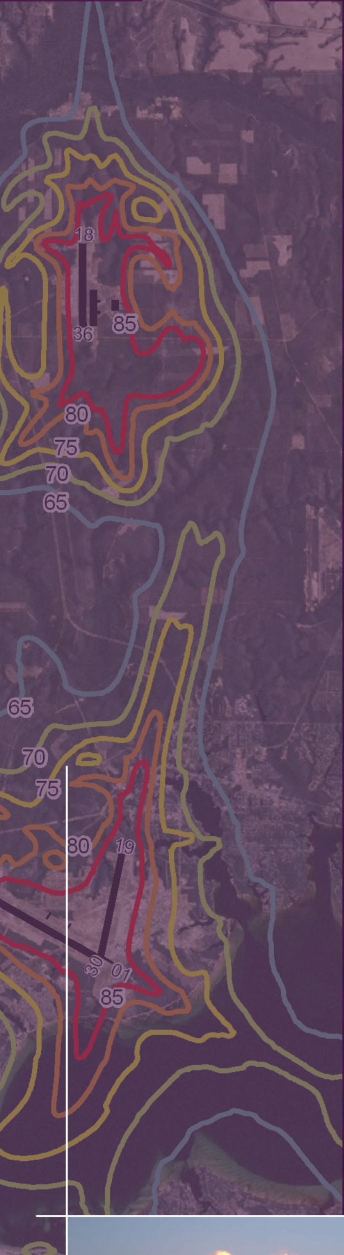



DNWG

DEPARTMENT OF DEFENSE
NOISE WORKING GROUP

# TECHNICAL BULLETIN

## Using Supplemental Noise Metrics and Analysis Tools

**December 2009**

**Supplemental noise metrics and analysis tools are used to produce more detailed noise exposure information for the decision process and to improve communication with the public about noise exposure from military activities.**

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

# INTRODUCTION

This Technical Bulletin on supplemental noise metrics and analysis tools is one of a series of Technical Bulletins issued by the Department of Defense (DoD) Noise Working Group (DNWG) under the initiative to educate and train DoD military and civilian personnel, contractors, and the public on noise issues. A better understanding of noise exposure by military personnel, local officials, other stakeholders and the general public may reduce and, possibly over time, minimize encroachment on installations by non-compatible noise sensitive development.

This Bulletin conveys timely information related to a new noise guidance document entitled "Improving Aviation Noise Planning, Analysis and Public Communication with Supplemental Metrics – Guide to Using Supplemental Metrics" (Guide), which is available from DNWG upon request. The guidance document, which is expected to be disseminated in the near future, was developed to enable the military services to communicate more effectively with the public regarding noise exposure from military activities.

The Guide is designed to facilitate program officials in their efforts to provide more useful information on the noise environment than solely using the long-term, cumulative metrics such as Day-Night Average Sound Level (DNL) and Community Noise Equivalent Level (CNEL), which is applicable in California. Supplemental analysis with additional metrics is not intended to replace these metrics when determining impacts in an Environmental Assessment (EA), or Environmental Impact Statement (EIS) performed under the National Environmental Policy Act (NEPA). It is not intended to replace the Federal land use/noise compatibility guidelines that are produced during the Navy, Marine Corps, and Air Force Air Installation Compatible Use Zones (AICUZ) studies, Army Installation Operational Noise Management Plan studies, and Joint Land Use Studies. There are no established criteria or standardized procedures for use of the supplemental metrics.

Both the Bulletin and the Guide provide information on how to use supplemental noise metrics and analysis tools in aviation noise analyses. The Guide includes a concise summary of the effects of noise on people; the background information and references from which these metrics were developed; a definition and explanation of each metric, describing when and how to use them; and examples showing how they have been used to assess different aspects of noise effects. This Bulletin summarizes the general information in the Guide, including guidance on when and how to use supplemental noise metrics.

# BACKGROUND

Because noise at higher levels, regardless of source, intrudes to varying degrees on many human activities, community response to the noise generated by military operations has long been regarded by policy makers to be the environmental effect that demands the most attention.

The Federal government adopted DNL in the early 1980's because it is the best single system of noise measurement that can be uniformly applied in measuring noise in the communities and around civilian airports and military facilities, and for which there is a relationship between projected noise and surveyed reaction of people to the noise. All references to the DNL metric in this document include CNEL when applied to noise analysis in California.

While the Federal government has accepted DNL as the best metric for land use compatibility guidelines, describing noise exposure solely with DNL may not be adequate to achieve broad public understanding of noise exposure. Simply looking at the location of their home on a DNL contour map does not answer the important questions: how many times airplanes fly over, what time of day, what type of airplanes, or how these flights may interfere with activities, such as sleep and watching television. The number and intensity of the individual noise events that make up DNL are vitally important to broad public understanding of the effects of noise around airfields. Thus, supplementing DNL or other long-term total sound energy average metrics with additional noise exposure metrics improves public understanding of noise exposure and decision makers' ability to make better informed decisions and to maintain compatible land uses around installations.

# DISCUSSION

## NOISE EFFECTS ON PEOPLE

In order to effectively select alternative noise metrics and apply them to specific local circumstances, responsible facility staff should have at least a basic understanding of the effects of noise on people.

### *Annoyance*

The primary effect of aircraft noise on exposed communities is one of long-term annoyance, defined by the Environmental Protection Agency (EPA) as any negative subjective reaction on the part of an individual or group. The scientific community has adopted the use of long-term annoyance as a primary indicator of community response because it attempts to account for all negative aspects of effects from noise, e.g., increased annoyance due to being awakened the previous night by aircraft and interference with everyday conversation. The concept of "percent highly annoyed" has been widely used to summarize and categorize people's responses to noise. While annoyance includes speech interference and sleep disturbance, they are listed separately to reflect the separate attention these effects have been given in research and analysis findings and reports.

### *Speech Interference*

The disruption of routine activities such as radio or television listening, telephone use, or conversation gives rise to frustration and irritation. The quality of speech communication is particularly important in classrooms, offices, and industrial settings, and can cause fatigue and vocal strain in those who attempt to communicate over the noise. The disruption of speech in the classroom is a primary concern, due to the potential for adverse effects on children's learning ability.

### *Sleep Disturbance*

Although there is no current scientific evidence for establishing a direct relationship between nighttime aircraft noise and irreversible long-term health effects (particularly stress-induced illnesses such as cardiovascular disease), sleep disturbance is none the less a major cause of annoyance for the public.

### *Noise-Induced Hearing Impairment*

Residents in communities immediately adjacent to airfields may express a concern regarding the effects of aircraft noise on hearing. Considerable data on hearing loss have been collected and analyzed by the scientific/medical community, and it has been well established that continuous exposure to high noise levels will damage human hearing.

### *Non-Auditory Health Effects of Noise*

Studies have been conducted to examine the non-auditory health effects of aircraft noise exposure, focusing primarily on stress response, blood pressure, birth weight, mortality rates, and cardiovascular health. Exposure to noise levels higher than those normally produced by aircraft in the community can elevate blood pressure and also stress hormone levels. However, the response to such loud noise is typically short in duration: after the noise goes away, the physiological effects reverse and levels return back to normal. In the case of repeated exposure to aircraft noise, the connection is not as clear. The results of most cited studies are inconclusive, and it cannot really be stated that a causal link exists between aircraft noise exposure and the various type of non-auditory health effects that were studied.

## SUPPLEMENTAL METRICS AND TOOLS

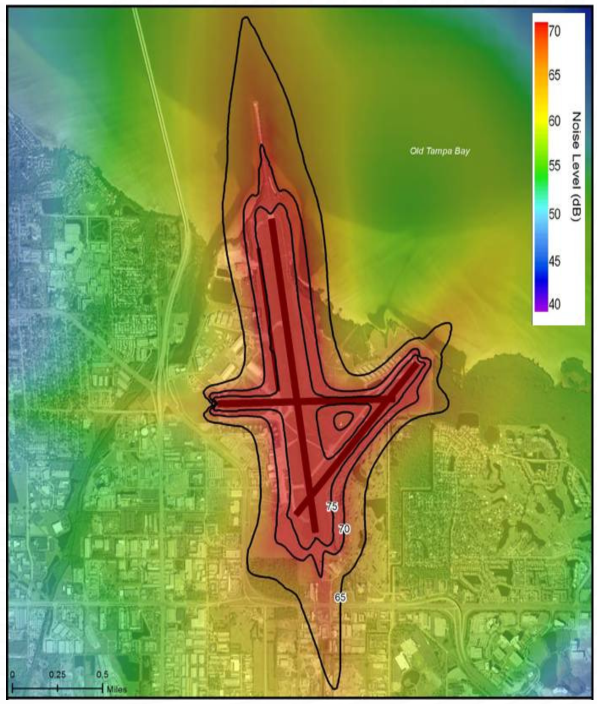
A complete description of aircraft noise exposure includes the total number of noise events, the frequency of the events, what time of day the events occur, and the noise levels of individual events from different aircraft types. The tools and metrics discussed in this section are a way forward from the single noise metric (DNL) approach to aviation noise description. Because they more clearly and completely communicate noise exposure to all stakeholders and enable project managers and decision makers to make better informed decisions, these additional metrics and tools are part of a more comprehensive and effective means of managing aviation noise.

### Supplemental Tools

The supplemental graphics, maps, tables, and other tools described below have been used with success in aviation noise management programs around the world to better communicate noise exposure.

#### *DNL Contours – Color Shading Techniques*

The public, project stakeholders, and installation staff that deal with community noise issues have raised concern about the traditional noise presentation that simply overlays the DNL 65, 70, 75, and 80 decibels (dB) noise contours on a study area map. While this serves a purpose in defining areas where land-use controls are recommended (AICUZ) or where additional analysis may be required (under NEPA), it implies that noise impacts do not extend beyond the DNL 65 dB threshold.




An alternative mapping technique shown in the accompanying figure using gradual color shading has been used successfully in presenting noise exposure to airport communities. The technique conveys a much better sense of the overall noise exposure throughout a large study area by combining both hard contour lines and gradual color shading. The color shading clearly shows that noise does not stop at the contour lines. This technique better acknowledges and communicates actual noise exposure, which in turn improves the credibility of the project owners, managers and the military. It should be noted that presenting the information in this way does not imply that additional DNL contour lines should be included or that any significance attached to the DNL 65 dB or higher contours has in any way changed. Instead, the intended message is that aircraft noise is heard well beyond the DNL 65 dB noise contour and that some noise sensitive receivers may complain that the noise is intrusive, particularly on a single event basis.

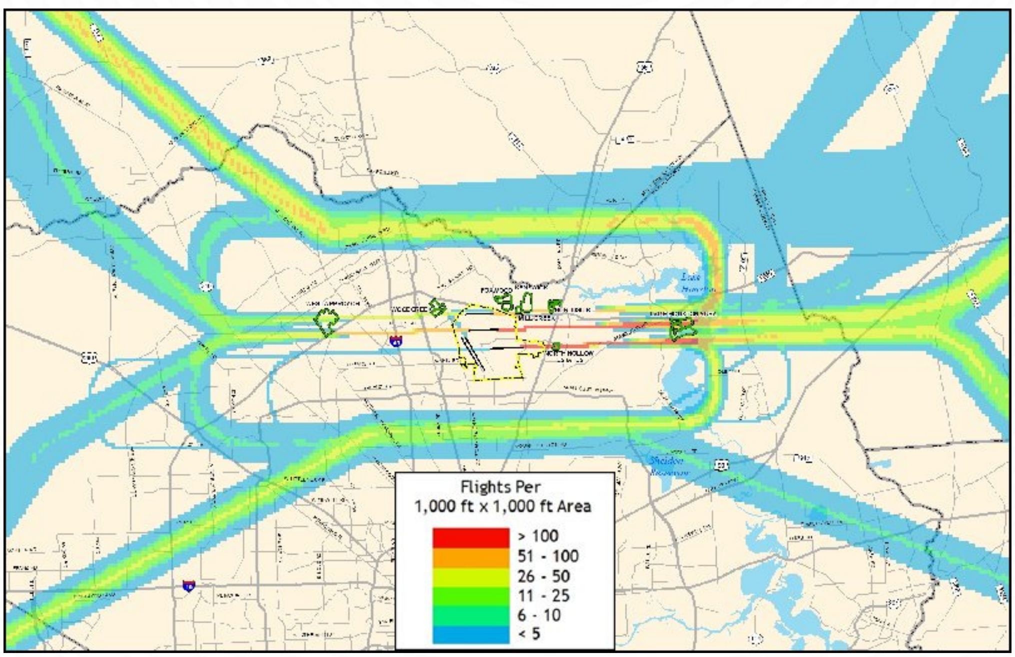
#### *Flight Track Maps*

The fundamental questions asked about the airfield noise environment are: where do the aircraft fly now, how many are there, and where will they fly in the future? To answer these questions it has been standard practice to overlay a set of flight tracks over a standard base map (or aerial photograph). The maps show that aircraft noise can extend beyond the immediate vicinity of the airbase, but might imply that noise exists only under the flight path. Furthermore, such graphics do not give any indication of how many aircraft are expected to use the flight tracks.

Flight frequency maps provide this additional information by marrying the operations and tracks onto a single graphic. The intent is to convey both the flight corridors and the number of operations associated with the flight tracks. The flight-frequency diagram shown as an example below provides a quick and easy-to-understand map of the main arrival flows for a particular runway.

Arrival and departure corridors can be combined, but this information may be confusing on a single graphic at a busy airfield. Separate graphics to show arrival and departure corridors best facilitate a complete understanding of the information. Presenting the flight corridors with gradual color shading to show the graduation of the frequency of operations effectively communicates the distribution of operations on the various flight tracks. While noise levels are not quantified, the graphic clearly communicates the general area that can expect overflights and exposure to aircraft noise, both close-in and far-away from the airport. This type of analysis is both a surrogate and a supplement to the noise analysis. Anecdotal information indicates that this type of disclosure is what the stakeholders have increasingly been demanding.

Flight frequency maps can also help the reader relate to and understand Accident Potential Zones developed for AICUZ studies.




Flight frequency maps are produced by Geographic Information System (GIS) software programs that can convert radar flight histories or other flight track information source to a color-shaded corridor on the background map or aerial photo. Production requires specialized GIS expertise and the use of associated software.

## Supplemental Noise Metrics

A number of noise studies have employed various supplemental metrics, and in each case, they communicated useful information that enhanced public understanding of the noise exposure and provided the decision makers with additional information upon which to make decisions that are more informed. The most appropriate metric(s) to use in any particular situation depends on the purpose of the noise analysis, the audience, and other details and circumstances that are unique to each local situation.

The noise metrics that have been useful to supplement DNL analysis for both military and civilian aircraft noise exposure around airfields and other noise sensitive areas include the following:

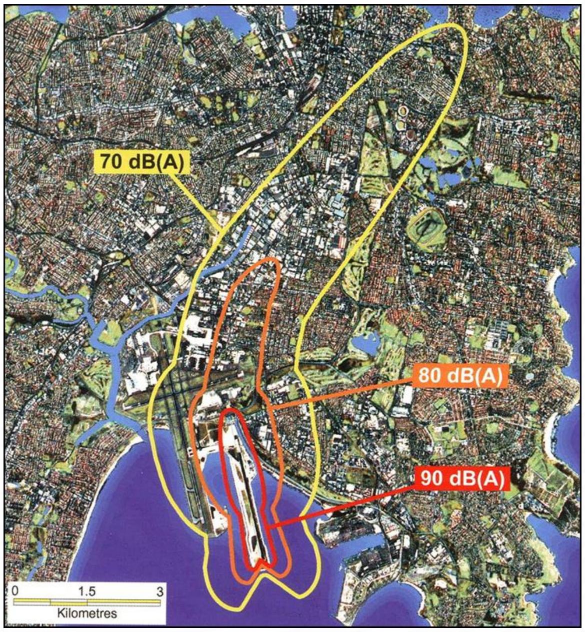
- Maximum A-weighted Sound Levels ($L_{max}$).
- Sound Exposure Level (SEL).
- Equivalent Sound Level ($L_{eq}$).
- Time Above (TA) a specified sound level.
- Number-of-Events Above (NA) a specified sound level.

This section describes the supplemental metrics, methods to present results, strengths and weaknesses, and technical requirements.

### *Maximum A-Weighted Sound Level, $L_{max}$*

The Maximum Sound Level, $L_{max}$, measured in decibels, is a common metric used to describe the maximum noise level from a single aircraft event. During an aircraft overflight, the noise level starts at the background noise level, rises to the maximum level as the aircraft flies close to the observer, and returns to the background level as the aircraft recedes into the distance. $L_{max}$ is the highest A-weighted sound level that occurs during the aircraft overflight. It can be presented as a level at discrete locations or points of interest (POI) during a given aircraft overflight, or it can be presented as a contour for a single complete overflight.

*Strengths and Weaknesses*




$L_{max}$ is a useful metric for comparing the levels of different aircraft types, either as a contour or at a geographic Point of Interest (POI). It is used in the assessment of speech intelligibility and interference. It is also one of the few noise metrics that people can understand and easily measure with simple equipment, and so it can be useful in communicating with the public.

$L_{max}$ describes the maximum level of a noise event, but does not take into account its duration, so that it provides some, but not a complete, measure of the intrusiveness of the event. An event with a relatively low $L_{max}$ but a longer duration can be just as intrusive as a short duration event with a higher $L_{max}$. A contour or value at a POI is valid for only the one aircraft for the flight track and profile simulated, and does not provide any information on the frequency of operations. The graphic is an example of $L_{max}$ contours for a departure of a B-767 aircraft from the Sydney Airport in Australia.

Technical Requirements

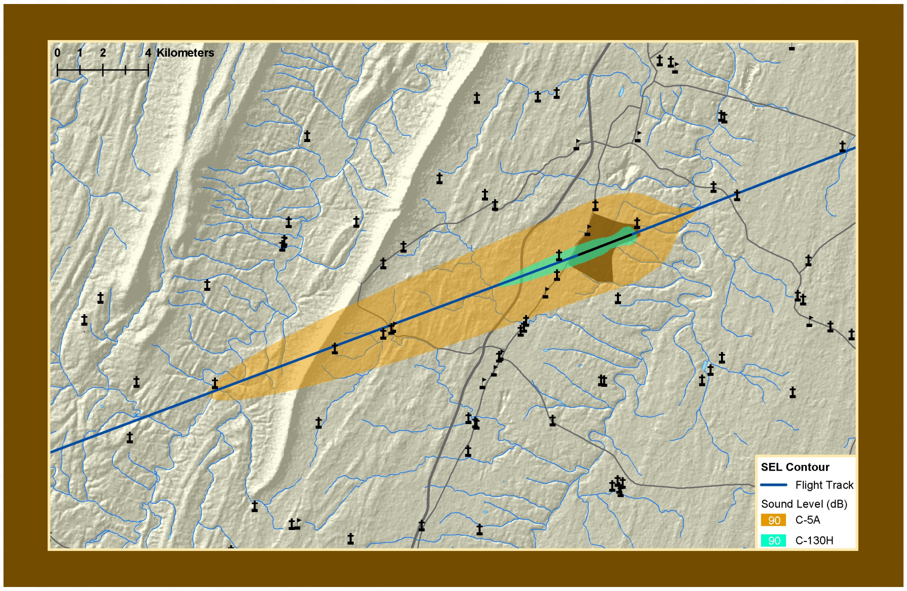
$L_{max}$ analysis in terms of contours or discrete values from flight events is not available in the publicly available version of DoD's NOISEMAP program suite for analyzing noise. It has recently been incorporated as an optional metric and this update will be available shortly. It will also be available in the Advanced Acoustics Model (AAM), which will be released in the near future. Map production requires specialized GIS expertise and the use of associated software.

### ***Sound Exposure Level, SEL***

The Sound Exposure Level (SEL) measured in A-weighted decibels, is a composite metric that combines both the magnitude and duration of a time-varying noise event, such as an aircraft overflight. As such, it represents the total noise exposure of an individual aircraft overflight. The duration of the event is the time from which the sound level exceeds a threshold level, rises to a maximum noise level during the aircraft flyover, and then decreases back to the threshold level. The SEL metric is a measure of the total acoustic energy in the event, but it does not directly represent the sound level heard at any given time. The numerical value of the SEL for a single aircraft event is typically 5 to 10 dB greater than the $L_{max}$ for that event. SEL is the building block for calculating DNL and $L_{eq}$.

*Strengths and Weaknesses*

A single-event noise contour) can be generated to illustrate the noise footprint of an individual aircraft event and is useful for comparing the relative noise levels produced by various aircraft. SEL can be used to analyze the single event benefits of various noise abatement measures under consideration. SEL contours can also be used to facilitate public understanding of the DNL metric, accomplished by graphically illustrating and comparing the SEL's of the various aircraft in the fleet. Research suggests that SEL correlates better with sleep disturbance than does the maximum noise level of an event.




Since SEL is the combination of level and duration, it is not quite as simple to comprehend as $L_{max}$. Moreover, it is not so easily measured with simple equipment. A contour or value at a POI is valid for only the one aircraft for the flight track and profile simulated, and does not provide any information on the frequency of operations.



*Technical Requirements*

A working knowledge is required of the NOISEMAP program suite, and in the near future, the AAM. Map production requires specialized GIS expertise and the use of associated software.

### Equivalent Sound Level, $L_{eq}$

The Equivalent Sound Level ($L_{eq}$), measured in decibels, is a cumulative noise metric that represents the average sound level (on a logarithmic basis) over a specified period of time; for example, an hour, a school day, daytime, nighttime, weekend, facility rush periods, or a full 24-hour day. It is an extension of the SEL metric in that it combines noise level and time of exposure over an extended time period.

*Strengths and Weaknesses*

$L_{eq}$ can be used to describe the total aircraft noise exposure over an extended period of time. For example, to better illustrate the difference between daytime and nighttime contributions to the DNL metric, 15-hour Day Average Sound Level (DL) and 9-hour Night Average Sound Level (NL) contours can be generated. A presentation of one-hour $L_{eq}$ values for each hour throughout the 24-hour day allows the community to understand how average sound levels are affected by high mission levels during various portions of the day, and to identify which are the noisiest and quietest hours in the day.

$L_{eq}$ can be shown in terms of noise contours on a map, or in combination with other metrics in tabular format for POIs.

*Technical Requirements*

A working knowledge is required of the NOISEMAP program suite, and in the near future, the AAM. Operational data is required for the time period of interest. Map production requires specialized GIS expertise and the use of associated software.

### Number of Events Above a Threshold Level, NAL

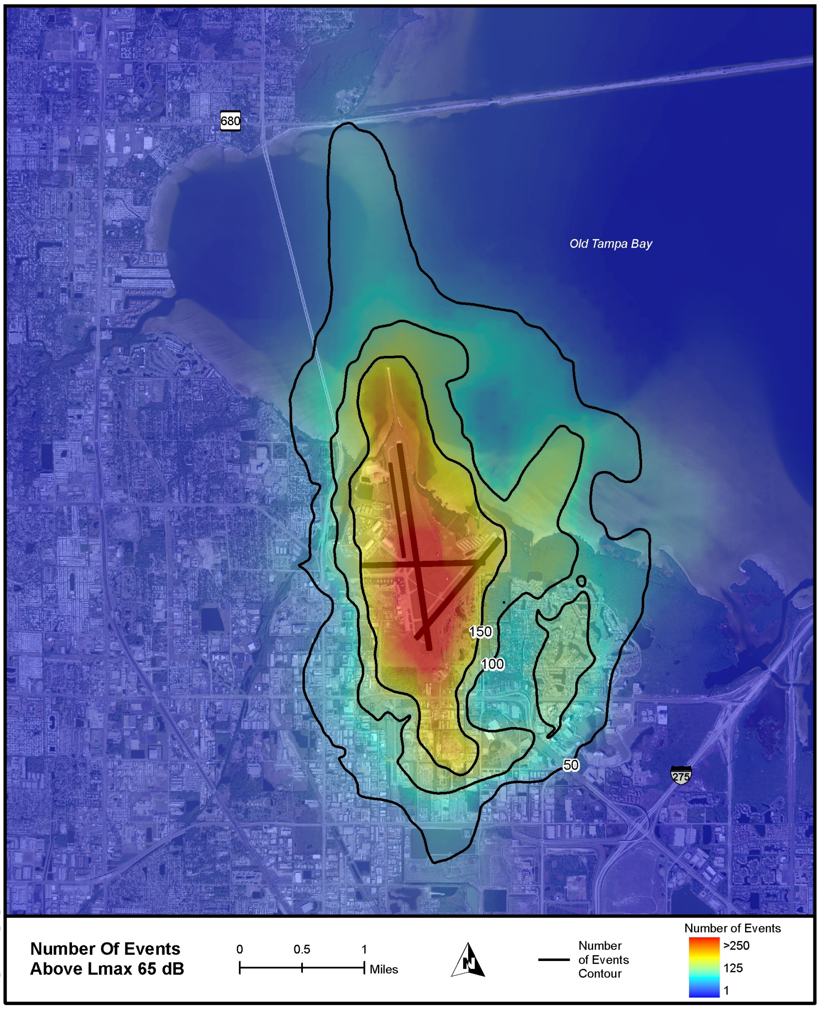
The Number-of-events Above metric (NA) provides the total number of noise events that exceed the selected noise level threshold during a specified period of time. Combined with the selected threshold level (L), the NA metric is symbolized as NAL. The threshold L can be defined in terms of either the SEL or $L_{max}$ metric, and it is important that this selection is reflected in the nomenclature. When labeling a contour line or POI on a map the NAL will be followed by the number of events in parentheses for that line or POI. For example, the noise environment at a location where 10 events exceed an SEL of 90 dB, over a given period of time, would be represented by the nomenclature NA90SEL(10). Similarly, for $L_{max}$ it would be NA90$L_{max}$(10). The period of time can be an average 24-hour day, daytime, nighttime, school day, or any other time period appropriate to the nature and application of the analysis.

NA can be portrayed for single or multiple locations, or by means of noise contours on a map similar to the common DNL contours. A threshold level is selected that best meets the need for that situation. An $L_{max}$ threshold is normally selected to analyze speech interference, whereas an SEL threshold is normally selected for analysis of sleep disturbance.

*Strengths and Weaknesses*

The NA metric has a distinct advantage in communicating current and projected noise exposure in a way not available through the use of other metrics or tools. It is the only supplemental metric that combines single-event noise levels with the number of aircraft operations. In essence, it answers the question of how many aircraft fly over a given location or area at or above a selected threshold noise level. Anecdotal evidence has shown that the public easily relates this metric to their everyday experience. When used in a comparison of scenarios, the public can more easily comprehend a change in numbers of events than they can changes in noise level.

NA has proven useful as a good indicator of the effects that airport noise will have on certain human activities – specifically, the number of times per day (or other time period) that speech could be interfered with, or the number of nighttime aircraft events that may cause some level of sleep disturbance.




Source: US Census TIGER/Line 2000, Wyle Laboratories, INM 6.1
Geographic Reference: 1983 State Plane Coordinate System, Florida West, Feet

NA analysis can be communicated through the use of noise contours overlaid on a local area map using color shading. An example is shown in the adjacent figure, where the NA contours detail the areas that are exposed to 50, 100, and 150 aircraft events (over an average 24-hour day) above an $L_{max}$ threshold value of 65 dB.

Note that the contours for different noise level thresholds should be mapped separately to avoid confusion. A word of caution and lesson learned - it is best to rely on one or maybe two threshold levels, because adding more may confuse the public and non-technical project officials and managers.

Simply increasing the amount of information and level of detail will not necessarily help the intended audience.

The results can be displayed using tables showing various NA values for the selected threshold levels for each of the operational scenarios or alternatives at POIs throughout the study area. The accompanying table is an example for seven POIs where the DNL is presented together with the number of events exceeding different $L_{max}$ values ranging from 55 to 85 dB (NA55$L_{max}$ to NA85$L_{max}$. In this case, the component parts of DNL are shown by extracting the aircraft events that occur above a range of threshold levels during the average annual day at a number of locations. Essentially, we are "looking inside" a given DNL at a POI by computing the number of aircraft events that exceed the specified thresholds (i.e., 55, 60, 65, 70, etc. dB).

**Example of NA $L_{max}$ Values Exceeded at Locations on DNL 60 and 65 dB Contours**

| Location | DNL (dB) | $L_{max}$ 55 dB+ | $L_{max}$ 60 dB+ | $L_{max}$ 65 dB+ | $L_{max}$ 70 dB+ | $L_{max}$ 75 dB+ | $L_{max}$ 80 dB+ | $L_{max}$ 85 dB+ |
|---|---|---|---|---|---|---|---|---|
| 1 | 60 | 155 | 76 | 36 | 11 | 3 | 1 | 0 |
| 2 | 60 | 201 | 104 | 46 | 13 | 2 | 0 | 0 |
| 3 | 60 | 204 | 106 | 49 | 16 | 1 | 0 | 0 |
| 4 | 60 | 171 | 95 | 49 | 19 | 4 | 0 | 0 |
| 5 | 65 | 254 | 139 | 83 | 44 | 18 | 3 | 0 |
| 6 | 65 | 235 | 131 | 81 | 44 | 19 | 4 | 0 |
| 7 | 65 | 253 | 170 | 98 | 50 | 19 | 4 | 0 |

The community can quickly see the number of exceedances for a series of thresholds (e.g., 55 dB through 85 dB $L_{max}$), allowing a good understanding of the increase or decrease in the number of events that will result between two (or more) different operational scenarios. An additional benefit is that this allows less dependence on establishing a "significant" outdoor sound level threshold for the analysis.

The most comprehensive results can be shown by presenting the NA contours on a map that also shows the noise sensitive POIs in the study, and then presenting the computed NA values for those specific points in separate supporting tables. The main advantage to using this technique is that the stakeholders can better understand the cumulative noise exposure from the individual aircraft events that occur over a given period of time over a wide range of threshold levels. The full effectiveness of the NA approach is realized when evaluating changes in noise exposure that will result from an operational change, particularly when comparing alternatives that will shift noise. This approach is effective in explaining the overall noise environment and any changes that are expected to occur with each alternative under consideration.

*Technical Requirements*

NA analysis was recently incorporated as an optional metric in the NOISEMAP program suite, and this update will be available shortly. NA analysis will also be available in the new AAM. Operational data for the time period of interest is required. Map production requires specialized GIS expertise and the use of associated software.

### *Time Above a Specified Level, TAL*

The Time Above metric (TA) is a measure of the total time that the A-weighted aircraft noise level is at or above a defined sound level threshold. Combined with the selected threshold level (L), the TA metric is symbolized as TAL. TA is not a sound level, but rather a time expressed in minutes. TA values can be calculated over a full 24-hour annual average day, the 15-hour daytime and 9-hour nighttime periods, a school day, or any other time period of interest, provided there is operational data to define the time period of interest. As with NA, when labeling a contour line or POI on a map, the TAL will be followed by the number of minutes in parentheses for that contour line or POI. As an example, TA65(60) calculated over a 24-hour day for a specific location indicates that the sound level at that location exceeds 65 dB for a total of 60 minutes spread over a 24-hour day.

TA has application for describing the noise environment in schools, particularly when comparing the classroom or other noise sensitive environments for different operational scenarios. TA can be portrayed by means of noise contours on a map similar to the common DNL contours, as shown in the accompanying figure. Hard contour lines are drawn to reflect selected TA values, such as 10, 20, and 40 minutes above 65 dB as shown in the graphic, using the gradual shading technique to show the variation in time-above values between the contour lines and further away from the airfield.

For analysis purposes, a threshold level or a series of thresholds levels, which require multiple contours/maps, or a table with a separate column for each threshold, should be selected that best meets the need for each situation – i.e., a predicted speech interference or sleep disturbance threshold value. An alternative presentation is to map a series of thresholds (e.g., 60 dB, 70 dB, and 80 dB) that corresponds to a single amount of time that is exceeded (e.g., 30 minutes per day).

The example below shows a tabular presentation of TA for a wide range of threshold levels at six study area POIs. The most comprehensive results can be shown by presenting the TA contours on a map that also identifies the POIs in the study, with corresponding tables presenting the computed TA values for those specific points.

**Time Above Sound Level Threshold for a 24-hour Period**

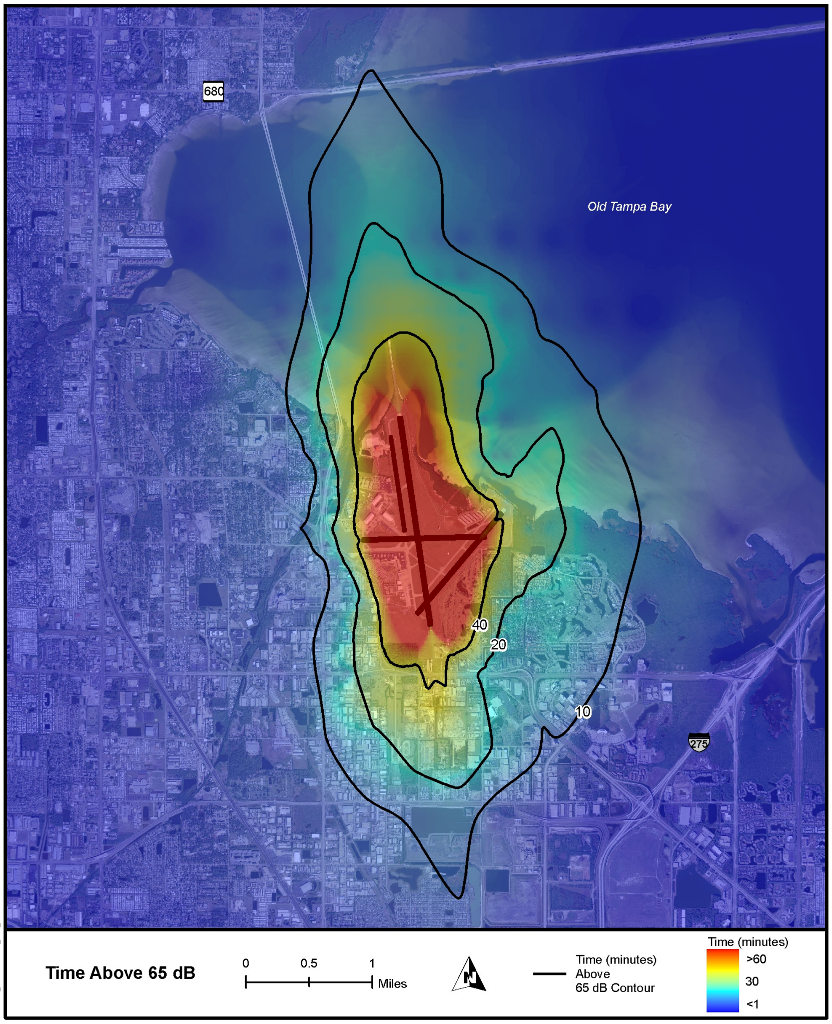
| Point | Time Above Sound Level Threshold (Minutes): | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 55 dB | 60 dB | 65 dB | 70 dB | 75 dB | 80 dB | 85 dB | 90 dB |
| 1 | 133 | 68 | 27 | 8 | 3 | 0 | 0 | 0 |
| 2 | 143 | 65 | 29 | 12 | 4 | 1 | 0 | 0 |
| 3 | 21 | 11 | 6 | 2 | 1 | 0 | 0 | 0 |
| 4 | 23 | 14 | 9 | 5 | 2 | 1 | 0 | 0 |
| 5 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |

*Strengths and Weaknesses*

When the TA results are displayed using tables to show the multiple POIs throughout the study area, the community can quickly and efficiently see the time that is exceeded for a series of thresholds (e.g., 60, 70, 80, and 90 dB), allowing a good understanding of the increase or decrease in time that will result between different operational scenarios. An additional benefit is that this approach relies less on a "one-size-fits-all" approach that results by establishing a "significant" outdoor sound level threshold level for TA analysis.

The TA is a useful descriptor of the noise impact of an individual event, and also for multiple events occurring over a certain time period. When computed for a full day, the TA can be compared alongside the DNL in order to determine the sound levels and total duration of events that comprise the corresponding DNL. TA analysis is usually conducted along with NA analysis so the results show not only how many events occur above the selected threshold(s), but also the total duration of those events above those levels for the selected time period.

Although the TA analysis indicates the number of minutes that an A-weighted sound level is exceeded, it does not provide a measure of maximum sound level that occurs during the selected time period. As an example, TA70(60) represents a noise environment in which a noise level of 70 dB is exceeded for 60 minutes per day, but an individual aircraft overflight could be much higher than 70 dB. The most comprehensive results can be shown by presenting the TA contours on a map that also identifies the noise sensitive points of interest in the study, with corresponding tables presenting the computed TA values for those specific points.




Source: US Census TIGER/Line 2000, Wyle Laboratories, INM 6.1
Geographic Reference: 1983 State Plane Coordinate System, Florida West, Feet

*Technical Requirements*

NOISEMAP is an integrated noise model that computes the overall noise exposure by combining the SEL's for all aircraft events within a particular time period. Time-based descriptors such as TA cannot be accurately modeled within NOISEMAP because the time history of each event is unknown. The TA can be approximated by assuming a standard time history for each aircraft event. TA can only be accurately calculated from a noise simulation model, such as AAM, that portrays the time histories of each event.



# FINDINGS/CONCLUSIONS

There are a few basic considerations and questions that need to be evaluated before selecting the most appropriate tools and metrics for any given project or noise study. Although there are similarities among projects, each project is somewhat unique. The toughest challenge comes in deciding which metrics and tools will contribute the greatest understanding of noise exposure, ensure consistent application DoD-wide, and extract the most value for the project.

It is important for the analyst or planner to consider the analysis from the viewpoint of a project stakeholder or interested citizen. Regardless of whether that person is a planning board member, an average citizen, or the base commander, it is quite possible the person will have little or no technical training in noise analysis.

Most project stakeholders and the general public do not want to wade through pages of technical data. They respond most positively and proceed more quickly toward project completion when the most straight-forward noise exposure data is presented in the main text with the detailed tabular data in an appendix for those wishing to see the complete technical information. For instance, if the noise effects in an educational setting are of primary concern, the analysis should focus on the one sound level threshold that best equates to speech interference and leave more-detailed information on other effects or thresholds to an appendix.

This section is designed to provide guidance to reap the full benefits of supplemental analysis by employing noise metrics and tools that best explain the expected outcome, including:

- Flight Tracks - Where do the aircraft fly now and where will they fly in the future?
- Aircraft Noise Levels – What are the most frequent and maximum noise levels for the events today and will they change in the future?
- Time of Day - When do events occur? Are there variations between day, night, evening, or are there typical periods of higher operations?
- Noise exposure beyond the DNL contours - What is the noise exposure beyond the contour lines where noise exposure levels are in the moderate range?
- Number of Events - How many aircraft events are there today and how many are likely to occur in the future?
- Duration – How much time out of a day, night, school hours, or other time period will noise be noticable or intrusive?

### Selection of Metrics

Planners are encouraged to use this Bulletin to facilitate the selection and application of the supplemental metrics and tools that will best communicate noise exposure and address the specific concerns of all stakeholders. Simply disclosing a set of DNL contours may not be adequate to provide the information desired by and satisfactorily respond to the typical stakeholder concerns listed above. The array of metrics available for analysis is presented in the accompanying table. The first three columns of the table describe the application for which the metric is intended, the metric to be employed, and the metric unit. The fourth and fifth columns list the recommended time period over which the metric should be calculated, and the recommended metric values to present. Planners first have to decide on which application(s) listed in the table are the most appropriate to their needs



for a particular analysis. Having defined the application(s), the planner can then select the most appropriate metric(s) listed in the table for each application.

**Guideline Values for Land-Use Studies (Outdoor Levels)**

| Application | Metric | Unit | Time Period | Recommended Outdoor Unit Values* |
|---|---|---|---|---|
| Policy Metric | DNL | dB | 24 Hrs | 60, 65, 70, 75, 80 dB |
| Annoyance | DNL | dB | 24 Hrs | 60, 65, 70, 75 dB |
| Aircraft Comparison | $L_{max}$ | dB | None | 75, 80, 85 dB |
| | SEL | dB | Single Event | 85, 90, 95 dB |
| Variation/Comparison of Average Levels | $L_{eq}$ | dB | 1hr, 15hr Day, 9hr Night | 65 dB |
| Speech Interference | NA ($L_{max}$) | Number Of Events | 15hr Day | 15, 30, 45, 60 events (Above 75 dB) |
| Sleep Disturbance | NA (SEL) | Number Of Events | 9hr Night | 1, 3, 5, 9, 18, 27events (Above 90 dB) |
| Classroom Speech Interference | $L_{eq}$ | dB | School Hours (8hr) | 60 dB (for scoping) |
| | NA ($L_{max}$) | Number Of Events | School Hours (8hr) | 8,16,24,32 events (Above 75 dB) |
| | TA | Minutes | School Hours (8hr) | 2, 4, 6, 8 minutes (Above 75 dB) |

*Unit values for plotting contours on study area map

The guideline values in the table assume an annual average day condition, but could also be applied for a peak operations period or some other condition. Note that the suggested time period for each metric in the table varies. If a greater range of values is necessary to fully communicate exposure levels to all stakeholders in the selected study area, presenting results in tabular form or on multiple graphics is recommended. In California, CNEL would be used instead of DNL with time periods of 12 hours for day and 3 hours for evening.

The applications listed in the table are further explained below:

### *Policy Metric*

DoD policy requires analysis of aviation noise impacts in the vicinity of airfields to include DNL contours. Showing contours in 5 dB increments from 65 dB to 80 dB is required, but additional contours (e.g., 60 dB) may be provided to fully communicate exposure in certain circumstances if local conditions warrant discussion of these noise levels or where significant noise complaints have been received in areas exposed to DNL less than 65 dB.

### *Annoyance*

DNL is the best available metric to relate aircraft noise to long term annoyance. Therefore, DNL contours in 5 dB increments from 60 dB to 75 dB are generally sufficient to communicate the noise exposure levels associated with the community annoyance. It should be noted that the dose-response relationship between DNL and annoyance varies over a wide range and is extremely location dependent. Thus it is inadvisable to use this relationship to predict the specific number or percentage of the local exposed population who are expected to be highly annoyed by aircraft operations at a given DNL. The relationship between noise and community annoyance is addressed in detail in DNWG Technical Bulletin, "Community Annoyance Caused by Noise from Military Aircraft Operations."

### *Aircraft Comparison*

Comparison of aircraft single event noise levels is useful in communicating the difference in noise exposure between aircraft types, particularly when a new aircraft type is being introduced to an airfield. Noise exposure comparisons showing single event $L_{max}$ footprints (contours) at 75, 80 and 85 dB are generally sufficient to identify locations around the airfield where single event noise levels may be intrusive, such as in classrooms. If nighttime operations are a concern, a comparison using the SEL metric should be considered because sleep disturbance predictions are correlated to the SEL metric. SEL contours are in the range 5 to 10 dB larger than the $L_{max}$ contours for a given aircraft at the same numeric dB level. For this reason, the recommended levels for plotting SEL contours are 85, 90 and 95 for most aircraft. Higher levels may be necessary to fully communicate the exposure of the highest performance aircraft.

### *Variation/Comparison of Average Levels*

The annual average day DNL cannot show the variations in average noise level between peak operation times and times with fewer operations. When operations vary considerably from the average, calculating the average noise level of operations occurring in various time periods using the $L_{eq}$ metric is recommended to communicate the average noise level for operations during selected periods. An appropriate time period, such as the peak operation day, peak hour of the day, or daytime vs. nighttime should be selected. Plotting these time average levels contours at $L_{eq}$ 65 dB is recommended. Plotting contours at additional levels is recommended if necessary to fully communicate the variations in exposure between selected time periods.

### *Speech Interference*

To communicate how often speech interference may occur during the 15 hour daytime period for the average annual day, busy day, or other selected time period, the $NA75L_{max}$ metric is recommended. Plotting contours for 15, 30, 45, and 60 events at or above 75 dB reflects an average of 1-4 events per hour at or above a level that many people find intrusive to communication and other activities in the outdoor environment. The 75 dB threshold also reflects indoor noise levels recommended by EPA, and includes the effect of a 25 dB building noise reduction with windows closed. Presenting NA results for POIs in a study area in tabular form over a range of threshold levels is effective in communicating how often noise events may be intrusive at various POIs in a study area. This method is particularly useful to compare the noise exposure changes that will occur among various operational scenarios.

### *Sleep Disturbance*

Prediction of sleep disturbance is advisable when nighttime operations are a consideration. Sleep disturbance is not just a factor of how loud, but also the duration of each noise event. Thus, sleep disturbance is best reflected with the SEL metric, which captures the total energy of each noise event no matter how loud and how long or short the duration. Similar to the speech interference discussion above, displaying the NA contours of 1, 3, 5, 9, 18, and 27 events correspond to 1, 3, and 5 events per night and 1, 2, and 3 events per hour, respectively, over the course of the nighttime period (2200-0659).

The American National Standards Institute (ANSI) and the Acoustical Society of America (ASA) have jointly approved a standard, ANSI/ASA S12.9-2008/Part 6, to predict awakenings associated with outdoor noise events heard in the home. The standard suggests methods for calculating the probability of awakening at least once to the sound from distributions of single noise events. The following table relates the recommended NA90 contour levels with the probability of each person exposed awakening at least once as calculated by the ANSI/ASA Standard Formula where all events are at SEL 90 dB.

**Probability of Awakening at Least Once From Multiple Events at SEL 90 dB**

| NA90SEL | Windows Closed* | Windows Open** |
|---|---|---|
| 1 | 1% | 2% |
| 3 | 4% | 6% |
| 5 | 7% | 10% |
| 9 | 12% | 18% |
| 18 | 22% | 33% |
| 27 | 32% | 45% |

* Windows Closed' assumes that there is a 25 dB noise level reduction (NLR) between the outdoors and indoors, e.g., 90 SEL outdoors is 65 SEL indoors.

**'Windows Open' assumes that there is a 15 dB NLR between the outdoors and indoors, e.g. 90 SEL outdoors is 75 SEL indoors).

The derivation of these predications of awakenings is explained in DNWG Technical Bulletin, "Sleep Disturbance from Aviation Noise."

### *Classroom Speech Interference*

If the study area defined during the scoping phase includes schools and operations during school day hours can be segregated out from the total day operations counts, then a school-day period (typically 8 hours) should be used in place of a 24-hour average to assess classroom speech interference. The next step in the scoping process is to identify the portion of the study area where aircraft noise could be a problem in classrooms.

The ANSI S12.60-2002 Standard recommends for the most common size of classroom a maximum one-hour-average A-weighted background noise level of 35 dB for steady noise, and 40 dB for unsteady noise from transportation sources. For this scoping task, the more conservative value of 35 dB is selected. In a windows closed school environment with an average noise level reduction (NLR) of 25 dB, 35 dB in the classroom is equivalent to 60 dB outdoors. Thus, the 60 $L_{eq}$ contour provides a first indication that aircraft noise might be a problem because the classroom noise levels could exceed the 35 dB background noise level. Once the schools have been identified, the next step is to assess the magnitude of classroom interference using NA75 ($L_{max}$).

The NA75 (outdoor level) is recommended because in a 'windows closed' school environment with an average NLR of 25 dB, the resulting 50 dB level is the widely accepted single event criteria threshold level for classroom speech interference. The recommendation of producing NA75 for events in multiples of 8 events (i.e., 8, 16, 24, 32) per 8-hour time period is given to simulate the effects of multiple aircraft events per hour (1, 2, 3, and 4 or more).

If classroom speech interference is of particular concern, additional analysis can be conducted to supplement the NA analysis with a TA analysis. TA analysis would show the number of minutes on average that class time is interrupted by the aircraft intrusions.

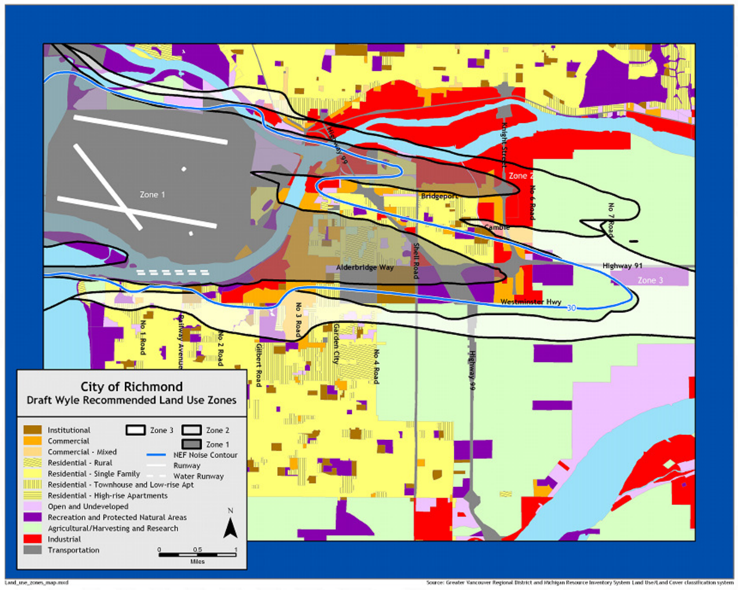
By computing the number of minutes in the time period selected for the NA analysis using the TA metric, the noise exposure communicated includes not only how many events occur, but the total time they will be above 75 dB (corresponding to the NA analysis threshold discussed above) or other threshold level. While NA analysis alone is effective in communicating noise exposure, TA results without NA results are much less effective. NA and TA results can be presented in contour format and in more detail in tabular format. If TA is presented in contour format, then the increments in minutes should be selected based on operational levels. The more operations during the selected time period, the larger the increments can be to best show the amount of time noise will exceed the selected threshold level. If operations are few, then one minute increments should be used.

Presenting NA and TA results for selected geographic locations in a study area in tabular form over a range of threshold levels is highly effective in communicating the number and duration of noise events that may be intrusive at each school located in a study area. This method is particularly useful to compare and show the noise exposure changes that will occur among various operational scenarios, and it highlights the smaller changes that are difficult to communicate by comparing DNL contours alone on a background map. NA and TA break the total sound energy that comprises DNL into its component parts, and these supplemental metric results are much easier for the average person to comprehend than DNL. When these results show that the number (NA) and total time (TA) of intrusive noise events in the classroom is low, public acceptance of the proposed action is more likely.

## Combined Effects Contours

Disclosing a set of DNL contours that are supplemented separately by NA contours that relate to sleep disturbance and speech interference shows the stakeholders and decision makers the average effects of annoyance, sleep disturbance and speech interference at various exposure levels. A more complete indication of the total combined noise effects can be provided by overlaying these separate effects contours on a single graphic with each contour clearly labeled, but with a single outer noise contour boundary highlighted to show the combined effects at the selected threshold levels.

In the Canadian airport example below, the daytime $NAL_{max}$ contours at levels associated with annoyance and speech interference and the nighttime NASEL contours associated with sleep disturbance were individually plotted on a single map along with the Noise Exposure Forecast (NEF) contour. (NEF 30 and DNL 65 dB contours are roughly equivalent). By combining the outer boundary of each contour, a single protection area was identified to address the combined effects of annoyance, speech interference and sleep disturbance. A more detailed summary of this example, including an explanation of which metrics were combined to form each zone boundary, is located in Appendix C of the Guide referenced in the Introduction above.




Separately, in the text of the document, but not on the contours themselves, the contour values can be ascribed to average effects (in terms of annoyance, speech interference, percentage of awakenings), with the clear statement that these are averages of research data, rather than specific local results.

# REFERENCES

Most of the information in this Bulletin was excerpted from, “Improving Aviation Noise Planning, Analysis and Public Communication with Supplemental Metrics – Guide to Using Supplemental Metrics.” Copies of that document, which has an extensive list of technical references, are available upon request from DNWG.

**Available on line at:**

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