Aircraft Noise Affecting the ThreeSixty at South Bay Community

HMMH Report No. 308270.003.001

December 2018

Prepared for:

Los Angeles World Airports
Environmental Programs Group - Noise Management
1 World Way
Los Angeles, CA 90045

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Executive Summary

This report is pursuant to a work item on the Los Angeles International Airport (LAX)/Community Noise Roundtable's Work Program. With concerns stretching back to 2015, the ThreeSixty at South Bay community has reported periods of louder aircraft noise from LAX. The community is approximately 1.1 miles south of LAX's southern boundary and accounts for approximately 2,000 residents in a gated resort-style residential area south of El Segundo Boulevard and west of Interstate 405 in Hawthorne, California. Los Angeles World Airports (LAWA) contracted with Harris Miller Miller & Hanson Inc. (HMMH), through Polytechnique Environmental Inc., to determine the cause(s) of the perceived increase in aircraft noise in the 360 Community and, if feasible, make noise reduction recommendations.

In this study, HMMH investigated and identified potential causes of perceived noisy periods in the past; conducted on-site noise and weather measurements with LAWA; collected daily noise observations from a community representative to further corroborate past periods of higher noise levels; and generated noise reduction recommendations, where applicable.

Analysis included comparing the community's documented noisy periods to LAX aircraft noise, aircraft operations and weather data from LAWA and the South Coast Air Quality Management District (SCAQMD). Nearly 2 months of continuous noise and weather data measured at and in coordination with the ThreeSixty community between March and May 2018 was also analyzed. From these analyses, we concluded:

Periods of increased noise levels at the ThreeSixty at South Bay community were highly correlated to regional temperature inversions and more frequent/stronger winds from the north and northwest, which is from LAX towards the community.

As the noise problem at the ThreeSixty community is primarily weather-related, and the source of the noise is from normal aircraft operations at LAX, there are no feasible recommendations that can be made at this time to mitigate weather-related noise issues as experienced at the ThreeSixty community.

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1 Introduction

Per the Los Angeles International Airport (LAX)/Community Noise Roundtable (Roundtable) Work Program[1], specifically Work Item A15 titled "Aircraft Noise Affecting 360 at South Bay Community", residents from ThreeSixty at South Bay (herein referred to as the '360 Community') reported that they experienced periodic prolonged stretches of loud noise from LAX aircraft operations beginning in November 2015 and continuing through October 2017. The residents generally reported loud noise in the evenings in the winter-spring months (November to April) for each year (360 Community 2017[2]). These prolonged stretches are referred to as 'past periods' in this report. In November 2017, the Roundtable's Hawthorne representative invited residents from the 360 Community to the Roundtable meeting to express their concerns about increased noise and requested Los Angeles World Airports (LAWA) conduct a study to determine the cause(s) of the perceived increase in aircraft noise and make noise reduction recommendations, if applicable.

Pursuant to Work Item A15, LAWA requested assistance from Harris Miller Miller & Hanson Inc. (HMMH), via prime contractor Polytechnique Environmental Inc., to investigate the aircraft noise issue at the 360 Community.

1.1 Report Organization

Sections 1.1 through 1.4 provide pertinent background information on the project. Section 2 describes the recent detailed noise measurements at the 360 Community in the March-May 2018 timeframe. Sections 3 through 6 provide the results of the study in terms of the effects of flight operations, winds, temperature inversions and other related factors, respectively. Section 7 provides overall conclusions for the study. Section 8 is the bibliography of references cited herein. Appendix A contains a thorough discussion of key terms and concepts relevant to this report, such as acoustics, the propagation of sound and airport operations. Appendices B and C provide additional data supporting the results presented in Sections 2 through 7. Appendix D contains the resident's daily noise log introduced in Section 2.

1.2 360 Community

As stated on their website[3], the 360 Community is a gated residential area with resort-style amenities located at the corner of El Segundo and Aviation Boulevards, 0.1 mile west of Interstate 405, in Hawthorne, California. Figure 1-1 depicts the location relative to LAX. The 360 Community homes range from single-story studio condominiums, to townhouses and 4-bedroom single-family homes. The ground elevation of the 360 Community is nearly the same as that of LAX, approximately 100 feet above Mean Sea Level (MSL), and tallest buildings rise to a height of four (4) stories. The 360 Community is comprised of approximately 610 residential dwelling units, built within the last 10 years, and nearly 2,000 residents. The 360 Community is approximately 1.1 miles from LAX's southern boundary and 1.6 miles south of LAX's Runway 25L.

[1] https://www.lawa.org/-/media/lawa-web/environment/files/noise-mgt/roundtable-work-program.ashx?la=en&hash=55D99044D76C693D380F16BBCFE7659A36D95C38

[2] This is how references are cited in this report. See the References section (section 8) for the bibliographical information.

[3] http://threesixtyhomes.com

1.3 LAWA's Noise Monitoring Terminals for LAX

LAWA's permanent Noise Monitoring Terminals (NMT) at LAX are also shown in Figure 1-1. NMTs named DEL1, LNX1, ESG2, ESG5 and DEL1 were identified to be of interest for the study due to their location relative to the 360 Community. DEL1 is approximately halfway between the 360 Community and LAX in the Del Aire community. LNX1 is located under the arrival flight path to Runways 25L/R in the Lennox community. ESG2 is located in the northwestern portion of the City of El Segundo. ESG5 is the easternmost NMT in El Segundo approximately equidistant to LAX's southern boundary as DEL1. ESG5's noise levels are primarily affected by departures from Runways 25L/R but are also affected by the reverse thrust of arrivals to Runways 25L/R. Each NMT consists of a microphone and windscreen mounted on a pole approximately 25 feet from the ground. Most NMTs are located on public property in the parkways next to the sidewalks of residential streets.

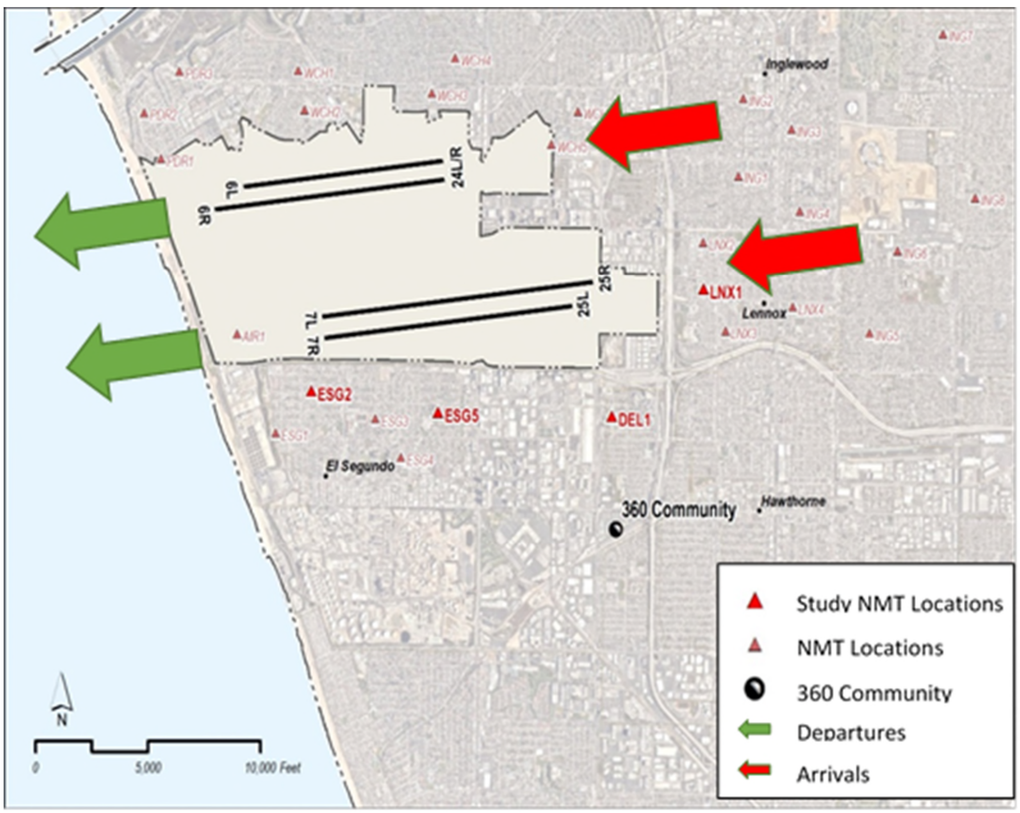

Figure 1-1. Map showing the location of LAX and 360 Community, direction of typical air traffic flow and nearby noise monitors.

The 360 Community is a little over a mile south of LAX. LAWA has several permanent noise monitors in the vicinity.

1.4 LAX Runway Layout and Typical Operational Flows

As shown in Figure 1-1, LAX has two pairs of runways called runway complexes. The northern complex consists of Runways 06L/24R and 06R/24L. The southern complex consists of Runways 07L/25R and 07R/25L.

As described in more detail in Appendix A, LAX has three operational flows named by the direction of aircraft operations, i.e., west, over-ocean and east. Westerly flow, where aircraft approach and depart

LAX to the west on Runway ends 24L, 24R, 25L and 25R, is typical at LAX between 6:30 a.m. and midnight. After midnight, the typical flow is over-ocean operations, which has aircraft departing west over the Pacific Ocean and arriving from the west over the ocean for noise abatement purposes. These two typical operational flows result in the majority of aircraft departing west, independent of the time of day. In East flow, which occurs during relatively rare times when there are strong winds coming from the east, aircraft approach and depart LAX to the east on Runways 07L, 07R, 06L and/or 06R.

1.5 Scope of Study

The scope of the study was to perform the following functions:

1. Investigate and identify conditions during 'noisy' and 'not noisy' periods in the past as reported by the 360 Community, the so-called 'past periods'
2. Collect on-site noise and weather measurements, and observations from the 360 Community for further investigation and identification of possible cause(s) of noisier versus quieter periods
3. Generate conclusions/recommendations per the study's objective

Regarding past periods, the 360 Community reported atypically noisier periods in the winter months, i.e., November 2015 to March 2016 and November 2016 to April 2017. They reported more noise in the evening/nighttime hours, i.e., 4 p.m. - 1 a.m. time period seemingly associated with departures from LAX. Although the 360 Community reported the May-October 2017 period as being a 'lull' in noise, they identified specific days in each of these months where they believed the noise was "excessive." For example, in October 2017, the 360 Community identified the following 13 days as having excessive noise: 5, 7, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26, and 27 (360 Community 2017).

The investigative analysis sought to determine whether correlations exist between the excessive noise periods, operational changes, if any, and/or weather patterns. The analysis consisted of the examination of noise data, LAX operational data and weather data.

There are many ways to examine noise data. In this study, noise data analysis was based primarily on daily aircraft Community Noise Equivalent Level (CNEL) from the relevant LAWA NMTs and from a temporary portable NMT deployed in the 360 Community, (see section 2). Other metrics examined include hourly Equivalent Sound Levels ($L_{eq(h)}$) [upon which CNEL is based] and, to investigate more of the low-frequency component of aircraft noise, C-weighted L_{eq} for individual events. CNEL is a noise metric required by the State of California to measure cumulative noise exposure and is calculated with weighted evening (7 p.m. to 10 p.m.) and nighttime (10 p.m. to 7 a.m.) hourly measurements. The evening and nighttime weightings account for people's higher sensitivity to noise during those hours. The aforementioned noise metrics are fully described in Appendix A.

Operational data for the study consisted primarily of numbers of flight operations on Runways 25L/R. Secondary data were airport operational flow and runway closure logs. Flight operations from the other more distant runways were considered to be not as critical to the noise situation at the 360 Community and were not analyzed.

Besides flight operations, engine maintenance run-ups were also considered for this study. Run-up operations are static engine-focused operations at various locations on the airfield. The term "run-up" is derived from the engine's throttle being cycled or temporarily advanced for purposes of engine testing or maintenance. Run-ups at LAX typically occur between the north and south runway complexes for short durations. Therefore, it is unlikely run-ups are the cause of the increased noise levels over extended periods at the 360 Community.

Weather data analyzed consisted of temperature, relative humidity, wind direction and speed [from a National Oceanic and Atmospheric Administration (NOAA) weather station based at LAX and a portable weather station at the 360 Community - see section 2], and temperature inversion data from the South Coast Air Quality Management District (SCAQMD). All of these weather parameters play an important role in the propagation of sound, as detailed in Appendix A.

2 Measurements at the 360 Community

LAWA, with HMMH oversight, collected noise measurement data at the 360 Community between March 2018 and May 2018 using a portable noise monitor. The 360 Community Homeowners Association selected a resident volunteer, who was previously involved in reporting noise comments to LAX along with other residents, to note the days and times he perceived as noisier when he was home. His location was also convenient because the portable monitors were set up on his roof. HMMH analyzed the collected data.

Sections 2.1 through 2.3 describe the site, instrumentation/set-up and background information on the measurements, respectively.

2.1 Noise Measurement Site

The noise and weather measurements were collected from the rooftop of a condominium (5440 Strand Avenue) situated in the 360 Community. Figure 2-1 is a photograph showing the placement of the noise and weather monitoring equipment. The location was approximately 350 feet south of El Segundo Boulevard, at an elevation of approximately 140 ft MSL. The microphone with a windscreen was elevated from the rooftop by 5 feet with a tripod. The microphone was approximately 45 feet from the air conditioning units to the southeast. The closest unit belonged to the resident of 5440 Strand Avenue who stated the residents rarely use air conditioning in the March-May period. Although operation of the air conditioners could have occurred during the measurements, the data from the portable noise monitor was downloaded into the LAX ANOMS noise monitoring system that has the ability to distinguish between aircraft and non-aircraft noise sources.

Figure 2-1. Photograph of Instrumentation Set-up (Sound Level Meter (left) and Weather Station (right)) at 360 Community, March 16, 2018, facing north towards LAX

Best practices for field measurements were followed in setting up the portable noise monitor. The location afforded good line-of-sight between the microphone and the airport/aircraft operations at LAX; there was minimal potential for disturbance/corruption by normal activities within the 360 Community or by reflecting surfaces (minimum 5' separation from the ground was exceeded with the microphone and tripod assembly).

2.2 Instrumentation and Set-up

Unattended outdoor long-term sound level measurements of sound levels were conducted with a precision-grade (Type 1) Sound Level Meter (SLM). The SLM continuously recorded 1-second A-weighted Equivalent Sound Levels (L_{eq}). The systems calibration was field checked at the beginning and end of the measurement period with an acoustical calibrator. [4]

A portable weather station was set-up within 10 feet of the SLM to simultaneously record/store 15-minute average values of: air temperature, relative humidity, atmospheric pressure, wind speed and direction. A listing of the pertinent measurement instrumentation and a copy of the SLM calibration certificate are contained in Appendix B.

The equipment was occasionally checked for functionality. Except for several days of missed weather data explained in the following section, the equipment experienced no malfunctions.

2.3 Measurements and Logging

The system was initially set up on Friday, March 16, 2018 and full-day outdoor noise levels were continuously measured starting on Saturday, March 17, 2018 through Sunday, May 13, 2018. During the site's installation and occasional system checks, notable noise sources at this site primarily included road traffic from El Segundo Boulevard and Interstate 405. Noise level and weather data were continuously uploaded from the SLM to LAWA's Aircraft Noise Operations and Monitoring System (ANOMS).

Due to malfunction, weather data from the 360 Community site was not available for the first 5 days of the measurement period, i.e., March 17 through March 21, 2018. Also, there were 7 days in April and May for which the temperature sensor provided faulty readings and was not consistent with temperature data from LAWA's on-airport temperature sensor.

The 360 Community resident, who was selected by the HOA and volunteered to log events that he deemed as being 'excessively noisy' throughout the measurement period, owns the condominium below the measurement site. HMMH provided the resident a logging sheet to record date, start time, stop time and a comment field. The resident was able to log events during the measurement period (March through May, 2018) mostly on weekdays, between 4 p.m. and 7 a.m., and during weekends when at home. The resident's log is Appendix C.

[4] The accuracy of the acoustical calibrator is maintained through a program established by the manufacturer in accordance with the National Institute of Standards and Technology.

The resident devised the following scale to rate the noisiness of audible aircraft operations:

- "1" for 'loud'
- "2" for 'excessively loud'
- "3" for 'extremely loud'

The resident also sometimes noted hours or partial hours of relative quiet which we assigned a "0" value. The resident logged his start and end times and rated the noise during these times.

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3 Effects of the Number of Aircraft Operations on Noise Levels

In general, if aircraft flight operations increase, then cumulative noise levels, such as CNEL, will increase. A rule of thumb is that CNEL increases by 3 dB with every doubling of flight operations (assuming all other factors, except doubling of operations, remain the same).

Sections 3.1 through 3.3 address the changes in operations and noise levels during the following periods, as reported by the 360 Community in an undated memorandum to the Roundtable and as measured on site:

- November 2015 through October 2017 (Section 3.1)
- May 2017 through October 2017 period, daily observations (Section 3.2)
- March 2018 through May 2018, daily on-site measurements (section 3.3)

3.1 Operations during Noisy and Quiet Days Reported by the 360 Community

In an undated memorandum provided to the Roundtable, the 360 Community commented upon the noisiness of the airport beginning in November 2015 and continuing to late 2017 (when the memorandum was received). Figure 3-1 shows the four past periods mentioned by the 360 Community, along with the overall CNEL due to aircraft[5] at DEL1 and the average daily number of flight operations[6] on the south complex (Runways 25L/R). DEL1 was chosen from the set of relevant NMTs due to its proximity to the 360 Community and the start of takeoff roll by departing aircraft on these runways. Operations on the north complex and over-ocean operations were not evaluated due to the greater distance separating the 360 Community from aircraft movements associated with those operations.

The 360 Community residents reported the November 2015 through March 2016 period being '*noisy 50 percent of the time'*. They said the noise '*subsided'* in April 2016 through October 2016. They said the noise '*returned with a vengeance*' in the November 2016 through April 2017 period. Lastly, the residents reported there being a '*lull*' in the noise, in general, in the May 2017 through October 2017 period but they identified certain days as being '*noisy*' (360 Community 2017). The (5-7 month) aircraft CNELs at DEL1 followed the trends reported by the 360 Community, i.e., the CNEL decreased from the previous period by 2.5 decibels (dB) when the noise reportedly 'subsided', increased by 4 dB during the next period when the noise 'returned with a vengeance' and decreased by 5 dB during the 'lull' period of May 2017-October 2017. While noise measurements at DEL1 correlated with the perception of noise reported by the 360 Community, operations at LAX (on Runways 25L and 25R) followed an opposite and seemingly counterintuitive trend. Average daily aircraft operations increased by 73 (7%) when noise "subsided" between April 2016 through October 2016, decreased by 137 (13%) when the noise

[5] LAWA's Aircraft Noise and Operations Monitoring System (ANOMS) identifies noise events as being due to aircraft based on analysis of radar flight tracking data, correlating an event to a flight track, if the event's Maximum Sound Level occurred when the track was within an allowed distance. The aircraft CNEL and aircraft Leq cited herein include all aircraft, i.e., aircraft associated with LAX and aircraft not associated with LAX (e.g., news/traffic-reporting helicopter hovering near a noise monitoring terminal, or traffic from Hawthorne airport).
[6] For the purposes of this study, a flight operation can be an arrival or a departure.

"returned with a vengeance" between November 2016 through April 2017, and increased by 60 daily operations (7%) during the 'lull' of May 2017-October 2017.

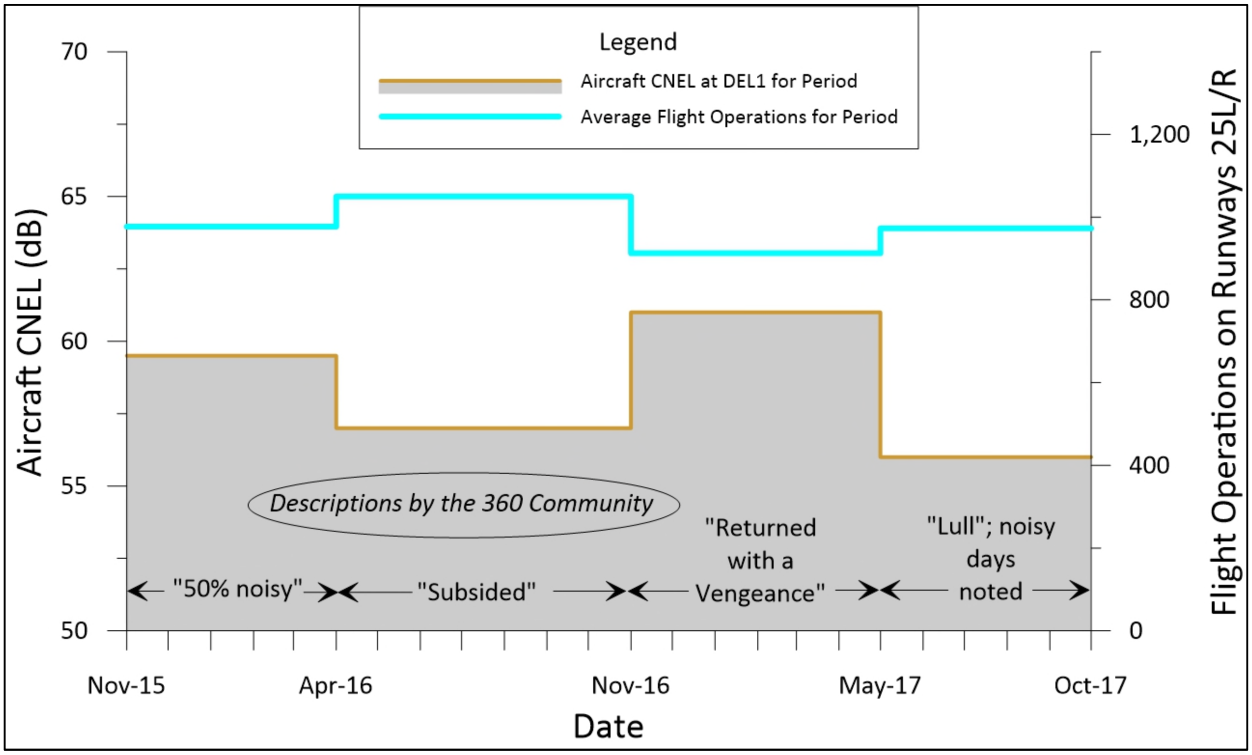

Figure 3-1. Comparison of Average Aircraft Noise Levels (CNEL) and Runway 25L/R Operations (Summary of Trends during Past Periods)

Source: 360 Community 2017; LAWA 2018b; HMMH

Seasonal increases and decreases in measured aircraft noise levels at DEL1 agreed with residents' observations but trended oppositely to aircraft departures and arrivals on runways 25L and 25R.

3.2 Operations during 360 Community-Reported Noisy Days during "Lull"

Figure 3-2 shows daily information for the May 2017 through October 2017 period when the residents noted 'noisy' days (shown as red diamonds in the figure).[7] ESG5 was added to the figure to give perspective and credence to the levels at DEL1. The gold and cyan colored arrows at the left and right sides of the graph depict the averages throughout the measurement period – 56 dB overall CNEL at DEL1 and 973 average daily flight operations, respectively. As mentioned above, the residents called this period a 'lull' compared to the previous period (November 2016 through April 2017). Most of the peaks in the daily aircraft CNEL time history for DEL1 and ESG5 correspond to the noisy days lending credence to the residents' observations with measured noise levels while operational numbers remained relatively flat. See Appendix B for plots of the other periods.

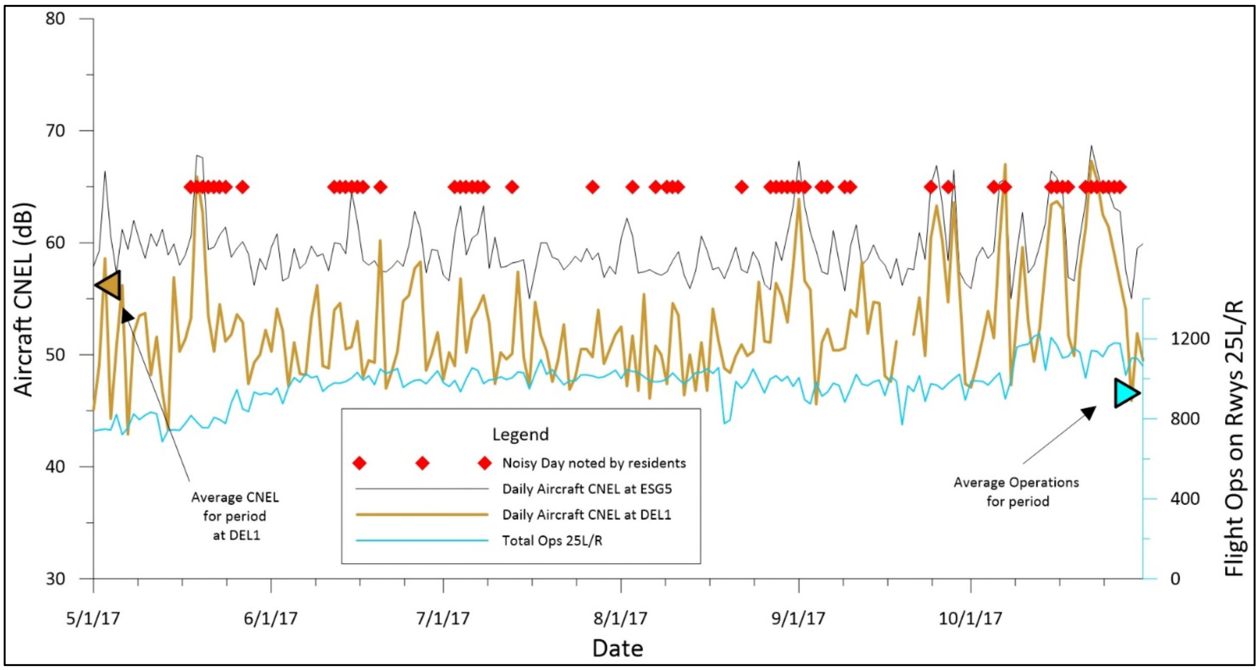

Figure 3-2. Comparison of Daily Aircraft Noise Levels (CNEL) and Runway 25L/R Operations May 2017 through October 2017

Daily aircraft noise measured at monitors was often correlated with resident's observations of noise but was not correlated with the number of daily flight operations.

[7] In their undated memorandum, the 360 Community only called out 'noisy' days for the May-October 2017 period.

To better summarize the daily data shown in Figure 3-2, an aggregate graph of the reported noisy days with the corresponding average CNELs from DEL1 is provided in Figure 3-3 to further illustrate the correlation between NMT CNELs and perception of noise in the 360 Community. The overall aircraft CNELs at DEL1 during days that the 360 Community perceived as 'noisy' and those they did not perceive as 'noisy' over the 6-month period were 59 dB and 53 dB, respectively. The average daily operations of the aggregate noisy and not-noisy days show very little change (987 and 967 operations during the noisy days and not-noisy days, respectively) which further supports the conclusion that operations do not play a role in the perceived and measured noise in the 360 Community. The minor increase in flight operations does not seem to be the cause of the 6 dB increase in overall CNELs. This analysis from daily values further supports the conclusions drawn from the "zoomed-out" analysis in Section 3.1. Daily noise measurements track well with the perceived noisiness in the 360 Community but the number of arrivals and departures on the south runway complex do not increase or decrease to the degree that would noticeably influence the noise levels in the 360 Community.

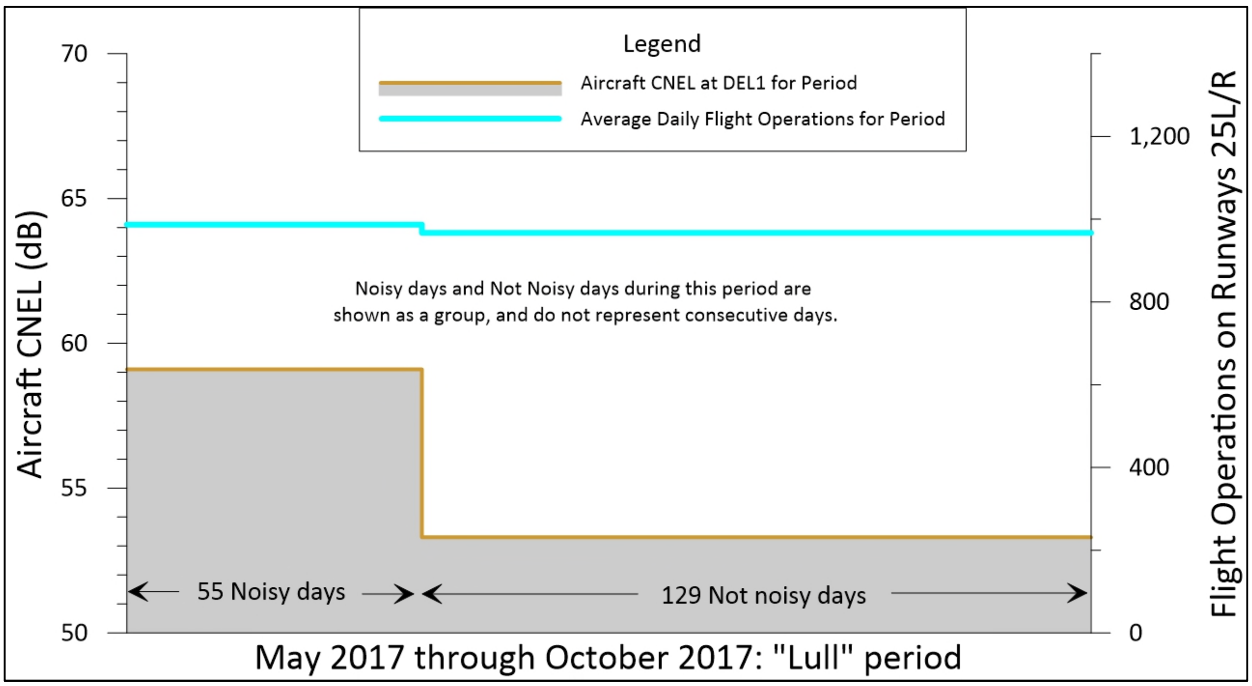

Figure 3-3. Comparison of Average Aircraft CNEL and Relevant Flight Operations for 'Noisy' and 'Not Noisy' Days May 2017 through October 2017

Aircraft noise levels measured at DEL1 during perceived 'noisy' days were greater than aircraft noise during 'not noisy' days, but the negligible difference in flight operations (987 and 967, respectively) does not explain the difference in aircraft noise.

Prior to the on-site measurements, October 2017 was the most recent period mentioned by the 360 Community in their memorandum to the Roundtable. Focusing on October 2017 for the moment (in Figure 3-2), average daily flight operations on Runways 25L/R were 15% greater in October than average daily flight operations for other months in the May-October 2017 period. The increase in October was caused by the closure of Runway 06L/24R which was fully closed for 23 days of the month (for an asphalt overlay project and maintenance[8]). The closure of Runway 06L/24R may have affected the 360 Community because the average number of noisy days per month increased from 8 for the May-September period to 13 in the month of October and average daily aircraft CNEL at DEL1 increased by 0.7 dB for the 23 closure days compared to the 8 non-closed days. See Appendix B for plots of runway closure.

3.3 Operations during On-site Measurements (with Resident Volunteer Logging of Noise Observations)

As in Section 3.2, Figure 3-4 provides an aggregate graph of the logged noise observations from the community volunteer with the corresponding average CNELs from noise measurements made in the 360 Community. The overall aircraft CNEL at the 360 site during days that the 360 resident perceived as 'loud', 'excessively loud' or 'extremely loud'[9] was 49 dB while the 'relatively quiet'-logged days[10] had an overall aircraft CNEL of 47 dB. Average daily flight operations during these two sets of days were nearly identical (770-780[11]). The minor increase in operations does seem to cause the 2 dB increase in overall CNELs.

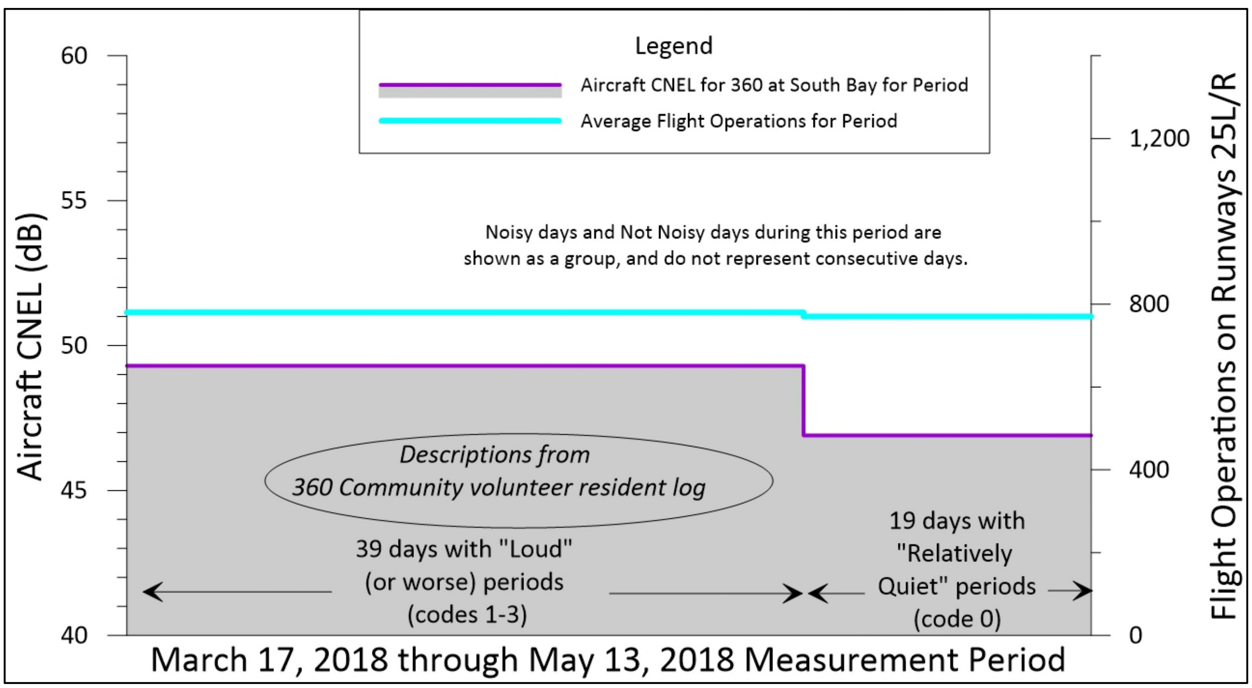

Figure 3-4. Comparison of On-site Aircraft Noise Measurements (CNEL) and Runway 25L/R Operations for 'Loud' and Quieter Days during the 2018 Measurement Period

[8] Runways are routinely closed for maintenance and sometimes for other circumstances. When runway closures are necessary, they usually occur between 12:30 a.m. and 6:30 a.m., when traffic is lightest. Whole runway complexes are seldom closed.

[9] Days dominated by periods with logging codes 1 through 3

[10] Days dominated by periods with logging code 0

[11] Daily flight operations on Runway 07L/25R typically average in the 900s but this runway was closed during the entire measurement period causing a 15-20% decrease; it was closed since January 2018. See Appendix B for plots of runway closure.

Aircraft noise levels measured at the 360 Community during 'loud' periods was greater than aircraft noise during 'relatively quiet' days but the difference in average flight operations does not explain the difference in aircraft noise.

Recall from section 2.3 the resident volunteer coded his perceived loudness as codes 1, 2 or 3 and we assigned code 0 to periods the resident volunteer described as 'relatively quiet'. Figure 3-5 shows:

- Noise codes (red diamonds for code 3, pink diamonds for code 2, gray dots for code 1 and green dots for code 0). Note the noise code pertains to times of each day, not one value per day. In other words, some days have more than one noise code associated with them.
- Daily average CNELs from the portable NMT measurements made at the 360 Community (purple line) from March through May 2018
- Daily average CNELs from DEL1 (gold line)
- Daily flight operations on the south runway complex (cyan line)

The gold and purple colored arrows depict the averages throughout the measurement period – 57 dB overall CNEL at DEL1, 47 dB overall CNEL at the 360 site, respectively, and 777 average daily flight operations depicted by the cyan colored arrow.

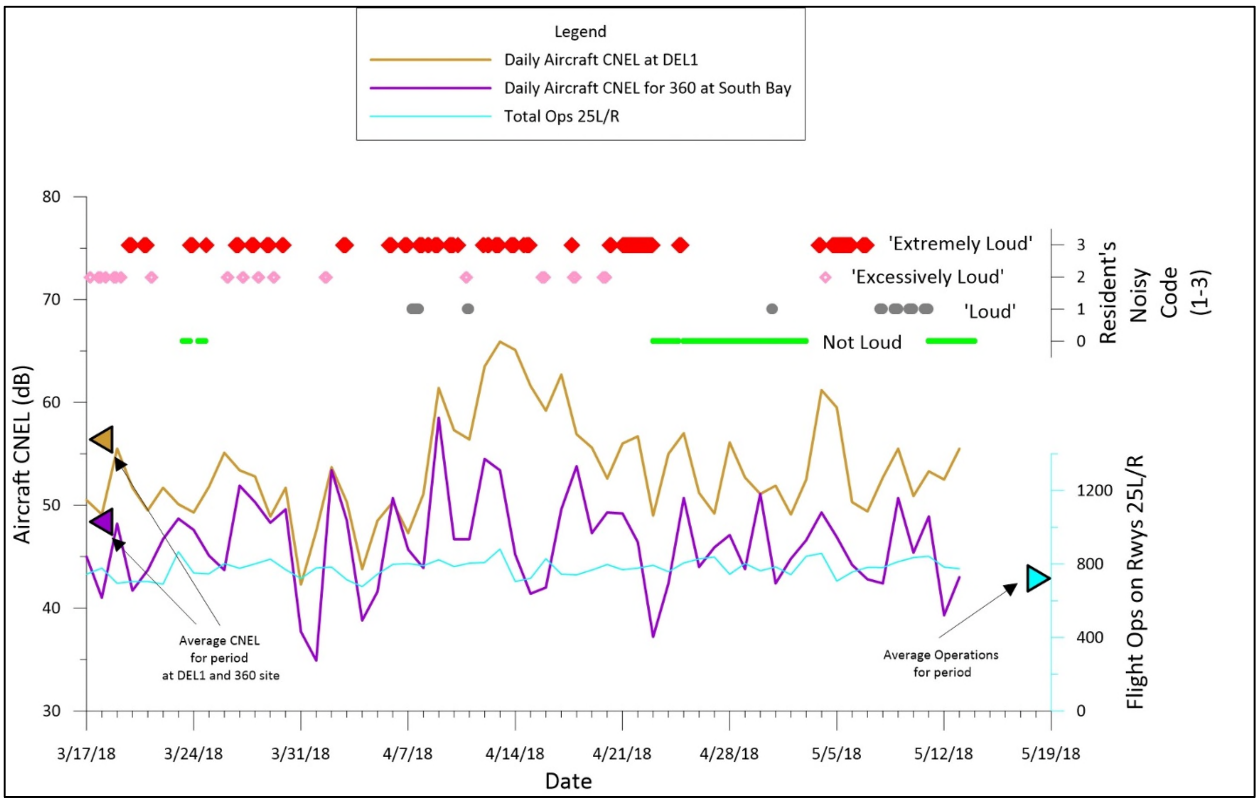

Figure 3-5. Comparison of Noise Observations (Resident Logging), Noise Measurements (CNEL), and Runway 25L/R Operations for the Measurement Period

Daily aircraft noise at the 360 site and at DEL1 correlated with resident's observation periods but not with daily flight operations. Daily aircraft noise correlated between DEL1 and the 360 site.

Figure 3-5 reveals the highest CNELs measured at the 360 Community and at DEL1 again correlate well[12] with the perceived/logged noisiness by the resident volunteer. Operations were relatively flat throughout and do not account for differences in noise measurements and observations during the 'loud' and 'relatively quiet' days, consistent with previous findings from "past" periods in Sections 3.1 and 3.2.

[12] Correlation coefficient of 0.5. A correlation coefficient of +1 indicates the strongest possible agreement and -1 the strongest possible disagreement.

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4 Contribution of Wind to Noise Levels

As described in Appendix A (section A.2.1.5), winds refract sound. For a receiver downwind from a noise source, wind refracts the sound downward, increasing its ability to propagate to the receiver, increasing its magnitude, relative to a no-wind condition. For a receiver upwind from a noise source, wind refracts sound upward, decreasing its ability to propagate to the receiver, decreasing or even shielding its magnitude, relative to a no-wind condition.

Due to the geographic location of the 360 Community, winds from the east, southeast and south put the 360 Community upwind from noise from LAX and tend to reduce noise exposure. These winds are favorable to the 360 Community. Winds from the west, northwest and north puts the 360 Community downwind from LAX noise and tend to increase noise exposure and are unfavorable to the 360 Community.

Hourly winds recorded at LAX's on-airport wind sensor and 15-minute winds recorded at the 360 Community were analyzed. For summarizing purposes, winds were deemed 'normal westerly' if their direction was between 240 and 280 degrees.[13] Winds were deemed 'favorable' to the 360 Community if their direction was from the east or south, i.e., between 60 and 230 degrees. Figure 4-1 depicts the wind terminology. Winds from the east and east-southeast reduce the aircraft noise at the 360 Community because the wind blows the aircraft noise (from LAX) away from that neighborhood. All other wind directions were deemed 'unfavorable' to the 360 Community. Wind speeds less than 3 miles per hour (mph) were not considered because winds at those low speeds play a minimal role in the propagation of sound.

Sections 4.1 and 4.2 discuss the effects of winds during October 2017 and the on-site measurement period, respectively.

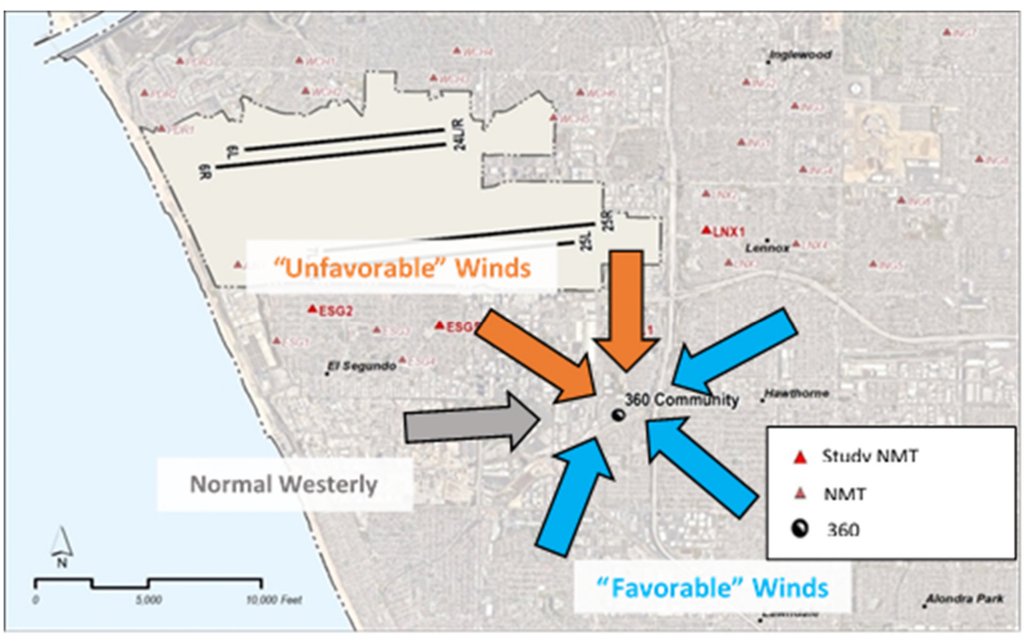

Figure 4-1. Wind Directions at 360 Community (favorable/unfavorable/normal westerly)

[13] All wind directions are relative to true north.

4.1 Winds during Noisy and Quiet Periods Reported by the 360 Community

Figure 4-2 summarizes the wind analysis for October 2017 and shows that wind direction and average speed contribute to noise from LAX at the 360 Community. Comparing the left and right pie charts and excluding the normal westerly winds, the quieter or 'not noisy' days reported by the 360 Community residents in their memorandum had 7% more favorable wind conditions than on 'noisy' days. Not only were more favorable winds on the 'not noisy' days, but the (favorable) winds were slightly stronger on the 'not noisy' days – the average (favorable) wind speed was 1.2 mph greater on the 'not noisy' days.

The 'noisy' days had 9% more unfavorable winds than 'not noisy' days. Not only were there more unfavorable winds on the 'noisy' days, but the winds were slightly stronger on the 'noisy' days -- the average (unfavorable) wind speed was 1.1 mph greater on the 'noisy' days.

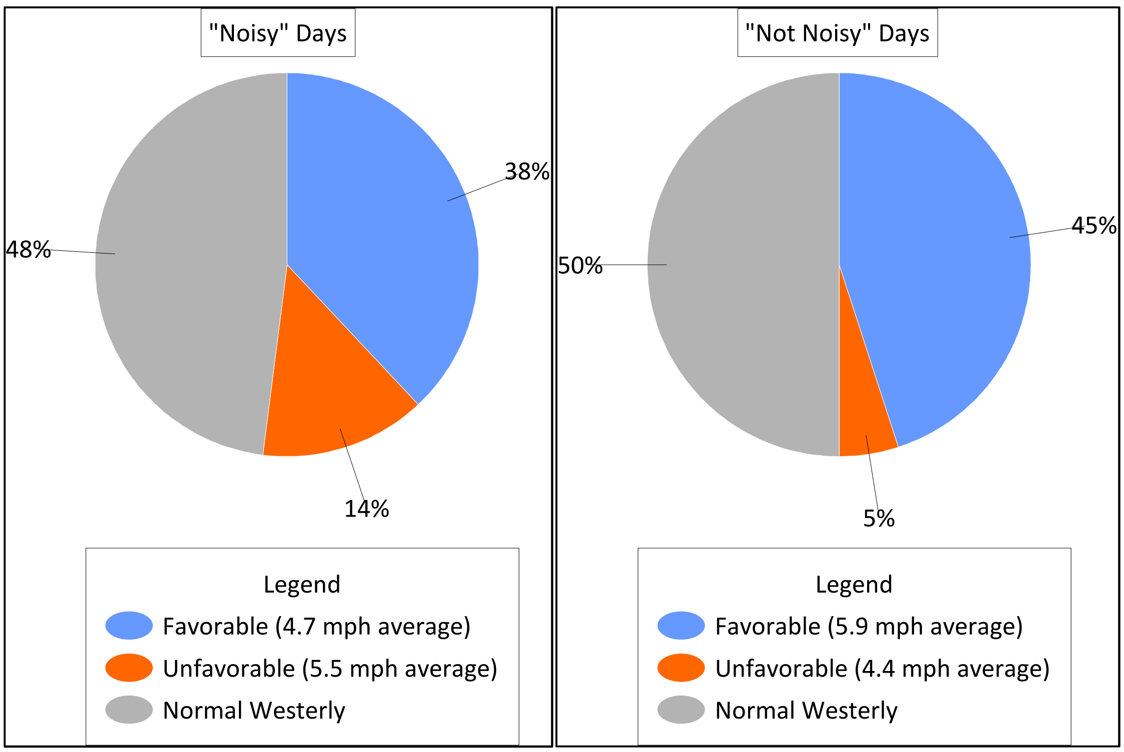

Figure 4-2. Distribution of Wind Directions (favorable/unfavorable/normal westerly) at LAX on Days Reported by the 360 Community as "Noisy" (left) and "Not Noisy" (right) during October 2017

"Noisy" days had more and stronger unfavorable winds than "not noisy" days.

4.2 Winds during On-site Measurements (with Resident Volunteer Logging of Noise Observations)

Figure 4-3 summarizes the wind analysis for the March-May 2018 on-site measurement period which had similar trends as the October 2017 analysis of the previous figure. The periods logged as 'relatively quiet' or 'nothing' by the 360 resident had 13% more favorable winds (with an average speed 0.3 mph greater) than during 'loud' periods.

The 'loud' periods had 5% more unfavorable winds (with an average speed 1.7 mph greater) than the 'relatively quiet' periods. Again, the quiet periods had more frequent and (slightly) stronger favorable winds, propagating LAX aircraft noise away from the Community than during the 'loud' periods. Conversely, the loud periods had more frequent unfavorable winds with higher average speeds (0.7 mph) to propagate more of the noise from LAX to the 360 Community than during other conditions.

Appendix B contains additional details of the analysis.

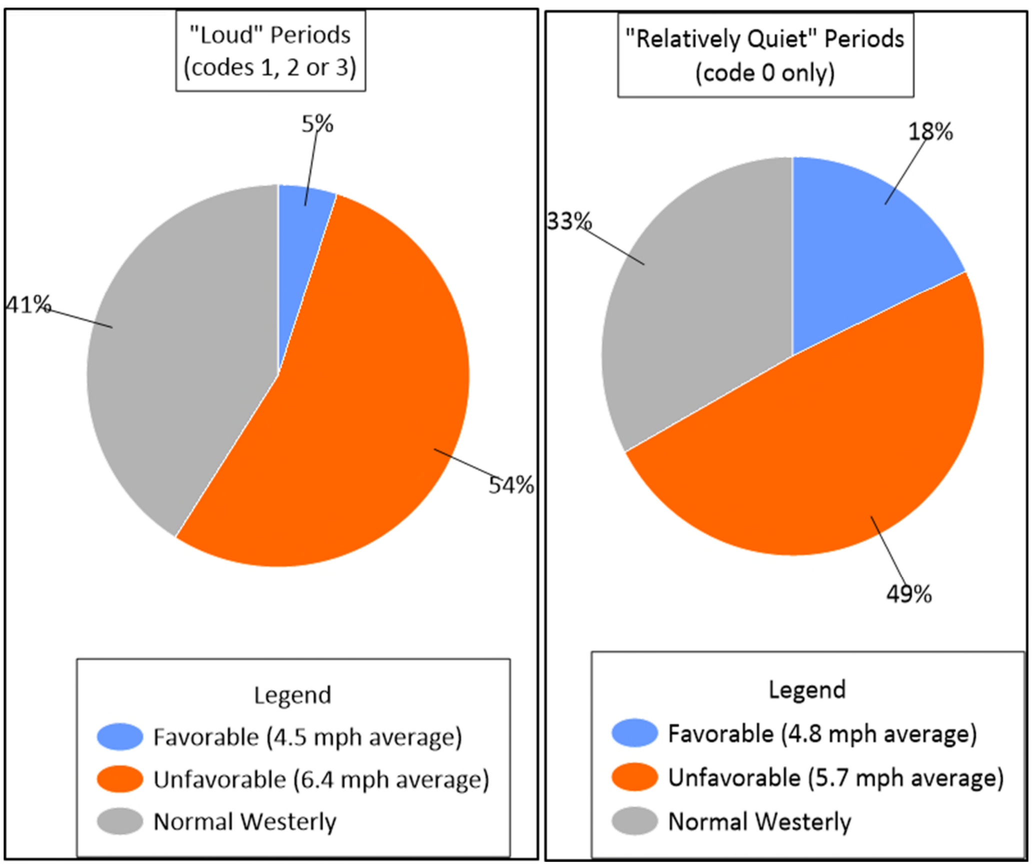

Figure 4-3. Distribution of Wind Directions for the Measurement Period (March 22, 2018 – May 13, 2018) at the 360 Community for Periods Logged by the 360 Resident as Varying Degrees of 'loud' (left) and 'relatively quiet' (right)

Loud periods had more and stronger unfavorable winds than quiet periods.

The resident's log included three occurrences where sudden and substantial changes were noticed, i.e., times he initially logged as quiet immediately followed by a log of it being suddenly noisier. One such occurrence was on Friday March 23rd. As shown in Figure 4-4, the resident logged most of the day as being "relatively quiet" (we assigned code 0 to that period), but starting at 7 p.m.(1900 in 24-hour format), he logged the noise as being "outrageously loud" and gave it code 3. During the first hour of the noticeable change in noisiness (at 7 p.m.) there was only a 3% increase in hourly flight operations compared to the prior hour. There is unexplained variability in the hourly sound levels at DEL1 and the 360 site. Appendix B shows similar plots for two other logged occurrences from the resident volunteer; it can be concluded that a contributing factor for two of the three sudden changes in description of the noise environment was the shift to unfavorable wind directions and increased wind speed.

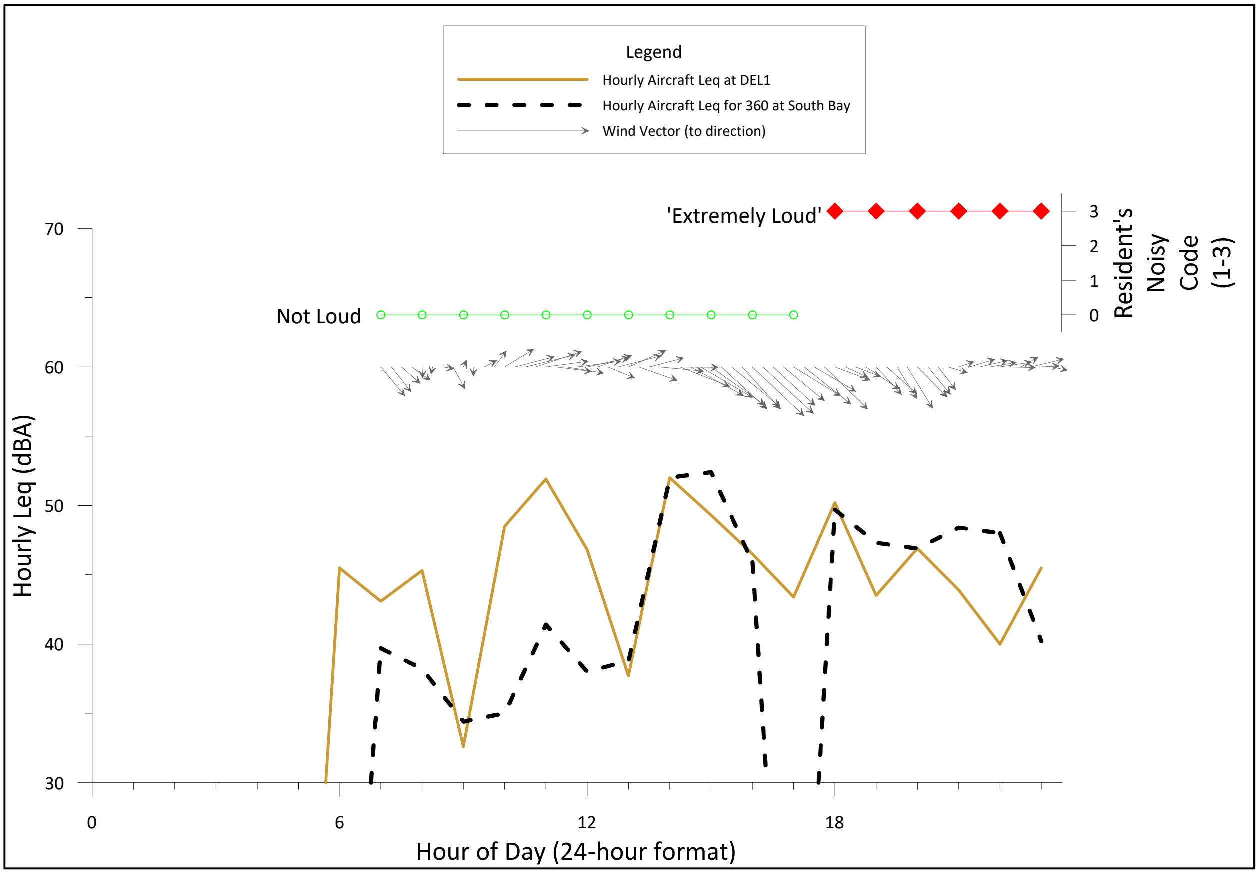

Figure 4-4. Hourly Aircraft L_{eq}, Flight Operations and Winds for Sudden Change on Friday, March 23, 2018

The reported 'extremely loud' period began approximately 2 hours after winds had shifted to an unfavorable direction and had grown in strength whereas operations had not increased. No correlation to hourly L_{eq}.

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5 Effects of Temperature Inversions on Noise Propagation

The speed of sound in the atmosphere is directly proportional to air temperature (i.e. sound travels faster at higher temperatures than at lower temperatures). Under normal atmospheric conditions, air temperature decreases with increasing altitude. Therefore, sound speed also decreases with altitude, causing sound to be refracted (or bent) upward into the atmosphere and away from the community, as shown in Figure 5-1.

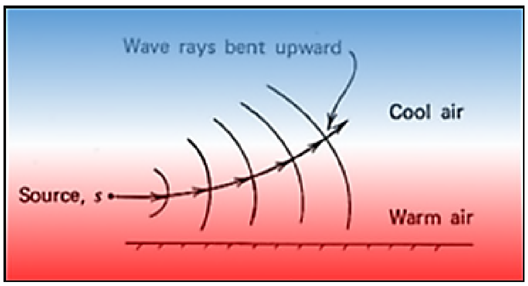

Figure 5-1. Refraction of Sound Waves in Atmosphere Under Normal Atmospheric Conditions

Source: Cuniff 1977

Noise is bent upward away from the ground in a standard atmosphere where temperature decreases with increasing altitude.

Under certain meteorological conditions, a "temperature inversion" develops where air temperature *increases* with altitude instead of decreasing with altitude. Temperature inversions cause sound to refract downward toward the ground instead of upward into the atmosphere, as shown in Figure 5-2. Temperature inversions are most common in the evening, at night, and early in the morning. Fall and winter seasons generally have the longest lasting and most days with temperature inversions.

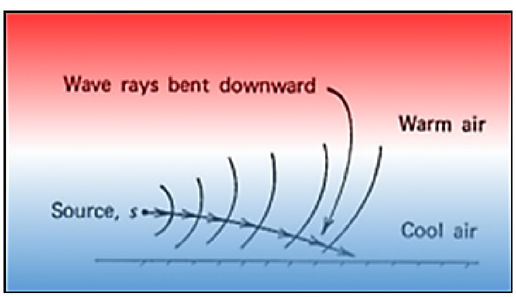

Figure 5-2. Refraction of Sound Waves Back to Ground during Temperature Inversions

Source: Cuniff 1977

Noise is bent downward toward the ground in an atmosphere where temperature increases with increasing altitude.

The altitude at which the temperature inversion begins is called the Inversion Base Altitude. Generally speaking, the base altitude is where the dissipation of sound up into the atmosphere stops and is instead refracted back down towards the ground. The downward refraction caused by temperature inversions also often allows sound rays with originally upward-sloping paths to bypass obstructions and ground effects, increasing noise levels at greater distances. For example, if the inversion base altitude is at 1,000 ft MSL, noise from an aircraft will follow the "normal" upward path potentially over buildings and trees but will bend back down into the community starting at the 1,000 ft altitude (instead of dissipating up into the atmosphere as it would under "normal" conditions). Daily Inversion Base Altitudes for the Southern California basin used in the analysis for the May-October 2017 past period and the April-May 2018 on-site measurement period in Sections 5.1 and 5.2 were obtained from the SCAQMD. See Appendix A, Section A.2.1.4 for a more comprehensive discussion of temperature inversion effects.

5.1 Inversion Base Altitudes and Air Temperature on 360 Community-Reported Noisy Days during "Lull"

Figure 5-3 focuses again on the individual noisy days during the past "Lull" period in noise reported by the 360 Community between May and October 2017. For each day during this period, the inversion base altitudes from SCAQMD and the daily average temperature (dashed black line) from NOAA's weather station at LAX were graphed. In the figure, the inversion base altitude is shown in solid blue with the numbering on the vertical axis reversed (i.e., it reads from low to high going down the page) to make the graph more readable. Also shown on Figure 5-3 is the daily aircraft CNEL at NMT DEL1 (gold line). From the figure, it can be seen that the inversion base altitude is generally much lower and the air temperature is higher on many of the individual 'noisy' days during the "Lull" period.

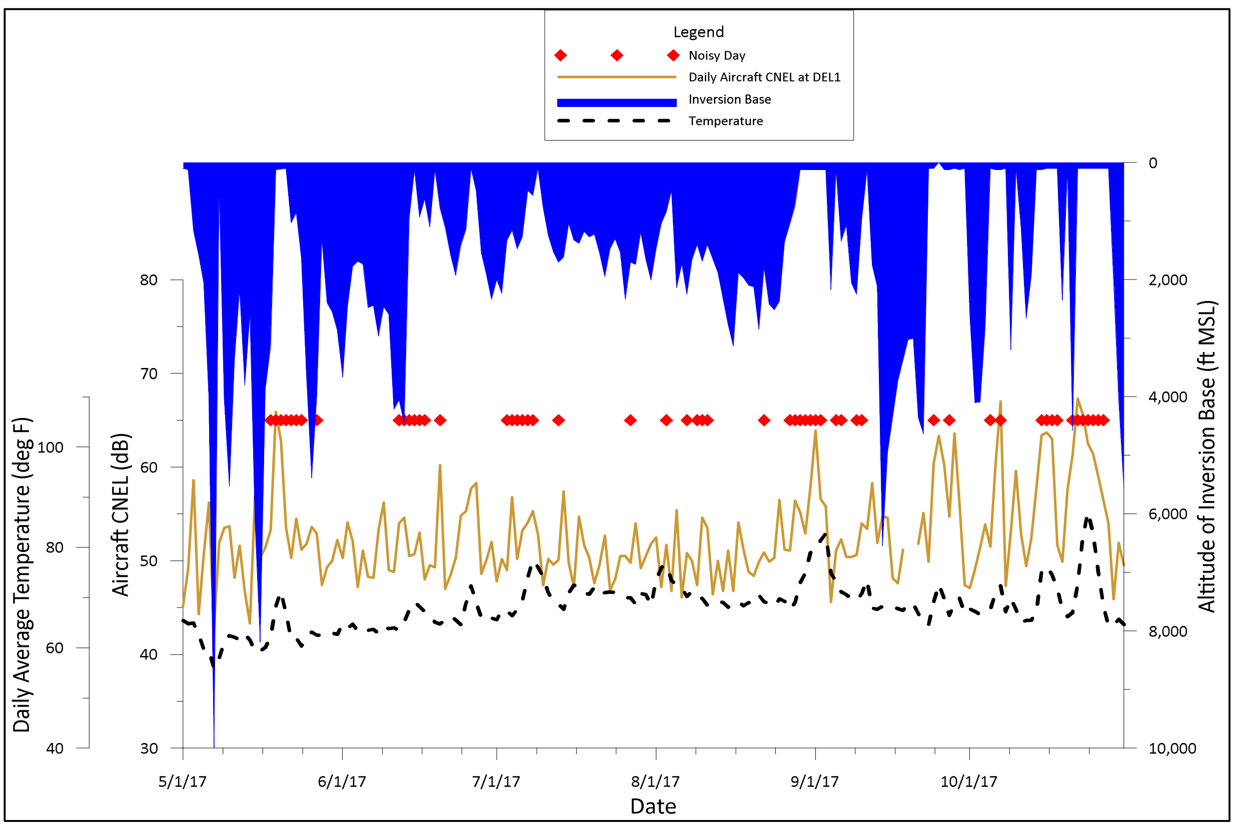

Figure 5-3. Comparison of Noise Observations, Aircraft Noise Measurements, and Weather May 2017 through October 2017

Temperature inversions were nearly twice as low (altitude-wise) on 'noisy' days as on 'not noisy' days.

Figure 5-4 presents a "zoomed in" view of the same chart for just October 2017 for a clearer view of the findings. On all but one of the reported noisy days, the inversion base altitude was just a few hundred feet from the ground and air temperature was generally higher.

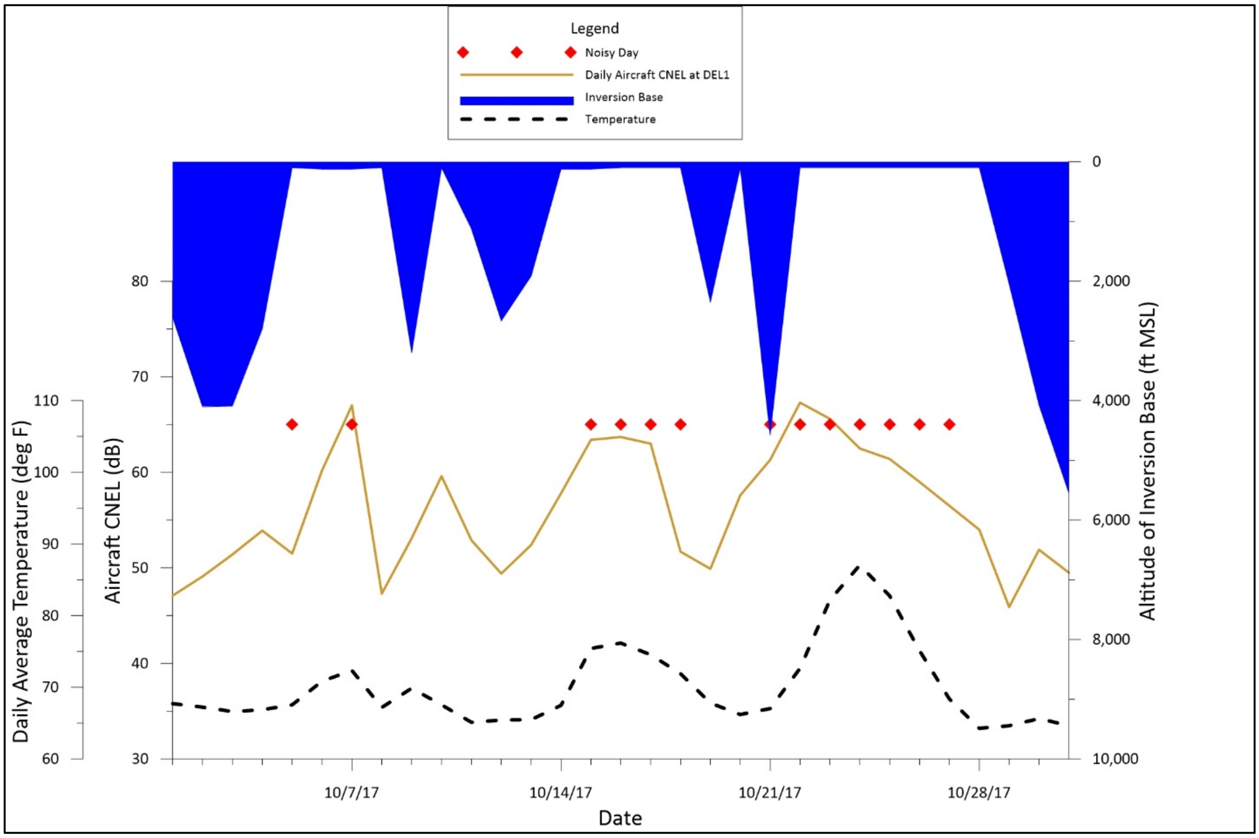

Figure 5-4. Daily Aircraft CNEL, Temperature and Inversion Base Altitude for October 2017

On days with low inversions (most 'noisy days'), the aircraft CNEL and air temperature were higher.

To better summarize the daily data during the "Lull" period, an aggregate graph of the reported noisy days with the corresponding average inversion base altitude and average CNEL from DEL1 is provided in Figure 5-5. As shown, the average inversion base altitude was over a thousand feet lower, and the daily aircraft CNEL at DEL1 was more than 5 dB higher on the 55 reportedly 'noisy' days. In layman's terms, more noise from LAX is refracted back to the community when lower inversion base layers exist. On the "not noisy" days, noise dissipated into the atmosphere more readily due to the higher inversion base altitudes.

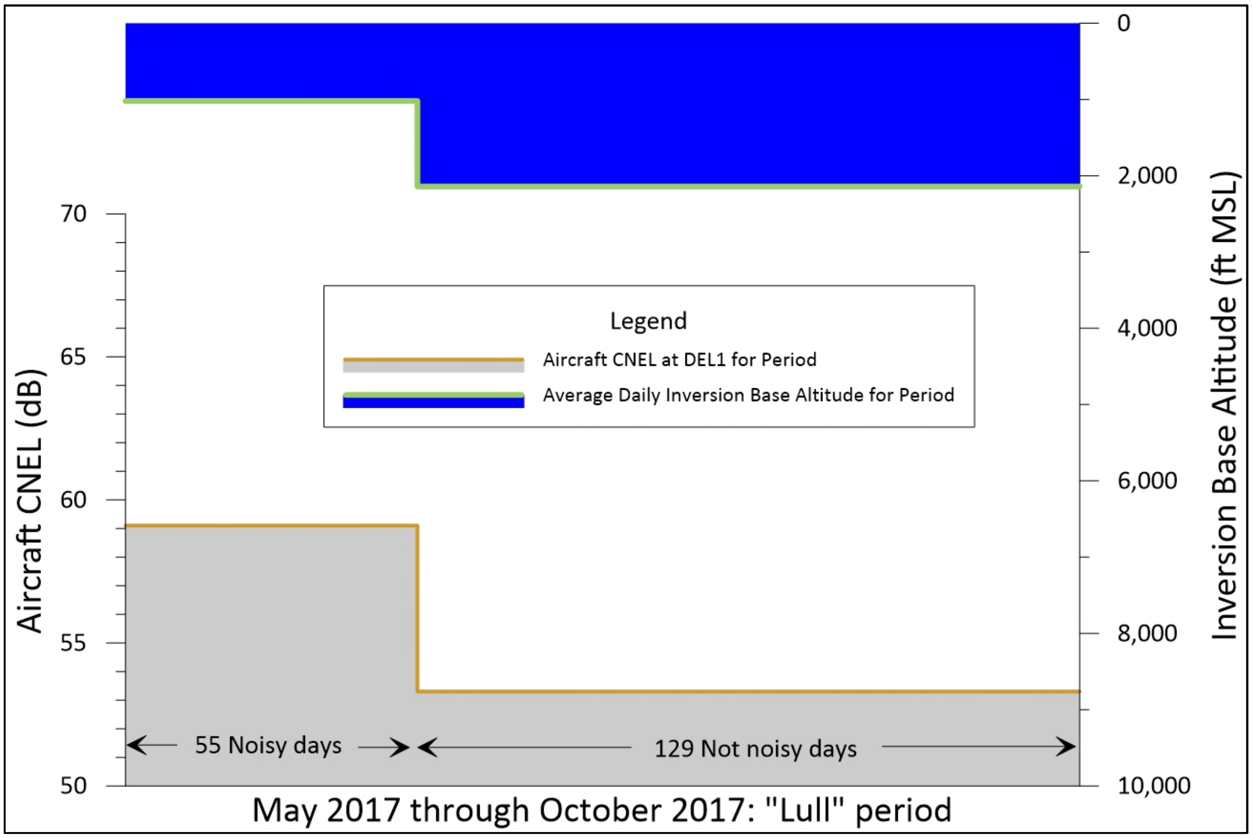

Figure 5-5. Comparison of Average Aircraft Noise Levels and Inversion Base Altitudes during the "Lull" Period

'Noisy' days were characterized by a significantly increased average CNEL at DEL1 and decreased average inversion base heights, compared to the 'not noisy' days.

5.2 Inversion during On-site Measurements (with Resident Volunteer Logging of Noise Observations)

Figure 5-6 shows the daily aircraft CNEL and air temperature for the 360 site for the March-May 2018 on-site measurement period, along with the resident's noise code and the inversion base altitude from the SCAQMD. As was observed during the "Lull" time frame, it can be seen that the inversion base altitude is generally much lower and the air temperature is higher on many of the logged 'loud' days than the 'relatively quiet' days during the on-site measurement period. From Figure 5-7, it can be seen that on the 39 days when the resident logged a 1, 2 or 3 for their noise code, i.e., thought it was 'loud', 'excessively loud', or 'extremely loud' , the average inversion base altitude was 1,925 ft MSL. On the 11 days when he only logged it being 'relatively quiet' (we assigned code 0), the average inversion base altitude was nearly double at 3,728 ft MSL.

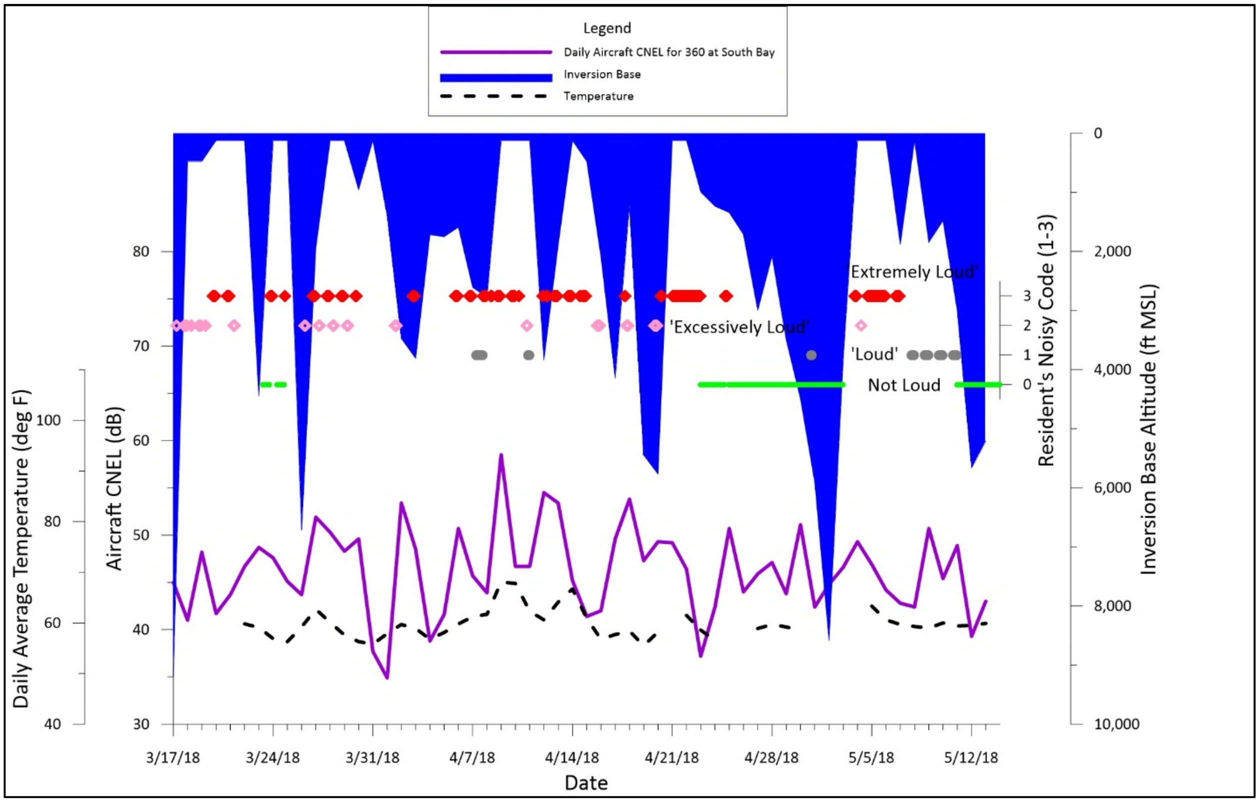

Figure 5-6. Daily Aircraft CNEL, Temperature and Inversion Base Altitude for the Measurement Period

Most times when the inversion base altitude was low, the 360 Community resident thought it was noisy.

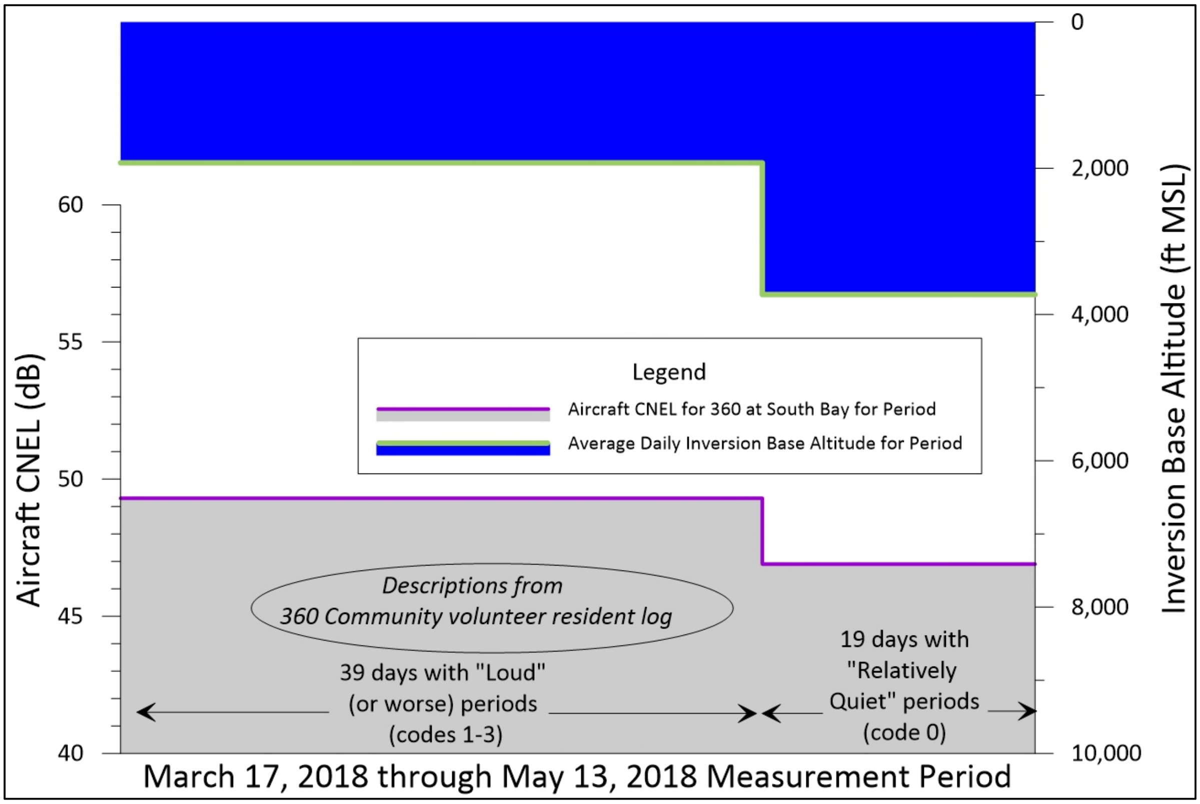

Figure 5-7. Comparison of Daily Inversion Base Altitude and Daily Aircraft CNEL for 'Loud' and 'Relatively Quiet' Days during the Measurement Period

'Loud' periods had a noticeably higher average CNEL and lower inversion base altitude.

5.3 Combined Effects

Winds, air temperature and temperature inversion can occur simultaneously to compound the noise situation at the 360 Community. In addition to the 3 'special' days discussed in section 4, there were 7 other days of importance during the measurement period when the resident noted his highest noisiness code (code 3) and logged additional comments such as "unbelievably loud" or "outrageous noise levels". Wind vector plots of these days are shown in Appendix B. On these 7 days, it was either a temperature inversion base altitude within 200 feet of the ground and/or winds which likely caused the resident's remarks. LAX's numbers of flight operations on Runway 25L/R were not out of the ordinary on these 7 days or the 3 days mentioned in section 4 and do not account for the drastic increase in noise observations.

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6 Jet Noise Directivity and Low Frequency Aspects

The following subsections briefly discuss directivity and low-frequency aspects of jet aircraft noise potentially affecting the 360 Community.

6.1 Directivity of Aircraft Noise

As explained in section A.2 of Appendix A, aircraft do not emit sound in all directions equally. The sound pattern produced by an aircraft depends on many factors, two of which are the engine type (jet or propeller) and mode of flight, e.g., takeoff/departure or arrival. The shape of the sound pattern around the aircraft is called its directivity. In general, the directivity for jet engines is typically a cardioid shape. Counterintuitively, the area of least A-weighted sound level is directly behind the jet engine.

Figure 6-1 shows the Maximum Sound Level (L_{max}) contours[14] for a single Boeing 737-800 departing Runway 25L (east to west). The 737-800 is the jet aircraft with the most flight operations at LAX and runway 25L was selected to show the “worst-case” scenario when Runway 25R is closed, as was the case on certain days during the March – May 2018 measurement period and LAX’s Preferential Runway Use policy was not in effect.[15] The jet engine directivity (the cardioid shape) is evident in the shape of the contours nearest the aircraft’s start of takeoff roll point at the endpoint of Runway 25L. As the noise propagates away from the runway (to contours of lower level), the southern lobe of the cardioid affects the 360 Community, demonstrating that the 360 Community (and parts of Del Aire and Hawthorne) can receive higher amounts of noise from jet aircraft beginning their takeoff roll from Runway 25L than from other areas.

6.2 Low Frequency aspects of Aircraft Noise

Another issue mentioned by the volunteer resident was he often hears a rumble or roar. Rumble and roar can be from the aircraft at the beginning of their takeoff roll for departures and for reverse thrust during landing roll for arrivals. Rumbles and roars are typically characterized by low frequency noise which is best measured with the C-weighting, instead of the A-weighting required in cumulative aircraft noise metrics such as CNEL.[16] The C-weighting is a better choice for low frequency sound than A-weighting because, as mentioned in Appendix A, C-weighting does not de-emphasize low frequency sound levels.[17]

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[14] The contours were produced with the Federal Aviation Administration’s Aviation Environmental Design Tool (AEDT).

[15] LAX Rules and Regulations, Section 13.4 (https://www.lawa.org/en/rules-and-regulations/lax-rules-and-regulations). The policy dictates aircraft on the south runway complex in west flow depart on the inboard runway, i.e., Runway 25R, instead of 25L.

[16] The A-weighting is required for CNEL because it approximates the sensitivity of the human ear to the frequency spectrum of transportation noises such as aircraft.

[17] Except those below approximately 125 Hertz.

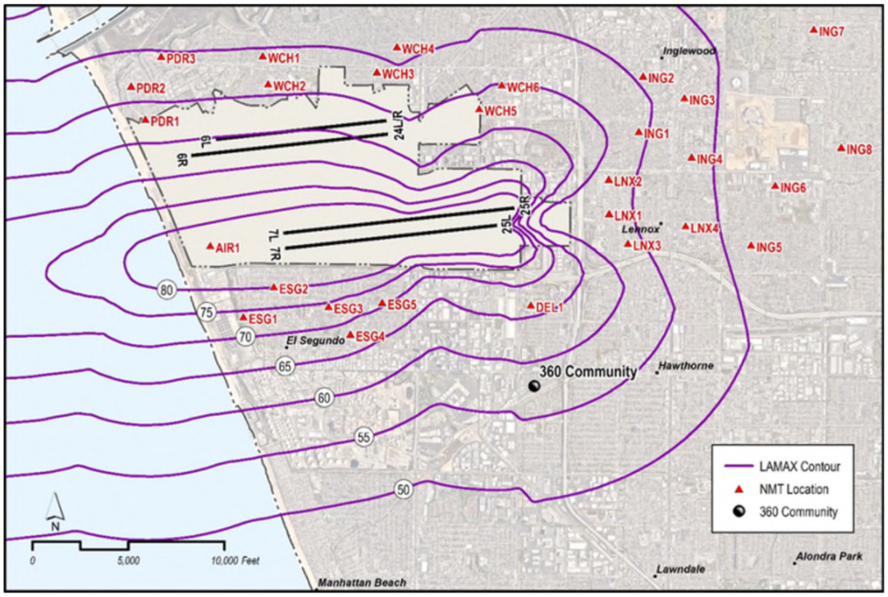

Figure 6-1. Modeled Single-Event A-weighted Maximum Sound Level (L_{max}) Contours for a Boeing 737-800 Departure from Runway 25L at LAX

The noise received by the 360 Community depends on the type of flight operation (i.e. arrival or departure). Departure noise is primarily from the start of the takeoff roll segment of the departure.

Although C-weighting is more appropriate for studying noise from explosions and sonic boom, C-weighting was explored for this investigation to estimate the potential for aircraft low-frequency noise at the 360 Community. For the period between April 12, 2018 and the end of the measurement period (May 13, 2018), C-weighted $L_{eq(h)}$ were compared to A-weighted $L_{eq(h)}$. Differences between C-weighted $L_{eq(h)}$ and A-weighted $L_{eq(h)}$ values were noted, with just over half (52%) showing C-weighted $L_{eq(h)}$ to be between 9 and 14 dB greater than A-weighted $L_{eq(h)}$. Although this may appear to be a large difference, sound level does not necessarily correlate with "loudness," particularly at the lower and higher ends of the audible frequency range. Low frequency noise may be part of the noise issue for the 360 Community, subject to similar atmospheric/temperature inversion effects, but is on the lower end of the audible noise spectrum.

7 Conclusions

The aircraft noise concerns of the 360 Community in Hawthorne were investigated and presented in this report and at the LAX/Community Noise Roundtable meeting on September 12, 2018, pursuant to a work item in the LAX/Community noise Roundtable Work Program. The goal of this investigation was to determine the causes of increased aircraft noise reported by the 360 Community during periods dating back to 2015, and to make noise reduction recommendations, if feasible.

In general, noise emanating from typical departure and arrival operations on LAX Runways 25L/R is likely noticeable at the 360 Community and in nearby areas due to the directivity of noise associated with takeoff roll (departures) and reverse thrust/landing roll (arrivals) on these runways. Examination of the November 2015 through May 2017 data found that the 360 Community's noise observations were substantiated by, and correlated well with, the daily noise levels recorded at a nearby permanent noise monitor (DEL1). However, the observations and measured noise levels were found to have an inverse relationship with the number of flight operations at LAX. The increase in noise levels measured at DEL1 or observed by the 360 Community did not correlate with a commensurate increase in numbers of operations at LAX, nor did the periods of decreased noise have decreased flight operations. This led to analyzing the possible effects of weather. Supplementing LAWA's noise monitor data with weather data from NOAA's weather station at LAX and with temperature inversion base data from the SCAQMD, the study further found that temperature inversions and unfavorable winds were the primary factors contributing to the extended periods of increased noise measured at DEL1 and as reported by the 360 Community for May 2017 through October 2017. A temperature inversion can hold sound closer to the ground and can cause it to travel farther from the source, while wind speed and direction play a role in increasing noise propagation to those downwind.

From March 2018 to May 2018, a portable noise monitor and weather station were deployed on site at the 360 Community to conduct continuous, unmanned measurements of noise and weather conditions, while a resident volunteer of the Community logged his perceptions of aircraft noise during the same 2-month period. Analysis of the data resulted in similar conclusions: increases in flight operations at LAX did not seem to be the cause for the observed noisy periods; rather, the noisy days, as reported by the resident volunteer, were positively correlated with the relatively low-altitude regional temperature inversions and more frequent/stronger winds from the north and northwest blowing from LAX toward the 360 Community.

As the noise problem at the 360 Community was found to be primarily weather-related, and the source of the noise from normal aircraft operations at LAX, there are no feasible recommendations that can be made at this time to mitigate weather-related noise issues as experienced at the 360 Community.

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Appendix A - Key Terms and Concepts

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Contents

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A.1 Fundamentals of Acoustics

Sound is a physical phenomenon consisting of minute vibrations (waveforms) that travel through a medium such as air or water. Audible sounds are those vibrations that can be sensed by the human ear. At the ear, sound waves vibrate the ear drum, which transmits the vibration via a network of bones to the cochlea. The cochlea then converts the vibration into neurological impulses that are interpreted by the brain as sound. One's experience and perception of sound depends on both the pattern of vibrations from the sound source and the way our hearing mechanism interprets these vibrations.

A sound *source* induces vibrations in the air which spread outward from the sound source as alternating bands of dense (compression) and sparse (expansion) air particles. This results in a variation of pressure above and below the baseline atmospheric pressure. The distance between successive compressions or successive expansions is the wavelength of the sound, and the number of compressions or expansions passing a fixed location per unit of time is the frequency of the sound. Frequency is normally expressed in cycles per second or Hertz (Hz); a sound having a 1,000 Hz frequency indicates that the alternating compression and expansion occurs 1,000 times per second. A high frequency sound is shorter in wavelength and lower frequency sound is correspondingly longer in wavelength. In contrast to frequency, which describes the cycling of impulses, the overall magnitude of such impulses that is the average amplitude of the variations of the pressure above and below atmospheric pressure is called the sound pressure.

Sound travels through air at about 1,100 feet per second; however, its speed is different speeds in other media (e.g., water). Therefore, to more fully characterize sound, its three defining characteristics are typically identified: (1) magnitude, (2) frequency spectrum, and (3) the variations of these two over a time interval.

Magnitude

Telephone engineers were among the first to extensively study the ear's response to sound pressure, finding that the ear responds to a broad range of sound pressures. A healthy human ear can detect a sound tone having a frequency a 1,000 Hz at sound pressures (amplitudes) as low as 20 micropascals. (This is expressed as 20 µPa and equals to 20 x 10^{-6} Pascals (Pa). For reference, standard atmospheric pressure at sea level is 101,325 Pascals. At the other end of an amplitude scale, the threshold of pain was found to occur around a sound pressure of 200 Pascals, or ten million times as large as the barely audible 20 µPa magnitude. Whether barely audible (20 µPa) or pain-inducing (200 Pa), these pressures are comparatively small variations around atmospheric pressure (101,235 Pa).

Since a human ear is able to respond to such a large range of sound pressures, early telephone engineers had a measurement problem. At the threshold of hearing, where the ear could detect a sound pressure of 20 µPa, an increase of 40 µPa was a noticeable change; yet at 10 Pa, that same increase of 40 µPa (or 0.00004 Pascals) was undetectable. Thus, a shorthand method for expressing the magnitude of a sound was necessary. Their solution was to develop a logarithmic scale based on the ratio of the sound pressure to a reference sound pressure.

> *A logarithm (base 10 "common" logarithm) is simply a power of 10. For example, 100 equals 10 times 10, which equates to 10^2. The logarithm of 100 is then 2 (log 100 = 2). Similarly, 10^3 equals 10 times 10 times 10, which equates to 1,000. Consequently, the log of 1,000 is 3.*

When units were standardized, the Bel, in honor of Alexander Graham Bell, was defined as the log of the square of the ratio of two sound pressures, with the decibel one tenth of that. The Bel itself proved to be too coarse of a unit, so the term decibels (dB) remained in common use. Values on the decibel scale are referred to as levels. The following equation shows the relationship of sound pressure level, L, in decibels to sound pressure where p is the pressure of the sound that is being compared and p_0 is the reference pressure against which p is compared.

$$L = 10\log 10\,(\frac{p^2}{p_0^2})$$

The level (in decibels) equals 10 times the log of the square of the quantity of measured sound pressure divided by 20 µPa (this squared quantity is proportional to the sound power). Recall that the sound pressure that is barely detectable by the human ear is 20 µPa. By using this as a reference, the telephone engineers “zeroed” the logarithmic scale for sound at the threshold of hearing.

A.1.1.1 Sensitivity to changes in loudness

Under laboratory conditions, people can detect single-decibel changes in sound level. But, when comparing sounds in our everyday experience, we are less sensitive to differences in sound intensities. From a practical standpoint, a 5-dB difference is the smallest change generally noticeable to the average listener. A change in sound level of about 10 dB is usually perceived by the average person as a doubling (or halving) of the sound’s loudness. This relation holds true for loud sounds and for quieter sounds across the speech frequencies.

A.1.1.2 Adding decibels

Because of the logarithmic nature of the decibel and the fact that sound pressure is a measure of the variation in air pressure, neither sound pressure level in decibels nor sound pressures in µPa can be added directly. However, the quantity inside the parentheses in the above equation, which is proportional to the sound energy, can be added. Note that if the sound pressure levels being added are quite different in magnitude, adding the lesser value to the greater value yields relatively little change to the higher value when expressed as dB and that adding sounds with equal sound pressure levels results in a three-decibel increase.

Frequency

As noted, frequency is the rate of vibrations for a sound and is measured in Hz where one Hz indicates one vibration (or cycle) per second. As with the ability to hear events of widely ranging pressure amplitudes described above, the human ear also hears sounds having widely ranging frequencies (e.g., from about 20 Hz to about 20,000 Hz). However, not all sounds in this wide range of frequencies are heard equally well by the human ear. The ear is most sensitive to sounds having frequencies in the range of 1,000 Hz to 4,000 Hz.

Some simple sound sources, such as a tuning fork, produce sounds with a single frequency (i.e., a pure tone). Most sounds however are more complicated and their signals consist of multiple many frequencies. A sound spectrum is a representation of a sound showing the magnitude of the various frequencies present in the sound. Knowledge of the frequency spectrum of a signal is important for the following reasons:

- People and animals have different hearing sensitivity and react differently to various frequencies. For instance, most people are familiar with a "dog whistle" which produces a signal that dogs can hear but humans cannot. This occurs because dog whistles produce a tone having a frequency above the range at which humans can hear but within the range of the dog's hearing. At the other end of the frequency scale, elephants communicate at frequencies below the range of human hearing.
- Structures respond to much lower frequencies (e.g., 1–30 Hz) than humans. Therefore, low-frequency sounds that people cannot hear can still create problems by inducing vibration in buildings.
- Different sound sources produce signals consisting of different frequency characteristics.
- Engineering solutions for reducing or controlling sound are therefore frequency-dependent.

High-quality measuring devices (e.g., sound level meters) are equally sensitive to sounds across the full range of human hearing. Therefore, to approximate the human perception of common environmental sounds, the acoustical community designed a range of frequency-based adjustments to be applied to measured sound levels. Today, two of these weighting systems remain in common usage, the A-weighting and C-weighting, which are shown in Figure A-1.

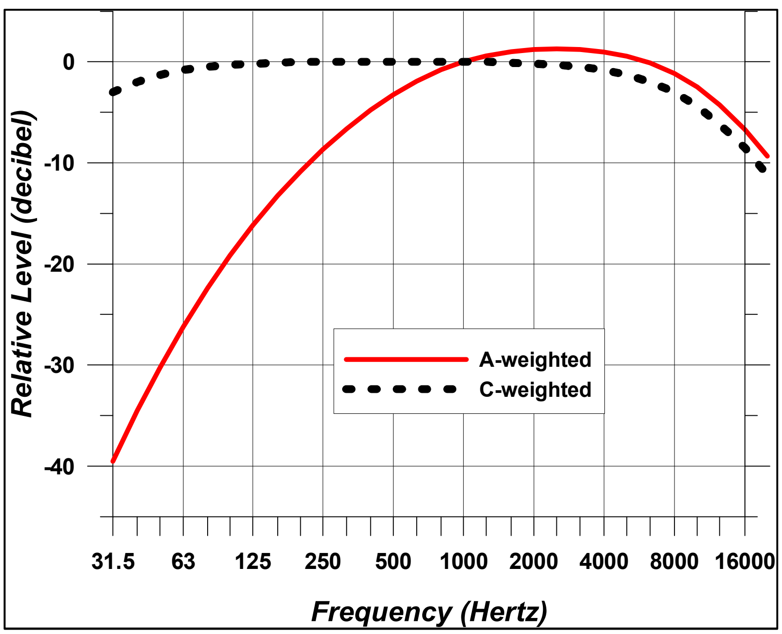

Figure A-1. A- and C-weightings as a function of frequency

A-weighting de-emphasizes frequencies below 1,000 Hz more than C-weighting.

These weightings are based on the response of human ears to moderate- (A-weighting) or high-level (C-weighting) sounds. For most industrial and transportation applications, A-weighting is used. For loud sounds with significant low frequency content, C-weighting is used. A-weighting applies progressively higher reductions to lower frequencies, mimicking the reduced sensitivity of human ears to low frequency sounds. However, in order to more accurately capture the low frequency energy and higher levels present, C-weighting, with its much slower roll-off at lower frequencies, is more appropriate for noise sources such as explosions and sonic booms.

In addition to representing human hearing sensitivity, A-weighted sound levels have been found to correlate better than other weighting networks with human perception of “noisiness.” One of the primary reasons for the improved correlation is the A-weighting network emphasizes the frequency range where human speech occurs, and noise in this frequency range interferes with speech communication. Another reason is the increased hearing sensitivity makes noise more annoying in this frequency range. For all of the above reasons, A-weighted sound levels are used worldwide in noise standards and regulations to address the effects and impact of noise on human activity.

Variation of Sound with Time

The third characteristic used to describe sound (after magnitude and frequency) is its relative stability over time. Sound can be classified into three categories that define its basic time pattern: steady state, intermittent, and impulsive.

Steady-state sound is a sound of consistent level and spectral content. Typical examples of steady-state sound are the sounds produced by ventilation or mechanical systems that operate more or less continuously.

Intermittent sounds are those that are produced for short periods. The sound temporarily rises above the background and then fades back into it. Intermittent sounds are typically associated with moving sound sources such as an aircraft overflight or a single-vehicle drive-by. Intermittent sound is typically a few minutes or less in duration.

Impulsive sound is of short duration (typically less than one second), low frequency, and high intensity. It has abrupt onset, rapid decay, and often a rapidly changing spectral composition. Impulsive sound is characteristically associated with such sources as large-caliber weapons, demolition activities, sonic booms, and many industrial processes (e.g., jackhammers, pile drivers). However, certain aspects of helicopter noise events are also impulsive.

A.2 Propagation of Sound

As sound travels from the source to the receiver, several factors influence the level and spectrum of the sound heard by a receiver. These factors generally result in a reduction, or *attenuation*, of the sound level:

- Spherical spreading
- Ground effects
- Attenuation through vegetation
- Attenuation due to barriers (including terrain)
- Atmospheric effects

Note that, for other than spherical spreading, all factors tend to have more effect on higher frequencies with low frequencies able to propagate over long distances with little attenuation. Hence, the “rumble” of jet departures or highway traffic can often be heard at large distances, while the higher frequency characteristics of the signal are lost.

Spherical Spreading and Noise Directivity

The sound from the point source, such as a generator, spreads in all directions like an expanding sphere. A rule of thumb in acoustics is that a spherically spreading sound decreases by 6 dB for every doubling of distance. Thus, with a reference distance of, say, 50 feet, increasing the distance from 200 feet to 300 feet does not provide as much reduction as increasing the distance from 100 to 200 feet. In practice, high-frequency sound is attenuated faster than 6 dB per doubling of the distance because some energy is lost in the medium (air) due to atmospheric effects at this frequency range. This loss, called excess attenuation, is dependent upon air temperature and humidity as well as the signal's sound frequency and is due to a process called vibrational relaxation in oxygen and nitrogen molecules.

Aircraft do not emit sound in all directions equally, i.e., omni-directionally. The sound pattern produced by an aircraft depends on many factors including the engine type (jet or propeller), the number of engines and how they are installed on the aircraft, e.g., over/under wing or rear mounted, the jet bypass ratio (engine design), wing flap configuration and mode of flight, e.g., takeoff/departure or arrival. The shape of the sound pattern around the aircraft is called its directivity. The directivity of aircraft with jet engines is typically a cardioid shape as shown in Figure A-2, with the larger lobes of the cardioid emanating approximately 45 degrees from the tail of the aircraft relative to the aircraft's longitudinal axis. Counter-intuitively, there is less sound directly behind a jet aircraft than off to its side.

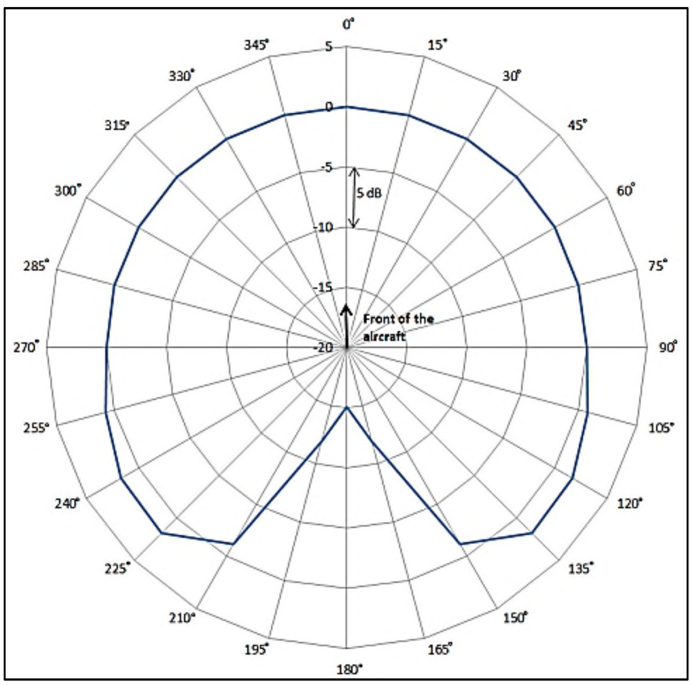

Figure A-2. General Sound Directivity from a Jet Aircraft

Source: FAA AEDT 2d Technical Manual

Jet aircraft noise is not omni-directional and more noise propagates at azimuths of 120-135 degrees.

Ground Effects

When sound propagates along the surface of the earth from a source to a receiver, it follows two paths. The first is a direct path from the source to the receiver and the second is a path that starts at the source, reflects off the ground, and then travels to the receiver. If the ground is hard, such as pavement or water (lakes, oceans, etc.), the sound reflects off the surface and adds to the sound from the direct path resulting in higher levels than the direct path alone. When sound reflects off of soft ground, such freshly-plowed earth, grass, or loose snow, some frequencies of the reflected sound experience a phase reversal, where the areas of high and low pressure become reversed. Adding this phase-reversed sound to the sound from the direct pathway results in a reduction in the total sound at the receiver. Thus, sound levels are generally higher when the sound propagates over hard ground as compared to soft ground. Another way of thinking of the way so-called ground-effect attenuation works is to think of the sound waves traveling above the ground on their way from the source to the receiver. If the ground under the traveling sound wave is hard, then none of sound is absorbed by the ground along the way. However, if the ground is porous and softer, then the soft ground will absorb some of the sound along the way, reducing the overall sound level at the receiver. Generally, the longer the sound propagation path and the softer the ground, the greater the degree of additional attenuation over soft ground will be.

A.2.1.1 Attenuation from vegetation

Wide areas of dense foliage provide some attenuation for higher frequency sound when they are located between a source and receiver. The vegetation must be dense enough to block the line of sight over even short distances and must extend well above the line of sight. The attenuation is negligible for low-frequency sound sources such as explosions, but increases with frequency. At 250 Hz, approximately 400 ft of dense foliage would be required to produce a noticeable 5 dB of attenuation for a sound source such as an aircraft run-up. At 1,500 Hz, approximately 250 ft of dense foliage would be required to produce 5 dB of attenuation for a sound source such as roadway traffic.

A.2.1.2 Attenuation due to barriers (including natural terrain)

Barriers, berms, and natural terrain can attenuate sound when they are located in the line of sight between the source and the receiver. This attenuation, which acousticians call insertion loss, increases with height, width, and proximity to either the source or the receiver. If there are gaps in a barrier, the potential benefits of acoustical shielding will be substantially reduced.

Atmospheric Effects

Weather (or atmospheric) conditions that influence the propagation of sound include humidity, precipitation, temperature and temperature gradient, wind, and turbulence (or gustiness). The effect of wind, turbulence in particular, is generally more important than the effects from other factors. Under calm wind conditions, the importance of temperature can increase, in particular, temperature changes occurring with altitude known as temperature gradients. This can sometimes influence propagation quite significantly. Humidity generally has little significance compared to the other effects.

The effects on propagation described below interact with each other and in some cases are additive. Specific/complex combinations of conditions influence propagation, and in order to predict how sound would propagate, it is important to understand these varied effects. This document is meant to introduce the reader to these topics.

A.2.1.3 Influence of humidity and precipitation

Humidity and precipitation rarely affect sound propagation in a significant manner. Humidity can reduce propagation of high-frequency noise under calm wind conditions. In very cold conditions, listeners often observe that noise sources such as aircraft sound "tinny," because the dry air increases the propagation of high-frequency sound. Rain, snow, and fog also have little, if any, noticeable effect on sound propagation. A substantial body of empirical data supports these conclusions.

A.2.1.4 Influence of temperature and temperature gradient

Air temperature affects the velocity of sound in the atmosphere. The speed of sound is proportional to the (square root of) temperature, thus sound travels faster in warmer air. As a result, if the temperature varies at different heights above the ground, sound will travel in curved paths rather than straight lines. Sound travels in waves, but a sound "ray" can be thought of as an imaginary line or path from a sound source in the direction of propagation. This bending of the sound path (or ray) is called refraction.

During the day, temperature normally decreases with increasing height. Under such "temperature lapse" conditions, when the air temperature decreases with height, the atmosphere refracts ("bends") sound waves upwards, and an acoustical shadow zone may exist at some distance from the noise source, as illustrated in Figure A-3.

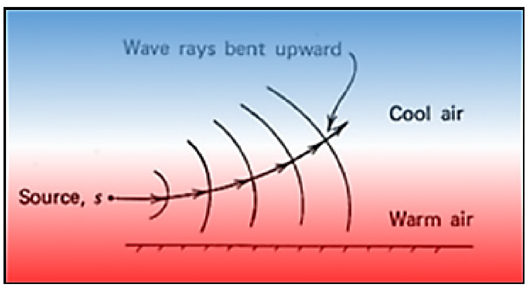

Figure A-3. Refraction of Sound Waves caused by Outdoor Temperature Variations – Standard Atmosphere

Source: Cuniff 1977

Noise is bent upward away from the ground in a standard atmosphere where temperature decreases with increasing altitude.

Under some weather conditions, an upper level of warmer air may trap a lower layer of cool air. Such an inversion of normal conditions (i.e., temperature gradients typically lapse with altitude) is most common in the evening, at night, and early in the morning when heat absorbed by the ground during the day radiates into the atmosphere. The effect of an inversion is just the opposite of lapse conditions: it causes sound propagating through the atmosphere to refract downward, as illustrated in Figure A-4. The downward refraction caused by temperature inversions often allows sound rays with originally upward-sloping paths to bypass obstructions and ground effects, increasing noise levels at greater distances. This type of effect is most noticeable at night, when temperature inversions are most common and when ambient sound levels are low enough that they do not otherwise mask distant noise sources.

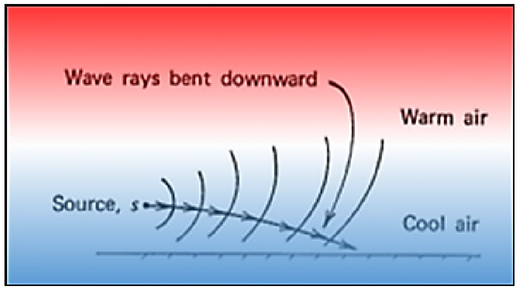

Figure A-4. Refraction of Sound Waves caused by Outdoor Temperature Variations – Temperature Inversion

Source: Cuniff 1977

Noise is bent downward toward the ground in an atmosphere where temperature increases with increasing altitude.

The two most common types of inversions are subsidence and radiative. Figure A-5 illustrates how temperature varies with altitude for these types of inversions. Subsidence and radiative inversions can happen simultaneously, as shown in Figure A-5(c). The height above the earth's surface, measured relative to MSL, where the temperature begins to decrease with altitude is called the inversion base height or altitude.

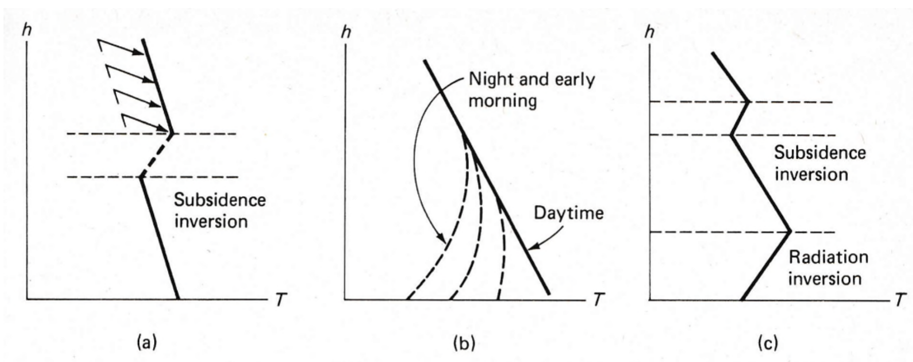

Figure A-5. Illustrations of Altitude versus Temperature for Three Types of Inversions (a) Subsidence Inversion, (b) Radiation Inversion, and (c) Combination of Subsidence and Radiation Inversions

Source: Wark and Warner 1981

Temperature inversions can occur on or near the ground or at altitude.

A subsidence inversion is caused by the adiabatic[18] compression and warming of a layer of air as it sinks to lower altitudes in the region of a high-pressure center. Subsidence inversions tend to persist for several days and are a common feature of the West coast of the United States for approximately 340 days of the year (Wark and Warner 1981).

Radiative inversions are caused by the surface layers of the atmosphere warming by heat conducted, convected and radiated by the earth's surface during the day, followed by a clear cooler night period. This type of inversion is strongest just before daylight and during clear skies and light winds Radiation inversions are most likely to occur during cloudless and windless nights and base heights are usually less than 1,600 feet (Wark and Warner 1981). Inversions in the Southern California region tend to be caused

[18] Relating to or denoting a process or condition in which heat does not enter or leave the system concerned.

by radiative inversions (Bassett 2018). Fall and winter seasons generally have the longest lasting and greatest numbers of inversions (Wark and Warner 1981).

For this study, inversion base height data was provided by the South Coast Air Quality Management District (SCAQMD). The data provided by the AQMD comes from upper air soundings taken around 4 a.m. at Marine Corps Air Station (MCAS) Miramar, near San Diego, California. Two-day forecasts are typically conducted on Friday and Sunday mornings. Since a measured sounding is not yet available for Saturday and Monday morning, respectively, the AQMD uses a model-predicted sounding for weekends. The AQMD stated the MCAS Miramar soundings are the closest (distance-wise) to LAX in the region and that data represents the entire Southern California air basin (Epstein 2018).

Temperature inversions at airports have the effect of increasing the aircraft noise exposure, making the noise sound louder at greater distances from the airport than would be the case during normal temperature gradients. Figures A-6 and A-7 are contours of SEL from an aircraft arriving and departing an airfield (traversing from left to right) for a clear day with a normal temperature gradient and for a clear night with a temperature inversion, respectively (Plotkin, Ikelheimer and Huber 2003). Note the contours for the inversion case are approximately 5 dB greater than the case without the inversion. Measurements can capture this effect. The capability of modeling the effect of temperature inversions on sound propagation is not currently included in the Federal Aviation Administration's (FAA) Aviation Environmental Design Tool (AEDT).[19]

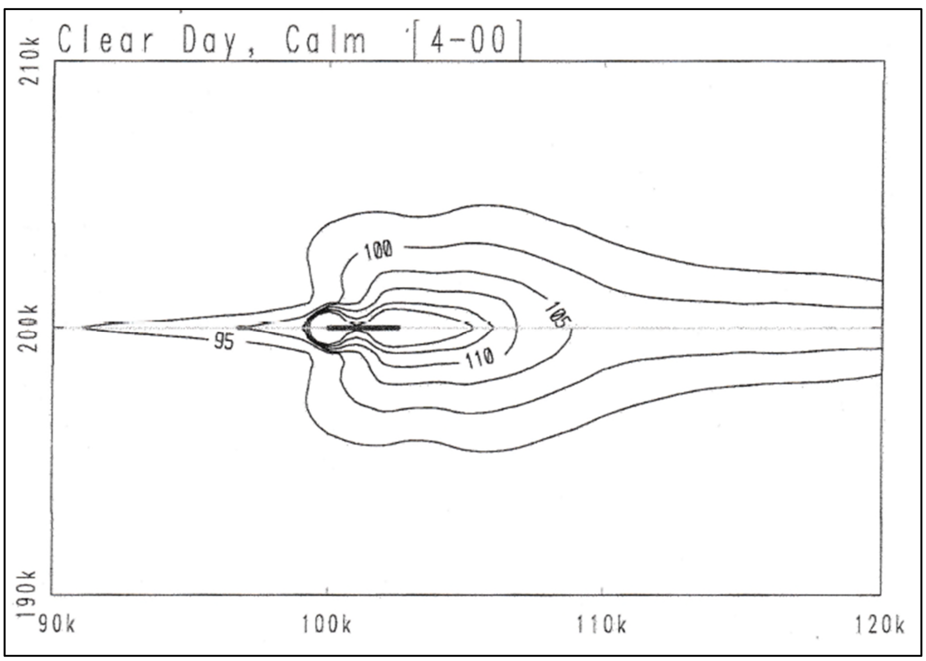

Figure A-6. SEL Contours for Approach and Departure (left to right) for Clear Day (normal lapse rate)

Source: Plotkin, Ikelheimer and Huber 2003

[19] AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences.

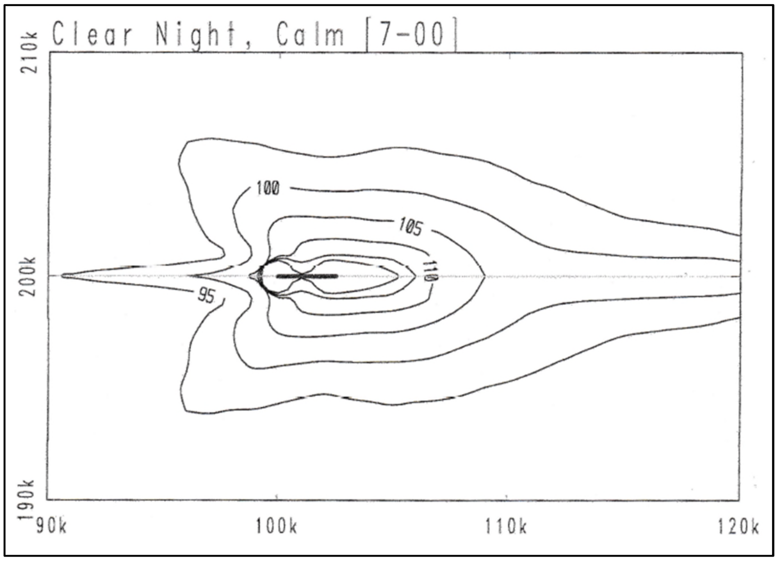

Figure A-7. SEL Contours for Approach and Departure (left to right) for Clear Night (inversion)

Source: Plotkin, Ikelheimer and Huber 2003

Temperature inversions increase the dimensions of single-event aircraft noise contours; they increase sound's ability to propagate.

A.2.1.5 Influence of wind

When the wind is blowing, the wind speed is faster above the ground than it is near the ground. That faster wind speed above the ground bends ("refracts") the sound waves traveling in it. When the sound is traveling with the wind, the faster wind bends the sound waves downward. When the sound is traveling into the wind, the faster head winds aloft slow the sound waves more, and the waves bend upward with the higher speeds at the ground. As shown in Figure A-8, for a receiver located downwind of a sound source, downward-bending sound waves will increase the loudness of sound emitted by a sound source, by bringing sound that travels well above the ground back down to listeners near the ground. With no wind, the direct sound path may include some shielding from terrain or buildings, or the path might have "soft" ground, such as grass-covered ground or plowed earth, that absorbs sound to some degree along the way. For a receiver located upwind of the sound source, sound waves bending upward away from the ground into the wind create a "shadow zone", and may not reach the listener on a direct path, so the magnitude of the sound is generally less than it is with no wind at all.

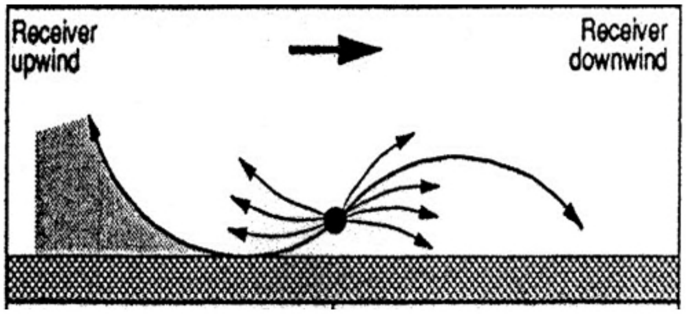

Figure A-8. Sound Propagation under Downwind and Upwind Conditions

Source: Ver and Beranek 2018

Winds refract sound away from an upwind receiver and towards a downwind receiver.

Winds at airports can move sound. Figure A-9 is a set of SEL from an aircraft arriving and departing an airfield (traversing from left to right) experiencing a light crosswind of 6 miles per hour (10 kilometers per hour) from the south (Plotkin, Ikelheimer and Huber 2003). Comparing to Figure A-6, the light crosswind has shifted the SEL footprint, primarily of the departure lobes, to the north. The capability of modeling the effect of wind on sound propagation is not currently included in the FAA's AEDT.

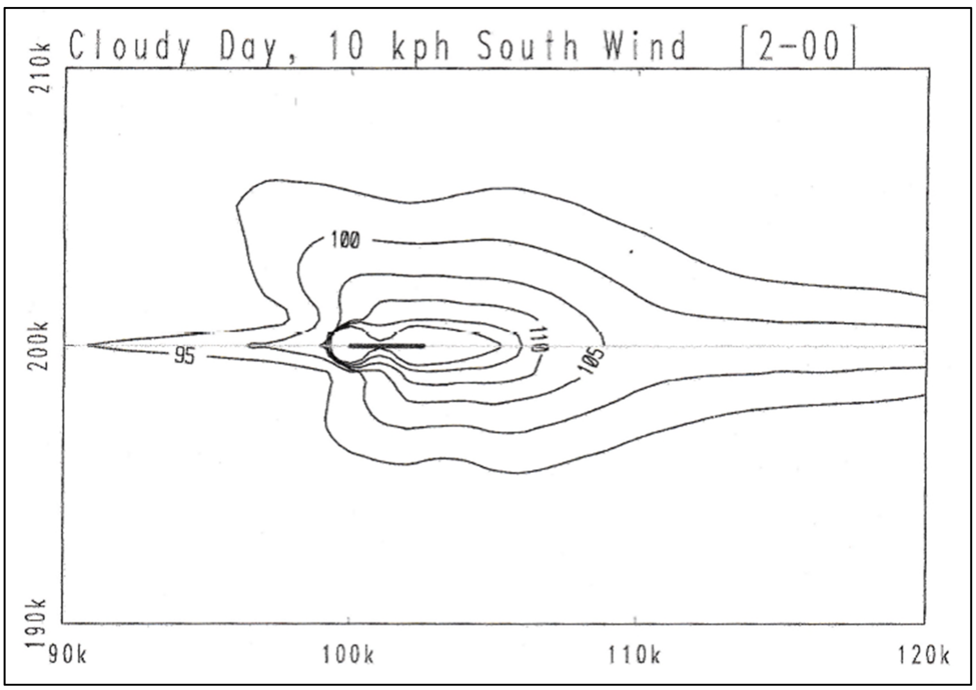

Figure A-9. SEL Contours for Approach and Departure (left to right) for Cloudy Day with 6 mph Crosswind from the South

Source: Plotkin, Ikelheimer and Huber 2003

Relatively light winds can make significant differences in shapes of noise contours, i.e., the propagation of sound.

A.3 Noise Metrics

Noise metrics may be thought of as measures of noise 'dose'. There are two main types, describing (1) single noise events (Single Event Noise Metrics) and (2) total noise experienced over longer time periods (Cumulative Noise Metrics). Note that all decibel values, whether they relate to basic scales, event metrics or cumulative metrics, are generally referred to as levels - indeed in acoustic measurement, a level is always a decibel value.

Single event metrics are indicators of the intrusiveness, loudness, or noisiness of individual aircraft noises. Cumulative metrics used to measure long-term noise are indicators of community annoyance. But for aircraft noise it is logical that they represent aggregations of single events in some way. A practical noise index must be simple, unambiguous, and capable of accurate measurement (using conventional, standard instrumentation). It must also be suitable for estimation or calculation from underlying source variables and robust, and not overly-sensitive to small changes in input variables.

Community annoyance research (much of which has been concerned with the noise of aircraft and road traffic), and the search for reliable long-term noise rating procedures, started in the mid- 1950s. As instrumentation for measuring long-term noise was very limited then and for some time afterwards, early noise indices tended to incorporate measures that could be obtained manually or by simple mechanical means. Aircraft noise near airports could (and still can) be characterized by statistics describing individual noise events, such as their average levels and numbers. The noise of heavy road traffic, on the other hand, is made up of a very large number of overlapping events and it was then more appropriate to determine level distribution statistics such as L_{10}, the level exceeded for 10% of the time. Overall, aircraft noise affects far fewer people than road traffic noise but can reach high exposure levels close to busy airports. Here a separate identification of event levels and numbers of events focuses attention on the relative contributions of these two variables to annoyance.

Community judgments about the suitability of a sound environment are rarely based on a single sound. Rather, multiple sources of sound accumulate to produce the overall experience of a "quiet" or "noisy" neighborhood. Noise, as noted at the outset of this appendix, is defined as unwanted sound. The receiver imparts a value judgement onto an otherwise neutral physical phenomenon (i.e., sound). In 1974, the Environmental Protection Agency (EPA) established a procedure to assess the cumulative, 24-hour exposure to noise for citizens of the United States. This procedure was published in what has become known as "the Levels Document." To explain this procedure, the sections below will define noise metrics, beginning with simple metrics and progressing to the more complex. Because these metrics typically were developed to systematically characterize sound in the context of evaluating its undesirable effects, they are ordinarily labeled as noise metrics.

Over the past 40 years, a wide variety of acoustic measures or rating scales have been developed for the purpose of quantifying the sound generated by particular sources. These measures of sound have been described by the Acoustical Society of America (ASA) and are defined in the American National Standards Institute (ANSI) publication, *Acoustical Terminology* (ref ANSI S1.1, 1994 (R2004)).

This great number of measures results from the wide variations in the description of specific spectral and temporal characteristics among sound sources. For an engineering analysis of the noise exposure of a particular source, one measure may have many advantages over another. For management of noise at airports (or military airfields) three cumulative measures are important: *Equivalent Sound Level* (L_{eq}), *Day-Night Average Sound Level* (DNL or L_{dn}), and *Community Noise Equivalent Level* (CNEL). However, to understand a cumulative measure, it is helpful to first describe another single-event measure, *Sound*

Exposure Level (SEL) in addition to the L_{max} described above because SEL is a metric accounts for duration in addition to the maximum pressure level that L_{max} quantifies.

Maximum Level (L_{max})

It is often convenient to describe a particular noise event by its *Maximum A-weighted Sound Pressure Level* (L_{max}). The sound level rises as the noise source nears the receiver and decreases as the noise source moves away.

Figure A-10 shows a plot of sound level changing with time (called a time history) of an aircraft passing a receiver on the ground and the L_{max} for the event.

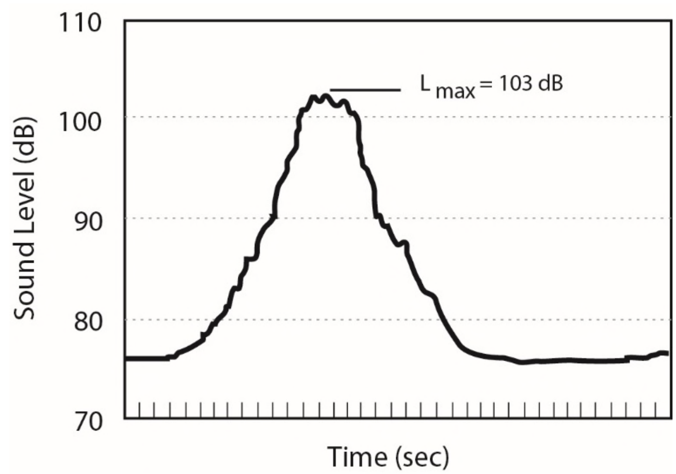

Figure A-10. Variation in Sound Level over Time and Maximum Sound Level

The maximum sound level is the highest level achieved during the period of interest.

Sound Exposure Level (SEL)

The SEL is defined as the total acoustic energy in an event from the time when the event's instantaneous sound level exceeds the background/ambient level to the time when the event's instantaneous sound level is less than background/ambient (typically computed or defined as a level that is 10 to 20 dB lower than the event maximum), normalized or compressed into a one-second interval. The SEL metric quantity. This single number, SEL, represents all the acoustic energy of an event as if that event had occurred within a one-second time period.

Figure A-11 shows an example of an aircraft time history, the resulting L_{max} and SEL.

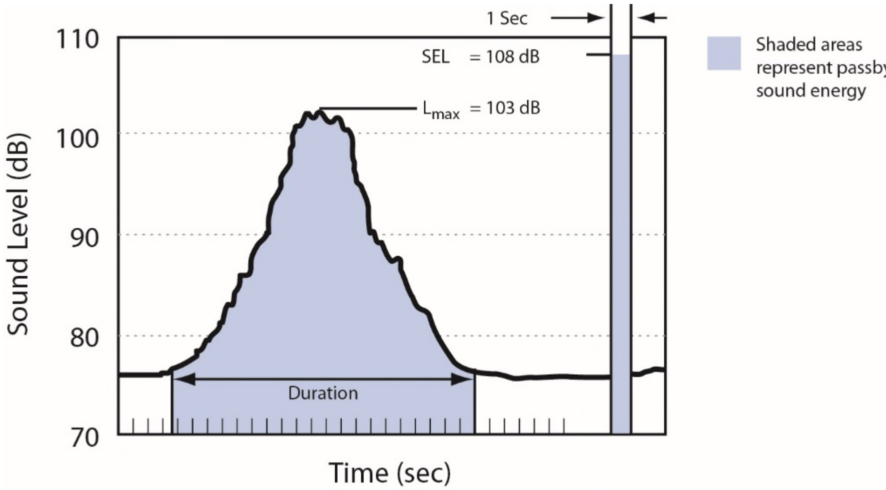

Figure A-11. Sound Exposure Level of a Noise Event

The sound exposure level takes into account the duration and magnitude of the sound.

Equivalent Sound Level (L_{eq})

The Equivalent Sound Level (L_{eq}) is defined as the level of continuous sound over a given period that would deliver the same amount of energy as the actual time-varying sound exposure. The L_{eq} captures the number of intrusions by measuring the average acoustic energy over a period of time in order to assess the cumulative effect of several events occurring over a period of time. The period can be of any length but it usually is a meaningful block of time such as an eight-hour L_{eq} for the office setting or a one-hour L_{eq} for a classroom environment or other purposes.

Figure A-12 illustrates the concept of hourly L_{eq} ($L_{eq(h)}$), based on a time history of sound levels for one hour. It is important to note that the $L_{eq(h)}$ does not normally match the L_{max} but is usually greater than most of the sound levels during the time history. This behavior is characteristic of most aircraft time histories.

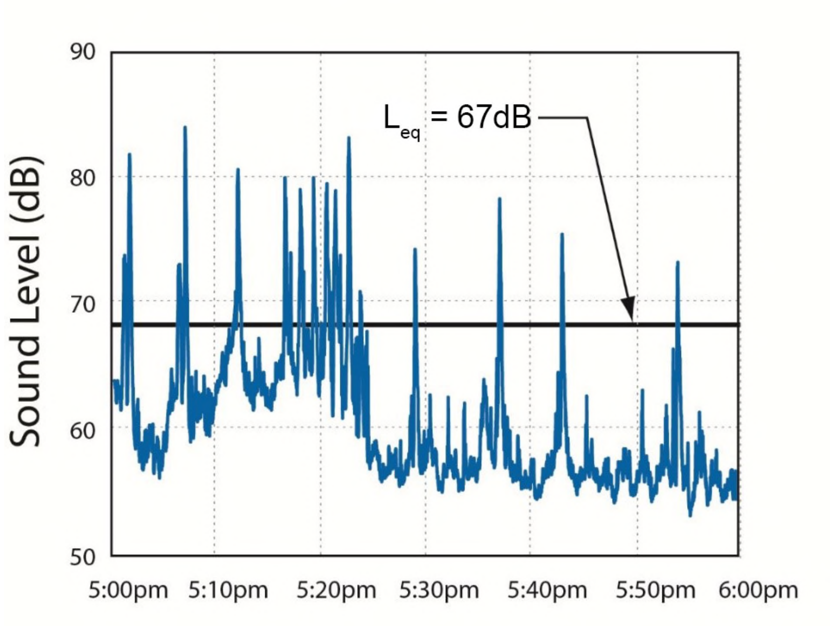

Figure A-12. Example of Hourly Equivalent Sound Level [$L_{eq(h)}$] Calculated from a Time History of Sound Levels

The equivalent sound level is not the mean sound level during the period of interest but the level of continuous sound delivering the same amount of acoustic energy as the actual time-varying sound.

Community Noise Equivalent Level (CNEL)

To capture the people's heightened sensitivity of nighttime noise, when ambient or background noise tends to diminish and the atmospheric conditions can tend to attenuate sound to a lesser degree (e.g., wind diminishes or temperature inversions might form), CNEL is calculated in three parts: a twelve-hour daytime L_{eq} (7 a.m. to 6:59 p.m.), a three-hour evening L_{eq} (7 p.m.to 9:59 p.m.) and a nine-hour nighttime L_{eq} (10 p.m.to 6:59 a.m.). When calculating the 24-hour CNEL, the evening L_{eq} is treated as if it were (nearly) 5 decibels higher and the nighttime L_{eq} is treated as if it were 10 decibels higher to account for the additional intrusiveness of noise at evening and night, respectively. An alternative way of describing this adjustment is that each event occurring during the evening and nighttime periods calculated is as if it were equivalent to three and ten daytime events, respectively.

Figure A-13 shows an example of CNEL calculated from $L_{eq(h)}$. The light blue bars are the base $L_{eq(h)}$. The cyan bars depict the evening penalty and the red-hashed bars denote the nighttime penalty. The CNEL, depicted by the red line in the figure, computed from the 24 $L_{eq(h)}$ values, is 66 dB for the day. Note, in this example, the CNEL is greater than all but six of the weighted $L_{eq(h)}$ values. This is typical of most CNEL calculations.

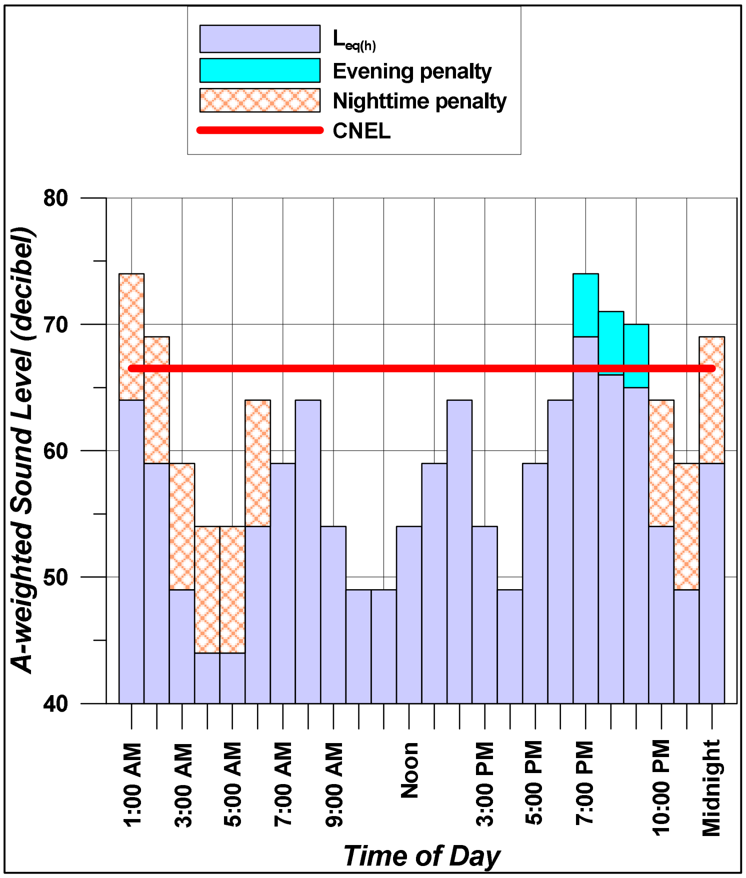

Figure A-13. Example of CNEL Calculated from $L_{eq(h)}$

CNEL is the 24-hour equivalent sound level but with weightings for evening and nighttime periods.

A.4 Noise Contours

Noise levels are usually presented at discrete, fixed observer locations or alternatively are presented as contours (i.e. lines/curves connecting points of equal values) depicting the area where the specified levels are exceeded. Noise levels are used - especially cumulative metrics - in assessment of effects from all domains of transportation noise: road, railway and air-traffic, as well as for the description of the noise produced from industrial sources, recreational activities etc. In practice, contours are almost always estimated via calculation (i.e., modeled) whereas values at specific locations can also be measured directly (except in the case of forecasted future activity).

A.5 Airport Flow Conditions and Runway Complexes

LAX has two groups of runways called runway complexes. The northern complex consists of Runways 24L/R and 06L/R. The southern complex consists of Runways 25L/R and 07L/R.

LAX has three flow conditions (LAWA 2018a). Westerly flow is the normal traffic pattern used at LAX during the daytime (6:30 a.m. to midnight) throughout the year. As depicted in Figure A-14, aircraft approach and depart the airport to the west due to the prevailing westerly wind. In West flow, departures are usually from the 'inboard' runways, i.e., 24L and 25R, and arrivals are to the 'outboard' runways, i.e., 24R and 25L.

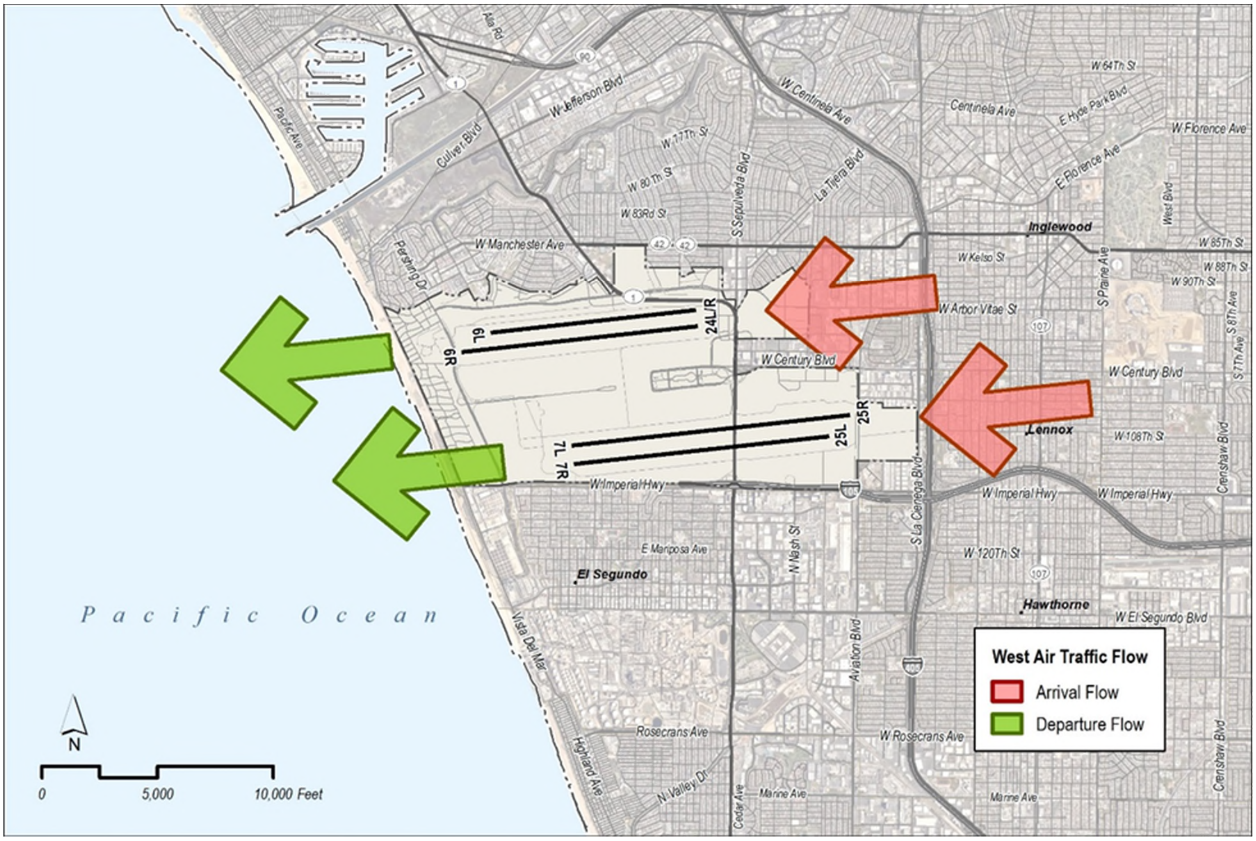

Figure A-14. Westerly Flow at LAX

In West flow, aircraft arrive from the east and depart to the west.

During the more noise-sensitive nighttime period between midnight and 6:30 a.m. and as depicted in Figure A-15, aircraft normally operate in what's called over-ocean flow where aircraft arrive and depart the 'inboard' runways, i.e., arrivals on 06R and 07L and departures on 24L and 25R. Considerations such as fog/low clouds at the shoreline, easterly winds, runway maintenance/repairs, FAA equipment problems and air traffic, may cause over-ocean operations to be canceled (and westerly flow activated).

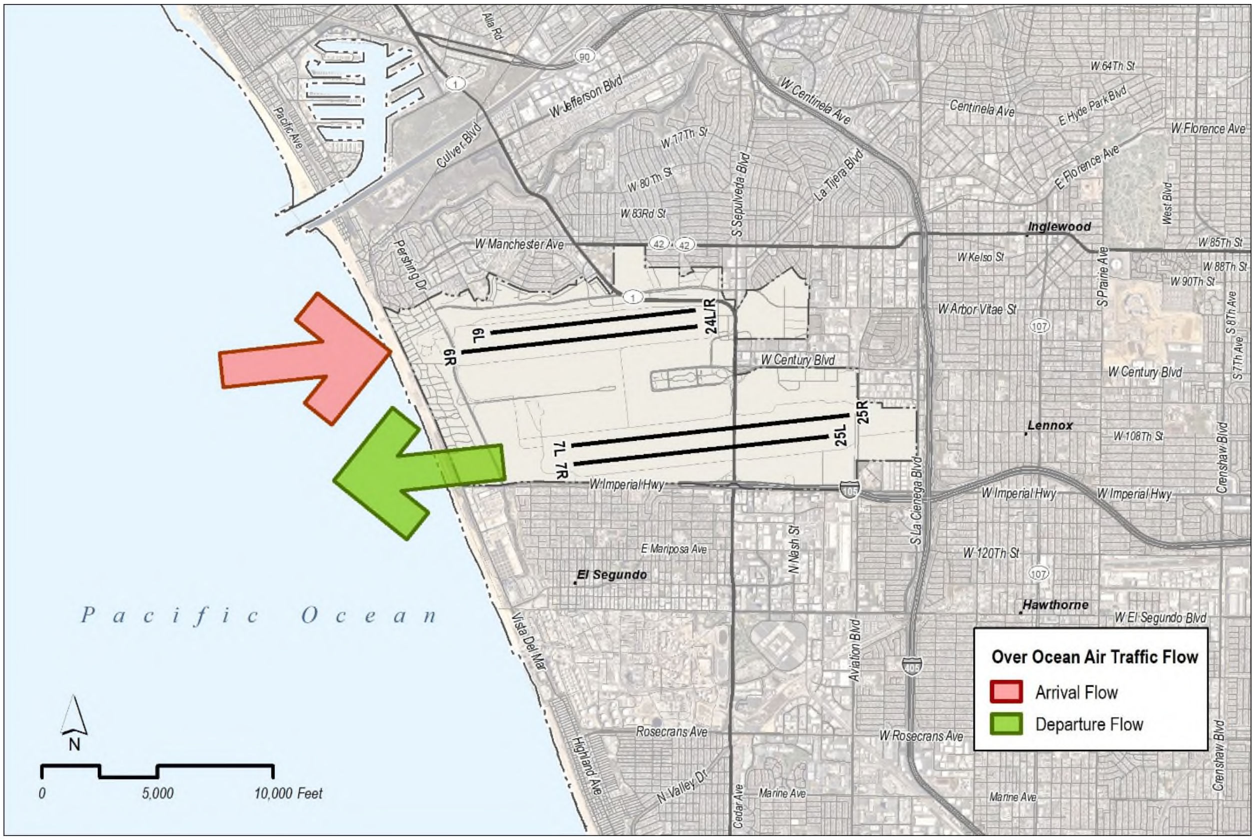

Figure A-15. An Example of Over-Ocean Flow at LAX

In Over-ocean flow, aircraft arrive from the west and depart to the west.

Easterly flow occurs during periods of abnormal winds [generally during rainstorms and Santa Ana (easterly winds)] when westerly or over-ocean operations cannot safely be accomplished. In East flow and as depicted in Figure A-16, departures are usually from the 'inboard' runways, i.e., 06R and 07L, while arrivals are to the 'outboard' runways, i.e., 06L and 07R.

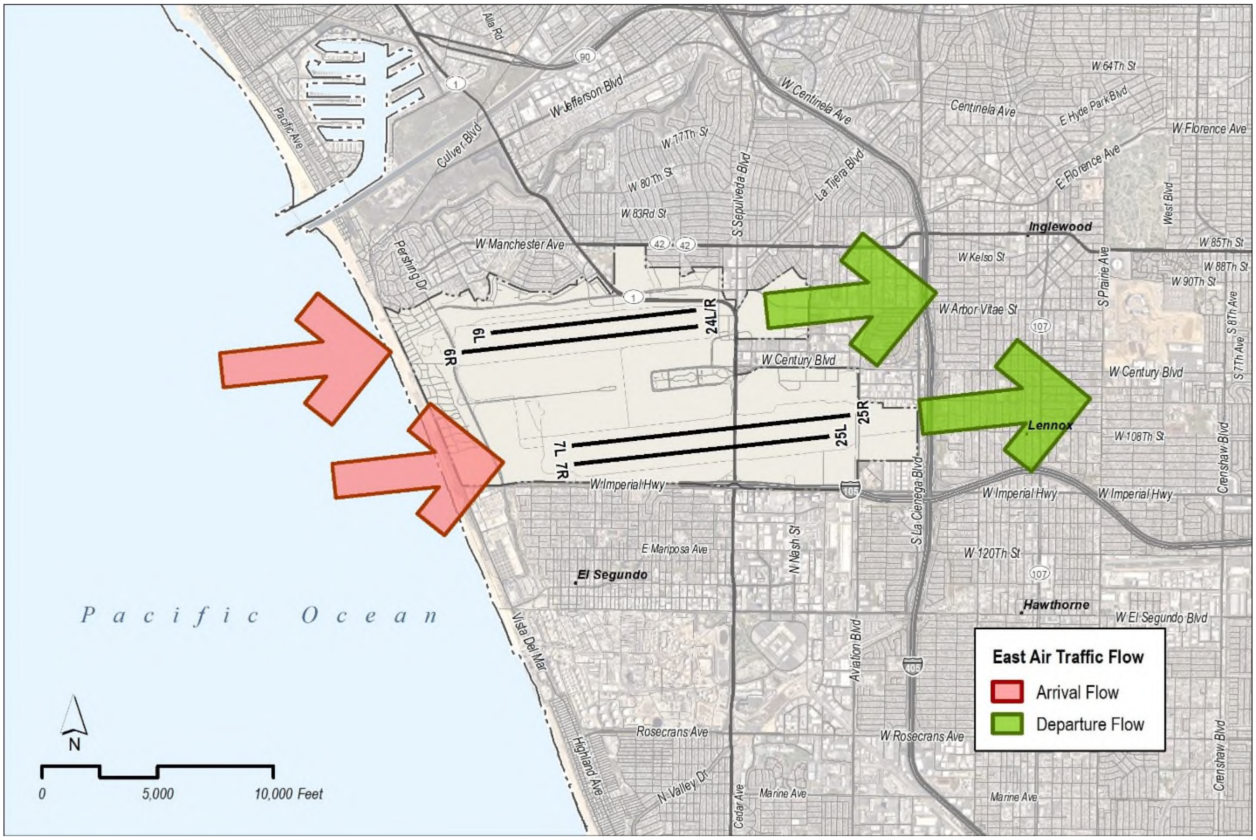

Figure A-16. Easterly Flow at LAX

In East flow, aircraft arrive from the west and depart to the east.

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Appendix B – Details

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Contents

Figures

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B.1 Instrumentation

The following instruments were used to conduct the field noise measurements:

- Brüel & Kjær (B&K) 3655 Precision-grade (Type 1) Sound Level Meter, Serial Number 3007161
- Acoustical Calibrator - Brüel & Kjær Type 4231 (94 dBA SPL @ 1000 Hz), Serial Number 3012877;
- Vaisala weather station, Model WXT 536, Serial Number M3420215.
- Global Positioning System –software app on a cell phone Polaris Navigation GPS V.8.63 (www.discipleskies.com)

The SLM calibration certificate is contained in section B.2.

The SLM was set on “Slow” response mode, and used the “A” weighting filter network. C-weighted data was later obtained from the manufacturer’s processing for checks into low-frequency noise.

B.2 Calibration Certificate

Brüel & Kjær
North America Inc.

The Brüel & Kjær Calibration Laboratory
3079 Premiere Parkway Suite 120
Duluth, GA 30097
Telephone: 770/209-6907
Fax: 770/447-4033
Web site address: http://www.bkhome.com

ACCREDITED

Calibration Certificate Number 1568.01

CERTIFICATE OF CALIBRATION

Certificate No: CAS-237105-F4G4F4-201

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CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2250	Serial No: 3007161
Microphone:	Brüel & Kjær	4952	Serial No: 2993532
Supplied Calibrator:	Brüel & Kjær	4231	Serial No: 3012877
Software version:	BZ7232 Version 4.5		

CLIENT:

Bruel & Kjaer EMS
2330 East Bidwell Street
Folsom, CA 95630

CALIBRATION CONDITIONS:

Preconditioning: 4 hours at 23 ± 3 °C
Environment conditions: See actual values in Environmental Condition sections

SPECIFICATIONS:

This document certifies that the instrument as listed under "Model/Serial Number" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurement. The calibration of the listed instrumentation, was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and ISO 10012-1. For "as received" and/or "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation This Certificate and attached data pages shall not be reproduced, except in full, without the written approval of the Brüel and Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. This instrument has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

Brüel and Kjær Model 3630 Sound Level Meter Calibration System Software 7763 Version 6.0 - DB: 6.01 Test Collection 2250-L-4952.

RESULTS:

As Received Condition	As Received Data	Final Data
_X_ Received in good condition	_X_ Within acceptance criteria	_X_ Within acceptance criteria
___ Damaged - See attached report	___ Outside acceptance criteria	___ Limited test - See attached details
	___ Inoperative	
	___ Data not taken	

Date of Calibration: 07 Aug. 2017

Certificate issued: 07 Aug. 2017

Roy Moss
Calibration Technician

John Atilik
Quality Representative

hmmh

CERTIFICATE OF CALIBRATION

Certificate No: CAS-237105-F4G4F4-201

Summary

Preliminary inspection	Passed
Environmental conditions, Prior to calibration	Passed
Reference information	Passed
Indication at the calibration check frequency	Passed
Acoustical signal tests of a frequency weighting, C weighting	Passed
Self-generated noise, Microphone installed	Passed
Self-generated noise, Electrical	Passed
Electrical signal tests of frequency weightings, A weighting	Passed
Electrical signal tests of frequency weightings, C weighting	Passed
Electrical signal tests of frequency weightings, Z weighting	Passed
Frequency and time weightings at 1 kHz	Passed
Level linearity on the reference level range, Upper	Passed
Level linearity on the reference level range, Lower	Passed
Toneburst response, Time-weighting Fast	Passed
Toneburst response, Time-weighting Slow	Passed
Toneburst response, Leq	Passed
Peak C sound level, 8 kHz	Passed
Peak C sound level, 500 Hz	Passed
Overload indication	Passed
Environmental conditions, Following calibration	Passed

The sound level meter submitted for periodic testing successfully completed the class 1 tests of IEC 61672-3:2006, for the environmental conditions under which the tests were performed.
However, no general statement or conclusion can be made about conformance of the sound level meter to the full requirements of IEC 61672-1:2002 because evidence was not publicly available, from an independent testing organization responsible for pattern approvals, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2002 and because the periodic test of IEC 61672-3:2006 cover only a limited subset of the specifications in IEC 61672-1:2002.

Conformance to the requirements of IEC 61672-3:2006, is demonstrated when the measured deviations extended by the actual expanded uncertainties of measurement, do not exceed the applicable tolerance limits given in IEC 61672-1:2002. (as specified in IEC 61672-3:2006 § 4.1)

Instruments

Category:	Type:	Manufacturer:	Serial No.:	Next Calibration Date:	Traceable to:
Adaptor	WA0302A, 12 pF	Brüel & Kjær	2454551	31 Dec. 2018	402090
Voltmeter	DMM34970A	Agilent	41030882	31 Jan. 2018	404103
Generator	Pulse Generator	Brüel & Kjær	2604447	31 Aug. 2017	CAS-212121-C8J1D8-805
Calibrator	4226	Brüel & Kjær	2590978	31 Jan. 2018	CAS-191009-G3K8K2-901
AmplifierDivider	3111 Output Module	Brüel & Kjær	2590603	31 Aug. 2017	CAS-212121-C8J1D8-805

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Preliminary inspection

Visually inspect instrument, and operate all relevant controls. (section 5)

	Result	Uncertainty
Visual inspection	OK	
Visual inspection	OK	

Environmental conditions, Prior to calibration

Actual environmental conditions prior to calibration. (section 7)

	Measured [Deg C/ kPa / %RH]
Air temperature	23.00
Air pressure	97.10
Relative humidity	52.00

Reference information

Information about reference range, level and channel. (section 19.h + 19.m)

	Value [dB]
Reference sound pressure level	94
Reference level range	140
Channel number	1

Indication at the calibration check frequency

Measure and adjust sound level meter using the supplied calibrator. (section 9 + 19.m)

	Expected [dB / Hz]	Measured [dB / Hz]	Uncertainty [dB]
Initial indication (supplied calibrator)	94.00	93.83	0.14
Calibration check frequency (supplied calibrator)	1000.00	1000.00	1.00
Adjusted indication (supplied calibrator)	94.00	93.83	0.14

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Acoustical signal tests of a frequency weighting, C weighting

Frequency weightings measured acoustically with a calibrated multi-frequency sound calibrator. Averaging time is 10 seconds, and the result is the average of 2 measurements. (section 11)

	Coupler Pressure Lc [dB]	Mic. Correction C4226 [dB]	Body Influence [dB]	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
1000Hz, Ref. (1st)	93.98	0.41	0.00	93.57	93.81	-1.1	1.1	0.24	0.20
1000Hz, Ref. (2nd)	93.98	0.41	0.00	93.57	93.80	-1.1	1.1	0.23	0.20
1000Hz, Ref. (Average)	93.98	0.41	0.00	93.57	93.81	-1.1	1.1	0.24	0.20
125.89Hz (1st)	94.00	-0.03	0.00	94.06	93.92	-1.5	1.5	-0.14	0.20
125.89Hz (2nd)	94.00	-0.03	0.00	94.06	93.87	-1.5	1.5	-0.19	0.20
125.89Hz (Average)	94.00	-0.03	0.00	94.06	93.90	-1.5	1.5	-0.16	0.20
3981.1Hz (1st)	93.81	2.24	0.00	91.01	91.69	-1.6	1.6	0.68	0.30
3981.1Hz (2nd)	93.81	2.24	0.00	91.01	91.69	-1.6	1.6	0.68	0.30
3981.1Hz (Average)	93.81	2.24	0.00	91.01	91.69	-1.6	1.6	0.68	0.30
7943.3Hz (1st)	93.46	5.02	0.00	85.67	86.48	-3.1	2.1	0.81	0.40
7943.3Hz (2nd)	93.46	5.02	0.00	85.67	86.48	-3.1	2.1	0.81	0.40
7943.3Hz (Average)	93.46	5.02	0.00	85.67	86.48	-3.1	2.1	0.81	0.40

Self-generated noise, Microphone installed

Self-generated noise measured with microphone submitted for periodic testing, and with sensitivity set to nominal microphone open circuit sensitivity. Averaging time is 30 seconds. An anechoic chamber is used to isolate environmental noise. (section 10.1)

	Max [dB]	Measured [dB]	Deviation [dB]	Uncertainty [dB]	
A weighted	21.10	18.08	-3.02	0.50	*
Monitor Level	24.10	5.86	-18.24	0.50	*

Self-generated noise, Electrical

Self-generated noise measured in most sensitive range, with electrical substitution for microphone, according to manufacturer's specifications. The noise is measured with sensitivity set to nominal microphone open circuit sensitivity.
Exceedance of the measured level above the corresponding level given in the instruction manual does not, by itself, mean that the performance of the sound level meter is no longer acceptable for many practical applications. (section 10.2)

	Max [dB]	Measured [dB]	Uncertainty [dB]	
A weighted	19.90	15.94	0.30	*
C weighted	20.10	16.48	0.30	*
Z weighted	25.90	21.73	0.30	*

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Electrical signal tests of frequency weightings, A weighting

Frequency response measured with electrical signal relative to level at 1 kHz in reference range. (section 12)

	Input Level [dBV]	Expected [dB]	Measured [dB]	El.+Acous. Resp. [dB]	Body Influence [dB]	Corr. Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
1000Hz, Ref.	-27.79	95.00	95.00	0.35	0.00	95.35	-1.1	1.1	0.35	0.12
63.096Hz	-1.59	95.00	95.01	0.39	0.00	95.40	-1.5	1.5	0.40	0.12
125.89Hz	-11.69	95.00	95.00	0.27	0.00	95.27	-1.5	1.5	0.27	0.12
251.19Hz	-19.19	95.00	94.96	0.21	0.00	95.17	-1.4	1.4	0.17	0.12
501.19Hz	-24.59	95.00	94.96	0.26	0.00	95.22	-1.4	1.4	0.22	0.12
1995.3Hz	-28.99	95.00	95.00	0.81	0.00	95.81	-1.6	1.6	0.81	0.12
3981.1Hz	-28.79	95.00	94.96	1.08	0.00	96.04	-1.6	1.6	1.04	0.12
7943.3Hz	-26.69	95.00	94.98	1.43	0.00	96.41	-3.1	2.1	1.41	0.12
15849Hz	-21.19	95.00	94.97	-6.13	0.00	88.84	-17.0	3.5	-6.16	0.12

Electrical signal tests of frequency weightings, C weighting

Frequency response measured with electrical signal relative to level at 1 kHz in reference range. (section 12)

	Input Level [dBV]	Expected [dB]	Measured [dB]	El.+Acous. Resp. [dB]	Body Influence [dB]	Corr. Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
1000Hz, Ref.	-27.79	95.00	95.00	0.35	0.00	95.35	-1.1	1.1	0.35	0.12
63.096Hz	-26.99	95.00	94.97	0.39	0.00	95.36	-1.5	1.5	0.36	0.12
125.89Hz	-27.59	95.00	95.02	0.27	0.00	95.29	-1.5	1.5	0.29	0.12
251.19Hz	-27.79	95.00	94.99	0.21	0.00	95.20	-1.4	1.4	0.20	0.12
501.19Hz	-27.79	95.00	95.03	0.26	0.00	95.29	-1.4	1.4	0.29	0.12
1995.3Hz	-27.59	95.00	95.03	0.81	0.00	95.84	-1.6	1.6	0.84	0.12
3981.1Hz	-26.99	95.00	94.97	1.08	0.00	96.05	-1.6	1.6	1.05	0.12
7943.3Hz	-24.79	95.00	94.98	1.43	0.00	96.41	-3.1	2.1	1.41	0.12
15849Hz	-19.29	95.00	94.94	-6.13	0.00	88.81	-17.0	3.5	-6.19	0.12

Electrical signal tests of frequency weightings, Z weighting

Frequency response measured with electrical signal relative to level at 1 kHz in reference range. (section 12)

	Input Level [dBV]	Expected [dB]	Measured [dB]	El.+Acous. Resp. [dB]	Body Influence [dB]	Corr. Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
1000Hz, Ref.	-27.79	95.00	95.00	0.35	0.00	95.35	-1.1	1.1	0.35	0.12
63.096Hz	-27.79	95.00	94.99	0.39	0.00	95.38	-1.5	1.5	0.38	0.12
125.89Hz	-27.79	95.00	94.99	0.27	0.00	95.26	-1.5	1.5	0.26	0.12
251.19Hz	-27.79	95.00	94.99	0.21	0.00	95.20	-1.4	1.4	0.20	0.12
501.19Hz	-27.79	95.00	94.99	0.26	0.00	95.25	-1.4	1.4	0.25	0.12
1995.3Hz	-27.79	95.00	95.00	0.81	0.00	95.81	-1.6	1.6	0.81	0.12
3981.1Hz	-27.79	95.00	94.99	1.08	0.00	96.07	-1.6	1.6	1.07	0.12
7943.3Hz	-27.79	95.00	94.98	1.43	0.00	96.41	-3.1	2.1	1.41	0.12
15849Hz	-27.79	95.00	95.00	-6.13	0.00	88.87	-17.0	3.5	-6.13	0.12

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Frequency and time weightings at 1 kHz

Frequency and time weighting measured at 1 kHz with electrical signal in reference range. Measured relative to A-weighted and Fast response. (section 13)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
LAF, Ref.	94.00	94.00	-0.4	0.4	0.00	0.12
LCF	94.00	94.00	-0.4	0.4	0.00	0.12
LZF	94.00	94.00	-0.4	0.4	0.00	0.12
LAS	94.00	94.00	-0.3	0.3	0.00	0.12
LAeq	94.00	94.00	-0.3	0.3	0.00	0.12

Level linearity on the reference level range, Upper

Level linearity in reference range, measured at 8 kHz until overload. (section 14)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
94 dB	94.00	94.00	-1.1	1.1	0.00	0.13
99 dB	99.00	99.00	-1.1	1.1	0.00	0.13
104 dB	104.00	104.00	-1.1	1.1	0.00	0.13
109 dB	109.00	109.01	-1.1	1.1	0.01	0.13
114 dB	114.00	114.02	-1.1	1.1	0.02	0.13
119 dB	119.00	119.02	-1.1	1.1	0.02	0.13
124 dB	124.00	124.02	-1.1	1.1	0.02	0.13
129 dB	129.00	129.03	-1.1	1.1	0.03	0.13
134 dB	134.00	134.03	-1.1	1.1	0.03	0.13
135 dB	135.00	135.03	-1.1	1.1	0.03	0.13
136 dB	136.00	136.02	-1.1	1.1	0.02	0.13
137 dB	137.00	137.03	-1.1	1.1	0.03	0.13
138 dB	138.00	138.03	-1.1	1.1	0.03	0.13
139 dB	139.00	139.03	-1.1	1.1	0.03	0.13
140 dB	140.00	140.02	-1.1	1.1	0.02	0.13
141 dB	141.00	141.03	-1.1	1.1	0.03	0.13
142 dB	142.00	142.03	-1.1	1.1	0.03	0.13
143 dB	143.00	143.02	-1.1	1.1	0.02	0.13

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Level linearity on the reference level range, Lower

Level linearity in reference range, measured at 8 kHz down to lower limit, or until underrange. (section 14)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
94 dB	94.00	94.00	-1.1	1.1	0.00	0.13
89 dB	89.00	89.00	-1.1	1.1	0.00	0.13
84 dB	84.00	84.00	-1.1	1.1	0.00	0.13
79 dB	79.00	79.00	-1.1	1.1	0.00	0.13
74 dB	74.00	74.00	-1.1	1.1	0.00	0.13
69 dB	69.00	69.00	-1.1	1.1	0.00	0.13
64 dB	64.00	63.99	-1.1	1.1	-0.01	0.13
59 dB	59.00	58.99	-1.1	1.1	-0.01	0.13
54 dB	54.00	54.00	-1.1	1.1	0.00	0.13
49 dB	49.00	49.00	-1.1	1.1	0.00	0.13
44 dB	44.00	44.01	-1.1	1.1	0.01	0.13
39 dB	39.00	39.04	-1.1	1.1	0.04	0.24
37 dB	37.00	37.04	-1.1	1.1	0.04	0.24
36 dB	36.00	36.07	-1.1	1.1	0.07	0.24
35 dB	35.00	35.08	-1.1	1.1	0.08	0.24
34 dB	34.00	34.08	-1.1	1.1	0.08	0.24
33 dB	33.00	33.13	-1.1	1.1	0.13	0.24
32 dB	32.00	32.14	-1.1	1.1	0.14	0.24

Toneburst response, Time-weighting Fast

Response to 4 kHz toneburst measured in reference range, relative to continuous signal. (section 16)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]	
Continuous, Ref.	137.00	137.00	-0.8	0.8	0.00	0.12	*
200 ms Burst	136.00	136.01	-0.8	0.8	0.01	0.12	*
2 ms Burst	119.00	118.93	-1.8	1.3	-0.07	0.12	*
0.25 ms Burst	110.00	109.85	-3.3	1.3	-0.15	0.12	*

Toneburst response, Time-weighting Slow

Response to 4 kHz toneburst measured in reference range, relative to continuous signal. (section 16)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]	
Continuous, Ref.	137.00	137.00	-0.8	0.8	0.00	0.12	*
200 ms Burst	129.60	129.39	-0.8	0.8	-0.21	0.12	*
2 ms Burst	110.00	109.96	-3.3	1.3	-0.04	0.12	*

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Toneburst response, Leq

Response to 4 kHz toneburst measured in reference range, relative to continuous signal. (section 16)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]	
Continuous, Ref.	137.00	137.00	-0.8	0.8	0.00	0.11	*
200 ms Burst	120.00	120.00	-0.8	0.8	0.00	0.11	*
2 ms Burst	100.00	99.96	-1.8	1.3	-0.04	0.11	*
0.25 ms Burst	91.00	90.86	-3.3	1.3	-0.14	0.11	*

Peak C sound level, 8 kHz

Peak-response to a 8 kHz single- cycle sine measured in least-sensitive range, relative to continuous signal. (section 17)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
Continuous, Ref.	135.00	135.00	-0.4	0.4	0.00	0.09
Single Sine	138.40	138.57	-2.4	2.4	0.17	0.12

Peak C sound level, 500 Hz

Peak-response to a 500 Hz half-cycle sine measured in least-sensitive range, relative to continuous signal. (section 17)

	Expected [dB]	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
Continuous, Ref.	135.00	135.00	-0.4	0.4	0.00	0.09
Half-sine, Positive	137.40	137.12	-1.4	1.4	-0.28	0.12
Half-sine, Negative	137.40	137.12	-1.4	1.4	-0.28	0.12

Overload indication

Overload indication in the least sensitive range determined with a 4 kHz positive/negative half-cycle signal. (section 18)

	Measured [dB]	Accept - Limit [dB]	Accept + Limit [dB]	Deviation [dB]	Uncertainty [dB]
Continuous	140.00	-0.4	0.4	0.00	0.20
Half-sine, Positive	144.74	-10.0	10.0	4.74	0.20
Half-sine, Negative	144.74	-10.0	10.0	4.74	0.20
Difference	144.74	-1.8	1.8	0.00	0.30

Environmental conditions, Following calibration

Actual environmental conditions following calibration. (section 7)

	Measured [Deg C/ kPa / %RH]
Air temperature	23.50
Air pressure	97.80
Relative humidity	52.00

B.3 Additional Analysis Results/Data

B.3.1 Noise and Operations

Figures B-1 through B-4 compare daily aircraft CNEL at four of LAWA's NMTs and daily flight operations on Runways 25L/R for each period, respectively. The data was provided by LAWA (LAWA 2018b). The daily aircraft CNEL for LNX1 is relatively constant at approximately 75 dB, which is expected given its location relative to the arrival paths to the south runway complex.[20] The CNEL at ESG2 is relatively constant at approximately 70 dB because of its relatively close distance from the airport. Daily aircraft CNEL varies at ESG5 and DEL1 more than the CNEL at LNX1 and ESG2 because ESG5 and DEL1 are further from the airport where other noise events in the community may be confounding the aircraft events. Daily aircraft CNEL at ESG5 is generally between 57 and 67 dB whereas it is between 45 and 65 dB at DEL1. Flight operations are shown in the cyan-colored lines and are associated with cyan-colored y-axis on the right-side of each figure.

Figure B-4 shows the days the 360 Community residents deemed 'noisy' as red diamonds. Most of the peaks in the daily aircraft CNEL time history for DEL1 and ESG5 correspond to the noisy days lending credence to the residents' claims.

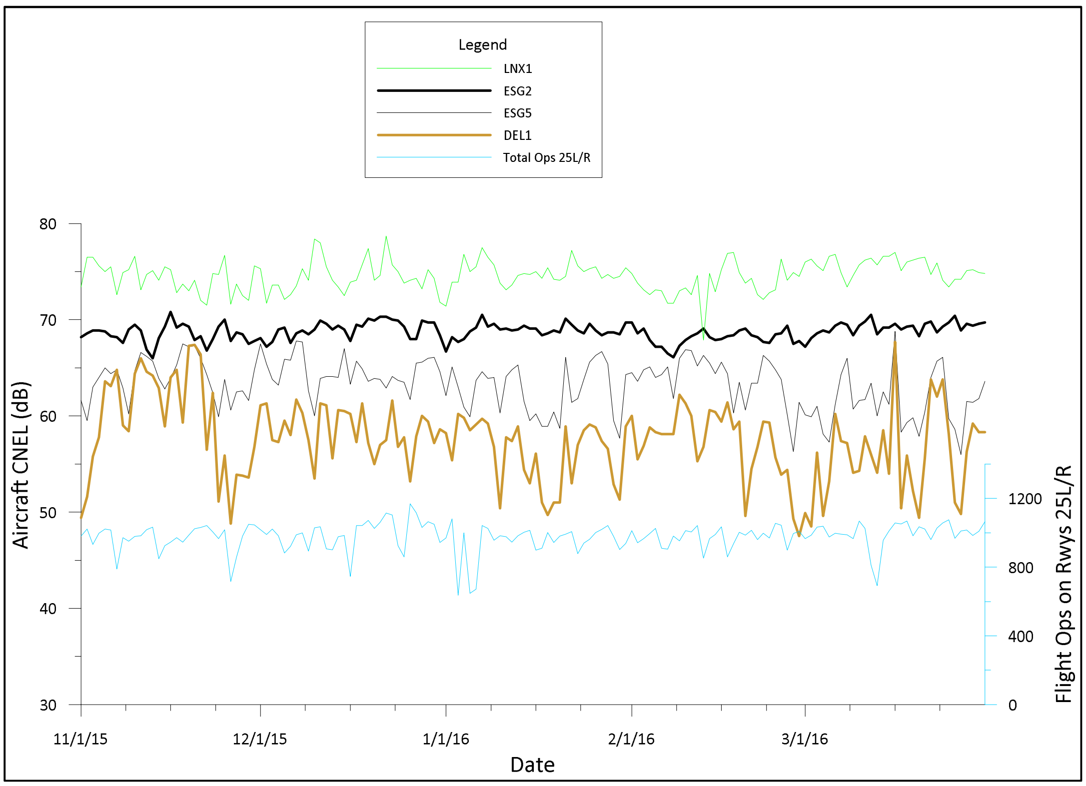

Figure B-1. Daily Aircraft CNEL and Relevant Flight Operations for November 2015 through March 2016

1) Daily CNEL is mostly unaffected by changes in daily flight operations of less than 20%. 2) NMTs further away from the airport exhibit more variation in daily CNEL than NMTs closer to typical flight paths.

[20] LNX1 data contains gaps due to the NMT not operating at least 75% of each day or due to technical issues.

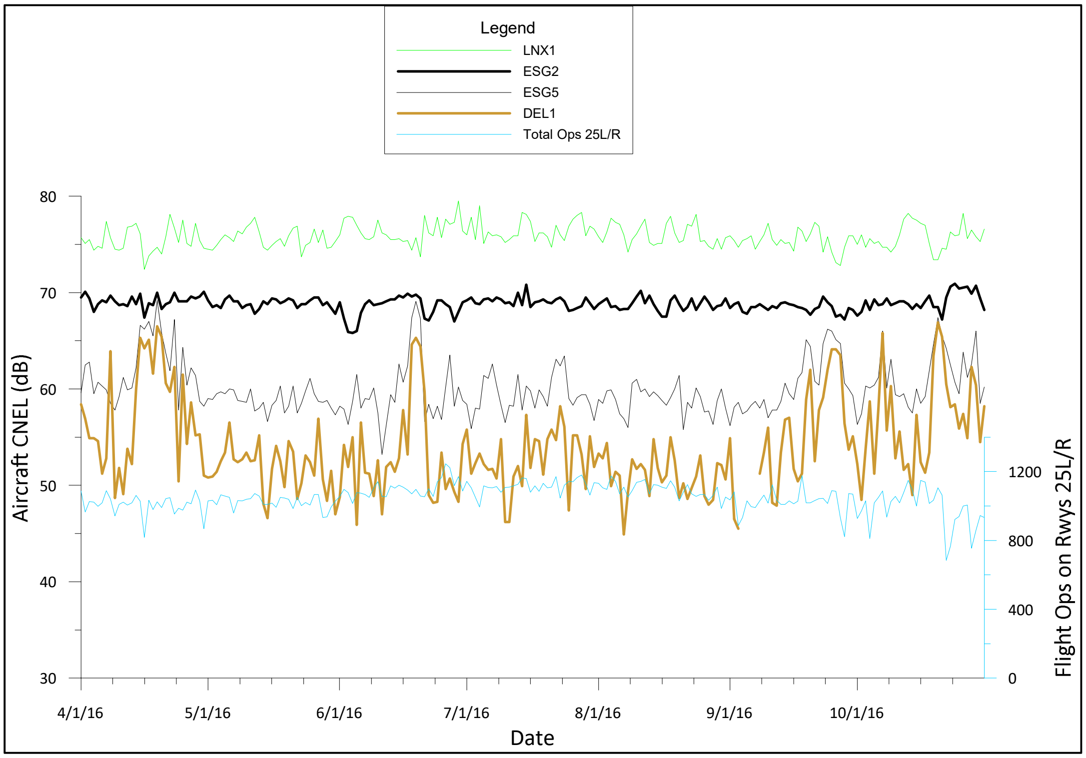

Figure B-2. Daily Aircraft CNEL and Relevant Flight Operations for April 2016 through October 2016

1) Daily CNEL is mostly unaffected by changes in daily flight operations of less than 20%. 2) NMTs further away from the airport exhibit more variation in daily CNEL than NMTs closer to typical flight paths. 3) Daily CNEL at DEL1 and ESG5 are highly correlated with each other but not correlated to changes in daily flight operations 4) Noise levels at DEL1 and ESG5 are generally lower than in the previous figure.

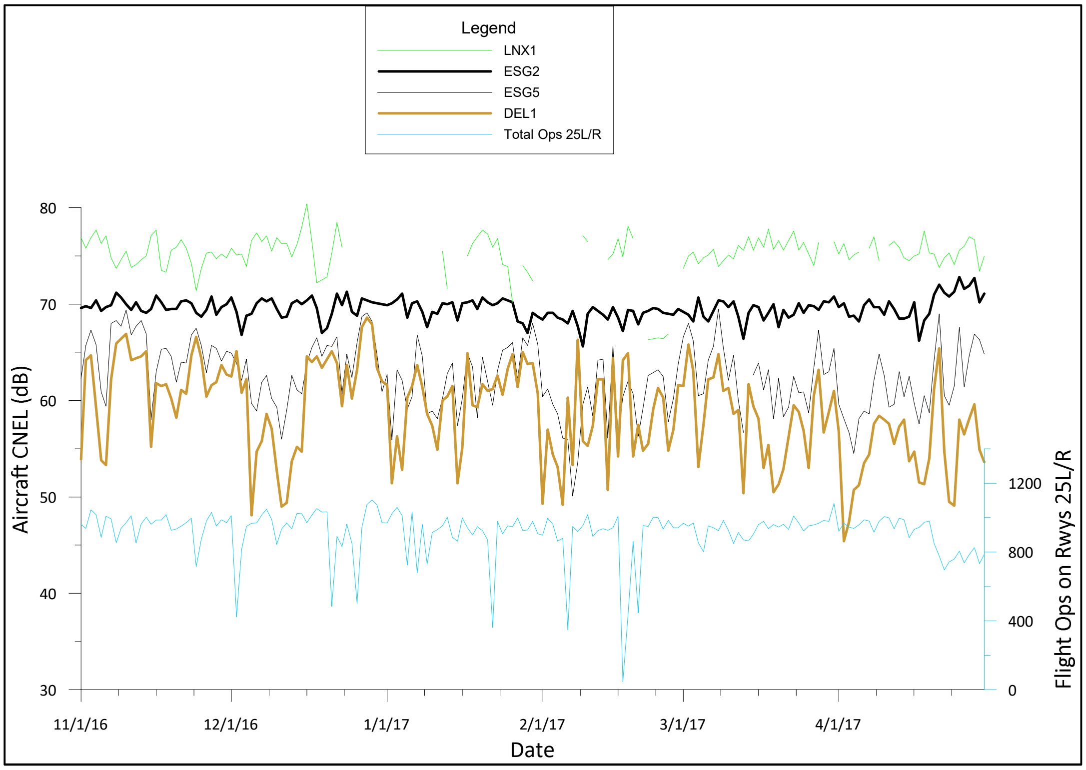

Figure B-3. Daily Aircraft CNEL and Relevant Flight Operations for November 2016 through April 2017

1) Daily CNEL is mostly unaffected by changes in daily flight operations of less than 20%. 2) NMTs further away from the airport exhibit more variation in daily CNEL than NMTs closer to typical flight paths. 3) Daily CNEL at DEL1 and ESG5 are highly correlated with each other but not correlated to changes in daily flight operations 4) Noise levels at DEL1 and ESG5 are noticeably higher than in the previous figure but flight operations are noticeably lower than in the previous figure.

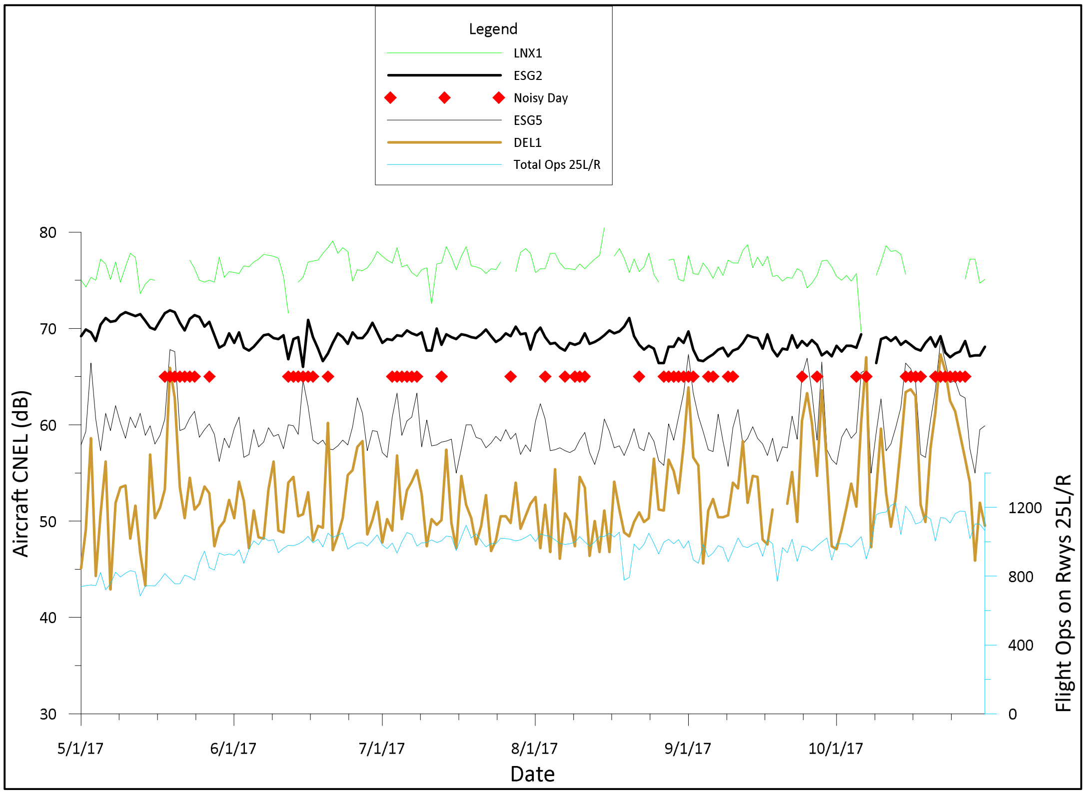

Figure B-4. Daily Aircraft CNEL and Relevant Flight Operations for May 2017 through October 2017

1) Daily CNEL is mostly unaffected by changes in daily flight operations of less than 20%. 2) NMTs further away from the airport exhibit more variation in daily CNEL than NMTs closer to typical flight paths. 3) Daily CNEL at DEL1 and ESG5 are highly correlated with each other but not correlated to changes in daily flight operations 4) Noise levels at DEL1 and ESG5 are noticeably lower than in the previous figure.

B.3.2 Flow Data

Figure B-5 compares the daily aircraft CNELs from DEL1 and ESG5 and 'noisy' days with the LAWA-provided number of daily hours in each flow. No easterly flow occurred in October 2017. The FAA deviated from Over-Ocean Operations and maintained West flow for more than half of the month. The flow condition does not correlate with the reports of 'noisy' days.

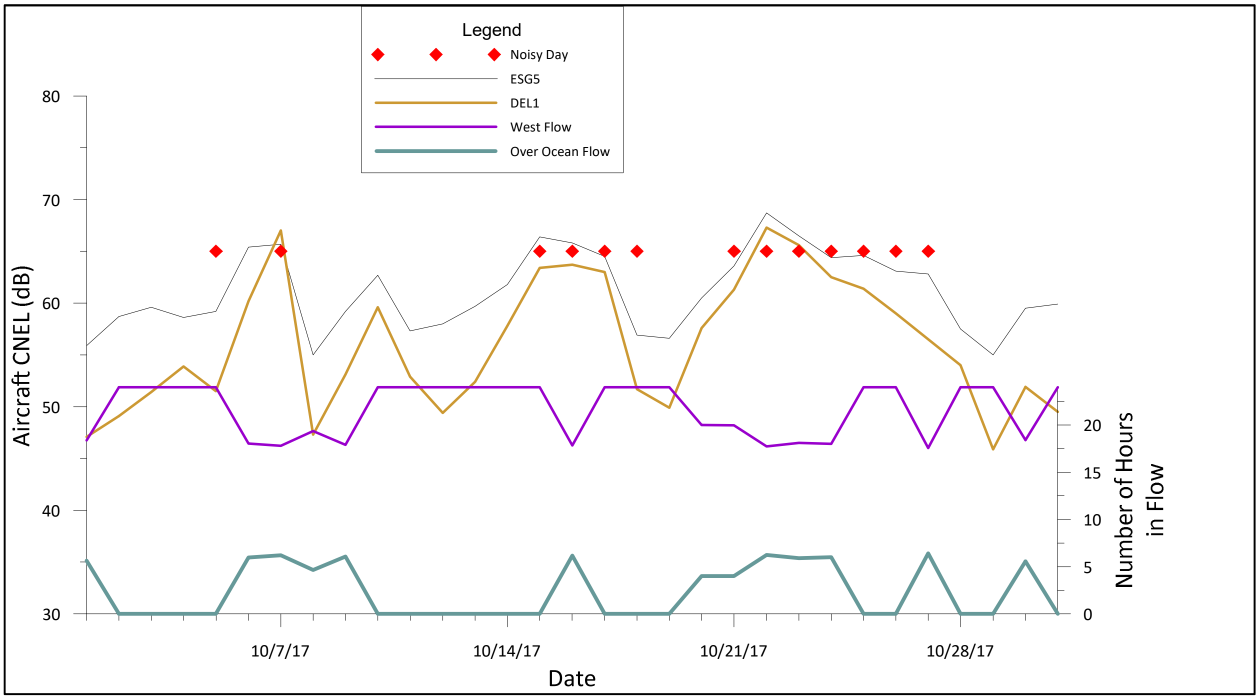

Figure B-5. Daily Aircraft CNEL and Airport Flow Condition for October 2017

1) LAX was in West flow for most of the time. 2) Only two of the noisy days had West flow for equal or less time than Over-ocean flow. 3) Most noisy days had higher sound levels at DEL1 and ESG5 than 'not noisy' days.

Figures B-6 and B-7 show the daily aircraft CNEL data from the 360 site, along with the resident's logged noisiness code and LAWA-provided number of daily hours in each flow, for the first and second halves of the measurement period, respectively. West flow dominated the measurement period. East flow occurred on March 22, 2018 for approximately 3 hours. The flow condition does not correlate with the 'excessively' or 'extremely' loud periods.

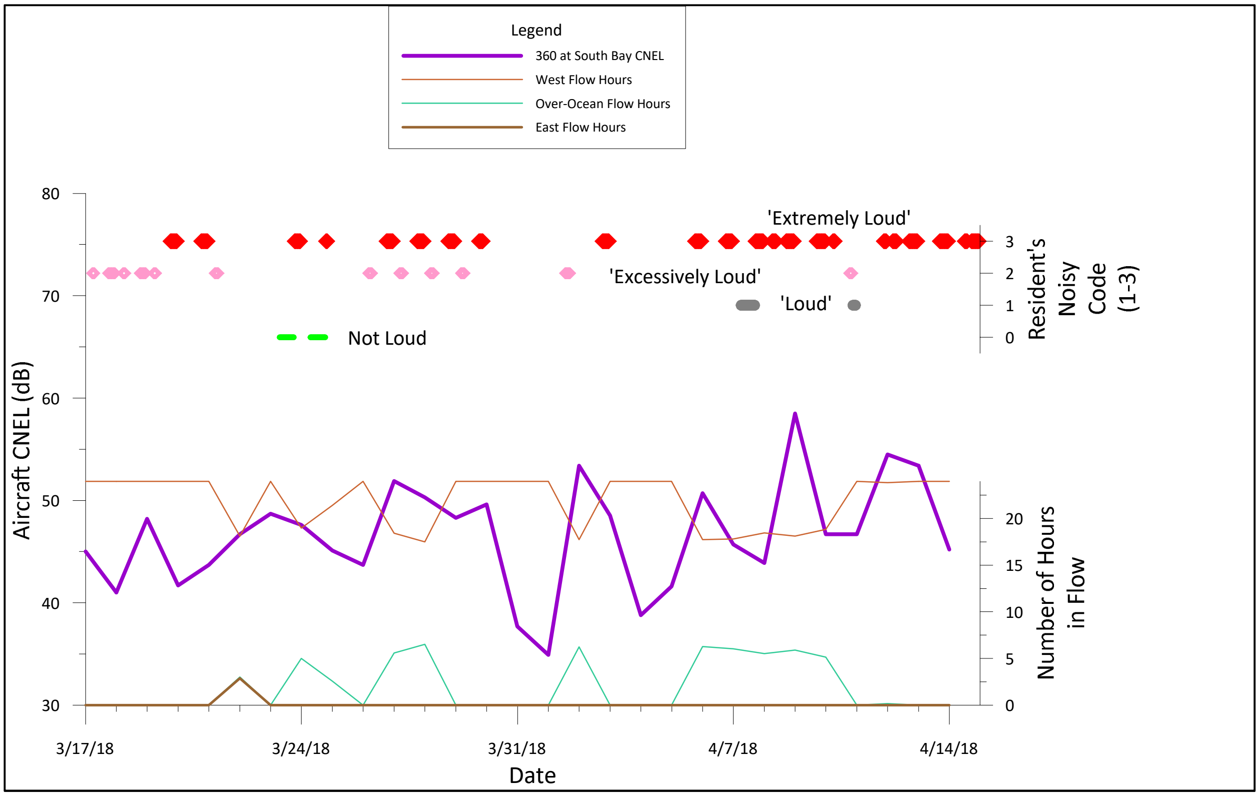

Figure B-6. Daily Aircraft CNEL and Airport Flow Condition for the First Half of the Measurement Period

1) LAX was in West flow for most of the time. 2) The loudness observations did not correlate with the flow condition or time in flow. 3) Daily aircraft CNEL at the 360 site correlated with over-ocean flow duration.

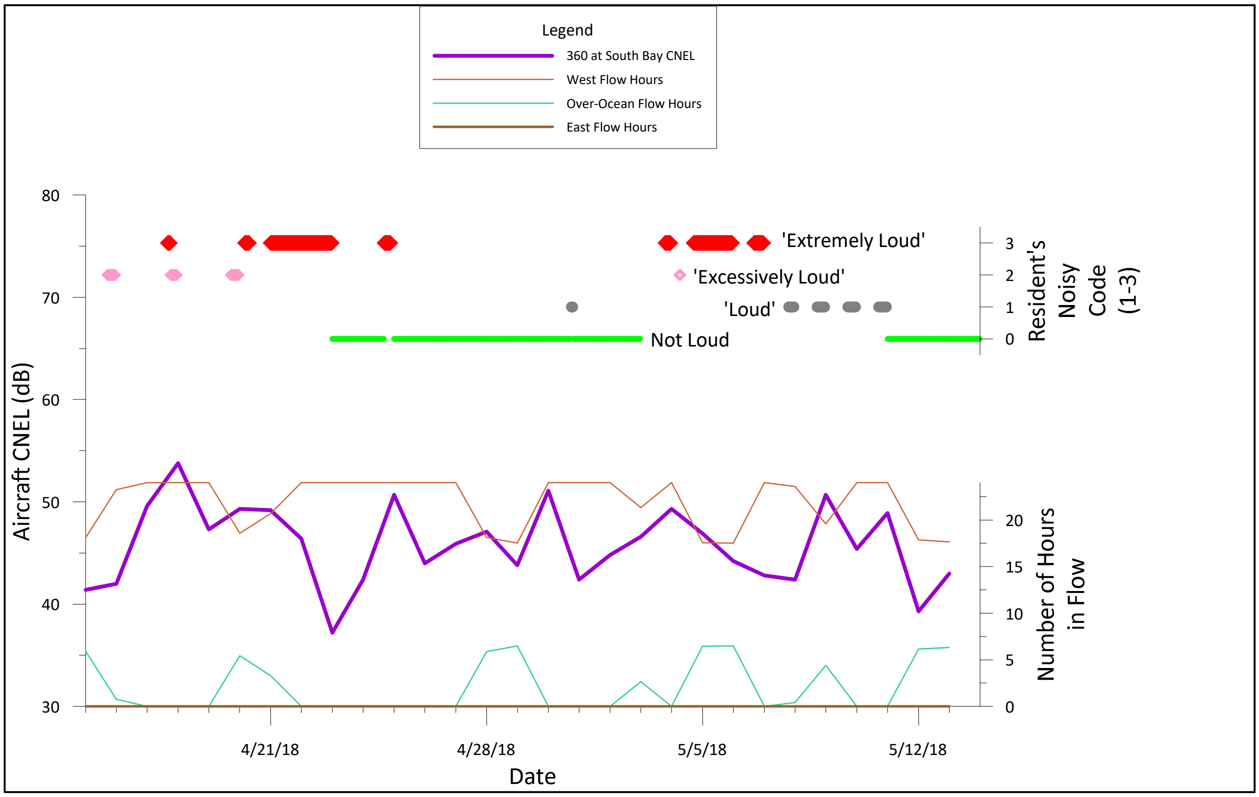

Figure B-7. Daily Aircraft CNEL and Airport Flow Condition for the Second Half of the Measurement Period

1) LAX was in West flow for most of the time. 2) The loudness observations did not correlate with the flow condition or time in flow. 3) Daily aircraft CNEL at the 360 site did not correlate with over-ocean flow duration.

B.3.3 Runway Closure

Figure B-8 compares the daily aircraft CNELs from DEL1 and ESG5 and 'noisy' days with the LAWA-provided number of daily hours each runway pair was closed. The northern outboard runway (Runway 06L/24R) was closed for most of the month, beginning October 9, 2017. During this closure, operations increased on the southern complex (closer to the 360 Community).

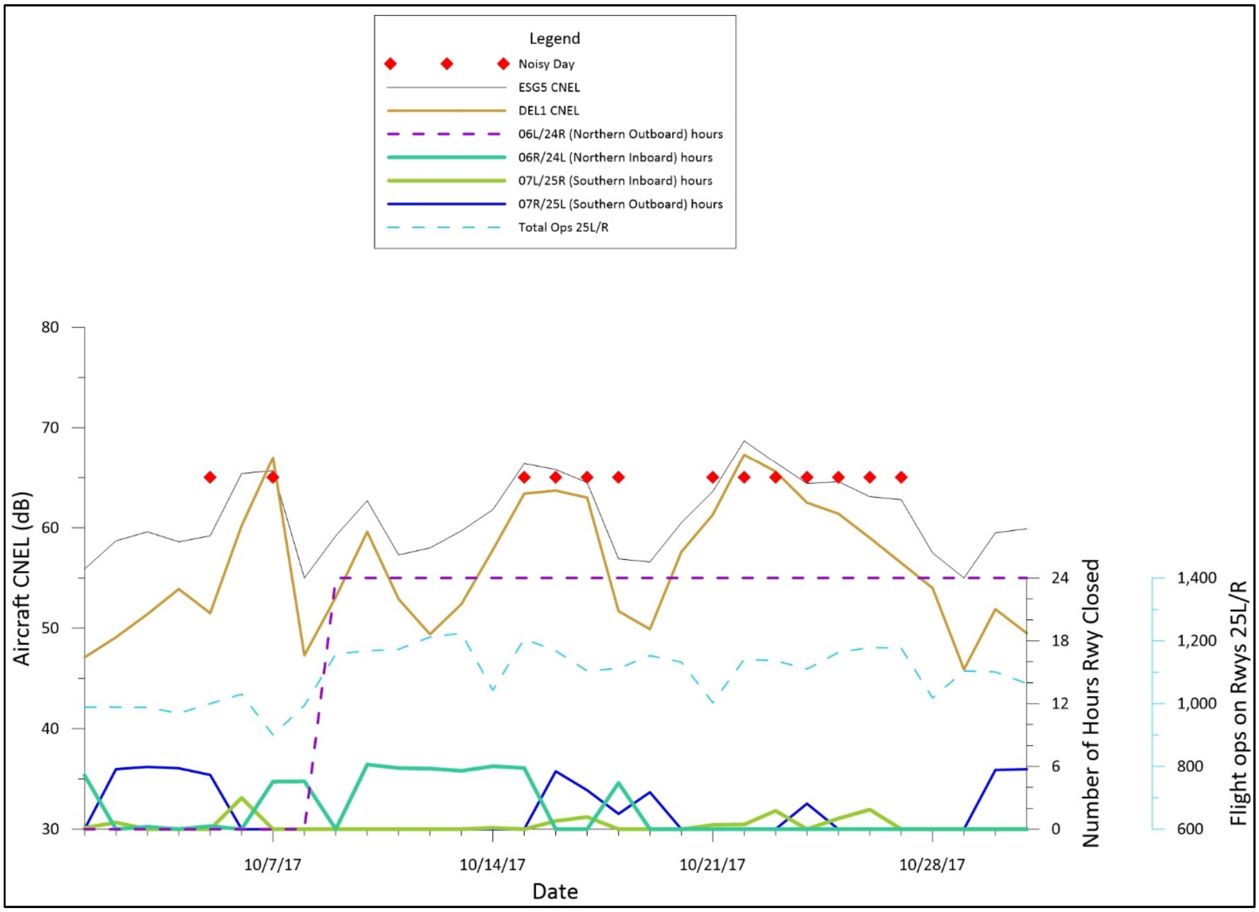

Figure B-8. Daily Aircraft CNEL, Runway Closure and Flight Operations for October 2017

1) Daily aircraft CNEL at DEL1 correlated with CNEL at ESG5. 2) Although there was an increase in operations on the southern runway complex, closer to the 360 Community, (caused by the closure of Runway 06L/24R), the operations did not correlate with the daily aircraft CNEL at DEL1 and ESG5; however, there were more noisy days logged during the Runway 06L/24R closure period.

Figures B-9 and B-10 show runway closure for the measurement period. The southern complex's inboard runway, Runway 07L/25R, was closed for the entire measurement period. In fact, its closure began on January 20, 2018. The westerly arrival and departure operations on the southern complex remained relatively constant even though Runway 07L/25R was closed and amongst closures of other runways. Runway closure does not correlate with any of the loud-logged periods. There were a few times (but not all) when the southern complex was closed and 'not loud' (code 0) was applicable.

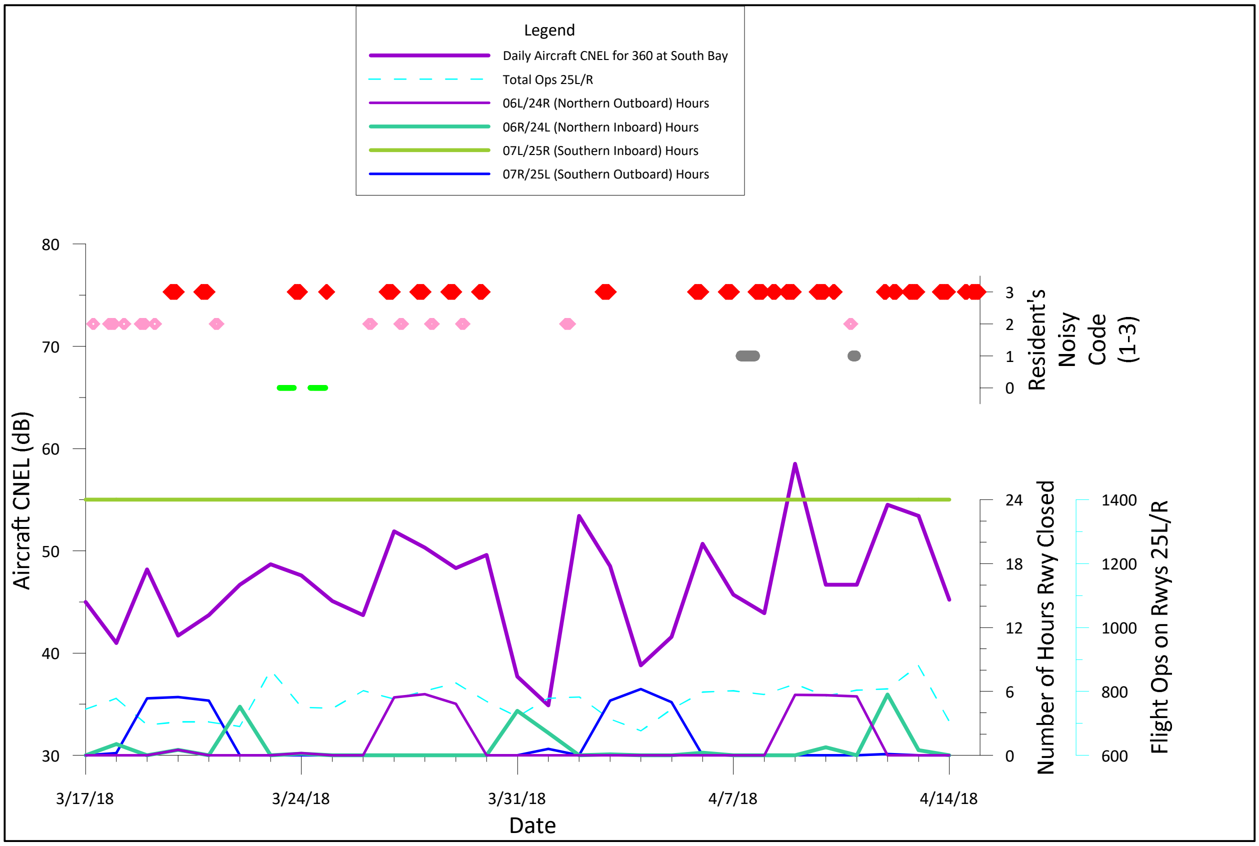

Figure B-9. Daily Aircraft CNEL, Runway Closure and Flight Operations for the First Half of the Measurement Period

1) Runway 07L/25R was closed the entire period. 2) Daily aircraft CNEL did not correlate with flight operations 3) Runway closure does not correlate with any of the loud-logged periods.

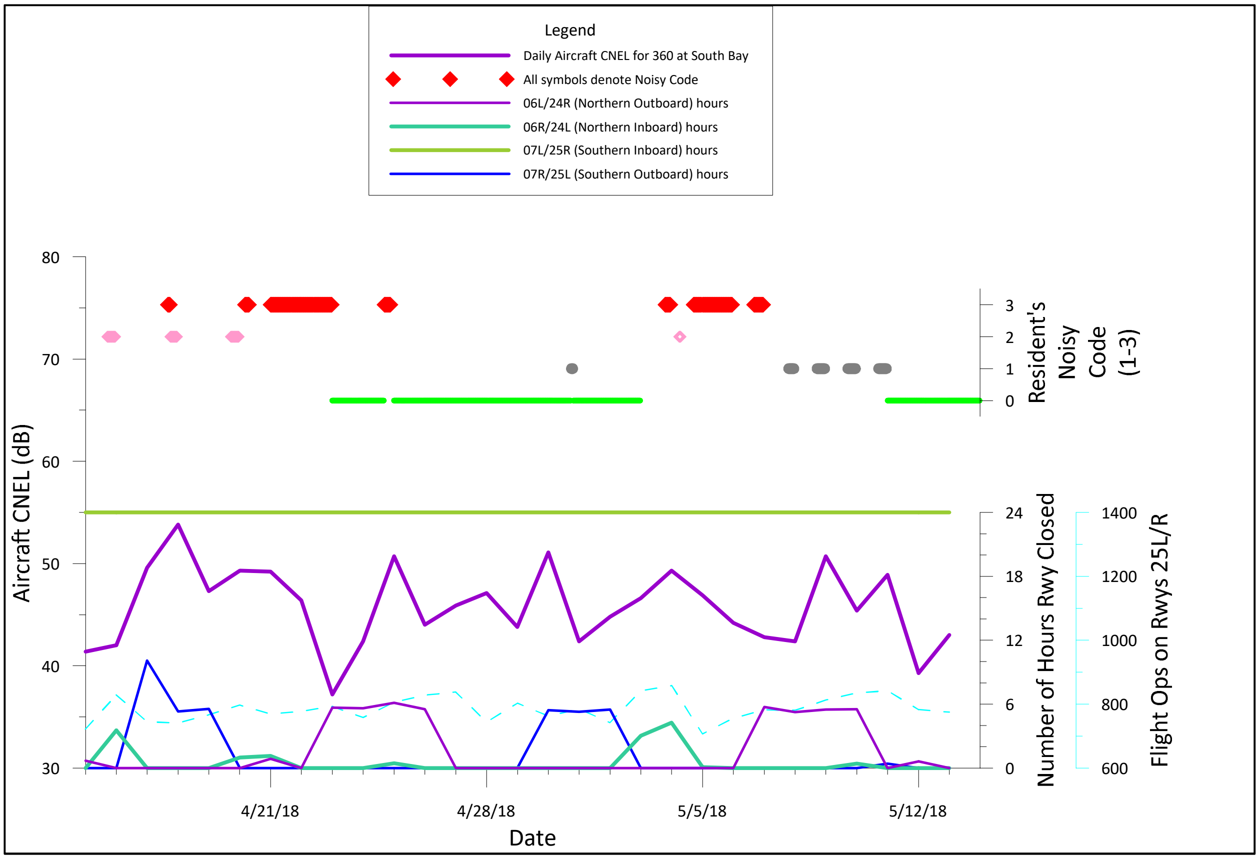

Figure B-10. Daily Aircraft CNEL, Runway Closure and Flight Operations for the Second Half of the Measurement Period

1) Runway 07L/25R was closed the entire period. 2) Daily aircraft CNEL did not correlate with flight operations 3) Runway closure does not correlate with any of the loud-logged periods.

B.3.4 Wind Direction and Speed

The LAX wind sensor is located on-airport, between Runways 25L and 25R nearly Taxiway H with geographic coordinates of 33.938° north latitude and -118.3888° (west) longitude. The source data is one-hour increments. Figures B-11 and B-12 show wind roses[21] for the LAX wind sensor for days reported as 'not noisy' and days reported as 'noisy', respectively, by the 360 Community. Winds speeds less than 3 mph were ignored. The noisy days had weaker winds from the west than the 'not noisy' days. The 'not noisy' days had more frequent and stronger winds from the east and east-southeast than the 'noisy' days.

[21] A "wind rose" shows the speed of winds and the frequency of those speeds. For this report, the 'petals' of the rose are wedges pointing to the wind's direction, i.e., the direction *from* which the wind is coming. The amount of time or frequency the wind blows from a certain direction is indicated in the wind rose as "% of Occurrence" and is shown by the length of the petals. The color of each petal/wedge is the range of speeds within which the frequency occurs.

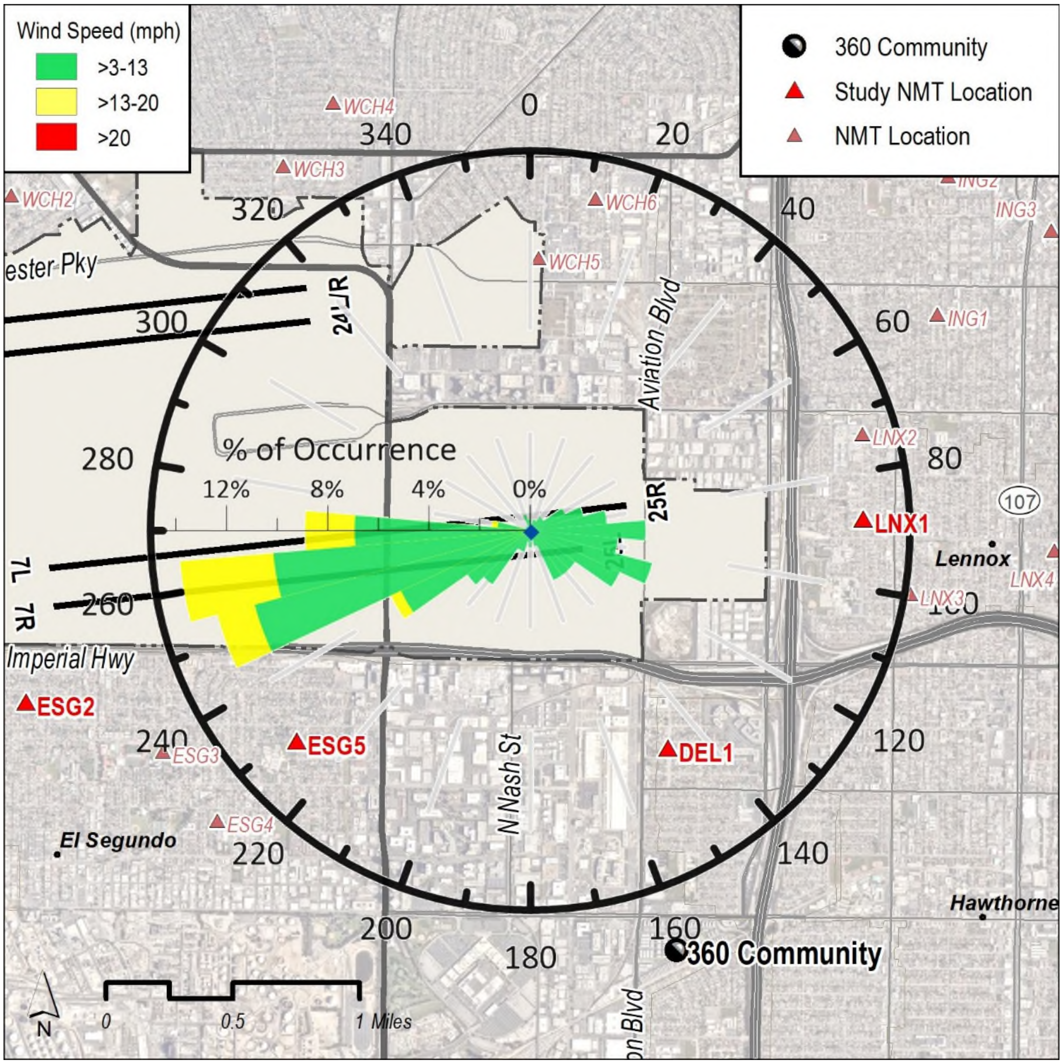

Figure B-11. Wind Roses for October 2017 for Not noisy days

Considerable occurrence of winds from the east and southeast and lack of winds from north.

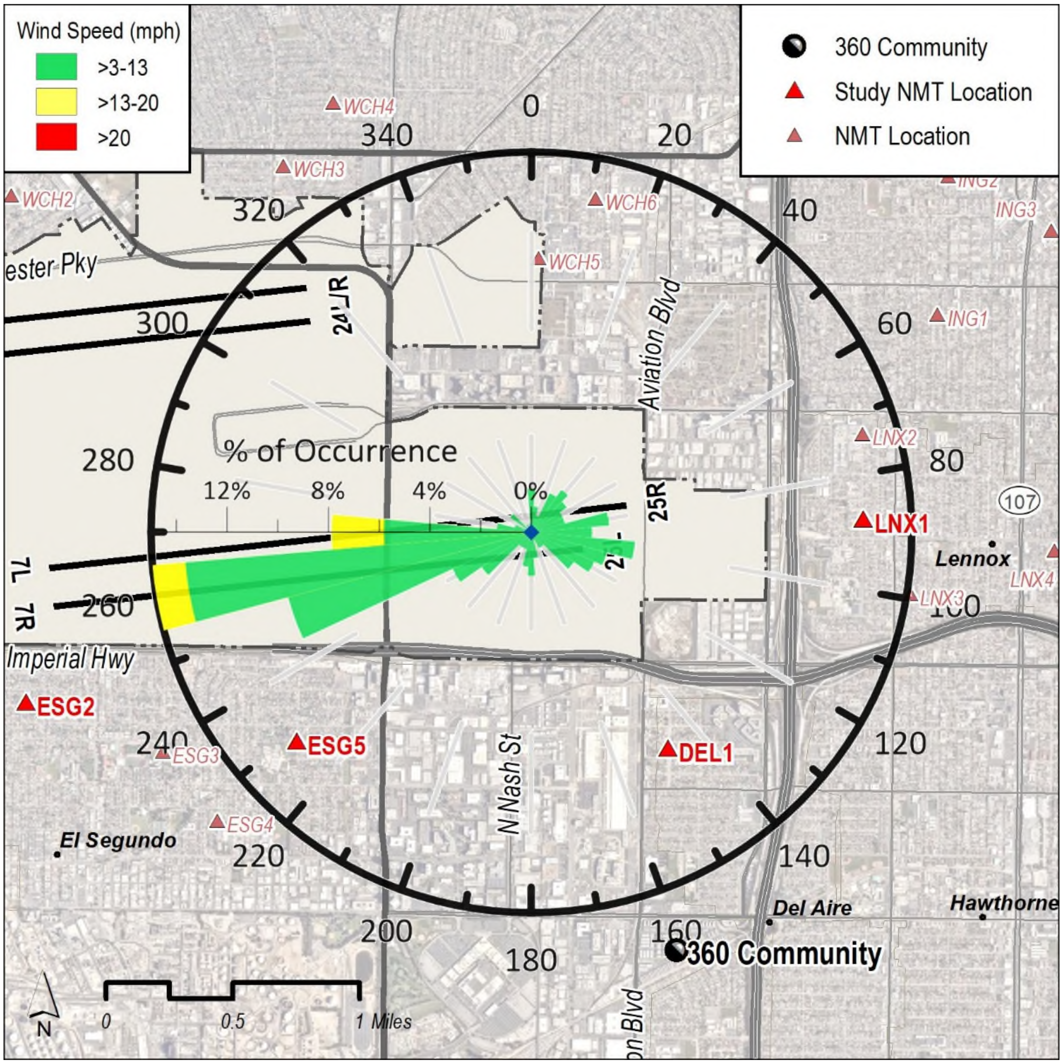

Figure B-12. Wind Roses for October 2017 for Noisy days

Noticeable occurrence of winds from the north and northeast and less winds from the east/southeast than on previous figure.

B.3.4.1 Summary Statistics

Figures B-13 and B-14 show wind roses for the wind sensor positioned at the 360 site for periods logged by the 360 Community resident during the March-May 2018 measurement period as:

- 'Nothing' or 'relatively quiet' (assigned code 0 only) and
- 'Loud', 'excessively loud' or 'extremely loud' (codes 1, 2 or 3).

The source data is 15-minute increments. The loud days had more frequent and (slightly) stronger winds from the north and northeast than the quiet days. The quiet days had more frequent and (slightly) stronger winds from the east and east-southeast than the 'noisy' days.

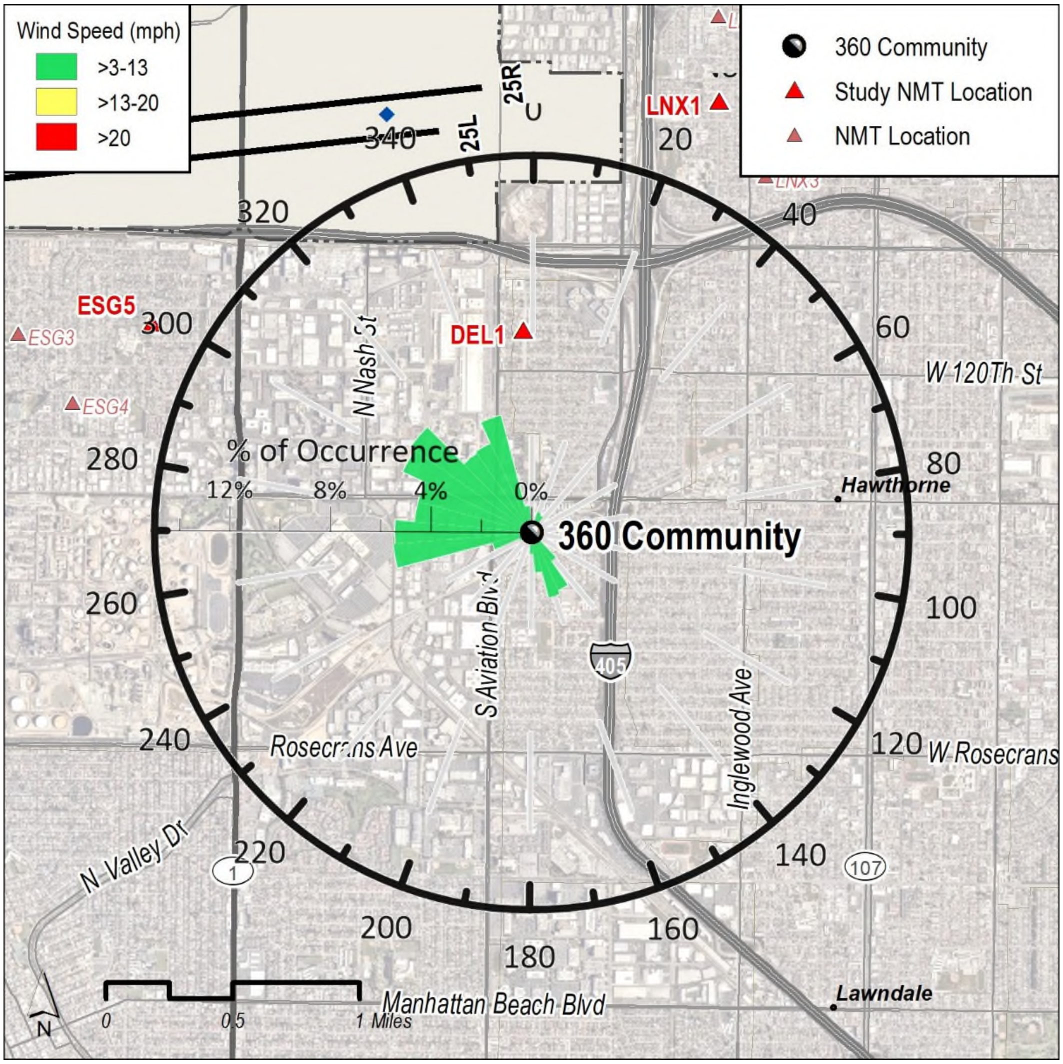

Figure B-13. Wind Roses for the Measurement Period (March 22, 2018 – May 13, 2018) at the 360 Site for (a) quiet periods, as judged by the resident

Although most winds are from the west and northerly directions, there is a noticeable occurrence of winds from the southeast.

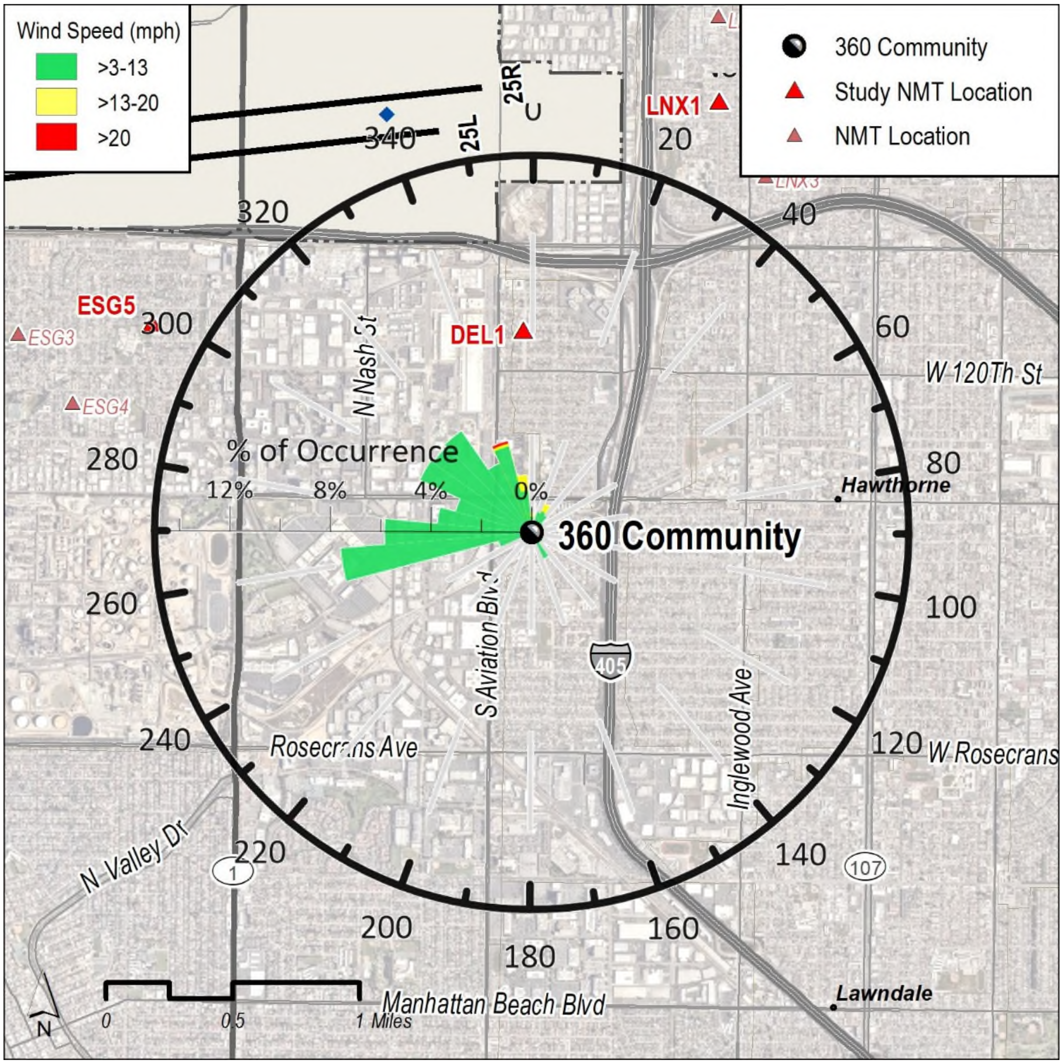

Figure B-14. Wind Roses for the Measurement Period (March 22, 2018 – May 13, 2018) at the 360 Site for loud periods, as judged by the resident

There is considerably less winds from the southeast and winds are slightly stronger from the north, compared to the previous figure.

B.3.4.2 Sudden Changes

Figures B-15 through B-17 show hourly L_{eq} [$L_{eq(h)}$] for the 360 site and DEL1, hourly departures and total flight operations on Runways 25L/R, and wind vectors for March 23rd, March 24th and April 7th. The wind vectors in the figures show the direction in which the wind was headed and the length of the line denotes the relative speed of the wind. On Friday March 23rd, the resident logged most of the day as being "relatively quiet", but starting at 7 p.m., he logged the noise as being "outrageously loud" and gave it code 3. During the first hour of the noticeable change in noisiness, March 23rd only had a 3% increase in hourly flight operations at 7 p.m. Saturday March 24th was logged similarly as March 23rd and during March 24th's first hour of the noticeable change in noisiness (7 p.m.), there was a 39% increase in hourly flight operations but the wind changed direction towards the 360 Community and increased speed a couple of hours prior to the logging change. On Saturday April 7th hourly flight operations near quadrupled at 6 a.m. when the resident started logging the noise as “loud” (code 1), but increased by only 9% at 5 p.m. when the resident changed his noise code from “loud” (code 1) to “extremely loud” (code 3). Noise levels did not increase during the resident’s noisier periods during these three days, however, noise levels were *higher* the hour or two prior to the periods of increased noisiness. Wind vectors for March 23rd and 24th show changes corroborating the noisier periods unlike April 7th’s wind vectors.

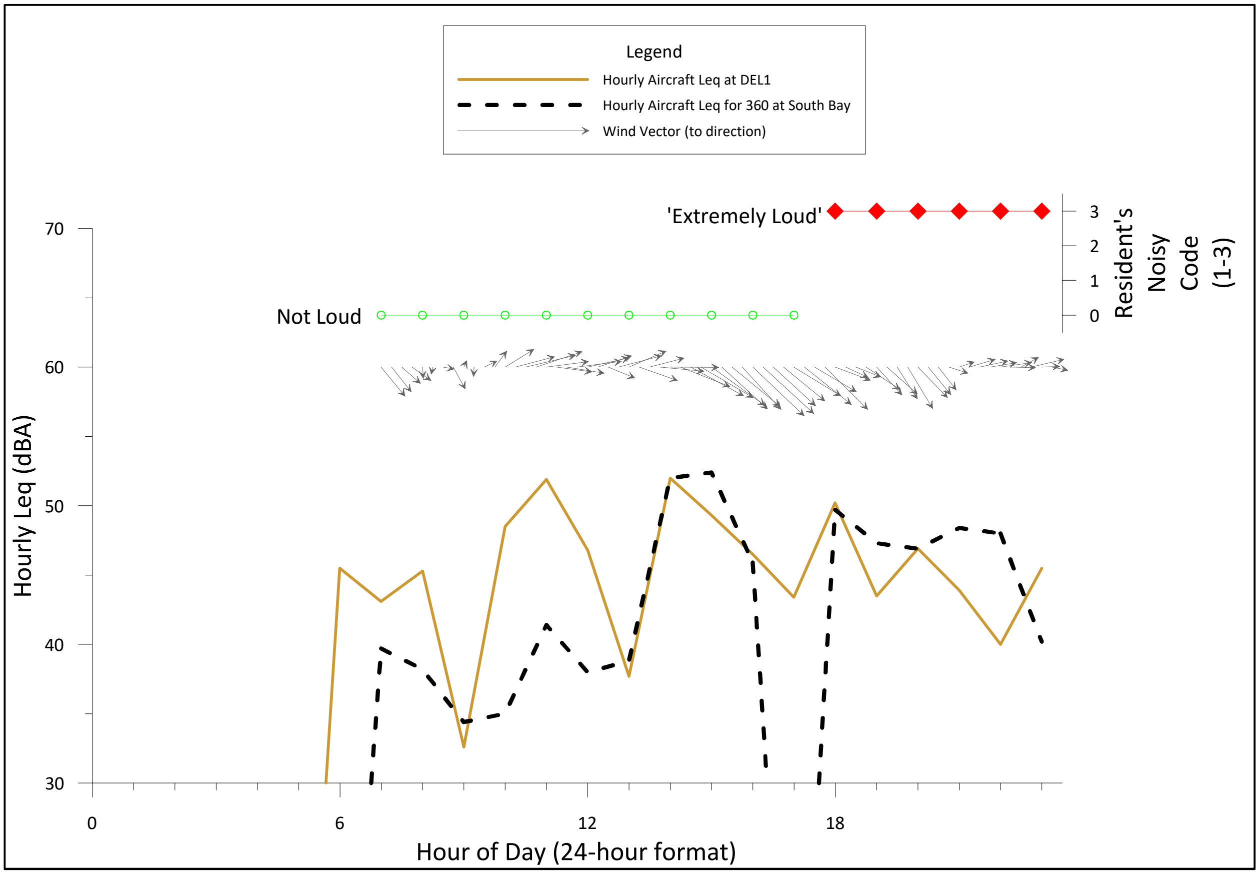

Figure B-15. Hourly Aircraft L_{eq}, Flight Operations and Winds for Sudden Change Period on Friday, March 23, 2018

The reported ‘extremely loud’ period began approximately 2 hours after winds had shifted to an unfavorable direction and had grew in strength whereas operations had not increased. No correlation to hourly L_{eq}.

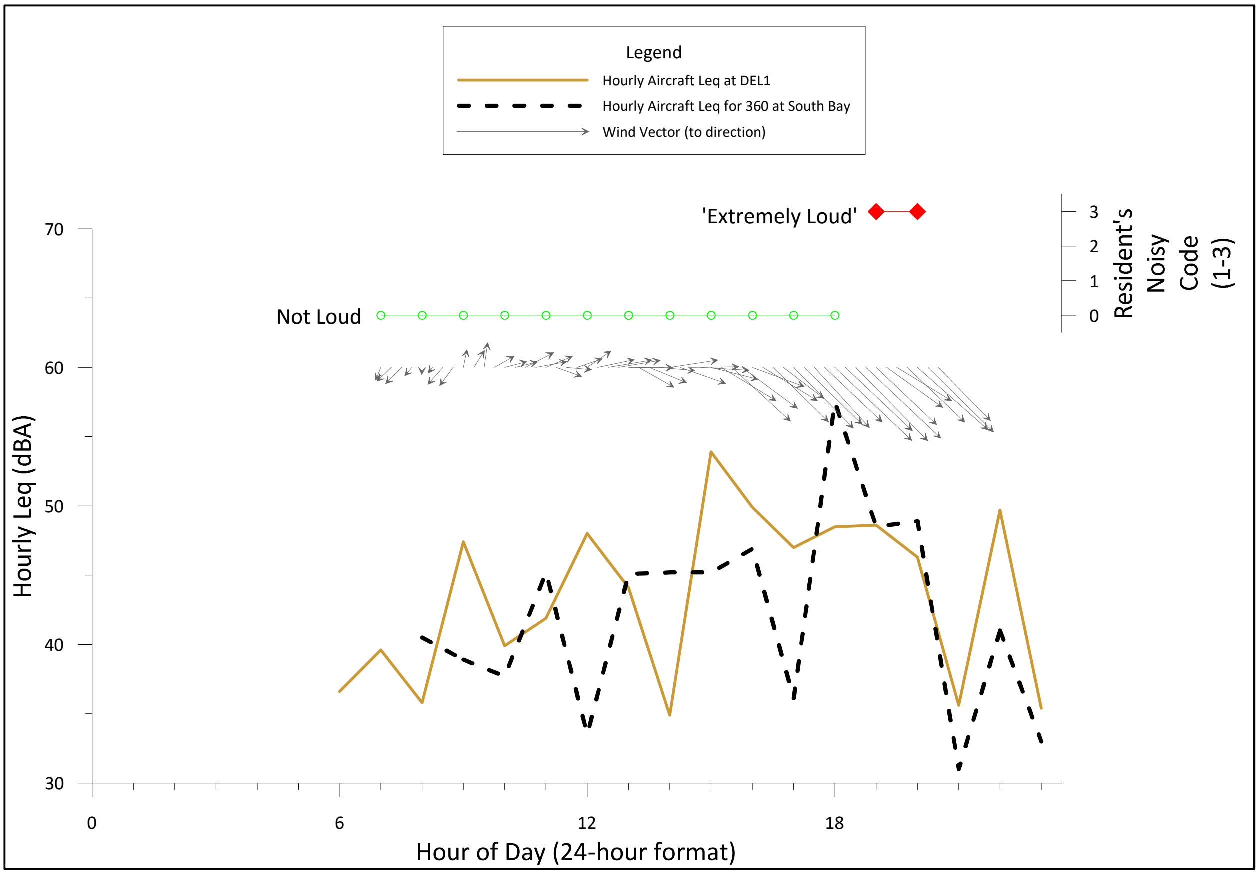

Figure B-16. Hourly Aircraft L_{eq}, Flight Operations and Winds for Sudden Change Period on Saturday, March 24, 2018

The reported 'extremely loud' period began approximately 1 hour after winds had shifted to an unfavorable direction and had grew in strength. Operations increased for the first hour of the 'extremely loud' period but then decreased and fluctuated. Correlation to hourly L_{eq} at the 360 site for the first hour or two of the 'extremely loud' period.

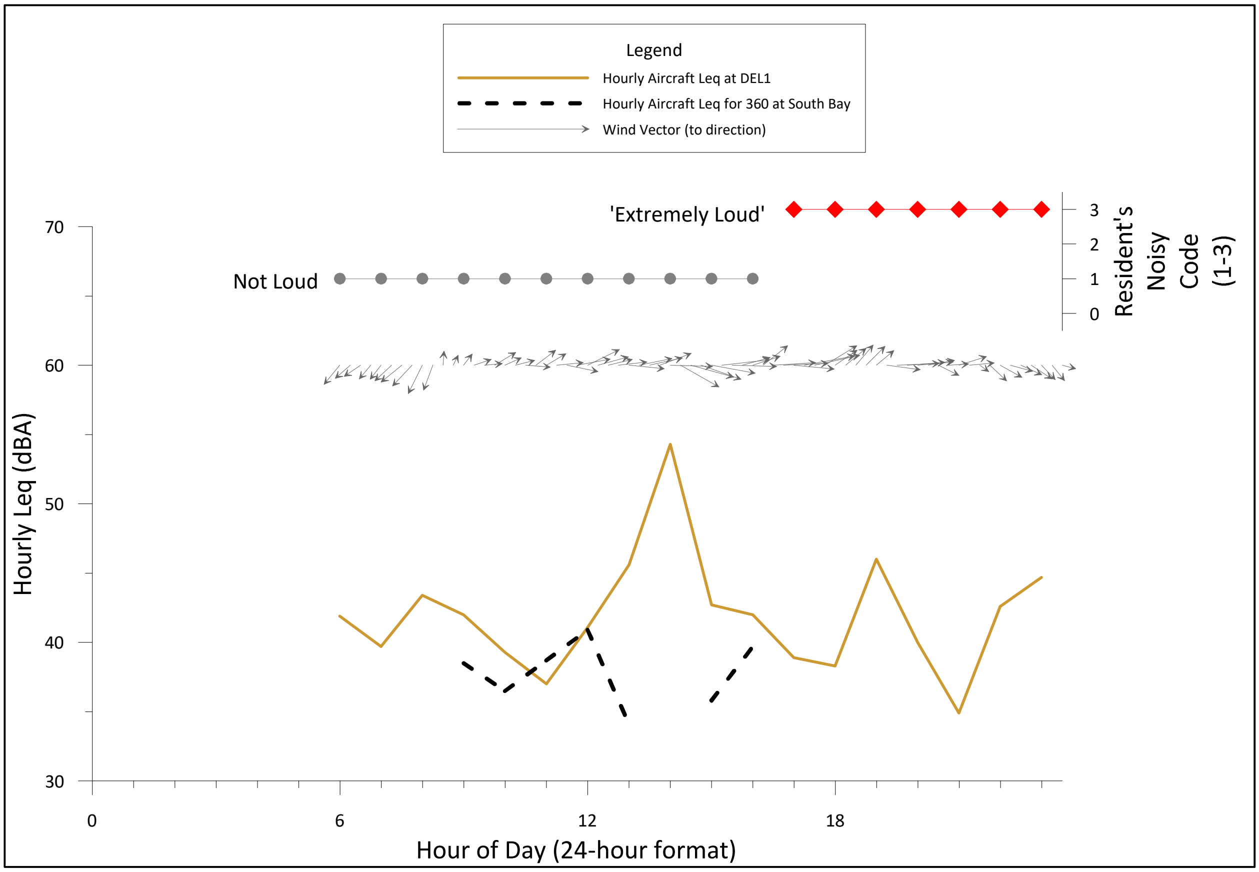

Figure B-17. Hourly Aircraft L_{eq}, Flight Operations and Winds for Sudden Change Period on Saturday, April 7, 2018

The reported 'loud' period correlated with increased operations at 6 a.m. but wind nor operations explain the change in observation to 'extremely loud' at 5 p.m. No correlation to hourly L_{eq} at DEL1.

B.3.4.3 Other Remarks

Other days of importance during the measurement period are the days when the resident noted his highest noisiness code (code 3) and when he made logged additional comments such as "unbelievably loud" or "outrageous noise levels". The following seven days have this characteristic and are shown in Figures B-18 through B-24: April 9th, April 21st and 22nd, and May 3rd through May 6th, respectively. On these 7 days, it was either an inversion base altitude within 200 feet of the ground and/or winds which likely caused the resident's remarks. As shown in these figures, LAX's numbers of flight operations on Runway 25L/R were not out of the ordinary.

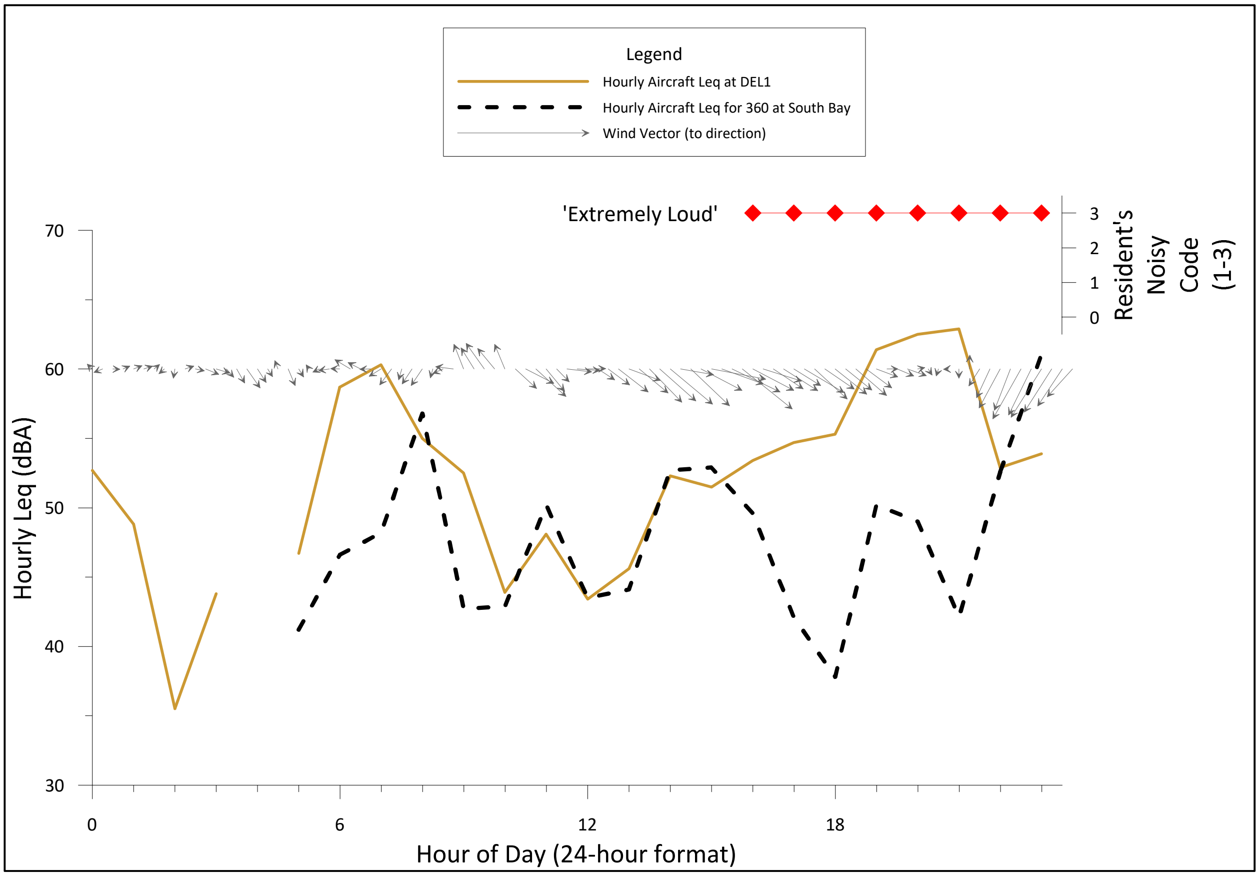

Figure B-18. Hourly Aircraft L_{eq}, Flight Operations and Winds for Monday, April 9, 2018

The reported 'extremely loud' period correlated with unfavorable wind direction and somewhat to hourly L_{eq} at 360 site and DEL1 but did not correlate to operations.

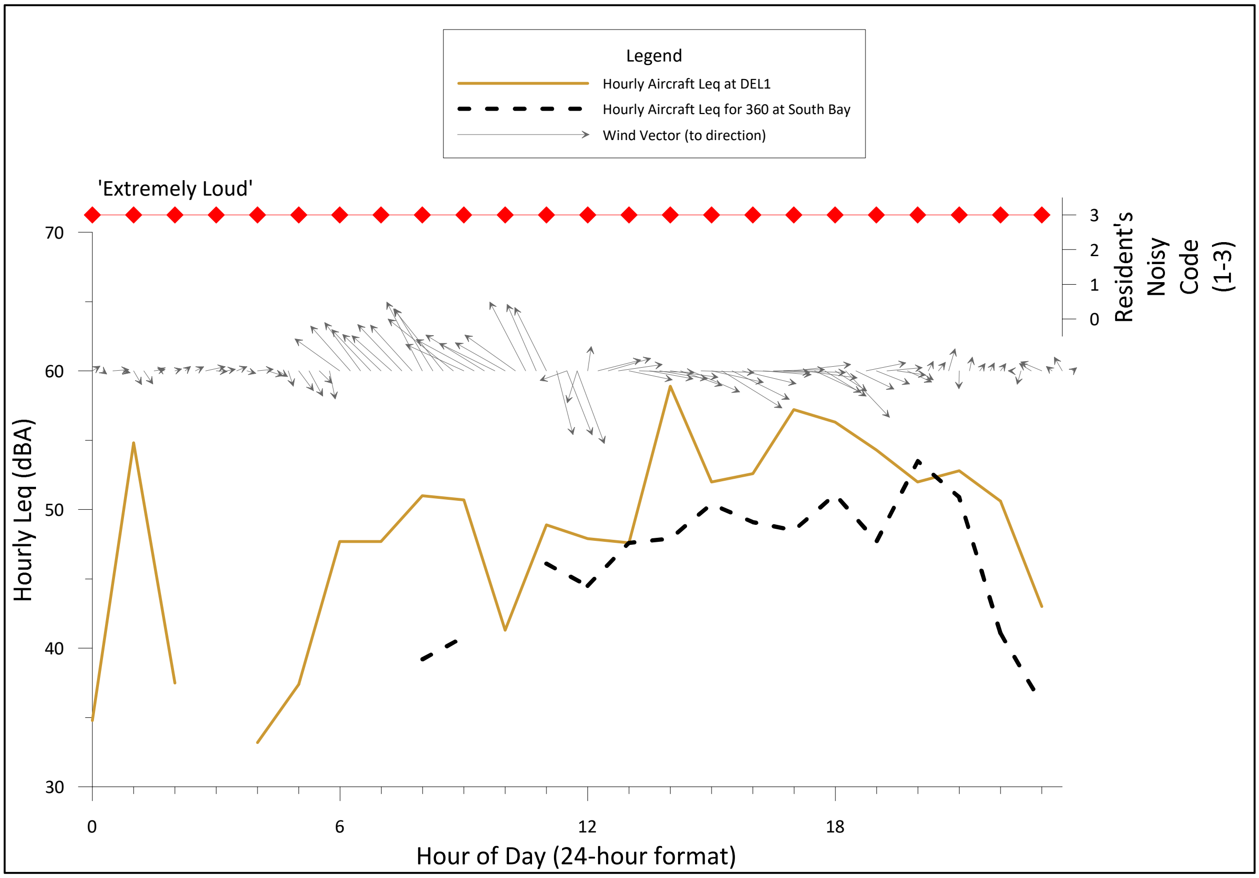

Figure B-19. Hourly Aircraft L_{eq}, Flight Operations and Winds for Saturday, April 21, 2018

Change in wind direction/speed nor operations explain the reported 'extremely loud' period throughout the entire day but hourly L_{eq} at the 360 site and DEL1 increased with change in wind direction from favorable to unfavorable around 2 p.m.

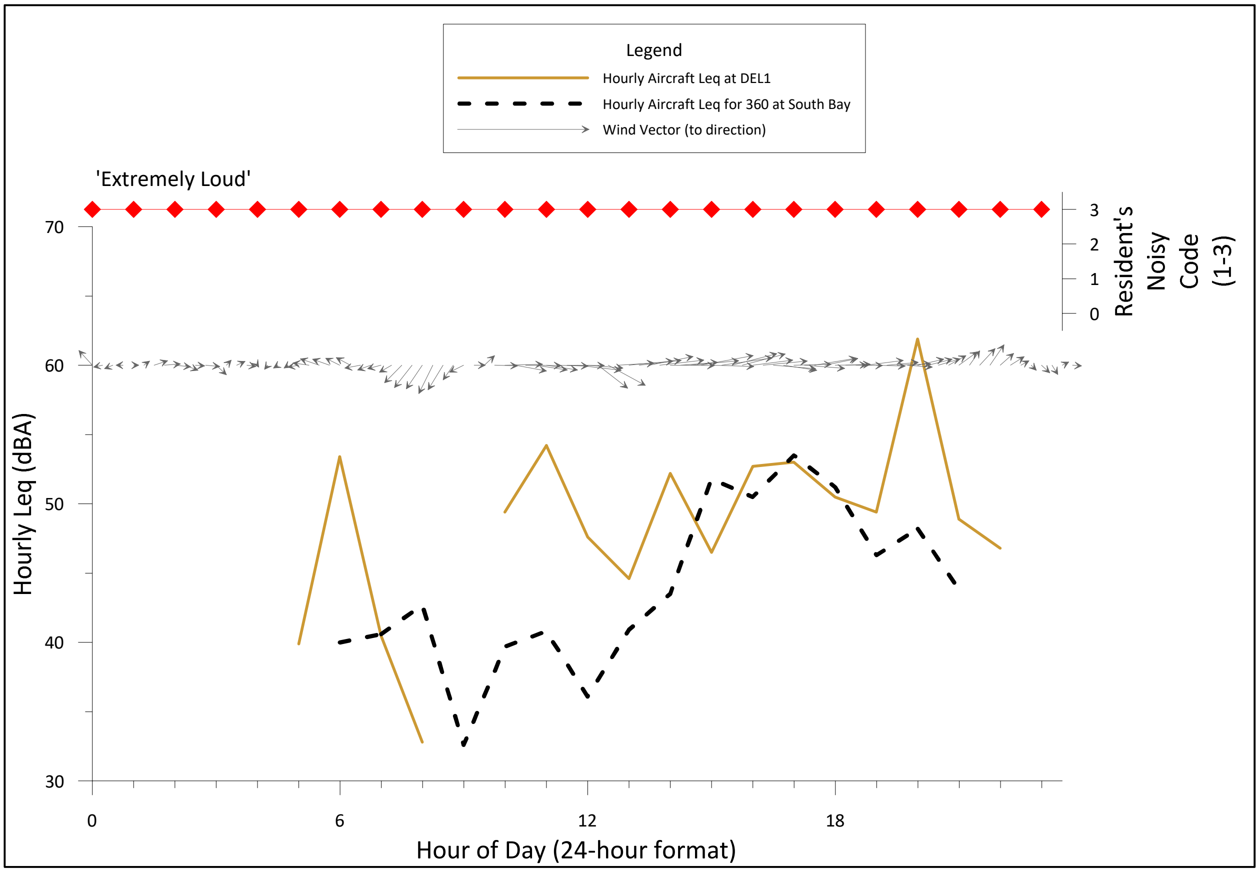

Figure B-20. Hourly Aircraft L_{eq}, Flight Operations and Winds for Sunday, April 22, 2018

Change in wind direction/speed nor operations explain the reported 'extremely loud' period throughout the entire day. Hourly L_{eq} at the 360 site and DEL1 are somewhat correlated with each other but not with operations or winds.

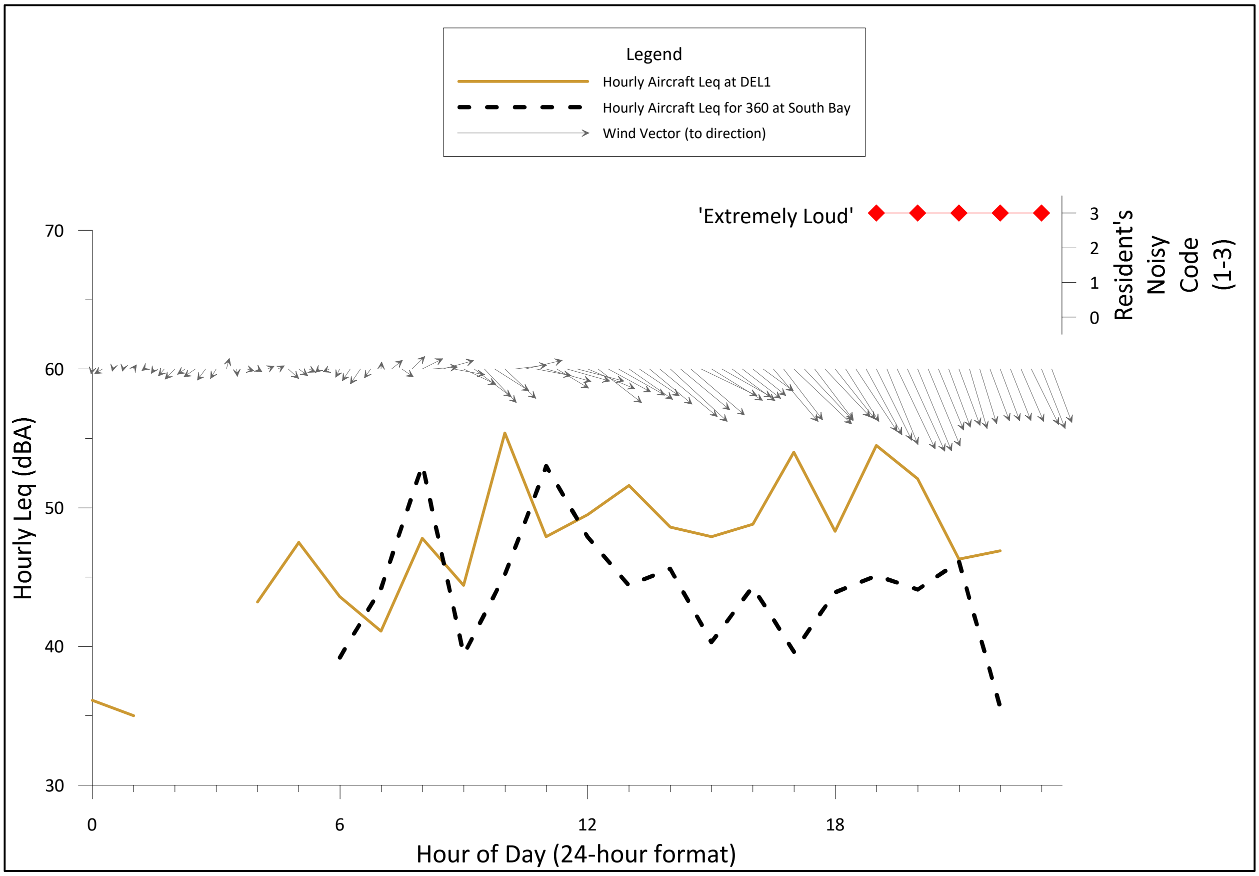

Figure B-21. Hourly Aircraft L_{eq}, Flight Operations and Winds for Thursday, May 3, 2018

The reported 'extremely loud' period correlated with unfavorable wind direction and somewhat to hourly L_{eq} at DEL1 but did not correlate to operations.

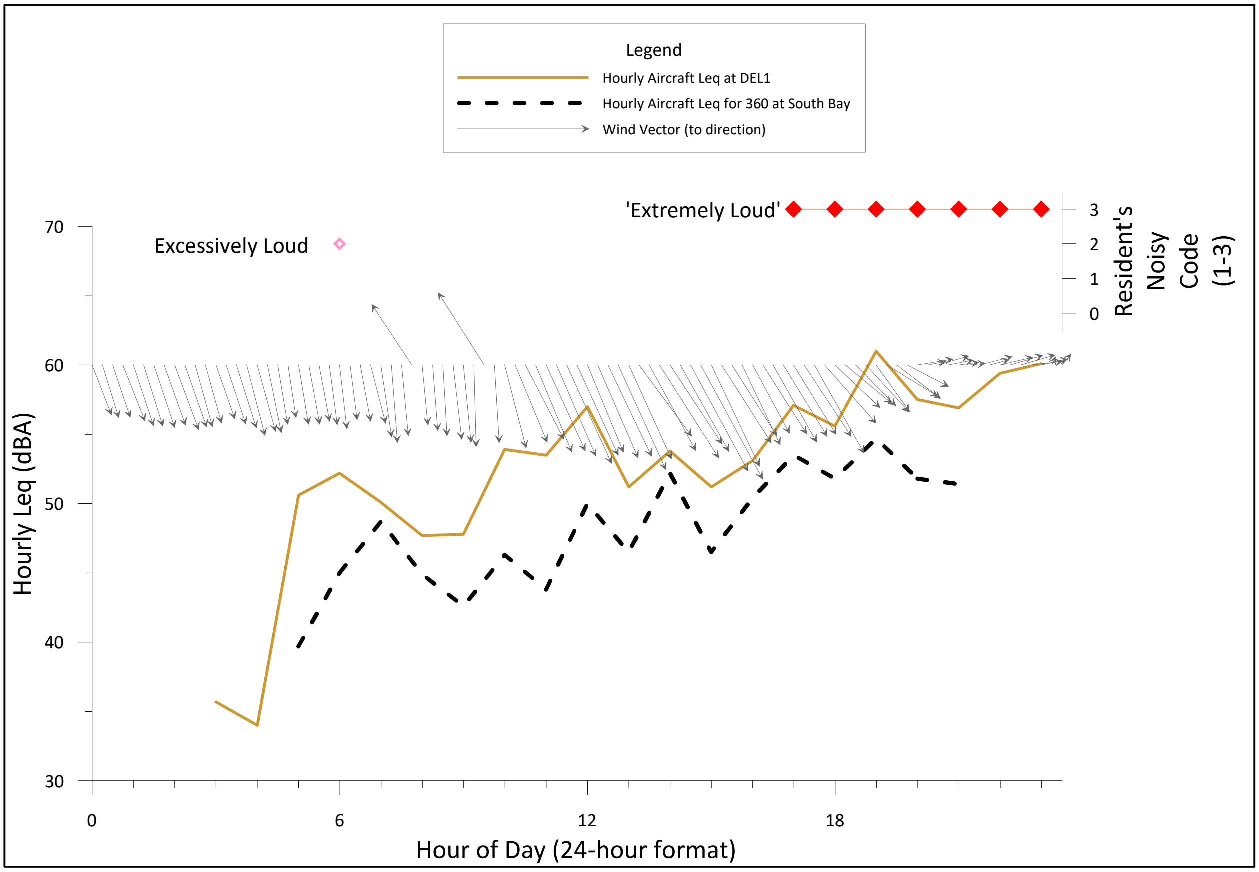

Figure B-22. Hourly Aircraft L_{eq}, Flight Operations and Winds for Friday, May 4, 2018

The reported 'extremely loud' period correlated with unfavorable wind direction and somewhat to hourly L_{eq} at the 360 site and DEL1 but did not correlate to operations.

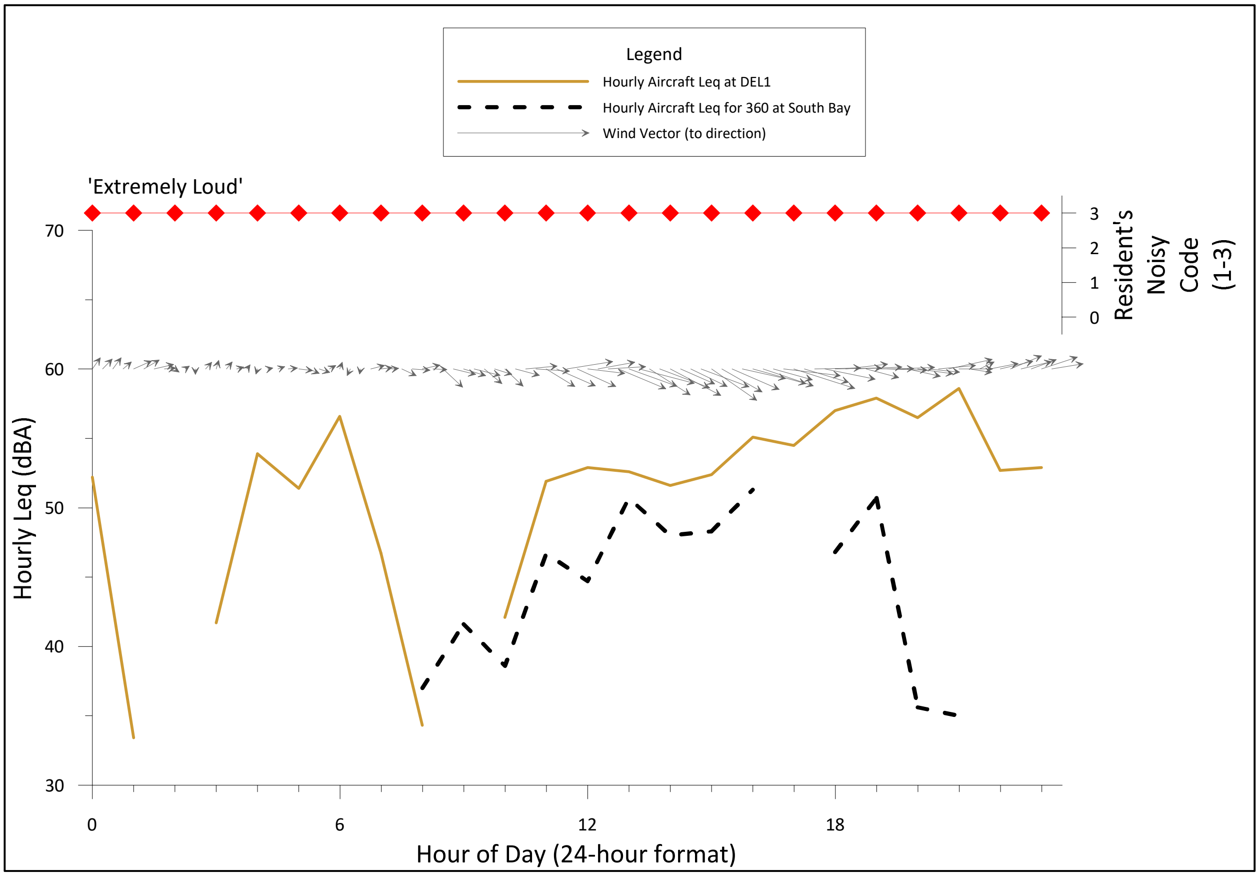

Figure B-23. Hourly Aircraft L_{eq}, Flight Operations and Winds for Saturday, May 5, 2018

Change in wind direction/speed nor operations explain the reported 'extremely loud' period throughout the entire day. Hourly L_{eq} at the 360 site and DEL1 are somewhat correlated with each other and winds but not with operations.

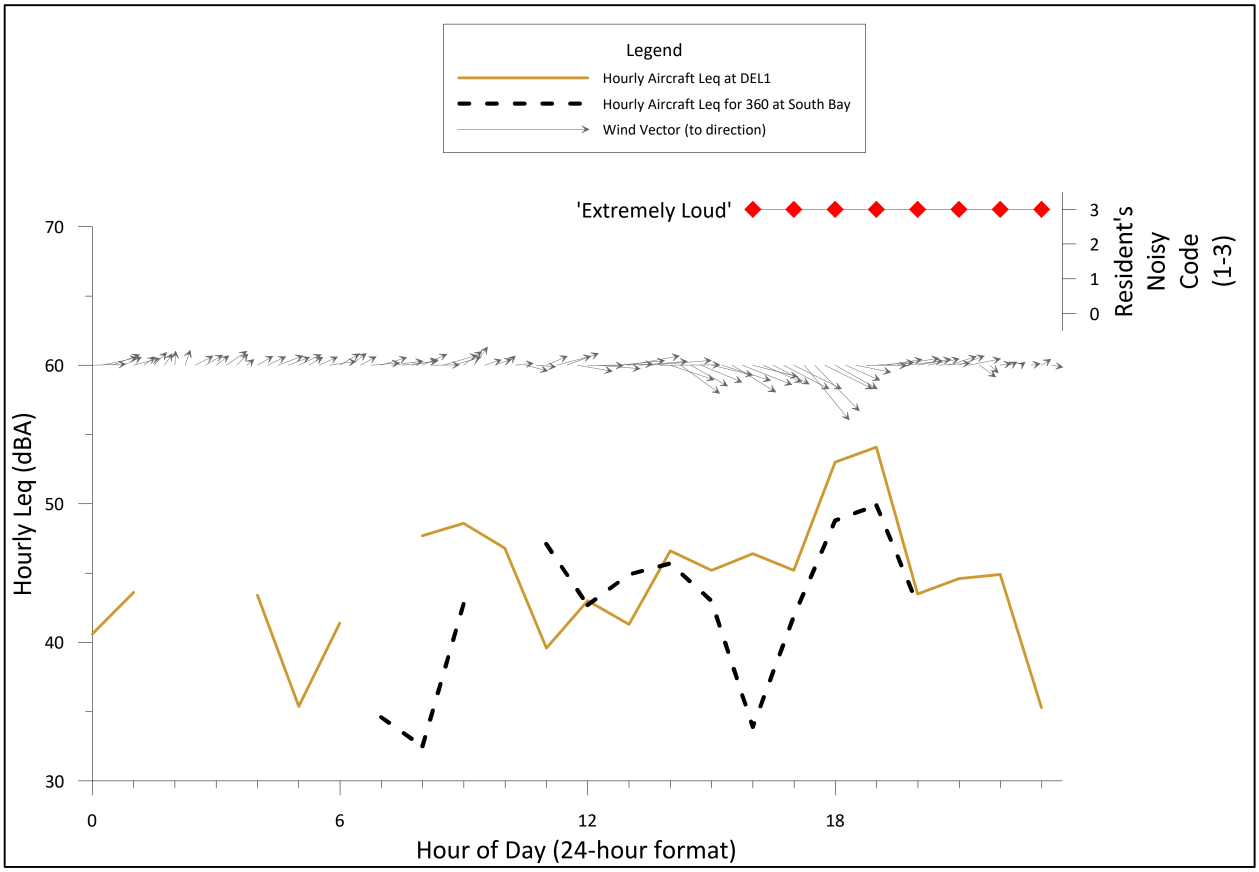

Figure B-24. Hourly Aircraft L_{eq}, Flight Operations and Winds for Sunday, May 6, 2018

The reported 'extremely loud' period correlated with unfavorable wind direction and somewhat to hourly L_{eq} at the 360 site and DEL1 but did not correlate to operations.

B.3.5 Temperature Inversion

Figure B-25 shows the following data for May 2017 through October 2017:

1. The days the 360 Community identified as 'noisy' (red diamonds)
2. The daily aircraft CNEL at NMT DEL1 (gold line)
3. The elevation of the base of the temperature inversion (solid blue area)
4. The daily average temperature (dashed black line)

Most days the daily aircraft CNEL increased at DEL1 and ESG5 when the inversion base was within a few hundred feet of the ground, the temperature increases (becomes hotter; sound speed increases). Most of the 'noisy' days are during days of low inversion base altitudes, thus temperature inversions were near the ground.

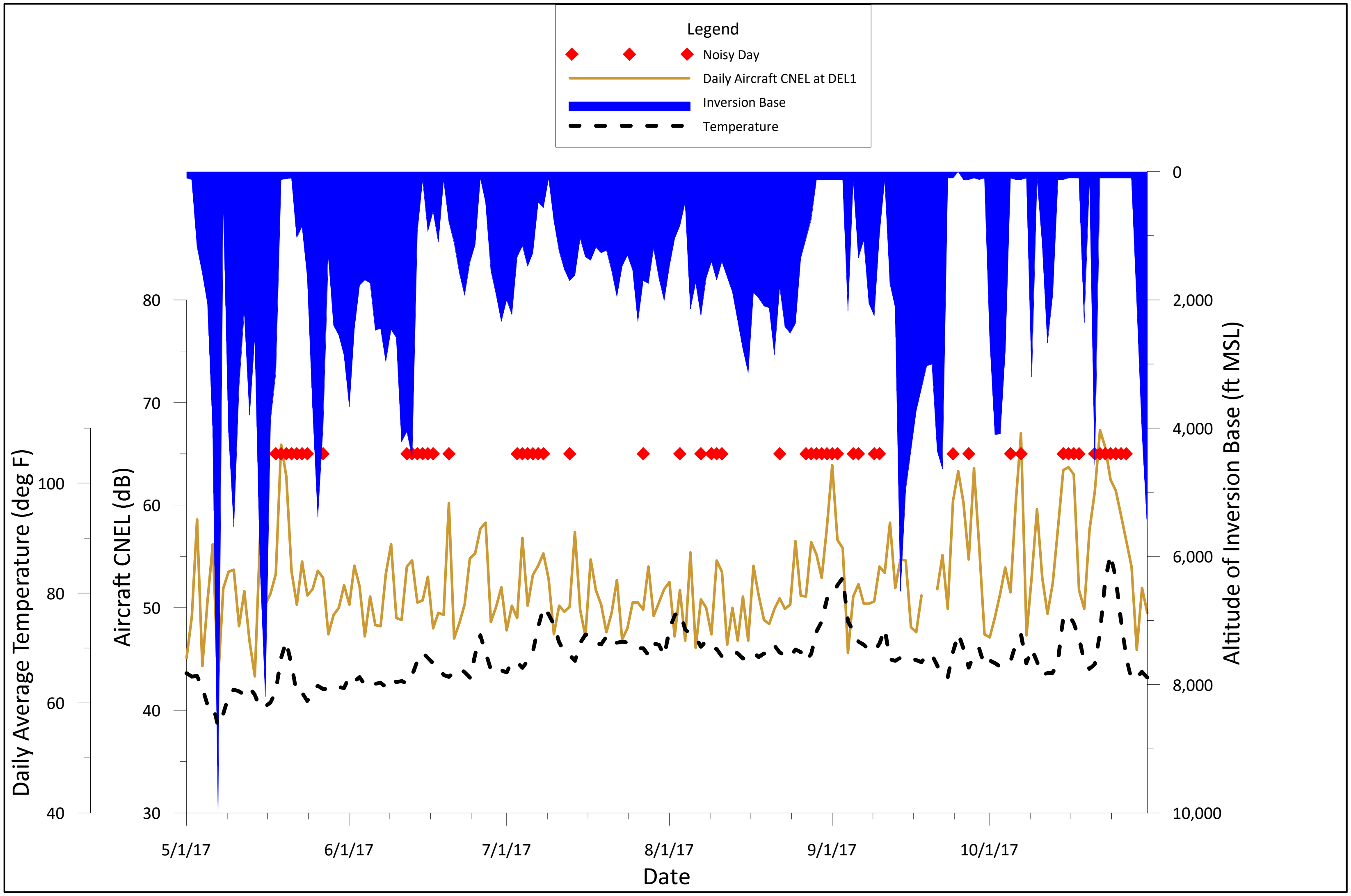

Figure B-25. Daily Aircraft CNEL, Temperature and Inversion Base Altitude for May 2017 through October 2017

Most of the 'noisy' days are during days of low inversion base altitudes, thus a temperature inversion near the ground.

Appendix C – 360 Community Volunteer Resident Log

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HARRIS MILLER MILLER & HANSON INC. **Project: ThreeSixty at South Bay**

Proj. #: 308270.003

RESIDENT MEASUREMENT SITE EVENT LOG

Name:	**Page: of**

2018 Date (mm/dd)	**Event Start Time (hh:mm a.m./p.m.)**	**Event Description / Comments** **Wind** (calm, light, moderate, variable); **Sky** (overcast, partly cloudy, clear, sunny, fog, rain, etc)	**Event Stop Time (hh:mm a.m./p.m.)**
Example: 3/15	3:15 p.m.	Loud until touchdown; calm, overcast	3:16 p.m.
3/16	6:00 p.m.	Level 2 Noise; Went to sleep at 11:00 p.m. and noise was still present	Went to sleep at 11:00 p.m. and noise was still present
3/17	5:00 a.m.	Level 2 Noise	Noise still present when I left premises at 7:00 a.m.
3/17	5:30 p.m.	Level 2 Noise	Went to sleep at 11:00 p.m. and noise was still present
3/18	5:00 a.m.	Level 2 Noise	Noise still present when I left premises at 7:00 a.m.
3/18	6:00 p.m.	Level 2 Noise	Went to sleep at 11:00 p.m. and noise was still present
3/19	5:00 a.m.	Level 2 Noise	Noise still present when I left premises at 7:00 a.m.
3/19	6:00 p.m.	Level 3 Noise (**Outrageously loud**); Cloudy; no wind; humidity 75%; Pressure 30.1	Went to sleep at 11:00 p.m. and noise was still present
3/20	6:00 p.m.	Level 3 Noise (**Outrageously loud**); overcast; West winds at 12M; humidity 75%; Pressure 29.1	Went to sleep at 11:00 p.m. and noise was still present
3/21	4:30 a.m.	Level 2 Noise; overcast	Noise still present when I left premises at 7:30 a.m.
3/22	Nothing		
3/23	6:51 p.m.	Quiet all day; Windows open; At 6:51 p.m., planes started roaring like a switch was turned on. Level 3 noise (**Outrageously Loud**); Clear; west winds at 8kt; humidity 84%	Went to sleep at 11:00 p.m. and noise was still present
3/24	6:55 p.m.	Quiet all day; Windows open; At 6:55 p.m., planes started roaring like a switch was turned on. Level 3 noise (**Outrageously Loud**); Clear	8:00 p.m.
3/26	4:00 a.m.	Level 2 noise	Noise still present when I left premises at 7:00 a.m.
3/26	6:00	Level 3 noise; Cloudy; West winds at 13kt; humidity 32%	Went to sleep at 11:00 p.m. and noise was still present

2018 Date (mm/dd)	Event Start Time (hh:mm a.m./p.m.)	Event Description / Comments **Wind** (calm, light, moderate, variable); **Sky** (overcast, partly cloudy, clear, sunny, fog, rain, etc)	Event Stop Time (hh:mm a.m./p.m.)
3/27	4:00 a.m.	Level 2 noise	Noise still present when I left premises at 7:00 a.m.
3/27	6:00 p.m.	Level 3 noise;	Went to sleep at 11:00 p.m. and noise was still present
3/28	4:00 a.m.	Level 2 Noise	Noise still present when I left premises at 7:00 a.m.
3/28	6:00 p.m.	Level 3 Noise; Cloudy; West winds at 7kt; Humidity 68%	Went to sleep at 11:00 p.m. and noise was still present
3/29	4:00 a.m.	Level 2 Noise	Noise still present when I left premises at 7:00 a.m.
3/29	6:00 p.m.	Level 3 Noise; Cloudy; West Winds at 11kt; Humidity 78%	9:00 p.m.
4/1	1:00 p.m.	Level 2 Noise	5:00 p.m.
4/2	6:00 p.m.	Level 3 Noise; Partly Cloudy; West Winds at 10kt; 70% humidity	Went to sleep at 11:00 p.m.and noise was still present
4/5	6:00 p.m.	Level 3 Noise; Overcast; West winds at 6 kt; 70% humidity	Went to sleep at 11:00 p.m.and noise was still present
4/6	6:00 p.m.	Level 3 noise; Mostly Cloudy; Southwest winds at 12kt; 73% humidity	Went to sleep at 11:00 p.m.and noise was still present
4/7	6:00 a.m.	Level 1 noise	5:00 p.m.
4/7	5:00 p.m.	Level 3 noise	Went to sleep at 11:00 p.m.and noise was still present
4/8	6:00 a.m.	Level 3 noise (outrageously loud; partly cloudy; east winds at 3 kt; 90% humidity	9:00 a.m.
4/8	5:00 p.m.	Level 3 Noise (outrageously loud); A few clouds; west winds at 11 kt; 70% humidity	Went to sleep at 11:00 p.m.and noise was still present
4/9	4:30 p.m.	Level 3 Noise (**unbelievably loud noise – enormously disruptive**); a few clouds; west winds ata 14kt; humidity 43%	Went to sleep at midnight p.m.and noise was still present
4/10	5:30 a.m.	Level 3 noise; Very loud	Noise still present when I left premises at 7:00 a.m.
4/10	6:00 p.m.	Level 2 Noise	9:00 p.m.
4/10	9:00 p.m.	Level 1 Noise	Went to sleep at 11:00 p.m.and noise was still present
4/11	9:00 p.m.	Level 3 Noise; Cloudy, West winds at 20kt; Humidity 76%	Went to sleep at 11:00 p.m.and noise was still present
4/12	4:00 a.m.	Level 3 noise	Noise still present when I left premises at 7:00 a.m.
4/12	4:30 p.m.	Level 3 noise	Went to sleep at 11:00 p.m.and noise was still present

2018 Date (mm/dd)	**Event Start Time (hh:mm a.m./p.m.)**	**Event Description / Comments** **Wind** (calm, light, moderate, variable); **Sky** (overcast, partly cloudy, clear, sunny, fog, rain, etc)	**Event Stop Time (hh:mm a.m./p.m.)**
4/13	4:30 p.m.	Level 3 Noise	Went to sleep at 11:00 p.m. and noise was still present
4/14	Noon	Level 3 noise	2:00 p.m.
4/14	5:00 p.m.	Level 3 noise	Went to sleep at 11:00 p.m. and noise was still present
4/15	5:00 p.m.	Level 2 Noise	Went to sleep at 11:00 p.m. and noise was still present
4/17	4:00 p.m.	Level 3 noise; Fair East Winds at 4 kt; 64% humidity	6:00 p.m.
4/17	6:00 p.m.	Level 2 noise; Fair East Winds at 4 kt; 64% humidity	Went to sleep at 11:00 p.m. and noise was still present
4/19	5:00 p.m.	Level 2 noise	Went to sleep at 11:00 p.m. and noise was still present
4/20	4:00 a.m.	Level 3 noise; Cloudy; East winds at 6 kt; 86% humidity	Noise still present when I left premises at 7:00 a.m.
4/21		All Morning; Day and Night; Level 3 noise (**Outrageous Noise levels**); Cloudy; West winds at 12kt; 63% humidity	
4/22		All Morning; Day and Night; Level 3 noise (**Outrageous Noise levels**); A few clouds; West winds at 10kt; humidity 63%	
4/23	Nothing		
4/24	4:30 p.m.	Level 3 noise	9:00 p.m.
4/25	Nothing		
4/26	Nothing		
4/27	Nothing		
4/28	Nothing		
4/29	Nothing		
4/30	Nothing	Please note that there was a helicopter circling very low over the community from approximately 6 to 7 p.m. Very loud. Nothing to do with LAWA	
5/1	Nothing		
5/2	Nothing		
5/3	7:00 p.m.	Level 3 Noise (**Outrageous**); Clear	Went to sleep at 11:00 p.m. and noise was still present

2018 Date (mm/dd)	**Event Start Time (hh:mm a.m./p.m.)**	**Event Description / Comments Wind** (calm, light, moderate, variable)**; Sky** (overcast, partly cloudy, clear, sunny, fog, rain, etc)	**Event Stop Time (hh:mm a.m./p.m.)**
5/4	6:00 a.m.	Level 2 Noise; partly cloudy; winds NE at 3kt; 90% humidity	Noise still present when I left premises at 7:00 a.m.
5/4	5:00 p.m.	Level 3 Noise (**Outrageous)**; Partly Cloudy; West winds at 18kt; 65% humidity	Went to sleep at 11:00 p.m. and noise was still present
5/5	ALL DAY AND NIGHT	Level 3 Noise (**Outrageous);** Mostly Cloudy; west winds at 10kt 75% humidity	Went to sleep at 11:00 p.m.and noise was still present`
5/6	4:00 p.m.	Level 3 Noise **(Outrageous**)	Went to sleep at 11:00 p.m.and noise was still present`
5/7	5:00 p.m.	Level 1 Noise	Went to sleep at 11:00 p.m.and noise was still present`
5/8	5:00 p.m.	Level 1 Noise	Went to sleep at 11:00 p.m.and noise was still present`
5/9	5:00 p.m.	Level 1 noise	Went to sleep at 11:00 p.m.and noise was still present`
5/10	5:00 p.m.	Level 1 noise	Went to sleep at 11:00 p.m.and noise was still present`
5/11	Nothing		
5/12	Nothing		
5/13	Nothing		