King County
Department of Natural Resources and Parks
Solid Waste Division

NOISE MODELING ASSESSMENT
CEDAR HILLS REGIONAL LANDFILL

October 2015

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Prepared for King County by:
Amec Foster Wheeler, Ramboll Environ US Corporation, and JGL Acoustics

ABSTRACT

The 2012 Perimeter Noise Study for the Cedar Hills Regional Landfill (CHRLF), prepared by King County Department of Natural Resources and Parks, Solid Waste Division (KCSWD), was inconclusive in determining the source of sound levels that exceeded the applicable King County sound level limits at perimeter locations around the facility. Therefore, noise modeling and Fast Fourier Transform (FFT) assessments were completed to determine whether noise from CHRLF or tenant activities would result in sound levels that exceeded applicable King County limits. To complete these assessments, sound levels measurements were taken of existing acoustically significant sources of CHRLF noise including at the active landfill, the North Flare Station (NFS), and truck activities, as well as at tenant facilities including the BioEnergy Washington (BEW) facility and cooling equipment associated with a cellular communications tower. Results of the modeling and FFT assessments concluded that ambient noises likely were responsible for most measured exceedances during the 2012 study. The only CHRLF-related activity that may have contributed to an exceedance of the King County limit was CHRLF truck traffic between the hours of 6 a.m. and 7 a.m., as received at a perimeter location near the southeast corner of the property. This assessment was completed using both detailed noise modeling and FFT analysis of recorded audio signals.

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS i
LIST OF TABLES ii
LIST OF FIGURES ii
LIST OF ATTACHED NOISE MODELING FIGURES ii
GLOSSARY iii
EXECUTIVE SUMMARY ES-1
PROJECT SCOPE ES-1
PROJECT RESULTS ES-1
CONCLUSIONS AND RECOMMENDATIONS ES-2
1.0 INTRODUCTION 1
1.1 CHARACTERIZING NOISE (MEASUREMENT METRICS AND DESCRIPTORS) 1
1.2 KING COUNTY NOISE CODE 4
2.0 TECHNICAL APPROACH 6
2.1 REVIEW OF 2012 REPORT 6
2.2 2014-2015 MEASUREMENTS AND SOURCE SOUND LEVEL DATA 8
2.3 NOISE MODELING 9
2.4 FAST FOURIER TRANSFORM (FFT) ASSESSMENT 10
2.5 QUALITY CONTROL 10
3.0 NOISE MODELING ASSESSMENT 10
3.1 SOURCE SOUND LEVEL MEASUREMENT DATA 10
3.2 NOISE MODEL SCENARIOS 17
3.3 2012 – EXISTING CONDITIONS 18
3.4 FUTURE CONDITIONS – FINISHED GRADE ELEVATION 22
4.0 FFT ANALYSIS 26
4.1 FFT SPECTRA 26
4.2 2015 SOURCE SOUND LEVEL MEASUREMENTS 27
4.3 2012 RECEIVER NOISE MEASUREMENTS 35
4.4 FFT SUMMARY 40
5.0 SUMMARY OF RESULTS 41
5.1 SUMMARY OF NOISE MODELING RESULTS 41
5.2 SUMMARY OF FFT RESULTS 42
5.3 GENERAL CONCLUSION 42

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

Table 1. King County Maximum Permissible Sound Levels 4
Table 2. CHRLF and Tenant Sources – Sound Power Level Data 11
Table 3. CHRLF Operating Periods 17
Table 4. Modeled Sound Sources during Nighttime, Early Morning, and Daytime Operations at CHRLF 18
Table 5. 2012 Conditions – Noise Modeling Results Summary 20
Table 6. Finish Grade Conditions for Areas 5, 6, and 7 - Noise Model Results Summary 24

LIST OF FIGURES

Figure 1. SLM Source Locations: BEW 12
Figure 2. SLM Source Locations: Trucks During Warm Up and at Scale 13
Figure 3. SLM Source Locations: North Flare Station 14
Figure 4. SLM Source Locations: CHRLF Active Landfill Area 15
Figure 5. SLM Source Locations: Cell Tower HVAC 16
Figure 6. FFT Analysis: Booster Blowers Noise Spectrum 28
Figure 7. FFT Analysis: BEW South Side 29
Figure 8. FFT Analysis: BEW S&R 30
Figure 9. FFT Analysis: BEW West 31
Figure 10. FFT Analysis: NFS Candlestick Flare at 48 feet 32
Figure 11. FFT Analysis: NFS at 50 feet 33
Figure 12. FFT Analysis: NFS at 940 feet 34
Figure 13. FFT Analysis: P5 at 10:01 p.m. on 9/26/2012 36
Figure 14. FFT Analysis: P5 at 10:01 p.m. on 9/26/2012 37
Figure 15. FFT Analysis: P5 at 5:59 p.m. on 9/26/2012 38
Figure 16. FFT Analysis: P1 at 9:00 p.m. on 9/25/2012 39

LIST OF ATTACHED NOISE MODELING FIGURES

Noise Modeling Figure 1. 2012 Topography and Noise Model Receptor Locations 44
Noise Modeling Figure 2. Finished Elev. Topography and Noise Model Receptor Locations 45
Noise Modeling Figure 3. 2012 Nighttime Conditions 46
Noise Modeling Figure 4. 2012 Early AM Conditions 47
Noise Modeling Figure 5. 2012 Daytime Conditions 48
Noise Modeling Figure 6. Finished Elevation Nighttime Conditions 49
Noise Modeling Figure 7. Finished Elevation Early AM Conditions, Area 5 50
Noise Modeling Figure 8. Finished Elevation Early AM Conditions, Area 6 51
Noise Modeling Figure 9. Finished Elevation Early AM Conditions, Area 7 52
Noise Modeling Figure 10. Finished Elevation Daytime Conditions, Area 5 53
Noise Modeling Figure 11. Finished Elevation Daytime Conditions, Area 6 54
Noise Modeling Figure 12. Finished Elevation Daytime Conditions, Area 7 55

GLOSSARY

A-weighting: A method of processing measured sound to reflect how audible that sound is to people. The measured sound pressure in each frequency composing the sound is adjusted by a weighting factor to match human hearing sensitivity to that frequency.

A-weighted decibels (dBA): The most-commonly used measure of noise exposure among people, which uses a logarithmic scale (the decibel) to represent a wide range of sound pressure levels.

ambient noise levels: The level of noise arising from all sources, as measured at a location.

amplitude: The range representing the height (from peak to valley) of the waves that comprise sound at a given frequency (distance between peaks).

average (equivalent) sound level (L_{eq}): The constant sound level in a given time period that conveys the same sound energy as the actual time-varying sound.

decibels (dB): The sound level measured in decibels, a logarithmic scale

hertz (Hz): The frequency from peak to peak of sound waves (in cycles per second)

FFT: Fast Fourier Transform, an analysis procedure to determine the narrow band spectrum of sound

noise: The intensity, duration and character of sounds from any or all sources.

maximum permissible sound level limits: The limits on noise levels at a receptor as established by King County in Title 12, Chapter 12.88 of the King County Code.

maximum sound level (L_{max}): The maximum sound level over a measurement interval determined by using a sound level meter set to "fast" response time. Equals 1/8 second sound level.

octave band: An interval of the sound frequency spectrum, such that the center frequency of the octave band is at the logarithmic center of the frequency range for that band; the frequency spectrum is divided so that the upper limit of each band is twice the preceding center frequency. The commonly used center frequencies in octave band analysis are 63, 125, 250, 500, 1000, 2000, 4000 and 8,000 Hz.

1/3 octave band: A further subdivision of the sound frequency spectrum, such that each octave band is divided into three logarithmically-centered bands, where the center frequency is defined by $10^{0.1N}$, where N is a whole number from 10 to 50.

pitch: A term to describe the frequency of a noise— a "high pitched" noise has a high frequency (short distance between sound waves).

receptor site: The location receiving the sound.

sound: A wave-form disturbance of pressure propagating through a medium, such as the air.

Sound Level Meter: An instrument for measuring sound levels that measures rapid variations in air pressure with time, using a microphone and signal processing electronics.

vibration: Repetitive displacement of an object in two or more dimensions, usually caused by a physical source of energy to an object.

white noise: Noise that has significant pressure in many frequencies, such that no one frequency dominates the spectrum.

DETAILED PERIMETER NOISE STUDY
AT CEDAR HILLS REGIONAL LANDFILL
Cedar Hills Regional Landfill
Maple Valley, Washington

EXECUTIVE SUMMARY

PROJECT SCOPE

King County Department of Natural Resources and Parks, Solid Waste Division (KCSWD) contracted with Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), in collaboration with Ramboll Environ US Corporation (Ramboll Environ) and JGL Acoustics, Inc. (JGL), to complete a noise modeling and Fast Fourier Transform (FFT) assessment of the Cedar Hills Regional Landfill (CHRLF). The purpose of the assessment was to determine whether noise from CHRLF and/or its tenants, including the BioEnergy Washington landfill gas to energy facility (BEW) and a wireless communications facility, are responsible for sound levels that exceed the King County sound level limits at perimeter locations. This evaluation was prepared to supplement a 2012 study completed by Amec Foster Wheeler that included sound level measurements of perimeter locations, but that study was inconclusive in determining the contributing sources that resulted in measured sound levels exceeding the King County limits.

The study documented in this report was completed using a combination of sound level measurements of both equipment and activities at the landfill, additional perimeter measurements, detailed noise modeling using the CadnaA noise model, and FFT analysis of audio data collected at CHRLF.

PROJECT RESULTS

The assessment found that noise emissions from CHRLF, including active landfill operations equipment, the North Flare Station, on-site truck haul traffic including engine operating cycles at the truck scale, did not result in sound levels that exceeded the King County noise limits at any of the perimeter locations during daytime hours. During nighttime hours prior to 6 a.m., CHRLF activity also did not exceed the King County nighttime noise limits at any perimeter location. During early morning hours, between 6 and 7 a.m., nighttime sound level limits were exceeded due to CHRLF trucks leaving the facility at P5 only. At all other perimeter location, nighttime noise levels during all hours (i.e., between 10 p.m. and 7 a.m.) were within King County limits.

Noise from the BEW facility was found to result in sound levels that exceeded the King County nighttime noise limit at one location, P5 during hours when that limit applies. This conclusion was supported by observations during the 2012 monitoring study. The FFT analysis was inconclusive in determining the source of noise received at P5, however this analysis was limited by difficulties in completely documenting all sound frequencies from the known sound sources such as BEW .

CONCLUSIONS AND RECOMMENDATIONS

This analysis provides a reasonably conclusive assessment of the environmental noise implications of CHRLF and tenant activity. Modeling results validate observations from 2012 that indicated the BEW facility is audible in many locations but is only acoustically significant at P5.

The assessment confirms that noise emissions from the North Flare Station have been greatly reduced since 2012 and no longer contain a tonal noise component that was formerly present at 1,000 Hz.

The assessment concludes that at most perimeter locations, ambient noises from sources unrelated to the CHRLF or tenant facilities are the most acoustically significant sound sources at all perimeter locations. Ambient noise sources were observed in 2012 to include the following: traffic from local area roadways (SE May Valley Road, Issaquah- Hobart Road SE, Cedar Grove Road SE, and others), aircraft noise, wildlife noise, noise from nearby residential and commercial activity, and other miscellaneous and undocumented noises.

At P5, CHRLF truck traffic was found to exceed nighttime sound level limits between 6 a.m. and 7 a.m.

The assessment summarized here is conclusive in its determination of sound source contributions at the landfill property perimeter locations.

CEDAR HILLS REGIONAL LANDFILL NOISE MODELING ASSESSMENT

Cedar Hills Regional Landfill
Maple Valley, Washington

1.0 INTRODUCTION

King County Department of Natural Resources and Parks, Solid Waste Division (KCSWD) contracted with Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), in collaboration with Ramboll Environ US Corporation (Ramboll Environ) and JGL Acoustics, Inc. (JGL), to complete a noise modeling and Fast Fourier Transform (FFT) assessment of the Cedar Hills Regional Landfill (CHRLF). The purpose of the assessment was to determine whether noise from CHRLF and/or its tenants, including the BioEnergy Washington facility (BEW) and a wireless communications facility, are responsible for sound levels that exceed the King County sound level limits at perimeter locations. This assessment was prepared to supplement a 2012 study completed by Amec Foster Wheeler that included sound level measurements of perimeter locations, but that study was inconclusive at determining the contributing sources that resulted in measured sound levels exceeding the King County limits.

The study documented here was completed using a combination of sound level measurements, both of equipment and activities at the landfill and perimeter measurements, detailed noise modeling using the CadnaA noise model, and FFT analysis of audio data collected at the CHRLF.

1.1 CHARACTERIZING NOISE (MEASUREMENT METRICS AND DESCRIPTORS)

Noise, in the environmental sense, is defined as any sound that is undesired or interferes with one's hearing of something.[1] Essentially, it is unwanted sound. Sounds occur from many sources, but a sound is considered noise when we expect peace and quiet, or when it interferes with sleep, thought, or our enjoyment of desirable sounds like conversation, nature, or music. Sound in a physical sense is a rapid fluctuation in ambient air pressure versus a reference level, transmitted through the air by spherical wave propagation.[2] As the variations in air pressure become larger (the waves increase in amplitude), a sound increases in loudness. The loudness is measured in decibels (dB), a logarithmic scale that conveniently represents a wide range of pressure variation. People vary in their ability to detect sounds, but human hearing generally ranges from about zero dB (barely detectible) to about

[1] Webster's New Collegiate Dictionary, G.&C. Merriam Co., Springfield, MA 1980

[2] Mestre, V.E., and D.C. Wooten, *Noise Impact Analysis*, Chapter 4 in Environmental Impact Analysis Handbook, Rau, J.G., and D.C. Wooten, Editors. McGraw-Hill, Inc., New York, NY 1980

120 dB (the threshold of pain).[3] Human sensitivity to changes in sound levels varies, but typically a sound level increase of 3 dB is perceptible under ideal listening conditions, 5 dB is clearly perceptible in most environments, and 10 dB is perceived as a doubling of loudness.[4] For comparison, typical levels of some common sounds are shown in the table below.

Typical Noise Environment	**Sound Pressure Level (dB)**
Jet aircraft takeoff at 100 feet	120
Motorcycle at 25 feet	90
Heavy truck at 50 feet	85
Garbage disposal	80
City street corner	70
Large store	65
Conversational speech	60
TV listening at 10 feet	55
Typical office	50
Living room	40
Quiet bedroom at night	30

Source: U.S. Environmental Protection Agency, Office of Noise Abatement and Control. *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*. 550/9-74-004. USEPA. Washington DC, 1974.

Along with the amplitude of sound waves, the distance between their peaks is important because it defines the pitch (or frequency) of the sound. Frequency is measured in hertz, or wave cycles per second. Many sound sources are things that vibrate, as when a hammer strike causes a sheet of steel to vibrate, or when a guitar string is plucked. The resulting vibration moves the air around the vibrating source, each movement creating a wave with a certain frequency. The vibration of the guitar string is at a single frequency, so it generates a pure tone, while the vibration of the sheet of steel is a combination of tones, each at a different frequency. Sound is therefore composed of multiple waves that move with specific amplitude and frequencies. So, sound can be physically described by its loudness (in dB) as a function of frequency (in hertz). Noises that are louder in one or a few frequencies can be very annoying, while noises that are equally loud in many frequencies can be described as "white noise," which tends to be less intrusive.

People with excellent hearing can detect sounds over a frequency range of 20 to 20,000 hertz. But people do not hear all frequencies equally well—we are most sensitive to frequencies between 1,000 hertz (Hz) and 4,000 Hz, and our sensitivity drops off at lower and higher frequencies. The A-weighting system was developed to adjust sound, by way of an A-weighting filter, to the characteristic sensitivity of human hearing. A-weighting, by way of a sound level meter, assigns an appropriate

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[3] Peterson, A.P.G., and E.E. Gross, Jr. *Handbook of Noise Measurement,* 7th Edition, General Radio Co., Concord, MA. 1972

[4] U.S. Department of Transportation, Federal Highway Administration, Office of Environment and Planning, Noise and Air Quality Branch, *Highway Traffic Noise Analysis and Abatement Policy and Guidance,* USDOT, Washington, DC, 1995

adjustment or "weight" to frequencies measured through a microphone, to approximately the frequency response of the human ear. These values are in A-weighted decibels (dBA), and this is the basic measure of sound commonly used when evaluating environmental noise. A broadband A-weighted sound is a logarithmic combination of all A-weighted frequencies to a single numerical description of the loudness. The resulting level is approximately correlated to the way humans hear.

Sounds are often more audible or discernible when they are isolated to one frequency and are higher in energy than other frequencies originating from the same noise source. These sounds are referred to as "pure tone." Pure tones, or noises that are defined as tonal, may be discernible in environments even where overall ambient levels are very low. An example would be construction back-up alarms, or a train horn.

Ambient noise levels vary continuously with time. As various sources of noise occur, the ambient noise level is louder at some times, and quieter at others. Statistical descriptors have been developed to describe this variation. The maximum sound level (L_{max}) is the highest sound level recorded, including instantaneous sounds that last only milliseconds. The average (equivalent) sound level for any time interval (such as a minute or an hour) is the logarithmically averaged sound level over that time interval, denoted as its L_{eq}. Along with the L_{eq} are other statistical values that define the percentage of time that exceeds a specific sound level. For example, over the course of an hour, noise levels may be above a relatively quiet level 90 percent of the time (54 minutes), or exceed a relatively loud level only 2.5 percent of the time (1.5 minutes), expressed as the L_{90} and $L_{2.5}$, respectively. It is useful to note that the L_{90} is commonly accepted as an approximate representation of background noise levels. In other words, events that exceed a noise level for 10 percent of the time can be attributed to infrequent and clearly audible short-term events, not considered representative of background conditions.

In general, the degree of a perceived noise impact depends, among other factors, on existing ambient sound levels versus the noise source in question, the frequency spectrum of the noise source, the timing and duration of the noise event, and the hearing abilities of the person listening.

Environmental noise is usually described in terms of certain "metrics" that allow comparison of sound levels at different locations or in different time periods. Federal regulatory agencies often use the equivalent sound level (L_{eq}) or the day-night sound level (L_{dn}) to characterize sound levels and to evaluate noise impacts. The L_{eq} is the level that if held constant over the same period of time would have the same sound energy as the actual, fluctuating sound.

Measured sound levels can be described in terms of the percentage of time a certain level is exceeded using a statistic called an interval "L_n." For example, the hourly L_{25} represents a sound level that is exceeded 25 percent of the time, or 15 minutes in an hour. Similarly, $L_{8.33}$ and $L_{2.5}$ are the sound levels that are exceeded 5 and 1.5 minutes in an hour, respectively.

1.2 KING COUNTY NOISE CODE

King County has recently adopted a new noise ordinance in the King County Code (KCC), effective May, 2015. The noise criteria established in the KCC apply to the CHRLF site and surrounding properties. These criteria are defined in KCC Title 12, Chapter 12.86 (KCC 12.86) and are reproduced in the table below.

Table 1. King County Maximum Permissible Sound Levels

District of Sound Source	District of Receiving Property Within King County			
	Rural	**Residential**	**Commercial**	**Industrial**
Rural	49 dBA	52 dBA	55 dBA	57 dBA
Residential	52 dBA	55 dBA	57 dBA	60 dBA
Commercial	55 dBA	57 dBA	60 dBA	65 dBA
Industrial	57 dBA	60 dBA	65 dBA	70 dBA

Abbreviations
dBA = A-weighted decibels

Note that for rural and residential receiving properties, the noise limits between 10:00 p.m. and 7:00 a.m. are reduced by 10 dBA.

The districts of sound source and receiving properties are based on zoning and are summarized as follows, as defined in KCC 12.86.030:

- **Rural** - includes zones designated in the King County zoning code as A and RA
- **Residential** - includes zones designated in the King County zoning code as UR and R-1 through R-48
- **Commercial** - includes zones designated in the King County zoning code as O, NB, CB and RB
- **Industrial** - includes zones designated in the King County zoning code as I and M and special uses

Note that sound level limits identified in Table 1 are based on the energy-average sound level over a given time period, or "Leq". KCC does not explicitly define the time period during which the limits in Table 1 shall apply. However, a one-hour time interval is most universally applied in jurisdictions where sound level limits are based on an Leq, unless otherwise specified. The limits in Table 1 are therefore understood to be the Leq sound level received over a 1-hour period, regardless of whether the sound source is constant over an hour or active only for a portion of the hour (i.e., non-continuous). When determining compliance of a sound source relative the limits identified in Table 1, KCC 12.86.110(A) states that sound level measurements shall be taken for a minimum of one-minute for “constant” sound sources (i.e., sources that emit a constant sound that would not change over a given time period), and a minimum of thirty-minutes for “non-continuous” sound sources (i.e., sources that are not continuous over a given time period). An example of a non-continuous sound source is a tipper at a landfill that operates periodically over an hour.

In addition to the maximum permissible sound level limits, KCC 12.86.520 exempts noise from various types of construction activity during specific times of day, as follows:

<u>12.86.520(1):</u> For heavy equipment, including crawlers, tractors, bulldozers, rotary drills and augers, loaders, power shovels, cranes, derricks, graders, off-highway trucks, ditchers, trenchers, compactors, compressors and other similar equipment:

- Exempt between the hours of 7:00 a.m. and 7:00 p.m. on weekdays, and between 9:00 a.m. and 7:00 p.m. on weekends

<u>12.86.520(2):</u> For impact type equipment, including pavement breakers, pile drivers, jackhammers, sandblasting tools or other types of equipment or devices that create impulse noise or impact noise.

- Exempt between the hours of 8:00 a.m. and 5:00 p.m. on weekdays, and between 9:00 a.m. and 5:00 p.m. on weekends

<u>12.86.520(3):</u> For all other construction activities:

- Exempt between the hours of 9:00 a.m. to 10:00 p.m. on weekdays, and between 9:00 a.m. and 8:00 p.m. on weekends

Note that KCSWD restricts solid waste truck hauling to CHRLF and landfill operation (and associated heavy equipment operations) as follows:

Truck trips to CHRLF - 7:00 a.m. to 9:30 p.m. weekdays (7:00 a.m. to 6:30 p.m. weekends)

Landfill operation - 6:00 a.m. to 6:00 p.m. on weekdays (6:00 a.m. to 5:00 p.m. weekends)

The KCC 12.86.120(B) states that "for any source of sound that has a pure tone component, the levels established by this chapter shall be reduced by 5 dB(A), but this reduction shall not be imposed on any electrical substation." This same chapter defines pure tones as "sound having the following qualities: a one third octave band sound pressure level in the band with the tone that exceeds the arithmetic average of the sound pressure levels of the two contiguous one third octave bands…"

- by 5 dB for center frequencies of 500 Hz and above,
- by 8 dB for center frequencies between 160 and 400 Hz, and
- by 15 dB for center frequencies less than or equal to 125 Hz

That is, a pure tone is a 1/3 octave frequency that is a higher sound level than neighboring 1/3 octave frequencies by a defined amount. Note that pure tones are typically assessed at a noise receptor, not near the noise source.

2.0 TECHNICAL APPROACH

The assessment documented in this report included several individual tasks. The following list provides an overview of the technical approach employed:

- Review of *2012 Draft Detailed Perimeter Noise Study at Cedar Hills Regional Landfill.* This review was completed to provide background information on perimeter monitoring locations, times of day when sound level limits were exceeded, conclusions of the study, and requirements for future assessments.
- Determination of sources that would require additional sound level measurements and ultimately noise modeling analysis.
- Sound level measurements at CHRLF including CHRLF sound sources, CGC, and tenant activities. Measurements included both source measurements and corresponding perimeter location measurements.
- Predictive noise modeling using the CadnaA modeling tool to consider 2012 conditions, and future finish-elevation conditions for CHRLF Areas 5, 6, and 7.
- Fast Fourier Transfer (FFT) analysis of audio data collected during source measurements, and at perimeter locations.
- Evaluation of the potential for CHRLF and/or CHRLF tenants, as well as neighboring facilities such as the Cedar Grove Compost (CGC) facility, to emit noise levels that are in excess of the applicable King County limits.

2.1 REVIEW OF 2012 REPORT

The 2012 report titled *Detailed Perimeter Noise Monitoring Study at Cedar Hills Regional Landfill* was reviewed for this assessment. Results were used to provide guidance for the modeling assessment completed as part of the study documented in this report. The following are general conclusions drawn from the 2012 study:

- Perimeter monitoring locations included P1, P2, P3, P4, and P5 (see **Noise Modeling Figure 1**)
- Sounds levels during daytime hours were generally higher than during nighttime hours at all perimeter locations
- King County sound level limits were exceeded during all hours of the day and night, and were mostly due to sources other than CHRLF or CHRLF tenants, such as traffic, aircraft, wildlife, and residential noises

- Following isolation and removal of non-CHRLF and CHRLF tenant noises, most measured sound levels were within the King County sound level limits

- There were several day and night periods where no audio data or notes were available to quantify the contribution of non-CHRLF and CHRLF tenant noises

- The following conclusions were drawn for each of the perimeter monitoring locations:

– P1: noise from operation of the landfill at Area 7 was noticeable during daytime hours. Also noticeable was noise from truck activity along the west perimeter road, the Cedar Grove Composting facility, the BEW plant, and other ambient noises. During nighttime hours at P1, ambient noises were dominant; however the BEW plant was often audible. Sound levels at P1 during nighttime hours at times exceeded the King County sound level limits due to miscellaneous sources that often were not recorded. Observer notes indicate that exceeded levels may have been due to traffic, aircraft, and wildlife.

– P2: noise from the North Flare Station (NFS) was audible during all hours of the day and night. The most notable tone was at approximately 1,000 Hz, likely originating from blower fans at the NFS. Noise levels from off-site traffic, likely along SE May Valley Road, were the highest levels received at P2. All sound levels that exceeded the King County limits were due to ambient noises; CHRLF and CHRLF tenants did not emit sounds that exceeded the limits during day or nighttime hours.

– P3: noise from the NFS was at times audible during both day and night hours, and most notable was a tone at approximately 1,000 Hz, likely originating from blower fans at the NFS. Noise from operation of the nearby Trinity Tree Farm and traffic along Issaquah-Hobart Road were the highest levels of noise received at P3.

– P4: The location of P4 was 180 feet inward (westward) from the property line to prevent disturbing neighbors during noise monitoring. Noise from aircraft, traffic, and a nearby HVAC unit were the most significant noises at this location. The HVAC unit, associated with a cellular communications tower, regularly cycled on and off . The BEW facility was audible mostly during nighttime hours. During early morning hours, truck activity and tracked equipment at CHRLF were audible. The King County sound level limits were exceeded during both daytime and nighttime hours. Daytime levels exceeding the limits were often due to miscellaneous activities that were not recorded or discernable. Nighttime levels exceeding the limits were due to the HVAC unit cycling on and off.

– P5: The noise environment at P5 was often dominated by truck traffic along the main access road to the landfill. Also audible, especially during nighttime hours, was the BEW plant. The King County sound level limits were exceeded on multiple occasions during both daytime and nighttime hours. Daytime levels exceeding the limits were often due to nearby truck traffic. Nighttime levels exceeding the limits were due to the BEW plant.

Other general conclusions from the 2012 study report include the following:

- During nighttime hours, between 10 p.m. and 6 a.m., activity at CHRLF included the BEW and CHRLF staff traffic traveling to and from the landfill site, as well as noise from the NFS

- Beginning at 6 a.m., activity at CHRLF increased when landfill trucks were started, warmed-up, and then exited CHRLF property
- Beginning at 7 a.m., landfill activity increased further with operation of landfill equipment including dozers, compactors, tippers, scrapers, and related support equipment

The access route to landfill Area 7 during the 2012 measurements was the west perimeter road (see **Noise Modeling Figure 1**).

2.2 2014-2015 Measurements and Source Sound Level Data

Sound level measurements of CHRLF and tenant equipment and activity were taken over several periods to document all acoustically significant sources of noise. Sound level measurements were taken using Type 1 sound level meters, including either Brüel & Kjær (B&K) Model 2250 or Larson Davis (LD) Model LxT meters. The meters were set to record 1/3 octave band frequency and broadband sound level data. The sound level meters had each been factory certified within the previous twelve (12) months and were field calibrated immediately prior to and following each day of measurement. The B&K meters are equipped with audio recording capabilities and were programmed to record high-quality audio. The LxT meters do not have audio capability and instead were placed in tandem with either a Tascam DR-05 or DR-40 digital audio recording device.

Measurements were taken over several periods. The following summarizes the sound level measurement schedule:

- December 9, 2014: Mid-day measurements included noise from the BEW plant; the CHRLF truck scale area; CHRLF active landfill equipment including compactors, loaders, scrapers, and tippers; and trucks along the west access road
- January 14, 2015: Early-morning measurements included noise from CHRLF truck warm-ups, entrance road noise, and the Cedar Grove Composting (CGC) facility
- June 8, 2015: mid-day measurements included noise from the North Flare Station (NFS) and the cellular tower HVAC system

The source sound level data listed above were tabulated for use in noise modeling.

During many of the measurements outlined above, ambient noise monitoring was conducted at one or more of the perimeter locations used during the 2012 study (and illustrated in **Noise Modeling Figure 1**.

These perimeter measurements were collected to document the contribution, if any, from the CHRLF or tenant sources. These were to be further verified through FFT analysis, if feasible (as summarized in Section 4).

2.3 NOISE MODELING

Noise modeling was completed using the Datakustik GmbH CadnaA noise model version 4.5.151. CadnaA is a three-dimensional noise modeling tool that allows for consideration of user-defined sound level information (e.g., taken from source sound level measurements); the intervening effects of buildings, terrain, vegetation, and other obstacles; as well as meteorology and other parameters. Sound levels are predicted at specific receptor locations. The modeling process considers the combination of individual sources and enables the user to identify which sound sources are most affecting any one receptor location. CadnaA was employed for this assessment because it allowed for a determination of the most acoustically significant sound sources at each perimeter location.

Topographical data was provided by King County and included the approximate topographical setting present in 2012 during the perimeter noise study. King County also provided the approximate topographical design of the landfill following the scheduled completion of CHRLF Areas 5, 6, and 7. That is, King County provided finished-grade elevations that were then built into the noise model to evaluate future landfill activity, on the assumption that the finished grade puts the landfill construction equipment and trucks at the highest location, from which their noise can carry the farthest because it is reduced the least by interaction with intervening topography and vegetation.

Modeling was completed to evaluate both 2012 conditions and acoustical conditions once the landfill is constructed to a finished grade. The 2012 modeling scenarios were completed to confirm the accuracy of the model and to determine the degree to which ambient noise (i.e., non-CHRLF or tenant noises) contributed to each monitoring location. It was noted during the 2012 measurements that at some locations there was a high level of influence from ambient sources including traffic on area roadways, wildlife, aircraft, and other neighborhood sources.

The following list summarizes the conditions considered in the noise modeling scenarios evaluated for this study:

- 2012: Nighttime
- 2012: Early Morning (6 - 7 a.m.)
- 2012: Daytime
- Finished Elevation: Nighttime
- Finished Elevation: Early Morning (6 - 7 a.m.), Area 5
- Finished Elevation: Early Morning (6 - 7 a.m.), Area 6
- Finished Elevation: Early Morning (6 - 7 a.m.), Area 7
- Finished Elevation: Daytime, Area 5
- Finished Elevation: Daytime, Area 6
- Finished Elevation: Daytime, Area 7

2.4 FAST FOURIER TRANSFORM (FFT) ASSESSMENT

An assessment of the audio data collected during source measurements and at perimeter locations was evaluated using Fast Fourier Transform (FFT) analysis. FFT is a method by which a sound waveform from an isolated time period is resolved into its individual sinusoidal sound frequencies. That is, specific sound frequencies and their relative amplitudes can be extracted from a single audio recording. The assessment was completed from audio data collected from specific sound sources (e.g., those at the BEW plant) and from audio collected at perimeter measurement locations. The results were compared to identify sound frequency signatures that could be correlated (i.e., matched), which might confirm the relative contribution of a sound source at a perimeter location. The FFT analysis supplemented the CadnaA noise modeling to potentially confirm results of the model and observations made during the 2012 perimeter measurements.

2.5 QUALITY CONTROL

To ensure the quality of sound level calculations and subsequent interpretations, sound level calculations and modeling data were reviewed to ensure accuracy. Calculations and model data were reviewed by senior staff of Ramboll Environ as part of standard Quality Assurance/Quality Control practices.

3.0 NOISE MODELING ASSESSMENT

The noise modeling assessment was completed for multiple landfill operating scenarios, divided into two main categories: 2012 conditions and finished-grade conditions. Each scenario was modeled to represent nighttime, early morning, and daytime operating conditions. Sound source data were collected per the methods summarized earlier in Section 0. The following discussion summarizes details of the sound source measurement data, as well as the details of the noise modeling assessment, including noise model input and output details and results.

3.1 SOURCE SOUND LEVEL MEASUREMENT DATA

Sound level measurements were collected on multiple occasions to document the noise emissions from a range of acoustically significant sources due to CHRLF and CHRLF tenants' equipment and/or activities. Table 2, following page, summarizes sound power data based on sound level measurements at CHRLF. These data were used in the CadnaA noise model to represent acoustically significant sound sources in each modeled scenario.

Descriptions of the measurement equipment used to capture sound level data, and a description of the CadnaA noise model, are provided earlier in this report in Sections 0 and 2.3, respectively.

Table 2. CHRLF and Tenant Sources – Sound Power Level Data

Source	Sound Power level (dB) by 1/1 Octave Frequency (Hz), and A-weighted total									
	31.5	63	125	250	500	1000	2000	4000	8000	Total (A)
BEW, South Side	71.3	92.4	98.0	97.7	96.9	96.7	94.2	88.3	81.9	104.3
BEW, S&R Door	69.6	87.0	94.3	91.0	93.2	96.3	96.6	87.5	83.0	102.1
BEW, East Door	63.1	75.3	82.6	85.9	87.3	88.3	87.7	78.6	74.2	94.0
BEW, North Door	76.3	87.6	90.1	95.1	99.9	102.2	101.4	92.4	85.9	106.8
BEW, Booster Blowers	73.7	81.6	96.0	94.6	98.3	99.6	101.3	96.0	90.3	106.2
BEW, West Side	69.4	87.7	95.1	101.1	110.2	111.0	106.2	100.9	90.1	114.8
Trucks at Scale	73.0	85.7	91.5	98.8	101.6	101.8	99.5	93.9	86.3	107.0
Trucks Warm Up	67.0	87.2	97.4	101.0	103.2	105.0	101.6	95.3	83.7	109.5
Truck Pass-by	78.8	83.7	88.1	92.7	96.6	98.7	98.2	92.3	84.0	103.7
NFS (1)	66.5	100.8	101.4	95.3	93.7	101.2	91.8	86.7	85.8	102.5
NFS (2)	68.0	79.7	83.4	87.6	96.9	95.5	93.9	88.8	79.4	101.0
Candlestick Flare	78.5	86.4	87.9	95.7	99.6	94.8	92.6	88.0	80.6	102.9
2 Compactors, 1 Dozer	78.6	90.9	110.6	110.5	112.0	112.0	111.1	105.4	96.0	118.6
1 Dozer	75.7	87.8	98.9	105.7	111.3	110.5	109.0	104.3	94.8	116.0
Scraper	73.3	79.4	86.8	98.0	99.4	103.2	103.9	97.7	91.7	108.3
Tipper, Idle	65.5	75.2	80.2	85.5	91.2	95.4	97.9	91.6	82.2	101.2
Tipper, Cycle	67.1	76.1	91.9	103.5	101.9	104.1	104.0	100.4	93.9	110.2
Cell HVAC	44.4	62.1	73.9	74.1	80.5	82.2	77.9	73.9	64.1	86.2

(1) NFS noise emissions as measured in 2012 at S2

(2) NFS noise emissions as measured in 2015 following application of noise control

The approximate locations of each sound source, and of each source sound level measurement (SLM), are illustrated on following pages in Figure 1 through Figure 5. Note that the location of each sound source is approximate, as sources often were of a large area of sources (e.g., trucks idling or the West side of BEW).

Figure 1. SLM Source Locations: BEW

BEW sources were collected at various distances, depending on the number of sources or the size of the sources being measured. There are two (2) booster blowers at the north end of the BEW, both of which were measured. Measurements of BEW West were taken in an area below the grade of BEW, but with a direct line of sight to the west side of the BEW. Measurements at BEW South were taken along the entrance to the east perimeter road, with a direct line of sight to the many cooling units and pumps located on the south side of the building. Measurements of both BEW S&R and BEW East Door were taken on the road running north-south along the east side of the BEW. The measurement at BEW N Door was taken at a diagonal to the open door at the north end of the BEW, along a chain linked fence.

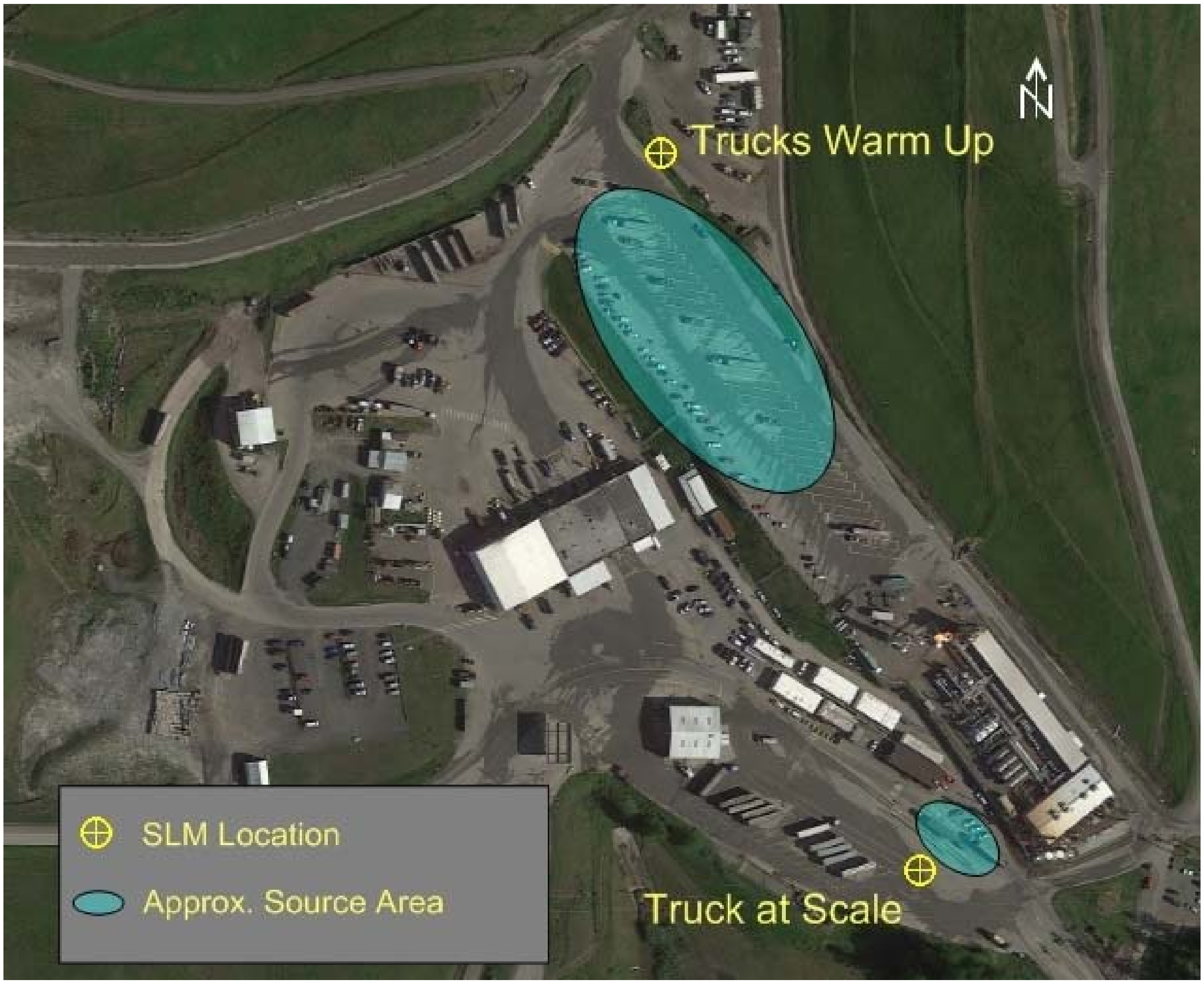

Figure 2. SLM Source Locations: Trucks During Warm Up and at Scale

Measurements of truck warm up activities were taken during early morning hours, as trucks warms up in the parking area, and then departed the site, circling to the left from the north end of the parking area, and out through the scale area. The truck scale measurement was taken as trucks entered and idled at the truck scale. The measurement of the truck scale was taken close enough to the source to minimize interference from the BEW or from other CHRLF activity.

Figure 3. SLM Source Locations: North Flare Station

The measurements of the NFS were taken during the 2012 study and again in 2015. The 2015 measurements documented the NFS following installation of noise control equipment. Note that the measurements taken in 2015 were located at the perimeter fence line on the north side of the NFS, and not influenced by noise from the candlestick flare. The measurement at 940 feet was taken for use in the FFT analysis (see Section 4).

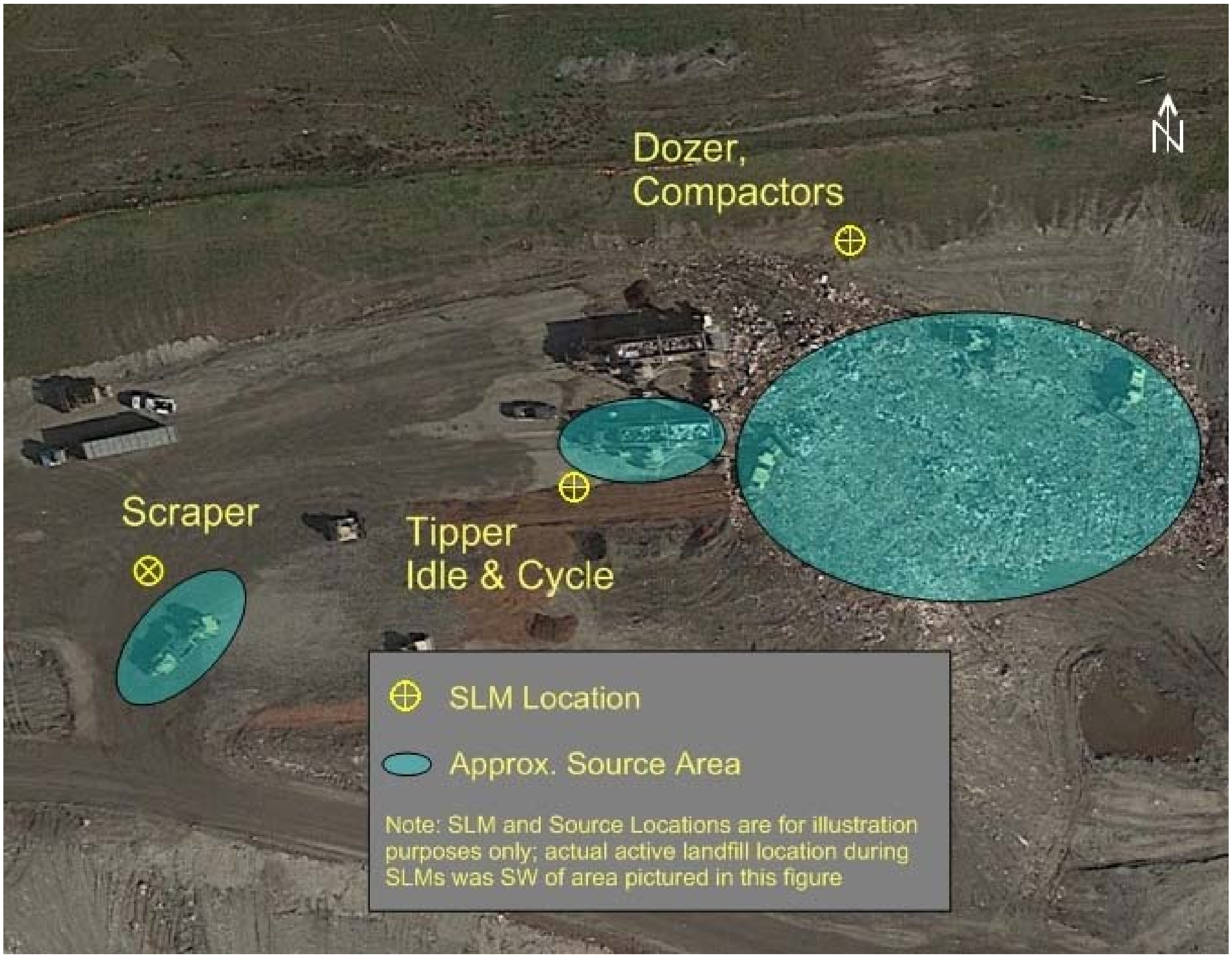

Figure 4. SLM Source Locations: CHRLF Active Landfill Area

As noted in the legend for Figure 4, above, the location of sources and measurements at the CHRLF active landfill area were in a different location during the December, 2014 field measurements, than is illustrated. The base map used to illustrate these measurements is of an area northeast of where actual measurements were taken. However, the intent of the figure is to illustrate the sources measured, and because active landfill equipment is frequently moved as areas are filled, this figure serves the intended purpose.

Figure 5. SLM Source Locations: Cell Tower HVAC

Note that the HVAC units measured are not visible in Figure 5, hidden underneath a canopy of trees. The measurement was taken on a gravel road, east of the HVAC units. The 2012 measurement location at P4 was further east of the source measurement location, and the property boundary can be seen further east, as a solid and faint white line running north-south.

3.2 Noise Model Scenarios

Equipment operating within the CHRLF varies over a 24-hour period. Landfill activity is most accurately divided into three (3) main times of day: nighttime, early morning, and daytime. **Table 3**, below, summarizes the operational activity each during each of these time periods, as well as the corresponding King County sound level limit that are applicable at the nearest adjacent property boundaries.

Table 3. CHRLF Operating Periods

Modeled Time Period	Description of Landfill Activity	Time Period	Applicable KC Sound Level Limit
Nighttime	BEW, NFS, and HVAC operate continuously, some staff traffic	10:00 p.m. – 6:00 a.m.	39 dBA
Early Morning	BEW, NFS, and HVAC operate continuously, truck warmup, scrapers, trucks exiting CHRLF	6:00 a.m. – 7:00 a.m.	39 dBA
Daytime	BEW, NFS, and HVAC operate continuously, scrapers, trucks accessing CHRLF, dozers, compactors, tippers	7:00 a.m. – 10:00 p.m.	49 dBA

Source: Ramboll Environ, Amec Foster Wheeler, King County

Note that sources which did not operate during certain time periods were excluded from the relevant scenario. For example, CHRLF active landfill equipment does not operate at nighttime and so was omitted from nighttime scenarios. A description of which sources were included in each scenario is provided in **Table 3**.

Table 4. Modeled Sound Sources during Nighttime, Early Morning, and Daytime Operations at CHRLF

Nighttime (10pm – 6am)	Early Morning (6am – 7am)	Daytime (7am – 10pm)
BEW	BEW	BEW
North Flare Station	North Flare Station	North Flare Station
Candlestick Flare	Candlestick Flare	Candlestick Flare
Cell Tower HVAC	Trucks Warm Up (8-10)	Trucks entering (12, 24 passes)
Employee Traffic	Trucks Leaving Site (58)	Scraper (4 passes)
	Scraper (4 passes)	Sweeper (4 passes)
	Sweeper (4 passes)	2 compactors
	North Flare Station	1 dozer
	Cell Tower HVAC	2 tipper engines
		tipper cycles
		Cell Tower HVAC

Source: Ramboll Environ, Amec Foster Wheeler, King County

3.3 2012 – Existing Conditions

Ramboll Environ constructed a noise model to represent landfill operations in 2012, as it was expected to have operated at the time of the 2012 Perimeter Noise Study. This modeling was intended to validate the noise model relative to acoustically significant and dominant sources of noise and to quantify the relative contribution of both CHRLF and tenant noise sources. Results from the noise model also were used to quantify the contribution of ambient noises.

King County provided the topographical data that were input to the noise model in 2-foot contour intervals and included the entire landfill area, building footprints of all CHRLF and tenant structures, on-site roads and parking areas, and property lines. Note that it is expected that the finished-grade elevations of Areas 5, 6, and 7 will occur by the year 2028, the end of the current projected life of the landfill.

Sound sources for each operating scenario are provided in **Table 4** (above), and sound power data for each source are provided in **Table 2**. Note that for the North Flare Station (NFS), sound level measurement data collected at S2 were used to calculate sound power levels at NFS. These measurements were of the NFS prior to installation of noise control equipment that was specifically targeted to reduce a noticeable tone emitted at approximately 1,000 Hz. [5]

[5] Note that noise from the Cedar Grove Compost (CGC) facility was preliminarily considered in this assessment through review of measurements at the nearest CHRLF property line with the CGC facility. However,

Table 5 summarizes the noise modeling results for the scenario representing 2012 conditions at each of the perimeter monitoring locations (i.e., P1 through P5). This table includes a summary of the average of the hourly L_{eq} measured sound levels at each location that were compared to model results in the validation process. The minor discrepancies between the noise modeling and measured levels are also described.

Note that the measured L_{25} was used as the basis for validating the noise model. As defined earlier in this report, the L_{25} is the sound level exceed for 25 percent of a given time period, and this metric represented the maximum permissible sound level limits that were established by King County prior to May 2015 in KCC 12.88, and that were in place at the time of this assessment (i.e., the new KCC noise ordinance defined earlier and summarized in Table 1 was not yet in place at the time of this assessment). However, note that the L_{25} is typically approximately equivalent to the hourly average sound level (L_{eq}). Noise sources considered in the CadnaA modeling were assumed to operate continuously over a 1-hour period, so the modeling results represent an hourly L_{eq} that can be compared within +/- 2 dBA of the measured L_{25}, and which can now be compared with the new sound level limits established in KCC 12.86. Note that with the exception of some very short-term exceedances of the L_{max}, most exceeded limits of the King County Code during the 2012 Perimeter Noise Study (then KCC 12.88) were of the L_{25}, which indicates continuous noises were the primary contributing noise sources.

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noise levels from CGC were far lower than the sources summarized in **Table 4** at all perimeter locations, so the compost facility was not considered further in this assessment.

Table 5. 2012 Conditions – Noise Modeling Results Summary

Receptor	Time Period	King County Maximum Permissible Sound Level Limits (Leq)	2012 Measured Sound Levels	MODELING CHRLF and Tenant Sources ONLY	2012 Measured - 2012 Modeled	Estimate of 2012 Ambient Levels due to non-CHRLF sources (2012 Measured – 2012 Modeled)	Notes/Comments
P1	Day	49	45	42	3	41	Model in close agreement; dominated by CHRLF activity
	Night	39	42	31	11	41	Ambient noises dominate at night, no dominant CHRLF noises
	Early a.m.	39	46	34	12	45	Ambient noises dominate in early morning, no dominant CHRLF noises
P2	Day	49	38	29	9	38	Ambient noises dominate during daytime, no dominant CHRLF noises
	Night	39	31	23	8	31	Ambient noises dominate at night, no dominant CHRLF noises
	Early a.m.	39	39	25	14	38	Ambient noises dominate in early morning, no dominant CHRLF noises
P3	Day	49	43	34	9	42	Ambient noises dominate during daytime, no dominant CHRLF noises
	Night	39	37	32	5	35	Ambient noises dominate at night, no dominant CHRLF noises
	Early a.m.	39	44	32	12	44	Ambient noises dominate in early morning, no dominant CHRLF noises
P4	Day	49	42	39	3	39	Model in close agreement
	Night	39	38	38	0	26	Model in close agreement
	Early a.m.	39	43	38	4	41	Model in fairly close agreement, high levels of ambient noises
P5	Day	49	47	45	2	43	Model in close agreement, trucks and BEW are dominant sources
	Night	39	44	41	3	40	Model in close agreement, BEW is dominant source
	Early a.m.	39	47	45	2	43	Model in close agreement, trucks and BEW are dominant source

Note: Shading denotes levels exceed King County maximum permissible sound level limit for a rural source affecting a rural receiver

The noise modeling results summarized in **Table 5** indicate that when CHRLF and tenant sources dominate the acoustic environment, the modeling predicted sound levels that were within 0 to 3 decibels of average measured sound levels. This is considered excellent agreement and indicates that the noise model is well calibrated. Depending on the time of day (i.e., daytime, nighttime, or early morning), the dominant sources of noise at P4 were the cell tower HVAC units and at P5 the dominant sources were trucks along the access route and the BEW plant. At both locations, the model-predicted sound levels from these sources are very near to what was measured. These comparative results indicate that the sound sources built into the model are accurately represented and that assessments of future scenarios (i.e., finished-grade elevations) are also accurately represented.

The results summarized in **Table 5** also suggest the likely contributing noises sources at each perimeter location for each time period considered. This estimate was performed by extracting the model-calculated sound level of CHRLF and tenant sources from the measured levels in 2012, with the assumption (validated above) that the model was accurately representing CHRLF and tenant sources. As was observed in 2012, and as is shown in the last column of **Table 5**, ambient noises unrelated to CHRLF sources often dominated the acoustic environment at each of the perimeter locations. These findings are summarized below:

- P1: Model-predicted daytime sound levels were in close agreement with measured conditions. During daytime hours, activity at the CHRLF active landfill area and vehicles on the west perimeter access road dominate the noise environment at P1. During nighttime and early morning hours, there was no activity at the active landfill, although measured levels at P1 were only a few dBA lower than during daytime hours. Observations during monitoring at P1 indicated that contributing sources at P1 during nighttime and early morning hours included local area traffic, aircraft, and wildlife (birds, etc.).

- P2: Measured levels during all periods were higher than predicted by the noise modeling representing CHRLF-related sources. Observations noted during the measurements indicated that during early morning and daytime hours, the noise environment at P2 often was dominated by traffic along SE May Valley Road and traffic noise from other local roadways. Other contributing sources included aircraft, neighborhood activities and wildlife.

- P3: Similar to P2, measured sound levels greatly exceeded sound levels predicted by noise modeling with CHRLF-related sources. Noise from CHRLF and tenant activity was rarely audible at this location. Dominant sources of ambient noises included traffic along Issaquah-Hobart Road SE, Cedar Grove Road SE, and SE May Valley Road, as well daytime noises from the adjacent tree farm.

- P4: Sound levels measured at P4 included noise from HVAC equipment associated with the nearby cellular communications tower on CHRLF property. The HVAC equipment noise cycled on and off and was noticeable and present throughout the monitoring program. During measurements in early morning hours, CHRLF noise was noted as potentially audible as trucks warmed up and moved off site. The noise modeling predicted sound levels within 0 to 4 dBA of the measured levels for all time periods. Differences between the measured and modeled sound levels were likely due to the influence of other ambient noises including local and distant traffic and neighborhood activities, aircraft, and wildlife.

- P5: Depending on the time of day, the noise environment at P5 is dominated by truck traffic on the CHRLF entrance road and/or by continuous activity of the BEW plant. Ambient noises included aircraft from Cedar Grove Road, and possibly other local roads. For all time periods, the model-predicted sound levels are within 1 to 3 dB of the measured levels, indicating CHRLF sources dominate the acoustic environment (as suggested during measurements). Model results indicate that CHRLF sources contribute to the acoustic environment at P5 to a greater degree than ambient noises such as aircraft and wildlife.

In summary, noise modeling results of 2012 conditions indicate the noise modeling is accurately predicting CHRLF and tenant activity, including the BEW plant operations and the cellular site HVAC units. This conclusion is based on the fact that in areas where such activity was observed to dominate the acoustical environment, the model-predicted levels are very similar to what was measured.

In areas where the modeling of CHRLF and tenant activity under-predicted measured levels, the quantitative estimates of ambient sound levels are consistent with the observer notes in the 2012 Perimeter Noise Study. That is, for areas P1, P2, and P3 during either some or all hours of the day, the dominant sources of noise were noted to come from traffic, aircraft, wildlife, and other miscellaneous sources that were not associated with CHRLF operations or tenants.

Conclusions of the noise modeling assessment for 2012 conditions indicate that the CadnaA noise model is accurately predicting noise emissions from CHRLF and tenant activity. Therefore, the noise modeling was suitable for predicting sound levels during activities at finished grade elevations for Areas 5, 6, and 7.

3.4 FUTURE CONDITIONS – FINISHED GRADE ELEVATION

Ramboll Environ conducted noise modeling to evaluate the noise emissions from CHRLF and tenant activity following the final grading of Areas 5, 6, and 7. Elevation data for final grading was provided by King County and built into the model. Note that grading information was only available for the cumulative final grading of Areas 5, 6, and 7, and not for each Area individually as the landfill is developed over the coming years. Therefore, the noise modeling for final grading elevation was completed assuming all three areas are graded to their final elevations. The locations of equipment operated during daytime hours at active landfill areas (e.g., compactors, dozers, tippers) were positioned at worst-case locations relative to each Area and the nearest off-site receiver location. The effect of this approach would be that the modeling would potentially overestimate noise impacts during periods when equipment would be operating at more distant and/or more shielded locations.

Graphical illustrations of the location of landfill equipment within each Area are included attached in each of the noise modeling figures (Noise Modeling Figures 3 through 12). Topography of both 2012 conditions and Finished Elevation are found in Modeling Figures 1 and 2.

Receptor locations considered in the noise modeling for finished landfill grades are identical to the receptor locations modeled for the 2012 modeling assessment (and are the same as the 2012 measurement locations). Note, however, that noise measurements at P4 were taken approximately 180 feet west of the eastern perimeter fence line, beyond which lies the nearest residential property to P4, so as not to disturb the residents of this home. Consequently, measurements taken at P4 included higher levels of HVAC noise from the nearby wireless communications facility than would be audible at the property line. Noise modeling of 2012 conditions (summarized in Section 2.3) placed P4 at the same location as the measurement to provide a more accurate validation of the noise model. However, for the assessment of future finish grade conditions, the P4 modeling receptor location was moved to the property line to more accurately represent CHRLF and tenant noise levels at the property boundary. It was noted during the 2012 monitoring study, and in Section 0, that the HVAC unit was the most acoustically significant sound source at P4. Moving P4 about twice the distance from the HVAC units results in an expected 6-dBA reduction in HVAC noise, which is especially notable during nighttime hours when no other CHRLF sound sources are audible.

The noise assessment of finished grade conditions assumed the equipment and activities of CHRLF and its tenants would remain identical to what was observed and modeled for 2012 (i.e., active landfill equipment, the BEW plant, cell tower HVAC, NFS, and others); the only changes were the location of CHRLF active landfill equipment as they work in each landfill area, and the related interior truck routes from the west perimeter road.

Note that for the NFS, noise control has been applied to the blowers since the 2012 measurements were taken, reducing the previously identified tone at approximately 1,000 Hz (as noted further in the FFT analysis section of this report, Section 4). New source measurements taken of the NFS were used in the modeling for finished grade conditions (the sound source information for the new NFS data are found in Table 2).

Results of the noise modeling assessment are summarized in **Table 6**.

Table 6. Finish Grade Conditions for Areas 5, 6, and 7 - Noise Model Results Summary

Receptor	Time Period	King County Maximum Permissible Sound Level Limits (Leq)	2012 Measured Sound Levels	Ambient Noise Levels	Modeling Results: Final Elevation CHRLF and Tenants ONLY			Modeling Results: Final Elevation CHRLF and Tenants *and Ambient Noise*			Increase over Existing Measured Levels		
					AREA7	AREA6	AREA5	AREA7	AREA6	AREA5	AREA7	AREA6	AREA5
P1	Day	49	45	41	48	36	41	49	42	44	4	-2	0
	Night	39	42	41	31	31	31	42	42	42	0	0	0
	Early a.m.	39	46	45	33	33	34	46	46	46	0	0	0
P2	Day	49	38	38	40	32	41	42	39	43	3	1	4
	Night	39	31	31	23	23	23	31	31	31	0	0	0
	Early a.m.	39	39	38	25	24	30	38	38	39	0	0	0
P3	Day	49	43	42	36	37	40	43	43	44	0	1	1
	Night	39	37	35	31	31	31	37	37	37	0	0	0
	Early a.m.	39	44	44	32	32	33	44	44	44	0	0	0
P4	Day	49	42	39	33	43	37	40	45	41	-2	3	-1
	Night	39	38	26	31	31	31	32	32	32	-6 (1)	-6 (1)	-6 (1)
	Early a.m.	39	43	41	32	35	33	41	42	41	-1	-1	-1
P5	Day	49	47	43	45	48	45	47	49	47	0	2	0
	Night	39	44	40	42	42	42	44	44	44	1	1	1
	Early a.m.	39	47	43	45	46	45	47	48	47	0	0	0

Note: Shading denotes levels exceeding the King County maximum permissible sound level limit for a rural source affecting a rural receiver

(1) Sound level reduction due to moving the position of the modeled receptor from 180 feet west of the property line, at the same location as measured in 2012, to a location exactly along the property. The property line location for P4 is is roughly double the distance from the measurement location, relative the acoustically dominant source sources at this location: HVAC unit.

Results of CHRLF and tenant activity only (i.e., sound levels without contribution of ambient noises such as aircraft, nearby traffic, wildlife, etc.), are found in **Table 6** under the column heading "Modeling Results: CHRLF and Tenants ONLY." In this column, the King County Leq sound level limit is exceeded only at P5. At P1 through P4, noise from CHRLF and its tenants is not expected to exceed the King County limit during development of Areas 5, 6, and 7.

As noted above, sound levels at P4 are lower than were predicted in the 2012 analysis because the location of P4 has been moved westward by 180 feet to the eastern property line.

The highest levels of daytime noise would occur at P1 during finish grade conditions of Area 7. This prediction is due to active landfill equipment operating within Area 7 at an elevated grade, which provides a more direct line of sight to P1 than when landfill equipment operates at a lower grade (e.g., during 2012).

At P5, modeling predicts the 39-dBA nighttime sound level limit would be exceeded during both nighttime and early morning hours. The most acoustically significant sources of noise at P5 during nighttime hours includes various noises generated by the BEW plant. During early morning hours, truck traffic along the CHRLF entrance road contributes to the overall levels received at P5, and the King County nighttime limit is exceed by both BEW and trucks leaving CHRLF. This conclusion is supported by the findings of the 2012 monitoring study that concluded the BEW plant and trucks leaving CHRLF were clearly audible during early morning hours at P5. Further it is supported by the average measured sound level data that documented an increase between nighttime hours and the time period between 6 a.m. and 7 a.m. (i.e., when trucks began leaving the site).

In **Table 6**, under the column heading "Modeling Results: CHRLF and Tenants *and Ambient Noise,*" sound levels at P1, P3, P4, and P5 exceed the King County sound level limits. As noted previously, ambient noise contributes significantly to the noise environment at perimeter locations P1, P3, and P4, and these non-CHRLF sources cause the predicted cumulative levels to exceed the King County limits at these locations. That is, ambient noises from traffic, airplanes, wildlife, etc., are resulting in elevated sound levels in excess of the King County limits, not activity at the CHRLF or its tenants.

Other noteworthy conclusions of the results summarized in **Table 6** include the following:

- At P1, daytime decreases in sound levels during Area 6 operation are due to CHRLF active landfill equipment and haul traffic being moved to the east side of the landfill. During development of Area 5, equipment would be farther from P1 but truck traffic would still use the west perimeter road.
- At P2, landfill operations at Area 5 and 7 during daytime hours would be higher than at Area 6. This is due to the location of the truck routes during development of Area 5 and 7 being nearer P2 than the east perimeter road used during Area 6 operations. Also, CHRLF equipment would be furthest from P2 during filling of Area 6.

- At P3, daytime sound levels due to CHRLF activity would be highest when operating at Area 5 because equipment would be nearest P3 when operating at Area 5.
- Note the NFS is acoustically negligible relative to background levels at both P2 and P3 during nighttime hours.
- At P4, early morning traffic conditions, likely from Cedar Grove Road SE, result in sound levels that exceed the King County nighttime limits. The highest level of daytime CHRLF activity noise occurs during operations in Area 6, when landfill equipment would be nearest P4.

4.0 FFT ANALYSIS

Selected portions of 2014 and 2015 measurement data were analyzed using Fast Fourier Transform (FFT) signal processing to examine the detailed frequency spectrum of individual noise sources. In addition, FFT analysis was performed on the recorded audio signals from measurements taken during the 2012 Perimeter Noise Study. The goal of the FFT analysis was to correlate the newly-measured source FFT spectrum with the FFT spectrum of the recorded ambient noise signal. For the BEW, newly measured perimeter data were also evaluated against BEW source measurement data.

Note that the following FFT analysis is more of a “frequency-matching” analysis as opposed to a more conventional cross-correlation analysis, the latter of which requires simultaneous measurements at different locations. Results of a frequency-matching analysis do not represent proof that a specific source is being detected at a specific receiving location, however if the frequencies match, it suggests that the two sounds are most likely related. On the other hand, strong tones present in a source measurement that are absent at a receiver location suggest that the source is insignificant at that receiver location.

Additionally, note that no correlation would be expected unless the dominant frequencies generated by the sources in 2012 are the same as those measured in 2014 and 2015. Fortunately, many of the most significant noise sources at the BEW plant are machines that operate at a fixed speed and emit noise at specific frequencies that do not change much over time.

4.1 FFT SPECTRA

The FFT spectra presented in this report identify the level of the noise in 1,800 frequency bands covering the frequency range from 0 Hz to 2,000 Hz. The width of each frequency band is 1.25 Hz, so this processing can distinguish very small changes in acoustic frequency. Each graph represents the average frequency spectrum over about 30 seconds of raw data. Dominant frequencies appear as peaks in the graph. The heights of the peaks represent the levels of the sound at that specific frequency. Some of the higher peaks indicate a specific tone is audible, and lower level peaks suggest inaudible tones. The audibility of a tone depends on the relative level of the tone in comparison to the nearby frequencies. ISO 1996:-2007 is an internationally recognized standard that includes a methodology for calculating the audibility of a tone and whether or not the tone is "prominent." In that standard, the audibility of a specific tone is measured by the quantity ΔLta, which is a measure of how strong the tone is compared to the nearby frequencies. Generally speaking, if ΔLta, is less than 0 the tone is not audible. If ΔLta, is greater than 6 the tone is prominent. Tones with ΔLta, values between 0 and 3 would be perceived as barely audible to most listeners, and ΔLta, values between 3 and 6 would be perceived as clearly audible, but not prominent. It should be noted that the lack of an audible tone does not mean that a specific source is not audible. It simply suggests that the noise is not tonal in nature.

It is important to note that because the graphs presented in this section are based on post-measurement processing of audio recordings, the vertical axes are shown in *relative* decibels (dB). That is, the sound levels presented in this section are not representative of actual sound levels, but rather illustrate a relative comparison between frequencies within each sound. Using relative decibel levels is acceptable for the frequency-matching FFT analysis where the focus is on the relative levels of frequencies instead of the absolute levels. The use of absolute sound levels was presented earlier in this report, in the assessment of CHRLF sound levels, as received at property boundaries.

4.2 2015 Source Sound Level Measurements

Source sound level measurements used in this FFT analysis were taken by Ramboll Environ on January 14, 2015 using a B&K Model 2250 sound level meter that also collected audio data for these sources. Audio data were recorded using an A-weighting filter. Table 2 summarizes the sound source measurement data collected for this assessment, and the location of sources and measurements is illustrated **in Figure 1 through 5** (**pages 12 through 16**).

[Figure 6](#) presents the narrow band spectrum of the booster gas blowers. The booster gas blowers, located at the north end of the BEW, draw in landfill gas from the transfer line of the NFS and feed it to the BEW plant. The measurement data used in this analysis were collected at a distance of 50 feet, directly north of the blowers. Noise from the blowers was the dominant noise source during this measurement. Results of the data analysis indicate that there are numerous peaks in this spectrum, but only one prominent tone at 131 Hz, with a ΔL_{ta} of 13.4 dB.

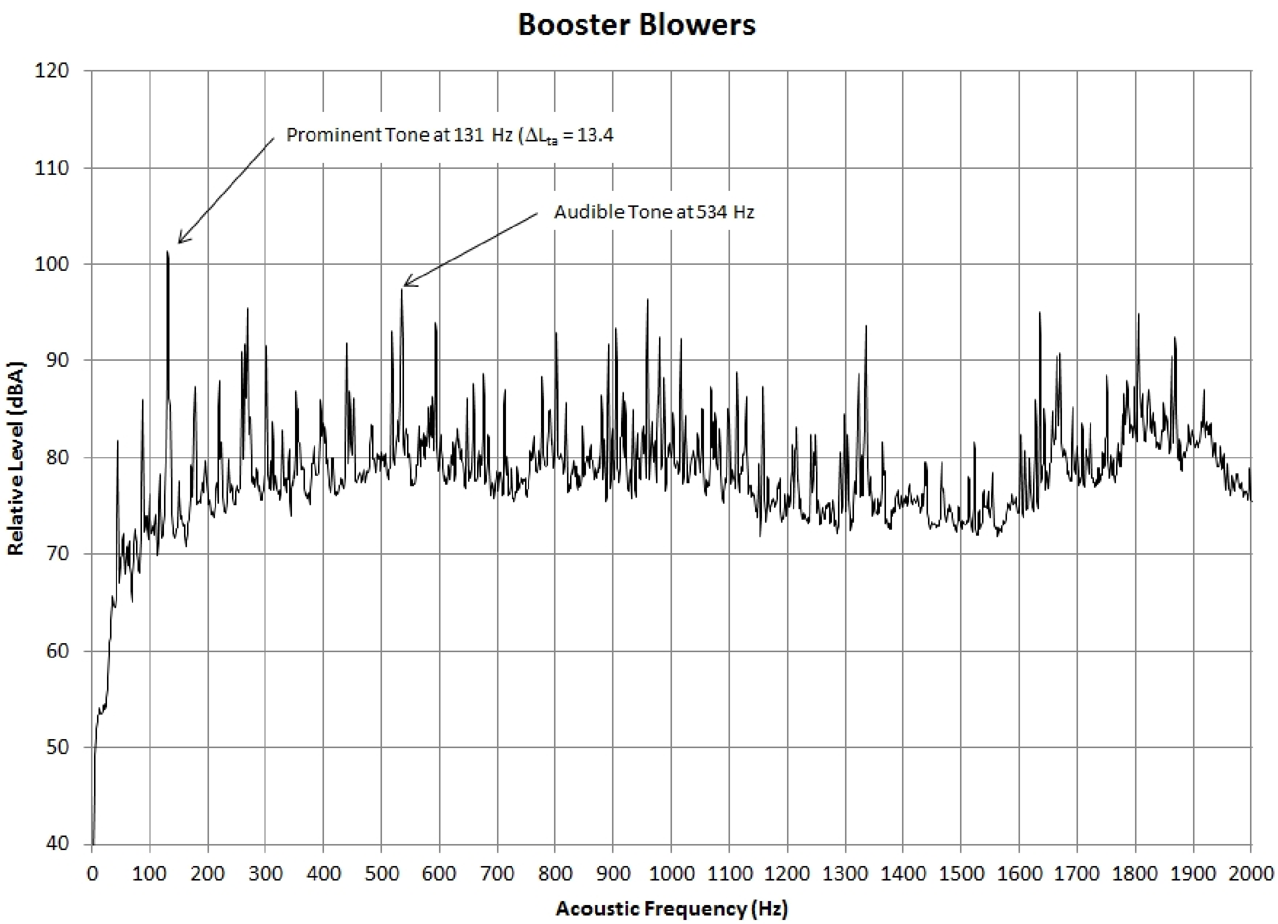


Figure 6. FFT Analysis: Booster Blowers Noise Spectrum

Figure 7 presents the narrow band spectrum measured at the south side of the BEW facility (identified in this report as BEW S). The measurement was taken at a distance of approximately 80 feet from the south wall of the BEW plant, in the road between the BEW and the parking area to the south, and represents equipment located outdoors on the south side of the facility. Noise from the south side of the BEW plant was the dominant noise source during this measurement. There are a few peaks in this spectrum, but only one prominent tone at 90 Hz, with a ΔL_{ta} of 8.8 dB. Note that a 90 Hz frequency is commonly radiated by diesel generators running at 1800 RPM.

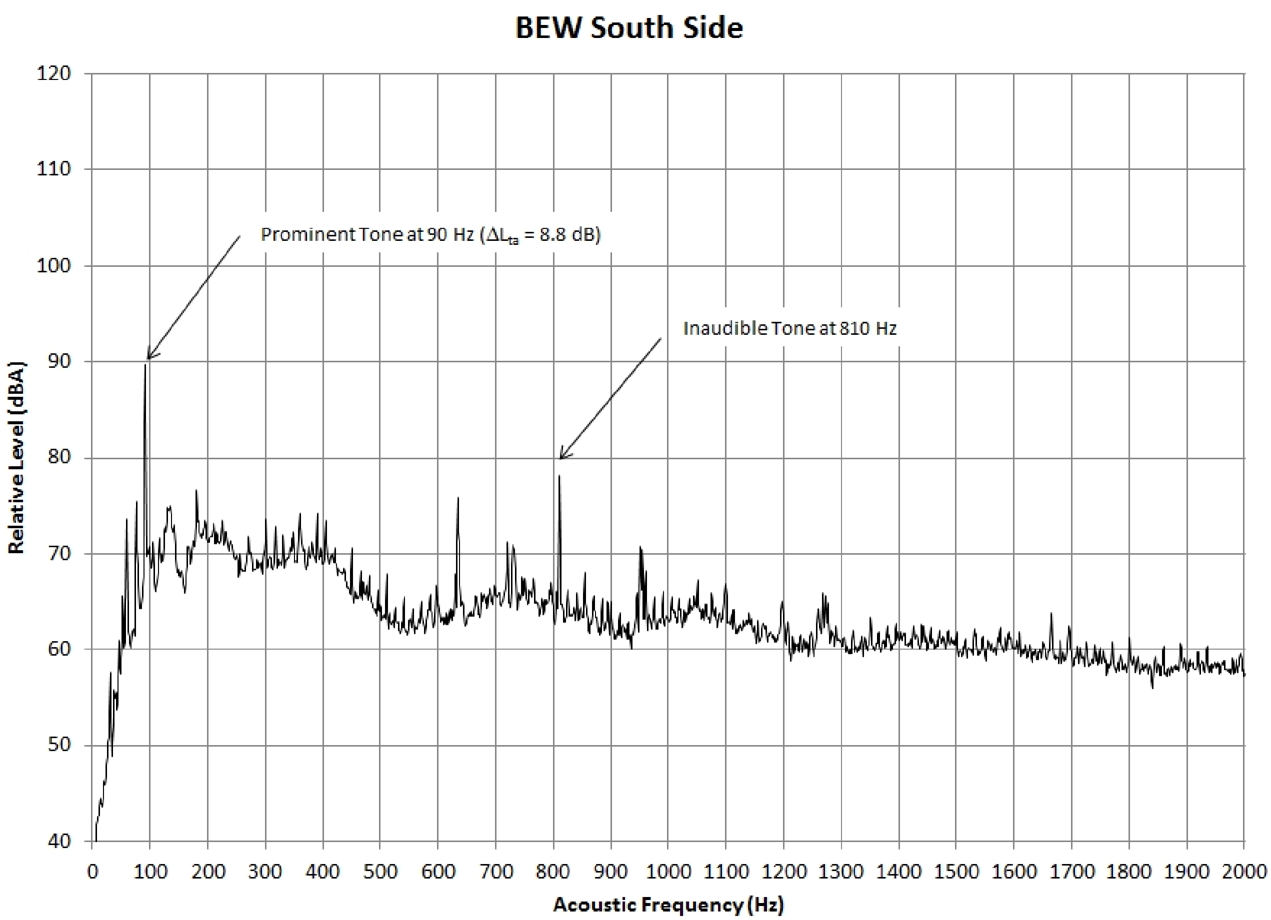


Figure 7. FFT Analysis: BEW South Side

Figure 8 presents the narrow band spectrum measured adjacent to the roll-up door along the east side of the BEW plant, at the shipping and receiving area of this facility (identified as BEW S&R). The door was closed at the time of the measurement because this door is typically closed. The measurement was taken approximately 42 feet directly east from the door. Noise from BEW S&R was the dominant noise source during this measurement. There are numerous low level peaks in this spectrum, but only one prominent tone at 90 Hz, with a ΔL_{ta} of 6.5 dB. Note that a 90 Hz frequency is commonly radiated by diesel generators running at 1800 RPM, and therefore this spectrum may be dominated by noise created by a generator engine block.

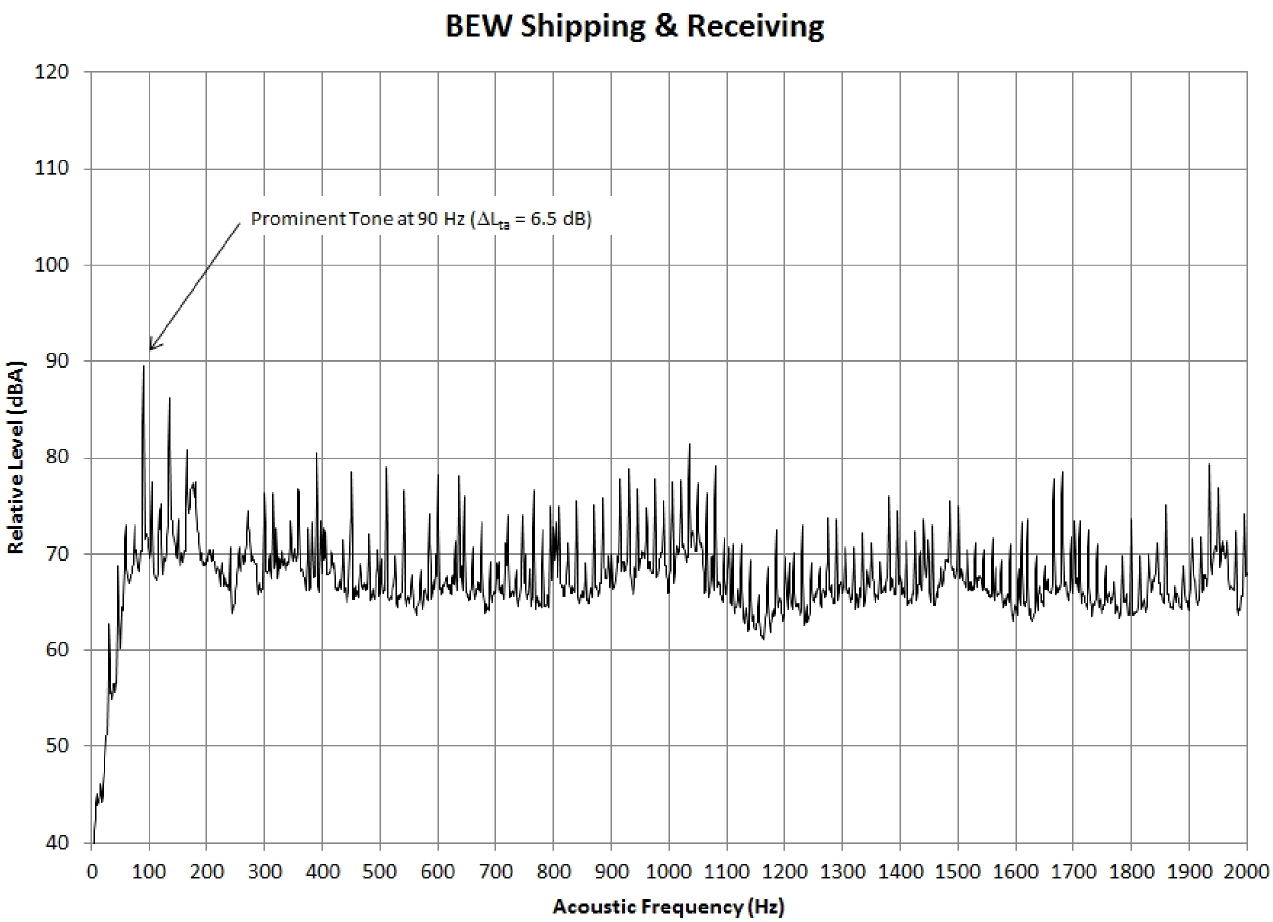


Figure 8. FFT Analysis: BEW S&R

Figure 9 presents the narrow band spectrum of a measurement taken at the west side of the BEW plant (BEW West). The measurement was taken in the paved area west of the large gas storage canisters at the BEW plant, approximately 15 feet below the grade of the facility, and at a distance of 66 feet. The measurement included several cycles of gas release noises at the BEW that are most audible along the west side of the facility. There are several peaks in this spectrum but only one prominent tone at 101 Hz, with a ΔL_{ta} of 6.5 dB.

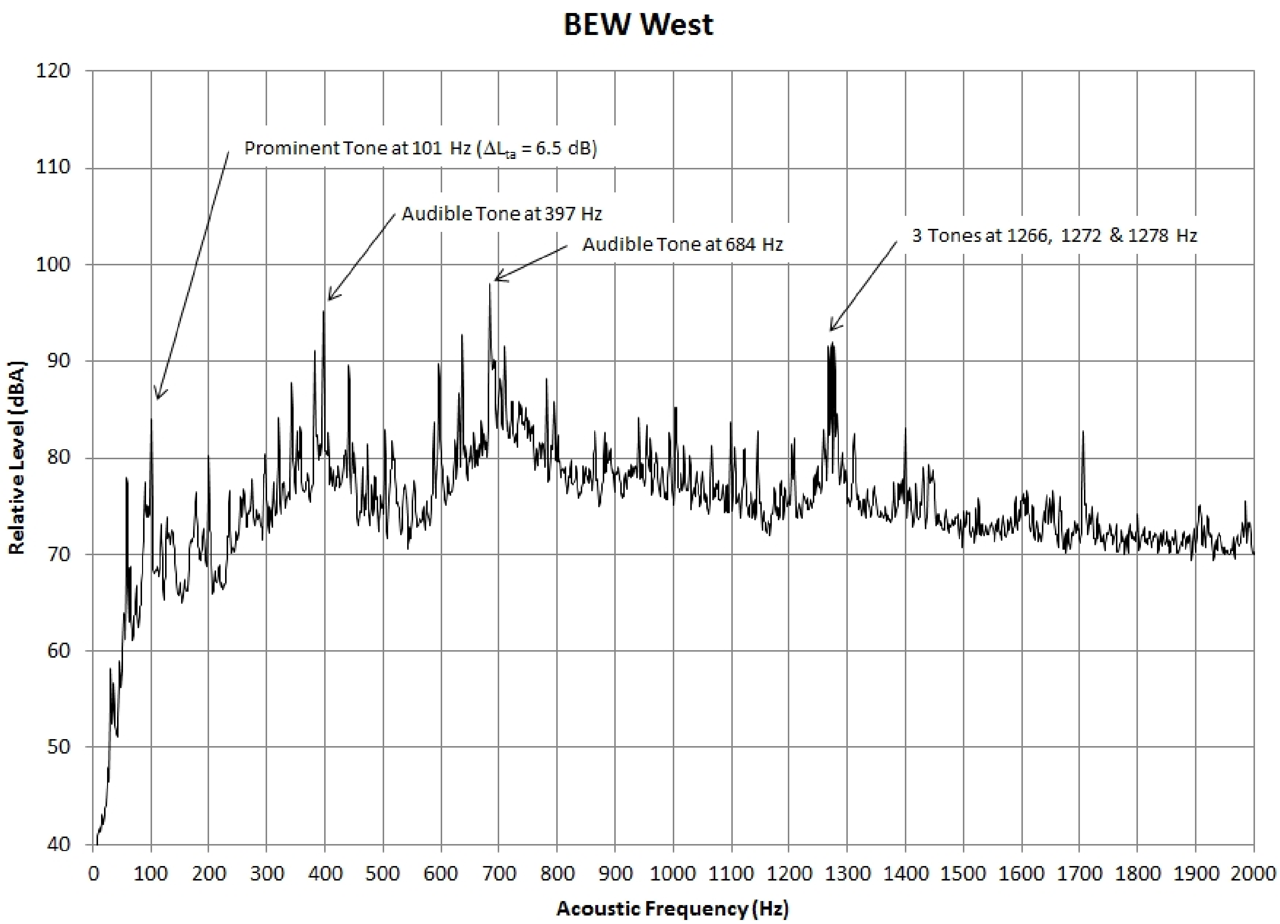


Figure 9. FFT Analysis: BEW West

[Figure 10](#) presents the narrow band noise spectrum measured 48 feet west of the candlestick flare at the NFS, identified as "candlestick." This flare has a smaller stack than the large diameter flare exhausts at the NFS. This source noise measurement was taken to document an acoustically-significant sound source at CHRLF for use in the noise modeling assessment (Section 2.3). An FFT analysis was completed for this source to evaluate its noise characteristics relative to noise emissions from the NFS.

As illustrated in Figure 10, there is a clear and prominent tone at 596 Hz, and there are no other tones in the spectrum at this location.

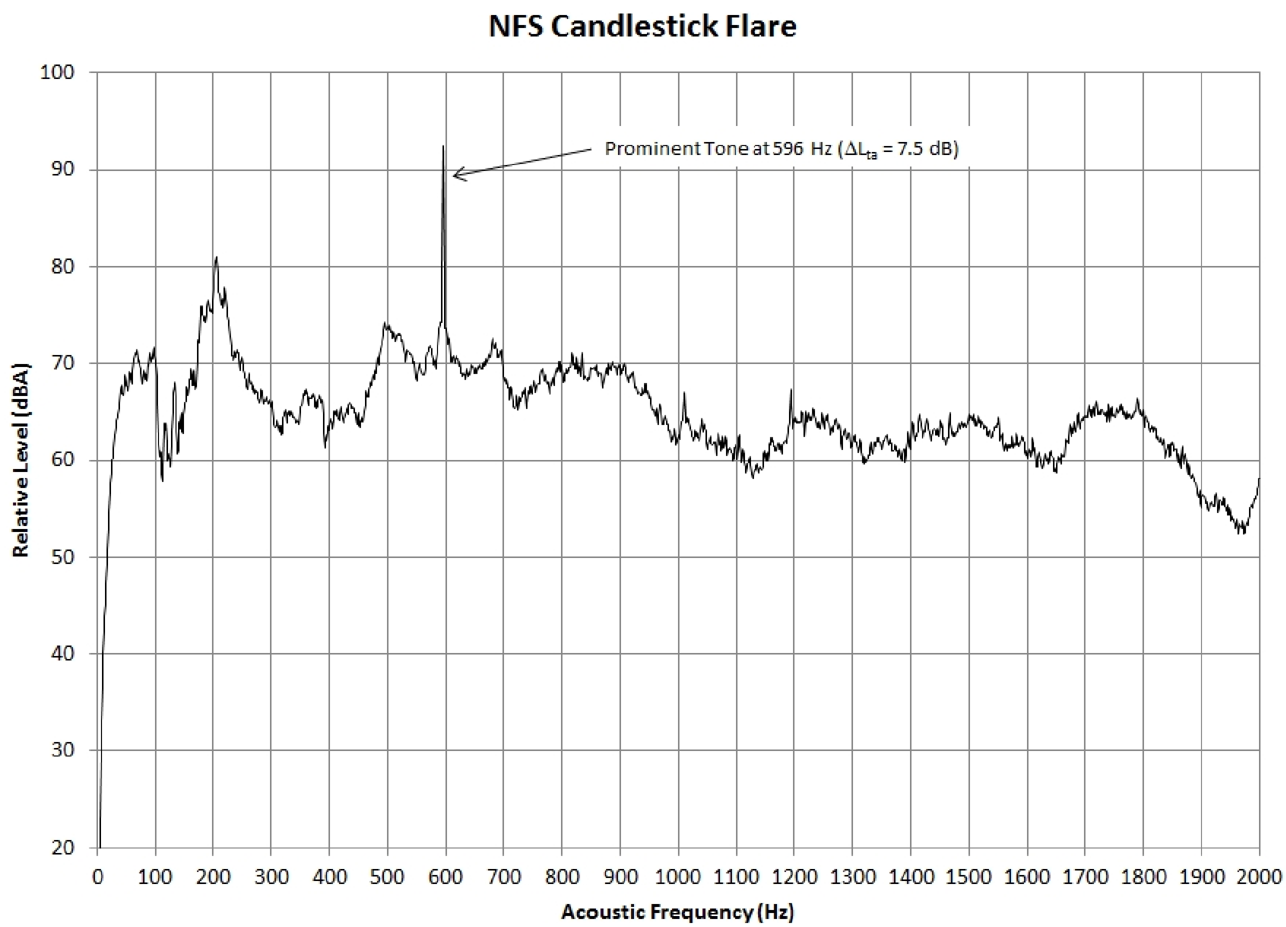


Figure 10. FFT Analysis: NFS Candlestick Flare at 48 feet

Figure 11 and Figure 12 are narrow band noise spectra of the NFS measured at 50 feet and 940 feet, respectively. Measurements of the NFS were taken because, as indicated previously, noise control has been implemented at the north flare station since the 2012 sound level measurements were taken, and as a result new sound level data were required for the noise modeling assessment. Further, the 2012 Perimeter Noise Study identified a clear and distinct tonal noise from the NFS at approximately 1,000 Hz.

As illustrated in Figure 11, there are no prominent tones at the NFS, although there is an audible tone at 1010 Hz with a ΔL_{ta} less than 3 dB that would fall into the barely audible category.

As illustrated in Figure 12, there are no prominent tones at a distance of 940 feet from the NFS. However, note that a tone from the candlestick is visible (but not audible) and the tone at 1010 Hz from the NFS is barely audible with a ΔL_{ta} of 2.4 dB.

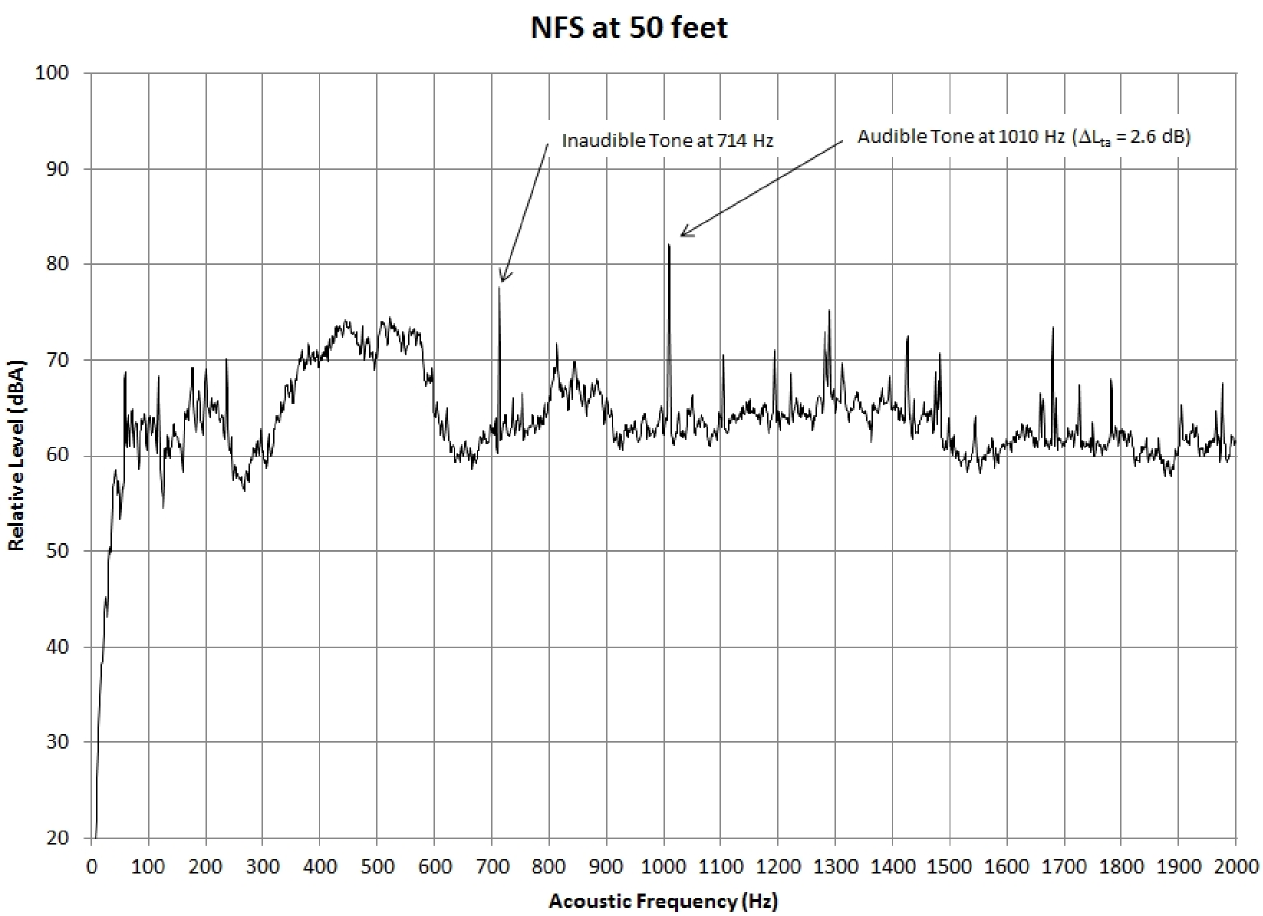


Figure 11. FFT Analysis: NFS at 50 feet

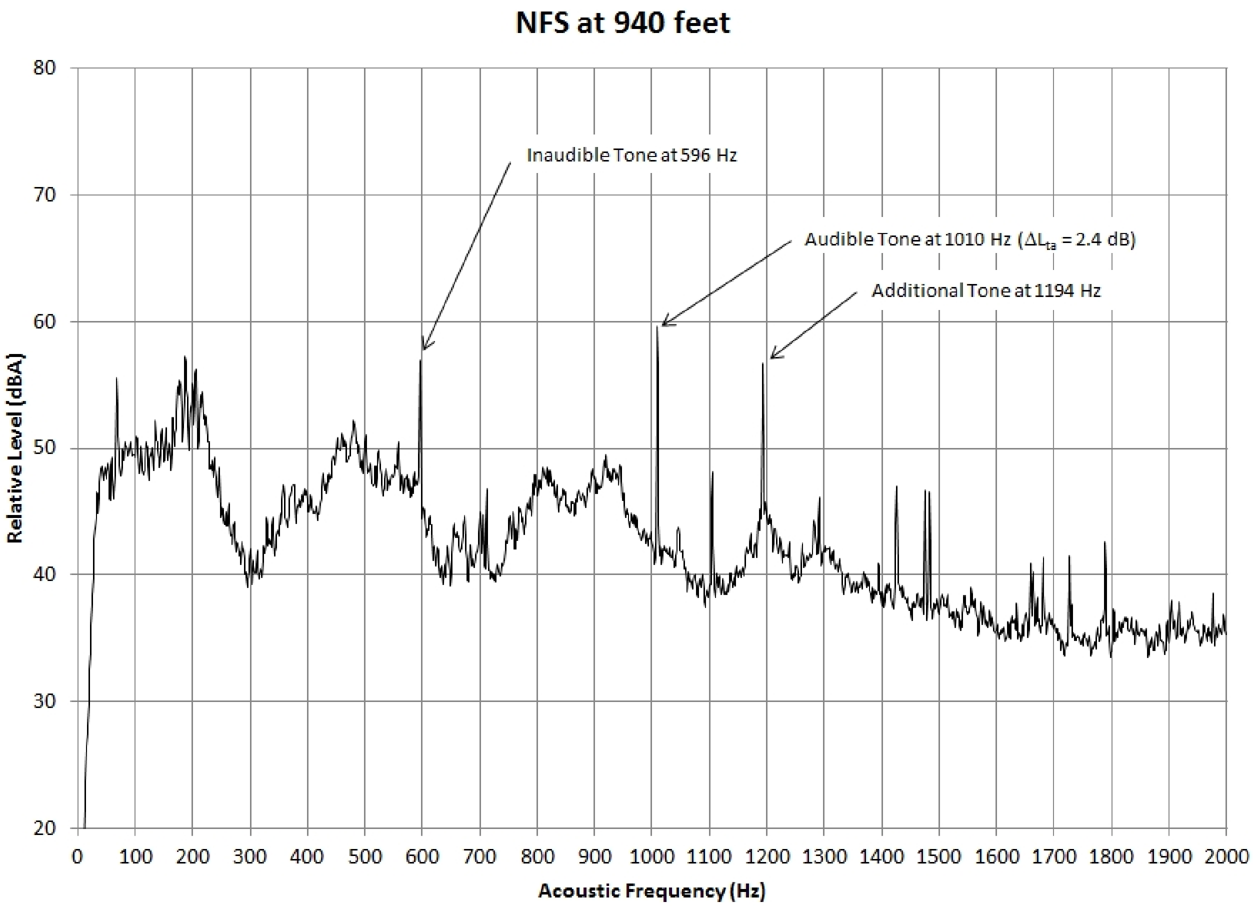


Figure 12. FFT Analysis: NFS at 940 feet

4.3 2012 Receiver Noise Measurements

Sound level measurements taken at perimeter receiver locations were collected in September and October 2012 by Amec Foster Wheeler (then AMEC Environment and Infrastructure, Inc.), and on January 14, 2015 by Ramboll Environ. Perimeter noise measurements in 2012 were taken using Larson Davis model 831 Type 1 sound level meters, and in 2015 using Larson Davis model LxT Type 1 sound level meters. The Model 831 meters in 2012 were programmed to record audio files that were un-filtered (i.e., not A-weighted or otherwise). In 2015, a hand-held Tascam DR-05 audio recorder was positioned next to the LxT to record audio, time synched to facilitate post-processing review.

Note that the following FFT results of perimeter noise measurements represent time periods that were either selected based on observer notes (see the 2012 report, Appendix A), or based on review of audio files recorded in January 2015.

Figure 13 presents the narrow band spectrum measured at P1 in 2015 during a period with little interference from truck traffic or ambient sources. The measurement was taken at 6:49 a.m., and there is only one notable tone at 397 Hz, but the level of this tone is inaudible at this location. Note that this frequency nearly matches one of tones illustrated in Figure 9 for the BEW West source, so it is highly likely that the noise at this frequency is radiating directly from a source that emits to the west side of the BEW plant. The fact that no other peaks appear in the spectrum presented in Figure 13 suggests that the noise at this location and time is not dominated by the fixed speed sources identified as having prominent or audible tones in Figure 6 through Figure 9 (i.e., the booster blowers, BEW S, and BEW S&R).

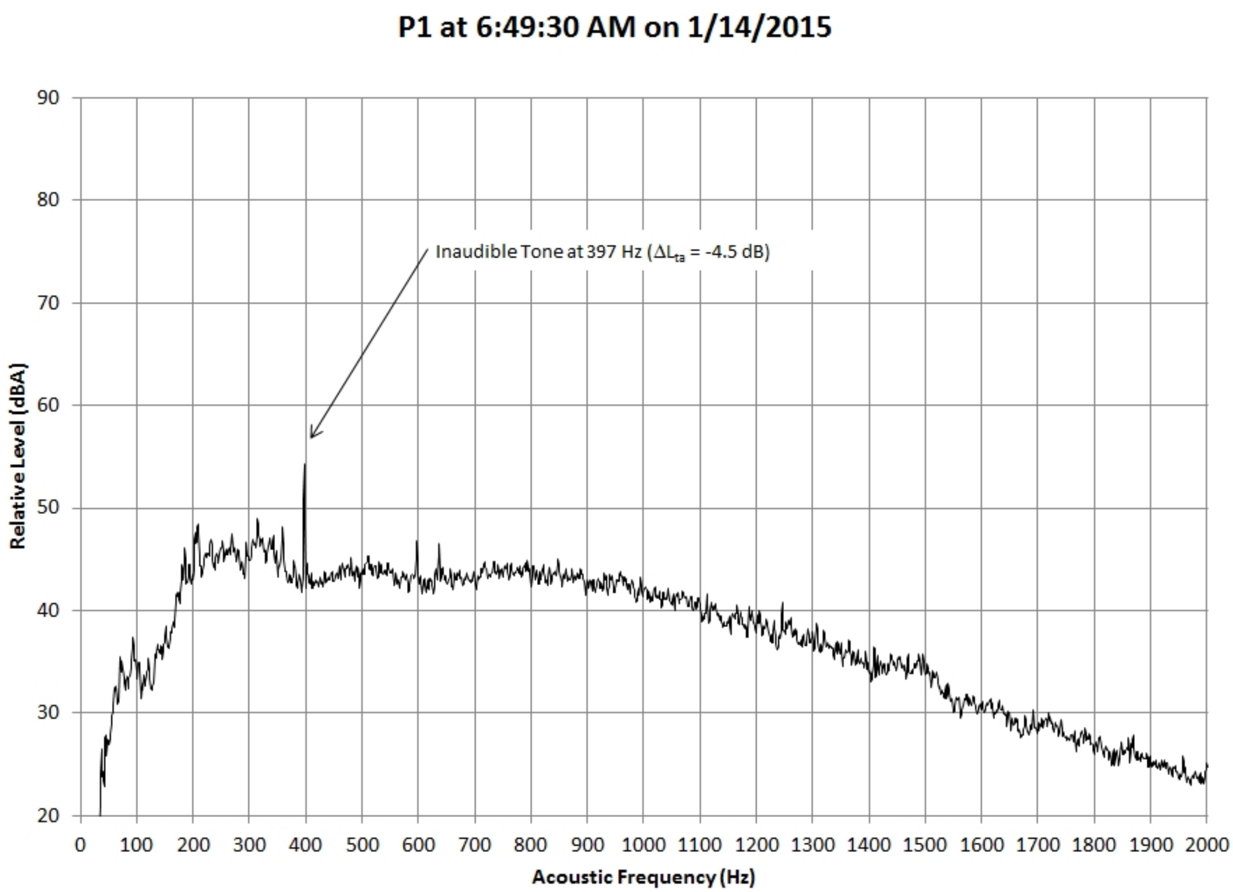


Figure 13. FFT Analysis: P5 at 10:01 p.m. on 9/26/2012

Figure 14 presents the narrow band spectrum measured at P5 during a period with little interference from truck traffic or ambient sources. There is only one notable tone at 1275 Hz, but the level of this tone is inaudible at this location. Note that this frequency nearly matches two of the three tones illustrated in Figure 9 for the BEW West source, so it is highly likely that the noise at this frequency is radiating directly from a source that emits to the west side of the BEW plant. The fact that no other peaks appear in the spectrum presented in Figure 14 suggests that the noise at this location and time is not dominated by the fixed speed sources identified as having prominent or audible tones in Figure 6 through Figure 8 (i.e., the booster blowers, BEW S, and BEW S&R).

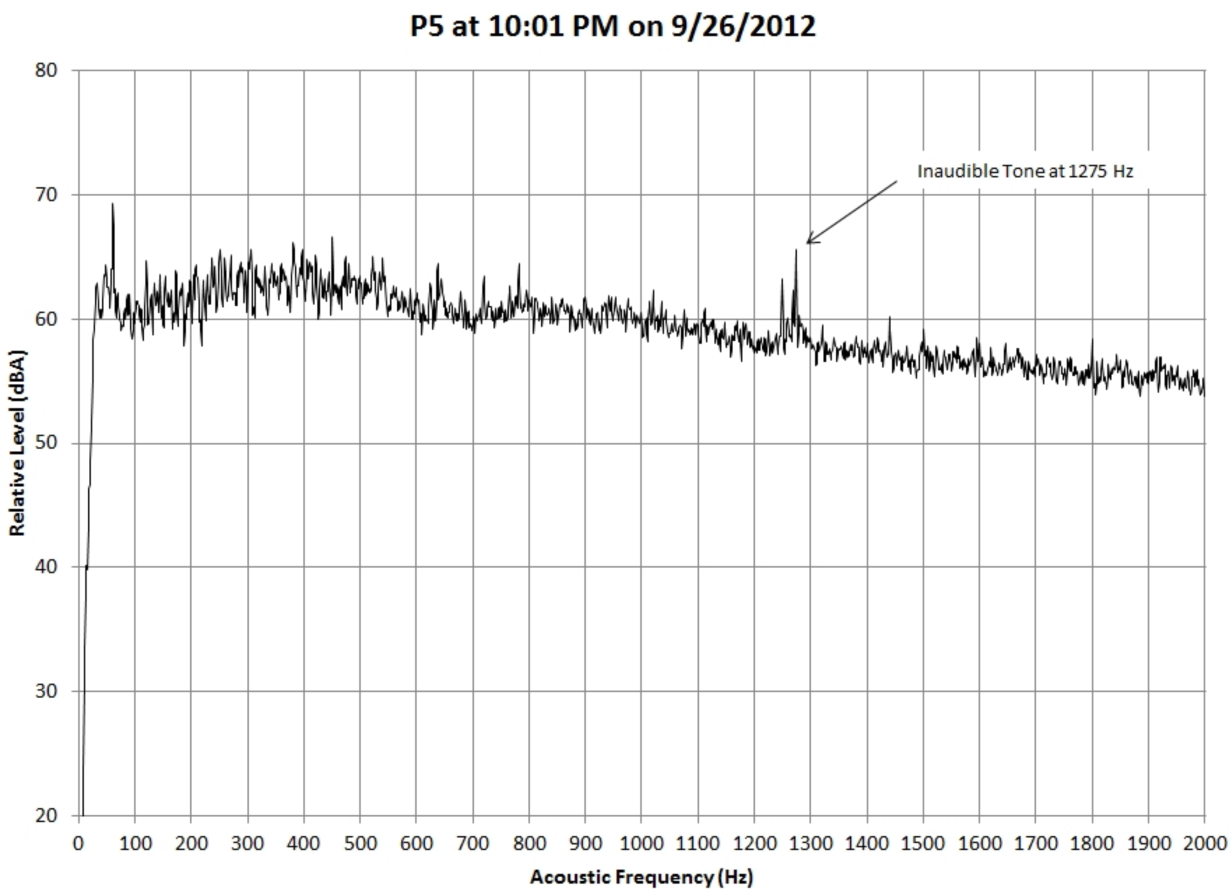


Figure 14. FFT Analysis: P5 at 10:01 p.m. on 9/26/2012

Figure 15 presents the narrow band spectrum measured at P5 taken on the same day as the data illustrated in Figure 14 but earlier on the same day. There is only one inaudible tone at 494 Hz at this location. Note that this frequency does not match any of the tones recorded in Figure 6 through Figure 9. The fact that there are no matching frequencies suggests that the noise measured at this location and time is not dominated by any of the fixed speed sources with prominent or audible tones identified in Figure 6 through Figure 9.

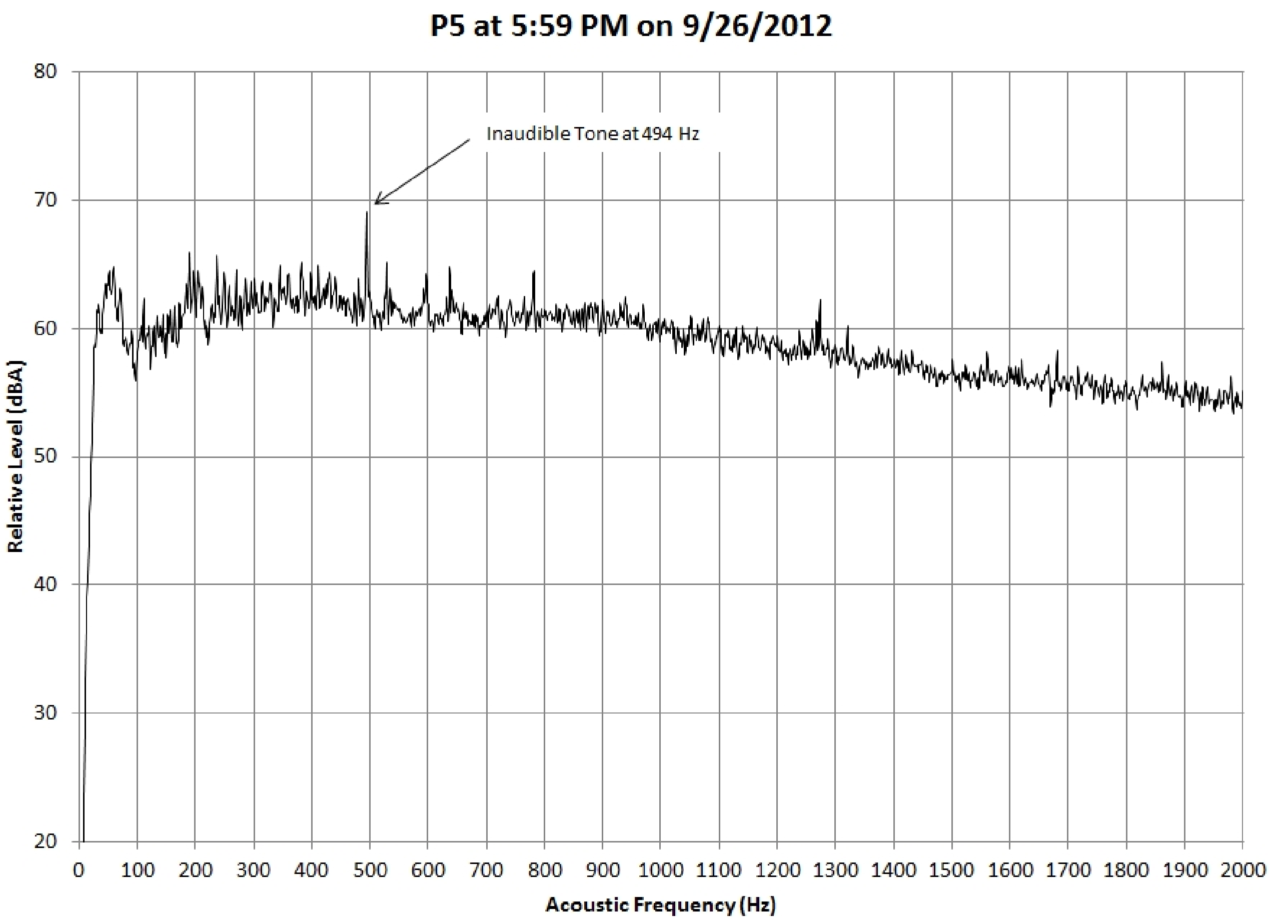


Figure 15. FFT Analysis: P5 at 5:59 p.m. on 9/26/2012

Figure 16 presents the narrow band spectrum measured at P1 at 9:00 p.m. on 9/25/2012. There are several tones in the spectrum, but none are prominent and none have a ΔLta greater than 2 dB. Only one tone (398 Hz) closely matches any of the other measured source level tones (the 397 Hz tone shown in Figure 13). The fact that there are no other matching frequencies in this spectrum suggests that the noise at this location and time may not have been dominated by any of the fixed speed sources identified as having prominent or audible tones in Figure 6 through Figure 9.

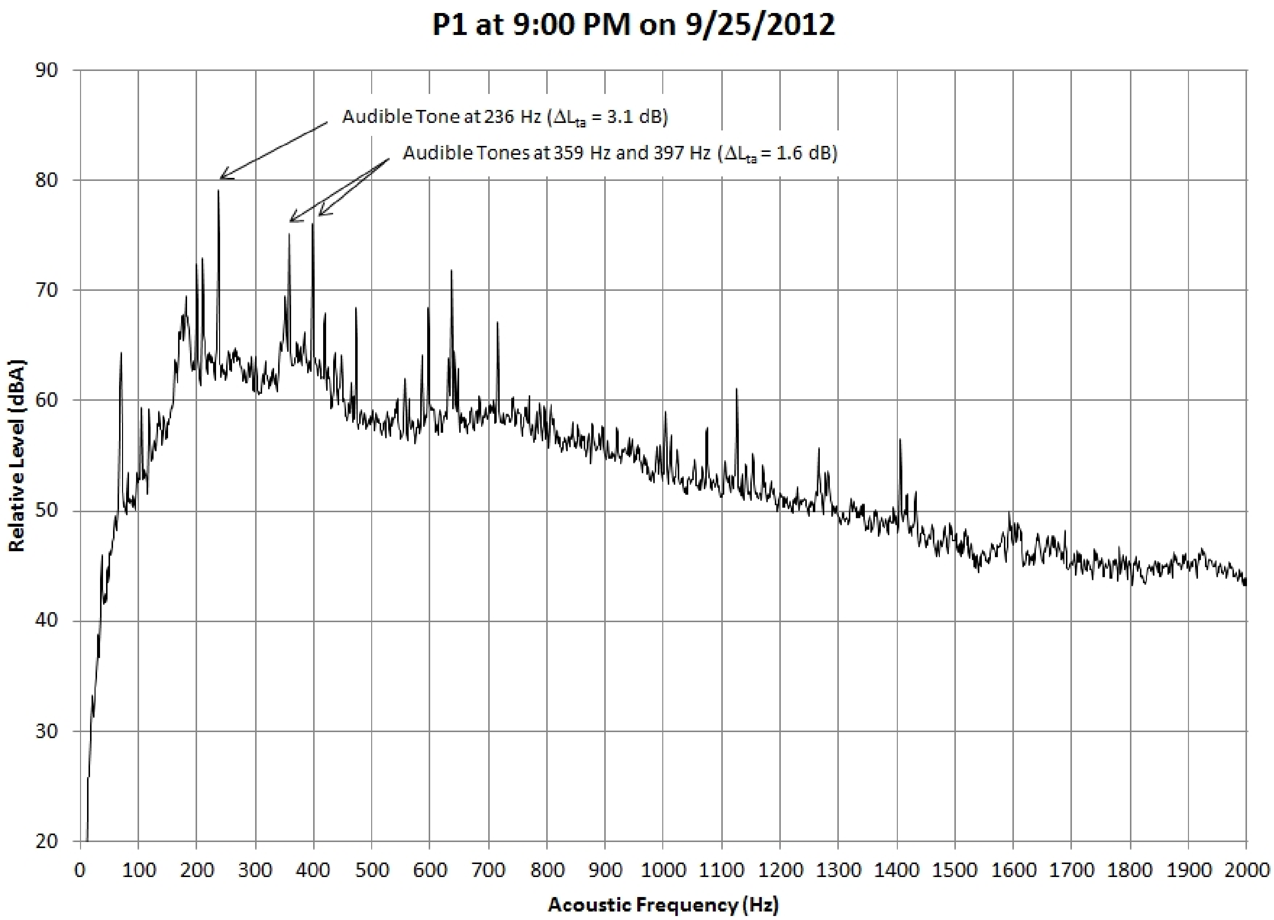


Figure 16. FFT Analysis: P1 at 9:00 p.m. on 9/25/2012

It is worth noting that BEW plant noise is clearly audible in each of the audio files, and the cyclic whine is audible in the measurement represented in Figure 16, even though this tone has a ΔLta less than 2 dB. Although noise source data illustrated Figure 6 through Figure 9 do not contain tones that clearly correlate to measured levels at P5, it is possible that noise from other areas within the BEW that were not distinctly represented by the source noise measurements result in the audible noise at P5.

4.4 FFT SUMMARY

The results of the FFT analysis suggest that the measured sound levels at P5 are not highly dependent on the noise generated by the fixed speed noise sources at the BEW plant. There was no evidence of a 90 Hz tone from the engine generators or the 131 Hz tone generated by the transfer line blowers at the north end of the BEW plant. The FFT spectrum at P5 appears to be dominated by broadband noise without any significant peaks. Based on audio recordings and field observations in 2012, it is most likely that noise from the BEW plant that is audible at P5 is from multiple sources within the BEW plant, including sources that may not have been represented by the source measurement data in this study. Note that every attempt was made to accurately document the acoustical footprint of the BEW plant; however, given the size and complexity of the facility, such a task can prove difficult.

The 2015 noise measurements 50 feet and 940 feet from the NFS indicate that the NFS blower tone at 1010 Hz is only barely audible. Therefore, the tonal noise from the NFS has been reduced significantly since the 2012 assessment.

5.0 SUMMARY OF RESULTS

5.1 SUMMARY OF NOISE MODELING RESULTS

Noise modeling results suggest that noise from daytime, early morning, and nighttime operations of the Cedar Hills Regional Landfill do not result in sound levels that exceed the King County sound level limits at the perimeter locations evaluated for this study. The highest levels of CHRLF-related noise were predicted at P1 during daytime hour operations at Area 7, when trucks would access the west perimeter road and landfill equipment would be nearest P1 (**Table 6**).

Noise from the BEW plant was found to result in sound levels that exceed King County limits at P5 only during nighttime and early morning hours (**Table 5**). During early morning hours, trucks leaving CHRLF also exceed the nighttime sound level limits, and as a result overall emissions at P5 were increased due to the contributions of both CHRLF trucks and the BEW.

Noise emissions from the NFS have been greatly reduced since 2012 and are no longer considered tonal. At the nearest receptors to the NFS (P2 and P3), sound levels from the NFS were considerably lower than ambient noise levels during all hours of the day.

The HVAC unit near P4 is a significant sound source. However, HVAC noise levels at P4 are within the King County limits.

Active landfill activity includes the use of compactors, dozers, loaders, tippers, scrapers, and trucks, among other less acoustically significant equipment. Noise emissions from the landfill will change as operations move from one area to the next, towards the finish grade elevation of the landfill. At P2 and P3, noise emissions during Area 5 operations would be highest because landfill equipment would be nearest. Similarly, at P4 noise levels would be highest when operating at Area 6.

Truck traffic also contributes to overall noise emissions from the landfill, and, depending on the truck routes used, will contribute to overall emissions at the nearest receptor locations. This modeling has assumed that truck traffic within the landfill will use the west perimeter road to access landfill Areas 5 and 7, and the east perimeter road to access Area 6.

In general, noise emissions from the landfill are not expected to change significantly between measured levels in 2012 and during activity at finish elevation. The largest potential increase in overall noise emissions would be at P1, where levels may increase by up to 4 dBA over measured 2012 conditions when working at Area 7, though still within daytime sound level limits. Similarly, at P2, sound levels from daytime activity at the landfill during Area 6 operations may increase by 4 dBA but would still be within the King County limits.

5.2 Summary of FFT Results

FFT analysis results suggest that the NFS no longer emits a tonal noise. This was concluded though assessment of noise measurements taken at 50 and 940 feet from the NFS and compared with data presented in the 2012 Perimeter Noise Study.

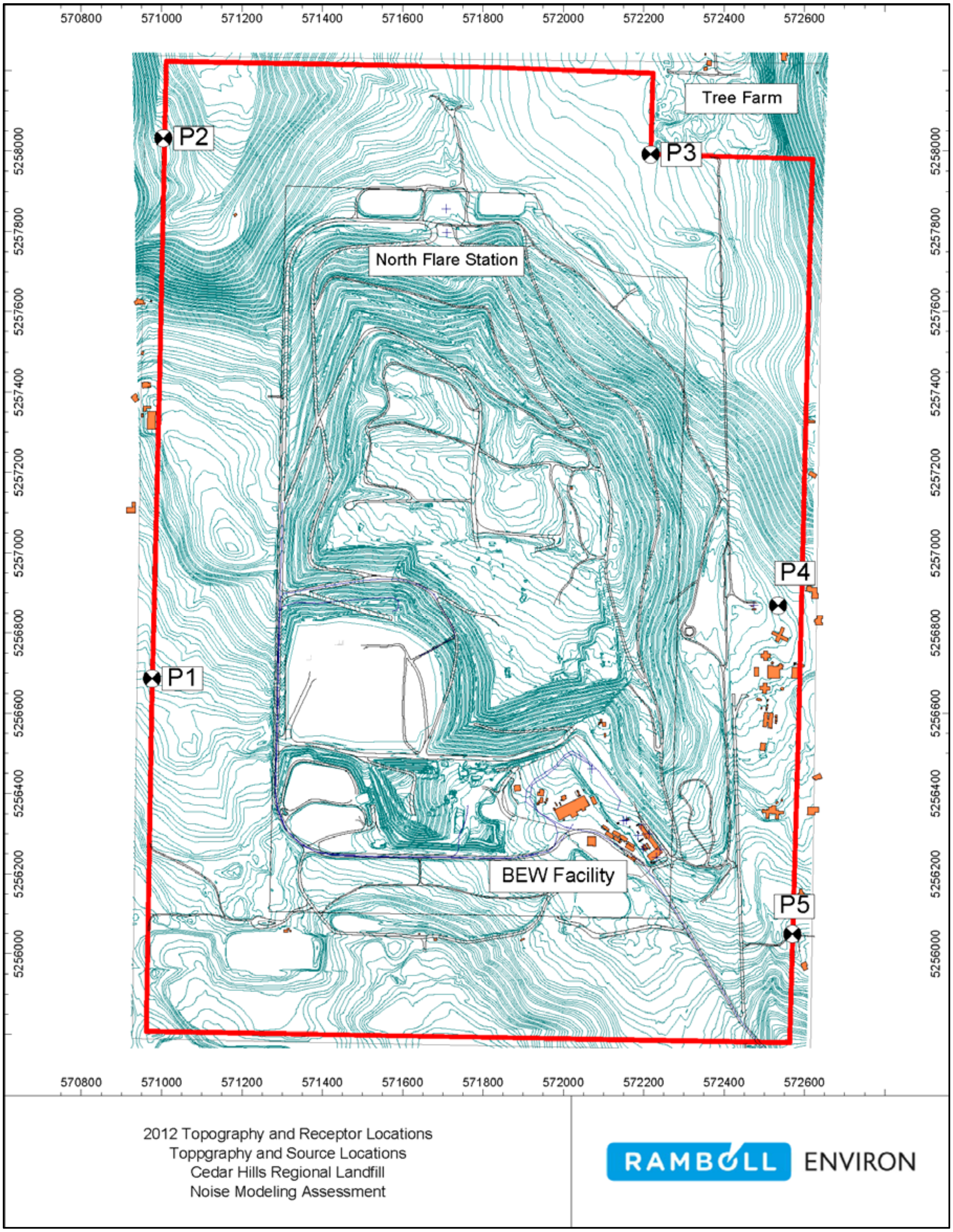
The FFT analysis was not conclusive regarding the source of noise emissions received at P5, based on select sound source measurements of the BEW plant that were used for this analysis. Playback of audio files and field notes from observations the 2012, however, indicate the BEW plant is indeed audible at P5, even if the sound is not tonal.

5.3 General Conclusion

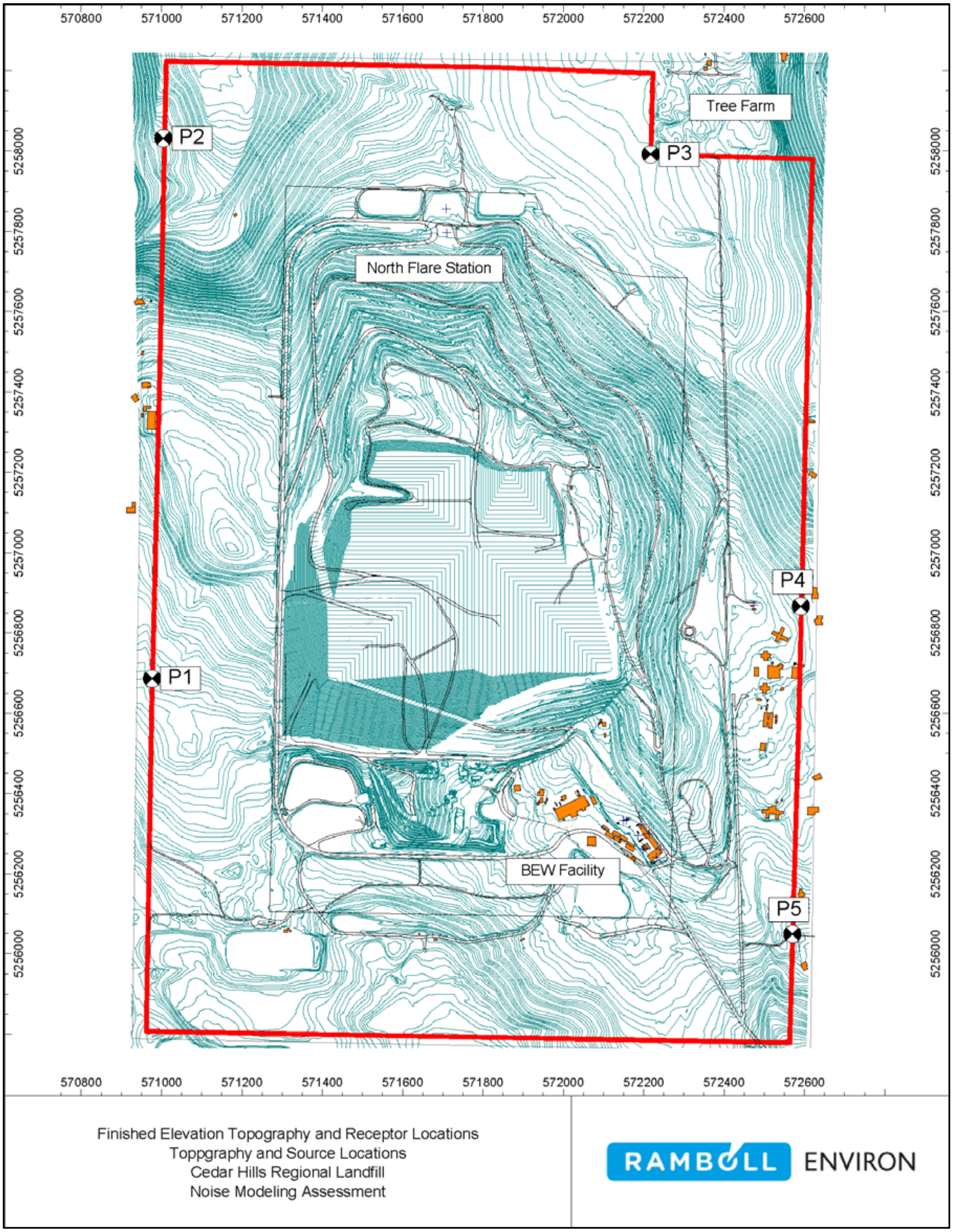
The intent of this assessment was to determine whether CHRLF and/or tenant activity generated noise emissions that exceeded the King County sound level limits. It was found that at P5 during nighttime and early morning hours, the BEW plant exceeded the applicable limits at P5 in 2012, and may continue to exceed limits at P5 during future operations at Areas 5, 6, and 7. Also, during early morning hours (before 7 a.m.) CHRLF truck traffic noise exceeded the limits at P5 and may continue to exceed the limits at P5 during future operations at Areas 5, 6, and 7. Noise control (whether administrative or physical) may be required to reduce these noise sources to within the applicable nighttime limits at P5.

At no other location does either CHRLF or tenant activity exceed the applicable King County daytime or nighttime limits. All measured and observed exceedances in 2012 are attributable to background ambient sounds.

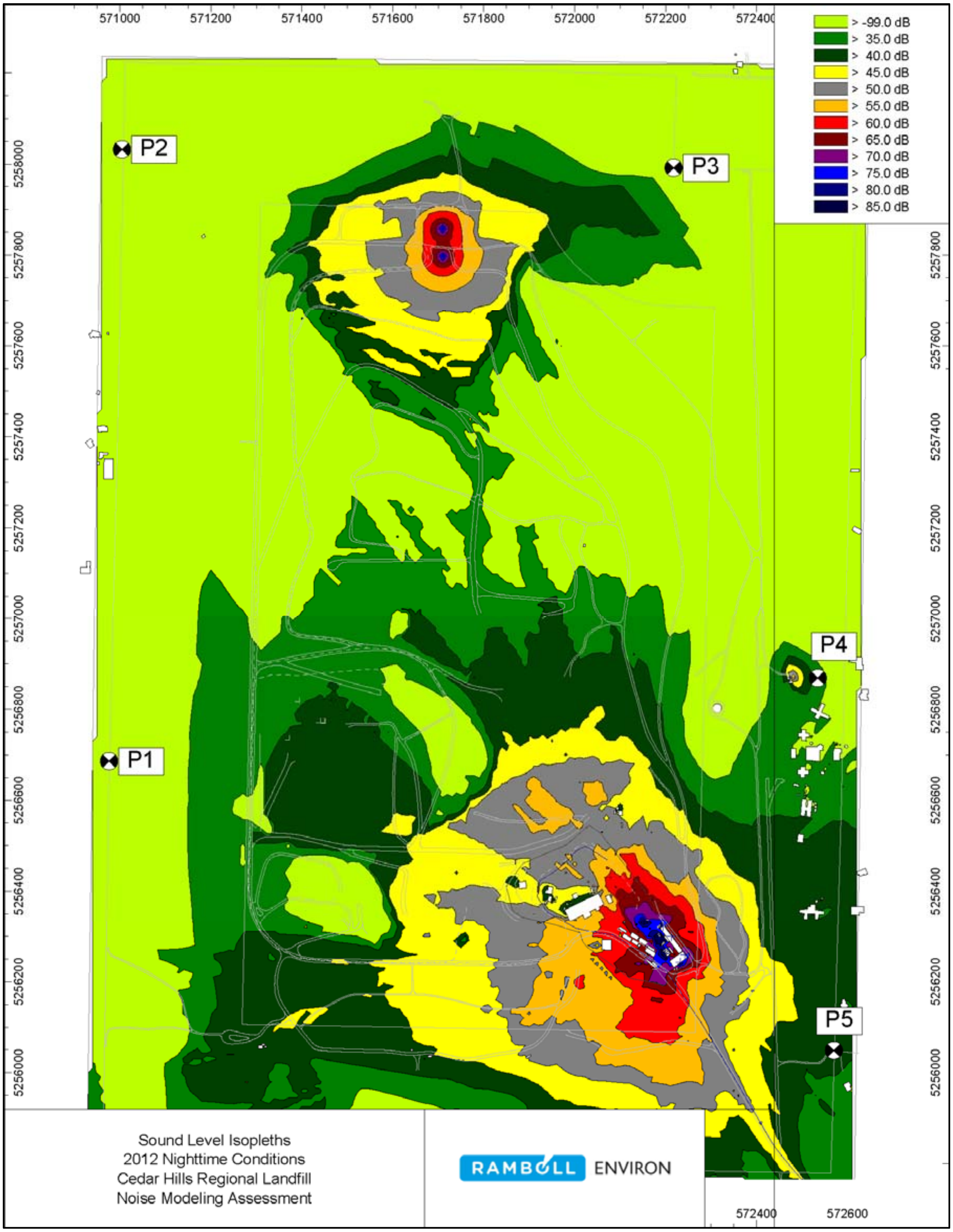
ATTACHED NOISE MODELING FIGURES



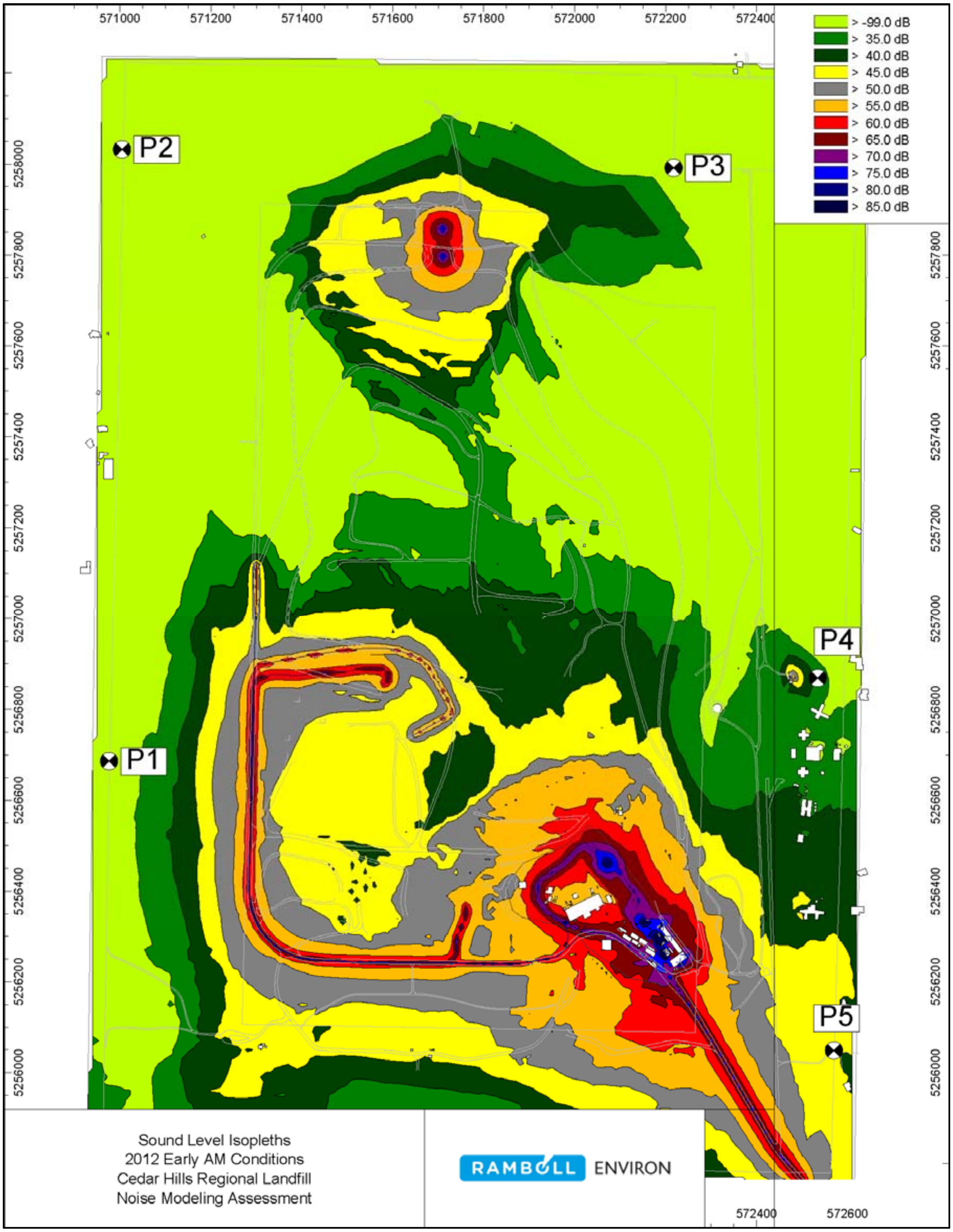
Noise Modeling Figure 1. 2012 Topography and Noise Model Receptor Locations



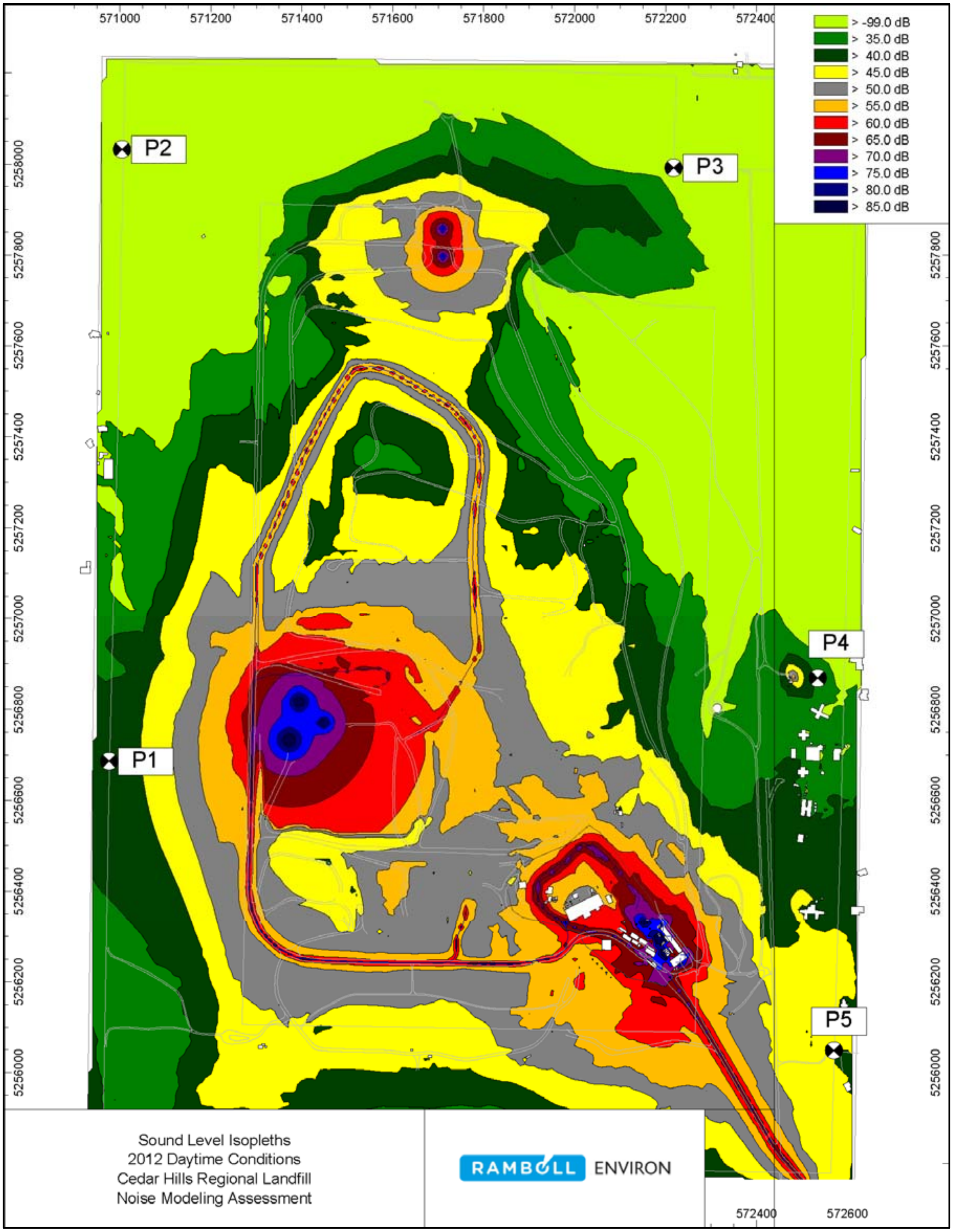
Noise Modeling Figure 2. Finished Elev. Topography and Noise Model Receptor Locations



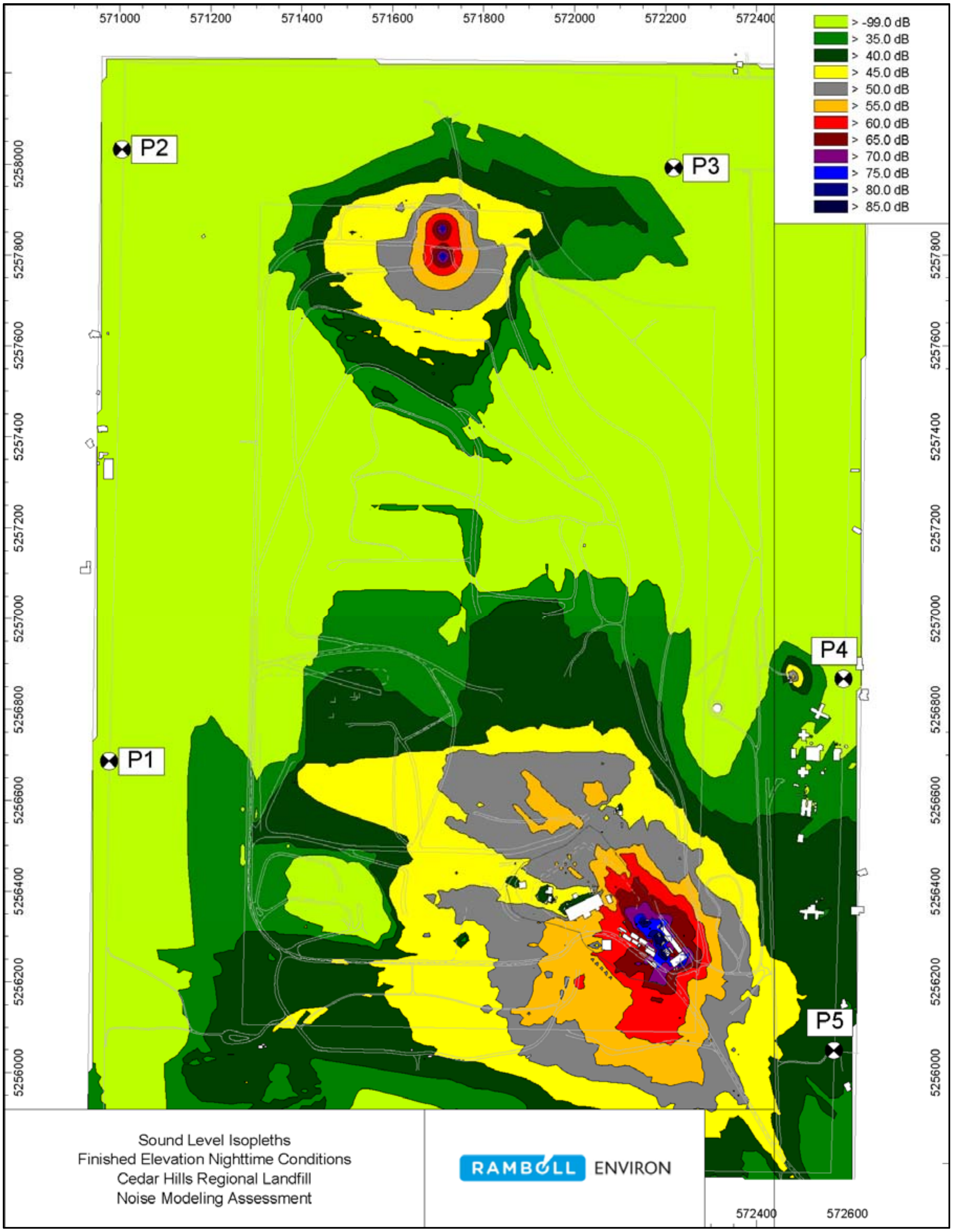
Noise Modeling Figure 3. 2012 Nighttime Conditions



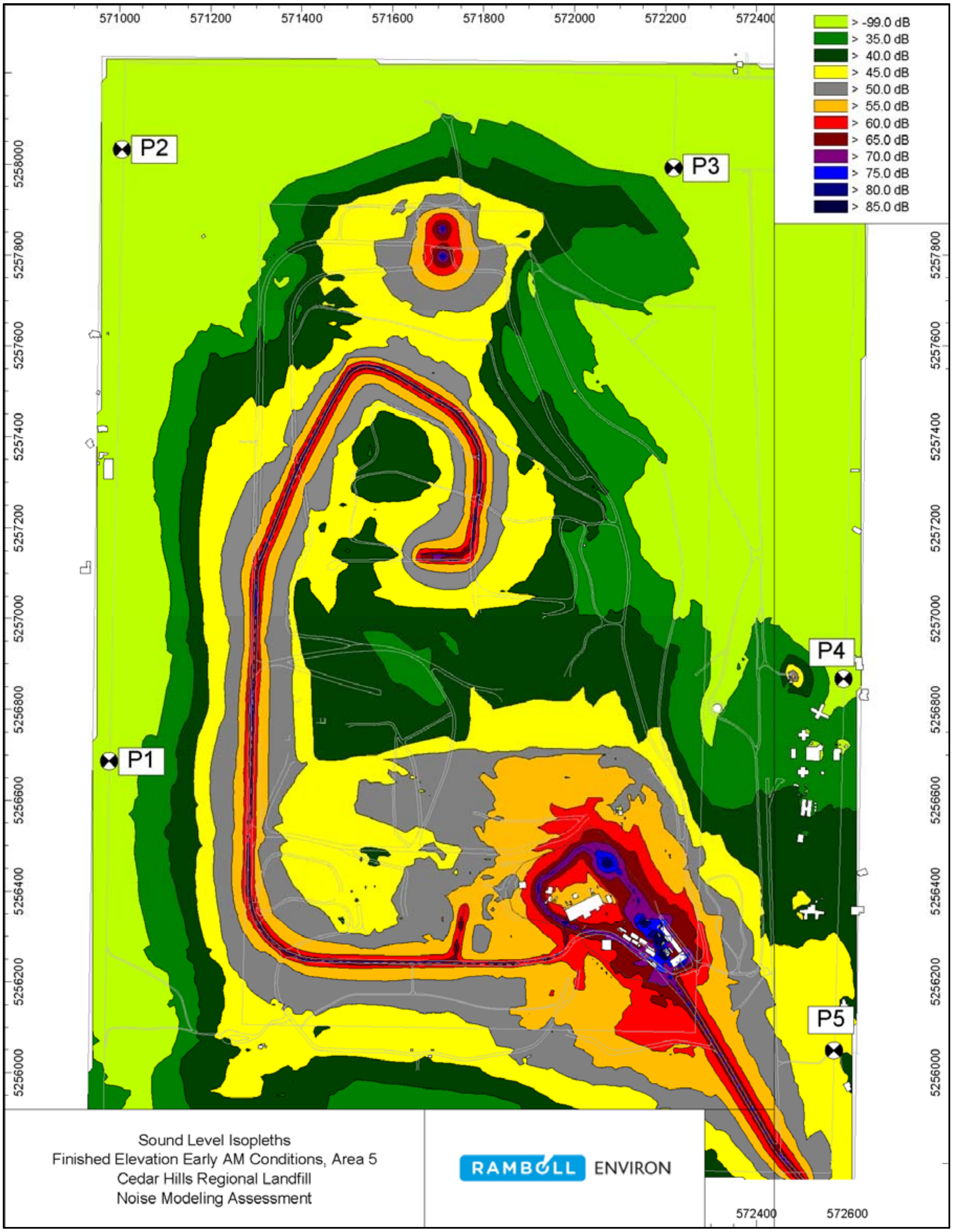
Noise Modeling Figure 4. 2012 Early AM Conditions



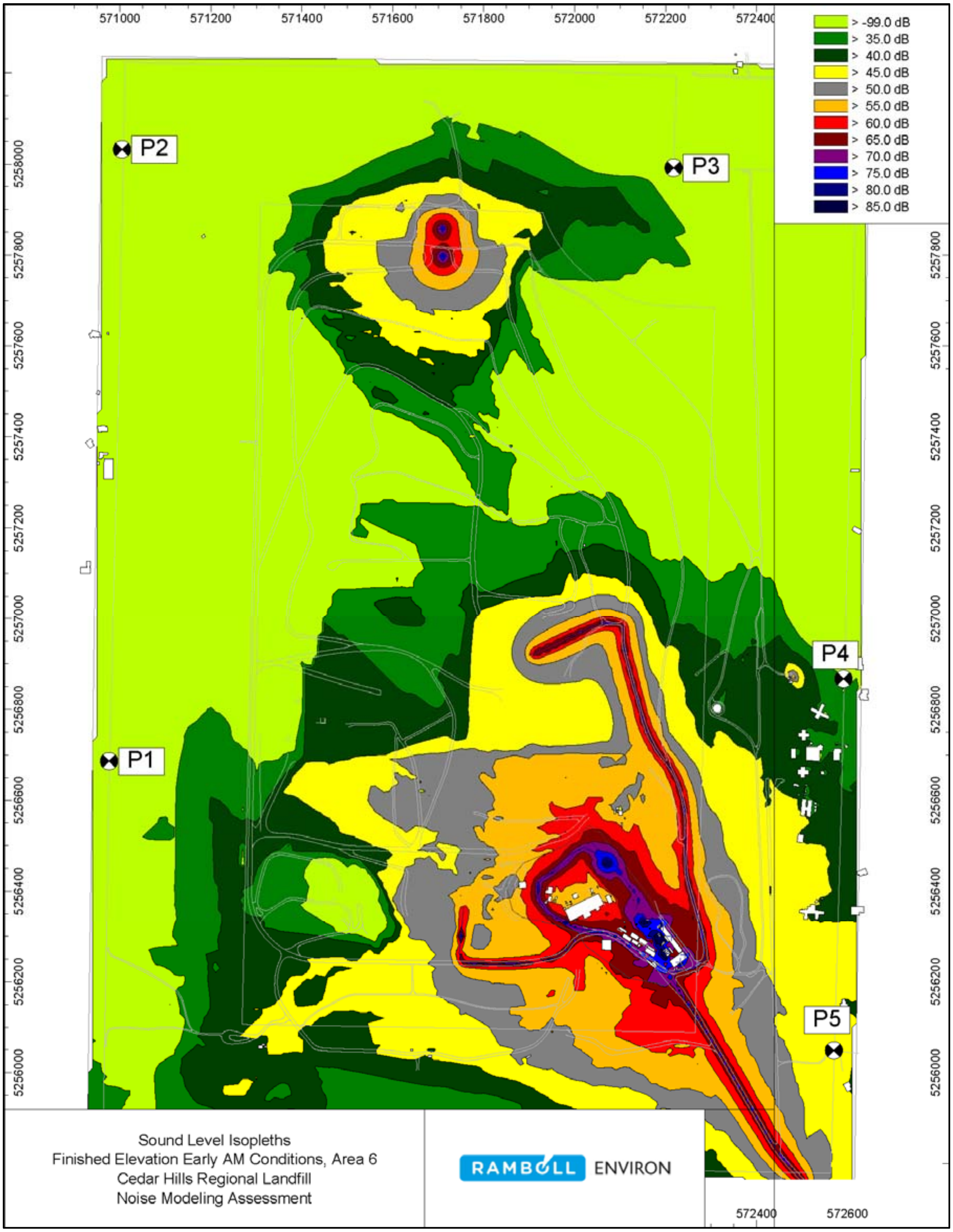
Noise Modeling Figure 5. 2012 Daytime Conditions



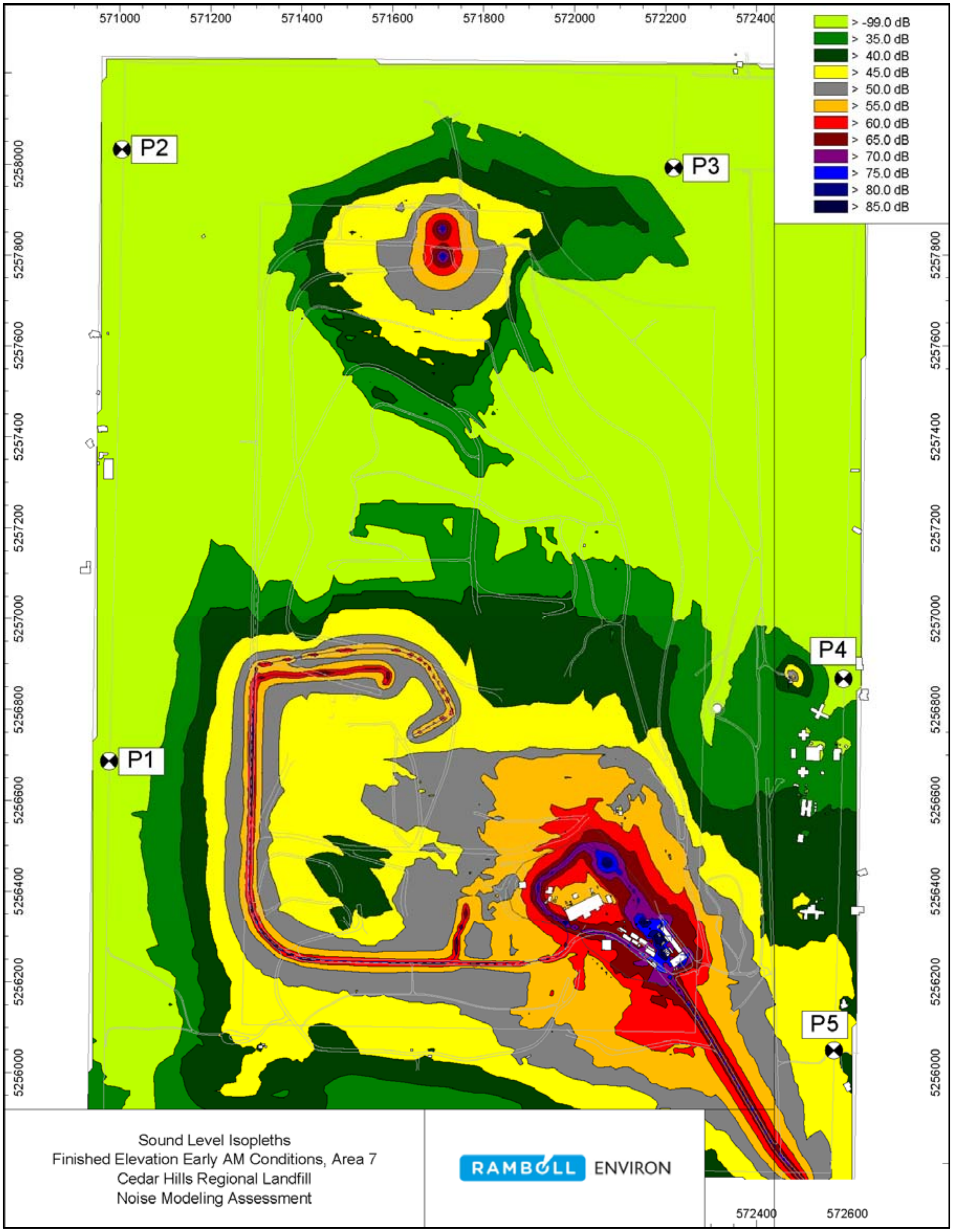
Noise Modeling Figure 6. Finished Elevation Nighttime Conditions



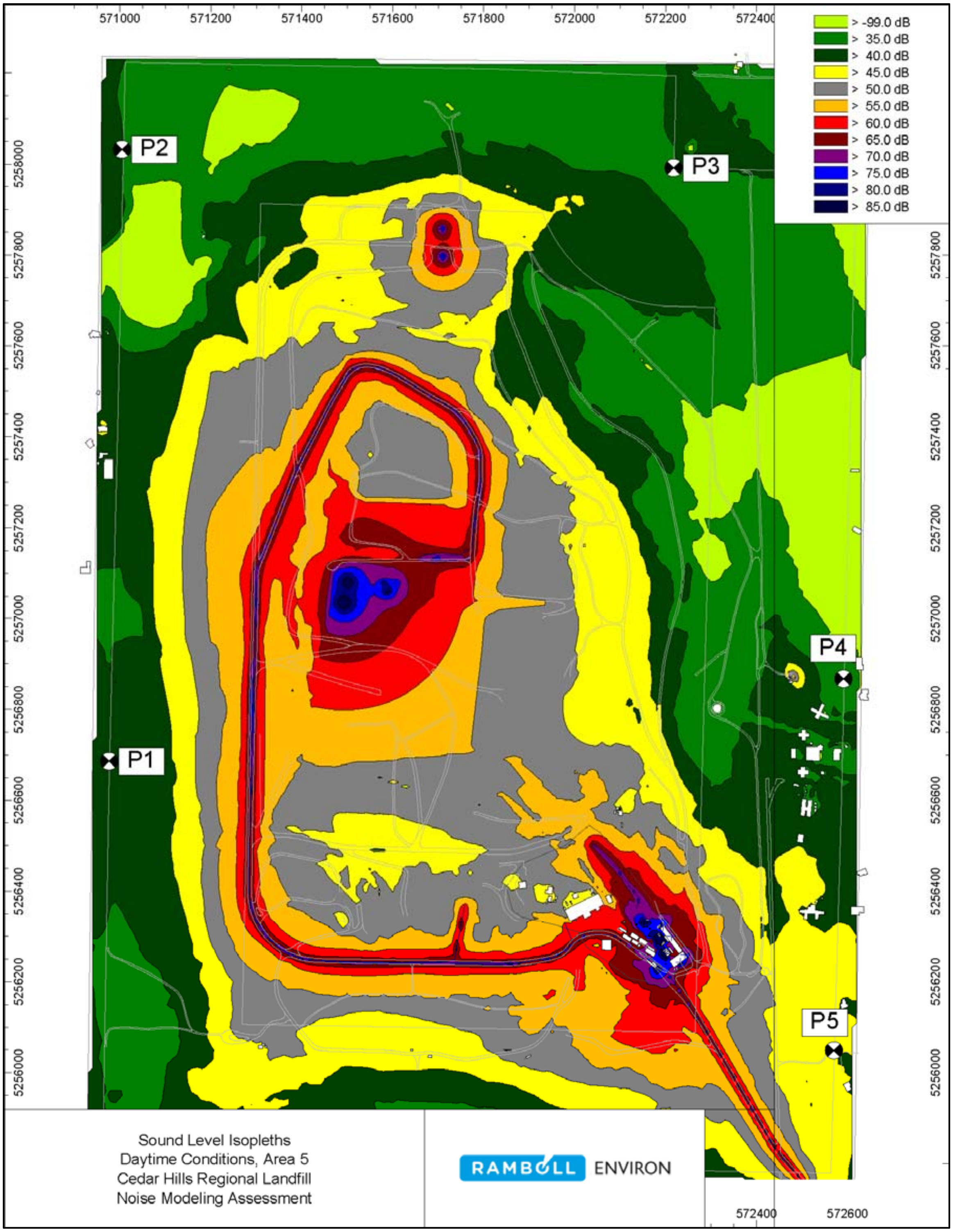
Noise Modeling Figure 7. Finished Elevation Early AM Conditions, Area 5



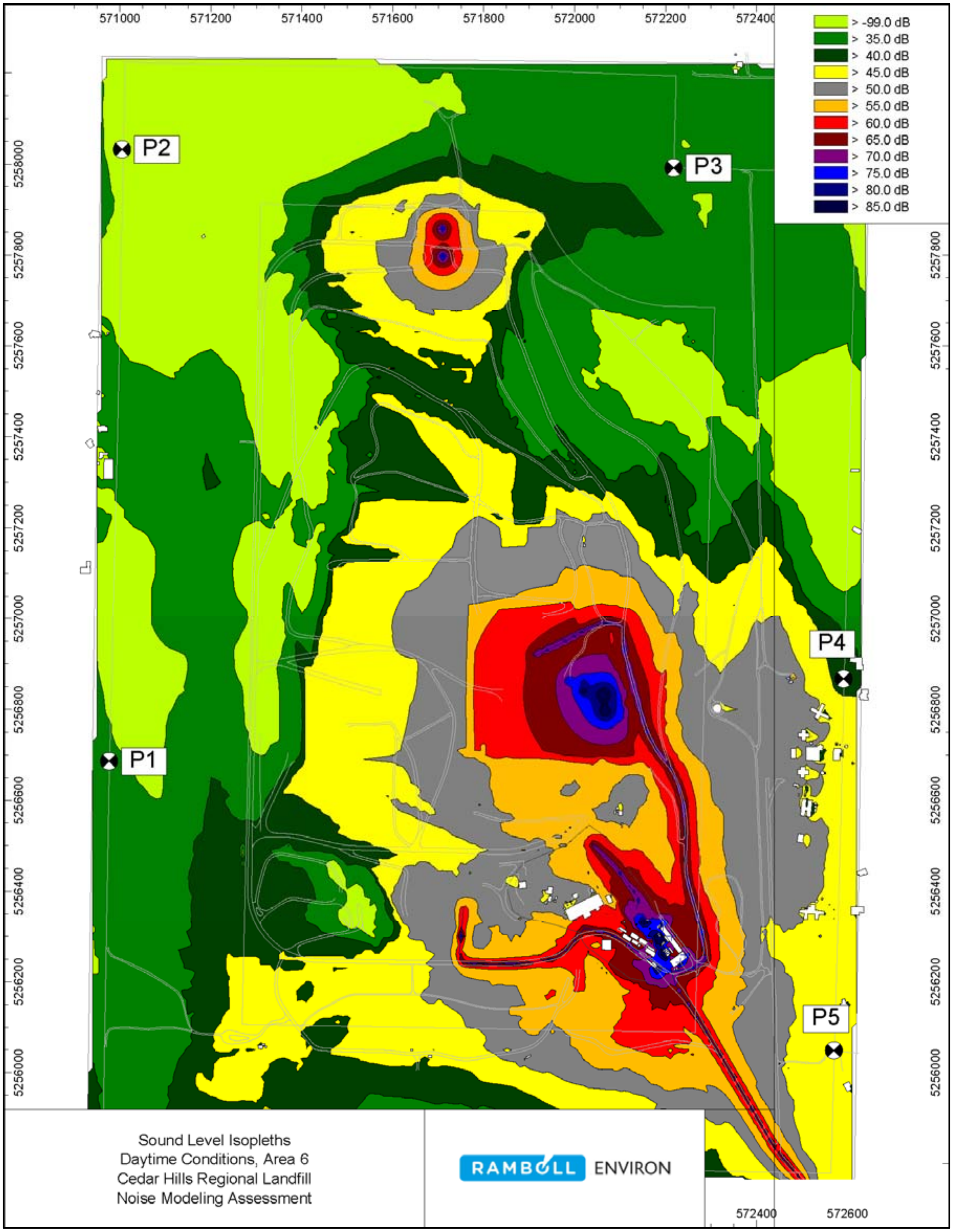
Noise Modeling Figure 8. Finished Elevation Early AM Conditions, Area 6



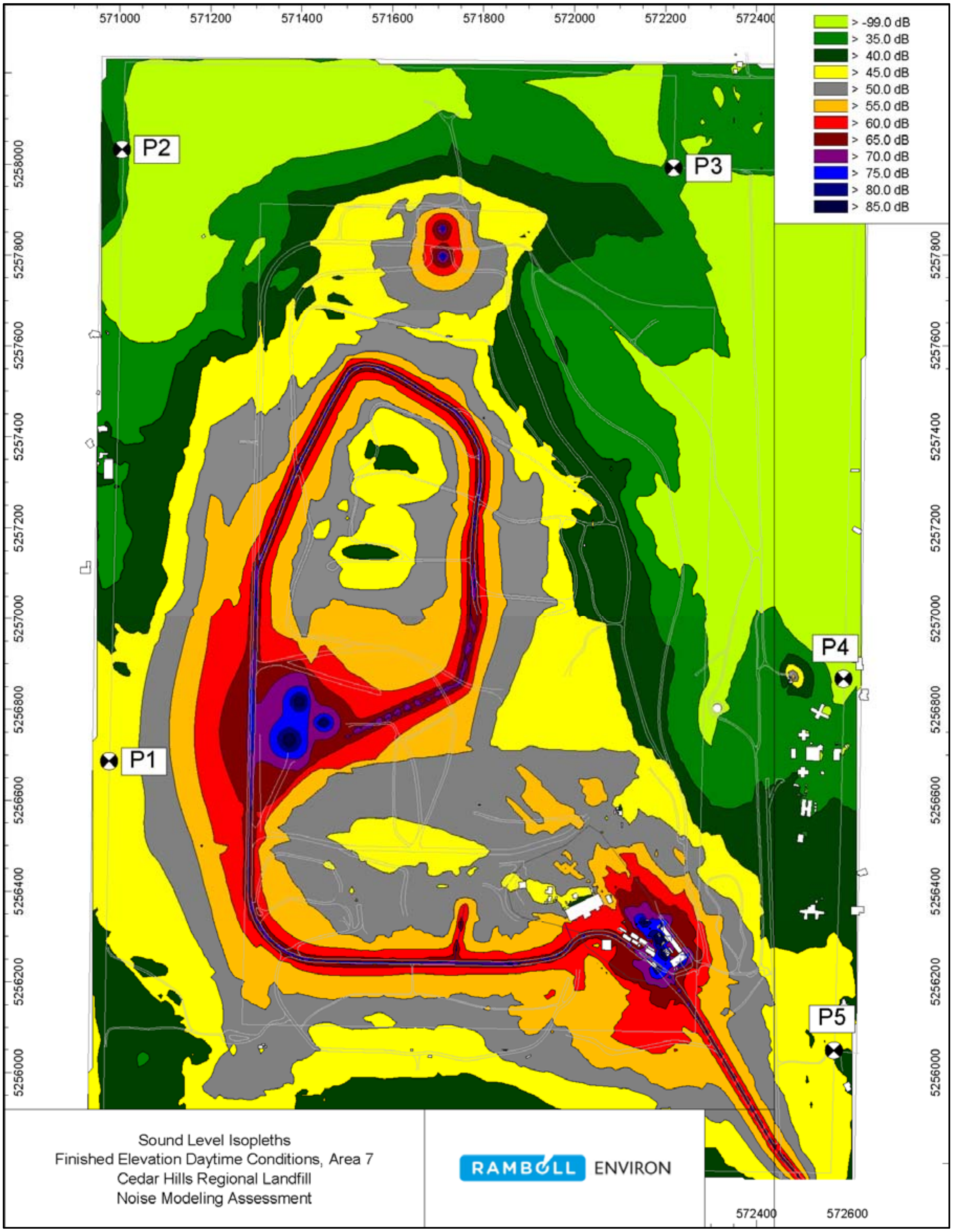
Noise Modeling Figure 9. Finished Elevation Early AM Conditions, Area 7



Noise Modeling Figure 10. Finished Elevation Daytime Conditions, Area 5



Noise Modeling Figure 11. Finished Elevation Daytime Conditions, Area 6



Noise Modeling Figure 12. Finished Elevation Daytime Conditions, Area 7