BEFORE THE COMMISSIONER ON BEHALF OF THE DUNEDIN CITY COUNCIL

UNDER	the Resource Management Act 1991
IN THE MATTER	an application for resource consent of LUC-2015-469
BY	Blueskin Energy Limited
	Applicant

BRIEF OF EVIDENCE OF VIRGINIA GAIL TOY

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Introduction

1. My full name is Virginia Gail Toy. I am a Senior Lecturer in Geology at the University of Otago.

2. I hold a PhD from the University of Otago, awarded in April 2008 for a thesis entitled "Rheology of the Alpine Fault mylonite zone: deformation processes at and below the seismogenic zone in a major plate boundary structure". I also hold a Master's of Philosophy in Earth Sciences from the Australian National university (2006), and MSc(Hons) and BSc degrees in Geology from the University of Auckland (2001, 1999 respectively). My expertise includes general geology of the Otago region, structural geology of faults and shear zones, scientific drilling, and tectonics. I was also employed as an Engineering Geologist in a consultancy in Auckland in 2001-2002, and have taught and supervised projects focusing on the applications of structural geology to geotechnical issues at Otago University while employed there as lecturing faculty since 2008.

3. I confirm that I have read the 'Code of Conduct for Expert Witnesses' contained in the Environment Court Consolidated Practice Note 2014. My evidence has been prepared in compliance with that Code in the same way as I would if giving evidence in the Environment Court. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express. Where I rely on the opinions of another person I have made that plain.

Porteous Hill

4. On 16 January 2016 I undertook a preliminary geological and geotechnical assessment of Porteous Hill, including drilling a series of hand auger boreholes and examining the geology of the site. I examined the geology in the field and using literature and online resources (e.g. aerial photographs, geologic maps, the Dunedin City Council's online 2nd Generation District Plan [2GP] maps). I prepared a preliminary report on geotechnical matters for BEL as part of their site

investigation and consent preparation process. A copy of this report is attached at **Appendix A**.

5. On 7 April 2016 I undertook further geological and geotechnical investigations of Porteous Hill, by excavating three test pits adjacent to the proposed turbine foundation sites. These were excavated to depths of 2.8 m (S site, turbine #1), and 2.2 m (N and W sites, turbines # 2 and 3 respectively).

6. During this investigation on 7 April 2016 I was accompanied onsite by Mr Mark Walrond (Engineering Geologist at Geosolve Ltd., who I understand will be officially engaged to undertake geotechnical investigations of the proposed turbine site and prepare foundation designs required to apply for building consent), and Mr Nigel Stevenson, a Karitane resident and 3rd year geology student at the University of Otago. Mr. Stevenson is currently undertaking a geological mapping project in the area – the results of which will partly fulfill the requirements for his BSc in geology and will provide further information to allow proper geotechnical design to be carried out for the turbine foundations.

7. As a result of the investigations we undertook on 7 April 2016 Mr Walrond is preparing a further report.

8. He has advised me that the conclusions and recommendations of that report are:

   - At this preliminary stage, the site appears well suited to the proposed development, with volcanic rock available at shallow depth at two of the three turbine sites. Further investigations are required for detailed design.
   - Extensive landslides occur on the flanks of Porteous Hill, however the crest is clearly underlain by volcanic rock and appears to be stable with subdued topography. Owing to the proximity of landslide features locally a cautious approach should however be adopted and further evaluation of slope stability is recommended based on full geotechnical review of existing information.
   - We recommend that additional geological mapping and a review of stereoscopic aerial photography should be carried out to better delineate the extents of slope instability and to determine any further requirement for investigation. Survey inputs to determine if benchmarks have moved

historically could be attempted and drilling is recommended to fully confirm the apparent absence of potential deep-seated landslides below the volcanic capping rocks.

- Attention will be required to assess the slopes below the sites. Cross sections should be generated and slope stability analysis carried out once the final platforms are confirmed and following additional mapping and subsurface investigations. These analyses should consider both static and seismic stability.
- Following excavation for pad foundations, careful mapping and evaluation of any defects and lineaments encountered will be required within the foundation excavations, and stability analysis should be carried at that stage to confirm safety factors.
- No mining has been carried out in the vicinity of the site and there is a very low likelihood of any natural subterranean cavities in the rock types on site. The rock types in this area are volcanic with no likelihood of calcareous sedimentary rocks at shallow or moderate depth. Consequently the likelihood of encountering sinkholes or other cavities associated with chemical weathering is considered very low.
- There are no potential sources of debris inundation, rock fall or rock roll that could affect these hill crest sites from upslope sources.
- Further geotechnical investigations are required for detailed design, particularly for Turbine Site 2 to verify the depth of soil cover and to determine if the landslide debris identified presents any slope stability design constraints.
- We recommend that the manufacturer should be asked to specify the type of testing required to meet their requirements, based on the preliminary ground model described in this report.
- The proposed earthworks and foundation design should be agreed with a geotechnical specialist prior to construction.
- All unsuitable materials identified in foundation excavations, particularly those softened by exposure to water, should be undercut and replaced with engineered fill during construction. Any fill that is utilised as bearing for foundations should be placed and compacted in accordance with NZS 4431:1989 and certification provided to that effect.
- Groundwater issues are not expected to result in geotechnical constraints. A geotechnical practitioner should inspect all excavations and

additionally any seepage, spring flow or under-runners that may be encountered during construction.

9. In addition to Mr. Walrond's summary, I made the following observations that I think should be accounted for in consideration of the resource consent application:

(a) The excavations revealed that my preliminary assessment, based on hand augers, was not entirely correct. During my investigation in February, based on 'refusal' of the hand auger, I inferred that solid volcanic rock underlay the site at depths ranging from 0.2 – 1.2 m. The test pits revealed that the sites are actually underlain by cobbles to boulders of intact rock ranging from 10-50cm diameter in a matrix of sand, silt and clay. This composite was deposited as a solid basalt >10 million years ago and has been subject to extensive *insitu* weathering in the interim. I suspect that, during hand-drilling, the auger was 'refused' when I encountered boulders of unaltered/unweathered basalt. These rock fragments, which comprise between 20 and 50% of the subsurface rock mass, are embedded in a very stiff, sand-silt-clay soil. The composite material is still a stiff to very stiff soil and I would expect that it will have sufficient bearing capacity to support the proposed towers, and will be sufficiently uniform to do so without differential settlement occurring.

(b) The depth to solid rock is greater than the depth of test pits (2.8 m at turbine site 1., 2.2 m at turbine site 2, 2.2 m at turbine site 3).

(c) We did not encounter groundwater in any of the test pits. I suspect that the long term groundwater level is below the base of our pits but this has been a very dry summer and I cannot predict what level the water will rise to during heavy rainfall. However, Mr. Stevenson has installed a number of piezometers in the area and intends to monitor groundwater levels in these over the coming winter, so better data should be available in future.

(d) The pits dug at proposed turbine sites 1 and 3 revealed material (below a surifical veneer of topsoil that has probably been disturbed by ploughing of fields) with an appearance characteristic of *in situ* weathering – in other words there was no indication it has been significantly disturbed (e.g. by lateral shearing as part of a landslide mass or similar) since its deposition.

(e) At site 2 we observed some slightly striated surfaces within the weathered volcanic clays, silts, sands and cobbles. These striae suggest the constituent materials have been sheared with respect to one another. The best explanation for this is that there has been some lateral disturbance of the soil mass by downslope sliding – this may have been slow and progressive over hundreds to thousands of years, or rapid during excessive rainfall events or Earthquake loading – so this sort of process might not present a hazard to the foundations of the turbine at this site. However, I strongly recommend that further investigations of potential stability be undertaken at this site before construction of the turbine. It would be best to check for significant surfaces that might present easy sliding surfaces in future by recovering intact drillcore from depths up to 2.0 m.

(f) There is a fairly steep slope on the eastern side of proposed turbine site 1. If the stiff weathered basalts that make up the highest 20 or so metres of the site do experience lateral shearing in future (which I suspect would only occur during extreme rainfall or the largest possible earthquake shaking indicated in NZ Seismic Hazard models), this slope presents a free face toward which downslope sliding could occur. The site should be subject to careful geotechnical assessment, and foundations of any turbine at the site should be set as far as possible to the west of the crest of steep slope – preferably at least 5.0m.

Conclusion

10. In conclusion, I agree with the Council's geotechnical advisor (Lee Paterson of MWH) who recommended that the site is generally geotechnically suitable for the proposed wind farm development. If properly sited, and with proper geotechnical investigation and design, we

believe that the turbine foundations will be stable and sound. However, we do think that further investigation of stability, particularly recovery of intact drillcores at proposed turbine site 2 to assess the prevalence and importance of the sheared surfaces we observed in spoil from the test pits, along with measurement of slope profiles and validation of slope stability models at all sites, is necessary.

11. I note that the draft proposed conditions for the resource consent (section 8 of the DCC Planner's Report) do not presently contain any requirement for further geotechnical investigation of the site. I recommend that such a condition should be added.

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Virginia Gail Toy

2 May 2016

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Appendix A

Geological and Geotechnical Report on Porteous Hill Wind Farm Site

Introduction

I (Virginia Toy) am a Senior Lecturer in Geology at the University of Otago, specialising in Structural Geology. Some years ago (2001-2002) I worked as an Engineering Geologist for private consultancies in the Auckland Region, where I was involved in foundation investigations for proposed housing, earthworks management for subdivisions, and undertook numerous slope stability analyses. At that time I was a member of the Institute of Professional Engineers of New Zealand (IPENZ), but I have not maintained this membership, and I have never been awarded registered engineer status. I have also worked at the University of Otago as faculty since 2008, during which time I have examined a lot of the geological terrain of the Otago region, as I have taught field geology and supervised a number of student projects mapping the Otago rock sequence, including a slope stability investigation of the Mt. Cargill Road by James Griffiths in 2014.

I have examined the proposed site of the wind turbine installation proposed by Blueskin Energy Ltd., and report on my observations herein. It is important to note that I am providing my personal opinion of the geotechnical aspects of the site, based on my own experience. My employers are not responsible for my opinions, and I reiterate that I am not a Registered Engineer. I strongly recommend that more thorough foundation investigations should be undertaken by an IPENZ Registered Engineer before construction of the turbines.

Terrain of the site

Proposed turbine sites 1 and 2 are on top of hills. These are comparatively flat, with increasing slopes leading downhill (<26-35°).

Proposed site 3 lies in a saddle, to the east of the crest of the ridge between the other two sites. The terrain slopes gently (~5°) toward the east.

Geology of the site

The site is underlain by basalts of the Dunedin Volcanic Group (Figs. 1, 2). These are solid volcanic rocks, ie. 'strong' to 'very strong' in the geotechnical sense (refer to classification in Appendix 1). They were deposited from 10-6 million years ago, and have since experienced substantial near-surface weathering, so now they are geotechnically 'highly-weathered' to 'completely -weathered' (App. 1). Weathering resulted in formation of a horizon of soil that is 'medium dense' to ' very dense' in the geotechnical sense (App. 1) with a thin veneer of topsoil (again, in the geotechnical sense, a soil containing substantial organic matter; App. 1). The soil contains numerous less weathered boulders of hard rock. These remnants can be observed outcropping at proposed turbine sites 1 and 2. The area around the immediate site is underlain by Tertiary sedimentary units (Fig. 2).

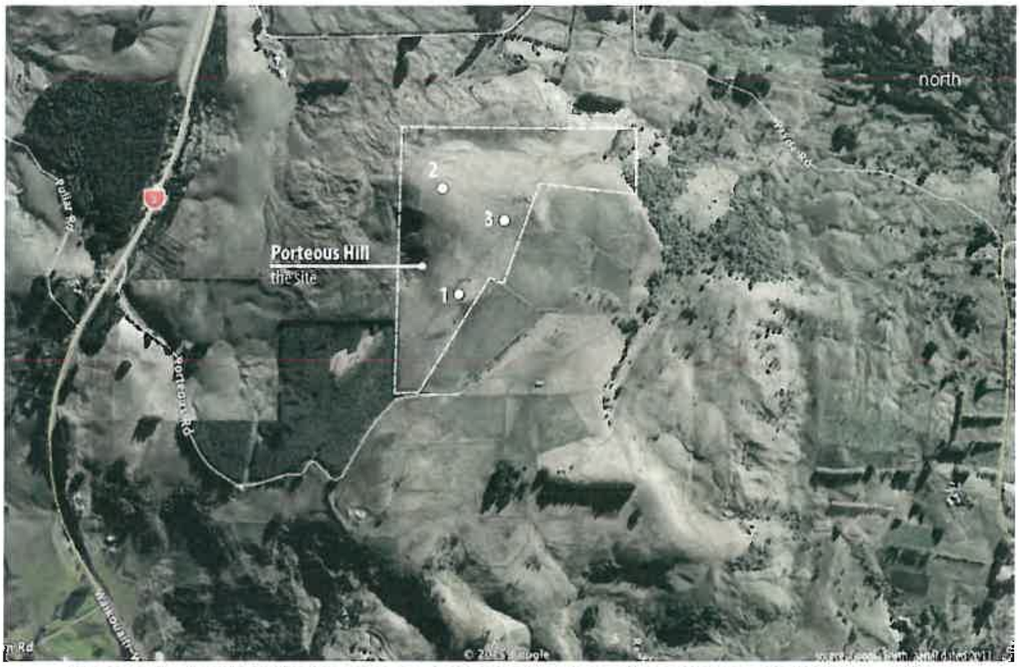

Figure 1: Aerial photograph demonstrating the proposed turbine sites

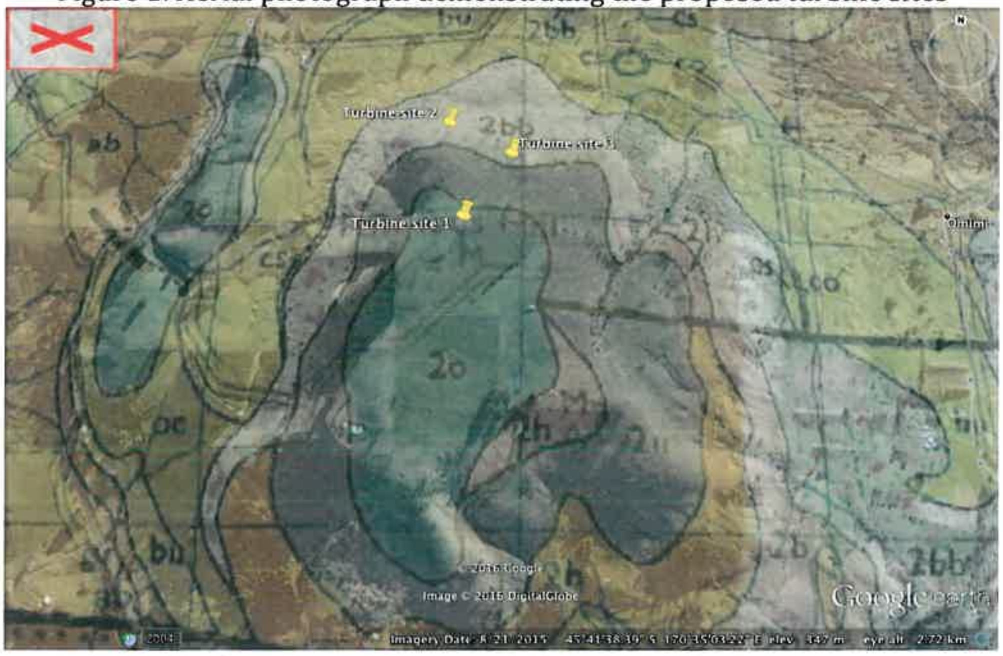

Figure 2: Geological map overlain on aerial photograph of the proposed turbine sites. The area covered is similar to that in Fig. 1. Geological units are either basalts (2o = olivine basalt; 2h = Waitati phonolite; 2m = mugearite; 2n = nepheline diorite); 2bb = basaltic breccia; or Tertiary sedimentary units (cs = Caversham sandstone; co = Concord greensand and Scroggs Hill limestone; br = Brighton formation limestone and shelly greensand; gr = Green Island loose sand; ab = Abbortsford mudstone). The Tertiary sediments are much more susceptible to landsliding than the basalts as they are comparatively unconsolidated.

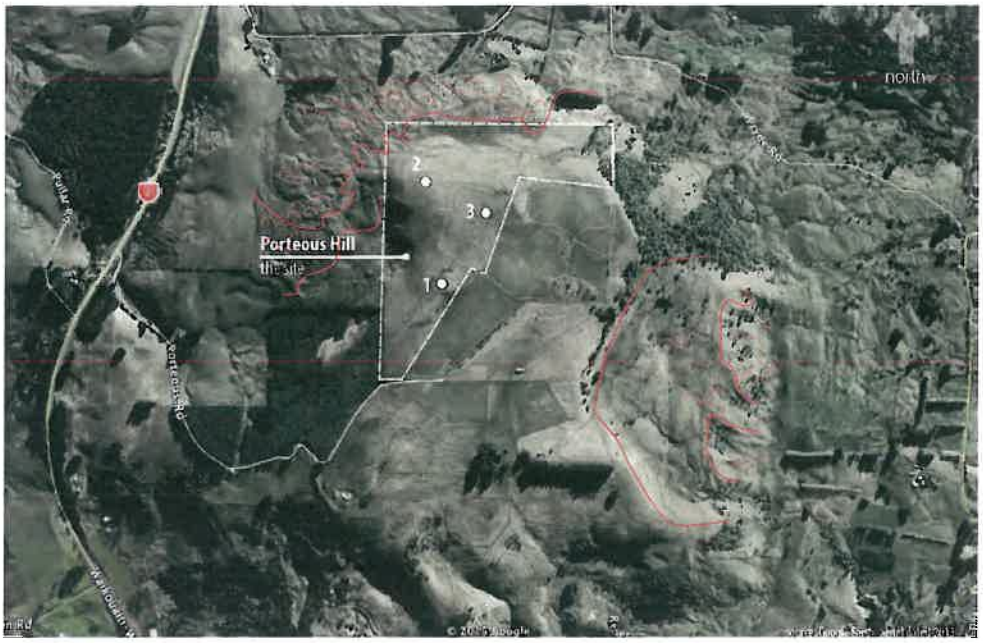

Figure 3: Aerial photograph of the proposed turbine sites with red annotations indicating typical topographic expression of landslides. Solid red lines are 'headscarps' – ie. the upslope limit of the slides; scallops indicate 'hummocky topography' typical of the slumped soil that has separated from the headscarp and slid downhill.

Hand auger borehole investigation

Hand auger boreholes were put down at all three proposed turbine sites on 16 January 2016. Logs of proposed turbine sites 1 and 3 are presented here (Figs. 4 and 5). At site 2, I attempted to drill 5 boreholes, but in all I encountered material that was too hard to auger (THAT) at <0.2m. A scala penetrometer test in one of these holes yielded >17 bolws/100mm, ie. a 'very dense' soil in the geotechnical sense (App. 1).

In both these boreholes I encountered a thin veneer of topsoil (<0.25m), with estimated organic content <30% (and probably <10%). The underlying soil was an orange-brown, slightly clayey fine sand containing subrounded clasts of weathered basalt and tuff <1cm diameter. Based on my observations of outcrops elsewhere in the Otago area, I infer this is a highly weathered basalt. Groundwater was not encountered in any of the boreholes. Scala penetrometer tests required >2.5 (and mostly >17) blows/100mm, demonstrating these are 'medium dense' to 'very dense' soils (App. 1).

HAND AUGER BOREHOLE LOG	DATE:	LOGGED BY:
LOCATION: Porteous Hill. Blueskin Energy Wind Turbine site 1	16 Jan 2016	Dr. Virginia Toy
JOB NUMBER:		

m	GRAPHICAL	DESCRIPTIVE LOG	WATER	SCALA (blows/100mm)	SAMPLE
0		TOPSOIL. 30 % organic matter, in silt + 20% fine-medium sand + 5% subrounded clasts <8mm of weathered volcanics. Slightly damp.	not encountered		
		WEATHERED BASALT. Dark brown streaked with orange, cream, light yellow silt to fine sand. Dry. <10% organic matter, reducing with depth.			
0.5				7.0	
		No more organic matter. Mostly medium orange, with pale orange and black streaks < 10% clay, very fine sand and silt with occasional rounded clasts of weathered basalt <1cm			
		Becomes damp. Medium sand now <5%.			
1.0		Gritty, drilled through a very weathered volcanic clast recovered as fine grey sand.		2.5	
		EOB - Too hard to auger (THTA)		3.0	
1.5					

HAND AUGER BOREHOLE LOG	DATE:	LOGGED BY:
LOCATION: Porteous Hill. Blueskin Energy Wind Turbine site 3 JOB NUMBER:	16 Jan 2016	Dr. Virginia Toy

m	GRAPHICAL	DESCRIPTIVE LOG	WATER	SCALA (blows/100mm)	SAMPLE
0		TOPSOIL. 10 % organic matter, in silt + 5% subrounded light grey + orange clasts <8mm.	not encountered		
		WEATHERED BASALT. Medium orange streaked with brown, orange, black, light grey Silt to fine + medium sand + subrounded clasts <1cm and weathered basalt patches (grey, sandy)<2cm. Dry. <5% organic matter, reducing with depth.		10.0	
0.5		Becomes slightly clayey, with light yellow, black and grey streaks in medium orange brown matrix		5.5	
		EOB - Too hard to auger (THTA)		10.0 20.0	
1.0					
1.5					

"Test pits"

During construction of a wind strength testing tower in February 2013, a number of <2.0m deep pits were dug near to proposed turbine site 2 (Fig. 6). I have examined photographs of these pits, and observe that the material recovered within them appear similar to the soil I recovered during the hand auger investigation reported herein. Again, groundwater was not encountered in any of these pits.

Figure 6: Photograph of test pit dug for testing tower foundation

Foundation conditions

As previously noted, the soils encountered at the site are 'medium dense' to 'very dense' in a geotechnical sense (App. 1). At the time of this investigation these soils were dry. I have read the recommendations of the turbine manufacturers (Enercon) for foundations, and tentatively suggest that they will be able to construct 'shallow foundations without buoyancy', the simplest of their proposed solutions. However, more thorough investigations of load bearing capacity of the soils should be undertaken using a cone penetrometer (CPT) before the turbines are constructed.

Slope stability

Where Tertiary sedimentary units outcrop elsewhere in the greater Dunedin area they are known to be prone to slope instability. Historically, large landslides have affected units like the Caversham sandstone and Abbotsford mudstone (e.g. the famous Abbotsford landslide in 1979; Stuart, 1979, Bishop & Turnbull, 1996). The 'Kilmog' area, close to the proposed site, is also renowned for slope instability issues that have affected State Highway 1 (Te Ara). Where Tertiary sediments (Fig. 2) outcrop around the proposed turbine site, the geomorphology indicates slope instability (Fig. 1). Acuate scarps and hummocky ground (Fig. 3) are a typical geomorphic expression of shallow-seated soil slides. In the Porteous Hill area, this landslide geomorphology is restricted to the slopes significantly downhill of the proposed turbine sites. There are no geomorphic signs of slope instability on the basaltic units that underlie the turbine sites themselves. This is testament to the relative competency of the soils derived from these units by weathering.

The revised Dunedin City Council 2nd Generation District Plan identifies 'slope awareness zones'. Slopes with inclinations $>12^0$ are typically investigated closely for landslide potential. The slopes adjacent to proposed turbine sites 1 and 2 are up to $26\text{-}35^0$. It is recommended that cross sectional profiles of these sites be constructed, and slope stability analyses undertaken before construction of the turbines. However, as previously noted, the strong, well-drained soils are not expected to be subject to slope instability.

Groundwater

I expect the sandy soils that underlie the site are fairly permeable. Absence of groundwater to depths of 2.0m in the test pits supports this inference. The Dunedin volcanic group rocks typically act as reservoirs for springs, such as those that emanate from Mihiwaka onto Blueskin Road and Mt. Kettle onto Mt. Cargill Road. These are replenished by meteoric water (ie. rainfall); recharge is by permeation of rain through the surface. The three proposed circular, 5.5m diameter turbine foundations will cover $71.3m^3$ of the total $>28{,}000m^3$ of the site (this is the area of a triangle encompassing all proposed turbines foundations). This is 0.25% of the area through which meteoric recharge usually occurs and I do not think there will be a significant effect on the total water volumes able to enter the soil mass as a consequence.

Elevated groundwater levels are also know to influence slope stability. However, since the soils are well-drained, groundwater was not encountered in any subsurface excavation to 2.0m depth, and because the construction of foundations should not significantly impact recharge or perturb runoff, I do not think this is a major concern. That said, it would be worthwhile to install piezometers around site 3 over winter to check

Also, the high permeability of the soils and absence of groundwater in boreholes suggests elevated water tables rarely develop within the thin soil veneer on the basalt underlying the site.

Conclusion

The site is underlain by very competent soils. These should provide very good foundation conditions, and should not be subject to landsliding. There will also be minimal effect on groundwater transfer through the area as a consequence of the construction of the foundations for the turbines.

References

Benson, W.N. 1969. Geological Map of the Dunedin District. New Zealand Geological Survey Miscellaneous Map Series, 1.

Bishop, D.G., Turnbull, I.M. (compilers) (1996). Geology of the Dunedin Area. Lower Hutt, NZ: Institute of Geological & Nuclear Sciences. ISBN 0-478-09521-X. 33pp.

Stuart, I. A. 1979. Landslide! The Abbotsford disaster. Dunedin: Allied Press.

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Dr. Virginia Toy

Senior Lecturer in Geology, University of Otago

Appendix:

NZ GEOTECHNICAL SOCIETY INC

ROCK > field guide sheet

FIELD DESCRIPTION OF ROCK

SEQUENCE OF TERMS - weathering - colour - fabric - rock name - strength - discontinuities - additional

SCALE OF ROCK MASS WEATHERING

Term	Grade	Abbreviation	Description
Unweathered (fresh rock)	I	UW	Rock mass shows no loss of strength, discolouration or other effects due to weathering. There may be slight discolouration on major rock mass defect surfaces or on clasts.
Slightly Weathered	II	SW	The rock mass is not significantly weaker than when fresh. Rock may be discoloured along defects, some of which may have been opened slightly.
Moderately Weathered	III	MW	The rock mass is significantly weaker than the fresh rock and part of the rock mass may have been changed to a soil. Rock material may be discoloured and defect and clast surfaces will have a greater discolouration, which also penetrates slightly into the rock material. Increase in density of defects due to physical disintegration.
Highly Weathered	IV	HW	Most of the original rock mass strength is lost. Material is discoloured and more than half the mass is changed to a soil by chemical decomposition or disintegration (increase in density of defects/fractures). Decomposition adjacent to defects and at the surface of clasts penetrates deeply into the rock material. Lithorelicts or corestones of unweathered or slightly weathered rock may be present.
Completely Weathered	V	CW	Original rock strength is lost and the rock mass changed to a soil either by decomposition (with some rock fabric preserved) or by physical disintegration.
Residual Soil	VI	RS	Rock is completely changed to a soil with the original fabric destroyed (pedological soil).

ROCK STRENGTH TERMS

Term	Field Identification of Specimen	Unconfined uniaxial compressive strength q_u (MPa)	Point load strength $I_{s(50)}$ (MPa)
Extremely strong	Can only be chipped with geological hammer	> 250	>10
Very strong	Requires many blows of geological hammer to break it	100 – 250	5 – 10
Strong	Requires more than one blow of geological hammer to fracture it	50 – 100	2 – 5
Moderately strong	Cannot be scraped or peeled with a pocket knife. Can be fractured with single firm blow of geological hammer	20 – 50	1 – 2
Weak	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow with point of geological hammer	5 – 20	<1
Very weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife	1 – 5	
Extremely weak (soil description required)	Indented by thumb nail or other lesser strength terms used for soils	<1	

Note: • No correlation is implied between q_u and $I_{s(50)}$

SPACING OF DEFECTS/ DISCONTINUITIES

Term	Spacing
Very widely spaced	>2 m
Widely spaced	600 mm – 2 m
Moderately widely spaced	200 mm – 600 mm
Closely spaced	60 mm – 200 mm
Very closely spaced	20 mm – 60 mm
Extremely closely spaced	<20 mm

APERTURE OF DISCONTINUITY SURFACES

Term	Aperture (mm)	Description
Tight	Nil	Closed
Very Narrow	> 0 – 2	
Narrow	2 – 6	
Moderately Narrow	6 – 20	Gapped
Moderately Wide	20 – 60	Open
Wide	60 – 200	
Very Wide	> 200	

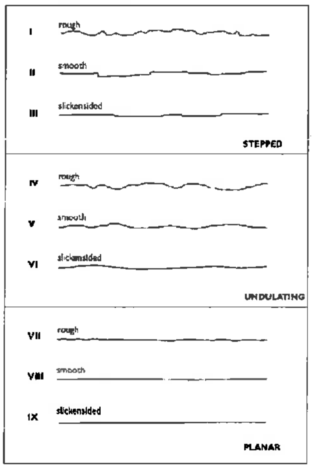
BEDDING THICKNESS TERMS

Term	Bed Thickness
Thinly laminated	< 2 mm
Laminated	2 mm - 6 mm
Very thin	6 mm - 20 mm
Thin	20 mm - 60 mm
Moderately thin	60 mm - 200 mm
Moderately thick	0.2 m - 0.6 m
Thick	0.6 m - 2 m
Very thick	> 2 m

BEDDING INCLINATION TERMS

Term	Inclination (from horizontal)
Sub-horizontal	0° – 5°
Gently inclined	6° – 15°
Moderately inclined	16° – 30°
Steeply inclined	31° – 60°
Very steeply inclined	61° – 80°
Sub-vertical	81° – 90°

ROUGHNESS AND APERTURE



compiled by KATE WILLIAMS design KARRYN MUSCHAMP

NZ GEOTECHNICAL SOCIETY INC

This field sheet has been taken from and should be used and read with reference to the document FIELD DESCRIPTION OF SOIL AND ROCK. Guideline For the Field Classification and Description of Soil and Rock for Engineering Purposes. NZ Geotechnical Society Inc, December 2005. **www.nzgeotechsoc.org.nz**

NZ GEOTECHNICAL SOCIETY INC

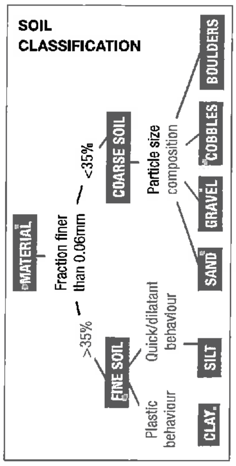
SOIL > field guide sheet

FIELD DESCRIPTION OF SOIL

SEQUENCE OF TERMS – fraction – colour – structure – strength – moisture – bedding – plasticity – sensitivity – additional

GRAIN SIZE CRITERIA

TYPE	COARSE									FINE		ORGANIC
	Boulders	Cobbles	Gravel			Sand				Silt	Clay	Organic Soil
			coarse	medium	fine	coarse	medium	fine				
Size Range (mm)	200	60	20	6	2	0.6	0.2	0.06		0.002		
Graphic Symbol												



PROPORTIONAL TERMS DEFINITION (COARSE SOILS)

Fraction	Term	% of Soil Mass	Example
Major	(....) [UPPER CASE]	≥ 50 [major constituent]	GRAVEL
Subordinate	(....) y [lower case]	20 – 50	Sandy
Minor	with some … with minor …	12 – 20 5 – 12	with some sand with minor sand
	with trace of (or slightly)…	< 5	with trace of sand (slightly sandy)

DENSITY INDEX (RELATIVE DENSITY) TERMS

Descriptive Term	Density Index (R_D)	SPT "N" value (blows / 300 mm)	Dynamic Cone (blows / 100 mm)
Very dense	> 85	> 50	> 17
Dense	65 – 85	30 – 50	7 – 17
Medium dense	35 – 65	10 – 30	3 – 7
Loose	15 – 35	4 – 10	1 – 3
Very loose	< 15	< 4	0 – 2

Note: • No correlation is implied between Standard Penetration Test (SPT) and Dynamic Cone Test values.
• SPT "N" values are uncorrected. • Dynamic Cone Penetrometer (Scala)

CONSISTENCY TERMS FOR COHESIVE SOILS

Descriptive Term	Undrained Shear Strength (kPa)	Diagnostic Features
Very soft	< 12	Easily exudes between fingers when squeezed
Soft	12 – 25	Easily indented by fingers
Firm	25 – 50	Indented by strong finger pressure and can be indented by thumb pressure
Stiff	50 – 100	Cannot be indented by thumb pressure
Very stiff	100 – 200	Can be indented by thumb nail
Hard	200 – 500	Difficult to indent by thumb nail

ORGANIC SOILS/ DESCRIPTORS

Term	Description
Topsoil	Surficial organic soil layer that may contain living matter. However topsoil may occur at greater depth, having been buried by geological processes or man-made fill, and should then be termed a buried topsoil.
Organic clay, silt or sand	Contains finely divided organic matter; may have distinctive smell; may stain; may oxidise rapidly. Describe as for inorganic soils.
Peat	Consists predominantly of plant remains. ***Firm***: Fibres already compressed together ***Spongy***: Very compressible and open stucture ***Plastic***: Can be moulded in hand and smears in fingers ***Fibrous***: Plant remains recognisable and retain some strength ***Amorphous***: No recognisable plant remains
Rootlets	Fine, partly decomposed roots, normally found in the upper part of a soil profile or in a redeposited soil (e.g. colluvium or fill)
Carbonaceous	Discrete particles of hardened (carbonised) plant material.

PLASTICITY (CLAYS & SILTS)

Term	Description
High plasticity	Can be moulded or deformed over a wide range of moisture contents without cracking or showing any tendency to volume change
Low plasticity	When moulded can be crumbled in the fingers; may show quick or dilatant behaviour

MOISTURE CONDITION

Condition	Description	Granular Soils	Cohesive Soils
Dry	Looks and feels dry	Run freely through hands	Hard, powdery or friable
Moist	Feels cool, darkened in colour	Tend to cohere	Weakened by moisture, but no free water on hands when remoulding
Wet			Weakened by moisture, free water forms on hands when handling
Saturated	Feels cool, darkened in colour and free water is present on the sample		

GRADING (GRAVELS & SANDS)

Term	Description	
Well graded	Good representation of all particle sizes from largest to smallest	
Poorly graded	Limited representation of grain sizes - further divided into:	
	Uniformly graded	Most particles about the same size
	Gap graded	Absence of one or more intermediate sizes

compiled by KATE WILLIAMS design KARRYN MUSCHAMP

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This field sheet has been taken from and should be used and read with reference to the document FIELD DESCRIPTION OF SOIL AND ROCK. Guideline For the Field Classification and Description of Soil and Rock for Engineering Purposes. NZ Geotechnical Society Inc, December 2005. **www.nzgeotechsoc.org.nz**