Noise Data Farming for the City of Boston

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Abstract

This project, completed for the City of Boston's Air Pollution Control Commission, initiated a process for the “farming” of noise data contained in noise impact assessments for new projects and noise complaint investigations. We created a protocol for these data to be submitted electronically, organized in one database, and mapped in Geographical Information Systems. We developed recommendations for conducting noise impact assessments and methods for analyzing the noise map to gain a comprehensive understanding of the noise environment in the city.

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Executive Summary

Noise pollution can affect the quality of life through a variety of ways. One of the health side-effects can include increased stress, blood pressure, and even sleep deprivation. Today, with almost 80% of Americans living in an urban setting, controlling noise pollution is an even more pressing issue. The Boston Environment Department (BED) addresses various issues regarding the health of the city and its inhabitants. The Air Pollution Control Commission (APCC), a division of the BED, addresses issues concerning noise pollution. One such issue is the amount of noise various sources are outputting. These noise sources include large mechanical systems such as heating and cooling units, fans, and generators. The APCC has two methods for collecting the noise data for these sources. The first method is through noise impact assessments contained in Environmental Impact Reports (EIRs) written by consultants. The second method is investigating noise complaints.

Data Collection

EIRs are written for any major new construction project within the City of Boston. Within the noise impact assessment section, the consultants demonstrate that the new project, once it is complete, will be compliant with noise level regulations. The consultants accomplish this task by taking noise measurements at sound measurement locations (SMLs) before construction starts. They then predict what the noise level will be at each SML after the project is complete. This prediction is based upon the summation of the lab-tested sound power levels of each noise source to be included in the project.

Noise complaints and investigations can provide valuable information about problem areas in the city. Currently, when the noise inspector receives a noise complaint, he or she will go to the complainant's residence, and after taking several measurements, try to find the party responsible for the offensive noise. EIR data and noise investigations contain valuable information about the city and its current noise environment, however, this information is difficult to interpret and use because it is buried in reports. One major task of the project was to take various sources of data and visually display them in a manner that is easy for the user to understand.

EIR Measurements Compared to Field Data

We closely analyzed two pilot areas: the West End and the South End of Boston. We looked at 10 EIRs and 53 noise complaints from these pilot areas. We discovered a large variance amongst the methods used and the data provided in the noise impact assessments from our two pilot areas. This included differences between the duration of the measurements taken, the time of day the measurements were taken, the number of SMLs for each EIR, and the description of the location. By conducting field measurements in the West End, at the same locations as in the EIRs, our team was able to determine the accuracy and dependability of the EIRs.

1) Appropriate duration for a field measurement

By conducting 20-minute and hour long readings at different SMLs, we discovered that there was no significant difference between the two measurements and the 20 minute measurements that were conducted in the EIRs is a sufficient length of time for conducting field measurements.

2) Time of day for conducting a field measurement

By analyzing measurements taken over a 24 hour period at different SMLs from the Columbus Center project, we were able to determine the quietest times, and therefore the best times for conducting field measurement to prove a new project will not have an impact on the noise environment.

3) Usefulness of EIR predictions for representing the current ambient noise levels

We compared the measurements that we made in the field in 2007 to the day and night EIR predictions. The daytime predictions and measurements were very similar, with 82% of the ambient levels being within 5 dBA. A change of 4-5 dBA is just starting to be noticeable to the human ear, and so that was the limit that we set. We interpreted a change of more than 5 dBA to indicate a noticeable change in the noise environment. When viewing the data from night predictions and night field measurements, it was the opposite. With 70% of the field measurements having a difference of more than 5 dBA than the EIR night measurements it can be concluded that the mechanical systems of the new projects affect the ambient noise level at night more. This may be due to the fact that at night there is not as much traffic, people, or other noise to overpower the source's noise output. This is also an indication that the sources are not generating the same noise level that was stated in the EIR, as they claimed that the ambient level of noise would not be affected during the day or night.

Standards for EIR Methods and Procedures

By analyzing the EIRs from our two pilot areas and our field measurements, we have determined which methods and procedures are necessary for providing the APCC with an understanding of the noise environment before and after construction. To eliminate any discrepancies between reports, and to make it easier for the APCC to accurately assess the EIRs, we recommend a standard for the methods used in collecting and the data provided for noise impact assessments contained in EIRs. These standards are:

1) Measure noise levels at a minimum of four different locations
2) Provide the latitude and longitude of each location
3) Provide the conditions during each measurement
4) Take two measurements taken at each location; one for day and one for night
5) Compute the L_{10}, L_{50}, L_{90}, and L_{EQ}, and the L_{90} for each octave band
6) Take each measurement over a 20 minute duration.
7) Take measurements at the quietest time of the day and night.
8) Provide the sound power level of each predicted noise source
9) Compute the noise impact of the development at the measurement locations
10) Take into account the acoustical and mechanical conditions when computing the impact at the sound measurement locations

As previously stated, the APCC's other major task involves enforcing noise regulations through complaint investigation. One problem the APCC has is discovering who owns what piece of malfunctioning equipment. We tried to make this process easier by mapping the noise sources identified in the EIRs by parcel. This will allow the inspector, from his or her desk, to access all the sources in the area of the complaint, identify the owner, and call directly from the office. Additionally, we have mapped the origin of the complaints from the West End and the South End in MapInfo. However, to make this layer work, two new fields had to be added to the already existing complaint log. These fields were Latitude and Longitude. The latitude and longitude are used for the origin of the complaint and will display a red flag on the map. This map illustrates complaint density in the pilot areas and in the future may provide valuable insight regarding ideal locations for continuous noise meters.

Electronic Database and MapInfo

We developed a single database using Microsoft Access for both of the APCC noise sources. As mentioned above, the APCC already had a database for complaint data that only needed a few minor yet essential changes. We also developed two tables for the EIR data; one table for the SMLs that would include the daytime and nighttime measurements as well as the predicted impacts at each SML, and one for the noise sources that contained each source identified in the EIR and its sound power level. The SMLs were mapped using the latitude and longitude, just like the complaint data, and were displayed as colored dots. The color and size of the dot was determined by the L_{90}, and the source data was mapped by parcel. While EIRs generally display ambient noise levels, complaint data highlights trouble areas.

For the SML layer, we have three layers; one layer for day measurements, one layer for night measurements, and a third for predicted impacts. We also created a field measurement layer by utilizing the data obtained as a result of conducting a series of measurements in our West End pilot area.

We recommend that the APCC continue to use the processes that we have developed over the course of our project to populate their database and the multiple layers representing the noise environment. Over time, as the database and map expands, so will the APCC's understanding of the noise environment and its effects on the City of Boston and its residents.

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1. Introduction

Noise is a form of air pollution that can affect an individual's quality of life, especially if one lives in an urban setting. The United States already has a large percentage of its population living in urban areas and that number is expected to rise steadily. According to the World Resources Institute, 79.1% of the United States' population was living in an urban or suburban setting as of 2005. This percentage is expected to be over 85% by the year 2030. These statistics are relatively large when compared to other developed countries such as Japan, whose urban population was 65.7% as of 2005 and is expected to be 73.1% in 2030 (EarthTrends, 2007). Increased urbanization means more public transportation, more industries and factories, and of course more thickly settled residential areas with their own heating and cooling units, private vehicles, and home-maintenance equipment; these factors all have the potential to greatly increase the noise levels.

Noise pollution is a type of pollution that does not affect the environment as much as it affects the quality of life of the people living in these polluted areas. According to the British Medical Bulletin, noise pollution has been linked to poor reading comprehension and poor long-term memory in children. It has been noted as a cause for stress, and has even been linked to high blood pressure (Stansfeld & Matheson, 68). For these reasons, many urban areas including Boston have developed their own regulations for noise levels in their cities. Boston's residents are affected on a daily basis by noise pollution as they are exposed to noise from airplanes, construction, factories, traffic, and people. Boston is home to Logan International Airport, one of the top 20 busiest airports in the nation (Massport, 2007). In addition, Boston was the site for the Central Artery and Tunnel Project, also known as the Big Dig and one of the grandest scale construction project ever undertaken in the United States (Thalheimer, 2000).

With Boston residents experiencing so much noise from a variety of different sources, there are three separate organizations that regulate noise, each with its own jurisdiction depending on the noise source: The Air Pollution Control Commission (APCC), the Boston Police Department, and The Massachusetts Port Authority. The APCC is a division of the Boston Environment Department (BED) that is responsible for monitoring and enforcing the established noise regulations in Boston. The APCC has, in general, jurisdiction regarding environmental noise from construction sites, industrial sites, ventilation, and air-conditioning equipment.

The APCC responds to noise complaints and conducts investigations to determine if there is a violation of the city's noise regulations, which were established as a result of a noise study of the city of Boston made in the 1970's. The APCC must also review all Environmental Impact Reports (EIRs) for major projects. Each EIR measures the ambient noise levels before the project and makes estimates of the ambient noise levels after the project. As such, the Air Pollution Control Commission has two typical sources of noise data. The first is measurements taken to investigate violations or during enforcement actions. The second source of data is submitted by project proponents as part of their EIR.

Currently, the APCC cannot determine how sources of noise assessed in different EIRs from different projects interact and impact the overall level of ambient noise as well as the density of complaints in a particular area. Reviewing each EIR separately gives the APCC only a limited understanding of the ambient noise level at locations across the city of Boston. Farming the available noise data by creating a process for electronic submission and visualization of EIR measurements and predictions as well as complaints could allow for insight regarding the city's noise environment and its affects on the city's inhabitants.

Our mission was to initiate the farming and mapping of noise data the APCC currently receives by developing a protocol for the electronic submission of noise impact assessments contained in EIRs and complaint investigation information. By creating a process for these data to be organized in one database and to be visualized on maps, the APCC will have maps representing both the ambient noise levels in the city and the density of noise related complaints throughout the city. The database and maps will aid the APCC in developing a comprehensive understanding of noise conditions within the city.

2. Background

As the population and economy of a city grows, so do the noise; people and commerce bring their noise with them. The city of Boston is no different. From the Big Dig to the smaller construction projects in South Boston to the traffic and rail noise that is ubiquitous in a city, Boston has its fair share of noise problems. In this background chapter, we will first give an introduction to noise pollution in general and in Boston. Next we will describe how noise pollution is regulated from the federal to the municipal level. We will also discuss particular regulations regarding construction in Boston, followed by a review of the Air Pollution Control Commission (APCC) and the roles it plays in noise regulation and abatement. Finally, we will discuss the sources of noise data available to the APCC and the creation of a map to visualize these data. This section will talk about the potential benefits of a noise map, the advantage of using Geographic Information Systems (GIS), methods of noise mapping and ultimately how those methods might be applied for the City of Boston.

2.1 Noise Pollution and its Effects

Lewis' Dictionary of Occupational and Environmental Safety and Health defines noise pollution as "an amount of noise in the environment considered to be excessive by the majority of the population" (Vincoli, 2000). Given that the perception of noise is subjective, the effect it has on individuals varies from one person to the next. This section will qualitatively define noise and how individuals are impacted by it.

In order to control noise pollution, countries, states, cities, and neighborhoods have developed their own regulations and restrictions on the allowable noise levels. To define these regulations, it is important to establish standards on what makes noise intolerable. Factors that are important to take into consideration when setting standards are the time of day, type of area (i.e. residential or commercial), and noise level. The noise level or "loudness" is measured in decibels. Decibels are defined by a logarithmic scale, which is nonlinear. In terms of sound power, an increase of 3 dB means sound has twice as much power as before, an increase in 10 dB means that the sound has ten times as much power as before, and an increase in 60 dB means that the sound is a million times more powerful than before (Wolfe, 2006). In terms of sound pressure, which is how sound is perceived by the human ear, an increase of a sound by 3 dB means that the sound increase is barely noticeable, an increase of 10 dB means that the sound is twice as loud as it was before, and an increase in 20 dB means that the sound is four times as loud (Thalheimer, 2007). Depending on one's location, the noise level exposure can vary greatly. Ambient noise levels can reach a low of 30 dB in rural areas. Urban areas often reach high ambient levels of 70 dB, and it's not unusual for the noise level to reach maximum values of 90 to 100 dB (Liu, D. H. F & Roberts, 1999). Table 1 lists the noise levels that are emitted from various everyday sources.

Table 1: Noise Levels from Various Areas from the Environmental Engineer's Handbook

Noise Sources	**Noise Levels (dB)**
Industrial	
Near large gas regulator, as high as	150
Foundry shake-out floor, as high as	128
Automobile assembly line, as high as	125
Large cooling tower (600' listening distance)	120-130
Construction	
Bulldozer (10' listening distance)	90-105
Oxygen jet drill in quarry (20' listening distance)	128
Rock drill (jumbo)	122
Transportation	
Jet takeoff (100' listening distance)	130-140
Diesel Truck (200' listening distance)	85-110
Passenger Car (25' listening distance)	70-80
Subway (heard from in car or on platform), as high as	110
Community	
Heavy Traffic, business area, as high as	110
Pneumatic pavement-breaker (25' listening distance)	92-98
Power lawn mower (5'listening distance), as high as	95
Barking dog (250' listening distance), as high as	65
Household	
Hi-fi in living room, as high as	125
Kitchen blender	90-95
Electric shaver, in use	75-90

Loud noises can certainly be annoying, but frequency and uniformity also play a role in how irritating a sound can be. The human ear is more sensitive to the middle range of frequencies in the sound spectrum and we cannot perceive sounds of very high or very low frequencies. There is a scale called the A-scale that weights the frequencies accordingly to the sensitivity of the human ear. A-weighted decibel values are abbreviated dBA and most regulations are based on this scale. Noises that vary in loudness and/or frequency are referred to as being non-uniform. These non-uniform noises tend to be much more of a nuisance as the variations in loudness and frequency make the sounds more annoying and fatiguing than steady noises (Liu, D. H. F & Roberts, 1999). It is also important to note that to the human ear, short noise pulses do not sound as loud as continuous noises having the same sound pressure level. A short pulse with a sound pressure level of 155 to 160 dB seems only as loud as a continuous noise with a sound pressure level of 130 to 135 dB. (Liu, D. H. F & Roberts, 1999). While brief noises may not seem as loud as continuous noises, a momentary pressure of 160dB is dangerously near the level at which eardrum rupture or middle ear damage can occur. The following paragraphs describe health effects of noise in greater detail.

Being exposed to loud and harmful sounds can cause damage to the sensitive hair cells of the inner ear and the hearing nerve (Liu, D. H. F & Roberts, 1999). These structures can be injured by two kinds of noise: loud impulse noise, such as an explosion, or loud continuous noise, such as that generated in a woodworking shop (NIDCD, 2002). Two injuries associated with noise exposure are Noise Induced Hearing Loss (NIHL) and acoustic trauma. NIHL is generally progressive as it is caused by exposure to the continuous type of noise over a long period of time, whereas acoustic trauma results in immediate hearing loss as it is generally caused by exposure to the impulse type of noise (Vincoli, 2000). Over 30 million Americans are exposed to hazardous sound levels on a regular basis, resulting in NIHL being one of the most common occupational related illnesses (Safety and health topics: Noise and hearing conservation, 2005).

While there are many noises that are not loud enough to cause us any physical harm, noises can certainly be a nuisance and interfere with our daily lives. Annoyance is a common response to undesired noises. The level of annoyance a listener experiences depends on many factors such as the characteristic of the noise, the source of the noise, the state of the mind of the listener, the surroundings of the listener, and even possible implications of the noise. For example, a sound heard at night can be more annoying than one heard by day, just as one that fluctuates can be more annoying than one that does not. Sounds that resemble other unpleasant sounds and are perhaps threatening can be especially annoying. A sound that is mindlessly inflicted and will not be removed soon can be more annoying than one that is temporarily and regretfully inflicted. Sounds with a visible source can be more annoying than sounds with invisible sources. A sound that is locally a political issue can have a particularly high or low annoyance (Liu, D. H. F & Roberts, 1999).

Sleep interference is one particular category of annoyance that results from noises. For someone who is in a light sleep, a sound that is 30-40 dB above the level of what they detect when they are awake can wake them up from their sleep (Liu, D. H. F & Roberts, 1999).

Depending on the level of annoyance, noises can prevent one from falling back asleep. While it is possible to become used to a sound and sleep through it, and some sounds even help induce sleep, generally the more unfamiliar a sound is, the more it can interfere with one's sleep (Liu, D. H. F & Roberts, 1999).

In addition to affecting one's sleep at night, noise can have an effect on one's performance during the day. Many tasks may require using auditory signals, either speech or non-speech. Noise loud enough to interfere with the perception of these auditory signals can certainly impede the performance of these tasks (Liu, D. H. F & Roberts, 1999). It is much more difficult to assess the effects of noise on tasks that require the use of one's mental or motor skills. Noise doesn't necessarily influence the overall rate of work, but high levels of noise can increase the variability of the rate of work (Liu, D. H. F & Roberts, 1999). For instance, noise from a stereo might increase the productivity of some workers if they perceive that noise as pleasant while it might slow others down who do not appreciate the noise as much.

Sound can have a negative effect on the body when it excites a fear reflex. Our fear reflex serves the purpose of heeding a warning of danger. If a noise excites the fear reflex in the event when there is no danger, it can cause physiological harm (Liu, D. H. F & Roberts, 1999).

2.2 Noise Regulations

While noise may be one of the lesser recognized pollutants by the public, it is regulated by the local and federal governments. The negative effect noise has on people's quality of life creates a need for regulation.

Only certain aspects of noise pollution are regulated by the federal government. The first area is occupational noise pollution, or noise that threatens the health and safety of workers. The U.S. Department of Labors' Occupational Safety and Health Administration (OSHA) is the agency that deals with regulations associated with occupational noise pollution (U.S Department of Labor; Occupational Safety & Health Administration, 2007). The Environmental Protection Agency writes and enforces regulations dealing with vehicular noise. This type of noise pollution is regulated by a federal agency because of the fact that state lines do not bound motor vehicles.

The Air Pollution Control Commission has regulations for noise levels within the city.

Boston has different noise regulations for each zoning district: residential, residential/industrial, and business. These regulations were developed as a result of a study of the noise environment in Boston conducted in 1971 by Bolt, Beranek, and Newman Inc. Bolt, Beranek, and Newman Inc. conducted surveys to determine how the public felt about Boston's noise environment in addition to taking measurements of noise levels around the city. Based on their findings, the city developed regulations for each zoning district. Table 2 shows acceptable decibel levels for the different zones.

Table 2: Acceptable decibel levels in Boston

TABLE OF ZONING DISTRICT NOISE STANDARDS

Maximum Allowable Octave Band Sound Pressure Levels

Octave Band Center Frequency of Measurement	Residential		Residential / Industrial		Business	Industrial
(Hz)	Daytime	All Other Times	Daytime	All Other Times	Anytime	Anytime
31.5	76	68	79	72	79	83
63	75	67	78	71	78	82
125	69	61	73	65	73	77
250	62	52	68	57	68	73
500	56	46	62	51	62	67
1000	50	40	56	45	56	61
2000	45	33	51	39	51	57
4000	40	28	47	34	47	53
8000	38	26	44	32	44	50
Single Number Equivalent	60 dBA	50 dBA	65 dBA	55 dBA	65 dBA	70 dBA

The regulation for noise during the day in a residential area is 60 dBA and is 50 dBA at night. This means that the noise during the day can actually be twice as loud as the noise at night in a residential area of Boston. In addition to the specific decibel levels specified above, the law also defines noise pollution as anything loud enough to cause a nuisance, be injurious to human or animal life, and to "unreasonably interfere with the comfortable enjoyment of life and property or the conduct of business" (Boston Environment Department, 2007).

Regulating noise, especially construction noise, is an ongoing issue for Boston's government. With all of the attention Boston received from the Big Dig and its many implications including an increase in construction noise, Boston developed several noise mitigation policies to limit the noise pollution and avoid negative political attention. Erich Thalheimer, the Big Dig's noise control manager commented to the Boston Globe, "This project is fully committed to dealing with noise" as they spent over $4 million on noise curtains, only used jackhammers during the day, disabled the alarms from trucks backing up, and did their night construction in mostly commercial areas (Palmer, 1996).

Even though the Big Dig is coming to an end, construction noise is still an issue in Boston. This is especially true for residents in South Boston where it is expected that over 5,500 condominiums will be built over the next couple of years (McConville, 2006). While there are still regulations for construction noise regulated by the Boston Environment Department, these smaller projects are not looked upon with nearly as much scrutiny as the Big Dig. Christine McConville of the Boston Globe comments, “Morning, noon, and night, on workdays, holidays, and weekends, the whir and grind of buzz saws echo through South Boston” (McConville, 2006).

It is important to note that whether it is a small renovation, or the largest project undertaken in the country, noise from construction affects people on a daily basis. It is important that all projects, (big or small) are monitored so that their noise levels can be managed to avoid lowering the quality of life of the neighboring inhabitants.

2.3 Noise Data Collected By the Air Pollution Control Commission

Much of the noise data that the APCC has comes from the noise impact assessments contained in Environment Impact Reports (EIRs), which are submitted for major construction projects. These assessments involve measuring the existing ambient noise level in the area and estimating the noise levels that the project will generate once it is completed. The consulting firms who submit the EIRs for the contractors of a major project conduct their noise analysis by determining the ambient level of noise at several locations in the immediate vicinity of the project as well as the surrounding neighborhoods. The sites, called sound measurement locations or SMLs, are chosen to gauge the ambient noise level in the immediate area or residential areas close to a project that is planned for an industrial area. This is done to ensure that noise that reaches these areas does not violate the stricter regulations for residential areas. Two series of measurements are taken at each SML over a 20 minute duration, one during the night and one during the day (Charles River Limited Partnership, 2001).

The metrics that noise engineers use to describe the noise at each SML are the L_{10}, L_{50}, L_{90}, $L_{eq,}$ in dBA and the L_{90} for each octave band. L_{10}, L_{50}, L_{90} are exceedance levels. An exceedance level Ln is the level of noise that n percent of the measurements are at or above. For example, to the find the $L_{10,}$ one looks at the highest 10% of the measurements and finds the lowest measurement from within the highest 10%. The lowest measurement from the highest

50% is the $L_{50,}$ and the lowest measurement from the highest 90% of measurements is the $L_{90.}$ The L_{10} is usually determined by occasional louder noises such as motor vehicles passing or planes overhead. L_{90} is minimally affected by intrusive noise sources, making L_{90} the ideal metric for describing the ambient noise level. (Thalheimer, 2007)

Another noise metric is the $L_{EQ,}$ which is the level of hypothetical steady sound that would have the same energy as the fluctuating noise levels recorded. Even though the L_{EQ} is a time average of the measured decibel levels, decibels are on a logarithmic scale and the average is computed using a linear mean, therefore the L_{EQ} is largely determined by the occasional loud, intrusive noises. This is why the L_{EQ} is not regarded as the best choice for the representation of the ambient noise levels when compared to the L_{90}.

All of the noise metrics can be reported in dBA, which, as mentioned above, weights the frequencies to which the human an ear is more sensitive. These noise metrics can also be provided for each octave band, which specifies the decibel level of each frequency.

In Environmental Impact Reports, the consultants also identify the sources of noise that will be part of the completed project, such as generators and Heating Ventilation and Air Conditions (HVAC) units. They determine what levels of noise these sources will generate and what impact they will have on the ambient noise levels at the SMLs. The consultants compare the projected impact at each SML with the current data they already have to ensure that the project will not increase the level of ambient noise in the vicinity or violate the regulations for daytime and nighttime noise levels. There is little if any discussion of mitigation measurements due to the fact that most reports state that the project will not result in a violation of noise levels.

The other form of noise data that the APCC has is data from complaints and complaint investigations. These data can be found in three forms. First, when a complaint is called in, it is logged by the inspector in a database. This database contains information regarding the name and address of the complainant, the location name and address of the alleged violation, a brief description, and any follow-up that was made (including measurements made if there is a violation). As the inspector handles these complaints on a case by case basis, she will generally contact the owner of the noise source and request that the issue be resolved. If the issue still isn't resolved, such as in the event that the source is unknown, the inspector will take much more extensive measurements by measuring each octave band. These measurements are the second form of complaint data. In some cases, the APCC may suggest that the owner of the source hire a contractor to take measurements and determine the cause of the noise and a solution to the problem. The measurements taken by the contractors are the third form of noise data.

2.4 Noise Mapping with Global Information System

APCC has useful data on noise pollution; however this information is fragmented and difficult to access. Each EIR is in a hardcopy form and is buried in one of the shelves in the APCC's library. Looking at each measurement or EIR separately only yields information about a single source or a single location. The APCC cannot determine how separate sources of noise interact and impact the overall level of noise. The APCC could try to look at multiple locations and noise interactions by digging out several reports, but it is impractical. By synthesizing all the data into one cohesive database or noise map, the APCC will gain a better understanding of the ambient noise level and noise pollution at locations all over Boston.

A noise map will provide useful information to the APCC and be a useful tool for its noise abatement activities, such as reviewing EIRs and investigating noise violations. A noise map may aid legislators in determining whether stricter noise regulations or ordinances are appropriate for areas particularly affected by noise pollution. A noise map could also prompt the APCC to propose measures to reduce noise pollution or noise annoyance, such as insulating the doors and windows of affected homes, schools, or building a sound wall. A noise map may yield useful information for a cost-benefit analysis on those measures or provide a way to check whether those measures have been as effective as desired. A noise map could also be helpful to people who are living or planning to live in Boston; the map can assist them in deciding where to live if they are particularly sensitive to noise.

Using Geographic Information Systems (GIS) is a way of capturing and managing all forms of data that are geographically referenced. Information can be organized by exact position on earth and then analyzed and viewed accordingly. This software is a crucial part of the creation of Boston's noise map. Because of the geo-referencing of all elements of data within GIS, the data in the map will be more useful to officials who are analyzing the map (European Commission Working Group Assessment of Exposure to Noise, 2006). GIS can be interfaced with other noise-mapping software to provide a fast and accurate assessment of the environmental impact of noise. Also, GIS is an effective medium for a noise map as information and images in GIS can be displayed on an internet web-page for presenting data to the public.

GIS has been used for noise maps and related tasks many times before, in fact, software packages have already been developed, such as TNoiseGIS, which is used for the calculation and visualization of traffic noise (Pamanikabud & Tansatcha, 2003).

There are two widely used methods for mapping noise. The first method is the simplest and most straight forward: it involves interfacing a sound measuring device such as a microphone or a decibel meter with a GPS device. Measurements taken from both these devices are simultaneously uploaded to a database, which then exports the data to a noise-mapping program (Cho & Kim, 2006). These data are then exported to GIS to process the final map. Although this method has been used before, it was limited to small areas. For instance, it was used to map noise in a 3x4 km area in Sanliurfa, Turkey (Yilmaz & Hocanli, 2006). Critics of this method point out that it would be expensive to place the devices over a large area and the accuracy of the map would be compromised if any of the devices were improperly placed, tampered with, or simply malfunctioned.

The second method is much more involved. It relies on collecting data on the sources of noise and acoustical data on each location in the map. These data are used to calculate a noise estimate which is then represented on a map. The accuracy of the estimate depends on the accuracy of all the measurements and data obtained. The final calculation is only as accurate as the least accurate datum used, so effort spent obtaining very accurate measurements of one aspect are wasted if the same accuracy cannot be obtained for all measurements. This method is more useful when trying to calculate precise noise data in a specific area and is overly complex for viewing general conditions. This is the method used by the European Union's IMAGINE (Improved Methods for the Assessment of Generic Impacts on the Noise Environment) and HARMINOISE (Harmonized Accurate and Reliable Methods for the EU directives on the Assessment and Management of Environmental Noise) projects. These projects aim to map the traffic, railway, airline and industrial noise in European cities.

The data contained in EIRs lends themselves to a method that is similar to method one. This seems like a good starting point for creating a noise map for Boston. In addition, if the data extracted from new EIRs is factored into the map, it would help to update and sustain the map. This way the City of Boston could farm data from new EIRS as opposed to investing time and money for its own studies. Measurements taken by the APCC to investigate alleged violations may be able to support a map based on method one as well. Using both of these data sources, our team set out to begin the construction of a noise map that the APCC will be able to maintain long-term.

3. Methodology

Our mission was to initiate the farming and mapping of noise data the Air Pollution Control Commission (APCC) currently receives by developing a protocol for the electronic submission of noise impact assessments contained in Environmental Impact Reports (EIRs) and complaint investigation information. By our team creating a process for these data to be viewed on maps, the APCC will gain a visualization of the ambient noise levels, the density of noise related complaints, and the sources of noise throughout the city as the database continues to populate. These tools are intended to help the APCC in developing a comprehensive understanding of noise conditions within the city.

In this chapter we will describe in detail the steps that we took in order to meet our goal. Our objectives included identifying existing noise data for pilot areas, conducting field measurements in the pilot areas, comparing the field measurements with EIR data, creating a database for the organization of noise data, and making recommendations for policy and process.

Objective 1: Identifying Existing Noise Data for Pilot Areas

Mapping the data for the entire city of Boston was beyond the scope of our seven week project. Instead we decided to analyze existing noise data from two pilot areas and take our own measurements out in the field to develop a feasible process for analyzing and mapping the data. The most important criterion for selecting the locations of these pilot areas was the availability of current noise data that the APCC has in their records; this noise data was found in both Environmental Impact Reports (EIRs) and records of measurements obtained in the course of enforcement actions.

The first pilot area was Boston's West End. The West End is a mixed-use commercial and residential area. The Massachusetts General Hospital, Government Center, and the TD Banknorth Garden are all notable landmarks of the West End. Construction and new development are common in this area. The director of the APCC recommended the West End because, as a mixed-use area and a frequent site of new development, this area has a significant amount of noise data associated with it.

Our group used data from four EIRs related to projects within the West End: the new ambulatory building for Massachusetts General Hospital (MGH), the Charles River Plaza, the West End at Emerson Place, and the Nashua Street Residences. Since all of the EIRs for the

West End were submitted within the past six years by Epsilon consultants, the methods used for obtaining noise measurements and estimates of noise were consistent.

The APCC also had data from thirteen noise complaints within the West End. The data contained the names and locations of both the complainant and the alleged violator in addition to any follow up that was made including noise measurements made by the inspector.

The second pilot area, which was also recommended by the director of the APCC, is the South End. The South End is one of Boston's major restaurant districts, making it a popular destination for both Bostonians and tourists. The South End is home to the Boston Ballet, the Boston Center for the Arts, Boston University Medical Center, and many art galleries and artists' studios.

This neighborhood was chosen because there have been a great deal of construction projects over the past decade and there is more development expected to take place in this area in the near future. The team used noise data from six EIRs for projects in the South End: Boston's Center for the Arts, The Dover Residences, Biosquare Phase II, Wilkes Passage Lofts, The Columbus Avenue Residences, and South End Place on Washington St. There were also approximately forty noise related complaints for the South End contained in the APCC's complaint log.

Objective 2: Conducting Field Measurements in Pilot Areas

Unlike the noise data in the EIRs for the West End, the South End had noise data that was inconsistently measured and estimated and didn't provide details of the exact measurement locations. The South End was not ideal for taking measurements in the field due to the fact that it is essential to know the exact location of sound measurement locations in order to make a comparison. Field measurements were therefore taken in the West End in the same locations as the SMLs contained in the EIRs.

There were two major reasons for us to take our own field measurements. The first was to compare the team's field measurements made in 2007 to the EIR data noise data taken between 2001 and 2004. This was to provide the APCC with a view of the changing noise environment and to determine the feasibility of using the EIR data for starting the map of the current ambient noise levels. The second reason for taking our own sound level measurements was to obtain an in depth view into the process used by EIR consulting companies for obtaining noise data out in the field and determine appropriate practices. This gave us information and evidence which was used to provide recommendations for improving the current process used by both the consultants as well as the APCC.

When taking field measurements we used a Quest model 2800 Integrating Sound Level Meter. The meter displays Sound Pressure Level, Max Level, Min Level, Sound Equivalency Level (SEL), Run Time, and L_{EQ}. The printout from the device can be captured on a computer using the program HyperTerminal (see appendix E for tutorial). The printout provides all viewable data including parameters such as the weighting scale and response time and a complete chart of exceedance levels from L_1 to L_{99}. The meter was mounted on a tripod as a means of keeping testing condition the same at all 17 measurement locations. A wind screen was used on the microphone to alleviate any interference from wind.

For our first field measurement objective of determining the feasibility of using the EIR data for starting the map of the current ambient noise levels, we attempted to limit the variability between the measurements made for the EIRs and the measurements made by the team. There are many variables that need to be accounted for when taking readings such as the time of day, day of the week, and season of the year that the measurements were taken, measurement location, wind speed, reading duration and even road conditions. All readings made by the team were taken during normal business days, around 12pm and 12am, on days when wind speed was measured at comparable levels (5-10 miles per hour maximum), and when road conditions were dry as stated in the reports. The readings were taken at all 17 SMLs for durations of 20 minutes.

For our second field measurement objective of obtaining an in depth view into the process used by EIR consulting companies for obtaining noise data out in the field and determine appropriate practices, some additional readings were required. To determine whether 20 minute readings are too easily influenced by short-term, loud events we took hour long readings and compared the L_{90} of the first 20 minutes with the L_{90} of the whole hour. We took these readings around noontime at the first and fourth sound measurement location in the Massachusetts General Hospital's New Ambulatory Wing EIR.

Objective 3: Comparing Field Measurements to Environmental Impact Reports

Our goal in comparing the EIR data to our own measurements was to gauge how much the ambient noise levels had changed since the EIR measurements were taken. To gain knowledge on how to compare noise data, we spoke with Erich Thalheimer, an acoustic engineer who worked on noise mitigation for the Big Dig in Boston. We learned that humans can recognize a change in the noise environment if it increases or decreases by 3 decibels or more; a change of 5 decibels or more is considered a noticeable difference. Therefore, for the purpose of our analysis, we decided that noise measurements within 3 dBA of the original noise measurement can be considered to be the same noise environment. Noise measurements with a change of 4 or 5 dBA from the original noise measurement can be considered to have a slight change in the noise environment. Noise measurements that differed from the EIR measurements by more than five decibels were then considered to indicate a significant change in the noise environment.

We compared the L_{10}, L_{50}, L_{90}, and L_{EQ} measurements for both day and night for all of the SMLs in our EIRs for the West End. We determined the percentage of measurements that could be considered the same or a slight change in the noise environment. In turn, we also found where the noise environments had changed. Both measurements that were the same and measurements that were different gave sufficient insight into the way the sound changes in the city of Boston.

<u>Objective 4: Creating a Database for the Organization of Noise Data</u>

Prior to our project, the APCC had all the EIR noise data in hardcopy forms. There was no database to organize and view the data. The APCC’s complaint log did contain some noise data organized electronically, but only for a small percentage of noise related complaints. There was also no database for organizing any extensive field measurements made by the APCC in the course of investigations. We decided to organize our database into four sub databases: complaints, EIR measurements and predictions, sources, and field measurements. In the following section, we will describe in detail the organization and execution of each sub database in Microsoft Access.

Complaint Data

The APCC’s complaint database is used by the inspector for all air-quality related complaints including idling from cars and dust and debris from construction sites. This database is a useful tool for the APCC and we wanted to modify it as little as possible. By including the option of entering longitude and latitude of the complaint's location and the parcel number of the source of the violation, we were able to visualize complaint density for our two pilot areas on a map in Geographical Information Systems (GIS). We added this option of entering latitude, longitude, and parcel numbers by simply adding these extra columns to the table of complaints. We then modified the APCC's form used to enter and view data in the database to include these text boxes.

Environmental Impact Report Measurements and Predictions

We wanted to create a database that would accommodate manual entry of data that is contained in existing EIRs and electronic entry of data contained in EIRs that will be submitted in the future. By analyzing existing EIRs, we were able to create a table of noise metrics and measurement conditions that appear to be common in approximately 80% of the reports. This table includes fields for entering all day and night conditions, wind speed, wind direction, L_{10} dBA, L_{50} dBA, L_{90} dBA, L_{EQ} dBA, and L_{90} octave band measurements at each SML in addition to projections of L_{90} dBA and L_{90} octave band measurements at each SML after completion of the project. We also added columns for the latitude and longitude of each SML, which is not common in EIR reports, but aided in mapping the data in GIS. To view all of the data for each SML in a manner that would be easier to follow than reading across a table with over fifty columns, we created a form that has tabs for day measurements, night measurements, and predictions. For the electronic submission of these data, the consultants who produce the data have the option of filling out one form for each SML, or they can fill out one row for each SML in a spreadsheet following the same format of our existing table; either way allows for the data to be easily appended as it is sent in.

Noise Sources

A database of projected noise sources described in EIRs will be helpful for the inspector of the APCC in the course of investigating noise complaints. Each project generally includes around six noise sources that could potentially have an impact on the noise environment including chillers, air handling units, cooling towers, generators, exhaust fans, and more. Most of the EIRs contain the projected L_{90} dBA and L_{90} octave band measurements in addition to the parcel ID for each source. We created this database by composing a table that contained all of the above data for each source. We also created a form containing all of the same fields. The consultants who submit EIRs have the option to fill out one form for each source, or fill out a row for each source on a spreadsheet that follows the exact same format as our existing table.

Field Measurements

Now that the APCC has the ability to download data from the Quest sound level meter to a computer in the form of a text file, we believed that it would be beneficial to have a database to organize these files. We took advantage of this database that we created in order to organize our own field measurements. To create this database, we created a table that included columns for the latitude and longitude of the location of the measurement in addition to columns for entering descriptions of conditions and pasting in the text file that the Quest meter produces. We created a form that included all of these fields that can be used for entering and viewing the data.

To connect all four of these sub databases and make one large database for viewing all noise data, we created a switchboard that allows a user to switch from one form to the next in order to view and enter new data. By importing the four tables into MapInfo and using the latitude and longitude or parcel number of the data points, we mapped data points onto a base layer of the City of Boston. The map has the following six layers for noise data: day measurements, night measurements, noise predictions, source data, field measurements, and complaint density.

Objective 5: Making Recommendations for Policy and Process

Through analyzing EIRs in both the West End and South End and conducting our own measurements, we gained a great deal of insight regarding methods for obtaining and organizing noise data. We also spoke with Carl Spector, director of the APCC, and Erich Thalheimer, a noise mitigation engineer, to determine what noise data are essential for describing the noise environment and what, in their opinion, is the best method for taking and reporting measurements. Based upon a comparison of the L_{10}, L_{50}, L_{90}, and L_{EQ} measurements obtained from the first 20 minutes of our one hour readings to the L_{10}, L_{50}, L_{90}, and L_{EQ} measurements obtained from the entire one hour reading, we determined what length of time is sufficient for determining the ambient noise level so that it is unlikely to be overly influenced by short-term loud events. We also analyzed the EIR measurements to determine how the ambient noise levels fluctuated throughout the 24 hours of a typical day. We made recommendations on the length of measurement and the time of day the measurement should be taken based upon our findings.

We also considered ways in which the city of Boston's noise regulations could be updated. We looked at EIRs from both the West End and the South End to determine the current standard for measuring the ambient noise level. Based on this and the opinion of noise experts like Erich Thalheimer, we considered how the regulations could specify "ambient noise" in terms of specific noise metrics such as L_{90} and L_{EQ}. In addition, we considered how noise measurement technology has improved since the regulations were written and whether that might warrant updating the regulations.

4. Results and Analysis

There were three different areas of our project that yielded results for analysis. The first area for analysis is the comparison between the contents of different Environment Impact Reports (EIRs). Analyzing EIRs provided us with insight into the EIR process and the differences and commonalities that exist between each report from projects in the West End and the South End. It also provided us with insight on how the noise levels fluctuated throughout the day. The second is our field measurements. The field measurements were conducted to provide a comprehensive view of the current noise conditions in the West End and to provide insight on how duration affects measurements. The final area for analysis is the Geographic Information Systems (GIS) mapping that was done of the given data. Mapping information gives a good visualization of data and the trends that emerge.

4.1 Analysis of Content in Environmental Impact Reports

We compared the similarities and differences between the methods used and data provided in all of the EIRs from our two pilot areas: the West End and the South End. We analyzed four EIRs from the West End, one from 2004, one from 2003, and two from 2001. All of these reports were submitted by the consulting company Epsilon. We also analyzed six EIRs from the South End; the earliest was from 1998 and the latest was from 2004. Four of these reports were submitted by the Daylor Consulting Group, one was submitted by Epsilon, and one was from Fort Point Associates. The following sections will discuss the commonalities between EIRs from projects in West End, the differences between EIRs from projects in the South End, and common differences between EIRs from the West End versus EIRs from the South End. We also analyzed how the ambient noise levels changed over the course of a typical day by studying measurements in the Columbus Center EIR, which was submitted in 2002 by Epsilon.

4.1.1 West End Environmental Impact Reports

The format for the ambient noise data was very similar for each of the West End EIRs. Each had four SMLs except for the Charles River Plaza report, which had five. Each report had both day and night measurements for each SML; measurements were taken at roughly noon and midnight, and the measurement periods were 20 minutes. The measurements for each report included the $L_{10,}$ L_{50}, and L_{90} in dBA. All but one report had L_{EQ} in dBA and L_{90} for each octave band. Each report contained a detailed description of the weather, traffic, and wind conditions during the reading. All of these factors can have an effect on the measurements, so it is important to include them in the report. Additionally, each report specified on a map or satellite picture the exact location of each SML.

The data for the predicted noise impacts of these projects were also very similar. Each report contained a list of noise sources and either the sound power level or the sound pressure level for each source. The sound power level of a noise source does not vary with distance from the source, but the sound pressure level does. The reference distance was specified if the sound pressure level was used. It was difficult to compare sound pressure levels because often times a different reference distance was given for each piece of equipment. For example, the EIR for the Massachusetts General Hospital (MGH) New Ambulatory Building gave the sound pressure level for a set of garage fans and a cooling tower as 90 dBA and 78 dBA respectively, which would cause one to think that garage fans would contribute more to the ambient noise. However, reference given for the garage fans was only 5ft, while the reference given for the cooling tower was 50ft. Each report also specified the predicted L_{90} in dBA at each SML, and three include the predicted L_{90} for each octave band.

4.1.2 South End Environmental Impact Reports

The format for the ambient noise data contained within the EIRs for the South End was much more varied. The number of SMLs varied from one (as seen in Wilkes Passage Lofts and South End Place Washington Street EIRs) to four (as seen in Boston Center for the Arts EIR). In general, the noise metrics were similar to the West End EIRs, and every report contained measurements of the L_{90}. However, the time that the measurements were taken at and the duration of the measurement varied greatly. One EIR had two 20 minute measurements for day and night, but others had measurements that were an hour or longer, and were also taken during peak traffic hours. Measurements taken at these times could easily be influenced by the noise from traffic. Also, the conditions during the measurement were not always noted in great detail.

4.1.3 Comparison of West End EIRs and South End EIRs

One significant difference between the South End EIRs and the West End EIRs is that only half of the reports in the South End had a map that showed exactly where each SML was.

The others contained just brief descriptions of the location. It is essential to know the exact location a measurement was taken because noise levels can vary over a short distance. For instance, two measurements for the EIRs in the West End, SML 1 from Massachusetts General Hospital and SML 3 from Charles River Plaza, were taken roughly a block away from each other on Blossom Street and differed by 17 dBA. The data would have seemed very inaccurate if they both simply said, "measurements were taken on Blossom Street."

Another significant difference was among the predicted noise impacts. Instead of describing the noise impacts the project would have at the SMLs, some EIRs from the South End described the impacts at a different set of locations, called modeling receptors. The reports did not specify the location of the modeling receptors. In addition, since the ambient noise level had not been established at the modeling receptors as it had for the SMLs, describing the projected noise impacts at the receptors does not reveal as much about how the project would impact the ambient noise levels.

4.1.4 Analyses of the 24 hour measurements from the Columbus Center EIR

The Columbus Center EIR contained continuous measurements taken from September 5th though 12th 2002 at four different SMLs. The L_{90} L_{50} and L_{10} in dBA were reported for each hour of each day. We analyzed the L_{90} measurements from the 5th and 6th as well as the 10th through the 12th, because they were workdays. We averaged the L_{90} for each hour from all five days at all four sites as shown in figure 5. We found that during the daytime hours, 7am to 6pm, the L_{90} is fairly constant except for a peak at 7am and 8am. During the nighttime, the L_{90} varies much more, but it is at its lowest between 1am and 4am.

4.2 Field Measurements in Pilot Areas

In this section we will discuss our findings from comparing the 20 minute measurements made by the team at each sound measurement location (SML) to the existing 20 minute measurements contained in all of the EIRs for the West End. We will also discuss our findings from taking both 20 minute and one hour long and measurements at Massachusetts General Hospital (MGH) SMLs one and four.

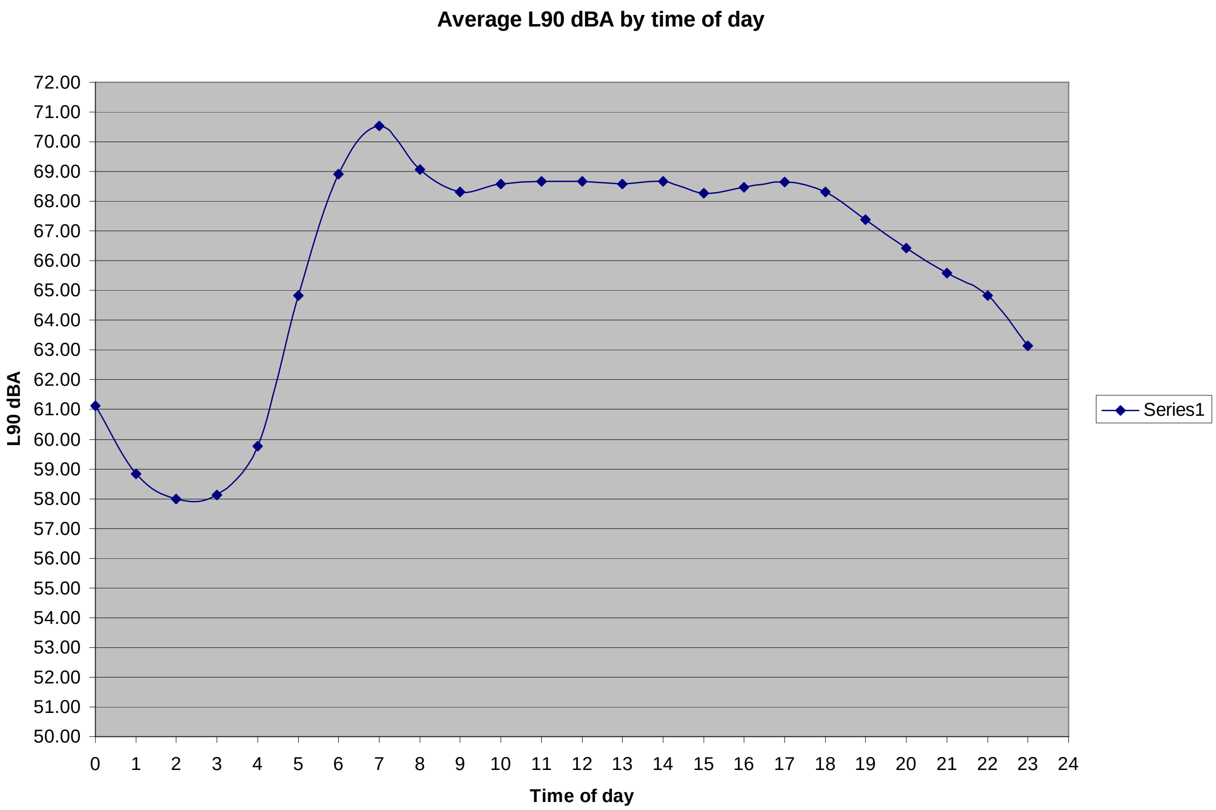

Figure 1: Average L90 by time of day

4.2.1 Comparing Field Measurements to Environment Impact Report Measurements

We compared the 20 minute measurements made in the field to the 20 minute measurements in the EIRs to find any similarities and/or differences. The daytime noise measurements from the EIRs and the test field measurements made by the team in terms of L_{10}, L_{50}, and L_{50} are shown in Table 3. The field readings that were taken at each SML location show that overall 55% were within three dBA of measurements contained in the EIR reports. That is, 28 of the total 51 readings showed no change in the noise environment from when sound measurements were taken in the EIRs. Measurements showing a slight change in the noise environment, a 4 to 5 dBA difference between measurements, comprised 20% of the total measurements. The remaining 25% of readings showed a significant change in the noise environment (over 5 dBA).

Table 3: Daytime Noise Measurements in 2001-2004 Environmental Impact Reports compared to 2007 Test Measurements.

Project	Site	Date	EIR L10	Test L10	EIR L50	Test L50	EIR L90	Test L90	
MGH New Ambulatory Building	NML 1	February 12, 2001	78	72	77	66	77	64	
MGH New Ambulatory Building	NML 2	February 12, 2001	69	81	63	78	61	74	
MGH New Ambulatory Building	NML 3	February 12, 2001	72	74	68	69	65	65	
MGH New Ambulatory Building	NML 4	February 12, 2001	66	62	53	56	46	53	
Charles River Plaza	SML 1	July 27, 2001	61	66	57	57	54	52	
Charles River Plaza	SML 2	July 27, 2001	72	76	68	70	62	65	
Charles River Plaza	SML 3	July 27, 2001	66	69	63	64	60	62	
Charles River Plaza	SML 4	July 27, 2001	68	68	63	64	60	61	
Charles River Plaza	SML 5	July 27, 2001	69	70	66	66	63	63	
Nashua Street Residences	Loc 1	September 13, 2004	69	74	67	68	64	63	
Nashua Street Residences	Loc 2	September 13, 2004	68	69	63	64	60	61	
Nashua Street Residences	Loc 3	September 13, 2004	67	69	65	66	63	64	
Nashua Street Residences	Loc 4	September 13, 2004	73	71	72	69	69	67	
Emerson Place	SML 1	January 13, 2003	63	74	61	71	60	66	*
Emerson Place	SML 2	January 13, 2003	61	65	59	63	58	62	*
Emerson Place	SML 3	January 13, 2003	65	70	60	64	58	62	*
Emerson Place	SML 4	January 13, 2003	68	76	65	72	63	69	*

Notes:

- * = Current construction influenced 2007 Field Measurements
- Green = difference between EIR measurement and test measurement 3dBA or less.
- Yellow = difference between EIR measurement and test measurement 4 or 5 dBA.
- Red = difference between EIR measurement and test measurement greater then 5 dBA.

Table 4: Nighttime Noise Measurements in 2001-2004 Environmental Impact Reports compared to 2007 Test Field Measurements

Project	Site	Date	EIR L10	Test L10	EIR L50	Test L50	EIR L90	Test L90
MGH New Ambulatory Building	NML 1	February 12, 2001	63	66	58	62	55	60
MGH New Ambulatory Building	NML 2	February 12, 2001	50	65	47	63	44	62
MGH New Ambulatory Building	NML 3	February 12, 2001	59	71	55	65	50	60
MGH New Ambulatory Building	NML 4	February 12, 2001	51	58	48	51	42	49
Charles River Plaza	SML 1	July 27, 2001	62	56	55	54	50	53
Charles River Plaza	SML 2	July 27, 2001	62	73	55	66	52	61
Charles River Plaza	SML 3	July 27, 2001	55	65	52	62	50	61
Charles River Plaza	SML 4	July 27, 2001	52	65	51	58	50	56
Charles River Plaza	SML 5	July 27, 2001	55	67	53	59	52	57
Nashua Street Residences	Loc 1	September 14, 2004	59	71	57	64	54	58
Nashua Street Residences	Loc 2	September 14, 2004	64	62	59	57	56	54
Nashua Street Residences	Loc 3	September 14, 2004	62	65	56	61	53	58
Nashua Street Residences	Loc 4	September 14, 2004	71	60	70	58	69	57
Emerson Place	SML 1	January 13, 2003	63	61	44	60	40	59
Emerson Place	SML 2	January 13, 2003	44	62	39	60	38	57
Emerson Place	SML 3	January 13, 2003	46	58	41	54	39	53
Emerson Place	SML 4	13-Jan-03	68	73	55	66	40	60

Notes:

- * = Current construction influenced 2007 Field Measurements
- Green = difference between EIR measurement and test measurement 3dBA or less.
- Yellow = difference between EIR measurement and test measurement 4 or 5 dBA.
- Red = difference between EIR measurement and test measurement greater then 5 dBA

However, four of the SMLs were highly affected by current daytime construction. Construction has different requirements for sound mitigation and therefore results in louder than normal ambient noise levels. After removing these readings, there were 39 measurements to be used for comparison. Test measurements that were within 3 dBA of EIR measurements comprise 72% of the total. Another 10% of the test measurements were considered to have just a slight change in the noise environment at a four or five dBA change. The final 18% of readings were then considered to have a significant change in the noise environment.

Aside from the measurements affected by construction, seven measurements had changed by more than 5 dBA. These measurements were all from three SMLs from the MGH new ambulatory wing project. For one SML all of the three readings had increased, for another all three had decreased, and for the third SML only the L_{90} increased while the L_{10} and L_{50} remained unchanged. This is most likely due to the fact that with new buildings the acoustics of the area had changed as well as the paths of the ambulances.

A similar analysis was done for the night time readings with much different results. As shown in Table 4, 36 of the 51 comparisons had more than a 5dBA difference, which accounted for 70% of the total. Test measurements that were four or five dBA different from the EIRs comprised 12% of the readings. Finally the last 18% or nine readings were within three dBA and were considered to have no change in the noise environment. All but one of the 15 nighttime L_{90} measurements that demonstrated a change in the noise environment showed an increase in ambient noise levels from the time that the EIR measurements were taken between 2001 and 2004 and the time that we made our measurements in 2007. Note that many of the daytime and nighttime noise readings shown in Tables 3 and 4 exceed the city's regulations for maximum allowable limit for a residential/industrial area. This result will be discussed further later in the chapter.

4.2.2 Comparing One Hour Long Measurements to 20 Minute Measurements

We compared the one hour long measurements to the 20 minute measurements to determine the whether measurement duration might influence the measured ambient noise level. These measurements were taken at the MGH SMLs 1 and 4. The measurements at SML 4 had L_{90} levels of 53 dBA for both the one hour reading and the 20 minute readings. The measurements at SML 1 had L_{90} levels of 64 dBA for both the 20 minute and hour long readings.

This shows that increasing the duration of the measurements from 20 minutes to an hour does not affect the measured L_{90}.

4.3 Maps in Geographic Information Systems

As we explained in our methodology section, we composed six layers over our base layer map of Boston. A layer is an overlay of information on top of the base map of Boston. It can be visually displayed through shapes, colors, shading, or even data from a database. The six layers include day measurements, night measurements, noise predictions, source data, field measurements, and complaint density. In this section, we will discuss our findings as a result of analyzing layers of the day and night measurements contained in Environmental Impact Reports, the layer of predictions made in EIRs, and the layer of complaints called into the Air Pollution Control Commission.

4.3.1 Day and Night Environmental Impact Report Measurements

Because EIR data will eventually populate the ambient noise map for the city, we studied how a map of these data could be interpreted. As a result of mapping the data for each sound measurement location contained in the EIRs for the West End, we discovered that the noise data are dispersed evenly throughout the area. This allowed us to make a rough estimate of the ambient noise levels in this neighborhood. In Figure 2 and 3, the pink shaded areas are the projects that each point on the map corresponds to. Additionally, each point is color and size coded by the L90. The pink and red points illustrate measurements over day regulations of 65 dBA for Figure 2, and night regulations of 55 dBA for Figure 3. The green and blue points represent measurements that are below the respective regulations. By studying Figure 2, it was discovered that more daytime L_{90} measurements fell within the 60 dBA and 65 dBA range than any other five decibel range. This is illustrated by the light green points on the map. This shows that most measurements are close to yet below the 65 dBA limit for industrial/residential areas. As described above, our own daytime measurements corroborate this finding. The trends found in the layer of daytime measurements made by the team were similar to those in the daytime EIR layer.

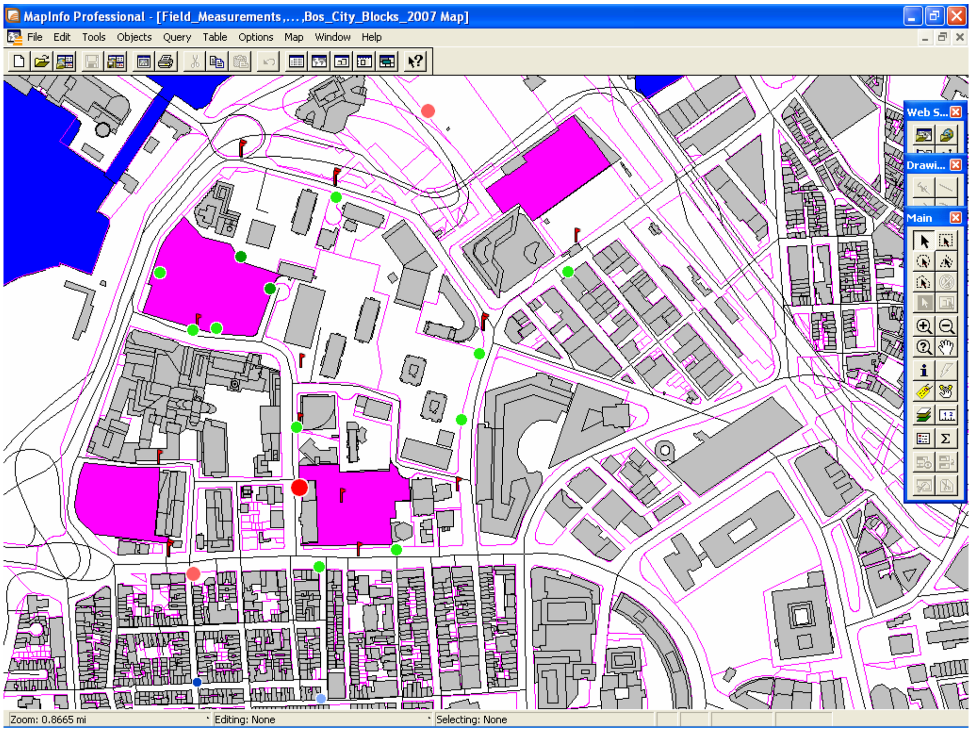

Figure 2: EIR Daytime Layer (West End)

There were reasonable explanations for the two outliers that were above 65 dBA. For example, an EIR for the Nashua Street Residences had an SML near North Station that had an L_{90} measurement of 69 dBA (illustrated with a pink point). Although it exceeds the regulatory limit, the measurement for this location is unsurprising as there are trains, heavy traffic, and pedestrians in this area. The MGH New Ambulatory building had an L_{90} of 77 dBA (illustrated with a red point) which was likely due to the truck deliveries, sirens, and Massachusetts General Hospital mechanical units that were described in the EIR to be present during the time of the measurement.

Mapping the nighttime noise also provided a rough estimate of the nighttime ambient noise levels. For night measurements in the West End, the regulations state that the ambient noise cannot exceed 55 decibels. As shown in Figure 3, there were only three out of the 17 L_{90} measurements from each SML contained in the EIRs for the West End that exceeded the 55 decibel limit. More nighttime L_{90} measurements fell between 50 dBA and 55 dBA than any other five decibel range. Similar to our findings for the daytime measurements, this shows that the ambient noise levels in the West End were generally close to but below the 55 dBA limit. The highest L_{90} was once again at the SML that is nearest to North Station, with the same noise level as recorded during the daytime (69 dBA). Another outlying measurement was from the EIR for the new MGH Ambulatory Building near Blossom Street which measured 55 dBA. The EIR listed various variables that occurred during the measurement that could have driven the reading higher than expected. These variables were traffic, pedestrians, sirens, and mechanical equipment at Mass General Hospital. Unlike our 2007 daytime measurements, our 2007 nighttime measurements (Figure 4) tell a slightly different story than the EIR nighttime measurements. Most of the nighttime measurements we made in 2007 fell in the 55 to 60 dBA range, indicating that the ambient noise in the West End is generally close to, yet above, the nighttime regulatory limit.

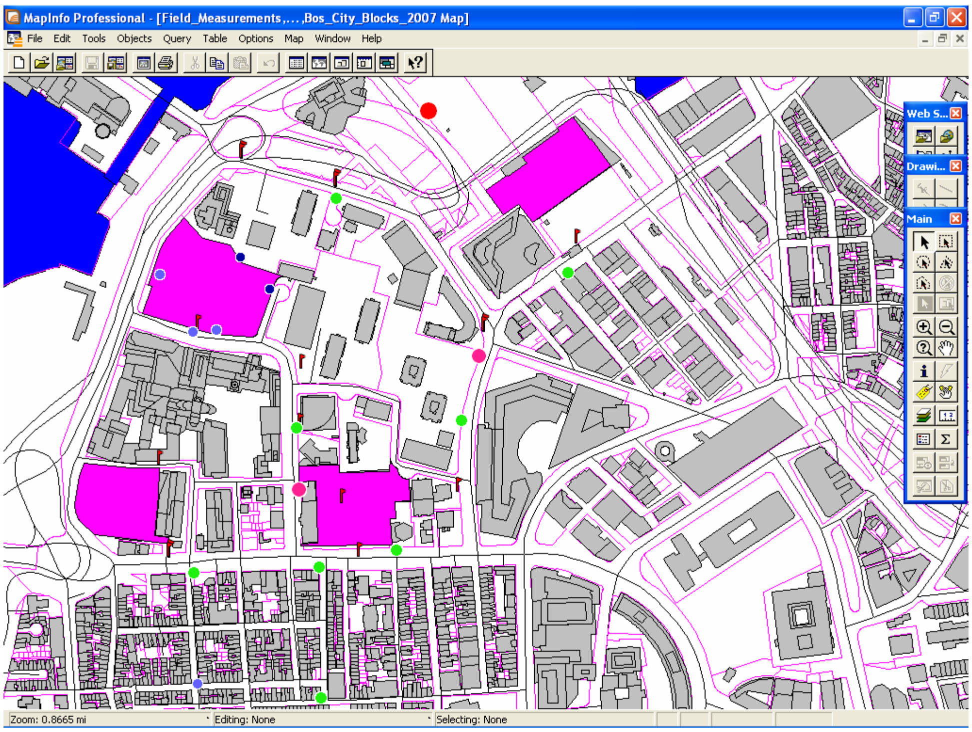

Figure 3: EIR Nighttime Layer (West End)

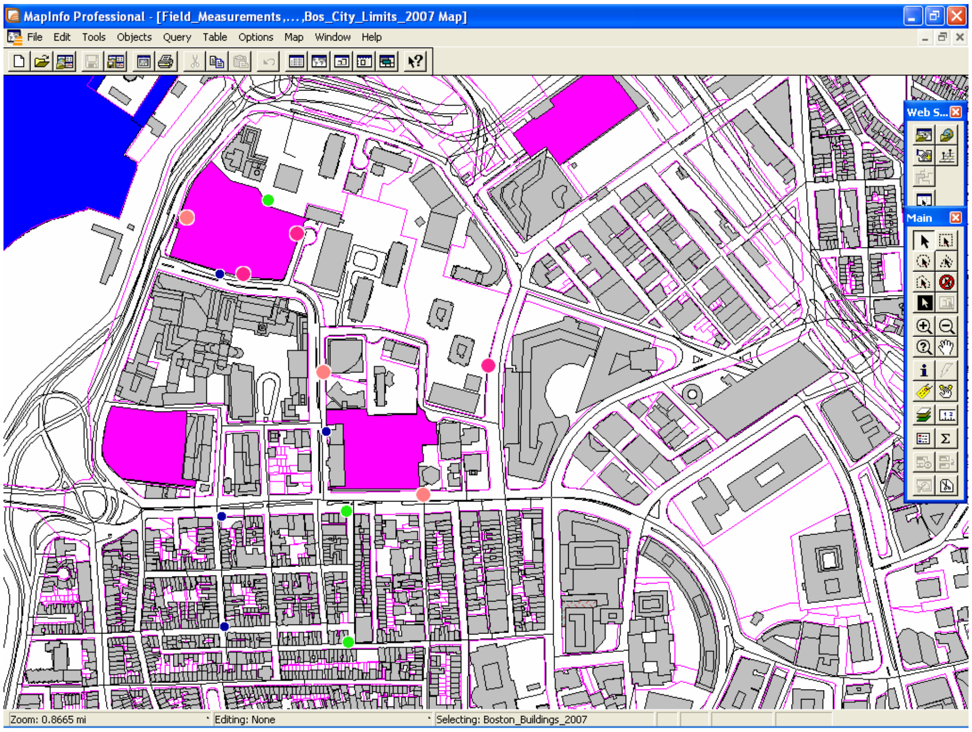

Figure 4: 2007 Nighttime Field Measurements Layer (West End)

4.3.2 Environmental Impact Report Predictions

The predictions in each EIR make an estimate of the sound level impact that the building will have on the environment at each SML. The predictions are an estimate of the sources alone, without factoring for the ambient noise. We mapped the predictions in MapInfo and compared them to the corresponding ambient measurements that we made in the field. Figure 5 shows the layer containing predicted noise level contribution at each SML.

We found that this map simply showed that all of the predictions were well below regulations. The predictions for the noise level that will be produced by the new project were at or below 45 dBA, and all were at least 5 dBA below the lowest measurement for their corresponding SML, indicating that the new project will not contribute to the ambient noise level. However, the nighttime measurements taken in 2007 showed that the ambient noise levels are significantly higher than those predicted in the EIRs from 2001-2004.

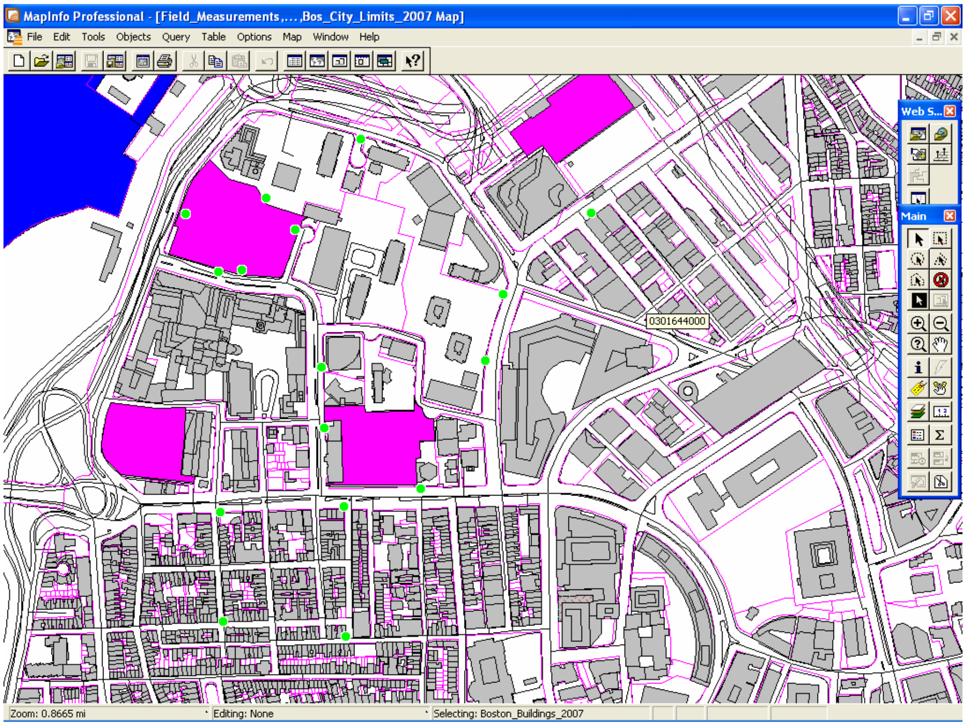

Figure 5: Predictions Layer (West End)

The EIR reports identify all the mechanical systems, or sources, that are being installed in or on the new building. We attached the source data to the parcel layer in MapInfo, allowing a user to click on any parcel and find the source information. By compiling data from all ten of the EIRs for the West End and South End neighborhoods and visually displaying the data on the map, we concluded that there wasn't enough data to populate the map in order to determine any correlations between the sources layer and the complaint and field measurement layers. While this map didn't provide any significant insight in regards to our project, we think that over time this map will be a useful tool for enforcement actions made by the APCC. Ideally, in the future, when the inspector receives a noise complaint in a certain area, he or she can look at the map to view all of the possible noise sources. The can also use the parcel number to determine who owns and maintains each of mapped sources. Figure 6 shows the four parcels that the EIRs for the West End were contained in. Attached to the parcel data is the source data, as illustrated on the right of the map with the "Info Tool".

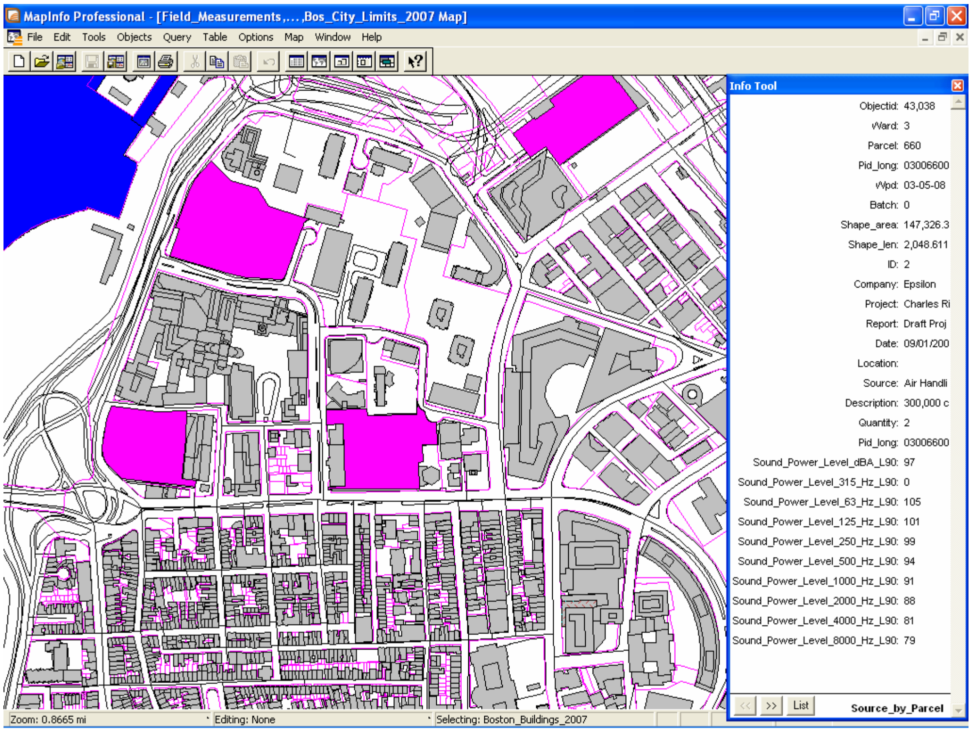

Figure 6: Source by Parcel Layer

5. Conclusions

After conducting our own field measurements in 2007 and comparing them to the measurements taken by the EIR consultants, we arrived at some conclusions. The conclusions that we arrived at are targeted toward the EIRs. These insights proved invaluable and led to several recommendations which we will discuss in the next section.

As a result of conducting extensive field measurements in the West End, we have come to the conclusion that nighttime ambient noise is affected more than daytime noise by new construction projects. The noise environment during the day has generally remained constant from the time the EIR readings were taken in 2001-2004 the time our field data was collected in 2007. The nighttime data, on the other hand, showed us that the nighttime noise environment has drastically changed. There is a logical explanation for this finding which is shown in our results chapter. Daytime ambient noise levels are higher than nighttime ambient noise levels. As a result, when a new source of noise is introduced into the environment such as an HVAC unit on a new building, it is going to have a greater impact on the lower ambient noise level at night.

Another conclusion made as a result of our field measurements made in 2007 is that most predictions contained in the EIRs for the West End, which stated the new project would have no impact on the noise environment, are incorrect. In most cases, the noise environment had greatly increased after completion of the project. There are many reasons these predictions can be inaccurate, such as the laboratory tests used to determine the sound power levels of the noise sources not accounting for outdoor conditions.

6. Recommendations

This chapter will discuss our recommendations concerning the preferred content and protocol for the noise assessments contained in EIRs. We go on to describe the protocol we recommend for submission of noise data as well as the conclusions we made from analyzing all of the layers of the map. Finally, we discuss our recommendations regarding the noise regulations in Boston.

6.1 Contact Consultants

We recommend that the APCC share the findings of our project with noise consultants in Boston. The predictions contained in past reports have not been checked and therefore with feedback the consulting companies can produce more accurate predictions. Realizing that predicting noise impacts is quite complicated, the use of further information contained in the noise maps should be useful in reaching a common goal of minimizing noise pollution.

6.2 Standards for Environmental Impact Report Methods and Procedures

Environmental Impact Reports contain information on the ambient noise levels in the area of the proposed project and the impact that the project will have on the noise environment after completion. The method used by the consultants to collect and present this information varies from one report to the next as no standards for these methods exist. By analyzing the EIRs from our two pilot areas and our field measurements, we have determined which procedures and methods are necessary for providing the APCC with an understanding of the noise environment before and after construction. We recommend that the APCC require the following set of standards for noise impact assessments in EIRs:

1) *Measure noise levels at a minimum of four different locations*

Noise levels can vary significantly from point to point; therefore data from too few locations may not represent the noise environment in the immediate area around the proposed project accurately.

2) *Provide the latitude and longitude of each location*

Once again, the noise can vary significantly from point to point. Noise measurements are only useful if one knows exactly where the measurements were taken. Providing latitude and longitude will also be helpful to the APCC as it allows the data to be plotted on a map. These coordinates must be in decimal form so that the data can be integrated into MapInfo.

3) ***Provide the conditions during each measurement***

Weather, road and traffic conditions, and time of year can all affect the level of ambient noise. A detailed description of these conditions should accompany each measurement.

4) ***Take two measurements at each location, one for day and one for night***

The noise environment and the regulations are different for day and night. Measuring only during the day is not sufficient to ensure compliance with Boston's regulations.

5) ***Compute the L_{10}, L_{50}, L_{90}, and L_{eq}, in dBA and the L_{90} for each octave band***

The A-weighted L_{90} is the best noise metric to describe the ambient noise; it is not affected by occasional intrusive noises. The EIR should include the L_{90} in dBA and the L_{90} in dB for each octave band because Boston has different regulations for each. While the L_{10}, L_{50}, and L_{eq} may not be good indicators of the ambient noise levels, each can provide information on a different aspect of the noise environment, and may be helpful to people studying the noise environment in the future.

6) ***Take each measurement over 20 minute durations***

Comparison of our 20 minute to our hour long readings showed little difference, suggesting that 20 minutes is a sufficient length of time for conducting field measurements. The L_{90} is minimally affected by loud, intrusive events and will generally be the same whether the reading is 20 minutes or one hour.

7) ***Take measurements at a quiet time of the day and night***

The measurements should be taken at the quietest time of the day and the night to ensure that measurements are not influenced by intrusive, short-term noises that may be more common during the times of day that are typically noisier. This would also prevent the consultants from over-estimating the ambient noise levels, ensuring that the project does not impact the noise environment, even when ambient noise levels are at their lowest. Our results show that at night, the quietest time was between the hours of 1am and 4am. During the day, we found that ambient noise levels were relatively constant from 10am through 6pm, but consultants should avoid taking measurements from 6am to 9am, when the noise levels are typically higher.

8) *Provide the sound power level of each predicted noise source*

Each piece of equipment for the proposed project that will contribute to the ambient noise level should be identified and the parcel number must be included so that these sources can be placed on the map. In addition, the sound power level of each piece of equipment should be provided in terms of the total A-weighted sound power level and the unweighted sound power level for each octave band. The current practice is to provide either the sound power level or sound pressure level. However, the sound pressure level is dependant on the distance from the piece of equipment. It is difficult to compare the sound pressure levels for different pieces of equipment if the reference distance used is different each time; therefore the sound power level should be used to enable an easy comparison.

9) *Compute the noise impact of the project at the measurement locations*

The sound power levels of each of the noise sources to be included in the new project are used to calculate the total impact that the new project will have on the noise levels at a particular modeling location. The modeling location should be the exact same location as where the day and night measurements were already made, enabling the noise levels that the project will generate to be directly compared with the measurements already made at those locations.

10) *Take into account the acoustical and mechanical conditions when computing the impact at the sound measurement locations*

The projected sound power levels for each piece of equipment are usually measured in a lab with near perfect conditions. That is necessary to ensure an accurate measurement by eliminating all variables. However, the conditions in which the equipment will be operating when the project is completed may be far from perfect. Surfaces around the equipment may reflect sound waves and amplify them. Also, the vibrations of a machine in operation may be transferred to the roof or whatever surface it is bolted to, which in turn could cause nearby objects to vibrate. It is important to take these factors into consideration and compute the impacts using a “worst case scenario” of how the sound could be reflected or amplified due to the acoustical and mechanical environment.

6.3 Protocol for Electronic Submission

We recommend that the APCC request the information submitted by consultants for noise impact assessments within EIRs to be in electronic format. Consultants will aid in populating the database by submitting their EIR data including day and night measurements made at each SML, predicted noise levels at each SML, and a list of noise sources that will be included in the project. The APCC can place the forms as seen in Appendix B on a website. Consultants can then submit data over the internet, or the consultants can submit the forms or tables as an attachment on the CD containing the electronic copy of the EIR that they submit along with their hardcopy. In the latter case, the consultants should be given a sample of our Access forms and tables that they can use as templates. Their tables can be easily appended to the APCC’s database.

We also recommend the APCC continue to populate the database. They already use the complaint log on a regular basis, and now they have the ability to visualize these data. Additionally, prior to this project, the APCC was unable to download data from the noise meter directly to the computer. Now that they have the ability to do so, they will be able to utilize the database to organize their data.

6.4 Utilize Noise Maps in MapInfo

If the APCC continues to populate the layers we created by updating the database, they will have an extremely useful tool for enforcing regulations. The following paragraphs will describe the recommendations for using each of the layers.

1) *Daytime EIR Measurements*

Daytime EIR measurements from 2000 and on are likely to be reasonably accurate for describing the ambient noise levels of an environment. Currently, with data from 17 locations mapped in the West End, it is possible to develop a gross estimate of the ambient noise throughout the entire West End. By utilizing the map, the ambient noise level in the West End can be described as being between 60 and 65 dBA.

2) ***Nighttime EIR Measurements***

Due to the fact that the nighttime EIR measurements were generally different from the field measurements that we took, the nighttime layer of the noise map can be useful in illustrating whether the EIR predictions were accurate or not. If the ambient noise levels change after the project is completed, it will be most apparent in the nighttime layer after post-construction field measurements are taken.

3) ***Predictions of Noise Level in EIRs***

We recommend that the APCC monitor this layer to determine if the consultants develop more accurate predictions. This can be determined by overlying the predictions layer with the EIR nighttime layer. After post-construction measurements are taken, if there are fewer changes in the ambient layer, then the predictions are more accurate.

4) ***Noise Sources contained in EIRs***

The map of Sources by Parcel will be useful to the APCC in the course of complaint investigation. Once this map is populated, we recommend that the inspector look at the source layer whenever she or he receives a mechanically related noise complaint and view all of the possible sources in the area; this information will certainly aid the complaint investigation process.

5) ***Complaint Data***

As the APCC continues to populate the complaint density map by including the longitude and latitude of the origin of the complaint in their log, they may begin to see multiple complaints clustered around small areas. We recommend that it may be beneficial for the APCC to invest in a continuous sound level meter in the near future. This type of device can be placed outside and left for extended periods of time to take continuous readings. The meter could be placed in these hot spots. This would save the APCC time as they will not have to send out their inspector multiple times to find a violation in noise regulations.

The map that we have created as a result of this project is an extremely useful and versatile tool. It has the ability to grow with the electronic submission of noise data and therefore has great potential. In the future, these layers can also be overlaid with other layers that the City of Boston may have to discover correlations that were never thought to have existed. For example, the daytime ambient noise layer can be overlaid with layers reflecting the health, safety, education, and lifestyles of the city's residents to make important discoveries.

6.5 Changing the Regulations

We recommend that the Boston regulations define maximum decibel limits in terms of the L_{90} computed for a measurement of at least 20 minutes. The current process for EIR data collection used by many leading consultants in the noise measuring field, advice from experts on the subject, and our own field measurements all lead us to this conclusion. Many areas of our research point to the L_{90} as being a good measure of ambient noise. Boston's regulations are quite clear on what the maximum limit is for noise levels. However, they do not state how the noise environment should be described in technical terms. It is possible for measurements made in a given noise environment to have an L_{90} that is compliant with the regulations and an L_{10} that is not. The regulations should also specify that the L_{90} be computed from at least 1000 individual readings. Current sound meters are able to take readings at a minimum rate of one per second; this should be easily achievable to anyone with access to current sound metering technology.

As the map continues to be populated, the APCC will be able to determine how closely the ambient noise levels throughout the city correspond to the regulations that limit the ambient noise. It may be that the current limits are still reasonable. However, the map may reveal areas with ambient noise levels higher than the current limit. The APCC may consider whether or not enforcing that limit is still practical for the area. We recommend the APCC use the map our team has developed to see if the ambient noise in these areas corresponds to a high complaint density or other health and safety factors, and use this information to inform their decision on whether to relax the regulations in those areas or pursue more aggressive noise abatement measures.

Conversely, the map may show that due to improved noise mitigation measures, the ambient noise levels may be significantly lower than the current limits. If this is the case, it may be worthwhile for the APCC to tighten regulations in these areas to ensure that these quiet oases are preserved.

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Appendix A

General Overview: Boston Environment Department (BED)

The overall mission of the Boston Environment Department (BED) is to protect Boston's environment and heritage. First founded in 1982 via Chapter 772, s 1-10, the BED has expanded to include six different sub-departments that handle myriad of issues within Boston. These sub-departments are the Boston Conservation Commission, Historic District Commissions, Boston Landmarks Commission, Central Artery Environment Oversight, City Archeology Program, and Air Pollution Control Commission. This division of labor assists in improving efficiency and responsiveness to issues. This appendix will briefly discuss each sub-department and their role in the BED.

Boston Conservation Commission

The Boston Conservation Commission (BCC) enforces the Massachusetts Wetland Protection Act (M.G.L. c131 s.40), the Massachusetts Rivers Protection Act (HB s. 18.26), and the Conservation Commission Act (HB s. 18.9). Employing seven commissioners, the BCC more specifically determines wetland boundaries, reviews proposed projects, and places conditions on projects that are in or near wetland areas. This includes any work within 100 feet of a wetland boundary, resource area, or flood plain. Hearings are regularly held twice a month to allow abutters and the public voice their concerns.

Historic Districts Commissions

The Historic Districts Commissions (HDC) is comprised of volunteers who have been nominated by local neighborhoods, and were then appointed by the mayor. There are eight historical districts which include: Aberdeen, Beacon Hill, Back Bay, South End, Bay State Road/Back Bay West, Bay Village, Mission Hill Triangle, and St. Botolph. Each of these districts reviews and approves proposed exterior design modifications within their respective neighborhoods. If approved, they will issue a Certificate of Appropriateness, which is valid in most districts for two years from the date of issuance. They do not have jurisdiction over use, occupancy issues, or other zoning matters. These issues must first be heard by the Zoning Board of Appeals before the historic district commission can make a ruling.

Boston Landmarks Commission

Boston has many cultural resources. These range from buildings, to different sites where people lived and worked. Protecting these landmarks is equivalent to protecting history itself. The Boston Landmarks Commission (BLC) does just this. Created in 1975 via state legislation (Chapter 772, M.G.L. 1975 as amended), the BLC identifies and preserves historic properties, as well as overseeing development and demolition activities. To have a property designated as a historic landmark, one must first petition the BLC for further study into the historic, social, cultural, architectural, or aesthetic implications of the site. The mayor, 10 registered voters, or a commission member can file a petition at any time. For the site to receive protective designation, it must meet four criteria. These are:

- Inclusion in the National Register of Historic Places;
- Relevance to the economic, social, or political history of the city;
- Involvement with people of historic importance;
- Representative of distinct architectural design from a historical period.

Central Artery Oversight

The Central Artery Oversight (CAO) was initially created so that the BED could focus more attention on the central artery project because if it’s unusually large size and scope. The BED states that the CAO’s responsibilities are “oversight of environmental mitigation measures, administering issuance of permits, review of CA/T documents, resolution of environmental complaints, enforcement of applicable environmental laws, regulations, and ordinances in addition to any environmental coordination, outreach, and monitoring necessary throughout all phases of the Project's planning, design, and construction stages”. In addition to those listed responsibilities, the CAO is also involved in developing the open spaces to compensate for the construction impacts. They are also transforming Spectacle Island from a dump, into a multi-use recreation area.

City Archeology Program

Staffed entirely by volunteers, the City Archeology Program (CAP) is involved in public outreach programs for both schoolchildren and the general public. CAP maintains all archeological findings located on public land, as well as 27 collections from the Commonwealth of Massachusetts that the City currently holds.

Air Pollution Control Commission

The Air Pollution Control Commission (APCC) is currently overseen by five commissioners, three who are appointed by the mayor, and two who are serving ex officio. These commissioners operate the APCC, which "…writes and enforces regulations, grants permits, advises other City Hall departments, holds public hearings, and cooperates with other local, regional, state, and federal agencies in the pursuit of common goals"(Boston Environment Department, 2007). The public hearings are held every three months and provide a means for which the APCC's work to be known and allows a time for input from the public.

The APCC addresses Air Pollution, Parking, Abrasive Blasting, and Noise. Air Pollution comes from vehicles, dust, generators, and smoke from industrial sites. The noise that is specifically addressed by the APCC is from ventilation equipment, HVAC systems, generators, and other sources. They do not have authority over airplane noise or any noise originating from Logan Airport.

Appendix B

Microsoft Access Database

1. The Switchboard

The switchboard allows easy navigation from one form to the next. When you open the database we created, the window shown in Figure 1 will appear. Select *Forms* under the *Objects* menu on the left side of the window and double-click on *Switchboard*.

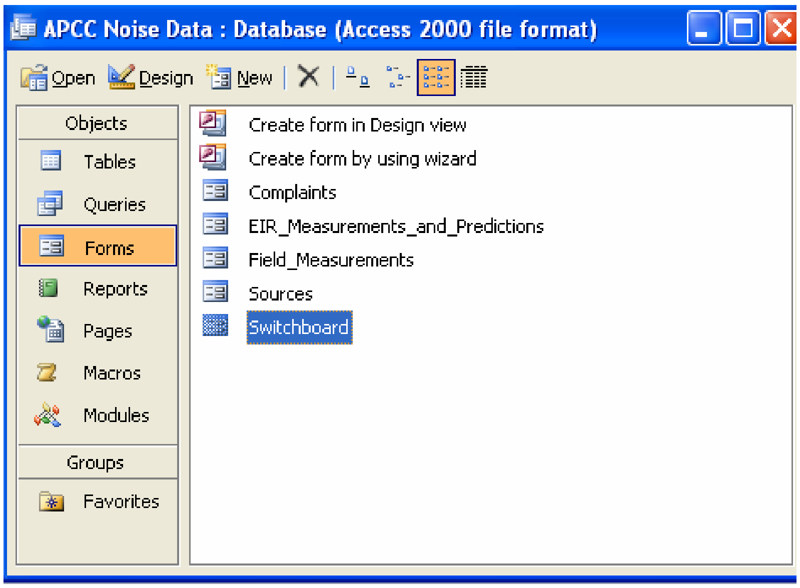


Figure 2: The Main Database Window

When the user first opens the switchboard, the menu shown in Figure 2 appears. The user has the option to select *Add Noise Data* or *View/Modify Noise Data*. The add mode allows the user to open up a blank form to add new records to the database. The view/modify mode allows the user to open up all existing records currently in the database.

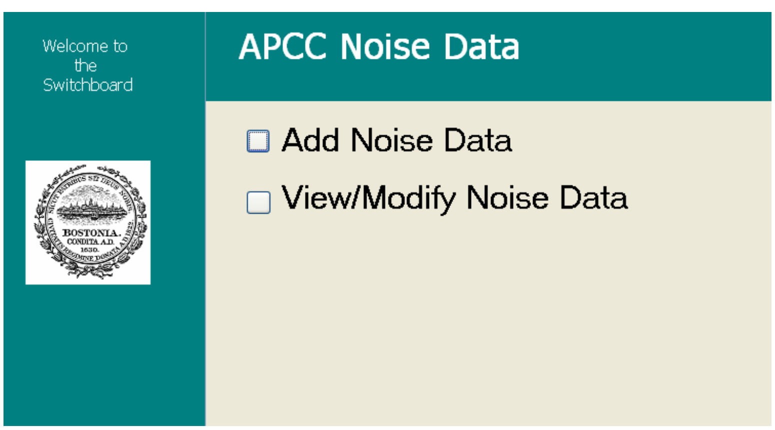


Figure 3: The Main Switchboard Menu

After the user selects which mode he or she would like to view the forms in, a secondary switchboard menu will appear as shown in Figure 3. The user has the option to choose which form he or she would like to view/add.

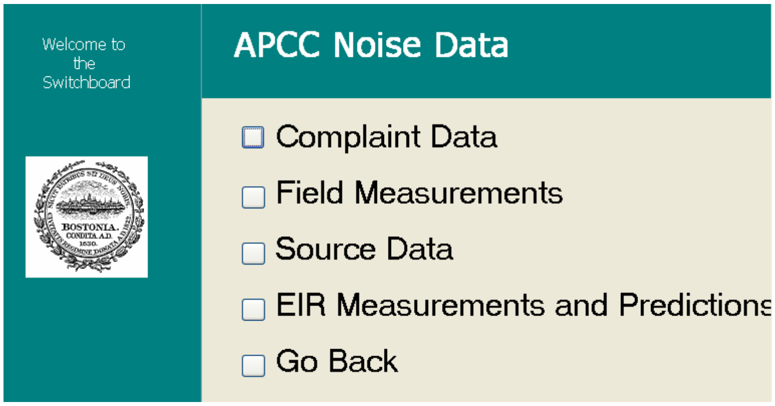


Figure 4: The Secondary Switchboard Menu

2. Definition of Fields for Each Form

This section provides figures of all five forms as they would appear in the *Add Noise Data* mode. For each form a description of the fields will be provided.

2.1 Complaint Log

The APCC already had forms for the complaint log shown below in Figure 4. We added fields for entering longitude, latitude, and parcel number. The definition for each field is shown below.

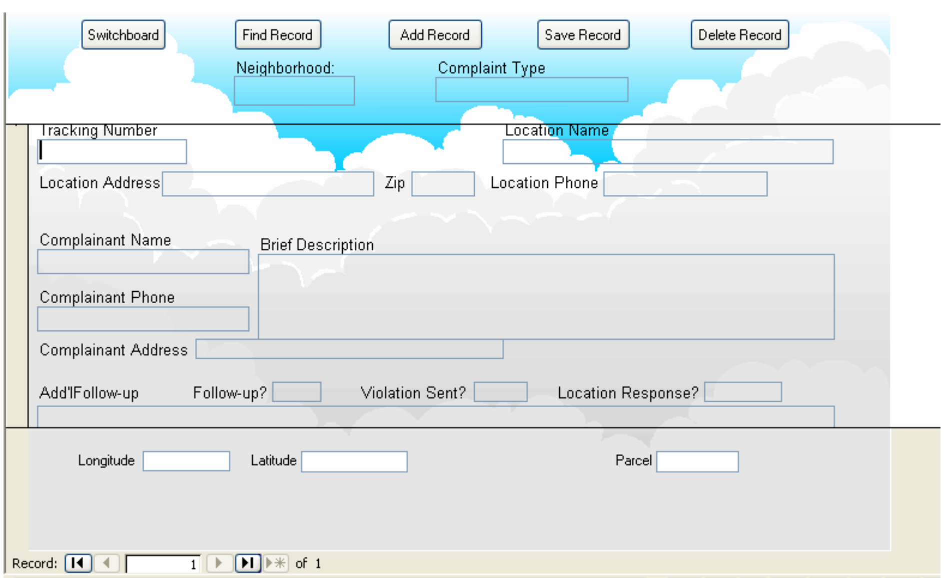


Figure 5: Complaint Log Form

Neighborhood: Name of Neighborhood (i.e. West End)
Complaint Type: Name of type of complaint (i.e. Noise – Construction)
Tracking Number: Number assigned by APCC
Location Name: Name of building causing disturbance (i.e. 7-Eleven)
Location Address: Street name and number of building causing disturbance
Zip: Zip Code of neighborhood
Location Phone: (XXX) XXX-XXXX
Complainant Phone: (XXX) XXX-XXXX
Complainant Address: Street name and number
Brief Description: Memo describing complaint
Add'l Follow-up: Memo describing steps APCC took
Follow-up?: Enter Yes/No
Violation Sent?: Enter Yes/No
Location Response?: Enter Yes/No
Longitude: Longitude of complainant address in decimal form
Latitude: Latitude of complainant address in decimal form
Parcel: Parcel ID of location causing disturbance

2.2 Field Measurements

The form we created for entering field measurements as a way to organize the readings the team took in 2007 is shown in Figure 5. The APCC may decide to use this database in the future as a way to organize their readings taken in the course of enforcement actions and link it to their complaint log form. The definitions for each of the fields are shown below.

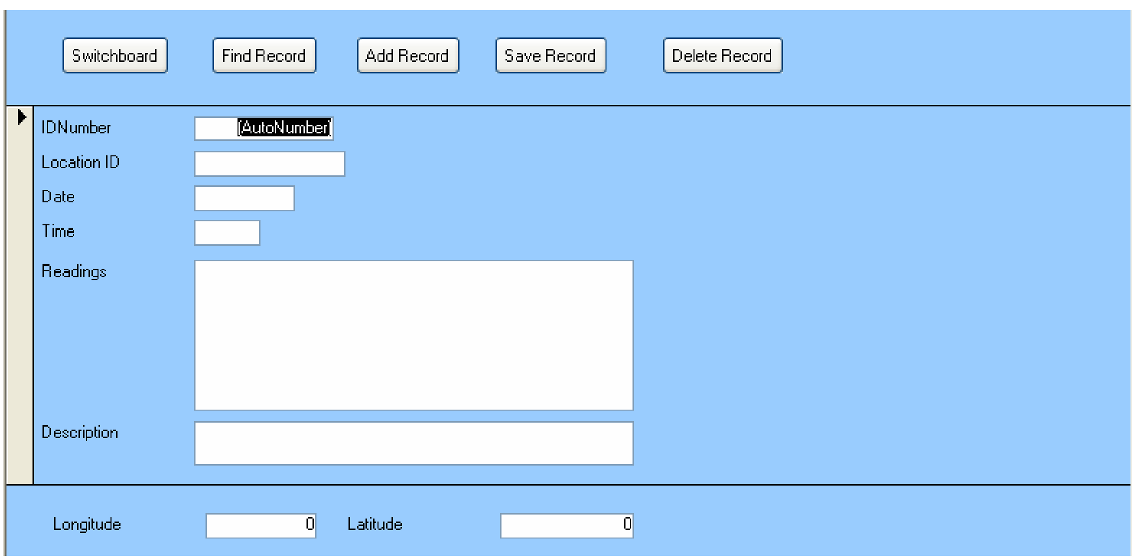


Figure 6: Field Measurements Form

IDNumber: AutoNumber
Location ID: Description of reading (i.e. MGH SML #1)
Date: Date of reading (i.e. 04/28/2007)
Time: Time of reading (i.e. 12:00 AM)

Readings: Cut and paste text file downloaded from the sound meter to the computer
Description: Conditions during time of reading (i.e. weather, roads, pedestrians)
Longitude: Longitude of reading location in decibels
Latitude: Latitude of reading location in decibels

2.3 EIR Measurements and Predictions

The consulting companies can fill out one form for each sound measurement location. The consultants can enter general data regarding the project, then, by selecting each tab, they can enter information regarding daytime measurements, nighttime measurements, and predictions.

2.3.1 General EIR Measurements and Predictions Data

The form for EIR daytime measurements, nighttime measurements, and predictions is shown below in Figure 6. The general fields that are not included in the tabs are described below.

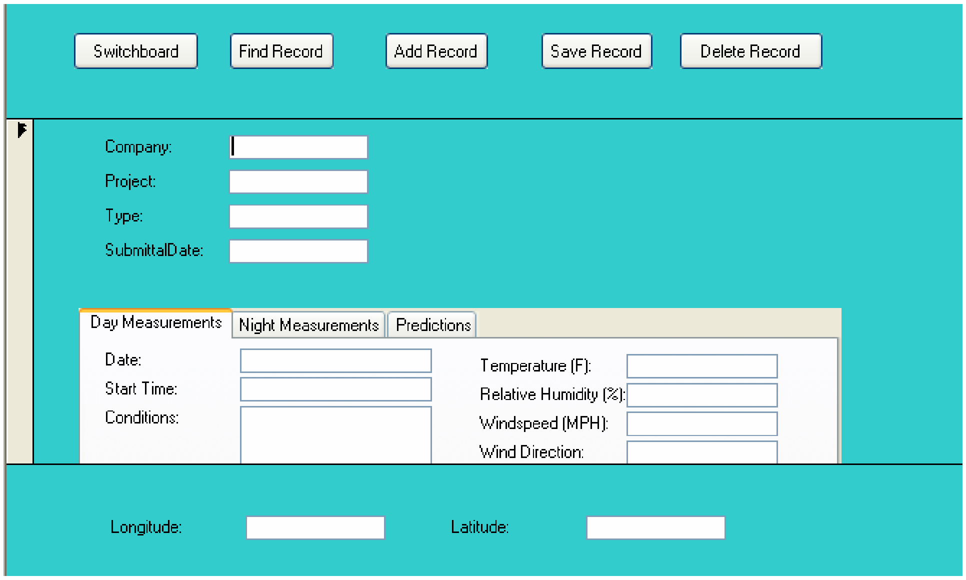


Figure 7: EIR Measurements and Predictions Form

Company: Consultants submitting report (i.e. Epsilon)
Project: Name of project (i.e. MGH New Ambulatory Wing)
Type: Select from list (Final EIR, Draft EIR)
SubmittalDate: Date of submission (i.e. 04/28/2007)
Longitude: Longitude of SML in decimal form
Latitude: Longitude of SML in decimal form

2.3.2 Day Measurements Data Tab

The fields displayed when the user selects the day measurement tab in the EIR measurements and predictions form are shown below in Figure 7. The definitions of each field are described below.

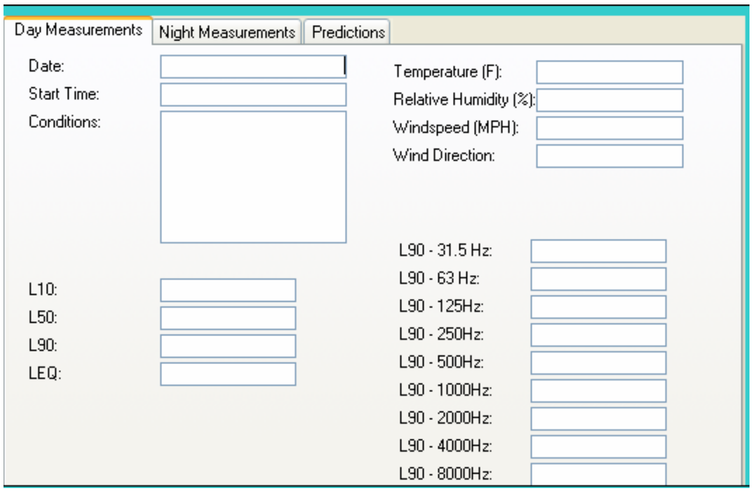


Figure 8: Day Measurements Tab in the EIR Measurements and Predictions Form

Date: Date of reading (i.e. 04/28/2007)
Start Time: Time of reading (i.e. 12:00 AM)
Conditions: Memo describing conditions (i.e. traffic, pedestrians, roads)
Temperature: Degrees Fahrenheit in integer form
Relative Humidity: % Humidity in integer form
Wind Speed: Wind speed MPH in integer form
Wind Direction: Name of direction (i.e. north)
L10: A-weighted L10 exceedance level in integer form
L50: A-weighted L50 exceedance level in integer form
L90: A-weighted L90 exceedance level in integer form
LEQ: A-weighted LEQ in integer form
L90 – 31.5Hz: L90 exceedance level for 31.5 Hz octave band in integer form
L90 – 63Hz: L90 exceedance level for 63 Hz octave band in integer form
L90 – 125 Hz: L90 exceedance level for 125 Hz octave band in integer form
L90 – 250 Hz: L90 exceedance level for 250 Hz octave band in integer form
L90 – 500 Hz: L90 exceedance level for 500 Hz octave band in integer form
L90 – 1000 Hz: L90 exceedance level for 1000 Hz octave band in integer form
L90 – 2000 Hz: L90 exceedance level for 2000 Hz octave band in integer form
L90 – 4000 Hz: L90 exceedance level for 4000 Hz octave band in integer form
L90 – 8000 Hz: L90 exceedance level for 8000 Hz octave band in integer form

2.3.3 Night Measurements Data Tab

The fields displayed when the user selects the night measurement tab in the EIR measurements and predictions form are shown below in Figure 8. The definitions of each field are described below.

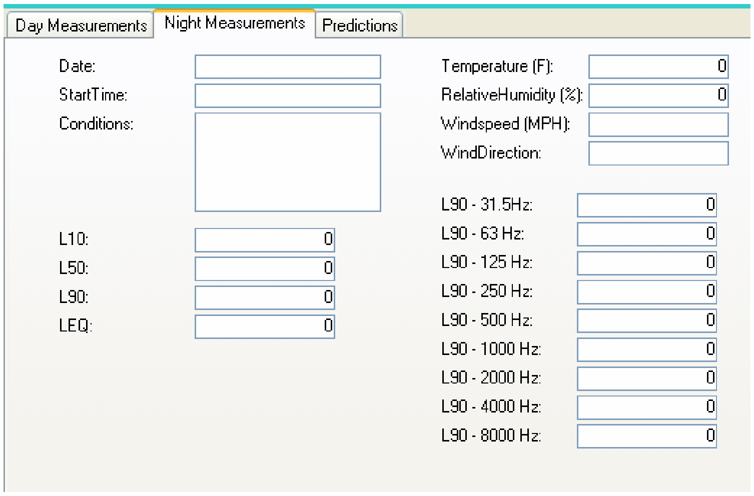


Figure 9: Night Measurements Tab in the EIR Measurements and Predictions Form

Date: Date of reading (i.e. 04/28/2007)
Start Time: Time of reading (i.e. 12:00 AM)
Conditions: Memo describing conditions (i.e. traffic, pedestrians, roads)
Temperature: Degrees Fahrenheit in integer form
Relative Humidity: % Humidity in integer form
Wind Speed: Wind speed MPH in integer form
Wind Direction: Name of direction (i.e. north)
L10: A-weighted L10 exceedance level in integer form
L50: A-weighted L50 exceedance level in integer form
L90: A-weighted L90 exceedance level in integer form
LEQ: A-weighted LEQ in integer form
L90 – 31.5Hz: L90 exceedance level for 31.5 Hz octave band in integer form
L90 – 63Hz: L90 exceedance level for 63 Hz octave band in integer form
L90 – 125 Hz: L90 exceedance level for 125 Hz octave band in integer form
L90 – 250 Hz: L90 exceedance level for 250 Hz octave band in integer form
L90 – 500 Hz: L90 exceedance level for 500 Hz octave band in integer form
L90 – 1000 Hz: L90 exceedance level for 1000 Hz octave band in integer form
L90 – 2000 Hz: L90 exceedance level for 2000 Hz octave band in integer form
L90 – 4000 Hz: L90 exceedance level for 4000 Hz octave band in integer form
L90 – 8000 Hz: L90 exceedance level for 8000 Hz octave band in integer form

2.3.4 Predictions Data Tab

The fields displayed when the user selects the predictions tab in the EIR measurements and predictions Form are shown below in Figure 9. The definitions of each field are described below.

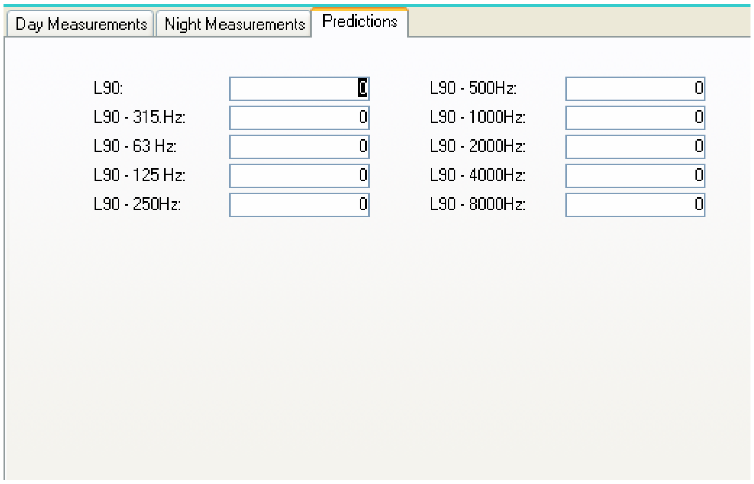


Figure 10: Predictions Tab in the EIR Measurements and Predictions Form

L90: A-weighted L90 exceedance level in integer form
L90 – 31.5Hz: L90 exceedance level for 31.5 Hz octave band in integer form
L90 – 63Hz: L90 exceedance level for 63 Hz octave band in integer form
L90 – 125 Hz: L90 exceedance level for 125 Hz octave band in integer form
L90 – 250 Hz: L90 exceedance level for 250 Hz octave band in integer form
L90 – 500 Hz: L90 exceedance level for 500 Hz octave band in integer form
L90 – 1000 Hz: L90 exceedance level for 1000 Hz octave band in integer form
L90 – 2000 Hz: L90 exceedance level for 2000 Hz octave band in integer form
L90 – 4000 Hz: L90 exceedance level for 4000 Hz octave band in integer form
L90 – 8000 Hz: L90 exceedance level for 8000 Hz octave band in integer form

2.4 Sources

The consulting companies can fill out one form for each source to be included in the new project. The form they use for this task is shown below in Figure 10. The definitions for each of the fields are shown below.

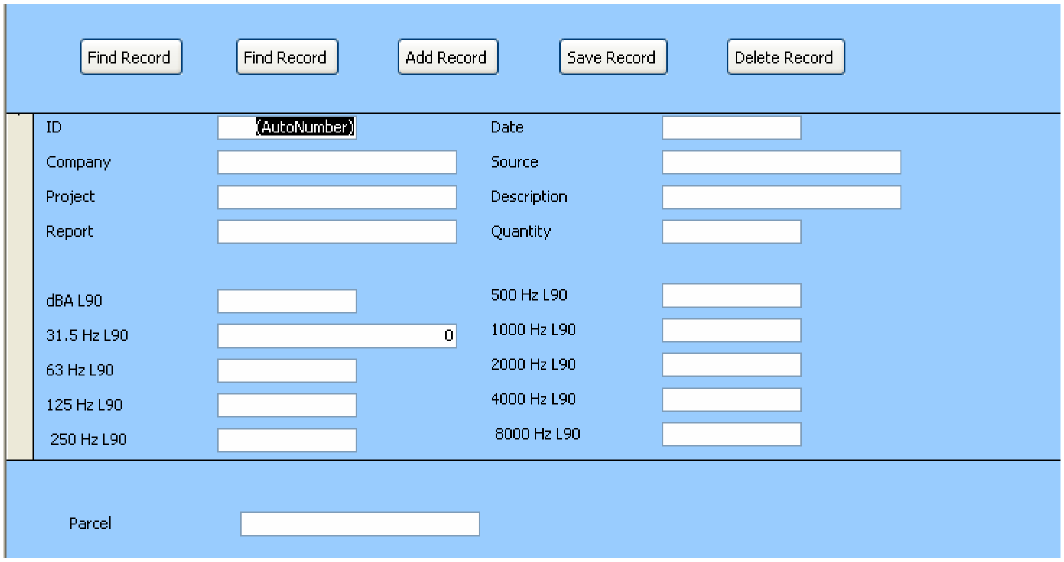


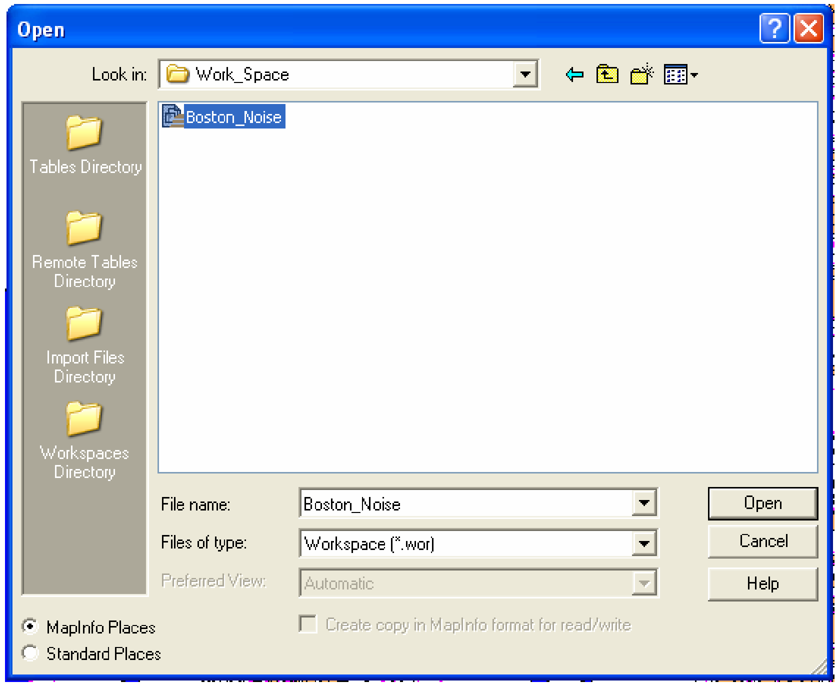
Figure 11: Form for Source Data Contained in EIRs

ID: AutoNumber
Company: Name of company (i.e. Epsilon)
Project: Name of project (i.e. MGH New Ambulatory Wing)
Report: Name of type of report (i.e. Final EIR)
Date: Date of submission (i.e. 04/28/2007)
Source: Name of type of source (i.e. cooling tower)
Description: Size of unit (i.e. 400 tons)
Quantity: Integer
L90: A-weighted L90 exceedance level in integer form
L90 – 31.5Hz: L90 exceedance level for 31.5 Hz octave band in integer form
L90 – 63Hz: L90 exceedance level for 63 Hz octave band in integer form
L90 – 125 Hz: L90 exceedance level for 125 Hz octave band in integer form
L90 – 250 Hz: L90 exceedance level for 250 Hz octave band in integer form
L90 – 500 Hz: L90 exceedance level for 500 Hz octave band in integer form
L90 – 1000 Hz: L90 exceedance level for 1000 Hz octave band in integer form
L90 – 2000 Hz: L90 exceedance level for 2000 Hz octave band in integer form
L90 – 4000 Hz: L90 exceedance level for 4000 Hz octave band in integer form
L90 – 8000 Hz: L90 exceedance level for 8000 Hz octave band in integer form

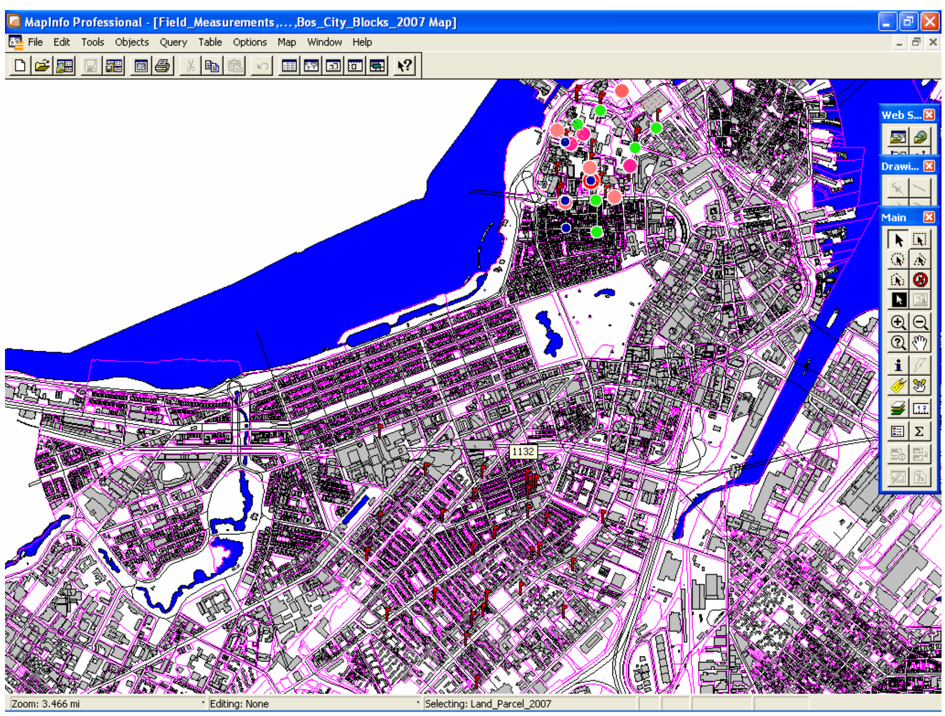
Appendix C

Using MapInfo v8.5 with Boston Noise Data Layers

Open MapInfo
In the Quick Start menu,
Select “Open a Workspace”
Click Open…
Select the
CD>Maps>Work_Space
Select Boston_Noise.wor
Click Open



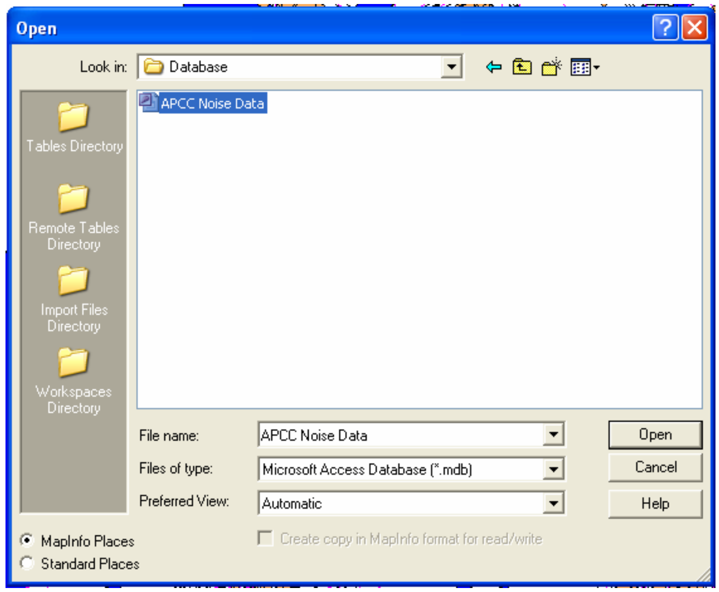
At this point, a map of Boston should be displayed, with additional layers. These layers include: EIR_Measurements_and_Predictions (illustrated by daytime L90, nighttime L90), Complaints, Field Measurements, and Parcels.



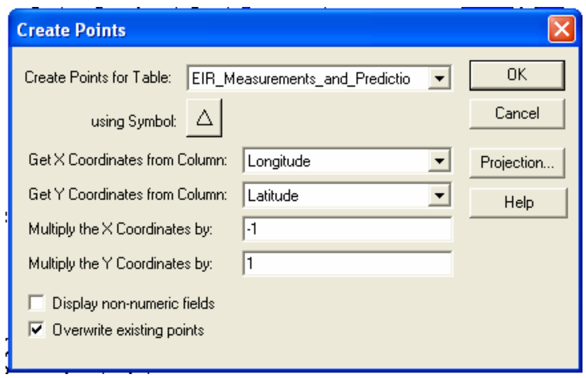
Loading a New Table into MapInfo

This section will guide you through loading a new table from Microsoft Access and visually mapping it.

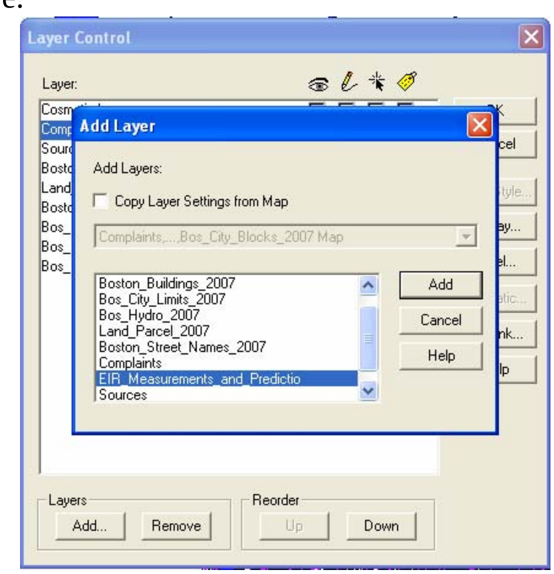
- ➢ On the toolbar Select File > Open
- ➢ Change the Files of type to Microsoft Access Database (*.mdb)
- ➢ Choose the Access file and Click Open
- ➢ Choose the Access Table and Click OK (if the definition already exists, you can overwrite it, but you will lose any data previously used)
- ➢ A new browser will appear with the data from your Access Table.



- ➢ To map this, have the Browser as your current window, and in the toolbar Select Table > Create Points…
- ➢ Select the table from the dropdown
- ➢ Choose the symbol you desire
- ➢ Input the column "Longitude" for the X-Coordinates and "Latitude" for the Y-Coordinates
- ➢ MapInfo is based on a quadrant system. This means that the Longitude must be negative. If it is not negative in your Access table, you can make it negative by multiplying the X-Coordinates by -1; otherwise, leave the next two boxes as they are.
- ➢ Click OK



- ➢ The points are still not displayed on the map; you must first add a new layer. To do so, Select Map > Layer Control
- ➢ In the Layers Box: Click Add…
- ➢ Choose your table and click add
- ➢ Click OK



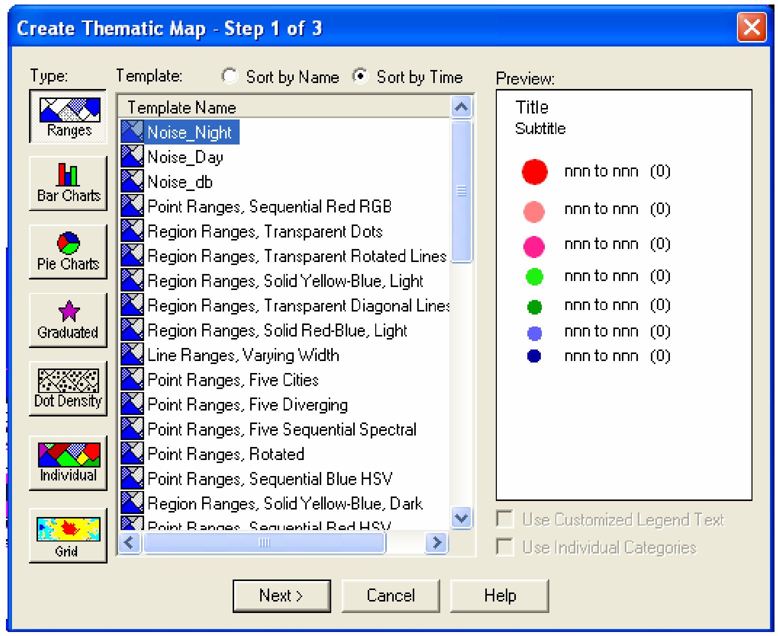
➢ Your Map should display the new information

Thematic Mapping

➢ In the toolbar select Map > Create Thematic Map…

➢ Step 1 of 3 - Select your desired theme (i.e. The L90 for Daytime EIR Datum is mapped using the template Noise_Day)

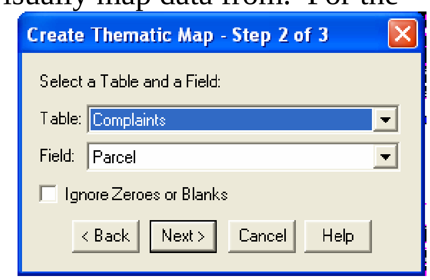
➢ Click Next



➢ Step 2 of 3 - Select which table and field you want to visually map data from. For the sake of this tutorial, we will select the Table: EIR_Measurements_and_Predictions and Field: L90_32Hz

➢ Leave the box “Ignore Zeroes or Blanks” blank

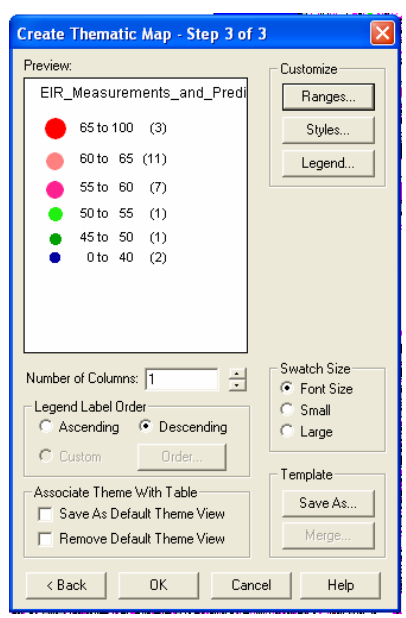
➢ Click Next



➢ In Step 3 of 3, you can change the color-coding, size, ranges, and legend.

➢ Click OK.

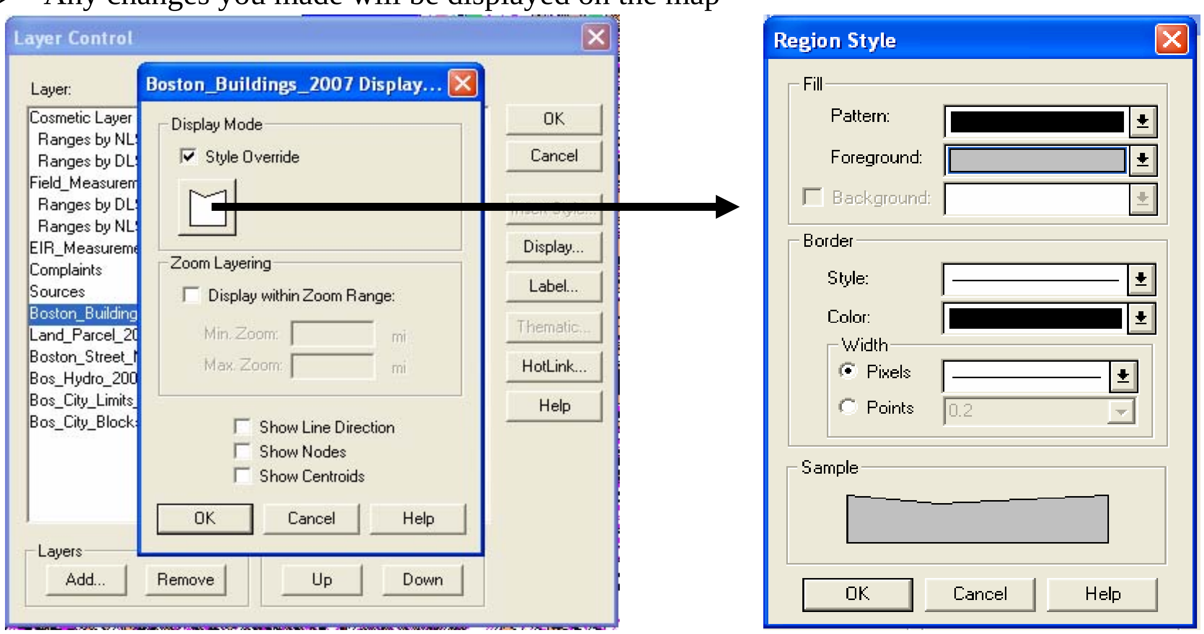
➢ The map should display the new data.



Altering information that is displayed

You can easily change which layers are displayed, which are on top, and even the coloring of base layers.

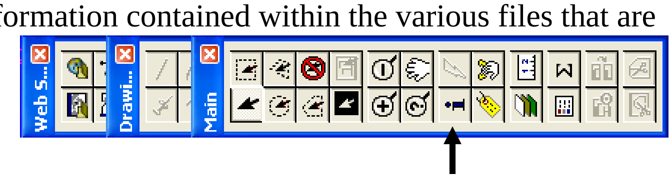
- In the toolbar>Map>Layer Control…
- A box titled Layer Control will appear. Within this box, you can select a layer, and by using the Up/Down buttons, move it to the foreground or the background. Additionally by checking/unchecking the column of boxes under the "eye", you will make the layers visible/invisible. The third column, under the picture of the arrow, will make a layer selectable when viewing the map. This is important if, when using the information tool, you only want to click on one specific layer, and ignore any others.
- Layers that are indented and start with "Ranges by" are the layers that correspond to the thematic mapping. These layers correspond to the tables below the indented range.
- To alter the coloring of layers, click the Display… button
- Check the Style Override box
- Click the button under the checkbox
- Within this box you can change the pattern, foreground, style, color.
- Click OK three times
- Any changes you made will be displayed on the map



Using the Info Tool

This will guide you through how to display all information about a specific point.

- In the main toolbar, click on the "**i**"
- Click any point on the map
- Select the information you want by double-clicking on the layer in the Info Tool box
- The new window will show all the information contained within the various files that are open



Appendix D

MapInfo Layers

There are many different ways to visually display databases, and in particular, noise databases. The team decided to make good use of MapInfo v8.5 because it can easily be interfaced with Microsoft Access. As Access was already being used by the Noise Inspector for the BED to log noise complaints, it was a logical progression of thought to use her databases as a stepping stone and developing it to include noise data from SML's, projected noise, and source data. This improved, more inclusive database can then be opened in MapInfo to display a large variety of different data.

MapInfo is based on using information contained within tables. When an Access table is first opened, MapInfo creates a .TAB file extension which converts the Access table into a table that MapInfo can understand. This .TAB file also tells MapInfo what to do with the information, and how to visually display it. A browser window can then be opened to display the table and the information contained within it, or a map window can be opened to illustrate the data within the table. Each .TAB file creates a layer in the map window. This layer can then be put on top or underneath other layers, colored, labeled, and a large variety of other things. These layers are what ultimately creates the map and displays the information that the user wants to know.
We first obtained base layers of the City of Boston from the BRA, these layers are what generate the "map" of Boston, populated by streets, buildings, and parcels. It took six layers to create the base map of Boston. These layers included Parcels, Streets, City Blocks, Buildings, City Limits, and Hydro. Upon loading these various layers into MapInfo, we were ready to begin importing our data into the map.

The first thing we did was import the Access tables for the day and night SML's. Using the command "Create thematic map", we created points on the map that showed each SML for the West End, color-coded and sized by the L90. The range was set at 5 dBA, because less than this much of a difference, the human ear does not recognize any difference in the noise level. This division also allows the user to know what points are over 65 dBA (the daytime noise limit), and which points are "safe" or below that maximum noise level. Over time, with the population of more SML's, and thus having a greater density of points, the user can then begin to understand the ambient noise level for the area, instead of just in the immediate vicinity of the

SML. Figure 1 illustrates the division for the thematic map and the points created as an additional layer on top of the base map.

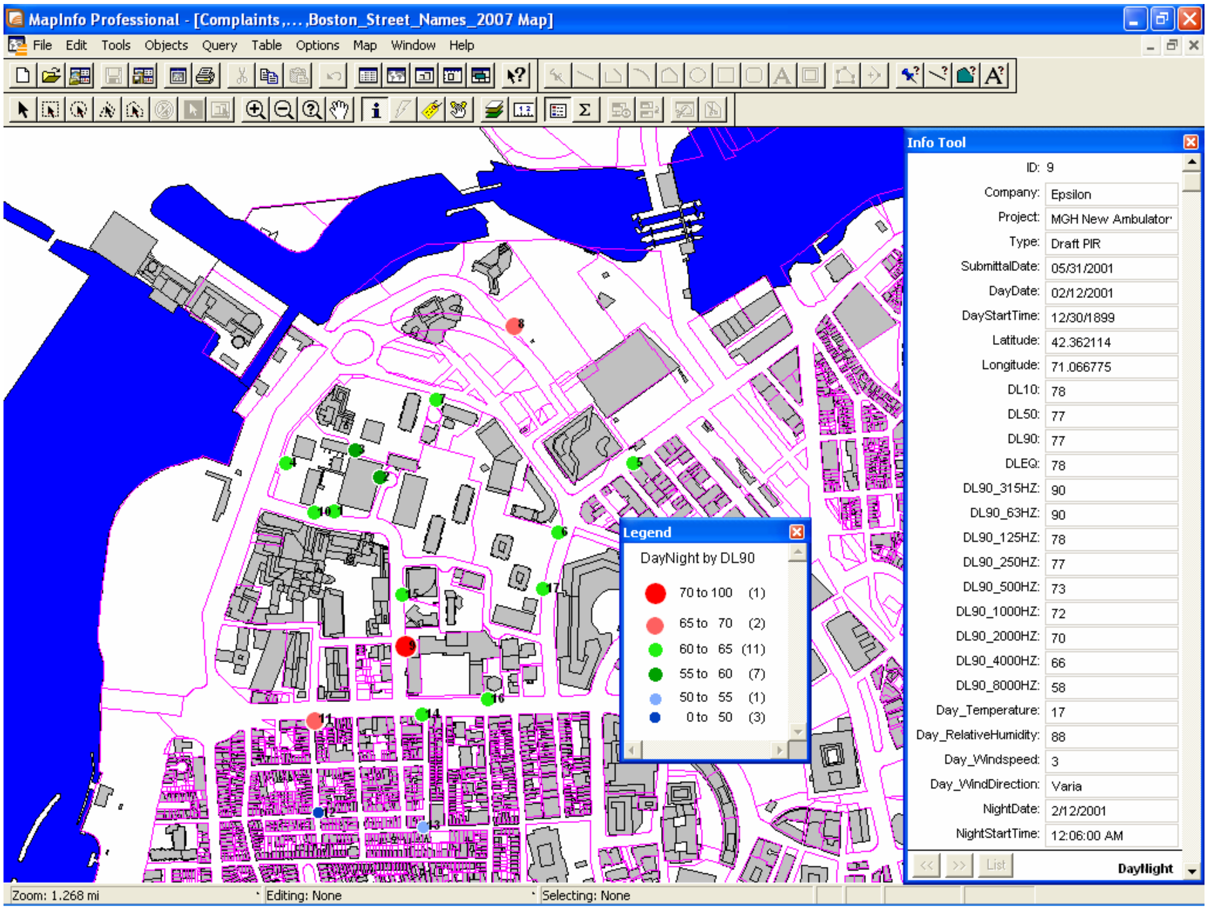


Figure 1: Base Map with Day SML's Layer

The legend in the preceding layer shows the division of the different point in dBA. Additionally, by using the "i" tool in the toolbar, the user can click on any point and the box "Info Tool" will be displayed, showing all the information contained within the table from that point. This box is showing the data for Point 9, which is the largest, red point on the map. By looking at the Info Tool, one can see that the DL90 (Day L90) is 77 dBA. This kind of information can assist the BED with enforcement. Obviously there is something that is generating a lot of noise at this point, and the Inspector can go out and investigate the different sources. This brings us to the next layer, the Source layer. With each EIR, a list of sources is given, i.e. Fans, HVAC, generators, Cooling Towers, etc., along with the various sound measurements attributed to those sources. Attached to each parcel is this source data. When the user, using the info tool, clicks on the parcel all the sources will be listed. This will allow ownership to be discovered in a much quicker, efficient way, in addition to whether or not the various sources can actually generate the level of noise that is being detected.

To assist the inspector even more, we have taken her Complaint database, the database that we originally started with and built off of, and added an additional layer to base map. This complaint layer has the origin of the complaints for the West End mapped using red flags. Once again, these points can be selected using the Info Tool, and the information about the complaint will be displayed. Adding this layer allows the Inspector to view the density of complaints, and hopefully work more from her office. If a person calls in with a complaint, she can log that, and, looking at the map, view the sources in the immediate area. This helps the BED because now the Inspector knows the ownership and location of each source, so she can simply go directly to the problem and serve a notice to the owner. Before, she would have to take initial readings, and then walk around until she found the problem. By using MapInfo to view complaint density, she has already cut-down on travel time and time spent looking for a source.

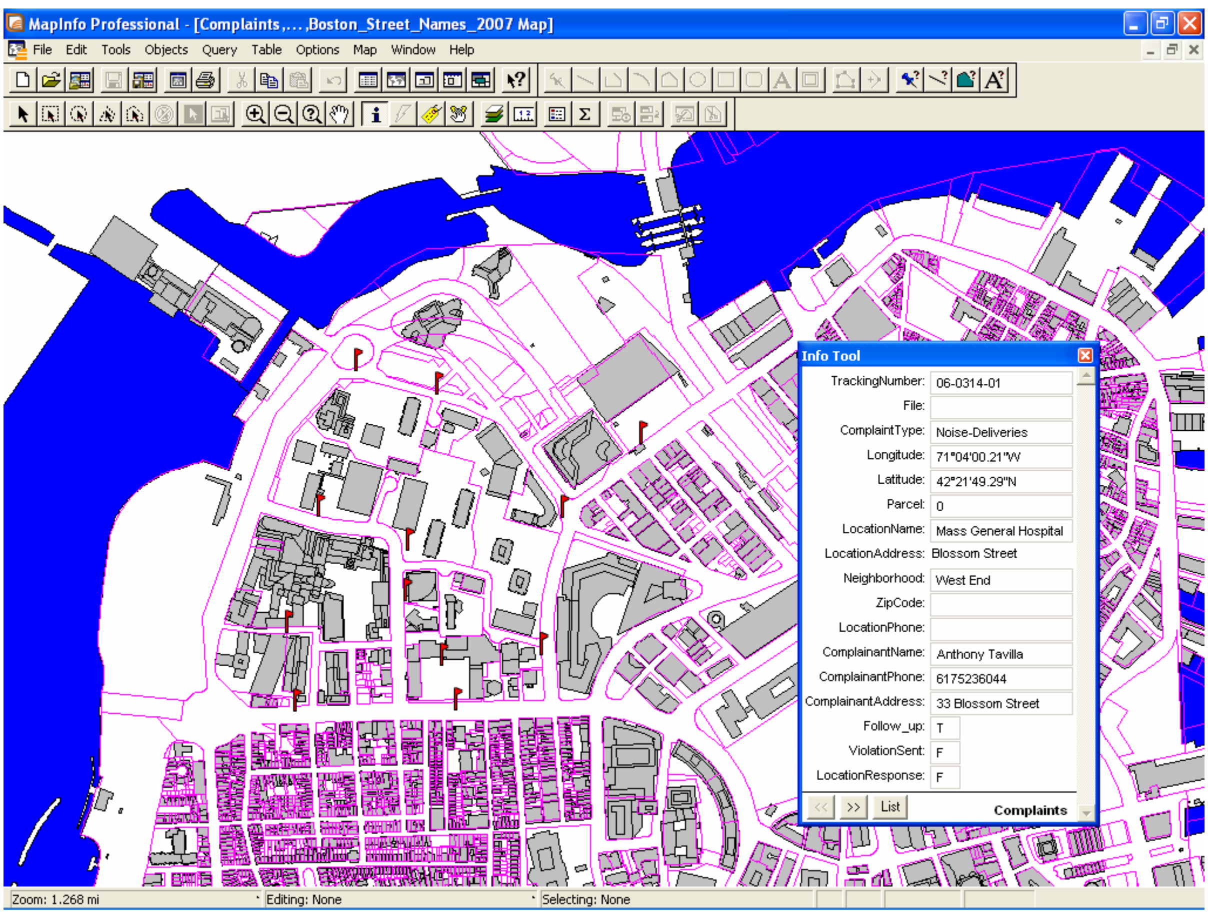


Figure 2: Base Map with Complaint Layer

We also incorporated our field measurements into the map, and they can be used to further populate the map. Unfortunately, they were taken at the same point as the SML's, so we cannot show them both at the same time, but it is an additional layer that shows more recent measurements, and gives the BED a better idea of the noise levels in the West End today. MapInfo is a very powerful tool, and one which can be developed further to the point where one day, the EIR Consultants can view the data online and populate the map with noise data on their own. Using the "Create thematic map" command, any type of information can be displayed. Information can by shown by L10, L50, Leq, or any octave band that is desired. The key is maintaining the Access tables and loading them into MapInfo. Once there, any new data that has been added to the Access table will be automatically displayed.

Appendix E

Quest Model 2800 Downloading Using HyperTerminal

The following is a guide for using the print feature on the Quest Model 2800 Integrating Sound Level Meter. Using the print function with a computer provides a direct download of the following information:

QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
DATE:________ SERIAL NO. ________ CALIBRATED: ___________

"A" WEIGHTING / SLOW RESPONSE

LEQ(dB)	MAX(dB)	MIN(dB)	SEL(dB)	RUN-TIME	OL-TIME
66.7	81.2	59.8	97.4	:20:00	

EXCEEDANCE LEVELS(dB)

	0	1	2	3	4	5	6	7	8	9
L00	81	75	74	73	72	72	71	71	71	70
L10	70	69	69	69	69	69	69	68	68	68
L20	68	68	68	68	67	67	67	67	67	67
L30	67	67	66	66	66	66	66	66	66	66
L40	66	66	66	66	66	66	66	66	66	66
L50	66	65	65	65	65	65	65	65	65	65
L60	65	65	65	65	65	65	65	65	64	64
L70	64	64	64	64	64	64	64	64	63	63
L80	63	63	63	63	63	63	63	63	63	63
L90	63	63	63	62	62	62	62	62	62	61

There are three parts needed for the download process. The first is the Model 2800 meter. The second is a cord to connect the meter to a computer's serial port. The third and final piece is a computer with the communication program HyperTerminal. This program comes standard with the Windows operating system.

1/8" into quest model 2800 Print jack

Figure A

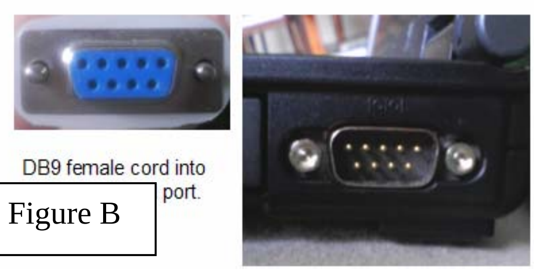
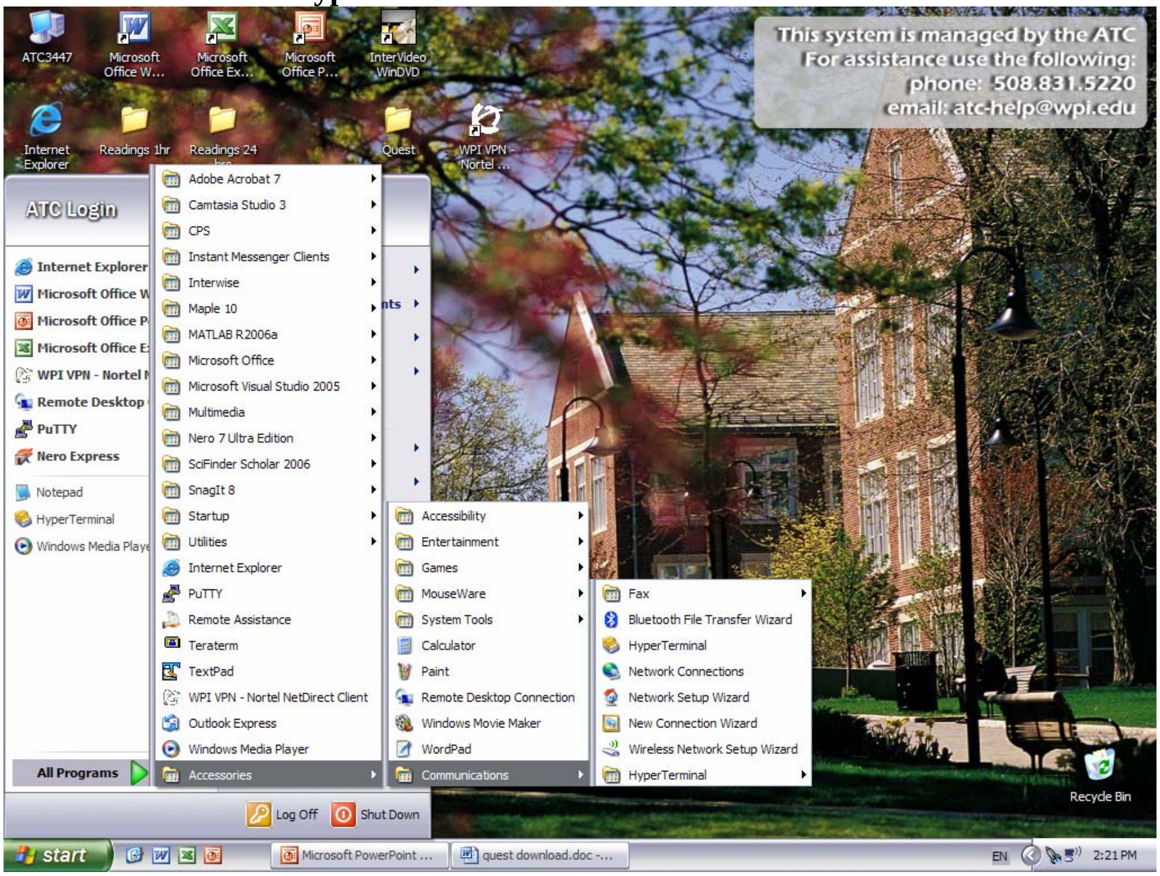

DB9 female cord into port.

Figure B

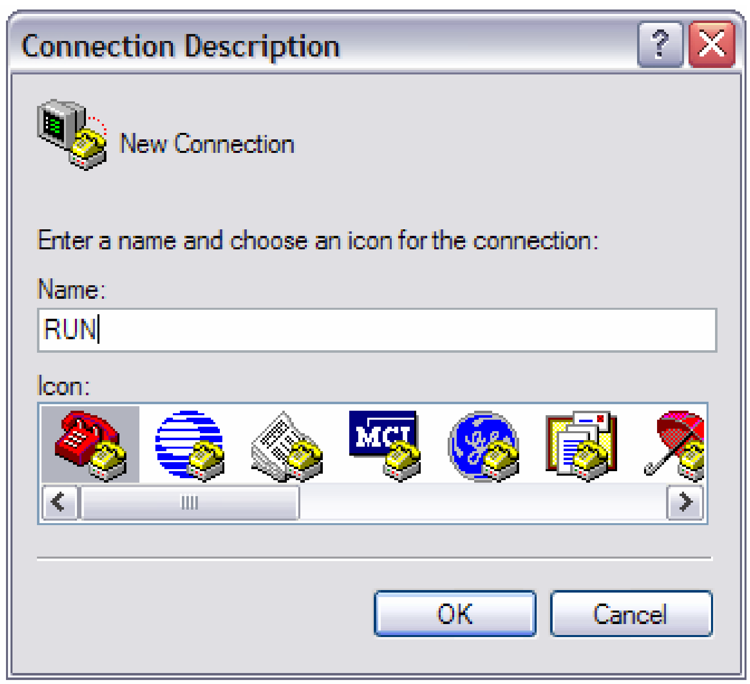
The first step is to connect the Quest meter with the computer. The meter comes with a cord having a 1/8" jack on one end (headphone plug) and a DB25 connector on the other end. You must connect the DB25 end to a DB9 serial port on a computer. Utilizing a DB25 to DB9 converter and then a DB9 extension cord enables connection to the computer. To connect, first plug the 1/8" end into the Quest meter output labeled Print (Fig A). Then connect the DB9 cord to the computer's serial port (Fig B).

Once the meter is connected to the computer you must open the HyperTerminal Program. Go to **Start** >**All Programs** >**Accessories**

>**Communications** > **HyperTerminal**.



The first screen encountered in HyperTerminal will be **Connection Description** and it will ask for a name as well as an icon for the connection. This does not have an effect on the download process and can be named anything. Name it something arbitrary such as RUN and click **OK**.



The next screen will be **Connect To** with four different places for entry. Under **Connect Using** select the COM port that the device is connected to on the computer. This is usually **COM1**. The other entry spaces should then turn Gray. Click **OK**.

This will bring you to the COM port Properties and needs to be set as follows.

Bits per second: = 2400 (Make sure to set the baud rate on the Quest meter to 2400. This can be done behind the battery. Consult your user manual for further instruction.)

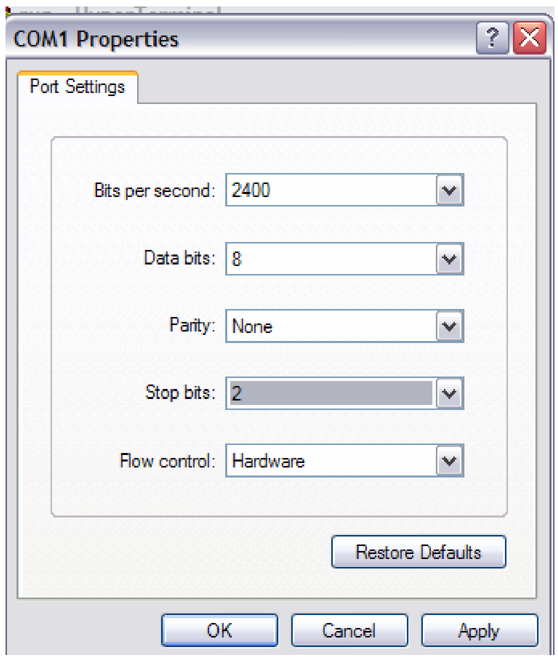
Data bits: = 8

Parity: = None

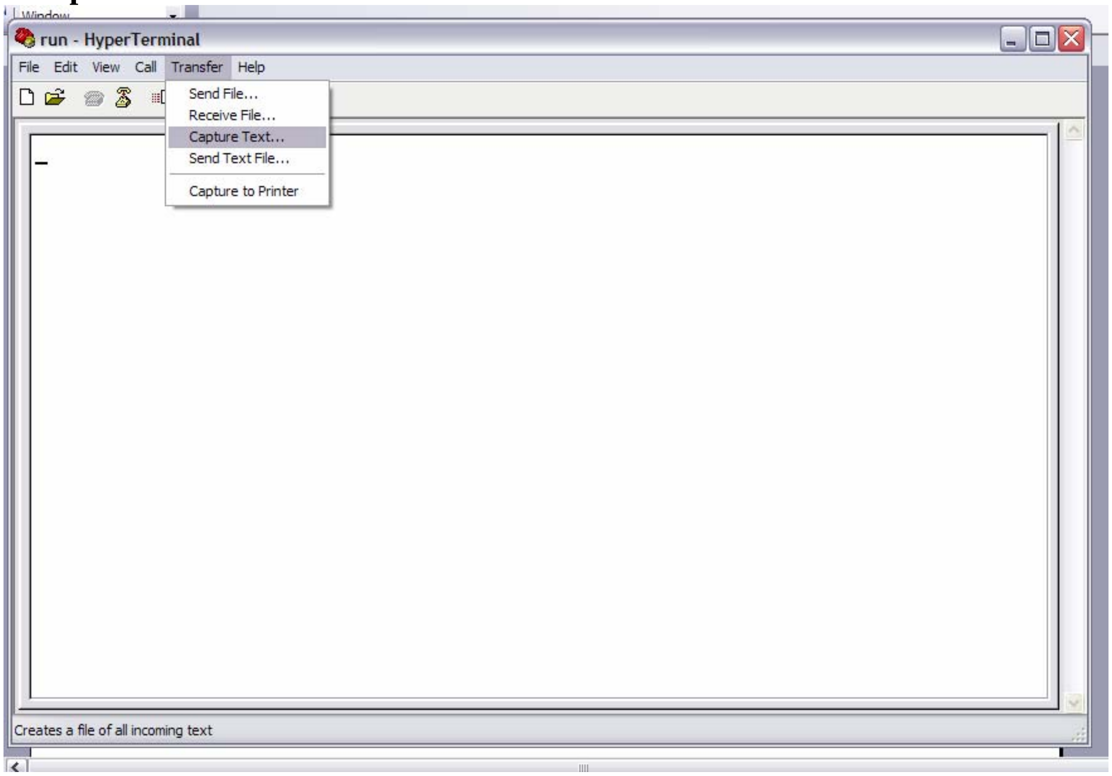
Stop bits: = 2

Flow control: Hardware

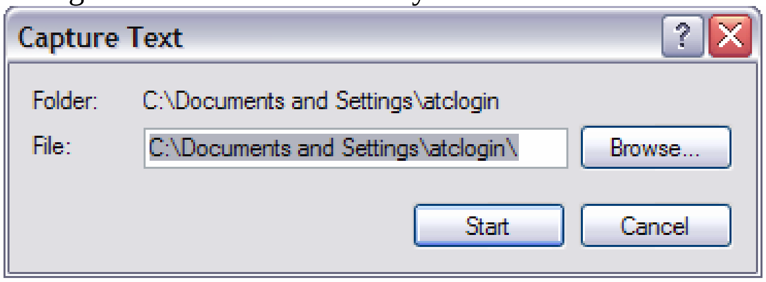
After setting everything click **Apply** and then **OK**.



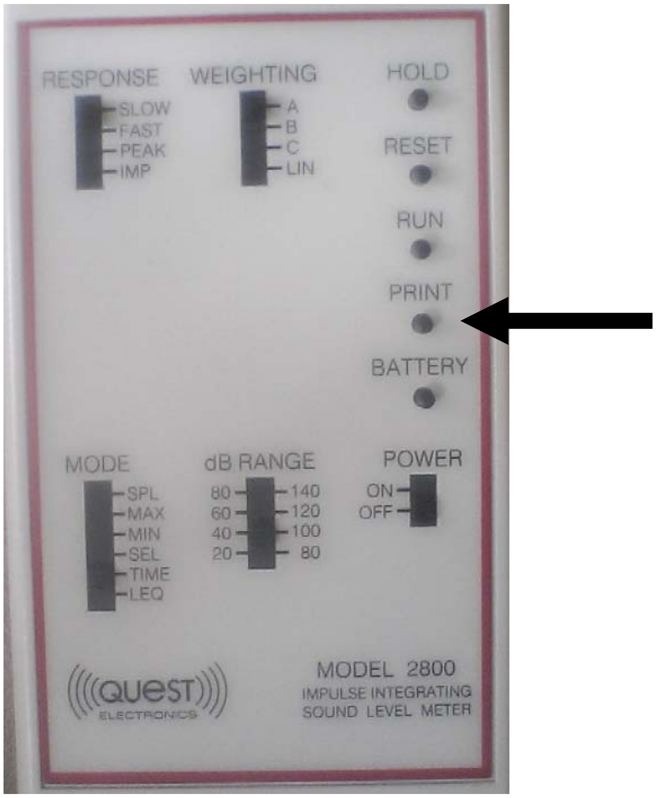
Now all the settings are correct and the connection is ready. To start the capture select **Transfer > Capture text**.



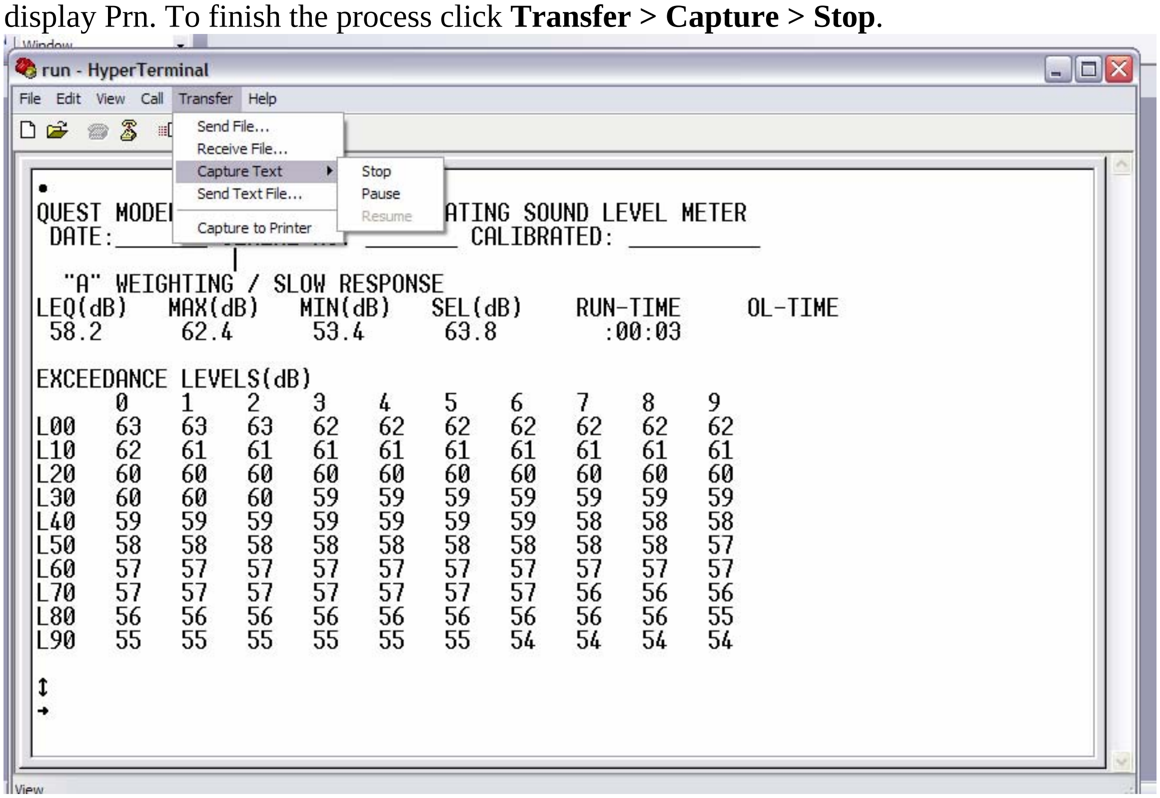
The Capture Text selection box will come up. Select a destination for your download file to go by using the **Browse…** tab. Once you have selected a destination click **Start**.



The program is now able to accept data from the com port. On the Quest devise press the Print button.



The display on the Quest device should now read Prn and the HyperTerminal program will show the data as it is downloaded. Once the download is complete the Quest device will no longer display Prn. To finish the process click **Transfer > Capture > Stop**.



The download is now complete. Close the window. It will ask if you are sure you want to disconnect now. Select **YES**. It will then ask if you would like to save the connection. Select **NO**. The file is now saved wherever you chose to save it in the earlier step.