Peat Slide Risk

Preventative Action

A Guide For Workers

WHITEFORD GEOSERVICES

22nd September 2009

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[A] Introduction - What Is Peat?

[B] Why Is Peat So Unstable?

[C] Whiteford *Geoservices*

How Can We Help?

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[A] Introduction - What Is Peat?

1. Where Does Peat Come From?

2. What Is Peat Composed Of?

3. Is There A High Potential For Instability In Peat?

4. Do I Have A Baseline Peat Site? – Should I Be Worried?

A1 Where Does Peat Come From?

- Organic soil derived from plant remains; shrubs, herbaceous vegetation and degradable parts of trees
- Deposited over extended period of time in temperate latitudes
- Prevalent only in regions of high rainfall

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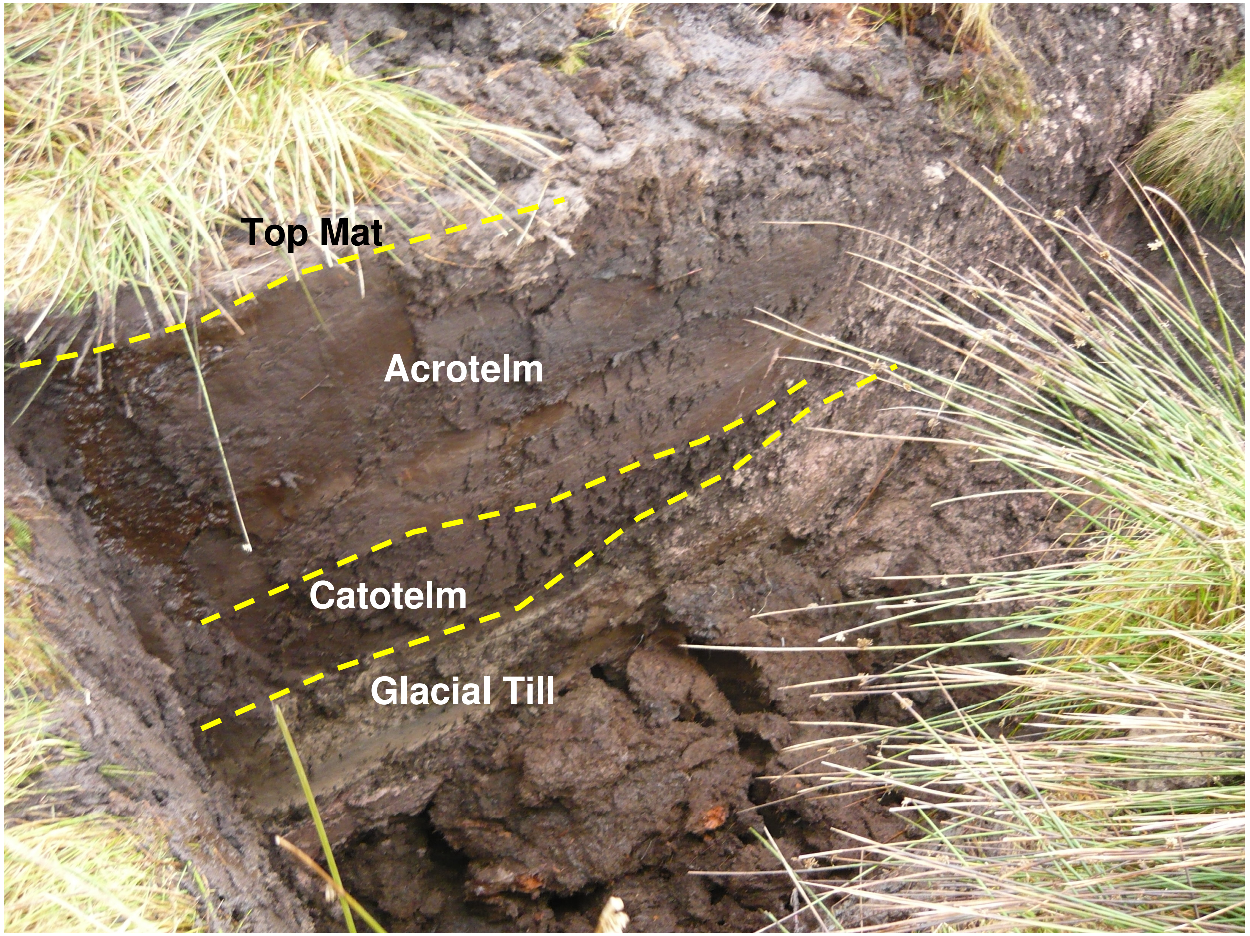
A1 Where Does Peat Come From?

- Often moves as a mass to cover large tracts of uplands areas
- Can form naturally up to 4m in thickness, but can migrate / flow to thicknesses well in excess of this figure.
- Extensively mined / extracted for use as fuel source, particularly in the nineteenth and early part of the twentieth centuries

A2 What Is Peat Composed Of?



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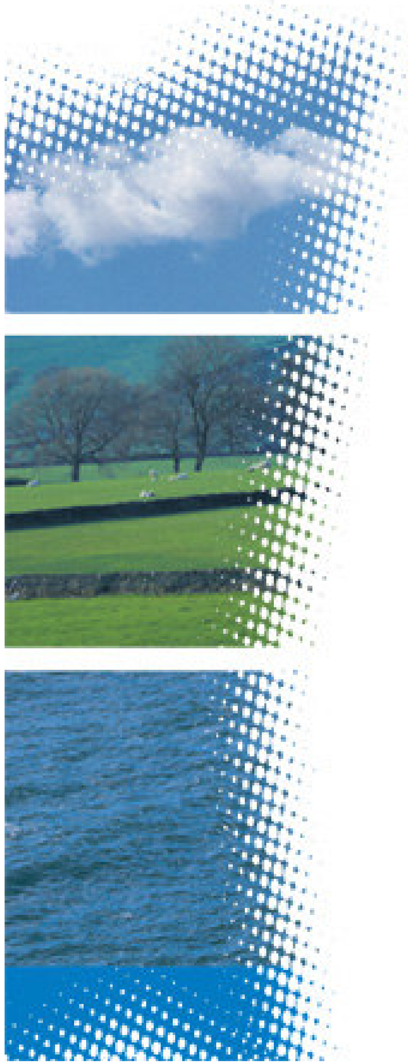

A2 What Is Peat Composed Of?

Contains generally three distinct parts

TOP MAT

- Living vegetation
- Herbaceous Plants, grasses, moss and lichens
- Moderate shear strength

ACROTELM

- Decomposing peat; highly fibrous
- Periodically saturated; high permeability
- Moderately to low shear strength, 0.2 – 1.3m thick

CATOTELM

- Completely decomposed peat; pseudo-amorphous to amorphous
- Permanently saturated; low permeability
- Very low shear strength; occurs below 1.3m depth

A3 Is There A High Potential For Instability In Peat?

- **YES**

- ***WHY?***

- **PEAT IS HIGHLY SENSITIVE TO A HOST OF FACTORS:-**

1. *Changes in slope*
2. *Changes in drainage patterns*
3. *Dewatering / desiccation*
4. *Loading*
5. *Cutting*
6. *Variations in rainfall*
7. *Vibration / Seismic / Sonic Activity*
8. *Propagation of local impacts*

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A4 Do I Have A "<u>Baseline Peat</u>" Site?

What is a "Baseline Peat" site?

- One where peat is present to such a level that it represents a peatland habitat and as such is highly sensitive to environmental change.

Simple Test

- A site should be designated "Baseline Peat" if the average peat thickness is 0.5m or more.

Should I Be Worried?

- ***<u>No</u>***

Concerned?

- ***<u>Probably</u>***

Informed?

- ***<u>MOST DEFINITELY!</u>***

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A4 To Be Informed Is To Be Prepared

Main Issues With Peat Sites

- Slope Failure; Peat Slide or Bog Burst
- Sensitive Hydrology
- Flora and Fauna
- Contamination Of Water Courses

Information You Should Have

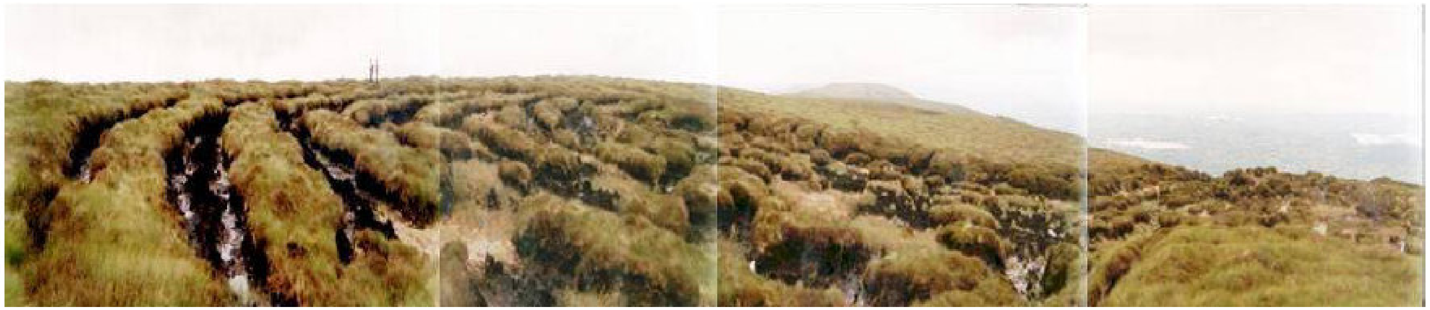
- Desk Study
- Walk Over Assessments
- Peat Probings / Gouge Sampling / Vane Testing

[B] You Should Always Ask The Following Questions About Your Construction Site?

1. Can The Risk Of Peat Slide / Bog Burst Be Averted On My Site During Construction?
2. Why Is Peat So Unstable?
3. What Triggers a Peat Slide / Bog Burst?
4. How Can I Measure Risk At My Site?
5. **What Can I Do To Prevent Peat Slide / Bog Burst?**

B1 Can Bog Burst / Peat Slide Be Averted?

- YES (Potentially, although some sites are unsuitable)
- Mitigation can always be applied to reduce the risk of slope failure from occurring
- However – it can ***never*** be completely ruled out



Bog Burst – Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

Peat Slide – Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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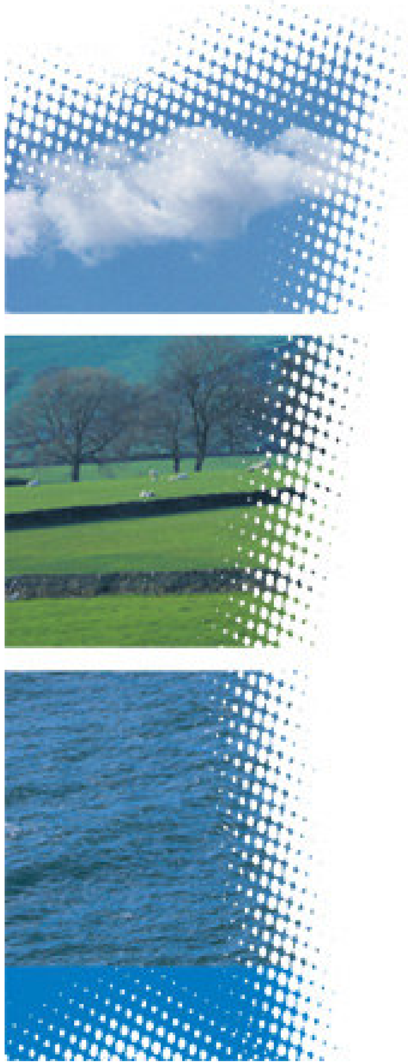


B2 Why Is Peat So Unstable?

- Exists in **Equilibrium of tension and compression** in the Top Mat and Acrotelm
- Any tear / cutting within the surface Mat / Shallow Acrotelm **compromises this shear strength**
- **Catotelm** is highly unstable and only **weakly permeable**
- Water flowing into the acrotelm from above can only flow into the catotelm, but not through it.
- Pore water pressure builds up steadily within the catotelm – water cannot escape – **high hydrostatic pressure**
- Incisions / Cuts into the base of the peat (catotelm layer) can cause a **rapid dewatering** of peat – BOG BURST
- In shallower peat – mechanism is PEAT SLIDE

B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

Steep Slopes

B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

Deep Peat

B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

Active Peat Instability

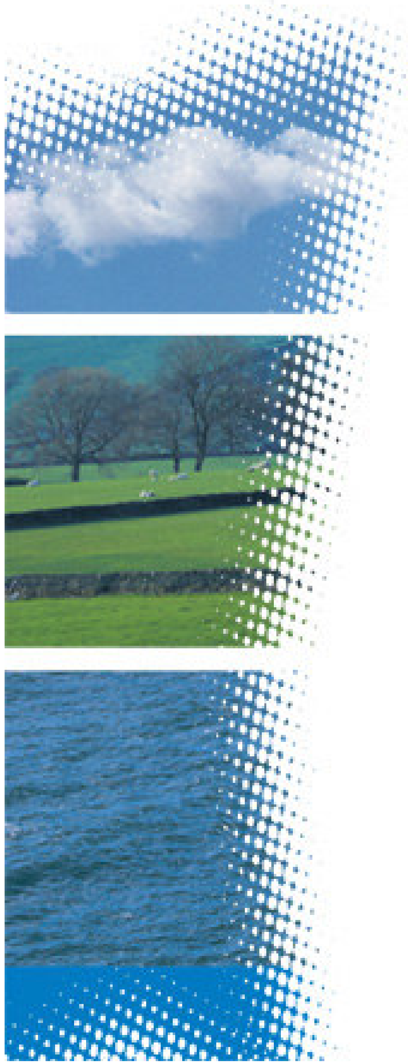
B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

- Incipient Peat Instability
- *Tension Cracks*
- *Peat Creep / Diamond Tears*
- *Peat Pipes*

Tension Cracks – Source: SE peat Slide Risk Assessment For Electricity Generating Plants,

Scottish Executive, Dec 2006



B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

Incipient Peat Instability

• *Peat Creep / Diamond Tears*

Diamond Tears – Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

Incipient Peat Instability

- *Peat Pipes*

Peat Pipes – Source: SE peat Slide Risk Assessment For Electricity Generating Plants,

Scottish Executive, Dec 2006

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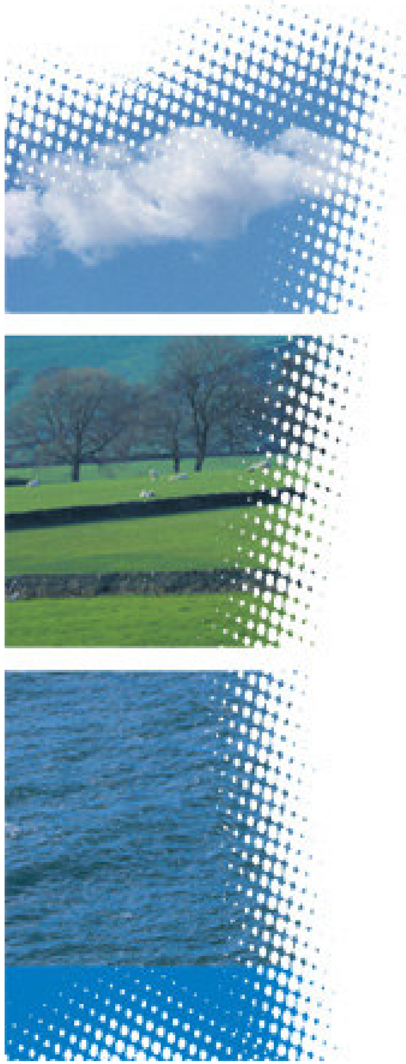

B3 What Triggers A Peat Slide / Bog Burst?

Environmental Factors

Relic Peat Instability

• *Landforms*

Peat Thrusts – Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

Peat Ridges – Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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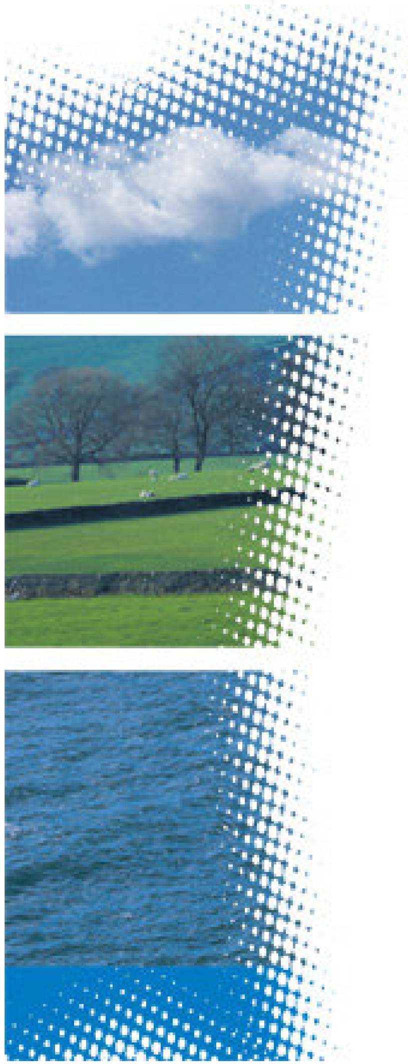


B3 What Triggers A Peat Slide / Bog Burst?

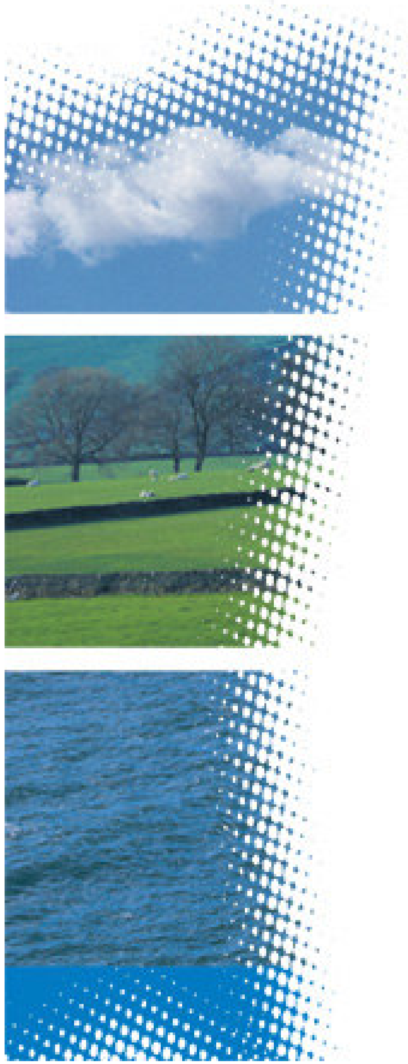
Triggering Incidents

- ***Periods Of Rapid / Excessive Rainfall***
- ***Changes In Hydrology (e.g. blocking drains etc.)***
- ***Excessive Dewatering Of Peat (e.g. highly positive drainage)***
- ***Loading Of Peat (e.g. disposal of more than 0.5m of spoil on peat >1.5m thick)***
- ***Unloading Of Peat (e.g. cuttings in excess of 1.5m deep)***
- ***Excessive Vibrations / Seismic / Sonic Activity (e.g. blasting, rock breaking)***

B4 Typical Data That Will Be Available For Your Construction Site?

Ground Investigation

- ***Desk Study (e.g. Geological maps, mines / water wells etc.)***
- ***Walk Over Assessments (Sinkholes, land slides etc.)***
- ***Analysis Of Topographic Data (Slope magnitude / direction)***
- ***Measurement Of Peat Thickness (Direct probing)***
- ***Measurement Of Peat Strength (Vane test)***
- ***Analysis Of Peat Competence (Peat coring – Von post)***



B4 How Can I Measure Risk At My Site?

Typical Topographic Data

Ardmore Wind Farm

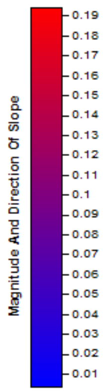
Slope Magnitude & Direction

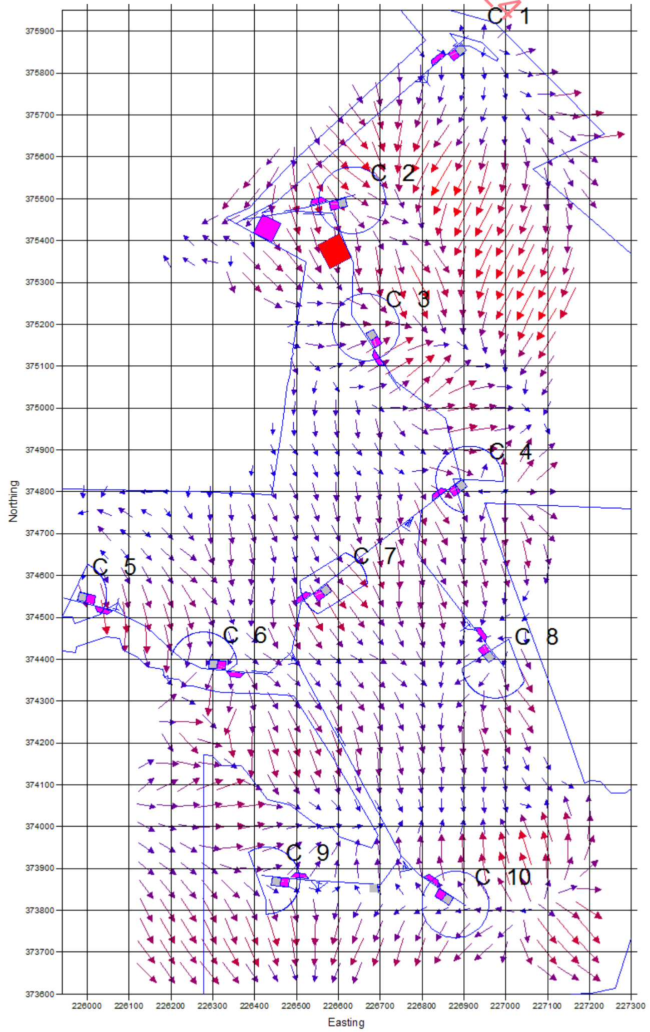
Vector Magnitude & Direction Plot

6th November 2008

NOTES:

1. Gridding carried out using a Kriging Function
2. Grid spacing of 50m applied to produce smoothed contours from collected data
3. Maximum peat depth encountered was 4.6m at E=227647, N=376656





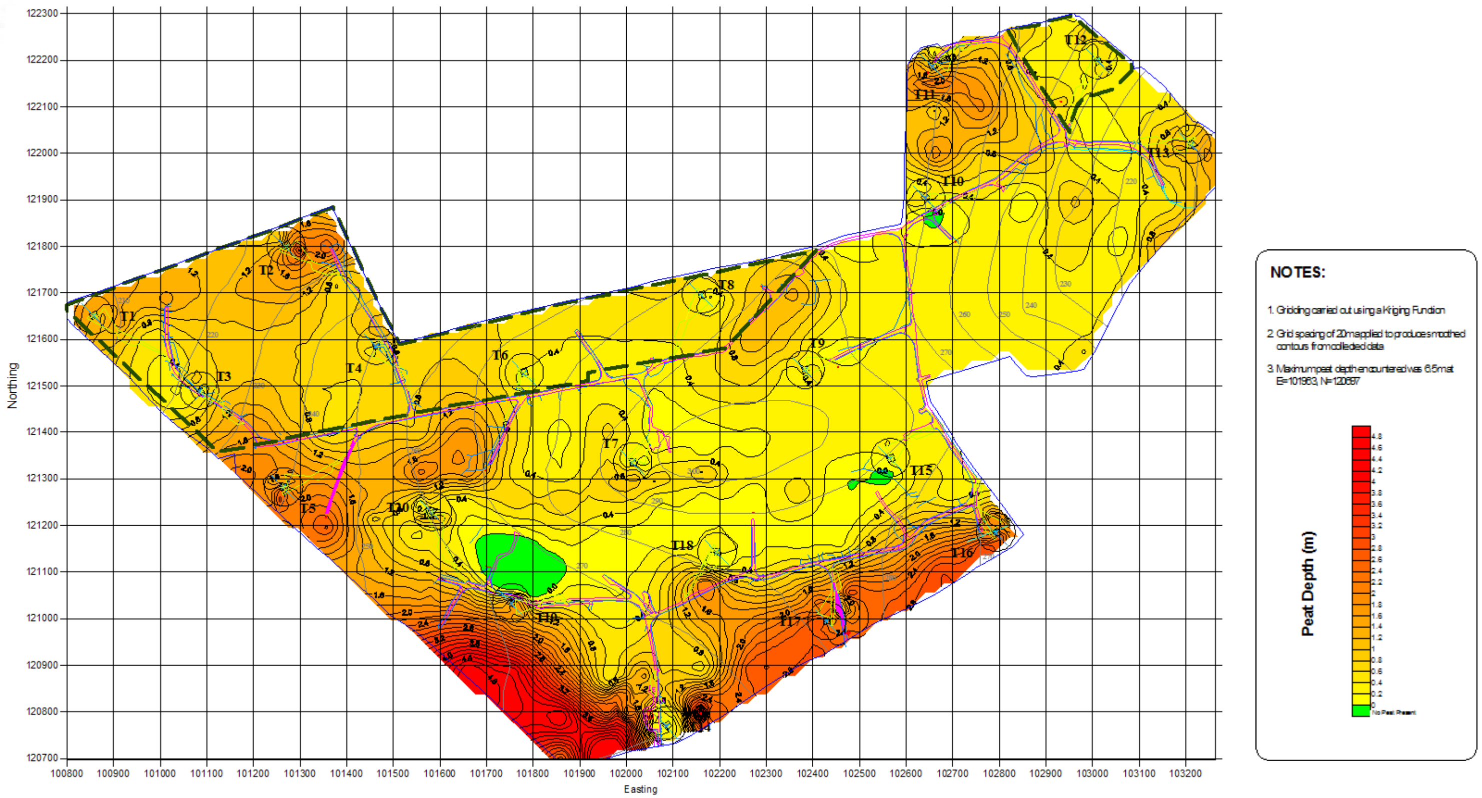
Peat Slide Risk – *Preventative Action*

B4 How Can I Measure Risk At My Site?

Typical Peat Thickness Data

Lisnamoyle Wind Farm
Peat Probing Survey

Contoured Peat Thickness (m)
20th December 2008



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B4 How Can I Measure Risk At My Site?

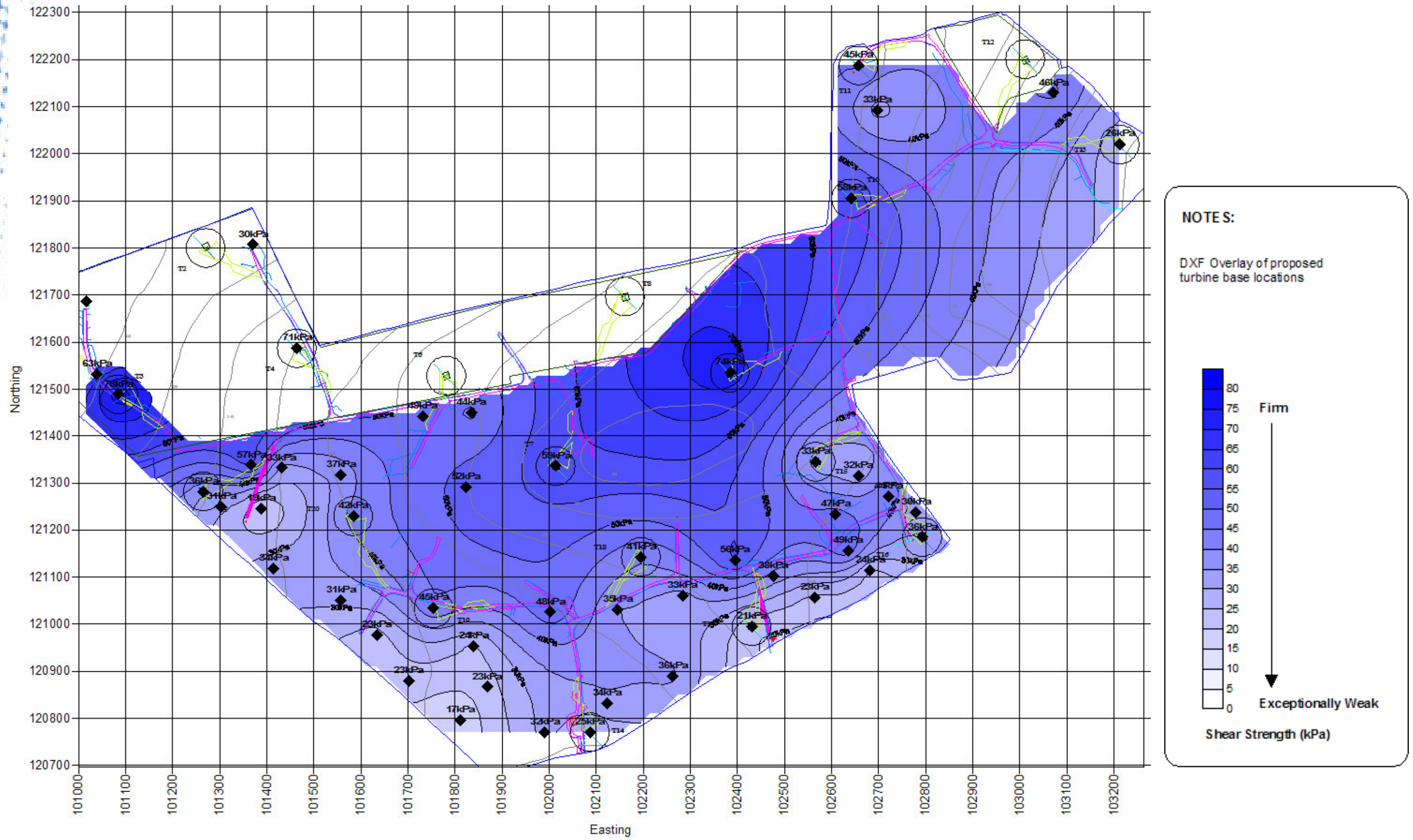
Typical Analysis Of Peat Strength

Lisnamoyie Wind Farm

Peat Assessment - Peat Strength

Average Shear Strength (0m - 1.5m)

28th December 2008



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B4 How Can I Measure Risk At My Site?

Typical Analysis Of Peat Competence – Von Post

Von Post Humification Scale - Lisnamoyle Wind Farm

Client : Lisnamoyle Wind Farm Ltd
Location : Virginia, Co. Cavan
Date : 12-13 November 2008

Turbine Locations

ID	Geographic Coordinates		Peat Characteristics														Peat Thickness (m)	Underlying Soil Type
	Easting	Northing	0.3 m	0.6 m	0.9 m	1.2 m	1.5 m	1.8 m	2.1 m	2.4 m	2.7 m	3 m	3.3 m	3.6 m	3.9 m	4 m		
T3	101085	121489	H4														0.27	Silty SAND & GRAVEL
T4	101464	121587	H4	H5													0.45	Sandy, gravelly SILT
T5	101265	121282	H4	H5	H5	H6	H6	H7	H8								2	Silty SAND & GRAVEL
T7	102014	121336	H4														0.25	Sandy, gravelly SILT
T9	102385	121535	n/a														n/a	Sandy SILT
T10	102642	121905	n/a														n/a	Sandy, gravelly SILT
T11	102657	122187	H3	H3	H4												0.9	Sandy, gravelly SILT
T12A	103071	122129	n/a														n/a	SILT
T13	103212	122020	H3	H4													0.6	Sandy, gravelly SILT
T14	102087	120771	H4	H4	H4	H5											1.05	Sandy, gravelly SILT
T15	102566	121345	H3	H3													0.5	Sandy, gravelly SILT
T16	102793	121185	H3	H3	H3	H4	H5	H5	H6								2.05	Sandy CLAY
T17	102430	120996	H3	H4	H4	H4	H5	H5	H6	H6	H7	H7	H7				3.1	Sandy, gravelly SILT
T18	102195	121143	n/a														n/a	SILT
T19	101754	121034	H3	H3	H4	H4											1.2	Silty SAND & GRAVEL
T20	101584	121230	H3	H4	H5												0.95	Sandy, gravelly SILT

Peat Characteristics

Note:
Green refers to new location (original location inaccessible due to very thick forest).

H1 - Completely undecomposed peat; only clear water can be squeezed from peat.
H2 - Almost undecomposed; mud free peat; water squeezed from peat is almost clear.
H3 - Very little decomposition; very slightly muddy peat; water squeezed from peat is muddy
H4 - Poorly decomposed; somewhat muddy peat; water squeezed from peat is muddy; residue is muddy but shows structure of peat.
H5 - Somewhat decomposed;muddy growth structure discernible but distinct; some peat passes through fingers when squeezed; compressed residue is muddy.
H6 - Somewhat decompsed; muddy; growth structure indistinct; less than one-third of peat passes through fingers when squeezed; residue very muddy.
H7 - Well decomposed; very muddy; growth structure indistinct; about one-half of peat passes through fingers when squeezed; exuded liquid has a "pudding-like" consistency.
H8 - Well decomposed; growth structure very indistinct; about two-thirds of peat passes through fingers when squeezed; residue consists mainly of roots and resistant fibers.
H9 - Almost completely decomposed; peat is mud-like; almost no growth structure can be seen; almost all of peat passes through the fingers when squeezed.
H10 - Completely decomposed; no discernible growth structure; entire peat mass passes through the fingers when squeezed.

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B4 How Can I Measure Risk At My Site?

Calculation Of Risk

- ***Quantitative Risk Assessment***
- ***Degree Of Risk = Likelihood x Effect***
- ***Hazard Ranking = Hazard x Exposure***

Success Depends On Correct Assessment Of HAZARD and EXPOSURE

Your Consultant Will Have Carried This Out Already – Using The Following Data

(Refer to Annex for details)

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B4 Typical HAZARDS

- ***Peat Depth In Excess Of 1.5m (i.e Cutting into the CATOTELM)***
- ***Level Peat Overlying Sloping Natural Soils / Rock***
- ***Presence Of Particularly Weak Peat***
- ***Cuttings in excess of 1.5m***
- ***Placement Of "Floating" Roads On Any Thickness Of Peat***
- ***Drainage (Positive Drainage Causes Settlement / Negative Drainage Causes Flooding)***
- ***Surface Loading Of Peat (Spoil Disposal > 0.5m Thick)***
- ***Presence Of Recent, Incipient and Relic Peat Instability***

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B4 Typical EXPOSURE

- ***An Event Likely To Cause Degradation Of Habitat***
- ***- Visual Scars***
- ***- Blockage Of Site Drainage***
- ***- Disruption To Site Construction Works***
- ***- Contamination Of Water Courses***
- ***- Damage To Construction Infrastructure / Public Infrastructure***
- ***- Injury / Death – Wildlife And Farm Animals***
- ***- Injury / Death – Workers / General Public***

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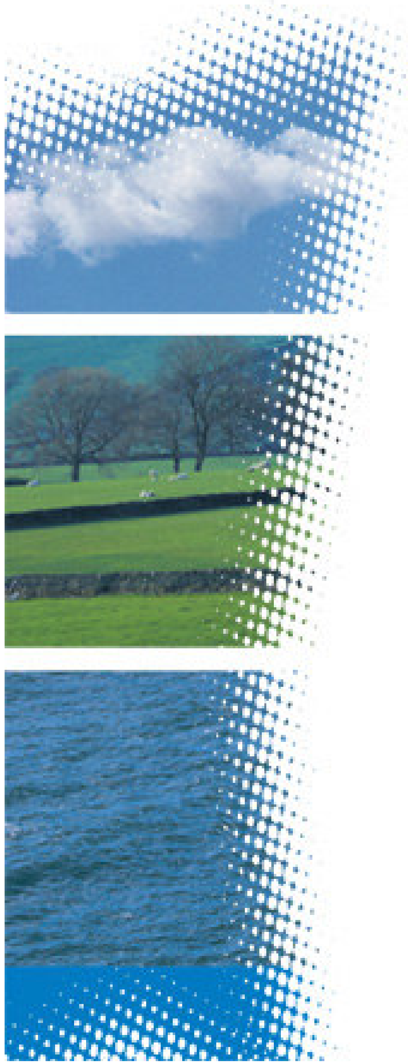

B5 Calculating the Hazard Ranking For Your Site

Typical Breakdown Of Dominant Risk Factors

(External Example – Looking At Effect Of Risk)

Peat Depth (m)	Risk Factor	Slope Angle	Risk Factor	Risk	Risk Factor
> 4.1m	7	12-13˚	7	High	13-14
3.6-4.1m	6	10-11˚	6	Medium/High	11-12
3.1-3.5m	5	7-9°	5	Medium	9-10
2.4-3.0m	4	5-6 °	4	Low/Medium	7-8
1.8-2.3m	3	4-5 °	3	Low	5-6
1.1-1.7m	2	3-4 °	2	Highly Unlikely	3-4
<1m	1	<3 °	1	Negligible	1-2

Alfred McAlpine, 2005

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B5 Calculating the Hazard Ranking For Your Site

Typical Assessment Scale Used

Scale	Likelihood	Probability of occurrence
5	Almost certain	> 1 in 3
4	Probable	1 in 10 - 1 in 3
3	Likely	1 in 10^2 - 1 in 10
2	Unlikely	1 in 10^7 - 1 in 10^2
1	Negligible	< 1 in 10^7

Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

Scale	*Exposure*	*Impact as % of total project cost or time*
5	Extremely high impact	> 100% of project
4	Very high impact	10% - 100%
3	High impact	4% - 10%
2	Low impact	1% - 4%
1	Very low impact	< 1% of project

Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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B5 Calculating the Hazard Ranking For Your Site

Hazard Ranking for each hazard zone		*Action suggested for each hazard zone*
17 - 25	Serious	Avoid project development at these locations
11 - 16	Substantial	Project should not proceed unless hazard can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce hazard ranking to significant or less
5 - 10	Significant	Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations
1-4	Insignificant	Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate

Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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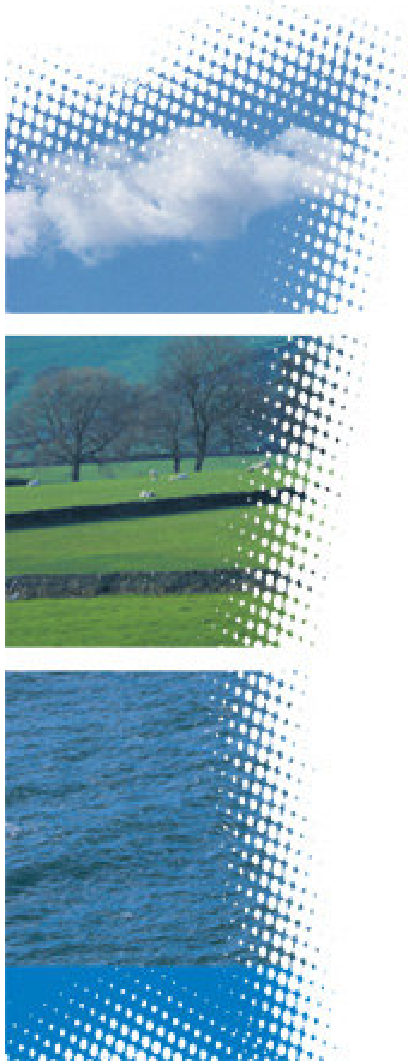

B5 Calculating the Hazard Ranking For Your Site

Typical Analysis (External Example)

Influences and Factors	Description	Scoring
Construction Elements	Turbine 24, associated hardstanding and access tracks are likely to be constructed on glacial tills and possibly weathered rock.	
Peat Depth:	0.5 to 1.5m; For scoring purposes peat depths are considered up to 2 m to reflect a conservative scenario.	1.5
Topography:	Mostly moderately sloping (6 to 15°) with negligible changes in grade.	1.5
Evidence of Instability:	No signs of instability observed.	1.0
Surface Hydrology:	Predominantly well-drained.	0.5
Scale:	Peat depths of up to 2m on rolling terrain.	2.25
Exposure:	Potential to impact on Afton Water / Afton Reservoir	2.0

Sensitivity Score = 1.125

Consequence Score = 4.50

Risk Score = 5.06, Low

Mott MacDonald, 2008

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B5 Calculating the Hazard Ranking For Your Site

Typical Risk Classification System Compared To Scottish Executive Guide

Risk Scoring	Risk Category	*Equivalent Hazard Ranking (S.E. Guide)*
> 90	Very High	*Serious*
40 - 90	High	*Substantial*
8 - 40	Medium	*Significant*
0.5 - 8	Low	*Insignificant*
0 - 0.5	Very Low	
0	Negligible (i.e. no significant depths of peat deposits present)	*Negligible*

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Peat Slide Risk – *Preventative Action*

B5 Calculating the Hazard Ranking For Your Site

Typical Risk Assessment Data (External Example)

Area	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Exposure	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Peat Depth	1.0	0.5	1.5	1.5	1.0	1.5	1.0	1.0	1.5	1.0	1.0	1.0	1.0	1.5
Relief	1.5	2.0	1.0	1.0	1.5	1.0	1.5	1.0	1.5	2.0	1.5	2.0	1.5	1.5
Scale *(Assumed Peat Depth x Relief)*	1.50	1.00	1.50	1.50	1.50	1.50	1.50	1.00	2.25	2.00	1.50	2.00	1.50	2.25
Consequence	**3.00**	**2.00**	**3.00**	**3.00**	**3.00**	**3.00**	**3.00**	**2.00**	**4.50**	**4.00**	**3.00**	**4.00**	**3.00**	**4.50**
Area	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Peat Depth	1.0	0.5	1.5	1.5	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5
Slope Angle / Gradient	1.00	1.50	1.50	1.00	1.00	1.00	1.50	1.00	1.00	2.00	1.50	2.00	1.00	1.50
Surface Loading	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Changes in Grade	1.0	1.0	1.7	1.4	1.0	1.0	1.0	1.7	1.0	1.0	1.7	1.0	1.0	1.0
Topography *(Slope Gradient x Surface Loading x Changes in Grade)*	1.00	1.50	2.55	1.40	1.00	1.00	1.50	1.70	1.00	2.00	2.55	2.00	1.00	1.50
Evidence	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Drainage	1.0	0.5	0.5	0.5	1.0	1.0	0.5	0.5	1.0	0.5	0.5	0.5	1.0	0.5
Surface Hydrology *(=Drainage)*	1.0	0.5	0.5	0.5	1.0	1.0	0.5	0.5	1.0	0.5	0.5	0.5	1.0	0.5
Sensitivity	**1.00**	**0.375**	**1.913**	**1.05**	**1.00**	**1.50**	**0.75**	**0.85**	**1.00**	**1.00**	**1.275**	**1.00**	**1.00**	**1.125**
Area	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Risk Rating Score *(Consequence x Likelihood)*	**3.00**	**0.75**	**5.74**	**3.15**	**3.00**	**4.50**	**2.25**	**1.70**	**4.50**	**4.00**	**3.83**	**4.00**	**3.00**	**5.06**
Qualitative Risk Assigned	L	L	L	L	L	L	L	L	L	L	L	L	L	L

Mott MacDonald, 2008

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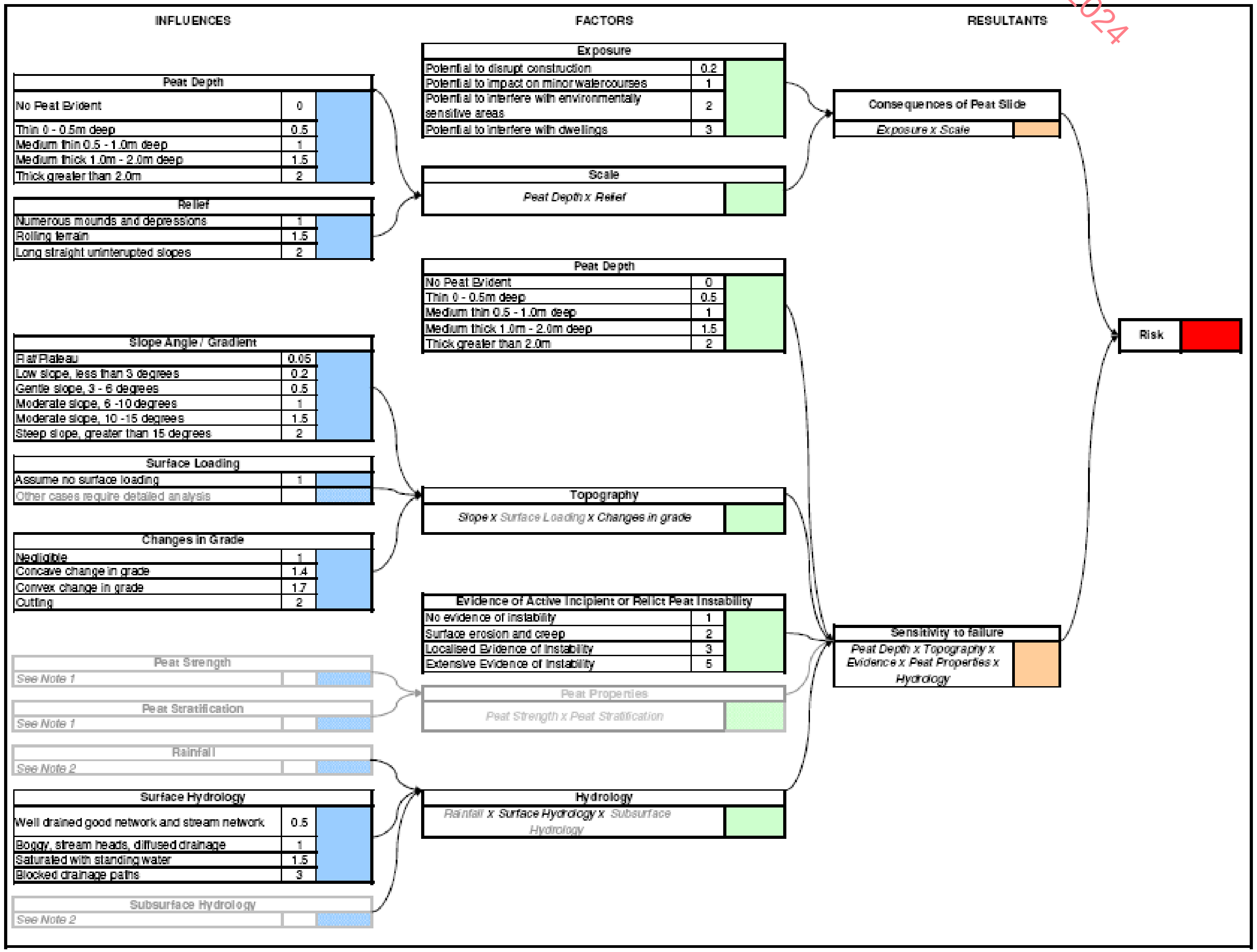
B5 Calculating the Hazard Ranking For Your Site



Mott MacDonald, 2008

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B5 What If Risk Is Calculated To Be…….

INSIGNIFICANT

The Standard Mitigation in the following section will be applicable.

SIGNIFICANT OR SUBSTANTIAL

Is It Possible To Mitigate To An Insignificant Level?

If YES proceed with specific peat slide mitigation in addition to the above.

If NO consider specific peat slide mitigation as well as long term monitoring

SERIOUS

It is unlikely that Serious Levels Of Peat Slide Risk Can Be Mitigated Against In The Current Climate

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B5 Standard Mitigations And Actions

1. Works should always be **supervised by qualified and experienced site staff.**
2. Refer to your detailed Construction Works Plan.
3. Areas of sensitive peat should be clearly mapped and marked out on site. If possible the area should be taped off.
4. **Peat Instability Register.** A file should be created to record observations on peat stability. This will take the form of a daily inspection sheet, signed off by a suitably qualified person. Typical observations are visual observation of slopes, floated road sections, movement detection systems etc. The system is designed to be transferable.
5. **Movement detection systems**. Lightweight canes can be set in lines within sensitive areas to visually determine peat movement.
6. **Effective emergency plan** for dealing with peat slide events.

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B5 Mitigations

7. **Immediate Stabilisation.** Stockpiles of crushed rock should be kept on site, for rapid mobilisation to stabilise slopes or stop flow reaching sensitive receptors.

8. **Defined peat storage / disposal sites**. These should be planned carefully, drainage specifically designed and clearly defined in terms of disposal thickness.

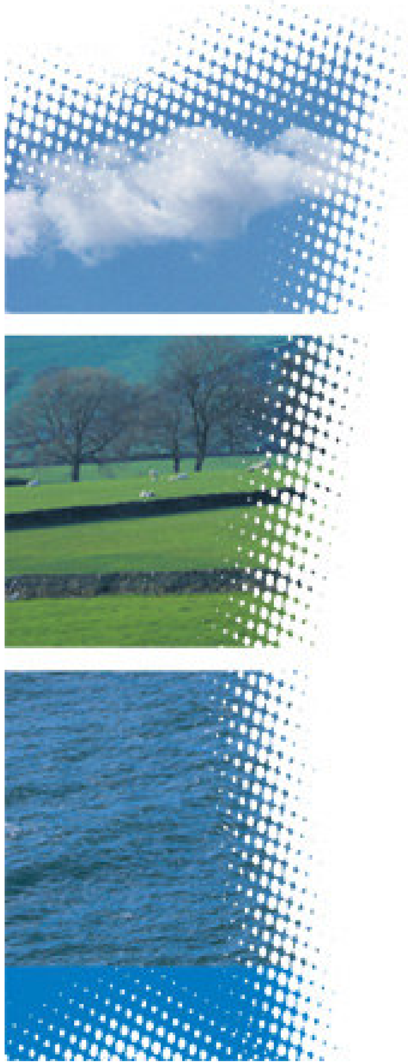
9. In general peat should not be loaded in excess of 0.5m adjacent to excavations unless location specific risk assessment carried out.

10. Drainage Systems must be maintained regularly (Weekly or better)

11. **Catch Wall Fences / Catch Ditches** have been shown to be useful when dealing with stopping small slide before they gather momentum

12. Frequent independent assessment of work practice should be undertaken

13. Regular **analysis of water courses** should be undertaken for indications of sediment infiltration – possible precursor to a peat slide



B5 Mitigations

14. Prior to placement of loads on **bases / crane pads etc. these should be tested** to ensure that overloading does not occur – potentially triggering a peat slide

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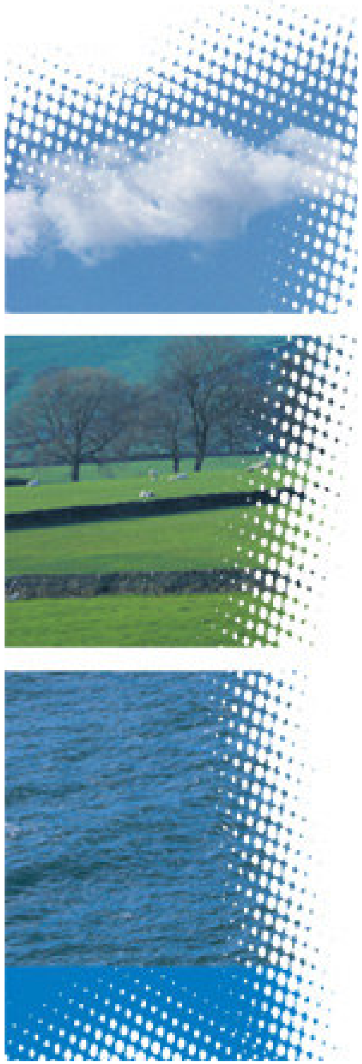
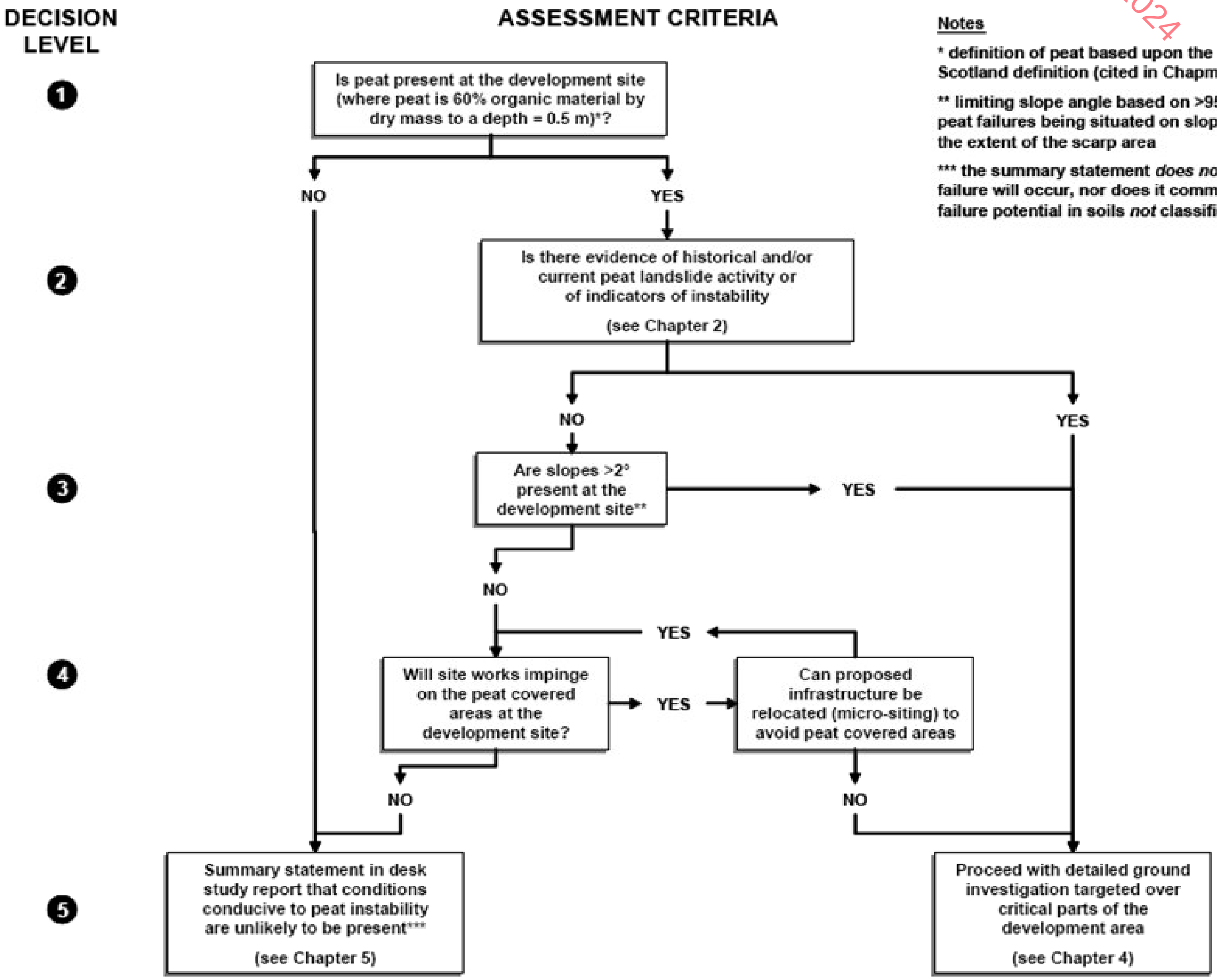


Typical Assessment Procedure That Will Have Been Undertaken At Your Site



Notes

* definition of peat based upon the Soil Survey for Scotland definition (cited in Chapman *et al.*, 2001)

** limiting slope angle based on >95% of published peat failures being situated on slopes > 2° within the extent of the scarp area

*** the summary statement *does not* imply that *no* failure will occur, nor does it comment upon failure potential in soils *not* classified as peat

Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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ANNEX Additional Reference Documents

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D1 Data Sources

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D1 Data Sources

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Tobin (2003) Report On The Landslides At Dooncarton, Barnachuille And Pollathamais, County Mayo. Mayo County Council.

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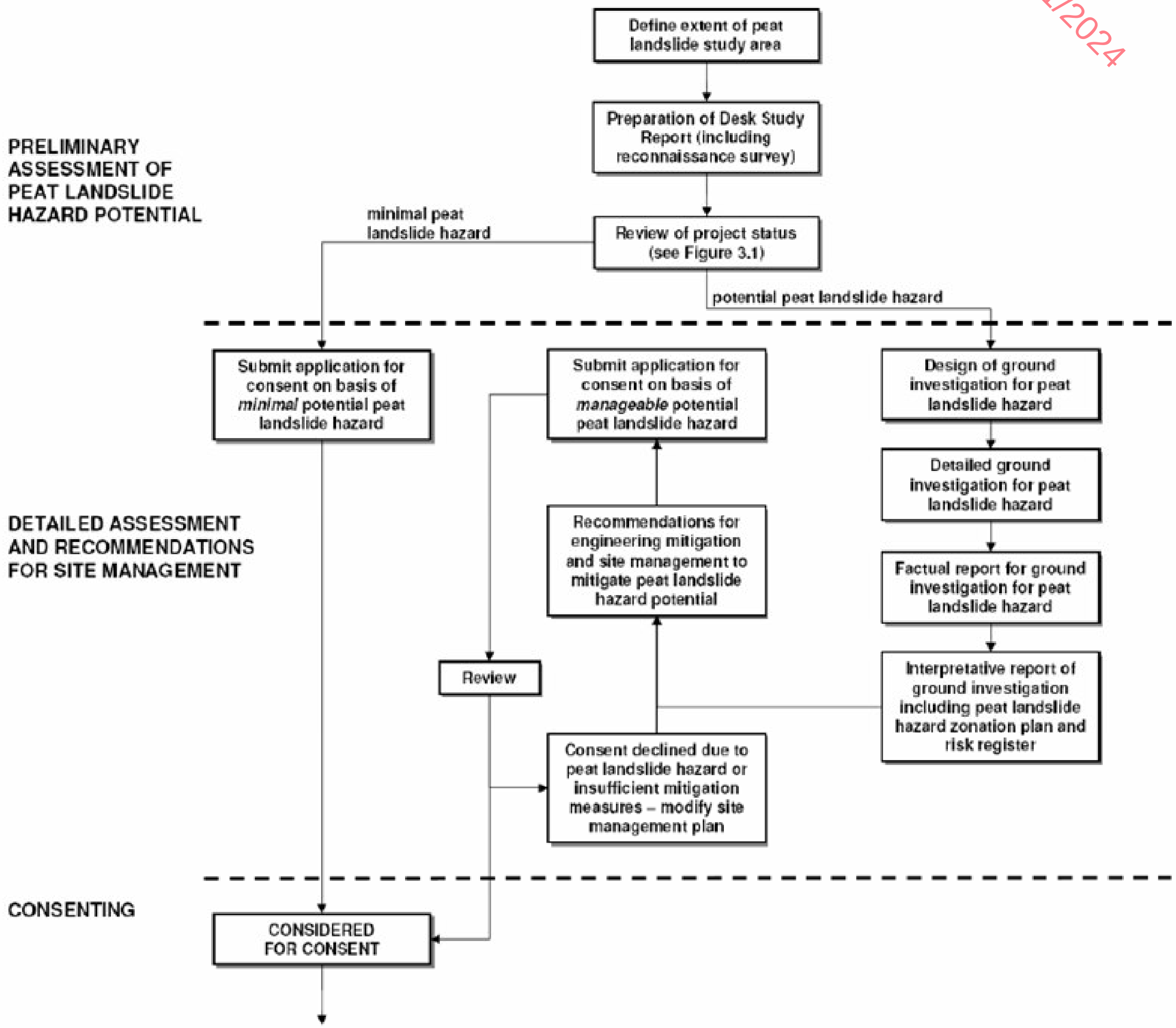
Peat Slide Risk – *Preventative Action*

Peat Risk Assessment – Typical Stages That Should Have Been Undertaken Prior To Commencement Of Construction



Source: SE peat Slide Risk Assessment For Electricity Generating Plants, Scottish Executive, Dec 2006

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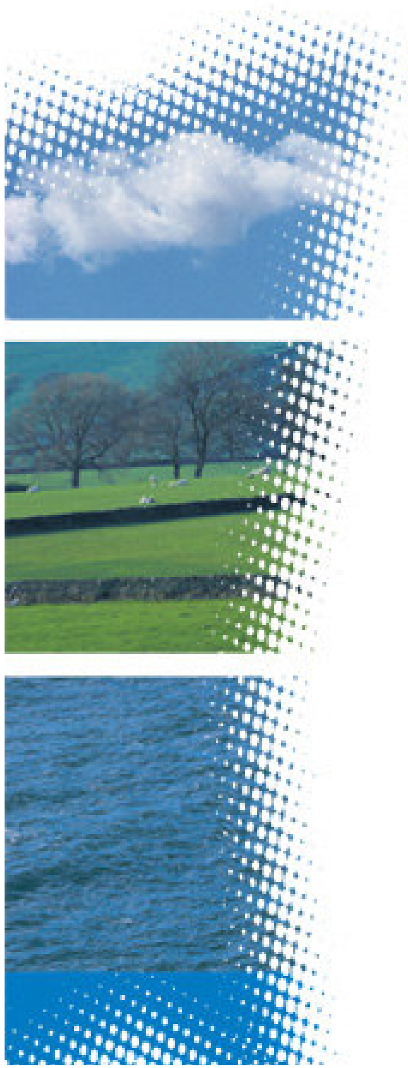

[C] Company Information

- Specialist Site Investigation Contractor
- Established 1996
- Areas Of Expertise:
    - *Geotechnical Ground Investigation*
    - *Geophysical Site Investigation*
    - *Environmental Land Assessment Services*
    - *Service Location Surveys*
    - *Electrical Design Services*
    - *Marine Geotechnical/Geophysical Investigations*
    - *Quarry Resource Mapping*
    - *Wind Energy Ground Investigation (c80 projects)*

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[C] Company Information

Approx. 1,000 Projects Complete To Date

- Clients Include:
  - *Government Bodies (central & local)*
  - *Private Developers*
  - *Engineering Consultants*
  - *Power Providers*
  - *Major Engineering and Construction Companies*

- Areas of Operation: *Ireland, UK, Europe & North America*

- Project size ranges from £5k to £1M

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[C] Previous Wind Energy Projects

Desk Study	•>25 projects *Examples Include:* •*Athybryanmore (Canavan Associates);* •*Altahullion Phase III (RES Ltd)*
Walk Over Assessment / SI	•>70 projects *Examples Include:* •*Dunmore Wind Farm (TCI Renewables)* •*Corkermore (Eco Wind)*
Peat Probing/Gouge Sampling/Vane Testing	•>40 projects *Examples Include:* •*Cloghboola (DW Consulting)* •*Dunneill (Airtricity)* •*Cloontooa (Wind Prospect)*