though it is unlikely that surface water runoff from the Site would reach this location, the groundwater catchment from this location is likely to encompass a portion of the wind farm Site but no turbines. Given the topography and distance between the property and nearest infrastructure, it is considered to be not at risk from reduced groundwater quality and not considered further.

4.1.16 Pencwm Cottage

Pencwm is supplied by a borehole, located 60m west of the Blue Lins Brook. There are no significant superficial deposits within the catchment, whilst sandstone and mudstone bedrock underlay area, designated a secondary aquifer of medium vulnerability. Similarly to a potential PWS supply to Pencwm, it is unlikely that surface water runoff from the Site would reach this location, though the groundwater catchment from this location is likely to encompass a portion of the wind farm Site but no turbines. Given the topography and distance between the property and nearest infrastructure, it is considered to be not at risk from reduced groundwater quality and not considered further.

4.1.17 Rock House

Rock House was not listed by PCC, however some details of the supply were provided by the resident at Nanthir (Lower). Upon the information provided, the supply is assumed to consist of a spring/well of which the exact location is unknown, however it is thought to be located upslope of the property, near a tributary of the Llaithddy Brook. It is assumed that the tributary catchment is potentially interacting with the water supply at this location, which drains a small portion of the middle area of the Site. This area of the Site drained by this tributary includes only a proposed access track and no turbines. Without appropriate mitigation however, the water supply would be considered at risk from a reduction in water supply, hydrochemical changes or accidental spillage/loss of chemicals and materials during the construction and operation of the Proposed Wind Farm Development. The Rock House supply is considered further in sections 5 and 6.

4.1.18 School House

No information has been supplied for the School House, either through PCC or from a survey response. A worst-case scenario has thus been assumed for this property, similarly to Glan Ithon Lodge, that the property abstracts from the minor watercourse adjacent to the house, which is a tributary of the Llaithddy Brook. The topographic catchment for this watercourse makes it unlikely that any surface water runoff from the Site would enter this watercourse, however it is possible that groundwater contributions may travel from the Site to this location. The bedrock is labelled as a secondary aquifer at this location, with medium vulnerability. Given the topography and distance (over 2km) between the property and nearest infrastructure, it is considered to be not at risk and not considered further.

4.1.19 Upper Llaithddu

Upper Llaithddu services the house and farm. The supply consists of a borehole located 300m west of the property within open fields. Superficial till deposits of diamicton (unsorted sediment with gravel in a mud matrix) overlay the borehole location, which are designated a secondary aquifer. This is underlain by sedimentary bedrock, which is a secondary aquifer. Though it is unlikely that surface water runoff from the Site would reach this location, the groundwater catchment from this location is likely to encompass a portion of the wind farm Site. However, given the topography and distance between the property and nearest infrastructure, it is considered to be not at risk from reduced groundwater quality and not considered further.

4.1.20 Upper Maens

The Upper Maens supply services the house. The supply consists of a borehole within fields adjacent to the property. Superficial till deposits of diamicton (unsorted sediment with gravel in a mud matrix) overlay the contributing catchment. The contributing topographic catchment for the borehole runs along the perimeter of the Site boundary, such that surface runoff from within the Site is unlikely to be conveyed towards the PWS. The groundwater catchment for the borehole is unlikely to be affected by the location of the turbines within the Site, since the three closest turbines 9, 10 and 11 are located either the other side of the ridge line from the PWS feature, or drain towards the south/west, away from the feature. It is therefore considered to be not at risk from reduced groundwater quality and not considered further.

4.2 Supplies Not Receiving Drainage from the Site

The PWS for the properties within this section do not receive drainage from the site, thus are not hydrologically connected. There are no potential risks to these supplies from the construction and operation of the Proposed Wind Farm development.

4.2.1 Bryn Heulog

The Bryn Heulog supply services the property. The supply is a spring located between tributaries of the Blue Lins Brook. It is considered that this source is not at risk from any overland flow routes from the wind farm site- the zone of contribution for this spring is small and extends to a localised topographical peak 1km east of the Site boundary and any flow from the west would be intercepted by the two minor tributaries, which bound the spring. Given the location of the spring on relatively high ground, bounded by two valleys, it is not considered to be hydrologically connected to the Site. Thus, there are no potential risks to the supply from the construction and operation of the Wind Farm and this PWS is not considered further.

4.2.2 Bwthyn Penygareg Supply

The Bwthyn Penygareg Supply services the house and polytunnels. Consisting of a spring, the supply is located near the source of a tributary of the Blue Lins Brook. The topographical catchment for surface water drainage is small, extending only 300m westwards to a local peak. The spring is located on the opposite side of the Blue Lins Brook to the windfarm Site, thus there is unlikely to be any risk from contaminants from the Site reaching this supply through groundwater. Therefore, there are no potential risks to the supply from the construction and operation of the Wind Farm and this PWS is not considered further.

4.2.3 Cwmderw Supply

The Cwmderw Supply is indicated as not currently in use by the property, according to the survey response received. The source consists of a well. As the well's zone of contribution is located outside of the drainage pathways of the Site and on the opposite side of Cwm Sbowt valley at a higher elevation to the Site, it is not hydrologically connected. Therefore, there are no potential risks to the supply from the construction and operation of the Wind Farm and this PWS is not considered further.

4.2.4 Pen Ithon Hall, Gorsty and Pen Ithon Lodge

The Pen Ithon Hall PWS also supplies Gorsty and Pen Ithon Lodge. They are serviced by a spring, well and a borehole. All of these features are located across the Blue Lins valley from the wind farm and draw water from a catchment extending north and east of this location. Therefore, there are no potential risks to the supply to these properties from the construction and operation of the Wind Farm and this PWS is not considered further.

4.2.5 Penygarreg

The Penygarreg Supply services the property. Consisting of a well, located 300m to the north of the property in open fields. Similarly to Bwthyn Penygareg, the topographical catchment for surface water drainage is small, extending only 200m westwards to a local peak. The spring is located on the opposite side of the Blue Lins Brook to the windfarm site, therefore is not within the same groundwater catchment. Therefore, there are no potential risks to the supply from the construction and operation of the Wind Farm and this PWS is not considered further.

4.2.6 Stables

The Stables supply services the property. It consists of a well located 100m to the north of the property within open fields. This is located across the Blue Lins valley from the wind farm and draws water from a catchment extending north and east of this location. Therefore, there are no potential risks to the supply to these properties from the construction and operation of the Wind Farm and this PWS is not considered further.

4.2.7 Upper Nanthir

PCC records show Upper Nanthir to be supplied by a borehole, however this has not been confirmed by a survey response. Assuming a borehole is located within the property grounds, this would be located across the Llaithddy Brook from the wind farm Site and drawing water from a catchment extending south of this location. Therefore, it is considered that there are no potential risks to the supply to this property from the construction and operation of the Wind Farm and this PWS is not considered further.

5 Mitigation

Due to the presence of the several PWS zones of contribution with the site, as described in Section 4.1, for 8 properties, mitigation measures are required to offset any of the potential effects. It is imperative that the quantity and natural runoff of water serving the supplies is not impacted upon during construction. The following mitigation measures are proposed as detailed in Chapter 10 of the EIA Report:

- An exclusion zone (conservatively defined as 50 m) has been applied in the vicinity of the watercourses in accordance with PPG5 (3).
- Relevant UK regulatory guidance (4) states that PWSs located within 100 m from roads, tracks and trenches, and 250 m from foundations or borrow pits, should be identified within the hydrological assessment. Therefore layout design constraints have been adopted to ensure that no construction will take place within the 250 m of any abstractions.
- Appropriate sustainable drainage systems (SuDS) will minimise erosion and potential pollution of the water environment this mitigation is embedded into the design of the windfarm infrastructure.
- Runoff and sediment control measures will be used to mitigate any potential impacts on the water quality during construction, whilst maintaining natural volumes of runoff and water resources.
- Overburden and stockpiles of materials will not be located up-gradient of the PWS'.
- If required, an additional measure of the use of flocculent could be used to facilitate the settlement of suspended solids. This should only be agreed to following consultation with the local Environmental Health Officer.
- A Pollution Prevention, Water Quality Monitoring and Emergency Response Plan will be in place to minimise the impact of any spillages/losses during construction and operation.
- A programme of Private Water Supply monitoring will be undertaken prior, during and following the construction phase to provide assurance as to the absence of PWS water quality impacts. This will involve collecting monthly samples at the source of the PWS and analysing concentrations of minerals within the sample including, pH, Total Petroleum Hydrocarbons (TPH), Suspended Solids, Electrical Conductivity, Heavy Metals and Microbiological parameters.

In addition, where the capture zones for Custogion are crossed due to the proposed infrastructure, there will be close monitoring of works in these areas by the Environmental Clerk of Works. It will be ensured that appropriate mitigation is placed here to prevent potential sediment laden runoff from entering PWS', along with close monitoring of the water supply quality. Should any changes in quality be identified appropriate action will be taken. It should be noted that both Custogion and Ddulley bank farm are agreed landowners for the windfarm. Additional secondary sediment control measures will be employed in these areas. Runoff from construction zones will be diverted away from the supplies. No refuelling or storage of equipment, materials or chemicals will occur within the zones of contribution. Equipment to contain and clean up any spills will be readily available at all times in this area.

For the Custogion supply, given its proximity to a turbine to the northwest, it is proposed that runoff from this turbine site is directed eastwards away from the PWS and that any micro-siting, including hard standing is situated further west across the ridge from the PWS. The supply is also within 30m, downslope of a proposed access track. Similar measures such as drains to divert any runoff away from the PWS will be incorporated to the detailed SuDS design. Any pipework between the spring and property would therefore be identified and protected.

6 Residual Impacts

The assessment of significance for the impact of wind farm activities on the general water environment is the same as used in the ES (Chapter 10). The residual impacts are detailed below and summarised in Table 6-1.

The Custogion Supply is located within 300m of three proposed turbines, though it is upslope of turbines 13 and 14, it remains potentially downslope of turbine 12 and is downslope of a proposed access track. The Site is relatively steep, thus not offering a great deal of natural attenuation for any sediment-laden runoff generated during construction. However given the distance of the turbine from the abstraction location, and incorporation of the proposed mitigation measures to the track construction/operation in terms of drainage, it is considered that there would be a small magnitude of change to the quality of the Custogion water supply. The significance of the residual effect on this highly sensitive water supply during the construction phase would therefore be minor, which is considered not significant.

The Ddulley Bank Farm Supplies (also serving Main Cottage) include a spring within the site boundary and two boreholes. These share largely the same contributing catchments, which are observed to extend within the wind farm Site boundary, however are considered to not overlap with the land occupied by any of the proposed wind turbines. Again, the Site is relatively steep, thus not offering a great deal of natural attenuation for any sediment-laden runoff generated during construction. However, given the direction of fall from the turbines away from the PWS locations, it is considered that there would be a small magnitude of change to the quality of the Ddulley Bank Farm. The significance of the residual effect on this highly sensitive water supply during the construction phase would therefore be minor, which is considered not significant.

Several PWS's have been identified as either potentially extracting from (assumed in a worst case in the absence of survey responses), or being hydraulically linked to the Blue Lins Brook, including Pabyllwyd Barn and Old House. A new supply at Pabyllwyd, would also share the same potential residual risks. The Blue Lins Brook has a large catchment, capturing runoff from the northern and potentially top of the middle Site area, which is the location of eight of the proposed turbines. The Site is again relatively steep at this location, thus not offering a great deal of natural attenuation for any sediment-laden runoff generated during construction. Given though the distance of the wind farm from the abstraction locations identified (the dilution factor involved on a large watercourse this far downstream of the site), and incorporation of the proposed mitigation measures, it is considered that there would be a negligible magnitude of change to the quality water supplies identified. The significance of the residual effect on this highly sensitive water supply during the construction phase would therefore be negligible, which is considered not significant.

PWS's have also been identified as either potentially extracting from (assumed as a worst case, in the absence of survey responses), or being hydraulically linked to the Llaithddy Brook and its tributaries, this includes the Old School and Rock House supply. The Llaithddy Brook has a large catchment, capturing runoff from the majority of the middle and southern site area, and is likely intercepting overland flow from turbines 10, 11, 12, 14, 16 and 17. For the Old School catchment, which may be draining this middle Site area, the Site is again relatively steep, thus not offering a great deal of natural attenuation for any sediment-laden runoff generated during construction. Given though the distance of the wind farm from the abstraction location identified (the dilution factor involved on a large watercourse this far downstream of the site), and incorporation of the proposed mitigation measures, it is considered that there would be a negligible magnitude of change to the quality water supply for this property. The significance of the residual effect on this highly sensitive water supply would therefore be negligible, which is considered not significant. For the Rock House supply, the tributary drains only a small portion of the Site including a proposed access track, though no further infrastructure. At this location the Site is again relatively steep, thus not offering a great deal of natural attenuation for any sediment-laden runoff generated during construction. With the incorporation of the proposed mitigation measures, it is considered that there would be a negligible magnitude of change to the quality of water supply for this property. The significance of the residual effect on this highly sensitive water supply during the construction phase would therefore be negligible, which is considered not significant.

(3) Guidance for Pollution Prevention (GPP) 5. (2018) Works and maintenance in or near water

(4) SEPA (2017). Land Use Planning System, SEPA Guidance Note 4: Planning advice on wind farm developments. Version 8.

Table 6-1 Summary of Residual Impacts from Construction

PWS at Risk of Impact	Mitigation	Implementation	Residual Effect
Custogion	Embedded mitigation Operational pollution prevention, water quality monitoring and emergency response plan.	Outline CEMP	Minor
Ddulley Bank Farm (also serving Mains Cottage)	Embedded mitigation. Operational pollution prevention, water quality monitoring and emergency response plan.	Outline CEMP	Minor
Pabyllwyd Barn	Embedded mitigation. Operational pollution prevention, water quality monitoring and emergency response plan.	Outline CEMP	Negligible
Old House	Embedded mitigation. Operational pollution prevention, water quality monitoring and emergency response plan.	Outline CEMP	Negligible
Old School	Embedded mitigation. Operational pollution prevention, water quality monitoring and emergency response plan.	Outline CEMP	Negligible
Rock House	Embedded mitigation. Operational pollution prevention, water quality monitoring and emergency response plan.	Outline CEMP	Negligible

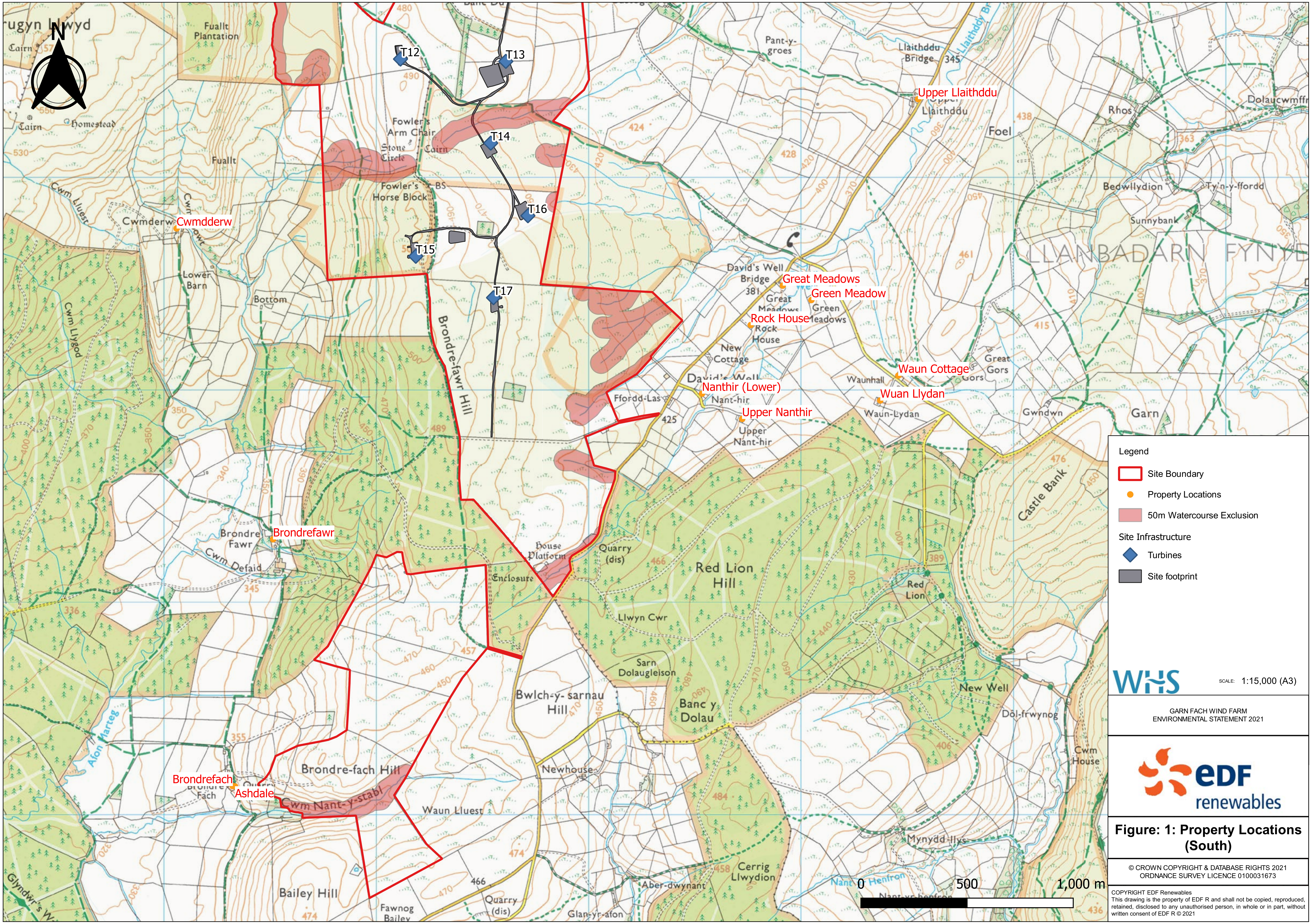
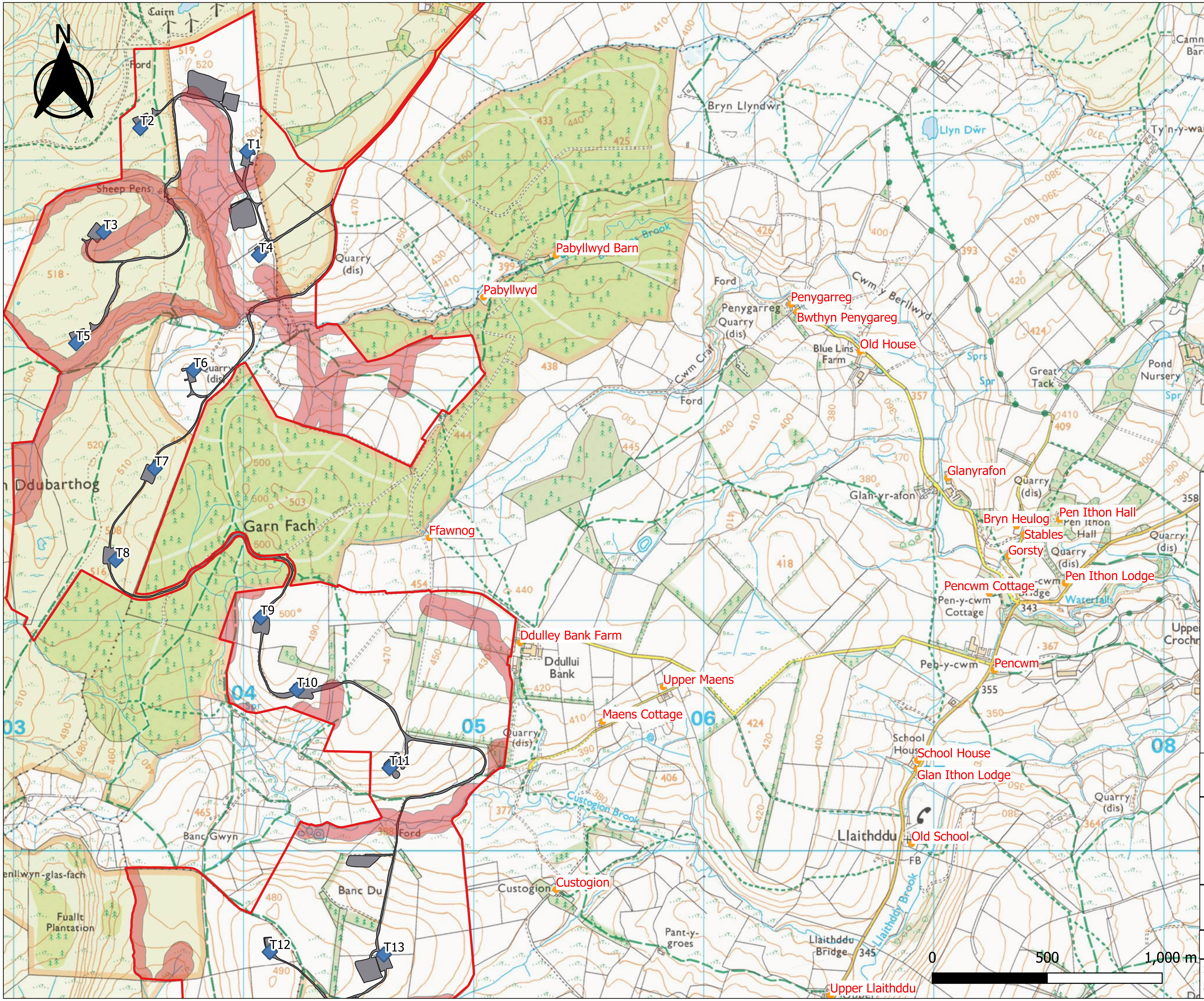


Figure: 1: Property Locations (South)



Legend

- Site Boundary
- Property Locations
- 50m Watercourse Exclusion

Site Infrastructure

- Turbines
- Site footprint

WHS

SCALE: 1:15,000 (A3)

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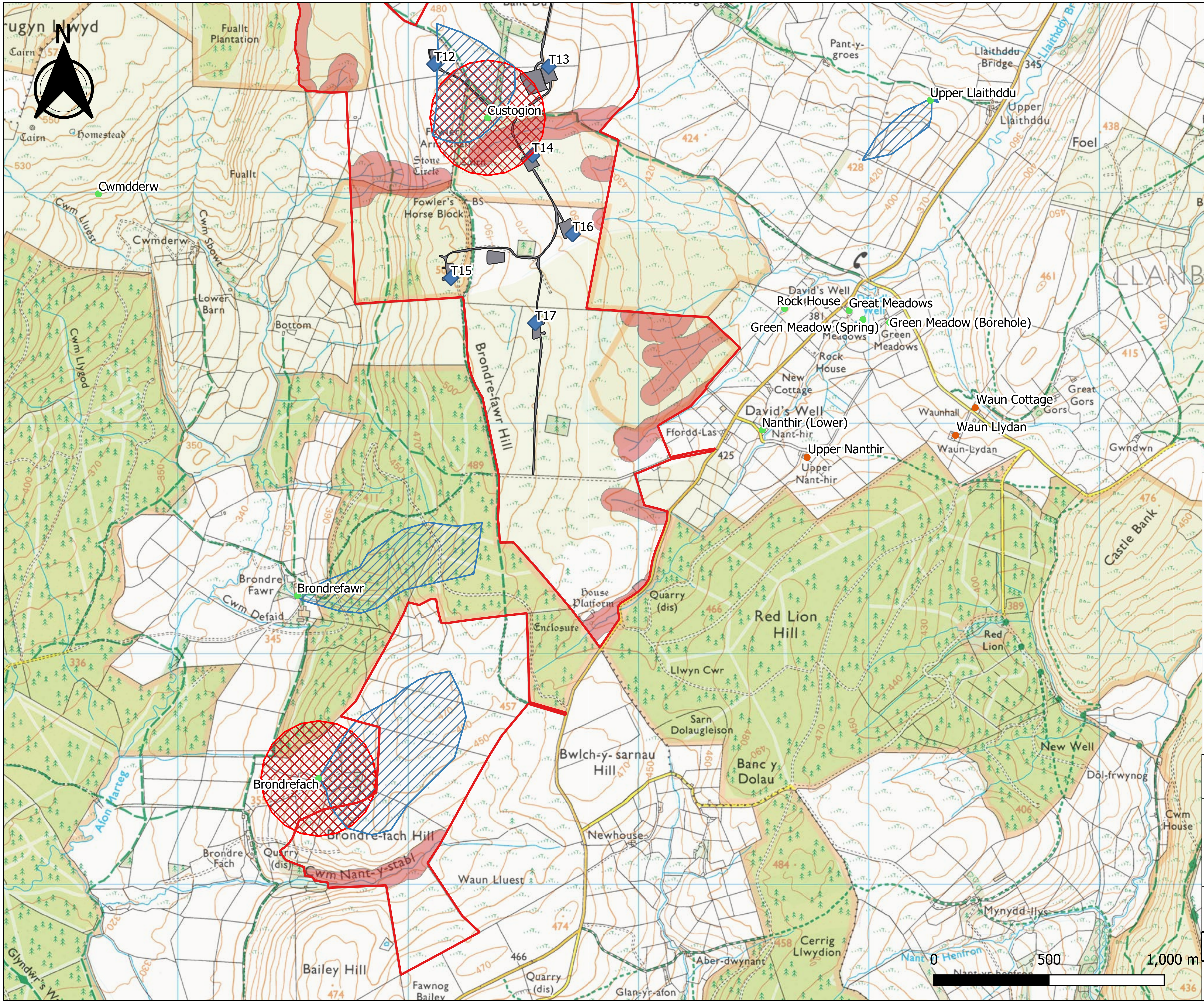
Figure 2: Property Locations (North)



Legend

- Site Boundary
- Zone of Contributions
- 250m Buffer
- 50m Watercourse Exclusion

PWS

- Confirmed
- Unconfirmed

Site Infrastructure

- Turbines
- Site footprint

WHS

SCALE: 1:15,000 (A3)

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Figure 3: Private Water Supply Locations (South)

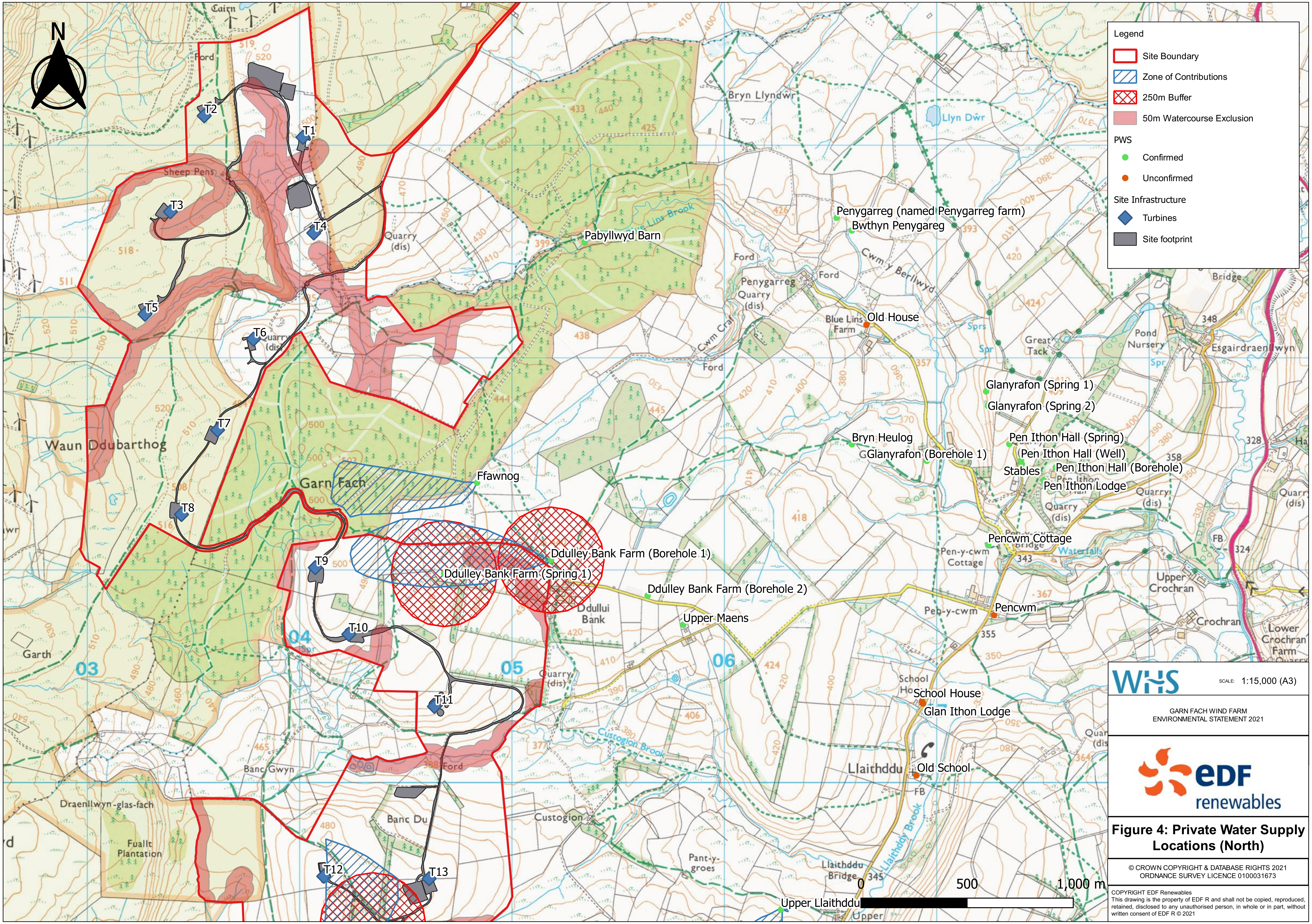

Figure 4: Private Water Supply Locations (North)

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Appendix 10.7- Garn Fach Wind Farm Outline Drainage and Surface Water Management Plan

Executive Summary

This outline drainage and surface water management plan details best practice procedures to prevent contaminated runoff from the construction site entering the surrounding water environment. The main pollution hazards include silts and sediments, oils, hydrocarbons and concrete. Mitigation measures during construction include appropriate surface water management, vegetation cover and temporary and permanent drainage scheme. The drainage scheme includes clay plugs, v-shaped ditches, settlement ponds, buffer strips and silt fencing. In addition, pollution control including prevention of spillages from construction materials/vehicles, will further mitigate pollution risks on the water environment.

Contents

1 Introduction

1.1 Background

Wallingford HydroSolutions Ltd (WHS) has been commissioned by Dulas to undertake an outline surface water management plan for the construction and operational phases of the proposed Garn Fach wind farm located to the south of Newtown, Powys (NGR: SO 03413 81467).

The plan will detail best practice procedures to prevent contaminated runoff from the construction site entering the surrounding water environment including both surface water and ground water receptors.

1.2 Scope

The surface water management plan includes recommendations for the most appropriate measures to manage surface water runoff at the site during the construction and operational phases of the project. It considers the scale and nature of the development in the context of surface water drainage and the relevant guidance and legislation. In summary, this report;

- Provides appropriate mitigation measures to manage the quality of surface water runoff during construction, with a provisional layout of mitigation features provided and further recommendations on construction methods based on best practice guidance.
- Provides appropriate mitigation measures to manage the treatment in addition to the rate and volume of surface water runoff during operation, with a provisional layout of mitigation features provided.

1.3 Sources of Information

The main sources of data and guidance used to inform this plan:

- National Resources Wales (NRW) Surface Water Flood Mapping – To help determine surface water flow paths across the site[1]
- Flood Estimation Handbook (FEH) Catchment Data - To define catchment boundaries[2]
- Defra Magic Map - To identify groundwater aquifers and source protection zones[3]
- BGS Geology of Britain Viewer - To identify bedrock and superficial deposits[4]
- Landis Soilscapes Map - To identify soil types[5]
- GIS layers of the proposed scheme provided by the client[6]
- OS Terrain 50m data has been used in the absence of available LiDAR.

2 Hazards

2.1 Surface Water

2.1.1 Silts and Sediment Pollution

Sediment pollution is the single main pollutant in rainwater runoff from construction sites. Any areas of exposed ground, earthworks (i.e. topsoil stripping of the site, excavation for utility trenches, culvert and outfall construction in the banks of watercourses) and stockpiles of granular or soluble material could result in the introduction of fine sediment into the watercourses on the site, particularly during periods of heavy rain if no mitigation measures are maintained. Run-off may also emanate from poor site drainage provision, washing and cleaning activities and after rainfall events that exceed the capacity of the drainage system to be installed.

The proposed scheme involves the construction of multiple wind turbines and a maintenance track through the upper catchment areas of a number of small watercourses. Where new tracks pass over watercourses, it is expected that crossings of suitable capacity will be installed. However, during heavy rainfall sediment from the construction area may be at risk of entering these watercourses with associated impacts.

There would be an increased pollution risk from elevated suspended solids which could potentially impact on the physical, chemical and microbiological water quality characteristics of the watercourses. Consequent impacts and heavy silt deposition could include impacts on aquatic vegetation by sediment coating of leaves; visual changes to the watercourse; damage to fish gills by sediment particles (if present); and silting. It should also be noted that soils across the majority of the track alignment are peaty with fine sediment sizes which increases suspension and makes sedimentation more likely.

2.1.2 Oils, Hydrocarbons, Concrete and Other Chemicals

Construction works may necessitate the use of heavy plant and machinery, as well as the temporary storage of oils and diesel at site compounds. Everyday operation and maintenance of this plant has the potential to result in chemical contamination of the environment through oil / fuel leaks from vehicles, chemical storage leaks and accidental spillages etc. which may become mobilised during storm events. Construction plant may also generate a

[1] NRW Surface Water Flood Maps (2021), https://naturalresources.wales/evidence-and-data/maps/long-term-flood-risk/?lang=en
[2] FEH Web Service (2021) https://fehweb.ceh.ac.uk/
[3] DEFRA Magic Map (2021) https://magic.defra.gov.uk/magicmap.aspx
[4] BGS Geology of Britain Viewer (2021) https://mapapps.bgs.ac.uk/geologyofbritain/home.html
[5] Landis Soilscapes Map (2021) http://www.landis.org.uk/soilscapes/
[6] Dulas (2021)

diffuse source of hydrocarbons and to a lesser extent heavy metals that could enter surface waters directly or via leaching through the subsoil.

2.1.3 Land Drainage

There is a risk of surface water flooding of working areas. This is most likely to occur during heavy rainfall events which exceed the capacity of any installed drainage system or due to ground conditions resulting in standing water. Impacts associated with flood risk can also occur due to construction activities such as ground reprofiling. The works may also have the potential to alter drainage pathways.

2.2 Groundwater

Key activities associated with the construction phase that have potential environmental impacts on groundwater are listed as follows:

- Site clearance;
- Construction of road access for construction works;
- Movement of construction machinery;
- Maintenance of construction machinery and equipment; and
- Earthworks, excavation and grading.

The above activities involve changes and/or movements in the terrain which can result in alterations to the dynamics of groundwater resources.

The construction phase will require site clearance, excavation and grading, temporary road access and establishment of temporary site facilities which can have negative effects on groundwater aquifers. These activities may alter water dynamics by:

- Disrupting or interrupting aquifer flow should earthworks (excavations) reach groundwater levels.
- Varying groundwater levels, should groundwater from these aquifers be used during construction (*e.g.* dewatering);
- Pollution (including chemical, siltation and changes in pH, redox and oxygen content) of groundwaters (*e.g.* from oil leaking from construction vehicles); and
- Release of existing pollution to the wider environment through the disturbance of contaminated soils.

Peaty soils are common across the site and the aquifer designation for the site is 'Secondary B' indicating predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures. Based on the BGS groundwater vulnerability maps, groundwater vulnerability varies from medium to high across the site. In this regard groundwater is expected to have limited but some interaction with the surface. Sufficient protection therefore needs to be provided to protect vulnerable groundwater in the area.

3 Construction

3.1 Water Quality Measures

The sections below outline the general measures to be followed based on specific measures for the scheme following consideration of local receptors, topography and the site layout. A section on how to manage spillage risk is also provided based on general best practice. Indicative drainage layout plans showing the location of the main sediment control measures are provided in Appendix 1.

3.1.1 General Measures

Good surface water management during construction is essential to ensuring that sediment does not pollute downstream watercourses. Therefore, the practices outlined below would be followed to reduce the risk of transport of pollutants and impact of increased surface water flows. All operations on NRW land including the design of temporary water managements works would adhere to Managing Forest Operations to Protect the Water Environment Practice Guide[7].

Vegetation cover would be retained for as long as possible to minimise the potential for soil stripping, and where bare ground is unused, new vegetation or alternative cover would be established at the earliest opportunity. If there is no time to establish grass cover on a slope, a roughened earthworks profile will provide better erosion control than leaving it smooth. Excavation would take place as soon as possible after the vegetation is stripped in order to minimise the period during which soil can be eroded. Where possible these works would be undertaken during dry months. Trenching or excavation activities in open land will cease during periods of intense rainfall and temporary bunding would be provided as required, to reduce the risk of sediment transport to the natural drainage system.

In terms of temporary site tracks, these would be completed as soon as possible and surfaced with a suitable temporary surface (e.g. crushed stone) to protect soils from runoff. Temporary fences or markers would also be used to ensure contractors disturb the minimum area only, preventing the tracking of heavy machinery across surrounding land for example.

The site would be developed in phases wherever possible with surface water runoff initially managed through a range of sediment treatment measures and temporary SuDS to reduce the runoff rate and volume of discharge to the local drainage network. Along steeper sections of the track where the velocity of surface runoff could pose a significant risk of scour through the construction site, phasing will be vital to reduce the area of exposed ground at any given time. All felling would be conducted in accordance with the UK Forest Standard[8] and the aforementioned Managing Forest Operations to Protect the Water Environment Practice Guide.

In both construction and operation, the movement of construction traffic would be controlled to minimise soil compaction and disturbance. Vehicle movements (to include HGVs and plant machinery) outside the defined tracks and hardstanding areas would be avoided where possible. Routine mechanical maintenance of vehicles will be carried out off-site or in a suitable designated area of the site.

Temporary drainage pathways would be established to direct surface water away from at risk areas and towards the surface water drainage network via sediment controls. The aim of the scheme would be to ensure that water from surrounding land is excluded from the area of development and where this is not possible the volumes draining onto the site are significantly reduced. There will be no unapproved discharge of foul or contaminated drainage from the Site either to groundwater or any surface waters, whether direct or via soakaway.

Clay plugs would be inserted within cable trenches at a frequency to suit the specific location to prevent gullying of trenches and preferential routing.

A programme of surface water quality monitoring would be undertaken before and during the construction phase to provide assurance as to the absence of water quality impacts.

3.1.2 Specific Measures

V-Shaped Ditches

For the proposed track, it is recommended that v-shaped ditches (or shallow ditches combined with bunds) be placed on the upslope side of the construction area. These will convey surface water from upslope to piped crossings beneath the construction areas. Where space allows and in locations where siltation is likely (i.e. steep slopes with limited vegetation cover) a geotextile sump upslope of each crossing could be used to offer further treatment. In areas at grade or fill areas where embankments are proposed, multiple piped crossings would be used to limit the volume of discharge draining to one outfall. For cuttings this will not be possible, and ditches will need to extend the full distance of the cutting until a suitable crossing point either at grade or across an embankment is reached. Where ditch lengths are significant it is recommended that check dams or straw bales be used to interrupt flows and provide some interim treatment. As standard, check dams would be in place where the longitudinal slope of a ditch exceeds 3% (see Figure 1).

[7] Forestry Commission, 2019. Managing Forest Operations to Protect the Water Environment.

[8] Forestry Commission, 2017. UK Forest Standard. Fourth Edition.

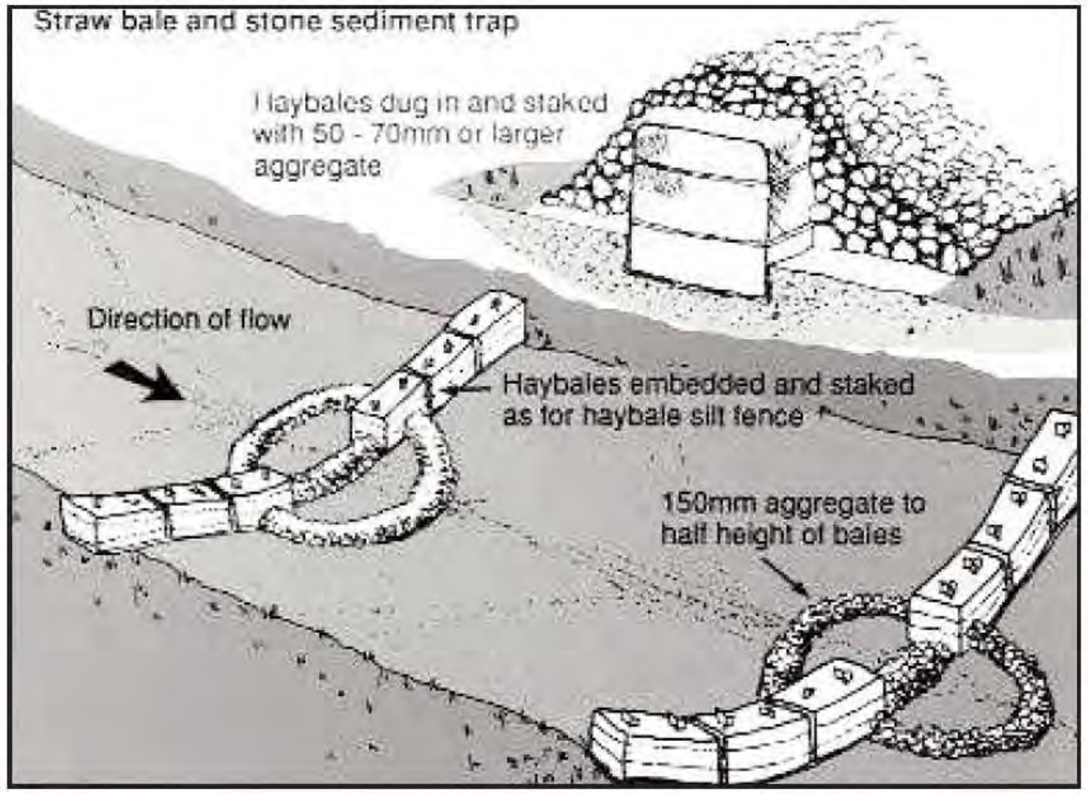


Figure 1 - Typical Layout of Check Dams (Source: CIRIA, 2006[9])

Buffer Strips

Downslope of the construction area, a buffer strip would run along the entire length of the excavated construction area. Widths of 5m have been demonstrated to be very effective in terms of water quality performance even for steeper slopes[10], provided the density of vegetation cover is sufficient. Therefore, where there is enough space available it is recommended that the minimum buffer strip width be set at 5m. Where slopes are significant, greater widths would be provided.

It is also recognised that the performance of buffer strips is limited in heavy soils such as peat. These are present across some of the site and in these locations, it is recommended that some of the additional sediment control measures outlined later in this section are considered.

This design philosophy assumes that the camber of the track will slope in one direction. If following detailed design, the road has a curved camber, this means runoff will fall to both sides so drainage channels in the form of v-shaped ditches will be required on both sides. In this scenario the buffer strip should be placed downslope of an adjacent ditch.

Settlement Ponds

Settlement ponds would be installed for use as part of the construction phase drainage prior to excavation. These would be sited downslope of the main construction areas including all of the turbines to effectively capture and treat runoff from these large areas. These will treat sediment load picked up by run-off from key construction zones. Once complete these will remain in place and be re-engineered to attenuate flows from the now impermeable areas of the turbine site. The ponds will be sized to ensure sufficient treatment during construction, more detail on this is provided in Section 5.

Silt Fencing

Silt fencing is recommended as a primary treatment method within the earthworks. These will act to break up any preferential flow paths and divert and filter runoff. It is recommended that these be spaced transversally across the construction area. In terms of spacing, they would be placed at more regular intervals where necessary, for example in steeper sections. Figure 2 shows an example of good practice silt fence installation.

Figure 2 - Example of good practice in silt fence installation (Source: Geosynthetics, 2021[11])

Watercourse Crossings

Whilst the tracks have been designed to minimise the number of watercourse crossings and use existing tracks located along the access route where possible, the creation of 4 new crossings and adoption of another 4 existing crossings would be required. If crossings are not designed correctly, desiccation could occur during periods of low flow, thus disconnecting the upper reaches of a stream (with potential ecological and resource consequences). The crossing would need to be sized appropriately to ensure that it would have the conveyance capacity for appropriate design floods. If not, the tracks in the vicinity of the crossing could flood, resulting in scour and potential track failure, thereby potentially releasing significant sediment into the surrounding watercourses. Where practicable, existing crossings will be utilised instead of creating new crossings. All new and existing crossings are labelled in the indicative drainage layout plans provided in Appendix 1.

Where existing crossings are adopted, these will be widened and strengthened as necessary with the commitment that the type of structure and bed profile will not be changed, and best practice drainage will be adopted.

Table 1 below details the locations of the new watercourse crossings and the proposed type. The detailed design of these would be confirmed by a survey of the watercourse prior to construction and would be agreed upon with NRW prior to construction. Examples of a water crossing structures are provided in the Environmental Statement (Figure 5-4a and 5-4b).

[9] CIRIA, 2006, Control of water pollution from linear construction projects Site guide (C649)
[10] CIRIA, 2015, The SuDS Manual (C753)
[11] Geosynthetics (2021) http://www.geosyn.co.uk/product/silt-stop-premium-and-high-flow-silt-fences

Table 1 - New Watercourse Crossings

Watercourse	Crossing NGR	Proposed Crossing Type
Unnamed tributary of the Llaethdy Brook	304561, 278686	Culvert with buried invert
Unnamed tributary of the Custogion Brook	304457, 279248	Culvert with buried invert
Blue Lins Brook	304024, 282336	Single span crossing
Unnamed tributary of the Blue Lins Brook	303984, 282908	Culvert with buried invert

Due to their relatively small size and catchment area, culverts with buried inverts are proposed for the three minor watercourses as the detrimental effects expected are minimal compared to the main watercourses in relation to cost. This is due to the retention of the natural bed formation with this type of culvert meaning flow rates and habitats remain in situ. The crossings would be designed to ensure they would not disconnect the watercourses at times of low flow and would have appropriate flood capacity. The bed profile would remain unchanged to prevent a change in geomorphology of the channel.

A single span crossing is proposed over the Blue Lins Brook given its large width and significance in the drainage network to ensure it has minimal impact upon the brook and minimises disturbance of the watercourse.

At all crossings silt fences would be erected along watercourse banks adjacent to, upstream and downstream of crossing locations in order to intercept polluted runoff during construction and trafficking, as required.

Additional Measures in Vulnerable Locations

It is recognised that some areas of the site are more vulnerable than others and these may require additional surface water protection measures. These areas would include, but are not limited to:

- Private Water Supply (PWS) exclusion zones ‘Custogion’ at NGR 305358, 279829 and ‘Ddulley Bank Farm’ at NGR 304680, 280984;
- Groundwater Dependent Terrestrial Ecosystems (GWDTE) outlined in the GWDTE assessment.
- Protected Sites (i.e. Site of Special Scientific Interest (SSSI) & Special Area of Conservation (SAC)), specifically the River Wye SAC, this is addressed within the Water Framework Directive Assessment;
- Existing overland flow paths/watercourses;
- Areas with heavy peat soils where the effectiveness of buffer strips are limited;
- Watercourse crossings;
- Slopes; and
- Stockpiles.

In these areas additional treatment measures would be provided. For example, where there are existing overland flow paths silt fencing could be placed perpendicular to flow direction to break the force of runoff reducing the risk of scour downslope. Where surface water conveyed by a ditch discharges directly to a watercourse, an additional level of protection would be provided along the banks of the watercourse. This should comprise a combination of buffer strips and silt fencing. For areas close to protected sites sediment treatment measures could be used in series to ensure any pollutants are successfully removed.

Particular care is required in the PWS exclusion zones (on which further details are provided in Appendix 10.6: Private Water Supply Risk Assessment) to ensure that runoff or spillages will not detriment water quality. The proposed ditches would ensure that the majority of construction runoff does not enter these zones. Where there is a risk of this happening, additional water quality measurements may need to be employed to counter this.

Where construction is taking place near GWDTE additional mitigation measures are required to ensure groundwater quantity is not reduced to these habitats. Turbines T12, T14, T16, T6, T15, T17, T4 and borrow pits require parallel to contour drainage upslope to prevent contamination of water and downslope to capture water and increase infiltration. There are several areas of access track near GWDTE habitats that require cross track drainage to maintain hydraulic continuity.

Meshes, netting, mat and sheeting made of natural or man-made material can be used and may prove particularly useful in locations where bare ground is unused. Specifically, biodegradable geotextiles such as coconut matting in conjunction with silt fencing could be used (see Figure 3).

Figure 3 - Coconut matting and silt fence (Source: CIRIA, 2006[12])

3.1.3 Spillage Risk

In addition to the specific measures outlined above, minimisation of pollution events during the construction phase will also be ensured by the adequate maintenance of vehicles, the responsible handling and storage of potentially polluting materials and liquids and suitable training of staff. In order to reduce the impact of accidental spillages (*e.g.* from plant fuel) during construction, appropriate planning will identify such risks and the precautionary measures to be taken such as:

- Equipment would be provided to contain and clean up any spills in order to minimise the risk of pollutants entering watercourses, GWDTE or flush areas.
- Temporary bunding would be provided as required, to reduce the risk of oil or chemical spills to the natural drainage system.
- Refuelling of vehicles and plant machinery would be confined to the designated fuelling areas and would be carefully controlled.

[12] CIRIA, 2006, Control of water pollution from linear construction projects Site guide (C649)

- Vehicles, plant machinery and equipment would be cleaned at designated washout areas located conveniently and within a controlled area of the Site.
- All fuel and chemicals would be stored within appropriately specified containers and within specifically designed stores / storage areas and would include appropriate measures to avoid spillages.
- Concrete batching and any onsite washout would occur in designated areas, which would be lined to prevent infiltration of high alkaline content flow and would be covered to minimise the ingress of rainwater to the containment areas.
- Drip trays would be placed under standing machinery.
- All solid and liquid waste materials would be properly disposed of in controlled landfill sites away from the Site.
- Training of staff in emergency procedures would be undertaken with spillage response kits easily accessible at all times.
- Areas at particular risk of spillage would have a temporary protective layer laid to prevent infiltration into the soil and reduce risk to groundwater.

4 Operation

It is envisioned that during the operational phase the general SuDS approach adopted during construction will continue to be used with ditches remaining in place to convey runoff from the tracks, buffer strips retained in vulnerable locations and settlement ponds sited adjacent to the turbine bases. Features such as silt fences which are key during the construction phase to control sediment produced from excavated areas can be removed and the removal of additional measures such as geotextile sumps would also be considered on a case-by-case basis given the reduced pollution hazard during the operational phase. This hazard is reduced due to a decreased frequency in the movement of materials, equipment and people on the site as well as increased vegetation over time. Keeping the main SuDS features installed would ensure that runoff quality is managed appropriately over the life of the project. Similarly to the construction phase, long term drainage solutions on NRW land would adhere to the Managing Forest Operations to Protect the Water Environment Practice Guide[13].

5 Storage Volume

Storage volumes will be provided on site during construction and operation. The primary purpose of storage during construction is to provide sufficient treatment of surface water runoff and reduce runoff rates and volumes from impermeable areas. During operation, these principles remain the same, however there is a more formal requirement to attenuate post-development flows and runoff volumes to pre-development greenfield conditions. The following sections detail how greenfield runoff has been estimated and used to determine provisional storage volumes.

5.1 Site Characteristics

The volume estimates for the development will be divided into parts based on the site boundary taking account of the varied geology across the site. As only the northern and central boundaries contain the proposed development as shown in Figure 4, a volume requirement for each will be estimated separately. Table 2 provides the values of the individual site area and impermeable area. The latter is based on the site footprint layer provided by Dulas where the construction zones have been taken as an impermeable area which construction will be restricted to. The internal access tracks are to be constructed from hardcore (compacted quarried primary aggregate) so they will remain essentially pervious surfaces. During construction an allowance for some impervious areas within the track construction zones would be made. This is considered a conservative estimate of the impermeable area of the proposed development.

Table 2 – Site total and impermeable areas

Site	Site Area (ha)	Impermeable Area (ha)
North	245.6	6.03
Central	377.9	5.35

Point descriptors have been taken from the FEH WebService to define the hydrological characteristics of the site. These have been extracted at the centroid of both site boundaries as shown in Figure 4 below.

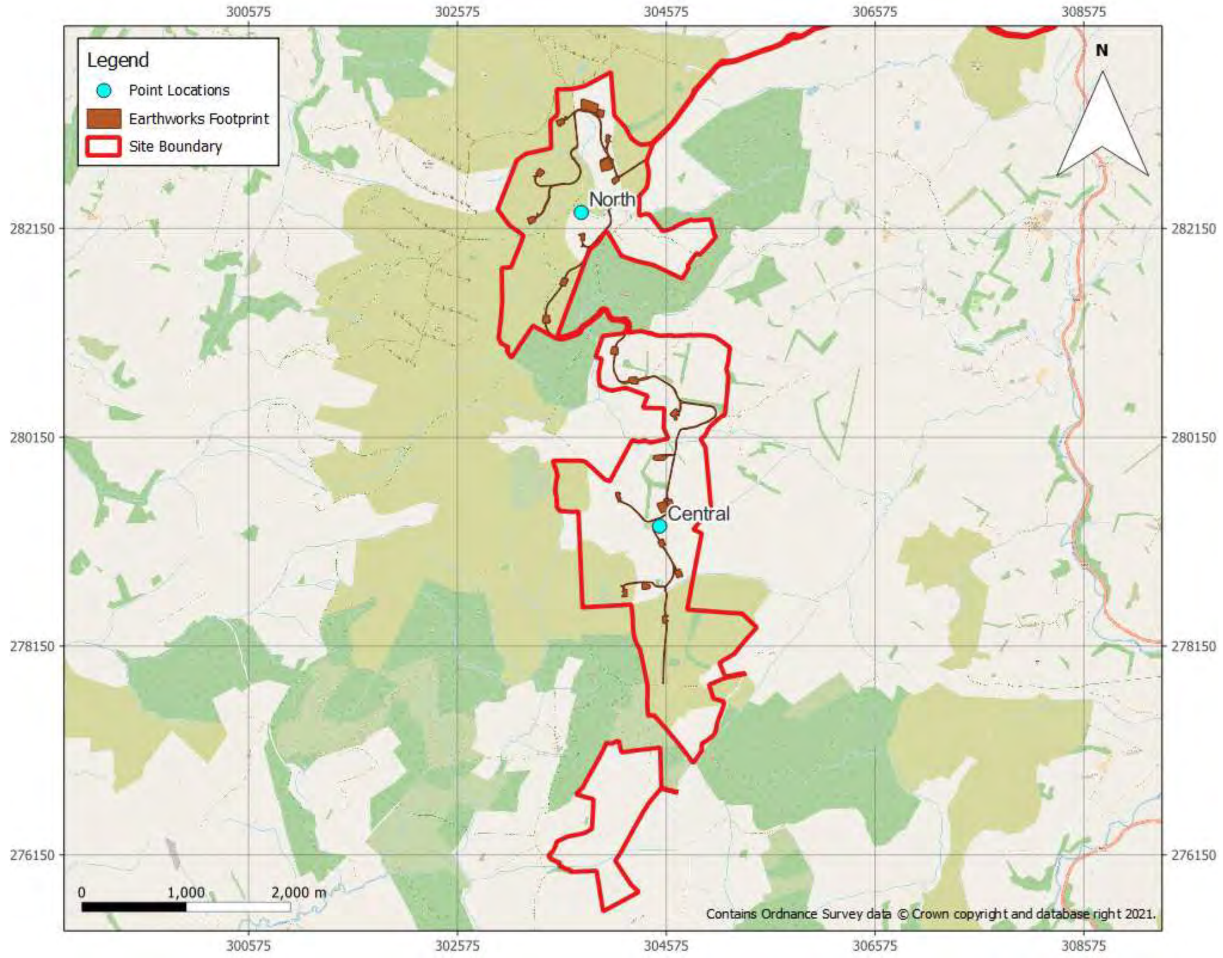


Figure 4 - Site area and point locations

5.2 Greenfield Run-off Rates

To estimate run-off and determine the volume requirements for the site, greenfield runoff rates have been calculated separately for both the north and central site boundaries using the point descriptor data summarised in Table 3. The calculations are based upon a combination of the Standard Average Annual Rainfall (SAAR), base flow index (BFIHOST) and the portion of time soils are wet (PROPWET). The BFIHOST value in the north was largely consistent across the site whilst for the central, it varied. The value taken was on the higher end and is considered a conservative approach in terms of storage provision.

[13] Forestry Commission, 2019. Managing Forest Operations to Protect the Water Environment.

Table 3 - ReFH Point Descriptors

Point Descriptor	North Boundary	Central Boundary
SAAR (mm)	1194	1139
PROPWET (mm)	0.49	0.49
BFIHOST19	0.257	0.348

Runoff rates for the existing greenfield land have been calculated using ReFH2, which is the current recommended method outlined in the CIRIA SuDS manual[14]. The rates and volumes have been estimated over the entire site areas and for a range of storms up to and including the 1 in 100 year event plus an allowance for climate change. Table 4 below presents the greenfield runoff rates as the unit rate per hectare. The associated calculations are provided in Appendix 2.

Table 4 - Greenfield Runoff Rates

Return Period	North - Greenfield Runoff Rate (l/s/ha)	Central - Greenfield Runoff Rate (l/s/ha)
1 in 2	9.76	6.50
1 in 30	22.13	14.53
1 in 100	29.37	19.23
1 in 100+40%	41.12	26.92

5.3 Estimated Volume

The provision of SuDS storage at a site can be achieved using two approaches;

- Providing long term storage – typically in the form of an offline storage which slowly releases captured water by infiltration.
- Providing attenuation only storage – utilised to store runoff and release at equivalent greenfield rates. Often utilised in isolation if inappropriate conditions for long term storage.

Given the expected ground conditions and tight working corridors associated with this project, SuDS storage has been sized using the attenuation only approach. This is deemed acceptable especially when considering the rural setting of the site and relative sparseness of the infrastructure proposed.

Causeway Flow v9.1 was used to determine the total storage volume required across each site area for a range of storm events. The required storage volumes are presented in Table 5 for a range of storm durations up to and including the 1 in 100 year event plus an allowance for climate change. In this case, the maximum outflow rate from the attenuation storage is limited to the equivalent greenfield rate for a given return period over the impermeable site area. The Causeway design calculations are included in Appendix 3. The volumes provided are considered to be an upper bound estimate of what will be required.

Table 5 - Storage Volume Estimates

Return Period	North Storage Estimate (m^3)	North Storage Estimate (m^3/ha)	Central Storage Estimate (m^3)	Central Storage Estimate (m^3/ha)
1 in 2	1070	177.5	1143	213.6
1 in 30	1832	303.8	1892	353.6
1 in 100	2294	380.4	2317	433.1
1 in 100+40%	3212	532.7	3244	606.4

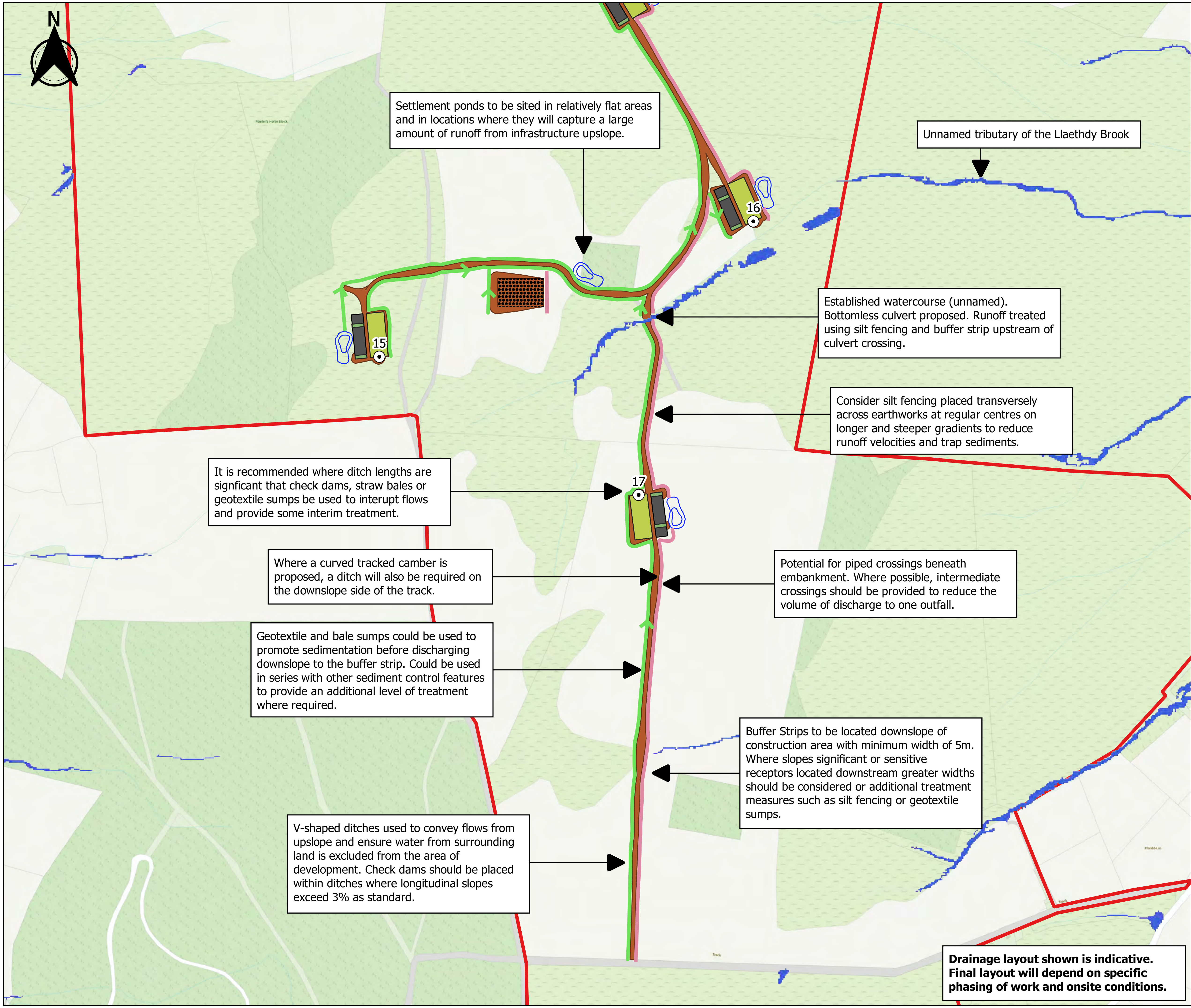
Current guidance notes an aspiration criterion that a storage volume equivalent to 15mm of rainfall should be provided to improve stormwater quality (termed “treatment volume”). 15mm of rainfall equates to 150m^3 storage per hectare of impervious area contributing. The values in Table 5 meet this criterion. The storage would be provided in line with the SuDS infrastructure shown in the indicative drainage layout plans in Appendix 1.

6 Conclusions and Recommendations

The main conclusions and recommendations for the surface water management plan are outlined below and an indicative layout provided in the plans in Appendix 1.

- Good surface water management during construction is essential to ensuring that sediment does not pollute downstream watercourses.
- Vegetation cover would be retained for as long as possible and track construction phased to minimise the potential for soil stripping.
- Temporary drainage pathways would be established to direct surface water away from at risk areas and towards the SuDS and surface water drainage network via sediment controls.
- The aim of the drainage scheme would be to ensure that water from surrounding land is excluded from the area of development and where this is not possible the volumes draining onto the site are significantly reduced.
- Further guidance provided in this document on construction activities, vehicle access/maintenance, felling and spillage control would also be followed to further ensure pollution control.
- For the proposed road, it is recommended that v-shaped ditches (ditches possibly combined with bunds) be placed on the upslope side of the construction area. These will convey surface water from upslope to piped crossings beneath the construction areas.
- Downslope of the construction area, a buffer strip would run along the entire length of the excavated construction area. Where there is enough space available it is recommended that the minimum buffer strip width be set at 5m. Vegetation would not be disturbed within this filter strip to enable treatment of any direct run-off from earthworks.
- If following detailed design, the road has a curved camber, this means runoff will fall to both sides so drainage channels in the form of v-shaped ditches will be required on both sides.
- Silt fencing is recommended as a primary treatment method within the earthworks. These will act to break up any preferential flow paths and divert and filter runoff. These would be set at regular intervals where necessary.
- It is recognised that some areas on site are more vulnerable than others and these may require additional surface water protection measures, including implementing a number of measures in series to ensure adequate treatment.
- It is envisioned that during the operational phase the general SuDS approach adopted during construction will continue to be used. However, several features such as silt fences will be removed given the reduced pollution hazard during the operational phase.
- Storage volumes will be provided on site during construction and operation to treat and control runoff. For the northern and central site areas, when considering the 100-Year event the provisional storage requirements are 380.4 m^3 and 433.1 m^3 per hectare, respectively.

[14] CIRIA (2015) The SuDS Manual (C753)



WHS

Legend

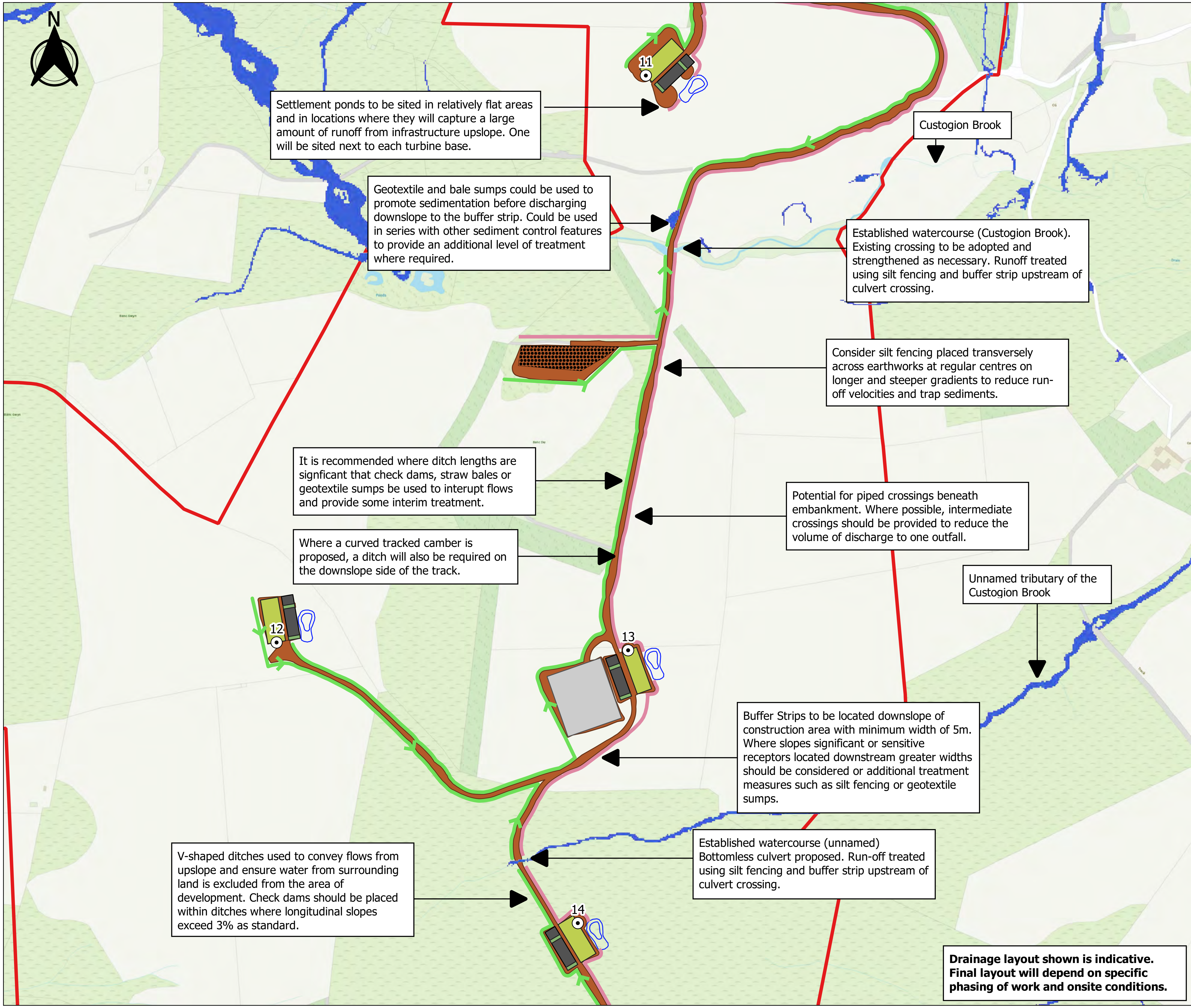
Site Footprint

- Turbine
- Site Boundary
- V-Shaped Ditches
- Buffer Strips
- Basins
- 30-Year Surface Water Flood Extent
- Blade Laydown Hardstandings
- Blade Laydown Clearing
- Borrow Pits
- Construction Compound
- Crane Pads
- Energy Storage
- Substation
- Earthworks Footprint

0 0.1 0.2 km

edf renewables

CLIENT	EDF RENEWABLES
PROJECT	GARN FACH WIND FARM
LOCATION	SOUTH OF NEWTOWN
PROJECT No.	WHS 1759
SCALE	1:5,000 (A3)
DRAWING TITLE	Outline Surface Water Management Strategy - Page 1 of 5
DRAWING No.	WHS1759-T02-0001
SHEET	0
REVISION	B



WHS

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0 0.1 0.2 km

edf renewables

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PROJECT	GARN FACH WIND FARM
LOCATION	SOUTH OF NEWTOWN
PROJECT No. WHS 1759	SCALE 1:5,000 (A3)

DRAWING TITLE

Outline Surface Water Management Strategy - Page 2 of 5

DRAWING No.	SHEET	REVISION
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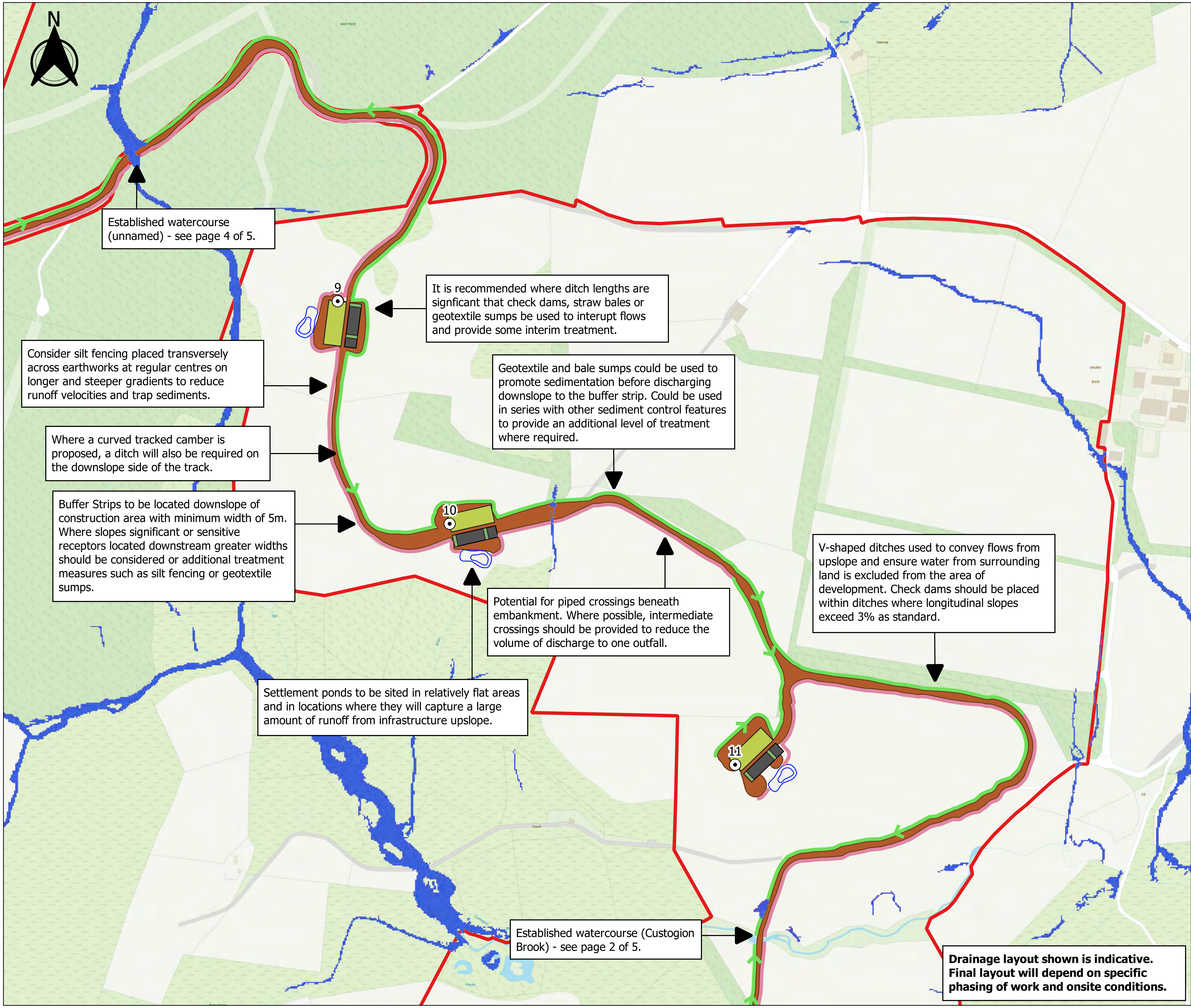

WHS

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0 0.1 0.2 km

edf renewables

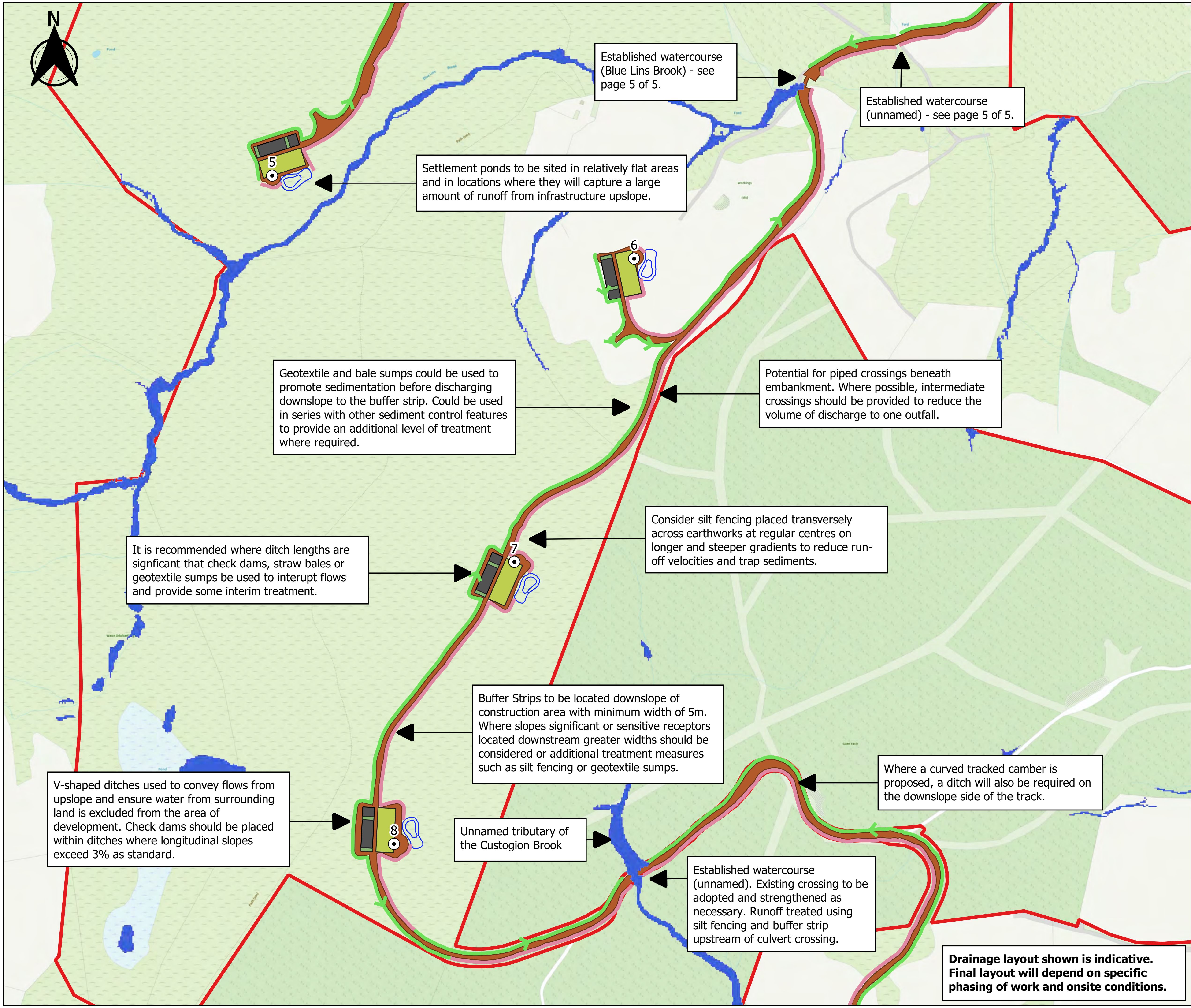
CLIENT	EDF RENEWABLES
PROJECT	GARN FACH WIND FARM
LOCATION	SOUTH OF NEWTOWN

PROJECT No.	WHS 1759	SCALE	1:5,000 (A3)

DRAWING TITLE

Outline Surface Water Management Strategy - Page 3 of 5

DRAWING No.	SHEET	REVISION
WHS1759-T02-0003	0	B



WHS

Legend

Site Footprint

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0 0.1 0.2 km

edf renewables

CLIENT	EDF RENEWABLES
PROJECT	GARN FACH WIND FARM
LOCATION	SOUTH OF NEWTOWN
PROJECT No.	WHS 1759
SCALE	1:5,000 (A3)
DRAWING TITLE	Outline Surface Water Management Strategy - Page 4 of 5
DRAWING No.	WHS1759-T02-0004
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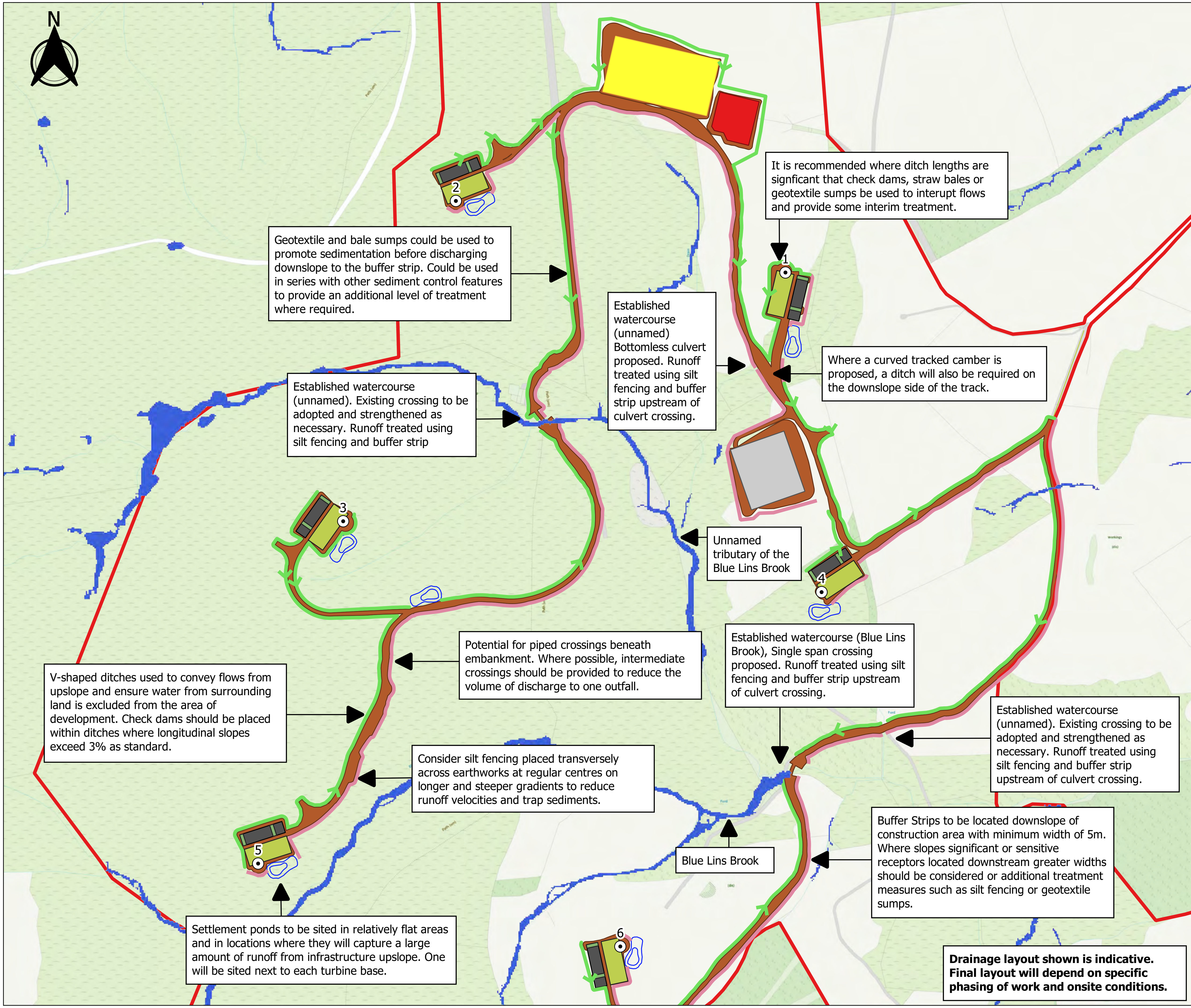

WHS

Legend

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0 0.1 0.2 km

edf renewables

CLIENT	EDF RENEWABLES
PROJECT	GARN FACH WIND FARM
LOCATION	SOUTH OF NEWTOWN
PROJECT No.	WHS 1759
SCALE	1:5,000 (A3)
DRAWING TITLE	Outline Surface Water Management Strategy - Page 5 of 5
DRAWING No.	WHS1759-T02-0005
SHEET	0
REVISION	B

ReFH2 Greenfield Runoff Estimate
Calculation Sheet

Site Name	Garn Fach
Site Location	Powys, Wales
X (Eastings)	304509
Y (Nothings)	279298
Engineer	Sam Pucknell
Checked by	Daniel Hamilton
Reference	WHS 1759
Revision	1
Date	16-Mar-21

Site Description

Total Area (ha)	377.908
Existing Developed area (ha)	0
SAAR (mm)	1139
PROPWET(mm)	0.49
BFIHOST19	0.35

Rainfall Parameters

Duration (hh:mm:ss)	03:45:00
Timestep (hh:mm:ss)	00:15:00
SCF (Seasonal correction factor)	0.77
ARF (Areal correction factor)	0.96
Seasonality	Winter

Loss Model Parameters

Cini (mm)	113.39
Cmax (mm)	254.82

Routing Parameters

Tp (hr)	1.78
Up	0.65
Uk	0.8

Baseflow Parameters

BF0 (m^3/s)	0.22
BL (hr)	31.31
BR	0.88

Growth Curves and Discharge rates

Event	*Q/Qmed*	*Q (l/s)*	*Q (l/s/ha)*
Q1	**-**	**2164.43**	**5.73**
Q2	1.00	2458.05	**6.50**
Q30	**2.23**	**5492.76**	**14.53**
Q100	**2.96**	**7268.79**	**19.23**
Q200	3.48	8545.51	22.61
Q1000	5.02	12343.11	32.66

ReFH2 Greenfield Runoff Estimate
Calculation Sheet

Site Name	Garn Fach
Site Location	Powys, Wales
X (Eastings)	304509
Y (Nothings)	279298
Engineer	Sam Pucknell
Checked by	Daniel Hamilton
Reference	WHS 1759
Revision	1
Date	16-Mar-21

Site Description

Total Area (ha)	246.5919
Existing Developed area (ha)	0
SAAR (mm)	1194
PROPWET(mm)	0.49
BFIHOST19	0.26

Rainfall Parameters

Duration (hh:mm:ss)	03:15:00
Timestep (hh:mm:ss)	00:15:00
SCF (Seasonal correction factor)	0.77
ARF (Areal correction factor)	0.97
Seasonality	Winter

Loss Model Parameters

Cini (mm)	130.64
Cmax (mm)	201.17

Routing Parameters

Tp (hr)	1.54
Up	0.65
Uk	0.8

Baseflow Parameters

BF0 (m^3/s)	0.18
BL (hr)	25
BR	0.32

Growth Curves and Discharge rates

Event	*Q/Qmed*	*Q (l/s)*	*Q (l/s/ha)*
Q1	**-**	**2101.10**	**8.52**
Q2	1.00	2406.06	**9.76**
Q30	**2.27**	**5458.06**	**22.13**
Q100	**3.01**	**7243.28**	**29.37**
Q200	3.54	8525.41	34.57
Q1000	5.12	12317.18	49.95

North	245.59							
Event	Q/Qmed	Q (m3/s)	Q (l/s)	Q (l/s/ha)	QImp (l/s)	Storage Re	/Site Area	/Imp Area
Q1		2.101102	2101.102	8.520564	2092.565			
Q2	1	2.406059	2406.059	9.75725	2396.283	1070	4.356855	177.4461
Q5	1.416252	3.407585	3407.585	13.81872	3393.74			
Q10	1.727682	4.156905	4156.905	16.85743	4140.015			
Q30	2.268465	5.458061	5458.061	22.13398	5435.885	1832	7.459587	303.8143
Q50	2.558666	6.1563	6156.3	24.96554	6131.287			
Q75	2.813943	6.770511	6770.511	27.45634	6743.003			
Q100	3.010432	7.243276	7243.276	29.37354	7213.847	2294	9.340771	380.4312
Q100 + 40	4.214605	10.14059	10140.59	41.12295	10099.39	3212	13.07871	532.67
Q200	3.543308	8.525407	8525.407	34.57294	8490.768			
Q1000	5.119235	12.31718	12317.18	49.94965	12267.14			

Storage Estimate

Return Period (years)	2	OK
Climate Change (%)	0	Cancel
Impermeable Area (ha)	6.030	Update
Peak Discharge (l/s)	58.836	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	461	
to	1070	
With infiltration (m³)		
from		
to		

Storage Estimate

Return Period (years)	30	OK
Climate Change (%)	0	Cancel
Impermeable Area (ha)	6.030	Update
Peak Discharge (l/s)	133.468	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	1093	
to	1832	
With infiltration (m³)		
from		
to		

Storage Estimate

Return Period (years)	100	OK
Climate Change (%)	0	Cancel
Impermeable Area (ha)	6.030	Update
Peak Discharge (l/s)	177.122	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	1507	
to	2294	
With infiltration (m³)		
from		
to		

Storage Estimate

Return Period (years)	100	OK
Climate Change (%)	40	Cancel
Impermeable Area (ha)	6.030	Update
Peak Discharge (l/s)	247.971	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	2110	
to	3212	
With infiltration (m³)		
from		
to		

Central	377.91							
Q1		2.164434	2164.434	5.727409	2164.445			
Q2	1	2.458049	2458.049	6.504359	2458.062	1143	3.02453	213.6449
Q5	1.403711	3.45039	3450.39	9.130238	3450.408			
Q10	1.705243	4.191572	4191.572	11.09151	4191.594			
Q30	2.234601	5.492759	5492.759	14.53465	5492.788	1892	5.006483	353.6449
Q50	2.51681	6.186444	6186.444	16.37024	6186.476			
Q75	2.765393	6.797472	6797.472	17.98711	6797.508			
Q100	2.957138	7.268792	7268.792	19.23429	7268.83	2317	6.131089	433.0841
Q100 + 40	4.139994	10.17631	10176.31	26.92801	10176.36	3244	8.584054	606.3551
Q200	3.476543	8.545514	8545.514	22.61268	8545.559			
Q1000	5.021505	12.34311	12343.11	32.66167	12343.17			

Storage Estimate

Return Period (years)	2	OK
Climate Change (%)	0	Cancel
Impermeable Area (ha)	5.350	Update
Peak Discharge (l/s)	34.798	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	550	
to	1143	
With infiltration (m³)		
from		
to		

Storage Estimate

Return Period (years)	30	OK
Climate Change (%)	0	Cancel
Impermeable Area (ha)	5.350	Update
Peak Discharge (l/s)	77.760	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	1177	
to	1892	
With infiltration (m³)		
from		
to		

Storage Estimate

Return Period (years)	100	OK
Climate Change (%)	0	Cancel
Impermeable Area (ha)	5.350	Update
Peak Discharge (l/s)	102.903	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	1562	
to	2317	
With infiltration (m³)		
from		
to		

Storage Estimate

Return Period (years)	100	OK
Climate Change (%)	40	Cancel
Impermeable Area (ha)	5.350	Update
Peak Discharge (l/s)	144.065	
Infiltration Coefficient (m/hr) (leave blank if no infiltration)		Calc
Required Storage (m³)	Calc	
from	2187	
to	3244	
With infiltration (m³)		
from		
to		

Appendix 10-8: Garn Fach Wind Farm Caron balance Assessment

Contents

1 Introduction

Wallingford HydroSolutions Ltd (WHS) has been commissioned by Dulas Ltd, on behalf of EDF Renewables, to complete a Carbon Balance Assessment for the proposed Garn Fach Wind Farm. This document forms an appendix to the Environmental Statement (ES) to accompany a planning application for a proposed 17 turbine windfarm to the south of Newtown, Powys, NGR: SO 03413 81467 covering an area of approximately 700ha.

This assessment has been completed using the latest version of the Scottish Government Carbon Calculator[1] tool in accordance with the associated guidance[2], which is used as standard throughout the UK. The Carbon Calculator determines the carbon emission savings and the carbon payback of wind farms and explores the potential implications under different scenarios of developments and assumptions about the site i.e. expected, best case and worst case scenarios. It discusses the potential carbon savings and carbon costs associated with the proposed development as follows:

- Carbon emission savings (based on emissions from different power sources);
- Loss of carbon due to production, transportation, erection, operation and decommissioning of the wind farm;
- Loss of carbon from backup power generation;
- Loss of carbon-fixing potential of peatland;
- Loss and/or saving of carbon stored in peatland (by peat removal or changes in drainage;
- Carbon saving due to improvement of habitat; and
- Loss and/or saving of carbon-fixing potential as a result of forestry clearance.

The methodology provides a balance of total carbon savings, including the impacts described above, and carbon losses over the life of the wind farm. It estimates the carbon payback time for the wind farm based on the source of power being displaced (i.e. the time needed to generate carbon savings equivalent to the amount of carbon lost). The raw data input to the online calculation tool is submitted as an Appendix to this report.

[1] Scottish Government Wind Farm developments on Peat Land: Carbon Calculator Tool v1.6.1 https://informatics.sepa.org.uk/CarbonCalculator/

[2] Calculating Carbon Savings from Wind Farms on Scottish Peatlands – A new Approach (Nayak et al., 2008; Nayak et al., 2010 and Smith et al., 2011).

It should be noted that estimates of emissions from peat removal within the tool are uncertain as they depend upon assumptions made on the rate or loss or gain of carbon in Scottish Soils. There are also several values which are fixed within the model and based on historic datasets which may now be outdated. However, the SEPA Carbon Calculator estimation tool is widely used by regulators and is accepted as the best practice form for calculating carbon savings from wind farm development on peatlands.

2 Input Data

The data inputs for the online calculator tool have been extracted from the source listed below:

- Garn Fach Windfarm ES, Chapter 5, Project Description.
- Garn Fach Windfarm ES Phase 2 Peat Survey completed by WHS in November 2020 and March 2021.
- Construction information provided by Pell Fischmann and Dulas via email (May 2021 and November 2021)
- Garn Fach Infrastructure Layout Shapefiles Named P7

Where site specific parameters were unavailable, default values suggested within the online guidance document were used along with professional judgement. A range of values for the required parameters were assessed to present a best and worst-case scenario. The expected values were used for all other input data. The input data can be seen in Appendix 1 (Ref: P9S8-U01G-3R34 v4).

3 Results

The model calculates carbon emission savings and losses from the various aspects of the model and also calculates a payback period based on the three counterfactual emission factors; coal fired plant, normal grid mix and fossil fuel mix as shown in Table 3-3. The counterfactual emission factors are fixed within the calculator tool, the values for coal-fired and fossil fuel-mix emission factors are based upon DUKES[3] data for the UK which is annually updated. The grid-mix emission factor is the list of emission factors used to report on 2016 greenhouse gas emissions as published by DECC[4].

This shows that even if the wind farm is replacing the normal fossil fuel sourced grid-mix of electricity generation, the proposed Garn Fach Wind Farm would produce a CO_2 saving of 117,275 tonnes per year.

Table 3-1: Estimate CO_2 emission savings

Windfarm CO2 emission saving over...	Expected values	Minimum Values	Maximum Values
Coal-fired electricity generation (t CO_2/yr)	239,761	226,061	253,462
Grid-mix of electricity generation (t CO_2/yr)	66,085	62,309	69,862
Fossil fuel-mix of electricity generation (t CO_2/yr)	117,275	110,573	123,976
Energy output from windfarm over lifetime (MWh)	7,818,300	7,371,540	8,265,060

Table 3-2 and Table 3-3 present the estimated losses and gains from the various aspects of the windfarm construction and operation. This shows that the improvement of degraded bogs will have a positive impact on carbon capture.

[3] Department for Business, Energy & Industrial Strategy. Digest of UK Energy Statistics (DUKES), available via: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[4] Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting- Conversion factors 2016. Available via https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2016

Table 3-2: Estimated CO_2 losses

Total CO_2 losses due to wind farm (t CO_2 eq.)	Expected values	Minimum values	Maximum values
Losses due to turbine lies (e.g. manufacture, construction, decommissioning)	75,500	75,500	75,500
Losses due to backup	50,261	50,261	50,261
Losses due to reduced carbon fixing potential	1,278	352	8,430
Losses from soil organic matter	21,751	510	26,1743
Losses due to DOC & POC leaching	2	0	29
Losses due to felling forestry	721	673	773
Total losses of carbon dioxide	**149,514**	**127,296**	**396,735**

Table 3-3: Estimated CO_2 Gains

Total CO2 gains due to improvement of site (t CO_2 eq)	Expected values	Minimum values	Maximum values
Change in emissions due to improvement of degraded bogs	0	0	0
Change in emissions due to improvement of felled forestry	0	0	0
Change in emissions due to restoration of peat from borrow pits	-415	0	-585
Change in emissions due to removal of drainage from foundations and hardstanding	-4,266	0	-36,077
Total change in emissions due to improvements	**-4,681**	**0**	**-36,662**

Table 3-4 demonstrates that the net emissions of carbon dioxide are estimated at 144,833 tonnes of CO_2, with an estimate payback period of 0.7 to 3.6 years. Thus, the proposed Garn Fach Wind Farm will produce a reduction in emissions from grid electricity of around 117,275 tonnes of CO_2 per year (this assumes that the wind farm replaces grid electricity generated from a fossil fuel mix).

Over the 30-year lifetime of the proposed wind farm, 3,518,250 tonnes of CO_2 will be by displacing a fossil fuel-mix electricity generation. Given the total net emissions of CO_2 due to the construction of the windfarm there will be a total net saving of 3,373,417 tonnes of CO_2 over the lifetime of the wind farm.

Table 3-4: CO2 Emissions and Payback Time

Results	Expected Values	Minimum Values	Maximum Values
Net emissions of carbon dioxide (t CO_2 eq)	144,833	90,635	396,735
Carbon Payback Time			
…coal-fired electricity generation (years)	0.6	0.4	1.8
…grid-mix of electricity generation (years)	2.2	1.3	6.4
…fossil fuel-mix of electricity generation (years)	1.2	0.7	3.6

4 Conclusions

The results show that the proposed Garn Fach Wind Farm is likely to produce a certain amount of CO_2 emissions, primarily from the construction phase, where carbon rich soils are excavated to construct foundations, access tracks and other infrastructure, or where changes to the hydrology of the site cause some loss of carbon from soils. However, the calculations indicate that these losses would be paid back within approximately 1.2 years of operation, through the displacement of fossil fuel generated electricity in the National Grid. Over the lifetime of the development 3,373,417 tonnes of CO_2 are expected to be saved from the production of wind energy relative to fossil fuel-mix electricity generation.

Appendix 1 Carbon Calculator Input Data (P9S8-U01G-3R34 v4)

Carbon Calculator v1.6.1
Garn Fach
EDF

Location: 52.433409 -3.391256

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	17	17	17	ES
Duration of consent (years)	30	30	30	ES
Performance				
Power rating of 1 turbine (MW)	5	5	5	ES
Capacity factor	35	33	37	ES
Backup				
Fraction of output to backup (%)	5	5	5	Dale et al 2004
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life ($tCO2\ MW^{-1}$) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	WHS Peat Survey Site visit
Average annual air temperature at site (°C)	9.2	5.2	13.2	https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcm95nm2h
Average depth of peat at site (m)	0.3	0.2	0.5	WHS Peat Survey Site Visit
C Content of dry peat (% by weight)	55.5	49	62	Birnie et al. 1991
Average extent of drainage around drainage features at site (m)	10	5	50	generic precautionary values
Average water table depth at site (m)	0.1	0.05	0.3	typical intact peat values
Dry soil bulk density ($g\ cm^{-3}$)	0.2	0.15	0.25	Default value taken from Lilly et al., 2010
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	10	10	15	Conservative estimate
Carbon accumulation due to C fixation by bog plants in undrained peats ($tC\ ha^{-1}\ yr^{-1}$)	0.25	0.12	0.31	default
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	1.82	1.8	1.85	ES
Average rate of carbon sequestration in timber ($tC\ ha^{-1}\ yr^{-1}$)	3.6	3.4	3.8	Default (Cannell, 1999)

Input data	Expected value	Minimum value	Maximum value	Source of data
Counterfactual emission factors				
Coal-fired plant emission factor ($t\ CO2\ MWh^{-1}$)	0.92	0.92	0.92	
Grid-mix emission factor ($t\ CO2\ MWh^{-1}$)	0.25358	0.25358	0.25358	
Fossil fuel-mix emission factor ($t\ CO2\ MWh^{-1}$)	0.45	0.45	0.45	
Borrow pits				
Number of borrow pits	2	2	4	Dulas email 18/05/2021
Average length of pits (m)	34	28	40	Calculated from layout shapefiles
Average width of pits (m)	91	65	138	Calculated from layout shapefiles
Average depth of peat removed from pit (m)	1.1	0.5	1.2	Phase 1 and 2 peat visits- interpolated peat depths
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	7.5	7	8	P7 development area shapefiles provided by Dulas
Average width of turbine foundations (m)	15	14.5	15.5	P7 development area shapefiles provided by Dulas
Average depth of peat removed from turbine foundations(m)	0.47	0.46	0.48	P7 development area shapefiles provided by Dulas
Average length of hard-standing (m)	62	61.5	62.5	P7 development area shapefiles provided by Dulas
Average width of hard-standing (m)	25	24.5	25.5	P7 development area shapefiles provided by Dulas
Average depth of peat removed from hard-standing (m)	0.47	0.46	0.48	P7 development area shapefiles provided by Dulas
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	12750	12750	12750	Email from Pell Frischmann dated 20/05/2021
Access tracks				
Total length of access track (m)	13452	13451	13453	Email from Dulas on 16/11/2021
Existing track length (m)	3662	3662	3662	Email from Dulas on 16/11/2021
Length of access track that is floating road (m)	0	0	0	No floating track
Floating road width (m)	5	5	5	No floating track
Floating road depth (m)	0	0	0	No floating track
Length of floating road that is drained (m)	0	0	0	No floating track
Average depth of drains associated with floating roads (m)	0	0	0	No floating track
Length of access track that is excavated road (m)	9790	9789	9791	Email from Dulas on 16/11/2021
Excavated road width (m)	7	5	15	Average estimated from drawing of earthworks footprint
Average depth of peat excavated for road (m)	0.4	0.1	1	Phase 2 peat survey by WHS
Length of access track that is rock filled road (m)	0	0	0	all tracks assumed to be excavated
Rock filled road width (m)	5	5	5	all tracks assumed to be excavated
Rock filled road depth (m)	0	0	0	all tracks assumed to be excavated
Length of rock filled road that is drained (m)	0	0	0	all tracks assumed to be excavated

Input data	Expected value	Minimum value	Maximum value	Source of data
Average depth of drains associated with rock filled roads (m)	0	0	0	all tracks assumed to be excavated
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	
Average depth of peat cut for cable trenches (m)	0	0	0	
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	
Area of additional peat excavated (m^2)	0	0	0	
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed
Improvement of C sequestration at site by blocking drains, restoration of habitat etc				
Improvement of degraded bog				
Area of degraded bog to be improved (ha)	0	0	0	Currently unspecified
Water table depth in degraded bog before improvement (m)	0.3	0.1	0.5	typical degraded peat values
Water table depth in degraded bog after improvement (m)	0.1	0.05	0.3	typical intact peat values
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10	5	15	estimated by hydrologist
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	20	15	25	wind farm lifetime minus time for improvement
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Currently unspecified
Water table depth in felled area before improvement (m)	0.3	0.1	0.5	typical degraded peat values
Water table depth in felled area after improvement (m)	0.1	0.05	0.3	typical intact peat values
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	10	5	15	estimated by hydrologist

Input data	Expected value	Minimum value	Maximum value	Source of data
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	20	15	25	wind farm lifetime minus time for improvement
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0.6	0.55	0.65	Email from Dulas indicating 2x borrow pits to be restored
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.3	0.1	0.5	typical degraded peat values
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.1	0.05	0.3	typical intact peat values
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	5	2	10	estimated by hydrologist
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	25	20	28	Wind farm lifetime minus time for improvement
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.3	0.1	0.5	typical degraded peat values
Water table depth around foundations and hardstanding after restoration (m)	0.1	0.05	0.3	typical intact peat values
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	2	1	5	estimated by hydrologist
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	No	No	No	
Will you attempt to block any gullies that have formed due to the windfarm?	No	No	No	Currently unspecified
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	Assumed
Will the habitat of the site be restored on decommissioning?	No	No	No	
Will you control grazing on degraded areas?	No	No	No	Currently unspecified

Input data	Expected value	Minimum value	Maximum value	Source of data
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	Assumed
Methodology				
Choice of methodology for calculating emission factors	IPCC default			

Forestry input data

N/A

Construction input data

N/A