Environmental Impact Assessment Report

Beinneun 2 Wind Farm

Volume 3

Technical Appendix A6.4: Groundwater-Dependent Terrestrial Ecosystems

Document prepared by Gavia Environmental Ltd for Beinneun 2 Ltd

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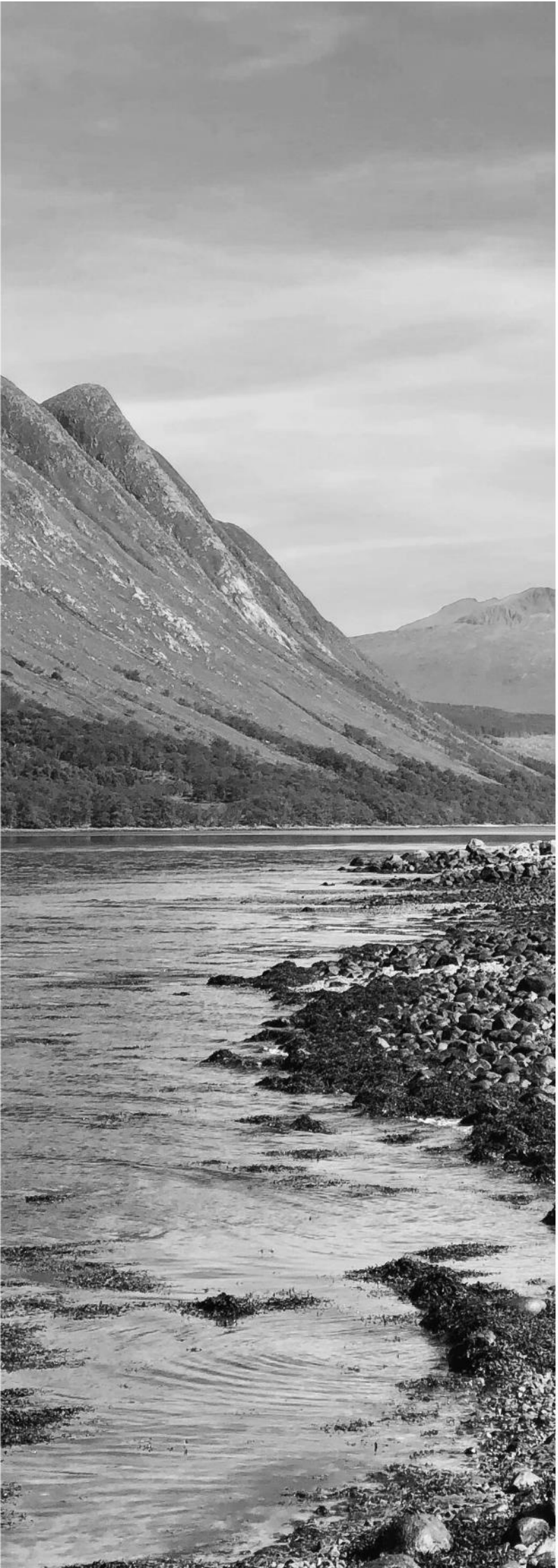

BEINNEUN 2 WIND FARM

TECHNICAL APPENDIX A6.4: GWDTE ASSESSMENT

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1	27/02/2025	HM/JDR	CB	MA	Initial issue
2	18/07/2025	AB			Changes

Quality assurance

This report has been prepared according to Gavia Environmental Quality Management Process. Gavia Environmental employs consultant scientists who are members of appropriate professional institutions and adhere to professional codes of conduct.

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Contents

1 Introduction

1.1 Scope of works

Gavia Environmental Ltd (Gavia) was commissioned by ENVAMS Ltd on behalf of Beinneun 2 Ltd (the 'Applicant') to undertake a groundwater-dependent terrestrial ecosystem (GWDTE) assessment for the proposed Beinneun 2 Wind Farm (the Site).

This report presents the findings of the geological desktop study, and subsequent GWDTE site survey undertaken on Friday 29th November 2024. During the site visit, water sampling was undertaken as well as the collection of additional targeted spot peat depth measurements to aid GWDTE identification. The collected field data was then compared to known data from the desk study, as well as known records from official guidance and site-specific control samples to identify and classify the 'actual' groundwater dependency.

The report provides a detailed screening of both potential and actual GWDTE habitats which were identified during the site walkover, and will be accompanied by a separate National Vegetation Classification (NVC) survey report (Gavia Environmental, 2025). The report objective is to assess the NVC survey outputs that indicated a potential moderate or high dependency on groundwater, and determine if any of these habitats had an actual moderate or high dependency on groundwater.

1.2 Proposed development

The proposed development will involve the erection of 19 new wind turbines spaced between NH 20714 06444 and NH 26610 04820. The proposed development is located approximately 5.4km northwest of Invergarry in the Highland Council area.

1.3 Limitations

On the day of the GWDTE survey, there were extensive areas of ice and snow present, with snow melt found commonly across the survey area. This additional water within the survey locations may have diluted the groundwater contribution to the water chemistry readings taken, hence the topography, geology and NVC data has been used extensively in this assessment.

2 Legislative background

2.1 GWDTE protection

GWDTEs are fully protected under the Water Framework Directive (WFD) 2000/60/EC (SNIFFER, 2009). The WFD is transposed into Scottish legislation in the Water Environment and Water Services (Scotland) Act (2003) (known as WEWS), which introduces regulatory controls to the Scottish Ministers and the Scottish Environment Protection Agency (SEPA) to protect and improve the Scottish water environment.

To fulfil the objectives of the WFD, any development must not cause a decline in the quality or quantity of groundwater supplied to a GWDTE. SEPA require any GWDTE located within 250m from excavations >1m deep to be avoided, or for any impacts to be mitigated against. SEPA consider any decline in groundwater status to be a contravention of the EU WFD.

3 Desk study

3.1 Geology

A review of the British Geological Survey (BGS, 2024) maps of the area indicate that the underlying bedrock is part of the Upper Garry Psammite Formation, composed primarily of psammite, a metamorphosed sandstone-like rock. In addition, across the Site are small, localised areas of igneous intrusions (a dyke swarm) formed of either; Monchiquite, Camptonite, microdiorite, diorite and an un-named ultramafic igneous formation. Due to the metamorphic composition of the surrounding bedrock body, it is expected that any water movement through the rock would be primarily through fracture flow, where present. It is a low productivity aquifer with a flow rate of 0.1-1 l/s (equivalent pumped borehole sustainable yield) (BGS 2015)[1]. In these conditions there is likely to be limited groundwater flow either within the bedrock, or towards the surface. There is potential for some limited flow to the surface at any prominent fractures present, such as at igneous intrusions and fault/fracture zones, however these are expected to be minimal and highly localised, if present.

BGS (2024) mapping indicate areas of hummocky glacial deposits (consisting of diamicton, sands and gravels) with localised areas of peat deposits spread across the Site. There are also areas of the Site which do not have any mapped superficial deposits. Targeted additional peat probing on site supports the BGS data suggesting that the superficial geology across the site is mostly sands and gravels below an often thin layer of peaty soil. Areas of deeper peat deposits are also present.

The National Soil Map of Scotland (Scotland's Soils 2024) indicates that the Site is underlain by predominantly 'Class 2' soils, which are likely to be comprised of deep-peat soil with occasional peaty soil. There is one small area of 'Class 3' soils located in the west of the Site. Class 2 soils are considered to be of a high restoration potential and contain peat-related vegetation. Peat deposits (greater than 50cm depth) are generally understood to be ombrotrophic in nature, meaning they are rainwater-fed rather than by other means such as groundwater or stream fed. Class 3 soils are considered to be of a lower restoration potential, as there is generally less deep peat found within these areas. Both these classes of peat/soil are indicative of a lack of groundwater dependent ecosystems, due to the high quality nature of the peat found within both areas.

Client-provided peat depth data further indicates the presence of deep peat within the Site boundary (a peat report is provided as Technical Appendix A12.2 of the Environmental Impact Assessment Report for the proposed development). 394 of 947 (41.6%) peat depth points taken in a previous survey were found to be over 50cm deep, further indicating the presence of deep peat within the Site. A plan showing the client-provided peat depth data is presented

[1] Ó Dochartaigh B É,Doce D D, Rutter H K and MacDonald A M. 2015. User Guide: Aquifer productivity (Scotland) GIS dataset, Version 2. Revised Report. *British Geological Survey Internal Report*, OR/15/003.

in Drawing 162008-9203 in Appendix A of EIA Report Technical Appendix A12.2, Peat Landslide Hazard and Risk Assessment.

3.2 Habitats

The Site was observed to be covered predominantly by open hillside. The dominant habitats across the Site were observed to be mosaics of M15 *Scirpus cespitosus– Erica tetralix* wet heath (moderate potential GWDTE) and M17 *Scirpus cespitosus – Eriophorum vaginatum* blanket mire habitats. The classifications are in accordance with the National Vegetation Classification (NVC) scheme and are outlined in detail in EIA Report Technical Appendix A6.1.

Of the habitats recorded during the NVC survey, the following potential GWDTE habitats were identified with a 'high' potential groundwater dependency:

- M6 - *Carex echinata–Sphagnum recurvum/auriculatum* mire;
- M16 - *Erica tetralix–Sphagnum compactum* wet heath; and
- CG10 – *Festuca ovina - Agrostis capillaris – Thymus praecox* grassland.

The following potential GWDTE habitats were identified with a 'moderate' potential groundwater dependency:

- M15 - *Scirpus cespitosus–Erica tetralix* wet heath;
- M25 - *Molinia caerulea–Potentilla erecta* mire;
- U5 - *Nardus stricta–Galium saxatile* grassland; and
- S27 – *Carex rostrata – Potentilla palustris* tall herb fen

Two habitats of note were found on site near to the GWDTE water sample locations, which were; *Carex echinata - Sphagnum recurvum* mire (M6) and *Erica tetralix - Sphagnum compactum wet heath* (M16), which were identified as having a high potential GWDTE classification. However, the M6 habitat was found to be thin and linear, running adjacent to a watercourse which indicates its dependant on rainfall/surface water rather than groundwater. The M16 habitat was found in small areas upon thin layers of peat and is associated with flushing telluric water from adjacent deeper peat deposits. Both habitats therefore have a low actual dependency on groundwater.

3.3 Designated sites

The Site lies outside any SSSI, SAC, SPA and Ramsar designated areas.

The eastern edge of the Site lies within a drinking water protected area (DWPA), with the majority of the unnamed watercourse catchment lying approximately 250m to the southeast of the Site, and 450m east of the nearest proposed wind turbine location.

There are multiple borehole records found within 2km of the site boundary. Most appear to be associated with the existing Beinneun Windfarm and a nearby dam construction.

3.4 Land use

A review of historical mapping indicates that the area of the Site and surrounding area has seen no significant land use changes since at least 1888, up until the construction of the existing Beinneun Windfarm and subsequent tracks in 2016.

4 Water chemistry results and associated peat depths

4.1 Water chemistry results

The survey area has been defined as all land within the applicant's boundary (Site boundary). Additionally, a further 250m buffer was applied for the purposes of the GWDTE assessment which may extend beyond the ownership boundary. A total of **41No.** water chemistry sample locations were sampled across the survey area in areas which had previously been identified to have high or moderate potential GWDTE habitats. During the survey, the temperature, pH, electrical conductivity, oxygen reduction potential and total dissolved solids of the water encountered were measured to determine whether there was an outflow of groundwater evident within the sample area. A known surface water control location was also sampled to provide a site specific comparison between different prevailing water chemistries. Refer to water chemistry reading ID:37 for the control reading used for surface waters in this report.

Water from a groundwater source is expected to have some water chemistry results which overlap with both rainwater, surface water and freshwater lakes/rivers, as seen in table 1 below. However, there are some ranges outside of the overlapping results which can indicate the presence of groundwater. Temperature is regularly taken at each sample location, with an expected groundwater range of between 7.38 °C and 12.1 °C (BGS & SEPA, 2015). Moreover, the water chemistry readings are rarely used on their own, with both habitat data, peat depth and geology contributing to the final assessment outcome. Bedrock geology can allow for extremely localised flows of groundwater out into the wider downslope area, as it is predominantly controlled by fracture flow, where an igneous intrusion or fault/fracture zone is present at the surface, within a wider area of metamorphic bedrock.

Table 1: Typical water chemistry result ranges for different water sources (Sanders, 1998)[2]

Water Origin	pH	Electrical Conductivity (mS)	Oxygen Reduction Potential (mV)	Total Dissolved Solids (ppm)
Rainwater	4 - 7	2 - 100	+400 - +600	10
Surface Water	6.5 – 8.5	2 - 100	+300 - +500	10 - 200
Groundwater	6 – 8.5	50 – 50,000	-200 - +100	100 – 50,000
Freshwater Lake/Stream	6.5 – 8.5	2 - 100	+300 - +500	50 - 250
Bog	<5	50 – 50,000	-100 - +100	Variable

During the survey, none of the sample locations gave clear readings indicative of a potential groundwater source. There was a large number of samples falling inside the shared ranges of surface water and rainwater readings. Due to the level of snowmelt on site at the time of survey, due care was given when analysing the results as there is potential for snowmelt to influence some readings. However, no obvious evidence of such influence was found in the water chemistry results. Once water chemistry was considered along with the habitat data, the peat depths at the sample locations and the underlying geology, it was determined that no significant groundwater outflows were present within the survey area, based on the sample locations tested. As such, most of the water present is considered to be either ombrotrophic or telluric in nature.

[2] Sanders, Laura L (1998). A manual of field hydrogeology, Prentice Hall, London: Prentice Hall International, Upper Saddle River, NJ, USA

This is based on;

- all of the measured pH results falling between 4.5 and 6.4,
- all electrical conductivity (mS) results falling between 11 and 60,
- all ORP (mV) results falling between 203-360 and total dissolved solids (ppm) falling between 5-26.

None of the water chemistry results displayed in Appendix C fall into expected clearly groundwater parameters displayed in table 1, suggesting low actual dependency on groundwater at all sample locations. Most ORP results fall slightly below the expected ranges for rainwater and surface water suggesting some telluric input across the site but not groundwater as higher ORP results would tend to be recorded.

4.2 Peat depths

Peat depth and indicated substrate were logged at each targeted moderate or high potential GWDTE peat depth sample location, as shown in Appendix B. The targeted areas were based on the NVC survey results. A handheld GPS was used to ensure survey records were carried out at the correct location. A total of **35No.** targeted survey points were probed across the survey area at a number of potential GWDTE habitats, to further refine the actual GWDTE dependency within these locations. These were used alongside the habitat data collected on site, as deeper peat is associated with telluric water, and is less likely to be associated with potential groundwater. Deeper peat has rainwater move through it at a slower rate which mineralises and alters the groundwater chemistry more than thin peat does. This rainwater-peat interaction can result in a telluric water chemistry profile.

The proposed turbine locations were inferred to be underlain by a mix of shallow peaty soils and deep peat based on peat depth data provided to us. Additional peat depth data was collected at the moderate or high GWDTE habitat areas. The maximum recorded depth being 268cm and the average being 53cm. The client-provided peat depth data indicated a maximum peat depth of 360cm, and an average depth of 58cm, based on a comprehensive third-party peat depth survey.

There were a range of substrates found across the surveyed areas, including bedrock, gravel, sand and clay, with bedrock and sand/gravel being the most common. As gravels and sands can act as moderately productive aquifers, on a local scale, in-situ water chemistry testing was undertaken across the site to indicate whether groundwater was present (see Figure 6.4.1 for locations and Appendix C for peat depth and underlying substrate results). Meanwhile, the clay deposits would be expected to act as a relatively impermeable barrier to groundwater flow due to size, shape and compaction of grains. The bedrock has been assessed as a low productivity aquifer (BGS, 2024), with flow only being through fracture flow, where present. Due to bedrock being indicated at many of the probe locations this would suggest that any surrounding sand and gravel layers would be limited in both thickness and spatial extent, and therefore be very limited as a pathway for significant groundwater flow. If thicker deposits of sands and gravels were present it is possible these could act as shallow aquifers.

The distribution of peat depths taken alongside the GWDTE water chemistry readings can be seen in Table 2 below. All peat depths are shown below in Appendix B and a selection of photos taken during the site visit are included in Appendix A. The number of areas of deep peat encountered on site indicate that there is a large volume of telluric and ombrotrophic water and non-groundwater dependent ecosystems present all year-round. Hence, due to this it is considered that there is a lack of actual GWDTE dependency within these areas.

Table 2: Peat depth distribution (Targeted peat depth probing at potential GWDTE locations)

Peat depth (cm)	Percentage of points (%)
< 10	28.6
10-25	25.7
25-50	11.4
50-100	14.3
> 100	20.0

5 GWDTE assessment

5.1 Potential and actual GWDTE presence

On the day of the GWDTE survey, there were extensive areas of ice and snow present, with snow melt found commonly across the survey area. This additional water within the survey locations may have diluted the groundwater water chemistry readings taken, hence the topography and NVC data has also been used extensively in this assessment. Some buffering of pH may occur due to snow melt which may may have slightly increased any telluric water pH levels which tends to range in pH from 3.5-5. All samples were recorded to have a range from 4.46 – 6.41 so assessed to be rainfall (pH range of 4-7) readings or slightly diluted telluric readings.

Two NVC communities identified during the ecological surveys have the potential to be highly groundwater-dependent (Gavia Environmental 2025). These were long, thin areas of an M17/M6 mosaic (*Carex echinata/Sphagnum recurvum* mire) and an M16 area (wet heath).

As the M16 habitat surrounding ID 14 (Appendix C), and M17/M6 mosaic surrounding ID 39 (Appendix C) are found across elongate, linear areas which run perpendicular to the slope.

ID 14 water chemistry: pH – 5.18, Electrical conductivity – 53mS, ORP – 245mV.

ID 39 water chemistry: pH – 6.03, Electrical conductivity – 53mS, ORP – 53mV.

Significant overland surface water flow was observed in both these areas during the Site survey. Therefore, they were determined to not be groundwater-dependent, hence must be a mix of rainwater/telluric fed sources. Therefore, these have been **assessed to be a low actual dependency GWDTE**.

In addition, some variation of M15 – M25 mosaic habitats which have a moderate potential dependency on groundwater were identified on site then further assessed for their actual groundwater dependency. The following water quality IDs were assessed for an indicator for actual dependency: ID 9, 15, 16, 20, 21, 30, 31, 32, 37 and 38. None of the chemistry readings met the water quality parameters to suggest they are dependent on groundwater. Furthermore, expected thin layers of sands and gravels found at the sample locations would not carry such large volumes of groundwater to create such widespread mosaics with a moderate or high degree of dependency on groundwater. Any water quality parameters which vary from typical ombrotrophic input are assessed as having telluric influence, mainly from water moving through deeper peat close to the sample locations. Therefore, these mosaic habitats have been **assessed to be low actual dependency GWDTEs**, due to the limited input of groundwater that is expected based on-site observations of topography, metamorphic fracture flow, thin or absent superficial transmissive layer and water chemistry readings which suggest ombrotrophic and telluric water origin.

All other areas of the survey area have been determined to have no or low actual dependency on groundwater.

5.2 Further guidance for actual GWDTE avoidance

As ground excavations and construction activities elicit a drawdown effect on groundwater if present near the surface, it is important to determine the distance between the proposed turbine locations and nearest actual GWDTE habitat. As LUPs guidance (SEPA, 2017) indicates that any excavations deeper than 1m have a large drawdown affect, then they must be undertaken at a distance greater than 250m from the nearest actual GWDTE habitat. There are no turbines proposed within a distance of 250m of a GWDTE.

6 Summary

The Site is located in an area of hilly topography characterised by a mix of shallow peaty soil and areas of deep peat habitat. High and moderate potential GWDTE habitats near to the proposed development (**High**: M6, M16, and CG10, **Mod**: M15, M25, S27 and U5) has been assessed as having low actual groundwater dependency due to the following factors which have been verified onsite:

- Thin or absent transmissive superficial layer will result in limited supply to these habitats due to lack of shallow aquifer
- Very thin layer of peaty soil present with deeper peat nearby which can introduce telluric water
- Metamorphic bedrock present which is expected to supply limited volumes of water and only via low rate fracture flow
- Water chemistry readings are in line with ombrotrophic parameters with telluric influence rather than groundwater influence
- The significant volumes of overland flow observed from rainfall and snow melt which helps explain dilution of otherwise telluric water chemistry results.

Through water chemistry testing, it was found that there were no areas with actual groundwater influence located within the survey area based on the samples undertaken (See table 1). This is based on all of the pH results falling between 4.5 and 6.4, all electrical conductivity (mS) results falling between 11 and 60, all ORP (mV) results falling between 203-360 and total dissolved solids (ppm) falling between 5-26. Results that vary from typical ombrotrophic input (See table 1 for range) and almost crossover with expected groundwater chemistry parameters (See table 1 for range) are assessed to have telluric input from water travelling through nearby deep peat within the catchment.

In regards to groundwater in the Site, negligible impacts on any groundwater supply present are expected from the development given the topographic setting and local hydrogeology. Alongside this, the multiple watercourses which are found within the Site should also experience negligible effects providing mitigation measures are adhered to. Pollution prevention measures should be put in place as part of a pollution prevention plan to ensure that both the groundwater and the watercourses are not affected, both at the source and further down the hillside. If unexpected shallow groundwater or fracture flow groundwater is encountered during the wind farm development mitigatory measures to avoid impacting on groundwater flow and/or quality should be put in place such as the avoidance of development or vehicle tracking in such areas. If the habitat can't be avoided for tracking, bog mats, culverts or piped boards (perforated boards) can help avoid impacts on groundwater by managing water flow without significantly altering natural groundwater levels and flow pathways. Decisions made to further avoid any unexpected GWDTE should be based on recommendations of the site ECoW or suitably qualified hydrologist during construction works.

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Appendix A: Site Photographs

Picture 1: An example of an M6 flush habitat which has a high potential GWDTE classification (within a broader area of M17 habitat),

Picture 2: An example of the hilly nature of the topography of the site.

Appendix B: Peat depth data

ID	Easting	Northing	Peat Depth (cm)	Substrate	Potential GWDTE dependency
1	219982	806672	37	Clay	Low
2	219612	806549	78	Bedrock	Low
3	220647	806459	3	Bedrock	Moderate
4	225053	806200	268	Bedrock	Low
5	220551	806134	210	Bedrock	High
6	220149	805774	7	Sand	High
7	225260	805658	12	Sand	Moderate
8	224698	805372	10	Bedrock	High
9	224841	805236	55	Gravel	High
10	224810	805235	7	Gravel	High
11	225266	805208	3	Bedrock	High
12	225395	805191	97	Clay	High
13	219668	805187	11	Bedrock	High
14	225212	805178	119	Sand	High
15	219896	805164	82	Bedrock	Low
16	225159	805160	146	Bedrock	High
17	220124	805028	5	Sand	Moderate
18	225042	805015	26	Sand - hit layer of ice at 15cm	Moderate
19	222550	805013	108	Gravel	Moderate
20	219653	804943	19	Bedrock	Moderate
21	222608	804937	126	Bedrock	High
22	219906	804902	12	Bedrock	Low
23	222768	804706	19	Bedrock	High
24	222761	804694	30	Bedrock	High
25	221773	804576	4	Gravel	High
26	221365	804525	186	Sand	High
27	221568	804524	96	Bedrock	Low
28	221234	804504	31	Gravel	High

ID	Easting	Northing	Peat Depth (cm)	Substrate	Potential GWDTE dependency
29	220264	804476	4	Gravel	High
30	219867	804465	6	Sand	Moderate
31	220891	804429	11	Bedrock	Moderate
32	222205	804346	12	Sand	High
33	220271	804320	9	Bedrock	High
34	220701	804238	14	Bedrock	High
35	220669	804153	18	Sand	High

Appendix C: Water Chemistry Results

ID	Easting	Northing	Water temperature (°C)	pH	Electrical conductivity (µS)	Oxygen reduction potential (mV)	Total dissolved solids (ppm)	Dominant Habitat
1	219982	806673	6.6	5.02	N/A	357	N/A	M15/M25
2	219613	806552	6	5.07	N/A	356	N/A	M6
3	220647	806459	5.5	4.97	N/A	360	N/A	M19
4	224578	806301	4.5	5.76	11	203	6	M15/M25
5	225000	806268	3.3	4.95	29	285	8	M17
6	225053	806200	4.9	5.37	16	262	5	M17
7	220551	806134	6.1	4.85	N/A	359	N/A	M19
8	220362	806031	5.9	5.43	N/A	325	N/A	M1
9	220149	805774	6.1	4.64	N/A	352	N/A	M12/M15
10	225260	805658	1.1	5.16	11	298	5	M17
11	224699	805371	3.5	4.72	22	327	9	M17
12	224810	805236	3.9	5.52	18	278	7	M17
13	224841	805236	2.5	5.41	13	282	6	M17
14	225266	805207	4.7	5.18	53	245	16	M16
15	225395	805188	3.7	4.46	32	329	12	M17/M15
16	219668	805187	5.2	5.24	19	328	6	M15
17	225212	805179	2.2	4.63	21	288	9	M16
18	219896	805164	4.2	4.92	27	327	13	M17
19	225158	805158	3.2	4.47	27	301	11	M16
20	220123	805028	2.4	5.16	34	314	13	M17/M15
21	225042	805015	0.8	5.8	31	222	6	M17/M15
22	222551	805014	5.5	5.56	28	278	16	M17/M15
23	219653	804943	6.1	4.85	23	339	9	M15
24	222608	804937	5.7	5.66	23	288	11	M17/M15
25	219906	804902	4.8	4.96	50	329	24	M15
26	222767	804705	4.5	6.15	32	252	12	M17/M15
27	222761	804694	4.8	6.32	31	236	14	M17/M15
28	222753	804671	5	5.98	40	248	19	M17/M15
29	221772	804575	3	4.96	37	318	14	M15
30	221366	804526	5.8	5.82	31	244	12	M17/M15
31	221570	804523	1.8	4.67	38	330	15	M17/M15
32	221233	804503	4.8	6.03	32	261	12	M17/M15
33	220264	804476	3.7	5.1	60	316	26	M15

ID	Easting	Northing	Water temperature (˚C)	pH	Electrical conductivity (µS)	Oxygen reduction potential (mV)	Total dissolved solids (ppm)	Dominant Habitat
34	219867	804465	6.2	4.87	31	324	12	M25/M6
35	220891	804429	6.7	6.02	31	273	14	M15/M17
36	220859	804424	4.9	5.59	29	296	12	M15/M17
37	222310	804421	5.7	6.28	35	230	16	M25
38	222205	804347	5.4	6.41	25	224	13	M15/M17
39	220272	804319	7.5	6.03	53	279	23	M17/M6
40	220701	804238	4	6.06	27	266	12	M15
41	220669	804152	6.1	4.87	36	321	13	M17
N.B. All cells without a reading are due to a malfunction with one of the water chemistry readers whilst on site, hence the data is not available (N/A).								

Appendix D: Figures

Figure 6.4.1 – Potential GWDTE monitoring points

Beinneun 2 Wind Farm
EIAR Chapter 6: Ecology
Technical Appenix 4

Figure 6.4.1
Potential Groundwater Dependent Terrestrial Habitats (GWDTE) Monitoring Points

Key

- Site Boundary
- 250m Buffer
- Development Footprint

Substrate Results

- Bedrock
- Clay
- Gravel/Sand

N

Scale @ A3: 1:25,000

0 640 1,300 m

GAVIA environmental

Date: 04-08-2025

Prepared By: AB

Reviewed By: SG

Approved By: CB