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Lessons Learned from Long-Term Noise Monitoring at Project West Wind.

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Abstract

Project West Wind is an operational wind farm located 8 km west of New Zealand's capital city, Wellington. The wind farm was granted resource consent (planning permission) from the Environment Court in May 2007 after the application was lodged with the Wellington City Council in July 2005. The site on which the wind farm is located was originally identified as being suitable for wind generation more than ten years earlier.

The consent granted for the wind farm had numerous conditions attached, of which 31 conditions (seven pages) related to operational wind farm noise and construction noise matters. One of the conditions of consent required continuous sound level monitoring to be undertaken at a minimum of four and maximum of five measurement locations and to be undertaken for a minimum period of two years.

Noise meters were set up at four locations around the wind farm site in July 2008, almost a full year prior to the wind farm being commissioned. The initial noise measurements were used to establish the background noise levels. A fifth meter was used in a portable configuration which allowed shorter-term measurements to be undertaken at a number of other locations.

Background noise measurements were gathered over the period of a year and subsequently operational noise measurements have been made over a year in order to assess the operational wind farm levels.

This paper discusses the lessons learned from the long-term noise measurement programme and other noise measurements made around the wind farm site.

1 Introduction

Wellington is the capital city of New Zealand. Project West Wind is a wind farm located on the hills, 8 km west of the city, adjacent to Wellington's west coast. The area has been investigated as a potential wind farm since 1994 as it has an excellent

wind resource with annual mean wind speed in excess of 10 m/s. Resource consent was lodged for the project in July 2005 with the Wellington City Council. The Council approved the project in December 2005 and that decision was appealed to the Environment Court. In May 2007 the Environment Court approved the project with some modifications including 66 rather than 70 turbines and some turbine relocations. The court finalised the conditions of consent in July 2007.

The Environment Court set down a number of conditions on the project and those conditions included numerous noise conditions[1]. While the noise conditions were issued by the Environment Court, they were largely agreed through caucusing of the five noise experts involved in the court process. Two experts were engaged by Meridian, two by the opposition groups and one by the Council. The Council expert was responsible for setting the originally proposed conditions, which then became the focus of discussions between experts.

The first of the wind turbines began generation in March 2009 with all 62 turbines operating in October 2009. When the wind farm commenced full operation there were a large number of calls to the free phone inquiries line set up as a requirement of the consent conditions. Noise monitoring revealed the turbines initially exhibited some tonality. Changes were made to the turbines to reduce the level of tonality from the wind farm and complaints have reduced significantly.

Noise measurements have been conducted at four locations for a period of two and a half years which included both background and operational noise levels. Measurements have been made at selected other locations and the results of the monitoring have been reported to the Wellington City Council. Brüel and Kjær noise monitoring terminals have been used for the measurement of both background and wind farm sounds. The reports issued to date show that the wind farm is complying with the conditions of consent[2,3].

The number of noise conditions placed on the project, together with the extensive range of noise measurements carried out has resulted in a number of findings and these are presented below.

2 Overall Process Used In New Zealand Standard NZS6808

The noise conditions for Project West Wind are based on the process outlined in NZS6808:1998. While this Standard has since been updated, the wind farm conditions were set three years prior to the updated version being released. The process followed in the Standard covers four overall steps:

- Sound pressure levels are predicted at residential locations surrounding the wind farm;
- Background sound pressure levels ($L_{A,95}$) are undertaken prior to the wind farm becoming operational;
- Operational noise levels ($L_{A,95}$) are taken once the wind farm is operational, these levels being a measurement of both the background plus the wind farm level;

- The wind farm noise levels are determined from the two sets of measurements (background levels and operational levels) and these wind farm levels should not exceed the limits.

In December 2007 a final noise prediction report was issued to the Wellington City Council (WCC) based on the wind farm layout to be used for construction and the measured sound power level of the Siemens SWT2.3-83VS wind turbine which was selected for installation at the West Wind site[4]. Noise predictions were made for 157 locations around the West Wind site over a range of different wind speeds. The results of the noise predictions were also represented as noise contours.

One of the noise conditions required in the installation of a minimum of four and a maximum of five permanent noise monitoring systems. In consultation with the WCC it was decided to install four permanent systems and configure a fifth system such that it could be moved to a number of different locations.

Based on the predicted noise levels an assessment was made of locations most suitable for the four permanent monitoring locations. These four locations were agreed with the WCC. A number of other sites were assessed as possible locations for noise monitoring and these were prioritised so that they could be used for temporary monitoring.

The noise monitoring equipment was installed in May 2008, approximately a year prior to the commissioning of the wind farm. This was done to obtain a detailed record of the background levels. The four permanent locations were each monitored for a period of about a year and additionally six other locations were each monitored for varying lengths of time, but for at least seven weeks each.

After the wind farm was commissioned, operational noise measurements were made over the period of about a year. The background levels were subtracted from the operational levels to determine the wind farm noise levels and these have been compared to both the predicted levels and the allowable limits.

The wind farm levels that were determined showed that the predicted wind farm levels were conservative in all cases (i.e. over prediction) by between 0 and 15 dB depending on the wind speed, wind direction and proximity of the measurement point to the turbine locations. The results were included in a compliance report issued to the WCC[3]. Examples of the results presented in that report are shown in Figures 1 to 6.

There are three key conclusions that can be made from the compliance assessment process.

1. The predicted noise levels were conservative, i.e. the operational levels derived for the wind farm from measurements taken were lower than the predicted operational levels.
2. While the wind farm limits comprised both a fixed part and background plus limit, in all cases the wind farm complied with the fixed part of the limit. This illustrates that the need to measure the background levels is not significant where predicted levels are lower than the fixed portion of the limit.
3. The whole process adopted in the New Zealand Standard in relation to undertaking predictions which are checked by means of compliance

measurements worked well and West Wind continues to comply with the limits imposed on the project.

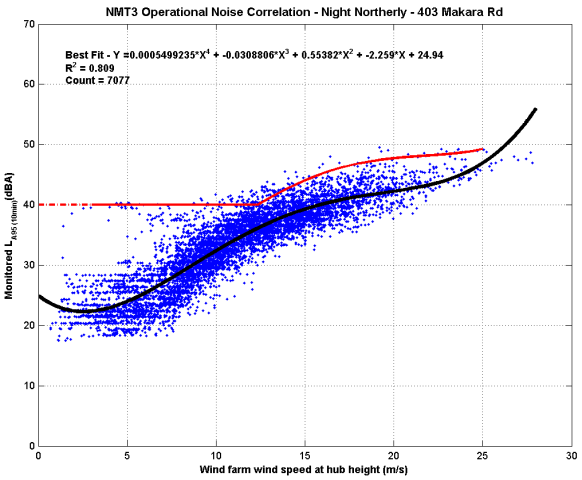

Figure 1. Operational, Night Northerly

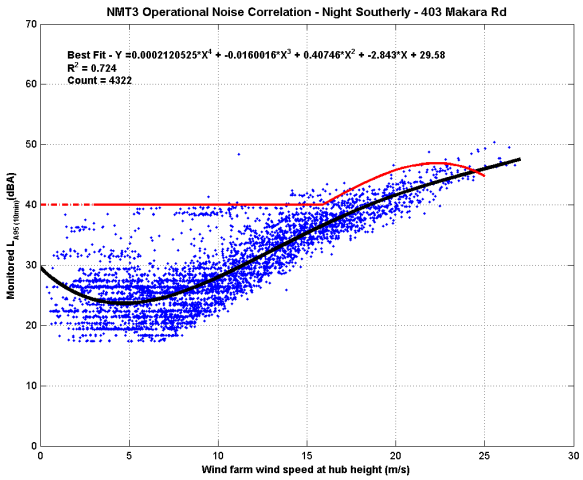

Figure 2. Operational – Night Southerly

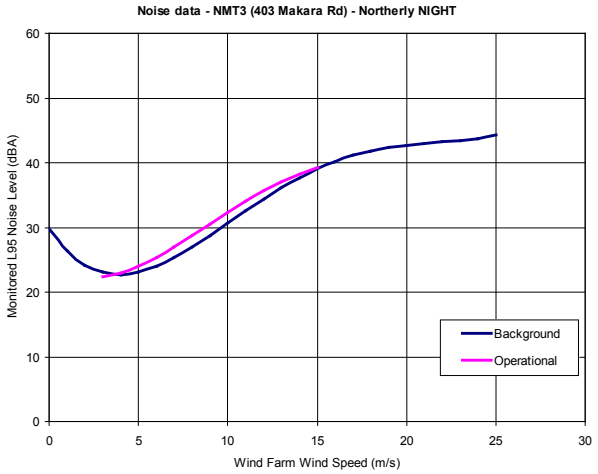

Figure 3. Background and Operational – Night Northerly

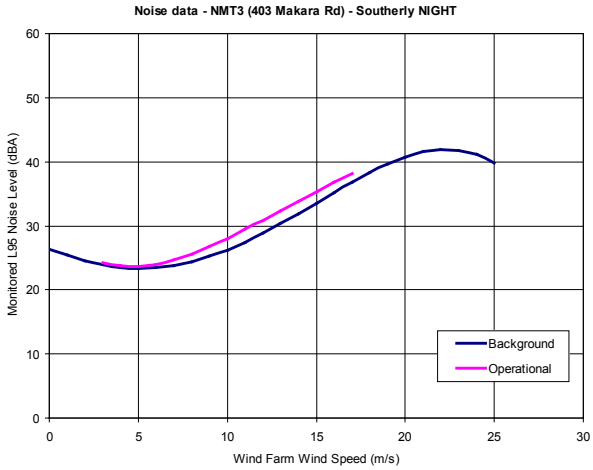

Figure 4. Background and Operational – Night Southerly

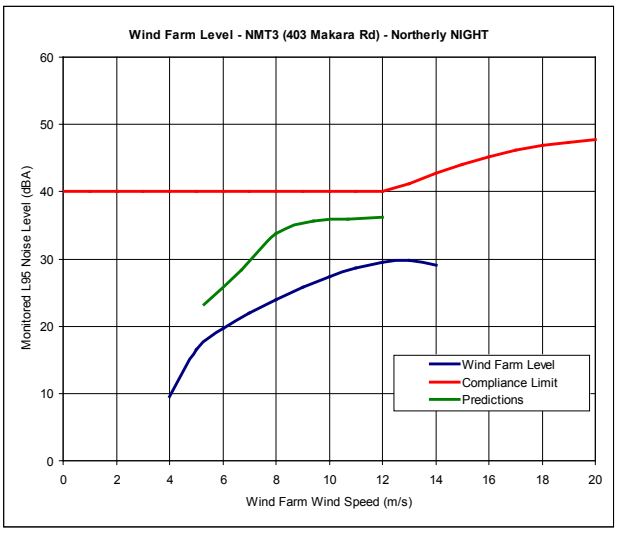

Figure 5. Wind farm level and prediction – Night Northerly

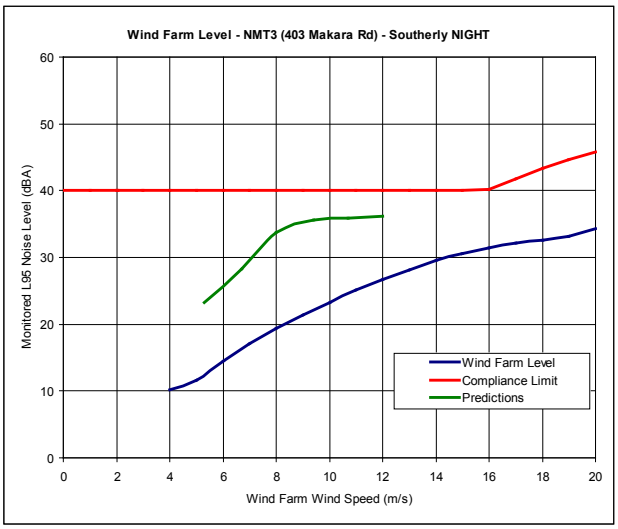

Figure 6. Wind farm level and prediction – Night Southerly

3 West Wind Secondary Limit

The West Wind conditions included a secondary limit in addition to the limit set out in NZS6808:1998. This modification to the NZS6808:1998 incorporates a more stringent secondary limit based on the background level and local 10 m wind speed. This secondary limit was written as:

"When the background sound conditions are at or below 25 dBA L_{95} determined from the appropriate regression curve, without the interference of the wind farm, and when the mean wind speed at a representative location for the dwelling is less than 1.5 m/s measured at a height of 10 m AGL, then noise from the wind farm shall not exceed 35 dBA L_{95} at the dwelling."

This condition required that 10 m wind speed measurements be made simultaneously with background measurements. Results from the measurements showed that conditions where the background levels were lower than 25 dBA and the local 10 m wind speed was less than 1.5 m/s were rare with the result that the 35 dBA limit applied only for a very small percentage of time and at some locations did not apply at all. It applied for different periods of time in northerly wind directions to southerly wind directions.

This particular condition was unnecessarily complicated and at some locations provided little or no additional benefit over the limits set out within NZS6808:1998[5]. This resulted in significant uncertainty around the background noise monitoring that took place prior to the wind farm becoming operational. The extent to which this condition created uncertainty was demonstrated through an enforcement order being taken out against Meridian during the construction period, in an attempt to have the commissioning of the wind farm delayed while numerous other background data sets were monitored. The community felt that it was necessary to undertake background noise measurements at a significantly greater number of locations than was initially proposed.

A simplified approach to what was intended by this condition has been included in the 2010 version of NZS6808.

4 Conditions need to be Clear and Unambiguous

Condition 40(d) of the West Wind Resource Consent conditions required:

"The implementation of an automatic control mechanism to de-rate or stop the wind turbine generators to ensure compliance with condition 17."

This condition was interpreted by some as the installation of a direct feed-back loop from the noise monitoring equipment to control the wind farm on an instantaneous basis. However, as the control mechanism was to ensure compliance with condition 17 i.e. the wind farm limits, which in turn are based on regression analysis, the control system was put in place to reduce the wind farm noise in the event a particular wind speed or wind direction was found to cause the operation of the wind farm to exceed the limits.

A control system was installed which had the ability to reduce the sound power level of selected turbines under any combination of; time of day, day of the week, wind speed and wind direction. The control system was tested on two turbines for a combination of different wind speed and direction values to ensure that it could perform the task required by the condition of consent.

The results of the compliance testing showed that the wind farm complied with the conditions of consent without having to alter its performance, and while a control system has been installed, it is not needed to alter the sound power level of the turbines.

Ultimately this condition was unnecessary as the wind farm had to comply with the limits irrespective of whether an "automatic control system" was in place or not. This condition simply states a mechanism that could be used to achieve compliance should the wind farm be found to be exceeding its limits. The condition did, however, raise the expectation of the community that the wind farm would be controlled on an instantaneous basis.

5 Specific Dates for Reports and Periods for Measurement

NZS6808:1998 suggests that 10 to 14 days of monitoring is indicative of the period required to measure both background and operational noise levels. If the consent conditions had followed NZS6808:1998 more closely, shorter measurement periods would have been used to quantify both the background and operational noise levels. Reporting of the results would have occurred after these "short-term" measurements had been completed.

The requirement to operate "permanent" noise monitoring equipment for a minimum of two years led to the measurement of background noise levels over the period of a year. When it came to the assessment of the operational levels, as they were compared against background levels monitored over such a significant period of time, there was a tendency to wait until more operational levels were monitored prior to issuing a formal compliance report. Periodic results were initially provided to the

Council on a monthly basis, however as these were not formal compliance reports, no formal statement was issued by the Council on the status of the compliance of the wind farm.

The use of the permanent noise monitoring equipment meant new data was always available for analysis and unfortunately the conditions of consent required analysed results to be presented to the Council within 21 days of the monitoring being completed. As the monitoring was on-going there was no definitive date for issuing a compliance report. The reporting process was further complicated by the fact that Meridian was in the process of consenting an adjacent Wind Farm (Mill Creek) which planned to use the same wind turbine as installed at West Wind.

6 Only One Test Method for Tonal Analysis

Condition 34 addressed special audible characteristics due to the presence of clearly audible tones. The condition included a test for tonality based on a 1/3 octave measurements and a level which a single 1/3 octave band should not exceed the arithmetic mean of the two adjacent bands. This is a very simple test to complete and can easily be performed and is historically the way in which Councils make an objective test for tonality.

The same condition, however, also stated that a sound may still appear tonal despite the 1/3 octave test not identifying a tone. In these cases the condition allowed for the sound to be assessed using the Joint Nordic Method Version 2 (JNM2).

The issue that arises is that the 1/3 octave test is less stringent than the JNM2 approach. Using the 1/3 octave approach to asses the tonal character is not definitive as the condition still allows for the more stringent JNM2 to be used. Ultimately, while the 1/3 octave test is included for a “quick” assessment, compliance cannot be certain until the JNM2 analysis has been completed. On this basis the 1/3 octave approach is redundant and should not be included together with an alternative more rigorous tonality test in conditions of consent.

7 Tonality

After the initial commissioning of the turbines, it was apparent that tonality in the wind farm sound was present to a greater level than expected. Measurements were undertaken close to the turbines to determine the frequencies of the particular tones.

A solution was implemented to the turbines which included a change to the maximum rotational speed and the fitting of tuned absorbers onto the gearbox. Measurements close to the turbine showed a reduction in the tonal peak of more than 6 dB. Numerous measurements were undertaken at locations around the wind farm subsequent to the changes and all of the measurements confirmed that a penalty was not required under the JMN2 assessment.

From the work undertaken here, it was apparent that while there was tonality present to a greater level than expected, working closely with the wind turbine supplier allowed changes to be made to the turbines which significantly reduced the level of tonality.

9 Conclusions

The operation of four permanent noise monitoring terminals for nearly three years around the Project West Wind site has led to significant scrutiny on the noise performance of the wind farm. During the monitoring and analysis periods, the conditions of consent have been scrutinised by a great number of people. Some of the lessons learned during this monitoring programme are:

- The process of undertaking compliance measurements in order to validate the initial predictions; as required by NZS6808:1998 worked well.
- The modifications made to limits set out in NZS6808:1998 for Project West Wind, led to a significant monitoring burden and very little additional benefit to the community. The uncertainty that the condition created was significant and unnecessary. This approach has been modified and included in the 2010 version of NZS6808 and provides greater benefit without additional monitoring requirements.
- Noise conditions need to be clear and simple to minimise the potential for the conditions to be misinterpreted.
- Only one test for tonality should be included in the conditions of consent.
- Taking a proactive approach to the wind farm noise does allow improvements to be made to the overall sound character.
- Overall, Meridian worked with the conditions of consent; however, we wouldn't want this particular set of conditions to become the norm for future wind farm consents.

References

[1] SR131428 and Environment Court Decision W 59/2007 dated 20th July 2007

[2] Hayes M and Botha P, Project West Wind, Wind Farm Noise Compliance Assessment, Version 2.0 March 2010.

[3] Botha P, Project West Wind, Wind Farm Noise Compliance Assessment – Update September 2010, Version 1 September 2010.

[4] Hayes, M, Project West Wind, Condition 18 Compliance Report, Report 1610-R3, December 2007.

[5] Botha P, "High Amenity Noise Limit in NZS6808:2010. – What is it and Where did it come from?" Proceedings of the International Symposium on Sustainability in Acoustics, ISSA 2010.