ASSESSMENT OF RAILWAY ACTIVITY AND TRAIN NOISE EXPOSURE:
A TEANECK, NEW JERSEY, CASE STUDY

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ABSTRACT OF THE THESIS

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Three train tracks run through Teaneck, NJ, a suburban city, unimpeded by road crossings; the tracks are as close as 7 meters to residential properties. In 2000, trains began idling in Teaneck for extended periods of time (up to 54 hours), exposing residents to persistent, elevated sound levels, as well as diesel emissions, and generating complaints. The goals of this study were to characterize the time-activity patterns of passby and idling trains; idling locations; and the sound emission levels of passbys, idling locomotives, and train horns over a one-year period. From October 2006 through November 2007, source sound levels were measured continuously with a Norsonic 121 sound-level meter and WAV files of actual sounds were recorded during train events. Concurrently, research staff visually noted train activities 24 hours/day, every third day, for three consecutive weeks each season, including train direction, track, idle location, locomotive-to-meter distance (idles), and other identifying information. Specific source characterization measurements of individual locomotives were made at measured distances with a hand-held Quest 2900 sound-level meter. Over this time period: ~1.2 trains passed per hour (1.1 daytime; 1.4 nighttime, 10 p.m.-7 a.m.); average passby duration was 2.8 minutes; and passbys were most frequent during the midnight hour. Trains tended to travel southbound during the day and northbound at night, resulting in horn blowing behind homes, while people slept, as the trains approached a grade crossing on Teaneck’s northern boundary. Idles averaged 87.2 minutes in duration, with the longest lasting ~36 hours. Idle events occurred equally in southern and northern Teaneck, but average idle durations in southern Teaneck were 2-3 times longer than all other locations. Train(s) idled in Teaneck for a total of ~10.7 hours/day, or 44.6% of the time. Average sound levels at 30.5 meters (100 feet) were: 78.1 dBA (peak: 84.9 dBA) for passby trains; 65.0 dBA (68.5 dBA) for single, idling locomotives; and 104.3 dBA (109.0 dBA) for train horns. Ambient sound-level measurements in neighborhoods had an Ldn of ~50 dBA. Sound emissions from train activity produced moderate-to-severe noise impacts in areas within 152 meters (500 feet) of the railway, especially during non-summer nights.

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1. INTRODUCTION

1.1 Motivation

Noise can be described in many ways, but the meaning most widely used by the general public defines noise as undesirable and/or excessively loud audible sounds impacting a person's ears. For instance, loud music blaring from a home may be perfectly acceptable to one neighbor who enjoys listening to the same kind of music; however, another neighbor may consider the music to be noise, e.g., unwelcome sound emissions. As a result, noise is subjective, with the defining criteria varying from person-to-person. Furthermore, the consequences of noise range can from a minor inconvenience; to the disruption of and interference with activities inside and outside the home; to physiological harm, such as increased agitation and tension, sleep deprivation/fatigue, and higher blood pressure (Saremi et al., 2008; Ising et al., 1999; Babisch, 2000). In addition to direct impacts on people, noise has also been shown to affect property values (Bellinger, 2006; Cushing-Daniels and Murray, 2005). To this day, exact and measurable physiological noise impacts remain difficult to quantify, but the anecdotal and real-world evidence is clear. Noise has genuine, tangible effects on peoples' lives and health.

Railways are notorious for sound-producing activities, many of which have delighted and fascinated children and train enthusiasts for nearly two hundred years. However, the same sounds have also been deemed annoying, upsetting, and completely aggravating to people who were unwillingly subjected to the sound emissions. Each individual's perception of railway sound emissions generally depends on the person's interest in trains as a hobby and the proximity of the person's residence to an active railway, especially tracks on which 1) train activities occur 24-hours a day; 2) horn use is prevalent; and 3) locomotive idling is possible. The issue of train noise adversely affecting people, especially those in residential neighborhoods, has become a major source of contention in the township (city) of Teaneck, New Jersey, during the past ten years because many of its residents have suffered from some level of all three types of train-noise impacts.

Teaneck is a suburban area located in northeastern New Jersey, less than 10 miles to the northwest of central New York City, New York, with approximately 40,000 residents (www.city-data.com). The township is largely residential and contains gradually varying terrain from about 6 meters (20 feet) above sea level to nearly 49 meters (160 feet) above sea level, with the lowest elevations running north-south through the middle of the city and providing an almost flat thoroughfare for three train tracks known as the West Shore Line or River Line. This rail line is nothing new to the area. Historical descriptions and aerial photographs of the township from the 1930's (**Figures 1.1 and 1.2**) indicate that at least two tracks have been running through the area for at least 80 years and, for a period in the middle of the 20th century, as many as four tracks were in active use. However, as the need for railroads decreased over the years, the line was reduced to only two tracks again by the early 1970's. The line was modified to its current state of three tracks (**Figure 1.3**) sometime in the year 2000, after the CSX Corporation took control of the rail line in 1999. This gave the railroad company more flexibility with its freight train movements and added capacity for stopping and idling trains when routing and trafficking issues arise.

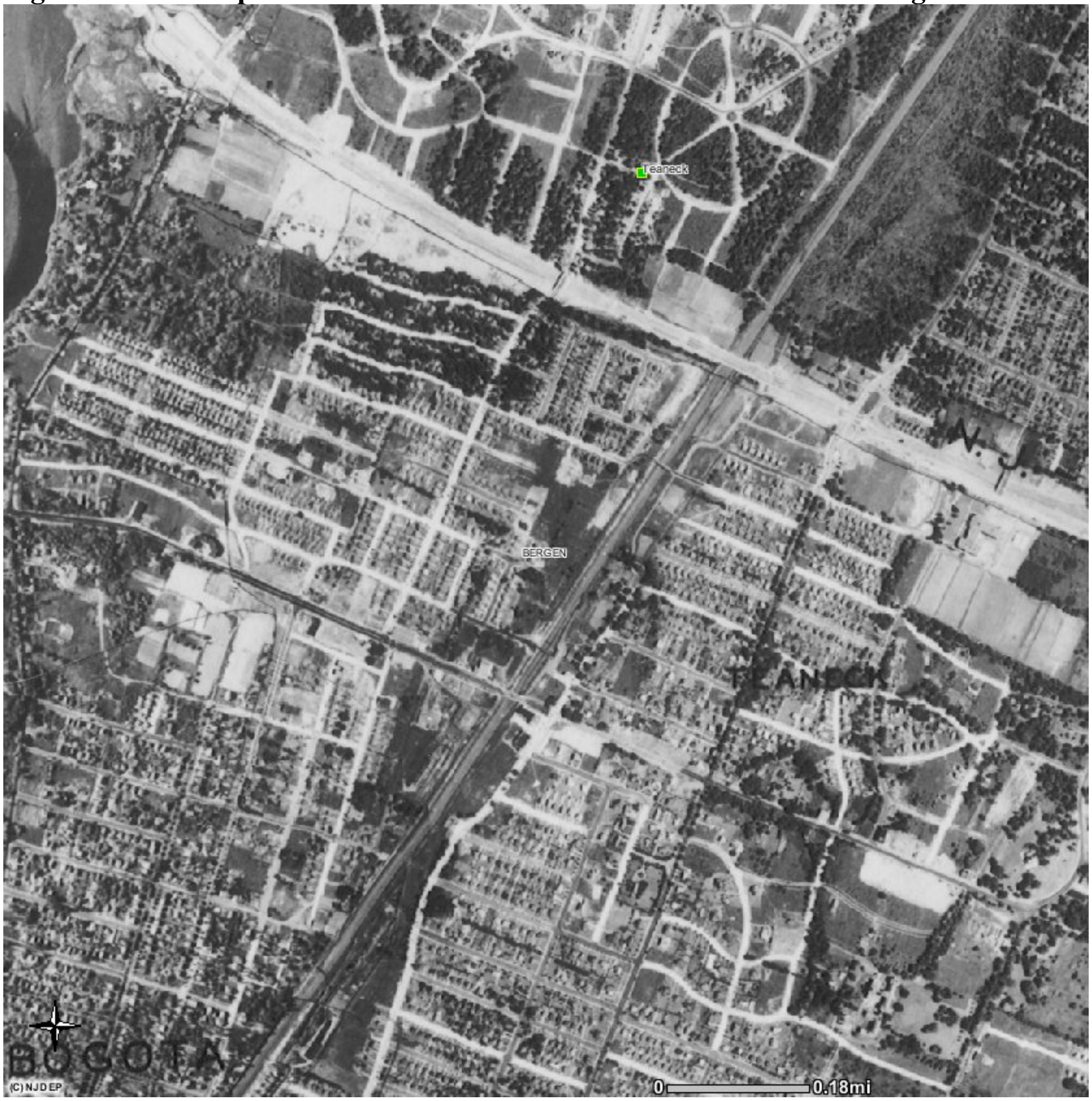
Railway sound emissions and the perception of noise by residents who live adjacent to railroad tracks are not unique to Teaneck; however, the train activities on this

Figure 1.1 Aerial photo of the rail corridor in northern Teaneck during the 1930s

Source: New Jersey DEP

part of the West Shore Line are distinct in that the 4.15 kilometers (2.58 miles) of track contain no at-grade crossings, places where streets intersect the tracks at the same elevation. In the early 20th century, when there were two tracks, Teaneck's township managers decided to build overpasses for all roads crossing the tracks (**Figures 1.1 and 1.2**), to improve the flow of vehicles and people between the two sides of the tracks. As a result, freight trains with lengths of nearly two miles can stop within Teaneck without

Figure 1.2 Aerial photo of the rail corridor in southern Teaneck during the 1930s



Source: New Jersey DEP

disrupting a single road. The result is idling of locomotives within 15 – 20 meters (about 50 – 70 feet) of occupied homes for as little as a couple minutes to more than two days. In the northern part of Teaneck, trains are even with the top of many backyard fences, allowing fully unobstructed train sound emissions to impact the homes.

Despite the long history of railroad tracks in Teaneck, idling trains only became a serious community concern in the year 2000, when the third track was re-installed.

Figure 1.3 Teaneck rail corridor with the current configuration of three tracks.

According to the transcript of the New Jersey Assembly Transportation Committee meeting on February 10, 2005 (NJATC, 2005), residents complained that CSX was using the township as a "parking lot" for idling trains. The aggravation expressed by residents at that time provided the primary motivation for the study described herein. As will be discussed in more detail later, the current study of railway operations on the West Shore Line in 2006 and 2007 included observations of idling trains with as few as one to as many as five locomotives running. Frequently two adjacent idling trains were present, and on multiple instances three trains idled simultaneously at the same location, blocking all of the tracks and creating significantly more sound and air pollution emissions than a typical single, idling train.

Beyond the specific sound-related problems associated with passby trains and idling locomotives, additional noises are produced by items on or within the train cars connected to the idling locomotives, as observed during the study and noted in NJATC, 2005. Other sound sources include refrigeration units attached to freight truck trailers and shipping crates being carried on the train cars; a small, continuously running generator engine at the back of the last train car, likely providing electrical power to a red warning light; and the contents of the train cars, namely automobiles, some of which have alarms and have been reported to repeatedly sound for over 24 hours within a clearly audible range of homes. Furthermore, the knuckling of train cars, as in the extension of the links between the cars, creates a loud shockwave of sound that propagates from the front to the back of the trains when they depart after idling. Many residents expressed additional worries related to the safety of people crossing the tracks through an idling train, often unaware of the possibility of passby trains. Numerous issues associated with railway activities have been raised by Teaneck residents. In response, the current study was designed to evaluate the time-activity characteristics of passing and idling trains, the location of idling, and the sound emission levels associated with each type of activity in order to inform the development of effective mitigation strategies.

To abate many of the problems associated with idling noise near homes in the interim, Teaneck officials requested that the locomotive companies idle the trains near a large, unused warehouse in the southern end of the township (**Figure 1.4**) and adjacent to a business park and forested area toward the northern end (**Figure 1.5**). The locations were selected because they had a large building(s) for blocking sound emissions on one side and an open space buffer on the other, both features which reduce the magnitude of sound reaching residences. However, evidence gathered during this study shows that trains stopped in numerous locations throughout Teaneck and even when they stopped in

Figure 1.4 An idling locomotive at the south end warehouse (facing west)

Figure 1.5 An idling locomotive at the north end business park (facing west)

the prescribed locations, trains with multiple locomotives idling extended beyond the barrier(s) (the first locomotive in **Figure 1.4** was even with the northern wall of the warehouse, but the second locomotive extended north to the last house on Thomas St., where no sound obstructions exist), causing much of the sound emissions to reach homes unimpeded. Thus, specification of idling locations was only occasionally effective. The study described herein was designed to provide key information needed to assess the exposure of Teaneck residents to train noise and to inform those developing train noise mitigation strategies for Teaneck.

1.2 Background

Sound emissions from railway activities have been studied in locations throughout the world, including Europe (Pronello, 2003; Talotte et al., 2003) and the Middle East (Ali, 2005). However, the vast majority of railway activity studies are focused on the impact of passenger trains in urban environments. The Teaneck train noise study fills a specific gap in knowledge by characterizing the time-activity of a freight train-only rail line with substantial idling in a suburban setting. This railway study was also unusual in scope: the measurements covered a full year and incorporated both short-term, hand-held sampling during intensive observation periods and long-term, continuous monitoring by an unmanned sound level meter.

As was previously mentioned, noise can have many adverse effects on peoples' attitude, well-being, and overall health. The severity of noise exposures (i.e., minimal, moderate, or severe) is routinely quantified using several standard sound level metrics. The key metrics calculated and analyzed for this study were: average during a specified time period (Leq); maximum (Lmax); minimum (Lmin); Sound Exposure Level (SEL);

and day-night average from midnight-to-midnight (Ldn). The average (Leq) time period is typically specified as one hour, but it can be any length of time, as long as the duration is noted. With regard to this study, most train events lasted much less than an hour, regularly resulting in Leq durations of only a few minutes. The SEL is the total amount of sound energy reaching a receiver during an event but compressed into one second, allowing events from different types of sound producing sources to be compared to one another. An event is a discrete sound-producing occurrence that has a limited duration, is above the accepted background or ambient sound level, and is of interest to someone, such as a train passing by or stopping near the meter. All sound levels were measured in decibels (dB) and the metrics were calculated using the A-weighted scale (dBA), which scales the sound levels at frequencies below 1 kilohertz (kHz) to emulate what the human ear can hear.

Ldn defines a cumulative decibel level for all sounds observed in a specific location during the course of a 24-hour period. The 24 hours are broken up into two periods: daytime (7 a.m. through 10 p.m.) and nighttime (10 p.m. through 7 a.m.), and sound levels at night are increased by a factor of 10 dBA to account for peoples' increased sensitivity to sound impacts during those hours (Hanson et al., 2006). Ldn is used in this study to evaluate the contribution of train sound emissions to existing, background sound levels at specified locations within the Teaneck community.

In this study, sound level measurements and supporting information were collected with multiple meters at multiple locations in Teaneck throughout the course of a year (Section 2), and used to characterize the sound levels and time-activity of train operations in Teaneck (Section 3). The results of this thesis will serve as the basis of a train noise exposure modeling study. Together, the field effort and modeling will be used to identify key sources of train noise and effective methods of train noise mitigation, (e.g., adjustments to train activity patterns, alternatives to the use of train horns, the construction of barriers, and/or the installation of auxiliary power supplies for idling locomotives).

1.3 Objectives

The primary focus of this thesis is to characterize the sources of community exposure to train noise in Teaneck, New Jersey, primarily from idling locomotives near residences. The specific aims are to: 1) document train activity, such as the frequency, duration, and temporal distribution of passbys and idles, over a one year period; 2) obtain extensive sound level measurements of all types of train activity and ambient sound levels using multiple automated and hand-held meters; and 3) compute time-activity statistics and spectral sound emission levels for use as inputs in an acoustical model. The extent and magnitude of noise impacts derived from this thesis research will subsequently be used to evaluate the sound impacts of current train activity; to predict the impacts of potential changes in train activity; and to assess the impacts of potential noise mitigation strategies on community noise exposure in Teaneck. Furthermore, many of the model inputs may be useful to other communities that are experiencing freight train-related noise problems.

The work presented in this thesis is the compilation of efforts from several train study personnel. The field study design was developed by this author working together with Eric Zwerling, Steve Szulecki, and Dr. Barbara Turpin. Field sampling was performed by this author along with Eric Zwerling and Francesco Maimone. This author served as the lead for data management and processing, developed the database that compiled the train activity and sound level results, and assembled the acoustic model base layers. This author supervised three undergraduate students: Craig Matis and Taylor Hays who conducted sound level data processing; and Sumantha Prasad who assisted with the construction of the buildings layer in the model and assembly of the hand-held meter dataset. Eric Zwerling and Steven Szulecki contributed their substantial expertise on noise measurement/modeling and directed the study with Barbara Turpin.

2. METHODS

2.1 Field Sampling

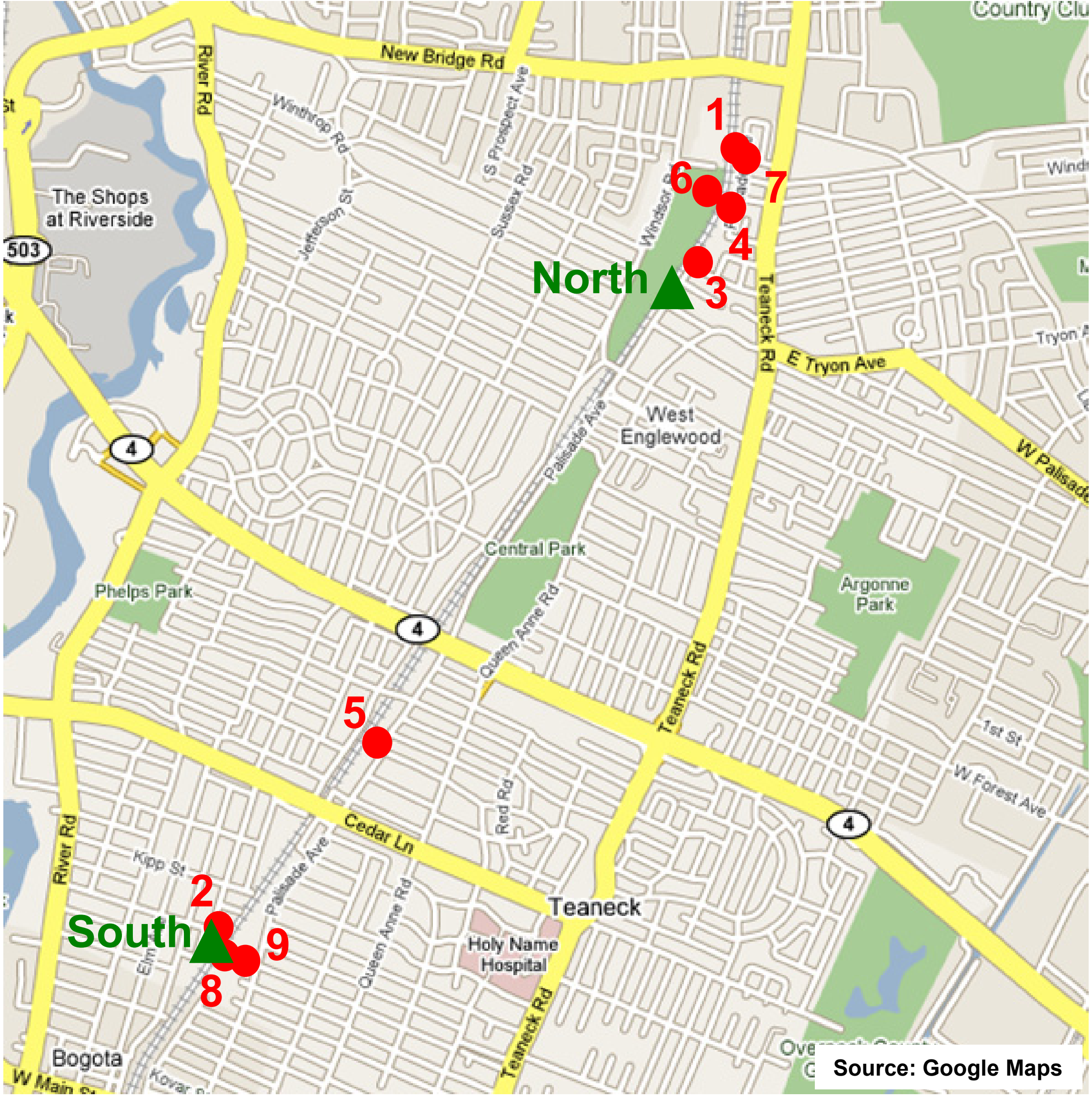
The Teaneck field sampling campaign (October 7, 2006 – November 21, 2007) was comprised of three main components: 1) continuous deployment of an unmanned, secured sound level meter and recorder (long-term meter); 2) in-person train activity observations and hand-held sound level measurements during intensive monitoring periods; and 3) in-person measurements of ambient sound levels in residential neighborhoods using both the long-term and hand-held meters. The primary goal of the long-term meter sampling was to determine the frequency, duration, temporal distribution, and sound levels of passby train events over the course of an entire year. The main goal of the in-person intensive monitoring campaign was to characterize the frequency, duration, temporal distribution, and sound levels of idling trains through visual observations and the collection of hand-held sound level measurements close to the idling locomotives (approximately 18-27 meters; 20-30 yards) and at multiple distances. The hand-held measurements at varying distances around the locomotives were used to "ground-truth" the sound propagation model results. Intensive monitoring also provided additional information for characterizing passby and idling train activity, including which track was in use, the direction of passing trains, the number of locomotives and train cars, the company name of the locomotive(s), and exact idling locations. The ambient sound level measurements were collected independently from the other two sampling components and used to evaluate the degree to which community noise levels were enhanced by train activity.

Monitoring location selection was critical to the success of the study. Initial scoping of train activity by study personnel and discussions with residents and township officials provided crucial information regarding idling locations: by request of the township, trains heading southbound are expected to idle adjacent to an unused warehouse on the south side of Teaneck and trains heading northbound are expected to idle next to a business park on the north side of Teaneck. The intent of the township's directive was to deter trains from stopping directly adjacent to or behind residences and to limit community exposure to train noise through shielding by the warehouse and business park buildings. The understanding that most idling takes place at or near these locations guided decisions regarding long-term meter placement and in-person observations.

Long-term monitoring occurred at nine locations in the southern, central, and northern sections of Teaneck (**Figure 2.1).** Most locations are within 15 to 20 yards of the nearest track and at the same elevation as the tracks in order to obtain unobstructed source sound level data from passby and idling trains. Long-term meter locations were chosen to meet several objectives: 1) characterize passby train activity and sound levels; 2) capture idling rate of occurrence, duration, and possibly sound levels in multiple locations; 3) avoid sound level interference from sources external to railway activities and obstructions between the trains and the meter; 4) provide easy site access for study personnel; and 5) minimize the risk of damage to the monitoring station by locating it within vegetative cover and away from areas frequented by people.

Intensive monitoring periods were conducted on a fixed schedule over a three-week period, each season, and involved staffed visual observations and sound level measurements with hand-held meters. Every third day during the three-week intensive periods, train study members monitored and logged train activity, in three 8-hour shifts,

Figure 2.1 Map of the various long-term meter locations (red circles) and "township-approved" idle locations (green triangles)



for a continuous 24 hours. This study design ensured that monitoring occurred across all days of the week and seasons, representing train activity and operations over the course of a year. When possible, based on the train idling location and duration, accessibility, and obstacles, train study personnel took hand-held sound level measurements perpendicular to the center of each running locomotive and at multiple distances from the train to capture sound level degradation as it propagated out into the surroundings. These data were used for source characterization of the idling locomotive(s) and for comparison with the output of the sound propagation model discussed in Section 2.3. Furthermore, if a train idled within visual range of the long-term meter during an intensive, the distance between the long-term meter and the locomotive(s) was measured and the sound levels collected by the long-term meter were used to enhance the sound source characterization derived from the hand-held measurements.

The final component of the sound level monitoring campaign involved establishing background sound levels within residential areas of Teaneck through in-person measurements. Sound level samples were measured on residential properties at various locations on both sides of the tracks, at multiple distances from the tracks, in the southern and northern portions of the township, and at three different times of the day: morning or evening rush hour; mid-afternoon; and middle of the night. This enabled the impact of sound emissions from railway activity on the Teaneck residents to be compared to the existing (background) sound levels.

To achieve the field sampling goals, multiple sound meters and several supplemental pieces of equipment were obtained.

2.1.1 Equipment

The key piece of equipment acquired for the long-term, continuous measurements was a NorSonic 121 sound level meter (NorSonic, Tranby, Norway) shown in **Figure 2.2**, which collected broadband and spectral sound level data from 0.125 Hertz (Hz) to 16 kilohertz (kHz) and calculated key sound level metrics. The meter was deployed as part of a sound level monitoring station that also included a microphone with an outdoor protection kit (NorSonic 1212, NorSonic, Tranby, Norway) and foam windscreen

(NorSonic 4520, NorSonic, Tranby, Norway); an adjustable height microphone stand; a removable 2 gigabyte (GB) flash memory card; two marine deep-cycle batteries to provide sufficient power and longevity even during exposure to cold winter temperatures when battery performance is reduced; and a large, industrial metal tool box with camouflage paint and chains for security purposes.

Figure 2.2 Sound analyzer and deep-cycle batteries

A second 2 GB data card and two additional batteries facilitated recharging and data retrieval during site visits. The station was self-contained and portable, allowing it to be deployed for 10 – 14 days without servicing.

Most long-term meter deployment locations were in undeveloped areas near the train tracks where there were bushes and trees but no sound-blocking obstacles between the tracks and the meter. At these locations the microphone was attached directly to the top of the tool box, approximately 0.75 meters (2.5 feet) above the ground. For two locations near Teaneck residences on the north side of the township, specific siting criteria had to be employed to prevent sound reflections and other sound-emitting devices from impacting and interfering with the measurements. The criteria consisted of placing the microphone at least 3 meters (10 feet) from the nearest large obstacle, such as a home, detached garage, or shed, and at a height greater than any smaller obstacles, such as fences; a height of 2 meters (6.5 feet) was sufficient. An additional consideration was the location of air conditioning units and other sound-emitting sources. Study personnel evaluated the surroundings and placed the microphone at a sufficient distance from any sound sources to make them irrelevant with respect to background sound levels or in a location that shielded the microphone from any obvious, stationary sound sources. Overall, the meter was remarkably reliable and the sound-level monitoring station worked exceptionally well.

Hand-held noise meters (Quest 2900 and Quest Sound Pro, Quest Technologies, Oconomowoc, Wisconsin) were also used for monitoring sound levels. The meters primarily measured sound imission levels at measured distances from idling locomotives during the intensive observation periods, where imission is the amount of sound received at a location away from the emission source. The Quest 2900 proved to be simple and reliable; it only stored Leq, Lmax, Lmin, and the sample duration of each measurement. However, because of it simplicity, it was very dependable and consistent. The Sound Pro meter is more sophisticated than the Quest 2900, measuring all of the same parameters as well as collecting spectral data from 16 Hz to 16 kHz. Unfortunately, the Sound Pro meter required frequent battery recharging and occasionally malfunctioned, resulting in the loss of six measurements. Measurements were taken using both meters, but due to the performance differences, many more samples were taken with the 2900 (132, of which 116 were valid) than with the Sound Pro (84, of which 61 were valid). Appendix B contains the complete data set.

In conjunction with the hand-held meters, observers used a laser rangefinder (Yardage Pro, Bushnell, Overland Park, Kansas) for measuring the exact distance the sound level measurement was from the source. The rangefinder had a functional range of 4.6 meters (5 yards) to 732 meters (800 yards) and an accuracy of 0.9 meters (1 yard). Having accurate distance measurements was critical to understanding sound propagation from the source because sound levels dissipate with distance, especially over soft terrain. Knowing the distance from the source for all measurements allowed the sound imission levels recorded by the meters to be standardized to a single distance of 30.5 meters (100 feet).

2.1.2 Long-term Monitoring

Continuous sound level data were collected by the long-term meter over 55 sampling periods between October 7, 2006, and November 21, 2007, and at multiple locations within Teaneck. These measurements provided an annual assessment, primarily of trains passing through Teaneck (“passbys”). However, idle events were occasionally detected, indicating the presence of a train in the vicinity of the meter, but without a distance measurement between the train and the meter, in most cases, the sound level data were not usable. Details about the sampling locations are included in **Table 2.1** and the sampling periods associated with each location are listed in **Table 2.2.** During this “annual” sampling campaign, 8815 hours (367.3 days) of data were collected. Of the

8815 hours of data, 8787 hours were valid, producing a data capture rate of 99.7%. The only invalid data resulted from a 28-hour period near the end of March 2007 when the microphone stand was blown over by strong winds. During this period, the occurrence and duration of passby trains were still noted, but these sound level data were excluded from all analyses. As discussed in more detail in Section 2.2, 41 of the 55 data sampling periods (291 days of data) were processed by study personnel, producing a dataset containing 7,532 passby events (804 of which occurred during intensive monitoring days), 206 idling events, and 3 "engines off" events.

The strategy initially designed for long-term monitoring involved placement of the long-term meter in locations along the tracks in north, central and south Teaneck. However, with experience at these sites it became clear that during non-intensive periods, the goals for long-term monitoring were best accomplished with data collected on the north side of Teaneck. This is because the north side (particularly Locations #1 and #6) had minimal interference from idling trains and extraneous noise sources. During intensive monitoring periods, when on-site staff could directly measure the distance between idling trains and the long-term meter, monitoring in both north and south was valuable because the data could be used to calculate sound imission levels during idling. Of the approximately 367 days on which sound level data were collected by the long-term meter, 69.9% were collected in the north (**Figure 2.1**, Locations #1, #4, #6, and #7). A total of 22.5% were collected at the township-approved idling locations (**Figure 2.1**, Locations #3 and #2 & #8), and 7.6% were collected at other locations in central Teaneck (**Figure 2.1**, Location #5, near the tracks) and southern Teaneck (**Figure 2.1**, Location #9, farther from the tracks). Across the seasons, 31.3% of the data were collected in the

Table 2.1 Long-term meter locations

Location	Map ID^a	Site Description	Distance to Track A m (yds)	Distance to Track B m (yds)	Distance to Track C m (yds)	Elevation Relative to Tracks m (yds)
1	92	North-side Home – Behind Back Fence	21.9 (24)	18.3 (20)	11.0 (12)	0 (0)
2	14	End of Thomas St.	14.6 (16)	18.3 (20)	25.6 (28)	4.57 (+5)
3	75	Charter School	20.1 (22)	16.5 (18)	9.14 (10)	0 (0)
4	81	North of Spice Factory	38.4 (42)	34.7 (38)	27.4 (30)	1.82 (+2)
5	40	Mid-Teaneck Parking Lot	27.4 (30)	23.8 (26)	16.4 (18)	5.49 (+6)
6	83	Givaudan Office Building	12.8 (14)	16.4 (18)	23.8 (26)	0 (0)
7	91.5	South of North-side Home	33.8 (37)	30.2 (33)	22.9 (25)	0 (0)
8	10	Soap Factory Side Rail	29.2 (32)	25.6 (28)	18.3 (20)	1.82 (+2)
9	9.5	End of Griggs Ave.	122 (133)	118 (129)	111 (121)	12.8 (+14)

[a] Identification numbers reference labeled aerial images in Appendix A.

fall, 23.0% in the winter, 23.6% in the spring, and 22.0% in the summer. Note, the annual sampling campaign began and ended in the fall. To compensate for disproportionate amount of data collected in the fall and for other reasons described in detail below, 13 periods of data totaling 76 days, were not processed (**Table 2.2**). The resulting processed dataset has a nearly equal seasonal distribution. A detailed discussion of the monitoring locations and their effectiveness in accomplishing study objectives are included here.

Locations #1 and #6 (**Figure 2.1**) were optimal for passby train monitoring. These locations were over 150 yards from any major roads; had very few extraneous, loud sound sources, and were not common idling spots (meaning nearly all trains were clean passbys). Also, at these locations train direction could be determined, in most cases, without an observer present because train-horn use patterns and loudness were distinctly different for north vs. southbound trains as they approached the grade crossing for New Bridge Road at the north end of Teaneck. Location #5 was chosen for similar reasons: it was away from primary roads and the probability of trains idling there was extremely low because of its centralized location. These factors allowed for the collection of clear passby data, but the centrality of Location #5 also meant that the meter measured the sound levels of every train that was slowing to stop at the north or south end of Teaneck. This was evidenced in the two weeks of processed Location #5 measurements by the 35 trains which stopped to idle before the entire train passed the long-term meter, causing each of those passbys to be recorded as separate events by the meter, often many hours apart. Trains slowing to idle and subsequently accelerating upon departure were identified as two passbys in the processed data, one with locomotive sound levels and one without, and only the events containing the locomotive sound levels were included in the passby analysis. All passby trains without a noted locomotive sound level were excluded from all analyses. These passbys had average durations 20 to 30 seconds longer than those at Locations #1 and #6. For this reason, the third week of data collected at this location was not processed and the location was not used for monitoring again. One additional piece of information gained from the data collected at this location was that sound levels tended to be several decibels lower than Locations #1 and #6 because of slower train speeds in many cases, indicating that residents living in central Teaneck receive less noise from passby trains than residents in the north and south ends.

Locations #2, #3, and #8 were chosen to obtain sound level and time-activity data for idling trains. Observations made during the first intensive monitoring period verified that the locations are near common idling locations and are accessible to study personnel. Location #2 is at the end of a dead end street, limiting vehicle traffic while being very accessible to study personnel. However, nearly all southbound trains which stopped and idled did so with the locomotives 40 to 60 yards south of the meter location, adjacent to the unoccupied warehouse. As a result, the geometric centers of the locomotives were far from the long-term meter and at a very sharp angle. The positioning of the idling locomotives relative to the meter was not optimal for sound-level measurements of idles. Despite the lack of useable data for idle imissions, the train time activity data were valid. In addition, when idling trains were not present and the track of the passby trains was noted by study personnel (i.e., during intensive monitoring days), the sound levels for those passbys could be determined; these were included in the analyses.

Location #3 was also at the end of a road and proximate to a single-building school. This location seemed, at first, to be a good choice because of the frequent number of trains observed to idle in this vicinity during the first few intensive days and the location's distance from major roads. However, data collection was complicated by vehicle traffic associated with the school during the morning and afternoon hours and business park activities, such as delivery trucks, garbage hauling, and landscaping equipment during mid-day. Cars, trucks, and busses passed within 8.2 meters (9 yards) of the long-term meter when leaving the school and the various other activities were frequently within 45 meters (50 yards). Fortunately, vehicle passby durations were typically less than five seconds; WAV files, recordings of what a person would hear if he was standing at the meter location during the event, could be used to positively identify and exclude non-train events; and the shape of the sound level profiles for the vehicle and non-train activity events were very distinct. Thus, train events from this location could be reliably identified and processed. Because of all the additional events triggered on the long-term meter, data processing took longer. Despite having valid and useable passby and idle data from this monitoring location, the meter was not deployed here again due to the complicating factors associated with the vehicle and business park activities.

Long-term monitoring Location #4 was in the yard of a house to the north of a spice production and shipping facility. Trains had been observed idling directly behind the house, making it a favorable place to deploy the meter. The meter was placed at the even with the back wall of the house to collect sound level data at the same distance from the tracks as an exposed residence. In addition, there were no obstructions between the meter and the track, enabling the collection of clean passby data. However, with experience at this location we found that this monitoring location was impacted by considerable noise associated with the shipping, receiving, and handling of goods by trucks and forklifts at a nearby spice facility. Study personnel were aware of the activity before selecting this location, but the frequency, duration, and amount of noise were substantially underestimated. As a result, only one week of sound level data collected at this location was processed due to the extra time required to distinguish the train passby activity data from the external noise sources.

Location #8 was collocated with an unused side rail, or rail spur, that ran nearly parallel to the three main tracks and was on the eastern side of track C (see track numbers in **Figure 2.3**). This location allowed positioning of the long-term meter opposite of the warehouse, directly even with the primary idling location. The meter was elevated 2 meters (2 yards) above the tracks, so that the microphone was at the same height as the middle of the locomotives and there were no obstructions between the source and the microphone. The site was about 100 meters (109 yards) from the nearest major road, reducing the chance for interference from extraneous sources. Track-side sound level measurements using the hand-held meter could also be easily made from this location and on 19 occasions, distance measurements from the long-term meter to an idling locomotive(s) were made. The side rail turned out to be an extremely valuable location.

The final location, #9, was selected to collect ambient sound level data. This location is farther from the tracks and a block from noise associated with the nearest road by homes, while still being accessible to train study staff and not requiring access to private property. Unfortunately, railway activity was still clearly discernible in the sound level data; therefore, the week of data collected at this site was not processed. To accomplish the collection ambient data, measurements were taken in spring 2008 with the long-term and hand-held meters in several Teaneck neighborhoods. These measurements are detailed in Section 2.1.5.

Overall, long-term meter placement was determined through a combination of advanced planning and adjustments to study activities based on the insights provided by field observations and data analysis. All monitoring locations except Location #9 produced valid, usable train passby activity data. Viable idling data were also obtained by the long-term from Locations #2, #3, and #8, with the vast majority of high quality idling data coming from Location #8 and the hand-held meters. The field measurements collected by the long-term meter, combined with the in-person observations made during the intensive monitoring periods, allowed study objectives to be achieved.

2.1.3 Long-term Meter Deployment

The NorSonic 121 meter was programmed to collect continuous sound levels at one second intervals for one week (168 hour) sampling periods. When sound levels exceeded an A-scale threshold of 65 decibels (dBA) for five consecutive seconds, an "event" was triggered causing the meter to 1) create an electronic data marker that was displayed in the data review software, NorReview, discussed in Section 2.2, and 2) record the actual sound received by the microphone in a WAV file. Event markers ended and recording of the WAV files ceased when sound levels dropped below 65 dBA for five consecutive seconds. To conserve the long-term meter's memory and disk space, events were set to last no longer than 15 minutes and WAV files were limited to a maximum duration of 1 minute, regardless of how long at event extended beyond those constraints. The event and WAV file durations were long enough to fully identify all trains and even most other sound producing sources, such as planes, vehicles, sirens, birds, children playing, thunder, and numerous types of landscaping equipment. The threshold of 65 dBA was chosen because it is substantially above background sound levels in most suburban and residential areas, including Teaneck, reducing the chance for excessive triggering of non-train events and WAV file recordings. The WAV files were extremely useful during data processing, allowing positive identification of the source of sound-producing activities occurring near the meter, whether or not train study personnel were present.

To test the long-term sound level meter and optimize the programmed settings for the measurement of train sound level emissions, the instrumentation was deployed for three separate 4-day periods in September 2006 on the track side of a residence in northern Teaneck (**Figure 2.1**, Location #1). The meter was located 13.7 meters (15 yards) from the nearest train track. During this pilot period, study staff optimized meter settings, verified that data collection was reliably triggered by passby trains, and that the meter was recording WAV files and storing the data to the flash memory card. Measurements collected during these September periods were excluded from all analyses because the meter setup, the station configuration, and the microphone siting criteria all varied slightly from the final configurations used during the official sampling campaign.

On October 7, 2006, the full station, including the meter, one deep-cycle battery, and the storage box, was deployed to Location #2 (**Figure 2.1)** for a complete week of testing in anticipation of the first intensive monitoring period. The meter was set to run for a full week (168 hours). After reviewing the data collected for the period of October 7 through October 14, it was determined that valid sound level data were collected and that the week should be deemed the first sampling period of the annual monitoring campaign. In total, sound level data were collected at nine different locations in Teaneck, eight of which were within 27.4 meters (30 yards) the tracks, and across 58 sampling periods (**Table 2.2**). Subsequently, the first intensive period began on October 14th. It was during this intensive period that train study personnel discovered how complicated it would be to capture idling with the long-term meter due to the numerous stopping locations. As a result, the long-term meter data were used primarily to characterize

Table 2.2 Long-term meter sampling periods, meter location during each period, and data processing status

Period	Loc.[c]	Processed	Period	Loc.	Processed
1: 9/9/06-9/13/06[a]	1	Yes	30: 4/20/07-4/27/07	1	Yes
2: 9/16/06-9/20/06[a]	1	Yes	31: 4/28/07-5/5/07	1	Yes
3: 9/20/06-9/24/06[a]	1	Yes	32: 5/5/07-5/12/07[b]	1	Yes
4: 10/7/06-10/14/06	2	Yes	33: 5/12/07-5/18/07[b]	1	Yes
5: 10/14/06-10/22/06[b]	2	Yes	34: 5/18/07-5/24/07[b]	1	Yes
6: 10/22/06-10/29/06[b]	3	Yes	35: 5/24/07-5/31/07	1	Yes
7: 10/29/06-11/5/06[b]	3	Yes	36: 5/31/07-6/7/07	1	No
8: 11/6/06-11/11/06	4	No	37: 6/7/07-6/14/07	1	No
9: 11/13/06-11/20/06	4	Yes	38: 6/15/07-6/22/07	1	No
10: 11/21/06-11/28/06	5	Yes	39: 6/22/07-6/29/07	1	No
11: 11/29/06-12/6/06	5	Yes	40: 6/29/07-7/2/07	7	Yes
12: 12/6/06-12/13/06	5	No	41: 7/6/07-7/7/07	7	Yes
13: 12/14/06-12/21/06	6	Yes	42: 7/10/07-7/17/07	7	Yes
14: 12/21/06-12/28/06	6	Yes	43: 7/17/07-7/24/07	7	No
15: 12/28/06-1/4/07	6	Yes	44: 7/24/07-7/31/07	7	Yes
16: 1/4/07-1/11/07	6	No	45: 7/31/07-8/7/07	7	No
17: 1/12/07-1/19/07[b]	6	Yes	46: 8/9/07-8/16/07[b]	8	Yes
18: 1/19/07-1/26/07[b]	6	Yes	47: 8/16/07-8/22/07[b]	8	Yes
19: 1/26/07-2/1/07[b]	6	Yes	48: 8/22/07-8/28/07[b]	8	Yes
20: 2/1/07-2/08/07[b]	6	Yes	49: 8/28/07-9/4/07	8	Yes
21: 2/9/07-2/16/07	2	Yes	50: 9/4/07-9/11/07	8	Yes
22: 2/16/07-2/23/07	2	Yes	51: 9/11/07-9/18/07	6	Yes
23: 2/23/07-3/02/07	2	Yes	52: 9/20/07-9/27/07	6	Yes
24: 3/2/07-3/9/07	2	Yes	53: 9/27/07-10/4/07	6	No
25: 3/9/07-3/16/07	2	Yes	54: 10/4/07-10/11/07	6	No
26: 3/19/07-3/26/07	1	Yes	55: 10/11/07-10/18/07	6	No
27: 3/29/07-4/5/07	1	Yes	56: 10/20/07-10/27/07	6	Yes
28: 4/5/07-4/12/07	1	Yes	57: 11/5/07-11/12/07	6	No
29: 4/13/07-4/20/07	1	Yes	58: 11/14/07-11/21/07	9	No

[a] Testing periods – data excluded from all analyses

[b] Intensive monitoring periods

[c] Locations are shown in Figure 2.1

passby activities while the detailed observations made during the intensive monitoring periods were used to characterize idle activities.

During approximately weekly visits, train study staff replaced the memory card and batteries, checked the meter accuracy against a calibrator, and, in some cases, moved the meter to a new location. Data were downloaded from the data card to a laptop to provide redundant data storage and to verify meter performance/data collection. After each site visit, the depleted batteries were brought back to Rutgers University for recharging (12 to 24 hours per battery), and data were downloaded from the data card to a study-specific computer for additional data storage redundancy. The data were also visually scanned using the NorReview (NorSonic, Tranby, Norway) software, to assist study personnel in quickly identifying problems with the meter or the monitoring location that might necessitate an unscheduled site visit and adjustments to the monitoring equipment.

2.1.4 Intensive Monitoring Periods

Seasonal, in-person intensive monitoring periods were designed and incorporated into the annual field sampling campaign to supplement the largely unmanned data collected by the long-term meter. The intensive monitoring campaign provided an annual assessment of the location, frequency, duration and sound levels of idling locomotives, as well as details and time activity information about passby trains not captured by the long-term meter. Hand-held sound level data collected during the intensives were used as inputs to an acoustical model that propagated train sound emissions into the community to assess population exposure to railway activity noise in Teaneck. The intensive regimen consisted four seasonal (fall, winter, spring, summer) periods during which three study staff members conducted comprehensive observations. Observations were made for 24 continuous hours every third day over a three week period each season, capturing all seven days of the week. The intensive days were spread over three weeks for multiple purposes: to reduce the influence of stagnant weather patterns and periods of anomalous weather; to prevent short periods of abnormal train activity from biasing observations; and to accommodate the work and school schedules of the train study staff. The dates and times of the 28 intensive monitoring days, as well as the long-term meter location on those days, are noted in **Table 2.3**. Each intensive day was split into three 8-hour shifts beginning in the early afternoon and continuing through the early afternoon of the next day.

Before the start of the first intensive and at least once during each of the other intensives, the Teaneck police department was notified, in person, of the activities associated with and personnel involved in the train noise study. The authorities were also alerted to the presence of the long-term meter near the tracks in case any suspicious calls were received. During the intensive period shifts, staff positioned themselves in parking lots adjacent to the tracks or on overpasses where they could ensure an unobstructed view of the tracks and/or trains idling on them. They logged any and all activities associated with the railway (e.g., passbys, idles, horns, and track utility vehicles), extraneous noise sources such as planes and weather conditions. When possible, hand-held sound level measurements were made perpendicular to, and at measured distances from, idling locomotives to obtain sound imission levels. Measurements were also taken at multiple distances, when feasible and practical, for comparison with the sound propagation model output.

Table 2.3 Intensive Monitoring Periods

ID	Season	Begin Time	End Time	Begin Day	End Day	Meter Location
1	Fall 2006	10/14/06 3 PM	10/15/06 3 PM	Saturday	Sunday	2
2	Fall 2006	10/17/06 3 PM	10/18/06 3 PM	Tuesday	Wednesday	2
3	Fall 2006	10/20/06 3 PM	10/21/06 3 PM	Friday	Saturday	2
4	Fall 2006	10/23/06 3 PM	10/24/06 3 PM	Monday	Tuesday	3
5	Fall 2006	10/26/06 3 PM	10/27/06 3 PM	Thursday	Friday	3
6	Fall 2006	10/29/06 3 PM	10/30/06 3 PM	Sunday	Monday	3
7	Fall 2006	11/01/06 3 PM	11/02/06 3 PM	Wednesday	Thursday	3
8	Winter 2007	01/16/07 1 PM	01/17/07 1 PM	Tuesday	Wednesday	6
9	Winter 2007	01/19/07 1 PM	01/20/07 1 PM	Friday	Saturday	6
10	Winter 2007	01/22/07 1 PM	01/23/07 1 PM	Monday	Tuesday	6
11	Winter 2007	01/25/07 1 PM	01/26/07 1 PM	Thursday	Friday	6
12	Winter 2007	01/28/07 1 PM	01/29/07 1 PM	Sunday	Monday	6
13	Winter 2007	01/31/07 1 PM	02/01/07 1 PM	Wednesday	Thursday	6
14	Winter 2007	02/03/07 1 PM	02/04/07 1 PM	Saturday	Sunday	6
15	Spring 2007	05/05/07 1 PM	05/06/07 1 PM	Saturday	Sunday	1
16	Spring 2007	05/08/07 1 PM	05/09/07 1 PM	Tuesday	Wednesday	1
17	Spring 2007	05/11/07 1 PM	05/12/07 1 PM	Friday	Saturday	1
18	Spring 2007	05/14/07 1 PM	05/15/07 1 PM	Monday	Tuesday	1
19	Spring 2007	05/17/07 1 PM	05/18/07 1 PM	Thursday	Friday	1
20	Spring 2007	05/20/07 1 PM	05/21/07 1 PM	Sunday	Monday	1
21	Spring 2007	05/23/07 1 PM	05/24/07 1 PM	Wednesday	Thursday	1
22	Summer 2007	08/09/07 1 PM	08/10/07 1 PM	Thursday	Friday	8
23	Summer 2007	08/12/07 1 PM	08/13/07 1 PM	Sunday	Monday	8
24	Summer 2007	08/15/07 1 PM	08/16/07 1 PM	Wednesday	Thursday	8
25	Summer 2007	08/18/07 1 PM	08/19/07 1 PM	Saturday	Sunday	8
26	Summer 2007	08/21/07 1 PM	08/22/07 1 PM	Tuesday	Wednesday	8
27	Summer 2007	08/24/07 1 PM	08/25/07 1 PM	Friday	Saturday	8
28	Summer 2007	08/27/07 1 PM	08/28/07 1 PM	Monday	Tuesday	8

To ensure consistent information collection during the intensive periods, a data book was designed containing all of the pieces of information desired from each passby or idling train (see Appendix C). In addition, a bound, free-form log book was used for more elaborate descriptions and notes, drawings of idling train scenarios, measurement locations, dialogue between train study staff, and related information. The standard set of information collected for each passby and/or idling train, as relevant, included:

- train arrival and departure times at the observers location;
- train event type (i.e., a passby or idle);
- number of locomotives;
- number of train cars (summer 2007 intensive only), using a hand-held counter;
- locomotive company name and identification numbers;
- train direction;
- track (i.e., A, B, or C as labeled in **Figure 2.3**);
- exact idling location(s) using the annotated aerial images (**Figure 2.3** and Appendix A);
- distance from long-term meter to idling trains, using the laser rangefinder;
- qualitative noise levels and train speeds;
- quantitative noise levels with the long-term noise meter for passbys on a known track and idles at a known distance from the meter; and
- quantitative noise levels from idling locomotives, at measured distances, with a handheld noise meter (winter, spring, and summer 2007 intensives only)

When possible (i.e., a train stopped to idle for a long enough period of time and in an accessible location), the observer recorded sound levels with a hand-held meter at a measured distance and increasing distances from the locomotives in nearby neighborhoods. The distance between the sound level measurements and the source locomotives ranged from 13.7 meters (15 yards) to as much as 161 meters (176 yards),

Figure 2.3 Satellite image of warehouse region on the south side of Teaneck, annotated with location numbers for assigning train idling position and track letters; a train was idling at location #10 on the day this image was taken.

Source: City of Teaneck

but the distance was typically 27-32 meters (30-35 yards). Hand-held measurements of this type were taken during the second half of the winter intensive (Quest 2900), the spring intensive (Quest 2900), and the summer intensive (Quest 2900/Sound Pro).

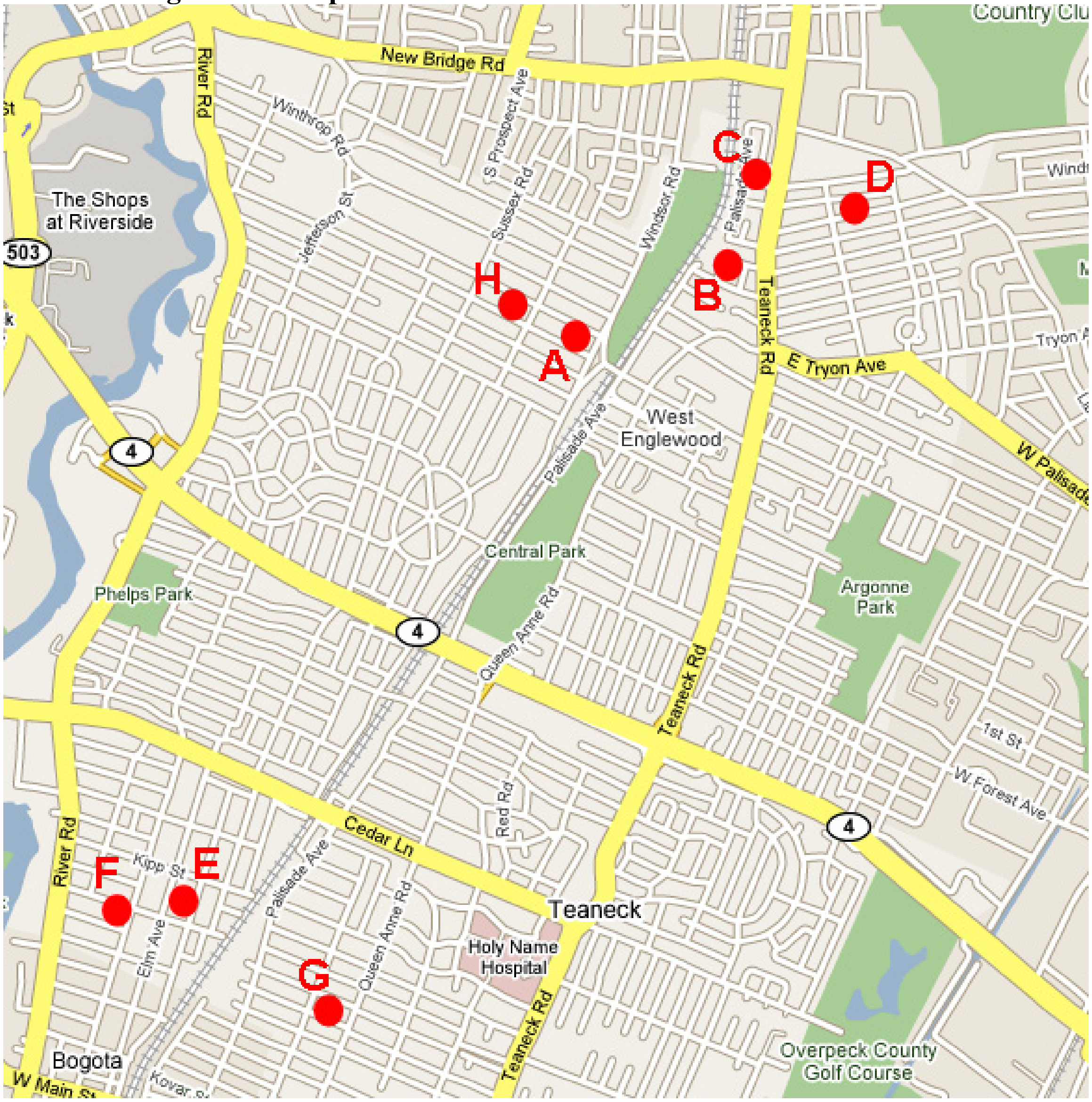
On-site observations made during the intensive monitoring periods were critical to the accurate characterization of the train activity in Teaneck. We were able to specify the location and duration of idling events and document that idling events occur in numerous locations throughout the study area. In total, train study personnel spent over 800 hours in the field during the course of the study, 672 hours during intensive periods. The in-person observations provided data that the unmanned, long-term meter could not, such as the exact distance of a specific sound source from the meter at the time of an idle, substantially enhancing the usefulness of the collected long-term meter data.

2.1.5 Ambient Sound Level Measurements

One of the goals of this study was to determine the contribution of sound emissions from trains to the ambient, or background, sound levels in residential neighborhoods. To do this, it was necessary to characterize existing sound levels in the neighborhoods when train activity was not occurring. Train study personnel began by choosing eight areas within Teaneck, at approximately 500 feet and 1200 feet from the railway, in residential neighborhoods on both sides of the tracks (**Figure 2.4**). In March 2008, preliminary measurements were taken from the sidewalk at each location during afternoon and evening rush hour periods, using both the Quest 2900 hand-held meter and NorSonic 121 long-term meter, which was operated in manual mode for the starting and stopping of 15-minute sampling periods, but with all other settings used during the annual monitoring campaign. Initial evaluation of the collected data indicated that measurements were highly influenced by passing vehicles on neighborhood roads, except for location B, which was at the end of a dead end street and near a vacant, undeveloped lot. Therefore, in early April 2008, letters were distributed to five homes in the vicinity of the remaining seven locations requesting access to private property. The intent was to take sound level measurements at distances half way between each home and its closest street.

After receiving a very positive response from nine residents in five of the locations, final measurements were taken with the long-term meter in late May 2008 at locations A, C, F, G, and H (data for B were retained from the April sampling), during daytime (10 a.m. to 4 p.m.), rush hour (6 a.m. to 9 a.m. or 4:30 p.m. to 7:00 p.m.), and overnight (12 a.m. to 5 a.m.) periods. The three time ranges were selected based on observed activity patterns in Teaneck and ensured that ambient measurements were

Figure 2.4 Map of ambient sound level measurement locations.



Base Map Source: Google Maps

obtained during the three types of activity patterns seen in suburban regions. Each measurement lasted 15 minutes and included the sounds from all typical neighborhood activities. The only activity excluded from the measurements was landscaping at a neighboring property, which was substantially louder than the ambient sound levels during the majority of each day. Measurements at locations D and E were not taken because property access was not granted from any of the homes in those two areas. The results of the ambient sampling are discussed in Section 3.5.

2.1.6 Data Time Standards

Observations and sound level data collected by the hand-held meters are stored and presented in Eastern Time (ET). Specifically, all final data are presented in ET. As a result, data collected during the late-fall and winter months are in Eastern Standard Time (EST) and data collected during the spring, summer, and early-fall months are in Eastern Daylight Time (EDT). Selecting ET as the standard for reporting purposes was a logical because it allowed train study personnel to more easily correlate the collected sound level data with hourly activity patterns of Teaneck residents and observations and log book entries made during the intensive monitoring periods. However, to produce a consistent long-term meter dataset and avoid complications with changing the meter's internal clock while it was deployed, all long-meter data were collected and stored in the database in EST. Raw data viewed in NorReview between October 7, 2006, and November 5, 2006, need to be shifted by 6/7 hours, depending whether ET was on EDT/EST, because they were collected in Norwegian Time as set by the manufacturer.

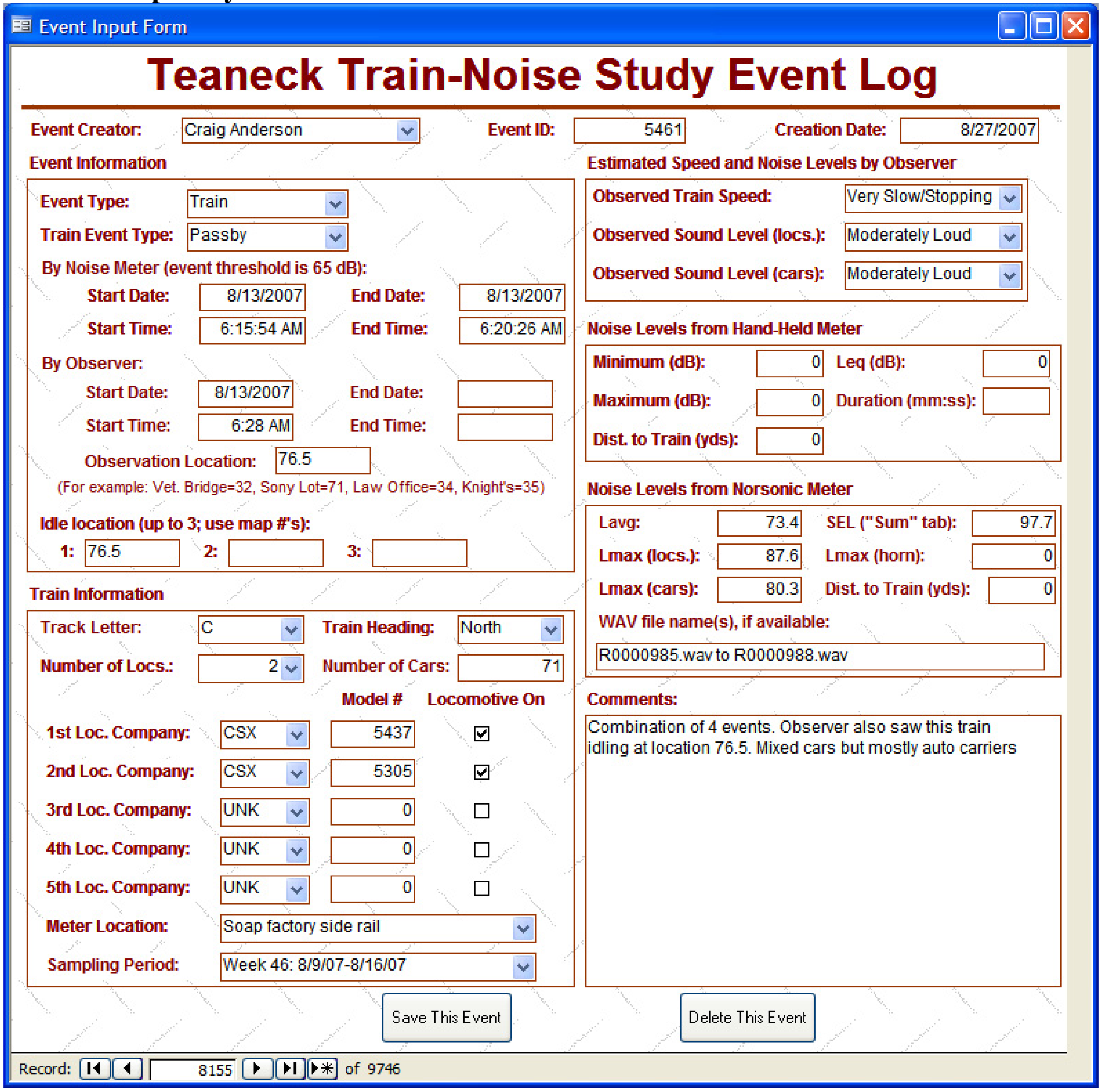
2.2 Data Processing and Storage

2.2.1 Train Study Database

Due to the large number of train events expected during the annual monitoring campaign and the need to manipulate, summarize, and extract information from the large dataset, a database (Microsoft Access, Office 2003) was created as the central data storage location. The database contains observations of train activity, all processed long-term meter data; corresponding hand-held meter data; supplemental information such as listings of the long-term meter sampling periods and locations and the intensive monitoring days; and queries and functions to perform calculations and allow study personnel to extract explicit pieces of information. The data record structure within Access is ideal for the train study events, which are comprised of the numerous and variable pieces of information listed in Section 2.1.4. In addition, the relational table feature allows information that is identical for many records, such as the meter locations and sampling periods, to be listed and stored once in separate tables and linked back to each data record with a single, unique identifier. Not only did this feature increase efficiency within the database and reduce its size, but it allowed for pieces of information from multiple tables to be quickly and easily linked for cross referencing and data querying. Furthermore, all of the tables, queries, forms, and data processing functions are contained in one database file, allowing for easy storage, transport, and backup of the entire train study events dataset.

Another feature within Access that aided data management, integrity, and consistency is the form feature. A data input form (**Figure 2.5**) was designed containing fields for nearly all of the pieces of information that could be stored for each event, providing one centralized location and format for creating and maintaining events in the database. The form also provided a fast and consistent way to view data records already entered into the database. All drop-down boxes on the form were populated with pre-defined entries to reduce the chance for typographical errors, to limit and standardize the values for each field, and reduce data entry time. The text box fields were constrained to either character strings with a specific character limit or numerical values with preset formats, such as an integer or a real number with one decimal place.

Figure 2.5 Data entry form within the train study database and a data record for a passby train event



Teaneck Train-Noise Study Event Log

Event Creator: Craig Anderson
Event ID: 5461
Creation Date: 8/27/2007

Event Information

Event Type: Train
Train Event Type: Passby
By Noise Meter (event threshold is 65 dB):
Start Date: 8/13/2007 End Date: 8/13/2007
Start Time: 6:15:54 AM End Time: 6:20:26 AM
By Observer:
Start Date: 8/13/2007 End Date:
Start Time: 6:28 AM End Time:
Observation Location: 76.5
(For example: Vet. Bridge=32, Sony Lot=71, Law Office=34, Knight's=35)
Idle location (up to 3; use map #'s):
1: 76.5 2: 3:

Estimated Speed and Noise Levels by Observer

Observed Train Speed: Very Slow/Stopping
Observed Sound Level (locs.): Moderately Loud
Observed Sound Level (cars): Moderately Loud

Noise Levels from Hand-Held Meter

Minimum (dB): 0 Leq (dB): 0
Maximum (dB): 0 Duration (mm:ss):
Dist. to Train (yds): 0

Noise Levels from Norsonic Meter

Lavg: 73.4 SEL ("Sum" tab): 97.7
Lmax (locs.): 87.6 Lmax (horn): 0
Lmax (cars): 80.3 Dist. to Train (yds): 0
WAV file name(s), if available:
R0000985.wav to R0000988.wav

Train Information

Track Letter: C Train Heading: North
Number of Locs.: 2 Number of Cars: 71

	Model #	Locomotive On
1st Loc. Company: CSX	5437	☑
2nd Loc. Company: CSX	5305	☑
3rd Loc. Company: UNK	0	☐
4th Loc. Company: UNK	0	☐
5th Loc. Company: UNK	0	☐

Meter Location: Soap factory side rail
Sampling Period: Week 46: 8/9/07-8/16/07

Comments:
Combination of 4 events. Observer also saw this train idling at location 76.5. Mixed cars but mostly auto carriers

Record: 8155 of 9746

The time and date fields also have an input mask, displaying the required format and moving the cursor accordingly as the user types. All study personnel involved in processing the sound level data did so systematically using the same form, ensuring that every entered event would be a unique record in the data table; each numeric, date, and time field was in the same format; and all calculated fields were computed the same way every time an event was saved. To create an event, the train study staff member viewed the sound level data in NorReview (discussed in Section 2.2.2) and filled out the form based on the information available for the event from the data and the log books. The person entering the information chose his or her name, but the event ID and the record creation date were automatically assigned by the database. Next, the event type, which was usually a train but could be anything from a plane, to vehicles, to weather (i.e. thunder, wind, rain), was selected, along with the type of train event (passby, passby+1 idle, passby+2 idles, idle, or engines off). Following the event descriptions are the start and end times of the event as detected by the meter and/or as noted by study personnel. The location at which the observation was made was also entered, if available, and up to three idle locations could be entered, since trains were occasionally observed to stop in one location but move to a different location at a later time.

The next section of the form contains characteristics about the track on which the train was traveling (A, B, or C); the direction the train was heading (north or south); the number of locomotives and attached cars; the company (i.e. CSX, Conrail, Norfolk Southern); the identification number listed on the side of each locomotive; and whether each locomotive was turned “on”. This information was usually only available for trains observed during the intensives, during the daylight hours when visible air emissions could be seen exiting the stack of each locomotive, and during idling. The last two items in this section of the form are the meter location and the sampling period.

The right side of the form includes three qualitative and subjective selections for observed trains to help relate the sound levels recorded by the long-term meter with the perceptions of someone viewing and listening to the train event from the side of the tracks. Below these items are input boxes for sound levels collected with the hand-held and long-term meters and a general comment box for noting additional details, descriptions, and information about each event. The contents of the qualitative and subjective fields were not used systematically in any calculations, but they provided supplemental information to assist data processors in creating the events and for assessing each event's data quality during analysis. Upon completion of the form, the event was saved and the form was navigated to a new record using the arrows at the bottom.

Another feature within Access that added tremendous power and flexibility to the input form is the incorporation of the Visual Basic programming language. Within the form and in the separate "Modules" section of the database, functions were written to perform additional calculations and data reformatting each time the "Save This Event" button was pressed on the form. For instance, to save time during data entry, if both a start date and an end date were entered for an event, which was usually the case, pressing the "Save This Event" button called a function to create a combined date-time value for both the start and end times of the event and compute the duration of the event in seconds, minutes, and hours; the hour of the day in which the event began; and the day of the week on which the event occurred, in numerical and text formats. In a fraction of a second, all of this information was compiled and the corresponding fields in the data table were updated accordingly.

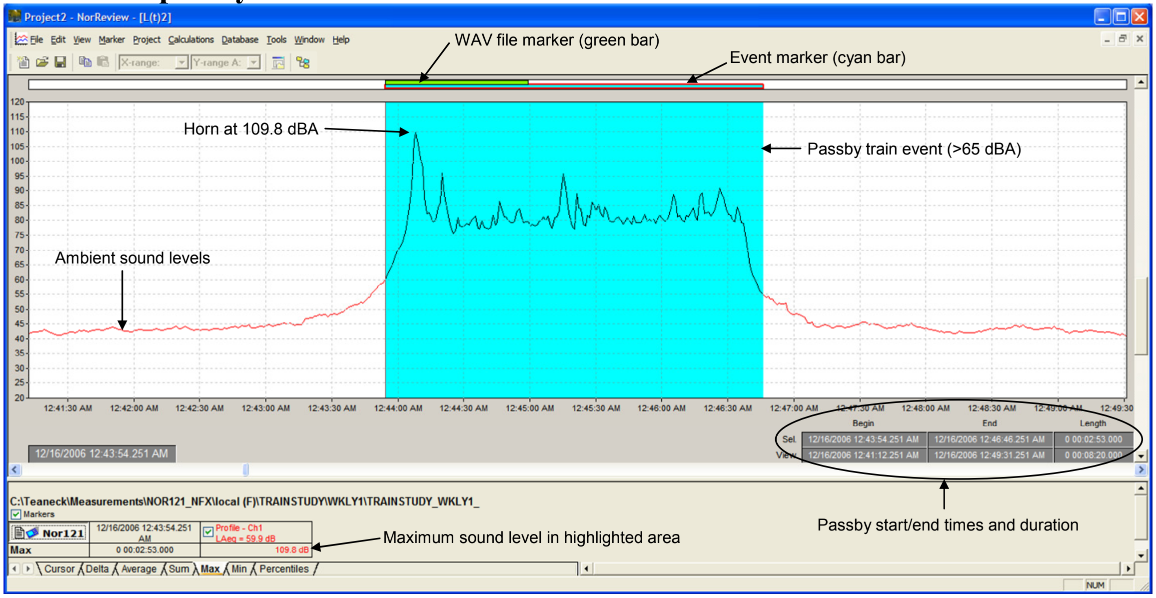
Using the data input form and NorReview, week-after-week of data was processed by multiple train study personnel, entering as much information as possible from NorReview and the intensive and weekly site visit data sheets and log books. Because this effort was very labor intensive, even with all of the efficiencies of the database and entry form, not all of the weekly sampling periods were processed, as was discussed in Sections 2.1.2 and 2.1.3. First, and foremost, all of the weeks spanning the intensive periods were processed. Second, weeks from each season and most monitoring locations were chosen to ensure that the events dataset would capture the annual variability of train activity at Teaneck, as described previously.

The final aspect of the Access database that was beneficial to this study is the query functionality. Through a simple design window, tables and queries were selected, allowing the user to choose any field(s) available within them. The selected fields could be displayed in the query results without any manipulation, or the fields could be converted to a new format They could be incorporated into "IF" statements to limit the results, used in equations for the computation of new fields, or their summary statistics could be viewed (e.g., mean, median, sum, count, maximum, minimum). In the end, dozens of queries were created and most query results were obtained in less than a second despite the large size of the database (~9,750 records). The performance and flexibility of the database structure aided the quick, consistent, and efficient analysis of results (Section 3).

2.2.2 Long-term Meter Data

All data collected with the NorSonic 121 long-term meter were viewed using the NorReview software package (Version 2.0, Type 1026, NorSonic, Tranby, Norway), designed specifically to work with sound level data. Each weekly sampling period has a separate set of folders and files associated with it, containing a varying number of event marker and WAV files depending on the number and types of sound producing events that occurred during the period. All of the files for each week were referenced in one, central "Nor-121.npf" file that was opened directly in NorReview. The sound profile for each sampling period was plotted in the main graph window, with the local clock time on the horizontal axis and decibels on the vertical axis. An example of a passby train event and ambient sound levels before and after the event is shown in **Figure 2.6**. Also shown are event markers (turquoise bar above the graph), triggered between when sound levels exceeded 65 dBA and dropped below 65 dBA, and WAV file markers (green bar above the graph). Based on the meter settings selected for this study, the event markers could be 15 minutes in duration; corresponding WAV files were recorded for no more than 1 minute, due to their large size (approximately 1 MB per minute). Some idling events occurring for many hours near the monitor created several hundred markers. This happened because air releases and the cycling of the locomotive engines and compressors caused sound levels to rise above the 65 dBA threshold and fall below it again approximately every minute for the majority of the idling event (**Figure 2.7**).

Figure 2.6 NorReview data window showing the continuous sound profile and a passby train event



12/16/2006 12:43:54.251 AM

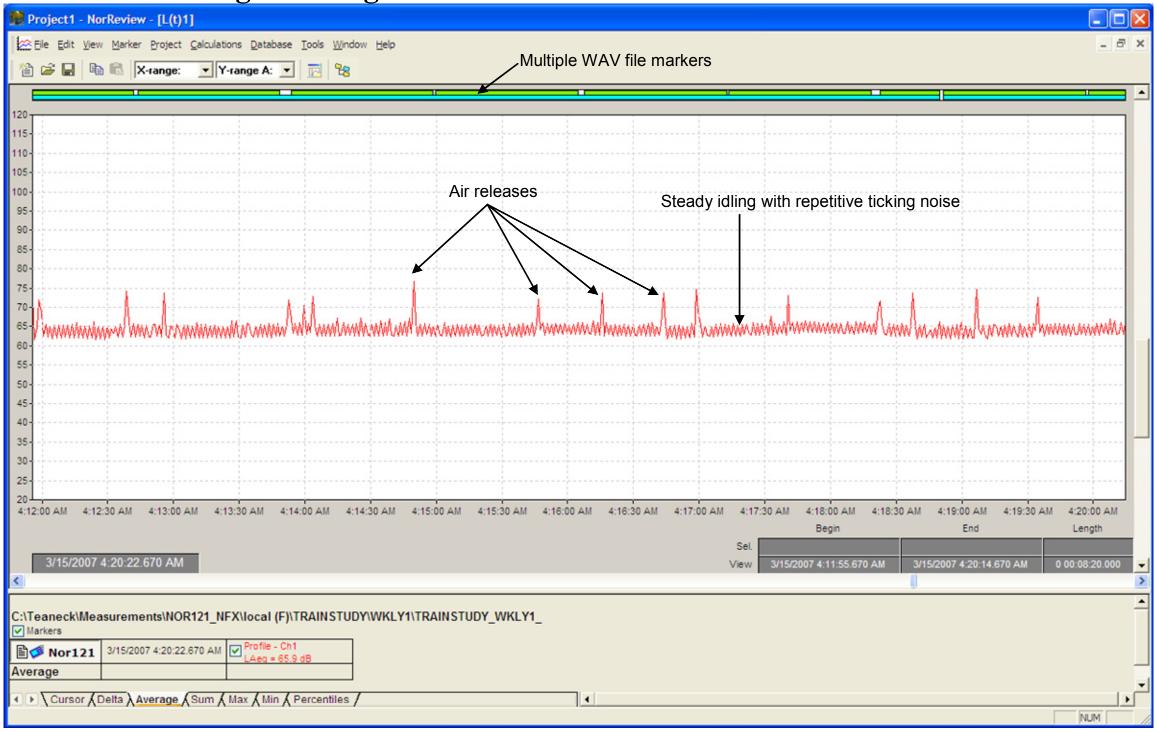
	Begin	End	Length
Sel.	12/16/2006 12:43:54.251 AM	12/16/2006 12:46:46.251 AM	0 00:02:53.000
View	12/16/2006 12:41:12.251 AM	12/16/2006 12:49:31.251 AM	0 00:08:20.000

C:\Teaneck\Measurements\NOR121_NFX\local (F)\TRAINSTUDY\WKLY1\TRAINSTUDY_WKLY1_

☑ Markers

Nor121	12/16/2006 12:43:54.251 AM	☑ Profile - Ch1 LAeq = 59.9 dB
Max	0 00:02:53.000	109.8 dB

Figure 2.7 NorReview data window showing multiple event and WAV file markers during an idling event



3/15/2007 4:20:22.670 AM

	Begin	End	Length
Sel.			
View	3/15/2007 4:11:55.670 AM	3/15/2007 4:20:14.670 AM	0 00:08:20.000

C:\Teaneck\Measurements\NOR121_NFX\local (F)\TRAINSTUDY\WKLY1\TRAINSTUDY_WKLY1_

Nor121	3/15/2007 4:20:22.670 AM	☑ Profile - Ch1 LAeq = 65.9 dB
Average		

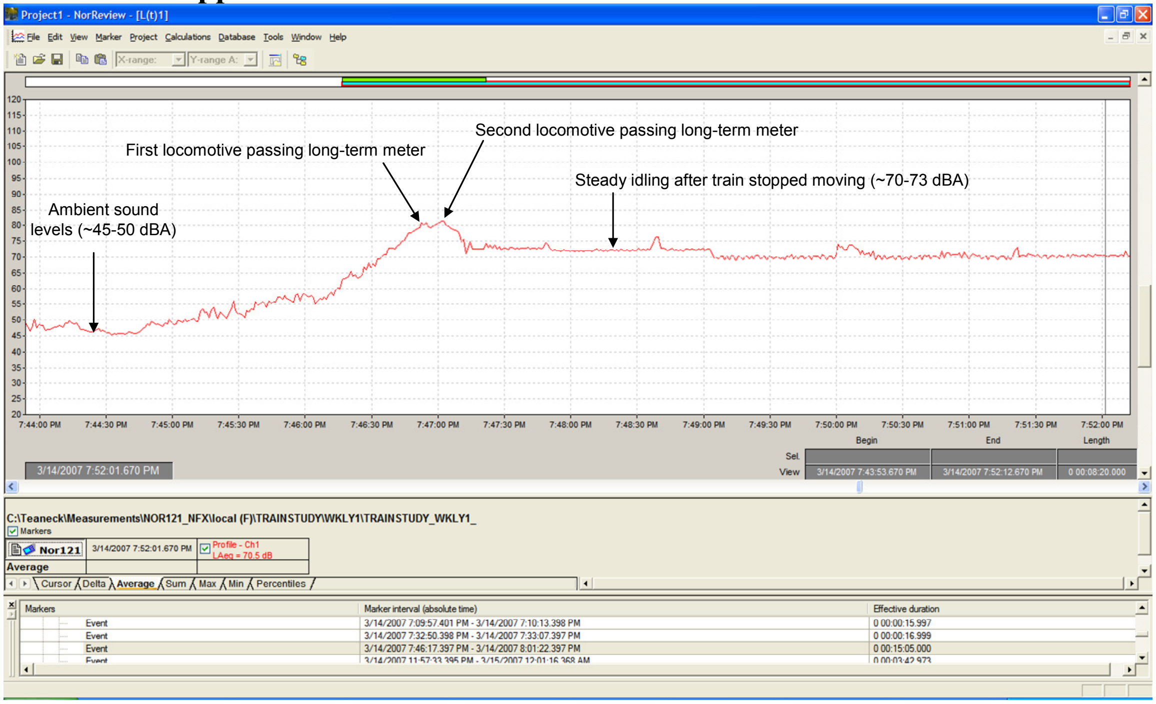
WAV files were played with an internal or external media player to verify the type of noise event (e.g., airplane, train idle, passby, horn).

The processing of each weekly sound profile consisted of first, setting the start time of the week to the correct time standard using a built-in time offset feature in NorReview. Because all long term monitor data collected after November 6, 2006 were collected in EST and the data were stored in the database in local time (EST or EDT, as appropriate), a one hour adjustment was made for data collected between March 11, 2007 and November 4, 2007. Once the proper local time was set, the train study staff member would begin scrolling forward through the sound level time series until a passby or idling event was found. Next, the WAV file was played and the event marker was selected, highlighting the event period. Occasionally, sound levels dropped below 65 dB during an event, causing the creation of multiple event markers and WAV files. In this case, the entire event was manually selected from the beginning of the first event marker through the end of the last marker. In other instances, no marker was created at all, even though the sound profile clearly indicated a train, either because the event was not loud enough or for some other reason the NorSonic 121 meter software did not trigger a marker. For train events without a marker, the user simply highlighted the event manually based on the 65 dBA trigger threshold.

Once the event marker was selected, the user would create a new event in the train study database using the event form, entering the type of event, the start and end time of the event, the meter location, the sampling period, and several sound level statistics available on tabs in the NorReview window: average, sum (also called SEL), and maximum. The user would then enter the maximum dBA value for the locomotive(s); all of the train cars combined; and the horn, if the horn was blown and it could be identified. For idling events, such as the one shown in **Figure 2.8**, only the locomotive sound level associated with the idling portion of the event, i.e. the steady portion of the sound profile after passage of the locomotives, was entered.

The direction in which a train was heading could usually be determined for passby events that occurred when the meter was located near the north-side grade crossing, based on the horn-use pattern by trains approaching the grade crossing as evidenced during intensives. For instance, if the horn was blown next to the meter when it was in locations #1 and #6 (reference **Figure 2.1**), as shown in **Figure 2.6**, then the train was heading northbound. However, if a distinct horn blowing pattern was evident in advance of the passby event (meaning multiple sharp spikes in sound levels and increasing maximum dBA levels for as long as five minutes before the train reached the

Figure 2.8 NorReview data window showing the slow approach of a train that stopped to idle with sound levels well above ambient before event



	Begin	End	Length
Sel.			
View	3/14/2007 7:43:53.670 PM	3/14/2007 7:52:12.670 PM	0 00:08:20.000

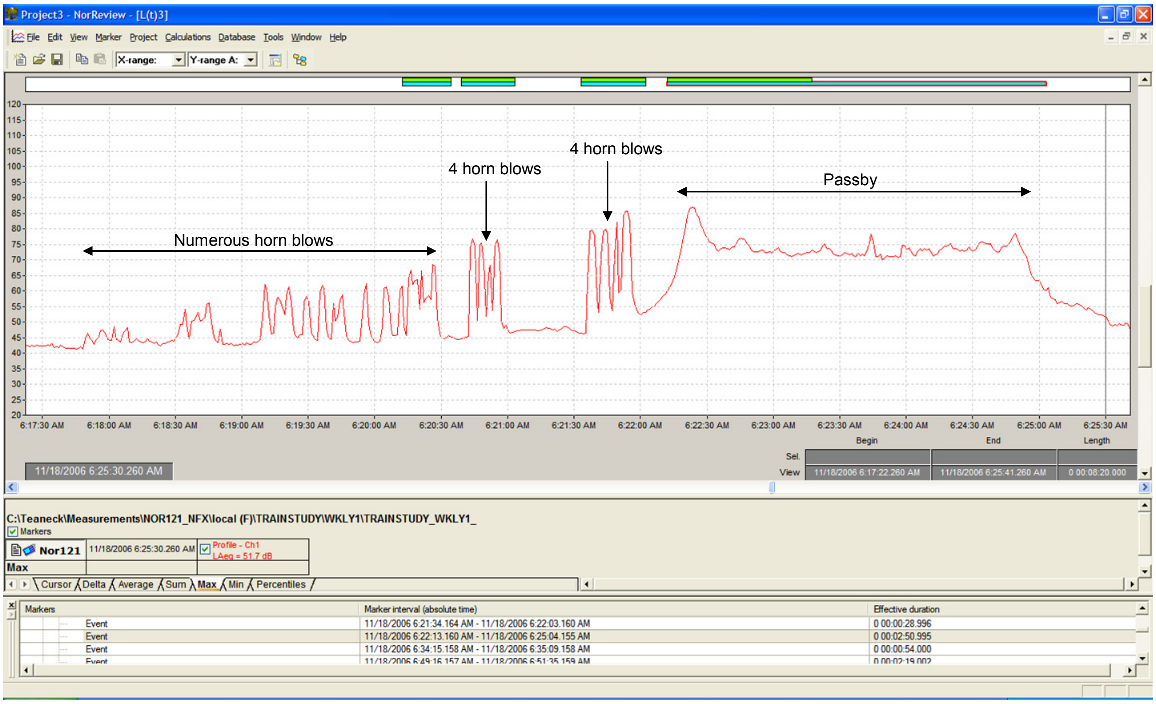
C:\Teaneck\Measurements\NOR121_NFX\local (F)\TRAINSTUDY\WKLY1\TRAINSTUDY_WKLY1_

☑ Markers

Nor121	3/14/2007 7:52:01.670 PM	☑ Profile - Ch1 LAeq = 70.5 dB
Average		

Markers	Marker interval (absolute time)	Effective duration
Event	3/14/2007 7:09:57.401 PM - 3/14/2007 7:10:13.398 PM	0 00:00:15.997
Event	3/14/2007 7:32:50.398 PM - 3/14/2007 7:33:07.397 PM	0 00:00:16.999
Event	3/14/2007 7:46:17.397 PM - 3/14/2007 8:01:22.397 PM	0 00:15:05.000
Event	3/14/2007 11:57:33.395 PM - 3/15/2007 12:01:16.368 AM	0 00:03:42.973

Figure 2.9 NorReview data window showing a typical horn blowing pattern ahead of a southbound train



	Begin	End	Length
Sel.			
View	11/18/2006 6:17:22.260 AM	11/18/2006 6:25:41.260 AM	0 00:08:20.000

C:\Teaneck\Measurements\NOR121_NFX\local (F)\TRAINSTUDY\WKLY1\TRAINSTUDY_WKLY1_

☑ Markers

Nor121	11/18/2006 6:25:30.260 AM	☑ Profile - Ch1 LAeq = 51.7 dB
Max		

Markers	Marker interval (absolute time)	Effective duration
Event	11/18/2006 6:21:34.164 AM - 11/18/2006 6:22:03.160 AM	0 00:00:28.996
Event	11/18/2006 6:22:13.160 AM - 11/18/2006 6:25:04.155 AM	0 00:02:50.995
Event	11/18/2006 6:34:15.158 AM - 11/18/2006 6:35:09.158 AM	0 00:00:54.000
Event	11/18/2006 6:49:16.157 AM - 11/18/2006 6:51:35.159 AM	0 00:02:19.002

meter) (**Figure 2.9**), then the train was heading southbound. This pattern reflects the fact that southbound trains tend to blow their horns as they approach and pass through several grade crossings in the city to the north of Teaneck and at Teaneck's northern boundary.

Frequently while processing the sound level data, events triggered by non-train sound sources (e.g., planes, vehicles, birds, sirens, landscaping equipment, thunder) were encountered. When a previously undocumented source type was encountered, an event was created in the train study database for documentation purposes, but for the most part, non-train events were simply ignored.

On occasion, multiple trains passed the meter concurrently, making the sound levels from the two or three trains nearly indistinguishable from one another. When this happened the average dBA levels for each train and the train car maximum dBA levels were not entered.

During the long-term monitoring campaign study personnel processed sound level data for 7,532 passby trains (regardless of whether or not there were idling trains and limited to trains with a noted locomotive sound level >0) from which hourly, daily, weekly, seasonal, and annual train activity patterns and average passby duration were derived. Of those 7,532 trains, data for 804 passbys were obtained during the intensive monitoring periods, when additional observational data were collected. For 765 of these trains, we know the track the train was traveling on and the direction it was heading. From this subset, the distance between the train and the long-term meter was calculated, allowing these sound levels to be used in sound level computations and for modeling.

NorReview was also used to compute ambient sound levels at the various long-term meter locations through the use of manually created exclude markers. The raw data collected for each sampling period included all activities that occurred near the meter, but also general background sound levels when no particular sound producing source was near the meter. Data processing personnel manually generated markers for all train events during selected weeks and excluded those periods from the sound level calculations, producing average Leq values for those monitoring locations without any train activity. Unfortunately, these derived ambient sound levels only have limited applicability to the study since they are focused along the rail corridor and not the surrounding neighborhoods. Ambient sound level measurements were made in the neighborhoods in April and May 2008 to supplement these.

To evaluate the sound contribution from each type of train activity, i.e., passby or idle, the markers for just passby events were enabled and then conversely, the passby events were excluded and the idle events were included. These various analysis techniques identified how much of the sound measured at the meter location was due to non-train activity, all train activities, passby trains alone, and idling trains. The results of this process are discussed in Section 3.

Data processing required standardized procedures and knowledge of the train study objectives, factors affecting the collected data, and behavioral characteristics and sound-producing activities of the trains in Teaneck. To increase the understanding of all data entry staff, each person spent at least one day in the field during an intensive observation period. Visually and audibly experiencing the trains and activity in Teaneck substantially improved the data processor's comprehension of the data viewed in NorReview and his or her ability to interpret features of the sound profiles.

2.2.3 Hand-Held Meter Data

The short-term data collected with the Quest 2900 meter were downloaded directly from the instrument to text files for input into a Microsoft Excel spreadsheet and the appropriate fields on the Access database entry form. For the Quest Sound Pro meter, the data were manually transferred by study staff using software designed specifically to work these data from a display screen to the same spreadsheet. The complete dataset for both meters is available in Appendix B. Very little processing was required for data from either meter and most of the effort was simply compiling the data into one centralized spreadsheet and inputting fields into train event records in the Access database.

2.3 Model Setup and Development

In this work, an acoustical model of Teaneck was constructed within commercial sound propagation modeling software (CadnaA, Version 3.7, Datakustik, Greifenberg, Germany), and field measurements were used to establish appropriate spectral inputs. This model will ultimately be used for several purposes: 1) to depict the sound emission propagation characteristics from freight train locomotives in a suburban, residential area during idling, passby, and horn use activities; 2) to evaluate the impacts of train sound level emissions on the community above existing background sound levels; 3) to provide a framework for evaluating sound emission impacts/benefits from potential scenarios not considered in this study and various noise mitigation strategies; and 4) to provide spectral model inputs that could reasonably be used in other suburban cities experiencing similar freight train noise problems. Predictive sound propagation modeling to determine the approximate spatial extent of sound emission impacts and areas of maximum noise impacts can provide considerable insight to those evaluating noise mitigation strategies and planning monitoring programs.

Two established sound propagation modeling software packages were considered for use in this study: SoundPLAN (Braunstein & Berndt GmbH, Sheldon, WA) and CadnaA (Datakustik, Greifenberg, Germany). Evaluation based on ease-of-use, cost, technical support, and reputation lead train study staff to choose the CadnaA model for this train noise study. Regardless of which model had been chosen, the model needed to be built from scratch, beginning with base layers, such as elevation and roads, and adding in buildings, the railway, and sound emission points. The process required multiple data sources and software packages.

2.3.1 Base Layers

The first of three geographical data layers prepared consisted of the roads, blocks, and land parcels for Teaneck Township. These data were obtained from the township itself. Because all three layers were exported from the same system, they were all mapped to the same projection and had the same units (feet). All steps used to establish the layers in CadnaA are detailed in Appendix D.

The second layer was a 10-meter resolution digital elevation map obtained from the U.S. Geological Survey. The steps performed with this layer in the ArcMap software (ESRI, Redlands, CA) to prepare the data for import into CadnaA are detailed in Appendix D.

The final layer, which contained over 2000 buildings (mostly homes) in Teaneck, was manually generated within CadnaA using high-resolution aerial images of Teaneck, parcel boundaries, and building heights obtained by train study personnel who drove around Teaneck from building-to-building, categorizing buildings by the number of stories. It was assumed that each story was 10 feet tall (3.048 meters). This estimate was validated for several buildings using a laser rangefinder and triangulation.

The version of CadnaA used for this study had a limitation of 1000 active buildings, which presented a problem due to the extensive area being modeled. As a result, the buildings were broken up into small groups based on the street and the building's location on the street. This process allowed staff to enable and disable buildings based on the location of interest for each model run. The model has since been upgraded to allow for an unlimited number of structures.

The procedure for creating the buildings is detailed in Appendix D and the completion of this layer in CadnaA enabled model runs to be performed once the inputs for idling trains (point sources in CadnaA) and passbys (railway activity or line sources in CadnaA) were determined.

2.3.2 Model Inputs

Analysis of the sound level data collected by the long-term and hand-held meters was performed to determine the inputs for the sound emitting features modeled in CadnaA. These and other results are presented in Section 3.

Multiple model inputs were necessary to account for the three main types of sound producing activities performed by the trains: idling, passby, and horn use. Average sound level measurements for a single idling locomotive were computed from hand-held noise measurements of 9 idling trains that only had one locomotive running and long-term meter measurements from 10 other idling trains with only one locomotive running and an observer present to measure the distance between the meter and locomotive.

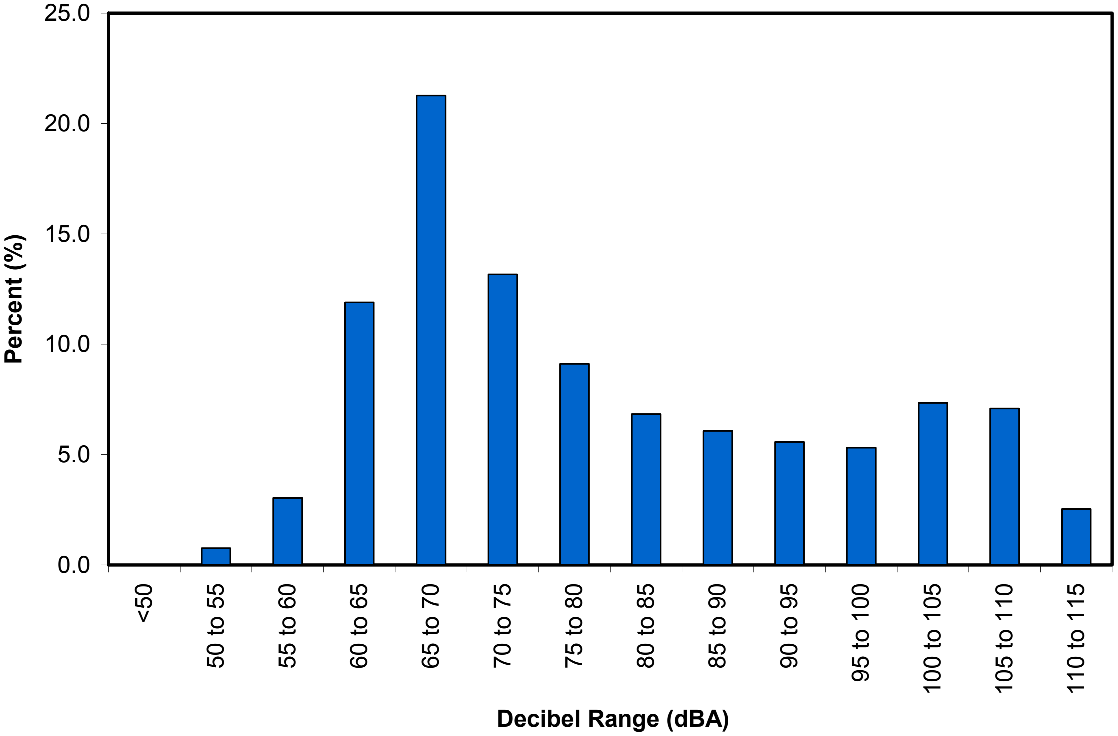
Sound level profiles were segmented into 10-minute periods, to simplify the process of filtering out sounds measured from non-idle related sources. In total, 4,311 minutes of data from 426 10-minute segments captured by the long-term meter, plus 11 measurements (51 minutes total) collected with the hand-held meters, were used to compute the average sound imission levels for a single locomotive. These values were the direct inputs for average single-locomotive idling scenarios in the model.

Sound emission levels for the average passby were derived using two methods. The first method used to determine passby sound levels involved averaging spectral sound level data for all passbys measured on four (4) intensive monitoring days (1/16/2007-1/17/2007; 1/22/2007-1/23/2007; 5/11/2007-5/12/2007; and 5/17/2007-5/18/2007). These four days were chosen because they all had at least the average number of daily passbys, 28, and they represented two monitoring locations. The sound level data for all trains for which the track and train heading were known and the horn did not impact the sound levels during the duration of the passby were obtained using NorReview. The resulting dataset included 83 samples out of 122 observed trains.

The second method used the complete database to confirm the sound level values computed from the four-day subset and entailed taking sound levels entered into the database for each passby and combining them with the track information collected by study personnel during the intensives and the distance measured from all long-term meter locations to each track. This resulted in a dataset of 246 trains for which all three sources of information were available. It also excluded passbys where horn use was noted, an idle was present, or some other interference was indicated by the observer/data processor. The sound level measurements were then standardized to 30.5 meters (100 feet) using a standard sound level decrease rate for moving sources of 3 dBA for every doubling of distance from the source (Hanson et al., 2006). However, because so much data was collected on the north side of Teaneck, near the grade crossing, nearly all of the southbound passbys had recorded horn use, even though the horns were blown long before the train reached the meter, meaning that the horns had no influence on passby sound levels and the trains were inadvertently excluded from the analysis. To determine an acceptable cut-point for including trains with noted horn use, a histogram of horn sound levels for all passbys measured and processed for monitoring locations #1 and #6 was produced (**Figure 2.10**). The data show a large drop in the rate of occurrence after the 65-70 dBA range, which corresponds to the maximum sound levels of southbound trains. As a result, all trains without horn use or those with horn sound levels <73 dBA were included in the computations. The resulting dataset increased to 425 trains. Unfortunately, this method cannot provide the spectral data necessary for the model inputs; therefore, the results can only be used for verification of the first method used to derive passby sound levels.

Horn blowing within Teaneck was mostly associated with passbys heading northbound between the spice facility (map locations #79-80; see Appendix A) and the grade crossing at the north end of Teaneck. These horns were quite loud, exceeding 100 dBA at 30.5 meters (100 feet) approximately 80% of the time, and residents living along the tracks in northern Teaneck complained about the horns waking them at night. To extract horn sound level data from NorReview, the peak decibel reading and associated spectral frequencies were noted for passbys that blew their horns exactly as they passed the meter (as determined by listening to the WAV files and by examining the shape of the

Figure 2.10 Distribution of horn sound levels for passbys on a known track (N_{trains} = 425)



sound profiles), ensuring that the distance between the horn and the meter was known. Only data from trains on the same four intensive days used to determine the passby sound levels were used to determine the average horn sound level and spectral frequency distribution, resulting in 20 samples.

The three types of sound level inputs were incorporated into the model together and independently to account for several train activity scenarios, such as a single idling train, multiple idling trains at the same location, passbys, and horn blowing adjacent to homes in northern Teaneck. The modeling of these scenarios is beyond the scope of this thesis.

2.4 Quality Assurance and Quality Control

During the long-term monitoring campaign, data review and processing occurred simultaneously with the sampling so that analysis of the sound levels and adjustments to the sampling methods and intensive monitoring procedures could be made during the study to ensure that objectives would be achieved. Changes to the monitoring, intensive observation, and hand-held measurement protocols were occasionally necessary to correct for data and information gaps. Of primary interest were the temporal and spatial activities of passbys, e.g. trains passing through Teaneck without stopping, and idles, e.g. the trains which stopped within Teaneck's boundaries and kept at least one locomotive running. Due to large amount of sound level data collected during the annual monitoring campaign and data redundancy in some of the meter locations with extensive sampling, data processing was limited to 41 of the 55 non-testing sampling periods, but included all weeks containing the intensive monitoring days. The following quality assurance and control procedures were implemented to ensure that high quality data were collected; that processing of the data was consistent and accurate; and that all components of the noise propagation model were incorporated properly and that output was reasonable with respect to measured sound levels.

2.4.1 Monitoring Equipment

The NorSonic 121 sound level meter was purchased new with a certified calibration from the manufacturer. Also, as is standard practice, a calibrator (Quest QC-10, Serial Number QID070226, with one setting of 114 dBA; certified annually in April 2006 and again in April 2007; or a Quest QC-20, Serial Number Q090900323, with dual settings of 94 dBA and 114 dBA; certified in October 2006) was used to verify the meter's accuracy when it was deployed in the field on October 7, 2006, and on 16 additional dates during the study. **Table 2.4** contains a list of the accuracy check dates, the duration, the calibrator setting, the long-term meter reading, and the difference between the setting and the reading. Over the 13 months of deployment, through the full range of weather and temperature variations common to northern New Jersey, the long-term meter generally remained within ±0.3 dBA, except on November 29, 2006, and September 11, 2007. However, because the calibrators have an output accuracy of ±0.3 dBA and the accepted accuracy of sound level meters is ±0.3 dBA, any readings within ±0.6 dBA of the calibrator decibel setting are considered valid.

Other quality assurance checks performed during weekly site visits and after monitor relocation included: noting battery voltage on the deep-cycle batteries; noting the internal battery gauge on the long-term meter; verifying the long-term meter's clock time; and physically evaluating of the storage box, microphone, pad locks and chains used to secure the station.

The hand-held Quest 2900 and SoundPro meters were certified annually. An accuracy check of the 2900 was performed in the field on January 22, 2007, matching both QC-20 calibrator settings of 94 and 114 dBA exactly, and again on May 5, 2007, registering 93.7 dBA and 113.7 dBA for the two QC-20 settings, respectively. An additional test was performed with the Quest 2900 by placing it vertically on top of the long-term meter box during an idling event on August 13, 2007. The Quest 2900 measured an average sound level of 69.0 dBA (Lmax=70.5 dBA), while the co-located long-term meter for the same period reported a 68.3 dBA (Lmax of 69.7 dBA).

Table 2.4 Long-term meter accuracy checks

Date	Duration	Calibrator Setting (dBA)	Meter Reading (dBA)	Difference (dBA)
10/7/2006	40 sec	94.0	94.1	+0.1
10/14/2006	50 sec	94.0	94.2	+0.2
10/29/2006	35 sec	94.0	93.9	-0.1
11/21/2006	30 sec	114.0	113.8	-0.2
	35 sec	94.0	93.8	-0.2
11/29/2006[a]	30 sec	94.0	94.5	+0.5
	25 sec	114.0	114.6	+0.6
1/4/2007	35 sec	94.0	94.0	0
1/19/2007	30 sec	114.0	114.0	0
	30 sec	94.0	93.8	-0.2
5/5/2007	30 sec	114.0	113.7	-0.3
	40 sec	94.0	93.7	-0.3
6/29/2007	30 sec	114.0	113.9	-0.1
	40 sec	94.0	93.8	-0.2
8/9/2007	35 sec	114.0	114.0	0
9/11/2007	45 sec	114.0	114.4	+0.4
	40 sec	94.0	94.5	+0.5
9/20/2007	1 min 30 sec	114.0	113.9	-0.1
9/27/2007	1 min 15 sec	114.0	113.9	-0.1
10/4/2007	1 min 30 sec	114.0	114.0	0
11/5/2007	1 min 25 sec	114.0	114.0	0
11/14/2007	45 sec	114.0	114.2	+0.2
3/17/2008[b]	25 sec	114.0	114.1	+0.1

[a] Study staff member noted that calibration was off by 0.5-0.6 dBA, but did not make any adjustments to the meter; [b] Calibration was performed before start of ambient measurements

2.4.2 Train Study Database

Data validation activities included the double-checking of event entries by a second staff member, the use of a standardized entry form, comparing entries with the study log books, and the use of Access queries and data sorting features. Many of the components and features of the Access database used to store the processed train activity data were designed to maximize data consistency.

For example, the start and end times of an event documented by the long term meter were entered using a 24-hour clock time. If 11 pm was entered as 11 rather than as 23, a negative "event duration" was generated. These errors were identified by sorting the main "Events" table in the database by the event duration; erroneous events were filtered to the top or bottom of the table. Similarly, for database entries such as the sampling period, a simple query showing a summary of the data processed by "sampling period" quickly revealed this type of data entry error by showing more than one row for the same sampling period. For example, period #28 might have 200 trains listed in the first row and then two additional trains in a second row. Other data validation checks involved the examination of a variety of statistics generated from the input data. Suspect records were few and in all cases were corrected after checking the original data.

The cross-referencing of entered events with log book entries was critical to data processing personnel for two main reasons: 1) it ensured that all train events, namely idles, were identified during the intensive monitoring periods, and 2) it guaranteed that the time offset used in NorReview to adjust the sound level data display from EST to EDT during the appropriate times of the year was properly changed each time the program was used. The log books also provided invaluable information during times when multiple trains were concurrently passing the meter. During these occurrences, the sound level profile in NorReview appeared as one long passby, when in reality it was two separate trains, and the log book entries allowed the events to be accurately entered into the database.

The final quality control method was the manual review of processed data and event entries by a second person. For all four of the seasonal intensives and many of the weeks where data processing was complicated by sound producing activities external to the railway, the train events in the database and the sound profiles in NorReview were viewed by a second staff member not involved in the original processing of the sampling period. This process occasionally identified data entry errors that were not detected through other means. The database was a fundamental tool for processing and storing this large dataset. It provided a high level of data integrity through intrinsic relational database design features and manual quality control checks performed by train study staff.

2.4.3 CadnaA Model

The primary quality assurance issue for construction of the CadnaA model layers was scaling. Distance plays a critical role in sound propagation; therefore, confirming that all layers and objects in the model were standardized to meters was essential.

As discussed in Section 2.3, the digital elevation layer was acquired in meters and the buildings were created within CadnaA, causing them to be in meters. However, the road, block, and parcel layers received from the City of Teaneck were in feet and had to be converted after import into CadnaA (the methods used for the conversion are detailed in Appendix D). Proper conversion of the layers was obvious because all of the features were aligned geographically as expected, based on staff experience gained through their extensive amount of time in Teaneck. However, to physically justify that all layers were correctly aligned, a free, external software package named Google Earth (Google, Mountain View, CA) was used. Google Earth provides high-resolution satellite images of the Earth combined with a digital terrain, allowing for the identification of relatively small objects, such as vehicles, specific trees, and telephone poles, and the elevation at any point. Built into the software is a ruler function, which calculates the distance between selected points, in any units chosen. Using these features, train study staff compared the distances between noise measurement locations and the tracks in the model with the measured (laser rangefinder) distances. This confirmed that the digital terrain map had been properly imported and adjusted from feet to meters in CadnaA.

An additional quality assurance technique employed in CadnaA was building height confirmation. All buildings entered into the model were assigned building height categories, i.e., the number of stories. To verify that building height assignments were accurate, actual building heights for each category were measured. The manual measurements of some one and two story homes, as well as some multi-story buildings, in Teaneck were made using the laser rangefinder and triangulation. At a fixed point, level with the base of a structure, the distance from the observer to the building was determined. A second measurement of the distance from the observer to the roof line of the building was then made. Assuming that the wall of the structure was at a 90° angle to the ground, the vertical height from the base of the building to the top of the roof was calculated. This measurement technique confirmed that each story of the average home was about 10 feet and that attic space typically added an additional 5 feet; therefore, one-story homes were created in the model as 1.5 stories, two-story homes were 2.5 stories, and three-story homes were 3.5 stories.

Noise propagation within the model was assumed to be accurate because the model is thoroughly tested by its developers. However, sound levels predicted by the noise propagation model were compared with sound level measurements taken at multiple distances from idling locomotives using the hand-held meters. The closest sound imission measurement to the locomotive, typically taken at about 27.4 meters (30 yards), was used to compute the source emission sound level, which was then propagated out into the community and compared with the hand-held distance measurements.

Overall, data processing was accomplished with only a few pieces of equipment, one full time person (myself) and five part-time study personnel. The data chain of custody remained with the one, full-time person (myself), and training/oversight regarding data processing methodologies were provided to all data processing personnel by one central staff member (myself), further ensuring the integrity of the train study dataset.

3. RESULTS

The results described below characterize the train activity within Teaneck, NJ during the period October 2006 – October 2007. In addition to characterizing the sources of train noise exposure, these data provide critical inputs for noise propagation and exposure assessment modeling.

3.1 Passby Trains

The average number of passbys per hour was 1.16 ± 0.11 (1σ) or 27.8 passbys per day and ranged from a minimum of 1 train (0.04 trains per hour) on December 25, 2006, to a maximum of 38 trains (1.58 trains per hour) on March 9, 2007. The number of passbys varied little between weeks, months, and seasons (**Figure 3.1**). A few days, including major holidays and extreme weather events, had substantially reduced railway activity. There were numerous hours without any passbys, 128 hours with four passbys, 20 hours with five passbys, and 1 hour with 6 passbys.

A higher percentage of passbys occurred at night than during the day (**Figure 3.2**), with an average of 1.4 per hour during typical sleeping hours (10 p.m. – 6:59 a.m.) compared to 1.1 per hour at other times (7:00 a.m. – 9:59 p.m.). Furthermore, the least amount of passby activity occurred on Mondays and a gradually increased through Thursday (**Figure 3.3**).

The direction the trains were heading **(Figure 3.4)** was used to extract information about horn usage near the north-side grade crossing. For each northbound train, the horn was blown an average of 3.1 times and for an average duration of 3.3 seconds, resulting in a total of 10.2 seconds of horn blowing per passby. This amount of horn use, combined with an average of 8.3 northbound trains per night and a sound level

Figure 3.1 Average number of passbys per hour by day (N_{days} = 291)

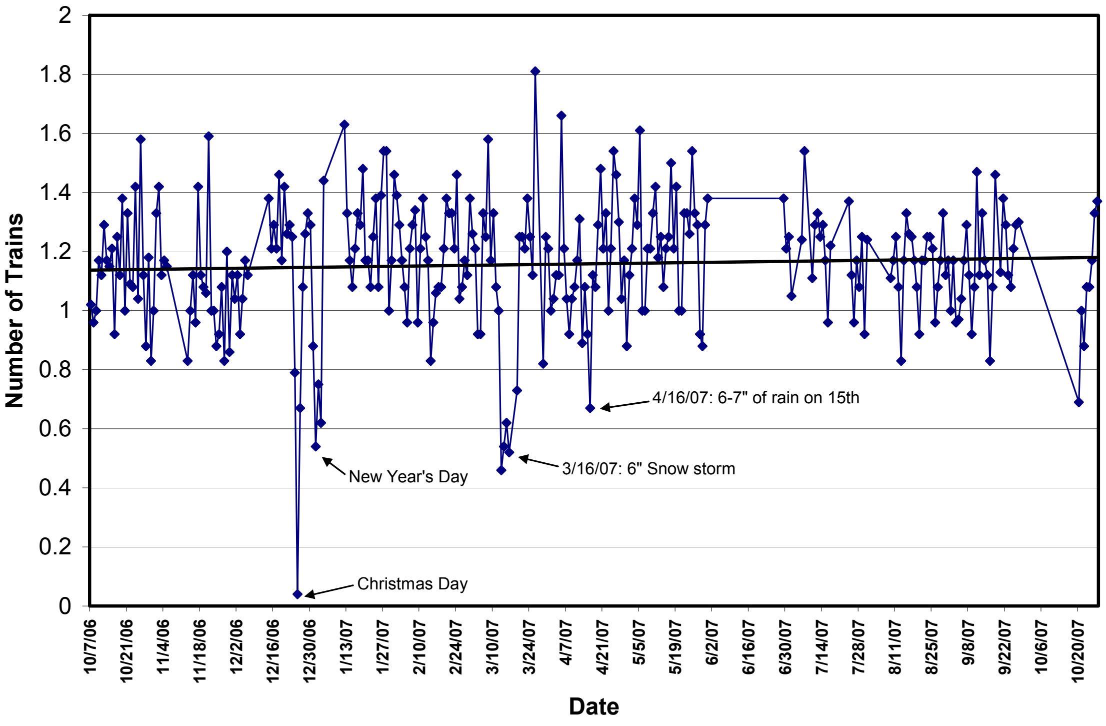


Figure 3.2 Percentage of passby trains by hour (N_{trains} = 7532)

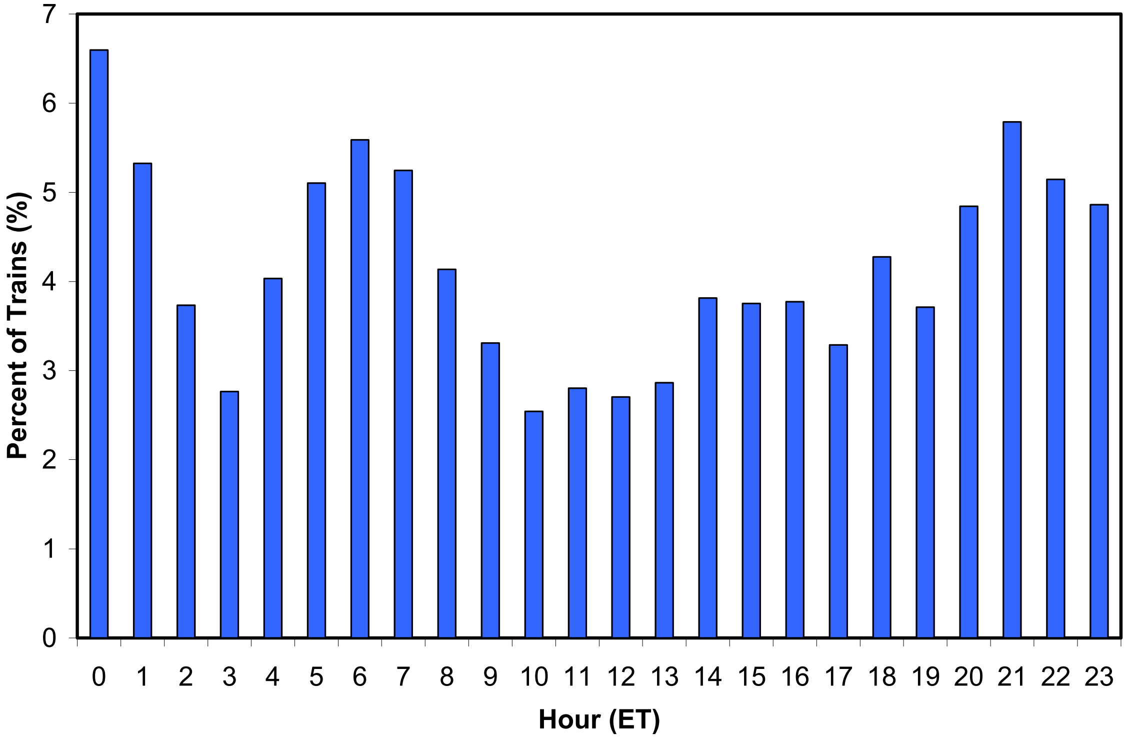


Figure 3.3 Average number of passbys and 1σ error bars by day of the week (N_{trains} = 7532)

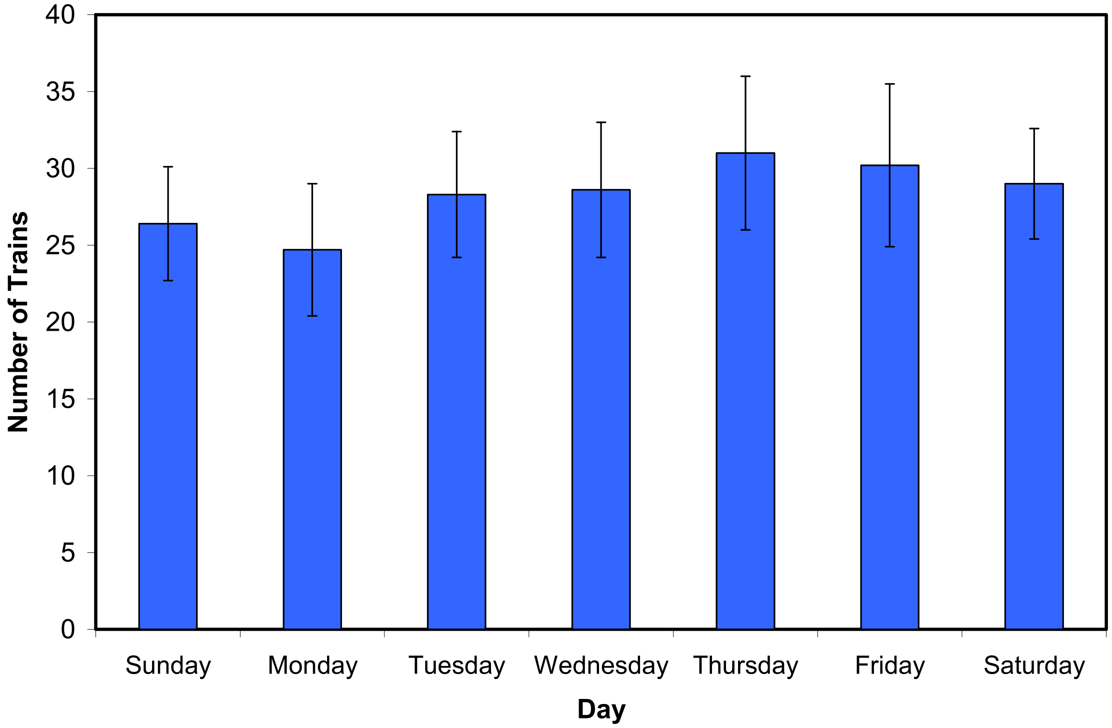
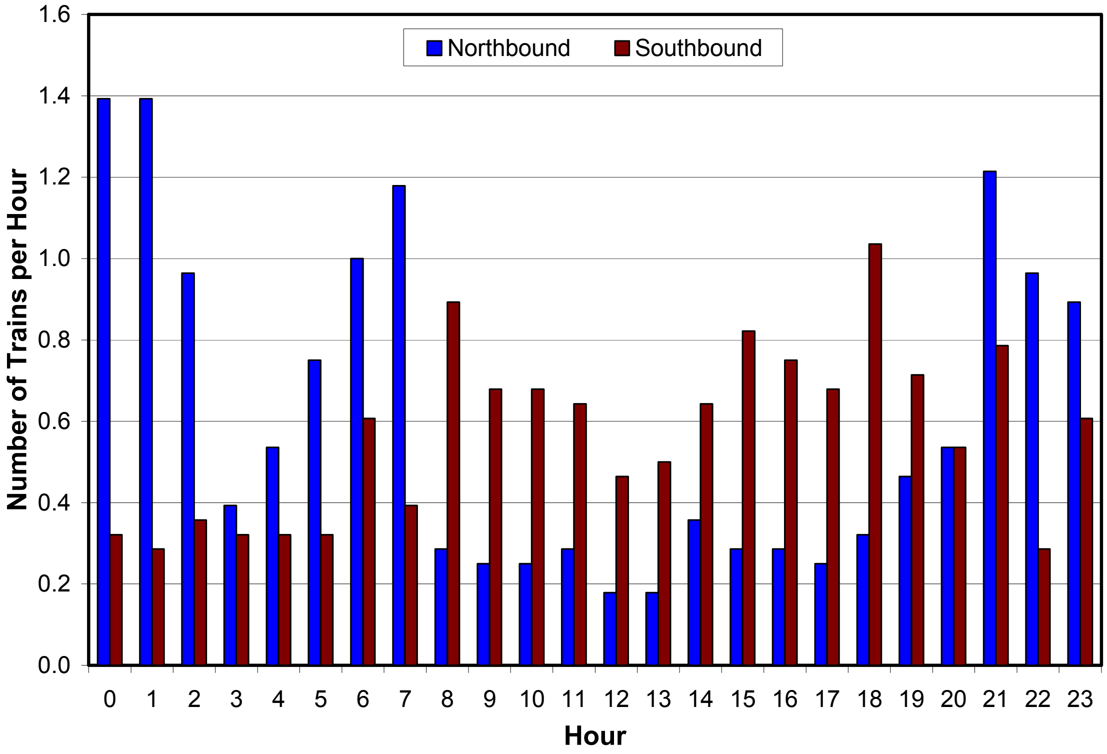


Figure 3.4 Number of passby trains per hour by direction and hour of the day (N_{trains} = 791)



of 104.3 dBA at 30.5 meters (100 feet) from the horn, is a major source of noise for residents living in houses adjacent to the tracks on the north end of Teaneck. Ironically, most of the southbound trains passed during the daytime, and blew their horns in Bergenfield (the city to the north of Teaneck), sufficiently far from Teaneck to result in minimal impact on Teaneck residents.

The duration of passby events varied greatly from a minimum of 12 seconds for a single locomotive without any train cars, to 30 seconds for the shortest train with cars, to nearly 19 minutes for extremely slow moving trains (**Figure 3.5**). However, over 92% of the passbys detected by the long-term meter and observers during the intensives were between 1 and 5 minutes in duration, with an average duration of 2.8 minutes, a standard deviation of 1.7 minutes, and a median of 2.5 minutes. This duration, combined with the number of passbys per hour, resulted in an average of 78 minutes of passby train noise per day for all areas along the tracks in Teaneck, which translates to 546 minutes per week or a total of 20 complete days of continuous passby activity per year. Note that the highest passby frequency occurred during the midnight hour, increasing the probability of sleep interruption by passbys and horns.

As was discussed in Section 2.3.2, multiple methods were used for analyzing the measured passby sound level data and determining a representative sound emission level. The first method produced an average sound level at 30.5 meters (100 feet) of 78.1 dBA, with a standard deviation of 3.9 dBA and a range of 67.5 dBA to 84.9 dBA. The corresponding spectral data are shown in **Table 3.1**. The second method used to determine passby sound levels resulted in an average of 77.7 dBA, a standard deviation of 5.1 dBA, and a range of 58.2 dBA to 90.4 dBA. The average sound levels computed with the first and second methods were comparable, within 0.4 dBA, providing confidence in the calculated average passby sound level of 78.1 dBA. While the second method used a larger data set, the result was a single Leq. Since the sound propagation model requires spectral data for inputs, the results of the first method were selected to represent passby sound levels.

Table 3.1 Spectral Inputs for the Average Passby Train

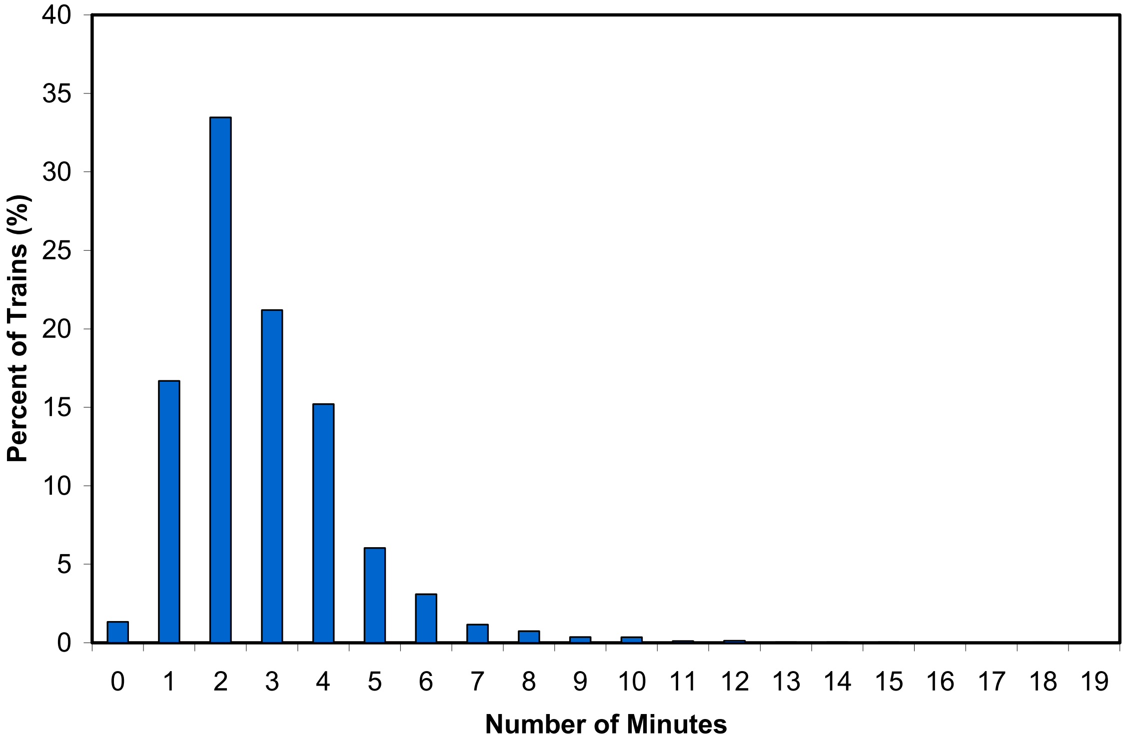
Frequency (Hz)	Z-Scale (dB)	A-Scale (dBA)
31.5	83.3	43.9
63	88.9	62.7
125	83.2	67.1
250	75.7	67.1
500	73.4	70.2
1,000	71.8	71.8
2,000	69.2	70.4
4,000	68.6	69.6
8,000	69.1	68.0
16,000	68.1	61.1

The above passby train activity defined how the observed sound levels should be applied within the model. However, the passbys were only part of the railway activities; idling trains were the other main component.

3.2 Idling Trains

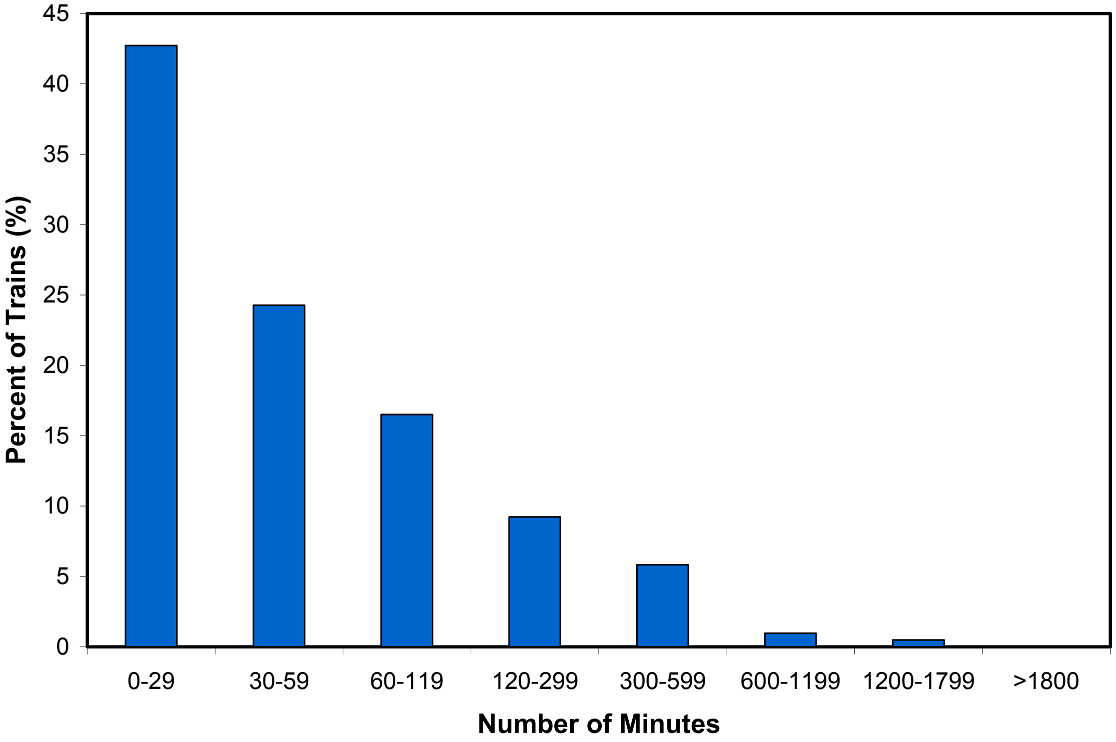
The primary purpose of this study was to characterize the time-activity, location, and sound levels of idling trains and their impact on the residents of Teaneck. Of the approximately 28 trains that passed through Teaneck each day, on average, about 7.4 (26%) stopped within the Teaneck Township limits and kept at least one locomotive running, resulting in a total of 206 observed idling events (192 unique trains; 14 that idled

Figure 3.5 Percentage of passby trains by duration (N_{trains} = 7532)



in multiple locations) during the 28 intensive monitoring days. On three occasions, train study staff observed a stopped train that had all locomotives "off", and those trains stopped for an average of 801 minutes (13.4 hours). The average idling duration was 87.2 ± 158 (1σ) minutes, the median duration was 34.5 minutes, and the idle duration ranged from 2 minutes to 20.5 hours. Long-term meter data indicated that one idle lasted 36.7 hours, over one-and-a-half days, based on the continuous sound level profile; this event was not observed in person. The distribution of idling trains by duration is shown in **Figure 3.6**. Based on the above statistics, Teaneck residents were exposed to approximately 642 minutes, or 10.7 hours, of idling train sound emissions per day, and the total amount of idling observed in a 24-hour period ranged from 30 to 1431 minutes. Idling varied considerably from week to week. For example, across the tracks from the warehouse on the south side of Teaneck nearly 98 hours (over 4 complete days out of 7)

Figure 3.6 Percentage of idling trains by duration (N_{events} = 206)



of idling occurred from 8/22/07 to 8/28/07, whereas less than two weeks later at the same location, the weekly idling only totaled 18.6 hours. On average, a train was idling in Teaneck 44.6% of the time, which over the course of a year translates to 163 entire days out of 365.

The average idling train had 2.4 ± 0.69 (1σ) locomotives, based on observations during the intensives. For 87 of the 206 idling events, study personnel were able to determine that the number of running locomotives was 2.1 ± 0.67. These are approximately the same numbers of locomotives that were observed for passbys (2.3 total locomotives and 2.0 running). The number of running locomotives will be used when defining idling sound sources in the acoustical model.

Idling was most prevalent after 4 p.m. and before 7 a.m. and trains were most likely to begin idling during the 6 a.m. hour (**Figure 3.7**). The 6 a.m. hour also had the highest average number of minutes with a train idling (**Figure 3.8**), and idling was most prevalent on Tuesdays (**Figure 3.9**). There were more than 20 minutes of idling per hour, on average, every hour of the day except from 12 – 3 p.m. (**Figure 3.8**). Sound impacts from idling are more likely to have been realized by residents because idles occurred preferentially during evening, overnight, and morning hours, when residents were more likely to be home.

As is shown in **Figure 3.10**, idle locations varied widely throughout Teaneck, with a fairly even distribution of idling locations across several map locations in the north end, but the location were mostly concentrated in the south end of Teaneck between a few locations near the warehouse.

Further characterization of the idling patterns was done by grouping the locations into one of five zones based on the maps in Appendix A:

Zone 1: Map locations 0 up to 32 (southern border of Teaneck to the Veterans Bridge/Cedar Lane)

Zone 2: Map locations 32 up to 64 (Veterans Bridge to the State Street Bridge)

Zone 3: Map locations 64 up to 72 (State Street Bridge to Galway Place)

Zone 4: Map locations 72 up to 81 (Galway Place to the Spice Factory)

Zone 5: Map locations 81 through 100 (Spice Factory to the north end of Teaneck)

Figure 3.7 Percent of idle start times by hour (N_{events} = 206)

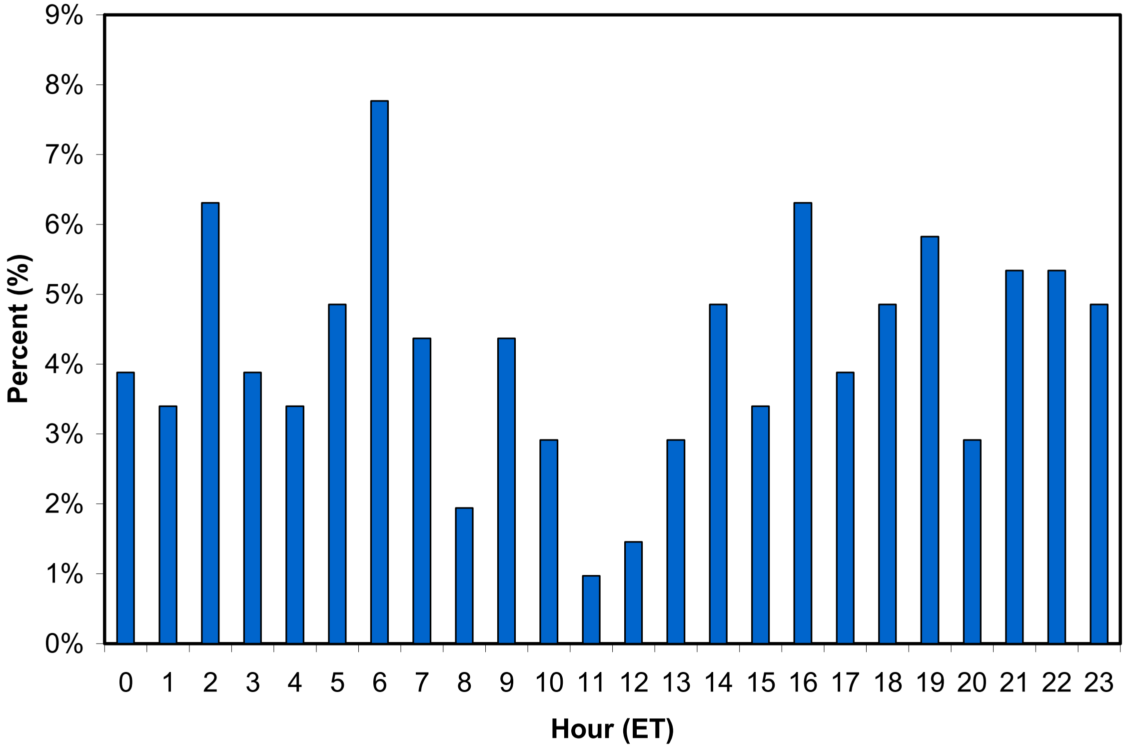


Figure 3.8 Average number of idling minutes per hour by hour of the day (N_{events} = 206)

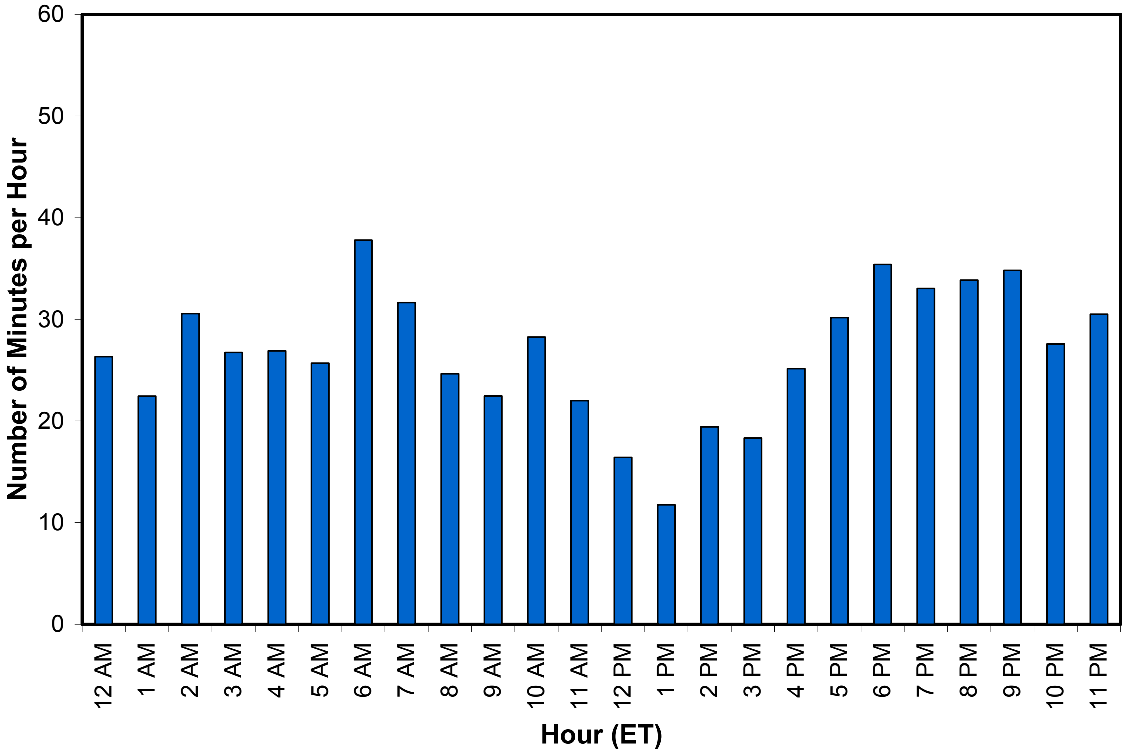


Figure 3.9 Percent of idling by day of the week (N_{events} = 206)

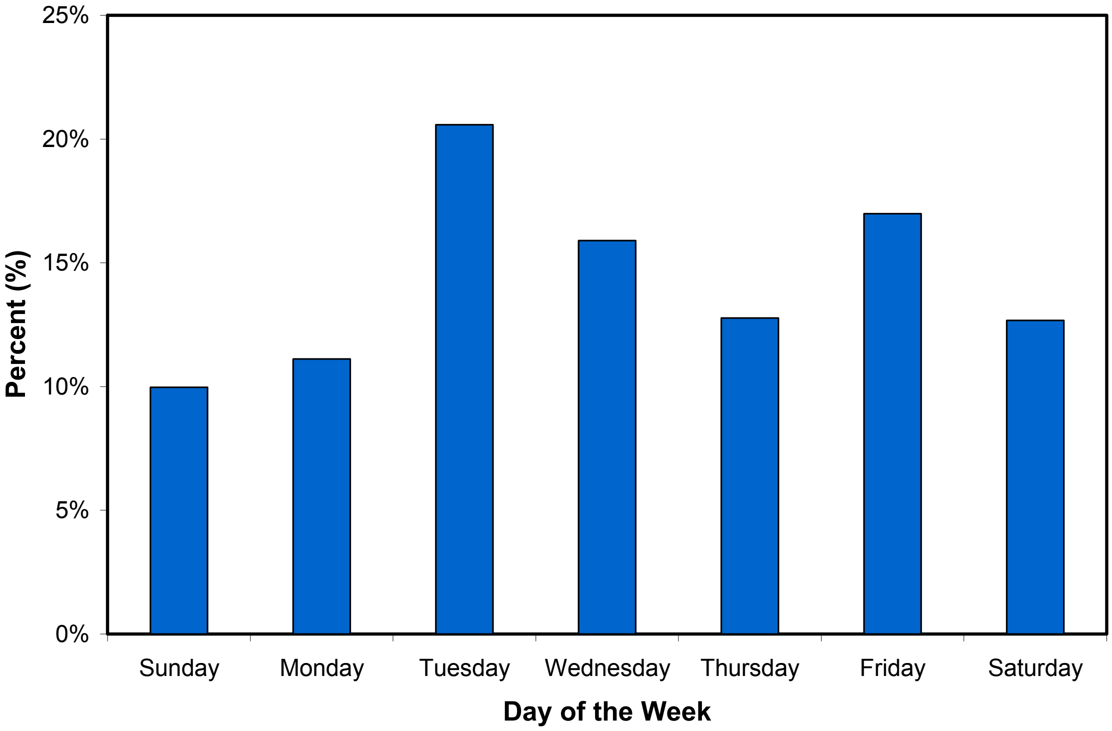


Figure 3.10 Distribution of idling events by map location number (N_{events} = 206). Number of events over the 28 intensive monitoring days.

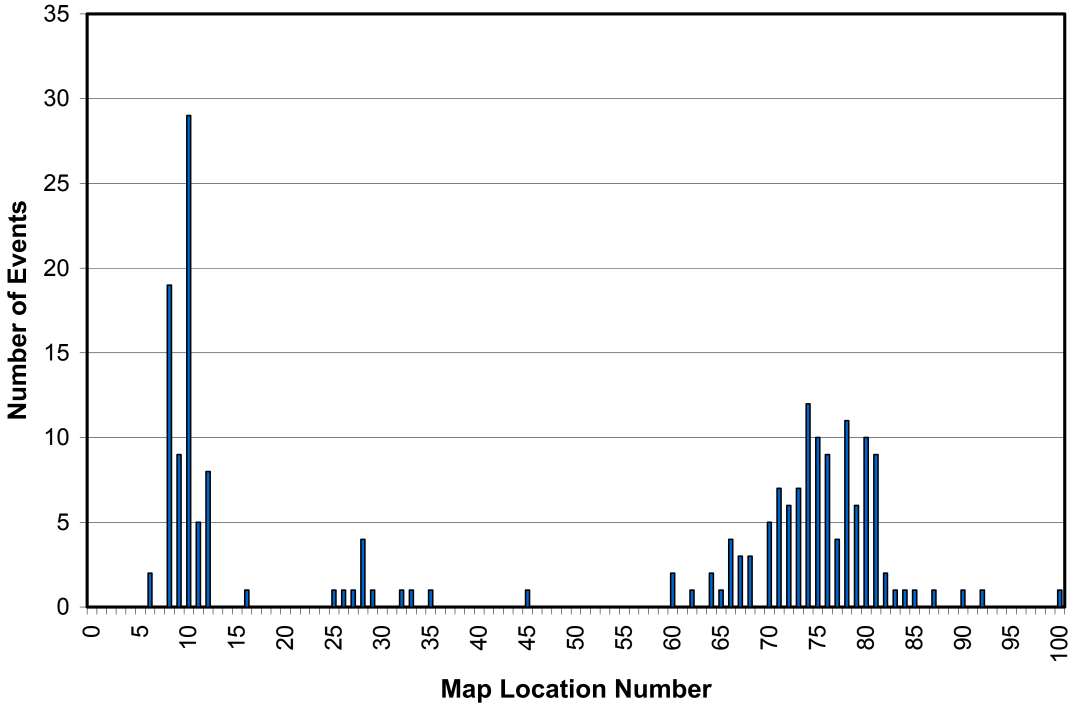


Figure 3.11 shows idling minutes per hour by zone. The largest number of minutes per hour can be attributed to idling near the warehouse (Zone 1). Other items to note are: 1) when idles do occur in Zone 5, they tend to be at night, and 2) the majority of idling in Zone 4 occurs between 2 and 10 am. The idling sound emissions in Zone 5 at night and the northbound passby horn use were the primary train noise complaints raised by residents on the north end of Teaneck.

Trains are about as likely to idle in Zone 1, near the warehouse at the south end of Teaneck, as they are to idle in Zone 4, between a commercial building area and the residential area toward the north side of Teaneck (Figure 3.12). However, the vast majority of idling, 68%, occurred in southern Teaneck (Zone 1; **Figure 3.13)** because the

Figure 3.11 Average number of idling minutes per hour by hour of the day and geographic zone

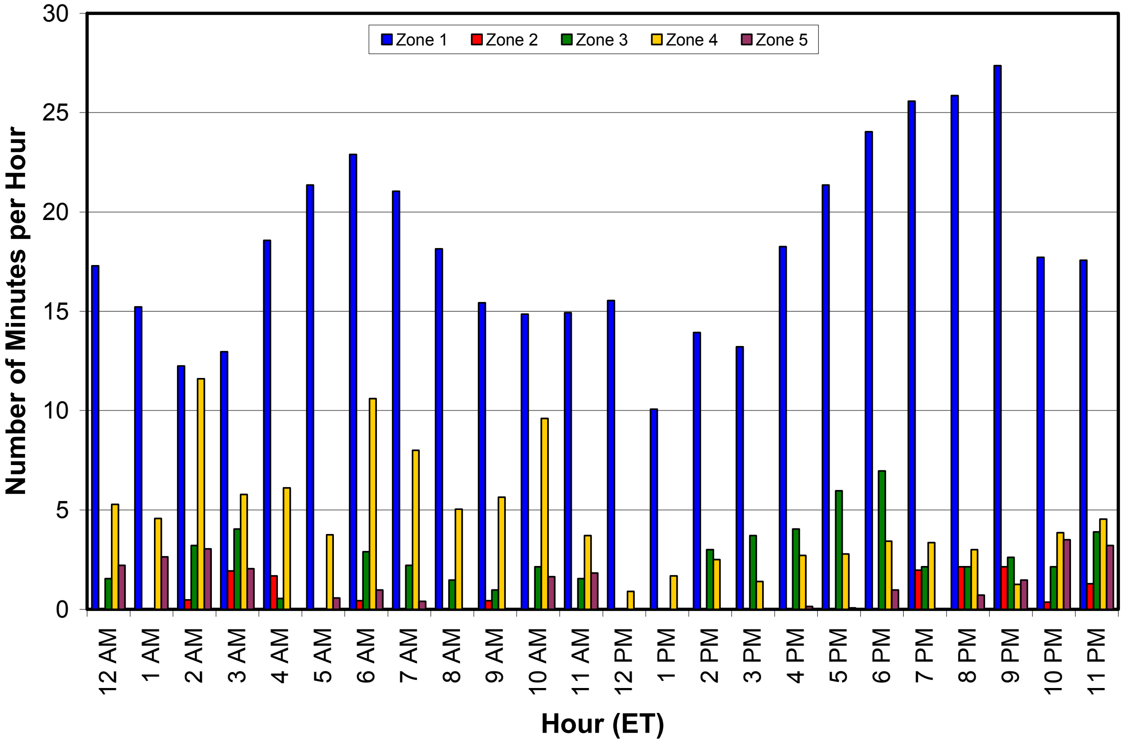


Figure 3.12 Percent of idling events by geographic zone (N_{events} = 206)

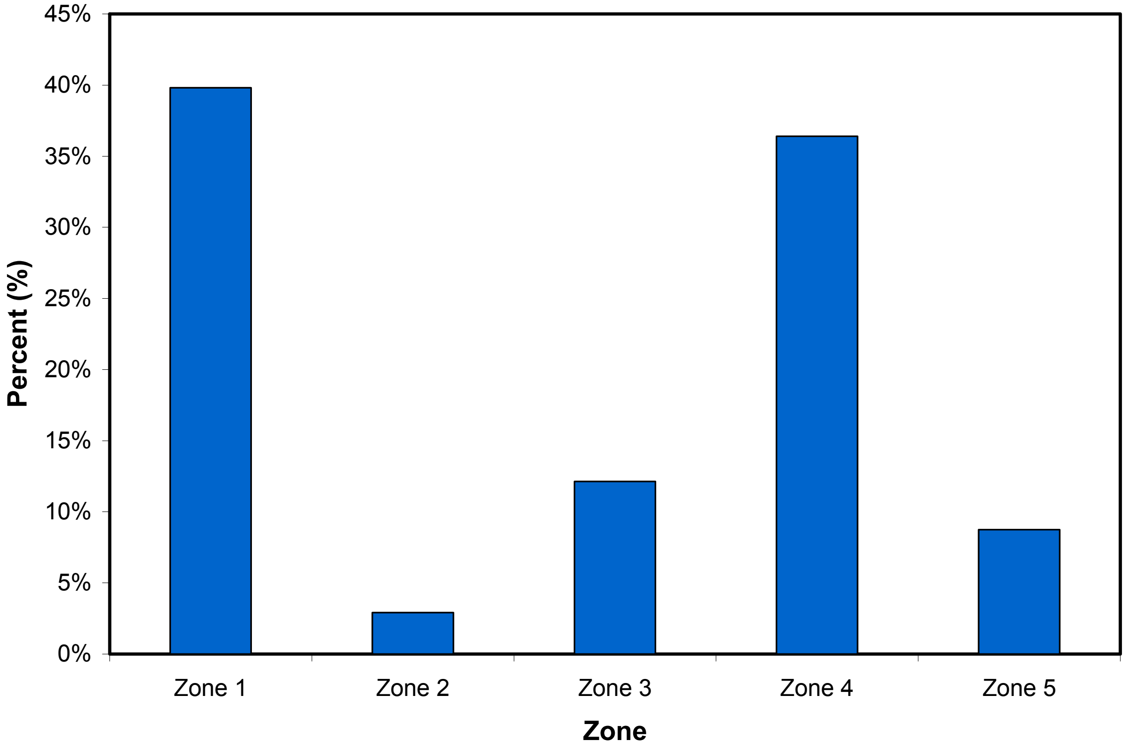


Figure 3.13 Percent of total idling minutes by geographic zone (N_{events} = 206)

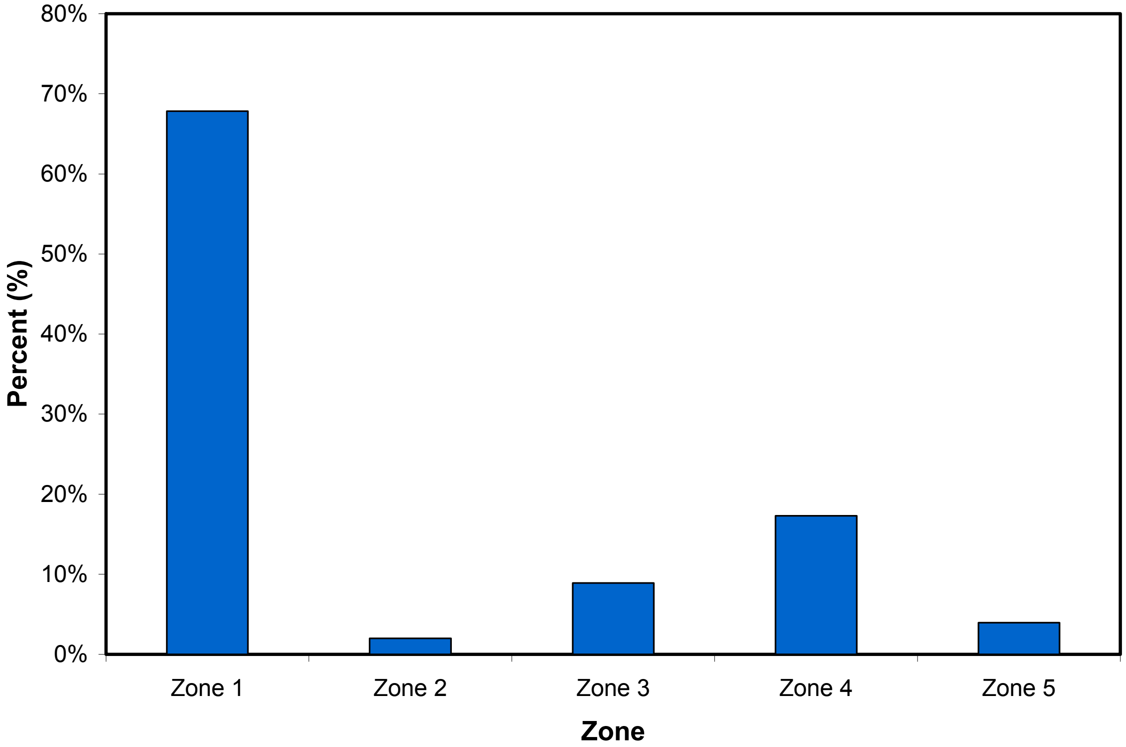
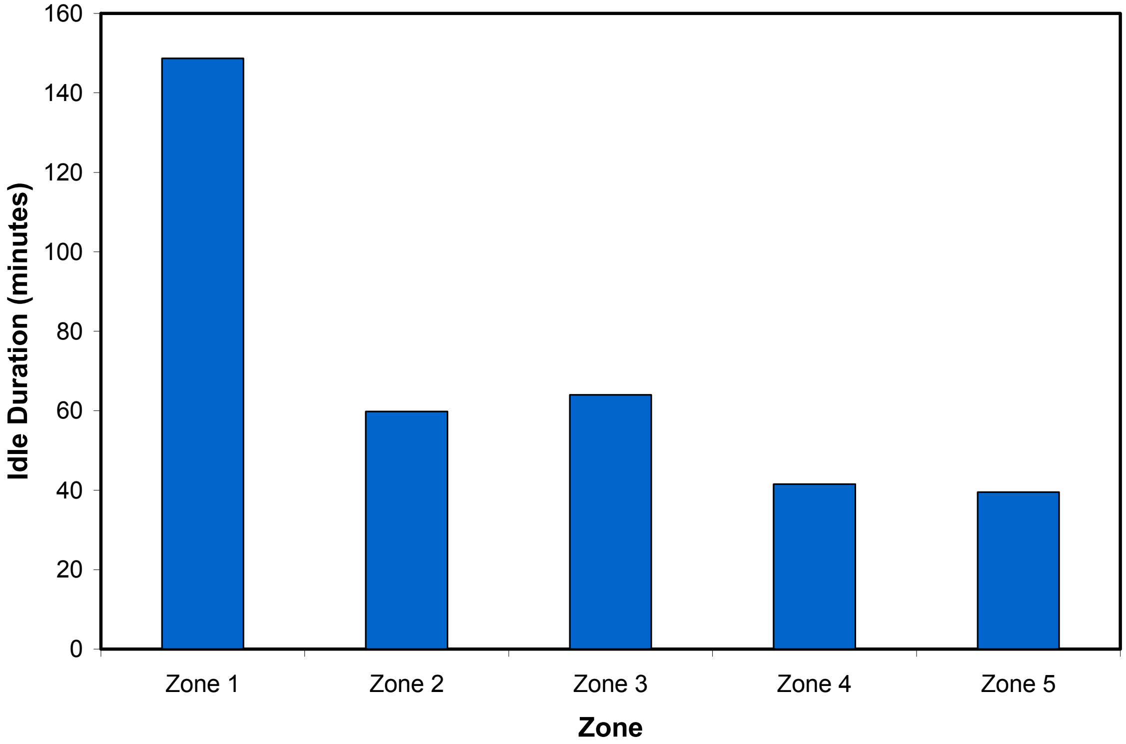


Figure 3.14 Average idling duration by geographic zone (N_{events} = 206)



average idle duration in Zone 1 was more than double that in any other zone (**Figure 3.14**). **Figure 3.12** also confirms that idling events rarely occurred behind residences on the very north end, Zone 5, where the homes are closest to the track (i.e., ~ 25 yards).

As discussed in Section 2.3.2, sound level measurements of single idling locomotives were made on several occasions using hand-held and long-term meter data. The combined sound level measurements resulted in an average sound level of 65.0 dBA, with a standard deviation of 2.7 dBA and a range of 60.9 dBA to 68.5 dBA, standardized to 30.5 meters (100 feet), and assuming a sound level decrease rate for stationary sources of 6 dB for every doubling of distance from the source (Hanson et al., 2006). The spectral frequencies and corresponding decibel levels in the Z-scale (un-weighted) and A-scale (weighted) are listed in **Table 3.2**.

Table 3.2 Spectral Inputs for the Average, Single Idling Locomotive

Frequency (Hz)	Z-Scale (dB)	A-Scale (dBA)
31.5	76.5	37.1
63	80.7	54.5
125	68.0	51.9
250	60.8	52.2
500	61.1	57.9
1,000	56.5	56.5
2,000	55.2	56.4
4,000	55.8	56.8
8,000	56.1	55.0
16,000	46.7	39.7

The above-mentioned idling activity patterns, durations, and locations will be combined with the sound level measurements to run the sound propagation model.

3.3 Train Horns

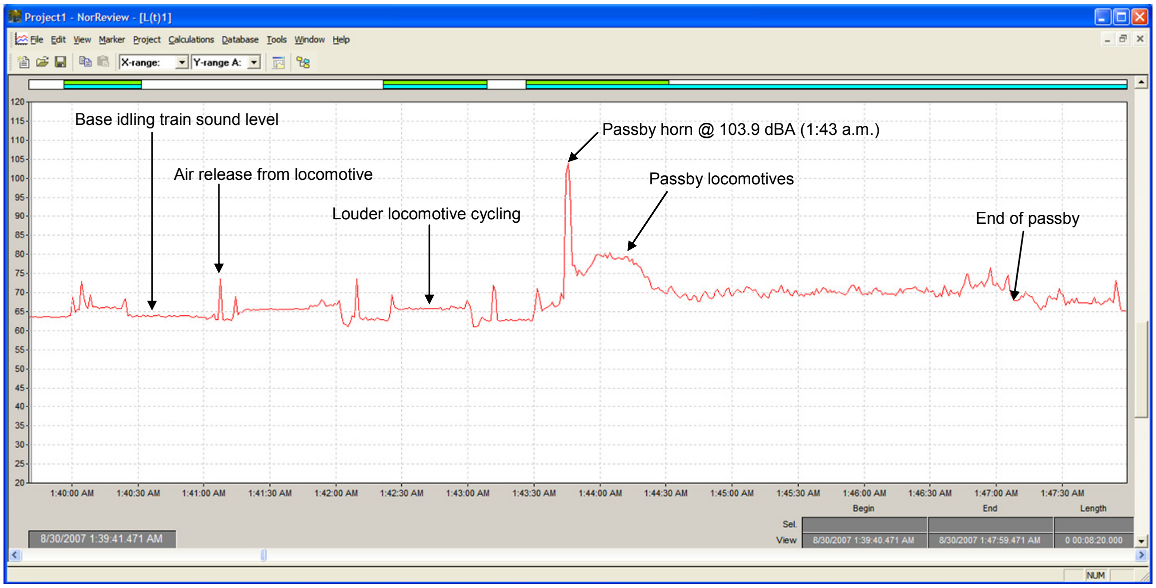
In addition to sound levels measured and analyzed for passby and idling trains, we also captured data from horn use behind homes near a grade crossing on the northern boundary of Teaneck. The average horn sound level was 104.3 dBA at 30.5 meters (100 feet), with a standard deviation of 3.9 dBA and ranged from a low of 94.2 dBA to a maximum of 109.0 dBA. The spectral data associated with the average horn sound level are included in **Table 3.3**.

Table 3.3 Spectral Inputs for the Average Horn from a Passby Train

Frequency (Hz)	Z-Scale (dB)	A-Scale (dBA)
31.5	88.6	49.2
63	98.5	72.3
125	93.0	76.9
250	96.6	88.0
500	103.8	100.6
1,000	100.3	100.3
2,000	93.9	95.1
4,000	86.5	87.5
8,000	79.9	78.8
16,000	71.9	64.9

An important observation made during the study was that passby trains frequently blew their horn as they approached the locomotives of an idling train (**Figure 3.15**). This practice was not systematic and seemed to be at the discretion of the train engineer, but none-the-less, the presence of the idling trains, especially in the southern end of Teaneck, resulted in horn use that most likely would not have occurred otherwise.

Figure 3.15 A passby blowing its horn as it passes an idling train



8/30/2007 1:39:41.471 AM

	Begin	End	Length
Sel.			
View	8/30/2007 1:39:40.471 AM	8/30/2007 1:47:59.471 AM	0 00:08:20.000

The above detailed time-activity data and spectral sound level data were used as inputs for running the acoustic model for passby, idling, and horn blowing scenarios.

3.4 All Trains

We collected and analyzed data to determine which train companies own and operate the locomotives, so as to identify the number of corporations that would need to be addressed and involved in future noise abatement efforts. For all passby and idle events observed during the intensives, study personnel noted the company name identified on the side of all locomotives, assuming that the labels were not obscured by other trains or obstacles or that there was enough light to actually read the labels. **Table 3.1** contains a listing of all companies and the corresponding percentage of the total number of locomotives observed. As expected, due to the company's ownership of the railway, the vast majority of the locomotives belonged to CSX, but it was obvious that numerous companies will need to be accounted for in any future railway policy and activity changes.

An additional item noted from each of the locomotives was the unit number, which uniquely identifies each locomotive within each company's fleet. Although no practical use of the information has been made, it was envisioned that if questions were raised with regard to measurements of a particular locomotive, the unit number could be used obtain specific information about the locomotive, such as the manufacturer, manufacture date, and engine power capacity.

Track usage was also analyzed. Track A is the westernmost track. Track B is the center track and is 3.6 meters (4 yards) east of Track A. Track C is the easternmost and is 7.3 meters (8 yards) east of Track B. Because of the fairly narrow rail corridor, e.g., 11

Table 3.4 Train companies operating on the West Shore Line.

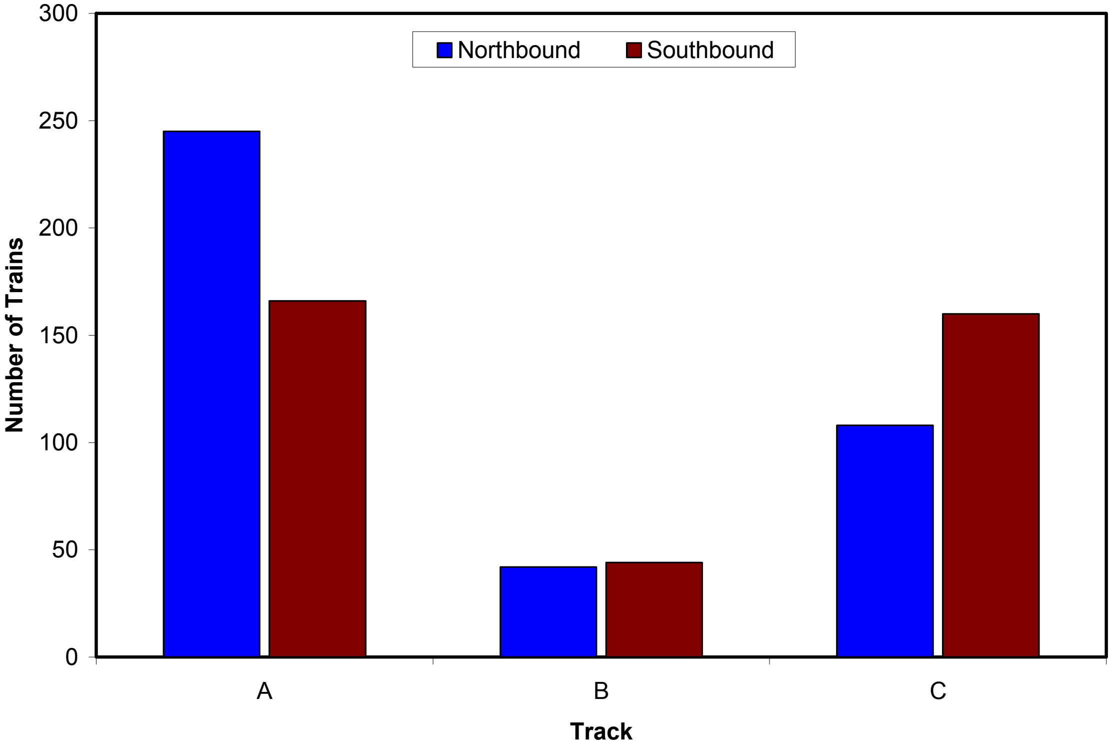
Abbreviated Name	Complete Name	Percent of Observed Locomotives[a]
BNSF	Burlington Northern Santa Fe Railway	1.2
CEFX	CIT Group/Capital Finance Incorporated	1.0
CELX	Celtran Incorporated	0.0
CON	Consolidated Rail Corporation (Conrail)	3.5
CSX	CSX Corporation	85.0
FURX	First Union Rail	0.1
GCFX	Alstom Canada Incorporated Transport	0.8
HCLX	Montell Canada Incorporated	0.3
HLCX	Helm Financial Corporation	2.1
LMS	Locomotive Management Services	0.5
MPRX	Motive Power & Equipment	0.1
NS	Norfolk Southern Railway Company	1.5
QG	Quebec Gatineau Railway Incorporated	0.1
RIO	Denver & Rio Grande Western	0.4
SP	Southern Pacific Railroad Company	0.0
UP	Union Pacific Railroad Company	3.4

[a] Values of 0.0% represent train companies for which only one or two locomotive(s) was observed.

meters (12 yards) between the outermost tracks, sound emissions from the railway were similar on both sides of the corridor regardless of the track on which the trains passed by or idled. However, there was a noticeable difference in the usage pattern. Track A was used most frequently by northbound trains, Track B was used equally by northbound and southbound trains, and Track C was used most by southbound trains (**Figure 3.16**). Out of the 206 idling events, 23% of the trains idled on Track A; 39% idled on Track B; and 38% idled on Track C. The comparable split between Tracks B and C makes sense because Track A is the continuous rail; the other tracks split off from and merged back into Track A.

Two additional characteristics of trains, for which information was collected during the intensives, were the numbers of locomotives and train cars. When possible, the observer also noted whether or not each locomotive was "on." However, this was

Figure 3.16 Track usage on the 28 intensive monitoring days (N_{trains} = 765)



only practical during daylight hours, when air emissions could be seen exiting the exhaust stack. Locomotive and train car counts were obtained for a total of 703 observed trains and a hand-held counting device was used to tally each car as it passed. There were an average of 2.3 ± 0.7 (1σ) locomotives per passby, of which an average of 2.0 were "on", and an average of 90.4 ± 36.3 (1σ) train cars. In addition, the number of locomotives ranged from one (1) up to six (6), while the number of train cars varied from a minimum of 16 up to a maximum of 214. Nine (9) locomotives were seen on one passby, but it did not have any train cars. Similar statistics for idling trains were discussed in the previous section.

3.5 Ambient Sound Level Measurements

Ambient sound level measurements were manually made with the long-term meter in late May 2008 at five of the locations (see **Figure 2.4**) noted in **Table 3.2**, during daytime (10 a.m. to 4 p.m.), rush hour (6 a.m. to 9 a.m. or 4:30 p.m. to 7:00 p.m.), and overnight (12 a.m. to 5 a.m.) periods to capture ambient sound levels during three types of activity patterns common to suburban areas. Measurements for location B were taken in April 2008 and were not re-sampled in May because they were not impacted by passing vehicles like the measurements in each of the other locations. All samples were 15 minutes in duration and included the sounds from all typical neighborhood activities. The results are shown in **Table 3.2**.

In addition to the raw data, Ldn, a composite 24-hour, day-night sound level where nighttime (10 p.m. – 7 a.m.) measurements are increased by 10 dB due to peoples' increased sensitivity to sound during those hours (Hanson et al., 2006), was computed using the method and equations detailed in Hanson et al., 2006, Appendix D, Option 3. The computation calls for the use of hourly sound levels, but 15-minute samples were used as inputs because, based on the extensive amount of staff time spent in Teaneck, they adequately represented an entire hour and limited the additional amount of time required to obtain the samples, especially during the overnight hours. As can be seen in the table, Location C had the loudest ambient sound levels and that makes sense because it was near Teaneck Rd., which is one of the busiest roads in the township and has all types of vehicles traveling on it, including heavy duty trucks and buses. The quietest location, B, also was logical based on observations made during measurement taking because it is far from Teaneck Rd. (137 meters/150 yards) on the east side, is at the end of a cul-de-sac where automobile activity is minimal, and has a school on the west side, with the railroad tracks beyond it at a distance of 137 meters (150 yards). Study personnel spoke with a resident who lives adjacent to the measurement location and the resident stated that idling trains and passby trains, with and without horns, were disturbing at night. With the nighttime sound levels being the lowest in this location out of all the measurement location, sound emissions from train activity would not have to be very loud to have a significant impact on the residents.

Table 3.5 Ambient Sound Level Monitoring Results

	Day Time			Peak Hour			Overnight			
Loc.	Leq dBA	Lmax dBA	Lmin dBA	Leq dBA	Lmax dBA	Lmin dBA	Leq dBA	Lmax dBA	Lmin dBA	Ldn[a] dBA
A	52.8	64.3	44.9	52.3	66.6	43.6	41.1	57.3	46.6	50.2
B	46.3	58.8	41.1	47.2	59.1	41.2	39.0	NA	NA	45.6
C	60.3	78.4	46.7	59.5	73.4	50.1	45.9	58.0	36.6	57.0
D	No Measurements									
E	No Measurements									
F	51.9	71.5	40.5	54.3	73.2	41.9	49.0	67.4	39.8	54.1
G	50.5	70.2	40.1	51.6	66.6	43.4	43.1	53.6	38.1	49.8
H	50.6	66.3	39.4	51.0	64.7	40.5	43.4	61.0	33.3	49.9

[a] Calculated using Option 3 in Appendix D of Hanson et al., 2006.

The ambient sound level data in neighborhoods were compared to neighborhood (propagated) sound levels from railway activity to assess the impact of various train activities on residents. Using the model input sound levels discussed in Section 3 for idling and passby trains and combining those with the guidelines that sound levels from a stationary source (idle) decrease by 6 dBA (3 dBA from a line source, such as passbys) for every doubling of distance away from the source (Hanson et al., 2006), average sound levels were calculated for Location B, assuming the trains were on track C, the nearest track to the location. For an idling train (stationary source) with one locomotive at 65.0 dBA @ 30.5 meters (100 feet), the sound levels at Location B, 137 meters (450 feet) away, would be ~59.1 dBA. This would be audible during the day since it is above the ambient sound level measured, but with an added penalty of 10 dBA at night, the sound levels would be 30 dBA louder than background. An increase this substantial would be considered severe (Hanson et al., 2006) and would confirm the comments made by the nearby residents that the trains are disturbing. A similar calculation for passby trains with an average sound emission level of 78.1 dBA @ 30.5 meters (100 feet), results in a daytime sound imission level at Location B of ~71.6 dBA. At night, this would produce a sound level of more than 40 dBA higher than the ambient levels measured. These calculations assume that there are no barriers between the train and the measurement location and that the resulting sound levels would vary based on the number of locomotives (this case only had one locomotive, but the average idle had 2.1), cycling of the engines, and air releases for the idling scenario and the speed, length, and throttle level of the trains for the passby scenario.

Additional impacts of train sound emissions will be modeled and are beyond the scope of this thesis.

4. MITIGATION STRATEGIES

A variety of train noise mitigation strategies can be used to reduce the residential impact of train noise in Teaneck. There are only a few options for mitigating passby train noise because of their relatively short durations and limited restrictions on railway commerce. Idling train noise is the result of controlled stopping of the trains for any number of reasons, such as train routing, the scheduling of shipments, and weather, and the continual operation of the locomotive engines. Because Teaneck has extended stretches of uninterrupted track, it is an ideal location for idling long freight trains. Fortunately, there are many options for controlling noise from stationary sources. Based on our observations, train engineers have significant flexibility in where they idle the locomotives, which allows for additional mitigation alternatives.

4.1 Train Activity Adjustments

The simplest and least costly option for reducing the impacts of idling sound emissions would be to alter the locations of the idling. The goal of this mitigation method is to have trains idling as far from residences as possible. The vast majority of trains by number and duration did idle in "approved" areas, so there was considerable compliance by the train engineers. However, trains were also observed to idle behind homes in the northern end of Teaneck and in areas north and south of the warehouse in the southern end. Even if there was 100% compliance with respect to idling in agreed locations, sound emission levels are still loud enough on many occasions, especially at night, to be audible at residences beyond the barriers and forested areas.

Reductions in passby-train noise are likely to occur if trains passed more slowly through Teaneck, since substantial sound emissions are generated from the wheels, rails, load of the locomotives. This kind of action would prolong the passby events, but reduce the average sound level and decrease the likelihood of disruption of human activities.

4.2 Sound Barriers

A second option would be to install sound barriers, or walls, as done in many highways in most major cities. These barriers would be installed in areas along the tracks where the homes are most affected by idling. This option is likely to reduce a range of sound impacts, but it is expensive and barriers only abate certain frequencies of sound that are efficiently attenuated by the material used and thickness chosen for the barriers (Hanson et al., 2006). Sound waves also refract over barriers, so if the distance between the sound sources (trains) and the sound receptors (homes) are not ideal, the effectiveness of the barrier is reduced (Hanson et al., 2006). In addition, many residents who are not bothered by noise may become unhappy with the interim noise generated by the construction of the barriers and the long-term aesthetics of a wall versus the current vegetation that exists between the tracks and homes. The location of the barriers would define the limits of the recommended idling areas, but there still is not a way to ensure that the train engineers will stop within those areas. Another major issue is that if the barriers are placed behind homes, the train engineers might actually idle longer, having the false impression that the barriers are attenuating all sound emissions, which is not the case.

Erecting barriers between sound sources and receptors often seems like a practical and straightforward idea, but in reality, these barriers might not be very successful in the abatement of idling noise in Teaneck because of sound refraction around the barriers; varying sound emission frequencies; and the potential for increased idling. In addition, some residents may find them to be unsightly, especially if they replace natural vegetation.

4.3 Auxiliary Power Units

To curtail the sound emissions from idling locomotives, the easiest solution is to turn off the locomotives. However, during cold weather and short stops, i.e., less then two hours, it is not feasible to turn off the locomotives due to 1) the risk of not being able to restart the cooled diesel engines, or 2) the duration of time required to start the engines and return them to operating conditions. In addition, the engines provide electrical power for the heating and cooling units on the locomotives used to keep the functional components warm during the cold periods (<7.2°C or <45°F) and the train staff cool during hot summer periods.

An alternative to turning off the engines, while retaining sufficient power to operate essential equipment, is the installation of auxiliary power units (APUs). APUs are essentially small electricity generators that run on the same diesel fuel as the locomotives. They have been installed on numerous freight train locomotives across the U.S., including many owned and operated by CSX (SWRI, 2004). The key advantage is that the APU's allow trains to stop anywhere because they do not require any external resources and because the units are installed within the locomotive. Any noise they produce is shielded by the locomotive's structure, greatly reducing sound emissions levels in comparison to the idling of locomotive engines. Beyond the noise-related benefit, the units greatly reduce fuel usage during idling, pollutant emissions from the fuel burning, and wear-and-tear on the locomotive engines.

The biggest hindrances to the installation of the APUs are space with the locomotives and cost per locomotive. The cost can be as much as tens of thousands of dollars (Montanez and Mahler, 2005). However, the reduction in fuel use and wear on the locomotive engines would make the installation of APUs extremely cost effective in the long run.

An alternate option to installing the APUs on each locomotive would be to install a track side power supply, allowing trains to plug into the power grid. This option would specify where the trains must stop due to the limited reach of the power device, which is good for Teaneck, but it would also still require some retrofitting of each locomotive and would decrease the flexibility in idling locations for the train companies.

The use of locomotives equipped with APUs or that are able to plug in to track-side power would be a very effective mitigation measure for idle noise in Teaneck, but the implementation of this solution across the hundreds of locomotives that pass through the township each week and the numerous locomotive companies would be challenging.

4.4 Wayside Horns

One of the primary noise concerns for the residents living at the north end of Teaneck is the train horn usage preceding the grade crossing between Teaneck and Bergenfield, especially for train heading northbound. As was previously shown, more trains pass through Teaneck northbound at night, contributing to a higher frequency of horn usage behind the homes on the eastern side of the track during the hours when people are sleeping and most susceptible to horn- related impacts. The most effective solution for noise reduction could be the installation of wayside horns at the grade crossing (Raub et al., 2003). This system consists of horns located at the grade crossing which are pointed perpendicular to the tracks, along the roadway, and are triggered by an approaching train (Gent et al., 2000). The horn sound emissions are focused on the vehicles they are intending to alert rather than on a broad area to the south of the grade crossing that includes many Teaneck residences. While these systems cost money to install, train study personnel observed that the grade crossing already contains arms that drop down, flashing lights, and ringing bells, all which are automatically triggered by approaching trains, so the majority of the infrastructure needed to operate the wayside horns and limit train-horn use is already in place.

The installation of the wayside horns at the north end grade crossing would vastly improve the quality of life for the hundreds of Teaneck residents that are impacted by train-horn noise, especially during the overnight hours. However, the use of wayside horns would not have any impact on the horns blown by passbys to alert those on idling trains. Passby horn use during idling events was very sporadic, though, and an activity that we noted during the study, not something the residents mentioned. The residents' complaints focused on the idling noise itself and horn use near the grade crossing.

While there are several options for mitigating the sound level emissions from various train activities in Teaneck, extensive cooperation by the railway companies will be essential for any of the methods to be successful. Additional efforts by locomotive manufacturers could also be effective at limiting noise emissions from the engines and other locomotive infrastructure.

5. CONCLUSIONS

The findings of this study indicate that passby and idling freight train activities are indeed prevalent in Teaneck Township and impose several sound-related impacts on several hundred residents. With approximately 28 passby trains (2.8 minutes/train) and 7.4 idling events (87.2 minutes/event) per day, on average, residents as a whole are exposed to 12 hours of train sound emissions daily. In addition, more passbys per hour occur at night than during the day (1.4 versus 1.1) and a higher percentage of the nighttime passbys are northbound, meaning residents living near the north end of Teaneck are exposed to frequent train sound emissions and horn use at night, when noise impacts are greatest.

In terms of idling sound levels, it was shown that the average idling locomotive produces enough noise to be considered a severe impact on many residences, especially at night, because the idling noise can be 20 to 40 of decibels higher than ambient sound levels, as was computed for ambient monitoring Location B. This partially explains why residents could clearly hear the idling locomotives and were bothered by it. The other reason was the variation in loudness associated with many of the observed idles due to cycling of the engines or air compressors on the locomotives and louder air releases for a couple seconds. Trains with a low steady idle were much less noticeable than those with variable noise output.

Extensive visual information collected during the intensive monitoring periods, combined with anecdotal data captured by the long-term meter showed that, while idling in unapproved areas does not appear to be as excessive as reports and complaints suggest that it was in the past, some trains continue to idle in areas outside of the locations approved by township officials.

The focus of this study was initially intended to be just idling trains and their noise impacts, but it quickly became clear that one of the most disruptive behaviors associated with the trains was the horn blowing. The two main reasons for it were 1) to alert those at the grade crossing on the northern edge of Teaneck and 2) to alert idling trains. The first reason is mandated for the safety of the public, but there are other methods for alerting people and vehicles at the grade crossing without having to blow the horn multiple times, at well over 100 dBA at 30.5 meters (100 feet), as the trains travel through the township. The second purpose for horn blowing is actually a consequence and function of idling. Mitigation of the horns for the grade crossing should be the first concern due to the numerous complaints about them by residents and the high decibel levels regularly impacting broad areas of the community at all hours of the day and night.

The amount of train activity during some of the hours was surprising, for example when there were 6 passbys in one hour, or when there were multiple idling trains on multiple tracks, while passbys simultaneously passed on the third track. There were many more spans of 4 or 5 hours without a single train, providing many hours of relief from the train noise. Unfortunately for Teaneck residents, the least active times tended to be during the day, when people are not likely home or sleeping, resulting in reduced noise impacts.

Overall, there are several issues that could be addressed with the mitigation strategies discussed, but it will take the will and cooperation of the township, the residents, and the train companies, and resources to reduce the exposure of impacted residents to train-related noise.

6. IMPLICATIONS

Several results from this case study could serve as valuable inputs and points of comparison for modeling studies elsewhere. Specifically, the sound-level frequency distributions determined for different types of train events will certainly be applicable to train-noise propagation modeling in other U.S. communities, namely those with residential impacts of idling, diesel freight locomotives and the use of horns near grade-crossings. Not only are the sound emission data usable for obtaining initial guidance before beginning sampling, the monitoring and observational methods we used to conduct this study provide a solid basis for anyone interested in performing a similar study in another location.

Our findings are consistent with complaints filed by Teaneck residents in several regards: both this study and residents report idling outside of approved areas; idles of excessive duration; and horn of sufficient volume to disturb and disrupt sleep during nighttime hours. However, the idling behavior that lead to complaints in the northern end of Teaneck did not seem to match the level of activity observed during the annual monitoring campaign. A substantive change in train activity just before the study began was corroborated through a conversation with a train engineer, who indicated that idling in Teaneck had been reduced due to the establishment of new idling locations north of Teaneck.

Another key observation made by residents and study personnel is that the trains produce significant air pollutant emissions, particularly when multiple trains, with multiple locomotives running, idled in the same location. On the occasions when we observed three concurrent idles, air emissions were clearly coming from the locomotive exhaust stacks; pollutants lingered between the trees and buildings lining the rail corridor;

emission plumes were seen drifting into adjacent neighborhoods; and the air was stifling to breathe. Studies show that emissions from the diesel burning engines, such as those on locomotives, consist of nitrogen oxides, sulfur dioxide, metals, toxics (e.g., benzene, PAHs), and particulate matter. These pollutants are known to have direct health impacts and lead to increased health risks (McEntee and Ogneva-Himmelberger, 2008). One study showed that emissions increase as engine load decreases, with maximum emissions occurring during idling (Sharma et al., 2005). As a result, an air pollution study to evaluate exposure to locomotive idling emissions during extended idling events would be warranted.

In conclusion there is a need to address horn noise in northern Teaneck and idling noise in all areas through adjustments in idling locations and the use of auxiliary power systems, whether on the trains or trackside. Changes to idling locations have already alleviated some of the train noise impacts and it is likely that the current economic slowdown is further reducing train noise impacts through reductions in the movement of goods. The implementation of mitigation strategies for horns would likely provide the largest residential reductions in the loudest train noise and the installation of APUs would significantly reduce noise from idling locomotives and would additionally yield the largest train-related air quality benefits. The people of Teaneck have a reasonable expectation of train noise since many knowingly purchased homes near active railroad tracks, but changes to railway activities since the takeover of the tracks by CSX pushed many residents beyond their tolerance thresholds. Out of common courtesy by the train companies and a need for the township to help its citizens, viable noise mitigation strategies should be actively considered.

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Appendix A

Idle Location Maps


VANDELINDA
JOHNSON
SHERMAN
PALISADE
GRIGGS
KIPP
THOMAS
CHESTNUT
CHESTNUT
LINDEN
TERHUNE
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CARROLL
DEMOTT
FRANCES
CEDAR
PALMER AVE
BARR
FRANCES
DEMOTT
BRINKERHOFF
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RAILROAD PLZ
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MANOR
PALISADE
32
WINDSOR
31
RAILROAD
30
DEMOTT
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WATER
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AMERICAN LEGION
ALMA
CHESTNUT
NORTH
KIPP
LINDEN


RIDGE
COLONIAL
KING
HOBSON
NJSH RT 4
CRANFORD
QUEEN ANNE
EDGEMONT
CARLTON
PALISADE
WINDSOR
WOODS
HADDON
BIRCH
WYNDHAM
CUMBERLAND
CLAREMONT
SUSSEX
ALDEN
BELLE
BEVERLY
CEDAR
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WALRAVEN
W ENGLEWOOD
LAUREL
THE PLAZA
PUBLIC RD
COURT
ROGERS
EVERGREEN
PINEWOOD
ALICIA
BEAUMONT
CHURCH
W FOREST
JOHN
QUEEN ANNE
PALISADE
61
60
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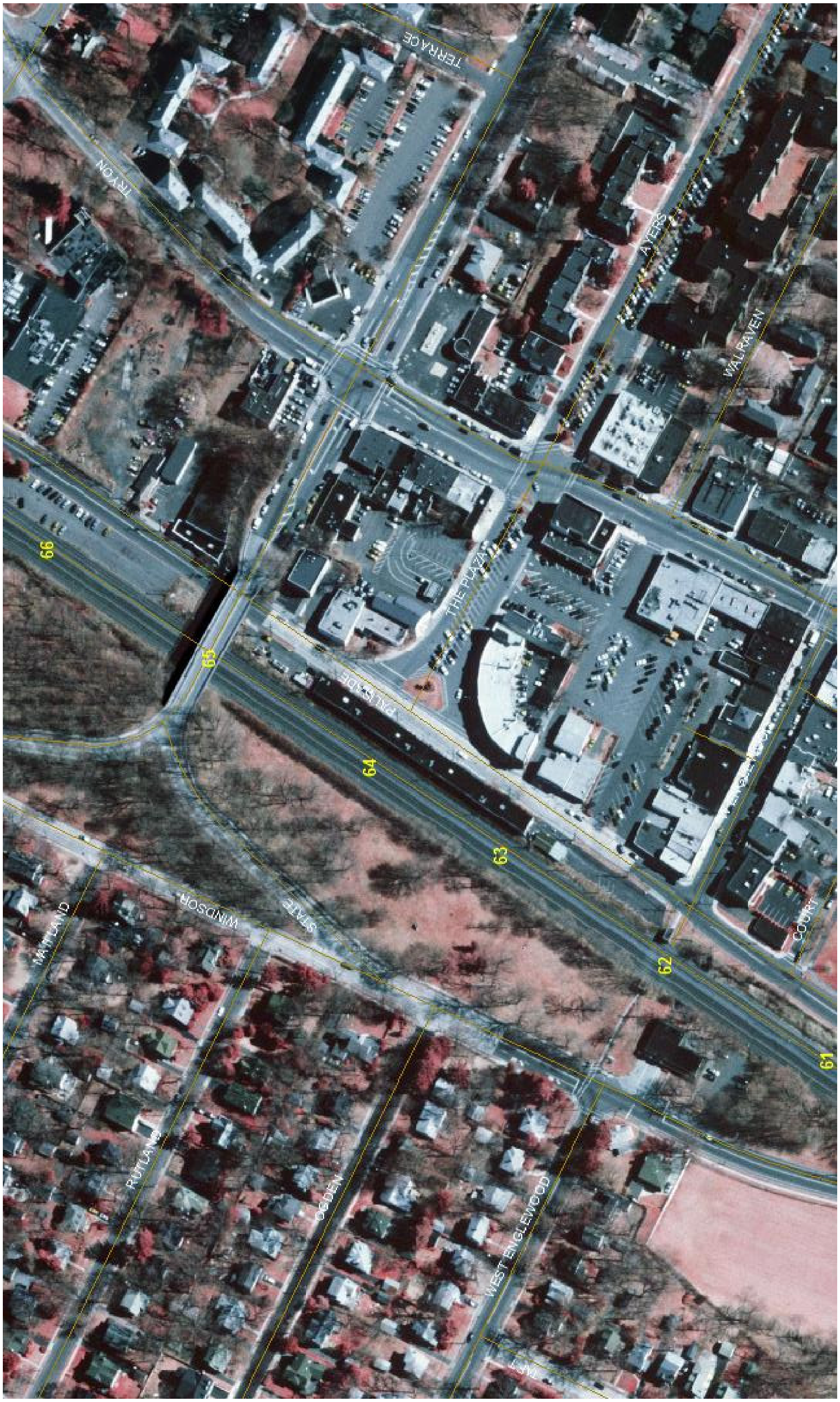
PRINCETON
DICKERSON
PENNINGTON
EMERSON
FOREST
WINDSOR
KENSINGTON
KENSINGTON
MAGNOLIA
EMERSON
FOREST
SUSSEX
LAMBERT
BELL
BILLINGTON
BILLINGTON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TRYON
AYERS
WALRAVEN
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THE PLAZA
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PALISADE
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COURT
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WINDSOR
STATE
MAITLAND
RUTLAND
OGDEN
WEST ENGLEWOOD


SACKVILLE
SHERBOURNE
BILTON
GALWAY
STEPHENS
GALWAY
TRYON
AMSTERDAM
PALISADE
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WINDSOR
CHURCHILL
WINTHROP
EDGEWOOD
STATE
WARWICK


WARD PLZ
VAN ARSDALE
IRVINGTON
STUYVESANT
VOORHEES
ARMORY
TEANECK
JEROME
ELMER
CLINTON
LIVINGSTON
SACKVILLE
PALISADE
GIVAUDAN
WINDSOR
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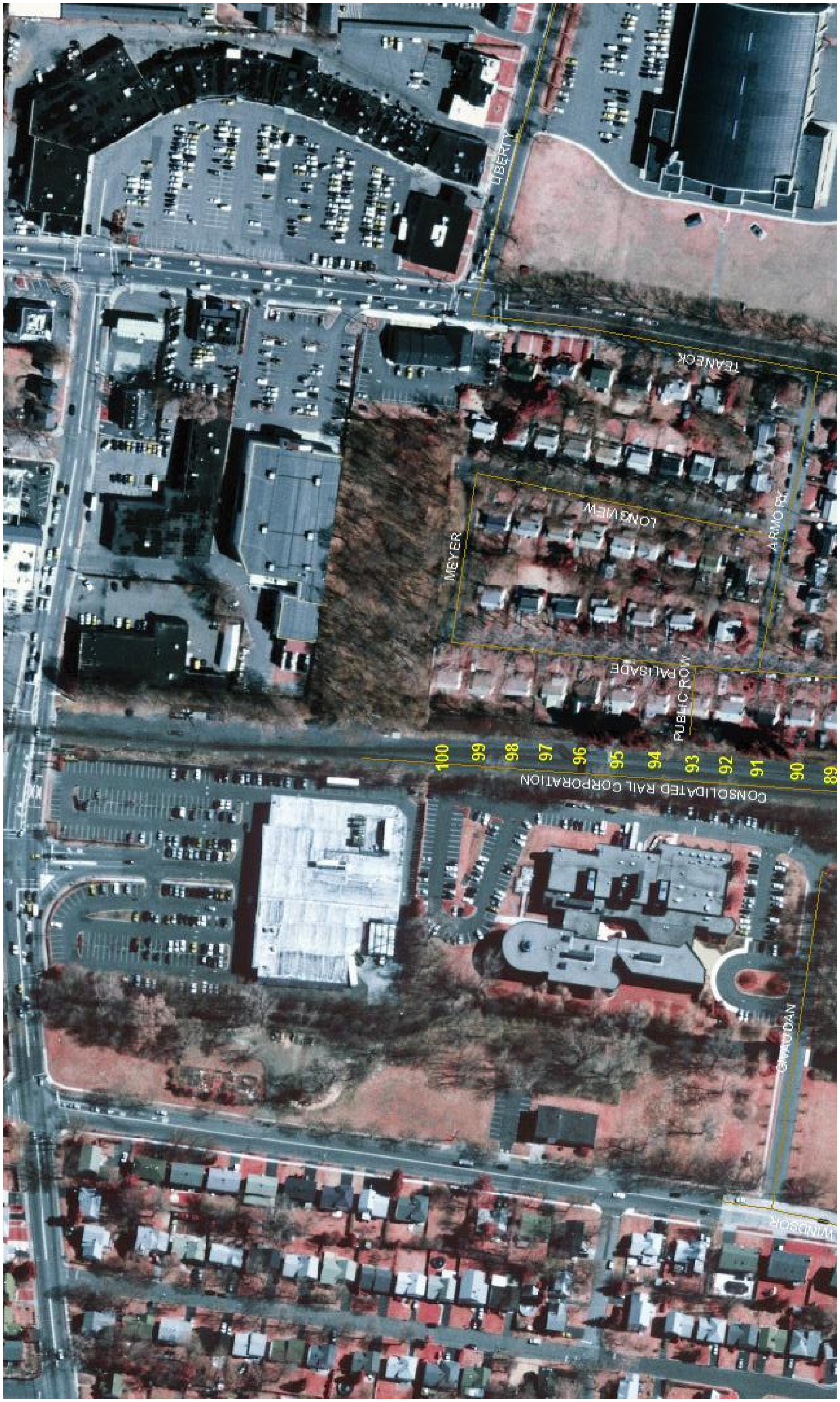
LIBERTY
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LONGVIEW
ARMORY
MEYER
PALISADE
PUBLIC ROW
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CONSOLIDATED RAIL CORPORATION
GRAUDAN
WINDSOR


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Appendix B

Data for Model Verification Scenarios & All Hand-Held Sound Level Measurements

Model Verification Scenarios

Model Verification Scenario	Meter	Date	Time (24h:m)	MemLoc# or Session#	Duration (m:s)	A Weighted Scale Leq	Lmax	Lmin	Distance (yds)	# locos	Valid	File name	Comments
1	Quest 2900	1/25/07	16:16	12	00:22	75.7	78.6	74.2	36	5			
	Quest 2900	1/25/07	16:17	13	00:26	75.2	80.5	72.6	36	5			
	Quest 2900	1/25/07	16:18	14	00:42	74.5	80.7	72.6	36	5			
	Quest 2900	1/25/07	16:19	15	00:31	72.6	73.9	71.6	34	5			
	Quest 2900	1/25/07	16:21	16	00:28	70.5	72.3	69.8	34	5			
	Quest 2900	1/25/07	16:22	17	00:54	65.7	71.6	62	88	5			
2	Quest 2900	8/22/07	09:39	1	01:45	69.6	78.8	64.4	30	2		TEA12	
	Quest 2900	8/22/07	09:42	2	02:58	69.4	77.6	64	30	2			
	Quest 2900	8/22/07	09:47	3	01:52	60.7	66.1	56.1	118	2			
	Quest 2900	8/22/07	09:52	4	02:19	53.6	57.8	49.9	176	2			
	Quest 2900	8/22/07	10:01	5	02:28	54.7	60.4	51.7	130	2			
3	Quest Sound Pro	8/19/07	7:11:01	Session102	1:30	69.1	73.4	67.7	28	2		csx7704-7:11 a.m.	
	Quest Sound Pro	8/19/07	7:15:54	Session102	1:31	69.8	73.9	68.6	24			gcfx3058-7:16 a.m.	
	Quest Sound Pro	8/19/07	7:33:16	Session102	1:31	57	62.8	54.1	64			csx7704-7:33 a.m.	
	~~Quest Sound Pro~~	~~8/19/07~~	~~7:44:14~~	~~Session102~~	~~0:54~~	~~53.6~~	~~61.1~~	~~49~~	~~120~~	~~2~~	~~No~~	~~Study127~~	~~No good; plane flew over~~
	~~Quest Sound Pro~~	~~8/19/07~~	~~7:45:45~~	~~Session102~~	~~0:22~~	~~52.5~~	~~57.2~~	~~49.7~~	~~120~~	~~2~~	~~No~~	~~Study128~~	~~No good; plane flew over~~
	Quest Sound Pro	8/19/07	7:46:44	Session102	1:32	51.4	57.3	49.4	120	2		gcfx3058-7:46 a.m.	
	Norsonic Meter	8/19/07	7:16:00 AM-7:25:59 AM EDT		10:00	61.6	74.3	66.7	30	2			Train with two locomotives, the first (CSX 7704) at 28 yards and quiet, but not "off", the second (GCFX 3056) at 30 yards and loud.
4	Quest Sound Pro	8/24/07	16:52:41	Session108	5:26	67.2	70.4	65.7	22	1		Study147	csx7844
	Quest Sound Pro	8/24/07	18:44:11	Session108	3:10	52.5	59.8	47	130	1		Study148	
	~~Quest Sound Pro~~	~~8/24/07~~	~~18:49:36~~	~~Session108~~	~~2:05~~	~~52~~	~~57.8~~	~~46.6~~	~~~110~~	~~1~~		~~Study149~~	~~Somewhat behind barrier; a loud cricket was nearby; should be used cautiously~~
	Quest Sound Pro	8/24/07	18:55:54	Session108	3:42	57.5	63	52.9	~70	1		Study150	
	Norsonic Meter	8/24/07	4:45:00 PM-4:54:59 PM EDT		10:00	61.1	64.1	59.2	38	1			Train with two locomotives, the first (CSX 7844) at 38 yards and "on", the second (CSX 8383) at an unknown distance (maybe ~55 yards), but "off"
5	Quest Sound Pro	8/25/07	7:31:10	Session109	1:30	68.8	76.2	66.7	22	2		csx5113-1	
	Quest Sound Pro	8/25/07	7:35:22	Session109	1:31	69.2	76.9	66.2	22	2		csx7822-1	
	Quest Sound Pro	8/25/07	7:53:29	Session109	1:17	54.7	60.2	52.7	118	2		csx5113-csx7822-118yds	
	Norsonic Meter	8/25/07	7:28:00 AM-7:37:59 AM EDT		10:00	60.5			47	2			Train with two locomotives, the first (CSX 5113) at 47 yards and "on", the second (CSX 7822) at ~70 yards and "on".
6	~~Quest Sound Pro~~	~~8/28/07~~	~~8:00:53~~	~~Session117~~	~~0:23~~	~~71~~	~~71.4~~	~~70.7~~			~~?~~	~~Study181~~	
	Quest Sound Pro	8/28/07	8:02:08	Session117	0:32	71.4	73	70.5	26	2		csx7503-1	CSX 7503 "on" with occasional cycling
	Quest Sound Pro	8/28/07	8:04:05	Session117	0:32	72.3	73.9	71	26	2		gcfx3100-1	GCFX 3100 "on" with steady noise
	Quest Sound Pro	8/28/07	8:10:15	Session117	0:44	56.7	61	56.1	150	2		Study184	Train horn to north may have influenced last few seconds
7	Quest Sound Pro	8/28/07	11:22:25	Session118	1:30	73	78.6	72	24	3		csx8400-1	CSX 8400, steady noise, no cycling, air releases infrequent, 3rd locomotive is off
	Quest Sound Pro	8/28/07	11:26:40	Session118	1:01	72.1	74.7	70.4	22	3		csx7376-1	CSX 7376
	Quest Sound Pro	8/28/07	11:54:40	Session118	0:26	58.8	59.3	58.1	70	3		csx8400-2	Taken east of the train, in cleared area to the north of the soap factory.
	Quest Sound Pro	8/28/07	13:00:20	Session118	0:51	53.7	54.5	53.3	118	3		csx8400-3	Taken at 590 Chestnut; CSX 8400 with steady idle noise
	Norsonic Meter	8/28/07	11:12:00 AM-11:21:59 AM EDT		10:00	67	71.3	63.5	36	3			Train with three locomotives, the first (CEFX 1105) at 28 yards and "off", the second (CSX 8400) at 36 yards and "on" and loud, the third (CSX 7376) at 50 yards and "on", but low noise.

Model Verification Scenarios (continued)

Model Verification Scenario	Leq Frequency Spectrum													Lmax Frequency Spectrum												
	Wt.	OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz	Wei	OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz
1																										
2																										
3	Z	88.5	81.7	62.3	86.8	72.4	60	65.5	62.4	60.7	60.9	58.9	47	Z	88.9	64	82.2	87.1	74	66.9	64.1	60.7	63.9	68.5	67.3	55.4
	Z	90.1	62.2	83.6	88.1	74.7	62.2	66.7	62.5	60.8	62.3	58.2	48	Z	90.5	66.2	84.1	88.6	75.3	63.4	67.9	64.3	64.6	68.9	67.3	57.3
	Z	75.4	55	68.1	73.4	63.4	52.1	51.1	49.7	48.6	49.7	46.2	32.7	Z	76.3	60	68.5	73.7	64.4	53.1	52.5	54.6	55.7	57.5	54.5	40.2
	~~Z~~	~~73.2~~	~~51.2~~	~~66.2~~	~~71.1~~	~~60.6~~	~~50.4~~	~~53.6~~	~~44.2~~	~~42~~	~~43.8~~	~~38.2~~	~~22.6~~	~~Z~~	~~74.5~~	~~59.1~~	~~68.6~~	~~71.6~~	~~62.8~~	~~61.1~~	~~63.2~~	~~52.8~~	~~49.1~~	~~52.1~~	~~47.8~~	~~30.8~~
	~~Z~~	~~73.5~~	~~53.9~~	~~67~~	~~71.4~~	~~60.9~~	~~46.8~~	~~48.3~~	~~44.1~~	~~42.8~~	~~45.3~~	~~39.9~~	~~22.9~~	~~Z~~	~~74.1~~	~~55.6~~	~~68~~	~~71.9~~	~~62.1~~	~~50.6~~	~~53.9~~	~~47.8~~	~~49.1~~	~~52.8~~	~~48.2~~	~~29.8~~
	Z	73.1	50.6	66.3	71.1	60.4	45.9	46.8	42.1	42.4	44.2	37.8	21.8	Z	73.5	53.3	66.7	71.5	61.3	48.7	50.1	46.3	49.6	52.9	48.4	30.5
	Z		61.0	77.8	87.7	71.8	59.4	64.6	61.0	60.1	60.3	58.5	49.5	Z		62.6	77.6	87.8	71.8	59.3	65.2	63.7	64.4	69.5	69.5	59.9
4	Z	85.5	81.6	80.2	78.5	72.4	68.2	66.1	58.9	57.2	52.2	51.9	41.3	Z	87.8	83.8	82.5	80.8	78.5	72	68	62.2	61.7	62.9	61.3	53
	Z	70.6	63.6	63.9	66.3	60.7	56.6	47.9	44.2	41.9	39.7	34	23.2	Z	75.2	69	70.8	69.2	67.5	63.7	56.8	54.7	48.4	44.5	41	31.8
	~~Z~~	~~70.6~~	~~65~~	~~62.5~~	~~65.3~~	~~62.6~~	~~53.6~~	~~43.5~~	~~42.3~~	~~38.9~~	~~35.1~~	~~45.9~~	~~20.9~~	~~Z~~	~~74.5~~	~~68.7~~	~~67~~	~~67.6~~	~~69.4~~	~~60.3~~	~~53.6~~	~~53.9~~	~~49.8~~	~~41.7~~	~~48.5~~	~~25.1~~
	Z	77.6	71.4	68.8	68.3	67.9	62.2	52.2	45.4	43.5	40.5	43	27.3	Z	88.5	76.9	71.2	70.5	74.6	68.9	53.8	47.7	49.1	47.4	53.6	36.2
	Z		76.5	75.8	76.8	64.3	58.8	60.6	53.6	50.7	45.4	46.9	37.6	Z		78.1	78	77.7	69.6	62.5	61.2	55.8	55.6	53.4	53.4	46.2
5	Z	85.9	81.5	79.5	80.7	72.1	66.6	65.3	60.4	59.5	59.9	62.1	56.5	Z	88.6	84.1	82.5	82.6	80.3	73.3	68	65	69.6	71.1	70.5	64.2
	Z	85.3	80.3	79.5	80.4	71.4	66	66.1	60.5	59.5	61.3	61.5	53.4	Z	87.8	83.1	82.7	82.5	78.8	72.9	69	66.2	69.3	73.2	70.8	65.2
	Z	73.9	69.2	65.4	68.4	63.6	55.8	53.2	46.5	43.9	42.1	39.6	22.7	Z	76.9	71.6	67.8	71.3	71.1	61.3	54.3	49.6	52.9	53.6	48.3	35.3
	Z		75.0	76.7	74.7	62.8	55.9	56.9	51.3	48.3	49.3	56.1	44.9													
6	~~Z~~	~~91.1~~	~~79.6~~	~~86.5~~	~~88.3~~	~~77.7~~	~~65.5~~	~~68.3~~	~~65.1~~	~~61.6~~	~~53.9~~	~~45.3~~	~~31.6~~	~~Z~~	~~91.7~~	~~81.3~~	~~87.2~~	~~89~~	~~78.3~~	~~66.5~~	~~69.1~~	~~65.7~~	~~62.7~~	~~55.4~~	~~49.1~~	~~37.1~~
	Z	91.5	80.6	86.8	88.5	79	67.1	68.4	65.1	61.8	56.1	48.3	38.7	Z	92.7	83.1	87.5	89.6	82	70.9	69.5	66.5	64.2	60.1	52.3	46.6
	Z	91	78.3	85.8	87.8	82.3	67	68.3	65	63.9	57.6	50.3	40.6	Z	92	80.9	86.5	88.5	85.4	70.6	69.2	65.8	65.4	62.8	60.1	50.9
	Z	76.9	63.7	71.5	74.5	65.3	54.4	54.5	48.5	44.3	41.4	41.2	19	Z	78.2	66.8	73.6	75.2	67.7	57.6	59.8	51.3	52.7	52	47.4	27.9
7	Z	89.1	62.5	76.9	88.2	76.6	65.5	68.3	66.3	62.8	63.6	68.4	62	Z	89.9	66	77.6	89	77.5	66.5	70.4	67.9	70.1	72.6	75	68.1
	Z	84.1	59.6	79.7	81.3	68.1	58.5	63.7	60.4	61.6	66	69.5	61.5	Z	84.5	62.2	80	82	68.8	59.4	65.2	61.5	63.4	69	72.9	65.4
	Z	73.8	58.2	63	70.6	65.3	52.6	54.8	51.9	51.3	48.6	49.6	37.6	Z	75.8	61	64.1	71.3	66	54	55.7	53	52.8	49.9	50.8	39.5
	Z	71.6	55.1	61.9	70.1	60.1	50.6	51.8	47.1	43.8	41.1	38.7	19	Z	74.2	59.9	66.5	72.2	62.8	54	53	48.4	46	42.8	45.1	27.4
	Z		62.7	75.7	85.1	73	62.4	63.5	59.4	58.3	56	57.3	45.6	Z		65.1	73	86.6	74.3	64.6	66	64.4	64.3	62.3	61.5	50.6

Hand-Held Sound Level Measurements

			MemLoc#		A Weighted Scale								Leq Frequency Spectrum												Lmax Frequency Spectrum											
	Date	Time (24h:m)	or Session#	Duration (m:s)	Leq	Lmax	Lmin	Distance	# locos	Valid	File name	Comments	Wt. OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz	Wei OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz
Quest 2900	1/22/07	23:24	1	02:06	68.2	75.4	66.3	30	2		TEA1																									
Quest 2900	1/22/07	23:27	2	01:11	69	78.1	66.9	24	2																											
Quest 2900	1/23/07	00:06	3	01:19	68.5	74	65.5	30	2																											
Quest 2900	1/23/07	00:07	4	00:13	70.2	77.1	65.7	n/a	2																											
Quest 2900	1/23/07	00:08	5	00:55	69	76.9	67.4	n/a	2																											
Quest 2900	1/23/07	02:32	6	02:21	67.3	76.2	60.3	28	2																											
Quest 2900	1/23/07	02:35	7	02:17	66.3	76.7	60.3	26	2																											
Quest 2900	1/23/07	04:58	8	00:53	67.5	74.3	56			No		No train during this time																								
Quest 2900	1/23/07	06:17	9	01:23	67.4	75.7	62.5	34	2																											
Quest 2900	1/23/07	06:31	10	03:54	68.9	79.3	65.8	36	2																											
Quest 2900	1/23/07	06:46	11	03:32	75	89.6	31.6	26	2	No		Very suspect Lmin																								
Quest 2900	1/25/07	16:16	12	00:22	75.7	78.6	74.2	36	5																											
Quest 2900	1/25/07	16:17	13	00:26	75.2	80.5	72.6	36	5																											
Quest 2900	1/25/07	16:18	14	00:42	74.5	80.7	72.6	36	5																											
Quest 2900	1/25/07	16:19	15	00:31	72.6	73.9	71.6	34	5																											
Quest 2900	1/25/07	16:21	16	00:28	70.5	72.3	69.8	34	5																											
Quest 2900	1/25/07	16:22	17	00:54	65.7	71.6	62	88	5																											
Quest 2900	1/25/07	17:13	18	00:02						No	TEA2	False start																								
Quest 2900	1/25/07	19:06	19	00:30	53.9	60	49.2			No		No good																								
Quest 2900	1/25/07	19:07	20	00:59	51.1	55.7	48.2	?	2																											
Quest 2900	1/25/07	19:11	21	00:11	63.2	64.6	61.1			No		No good																								
Quest 2900	1/25/07	19:11	22	01:17	63.2	67.5	60.9	?	2																											
Quest 2900	1/25/07	22:39	23	03:29	71.8	80.1	69.7	20	2																											
Quest 2900	1/26/07	01:59	24	00:39	76.2	76.6	75.4	22	2																											
Quest 2900	1/26/07	02:00	25	01:10	77.1	81.6	74.6	22	2																											
Quest 2900	1/26/07	02:01	26	00:18	77.2	79.7	76	22	2																											
Quest 2900	1/26/07	07:13	27	06:58	76.3	88.6	68.6	22	2																											
Quest 2900	1/26/07	10:38	28	05:16	70.4	83.4	64.7	50	2																											
Quest 2900	1/26/07	10:47	29	03:16	75.3	88.1	67	22	2																											
Quest 2900	1/28/07	14:30	1	05:01	77.1	86.3	65.1	18	2		TEA3																									
Quest 2900	1/28/07	17:41	2	02:26	63.7	74.4	61.8			No		Not recorded in logbook																								
Quest 2900	1/29/07	12:45	3	01:31	71.1	77.7	69.4	30	3																											
Quest 2900	1/29/07	12:48	4	01:22	74.6	84.4	60.3	26	3																											
Quest 2900	1/29/07	12:50	5	01:25	72.3	79.3	69.1	30	3																											
Quest 2900	2/1/07	02:02	1	00:52	70.3	78.7	67.6	30	2		TEA4																									
Quest 2900	2/1/07	02:05	2	00:33	68.8	88	67.7	32	2	No		Horn																								
Quest 2900	2/1/07	02:06	3	00:19	69.5	72.8	68.2	32	2	No		Horn																								
Quest 2900	2/1/07	02:37	4	00:33	78.9	85.3	64.7			No		Not recorded in logbook																								
Quest 2900	2/1/07	02:39	5	01:03	77.2	84.8	74.7	32	3																											
Quest 2900	2/1/07	02:42	6	00:37	71.2	75.2	68.3	26	3																											
Quest 2900	2/1/07	02:43	7	00:14	70.9	74.3	69.4	26	3																											
Quest 2900	2/1/07	02:43	8	00:44	72.9	75.7	69.3	18	3																											
Quest 2900	2/1/07	06:43	9	01:22	67.3	68.4	66.8	22	2																											
Quest 2900	2/1/07	06:46	10	01:17	69.1	69.7	68.7	22	2																											
Quest 2900	2/4/07	06:41	1	02:02	75.8	88.5	68.1	20	2		TEA5																									
Quest 2900	2/4/07	06:44	2	01:53	76.4	88.5	69	20	2																											
Quest 2900	2/4/07	06:46	3	01:35	71.8	83.3	65.9	34	2																											
Quest 2900	2/23/07	07:35	4	03:42	69	78.2	66.4	34	2																											
Quest 2900	2/23/07	07:42	5	03:11	61.9	66.3	59.4	?	2																											
Quest 2900	5/4/07	13:46	1	00:03	51.6	51.6	51.6			No	TEA6	Time is EST																								
Quest 2900	5/4/07	13:46	2	00:01						No		Time is EST																								
Quest 2900	5/6/07	03:29	3	01:20	73.1	85.5	68.2	n/a	4			Time is EST																								
Quest 2900	5/6/07	03:30	4	00:08	72.4	79.7	64.9	n/a	4			Time is EST																								
Quest 2900	5/6/07	03:31	5	00:11	66.8	68.1	65.7	n/a	4			Time is EST																								
Quest 2900	5/6/07	03:32	6	02:06	74.1	87.6	69.6	n/a	4			Time is EST																								
Quest 2900	5/6/07	04:55	7	01:05	62.4	65.3	61.7	20	2			Time is EST																								
Quest 2900	5/8/07	12:36	8	00:27	66.7	69	61.2			No		Time is EST; measurement no good																								
Quest 2900	5/8/07	12:37	9	08:22	62.9	68.8	58.9	37	2			Time is EST; only one locomotive on																								
Quest 2900	5/11/07	15:45	1	07:15	63.4	68.1	61.7	63	2		TEA7																									
Quest 2900	5/11/07	15:53	2	01:33	55.8	58.1	54.7	96	2																											
Quest 2900	5/11/07	18:15	3	05:45	71.9	85.6	47.5	19	2																											
Quest 2900	5/11/07	18:29	4	11:20	69.4	80.8	60.4	27	2+2	No		Too much going on; 2 idles, passby occurs, 1 idle starts leaving																								
Quest 2900	5/11/07	18:43	5	05:11	69.5	83.5	67.4	25	2			Only one locomotive on																								
Quest 2900	5/12/07	05:56	6	01:57	74.3	86.2	68	20	2																											
Quest 2900	5/12/07	05:59	7	02:02	74.4	88.2	67.1	20	2																											
Quest 2900	5/12/07	06:40	8	02:54	63.1	70.7	60.1	40	2																											
Quest 2900	5/12/07	09:52	9	02:06	71.3	85.3	67.7	20	2																											
Quest 2900	5/12/07	09:55	10	02:01	72.4	86.4	68.3	20	2																											
Quest 2900	5/14/07	13:47	11	01:05	73	85.4	69.5			No		No good																								
Quest 2900	5/14/07	13:48	12	03:43	73.5	87	68.9	13	2																											
Quest 2900	5/14/07	13:52	13	06:00	75.5	91.4	41.6	11	2	No		Min and Max levels in the same second (13:57:49) (?)																								
Quest 2900	5/14/07	22:08	1	01:04	71.6	78.6	68.2	23	2		TEA8																									
Quest 2900	5/14/07	22:10	2	01:03	72	77.8	68.5	18	2																											
Quest 2900	5/14/07	23:53	3	00:18	64.8	65.2	64.3	n/a	2																											
Quest 2900	5/14/07	23:59	4	00:11	69.4	71.1	67.7	n/a	2																											
Quest 2900	5/14/07	23:59	5	00:07	70.8	74.6	70.1	n/a	2																											
Quest 2900	5/14/07	23:59	6	00:17	72.2	79.9	69.6	n/a	2																											
Quest 2900	5/15/07	02:06	7	02:43	72.2	73.5	71	30	2																											
Quest 2900	5/15/07	02:09	8	01:34	72.4	73	71.9	30	2																											
Quest 2900	5/17/07	01:50	9	09:26	63.8	77	62.3	24	2			Only one locomotive on																								
Quest 2900	5/17/07	18:43	1	01:24	72.8	78	71.7	22	4		TEA9																									
Quest 2900	5/17/07	18:45	2	01:04	79	91.5	72.4	18	4																											
Quest 2900	5/17/07	18:46	3	01:16	75.1	86.3	72.3	n/a	4																											
Quest 2900	5/17/07	18:48	4	01:31	71.7	75.5	70.7	14	4																											
Quest 2900	5/17/07	18:50	5	01:52	74.4	75	73.9	15	4																											
Quest 2900	5/17/07	18:52	6	02:03	67.4	68.5	66.4	65	4																											
Quest 2900	5/17/07	18:56	7	01:59	60.3	64.7	59.1	71	4																											
Quest 2900	5/17/07	19:11	8	05:20	66.7	77.4	64.6	25	3																											

Hand-Held Sound Level Measurements (continued)

			MemLoc#		A Weighted Scale								Leq Frequency Spectrum													Lmax Frequency Spectrum												
	Date	Time (24h:m)	or Session#	Duration (m:s)	Leq	Lmax	Lmin	Distance	# locos	Valid	File name	Comments	Wt.	OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz	Wei	OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz
Quest 2900	5/17/07	23:52	1	02:23	77.4	90.4	69.2	22	3		TEA10																											
Quest 2900	5/17/07	23:56	2	01:18	75.9	86.1	69.6	23	3																													
Quest 2900	5/17/07	23:58	3	01:01	73	80.9	71.3	23	3																													
Quest 2900	5/18/07	12:49	4	01:47	72.8	83.7	71.6	19	2																													
Quest 2900	5/18/07	12:55	5	00:31	73.9	81.2	71.6	26	2	No		Plane																										
Quest 2900	5/18/07	12:55	6	00:51	72.4	80.9	71.6	26	2																													
Quest 2900	5/18/07	13:35	7	01:42	72.7	74.9	71.2	23	2																													
Quest 2900	5/18/07	13:37	8	01:41	76.7	78.5	74.6	20	2																													
Quest 2900	5/18/07	15:46	9	01:58	70.9	77.2	67.4	18	2																													
Quest 2900	5/18/07	15:49	10	04:11	72.7	90.6	68.5	16	2	No		Horns																										
Quest 2900	5/18/07	15:53	11	00:57	70	71.8	68.6	16	2																													
Quest 2900	5/20/07	15:02	12	00:07						No																												
Quest 2900	5/20/07	15:03	13	41:05	64.1	82.2	41.6			No		Meter started in error																										
Quest 2900	5/20/07	18:20	14	01:13	63	69.8	56.9	24	2																													
Quest 2900	5/20/07	18:23	15	01:24	61.5	67.8	57.1	23	2																													
Quest 2900	5/21/07	12:49	16	02:00	68.3	76.3	64.3	25	2			Only one locomotive on																										
Quest 2900	5/24/07	05:59	1	01:37	72.6	85.5	69.7	18	2		TEA11																											
Quest 2900	5/24/07	06:01	2	02:15	74.8	92	70.1	18	2																													
Quest 2900	5/24/07	10:48	3	02:04	75.6	87.5	73.2	20	2																													
Quest 2900	5/24/07	10:52	4	02:50	70.9	80.4	69.3	28	2																													
Quest 2900	7/10/07	14:28	5	02:28	64.5	74.1	60.2	25	2			Only one locomotive on																										
Quest 2900	7/17/07	15:24	6	01:31	67.8	70.8	66.8	24	4																													
Quest 2900	7/17/07	15:27	7	01:50	71.4	81.9	68.8	22	4																													
Quest 2900	7/17/07	15:31	8	01:33	72.8	75.3	72	20	4	No		Plane																										
Quest 2900	7/17/07	15:33	9	00:53	72.6	73.6	71.9	20	4			Same train as previous; plane only seems to have affected Lmax																										
Quest 2900	7/17/07	15:34	10	01:56	72.5	73.6	72	16	4																													
Quest 2900	8/13/07	06:23	11	02:11	68.6	75.7	66.8	22	3																													
Quest 2900	8/13/07	06:26	12	02:09	71.3	81.3	67.4	24	3																													
Quest 2900	8/13/07	06:32	13	01:49	75.6	86.9	69.3	16	2+3			Measurement is of train with 2 locs																										
Quest 2900	8/13/07	07:08	14	01:37	69.7	76	65.6	18	2 (1 on)	No		2nd loc turned on during measurement																										
Quest 2900	8/13/07	10:09	15	02:49	69	70.5	68.2	28	2			Distance from locomotive to long term meter was 28 yards; Quest meter placed																										
Quest 2900	8/13/07	10:20	16	01:59	68.3	69.5	67.4	28	2																													
Quest 2900	8/13/07	12:28	17	00:39	60.9	61.5	60.2	62	2																													
Quest 2900	8/13/07	12:31	18	01:25	66.4	74.7	64.3	32	2																													
Quest 2900	8/22/07	09:39	1	01:45	69.6	78.8	64.4	30	2		TEA12																											
Quest 2900	8/22/07	09:42	2	02:58	69.4	77.6	64	30	2																													
Quest 2900	8/22/07	09:47	3	01:52	60.7	66.1	56.1	118	2																													
Quest 2900	8/22/07	09:52	4	02:19	53.6	57.8	49.9	176	2																													
Quest 2900	8/22/07	10:01	5	02:28	54.7	60.4	51.7	130	2																													
Quest 2900	9/27/07	14:35	6	01:53	67.4	74.9	65.2	30	2																													
Quest 2900	9/27/07	14:38	7	01:46	70.1	80.4	67.2	20	2																													
Quest 2900	10/20/07	18:05	1	04:07	73.8	83.3	41.6	23	2		TEA13																											
Quest 2900	10/20/07	18:11	2	00:20	58.8	61.4	55.9	90	2																													
Quest 2900	10/20/07	18:14	3	00:32	58.5	61.5	54.8	90	2																													
Quest Sound Pro	8/10/07	3:40:28	tea081007	1:40	68.6	78.6	65.9	7	2		loc47																											
Quest Sound Pro	8/18/07	17:06:13	Session97	1:20	67.3	68.1	66.8			No	Study114	Animal sounds interfered with																										
Quest Sound Pro	8/18/07	17:10:19	Session98	1:57	77.9	87.6	67.3			No	scratch	No good																										
Quest Sound Pro	8/18/07	17:51:31	Session99	6:55	67.3	68.8	66.9	29			Study116	Only one locomotive on/audible	Z	87.2	65.8	76.7	85.5	76.9	59.8	63.6	60.3	55.2	44.8	56	31.2	Z	94	83	79.8	86.3	77.9	68	66.9	61.5	57.1	59.1	50.9	40.9
Quest Sound Pro	8/18/07	18:19:33	Session100	2:16	53.5	56.9	52.6				Study117	86 yds to guardrail, corner of Thomas	Z	76.3	52.8	71	73.8	65.8	48.1	45.7	43.6	40.1	36.9	27.1	18.1	Z	80.7	64.4	71.8	74.7	68	55.9	50.7	53.3	49.2	50.2	41.7	24.7
Quest Sound Pro	8/18/07	18:40:16	Session100	0:22	65.9	70.9	63.4			No	Study118	No good	Z	85.6	69.2	81.7	82.1	76.3	73.4	68.6	64.6	61.9	55.1	38.5	27.4	Z	82.9	66.9	78.9	78.5	74.4	68.1	63.1	55.6	58.9	48.4	34.5	20.5
Quest Sound Pro	8/18/07	18:45:09	Session100	0:02	53.9	54	53.8				Study119		Z	74.9	54.2	71.2	71.9	62.7	51.9	47.3	46.4	44.4	41.9	34.1	17.9	Z	75	56	71.3	72	63.3	52.7	47.7	46.8	44.7	42.3	34.4	18.5
Quest Sound Pro	8/18/07	18:45:27	Session100	0:27	54.7	57.6	53			No	Study120	No good	Z	74.6	55.2	71.6	70.7	62	52.2	48.4	48.9	45.8	45	37.1	21.4	Z	75.4	61.8	72.1	72.2	63	57	52.3	53.5	50.7	52	43.5	25.9
Quest Sound Pro	8/18/07	18:46:00	Session100	5:37	53.5	57.7	52	98+	1		Study121	98 yards to vegetative buffer; 590 chestnut, plane from 2:16 to 3:15	Z	74.5	56.2	71.4	70.6	61.5	51.5	47.9	46.7	43.1	43.7	36.7	21.4	Z	77.7	69.5	73.6	75.4	65.5	61.6	55.5	49.2	50.5	51.9	43	36
Quest Sound Pro	8/18/07	19:10:30	Session101	3:05	54	63.6	49.5				Study122	NE corner of apt. building, barking dog,	Z	72.6	53.1	69	68.7	58.7	51.7	51.5	49.4	42.7	38	31.5	18	Z	80.9	70.5	63	70	61.8	63.2	61.8	60.6	53.3	46.1	37.9	24.3
Quest Sound Pro	8/18/07	19:26:56	Session101	4:48	52.4	56.3	51.4			No	Study123	Plane from 1:45 to 2:13	Z	70.3	53.9	62.4	68.8	59	48.4	45.9	45.7	41.4	45.7	38.1	19.8	Z	73.1	61.4	64.7	71.8	63	51.5	56.1	49.3	49.6	50.2	43.8	33.4
Quest Sound Pro	8/19/07	7:11:01	Session102	1:30	69.1	73.4	67.7	28	2		csx7704-7:11 a.m.		Z	88.5	81.7	62.3	86.8	72.4	60	65.5	62.4	60.7	60.9	58.9	47	Z	88.9	64	82.2	87.1	74	66.9	64.1	60.7	63.9	68.5	67.3	55.4
Quest Sound Pro	8/19/07	7:15:54	Session102	1:31	69.8	73.9	68.6	24			gcfx3058-7:16 a.m.		Z	90.1	62.2	83.6	88.1	74.7	62.2	66.7	62.5	60.8	62.3	58.2	48	Z	90.5	66.2	84.1	88.6	75.3	63.4	67.9	64.3	64.6	68.9	67.3	57.3
Quest Sound Pro	8/19/07	7:33:16	Session102	1:31	57	62.8	54.1	64			csx7704-7:33 a.m.		Z	75.4	55	68.1	73.4	63.4	52.1	51.1	49.7	48.6	49.7	46.2	32.7	Z	76.3	60	68.5	73.7	64.4	53.1	52.5	54.6	55.7	57.5	54.5	40.2
Quest Sound Pro	8/19/07	7:44:14	Session102	0:54	53.6	61.1	49	120	2	No	Study127	No good; plane flew over	Z	73.2	51.2	66.2	71.1	60.6	50.4	53.6	44.2	42	43.8	38.2	22.6	Z	74.5	59.1	68.6	71.6	62.8	61.1	63.2	52.8	49.1	52.1	47.8	30.8
Quest Sound Pro	8/19/07	7:45:45	Session102	0:22	52.5	57.2	49.7	120	2	No	Study128	No good; plane flew over	Z	73.5	53.9	67	71.4	60.9	46.8	48.3	44.1	42.8	45.3	39.9	22.9	Z	74.1	55.6	68	71.9	62.1	50.6	53.9	47.8	49.1	52.8	48.2	29.8
Quest Sound Pro	8/19/07	7:46:44	Session102	1:32	51.4	57.3	49.4	120	2		gcfx3058-7:46 a.m.		Z	73.1	50.6	66.3	71.1	60.4	45.9	46.8	42.1	42.4	44.2	37.8	21.8	Z	73.5	53.3	66.7	71.5	61.3	48.7	50.1	46.3	49.6	52.9	48.4	30.5
Quest Sound Pro	8/19/07	8:48:20	Session102	0:51	71.2	73.6	70.2	26	3		up9820-8:50 a.m.	Only one locomotive cycling higher than base noise, which is moderately loud	Z	96.6	78.6	89.8	94.9	77.6	68.1	67.3	63.2	60.8	59.3	52.8	44.7	Z	98.4	81.5	91.8	96.7	82.8	75.2	69.2	64.9	63.9	63.8	60.6	53.7
Quest Sound Pro	8/19/07	8:50:32	Session102	1:28	72.5	78.7	71.5	26	3		up4591-8:51 a.m.	Moderate idle noise	Z	95.8	77.3	89.5	93.9	77.5	66	68.3	66.4	62.5	62.4	55.7	46.5	Z	97	81.7	90.8	95.1	82.1	73.2	69.4	67.5	72.1	73.4	71.6	63.4
Quest Sound Pro	8/19/07	8:53:39	Session102	1:07	70.5	74.2	69.6	26	3		up4310-8:54 a.m.	Moderate idle noise	Z	94.4	73.7	87.8	92.7	76.3	62.4	66.6	63.4	60.2	61.7	57.7	44.9	Z	95.9	78.6	89.7	94.1	77.7	68.1	68	67.4	64.3	68.8	68.1	60.2
Quest Sound Pro	8/21/07	18:06:54	Session105	3:05	63.5	64.7	62.3	43.75	2		Study135	At curb between 1760 &	Z	85	60.6	82	81.2	72.8	53.7	57.3	55.6	54.3	55	45.9	35.3	Z	86.2	64.6	82.9	83	75.4	55	58.3	57.7	58.4	62.3	60.9	51.6
Quest Sound Pro	8/21/07	18:11:44	Session105	1:07	60.9	64.1	59.8	85	2		Study136		Z	80.7	59.3	71.9	79.6	69.1	51.5	50.8	52.8	53.8	49.9	40	26.9	Z	82	63.6	75.2	81	71	55.9	53	54.4	56.8	58.3	55.5	46.2
Quest Sound Pro	8/21/07	18:13:33	Session105	0:18	58.4	61.8	56.9			No	Study137	No good	Z	78.4	58.6	74	75.7	66.3	50.6	53.6	52.9	49.3	46	33.8	20	Z	79	60.5	74.6	76.5	67.4	53.6	58.6	59.2	50.6	48	37.9	23.9
Quest Sound Pro	8/21/07	18:14:47	Session105	0:42	56.4	59.5	54.4			No	Study138	No good	Z	75	60.1	69.4	72.2	63.2	51.6	49.9	50.8	49.2	45.2	37.7	26.3	Z	77.7	68.4	71.2	75.5	70.3	57.2	54.5	54.4	51.7	51.9	48.8	36.3
Quest Sound Pro	8/21/07	18:16:43	Session106	0:44	61.4	75.8	50.8	115	2		Study139	At curb, train mid to high idle	Z	80	66.5	74.8	76.5	69.7	57.6	55.8	56.1	53.8	48.6	39.8	25.9	Z	90	78.4	82.4	84.5	82.5	70.2	69	74.4	66.2	63.9	54.6	41.7
Quest Sound Pro	8/22/07	9:36:24	Session107	0:13	69.8	72.7	66.3			No	Study140	Battery died during measurement	Z	89.2	80.6	84	85.6	79.6	69.7	65.2	62.1	61.2	56.3	49.4	40.2	Z	93	84.4	88.5	89.7	81.7	70.9	67.6	66.5	64.6	60.4	53	44.4

Hand-Held Sound Level Measurements (continued)

					A Weighted Scale									Leq Frequency Spectrum														Lmax Frequency Spectrum											
	Date	Time (24h:m)	MemLoc# or Session#	Duration (m:s)	Leq	Lmax	Lmin	Distance	# locos	Valid	File name	Comments	Wt.	OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz	Wei	OFF	16Hz	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	16kHz
Quest Sound Pro	8/24/07	14:40:14	Session108	5:10	70.8	88.1	66.9	22	2	No	Study141	Only one locomotive on	Z	88.3	66.3	84.3	84.9	75.3	62.1	64.5	62.8	60.5	63.7	64.5	59.8	Z	94.4	77.4	85.3	87.8	81	74.7	71.1	69.9	77	83.6	85.4	80.7
Quest Sound Pro	8/24/07		Session108					78		No	Study142	Motorcycle@3:14, Loud Truck@3:42; plane overhead; data missing from																										
Quest Sound Pro	8/24/07	15:02:35	Session108	2:49	74.2	81.2	73.1	22, 26	2		Study143	Higher idle, 22 yards to CSX8832, 15 yards to CSX519	Z	94.9	75.4	89.7	92.6	82.3	67.5	68.4	67.2	67	62.9	61.9	56.9	Z	95.7	79.5	90.5	93.4	83.4	71.8	70.1	68.8	73.2	76.1	77.1	72.6
Quest Sound Pro	8/24/07	15:06:49	Session108	3:33	77.2	86.9	75.1	15	2		Study144	CSX519 - most, if not all, audible sound at this distance from 519	Z	95.6	80.1	89.4	93.3	85	72	72.7	69.6	68.4	68	68.4	59.7	Z	96.7	82.2	90.6	94.3	86.6	74.2	74.2	73.2	78	81.7	83.8	74.5
Quest Sound Pro	8/24/07	15:13:21	Session108	2:03	76.8	84.4	75.4	15	2		Study145	CSX8832	Z	99.1	76.5	95	96	83.9	69.3	71.5	71.7	68.5	64.9	94.6	60	Z	100.2	82.6	95.6	96.5	84.6	73.1	73.2	73.1	74.7	78.9	81.2	76.4
Quest Sound Pro	8/24/07	15:16:36	Session108	10:13	74.8	86.4	52	15	2	No	Study146	Full departure of train, 15 yds from CSX8832;, ambient after 8:45 - lots of traffic on road, jet overhead	Z	92.4	82.9	85.2	89.4	81.7	74.2	69.8	69	66.8	62.9	57.5	49.3	Z	100	92.8	95.2	99.6	90.8	86.7	80.2	81.4	80.8	77	78	73.7
Quest Sound Pro	8/24/07	16:52:41	Session108	5:26	67.2	70.4	65.7	22	1		Study147	csx7844	Z	85.5	81.6	80.2	78.5	72.4	68.2	66.1	58.9	57.2	52.2	51.9	41.3	Z	87.8	83.8	82.5	80.8	78.5	72	68	62.2	61.7	62.9	61.3	53
Quest Sound Pro	8/24/07	18:44:11	Session108	3:10	52.5	59.8	47	130	1		Study148		Z	70.6	63.6	63.9	66.3	60.7	56.6	47.9	44.2	41.9	39.7	34	23.2	Z	75.2	69	70.8	69.2	67.5	63.7	56.8	54.7	48.4	44.5	41	31.8
Quest Sound Pro	8/24/07	18:49:36	Session108	2:05	52	57.8	46.6	~110	1		Study149	Somewhat behind barrier; a loud cricket	Z	70.6	65	62.5	65.3	62.6	53.6	43.5	42.3	38.9	35.1	45.9	20.9	Z	74.5	68.7	67	67.6	69.4	60.3	53.6	53.9	49.8	41.7	48.5	25.1
Quest Sound Pro	8/24/07	18:55:54	Session108	3:42	57.5	63	52.9	~70	1		Study150		Z	77.6	71.4	68.8	68.3	67.9	62.2	52.2	45.4	43.5	40.5	43	27.3	Z	88.5	76.9	71.2	70.5	74.6	68.9	53.8	47.7	49.1	47.4	53.6	36.2
Quest Sound Pro	8/24/07	22:29:19	Session108	1:11	73.8	86.5	68.6	28	3		csx5326		Z	92.5	84.1	83.4	90.6	78.5	73.6	66.2	66.1	64.1	64.1	62.6	56.7	Z	98.3	87.5	92.3	94.3	90	86.8	80.1	75.8	73.4	73.8	73.6	67.8
Quest Sound Pro	8/24/07	22:31:57	Session108	1:02	71.7	82	66.6	30	3		csx5245		Z	90.5	84.9	84.1	86.5	77.3	68.5	66.5	64.5	62.8	63.2	62.6	54.1	Z	93.2	87.7	86.6	90.1	81.8	73.2	68.6	71.8	75.2	76.5	76.7	67
Quest Sound Pro	8/24/07	22:34:25	Session108	0:47	68.8	72.7	67.3	28	3		csx8020		Z	92.5	80.5	81.6	91.6	74.9	66.6	62.6	61.5	58.8	57	54.4	41.8	Z	94.3	83.7	83.5	93.4	79.5	70.4	64.2	64.6	65.8	65.5	64.5	50.8
Quest Sound Pro	8/24/07	22:43:20	Session108	0:05	54.5	55	54.4			No	Study154		Z	79.6	67.7	68.9	78.7	57.4	53.9	47.3	44.4	42.6	43.5	38.3	17.7	Z	80.1	68.6	69.6	79.2	57.9	54.4	47.7	45	43.2	45.5	39.3	18.7
Quest Sound Pro	8/25/07	7:31:10	Session109	1:30	68.8	76.2	66.7	22	2		csx5113-1		Z	85.9	81.5	79.5	80.7	72.1	66.6	65.3	60.4	59.5	59.9	62.1	56.5	Z	88.6	84.1	82.5	82.6	80.3	73.3	68	65	69.6	71.1	70.5	64.2
Quest Sound Pro	8/25/07	7:35:22	Session109	1:31	69.2	76.9	66.2	22	2		csx7822-1		Z	85.3	80.3	79.5	80.4	71.4	66	66.1	60.5	59.5	61.3	61.5	53.4	Z	87.8	83.1	82.7	82.5	78.8	72.9	69	66.2	69.3	73.2	70.8	65.2
Quest Sound Pro	8/25/07	7:53:29	Session109	1:17	54.7	60.2	52.7	118	2		csx5113-csx7822-118yds		Z	73.9	69.2	65.4	68.4	63.6	55.8	53.2	46.5	43.9	42.1	39.6	22.7	Z	76.9	71.6	67.8	71.3	71.1	61.3	54.3	49.6	52.9	53.6	48.3	35.3
Quest Sound Pro	8/25/07	9:58:06	Session110	2:18	72.9	84.4	65.6	20	4		csx5330-1	1st locomotive on, 2nd off, 3rd and 4th blocked by hardware store	Z	88.5	81.2	82.2	84.8	74.9	70.8	67.6	64.7	62.9	65.6	66.9	61.8	Z	94.3	88.5	86.5	91.6	80.3	78	70.6	73	76.4	79.8	79.8	73.8
Quest Sound Pro	8/25/07	10:05:14	Session110	0:58	60.9	69.3	58.3	100		No	Study159	Interference by other noise sources	Z	79.5	70.8	72.8	76.2	70.6	61.3	52.7	53	51.5	49.8	48.2	34.3	Z	82.2	73.6	76.4	79.1	73.7	65.5	57.2	61	63.4	63	61.7	45.6
Quest Sound Pro	8/25/07	10:07:06	Session110	0:27	61.6	68.5	57.6	100		No	Study160	Interference by other noise sources	Z	79.2	68.7	70.6	76.3	69.7	60.7	54.7	54.8	53.2	52	48.4	36.5	Z	82.4	73.8	75.1	80.5	73.3	63.4	57.2	59.9	63	62.8	57.5	45.9
Quest Sound Pro	8/25/07	10:30:56	Session110	0:28	55.3	60.1	52.8			No	Study161	Interference by other noise sources	Z	74.4	67.7	67	70.3	62.6	54.3	49	48.3	45.3	43	48.6	24.8	Z	76.2	71	69.2	73.7	64.7	58.3	52.6	52.9	53.9	53.3	50.9	32.4
Quest Sound Pro	8/25/07	10:31:40	Session110	0:33	55.1	59.5	52.2			No	Study162	Interference by other noise sources	Z	74.3	68.8	67	70.1	62	53	48	47.4	46.6	44.2	48.6	28.2	Z	77.9	74	70.5	73	66.7	56	52.3	50.4	55.2	52.7	51.9	40.3
Quest Sound Pro	8/25/07	10:32:44	Session110	0:42	58.6	70.7	54			No	Study163	Interference by other noise sources	Z	77.5	68.8	69	70.1	63.3	55.8	57.9	49.8	46.6	42.7	51.4	27	Z	81.4	74.7	71.9	73	65	64.2	72.7	61.6	57.4	53.5	52.8	34.4
Quest Sound Pro	8/25/07	10:34:06	Session110	0:39	56.4	61.1	54.4			No	Study164	Interference by other noise sources	Z	74.8	69.4	68.4	70.2	62.5	54.8	49.1	47.2	46	45.6	52.6	29.8	Z	78.1	74.8	71.8	73	66.1	58.9	53.1	51.8	54.8	54.7	54.9	39.5
Quest Sound Pro	8/25/07	10:45:21	Session110	1:18	60	68.3	57	56	4		csx8622-1	CSX8622 (off), between houses	Z	80	74.8	74.5	75.2	64.6	59.8	52.5	52.7	50.8	51.4	52.4	40.4	Z	83.8	80.7	78.3	78.5	68.5	64.3	55	59.3	61.7	63.2	60.9	49.5
Quest Sound Pro	8/25/07	10:49:14	Session110	1:44	59.2	68.8	55.5	74	4		csx5330-2	Between houses	Z	79	73.4	72.2	75.4	65.3	56.3	51.8	51.3	50.3	51	51.4	39	Z	82.1	78.5	74.8	79.2	69.2	61.9	54.5	58.9	61.9	64	62	51.4
Quest Sound Pro	8/25/07	10:58:12	Session110	0:44	60.3	65.1	59.2	56	4		csx5864-1	CSX5864, between houses at location	Z	79.8	72.2	71.2	77.6	65.9	57.7	54.4	54.6	50.7	49.7	48.4	38.4	Z	81.7	76.7	73.2	79.6	67.9	60.2	55.2	55.5	58	59.8	56.7	46.2
Quest Sound Pro	8/25/07	11:04:03	Session110	0:31	60.8	66.2	59.4			No	Study168		Z	79.5	73.3	72.2	76.4	64.9	56.8	56	53.9	51.8	52.5	50.9	38.2	Z	81.7	76.5	74.5	79.5	66.9	58.8	58.6	58	59.1	61.2	57.3	45.1
Quest Sound Pro	8/25/07	11:05:48	Session110	0:56	60	66	58.3	56	4		csx7572-1	CSX7572, between houses	Z	79.2	73.1	72.3	76	65.6	56.6	55.4	53.4	50.5	50.4	50.7	39.4	Z	82	75.8	74.1	79.5	68.7	59.6	56.6	57.6	58.2	61.1	60	53
Quest Sound Pro	8/25/07	11:19:36	Session110	0:31	62	68.4	59.9	66	4		csx8622-2	Even with second locomotive, CSX8622, which was off	Z	82.2	73.8	76	79.6	66.8	54.9	57.6	57.5	52.3	50.5	47.1	35.5	Z	85.5	79.3	78.9	84	70.3	59	61.4	60.2	61.6	63	59.4	49.4
Quest Sound Pro	8/27/07	13:33:54	Session111	1:30	72.2	76.3	71.2	15	3		cefx3120-1	2nd locomotive, moderate noise	Z	88.5	80.3	81.9	85.1	76.5	98.7	70.6	66	62.5	61.1	56.9	45.2	Z	90.7	83.8	85.2	86.7	79.4	72.7	71.7	67.5	67.5	69.7	69.5	59.5
Quest Sound Pro	8/27/07	13:37:10	Session111	1:30	76.9	78.8	76.5	14	3		csx4431-1	3rd locomotive, loud noise	Z	94	79.9	86.4	92.2	80.1	70.2	75.2	72.1	68	64	56.9	45.4	Z	94.7	82.5	87.2	92.8	80.8	71.9	75.7	73.4	70.3	71	69	61.7
Quest Sound Pro	8/27/07	13:41:16	Session111	2:00	71.5	78.2	69.4	16	3		csx5259-1	1st locomotive, loud noise with cycling and air releases	Z	89.7	82.4	84.1	85.6	77.7	70.9	69	64.5	61.7	59.9	58	48.2	Z	91.9	85.5	86.6	87.6	83.6	76.9	70.7	69.6	71.4	72.3	71.5	62.4
Quest Sound Pro	8/27/07	14:48:30	Session112	2:01	67.8	76.8	67	15	2		bnsf838	BNSF 838 "on" with steady noise	Z	83.8	75.4	78.4	80.1	69	66.8	66.5	61.5	58.1	56.1	55.6	45.4	Z	85.1	78.2	81.1	81.5	70.5	67.8	68.2	63.6	67.9	72.7	71.3	64
Quest Sound Pro	8/27/07	14:52:14	Session112	1:27	75.2	88.8	70.2	12	2		bnsf548	BNSF 548 "on" with steady noise and very infrequent cycling	Z	87.7	77.1	82.8	81.4	80.6	76.8	70.4	66.2	64.7	67	67.7	63	Z	92.4	80.3	85	83.9	89.1	85	74.3	71.9	78.1	84.5	85.7	81.3
Quest Sound Pro	8/27/07	23:45:07	Session113	1:38	68.6	80.7	63.3	~34	3	No	cefx3120	Could not get good distance	Z	85.9	77.5	80.1	82.7	74.3	62.4	61.1	60	58.9	62.8	60.5	53.3	Z	89.7	81	83.5	68.8	79.4	65.9	63.4	67.8	72.8	76.1	76	69.9
Quest Sound Pro	8/27/07	23:48:40	Session113	2:05	69.1	79	66.3	34	3		csx5259	34 yds, end of t is loc	Z	88.2	79.7	82.3	85.5	72.7	63.2	64.4	60.8	58.3	63.2	60.1	51.3	Z	92	82.2	84.9	90.4	79.7	66.7	67.2	67.3	69.4	75.2	74.2	65.8
Quest Sound Pro											Study178	Data missing from computer and log																										
Quest Sound Pro											Study179	Data missing from computer and log																										
Quest Sound Pro											Study180	Data missing from computer and log																										
Quest Sound Pro	8/28/07	8:00:53	Session117	0:23	71	71.4	70.7			?	Study181		Z	91.1	79.6	86.5	88.3	77.7	65.5	68.3	65.1	61.6	53.9	45.3	31.6	Z	91.7	81.3	87.2	89	78.3	66.5	69.1	65.7	62.7	55.4	49.1	37.1
Quest Sound Pro	8/28/07	8:02:08	Session117	0:32	71.4	73	70.5	26	2		csx7503-1	CSX 7503 "on" with occasional cycling	Z	91.5	80.6	86.8	88.5	79	67.1	68.4	65.1	61.8	56.1	48.3	38.7	Z	92.7	83.1	87.5	89.6	82	70.9	69.5	66.5	64.2	60.1	52.3	46.6
Quest Sound Pro	8/28/07	8:04:05	Session117	0:32	72.3	73.9	71	26	2		gcfx3100-1	GCFX 3100 "on" with steady noise	Z	91	78.3	85.8	87.8	82.3	67	68.3	65	63.9	57.6	50.3	40.6	Z	92	80.9	86.5	88.5	85.4	70.6	69.2	65.8	65.4	62.8	60.1	50.9
Quest Sound Pro	8/28/07	8:10:15	Session117	0:44	56.7	61	56.1	150	2		Study184	Train horn to north may have influenced last few seconds	Z	76.9	63.7	71.5	74.5	65.3	54.4	54.5	48.5	44.3	41.4	41.2	19	Z	78.2	66.8	73.6	75.2	67.7	57.6	59.8	51.3	52.7	52	47.4	27.9
Quest Sound Pro	8/28/07	11:22:25	Session118	1:30	73	78.6	72	24	3		csx8400-1	CSX 8400, steady noise, no cycling, air releases infrequent, 3rd locomotive is off	Z	89.1	62.5	76.9	88.2	76.6	65.5	68.3	66.3	62.8	63.6	68.4	62	Z	89.9	66	77.6	89	77.5	66.5	70.4	67.9	70.1	72.6	75	68.1
Quest Sound Pro	8/28/07	11:26:40	Session118	1:01	72.1	74.7	70.4	22	3		csx7376-1	CSX 7376	Z	84.1	59.6	79.7	81.3	68.1	58.5	63.7	60.4	61.6	66	69.5	61.5	Z	84.5	62.2	80	82	68.8	59.4	65.2	61.5	63.4	69	72.9	65.4
Quest Sound Pro	8/28/07	11:54:40	Session118	0:26	58.8	59.3	58.1	70	3		csx8400-2		Z	73.8	58.2	63	70.6	65.3	52.6	54.8	51.9	51.3	48.6	49.6	37.6	Z	75.8	61	64.1	71.3	66	54	55.7	53	52.8	49.9	50.8	39.5
Quest Sound Pro	8/28/07	13:00:20	Session118	0:51	53.7	54.5	53.3	118	3		csx8400-3	Taken at 590 Chestnut; CSX\8400 with steady idle noise	Z	71.6	55.1	61.9	70.1	60.1	50.6	51.8	47.1	43.8	41.1	38.7	19	Z	74.2	59.9	66.5	72.2	62.8	54	53	48.4	46	42.8	45.1	27.4
Quest Sound Pro	9/4/07	14:12:52	Session119	1:30	73.9	84.4	71.5	14	3		csx4567-1	CSX 4567 on with air releases	Z	87.1	70.8	82.5	84.2	72.9	67.2	69.4	65.8	67.4	66.2	64.3	58.6	Z	89.5	73.5	83.4	85.7	77.5	69.2	73.2	75.7	78.1	79.9	79.7	74.8
Quest Sound Pro	9/4/07	14:16:39	Session119	1:31	73.8	83	71.8	13	3		csx7891-1	CSX 7891 on with air releases	Z	89.5	72.3	86	84.9	75	68.6	70	66	65	66.6	65.4	58.4	Z	94.4	77.4	86.8	86	76.4	69.7	72	72.2	74.6	78.7	78.9	73.1
Quest Sound Pro	9/4/07	14:20:07	Session119	1:31	80.5	83.6	78.4	8	3		csx8206-1	CSX 8296 on with ticking	Z	93.1	72.4	90.3	87.3	83.2	77.2	76	73.8	71.1	71.5	73.6	70	Z	94.6	75.5	92.1	88.7	85.8	80.3	76.7	76.2	74.6	78.2	78.7	75.2
Quest Sound Pro	9/4/07	14:39:50	Session120	0:01	70.1	70.2	70.1				Study192		Z	86.6	78.3	78.2	84.1	75.5	69.8	67.9	63.6	60.9	57.9	56.8	46.6	Z	86.9	78.7	78.6	84.5	75.7	70.1	68.2	63.8	61.1	58.1	57.1	46.8
Quest Sound Pro	9/4/07	14:40:15	Session121	0:21	71.9	79.5	68.5	24			csx7314-1	CSX 7341 on and cycling	Z	87	78.7	77.8	84.3	76.2	69.8	69.4	64.1	63.2	63.1	61.9	53.9	Z	89.6	81.6	80	87.6	80.4	72.5	72.7	67.5	71.5	74.8	75.2	68
Quest Sound Pro	9/4/07	14:42:50	Session121	1:31	72.1	79.8	68.5	22			csx7819-1	CSX 7819 cycling with air releases	Z	88	79.1	78.1	85.8	76.1	70.8	68.6	65.1	63.5	63.2	59.6	49.7	Z	91.8	82.2	80.5	87.6	80.9	74.7	72.7	74.5	72.5	75.1	71.6	62
Quest Sound Pro	9/11/07	14:06						24	2	No	Study195	24 yds to CSX 7824 (on with cycling), 32 to LMS7922 (off with ticking/air releases); data missing from computer																										
Quest Sound Pro	9/11/07	14:30						118	2	No	Study196	Driveway of 590 Chestnut; data missing from computer																										

Appendix C

Train Event Data Book

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

NOISE TECHNICAL ASSISTANCE CENTER
DEPARTMENT OF ENVIRONMENTAL SCIENCES

Teaneck Train-Noise Exposure Study

PARTICIPANT DATA BOOK

Household Name____

Address____

Observation Start Date ________________
End Date ________________

Participant Datasheet

Address:

Please read instructions at beginning of binder prior to completing the table below. Remember, complete one row for each train event and indicate times in which data cannot be obtained.

If possible

Column 1 **Train Arrival** (Date/Time)	*Column 2* **Train Departure** (Date/Time)	*Column 3* **Idling, Engines Off, or Pass-by?**	*Column 4* **Hear Train Noise?** (Yes/No; Indoor/Outdoor)	*Column 5* **How many locomotives** (engines) **are present on the train?**	*Column 6* **Model # of each locomotive on train, On/Off** (See instructions)	*Column 7* **Track Letter** (a,b,c- use map) **& train direction** (North, South)	*Column 8* **Location of Idling Locomotive** (5, 86, 12, 91 etc. use map)	*Column 9* **Initials/Comments** (See instructions)
4/28/2006 9:15AM	4/28/2006 11:15AM	[✓ Idle] Engines Off Pass-by	Yes, Indoor	4	Locomotive 1: CSX9023- On Locomotive 2: HLEX7204- On Locomotive 3: CSX8733- Off Locomotive 4: CSX7846- On	b, North	6	FM. (See examples in instructions—also, add your own important comments)
ND		~~Idle~~ ~~Engines Off~~ ~~Pass-by~~	*4/28/2006 11:15AM – 5:00PM ----NO DATA---- everyone at work or school*					
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						

Column 1 **Train Arrival** (Date/Time)	*Column 2* **Train Departure** (Date/Time)	*Column 3* **Idling, Engines Off, or Pass-by?**	*Column 4* **Hear Train Noise?** (Yes/No; Indoor/Outdoor)	*Column 5* **How many locomotives** (engines) **are present on the train?**	*Column 6* **Model # of each locomotive on train, On/Off** (See instructions)	*Column 7* **Track #** (a,b,c- use map) **& train direction** (North, South)	*Column 8* **Location of Idling Locomotive** (5, 86, 12, 91 etc. use map)	*Column 9* Initials/Comments
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						
		Idle Engines Off Pass-by						

Participant Datasheet Instructions: Please complete the provided datasheets to the best of your ability using the column-specific directions below. Complete one row for each train event. Also indicate date and times in which nobody in your residence was able to obtain data, and a brief explanation, such as “everyone sleeping”, “everyone at work &/or school”. “morning walk”, “vacation” etc. Two examples are provided on the first datasheet. GIS maps are provided in the end of this binder to complete table columns 7 and 8.

Columns 1: Indicate train arrival date and time in the following formats: mm/dd/yyyy, hh:mmAM or hh:mmPM.

For example, if the train arrived on July 4, 2006 at 4:30PM, input the following information into the table: 07/04/2006, 04:30PM

Columns 2: Indicate train departure date and time in the following formats: mm/dd/yyyy, hh:mmAM or hh:mmPM.

See example above

Column 3: Indicate whether the train is idling (train remained still with engine on), is present but has no engines on (engines off), or if it passed-by by circling the appropriate response.

Column 4: Indicate if you hear the train (Yes or No), and whether you are inside or outside (Indoor or Outdoor) of your home during the event.

Column 5: Indicate how many locomotives (engines) are present on the train. The first locomotive is the beginning of the train. For example, if one train is present with four attached locomotives, place “4” in this column.

Column 6: If possible, indicate the model number of each locomotive on the train. For example, if the train has multiple locomotives, provide information in the following format: locomotive 1: CSX9023, - locomotive 2: HLEX7204, locomotive 3: CSX8733, locomotive 4: CSX7846 etc. Also indicate which train locomotives appear to be “on” by indicating “On” or “Off” next to the locomotive model number.

If it is not possible or convenient to identify the locomotives by model number, then simply identify them as #1, #2, etc., starting at the front of the train and working back. Then, if possible, note whether each locomotive is idling.

Column 7: Indicate which track the train is on (a, b, or c). Track a is the west-most track, while Track c is the east-most track (see map at back). Also, indicate which direction (North or South) the train is facing; this is the opposite direction of the train cars and is the direction the first locomotive faces.

Column 8: Using maps included at the end of this data book, indicate location number where the locomotive of the train is located. If no number represents the idling location, fill-in the closest number and use quarter distances (0.25, 0.50, 0.75). For example, if the train is idling halfway between location numbers 2 and 3, place “2.5” in the data sheet.

Column 9: Provide your initials and necessary comments. Comment examples should include: “loud”, “quiet”, “house vibrates”, “house not vibrating”, “fumes in house”, “no fumes in house”, etc. Provide information you believe is important for the study team to know.

IMPORTANT NOTES:

- If you can’t determine the answer for any boxes, simply write “ND” for no data. For instance, if you know that the train is idling, but can not see the locomotives, then just write “ND” in the box for Column #6, which asks for identifying information regarding the locomotives.
- It is not uncommon for several trains to simultaneously idle, and for pass-by events to occur during idling events. An overlap in train arrival and train departure times will reflect this. Record as many train events as possible.
- If you arrive or leave your home in the middle of a train event, or are not sure of the arrival or departure time, leave the appropriate train arrival or departure time blank. However, fill-in the remaining columns as best as possible.

Contact Francesco Maimone at TeaneckTrainStudy@envsci.rutgers.edu or 732-932-8065 voice mailbox #5 for any questions regarding the Participant Datasheet. Data books will be collected periodically by study team members.

Appendix D

Methods and Standard Operating Procedures for Creating Base Layers in CadnaA

1.1 Creating Elevation Contours for Use in CadnaA

1) Go to the U.S.Geological Survey web site to download data: http://seamless.usgs.gov
2) Select "View & Download United States Data"
3) Select area to download or under the "Download" menu item, chose the "Define Download Area By Coordinates", select "Switch to Decimal Degrees" at the bottom of the window, and enter the following coordinates: West: -74.034491, East: -73.98875, North: 40.919676, South: 40.872176
4) Select "Add Area", then in the resulting window, choose "Modify Request" (ignore the no data products statement)
5) Toward the bottom of the long list, uncheck the box for "National Elevation Dataset (NED) 1 Arc Second", wait for the page to reload, then choose the option below it "National Elevation Dataset (NED) 1/3 Arc Second", for 10 meter resolution data (more information is available here: http://ned.usgs.gov/). At the time of this study, the 1/9 Arc Second, or 1 meter resolution, data did not exist for the Teaneck, NJ, region.
6) At the bottom, choose "Save Changes and Return to Summary". The window should then list the area requested and a file size of about 2 MB.
7) Press the "Download" button and when it finished, unzip the file into its own folder
8) Open ArcMap (Version 9.2 was used for this project)
9) Navigate to the folder containing the raster dataset and choose the file with an eight digit number for a name, such as "97664505". The data should appear in the Arc Map display window as a contour map shaded in black, white, and gray.
10) From the button menu bar, choose the red toolbox to display the ArcToolbox window, if it is not open already.
11) In the ArcToolbox window, under "Conversion Tools", choose "From Raster", then "Raster to Point". This step creates Height Points for direct use in CadnaA.
12) For the "Input Dataset", choose the filename with the 8-digit number, name the output file to something like "Height_Points.shp", and choose "OK".
13) In the ArcToolbox window, under "Data Management Tools" choose "Projections and Transformations", then "Feature", then "Project". This step projects the new height points on to the same coordinate system as the layer files from Teaneck Township so that all of the layers will align properly.
14) For the "Input Dataset", choose the points file name that was just created, then for the "Output Coordinate System", select the button to the right of the text box, select "Import", find the road shape files (.shp) received from Teaneck Township and load the one with the name "60_roads.shp", give the new projected files a name, then select "OK".
15) In the "Layers" section of ArcMap window, right-click on the new projected layer name, select "Data", then "Export Data", choose a file name, then "OK". The resulting shapefile can be imported directly into the CadnaA model.

1.2 Importing Data Layers into CadnaA

1) Open CadnaA and select "Import" from the "File" menu option
2) Browse to the desired import file: roads, blocks, parcels, projected height points
3) Before pressing "Open", choose the "Options" button
4) Depending on the type of layer being imported (roads = "Road"; block and parcels = "Aux. polygons"; height points = "Height Points"), enter in the text box next to the type label, a unique part of the file name for one of the shape files followed by an asterisk to load all files associated with the shapefile, such as "60_roads*". Do not include the period before the extension of the file name or the import will fail.
5) If height points are being imported, in the same "Options" window, enter in the "Transform Attributes" text box "MEMO=GRID_CODE", which will assign the elevation value stored as the name "GRID_CODE" in the shapefile to the memo field in CadnaA, then proceed with step 5.
6) Select "OK", then "Open". The layer will load into CadnaA and should appear in the window. If not, try zooming out several levels.

Once the layer is loaded, separate steps need to be performed, depending on the layer imported, to finish loading all attributes of each layer, standardize the layers to the same scale, and fit the layers to the terrain.

7) For height points:
   a. Select one of the points in CadnaA, right-click on it and choose "Modify Objects…"
   b. In the "Action" drop-down box select "Modify Attribute…", select "Height Points" in the "Object Types" section, and press "OK".
   c. For the "Attribute", select "Z", for the vertical coordinate, choose the radio button next to "Arithmetic", and enter "MEMO" in the text box after "New Value ="
   d. Press "OK" and then choose "All" on the "Change Objects" window. The count will cycle through all height points. To verify that the elevation was properly assigned to the z-coordinate of the height points, select a point, right-click on it, and choose "Edit". The "Height Z" value should be a non-zero value in meters, which were the units of the elevation file.
   e. From the menu bar, choose "Options", then "Limits", and then "Calc", to compute the limits of the window to the area covered by the height points. Press "OK" and the window size will be adjusted.
   f. Next, in the main CadnaA window, in the menu drop-down box that says "Day", choose "Ground".
   g. From the menu bar, choose "Grid" and the "Calc Grid". The calculation should only take a minute or two.
   h. From the menu bar, choose "Grid", "Appearance", and "Areas of Equal Sound". Set the "Lower Limit" to zero, the "Upper Limit" to anything above 53, the maximum elevation in Teaneck, and the "Interval" to one. Pressing the "Options>>" button allows the colors to be set. Once

finished, press “OK” and filled contours will be drawn under the heights points.

    i. Press “Alt-F12” to create contour lines from the gridded elevation output.
    j. Select a contour line, right-click and choose “Modify Objects…”, in the “Action” drop-down box select “Modify Attribute…”, select “Contour Line” in the “Object Types” section, and press “OK”.
    k. For the “Attribute”, select “ID”, choose the radio button next to “Replace Strings”, enter “*” in the text box after “Find What” and “CONTOUR_###” in the “Replace With” box, and make sure the last box at the bottom is checked.
    l. Press “OK” and then choose “All” on the “Change Objects” window. The count will cycle through all contour lines. To verify that the ID was properly assigned to each contour line, select a line, right-click on it, and choose “Edit”. The “ID” value should be a string with the format of “CONTOUR_[number]”.
    m. Finally, select a height point, right-click and choose “Modify Objects…”, in the “Action” drop-down box select “Delete”, select “Height Point” in the “Object Types” section, and press “OK”.
    n. Press “OK” and then choose “All” on the “Change Objects” window. The count will cycle through all height points until they are deleted.

8) For the roads:
    a. Select one of the road segments making up the line running north-south through the middle of Teaneck (this is actually the railway), right click on it and choose “Connect lines…”, deselect the option “Check ID”, select “First Point”, “Last Point”, and “Rekursively”, and then press “OK”. This will connect all of the segments, creating one continuous line for the railway.
    b. Select the new line, right click on it and choose “Convert to Railway”. This will create a track that is assumed to be the middle one, or track B.
    c. Select the new railway, right click on it and choose “Parallel Object”, select “Railway” for the object option, select “Left from Active Object”, enter a distance of 4 m, and press “OK”. This will create a track on the west side of the original railway, or track A.
    d. Repeat the previous step, but select “Right from Active Object” and enter a distance of 8 m. This will create a track on the east side of the original railway, or track C.
    e. The railways default to no activity.
9) For the blocks:
    a. No additional operations need to be performed on the blocks after import.
10) For the parcels:
    a. There are two parcels with erroneous diagonal lines, one in the southeastern portion of the map and one in the northwestern portion of the map. To remove the diagonal lines, select one of the polygons, right click on it and choose “Edit”, deselect “Closed Polygon”, and press “OK”. This will prevent the drawing of a line from the first point of the polygon to the last, which are not at the same location.

   b. Repeat the previous step for the other polygon.

11) Convert all components from feet to meters:
    a. Anywhere in the map window, right click and choose “Modify Objects…”.
    b. In the “Option” drop-down box, select “Transformation…”
    c. In the bottom portion of the window, select “Contour Line” and press “OK”
    d. In the resulting window, select “General Transformation”, enter “x*0.3048” for “Xnew”, enter “y*0.3048” for “Ynew”, and press “OK”. Only the X and Y coordinates need to be adjusted because the Z coordinate is already in meters. Make sure you enter the zero before the decimal place or the transformation will not be performed.
    e. Repeat steps a through c, but select “Road”, “Railway” and “Aux. Polygon” in step c.
    f. Repeat step d, but also enter “z*0.3048” for “Znew” before pressing “OK”.
12) Re-grid the ground layer by choosing “Grid” from the menu bar and then selecting “Calc Grid”.
13) Adjust the workspace to fit the transformed features by choosing “Options” from the menu bar, then “Limits”, then “Calc”, and then “OK”.
14) Fit the features to the terrain:
    a. Anywhere in the map window, right click and choose “Modify Objects…”.
    b. In the “Option” drop-down box, select “Modify Attribute…”
    c. In the bottom portion of the window, select “Road” and “Aux. Polygon” and press “OK”.
    d. In the resulting window, select “HA_ATT” for “Attribute”, select “Replace String”, enter “a” (as in absolute) for “Find What”, enter “\r” (as in relative) for “Replace With”, and press “OK”. This will convert all of the road and polygon Z coordinates from absolute to relative.
    e. Repeat steps a through c, but in step b, select “Fit Object to DTM” (or Digital Terrain Map” in the “Option” drop-down box.
    f. In the resulting window, select “All”.

Once the all of the layers were set, the orthoimagery (hi-resolution aerial imagery) received from Teaneck Township were loaded into CadnaA as bitmaps, using the same coordinate system as the other layers, for use in creating the buildings.

1.3 Creation of Buildings in CadnaA

1) Open “Teaneck_Roads_Railway_Maps.cna.”
2) Right click anywhere on the grid and select “Modify Objects…” from the context menu. In the “Action:” pull-down menu, choose “Activation…”; under “Object types:” choose Building. Make sure the “don’t care” radio button is selected for “Activation:” and click “OK”. Change the activation to “inactive.” This will cause all of the current buildings to appear as dashed lines.

3) Draw a polygon over the bitmap image of each desired building using the "Aux. Polygon" button in the lower left corner of the toolbox window. Double click on the border of the building to bring up the Building dialogue box. Check the activation check-box to a check with a grey background (indeterminate).
4) Assign IDs to the buildings you have just added based on the street name. Reference the file Teaneck Train Locations 7-27-06.mxd for street names and reference the file "The One With Everything.cna" for IDs of existing buildings along a street. (ie, If you are adding more buildings to Elm Street going north, reference "The One With Everything.cna" for the last letter designation used to determine which letter to start with for a new block.
    a. The format is STREETNAME_E_A, STREETNAME_E_B, STREETNAME_E_C, etc. for houses on the eastern side of a street that runs north-south and STREETNAME _W_A, STREETNAME_W_B, STREETNAME_W_C, etc. for houses on the western side of a street that runs north-south. The A, B, C designation starts with A as the southernmost and Z as the northernmost.
    b. The format is STREETNAME_S_A, STREETNAME_S_B, STREETNAME_S_C, etc. for houses on the southern side of a street that runs east-west and STREETNAME _N_A, STREETNAME_N_B, STREETNAME_N_C, etc. for houses on the northern side of a street that runs east-west. The A, B, C designation starts with A as the westernmost and Z as the easternmost.
5) Click on the Geometry… button and make sure the pull-down is set to "Interpolate from First/Last Point." Under "First Point" enter the value of the building height. The height is determined by multiplying 3.048 to the number of stories. Also make sure the "Relative" radio button is selected. Click "OK" to exit the dialogue box, and then click "OK" to exit the Building dialogue box.
6) Save the file, and then save the file again using "Save As…" to give the file a new name. Make sure you continue working in the new file so that the old file remains the same.
7) Right click anywhere on the grid and select "Modify Objects…" from the context menu. In the "Action:" pull-down menu, choose "Delete…" Under "Object types:" choose Bitmap. Make sure the "don't care" radio button is selected for "Activation:" and click "OK".
8) Right click anywhere on the grid again and select "Modify Objects…" from the context menu. In the "Action:" pull-down menu, choose "Delete…" Under "Object types:" choose Building. Make sure the "only inactive" radio button is selected for "Activation:" and click "OK".
9) Right click anywhere on the grid again and select "Modify Objects…" from the context menu. In the "Action:" pull-down menu, choose "Transformation…" Under "Object types:" click on "All" and then click "OK". Choose the "General Transformation" radio button and for the box for Xnew, type x*0.3048, and for the box for Ynew, type y*0.3048.
10) In the Options menu, select "Limits." Click on the "Calc" button and then click "OK."
11) Save and close the file.

12) Open The One With Everything.cna. In the File menu, select "Import…" When the dialogue box opens, make sure the "Files of type:" pull-down menu is set to "Cadna/A." Click on "Options…" Click on the radio button for "Select Object-Types:" and click on "Buildings." Click "OK." Choose file you have just created to be the file to be imported, and click on "Open." The buildings you have just created should be present in The One With Everything.cna.
13) Right click anywhere on the grid again and select "Modify Objects…" from the context menu. In the "Action:" pull-down menu, choose "Fit Object to DTM" and under "Object types:" choose Building. Make sure the "don't care" radio button is selected for "Activation:" since the buildings that were already there will have already been fit to the DTM and the new buildings still need to be fit to the DTM, and click "OK."

1.4 Creating Variants in CadnaA

Variants are modeling scenarios within Cadna. It is possible to have multiple variants within one Cadna file, which is beneficial because if the properties of one object change, the properties only have to be changed once instead of multiple times in separate files.

To add a variant, select "Variant…" from the Tables menu and click on one of the pre-numbered variants in the left hand side menu. Confirm that there is a check in the check box next to "Use Variant" and enter a description of the modeling scenario in the variant's "Name" field.

1.5 Adding Buildings to Groups in CadnaA

Objects must be in a group to enable them to be added to a variant and it is beneficial to have them in a variant so that they are not forced to always be active or inactive, regardless of which variant is chosen. To add buildings to a group, select "Group…" from the Tables menu. Each group has a descriptive name. The "Expression" field specifies which IDs are in a particular group. For example, the actual roads are encompassed in the group "Roads", which has an expression of ROADS*, with * being a wildcard indicator that any object with an ID starting with "ROADS" will be included. Each idle point source exists in its own group so that one variant may have one idle without being affected by another idle. If a north-south running street is long enough that it is bisected by Route 4, such as Sussex, it is split into a group that has the houses north of Route 4, indicated by (North of Route 4) after the name and a group that has the houses south of Route 4, indicated by (South of Route 4) after the name. If the added buildings are See section 18.2.1 of the CadnaA manual for details on the operators used for adding multiple IDs to a group.

1.6 Calculating the Sound Level Contour Grid in CadnaA

1) In the Grid menu, select "Properties…". Make sure the Receiver Height (m): is set to 1.50. Click on the "Options>>" button and make sure there are checks in the "Define Grid over entire Limits" checkbox and the "Use Heights of

Buildings" checkbox. Also make sure that the "Exclude Sound Sources" and "Exclude Buildings" checkboxes do not have checks in them. Click "OK."

2) In the Calculation menu, select "Configuration…"
    a. On the Country tab, make sure the Country is set to "International."
    b. On the General tab, make sure the "Extrapolate Grid 'under' Buildings" check box is checked.
    c. On the Ref. Time tab, make sure that Allocation Hours boxes from 00 to 06 and 22 to 23 (in the top row) are designated N and the boxes from 07 to 21 (in the top row) are designated D. Also, make sure there is "10.0" in the "Night-time Penalty (dB)."
    d. On the Eval. Param. tab, in row 1, under "Type," choose "Ld" and make sure that the check box is checked and the "Name" box is "Day." In row 2, under "Type," choose "Ln" and make sure that the check box is checked and that the "Name" box is "Night."
    e. On the DTM tab, make sure the value in the "Standard Height (m):" box is 0.00. For "Model of Terrain", choose the "Triangulation" radio button.
    f. On the Ground Absorption tab, set the default ground absorption, G, to 1.00. Also ensure the "Roads/Parking Lots are reflecting (G==0)" and "Buildings are reflecting (G==0)" checkboxes are checked.
    g. On the Reflection tab, make sure the "max. Order of Reflection" is 1.
3) Chose the variant that you want to calculate the grid for from the drop-down box on the toolbar.
4) In the Grid menu, choose "Calc Grid." For simple idling scenarios with only a couple of locomotives (point sources) in one part of Teaneck, the sound levels contours should be drawn in about 30 minutes.