Kennedy Jenks

7000 N Mopac Expressway, Suite 200
Austin, TX 78731
(512) 852-3000

Ullrich Water Treatment Plant Site Sound Propagation Study

Letter Report

5 May 2023

Prepared for

Austin Water
City of Austin
625 E 10th Street
Austin, TX 78701

KJ Project No. 2245006.00
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List of Abbreviations/Symbols

CNEL	Community Noise Equivalent Level
dB	decibel
dBA	A-weighted decibel
Hz	Hertz
L_d	Daytime equivalent A-weighted sound level between the hours of 0700 and 2200
L_{dn}	Day-night average sound level; 24-hour A-weighted equivalent sound level
L_{eq}	Equivalent continuous A-weighted sound level over a given time interval
L_n	Nighttime equivalent A-weighted sound level between the hours of 2200 and 0700
L_{max}	Maximum equivalent A-weighted sound level for a given time interval or event
L_{min}	Minimum equivalent A-weighted sound level for a given time interval or event
SMP	Sound Measurement Plan
VdB	vibration decibel

Section 1: Introduction

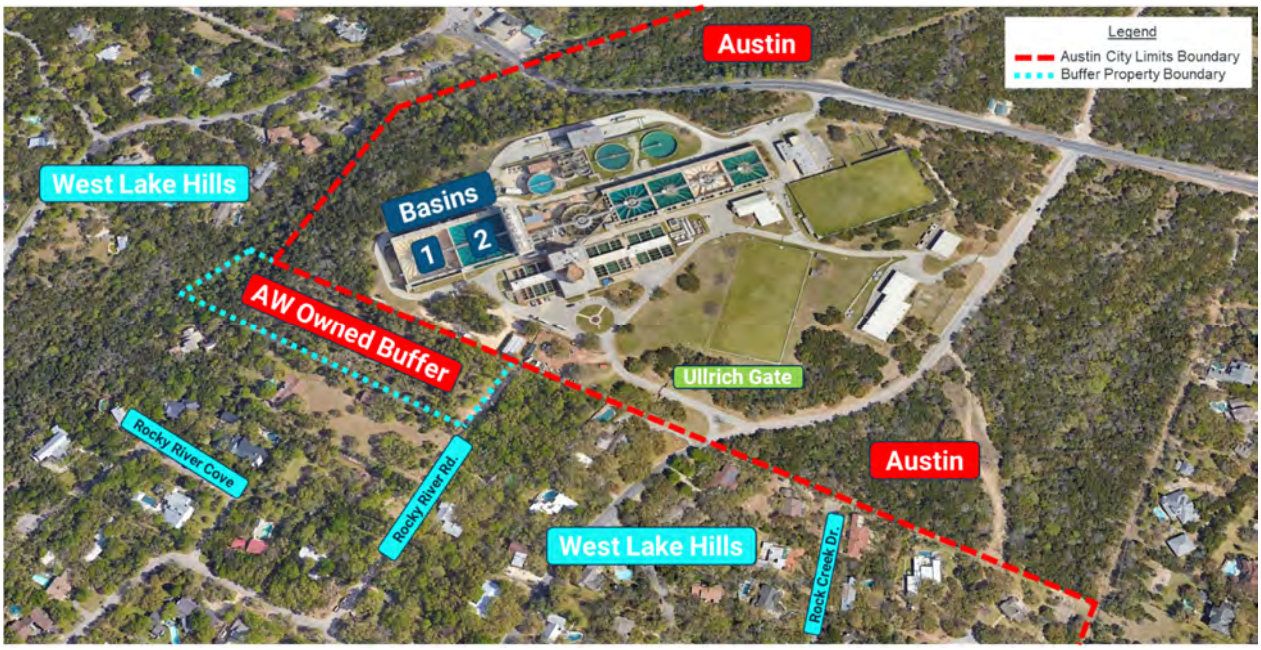
1.1 Project Background

The City of Austin (COA) treats water from the Lower Colorado River at three water treatment plants (WTPs) on COA owned property to distribute safe, reliable high-quality drinking water to more than one million customers. The COA treats and filters the surface water in accordance with federal and state regulations to remove and inactivate any contaminants prior to distribution. The COA's water treatment approach includes screening, oxidation, coagulation, flocculation, sedimentation, filtration, and disinfection to provide drinking water quality.

The Ullrich Water Treatment Plant (UWTP) is the largest of the three plants, was built in 1969, and has a rated design treatment capacity of 167 million gallons per day (MGD). The plant is located on COA property adjacent to the City of West Lake Hills (COWLH) and is operated by Austin Water (AW). The plant has undergone several expansions and renovations over the years and was expanded to its current treatment capacity in 2006.

AW identified the need to perform a site acoustic study for the UWTP to determine sources of sound and ground vibration at the plant that exceed existing COA and COWLH ordinances or significantly affect adjacent properties. The goal of the study is to document any sources of noise at the treatment plant exceeding the ordinances and to suggest sound mitigation strategies the COA can implement to serve as a good neighbor to the COWHL. The results of the study will be compared to historical data captured in the 2008 Environmental Noise Report prepared by Nelson Acoustics (2008 Nelson Acoustics Report). Figure 1-1 shows an aerial overview of the site.

Figure 1-1: Site Aerial of City Limits Between COA and COWLH



1.2 Project Scope

Kennedy/Jenks Consultants (Kennedy Jenks) was tasked with leading a Sound Propagation Study as part of the 2019 Small Scale Water and Wastewater Facilities Engineering Services Rotation List (PA190000065). Kennedy Jenks specializes in water treatment infrastructure engineering design, their subconsultant Collaboration in Science and Technology (CSTI) Acoustics specializes in acoustics, noise, and ground vibration control.

This team worked in conjunction to balance the understanding of the equipment and treatment processes of a large and complex water treatment plant and the intricacies of sound and ground vibration. Kennedy Jenks and CSTI reviewed the original 2008 Nelson Acoustics Report, established a Sound Measurement Plan for testing at the UWTP, collected the sound and ground vibration data as outlined, and provided a preliminary analysis presentation of the collected data to the COA on January 23, 2023.

This Letter Report summarizes the efforts and results associated with the sound and ground vibration studies, compares the data with the historical data documented in the 2008 Nelson Acoustics Report, evaluates the relationship of community sound and ground vibration levels with plant operations, and assesses compliance with current COA and COWLH ordinances. Additionally, the report identifies areas of operation where noise mitigation measures or operational changes may provide a reduction in sound and provides recommendations for future investigation and analysis.

1.3 Study Objectives and Work Plan

The objectives of the study performed by Kennedy Jenks and CSTI Acoustics are summarized below:

- Review of Background Data:
    - Review 2008 Nelson Acoustics Report to determine conclusions and locations of original testing;
    - Identify any facility changes since 2008 that could affect the study inputs or preferred measurement locations; and
    - Review operation conditions at the plant to develop baseline conditions.
- Measure and analyze current conditions:
    - Sound levels for comparison with 2008 Nelson Acoustics Report;
    - Determine sound power levels of the equipment to predict community noise impacts;
    - Sound levels from basin cleaning operations;
    - Sound reduction achieved by indoor lime blower; and
    - Ground vibration levels.

Section 2: Background

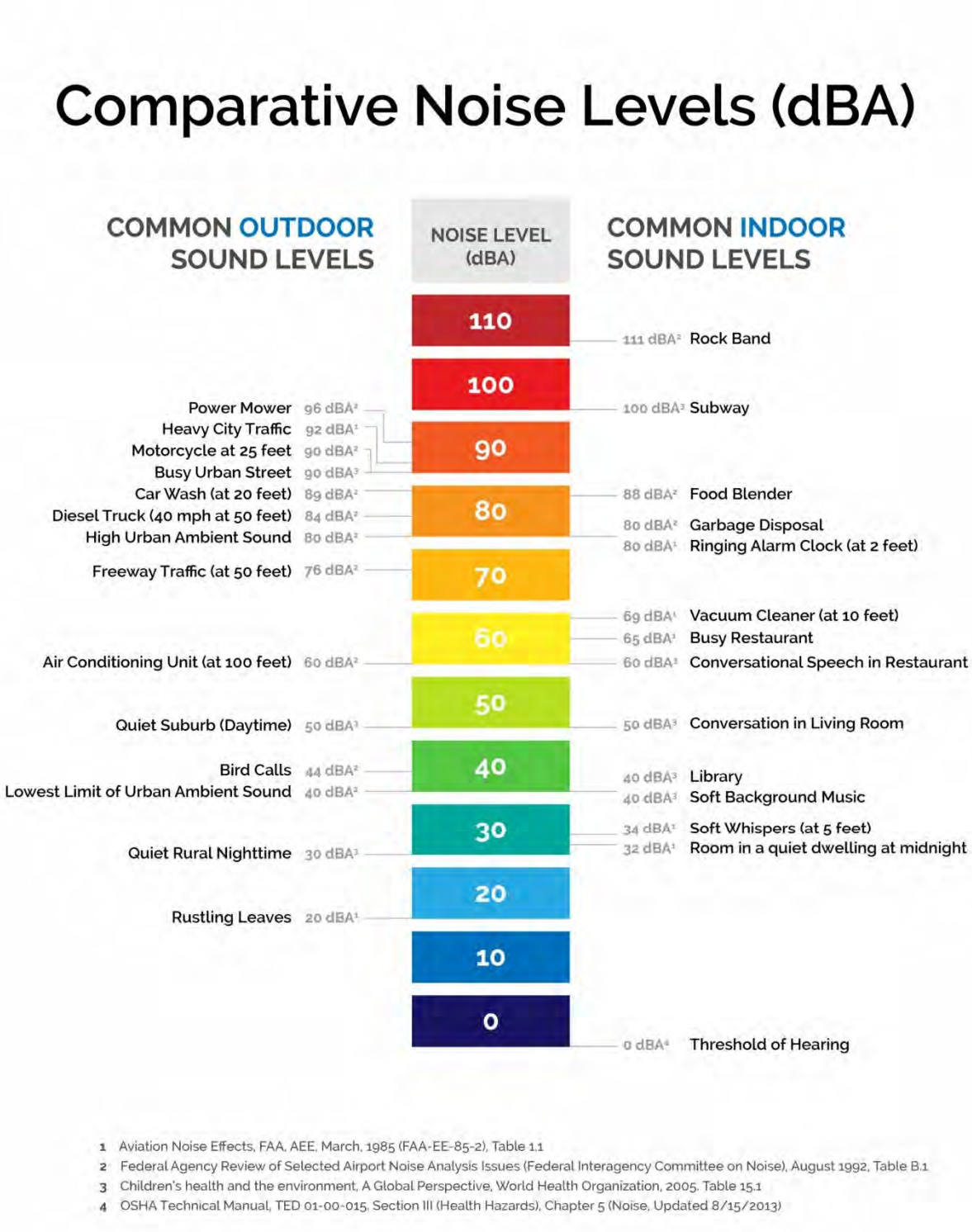
2.1 Fundamentals of Sound and Ground Vibration

Frequency is the range of sound pitch, measured in Hertz (Hz) or cycles per second. The more frequent the sound waves, the higher the pitch and higher the Hertz number. An octave is the interval between two points where the frequency of the second point is twice the frequency of the first. An octave band consists of all the frequencies within an octave; sounds at different frequencies are often grouped together in octave bands.

Sound level is measured on a logarithmic scale of sound pressure known as a decibel (dB). Each interval of 10 decibels indicates a sound energy ten times greater than before; this is perceived by the human ear as twice as loud. A-weighted decibels (dBA) adjust sound pressure towards the frequency range of human hearing, and dBA levels are the most common unit used for sound related ordinances. Figure 2-1 highlights dBA levels associated with common events.

Noise statistical descriptors are typically based on averages compared to instantaneous noise levels. Equivalent sound level (L_{eq}) is a descriptor and is described as the average A-weighted sound level measured over a given time interval. Maximum noise level (L_{max}) is the maximum measured during a specific period while L_{min} is the minimum variation during a sample. Day-night average sound level (L_{dn}) is the average equivalent sound level over a 24-hour period with a penalty added for noise during nighttime hours, and the Community Noise Equivalent Level (CNEL) is an average A-weighted sound level measured over a 24-hour period with a penalty for both evening hours and nighttime hours.

Figure 2-1: Federal Aviation Administration Comparative Noise Levels

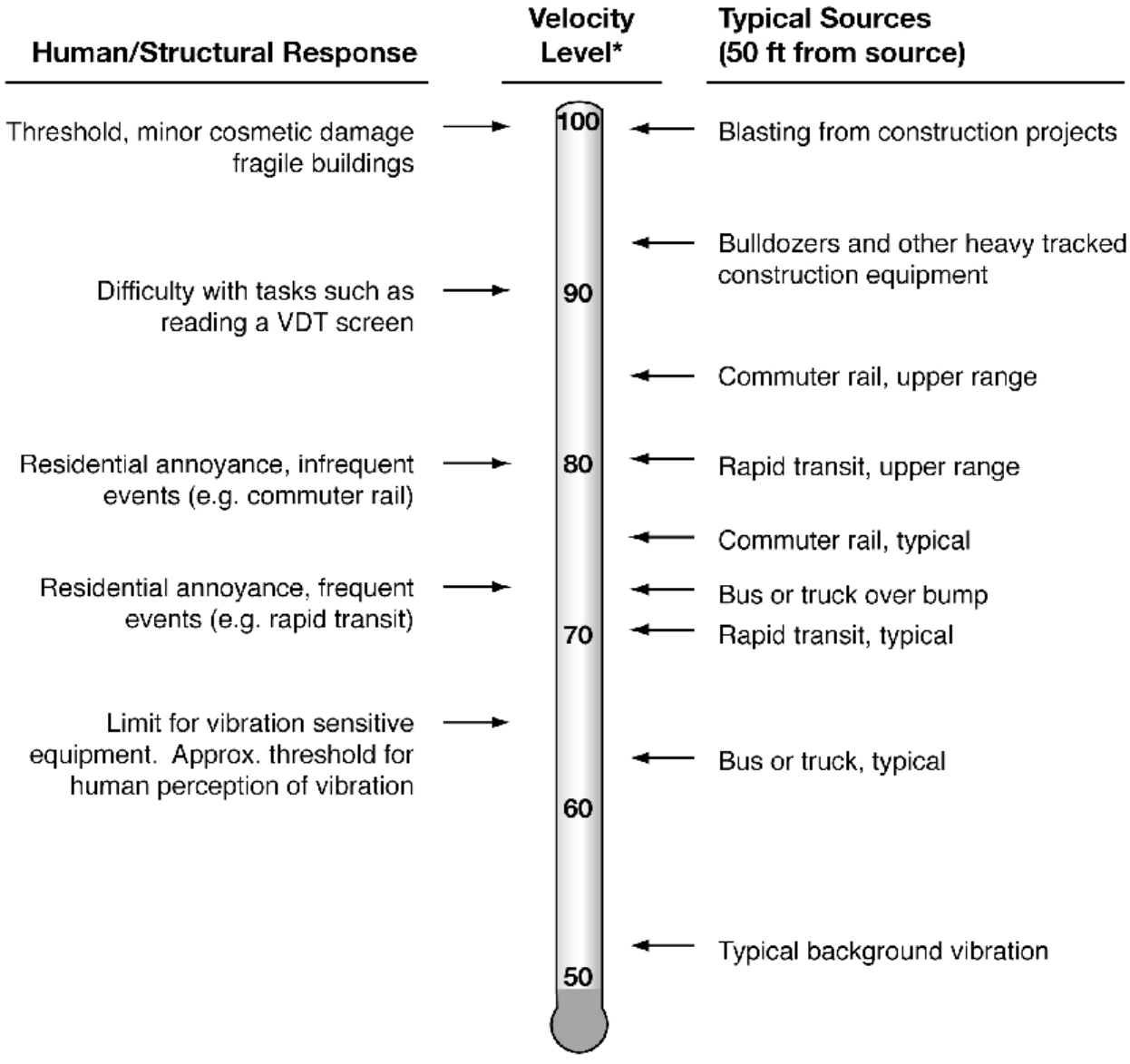


(Source: https://faabostonworkshops.com/project-information/aircraft-noise-overview/)

Ground vibration is expressed in vibration decibels (VdB) and is a logarithmic scaling used to describe human response to vibration. Vibration data may also be expressed in acceleration, velocity, or displacement; data can be easily converted using a standard equation that includes the level and the frequency. Typical levels of ground-borne vibration are shown in Figure 2-2; the background vibration velocity level observed in residential areas is approximately 50-VdB.

Refer to CSTI Acoustics' supporting fundamental information in **Appendix I** for further sound and ground vibration information.

Figure 2-2: USDOT Typical Levels of Ground-Borne Vibration



** RMS Vibration Velocity Level in VdB relative to 10^{-6} inches/second*

(Source: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Noise_and_Vibration_Manual.pdf)

Sound is complex to manage, not only in an environment like UWTP but in general, considering the broad range of factors that can influence noise levels. For example, sounds at the site are produced at different times of day and for different lengths of time; sound can be produced by a variety of sources such as mechanical equipment, water splashing, alarms, and truck traffic. Atmospheric sound propagates best downwind, attenuates with distance, and can reflect off solid surfaces (i.e. tanks, buildings). Additionally, sound in the atmosphere can only be slightly reduced by vegetation and moderately reduced by walls.

2.2 Noise and Ground Vibration Criteria

UWTP, located within the COA limits, shares a property line to the northwest and southwest with the COWLH. The nearest residents to the plant are within the COWHL. UWTP is required to meet the noise requirements of the State of Texas (State) and the COA.

2.2.1 State of Texas

The State of Texas prohibits making unreasonable noise in a public place. Per Texas Penal Code § 42.01(C)(2), a noise is presumed to be unreasonable if the noise exceeds a decibel level of 85 after the noise emitter is notified by a magistrate or peace officer that the noise is a public nuisance. Additionally, the Texas Commission on Environmental Quality (TCEQ) does not hold any legal requirements for noise pollution issues.

2.2.2 City of Austin

COA's Code of Ordinance §9-2-1(3) defines "Decibel" as the A-weighted sound level (dBA).

COA's Code of Ordinance §25-2-1067(B) states the noise level of mechanical equipment may not exceed 70-dBA at the property line.

COA's Code of Ordinance §25-2-648 - Planned Development Area (PDA) Performance Standards states that earth borne vibration may not exceed the limits of Column I in Table 2-1 below and has a more stringent limit of vibration at a residential area boundary line or within 80-feet of a residential area boundary line that is located in a street right-of-way by Column II.

Table 2-1: Vibration Criteria for Earth Borne Vibrations per §25-2-648

Frequency (cycles per sound)	Column I Displacement (inches)	Column II Displacement (inches)
0 to 1	0.0020	0.0008
1 to 10	0.0010	0.0004
10 to 20	0.0008	0.0002
20 to 30	0.0005	0.0001
30 to 40	0.0004	0.0001
40 and over	0.0003	0.0001

2.2.3 City of West Lake Hills

The City of West Lake Hills Code of Ordinances Article 12.02 has adopted a noise ordinance with prohibition against “any unreasonably loud, disturbing, unnecessary noise which causes material distress, discomfort or injury to persons of ordinary sensibilities” and also prohibits “any noise of such character, intensity and continued duration, which substantially interferes with the comfortable enjoyment of private homes by persons of ordinary sensibilities”.

COWHL Code of Ordinances §24.02.003(1) limits any vibration produced to exceed 0.002g peak measured at any point beyond the lot line. §24.02.003(2) also references the maximum permissible sound pressure levels at the lot line for noise radiated continuously from a facility from 7AM-7PM.

CSTI Acoustics was unable to quantify sounds from AW’s UWTP against the criteria as the pressure levels in frequency bands can only be measured from sound level meters which are no longer commercially available. Furthermore, the ordinance references the limits were established from the NC-30 curve in L.L. Beranek’s book *Noise Reduction* (1960); in Beranek’s later book, *Noise and Vibration Control* (1971).

2.3 2008 Nelson Acoustics Report

In 2008, Nelson Acoustics prepared a report for the COA with the primary purpose to compare plant noise to outdoor environmental noise during nighttime hours from relevant government codes—State of Texas, Penal Code, COA Municipal Code, US Environmental Protection Agency (EPA), and the COWLH Municipal Code. Spot sound measurements and ground vibration measurements were not included in the 2008 Nelson Acoustics Report.

2.3.1 Measurement Methodology

The measurements performed in 2008 by Nelsons Acoustics included sound monitoring at four different locations around UWTP over 16-hour intervals (from 4:00 PM to 8:00 AM each day) for four consecutive nights starting on October 8, 2007.

Two monitors were placed by residences near UWTP to quantify the sound at homes and the remaining two monitors were placed on-site to document sound from UWTP. In the report, the monitors were referred to as “offsite south” (OFS), “offsite southwest” (OFSW), “onsite west” (ONW), and “onsite southwest” (ONSW) to describe the monitor’s location relative to the plant; these locations are shown in Figure 2-3.

The monitors collected A-weighted equivalent (L_{eq}), maximum (L_{max}), and minimum (L_{min}) sound levels; statistical sound levels (L_1, L_{10}, L_{50}, and L_{90}) were also collected. The “offsite southwest” monitor took audio recordings of loud events. These recordings were used to determine the sources of transient sounds or a sudden increase in sound level over a short period of time, such as automobiles, aircraft flyovers, trains, and the nearby fire station.

Nelson Acoustics additionally took 52 spot measurements to help identify noise sources at the plant that might be audible offsite. These measurements included A-weighted L_{eq} and octave band sound levels.

Figure 2-3: 2008 Nelson Acoustics Report Sound Monitoring Locations

2.3.2 Conclusions

Key conclusions from the Nelson Acoustics Report are summarized as follows:

- Sound from the plant was continuous during nighttime hours.
- No nighttime transient events associated with the plant were identified.
- The A-weighted sound levels significantly increased each night due to insect noise; insect noise should not be used in comparison with noise criteria as the insect noise observed (frequencies of 2 kHz) was louder than the noise from UWTP.
- The L_{dn}, L_d, and L_n values were calculated instead of exact data points as the monitors did not run for 24-hour periods; values were estimated through spot measurements, monitor interval recordings, and overall trends.
- Sound levels from the plant at both offsite locations never exceeded 70-dBA, thus meeting codes required by the State, the COA, and the EPA.
- Sound levels were affected by weather conditions (downwind conditions, temperature inversions) with a potential of mistaking plant sounds for train and highway noises.
- UWTP's position atop a hill makes homes more exposed to environmental noise events from many directions and long distances.

2.4 Noise Control Changes Post 2008 Nelson Acoustics Report

As a result of the 2008 Nelson Acoustics Report and to help minimize noise, AW made several adjustments to UWTP operations. Sludge truck parking was relocated away from the adjacent properties to the southwest, sludge truck weigh-in was relocated to the scales on the southern side of the plant, and truck idling during weigh-in was prohibited. Additionally, overnight sludge hauling traffic was reduced during peak plant water production periods and eliminated during lower demand periods. The COA also restricted deliveries, routine maintenance, and construction activities to daytime hours (7:00 AM – 5:00 PM) in consideration of the community.

Prior to November 2022, truck mounted blowers were used to unload lime from delivery trucks to the storage silos. The blowers produced loud sounds at the blower intake and along associated piping. As an effort to be a good neighbor and reduce noise, the permanent blower was put back in service, eliminating the need for using outdoor truck blowers, to better attenuate the sound and COA is enforcing use of the indoor blower for the benefit of neighbors.

2.5 Normal Operations and Sounds

Several sources of noise have been identified during normal operations at UWTP. Routine maintenance and on-going construction activities occur during the daytime on weekdays. Small motors are used for mixing and stirring basins and for pumps. Basin discharge waterfalls produce a small noise from flowing water. Transformers and HVAC equipment can also account for noise observed during operations. Some vehicles and operations are equipped with back-up alarms that can periodically be triggered.

Noise impacts from transportation sources include trucks that arrive on each weekday morning to deliver lime and trucks on site to remove sludge from the facility on a regular basis. Lime is transferred to storage containers just east of Basin 2 and is a consistent source for noise complaints from neighbors. Sludge trucks driving over bumps by the sludge scales have been identified as a source of noise from the site. Figure 2-4 presents site photos taken during the study.

Figure 2-4: Normal Operations and Sources of Sound at Ullrich

Through the treatment process, lime scale accumulates within the basin and on basin surfaces. To maintain operations of the system, each basin requires periodic cleaning from a specalized contractor to remove lime scale from basin surfaces. During the process, contractors spray

water at high pressure to remove the lime scale; the water is pressurized with diesel-powered pumps with up to four pumps running at a time. The water and scale residue are then vaccumed from the bottom of the basin using a truck-mounted vaccum. The sounds associated with this process are produced by the vendor equipment and not by equipment that is part of the UWTP. Pictures captured during the process are shown in Figure 2-5.

Figure 2-5: Basin Cleaning Operations

Section 3: 2022 CSTI/KJ Data Collection

The goal of this study was to:

- Compare the current noise study results to the 2008 results,
- Expand the area and time frame of monitoring,
- Include measurements of infrequent plant operations that generate sources of noise, and
- Include ground vibration measurements, which were not measured in the 2008 study.

3.1 Conditions

Sound levels and ground vibration measurements were collected at the site over five days from Thursday, November 17, 2022 to Monday, November 21, 2022. The facility was operating under normal conditions while ongoing construction on a new parking lot was being conducted on weekdays. Basin 2 was cleaned on November 17 and November 18.

The main effect weather has on sound propagation is that sound levels are higher downwind of a noise source. The data collection occurred during a cold, cloudy weather period and with limited insect activity noise interference. The wind was coming from the north and northeast on several days of the study, which would generate the most sound to the adjacent residents. The sound levels in the community south of the facility will be lower when the wind is out of the south. Table 3-1 summarizes the weather conditions throughout the study.

Table 3-1: Weather Conditions

	November 2022				
Condition	**17 Thursday**	**18 Friday**	**19 Saturday**	**20 Sunday**	**21 Monday**
Temperature (ºF)	40 –58	48 – 55	37 – 47	39 – 47	41 – 45
Humidity (RH)	34 – 97	49 – 86	70 – 97	48 – 93	82 – 100
Wind direction & mph	Var, 0 – 6	Var, 0 – 7	N, 6 – 20	NNE 3 – 10	NE 3 – 9
Sky/Rain	Cloudy	Cloudy	Light rain	Cloudy	Light rain

3.2 Measurement Methodology

The Sound Measurement Plan (SMP) was developed by CSTI & Kennedy Jenks. The COA reviewed the SMP and requested an expansion of the testing sites and duration, to add additional data points, prior to approving the final SMP. Refer to **Appendix I** for additional details on data collection.

3.2.1 Sound Measurement Positions and Noise Sources

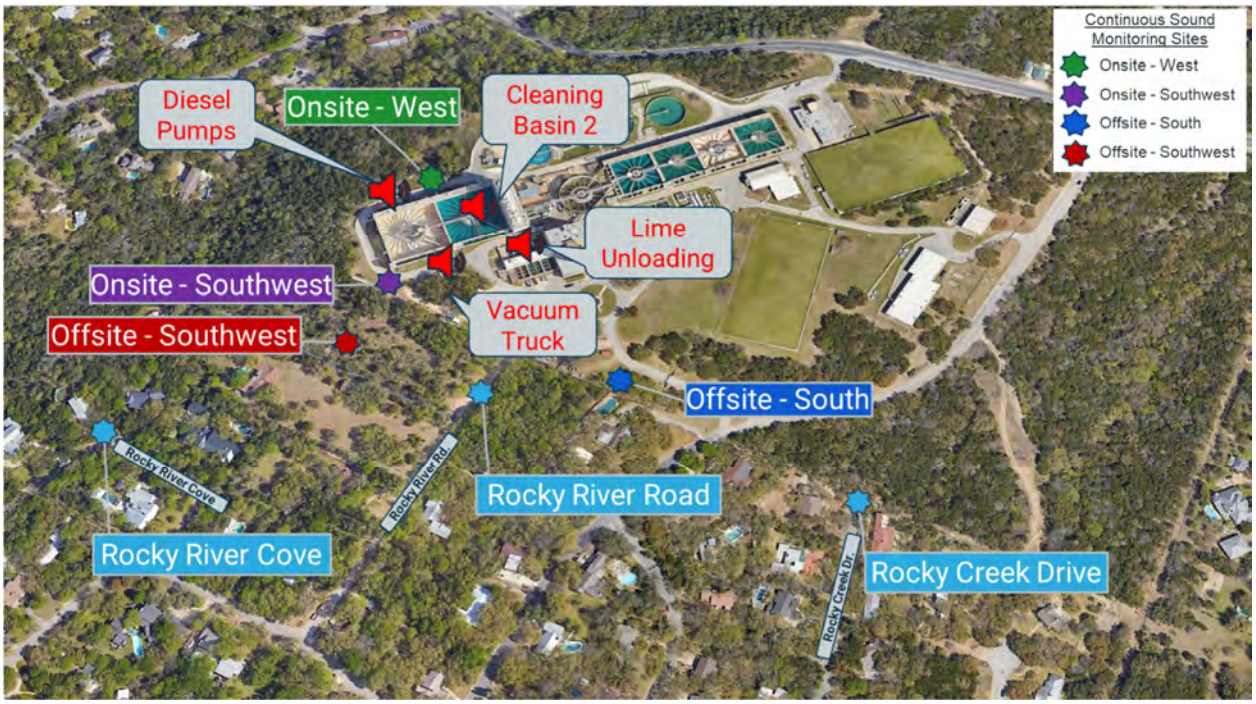
Sound monitoring was conducted at similar locations as the previous study—two monitoring locations by residences and two monitors on-site. In comparison to the 2008 Nelson Report, additional spot measurement sites were considered, including main offsite positions at Rocky River Rd (RRR), Rocky River Cover (RRC), and Rocky Creek Drive (RCD). Sound measurement positions are described in Table 3-2 and shown in Figure 3-1. Refer to **Section 3.2.3** for ground vibration Measurement Positions.

Table 3-2: Sound Measurement Positions

Abbreviation	Site Description	Sound Monitoring Site 2008	Sound Monitoring Site 2022	Spot Sound Measurement Site 2022
ONW	Onsite West (near diesel pumps)	X	X	
ONSW	Onsite Southwest (fence by Basin 1)	X	X	
OFS	Offsite South (near Ullrich gate)	X	X	
OFSW	Offsite Southwest (in buffer zone)	X	X	
RRR	Rocky River Rd (North end)			X
RRC	Rocky River Cove (Site 5-on road)			X
RCD	Rocky Creek Drive (North end)			X

Note: Refer to Section 3.2.3 for Vibration Measurement Positions

Figure 3-1: Map of Main Sound Measurement Positions and Noise Sources



3.2.2 Continuous Sound Monitoring Measurements

The sound monitor locations are identified in Figure 3-1; the sound monitors were attached to tree limbs to recreate similar conditions from 2008 based off building landmarks and nearby

features with the exception of the Offsite Southwest site in the buffer area. The selected site was within a best assumed proximity to the previous study as the exact location could not be determined due to clearing. The monitors ran continuously over the five-day period with the exception of the Offsite South and Offsite Southwest sound meters, which experienced a brief outage as batteries failed Sunday morning and were replaced on Monday morning. This did not influence any results as there were no events outside of normal operations during that brief period as well as substantial, consistent data collected from the previous days. Sound monitoring was collected for two days with daytime noise from Basin 2 cleaning (November 17 to 18) and for three days after basin cleaning to establish normal baseline conditions (November 19 to 21).

3.2.3 Spot Sound Measurements

CSTI Acoustics took additional spot measurements to help identify noise sources at the plant that might be audible offsite and to establish normal baseline conditions at these positions. Spot sound measurements were taken for approximately one minute at various locations, including monitoring locations and offsite at the Rocky River Cove, Rocky River Road, and Rocky Creek Drive positions as highlighted in Figure 3-1. Measurement locations were selected to best assess the sound of each source while minimizing the effects of other sound sources. Spot sound measurements were not included in the 2008 Nelson Acoustic Report.

3.2.3.1 Community Sites

Spot sound measurements were taken over the duration of the study at the following community site locations:

- Near the sound monitors
- Fence line
- Property line
- Adjacent to residences of the UWTP property
- Public streets: Rocky River Cove, Rocky River Road, Rocky Creek Drive
- Private drive nearest to the southwest border

3.2.3.2 Normal Baseline Conditions

After basin cleaning was completed, spot sound levels close to loud, critical equipment were taken in the immediate vicinity of the sound source moving away towards the nearest property line and/or fence line. This was done to determine how much sound from each operation is propagated to the property line/nearest residences during normal operating conditions. The team also captured video to document the reduction of sound towards the property line. Construction trailer HVAC equipment, cellphone tower HVAC equipment, and ventilation fans were not operating during the time of the study. Spot sound levels were taken for the following items:

- Basin discharge waterfall

- Pumps
- Blowers
- Air compressors

3.2.3.3 Lime Loading

During the lime deliveries on the first two days of the study (November 17 to 18), operations utilized the indoor lime blower. Comparatively, the truck-mounted blower was used on the final day of the study (November 21). Detailed sound measurements were taken in the same process as the baseline conditions (sound source vicinity start to property/fence line) and the team captured video to document the reduction of sound towards the property line for:

- Indoor blower inlet (November 17 to 18)
- Indoor blower casing (November 17 to 18)
- Motor driven blower
- Associated piping from the blower to the lime storage
- Truck noises
- Truck-mounted blower without using indoor blower (November 21 only)

The field team inspected the interior of the blower building on the first day of the study (November 17). The field team also reported the lime offloading process typically took 2-hours.

3.2.3.4 Basin Cleaning

Basin cleaning operations were completed on November 17 to 18. For Basin 2 cleaning, the pumps and vacuum truck were located outside the basin between Basins 1 and 2; it can be assumed that sound levels may be similar during the cleaning of Basin 1 using the same staging. Other basins are located over 200-feet away and would be expected to produce lower sound levels. Spot measurements were conducted in the same process as baseline conditions (sound source vicinity start to property/fence line) and the team captured video to document the reduction of sound towards the property line. Detailed sound measurements were included for:

- Pumps
- Pump drive motors/engines
- Vehicles
- Spraying/Blasting within Basin 2
- UFC Flocculation Skirt/Hood Cleaning

3.2.4 Ground Vibration Measurements

Ground vibration levels were measured at fourteen positions around the property line of the site to assess possible ground vibration impacts in the vicinity (Figure 3-2). On November 18, Measurements were made in the X, Y, and Z axis on a metal object on the ground, such as a pipe, shipping container, or similar structure; an example is shown in Figure 3-3. Additional measurements were taken near residences with ground vibration related complaints. No ground vibration readings were taken as part of the 2008 report. Refer to **Section 3.2** for Sound Measurement Positions.

Figure 3-2: Map of Ground Vibration Measurement Positions

Figure 3-3: Example of Ground Vibration Measurement Equipment Setup

3.2.5 Instrumentation

The sound meters used in data collection were calibrated Type 1 sound level meters equipped with appropriate wind screens. Calibration certificates are presented in **Appendix I** for all instrumentation. In alignment with the 2008 Nelson Acoustics Report, the monitors collected A-weighted equivalent (L_{eq}), maximum (L_{max}), and minimum (L_{min}) sound levels. The monitors also collected statistical sound levels for L_1, L_{10}, L_{50}, and L_{90}.

In advancement of the 2008 Nelson Acoustics Report, all sites were programmed to make audio recording of loud sounds to determine the source of the transient sounds instead of just the Offsite Southwest sound monitoring site. The sound-monitoring equipment for this study was also able to measure spectral information (1/3 octave band data) which the monitors from the previous study could not measure. The spectral information offers a better understanding of the hertz range specific to different noises, which can be informative when developing noise control measures. Lastly, the sound meter with an accelerometer adapter was used in the 2022 study to measure ground vibration.

Section 4: Results

4.1 Sound Monitoring Data

The data points from the study were collected from each monitor. Figure 4-1 shows all the sound monitoring data from November 17 to 21, 2022. Each color represents a different monitoring location while particularly the red line is measured in the AW owned buffer property nearest the residences. Some examples of louder sounds have been identified and labeled in the figure such as an aircraft flyover or lawn maintenance.

The sound monitoring nighttime results from the 2008 Nelson Acoustics Report is overlayed with the nighttime 2022 Sound Monitoring Data for comparison in Figure 4-2. For ease of assessment, 2022 data was plotted with the same color for each measurement position that was used for presenting 2007 measurements. Data from 2007 was only collected in the evenings (4 PM – 8 AM each night) and experienced high insect activity while 2022 data was taken continuously to cover both day and night and had minimal interference with insect noise as the study was conducted during cool weather. The 2022 data also included new data points by capturing basin cleaning operations and community sites. Both studies experienced measurements of brief, loud sounds primarily attributed to aircraft flyovers and the 2022 study can attribute an identified peak during daytime hours to the basin cleaning on November 17 and 18 shown in Figure 4-1.

Supporting details can be found in **Appendix I** and the comprehensive set of raw data will be provided separately from this report.

Figure 4-1: 2022 Continuous Sound Monitoring Data

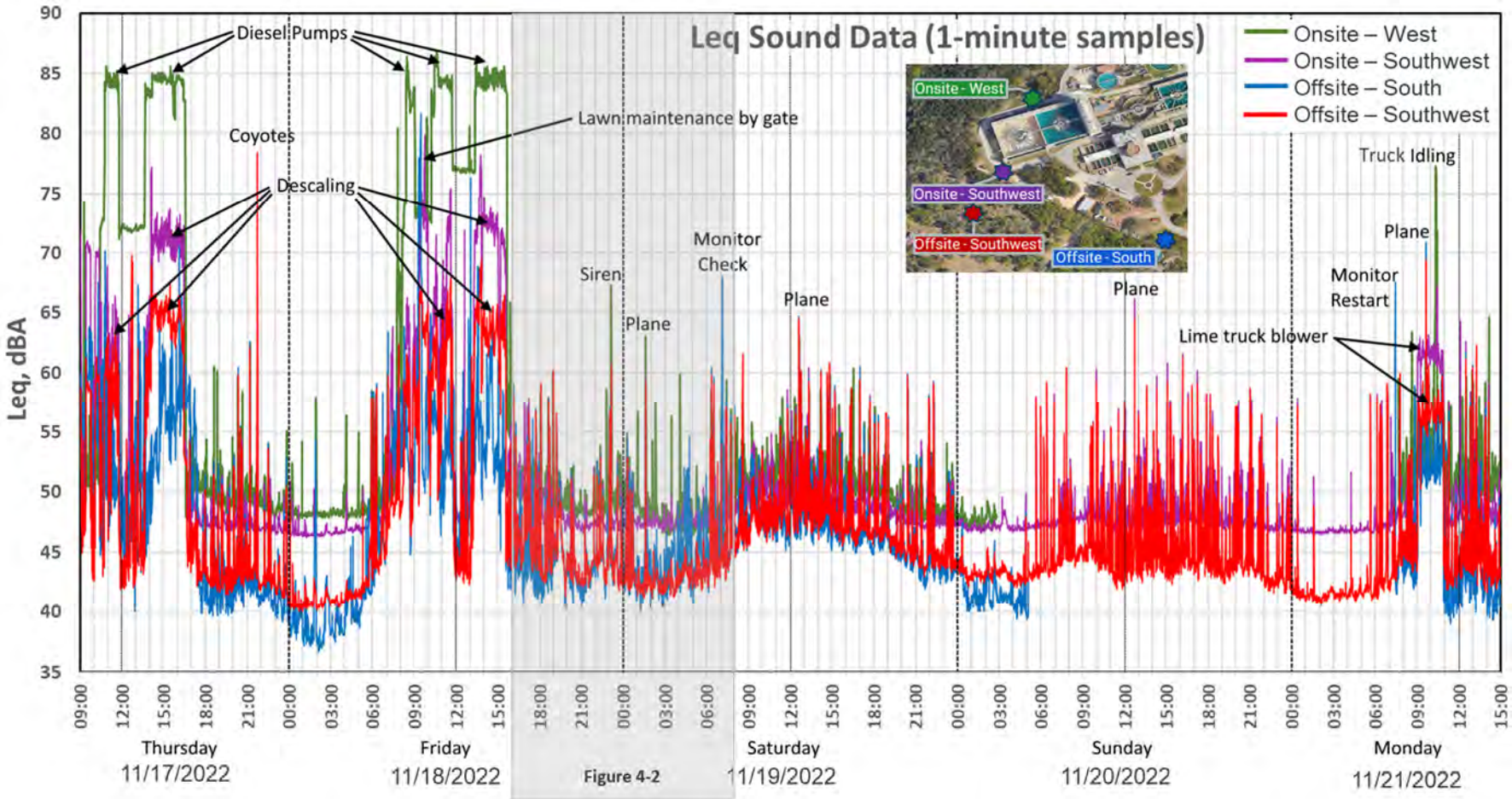
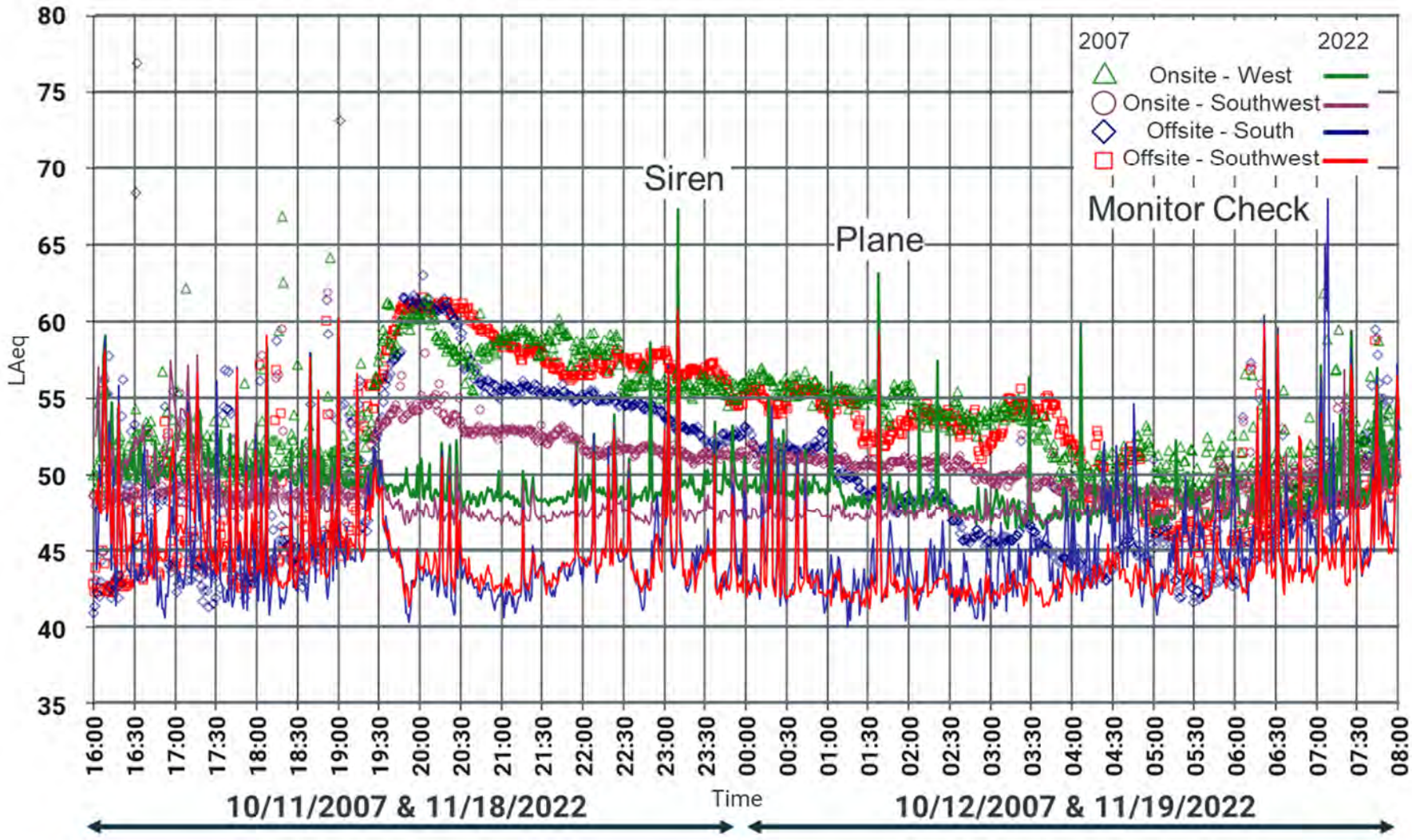


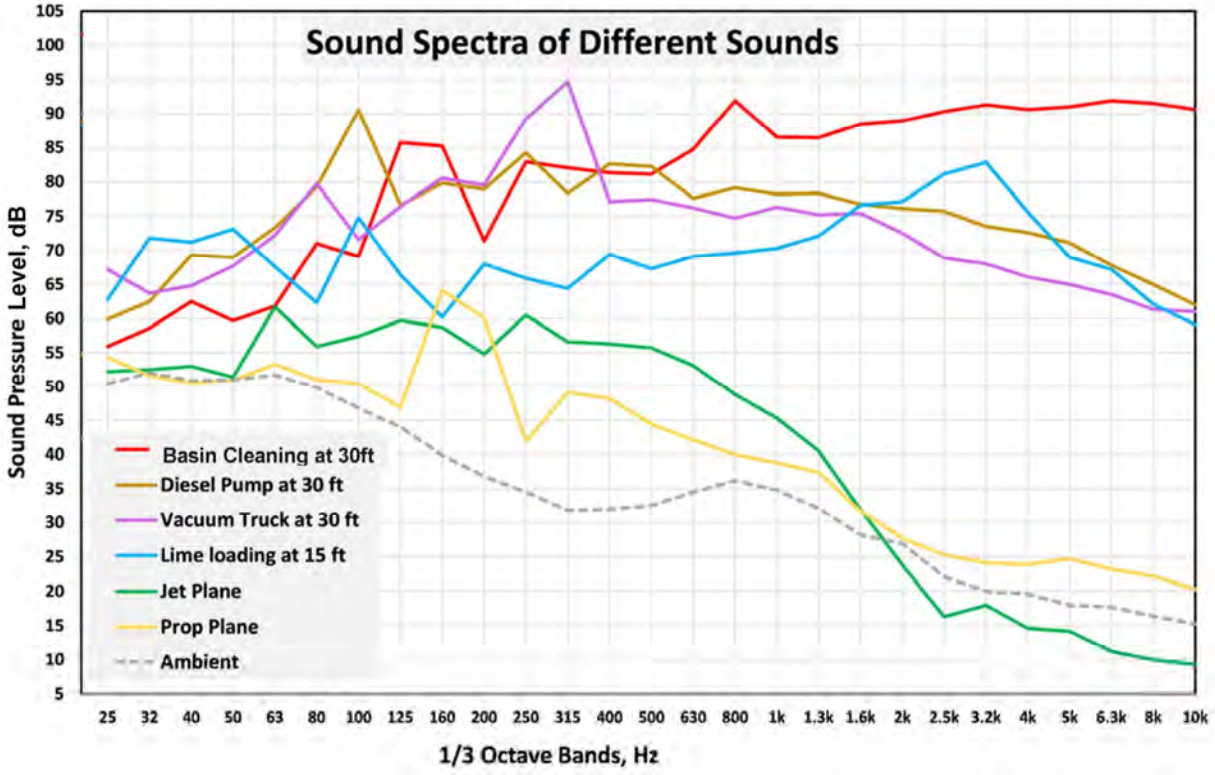
Figure 4-2: Nighttime Sound Monitoring Data Comparison from 2007 Nelson Data to 2022 Data



4.1.1 Equipment Noise Impacts

Figure 4-3 shows the frequency range of equipment noise at the source and that all sound levels vary over time. Low-frequency sounds are located to the left and high frequency sounds are to the right. The sharp peaks observed indicate tonal sounds, and basin cleaning operation related sounds are primarily high-frequency noise.

Figure 4-3: Equipment Noise Spectra at Source



4.2 Summary of Sound Study Results

During the sound monitoring study, sounds were recorded from the normal operations, lime loading, and basin cleaning operations. Normal operations sounds occur 24 hours a day, 7 days a week. Lime loading occurs during daytime hours for approximately 2 hours per day. Measurements were taken from lime loading operations using a truck-mounted blower and from an a blower inside a building. Basin Cleaning operations occurred on weekdays between the hours of 8 am to 5 pm. Table 4-1 summarizes the sound levels observed for different operations across the sites. The majority of sound levels within the Ullrich facility during normal operations are below 70 dBA and none of the sound levels exceeded 70 dBA at any of the offsite sound monitoring sites or offsite spot sound measurements.

Table 4-1: Summary of Sound Levels for Different Operations

	Site						
	Onsite West	Onsite Southwest	Offsite South	Offsite Southwest	Rocky River Rd	Rocky River Cove	Rocky Creek Dr
Condition	**Sound Levels, dBA**						
Normal operations (ambient)	48	47-48	38-43	41-43	38-40	35-42	36-40
Lime Loading w/ truck mounted blower	-	62	53	57	52	45	-
Lime loading w/ indoor blower	-	50	41	47	<47	<41	-
Basin cleaning, diesel pumps	85	-	-	-	-	-	-
Basin cleaning, vacuum truck	-	71	<54	63	52	45	-
Basin cleaning, hydroblasting	-	70-73	55-60	63-66	52-54	46	-

Note: Many of readings shown in the data and in Figure 4-1 that are in the 50-60 dBa range can be correlated to aircraft flyovers with the recordings from the sound monitors.

Table 4-2 captures typical sounds from the facility and those not sourced from the facility observed in the COWLH community during the study. Additionally, the basin 1 waterfall was noted as faintly audible in the nearby buffer zone. Back-up alarms for trucks and construction equipment were also audible in the community.

Table 4-2: Summary of Typical Sounds in the Community

Source	Sound Source	Sound Level
From UWTP	Normal operations	38 dBA
	Truck-mounted lime blower	57 dBA
	Back-up alarms	40 – 45 dBA
	Basin cleaning, diesel pumps	Shielded(1)
	Basin cleaning, vacuum truck	63 dBA
	Basin cleaning, hydroblasting	63 – 66 dBA
Environment	Natural quiet	35 – 42 dBA
	Distant traffic	40 dBA
	Aircraft flyover	50 – 60 dBA(2)
	Natural sounds (winds, birds, insects)	30 – 63 dBA(2)
	(coyotes)	78 dBA(2)

(1) Not audible to South or Southwest.
(2) Intermittent environmental sound sources recorded as part of the 2022 Study.

For intermittent noisy operations such as lime loading and basin cleaning, there is significant attenuation due to distance to residences, shielding from buildings and topography, and effects of foliage and ground absorption. The sound level observed in the community were dependent on the level produced by the equipment and the location of equipment during the operations.

Table 4-3 shows the difference of sound levels in the immediate vicinity of the sound source compared to the level recorded at the offsite southwest monitoring site located in the buffer property. There is a consistent decrease of over 27 dBA for each event which corresponds to over a 80% reduction in perceptible sound. Additionally, the indoor lime blower reduced the noise of the lime truck unloading operation by about 12 dBA when compared to the truck-mounted blower**.** Functionally this represents over a 50% reduction in perceptible sound and a 90% reduction of sound energy.

Table 4-3: Sound Attenuation Effects of Distance and Shielding

Sound Source	dBA at 30-ft	dBA at Offsite Southwest	% Reduction in Sound Energy	% Perceived Reduction in Sound Level
Basin Cleaning	100	66	99.96%	90.5%
Vacuum Truck	90	63	99.80%	84.6%
Truck Blower	92	57	99.97%	91.2%
Indoor Blower	80	47	99.95%	89.8%

4.2.1 Comparisons of Sound Levels with Criteria

The UWTP meets all applicable noise and ground vibration requirements. All sound levels are under the State's noise limit of 85 dBA and under COA's residential limit of 70 dBA at both the continuous and spot offsite noise monitoring locations. In terms of COWLH, ambient sound levels at Site Offsite Southwest, Rocky River Road, Rocky River Cove, & Rocky Creek Drive are typically 40 dBA and increased up to 50 to 60 dBA when planes flew overhead. Noise levels during normal plant operation were recorded at an average of 38 dBA from the sound monitoring sites.

4.3 Summary of Ground Vibration Levels

4.3.1 Comparisons of Ground Vibration Levels with Criteria

COA limits earth-borne vibration at a residential area boundary line according to the displacements listed in **Section 2.3.2**; the measurements were made in acceleration and were converted to displacement for comparison with COA limits. COWLH has a vibration limit of 0.002 g peak measured at any point beyond the lot line. Vibrations were not tangible or noticeable at any location observed.

Figure 4-4 shows the ground vibration measurements compared to the COA's criteria. The plotted "Typical" data represents 37 of the 46 ground vibration measurements made at 14 positions at the site perimeter. The residences were further away from the site and will have lower ground vibration levels than those observed at the perimeter. Unplotted ground vibration measurements were excluded due to additional measurements at the same positions being notably lower and when adjacent measurement locations did not show any increase in ground vibration.

Figure 4-5 shows the ground vibration measurements compared with COWLH's criteria. None of the ground vibration measurements were found to exceed COWLH's criteria.

Figure 4-4: Ground Vibration Measurements Compared with COA Ordinance

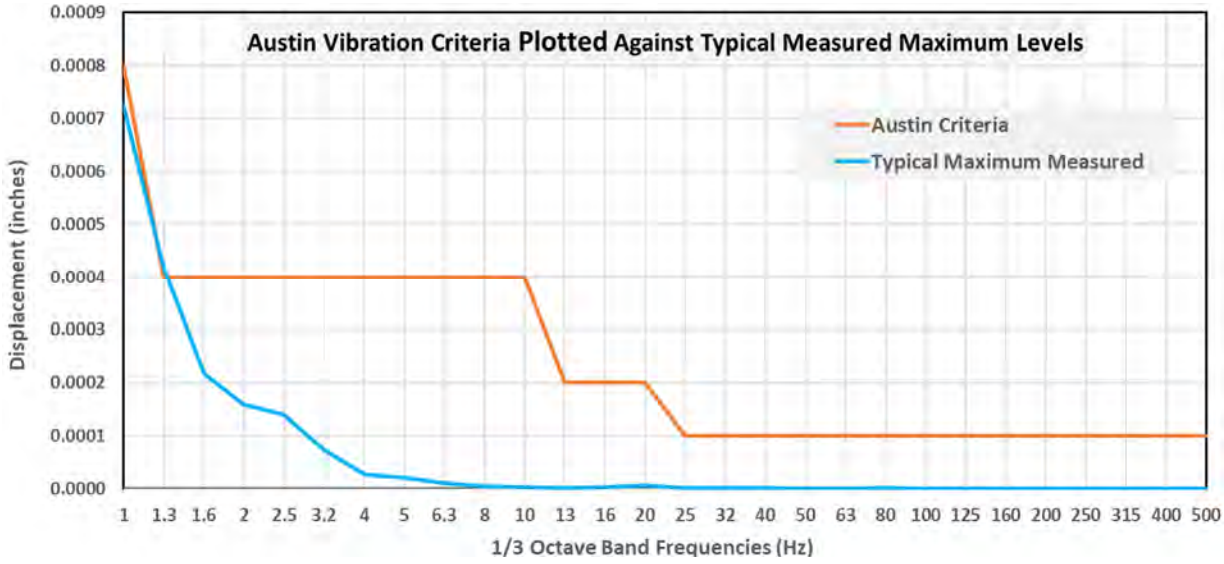
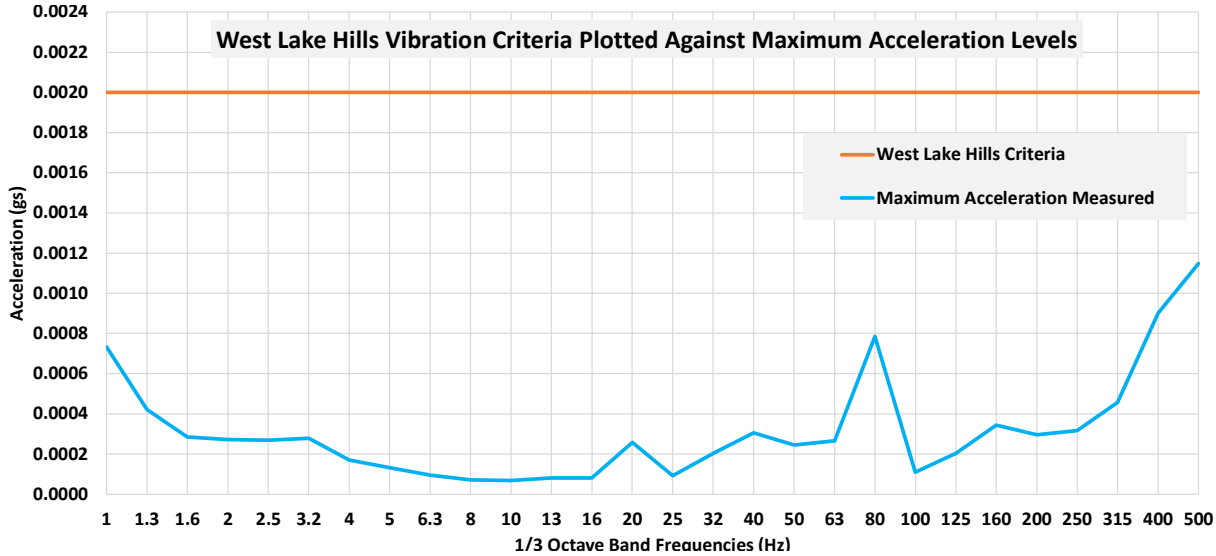


Figure 4-5: Ground Vibration Measurements Compared with COWLH Ordinance



4.4 Next Steps

To further assess potential mitigation efforts, a 3-D computer sound model for normal operations and intermittent operations for the UWTP would be informational. The model would be effective in comparing different noise treatments such as noise barriers at various locations and heights as well as sound absorption. Additionally, a technical report will be produced from the modeling efforts with recommendations for future noise mitigation alternatives. This report will be presented in a presentation to Austin Water and the residents of COWLH.

References

Comparative Noise Level Figure, Federal Aviation Administration, Environmental Assessment-Boston Logan RNAV (GPS) RWY 4L. September 2020. https://faabostonworkshops.com/project-information/aircraft-noise-overview/

US. Federal Transit Administration. Office of Planning and Environment. Transit Noise and Vibration Impact Assessment. By Carl E. Hanson, David A. Towers, and Lance D. Meister. FTA-VA-90-1003-06. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Noise_and_Vibration_Manual.pdf

Appendix I

CSTI Report No. R-1303-2 / Austin Ullrich WTP Noise Study

Collaboration in Science and Technology Inc.
CONSULTANTS IN ACOUSTICS, NOISE, AND VIBRATION

AUSTIN ULLRICH WTP NOISE STUDY

CSTI REPORT NO. R-1303-2
CSTI PROJECT NO. 6869

5 MAY 2023

Prepared By:
CSTI acoustics

Prepared For:
Kennedy/Jenks

16155 Park Row Blvd., Suite 150, Houston, TX 77084-6971 Ph: 281.492.2784 Fax: 281.492.1434
www.cstiacoustics.com

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1. INTRODUCTION

Collaboration in Science and Technology Inc. (CSTI) was retained by Kennedy/Jenks on behalf of the City of Austin to conduct a noise study of the Ullrich Water Treatment Plant (WTP) located in Austin, TX to compare with a previous noise study conducted by Nelson Acoustics in 2007/2008 and to provide additional information on community sound levels, intermittent sounds, daytime sounds, and ground vibration.

Sound levels were monitored over five days from November 17 to 21, 2022 at a time when Basin 2 was being cleaned. Spot sound measurements were taken around the facility and in the neighborhood to the south. Detailed sound measurements were made of noisy equipment and operations including the lime loading, pumps for basin cleaning, the vacuum truck for basin cleaning, and the descaling of the basin.

Ground vibration measurements were taken along the property line of the facility.

The weather during the sound measurements was:

Table 1. Weather

Condition	November 2022				
	17 (Thursday)	18 (Friday)	19 (Saturday)	20 (Sunday)	21 (Monday)
Temperature (ºF)	40 –58	48 – 55	37 – 47	39 – 47	41 – 45
Humidity (RH)	34 – 97	49 – 86	70 – 97	48 – 93	82 – 100
Wind direction & mph	Var, 0 – 6	Var, 0 - 7	N, 6 - 20	NNE 3 – 10	NE 3 – 9
Sky/Rain	Cloudy	Cloudy	Light rain	Cloudy	Light rain

The main effect of weather on sound propagation is that sound levels are higher downwind of a noise source. The wind was out of the north to northeast on several days, and sound levels in the community south of the facility will be lower when the wind is out of the south.

There are many ways of defining sound as discussed below:

Frequency – Measured in Hz (cycles per second). Sounds at different frequencies are often grouped together in octave bands.

Loudness

- **Level** (Amplitude or volume) – Measured in decibels (dB)
- **dBA** (A-weighted sound level) – Single-number rating of "loudness" at all frequencies combined.
- **dBC** (C-weighting sound level) – used less often, more emphasis on low frequencies.

Variations in frequency and level over time – Quantified in several ways including:

- **Lmax** (maximum during sample)
- **Lmin** (minimum during sample)
- **Leq** (equivalent sound level – a type of average)

LOSHA/TWA (time-weighted average).

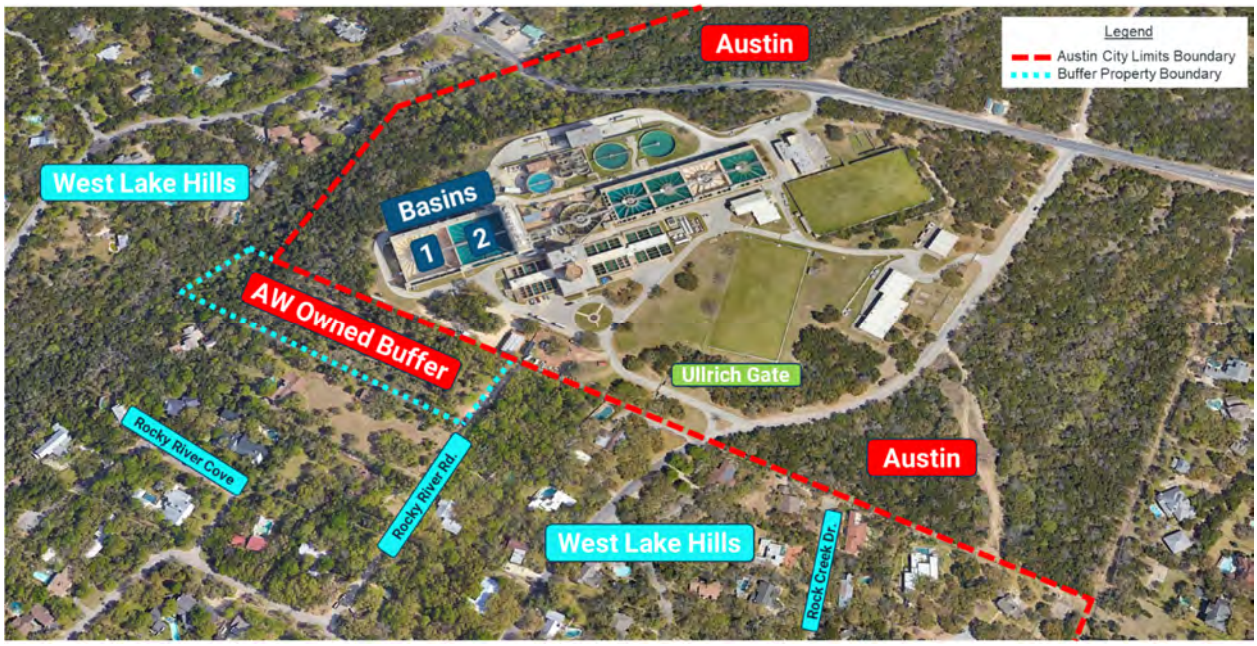
Most noise ordinances use the "dBA" level, which is a good measure of the loudness of sound at all frequencies. Some ordinances also limit sound levels at specific frequencies.

Ground vibration levels are normally limited at different frequency bands. The limits may be in terms of acceleration, velocity, or displacement. Vibration data can be converted between acceleration, velocity, or displacement using standard equations that include the vibration level and the frequency band.

2 SITE DESCRIPTION

The Ullrich Water Treatment Plant is located with all its equipment within the Austin city limits. The site property line to the northwest and southwest is adjacent to the city limits of the City of West Lake Hills, and the nearest residences are within West Lake Hills. Austin Water also owns a buffer zone to the south of the facility. Figure 1 presents an aerial view of the WTP and surrounding neighborhood.

Figure 1. Aerial View of Ullrich Facility



2. INSTRUMENTATION

The acoustical instrumentation used for the sound and vibration measurements is described in Table 2.

Table 2. Acoustical Instrumentation

Manufacturer & Model	Description	Serial Number
Rion NL-62	Sound Level Meter	01030561
Rion NL-52	Sound Level Meter/Monitor	01021297
Rion NL-52	Sound Level Meter/Monitor	00331834
Rion NL-52	Sound Level Meter/Monitor	00843243
Rion NL-52	Sound Level Meter/Monitor	00253710
Rion NC-74	Sound Level Calibrator	34172711
Rion PV-86	Accelerometer	0552

All of the sound meters used in the study are calibrated Type 1 sound level meters in accordance with ANSI S1.4, American National Standard Specification for Sound Level Meters. These meters were equipped with wind screens and set on the "slow" meter response as called for by most noise ordinances. The meters meet all requirements of the Austin and West Lake Hills noise ordinances.

For the ground vibration measurements, a calibrated Type 1 sound meter was used with an adaptor for an accelerometer to measure vibration.

Calibration certificates are presented in Appendix A.

3 NOISE AND VIBRATION CRITERIA

Though the Ullrich facility is located within the Austin city limits, the nearest residences are located within the City of West Lake Hills.

3.1 State of Texas

The State of Texas prohibits making unreasonable noise in a public place. A noise is presumed to be unreasonable if it exceeds a "decibel level" of 85 after the noise emitter is notified by a magistrate or peace officer that the noise is a public nuisance, according to Texas Penal Code Ann. § 42.01(c)(2). The Texas Commission on Environmental Quality (previously the Texas Air Pollution Control Board) states on their website that they do not address noise pollution issues.

3.2 City of Austin

Section 25-2-1067 (B) of the Austin Ordinance, Design Regulations states that "The noise level of mechanical equipment may not exceed 70 db at the property line." Elsewhere in the ordinance, "dB" is defined as "dBA". The 70 dBA ordinance was referenced in the previous Nelson report.

The ground vibration criteria from the Austin ordinance are in Section 25-2-648 for Planned Development Performance Standards. The limits for earth-borne vibration presented in the table below are from Column II of the ordinance (the more stringent of the two columns) that applies at "a residential area boundary line or within 80 feet of a residential area boundary line that is located in a street right-of-way."

Table 3. Austin Ground Vibration Limits

Frequency (cycles per second)	Displacement (inches)
0 to 1	.0008
1 to 10	.0004
10 to 20	.0002
20 to 30	.0001
30 to 40	.0001
40 and over	.0001

3.3 City of West Lake Hills

The City of West Lake Hills Code of Ordinances Article 12.02 prohibits "any unreasonably loud, disturbing, unnecessary noise which causes material distress, discomfort or injury to persons of ordinary sensibilities" and also prohibits "any noise of such character, intensity and continued duration, which substantially interferes with the comfortable enjoyment of private homes by persons of ordinary sensibilities".

Ordinances §24.02.003(1) limits any ground vibration produced to exceed 0.002g peak measured at any point beyond the lot line. §24.02.003(2) also references the maximum permissible sound pressure levels at the lot line for noise radiated continuously from a facility from 7:00 pm to 7:00 am.

The noise ordinance references sound pressure levels in frequency bands which have not been used since the 1960s and cannot be measured with any available, calibrated sound meters. The ordinance notes that limits were from the NC-30 curve in L.L. Beranek's 1960 book, Noise Reduction. In Beranek's later book, Noise and Vibration Control, he discusses that the NC curves are intended for ***indoor***, not outdoor spaces with a limit of NC-25 to NC-40 recommended for inside bedrooms. Indoor criteria are normally much lower than outdoor criteria because of the sound reduction provided by the building walls.

For the reasons of the octave bands, which are no longer measurable with today's sound level meters, and the application of an indoor criterion at the property line, we have concluded there is no measurable quantitative noise ordinance for the City of West Lake Hills. As such, the criteria used as a comparison point for the study was Section 25-2-1067 (B) of the Austin Ordinance as discussed above.

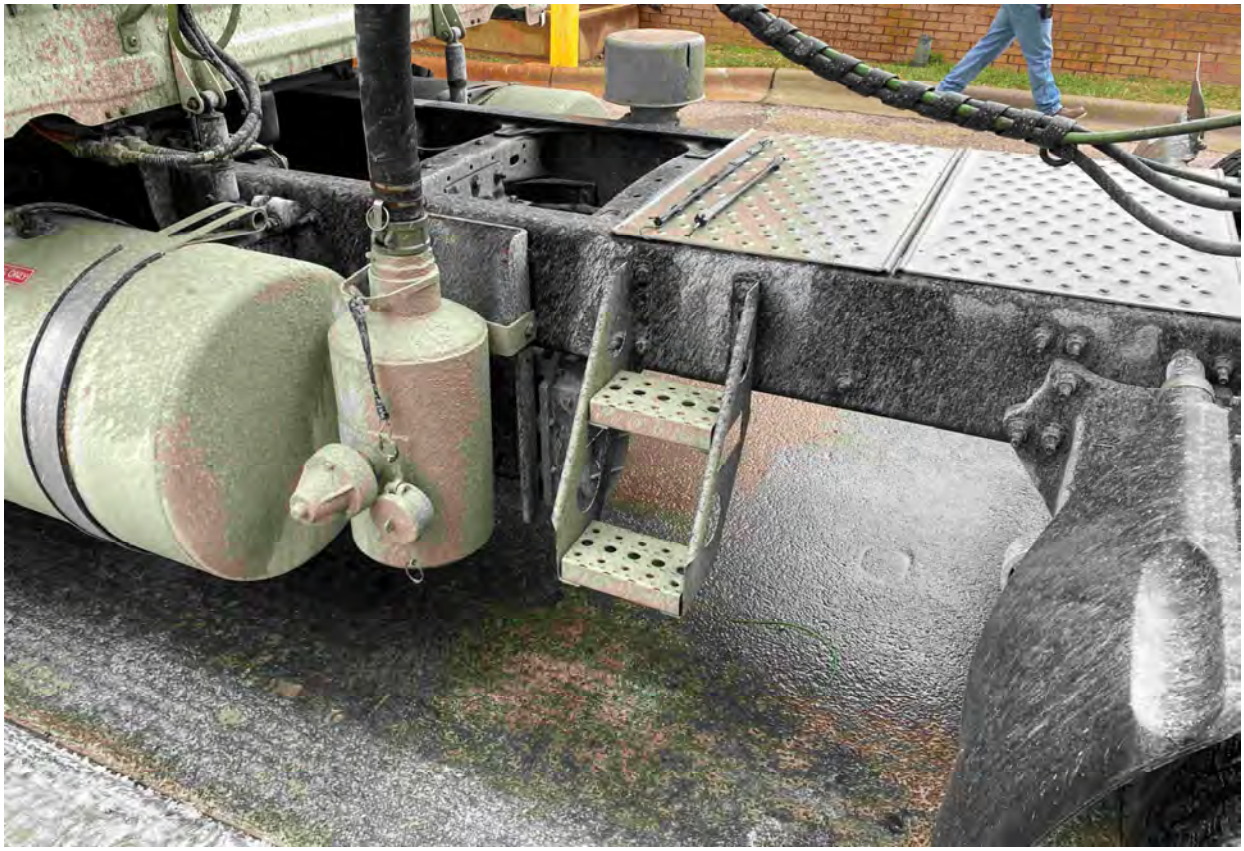
4 SOUND MEASUREMENTS

Arno Bommer of CSTI acoustics conducted measurements at the Ullrich facility on November 17 to 21, 2022. The facility was operating normally during the measurements. Multi-day sound monitoring is discussed in Section 5. In this section, we discuss spot measurements made at various locations typically for 1 minute or less. Measurement locations were selected to best assess the sound of each sound source while minimizing the effects of other sound sources.

4.1 Lime Loading Noise

The facility uses lime in water treatment. Lime is delivered by trucks, normally in the morning on weekdays. Until fall 2022, blowers mounted on the trucks were used to convey lime into storage silos inside a building. The blowers produced loud sounds at the blower intake and along the associated piping. A truck-mounted blower is shown in Figure 2.

Figure 2. Truck Mounted Blower



To reduce this noise, a permanent blower was installed inside an acoustically treated room inside the building. This blower was newly reconfigured and enhanced such that the truck-mounted blowers are no longer necessary.

Figure 3. Blower Inside Building

We made sound measurements around the lime-loading area, at the property line, and in the community with lime loading done with the interior blower and with a truck-mounted blower. The measurements showed that the treatment (using the newly reconfigured blower) reduced the lime-loading noise by 10 to 12 dBA.

4.2 Basin Cleaning Noise

There are several major noise sources associated with the basin cleaning:

- Water is pressurized with diesel-powered pumps (up to 4 running at a time).
- Water is sprayed at high pressure to remove lime scale from basin surfaces.
- The water and scale residue are then vacuumed from the bottom of the basin using a truck-mounted vacuum.

This equipment is shown in the following photographs:

Figure 4. Diesel Powered Pumps

Figure 5. Descaling Within Basin

Figure 6. Vacuum Truck

These sounds are produced by equipment provided by vendors, not by equipment that is part of the Ullrich facility. The sound level in the community is dependent on the level produced by the equipment and the location of the equipment. For the cleaning of Basin 2 that we measured, the pumps and vacuum truck were located outside the basins between Basins 1 and 2, so sound levels may be similar during the cleaning of Basin 1. The other basins at Ullrich are much further away from the community and would be expected to produce lower sound levels in the community.

4.3 Other Equipment Noise

Most of the permanent equipment at Ullrich is small and produces low levels of sound. This includes:

- Small pumps and motors
- Motors, gears, and stirrers
- Transformers
- HVAC equipment
- Basin waterfalls

The waterfall by Basin 1 is faintly audible in the nearby buffer zone, but this steady, broad-band sound is a type of sound that is not generally found to be objectionable.

Figure 7. Small Motors above Basin

Figure 8. Basin 1 Waterfall

Backup alarms for trucks and construction equipment are sometimes audible in the community. The facility is laid out such that vehicles seldom have to back up, but we noticed that while we were there, the construction equipment was frequently sounding backup alarms.

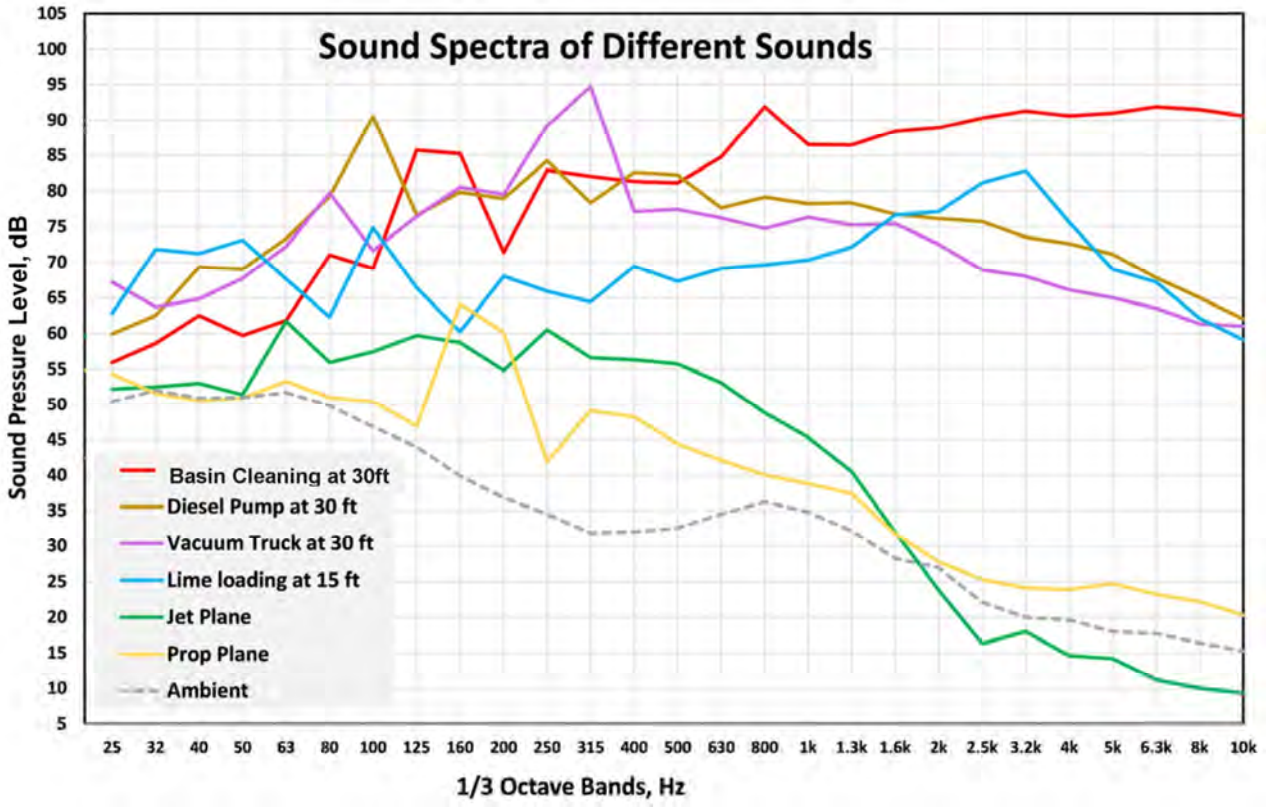
While we were at the site, we did not see any operations of the sludge removal. This involves loading trucks inside a building at the north edge of the facility. There are centrifuges inside the building, but the room with the centrifuges is acoustically treated. We did not hear about any community complaints regarding this operation.

Figure 9. Centrifuge in Sludge Building

4.4 Sound Spectra

All sound measurements were made in 1/3 octave bands in addition to the "dBA" levels that are useful representations of the loudness. The sound spectrum is important because sound at different frequencies propagates differently. The spectra of some of the sound sources are presented in the following figure.

Figure 10. Sound Spectra Measured at Site



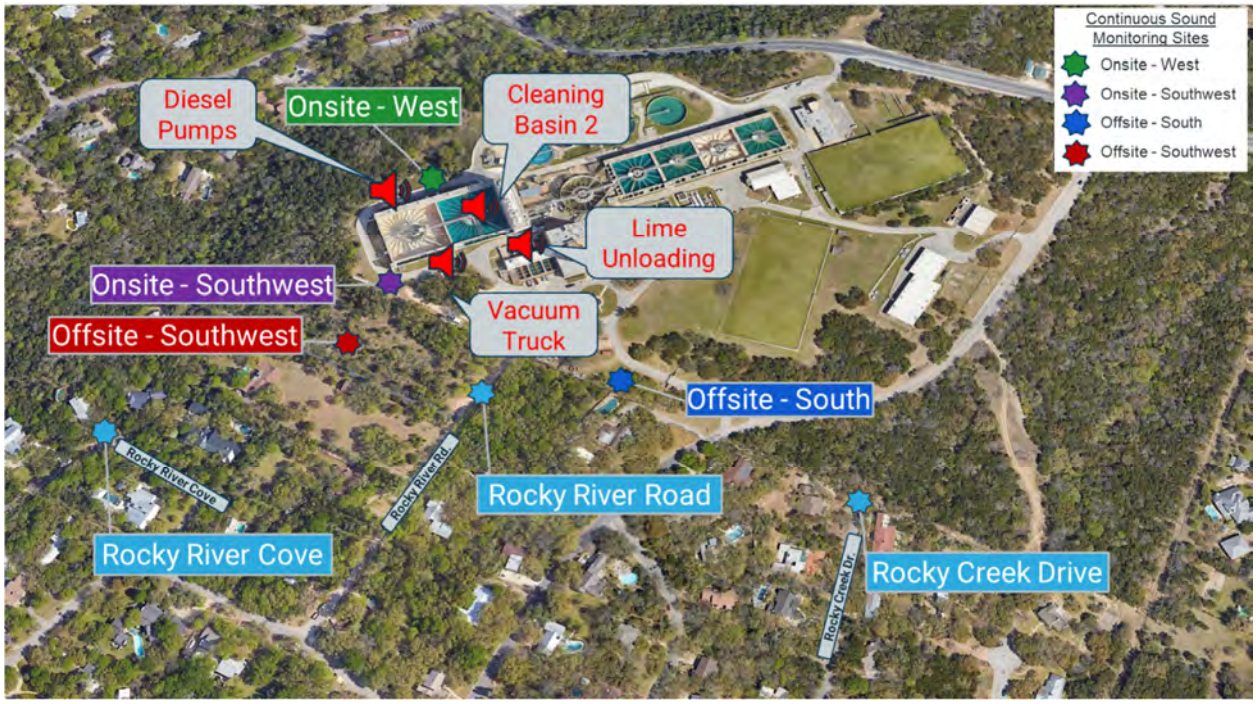
For Figure 10:

- Low-frequency sounds are to the left.
- High-frequency sounds are to the right.
- Sharp peaks indicate tonal sounds.
- Basin Cleaning operations sounds are primarily high-frequency noise.
- All sound levels vary over time.

4.5 Fence Line and Community Sound Measurements

Figure 11 presents the main sound measurement locations at the fence line and in the surrounding community.

Figure 11. Sound Measurement Locations



24-hour monitoring was conducted over five days at four positions. The abbreviations for these positions that was used in the Nelson report are:

ONW: Onsite West (Near diesel pumps)
ONSW: Onsite Southwest (Fence by Basin 1)
OFS: Offsite South (near Ullrich Gate)
OFSW: Offsite Southwest (in buffer zone)

Spot sound measurements were taken at the four monitoring locations, at the community locations marked in light blue on the figure above, and at other locations in and around the site. Sound levels of normal plant operations and of specific operations, such as the basin cleaning and lime loading, were measured. Basin cleaning operations were conducted on November 17 and 18, 2022. Lime loading was conducted on November 17, 18, and 21, 2022.

The facility was operating normally during the sound measurements. There was some construction activity going on involving an expanded parking area near the circle at the entrance. This produced intermittent sounds audible along the southwest property line and in the community including equipment backup alarms.

The following table summarizes the sound levels from differ operations at the locations shown in the previous figure:

Table 4. Summary of Sound Measurements

Condition:	Site						
	Onsite - West	Onsite - Southwest	Offsite - South	Offsite - Southwest	Rocky River Rd	Rocky River Cove	Rocky Creek Dr
	Sound Levels, dBA						
Ambient (normal operations)	48	47-48	38-43	41-43	38-40	35-42	36-40
Lime Loading Truck mounted blower	-	62	53	57	52	45	-
Lime Loading w/ building blower	-	50	41	47	<47	<41	-
Basin Cleaning - Diesel pumps	85	-	-	-	-	-	-
Basin Cleaning- Vacuum Truck	-	71	<54	63	52	45	-
Basin Cleaning- Hydroblasting	-	70-73	55-60	63-66	52-54	46	-

As shown in the table, ambient sound levels with the facility operating normally are low at all of the sites near the residences.

The truck-mounted lime blower is clearly audible in the community, producing a tonal, whining sound that isn't loud but can be easily detected. With the newly reconfigured lime blower inside the building, this sound is inaudible at most locations at most times and can only be heard when ambient sound levels are low.

The basin cleaning is also plainly audible in the community, with the vacuum truck producing a clear low-frequency tone.

Sound levels within the Ullrich facility during normal, continuous operations ("Ambient" conditions) are low (below 70 dBA at Onsite Southwest). At Onsite Southwest, sound levels increase to a maximum of 73 dBA during intermittent noisy operations, like lime loading and basin cleaning. At the buffer site (Offsite-Southwest) and all of the community sites (Rocky River Rd, Rocky River Cove, and Rocky Creek Dr.), the sound levels are below the Austin Noise Limit of 70 dBA under all conditions.

For all sounds, there is attenuation due to:

- Distance to the residences,
- Shielding from buildings and topography, and
- Some minor effects of foliage and ground absorption.

The following figure presents the A-weighted sound levels (dBA) measured in the community during basin cleaning with the vacuum truck operating. As shown, sound levels generally decrease with increases in distance from the facility.

Figure 12. Sound Levels Measured in Community

5 MULTI-DAY SOUND MONITORING

Sound monitors were set up at the four positions previously discussed. These were identical to the locations used in the Nelson study with the possible exception of the Offsite Southwest site in the buffer area. The exact location of the previous Offsite Southwest monitoring could not be determined (the site had been partially cleared since then), but the location we selected for the monitor was probably within 50 ft of the previous location.

All four monitors were programmed to make audio recordings of loud sounds that could be listened to in order to identify the sources of the sounds.

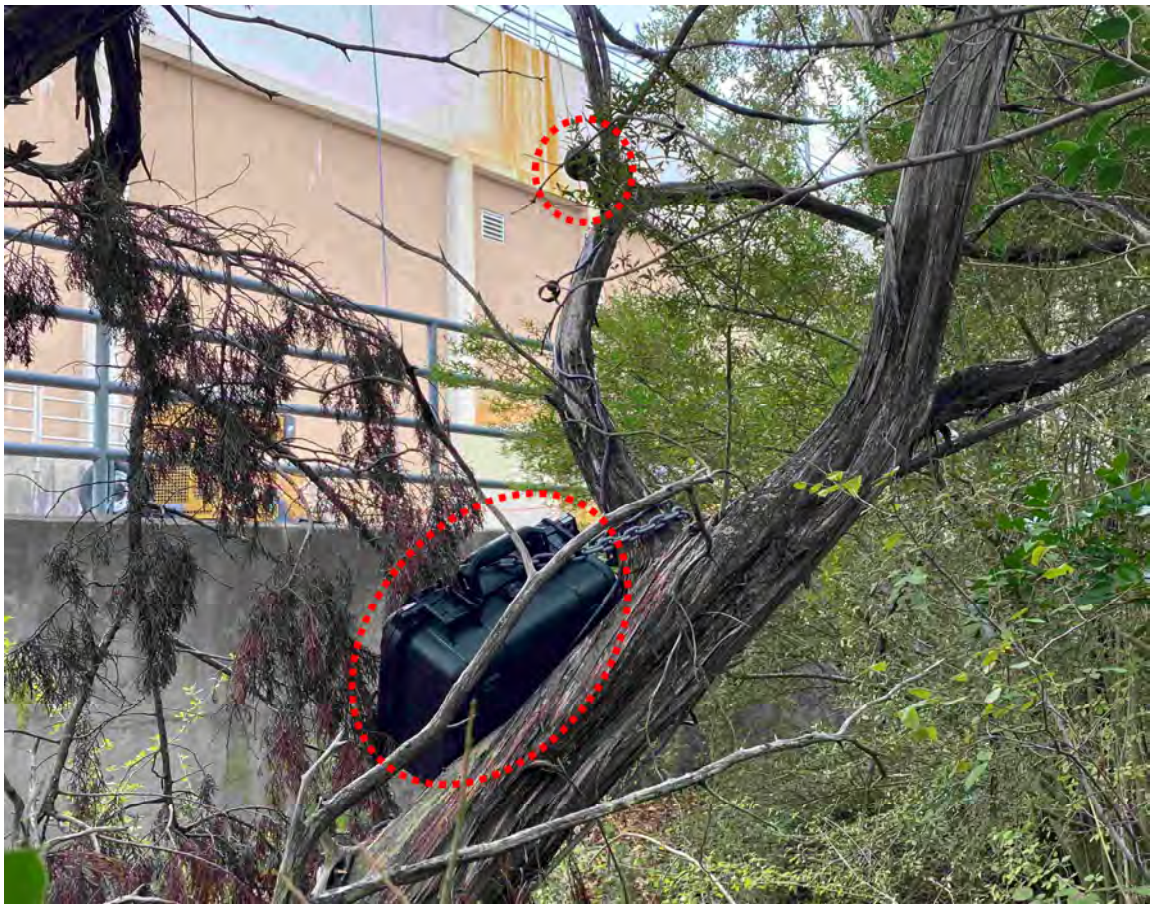
Photos of the monitors at the locations are shown in Figures 13 to 16.

Figure 13. Monitor Offsite Southwest

Figure 14. Monitor Offsite South

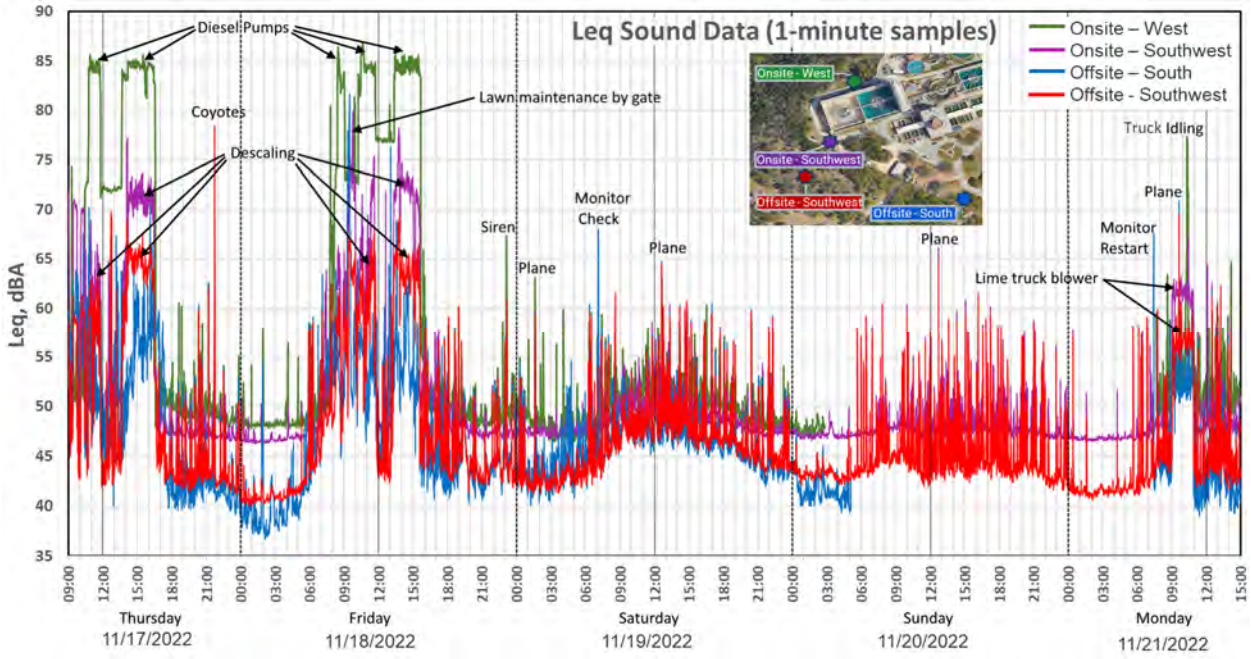
Figure 15. Monitor Onsite Southwest

Figure 16. Monitor Onsite West



The following figure shows the Leq (average) sound levels at all four monitors over 5 days.

Figure 17. Sound Monitoring Data

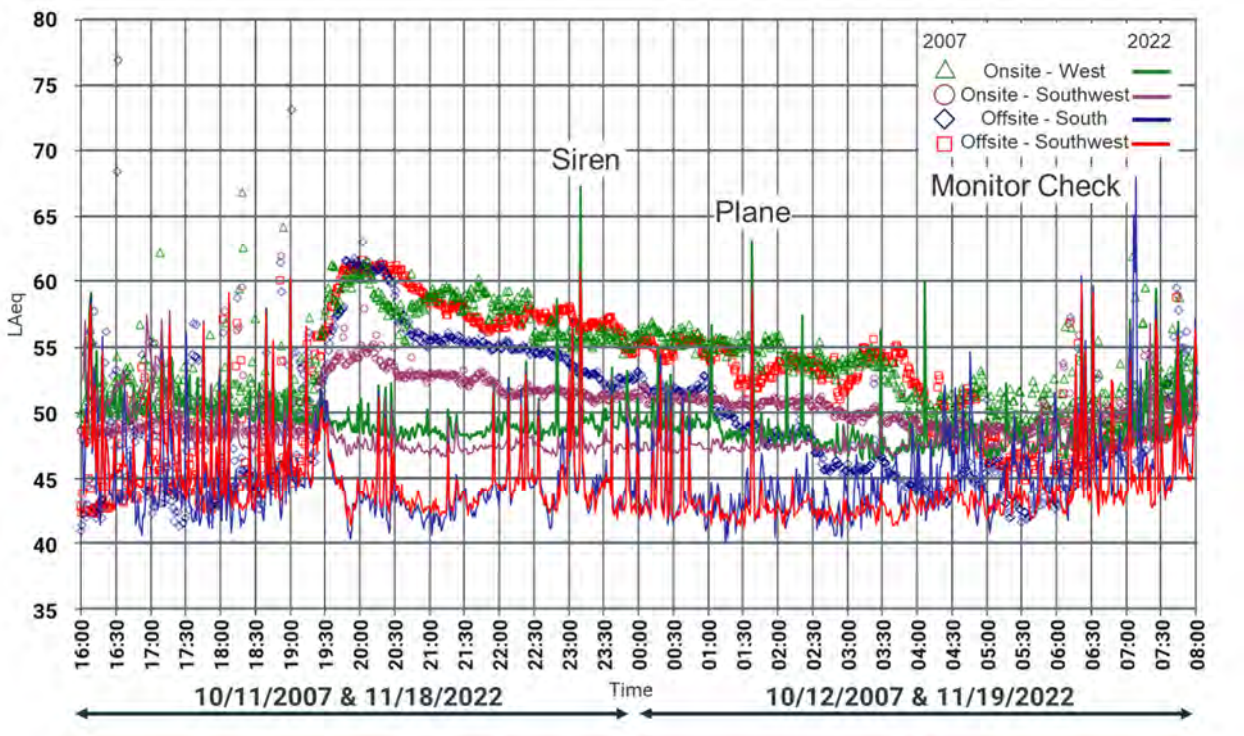


This graph shows all of the sound monitoring data from November 2022. Each color represents a different monitoring location. The red line is measured at Offsite Southwest in the buffer zone nearest the residences. Time goes from left to right over four days. Louder sounds are indicated as higher up on the graph. The most important data from this chart are:

- On the left, there are high sound levels from the basin cleaning on two separate days. The green line shows the sound levels from the diesel pumps at a nearby monitor. The red line shows sound levels of about 65 dBA in the buffer zone.
- There are many brief spikes in the data. These are most commonly from planes flying overhead, though some are from other sources such as sirens or animals. Only the loudest ones are labeled.
- One the right of the graph, you can see the sound levels from testing with the blower on a lime truck. As shown with the red line, it produced a sound level of about 57 dBA in the buffer zone.
- When there are no sounds from basin cleaning or the truck lime blower and when the spikes from planes and sirens are excluded, the sound levels at all four locations are typically 50 dBA or below.
- On Sunday morning, the batteries failed on two monitors (Onsite West and Offsite South), and they were restarted on Monday morning. The other two monitors ran continuously for all five days.

The following figure compares our 2022 monitoring data with monitoring data from 2007 made at the same four locations.

Figure 18. Comparison of Nelson and CSTI Monitoring Data



In order to compare the 2022 measurements with the 2007 measurements, we plotted the data for one evening from each year. The 2007 monitoring was conducted only from 4 pm to 8 am each day and not during the daytime. For ease of comparison, 2022 data was plotted with the same color for each measurement position that was used for presenting 2007 measurements.

The 2007 data is shown alone with symbols representing each measurement sample. Sound levels increase from about 8 pm (20:00) until 4 am. This is due to insect sounds at night in October. The 2022 measurements were made in November when there were no insect sounds at night, so the 2022 data does not increase at night.

At the left and right ends of the graph (where there is no insect noise), the lower levels for each color (ignoring the spikes from planes) are very similar for the dots in 2007 and the lines in 2022. The blue and red data, representing the south site and the buffer site, are about 45 dBA. The purple and green data, representing the onsite west and southwest locations, are about 50 dBA.

Our summary comparing the 2022 monitoring data with the 2007 data is:

- 2007 data was for only evenings (4 pm to 8 am each night).
- 2022 data was taken continuously to cover both day and night.
- 2007 data was in October, and there was insect noise at night.
- 2022 data was in November during cool weather without insect noise.
- Measurements from 2007 and 2022 both show brief, loud sounds, primarily from aircraft.
- 2022 data includes basin cleaning operations (but not in the evening as presented in the figure).

The sound levels in 2007 (without insects) are comparable to the 2022 data.

The graphs of the Nelson data for all four sites are presented in Appendix B.

The complete data for the 2022 sound monitoring is presented in separate Excel spreadsheets.

6 VIBRATION MEASUREMENTS

No ground vibration measurements were made as part of the 2007/2008 study. Ground vibration measurements were taken around the property line of the Ullrich plant on November 18, 2022. The measurement locations are shown in Figure 19. The measurement data is presented in a separate Excel spreadsheet.

Figure 19. Ground Vibration Measurement Locations

The City of Austin limits earth-borne vibration at a residential area boundary line according to the displacements listed in the adjacent table below.

Table 5. Austin Ground Vibration Limits

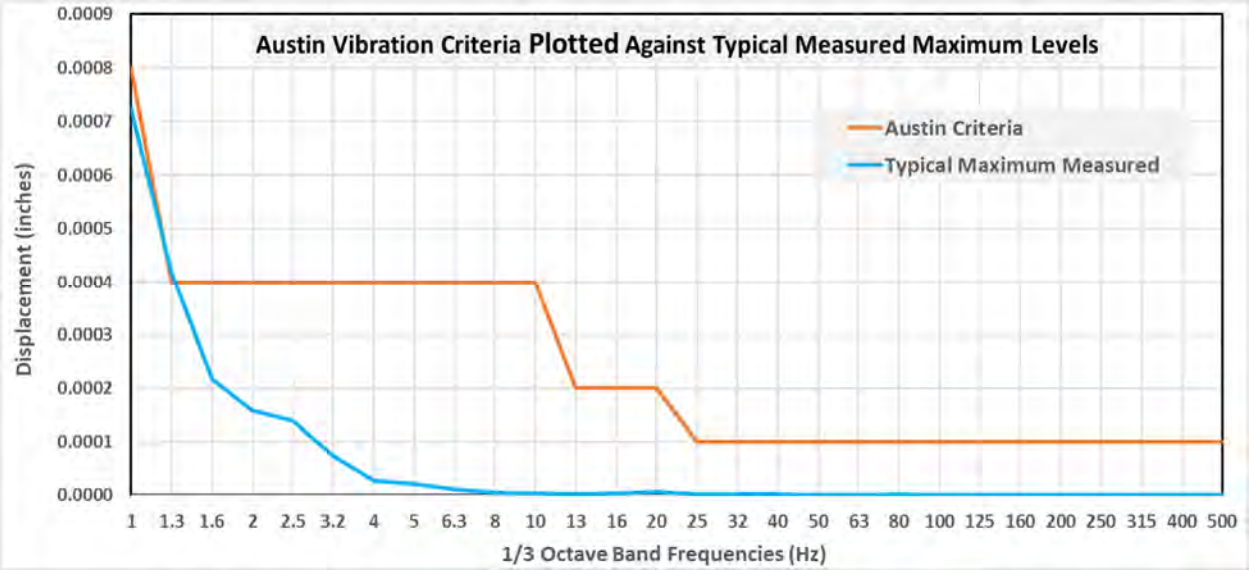
Frequency (cycles per second)	Displacement (inches)
0 to 1	.0008
1 to 10	.0004
10 to 20	.0002
20 to 30	.0001
30 to 40	.0001
40 and over	.0001

The City of West Lake Hills has a ground vibration limit of 0.002 g peak acceleration measured at any point beyond the lot line. This is a different unit of measurement (acceleration versus displacement) and is generally less stringent. Our measurements were made in acceleration and were converted to displacement for comparison with the City of Austin limits.

The following figure compares the Austin vibration criteria with the "Typical" measured ground vibration data representing 37 of the 46 vibration measurements made at the 14 positions around the site perimeter. Unplotted vibration measurements were determined to be erroneous readings due to:

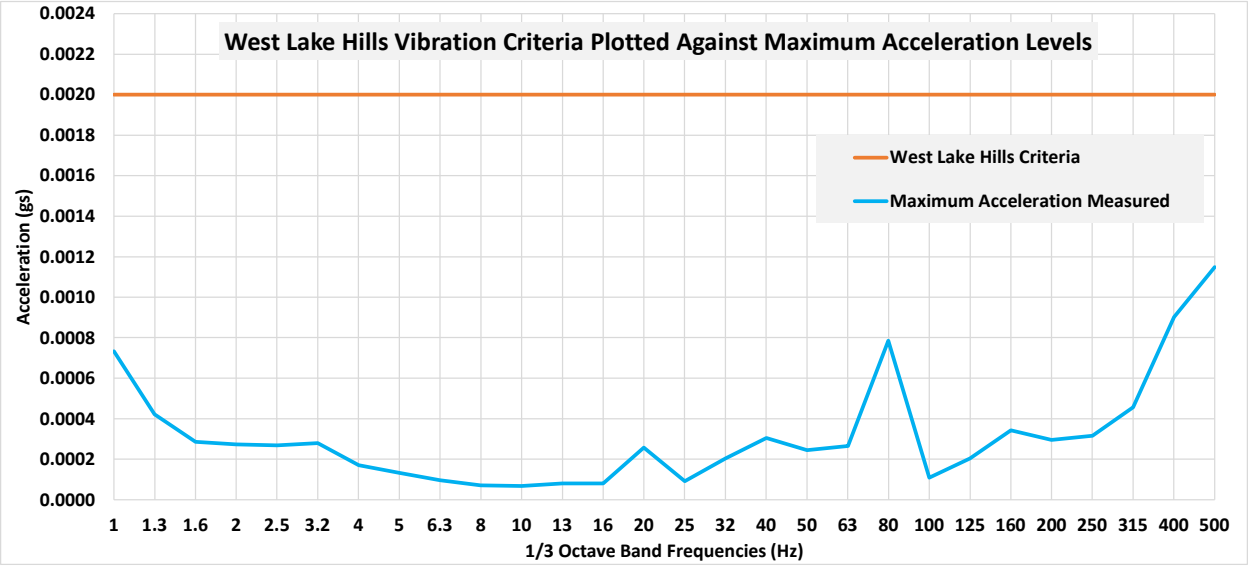
- Other measurements at the same positions just before or after the unplotted data were significantly lower.
- Measured ground vibration levels at adjacent locations were significantly lower.
- The vibration meter was probably still settling after being mounted at the measurement location.
- No ground vibration was noticeable/feelable at any of the locations.

Figure 20. Ground Vibration Comparison with Austin Ordinance



The following figure compares the measured ground vibration data with the West Lake Hills vibration criteria. None of the vibration measurements were found to exceed the ordinance.

Figure 21. Ground Vibration Comparison with West Lake Hills Ordinance



The residences are much further away from the site than the property line and will have much lower vibration levels. The measurements indicate that vibration levels will be imperceptible in all residences and will not interfere with any uses of property.

7 NOISE MITIGATION

Successful noise mitigation must be tailored to address the objectionable characteristics of sound. This is affected by:

- The frequency of the sound.
- The presence of distinct tones/pitches.
- The loudness of the sound.
- The loudness of background sound (masking).
- The time of day the sound occurs.
- The length of time the sound lasts.

Sound at the Ullrich site can be produced by:

- Mechanical equipment
- Water splashing
- Alarms
- Truck traffic

Sound in the atmosphere:

- Attenuates with distance.
- Propagates best downwind.
- Reflects off solid surfaces.
- Is only slightly reduced by vegetation.
- Is moderately reduced by walls.
- Some sound will curve over walls (especially low-frequency sounds).

Sound can be reduced by:

- Sound absorption on reflective surfaces.
- Noise barriers.
- Equipment treatments (like silencers).

Due to the complexities of noise control, especially with respect to the performance of noise barriers, we recommend 3D computer noise modeling to assess the benefits of different noise-control options.

8 FUTURE PLANS

To evaluate possible methods of noise control, it is useful to create a 3-D computer sound model of the Ullrich facility. The model could be used to analyze sound from normal operations or intermittent operations such as basin cleaning.

The model could be used to assess the effectiveness of different noise treatments such as noise barriers and sound absorption. For the noise barriers, various locations and height could be evaluated. Further enhancement of the lime blower treatment will also be investigated.

The results of the noise modeling of possible treatments will be discussed in a future report.

9 SUMMARY

Collaboration in Science and Technology Inc. (CSTI) was retained by Kennedy/Jenks on behalf of the City of Austin to conduct a noise study of the Ullrich Water Treatment Plant (WTP) located in Austin, TX to compare with a previous noise study conducted by Nelson Acoustics in 2007. Sound levels were monitored over five days from November 17 to 21, 2022 while

spot sound measurements were taken around the facility and in the neighborhood to the south. Detailed sound measurements were made of noisy equipment and operations including the lime loading, pumps for descaling, vacuum truck for descaling, and the descaling itself. Ground vibration measurements were taken along the property line of the facility.

At the buffer site (Offsite-Southwest) and all of the community sites (Rocky River Rd, Rocky River Cove, and Rocky Creek Dr.), the sound levels are below the Austin Noise Limit of 70 dBA under all conditions. Typical sounds from the Ullrich facility measured in the buffer zone (Offsite Southwest) between the facility and the residences are:

- Normal operations: 42 dBA
- Truck-mounted lime blower: 57 dBA
- Newly reconfigured lime blower inside building: 47 dBA
- Back-up alarms: about 40 to 45 dBA
- Basin Cleaning, diesel pumps: shielded and not audible to south or southwest
- Basin Cleaning, vacuum truck: 63 dBA
- Basin Cleaning, hydra-blasting: 63 to 66 dBA
- Austin noise limit: 70 dBA

Typical sounds in the community *not* from the Ullrich facility are:

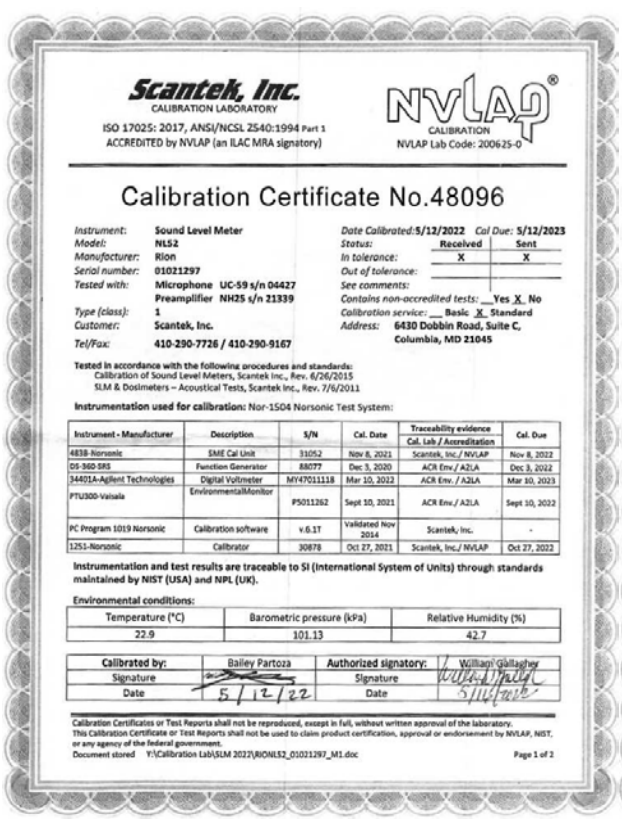
- Natural quiet: 35 to 42 dBA (includes inaudible steady sound from Ullrich)
- Distant traffic: 40 dBA
- Planes overhead: 50 to 60 dBA
- Natural sounds (wind, birds, insects, etc.): 30 to 63 dBA (78 dBA for coyotes one evening)

The recently reconfigured lime blower reduced the noise of the lime truck unloading operation by 10 to 12 dBA. Functionally this represents a 50% reduction in perceptible sound and a 90% reduction sound energy.

For comparisons with the applicable criteria:

- All sound levels are under the Texas State noise limit of 85 decibels.
- All sound levels are below Austin's 70 dBA limit.
- The Ullrich facility does not exceed any applicable noise or ground vibration ordinances.

APPENDIX A. CALIBRATION CERTIFICATES



Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.48096

Instrument: **Sound Level Meter**
Model: **NL52**
Manufacturer: **Rion**
Serial number: **01021297**
Tested with: **Microphone UC-59 s/n 04427**
Preamplifier NH25 s/n 21339
Type (class): **1**
Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726 / 410-290-9167**

Date Calibrated: **5/12/2022** *Cal Due:* **5/12/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		

See comments:
Contains non-accredited tests: __Yes X No
Calibration service: __ Basic X Standard
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/26/2015
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4838-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
DS-360-SRS	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Mar 10, 2022	ACR Env. / A2LA	Mar 10, 2023
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
22.9	101.13	42.7

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	5/12/22	Date	5/16/22

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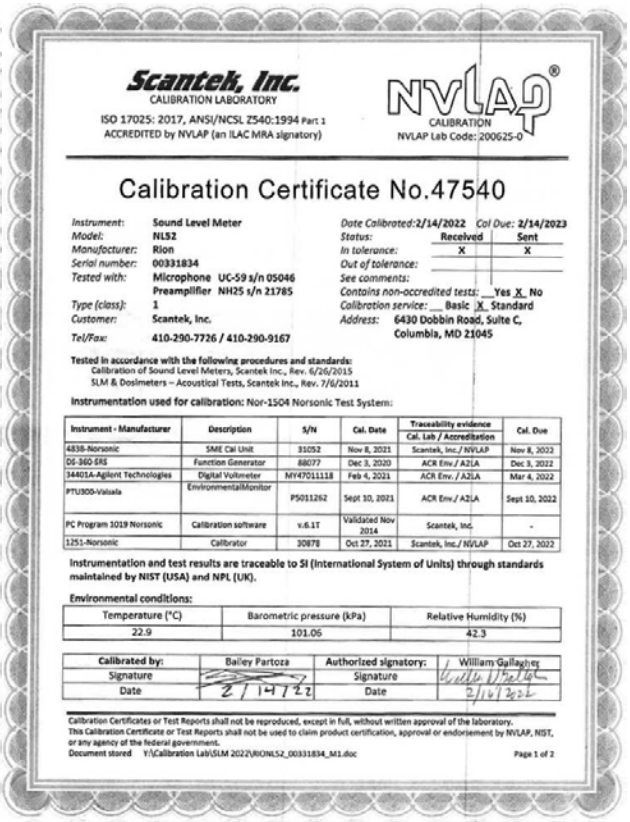

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.47540

Instrument: **Sound Level Meter**
Model: **NL52**
Manufacturer: **Rion**
Serial number: **00331834**
Tested with: **Microphone UC-59 s/n 05046**
Preamplifier NH25 s/n 21785
Type (class): **1**
Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726 / 410-290-9167**

Date Calibrated: **2/14/2022** *Cal Due:* **2/14/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		

See comments:
Contains non-accredited tests: __Yes X No
Calibration service: __ Basic X Standard
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/26/2015
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4838-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
DS-360-SRS	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Mar 4, 2022
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
22.9	101.06	42.3

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	2/14/22	Date	2/16/2022

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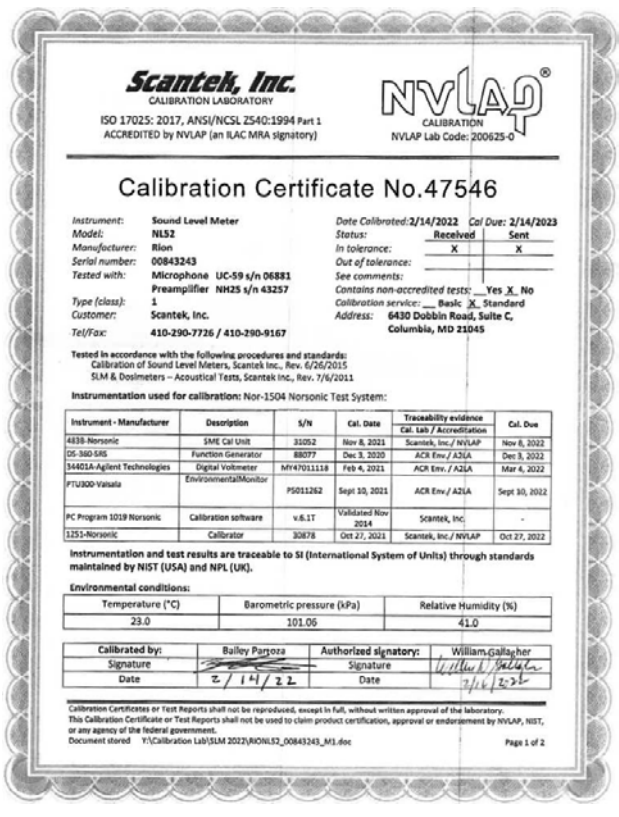

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.47546

Instrument: **Sound Level Meter**
Model: **NL52**
Manufacturer: **Rion**
Serial number: **00843243**
Tested with: **Microphone UC-59 s/n 06881**
Preamplifier NH25 s/n 43257
Type (class): **1**
Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726 / 410-290-9167**

Date Calibrated: **2/14/2022** *Cal Due:* **2/14/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		

See comments:
Contains non-accredited tests: __Yes X No
Calibration service: __ Basic X Standard
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/26/2015
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4838-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
DS-360-SRS	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Mar 4, 2022
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
23.0	101.06	41.0

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	2/14/22	Date	2/16/22

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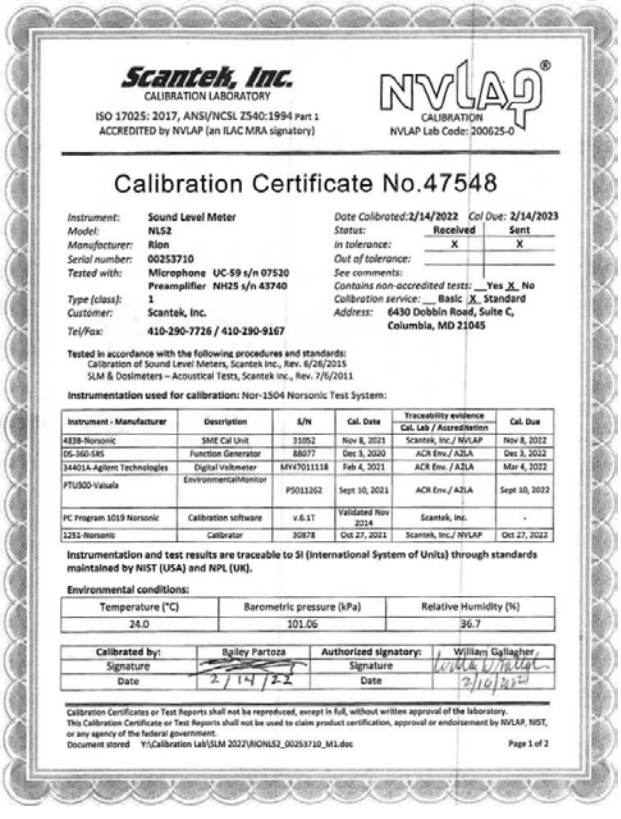

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.47548

Instrument: **Sound Level Meter**
Model: **NL52**
Manufacturer: **Rion**
Serial number: **00253710**
Tested with: **Microphone UC-59 s/n 07520**
Preamplifier NH25 s/n 43740
Type (class): **1**
Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726 / 410-290-9167**

Date Calibrated: **2/14/2022** *Cal Due:* **2/14/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		

See comments:
Contains non-accredited tests: __Yes X No
Calibration service: __ Basic X Standard
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/26/2015
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4838-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
DS-360-SRS	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Mar 4, 2022
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
24.0	101.06	36.7

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	2/14/22	Date	2/16/22

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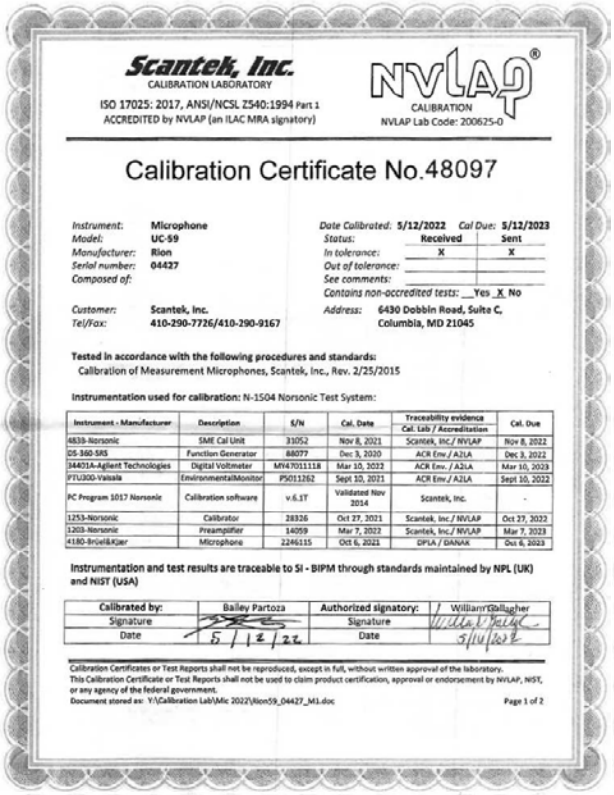

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.48097

Instrument: **Microphone**
Model: **UC-59**
Manufacturer: **Rion**
Serial number: **04427**
Composed of:

Date Calibrated: **5/12/2022** *Cal Due:* **5/12/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No

Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726/410-290-9167**
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 2/25/2015

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4839-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
05-360-SR5	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Mar 10, 2022	ACR Env. / A2LA	Mar 10, 2023
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022
1203-Norsonic	Preamplifier	14059	Mar 7, 2022	Scantek, Inc./ NVLAP	Mar 7, 2023
4180-Brüel&Kjær	Microphone	2246115	Oct 6, 2021	DPLA / DANAK	Oct 6, 2023

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	5/12/22	Date	5/16/2022

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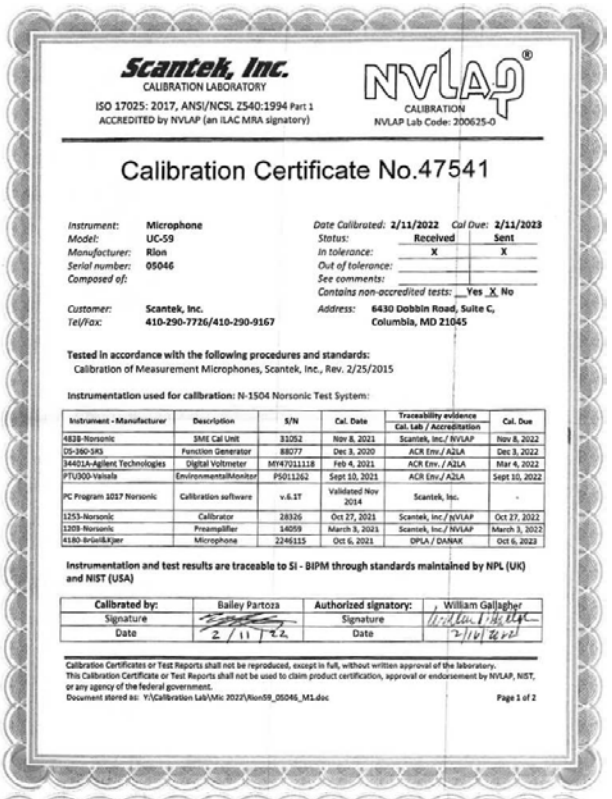

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.47541

Instrument: **Microphone**
Model: **UC-59**
Manufacturer: **Rion**
Serial number: **05046**
Composed of:

Date Calibrated: **2/11/2022** *Cal Due:* **2/11/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No

Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726/410-290-9167**
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 2/25/2015

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4839-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
05-360-SR5	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Mar 4, 2022
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022
1203-Norsonic	Preamplifier	14059	March 3, 2021	Scantek, Inc./ NVLAP	March 3, 2022
4180-Brüel&Kjær	Microphone	2246115	Oct 6, 2021	DPLA / DANAK	Oct 6, 2023

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	2/11/22	Date	2/16/2022

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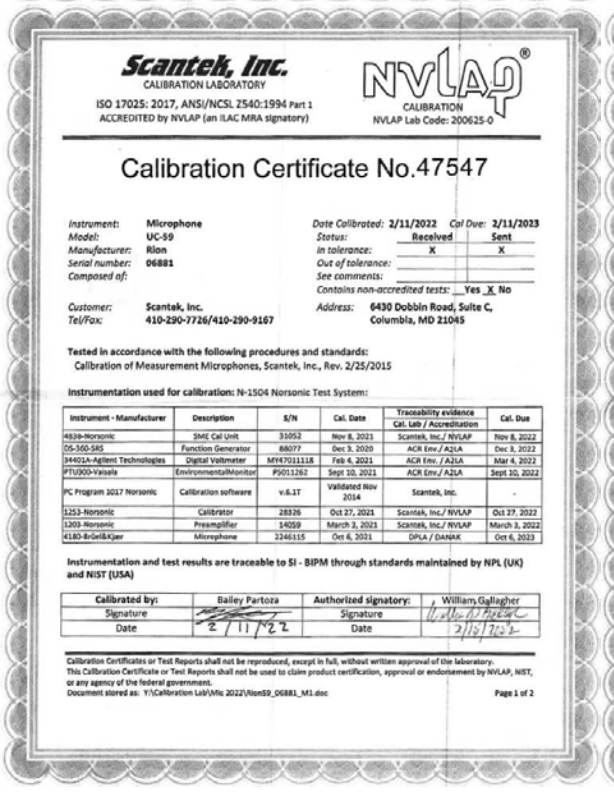

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.47547

Instrument: **Microphone**
Model: **UC-59**
Manufacturer: **Rion**
Serial number: **06881**
Composed of:

Date Calibrated: **2/11/2022** *Cal Due:* **2/11/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No

Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726/410-290-9167**
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 2/25/2015

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4839-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
05-360-SR5	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Mar 4, 2022
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022
1203-Norsonic	Preamplifier	14059	March 3, 2021	Scantek, Inc./ NVLAP	March 3, 2022
4180-Brüel&Kjær	Microphone	2246115	Oct 6, 2021	DPLA / DANAK	Oct 6, 2023

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	2/11/22	Date	2/16/2022

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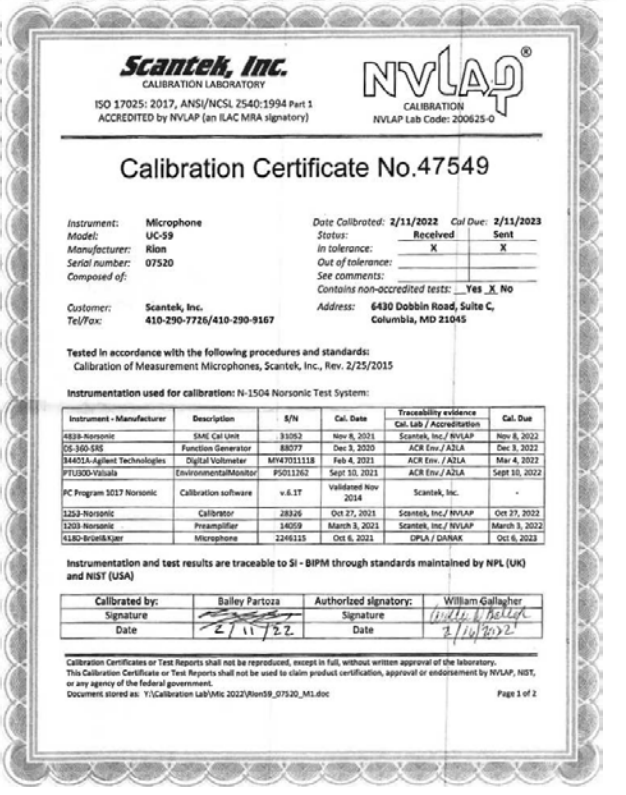

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.47549

Instrument: **Microphone**
Model: **UC-59**
Manufacturer: **Rion**
Serial number: **07520**
Composed of:

Date Calibrated: **2/11/2022** *Cal Due:* **2/11/2023**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No

Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726/410-290-9167**
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 2/25/2015

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
4839-Norsonic	SME Cal Unit	31052	Nov 8, 2021	Scantek, Inc./ NVLAP	Nov 8, 2022
05-360-SR5	Function Generator	88077	Dec 3, 2020	ACR Env./ A2LA	Dec 3, 2022
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Mar 4, 2022
PTU300-Vaisala	EnvironmentalMonitor	P5011262	Sept 10, 2021	ACR Env./ A2LA	Sept 10, 2022
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Oct 27, 2021	Scantek, Inc./ NVLAP	Oct 27, 2022
1203-Norsonic	Preamplifier	14059	March 3, 2021	Scantek, Inc./ NVLAP	March 3, 2022
4180-Brüel&Kjær	Microphone	2246115	Oct 6, 2021	DPLA / DANAK	Oct 6, 2023

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by:	Bailey Partoza	Authorized signatory:	William Gallagher
Signature		Signature	
Date	2/11/22	Date	2/16/2022

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APPENDIX B. MONITORING FIGURES FROM NELSON REPORT

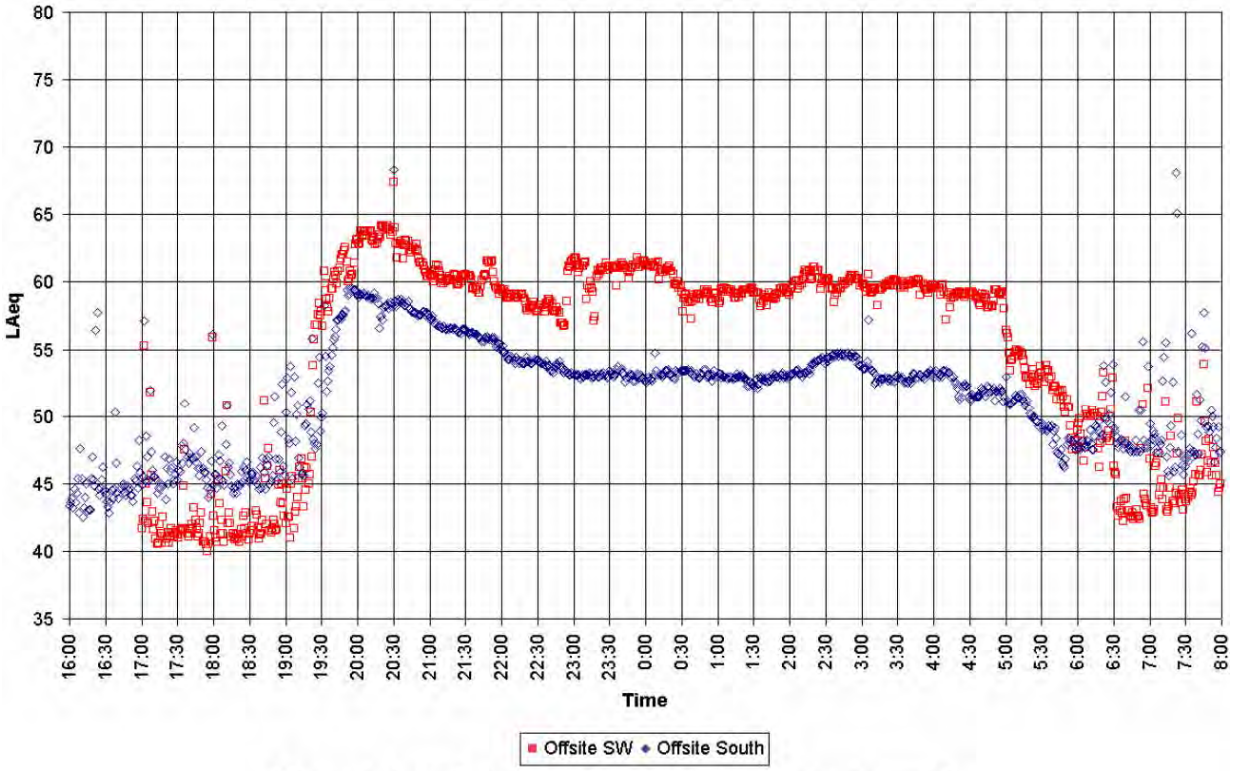

Figure 6.1: October 08-09, 2007, Unprocessed

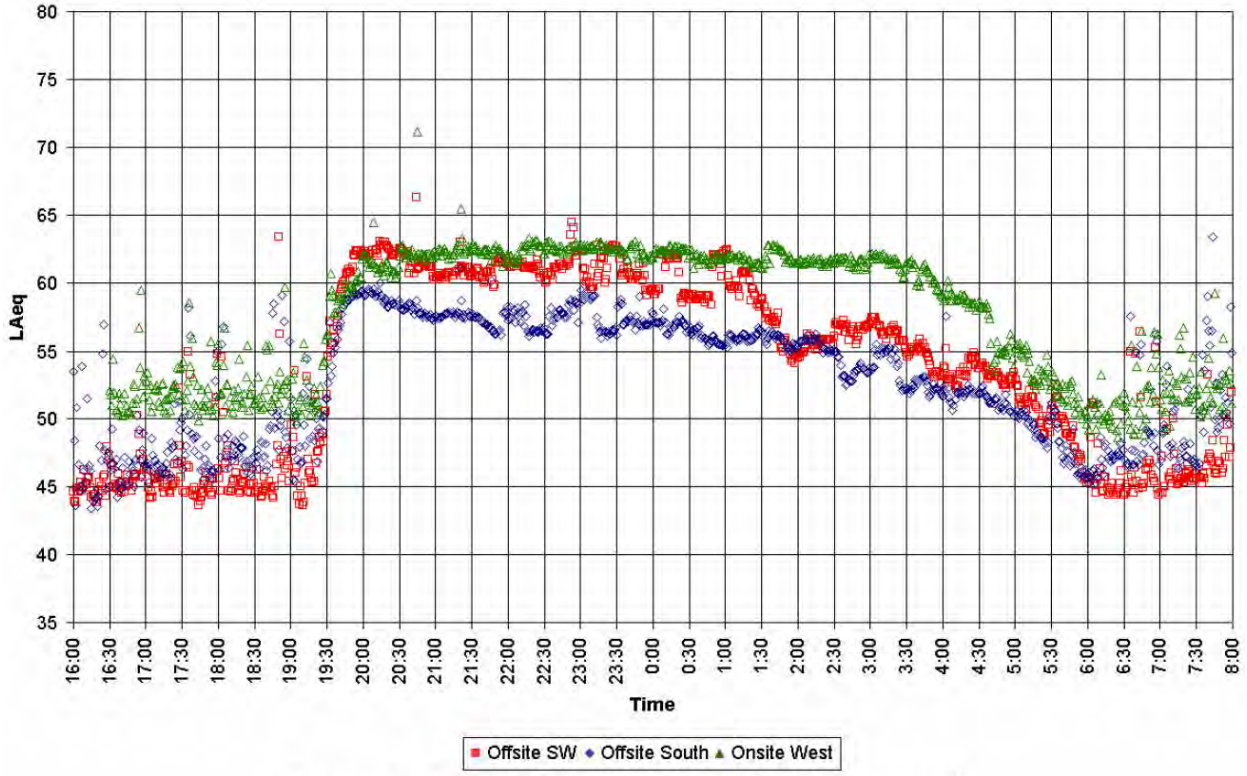

Figure 6.2: October 09-10, 2007, Unprocessed

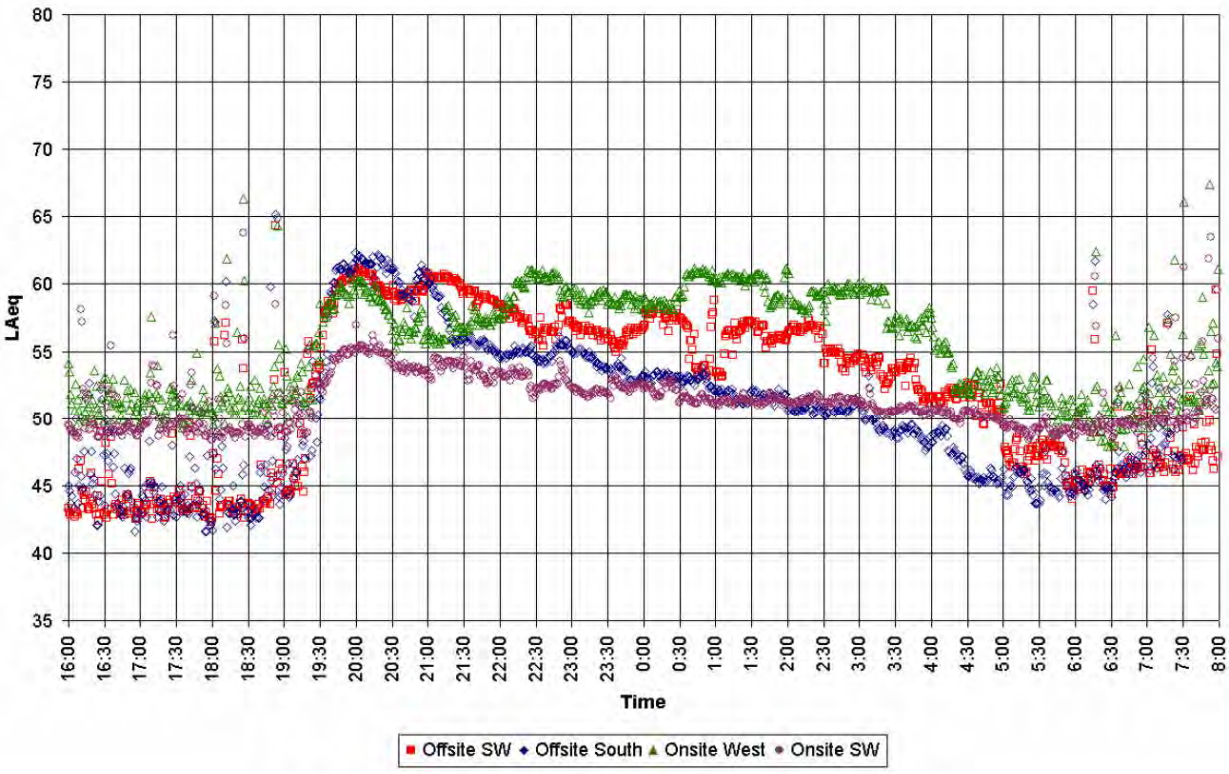

Figure 6.3: October 10-11, 2007, Unprocessed

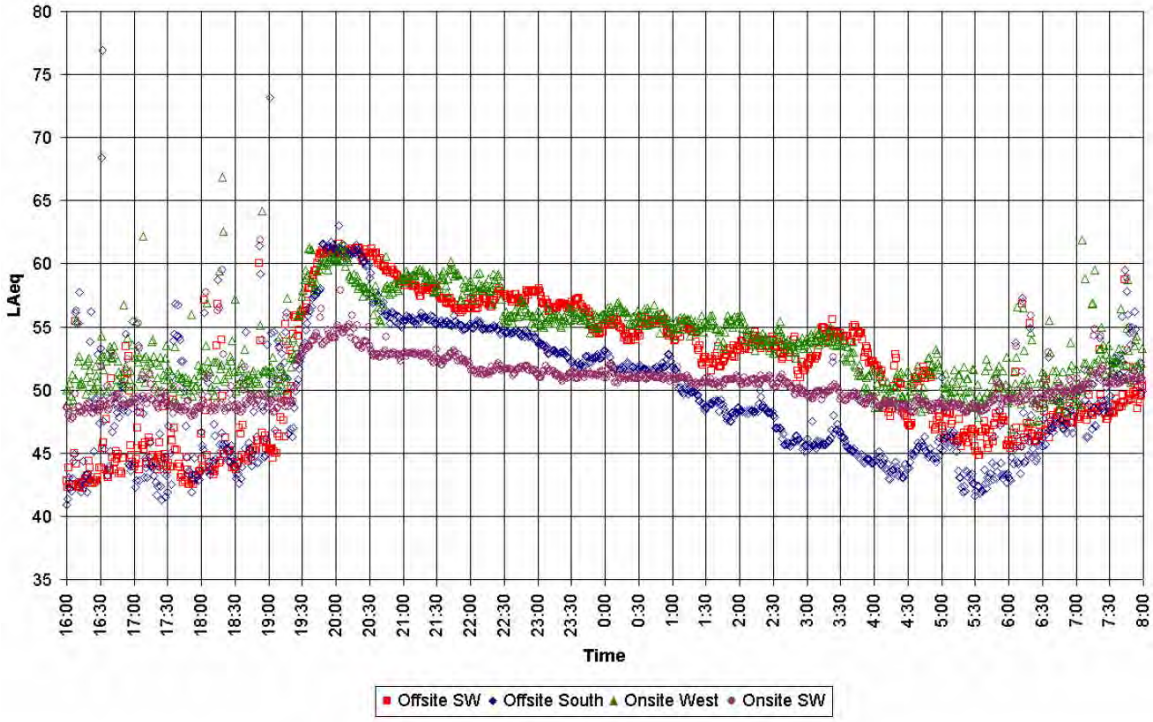

Figure 6.4: October 11-12, 2007, Unprocessed