January 26, 2023

Mr. George F. Connors
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Subject: Mobile Source Sound Study
Master Paving and Middlesex Asphalt Services Building
157-165 Lowland Street, Holliston, MA

Dear Attorney Connors,

Master Paving and Middlesex Asphalt Services proposes to build a contractor's garage on the existing industrially zoned land at 157-165 Lowland Street in Holliston, MA. Figure 1 an aerial image showing the location of the proposed facility and locations of nearby residences. As you have requested, we have evaluated mobile equipment sound levels at nearby residences and have recommended noise controls that will maintain mobile sound levels within voluntary design goals based on the ambient sound level existing prior to facility construction and operation. It is our opinion that achieving these design goals will avoid producing a noise nuisance prohibited by the Commonwealth of Massachusetts regulations limiting sound impacts.

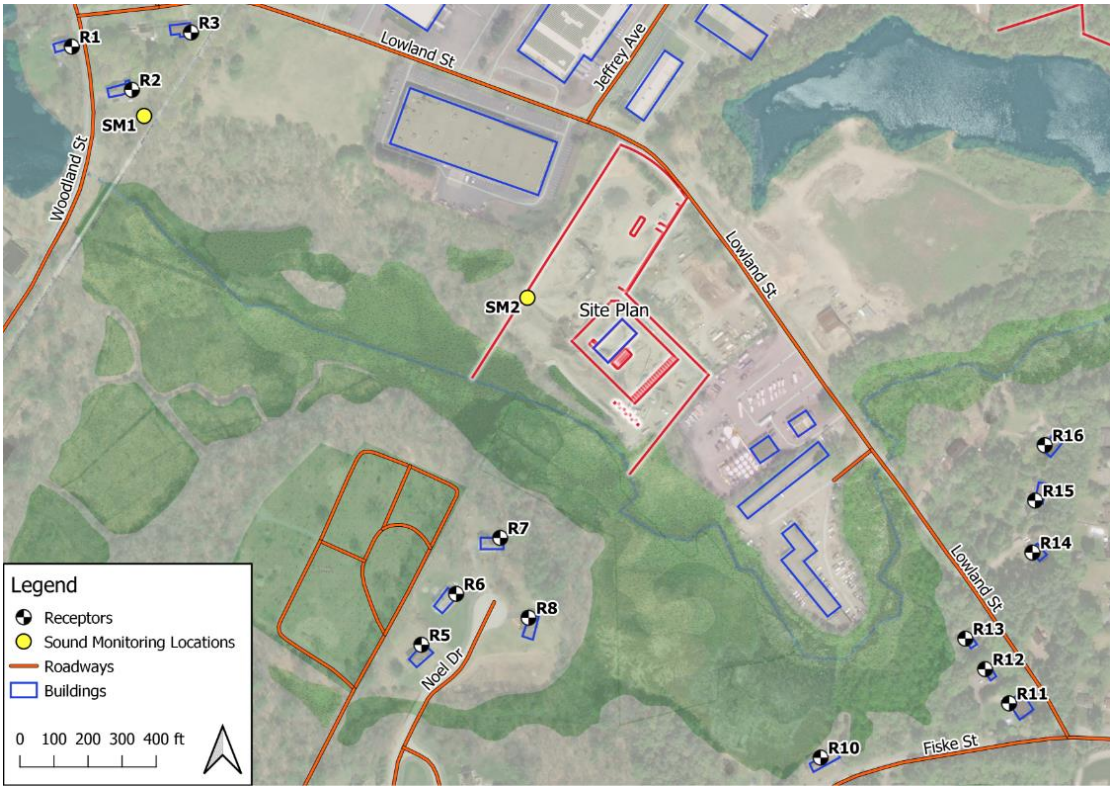

Figure 1 - Area plan of the proposed facility and receptor study locations R1-R16
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

This report outlines voluntary design goals as they pertain to mobile source activity, sound monitoring completed as required to establish these design goals, and computer modeling to estimate mobile source sound levels transmitted to nearby residences. A glossary of terms used in acoustics and in this report is presented in Appendix A. MassDEP noise policy is attached in Appendix B.

Nearest residences are south of the site along Noel Drive, east of the site on Lowland and Marilyn streets, and northwest of the site on Woodland Street, at distances of 451 feet, 1079 feet, and 1293 feet from the proposed facility property line, respectively. The nearest residence is 34 Noel Dr, to the south of the site.

Sound Monitoring

To document existing ambient sound levels and to determine the ambient sound level used to set design goals, Cavanaugh Tocci monitored sound levels at two locations identified as SM1 and SM2 in Figure 1. Measurements were completed over a seven-day period from Thursday, September 15 to Wednesday, September 21, 2021. Ambient sound levels at the measurement locations are representative of those at nearby residences. During daytime hours, on the days monitored, usual existing industrial activity on nearby properties was audible in the project area. There was little or no industrial activity at night on nearby properties.

Sound levels were monitored using Rion NL-52 meters set to fast meter response and calibrated before use. The microphone was mounted to a tree with a windscreen, at a height of about 5-6 feet above grade. These instruments and their use conform to IEC 61672 for Class 1 precision sound measurement instrumentation. The meters recorded sound level data onto flash cards that, after the completion of measurements, were removed from the units and downloaded into a PC.

The monitors were programmed to measure several hourly A-weighted sound level descriptors including the 90th percentile sound level ($L_{AF90,1\text{-}hr}$), equivalent sound level ($L_{Aeq,1\text{-}hr}$), and first percentile ($L_{AF01,1\text{-}hr}$) sound level.

- The 90th percentile sound level ($L_{AF90,1\text{-}hr}$) is the residual sound level in an area and is the lowest level of sound typically occurring. It is the A-weighted sound level exceeded 90% of each hour monitored. It is of special relevance as the MassDEP Noise Policy defines the background sound level as the lowest $L_{AF90,1\text{-}hr}$ reached.
- The equivalent sound level ($L_{Aeq,1\text{-}hr}$) is the energy average sound level for each hour monitored.
- The first percentile sound level ($L_{AF01,1\text{-}hr}$) is the sound level exceeded one percent of each hour and is representative of the highest sound levels reached in each hour.

Sound monitoring data measured at SM1 and SM2 are shown in Figures 2 and 3. As with most acoustic environments, sound levels are generally higher during the day than during the night. Weather data have been shown alongside sound monitoring data to identify any occasions when weather conditions might have influenced sound levels. These data are as obtained from the National Weather Service's

(NWS) Automated Surface Observing Systems (ASOS) program for station OWD (Norwood Memorial Airport)[1].

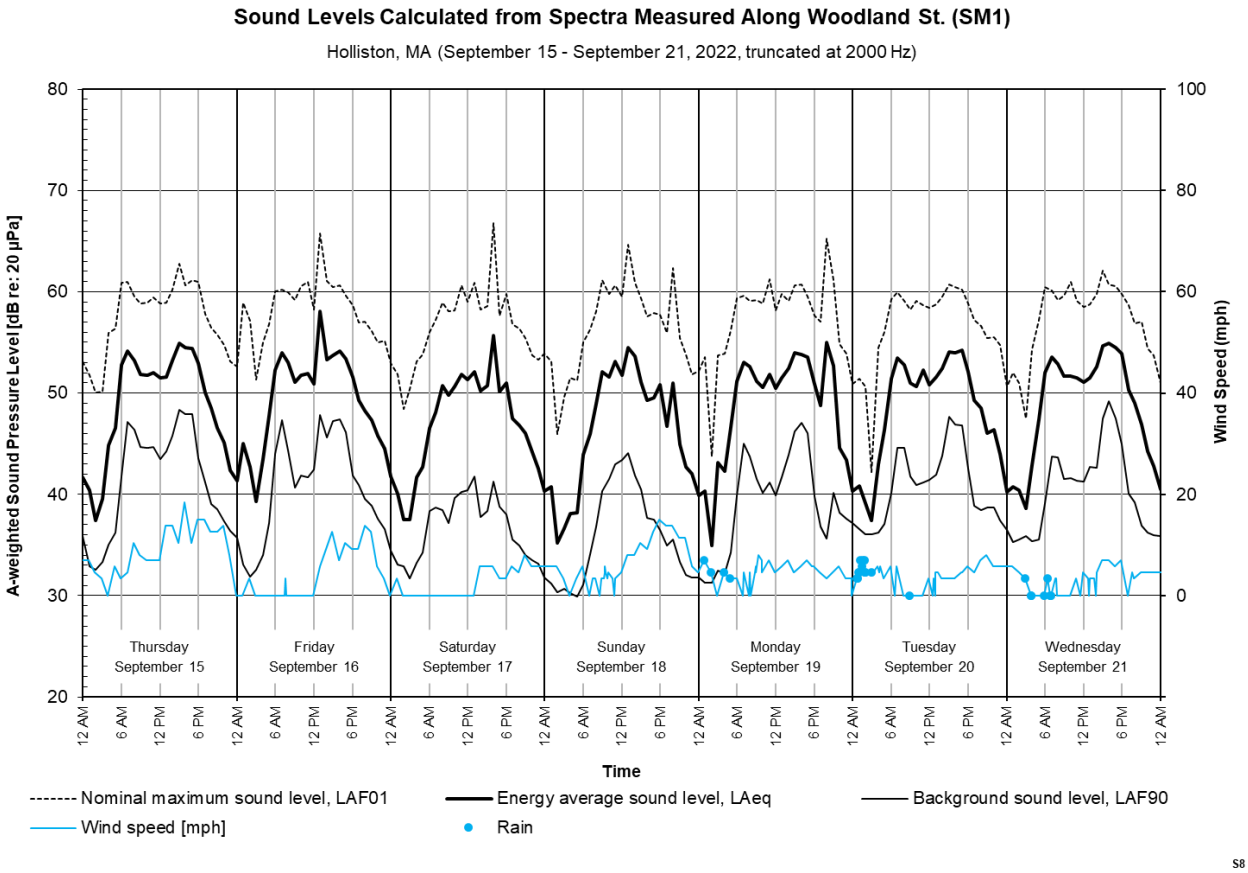

Figure 2 – Sound monitoring data measured at SM1 with truncation at 2kHz
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

[1] https://mesonet.agron.iastate.edu/request/download.phtml?network=MA_ASOS

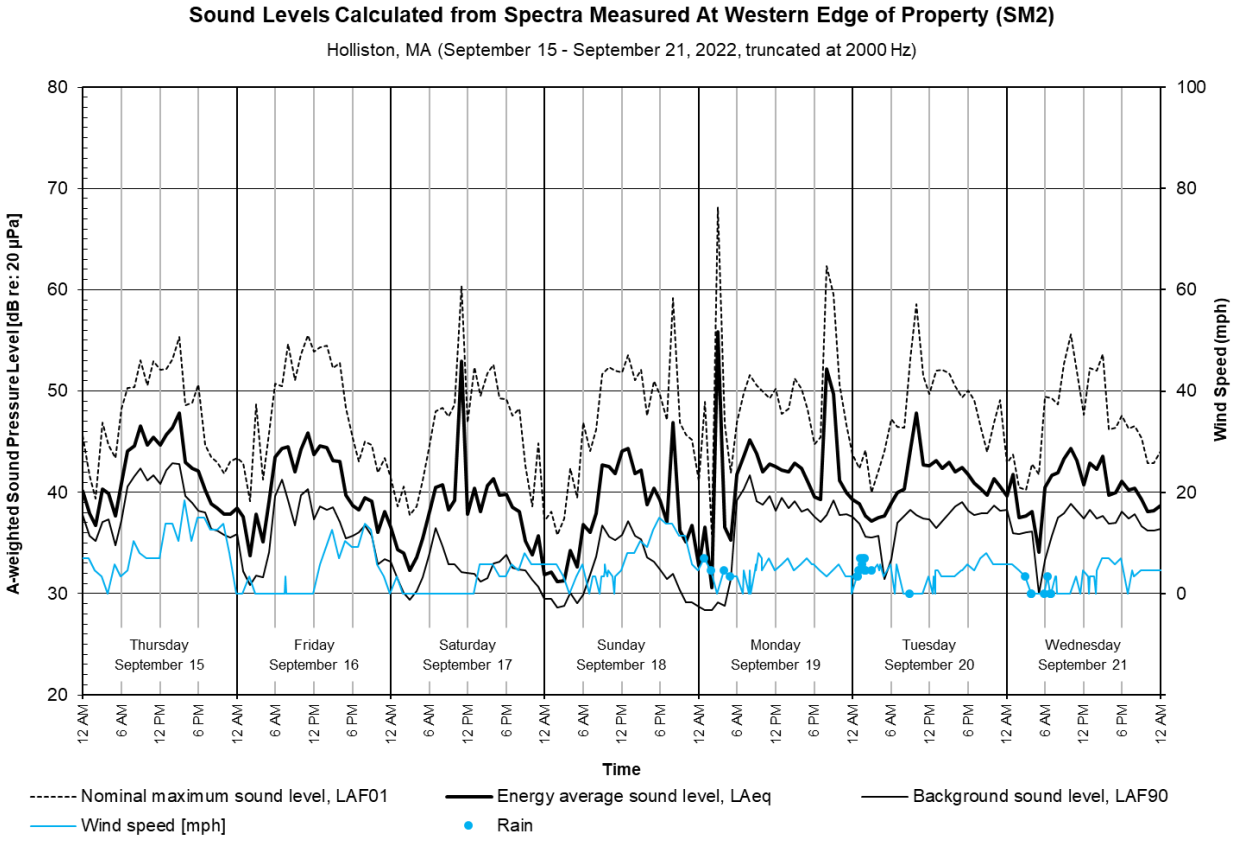

Figure 3 – Sound monitoring data measured at SM2 with truncation at 2kHz
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

Applicable Codes for Stationary Sources

This section outlines codes applicable to sound potentially emitted by the proposed facility. Applicable codes are as follows:

- Holliston Zoning By-Laws (May 6, 2019)
- Commonwealth of Massachusetts 310 CMR 7.10
- Massachusetts Department of Environmental (MassDEP) Noise Policy 90-001

Holliston 2019 Zoning Bylaw

The Holliston 2019 Zoning By-Law provisions setting limits on sound emitted by this project are provided in Section V-N, "Performance Standards", subsection 4, "Noise". The provision is as follows:

> V-N PERFORMANCE STANDARDS
>
> 4. Noise. No use shall be permitted within the Town of Holliston which, by reason of excessive noise generated therefrom, would cause nuisance or hazard to persons or property. Exempt from the provisions of this subsection are (a) vehicles not controlled by an owner or occupant of a lot within the town, (b) temporary construction activities occurring during the hours of 7 a.m. to 6 p.m. on weekdays and 8 a.m. to 6 p.m. on Saturday, (c) occasionally used safety signals, warning devices, emergency pressure relief valves, or other such temporary activity, (d) use of power tools and equipment such as lawn mowers, snow blowers, chainsaws, tractors, and similar equipment for the maintenance of property between the hours of 7 a.m. and 8 p.m. on weekdays and 8 a.m. and 6 p.m. on weekends. For the purposes of this by-law the standards in the following shall apply:
>
> Ambient Noise Level. No person shall operate or cause to be operated any source sound in a manner that creates a sound level of 10 dBA above ambient, as set forth in 310 CMR 7.10, measured at the property boundary of the receiving land use nor shall any source produce a pure-tone condition at the property line (or at the nearest inhabited buildings). A pure tone condition exists if the sound pressure level, at any given octave band center frequency, exceeds the levels of the two adjacent octave bands by three (3) or more decibels.

MassDEP Noise Policy

The general prohibitions of the Commonwealth of Massachusetts 310 CMR 7.10 U (1) do not establish specific, measurable limits in decibels, which can be used for engineering design purposes, and above which there may be a noise nuisance condition. The responsibility and authority for identifying when a condition of noise exists has been assigned to the Massachusetts Department of Environmental Protection (MassDEP). MassDEP Noise Policy 90-001 (see Appendix B) states the following:

> *A source of sound will be considered to be violating the Department's noise regulation (310 CMR 7.10) if the source:*
>
> 1. *Increases the broadband sound level by more than 10 dB(A) above the ambient, or*
>
> 2. *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.*
>
> *These criteria are measured both at the property line and at the nearest inhabited residence. Ambient is defined as the background A-weighted sound level that is exceeded 90% of the time measured during equipment operating hours. The ambient may also be established by other means with the consent of the Department.*

Design Goals for Mobile Sound Sources

This report focuses only on mobile source sound related to Master Paving use of the property and building. It is our understanding that the MassDEP Noise Policy applies to stationary equipment and does not apply to sound produced by mobile vehicles. However, mobile source sound must comply with the more general Commonwealth of Massachusetts regulation prohibiting a noise nuisance.

Compliance with 310 CMR 7.10 U (1) will be attained by achieving the recommended design goals for mobile equipment sound in Table 1. Our recommended design goals are the average lowest daily hourly A-weighted 90th percentile sound level measured during operating hours plus margins of 5 dBA for tonal sound, such as that produced by back-up alarms, and 10 dBA for other continuous sounds such as sound produced by vehicles operating on-site.

Monitoring Location	Average Ambient during Operating Hours ($L_{AF90,1\text{-}hr}$)	*Design Goal for Continuous (+10 dB) (dBA)*	*Design Goal for Tonal (+5 dB) (dBA)*
SM1 (R1-R4)	40	50	45
SM2 (R5-R16)	35	45	40

[1]Monday-Saturday, 7:00 am-7:00 pm

Table 1. Voluntary design goals for mobile source sound during operating hours Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

Means to achieve these goals include screening of sound by barriers and the proposed on-site building, as well screening by existing earth berms. It is our opinion that mobile source sound within the recommended design goals constitutes compliance with Massachusetts 310 CMR 7.10 U (1) and with the Town of Holliston 2019 Zoning By-Law.

Computer Modeling

Computer modeling has been used to estimate facility mobile source sound levels at nearest residences. Estimated sound levels have been compared with voluntary design goals applicable to mobile equipment sound transmitted to nearest residential uses.

Modeling of facility sound was completed using Cadna/A (Datakustik GmbH, Version 2022 MR 1, 32-bit). Cadna/A is a computer program that implements the modeling techniques of ISO 9613-1 and ISO 9613-2 to estimate source sound levels at community receptor locations. The Cadna model accounts for propagation losses of facility sound associated with distance, shielding by intervening structures, berms, barriers, and topography, and absorption of sound by the atmosphere and porous surfaces.

The Cadna model applies propagation losses to facility equipment sound power levels to estimate sound pressure levels at nearby residences. Sound power level quantifies the amount of sound energy produced by a source and is expressed in decibels referenced to 1 picoWatt (pW or 10^{-12} watts).

	Octave band center frequencies (Hz)									
Sources	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**A**
Truck Back-up Alarm	54	68	78	79	89	107	91	86	77	107
Truck High Idle	100	104	102	103	103	99	97	92	85	105
Truck Pass-by	107	104	110	109	107	105	101	98	94	110

Table 2 – Sound power spectra of mobile facility sources [dB re: 1 pW]
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

Figure 1 identifies sixteen nearby residential locations used in this study. Figure 4 shows four facility source groups on-site. Source locations SL01, SL06, SL07, and SL08 are the locations of the mobile source activities of Table 2. Sound sources were placed to conservatively characterize the potential effect (worst-case) of sources on the community.

Figure 4 – Mobile facility sound source locations used in computer modeling, SL01, SL06, SL07, and SL08
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

Sound Controls

Noise controls placed in the locations indicated in Figure 5 with minimum lengths and top-edge elevations specified will reduce all mobile sound levels to within the voluntary design goals. The barriers must be solid, not slotted such as would be the case with a stockade style fence, have a surface weight not less than 4 psf, and must not be undercut by more than 2 inches. Estimated facility sound levels at all sixteen receptor locations with the noise controls implemented in Figure 5 are listed in Table 3. Additionally, the levels modeled here are the maximum sound levels expected during site operations, thus in most cases operations on-site would not be expected to exceed voluntary design goals. Furthermore, these voluntary design goals are conservative, so the risk of impact on the community due to mobile source sound is low.

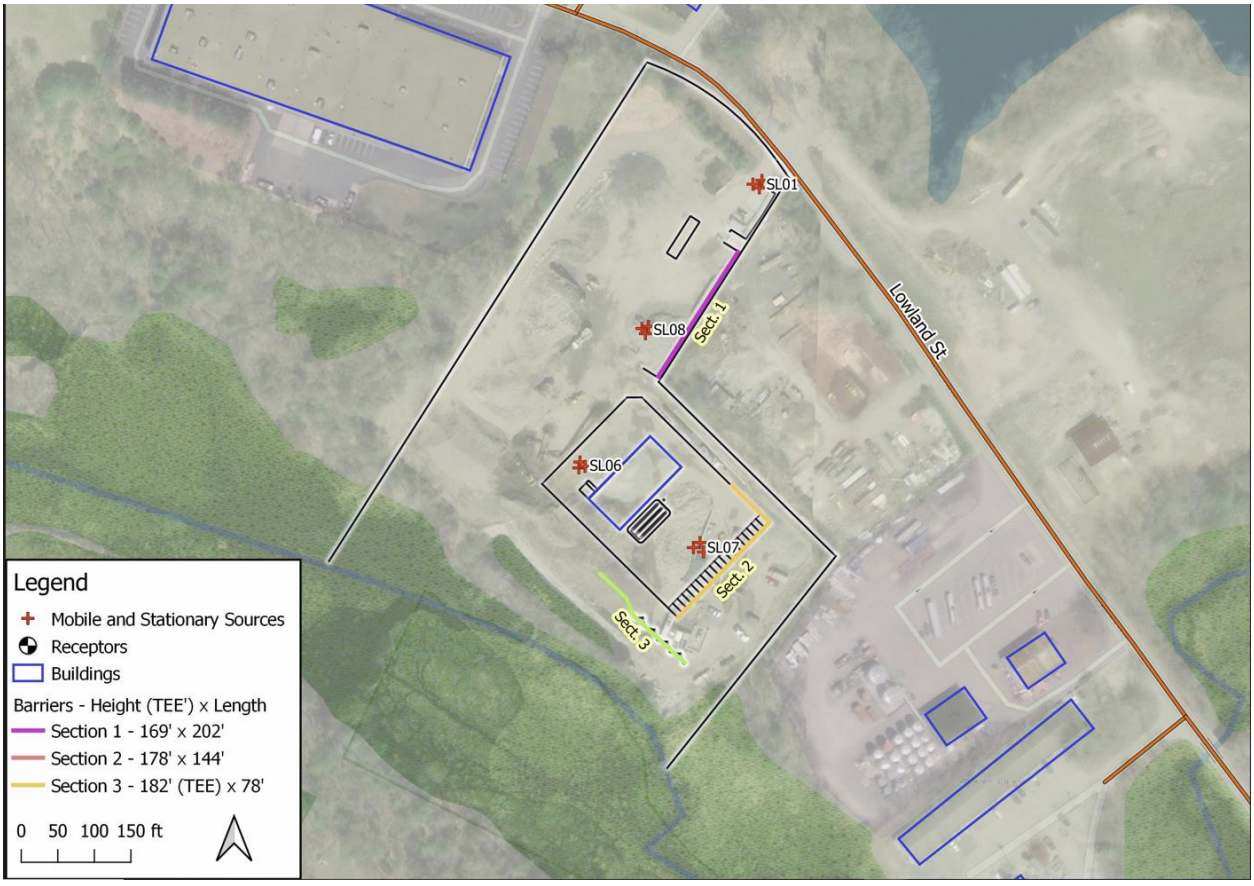

Figure 5 – Sound control barriers with top-edge minimum elevation as specified in the legend for each barrier
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA

Name	*SL*	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*	*R11*	*R12*	*R13*	*R14*	*R15*	*R16*
Backup Alarm Tonal Truck	SL01	25	26	25	30	29	34	39	32	36	35	29	35	39	40	40	41
Truck High Idle	SL01	26	26	26	30	31	34	37	35	35	32	28	33	38	37	38	40
Truck Pass-by	SL01	31	32	32	37	36	38	42	39	40	37	33	38	43	42	43	44
Backup Alarm Tonal Truck	SL06	34	35	36	37	27	29	33	31	28	36	23	24	24	24	24	30
Truck High Idle	SL06	32	34	37	35	29	31	35	33	30	34	26	28	27	26	27	31
Truck Pass-by	SL06	38	39	42	41	34	36	40	39	36	39	31	33	32	32	32	36
Backup Alarm Tonal Truck	SL07	28	30	29	29	38	37	**45**	**42**	**43**	**46**	39	39	40	40	**45**	**47**
Truck High Idle	SL07	29	30	30	30	37	36	46	39	39	42	36	37	37	37	41	44
Truck Pass-by	SL07	35	36	36	36	43	41	**51**	44	44	**47**	40	42	42	42	46	**48**
Backup Alarm Tonal Truck	SL08	33	33	36	29	31	35	41	38	33	36	23	29	29	29	30	37
Truck High Idle	SL08	32	33	34	29	31	35	39	37	33	35	27	31	32	31	32	37
Truck Pass-by	SL08	37	38	39	34	36	40	44	42	36	37	35	36	36	36	36	37

**Table 3 –Mobile source sound levels transmitted to nearby receptor locations:
w/sound control barriers as indicated in Figure 5
Proposed MP & MAS Building, 157-165 Lowland Street, Holliston, MA**

Estimated mobile equipment sound levels at nearby receptors in Table 3, with the a few exceptions, will achieve our recommended design goals. In the few exceptions noted in **red** text, levels may momentarily exceed design goals and may be audible, depending on equipment location on-site and during quietest times of the day.

Conclusions

Master Paving and Middlesex Asphalt Services proposes to build a contractor's garage on the existing industrially zoned land at 157-165 Lowland Street in Holliston, MA. This Cavanaugh Tocci report summarizes recommended design goals for mobile source sound subject to the general provisions of the Massachusetts noise regulation in 310 CMR 7.10 U. Vehicles permitted on public roads are not subject to the specific, measurable limits of the MassDEP Noise Policy, nevertheless, must not create a noise nuisance as prohibited by the Massachusetts noise regulation.

Sound produced by on-site truck movements and transmitted to nearby residences has been determined using computer modeling conforming to the methods of ISO 9613-2. With the three barrier sections shown in Figure 5 totaling 624 feet in length, sound levels may momentarily exceed design goals and may be audible at residences south and east of the site, depending on equipment location on-site and during quietest times of the day. It is our opinion that facility mobile equipment sound will not produce a noise nuisance as prohibited by Massachusetts 310 CMR 7.10 U and the Holliston 2019 Zoning By-Law.

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If we can provide any further detail, please do not hesitate to contact us. Thank you.

Sincerely,

Gregory C. Tocci, *Senior Principal Consultant*

Liam E. Maloney, Senior *Consultant*

Appendix A

Glossary

Glossary

The definitions of acoustical terms used in this appendix are most often based on American National Standards Institute (ANSI) S1.1-1994 Acoustical Terminology.

A-Weighting (dBA)

The filtering of sound that replicates the human hearing frequency response. The human ear is most sensitivity to sound at mid frequencies (500 to 4,000 Hz) and is progressively less sensitive to sound at frequencies above and below this range. A-weighted sound level is the most used descriptor to quantify the relative loudness of various types of sounds with similar or differing frequency characteristics.

Absorption

The attenuation (or reduction) of sound level that results when sound propagates through a medium (usually air) or through a dissipative material (sound absorptive material) such as glass fiber or open-cell foam. In the case of sound absorptive materials used in the building industry, attenuation of sound is produced by the conversion of molecular motion, which is sound, into thermal energy due to friction of air molecules with fibrous or cellular materials.

Acoustics

(1) Acoustics is the science of sound, including its production, transmission, and effects.

(2) The acoustics of a room are those qualities that together determine its character with respect to the perception of sound.

Ambient Noise

Ambient noise encompasses all sound present in an environment, being usually a composite of sounds from sources near and far.

Background Sound

The lowest sound level typically occurring during a monitoring period. Specifically defined for its purposes by the Massachusetts Department of Environmental Protection (MassDEP) as the A-weighted sound level that is exceeded 90% of the time measured during equipment operating hours. When the ambient sound level is measured in hourly increments, the background sound level is symbolized as $LAF_{90,1\ hr}$ where "A" indicates A-weighting, "F" indicates the sound level meter was set to fast meter response, "90, 1-hr" indicates that the level reported is cumulatively exceeded 90% of a one-hour period.

Band Pass Filter

The filtering of sound within specified frequency limits or frequency bands. The audible frequency range is often sub-divided into octave, one-third octave, or other fractions of octave bands. In this study,

sound energy over the audible frequency range is divided into octave bands. The octave band center frequencies listed in tables of the report are 31.5, 63, 250, etc. up to 8,000 Hz.

Barriers

A solid obstacle that blocks the line-of-sight between a sound source and a receiver, thereby providing barrier attenuation, i. e., reducing sound level at the receptor. Sound attenuation provided by barriers is related to the transmission loss through the barrier material and diffraction of sound over and around the barrier. Barriers used to reduce sound at a receiver location be solid, not slatted such as would be the case with a stockade style fence, have a surface weight not less than 4 psf, and must have no or limit undercut depending on application.

Community Noise Exposure Level (CNEL)

The 24-hour energy average sound level where a 10 dB "penalty" is applied to sound occurring at night between 10:00 PM and 7:00 AM, and a 5 dB penalty is applied to sound occurring during evening hours between 7:00 PM and 10:00 PM. The penalties are intended to account for the increased sensitivity of a community to sound occurring during evening and nighttime hours.

Day Night Sound Level (DNL, L_{dn})

The 24-hour energy average sound level where a 10 dB "penalty" is applied to sound occurring at night between 10:00 PM and 7:00 AM. The 10 dB penalty is intended to account for the increased sensitivity of a community to sound occurring at night.

Decibel (dB)

A dimensionless unit which denotes the ratio between two quantities that are proportional to power, energy, or intensity. One of these quantities is a designated reference by which other quantities of identical units are divided. The sound pressure level in decibels is equal to 10 times the logarithm (to the base 10) of the ratio between the pressure squared divided by the reference pressure squared. The reference pressure used in acoustics is 20 microPascals (µPa).

Energy Average Sound Level

In real-world circumstances, sound levels vary considerably over time. The L_{eq} is the energy average or equivalent sound level over a monitoring time interval. It is a hypothetical continuous sound level that contains the same sound energy as the actual sound level occurring during the time interval. A letter symbol (such as A or C, i.e. LA_{eq}) typically implies A-weighting frequency (i.e., the energy average sound level in dBA). In addition, the duration of measurement is typically stated (i.e. $LA_{eq,1\text{-hr.}}$).

Frequency

Frequency is the number of oscillations or cycles per unit time. In acoustics, frequency usually is expressed in units of Hertz (Hz), where one Hertz is equal to one cycle per second. In this study, sound levels have been quantified over ranges or bands of frequency, specifically octave bands.

Noise

Noise is undesired or unwanted sound that is perceived as an annoyance to a receptor.

Octave

The ratio of the upper and lower frequencies of an octave band that equals two. For example, the upper and lower frequencies of the 1,000 Hz octave band are approximately 708 and 1,413 Hz.

Octave Band

Groups of frequencies defined by standards where the upper frequency of each band is equal to twice the lower frequency of each band. Octave bands are usually named by their geometric center frequency. For example, the octave band extending between 44.7 Hz and 89.1 Hz is called the 63 Hz octave band. The octave band extending between 89.1 Hz and 178 Hz is called the 125 Hz octave band. The full complement of octave bands in the audible frequency range is as follows: 31, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz.

Octave Band Sound Pressure Level

Sound pressure level for all sound contained within a specified octave band.

Percentile Sound Levels

Besides frequency and level, environmental sounds exhibit a time-varying or temporal characteristic. The temporal character of noise level can be illustrated by considering noise levels that occur near a highway. During the day, traffic sound levels are generally high, increasing to higher peaks when a noisy truck or multi-vehicle platoon passes and decreasing to a lower level between vehicle pass-bys. At night, when traffic volumes are lower, the same variation occurs, but is centered around a lower level.

Environmental sound descriptors are quantifications of sound that combine, into a single value, the three chief features of environmental sound: level, frequency, and temporal characteristics.

The use of A-weighted sound pressure level combines the first two characteristics—level and frequency—into a single number. Then, by averaging A-weighted sound pressure levels over time in various fashions, acoustical descriptors that combine all three features can be developed.

Commonly used descriptors are percentile A-weighted sound levels, A-weighted sound pressure levels exceeded for specific percentages of time within a specific noise monitoring period. For example, the one-hour 50^{th} percentile A-weighted sound level, symbolized as the $LA_{50,1\text{-}hr}$, is the A-weighted sound level cumulatively exceeded a total of 30 minutes out of a continuous 60-minute period. Likewise, the $LA_{10,20\text{-}min}$ is the A-weighted sound level cumulatively exceeded a total of two minutes out of a continuous 20-minute period.

Percentile A-weighted sound levels most often are used to assess the time-varying character of environmental sound. The residual sound level (defined as the nearly constant, low level of sound produced by distant motor vehicle traffic or industrial activity) is indicative of the lowest sound level in a monitoring period. The residual or background sound level is commonly defined as the LA_{90}, i.e., the A-weighted sound level exceeded 90% of a monitoring time period.

Sound

(1) Sound is an oscillation in pressure, stress, particle displacement, particle velocity, etc., in a medium.

(2) Sound is an auditory sensation evoked by the oscillation described above.

Sound Pressure

The sound pressure at a point is the total instantaneous pressure at that point, in the presence of a sound wave, minus the static pressure at that point.

Sound Pressure Level

The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the sound pressure to the reference pressure. The reference pressure shall be explicitly stated and is defined by standards.

Unless otherwise specified, the sound fields on both sides of the partition are assumed to be diffuse.

Spectrum

A group of sound levels in frequency bands covering a wide frequency range. Generally, this term is used with some modifier indicating the resolution bandwidth, e.g., octave band spectrum or one-third octave band spectrum.

Appendix B

Massachusetts Department of Environmental Protection (MassDEP) Noise Policy 90-001

The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Quality Engineering
Division of Air Quality Control
One Winter Street, Boston 02108

February 1, 1990

DAQC Policy 90-001

DIVISION OF AIR QUALITY CONTROL POLICY

This policy is adopted by the Division of Air Quality Control. The Department's existing guideline for enforcing its noise regulation (310 CMR 7.10) is being reaffirmed.

P O L I C Y

A source of sound will be considered to be violating the Department's noise regulation (310 CMR 7.10) if the source:

1. Increases the broadband sound level by more than 10 dB(A) above ambient, or

2. 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.

These criteria are measured both at the property line and at the nearest inhabited residence. Ambient is defined as the background A-weighted sound level that is exceeded 90% of the time measured during equipment operating hours. The ambient may also be established by other means with the consent of the Department.

Approved: February 1, 1990 Effective: Immediately

Barbara A. Kwetz
Acting Director
Division of Air Quality Control