TITLE PAGE

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NOISE MONITORING IN SAN JUAN, PUERTO RICO

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This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of the Noise Control Area of the San Juan Environmental Quality Board or Worcester Polytechnic Institute.

This report is the product of an education program, and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be construed as a working document by the reader.

Abstract

The Environmental Quality Board (EQB) of Puerto Rico is currently monitoring sound levels throughout randomly selected areas of San Juan using the Norsonic-121 Sound Analyzer. In order to improve the quality of life for the citizens of San Juan, the EQB collected sound levels to assess those areas where sound becomes an issue of noise pollution. This project proposal presents previous research about noise pollution, as well as the methods used to gather both sound levels throughout San Juan and local opinions on the issue. Noise complaints and residential surveys regarding noise were analyzed as a first step in understanding how some people of San Juan feel about the issue. Use of the Norsonic-121 provided the actual sound level data that could then be quantitatively analyzed for noise pollution. A sound profile was then constructed from all monitored sites to represent the sound pattern of San Juan. Once the profile is completed by the EQB, it will be used as evidence to document the noise pollution problem, to amend current noise legislation, and provide funding for more efficient noise regulation enforcement. Also, from the analysis of the sound profile, identified sound sources, noise complaints, and residential surveys, suggestions and recommendations were made to the EQB about possible methods to decrease sound levels by reducing some of the prominent sources of sound.

Executive Summary

Noise pollution is a worldwide problem that affects people, economic growth, and the environment, drastically reducing the quality of life. Health problems due to excessive noise level exposure include sleep disruption, high blood pressure, elevated stress levels, hearing loss, nervous behavior, and anxiety. San Juan has a large noise problem. As a commonwealth of the United States, Puerto Rico is subject to the noise policies of the federal government, as well as its own specific policies. Still, there is an urgent need for clearer legislation and stricter enforcement around the island. To date, noise control is based mostly on a police officer's opinion about what is excessive noise. Because this is subjective judgment, it is hard to enforce, and consequentially, many noise policies are not enforced at all.

Until now the noise pollution problem has not been sufficiently documented. With our assistance, the Noise Control Area of the Environmental Quality Board is in the process of conducting the first community-wide noise project documenting the current decibel levels of the island of Puerto Rico. From this project, the Noise Control Area hopes to determine the status of San Juan's acoustic environment as a first step towards reducing the problem. To facilitate this, we followed a research plan established by the EQB and created a time-versus-sound level graph representative of the entire city. We split the city up into six sections and randomly selected various locations within these sections. Stations were set up at each of the sites and the sound levels were monitored for 24 hours using a machine called the Norsonic-121. With only 24 sites to date, the project is a work in progress that over the next few years will encompass several hundred monitoring sites in order to create an accurate representative sound pattern of the city.

From the 24 sites that have been monitored thus far, a graph has been created displaying the sound level profile of the city of San Juan shown in Figure A.

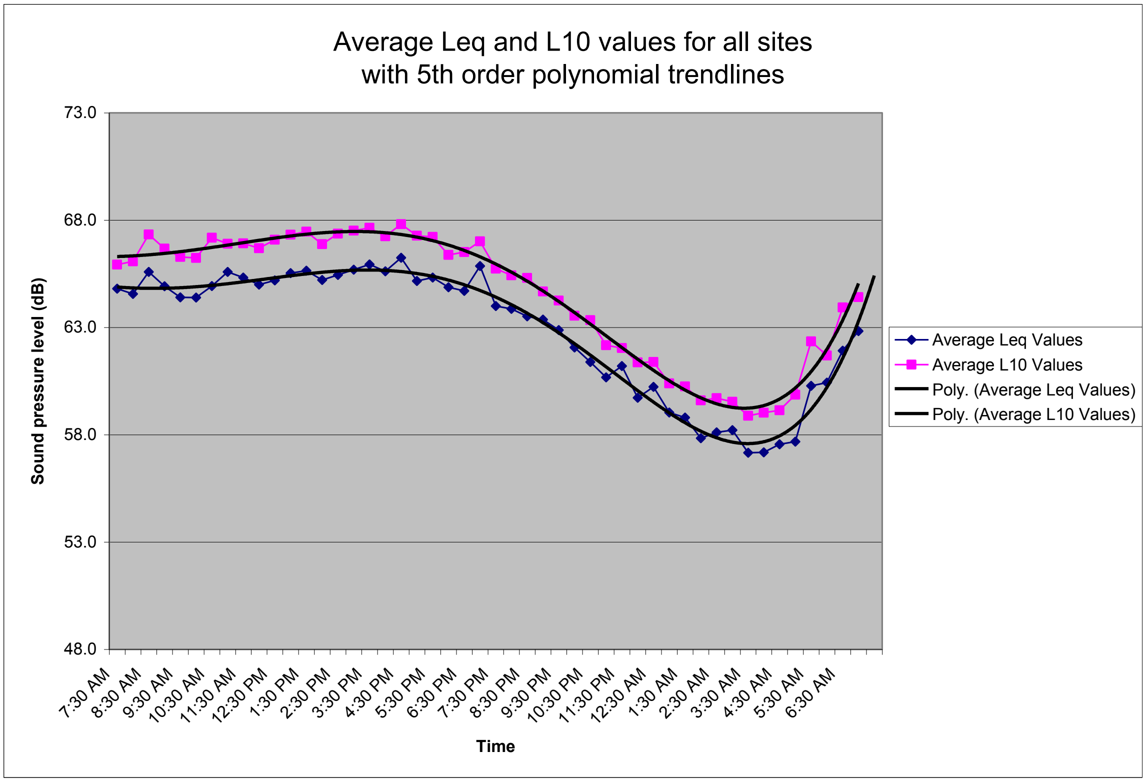

Figure A: Sound Level Profile of San Juan Displaying the 24 Monitored Sites

In order to begin reducing the noise problem one must first determine the prominent sources of noise. Through the use of random sampling we obtained the decibel levels occurring at the sampled sites. In addition to the decibel levels, we also manually documented the dominant sources of sound in the areas monitored. However, noise and sound are not synonymous. Noise occurs when a sound is perceived to be annoying or disruptive. In order to get a sense of how people perceive these sounds, we looked at two different sources: the residential noise complaints received by the EQB, and surveys regarding people's perceptions of noise pollution that were administered both to police officers of Puerto Rico and teachers of the island of Vieques. This data helped us to distinguish the difference between the prominent sources of sound versus prominent sources of noise. We determined vehicular traffic to be the most prominent source of noise, encompassing many different sources in itself. Vehicles emit noise from the engine, the exhaust, the tires contact with the road, the stereo, the horn, and the vehicle's alarm system. Additional sources of noise come from trash collection, megaphones and loudspeakers, personal stereos, construction equipment, and other types of machinery.

With the prominent contributors of noise identified we could begin to make recommendations on how to reduce the problem. In order to eliminate the subjectivity regarding what police officers considered excessive noise, it will be necessary to place numerical values on regulations and well as specific sources. In order to do this, police officers will have to be equipped with the appropriate sound measuring devices and trained to calibrate and operate the equipment.

Other methods of noise reduction exist aside from legislation. Traffic noise can be decreased by a number of different techniques such as sound barriers, noise emission tests, changing the pavement type, and increasing public transportation. Sound insulation could be used more prevalently in homes as well as within industrial businesses. Promoting education and noise awareness among school and society is another effective way to reduce noise.

The preliminary data that we helped to collect reinforces our assertion of San Juan's noise problem and suggests the necessity for noise reduction measures. With appropriate funding and cooperation from law enforcement, the Environmental Quality Board can begin to write both clear and concrete legislation regarding noise. Definitive legislation will lead to more efficient enforcement while additional funding will provide other forms of noise reduction. At the culmination of this project, a reduction of noise will create a more enjoyable and acoustically favorable environment for the residents of San Juan, ensuring both peaceful living and an increase in the quality of life.

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1.0 Introduction

Noise pollution continuously affects people, economic growth, and the environment in nations worldwide (Bugliarello, 1976). In urban areas especially, this problem drastically reduces the quality of life. Although every city is different, noise is created and influenced by a variety of common sources. These include, but are not limited to industry, traffic, culture, and the natural environment (Wieland, 2003; El-Fadel, 2000; Pearce, 1985; and Helmkamp, Talbott, and Margolis, 1984).

In the densely populated city of San Juan, Puerto Rico, there is a serious noise problem. Because it is a commonwealth of the United States, Puerto Rico follows the noise policies of the federal government. The need for new local legislation is imperative because current U.S. policies and their enforcement have proven to be insufficient to meet the needs of the citizens of the island (EQB, 2004).

Noise pollution is a complex interaction among people, the sound they make, and the environment in which they live. Sound becomes an issue of noise pollution when it adversely affects people. Noise has been extensively linked to a number of societal problems, most importantly health problems, including sleep disruption (García, Miralles, García, and Sempere, 1990), high blood pressure (Evans, 2001), elevated stress levels (Grotvedt, 1990), hearing loss (Bahadori and Bohne, 1993), nervous behavior, and anxiety (Grotvedt, 1990). In understanding the serious impact noise has on health, it becomes apparent why stricter legislation is ultimately necessary.

To create effective noise legislation, it is necessary to collect different sounds and sound intensities throughout multiple locations of the city. To this date, the Environmental Quality Board (EQB) of Puerto Rico has gathered preliminary sound level data throughout Old San Juan, but there are additional locations within the districts of Santurce and Rio Piedras that need to be monitored in order to create a representative sample for the city.

In our project we assisted the EQB in collecting and analyzing noise level data from San Juan to expand their knowledge on the issue of noise pollution in the city. The sound level data and residential noise complaints were compiled in an effort to understand the behavior of the sound patterns in San Juan, the levels of exposure to residents, and to suggest strategies that will reduce the problem.

2.0 Introduction to Noise Pollution

Noise pollution is a complicated societal issue that involves much more than just the noise itself. To understand noise pollution one must understand the difference between noise and sound, different sources that produce noise, and various effects that noise has on individuals, society, and the economy. Because of these complex and serious issues, governments have implemented noise policies that regulate and reduce noise pollution to promote the wellbeing of their citizens. However, many of these policies, including the policies of the Commonwealth of Puerto Rico, have proven to be insufficient in controlling noise and therefore need to be altered. These are topics that will be discussed in this chapter.

2.1 Sound

Sound, at its most basic level, is a variation of pressure caused by vibrations (Taylor, 1970). Our ear converts these pressure waves into electrical signals to be interpreted by our brain; larger pressure variations yield louder sounds. Also, the frequency of these pressure waves corresponds to the pitch; higher frequencies yield higher pitches and vice versa.

2.1.1 Decibels

The most sensitive human ear can detect sounds of 1×10^{-12} watts/m^2, where watts/m^2 is the unit of sound intensity. Some of the largest known intensities can be in the hundreds of millions of watts/m^2 (Taylor, 1970). Sound intensities are measured on the logarithmic scale called the decibel. The decibel itself is unitless because it is the logarithm of the ratio of the specific sound intensity and a reference intensity, which is the lowest audible sound intensity (Taylor, 1970).

Equation 1

$$dB = 10 \log_{10} (\text{Intensity} / \text{Reference Intensity})$$

It is important to realize the consequences of the logarithmic scale. Many people have the misconception that decibels can be added, subtracted, multiplied, and divided like normal numbers, but this is not true. For instance, an increase in ten decibels actually means that the sound intensity has increased ten fold. An increase in 20 decibels means that the sound has increased 100 times and so on. The sound doubles in intensity after an increase of approximately 3dB (Taylor, 1970). Table 1 uses equation 1 to display selected intensities and their corresponding decibel levels.

Table 1: Sound Intensity vs. Decibel Level

Sound Intensity (W/m^2)	Decibel
100 000 000	200
10 000 000	190
1 000 000	180
100 000	170
10 000	160
1 000	150
100	140
10	130
1	120
.1	110
.01	100
.001	90
.000 1	80
.000 01	70
.000 001	60
.000 000 1	50
.000 000 01	40
.000 000 001	30
.000 000 000 1	20
.000 000 000 01	10
.000 000 000 001	0

2.1.2 Decay Rate of Sound

Distance greatly impacts how sound is perceived by the human ear. The greater the distance between the human ear and a sound, the quieter the sound seems. This relationship is explained by sound intensity, which dissipates with the increasing distance (Nave, 2000). The initial sound has a certain power. The power divided by the area gives the intensity, measured in watts/m^2. The following equation (Equation 2) relates the intensity to the initial power depending on the distance (r) from the source.

Equation 2

$$I = P / (4\pi r^2)$$

The intensity decreases exponentially as the distance increases. This means that if the distance doubles the sound intensity decreases by four times. If the distance is tripled the intensity decreases by nine times. In terms of decibels, as the distance doubles the decibel level decreases by approximately 6dB (Nave, 2000).

2.1.3 Decibel Weighting

The human ear is more sensitive to certain frequencies than others, specifically, frequencies in the range of 3,000-4,000 Hz (Nave, 2000). This means that in order to achieve the same loudness one would have to increase the decibel level of the lower and higher frequencies. The Equal Loudness Curve, also known as the Fletcher-Munson Equal Loudness Curves, depicts the equivalent decibel level required to achieve the same loudness for any audible frequency. These curves are displayed in Figure 1.

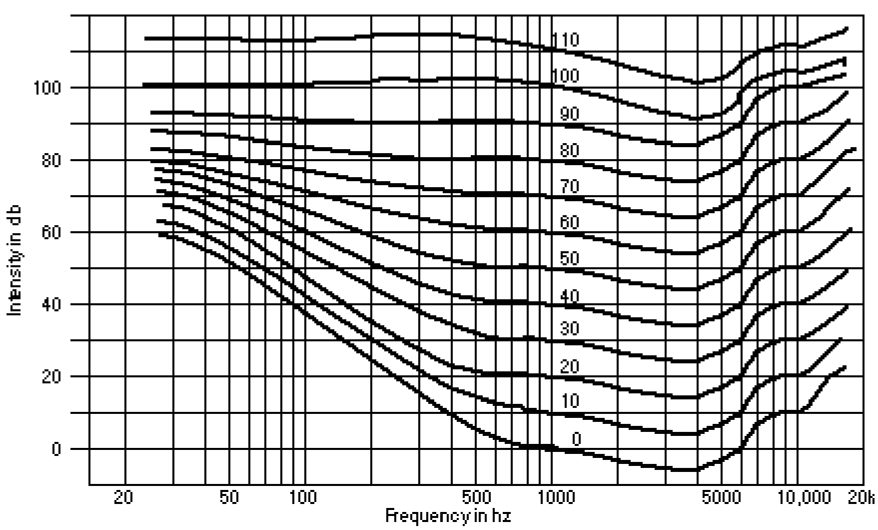


Figure 1: The Fletcher-Munson Equal Loudness Curves

Multiple weighting systems (dBA, dBB, dBC, and dBD) have been devised to compensate for different sensitivities. The A-weighted decibel (dBA) is specifically designed to compensate for sensitivity of the human ear and is the most common of the weighting systems used (Taylor, 1970). This means that decibel levels of higher and lower frequencies are scaled down and midrange frequencies (approximately 1000Hz to 5000Hz as shown in Figure 1) are scaled up.

2.1.4 Statistical Application of the Decibel

The decibel level is useful in a variety of different level indicators. These indicators include Leq, L10, L50, L90, Lmax, and Lmin. Because sound levels fluctuate over a given amount of time it is necessary to find the equivalent constant sound level (Leq). This number is essentially the average sound level over a given time interval. L10 is the highest decibel level that was exceeded for ten percent of the time interval. Similarly L50 and L90 are the highest decibel levels that were exceeded for fifty and ninety percent of the time interval, respectively. These indicators give a sense of how much the sound levels fluctuate with respect to the given average. The higher these values are the greater the deviation from the average. Consequentially, L10 levels are higher than the L50, which are higher than the L90. For example, one may find near a highway Leq, L10, L50, and L90 to be 70dB, 110dB, 68dB and 55dB, respectively. This means that the equivalent decibel level for the time period was 70dB. Also, 10 percent of all the sound levels were at least 110dB, fifty percent were over 66dB, and ninety percent were over 55dB. As one would expect, Lmax and Lmin are the maximum and minimum levels obtained over the given period.

2.2 Noise

Whether or not a sound is considered to be "noise" depends on a person's individual perception of whether the sound is pleasant or undesirable; in this sense the perception of noise changes from person to person. How one classifies noise depends on a number of different factors. Noise depends on the sound, where the sound is created or heard, and who is hearing the sound. Generally, a sound is considered to be a noise because of its unexpectedness (a gun shot), unattractiveness (traffic noise), and intermittency (a recurring sound at any given interval of time) (Suter, 1989). Although not usually the loudest, noises falling into one of these three categories, are the most damaging to an individual causing irritation and frustration (Suter, 1989).

Another factor that defines what is determined to be noise is governmental policy, which is developed to regulate and reduce noise to protect the welfare of its people. The rest of this chapter will focus on the sources of sound and their role in noise, how legislation attempts to regulate and limit these noises, and how noise has detrimental implications for multiple societal issues.

2.2.1 Personal Reactions to Noise

To elaborate on the way different people respond to noise, one needs to consider the fact that some people are more sensitive to noise than others (Jones, 1990). Sensitivity may be dependent upon where someone lives, city versus small town; where one works, industry versus library; or simply personal preference of environmental/background noise. It was stated by Dylan Jones (1990) that extroverts tend to be attracted to higher levels of noise compared to introverts. Extroverts also are able to tolerate louder noise intensities.

Aside from personal preference, research measuring the effect noise has on health has to take into account whether people are angrier at the noise being produced or the producer of the noise (Browne, 1990). For example, if an apartment tenant hates their neighbor and complains to the landlord about all the noise being made next door, are they really angry with the noise or the neighbor? Another example could be someone living near a factory, is he or she truly irritated by the excessive noise from the factory or is he or she an environmental activist with a grudge against any and all types of industry.

2.3 Sources of Noise

The sources of noise in an urban environment are much different than those found in a rural area. Since the team will be monitoring urban areas (San Juan), this background will focus on noises found in an urban setting.

2.3.1 Transportation (Traffic) Noise

A number of different variables produce traffic noise from automobiles. In this section automobiles include cars, trucks, and busses. These factors include the pavement type, vehicle mix (what types of vehicles are on the road), and intersection type (El-Fadel, 2000).

Vehicle noise is primarily caused by tires on the pavement, except in cases when a vehicle is traveling at less than 40kph (25mph), where the engine and exhaust noises are dominant. A study performed by the American University of Beirut on the analysis of traffic management techniques shows that in the city of Beirut the average traffic noise at intersections was 76dB, with peaks reaching 104dB (El-Fadel, 2000). Although the vehicle mix, pavement type, and the existence of any intersections are certainly different in San Juan than in Beirut, this study gave a general idea of traffic noise in an urban environment.

Currently, the people of San Juan rely on bus services and personal cars to travel throughout the city. The only commuter rail service is the Tren Urbano, a mass transportation system that has yet to open its doors to the public. Since this service has yet to start running its trains regularly, the noise analysis performed in March and April of 2004 did not include noise from the Tren Urbano. Considering a subway car can produce noise exceeding 100dB, the Tren Urbano project will certainly affect noise levels along its route. An analysis of the noise pollution factors due to Tren Urbano will be necessary once the train is running.

2.3.2 Environmental Noise

Within an urban area, environmental noise is not typically an issue due to the fact that background noise created by humans dominates the sounds produced by nature. However, into the night hours when the traffic and social noise of the streets decreases, noise from a number of sources may become a problem for the citizens of San Juan as they are trying to sleep.

The male coqui frog, which is the national mascot of Puerto Rico, has a nightly song that can reach 90dB. The frog has become enough of a problem in Hawaii that the Environmental Protection Agency (EPA) has determined it to be an official pest, and has called for its eradication (Wieland, 2003). The coqui is beloved in Puerto Rico however, and the Puerto Rican government lobbied the US Government to end the eradication program (Associated Press, 2003). Due to the national interest in the plight of the coqui, the noise produced from them may not be considered to be problematic among the island residents. The noise from the coquis, along with noise produced by other animals, will most likely be the majority of the noise produced by environmental sources.

2.3.3 Residential Noise

The noise produced by the residents of an area is always difficult to approximate, as the conditions that produce the noise vary greatly by neighborhood. These noises may come from any of the following sources:

- restaurants,
- nightclubs and bars,
- boom boxes and outdoor social gatherings,
- lawnmowers and other residential tools,
- sirens and alarms,
- concerts,
- construction,
- advertising, and
- pets.

Although this is not an all-inclusive list, most of the residential sources of noise generally come from one of these areas.

2.3.4 Industrial Noise

Industrial noise within an urban area can be very substantial, depending on the type of factory, the area, and its proximity to nearby communities. It can affect both the surrounding residents and the employees. A study done in a Pittsburgh factory reports an average functioning noise level of above 90dB (Helmkamp, Talbott, Margolis, 1984). A typical milk bottling factory produces 93-100dB (Pearce, 1985). In Scotland, a whisky bottling factory had an operational noise level of approximately 113dB.

Individuals who work in these conditions may suffer from numerous health effects that will be discussed in more depth in section 2.5. However, despite the risks that noise poses to the individual workers, the costs of reducing noise levels have generally been prohibitively expensive (Pearce, 1985). For example, to reduce noise levels of the steel industry to 90dB in Great Britain, it is estimated to cost almost one hundred million dollars (McLaughlin, 1977). In addition, company executives fear that if they were to control noise levels more strictly, employees would become more aware of the damaging effects the noise is having on their health and be more likely to sue the company for compensation (Pearce, 1985).

2.3.5 Construction Noise

Construction, although usually not permanent, creates noise that can also be very loud during the working hours of the day (Pearce, 1985). The types of machinery used play a very important role in how much sound a construction site produces. As the project size increases, the size of the machines and the workforce needed to increase as well. With these characteristics, one could also anticipate greater sound levels.

Air compressors emit over 90dB, pile drivers can be over 105dB, rock drills and pneumatic hammers can be over 113dB (Pearce, 1985). However, the cost of reducing these sound levels can be significant. The same 90dB dump truck can be purchased in a quieter 82dB model for 20% more money (Pearce, 1985). With tight budgets, companies are often unable to afford the quieter model, if any, when purchasing equipment. “The construction industry has been very reluctant to improve the situation. It is worried about the cost,” stated Angus McAvoy from CIRIA, a leading construction broker in the United Kingdom, “The only time that construction firms become concerned about noise is if they face complaints from local residents” (Pearce, 1985). Although hearing protectors such as ear plugs and ear muffs are a low cost countermeasure, they can be dangerous in that they prevent the workers from hearing crucial warning signals (Pearce, 1985).

Restrictions have been placed in numerous European countries to limit construction noise. In France, construction equipment must be approved by local authorities before it can be operated on site. Germany has adopted similar laws that lay down noise emission limits on construction equipment (Alexandre, 1975). General noise legislation governing Puerto Rico will be discussed in section 2.4.2.

2.4 Noise Legislation

Attempting to regulate or reduce noise in any given environment is an exceptionally difficult task regardless of whether it is in an urban, suburban, or rural location because the distinction between sound and noise is dependent upon the opinion and preference of the affected person. This makes it unclear as to when a sound is so unwanted or annoying that it is to be considered illegal because people’s perceptions of “noise” vary significantly. Some people have a higher tolerance for sounds than others, dependent upon many different factors including age, sex, and location of the individual. For example, a car alarm recorded at a decibel level of 70dB might be bothersome to one individual, but not to his or her neighbor. This makes it difficult for government agencies to implement and enforce laws or policies to control noise pollution because there is no standard definition of illegal noise.

2.4.1 The Noise Control Act of 1972 and The Quiet Communities Act of 1978

Puerto Rico, although self-governing, is a commonwealth in association with the United States. This means that many laws are regulated by the federal government. *The Noise Control Act of 1972* manages noise nationwide and forms a foundation for all other noise policies across the country. This act was originally drafted to promote an environment for Americans free from noise that jeopardizes their health. However, this Act has proven to be inefficient in many areas (U.S. Department of Housing and Urban Development, 1991). This Act groups every area of the country together, classifying them as one noise pattern, meaning that every region in the United States experience the same cycle of daily sounds. This is completely unrealistic considering there are diverse locations of the United States ranging from rural farmlands to urban cities. Legislation that regulates noise in a large urban area is more complex than legislation that regulates noise in a small rural town. There will be similarities between the two policies, but each will have very unique stipulations based on the population density of the location (Maling, Jr., 2002). For this reason, the United States drafted the Quiet Communities Act to encourage noise regulation programs at both the State and community level (U.S. Department of Housing and Urban Development, 1991).

This Act led to the implementation of many new policies that cater to the individual state, city, or town, which are much more specific than the Noise Control Act.

These guidelines follow standards that must be taken into account when attempting to reduce noise pollution. For instance, it is not practical to draft a law reading -- All noise levels must remain below 85 decibels at all hours of the day – without taking into account the commercial and residential needs in that particular area. In Cooperstown, New York, along with many other cities of the U.S., lawmakers in the given area consider an array of factors including volume, duration of the noise, the time of day, proximity to residential sleeping facilities, and the volume and intensity of the background noise. These factors are accounted for when formulating suggestions regarding new noise policy for Puerto Rico.

2.4.2 Introduction of Noise Legislation Specific to Puerto Rico

Currently, Puerto Rico has noise policies that are ineffective (EQB, 2004). The noise pollution problem of the island provides evidence that these policies need to be modified. Current legislation includes specific policies implemented by the Government of Puerto Rico and more general laws implemented by the United States federal government (EQB, 2004).

2.4.2.1 Topics Addressed by Noise Policies in Puerto Rico

The noise regulations of Puerto Rico cover a broad range of topics; however they are not described in detail (Public Law 71, 1940). This makes enforcement of the policies difficult because they are not specific. The laws of Puerto Rico address:

- the suppression of unnecessary noise,
- a definition of unnecessary noise,

- radios and other devices that can be heard in the streets,
- penalties when noise policies are violated,
- the noises of ambulances, fire trucks, and church bells, and
- regulations of bombing noise

2.4.3 Environmental Quality Board (EQB)

The Environmental Quality Board (EQB) of Puerto Rico is the island's leading governmental agency for the protection of the environment. There are different departments within the agency that are assigned to different issues regarding the environment and its effects on the community. For example, there are departments that handle noise control, water quality, and air quality. We worked with The Noise Control Area in an effort to reduce noise pollution in the city of San Juan. This program is responsible for establishing and enforcing regulation on noise control, promoting noise policies, and educating the general public about noise pollution and its effects. The Noise Control Area also designs and executes studies and projects to gain a better understanding of noise and how it affects the lives of the citizens in Puerto Rico (Mujica Cotto, 2003).

Residents generally make noise complaints to the EQB because they are the leading agency responsible for documentation and investigation into any and all noise complaints (EQB, 2004). It is possible to make complaints to the police, however, most of the time the police simply refer them to the EQB. On an average, the Board receives about 3,400 registered noise complaints per year (Rust, 2004). Most of these complaints are from residents of metropolitan areas, especially those of San Juan including Old San

Juan, Santurce, and Rio Piedras. These complaints are generally regarding the unusually high sound levels of the streets from sources like vehicles and night clubs (Alcaide, 2004). Although the laws state that decibel levels of residential areas are not to exceed 65 dB during the day and 50 dB during the night, it is common to encounter daytime levels of about 80 dB and levels of about 55 dB at 3am (Pérez, 2004).

The EQB responds to a violation depending on its nature and intensity. If the noise violation is serious enough, a citation will be issued immediately (EQB, 1987). The citation can either be a 24-hour Notice of Violation or Summons that shall not exceed 30 days. If the violator fails to comply with the order and the noise has not relinquished within the given time period, the penalty will be determined by the Public Policy Environmental Act, which usually includes a fine. The amount of the fine depends upon the magnitude of the violation, also taking into account reasons for why the offender failed to comply with the citation. The Board has the power to suspend or revoke any approval, dispensation, or other authorization issued under the Regulation for the Control of Noise Pollution, the document that outlines the rules and regulations regarding noise of the Commonwealth of Puerto Rico (EQB, 1987).

2.4.3.1 Plan of Action to Reduce Noise

The EQB has initiated a plan of action to regulate and reduce the noise pollution of Puerto Rico (EQB, 2004). The comprehensive noise control plan for the island will include recommendations to reduce noise levels. It will manage the noise problem by providing mechanisms for mitigation and planning to induce the promotion of noise control for the population of Puerto Rico.

This plan, which will first concentrate on metropolitan areas of the island, consists of two parts. The first part includes a description of the problematic noises of Puerto Rico and the health effects associated with the noise. In this part, the EQB will also determine approximately how many people are affected by the current noise problem. The members of the Noise Control Area predict that they will find that citizens are affected by noise differently in various aspects of their life including health, education, and sleep patterns (EQB, 2004).

In the second stage, the EQB will establish the Problematic Noise Public Policy of the Free Associated State of Puerto Rico (EQB, 2004). This will outline the steps that government agencies will take in order to decrease unwanted noise. It will propose the implementation of necessary actions that will reduce ambient noise, eliminate exposure to noises of unusually long duration or high amplitude, and reduce noise around areas that should remain tranquil, such as learning environments. This policy will also educate citizens about unwanted noise and give suggestions as to what each individual can do to help reduce the noise pollution problem (EQB, 2004).

Based on past research, the EQB (2004) has recorded the daily sound levels of the various areas in Puerto Rico. The basic sound pattern is summarized by the model shown in Figure 2. The line begins as a high, steady curve during daytime hours and then suddenly drops very late into the night for a brief interval before increasing drastically within the first few morning hours. This drastic change causes residents of the island to respond differently than if the change was gradual (EQB, 2004). Because the transition of decibel levels from day to night is so rapid, the human ear does not have the time to adjust to the difference. Therefore, residents find changes to be more disruptive than if the decibel level transition was more gradual. The main goal of the EQB is to bring these levels closer together and increase the transition time between the two. This will allow more time for the residents to adjust to the decibel level changes on a daily basis, which will lessen the negative effects of the noticeable change (EQB, 2004).

The first objective of the EQB is to decrease the high decibel levels sustained during daytime hours. By lowering the decibel levels during the day, the EQB hopes to maximize the time when quieter decibel levels occur. The second objective of the EQB is to have a gradual increase in decibel levels as the night transitions into day. As shown by the black dots in Figure 2, the increase in decibel levels at the present time is rapid. By increasing the time during the night when low decibel levels occur, decreasing the time when high decibel levels during the day occur, and forcing a gradual transition from night to day, the EQB hopes to create a more sustainable and uniform acoustic environment for the citizens of San Juan. The sound characteristics currently observed by the EQB are shown by the line formed by the black dots in Figure 2. The sound characteristics that the EQB would like to see after creating new noise control legislation is displayed in the line formed by the red dots in Figure 2.

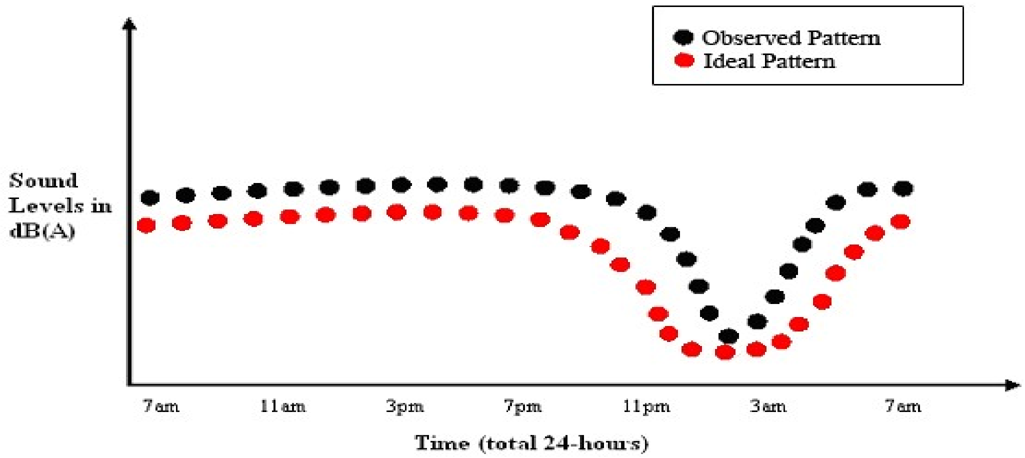


Figure 2: Model of Sound Level Characteristics over a 24-Hour Period

2.4.3.2 Current Noise Control Regulations

Current regulations for noise control are specific to four types of zones. Zone 1 is defined as any residential area or building where people reside. The types of dwellings include but are not limited to the following:

- hotels,
- campsites,
- summer homes,
- cabins,
- student dormitories,
- orphanages,
- asylums,
- apartments, and
- permanent homes.

Zone 2 is defined as any commercial establishment uninhabited by humans, but where noise levels may interfere with conversation between individuals. These enterprises include but are not limited to the following:

- night clubs,
- restaurants,
- gas stations,
- funeral parlors,
- animal shelters or kennels,
- cafeterias,
- veterinary clinics,
- car washes,
- auto repair shops,
- theaters,
- recreational parks,
- churches,
- beaches,
- race tracks, and
- stadiums.

Zone 3 is defined as any industrial location where decibel levels are expected to be higher than those levels present in the other zones. These areas include but are not limited to the following:

- mining sites,

- warehouses or wholesale shops,
- refineries,
- thermoelectric generating plants and petrochemical plants,
- poultry and dairy farms,
- light and heavy industry,
- hardware stores,
- lumberyards,
- quarries, and
- truck terminals.

Zone 4 is defined as an area surrounding an institution that demands extraordinary quietness. These institutions include but are not limited to the following:

- mental health hospitals,
- hospitals,
- court houses, and
- clinics.

Based upon the various areas that coexist within a confined space throughout Puerto Rico, the decibel level limit for any and all sounds emitted or received by each of the four zones are displayed in Table 2. These current decibel value limits are based upon a measurement known as L10, where 'L' stands for 'level' (Environmental Quality Board, 1987). The L10 represents the decibel level that is exceeded 10% of the time during a measurement period. For example, if the L10 of a half-hour measurement period is 65dB, this indicates that for the 30 minutes that were measured for sound, decibel levels of 65dB or more were emitted for 3 minutes of the time. Exemptions from the limitations displayed in Table 2 include but are not limited to the following only between the hours of 7:01am – 10:00pm:

- temporary reparation projects on homes and buildings,
- discharge of fire arms within certified firing ranges or during hunting season,
- restoration of property after a public or natural disaster,
- any emergency work engaged to protect the health and safety of members of the community,
- parades, and
- the installation and repair of public service utilities (Environmental Quality Board, 1987).

Table 2: Decibel Level Emission Limits among Zoning Areas in Puerto Rico (Environmental Quality Board, 1987)

EMITTING SOURCE	**RECEIVING ZONES**							
	ZONE 1 (Residential)		**ZONE 2 (Commercial)**			**ZONE 3 (Industrial)**		**ZONE 4 (Quiet)**
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
ZONE 1 (Residential)	**60dB**	**50dB**	**65dB**	**55dB**	**70dB**	**60dB**	**50dB**	**45dB**
ZONE 2 (Commercial)	**65dB**	**50dB**	**70dB**	**60dB**	**75dB**	**65dB**	**50dB**	**45dB**
ZONE 3 (Industrial)	**65dB**	**50dB**	**70dB**	**65dB**	**75dB**	**75dB**	**50dB**	**45dB**

It is important to note that while monitoring sound, the noise regulations shown in Table 2 are modified when considering background noise. If background noise is loud enough, it may interfere with the recording of problematic noise sources. The first rule for background noise adjustments reads as follows: if the decibel levels pertaining to background noise are less than those figures in Table 2 by more than 5dB, then these limits apply to the monitored area. For example, if the background noise recorded during the night for zone 2 is 49dB, six decibels lower than the limit of 55dB, then the decibel limit remains at 55dB. However, if the background noise levels are only 1-4dB lower than those figures in Table 2, then 3dB should be added to the figures pertaining to that zone and time of day. For example, if a residential site (zone 1) is monitored during the day, and the background noise is recorded at 58dB, two decibels lower than the limit of 60dB, then the decibel limit will be increased by 3dB to a final limit of 61dB. Finally, if the background noise is greater than those decibel limits determined in Table 2, then 5dB should be added to those figures. For example, for a zone 3 area during the daytime where background noise is recorded at 73dB, exceeding the limit of 70dB, then the limit will be increased by 5dB to make a final decibel level emission limit of 75dB.

In addition to decibel level emission limits for the four zoning types set forth by the Commonwealth of Puerto Rico, the Environmental Quality Board has also defined the maximum permissible vehicular decibel levels when measured from a distance of 50 feet. These levels are displayed in Table 3.

Table 3: Maximum Permitted Decibel Levels for Vehicles Measured from a Distance of 50 feet (Environmental Quality Board, 1987)

Type of Vehicle	Speed (35mph or less)	Speed (over 35mph)	Stationary (neutral)
Motor vehicle of 10,000lbs. or more (gross weight)	86dB	90dB	88dB
Motorcycle	80dB	84dB	88dB
Others	76dB	80dB	88dB

Lastly, regulations are also defined for all new vehicles and motorcycles. These maximum permissible decibel levels for all new motor vehicles and motorcycles are shown in Table 4.

Table 4: Maximum Permissible Levels for New Vehicles and Motorcycles (Environmental Quality Board, 1987)

TYPE OF VEHICLE	MAXIMUM PERMISSIBLE LEVEL
Motor vehicle with a gross weight of 10,000lbs. or more manufactured between 1975-1977	86dB
Motor vehicle with a gross weight of 10,000lbs. or more manufactured between 1978-1983	83dB
Motor vehicle with a gross weight of 10,000lbs. or more manufactured between 1983-1985	80dB
Motor vehicle with a gross weight less than 10,000lbs manufactured after 1975	80dB
Street motorcycles manufactured between 1975 and 1986	83dB
Street motorcycles manufactured after 1986	80dB
Moped type street motorcycles manufactured after 1983	70dB

According to José Alicea Pou, director of the noise control office of the Environmental Quality Board, all of these decibel level limitations were based on regulations set forth by other nations throughout the globe. Although the World Health Organization has international standards, each country has the liberty to create and enforce its own individual noise control regulations. This is important to note because no extensive research has been performed to establish those sounds characteristic of the island of Puerto Rico, which is why the EQB is now undertaking the first community-wide noise study of the island. All current noise control regulations for Puerto Rico were instead implemented after researching the effectiveness of other international legislation. Because the creation of Puerto Rico's current legislation was not based upon the sounds characteristic of the island, this could be a major cause for either lack of enforcement or the creation of unnecessary laws.

2.4.3.3 Community Noise Project

The Environmental Quality Board's noise reduction plan of action includes the first extensive community noise project for the San Juan area. This study is designed to document the noise levels and noise behavior over 24-hour periods in different locations throughout Puerto Rico, starting with metropolitan areas. There are different phases of this project that concentrate on different districts of the city. Since last year, when the project began, the EQB has completed phase one and is now working on phase two, which involves the metropolitan areas of Santurce and Rio Pedras (EQB, 2004). Based on these data The National Noise Policy for Puerto Rico is expected to be drafted by the middle of next year (Mujica Cotto, 2003).

2.4.4 Problems with Noise Legislation Enforcement

Once policies are written, the problem of enforcement still exists. Most government officials can only act upon noise problems if a complaint is made. However, many times the noise has diminished or terminated by the time the police arrive at the scene. Some places have experimented with sound meters that are placed randomly throughout the city or town. In the city of Chattanooga, Tennessee, these meters were used to monitor sound and found to be inefficient because they had to be facing the source of the sound to retrieve accurate readings. In addition to this, the sound meters were much too expensive (Gang, 2002). Another reason officers face a problem regarding enforcement of noise policies is that many of the ordinances read that “unusually loud or unnecessary noise” is prohibited, but they do not define what would qualify as “unusually loud” (O’Konowitz, 2003). This leaves the judgment up to the official, who might have an entirely different perception of loud than the offender (O’Konowitz, 2003). This issue must be considered when developing noise legislation in San Juan to ensure that both the enforcers and offenders have the same understanding of “unusually loud” noise.

2.4.5 Economic Issues of Noise Legislation Enforcement

Another very important factor regarding enforcement of noise regulation is the serious economic issue of attempting to regulate sound. If new legislation says that a certain company is breaking noise codes, that company is forced to look into different ways to reduce sound. This might be costly or inefficient, causing significant decreases in company productivity, which undoubtedly has a negative impact on the economy (Rosenhouse, 2001).

Many factors are taken into consideration when drafting noise policies in order to protect an individual from possible detrimental health effects of noise. The laws of a city might prohibit a young adult from blaring loud music after 11 p.m. on a Saturday night, which may seem unfair to him, but not to a 70-year-old neighbor who is trying to sleep. This scenario, although very simple, exemplifies the varying effects noise policy has on different people. Overall however, noise policy is implemented to ensure the wellbeing and happiness of people by reducing unwanted noise, which has been strongly linked to a variety of detrimental health effects.

2.5 Adverse Health Effects of Noise

Numerous research studies have been documented analyzing the relationship between loud or annoying noise and its effects on one's health. Because each person responds differently to the variety, intensity, frequency, and volume of those sounds considered to be contributing factors of noise pollution, it is difficult to analyze the relationship between noise and health. In addition to this, each individual has a different opinion on what they consider to be disruptive harmful noise. One person's noise may be another person's music or enjoyment.

2.5.1 Hearing Loss

One health effect associated with noise pollution is hearing loss, both temporary and permanent. Hearing loss is a common consequence of excessive exposure to large intensities of noise in such places as concerts, industrial work areas, arcades, airports, etc. (Bahadori and Bohne, 1993).

In one study regarding the physiological effects of industrial noise, white noise, heavy metal music, and classical music, decibel level measurements ranged between 90-140dB for a German symphonic orchestra (Strasser, Irle, and Scholz, 1999). It was also found that comparable hearing loss risks are associated with heavy metal music and industrial noise (Strasser et al, 1999).

2.5.1.1 Physiology of Hearing Loss

The physiological damage resulting from excessive noise affects the organ of Corti located within the cochlea of the inner ear. The organ of Corti has numerous sensitive hairs that, when stimulated, transmit the sound vibrations to the cochlea nerve. The cochlea nerve then sends the auditory information to the brain in the form of electrical impulses (Bahadori and Bohne, 1993).

2.5.1.2 Hearing Loss in Industry

Hearing loss is a common problem faced by people as a result of chronic exposure to noise throughout their lifetime. It has been shown that during a lifetime of industrial work, 70dB or higher is the level at which hearing loss damage begins to be significantly noticeable and measurable (Pearce, 1985). However, when exposed to a continuous decibel level of 75dB for a lifetime of work (8am-5pm, 5 days per week, for 40 years or more), hearing damage is doubled compared to the damage resulting from everyday noise (Pearce, 1985). These decibel values are extremely troubling when compared to the accepted 90dB norm for a "safe" industrial working environment. As mentioned earlier, the difference of twenty decibels constitutes an astounding increase of one hundred times the intensity.

2.5.2 Noise Annoyance and Psychiatric Problems

There is research indicating that people with psychiatric problems are more easily annoyed by neighbor noise (running up and down stairs, running water, yelling, parties…etc.) than people without psychiatric problems (Grotvedt, 1990). A study was performed in Norway that shows people with nervous conditions, such as strong heart palpitations, fear, nervousness, and restlessness, find that they are more annoyed with noise created by their neighbors. It is noted that people who are the most annoyed by noise are between the ages of 35-54 and that more females have problems with noise than males (Grotvedt, 1990). However, the author does note that there were more people interviewed between the ages of 35-54 and that this may account for the significant variation among age groups. Also, it is questionable as to whether or not the population studied had just indoor neighbor noise issues or outdoor noise issues as well. In addition to this, patients were allowed to self-diagnose themselves without any standard diagnosis protocol. Thus, both researchers and readers need to be aware that the validity of this experiment and amount of error may be skewed.

2.5.3 Human Performance and Noise

The effects of noise on human performance have also been studied. It has been found that noise tends to impair speech recognition and cognitive function, decrease responses to environmental stimuli, disrupt reading, and interfere with work performance. (Jones, 1990).

2.5.3.1 Noise and Accidents in Industry

A universal problem facing most people in noisy environments is that noise decreases attention to detail and safety, as well as degrading the ability to hear warning signals such as shouts and sirens. A review article by P.A. Wilkins and W.I. Acton (1982) found *suggestive* evidence discovered by previous researchers that noise may be a significant contributor to industrial accidents. The use of protective hearing equipment was also addressed because for people who have some form of hearing loss, protective equipment lessens their already reduced ability to discern warning signals.

One of the articles reviewed by Wilkins and Acton (1982) stated that when a motorway viaduct collapsed during construction killing three men, warning shouts were inaudible due to the loud equipment being used on site. In another case reported by the Environmental Protection Agency, a man lost his hand that had gotten caught in a machine because his screams could not be heard or responded to over the noisy environment of his workplace. The last example in the review article described a railway worker being struck by a train. His death could have possibly been prevented if he had heard the siren warning him of an oncoming train. Unfortunately, the man did not hear the warning because he had been standing near a noisy machine that had masked the siren (Wilkins and Acton, 1982).

Although this review article used previous studies that could not fully support the theory that noise is a contributor to accidents, the issues presented here (decreased attention span, focus, and ability to decipher warning signals) are not so different from everyday personal experiences in noisy environments. For example, noisy environments increase the difficulty of carrying on a conversation, concentrating on a task for work, talking on the phone, or hearing an oncoming car.

2.5.4 Sleep Disturbance and Noise

A common effect of noise pollution on health is the disruption of sleep. In Valencia, Spain, environmental noise in urban sites, specifically traffic and pubs, was found to be both the most irritating and disturbing during sleep (García, Miralles, García, and Sempere, 1990). It is stated in this study that road traffic is one of the most frequent contributors to urban noise pollution and annoyance; even in the quieter sites studied in Valencia, traffic noise was found to disrupt sleep. It was discovered that there is more traffic noise annoyance in educated people or those of higher socioeconomic status than those of less educated people or those of lower socioeconomic status. The authors also found that the older a person was, the more sleeping disturbances they experienced (García et al, 1990). According to the results, the correlation coefficient, describing the relationship or link between noise and sleep deprivation, was smaller than desired (less than 0.5). To expand on the issue of the correlation coefficient, in order to have convincing statistical data, the coefficient should be as close to a value of one as possible. For example, if the coefficient is 0.8 or 1.3, these values are closer to one, and thus more statistically valid than values of 0.5 or 1.6. The closer to one the correlation coefficient is, the stronger the relationship between the variables you are studying. So, in this case, the statistical analysis linking noise and sleep deprivation cannot be accepted without question.

2.5.5 Detrimental Health Problems and Noise

Aside from sleep deprivation, annoyance, hearing loss, and decreased work performance, noise pollution has been exhaustively linked to a number of other adverse health effects. A study in Austria, conducted by Cornell University, found evidence that noise causes detrimental health symptoms in children (Evans, 2001). Children living in noisy areas displayed higher resting systolic blood pressure, increased heart rate, and elevated stress levels versus children with the same social background that lived in quieter areas of Austria (Evans, 2001).

In an article written by Malcolm Browne (1990) from The New York Times, multiple studies relating health effects to excessive noise are reviewed. Browne states that in Amsterdam, six years after the opening of a new runway, the purchasing rate of anti-hypertension drugs doubled for nearby residents. In a second study conducted in Poland, it was found that repetitive exposure to noise levels ranging between 85 and 115dB increased the number of cases of both ulcers and hypertension. A third study showed that residents within close proximity to a runway in the Los Angeles International Airport had higher incidences of strokes, cardiovascular deaths, suicide and murder as compared to the rest of the city. Browne did state that the researchers of the third study pointed out that these incidences were not entirely caused by noise; there are other factors contributing to the health effects and crime-related occurrences (Browne, 1990).

Browne also used a comment made by Dr. David C. Glass from the State University of New York at Stony Brook, stating that there is evidence linking noise to the degradation of the immune system (Browne, 1990). Lastly, studies performed by Dr. Jeffrey D. Fisher, Dr. Paul A. Bell and Dr. Andrew Baum in the book Environmental Psychology seem to suggest that noise amplifies aggressive behavior, in addition to decreasing the tendency to help others. Subjects of one of their studies were taunted into anger by the researchers and then placed into rooms where noise levels were controlled. It was found that subjects located in a noisier room pushed a button that would electrically shock the researcher who had angered them significantly more often, and for longer amounts of time, than those subjects located in a quieter room. Another study found that if the researchers pretended to drop books on a sidewalk where construction was taking place, people were less likely to help pick up the books compared to instances where no construction was taking place (Browne, 1990).

2.6 Conclusion

Noise pollution is a serious problem that must be dealt with because it has numerous adverse effects on personal health and community. A vital step in creating noise legislation is to first assess and document noise levels throughout different areas of the city. This is crucial because it expands the researchers' knowledge of the studied city. As previously discussed, there are a number of factors, such as the sound itself, the context of the sound, the location, the people involved, and their culture, that contribute to the perception of noise and must be taken into consideration when proposing legislation. Once all factors of noise pollution in a given region are studied and assessed, any noise pollution problem can be efficiently managed using new or modified legislation that is dependent on the needs and characteristics of that city. In the case of San Juan, Puerto Rico, the sound levels were recorded and studied and the opinions of police officers and complaints by citizens were analyzed. By documenting each of these components of the noise pollution problem in San Juan, ideas and suggestions regarding more efficient legislation for the city were much easier to formulate because the future legislation will be based upon the characteristics of San Juan's noise problem.

3.0 Methodology Introduction

As discussed earlier, noise pollution is a complex issue that involves much more than the sound itself. Bearing this in mind, it is necessary to investigate how individual aspects of sound and its perception integrate to cause noise pollution. By fully understanding noise pollution and its effects, one can create legislation to reduce it. There are many facets of the noise pollution problem that the members of the EQB are taking into consideration before drafting new legislation. We assisted them in the process of creating a sound level profile for the city. This profile contained information gathered from randomly selected locations that are monitored for a period of 24 hours using a device called the Norsonic-121. The EQB chose random sampling as a method to ensure a sample representative of the entire city. The areas of the city were divided by a grid with each square encompassing approximately one block. We numbered each square and randomly selected blocks pertaining to numbers generated by Microsoft Excel. After each site was evaluated for safety, they were monitored for a period of 24 hours. The sound levels of each monitored location were represented by a line on a graph. After a site was completed, its respective line was added to the graph, creating a profile of the different sound patterns in San Juan. From this data, the EQB can identify problematic periods during the day where sound levels need to be regulated by new noise legislation.

We also assisted the EQB in identifying prominent sources of noise in each monitored site. The prominent sources are those sources that generated the highest decibel levels during a 30 minute time period at each specific site. With this information, the EQB will make definitive suggestions regarding what sources of noise are the primary causes of noise pollution and how they can be controlled by future legislation and more effective enforcement. The Nor-121 is not programmed to identify these sources; therefore, they are recorded using an apparatus called the Brüel & Kjær. For example, when a car passed by the device and caused an increase in the sustained decibel levels of the Brüel & Kjær, we knew to write the decibel level down under the category "cars". In addition to this, if an airplane passed by overhead, we knew to write the corresponding decibel level from the Brüel & Kjær in the category "airplanes".

However, because "noise" is characterized by an individual and the obtained data does not include personal opinion, one cannot directly link the identified sources to the noise pollution problem. To determine what sources contribute to the problem, we studied noise complaints recorded by the EQB between the years 1998 and 2003. The complaints were grouped according to their origin of sound and then analyzed to determine which sources were most irritating to the residents of San Juan.

To gain more insight into personal opinions regarding the noise problem, we also analyzed surveys that were administered to police officers and teachers of Puerto Rico and Vieques, respectively, in August of 2003. The responses reveal how they feel about the noise problem and which sources they believe are the main causes of annoyance in their neighborhoods. This data combined with residential complaints was then compared and correlated to the data obtained from the Brüel & Kjær for the identification of noise sources. From here, suggestions were made regarding the implementation of future noise legislation and recommendations for future noise control policies in an effort to improve the quality of life for the residents of Puerto Rico.

3.1 Characterizing Sound in San Juan

To determine how sound affects people in San Juan, one must first take the sound levels in a given area into consideration. To create a proper database of these sound levels, we used the Norsonic-121 Environmental Noise Analyzer. The name of this device is a misnomer in that the Nor-121 actually records and analyzes sound levels, not noise levels, which as previously stated are two very different concepts. A picture of the Nor-121 can be seen in Figure 3.

Figure 3: Norsonic Nor-121 Sound Analyzer (Norsonic, 2004)

The Nor-121 is a stand alone sound analyzer that records in real-time the weighted decibel levels, frequencies, and the actual sounds of background noise to an internal hard drive. This device constructed graphs of time versus sound level, which were later analyzed in conjunction with the noise complaint and police survey information we gathered.

Logistically, it is not possible to use the machine to monitor sound levels throughout the entire city. In light of this, various sites were randomly selected by the Environmental Quality Board with our assistance. We monitored sound levels during a 24-hour period at each determined site and combined all data to create a general overview summarizing the sound pattern of the city.

3.1.1 Selection of Monitoring Locations

Within San Juan, there are three major districts known as Old San Juan, Santurce, and Rio Piedras. Rio Pedras, the largest of the three districts, was divided into four sections for a combined total of six sections.

The six sections of San Juan were represented on six different maps, each of which was divided into smaller quadrants estimated to represent one square block of the city. Each quadrant that contained land was numbered. From there, we used Microsoft Excel to generate a table of randomly selected numbers for each map. From this table, the randomly selected quadrants were visited and evaluated for safety by the EQB. The first 2% of the total number of quadrants found to be safe were used for the monitoring process. The EQB felt that 2% of the total number of quadrants was a large enough sample to be representative of each section. If after all monitoring was completed, and the agency felt that 2% was not a great enough sample to be significantly representative, further data collection would be done, meaning that more sites in each of the six areas would be randomly selected and monitored.

Although we assisted the members of the EQB with numbering the maps of all areas, we only helped them to monitor the areas of Santurce and northern Rio Piedras, the second and third areas of the project, respectively. The first completed area, Old San Juan, was finished in 2003. For this reason, we only had access to data from three of the six total areas of the city. Data from the other three areas will not be collected until after we finish our project, meaning that we only had access to half of the data that will be collected from the EQB's entire noise study. From the data that we helped to collect, we were able to draw some preliminary conclusions regarding the sound pattern of San Juan. However, those conclusions were not fully representative because our sample did not include the entire 2% of the desired sampling of the city. Shown in Figure 4 is a map of the Old San Juan with the seven monitored sites indicated by the small blue icons. Figures 5, 6, and 7 are maps of Santurce, northern Rio Piedras, and western Rio Piedras, all three of which we assisted the EQB in monitoring. Again, the monitored stations are indicated by the small blue icons.

Figure 4: Map of Locations of Monitored Stations in Old San Juan

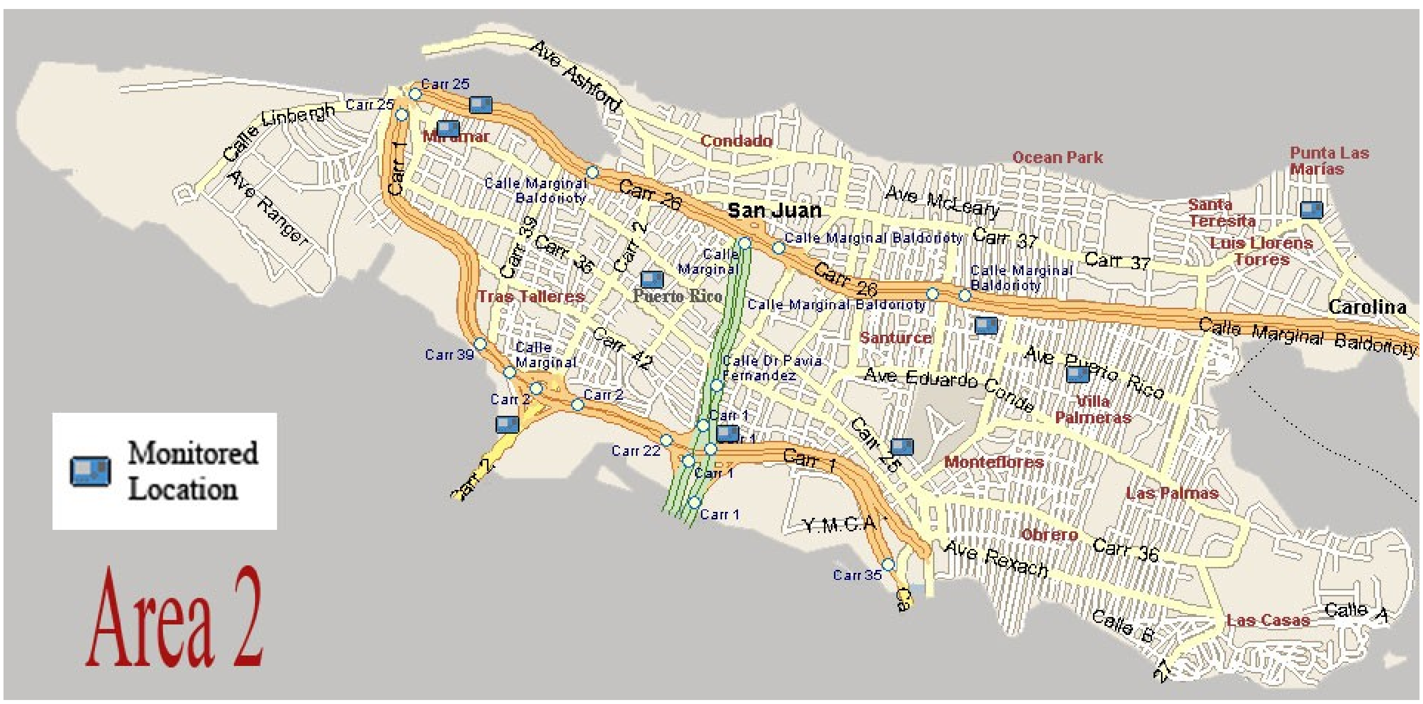


Figure 5: Map of Locations of Monitored Stations in Santurce

Figure 6: Map of Locations of Monitored Stations in Northern Rio Piedras

Figure 7: Map of Locations of Monitored Stations in Western Rio Piedras

3.1.1.1 Why Randomly Sample for the Selection of our Monitoring Sites?

In choosing a statistical sample it was important to keep in mind what we hoped to achieve. Our goal was to obtain a general overview of sound levels and sources of sound in the city of San Juan. Because San Juan is so large, it is not feasible to monitor every block of the city with the time and resources allotted. With this in mind the EQB chose to monitor a smaller number of locations to create a representative sample. In order to ensure this sample was representative, the monitored sites were chosen completely at random. This random sampling included residential, commercial, and industrial areas throughout the city, thus all types of areas in San Juan were monitored.

Noise affects people. These same people also create noise. Therefore, wherever you find noise, you will most likely find people that are being affected by that noise. It is true that a majority of people are affected by noise when they are in their homes. However, to say noise only affects people at home would be a vast oversimplification, so a sampling of non-residential areas is also necessary. If your sample included strictly residential areas with notoriously high sound levels, you will always find a noise problem, thus your results would be biased. The data would not give a broad representation of the entire city because it would not encompass those areas that may not be perceived to be noisy, but do, in fact, display high decibel levels. If you monitored only “loud” areas in order to support your claim, your results would not be valid. On the other hand, if you took a random sample of the representative area and found that most of your samples had very high decibel levels, your conclusion of the existence of an extensive noise problem would be more statistically credible because you took into consideration every possible area of the city, not just specific locations that were believed to be “loud” before the study was conducted.

3.1.2 Placement of the Norsonic-121

In order to record the sound levels over the course of a full day, the Environmental Quality Board began by placing the Norsonic-121 at 6am in the morning at the first of three monitoring locations. Depending upon the location, the Nor-121 was set up in two different ways. If the EQB was unsure of the safety of the equipment in a location, the Nor-121 was kept inside one of their vehicles known as the UR-Mobil. When available, the San Juan Police Department would assist the EQB by stationing an officer by the UR-Mobil for the 24-hour monitoring period. This ensured the safety of both the Nor-121 and the UR-Mobil. If the EQB found a safe inconspicuous spot at the monitoring location to place the Nor-121, they secured it by chaining it down in a plastic suitcase. Examples of locations that were suitable to maintain the device without the UR-Mobil were residential homes, commercial buildings, or hotels.

A microphone attached to the Nor-121 captured all environmental sounds of the area. The microphone sent collected sound information to the internal hard drive of the Nor-121, where it was recorded and stored. The microphone was either secured on top of the UR-Mobil or attached outside to some structure such as a gate, railing, telephone pole, or porch in those areas determined to be safe and inconspicuous.

3.2 Source Identification

Because the Norsonic-121 is not programmed to record the individual sources of sound during the 24-hour monitoring period, we had to use an additional device called the Brüel & Kjær Type 2236 to record these sources. This device was used to identify the decibel levels of the sound sources at the given areas.

Each monitoring site was visited three to four times a day depending upon the time available, traffic, weather, and safety. During these visits, sound sources were recorded for a period of 30 minutes. Our group was split into two shifts, each containing two students, in order to cover two work periods of nine hours each. The two shifts maximized the amount of source identification during the course of the 24-hour monitoring periods. The recording began with the first shift of students at 7am and ended at 2:30pm. The second shift started data collection at 3pm and ended at 11:30pm. Recording visits were scheduled for 7am, 10am, 4pm, 7pm, and 10pm. At each of the scheduled times, the three monitoring sites were visited and recorded. For example, at 7am we would arrive at the first station and monitor for 30 minutes. Continuing on to the second station, we would arrive at 8am and monitor for 30 minutes. Lastly, we would travel to the third station, arrive at 9am and monitor for 30 minutes. Once the third station was completed, we would return to the first site at 10am to repeat the scheduled cycle.

During the recording period, the highest decibel levels were manually recorded using the Brüel & Kjær for the identification of decibel levels. The recorded sources of high decibel levels varied with each monitored location. When monitoring a quiet, residential area where ambient levels are low, a "high" level may be about 60dB. Consequently, in a louder area, a "high" level may be around 75dB. The time of day also influenced what was considered to be a high decibel level. For example, decibel levels were expected to be higher in the day and lower at night. A sound registering at 55dB would be recorded at night, but not during the day because it would be masked by louder environmental sounds.

Each manually recorded decibel level was categorized according to the following sources:

- cars,
- trucks,
- busses,
- motorcycles,
- airplanes,
- horns and alarms,
- music, and
- other.

The results obtained from each 30-minute time interval were then compiled to determine the more prominent sources of sound at the given location.

3.3 Assessment of Noise Complaints

To determine which sounds are more irritating to the residents of Puerto Rico, we analyzed a database of the number of complaints received throughout the island from the years 1998 to 2003. Because the EQB receives complaints regarding such issues as noise, air, land, and water, we had easy access to this data. We assisted the EQB in documenting the noise complaints in Microsoft Excel up to the year 2003 and graphed them on a pie chart displaying the percent distribution of the sources of the complaints. We reviewed these to determine the following:

- total number of noise-related complaints,
- the percentage of noise complaints the EQB received as compared those complaints from air, water, and land, and
- the sources of the noise complaints and how often they appear.

We separated the 1,987 noise complaints from the past 6 years into the following categories based upon the source of the complaint:

- music,
- factories,
- electrical plants,
- air conditioning,
- construction,
- trucks,
- alarms,
- explosions,
- trash collection,
- churches, schools, and hospitals,
- vehicles,
- “undefined” machinery (shop), and
- “defined” machinery (equipment, tools, etc.)

The percentage of each noise source contributing to the total number of complaints was then calculated using Microsoft Excel. The total complaint distribution was displayed in a pie chart, which provided a visual aid as to compare the different noise sources.

After analyzing the complaints, we identified those prominent sources of noise that contribute to the noise pollution problem of Puerto Rico. The EQB was informed of both the noise sources and general profile of the sound level in San Juan once they were known. Furthermore, methods that should be used by the EQB to obtain these lower ranges were developed and explained.

3.4 Prominent Sound Sources According to San Juan Residents

In August of 2003 José Alicea Pou, director of the Noise Control Area of the EQB, conducted seminars at local police academies throughout the island, as well as in schools of the island of Vieques. The purpose of these seminars was to inform officers, teachers, and students about the noise pollution problem they currently face. After each class, a survey was distributed to the officers and the teachers who attended the seminars. They were asked to complete the survey as citizens of the island and not as officers or teachers. Because these surveys were conducted in Spanish, the following references to this survey are translations from the original. The groups were questioned on topics specific to the noise of their respective community. Topics addressed in these surveys regarding sources of sound were included within the following categories:

- airplane traffic,
- vehicular traffic,

- construction,
- neighbors,
- night clubs,
- commercial activities,
- industry, and
- mechanical and electrical equipment.

After creating a database of the information gathered from these surveys using Microsoft Excel, we analyzed this data to determine what sources within each category were the most problematic. For example, for the category of airplane traffic, there were seven sources including:

- commercial airplanes,
- private airplanes,
- small airplanes,
- military airplanes,
- commercial helicopters,
- private helicopters, and
- military helicopters.

After determining the prominent sound sources according to the officers and teachers, we compared them to data retrieved from the residential complaints and the Brüel & Kjær data. We looked for a correlation among the sources identified by the Brüel

& Kjær and the sources revealed from the noise complaints and residential surveys to determine if people complain about the loud sources that we identified.

Within the surveys, there is a section that asks the respondent to describe his or her reactions to unwanted noise. The participant was supposed to answer ‘yes’ or ‘no’ to the 18 following reactions:

- irritated,
- depressed,
- anger,
- nervous,
- anxious,
- tired,
- lack of concentration,
- loss of tranquility,
- affects health,
- need to leave the house,
- tense,
- secure,
- relaxed,
- easy-going,
- worried,
- well,
- none of the above, and
- other.

Their answers revealed whether or not they experienced any of the above reactions when exposed to noise. We analyzed this data using Microsoft Excel by calculating percentages of the officers' and teachers' reactions to the questions. The calculations helped to determine which reactions were most common among the participants. This was useful because it provided insight into how people feel about noise, how they respond to noise, and what emotions they experienced when exposed to noise.

Lastly, the survey asked participants whether or not they are satisfied with current practices of noise control in Puerto Rico. The possible responses are one of the following: completely satisfied, not satisfied, and not familiar with current practices. This information was invaluable because it gave a direct answer regarding the officers' and teachers' present views on current noise policies.

The survey was distributed after the participants were informed about the noise pollution problem in Puerto Rico at each seminar. The timing of the survey distribution could have caused large discrepancies with the data obtained from the surveys because the respondents' views on noise pollution may have changed after the seminar or class. Any response by an officer or teacher should have been documented prior to the information session, thus eliminating the chance of biased responses. Members of the EQB were aware of the way the surveys were conducted and that it might pose a problem. This was not a concern for the agency however, because their main priority at each of the seminars was to inform the police officers and teachers about noise pollution.

Microsoft Excel was again used in order to analyze the results from the question regarding personal opinion on current noise policies. Percentages were calculated to determine the most popular responses among the officers and teachers. This indicated whether or not the participants were content with noise control regulations and policies at the time the survey was administered. This analysis provided further insight into the necessity of future noise legislation.

3.5 Methodology Conclusion

By building a sound level database and then identifying the sources of the sounds at the monitored locations, we built a profile of the sounds that affect the residents of San Juan. In order to determine what sounds were considered to be detrimental to the residents, and to get a better idea as to what the population of the city felt was noise pollution, we used the survey results and residential noise complaints.

Once the survey and complaint analyses were completed, we analyzed the data from the Norsonic to gain an understanding of the profile of the sound being collected. This profile, accompanied by the opinions of the residents (obtained through the survey results and the complaint analysis), helped to identify those sources of noise pollution on the island that were bothersome to residents. After all of the monitored locations were compiled and reviewed, we were able to present the data and compare this to the EQB's model of current noise patterns shown in Figure 2 of the Literature Review Section.

After we analyzed the pattern of the noise, it became possible to determine what actions needed to be taken in order to correct this problem. Within the surveys, officers and teachers were asked whether or not current legislation was sufficient. The analysis of this question was critical in providing more evidence to support the case that existing legislation and enforcement need to be modified.

4.0 Results

4.1 Sound Measurement from the Norsonic-121 and Brüel & Kjær

The Norsonic-121 recorded the sound levels over a 24-hour period at 27 different locations throughout the districts of Santurce and Rio Pedras. Below are brief descriptions of the monitored sites and the sounds identified by the Brüel & Kjær at each site.

Area 1: Old San Juan

This area was completed by EQB before we arrived in Puerto Rico. The sound patterns were recorded in those areas.

Area 2: Santurce

Station 1: This station was located on route 26 across the lagoon from the Condado peninsula. The constant traffic created a relatively high decibel level that remained above 70dB for a majority of the day. Sound sources identified included cars, trucks, motorcycles, and airplanes.

Station 2: This station was located in Central Park near a highway. The constant traffic produced high decibel levels. The occasional large truck was very loud, sometimes exceeding 88dB. We found that cars, trucks, and busses contributed to a majority of the higher sound levels.

Station 3: This station was located at PepBoys, just off of route 26 in the central part of Santurce. Traffic from the nearby highway and adjoining parking lot contributed the majority of the monitored sound levels. In this area, cars, horns, and trucks were prominent sources of sound.

Station 4: This was a parking lot for a small government office. There were no busy streets in close proximity, so the site remained relatively quiet with a slight increase in decibel level caused by an occasional car passing through. Cars were the only prominent sound source identified in this area.

Station 5: This station was located in the parking lot of the Universidad Sagrado Corazón in the southwestern part of the campus. Traffic from the nearby street caused much of the elevated sound levels, but overall the site remained fairly quiet. Prominent sources identified included voices, cars, airplanes, and horns.

Station 6: This station was a very open, one-way residential side street. Vehicular traffic made a majority of the noise. Most of the higher sound levels were caused by cars, dogs, voices, or motorcycles.

Station 7: This station was on a narrow side street off of a main road. The traffic was not as frequent but the tall buildings on each side combined with the narrowness of the one-way street accentuated whatever noises were present. There was also a large ventilation fan running fairly constant at 65dB.

Station 8: Due to technical complications, data was not collected from station 8.

Station 9: This station was located in a run-down section of the city, very close to a highway that contributed to much of the environmental noise. In the morning, chirping birds created sound levels as high as 70dB. Other than the nearby highway, there were very few cars.

Station 10: This station was in Ocean Park, just east of the Condado. The nearby street, Calle Diego, had a high traffic flow for a simple two-way street. Cars produced sound levels up to 80dB. Since Calle Diego was a smaller street, there were very few tractor-trailer trucks. However, buses and smaller trucks exceeded 84dB.

Area 3: Northern Rio Piedras

Station 1: This station was located at a truck loading station in the middle of a shipyard. Trailer trucks continuously passed through the shipyard throughout most of the day. There were also large machines used to pick up empty trailers and stack them. Much of these high levels were masked by a large electric generator that turned on and off periodically throughout the day. Prominent noise sources identified by the Brüel & Kjær in this area included cars, trucks, and horns.

Station 2: This station was located in an open residential street. There was a significant amount of traffic heading to a nearby busy street that caused a majority of the higher sound levels. We found that cars, trucks, motorcycles, horns, and dogs were the main sources of sound in this area.

Station 3: This station was located in another open residential street. There was light traffic, which contributed to generally low decibel levels. Cars were found to be the main sound source at this station.

Station 4: This station was located in an open residential street. There was light traffic. The main sound contributors were cars, trucks, and airplanes.

Station 5: Due to technical complications, data was not collected from station 5.

Station 6: This station was located in a residential street. Traffic in the area consisted of mostly cars and small trucks, which, combined with some passing airplanes, contributed to most of the higher decibel levels.

Station 7: This station was located in an open residential street. Sparse traffic contributed to a majority of the noise.

Station 8: This station was located at a Y-intersection near a grade school. During the day, the majority of the sound originated from children's voices in the schoolyard and vehicular traffic. After school let out, the area became relatively quiet with an occasional car or truck.

Station 9: This station was located inside of an ROTC training center. It was located at the intersection of two busy roads. However, the slope of the land blocked much of the traffic noise and the station remained quiet. Sources identified included cars and trucks.

Station 10: This station was located in a residential area on Francisco Street near Roosevelt Avenue. Prominent sources were cars, trucks, airplanes, dogs, and birds.

Area 4: Western Rio Piedras

Station 1: This station was located on Caparra Terrace, another residential area. Sounds that dominated originated from cars and voices.

Station 2: This station was located on a side street off of a main street. Most sounds came from airplanes and the vehicular traffic of the main road.

The data we collected at the 20 sites described above represented only about 10 percent of the EQB's entire noise data collection project. The EQB will continue with the study for the remainder of this year to monitor the final three areas of the city to complete a total of six areas. Because of this, the conclusions that we have drawn are not complete, but we feel that they will be sustained once the project is complete.

A majority of the data from the stations followed the general curve of the hypothesis of the sound profile proposed by the EQB, presented in Figure 2 of the Literature Review. Throughout the day, sound levels remained fairly high until late into the night when the levels dropped for a few hours. However, as one can see from our graphs of time versus decibel levels (see appendix), some of the sustainable decibel levels were difficult to compare to the model because large fluctuations existed within these plots. As discussed earlier, these fluctuations in sound level generally increase the annoyance that sound has on a person because the human ear cannot attenuate to such drastic changes. To form a general profile for the entire area we averaged L10 and Leq profiles of all the stations we monitored. These profiles are shown in Figure 8. After fitting the averaged data with a best-fit line, it is easy to see how similar the overall sound levels of the city are with the anticipated profile. The EQB can then use this sound level data to make improvements to noise legislation to decrease the drastic sound fluctuation during the day.

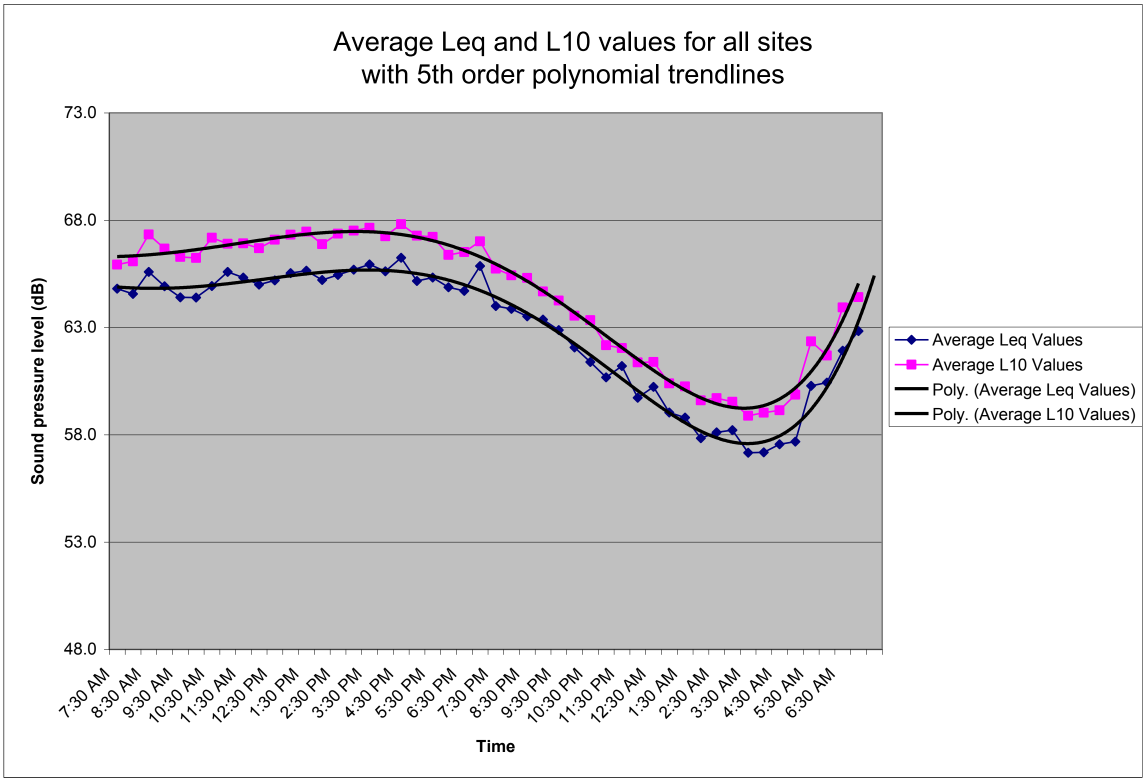


Figure 8: Average Leq and L10 profiles of all the monitored sites in San Juan

Our data showed that different parts of the city had different sound level profiles. One can see that the equivalent decibel levels vary significantly from the loudest to the quietest in Figure 8. To clarify, "loud" stations were those that displayed higher decibel levels as compared to the others. Similarly, "quiet" stations were those that displayed lower sustained decibel levels. The loudest station was located in a shipyard that experienced continuous movement of trucks and equipment. At this site, there was a large electric generator that operated at a very high decibel level, substantially increasing the area's sustained decibel level. This station recorded an average equivalent decibel level of over 80dB. The quietest station was located in an isolated university parking lot, where only an occasional car passed. This location had a sustainable decibel level of lower than 60dB, meaning that any given site's average decibel level could be as much as 20dB different from the average of another.

This, however, is the extreme. We found that some of the monitored sites only differed by one or two decibels. Random selection explains why the data varies extensively. If we had chosen the given sites based on the previous knowledge that they were “noisy”, the data would not be representative of San Juan because most of the sites would follow a similar sound pattern. More importantly, we would find that sustained sound levels fell within a five to ten decibel deviation. Although this data might be easier to compile and present a better argument of the city’s problem in noisy areas, it would be biased and demonstrate an incorrect overview of the general sound pattern of San Juan.

After concluding that random selection was the correct approach to this study, we combined all sound level data from the acoustically different monitored areas to create a general profile representing the sound pattern for all of San Juan. This data was useful to both document the current sound levels of the different areas of San Juan, as well as San Juan as a whole. We found that most of the sustained decibel levels exceeded either 55dB during the nighttime hours or 65dB during the day, thus displaying the noise pollution problem of the city. From here, the EQB will use the sound profile when proposing new legislation for the city to hopefully alter the current sound patterns to fit the model they wish to achieve as shown by the color line in Figure 2 of the Literature Review.

While monitoring, we encountered some difficulties that hindered the data collection process. The Norsonic-121, the device used to monitor sound levels, gave us the most problems. On many occasions, it completely failed at some point during the 24-hour monitoring period. When this happened, we were forced to discard all data collected before system failure because it was not representative for the entire day. This happened many times, especially during the first few days of the project. Initially, we thought that the problem existed with the instrument's batteries. However, after careful inspection, that was not found to be the problem. Technicians at the EQB then contacted Norsonic and from the information received, they concluded that the failures were due to a malfunction of the software within the instrument. The technicians then inspected the instruments, updated the software, and calibrated the batteries' warning levels. From then on, there were still some failures, but they did not occur as frequently as they had during the first two weeks of the project.

Another problem that occurred when using the Norsonic was human error during setup of the instrument. There were many settings in the device that need to be properly adjusted before starting the monitoring. Sometimes, one of the EQB employees would mistakenly set the wrong option within the machine. On one occasion, an improperly connected microphone caused the Norsonic's recorded levels to be very low. In all cases the data that was improperly collected was discarded before completing the analysis of the overall sound levels.

4.1.1 Identified Sources of Sound

Automobiles were the leading source of sound at almost all of the sites we monitored. With such a dense population in San Juan (approximately 2 million), this was not a surprise. Cars, trucks, motorcycles, and buses were found everywhere, but in varying degrees. The more residential and secluded the area, the fewer trucks and buses drove by. Conversely, the closer the area was to an urban or industrial area the greater the number of trucks and buses that drove by. In any event, cars were more frequent than trucks or buses, but operated at a much lower decibel level. The trucks and buses, although infrequent in comparison to passenger cars, operated at much higher decibel levels, especially when accelerating. Car stereos, horns, and car alarms contributed to the sound level emitted by a vehicle. Car stereos and horns exceeded 80dB at times, while car alarms rarely exceeded 70dB.

Although these recorded sources were the prominent sources of sound at the monitored sites, they were not necessarily the most prominent sources of noise. Because only personal opinion can distinguish sound from noise, it is unrealistic to state that vehicular traffic is the main contributor to the city's noise pollution problem. Although we determined that cars, trucks, and busses cause a majority of the higher sound levels at the monitored sites, we could not conclude that they were most bothersome to people. For this reason, we analyzed noise complaints and police surveys to determine if residents considered vehicles and the other sources of sound to be irritating.

An obstacle that we encountered when collecting sound sources from the monitored sites was the weather. When it was raining, we could not record sources because sounds from the rain masked most sounds arising from vehicles, music, planes, etc. Rain was especially a problem when the microphone was placed on top of the company vehicle. The sound of the rainfall against the roof of the car produced large sound levels that skewed the data.

When it was very windy outside, the Brüel & Kjær revealed decibel levels that were much higher than expected because it recorded not only different sounds, but also moving air. We observed that this was much like the loud sound heard when one blows into a microphone or the sound one hears when someone blows into his or her ear. By facing the Brüel & Kjær away from the direction of the wind, we reduced sound level discrepancies of recorded sources. However, this did not completely resolve the problem.

Wind did not affect the sound levels recorded by the Nor-121 because the microphone used to detect environmental sounds was equipped with a wind screen. This device blocks any wind that may have cause elevated decibel levels. In future experimentation, when recording sources using the Brüel & Kjær, one should consider using a wind screen to eliminate high decibel levels that are produced by moving air. Recordings using a wind screen are more reliable and consistent and, therefore, easier to analyze and draw conclusions from.

Another problem that we encountered when performing sound source identification involved our safety and the safety of EQB technicians. When initially choosing a location, safety was always taken into consideration. On some occasions a location would be determined to be safe for the equipment and observers, but upon further review of the location, it was found unsafe for the observers to complete source measurements after dark. In these cases the Norsonic continued to collect data, but the evening censuses were not completed. This did not alter our results greatly, but it did eliminate sound source identification in some areas that would have been conducted after dark.

The residents of the area monitored were not always understanding or willing to allow the monitoring or censuses to take place. Since in some cases the microphone for the Norsonic needed to be placed in someone's yard or attached to his or her house, the EQB first needed permission from the house owners. Although very few of the residents that were asked to participate refused to do so, in one occasion the resident did not awake during the morning hours to allow setup of the Norsonic. At another site where the UR-Mobil was set up, residents of the area placed a cardboard box on top of the microphone during nighttime hours. The EQB hypothesized that this was because the residents felt that they were being monitored by the police and decided to try to stop this by placing the cardboard box. Because this altered the sound levels recorded by the device, this data was ignored in the final analysis.

4.2 Noise Complaints vs. Other Complaints Received by the EQB

To determine the distribution of the complaints received by the Environmental Quality Board in the year 2002, we reviewed 1490 complaints regarding air, land, water, and noise that were previously entered into Microsoft Excel. Of the total number of complaints, the distribution was as follows:

- Air: 597 complaints
- Water: 369 complaints
- Land: 231 complaints
- Noise: 293 complaints

Based on the results presented in the pie chart (Figure 9) displaying the percent distribution of the various complaints, we found that noise complaints constitute 20 percent of the total complaints received. Of the complaints recorded by the EQB on these four environmental issues, noise is not complained about as often as air and water. However, it does present more of a problem than land according to residents. This could explain why the EQB's current study is the first extensive community wide project to document the noise problem of the island. It is possible that the agency has invested most of the government's time and money into air and water over the past years in an effort to reduce those issues that people are more concerned with.

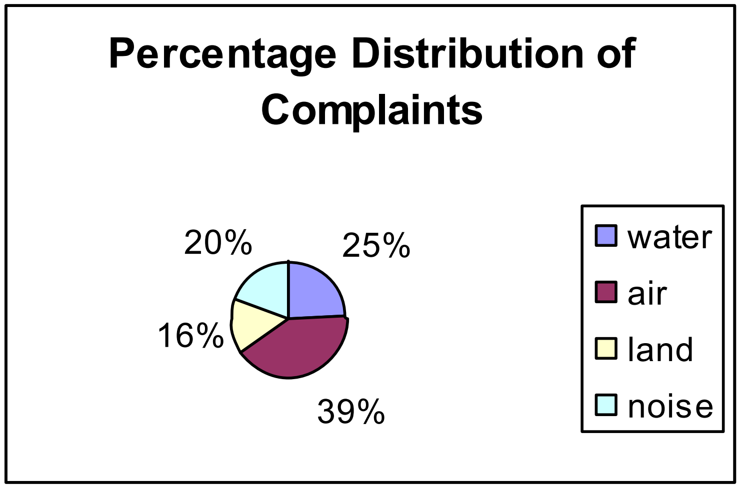


Figure 9: Percentage distribution of complaints recorded by the EQB in 2002

4.2.1 Noise Sources from Complaints

Between the years 1998-2003, the EQB has recorded 1,987 residential noise complaints. We computed the percentage distribution of each source of the complaints (see figure 10). The results were as follows:

- Machinery (defined) noise: 10%
- Plant noise: 14%
- Air conditioning noise: 7%
- Trash collection noise: 1%
- Construction noise: 7%
- Trucks: 6%
- Alarms: 6%
- Music: 24%

- Explosions: 0%
- Residential noise (churches, schools, hospitals, etc.): 8%
- Vehicles: 2%
- Machinery (undefined) noise: 5%
- Factory noise: 10%

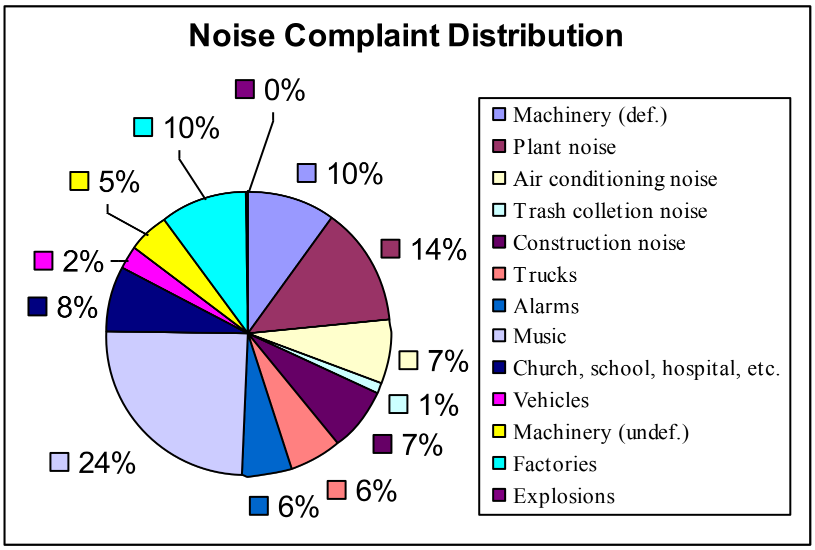


Figure 10: Percentage distribution of noise complaint sources recorded by the EQB from 1998-2003

According to the percentages shown by Figure 10, the four most prominent sources of noise complaints arose from music, machinery, plant noise, and factories for the years 1998-2003. Because these sources are identified as bothersome or irritating to residents of the San Juan area, they are not only considered sources of sound, but also contributors to the noise pollution problem.

The results from the complaints compared to the results of the data collected by the Brüel & Kjær varied significantly. We found that at the monitored sites, the major contributor of sound was vehicular traffic. The complaints, however, revealed that only

2% of the complaints were of vehicles. For this reason, we could not make any direct correlation between the complaints and the identified sound sources. A possible explanation to this could be that people become accustomed to noise created by traffic because they encounter it nearly every day. However, if one is not used to continuous daily traffic, he or she may feel it is ineffective to complain because nothing can be done to reduce the problem. More specifically, if one were to complain about the density of traffic flow in his or her residential area, nothing will be accomplished because traffic flow cannot be easily controlled.

In addition to this, the EQB does not document complaints for which no action can be taken. This may explain why there are not as many traffic complaints as we had hypothesized after collecting sound level data from the Brüel & Kjær. When the agency receives a complaint on the traffic flow of a person's neighboring street, they realize that the agency cannot respond to such a complaint and therefore discard it. Because no record is kept, our analysis on the complaints may contain discrepancies. However, like the surveys, our purpose of reviewing these complaints was only to identify some of the sounds that irritate the citizens of the island and, therefore, are contributors to the noise pollution problem

4.3 Officer and Teacher Survey Results

The 335 surveys distributed to police officers throughout Puerto Rico and teachers of the island of Vieques were vital information in determining how noise and its sources irritate residents of the Commonwealth.

The main portion of the survey asked participants to rank their tolerance of a variety of everyday sounds that affect them at home. Each everyday sound had its own separate category within the survey. The responses that participants could use to rank their tolerance were as follows:

A. Intolerable
B. Irritating
C. Moderate
D. Acceptable
E. None
F. Not Applicable

When analyzing the responses, letters D and E were combined to represent the percentages of participants who found those sounds to be tolerable. If respondents answered the question with the letter D, then they found the sound source to be acceptable. If they answered with the letter E, then this indicated that they had no opinion regarding those sounds for which they were asked. Since they did not find the sound(s) to be the least bit bothersome, which would have been represented by either choices A, B, or C, any participant that responded with the letter E was assumed to be tolerable of the sound.

Responses A, B, or C represent three ranks on the level of how bothersome the sound in question was to the participant. Because they all refer to some level of frustration, all three were combined together to represent the total percentages of respondents who found those sounds to be aggravating.

In tables 5 through 12, unacceptable levels are highlighted in orange, while acceptable levels are highlighted in green. Because this survey was used to determine people's perceptions of sound, only those persons who felt that the question was applicable to them were analyzed. Thus, all questions that were responded to with "not applicable," or choice F, were ignored.

For the remainder of this section, the heading of each lettered column in the tables represents one of the opinions regarding the level of tolerance listed above. It is important to keep in mind when reading the following tables that each percentage respective to the lettered column is a distribution only of those participants who indicated that the sound was in some way applicable to them. An example of this is described in Table 5.

4.3.1.1 Aircraft Sounds

Participants were asked what type of aircraft was perceived in their home and what level of annoyance they felt from each of the seven aircraft types listed in Table 5.

Table 5: Percent Distribution of Participant Responses to Aircraft Sounds

	A	B	C	D	E	Applicable
1. Commercial Airplanes	9%	15%	20%	37%	19%	65%
2. Private Airplanes	3%	14%	20%	39%	24%	72%
3. Small Airplanes	3%	14%	19%	46%	18%	78%
4. Military Airplanes	13%	20%	15%	28%	25%	62%
5. Commercial Helicopters	4%	15%	24%	36%	21%	67%
6. Private Helicopters	4%	13%	22%	39%	22%	72%
7. Military Helicopters	9%	21%	17%	33%	20%	67%

To begin interpreting this table, it is important to state that the "applicable" column to the extreme right displays how many participants answered with one of the letters other than "F- not applicable." This means that the officers and teachers hear or experience the respective sound in some way at home. As examples, for commercial airplanes, 65% of participants answered with either response A, B, C, D, or E, indicating that they do experience commercial airplane sound at home; 72% of participants experience private airplane sound in some way; 78% experience small airplane sound; and 62% experience military airplane sound.

Of all the officers and teachers that hear or experience any of these sounds in their homes, less than 50% of participants said that the sound they perceived was unacceptable for each aircraft category. This figure was calculated by adding columns A, B, and C together for each of the seven aircrafts. For example, for private helicopters, columns A, B, and C total 39%. This figure indicates that of the total 72% of participants who did experience private helicopters at their home, only 39% felt that the sound was bothersome or unacceptable in some way.

From this table, it is apparent that out of the seven types of aircraft, military aircraft was the most problematic for people because they have the highest total percentages of those responses (A, B, and C) indicative of some level of annoyance to the sound. 48% of applicable homes responded that military airplanes were bothersome while 47% applicable homes said that military helicopters were frustrating. In addition to military aircraft, the third most unacceptable aircraft sound originates from commercial airplanes with 44% of applicable participants displaying that commercial airplane sound is bothersome in some way.

When monitoring sound, we found that airplanes traveling overhead caused a dramatic increase in decibel level, sometimes up to 30dB, of the ambient noise. As shown in this data, however, airplane noise was not found to be irritating to the respondents. This can be explained by the frequency of passing airplanes. When monitoring with the Brüel & Kjær, we found that at a majority of the sites, only about two or three airplanes were recorded within the 30-minute period. For this reason, we concluded that airplanes do not contribute greatly to the island's noise pollution problem.

4.3.1.2 Automobile Sound

The first question of the automobile sound section asked participants where traffic sound near their homes originated from. When looking at this data, keep in mind that vehicular traffic was identified as the main contributor to sound according to our sound source monitoring using the Brüel & Kjær. In total, 68% of the survey participants felt that traffic sound audible from their homes came from either large city roads or small streets. Only 4.4% of respondents felt that traffic sound came from major highways.

Next, participants were asked to identify the source that they believed traffic noise in their homes to originate from. The results are shown in Table 6.

Table 6: Percent Distribution of Participant Responses to Automobile Sound

	A	B	C	D	E	Applicable
1. Busses	4%	18%	37%	25%	16%	62%
2. Trucks	12%	31%	28%	19%	11%	85%
3. Motorcycles	19%	35%	20%	21%	5%	94%
4. Cars	8%	18%	31%	40%	3%	99%
5. Service Vehicles	5%	12%	29%	41%	14%	85%
6. ATVs	35%	34%	10%	12%	10%	85%
7. Other	31%	17%	10%	31%	10%	41%

Out of the seven choices of automobiles, the major annoyance to participants in this section was all-terrain vehicles (ATVs), causing 79% of the applicable homes to rate ATV sound as unacceptable. This is significant considering that of the 85% of individuals who claimed that ATV sound was applicable to their homes, 79% of them stated that it was frustrating in some fashion.

It is very important to note that there might be a discrepancy with the results of the ATV category because it was written in the survey as “fourth truck,” when it should have been written as “4-tracks,” as they are known in Puerto Rico. Although pure speculation, this typo may have caused misinterpretation among the respondents of the survey, causing them to answer differently.

Other problematic sources of automobile sound identified by the respondents were motorcycles, heavy trucks, and busses. These were found to be bothersome to some degree to 74%, 71%, and 59%, respectively, of those who were affected by each source.

Cars, which are the majority of the vehicle mix on the roads, were the fourth most troublesome sound to the survey respondents with 57% stating that car sound was unacceptable. In looking at the sources data from the Brüel & Kjær, a link was observed between the 57% of survey participants who are bothered by car sounds and the fact that cars were the primary source of sound at the monitoring sites. The evidence that a majority of the respondents are bothered by car sounds and, as mentioned earlier, the sounds of heavy trucks, proved that vehicular traffic was not only a source of sound, but also a source of noise. According to the residents who were given this survey, vehicular noise was irritating and was therefore considered to be a main contributor to the noise pollution problem of the city.

4.3.1.3 Construction Sound

In this section, participants were asked which of the following construction sounds were heard in their homes, and of them, what was the level of annoyance experienced with each of the following. The responses are shown in Table 7.

Table 7: Percent Distribution of Participant Responses to Construction Sound

	A	B	C	D	E	Applicable
1. Heavy Machinery	17%	25%	20%	18%	20%	63%
2. Truck Traffic	14%	33%	19%	20%	15%	71%
3. Employees	8%	14%	27%	25%	27%	65%
4. Explosions	34%	17%	7%	9%	33%	33%
5. Others	31%	0%	13%	0%	56%	23%

Of the applicable homes, 66% found that truck sound during construction produced unacceptable noise. 62% of officers and teachers felt that the heavy machinery produced unacceptable noise. Explosions, while unacceptable to 59% of applicable homes, were applicable to only 33% of all the homes surveyed.

Construction complaints constituted only a small percentage of all the noise complaints. According to this survey, however, many people were in fact bothered by the noise of construction sites. This discrepancy can be explained because many of the individual construction sources as explained in this section are split up into different groups of the complaints. For example, heavy machinery and truck traffic are separated into the complaint groups 'machinery' (either defined or undefined) and 'trucks'. Because complaint sources were not as specific as the sources questioned about in this survey, it is difficult to make any correlation between the two.

4.3.1.4 Residential Sound

Officers and teachers were asked which of the following sounds were heard in their home caused by neighbors and what level of annoyance each source posed in their lives. The results are as shown in Table 8.

Table 8: Percent Distribution of Participant Responses to Residential Sound

	A	B	C	D	E	Applicable
1. Stereos	12%	18%	29%	32%	10%	96%
2. Television	1%	7%	30%	44%	17%	93%
3. People's voices	2%	10%	25%	51%	11%	94%
4. Doors	1%	5%	25%	45%	24%	87%
5. Children	0%	6%	29%	52%	12%	94%
6. Dogs and domestic animals	7%	20%	25%	39%	9%	92%
7. Foot traffic	1%	3%	17%	49%	31%	79%
8. Vacuum cleaners	1%	8%	21%	46%	24%	81%
9. Air conditioners	2%	3%	21%	49%	24%	83%
10. Car engine noise	2%	7%	22%	58%	11%	90%
11. Car repairs	6%	11%	19%	37%	28%	77%
12. Alarms	10%	19%	16%	32%	23%	79%
13. Music from vehicles	24%	29%	17%	23%	6%	94%
14. Megaphones	24%	24%	18%	21%	13%	85%
15. Trash collection	7%	21%	25%	39%	9%	94%
16. Loudspeakers	17%	25%	20%	23%	15%	85%
17. Others	26%	20%	17%	29%	9%	47%

Music from vehicles was the second most applicable question in this section to officers and teachers, with 71% of applicable homes finding the noise from these stereos to be unacceptable. Megaphones and loudspeakers were the second and third most unacceptable sound, with 66% and 62%, respectively, stating that these sounds are bothersome. The only discrepancy with this data is that in the survey, the Spanish words for megaphone and loudspeakers were very similar. In fact, the words were so similar that they could have led to misinterpretation or confusion of the participants. This part of the survey could have been better clarified with more precise vocabulary.

Stereos, which were applicable to 96% of homes, were unacceptable to 58% of respondents. Trash collection was also found to create unacceptable noise, frustrating 52% of applicable homes, while alarms were found to be unacceptable to 45% of applicable homes. Lastly, television, voices, doors, children, foot traffic, vacuum cleaners, air conditioners, car engine noise, and car repairs were all found to be unacceptable to fewer than 40% of all the applicable homes, with at least 77% of those homes declaring that each sound source was applicable to their daily lives.

4.3.1.5 Nightclub Sound

Participants were asked which of the following sounds were heard in their residence and what levels of annoyance they experienced from each component of nightclub sound. The results of this section are displayed in Table 9.

Table 9: Percent Distribution of Participant Responses to Nightclub Sound

	A	B	C	D	E	Applicable
A. Live music	14%	21%	18%	20%	27%	46%
B. Night club clients	13%	17%	15%	21%	35%	39%
C. Juke boxes	14%	16%	13%	24%	33%	41%
D. Others	24%	16%	8%	20%	32%	29%

Nightclub music was only found to be applicable to 46% of the surveyed population. Of these, 53% found the sound produced by the live music to be unacceptable, with clients and juke boxes both at around 44%.

Music was complained about most by the residents of San Juan. This noise could have indeed originated from a nightclub, however, most of the music sources we identified when monitoring were those of car stereos. Because less than a majority of the people who were surveyed were actually affected by nightclub noise, we can draw the conclusion that the majority of music complained about by residents most did not originate from night clubs.

4.3.1.6 Commercial Areas

Respondents were asked if they were affected by the following sound emitting factors that are associated with commercial areas. Many were found to be not applicable. This may be explained because many residential areas are not located near commercial areas, for safety and comfort reasons.

Table 10: Percent Distribution of Participant Responses to Commercial Sound

	A	B	C	D	E	Applicable
1. Store visitors	7%	10%	23%	34%	26%	51%
2. Commercial vehicle traffic	6%	16%	25%	31%	23%	50%
3. Roadside vendors	7%	15%	25%	29%	25%	54%
4. Others	13%	9%	17%	30%	30%	27%

Only 54% of survey applicants felt affected by commercial sound in their homes, and of that number less than 46% found that commercial sounds were unacceptable. This means that less than a quarter of all respondents found this noise to be unacceptable.

4.3.1.7 Industrial Areas

Table 11: Percent Distribution of Participant Responses to Industrial Sound

	A	B	C	D	E	Applicable
1. Industrial loading and unloading	13%	18%	21%	13%	34%	32%
2. Industry employees	3%	14%	26%	20%	36%	32%
3. Truck traffic	16%	27%	23%	14%	20%	49%
4. Industrial Machinery	12%	21%	20%	18%	30%	37%
5. Others	15%	0%	20%	5%	60%	20%

Industrial noise was applicable to the least number of individuals of any category in the survey. Similar to commercial areas, this was probably because very few residential areas are found near industrial areas. Although industrial truck traffic was heard in only 49% of homes, it was the most heard sound of any of the residential sounds. Of this 49%, 66% of the officers and teachers felt that this sound was unacceptable.

4.3.1.8 Electrical Equipment for Commercial, Industrial and Residential Use

Machinery constituted a large percentage of the total number of noise complaints. Using this survey, we determined those machines that generated more of a problem to the San Juan residents.

Table 12: Percent Distribution of Participant Responses to Equipment Sound

	A	B	C	D	E	Applicable
A. Lawnmowers	7%	29%	27%	31%	7%	92%
B. Electric generators	9%	26%	23%	26%	17%	73%
C. Tools	6%	20%	25%	33%	16%	83%
D. Central air conditioning	3%	7%	24%	37%	29%	68%
E. Water pumps	2%	7%	23%	30%	38%	59%
F. Others	29%	0%	12%	29%	29%	23%

Lawnmowers affected 92% of the surveyed homes, and 62% of homes found this sound to be unacceptable to them. Electric generators were unacceptable to 57% of affected homes and tools were unacceptable to 51% of affected homes. Both air conditioning and water pumps were unacceptable to less than 35% of affected homes.

Electric generators were also identified as a source of sound using the Brüel & Kjær. They were found to operate at very high, constant decibel levels, however, we were unsure whether or not they were considered to be problematic to residents. These results proved that they were, in fact, contributors to the noise problem and needed to be dealt with.

The topics of lawnmowers and tools in this category fit into the complaint category of machinery. From these results, one can deduce that a majority of residents are bothered by lawn mowers and tools, however, the assumption cannot be made that these are the most prominent sources of machinery noise because other forms of machinery were not evaluated in this question.

4.3.1.9 General Questions Section

Within a "general questions" section of the survey, participants were asked to answer 'yes' or 'no' to six statements. Those statements and their answers are shown in Table 13:

Table 13: Officer and Teacher Responses to General Questions in the EQB Survey about Noise

STATEMENT	YES	NO
You are part of or contribute to noise	23%	77%
Noise irritates you	58%	42%
Noise bothers you at this moment	79%	21%
Personally you are worried about noise	65%	35%
You believe noise affects your daily life	61%	39%
You believe noise affects your personality	44%	56%

Upon initial analysis of these results, the percentages of responses for the first statement seemed quite peculiar. If the surveys were completed *after* an information seminar about noise, it would seem likely that the officers and teachers should understand that they do contribute to noise. As examples, every car driven by a resident of the island amplifies the noise created on streets and, similarly, conversations and music contribute to ambient noises.

However, once the introductory paragraph to these general questions in the survey was translated, we began to see why only 23% of respondents said that they are part of or contribute to noise. The introduction reads as follows, "If you answered part of the previously presented questionnaire, you are a victim of one of the contaminants that most affects the island population: Noise. To continue, we present some general questions about noise.” This paragraph is a poor introduction in that it has nothing to do with the following questions and could create a bias before the officers and teachers had even read the six statements.

The more important statements of this section are “Noise irritates you,” “Personally you are worried about noise,” “You believe noise affects your daily life,” and “You believe noise affects your personality” because the percentages of the responses are good indicators about how the community feels about noise. 58% of participants are irritated by noise, 65% are worried about noise, and 61% believe noise affects their daily lives. Because the surveys reveal that over half of the respondents are negatively affected by noise in some way, indicated by their responses, this is crucial evidence that supports the goal of the EQB to strengthen or create new noise control legislation.

The question that asks if noise bothers you at this moment is not a very useful indicator for how the community perceives or feels about noise in their lives. The statement refers to the time directly after the seminar when participants were already informed of the harmful effects of noise and how the EQB is attempting to solve the issue of noise pollution. Therefore, it is highly likely that the officers and teachers would have surely been bothered by noise at that point, especially hearing about the problems and harmful effects that noise can create.

4.3.1.10 Responses to Emotions Felt When Exposed to Noise

The participants were also asked to answer ‘yes’ or ‘no’ as to whether or not they experienced any of the 18 emotions/reactions, listed in the survey, when exposed to noise. The emotions/reactions to noise and the percentages of the chosen responses are shown in Table 14.

Table 14: Officers' and Teachers' Emotions/Reactions to Noise

EMOTION/REACTION	YES	NO
Irritated	58%	42%
Depressed	20%	80%
Angry	60%	40%
Nervous	29%	71%
Anxious	41%	59%
Tired	32%	68%
Lack of concentration	65%	35%
Loss of peace and tranquility	66%	34%
Health is affected	35%	65%
Need to leave their home	44%	56%
Tense	50%	50%
Safe	26%	74%
Relaxed	15%	85%
Easy-going	18%	82%
Worried	49%	51%
Well	24%	76%
None of the above	16%	84%
Other	21%	79%

The emotions and reactions experienced by a majority of the participants were:

- Loss of peace and tranquility: 66%
- Lack of concentration: 65%
- Anger: 60%
- Irritation: 58%

By reviewing the four responses as an entire unit, the basic underlying theme is that people's lives are disrupted by noise. However, they do not indicate what noises or sounds create these emotions or reactions in people. This information would have been invaluable to the EQB because it would give more insight as to what specific sources of sound cause each reaction. From this, the EQB could have concentrated more on reducing the problematic sources that cause the most negative effect on the residents of San Juan.

The personal reaction survey portion is very important for the EQB in determining how humans respond to noise. Because the four reactions are obvious social problems associated with noise, the EQB has concrete evidence explaining why noise control is important for bettering the lives of San Juan's citizens. In addition to this, although the responses do not determine what sounds or noises cause the officers' and teachers' reactions to noise, they may provide insight into the motivation behind the residential complaints that the EQB receives on a daily basis.

The emotions and reactions chosen the least by participants were as follows:

- Relaxation: 15%
- None of the above: 16%
- Easy-going: 18%
- Depression: 20%
- Others: 21%
- Well: 24%
- Safe: 26%

From these seven choices, it is most important to see that relaxation, easy-going, well, and safe are four reactions to noise that reinforce the trend observed from the most popular emotions above. The results suggest that residents do not feel any of these "positive" reactions in the presence of noise.

Depression was not a surprising answer as well since noise is more of an irritant than a depressant. Although noise may amplify the irritation and unhappiness someone who is depressed may experience, it is very hard to prove that noise alone causes depression. Depression is known to be a long-term psychological development caused by many different factors, not solely noise.

The responses of ‘others’ and ‘none of the above’ are also difficult to analyze because often the participant rapidly perused the survey, filling in all of the ‘no’ responses to every question. For this reason, none of the respondents filled in the ‘others’ category as additional responses to noise experience by the participants. Therefore, it is simpler to say that in the presence of noise, people become irritated, angry, lose concentration and tranquility, do not feel relaxed or easy-going, and do not feel well or safe. All of these reactions lead to the conclusion that noise does negatively affect the Puerto Rican population.

4.3.1.11 Participants Satisfaction with Current Noise Regulations

The second to last question of the survey raised the question of how satisfied the respondents were with current mechanisms for noise control. The possible responses and their percentages are listed in Table 15.

Table 15: Survey Responses Regarding Satisfaction with Current Noise Control Mechanisms

RESPONSE	PERCENTAGE
Completely satisfied	39%
I am not satisfied	53%
I don’t know of a mechanism	8%

The majority of the respondents (53%) were not satisfied with current noise control mechanisms, thus providing the EQB with a definitive reason to press for new or modified future noise control legislation. This question combined with the previous section on how people are affected by noise give powerful evidence to support the need for new or modified noise control legislation because current legislation is obviously not fulfilling its main priority: to protect the quality of life of the citizens of Puerto Rico.

4.3.1.12 Importance of Noise Pollution to Survey Respondents

The final question in the survey asks participants about the level of importance that noise pollution has in their own lives. The possible answers and their percentages are as follows in Table 16:

Table 16: Level of Importance Noise Pollution Has in the Lives of the Survey Participants

RESPONSE	PERCENTAGES
Very important	84%
Regular importance	15%
Of little importance	1%
Not important to me	0%

This question is also vital in obtaining a definitive answer directly from those persons that noise affects. The overwhelming 84% of participants who agree that noise pollution is very important in their own lives show that the citizens of the island take the issue seriously. In combination with the previous sections of this survey, it can be deduced that the people of Puerto Rico take noise pollution seriously, noise does negatively affect their lives daily in some fashion, and they are not satisfied with current noise control practices. Granted this statement does not apply to everyone who partook in the survey, but for the majority of respondents, this statement does apply, adding further to the motivation and evidence the EQB has in achieving its goal of new or modified noise control legislation.

4.4 Summary of Results

All of our results provided further evidence supporting the evidence that there is a noise pollution problem in San Juan. The most pertinent verification of the problem is displayed in the sound level database that we compiled which summarized the general sound profile of the city. Of the 23 sites that have been monitored, we found that the Leq during daytime hours remained around 64dB, a very high number considering that people are moderately annoyed by those sound levels above 50dB and seriously annoyed by levels around 55dB (WHO, 1999).

While creating the sound level database, we identified sources of sound that caused a majority of the high decibel levels. These prominent sources were found to be those of vehicular traffic, including both cars and trucks. They were then identified as not only sources of sound, but also sources of noise because survey results revealed that a majority of the participants found vehicular traffic to be bothersome.

Along with the surveys, the complaints also disclosed sources of sound that irritate an individual. Most complained about sources included music, machinery, plant noise, and factory noise. Music, which constituted about 26% of the total complaints from years 1998-2003, could have arisen from a number of sources, including car stereos, home stereos, and nightclubs. However, the data we collected from the Brüel & Kjær revealed that most of the music sources came from car stereos.

Machinery was also one of the main sources of noise that was complained about. Complaints about machinery included noise emitted by equipment, such as lawn mowers and weed whackers, as well as noise emitted by a shop. To clarify what types of machinery were most bothersome to people in this category, we assessed survey results. They showed that lawn mowers and power tools were irritating to residents; however, no definite conclusions could be drawn because those were the only forms of machinery that were evaluated in the surveys.

Electrical plant noise generated 14% of the total complaints. However, the survey did not contain a section that was related to plant noise so therefore we could not determine an approximation of how many people are, in fact, affected by plant noise. Because this source constituted such a large percentage of the total number of complaints, we still considered it to be a considerable part of the noise problem.

Factories generated a large number of noise complaints as well. The survey contained a section that evaluated the respondents' perception of industrial noise. We found that the most bothersome noises in an industrial environment were created by large trucks and industrial machinery.

The surveys also evaluated residents' personal opinions on noise and how it affects them individually. After analyzing the data, we concluded that noise does affect a majority of residents during their daily lives. More specifically, noise causes loss of peace and tranquility, lack of concentration, anger, and irritation. This evidence verifies that noise does in fact have negative effects on individuals and can therefore be detrimental to the health and well-being of a society.

The survey also revealed that a majority of the respondents were not satisfied with current mechanisms for noise control in San Juan. Using our project, legislators will have evidence to prove the necessity for new amendments of current noise legislation and noise control enforcement. From there, they can make modifications that will hopefully restore residents' satisfaction with the island's approach to noise control.

The sources of sound that created the high sustained decibel levels stated above compose the majority of the noise pollution problem in San Juan. By reducing any of those sources, sound levels of an area will decrease, thus improving the quality of life. Possible methods of reduction will be discussed further in the following chapter.

5.0 Discussion and Conclusion

By taking the average of each of the randomly selected stations, we were able to design an approximate sound profile of San Juan's acoustic environment. A majority of the monitored sites were strictly residential. By comparing the residential sound regulations found in Table 2 in the Literature Review with the average decibel levels for all the monitored sites as shown in Figure 8 in the Results Section, one can clearly see the excessive levels of sound the residents of San Juan are exposed to. The sound level profile of San Juan that we have helped to create provides evidence for the necessity of new or modified noise legislation and stricter enforcement to reduce the noise pollution problem of San Juan.

Currently, the decision of whether or not emitted decibel levels are in violation of Puerto Rico's sound regulations is based upon whether or not the police officer thinks a sound is excessive. Because this is personal opinion, it is very difficult to enforce these regulations. To solve this problem, legislators want to clarify these regulations by creating objective standards, based in part on our preliminary data collection, combined with data collected by the EQB. These guidelines will make it easier to enforce noise regulations because no room will exist for varied interpretation. However, in order to accurately document these noise levels, the officers will need sound monitoring equipment as well as training on how to utilize the equipment. Additional funding will be required in order to supply the equipment and train the officers.

Using the Brüel & Kjær, we were able to identify prominent sources of sound. Upon further investigation of the documented complaints and administered surveys, we were able to distinguish which of these sounds were considered noise. We found that the most prominent sources of noise came from vehicular traffic, music, machinery, and factories. Possible noise reduction techniques will be discussed in the following paragraphs.

Vehicular traffic was the single most prominent source of noise identified at the monitored sites. The nature of vehicular noise varied significantly, from the noise emitted by a vehicle's engine or stereo system to the noise from its horn or tires on the road. Because traffic noise is the main cause of excessive decibel levels, decreasing it would significantly decrease San Juan's noise problem. To do this, one must consider many different factors affecting either the noise of an individual vehicle or the noise of vehicular traffic as a whole.

The Environmental Protection Agency has established standard noise emission levels that vehicle manufacturers must comply with. Modifications to the vehicle or even normal use can cause the noise emissions to exceed the standards. Some European countries have mandated noise emission tests during vehicle inspection. Similar laws could be adopted in Puerto Rico to ensure vehicles remain within the EPA's suggested limitations even after years of use.

There are many other noises that originate from a vehicle that are more difficult to regulate. Car horns are loud but are not used very often, except near busy intersections. Unfortunately, there is no way to limit a horn's frequent use since they are one of a vehicle's primary safety features. In addition to this, any possible future legislature regulating the use of a car horn would create problems once again with enforcement because the determination of either unnecessary or excessive honking will have to be based on the officers' personal discretion. The same could be said for car alarms. They are intended for protection of property but excessive false alarms help categorize this safety feature as more of a nuisance than as protection. Future car alarms might rely less on a loud distinguishable sound and more on other modes of alerting the owner or authorities of a crime in progress. For example, future technology might allow the availability of alarm systems where the vehicle owner's key chain becomes the signal rather than the present-day loud alarm systems that sound from the cars themselves. Another possibility is to try to decrease the price of car tracking systems that are currently available for car owners to make them more affordable. Either of these suggestions may be more valuable and useful than the current alarm systems used today.

Aside from regulations that reduce vehicular noise at an individual level, there are other ways of decreasing the noise emitted by vehicular traffic as a whole. According to the Federal Highway Administration (2004), there are three different factors that affect traffic noise. They are the volume of the traffic, the speed of the traffic, and the number of trucks in the traffic flow (FHWA, 2004). When there are many vehicles on the road, the speed limit is high, or there is a large number of trucks in the traffic flow, traffic noise is excessive. Therefore, when any of these factors is decreased, traffic noise significantly decreases.

Noise levels of a street where traffic flows at a rate of about 2,000 cars per hour is twice as loud as if there were only 200 cars per hour (FHWA, 2004). It is not feasible to decrease traffic flow by 1800 cars per hour. However, there are some ways to minimize road usage. In some cities, there is a separate lane designated for those cars containing two or more persons known as the car pool lane. This is a fast-moving lane that persuades people to drive together, therefore reducing the number of cars on the road. Funding provided, adding a car pool lane to existing highways could be a possible way to reduce the noise problem in San Juan.

The use of a train or subway system also reduces traffic noise. Currently, the city is in the final testing stage of a train system, Tren Urbano, which will open its doors to the public within the next few months. This will hopefully decrease the amount of cars on the road as more residents will have easy access to this inexpensive, convenient transportation system.

The speed of traffic has a large impact on vehicular noise (FHWA, 2004). However, to achieve a noticeable difference in sound levels, a speed limit must be reduced by at least 20 miles per hour. This also would be an almost insurmountable task as this is unrealistic especially in those areas of high speed, such as highways. An alternative to this would be managing current traffic. A change in the location of some traffic lights, or even the removal of some lights in sections of the city where they are ineffective, may eliminate the constant stop and go and resulting back-up of the traffic flow. This change may also help to decrease the use of horns resulting from traffic jams as well as the noise from a vehicle's initial acceleration.

The number of trucks and busses in the city create a significant amount of noise. Although we identified many more cars than trucks and busses during source monitoring, the sound levels of trucks and busses were much higher than those of cars. According to the Federal Highway Administration (2004), one truck traveling at 55 miles per hour sounds as loud as 28 cars traveling at the same speed. One way to reduce this problem is to restrict the times that a truck may pass through a given street, especially if that street is located in or near a residential area. For example, a law might forbid a truck to pass through a residential street during nighttime hours, starting at 10pm and ending at 7am. This could help eliminate annoying sounds that may disturb the sleeping patterns of the residents in that area. As for daytime hours, although it is impossible to completely hinder the operation of trucks and busses through residential areas, alternate routes could be suggested by Puerto Rico's government, so as to reduce the amount of them that pass through residential areas each day. As an additional suggestion, diesel engine manufacturers have placed quiet diesel engines on the market that vary in price by only a few thousand dollars. Eventually, the Commonwealth could impose new regulations for trucks and busses on the limit of decibel levels that can be emitted by their engines, forcing them to transition over to the quiet diesel engines by a certain future date.

Another factor that affects traffic noise is the pavement type of the roads. New research has shown that more porous asphalt has a greater capability to absorb the sound emitted by passing vehicles. The use of porous asphalt shows reduction of sound levels by 2-6dBA. Any construction of new roads or repaving of older roads in San Juan should be paved with porous asphalt.

If it is not possible to reduce sound levels by restricting the producers of sound, another alternative is to reduce sound transmission using sound barriers. A sound barrier is a physical object, usually a wall that stands in between the source of the sound and those affected by it. The use of sound barriers is not limited to traffic use. Many airports and train systems have sound barriers around their perimeter or along the length of the track, respectively. Installation requires a certain amount of space that is not usually available. Because of this, it would not be feasible to install these barriers in the busy city streets. However areas such as highways often have the accommodations for these sound barriers and present an effective method of noise reduction.

Music also presents a problem for residents. The source of music arises mostly from cars, homes, and nightclubs. Music for some is a good thing. However, when subjected to loud music, one may become irritated, especially during the nighttime hours. Although there are current regulations that forbid excessive music levels, the enforcement of these regulations is based on personal opinion. Once again, the necessity of numerical standards for acceptable decibel levels is evident, as many current regulations do not contain numerical figures. In addition to this, even if numerical standards are included into the legislature, police officers still need sound monitoring equipment in order to directly determine whether or not the sound source is in violation of noise regulations.

Although both machinery and factories present problems because of their effects on people, attempts to regulate them will prove difficult at best. One way to help reduce emitted decibel levels would be to modify existing construction codes so that the installation of sound-reducing insulation throughout all factories, electrical plants, machine shops, car repair shops, and industrial work stations is mandatory. To further this advancement, the government of Puerto Rico could try to give some incentive for contractors to construct buildings close to noisy areas so that they will act as sound barriers. In the future, when contractors and developers want to build residential areas that would be close to a noisy area, the construction of buildings should first be considered so that the level of exposure on residents is at a minimum. New building codes for the construction of all residential houses should also be modified so that developers are always required to install sound-reducing insulation. All of these precautions will help to prevent the disturbance and decline of the quality of life for the residents of San Juan.

One major preventative measure for noise reduction is educational awareness. One of the most efficient preventative methods that could be used for any societal or environmental issue is to educate society on issues that affect them directly. By exposing the noise pollution problem as much as possible via newspapers, advertisements, billboards, letters, pamphlets, television, etc., the EQB can greatly advance efforts of reducing sound levels once people understand that there is a problem and that it does affect their health. Another way to accomplish this task is to educate children in Puerto Rico's schools. By making yearly visits to schools and addressing the problem in positive ways, children will mature throughout the early years always aware of how their actions affect their acoustic environment.

Lastly, the efforts made by the EQB to create a sound level profile of San Juan should not be the first and last research project completed on the noise pollution problem of Puerto Rico for the next few decades. Research on noise needs to be continuous in order to maintain the success that will result from this project. Additional research will help the Noise Control Area in monitoring future successes and flaws in any new legislative amendments or methods of controlling noise that result from this project. As a final point, in order to keep the public interested in the issue of noise pollution, research needs to advance so that the most current and updated facts are relayed to those who are directly affected.

Although all of the suggestions above will help to bring the sound levels throughout the city closer to the goal that the EQB has set (shown in Figure 2), it is important to understand that this is only an ideal goal, one that perhaps will never be accomplished in all sections of the city. A major reason for this is that there will always be sections of San Juan and throughout Puerto Rico, such as industrial areas, which will occasionally exceed governmental standards. By developing new legislation and increasing noise awareness among citizens and police as well as educating society on the laws and the effects of noise, a decline in sound levels throughout the city where levels gradually approach the ideal pattern established by the EQB will hopefully be observed through future research.

Until acceptable sound patterns are obtained via additional research, noise control methods, and new or modified legislation, the continuation of the Noise Control Area's project to create a sound level profile should remain intact. The efforts of this agency are vital as the first giant steps towards bettering the quality of life for the citizens of Puerto Rico. Because of this research, the first major advance in noise control that is specific to the problems and characteristics of Puerto Rico will be accomplished. In addition to this, the first collection of evidence documenting that there is a noise pollution problem in San Juan is in the process of being completed. This evidence will hopefully grant the Noise Control Area with the funding needed to accomplish the monumental task of reducing noise in the city. Government funding should also provide the agency with the financial support to promote noise awareness throughout society, to continue and advance additional research regarding noise throughout the island of Puerto Rico, and to give financial aid to other municipalities throughout Puerto Rico. This will support their future respective sound monitoring projects once the effectiveness and success of San Juan's sound monitoring project is evaluated. In conclusion, the continued support of this project cannot be stressed enough. If it is successfully completed, the acoustic environment of the island will become more favorable for its citizens.

The quality of a person's life should not be taken for granted, and any effort that is made to increase the quality of life, especially when the efforts are focused on something as monumental as noise in one's community and the effects it has on one's health, those efforts should be rewarded and continued assistance from the government.

6.0 Sources

Alexandre, A. (1975). Noise Regulations in OECD Countries. Environmental Science and Technology, 9, 1020-1024.

Bahadori, Robert S. and Bohne, Barbara A. (April 1993). Adverse Effects of Noise on Hearing. American Family Physician, 47, (5) 1219-1230.

Browne, Malcolm W. (1990, March 6). Reasearch on Noise Disappears In the Din. The New York Times, pp. C1, C11.

Bugliarello, G., Alexandre, A., Barnes, J., and Wakstein, C. (1970). The Impact of Noise Pollution. New York: Robert Maxwell.

The Bureau of National Affairs, Inc. (1972). Noise Control Act of 1972. Public Law 92-574.

Cornman, Dave. (1996). Effects of Noise on Wildlife. Retrieved February 2, 2004 from The World Wide Web http://www.naturesounds.org/conservENW.html

Cotto, Esteban M. (2003, Nov. 25). Noise Monitoring Project in San Juan, Puerto Rico. Letter addressed to Dr. Susan Gerstenfeld, p. 1-2.

El-Fadel, M. and Chahine, M. (2002 Jan-Feb). Case History: An assessment of the economic impact of airport noise emissions near Beirut International Airport. Noise Control Engineering Journal, 50 (1), 30-36.

El-Fadel, M. and Sbayti, H. (2000). Noise control at congested urban intersections. Noise Control Engineering Journal, 48, 206-213.

Environmental Quality Board. (1940-2003). List of Laws and Regulations for Stationary Levels Regarding Noise. Commonwealth of Puerto Rico. Office of the Governor. San Juan, Puerto Rico.

Environmental Quality Board. (1987, February 25). Regulation for the Control of Noise Pollution, amended version. Commonwealth of Puerto Rico. Office of the Governor, 1-27. San Juan, Puerto Rico.

Environmental Quality Board. (2004). Work Plan for Studying Urban Noise and Historical Sound in San Juan, Puerto Rico. Commonwealth of Puerto Rico. Office of the Governor. San Juan, Puerto Rico.

Evans, Gary. (2002, October 7). Study of German Children Living Near Airports Shows Jet Aircraft Noise Impairs Long Term Memory and Reading Ability. Cornell News.

Evans, Gary. (1998, March 4). Airport Noise is Harmful to the Health and Well-Being of Children and May Cause Lifelong Problems, Cornell Study Shows. Cornell News.

Evans, Gary. (2001, January 22). Even Low Level Office Noise Can Increase Health Risks and Lower Task Motivation for Workers, Cornell Researchers Find. Cornell News.

Evans, Gary. (2001, May 22). Cornell Researchers and his Co-authors Find Everyday Traffic Noise Harms the Health and Well-Being of Children. Cornell News.

Fan Ng, Cheuk. (2000). Effects of Construction Noise on Residents: A Quasi-Experiment. Journal of Environmental Psychology, 20, 375-385.

The Free Associated State of Puerto Rico. (1940, April 26). Public Law Number 71, Law of Crimes Against Public Peace, Sections 1-6.

Gang, Duane W. (2002). Proposed law aims to measure noise levels around town, Chattanooga Times Free Press, B1, Retrieved January 31, 2004 from LexisNexis Academic Search database http://web.lexis-nexis.com/universe

García, A., Miralles, J.L., García, A.M., and Sempere, M.C. (1990). Community Response to Environmental Noise in Valencia. Environmental International, 16, 533-541.

Grøtvedt, Liv. (1990). Neighbour Noise Annoyance and Psychiatric Diseases. Environmental International, 16, 543-546.

Helmkamp, J. Talbott, E., and Margolis, H. (1984). Occupational Noise Exposures and Hearing Loss Characteristics of a Blue Collar Population. Journal of Occupational Medicine, 26, 12.

Hildebrand, James L. (1970). Noise Pollution and the law. Buffalo: W. S. Hein.

Jones, Dylan. (1990). Recent Advances in the Study of Human Performance in Noise. Environmental International, 16, 447-458.

Kuwano, S., Mizunami, T., Namba, S., and Morinaga, M. (2002). The Effect of Different Kinds of Noise on the Quality of Sleep Under Controlled Conditions. Journal of Sound and Vibration, 250, 83-90.

Lang, Susan. (1998, March 12). Airport Noise Can Seriously Affect the Health and Psychological Well-Being of Children. Cornell University News Service.

Lipscomb, David M. and Taylor, Arthur C. (1978). Noise Control: handbook of principles and practices. New York: Van Nostrand Reinhold Co.

Maling, George C., Jr. (2002). An Overview of the U.S. Noise Policy. Dayton.

McLaughlin, L. (April 26, 1977). High Cost Expected for Industrial Noise. The Boston Globe.

Microsoft Streets & Trips 2003. Version 11 [Computer Software]. (2003). Redmond, WA: Microsoft Corporation.

Nave, Carl R. (2000). Sound; Inverse Square Law. Georgia State University. Department of Physics and Astronomy. Retrieved from The World Wide Web on February 22, 2004 http://hyperphysics.phy-astr.gsu.edu/hbase/acoustic/invsqs.html#c1

Norsonic. (2004). Environmental Analyzer Nor-121. Retrieved on February 29, 2004 from the World Wide Web: http://www.norsonic.com/web_pages/nor-121_page.html

O'Konowitz, Tom. (2003). Loud van has Elgin looking at tightening noise laws. Chicago Daily Herald, p. 3, Retrieved January 31, 2004 from LexisNexis Academic Search database http://web.lexis-nexis.com/universe

Patton, M.Q. (1990). Qualitative evaluation and research methods (2nd ed.). Newbury Park, CA: Sage.

Pearce, F. (1985). Noise: Industry Turns a Deaf Ear. The New Scientist.

Rosenhouse, Giora. (2001). Active Noise Control. Boston: Wit Press.

Rust, Jon. (February 5, 2004). EQB to design and implement islanwide noise control plan. The San Juan Star, 13.

Serway and Beichner. (2000). Physics for Scientists & Engineers, 5th. Ed. New York: Saunders Pub.

Strasser, H., Irle H., and Scholz, R. (1999 Sep-Oct). Physiological cost of energy-equivalent exposures to white noise, industrial noise, heavy metal music, and classical music. Noise Control Engineering Journal, 47 (5), 187-191.

Suter, Alice H. (1989, Nov-Dec). Noise Wars. Technology Review, 42-49.

Taylor, R. (1970). Noise. Middlesex, England: Penguin Books LTD.

Uprety, Sanjay. (1995, February 17). Noise pollution: A challenge for planners, architects. The Rising Nepal, 55-57.

U.S. Department of Housing and Urban Development. (1991). The Noise Guidebook, Washington, D.C., U.S. Government Printing Office, Retrieved on February 1,

2004 from
http://www.hud.gov/offices/cpd/energyenviron/environment/resources/guidebooks/noise/index.cfm

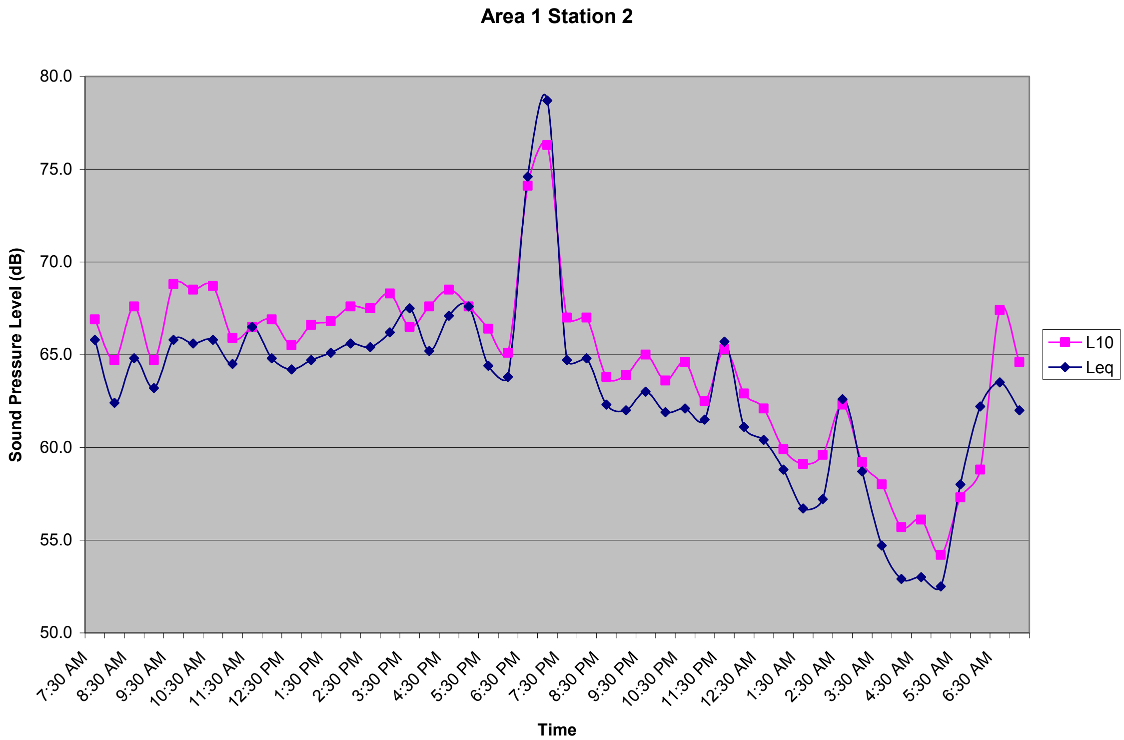
Wieland Associates. (2003, Spring). Wanted, Dead or Alive. Sound Advice, 6, 2-4.
Groups sue to protect coqui frogs in Puerto Rico. (2003, June 12). *Associated Press.*

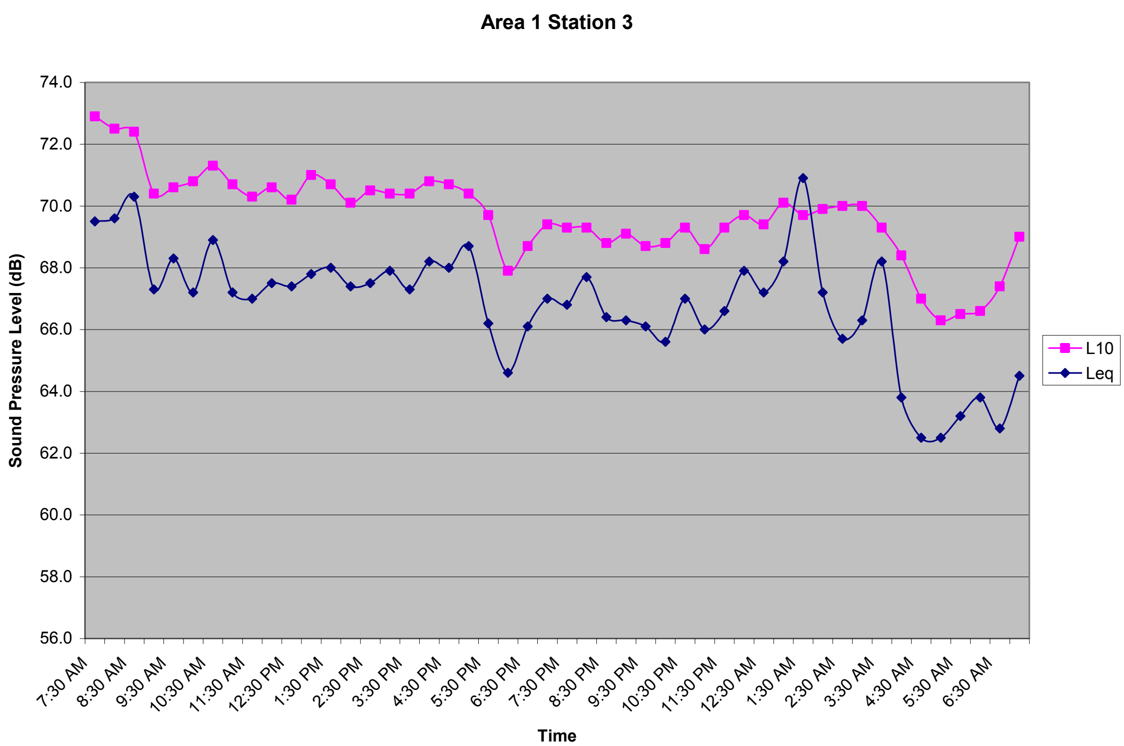
Wilkins, P.A. and Acton, W.I. (1982). Noise and Accidents – A Review. British Occupational Hygiene Society, 25 (3), 249-260.

World Health Organization. (1995). Guidelines for Community Noise. Stockholm University and Karolinska Institute. Stockholm, Sweden.

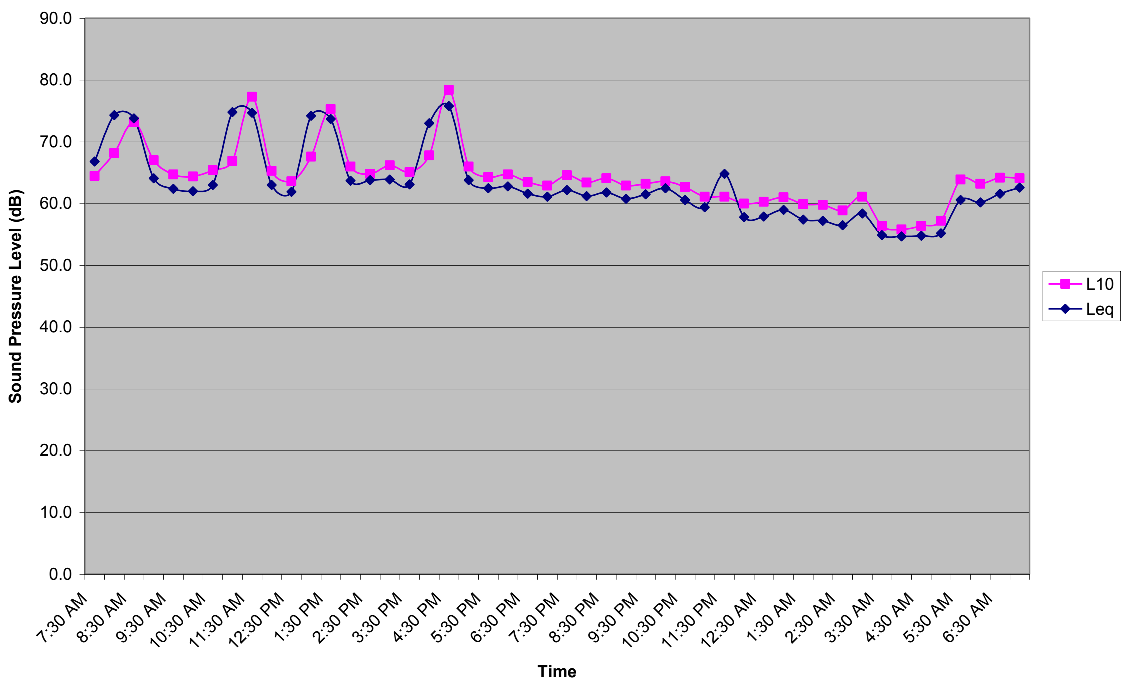
7.0 Appendix

Time vs. Sound Pressure Level for Monitored Sites

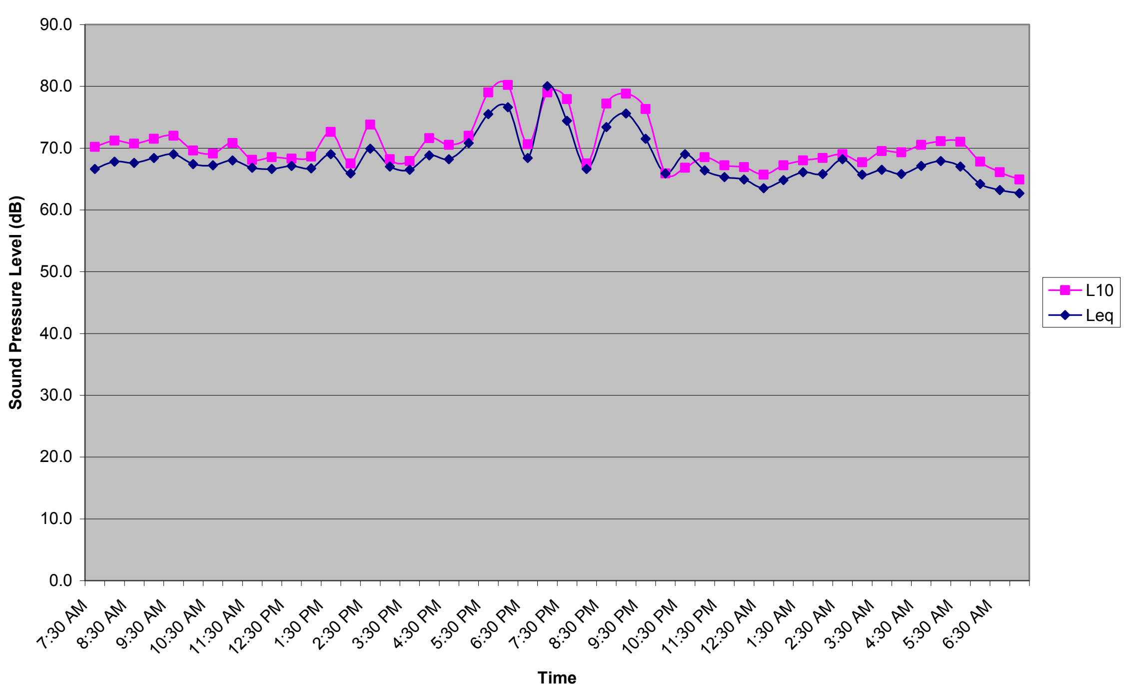




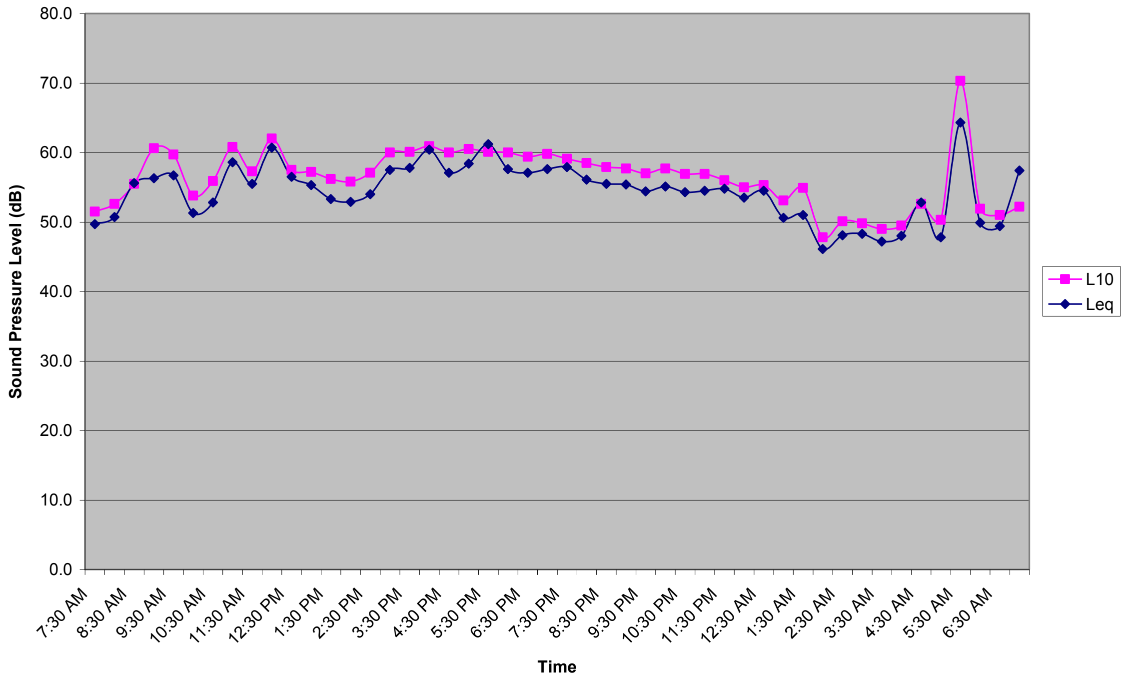
Area 1 Station 4



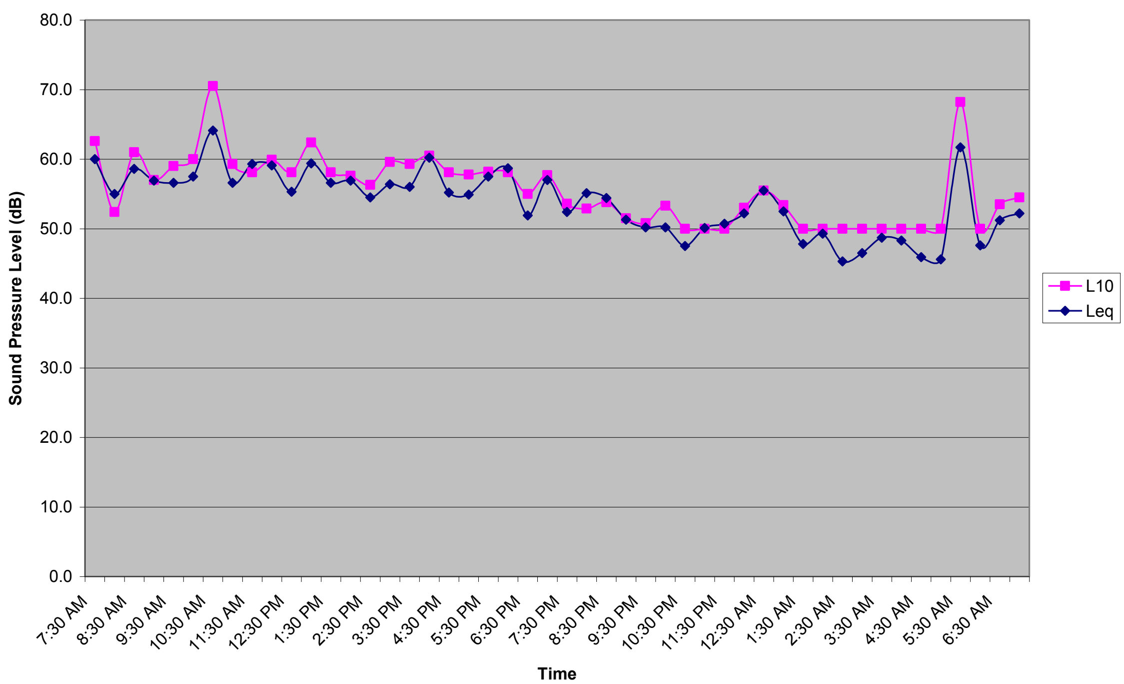
Area 1 Station 5

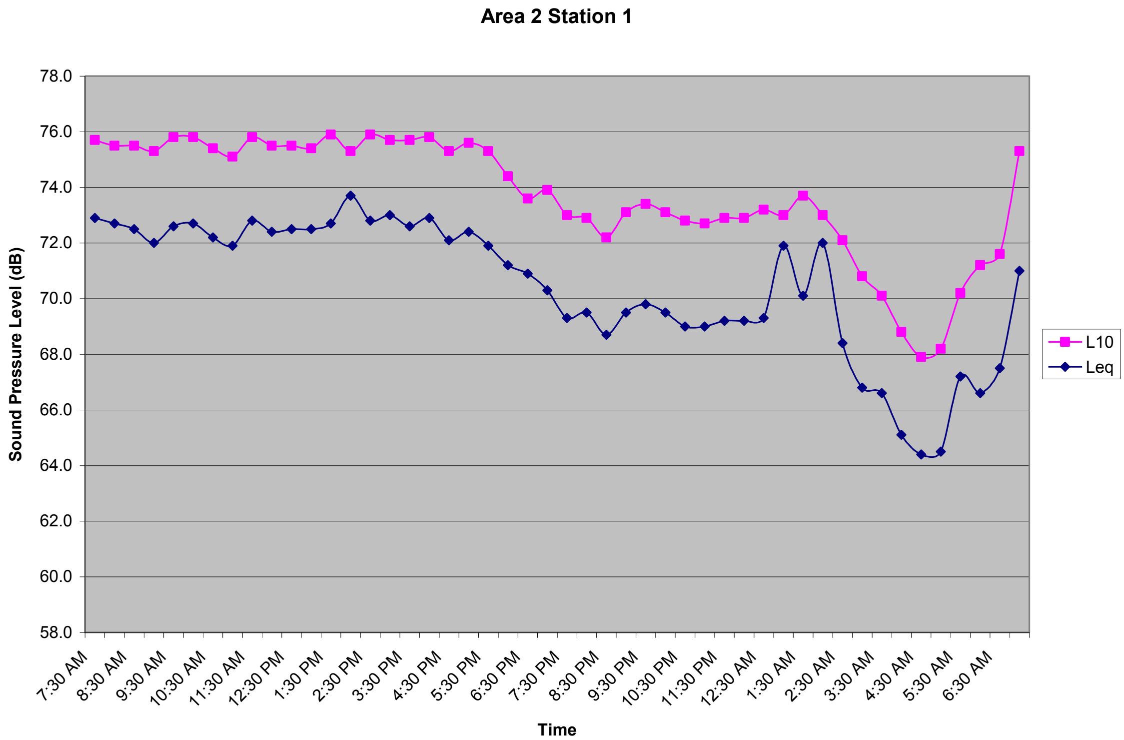


Area 1 Station 6



Area 1 Station 7




Area 2 Station 1
78.0
76.0
74.0
72.0
70.0
68.0
66.0
64.0
62.0
60.0
58.0
Sound Pressure Level (dB)
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
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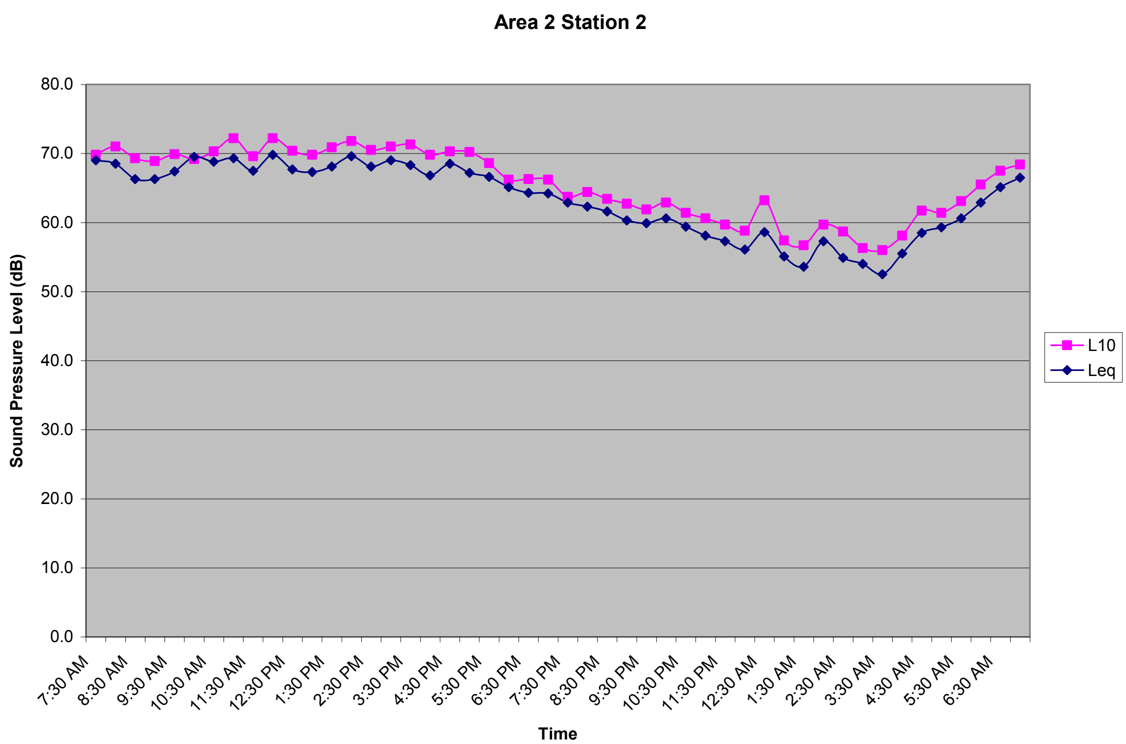
1:30 AM
2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq


Area 2 Station 2
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Sound Pressure Level (dB)
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
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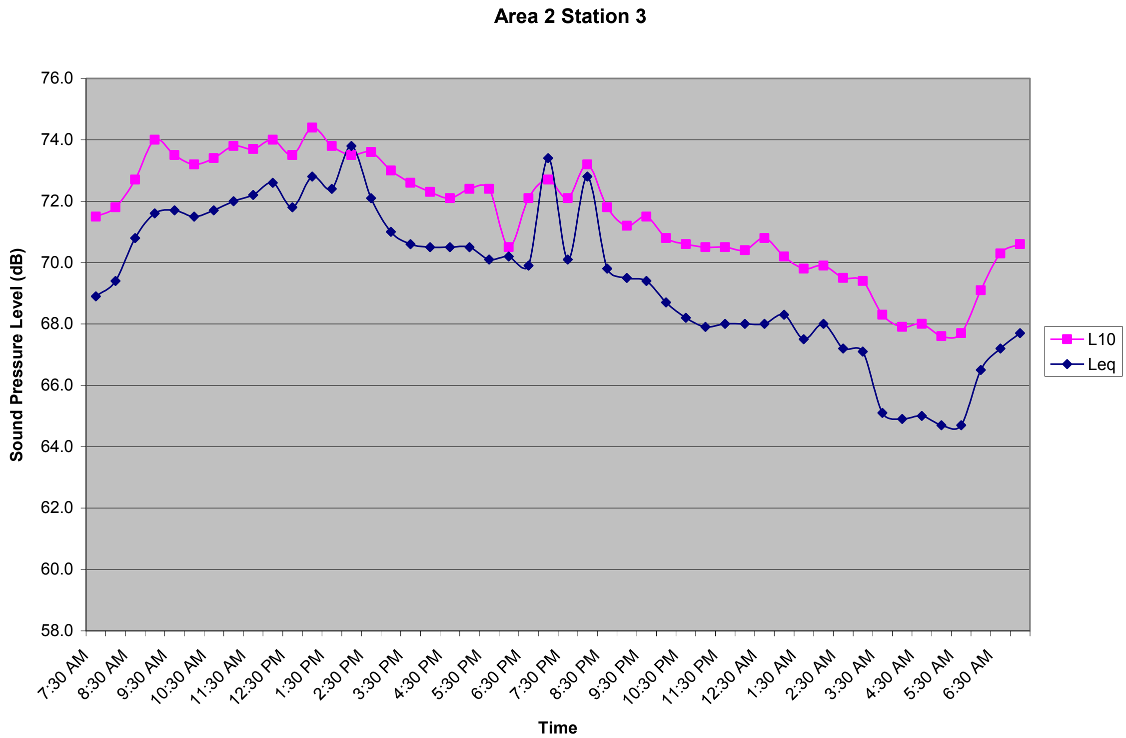
2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq


Area 2 Station 3
Sound Pressure Level (dB)
76.0
74.0
72.0
70.0
68.0
66.0
64.0
62.0
60.0
58.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
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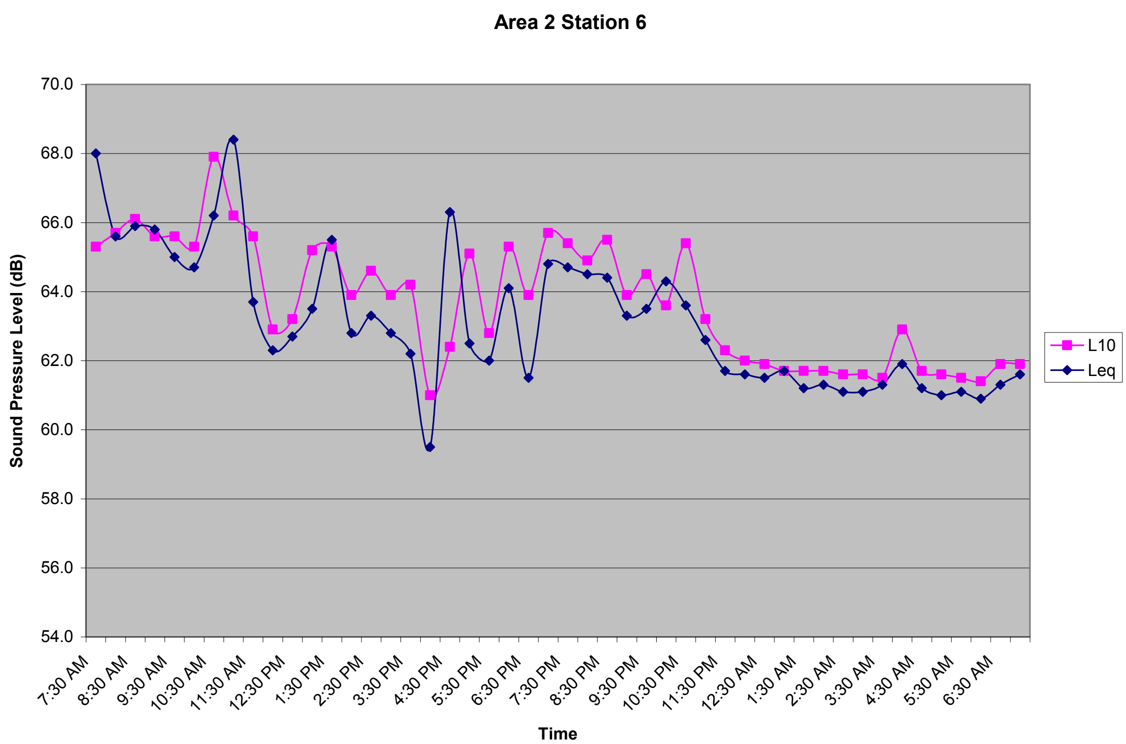
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq


Area 2 Station 6
Sound Pressure Level (dB)
70.0
68.0
66.0
64.0
62.0
60.0
58.0
56.0
54.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
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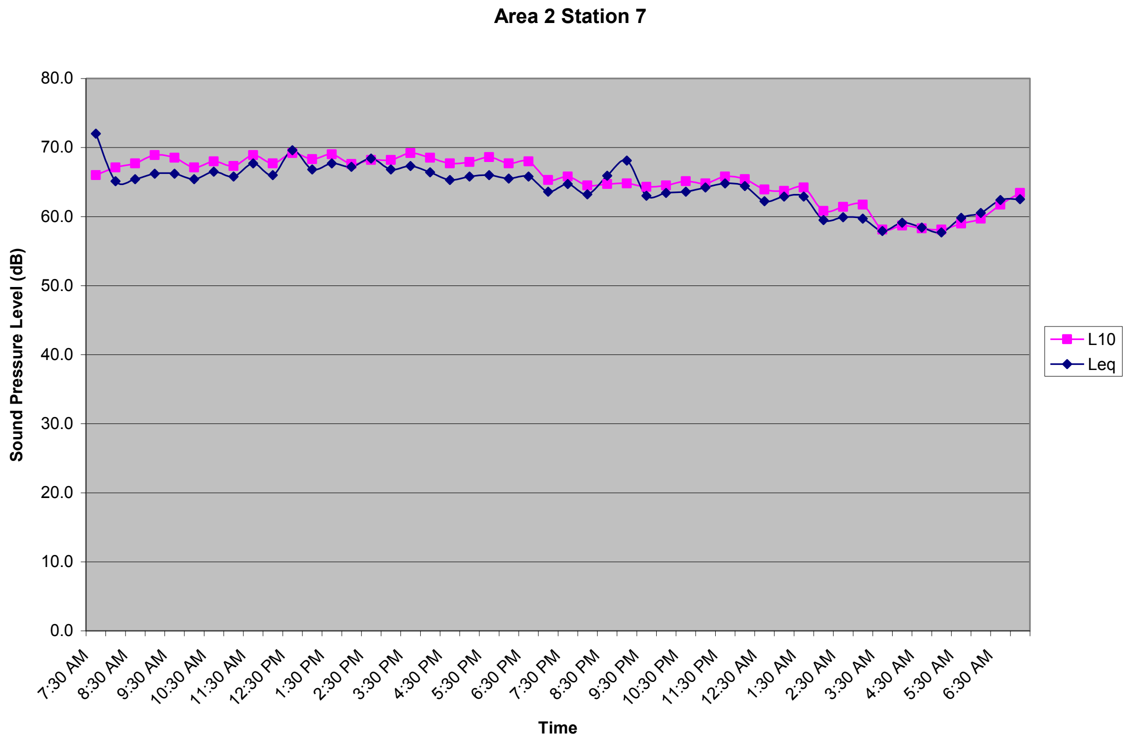
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq


Area 2 Station 7
Sound Pressure Level (dB)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
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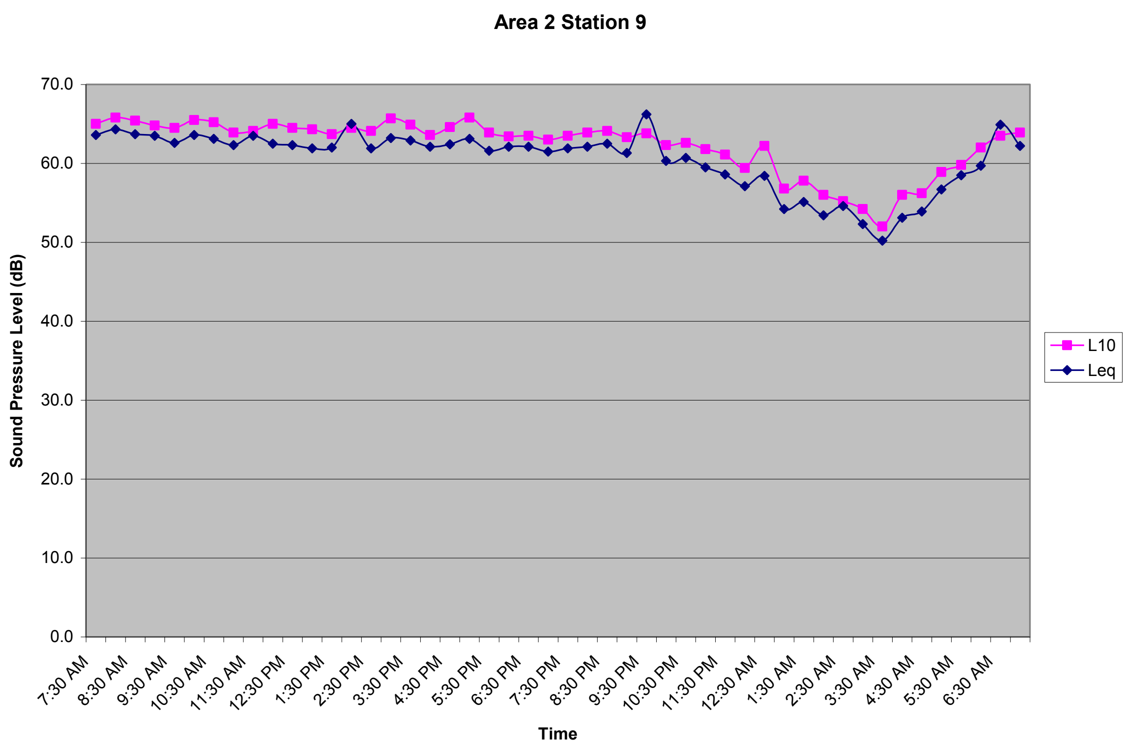
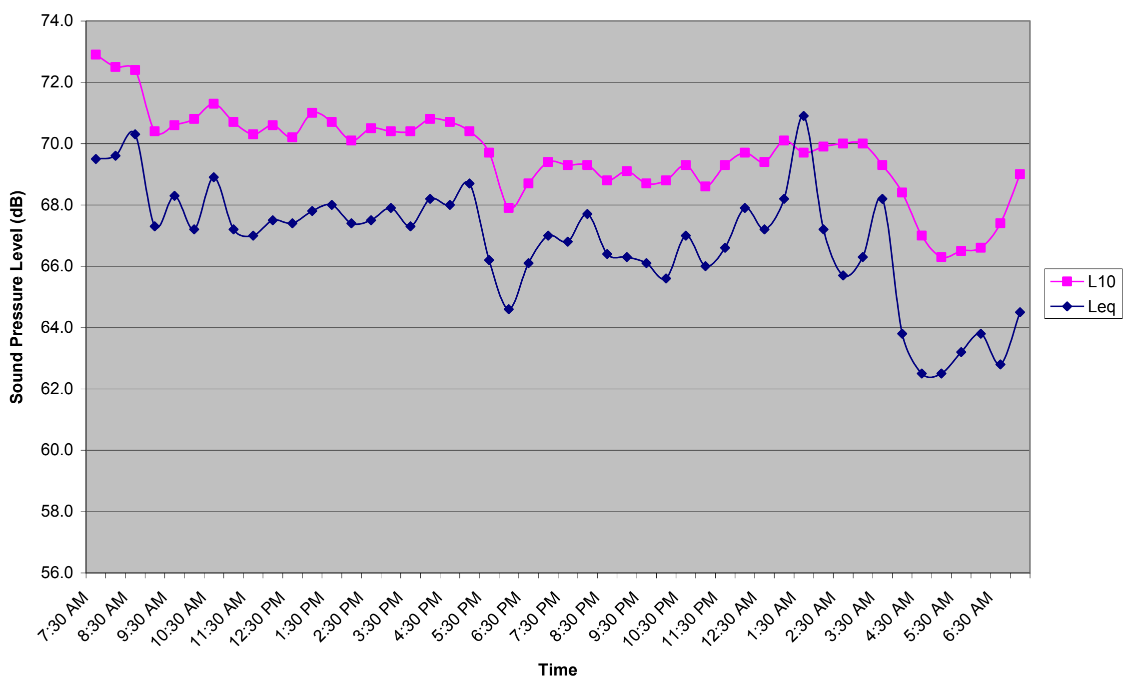
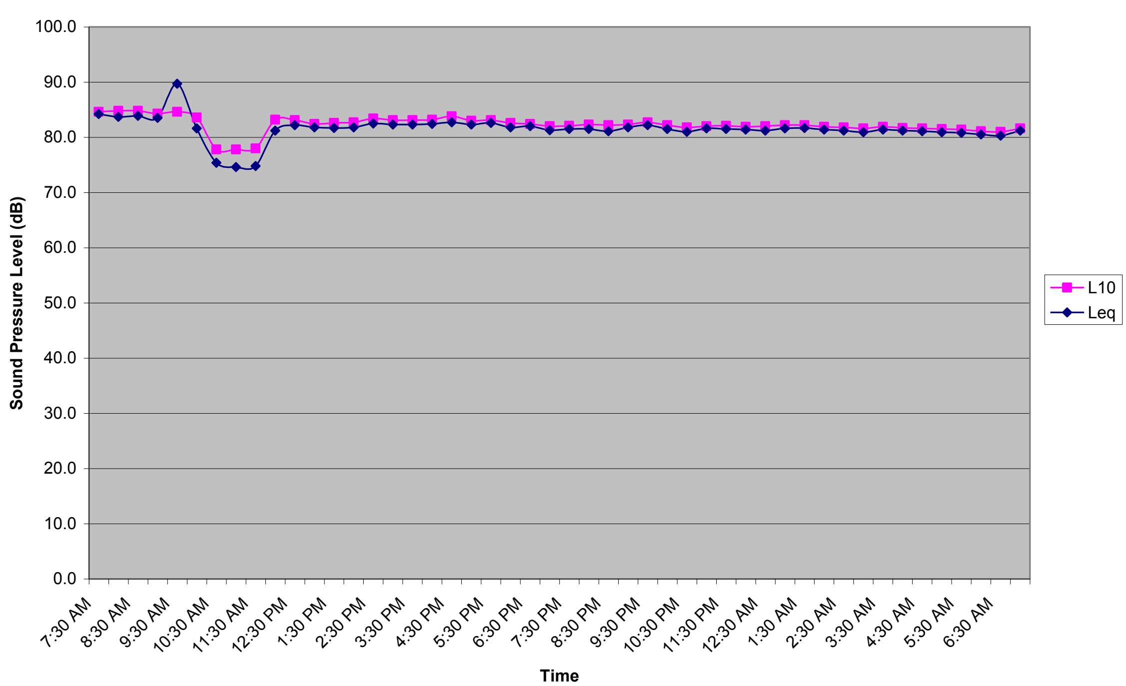
5:30 AM
6:30 AM
Time
L10
Leq


Area 2 Station 9
Sound Pressure Level (dB)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
12:30 AM
1:30 AM
2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq

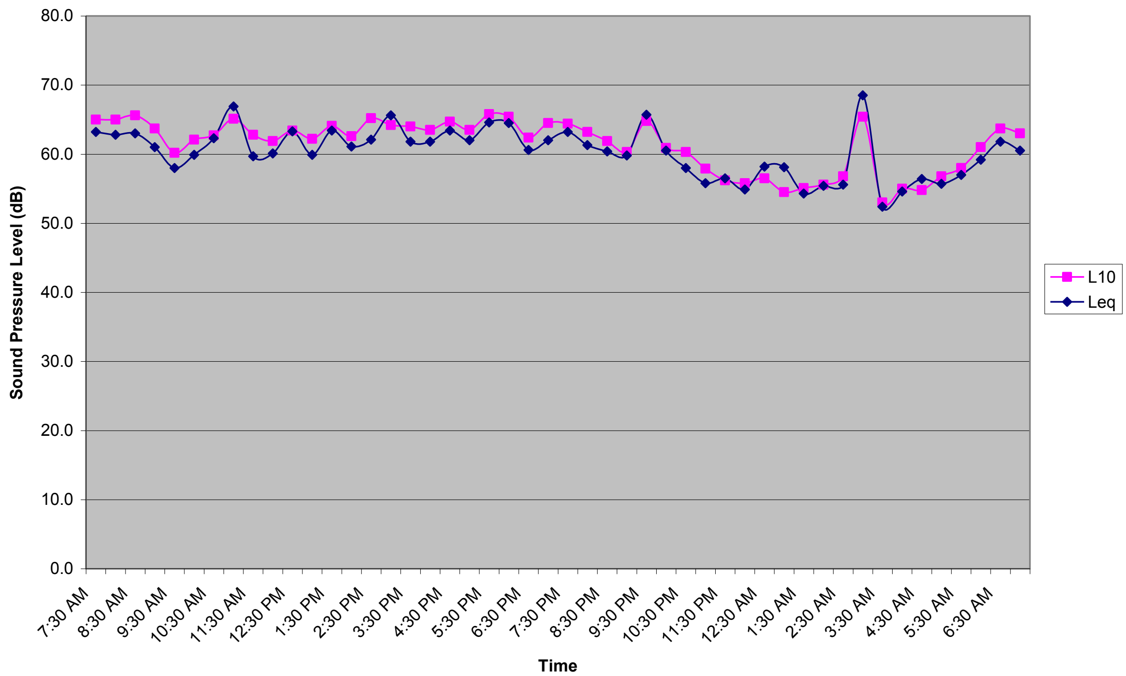
Area 2 Station 10



Area 3 Station 1



Area 3 Station 2



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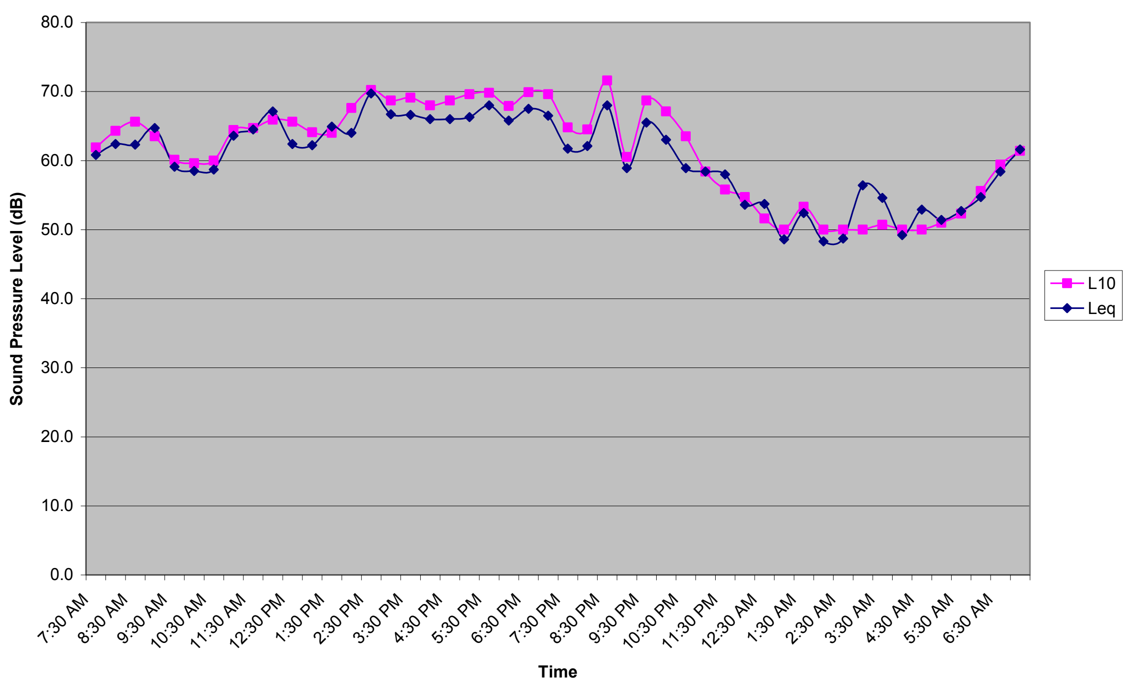

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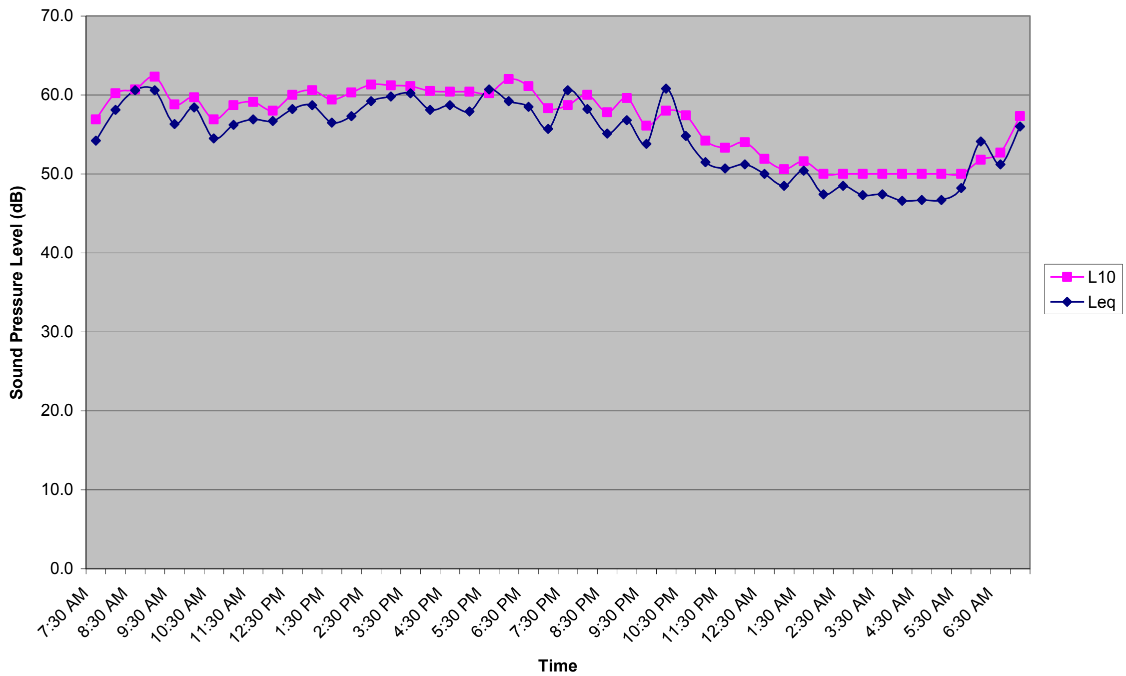

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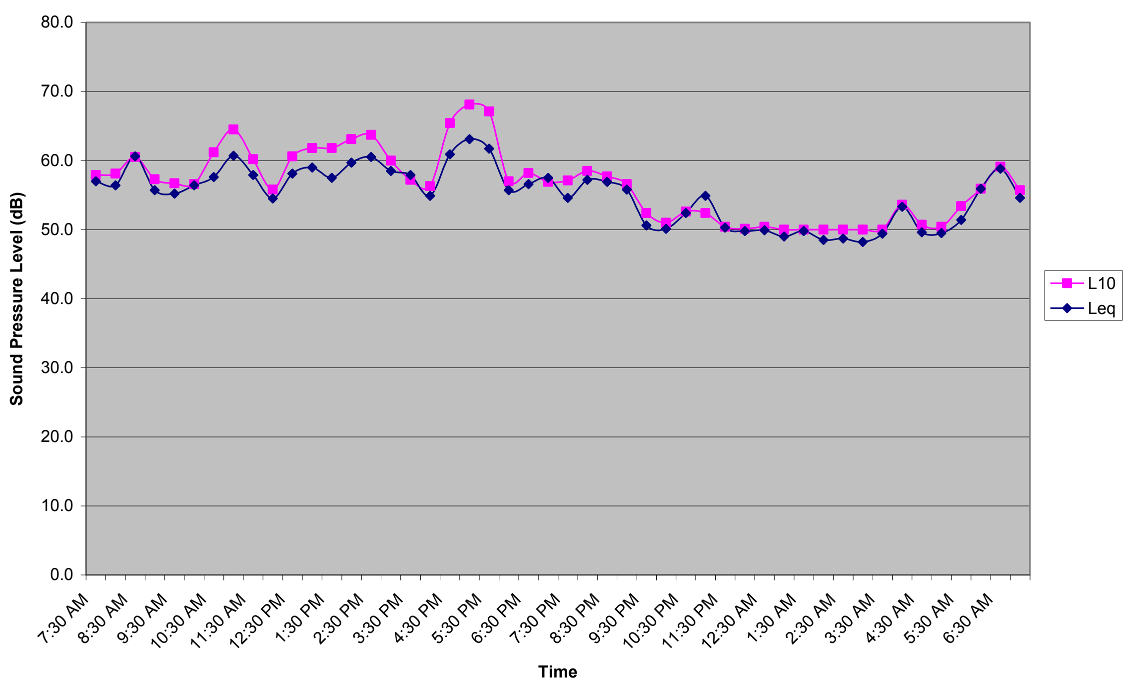

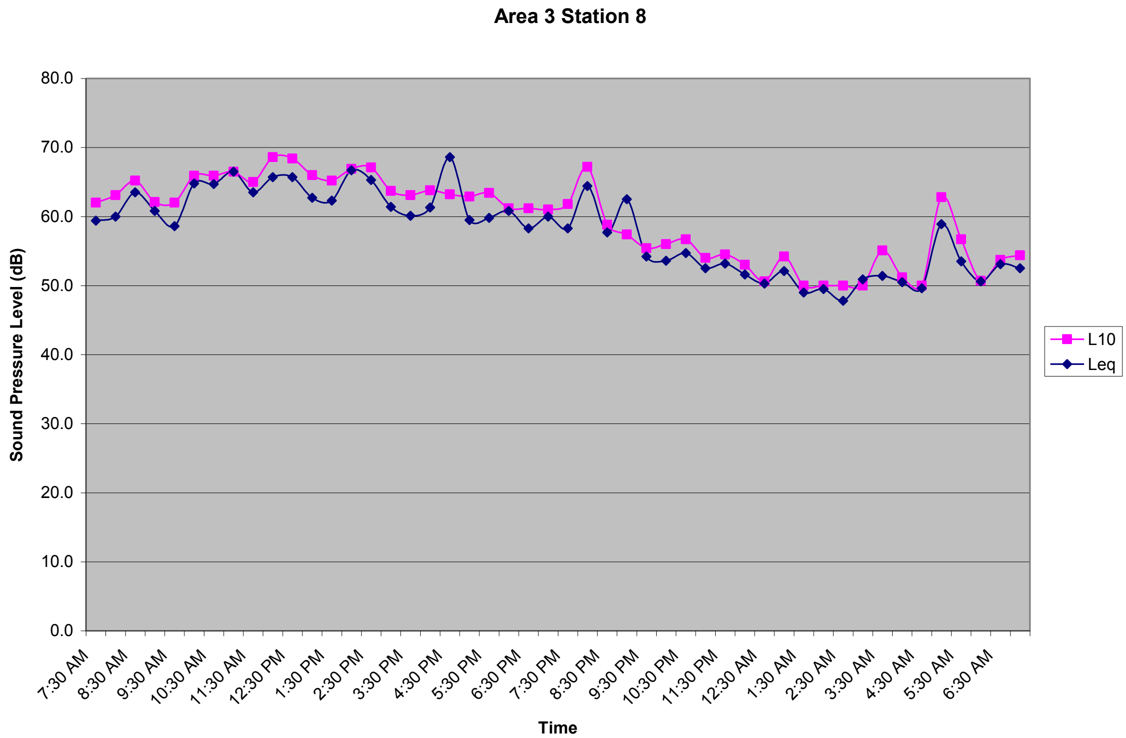
Area 3 Station 8
Sound Pressure Level (dB)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
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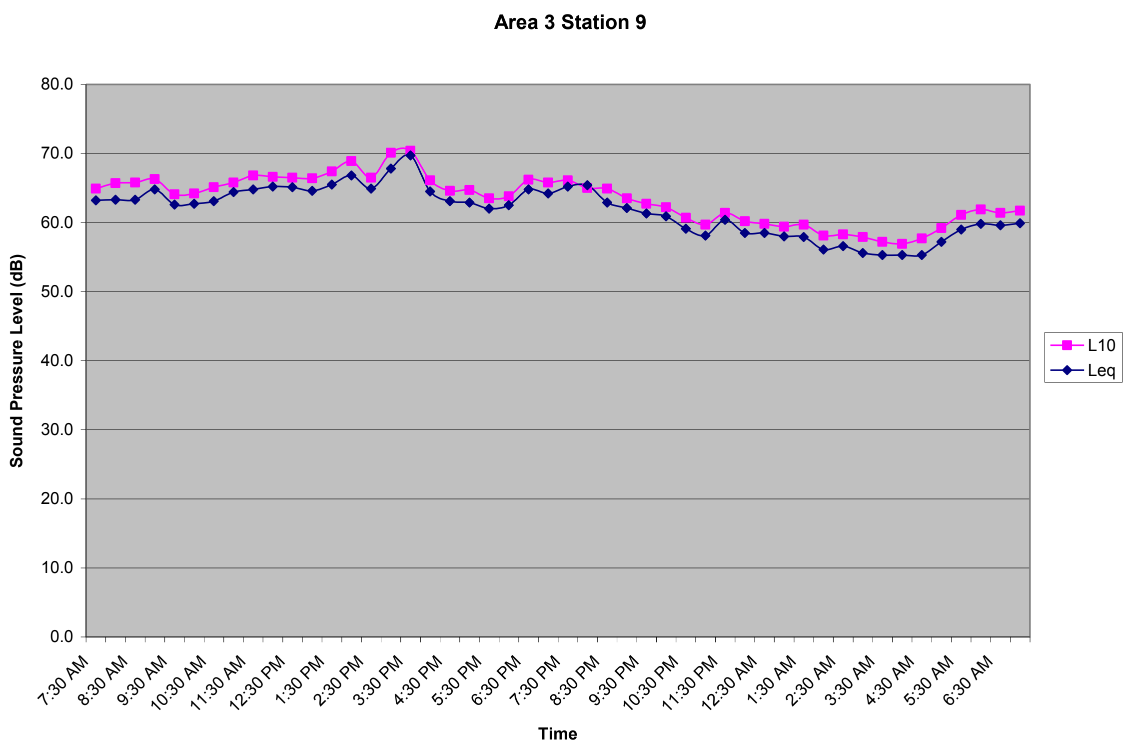
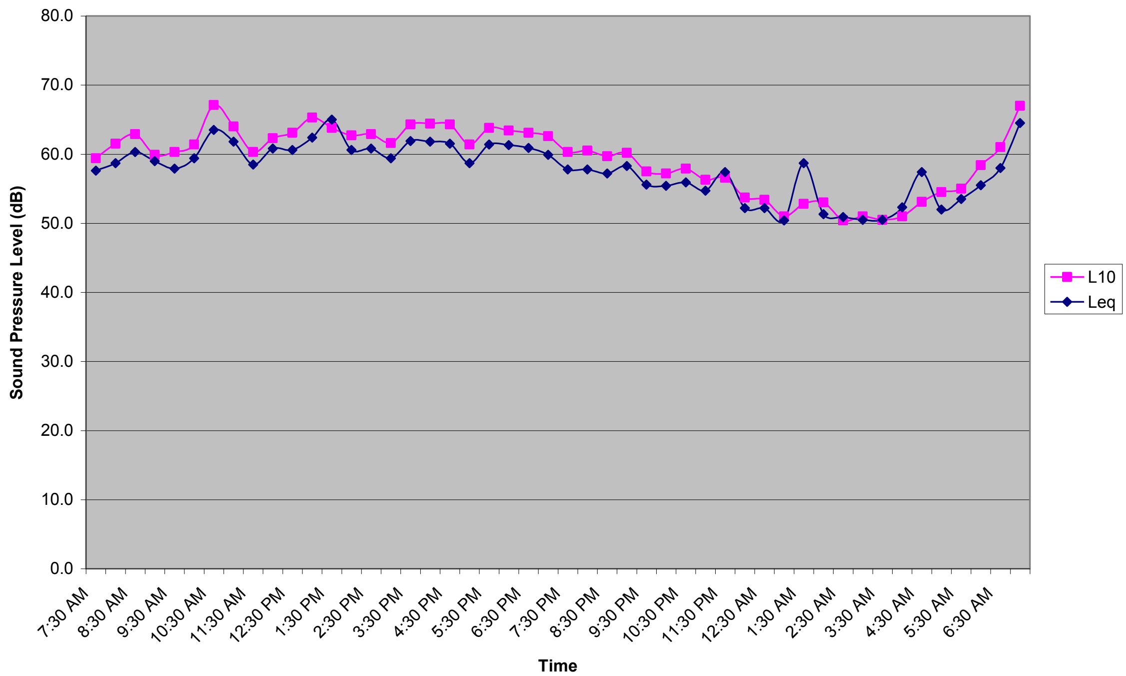
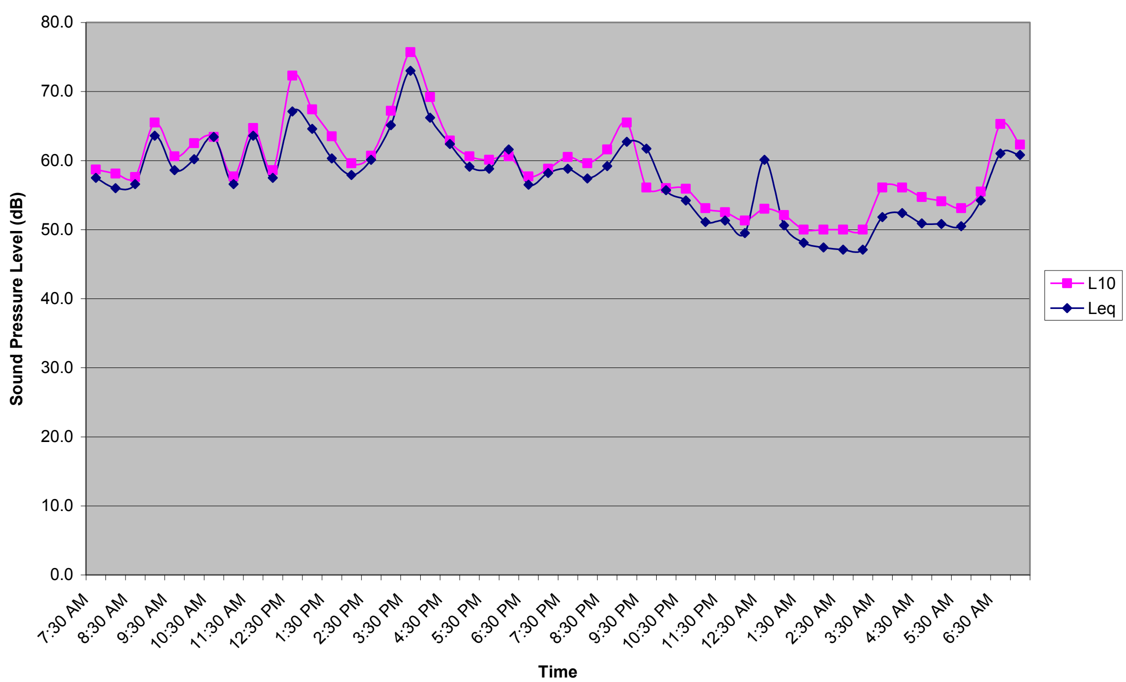
5:30 AM
6:30 AM
Time
L10
Leq

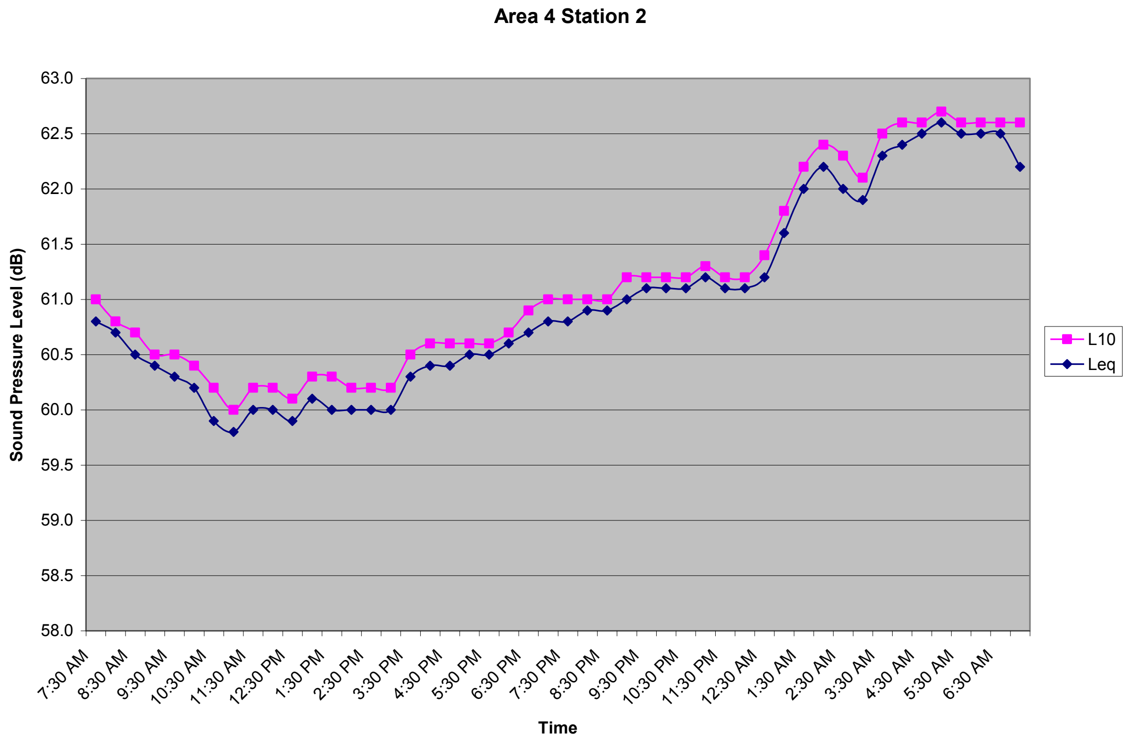

Area 3 Station 9
Sound Pressure Level (dB)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
12:30 AM
1:30 AM
2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq

Area 3 Station 10



Area 4 Station 1




Area 4 Station 2
Sound Pressure Level (dB)
63.0
62.5
62.0
61.5
61.0
60.5
60.0
59.5
59.0
58.5
58.0
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
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2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
Time
L10
Leq