Jacobs

Memorandum

2020 SW Fourth Avenue, Suite 300
Portland, Oregon 97201
United States
T +1.503.235.5000
F +1.503.736.2000
www.jacobs.com

Subject **Acoustical Analysis of Stroud Battery Energy Storage Project**

Attention Todd Ellwood/Stroud ESS, LLC

From Mark Bastasch, P.E. (OR), INCE Bd. Cert.

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1. Introduction

Jacobs Engineering Group Inc. (Jacobs) has prepared this acoustical analysis to document predicted sound levels from the Stroud Battery Energy Storage Project (Project) proposed for development by Stroud ESS, LLC, a subsidiary of Terra-Gen Power, LLC, in the City of Lancaster, California. The analysis compares the Project sound levels to the City of Lancaster's acoustical requirements.

1.1 Project Description

Stroud ESS, LLC, proposes to construct, own, and operate the Project, a lithium-ion battery energy storage facility capable of delivering up to 250 megawatts of energy storage capacity and associated ancillary services into the California electric grid. The Project will comprise lithium-ion battery modules installed in racks housed in purpose-built outdoor Battery Energy Storage System enclosures, associated equipment, a Project-specific substation, and a generation tie-line connecting the Project to the adjacent existing Southern California Edison 500-kilovolt Antelope Substation.

1.2 Fundamentals of Acoustics

Acoustics is the study of sound, and noise is defined as unwanted sound. Airborne sound is a rapid fluctuation or oscillation of air pressure above and below atmospheric pressure creating a sound wave. Acoustical terms used in this section are summarized in Table 1.

Table 1. Definitions of Acoustical Terms

Term	Definition
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise or sound at a given location. The ambient noise level is typically defined by the L_{eq} level.
Background Noise Level	The underlying ever-present lower level noise that remains in the absence of intrusive or intermittent sounds. Distant sources, such as traffic, typically make up the background. The background level is generally defined by the L_{90} percentile noise level.
Intrusive	Noise that intrudes over and above the existing ambient noise level at a given location. The relative intrusiveness of a sound depends upon its

Table 1. Definitions of Acoustical Terms

Term	Definition
	amplitude, duration, frequency, time of occurrence, tonal content, the prevailing ambient noise level as well as the sensitivity of the receiver. The intrusive level is generally defined by the L_{10} percentile noise level.
Sound Pressure (Noise) Level Decibel (dB)	A unit describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micropascals (20 micronewtons per square meter).
A-Weighted Sound Pressure (Noise) Level (dBA)	The sound level in decibels as measured on a sound level meter using the A-weighted filter network. The A-weighted filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise. All sound (noise) levels in this report are A-weighted.
Equivalent Noise Level (L_{eq})	The average A-weighted noise level, on an equal energy basis, during the measurement period.
Percentile Noise Level (L_n)	The noise level exceeded during n percent of the measurement period, where n is a number between 0 and 100 (for example, L_{90})
Community Noise Equivalent Level (CNEL)	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels from 10:00 p.m. to 7:00 a.m. and 5 decibels from 7:00 p.m. to 10:00 p.m.

The most common metric is the overall A-weighted sound level measurement adopted by regulatory bodies worldwide. The A-weighting network measures sound to the way in which a person perceives or hears sound. There is consensus that A-weighting is appropriate for estimating the hazard of noise-induced hearing loss. With respect to other effects, such as annoyance, A-weighting is acceptable if largely middle-and high-frequency noise is present; however, if the noise is unusually high, at low frequencies, or contains prominent low-frequency tones, the A-weighting may not give a valid measure.

A-weighted sound levels are typically measured or presented as equivalent noise level (L_{eq}), which is defined as the average noise level, on an equal energy basis for a stated period of time, and is commonly used to measure steady-state sound or noise that is usually dominant. Statistical methods are used to capture the dynamics of a changing acoustical environment. Statistical measurements are typically denoted by L_{xx}, where xx represents the percentile of time the sound level is exceeded. The L_{90} measurement represents the noise level that is exceeded during 90 percent of the measurement period. Similarly, L_{10} represents the noise level exceeded for 10 percent of the measurement period.

Some metrics used in determining the impact of environmental noise consider the different response that people have to daytime and nighttime noise levels. During the nighttime, exterior background noises are generally lower than the daytime levels. However, most household noise also decreases at night and exterior noise becomes more noticeable. Furthermore, most people sleep at night and are sensitive to intrusive noises. To account for human sensitivity to nighttime noise levels, the Community Noise Equivalent Level (CNEL) was developed. CNEL is a noise index that accounts for the potential greater annoyance of noise during evening and the nighttime hours.

CNEL values are calculated by averaging hourly L_{eq} sound levels for a 24-hour period, and applying a weighting factor to the evening and nighttime L_{eq} values. The weighting factor, which reflects the increased sensitivity to noise during the evening and nighttime hours, is added to each hourly L_{eq} sound level before the 24-hour CNEL is calculated. For the purposes of assessing noise, the 24-hour day is divided into the following three time periods and weighting factors:

- Daytime: 7:00 a.m. to 7:00 p.m. (12 hours) weighting factor of 0 dB
- Evening: 7:00 p.m. to 10:00 p.m. (3 hours) weighting factor of 5 dB
- Nighttime: 10:00 p.m. to 7:00 a.m. (9 hours) weighting factor of 10 dB

The three time periods are averaged to compute the overall CNEL value. For a continuous noise source, the L_{dn} value is easily computed by adding 6.7 dBA to the overall 24-hour noise level (L_{eq}). For example, if the expected continuous noise level from a facility was 60.0 dBA, the resulting CNEL from the facility would be 66.7 dBA.

The effects of noise on people can be listed in three general categories:

1) Subjective effects of annoyance, nuisance, and dissatisfaction
2) Interference with activities such as speech, sleep, and learning
3) Physiological effects such as startling and hearing loss

In most cases, environmental noise produces effects in the first two categories only. However, workers in industrial plants may experience noise effects in the third category. No completely satisfactory way exists to measure the subjective effects of noise or to measure the corresponding reactions of annoyance and dissatisfaction. This lack of a common standard is primarily due to the wide variation in individual thresholds of annoyance and habituation to noise. Table 2 shows the relative A-weighted noise levels of common sounds measured in the environment and in industry for various sound levels.

Table 2. Typical A-weighted Sound Levels

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	— 110 —	Rock band
Jet fly-over at 1,000 feet		
	— 100 —	
Gas lawn mower at 3 feet		
	— 90 —	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	— 80 —	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 100 feet	**— 70 —**	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	**— 60 —**	
		Large business office
Quiet urban daytime	**— 50 —**	Dishwasher next room
Quiet urban nighttime	**— 40 —**	Theater, large conference room (background)
Quiet suburban nighttime		
	— 30 —	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	— 20 —	
		Broadcast/recording studio
	— 10 —	
Lowest threshold of human hearing	**— 0 —**	Lowest threshold of human hearing

Source: Caltrans 2013.

2. Regulatory and Environmental Setting

This section describes the laws, ordinances, regulations, and standards that apply to construction and operational sound levels attributable to the Project.

2.1 Construction

The City of Lancaster's noise regulations are presented in the municipal code and the general plan for the city. *A Codification of the General Ordinances of the City of Lancaster, California* (City of Lancaster 2022) includes the following ordinances pertaining to noise:

8.24.030 - Loud, unnecessary and unusual noises prohibited*: Notwithstanding any other provision of this chapter, and in addition thereto, no person shall make, cause or suffer, or permit to be made upon any premises owned, occupied or controlled by him/her any unnecessary noises or sounds which are physically annoying to persons of ordinary sensitiveness which are so harsh or so prolonged or unnatural or unusual in their use, time, or place as to occasion physical discomfort to the inhabitants of any neighborhood. All animals shall be so maintained.*

8.24.040 - Loud, unnecessary and unusual noises prohibited—Construction and building*: Except as otherwise provided in this chapter, a person at any time on Sunday or any day between the hours of eight p.m. and seven a.m. shall not perform any construction or repair work of any kind upon any building or structure or perform any earth excavating, filling or moving where any of the foregoing entails the use of any air compressor, jack hammer, power-driven drill, riveting machine, excavator, diesel-powered truck, tractor or other earth-moving equipment, hard hammers on steel or iron or any other machine tool, device or equipment which makes loud noises within five hundred (500) feet of an occupied dwelling, apartment, hotel, mobile home or other place of residence.*

Exceptions to these ordinances are included in Section 8.24.050:

8.24.050 - Exceptions.

A. The provisions of Section 8.24.040 do not apply to any person who performs the construction, repair, excavation or moving work pursuant to the express written permission of the city engineer to perform such work at times prohibited in Section 8.24.040. Upon receipt of an application stating the reasons for the request, the city engineer may grant such permission if he finds that:

1. *The work proposed to be done is effected with the public interest; or*
2. *Hardship or injustice or unreasonable delay would result with the interruption thereof with the hours and days specified in Section 8.24.040; or*
3. *The building or structure involved is devoted or intended to be devoted to a use immediately incident to public interest.*

B. The provisions of Section 8.24.040 do not apply to the construction, repair or excavation during prohibited hours as may be necessary to restore property to a safe condition following a public calamity or work required to protect persons or property from imminent exposure to danger or work by private or public utility companies when restoring utility service.

2.2 Operations

The *General Plan 2030 for the City of Lancaster* (General Plan) (City of Lancaster 2009) identifies goals, objectives, and policies to limit sound levels and facilitate land use compatibility between adjacent uses. The General Plan presents noise compatible land use objectives identifying the maximum exterior and interior CNELs by land use (Table 3).

Table 3. Noise-Compatible Land Use Objectives from the City of Lancaster General Plan 2030

Land Use	Maximum Exterior CNEL	Maximum Interior CNEL
Rural, Single Family, Multiple Family Residential	65 dBA	45 dBA
Schools: Classrooms Playgrounds	 65 dBA 70 dBA	 45 dBA --
Libraries	--	50 dBA
Hospitals/Convalescent Facilities: Living Areas Sleeping Areas	 -- --	 50 dBA 40 dBA
Commercial and Industrial Office Areas	70 dBA --	-- 50 dBA

The current land use for adjacent parcels is vacant or industrial (Southern California Edison substation, transmission lines) and the Project will co-locate additional industrial-like facilities in the same area. Consistent with Project discussions between Stroud ESS, LLC, and the City, this analysis is based on a CNEL requirement of 70 dBA at the property line given the existing adjacent industrial land uses. Additional General Plan policies are summarized as follows:

> ***Policy 4.3.1:*** *Ensure that noise-sensitive land uses and noise generators are located and designed in such a manner that City noise objectives will be achieved.*
>
> ***Specific Action 4.3.1(d):*** *When proposed projects include uses that could be potentially significant noise generators, require noise analyses to be prepared by an acoustical expert, including specific recommendations for mitigation when: 1) the project is located in close proximity to noise sensitive land uses or land which is planned for noise sensitive land uses, or 2) the proposed noise source could violate the noise provisions of the General Plan or Municipal Code.*
>
> ***Specific Action 4.3.1(h):*** *Ensure that new commercial and industrial activities (including the placement of mechanical equipment) are designed so that activities comply with the maximum noise level standards at the property line of adjacent uses, thereby minimizing impacts on adjacent uses (see [General Plan] Table 3).*
>
> ***Policy 4.3.2:*** *Wherever feasible, manage the generation of single event noise levels (SENL) from motor vehicles, trains, aircraft, commercial, industrial, construction, and other activities such that SENL levels are no greater than 15 dBA above the noise objectives included in the Plan for Public Health and Safety.*
>
> ***Specific Action 4.3.2(d):*** *As a condition of approval, limit non-emergency construction activities to daylight hours between sunrise and 8:00 pm.*

The Project is in compliance with the applicable noise ordinance requirements and General Plan noise element policies. Consistent with City requirements and policies, the Project retained an acoustical expert to prepare a noise analysis; demonstrated compliance with the Table 3 limits for industrial uses; and limited the hours of construction.

3. Methods and Results

This section describes the methodology followed to conduct the assessment and the corresponding results derived for construction and operations, respectively.

3.1 Construction

Construction activities will utilize equipment commonly employed for site grading and equipment installation (such as bulldozers, compactors, scrapers, trucks, and cranes).

Decibels cannot be directly added arithmetically (for example, 50 dBA plus 50 dBA does not equal 100 dBA). When two sources of equal level are added together, the result will always be 3 dB greater (for example, 50 dBA plus 50 dBA equals 53 dBA, and 70 dBA plus 70 dBA equals 73 dBA). If the difference between the two sources is 10 dBA, the level (when rounded to the nearest whole dB) will not increase (for example: 40 dBA plus 50 dBA equals 50 dBA, and 60 dBA plus 70 dBA equals 70 dBA) (Caltrans 2013).

The decrease in sound level caused by distance from any single sound source normally follows the inverse square law; that is, the sound pressure level changes in inverse proportion to the square of the distance from the sound source. In a large, open area without obstructive or reflective surfaces, a general rule is that at distances greater than approximately the largest dimension of the noise emitting surface, the sound pressure level from a single source of sound drops off at a rate of 6 dB with each doubling of the distance from the source. Sound energy is absorbed in the air as a function of temperature, humidity, and sound frequency; this attenuation can be up to 2 dB over 1,000 feet (Caltrans 2013). The drop-off rate will also vary based on terrain conditions and the presence of obstructions in the sound's propagation path.

As described in the Federal Transit Administration's (FTA's) *Transit Noise and Vibration Impact Assessment Manual* (FTA 2018), the average noise level from each piece of equipment is determined by the following equation for geometric spreading:

$$\text{Typical Noise Level at 50 feet} + 10 \times \log(Adj_{usage}) - 20 \times \log(\text{distance to receptor}/50) - 10 \times G \times \log(\text{distance to receptor}/50)$$

Because specific construction methods or daily schedules for the Project have not been determined, and construction is, by its nature, a dynamic activity, the following scenario was evaluated.

Where:

> Usage factor (Adjusage) = 1 (equipment is operating continuously)
>
> Ground effect factor (G) = 0, representing hard ground (such as a ground condition that does not result in additional attenuation)

The total noise level then becomes solely a function of the type of equipment operating and the distance from the equipment to the noise receptor (i.e., point of evaluation).

Noise levels from construction equipment operations were estimated based on data from the Federal Highway Administration's (FHWA's) *Roadway Construction Noise Model User's Guide* (FHWA 2006) and the *Transit Noise and Vibration Impact Assessment Manual* (FTA 2018). These data represent the most recent and comprehensive tabulation of noise from common pieces of heavy equipment. Table 4 tabulates the construction equipment noise levels reported by FHWA. The Project will not utilize all equipment listed; rather, the list is presented in whole for context.

Table 4. Typical Construction Equipment Noise Levels

Equipment Description	Acoustical Usage Factor (%)	Specified Lmax at 50 feet (dBA)	Actual Measured Lmax at 50 feet (dBA)	Actual Data Samples (No.)
All other equipment > 5 hp	50	85	-	0
Auger drill rig	20	85	84	36
Backhoe	40	80	78	372
Bar bender	20	80	-	0
Blasting	-	94	-	0
Boring jack power unit	50	80	83	1
Chainsaw	20	85	84	46
Clam shovel (dropping)	20	93	87	4
Compactor (ground)	20	80	83	57
Compressor (air)	40	80	78	18
Concrete batch plant	15	83	-	0
Concrete mixer truck	40	85	79	40
Concrete pump truck	20	82	81	30
Concrete saw	20	90	90	55
Crane	16	85	81	405
Dozer	40	85	82	55
Drill rig truck	20	84	79	22
Drum mixer	50	80	80	1
Dump truck	40	84	76	31
Excavator	40	85	81	170
Flatbed truck	40	84	74	4
Front end loader	40	80	79	96
Generator	50	82	81	19
Generator (less than 25 kVA, VMS signs)	50	70	73	74
Gradall	40	85	83	70
Grader	40	85	-	0
Grapple (on backhoe)	40	85	87	1
Horizontal boring hydraulic jack	25	80	82	6
Hydra break ram	10	90	-	0
Impact pile driver	20	95	101	11
Jackhammer	20	85	89	133
Mounted impact hammer (hoe ram)	20	90	90	212
Pavement scarifier	20	85	90	2

Table 4. Typical Construction Equipment Noise Levels

Equipment Description	Acoustical Usage Factor (%)	Specified Lmax at 50 feet (dBA)	Actual Measured Lmax at 50 feet (dBA)	Actual Data Samples (No.)
Paver	50	85	77	9
Person lift	20	85	75	23
Pickup truck	40	55	75	1
Pneumatic tools	50	85	85	90
Pumps	50	77	81	17
Refrigerator unit	100	82	73	3
Rivet buster and chipping gun	20	85	79	19
Rock drill	20	85	81	3
Roller	20	85	80	16
Sand blasting (single nozzle)	20	85	96	9
Scraper	40	85	84	12
Shears (on backhoe)	40	85	96	5
Slurry plant	100	78	78	1
Slurry trenching machine	50	82	80	75
Soil mix drill rig	50	80	-	0
Tractor	40	84	-	0
Vacuum excavator (Vac-truck)	40	85	85	149
Vacuum street sweeper	10	80	82	19
Ventilation fan	100	85	79	13
Vibrating hopper	50	85	87	1
Vibratory concrete mixer	20	80	80	1
Vibratory pile driver	20	95	101	44
Warning horn	5	85	83	12
Welder or torch	40	73	74	5

Source: FHWA 2006.

- = not available

hp = horsepower

kVA = kilovolt(s)-ampere

Lmax = maximum sound level

VMS = variable message signs

A review of the equipment noise levels presented in Table 4 shows that the loudest equipment generally emits noise in the range of 80 to 90 dBA at 50 feet. Noise at any specific receptor is dominated by the closest and loudest equipment. The type, number, and duration of equipment anticipated to be used near any specific receptor location will vary over time. Therefore, a typical noise estimate was developed based on the general assumption of multiple pieces of loud equipment operating near each other. Specifically, the scenario evaluated uses five pieces of general construction equipment working near each other, as follows:

- One piece of equipment generating a reference noise level of 85 dBA at 50 feet at the edge of the construction or work area
- Two pieces of equipment generating 85 dBA reference noise levels located 50 feet farther away from the edge of the construction or work area
- Two more pieces of equipment generating 85 dBA reference noise levels located 100 feet farther away from the edge of the construction or work area

Table 5 summarizes the expected average equipment noise levels at various distances, based on this scenario.

Table 5. Average Equipment Noise Levels Versus Distance

Distance from Activity (feet)	Average Noise Level (dBA)
50	87
100	83
200	78
400	73
800	67
1,600	62
3,200	56

To minimize construction sound levels, the Project will implement the following noise minimization measures, as feasible:

- Construction operations shall not occur between 8 p.m. and 7 a.m. on weekdays or Saturday or at any time on Sunday. The hours of any construction-related activities shall be restricted to the periods and days permitted by local ordinance.
- The onsite construction supervisor shall have the responsibility and authority to receive and resolve complaints. A clear appeal process to the owner shall be established prior to construction commencement that will allow for resolution of noise problems that cannot be immediately solved by the site supervisor.
- Electrically powered equipment shall be used instead of pneumatic or internal combustion power equipment, where feasible.
- Material stockpiles and mobile equipment staging, parking, and maintenance areas shall be located as far away as practicable from noise-sensitive receptors.
- The use of noise-producing signals, including horns, whistles, alarms, and bells, shall be for safety warning purposes only.
- No Project-related public address or music system shall be audible at any adjacent receptor.
- All noise-producing construction equipment and vehicles using internal combustion engines shall be equipped with mufflers, air-inlet silencers where appropriate, and other shrouds, shields, or other noise-reducing features in good operating condition that meet or exceed original factory

specifications. Mobile or fixed "package" equipment (e.g., arc-welders, air compressors) shall be equipped with shrouds and noise-control features that are readily available for the type of equipment.

3.2 Operations

Battery energy storage systems consist of a battery charging and discharging system. Inverters convert the direct current from and to the battery to alternating current for transmission from and to the step-up transformers. The step-up transformers in turn modify the voltage to be consistent with electrical grid requirements.

An acoustical model of the proposed Project was developed using source input levels derived from data supplied by manufacturers, Stroud ESS, LLC, or information found in the technical literature. The sound levels presented represent the anticipated steady-state level from the Project with essentially all equipment operating during the day or night.

Standard acoustical engineering methods were used in the noise analysis. The acoustical model, CadnaA by DataKustik GmbH of Munich, Germany (DataKustik 2022), is a sophisticated tool that enables one to fully model complex industrial plants. The sound propagation factors used in the model have been adopted from International Organization for Standardization (ISO) 9613-2 *Acoustics—Sound Attenuation During Propagation Outdoors*. Atmospheric absorption was estimated for conditions of 10 degrees Celsius and 70 percent relative humidity (conditions that favor propagation) and computed in accordance with ISO 9613-1. The model divides the proposed Project into a list of individual sound sources representing each piece of sound-emitting equipment. The sound power levels representing the standard performance of each of these components are assigned based on data supplied by manufacturers or information found in the technical literature. Using these sound power levels as a basis, the model calculates the sound pressure level that would occur at each receptor from each source after losses from distance, air absorption, and other factors are considered. The sum of all these individual levels is the total plant level at the modeling point.

The ISO 9613-2 method is based on an omnidirectional downwind condition. That is, the sound prediction algorithms assume every point at which sound level is calculated is downwind of all sound-emitting equipment simultaneously. In essence, the prediction assumes each receiver or prediction point is a "black hole" and the wind is blowing from each source and into this black hole. While this is physically impossible, the ISO 9613-2 model has been widely and successfully used to develop acoustical models for power facilities. Numerous agencies and regulatory bodies rely on properly conducted ISO 9613-2 modeling. The ISO 9613-2 parameters used in this assessment are a receptor height of 1.5 meters and mixed ground factor of G=0.5 (where G may vary between 0 for hard pavement or water and 1 for acoustically absorptive ground such as plowed earth).

While final equipment selection will occur as design progresses, a representative acoustical model was developed based on approximately 480 battery energy storage containers, 120 inverters, two step-up transformers, and miscellaneous electrical cabinets and equipment. As is typical at this stage of a project design, these data are representative and detailed vendor specifications will ultimately be developed to ensure the Project complies with the applicable requirements.

Modeled sound pressure level contours based on the preliminary equipment layout are presented on Figure 1. The predicted sound levels at the property line comply with the commercial and industrial criteria of 70 dBA CNEL. As is typical at this stage of a project, final detailed design information is still under development. Therefore, these results are indicative, based on an early layout developed to support Project permitting. Noise generated during the testing and commissioning phase of the Project is not expected to substantially differ from that produced during normal full-load operation. Operational traffic is anticipated to be minimal, primarily pickup trucks used by a small operation and maintenance staff for periodic maintenance.

4. Conclusion

The results of the acoustical model developed for the proposed Project and depicted on Figure 1 demonstrate that the predicted operational sound levels are expected to comply with the City of Lancaster's commercial/industrial 70 dBA CNEL requirement at the property line. Construction represents a temporary noise-generating activity and minimization measures have been identified including prohibiting construction between 8 p.m. and 7 a.m. on weekdays or Saturday or at any time on Sunday.

5. References

California Department of Transportation (Caltrans). 2013. *Technical Noise Supplement to the Traffic Noise Analysis Protocol: A Guide for the Measuring, Modeling, and Abating Highway Operation and Construction Noise Impacts*. September. Division of Environmental Analysis, Environmental Engineering, Hazardous Waste, Air, Noise, Paleontology Office, Sacramento, California. Accessed July 2022. https://dot.ca.gov/-/media/dot-media/programs/environmental-analysis/documents/env/tens-sep2013-a11y.pdf.

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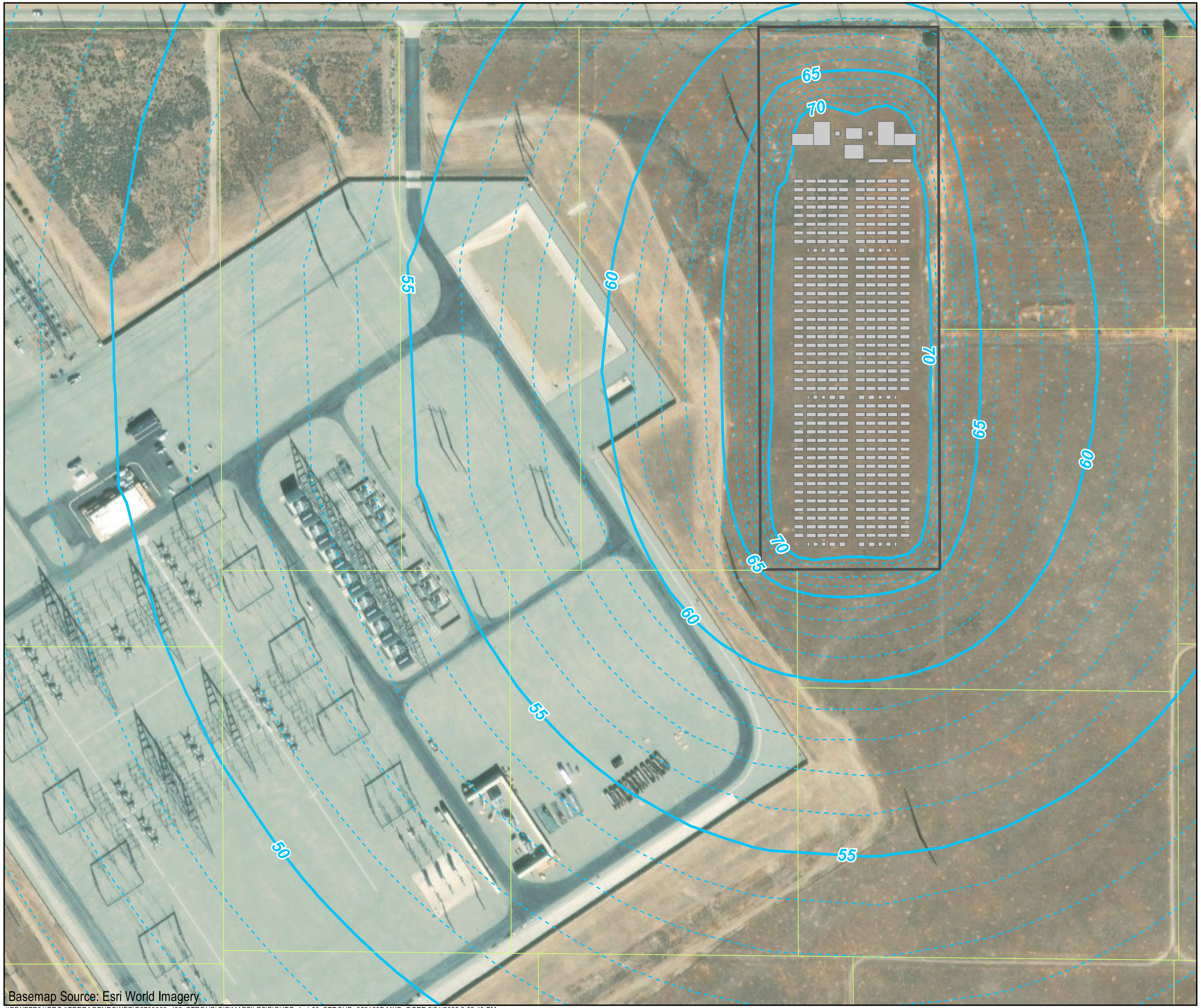

LEGEND

Predicted BESS Sound Level (dBA CNEL)

- 5 dBA Contour Interval
- 1 dBA Contour Interval
- Modeled Equipment
- Site Boundary
- Parcel Boudary

Notes:
BESS = Battery Energy Storage System
CNEL = Community Noise Equivalent Level
dBA = A-Weighted Sound Pressure (Noise) Level Decibel

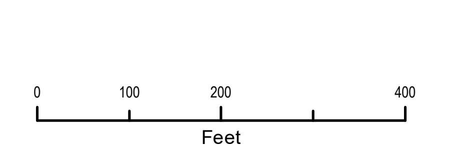

Figure 1
Predicted Sound Level Contours (dBA CNEL)
Stroud Battery Energy Storage Project
City of Lancaster, California