Technical Appendix 8.5: Groundwater Dependent Terrestrial Ecosystems

Technical Appendix 8.5: Groundwater Dependent Terrestrial Ecosystems (GWDTEs)

1.1 Introduction

1.1.1 This Technical Appendix provides a summary of Groundwater Terrestrial Ecosystems (GWDTEs) within the context of the Proposed Development. This Technical Appendix provides a description of geological and hydrogeological conditions underlying the Site. Characterisation of the potential GWDTEs identified within the Site takes into account National Vegetation Classification (NVC) surveying carried out by MacArthur Green in September 2023, and hydrological surveying carried out by Ramboll in April 2024. Hydrogeological assessment of the identified potential GWDTEs is provided with associated mapping.

1.1.2 This TA is supported by the following:

- Figure 8.4: Superficial Geology;
- Figure 8.3: Bedrock Geology;
- Figure 8.6: Carbon and Peatland Soils;
- Figure 8.5.1: Hydrogeology;
- Figure 8.5.2: NVC GWDTE Classification; and
- Figure 8.5.3: Ramboll GWDTE Assessment.

1.1.3 Excavation of soil and bedrock during the construction phase of the Proposed Development may cause localised disruption and interruption to groundwater flow. Interruption of groundwater flow would potentially reduce the supply of groundwater to GWDTEs thereby causing an alteration/ change in the quality and/ or quantity of and/ or the physical or biological characteristics of the GWDTE. Contamination of groundwater may also cause physical or chemical contamination to the GWDTE.

1.1.4 Following identification of potential GWDTEs from NVC mapping data, the hydrological and hydrogeological desktop study information has been used to help qualitatively determine the potential sensitivity of each potential GWDTE, together with subsequent further site reconnaissance carried out by Ramboll.

1.1.5 Further details with regard to each GWDTE identified are provided below. The sensitivity of each of the GWDTE receptors has been classed based upon classifications provided within SEPA's guidance LUPS31[1].

1.2 Geology

Superficial Geology

1.2.1 According to the British Geological Survey's (BGS) 'Geology Viewer' website (1:625,000), the superficial deposits (**Figure 8.4, EIAR Volume 3a**) underlying the Site predominantly comprise Devensian Till (Diamicton) with alluvium, gravel, sands and silts mapped along the River Clyde and burns. Peat is shown mapped in the central part of the Site to the west of White Rig. Areas of glaciofluvial sands and gravels are also shown to the south of Mill Burn in the northern part of the Site, and in smaller areas across the Site. The higher parts of the Site are shown as unmapped indicating that there are potentially no superficial deposits present.

1.2.2 There are extant and disused quarries present at the Site which are understood to been used for both rock and sand and gravel extraction, and quarry operations were observed to be in operation during hydrological surveying. Areas of re-instated ground were observed on the site adjacent to areas on which current quarrying operations are being carried out.

Bedrock Geology

1.2.3 The underlying bedrock (**Figure 8.3, EIAR Volume 3a**) across most of the western part of the Site is mapped as the Auchtitench Sandstone Formation, comprising volcaniclastic conglomerate. The central part of the Site is mapped as the Marchburn Formation, comprising wackes, and the eastern part of the Site is mapped as the Kirkcolm Formation, again comprising wackes.

Soils and Peat

1.2.4 A review of the SNH Carbon Rich Soil and Deep Peat and Peatlands Habitat Map (2016)[2], confirms that areas of peat and organic material are anticipated to be present across the western parts of the Site. Most of the peat is classified as Class 3 or Class 5, however, there is a large area of Class 1 peat indicated to be located in the area to the south of the B7078 road ('nationally important carbon rich soils, deep peat and priority peatland habitat') coinciding with the Red Moss SSSI/SAC. The majority of the western part of the Site is shown as comprising Class 3 peat with smaller areas of Class 5. The eastern part of the Site is shown as comprising mineral soils.

1.2.5 Findings of detailed peat surveying and assessment of potential impacts on underlying peat resources are provided in **Technical Appendix 8.1: Peat Depth Survey Results (EIAR Volume 4)**.

Groundwater Bodies

1.2.6 According to BGS 1:625,000 hydrogeological mapping (Figure 8.5.1 of this Technical Appendix), the northern area of the Site (forming approximately 40% of the total Site area) is underlain by an aquifer of the Lanark Group which is classified by the BGS as a Moderately productive aquifer. The south of the Site is underlain by an aquifer of the Kirkcolm Formation which is classified by the BGS as a Low productivity aquifer. While groundwater may be present within isolated areas of glacial or alluvial deposits, areas of Till (diamicton) and areas where no superficial deposits are recorded likely to be of very limited productivity.

1.3 National Vegetation Classification

1.3.1 A number of potential Highly and Moderately GWDTE were identified after NVC surveys, conducted by MacArthur Green in September 2023. SEPA classification is modified from the UKTAG (2008)[3] list of NVC communities and associated groundwater dependency scores.

1.3.2 Figure 8.5.2 (of this Technical Appendix) shows NVC communities identified through ecological surveying and confirms which are considered to have the potential to be of 'Moderate' or 'High' potential of groundwater dependency; and which have therefore been assessed further within this report. Details of vegetation communities identified on the site are set out in Chapter 6: Ecology and associated Technical Appendices.

1.3.3 Hydrological and hydrogeological desktop study information, as well as Site-specific conditions informed by surveying carried out by Ramboll in April 2024 have been used to qualitatively determine the sensitivity of potentially groundwater dependant habitats (Figure 8.5.3 of this Technical Appendix).

[1] Land Use Planning System SEPA Guidance Note 31Guidance on Assessing the Impacts of Development Proposals on Groundwater Abstractions and Groundwater Dependent Terrestrial Ecosystems, V3 2017. Available online: LUPS31. [accessed 05/2024]

[2] SNH Carbon and peatland 2016 map: https://soils.environment.gov.scot/maps/thematic-maps/carbon-and-peatland-2016-map /

[3] UK Technical Advisory Group on the Water Framework Directive, 2012 Technical Report on GWDTE threshold values.

1.3.4 The assessment includes consideration of:

- the direct hydrological connection of a potential GWDTE to surface water sources;
- underlying geological conditions including the productivity of bedrock and superficial geology, the presence of peat soils and permeability of upgradient geology;
- topography and the presence of rills or runnels indicative of surface runoff;
- the presence of indicative 'flush' patterns of vegetation communities;
- land use; and
- the relative proportion of NVC communities and the potential dominance of non-GWDTE communities within surveyed areas.

1.3.5 Surface water flow accumulation across the Site has been assessed through the use of ArcMap Hydrology tools, based on 1 m Digital Terrain Modelling (DTM) obtained from SEPA. Analysis of flow conditions across the terrain surface was used to determine likely overland flow paths that receive and convey surface water flows from a cumulative upslope catchment of 1000 m² or greater, in order to provide assessment in line with ground observations of flow paths, aerial imagery and OS mapping of watercourses. This was compared to areas of vegetation identified as potential GWDTE to determine areas where surface water supplies are likely to contribute a significant proportion of water supplies to vegetation communities (i.e. indicating areas are less likely to be dependent on groundwater supplies).

1.3.6 Due to the extent of areas assessed as potentially groundwater dependent, hydrological and hydrogeological assessment has been provided below in Table 8.5.1 for areas across the Site. Where more detailed assessment has been provided for specific locations, these are referenced by the polygon ID assigned during ecological surveying.

Table 8.5.1: Potential GWDTE Locations: Hydrological and Hydrogeological Assessment					
Setting			**Hydrological Assessment of Groundwater Dependency**		
Land Package	**Hydrology**	**Hydrogeology**	**Highly Dominant**	**Highly Sub-Dominant**	**Moderate Dominant**
Area 1 - The largest, most northerly land parcel, crossed from northwest to southeast by the M74. South boundary formed by the B7078. Turbines 1-9, 10-16 and 21	A watershed runs from Outer Law at the north-western boundary of the area to White Rig, Little Hill and Netherton Farm in the southeast. To the north of this watershed, tributaries of the Mill Burn (East Thirstone Burn and Woolly Sike) flow to the north. In the southern portion, tributaries of Black Burn (Wildshaw Burn, West Thirstone Burn) flow in a generally southerly direction towards Black Burn.	Bedrock geology: Marchburn Formation - Wacke; Auchtitench Sandstone Formation - Volcaniclastic-Conglomerate; very limited areas (<5% total area) Duneaton Volcanic Formation - Basaltic-Andesite and Auchtitench Sandstone Formation - Sandstone Superficial Geology: Predominantly Till - diamicton; small areas of Peat - Peat, Alluvial Deposits, and Glaciofluvial Deposits - Sand and Gravel. Hydrogeology (BGS 1:625,000): Moderately productive aquifer. Southeast, Low productivity	North of M74 Potential 'High' GWDTE adjacent to Mill Burn and in an area of drains and surface water accumulation (flowing towards Mill Burn). ***Non GWDTE***. Further areas in the north are adjacent to tributaries and associated overland flow paths from upslope areas. ***Non GWDTE***. J233 - no clear source of SW accumulation. Linear feature between T8 and T9, cross slope M6c "Acid neutral Flush". No source of groundwater emergence was observed at this location and the area is in connection to other rain-fed habitats. ***Moderate GWDTE*** J272, J280 marshy grassland (M23) distributed area not consistent with flush. ***Non GWDTE***. South of M74 Predominantly correspond with areas of surface water accumulation. ***Non GWDTE.*** E279 - A spring is present in the most south easterly area, downslope of which is an area of non-GWDTE habitat and a small, isolated areas of M23 (Marsh/Marshy Grassland). An historical 'reservoir' is present at this location and groundwater emergence was observed. ***High GWDTE***	Correlate with areas of lower lying areas in connection to watercourses and areas of surface water accumulation. ***Non GWDTE*** A central area (J236) is an upslope area crossed by several flow paths (although does not correspond to obvious topographic feature). Upland area not characteristic of surface water emergence. ***Non GWDTE***.	Characterised by vegetation communities of Wet Modified Bog, Marsh/Marshy Grassland and Unimproved Acid grassland. Distribution of these areas is not characteristic of areas of groundwater emergence (at changes in slope gradient or isolated flush locations, with areas crossing water shedding upslope areas). Distribution of these vegetation communities is indicative of rainfed vegetation communities**.** ***Non GWDTE***
Area 2 - South westerly land parcel, to south of B7078. B740 eastern boundary. Turbines 17-19	Drains in a generally southerly direction towards the Black Burn which forms the southern boundary of the area. Wildshaw burn and West Thirstone Burn flow in a generally southerly direction across the centre of the area towards Black Burn.	Bedrock geology: Auchtitench Sandstone Formation - Volcaniclastic-Conglomerate; very limited area in southeast Duneaton Volcanic Formation - Basaltic-Andesite Superficial Geology: Predominantly Till - diamicton; areas of Peat - Peat and Alluvial Deposits. Hydrogeology (BGS 1:625,000): Moderately productive aquifer.	All areas correspond with the pattern of surface water flow accumulation. High NVC GWDTE areas are in connection with watercourses and flow paths identified through topographic assessment. Aerial imagery shows the presence of cut drains to the east of West Thirstone Burn with which High NVC GWDTE vegetation communities are associated and the presence of surface water flow paths from the east. ***Non GWDTE.***	Correlate with areas of lower lying areas in connection to watercourses and areas of surface water accumulation. ***Non GWDTE***	Limited areas generally associated with Highly Dominant and Highly Non-dominant areas. Distribution of these vegetation communities is indicative of rainfed vegetation communities. ***Non GWDTE***
Area 3 - Land south of the B7078 bound to the west by the B740 and to the east by Duneaton Water. Turbines 20 and 22, Solar panel array in east	The ridge of Black Hill bisects the area from northwest to southeast. Approximately 50% of the area in the south drains to Black Burn and two small unnamed tributaries of the Black Burn are present in the west of the area. The remainder of the site drains to the north and east, a drain is located at the north boundary of the parcel - and a further land drain flows from the east.	Bedrock geology: Marchburn Formation - Wacke; Kirkholm Formation - Wacke; limited seam of Auchtitench Sandstone Formation - Sandstone Superficial Geology: Predominantly Till - diamicton; small areas of Glaciofluvial Deposits - Sand and Gravel. Hydrogeology (BGS 1:625,000): Low productivity	Areas in the west and south of the site are adjacent to watercourses or located on lower-lying ground close to watercourses, characterised by surface water accumulation. ***Non GWTE*** E534, E539, E491, E492, E488, E474, E484, E483, E469, E371, E482, E371, E474, E468, E467, E461, E460 Areas to the northeast of Black Hill are associated with lower slopes of the hill as slope gradients decrease. There is the potential for a combination of surface water runoff and groundwater emergence to support these habitats. Based on the Low productivity of the underlying aquifer and the pattern of surface water runoff from upslope areas, surface water runoff would represent a significant proportion of water supply to these habitats. These areas are characterised by Marsh/Marshy Grassland found widely both locally and regionally, and which are presently grazed land.	One very limited area (<5% total area) present at the north-eastern extent of the area. On lower-lying area in connection to Duneaton Water***. Non GWDTE***	Pattern of distribution not indicative of flush communities. Terrain modelling suggests some small hillside depressions on the south of Black Hill that could be indicative of groundwater emergence, upslope of GWDTE areas (E422, E438, E434, E433, E436). Not all Moderately Dominant areas are downslope of such features. Based on the Low productivity of the underlying aquifer and the pattern of surface water runoff from upslope areas, surface water runoff is likely to represent the dominant water supply to these habitats. These areas are characterised by Unimproved Acid Grassland/Marsh/Marshy Grassland Mosaic found widely both locally and regionally, and which are presently grazed land. ***Moderate GWDTE*** *Not surveyed, not within area of proposed development and no development proposed in the potential zone of contribution.*

Table 8.5.1: Potential GWDTE Locations: Hydrological and Hydrogeological Assessment					
Setting			**Hydrological Assessment of Groundwater Dependency**		
Land Package	**Hydrology**	**Hydrogeology**	**Highly Dominant**	**Highly Sub-Dominant**	**Moderate Dominant**
			Emergence of groundwater was observed at a break in gradient of the slope at the upper extent of potential GWDTE areas. Areas of NVC GWDTE communities are distributed across the slope and are characterised by water accumulation on slopes with lower gradient (i.e. characteristic of water supply from shallow groundwater from soils and surface water accumulation, not emergence of groundwater from the underlying geology). Drain cutting was observed across these areas and there is a significant catchment above these areas from which surface water runoff would occur. ***Moderate GWDTE***		
Area 4 - eastern parcels, east and south of Duneaton water and to the west of the River Clyde Main area of solar panel arrays	Land slopes in a generally easterly direction towards the River Clyde. River Clyde at eastern boundary.	Bedrock geology: Kirkholm Formation - Wacke; Very limited seam of Auchtitench Sandstone Formation - Sandstone Superficial Geology: Predominantly Till - diamicton; small areas of alluvium adjacent to River Clyde. Hydrogeology (BGS 1:625,000): Low productivity	Two small areas present at the northern extent of the land parcels, associated with surface water accumulation. ***Non GWDTE***	Small area in southwest associated with surface water flow paths from upslope areas. ***Non GWDTE*** Small area in northwest (<5% total area) indicative of localised surface water accumulation. ***Non GWDTE*** One area in north located centrally between M74 and River Clyde, associated with surface water flow paths. ***Non GWDTE***	Potential GWDTE habitats in the south of the site are distributed across upland, water shedding areas and slopes of Craighead Hill. There are no features suggestive of groundwater emergence at this location. ***Non GWDTE*** Vegetation communities in the north area are in connection to upslope pathways of surface water runoff and there are no features suggestive of groundwater emergence at this location. ***Non GWDTE*** In the northeast LiDAR terrain data indicates an undulating surface and grazed land in this area includes grazed grassland. ***Non GWDTE***

1.3.7 Table 8.5.2 summarises the species present in the areas of high GWDTE potential and the likely degree of dependency on the underlying groundwater body, according to Site specific hydrological conditions (Figure 8.5.3 of this Technical Appendix).

Table 8.5.2: Ramboll Groundwater Dependency Assessment

Polygon ID	Habitat Description	NVC Communities	%	Ecological Assessment	Hydrological Assessment	Shape Area
J233	Acid Neutral Flush	M6c	100	Highly Dominant	Moderate	7800.23
E371	Marsh/Marshy Grassland	M23a/M25a/U4b	60/25 /15	Highly Dominant	Moderate	30908.76
E422	Unimproved Acid Grassland/Marsh/Marshy Grassland Mosaic	U5/M25a/ M25b	40/40 /20	Moderately Dominant	Moderate	98025.09
E433	Unimproved Acid Grassland/Marsh/Marshy Grassland Mosaic	Je/U5	60/40	Moderately Dominant	Moderate	1485.27
E434	Wet Dwarf Shrub Heath	M15b	100	Moderately Dominant	Moderate	1323.65
E436	Unimproved Acid Grassland/Marsh/Marshy Grassland Mosaic	U4/Je	50/50	Moderately Dominant	Moderate	2632.56
E437	Marsh/Marshy Grassland	Je	100	Moderately Dominant	Moderate	742.21
E438	Marsh/Marshy Grassland	Je	100	Moderately Dominant	Moderate	255.05
E460	Marsh/Marshy Grassland	M23a	100	Highly Dominant	Moderate	1431.42
E461	Marsh/Marshy Grassland	M23a	100	Highly Dominant	Moderate	2448.72
E467	Marsh/Marshy Grassland	M23a	100	Highly Dominant	Moderate	1606.73
E468	Marsh/Marshy Grassland	M23a	100	Highly Dominant	Moderate	2523.44
E469	Marsh/Marshy Grassland	M23b/M23a	70/30	Highly Dominant	Moderate	7537.03
E482	Marsh/Marshy Grassland	M23a/M25a/U4b	60/25 /15	Highly Dominant	Moderate	3774.28
E474	Marsh/Marshy Grassland	M25a/M23a/M6d	45/30 /25	Highly Dominant	Moderate	77937.20
E483	Marsh/Marshy Grassland	M23b	100	Highly Dominant	Moderate	1452.79
E488	Marsh/Marshy Grassland	M23a	100	Highly Dominant	Moderate	2259.57
E491	Acid Neutral Flush	M6d	100	Highly Dominant	Moderate	3084.18
E492	Acid Neutral Flush	M6d	100	Highly Dominant	Moderate	420.71
E534	Marsh/Marshy Grassland /Acid Neutral Flush Mosaic	M6d/Ja/M25a/M 23a	40/35 /15 /10	Highly Dominant	Moderate	52815.78
E539	Marsh/Marshy Grassland	M23b	100	Highly Dominant	Moderate	2397.45
E484	Marsh/Marshy Grassland	M23a	100	Highly Dominant	Moderate	5377.10

1.3.8 The locations of potentially groundwater dependent habitats have been considered in the design layout for the Proposed Development and avoided where possible. As a result, the majority of areas that were classified as potentially groundwater dependent are not directly impacted or in hydraulic continuity with proposed Site infrastructure.

1.3.9 Therefore, there are only very limited areas where the Proposed Development could directly impact on potential GWDTE habitats:

- a proposed access track to the east of Black Hill and proposed solar panels to the east of this track are situated on areas assessed to be moderately dependent on groundwater. Shallow groundwater emergence was observed at a location upslope of the track (approximately 200 m west) from where flows are conveyed above ground, including via cut drainage channels across areas characterised by NVC GWDTE habitats. Under current conditions surface water flows are to the east across the route of the proposed track. An area of Marsh/Marshy Grassland extends towards Duneaton Water (observed to be a surface water flow path).
- The access track to Turbine 22 crosses a very small area of Marsh/Marshy Grassland /Acid Neutral Flush Mosaic and Turbine 22 is located upslope of this vegetation community.

1.3.10 There is the potential for an indirect impact on GWDTE as a result of a proposed borrow pit search area and access track upslope of GWDTE Polygon ID E491 (M6d Acid Neutral Flush), which is located to the north of T22. Aerial imagery records a network of cut drainage channels in the area of these vegetation and this was observed during the hydrology site walkover. Upslope groundwater emergence was not observed at these locations during the site walkover and shallow depressions on the proposed borrow pit search area appeared to be small, disused quarries.

1.4 Mitigation and Further Assessment

1.4.1 A number of High and Moderate GWDTE areas (as defined based on NVC communities classification and SEPA guidance) have been identified through ecological assessment of the Site. However, site-specific hydrogeological and hydrological assessment shows that the majority of these areas are not dependent on groundwater supplies. Therefore, further mitigation or assessment of impact on groundwater supplies in these areas is not required.

1.4.2 Direct habitat loss of areas identified as potentially groundwater dependent are limited to small areas which are assessed to be of moderate groundwater dependency, based on Site-specific hydrological and hydrogeological assessment.

1.4.3 At these locations, areas of NVC GWDTE communities are distributed across wide areas characterised by water accumulation on slopes with lower gradient (i.e. characteristic of water supply from shallow groundwater from soils and surface water accumulation, not emergence of groundwater from the underlying geology or 'flush' habitats). Drain cutting was observed across these areas and there is a significant catchment above these areas from which surface water runoff would occur.

1.4.4 At the location where an access track to the solar array to the east of Black Hill is proposed, cross drainage would ensure that water supply was maintained from upslope areas to areas of habitats on lower areas nearer Duneaton Water, to the east of the track.

1.4.5 In order to ensure that water supplies are maintained to the area downslope of Turbine 22, cross drainage and surface water drainage features would ensure that clean runoff would be directed to the lower side of the turbine hardstand. The drainage of the hardstand would also ensure that any shallow groundwater emerging from the cut slope at the upper side of the level hardstand would be directed to downslope habitats.

1.4.6 Borrow pits would be situated within the proposed search areas to avoid more sensitive habitats, as far as practicable. Upslope cut off drains would ensure that clean surface water runoff would be directed around borrow pit locations. Any runoff from the worked area of borrow pits would flow to suitable SUDS measures that allow settlement of sediments before distribution to downstream vegetated areas. Therefore, water supply would be maintained to vegetation communities E491 and E492 (M6d Acid

Neutral Flush at Borrow Pit Search Area 5)) during construction and operation preventing loss in water quality supply or desiccation of these habitats.

1.4.7 It is noted that the locations assessed are in connection with habitats present across the wider Site that would be reliant on the continued supply of surface water runoff. As such, it is considered that the maintenance of quality and quantity in surface water distribution across these areas will be important. Suitable drainage and surface water measures would be used to maintain hydrological connectivity in peatland and wetland habitats and prevent deleterious impacts on surface water distribution, which would be addressed in a CEMP for the Site to be developed by the contractor. Best practice measures would include the following:

- avoidance of direct impact by construction activity in such areas;
- implementation of Sustainable Drainage System (SuDS) measures to maintain quality of water supply;
- maintenance of flow paths/ redistribution of water where diverted; and
- implementation of pollution prevention and control measures.