Memorandum

To: Timothy S. Higgins
Town Administrator
Town of Lincoln
16 Lincoln Road
Lincoln, MA 01773

Date: May 31, 2019

Project #: 14249.00

From: Jason Ross, P.E., Director of Noise and Vibration

Re: Pierce House Music Tests

Background

The Pierce House in Lincoln, MA is a facility which hosts a wide range of events such as weddings, and birthday parties and can accommodate between 170 and 200 people with a dance floor and music under a tent. The Pierce House is a site only facility, so it does not provide event planning or day of event coordination. Music for events is arranged directly by the renter of the facility and the musical equipment (i.e. instruments and amplified speakers) are provided directly by the musicians. VHB understands that some members of the community have expressed concern with and have become annoyed by audible sound from the events at their residences. VHB conducted a sound study in May 2018 to evaluate ambient sound conditions with and without musical events and to assess the sound conditions in relation to applicable noise regulations and standards. The sound study included measurements at eight locations including long-term (3-5 day) measurements at five locations including evening periods when no events occurred at the Pierce House and when two separate music events occurred including a 10-piece band on Saturday May 26, 2018 and a DJ with amplified speakers on Sunday May 27, 2018. See VHB memorandum "Draft Pierce House Sound Study" dated June 18, 2018 for further information.

Introduction

VHB has conducted tests at the Pierce House on May 7, 2019 to evaluate music levels inside the facility tent and at a location along the western property line which is across the street from the closest residential property at 22 Weston Road. The goal of this testing was to identify ways that sound levels can be reduced in the community while still maintaining acceptable levels inside the tent. Testing involved simultaneous measurements inside and outside of the tent with a range of conditions to determine how to improve the sound attenuation between the tent and the community. Tests were conducted at a range of interior tent volumes, a range of bass levels, two different music selections, several speaker types and configurations, and with and without the outer clear vinyl cover along the sides of the tent. The testing did not include the use of acoustical curtains along the edges of the tent.

Pierce House Music Policy

According to Pierce House policies, outdoor music must cease promptly at 10 p.m. on Fridays and Saturdays and 9 p.m. Sunday through Thursday evenings. Exceptions are granted for Sundays before a Monday holiday. Indoor music is permitted until 10 p.m. Amplified music is permitted within reason, but during summer months when windows are open, the sound must be kept to a specified decibel limit. Subwoofers are not permitted. The tent area surrounding the musicians must be enclosed, and speakers must face the house or the woods off the south side of the house. Band size is limited to 7 pieces (includes singer). Bands may not invite friends or clients to the property.

101 Walnut Street
PO Box 9151
Watertown, MA 02472-4026
P 617.924.1770

Ambient Sound Levels

As described in VHB's memorandum in June 2018, ambient sound measurements were conducted at five locations at and near the Pierce House from May 23 to May 25, 2018 when there were no events occurring at the Pierce House. The Massachusetts Department of Environmental Protection (MassDEP) defines the "ambient" sound level as the background L_{90} sound level measured during periods of time the subject sound source may be present. Ambient L90 sound measurements during the evening hours when events may occur at the Pierce House are summarized in the table below. This table shows that the average L90 sound level was 39 dBA across all measurement locations. There was not a substantial change in ambient levels throughout the evening period from 6:00 to 10:00 PM.

Table 1. Ambient L90 Sound Levels (dBA)

Hour	Pierce House	28 Weston			16 Trapelo			14 Beaver Pond			45 Trapelo	
Date	5/25/18	5/23/18	5/24/18	5/25/18	5/23/18	5/24/18	5/25/18	5/23/18	5/24/18	5/25/18	5/25/18	Average
6–7 PM	37	39	41	38	44	48	41	39	39	35	41	**40**
7-8 PM	36	38	39	36	40	43	37	43	39	39	39	**39**
8-9 PM	37	38	37	37	37	39	37	46	40	38	41	**39**
9-10 PM	45	40	36	41	33	37	38	38	36	39	43	**39**

MassDEP Noise Regulation

MassDEP adopted a Noise Control Regulation, 310 CMR 7.10, under the authority of M.G.L. Chapter 111, Section 142B and 142D. The Noise Control Regulation is used to limit the potential for noise impact from industrial and commercial sources of sound. The MassDEP regulation limits sound according to the following conditions:

"No person owning, leasing, or controlling a source of sound shall willfully, negligently, or through failure to provide necessary equipment, service, or maintenance or to take necessary precautions cause, suffer, allow, or permit unnecessary emissions from said source of sound that may cause noise."

The MassDEP has established a Noise Level Policy for implementing this regulation. The MassDEP policy for implementing its noise regulation is contained in DAQC Policy 90-001 which states that a source of sound violates the Department's noise regulation if the source:

- Increases the broadband sound level by more than 10 dB(A) above ambient, or
- Produces a "pure tone" condition – when any octave-band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.

Because the MassDEP noise regulation is primarily geared towards stationary sources of sound that do not fluctuate substantially, there is no formal guidance on whether to compare the maximum sound level, Leq, or other statistical measure to the background ambient (L_{90}). Based on the variability of music generated at the Pierce House, VHB has compared the L50 sound level while music is played to the ambient L90.

Therefore, based on the MassDEP Noise Regulation and the average ambient sound level of 39 dBA (L90) in the community, sound levels with music should not exceed 49 dBA (L50).

Music Tests

VHB coordinated with Nancy Beach from the Pierce House, Bill DiOrio from Sound City and Bob Green for the music testing. All speakers were setup on the south end of the tent. The speakers tested included the following:

- Two 15-inch JBL PRX715 public/address speakers (2-way speakers) as part of Sound City's typical DJ setup. These speakers have a 90-degree horizontal and 50-degree vertical dispersion which is typical for this type of speaker.
- Two 12-inch Mackie SR450 public/address speakers (2-way speakers). These speakers have a 90-degree horizontal and 45-degree vertical dispersion which is typical for this type of speaker.
- One Bose L1 Compact Speaker. This speaker has a 180-degree horizontal and 40-degree vertical dispersion, so it is not very directive.

All sound measurements were conducted with sound level meters that meet the American National Standards Institute Type 1 requirements for accuracy. Data collected included one-second time histories of overall A-weighted and 1/3-octave band sound levels.

Figure 1 shows the sound measurement locations within the tent and along the property line, which was 200 feet away from the tent, as well as the speaker locations in the south end of the tent (see additional photos in the Appendix). Sound levels at the 22 Weston Road building, approximately 100 feet farther from the property line measurement location, are estimated to be approximately 3 dBA quieter based on general sound propagation principles.

Figure 1. Sound Measurement Locations

"September", a typical dance song by Earth Wind and Fire, was played for all tests. A standard version of the song was played for some tests and a dance mix version with additional bass content was played for other tests. Some tests reduced the bass content through the DJs mixing board. The bass levels, particularly in the 125-Hz Octave were found to be a significant contributor to the overall sound levels. Outside the tent near the property line, the bass content of the music was most audible. At even farther locations through the community, the amount of bass in the music is an even more significant factor.

Table 2 presents the results of the music tests including the L50 sound level within the tent and at the property line, the attenuation between the two locations, the estimated sound levels at the nearest residential building (22 Weston Road) and the estimated additional attenuation needed to keep sound levels at the residential building below 50 dBA. Sound levels at the 22 Weston Road building are estimated to be 3 dBA below the measurement location.

Table 2. Music Test Results

Song Version	Tent Volume	Bass	Vinyl Siding	Speakers	Sound Level (dBA, L50)				
					Tent	Property Line	Tent to Property Line Sound Attenuation	Estimated Sound Level at 22 Weston Road (Building)	Estimated Attenuation Needed to be Below 50 dBA at 22 Weston Road Residence
Standard	Med/High	Normal	On	(2) JBL PRX715	86	64	22	61	12
Standard	Med	Normal	On	(2) JBL PRX715	82	60	22	57	8
Standard	Med	Normal	On	(2) JBL PRX715	78	56	22	53	4
Standard	Med	Low	On	(2) JBL PRX715	80	51	29	48	None
Standard	Med	Low	Off	(2) JBL PRX715	78	52	26	49	None
Standard	Med/Low	Low	Off	(2) JBL PRX715 (Placed On Ground)	76	51	25	48	None
Dance Mix	Med	High	Off	(2) JBL PRX715	82	62	20	59	10
Dance Mix	Med/Low	High	Off	(1) Bose L1	76	55	21	52	3
Standard	Med/High	Normal	Off	(2) JBL PRX715 & (2) Mackie SR450	87	62	25	59	10
Standard	Med	Normal	Off	(2) JBL PRX715 & (2) Mackie SR450	80	58	22	55	6
Standard	Med	Low	Off	(2) JBL PRX715 & (2) Mackie SR450	83	60	23	57	8
Standard	Med	Low	Off	(2) JBL PRX715 & (2) Mackie SR450	76	52	24	49	None

The results show that when music levels were at low to medium volume in the tent (76 to 80 dBA L50) with low bass levels, sound levels were 51 to 52 dBA (L50) at the property line. Under these conditions, it is estimated that sound levels would be below 50 dBA at the nearest residential building at 22 Weston Road. However, these music volumes in the tent are significantly quieter than the volume that DJs are accustomed to playing during most events.

When music levels were at medium or high volumes with normal bass levels (78 to 86 dBA L50), sound levels at the property line ranged from 55 to 64 dBA (L50) and would exceed 50 dBA at the nearest residential building at 22

Weston Road. Music levels between 78 and 86 dBA inside the tent are more typical of the levels played during most events.

The first four tests were conducted with the clear vinyl siding surrounding the tent and the remaining tests were conducted without the vinyl siding. The vinyl was found to reduce sound approximately 1 dBA and was not a significant factor in the tests although it did reduce some of the very high frequency music from the tent.

Next Steps

Since the Pierce House needs to provide an acceptable music volume inside the tent for their events and the community has expressed strong interest in reducing sound, additional sound attenuation and control measures are needed. As shown in Table 2, to facilitate playing music at the highest volume tested (86 dBA inside the tent), it would be necessary to provide 12 decibels of additional attenuation to be below 50 dBA at the nearest residential building at 22 Weston Road. Additional attenuation may be warranted to achieve sound levels below 50 dBA at the nearest residential property line. It is anticipated that achieving acceptable sound levels at the closest residential receptor locations would result in acceptable sound levels throughout the community although other locations should continue to be evaluated.

Possible solutions to reduce sound in the community and provide an acceptable volume inside the tent is to control the music volume and bass content, install acoustical curtains around the tent, and utilize more directional speakers.

The Pierce House currently prohibits the use of subwoofers by DJs which is a helpful step to controlling the sound levels in the community. The tests indicated that further attenuation of the bass levels through the DJ mixing board can provide approximately 3 dBA of sound attenuation. The Pierce House should continue to work with DJs to advise them on reducing bass levels.

Installing acoustical curtains around a portion of the tent could be effective at reducing sound levels by approximately 5 to 15 dBA depending on their type and application. When curtains just block the line of sight between the speakers and a place in the community, they typically will provide 5 dBA of sound attenuation. To achieve greater attenuation, the material must extend beyond where it just blocks the line of sight. VHB recommends that a sound model be developed to help determine effective locations to place the curtains.

Acoustical curtains need to be of sufficient mass and sound transmission classification (STC) rating to minimize sound transmitting through the material. The STC rating should be nominally 10 or more above the sound attenuation that it is intended to provide. So, if the goal is to provide up to 15 dBA of sound attenuation, the material should have an STC rating of 25 or more. The acoustical curtains must be placed sufficiently around the edge of the tent and possibly along portions of the tent roof so that the primary path for sound is not through the curtain material but is from sound diffracting around the edges of the acoustical curtain. VHB will work with the Pierce House to identify possible locations to place DJ speakers and the type of acoustical curtains to maximize sound attenuation. VHB recommends that acoustical curtains be installed and tested as the initial approach to reducing sound in the community. Depending on the results of the acoustical curtains, it may be necessary to evaluate additional sound attenuation measures such as different speakers.

Installing semi-permanent speakers in the tent specifically designed to control sound may be an effective solution although there could be technical challenges for DJs, who typically bring their own sound equipment, to use a house system owned by the Pierce House. None of the speakers tested was particularly directive (as indicated by the horizontal and vertical dispersion which ranged from 90 to 180 degrees), so there was not a significant difference in

results among the speakers tested. Orienting the speakers in different directions showed to have a minimal effect since they were not very directional. Using speakers with a substantially narrower horizontal and vertical dispersion may help focus sound in the tent and away from the community. However, most speakers with high directivity do not generate a significant amount of low frequency sound and may not be ideal for playing music. For example, one possible solution could be to hang parabolic speakers (see below) from the tent ceiling. These speakers are effective at focusing sound near the source with a dispersion angle of 30 degrees. Numerous speakers would be needed to effectively produce sound over the entire dance floor and create an even sound field. These speakers cost approximately $500 each, not including amplifiers. However, these speakers only generate sound levels down to approximately 130 to 170 Hz, so there would be substantially less bass compared to traditional DJ equipment such as the 12-inch or 15-inch public address speakers which generate sound down below 50 Hz.

Depending on the results of the acoustical curtain installation, the Pierce House may want to reach out to vendors of more directional speakers to see if a DJ could demo speakers at an upcoming event to determine if this could be an effective means of reducing sound in the community. Such tests are highly recommended prior to purchasing any sound equipment.

Photos

Pierce House Tent with Clear Vinyl Siding

Tent and Property Line measurement Locations

Outside Tent (South End)

Inside Tent (Facing South)

Property Line Measurement Location (22 Weston Road in Background)

Sound Level Concepts

Sound is the rapid fluctuations of air pressure above and below ambient pressure levels. Noise is defined as unwanted or excessive sound. Sound becomes unwanted when it interferes with normal activities such as sleep, work, communication or recreation. How people perceive sound depends on several measurable physical characteristics including:

Sound Level - Sound level is based on the amplitude change in pressure and is related to the loudness or intensity. Human hearing covers a wide range of changes in sound pressure amplitude. Therefore, sound levels are most often measured on a logarithmic scale of decibels (dB) relative to 20 micro-pascals. The decibel scale compresses the audible range of acoustic pressure levels, which can vary from the threshold of hearing (0 dB) to the threshold of pain (120 dB). Because sound levels are measured in dB, the addition of two sound levels is not linear. For example, adding two equal sound levels results in a 3 dB increase in the overall level. Research indicates the general relationships between sound level and human perception are as follows:

- A 3-dB increase is a doubling of acoustic energy and is approximately the smallest difference in sound level that can be perceived in most environments.
- A 10-dB increase is a tenfold increase in acoustic energy and is generally perceived as a doubling in loudness to the average person.

Frequency - Sounds are comprised of acoustic energy distributed over a range of frequencies. Acoustic frequencies, commonly referred to as tone or pitch, are typically measured in Hertz. Human hearing generally ranges from 20 to 20,000 Hz; however, the human ear does not perceive sound levels from each frequency as equally loud. To compensate for this phenomenon in perception, a frequency filter known as A-weighting is commonly used to evaluate environmental noise levels and sound levels are denoted as "dBA".

- Sound levels reported in octave or one-third-octave frequency bands are often used to describe the frequency content of different sounds. Some sources of sound can generate "pure tones" which is when there is a concentration of sound within a narrow frequency range such as a whistle. Humans can hear pure tones very well and such conditions can be a cause of increased annoyance.

A variety of sound level descriptors can be used for environmental noise analyses. These descriptors relate to the way sound varies in level over time. The following is a list of common sound level descriptors:

- **Statistical Sound Levels** – Sound level metrics, such as L_{10}, L_{50} or L_{90}, represent the levels that are exceeded for a particular percentage of time over a given period. For example, L_{10} is the level that is exceeded for 10 percent of the time. Therefore, it represents the higher end of the range of sound levels. The L_{90}, on the other hand, is the level that is exceeded 90 percent of the time, and therefore, is representative of the background sound level. The L_{50} sound level metric represents the median sound level and has been selected to represent sound from the music events because it is the most representative of the continuous sound caused by the music events. The maximum and Leq sound levels can easily be influenced by sources other than the music such as cars passing by.
- **Energy-Average Sound Level (Leq)** - Leq is a single value, which represents the same acoustic energy as the fluctuating levels that exists over a given period of time. The Leq takes into account how loud noise events are during the period, how long they last, and how many times they occur. Leq is commonly used to describe environmental noise and relates well to human annoyance.

- **Day-night Average Sound Level (Ldn)** - Ldn is similar to the Leq in that it is a single value, which represents the same acoustic energy as the fluctuating levels, that exists over a 24-hour period. The Ldn takes into account how loud sound events are, how long they last, how many times they occur over a 24-hour period, and whether they occur during the day (7:00 AM to 10:00 PM) or night (10:00 PM to 7:00 AM). Sound that occurs during the night is given a 10-dB penalty to account for increased sensitivity to noise at night.
- **Maximum Sound Level (Lmax)** – Many sources of sound, including mobile sources and stationary sources, change over time. It is common to describe sound in terms of the maximum (Lmax) sound level emissions. Table 1 presents a list of the maximum sound levels of common outdoor and indoor sources.

Table 3. Maximum Sound Levels of Common Outdoor and Indoor Sources

Outdoor Source	Sound Level (dBA)	Indoor Source
	110	Rock Band at 5 m
Jet Over Flight at 300 m	**105**	
	100	Inside New York Subway Train
Gas Lawn Mower at 1 m	**95**	
	90	Food Blender at 1 m
Diesel Truck at 15 m	**85**	
Noisy Urban Area—Daytime	**80**	Garbage Disposal at 1 m
	75	Shouting at 1 m
Gas Lawn Mower at 30 m	**70**	Vacuum Cleaner at 3 m
Suburban Commercial Area	**65**	Normal Speech at 1 m
	60	
Quiet Urban Area—Daytime	**55**	Quiet Conversation at 1 m
	50	Dishwasher Next Room
Quiet Urban Area—Nighttime	**45**	
	40	Empty Theater or Library
Quiet Suburb—Nighttime	**35**	
	30	Quiet Bedroom at Night
Quiet Rural Area—Nighttime	**25**	Empty Concert Hall
Rustling Leaves	**20**	
	15	Broadcast and Recording Studios
	10	
	5	
Reference Pressure Level	**0**	Threshold of Hearing

Source: Highway Noise Fundamentals. Federal Highway Administration, September 1980.