



PSM LLC
Pickleball Sound
Mitigation

Pickleball Sound Assessment Report with Recommendations

Villages at West Neck

Virginia Beach, VA

by

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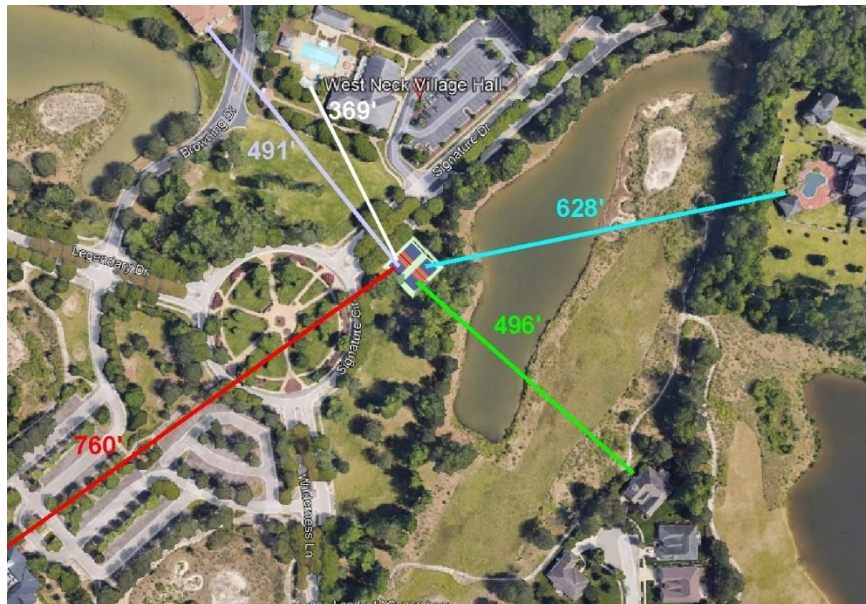
I. Executive Summary

The Villages at West Neck is considering adding two new pickleball courts in the vicinity of the Village Hall along Signature Drive. PSM Consulting LLC has been asked to review the location regarding the sound impact Pickleball play will have on the surrounding area, including: the pool and Village Hall indoor rooms, single family residences, condominium buildings and The Signature Clubhouse. PSM Consulting has also been asked to make recommendations on the court location and the orientation of the courts, as well as any sound mitigation measures that may be required to meet the City of Virginia Beach Noise Ordinances and “good neighbor” guidelines.

After reviewing the proposed site, to the east of Signature Drive, between the Village Hall and the traffic circle, we believe it is an appropriate location. Using the proposed court layout and applying predictive acoustic software analysis, we believe that by adding 12 ft high sound mitigation barrier material to the eastern fence, sound pressure levels are calculated to be near or below 50 dBA at the outside of all surrounding properties. This is much lower than the noise ordinance limit, which is 65 dBA inside a residence, between 7:00am and 10:00pm and 55 dBA inside a residence between 10:00pm and 7:00am. It means the distinctive sound of pickleball hits may be heard faintly at times, but not be found annoying by “reasonable people with normal sensitivity.” Barriers on the other fences are not recommended as necessary; however, the addition of vegetation (hedges) will help reduce propagation of sound and block wind for players.

II. Overview of the Site

(north)



The 2 proposed pickleball courts run parallel to Signature Drive with the primary hitting axis northeast-southeast. Sound propagation from pickleball play is somewhat directional, with about 3-5 dB lower levels perpendicular to the axis of play, i.e. towards the single-family residences to the east and condominium to the west.

There are 25 ft high dense trees on both sides and the median of Signature Drive to the west of the courts. The bushes along the Village Hall to the north are dense and at least 12 ft high. The bushes between the pool/recreation area are not as tall, nor as dense, but will offer some sound mitigation. The trees to the east of the courts are tall and mature, but they are expected to only modestly block sound in this direction.



On the east side of the pond, towards the northeast, there is a dense tree line blocking the line of sight (and sound). Towards The Signature Clubhouse there are numerous smaller trees.

The pond to the east of the courts acts like a reflective surface and reduces the ground absorption of sound in this direction. The modeling software has been programmed to take this phenomenon into account. The changes in elevation are less than 10 ft and there are no significant earth berms or barriers between the courts and residential properties.

The condominiums on Browning Dr are multi-story, so consideration will be given both to potential ground level and upper level noise issues.

There are two airports within 5 miles, but highways, commercial or residential centers, and industrial noise sources are not nearby that might increase the ambient sound level above an expected 45-50 dBA.

III. A Description of Pickleball Sound Characteristics

Pickleball Sound

Pickleball is a game played typically by four people with paddles, a ball, and a net on a court that is approximately one half the size of a tennis court. The paddles are made of wood, plastic, or composite materials, and the ball is made of plastic. The sound generated by pickleball is louder than the sound generated by tennis play, and it has a higher, more annoying, pitch. Homeowners in proximity to pickleball courts hear a “louder” sound than from tennis. At elevated levels, pickleball sounds are considered as noise and can become bothersome and intrusive.

Properties of Pickleball Sound

Sound is generated when an object vibrates and excites the air molecules with which it is in contact. These vibrating air molecules create sound waves that radiate outward from the source of the sound at a speed of 1087 feet per second. As sound moves away from the source, it decreases in amplitude at a rate of 6 dB for each doubling of distance. The sound level or loudness is measured in decibels (dB). The louder the sound, the higher the dB level that is measured, and the more likely the sound will be an annoyance. The tonal quality is the combination of low frequency and high frequency components of the sound. Frequency is measured in cycles per second or Hertz (Hz). Most sounds include a combination of low frequency booming tones and high frequency shrill or sharp tones. Sound also varies with time. A steady state noise is continuous with little or no change in level or frequency content. Impulse noises have short duration and may or may not be repetitive and recurring.

A pickleball impact is an impulsive sound with a duration of 10 to 20 milliseconds. The highest sound energy occurs in the first 2 to 5 milliseconds and then decays to a lower level. In a game of pickleball, a rally will involve several impacts spaced by intervals of less than a second to more than 2 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.

When pickleball play involves 2 or more courts, the sound from 2 or more games does not increase the overall sound level. This is because each pickleball impact is a discrete event. The number of impacts per hour will increase from pickleball on multiple courts but the overall sound levels will not increase.

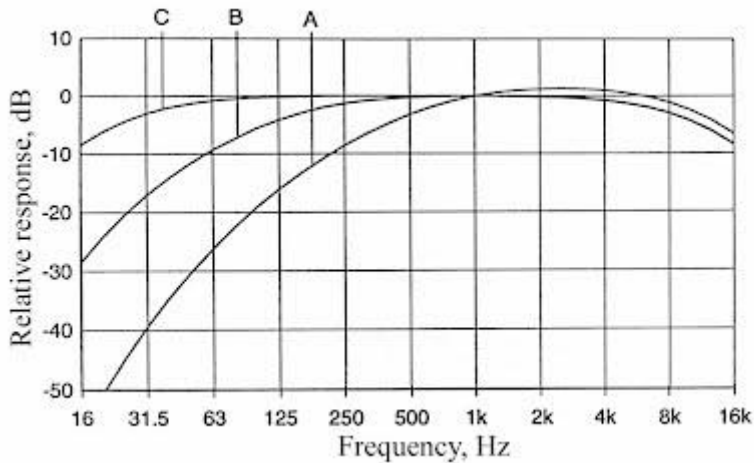
Human Hearing and Annoyance

The human ear is sensitive to a sound’s level, its frequency content, and its duration. The higher the sound level, the greater the annoyance becomes. Each 10 dB increase in sound level is perceived as a doubling in the sound level,

which is a 100% increase. Each 6 dB increase is perceived as a 50% increase and each 3 dB increase is perceived as a 23% increase. The human ear is more sensitive to high frequency sounds than to low frequency sounds. It is also sensitive to the duration of a noise.

dBA vs. dBC

dBA and dBC are the two most common ways of weighting sound measurements. What this means is that the sound being measured is not being measured equally at all frequencies. Below is a graph showing the actual measurement curves for A, B, and C.



These are important because they are approximations of how the human ear actually hears sound.

A sound level meter that measures the sound pressure level with a "flat" response will indicate the strength of low frequency sound with the same emphasis as higher frequency sounds. Yet our ear perceives low frequency sound to be of less loudness than higher frequency sound.

The A weighting curve is the most accurate approximation to the human ear at "normal" sound levels.

Unfortunately, human perception of loudness, vis-a-vis frequency, changes with loudness. When a sound is very loud, 100 dB or more, the perception of loudness is more consistent across the audible frequency band. "B" and "C" weightings reflect this trend. "B" weighting is rarely used.

Notice that "C" weighting is appropriate when measuring very loud sounds. A rock concert is an example of when it should be used.

(Source: Bruce Jellison, "[Understanding sound terms](#)")

Typical Sound Levels

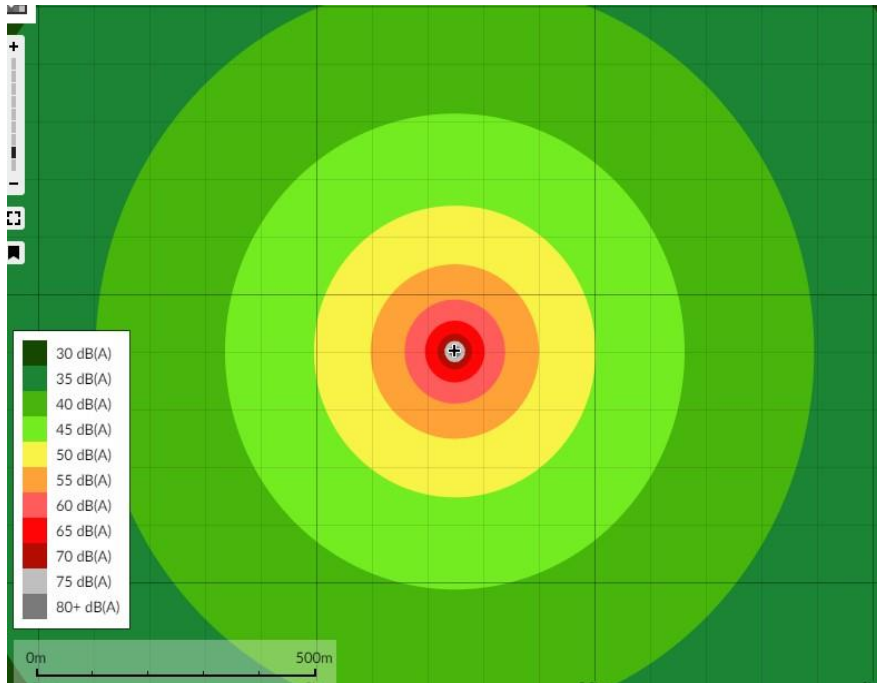
Human hearing normally has a very large range of hearing capability, usually expressed in decibels above a selected sound pressure level of 20 micropascals and designated at zero dB. Human hearing has a lower sensitivity to low pitch sounds and readings of meters and sound software are usually adjusted to account for this by using the A scale. As seen on the chart, a quiet library is usually about 40 dBA

This chart illustrates that sounds in the range of 60 to 75 dBA and comparable to the loudness of normal conversation and to the sound levels usually present in a busy restaurant. Pickleball sound at 100 feet is usually under 70 dBA with no sound barrier and under 60 dBA with a ten ft high sound barrier. The height of the barrier can be adjusted to achieve sound level reduction with a basic goal of having pickleball sound not frequently exceed normal background sound levels.



Sound Propagation

Sound travels away from its source with a reduction of 6 dB for each doubling of distance away from the source. The following diagram shows sound propagating away from a point source over level ground using a noise modeling tool. This diagram 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. The 6 dB reduction for every doubling of distance is evident in the increasing diameter of each ring outward from the center.



Sound propagating away from a point source in a horizontal plane.

Sound also propagates away from a source in the vertical direction. The following diagram shows a three dimensional view of the vertical plane of sound propagation together with the horizontal plane. **This becomes important to estimate the sound traveling to a second story window.**



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

IV. The Measurement of Pickleball Sound Levels

Sound is simply a variation in air pressure over a period of time. A calibrated microphone connected to a device that measures the electrical output and records the peak sound pressure or averages the sound power over a defined period of time constitutes a sound measurement system. The measurements are generally done over time periods defined according to national measurement standards. In the US those standards are set by the American National Standards Institute or ANSI.

While ANSI defines a number of acoustics terms, pickleball has a usual time duration of about 10 to 20 milliseconds (ms). PSM Consulting LLC selects the Fast mode for measuring these short duration sounds, which has a 125 ms averaging period.

Background noise levels can be as low as 40 dBA but in areas with regular traffic, the average sound level will often be twice as loud or 50 dBA, or more. While measuring these levels can be done acceptably with a sound level meter, a more accurate method that measures multiple parameters simultaneously is to use a calibrated microphone connected to a computer running sound power level measurement software.

V. City of Virginia Beach Noise Ordinances and ANSI S12.9-2007

Virginia Beach Code of Ordinances, Chapter 23 -Offences

Article II. – NOISE

Sec. 23-63. Declaration of findings and policy

City council hereby finds and declares that excessive sound is a serious hazard to the public health, welfare, peace and safety and the quality of life; that a substantial body of science and technology exists by which excessive sound may be substantially abated; that the people have a right to and should be ensured an environment free from excessive sound that may jeopardize the public health, welfare, peace and safety or degrade the quality of life; and that it is the policy of the city to prevent such excessive sound to the extent such action is not inconsistent with a citizen's First Amendment rights.

Sec. 23-69. Maximum sound levels and residential dwellings

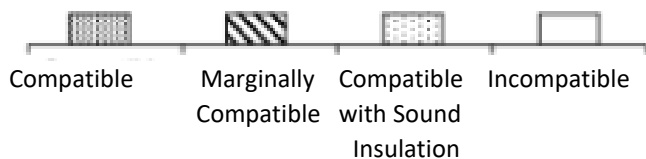
a) *Nighttime.* No person shall permit, operate or cause any source of sound to create a sound level that can be heard in another person's residential dwelling during the hours **between 10:00 p.m. and 7:00 a.m. in excess of 55 dBA when measured inside the residence** at least four (4) feet from the wall nearest the source, **with doors and windows to the receiving area closed.**

(b) *Daytime.* No person shall permit, operate or cause any source of sound to create a sound level in another person's residential dwelling during the hours **between 7:00 a.m. and 10:00 p.m. in excess of 65 dBA when measured inside the residence** at least four (4) feet from the wall nearest the source, **with doors and windows to the receiving area closed.**

ANSI Standard S12.9-2007

American National Standards Institute establishes recommended standards for quantifying annoyance caused by sound. They are based on attitudinal survey studies funded by various federal agencies. These standards are voluntary and are not law, although they may be referenced in state or federal law.

Part 5: Sound Level Descriptors for Determination of Compatible Land Use



This ANSI table suggests a daytime **residential limit of 50-55 dBA.**

Comments on Ordinances and Guidelines:

Normally, two elements are considered when determining what is an acceptable level of sound:

1. How much is the “unwanted sound” level greater than the background level?
2. What do scientific studies suggest are the levels that “reasonable people of normal sensitivities” find acceptable?

-
1. Ambient Sound. As mentioned earlier, the only extraneous noise generating sources nearby are airports, so without having the actual ambient measurements, it would be expected that the level is about 45-50 dBA. Generally accepted practice would be to try to limit noise to within 5 dB of the background. This suggests a **goal of 50-55 dBA**.
 2. The Virginia Beach Noise Ordinance does not address impulse sounds like pickleball, which is not uncommon for municipalities. In the absence of regulations that are relevant to pickleball characteristics, we believe a valid “good neighbor” standard can be established using the ANSI S12.9 guidelines. At West Neck, that **guideline of 50-55 dBA** happens to coincide with the Ambient Sound goal.
 3. PSM Consulting LLC has experience with locations throughout the US and our conclusion is that residential neighborhoods have few complaints, when pickleball sound pressure levels are around 50 dBA, so we strive to design solutions that are near that goal.

VI. Pickleball Sound Mitigation Methods

Court Location

The most obvious way to reduce noise complaint issues with is to locate the courts away from those who may be inconvenienced. For existing pickleball installations this is not a solution, but for planning purposes for future courts, this is an important consideration.

Acoustical Barriers

Acoustical barriers block the direct path of sound that travels from a source to a receiver. Barriers must be massive enough to block sound that could pass through them. The minimum recommended weight for any barrier is 1 pound per square foot. The barrier must be solid with no holes, no gaps at the bottom, and no gaps between adjoining vertical panels. Any holes or openings will allow

sound to leak to the other side. Earth mounds and buildings can act 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. Often they are not massive and solid enough to block sound, so only a small amount of attenuation may be achieved without a dense planting of hedges.

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. The general guideline for a barrier is that lowest noise level will be measured with a receiver as close as possible to the highest possible barrier.

Recommended vendors for barrier walls are:

- DDS Acoustical Specialties, Westfield, MA, 413-248-8118
- 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/>

Noise barriers must weigh at least 1 pound per square foot to be effective. A contractor must be consulted to assure that fences 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 composites and surfaces are being used resulting in many different paddle types with different noise levels. Appendix A shows paddles tested in our laboratory in Pittsburgh that demonstrate better than average noise performance.

Recommended Balls

While many plastic balls are approved by USA Pickleball for recreational and tournament play, some balls produce slightly lower sound levels when struck with a paddle. The difference in sound levels among balls is much less than the difference among paddles (3 dB or less.) PSM has evaluated several commercially available pickleballs. Recommended balls with lower sound levels can be found in Appendix B.

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

Court Time

Restricting play time is the equivalent of an on-off switch for pickleball. If needed, change the available hours for play.

VII. Predicted Sound Levels

The color dB maps which follow show sound levels assuming these very hard pickleball strike parameters;

Frequency – 1200 Hz

Max source sound level – 108.4 dBA

Height of strike – 5 ft

Height of receiving point – 5 ft

Ground effect coefficient factor – 0.5

Pickleball hits come from different points on the courts, so there are four source points in the pickleball courts area, marked by crosses, (+ red means “off”, + black means “on”)

The white circles are receiving points with measurement numbers in dBA. At the condo buildings, one receiver is at a height of 1.5m (5 ft) the other is at 4.6m (15 ft).

With no sound barriers and the sound source point in the southeast corner of the pickleball courts



With no sound barriers and the sound source point in the northeast



With 12 ft barrier on the east fence and the sound source point in the southeast



Note the lower levels at homes across the pond to the southeast.

With 12 ft barrier on the east fence and the sound source point in the southwest



Note the levels go up at homes across the pond to the southeast, when playing is in the southwest court. It is because the sound bends around and goes over the barrier. Remember that sound perpendicular to the axis of play is reduced by 3-5 dB, so the levels are still below the 50 dBA goal.

With 12 ft barrier on the east fence and the sound source point in the northwest



When play is in this corner, the levels at the condo building go up, but they remain near the 50 dBA goal.

VIII. Conclusions and Recommendations

The primary objectives were to determine:

1. For the proposed location, will the sound propagating from pickleball play at these courts be annoying to residents and members at the community areas?
2. Will there be compliance with governmental regulations?
3. What sound mitigation options will be most effective?

Comments:

1. Based on the results from predictive modeling, **the sound pressure levels without mitigation will meet Virginia Beach Noise Ordinance limits.**
2. If The Villages at West Neck choose to adopt the “good neighbor” guidelines suggested by ANSI S12.9 and PSM Consulting LLC, **a barrier 12 ft high on the east fence is recommended.**
 - Install 1 pound/sq ft mass-loaded vinyl sound mitigation barrier panels on the east fence, at least 12 ft high, without gaps between panels or at the bottoms of the panels. The fences need to be constructed to hold the weight of these panels and withstand wind loads.
3. Additional options for reducing sound:
 - Add hedges 8-10 ft high around the courts, blocking line of sight to sound sensitive area.
 - Educate players and encourage the use of quiet rated paddles and balls.

IX. The Author's Credentials

Dale Van Scoyk is a graduate of Purdue University, awarded a BS degree in Electrical Engineering. He has MBA training from Arizona State University.

He has over 25 years experience with industrial equipment design and manufacturing. He has written white papers and delivered presentations for the Institute of Electrical & Electronic Engineers (IEEE) on electromagnetic noise measurement and suppression, as well as light wave spectrum analysis, perceived light pollution and LED light technology topics.

Dale is a resident of Bonita Springs, FL and a year-round pickleball competitor in Wisconsin and Florida. He is a USA Pickleball Certified Referee, an Ambassador and a PPR Certified Pickleball Instructor. He has worked with multiple municipalities in the U.S. on tennis court conversions for dual use pickleball courts in residential areas, where noise abatement techniques were required.

X. Disclaimer

The sound levels in this report are as measured or they are estimates of what levels should be expected. Actual levels will vary over time, and they are player and equipment dependent. Sound level is probabilistic, meaning that it has averages and other statistical characteristics including standard deviations and sound level probability distribution curves, but pickleball sound level has no exact single level.

This report makes no guarantee of performance of the sound mitigation methods described. In addition, it is not possible to determine what any person believes is an acceptable sound level. The measurements and estimates of background sound levels are also probabilistic in nature; these levels will vary from one neighborhood to another and from one measurement method to another over time.

Our recommendations for sound barrier types assume that the site will have proper structural support, designed by others. This should include an analysis of the wind loading limitations of fences and a plan to protect installed sound barriers from flood water.



The Pickleball Paddle Blue List

Quieter Pickleball Paddles

List updated: February 23, 2024

Introduction: The following paddles have been selected and qualified for ‘Blue List’ status through a testing procedure that uses a combination of metrics in addition to loudness (sound pressure). This includes measuring the ‘pitch’ and duration of the sound produced when a pickleball is struck by a paddle.

These metrics were selected after reviewing with players and non-players the characteristics of a typical pickleball hit including input from some who consider impulse sounds of this type to be annoying.

The resulting criteria were established by PSM LLC in 2022 as a means of recommending paddles to communities and pickleball clubs that are attempting to mitigate the sound of pickleball.

Test Procedure: PSM LLC is a pickleball acoustics consulting firm. We have built a tall (16 feet) echo free (or anechoic) ball drop chamber for testing pickleballs and paddles. A calibrated microphone is mounted in this chamber and a computer outside the chamber analyzes the microphone output using REW and Audacity software.

Criteria: The paddles listed have a sound pressure level (SPL) below that generated by a selected standard ½ inch thick fiberglass faced paddle, currently the Gamma 412 model. In addition, these paddles have their main spectral energy density below 900 Hz and a decay time of the primary vibration mode to less than 10% of its initial peak value of under 5 milliseconds. This ensures that there is no well defined “pitch” to the sound produced.

Using This List: PSM LLC updates the list as it tests and identifies additional paddles that meet the criteria.

Updating This List: To arrange additional paddle or pickleball testing, contact PSM LLC via email at bob@pickleballsound.com.

For an updated version of [The Blue List](#), see the PSM LLC website (pickleballsound.com) as well as the Pickleball Sound Mitigation Facebook group page. [The Pickleball Paddle Blue List](#) is copyright free.

Quieter Paddle Guidance: *Tests have shown paddles at least 16 mm thick with carbon fiber surfaces and deemed to be “Control” models by paddle suppliers are generally quieter and have a lower main pitch sound. There are numerous models now on the market that meet this criteria that PSM LLC has not tested and they are not on The Blue List.*

THE PICKLEBALL PADDLE BLUE LIST
PICKLEBALL SOUND MITIGATION LLC
www.pickleballsound.com

(paddles listed alphabetically by vendor name)

Paddle Vendor	Paddle Model Name	Notes
CRBN	1 & 2	
Diadem	Vice	1
Diadem	Warrior	
E6	16s	
Electrum	E Pro II	
Focus	Silencer	
Franklin	Pro Series 16 mm	
Gamma	Obsidian 16	
Gearbox	CX11, CX14, GX5 & GX6	
Joola	Ben Johns 16 mm, Radius	
Joola	Simone Jardim 16 mm	
Master Athletics	Q1	1
One More	Vibe	
One More	Pro Custom	
Owl Sport	Owl CX, CXE	
Pickleball Rocks	The Dude	
Pickleball Rocks	Pink Widow	
Pro Drive	DRIVE	
Pro Kennex	Pro Speed	
Pro Pickleball	Infinity Widebody 16 MM	
Selkirk	Amped Epic	
Selkirk	Vanguard Invikta	
TMPR	Tantrum and TC-16	
Versix	Pro XL	
Wild Monkeys	Grizzly	
Wowly	Surge XL	
Wolfe	Bite	

Note 1: Not USA Pickleball Approved

Somewhat Popular Quieter Balls: The Onix Fuse and Pure 2 outdoor models

The very quietest USA P tournament approved ball: The Monarch Outdoor ball by Dicks Sporting Goods

Appendix B –

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 only 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 recommended paddle and ball combination for lowest noise is the OWL Sport CX or CXE paddle and the Monarch Gen 2 Outdoor Ball. This combination can provide 10 dB noise reduction over the loudest paddles and loudest balls. Wildcat Run could provide this gear as the standard for pickleball play or simply to mandate its use by each player at the players' expense. The Owl Sport paddle is rated as a low noise paddle by USA Pickleball and was recently approved for tournament play.