

D R A F T

# PANAMA AES COSTA NORTE PROJECT NOISE ANALYSIS

Prepared for

AES Panama

AECOM Project No. 60479502



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## List of Acronyms and Abbreviations

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AES	Applied Energy Services, The AES Corporation
CEC	California Energy Commission
CTG	combustion turbine generator
dB	decibel
dba	A-weighted decibel
EHS	environmental, health and safety
EPC	engineering, procurement, construction
EPRI	Electric Power Research Institute
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GE	General Electric
HPD	hearing protection devices
HRSG	heat recovery steam generator
Hz	Hertz
ID	Identification
IFC	International Finance Corporation
ISO	International Organization of Standardization
kV	kilovolt
L <sub>10</sub>	sound level exceeded for a cumulative 10% of a time period
L <sub>50</sub>	sound level exceeded for a cumulative 50% of a time period
L <sub>90</sub>	sound level exceeded for a cumulative 90% of a time period
L <sub>d</sub>	daytime sound level
L <sub>dn</sub>	day-night sound level
LDO	light diesel fuel oil
L <sub>eq</sub>	equivalent sound level
L <sub>max</sub>	maximum sound level
L <sub>min</sub>	minimum sound level
L <sub>n</sub>	nighttime sound level
LNG	liquefied natural gas
mps	meters per second
MW	Megawatt
NSR	noise-sensitive receiver
PWL, L <sub>w</sub>	sound power level
RCNM	Roadway Construction Noise Model
SPL, L <sub>p</sub>	sound pressure level
STG	steam turbine generator
WBG	World Bank Group
WHO	World Health Organization

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# SECTION ONE

## Executive Summary

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## SECTION 1 EXECUTIVE SUMMARY

Construction and operation noise emission associated with two phases of the proposed AES Costa Norte power block facility (the Project) were predicted to determine potential adverse effects to onsite workers and to the surrounding communities.

Predicted Project construction noise levels, with and without the inclusion of pile driving activity, would be considered compliant with daytime jurisdictional thresholds at nearest representative NSRs when these activities occur during the day. The levels would also appear to be compliant with WBG and WHO guidelines for daytime exterior noise levels at an NSR. At night, when applicable noise limits are more stringent, noise from construction that includes pile-driving activity would risk causing a non-compliance condition and thus would result in an adverse noise effects for at least two of the three representative NSRs studied in this analysis. Similarly, construction noise that includes pile-driving would also be louder than the nighttime standards per WHO and WBG.

After Project systems have been installed and are operating normally, predicted operational noise levels within the site boundary may exceed 75 dBA (with respect to listeners standing on the ground, such as onsite workers) up to a distance of approximately 40 meters from noise-producing Project equipment surfaces. Per Project design standardization requirements, these outdoor areas that are expected to experience operation noise levels in excess of 75 dBA and are co-located with anticipated site worker traffic or activities would be expected to feature appropriate signage indicating this elevated noise level.

Compared with jurisdictional noise limits (60 dBA), nominal Project operations during the daytime hours would be compliant at all three representative NSRs studied in this analysis. Furthermore, daytime Project operation would also appear to comply with WHO and WBG guidance thresholds (55 dBA).

Only during an infrequent but “worst-case” wind scenario for Phase 2 (when six CTGs and two STGs are operating) would noise from Project operations exceed the nighttime jurisdictional limit of 50 dBA at the nearest of the three NSRs. With respect to the WHO and WBG 45 dBA guidance limit, all three representative NSRs for Phase 2 would appear to be at risk of non-compliance under this worst-case meteorological condition.

Analysis of individual sources in the Project operations noise model scenarios developed for the discussion of potential adverse noise effects suggests that the exhaust stacks are the loudest—and by a margin of several dBA above the next-loudest acoustical contributors. Therefore, were the Project to seek greater likelihood of compliance with the nighttime jurisdictional limit of 50 dBA and the WHO and WBG 45 dBA  $L_{eq}$  nighttime guidance threshold, this noise study suggests consideration of exhaust stack muffler upgrades that—if designed and implemented properly—would reduce these loudest Project operations noise contributors and help yield overall noise reduction to an A-weighted dB level at the nearest representative NSRs.

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## SECTION TWO

## Introduction

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### SECTION 2 INTRODUCTION

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The purpose of this noise analysis is to estimate existing and future noise levels and evaluate potential adverse noise effects associated with the construction and operation of the proposed AES Costa Norte facility (the Project or Facility).

#### 2.1 PROJECT DESCRIPTION

The power block of the Project will consist of three (3) combustion turbine generators (CTGs) in a 3x3x1 combined cycle configuration, including three (3) heat recovery steam generators (HRSGs), and a steam turbine-generator (STG). The Facility is located in the Province, District, and City of Colón, Panama. The CTGs will be GE Frame 6FA.03 units, firing gaseous, liquefied natural gas (LNG) as the primary fuel for start-up and normal operation, and light diesel fuel oil (LDO) for start-up and as back-up fuel. A second phase of construction may occur at a later date, introducing a second array of three (3) additional CTGs, three (3) HRSGs and an STG to the southeast of the Phase-1 arrangement.

LNG will be supplied to the power blocks from an adjacent LNG facility, capable of receiving, storing, vaporizing and distributing LNG to the Project. The LNG receiving terminal is dedicated to gas supply to one (1<sup>st</sup> phase) and thereafter two power blocks of 380 MW each. In a later phase, the terminal will additionally allow ship loading, for LNG bunkering purpose, and truck filling. For purposes of this noise analysis, the LNG facility is not part of the studied Project. Noise assessment is limited only to the three or six-unit CTG and STG combinations associated with the two power blocks to be built over two separate construction phases.

#### 2.2 ACOUSTIC FUNDAMENTALS

Noise is generally defined as loud, unpleasant, unexpected, or undesired sound that is typically associated with human activity and that interferes with or disrupts normal activities. Although exposure to high noise levels has been demonstrated to cause hearing loss, the principal human response to environmental noise is annoyance. The response of individuals to similar noise events is diverse and influenced by the type of noise, the perceived importance of the noise and its appropriateness in the given environmental setting, the time of day and the type of activity during which the noise occurs, and the sensitivity of the individual.

Sound is a physical phenomenon consisting of minute vibrations that travel through a fluid medium, such as air, and are sensed by the human ear. Sound is generally characterized by several variables, including frequency and intensity. Frequency describes the pitch of the sound and is measured in Hertz (“Hz”), while intensity describes the sound’s loudness and is measured in decibels (“dB”). Decibels are measured using a logarithmic scale. A sound level of 0 dB is approximately the threshold of human hearing and is barely audible under extremely quiet listening conditions—it is not the complete absence of sound but the lowest level that can be heard by an average healthy human ear. Normal speech has a sound level of approximately 60 dB. Sound levels above approximately 110 dB begin to be felt inside the human ear as discomfort and eventually pain at 120 dB and higher levels. The minimum change in the sound level of individual events that an average human ear can detect is about 1 to 2 dB. A 3 to 5 dB change is readily

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perceived. A change in sound level of about 10 dB is usually perceived by the average person as a doubling (or if -10 dB, halving) of the sound's loudness.

Due to the logarithmic nature of the decibel unit, sound levels cannot be added or subtracted directly and are somewhat cumbersome to handle mathematically; however, some simple rules are useful in dealing with sound levels. First, if a sound's amplitude is doubled, the sound level increases by 3 dB, regardless of the initial sound level. For example: 60 dB + 60 dB = 63 dB, and 80 dB + 80 dB = 83 dB.

Sound level is usually expressed by reference to a known standard. In expressing sound pressure level ("SPL" or  $L_p$ ) on a logarithmic scale, the sound pressure is compared to a reference value of 20 micropascals ( $\mu\text{Pa}$ ). SPL depends not only on the sound power ("PWL" or  $L_w$ ) of the source, but also on the distance from the source and on the acoustical characteristics of the space surrounding the source.

Hertz is a measure of how many times each second the crest of a sound pressure wave passes a fixed point. For example, when a drummer beats a drum, the skin of the drum vibrates a number of times per second. When the drum skin vibrates 100 times per second it generates a sound pressure wave that is oscillating at 100 Hz, and this pressure oscillation is perceived by the ear/brain as a tonal pitch of 100 Hz. Sound frequencies between 20 and 20,000 Hz are within the range of sensitivity of the best human ear.

Sound from a tuning fork contains a single frequency (a pure tone), but most sounds one hears in the environment consist of multiple frequencies that differ in amplitude. The method commonly used to quantify such sounds consists of evaluating a range or spectrum of frequencies according to a weighting system that reflects average healthy human hearing sensitivity, which tends to be best in the mid-range frequencies usually associated with speech but poorer at the low and high frequency extremes. This weighting system, applied as standardized decibel adjustments for each one-third or full octave band that makes up the audible spectrum, is called "A-weighting," and the decibel level measured (after application of these adjustments to the "raw" or unweighted decibel levels across the audible spectrum) is called the A-weighted sound level ("dBA"). In practice, the level of a noise source is conveniently measured using a sound level meter that includes a filter corresponding to the dBA curve.

Although the dBA may adequately indicate the level of environmental noise at any instant in time, community noise levels vary continuously. Most environmental noise includes a mixture of noise from distant sources that creates a relatively steady background noise in which no particular source is identifiable. A single descriptor called the equivalent sound level ( $L_{eq}$ ) may be used to describe sound that is changing in level.  $L_{eq}$  is the energy-mean dBA during a measured time interval. It is the "equivalent" constant sound level that would have to be produced by a given source to equal the acoustic energy contained in the fluctuating sound level being measured over the specified time period. In addition to the energy-average level, it is often desirable to know the acoustic range of the noise source being measured. This is accomplished through the maximum ( $L_{max}$ ) and minimum ( $L_{min}$ ) instantaneous level indicators that represent the root-mean-square maximum and minimum noise levels measured during the monitoring interval. The  $L_{min}$  value obtained for a particular monitoring location is often called the acoustic floor for that location.

To describe the time-varying character of environmental noise, statistical noise descriptors  $L_{10}$ ,  $L_{50}$ , and  $L_{90}$  are commonly used. They are the noise levels equaled or exceeded ten percent (10%), fifty percent (50%), and ninety percent (90%) of the measured time interval, respectively. Sound levels associated with

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The  $L_{10}$  typically describe transient or short-term events, half of the sounds during the measurement interval are softer than  $L_{50}$  and half are louder, while levels associated with  $L_{90}$  often describe background noise conditions and/or continuous, “steady-state” sound sources. By way of example, the din of background sound (e.g., indistinguishable traffic noise from a network of nearby roadways and building mechanical systems) measured at a receiver location would reasonably be represented by the  $L_{90}$  value, while momentary louder sound from occasional commercial jets passing overhead during the measurement period (e.g., a continuous hour) would probably exhibit a much higher  $L_{10}$  value.

Finally, another sound measure known as the Day-Night Average Sound Level ( $L_{dn}$ ) is defined as the A-weighted average sound level for a continuous 24-hour day. As part of its derivation from hourly or representative daytime and nighttime SPL, the calculation of  $L_{dn}$  applies a +10 dB penalty to hourly sound levels (i.e., makes them louder) during the nighttime period (10:00 p.m. to 7:00 a.m.), which helps compensate for apparent increased human sensitivity to noise during these quieter nighttime hours.

The  $L_{dn}$  value is typically used to define acceptable land use compatibility with respect to noise. Because of the time-of-day penalties associated with the  $L_{dn}$  descriptor, the  $L_{eq}$  for a continuously operating sound source during a 24-hour period will be numerically less than the calculated  $L_{dn}$  value. Sound levels of typical noise sources and environments are provided in Figure 2.1-1 to provide a frame of reference.

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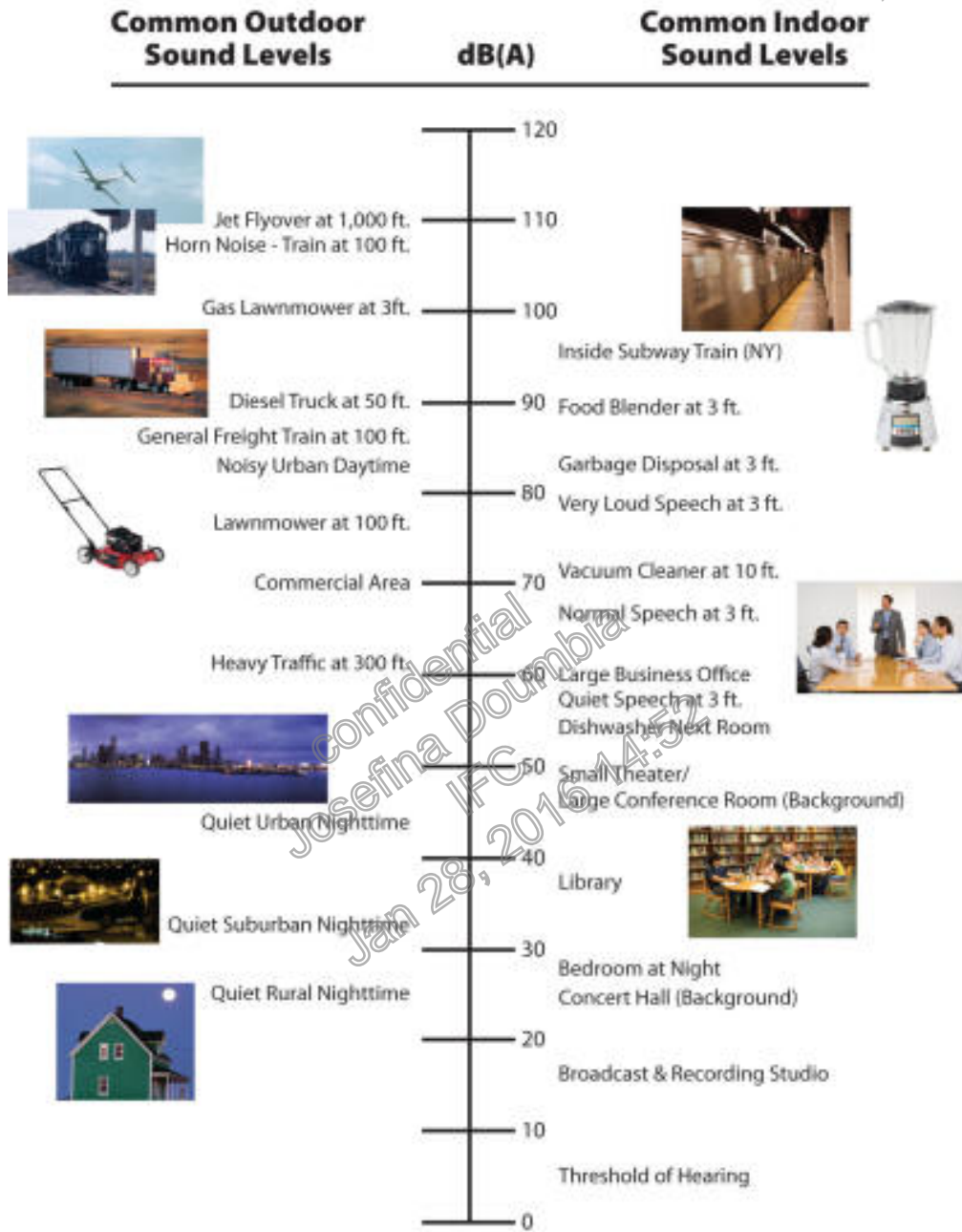
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**COMMON SOUND LEVELS**



Source: IDOT (2014)

**Figure 2.1-1**  
**Sound Pressure Levels of Typical Noise Sources and Noise Environments**

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# SECTION THREE

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## SECTION 3 AFFECTED ENVIRONMENT

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### 3.1 PROJECT SITE AND VICINITY

Figure 3.1-1 shows the Costa Norte Site boundary (blue outline tagged “Fenceline” at its western corner) in relation to the surrounding area, as well as nearby roads and other area features. The Project will be sited on the west side of Canal Frances, west of Via a Cristobal. The site is surrounded by industrial, seaport, and undeveloped land uses, with the closest existing residential neighborhood, Ciudad Arco Iris (Rainbow City, represented by R-02 and R-01), located directly to the east. Other nearest towns are located to the northeast (Cristóbal, represented by R-03, and Barrio Sur) and Southeast (Margarita, a community southeast of Ciudad Arco Iris).



**Figure 3.1-1  
Costa Norte Project Site and Vicinity**

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Affected Environment

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### 3.2 AMBIENT NOISE ESTIMATES

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At each of the three representative noise-sensitive receivers (NSR) near to the Project, the existing outdoor ambient sound environment can be coarsely predicted with a technique based on parameters and data described in pages 5-14 and 5-15 (including Table 5-7) of the United States of America's Federal Transit Administration (FTA) Transit Noise and Vibration Impact Assessment (FTA, 2006) guidance manual. In summary, Table 5-7 from the FTA guidance manual provides estimates of daytime and nighttime  $L_{eq}$  at various distance ranges from different types of surface transportation routes. The information can be recast as numerical expressions that estimate outdoor ambient sound levels with user input values for distance between the surface transportation route (i.e., rail, highway, "other roadway") and the receiver location of interest.

When the NSR is very distant from a railroad, highway or street (i.e., greater than 800 feet), FTA guidance suggests a population density technique can be used to estimate the ambient sound level. The correlation of population density with an estimated outdoor ambient sound level presumes that higher population per unit area will represent greater intensity and/or frequency of human activities (and noise-producing infrastructure, such as building ventilation and climate-control systems) and thus have the potential for contributing more noise to an aggregate level that already includes sound sources associated with the natural environment.

A computer spreadsheet was prepared to calculate ambient outdoor  $L_{dn}$  from this FTA-based technique for each NSR as shown in Table 3.1-1. Only the four nearest indicated noise types were considered; and due to the presence of nearby existing industrial facilities and surface transportation routes, population density was neglected as an ambient noise estimation factor.

**Table 3.1-1**  
**Estimation of Existing Outdoor Ambient Sound Levels**

Receiver ID	Distance from Nearest Rail to Measured Location (meters)	Distance from Nearest Freeway to Measured Location (meters)	Distance from Nearest Highway to Measured Location (meters)	Distance from Nearest Street to Measured Location (meters)*	Distance from Nearest Industrial to Measured Location (meters)	Estimated $L_{dn}$
R-01	23	1038	0	8	90	70
R-02	468	329	0	94	488	55
R-03	152	0	105	8	113	66

\* considered 8 meters if actual measured distance is less than or equal to 8 meters.

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**SECTION FOUR**

**Laws, Ordinances, Regulations and Standards**

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**SECTION 4 LAWS, ORDINANCES, REGULATIONS, AND STANDARDS**

Noise exposures are assessed and regulated with respect to applicable jurisdictional ordinances and policies, as well as relevant industry guidance.

**4.1 GLOBAL**

*WHO Guidelines for Community Noise*

The World Health Organization (WHO) offers guideline noise threshold values for community noise in specific environments. Table 4.1-1 reproduces guidance limits that appear in its Guidelines for Community Noise document (Berglund, 1999).

**Table 4.1-1  
Guideline Values for Community Noise in Specific Environments**

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]
Outdoor Living Area	Serious annoyance, daytime and evening	55	16
	Moderate annoyance, daytime and evening	50	16
Dwelling (indoors)	Speech intelligibility and moderate annoyance, daytime and evening	35	16
Bedrooms (indoors)	Sleep disturbance, night-time	30	8
Bedrooms (outdoors)	Sleep disturbance, window open (outdoor values)	45	8
School Classrooms and Pre-Schools (indoors)	Speech intelligibility, disturbance of information extraction, message communication	35	during class
Pre-school Bedrooms (indoors)	Sleep disturbance	30	sleeping-time
School, Outdoor Playground	Annoyance (external source)	55	during play
Hospital, Ward Rooms (indoors)	Sleep disturbance, night-time	30	8
	Sleep disturbance, daytime and evenings	30	16
Hospitals, treatment rooms, indoors	Interference with rest and recovery	1	
Industrial, Commercial, Shopping and Traffic Areas (indoors and outdoors)	Hearing impairment	70	24
Outdoors in Parkland and Conservation Areas	Disruption of Tranquility	2	

Source: Berglund (1999)

1. As low as possible;

2. Existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low.

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## SECTION FOUR

## Laws, Ordinances, Regulations and Standards

From its Environmental, Health, and Safety (EHS) Guidelines (International Finance Corporation [IFC], 2007), the World Bank Group indicates that noise from a power plant should not exceed an hourly  $L_{eq}$  of 55 dBA at residential, institutional or educational receptors during the daytime (7 a.m. to 10 p.m.) and 45 dBA hourly  $L_{eq}$  during nighttime hours (10 p.m. to 7 a.m.).

### 4.2 FEDERAL

The following are interpretations of what AECOM understands are the most current Panamanian executive decrees identified as applicable to noise with respect to this Project.

#### *Ministry of Health (MINSa) - Executive Decree 306*

##### **Original (2002)**

In 2002, the government of Panama enacted Decree 306 that adopted the regulations for noise control in public spaces, residential areas, and occupational environments. This law establishes maximum permissible levels for a work shift of 8 hours for three types of jobs:

- A. Jobs with constant and intense mental activity (50 dBA),
- B. office work or similar (60 dBA), and
- C. Others (85 dBA).

##### **Update (2004)**

Executive Decree 306 of 2002 adopts the regulations for noise control in public spaces, residential areas as well as in the workplace.

Article 1: The following noise levels are determined, for residential and industrial areas as well:

*6:00 am to 9: 59 pm – Maximum noise level: 60 dBA*

*10:00 pm to 5:59am – Maximum noise level: 50 dBA*

*Noise measurement for determining violations of this rule will be made at the affected residences.*

### 4.3 LOCAL

No local ordinances or laws were identified relating to noise within the City of Colon.

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### SECTION 5 PREDICTED PROJECT NOISE LEVELS

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#### 5.1 CONSTRUCTION NOISE

During construction activities, a varying number of construction equipment and personnel will be in the area, resulting in varying levels of construction noise. Conventional construction activities at the Project site would result in a short-term, temporary increase in the ambient noise level resulting from the operation of construction equipment and vehicles. The increase in noise level would be primarily experienced close to the noise source. The magnitude of the noise effects would depend on the type of construction activity, noise level generated by construction equipment, duration of the construction phase(s), and the distance between the noise source and receiver.

Project construction noise levels were estimated with a method based on the general assessment technique as described in the Federal Transit Administration (FTA) Transit Noise and Vibration Impact Assessment (FTA, 2006) guidance manual and includes consideration of the following factors:

- The two loudest expected construction equipment or vehicles of a construction phase (e.g., a paver and a crane) are assumed to operate at full power, and from a common geographic center of the construction area.
- Reference  $L_{\max}$  sound levels for construction equipment (e.g., paver and crane) at a distance of 50 feet are based on actual measurement data as described in Table 1 of the Federal Highway Administration (FHWA) Roadway Construction Noise Model (RCNM) User's Guide (FHWA, 2006).
- Sound propagation attenuates sound energy due to geometric divergence from a point source (at rate of approximately 6 dBA reduction per doubling of distance), atmospheric acoustical absorption (approx. 1 dBA per 1,000 feet distance traversed), and ground absorption (up to 4.8 dBA) per applicable International Organization of Standardization (ISO) 9613-2 (ISO, 1996) standards, guidelines and data.
- Construction activity was assumed to occur during no more than a twelve-hour long period on a given day, during daytime hours (7 a.m. to 10 p.m.).

On the expectation that pile driving activity would occur to help establish foundations prior to installation of Project heavy equipment and systems, construction noise was estimated for two scenarios: 1) without pile-driving activity, during which a paver and a crane would be the loudest two types of equipment; and, 2) excavator and impact pile driver.

As the exact location of mobile and stationary construction equipment is not yet known, the acoustic center-point (from which the aggregate of all noise-producing construction activities emits) is considered to be at the geographical center of each new CTG installation location, where, on average, most of the construction activity would likely be located when each of the three new CTGs are installed. This is considered a reasonable approximation when one notes that the largest dimension of this construction

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# SECTION FIVE

## Predicted Project Noise Levels

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zone (i.e., the footprint of a proposed CTG location) is generally small compared to the distances between it and the closest receivers.

The predicted construction noise level for each of these two scenarios at each of the three studied representative NSR are summarized in Tables 5.1-1 and 5.1-2.

**Table 5.1-1  
 Predicted Construction Noise Levels (average hourly Leq) at Nearest Noise-Sensitive Receivers –  
 Phase 1: Paver + Crane**

Sensitive Receiver Identification (see Figure 3.1-1)	Direction from Center of Proposed Costa Norte Site	Distance from Center of Project Footprint (meters)	Predicted Range of Average Hourly SPL (dBA Leq)
R-01	East	1,262	41
R-02	Northeast	1,582	38
R-03	North-Northeast	1,965	35

**Table 5.1-2  
 Predicted Construction Noise Levels (average hourly Leq) at Nearest Noise-Sensitive Receivers –  
 Phase 2: Excavator + Impact Pile Driver**

Sensitive Receiver Identification (see Figure 3.1-1)	Direction from Center of Proposed Costa Norte Site	Distance from Center of Project Footprint (meters)	Predicted Range of Average Hourly SPL (dBA Leq)
R-01	East	1,262	54
R-02	Northeast	1,582	51
R-03	North-Northeast	1,965	48

Predicted Project construction noise levels, with and without pile driving activity, as shown in Tables 5.1-1 and 5.1-2 would be considered compliant with daytime jurisdictional thresholds as described in Section 4.2: 60 dBA during the day. The levels would also appear to be compliant with WBG and WHO guidelines for daytime exterior noise levels at an NSR: 55 dBA hourly Leq. At night, however, when applicable noise limits are more stringent (50 dBA), noise from construction that includes pile-driving activity would cause non-compliance and thus would result in an adverse noise effects for at least two of the representative NSR. Similarly, construction noise that includes pile-driving would also be louder than the 45 dBA nighttime standard per WHO and WBG.

## 5.2 OCCUPATIONAL NOISE

### 5.2.1 Construction

Outdoor sound levels within the Project boundary during construction may exceed the 85 dBA threshold near certain operating or idling powered mobile and stationary equipment, but these levels will diminish with distance from these sources. Consistent with regulatory compliance requirements, Project contractors

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will post warnings with respect to areas that may be noise level hazards and provide construction workers with approved hearing protection devices (HPD) as part of an applicable hearing conservation program.

### 5.2.2 Operation

After Project systems have been installed and are operating normally, predicted operational noise levels within the site boundary may exceed 75 dBA, as shown in Figure 5.2-1. Per Project design standardization requirements (Section 7.2 of the Engineering, Procurement and Construction [EPC] Technical Specification), “signage shall be provided at all entrances to rooms/areas where the noise level exceeds 75 dB(A).” So for Project outdoor areas shown in Figure 5.2-1 that are expected to experience operation noise levels in excess of 75 dBA and are co-located with anticipated site worker traffic or activities, such signage would be expected.



**Figure 5.2-1**  
**Predicted Operation Noise – Outdoor Area in excess of 75 dBA**

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### 5.3 OPERATIONAL NOISE

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#### 5.3.1 Prediction Methods

The Cadna/A<sup>®</sup> Noise Prediction Model (Version 4.4.145) was used to estimate sound levels at noise-sensitive receivers due to Project operation scenarios. Cadna/A<sup>®</sup> is a Windows<sup>®</sup> based software program that predicts and assesses noise levels near industrial noise sources based on the ISO 9613-2 standard for noise propagation calculations. The model uses industry-accepted propagation algorithms and accepts Sound Power Level, or PWL (in dB re: 1 pico Watt) provided by equipment manufacturers and other sources. The calculations account for classical sound wave divergence, plus attenuation factors resulting from air absorption, basic ground effects, terrain, and barrier/shielding effects. The following buildings and structures have been included in the prediction model (depending on studied scenario):

- Generator barriers; and,
- Stacks associated with the proposed new GE 6FA.03 units.

Calculations were performed using un-weighted octave band sound power levels as inputs from each pre-defined noise source, as summarized in Table 5.3-1. For noise sources lacking client-supplied sound data, sound levels were based on noted references and/or appropriate calculation methods and assumptions based on available Project description information at the time this Report was prepared. For example, the PWL (at OBCF resolution) for the last three equipment categories shown in Table 5.3-1 are based on sound levels of similar equipment presented in the predictive operation noise analysis for the proposed Pio Pico Energy Center project in southern California, USA.

**Table 5.3-1  
Roster of Major Noise-Producing Project Operations Sound Sources**

Major Noise-Producing Project Operations Source Type	Unweighted PWL per Octave-Band Center Frequency (OBCF, Hz)									Overall dB	Overall A-weighted (dBA)
	31.5	63	125	250	500	1000	2000	4000	8000		
CTG Exhaust Stack	119	116	121	120	115	108	100	92	76	125.8	116
CTG Inlet	102	106	99	98	87	78	74	81	77	108.5	92.3
CTG Generator	110	110	109	108	108	107	106	101	92	117.1	112.1
CTG Compartment	113	115	110	108	105	103	109	104	99	119.3	112.8
CTG Exhaust Duct	117	114	112	105	104	102	100	99	96	120	108
HRSB Transition	125	121	117	113	109	106	103	97	84	127.2	111.9
HRSB Boiler	121	116	113	109	104	102	99	93	79	123	107.6
CTG Transformer	102	108	110	105	105	99	94	89	82	114	105.4
Steam Turbine Package	115	121	119	114	110	106	103	95	89	124.4	112.5
Steam Turbine Transformer	102	108	110	105	105	99	94	89	82	114	105.4
Generator Package	115	121	119	114	110	106	103	95	89	124.4	112.5
Major Pumps	103	109	107	106	105	104	103	102	98	114.6	109.9
Lube Oil Module	104	106	102	101	100	99	98	97	89	110.9	104.8
Fuel Gas Compressor Skid *	117	108	107	106	90	79	73	63	61	118.2	98.8
Fuel Gas Metering Skid *	0	0	0	77	79	84	94	92	84	96.7	97.6
Air Compressor Skid *	86	93	91	91	88	87	86	85	81	98.4	93.1

\* Source: Pio Pico Energy Center Project (CEC, 2014)

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Aside from the PWL of individual equipment as shown in Table 5.3-1, additional model parameters were extracted from the client-provided Annex 1 to EPC Contract document, which helped determine the influence of typical air and ground absorption effects as follows:

- Air temperature = 20° C
- Relative humidity = 90%
- Wind Speeds = 0 m/s, 6.6 m/s at 17.9°, 3.2 m/s at 274.3°
- Project site and vicinity ground absorption coefficient = 0.7

While temperature and relative humidity in the Project vicinity can range between different daily and seasonal extremes, the values shown above are typical and conservative with respect to sound attenuation from air absorption. Audible sound, particularly of higher frequencies, travels farther when there is more moisture in the air. Hence, air absorption is relatively poor in a moist climate with high humidity but better in a dryer climate.

With respect to ground absorption, the coefficient values can range from zero (0) that represents a hard or otherwise acoustically reflective surface such as smooth concrete or a body of water, to unity (1) that would represent a porous surface such as loose, tilled soils and/or vegetative ground cover. Due to the Project vicinity being predominantly dense tropical ground covering and vegetation (high acoustical absorption), an average coefficient value of 0.7 was deemed appropriate.

### 5.3.2 Modeled Receivers

A total of three noise-sensitive receivers were identified as nearest representatives of neighboring residential communities. Tables 5.3-2 and 5.3-3 indicate the approximate distances between these representative NSRs and the nearest CTG exhaust stack for Phase 1 and Phase 2 of the Project, respectively.

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**Table 5.3-2**

**Approximate Distances from Nearest Receivers to Nearest Project Exhaust Stack for Phase 1 (3-CTG Array) Arrangement**

Receiver ID	Town	Receiver Type	Distance From Nearest Exhaust Stack (km)
R-01	Ciudad Arco Iris	Unknown Structure	1.27
R-02	Ciudad Arco Iris	Single-Family Residence	1.56
R-03	Cristobal	Multi-Family Residence	1.92

**Table 5.3-3**

**Approximate Distances from Nearest Receivers to Nearest Project Exhaust Stack for Phase 2 (6-CTG Array) Arrangement**

Receiver ID	Town	Receiver Type	Distance From Nearest Exhaust Stack (km)
R-01	Ciudad Arco Iris	Unknown Structure	1.17
R-02	Ciudad Arco Iris	Single-Family Residence	1.5
R-03	Cristobal	Multi-Family Residence	1.92

### 5.3.3 Modeled Scenarios

A total of six Project operation scenarios were modeled with the CadnaA sound propagation prediction software, accounting for two Project phases: Phase 1, upon completion of which three CTGs and an STG will be operating; and Phase 2, upon completion of which six CTGs and two STGs will be operating. For each studied Project phase, three meteorological cases were considered as follows:

1. Calm conditions, characterized by winds less than 0.5 meters per second in any direction;
2. Northerly winds, characterized by winds originating from a heading of 18 degrees (with respect to zero degrees as north) and traveling at 6.6 meters per second (mps); and,
3. Westerly winds, characterized by winds originating from a heading of 274 degrees (with respect to zero degrees as north) and traveling at 3.2 mps.

The second of these, based on information gleaned from the aforementioned client-provided EPC Contract Annex 1 document, is considered a “dominant” case based on the probability of occurrence. And while its wind speed is only half that of the second case, one might consider the third case a “worst” condition since it causes sound to travel downstream towards the representative NSRs east of the Project site.

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### 5.3.4 Predicted Project Operation Noise

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Tables 5.3-4 and 5.3-5 present the predicted aggregate Project operation noise level at each of the three studied representative NSRs for each meteorological conditions case of Project Phase 1 and Phase 2, respectively. Figures 5.3-1, 5.3-2 and 5.3-3 illustrate predicted Project operations noise iso-pleths (i.e., “contours” of equal sound pressure level) for the three meteorological conditions cases of Phase 1; and, Figures 5.3-4, 5.3-5 and 5.3-6 illustrate the same Project operations noise contours for Phase 2. Note that these noise contours and the tabulated values appearing in Tables 5.3-4 and 5.3-5 exclude the contribution of the existing outdoor ambient sound environment, so that Project-only noise may be directly compared with the applicable thresholds.

**Table 5.3-4  
Predicted Noise Levels for Phase 1 (3-CTG Array) Operations**

Receiver ID	Distance From Project Center (meters)	Predicted Project Operations Noise Level (Leq, dBA)		
		Calm Conditions (Winds < 0.5 mps)	Dominant Wind (Northerly, 6.6 mps)	Worst-Case Wind (Westerly, 3.2 mps)
R-01	1338	42	39	48
R-02	1635	40	35	46
R-03	1982	36	30	42

**Table 5.3-5  
Predicted Noise Levels for Phase 2 (6-CTG Total Array) Operations**

Receiver ID	Distance From Project Center (meters)	Predicted Project Operations Noise Level (Leq, dBA)		
		Calm Conditions (Winds < 0.5 mps)	Dominant Wind (Northerly, 6.6 mps)	Worst-Case Wind (Westerly, 3.2 mps)
R-01	1223	46	42	52
R-02	1561	43	38	49
R-03	1982	39	33	45

Compared with jurisdictional noise limits described in Section 4, values in Tables 5.3-4 and 5.3-5 suggest that nominal Project operations during the daytime hours would be compliant with 60 dBA. Furthermore, as no level exceeds 55 dBA, daytime Project operation would also be expected to comply with WHO and WBG guidance thresholds.

Only the “worst-case” wind scenario for Phase 2 presents a risk of Project operations noise exceeding the nighttime jurisdictional limit of 50 dBA at the nearest of the three NSRs. With respect to the WHO and WBG 45 dBA guidance limit, all three representative NSRs for Phase 2 would appear to be at risk of non-compliance under worst-case meteorological conditions.

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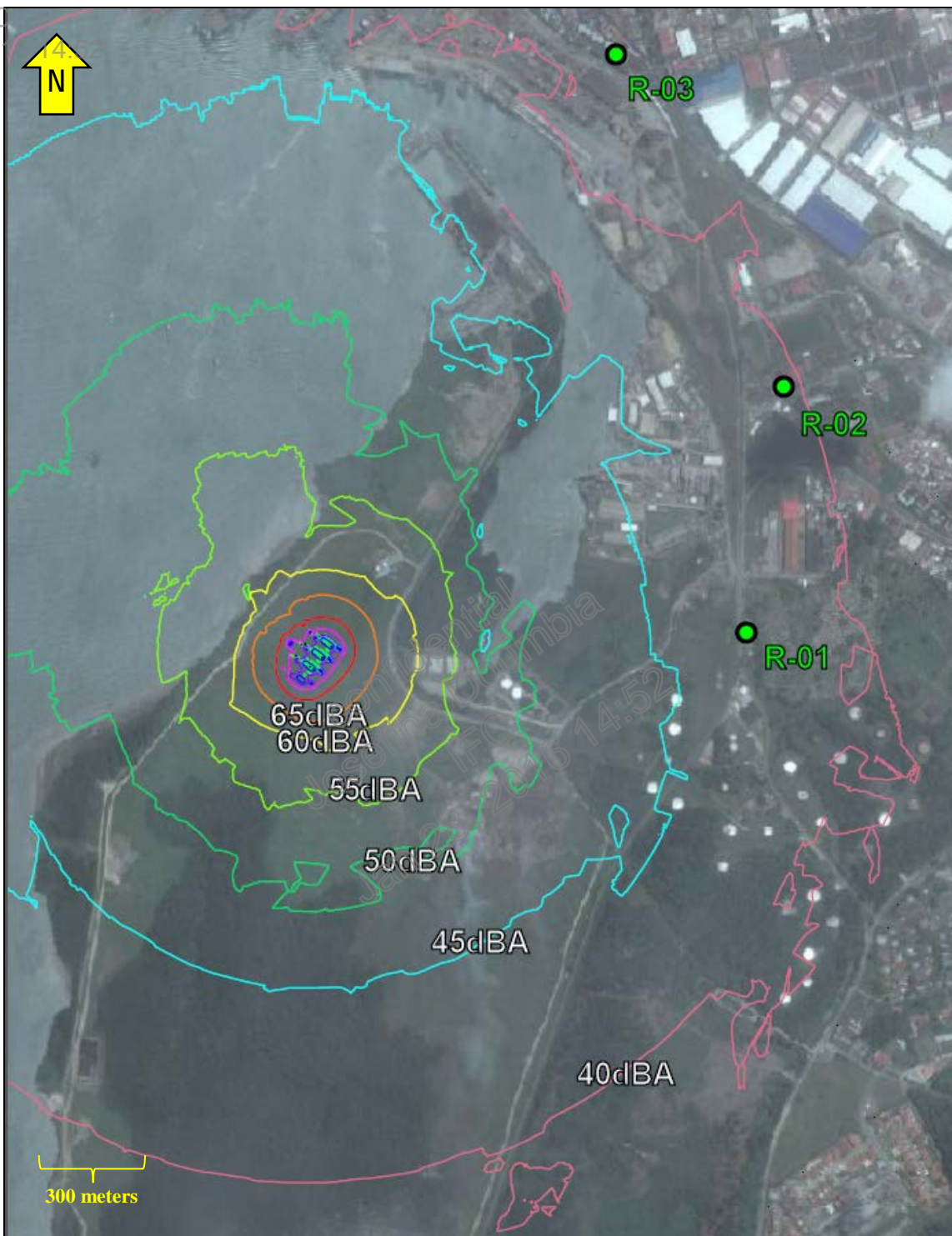
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**Figure 5.3-1**

**Predicted Project Operation Noise Contours – Phase 1 (3-CTG Array), Calm Conditions**

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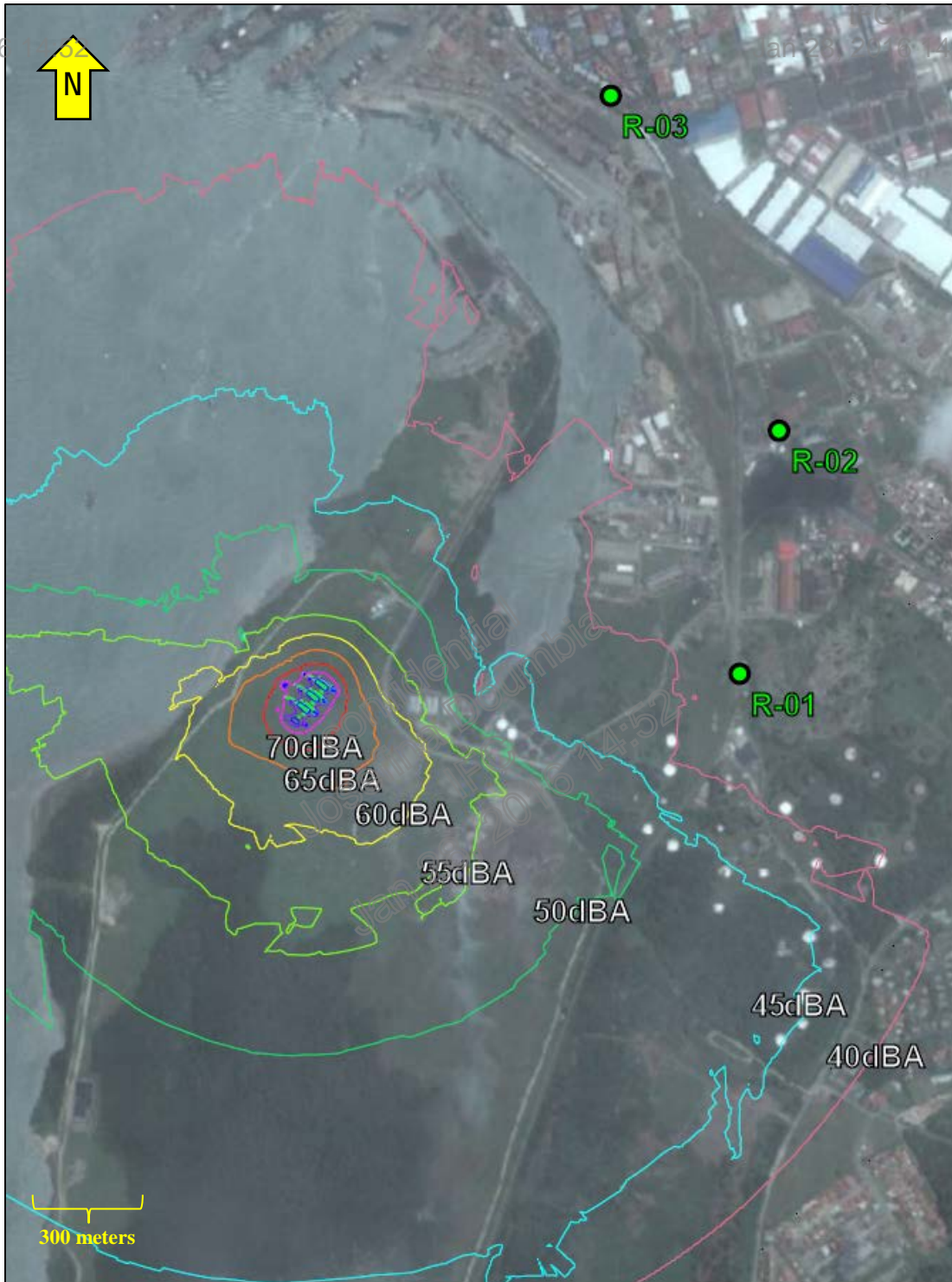


Figure 5.3-2

Predicted Project Operation Noise Contours – Phase 1 (3-CTG Array), Northerly Wind Conditions

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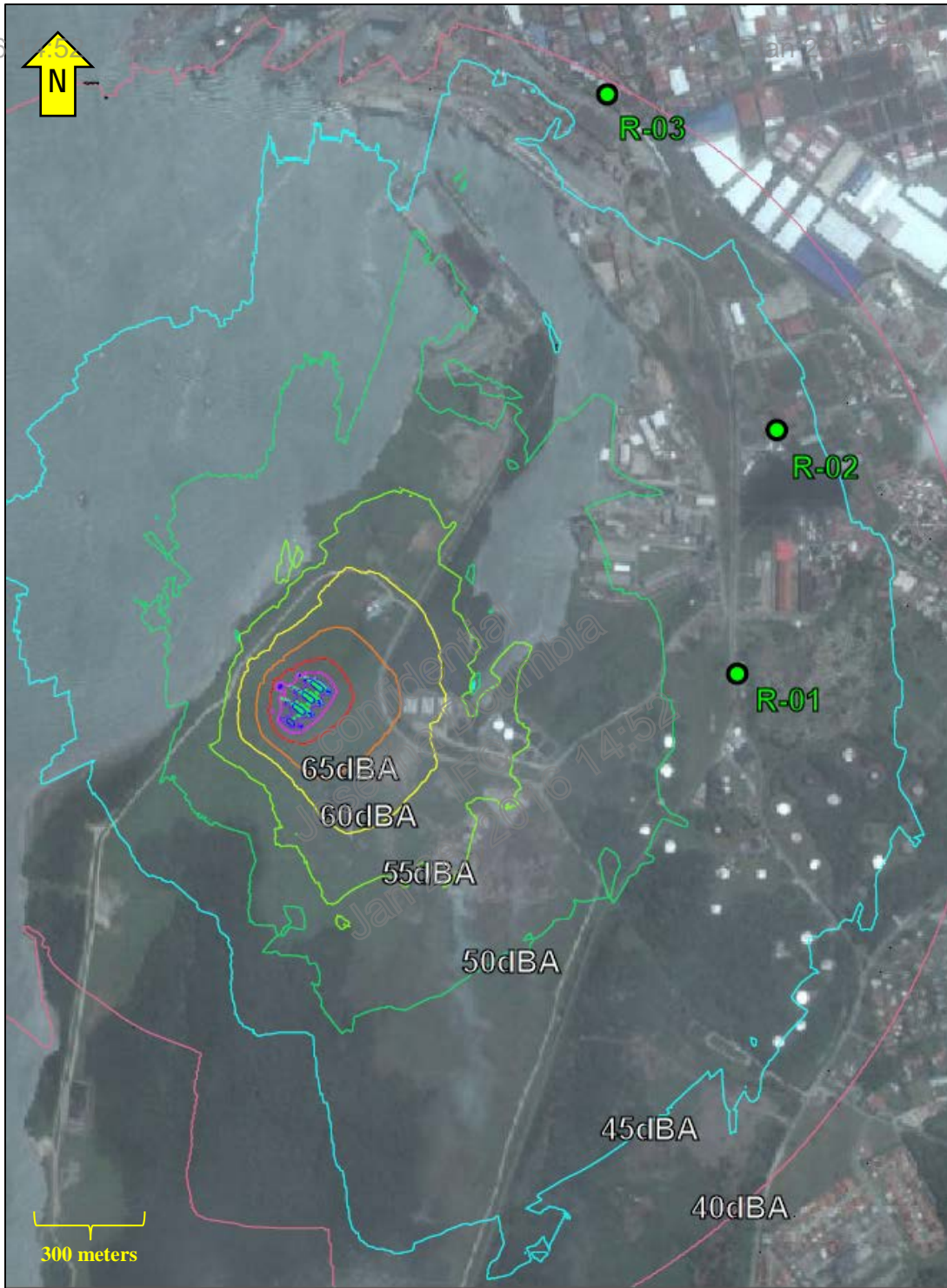


Figure 5.3-3

Predicted Project Operation Noise Contours – Phase 1 (3-CTG Array), Westerly Wind Conditions

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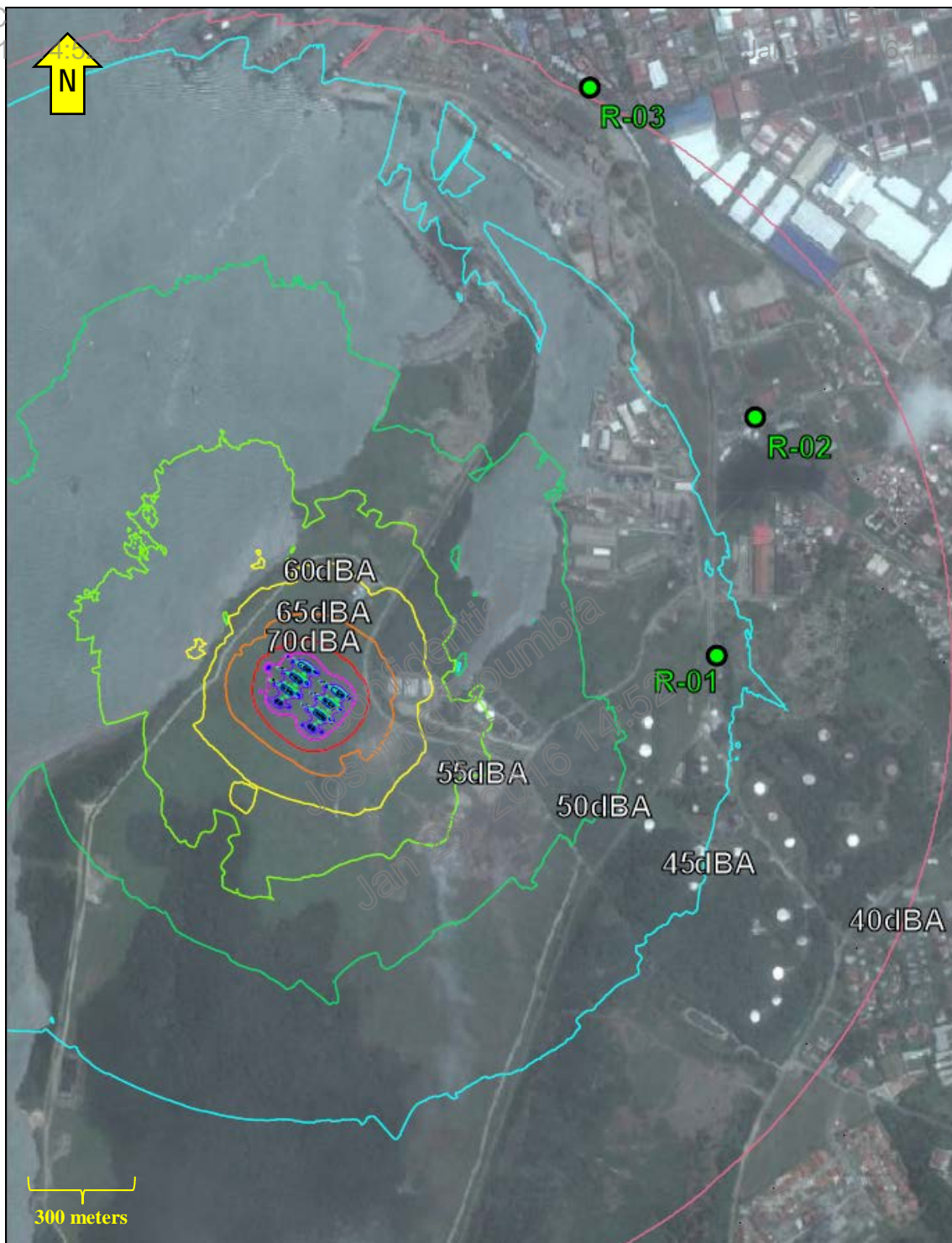
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**Figure 5.3-4**

**Predicted Project Operation Noise Contours – Phase 2 (6-CTG Array), Calm Conditions**

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**Figure 5.3-5**

**Predicted Project Operation Noise Contours – Phase 2 (6-CTG Array), Northerly Wind Conditions**

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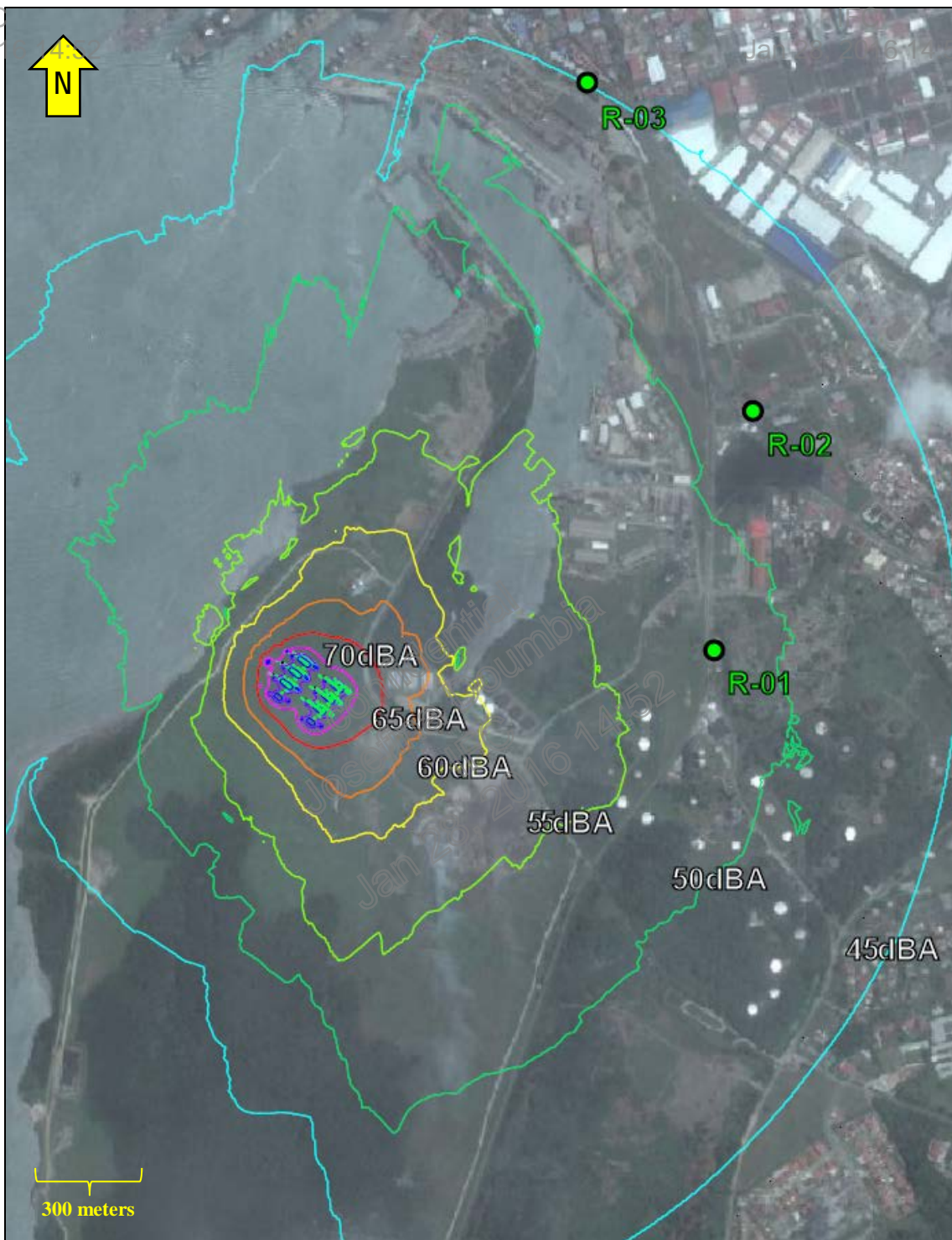
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**Figure 5.3-6**

**Predicted Project Operation Noise Contours – Phase 2 (6-CTG Array), Westerly Wind Conditions**

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### 5.3.5 Power Transmission

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Noise sources associated with power transmission include occasional breaker operation in the substation, corona noise, and very low magnetostriction hum from the conductors. Breaker noise is considered impulsive in nature, lasting a very short duration and may occur only a few times per year. Corona noise is characterized as having high frequency components, like a buzz, and low frequency tones that are best described as humming sounds. While corona noise usually worsens when the transmission line conductors are wet, such as during rainfall, these conditions often provide sources of their own that help mask the increase.

The Electric Power Research Institute (EPRI) has conducted noise studies and has published reference material on transmission line noise. Consistent with industry-accepted acoustic textbooks' discussion of propagation of noise from a line source, EPRI states that noise produced by a conductor decreases at a rate of 3 dB per doubling of distance from the source. The EPRI Transmission Line Reference Book indicates that the audible noise from a typical 525-kilovolt ("kV") line with two conductors per phase would likely be less than 40 dBA at a distance of 40 feet from the outside conductor at ground level. If only one conductor per phase is used, the noise level will be less.

Although the newly installed three (3) CTG units would require new onsite generation interconnections, the anticipated low magnitude of corona noise emission as discussed above is—when compared to existing measured sound levels in the vicinity as presented in Table 3.1-1—either less than or not expected to create a significant increase in ambient noise.

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# SECTION SIX

## Recommended Project Design Features

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### SECTION 6 RECOMMENDED PROJECT DESIGN FEATURES

#### 6.1 CONSTRUCTION

Per Section 5.1, expected noise from daytime construction activities should be compliant with jurisdictional requirements. Hence, no additional noise control and sound abatement measures or practices—apart from those already described in Project EPC documents—should be required.

#### 6.2 OPERATION

Analysis of individual sources in the Project operations noise model scenarios developed for the discussion of potential adverse noise effects in Section 5.2 suggest that the exhaust stacks are the loudest—and by a margin of several dBA above the next-loudest acoustical contributors. Therefore, were the Project to seek greater likelihood of compliance with the nighttime jurisdictional limit of 50 dBA and the WHO and WBG 45 dBA  $L_{eq}$  nighttime guidance threshold, this noise study suggests consideration of exhaust stack muffler upgrades that—if designed and implemented properly—would reduce these loudest Project operations noise contributors and help yield overall noise reduction to an A-weighted dB level at the nearest representative NSRs.

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## References

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# SECTION EIGHT

# Statement of Limitations

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## SECTION 8 STATEMENT OF LIMITATIONS

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Background information on the Project, including EPC specifications and other data, have been furnished to AECOM by AES and/or third parties, which AECOM has used in preparing this report. AECOM has relied on this information as furnished, and is neither responsible for nor has confirmed the accuracy of this information.

Portions of this report have been prepared based on certain key assumptions made by AECOM which substantially affect the conclusions and recommendations of this report. These assumptions, although thought to be reasonable and appropriate, may not prove to be true in the future. The conclusions and recommendations of AECOM are conditioned upon several assumptions. Noise levels found in this report include those predicted with CadnaA sound propagation modeling software, a commercially-available program not proprietary to AECOM. This report assumes that the algorithms within the CadnaA program are correct and accurately reflect ISO 9613-2 and other relevant standards for predictive modeling of outdoor noise propagation.

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