SUMMARY

Mainstream Renewable Power are in the process of seeking environmental consent for the planned Neart na Gaoithe Offshore Wind Farm site location in the Firth of Forth, North Sea. The proposals for the wind farm include 2No. subsea transmission cables, which landfall at Thorntonloch beach, approximately 6km south of Dunbar, Scotland.

The intention is that the landfall of the transmission cables will be constructed by means of Horizontal Directional Drilling. The intended landfall cable route corridor is bounded to the north by Thorntonloch Holiday Park and B&B and to the south by Thornly Farm.

This report provides an assessment of the potential impact of groundbourne vibration resulting from the horizontal directional drilling. A number of leading companies and relevant bodies have been contacted for the preparation of this document.

A reputable contractor, experienced in the installation of landfalls and the control of vibrations to current standards should be selected to complete the proposed works.

Based on currently available information no significant impact of vibration is envisaged and there should be no need for mitigation measures or vibration monitoring. However, it is recommended that this assessment should be revised in the event that the intended location of the HDD is moved significantly.

1. INTRODUCTION

Mainstream Renewable Power (MRP) are in the process of seeking environmental consent for the planned Neart na Gaoithe Offshore Wind Farm site (NNG) location in the Firth of Forth, North Sea. The proposals for the wind farm include 2No. subsea transmission cables, which landfall at Thorntonloch beach, approximately 6km south of Dunbar, Scotland.

The intention is that the landfall of the transmission cables will be constructed by means of Horizontal Directional Drilling (HDD). The onshore cable route will connect with a substation located approximately 2km east of the Aikengall onshore wind farm site. The intended landfall cable route corridor is bounded to the north by Thorntonloch Holiday Park and B&B and to the south by Thornly Farm, as indicated in Drawing C292 T02- D01 Landing Site Location Plan. At the time of this report the exact location of the transition pit for the connection between the offshore and onshore cables is unknown.

As the landing site for the transmission cable is in the vicinity of potential receptors, MRP wish to determine the potential environmental impact of the intended installation method i.e. HDD with regard to vibration, particularly any vibration impact on the surrounding caravan park, B&B and farm. Cathie Associates have been commissioned to undertake a high-level assessment of the potential impact of groundbourne vibration on the surrounding area.

The main objectives of this report are listed as follows:

- Determine the geological setting of the cable landing site on the foreshore at Thorntonloch, taking account of both onshore and offshore geological characteristics.
- Undertake consultations with the HDD industry with regard to potential vibration effects of HDD techniques.
- Determine potential environmental impact on the surrounding area with regard to vibration resulting from HDD activities.
- Recommend potential environmental mitigation measures, if required.

2. LANDING SITE DATA REVIEW

2.1 Cable Landing Site Description

The intended landing site of the 2No. subsea transmission cables is Thorntonloch beach, approximately 6km south of Dunbar, Scotland.

The intended landfall cable route corridor is bounded to the north by Thorntonloch Holiday Park and B&B and to the south by Thornly Farm, as indicated in Drawing C292 T02- D01 Landing Site Location Plan.

Immediately to the north of the landing site lies the estuary for the Thronton Burn, which is crossed inland by the onshore cable route. The foreshore area comprises of a gently sloping sandy beach stretching for approximately 200m from the raised sand dunes to the mean low water springs mark. Bedrock is noted to outcrop at the surface both to the north and to the south of Throntonloch beach.

2.2 Geological Mapping Summary

2.2.1 Superficial Sediment Coverage

BGS mapping of the sea bed sediments [Ref 1] denotes thin patchy sediments in the area offshore of the landing site with a prevalence of bedrock outcropping at the surface. Further offshore, the sediments are suggested to mainly comprise of gravelly sands [Ref 2].

The foreshore comprises of marine beach deposits, whilst inland raised marine deposits of Flandrian age dominate, as indicated in Drawing C292 T02–D02 Superficial Deposits. Further inland along the onshore cable route corridor superficial sediments of alluvium and glaciofluvial deposits dominate. Available borehole records (see section 2.2.3) do not provide detailed information on the composition of these superficial sediments.

2.2.2 Quaternary Deposits

BGS mapping of the quaternary deposits indicates an erosional and/or non-depositional hiatus in the area offshore from the landing site in keeping with other mapping showing bedrock outcropping at the surface.

As indicated in Drawing C292 T02–D02, a former coastline has been identified approximately 50 to 100m inland of the present coastline, along with a wider estuary mouth for the Thornton Burn. Glacial meltwater channels have been identified both to the north and to the south of the landfall cable route corridor. However no detailed information is currently available regarding the composition of the glacial meltwater channels.

Approximately 750m to the north of the landing site a normal (inferred) fault is noted to trend in an east-west direction (also present in the solid geology).

2.2.3 Solid Geology

As indicated in Drawing C292 T02-D03 Solid Geology, the solid geology of the landfall cable route is dominated by rocks of the Ballagan (Carboniferous) Formation, which are suggested to comprise mainly of shale and cementstone lithologies [Ref 4].

A more detailed description of the Ballagan Formation provided by the BGS [Ref 5] is given as mudstones and siltstones, with nodules and beds of ferroan dolomite (cementstones), the beds are generally less than 0.3m thick. Desiccation cracks are common and the rocks commonly show evidence of brecciation during diagenesis.

This description is generally in keeping with two borehole logs, which have been obtained from the BGS and are included in Appendix B. Borehole 13 is located approximately 500m to the north west of the intended landing site, whilst Borehole 9 is located approximately 1km to the south. The borehole logs show shallow bedrock (friable sandstones, mudstones, siltstones) at approximately 2.7m below ground level (4.2mOD) to the north of Thorntonloch beach and at 8.5m below ground level (103.5mOD) to the south. It is also noted that coal lenses are recorded in both borehole logs at depths of 20m (BH 13) and 10.7m (BH 9) below ground level.

3. LANDING SITE CABLE INSTALLATION REVIEW

3.1 HDD Methodology

HDD is an alternative technique to traditional open trenching methods for the installation of cables (and pipes or ducts) underground. HDD offers the advantage of avoiding disturbance to surface structures and has become a routine construction technique for sensitive sites.

The technique involves drilling a pilot bore from a launch pit on one side of the planned installation to an exit pit on the other. The position, depth, pitch and roll of the drill head is monitored using a transmitter device, and adjusted as necessary to maintain the planned course of the installation. Once complete, the pilot drill head is removed from the drill string and replaced with an appropriate hole opening device which is pulled back through the bore to increase the hole diameter. Once the hole diameter has been increased sufficiently, the cable is attached by means of a swivel and towing head and installed as the drill string is retracted.

3.2 Construction Vibration Studies

Construction activity can result in varying amounts of groundbourne vibration, depending on the type of plant used, the methods employed and the ground conditions encountered. Operation of HDD equipment will cause groundbourne vibrations, which spread through the ground and diminish in intensity with distance. Structures founded in the vicinity of HDD can respond to this technique to varying degrees, ranging from no perceptible effects at the lowest levels to slight damage at the highest levels, although such high level cases are noted to be rare, located directly above the path of the HDD route and triggered by excessive settlement.

Several key guidance documents have been published in the UK concerning levels of construction vibration including but not limited to:

- BS 6472 Evaluation of human exposure to vibration in buildings
- BS 7385 Evaluation and measurement for vibration in buildings: Guide to damage from groundbourne vibration
- TRL Report 429 Groundbourne vibration caused by mechanised construction works

A consultation into the impacts of HDD related vibrations has been undertaken and preliminary findings suggest that there are currently no nationally agreed limits specifically pertaining to HDD operations. The following companies and relevant bodies have been contacted with initial feedback indicating that no relevant research has been carried out on this subject to date:

- UK Society for Trenchless Technology
- LMR Drilling UK Ltd
- JMH Directional Drilling
- Drilline Products

The consultation highlighted the importance of site specific data with particular emphasis placed on:

- The strength of rock/soil
- Depth of drilling
- Size of bore
- Presence of ground water

Notwithstanding the lack of site specific data, the distances involved were suggested by the firms to be sufficiently great so as to avoid problems with groundbourne vibration due to the proposed HDD activities. Furthermore, JMH Directional Drilling cited previous experience of directional drilling beneath caravan parks and in the vicinity of caravans.

3.3 Vibration Assessment

In the absence of specific guidelines relating to vibration levels from HDD drilling, the following assessment has been based on the construction vibration guideline documents listed in section 3.2.

Vibration is measured in peak particle velocity (ppv) units, measured in mm/sec. Values of peak particle velocity associated with cosmetic damage in buildings are presented in British Standard BS 7385-Part 2, table 1 [Ref 6]. This table (reproduced overleaf) shows that the ppv (mm/sec) limit for unreinforced or light framed structures is in the order of 15mm/sec.

Transport Research Laboratory (TRL) Report 429 [Ref 7] contains information regarding vibration magnitudes associated with large tunnelling projects (tunnel boring machines and tunnels constructed with blasting). This information deals with tunnelling projects with significant tunnel diameters and provides reasonable data on upper bound levels of vibration expected from large scale tunnelling. Peak particle velocity values are logarithmically proportional to the distance from the vibration source in tunnelling projects. This fact is well documented in Figure 46 of the TRL report, reproduced in Figure 1.

Table 1: BS 7385-Part 2, Table 1 – Transient vibration guide values for cosmetic damage

Line (see Figure 1)	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commerical type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

NOTE 1 Values referred to are at the base of the building (see **6.3**).

NOTE 2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

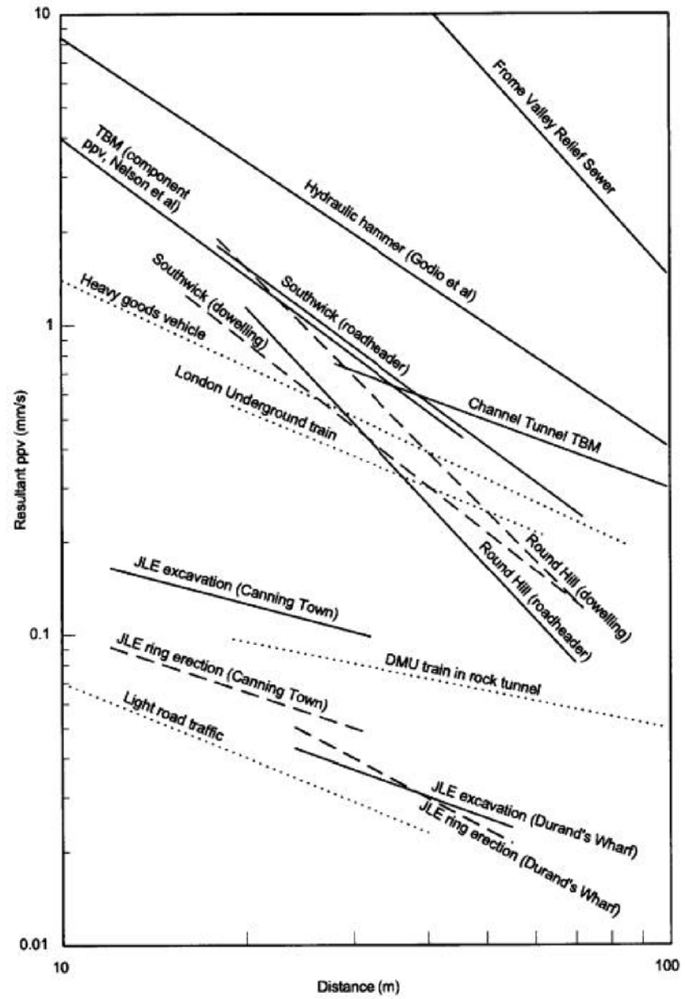


Figure 1: TRL 429 Figure 46b Upper-bound lines for blasting data from the Frome Valley sewer compared with those for various operations

The present project is of a much smaller scale and the proposed diameter is likely to be an order of magnitude smaller than some of the tunnels in Figure 1, however this information could be used to anticipate extreme upper bound levels of vibration expected in the vicinity of the site.

The closest receptor to the assumed section of directional drilling required for this project is the southern extent of the Thorntonloch Caravan Park situated approximately 70m to the

north west of the likely position of the launching pit for the directional drilling section. Based on the data presented in TRL 429 regarding the Jubilee Line Extension (JLE in Figure 1), constructed with a large tunnel boring machine, vibrations not exceeding 0.1mm/sec are expected at distances in excess of 70m. Based on table 1 from BS 7385, this level of vibration is considered negligible with regards to risk to structures (Table 1).

Thresholds for human perception of vibration below which 'adverse comments or complaints of vibration are rare' are defined in BS 6472 [Ref 8], and are dependent upon the position of the person i.e. standing, sitting or lying down. In the most sensitive case (standing) this threshold is defined as 0.141mm/sec between 8Hz and 80Hz (the threshold is higher at lower frequencies). This threshold is well above the levels which a large tunnelling boring machine project such as the JLE would generate at 70m from the source. Based on the much smaller nature of the works planned and the values available in the existing literature, vibrations associated with the HDD works proposed are anticipated to be negligible.

3.4 Mitigation of Construction Vibration

Based on the assessment of vibration from tunneling presented above, it is proposed that mitigation measures and vibration monitoring are not be required for the HDD operations.

Operation of the plant at surface should be carried out in accordance with British Standard BS 5228:2009 [Ref 9].

4. CONCLUSIONS AND RECOMMENDATIONS

Currently there appears to be no studies relating to the impacts of vibration from horizontal directional drilling. Several leading HDD companies and relevant bodies have been consulted; at the time of writing there is no evidence of relevant technical literature discussing effects of vibration associated with HDD projects.

Based on existing UK guidelines and vibration data gathered for significant tunnelling projects, the proposed HDD activities are deemed to be of sufficient distance from potential receptors that significant disturbance should be safely avoided, negating the need for mitigation measures or vibration monitoring.

A reputable contractor, experienced in the installation of landfalls and the control of vibrations to current standards should be selected to complete the proposed works.

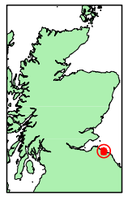
It is recommended that this assessment should be revised in the event that the intended location of the HDD is moved significantly.

5. REFERENCES

1. BGS (1986). Tay Forth Sea Bed Sediments, 1:250 000.
2. BGS (1994). United Kingdom Offshore Regional Report - The Geology of the Central North Sea, HMSO, London.
3. BGS (1987). Tay Forth Quaternary Geology, 1:250 000.
4. BGS (1986). Tay Forth Solid Geology, 1:250 000.
5. BGS (2012). http://data.bgs.ac.uk/doc/Lexicon/NamedRockUnit/BGN.html, accessed September 2012.
6. British Standards Institute (1993). BS 7385:1993 Evaluation and measurement for vibration in buildings: Guide to damage from groundbourne vibration.
7. Transport Research Laboratory (2000). TRL Report 429 Groundbourne vibration caused by mechanised construction works.
8. British Standards Institute (1992). BS 6472:1992 Evaluation of human exposure to vibration in buildings.
9. British Standards Institute (2009). BS 5228:2009 Code of practice for noise and vibration control on construction and open sites- Part 2: Vibration.

Appendix A : Drawings

Location Map



Scale/Projection

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Meters

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Projection: Transverse Mercator
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False Northing: -100,000.0000
Central Meridian: -2.0000
Scale Factor: 0.9996
Latitude Of Origin: 49.0000
Units: Meter

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Legend

Cable Route Corridor

Revision Status

Rev	Date	Details of Changes	Drawn	Check
01	03/09/12	First Issue	PSL	CMI

CATHIE ASSOCIATES

MAINSTREAM RENEWABLE POWER

Project Title

Neart na Gaoithe Offshore Wind Farm

Report Title

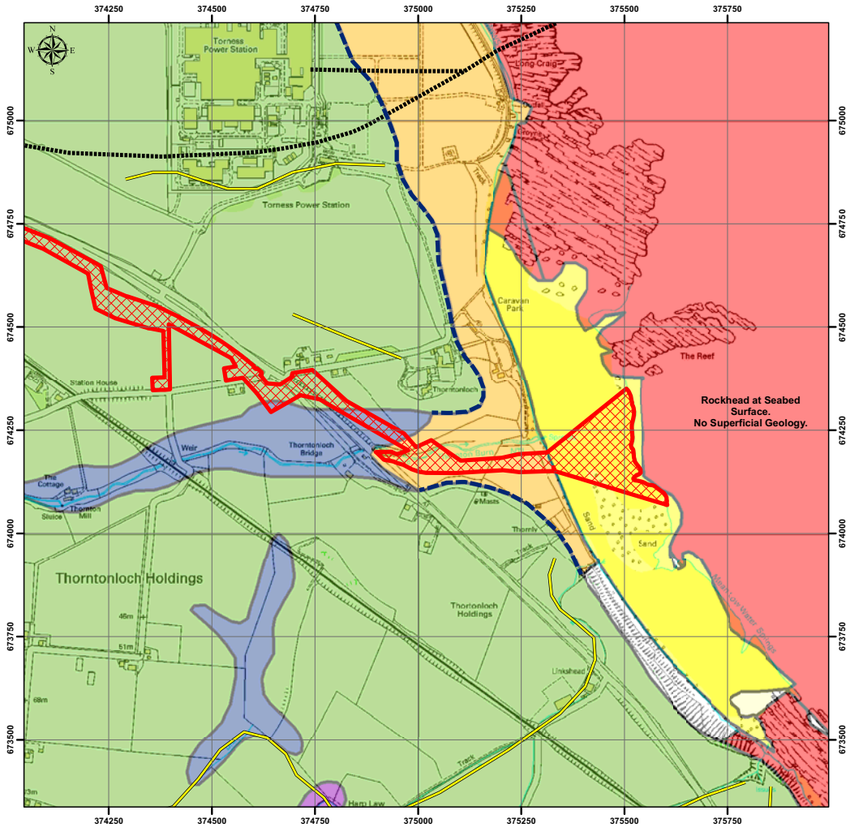
Export Cable Route Landing Site Assessment

Drawing Title

Landing Site Location Plan

Drawing No.	Date	Rev
C292-T02-D01	03/09/12	01

Path: V:\Projects\C292 NNG\C292-T02-D01.mxd



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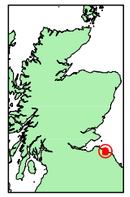

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Legend

Red Line Boundary

Linear Geological Features

Former Coastline

Glacial Meltwater Channel

Normal fault, inferred

ALLUVIUM

GLACIOFLUVIAL DEPOSITS

MARINE BEACH DEPOSITS

RAISED MARINE DEPOSITS OF FLANDRIAN AGE

TILL, DEVENSIAN

ROCK

Revision Status

Rev	Date	Details of Changes	Drawn	Check
01	03/09/12	First Issue	PSL	CMI

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Project Title

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Drawing Title

Superficial Deposits

Drawing No.	Date	Rev
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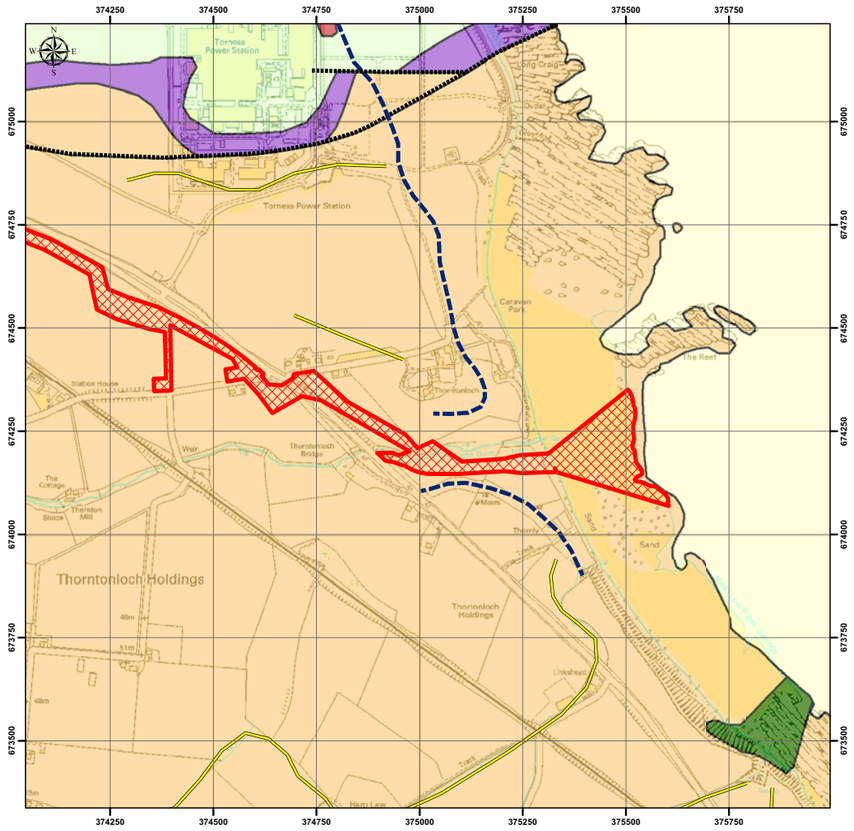

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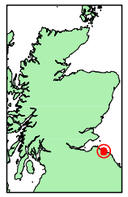

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Central Meridian: -2.0000
Scale Factor: 0.9996
Latitude Of Origin: 49.0000
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Legend

- Red Line Boundary

Geological Features

- Former Coastline
- Glacial Meltwater Channel
- Normal fault, inferred
- BALLAGAN FORMATION
- BLACKHALL LIMESTONE
- HURLET LIMESTONE
- LINKHEAD LIMESTONE
- LOWER LIMESTONE FORMATION
- CARBONIFEROUS DINANTIAN
- CALCIFEROUS SANDSTONE MEASURES

Revision Status

Rev	Date	Details of Changes	Drawn	Check
01	03/09/12	First Issue	PSL	CMI

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Project Title

Neart na Gaoithe Offshore Wind Farm

Report Title

Export Cable Route Landing Site Assessment

Drawing Title

Solid Geology

Drawing No.	Date	Rev
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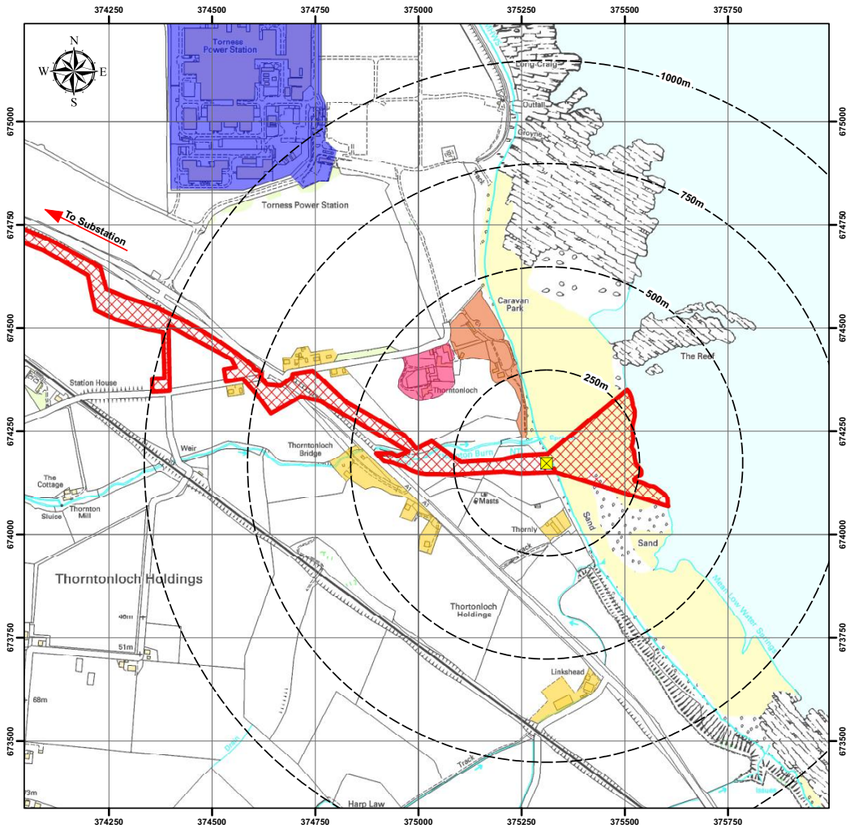
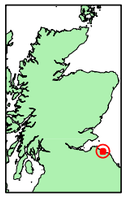


Location Map



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False Northing: -100,000.0000
Central Meridian: -2.0000
Scale Factor: 0.9996
Latitude Of Origin: 49.0000
Units: Meter

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Legend

- Cable Route Corridor
- Assumed Launch Pit Location

Receptors

- Thorntonloch Caravan Park (approx. 70m from launching pit)
- Thorntonloch House (approx. 300m from launching pit)
- Torness Power Station (approx 900m from launching pit)
- Other Residential Properties

Revision Status

Rev	Date	Details of Changes	Drawn	Check
01	03/09/12	First Issue	PSL	CMI

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MAINSTREAM RENEWABLE POWER

Project Title

Neart na Gaoithe Offshore Wind Farm

Report Title

Export Cable Route Landing Site Assessment

Drawing Title

Proximity of Receptors to Launch Pit

Drawing No.	Date	Rev
C292-T02-D04	03/09/12	01

Path: V:\Projects\C292 NNG\C292-T02-D04.mxd

Appendix B : Borehole Logs

SECTION OF BORE LB 33. TORNESS

NGR 75002 74853

13.

Surface Level 6.87 m O.D.

Communicated by A. DAVIES

Date of boring or sinking 1975 Borer Soil Mechanics Ltd.

One-inch Map Six-inch Map NT 77 SW

958116 4M 2/75 J.F.&S. 275

	Thickness		Depth from Surface	
	Metres		Metres	
Surface	2	70	2	70
Sandstone, buff, medium grained, irregular rusty staining, fairly friable, scarce thin clayey partings, carbonaceous micaceous laminae	16	33	19	03
Sandstone, grey, very coarse bands with irregular foul coal lenses and ribs, some clayey fragments, foul coal lenses up to 6 cm at 19.95 m, 20.20 m, 20.50 m	2	11	21	14
Sandstone, grey, fine to medium grained, few wispy micaceous laminae, rather massive	1	81	22	95

9

SECTION OF Birnieknowes Borehole

N.G.R. NT 75807917

Surface Level 112 O.D.

Communicated ..... by .....

Date of boring or sinking Apr.-Aug. 1968 Borer CEMENTATION

One-inch Map 33 Six-inch Map NT 77 SE

Unless otherwise stated the recovery is 100%.

[SPECIMENS COLLECTED: BEA 834 – 1568]

	Thickness Ft.	Thickness In.	Depth from Surface Ft.	Depth from Surface In.
Superficial deposits	8 / 28	53 / 0	8 / 28	53 / 0
"Dark Shale" (Borer's log) (Rec. nil)	2 / 7	14 / 0	10 / 35	67 / 0
Mudstone, grey, soft, some silty bands, pale brown IS. ribs, few IS. nodules, scattered carbonaceous plant scraps	1 / 4	50 / 11	12 / 39	17 / 11
COAL dull, canneloid, splinty		25 / 10	12 / 40	42 / 9
Sandstone, pale brown, fine-medium-grained, carbonaceous top, rootlets to 43'6", few carbonaceous/micaceous laminae towards base	1 / 3	14 / 9	13 / 44	56 / 6
Sandstone, silty, pale brown with carbonaceous siltstone ribs, micaceous, small slumps fairly common in top 9"	1	33 / 1	13 / 45	89 / 7
Siltstone, grey, pale grey sandy ribs, abundant plant scraps on some bedding planes	1	51 / 8	14 / 47	40 / 3
Siltstone, grey, micaceous, irregular sandstone patches and films, scattered carbonaceous plant fragments, some sandy bands	2	69 / 3	15 / 49	09 / 6
Sandstone, pale brown, fine to medium-grained, some coarse bands, many carbonaceous/micaceous laminae in top 1 ft 6 in. showing slumping, fine carbonaceous rootlets, fairly massive from 52-64 ft with sporadic carbonaceous/micaceous laminae s showing some poor cross-bedding; below 64 ft, sandstone a buff colour with many carbonaceous/micaceous laminae showing some slumping and ?burrows - especially abundant from 73-76 ft, friable bands throughout	11 / 38	61 / 1	26 / 87	70 / 7
Siltstone, dark grey, carbonaceous and pyritous plant scraps DIP FLAT	1	35 / 2	27 / 88	05 / 9
Sandstone, grey, fine-grained, abundant carbonaceous and coaly plant scraps	1	31 / 0	27 / 89	36 / 9
Seatclay, grey, blocky, sandy bands, few small pale brown IS. nodules	1	45 / 6	27 / 91	81 / 3
Sandstone, grey, fine-medium-grained, abundant carbonaceous/micaceous laminae, coaly laminae		23 / 9	28 / 92	04 / 0
Mudstone, grey, blocky, non-bedded, few small lipes, much broken, lower 2 ft crushed structureless ?FAULT POSITION (Rec. 4'0")	1 / 5	43 / 0	29 / 97	57 / 0
Mudstone, grey, non-bedded, silty patches, patches of sphaerosiderite in top 2 ft, silty mottled reddish-brown lower 1'9", lipy throughout	2 / 6	05 / 9	31 / 103	62 / 9
Silty mudstone, grey, finely micaceous	1	31 / 0	31 / 104	93 / 9
Seatclay, dark grey top, grey below, lipy	2	61 / 3	32 / 107	61 / 0
Mudstone, grey, blocky, poorly bedded, patches of sphaerosiderite, silty patches	1	46 / 6	33 / 108	07 / 6
Seatclay, grey, soft	1	31 / 0	33 / 109	38 / 6
Mudstone, silty, grey, plant scraps, blocky, poorly bedded	1	33 / 12	33 / 110	71 / 7
Siltstone, grey, finely micaceous, sandy laminae		5	33 / 111	83 / 0
Sandstone, pale buff, fine-medium-grained, micaceous, carbonaceous/micaceous laminae scattered at top, common in lower 1 ft 3 in	1 / 5	53 / 0	35 / 116	36 / 0
COAL, foul, sparse bright laminae		05 / 2	35 / 116	41 / 2
	25	41		