IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of a Board of Inquiry appointed under s146 of the Resource Management Act 1991 to consider an application by Mighty River Power Limited for resource consents to construct, operate, and maintain a wind farm at Turitea

---

REBUTTAL EVIDENCE OF GAVIN JOHN ALEXANDER

Introduction

1. My name is **Gavin John Alexander**. I am a **Technical Director** within the Geotechnical Group of **Beca Infrastructure Limited** ("**Beca**") based in Auckland.

2. My qualifications and experience relevant to the evidence I shall give are set out below.

   (a) I have been involved in geotechnical and civil engineering for the past 28 years, specialising in geotechnical engineering since 1986.

   (b) I hold a Bachelor of Civil Engineering from the University of Auckland, and a Masters degree from Imperial College, London, in Soil Mechanics and Engineering Seismology. My MSc dissertation was focussed on the seismic stability of slopes.

   (c) I am a New Zealand Chartered Professional Engineer, a Fellow of the Institution of Professional Engineers of New Zealand, and a Member of the New Zealand Geotechnical, Structural Engineering and Large Dam Societies.

   (d) Over the past 23 years I have provided geotechnical advice on a broad range and scale of civil, commercial, industrial and land development projects. These projects have included slope stability assessments and slope failure investigations ranging from localised projects (such as individual house sites) to a landslide of two million cubic metres of material. I have also directed and reviewed geotechnical components of electricity generation, transmission, and highway projects in many parts of New Zealand.

3. I confirm that I have read the "Code of Conduct for Expert Witnesses" contained in the Environment Court Consolidated Practice Note 2006. 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.

4. I have been involved with the Turitea Wind Farm project since early 2006 when Beca was commissioned by Mighty River Power to carry out, among

other things, a preliminary geotechnical investigation and to provide initial advice on associated design issues.

Scope of evidence

5. My evidence expands on the geotechnical work embodied in the evidence of **Christopher David James** in order to respond to geotechnical issues raised in the evidence of **Dr Alan Sandford Palmer**. It covers the following matters:

   (a) Presentation of the preliminary geotechnical investigations and assessment carried out for the project;

   (b) Description of geotechnical considerations for the wind farm project generally, in particular relating the recommendations from my earlier work to the currently proposed scheme;

   (c) Description of the ongoing geotechnical work to be carried out during design and construction of the Turitea Wind Farm; and

   (d) My direct response to the evidence of **Dr Alan Sandford Palmer.**

Geotechnical assessments undertaken

6. Beca was commissioned by Mighty River Power in 2005 to provide a report outlining the geotechnical aspects of the proposed Turitea Wind Farm.

7. A number of site visits were undertaken in the wind farm project area in early 2006, and subsequently supplemented by desk top reviews of available geotechnical and geological information.

8. Initial geotechnical investigations were undertaken at selected locations across the wind farm site. Preliminary investigations were undertaken to characterise soil and rock properties at the site, and to provide preliminary information for the design of foundations for wind turbines. Those investigations included five machine boreholes drilled to depths of up to 24.7 metres (m), eleven test pits excavated at accessible locations across the project area, up to 4 m in depth, one hand auger bore taken to 1.2 m depth and logging of five rock outcrops.

9. Laboratory testing was carried out on selected samples obtained from the field investigations to allow an assessment to be made of earthworks characteristics.

10. On the basis of those investigations, Beca prepared a report entitled "Turitea Wind Farm – Preliminary Geotechnical Report" dated July 2006 (the "**Geotechnical Report**"), which is attached as **Appendix One**. I spent time on site assessing conditions, planning the field investigations, and subsequently directed the preparation of the Geotechnical Report, and confirm its contents.

11. I attach a plan of the preliminary investigation layout as **Appendix Two**. This map comprises Figure 1 from the Geotechnical Report updated with the current wind farm layout.

12. In March 2007 Beca prepared an assessment of the lower lying "saddle" portion of South Range Road within the south east portion of the Turitea Wind Farm. More recently, a digital photogrammetric assessment of geomorphology has been undertaken, with a particular focus on potential areas of large scale slope instability in the vicinity of the site. I directed both of these studies.

13. I attach as **Appendix Three** a plan showing areas of large scale instability in the vicinity of the Turitea Wind Farm that have been identified in our photogrammetric assessment.

Geology of the wind farm project area

14. I attach a geological map of the region as **Appendix Four**. This map comprises Figure 2 from the Geotechnical Report updated with the current wind farm layout. The geology of the area is typified by the features described below.

15. The proposed Turitea Wind Farm is located entirely on the Tararua Range, which is formed of interbedded greywackes and argillites of the geological unit known as the Esk Head Belt. Across the project area, these rocks are variably deformed and sheared, ranging from coherent or transposed beds to broken formation and melange. For simplicity, I refer to those parts of the site directly underlain by these rocks as "greywacke terrain."

16. Younger alluvial sediments deposited during the Quaternary (i.e. within the last 1.8 million years) are observed to occur within the uplifted infilled depression that forms Browns Flat. These sediments include a cyclic

deposition of alluvial gravels and finer grained silts, with occasional volcanic ash and organic layers.

17. Elsewhere across the site, Quaternary Deposits are observed to cap hills, and are up to 2.5m thick. These sediments include pockets of loess, and alluvial gravels and silts.

Geotechnical and Geological Hazards

18. Potential geotechnical and geological hazards for the project include the following:

- Earthquake Hazards and Faulting;
- Slope Instability; and
- Liquefaction.

I discuss these in turn below, in relation to the project as currently defined.

Earthquake hazards and faulting

19. The Wairarapa has been one of New Zealand's most seismically active regions during historical times. Seismic risk will be assessed at the detailed design stage of the Turitea Wind Farm project for the wind turbine structures, and associated infrastructure in accordance with usual design standards, i.e. NZS 1170.5 2004 Structural Design Actions; Part 5: earthquake actions – New Zealand.

20. The Wellington Fault, located some 1000 m east of the project area, and Northern Ohariu North Fault is located some 1.5 km southwest of the site. These two faults are mapped as the only active faults occurring within 10km of the project area. Records held by GNS Science ("**GNS**") indicate that the Wellington Fault has a recurrence interval of approximately 3000 to 5000 years, and 1000 to 4000 years on the Northern Ohariu Fault.

21. Design works carried out in accordance with the New Zealand Earthquake standard referred to above must take into account this historical information when determining current earthquake design requirements.

22. In the event that an earthquake of significant magnitude occurs during the operational lifetime of the wind farm, the potential effects will include ground

shaking and may include fault rupture along the fault trace, liquefaction within recent sandy Quaternary Deposits, and/or slope instability on marginally stable slopes.

23. According to the Ministry for the Environment's report "Planning for Development of Land on or close to Active Faults" (2003), to avoid the risk of the effects of fault rupture it is recommended that no structures are located within 20 m either side of the fault trace, where the fault trace is well defined. The two faults are outside the project area so fault rupture is not expected to be an issue to the project.

24. Potential mitigation measures for the remaining hazards from active faults (i.e. liquefaction and slope instability) are addressed separately below.

Slope Instability

25. Instability features identified in this assessment comprise large scale deep seated landslides. These features are shown in the Instability Map attached as **Appendix Three**.

26. Large-scale landslide features are best avoided where possible to limit the need for expansive engineering works, however, well established mitigation measures will be adopted to address localised and shallow instability features near structures and access roads where required. Such measures typically include:

    (a) the careful positioning of wind turbines and roads to avoid steeper slopes such as ridge crests or spurs;

    (b) trimming back steep slopes to more stable profiles;

    (c) installing drainage to reduce water pressures; and/or

    (d) constructing localised retaining measures.

27. I am confident that such measures will address any risk posed by shallow and localised instability to the wind turbines, access roads, and other wind farm infrastructure.

Liquefaction

28. Liquefaction is the process by which loose and saturated sandy soils shaken under earthquake (or other dynamically applied) loads begin to behave as a liquid. The loose soil will tend to contract under this loading. When the soil is saturated, pressures build up in the pore water resulting in the soil losing most of its "shear strength", or the effective stress between solid particles in the soil. This condition persists until the excess water pressure within the soil pores dissipates. Effects may occur during and continue for a short period after earthquake shaking and comprise loss of strength and surface settlement.

29. From my desktop review of the geology and the site inspections undertaken, the liquefaction potential of loose sandy deposits within the site is most likely to only occur within the central areas of Browns Flat (based on subsurface investigations in the area) and therefore the risk to the project overall is considered to be low.

30. During the course of geotechnical investigations undertaken for detailed design, the liquefaction potential of all wind turbine sites will be assessed.

31. In addition to relocating structures, there are various other means by which the potential effects of liquefaction on structures can be managed. A piled foundation option, founded below the liquefiable layers, would be more appropriate in those circumstances, and would be effective in addressing any risks posed.

Geotechnical considerations for the Turitea Wind Farm

32. Geotechnical considerations for the project can be divided as follows:

- Earthworks for roads, platforms and switchyards;
- Foundations for wind turbine generators;
- Surplus fill disposal sites; and
- Transmission line alignment.

I discuss these in turn below, in relation to the project as currently defined.

Earthworks for roads, platforms and switchyards

33. The Turitea Wind Farm has been designed so that wherever practicable, earthworks for turbine platforms are located clear of large scale instability. This is consistent with my recommendations for the site, and can been seen in **Appendix Four.** Variable conditions in the greywacke terrain are expected to be identified during the earthworks being undertaken. This is an inevitable consequence of the interbedded and sheared nature of the rock, and the mantle (in places) of younger deposits from various sources. However,with the exception of the weak alluvial soils in Browns Flat, the soils and rocks present at the site do not pose any specific construction difficulties. The boundary between soil and rock is clearly defined, the sheared rock can be expected to be relatively easy to excavate, and to incorporate in structural fills.

34. I understand from the wind farm layout drawings appended to the evidence of Mr James that the wind farm has been re-designed, and now avoids the alluvial soils of Browns Flat, so this is no longer a construction issue.

35. My inspection of existing cut faces along South Range Road and on the access track from Greens Road to the west identified that steep cut slopes would perform well in the greywacke terrain. Based on these observations, the Geotechnical Report contains, in Section 8.2, preliminary recommendations for cut and fill slopes (referred to in the report as batters). Those recommendations concluded that cut batters of 1 vertical on 1 horizontal would be suitable for most situations. The report also identified the potential to cut short term cut slopes steeper, at between 2 to 4 vertical on 1 horizontal, providing the potential for localised “dropouts” was accepted and managed. These recommendations have been adopted for the construction of the Turitea Wind Farm, where the proposed approach for the majority of cut slopes is to cut them steep and clean up any dropouts that occur during the construction phase. These matters are outlined further in the evidence of Mr James.

36. In bush areas, where vegetation assists in stabilising shallow soils on slopes through binding of the roots to the soil, steeper cut slopes have the advantage of reducing the amount of vegetation being cleared and therefore reduce the risk of shallow failures. In contrast flatter batter slopes would increase the amount of vegetation being cleared and reduce this effect.

37. There will, inevitably, be some locations identified in the course of detailed investigation, design, and construction, where flatter cut slopes are appropriate. Where identified, these will be formed from the start of excavation, or re-shaped part way through. This is common practice for large earthworks projects, where actual site conditions are not fully apparent until work is underway.

38. Dropouts, and areas where the cut slope is eased to accommodate less favourable conditions, may have the effect of increasing the area of vegetation affected and increase earthworks volumes. I understand from recent discussions with Mr James that he has made an allowance for this in his assessment of the total amount of vegetation clearance required and proposed earthworks volumes.

39. Competent weathered greywacke material identified in exposures and the bores is ideal for the construction of structural fills, with appropriate assessment and detailing. Fills will be keyed into sound material at the toe, and benched into the underlying ground (after topsoil has been stripped). I understand that this has been successfully used at Tararua Stage 3 Wind Farm Development.

40. The Geotechnical Report recommends fill batters of 1 vertical on 2 horizontal, a recommendation that has been adopted for the construction of the Turitea Wind Farm.

41. The current earthworks designs are, therefore, consistent with the recommendations of the Geotechnical Report.

42. Standards of material selection and hence margins against slope instability for fills in critical areas (for example in the direct catchment of the Lower Turitea Reservoir), will be higher. This will be achieved by constructing these fills entirely from selected greywacke rockfill won from the lower parts of deeper cuts.

Foundations for wind turbine generators

43. In respect of the earthworks to be completed, in accordance with my recommendations, the foundations for the Turitea Wind Farm have been located clear of large scale instability, as can be seen in **Appendix Four.**.

44. With the removal of turbines from Browns Flat since preparation of the Geotechnical Report in 2006, I expect turbine foundations will predominantly comprise large spread pads founded on cut platforms in rock. Localised weaker zones in the rock mass will be dealt with by either minor adjustment to the foundation location or depth, or by constructing piles to take the foundation loads down to more competent materials.

Surplus fill disposal sites

45. The Turitea Wind Farm has been designed so that surplus fill disposal sites are located clear of large scale instability.

46. The design and construction of fill disposal sites requires similar considerations to structural fills, as I have discussed in paragraphs 26 and 27 above. The disposal sites do need to accommodate all surplus material, including near surface soils, so will require zoning, particularly on steeper sites.

47. Site preparation will include undercutting to remove soft or wet materials and installation of under-drainage where seepage is encountered.

48. A toe key and an outer face of greywacke rockfill will be constructed, sized to achieve a batter slope of 1 vertical on 2 horizontal or flatter where site conditions dictate. The materials placed behind this outer zone will comprise a mixture of soil and surplus excavated rock. Layers of better material will be used where needed to facilitate construction and improve internal drainage.

Transmission line alignment

49. As for all other significant construction work, transmission structures for the Turitea Wind Farm will be located on ridge spurs clear of large scale instability.

50. Smaller scale instability will be assessed on site and avoided where practicable or accommodated with local slope stabilisation works or foundation strengthening.

Geotechnical work during design and construction

51. Further geotechnical investigation, analysis, and design will be undertaken during the detailed design phase and throughout wind farm construction. I

have set out below the approach that I recommend be adopted for the various components of the Turitea Wind Farm.

Earthworks for roads, platforms and switchyards

- Characterise site conditions and materials by undertaking further mapping and subsurface investigation using a combination of machine bores, test pits, hand auger bores and laboratory testing, paying particular attention to the larger cuts and fills;
- Classify the various materials that will be encountered, determining uses, specifying placement criteria, and assessing long term performance; analyse stability of representative smaller and all larger or more critical cuts and fills;
- Document on construction drawings; and
- Inspect to confirm design expectations during construction and modify as required to reflect site conditions exposed.

Foundations for wind turbine generators

- Put down at least one machine bore at each site to identify excavation and foundation conditions (noting that this may be staged through design and construction depending on the level of cost certainty desired when tendering the construction work);
- Consider geophysical testing to explore variations in conditions across foundation area; analyse foundation performance and sizing;
- Document on construction drawings; and
- Confirm by inspection and testing during construction.

Surplus fill disposal sites

- Prepare an engineering geological map of each site to be used and its surrounds; undertake subsurface investigation of soils, depth to rock and groundwater conditions;
- Analyse stability, considering zoning of fill and any particular material requirements to achieve design margins against instability;

- Document on construction drawings; and
- Confirm by inspection and testing during construction.

Transmission line alignment

- Conduct a geotechnical assessment of each tower location with the transmission designer to assess local stability;
- Modify locations if necessary and assess likely foundation type and geotechnical investigation;
- Confirm foundation type and size on completion of geotechnical investigation;
- Document on construction drawings; and
- Confirm by inspection and testing during construction.

Evidence of Dr Alan Sandford Palmer

52. I concur with Dr Palmer's observations in his paragraphs 10 to 12 and 15 regarding the underlying geology, the heavily sheared nature of the rock, and the rugged terrain that characterises parts of the site.

53. I also concur with Dr Palmer's paragraph 13 that variable conditions will be encountered in excavations.

54. These observations were clear to me from the early stages of our geotechnical investigations, and are reflected in the resulting recommendations in the Geotechnical Report. Those recommendations have been incorporated in the current design of the Turitea Wind Farm.

55. I dispute Dr Palmer's inference in paragraph 13 that much more excavation than planned might be required. I expect that, in some localised places, more excavation than is currently calculated (based on 4 vertical on 1 horizontal cut batters) will be required, as dropouts are cleaned up and weaker ground is cut back flatter. However, in the context of the project as a whole, I am confident that the volume of such additional excavation at localised sites will not be excessive, and understand from discussions with Mr James that

considerable additional volume can be readily accommodated within the nominated fill disposal sites.

56. I question the relevance of the extract quoted in Dr Palmer's paragraph 14 which describes foundation construction and grouting during construction of the Turitea water supply dam in 1953 -1956. Considerations for water tightness and abutment and foundation stability for a large dam are much more rigorous than is required for general civil engineering earthworks, often requiring detailed excavation and grouting. I agree that care will clearly be required when excavating higher cut faces. Established design approaches and construction techniques exist to manage these risks, and will be adopted for this project.

Conclusion

57. The current proposal for the Turitea Wind Farm, as described in the evidence of Mr James, is consistent with the recommendations contained in the Geotechnical Report.

58. In my view the site has been sufficiently well characterised to provide a high level of confidence that the geotechnical constraints have been identified, and that these can be addressed by adopting well-established engineering solutions.

5 June 2009

G J Alexander