Appendix C: Acoustical Reports for Beech Ridge Wind Project

Report C-1. Acoustical Study of Proposed Beech Ridge Wind Farm, Greenbrier County, WV (Acentech 2006)

Report C-2. Acoustical Study of Proposed Expansion/Modification of Beech Ridge Wind Farm, Greenbrier County, WV (Acentech 2011)

Acentech Report No. 359R

Acoustical Study of Proposed Beech Ridge Wind Farm Greenbrier County, WV

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1. Introduction

Invenergy Wind LLC has proposed to design, construct, and operate a nominal 200 MW wind farm at a mountainous rural site in southeast West Virginia. In support of this project, Invenergy has requested that Acentech Incorporated perform an acoustical study of this project and provide information for review by the West Virginia Public Service Commission (WVPSC) during the site permitting process. To date, Acentech has reviewed the facility and site drawings, equipment information, and the revised noise study guidelines of the WVPSC that were provided to us by Invenergy; toured the project area; conducted sound measurements and observations of the existing ambient conditions at representative community locations; and estimated construction and operation sound levels for the facility. This report presents the ambient sound measurements and results of our acoustical study.

2. Description of Proposed Facility and Site

The proposed wind power project consists of up to 124 General Electric (GE) Model 1.5sle wind turbine generators (WTGs) and associated equipment, with each WTG to be mounted on individual 80-meter tall towers across 20 miles of ridgelines in Greenbrier County, WV. The associated equipment includes a 2 MVA transformer at each WTG tower, 34.5kV underground transmission lines for the electrical collection system, a 34.5/138kV substation with a 200 MVA main transformer and service building, and a 138kv overhead transmission line for connection to the power grid. Figure 1 displays the wind turbine lines (A through J) overlaid on a map of the region.

Each GE Series 1.5sle wind turbine incorporates a horizontal-axis propeller that drives a gearbox and generator mounted to the top of an 80-m (260-ft) high tower. A nacelle for weather protection and noise control encloses the gearbox and generator. The 77-m (250-ft) diameter rotor has three blades, which attach to a hub that contains active blade pitch control; this system provides for peak aerodynamic efficiency over a range of wind conditions. During routine operation, the rotational speed of the rotor will range from 10 to 20 revolutions per minute; and at wind speeds below 3.5 m/s (8 mph) and at wind speeds above 25 to 30 m/s (56 to 67 mph), it will not operate. The rated capacity of this unit is 1.5 MW at a wind speed of 12 m/s (27 mph). The WTGs include the following noise control treatments into its design: impact noise insulation of the gearbox and generator, reduced-noise gearbox, reduced-noise nacelle; vibration isolation mounts, and quieted-design rotor blades.

The wind farm is located on the mountain ridges to the north of Rt. 60 and I-64 and south of the Monongahela National Forest, and to the west of Rt. 219, and to the east of Big Clear Creek. Lightly traveled paved and unpaved roads cross this rural area, which is dotted with scattered homes and seasonal hunting cabins, and with several small groups of homes and churches in settlements such as Duo, Leonard, Cordova, Friar's Hill, Trout, and Williamsburg. The substation will be constructed in the center of the wind farm with the overhead transmission line running to the northwest from the substation out to the external power grid.

3. Guidelines for Noise Studies

The WVPSC Guidelines for Noise Studies for Siting Certificates include:

- Preconstruction – identify land uses and existing ambient sound levels (Ldn) in communities within one mile of the facility.

- Construction – predict construction noise associated with blasting, earthmoving, pile driving, erection, traffic, and equipment installation at the nearest property boundary and within one mile and five miles from the facility. Identify noise sensitive areas within one mile and five miles of the facility. The noise sensitive areas include hospitals, schools, residences, cemeteries, parks, and churches. Describe construction equipment, procedure, and potential noise mitigation options.

- Operation – predict operation noise and identify land uses and type of structures (residential, commercial, or industrial) within one mile of the facility. Describe equipment and procedures to mitigate potential noise.

Information on the preconstruction ambient, construction, and operation sounds for the facility are presented in the following sections. Please refer to "Appendix A - Sound in Lay Terms" for a useful overview of sound and its measurement.

4. Preconstruction Ambient Sound Measurements

Figure 2 is a map of the project area with an overlay of the proposed turbine sites, land use classifications, the community sound measurement locations, and the measured day-night sound levels (Ldn). Table 1 describes the six monitoring locations selected for the ambient survey that Acentech conducted over a nominal one-week period in late September to early October 2005. The acoustic environment and nearby land uses were observed at these locations, and they were judged representative of those at the noise sensitive receptors, such as residences and churches, in the community bordering the project site.

The weather during the survey was seasonal and ranged from clear to cloudy skies with some rain early in the survey, calm to windy conditions, and temperatures from about 70ºF during the day down to about 50ºF at night. As Table 1 notes, most of the monitoring locations are near homes or small groups of homes and seasonal hunting cabins; and the locations range from 900 ft. (seasonal hunting cabins) to 3200 ft.* and 7800 ft. (year-round homes) from the nearest WTG location. The purpose of the survey was to characterize the existing land uses, sound sources, acoustic environment, and specifically, representative long-term Ldn values in the area. Figures 3 through 12 display photographs of the six locations where the A-weighted sound levels were monitored continuously during the survey. The field team also collected short-term measurements and observations during visits to each monitoring location. The observed sources typically included wind in trees, local traffic, birds, insects, aircraft, and a flowing creek. The results of these supplemental short-term measurements will be maintained in our project files. Table 2 lists the instruments that were employed for the ambient survey.

Figures 13 through 18 display the variations in sound levels that were measured at the six locations. To address the WVPSC Noise Guidelines for Noise Studies, the figures show the Leq sound level for each hour, and also, indicate the Ldn sound level for the nominal one-week period. As mentioned above, Appendix A provides an overview on sound and its measurement, and in particular, discusses the Leq and Ldn descriptors. Please note that Leq sound levels include both the steady background sounds (steady wind in trees or rushing stream) and the short-term intrusive sounds (e.g., bird chirps or local car passby). Of most significance, the data indicate that the long-term Ldn sound levels ranged from 49 dBA to 52 dBA, with an average value of 50 dBA and a standard deviation of 1.5 dBA across the six locations. Table 3 lists the long-term Ldn values measured at each location. The measured Ldn values, sound source types, and land uses are relatively uniform across the one-mile buffer area, and the study area contains no dominant existing sound sources that would generate sound contours, for example, a factory or a well-traveled Interstate highway. Therefore, the ambient sound level contours are flat within this area so that no individual contours are shown on Fig. 2, but instead, individual measured Ldn values are given.

* Homeowners in Little Beech Knob area (Location 2) to participate in project; otherwise, approximate distance to nearest WTG would be one mile.

5. Construction Noise Estimates and Mitigation Measures

Construction of the Beech Ridge Wind Farm is scheduled to start in Spring 2007 and continue to November 2007. Initial activities (Phase I) will include improvements and new construction of facility access roads; then clearing, excavation, foundation, and backfill work at the WTGs and the substation. Concrete for the project will be made at temporary on-site batch plants using trucked-in materials. Phase I activities will be followed by Phase II activities, which are comprised of erection of the WTG towers and installation of the WTGs; trenching and installation of the electrical collection system; and installation of substation equipment. Finally, prior to commercial operation, the individual equipment items and the entire facility will be tested and commissioned during Phase III.

A majority of the construction activities associated with the proposed project will be conducted during daylight hours. At times over the planned construction schedule, the construction activities will be audible to nearby residents. Any construction at the facility in the evening and nighttime is expected to be limited to relatively quiet activities and to be less noticeable than in the daytime.

The following mitigation measures will be employed during the construction phase of the project:

- Effective exhaust mufflers in proper working condition will be installed on all engine-powered construction equipment at the site. Mufflers found to be defective will be replaced promptly.

- Require contractors to comply with federal limits on truck noise.

- Construction contractors will be required to ensure that their employee and delivery vehicles are driven responsibly.

- Nighttime construction work that does occur will generally be limited to relatively quiet activities, such as welding and installing equipment, cabling, and instrumentation.

- Notify the community in advance of any blasting activity.

Construction sound that may be heard off-site will vary from hour-to-hour and day-to-day in accordance with the equipment in use and the operations being performed at the site. Since the construction activity at the site will be temporary, will occur mostly in the daytime hours, and will produce sounds that are already familiar to the community, its overall noise impact on the community beyond 1000 ft. of the nearest turbine is not expected to be significant. The community currently experiences sound from timber operations, and has in the past and may in the future, experience sound from mining operations. In fact, mining is currently on-going in the region to the south and west of the project.

Typical on-site equipment used to construct the wind farm project will include trucks, cranes, dozers, excavators, trenchers, graders, and batch plants. Representative equivalent sound levels associated with these construction equipment during the workday are listed in Table 4. For example, with 2 trucks, 1 dozer, and 1 excavator operating at a WTG, the calculated equivalent sound level during the workday is 54 dBA at 1550 ft. (nearest property boundary and closest residence in Little Beech Knob* to WTG) and 41 dBA at 4000 ft. The reported sound levels are based on the results of extensive previous acoustical studies of engine-powered construction equipment. Figure 19 displays the contours of the estimated maximum Ldn sound levels over the entire study area for Construction Phase 1, which include the contributions of construction truck traffic, with comparisons to the measured preconstruction ambient Ldn values. These contours were developed with a commercial computer noise modeling program, Cadna/A. This program employs ray-tracing technology that accounts for various factors, including geometric spreading, atmospheric absorption, and wind conditions; for our modeling, we used wind rose data that were collected at the Beech Ridge site.

6. Station Sound Estimates and Mitigation Measures

The range of sound levels that will propagate from the wind turbine generators to various locations in the community around the site have been predicted. The project is addressing the facility sound with the purchase of the General Electric 1.5sle wind turbine generator, which incorporates the following noise control treatments into its design:

- Noise insulation of the gearbox and generator
- Reduced-noise gearbox
- Reduced-noise nacelle
- Vibration isolation mounts
- Quieted-design rotor blades

In addition, the project will specify and purchase high-efficiency, reduced-noise transformers. The estimated Ldn operating sound levels for the six community monitoring locations, and also,

* Homeowners in Little Beech Knob area (Location 2) to participate in project; otherwise, approximate distance to nearest WTG would be one mile.

Friars Hill, Trout, and Williamsburg, are listed in Table 5. Of added note, Figures 20 and 21 (without and with land use classifications, respectively) display the Ldn sound contours for the operating facility. The estimated Ldn values and contours for the operating phase were developed with the computer noise modeling program, Cadna/A. The estimated values at the community monitoring locations with year-round residences for the wind farm Ldn sound levels range from 17 dBA to 41 dBA*, which compare to the measured preconstruction ambient values of 49 dBA to 52 dBA. The facility sound estimates assume maximum sound output of all 124 wind turbine generators, which occurs under conditions of maximum rated wind speed (27 mph). Under conditions of reduced wind speeds, the background sound associated with wind in trees would be less; however, the WTG sound emissions would also be less.

The project sound levels are estimated on a time-weighted basis (Ldn) for outdoor locations; for indoor locations, these levels would be reduced by 12 dBA with the windows open and by 24 dBA or more with the windows closed. Although we judge that the wind farm may be heard at times in the community at distances of 4000 ft. from the project, our measurements and estimates indicate that the long-term Ldn sound levels of the wind farm will be significantly less than the existing ambient Ldn levels at that distance for both outdoor and indoor locations.

7. Noise Impact Assessment

As noted in Section 5, the majority of the construction activities associated with the project will be conducted during the daylight hours, and it will vary over time, depending on the equipment in use and the operations being performed at the site. The temporary noise associated with construction of the project will be similar to the noise produced during excavation, grading, and steel erection activities at many other mid-size building projects, and the current timber and mining activities in the region.

The project will be available to operate 24-hours per day and seven days per week. It is expected that routine operation will produce day-night sound levels in the community that are similar to or lower than the measured existing ambient day-night sound levels.

Community residents at 4000 ft. from the project may at times hear sounds associated with construction or operation of the project, but the overall impact is not expected to be significant at either outdoor or indoor locations.

* Homeowners in Little Beech Knob area (Location 2) to participate in project; otherwise, wind farm Ldn sound levels would range up to 39 dBA at year-round community residences in the vicinity of the project.

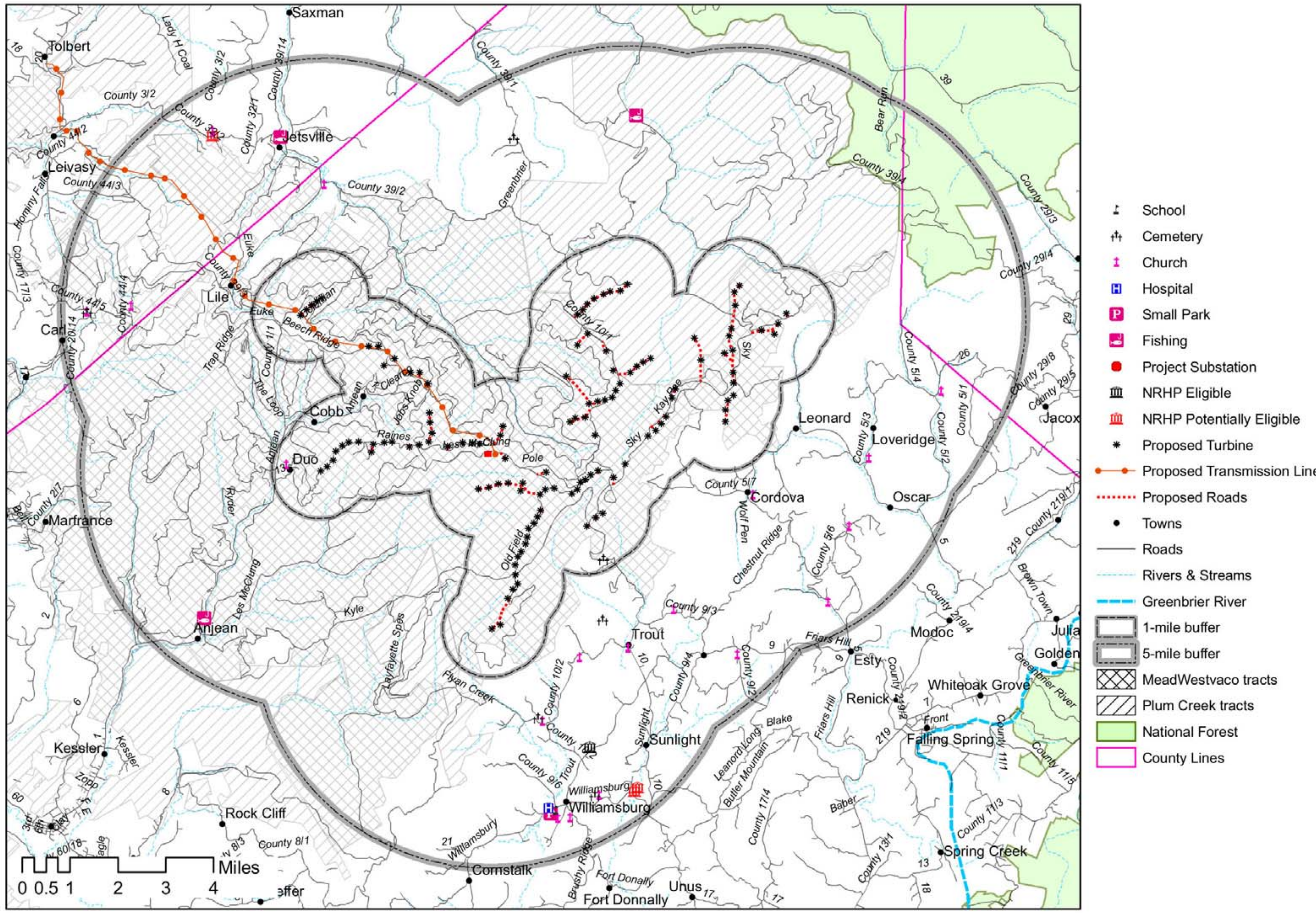


Figure 1. Area Map with Proposed Beech Wind Farm Showing Turbine Locations and One-Mile and Five-Mile Buffer Zones.

<u>Notes</u>

Measured Ldn sound levels, sound sources, and land uses were relatively uniform within the one-mile buffer zone, resulting in a flat ambient sound contour for the area.

Number of residential structures within 1-mile buffer at Little Beech Knob – 10; Leonard-Cordova – 10; south of B-turbines – 4; Duo – 29; and hunting camp – 15.

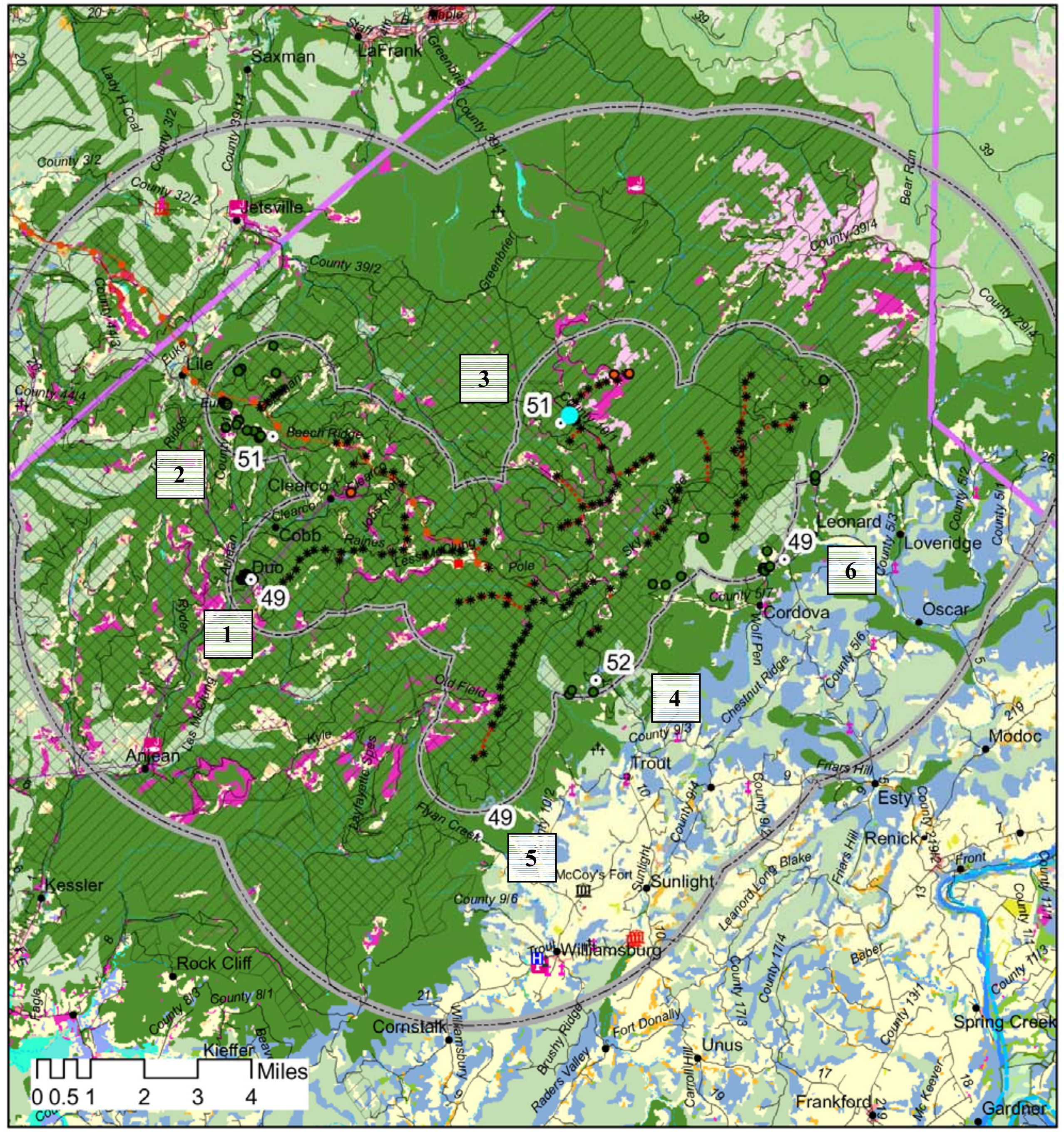


Figure 2. Area Map with Community Sound Monitoring Locations 1 through 6 and Average Measured Existing Ambient Day-Night Sound Levels (Ldn) during September - October 2005 Sound Survey.

Figure 3. View of Location 1 (Town of Duo).

Figure 4. View of Church near Location 1 (Town of Duo).

Figure 5. View of Location 2 (Little Beech Knob).

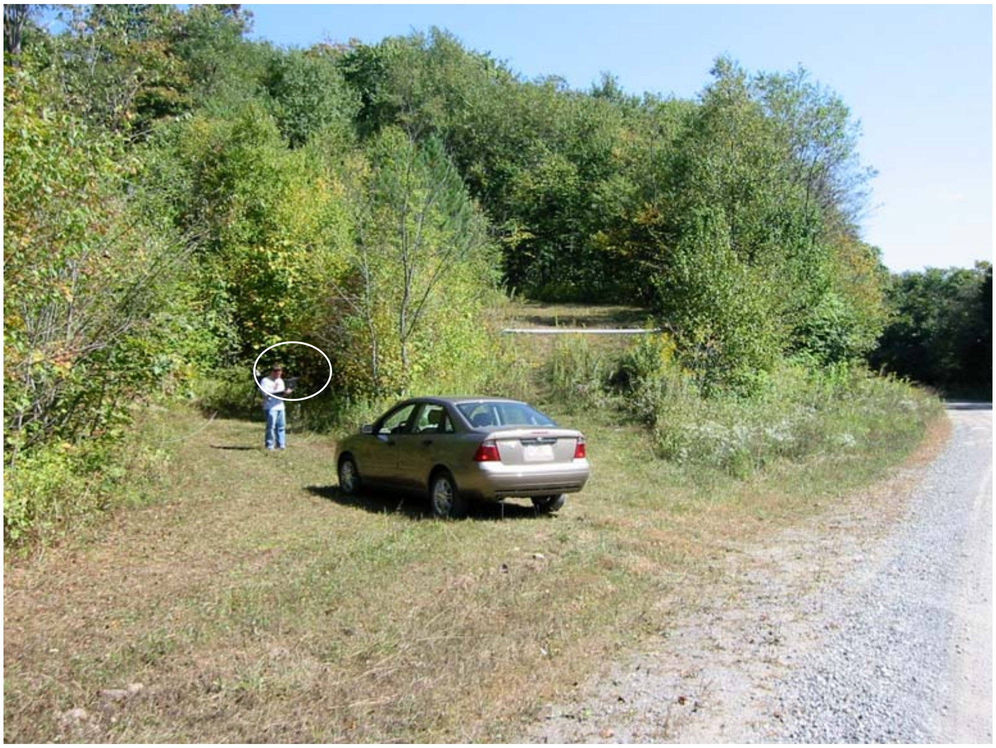


Figure 6. Close-in View of Location 2 (Little Beech Knob).

Figure 7. View of Location 3 (Hunting Cabins).

Figure 8. View of Cabin near Location 3 (Hunting Cabins).

Figure 9. View of Location 4 (Home South of B Turbine Line).

Figure 10. View of Location 5 (Flynn's Creek).

Figure 11. View of Location 6 (Leonard/Cordova).

Figure 12. View of Road near Location 6 (Leonard/Cordova).
(short-term measurement taken at road without traffic; long-term monitoring performed away from road)

Figure 13. Hourly Leq A-Weighted Existing Ambient Sound Levels Measured at Location 1 (Town of Duo) during 27 September – 5 October 2005.

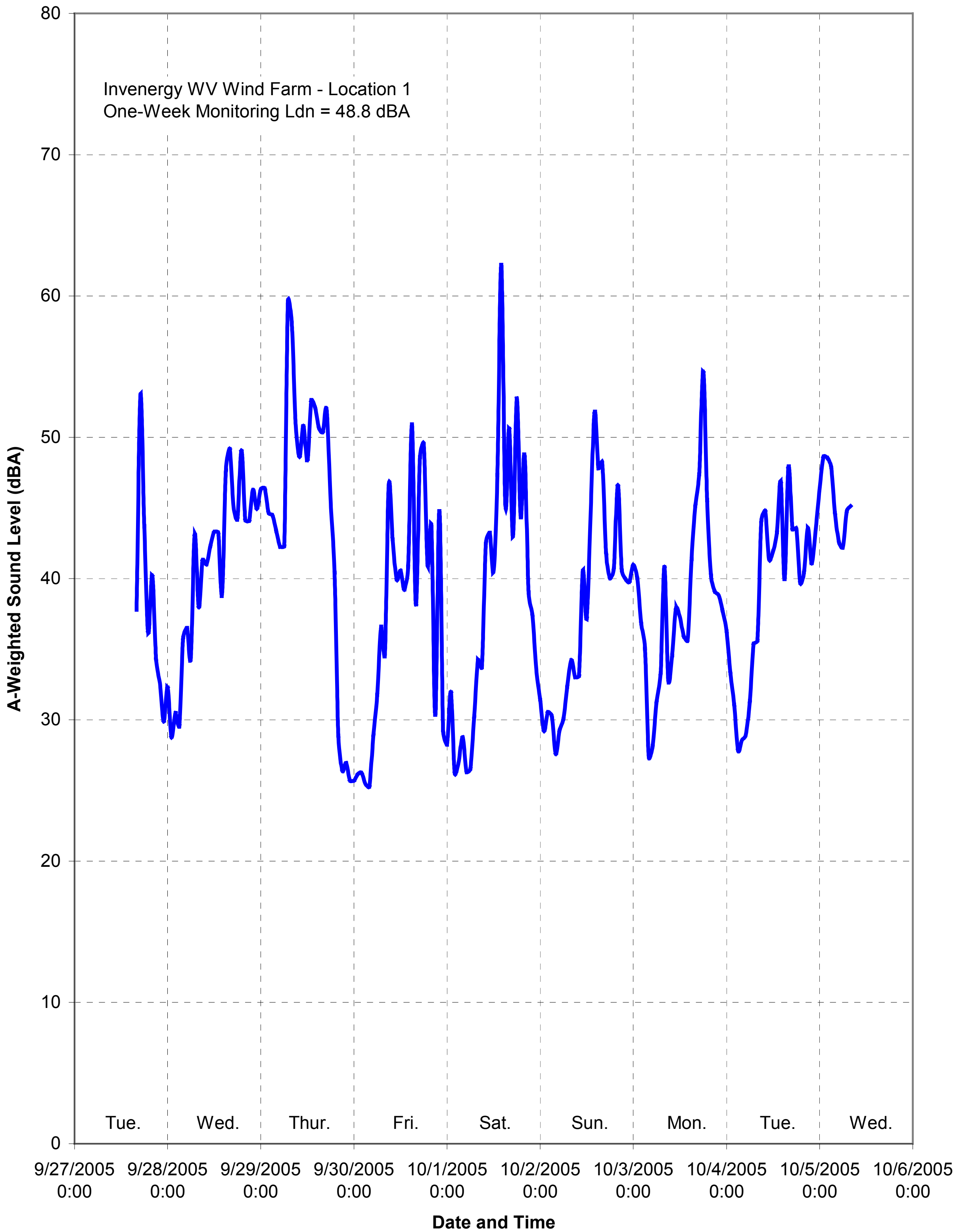


Figure 14. Hourly Leq A-Weighted Existing Ambient Sound Levels Measured at Location 2 (Little Beech Knob) during 27 September – 5 October 2005.

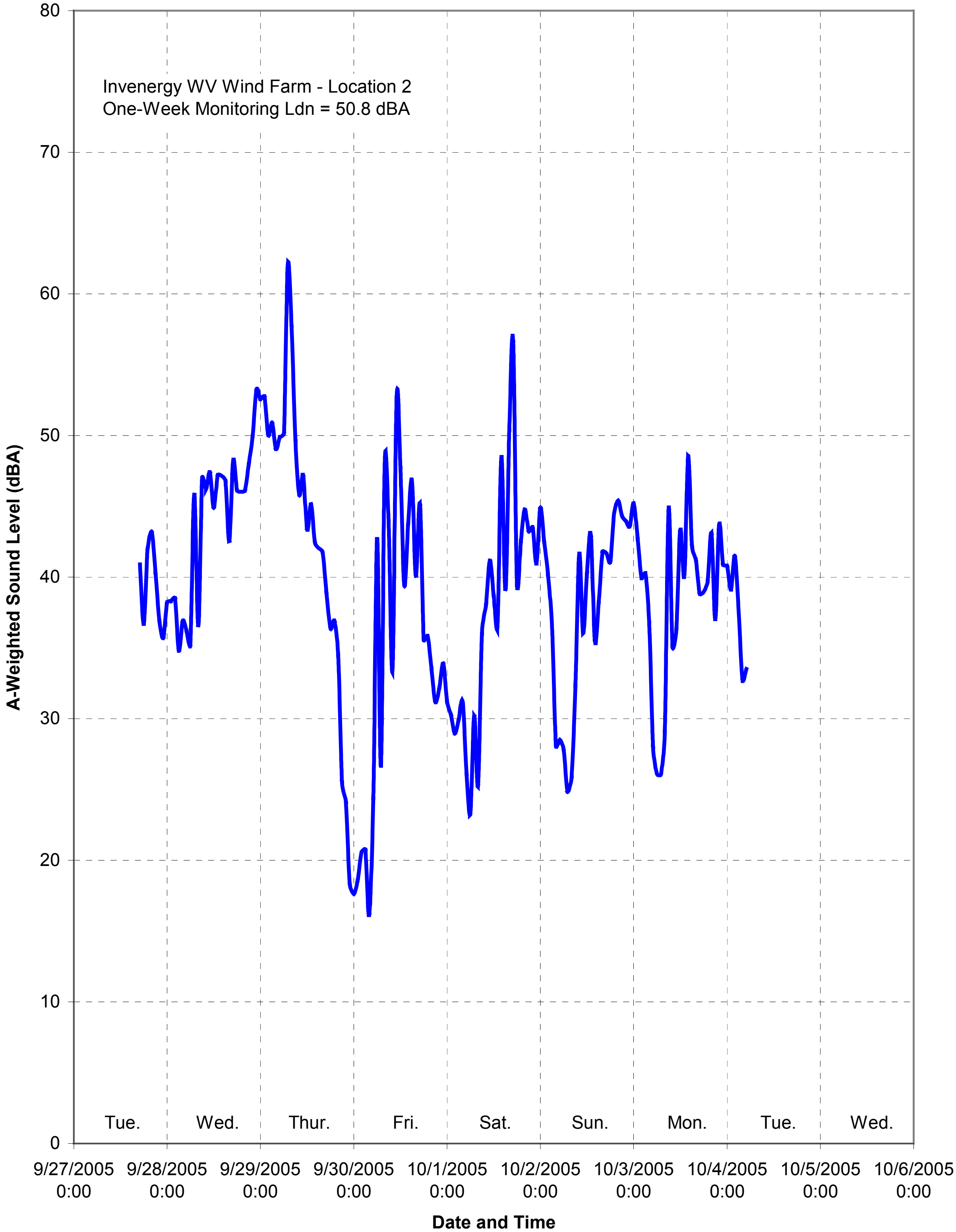


Figure 15. Hourly Leq A-Weighted Existing Ambient Sound Levels Measured at Location 3 (Hunting Cabins) during 27 September – 5 October 2005.

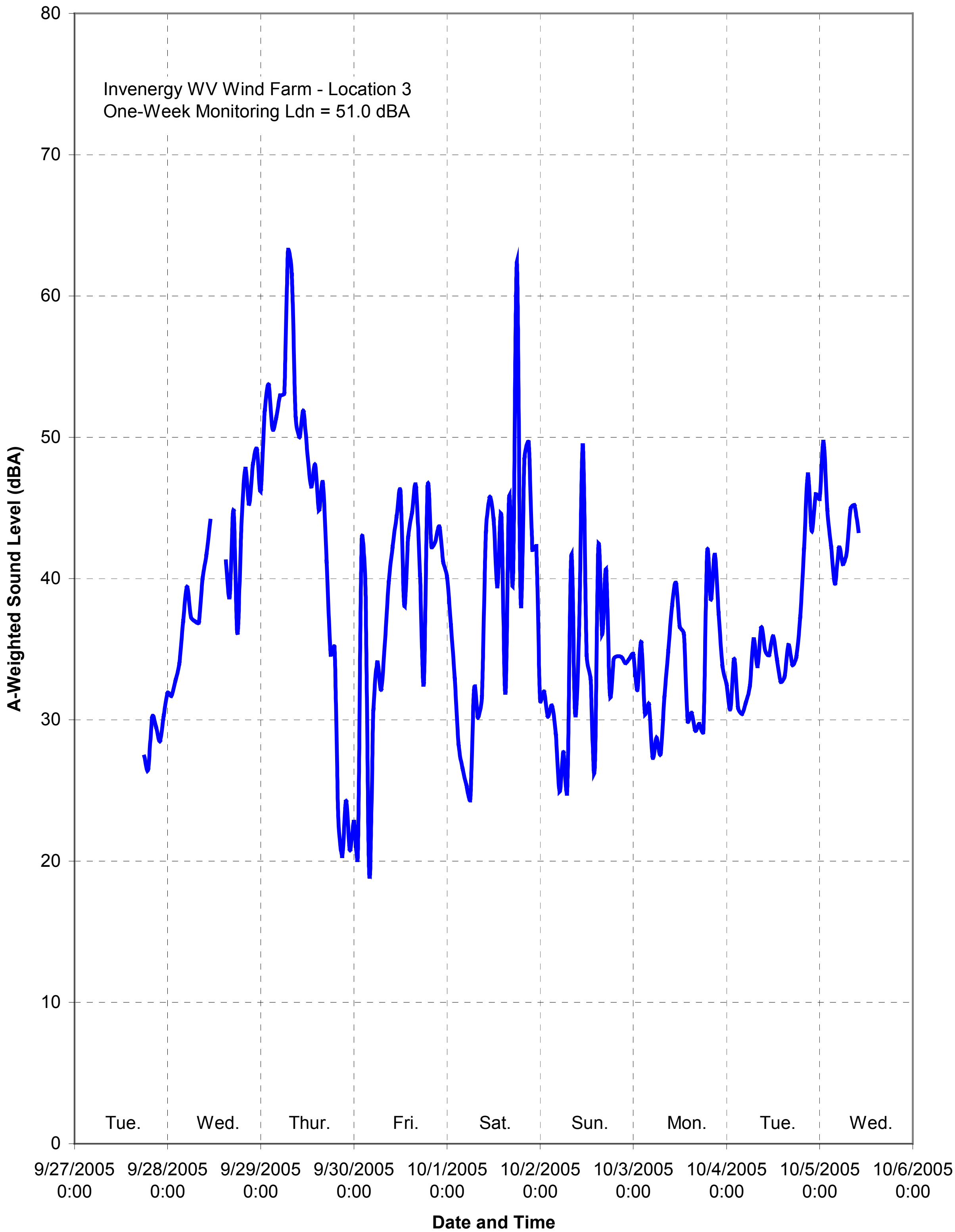


Figure 16. Hourly Leq A-Weighted Existing Ambient Sound Levels Measured at Location 4 (Home South of B-Turbine Line) during 27 September – 5 October 2005.

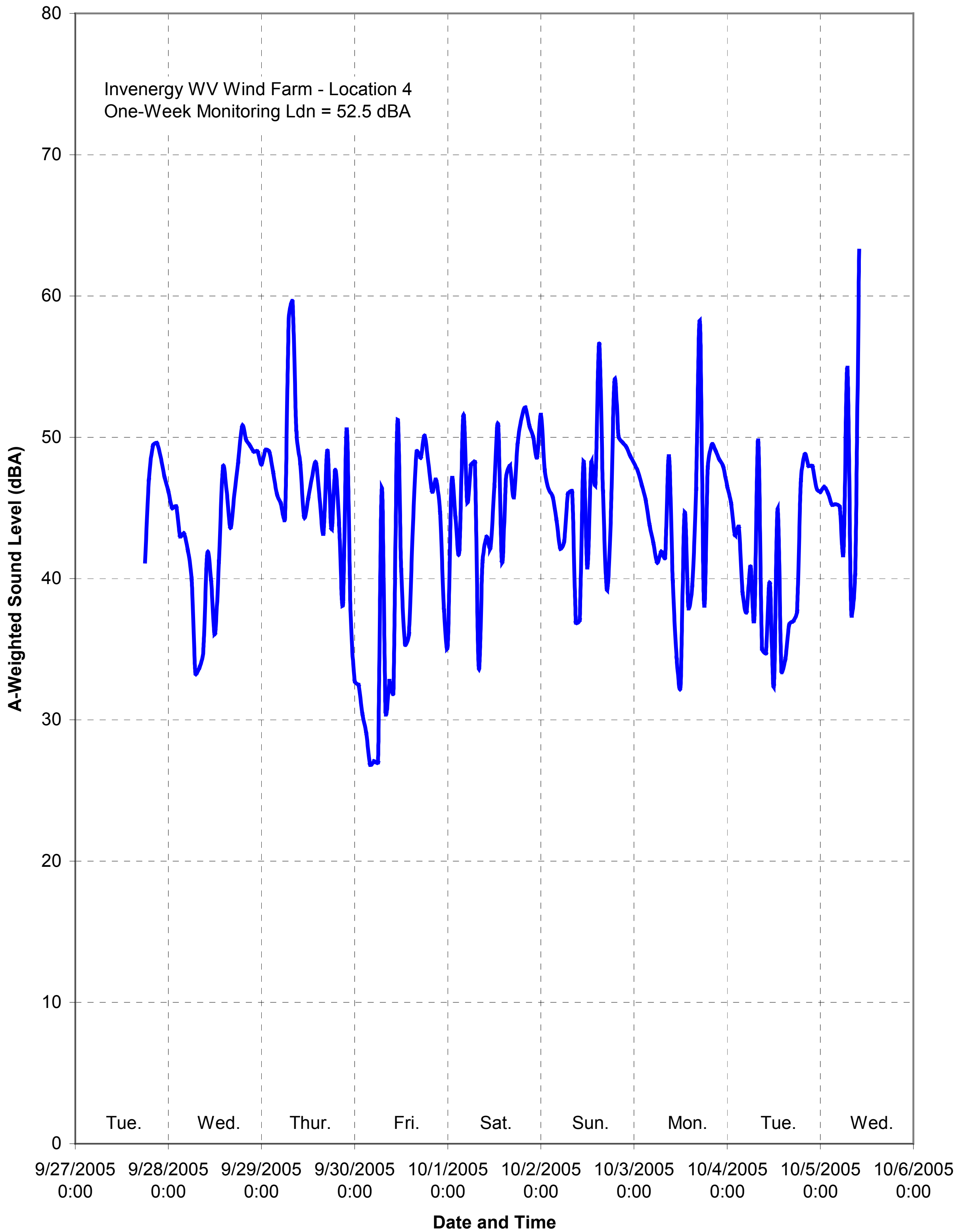


Figure 17. Hourly Leq A-Weighted Existing Ambient Sound Levels Measured at Location 5 (Flynn's Creek) during 27 September – 5 October 2005.

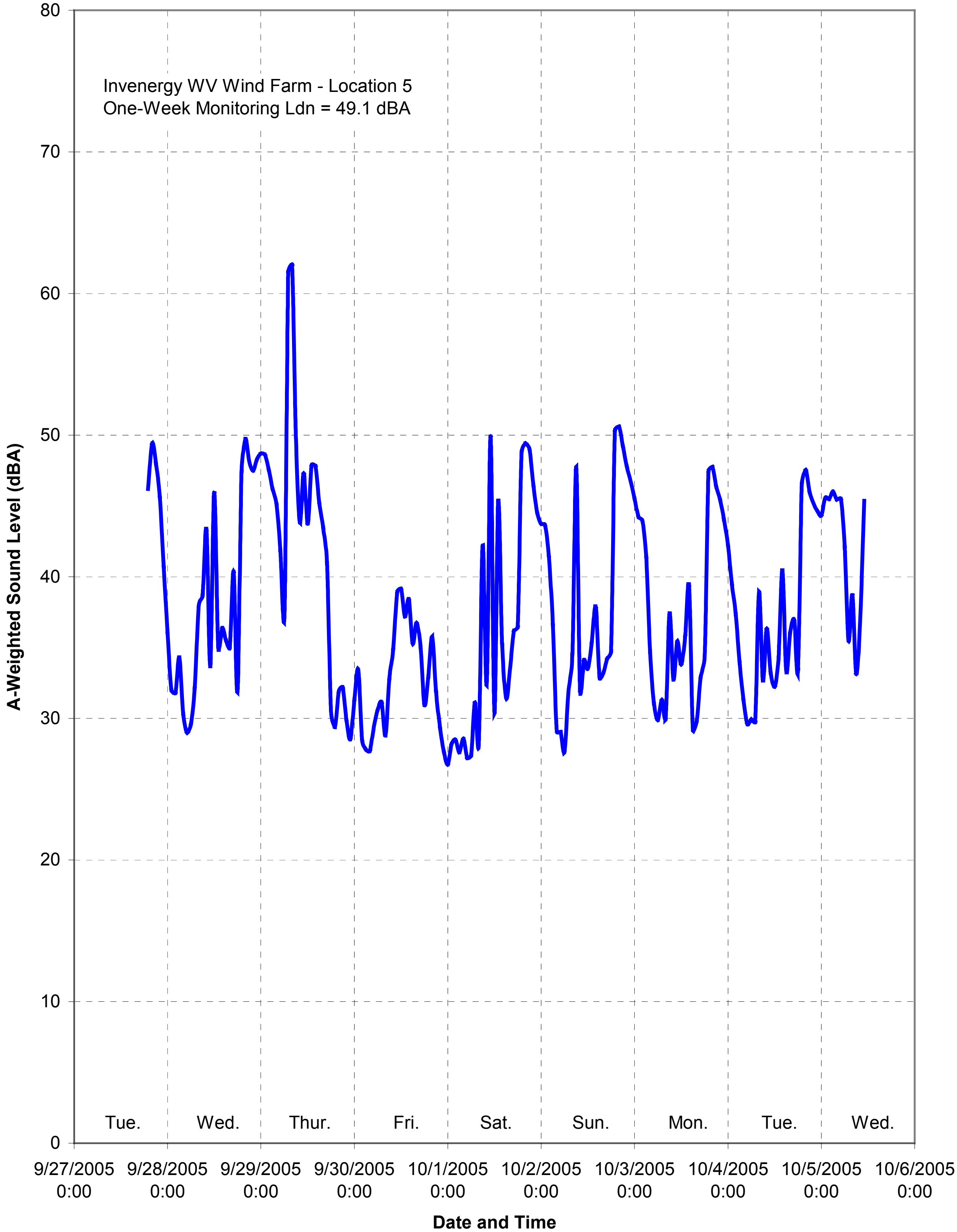
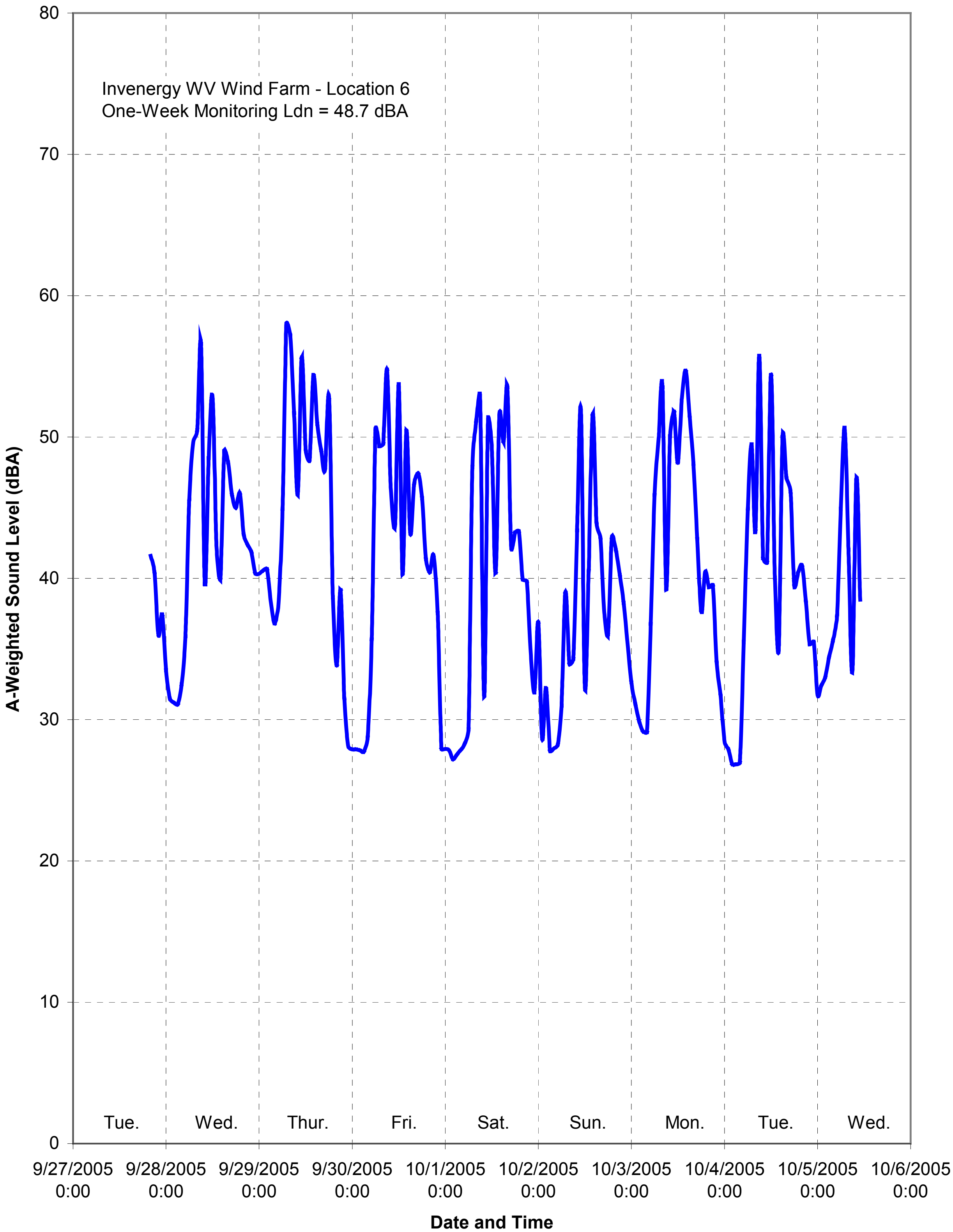
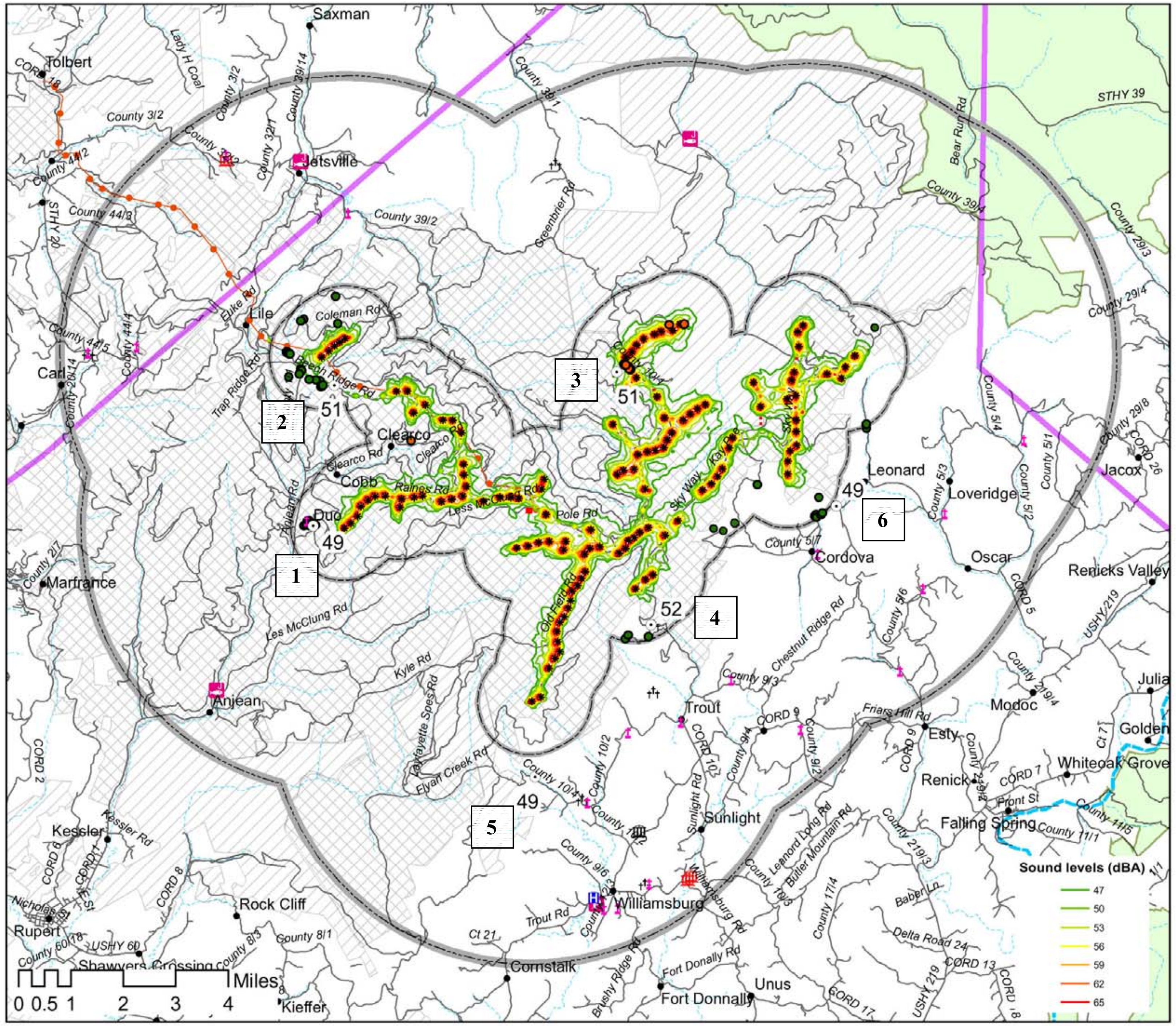


Figure 18. Hourly Leq A-Weighted Existing Ambient Sound Levels Measured at Location 6 (Leonard/Cordova) during 27 September – 5 October 2005.





Notes
Number of residential structures within 1-mile buffer at Little Beech Knob – 10; Leonard-Cordova – 10; south of B-turbines – 4; Duo – 29; and hunting camp – 15.

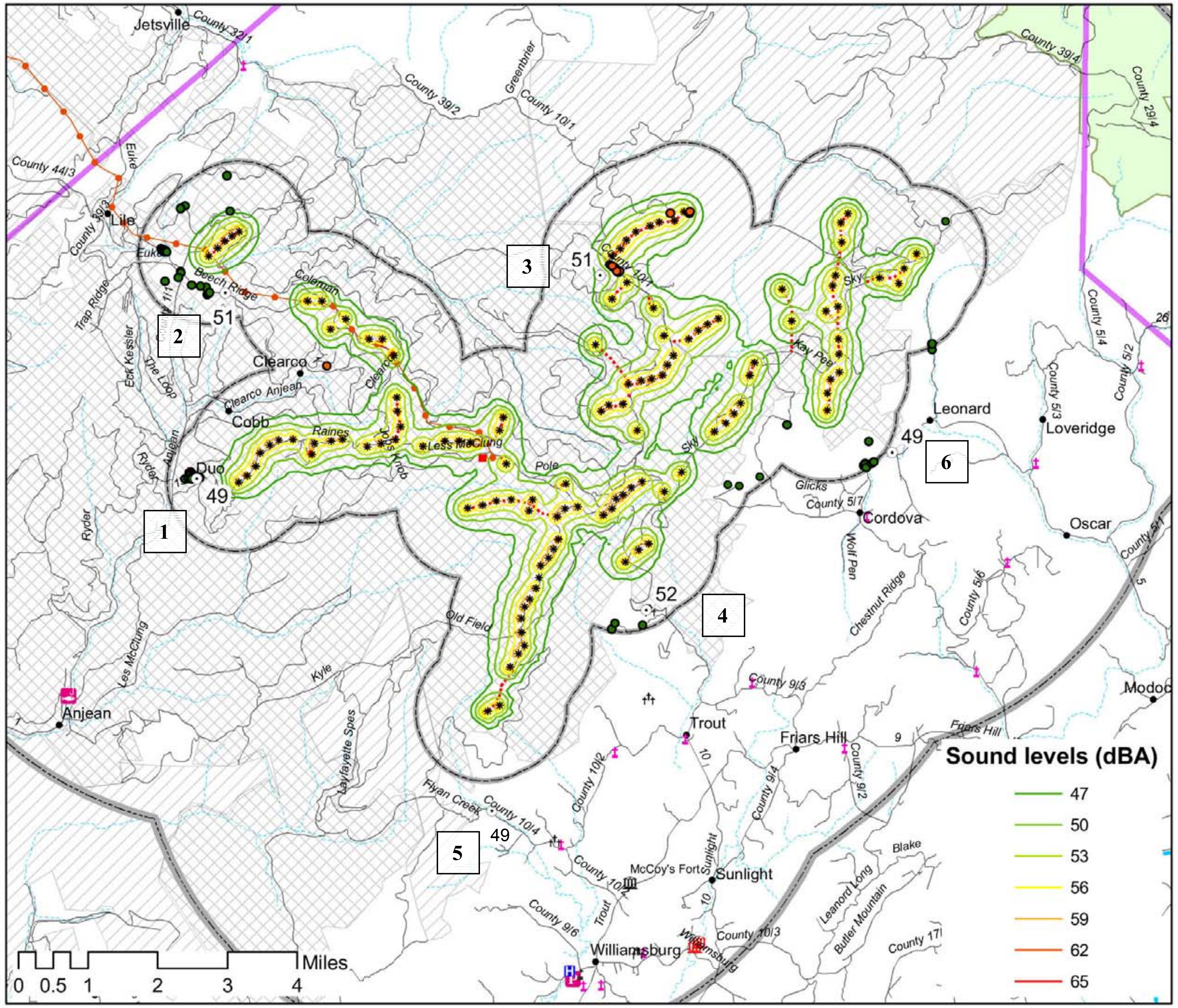
Contours of construction sound only, assuming construction at each WTG simultaneously, and do not include contribution of ambient sound.

Numerous scattered residences are located in the general area from Leonard through Williamsburg between the one-mile and five-mile perimeters, with fewer residences along roads in the other areas.

- Measurement Locations
- Residential Structures*
- Seasonal Homes/Hunting Cabins
- Church
- School
- Cemetery
- Hospital
- Small Park
- Fishing
- Project Substation
- NRHP Eligible
- NRHP Potentially Eligible
- Proposed Turbine
- Proposed Transmission Line
- Proposed Roads
- Towns
- Roads
- Rivers & Streams
- Greenbrier River
- 1-mile buffer
- 5-mile buffer
- MeadWestvaco tracts
- Plum Creek tracts
- County Lines
- National Forest

* Includes barns, garages, trailers, etc.

Figure 19. Area Map of Proposed Beech Ridge Wind Farm with Estimated Construction Sound Level Contours Compared to Average Measured Existing Ambient Ldn Sound Levels at Locations 1 to 6.



Notes

Number of residential structures within 1-mile buffer at Little Beech Knob – 10; Leonard-Cordova – 10; south of B-turbines – 4; Duo – 29; and hunting camp – 15.

Contours of operation sound only and do not include contribution of ambient sound.

Land use classifications not shown on this figure for clarity; see Figure 21 for Operation Sound Level Contours on map with land use classifications.

Figure 20. Area Map of Proposed Beech Ridge Wind Farm with Estimated Operation Sound Level Contours Compared to Average Measured Existing Ambient Ldn Sound Levels at Locations 1 to 6.

<u>Note</u>
Number of residential structures within 1-mile buffer at Little Beech Knob – 10; Leonard-Cordova – 10; south of B-turbines – 4; Duo – 29; and hunting camp – 15.

Contours of operation sound only and do not include contribution of ambient sound.

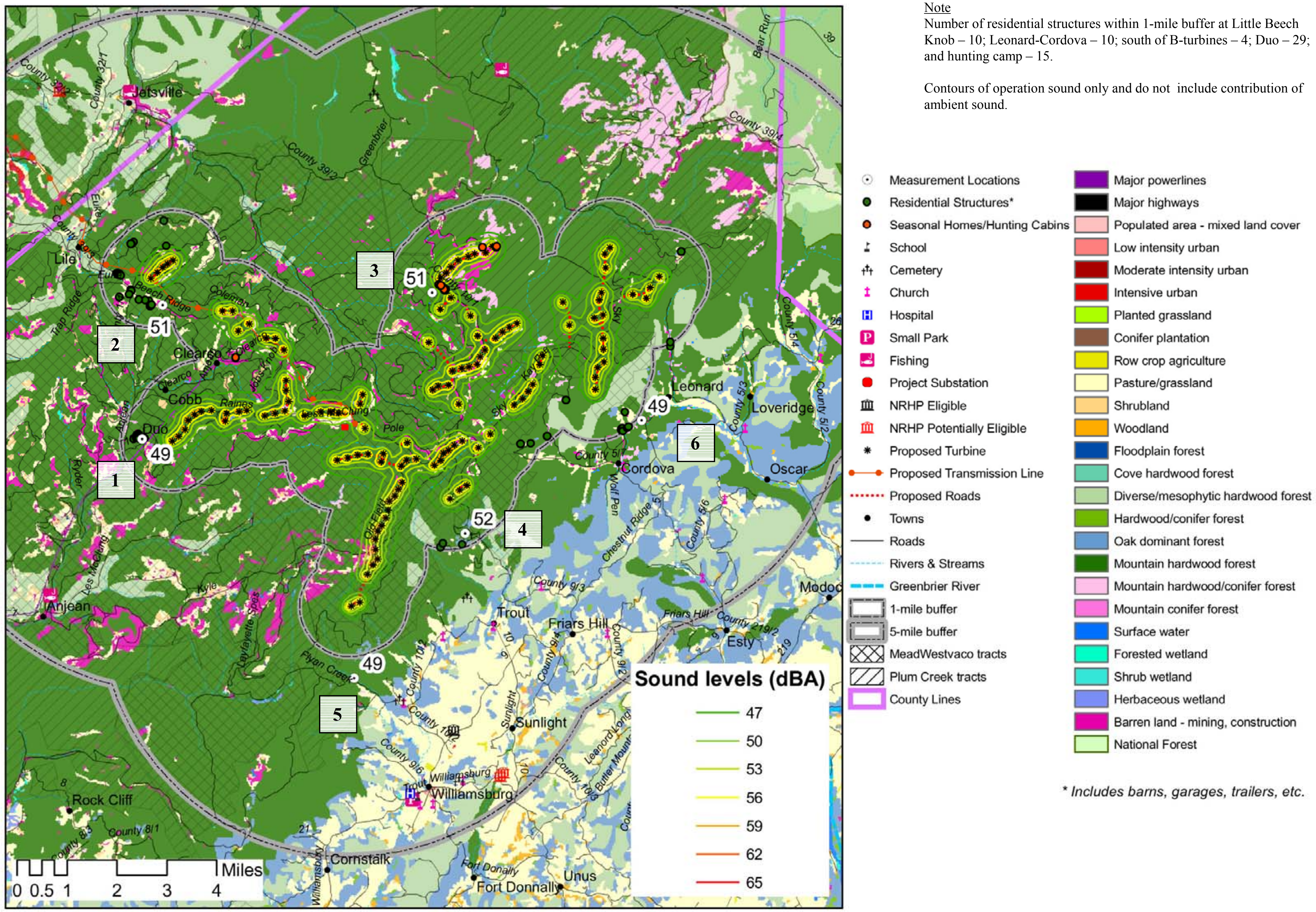


Figure 21. Area Map of Proposed Beech Ridge Wind Farm with Estimated Operation Sound Level Contours Compared to Average Measured Existing Ambient Ldn Sound Levels at Locations 1 to 6. Includes Land Use Classifications.

Table 1.
Description of Monitoring Locations for Preconstruction Ambient Sound Survey.

Location	Description	Approx. Dist. (ft.) to Nearest WTG
1 – Town of Duo	hamlet with several homes and small church	3600
2 – Little Beech Knob*	few rural homes	3200
3 – Hunting Cabins	group of seasonal hunting cabins	900
4 – Home South of B-Turbine Line	rural home	4100
5 – Flynn's Creek	scattered rural homes, farms, and church	7800
6 – Leonard/Cordova	road between two small settlements	6000

* Homeowners in this area to participate in project; otherwise, approximate distance to nearest WTG would be one mile.

Table 2.
Type of Acoustic Instrumentation Used for Ambient Sound Survey during 27 September - 5 October 2005.

Instrument Type	Manufacturer	Model
Continuous Sound Level Monitors	Rion	NL-31 & NL-32
Preamplifiers	Rion	NH-21
1/2" Microphones	Rion	UC-53A
Calibrator	Bruel & Kjaer	4231
Precision Sound Level Meter and Octave Band Analyzer	Rion	NA-27
Preamplifier	Rion	NH-20
1/2" Microphone	Rion	UC-53A
Calibrator	Norsonic	1251

Table 3.
Summary of Monitoring Locations and Ldn Sound Levels (dBA) Measured during Ambient Sound Survey (27 September - 5 October 2005).

Location	GPS Reading			Dist. to Nearest WTG (ft.)	Ambient Ldn*
	N	W	Elev. (ft.)		
1 – Town of Duo	38° 04.361’	80° 35.889’	3444	3600	49
2 – Little Beech Knob**	38° 06.611’	80° 35.343’	3990	3200	51
3 – Hunting Cabins	38° 06.911’	80° 29.196’	3875	900	51
4 – Home South of B-Turbine Line	38° 02.608’	80° 28.715’	3170	4100	52
5 – Flynn’s Creek	38° 00.098’	80° 31.169’	2439	7800	49
6 – Leonard/Cordova	38° 04.562’	80° 24.818’	2470	6000	49

* Ldn measured over 186 hours at Locations 1 and 3 – 6; and measured over 157 hours at Location 2.

** Homeowners in this area to participate in project; otherwise, approximate distance to nearest WTG would be one mile.

Note that across the six locations, measured average Ldn of 50 dBA with a standard deviation of 1.6 dBA.

Table 4.
Estimated Equivalent Sound Levels (Leq*) of Representative Construction Equipment at Various Distances.

Equipment	Construction Sound Levels (dBA)			
	1550 ft. †	4000 ft.	1 mile	5 miles
Phase I – Preparation & Foundation				
Blasting	60**	47**	43**	14**
Pile Driving	59**	46**	42**	13**
Dozer	49	36	32	3
Excavator	50	37	33	4
Trencher	50	37	33	4
Grader	48	35	31	2
Roller	45	32	28	<0
Trucks	44	31	27	<0
Batch Plant	41	28	24	<0
Phase II – Erection & Installation				
Trucks	44	31	27	<0
Crane	50	37	33	4
Phase III – Test & Commission				
Trucks	44	31	27	<0

* Estimated Leq sound levels over a 10-hour daytime shift. 24-hr Ldn would be 4 dBA less than each Leq.

† Estimated sound levels at nearest property boundary and year-round community residence (closest residence in Little Beech Knob to WTG). Homeowners in this area to participate in project; otherwise, approximate distance to nearest WTG would be one mile. Estimated sound levels for a group of temporary residences closer to a WTG (Location 3 – seasonal hunting cabins) would be 6 dBA greater than these levels.

** Estimated values for blasting and pile driving are maximum (Lmax) sound levels, not Leq.

Reference: ESEERCO Power Plant Construction Noise Guide, BBN Report No. 3321, May 1977.

Table 5.
Comparison of Average Measured Ldn Sound Levels during Ambient Sound Survey with Estimated Ldn Sound Levels for WTG Facility (dBA).

Location*	Dist. to Nearest WTG (ft.)	Average Measured Ambient Ldn	Estimated Facility Operation - Ldn
1 – Town of Duo	3600	49	39
2 – Little Beech Knob**	3200	51	41
3 – Hunting Cabins	900	51	52
4 – Home South of B-Turbine Line	4100	52	35
5 – Flynn's Creek	7800	49	28
6 – Leonard/Cordova	6000	49	34
Trout	15,000	--	30
Friars Hill	22,000	--	25
Williamsburg	21,000	--	17

* Comparisons provided for the actual sound monitoring locations; in some areas, residences are located closer to wind turbines.

** Homeowners in this area to participate in project; otherwise, approximate distance to nearest WTG would be one mile.

Appendix A

Sound in Lay Terms

Sounds we hear come from small pressure oscillations, or sound waves, that travel through the air and actuate our hearing mechanism. These airborne pressure oscillations cause the eardrum and small bones of the middle ear to vibrate. These vibrations are transmitted to the fluid-filled cochlea of the inner ear's sensory organ. Sensory hair cells then transduce these vibrations into nerve impulses that are transmitted to the brain where they are perceived and interpreted.

Noise is often defined as unwanted sound and the degree of disturbance or annoyance of an intruding noise depends on various factors including the magnitude and nature of the intruding noise, the magnitude of the background or ambient sound present without the intruding noise, and the nature of the activity of people in the area where the noise is heard. For example, people relaxing at home generally prefer a quiet environment, while factory employees may be accustomed to relatively high noise levels when at work.

The magnitude, or loudness, of sound waves (pressure oscillations) is described quantitatively by the terms sound pressure level, sound level, or simply noise level. The magnitude of a sound is measured in decibels, abbreviated dB. Decibels are used to quantify sound pressure levels just as degrees are used to quantify temperature and inches are used to quantify distance. The faintest sound level that can be heard by a young healthy ear is about 0 dB, a moderate sound level is about 50 dB, and a loud sound level is about 100 dB. Various common outdoor sound levels are listed below.

130 dBA	Loud siren at 100 feet
95 dBA	Pile Driver at 100 feet
80 dBA	Truck at 100 feet
65 dBA	Lawn mower at 100 feet
60 dBA	Average speech
55 dBA	Automobile 30 mph at 100 feet
50 dBA	Quiet urban daytime
35 dBA	Quiet suburban nighttime
25 dBA	Quiet rural nighttime

Sound energy spreads as it travels away from its source causing the sound level to diminish. Other factors that reduce sound levels include absorption in the atmosphere, diffraction and refraction in the atmosphere, and terrain.

The frequency of a sound is analogous to its tonal quality or pitch. The unit for frequency is hertz, abbreviated Hz (formerly cycles per second or cps). Thus, if a sound wave oscillates 500 times per second, its frequency is 500 Hz. The fundamental frequency of Middle C on a piano keyboard, for example, is 262 Hz. However, most sounds include a composite of many frequencies and are characterized as broad band or random. The normal frequency range of human hearing extends from a low frequency of about 20 to 50 Hz (a rumbling sound) up to a high frequency of about 10,000 to 15,000 Hz (a hissing sound) or even higher for some people. People have different hearing sensitivity to different frequencies and generally hear best in the mid-frequency region that is common to human speech, about 500 to 4000 Hz.

Appendix A Con't.

Sound level meters are usually equipped with electronic filters or weighting circuits, such as specified in standards ANSI S1.4 or IEC 651, for the purpose of simulating the frequency response characteristics of the human ear. The A-weighting filter included with essentially all sound level meters is most commonly employed for this purpose because the measured sound level data correlate well with subjective response to sounds. Sound levels measured using the A-weighting network are designated by dBA.

The background or ambient acoustic environment in most communities varies from place to place and varies with time at any given location due to the composite of many nearby and distant sound sources. The ambient environment includes high sound level single-events such as the passby of an airplane or nearby car, the barking of a dog, thunder, or a siren. The ambient acoustic environment also includes relatively steady residual or background sounds caused by sources such as distant traffic and ventilation equipment. The quantity of the single-event sounds and the amplitude of the background sounds are usually least during the late night hours from about midnight to 5:00 am. Indeed, the ambient sound level at a location is related to the amount of human activity in its vicinity. The amplitude statistics of this rather complex acoustic environment are considered to be non-Gaussian (because of the presence of the lower-level residual background sounds) and non-stationary (because of diurnal and seasonal variations).

At any location, a complete physical description of the ambient acoustic environment might include its sound level at various frequencies, as a function of time. As a first step towards simplifying this multi-dimensional description, it has become common practice to eliminate the frequency variable by measuring the A-weighted sound level (dBA), as observed on a standard sound level meter. The A-weighting filter emphasizes the mid-frequency components of sounds to approximate the frequency response of the human ear. A-weighted sound levels correlate well with our perception of most sounds.

To evaluate impacts and report time-varying ambient sound levels it is common practice, using the A-weighted scale, to measure the equivalent sound level and the day-night sound level. The equivalent sound level (Leq) is the level of a steady-state sound that has the same (equivalent) energy as the time-varying sound of interest, taken over a specified time period. Thus, the equivalent sound level is a single-valued level that expresses the time-averaged total energy of the entire ambient sound energy. It includes both the high-level single event sounds and the relatively steady background sounds. The day-night sound level (Ldn) is simply the average equivalent sound for 24-hours after 10 dBA has been added to the nighttime sound levels from 10pm to 7am. Adding 10 dBA to the nighttime sound levels accounts for people's expectations that nighttime be a quiet period. Both the equivalent sound level and the day-night sound levels have been selected by the U.S. Environmental Protection Agency (USEPA) as the best descriptors to use for the purpose of identifying and evaluating levels of environmental noise. EPA has identified an Ldn level of 55 dBA as protective of the health and welfare of humans. In addition, the Federal Energy Regulatory Commission (FERC) employs an Ldn level of 55 dBA as its criterion during review of proposed projects.

As part of the application process, the West Virginia Public Service Commission (WVPSC) Guidelines for Noise Studies for Siting Certificates require a project to submit preconstruction ambient Ldn data and facility operation Ldn estimates for review in addition to information on construction noise.

Acentech Report No. 421

Acoustical Study of Proposed Expansion/Modification of Beech Ridge Wind Farm Greenbrier County, WV

July 2011

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1. Introduction

Beech Ridge Energy LLC has successfully designed, certificated, and constructed a portion of a large-scale wind farm in Greenbrier County, West Virginia consisting of 67 turbines and 100 MW of turbine capacity at a mountainous rural site in the southeast portion of the state. Beech Ridge Energy LLC successfully operates these 67 turbines and now proposes to continue construction of the certificated facility to the west by installing up to 85.5 MW of turbine capacity. At the request of Beech Ridge Energy LLC, Acentech Incorporated has performed an acoustical study of the expansion area and provided information for review by the West Virginia Public Service Commission (WVPSC) for the site permitting process. Acentech has to date reviewed the facility and site drawings, equipment information, and the noise study guidelines of the WVPSC; toured the project area; conducted sound measurements and observations of the existing ambient conditions at representative community locations; and estimated construction and operation sound levels for the facility. This report presents the ambient sound measurements and results of our acoustical study.

2. Description of Proposed Facility and Site

The proposed expansion consists of up to 33 General Electric (GE) Model 1.6xle-100 wind turbine generators (WTGs) and associated equipment, with each WTG including its 100-meter diameter rotor to be mounted on individual 100-meter tall towers across about 8 square miles of ridgelines in Greenbrier County, WV. The associated equipment includes a 2 MVA transformer at each WTG tower, and 34.5kV underground transmission lines for the electrical collection system that will connect into the existing 34.5/138kV substation with a 200 MVA main transformer and 138kv overhead transmission line or supplemental substation/transmission line that would connect to the existing project related transmission line. The service center for the existing portion of the wind farm, which is located in the northern section of the proposed expansion area, will also serve the expanded facility. Figure 1 displays the proposed new wind turbines overlaid on a map of the region. The study evaluated 47 potential locations for the 33 turbines, and therefore, included 14 alternate locations.

Each GE Model 1.6xle-100 wind turbine incorporates a horizontal-axis propeller that drives a gearbox and generator mounted to the top of a 100-m (328-ft) high tower. A nacelle for weather protection and noise control encloses the gearbox and generator. The 100-m (328-ft) diameter rotor has three blades, which attach to a hub that contains active blade pitch control; this system provides for peak aerodynamic efficiency over a range of wind conditions. During routine operation, the rotational speed of the rotor will range from 9.75 to 16.18 revolutions per minute; and at wind speeds below 3 m/s (6.7 mph) and at wind speeds above 25 to 30 m/s (56 to 67 mph), it will not operate. The rated capacity of this unit is 1.6 MW at a wind speed of 11 m/s (24 mph). The WTGs include the following noise control treatments into its design: impact noise insulation of the gearbox and generator, reduced-noise gearbox, reduced-noise nacelle; vibration isolation mounts, and quieted-design rotor blades.

The existing wind farm and proposed area are located on the mountain ridges to the north of US Rt. 60 and I-64 and south of the Monongahela National Forest, and to the west of Rt. 219, and to the east of WV Rt. 20. Lightly traveled paved and unpaved roads cross this rural area, which is dotted with scattered homes and seasonal hunting cabins, and with several small groups of homes in settlements such as Duo. The existing substation is located to the east of the proposed expansion area and in the center of the existing wind farm with the overhead transmission line running to the northwest from the substation out to the external power grid.

3. Guidelines for Noise Studies

The WVPSC Guidelines for Noise Studies for Siting Certificates include:

- Preconstruction – identify land uses and existing ambient sound levels (Ldn) in communities within one mile of the facility.

- Construction – predict construction noise associated with blasting, earthmoving, pile driving, erection, traffic, and equipment installation at the nearest property boundary and within one mile and five miles from the facility. Identify noise sensitive areas within one mile and five miles of the facility. The noise sensitive areas include hospitals, schools, residences, cemeteries, parks, and churches. Describe construction equipment, procedure, and potential noise mitigation options.

- Operation – predict operation noise and identify land uses and type of structures (residential, commercial, or industrial) within one mile of the facility. Describe equipment and procedures to mitigate potential noise.

Information on the preconstruction ambient, construction, and operation sounds for the facility are presented in the following sections. Please refer to “Appendix A - Sound in Lay Terms” for a useful overview of sound and its measurement.

4. Preconstruction Ambient Sound Measurements

Figure 2 is a map of the project area with an overlay of the proposed turbine sites, land use classifications, the community sound measurement locations, and the measured day-night sound levels (Ldn). Table 1 describes the four monitoring locations selected for the ambient survey that Acentech conducted over a nominal one-week period in the first half of February 2011. The acoustic environment and nearby land uses were observed at these locations, and they were judged representative of those at the noise sensitive receptors, such as residences and churches, in the community bordering the expansion site.

The weather during the survey was seasonal and ranged from clear to cloudy skies with very little snow, calm to windy conditions, and temperatures from about 0ºF to 15ºF during the first half of the survey, and warming to 30ºF to 40ºF near the end of the survey. As Table 1 notes, most of the monitoring locations are in close proximity to nearby homes/seasonal residences or small groups of homes, and the monitoring locations range from 1600 ft. to 10,600 ft. from the nearest proposed new WTG location. The monitoring location in the Town of Duo that is 10,600 ft. from the nearest proposed new WTG is also 3600 ft. from the nearest existing operating wind turbine.

The purpose of the ambient survey was to characterize the existing land uses, sound sources, acoustic environment, and specifically, representative long-term Ldn values in the area. Figures 3 through 6 display photographs of the four locations where the A-weighted sound levels were monitored continuously during the survey. The field team also collected short-term measurements and observations during visits to each monitoring location. The observed sources typically included wind in trees, local and distant traffic, dogs, birds, aircraft, distant mining industry, and a flowing creek. The sound of the existing wind facility was observed at the Town of Duo location during one visit before the local wind speed picked up and the associated sound of wind in the trees masked the turbine sound; in general, the wind was from the southwest and the Duo location was typically crosswind/downwind of the nearest turbines at the time. The average sound levels at the Duo location ranged from 41 dBA to 43 dBA during the time when the wind facility sound was observed, and although the nearest turbines could be heard at times, the field team judged that turbine sound did not significantly influence the average sound levels. As the ambient data below indicate, the long-term Ldn sound level at the Duo location was similar to the Ldn levels measured at the three other community monitoring locations that are much farther from the existing wind facility. Table 2 lists the instruments that were employed for the ambient survey.

Figures 6 through 9 display the variations in sound levels that were measured at the four locations. To address the WVPSC Noise Guidelines for Noise Studies, the figures show the Leq sound level for each

10-minute interval, and also, indicate the Ldn sound level for the nominal one-week period. The figures, in addition, present the wind speeds for each 10-minute interval that were measured at the two nearby meteorological towers operated by Beech Ridge Energy LLC . As mentioned above, Appendix A provides an overview on sound and its measurement, and in particular, discusses the Leq and Ldn descriptors. Please note that Leq sound levels include both the steady background sounds (steady wind in trees, rushing stream, or distant industry) and the short-term intrusive sounds (e.g., dog barks or local car passby). Table 3 lists the long-term Ldn values measured at each location. Of most significance, the data indicate that the long-term Ldn sound levels ranged from 47 dBA to 50 dBA, with an average value of 48 dBA and a standard deviation of 1 dBA across the four locations. The measured Ldn values, sound source types, and land uses are relatively uniform across the study area and the ambient sound level contours are judged to be generally flat within this area. Therefore, Fig. 2 displays the individual measured Ldn values, but no individual contours.

5. Construction Noise Estimates and Mitigation Measures

Initial construction activities (Construction Phase I) will include improvements and new construction of facility access roads; then clearing, excavation, foundation, and backfill work at the WTGs and the substation. Concrete for the project will be made at temporary on-site batch plants using trucked-in materials. Phase I activities will be followed by Phase II activities, which are comprised of erection of the WTG towers and installation of the WTGs; trenching and installation of the electrical collection system; and installation of substation equipment. Finally, prior to commercial operation, the individual equipment items and the entire facility will be tested and commissioned during Phase III.

A majority of the construction activities associated with the proposed project will be conducted during daylight hours. At times over the planned construction schedule, the construction activities will be audible to nearby residents. Any construction at the facility in the evening and nighttime is expected to be limited to relatively quiet activities and to be less noticeable than in the daytime.

The following mitigation measures will be employed during the construction phase of the project:

- Effective exhaust mufflers in proper working condition will be installed on all engine-powered construction equipment at the site. Mufflers found to be defective will be replaced promptly.

- Require contractors to comply with federal limits on truck noise.

- Construction contractors will be required to ensure that their employee and delivery vehicles are driven responsibly.

- Nighttime construction work that does occur will generally be limited to relatively quiet activities, such as welding and installing equipment, cabling, and instrumentation.

- If blasting is required, it will be conducted in accordance with standard industrial practices and include those requirements established by the WVPSC in its original approved siting certificate for the Beech Ridge Facility with the overall goal of reducing potential impacts to nearby residents.

Construction sound that may be heard off-site will vary from hour-to-hour and day-to-day in accordance with the equipment in use and the operations being performed at the site. Since the construction activity at the site will be temporary, will occur mostly in the daytime hours, and will produce sounds that are already familiar to the community, its overall noise impact on the community beyond 1000 ft. of the nearest turbine is not expected to be significant. Note that the community currently experiences sound from timber and mining operations.

Typical on-site equipment used to construct the wind farm project will include trucks, cranes, dozers, excavators, trenchers, graders, and batch plants. Representative equivalent sound levels associated with these construction items during the workday are listed in Table 4. For example, with 2 trucks, 1 dozer, and 1 excavator operating at a WTG, the calculated equivalent sound level during the workday is 53 dBA at 1640 ft. (e.g., residential structure B-23 in Table 7) and 44 dBA at 3330 ft. (e.g., residential structure GB-0125) from a proposed new turbine. The reported sound levels are based on the results of extensive previous acoustical studies of engine-powered construction equipment. Figure 11 displays the contours of the estimated maximum Ldn sound levels over the entire study area for Construction Phase 1, with comparisons to the measured preconstruction ambient Ldn values. The sound estimates for the expansion study assume construction activity at all 47 potential turbine locations, although only 33 turbines will be constructed. These contours were developed with a commercial computer noise modeling program, Cadna/A. This program employs ray-tracing technology that accounts for various factors, including geometric spreading, atmospheric absorption, and ground conditions; for the purpose of our modeling, we have assumed that the community is always downwind from the project equipment.

6. Station Sound Estimates and Mitigation Measures

The range of sound levels that will propagate from the wind turbine generators to various locations in the community around the site has been predicted. The project is addressing the facility sound with the purchase of the General Electric 1.6xle-100 wind turbine generator, which incorporates the following noise control treatments into its design:

- Noise insulation of the gearbox and generator
- Reduced-noise gearbox
- Reduced-noise nacelle
- Vibration isolation mounts
- Quieted-design rotor blades

In addition, the project will specify and purchase high-efficiency, reduced-noise transformers. The estimated A-weighted Ldn operating sound levels for the four community monitoring locations are listed in Table 5; and for the 21 residential structures within one mile of the project, the estimates are shown in Table 7 and plotted versus distance to the nearest WTG on Fig. 12. Of added note, Figs. 13 and 14 (respectively, without and with land use classifications) display the A-weighted Ldn sound contours for operation of the proposed facility expansion. Similar to the estimated construction noise values, the estimated Ldn values and contours for the operating phase were developed with the computer noise modeling program, Cadna/A. Measurements and observations made by the field team in February 2011 along Cold Knob Road about one mile east of the existing A-line turbines during a time with favorable turbine operating, background sound, and sound propagation conditions, support the Cadna modeling procedure. The estimated values for the wind farm Ldn sound levels range at the community monitoring locations from 33 dBA to 47 dBA and at the 21 residential structures within one mile of the project from 38 dBA to 47 dBA, which compare to the measured range of preconstruction ambient Ldn values of 47 dBA to 50 dBA. The facility sound estimates assume maximum sound output of all wind turbine generators at 47 potential locations, which occurs under conditions of maximum rated wind speed [11 m/s (24 mph) to cutout]. As previously noted, the study evaluated all 47 potential locations for the turbines although only 33 turbines will be installed as part of the expansion phase. Under conditions of reduced wind speeds, the background sound associated with wind in trees would be less; however, the WTG sound emissions would also be less.

The project sound levels are estimated on a time-weighted basis (Ldn) for outdoor locations; for indoor locations, these levels would be reduced by 12 dBA with the windows open and by 24 dBA or more with the windows closed. We anticipate that the wind farm will be heard at times in the community at distances of 1600 ft. from the project, however, ambient sounds will provide useful masking of the turbine sound and our measurements and estimates indicate that the long-term Ldn sound levels of the wind farm will be similar or less than the existing ambient Ldn levels at that distance for both outdoor and indoor locations. And at greater distances, the long-term Ldn sound levels of the wind farm are estimated to be significantly less than the existing ambient Ldn levels.

To address the potential issue of low frequency sound for the expansion project, we employed the Cadna model to estimate the C-weighted Ldn sound levels for the proposed new turbines; these estimates, including comparisons with the measured ambient C-weighted Ldn values, are presented on Figs. 15 and 16 and listed in Tables 6 and 7. As described in Appendix A, the C-weighted sound level (dBC) slightly de-emphasizes the low and high frequencies relative to the mid frequency components of sound. The de-emphasis of low frequency sound with the C-weighting filter is less than with the A-weighting filter, which results in a measured C-weighted sound level being greater than its corresponding A-weighted sound level at a given community location. By comparing an A-weighted sound level (dBA) with a C-weighted sound level (dBC), one can determine the low frequency component of the sound. The estimated C-weighted Ldn sound levels for the wind farm range from 52 dBC to 62 dBC at the community monitoring locations and from 54 dBC to 62 dBC at the 21 residential structures within one mile of the project; these estimates compare to the similar range of measured preconstruction ambient C-weighted Ldn values of 55 dBC to 73 dBC across the monitoring locations.

The study also considered the potential additive effects of the existing and the proposed expansion on the sound levels in the community. The Town of Duo is located between the existing wind facility and the proposed expansion area. Most of the residences in the town are approximately two miles from the nearest turbines of the proposed expansion and about 3600 ft. from the nearest existing turbines. The estimated Ldn sound levels at these residences due to the proposed new turbines are modest and range from 31 to 34 dBA. And the Ldn sound levels from wind farm operation for most of the locations are estimated to increase about 1 dBA with the addition of the proposed new turbines compared to the current levels with only the existing turbines. As noted previously in this report, the sound model is conservative as it assumes that all turbines are operating at maximum sound power output and that all locations, including the Duo locations, are downwind of all turbines at all times.

7. Noise Impact Assessment

As noted in Section 5, the majority of the construction activities associated with the project will be conducted during the daylight hours, and it will vary over time, depending on the equipment in use and the operations being performed at the site. The temporary noise associated with construction of the project will be similar to the noise produced during excavation, grading, and steel erection activities at many other mid-size building projects, and the current timber and mining activities in the region.

Similar to the existing wind turbine facility, the expansion facility will be available to operate 24-hours per day and seven days per week; and it may be heard at times in the community during turbine operation. It is expected that routine operation will produce day-night sound levels in the community that are similar to or lower than the measured existing ambient day-night sound levels.

Figure 1. Area Map with Proposed Beech Ridge Phase II Wind Farm Showing Turbine Locations and One Mile and Five-Mile Buffer Zones.

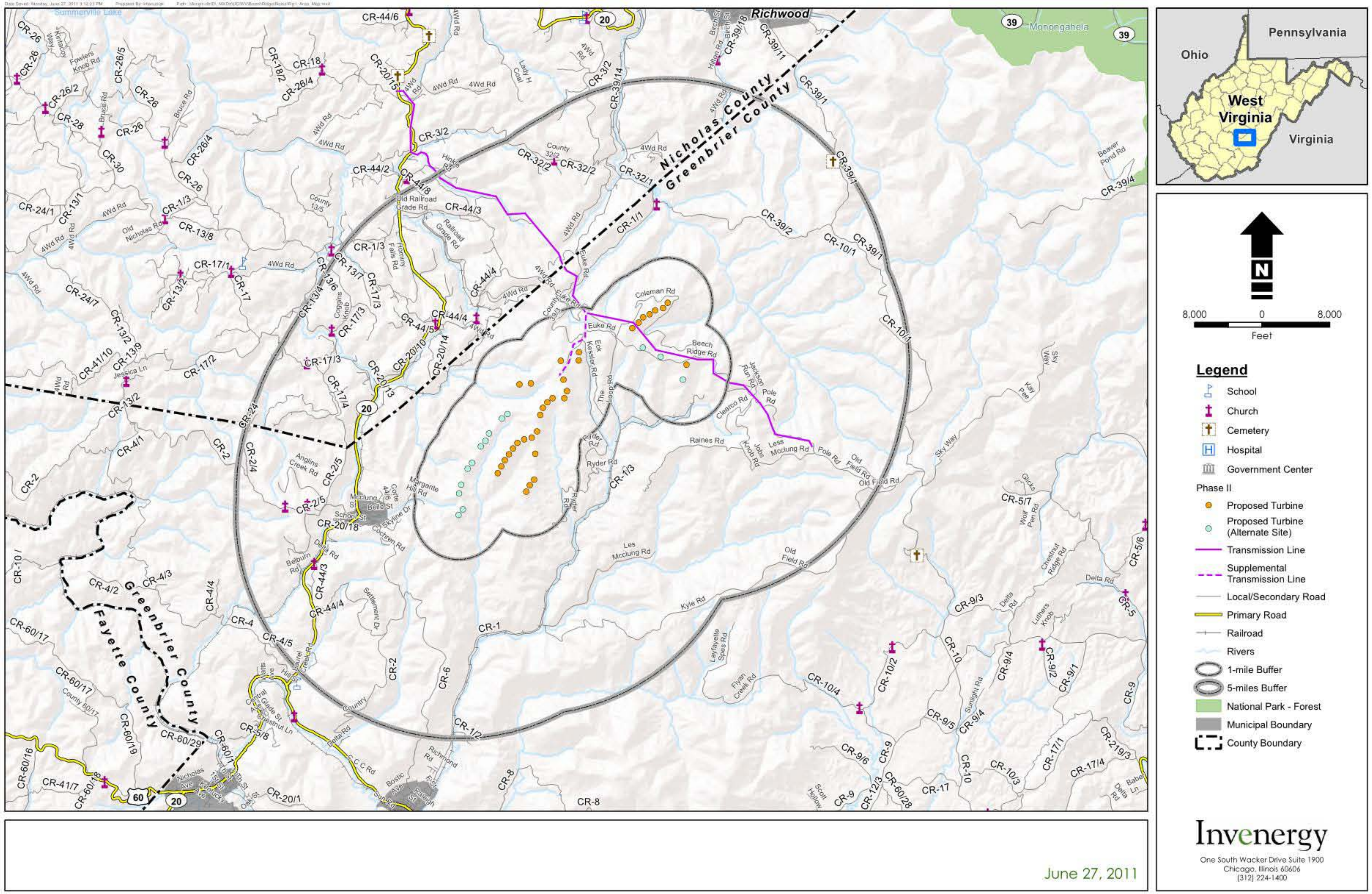
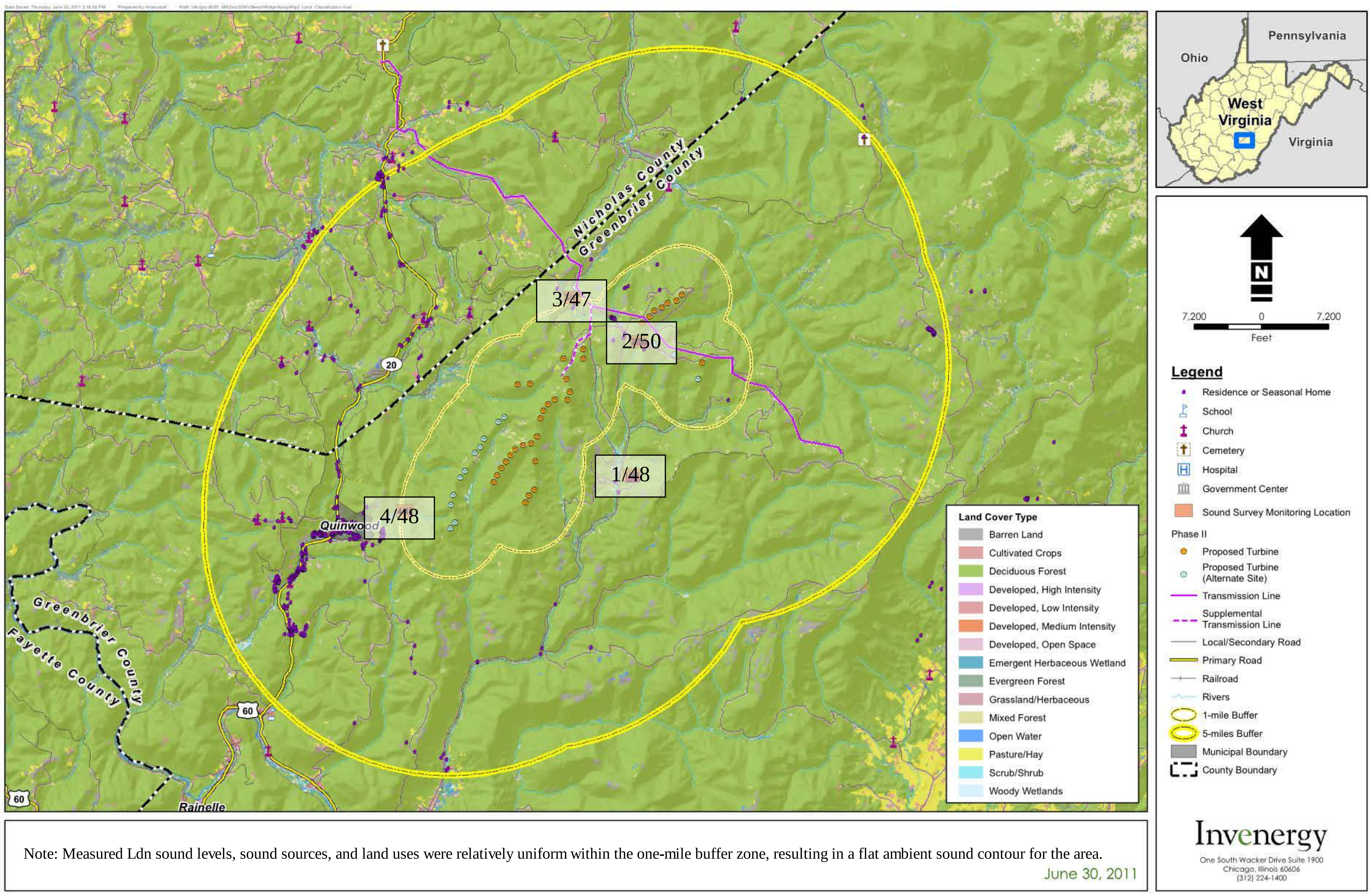


Figure 2. Area Map Showing Land Use Classifications with Community Sound Monitoring Locations 1 through 4 and Average Measured Existing Ambient A-Weighted Day-Night Sound Levels (Ldn, dBA) during 4 – 15 February 2011 Sound Survey.



Note: Measured Ldn sound levels, sound sources, and land uses were relatively uniform within the one-mile buffer zone, resulting in a flat ambient sound contour for the area.

Figure 3. View Looking SW from Location 1 (Town of Duo).

Figure 4. View Looking E from Location 2 (Beech Ridge Road).

Figure 5. View Looking SE from Location 3 (NW of Project Site).

Figure 6. View Looking NE from Location 4 (Town of Quinwood).

Figure 7. Leq A-Weighted and C-Weighted Existing Ambient Sound Levels Measured at Location 1 (Town of Duo) and Wind Speeds for 10-Minute Intervals during 4 – 15 February 2011.

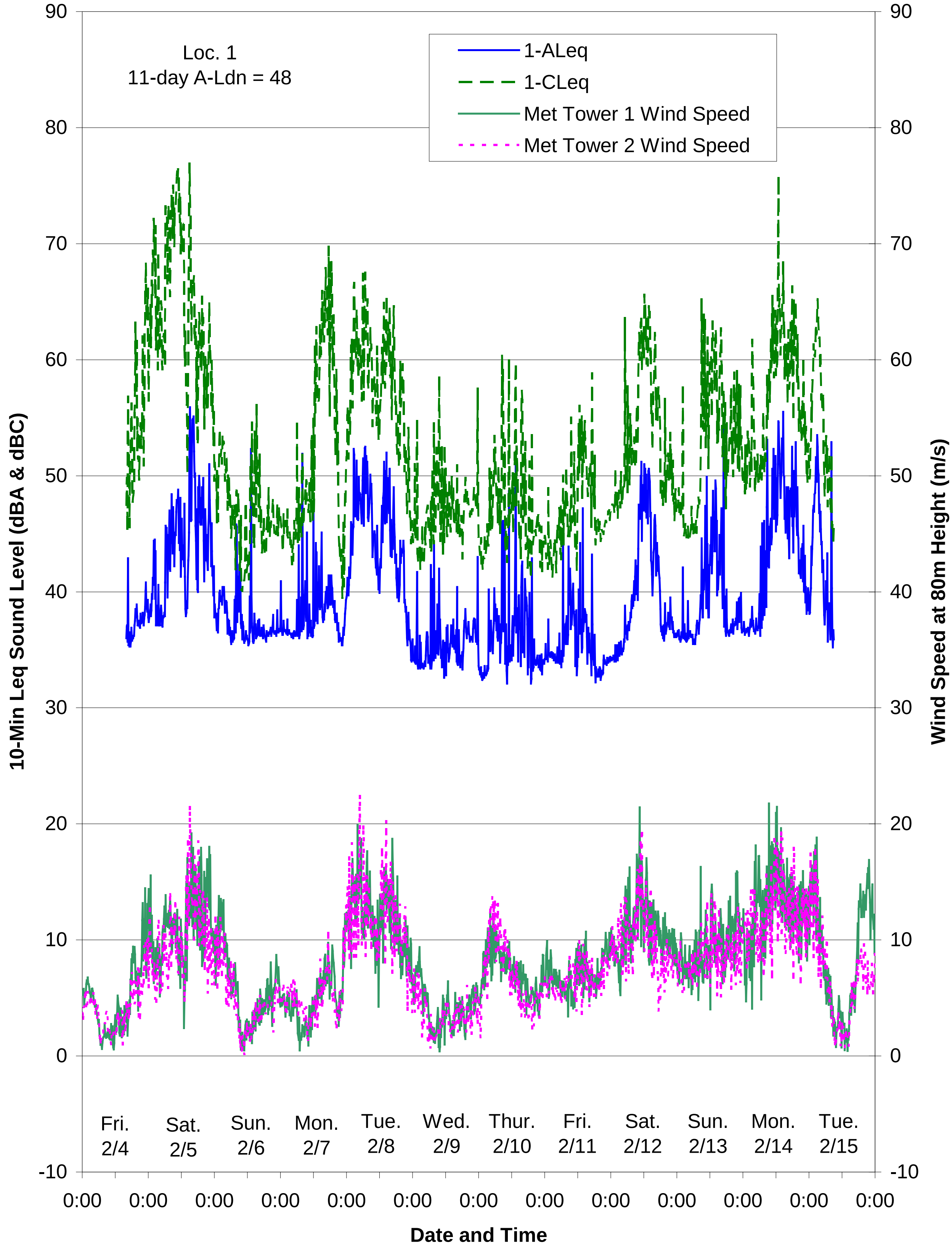


Figure 8. Leq A-Weighted and C-Weighted Existing Ambient Sound Levels Measured at Location 2 (Beech Ridge Road) and Wind Speeds for 10-Minute Intervals during 4 – 15 February 2011.

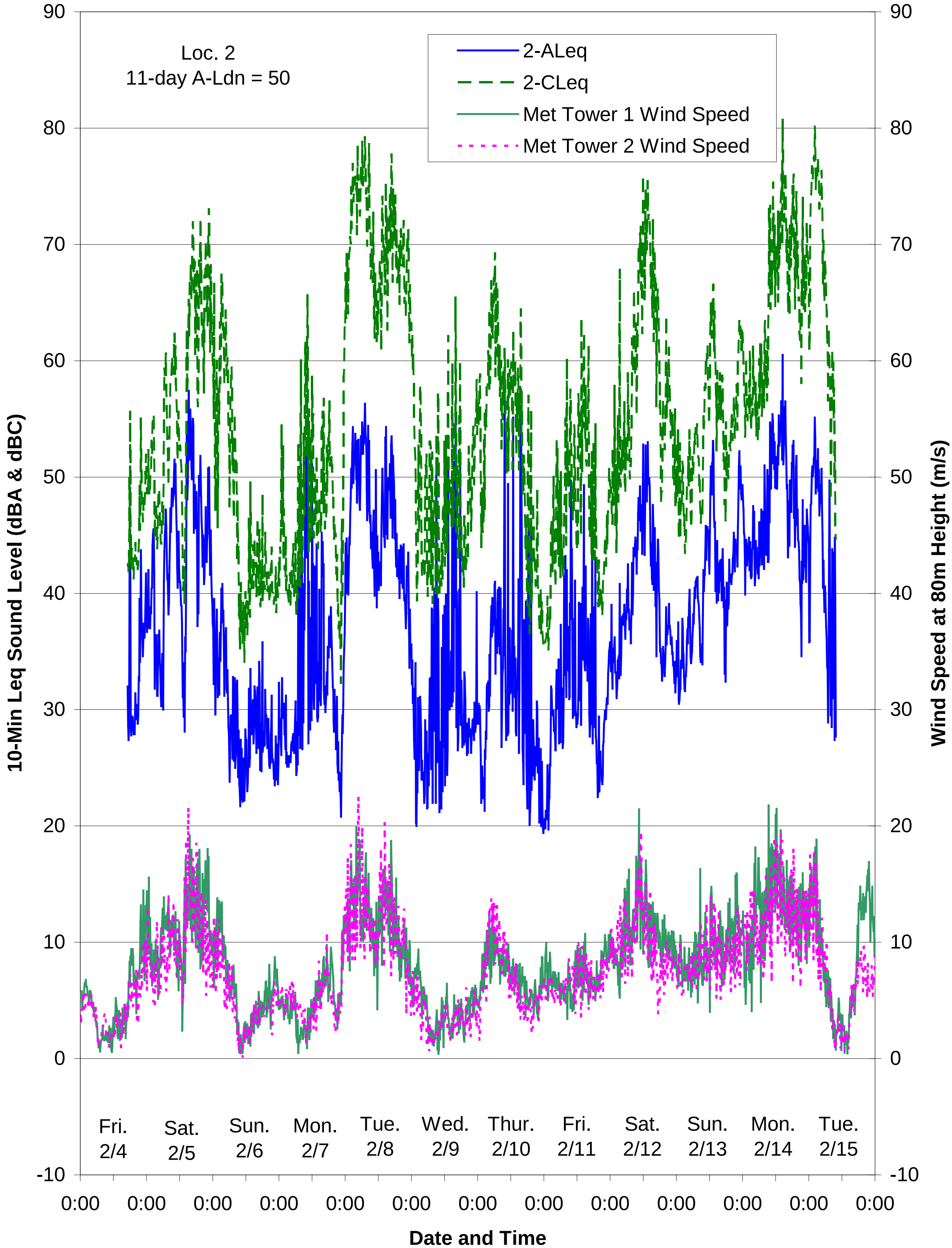


Figure 9. Leq A-Weighted and C-Weighted Existing Ambient Sound Levels Measured at Location 3 (NW of Project Site) and Wind Speeds for 10-Minute Intervals during 4 – 15 February 2011.

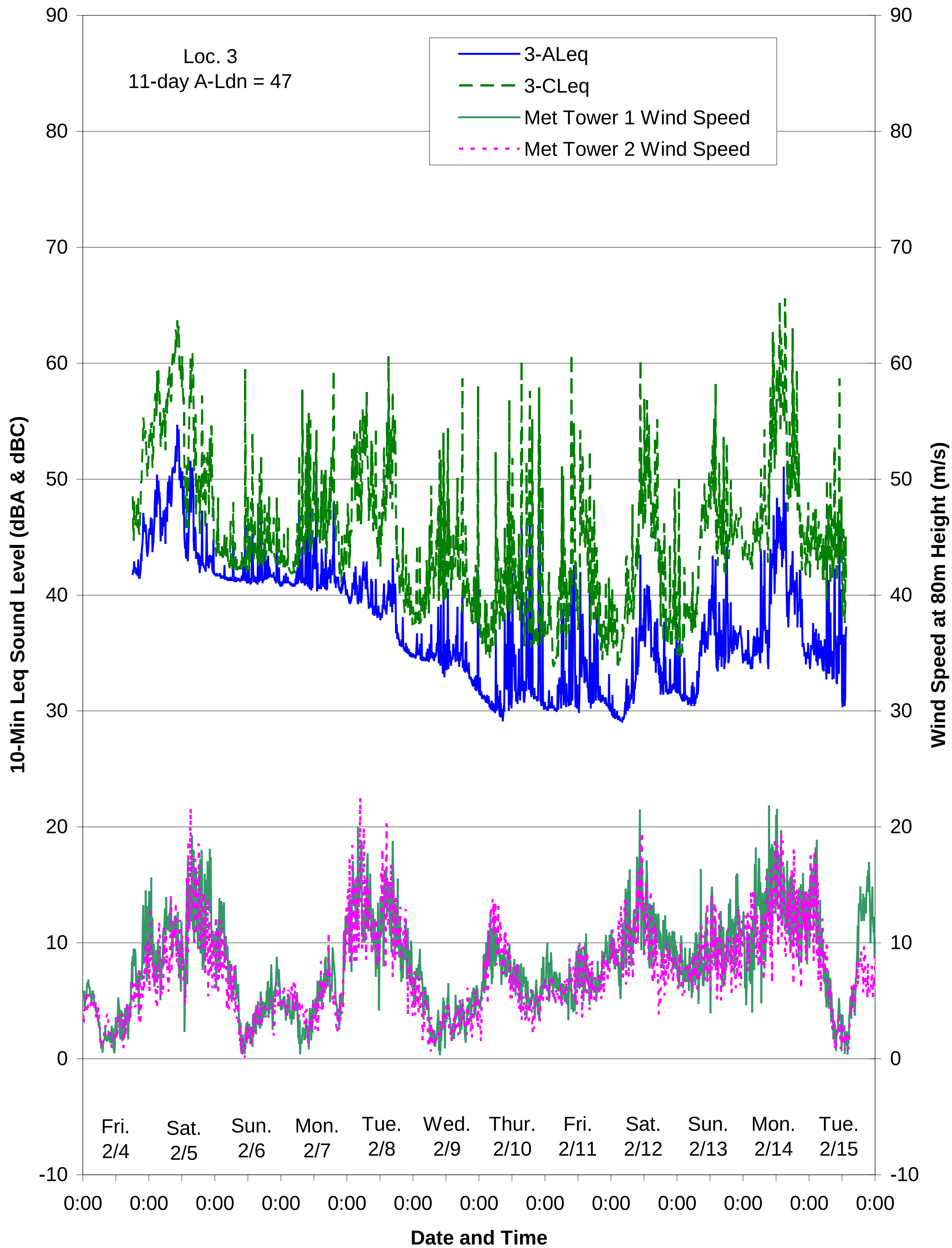


Figure 10. Leq A-Weighted and C-Weighted Existing Ambient Sound Levels Measured at Location 4 (Town of Quinwood) and Wind Speeds for 10-Minute Intervals during 4 – 15 February 2011.

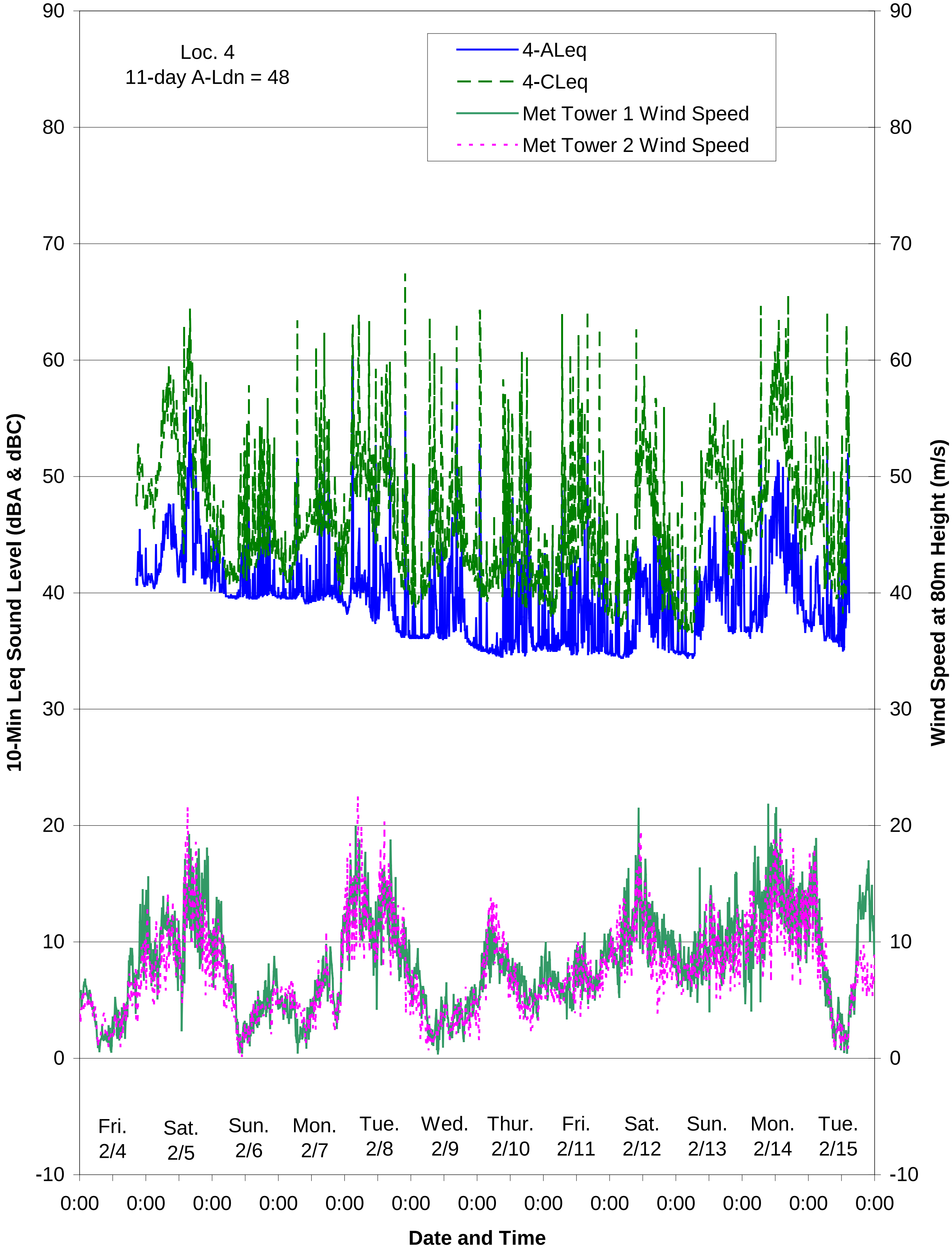


Figure 11. Area Map of Proposed Expansion of Beech Ridge Wind Farm with Estimated Construction A-Weighted Ldn Sound Level Contours Compared to Average Measured Existing Ambient A-Weighted Ldn Sound Levels (dBA) at Locations 1 to 4.

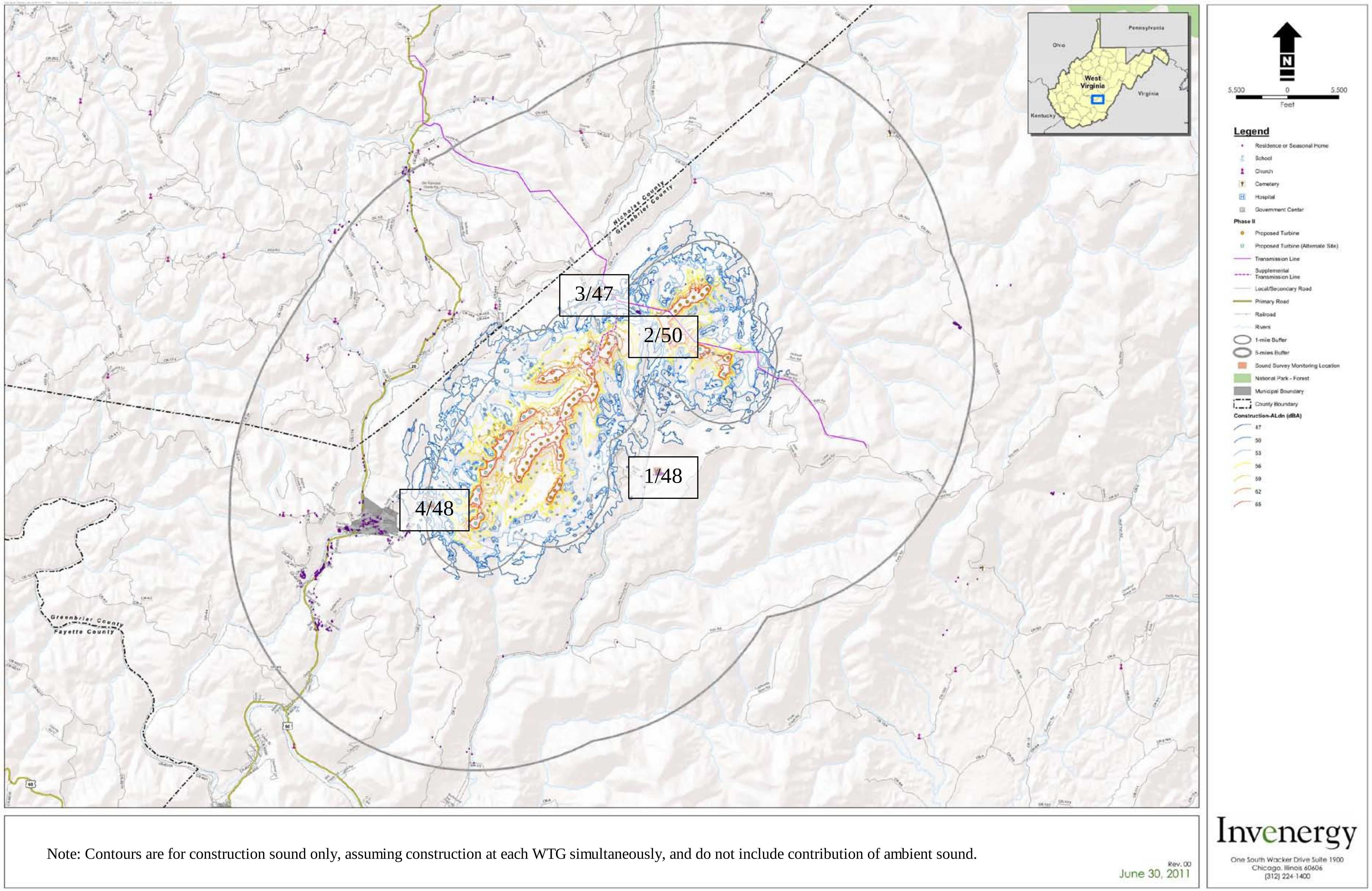


Figure 12. Estimated A-Weighted Ldn Sound Level for Operation (dBA) of Proposed Expansion of Beech Ridge Wind Farm at 21 Residential Structures within One Mile of Project Boundary.

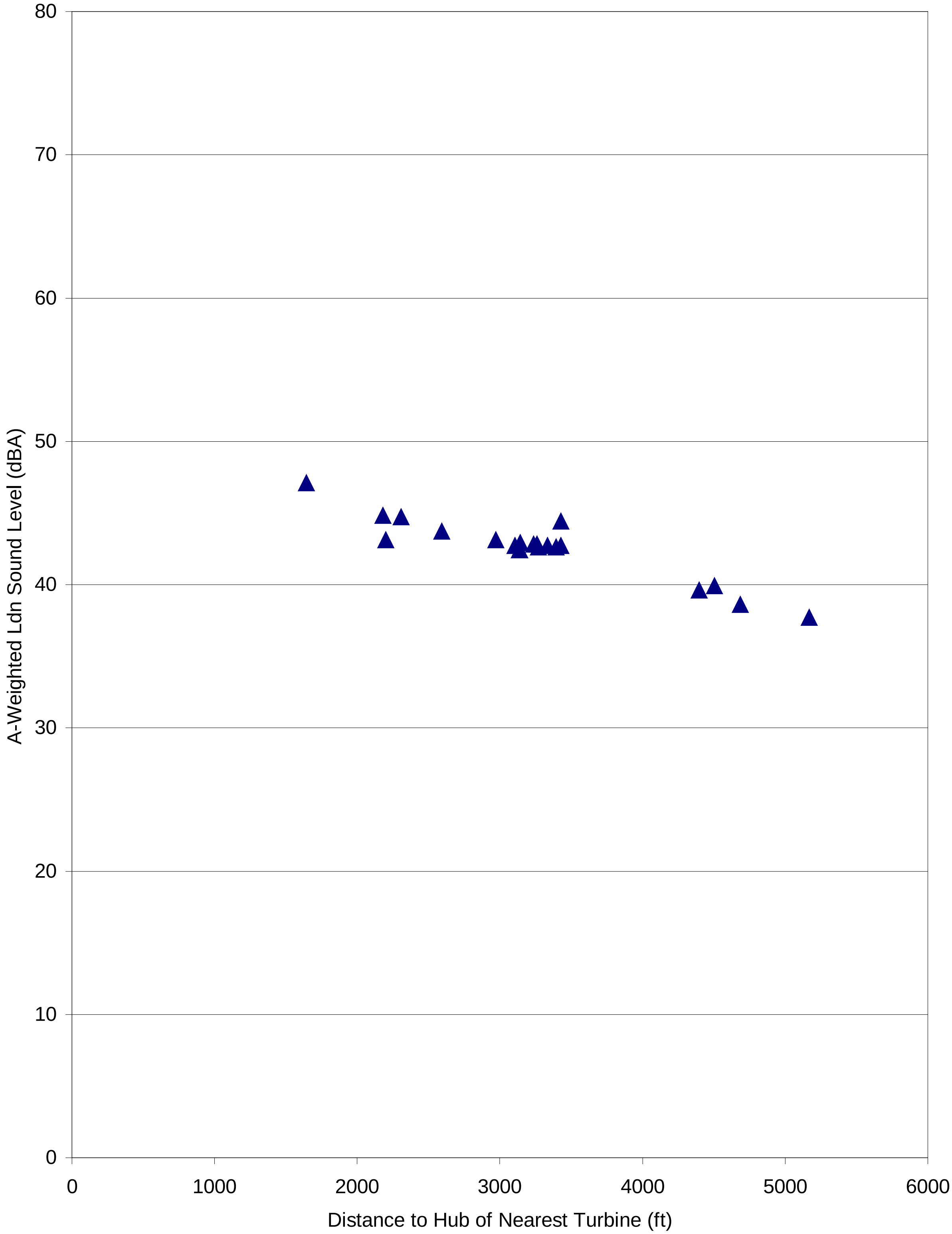
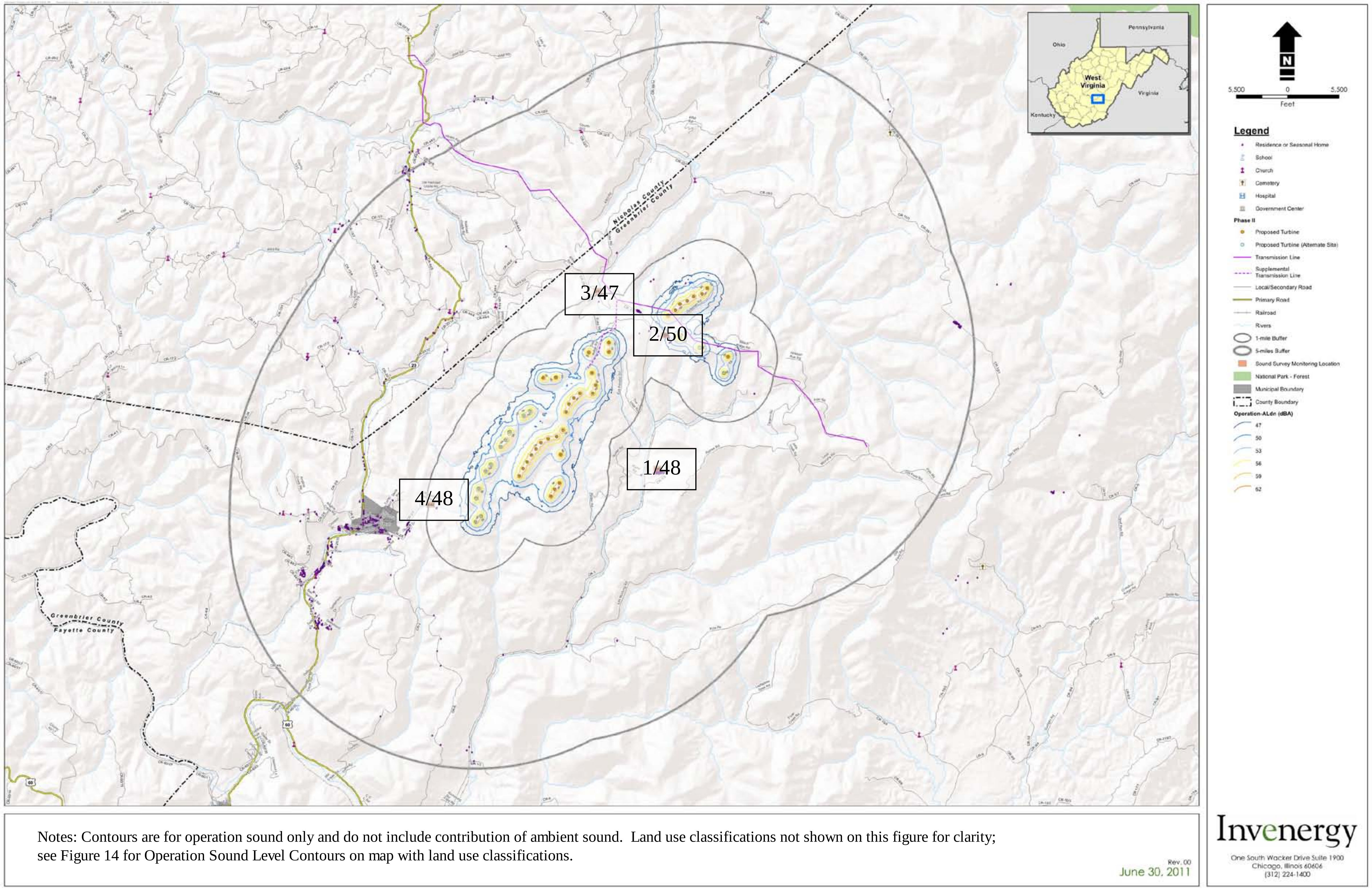
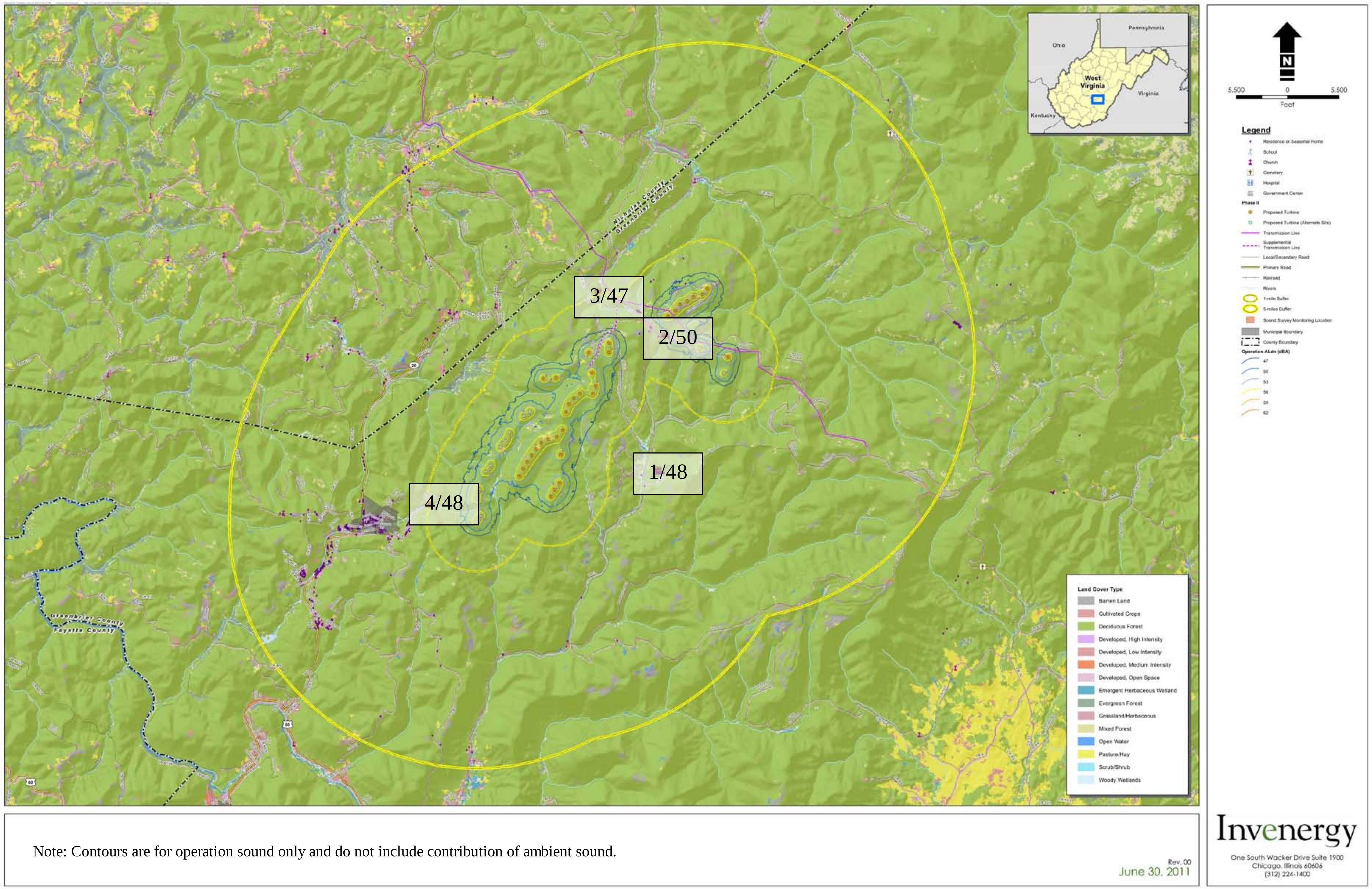


Figure 13. Area Map of Proposed Expansion of Beech Ridge Wind Farm with Estimated Operation A-Weighted Ldn Sound Level Contours Compared to Average Measured Existing Ambient A-Weighted Ldn Sound Levels (dBA) at Locations 1 to 4.



Notes: Contours are for operation sound only and do not include contribution of ambient sound. Land use classifications not shown on this figure for clarity; see Figure 14 for Operation Sound Level Contours on map with land use classifications.

Figure 14. Area Map of Proposed Expansion of Beech Ridge Wind Farm Showing Land Use Classifications with Estimated Operation A-Weighted Ldn Sound Level Contours Compared to Average Measured Existing Ambient A-Weighted Ldn Sound Levels (dBA) at Locations 1 to 4.



Note: Contours are for operation sound only and do not include contribution of ambient sound.

Figure 15. Estimated C-Weighted Ldn Sound Level for Operation (dBC) of Proposed Expansion of Beech Ridge Wind Farm at 21 Residential Structures within One Mile of Project Boundary.

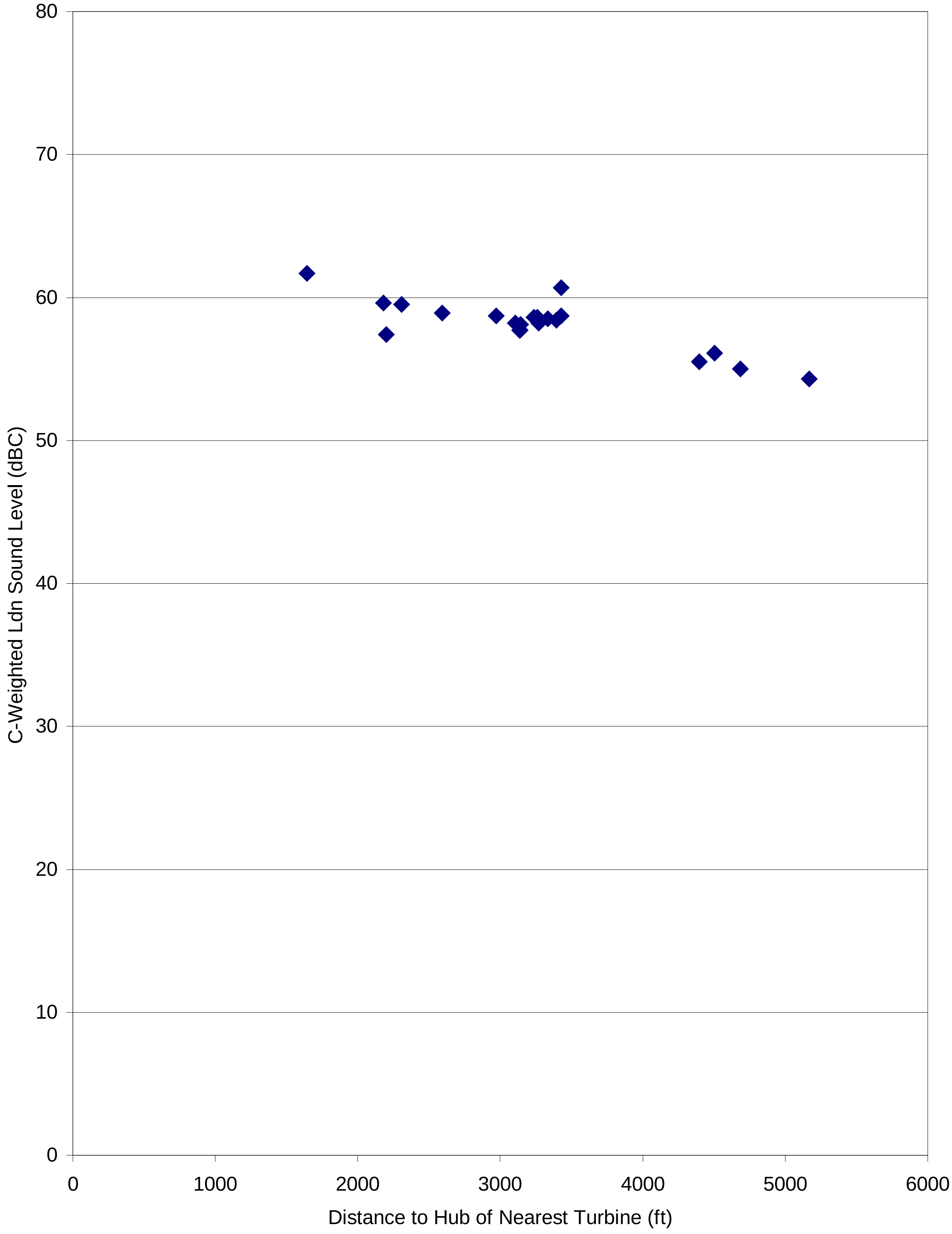
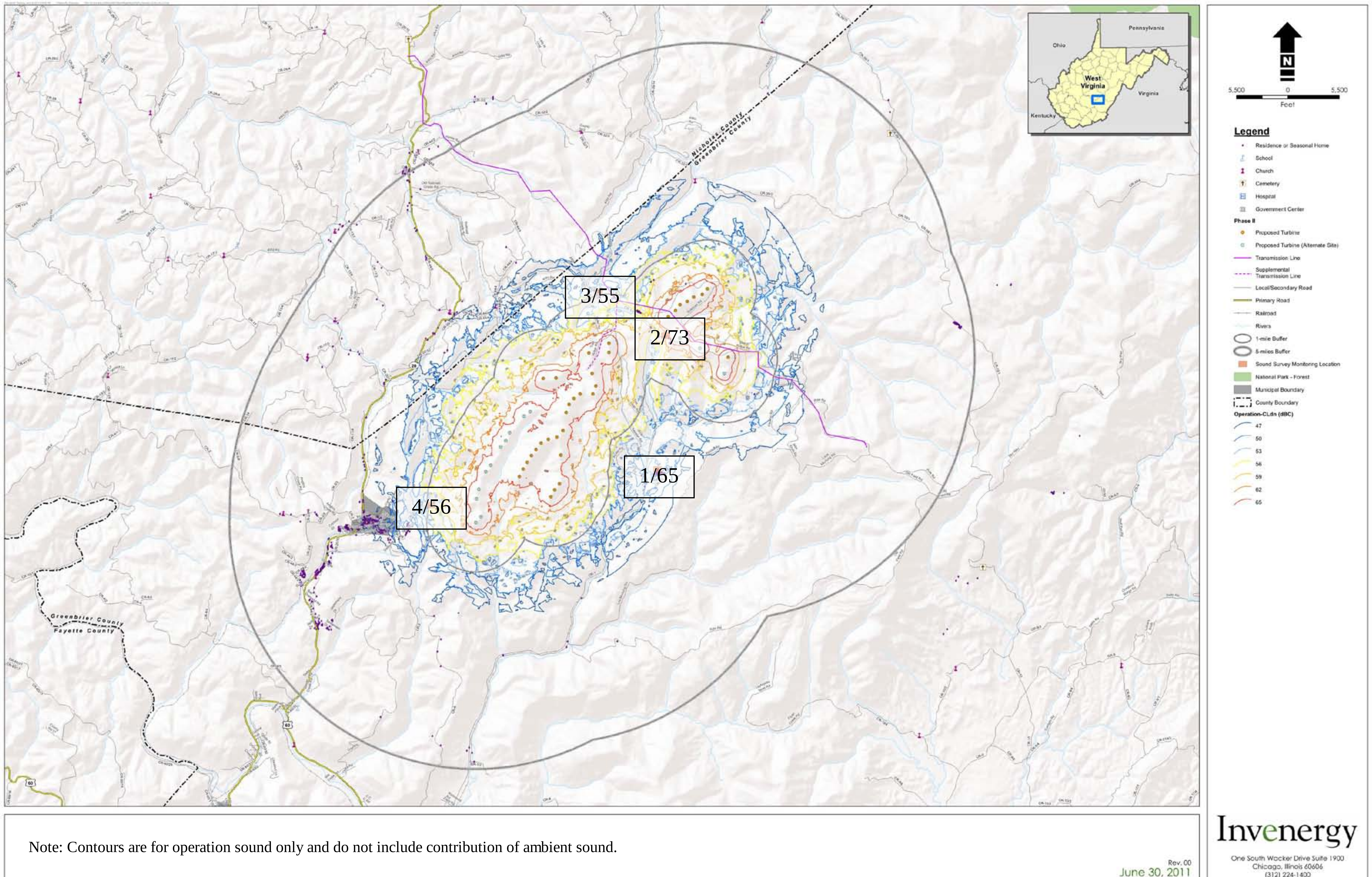


Figure 16. Area Map of Proposed Expansion of Beech Ridge Wind Farm with Estimated Operation C-Weighted Ldn Sound Level Contours Compared to Average Measured Existing Ambient C-Weighted Ldn Sound Levels (dBC) at Locations 1 to 4.



Note: Contours are for operation sound only and do not include contribution of ambient sound.

Table 1.
Description of Monitoring Locations for Preconstruction Ambient Sound Survey
(4 - 15 February 2011).

Location	Description	Approx. Dist. (ft.) to nearest WTG
1 – Town of Duo	hamlet with several homes and small church	10,500 (3600*)
2 – Beech Ridge Road	very few scattered rural homes	1600 †
3 – NW of Project Site	near hamlet with several homes	5800
4 – Town of Quinwood	near hamlet with several homes	5000

* Nearest WTG is at existing operating wind facility.

† Monitoring location is closer to a proposed WTG location than the nearest residential structure.

Table 2.
Type of Acoustic Instrumentation Used for Ambient Sound Survey
(4 - 15 February 2011).

Instrument Type	Manufacturer	Model
Continuous Sound Level Monitors	Rion	NL-31 & NL-32
Preamplifiers	Rion	NH-21
1/2" Microphones	Rion	UC-53A
Calibrator	Bruel & Kjaer	4231
Precision Sound Level Meter and Octave Band Analyzer	Rion	NA-27
Preamplifier	Rion	NH-20
1/2" Microphone	Rion	UC-53A
Calibrator	Norsonic	1251

Table 3.
Summary of Monitoring Locations and Ldn Sound Levels (dBA) Measured during Ambient Sound Survey (4 - 15 February 2011).

Location	GPS Reading (UTM)			Dist. to Nearest WTG (ft.)	Ambient Ldn*
	Easting (m)	Northing (m)	Elev. (m)		
1 – Town of Duo	535224	4213961	1033	10,500	48
2 – Beech Ridge Road	535472	4218322	1206	1600 †	50
3 – NW of Project Site	533286	4219763	971	5800	47
4 – Town of Quinwood	527828	4212790	921	5000	48

* Ldn measured for over 255 hours at Locations 1 - 4.

† Monitoring location is closer to a proposed WTG location than the nearest residential structure.

Note that across the four locations, measured average Ldn of 48 dBA with a standard deviation of 1 dBA.

Table 4.
Estimated Equivalent Sound Levels (Leq*) of Representative Construction Equipment at Various Distances.

Equipment	Construction Sound Levels (dBA)			
	1640 ft. †	**3330 ft. ****	**1 mile**	**5 miles**
<u>Phase I – Preparation & Foundation</u>				
Blasting	59††	50††	43††	14††
Pile Driving	58††	49††	42††	13††
Dozer	48	39	32	3
Excavator	49	40	33	4
Trencher	49	40	33	4
Grader	47	38	31	2
Roller	44	35	28	<0
Trucks	43	34	27	<0
Batch Plant	40	31	24	<0
<u>Phase II – Erection & Installation</u>				
Trucks	43	34	27	<0
Crane	49	40	33	4
<u>Phase III – Test & Commission</u>				
Trucks	43	34	27	<0

* Estimated Leq sound levels over a 10-hour daytime shift. 24-hr Ldn would be 4 dBA less than each Leq. Above estimates do not include attenuation due to any terrain shielding (i.e., estimates assume line-of sight to receptor).

† Estimated sound levels at residential structure B-23 in Table 7.

** Estimated sound levels at residential structure GB-0125 in Table 7.

†† Estimated values for blasting and pile driving are maximum (Lmax) sound levels, not Leq.

Reference: ESEERCO Power Plant Construction Noise Guide, BBN Report No. 3321, May 1977.

Table 5.
Comparison of Average Measured A-Weighted Ldn Sound Levels during Ambient Sound Survey with Estimated A-Weighted Ldn Sound Levels for WTG Facility (dBA).

Location*	Dist. to Nearest WTG (ft.)	Average Measured Ambient A-Weighted Ldn	Estimated Facility Operation A-Weighted Ldn
1 – Town of Duo	10,500	48	34
2 – Beech Ridge Road	1600	50	47
3 – NW of Project Site	5800	47	37
4 – Town of Quinwood	5000	48	38

* Comparisons provided for the actual sound monitoring locations; in some areas, residences are located closer or farther from WTGs.

Table 6.
Comparison of Average Measured C-Weighted Ldn Sound Levels during Ambient Sound Survey with Estimated C-Weighted Ldn Sound Levels for WTG Facility (dBC).

Location*	Dist. to Nearest WTG (ft.)	Average Measured Ambient C-Weighted Ldn	Estimated Facility Operation C-Weighted Ldn
1 – Town of Duo	10,500	65	53
2 – Beech Ridge Road	1600	73	62
3 – NW of Project Site	5800	55	54
4 – Town of Quinwood	5000	56	52

* Comparisons provided for the actual sound monitoring locations; in some areas, residences are located closer or farther from WTGs.

Table 7.
Estimated A-Weighted and C-Weighted Ldn Sound Levels (dBA and dBC) for WTG Facility at Residential Structures within One Mile of Expansion Area.

Residential Structures w/in 1 mile of Expansion	GPS Reading (UTM)			Dist. to Nearest WTG (ft.)	Estimated Facility Operation A-Weighted Ldn (dBA)	Estimated Facility Operation C-Weighted Ldn (dBC)
	Easting (m)	Northing (m)	Elev. (m)			
B-23	535465	4218274	1199	1640	47	62
B-17	535003	4218608	1202	2180	45	60
B-18	535019	4218572	1198	2200	43	57
B-24	535259	4218288	1202	2310	45	60
B-19	534949	4218464	1195	2590	44	59
B-15	534684	4219070	1142	2970	43	59
B-14	534645	4219087	1138	3100	43	58
B-11	534641	4219112	1133	3130	42	58
B-13	534640	4219114	1133	3140	42	58
B-12	534636	4219098	1137	3140	43	58
B-10	534606	4219098	1135	3240	43	59
B-9	534601	4219104	1134	3260	43	59
B-8	534602	4219129	1132	3270	43	58
GB-0125	534579	4219112	1132	3330	43	59
B-7	534563	4219127	1132	3390	43	58
B-6	534557	4219150	1132	3430	43	59
B-16	534635	4218382	1262	3430	44	61
235	528032	4212705	922	4400	40	56
234	528003	4212678	924	4500	40	56
GB-0126	533309	4219424	961	4680	39	55
GB-0128	533341	4219584	952	5170	38	54

Appendix A

Sound in Lay Terms

Sounds we hear come from small pressure oscillations, or sound waves, that travel through the air and actuate our hearing mechanism. These airborne pressure oscillations cause the eardrum and small bones of the middle ear to vibrate. These vibrations are transmitted to the fluid-filled cochlea of the inner ear's sensory organ. Sensory hair cells then transduce these vibrations into nerve impulses that are transmitted to the brain where they are perceived and interpreted.

Noise is often defined as unwanted sound and the degree of disturbance or annoyance of an intruding noise depends on various factors including the magnitude and nature of the intruding noise, the magnitude of the background or ambient sound present without the intruding noise, and the nature of the activity of people in the area where the noise is heard. For example, people relaxing at home generally prefer a quiet environment, while factory employees may be accustomed to relatively high noise levels when at work.

The magnitude, or loudness, of sound waves (pressure oscillations) is described quantitatively by the terms sound pressure level, sound level, or simply noise level. The magnitude of a sound is measured in decibels, abbreviated dB. Decibels are used to quantify sound pressure levels just as degrees are used to quantify temperature and inches are used to quantify distance. The faintest sound level that can be heard by a young healthy ear is about 0 dB, a moderate sound level is about 50 dB, and a loud sound level is about 100 dB. Various common outdoor sound levels are listed below.

130 dBA	Loud siren at 100 feet
95 dBA	Pile Driver at 100 feet
80 dBA	Truck at 100 feet
65 dBA	Lawn mower at 100 feet
60 dBA	Average speech
55 dBA	Automobile 30 mph at 100 feet
50 dBA	Quiet urban daytime
35 dBA	Quiet suburban nighttime
25 dBA	Quiet rural nighttime

Sound energy spreads as it travels away from its source causing the sound level to diminish. Other factors that reduce sound levels include absorption in the atmosphere, diffraction and refraction in the atmosphere, and terrain.

The frequency of a sound is analogous to its tonal quality or pitch. The unit for frequency is hertz, abbreviated Hz (formerly cycles per second or cps). Thus, if a sound wave oscillates 500 times per second, its frequency is 500 Hz. The fundamental frequency of Middle C on a piano keyboard, for example, is 262 Hz. However, most sounds include a composite of many frequencies and are characterized as broad band or random. The normal frequency range of human hearing extends from a low frequency of about 20 to 50 Hz (a rumbling sound) up to a high frequency of about 10,000 to 15,000 Hz (a hissing sound) or even higher for some people. People have different hearing sensitivity to different frequencies and generally hear best in the mid-frequency region that is common to human speech, about 500 to 4000 Hz.

Appendix A Con't.

Sound level meters are usually equipped with electronic filters or weighting circuits, such as specified in standards ANSI S1.4 or IEC 651, for the purpose of simulating the frequency response characteristics of the human ear. The A-weighting filter included with essentially all sound level meters is most commonly employed for this purpose because the measured sound level data correlate well with subjective response to sounds. Sound levels measured using the A-weighting network are designated by dBA.

The background or ambient acoustic environment in most communities varies from place to place and varies with time at any given location due to the composite of many nearby and distant sound sources. The ambient environment includes high sound level single-events such as the passby of an airplane or nearby car, the barking of a dog, thunder, or a siren. The ambient acoustic environment also includes relatively steady residual or background sounds caused by sources such as distant traffic and ventilation equipment. The quantity of the single-event sounds and the amplitude of the background sounds are usually least during the late night hours from about midnight to 5:00 am. Indeed, the ambient sound level at a location is related to the amount of human activity in its vicinity. The amplitude statistics of this rather complex acoustic environment are considered to be non-Gaussian (because of the presence of the lower-level residual background sounds) and non-stationary (because of diurnal and seasonal variations).

At any location, a complete physical description of the ambient acoustic environment might include its sound level at various frequencies, as a function of time. As a first step towards simplifying this multi-dimensional description, it has become common practice to eliminate the frequency variable by measuring the A-weighted sound level (dBA), as observed on a standard sound level meter. The A-weighting filter emphasizes the mid-frequency components of sounds to approximate the frequency response of the human ear. A-weighted sound levels correlate well with our perception of most sounds.

Another weighting network employed in most sound level meters is the C-weighting network. The C-weighted sound level (dBC) slightly de-emphasizes the low and high frequencies relative to the mid frequency components of sound. The de-emphasis of low frequency sound with the C-weighting filter is less than with the A-weighting filter. By comparing an A-weighted sound level (dBA) with a C-weighted sound level (dBC), we can determine the low frequency component of the sound.

An increase or decrease of the outdoor ambient sound level in a community by 1 or 2 dB is generally not noticeable. Whereas a change of the ambient sound level by 5 or 6 dB is generally noticeable and an increase or decrease of the ambient sound level by 10 dB is generally considered to represent a doubling or halving of the perceived sound.

To evaluate impacts and report time-varying ambient sound levels it is common practice, using the A-weighted scale, to measure the equivalent sound level and the day-night sound level. The equivalent sound level (Leq) is the level of a steady-state sound that has the same (equivalent) energy as the time-varying sound of interest, taken over a specified time period. Thus, the equivalent sound level is a single-valued level that expresses the time-averaged total energy of the entire ambient sound energy. It includes both the high-level single event sounds and the relatively steady background sounds. The day-night sound level (Ldn) is simply the average equivalent sound for 24-hours after 10 dBA has been added to the nighttime sound levels from 10pm to 7am. Adding 10 dBA to the nighttime sound levels accounts for people's expectations that nighttime be a quiet period. Both the equivalent sound level and the day-night sound levels have been selected by the U.S. Environmental Protection Agency (USEPA) as the best descriptors to use for the purpose of identifying and evaluating levels of environmental noise. EPA has identified an Ldn level of 55 dBA as protective of the health and welfare of humans. In addition, the Federal Energy Regulatory Commission (FERC) employs an Ldn level of 55 dBA as its criterion during review of proposed projects.

As part of the application process, the West Virginia Public Service Commission (WVPSC) Guidelines for Noise Studies for Siting Certificates require a project to submit preconstruction ambient Ldn data and facility operation Ldn estimates for review in addition to information on construction noise