REPORT

CONTINUOUS SOUND MONITORING FEASIBILITY STUDY

KINGDOM COMMUNITY WIND

12.22.2013

the science of insight

PREPARED FOR:
GREEN MOUNTAIN POWER

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

As part of its Certificate for Pubic Good (CPG), Kingdom Community Wind is required to conduct sound monitoring four locations around the project for two weeks in each of winter, spring, summer, and fall, for the first two years of operation.

A sound monitoring protocol was established and approved by the Public Service Board (PSB) on April 3, 2012. The protocol includes a means for third party review, details of the duration of monitoring, the frequency of monitoring, specific locations, logistics, inside-to-outside testing protocols, and methods to exclude background sound.

Since that time, compliance sound monitoring has been conducted over five seasons, from Fall 2012 to Fall 2013.

On September 25, 2013, the PSB issued a Procedural Order directing,

> "…GMP to undertake an investigation into the feasibility of continuous monitoring for the Project and to file a report with the Board within 90 days of the date of this Order."

This report is the feasibility study requested by the PSB, filed on behalf of GMP. It includes information on

1) The components of a continuous sound monitoring system
2) Installation, maintenance, management, reporting, and operational considerations
3) How the measurements can be adjusted to remove background sound
4) Specifics on available continuous sound monitoring systems
5) The technical and price feasibility of continuous monitoring, and
6) A summary of the findings.

"Continuous monitoring" can mean several things. In general, "continuous" is 24 hours per day over some defined period. Since that period was not defined by the Order, we will assume it is longer than the two weeks per season that is currently required – from a minimum of one full season to a year or more. The number of sites could include a single site to all four current sites. The background methodologies can include those that were defined in the Monitoring Protocol or new methods. This report evaluates as many of these options for continuous monitoring as possible.

2.0 COMPONENTS

Continuous sound monitoring requires equipment that can be left unattended indefinitely. While many systems do not need to be visited at all, except during breakdowns, some systems may require regular maintenance visits. We will consider all these in evaluating required components.

2.1 | SITES AND LOCATIONS

A monitoring "site" is a place where one or more sound monitors could be placed. A "location" is a specific microphone location within that site. For example, the Nelson farm location currently is monitored at two locations – a primary and background location.

The PSB Procedural Order only mentions the Nelson Farm site in its discussion, but the order does not specifically state whether the feasibility study should be limited to evaluating continuous monitoring only at that site.

As a result, we have assumed that alternatives could include sound monitoring at site combinations such as:

- The Nelson Farm only
- The Nelson Farm and the exiting monitoring site on Farm Road, as these two are closest to the only neighbors to appear at the penalty hearing.
- The Nelson Farm and Eden Road, as these were the only two sites to record sound violations
- All sites except VT 100, since the VT 100 site has recorded very low turbine sound levels, there are no continuing complainants on that side of the ridge, and the site has poor cellular and power availability.
- All four sites currently monitored.

Locations within these sites can be the same as currently monitored, or can be adjusted in consultation with the landowner if a more permanent installation is warranted.

2.2 | POWER

Monitoring under the current protocol uses batteries that require changing at scheduled intervals.

For long-term continuous monitors, batteries can still be used, but given the additional labor and cost to charge and replace batteries, and higher power draws of communications equipment, other power systems can be more cost effective.

The most efficient solution is line power. Line power is available to the homes at the Nelson Farm, Eden Road, and Farm Road, however, connecting that power to the monitoring system would require permission of the property owners for connection to their system with some type of above or underground wiring, , or relocation of the monitoring system near a power line right-of-way.

Line power is not readily available at the VT 100 site.

Solar is the most practical option where full sunlight is available. This would be at the Nelson Farm and Farm Road. The solar must be accompanied with about a month of battery storage to operate the systems at night, when snow is covering the panels, and during cloudy days. Solar is not practical at Eden Road and VT 100 sites, since these are wooded. At Eden Road, there is a more exposed location to the west, which could be used assuming permissions are granted.

If line power is not available or allowed by the property owner(s), and solar is impractical then fuel cell generators could be considered. Fuel cell generators would provide more power than is needed, but can be used at wooded sites like Eden Road and VT 100, where there is little solar insolation. Fuel cells that can operate in very cold temperatures are more costly than other power options, create some noise through their cooling system, and will require replacement fuel at regular intervals.

2.3 | SOUND LEVEL PARAMETERS

To meet the requirements of the CPG and the sound monitoring protocol, the system must be able to log 1/3 octave band sound levels and record audio. While the standard imposed is based on a 1-hour Leq, the tonality standard requires spectral data collection. We recommend 1-second data be logged to allow for the filtering of short-term events. Audio recordings are used, if needed, to identify sound sources. These requirements are the same as the current monitoring protocol.

There is one system being considered that does not collect spectral sound data. Were this system used, then the tonal standard could not be evaluated.

2.4 | COMMUNICATIONS

Systems such as these can collect many megabytes of data each day. This data can be downloaded manually by visiting each site once per week, such as is done under the current monitoring protocol. However, given the additional labor involved for long-term continuous monitoring, it is more cost-effective to connect to the sound monitoring system remotely. In addition, remote communications can be used to check system integrity. Most sound monitoring systems that allow for communications allow the user to download data, check on power levels, check calibrations, install firmware, and listen to audio, for example.

The four communication options available are:

1) Wifi – This is the same as the wireless systems used in homes and offices. The system would connect wirelessly to the router inside the home. This would only be available if homes have wireless internet and if the property

owner allows access to their wireless system. The monitor would also have to be located close enough to the home to get a wifi signal.

2) Cellular – A cellular system operates on same radio bands as cell phones. Data speeds can be 1G, 3G, and 4G. 1G coverage is the slowest, and would allow unlimited access to stored data, but would allow only limited downloads of audio. Cellular radio strength is unreliable in most of the study area. Some systems are only compatible with 3G. The area around the project is sparsely covered by cellular signals. The Nelson Farm is only available to AT&T customers, and there is a spotty Verizon signal at VT 100 and Farm Road. There is no reliable service at Eden Road that we are aware of.
3) RF link – An RF link is a line-of-sight radio link to a receiver with an internet connection. The RF link would be possible at the Nelson Farm and Farm Road, as these have a clear, direct line-of-sight to the turbines at the top of the ridge. RF modems may be possible at the more heavily wooded Eden Road and VT 100 sites with a tower.
4) Satellite – If none of the above systems are available, satellite modems can be used. The satellite dish must have a clear line of sight to the geosynchronous satellite location, which may be an issue in the more heavily wooded VT 100 and Eden Road sites, without a tower.
5) Manual checks – If wireless communication is not available, staff would visit each site once per week to check the system, perform maintenance, replace batteries (if needed), and download data.

2.5 | DATA STORAGE

While the sound monitoring systems are regularly downloaded, communication failures do occur. As such, the system should be capable of storing at least two weeks of data, and preferably, one month. In addition, since communications equipment is the largest power user, fewer longer downloads are generally more efficient than more frequent shorter downloads.

2.6 | WEATHER PROTECTION

The monitoring system that is currently used includes weather proof wind screens and water-proof enclosures that lie on the ground. For permanent systems, more rugged above-ground installations are used. Microphone systems must be fully protected, and include the use of microphone desiccants.

If line power is available, enclosures can be heated. This would allow for operation below 14°F. Anemometers should be heated, as well, to provide for continuous operation in cold temperatures.

2.7 | SELF-CALIBRATION

Since these systems can run un-attended, they must be able to self-calibrate. Self-calibration systems are either acoustic or electrostatic. Calibration is generally done once per day.

2.8 | DATA ACCESS

Data under the current protocol is downloaded manually by visiting each site. Downloads at each location can take from 10-minutes to several hours depending on the system.

For a continuous solution, it is generally more cost effective if data communications is available at the site to download data remotely. Data is downloaded on a fixed schedule by automated servers, usually from one to four times per day. Data must also be available to the acoustical consultant on an as-needed basis. Thus, either the servers are run by the consultant or an internet-portal is provided to access the data. Some systems allow for password-accessed web portals where real-time observations of the sound levels and audio can be made.

If remote communications is challenged or unreliable, manual downloads are still feasible but will require a slight lag from the time of the sound level concern to the sound level data becoming available.

2.9 | AUDIO

The system must have audio recording capabilities. Some systems collect data at set intervals (such as 5 seconds every one minute), some continuously record, but only upload files on request, others can trigger recording if certain conditions are met (sound levels, rise times, etc). External connections to mp3 recorders can also be made, but these generally have to be downloaded manually. Continual audio, while required under the protocol, may not be practical for continuous sound monitoring due to large data storage and transmission requirements.

2.10 | METEOROLOGICAL INSTRUMENTS

Meteorological instruments are required to accompany the sound monitoring system. These instruments must include wind speed, temperature, humidity, and rainfall. Wind direction is optional. Since meteorological instruments for continuous systems are generally mounted high, there is a greater chance for icing. As such they should be heated.

Many continuous sound monitoring systems are designed to operate with specific meteorological instruments. The most reliable of these are heated ultrasonic wind sensors which have no moving parts.

3.0 INSTALLATION, MAINTENANCE, MANAGEMENT, REPORTING, AND OPERATIONAL CONSIDERATIONS

This section discusses the issues around installation, maintenance, management, reporting, and operations.

3.1 | SITE PREPARATION & SECURITY

The monitoring system currently in use involves a case enclosing the sound monitor on the ground and a microphone mounted on a wood stake. This is not practical for a continuous monitoring system. Leaving these types of systems out continuously makes them susceptible to damage from insect infestations, water infiltration, animals chewing on wires, the wood rotting, and animals knocking over the microphone or chewing on the wind screen.

If a permanent installation is required, then the site should be prepared with a concrete pad for the power systems and microphone mast. For systems installed for one year or less, a temporary tower can be constructed, but secured and guyed.

The microphone should be placed on a small pole or tower, which would include the meteorological instruments. The microphone and instrument heights should be at least eight feet above ground to prevent animal damage and tampering.

For remote site, security is a concern. If the monitoring location is not near a home, fencing would be required. Some systems include remote intrusion sensors which send alerts when the someone opens the case.

3.2 | INSTALLATION

With the current monitoring system, property owner permission has not been a significant issue since the systems are temporary. More permanent installations may additional landowner or town approvals. Prior to installation, negotiations with property owners should occur to provide for any necessary agreements, including easements for the site and site access, if needed. Easements and/or other permissions would need to be obtained for any permanent equipment in a pubic or utility right-of-way.

Installation of hard components (concrete pad, towers, poles, cabinets, solar panels, etc.) can be done by contractors. Line power connections, if needed, would be done by a licensed electrician. The local telecommunications company would install a dedicated internet connections, if needed.

Installation of sound monitoring equipment would be done by a manufacturer representative. If they are not available, an acoustical consultant familiar with similar systems can install and test the system. Installation of a permanent sound monitoring system generally takes two days for each location.

3.3 | MAINTENANCE

Continuous sound monitoring systems, even if self-contained, require off- and on-site maintenance. Given the extreme humidity and temperature environments in which these systems work, our experience has shown that equipment failures can be common. Typical system failures include power systems, communication systems, and sound monitor electronics.

The system will require periodic checks to assure that the microphones are free of debris, cables are intact, and that all systems are operating nominally. We would recommend on-site visits once per month. The vendors of rental units tend to provide maintenance themselves. Otherwise, maintenance would be managed under the direction of GMP.

For systems without communications or solar/line power, maintenance visits would need to be made once per week to change out batteries and/or download data.

3.4 | MANAGEMENT

The system requires management for installation and operations. It is best to have the management done by one person, who can reach out to whomever is required to address any issues that come up. Management is best done by GMP, and would require a portion of an FTE. However, responsibilities can be delegated to others at GMP and to a sound consultant for specific services.

During installation, the manager would coordinate all installation issues, including access and permissions, installation, and commissioning. After installation, the manager would coordinate maintenance, repairs, and reporting. This would involve periodic checks to the monitoring system, receiving daily and/or real-time alerts indicating problems with the system, coordinating repairs, and assuring that reporting is done as needed.

The system needs to be checked regularly to assure that data is continuing to flow to the storage servers from the sound level meter. Some monitoring systems have automated alerts, while others need to be checked on regular basis, either remotely or on-site.

As noted above, system failures can be common. The manager would identify problems with the system, and see if that problem can be fixed remotely. If not, field staff would be sent to the sound monitor. If the monitor can't be fixed in the field, then components need to be removed and repair and/or replaced. The manager would either do this directly or assign staff or consultants.

3.5 | REPORTING

The level of reporting will depend on the purposes of the continuous sound monitoring system. The least-cost option is to report only when complaints are filed. In this case, the sound monitor would be set up to identify sound levels and record audio when a resident calls in a complaint according to the established protocol. Since the system continuously logs data, complaints made up to several days later can be evaluated by reviewing only that data during the complaint period.

There are several cost advantages of complaint-only reporting. First, some systems operate with circular memory. As an example, audio files can get very large and are difficult to download with existing data speeds in the area. Many systems are set up so that the audio is not continually downloaded to a server, but only on request. When the memory on the monitoring system is filled, the newer audio overwrites the older audio in a circular fashion. In addition, complaint-only reporting would reduce the frequency and time spent reporting.

If complaint-only reporting is not desired, then the second alternative is triggered reporting. That is, reporting would only be done when the monitoring system finds sound levels that exceed 45 dBA $Leq_{(1\text{-hour})}$, whether or not from the turbines. Depending on the location and/or time of year, this can be infrequent or frequent. For example, background sound levels are higher at the VT 100 site due to traffic and biogenic sound increases in the spring and summer. The process for investigating and reporting exceedances of 45 dBA would involve:

1) Processing logged sound levels
2) Assessing the background sound level
3) Subtracting background from turbine sound levels
4) Downloading and listening to audio of the event,
5) Creating spectrograms to help identify events
6) Downloading meteorology to see if rain or wind contributed to the event

The last option is that reporting is done whether or not the 45 dBA level was exceeded. Reports would be prepared on a regular interval, for example two weeks, one month, or quarterly. As with triggered reporting, all potential exceedances of the CPG would be investigated.

Continually processing the data would require up to one consultant FTE, depending on how many sites are evaluated.

This feasibility study assumes that the remaining seasons of sound monitoring would take place if continuous monitoring is implemented. That is, the remaining two-week monitoring periods will still take place at each location, and reports will be filed according to the protocol. However, the protocol may be adjusted such that locations with continuous monitors would not require the addition of short-term monitoring equipment.

3.6 | CONTINUOUS, EXTENDED SHORT-TERM, OR TRIGGERED OPERATION

While much of the discussion in Sections 2 and 3 has been about larger scale automated systems that run continuously, smaller scale systems can be put into place. These include:

- Extended short-term sound monitoring – For the remaining three monitoring periods, extend the monitoring for, say two additional weeks each season. This will provide coverage for one month per season at each site, or 33% of the remaining monitoring period
- Set up a system that is triggered by a resident. That is, when a landowner feels that the turbines are loud, they would press a button on a primary and background sound monitor that would trigger it to record over a one-hour period. Those data can then be collected manually or via wireless connection on a regular basis. One advantage of resident-triggered data collection is that it would be focused on complainants and on times of complaints. In addition, the system only records audio when the button is pressed and thus reduces privacy concerns. However, it involves cooperation of the resident to trigger the two sound level meters on their property.

4.0 BACKGROUND METHODOLOGY

The background sound methods identified in the Monitoring Protocol include:

1) Eliminating sound level readings in all but a limited set of conditions representing the worst-case.
2) Turning off wind turbines at regular intervals – The method is currently being used. Turbines are currently shut down five times within a 24 hour period.
3) Adding a microphone opposite the turbine side of the home. This method is currently being used.
4) Measuring background at off-site locations.
5) Creating a model of background sound based on time-of-day and wind speed.

4.1 | METHOD 1 – ALLOW MEASUREMENTS ONLY UNDER HIGH WIND SHEAR

Method 1 was not chosen as a background method under the Protocol because it is only valid under a very strict set of conditions – basically high wind shear under downwind conditions. The advantage of Method 1 is that it only requires a single sound level meter and background sound levels do not need to be quantified. The assumption is that under high wind shear, there is no wind near the ground and most of the audible sound is the wind turbine. This assumption would have to be confirmed by listening to events that exceeded the standard. The disadvantage is that if complaints are made outside this narrow set of conditions, then there is no way to assess turbine-related sound and the data is not valid.

Method 1 is modeled after the Maine Department of Environmental Projection wind turbine noise regulations (Chapter 375.10 (I). Under these regulations, the project is deemed compliant if the average of 12 ten-minute Leqs are below the standard. Compliance monitoring is done once the first year and every five years thereafter, or in response to a complaint. The method is not intended to be used for continuous compliance assessment.

There is a single permanent sound monitoring installation at the Spruce Mountain wind project in Maine. It is used to do one annual compliance test per year according to a protocol similar to Method 1, and can be queried in response to complaints. Continuous compliance assessments are not required or conducted. Valid data is limited to downwind conditions with high wind shear.

4.2 | METHOD 2 – TURN OFF WIND TURBINES AT REGULAR INTERVALS

Methods 2 and 3 are currently being used to assess background sound levels. Method 2 requires turning wind turbines off at regular intervals. Currently, this is done for 20 minutes five times a day during the monitoring period. According to GMP, constant shutdowns and startups, especially during cold weather can lead to maintenance issues, and lost revenue during the shutdowns. If Method 2 is to be continued, then some other rate, duration, and/or trigger of shutdown would be needed.

4.3 | METHOD 3 SET UP MONITORS BEHIND BUILDINGS

Method 3 requires two sound monitors at each location – one primary and one background. Since the VT 100 site has no building, Method 3 could not be used there. The cost of a second monitoring system at each site is considered in Section 6.

4.4 | METHODS 4 AND 5 – OFF SITE MONITORING AND BACKGROUND SOUND MODEL

Method 4 was found not to be accurate during pre-construction sound monitoring.

Method 5 is inherently inaccurate and was not chosen as a primary method. In addition, since the project is constructed, there is insufficient data to create a model of background sound levels.

4.5 | NEW METHOD – DIRECTIONAL MICROPHONES

There are two new sound measurement systems on the market that incorporate directional microphones. Directional microphones only pick up sound coming in a specific direction.

There is a three-microphone system that can be directed in any direction on an X-Y plane, and there is a four microphone system that can be directed in any single direction range (X-Y-Z). The advantage of these systems is that, if there is no intervening noise source in the programmed direction, the monitors will only pick up sound from the wind turbines. No additional background monitor would be needed. The disadvantage of these systems, is that they are costly and have not been used to measure wind turbines to our knowledge. In addition, the three-microphone unit would pick up wind-induced, and other sound between the wind turbines and the monitor. Use of this technology would require a “proof-of-concept” to test whether they are comparable to the methods currently used to remove background sound.

The three-dimensional microphone array is superior, in that it is less likely to pick up noise from sources along the slopes of the ridgeline, since it can be pointed directly at the turbines. This system is more expensive, and would also require a test to compare its accuracy against the background methods currently in use.

5.0 COMPARISON OF SYSTEMS

We conducted an in-depth review of manufactures and systems integrators, and have identified nine vendors with systems that can be used for continuous sound monitoring.

A matrix has been prepared to allow a direct comparison of system capabilities. This includes the nine systems and 11 system attributes. These are shown in Appendix A and summarized below. Where possible, we have assumed a four-monitor system, which can be used for two sites (one primary and one background microphone).

Costs to purchase equipment ranged from $45,500 to $153,000, depending on features. Costs to rent equipment ranged from $100,000 to $113,000 per year, although additional years could be lower.

Unless otherwise noted, the equipment capital cost do not include labor, other required materials, turbine wear & tear, or lost revenue from lost power and station service costs during shutdowns.

5.1 | BRUEL & KJAER

Bruel & Kjaer provides one-microphone and two-dimensional directional-microphone systems as a "turn-key" solution. Both systems can be installed and managed by Bruel & Kjaer. Data is downloaded by Bruel & Kjaer over a 3G network (if available). Reports are provided as needed and data is available through a website. Compliance analyses would be done independently by a noise control engineer and is not included in their service. They do not offer short-term rentals for the directional microphone system, so no proof-of-concept can be conducted.

FIGURE 1: B&K SENTINAL

GMP would not own the equipment and the equipment would be returned to Bruel & Kjaer at the end of the data collection term.

Bruel & Kjaer is not currently offering an option to test the system out before committing to a long-term rental.

5.2 | LARSON DAVIS

Larson Davis provides an outdoor monitoring system based on their LD-831 sound monitor. This system is currently installed at Spruce Mountain in Maine, which is the only continuous monitoring system at a wind farm in the U.S. that we know of. RSG servers

FIGURE 2: LD831

download data from this system four times a day, and RSG manages the data processing and reporting (once per year).

The Larson Davis system uses a cellular modem, and has integrated logging for weather instruments.

Larson Davis provides the equipment and can install the system. Larson Davis staff will be on site during commissioning. Audio is not continuous.

5.3 | SVANTEK

Svantek offers a continuous outdoor sound monitoring system, including software connectivity. Installation and management of the system is not provided by the manufacturer.

Servicing is provided by the distributor, but some servicing requires that the unit be sent back to the manufacturer in Poland.

FIGURE 3: SVANTEK

The system includes integrated weather instruments and software for data access and downloads. Logging of sound level can be continuous or triggered by sound events.

5.4 | 01 DB

01 dB offers a continuous outdoor sound monitoring system, including software, communications, and weather equipment.

The system must be sent to France for servicing and Quebec for calibration.

Software is provided to download the data and regular intervals. Audio can be recorded continuously or triggered by sound levels.

5.5 | CIRRUS

Cirrus offers a noise monitoring system, including integrated communications and meteorological systems.

The sound monitoring can be triggered by a combination of different types of events, or run continuously. The software includes data management and email alerts when thresholds are reached. Tonal noise can automatically be detected.

5.6 | NORSONIC

Norsonic offers a continuous sound monitoring system. Due to power requirements, line power is required. Norsonic can house the data at a cost. Email notification is available when sound levels exceed thresholds.

Audio recording can be triggered or continuous.

5.7 | SCANTEK

Scantek represents several sound monitor manufacturers, and they have put together their own sound monitoring system, the ScanMonitor. They do not provide installation.

The system comes with a website capability and remote download by the user. Alerts can be programmed for several things, including the opening of the cabinet and sound thresholds. Like many of the others, the system is not certified for temperatures below 14°F.

5.8 | RION

Rion makes the NA-37A with a sound arrival directionality option. It is a four-microphone system, which picks up sound coming from any specified direction. The advantage of this system over the Bruel & Kjaer three-microphone unit is that the Rion can be directed up to the turbines, minimizing intervening sound from the trees along the ridge. The Rion only captures 1-second A-weighted sound levels and audio. It does not collect 1/3 octave band levels and cannot be used to assess tonality. It does record compressed audio which can be downloaded.

FIGURE 4: RION NA37A

5.9 | SANCHEZ INDUSTRIAL DESIGN

Sanchez Industrial Design (SID) does not manufacturer sound level meters, but puts together systems for long-term and continuous sound monitoring. Their system is based on a Larson Davis LD824. They provide on-site servicing and installation. Line power is preferred, and solar can only be used in a cleared area. RF modems are available with a 10-mile line-of-sight range. The equipment is rented to GMP and would be returned to SID after the monitoring is complete.

FIGURE 5: SANCHEZ INDUSTRIAL DESIGN ECOEARS

6.0 FEASIBILITY

6.1 | TECHNICAL

Technical feasibility refers to whether or not monitoring can be done, without consideration of cost.

From a technical standpoint, continuous long-term sound monitoring is most feasible at Eden Road, Nelson, and Farm Road. The equipment for monitoring is available in the marketplace, and would have to be adapted for the specific site, power, and communications conditions at each location.

VT 100 is the least feasible, as it is remote from line power and too wooded for solar.

Based on our conversations with GMP, turbine shutdowns continuously every six hours is not considered feasible given its impact on power production, and wear and tear on the turbines. There would also be an impact on power reliability, but this aspect is outside the scope of this report. More information about these items are submitted in a separate letter from GMP.

Sound-level-triggered monitoring is not considered technically feasible because the primary monitor could be triggered with a high-enough sound level, but the background monitor could be experiencing lower sound levels. As such, other than resident triggers, monitoring systems would have to operate and log continuously.

6.2 | ACCURACY

If the monitoring results are to be used for compliance purposes, they would need to be accurate. The minimum level of accuracy, in this case, would be set by the methods currently in use (Methods 2 and 3) and Method 1 from the protocol.

Single microphone systems would therefore not be acceptable, unless turbine shutdowns are implemented or Method 1 is used. If turbine shutdowns are to be continuous, they would either be implemented with less frequency or in response to immediate complaints.

Method 1 would also be considered an accurate one-microphone method, as it is intended only to monitor at very low surface wind speeds, thus eliminating wind noise from the background sound. However, as noted above, these conditions tend to be infrequent, and sound levels gathered by the system outside of these conditions would be considered invalid.

Systems which utilize a primary microphone and a background microphone behind a structure would be feasible, since they are allowed under the protocol.

6.3 | FIELD EXPERIENCE/PROOF OF CONCEPT

The only system we know of that has been used for continuous sound monitor of wind turbines, is the Larson Davis LD 831.

While this is the case, monitoring systems designed for remote continuous operations are not specific to the sound source. So most of the systems outlined here would have the required field experience.

The two exceptions are the Bruel & Kjaer and Rion directional microphone systems. These have, to our knowledge, never been used for continuous monitoring of wind turbines, and it is has not been shown that they can operate with the same or better accuracy of the existing background methods currently in place. While these systems are promising, we recommend they be field tested against the current monitoring system. If they can be shown to accurately identify turbine noise and eliminate background noise, then they would be considered feasible.

Bruel & Kjaer has indicated that because of the long setup time, short-term feasibility testing is not offered. We have not yet heard from Rion as to whether a short-term rental of the NA37A is available for comparison testing.

6.4 | COST

There are a large number of ways to conduct continuous sound monitoring – combining equipment, power options, communications, installation, locations, duration, and report.

To simplify matters, we will assume six scenarios for comparison. For the scenarios that involve equipment maintenance, data management, and reporting by a consultant, we have assumed dedication of one RSG FTE and reporting approximately 12 times per year including four quarterly reports with eight shorter complaint-specific reports.

These costs are estimates and not bids. Costs can and will vary depending on specific requirements.

RESIDENT-TRIGGERED SOUND MONITORING FOR ONE YEAR FOR TWO SITES

In this scenario, the sound monitoring system would remain inactive until the resident triggers it by pressing a button on both primary and background monitors. After activation, the monitors would log sound levels and record audio for one hour. The cost for equipment and software would be approximately $87,000 excluding power and communication systems. Installation, if completed by RSG or a contractor with comparable rates, would cost approximately $8,000 per site. Equipment maintenance, data management, and reporting would be approximately $225,000 for one year for two sites. The total cost for this option for one year would be approximately $328,000 excluding power and communication systems.

CONTINUOUS SOUND MONITORING AND REPORTING FOR ONE YEAR AND ADDITIONAL YEARS AT TWO SITES

The cost of equipment for continuous monitoring at two sites ranges between $120,000 and $150,000 excluding power and communication systems. Installation and commissioning would be $8,000 to $10,000. Equipment maintenance, data management, and reporting by a consultant would be $270,000. The total cost for one year is approximately $406,000 to $438,000.

For a managed rental solution, the lowest price, including installation, equipment maintenance, and data management for three years is $175,000. For four monitors for one year, the cost estimate is $100,000. Consulting costs for reporting would need to be determined after data formatting and delivery from the service, but it is expected to cost at least $186,000 for four monitors for one year, assuming evaluation of all periods over 45 dBA, tonality assessment, and monthly compliance reports. The total cost for one year is approximately $286,000.

PERMANENT INSTALLATIONS AT TWO SITES

A permanent continuous sound monitor at two sites would have similar equipment costs except the equipment would be pad mounted. The estimated cost for four concrete pads would be $8,000 to $10,000 at each site. Equipment maintenance, data management, and reporting would be $270,000 per year, assuming continual compliance monitoring and monthly reports. Triggered data evaluation would have lower labor costs.

PERMANENT INSTALLATIONS AT FOUR SITES

The cost for this system would be approximately two times the two-site installation.

DIRECTIONAL SOUND MONITORING AT TWO SITES

For this option, a specialized monitoring system that can measure sound levels specifically from the direction of the turbines would be used. The cost of equipment, software, and solar power is approximately $100,000, excluding communication costs and installation. A rental service that provides the installation and data management would be approximately $200,000.

Since this more complex system has not been used in a wind turbine application that we are aware of, there would be additional costs associated with a proof-of-concept study to make sure that this system is at least as accurate as the existing monitoring methodology. The proof-of-concept study would involve potentially importing the system from overseas to test at the site for some period of time. At this time, there is no short-term rental solution for directional sound monitoring. The study would have the existing system and the directional system run side by side for two weeks. An evaluation would be made of the existing system and background protocols with the direction monitoring system sound levels. A proof-of-concept study would not be possible for the rental service option as the equipment provider would not provide short-term rental periods and setup for the study to be conducted.

After the concept study, a more accurate maintenance and reporting estimate could be provided, but currently maintenance and reporting costs are expected to be approximately $340,000 for a purchased system with monthly compliance reports. The total cost for this option excluding communication costs would be approximately $325,000 for a rented system and $440,000 for a purchased system.

EXTENSION OF SHORT-TERM MONITORING TO FOUR WEEKS IN THE THREE REMAINING SEASONS

If the monitoring periods that are currently planned for the winter, spring, and summer of 2014 were extended to four weeks in each season, the total the cost for this option including equipment fees, data management, and reporting by a consultant would be $110,000.

SHUTDOWN COSTS

Turbine shutdowns are a cost in terms of lost revenue, station service costs (power required to operate the turbines during a shutdown), and additional wear and tear.

According to GMP, if the current protocol is continued, it would involve four shutdowns per day. For a full year, the value of energy, PTC and REC's is on average $100/MWH. Assuming an average of 6.67 MWHs lost during each shutdown (20 MWH/hour on average), this equates to 9,733 MWHs of total loss. Multiply by the $100/MWH and the total lost revenue is $973K. There would also be additional station service cost of about $30,000. The total cost for one year of continuous shutdowns along these lines is about one million dollars.

7.0 SUMMARY & CONCLUSIONS

In conducting this feasibility study, we assessed the feasibility of continuous monitoring from a technical and cost perspective.

As part of this study, we investigated many other wind power projects through our contact with developers, other consultants, and equipment manufacturers. Based on this investigation, and our experience, we could only locate one wind project with a sound monitoring system in place continuously. This system is the Larson Davis LD 831, which is included in this report. From this continuous monitor, only data from a very specific set of weather conditions (Method 1) is considered valid, and compliance analyses are only conducted once per year on twelve 10-minute periods, even though the monitor continuously operates.

Continuous monitoring at Kingdom Community Wind is technically feasible. Ultimately, it must be determined whether the additional costs for continuous monitoring along with the other factors, i.e. impacts of turbine shutdowns, result in a feasible process.

From a technical standpoint, to produce valid sound data, it is important to account for background sound levels. The most accurate proven method, from the various methods reviewed, is PSB approved Method 2 which involves shutting the turbines off periodically or under specified conditions. Other methods outlined in the report include Method 3 which has higher equipment costs associated with two systems for each site, Method 1 which is limiting in terms of conditions for which data is considered valid, and a new method of measuring sound levels from a specific direction which is untested in this application.

Using the preferred Method 2 to conduct continuous sound monitoring 24/7 for one year at two sites would cost between $400,000 and $500,000. This price excludes the costs for power systems, communications and commissioning, as well as lost power production, and station service costs during shutdowns. According to GMP, these two latter costs would be approximately one million dollars per year if the current four-per-day shutdown schedule is continued. Including these additional items would bring the total cost for continuous monitoring to over $1.4 million.

Given that, sound levels are often contaminated in the spring and summer by insect noise, and that there is the highest probability for higher sound power production in the winter and spring with higher average wind speeds during those seasons, there may be better alternatives to year-long 24/7 continuous monitoring. Since the past violations occurred only during cold weather conditions and summer levels were well below the standard, monitoring could be limited to these cold-weather months, e.g. November to March.

In summary, if some type of continuous monitoring is desired, the most cost effective sound monitoring would meet the following conditions:

- It would operate during periods when violations of the sound standard are most likely to occur (cold weather months)
- It would be installed only at sites which are generating noise complaints (Nelson Farm and/or Farm Road)
- Data would be evaluated and reported only during periods which generated complaints (which would require prompt action on the part of a participating resident to register complaints such that GMP could schedule a shutdown), and
- It would be of limited duration, until such time as the regulators are comfortable that GMP is operating within its permit limits or enough data is collected to meet whatever research objectives are established for the monitoring.

In this way, monitoring is focused most efficiently while providing compliance quality data.

APPENDIX A. EQUIPMENT INFORMATION

TABLE 1: SOUND MONITORING SYSTEM CAPABILITIES MATRIX

Vendor	Summary	Installation	Management Options	Servicing Options	Power Source	Communications (line, cell phone, etc.,)	Storage Capacity	Data Access (website, manual download, etc.,)	Audio File Capability	MET System Compatibility	Experience with Wind farms	Notes & Background Methodology
Bruel and Kjaer	**Full Service sound monitoring, including installation, servicing and management. 2D directional microphone available**	Yes , can provide all or provide drawings	B&K Manages all data collection, data compilation, and maintenance	B&K services equipment as needed	Requires line power. However solar option exist at an extra cost	Requires internet either through hardwire, wifi, cellular, or satalite	Can store onsite up to 30 days. Data is stored on their servers.	Data can be accessed via website. Data can be displayed as background corrected level. Client can download 1-second data, including 1/3 octaves	Audio recording is triggered by a level, but even if it is not triggered, audio can be pulled from the local system. Trigger level can change with wind speed.	Tied to Vaisala.	Single point has been installed at a wind farm, but 3-microphone has not been used as a continuous monitor.	B&K has a 2-axis(horizontal only) directional microphone option which will not pinpoint sound from wind turbines at a different elevation. Direction is selected as a 5 degree resolution, and as a range. No accurate way of differentiating background without turbine shutdown.
Larson Davis	**Equipment supplier only**	Pole/cement 3rd party, instrument installation by LD	No	No	Solar (third party, but equipment is obtained by LD) or line	Cellular, Line	2 GB internal - optional computer has 11 GB. Data is generally downloaded at least one time per day.	DNA, G3 (like spruce), Noise Tutor (emails data or downloads to FTP site, also allows public viewing or recent sound levels) Noise Tutor requires about 8 watts of power so isn't recommended for solar powered systems	Noisetutor - 831 sound recording option separate	Tied to Vaisala.	One LD 831 system is set up for continuous moniotiring at Patriot Renewable's Spruce Mountain. RSG runs the data and Patriot manages servicing	
Svantek	**Equipment supplier only**	Provide Equipment Only - List of Recommended Installers	No	Servicing is covered by distributor - may have to be sent back for poland	Solar panels (interface is internal) solar panels are 3rd party - line power is possible (DC) - internal batteries will last 48 hours	Cell Service, LAN, WIFI, phone line service	16 GB - MicroSD	Web browser or server application for audio streaming, data downloading, audio downloading, gps coordinate downloads, remote system configuration, and current results views	Both Continuous and Event/Trigger	Wind Speed, Wind Direction, Temperature, Humidity, Ambient Pressure, Rain with optional weather station	Yes	
01 dB	**Equipment supplier only**	Can Recommend Installers	No	Have to send it back to France for servicing or to Quebec for calibration	Solar Possible will require large solar panels (200 W heater) - line power better - connect solar panels to external battery then to duo	G3 Modem within DUO - works with AT&T - Wifi (directly to DUO and to external) - Ethernet	64 GB - SD Card	FTP server within the DUO can transfer files - supply software that will download the data automatically at an interval -- export setup from 1 DUO to others	.biv format - openable with audacity - can be transformed into .wav from there 51.2 kHz to 1.6 kHz sampling rate - continuously or based on triggers	Vaisala weather station plugs directly into DUO records	Yes	Note: have an IEC 61400-11 kit.
Cirrus	**Equipment supplier only**	by client	Yes	Yes	Mains, Battery, or Solar	3G, GPRS, Wi-Fi, LAN, or Radio Modem	32 GB Factory Installed	Yes, Noise-Hub Software, or Cirrus Cloud Server Hosting of Data and web interface	Triggered audio recording only with qualities from 96kHz/32bit down to 16kHz/16Bit	Weather Sensor Options for wind speed, direction, temperature, relative humidity, barometric pressure, rainfall	Yes, in Europe	Email, Twitter, and SMS Alerts; Automatic tonal noise detection
Norsonic	**Equipment supplier only**	by client	Norsonic has data hosting and reporting options	Nor1530	Mains with battery backup	LAN, Bluetooth, ADSL, Wifi, GMPRS, 3G	64 GB - SD Card	website capability (NorWeb), Downloaded to NorMonit,	triggered or continuous audio recording at 8, 16, or 24 bits and 12 or 48 kHz sampling	Weather monitoring capability	??	Email and SMS notifications for sound thresholds, Requires a server with IIS and SQL
Rion - Scantek ScanMonitor	**Equipment supplier only**	by client	??	??	Mains, Battery, or Solar	GSM/GPRS, WiFi, or Ethernet	"high capacity local memory"	Website capability, Remote download	Yes	??	??	Unauthorized box opening detection, and service necessary notifications
Rion NA-37A	**Equipment supplier only. Includes 3D directional microphone, but does not collect 1/3 octave bands for tonal sound analysis.**	by client	??	??	100 to 250 V AC, or external power supply 12V DC (11.5 to 15 V) and Battery backup power	LAN, mobile router	256MB to 2 GB	LAN, Data copy to USB Flash,	Compressed for long-term recording & PCM for analysis	Vaisala	??	3D sound arrival direction sensing, GPS Automatic Time Correction. Does not measures 1/3 octave band levels
Sanchez Industrial Design	**Advertises continuous sound monitoring systems from 3rd pary componants**	Can do on-site installation, they have rugged alumimum frames anchored to ground	Want someone local to check out every 3 months	On-site servicing as needed	AC power or solar. Solar only if it is a cleared area	Wifi or celluar or long-range radio modem to a building with internet access. 10 mile range with perfect line of site.	Downloaded real time, or USB stick of any size of backup (6 mos or year)	Access via website. Data is displayed in minimum 1 minute interval. 1-sec data is accessible via FTP site. 1 file per day	Can do audio with a level trigger, but cannot transmit due to file size. Data can be collected manually.	Vaisala	Has monitored up to 3 to 6 months, but know of no permanent installations	Can do video and pictures during measurement