JACOBS

# B9075 Sandwater Road

Viking Energy Wind Farm

## Appendix 10.3 - Peat Landslide Hazard and Risk Assessment

B1486007/SR/PLHRA | 1

9th May 2016

# B9075 Sandwater Road

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## Contents

# Executive Summary

In April 2012, Viking Energy Wind Farm (VEWF) gained consent to build the 'Viking Wind Farm' comprising 103 wind turbines across mainland Shetland. The 'Viking Wind Farm' relies on a number of access points from the local road network. One of these is the B9075, Sandwater Road, which will require improvements to allow access for construction plant and materials. The intention is to re-align sections of the existing B9075, to the north of the current alignment, and replace or upgrade other sections.

The section of the existing B9075 to be upgraded and realigned is approximately 2.26km long and orientated east to west across the central part of the wind farm development. Preliminary work provided by VEWF shows the proposed construction will comprise cuttings and embankments. Embankment slopes are anticipated to be 1V:2H and permanent cutting slope gradients are anticipated to be 1V:4H. Bridges, culverts, services, slope drainage, compound areas or borrow-pits are excluded at this stage.

The superficial deposits at the site comprise peat with bedrock locally shown at or near to the surface. River Alluvium is recorded at the far western section of the site associated with Burn of Weisdale, with Glacial Till likely to be encountered at the eastern end of the site. Made Ground is anticipated locally along the existing roads (B9075, A970 and connecting unnamed tracks) associated with the existing road pavement construction and also along existing utilities corridors. The solid geology comprises alternating bands of the Whiteness Limestone, Colla Firth Group and the Weisdale Limestone, with this structure governing the north – south alignment of the ridges and valleys at the site. A fault is located approximately 100m to the south-west of the site.

Sand Water Loch, a Site of Special Scientific Interest (SSSI) fed by the Burn of Pettawater, is located south of the existing B9075. Sand Water is a shallow, mesotrophic loch (mid-nutrient status, generally sensitive to nutrient-enrichment) with open-water transition fen (extensive beds of common club-rush *Schoenoplectus lacustris*). The proposed development crosses the Mid Kame Ridge in the centre of the site, the Burn of Pettawater to the east and the Burn of Weisdale to the west.

Three ground investigations have been carried out at the site, with the most relevant being the 2013 investigation. This investigation found the peat thickness tends to be greater on the foot slopes of the Mid Kame Ridge, possibly due to historical peat slumping to either side of the ridge and material accumulating on the foot slopes.

A peat landslide and hazard risk assessment was carried out for the site, by splitting the site up into 100m chainage blocks and designating a susceptibility score for the following primary and secondary factors for each 100m chainage block. The primary factors assessed include surface slope angle and peat thickness, with secondary factors assessed including sub-stratum and peat interface, peat strength, hydrology, evidence of peat instability and rainfall and climate. Both primary factors are fundamental for producing a peat slide and have therefore been allocated a greater weighting in relation to the hazard score. In addition to the susceptibility score, each 100m block was also given an exposure score based on the proposed development's proximity to receptors within the surrounding area. These scores are combined together to give the overall Peat Slide Score and Risk Assessment Rank. This is intended as a means of comparing the 100m sections across the site and to prioritise mitigation.

The peat landslide hazard and risk assessment indicated there are three sections of the proposed development that have been assessed to present a medium to high risk of peat sliding. The three areas are located between chainages 0m to 900m, 1300m to 1800m and 1900m to 2200m. The risk of instability in other sections of the proposed route was assessed as very low to low risk. The high risk areas have been allocated due to the sites' proximity to water bodies, greater peat thicknesses and surface slope angles.

These findings should be assessed in more detail following further targeted ground investigation and analysis, with consideration given to the construction methodologies and mitigation methods that are included in this report.

# 1. Introduction

## 1.1 Background

In April 2012, Viking Energy Wind Farm (VEWF) gained consent to build the 'Viking Wind Farm' comprising 103 wind turbines across mainland Shetland. The 'Viking Wind Farm' relies on a number of access points from the local road network. One of these is the B9075, Sandwater Road, which will require improvements to allow access for construction plant and materials. The intention is to re-align sections of the existing B9075, Sandwater Road, to the north of the current alignment, and replace or upgrade other sections.

The proposed development will connect to the proposed Kergord Access Track which, once constructed, will lead to a new converter sub-station, located in Upper Kergord. The proposed development will pass through an area of extensive and highly variable peat cover. Enabling works for the road will impact on these peat deposits and hence a Peat Landslide Hazard and Risk Assessment (PLHRA) is required to support the planning application as part of the Environmental Impact Assessment (EIA).

Jacobs was commissioned, in January 2016, to prepare the PLHRA for the proposed development. The PLHRA has been undertaken in accordance with Scottish Executive guidance[2] (December 2006) and Scottish Environment Protection Agency[16] (SEPA) guidance (January 2012).

## 1.2 Scope and Structure of the Report

The PLHRA includes a summary of desk study information and fieldwork records. These records were used to model ground conditions and assess the risk of peat instability, through a pseudo-quantitative hazard/susceptibility scoring system. The assessment was used to classify the risks associated with construction of the proposed development and identify mitigation measures to be adopted during construction. This report is structured to reflect the stages of data gathering, site reconnaissance and investigation, risk assessment and risk management, in accordance with the PLHRA guidance. The sections contained within this report are as follows:

- Desk Study - a summary of the geology, hydrology, hydrogeology, geomorphology, topography, site history, potential environmental receptors and existing ground investigation.
- Site Reconnaissance and Fieldwork - a summary of the site reconnaissance findings and peat probing/coring surveys.
- PLHRA - a hazard and risk peat slide assessment, which is based on available information such as peat thickness, peat type, local site conditions, hydrology and slope gradient.
- Construction Methodologies and Control Measures – mitigation and construction.

## 1.3 Limitations

The findings of this report are based on information obtained from a variety of sources, as detailed in the references in Section 7. These are assumed to be reliable, but nevertheless the authenticity or reliability of the information cannot be guaranteed.

This initial PLHRA assessment is based on an agreed scope of works with VEWF to support a planning application for the proposed development. It is not intended to describe the full extent of conditions across the site, and appropriate ecological and hydrological constraints will be considered separately outside this report. It is anticipated that further investigation and site reconnaissance will be required in order to further develop the PLHRA prior to construction.

This report is provided to identify the potential for peat slides along the proposed route and so enable VEWF to manage the risk. These risks can be reduced through the implementation of mitigation measures, which may be defined following additional research and investigation works. Recommendations for mitigation measures and recommended additional research and investigation works are identified, along with their anticipated impact on risk.

## 1.4 Site Description

The Viking Wind Farm development is located on the Shetland mainland. The existing B9075, Sandwater Road, is orientated east to west across the central part of the wind farm development. The road is a single lane carriageway with several passing points and is slightly elevated above the surrounding ground in the east valley base. The site is approximately 2.2km long and covers sections of the re-alignment to the north of the existing B9075. Figure 1-1 shows the site location in the central mainland, Shetland.

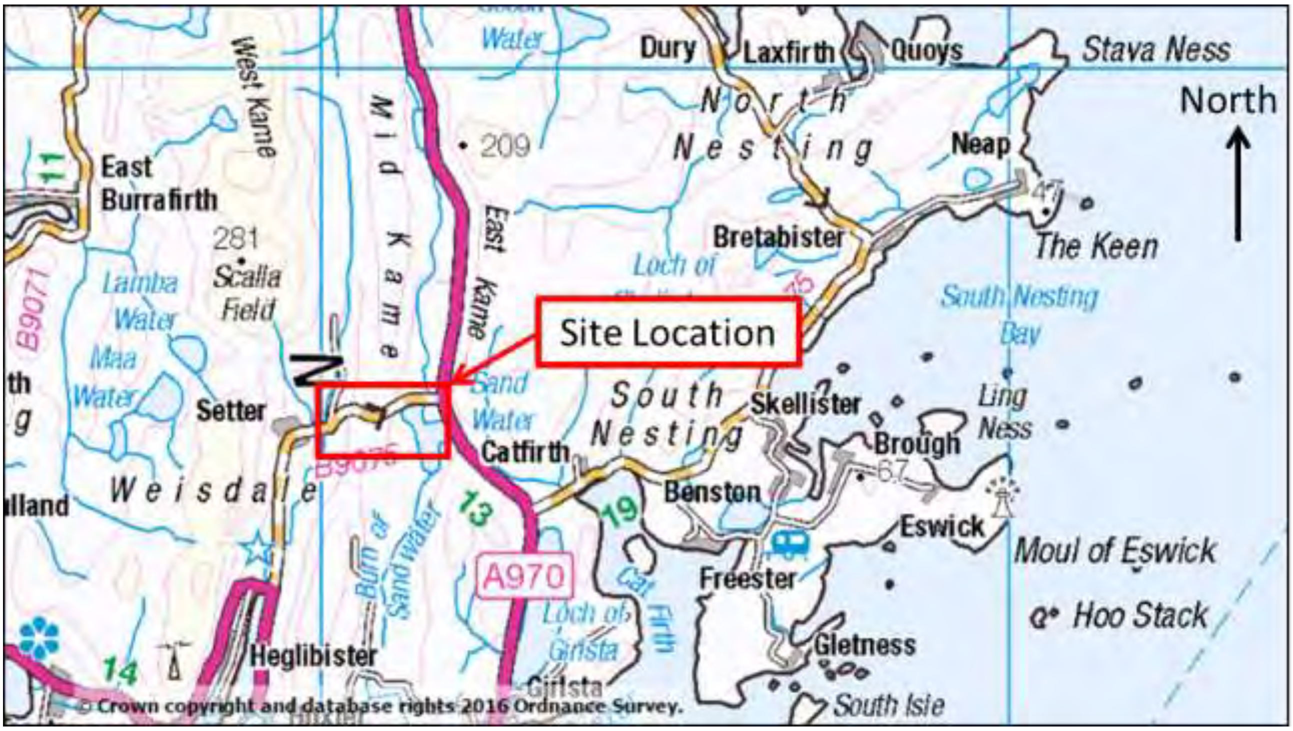


**Figure 1-1: Extract from the Ordnance Survey OpenData Viewer of the Shetland Mainland (1:250,000 Scale) [8].**

At the western extent of the site there is a junction with the Upper Kergord track, which runs north from existing B9075 to Upper Kergord. At the eastern extent of the site there is a junction between the B9075, and the A970. At chainage 850m an unnamed track runs north from the existing B9075 and provides access to a small peat excavation area. The existing B9075, Sandwater Road, is located north of Sand Water Loch, and crosses the Burn of Pettawater to the east and the Burn of Weisdale to the west. The existing B9075 crosses over the Mid Kame Ridge with Whaa Field hill to the north of the site and Clingera hill to the south. The national grid reference for the general location is 441846 155237. The nearest postcode for the centre of the site is ZE2 9LP.

Sand Water Loch is defined as a Site of Special Scientific Interest (SSSI). The Loch is located to the south of the existing B9075 and is fed by the Burn of Pettawater. The extents of the SSSI are limited to the Loch itself[17]. The SSSI is a shallow, mesotrophic loch (mid-nutrient status, generally sensitive to nutrient-enrichment) with open-water transition fen (extensive beds of common club-rush *Schoenoplectus lacustris*). It has been agreed in the Viking Wind Farm ES Addendum, and with the consultees, that any alterations made to the existing B9075 should only take place to the north of the existing road so that the works do not encroach onto the SSSI. This is a key consideration and will provide a level of separation of construction works from the SSSI[1].

The proposed route corridor may be considered to comprise four areas of common character. The extents of each area are indicated on Figure 1-2.

A. Low-lying area of open land, located within the Petta Dale valley. The Burn of Pettawater flows southwards at the base of valley into Sand Water Loch, under a bridge for the existing B9075. There is a complex network of smaller watercourses that confluence with the Burn of Pettawater and directly into the Sand Water Loch. Vegetation is a mix of short grass and reeds to the east and heather and moss to west. A small fenced-off field is located at the eastern end. Overhead electricity cables and underground water mains cross this section of the road.

B. This section crosses the main ridge via a col between Whaa Field (north) and Clingera (south), through an area called Lamba Scord. Vegetation is a mix of heather and moss. On the eastern ridge slope there is an unnamed track branching off the existing B9075, leading to a small peat excavation area (a possible local source of fuel).

C. At the western end, there is a large mid-slope plateau covered with heather and moss, with numerous minor watercourses that confluence into the Burn of Swirtars. The remaining land is covered with short grass and occasional pockets of reeds. Reeds are located around minor streams, flowing west towards the Burn of Weisdale. This section forms the eastern slope of the Valley of Kergord and the land is used for grazing livestock.

D. Low-lying agricultural land, used for grazing livestock, to either side of the Burn of Weisdale.

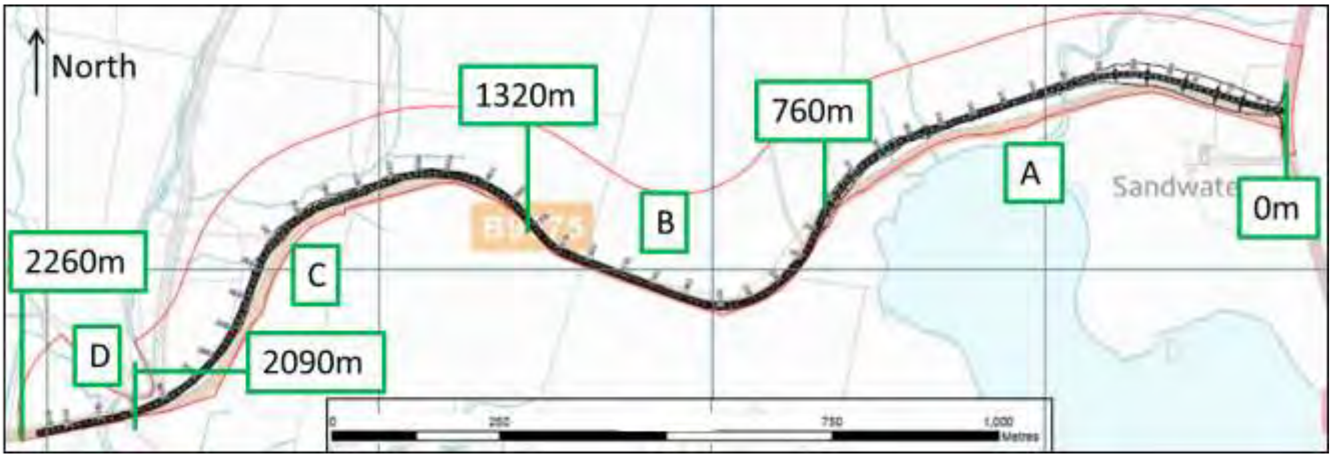


**Figure 1-2: Plan view of the site showing the proposed development alignment and the site divided into the four areas with approximate chainages.**

Reference should be made to the Sandwater Site Plan in Appendix C of this report, which contains a more detailed drawing of the proposed development and chainages.

## 1.5 Proposed Construction

The provisional earthworks (cuttings and embankments) associated with the proposed development, have been provided by VEWF and are taken from the 'Hunters Track' drawing[14] in Appendix A. Table 1-1 states the typical values for the proposed cutting depths and embankment heights. Embankment height is relative to the existing ground level, but the full embankment construction will extend to the base of peat, with a 1V:2H slope gradient. Excavation will extend to the base of the peat, and then be built-up using selected granular fill. These measurements have been estimated at 100m chainage intervals, starting in the east of the proposed development running towards the west. Permanent cutting slope gradients are anticipated to be 1V:4H. Bridges, culverts, services, slope drainage, compound areas or borrow-pits are excluded at this stage. The proposed construction for each of the four areas, as shown on Figure 1-2, is as follows:

A. A new road alignment is situated up to 50m north of the existing road alignment from chainage 0m to 760m before re-joining the existing road alignment. Approximately 50% of this section is an embankment (up to 7.7m high).

B. The existing road skirts around Whaa Field and will be widened between chainage 760m and 1320m.

C. A new road alignment will be constructed partly on a side-long embankment between chainage 1320m and 2090m north of the existing road.

D. At chainage 2090m the proposed development re-joins the existing B9075 to the east of the Burn of Weisdale.

The eastern extent of the proposed development between chainage 0m to 400m rises on embankment, up to 7.7m high above existing ground level. Elsewhere along the route, earthwork cuttings and embankments are minor, relative to existing ground level, but will entail the excavation and removal of peat to full thickness throughout the route.

| Chainage (m) | | Proposed Earthworks Relative to Existing Ground Level | |
|---|---|---|---|
| From | To | Typical Cutting Depth (m) | Typical Embankment Height (m) |
| 0 | 100 | - | 5.3 |
| 100 | 200 | - | 7.7 |
| 200 | 300 | - | 5.2 |
| 300 | 400 | - | 2.7 |
| 400 | 500 | 0.6 | 0.2 |
| 500 | 600 | 0.8 | 0.6 |
| 600 | 700 | - | 1.5 |
| 700 | 800 | - | 1 |
| 800 | 900 | - | 0.5 |
| 900 | 1000 | 0.5 | - |
| 1000 | 1100 | 0.1 | 0.1 |
| 1100 | 1200 | - | 0.3 |
| 1200 | 1300 | 0.6 | - |
| 1300 | 1400 | - | 0.6 |
| 1400 | 1500 | - | 0.8 |
| 1500 | 1600 | 0.5 | 1.3 |
| 1600 | 1700 | - | 2.4 |
| 1700 | 1800 | - | 1.6 |
| 1800 | 1900 | 1.2 | 0.4 |
| 1900 | 2000 | 0.5 | - |
| 2000 | 2100 | - | 0.6 |
| 2100 | 2200 | - | - |
| 2200 | 2260 | - | - |

**Table 1-1: VEWF Proposed Earthworks and Construction**

# 2. Desk Study

## 2.1 Site History and Land Use

Online records[7] (www.old-maps.co.uk) indicate the site has remained as open land from 1880 to 1973 (1:10,560, and 1:10,000 scale maps were reviewed). A track is shown along the site, which was later developed into the existing B9075, Sandwater Road, circa 1973. No other significant land use changes were apparent.

## 2.2 Aerial Photographs

Figure C1, in Appendix C of this report, shows the aerial imagery provided by VEWF. This was reviewed along with online sources[9] (www.google.co.uk/maps and www.bing.com/maps), that confirm the current site description in Section 1.4. The images show the numerous watercourses and change in vegetation alongside the existing B9075. A small quarry is shown approximately 50m to the north-east of the site, along the A970.

## 2.3 Geology

The geology at the site has been assessed using the published geological mapping available for the area. The Geological Survey of Scotland, Central Shetland solid and drift maps[6] have been used and are summarised in Sections 2.3.1 and 2.3.2, below, respectively.

### 2.3.1 Superficial Deposits and Made Ground

The superficial deposits at the site mainly comprise blanket and hill peat with bedrock locally shown at or very near the surface in the west. River Alluvium is recorded at the far western section of the site, associated with Burn of Weisdale. Glacial Till is likely to be encountered beneath the existing peat deposits at the eastern end of the route, in the vicinity of the junction with the A970. Made Ground is anticipated to be found along the existing B9075, the A970 and two unnamed tracks that run north from the existing B9075. Made Ground is also anticipated locally around the electricity and water services.

### 2.3.2 Solid Geology

Within central Mainland Shetland, the boundaries between successive rock formations trend in a north-south direction, and this governs the alignment of the valleys and ridges that characterise the local landscape. Accordingly, the extent of rock formations that sub-crop beneath the proposed development may be defined relative to route chainage ranges, as stated below. Chainage 0m is located at the eastern end of the proposed development:

A. Whiteness Division, Colla Firth Group. Chainage 0m to 550m comprises crystalline limestone with subordinate hornblende-schist, which has vertical bedding and layering. Chainage 550m to 760m comprises strongly laminated semipelitic and psammitic granulite with some bands of pelitic schist, calc-silicate granulite and crystalline limestone (plunge of lineation 10 degrees).

B. Whiteness Division, Colla Firth Group. Chainage 760m to 1320m: comprising strongly laminated semipelitic and psammitic granulite with some bands of pelitic schist, calc-silicate granulite and crystalline limestone. Horizontal lineation.

C. Whiteness Division, Colla Firth Group. Chainage 1320m to 1550m: comprising strongly laminated semipelitic and psammitic granulite with some bands of pelitic schist, calc-silicate granulite and crystalline limestone. Chainage 1550m to 1700m: Whiteness Division, Weisdale Limestone comprising crystalline limestone. Plunge of lineation 10 degrees. Chainage 1700m to 2090m: Whiteness Division, Weisdale Limestone comprising quartzite and gritty quartzite with semipelitic granulite.

D. Whiteness Division, Weisdale Limestone. Chainage 2090m to 2260m: comprising of crystalline limestone with calc-silicate. Vertical bedding and layering.

The solid geology governs the north – south alignment of the ridges and valleys on the Mainland Shetland. East Kame, Mid Kame and West Kame represent three such ridge features within the proposed work area. There is a vertical ‘strike-slip’ fault (dextral movement) located approximately 100m to the south-west of the site, orientated northwest-southeast. The fault is not anticipated to be within influence of the site.

## 2.4 Topography

The regional topography is dominated by north-south trending ridges and valleys. The far western extent of the site is located in the Valley of Kergord, at approximately 30m above Ordnance Datum (AOD). In the centre of the site, the Whaa Field ridge increases to a high point of 120m AOD north of the proposed development and Clingera hill to a high point of 107m AOD, to the south. To the east of the site the ground level is approximately 40m AOD at Pettawater Burn, rising gently to 50m AOD at the intersection of the existing B9075 and the A970. Whaa Field and Clingera are located within the Mid Kame ridge which runs north-south through the site. Scalla Field is located on the West Kame ridge, which is located west of the Valley of Kergord. The East Kame ridge is located immediately east of the A970.

## 2.5 Hydrology and Hydrogeology

The Burn of Pettawater, within the eastern section of the site, flows in a southerly direction towards Sand Water Loch. The Burn of Weisdale is the main river through the Valley of Kergord, within the western section of the site. This burn flows along the floor of the valley in a southerly direction. The route crosses the Burn of Swirtars and an associated minor tributary, which flow westwards, towards the Burn of Weisdale, at an approximate chainage of 1650m. Two other tributaries flow north-northwest and south-southeast into Sand Water Loch, passing across the proposed route at approximate chainages of 565m and 620m respectively.

The site is underlain by crystalline metamorphic bedrock where groundwater flow will be limited to near-surface fracture systems, joints and fault lines. The Weisdale Limestone is susceptible to dissolution which may result in the formation of karst features, such as the ‘shake holes’ evident in Upper Kergord. The presence of these karst features may give rise to sudden and localised fluctuations in groundwater pressure.

Groundwater flow within peat is considered as a diffusive process and, as a result, bodies of peat may store water and release it continuously within a catchment, for long periods following a rainfall event. However runoff from some peatlands can be ‘flashy’, with short lag times following storm events. Aerial photographs indicate there is a well-developed network of surface drainage channels across the site.

## 2.6 Geomorphology

Relatively steep slopes to either side of the Mid Kame ridge were formed during glaciation. The regional glacial flow is reported to have been in a westerly direction. There is a large mid-slope plateau to the west of Whaa Field hill and a small isolated area of raised ground to the south of the A970 junction with the existing B9075. Formation of these raised areas may be similar to ’roches moutonnee’ features, formed during glacier movement across areas of relatively stronger bedrock.

## 2.7 Receptors

The principal receptors that could be susceptible to impacts from the proposed development include:

- Sand Water Loch (SSSI).
- Burn of Weisdale, Burn of Pettawater and the Burn of Swirtars watercourses.
- Foundations of the existing B9075 and services.
- The minor track located at approximate chainage 845m, providing access to a potential local fuel source.
- Services comprising a water mains and overhead power line orientated east-west.

- Property located at the eastern extent of the site, located approximately 100m to the south of the existing B9075.
- Natural ecological habitats and minor watercourses and water bodies in close proximity to the proposed development.

# 3. Site Reconnaissance and Fieldwork

## 3.1 Site Reconnaissance

An initial site reconnaissance was undertaken by Jacobs in September 2013. The aim of the site reconnaissance was to zone the site into areas with similar character and geomorphology, and to identify features that may be indicative of ongoing peat instability, e.g. hags, breaks in slope, drainage channels, gullies and relict instability features. Numerous back scarps were recorded along the western slopes of the Mid Kame Ridge. Photos and descriptions of relevant features observed during the reconnaissance survey are presented in Appendix B.

## 3.2 Fieldwork

The fieldwork was undertaken in three phases, under the direction of VEWF. The investigations were limited to the north side of the existing B9075 because of access restrictions to the south. The most relevant investigation to the proposed alignment was undertaken in 2013 and is described in further detail in Section 3.2.2. Figure 3-1 shows the areas of the ground investigations undertaken during 2009, 2013 and 2015.

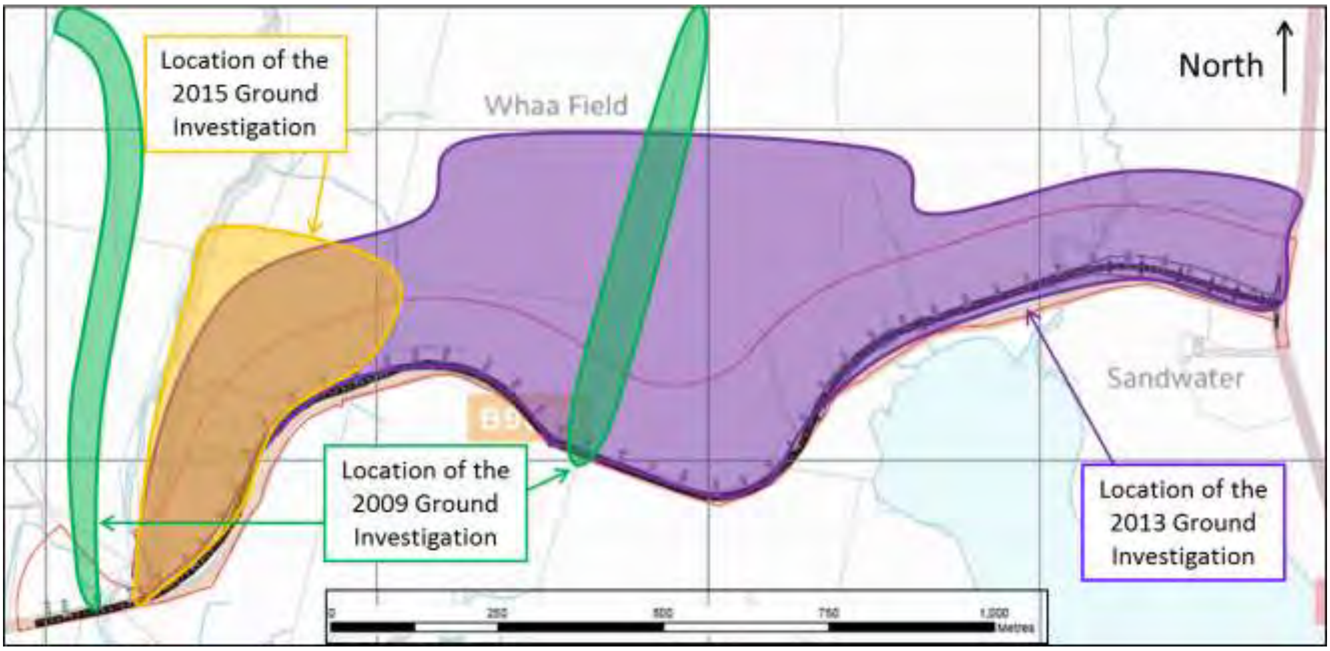


**Figure 3-1: Sketch plan showing the approximate areas of ground investigation undertaken at the site.**

### 3.2.1 Peat Investigation 2009

A feasibility stage ground investigation was complete by Mouchel[3], under the direction of VEWF in 2009. This initial peat stability assessment covered the full Viking Wind Farm area, including potential turbine locations and potential access tracks to consider early development options that have lately been superseded. Peat probes were complete along two linear tracts that run north from the middle and the far western extent of the site respectively.

### 3.2.2 Peat Investigation 2013

A ground investigation was undertaken at the site in October 2013 by Raeburn Drilling and Geotechnical Ltd[5] under the direction of VEWF. The investigation comprised peat probing and coring along the alignment of the proposed development and in an area to the north of the proposed development. The peat probes were terminated once a marked change in resistance was observed, which would indicate the presence of dense material underlying the peat. This is likely to be bedrock, although glacial till could be present in isolated areas across the site. A drawing titled 'Peat Probes'[13] in Appendix C give the specific locations of each probe. Peat core logs are available on request. The peat investigation was divided into three linear corridors and a broader zone further along the main ridge to the north. These sections are defined as follows:

- Row A – alignment of the proposed development.
- Row B – Central alignment ~100m north of the alignment of the proposed development.
- Row C – North alignment ~150m north of the alignment of the proposed development.
- Area D - Whaa Field ground investigation along the ridge to the north of the proposed development.

The typical peat thicknesses for the three rows of peat probing/coring are shown in Figure 3-2, Figure 3-3 and Figure 3-4. The peat thickness tends to be smaller where the topography increases around Whaa Field between chainage 800m and 1200m and between chainage 1600m and 2200m. This could be due to peat slumping either side of the Mid Kame Ridge and on the western flank of the East Kame Ridge, with material accumulating on the foot slopes. This slipped material may only exhibit residual shear strengths. This data has also been plotted on Figure A2 in Appendix A.

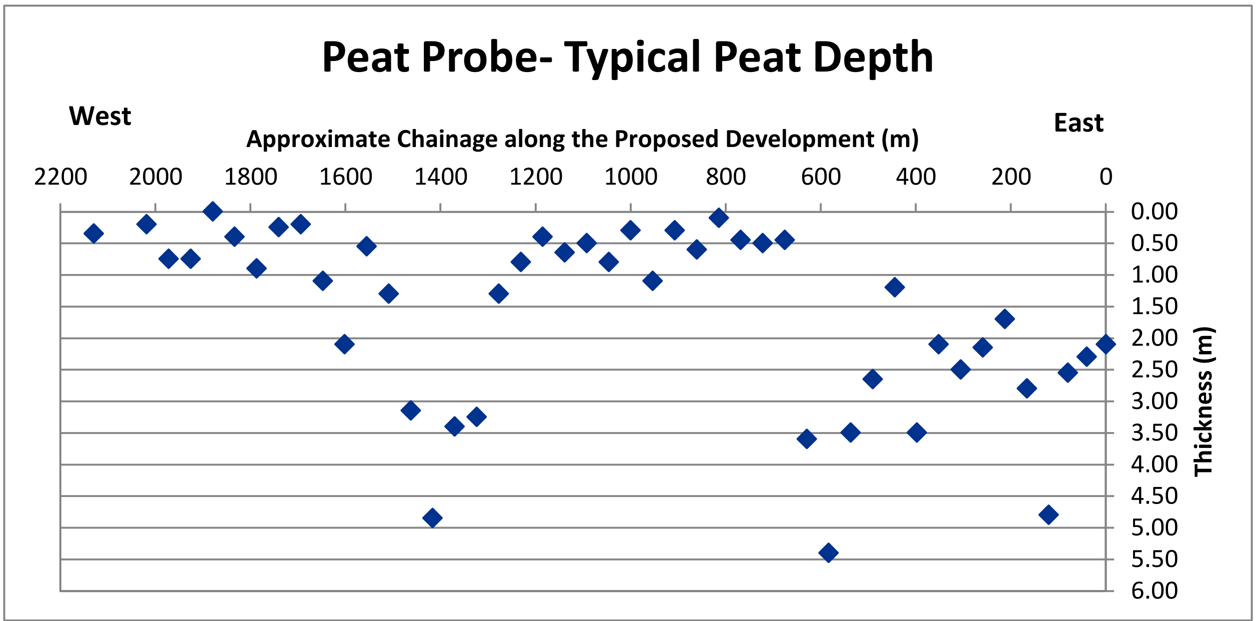


**Figure 3-2: Typical Peat Thicknesses along the Northern Alignment ~150m to the North of the Proposed Development.**

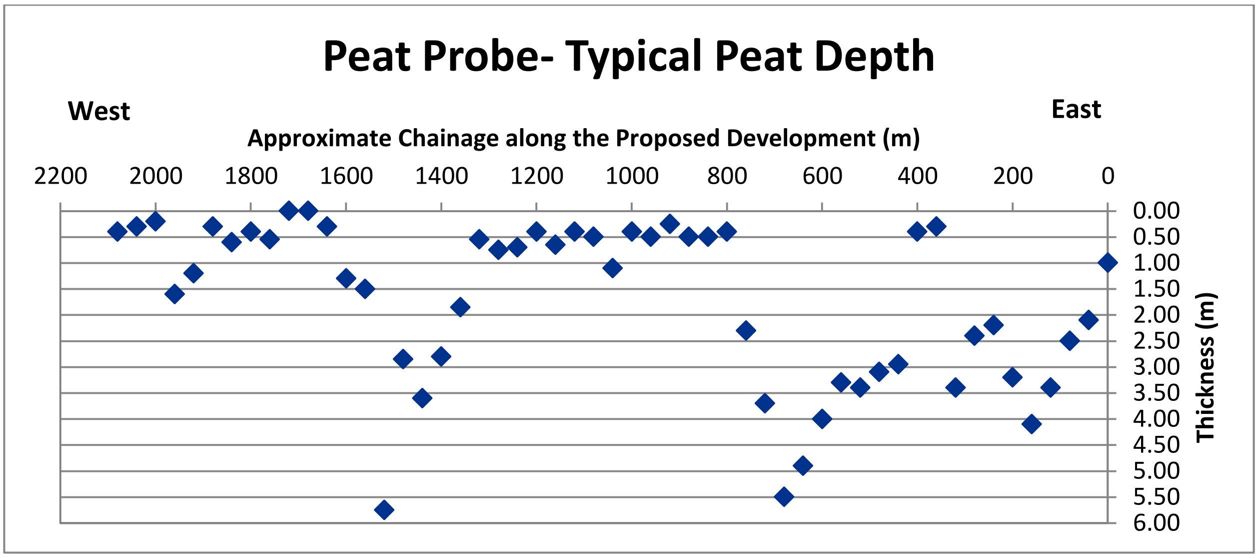


**Figure 3-3: Typical Peat Thicknesses along the Central Alignment ~100m to the North of the Proposed Development.**

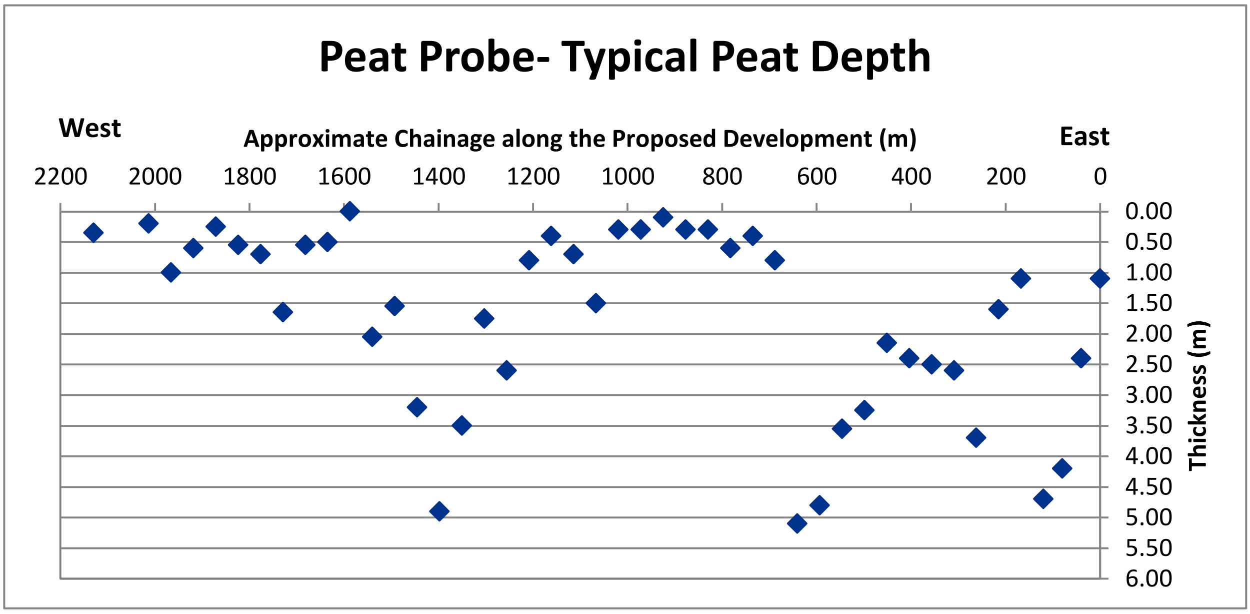


**Figure 3-4: Typical Peat Thicknesses along the Proposed Development.**

Peat cores were undertaken in 2013 by Raeburn Drilling Ltd to obtain samples for laboratory testing and permit classification of peat deposits using the von Post method, in accordance with SEPA guidance. The log descriptions of recovered peat samples have been used to inform aspects of the peat slide assessment. The peat logs are available on request and the classification by von Post method is summarised in Table 3-1.

| Degree of Humification | Decomposition | Plant Structure | Content of Amorphous Material | Associated Extrusion |
|---|---|---|---|---|
| H1 | None | Easily Identifiable | None | Clear, colourless |
| H2 | Insignificant | Easily Identifiable | None | Yellowish |
| H3 | Very Slight | Still Identifiable | Slight | Brown, muddy |
| H4 | Slight | Not Easily Identifiable | Some | Dark brown, muddy |
| H5 | Moderate | Recognisable but Vague | Considerable | Muddy with some peat |
| H6 | Moderately Strong | Indistinct | Considerable | Dark brown with peat |
| H7 | Strong | Faintly Recognisable | High | Dark brown with peat |
| H8 | Very Strong | Very Indistinct | High | Uniform peat paste |
| H9 | Nearly Complete | Almost recognisable | High | No free water |
| H10 | Complete | No discernible | High | No free water |

**Table 3-1: Von Post Classification**

The moisture content of peat is estimated on a scale of 1 (dry) to 5 (very high), designated as B1 to B5 and this is used in combination with the von Post classification to characterise the peat. It should be noted that the moisture content value is assessed by the logging engineer, based on their experience with peat samples. The Moisture Content Classification is shown in Table 3-2.

| Grade | Moisture Content |
|---|---|
| B1 | Dry Peat |
| B2 | Low Moisture Content |
| B3 | Moderate Moisture Content |
| B4 | High Moisture Content |
| B5 | Very High Moisture Content |

**Table 3-2: Moisture Content Classification**

The composition of peat typically varies with depth, and two distinct zones can form in peat bodies: an upper acrotelm layer and a lower catotelm layer. The characteristics of the two zones are described below.

- Acrotelm: This layer comprises decomposing peat that lies above the average water table and is of relatively high permeability. It is typically a fibrous peat with low levels of humification. The acrotelm is typically up to 1.0m in thickness, but can be thicker under dry conditions. This layer is typically scored from H1 to H5 on the von Post classification and typically has greater water content (e.g. B4 and B5).
- Catotelm: This layer consists of dense, compact peat that is permanently saturated and lies below the water table. The upper surface of the Catotelm is typically found at depths of 1.0 to 1.5m below ground surface, with its base defining the bottom of the peat mass. This layer comprises pseudo-fibrous to amorphous peat. This layer is typically scored as H6 to H10 on the von Post classification scale.

Figure 3-5 shows the respective thicknesses of the acrotelm and catotelm layers at peat core locations across the proposed alignment (Row A), central alignment (Row B), northern alignment (Row C) and the Whaa Field ridge (Area D). Figure 3-6 shows the moisture content of the peat samples extracted within the peat cores across the scheme.

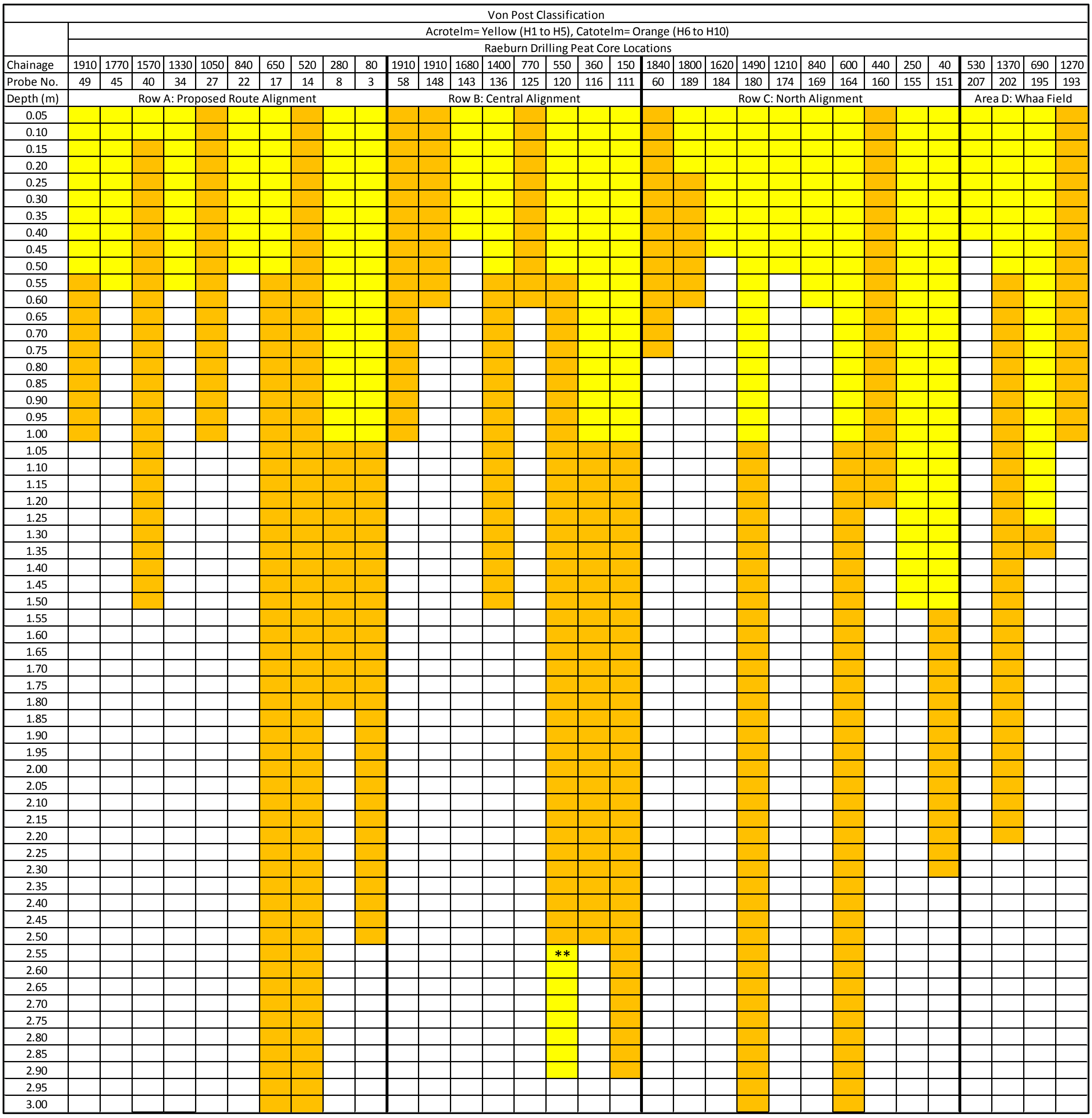


**Figure 3-5: Acrotelm (highlighted in yellow) and Catotelm (highlighted in orange) depth ranges at peat core locations along the proposed development and the adjacent area to the north.**

** Note: Probe No.120 recorded H5 material at 2.5m to 2.9m below ground level, which is considered in this specific instance as a Catotelm layer, given the depth and stratification.

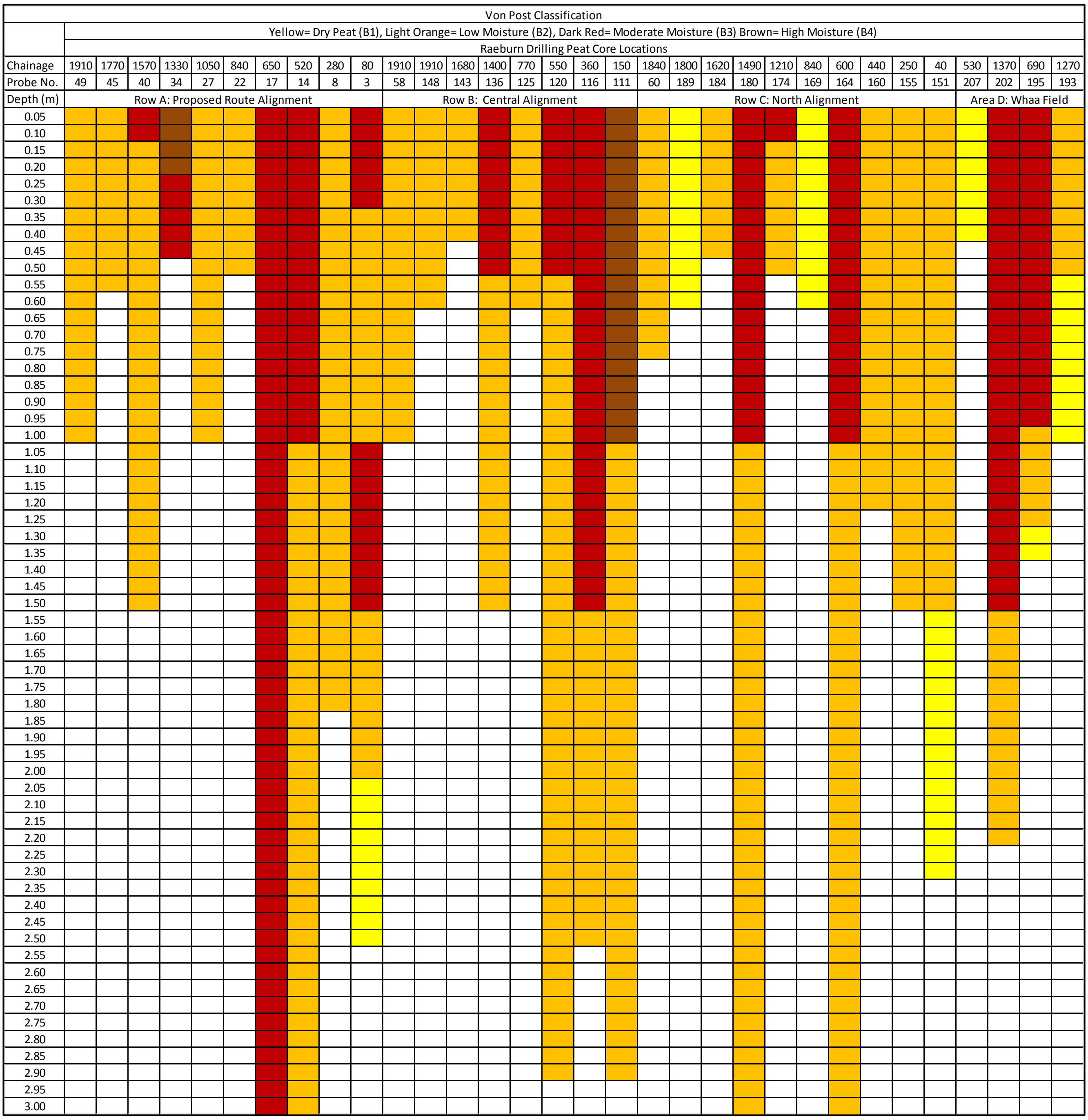


**Figure 3-6: Moisture content class (B1 highlighted in yellow, B2 highlighted in light orange, B3 highlighted in dark red and B4 highlighted in brown) of peat samples recovered at peat core locations along the proposed development and the adjacent areas to the north.**

### 3.2.3 Peat Investigation 2015

A ground investigation was undertaken at the western extent of the site in November 2015 by RPS Group Ltd[4] under the direction of VEWF. The investigation targeted a previously proposed enabling works compound. 206 probe holes were sunk on a square grid at 20m centres and taken to termination depths between 0.38m to 3.62m. The peat probe location plan is located in Appendix C entitled ‘Kergord Peat Probing’[12].

# 4. Peat Landslide and Hazard Assessment

The proposed development may increase the likelihood of peat instability. The works that are likely to give rise to an increase in risk are:

- the removal of lateral support during excavation and removal of peat to full thickness;
- the obstruction or alteration of existing drainage pathways through the peat mass, leading to localised increases in porewater pressure; and
- the creation of tension cracks in the peat due to pressure relief, which may subsequently allow rain and snow melt water to percolate into the peat mass.

## 4.1 Methodology of Hazard and Risk Assessment

Risk of instability has been assessed with reference to the Scottish Executive guidance[2] (December 2006), using the available data from the desk study, site reconnaissance and site investigations. This initial assessment procedure is a pseudo-quantitative assessment, based on the assignment of hazard scores for a number of factors that are known to contribute to instability in peat. Research[20&21] has established that the two primary factors that make a peat mass more susceptible to sliding failure are the surface slope angle and the thickness of the peat deposit. Peat deposits greater than 1m thick are likely to have a developed layer of saturated amorphous peat, known as catotelm, which can represent a zone of weakness within the peat mass. Ground surface sloping at angles as shallow as 5° (8.7%) can give rise to out of balance forces within the peat that can drive movement. Other environmental and man-made influences may exacerbate the risk of failure where the two primary risk factors exist together.

Primary factors:

- surface slope angle; and
- peat thickness.

Secondary factors:

- sub-stratum and peat interface;
- peat strength;
- hydrology;
- evidence of peat instability; and
- rainfall and climate.

For any given location along the proposed development, scores are assigned in respect of each contributory factor, based on factual evidence. An overall susceptibility score is then derived by multiplying the sub-scores for each factor together. Where a hazard is not considered to adversely affect stability of the peat mass, that factor is assigned a score of one, and will have a neutral impact on the overall susceptibility score.

Susceptibility scores have been derived for each chainage block (100m intervals). The highest score for each factor has been adopted where there is an absence of supporting information and where further investigation and analysis are required.

A simple scoring system has been developed in accordance with the PLHRA Scottish Executive guidance[2] to determine susceptibility and exposure ranks along the proposed development. The score is determined as follows:

**Overall Peat Slide Score = Susceptibility Score x Exposure Score**

- Susceptibility Score - is defined as the possibility or likelihood of a peat failure event occurring within the site.
- Exposure Score - is defined as the impact that this event may have within the site.
- Overall Peat Slide Score - is determined by multiplying the above two scores together. This score is intended as a means of comparing different sites and as a tool for prioritising mitigation.

## 4.2 Factors Influencing Susceptibility to Peat Failure

### 4.2.1 Surface Slope Angle

Surface slope angles along the route have been established using LiDAR data[11] and topographical plans. Research indicates that failures have occasionally occurred on slope angles as low as 4°, with progressively increasing susceptibility as the slope angle increases[20&21]. Whilst peat is known to have failed on relatively gentle slope angles, areas of level ground are considered to have a lower likelihood of failure as there is no gravitational driver to facilitate movement. Slopes greater than 15° tend to have little or shallow peat, however further targeted investigation would need to be undertaken at these locations to confirm this. Areas with steep slopes >25° are generally located alongside incised stream channels. The score system for surface slope angle is presented in Table 4-1. The terminology for the 'Likelihood of failure' is taken from MacCulloch, 2006.

| Surface Slope Angle | Score | Likelihood |
|---|---|---|
| Slope < 5° | 1.0 | Unlikely / Negligible |
| 5° ≤ Slope < 10° | 2.0 | Possible |
| 10° ≤ Slope < 15° | 2.5 | Likely |
| Slope ≥ 15° | 3.0 | Very Likely |

**Table 4-1: Slope Angle Hazard Score System**

### 4.2.2 Peat Thickness

Ground investigation at the site has proved peat thicknesses of up to 5.75m. Thicker peat deposits appear to have accumulated on the footslopes to either side of Mid Kame, which could represent historical peat slides. Peat material from potential historic peat slides may have been sufficiently disturbed to weaken it, such that the material has only residual strength. For the hazard score system, four thickness ranges have been considered. Research states that susceptibility typically increases with peat thickness greater than 1m, based on a single layer profile[20&21]. The hazard score progressively increases with peat thickness, as peat deposits in excess of 1m thick are likely to have developed a saturated and amorphous catotelm layer, which is likely to represent a weak layer within the peat mass. The peat thickness has been determined using data available from the ground investigation mentioned in Section 3.2. The score system for peat thickness is presented in Table 4-2.

| Peat Thickness | Score | Likelihood |
|---|---|---|
| Peat < 1.0m | 1.0 | Unlikely / Negligible |
| 1.0m ≤ Peat < 1.5m | 2.0 | Possible |
| 1.5m ≤ Peat < 2.0m | 2.5 | Likely |
| Peat ≥ 2.0m | 3.0 | Very Likely |

**Table 4-2: Peat Thickness Hazard Score System**

### 4.2.3 Sub-Stratum and Peat Interface

The sub-stratum and peat interface factor has been divided into four categories and are based on published literature[20]. This factor is governed by the type of sub-stratum and the degree of roughness. The gradient of the interface is not considered within this factor. Sub-stratum was not examined during the ground investigation in 2013 and there were limited outcrops observed during the site reconnaissance. At the western end of the scheme, a small outcrop (Photo 28, Appendix B) was observed with peat overlying gravelly clay (cohesive subsoil). Therefore a conservative score of 2.0 was adopted across the site. This factor should be developed with further investigation of the sub-stratum. The hazard score system for peat sub-stratum and interface is presented in Table 4-3.

| Sub-Stratum and Peat Interface | Score | Likelihood |
|---|---|---|
| Rough and irregular rockhead or granular subsoil of sand and gravel | 1.0 | Unlikely / Negligible |
| Undulating rockhead or granular subsoil | 1.5 | Possible |
| Planar and regular rockhead or cohesive subsoil | 2.0 | Likely |
| Smooth, polished and regular rockhead or cohesive subsoil of clay | 2.5 | Very Likely |

**Table 4-3: Sub-Stratum Hazard Score System**

### 4.2.4 Peat Strength

The peat strength factor is divided into four categories, based on research by Nichol, 2006[20]. Peat strength is calculated from in-situ shear vane tests. The 2009 investigation[3] included four boreholes with in-situ shear vane tests, distributed across the Viking Wind Farm. These tests recorded marginally higher shear strengths (up to 35kPa) within the upper parts of the acrotelm strata (<0.5m bgl). Lower shear strengths (up to 23kPa) were recorded from 0.5m to 1.0m bgl. The 2013 and 2015 investigations did not undertake shear vane tests and therefore a conservative score of 2.5 has been adopted along the proposed development, pending confirmatory further investigation. The hazard score system for peat strength is presented in Table 4-4.

| Peat Strength | Score | Likelihood |
|---|---|---|
| Shear Vane 40kPa | 1.0 | Unlikely / Negligible |
| Shear Vane 30kPa | 1.5 | Possible |
| Shear Vane 20kPa | 2.0 | Likely |
| Shear Vane 10kPa | 2.5 | Very Likely |

**Table 4-4: Peat Strength Hazard Score System**

### 4.2.5 Hydrology

Surface hydrology features and other indicators of ground saturation, such as vegetation cover and peat pipes, were recorded along the proposed development, based on aerial imagery and site reconnaissance. Variations in the types of vegetation can be used as an indicator of peat saturation. Vegetation typically ranged from heather/grass on well drained slopes, and reeds/mosses in saturated lower ground. The lower ground also exhibited standing water bodies, blocked drainage paths and peat pipe collapse. Peat slides can be triggered along natural drainage lines where a high moisture content increases the likelihood of failure. Saturated areas may reduce the natural strength of the peat and increase the pore water pressure, hence increasing the likelihood of failure. Relatively well drained, drier areas are considered less susceptible to failure. The hazard score system for hydrology is presented in Table 4-5.

| Hydrology | Score | Likelihood |
|---|---|---|
| None Evident | 1.0 | Unlikely / Negligible |
| Occasional | 1.5 | Possible |
| Frequent | 2.0 | Likely |
| Many | 2.5 | Very Likely |

**Table 4-5: Hydrology Hazard Score System**

### 4.2.6 Evidence of Peat Instability

Areas with potential peat instability features were recorded along the alignment of the proposed development during the site reconnaissance in September 2013. This factor is based on the frequency[20&21] of natural and man-made features that could indicate historical instability or precursors to peat instability across the site. Areas with breaks-in-slope, erosion, creep, man-made cuttings etc. were typically scored higher. The hazard score system for the 'evidence of peat instability' is presented in Table 4-6.

| Evidence of Peat Instability | Score | Likelihood |
|---|---|---|
| None Evident | 1.0 | Unlikely / Negligible |
| Occasional | 1.5 | Possible |
| Frequent | 2.0 | Likely |
| Many | 2.5 | Very Likely |

**Table 4-6: Evidence of Peat Instability Hazard Score System**

### 4.2.7 Rainfall and Climate

Increased rainfall may be a significant trigger for peat slides, potentially surcharging any peat pipes within the ground, resulting in the build-up of excess pore water pressures. Rainfall may also lead to localised flooding events along the main burns that have large catchment areas. These localised flood events could also cause destabilising effects in the peat deposits. Landslides typically occur following the regression of flood waters, as excess porewater pressures may continue to exist within earth slopes above the fallen river. McCulloch[21] states that peat slides are more susceptible after periods of prolonged dry weather that may result in the formation of shrinkage cracks within the peat. Subsequent rainfall is able to percolate into the peat via such cracks, leading to the localised build-up of destabilising porewater pressures. The average annual rainfall has been determined by using rainfall records (1209mm) at Lerwick Weather station[19]. A score of 1.5 (moderate precipitation) has been calculated using research by Nichol, 2006[20]. The hazard score system for rainfall and climate is presented in Table 4-7.

| Rainfall and Climate | Score | Likelihood |
|---|---|---|
| Low to Moderate Precipitation | 1.0 | Unlikely / Negligible |
| Moderate Precipitation | 1.5 | Possible |
| High Precipitation | 2.0 | Likely |
| Very High Precipitation | 2.5 | Very Likely |

**Table 4-7: Rainfall and Climate Hazard Score System**

## 4.3 Susceptibility Ranking and Assessment

Each of the hazards identified in Section 4.2 have been allocated a hazard score at 100m chainage intervals. The individual hazard scores can be multiplied together to calculate a peat slide susceptibility score as follows:

**Peat Slide Susceptibility Value =** Surface Slope Angle x Peat Thickness x Sub-Stratum and Peat Interface x Peat Strength x Hydrology x Evidence of Instability x Rainfall and Climate

These scores are summarised in Table 4-8, with chainage 0m at the eastern end of the site. The results of the hazard scores and susceptibility values have also been plotted graphically on Figures A1 to A7 in Appendix A.

| Chainage | | Peat Susceptibility Scores | | | | | | | Peat Slide Susceptibility Value |
|---|---|---|---|---|---|---|---|---|---|
| | | Primary Factors | | Secondary Factors | | | | | |
| | | Surface Slope Angle | Peat Thickness | Sub-Stratum and Peat Interface | Peat Strength | Hydrology | Evidence of Peat Instability | Rainfall and Climate | |
| From | To | Score | Score | Score | Score | Score | Score | Score | Score |
| 0 | 100 | 2 | 3 | 2 | 2.5 | 1.5 | 2.5 | 1.5 | 168.8 |
| 100 | 200 | 1 | 3 | 2 | 2.5 | 2 | 1 | 1.5 | 45.0 |
| 200 | 300 | 2 | 3 | 2 | 2.5 | 2 | 2.5 | 1.5 | 225.0 |
| 300 | 400 | 2 | 3 | 2 | 2.5 | 2.5 | 1.5 | 1.5 | 168.8 |
| 400 | 500 | 2 | 3 | 2 | 2.5 | 1.5 | 1 | 1.5 | 67.5 |
| 500 | 600 | 2 | 3 | 2 | 2.5 | 2.5 | 1.5 | 1.5 | 168.8 |
| 600 | 700 | 1 | 3 | 2 | 2.5 | 2.5 | 1.5 | 1.5 | 84.4 |
| 700 | 800 | 3 | 3 | 2 | 2.5 | 1.5 | 1.5 | 1.5 | 151.9 |
| 800 | 900 | 3 | 1 | 2 | 2.5 | 1 | 1.5 | 1.5 | 33.8 |
| 900 | 1000 | 3 | 1 | 2 | 2.5 | 1 | 1 | 1.5 | 22.5 |
| 1000 | 1100 | 2 | 1 | 2 | 2.5 | 1 | 1 | 1.5 | 15.0 |
| 1100 | 1200 | 2 | 1 | 2 | 2.5 | 1 | 1.5 | 1.5 | 22.5 |
| 1200 | 1300 | 3 | 1 | 2 | 2.5 | 1 | 2 | 1.5 | 45.0 |
| 1300 | 1400 | 2.5 | 3 | 2 | 2.5 | 1.5 | 1.5 | 1.5 | 126.6 |
| 1400 | 1500 | 2 | 3 | 2 | 2.5 | 1.5 | 1 | 1.5 | 67.5 |
| 1500 | 1600 | 3 | 2 | 2 | 2.5 | 2.5 | 1.5 | 1.5 | 168.8 |
| 1600 | 1700 | 2.5 | 2 | 2 | 2.5 | 2.5 | 1.5 | 1.5 | 140.6 |
| 1700 | 1800 | 3 | 1 | 2 | 2.5 | 2.5 | 1.5 | 1.5 | 84.4 |
| 1800 | 1900 | 2.5 | 1 | 2 | 2.5 | 1.5 | 1 | 1.5 | 28.1 |
| 1900 | 2000 | 2 | 1 | 2 | 2.5 | 2 | 1.5 | 1.5 | 45.0 |
| 2000 | 2100 | 2 | 1 | 2 | 2.5 | 2 | 1.5 | 1.5 | 45.0 |
| 2100 | 2200 | 2 | 1 | 2 | 2.5 | 2.5 | 1 | 1.5 | 37.5 |

**Table 4-8: Susceptibility Hazard Scores for the proposed development**

A border is shown on Table 4-8 between the primary and secondary factors, to acknowledge that if one or both primary factors are neutral (score of 1), there is negligible or very low risk of failure. The peat slide susceptibility score for each 100m chainage interval is then ranked as shown in Table 4-9. The peat slide susceptibility score ranges have been developed into a rank from 1 to 5 (very low to very high), in order to group and prioritise the potential likelihood of peat slide risk. The susceptibility score boundaries between each rank have been determined using a general site assessment and SEPA guidance[16]. The peat slide risk assessment rankings are provided in Table 4-12.

| Peat Slide Susceptibility Score | Peat Slide Susceptibility Rank | Likelihood |
|---|---|---|
| 0 to 30 | 1 | Very Low |
| 30 to 60 | 2 | Low |
| 60 to 120 | 3 | Medium |
| 120 to 240 | 4 | High |
| > 240 | 5 | Very High |

**Table 4-9: Peat Slide Susceptibility Ranking**

The results in Table 4-8 and Table 4-12 shows the site is split into roughly equal sections of very low to low risk of peat slide and medium to high risk of peat slide. An area at high risk of peat slide is located at chainage 0m to 100m, with two areas of medium to high risk of peat slide located at chainage 200m to 800m and at 1300m to 1800m. These areas are at risk mainly due to an increased surface slope angle and a greater peat thickness. The remaining areas of peat along the route are assessed to be of very low to low risk of peat slide. These results are shown graphically on Figure A8 in Appendix A.

## 4.4 Exposure Ranking and Assessment

An exposure ranking system has been developed to rank the exposure of a receptor in relation to its location to the construction of the proposed development. The main receptors that could be vulnerable to peat slides induced by the new construction include:

- **Watercourses within and surrounding the site.** An obstruction to a watercourse along the development could lead to destabilisation of a large area surrounding the site. Construction of the embankments along the proposed development will consolidate the peat and reduce the hydraulic conductivity. Any peat located upslope of the embankment is likely to become more saturated (less stable) following construction of the embankment.

- **Access tracks and public roads.** The main impact would be residents and users of the proposed development and the two unnamed tracks running north, although access during construction will be managed by the contractor. The A970 is located upslope of the route and is not considered a potential receptor.

- **Existing buildings and infrastructure.** There is a residential building at the far eastern end of the site at the junction between the existing B9075 and the A970. Although this is positioned on high ground away from the influence of the route.

- **Environmental**. Potential peat failure could result in sediments entering or blocking watercourses and Sand Water Loch, potentially resulting in loss of habitat at the site. Hydrological features such as burns and Sand Water Loch have been considered as sensitive receptors for negative environmental impacts in the event of a peat slide.

The developed exposure ranking system is shown in Table 4-10.

| Distance from Receptor | Rank | Exposure |
|---|---|---|
| 0m-25m | 5 | Extremely High Impact |
| 25m-50m | 4 | High Impact |
| 50m-100m | 3 | Medium Impact |
| 100m-150m | 2 | Low Impact |
| >150m | 1 | Negligible Impact |

**Table 4-10: Exposure Ranking System**

An exposure score has been given to each 100m chainage interval with chainage 0m at the eastern end of the site, as shown in Table 4-12. These results are shown graphically on Figure A9 in Appendix A.

## 4.5 Overall Peat Slide Ranking

The peat slide susceptibility and exposure ranking systems can be combined into an overall peat slide ranking. Table 4-11 separates the overall peat slide scores into ranks, as a means of comparing different sections of the site and as a tool for prioritising risk reduction measures and mitigation works. This table is based on Scottish Executive guidance[2] (December 2006) and Scottish Environment Protection Agency[16] (SEPA) guidance (January 2012). The overall peat slide ranking was based on available information and was assessed prior to availability of the final track layout; therefore ranking may need to be refined through further investigation and analysis.

| Overall Peat Slide Ranking | |
|---|---|
| 21 to 25 | Very High |
| 11 to 20 | High |
| 6 to 10 | Medium |
| 2 to 5 | Low |
| 0 to 1 | Very Low |

**Table 4-11: Overall Peat Slide Ranking Bands.**

A matrix of the overall peat slide ranking is provided in Table 4-12, for each 100m interval with chainage 0m at the eastern end of the site. There is a medium to high risk of overall peat slide between chainages 0m to 900m as the site is proximal to the Burn of Pettawater and Sand Water Loch. There is a second area of medium to high risk of overall peat slide between chainages at 1300m to 1800m as the site is proximal to burns associated with the Burn of Weisdale. An area of medium risk of overall peat slide is located between chainages 1900m to 2200m due to the sites proximity to the Burn of Weisdale. The remainder of the site has been characterised as very low to low risk and there are no areas identified to present a very high risk of instability. It should be noted that conservative scores have been adopted in the risk assessment, by default, where factual information is absent or scarce.  Accordingly, the assessment is considered to represent a worst credible assessment of potential instability.  The findings of the assessment are presented graphically on Figure A10 in Appendix A of this report.

| Chainage | | Peat Slide Susceptibility Rank | Exposure Rank | Overall Peat Slide Ranking | Risk Assessment Rank |
|---|---|---|---|---|---|
| From | To | Score | Score | Score | Score |
| 0 | 100 | 4 | 4 | 16.0 | High |
| 100 | 200 | 2 | 3 | 6.0 | Medium |
| 200 | 300 | 4 | 5 | 20.0 | High |
| 300 | 400 | 4 | 5 | 20.0 | High |
| 400 | 500 | 3 | 5 | 15.0 | High |
| 500 | 600 | 4 | 5 | 20.0 | High |
| 600 | 700 | 3 | 5 | 15.0 | High |
| 700 | 800 | 4 | 3 | 12.0 | High |
| 800 | 900 | 2 | 5 | 10.0 | Medium |
| 900 | 1000 | 1 | 1 | 1.0 | Very Low |
| 1000 | 1100 | 1 | 1 | 1.0 | Very Low |
| 1100 | 1200 | 1 | 1 | 1.0 | Very Low |
| 1200 | 1300 | 2 | 1 | 2.0 | Low |
| 1300 | 1400 | 4 | 2 | 8.0 | Medium |
| 1400 | 1500 | 3 | 5 | 15.0 | High |
| 1500 | 1600 | 4 | 5 | 20.0 | High |
| 1600 | 1700 | 4 | 5 | 20.0 | High |
| 1700 | 1800 | 3 | 5 | 15.0 | High |
| 1800 | 1900 | 1 | 4 | 4.0 | Low |
| 1900 | 2000 | 2 | 5 | 10.0 | Medium |
| 2000 | 2100 | 2 | 5 | 10.0 | Medium |
| 2100 | 2200 | 2 | 5 | 10.0 | Medium |

**Table 4-12: Overall Peat Slide Risk Assessment Rank**

# 5. Construction Methodologies and Mitigation Measures

## 5.1 General

Section 4.5 identified localised areas in the eastern and western valleys along the alignment of the proposed development with high peat slide risk. The following presents a discussion of potential construction methodologies and mitigation measures that could be implemented to reduce the risk of peat slide susceptibility and subsequent risk and potential impacts of the proposed development.

## 5.2 Construction Methodologies

The primary form of mitigation is to avoid the areas of high peat hazard altogether. The majority of the site is in areas with low to medium risk, which may be reduced with further investigation and micro-siting (i.e. small adjustments to the track alignment) at later stages. Areas of high risk are located at the eastern extent of the site and on the western mid-slope plateau, mainly associated with thick peat.

The following provides an indicative list of monitoring measures and construction methodologies that could be implemented to reduce the risk of overall peat slide susceptibility for the detailed design to supplement mitigation measures:

- The risk assessment and stability assessments will be updated and revised as design and construction progresses. This may require additional geotechnical investigation and stability analysis including probing and coring, as required.
- The typical embankment construction, shown on the Standard Details, Typical Sections drawing, number R/X/-01 Rev B, does not yet detail the foundation conditions. VEWF provisionally require the full thickness of peat beneath the earthworks footprint (1V:2H to sub-stratum) to be excavated and replaced with imported fill, given the high vehicle live loadings.
- The Standard Details drawing[15&18] in Appendix C shows permanent cuttings to be 1V:2H (27 degrees), which are considered to be too steep within peat bodies and are likely to be unstable. A safe slope gradient of 1V:4H is considered more likely to be feasible for permanent cutting slopes formed in peat.
- Temporary stockpile locations, are not yet defined and should be reviewed in the detail design phase.
- Rockfill buttresses to be used on the upslope at watercourse crossings to provide stability as required.
- The extent of and duration of excavations in peat will be minimised, for example, only opening short sections of excavation, rather than continuous unsupported slopes.
- A robust drainage design with reference to the Standard Details, Typical Sections drawing, number R/X/-01 Rev B should be installed to minimise disturbance of the current hydrology and to generate areas of concentrated flow (particularly when crossing watercourses). The design of the embankment should increase the hydraulic continuity beneath the track, using cross drains or similar.
- Drainage measures, for example silt traps, should be introduced to minimise sedimentation into natural watercourses.
- Localised cut off trenches, settlement ponds or barriers at watercourses and crossings should be reviewed in advance by a suitably experienced geotechnical engineer.
- Peat slide monitoring systems should be installed as required and would need to provide adequate warning to enable evacuation or allow remedial actions to be taken. This may consist of real time

monitoring by continuous total station surveying or inclinometers with real time data logging and computer controlled alarms.

- Continued maintenance of drainage systems and slopes will be undertaken, including methodologies to ensure that accelerated degradation and surface erosion of exposed peat does not occur.
- Development of an emergency plan and procedures in the event of a slide.

The above list is not exhaustive and a detailed geotechnical design of particular sections of the proposed development should be completed during the pre-construction phase under the management of the Principal Contractor.

Construction methodologies will be based on the location-specific mechanical characteristics of the peat deposits and morphology of the underlying strata, taking into account further targeted ground investigation. It is recommended that an appropriately qualified geotechnical engineer be appointed as a supervisor on-site to provide advice during setting out and construction works.

## 5.3 Mitigation Measures

If the medium to high peat slide risk is confirmed during detailed pre-construction site investigation, mitigation measures should be implemented by VEWF and the appointed infrastructure contractor. These mitigation measures should be similar to the following:

- adequate staff training to raise awareness of the risks and tell-tale signs of peat slides;
- develop methodologies to ensure that accelerated degradation and erosion of exposed peat deposits does not occur;
- regular monitoring, for example, instrumentation regular visual and survey observations; and
- development of an emergency plan and procedures in the event of a peat slide.

## 5.4 Geotechnical Risk Register

It is recommended that a Geotechnical Risk Register is compiled and regularly updated, with an emphasis on peat instability, in order to identify risks that may arise during construction.

# 6. Conclusion

A review of the published historical site maps, geological information and relevant background literature has been undertaken for the proposed development. Site reconnaissance and site investigations were undertaken to supplement the desk study information and enable a hazard and risk assessment for peat instability to be conducted.

Reference has been made to the Scottish Executive guidance[2] (December 2006) and the Scottish Environment Protection Agency[18] (SEPA) guidance (January 2012) for the PLHRA to provide an assessment of the proposed development based on the current available data. The findings of the site reconnaissance and site investigations have allowed a peat slide ranking system to be developed. This takes into account the susceptibility of the site to peat and the exposure of receptors to the proposed development.

The conclusion of this assessment is that there are three sections of the proposed development that have a medium to high risk of peat sliding. One area between chainages 0m to 900m is at a medium to high risk of peat slide due to great peat thicknesses and the sites proximity to the Burn of Pettawater and Sand Water Loch. A second area at medium to high risk of peat slide is located between chainages 1300m to 1800m. This risk is caused by increased surface slope angles, greater peat thicknesses and proximity to the proposed excavation works by tributaries of the Burn of Weisdale. A third area with medium risk of peat slide is located between chainages 1900m to 2200m. This area is proximal to the Burn of Weisdale. The risk of instability in other sections of the proposed route has been assessed as very low to low risk.

These findings can be assessed in more detail during subsequent stages and following further targeted ground investigation and analysis. However, to mitigate against the potential effects of a peat slide, consideration should be given to the construction methodologies and mitigation methods discussed in Section 5.

Minimal cuttings are proposed along the site with a maximum 1.2m cutting proposed at chainage 1800m to 1900m which due to the proximity of a Burn at 1780m could result in the underdrainage of the peat in that area. However, it is considered that through additional ground investigation, analysis and the implementation of mitigation measures, the risks and subsequent impact of potential peat slides can be adequately controlled. We recommend that an experienced engineer be appointed to complete a detailed geotechnical design for predetermined sections of the proposed development that are deemed to be at higher risk of peat slide.

# 7. References


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3. Mouchel, Viking Energy Wind Farm, Viking Wind Farm, Peat Stability Assessment, March 2009;

4. Kergord Peat Probing, Ground Investigation, RPS Group Ltd, Viking Wind Farm, Shetland, October 2015;

5. Peat Probing Ground Investigation, Raeburn Drilling Ltd, (Contract 23186), September 2013;

6. Geological Survey of Scotland, Central Shetland, Map Sheet 128, Solid (1981) and Drift (1982);

7. Historical OS sheets, Ordnance Survey, OS County Series, 1880 (1:10,560), 1902 (1:10,560) and 1973 (1:10,000) ( www.old-maps.co.uk);

8. Ordnance Survey OpenData Viewer, 1:250,000 Scale Colour Raster (https://www.ordnancesurvey.co.uk/opendata/viewer/);

9. Aerial Photographs (www.google.co.uk/maps and www.bing.com/maps), February 2016;

10. B9075 Sandwater Road Alignment Figure 4.1, Viking Energy, 1:10,000 scale, April 2016;

11. Viking_LiDAR_SSER, Shapefiles (GIS arcview, 12.5cm imagery resolution) received from VEWF, 17th February 2016;

12. Peat Probing Drawings Page. 3, RPS Group Ltd, Viking Wind Farm, Shetland, Kergord Peat Probing, Ground Investigation, Scale 1:2,500, 27th October 2015;

13. Peat Probe Location Plan, SSE Renewables Developments (UK) Ltd, Scale 1:8,000, 5th September 2013;

14. Hunters-track-earthworks, draft CAD drawing showing the track alignment, cutting and embankment slopes and track chainage, received 7th January 2016;

15. Standard Details, Typical Sections drawing, number R/X/-01 Rev B, August 1989;

16. Developments on Peatland: Guidance on the assessment of peat volumes, re-use of excavated peat and the minimisation of waste, Scottish Renewables, Scottish Environment Protection Agency, Version 1, January 2012;

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18. Standard Details, Typical Sections drawing, number R/X/-02 Rev B, August 1989.

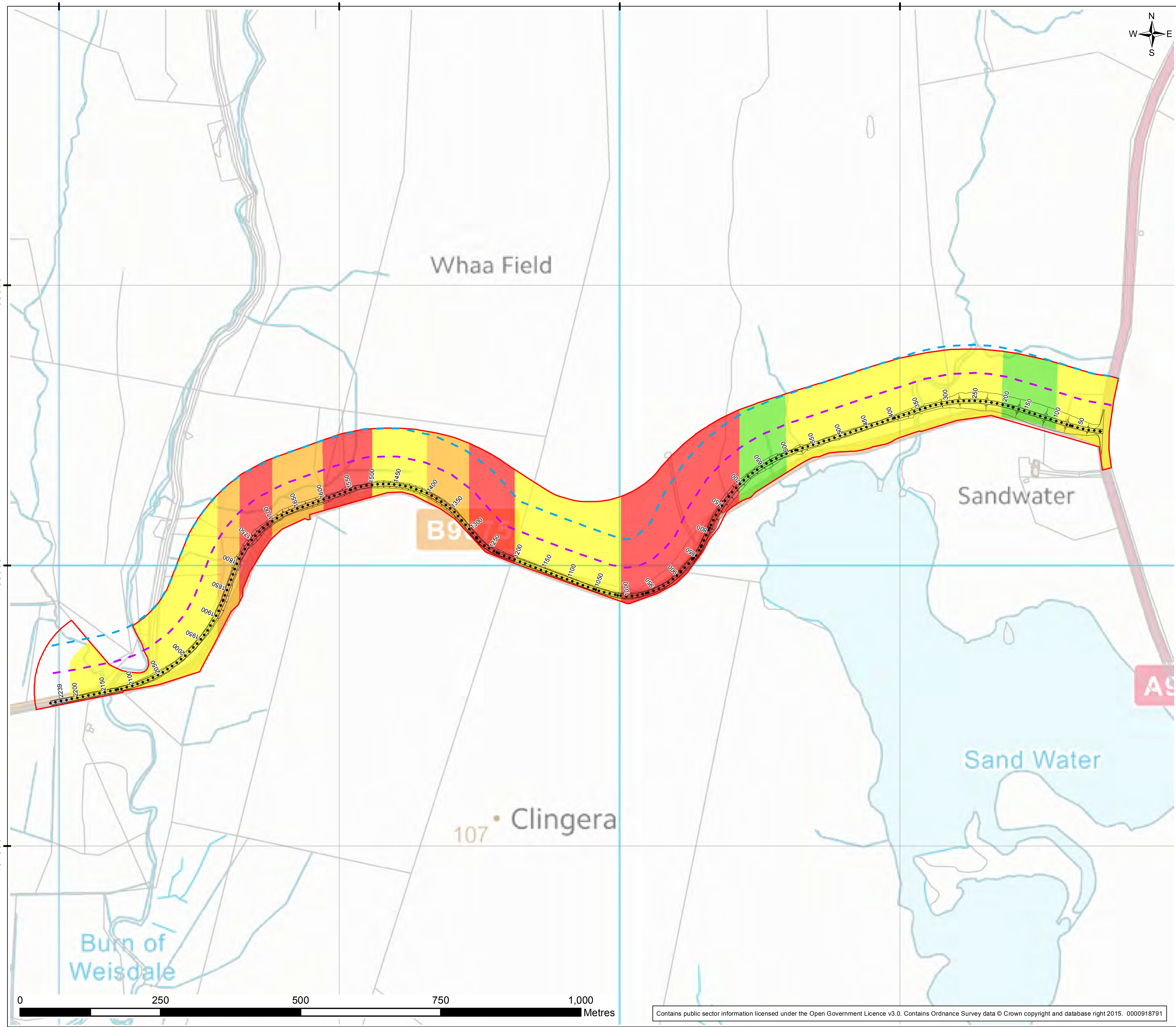
19. Average Monthly and Annual Rainfall, Lerwick Weather Station, Shetland, (www.shetland.climatemps.com) , February 2016

20. Nichol, D., 2006. Peatslide hazard rating system for wind farm development purposes. Proceedings of the 28th Annual Conference of the British Wind Energy Association (BWEA28), 10-12 October 2006, Glasgow, B2.

21. MacCulloch, F. Guidelines for the risk management of peat slips on the construction of low volume/low cost roads over peat. Forestry Commission Civil Engineering Department, January 2006.

# Appendix A. GIS Figures

# Appendix A. GIS Figures



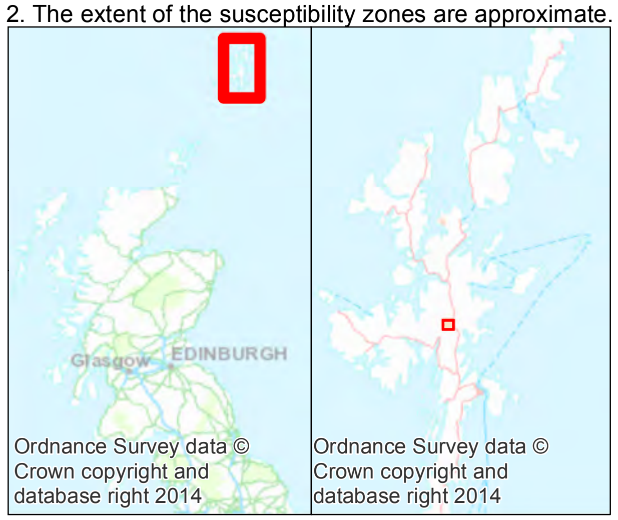

# FIGURE A1

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone
- 100m Buffer Zone

| Surface Slope Angle | Score |
| --- | --- |
| Slope <5° | 1.0 |
| 5° ≤ Slope < 10° | 2.0 |
| 10° ≤ Slope < 15° | 2.5 |
| Slope ≥ 15° | 3.0 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.

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Project
B9075 SANDWATER ROAD

Drawing Title
PEAT SUSCEPTIBILITY SCORES - SURFACE SLOPE ANGLE

INITIAL ISSUE

| Scale @ A3 | 1:6,500 | DO NOT SCALE |
| --- | --- | --- |
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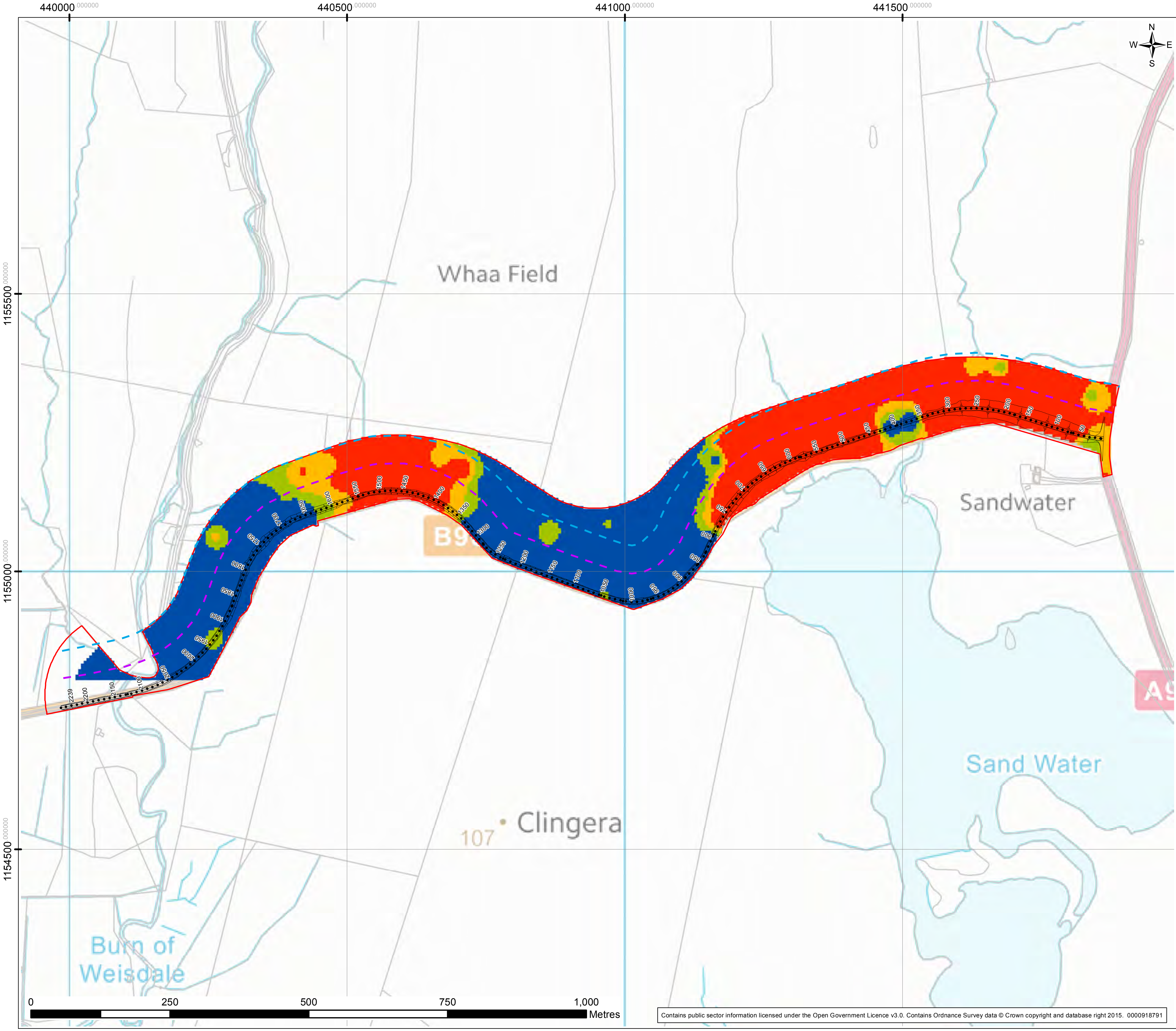


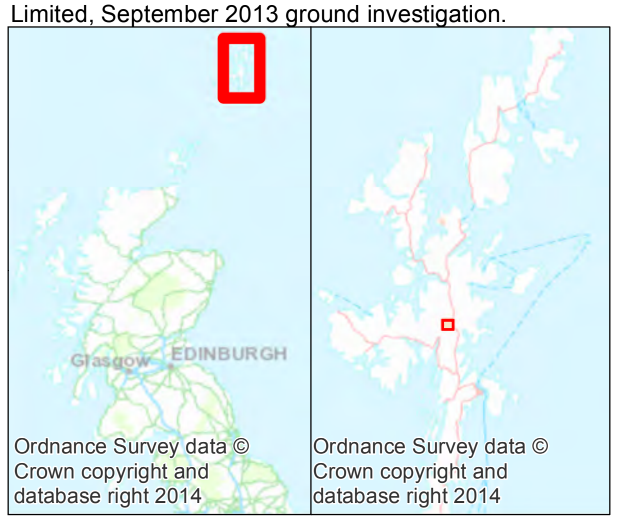

# FIGURE A2

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone
- 100m Buffer Zone

| Indicative Peat Thickness Ranges | Score |
|---|---|
| Peat < 1.0m | 1.0 |
| 1.0m ≤ Peat < 1.5m | 2.0 |
| 1.5m ≤ Peat < 2.0m | 2.5 |
| Peat ≥ 2.0m | 3.0 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The depth data is derived from the Raeburn Drilling Limited, September 2013 ground investigation.

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Drawing Title

PEAT SUSCEPTIBILITY SCORES - INDICATIVE PEAT THICKNESS

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| Scale @ A3 | 1:6,500 | DO NOT SCALE |
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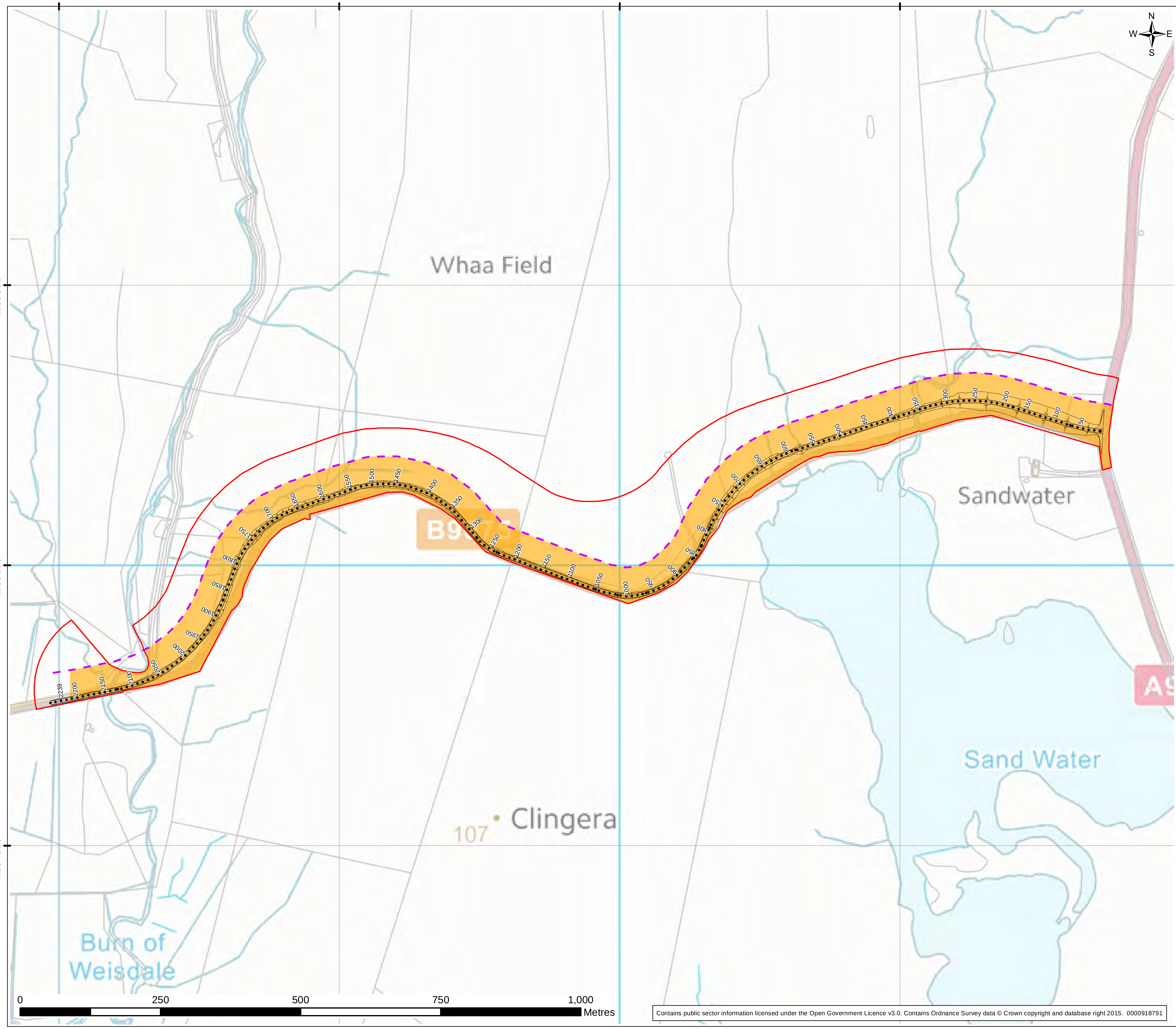


# FIGURE A3

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Sub-Stratum and Peat Interface | Score |
| --- | --- |
| Rough Rockhead or Granular Subsoil | 1.0 |
| Undulating Rockhead or Granular Subsoil | 1.5 |
| Planar Rockhead or Cohesive Subsoil | 2.0 |
| Smooth Rockhead or Cohesive Subsoil | 2.5 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.






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PEAT SUSCEPTIBILITY SCORES - SUB-STRATUM AND PEAT INTERFACE

INITIAL ISSUE

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| --- | --- | --- |
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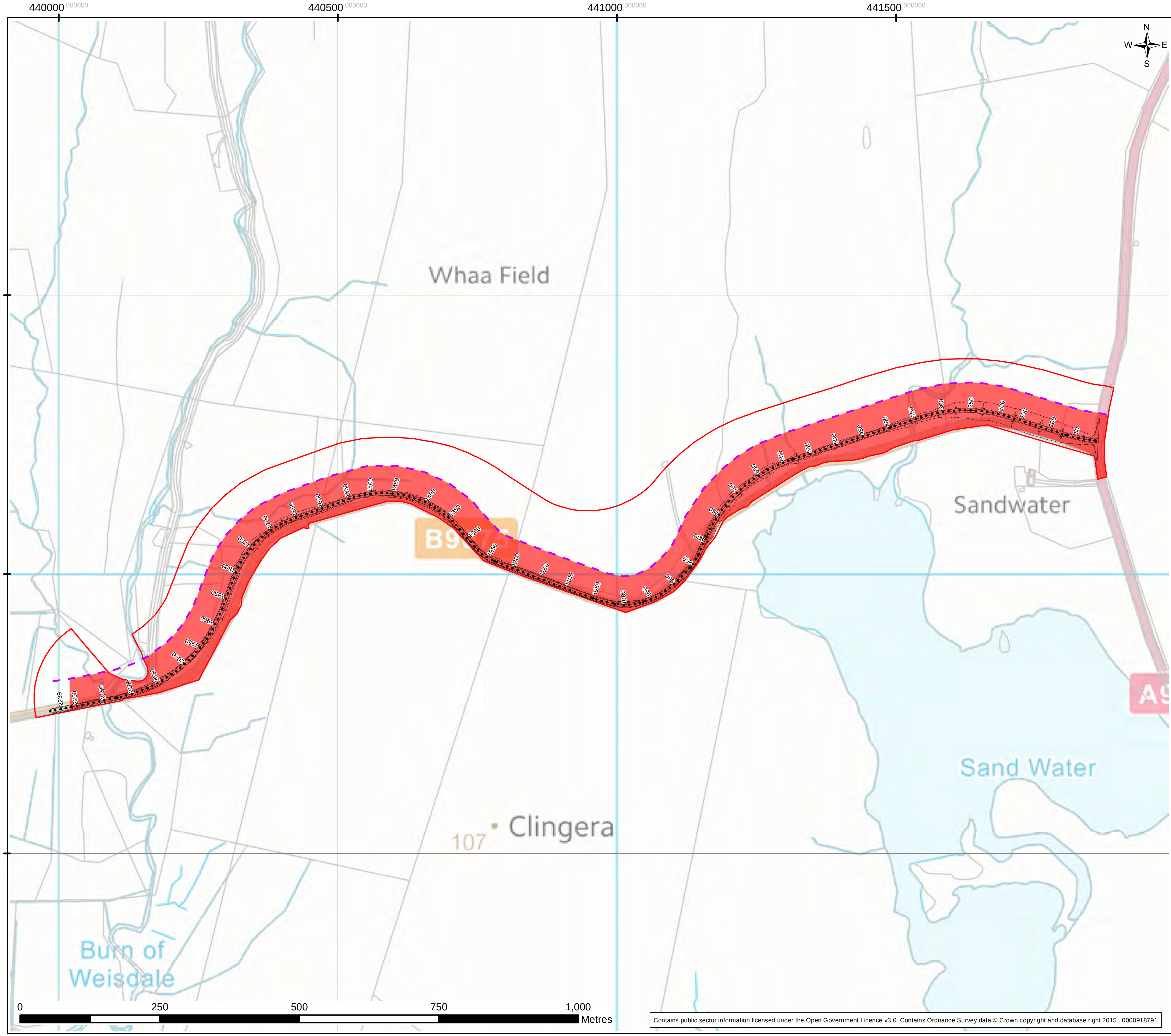




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# FIGURE A4

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Peat Strength | Score |
|---|---|
| Shear Vane 40kPa | 1.0 |
| Shear Vane 30kPa | 1.5 |
| Shear Vane 20kPa | 2.0 |
| Shear Vane 10kPa | 2.5 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.






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|---|---|---|
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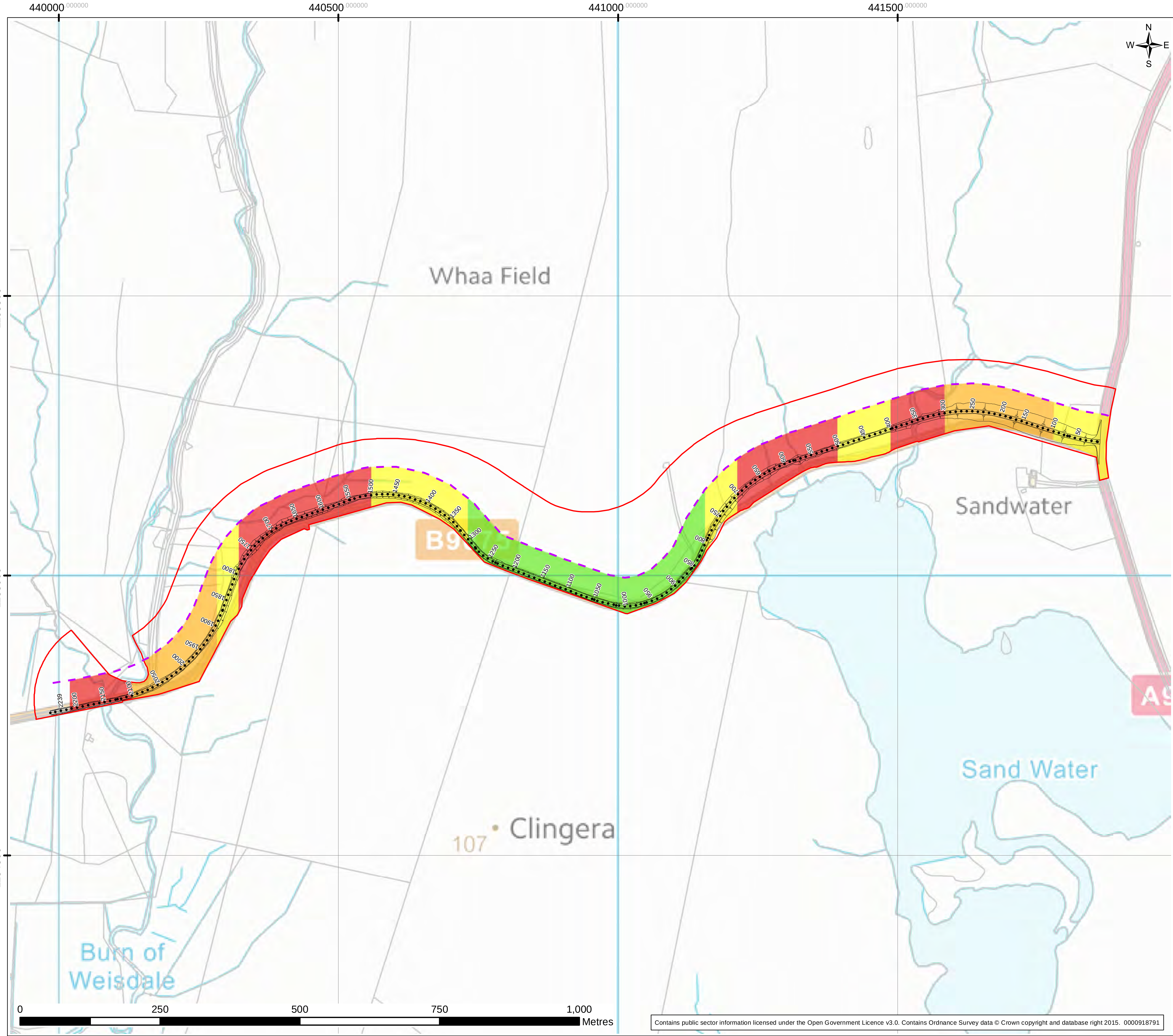


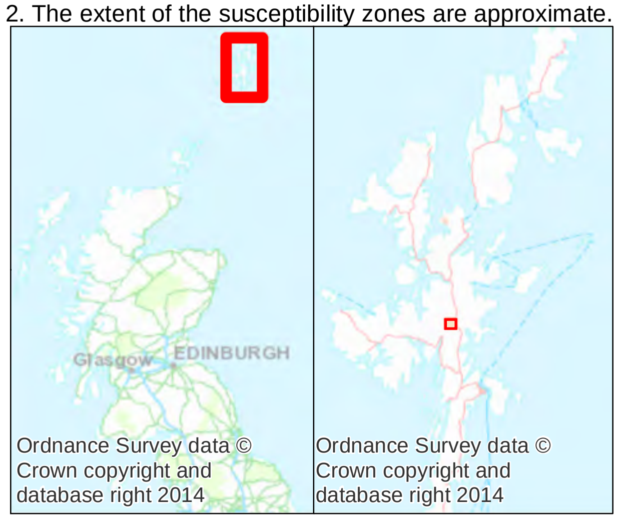

# FIGURE A5

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Hydrology | Score |
|---|---|
| None Evident | 1.0 |
| Occassional | 1.5 |
| Frequent | 2.0 |
| Many | 2.5 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.

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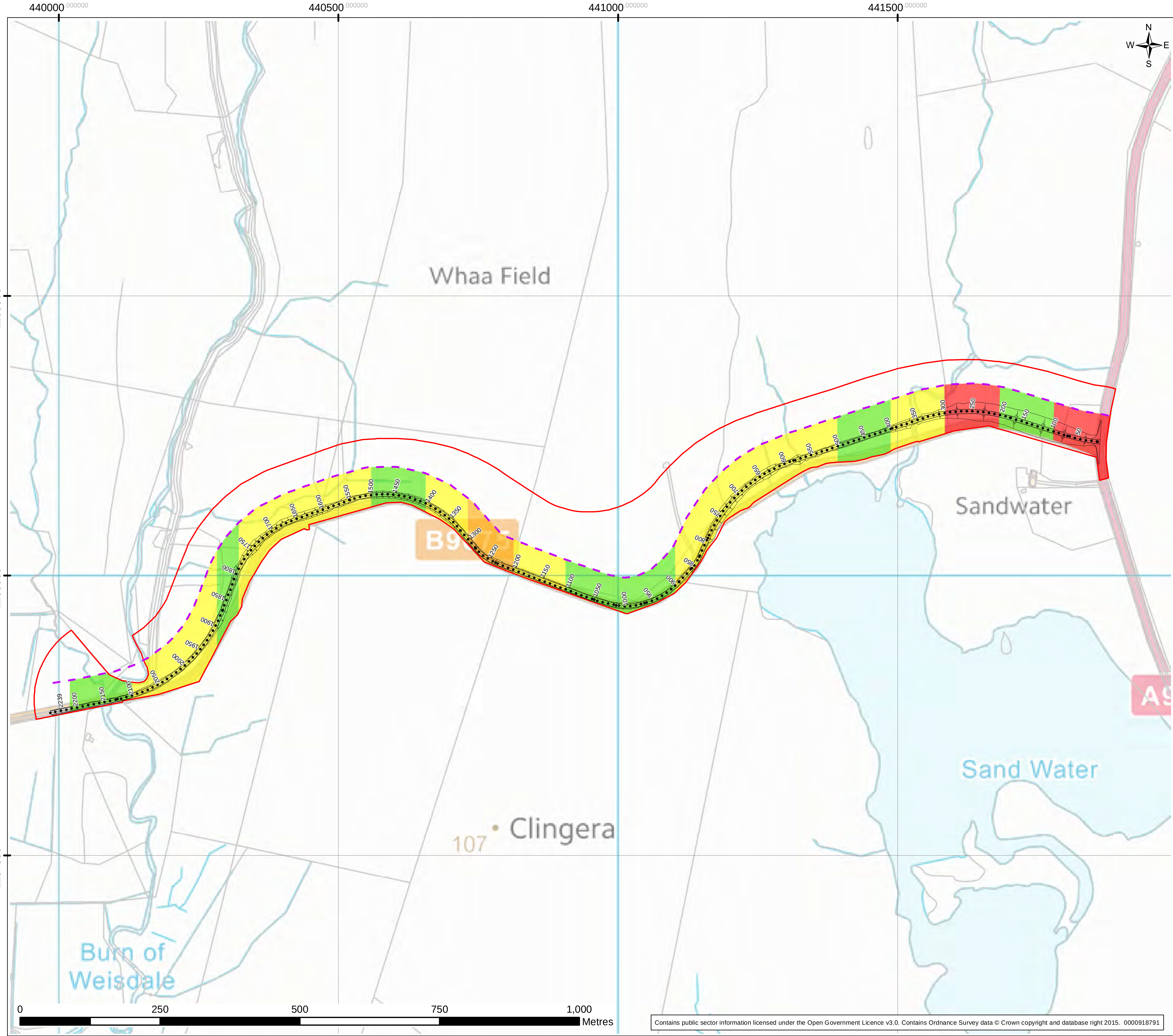




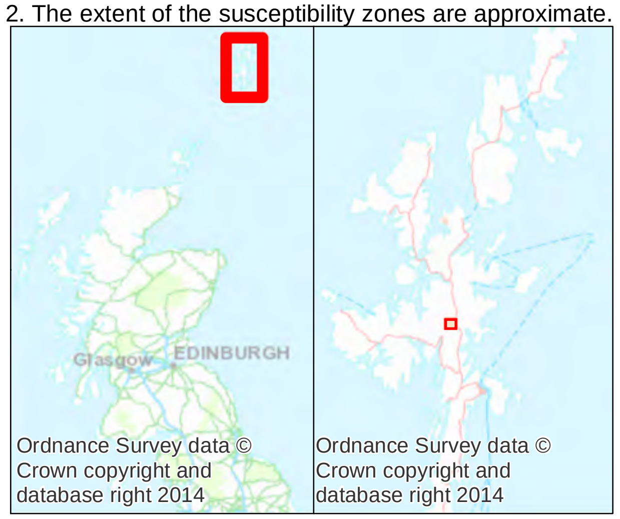
# FIGURE A6

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Evidence of Peat Instability | Score |
|---|---|
| None Evident | 1.0 |
| Occassional | 1.5 |
| Frequent | 2.0 |
| Many | 2.5 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.





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PEAT SUSCEPTIBILITY SCORES - EVIDENCE OF PEAT INSTABILITY

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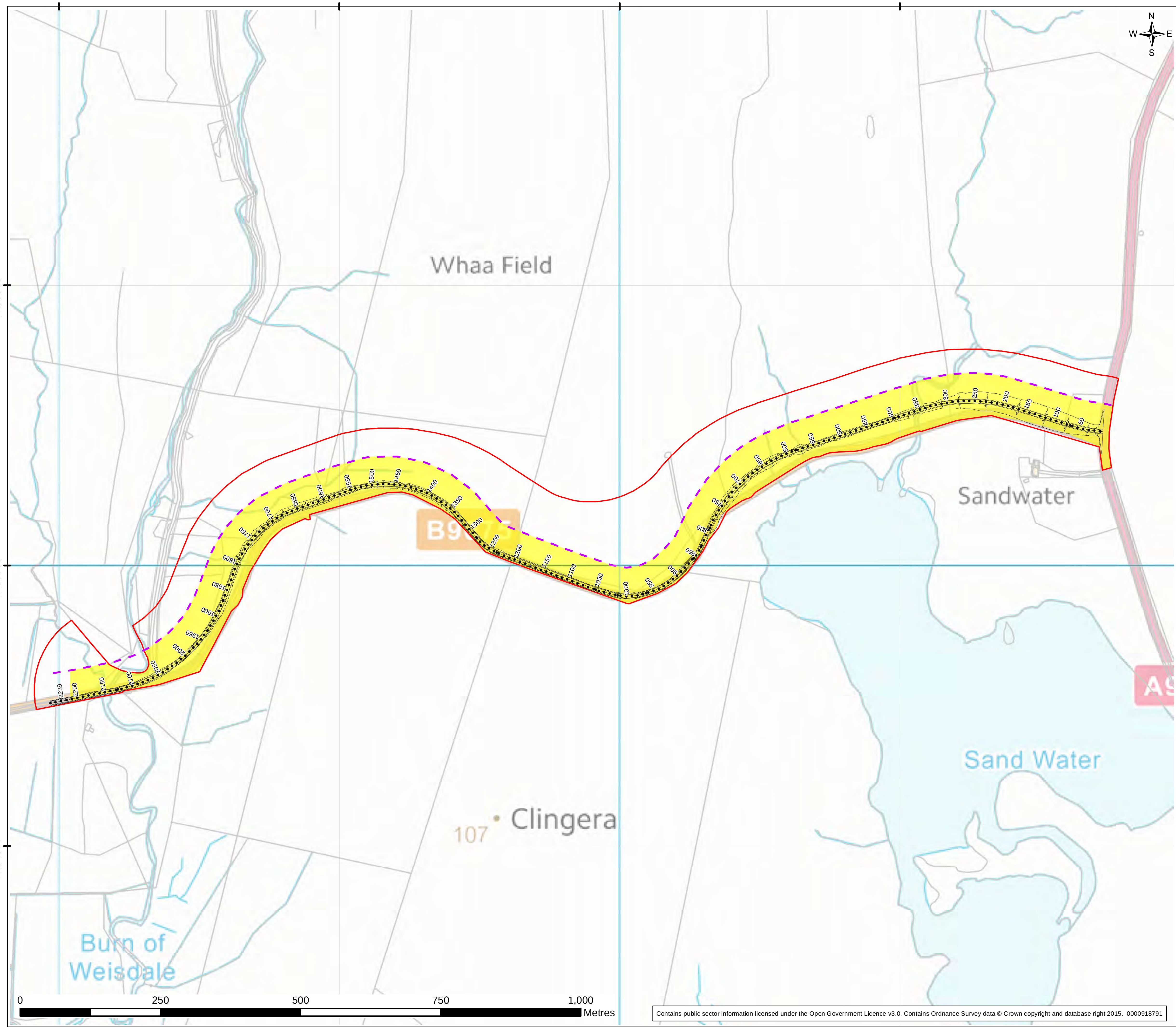
# FIGURE A7

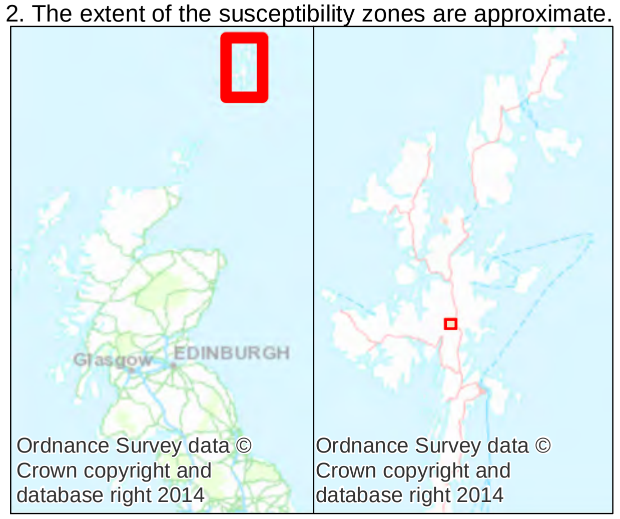



Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Rainfall and Climate | Score |
|---|---|
| Low to Moderate Precipitation | 1.0 |
| Moderate Precipitation | 1.5 |
| High Precipitation | 2.0 |
| Very High Precipitation | 2.5 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.



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PEAT SUSCEPTIBILITY SCORES - RAINFALL AND CLIMATE

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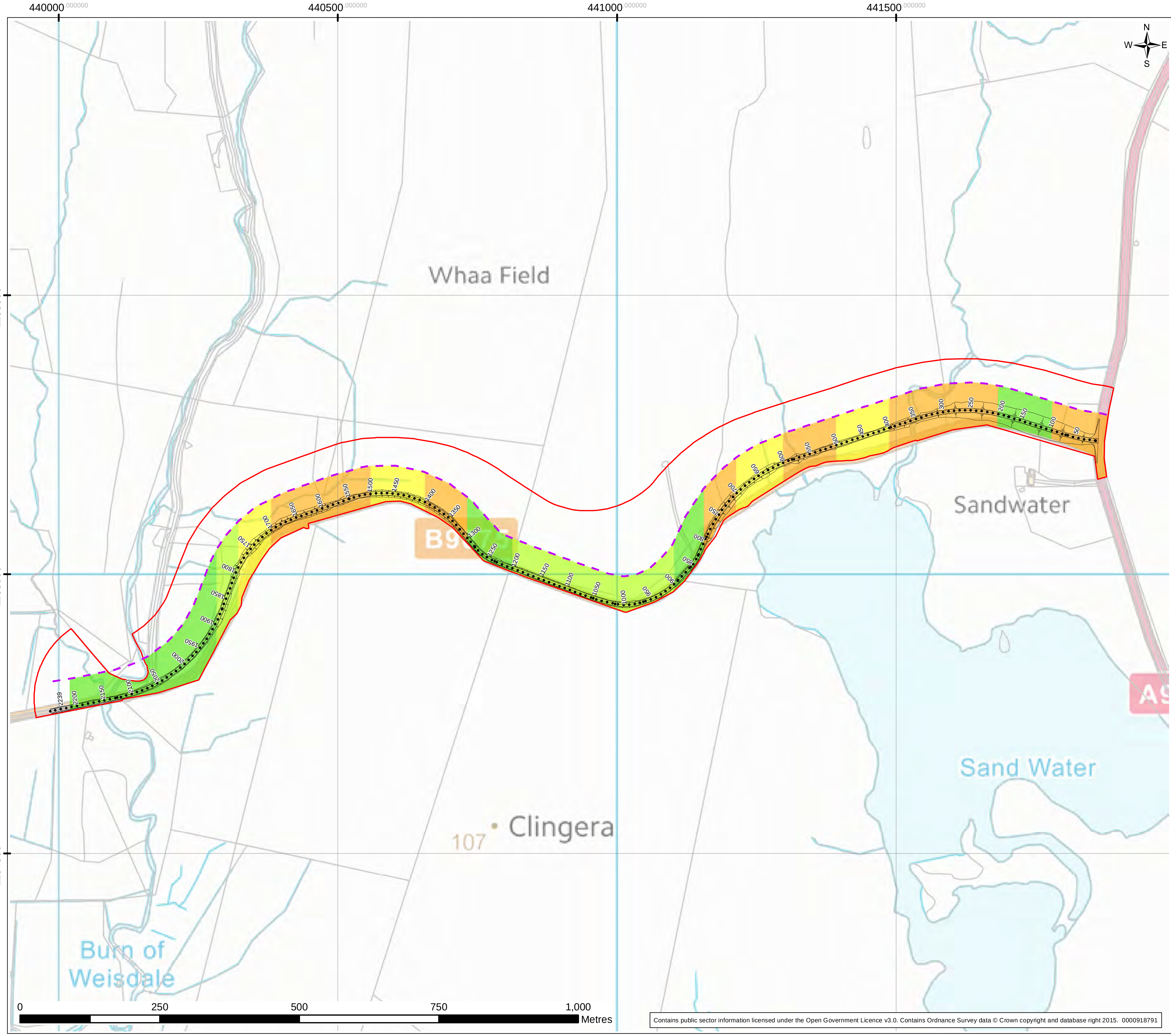


# FIGURE A8

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Susceptibility Rank | Score |
|---|---|
| Very Low | 0 to 30 |
| Low | 30 to 60 |
| Medium | 60 to 120 |
| High | 120 to 240 |
| Very High | >240 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.



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PEAT SUSCEPTIBILITY RANK

INITIAL ISSUE

| | | |
|---|---|---|
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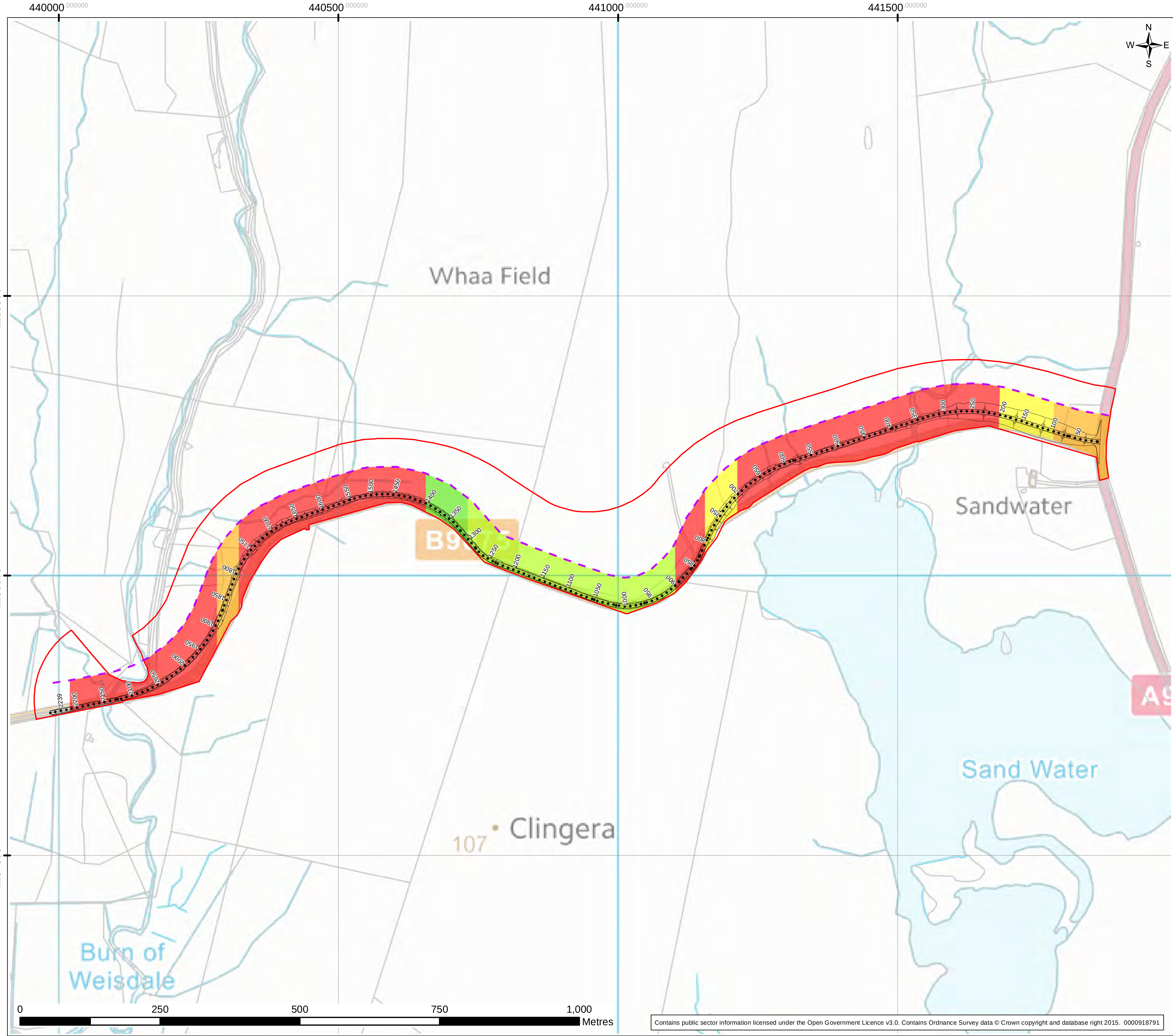


# FIGURE A9

Legend

Site Boundary

Proposed Development

Chainage Along the Proposed Development (received 17/12/15)

50m Buffer Zone

| Exposure Rank | Score |
|---|---|
| Negligible Impact | >150m |
| Low Impact | 100m - 150m |
| Medium Impact | 50m - 100m |
| High Impact | 25m - 50m |
| Extremely High Impact | 0m - 25m |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.



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PEAT EXPOSURE RANK

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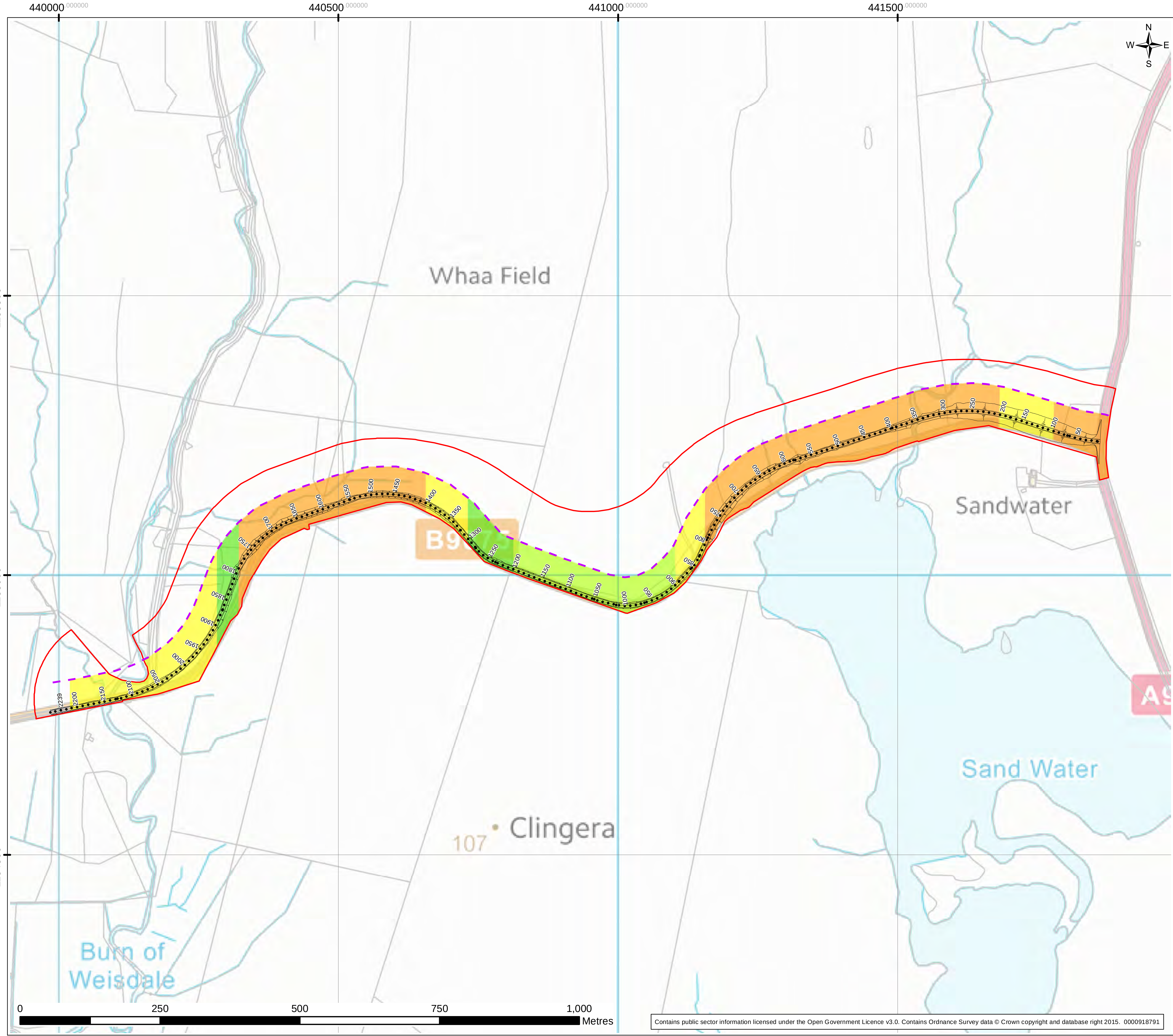


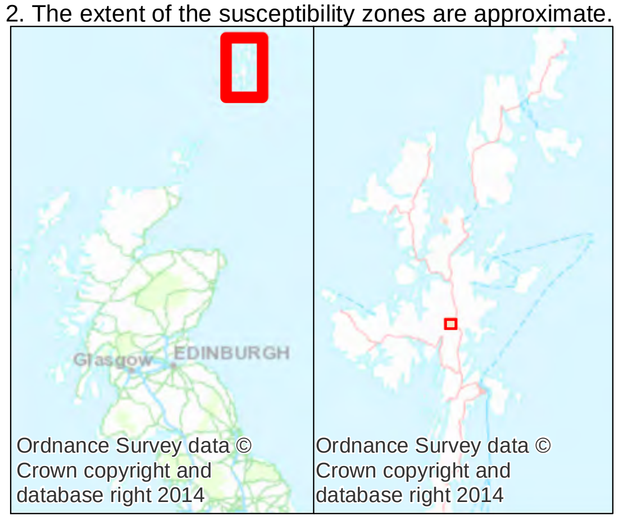

# FIGURE A10

Legend

- Site Boundary
- Proposed Development
- Chainage Along the Proposed Development (received 17/12/15)
- 50m Buffer Zone

| Overall Peat Slide Rank | Score |
|---|---|
| Very Low | 0-1 |
| Low | 2-5 |
| Medium | 6-10 |
| High | 11-20 |
| Very High | 21-25 |

NOTES:
1. Refer to B9075 Sandwater Road, Peat Landslide Hazard Risk Assessment, B1486007/SR/PLHRA.
2. The extent of the susceptibility zones are approximate.

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Drawing Title

OVERALL PEAT SLIDE RANKING

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# Appendix B. Site Reconnaissance

The following documents are available on request:

- Site Photos (No.01 - 65), Notes and Co-ordinates
- Potential Hazard List Table
- Figure B1 – Site Reconnaissance Photo Reference Plan
- Figure B2 – Site Reconnaissance General Hazard Location Plan

# Appendix C. Drawings

The following documents are available on request:

- Peat Probe Location Plan, SSE Renewables Developments (UK) Ltd, 1:8,000 scale, 5th September 2013;
- Peat Probing Drawings Page. 3, RPS Group Ltd, Viking Wind Farm, Shetland, Kergord Peat Probing, Ground Investigation, Scale 1:2,500, 27th October 2015;
- Figure 4.1 Environmental Statement (ES) - Draft CAD drawing 'hunters-track-earthworks', showing the track alignment, cutting and embankment slopes and track chainage (received 07/01/16);
- Figure 4.2a Environmental Statement (ES) - Standard Details, Typical Sections, Shetland Islands Council, drawing number R/X/-01 Rev B, August 1989;
- Figure 4.2b Environmental Statement (ES) - Standard Details, Typical Sections, Shetland Islands Council, drawing number R/X/-02 Rev B, August 1989;
- Sandwater Road, Viking Energy Windfarm LLP, 1:5,000 Scale, 16th December 2015;
- Figure C1- Sandwater Road Aerial Photography, Jacobs, 2016; and
- Figure C2- Sandwater Road Site Plan, Jacobs, 2016.

# Appendix D. Peat Core Logs 2013

The following documents are available on request:

- Peat Core Logs (A03 to Ac207) from the 2013 Investigation by Raeburn Drilling

# Appendix E. Peat Probe Data 2013

The following documents are available on request:

- Peat Probe Data from the 2013 Investigation by Raeburn Drilling

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