FINAL

KNIGHTDALE BESS

Noise Study Report

B&V PROJECT NO. 419596.41.0604

PREPARED FOR

Duke Energy

12 SEPTEMBER 2024

BLACK & VEATCH

Prepared by:

Digitally signed by Neil Woodson
Date: 2024.09.27 17:52:43-05'00'

Signature

09/27/24

Date

Neil Woodson

Printed Name

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Acronyms and Abbreviations

ANSI	American National Standards Institute
BESS	Battery Energy Storage System
C	Degrees Celsius
Code	Wake County Code
dBA	A-weighted decibels
F	Degrees Fahrenheit
ft	feet
IEC	International Electrotechnical Commission
ISO	International Organization for Standards
L_{eq}	Equivalent-continuous (“average”) sound level
L_{max}	Maximum sound level
L_p	Sound pressure level
L_w	Sound power level
mph	Miles per hour
MVA	Mega-volt Ampere
NML	Noise Monitoring Location
OCI	Overland Contracting Incorporated
OSHA	Occupational Safety & Health Administration
Project	Knightdale BESS

1.0 Introduction and Approach

Overland Contracting Inc. (OCI) performed an acoustical analysis for the future operation of a new Battery Energy Storage System (BESS) site and substation located just outside the Town of Knightdale, North Carolina, in Wake County. Operation of the project equipment is subject to noise requirements established in the Town of Knightdale Code. The purpose of this project acoustical report is to:

1. Provide a summary of applicable regulations.
2. Provide acoustical design details for project equipment sound sources and other pertinent architectural and mechanical design features that affect sound propagation.
3. Provide the results of the acoustical analysis of the future operation of the project. The results of the acoustical analysis are evaluated with respect to applicable regulatory requirements.
4. Provide details of acoustical mitigation measures required to ensure the future operational project noise emissions will not exceed applicable sound level limits.

2.0 Regulatory Review

2.1 Applicable Code

The project is subject to the requirements of the Occupational Safety & Health Administration (OSHA) regarding occupational noise exposure. Equipment outlined herein is generally expected to be supplied to support OSHA requirements (i.e., near-field sound levels at or below sound levels of 85 to 90 dBA). However, some areas of the operational facility could experience higher sound levels due to inherently noisier equipment, reflective sound, or high density of noise sources. Such areas are typically identified by the Owner's Safety Management team and should be designated as requiring personnel to wear hearing protection.

OCI's research did not identify a State-level noise code that would be applicable to the State of North Carolina.

Wake County Unified Development Ordinance outlines noise limits for industrial sites in Article 17, Section 11, Paragraph 3. The regulation is receiver-based, so specific limits are determined by the type of receiver and implemented at the property boundary. As the neighboring plot to the west is planned for residential use, the received limit is 55 dBA during daytime (7:00 AM to 9:00 PM) and 45 dBA during nighttime (9:00 PM to 7:00 AM).

The Town of Knightdale Code of Ordinances describes prohibited noise in Section 84.04. This regulation is a subjective limit that does not define any measurable noise characteristic to target. The Project must not produce any "disturbing noise" which is defined as "noise which is perceived by a person of ordinary sensibilities as interrupting the normal peace and calm of an area." Additionally, the Town of Knightdale Unified Development Ordinance outlines noise limits and requirements for grid-scale battery storage facilities in Section 5.10(H)(6): "a Third-Party Noise Analysis shall be submitted establishing that the grid-scale battery storage facility as designed will not exceed noise level limits at the property line(s) set forth in the applicable noise ordinance." As the Project site falls outside of the Town Limits, but within the Town's extra-territorial jurisdiction, Section 5.10.(H)(7) states that "the noise level limits set forth in Wake County's Code of Ordinances shall apply," which are provided in the above paragraph.

2.2 Project Impact

The Wake County noise limit is the most stringent of applicable code and if the Project demonstrates compliance with the County then compliance with the Town of Knightdale is expected.

As the facility is expected to be continuously operated, the more restrictive nighttime limit will guide the acoustic design and mitigation requirements for the Project.

3.0 Project Acoustical Model Methodology

A Project acoustical model was developed using noise prediction software (DataKustik's Cadna/A version 2023) that implements the calculation methodologies of ISO 9613. The model simulates the outdoor propagation of sound from each noise source and accounts for sound wave divergence, atmospheric and ground absorption, sound directivity, and shielding due to interceding barriers and terrain. A database was developed which specifies the location, octave-band sound power levels, and sound directivity of each noise source. A receptor grid was specified that covers the entire area of interest. The model calculates the overall A-weighted sound pressure levels within the receptor grid based on the octave-band sound level contribution of each noise source. A noise contour plot is produced based on the overall sound pressure levels within the receptor grid, including specific receptor locations.

Project noise modeling was based on normal operations of the proposed Project equipment and does not include any existing noise sources. To account for shielding from local terrain, topographical data was included in the acoustical model sourced from USGS. A 3D view of the acoustical model is shown in Figure 1, and a general layout drawing is shown in Figure 2. Details of Project equipment sound levels, Project building architectural acoustical requirements, and any required supplemental noise mitigation measures that have been incorporated into the Project acoustical model can be found in Section 4.0.

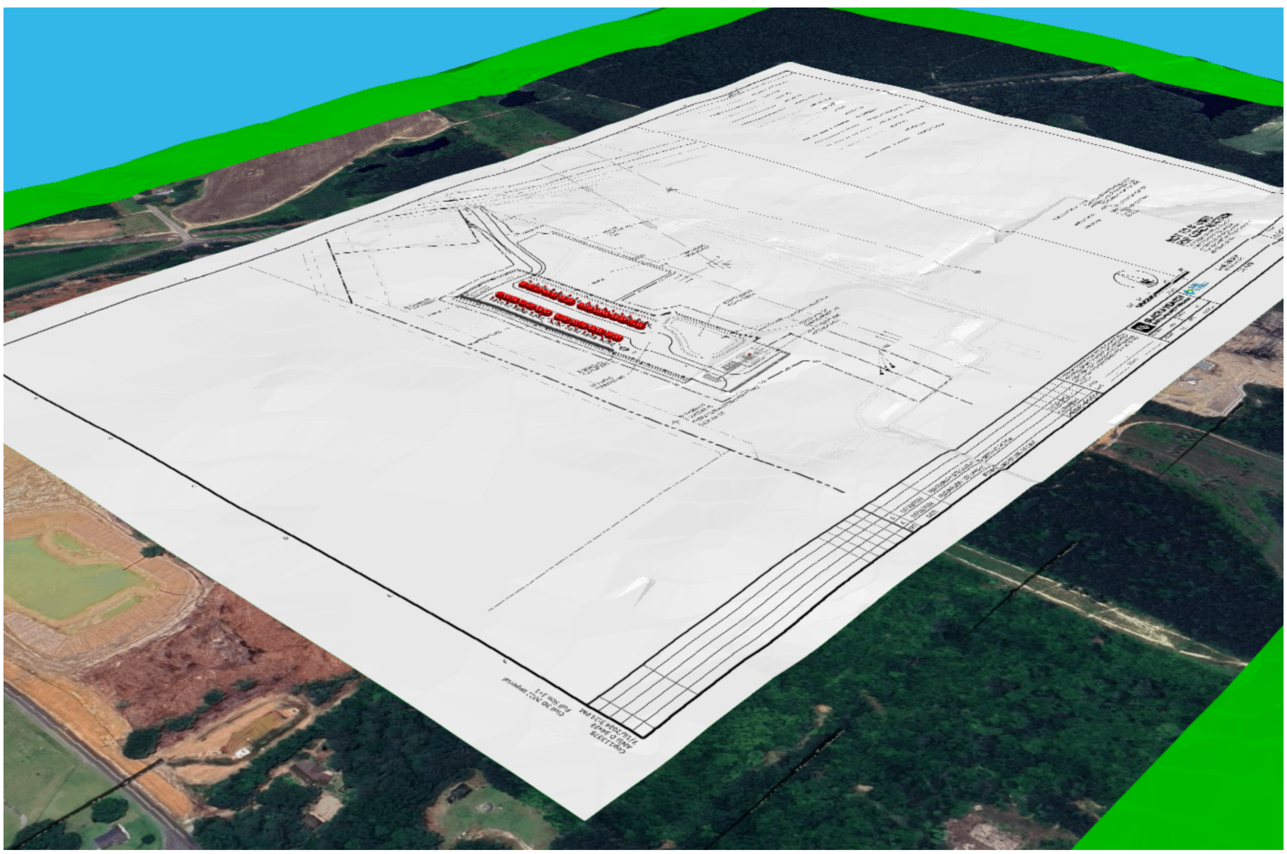

Figure 1 – 3D view of Project site from acoustical model (looking northeast).

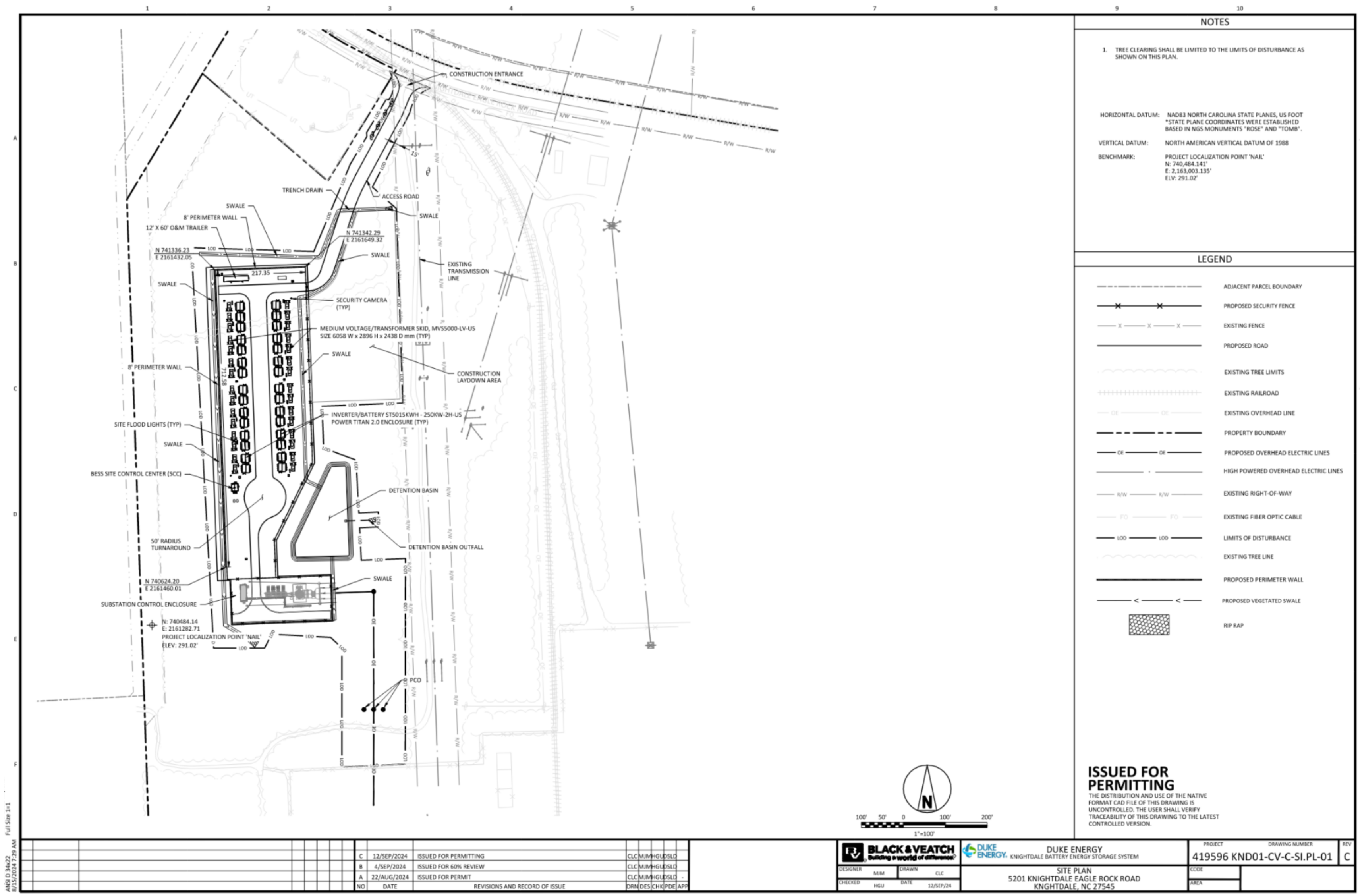

Figure 2 – Proposed layout of the Project. (419596 KND01-CV-C-SI.PL-01 Rev. A [09-12-2024])

4.0 Project Equipment

4.1 Drawings

Equipment specifications and the arrangement of equipment in the acoustical model are based on information and drawings provided by the Project design team. The acoustical model was built primarily using layout drawing 419596-KND01-CV-C-SI.PL-01 (Rev. C) as shown in Figure 2. This report includes the most current drawings and equipment information at the time of issue.

4.2 Equipment Sound Levels

Equipment sound levels provided by vendors were compiled by project staff from Black & Veatch. Some equipment either does not have supplier sound level data, or it was unclear whether the sound level data was at a specified distance or an overall sound power level. In these instances, an estimation or calculation was made. Transformer noise was estimated using International Electrotechnical Commission (IEC) Standard 60076-10 (2016): Power Transformers – Determination of sound levels.

Table 1 – Equipment Sound Levels

Equipment Name	QTY	Expected Sound Power Level	Source
Substation Step-up Transformer (Hyosung 3ø, 115 MVA max)	1	95 dBA L_w (Note 1)	Estimated (Note 2)
PCS Skid Transformer	30	66 dBA L_w (Note 1)	Estimated (Note 2)
BESS - Titan 2.0 (2H, HX)	60	87 dBA L_w (Note 1) (Daytime, 45°C) 81 dBA L_w (Note 1) (Nighttime, 35°C)	Sungrow Test Data (Note 3)

Notes:
1) **L_w – Sound power level (reference 1 pW).**
2) **IEC 60076-10**
3) **Vendor data reported a +2.9 dB uncertainty, which was applied to the model.**

Sungrow supplied detailed acoustic test data for the Titan 2.0 units specified for the Project. The sound pressure and power levels were given for varying load and ambient temperature. The low-noise treatment option, as selected by the Project, provides an overall sound power level reduction of 20 dBA, and a 35 dB reduction at the peak frequency band of 500 Hz, as compared to the non-mitigated BESS option. The two highest tested ambient temperatures were for 45°C (113°F) and 35°C (95°F). Under higher ambient temperatures, the BESS cooling system operates at a higher load and produces more noise, as shown in Table 1.

Regional historical meteorological data showed that the 45°C ambient temperature represents a reasonable worst-case scenario at extreme summertime temperatures for the BESS noise levels at daytime, and the 35°C operation is representative of a worst-case expected ambient nighttime. It should be noted that nighttime temperatures of 35°C are extremely rare in this region.

5.0 Modeling Results

5.1 Scenarios

The BESS are the largest noise contributors for the Project, due to the equipment quantity and their proximity to the property border. The site layout includes a masonry wall in accordance with the Town of Knightdale UDO, Section 5.10(H)(4), spanning the length of the northern and western sides of the BESS units. The model results indicated that length of the wall sufficiently reduces the BESS noise emitted to the surrounding community.

Scenario 1 models the Project noise expected from the equipment layout during the daytime with a property boundary limit of 55 dBA and ambient temperature of 45°C (as seen by the BESS cooling systems). Scenario 2 represents the same equipment layout and barrier but models the nighttime operation with a noise limit of 45 dBA and ambient temperature of 35°C (as seen by the BESS cooling systems).

5.2 Predicted Sound Levels

The acoustical modeling results are presented below. Table 2 shows the expected sound levels at the nearest property boundaries in each cardinal direction. Evaluation height is specified at 5 feet (1.5 meters). The predicted sound levels assume worst-case conditions (transformers in ONAF conditions) and continuous operation. The predicted sound levels only include sound contributions from the future BESS equipment and are exclusive of any other sound sources, including background noise.

Table 2 – Project Sound Levels at Property Boundaries

Property Boundary	Maximum Predicted Sound Level	
	Scenario 1, Daytime 55 dBA Limit, 45°C	**Scenario 2, Nighttime 45 dBA Limit, 35°C**
North	44 dBA	41 dBA
East	41 dBA	39 dBA
South (Residential)	43 dBA	42 dBA
West (Residential)	48 dBA	45 dBA

Scenario 1 is predicted to meet the 55 dBA daytime noise limit with a comfortable margin, as shown in Figure 3. Scenario 2 is predicted to meet the 45 dBA nighttime noise limit, as shown in Figure 4.

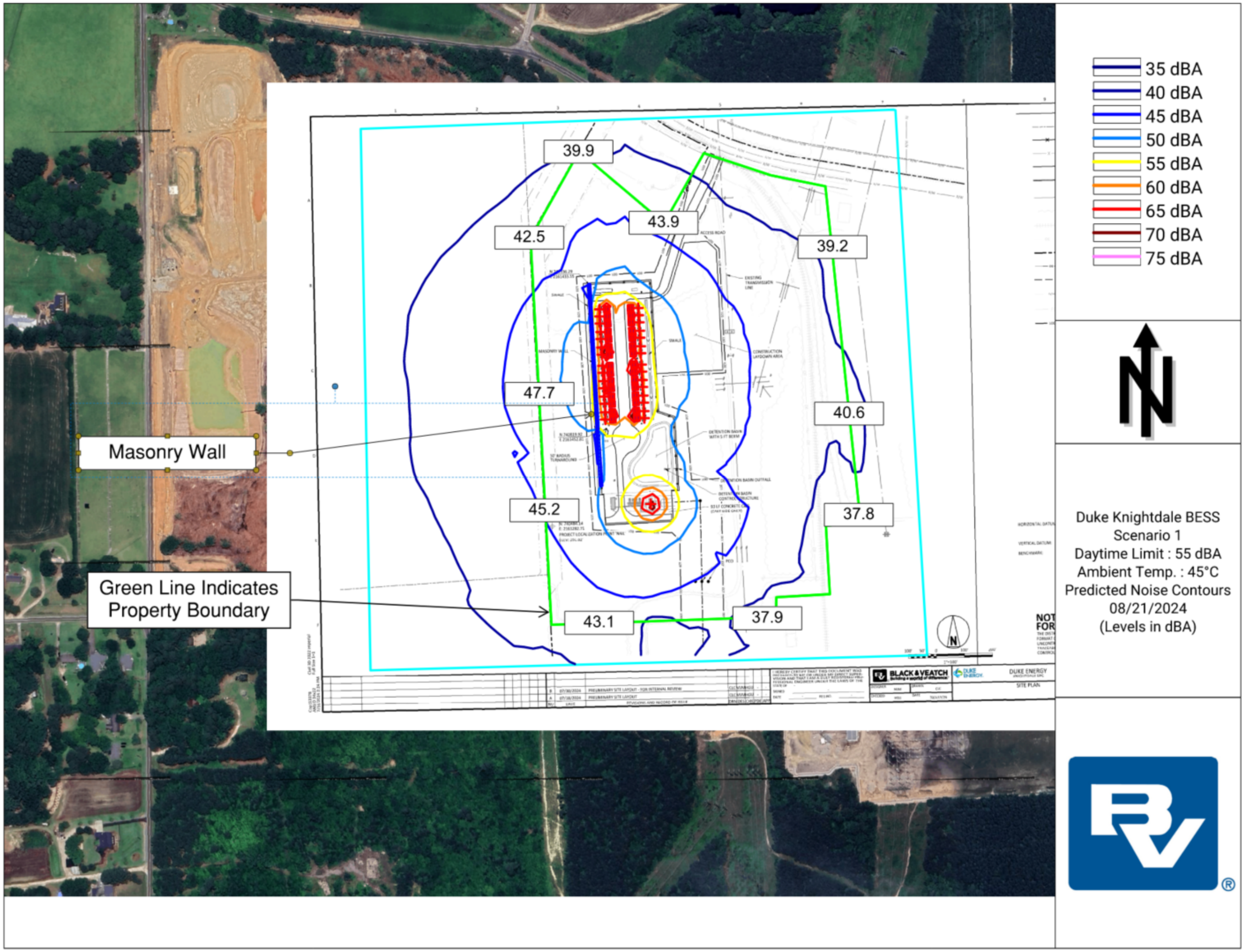

Figure 3 – Noise Contour Map for Scenario 1: Daytime operation (L_p in dBA)

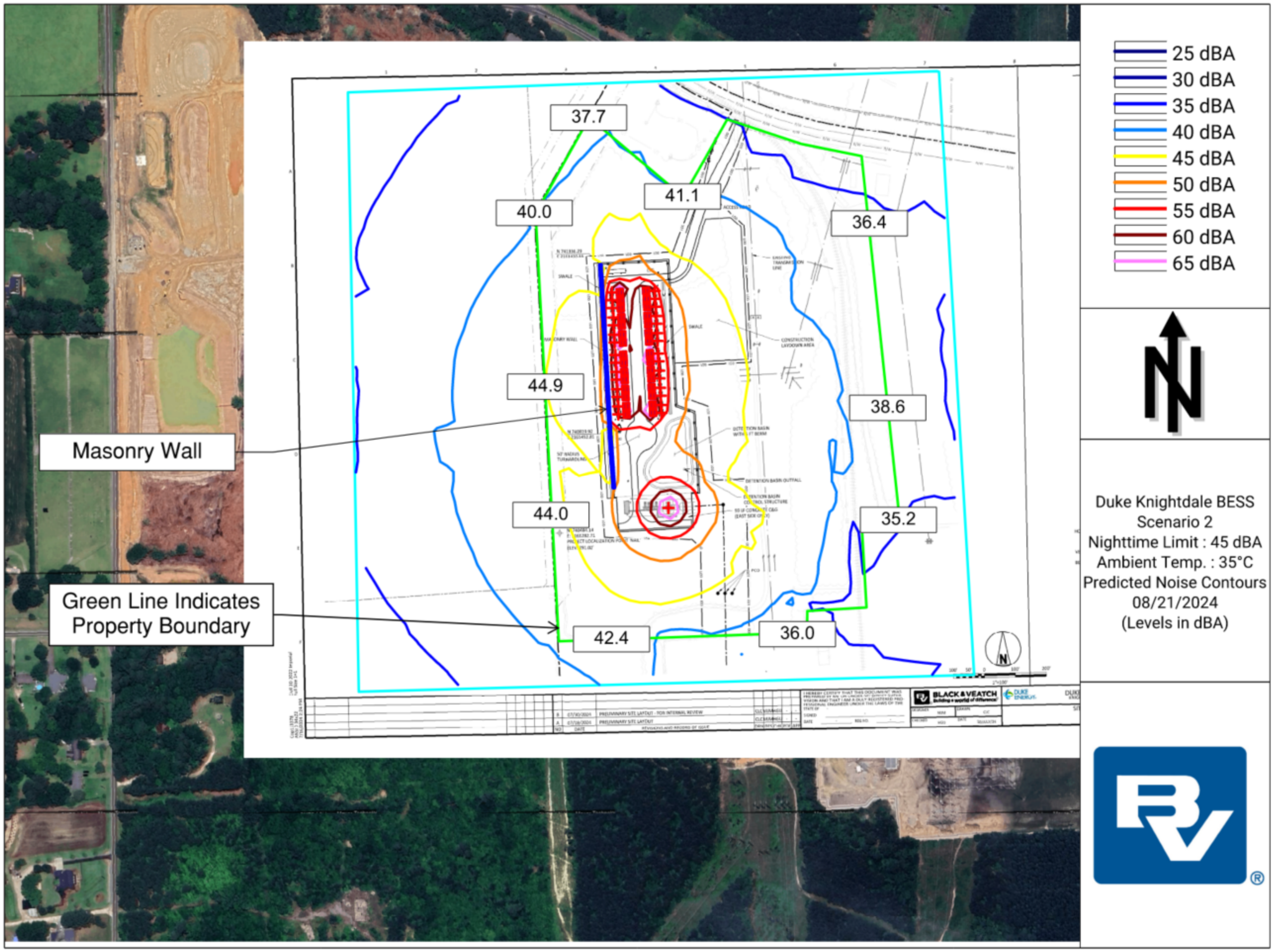

Figure 4 – Noise Contour Map for Scenario 2: Nighttime operation (L_p in dBA).

6.0 Conclusion

This noise report provides a regulatory review and acoustical analysis for the future operation of the Duke Knightdale BESS site located in Wake County, North Carolina.

Regulations and standards related to environmental sound emissions were investigated and reviewed to determine applicability to the project. The guiding applicable regulation was determined to be Wake County's objective, receiver-based noise code (see section 2.1). Due to continuous operation, the more stringent nighttime limit is the governing case for noise mitigation. This limits the maximum received level to 45 dBA at any location beyond the property boundary.

Compliance with the noise limit is entirely dependent on the design and performance of the BESS units. All 60 units shall be equipped with low-noise cooling systems.

The acoustical analysis for the future BESS equipment predicts levels ranging from 38 dBA to 48 dBA at the property boundaries for Scenario 1, which is compliant with the daytime limit of 55 dBA. Under Scenario 2, the predicted levels for the future BESS equipment range from 35 dBA to 45 dBA, which is compliant with the nighttime limit of 45 dBA.

Appendix A. Acoustical Terminology

SOUND ENERGY

Sound is generated by the propagation of energy in the form of pressure waves. Being a wave phenomenon, sound is characterized by amplitude (sound level) and frequency (pitch). Sound amplitude is measured in decibels, dB. The decibel is the logarithmic ratio of a sound pressure to a reference sound pressure. Typically, 0 dB corresponds to the threshold of human hearing. A 3 dB change in a continuous broadband noise is generally considered "just barely perceptible" to the average listener. A 5 dB change is generally considered "clearly noticeable" and a 10 dB change is generally considered a doubling (or halving) of the apparent loudness (Bies and C.H. Hansen, Engineering Noise Control, 2009). For reference, the sound pressure levels and subjective loudness associated with common noise sources are shown in Table A-1 as well as perceived changes in loudness and acoustic energy loss in Table A-3.

Frequency is measured in hertz, Hz (cycles per second). Most sound sources (except those with pure tones) contain sound energy over a wide range of frequencies. In order to analyze sound energy over the range of frequencies, the sound energy is typically divided into sections called octave bands. Octave bands are identified by their center frequencies including 31.5, 63, 125, 250, 500 1000, 2000, 4000, and 8000 Hz. For more detailed analyses, narrow bands such as 1/3-octave bands or 1/12-octave bands are employed. The sum of the sound energy in all of the octave bands for a source represents the overall sound level of the source.

The normal human ear can hear frequencies ranging from 20 Hz to 20,000 Hz. At typical sound pressure levels, the human ear is more sensitive to sounds in the middle and high frequencies (1,000 to 8,000 Hz) than sounds in the low frequencies. Various weighting networks have been developed to simulate the frequency response of the human ear. The A-weighting network was developed to simulate the frequency response of the human ear to sounds at typical environmental levels. The A-weighting network emphasizes sounds in the middle to high frequencies and de-emphasizes sounds in the low frequencies. Most sound level instruments can apply these weighting networks automatically. Any sound level to which the A-weighting network has been applied is expressed in A-weighted decibels, dBA. To characterize sound that contains relatively more low frequency energy—and to approximate the ear's response to relatively high sound levels—the C weighting network was developed. C weighting places more equal emphasis on low and high frequencies relative to A-weighting. Any sound level to which the C-weighting network has been applied is expressed in C-weighted decibels, dBC.

SOUND LEVEL METRICS

Noise in the environment is constantly fluctuating, such as when a car drives by, a dog barks, or a plane passes overhead. Therefore, noise metrics have been developed to quantify fluctuating environmental noise levels. These metrics include the equivalent-continuous sound level and the exceedance sound levels.

The equivalent-continuous sound level, L_{eq}, is used to represent the equivalent sound pressure level over a specified time period. The L_{eq} metric is the sound level of a steady-state sound that has the same (equivalent) total energy as the time-varying sound of interest, taken over a specified time period and covering a specified set of conditions. Thus, L_{eq} is a single-value level that expresses the time-averaged total energy of a widely varying or fluctuating sound level.

The exceedance sound level, L_x, is the sound level exceeded "x" percent of the sampling period and is referred to as a statistical sound level. The most common L_x values are L_{90}, L_{50}, and L_{10}. L_{90} is the sound level exceeded 90 percent of the sampling period. The L_{90} sound level represents the sound level without the influence of loud, transient noise sources and is therefore often referred to as the residual or background sound level (ANSI S12.9, Quantities and Procedures for Description and Measurement of Environmental Sound, 2003). The L_{50} sound level is the sound level exceeded 50 percent of the sampling period or the median sound level. The L_{10} sound level is the sound level exceeded 10 percent of the sampling period. The L_{10} sound level represents the occasional louder noises and is often referred to as the intrusive sound level. As previously discussed, the L_{90} environmental sound level typically represents the background (residual) sound level.

The variation between the L_{90}, L_{50}, and L_{10} sound levels can provide an indication of the variability of the acoustical environment. If the acoustical environment is perfectly steady, all values are identical. A large variation between the values indicates the environment experiences highly fluctuating sound levels. For instance, measurements near a roadway with frequent passing vehicles may cause a large variation in the statistical sound levels.

TYPICAL COMMUNITY SOUND LEVELS

Typical background (residual) sound levels in various types of communities are outlined in Table A-2 for reference. However, it is important to remember that each community is unique with regard to the sources of noise that contribute to the background sound levels.

HUMAN RESPONSE TO SOUND

Human response to sound is highly individualized. Annoyance is the most common issue regarding community noise. The percentage of people claiming to be annoyed by noise will generally increase as environmental sound levels increase. However, many other factors will also influence people's response to noise. These factors can include the character of the noise, the variability of the sound level, the presence of tones or impulses, and the time of day of the occurrence. Additionally, non-acoustical factors, such as the person's opinion of the noise source, the ability to adapt to the noise, the attitude towards the noise and those associated with it, and the predictability of the noise can also influence people's response. Response to noise varies widely from one person to another and with any particular noise, individual responses will range from "highly annoyed" to "not annoyed".

Table A-1 Typical Sound Pressure Levels Associated with Common Noise Sources

Sound Pressure Level, dBA	Subjective Evaluation	Common Outdoor Environment or Source	Common Indoor Environment or Source
140	Deafening	Jet aircraft at 75 ft	
130	Threshold of pain	Jet aircraft during takeoff at a distance of 300 ft	
120	Threshold of feeling	Elevated Train	Hard rock band
110	Extremely loud	Jet flyover at 1000 ft	Inside propeller plane
100	Very loud	Power mower, motorcycle at 25 ft, auto horn at 10 ft	
90	Very loud	Propeller plane flyover at 1000 ft, noisy urban street	Full symphony or band, food blender, noisy factory
80	Moderately loud	Diesel truck (40 mph) at 50 ft	Inside auto at high speed, garbage disposal, dishwasher
70	Loud	B-757 cabin during flight	Close conversation, vacuum cleaner, electric typewriter
60	Moderate	Air-conditioner condenser at 15 ft, near highway traffic	General office
50	Quiet		Private office
40	Quiet	Farm field with light breeze, birdcalls	Soft stereo music in residence
30	Very quiet	Quiet residential neighborhood	Bedroom, average residence (without TV and stereo)
20	Just audible		Human breathing
10	Threshold of hearing		
0			

Source: Adapted by Black & Veatch from *Architectural Acoustics,* by David M. Egan (1988) and *Architectural Graphic Standards,* by Ramsey and Sleeper (1994).

Table A-2 Typical Daytime Background Sound Levels in Various Types of Communities

Type of Community	Typical Daytime Background Sound Pressure Level, dBA
Very Quiet Rural Areas	31 to 35
Quiet Suburban Residential	36 to 40
Normal Suburban Residential	41 to 45
Urban Residential	46 to 50
Noisy Urban Residential	51 to 55
Very Noisy Urban Residential	56 to 60
Adjacent Freeway or Major Airport	n/a

Source: Adapted by Black & Veatch from *Community Noise,* by the U.S. Environmental Protection Agency, (December 1971).

Table A-3 Decibel Changes in Relation to Perceived Loudness

Sound Level Change (+/-)	Relative Loudness
0 dBA	Reference
3 dBA	Barely Perceptible Change
5 dBA	Readily Perceptible Change
10 dBA	Doubling/Halving of Loudness
20 dBA	Four-times or ¼ the Loudness
30 dBA	Eight-times or 1/8 the Loudness

Source: Adapted by Black & Veatch from *Highway Traffic Noise Analysis and Abatement Policy and Guidance,* by the U.S. Department of Transportation FHA (December 2017).