BAP acoustics

August 30th, 2021

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AC2930: Noise Assessment and Guidelines for Outdoor Pickleball Courts in Vancouver Technical Report

Dear Nicole,

As requested, we have conducted a community noise assessment for outdoor pickleball (PB) courts within City of Vancouver parks. The assessment involved measuring PB noise levels at four City of Vancouver parks, comparing the measured PB noise levels to the City of Vancouver Noise Bylaw, and developing PB noise models to assist in the development of a planning guideline. This report presents the results of our assessment.

1 NOISE CRITERIA

The City of Vancouver Noise Control Bylaw No. 6555 (hereafter referred to as the "Noise Bylaw") restricts noise levels in Quiet Zones (i.e., residential zones) to 55dBA during the daytime (7:00 a.m. to 10:00 p.m.) at a relevant point of reception. For noise emitted from a park and received on a residential property, the point of reception would typically be the sidewalk adjacent to the property.

A logical design noise criterion for PB noise within the City of Vancouver would then be a 55 dBA limit at the nearest relevant point of reception. However, the impulsive nature of PB noise (i.e., racquet strikes, players yelling) tends to render it more objectionable than other types of community noise. In accordance with ISO 1996-1:2006, we recommend applying a +5dBA to the level of measured or predicted PB noise at the nearest points of reception to better account for the impulsive characteristics of PB noise. Under this approach, the design limit for PB noise would then be effectively reduced to 50 dBA.

2 MEASUREMENT DESCRIPTION

Noise surveys were carried out at the following parks:

- Queen Elizabeth Park (5:15 p.m.-6:30 p.m., June 9, 2021)
- Memorial West (5:15 p.m.-6:30 p.m., June 10, 2021)
- Pandora Park (12:00 p.m.-12:30 p.m., June 19, 2021)
- Cedar Cottage Park (10:45 a.m.-11:15 a.m., June 19, 2021)

While at least one PB court was active, we measured the resulting noise levels at the nearest residential properties and at a 15 m setback position. All measurements were performed at a height of approximately 1.7 meters above ground level using Type 1 sound level meters which meet the international standards of IEC 61672-1:2002. The sound level meters were calibrated before the measurements and checked afterwards.

2.1 Queen Elizabeth Park

At Queen Elizabeth Park, there are eight dedicated PB courts that were converted from tennis use. Seven of the PB courts are clustered at the northeast corner of the park (see attached Figure1). The eighth court is in the southeast. There is a concrete wall which runs along a section of the eastern edge of the northeast PB courts. Due to its location, this wall would not be influencing noise levels at the residences. The PB courts are elevated above the residences along Kersland Drive and 37th Avenue. As such, the intervening terrain provides some noise shielding to the residences.

2.2 Memorial West Park

At Memorial West Park, there are four shared PB/tennis courts at the northeast area tennis court. The intervening terrain between the courts and residences on West 31st avenue is flat.

2.3 Pandora Park

At Pandora Park, there are six shared PB/tennis courts at the two south tennis courts. The intervening terrain between the courts and residences on West 31st Avenue is flat.

2.4 Cedar Cottage Park

At Cedar Cottage Park there are two shared PB/tennis courts located in the basketball courts. The intervening terrain between the courts and residences on East 10th Avenue is flat.

3 MEASUREMENT RESULTS

Table 1 summarizes the results of the PB noise measurements in terms of the equivalent sound level (L_{eq}) measured at the residential properties and at the 15 m setback positions (Please refer to Appendix A for a definition of L_{eq} and other acoustical terminology). Figures 1 to 4 (attached) provide site plans for the four parks showing the layouts of the PB courts and locations of the noise measurements.

Table 1: Pickleball noise measurement results

Park	Measurement Location	Setback Distance (m)	# of Active Courts	Dominant Noise Source	L_{eq} (dBA)
Queen Elizabeth	East of courts (north)	15	7	PB	59
	East of courts (centre)	15	7	PB	52
	East of courts (south)	15	7	PB	56
	280 West 37th Avenue	69	7	Local road traffic, tennis	53
	5207 Kersland Drive	149	7	Local road traffic, tennis	54
Memorial West	East of courts	15	1	PB	53
	3749 West 31st Avenue	25	1	PB	51
Pandora	West of courts	15	1	PB	53
	2272 Franklin Street	19	2	PB	46
Cedar Cottage	South of courts	15	1	Clarke Road Traffic	57
	1324 East 10th Avenue	5	1	Clarke Road Traffic	59

The following sub-sections discuss the measurement results in more detail.

3.1 Queen Elizabeth Park

At the time of the measurements, the seven northeast PB courts were active. PB noise was not clearly audible at the residential measurement locations relative to other sources of community noise such as local road traffic and tennis. While the noise levels measured at the residential locations were dominated by noise from local traffic, they were lower than the 55 dBA Noise Bylaw limit. As such, it can be concluded that PB noise was in compliance with the Noise Bylaw.

3.2 Memorial West

At the time of the measurements, one of the four PB court was active. Noise levels at the residential measurement location were dominated by PB noise and were in compliance with the Noise Bylaw.

3.3 Pandora Park

At the time of the residential measurements, two of the six PB court were active. Noise levels at the residential measurement location were dominated by PB noise and were in compliance with the Noise Bylaw.

3.4 Cedar Cottage Park

At the time of the measurements, one of the two courts was active. Noise levels at the residential measurement location were dominated by Clarke Road traffic noise. As such, while overall noise levels were higher than the Noise Bylaw limit, it is unclear if PB noise was in exceedance.

4 NOISE MODEL

4.1 Description

We used Datakutisk's CadnaA software to create noise propagation models for the PB courts at each of the four parks. The software implements the outdoor sound propagation procedure presented in standard ISO 9613-2 for modelling noise emissions from industrial sources (i.e., point sources, line sources, and area sources) under meteorological conditions that are favorable to sound propagation (i.e., downwind noise receivers or temperature inversion).

The models were created using data collected from the noise measurements and from the City of Vancouver's GIS database. The models were then used to investigate the effectiveness of noise mitigation measures. In addition, we also developed a generalized PB court model to assist with development of the planning guidelines.

To establish a generalized sound emission level for a single PB court, we reviewed the sound data collected from the four parks. We were unable to use the data from Cedar Cottage Park due to the dominance of traffic noise at both measurement locations. Our analysis indicated that the sound power level of a single court varied from 91 to 92 dBA between the three parks with an average level of 91 dBA. The measurement results were then very consistent between the three parks.

To account for the distributed nature of pickle ball court noise (i.e., the potential for noise to be created at any position within the court), we modelled PB noise as an area source. In the model, PB noise is evenly distributed over the entire court area. We positioned the area source at a height of 1.5 m above the court. This height was chosen based on a conservative estimate of the median height at which PB noise would typically be produced (elevated sources then to produce higher noise levels, especially at greater setback distances).

The models consider the following factors which affect sound propagation:

- **Geometric divergence**: As sound waves travel away from their source; the wavefront increases in size and the acoustic energy becomes distributed over larger and larger areas. Consequently, the sound level decreases as the distance from the source increases.

- **Atmospheric absorption**: As sound propagates through the atmosphere, it loses energy losses due to molecular friction and relaxation processes. Atmospheric absorption primarily affects higher frequency sounds.

- **Ground effect**: Sound travelling over acoustically "soft" ground (e.g., grass, loose dirt) attenuates more rapidly than sound travelling over acoustically "hard" ground (e.g., pavement, water).

- **Reflections:** Surfaces can reflect sound and increase the resulting sound level at a point of reception.

- **Shielding:** Obstacles such as walls, screens, or earth berms placed between the sound source and sound receptor can "shield" the sound receptor and reduce the resulting sound level. In general, an obstacle or barrier that breaks the line-of-sight between the sound source and sound receptor will achieve a reduction of approximately 5 dBA.

These phenomena are described in more detail in Appendix A.

4.2 Model Results – Full-Capacity Noise levels

Since our measurements did not always reflect full capacity courts, or in other cases were contaminated by other source of community noise, we used the noise models to predict full-capacity PB noise levels for comparison with the Noise Bylaw. Table 2 presents the results of this modelling.

Table 2: Model results, full court capacity pickleball noise levels

Park	Number of Courts	Residential Property	Full-Capacity PB Noise Level
Queen Elizabeth	7	280 West 37th Avenue	44
Queen Elizabeth	8[1]	280 West 37th Avenue	50
Memorial West	4	3749 West 31st Avenue	57
Pandora	6	2272 Franklin Street	60
Cedar Cottage	2	1324 East 10th Avenue	59

Table Notes:

1. Includes the isolated pickleball court to the south of the main pickleball court area.

Our analysis indicates that there is a potential for bylaw non-compliance at three of the four parks.

4.3 Model Results – Mitigation

The most feasible approach to mitigating PB noise would be to construct noise barriers around the courts. While we understand there are "quiet" PB paddles and balls commercially available, we do not expect these would be a viable mitigation measure as they would be difficult to regulate. Since most PB courts are surrounded by chain-link fences, the noise screens could be constructed by attaching dense, solid sheets to the fences (e.g., Acoustifence). Alternatively, sound absorptive noise screens are also available but are significantly more expensive (e.g., Kinetics KBC).

For a noise barrier to be effective, it should have the following characteristics:

- Solid and to the extent possible free of gaps.
- A minimum height of 3 m.
- Constructed of a material with a minimum surface density of 5 kg/m^2.

To avoid impacts from reflected sound:

- Where three-sided barriers are used, the open side should face away from any residential receptors which are closer than the setback distances recommended in Tables 4 and 5 or a sound absorptive barrier should be used.
- Where dwellings overlook a pickleball court, sound absorptive barriers should be used if the setback distances recommended in Tables 4 and 5 cannot be maintained.

The noise models were used to evaluate the effectiveness of surrounding the courts with 3 m, sound-reflective screens. For each park, noise levels were then calculated at the nearest residential properties with and without the noise screens in place. Table 3 presents the results of this analysis including the insertion losses (i.e., reductions in pickleball sound levels) predicted for each of the screens.

Table 3: Model results, mitigation

Park	Number of Courts	Residential Property	PB Specific Noise Level L_{eq}(dBA)		Insertion Loss (dBA)
			No Screen	3 m Screen	
Queen Elizabeth	7	280 West 37th Avenue	44	40	4
Queen Elizabeth	8[1]	280 West 37th Avenue	50	41	9
Memorial West	4	3749 West 31st Avenue	57	48	9
Pandora	6	2272 Franklin Street	60	52	8
Cedar Cottage	2	1324 East 10th Avenue	59	52	7

Table Notes:

1. Includes the isolated pickleball court to the south of the main pickleball court area.

Table 3 shows that with a 3 m noise screen in place, PB noise levels are predicted to range from L_{eq} 40 to 52 dBA at the four parks. The variation in results between the parks are due to differences in setbacks, numbers of courts, court layouts, and the intervening terrain.

At the three parks where Noise Bylaw exceedances were predicted (Memorial West, Pandora, and Cedar Cottage), the introduction of the 3 m noise screen is predicted to reduce PB noise levels below the 55 dBA limit.

4.4 Model Results – Setback Investigation

We used the generalized PB noise model to investigate setback distances that would be required to meet the 55 dBA Noise Bylaw limit and the proposed 50 dBA design target. Results were generated for scenarios involving varying numbers of courts, varying ground surfaces, and with and without a 3m noise screen. To be conservative, we have assumed:

- Flat ground
- No attenuation due to foliage
- An average reduction of 5 dBA due to the introduction of a 3 m screen.

Tables 4 and 5 present the results of this analysis which can be used to assist in development of a planning guideline. Please note that the setback distances for the mitigated courts assume the point of reception is at most 2m above ground level. If the point of reception is elevated above the courts (i.e. multi-family building), the mitigation will not be effective.

Table 4: Model results, setback distances for 55 dBA

Number of Courts	Setback Distance required to meet 55 dBA (m)			
	No Noise Screen		3 m Noise Screen[1]	
	Hard Ground	Soft Ground	Hard Ground	Soft Ground
2 (1x2 grid)	35	30	20	15
4 (2x2 grid)	50	45	25	20
6 (2x3 grid)	55	50	30	25
9 (3x3 grid)	70	55	35	30

Table Notes:
1. Does not apply to situations where the point of reception overlooks the courts

Table 5: Model results, setback distances for 50 dBA

Number of Courts	Setback Distance required to meet 50 dBA (m)			
	No Noise Screen		3 m Noise Screen[1]	
	Hard Ground	Soft Ground	Hard Ground	Soft Ground
2 (1x2 grid)	65	50	35	30
4 (2x2 grid)	90	75	50	45
6 (2x3 grid)	105	85	55	50
9 (3x3 grid)	140	105	70	55

Table Notes:
1. Does not apply to situations where the point of reception overlooks the courts

We trust this has provided you with all the information you require at this time. Please let us know if you have any questions.

Sincerely,

Andrew Williamson, P.Eng.
Principal Consultant

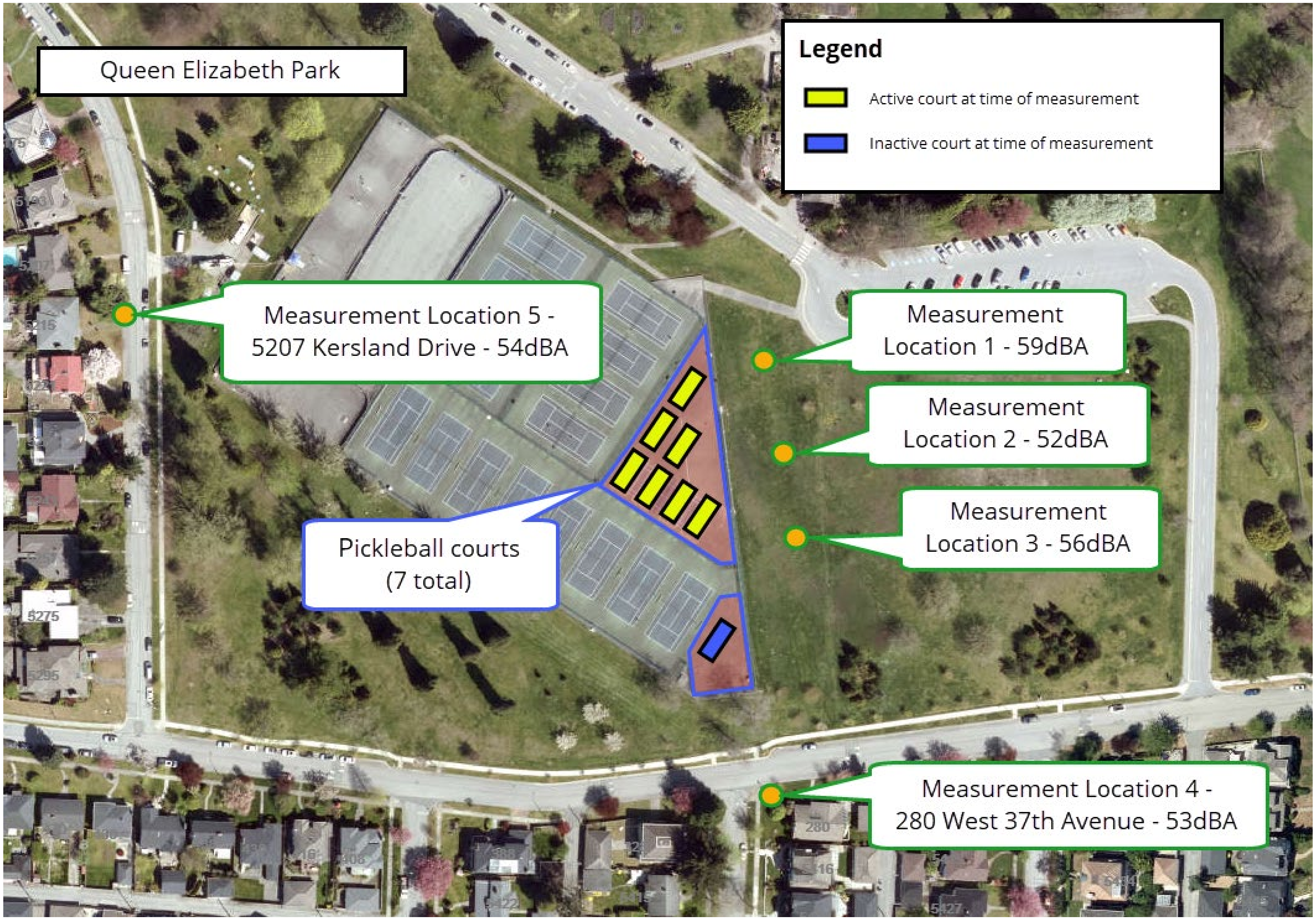

Figure 1: Queen Elizabeth Park Pickle Ball Courts and Measurement Locations

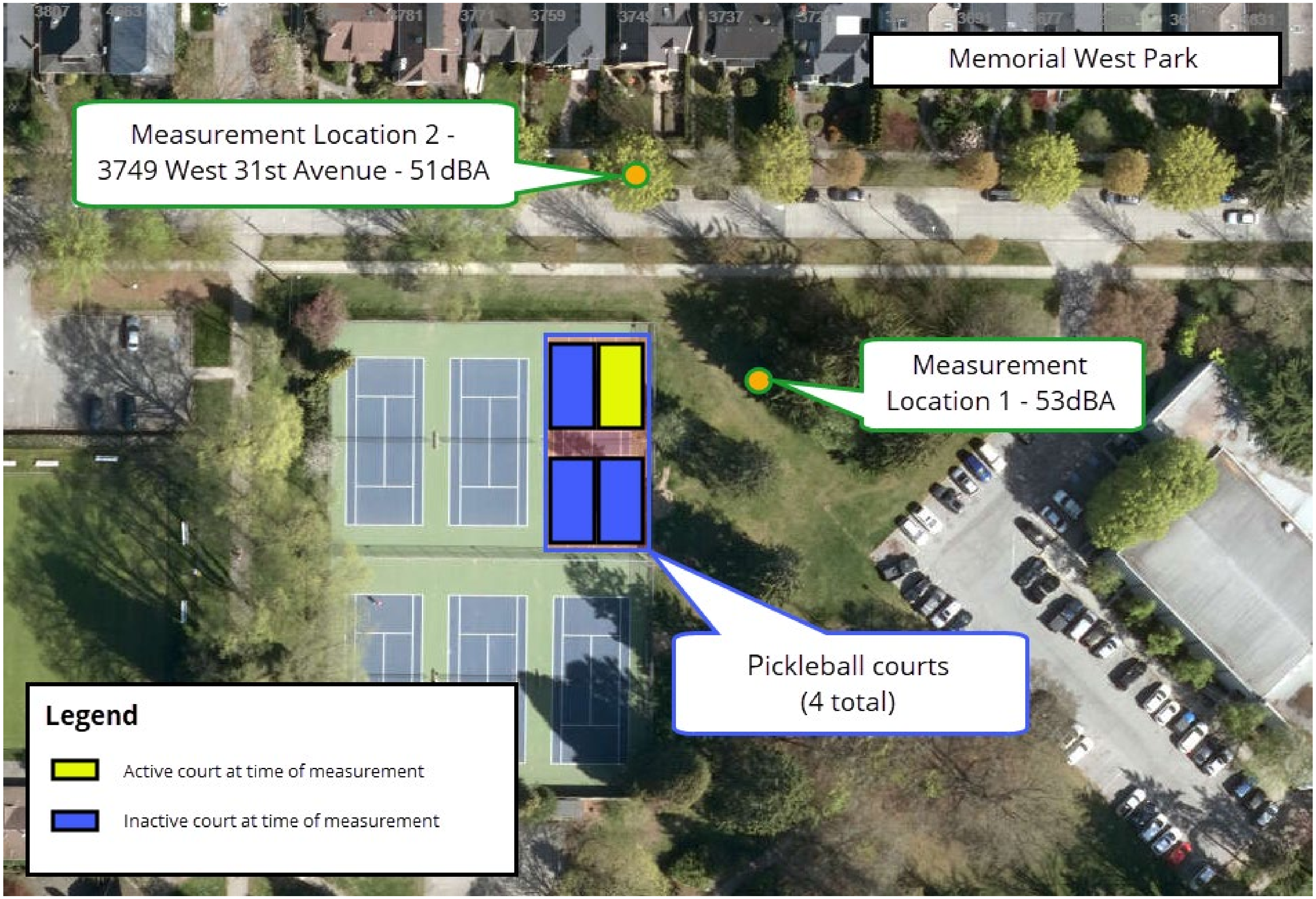

Figure 2: Memorial West Park Pickle Ball Courts and Measurement Locations

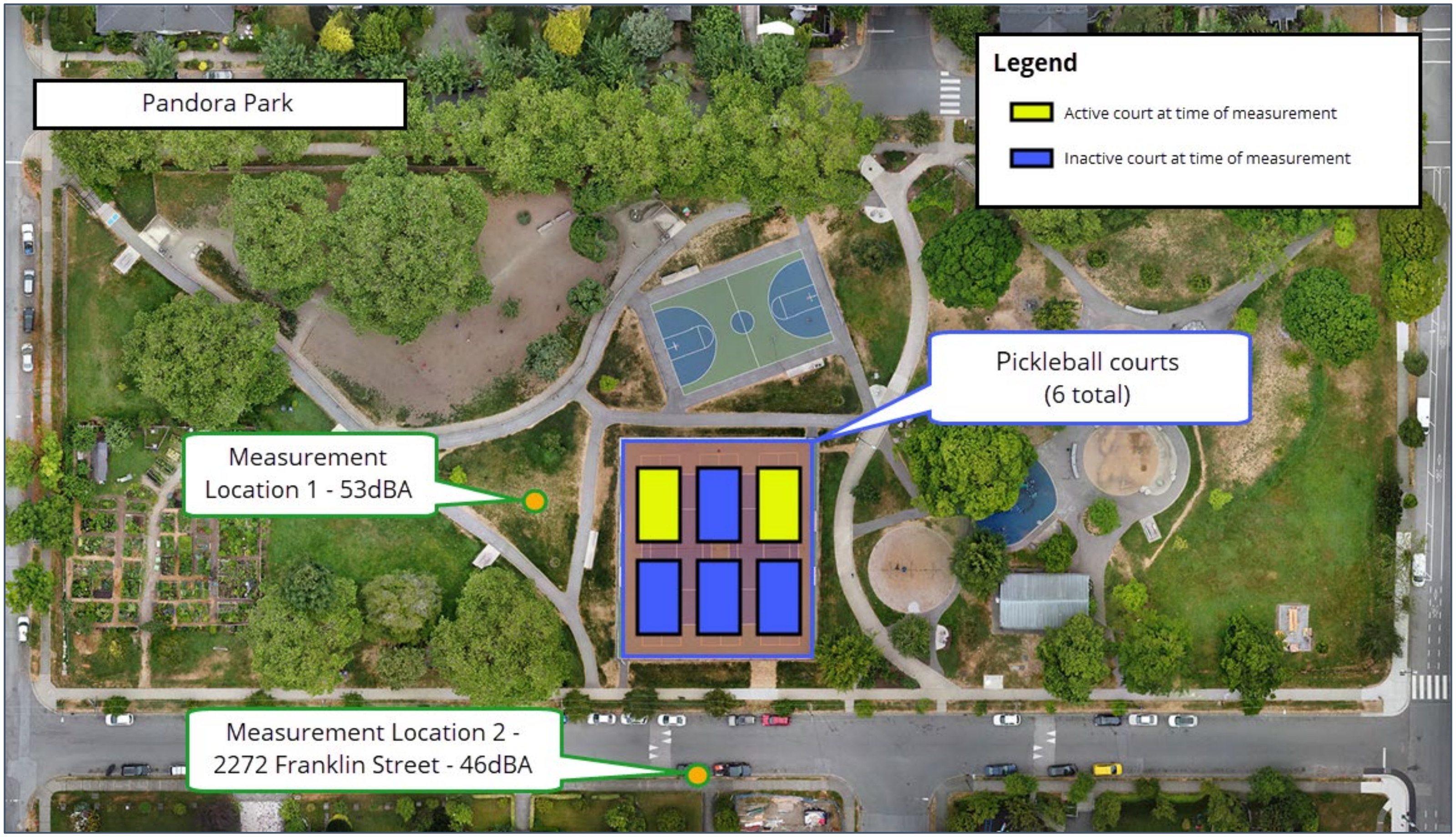

Figure 3: Pandora Park Pickle Ball Courts and Measurement Locations

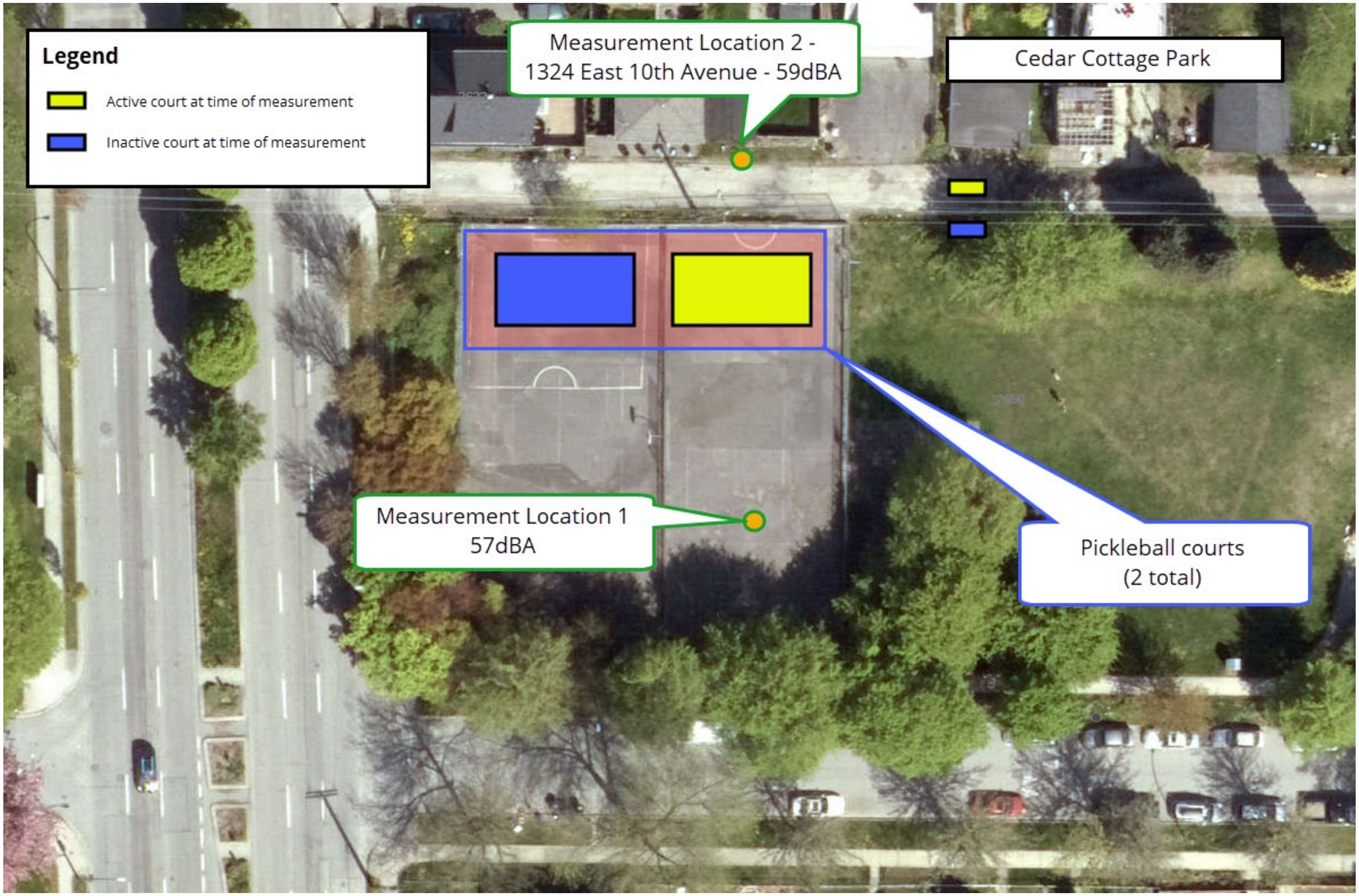

Figure 4: Cedar Cottage Park Pickle Ball Courts and Measurement Locations

APPENDIX A – BASIC ACOUSTICS

Basics of Sound

The phenomenon we perceive as sound results from fluctuations in air pressure close to our ears. These fluctuations result from vibrating objects, such as human vocal cords, loudspeakers and engines etc. Sound pressure is measured using the Pascal. The ratio of the quietest to the loudest sound that the human ear can hear is a billion to one. Therefore, sound pressure is commonly expressed using the logarithmic decibel (dB) unit. When sound pressure is expressed in decibels, it is called sound pressure level. The loudest sound pressure level we can hear without immediately damaging our hearing is 120dB and the faintest sound we can detect is 0dB.

Human sound perception depends on both the level and the frequency content of a given sound source. Frequency is defined as the number of times per second that pressure fluctuations occur. The frequency reflects the pitch of the sound. It is expressed in Hertz (Hz). The average young human listener can perceive sound frequencies from 20 Hz to 20,000 Hz. Human hearing is less sensitive to low frequency sound levels (below 200 Hz) and to high frequency sound levels (above 5000 Hz). The human ear is most “tuned” to the vocal frequency range between 200 Hz and 5000 Hz. For acoustic engineering purposes, the audible frequency range is normally divided up into discrete bands. The most commonly used bands are octave bands, in which the upper limiting frequency for any band is twice the lower limiting frequency, and one-third octave bands, which are the result of subdividing each octave band into three. The bands are described by their centre frequency value. The range that is typically used for environmental purposes is from 31 Hz to 8 kHz (octave bands).

Acoustic Metrics

A-weighting

The microphone of a sound level meter, unlike the human ear, is designed to be equally sensitive to sound throughout the audible frequency range. To compensate for this, the A-weighting filter of a sound level meter is used to approximate the frequency sensitivity of the human ear. As such, A-weighted sound pressure levels (dBA) give less emphasis to low and high frequencies, and are correspondingly tuned to the vocal frequency range between 200 Hz and 5000 Hz.

L_{Aeq}

The A-weighted equivalent continuous sound pressure level (L_{Aeq}) is the most common acoustic metric used to describe sound levels that vary over time. The L_{Aeq} is an energy average. It is calculated by storing and logarithmically averaging the sound of all events recorded during the measurement period. The L_{Aeq} can be measured over any time period.

L_d

The A-weighted equivalent continuous sound pressure level (L_{Aeq}) evaluated over the 15-hour time period between 07:00 to 22:00 hours.

L_n

The A-weighted equivalent continuous sound pressure level (L_{Aeq}) evaluated over the 9-hour time period between 22:00 to 07:00 hours.

L_{90}

The sound exceeded over 90% of the time during the measurement period. The L_{90} represents the background noise level measured between discrete noise events, such as car pass-bys.

Example: A quiet fan is running at a continuous level of 30dBA at a specific measurement location. During a 10-minute measurement period, there are 9 minutes of car pass-by events that exceed the sound level of the fan. The L_{90} of the measurement is 30dBA, because this level was exceeded for over 90% of the measurement duration.

Basics of Outdoor Sound Propagation

As sound waves propagate through the environment, energy is lost through geometrical divergence, atmospheric absorption, refraction in the atmosphere, ground effects and the screening of obstacles.

Geometrical Divergence

Sound intensity decreases with increasing distance from a sound source. Losses from geometrical divergence result from the spreading of the sound source energy over larger and larger areas as the distance between the original sound source and receiver position increases. Sound attenuation through geometrical divergence is nominally independent of frequency, weather and atmospheric absorption losses.

Atmospheric Absorption

Sound waves propagating through free air are attenuated through a combination of classical (heat conduction and shear viscosity) losses and molecular relaxation losses. At long outdoor propagation distances and for higher frequencies, attenuation due to atmospheric absorption is usually much greater than the attenuation due to geometrical divergence.

Refraction

The speed of sound relative to the ground is a function of temperature and wind velocity. Both temperature and wind velocity vary with height. Temperature and wind gradients therefore cause sound waves to propagate along curved paths. On a hot summer day, solar radiation heats the earth's surface resulting in warmer air near the ground. This condition is called a temperature lapse. It causes sound rays to curve upwards. An opposite condition, called a temperature inversion, results when air is cooler at the ground surface than at higher elevations. Sound paths curve downwards during such a condition.

Wind also causes sound waves to bend upwards or downwards. Sound will propagate upwind when a source is downwind of a receiver. Wind speeds increase with height and this leads to a negative sound speed gradient. Sound waves will bend upwards under this condition.

Ground Effect

The ground effect refers to the interference (destructive and constructive) between sound reflected off the ground surface and sound travelling directly between a source and receiver. Ground effect interference has the potential to both enhance and attenuate sound as it propagates through the outdoors. The ground effect is sensitive to the acoustical properties of the ground surface.

Screening

Intervening terrain and artificial barriers (such as buildings or noise barriers) can attenuate sound by interrupting its path to a receiver. Screening effects are most pronounced when the screening obstacle completely blocks line of sight from the receiver to the sound source.