PSM LLC
Pickleball Sound Mitigation

Pickleball Sound Study
for
Manchester-by-the-Sea, MA
by
Pickleball Sound Mitigation LLC

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Executive Summary

Pickleball Sound Mitigation LLC (PSM) estimated the sound from pickleball play from courts in Manchester-by-the-Sea using noise measurements from similar pickleball sites and noise modeling software. Noise levels were analyzed with no barriers in place and with several sound mitigation strategies applied. Noise maps for this site were also created to provide noise contours for the surrounding area and for evaluating each strategy. These maps can be used to judge the validity of pickleball noise objections and complaints.

The Massachusetts and Boston noise ordinances do not have enough detail to quantify the impulsive noise levels from pickleball play since they are based on continuous noise. They both would understate the perceived loudness and annoyance from pickleball impacts. An improved noise standard developed by PSM with a noise limit of 50 dB LAFmax (or higher depending on background sound) was used to assess the annoyance of pickleball noise levels for these courts. This standard has been successfully used with other pickleball noise studies.

Pickleball noise levels at the property line at 142 Summer Street and at 8 Forest Street were 72 dB LAFmax and 65 dB LAFmax respectively with no sound mitigation in place. These levels are above 50 dB LAFmax limit and would be considered bothersome or annoying. Three different noise source locations on the courts were evaluated to select one location for detailed studies of noise mitigation strategies.

A sound barrier on the north fence of the pickleball courts is the most effective method for reducing noise propagating to homes at 142 Summer Street and 8 Forest Street. Sound barriers 10 feet to 14 feet tall will reduce sound but will not lower the sound sufficiently to a level where it is not bothersome. A 20 foot tall barrier, if feasible, is required to reduce pickleball sound to a level where it is not bothersome.

Recommended paddles and balls for lower noise were identified. While this recommended equipment can reduce sound levels, their use alone cannot provide sufficient noise reduction to achieve target noise levels without a sound barrier also installed. The use of quieter paddles and balls together with a 12 foot sound barrier will bring pickleball noise to acceptable levels for these two residences. This combination produces a 20 dB noise reduction which would be perceived as 1/4 as loud as without mitigation.

Additional noise mitigation options for pickleball include restricting court time or installing a tennis bubble over the courts. The tennis bubble could provide year-round play for the community.

If the 12 foot sound barrier, the recommended equipment, and the restricted court time are not feasible options, then pickleball play should be moved to another location to preserve the quality of life in Manchester-by-the-Sea.

Introduction

Pickleball is a game played with two to four players using paddles, a ball, and a net on a court that is approximately one half the length and one half the width of a tennis court. The paddles are made of wood, plastic, or composite materials, and the ball is made of plastic. Each paddle and ball impact during a game creates a short pulse of sound that varies in intensity, duration, and frequency content. For homeowners near pickleball courts, pickleball sounds can become bothersome and intrusive.

To help explain the details in this sound study for the pickleball courts at Manchester-by-the-Sea, MA, background information is provided on pickleball sound impulses, sound measurements, human hearing, the local noise ordinance, and a recommended standard for evaluating sounds from pickleball play. Sound levels are presented at several locations for the current pickleball courts with no sound barriers in place and at the same locations for various sound mitigation options.

The Sounds of Pickleball

A typical pickleball game will produce a series of random paddle and ball impacts each time the ball is struck. These impacts are described as "popping sounds of varying loudness." The loudness of each impact varies based on a player's position on a court, the paddles and balls being used, the skill level of each player, and the force of each impact.

Figure 1 shows a typical time history of a paddle and ball impact. The pickleball impact is an impulsive sound with a duration of 10 to 20 milliseconds and with peak acoustical energy near 1000 Hz, which corresponds with the most sensitive region of human hearing. Impulsive sounds are defined as sounds lasting less than one second with an abrupt onset and abrupt decay (1). The highest sound energy occurs in the first 3 to 5 milliseconds and then decays to a lower level.

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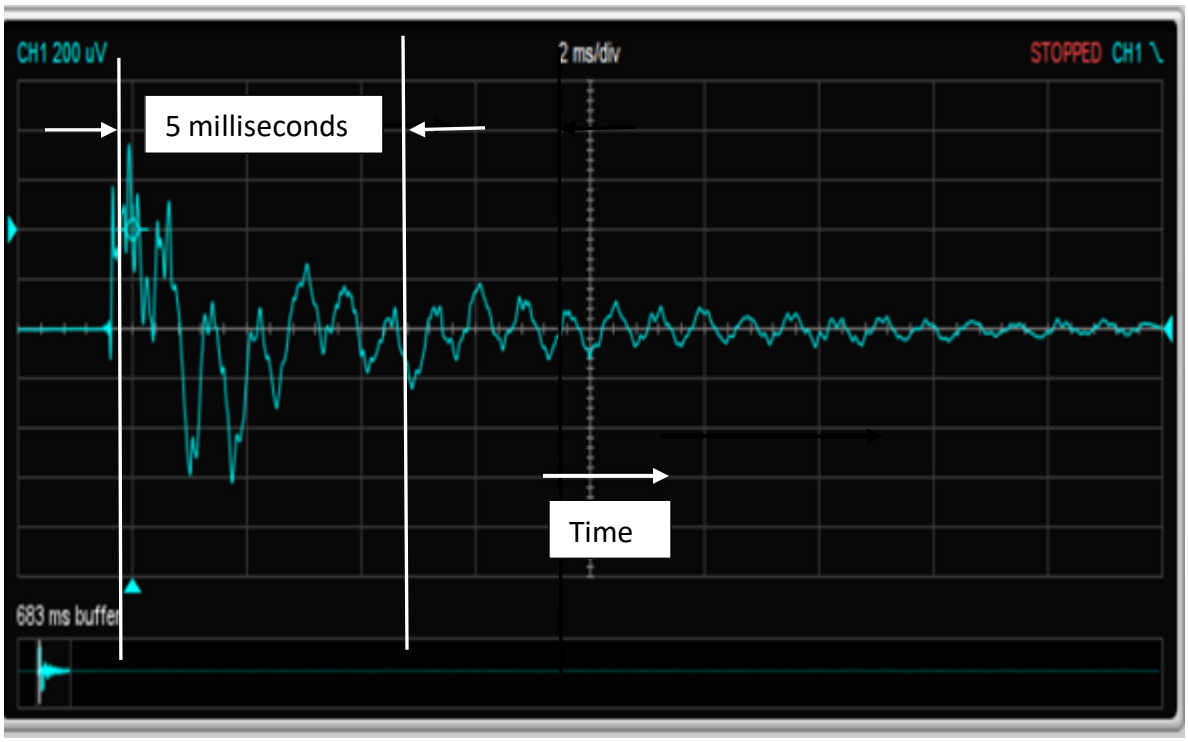

Figure 1 – Time history of pickleball sound

Figure 1 represents the sound of one pickleball impact. In a game of pickleball, a rally will involve several impacts spaced by intervals of less than one second to more than two seconds until the rally is over. A game involves several rallies until a team wins. The result is that pickleball impacts will occur randomly during the duration of a game.

The multiple impacts from pickleball play display a statistical behavior that mirrors the normal bell curve with an average sound level and high and low sound levels. An average noise level means that noise levels will be below the average 50% of the time and above the average 50% of the time. A noise mitigation solution based on an average noise level will only address the midpoint of the sound levels. Sounds will still be audible above this midpoint. To be effective, a noise study must consider the highest noise levels rather than an average noise level. This has been taken into consideration for this noise analysis.

Measurement of Pickleball Sound

Sound is measured with a sound level meter as shown in Figure 2. The units of sound measurement are decibels, abbreviated as dB. Higher dB levels represent louder sounds.

Figure 2 - Sound Level Meter

Reference dB levels for common sounds follow.

- 30 dB – library, a whisper
- 40 dB – refrigerators, quiet offices, quiet residential area
- 50 dB – moderate rainfall, large offices
- 60 dB – normal conversation, electric toothbrushes
- 70 dB – washing machines, hairdryers, highway noise, city streets
- 80 dB – truck traffic, alarm clocks, garbage disposals
- 90 dB – lawnmowers, blenders, power tools
- 100 dB – factory machinery
- 110 dB - car horns
- 120 dB – ambulance sirens, jet planes at takeoff

The human ear does not hear all sounds equally. It has more sensitivity in a mid-frequency range of 1000 to 4000 Hz and has diminished sensitivity at frequencies above and below this range. A frequency weighting can be applied to any sound measurement to match the hearing sensitivity of the human ear. This is called the A-weighting and is shown in Figure 3. Decibel measurements with the A-weighting are listed as dBA.

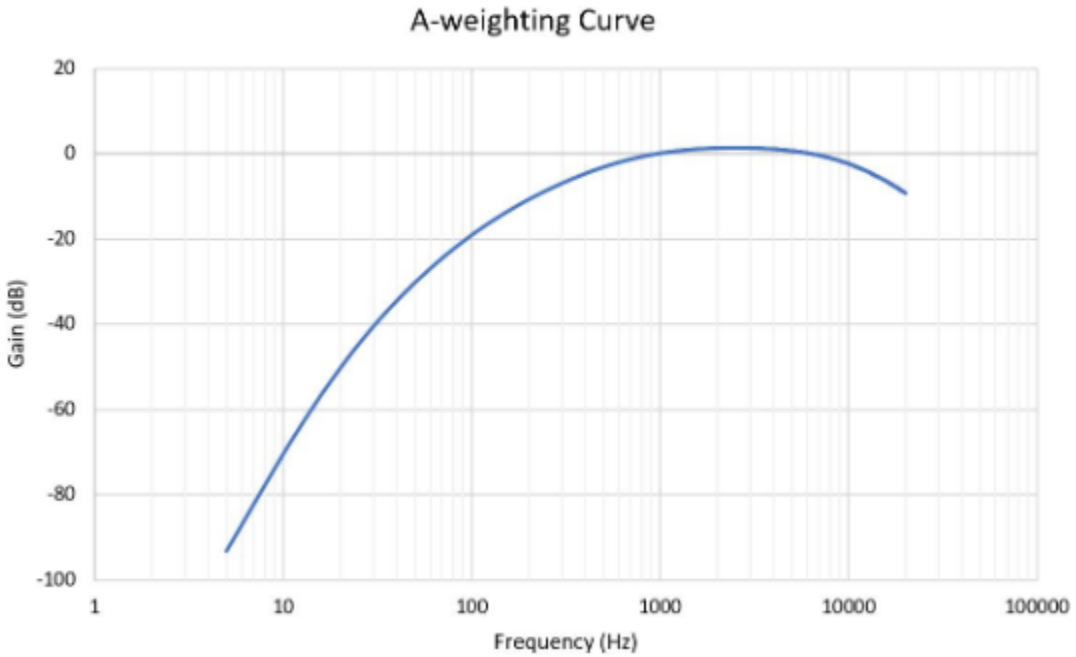

Figure 3 - A-weighting frequency corresponding to human hearing sensitivity

Because sound is not constant and varies with time, the sound level meter has several measurement settings to average these sound fluctuations over the measurement period (1). These settings report the sound level for the measurement period selected. The meter setting must be properly selected to capture both the sound level and the duration of the sound.

What measurement setting is best for pickleball play? The best measurement is the value that correlates with human annoyance and that can be easily measured. Sounds with short durations, like pickleball sound, are best measured with a fast averaging time plus a maximum hold setting. The maximum hold setting "listens" for the maximum sound level in the fast time averaging interval. In this manner, the maximum level of these rapid fluctuations can be captured over the averaging interval. The fast setting will always measure a higher value than a slow setting for a pickleball impact. The peak setting will measure an even higher level than a fast setting, but it neglects the ringing or duration critical to human annoyance and does not have an A-weighting.

When the A-weighting setting on a sound level meter is selected, dB measurements are described as dBA. If the sound level (L) is measured with an A-weighting (A) and a fast (F) setting, it is described as LAF. When the maximum level is captured in the measurement interval, this is called LAFmax. Unless otherwise noted, pickleball sounds in this report will be described in units of LAFmax.

Any longer time averaging will understate the loudness of short duration pickleball impact heard by the human ear. This is because the maximum sound level from a short duration pickleball impact is averaged with many lower levels of background sound to yield lower average sound levels. Different time averaging

intervals will report different dB levels for the same sound event. For pickleball sound, LAFmax best corresponds to human hearing response.

Noise Maps

Noise maps were created using the dBmap.net Noise Mapping Tool, which is a commercial software (2). The topography of the surrounding area was applied to the noise map before the positions for a noise source and receivers were selected. Ground elevations were selected from Google Earth. In addition, homes were added in the vicinity of the pickleball courts. The size of each home together with the roof height and roof slope were selected from Google Earth and applied to the model for each site. The pickleball noise source was then placed at the court location and receiver locations were selected. Because this is a European software, all distances, site elevations, building sizes, and barrier heights must be added to the model in meters. The resulting noise maps with distance scales can only be shown in meters. (One meter = 3.3 feet)

All noise maps have the legend shown in Figure 4. Each colored band represents a 5 dB change in sound level, with the number beside each band indicating the lowest sound level within the band. In addition, sound maps shown in color have white lines within each band of colors to show the 1 dB changes within this 5 dB interval.

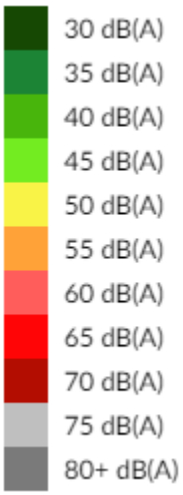

Figure 4 – Colored legend for noise maps

For example, the yellow band indicates noise levels from 50 dBA to 54.9 dBA; the orange band indicates noise levels from 55 dBA to 59.9 dBA; and the pink band indicates noise levels from 60 dBA to 64.9 dBA The colors represent increasing sound levels from 30 dBA in dark green to over 80 dBA in dark grey. Noise levels that are not bothersome and that are consistent with low background sound levels are the green zones – light green, medium green, and dark green. In this way, a noise map can be viewed with a focus

on “non-green“ zones as areas where objections to pickleball noise might occur, depending on background sound levels.

All noise maps are shown with north oriented to the top of each map. This provides a link to any local maps which also have north oriented to the top of the map.

Sound Propagation

Sound travels away from its source with a reduction of 6 dB for each doubling of distance from the source. Figure 5 shows sound propagating away from a point source over level ground using the noise modeling tool (2). This figure shows the horizontal plane of sound propagation. Each colored ring represents a 5 dB decrease of sounds as indicated by the legend. Sound decreases in level as a listener moves away from a sound source or as the sound source is moved farther away from a stationary listener. (Distances in noise plots can only be shown in meters because the software used is a European software which only displays meters. One meter = 3.3 feet) The 6 dB reduction for every doubling of distance is evident with the increasing diameter of each ring outward from the center.

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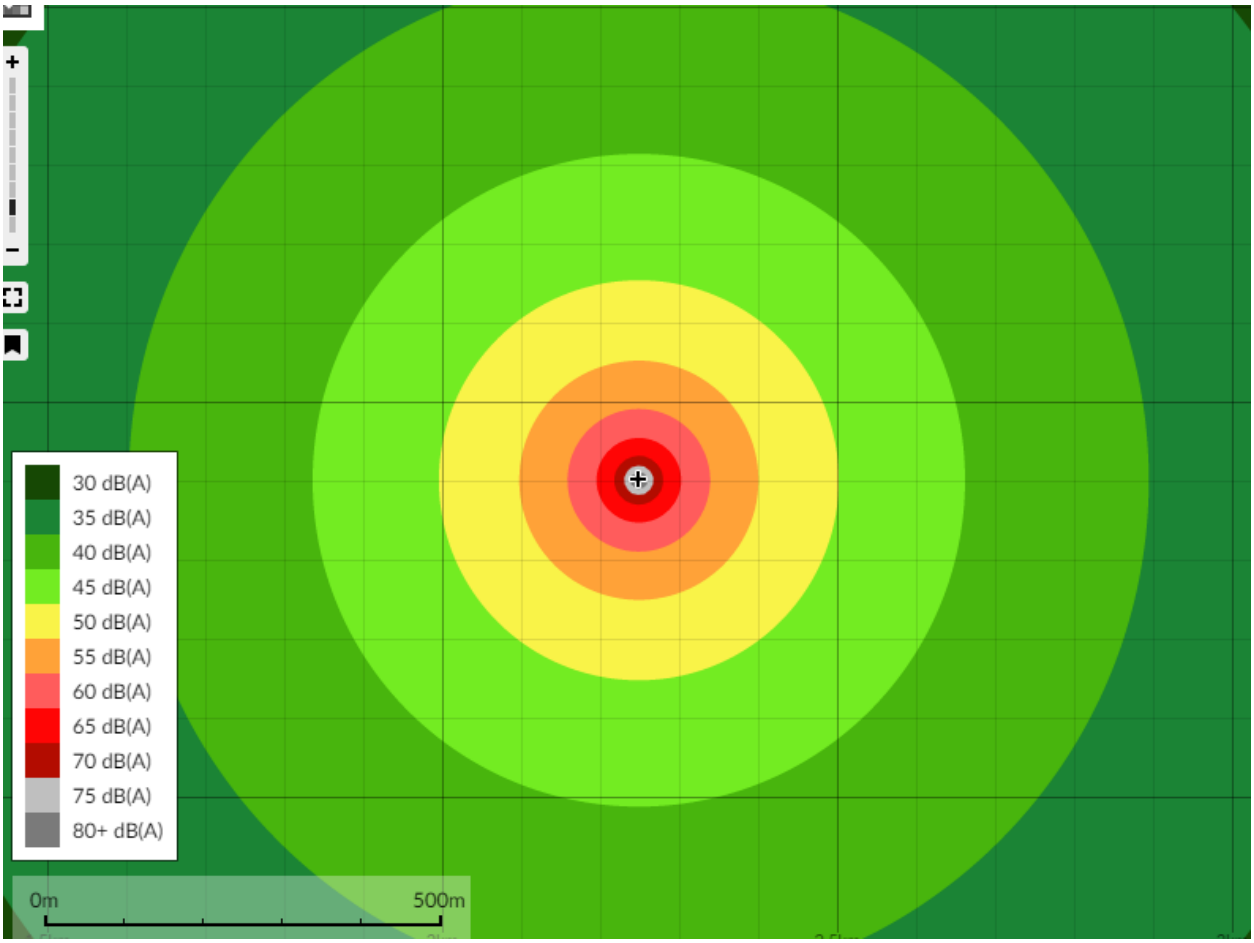

Figure 5 – Sound propagating away from a point source in a horizontal plane (1 meter= 3.3 feet)

Sound also propagates away from a source in the vertical direction. Figure 6 shows a three dimensional view of the vertical plane of sound propagation together with the horizontal plane. (The noise mapping software does not display distances in three dimensional plots.) The three dimensional behavior of sound becomes important to estimate the sound traveling up a hill side, to a second story window, or to an apartment balcony.

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Figure 6 – Sound propagating away from a point source in a horizontal and vertical plane

Human Hearing and Annoyance

The human ear is sensitive to a sound's level, its frequency content, its duration, and its frequency of occurrence (3). All of these contribute to annoyance. The higher the sound level, the greater the annoyance becomes. The human ear is only sensitive enough to detect a change in sound level of 3 dB. Each 10 dB increase in sound level is perceived as a doubling in the sound level. In the same manner, each decrease of 10 dB is perceived as one half the loudness. A 20 dB increase is perceived as 4 times as loud. Similarly, a 20 dB decrease is perceived as 1/4 as loud.

Hearing is more sensitive to high frequency sounds than to low frequency sounds. Sound measurements made with an A weighting scale match the frequency sensitivity of the human ear. These are described as dBA.

Another factor in annoyance is the interval or space between sounds. Intermittent sounds are considered more annoying than a steady state sound of the same dB level. All these elements contribute to annoyance and are critical to the noise measurements that are referenced in noise ordinances.

Noise Ordinances

In simple terms, noise is sound that annoys. Community noise ordinances establish noise limits so that noise is neither annoying nor bothersome, even though it may be audible. These ordinances are not intended to establish a limit where sound is inaudible. They are intended to establish a limit where the

presence of noise above a background noise level will not be objectionable. The background noise level is the result of wind, trees, birds, normal ambient sounds, and sometimes traffic.

An effective noise ordinance must address both continuous noise and impulsive noise. Continuous noise is noise that is steady without abrupt changes. Impulsive noise is noise lasting less than one second that has a rapid onset and rapid reduction. This impulsive noise can also be intermittent in nature.

Because continuous sounds and impulsive sounds have different characteristics that cause them to be perceived differently by human hearing, the noise limits for both types of sounds must be separately stated. This is because the ear responds differently to continuous and impulsive noises.

The limits for impulsive sounds are less well defined in noise ordinances. Without a limit for impulsive noise, the continuous noise limits can be incorrectly applied to an impulsive noise. This can lead to situations where the measurement of an impulsive noise using the procedures for continuous noise indicate the noise level is not in violation of a noise ordinance, yet community noise complaints exist. Even when an ordinance includes a limit for impulsive noise, the noise measurement technique must be stated (4). Pickleball is an impulsive sound requiring a measurement method and limit within the ordinance.

Massachusetts Noise Regulations

The Commonwealth of Massachusetts DAQC Policy 90-001 (5) defines a sound violation when sound at a property line is more than 10 dBA above the ambient sound. This ordinance does not state the measurement setting for a meter. Without further information on the metric to be used for impulsive noise from pickleball, this ordinance would understate the level of pickleball noise.

The Boston, MA Noise Ordinance 16 -26.1.c.1 (6) defines a sound violation when sound is above 70 dBA. This ordinance also does not state the measurement setting for a meter. Without further information on the metric to be used for impulsive noise from pickleball, this ordinance would understate the level of pickleball noise.

Both ordinances are based on continuous noise which is different from the impulsive noise from pickleball play.

Recommended Standard for Pickleball Sound

PSM has used its experience with pickleball sound measurements to develop a standard for pickleball sound. This standard sets an LAFmax level where pickleball sound would not be annoying. The PSM noise standard varies based on the background sound. Background should be measured with LAeq, which is the long term average of sound fluctuations with an A-weighting. This measurement is commonly used for environmental noise studies of background sound.

The recommended noise limit at a property line for pickleball play to avoid annoyance follows.

- When the background sound level is at or below 47 dB LAeq, the noise limit for pickleball noise should be 50 dB LAFmax.
- When the background sound level is above 47 dB LAeq, the noise limit for pickleball noise should be 3 dB LAFmax above the background level.

These limits refer to noise levels at a property line. These guidelines provide a variable limit for pickleball noise depending on the ambient sound levels.

If pickleball courts are in a quiet residential neighborhood with background sound at 47 LAeq, then a limit for pickleball noise at 50 dB LAFmax should be set. With the background sound level at 47 dB LAeq, pickleball impacts at 50 dB LAFmax will be faintly audible. For any lower levels of background sound, pickleball impacts will be perceptible but not bothersome due to the 50 dB LAFmax limit.

Pickleball sound at 50 dB LAFmax should not be bothersome to a reasonable person for these reasons.

- 50 dB LAFmax is the noise level of a large, busy office.
- 50 dB LAFmax is not loud enough to be objectionable even due to its intermittent nature.

If pickleball courts are in a busy city center with high background noise from traffic at 55 LAeq, then a limit for pickleball noise at 58 dB LAFmax should be set.

These guidelines are recommended to avoid community annoyance from pickleball play. Higher noise levels may be acceptable at a property line without annoyance depending on the property owner. Noise levels farther from a property line will generally be lower due to this additional distance unless reflected sound paths from hard surfaces combine at this greater distance.

Manchester-by-the-Sea Pickleball Courts

The pickleball courts at Manchester-by-the-Sea are located next to Route 127 with residential properties across the street on Forest Street and Summer Street. Figure 7 shows the aerial view of this area from Google Earth (7). Six pickleball courts are planned in the orientation shown. The courts are surrounded by a 10 foot chain link fence on the north side and a 6 foot chain link fence on all other sides. Primary consideration was requested for the properties at 8 Forest Street and 142 Summer Street. (8) The north fence is 220 feet from the property line for 8 Forest Street and 80 feet from the property line for 142 Summer Street. These are shown with white arrows.

Figure 7 - Aerial view of pickleball courts at Waterstone of Carmel from Google Earth

The topography of the site was added to the sound map using elevations from Google Earth. The topography included a slight change in elevation between the courts and the surrounding property and a lower elevation near Brick Pond. Background sound was not measured at this site but would be expected to range from 47 LAeq to 55 LAeq, consistent with residential neighborhoods and lightly traveled roads. Since traffic is not always present, a pickleball noise limit based on 47 LAeq would be 50 LAFmax to avoid annoyance.

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Manchester-by-the-Sea Pickleball Noise Analysis

Pickleball noise can come from any location on these courts when the ball is stuck. The location producing the loudest impact will be the Non-Volley Zone that is closest to the receiver. With 3 courts near the north fence, a pickleball noise source was individually placed on each court closest to the north fence to study the sound that was generated. The loudness of the source was based on measurements from similar pickleball courts. The source is shown by the black cross on each court in the following figures. Several cases were compared and will be described individually. A summary of cases can be found in Table 1.

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Case 1 – no sound barriers, position 2

To determine the variation in noise based on source location, three court positions for the sound source were analyzed. Figure 8 shows the LAFmax noise levels with the source at the center court (position 2) for selected receiver locations. Primary attention will be given to noise levels at the homes at 142 Summer Street and 8 Forest Street. All sound levels are above 50 dB LAFmax and would be considered bothersome and objectionable.

A summary of these results and the results for all other cases can be found in Table 1.

Figure 8 – Case 1, no sound barriers

Case 2 – no sound barriers, position 1

Figure 9 shows the LAFmax noise levels with the source at the left court (position 1) for selected receiver locations. All sound levels are above 50 LAFmax and would be considered bothersome and objectionable. Compared to Case 1 in Figure 8, a 1 dB change is seen at the critical locations. This change would not be perceptible to human hearing.

Figure 9 – Case 2, no sound barriers

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Case 3 – no sound barriers, position 3

Figure 10 shows the LAFmax noise levels with the source at the right court (position 3) for selected receiver locations. All sound levels are above 50 LAFmax and would be considered bothersome and objectionable. Compared to Case 1 in Figure 8, a 1 dB change is seen in the sound levels at 142 Summer Street and no change is seen at 8 Forest Street. This insignificant change would not be perceptible to human hearing.

This comparison of case 1, 2, and 3 shows that each court will generate similar noise levels at the selected receiver locations. For all further studies, the noise source will be placed at the center court (position 2).

Figure 10 – Case 3, no sound barriers

Case 1 – no sound barriers, position 2, colored sound map

Figure 11 shows the results from Case 1 but with colored noise contours. Within each color band, the white lines indicate 1 dB changes in level. This figure is helpful to display areas where the noise will not be objectionable. These are the areas in shades of green with sound levels decreasing from light green to dark green. The areas in shades of yellow, orange, pink , and red indicate progressively higher noise levels. The goal for a home (or a property line) would be a green zone. LAFmax noise levels are also shown at the center of each 16.4 ft by 16.4 foot grid (5 m x 5 m grid) on this map. This grid can be used to determine the sound levels at any other location on this map. The colored noise map in Figure 11 shows several conclusions of sound propagation away from the pickleball courts.

- Sound levels decrease with distance from the source, much like the contours in Figure 5.
- Noise levels at property lines are above the target of 50 dB LAFmax.
- The sound levels in the backyards are lower than the sound levels at the property lines. The homes function as sound barriers and block a direct line of sight from the backyards to the courts.

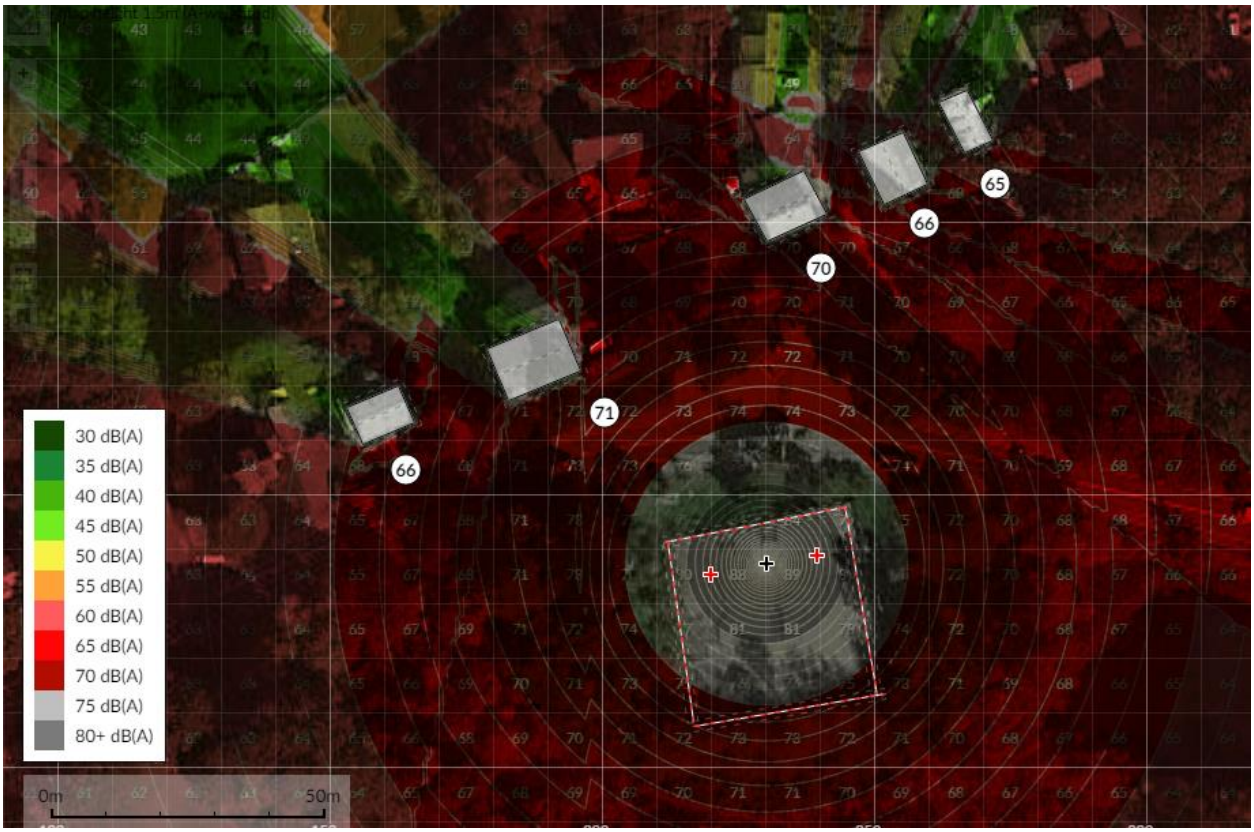

Figure 11 – Case 1, no barriers with colored sound contours

All future cases will show colored sound contours. For no objections to pickleball noise, the goal will be to have property lines and critical homes in a green zone. Sound barriers to reduce noise will be compared.

Case 4 – 10 foot sound barrier on north fence

Figure 12 shows the LAFmax noise levels with the source at the center court for the selected receiver locations with a 10 foot sound barrier on the north fence. The conclusions are:

- The sound barrier reduces pickleball sound from 9 to 11 dBA depending on location.
- The pickleball noise levels are still above 50 dB LAFmax and would be considered bothersome.

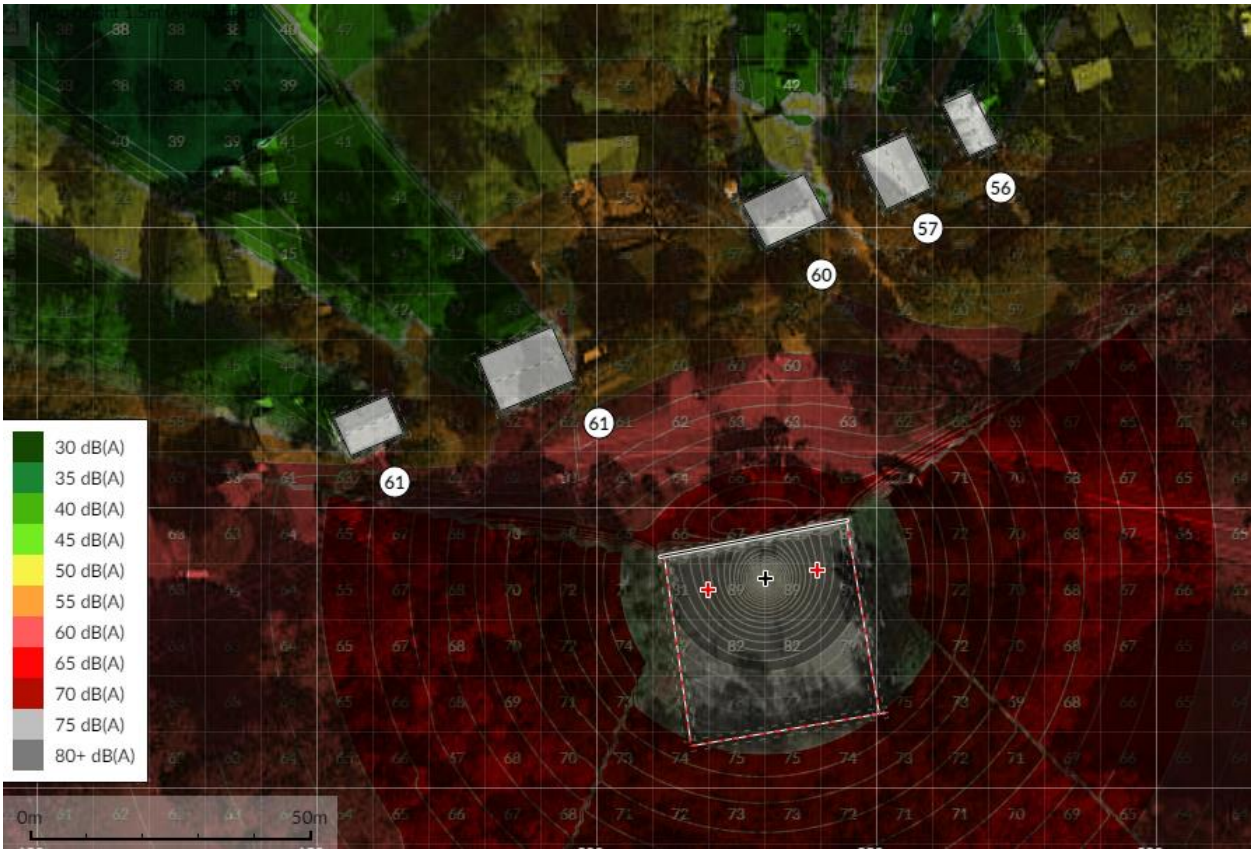

Figure 12 – Case 4, 10 foot sound barrier on north fence

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Case 5 – 10 foot sound barrier on north fence, 6 foot sound barrier on east and west fences

Figure 13 shows the LAFmax noise levels with the source at the center court for the selected receiver locations with a 10 foot sound barrier on the north fence and 6 foot sound barriers on the east and west fences. The conclusions are:

- The added 6 foot sound barriers on east and west fences only reduce sound 1 dB, which would be imperceptible to human hearing.
- These side barriers would not be cost effective.
- The pickleball noise levels are still above 50 dB LAFmax and would be considered bothersome.

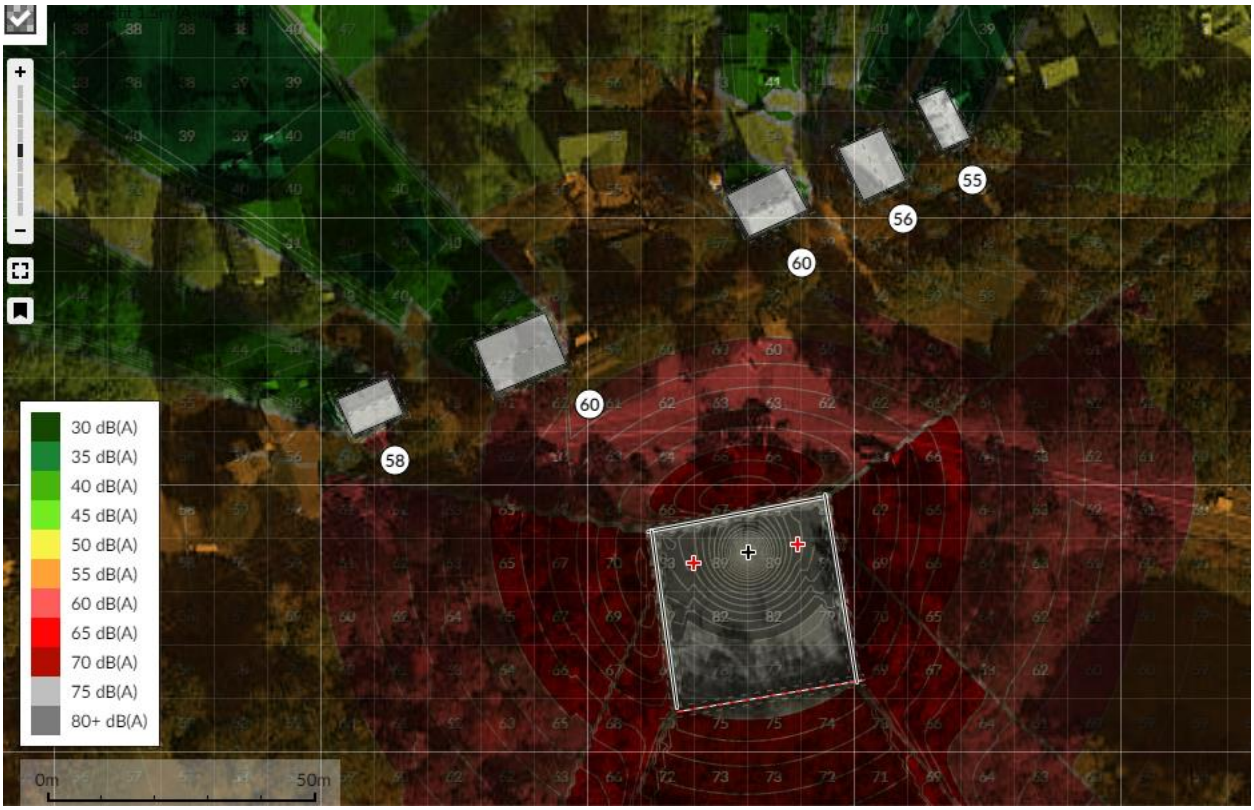

Figure 13 – Case 5, 10 foot sound barrier on north fence, 6 foot sound barriers on east and west fence

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Figure 14 is a three dimensional view of the sound field to each of the nearby homes. The homes are shielded from pickleball sound by the 10 foot sound barrier on the north fence. The 6 foot sound barriers on east and west fences have very little impact in the northerly direction to these nearby homes. They are not in a direct line of sight to the courts. Attention can now be focused on the proper height of the sound barrier on the north fence to reduce noise to an acceptable level.

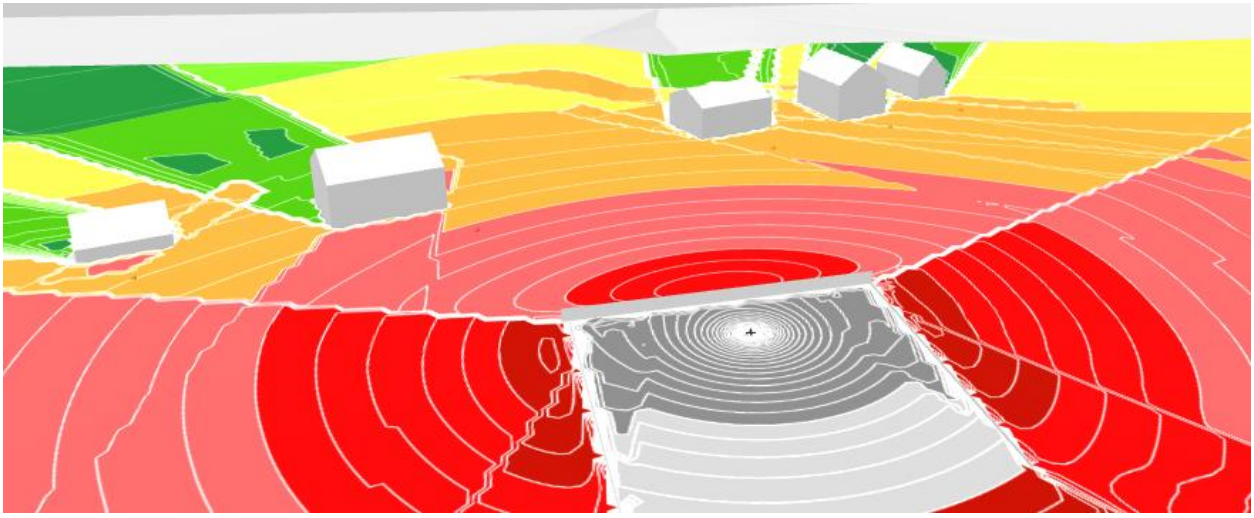

Figure 14 – Case 5, 10 foot sound barrier on north fence, 6 foot sound barriers on east and west fence – 3D view

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Case 6 – 12 foot sound barrier on north fence, no barrier on east and west fences

Figure 15 shows the LAFmax noise levels with the source at the center court for the selected receiver locations with a 12 foot sound barrier on the north fence and no sound barriers on the east and west fences. The conclusions are:

- The change from 10 feet to 12 feet for the sound barrier reduces sound 3 dB at all locations but the sound levels are still above the recommended noise levels.
- The pickleball noise levels are still above 50 dB LAFmax and would be considered bothersome.

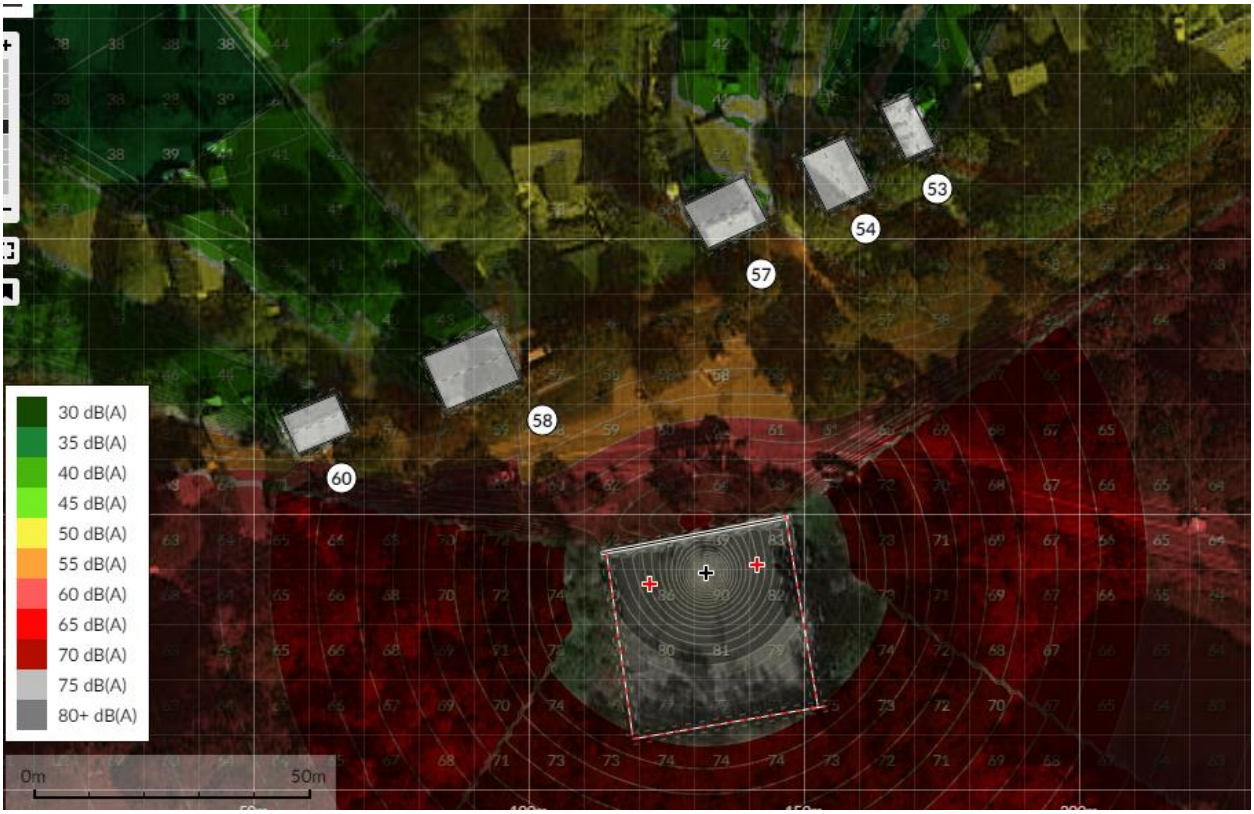

Figure 15 – Case 6, 12 foot sound barrier on north fence

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Case 7 – 14 foot sound barrier on north side, no barrier on east and west sides

Figure 16 shows the LAFmax noise levels with the source at the center court for the selected receiver locations and with a 14 foot sound barrier on the north fence and no sound barriers on the east and west fences. The conclusions are:

- The change from 12 feet to 14 feet the sound barrier reduces sound 1 to 2 dB at all locations, but the sound levels are still above the recommended noise levels.
- The pickleball noise levels are still above 50 dB LAFmax and would be considered bothersome.

Figure 16 – Case 6, 14 foot sound barrier on north fence

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Case 8 – 20 foot sound barrier on north side, no barrier on east and west sides

Case 8 examined the barrier height required to bring noise to the recommended levels of 50 dB LAFmax. Figure 17 shows the LAFmax noise levels with the source at the center court for the selected receiver locations with a 20 foot sound barrier on the north fence and no sound barriers on the east and west fences. The conclusions are:

- The change from 14 feet to 20 feet for the sound barrier reduces sound 3 dB at all locations.
- The pickleball noise levels are just above 50 dB LAFmax at 142 Summer Street and would be marginally bothersome.
- The pickleball noise levels are below 50 dB LAFmax at 8 Forest Street and would not be bothersome.
- The incremental noise reduction benefits of this barrier decrease become expensive for material and fence design.
- It is unlikely that a 20 foot barrier will be feasible in this location.

Other alternatives for noise mitigation will examine the impact of quieter pickleball paddles and balls.

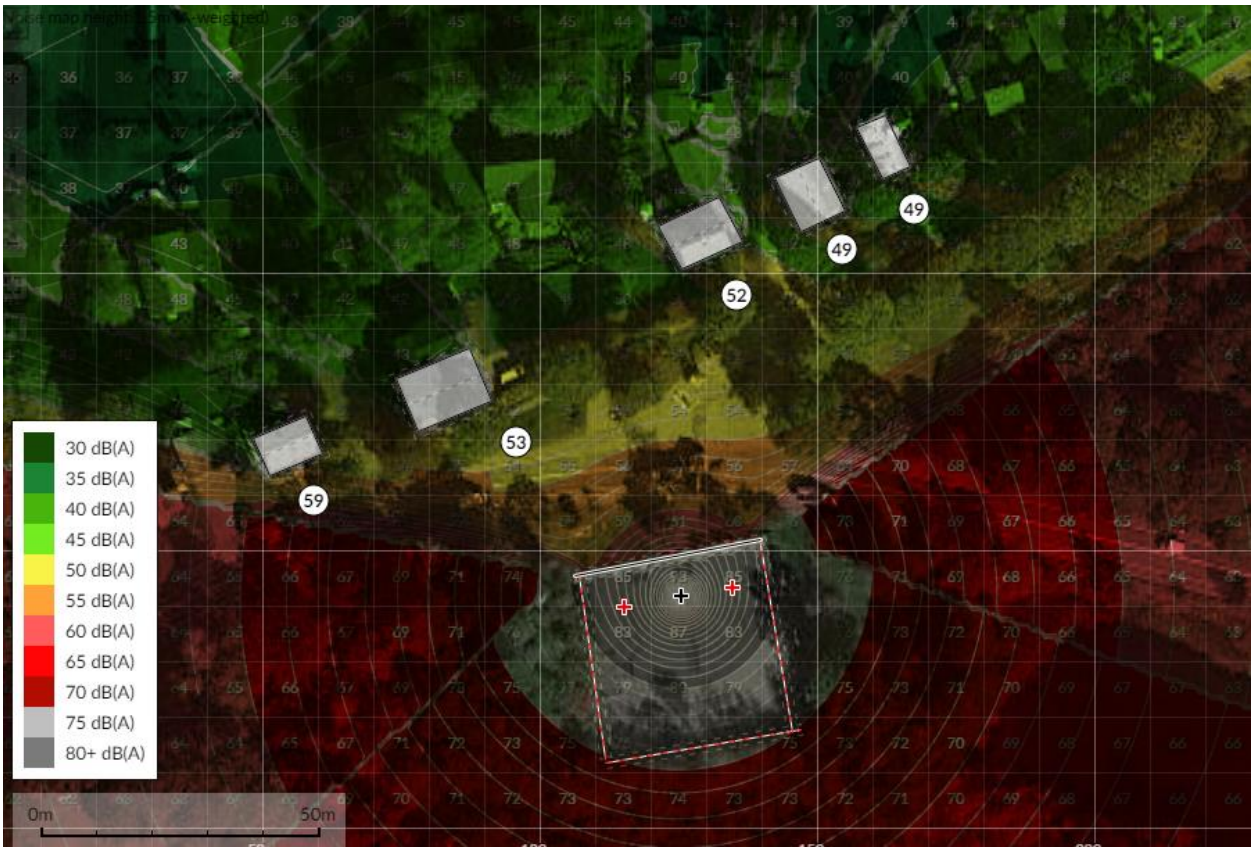

Figure 17 – Case 6, 20 foot sound barrier on north fence

Case 9 – 12 foot sound barrier on north fence, recommended gear

Recommended pickleball gear can reduce the noise so that lower fence heights can be considered. A combination of quieter paddles and balls can reduce noise by 8 dB or more. Figure 17 shows the LAFmax noise levels with the source at the center court for the selected receiver locations with recommended pickleball paddles and balls, with a 12 foot sound barrier on the north fence, and with no sound barriers on the east and west fences. The conclusions are:

- The combination of a 12 foot sound barrier and recommended paddles and balls reduces the pickleball noise to 50 dB LAF max or below at the target locations.
- This combination produces a 20 dB noise reduction which would be perceived as 1/4 as loud as without mitigation.
- All adjacent properties are in a green zone for noise.

Figure 16 – Case 6, 12 foot sound barrier on north fence and recommended gear

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Table 1 shows the summary results for Case 1 to Case 9.

Table 1 – Summary of Case 1 to Case 9

	dB LAFmax at each address		
	142 Summer St	**4 Forest St**	**8 Forest St**
Target dB LAFmax	50	50	50
Case number			
1 - Position 2, no sound barriers	71	70	65
2 - Position 1, no sound barriers	72	70	64
3 - Position 3, no sound barriers	70	71	65
4 - Position 2, 10 foot barrier N side	61	60	56
5 - Position 2, 10 ft barrier N, 6 ft barrier E + W sides	60	60	55
6 - Position 2, 12 foot Barrier N side	58	57	53
7 - Position 2, 14 foot Barrier N side	56	55	52
8 - Position 2, 20 foot Barrier N side	53	52	49
9 - Position 2, 12 feet Barrier N side, recommended gear	50	49	45

Sound Barriers

Sound barriers block the direct path of sound that travels from a source to a receiver. A barrier must be massive enough to block sound that could pass through it. The recommended weight for a barrier is 1 pound per square foot. A small amount of sound still passes over the top or around the edges. With this weight barrier, the sound reduction is limited only by the height and width of the barrier.

The barrier must be solid with no holes, no gaps at the bottom, and no gaps between adjoining panels. Any holes or openings will allow sound to leak to the other side. Earth mounds and buildings can function as barriers if they disrupt a direct path of sound. Shrubs, bushes, and trees are not barriers even though they block a line of sight. They are not massive enough and not solid enough to block sound. A small amount of sound attenuation may be achieved with a dense planting of hedges, but this would not provide more than 2 to 3 dB sound reduction.

The effectiveness of any barrier is controlled primarily by its height and then by its width. The barrier must be tall enough and wide enough so that it minimizes the sound that is diffracted or bent over the top and around the edge. The amount of sound diffracted over the top and edge can be minimized as the barrier becomes higher and longer. In some cases, it may be best to enclose all four sides of a pickleball court with the highest barrier possible. If there are no homes exposed to pickleball sound from a side of the court, then a barrier can be eliminated on that side.

Recommended vendors for barrier walls are:

- Insul-Quilts USA, South El Monte, CA, 833-853-6444, https://www.insulquilt.com/
- Acoustiblok, Tampa, FL, 813-980-1400, https://acoustiblok.com/acoustiblok-soundproofing-product-lines/acoustifence-noise-reducing-fences/
- eNoise Control, Noblesville, IN, 866-481-2024, https://www.enoisecontrol.com/
- DDS Acoustical Specialties, Westfield, MA 413-248-8118, https://ddsacoustical.com/

Noise barriers should weigh one pound per square foot to be effective as a barrier. The effectiveness of a higher weight is often compromised by the sound that is diffracted over the top or around an edge. A contractor must be consulted to assure that an existing fence or a new fence can support the added weight of a barrier. Wind loads on the barrier are also to be considered.

Recommended Paddles

As pickleball technology has evolved, new composite materials are being used in many different paddles. USA Pickleball, the governing body for the sport, has approved over 1,700 paddles for tournament play. Each paddle can produce a different noise level. Some paddles produce a lower noise level than others. However, the technology has not evolved to the point where any paddle can be considered a silent paddle.

Table 2 lists recommended paddles that are quieter than paddles made several years ago based on tests in a chamber designed by PSM LLC as of April 23, 2023. These 30 paddles represent a preferred subset of over 150 paddles that have been tested. These paddles will reduce but not eliminate noise.

A mandate to use paddles from an approved list is always hard to enforce for recreational players. One strategy for the community would be to purchase enough paddles from this list for all courts, to supply these paddles as loaner paddles for pickleball play, and to only allow pickleball play with these paddles.

Table 2 – Recommended lower noise paddles from PSM testing

Paddle vendor	Paddle model name	Notes
CRBN	1	
CRBN	1X	
CRBN	2	
Diadem	Vice	1
Diadem	Warrior	
E6	16s	
Electrum	E Pro II	
Franklin	Pro Series 16 mm	2
Gearbox	CX11	
Gearbox	CX14	
Gearbox	GX5	
Gearbox	GX6	
Joola	Ben Johns 16 mm	
Joola	Simone Jardim 16 mm	
Joola	Radius	
Master Athletics	Q1	1
One More	Vibe	
One More	Pro Custom	
Patriot Pickleball	Sniper	3
Pro Drive	DRIVE	
Pro Kennex	Pro Speed	
Pro Kennex	Ovation	
Selkirk	Amped Epic	
Selkirk	Vanguard Invikta	
TMPR	Tantrum	
TMPR	TC-16	
Wild Monkeys	Grizzly	
Wolfe	Bite	
Your Pickleball Place	Maxor	3
Your Pickleball Place	Whisper QT	3
1 - This model is not approved by USA Pickleball for sanctioned tournament play		
2 - Formerly the Ben Johns Model		
3- These older models meet the criteria, but availability is unknown		
PSM list as of 4/8/23		

Recommended Balls

While many balls are approved for pickleball play, some balls produce slightly lower sound levels when struck with a paddle. PSM has evaluated several commercially available pickleballs. The difference in sound levels among balls is much less than the difference among paddles and can be 1 to 2 dB. However, this has an additive effect with recommended paddles.

Recommended balls with lower sound levels are:

- Onix Fuse G2 outdoor
- Penn 40
- Wilson 32
- Monarch Gen 2 outdoor
- Aviana Outdoor Green A210G

A mandate to use balls from an approved list is always hard to enforce for recreational players. One strategy for the community would be to purchase 100 or more balls from this list, to supply these balls for pickleball play, and to only allow pickleball play with this model of ball.

A recommended paddle and ball combination for lowest noise is the Master Athletics Q1 paddle or Diadem Vice paddle and the Monarch Gen 2 outdoor ball. This combination can provide over 8 dB reduction over the loudest paddles and loudest balls. The community could decide to provide this gear at each site as the standard for pickleball play or simply to mandate its use by each player at the players' expense. Note that while the Master Athletics Q1 and Diadem Vice are rated as low noise paddles, neither are approved for tournament play.

It must be emphasized that these recommended paddles and balls are not alone sufficient to reduce noise levels without a barrier in place at the Manchester-by-the-Sea courts.

Other Sound Mitigation Options

Additional sound mitigation options are possible. These include restricted court time and court enclosures. They will be presented as alternative options beyond higher, longer barriers and recommended equipment.

Restricting play time is the equivalent of an on-off switch for pickleball. This can be controlled on courts with a gated entry that can be locked. However, restricted play time has the disadvantage of limiting the hours of court availability. This is something a community should review based on the availability of alternate courts and the number of pickleball players. This may have the greatest chance of appeasing neighbors exposed to pickleball sound by limiting play during critical hours of the day.

Air supported structures (known as tennis bubbles) are often used for winter tennis or golf. The walls do not provide as much sound reduction as a metal building structure, but they may be sufficient for

pickleball noise reduction. The roof of the air supported structure blocks sound that travels over the top of a sound barrier.

Conclusions

The following conclusions are made from the results in this study.

1. Noise ordinances for the State of Massachusetts and for Boston do not properly address the impulsive noise from pickleball and cannot be effectively used to judge objectionable noise levels from pickleball. Both ordinances fail to state measurement procedures to quantify pickleball noise and would understate the annoyance from pickleball.
2. An improved standard for pickleball noise limits was outlined using LAFmax as the preferred measurement method. LAF max levels above 50 dB LAFmax would be considered either a nuisance or bothersome.
3. Noise level predictions using sound mapping software indicate that LAFmax noise levels from pickleball courts with no sound mitigation in place are above a recommended limit of 50 dB LAFmax at the property line of the homes at 142 Summer Street and 8 Forest Street.
4. Sound barriers of various heights were evaluated on the north, east, and west fences of the pickleball courts. A barrier on the north fence is more effective than a barrier on the east or west fences.
5. Each successive increase in height of the barrier on the north fence from 10 to 20 feet reduced the sound but a point of diminishing returns is reached as the height is increased.
6. With a 12 foot sound barrier on the north fence and with recommended paddles and balls, the noise can be reduced to levels of 50 dB LAFmax or below that would not be considered bothersome at the two critical residences.
7. Additional sound mitigation strategies with restricted court times and enclosures (tennis bubbles) are possible as alternative solutions, especially if recommended equipment cannot be monitored and controlled.

Recommendations

The following recommendations are made for the pickleball courts at Manchester-by-the-Sea.

1. Extend the chain link fence from 10 feet to 12 feet, install a 12 foot sound barrier, and limit play to recommended paddles and balls to reduce pickleball noise to a level where it would not be bothersome to 142 Summer Street, and 8 Forest Street.
2. Restrict hours of pickleball play to the times when pickleball noise will be least bothersome.
3. Install a tennis bubble over the courts for year-round play as an added community amenity.
4. Add a city ordinance for pickleball noise using the variable noise limits defined by LAFmax and background noise to better quantify the annoyance potential of pickleball noise for Manchester-by-the-Sea.

5. If recommended equipment, improved barriers, restricted court time, or a tennis bubble are not feasible, then pickleball play should be moved to another location to preserve the quality of life in Manchester-by-the-Sea.

PSM LLC has provided these results on pickleball sound to Manchester-by-the-Seal to balance the spirit of the community's recreational use of its pickleball courts with the quality of life of its residents. PSM LLC is available to answer any questions related to this work.

Disclaimer

The results, conclusions, and recommendations presented here are based on information provided to PSM LLC by the client and on measurements made using calibrated equipment and standard acoustical practices. These results are intended to address maximum noise levels from play. Pickleball sound assessment is a random process where the noise from each impact and from each game can vary based on player skill, force of impact, and equipment in use. Sound levels from pickleball are random impulsive events, meaning that it is predictable over a range and has averages and other statistical characteristics, but it has no exact single level. Actual sound levels will vary over time. In addition, it is not possible to determine what any particular person believes is an acceptable sound level. Because additional variables may be associated with the site, the players, or the equipment in use, PSM LLC assumes no liability for work undertaken by the client based on these recommendations, or for results that do not conform to the client's expectations.

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Principal Acoustical Engineer
PSM LLC

Robert Unetich, PE
Owner and Principal
PSM LLC

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PSM LLC Information

Pickleball Sound Mitigation LLC

PSM LLC was created in 2022 after 8 years of pickleball noise studies and advice on pickleball noise mitigation. This work included field measurements of pickleball play at multiple sites, analysis of the noise from different pickleball paddles and balls, consultation with USA Pickleball on equipment standards, and evaluation of suppliers of noise barrier systems. PSM has designed successful noise reduction systems for pickleball courts and has evaluated multiple paddles and balls to create lists of "quieter" paddles and balls. It has also completed field studies of pickleball noise to provide guidance to homeowners regarding local noise ordinances. In total, PSM has completed or has been involved in noise surveys and recommended noise mitigations measures for 23 pickleball sites, including seven in California. PSM is at the forefront of pickleball technology and is working directly with USA Pickleball to develop acoustical test methods for paddles, to identify quieter gear, and to create improved community standards for pickleball noise. It is also working with paddle manufacturers to help bring improved, quieter paddles to market. PSM LLC is in the final stages of developing the industry's first anechoic chamber for testing both pickleball paddles and balls under controlled speed conditions. This will yield baseline data on paddles without the variables of wind, background noise, and player skill in hitting the ball. PSM LLC is also working on an air gun that will shoot pickleballs at a controlled speed for detailed studies of pickleball noise.

The mission of PSM is to support pickleball clubs, pickleball players, communities, parks, country clubs, and homeowner associations with an understanding of pickleball noise and of strategies and measures to control pickleball noise.

Robert Unetich, PE

Robert Unetich is the founder of PSM LLC. He is an avid pickleball player, a USA Pickleball Certified Referee, and the owner of the Pickleball School. He is the creator of the Facebook group, Pickleball Sound Mitigation, which has over 400 followers. His professional background includes over 50 years of industrial experience in electrical engineering, radio wave propagation, and signal processing. He is the owner of GigaHertz LLC, a manufacturer of custom electrical equipment. He has an electrical engineering degree from Carnegie Mellon University. His work in pickleball noise mitigation began when he was asked to investigate ways that the sound of pickleball might be reduced at residences near his home. That work involved careful analysis of work done by acoustical engineers in solving sound problems and at methods of reducing the

level of annoyance experienced by neighbors of pickleball courts. His professional associations include:

- The Institute of Electrical and Electronics Engineers
- Professional Engineer, registered in Pennsylvania
- The Acoustical Society of America

Barry Wyerman, PhD, PE

Barry Wyerman, PhD, is the Principal Acoustical Consultant for PSM LLC. He is a pickleball player and a USA Pickleball Level 2 Referee. His professional background includes over 45 years of acoustical experience in creating innovative acoustical products, solving industrial noise control and vibration problems, and designing solutions for automotive noise and vibration control. He is the owner of Acoustical Design and Consulting, LLC, which provides engineering and consulting support in all areas of acoustics and noise control. He has a BS degree in physics from Ohio University and MS and PhD degrees in engineering acoustics from Penn State University. He became involved in pickleball noise mitigation when he met Bob Unetich at a pickleball court and provided initial recommendations on pickleball noise control from his work experience and acoustical training. His professional associations include:

- The Acoustical Society of America
- Society of Automotive Engineers, Noise and Vibration Committee
- Society of Automotive Engineers, Acoustical Materials Committee
- Professional Engineer, registered in Ohio

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