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16. ABSTRACT

The Volpe Center Acoustics Facility, in support of the California Department of Transportation, participated in a long-term study to assess several types of pavement for the purpose of noise abatement. On a 6.4-km (4-mi) stretch of a 2-lane highway in Southern California, several asphalt pavement overlays were examined. Acoustical, meteorological, and traffic data were collected in each pavement overlay section, where microphones were deployed at multiple distances and heights. Single vehicle pass-by events were recorded primarily for 3 vehicle types: automobiles, medium trucks, and heavy trucks. Data were analyzed to determine the noise benefit of each pavement as compared to the reference dense-graded asphalt pavement; this includes a modified Statistical Pass-By Index as well as average LAFmx values for each vehicle type. In addition, 1/3-octave band data were examined. Results from the study indicate that applying a quieter pavement overlay can reduce wayside-measured sound levels.

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DISCLAIMER STATEMENT

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1 INTRODUCTION

1.1 Background

Noise pollution from highways is a serious environmental issue in California and the California Department of Transportation (Caltrans) is actively researching ways to reduce it. Because of noise impacts Caltrans has built hundreds of miles of sound walls costing hundreds of millions of dollars. In addition to their great expense sound walls have other drawbacks. For instance a sound wall attenuates noise only within the acoustical shadow of the wall, thereby benefiting only those directly behind it. Quieter pavements have the potential to help reduce highway traffic noise, both at the tire/pavement interface and through absorption of propagating sound. Several aspects of this non-traditional method of noise abatement are currently being investigated in many parts of the world[1]. This work includes: developing noise measurement methodologies, developing pavement design parameters, quantifying pavement related sound level reduction and its longevity, and introducing algorithms for pavement noise reduction into traffic noise prediction models. Caltrans would like to add quieter pavements to its noise abatement repertoire. Therefore, it is conducting several studies, using various measurement methodologies, to help determine the amount and longevity of noise reduction for various types of quieter pavements and surface treatments.

1.2 Study Overview

The major objectives of this study were to determine:

- the decrease of overall noise emanating from a typical California vehicle fleet traveling over a Portland Cement Concrete (PCC) pavement treated with different asphalt pavement overlays, and
- the longevity of that overall noise decrease.

The research site was a 6.4-km (4-mi) two-lane stretch of SR138 in Los Angeles County in southern California northwest of Lancaster, about 130 km (80 mi) north of Los Angeles. The pavements were assessed for their possible use in noise abatement. Additionally, the research gathered valuable information relating to the potential inclusion of pavement noise effects for a large range of pavement types to assist further development of the Federal Highway Administration's Traffic Noise Model® (FHWA TNM)[2-5]. This model is mandatory for use in determining noise impacts in the vicinity of highways and designing noise abatement features, for projects receiving U.S. Federal aid.

For the Thin Lift Study, a total of five pavement sections were constructed and evaluated:

1. dense-graded asphaltic concrete (DGAC) of 30 mm (1 in) thickness;
2. open-graded asphaltic concrete (OGAC) of 75 mm (3 in) thickness;
3. OGAC of 30 mm (1 in) thickness;
4. rubberized asphaltic concrete (RAC), Type O (open) (RAC) of 30 mm (1 in) thickness; and
5. bonded wearing course (BWC) of 30 mm (1 in) thickness.

Additional details on the pavement sections are provided in Section 2 of this report.

A modified Statistical Pass-By Method (SPB)[6] was the primary noise measurement methodology used in this study. The SPB measured the wayside noise level at established points adjacent to the highway. Wayside data were collected in all pavement test sections simultaneously, allowing for direct comparisons of the reference section to the other test sections. The SPB application was supplemented with measurements of pavement sound absorption, applying a methodology that utilizes effective flow resistivity[7], along with other methodologies including On-Board Sound Intensity.[8] Noise measurements were made for pavement aged up to 52 months. Data were analyzed and are reported in terms of individual vehicle types (both broadband and spectrally) and the SPB index, examining differences among the aging pavements. The DGAC (typical of standard asphalt) served as the reference pavement to which all other pavement types were compared.

1.3 Report Organization

Following this introduction, Section 2 describes the measurement sites, including the pavement types. Section 3 describes the data collection procedures and methodologies including the dates of data collection. Section 4 details the data analysis procedures. Section 5 reports the study results and discusses the performance of the pavements, both overall, and for individual vehicle types. Conclusions are in Section 6, while references are in Section 7. Also included in this report are several appendices, to supplement the related sections. Appendix A shows the measurement sites. Appendix B shows instrumentation used in the study. Appendix C shows tables and plots for the vehicle pass-by data. Appendix D shows tables and plots for the overall pavement performance. Appendix E shows tables and plots for the pavement performance by vehicle type, and Appendix F shows results for the test vehicle.

2 MEASUREMENT SITES

2.1 Site Locations

The study location was a 6.4 km (4mi) long stretch of LA138 located in the Mojave Desert of Southern California about 32 km (20 mi) northwest of Lancaster and 130 km (80 mi) north of the city of Los Angeles (fig.1). The testing area extended from station 101.16+00 to 180.00+00, from 230th Street West to 0.2 km (0.12 mi) west of 180th Street West. The eastern most part of the test area was not used for the wayside noise testing.

In the research area LA138 is a two-lane highway with one lane of traffic in each direction and a posted speed limit of 55 mph (fig2). It has relatively sparse traffic with a substantial percentage of heavy trucks. The ADT was 4000-5000.

Figure 1. LA138 pavement testing area map.

Figure 2. LA138 pavement testing area photograph.

2.2 Five Test Sections

The LA138 research area contained five main test sections. The sites and associated pavement types are summarized in Table 1. Illustrations for each site and pavement type are included in Appendix A. The shortest overlay covers a distance of 0.4 km (0.25 mi) while the total of all five sections spans the entire 6.4 km (4 mi) segment of LA 138.

Table 1. Locations and compositions of pavement overlay types tested on LA138.

Site	Pavement type	Specified thickness	Specified maximum aggregate size*	Measured % air void content**
Site 1 (reference section)	Dense-graded asphalt concrete (DGAC) STA 101+16.60 to 108+00.00	30 mm	12.5 mm	9% center
Site 2	Open-graded asphalt concrete (OGAC, 75 mm) STA 108+00.00 to 120+00.00	75 mm	12.5 mm	12% center
Site 3	Open-graded asphalt concrete (OGAC, 30 mm) STA 120+00.00 to 148+00.00	30 mm	12.5 mm	15% center
Site 4	Rubberized asphalt concrete type O (RAC Type O) STA 148+00.00 to 168+00.00	30 mm	12.5 mm	12% center
Site 5	Bonded wearing course (BWC) STA 168+00.00 to 174+ 00.00	30 mm	12.5 mm	7% center

* Pavement analyses show finer gradations than the standard specifications; actual gradations are similar and not listed here.[9]

** Measured air void content in the center of the lane shows percentages lower than specified.[9]

Prior to constructing the pavement overlays summarized in Table 1during May and June 2002, LA138 was treated with a leveling course of new DGAC that was completed December 2001. Construction of the leveling course was necessary due to the poor condition of the roadway's DGAC pavement[10] that was estimated to be at least 20 years old.

3 DATA COLLECTION

Wayside noise measurements were performed with existing traffic to help determine the noise reduction over time for the four pavements as compared to DGAC. The methodologies applied in this study are described first, followed by the specifications for the data collected and instrumentation used, and lastly, the data collection sessions performed are listed by date and pavement age.

3.1 Methodologies

In this study two methods of noise measurement, wayside vehicle bypass and pavement sound absorption, were utilized to compare the noise generated at the different thin lift surface treatments.

3.1.1 Wayside vehicle pass-by noise

Data collection for wayside vehicle pass-by noise generally conformed to the Statistical Pass-By Method (SPB) standard, ISO 11819-1.[6] However, the number of measurement locations was augmented and the data analysis was modified to meet the requirements of this study (described in Section 4). Acoustical, meteorological, traffic speed and identification data were collected for all pavement overlay sections simultaneously. Microphones were deployed at the following distances (from the center of the near travel lane) and heights:

1. distance: 7.5 m (25 ft), height: 1.5 m (5 ft) above the ground (low), which ranged from ~1.2-1.5 m (~4-5 ft) above the roadway surface, depending on the site;
2. distance: 15 m (50 ft), height: 1.5 m (5 ft) above the ground (low, FHWA recommended distance[11]);
3. distance: 15 m (50 ft), height: 4.5 m (15 ft) above the ground (high); and
4. at Sites 1 and 2, distance: 60 m (200 ft), height: 1.5 m (5 ft) above the ground (low).

Figure 3 shows the instrumentation deployed on one of the LA138 sites, and Figure 4 shows the complete instrumentation set-up. Each of the sites was relatively flat with mostly medium- to hard-packed dirt; there were occasional grasses and shrubs (depending on the measurement session, some sites, usually Sites 3 and 4, had more shrubs than the others). Other key factors of applying the SPB methodology to this study are listed below Figures 3 and 4.

Figure 3. Example of the deployed instrumentation along LA 138.

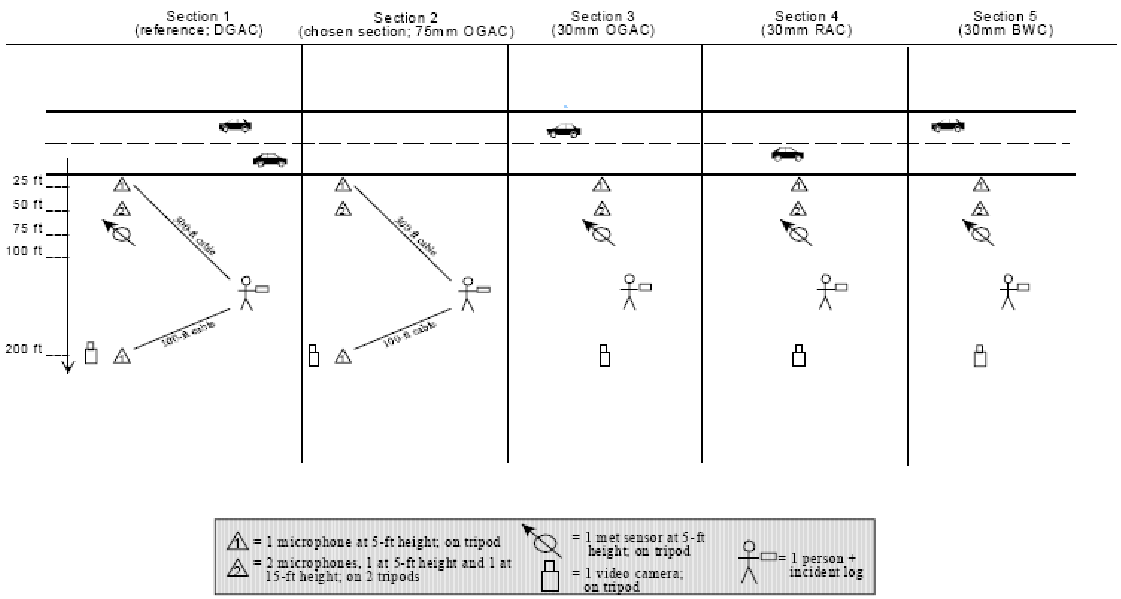


Figure 4. Diagram of the full instrumentation setup at the LA 138 test site (not to scale).

Originally, it was thought that traffic flow could be recorded continuously, so that the average 5 to 15-minute sound level for each site could be determined. After the preliminary measurements it was determined that the traffic on LA138 was too sparse to apply the continuous flow / sound level averaging methodology. At that time, it was determined that the SPB methodology would be more appropriate to measuring at the LA138 sites.

In addition to using SPB methodology sound intensity was also measured at four different speeds at each of the 5 pavement sites via controlled pass-bys with a single test vehicle. The test vehicle was a Subaru Outback with Goodyear Aquatred 3 tires. It was provided and operated by Illingworth and Rodkin, Inc. The vehicle was on site primarily for conducting On-Board Sound Intensity Measurements, and secondarily to serve as a test vehicle for the pass-by measurements. Maximum sound levels (average L_{AFmx}) were measured and compared among the 5 pavement sites.

3.1.2 Sound absorption of pavement

Measurements of pavement sound absorption data were collected in general conformance with the Template Method for Ground Impedance standard, ANSI S1.18-1999, one-parameter model, geometry A. This method uses a specified geometry for a source and two microphones[7]. The effective flow resistivity (EFR), table was augmented to include a broader and finer range of values, and the data analysis was modified to meet the requirements of this study. EFR is a measure of sound absorption and a preliminary metric before obtaining acoustical ground impedance. This methodology is still experimental for the purposes of distinguishing types of pavements.

3.2 Data and Instrumentation

Data were collected in all pavement test sections simultaneously, allowing for direct comparisons of the reference section to the other test sections and also to observe the degradation of noise benefits of individual sections over time (exception: measurements at Site 5 were stopped after the pavement was aged 16 months; see Section 3.2 for an explanation). Microphones were deployed in multiple configurations, the set-up dependent on the test section and the date of data collection. The new DGAC leveling course was used for the baseline set of measurements. Although baseline wayside noise measurements were performed with the old DGAC (referred to as preliminary measurements later in this report), analysis and results are not reported here since baseline data were re-collected with the December 2001-constructed DGAC leveling course.

In addition to acoustical data collection, meteorological data, traffic composition and speed data, ground impedance (sound absorption), event descriptions log, and extraneous noise log data were also acquired. After each set of measurements, all data were analyzed. Following is a discussion of each type of data that was collected, the procedure of collecting the data, the primary instrumentation used, and the parameters of the data collected.

3.2.1 Acoustical data

Acoustical data were collected as described in Section 3.1.1 and Figures 3 and 4 to provide data at FHWA-recommended positions[11] and to obtain a better understanding of the tire/pavement noise farther from the vehicles. Data were recorded continuously with a sound level meter or spectrum analyzer, and also captured with a DAT recorder, where vehicle pass-by events were later extracted. The acoustical data consists of continuous, 1-second time histories, along with the A weighted fast response maximum sound levels (LAFmx), using Type 1 sound level meters and spectrum analyzers. Data were also recorded to Digital Audio Tape (DAT).

The primary acoustical instruments used were:

- LDL Model 820 Sound Level Meters (some with frequency-weighting circuits appropriate for use with B&K Model 4155 and 4189 microphones for grazing incidence);
- LDL Model 2900 2-Channel Spectrum Analyzers;

- B&K Model 4155 and 4189 or GRAS Model 40AE ½-in Microphones; (make/model matched to the appropriate sound level meter);
- B&K Model 2671 Preamplifiers;
- B&K Model WB 1372 Power Supplies;
- B&K Model 0237 Foam Windscreens; and
- Sony Model TCD-D100 Digital Audio Tape (DAT) Recorders.

The sound level meters and spectrum analyzers were set up to continuously measure A-weighted equivalent sound levels (Leq) in one second intervals. For the sound level meters, the L_{AFmx} values for each second of data are also available. One-third octave band data were stored for the spectrum analyzers. DAT recordings permitted sound level meter or spectrum analyzer processing at a later time. Prior to measurements, all microphone/sound level meter and spectrum analyzer systems were time synchronized; then each was calibrated, and the electronic noise floor were established. Each system was also calibrated at the end of each measurement day to document any sensitivity drift.

When the weather permitted the acoustical data were recorded continuously for up to six hours per day, with the exception of saving files in the spectrum analyzers every two hours and changing the DAT tapes after four hours. Occasionally, seven hours of data were recorded. Three full days of data collection typically allowed for an adequate number of pass-by events for the SPB, paired measurement methodology (described in Section 4.1).

3.2.2 Meteorological data

Meteorological sensors were deployed at each measurement site except for Site 2. The primary meteorological instruments used were Qualimetrics Transportable Automated Meteorological Stations (TAMS), and a HP 200 LX Palmtop Computer. The sensors were placed 75 feet from the roadway at a height of 5 feet above the ground. Wind speed, wind direction, air temperature, and relative humidity data were collected during all acoustical data collection. These data were recorded in one-second intervals. Site 2 which was close to Site 1 was equipped with a hand held wind anemometer. Prior to measurement sessions, all meteorological systems were time-synchronized with the acoustical instrumentation. Acoustical data collected during wind speeds exceeding 5 m/s or 11 mph were eliminated during data analysis.

3.2.3 Traffic data

At each measurement location, highway traffic passing the site was continuously recorded using a video camera during all data collection sessions. Video cameras were used to minimize the influence on drivers that might have been caused by the presence of a radar gun. The primary traffic recording instruments used were Sony 8-mm or Hi-8 Video Cameras. A television with a VCR was used for post-measurement data analysis. The cameras were placed at distances varying from about 200- 300 feet from the roadway and five feet above the ground. This was close enough to the roadway to allow identification of vehicles while viewing the videotape, and far enough away to allow speed calculations. Distinctive landmarks and the associated separation distances were documented for speed calculation purposes. During the October 2006 measurements a radar gun facing downstream was used to obtain speeds at Site 4 to validate video-based speed measurements. In 2006 this site was the easternmost measurement site. The radar gun was pointed downstream (measuring the speeds of vehicles traffic traveling from west to east), so as not to influence driver behavior at any of the sites, while still allowing for the validation of vehicle speeds. Prior to measurements, all video cameras were time-synchronized with the acoustical instrumentation.

3.2.4 Pavement data

The structure, condition and temperature of a pavement can influence its noise production and propagation characteristics. For instance pavement temperature can influence tire/road noise by about -1 dB per 10° C (50° F), hotter being quieter[1]. So, pavement data were collected during this study to enhance the understanding of how pavement influences noise. At each measurement site, temperature guns (Extech Model 42520 IR Thermometer) were used at least once an hour during acoustic measurement to determine and log the pavement temperature. Two core samples were taken at least once a year from each pavement section and analyzed to determine the pavement's macro texture and porosity.

Additionally during 2001 and 2002 ground impedance measurements were performed in accordance with ANSI S1.18[7] to determine the effective flow resistivity (EFR) of each pavement type. The primary instrumentation used were two of the ½-in microphones and a spectrum analyzer (listed in Section 3.2.1), a Larson Davis SRC20 tone generator, and a driver feeding a long narrow tube to simulate a point source.

3.2.5 Pass-by event log and extraneous noise log data

Individual vehicle pass-by events were evaluated in real time at each site for acceptability using observer logs. Identification of clean pass-by events was in conformance with ISO 11819-1, which includes the elimination of vehicles with atypical sounds. At each measurement site, personnel used an HP 200 LX palmtop computer electronic log to identify all acceptable vehicle pass-by events (including the type of vehicle, a brief description, and the time of the event) and to note the description and time of any noise event that may have possibly contaminated the acoustical data. Prior to measurements, all electronic logs were time-synchronized with the acoustical instrumentation. Additional acceptability tests were conducted during post-analysis.

Observers noted the type of each vehicle in each acceptable pass-by event. The following types were used:

- automobiles (including cars, pick-up trucks, and sports utility vehicles) were vehicles with 2 axles, 4 tires, and generally < 4,500 kg or 9,900 lb;
- medium trucks were vehicles with 2 axles, more than four tires, and generally > 4,500 kg or 9,900 lb and < 12,000 kg or 26,400 lb; and
- heavy trucks are vehicles with 3 or more axles and generally > 12,000 kg or 26,400 lb.
- buses and motorcycles were identified but not included in this analysis due their low numbers.

The logs were also used to identify extraneous noise events that may have contaminated the vehicle pass-by noise measurements. Observers listened for acoustical contamination from nearby vehicles or other sources and followed general guidelines for identifying a clean event, typically by allowing for 300 feet or 5 seconds of vehicle separation distance with more time or distance for heavy trucks.

3.3 Data Collection Sessions

Noise data was collected during a series of data collection sessions. This series consisted of preliminary measurements prior to the overlays being paved, baseline measurements with the DGAC overlay aged 3 months; and post-overlay measurements, with the pavement overlays aged 4, 10, 16, and 52 months. Each measurement session occurred over a period of several days and included four to seven hours of continuous attended noise measurements taken simultaneously at each site with a minimum of 300 pass-by events.

In collecting data at the LA138 sites, wind played a major role in determining the time of year and number of days required to collect useful data. Even with careful consideration, the wind limited the amount of data collected (see Section 3.2.2 for wind speed restrictions).

Preliminary Measurements were performed during May 2001 with the existing old DGAC. This set of measurements was originally going to be used as the baseline set of measurements until it was determined by Caltrans and University of California Pavement Research Center that the pavement was structurally failing and would not support pavement overlays[10]. Also, at some of the sites, cracks in the pavement acoustically contaminated the collected data. For this set of measurements, a continuous flow/sound level averaging methodology was applied, and data were collected on both sides of the highway at 16 different sites. However, not all measurements were made simultaneously. At this point in time the study was going to include more than 5 pavement types. The data were collected for 7 days. Pass-by events were not logged since that type of methodology was not being used at that time. However, all other data were collected in a manner similar to that for all subsequent measurements, and the 16 sites included the 5 sites measured in subsequent measurements. Some of the May 2001 data could be used to extract vehicle pass-by events if it is ever of interest to compare the very old DGAC to the newer overlays.

Baseline Measurements were performed during March 2002 with a new DGAC leveling course, aged approximately 3 months. The leveling course covered all pavement test sections. The original 16 sections were reduced to 5 sections. For these measurements, the SPB methodology was applied. The data were collected for a period of 5 days. Over 600 vehicle pass-by events were collected at each pavement site but, some events were eliminated during data analysis because they did not meet quality criteria. EFR data were collected. The March 2002 data allow for a direct comparison among sites, with the variability of pavement removed.

Post-Overlay Measurements were performed with the pavement overlays aged 4, 10, 16, and 52 months. Specific details are indicated below.

In October 2002 the overlays were aged approximately 4 months. This set of measurements was performed with 5 overlays covering the DGAC leveling course. The SPB methodology was applied as the data were collected over 4 days. More than 500 vehicle pass-by events were collected at each pavement site but, some events were eliminated during data analysis because they did not meet quality criteria. EFR data were collected during this session.

In March 2003 the overlays were aged approximately 10 months. This set of measurements was performed with the same 5 overlays as in the October 2002 collection session. Again, the SPB methodology was applied. The data were collected for 2 days. Over 300 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events were eliminated as described in that section).

In October 2003 the overlays were aged approximately 16 months. This set of measurements was performed with the same 5 overlays as in the October 2002 collection session. The overlays were aged approximately 16 months. Again, the SPB methodology was applied. The data were collected for 3 days. Over 500 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events were eliminated as described in that section).

In October 2006 the overlays were aged approximately 52 Months. This set of measurements was performed for 4 of the 5 overlays. Site 5 BWC was excluded because the results of the October 2003 measurements indicated that BWC was not quieter than DGAC. Thus, to save funds Caltrans and the Volpe Center agreed to discontinue wayside measurements for Site 5, BWC. Again the SPB methodology was applied. The data were collected for 3 days. Over 700 vehicle pass-by events were collected at each pavement site (this is a field count – during data analysis, events were eliminated as described in that section).

4 DATA PROCESSING AND ANALYSIS

Upon acquiring all of the data, processing and analysis for the acoustical, meteorological, traffic, pavement temperature and EFR, pass-by event log, and extraneous noise log data were performed. Thorough pavement analyses were performed by the University of California Pavement Research Center; more information about the LA138 pavements can be found in the UCPRC 2006 reference.[9]

4.1 SPB Methodology Applied to Thin Lift Study

A modified SPB analysis was performed for each of the data sets. The result of applying the SPB methodology was a single number called the Statistical Pass-By Index (SPBI), accounting for noise from automobiles, medium trucks, and heavy trucks. Intermediate results for each vehicle type (part of SPBI calculations) were also extracted. For the processing and analysis the following key factors applied:

- The SPB paired measurements technique was used. This technique employs the selection of the same vehicles from the traffic stream as they pass each measurement site, thus improving accuracy due to the elimination of differences in traffic composition. For determining the overall performance of the pavements, four pairs of sites were examined; Site 1 and Site 2, Site 1 and Site 3, Site 1 and Site 4, and Site 1 and Site 5.
- The baseline set of data (March 2002) was used to determine site biases, without the influence of pavement type. Differences in average baseline sound levels for each site pair were calculated, determining each site bias, which was applied to the average post-overlay sound levels.
- For the spectral sound level processing and analysis, the paired measurement technique was extended to include all sites. Analysis included the exact same vehicle set for each site being examined. Using identical vehicle sets reduced the number of pass-by events included in the averages for the spectral levels. Because of this reduction in number of pass-by events and the collection of fast response values (LAFmx), it was determined that site bias values could not be considered in the spectral comparison. Therefore, spectral data are presented as measured. For the spectral results, sound levels for several pass-by events of the same vehicle type were arithmetically averaged for each 1/3-octave band.
- The speed category of interest for this study is “highway speeds”. The ISO 11819-1 standard sets the minimum highway speed to be 100 km/h (~60 mph) for automobiles. For medium and heavy trucks, the standard allows for unspecified lower speeds. Reviewing all of the recorded traffic on LA138, it is clear that lower minimum speeds apply to the LA138 site, and that many pass-by events (~15 %) would be forfeited if applying the ISO restriction. To better capture the traffic on LA138 and use highway speeds that are more appropriate for the U.S., the minimum automobile highway speed was dropped to ~90 km/h (55 mph); the minimum medium and heavy truck speed were set at ~80 km/h (50 mph).
- In order to calculate the SPBI, the standard requires a minimum number of clean pass-by events for each vehicle category: 100 for automobiles and 80 for combined medium and heavy trucks, with a minimum of 30 medium trucks and a minimum of 30 heavy trucks. These requirements are based on using single measurements, as opposed to using paired measurements. Using paired measurements should allow the requirements to be relaxed. In the current study, standard minimum requirements for the medium and heavy

trucks were not always met; however, the totals appear to be adequate for a paired measurement analysis with the modified SPBI calculations. Typically, 100 or more automobiles and 30 or more heavy trucks were included in each of the averages. The combined medium and heavy trucks numbers did not always reaching the standard minimum of 80. Therefore, the baseline measurements yielded fewer pass-by events, although enough to determine site biases.
- Calculating the SPBI first requires calculating the vehicle sound level (Lveh), for each vehicle type; automobiles, medium trucks, and heavy trucks. Lveh is a representative (an "average") sound level for a specific vehicle type for the highway speed category. In the ISO 11819-1 standard, Lveh uses a regression through the accumulated maximum sound level (LAFmx) data points for each vehicle type; a single number, Lveh, is extracted from the regression line at a specified reference speed. It was determined that the regression methodology breaks down when the minimum number of vehicle pass-bys is not obtained or when speeds are off even by small amounts. There is error associated with obtaining vehicle speeds, whatever the methodology and instrumentation. After a brief investigation with LA138 data, it was determined that the linear arithmetic average of the LAFmx data for all the events equaled the single value extracted from the regression line at the reference speed for data sets with the minimum number of events achieved. Thus, for the current study, Lveh is obtained by taking the linear arithmetic average LAFmx of all events for each vehicle category. A side benefit to obtaining Lveh in this manner is that it relaxes the need for precise vehicle speeds. So, for the current study, where there are limitations to obtaining precise speed data and where the SPB minimum numbers for events were occasionally not met, the LAFmx averages were calculated for all events for highway speeds greater than 90 km/h (55 mph) for automobiles and 80 km/h (50 mph) for medium and heavy trucks. Any pass-bys greater than 145 km/h or 90 mph were eliminated.
- The equation below was applied to calculate the SPBI.[6] The modified SPBI is calculated using the LAFmx averages as the Lveh variables in the equation. The vehicle mix ratios in the equation were maintained as in the standard, and the speeds were updated to better represent approximate average speeds at the sites on LA138: 100 km/h (60 mph) for autos, and 90 km/h (55 mph) for medium and heavy trucks.
- ISO 11819-16 provides discussion of expected errors and uncertainty for the SPB method.
- The parameters calculated and presented for this study include the modified Lveh for each of the three vehicle types and also the modified SPBI for highway speeds.

SPBI = 10*log[W1*10^(L1/10) + W2a*(v1/v2a)*10^(L2a/10) + W2b*(v1/v2b)*10^(L2b/10)],

where SPBI = Statistical Pass-By Index, for a standard mix of light and heavy vehicles
Lx = Vehicle sound level for vehicle category x – refer to Section 3.2.5 for vehicle categories (average LAFmx for each vehicle type is applied; this differs from Lveh calculations in ISO 11819-1)
Wx = Weighting factor, which is the proportion of vehicle category x in the traffic (taken from Table 1 in ISO 11819-1)

vx = Reference speed of vehicle category x [60 mph (~100 km/h) for autos, 55 mph (~90 km/h) for medium and heavy trucks; reference speeds differ from those in Table 1 in ISO 11819-1].

4.2 Processing Procedure

4.2.1 Modified SPBI and average vehicle sound level

First, pass-by events were extracted from the vehicle pass-by event log for each site and the vehicle type, description, and time were entered into a spreadsheet. Events were eliminated when comments indicated that the event may not have been acceptable. Events were also eliminated when sound levels both before and after the pass-by event were not 10 decibels below the event maximum sound level. That is, events were eliminated when the vehicle pass-by event was acoustically influenced by another sound source. Next, pass-by events were paired for each of the four site pairs. Only pass-by events that were deemed to be acoustically clean at both sites were retained. Meteorological data were then extracted for each event for each site. The average wind speed 10 seconds before and after each pass-by event was calculated, and the maximum wind speed was extracted. Events with maximum wind speeds exceeding 5 m/s (11.24 mph) were eliminated. Pavement temperatures for each event were also entered into the spreadsheet. Using the remaining list of pass-by events, vehicle speeds were extracted from the videotapes and entered into the spreadsheets with the corresponding pass-by events. If the speeds were not in the same speed category for both sites for a site pair, the vehicle pass-by event was eliminated. Finally LAFmx was determined for each remaining vehicle pass-by event for each site. The pass-by data can be seen in Appendix C. For each site pair, vehicle type, microphone location, and pavement age, tables show the average pass-by LAFmx (also shown graphically in Appendix E, Section 1) and standard deviation; the average vehicle speed and standard deviation; and the average, maximum, and minimum pavement and air temperatures. Plots show all the LAFmx data points with regression lines and equations.

The modified SPBI was then calculated. First, the data were sorted into three vehicle categories: automobiles, medium trucks, and heavy trucks; then the data were sorted into vehicle speed categories. Most of the events fell within the highway speed category, and all remaining analysis was performed just for that category. The average LAFmx was calculated for each vehicle category for each pavement site; these averages were determined to be the modified vehicle sound levels (modified Lveh). Then the ISO 11819-1 equation is used to calculate the SPBI.

The results that are reported are the average LAFmx (modified Lveh) for each of the three vehicle types for each of the pavement sites (Appendix C and Appendix F, Section 1). Also reported is the modified SPBI for each of the pavement sites (Appendix E). Each of these parameters was calculated for each of the microphone locations (except the 200-ft microphones).

4.2.2 Test vehicle

The test vehicle data were included in the SPBI calculations if the event met all the criteria described above. In addition, the test vehicle data were separated from the other data. The average LAFmx was calculated for each speed (40, 50, 60, and 70 mph;

~65, 80, 100, and 112 km/h) for each pavement site. These averages were plotted across speed for comparison.

4.2.3 Existing traffic spectral data

Spectral sound level data were also analyzed, including identical vehicle sets for each site being examined. For this small set of vehicles, the LAFmx values and the spectral data were examined for all microphones, including the microphones located at 200 ft (60 m) at Sites 1 and 2.

4.2.4 Sound absorption of pavement

For the pavement sound absorption data (EFR), the average sound level delta was determined for each of thirteen frequencies for the two microphone positions in the instrumentation set-up. The EFR values were extracted for each type of pavement using a table that matched deltas and frequencies to theoretically calculated ground absorption curves (based on the ANSI S1.18-specified geometry). The table provided in the ANSI standard has little resolution and excludes higher impedance surfaces. As such, a new table with greater resolution was generated, and the effectiveness of this type of methodology for determining differences in pavement surfaces was evaluated. During this evaluation process, it was determined that further analysis techniques (beyond those in ANSI S1.18) are necessary to allow for extraction of EFR values related to various pavement types. A "curve selecting" methodology was developed. This method first examines peaks and dips in the absorption curves (and based on that, limits the possible range of EFR values), then the method normalizes the data to better match amplitudes (assuming cement concrete is 20,000 cgs rayls – acoustically hard, reflective ground), and then matches amplitudes at specific frequencies. Preliminary results related to this analysis technique are presented in the Section 5.4.

Due to funding constraints, it was agreed between Caltrans and the Volpe Center that the EFR data captured for the LA138 study could be used in the FHWA TNM Pavement Effects Implementation Study. Starting in 2006, development of the EFR data analysis technique and assessment was funded by FHWA, and information to date from the FHWA study is included in this report.

5 RESULTS AND DISCUSSION

The LA130 Thin Lift Study generated an extensive data set. The following results are included in this section and corresponding appendices: 1) overall performance of the pavements over time, compared to DGAC; 2) pavement performance by vehicle type, both broadband and spectral examinations; 3) pavement performance for the test vehicle (broadband only); and 4) pavement performance related to sound absorption of the pavement. There are some limitations to the results presented, related to microphone positions and pavement age; each subsection will note which results are being presented.

5.1 Overall Performance of Pavements

The performance over time of each of the pavements tested compared to the DGAC of the same age can be seen in Table 2 and Table 3. Table 2 shows the SPBI *values* and Table 3 shows the differences or *deltas* between the SPBI values. An attempt was made to remove any site bias by applying corrections determined with the baseline measurements – refer to Appendix D, Section D.3 for more information on site bias corrections. In addition to the tables, Figure 5 shows the SPBI *deltas* over time for just the 7.5 m (25 ft) microphone position (as an example); plots for other microphone positions can be found in Appendix D, Section D.2. Plots of the SPBI *values* over time can be found in Appendix D, Section D.1.

As can be seen in Table 3 and Figure 5, the results of using the modified SPB methodology over a 52-month period indicate that OGAC 75 mm was the quietest pavement, with the average noise reduction benefit over DGAC of 3.3 dBA. This benefit ranged from 2.6-3.8 dBA, depending on microphone position and pavement age. It should be noted that the low microphone at the 15-m (50-ft) position showed the least benefit. For each microphone position, the benefit varied only slightly over time (< 1 dBA).

The second quietest pavement was RAC Type O 30 mm, with an average noise reduction benefit over DGAC of 2.3 dBA. This benefit ranged from 1.4-2.7 dBA, depending on microphone position and pavement age. All microphone positions showed approximately the same benefit, with the exception of the 15-m (50-ft) high microphone with the pavement aged 16 months. For each microphone position, the benefit varied only slightly over time (≤ 1 dBA).

The third quietest pavement was OGAC 30 mm, with an average noise reduction benefit over DGAC was 1.7 dBA. This benefit ranged from 1.1-2.4 dBA, depending on microphone position and pavement age. The two 15-m (50-ft) microphone positions often showed almost the exact same benefit (except for the pavement aged 16 months). For each microphone position, the benefit varied only slightly over time (< 1 dBA).

Table 2. Post-overlay measurements: sound levels for each pavement type (SPBI*) by site pairs with identical vehicle sets.**

*modified SPB methodology

other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* (dBA)							
		Site 1 (DGAC, 30 mm)	Site 2 (OGAC, 75 mm)	Site 1 (DGAC, 30 mm)	Site 3 (OGAC, 30 mm)	Site 1 (DGAC, 30 mm)	Site 4 (RAC Type O, 30 mm)	Site 1 (DGAC, 30 mm)	Site 5 (BWC, 30 mm)
4 months	7.5 m (25 ft) low	82.1	78.9	82.0	80.6	82.1	79.7	na	na
	15m (50 ft) low	75.3	72.7	75.3	73.6	75.3	72.7	75.3	75.5
	15m (50 ft) high	77.1	73.8	77.1	75.4	77.2	75.1	76.9	76.2
10 months	7.5 m (25 ft) low	82.3	78.7	82.6	80.6	82.7	80.0	82.7	80.6
	15m (50 ft) low	75.2	72.4	75.5	73.8	75.7	72.9	75.6	76.0
	15m (50 ft) high	77.4	73.7	77.7	75.8	77.8	75.4	77.9	75.9
16 months	7.5 m (25 ft) low	82.5	79.0	82.4	80.7	82.4	80.2	82.5	80.7
	15m (50 ft) low	75.6	72.6	75.5	73.9	75.5	73.3	75.4	75.9
	15m (50 ft) high	77.5	74.4	77.3	76.2	77.3	75.9	77.4	75.9
52 months	7.5 m (25 ft) low	83.2	79.4	83.5	81.2	83.6	81.3	na	na
	15m (50 ft) low	75.5	72.5	75.9	74.1	75.9	73.6	na	na
	15m (50 ft) high	78.0	74.2	78.4	76.7	78.5	76.5	na	na

Note: This table is also seen in Appendix D (Table D-1), with baseline values included. SPBI values with site bias not removed can be seen in Appendix D, Table D-2.

The final pavement, BWC 30 mm, was actually louder than DGAC for one of the microphone positions, and had an average noise reduction benefit over DGAC of 0.9 dBA. This "benefit" ranging from -0.5 (no benefit) to 2.1 dBA, depending on microphone position and pavement age. Although the BWC sometimes showed about a 2 dBA benefit at the 7.5-m (25-ft) and high 15-m (50-ft) positions, there was no indication of a benefit at the low 15-m (50-ft) position. For each microphone position, the benefit varied somewhat over time (< 2 dBA). The BWC 30 mm at Site 5 should not be considered a quieter pavement.

As mentioned, the pavement benefits varied somewhat by microphone position, although the general trends were the same and different results were obtained for each pavement type. Possible contributions to the variation include: differences in angle of reflection off pavement; differences in the ground effect during propagation; and possible differences in meteorological effects during propagation, although care was take to minimize the meteorological effects. This aspect of the study should be further investigated because results could affect future guidance on microphone placement for wayside tire/pavement noise measurements.

Table 3. Post-overlay measurements: site differences due to type of pavement (SPBI* deltas) by site pairs with identical vehicle sets.**
*modified SPB methodology ** other sites **calibrated to Site 1 to remove site bias unrelated** to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* delta (dBA)			
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)	Site 3 – Site 1 (OGAC, 30 mm – DGAC)	Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)	Site 5 – Site 1 (BWC, 30 mm – DGAC)
4 months	7.5 m (25 ft) low	-3.1	-1.5	-2.5	na
	15m (50 ft) low	-2.6	-1.7	-2.6	0.2
	15m (50 ft) high	-3.2	-1.7	-2.1	-0.7
10 months	7.5 m (25 ft) low	-3.6	-2.0	-2.6	-2.1
	15m (50 ft) low	-2.8	-1.8	-2.7	0.4
	15m (50 ft) high	-3.6	-1.9	-2.4	-2.0
16 months	7.5 m (25 ft) low	-3.5	-1.7	-2.3	-1.8
	15m (50 ft) low	-2.9	-1.5	-2.2	0.5
	15m (50 ft) high	-3.1	-1.1	-1.4	-1.5
52 months	7.5 m (25 ft) low	-3.8	-2.4	-2.3	na
	15m (50 ft) low	-3.0	-1.7	-2.3	na
	15m (50 ft) high	-3.8	-1.7	-2.0	na
Average (all locations, all time)		-3.3	-1.7	-2.3	-0.9

Note: Decibel values show in Table 3 may not agree with the source data in Table 2 due to rounding. A slightly modified version of this table is seen in Appendix D (Table D-3), with baseline values included. SPBI deltas with site bias not removed can be seen in Appendix D, Table D-4.

It should be noted that the modified SPBI values (not the deltas) showed a general trend of slightly increasing over time for all pavements types except BWC. Data are not available to identify trends for this pavement type. Please refer to Figure 6 as an example (also found in Appendix D, Figure D-5), which shows the increase in SPBI values over time, as compared to values at four months, for the 7.5-m (25-ft) position. Plots for the other microphone positions are found in Appendix D, Figures D-6 and D-7). Although there was variation by microphone position, DGAC increased approximately 1.5 dBA over 52 months. OGAC 75 mm increased approximately 0.5 dBA. OGAC 30 mm increased approximately 1.5 dBA. RAC Type O increased approximately 1.5 dBA. Because there were only slight sound level increases for test and reference pavements, the SPBI deltas were fairly consistent over time. However, because the increase in SPBI values for each of the test pavements can vary from DGAC, the SPBI deltas can be slightly affected. As an example, for the 7.5-m (25-ft) position, Figure 6 shows that DGAC increased over time more than both the OGAC pavements. This is reflected in the Figure 5 SPBI delta plot, where it is seen that the deltas (the benefits) for the OGAC pavements increased slightly at 52 months. Measurements taken beyond the age of 52 months would help to further determine trends related to age, both for the SPBI values and the deltas (benefit over DGAC).

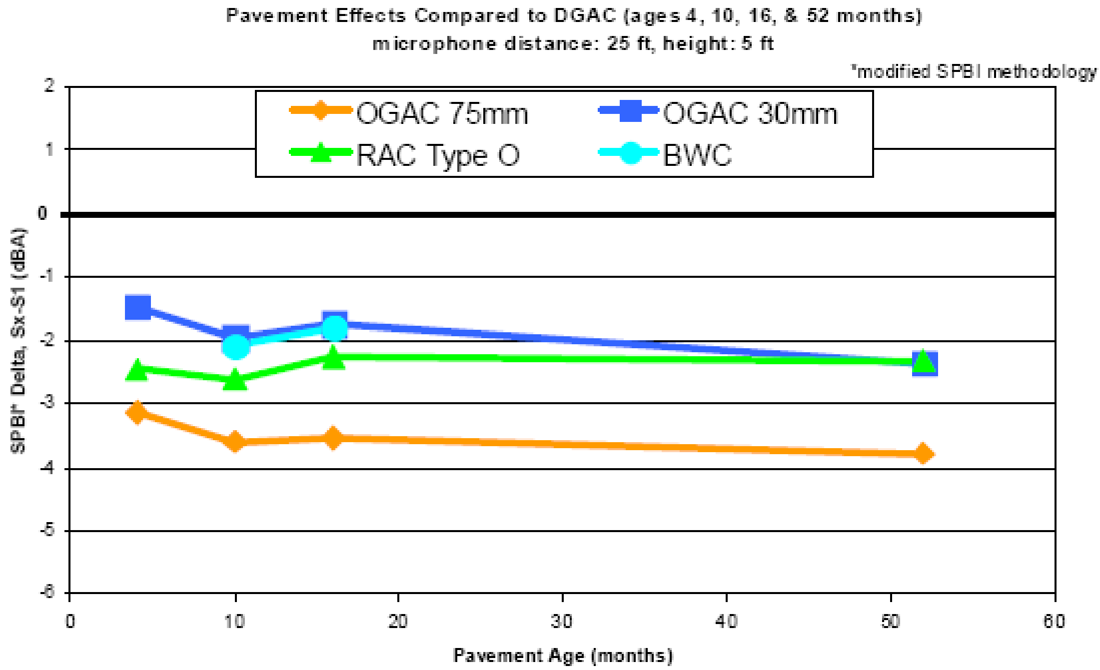


Figure 5. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI (limited data for BWC). Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft). Note: This plot can also be seen in Appendix D, Figure D-12. Refer to Figures D-13 and D-14 for the other two microphone positions.

5.2 Pavement Performance by Vehicle Type

The pavement performance by vehicle type is presented in terms of both broadband and spectral sound levels.

5.2.1 Broadband examination

For this examination, the average L_{AFmx} values for automobiles (autos), medium trucks (med trucks), and heavy trucks (hvy trucks) are considered. Table E-1 in Appendix E shows the average L_{AFmx} values. The baseline values are used to remove site bias, then each of the test pavements is compared to the DGAC (Site 1); the average differences or deltas between the test pavements and DGAC can be seen in Table 4.

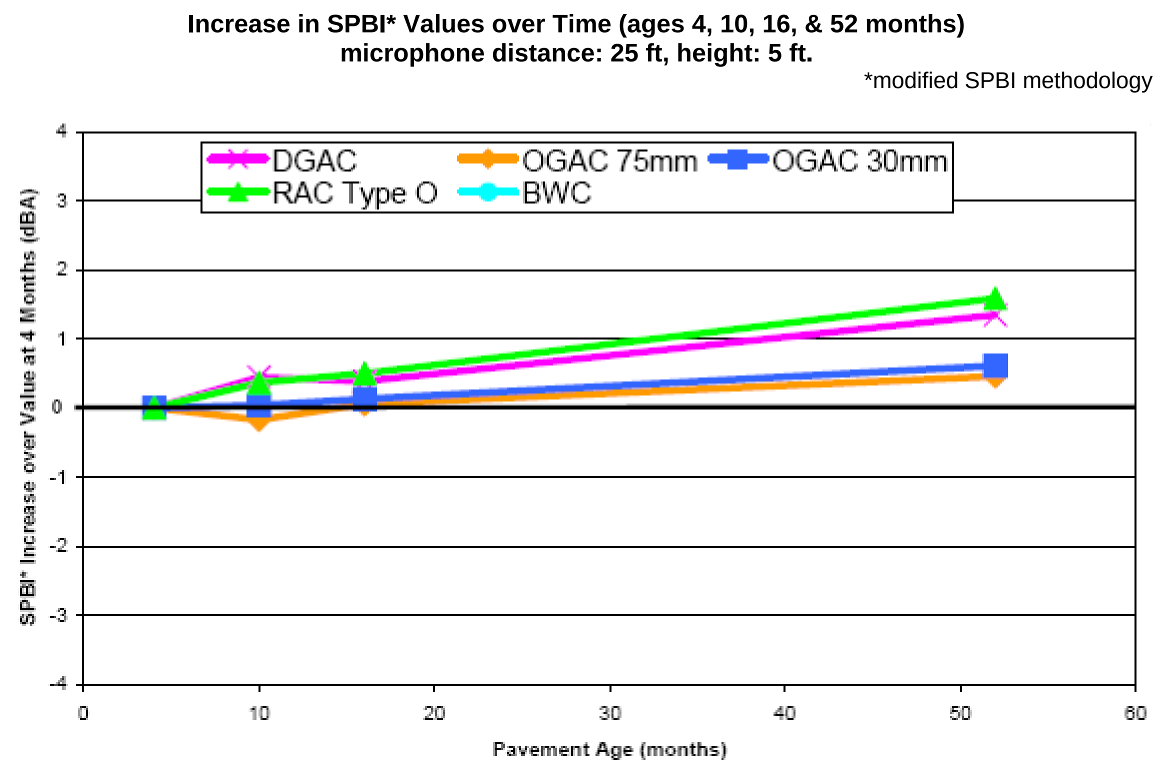


Figure 6. Increase in SPBI* values over time, as compared to values at 4 months. Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft). Note: This plot can also be seen in Appendix D, Figure D-5. Refer to Figures D-6 and D-7 for the other two microphone positions.

As shown in Table 4, the noise benefit relative to the reference DGAC of the same age, listed in order of the best performance (considering pavement benefits as average over all microphone locations and time), is as follows:

1. OGAC 75 mm: 3.7 dBA for autos, 3.1 dBA for med trucks, and 3.0 dBA for hvy trucks;
2. RAC 30 mm: 3.5 dBA for autos, 2.0 dBA for med trucks, and 1.3 dBA for hvy trucks;
3. OGAC 30 mm: 2.6 dBA for autos, 1.2 dBA for med trucks, and 1.2 dBA for hvy trucks; and
4. BWC 30 mm: 0.4 dBA for autos, 0.4 dBA for med trucks, and 1.1 dBA for hvy trucks.

It should be noted that the order of performance is the same for all vehicle types. It should also be noted that there is a greater benefit for automobiles than for medium or heavy trucks, except in the case of the BWC (Site 5). Lastly, it should be noted that the difference in benefit comparing automobiles to either medium or heavy trucks is not consistent among pavement types; for example, the difference in average benefit between automobiles and heavy trucks for OGAC 75 mm is 0.7 dBA, and the difference for RAC 30 mm is 1.4 dBA. This indicates that some pavements can reduce noise about the same amount for both automobiles and heavy trucks, where as other pavements see more of a disparity in reduction between vehicle types.

Figure 7 shows the average difference observed between the four test pavements and the reference DGAC, of the same age, at the 7.5 m (25 ft) position for automobiles and heavy trucks. Results for the other microphone positions can be seen in Appendix E, Figures E-2 and E-3. As with Table 4, Figure 7 also indicates that the noise benefit provided by each of the test pavements was greater for automobiles than for heavy trucks (except for BWC). This is also indicated for each of the other microphone positions and also when site bias is not considered. Table 4 and Figure 7 also indicate that increasing the thickness of the OGAC layer provided additional benefit for both automobiles and heavy trucks. In addition, rubberized asphalt seemed to provide additional benefit for automobiles, when comparing the OGAC and RAC of the same thickness.

These results can be considered when choosing or designing a pavement for highways. When targeting a highway with a low percentage of heavy truck traffic, 30 mm of RAC Type O may be almost as effective as 75 mm of OGAC. However, when heavy trucks are dominant, 75 mm of OGAC should reduce the traffic noise more than 30 mm of RAC Type O.

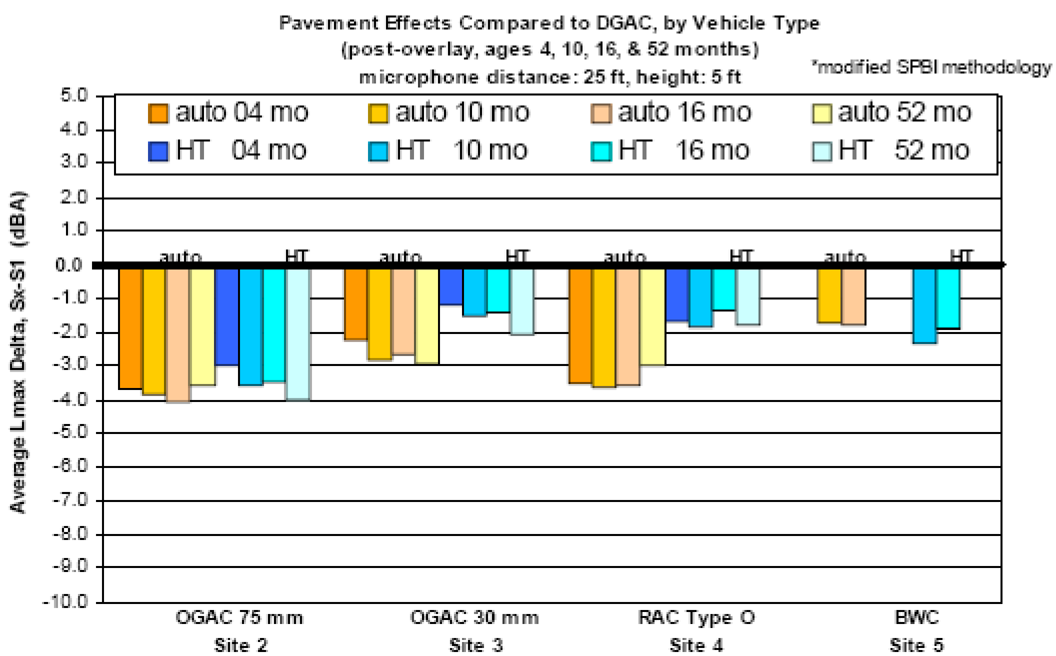


Figure 7. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft). Note: This plot can also be seen in Appendix E, Figure E-1.

Table 4. Post-overlay measurements: for each vehicle type, site differences due to type of pavement (Lveh* deltas) by site pairs with identical vehicle sets. **
*modified SPB methodology
**other sites calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	Modified Lveh* (or average L_{AFmx}) delta (dBA)											
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)			Site 3 – Site 1 (OGAC, 30 mm – DGAC)			Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)			Site 5 – Site 1 (BWC, 30 mm – DGAC)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
4 months	25 ft (7.5 m) low	-3.7	-2.9	-3.0	-2.2	-0.6	-1.2	-3.5	-2.0	-1.7	na	na	na
	50 ft (15 m) low	-3.1	-2.4	-2.4	-2.3	-0.5	-1.6	-4.0	-2.3	-1.3	0.5	1.0	0.0
	50 ft (15 m) high	-4.0	-3.4	-2.5	-2.7	-0.6	-0.9	-3.3	-1.7	-1.1	0.0	0.4	-1.0
10 months	25 ft (7.5 m) low	-3.9	-3.3	-3.6	-2.8	-2.4	-1.5	-3.6	-2.6	-1.8	-1.7	-1.6	-2.3
	50 ft (15 m) low	-3.0	-2.6	-2.7	-2.4	-1.6	-1.5	-3.6	-3.2	-1.6	0.7	-0.3	0.4
	50 ft (15 m) high	-4.2	-3.9	-3.0	-2.6	-2.0	-0.9	-3.4	-1.8	-1.6	-0.9	-1.3	-2.3
16 months	25 ft (7.5 m) low	-4.1	-3.0	-3.4	-2.7	-1.0	-1.4	-3.6	-2.2	-1.4	-1.8	-1.1	-1.9
	50 ft (15 m) low	-3.6	-2.7	-2.7	-2.1	-0.4	-1.4	-3.7	-2.6	-0.8	0.7	0.3	0.4
	50 ft (15 m) high	-3.7	-2.9	-2.5	-2.4	-0.2	0.0	-2.8	-1.0	-0.4	-0.8	-0.8	-1.6
52 months	25 ft (7.5 m) low	-3.6	-3.3	-4.0	-2.9	-2.1	-2.1	-3.0	-1.6	-1.8	na	na	na
	50 ft (15 m) low	-3.1	-2.6	-2.9	-2.7	-1.3	-1.4	-3.9	-2.2	-1.0	na	na	na
	50 ft (15 m) high	-4.0	-4.4	-3.4	-2.8	-2.0	-0.6	-3.1	-1.2	-1.1	na	na	na
Average (all locations, all time)		-3.7	-3.1	-3.0	-2.6	-1.2	-1.2	-3.5	-2.0	-1.3	-0.4	-0.4	-1.1

Note: A slightly modified version of this table is seen in Appendix E (Table E-2), with baseline values included. Lveh deltas with site bias not removed can be seen in Appendix E, Table E-3.

5.2.2 Spectral examination

For this examination, averages of LAFmx spectral data by vehicle type are considered; the vehicle types examined here are automobiles and heavy trucks. The spectral data can be examined in several different ways, each providing a useful perspective, including: 1) comparing different pavements for a single pavement age and single microphone location; 2) comparing different pavement ages for a single pavement and single microphone location; and 3) comparing different microphone locations for a single pavement and pavement age. Data for all these scenarios are presented as plots in Appendix E. This data set has *not* been adjusted for site bias and includes far fewer data points than the average LAFmx data (broadband) discussed in the previous sub-section.

Presented first is an example of scenario one: comparing different pavements for a single pavement age and single microphone location. Figure 8 shows the A-weighted measured 1/3-octave band levels for the reference DGAC pavement and the four test pavements at the 7.5-m (25-ft) position for the pavement aged 16 months, for automobiles and heavy trucks. Please refer to Appendix E, Figures E-4 through E-18 for all microphone positions and pavement ages.

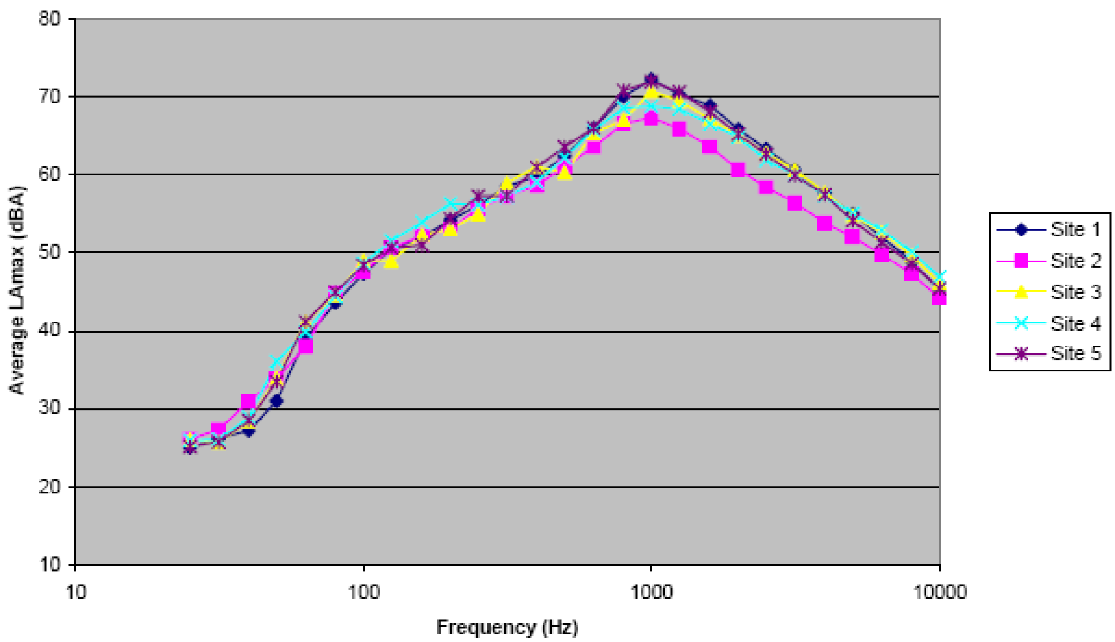
The top plot in Figure 8 shows the spectral levels for automobiles. It indicates that the quieter pavements provided noise benefits in a critical range around 1000 Hz; for the DGAC (Site 1), ~70% of the energy was in the 800-1600 Hz range, where the quieter pavements showed a noticeable reduction (except BWC). The additional thickness for the OGAC (Site 2) provided additional benefit (over Site 3) for frequencies greater than or equal to 1000 Hz. Also the rubberized pavement (Site 4) seemed to provide additional benefit over the open-graded of equal thickness (Site 3) at the most dominant frequency, 1000 Hz. The BWC (Site 5) provided no noticeable benefit.

The bottom plot in Figure 8 shows the spectral levels for heavy trucks. It indicates that the quieter pavements provided noise benefits in a critical range around 1000 Hz; for the DGAC, ~60% of the energy was in the 630-1600 Hz range, where the quieter pavements showed a noticeable reduction. The frequency of 500 Hz was also a critical frequency for heavy trucks (~17% of the total energy for DGAC); where very little reduction was seen due to the quieter pavement types. As with the automobiles, the additional thickness for the OGAC provided additional benefit for frequencies greater than or equal to 1000 Hz.

Again the rubberized pavement provided additional benefit over the open-graded of equal thickness at 1000 Hz, but this was not the most dominant frequency for heavy trucks. There was some benefit with rubberized pavement at 500 Hz. The BWC provided a small benefit at frequencies 630 Hz and up.

Results for other microphone positions and pavement ages were similar. Some variation occurred with the range of 1/3-octave bands affected. For example, the lower 1/3-octave band for the range of benefit of the thicker OGAC over the thinner one ranged from 800 Hz to 1250 Hz. Also, the benefit of RAC over OGAC of the same thickness can showed an effect above 1000 Hz.

It should also be noted that a trend is seen when considering the noise benefits of pavement as a function of distance. Appendix E, Figures E-7, E-11, and E-15 show the results for DGAC and the thick OGAC at the 60 m (200 ft) distance, each figure representing a different pavement age. In the plots for both automobiles and heavy trucks, it can be seen that some lower frequencies that were contributing little, if any, to the overall sound level closer to the road, were within 10 dBA of the dominant frequency, and were contributing to the overall sound level at 60 m (200 ft). These lower frequencies saw little, if any, benefit due to the quieter pavement. To demonstrate the distance effect and lower frequency contributions, an example is described here. For the pavement aged 4 months, the benefit of OGAC over DGAC at a distance of 7.5 m (25 ft) was 3.3 dBA for automobiles and 2.3 dBA for heavy trucks (broadband). At a distance of 60 m (200 ft), the benefit was 2.5 dBA for automobiles and 1.1 dBA for heavy trucks. So the benefit for automobiles was reduced by 1.0 dBA over 52.5 m (175 ft), and the benefit for heavy trucks was reduced by 1.4 dBA over 52.5 m (175 ft).



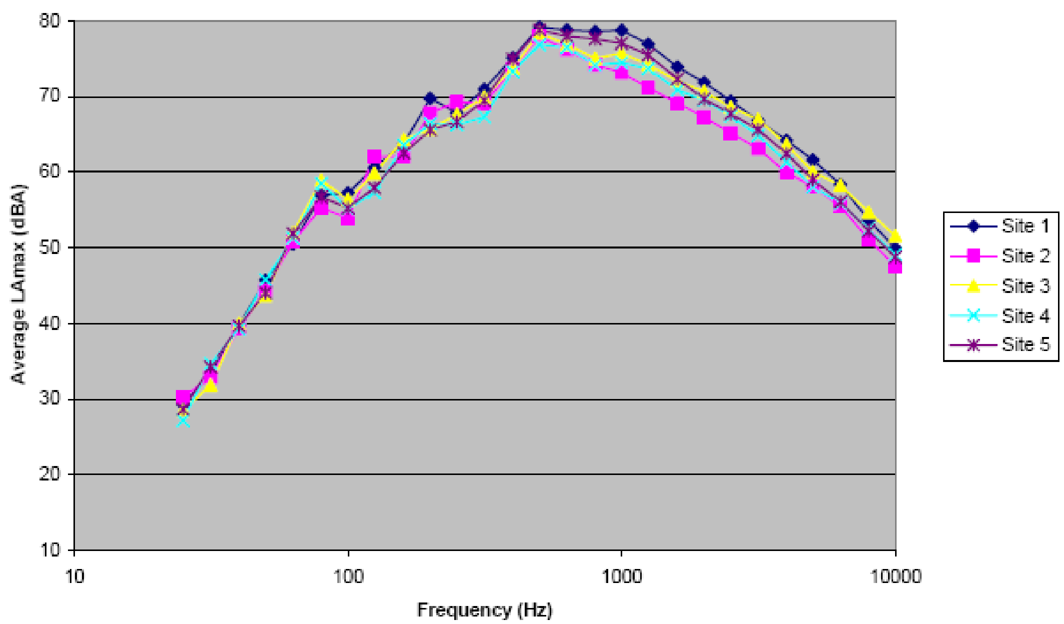


Figure 8. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 25 ft, height 5 ft.

The second scenario, comparing different pavement ages for a single pavement and single microphone location, is presented in Appendix E, Figures E-19 through E-23. For automobiles, trends based on pavement age appeared to be microphone location dependent for all but the DGAC, which did not show clear trends. For the 7.5 m (25 ft) location, frequencies from about 400 to 1000 Hz got louder with age. For the 15 m (50 ft) locations, there was some increase in sound level below 1000 Hz, but frequencies above 1000 Hz also got louder with age. For heavy trucks, no aging trends can be identified. Further investigations are necessary to extract meaning from these trends or lack of trends.

The third scenario, comparing different microphone locations for a single pavement and pavement age, is presented in Appendix E, Figures E-24 through E-28. These plots show how the spectral shape evolved through propagation. The lower frequencies (below 1000 Hz) became more important to the overall sound level, as discussed in the first scenario.

The **spectral content should be considered when choosing or designing a pavement for highways**. In this study, critical differences among the quieter pavements started around 1000 Hz, although benefits for all pavements affected lower frequencies, in many cases, down to about 630 Hz. Thicker layers of both OGAC and RAC should be investigated to determine if the benefit due to thickness can expand down to 500 Hz, which would help reduce heavy truck noise.

5.3 Pavement Performance for Test Vehicle

The test vehicle data were included in the SPBI calculations if the event meets all the criteria previously described. In addition, the test vehicle data were separated from the other data. The average LAFmx was calculated for each speed (~65, 80, 100, and 112 km/h; 40, 50, 60, and 70 mph) for each pavement site. The microphone positions analyzed were the low and high microphones at 15 m (50 ft). The data sets analyzed were for the pavements aged 4 months, 10 months, and 16 months (52 months excluded).

Test vehicle LAFmx values are in Appendix F, Tables F-1 and F-2. F-1 shows the site-bias-removed data and F-2 shows the average measured data. Figure 9 shows an example of the test vehicle results for the four different speeds on pavement aged 16 months, at the low microphone position at 15 m (50 ft). Similar plots for the other pavement ages and the higher 15 m (50 ft) microphone position are found in Appendix A, Section F.1. The general trend was that OGAC 75 mm was the quietest pavement, followed by RAC Type O 30 mm, OGAC 30 mm, BWC 30 mm, and then DGAC, considering both microphone positions and the other pavement ages.

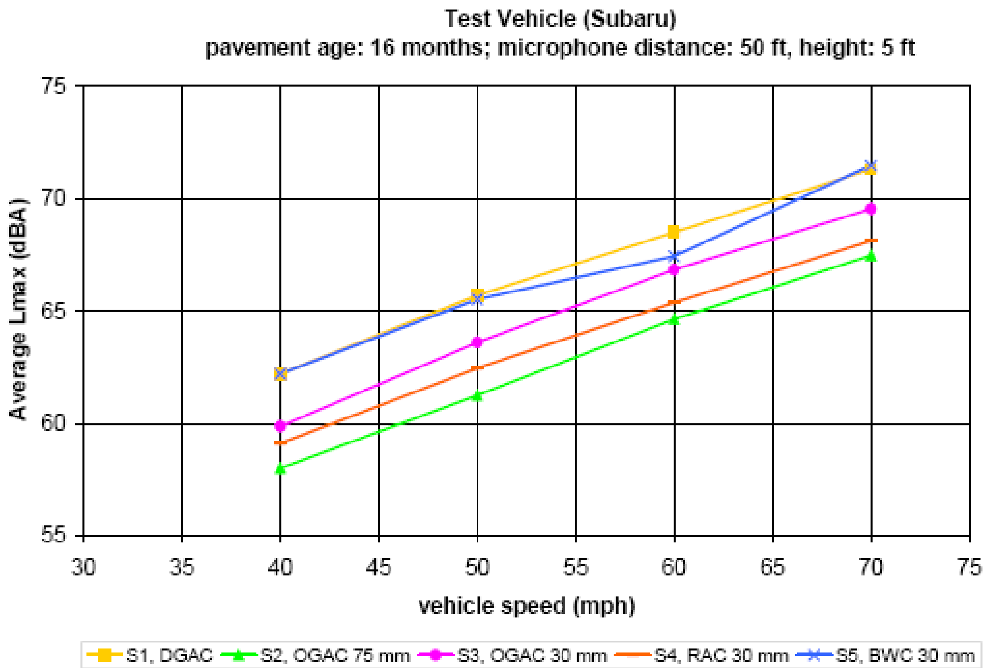


Figure 9. Test vehicle average L_{AFmx} values for pavement aged 16 months, multiple speeds. Microphone position: distance 15 m (50 ft), height 1.5 m (5 ft). Site bias removed.

Data are presented in Table 5 as average LAFmx differences (Site x minus Site 1) over time. Both measured and site-bias-removed LAFmx values can be found in Appendix F, Tables F-2 and F-1, respectively. The figures that follow present samples of the data. Figure 10 shows the average LAFmx differences (deltas) (Site x minus Site 1) for only the 16-month old pavements, for the low 15-m (50-ft) position, for 60 mph (the plot for the high microphone position can be seen in Appendix F, Figure F-4). For all results, site bias has been removed by applying the differences found with the baseline measurements.

Table 5 and Figure 10 again show the general trend that OGAC 75 mm was the quietest pavement, followed by RAC Type O 30mm, OGAC 30 mm, BWC 30 mm, and then DGAC. Table 5 shows that the benefit of OGAC 75 mm over the DGAC ranged from 2.7-4.9 dBA; OGAC 30 mm over the DGAC ranged from 1.1-3.5 dBA; RAC over the DGAC ranged from 2.5-5.0 dBA; BWC over the DGAC ranged from -0.2 (no benefit) to 1.5 dBA, where the benefits varied over microphone position, speed, and time.

Table 5. Post-overlay measurements: for the test vehicle, site differences due to type of pavement (average L_{AFmx} deltas). Site bias removed.*

**other sites calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements of test vehicle)

Pave-ment age	Micro-phone location	Average L_{AFmx} delta (dBA)															
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)				Site 3 – Site 1 (OGAC, 30 mm – DGAC)				Site 4 – Site 1 (RAC type O, 30 mm – DGAC)				Site 5 – Site 1 (BWC, 30 mm – DGAC)			
		Speed (mph)															
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
4 months	50 ft (15 m) low	-3.4	-3.1	-3.3	-2.7	-3.5	-3.1	-2.4	-1.8	-3.9	-4.4	-3.2	-3.1	-1.3	-1.0	-0.8	-0.3
	50 ft (15 m) high	-3.6	-3.9	-4.8	-4.2	-2.5	-2.2	-2.9	-1.8	-4.0	-3.4	-4.0	-4.0	-0.9	-0.6	-0.8	-0.2
10 months	50 ft (15 m) low	-3.4	-3.6	-3.6	-3.6	-2.4	-2.9	-1.1	-1.8	-2.8	-4.3	-2.5	-3.3	-1.3	-1.4	-0.3	-0.1
	50 ft (15 m) high	-3.7	-4.5	-4.7	-4.9	-2.0	-2.4	-1.8	-2.8	-4.0	-3.5	-3.5	-5	-1.4	-0.8	-0.7	-0.8
16 months	50 ft (15 m) low	-4.2	-4.5	-3.9	-3.8	-2.3	-2.1	-1.7	-1.8	-3.1	-3.3	-3.1	-3.2	0.0	-0.2	-1.1	0.2
	50 ft (15 m) high	-3.7	-4.5	-4.5	-4.3	-1.8	-2.0	-2.2	-2.0	-3.8	-2.7	-3.8	-4.4	-0.6	0.1	-1.5	-0.5
Average (both locations, all time)		-3.7	-4.0	-4.1	-3.9	-2.4	-2.5	-2.0	-2.0	-3.6	-3.6	-3.4	-3.8	-0.9	-0.7	-0.9	-0.3
Average (both locations, all time, all speeds)		-3.9				-2.2				-3.6				-0.7			

Note: A slightly modified version of this table is seen in Appendix F (Table F-3), with baseline values included.

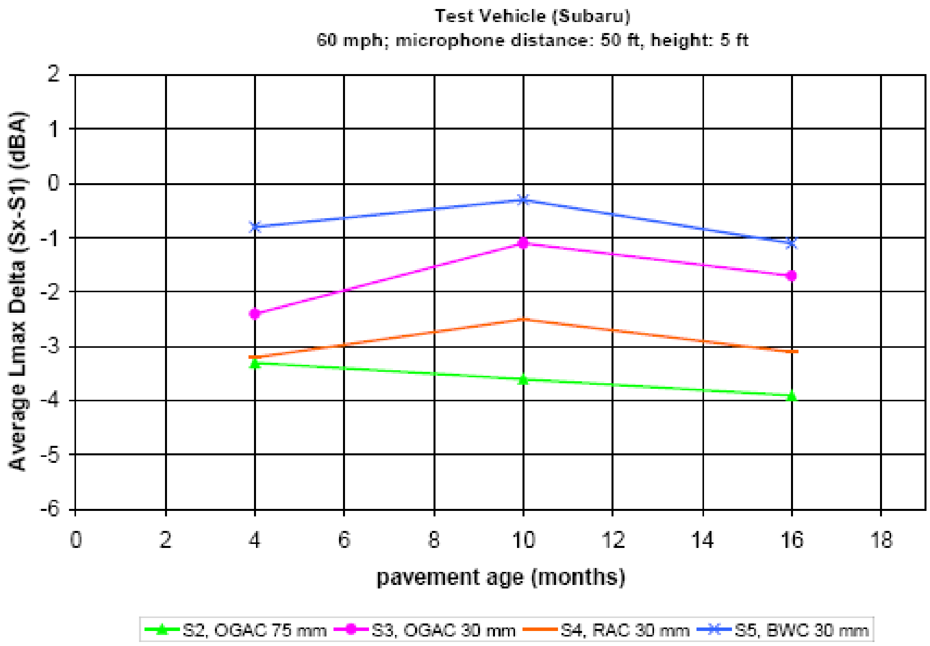


Figure 10. Test vehicle average L_{AFmx} deltas (Site x minus Site 1) for pavement ages 4 months, 10 months, and 16 months, 100 km/h (60 mph). Microphone position: distance 15 m (50 ft), height 1.5 m (5 ft). Site bias removed.

5.4 Pavement Performance Related to Sound Absorption

The sound absorption of the pavements tested on LA138 was examined in terms of the effective flow resistivity (EFR), data collection and analysis is briefly described in previous sections. This section expands more on the data analysis process in addition to the results, since the analysis process evolved as results were obtained.

Initial investigations using data from LA138 and other locations determined that the original ANSI S1.18 methodology provided reasonable values for extreme ground surfaces. For example, the differences between lawn and cement concrete were readily apparent: lawn is associated with an EFR value of 300 cgs rayls, and cement concrete is associated with an EFR value of 20,000 cgs rayls. Based on the success with extreme ground types, the standard was expanded upon to include finer resolution and greater range in the potential EFR values (ANSI S1.18 is very limited in this aspect because it was likely not intended to be sensitive to similar ground types). New EFR deltas/curves were calculated for EFR values of 100 to 20,000 cgs rayls in steps of 100.

Data LA138 and other data Volpe has collected were analyzed again using the new EFR curves. Although it was possible to extract EFR values for extreme ground types, sensitivity in the pavement range was still not possible. Upon further investigation of the theoretical and measured curves, it was seen that the measured amplitudes do not match the theoretical amplitudes, so reasonable curve matching was not possible. Based on this information, it was determined that the analysis methodology needed to be adapted to allow for the extraction of EFR values related to various pavement types. The new curve selecting analysis methodology is described in Section 4.2.4.

Applying the curve selecting methodology to the measured data, reasonable EFR values for various pavement types were extracted. These values are shown in Table 6.

Pavement type	Sidewalk (cement concrete)	Old DGAC	New DGAC (30mm thick)	New OGAC (30mm thick)	New RAC (30mm thick)	New OGAC (75mm thick)
EFR value [cgs rayls, g/(s·cm3) or (kPa·s)/m2]	20,000	14,500	8,800	8,700	6,100	4,200

Table 6. Extracted reasonable EFR values for various types of pavements.

These values are characterized as reasonable because: 1) absorptive pavement can very likely be just as absorptive as hard packed soil (or a dirt road), which has a published EFR value of 5,000 cgs rayls; and 2) the order of EFR values from highest to lowest corresponds with the order of modified SPBI levels (loudest to quietest) for the new LA138 pavements.

6 CONCLUSIONS

The research conducted in Caltrans Thin Lift (LA138) Study provides: 1) information for ranking the tested asphalt pavements according to noise reduction capabilities. 2) Sound level information on a broadband and spectral basis, by vehicle type, to help determine appropriate applications for the pavements tested and to help design quieter pavements. 3) Data that may be used to include or help validate pavement effects in traffic noise predictions.

Results from the study indicate that applying a quieter pavement overlay can reduce wayside measured sound levels.[a] The amount of reduction measured was vehicle-type dependent, and the relative noise reduction was maintained over 52 months when comparing test pavements and the reference pavement of the same age. Although the noise reduction was maintained when comparing pavements of the same age, each of the pavements tested showed some deterioration in noise benefit as it aged. The deterioration of the noise benefit over 52 months was up to 1.5 dBA depending on the pavement type.

Of the pavements examined, the OGAC 75 mm thickness provided the greatest noise benefit, as compared to the reference DGAC 30 mm, with noticeably more benefit than the thinner overlays at frequencies greater than or equal to 1000 Hz. Considering all data sets (including ages 4-52 months and multiple microphone positions) the average OGAC 75 mm benefit over DGAC was 3.3 dBA. The RAC Type O 30 mm and OGAC 30 mm also provided noise benefits. The average RAC Type O 30 mm benefit was 2.3 dBA, and the average OGAC 30 mm benefit was 1.7 dBA. The rubberized asphalt provided extra benefit at some critical frequencies (frequencies with substantial contribution to the broadband noise level), which affected the overall sound level for automobiles more than for heavy trucks. The overlay of BWC 30 mm was actually louder than DGAC for one of the microphone positions, while the average benefit over DGAC for all microphone positions is 0.9 dBA. The BWC 30 mm should not be considered a quieter pavement.

When examining the results by vehicle type, the following was observed: 1) the *order* of the performance (most noise reduction to least noise reduction) was the same as indicated in the overall results. 2) The *order* of the performance was the same for automobiles, medium trucks, and heavy trucks. 3) For the quieter pavements, each of the pavements provided greater reductions for automobile noise than for medium or heavy truck noise. And 4) some pavements reduced noise about the same amount for both automobiles and heavy trucks, where as other pavements saw more of a disparity in reduction among vehicle types. The disparity between vehicle types indicates the importance of accounting for light and heavy vehicles when assessing the noise reduction benefits of pavements.

Spectral results indicated that quieter pavements did provide noise reduction in a critical range around 1000 Hz, although little to no benefit was seen around 500 Hz, a frequency band with substantial energy for heavy trucks. Spectral results also indicated

[a] The amount of reduction reported in literature is highly dependent on the reference pavement used for comparison. The Caltrans Thin Lift Study uses a reference asphalt pavement with the same nominal aggregate size and same age as the other test pavements, resulting in relatively small reductions: on average, about 3 dBA or less. It should be noted that decreases in overall sound level of less than 3 dBA are not typically considered to be perceptible,[12] although changes in spectral content may be perceived.

that some lower frequencies that were contributing little, if any, to the overall sound level closer to the road, were within 10 dBA of the dominant frequency farther from the road, and were contributing to the overall sound level, as expected due to propagation effects. These lower frequencies saw little, if any, benefit due to the quieter pavement. One example showed the benefit for automobiles decreasing 1.0 dBA, and for heavy trucks decreasing 1.4 dBA, over a distance of 52.5 m (175 ft).

Results from the test vehicle data were similar to those for autos in the existing traffic, identifying this vehicle as being a good representative of the auto category. Test vehicle data showed that noise reduction due to pavement is fairly consistent over speeds ranging from 40 mph to 70 mph (~65 to 112 km/h). This is encouraging when considering the use of pavement for noise abatement on roadways with medium- or high-speed traffic.

Concerning pavement sound absorption, applying an adapted ANSI S1.18 methodology to measure effective flow resistivity (EFR) showed reasonable results. For the test pavements, EFR values from highest to lowest corresponded with the order of modified SPBI levels (loudest to quietest). The method and results still need to be validated before conclusions can be reached regarding the relationship between wayside noise levels and pavement absorption and before specific pavement EFR values can be used as part of noise prediction.

In order to further understand noise benefits related to quieter pavements, the following research should be conducted:

- Measurements and analysis for the pavements on LA 138 aged beyond 52 months. This work will help determine the longevity of noise reduction benefits, and is a necessary component before using quieter pavements for noise abatement.
- Investigate thicker layers of both OGAC and RAC. This would help to determine if the benefit due to thickness can expand down to 500 Hz, which would help reduce heavy truck noise.
- Further investigate the variation of measured pavement benefits by microphone position. Results of such an investigation could affect future guidance on microphone placement for wayside tire/pavement noise measurements. It is clear when examining the SPB results that different values for benefit can be obtained for the three different microphone positions (25 ft low, 50 ft low, and 50 ft high), but which one is best characterizing the pavement benefit? That is difficult to determine. The low 50-ft position better captures the angle for sound propagating toward communities adjacent to highways, although it is more influenced by the ground than the other positions. The 25-ft and high 50-ft positions minimize ground effects, but capture angles for sound propagation that may not be representative of what the communities are receiving. The low and high 50-ft positions are more influenced by meteorological effects than the 25-ft position, although care can be taken to minimize these effects. The 25-ft position is more likely to be influenced by near-field effects, and there is the possibility that distinct individual sound sources on a vehicle, particularly for heavy trucks, may be influencing what is captured as the maximum sound level when the vehicle drives by.
- Further examine pavement sound absorption. Validate the modified ANSI S1.18 EFR measurement and analysis method and continue measurements over time.

This may provide EFR data for input into traffic noise models for more accurate noise predictions. Also, examine relationships between EFR and wayside sound levels. This may help to determine the potential noise benefit of a pavement while minimizing wayside measurements.

7 REFERENCES

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APPENDIX A. MEASUREMENT SITE PHOTOS

This appendix shows photos and descriptions of each pavement type and photos of each measurement site.

A.1 Pavement Types

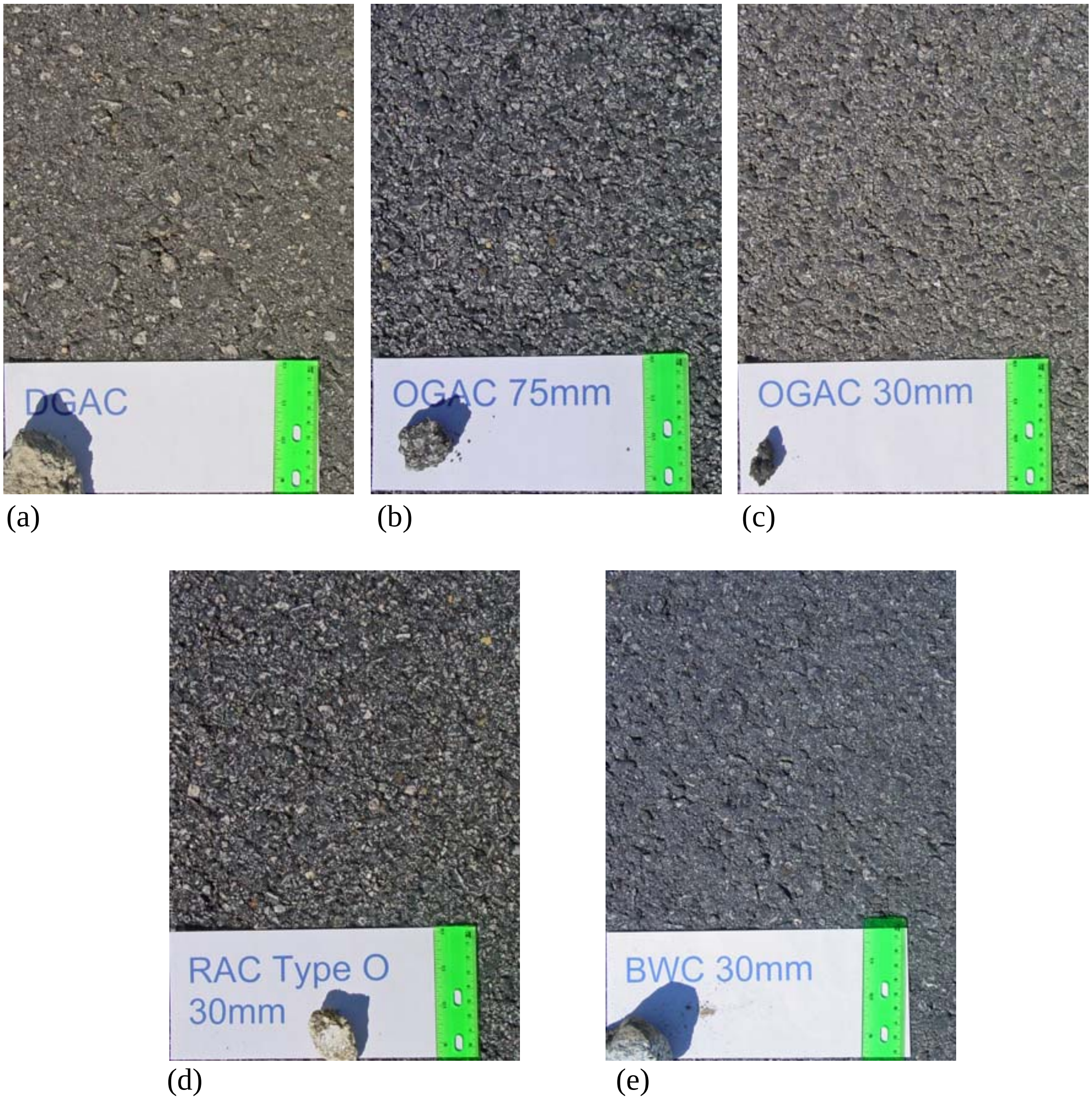


Figure A-1. Pavement types for asphalt overlays on LA138.

(a) Pavement section 1 (Site 1): dense-graded asphaltic concrete (DGAC) of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 9%.

(b) Pavement section 2 (Site 2): open-graded asphaltic concrete (OGAC) of 75 mm (3 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 12%.

(c) Pavement section 3 (Site 3): OGAC of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 15%.

(d) Pavement section 4 (Site 4): rubberized asphaltic concrete, Type O (open) (RAC) of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 12%.

(e) Pavement section 5 (Site 5): bonded wearing course (BWC) of 30 mm (1 in) thickness; specified maximum aggregate size = 12.5 mm (1/2 in), measured center lane air void content = 7%.

A.2 Site 1 (S1): DGAC 30mm

Figure A-2. LA138 Site 1 (S1), DGAC 30 mm.

A.3 Site 2 (S2): OGAC 75mm

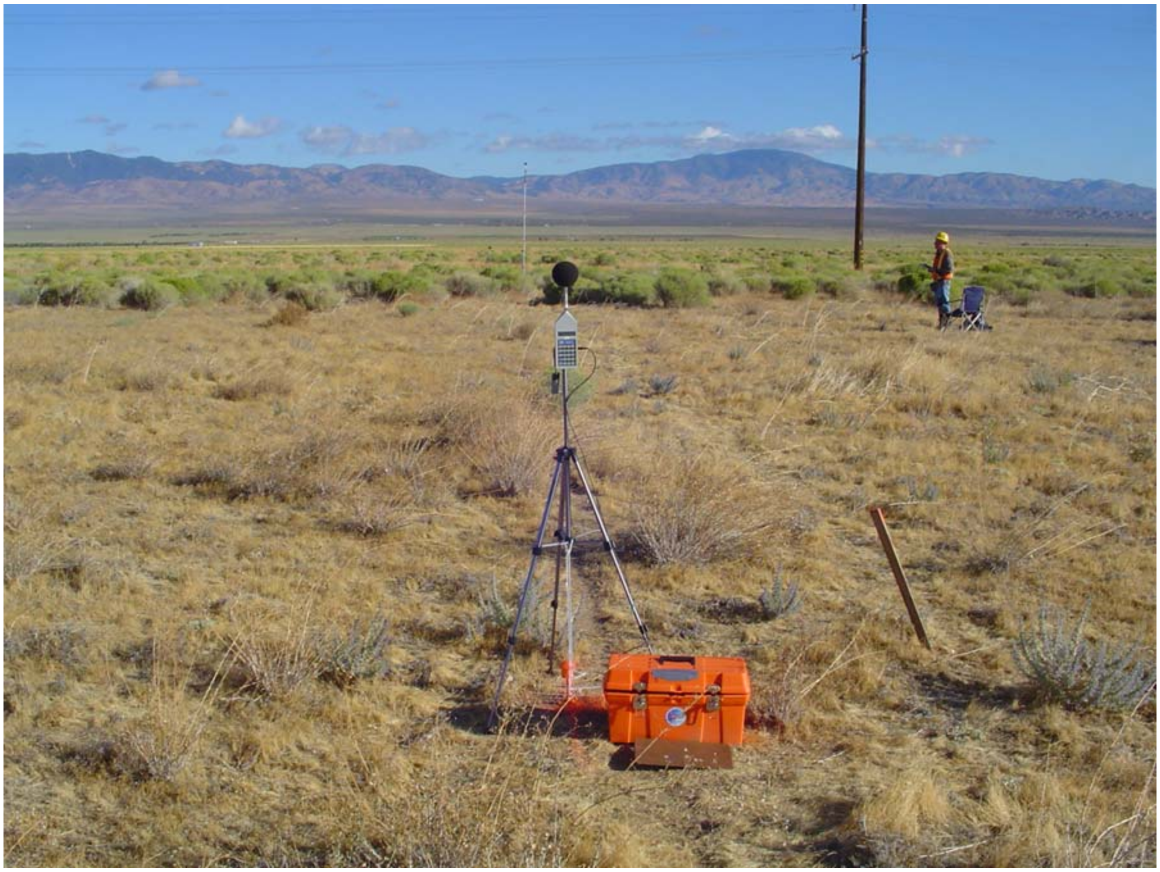


Figure A-3. LA138 Site 2 (S2), OGAC 75 mm.

A.4 Site 3 (S3): OGAC 30mm

Figure A-4. LA138 Site 3 (S3), OGAC 30 mm.

A.5 Site 4 (S4): RAC Type O 30mm

Figure A-5. LA138 Site 4 (S4), RAC Type O 30 mm.

A.6 Site 5 (S5): BWC 30mm

Figure A-6. LA138 Site 5 (S5), BWC 30 mm.

APPENDIX B. INSTRUMENTATION PHOTOS

This appendix shows the instrumentation utilized for data collection, including instrumentation for collection of acoustical data, meteorological data, traffic data, pavement data, vehicle pass-by event identification, and extraneous noise event identification.

B.1 Acoustical Data Collection Instrumentation

Figure B-1. Deployed sound level meters (LDL Model 820 Sound Level Meters) and DAT recorder (Sony Model TCD-D100 Digital Audio Tape (DAT) Recorder).

Figure B-2. Deployed spectrum analyzers (LDL Model 2900 2-Channel Spectrum Analyzers).

B.2 Meteorological Data Collection Instrumentation

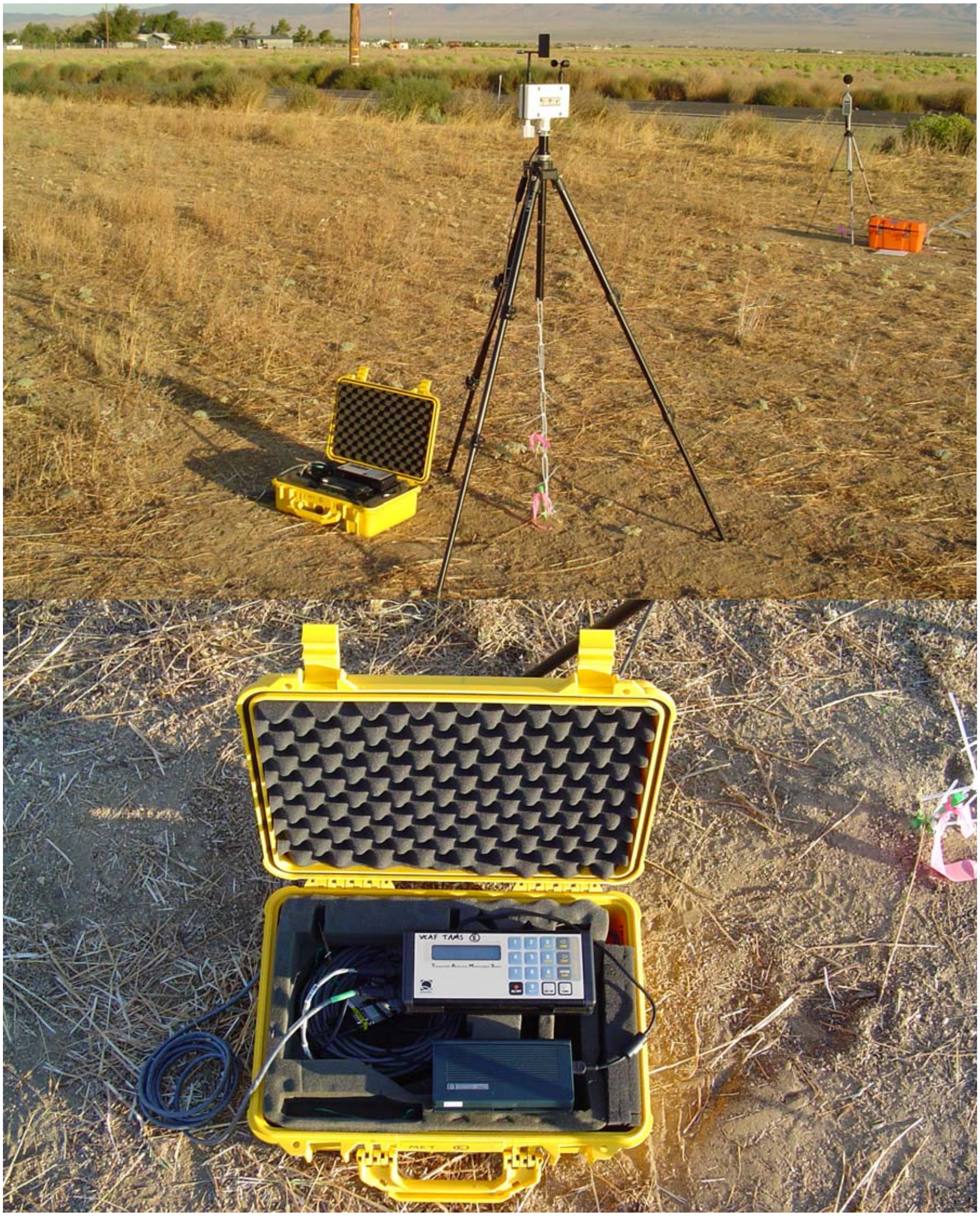


Figure B-3. Deployed meteorological data collection system (Qualimetrics Transportable Automated Meteorological Stations (TAMS)).

B.3 Traffic Data Collection Instrumentation

Figure B-4. Video cameras and radar gun.

B.4 Pavement Data Collection Instrumentation

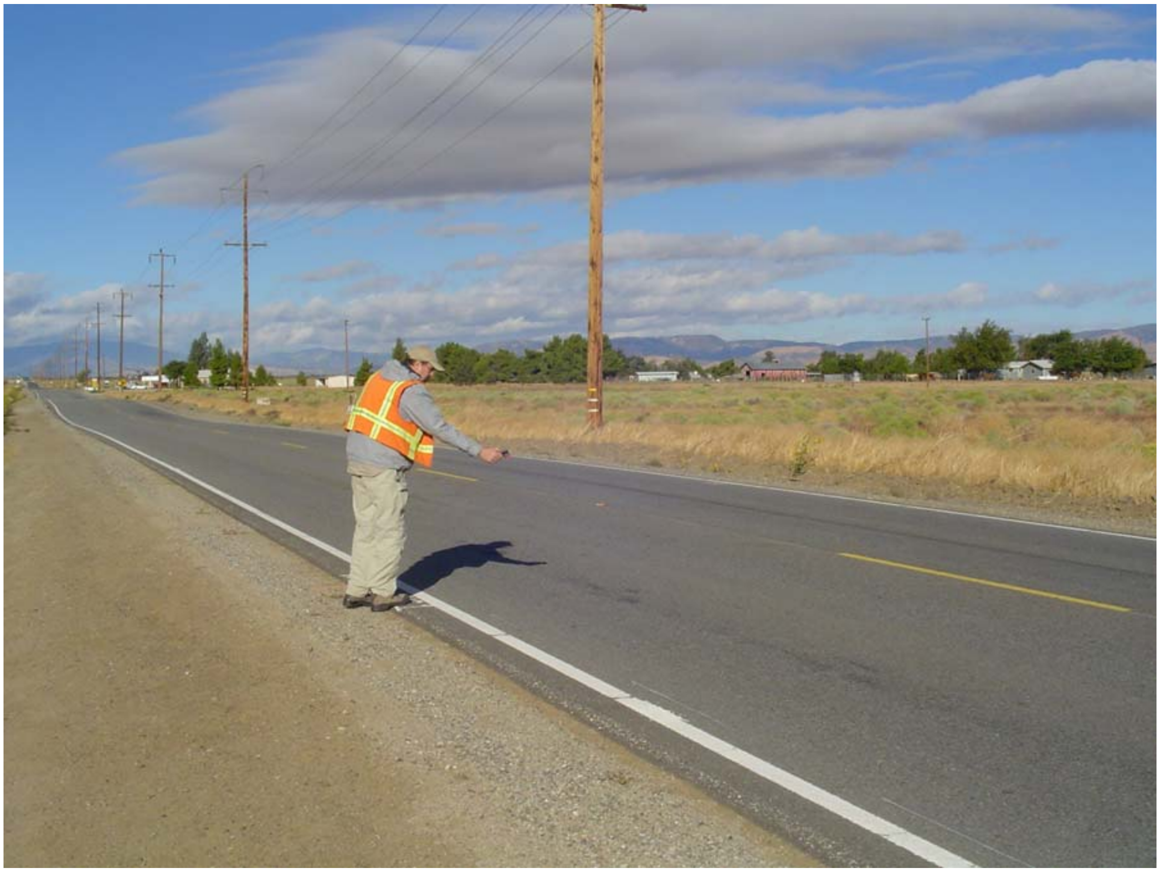


Figure B-5. Infrared temperature gun (also seen in Figure B-2).

B.5 Pass-By Event Identification and Extraneous Noise Event Identification Data Collection Instrumentation

Figure B-6. Palmtop computer for logging (HP 200 LX palmtop computer) (also seen in Figure B-2).

APPENDIX C. VEHICLE PASS-BY DATA

The first section in this appendix shows summary tables of vehicle pass-by data, including the average pass-by sound level, vehicle speed data, and air and pavement temperature data. The remaining sections (listed by age, starting with the pre-overlay baseline measurements, then post-overlay 4 months, 10 months, 16 months, and 52 months) show plots of the pass-by events (sound level as a function of speed) with corresponding regression lines and equations. Data shown in this appendix are by site pairs and by vehicle type for each age and each microphone location.

C.1 Vehicle Pass-By Summary

This section summarizes the vehicle pass-by data, providing values for each site pair, each vehicle type, each microphone location, and each pavement age. Each of the tables show: 1) number of pass-by events; 2) average pass-by sound level (A-weighted maximum sound level, L_{AFmx} – listed as Lmax) and standard deviation; 3) average vehicle speed and standard deviation; 4) average, maximum, and minimum air temperature; and 5) average, maximum, and minimum pavement temperature.

Table C-1. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 25 ft, height 5 ft. Vehicle type: automobile.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		104	104	141	141	99	99	74	74
	Lmax (dBA)	average	76.5	76.5	76.4	77.5	76.6	77.8	76.4	77.5
		standard deviation	2.5	2.6	2.9	2.9	2.8	2.6	2.7	2.6
	vehicle speed (mph)	average	63.3	67.3	64.8	73.6	64.4	75.7	64.2	69.4
		standard deviation	6.1	7.0	6.3	5.8	5.8	6.2	6.1	6.6
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		150	150	104	104	105	105	na	na
	Lmax (dBA)	average	78.6	74.8	78.4	77.3	78.6	76.3	na	na
		standard deviation	2.4	2.6	2.4	2.4	2.5	2.4	na	na
	vehicle speed (mph)	average	66.7	68.9	65.7	74.3	65.1	73.3	na	na
		standard deviation	6.6	6.7	5.6	6.9	5.7	7.0	na	na
	air temperature (deg F)	average	64	64	63	63	63	61	na	na
		maximum	74	73	74	75	73	74	na	na
		minimum	47	47	40	39	41	40	na	na
	pavement temperature (deg F)	average	83	81	82	75	81	78	na	na
		maximum	109	120	109	111	109	103	na	na
		minimum	47	47	46	42	46	46	na	na
10 months	number of data points		113	113	89	89	82	82	79	79
	Lmax (dBA)	average	78.9	75.0	78.8	77.1	78.9	76.5	79.0	78.4
		standard deviation	2.2	2.4	1.8	2.1	2.3	2.6	1.9	2.0
	vehicle speed (mph)	average	66.3	66.4	66.5	70.0	66.1	68.4	66.4	67.9
		standard deviation	6.4	6.6	5.7	7.0	6.0	7.0	6.4	6.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		136	136	107	107	97	97	107	107
	Lmax (dBA)	average	78.8	74.7	78.9	77.3	78.6	76.2	78.7	78.1
		standard deviation	2.3	2.7	2.3	2.4	2.3	2.5	2.3	2.2
	vehicle speed (mph)	average	64.7	65.6	64.3	67.5	64.4	69.0	63.6	67.7
		standard deviation	5.6	5.4	5.7	7.3	5.9	6.6	5.3	5.8
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		166	166	108	108	74	74	na	na
	Lmax (dBA)	average	79.6	76.0	79.7	78.0	79.6	77.8	na	na
		standard deviation	2.1	2.4	2.3	2.6	2.1	2.3	na	na
	vehicle speed (mph)	average	70.7	71.1	70.4	68.8	69.1	66.5	na	na
		standard deviation	7.1	7.2	6.1	6.4	7.0	6.8	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-2. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 25 ft, height 5 ft. Vehicle type: medium truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		5	5	10	10	3	3	5	5
	Lmax (dBA)	average	83.6	83.9	81.0	81.6	81.9	82.3	81.3	81.9
		standard deviation	1.9	1.7	3.7	4.1	3.3	2.3	3.2	3.4
	vehicle speed (mph)	average	61.6	66.5	61.1	73.0	71.1	77.7	65.0	59.7
		standard deviation	7.6	5.4	6.2	5.8	10.5	6.6	10.6	4.3
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		13	13	8	8	9	9	na	na
	Lmax (dBA)	average	82.8	80.2	82.4	82.3	82.0	80.5	na	na
		standard deviation	1.7	2.0	1.9	2.2	1.6	1.5	na	na
	vehicle speed (mph)	average	61.2	62.2	62.7	69.7	62.0	66.8	na	na
		standard deviation	3.4	3.8	4.6	7.2	3.0	4.4	na	na
	air temperature (deg F)	average	64	64	63	63	63	61	na	na
		maximum	74	73	74	75	73	74	na	na
		minimum	47	47	40	39	41	40	na	na
	pavement temperature (deg F)	average	83	81	82	75	81	78	na	na
		maximum	109	120	109	111	109	103	na	na
		minimum	47	47	46	42	46	46	na	na
10 months	number of data points		10	10	7	7	3	3	5	5
	Lmax (dBA)	average	82.5	79.4	86.7	85.7	82.8	80.6	82.5	81.5
		standard deviation	2.2	2.7	1.4	1.8	2.3	2.3	1.8	1.6
	vehicle speed (mph)	average	62.0	59.6	60.1	59.7	63.1	60.4	63.9	66.0
		standard deviation	5.7	6.1	6.4	5.8	6.1	4.6	5.6	6.7
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75
		minimum	58	58	59	61	57	60	57	60

	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		19	19	14	14	11	11	15	15
	Lmax (dBA)	average	82.7	79.9	83.1	82.7	83.6	81.8	83.4	83.0
		standard deviation	2.3	2.8	2.3	2.5	2.5	2.3	2.9	3.1
	vehicle speed (mph)	average	60.2	61.4	60.2	64.9	62.1	68.4	61.3	65.4
		standard deviation	4.6	4.8	4.6	4.4	4.9	4.7	5.2	5.3
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		19	19	17	17	13	13	na	na
	Lmax (dBA)	average	82.8	79.7	84.4	82.8	83.1	81.9	na	na
		standard deviation	3.5	3.3	3.2	3.0	4.1	4.5	na	na
	vehicle speed (mph)	average	64.6	65.8	67.7	67.0	65.5	63.4	na	na
		standard deviation	8.2	7.4	8.3	7.8	6.9	5.0	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-3. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 25 ft, height 5 ft. Vehicle type: heavy truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		8	8	5	5	3	3	10	10
	Lmax (dBA)	average	83.4	84.0	83.6	84.1	82.2	82.1	84.0	85.7
		standard deviation	2.3	2.9	2.1	2.3	2.4	1.0	2.9	3.1
	vehicle speed (mph)	average	59.8	61.4	62.2	70.1	58.9	71.4	76.4	48.7
		standard deviation	4.1	5.8	7.6	8.1	3.0	7.7	8.3	5.5
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		50	50	40	40	46	46	na	na
	Lmax (dBA)	average	85.9	83.5	86.0	85.3	86.1	84.3	na	na
		standard deviation	2.1	2.1	2.1	2.1	2.0	2.2	na	na
	vehicle speed (mph)	average	59.6	61.0	59.5	64.5	59.2	63.8	na	na
		standard deviation	3.6	3.5	3.7	4.7	3.0	4.0	na	na
	air temperature (deg F)	average	64	64	63	63	63	61	na	na
		maximum	74	73	74	75	73	74	na	na
		minimum	47	47	40	39	41	40	na	na
	pavement temperature (deg F)	average	83	81	82	75	81	78	na	na
		maximum	109	120	109	111	109	103	na	na
		minimum	47	47	46	42	46	46	na	na
10 months	number of data points		25	25	20	20	12	12	14	14
	Lmax (dBA)	average	86.3	83.3	86.7	85.7	86.7	84.8	86.8	86.2
		standard deviation	1.9	2.1	1.4	1.8	2.3	2.6	1.5	1.9
	vehicle speed (mph)	average	59.6	59.7	60.1	59.7	60.6	60.7	60.8	58.3
		standard deviation	5.8	5.5	6.4	5.8	5.2	3.8	5.1	2.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		53	53	44	44	44	44	37	37
	Lmax (dBA)	average	86.6	83.7	86.3	85.4	86.4	84.9	86.5	86.2
		standard deviation	1.5	1.8	1.5	1.9	1.6	2.0	1.6	1.1
	vehicle speed (mph)	average	58.9	60.6	58.5	61.0	58.6	62.3	59.1	62.3
		standard deviation	3.3	3.5	2.8	3.8	3.4	4.2	3.2	3.0
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		54	54	43	43	35	35	na	na
	Lmax (dBA)	average	87.2	83.8	87.5	85.9	87.8	85.9	na	na
		standard deviation	2.3	2.2	2.0	2.4	1.6	2.1	na	na
	vehicle speed (mph)	average	64.2	65.1	63.6	61.8	63.8	61.1	na	na
		standard deviation	5.4	5.0	5.3	5.5	3.4	3.9	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-4. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 5 ft. Vehicle type: automobile.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		104	104	141	141	99	99	74	74
	Lmax (dBA)	average	69.3	70.0	69.1	70.1	69.4	71.2	69.2	68.5
		standard deviation	2.5	2.6	2.9	3.0	2.9	3.2	2.8	2.4
	vehicle speed (mph)	average	63.3	67.3	64.8	73.6	64.4	75.7	64.2	69.4
		standard deviation	6.1	7.0	6.3	5.8	5.8	6.2	6.1	6.6
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		150	150	104	104	105	105	86	86
	Lmax (dBA)	average	71.2	68.9	71.3	69.9	71.5	69.3	71.4	71.1
		standard deviation	2.6	2.8	2.5	2.5	2.6	2.6	2.3	2.1
	vehicle speed (mph)	average	66.7	68.9	65.7	74.3	65.1	73.3	65.4	72.4
		standard deviation	6.6	6.7	5.6	6.9	5.7	7.0	6.2	7.2
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		113	113	89	89	82	82	79	79
	Lmax (dBA)	average	71.2	68.9	71.2	69.7	71.2	69.4	71.3	71.2
		standard deviation	2.2	2.5	2.0	2.3	2.4	2.7	2.1	2.0
	vehicle speed (mph)	average	66.3	66.4	66.5	70.0	66.1	68.4	66.4	67.9
		standard deviation	6.4	6.6	5.7	7.0	6.0	7.0	6.4	6.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		136	136	107	107	97	97	107	107
	Lmax (dBA)	average	71.3	68.4	71.4	70.2	71.2	69.3	71.2	71.2
		standard deviation	2.4	2.9	2.4	2.4	2.4	2.6	2.4	2.3
	vehicle speed (mph)	average	64.7	65.6	64.3	67.5	64.4	69.0	63.6	67.7
		standard deviation	5.6	5.4	5.7	7.3	5.9	6.6	5.3	5.8
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		166	166	108	108	74	74	na	na
	Lmax (dBA)	average	71.7	69.3	71.9	70.2	71.8	69.7	na	na
		standard deviation	2.3	2.5	2.4	2.9	2.1	2.2	na	na
	vehicle speed (mph)	average	70.7	71.1	70.4	68.8	69.1	66.5	na	na
		standard deviation	7.1	7.2	6.1	6.4	7.0	6.8	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-5. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 5 ft. Vehicle type: medium truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		5	5	10	10	3	3	2	2
	Lmax (dBA)	average	76.4	77.3	74.4	74.3	75.0	76.2	74.9	74.5
		standard deviation	1.8	1.8	3.7	4.0	1.9	2.4	3.3	2.5
	vehicle speed (mph)	average	61.6	66.5	61.1	73.0	71.1	77.7	65.0	59.7
		standard deviation	7.6	5.4	6.2	5.8	10.5	6.6	10.6	4.3
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		13	13	8	8	9	9	9	9
	Lmax (dBA)	average	75.9	74.5	75.5	74.9	75.0	73.8	74.6	75.2
		standard deviation	1.9	2.3	2.1	2.5	1.7	1.7	1.3	2.9
	vehicle speed (mph)	average	61.2	62.2	62.7	69.7	62.0	66.8	61.9	64.4
		standard deviation	3.4	3.8	4.6	7.2	3.0	4.4	4.8	2.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		10	10	7	7	3	3	5	5
	Lmax (dBA)	average	75.0	73.4	80.0	78.9	76.1	74.0	75.0	74.3
		standard deviation	2.2	2.5	1.6	2.0	2.4	2.1	2.3	2.0
	vehicle speed (mph)	average	62.0	59.6	60.1	59.7	63.1	60.4	63.9	66.0
		standard deviation	5.7	6.1	6.4	5.8	6.1	4.6	5.6	6.7
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		19	19	14	14	11	11	15	15
	Lmax (dBA)	average	75.6	73.9	76.1	75.5	76.6	75.1	76.3	76.2
		standard deviation	2.6	2.9	2.6	2.5	2.8	1.9	3.2	3.0
	vehicle speed (mph)	average	60.2	61.4	60.2	64.9	62.1	68.4	61.3	65.4
		standard deviation	4.6	4.8	4.6	4.4	4.9	4.7	5.2	5.3
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		19	19	17	17	13	13	na	na
	Lmax (dBA)	average	74.8	73.2	76.5	75.1	75.2	74.1	na	na
		standard deviation	3.5	3.2	3.4	3.2	4.0	4.6	na	na
	vehicle speed (mph)	average	64.6	65.8	67.7	67.0	65.5	63.4	na	na
		standard deviation	8.2	7.4	8.3	7.8	6.9	5.0	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-6. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 5 ft. Vehicle type: heavy truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		8	8	5	5	3	3	9	9
	Lmax (dBA)	average	76.9	77.7	76.8	77.2	75.5	74.9	77.2	76.5
		standard deviation	2.5	2.7	2.6	2.0	2.1	1.5	3.4	2.7
	vehicle speed (mph)	average	59.8	61.4	62.2	70.1	58.9	71.4	76.4	48.7
		standard deviation	4.1	5.8	7.6	8.1	3.0	7.7	8.3	5.5
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		50	50	40	40	46	46	45	45
	Lmax (dBA)	average	79.5	77.9	79.5	78.3	79.5	77.6	79.5	78.9
		standard deviation	2.3	2.2	2.3	2.2	2.1	2.0	1.9	1.5
	vehicle speed (mph)	average	59.6	61.0	59.5	64.5	59.2	63.8	59.2	64.3
		standard deviation	3.6	3.5	3.7	4.7	3.0	4.0	3.3	4.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		25	25	20	20	12	12	14	14
	Lmax (dBA)	average	79.5	77.6	80.0	78.9	80.0	77.8	80.0	79.7
		standard deviation	2.2	2.5	1.6	2.0	2.6	2.8	1.7	2.3
	vehicle speed (mph)	average	59.6	59.7	60.1	59.7	60.6	60.7	60.8	58.3
		standard deviation	5.8	5.5	6.4	5.8	5.2	3.8	5.1	2.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		53	53	44	44	44	44	37	37
	Lmax (dBA)	average	79.9	78.0	79.6	78.6	79.6	78.3	79.6	79.4
		standard deviation	1.7	1.9	1.8	1.7	1.8	1.9	1.8	1.2
	vehicle speed (mph)	average	58.9	60.6	58.5	61.0	58.6	62.3	59.1	62.3
		standard deviation	3.3	3.5	2.8	3.8	3.4	4.2	3.2	3.0
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		54	54	43	43	35	35	na	na
	Lmax (dBA)	average	79.6	77.6	79.9	78.9	80.2	78.7	na	na
		standard deviation	2.3	2.3	1.9	2.6	1.7	2.1	na	na
	vehicle speed (mph)	average	64.2	65.1	63.6	61.8	63.8	61.1	na	na
		standard deviation	5.4	5.0	5.3	5.5	3.4	3.9	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-7. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 15 ft. Vehicle type: automobile.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		104	54	114	114	84	84	58	58
	Lmax (dBA)	average	71.1	71.6	71.0	72.1	71.3	72.4	71.3	71.5
		standard deviation	2.4	2.2	2.5	3.0	2.7	2.3	2.6	3.3
	vehicle speed (mph)	average	63.3	67.3	64.8	73.6	64.4	75.7	64.2	69.4
		standard deviation	6.1	7.0	6.3	5.8	5.8	6.2	6.1	6.6
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		150	150	104	104	105	105	86	86
	Lmax (dBA)	average	73.3	69.8	73.3	71.8	73.4	71.2	73.4	73.7
		standard deviation	2.3	2.5	2.3	2.3	2.4	2.4	2.1	2.4
	vehicle speed (mph)	average	66.7	68.9	65.7	74.3	65.1	73.3	65.4	72.4
		standard deviation	6.6	6.7	5.6	6.9	5.7	7.0	6.2	7.2
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		113	113	89	89	82	82	79	79
	Lmax (dBA)	average	73.5	69.9	73.5	72.0	73.6	71.3	73.7	73.0
		standard deviation	2.1	2.2	1.7	2.5	2.2	2.5	1.9	1.9
	vehicle speed (mph)	average	66.3	66.4	66.5	70.0	66.1	68.4	66.4	67.9
		standard deviation	6.4	6.6	5.7	7.0	6.0	7.0	6.4	6.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		136	136	107	107	97	97	107	107
	Lmax (dBA)	average	73.3	70.1	73.5	72.2	73.2	71.4	73.2	72.7
		standard deviation	2.2	2.5	2.3	2.3	2.2	2.4	2.2	2.2
	vehicle speed (mph)	average	64.7	65.6	64.3	67.5	64.4	69.0	63.6	67.7
		standard deviation	5.6	5.4	5.7	7.3	5.9	6.6	5.3	5.8
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		166	166	108	108	74	74	na	na
	Lmax (dBA)	average	74.3	70.7	74.5	72.9	74.3	72.2	na	na
		standard deviation	2.0	2.3	2.2	2.3	2.0	2.2	na	na
	vehicle speed (mph)	average	70.7	71.1	70.4	68.8	69.1	66.5	na	na
		standard deviation	7.1	7.2	6.1	6.4	7.0	6.8	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

Table C-8. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 15 ft. Vehicle type: medium truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		4	4	7	7	2	2	3	3
	Lmax (dBA)	average	78.0	78.9	75.7	75.9	77.1	77.0	74.8	75.4
		standard deviation	2.1	1.9	2.8	3.1	2.5	2.2	2.8	3.8
	vehicle speed (mph)	average	61.6	66.5	61.1	73.0	71.1	77.7	65.0	59.7
		standard deviation	7.6	5.4	6.2	5.8	10.5	6.6	10.6	4.3
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		13	13	8	8	9	9	9	9
	Lmax (dBA)	average	77.3	74.8	77.1	76.8	76.8	75.0	76.2	77.1
		standard deviation	2.0	2.4	2.0	2.3	1.7	1.9	1.2	2.8
	vehicle speed (mph)	average	61.2	62.2	62.7	69.7	62.0	66.8	61.9	64.4
		standard deviation	3.4	3.8	4.6	7.2	3.0	4.4	4.8	2.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		10	10	7	7	3	3	5	5
	Lmax (dBA)	average	76.8	73.8	82.1	80.7	77.1	75.2	76.6	75.8
		standard deviation	2.1	2.5	1.8	1.9	2.4	2.0	2.0	2.0
	vehicle speed (mph)	average	62.0	59.6	60.1	59.7	63.1	60.4	63.9	66.0
		standard deviation	5.7	6.1	6.4	5.8	6.1	4.6	5.6	6.7
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

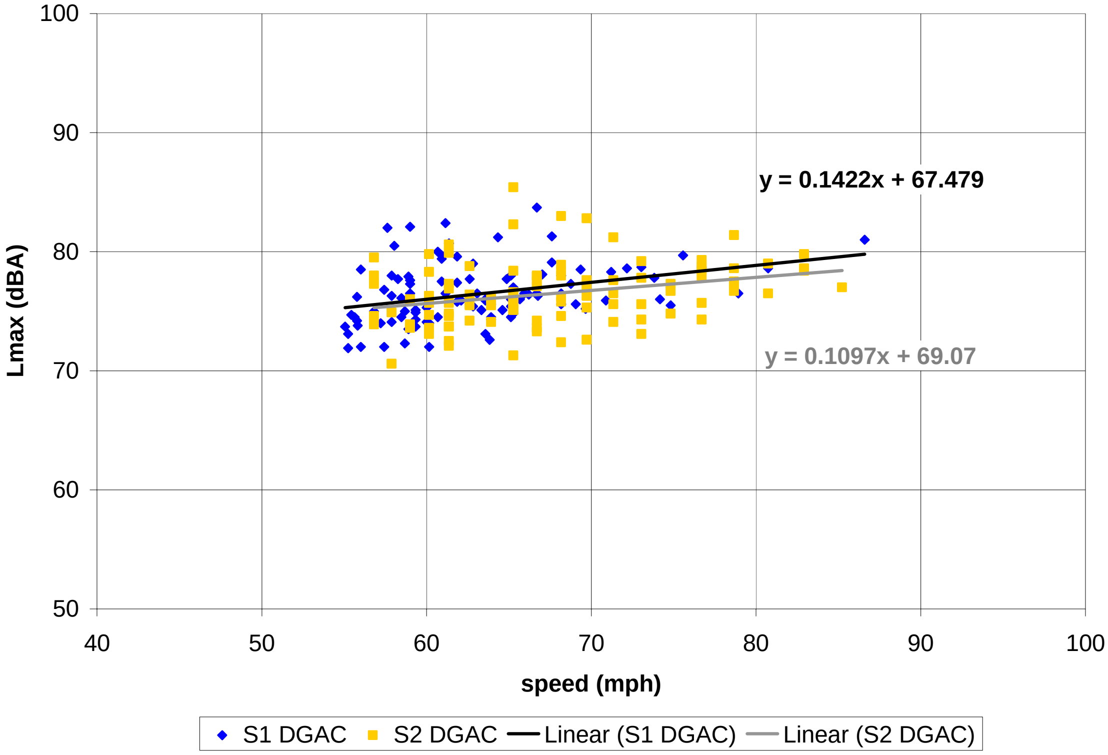
		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		19	19	14	14	11	11	15	15
	Lmax (dBA)	average	76.9	74.9	77.4	77.4	77.9	76.7	77.6	77.4
		standard deviation	2.5	2.8	2.4	2.6	2.7	2.4	3.2	3.3
	vehicle speed (mph)	average	60.2	61.4	60.2	64.9	62.1	68.4	61.3	65.4
		standard deviation	4.6	4.8	4.6	4.4	4.9	4.7	5.2	5.3
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		19	19	17	17	13	13	na	na
	Lmax (dBA)	average	77.7	74.2	79.3	77.5	77.7	76.4	na	na
		standard deviation	3.7	3.4	3.2	3.1	4.1	4.5	na	na
	vehicle speed (mph)	average	64.6	65.8	67.7	67.0	65.5	63.4	na	na
		standard deviation	8.2	7.4	8.3	7.8	6.9	5.0	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

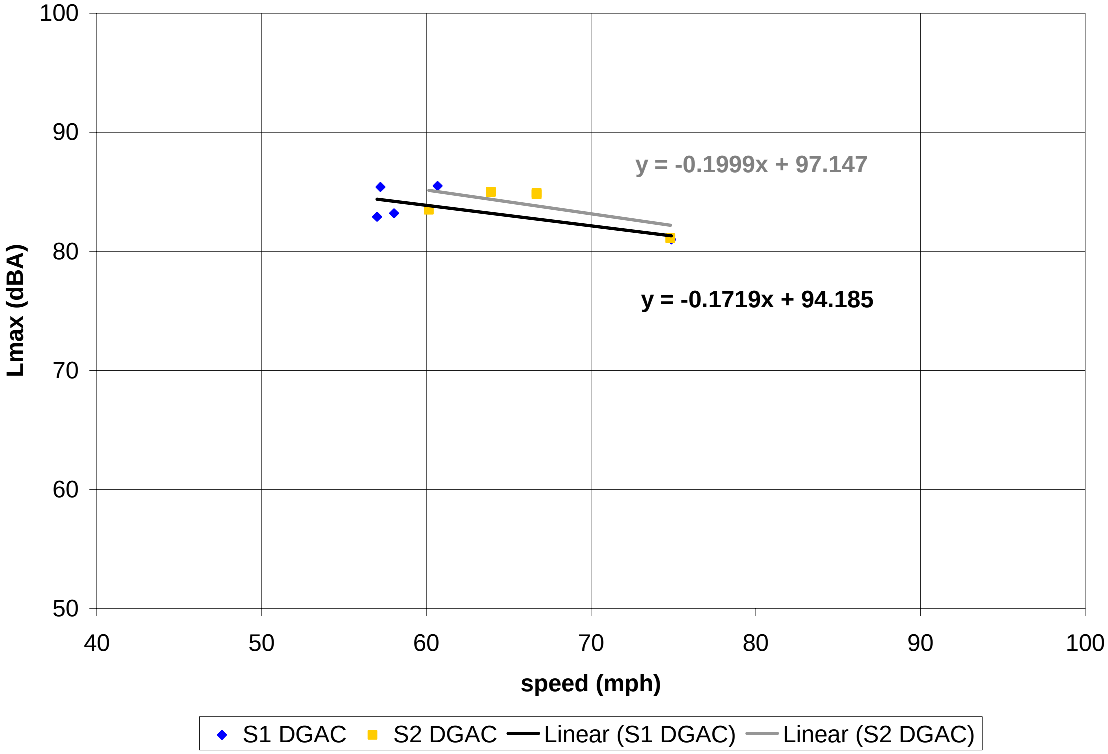
Table C-9. Pre- and Post-overlay measurements: sound levels for each pavement type (Lveh) by site pairs with identical vehicle sets. Microphone location: distance 50 ft, height 15 ft. Vehicle type: heavy truck.

			Site 1	Site 2	Site 1	Site 3	Site 1	Site 4	Site 1	Site 5
baseline	number of data points		1	1	1	1	3	3	1	1
	Lmax (dBA)	average	75.1	75.1	75.1	74.7	77.4	76.3	82.8	83.9
		standard deviation	na	na	na	na	2.9	2.0	na	na
	vehicle speed (mph)	average	59.8	61.4	62.2	70.1	58.9	71.4	76.4	48.7
		standard deviation	4.1	5.8	7.6	8.1	3.0	7.7	8.3	5.5
	air temperature (deg F)	average	63	63	65	66	65	66	65	66
		maximum	74	73	76	77	76	76	75	75
		minimum	49	50	46	46	49	51	49	51
	pavement temperature (deg F)	average	88	88	85	87	83	80	78	80
		maximum	103	110	114	108	114	101	108	99
		minimum	51	51	47	49	51	52	49	49
4 months	number of data points		50	50	40	40	46	46	45	45
	Lmax (dBA)	average	81.1	78.6	81.2	79.9	81.3	79.1	81.0	81.1
		standard deviation	2.4	2.4	2.3	2.4	2.2	2.2	1.8	2.0
	vehicle speed (mph)	average	59.6	61.0	59.5	64.5	59.2	63.8	59.2	64.3
		standard deviation	3.6	3.5	3.7	4.7	3.0	4.0	3.3	4.1
	air temperature (deg F)	average	64	64	63	63	63	61	62	61
		maximum	74	73	74	75	73	74	73	74
		minimum	47	47	40	39	41	40	40	40
	pavement temperature (deg F)	average	83	81	82	75	81	78	81	78
		maximum	109	120	109	111	109	103	107	108
		minimum	47	47	46	42	46	46	46	46
10 months	number of data points		25	25	20	20	12	12	14	14
	Lmax (dBA)	average	81.5	78.5	82.1	80.7	82.2	79.5	82.4	81.1
		standard deviation	2.3	2.3	1.8	1.9	2.7	2.9	1.9	2.0
	vehicle speed (mph)	average	59.6	59.7	60.1	59.7	60.6	60.7	60.8	58.3
		standard deviation	5.8	5.5	6.4	5.8	5.2	3.8	5.1	2.6
	air temperature (deg F)	average	68	68	68	69	67	68	68	68
		maximum	74	75	75	75	74	73	74	75

		minimum	58	58	59	61	57	60	57	60
	pavement temperature (deg F)	average	76	81	76	81	74	80	75	81
		maximum	99	108	99	101	99	103	99	102
		minimum	45	57	43	49	43	56	43	60
16 months	number of data points		53	53	44	44	44	44	37	37
	Lmax (dBA)	average	81.8	79.3	81.4	81.0	81.6	80.1	81.6	81.1
		standard deviation	1.6	2.1	1.7	2.0	1.8	2.0	1.8	1.2
	vehicle speed (mph)	average	58.9	60.6	58.5	61.0	58.6	62.3	59.1	62.3
		standard deviation	3.3	3.5	2.8	3.8	3.4	4.2	3.2	3.0
	air temperature (deg F)	average	83	83	82	83	83	82	83	81
		maximum	91	91	91	91	91	93	91	92
		minimum	66	66	65	57	65	57	65	57
	pavement temperature (deg F)	average	95	98	92	90	94	95	93	93
		maximum	119	121	119	115	119	116	119	120
		minimum	63	58	63	60	63	63	63	54
52 months	number of data points		54	54	43	43	35	35	na	na
	Lmax (dBA)	average	82.1	78.8	82.4	81.4	82.8	80.6	na	na
		standard deviation	2.5	2.4	2.1	2.6	1.8	2.1	na	na
	vehicle speed (mph)	average	64.2	65.1	63.6	61.8	63.8	61.1	na	na
		standard deviation	5.4	5.0	5.3	5.5	3.4	3.9	na	na
	air temperature (deg F)	average	66	66	67	67	68	69	na	na
		maximum	78	78	78	78	79	78	na	na
		minimum	47	48	47	46	51	45	na	na
	pavement temperature (deg F)	average	73	70	75	74	78	76	na	na
		maximum	108	100	108	101	108	100	na	na
		minimum	36	54	31	50	37	47	na	na

C.2 Pre-Overlay Baseline





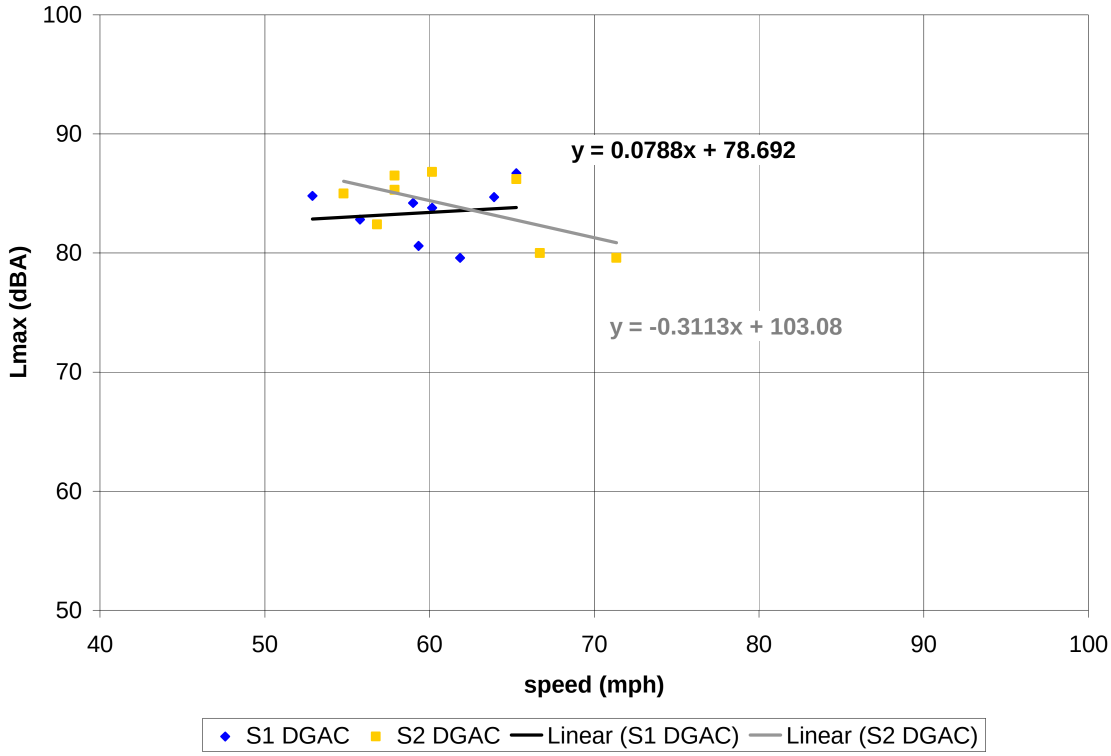
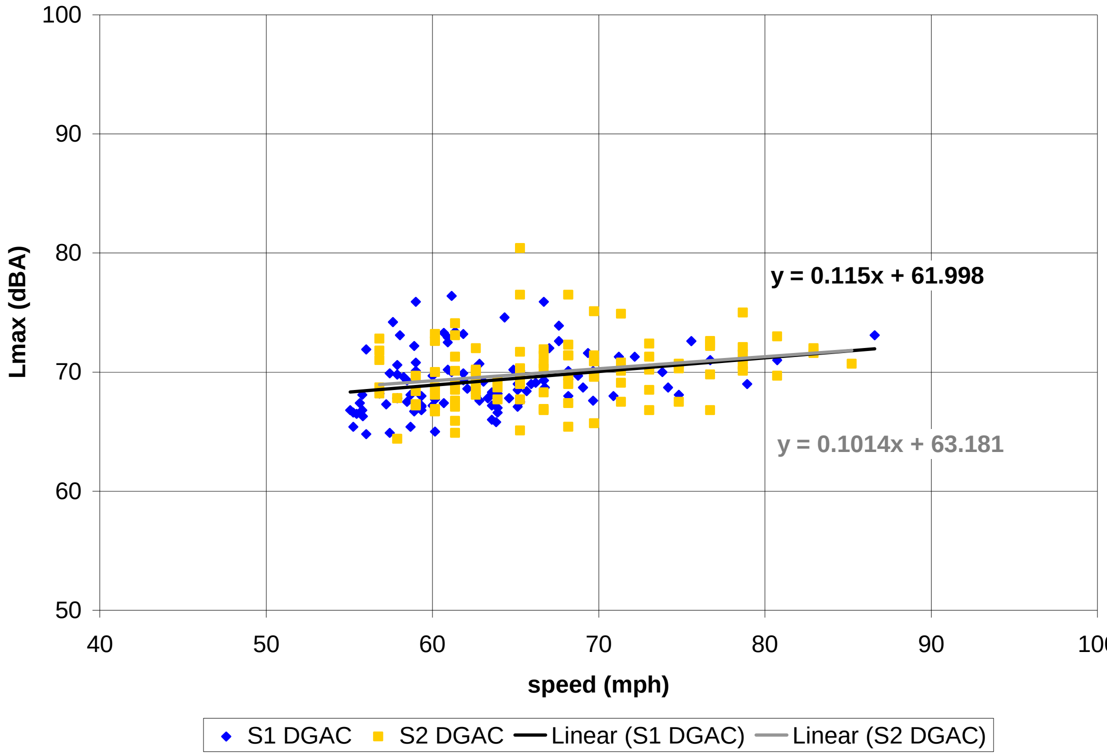
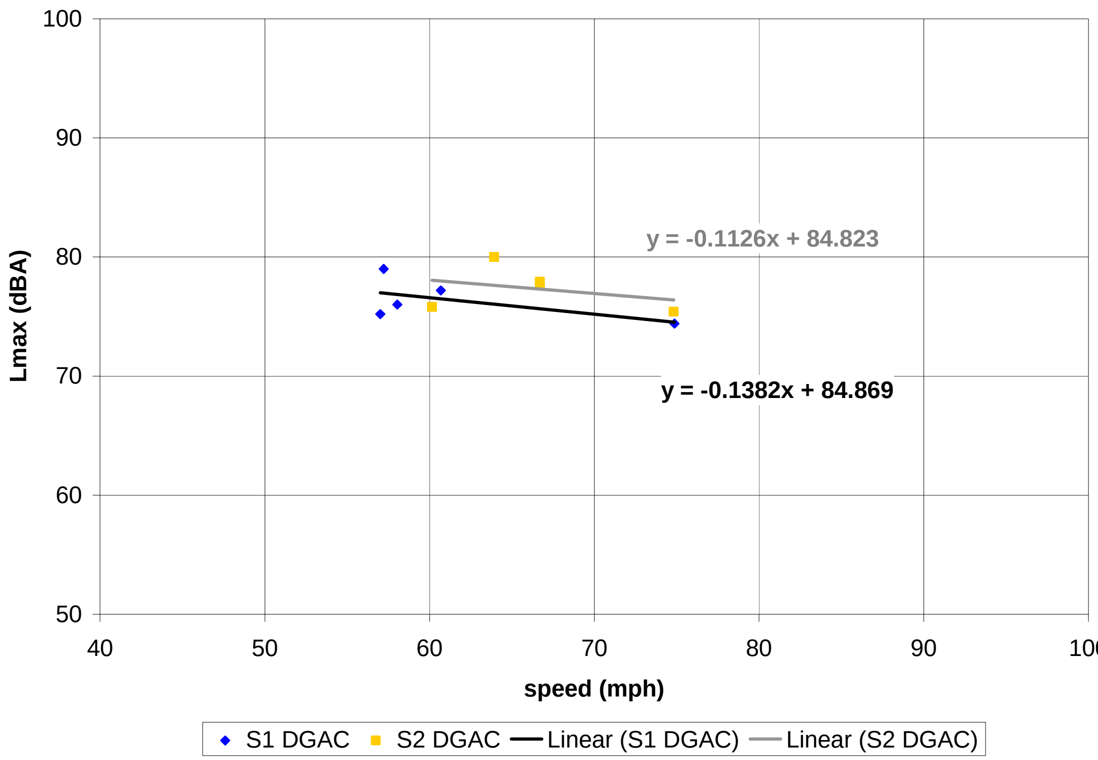


Figure C-1. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 2 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.115x + 61.998
y = 0.1014x + 63.181
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = -0.1126x + 84.823
y = -0.1382x + 84.869
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)

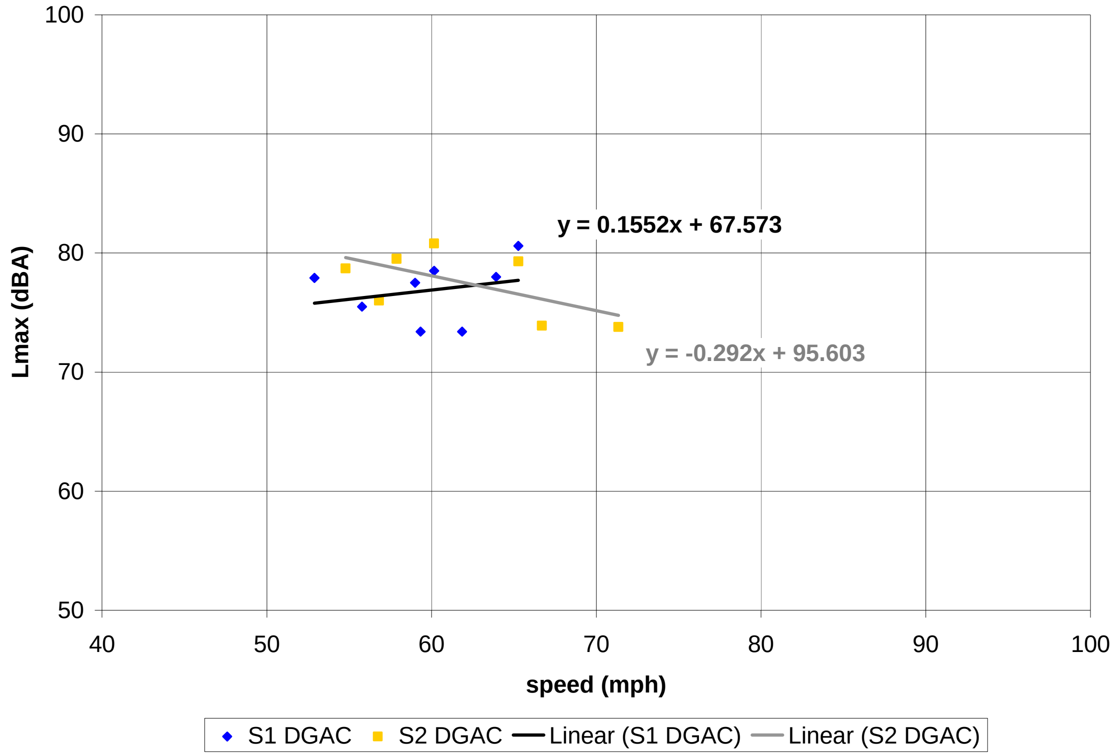
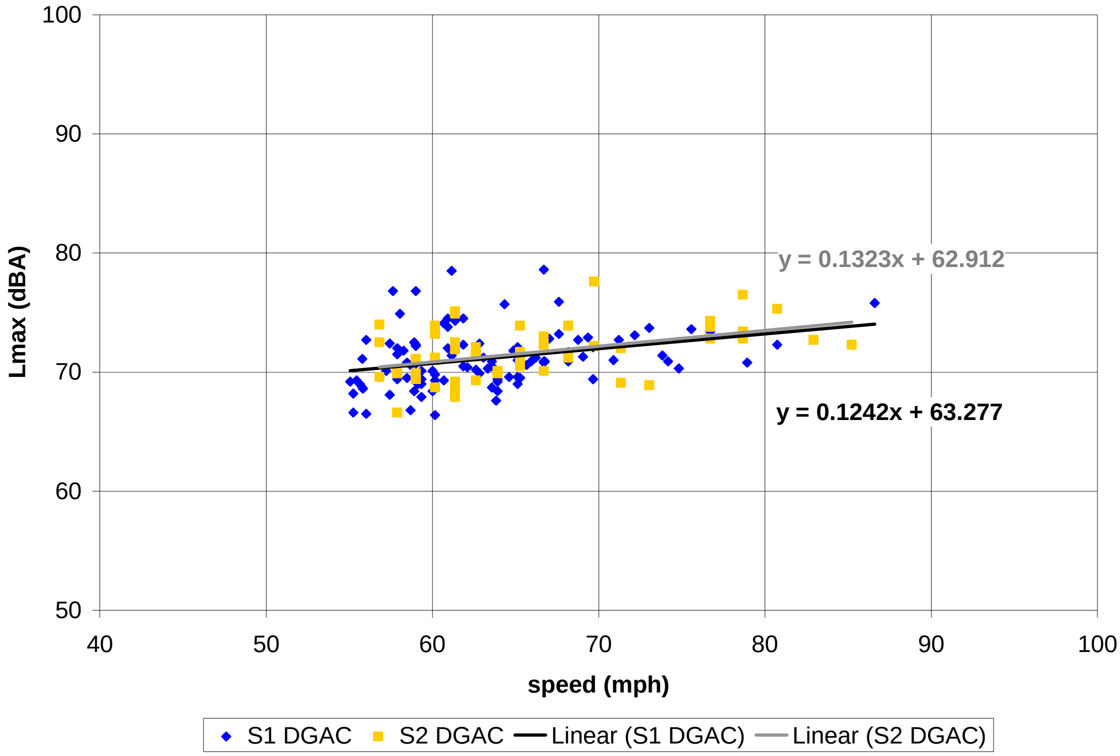
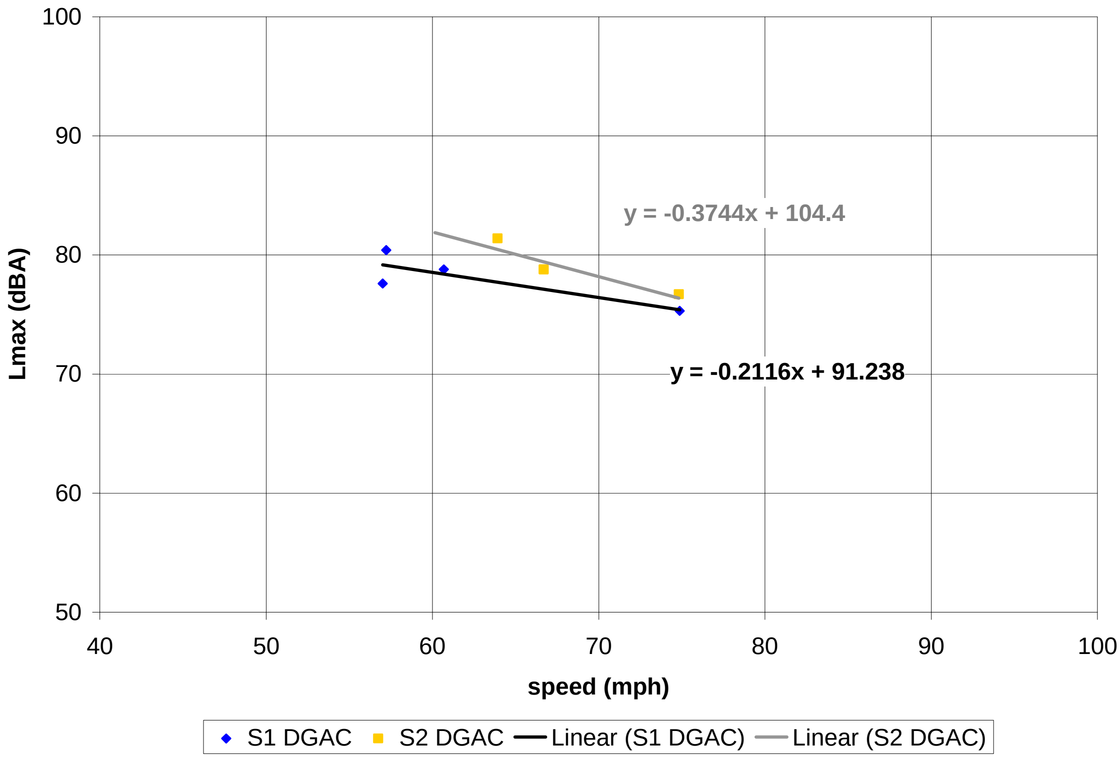


Figure C-2. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 2 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1323x + 62.912
y = 0.1242x + 63.277
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = -0.3744x + 104.4
y = -0.2116x + 91.238
S1 DGAC
S2 DGAC
Linear (S1 DGAC)
Linear (S2 DGAC)

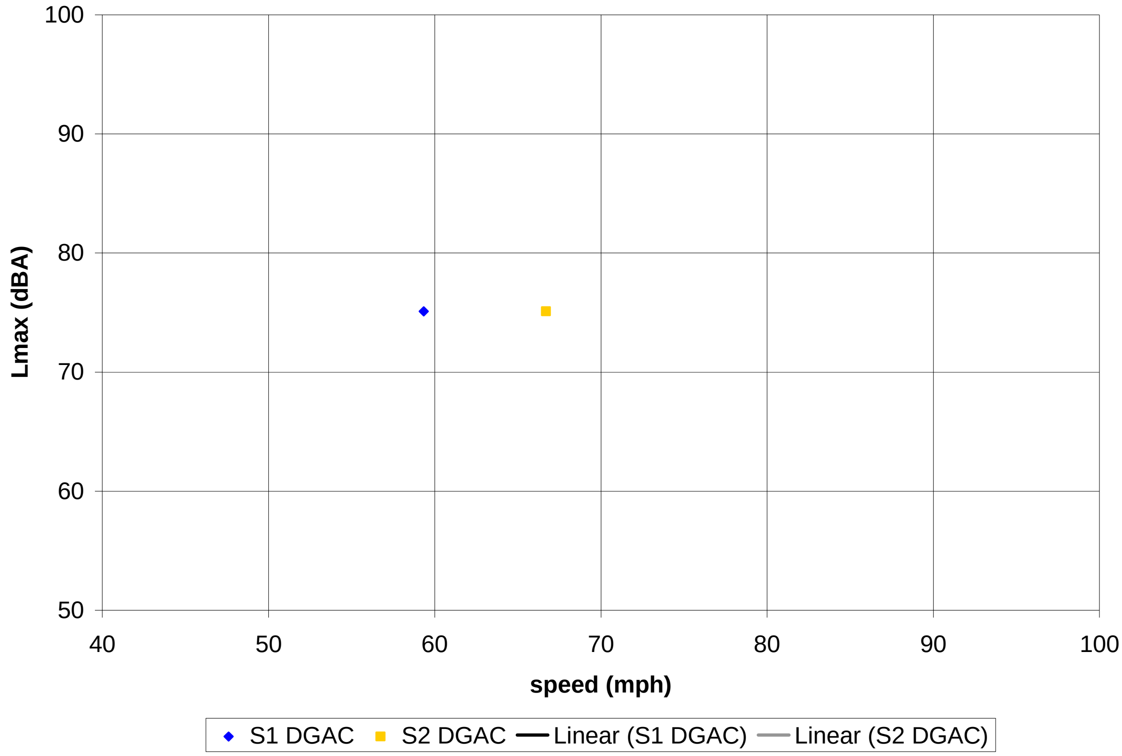
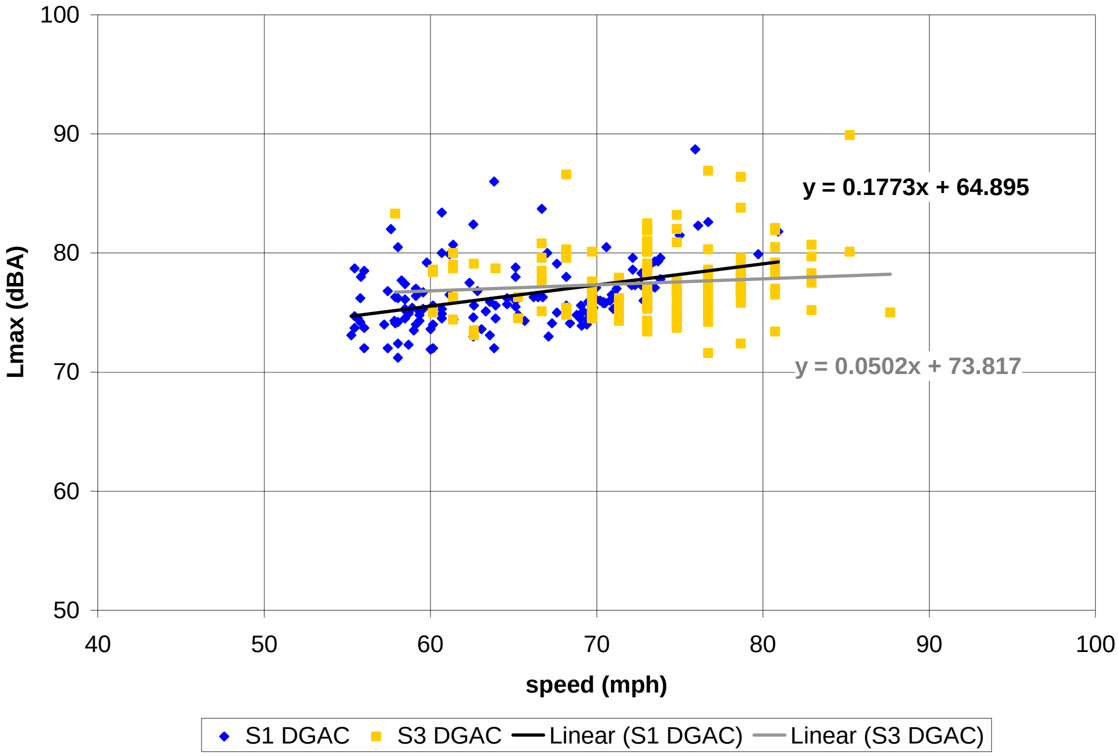
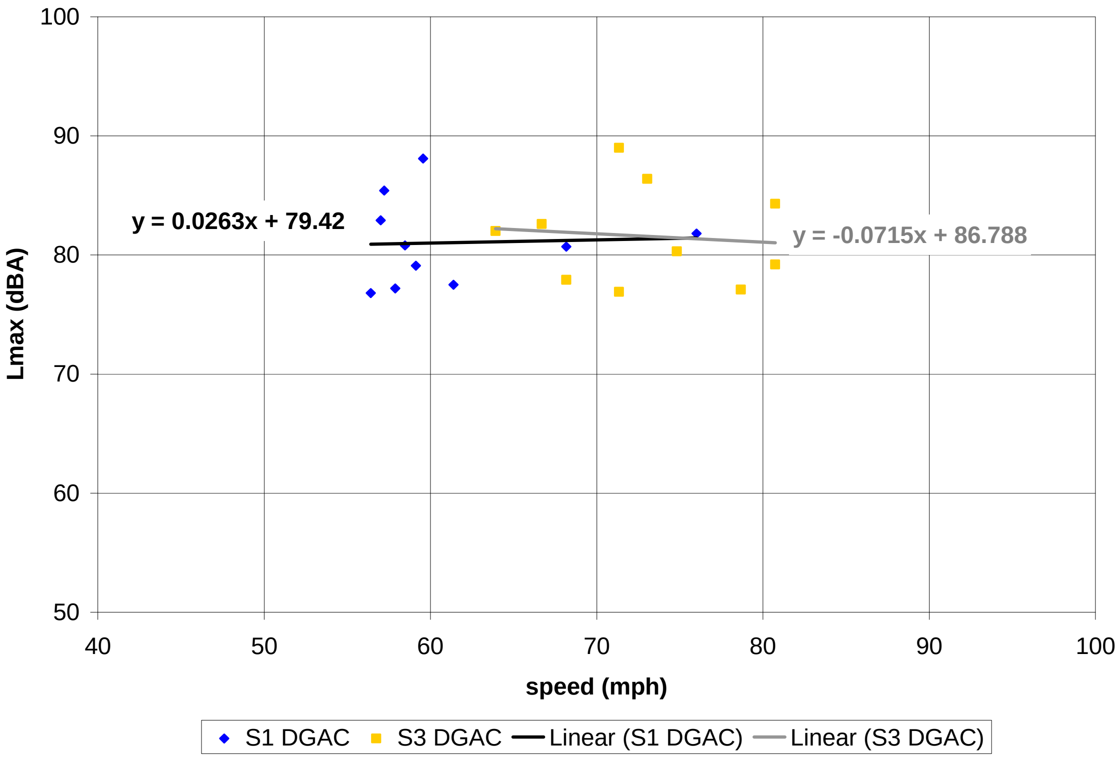


Figure C-3. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 2 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1773x + 64.895
y = 0.0502x + 73.817
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0263x + 79.42
y = -0.0715x + 86.788
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)

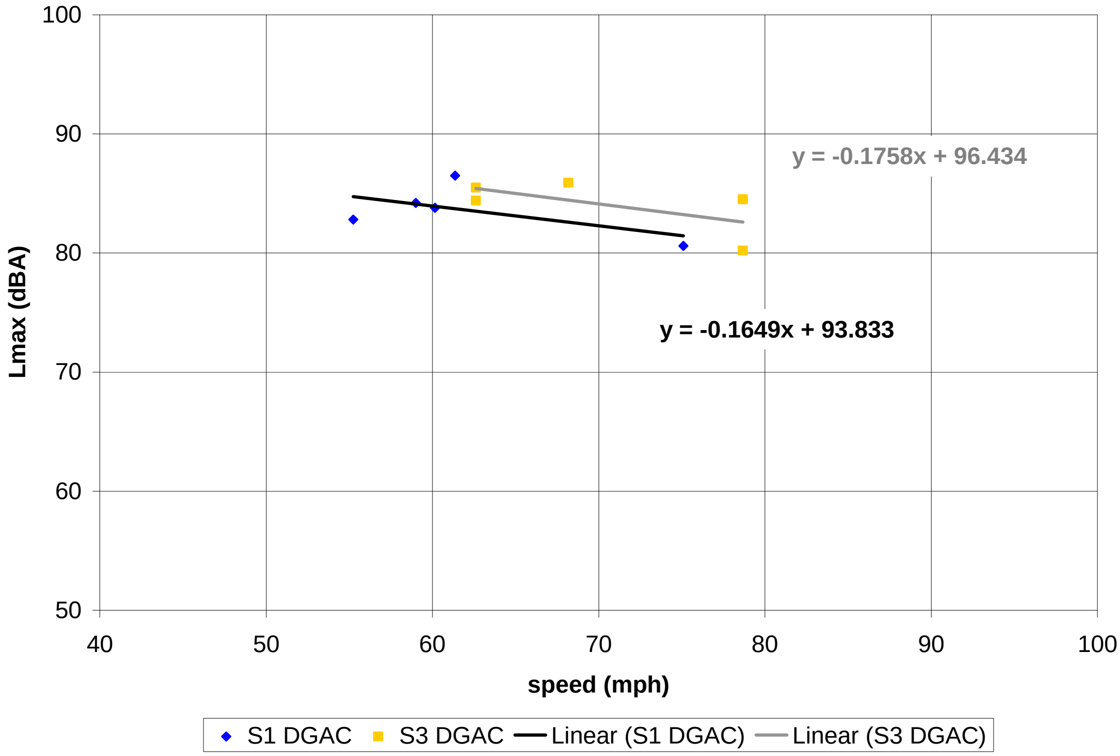
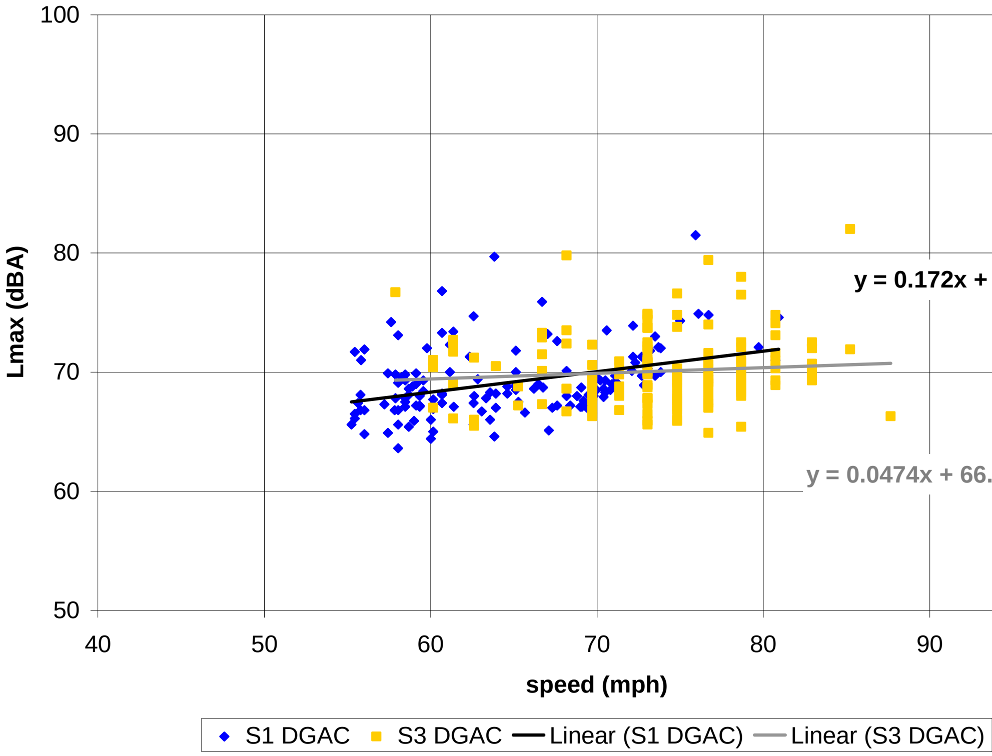
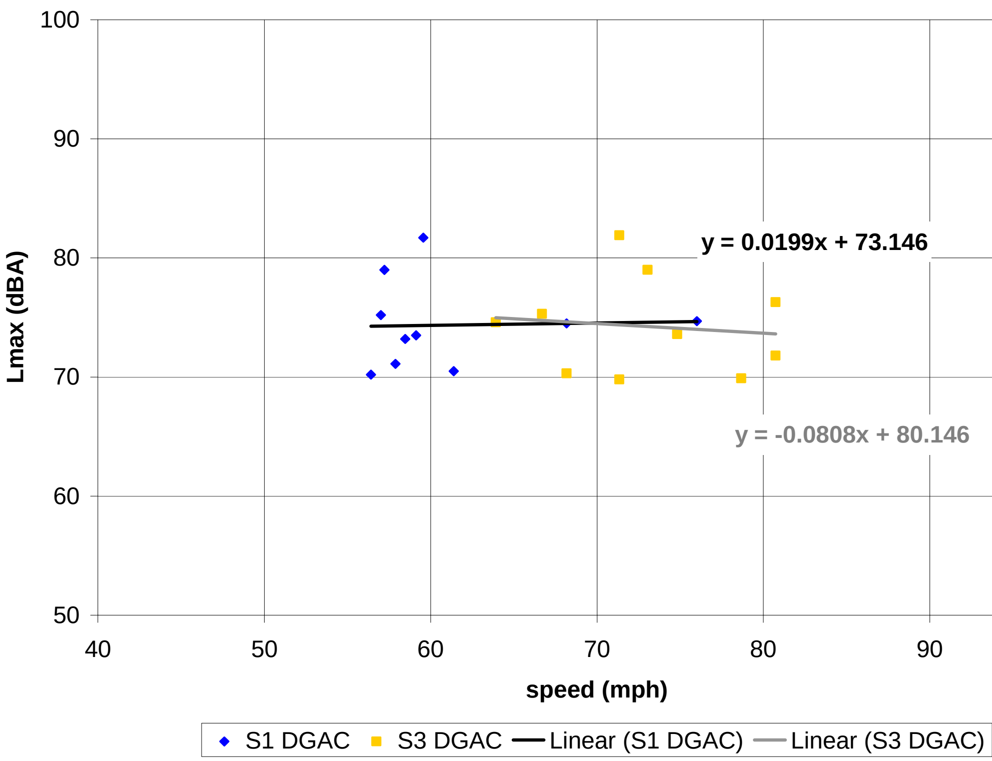


Figure C-4. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 3 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



Lmax (dBA)
speed (mph)
y = 0.172x + 58
y = 0.0474x + 66.578
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)



Lmax (dBA)
speed (mph)
y = 0.0199x + 73.146
y = -0.0808x + 80.146
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)

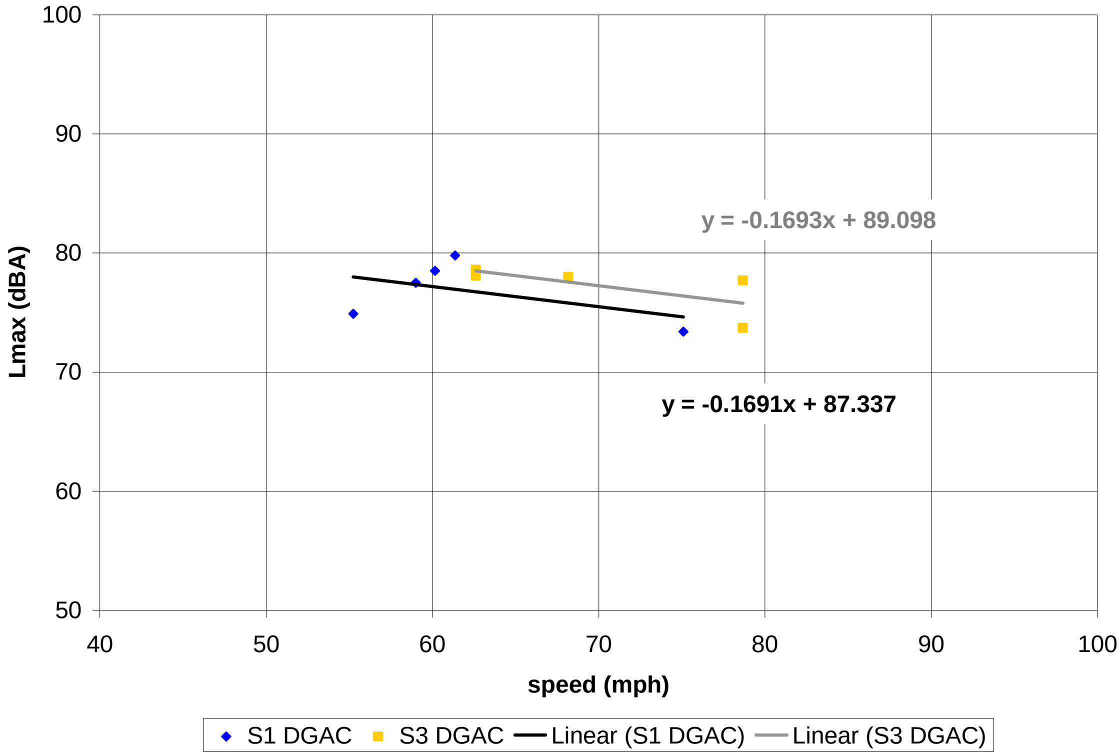
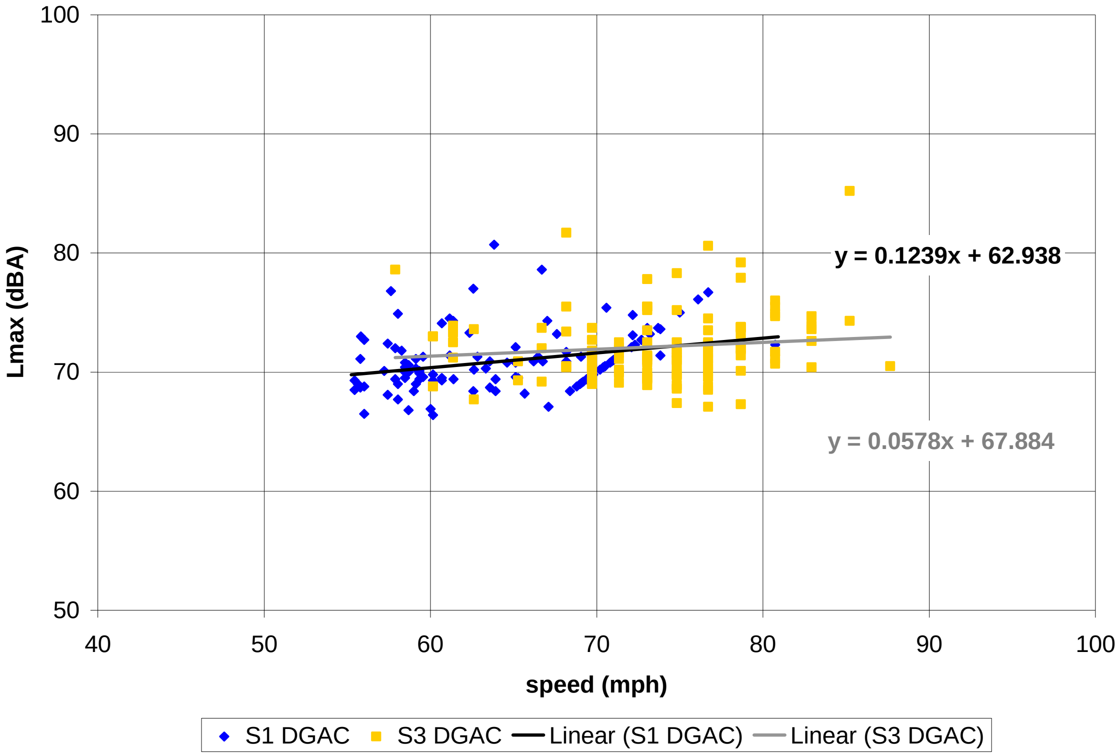
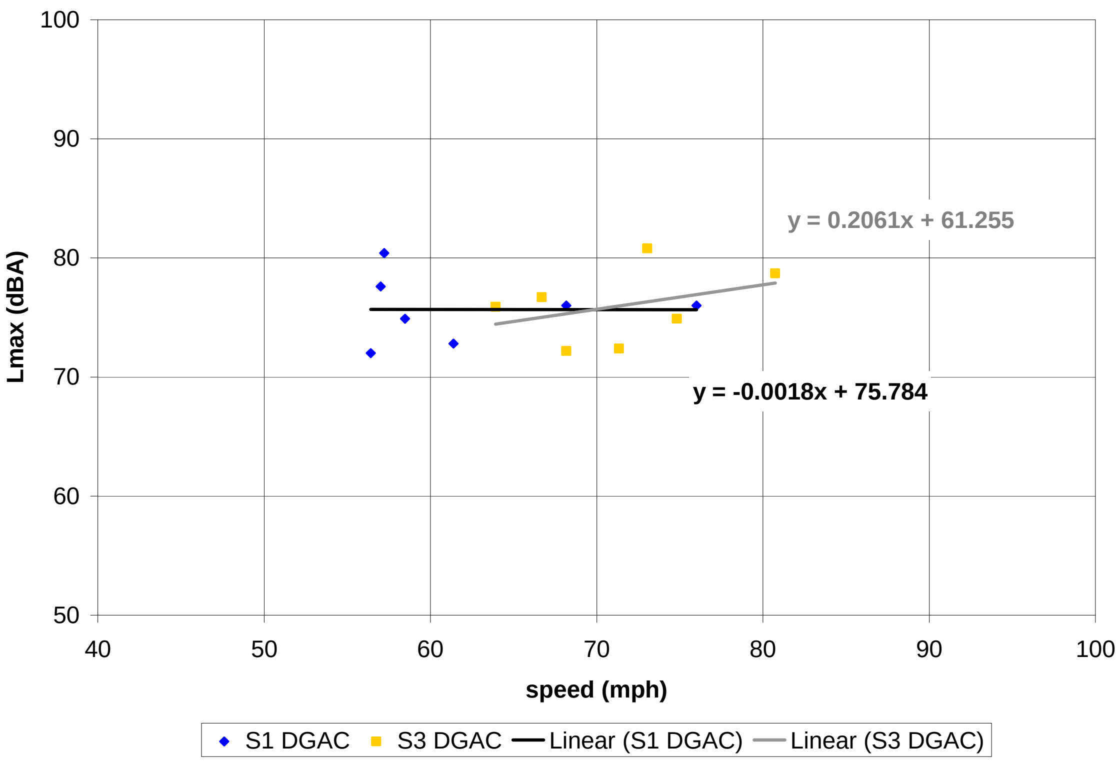


Figure C-5. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 3 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1239x + 62.938
y = 0.0578x + 67.884
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2061x + 61.255
y = -0.0018x + 75.784
S1 DGAC
S3 DGAC
Linear (S1 DGAC)
Linear (S3 DGAC)

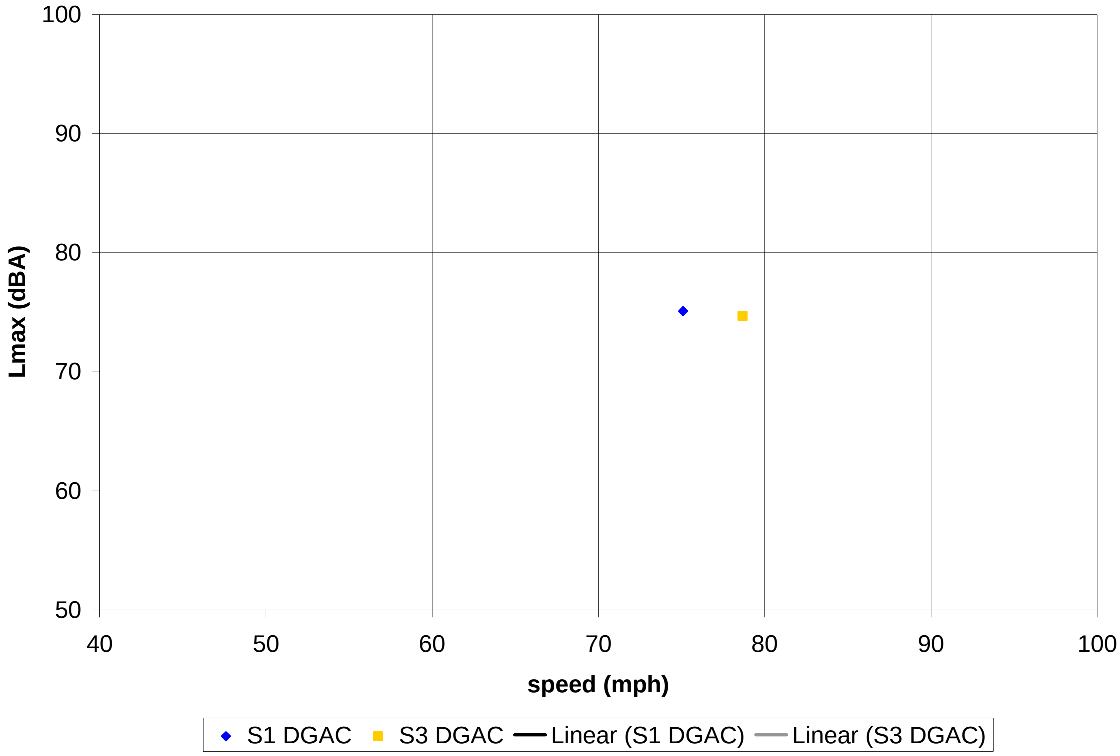
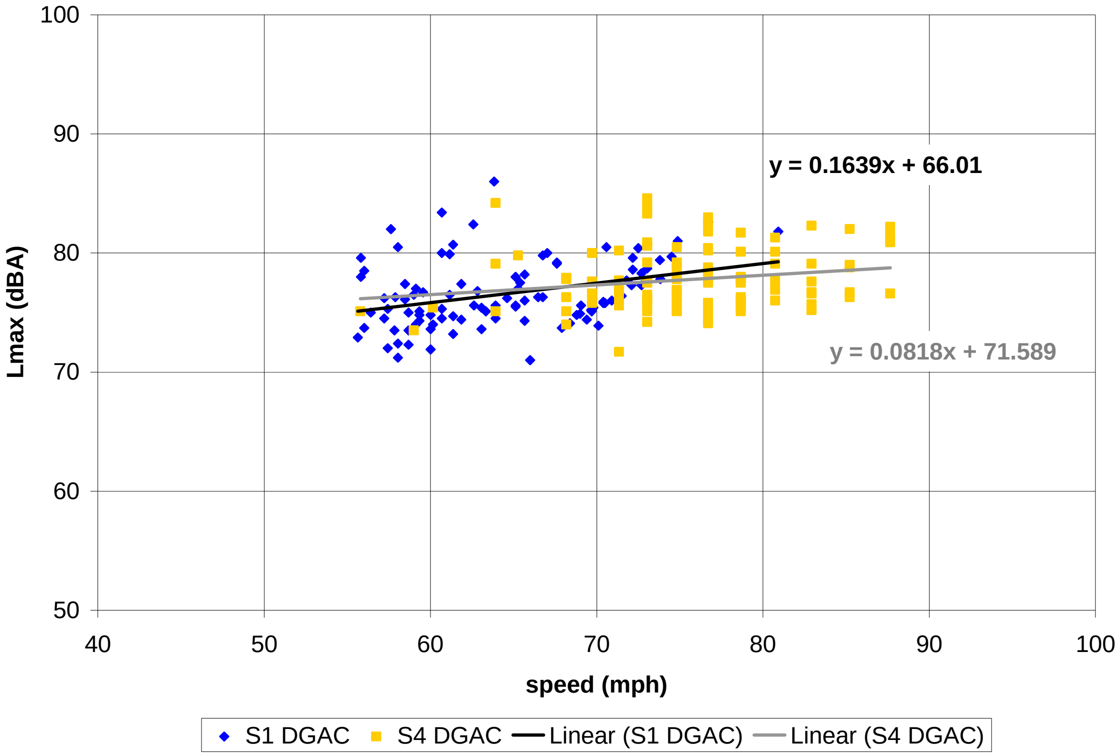
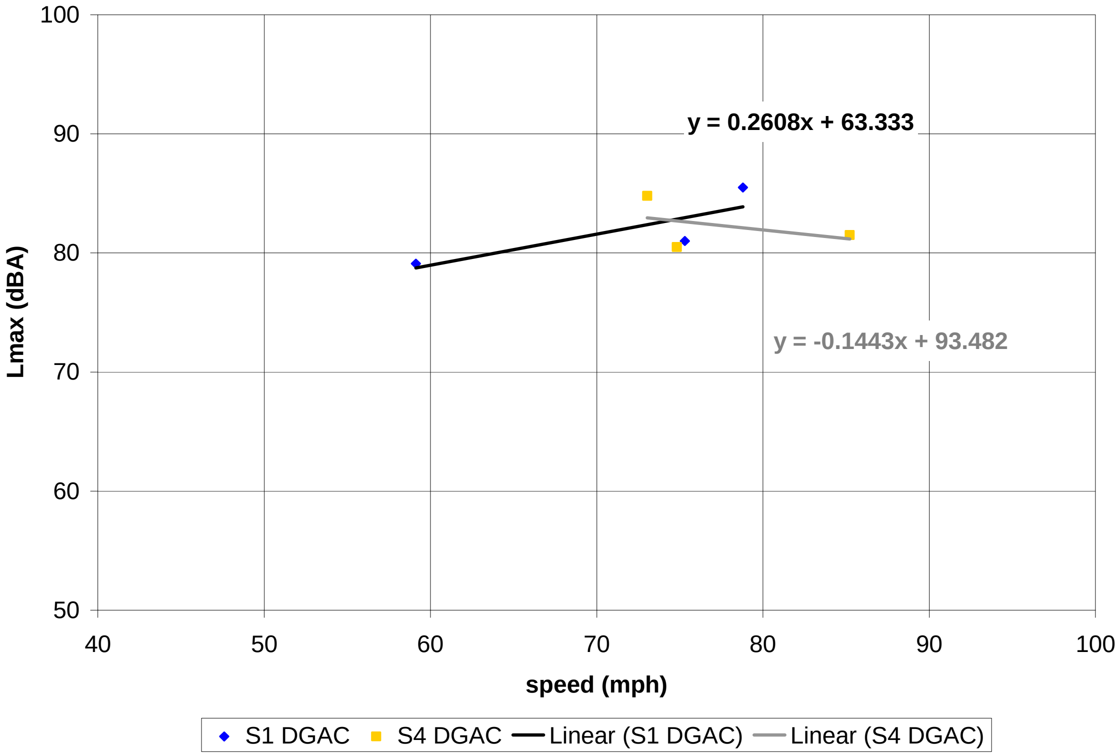


Figure C-6. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 3 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1639x + 66.01
y = 0.0818x + 71.589
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2608x + 63.333
y = -0.1443x + 93.482
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)

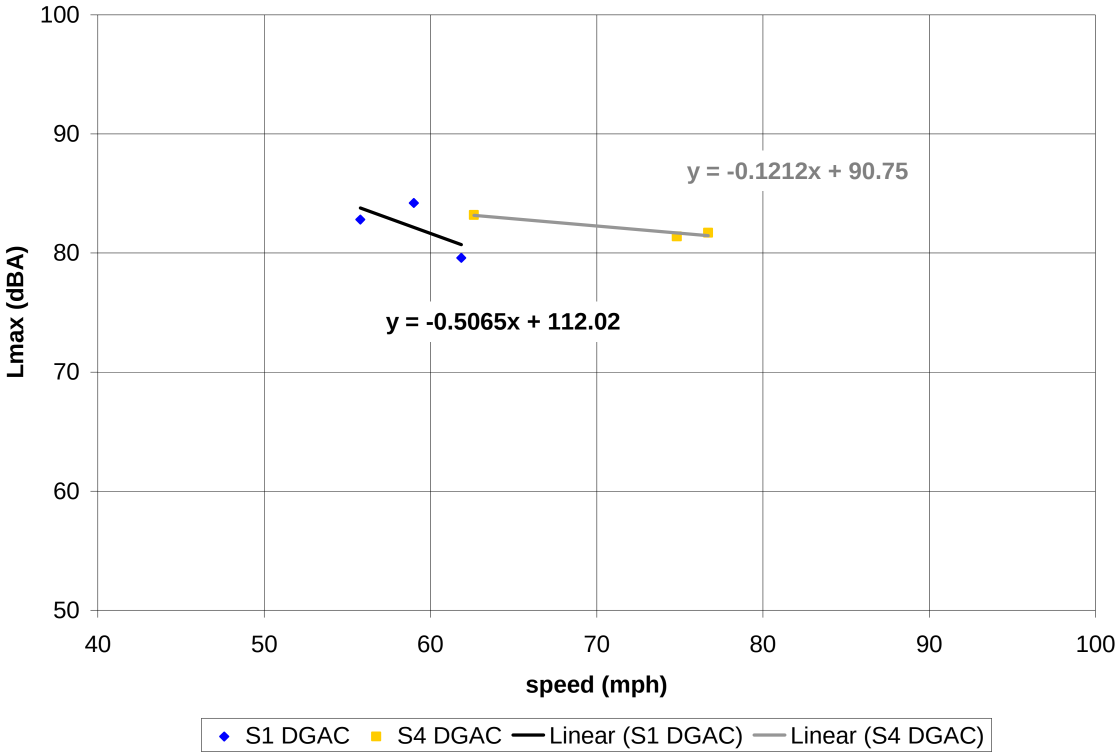
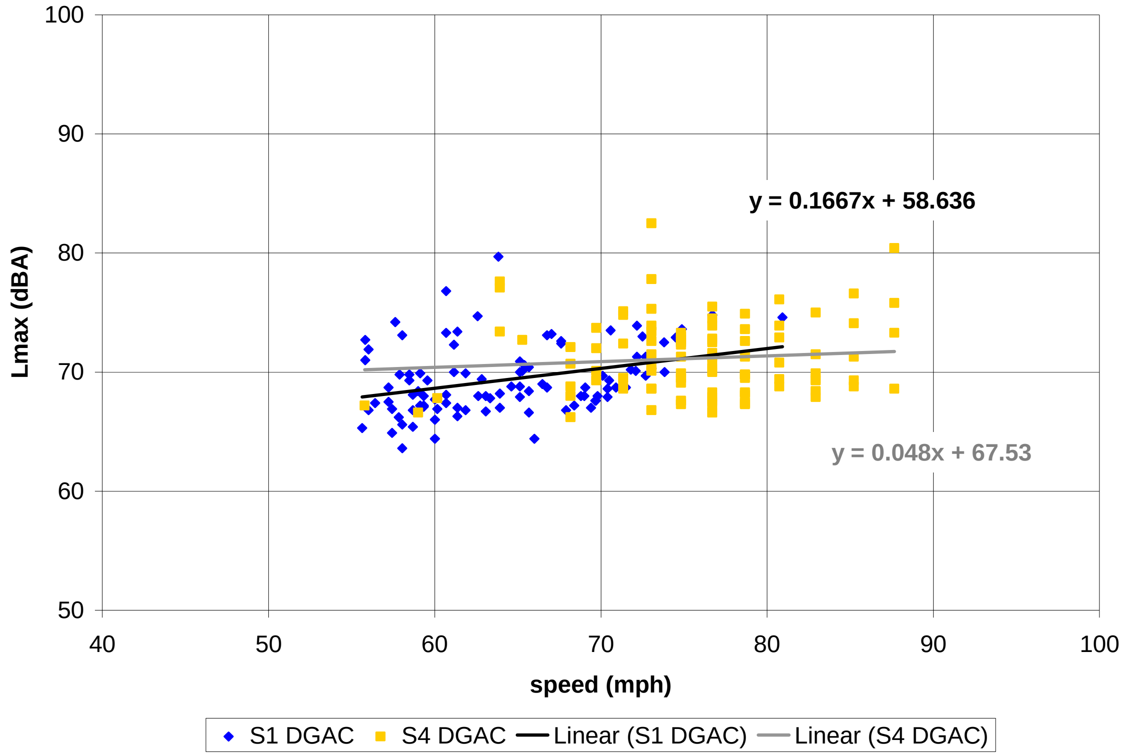
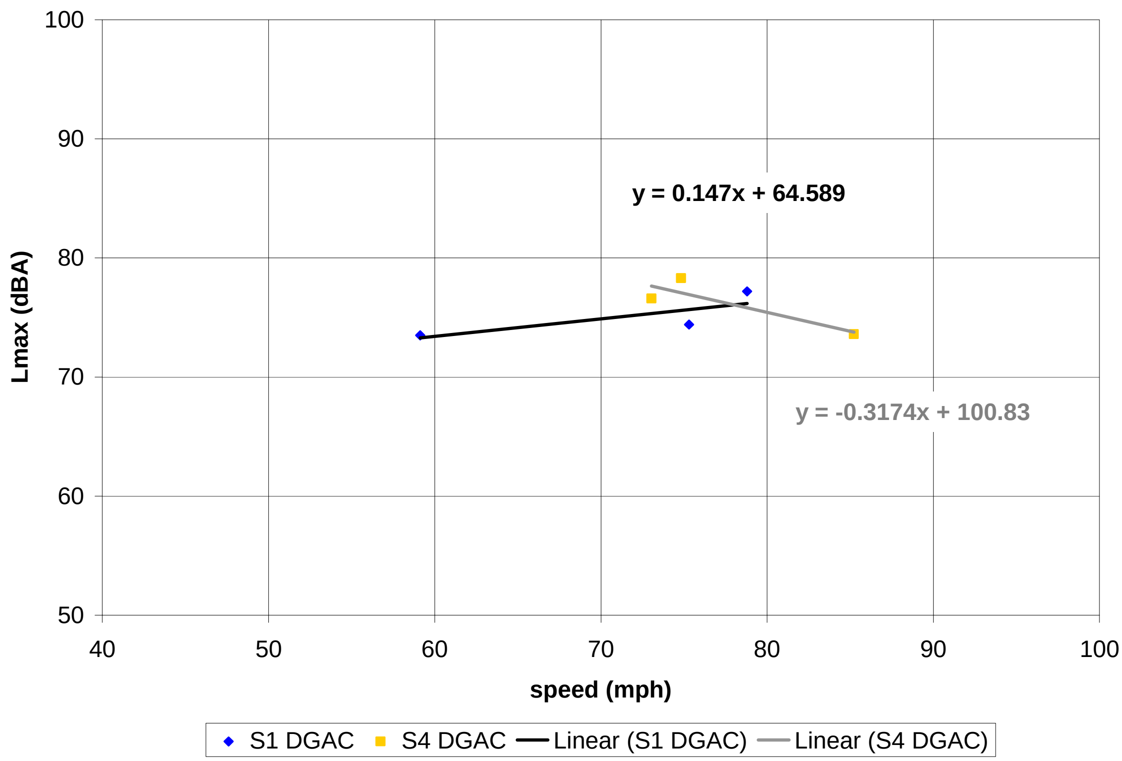


Figure C-7. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 4 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


y = 0.1667x + 58.636
y = 0.048x + 67.53
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)


y = 0.147x + 64.589
y = -0.3174x + 100.83
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)

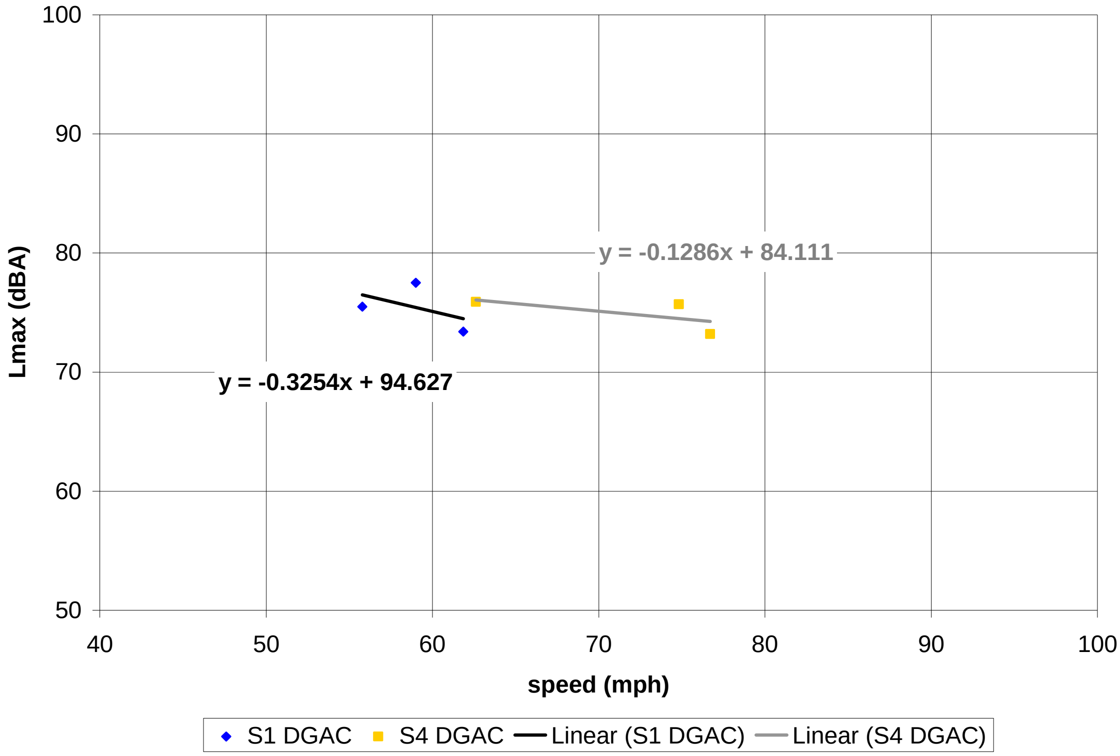
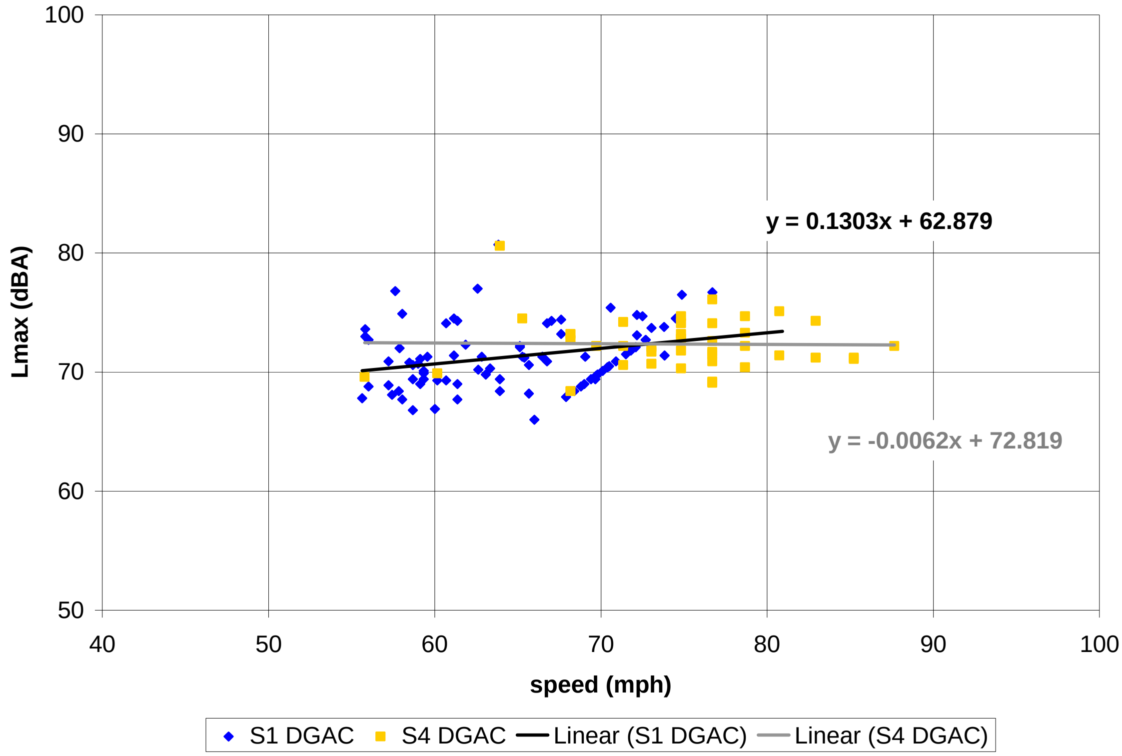
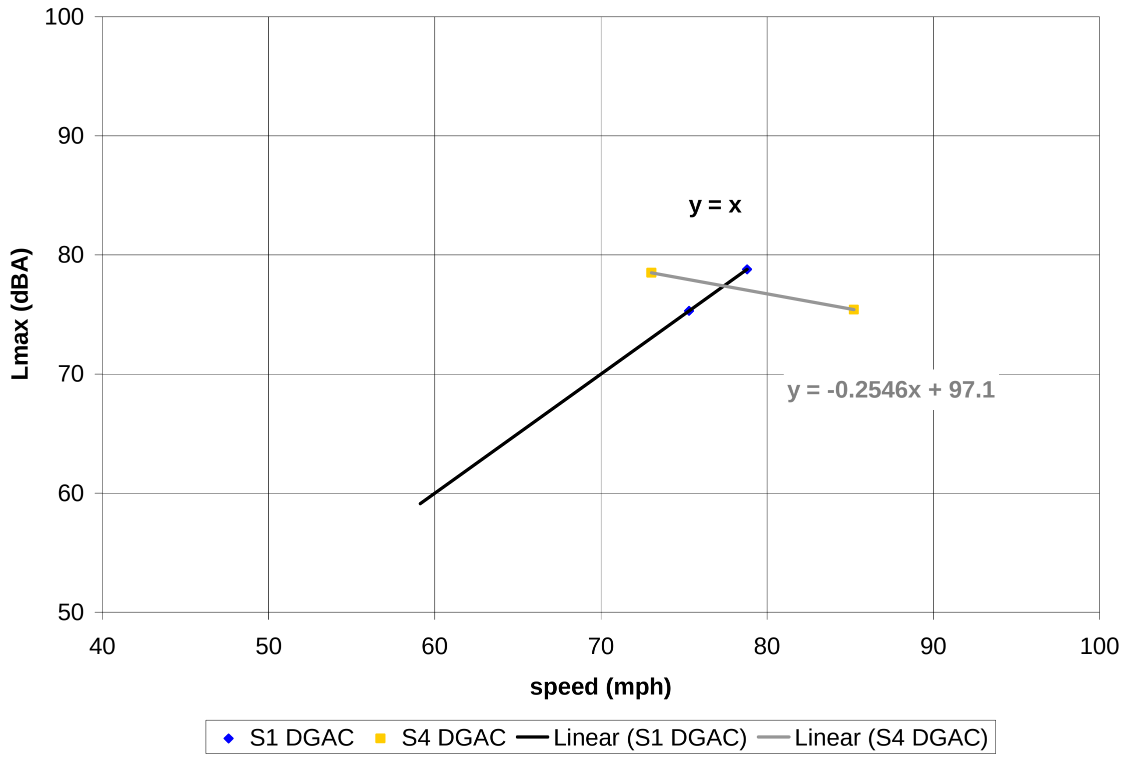


Figure C-8. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 4 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1303x + 62.879
y = -0.0062x + 72.819
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = x
y = -0.2546x + 97.1
S1 DGAC
S4 DGAC
Linear (S1 DGAC)
Linear (S4 DGAC)

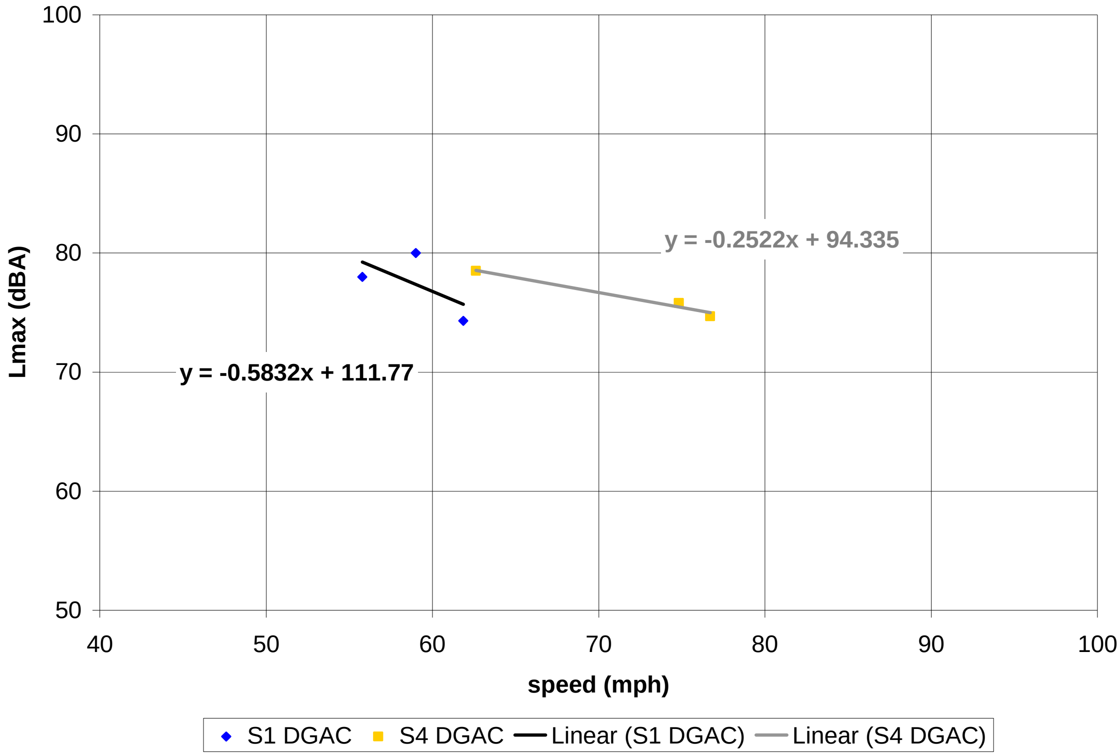
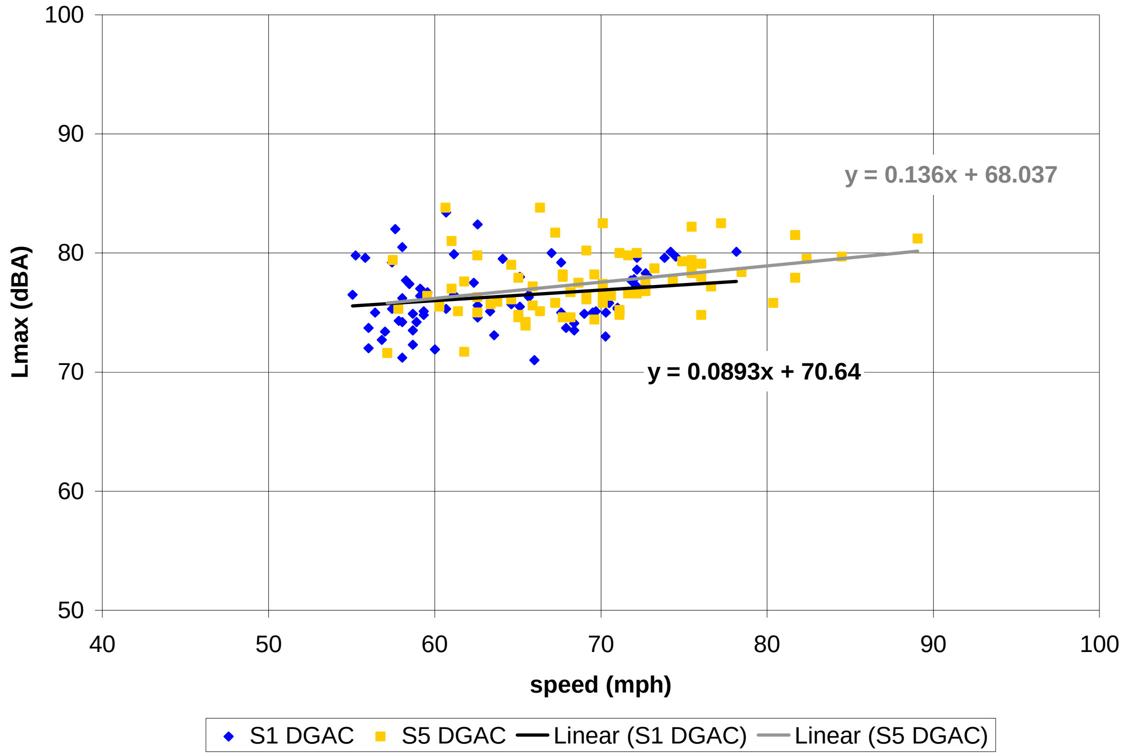
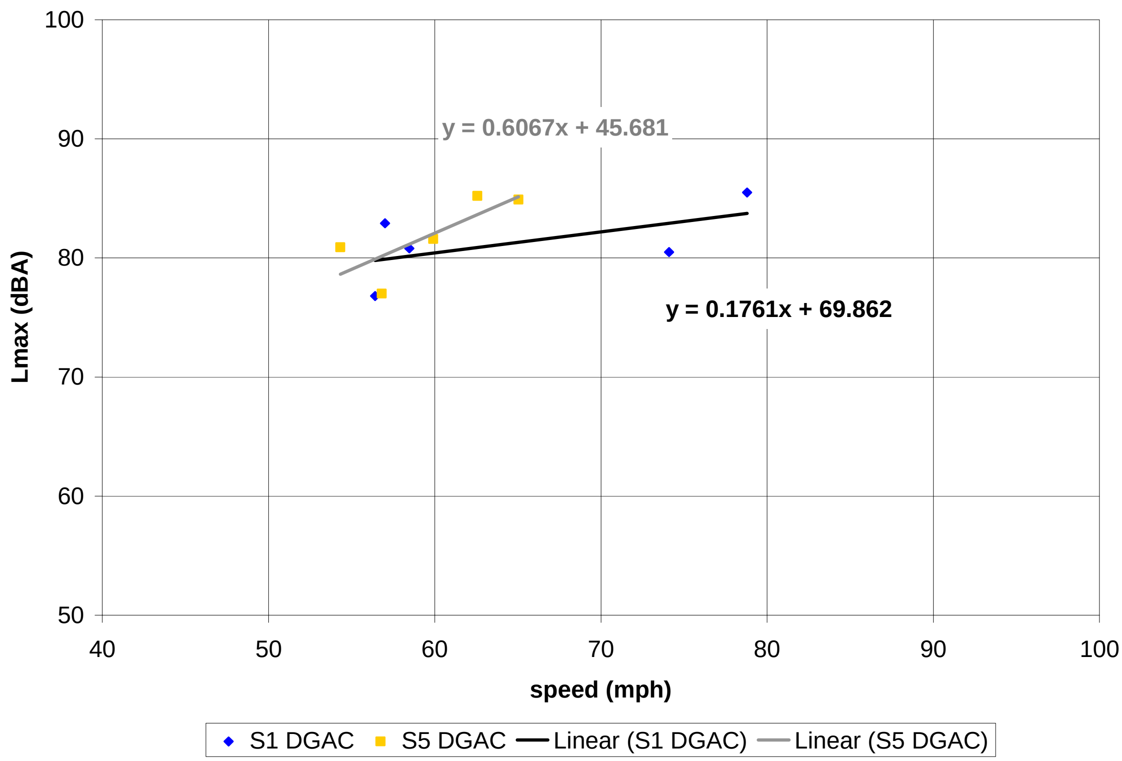


Figure C-9. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 4 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.136x + 68.037
y = 0.0893x + 70.64
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.6067x + 45.681
y = 0.1761x + 69.862
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)

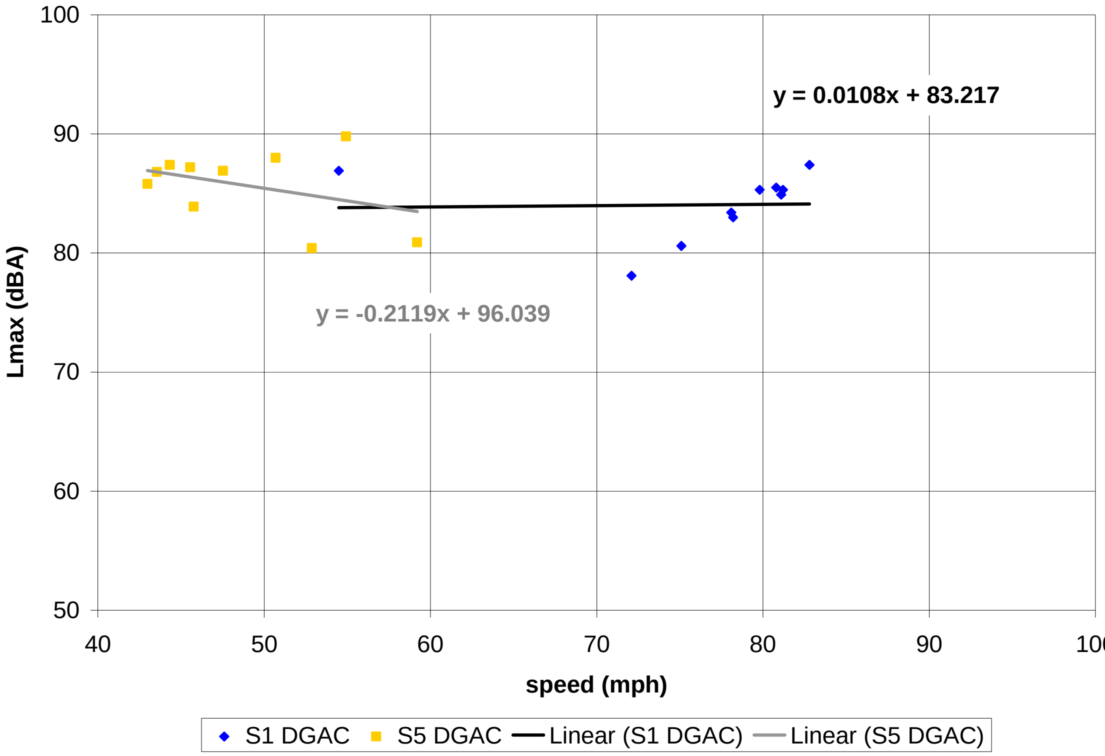
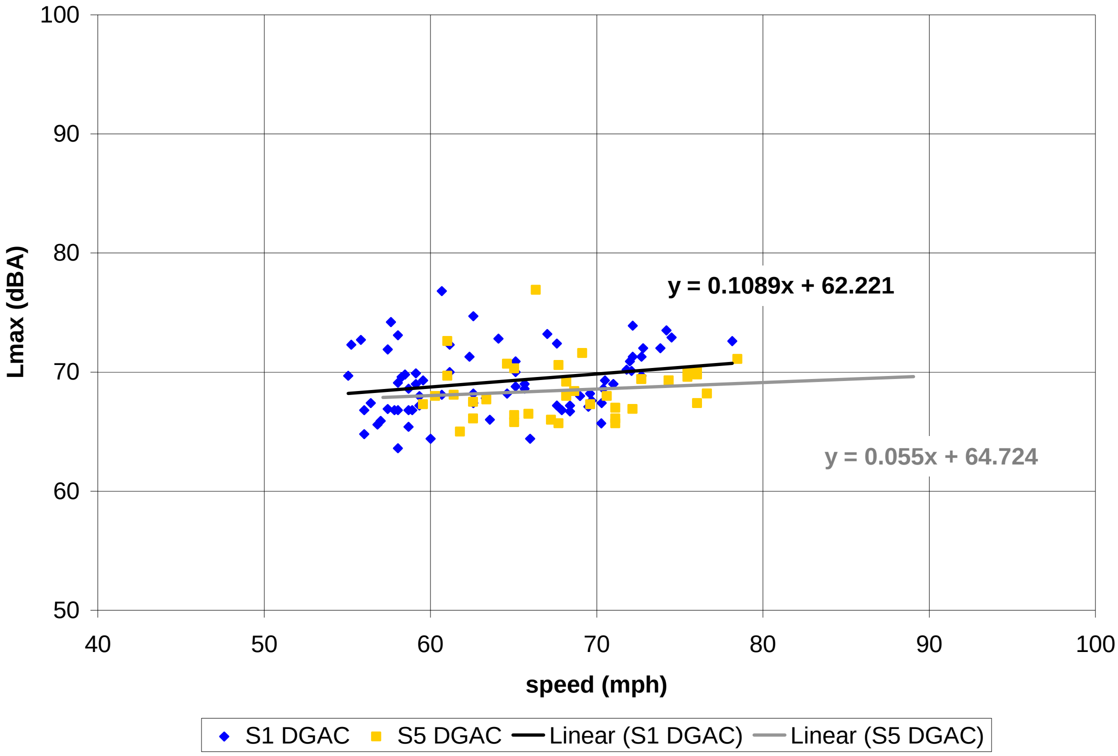
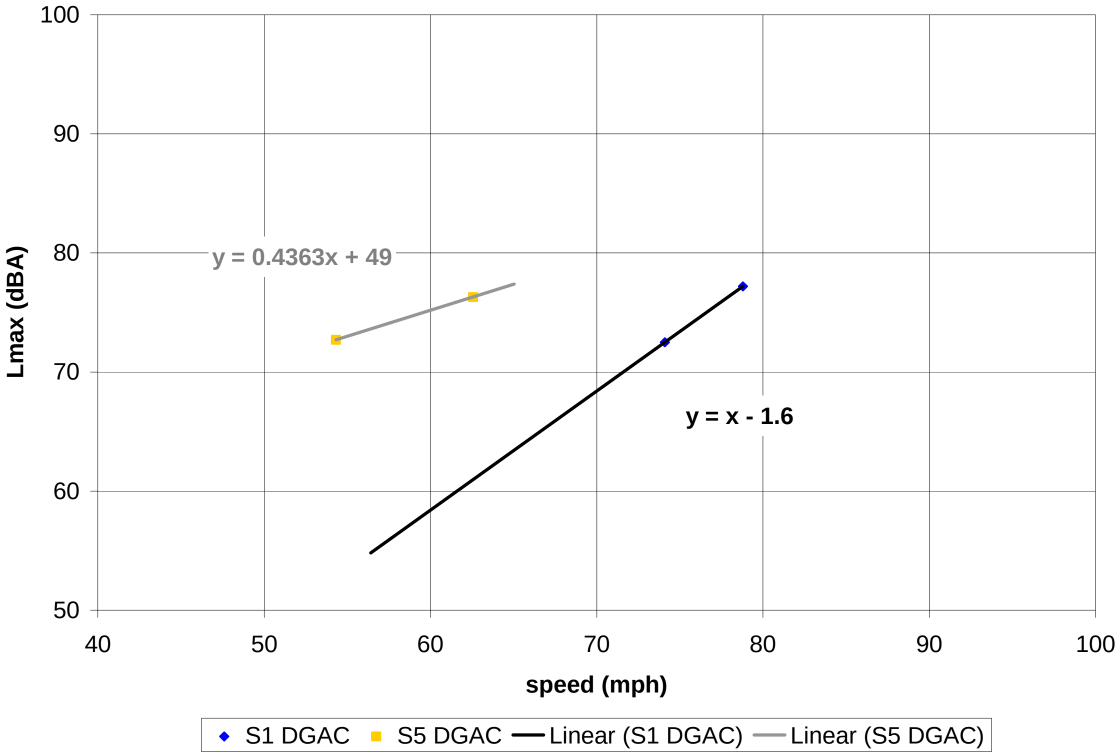


Figure C-10. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 5 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1089x + 62.221
y = 0.055x + 64.724
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)



100
90
80
70
60
50
Lmax (dBA)
y = 0.4363x + 49
y = x - 1.6
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)

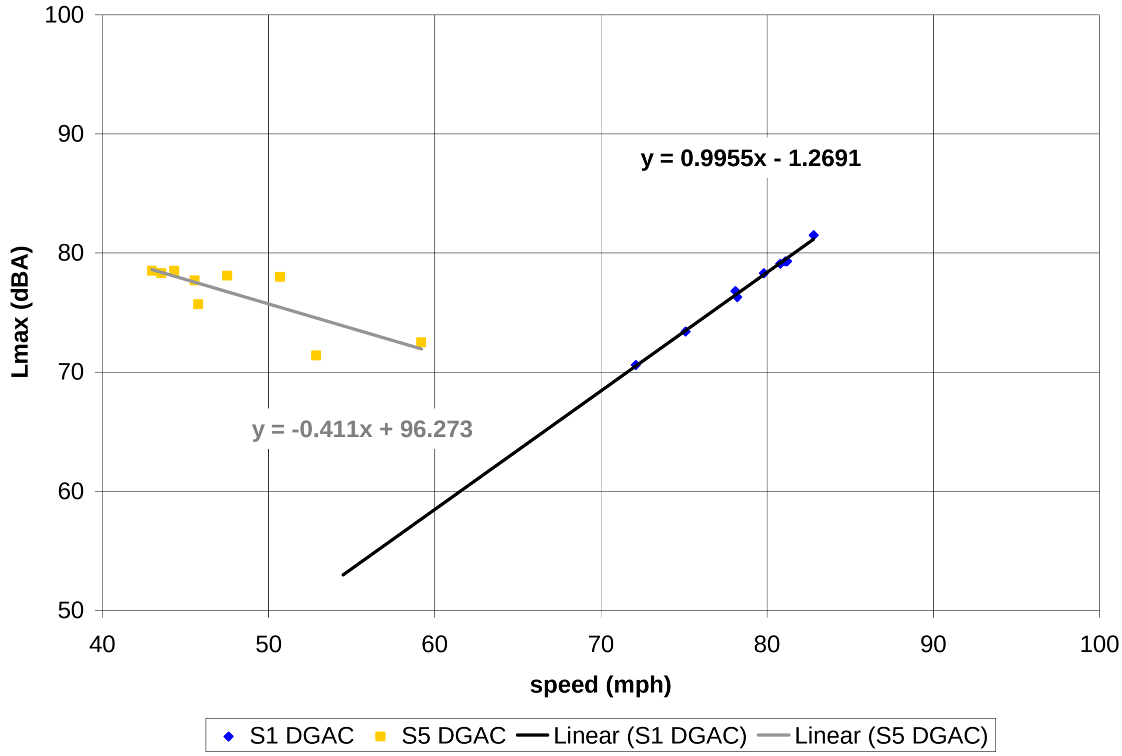
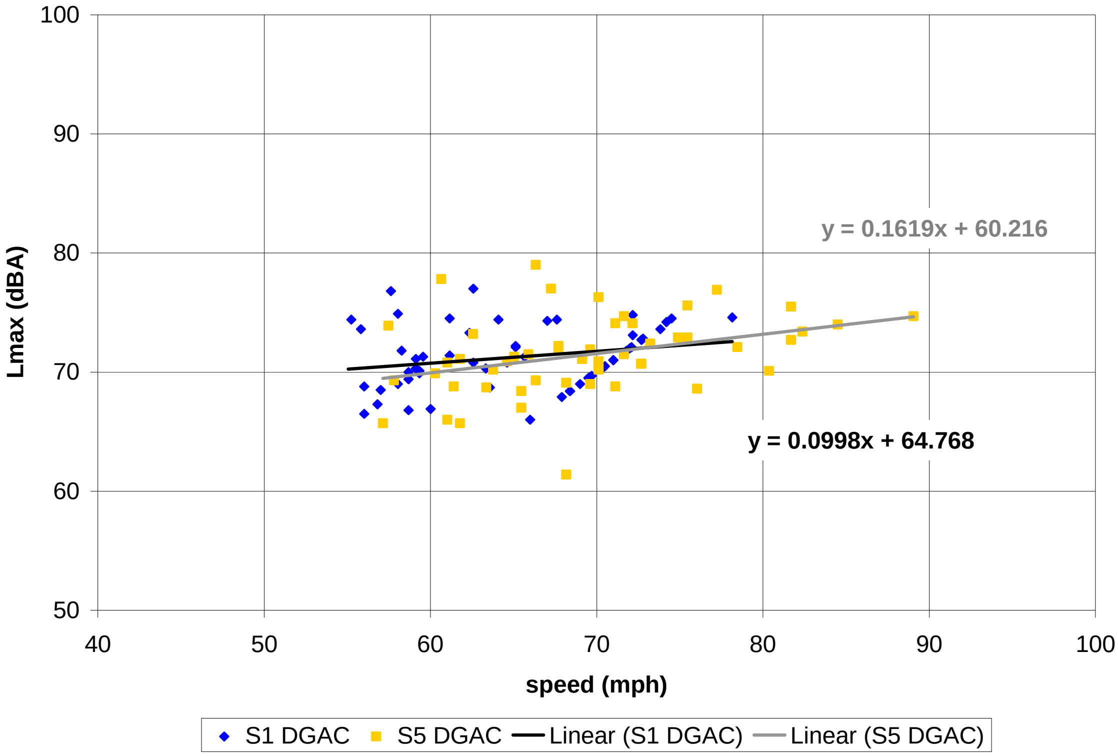
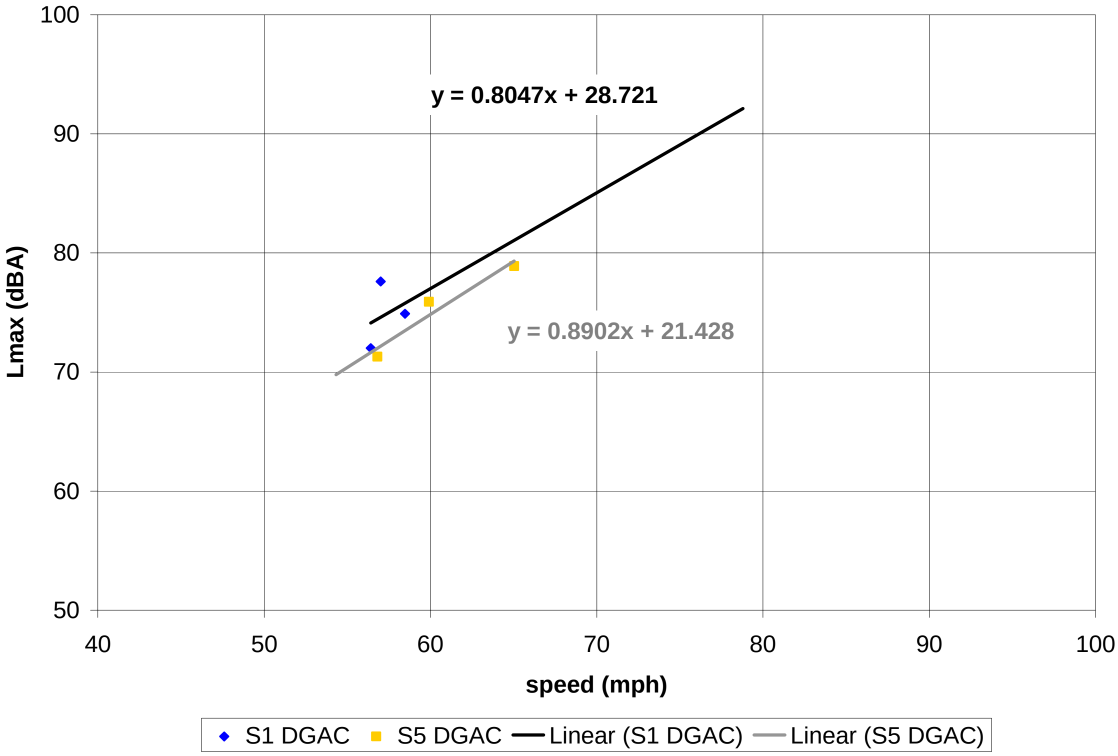


Figure C-11. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 5 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1619x + 60.216
y = 0.0998x + 64.768
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.8047x + 28.721
y = 0.8902x + 21.428
S1 DGAC
S5 DGAC
Linear (S1 DGAC)
Linear (S5 DGAC)

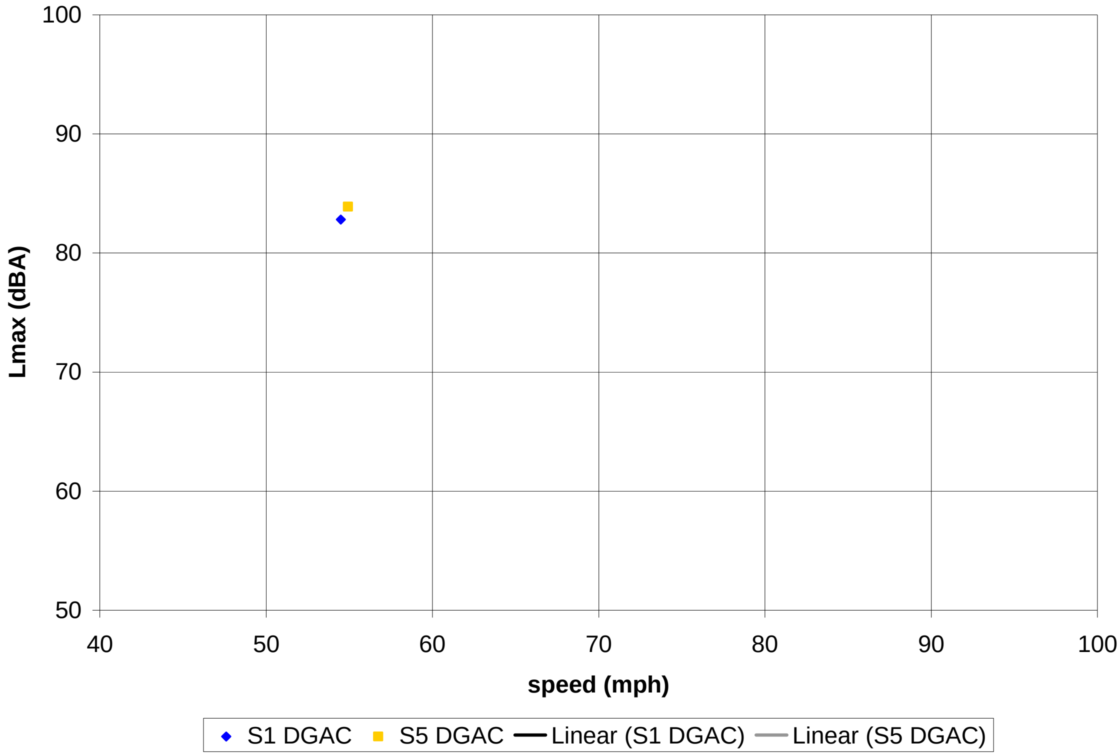
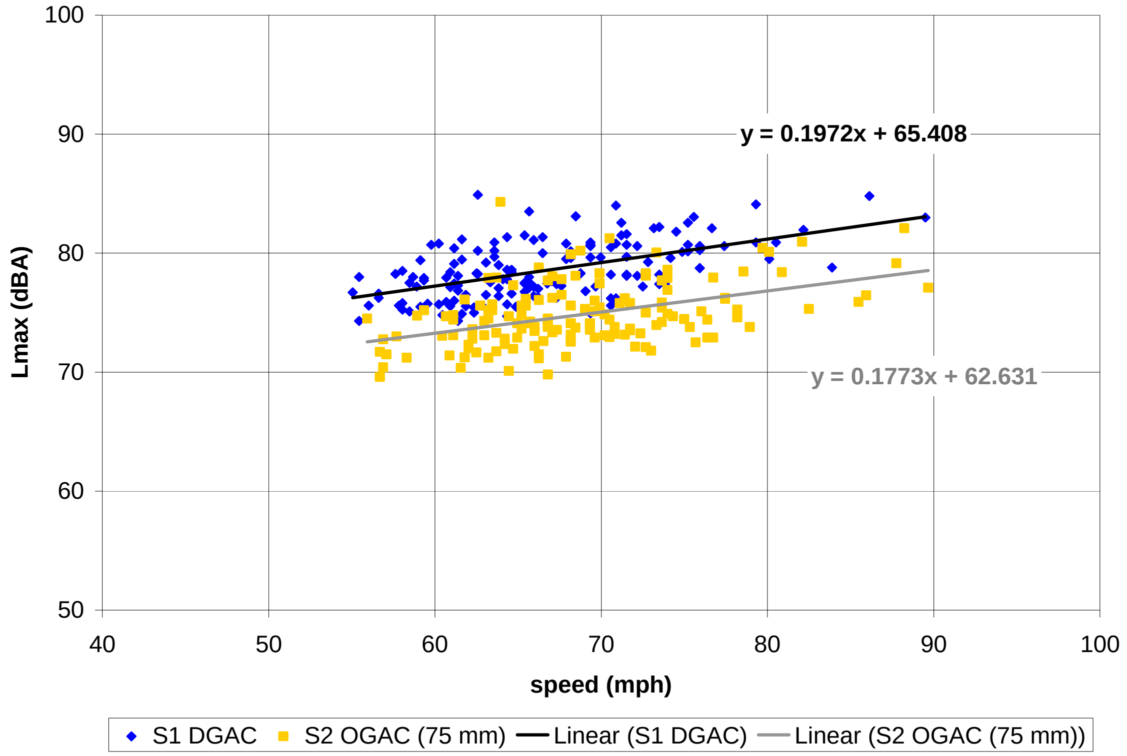
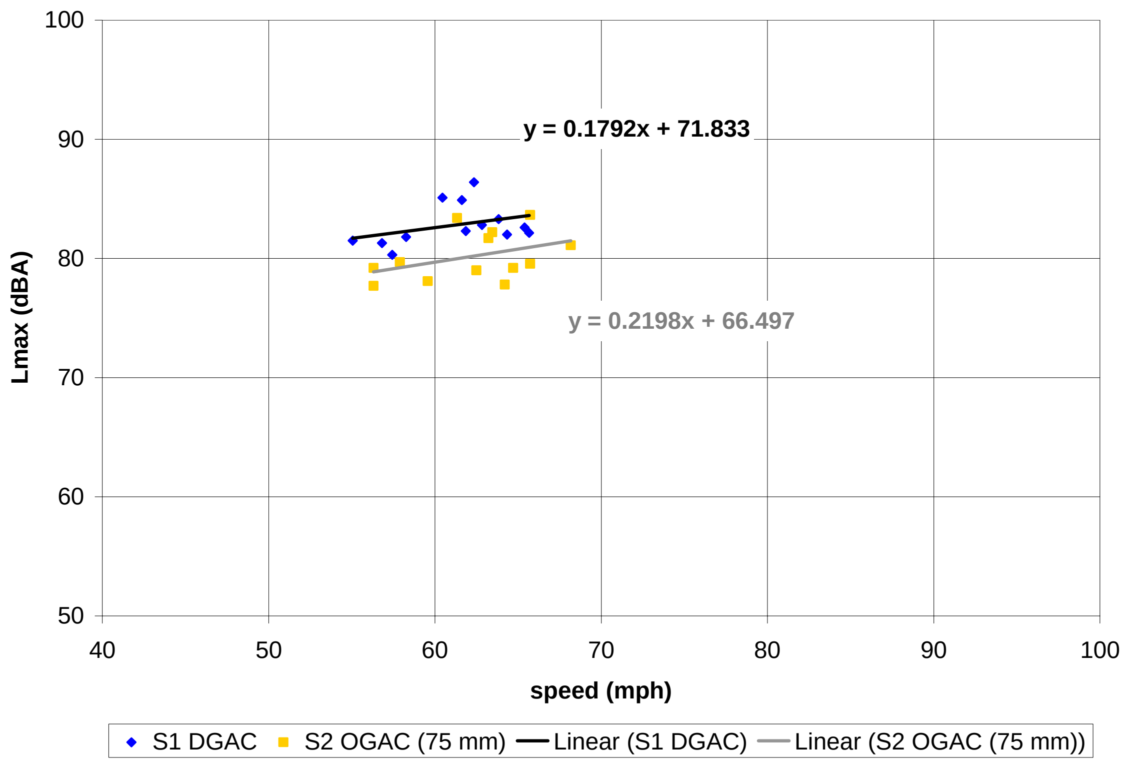


Figure C-12. (this and previous page) Vehicle pass-by data, pre-overlay; Site 1 (DGAC), Site 5 (DGAC). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.3 Post-Overlay – Pavement Age: 4 months





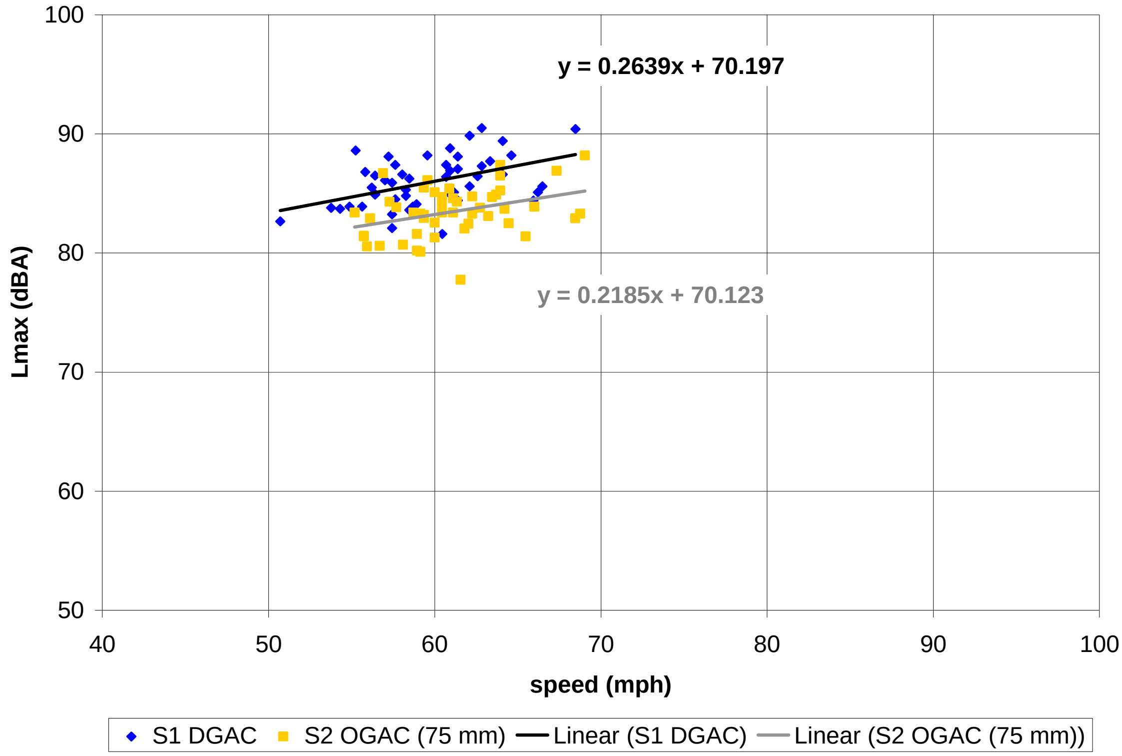
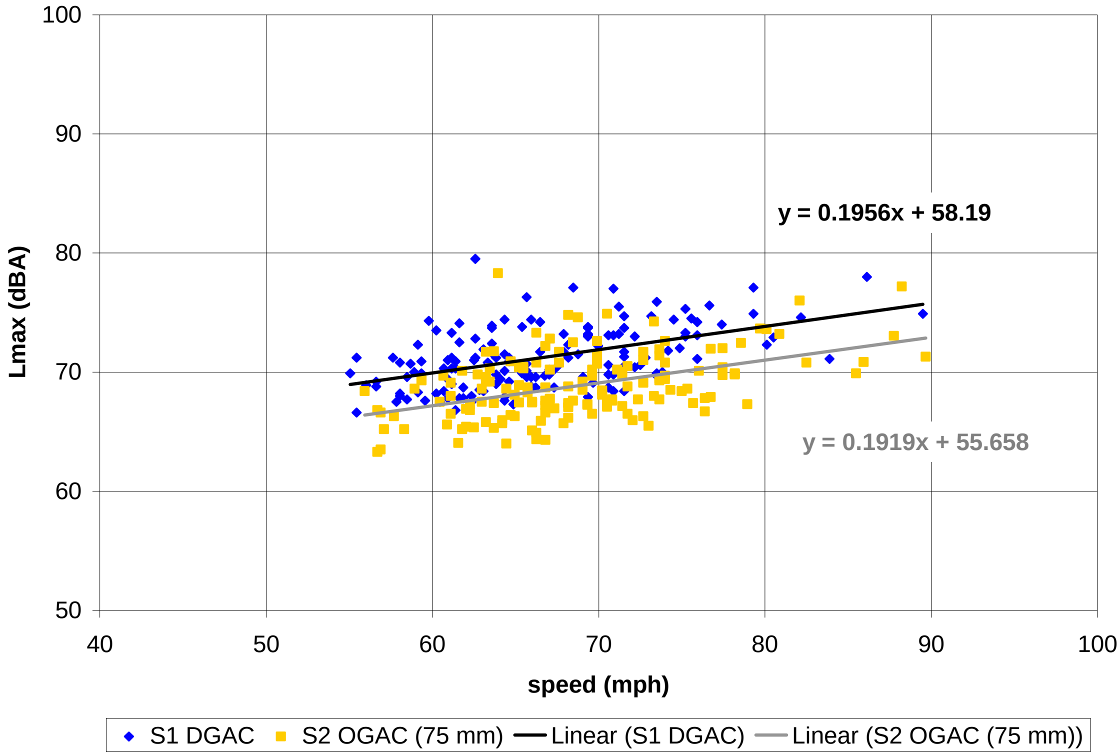
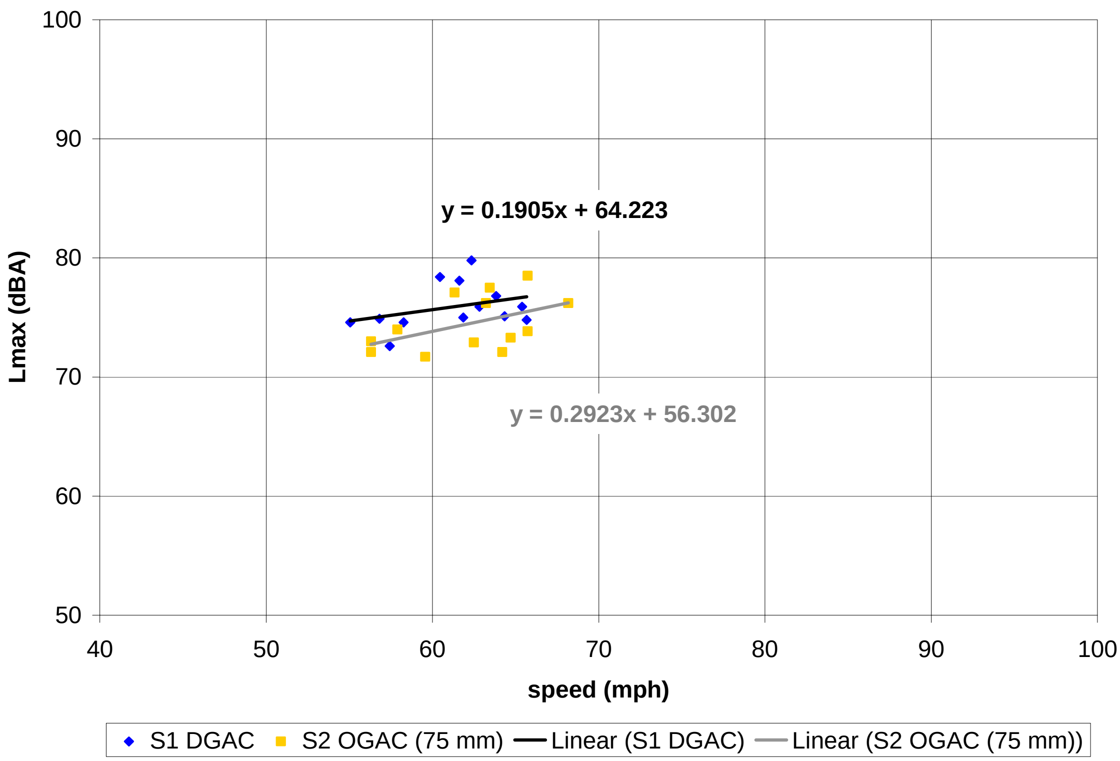


Figure C-13. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1956x + 58.19
y = 0.1919x + 55.658
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1905x + 64.223
y = 0.2923x + 56.302
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

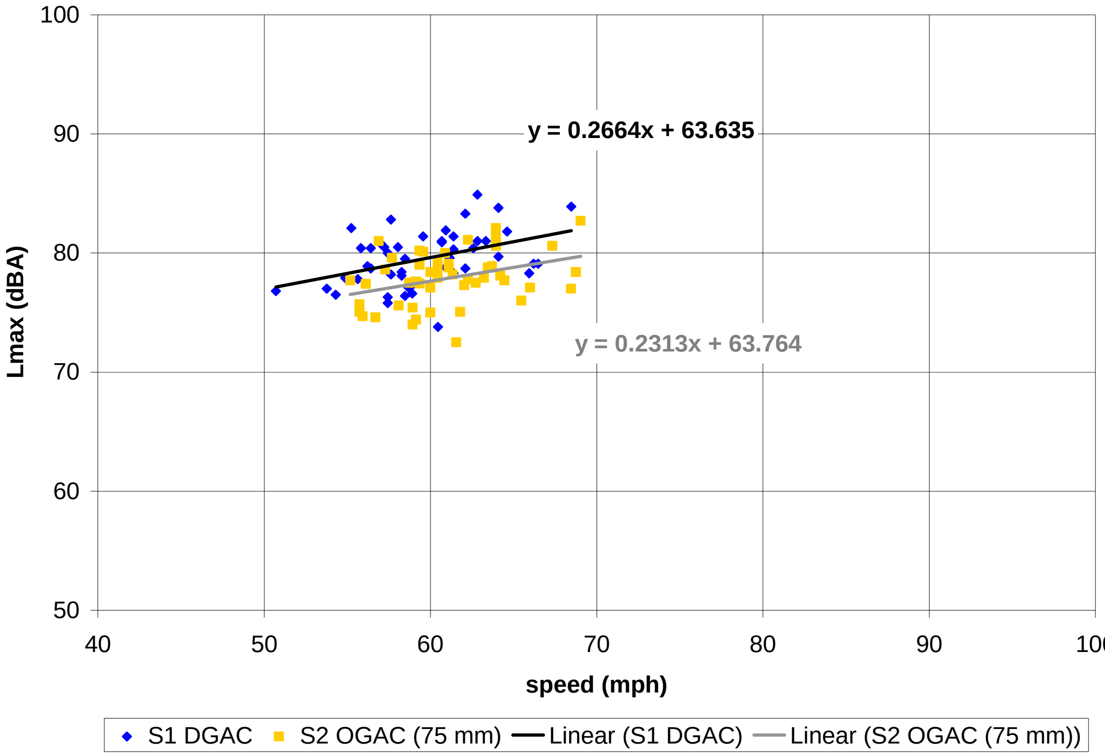
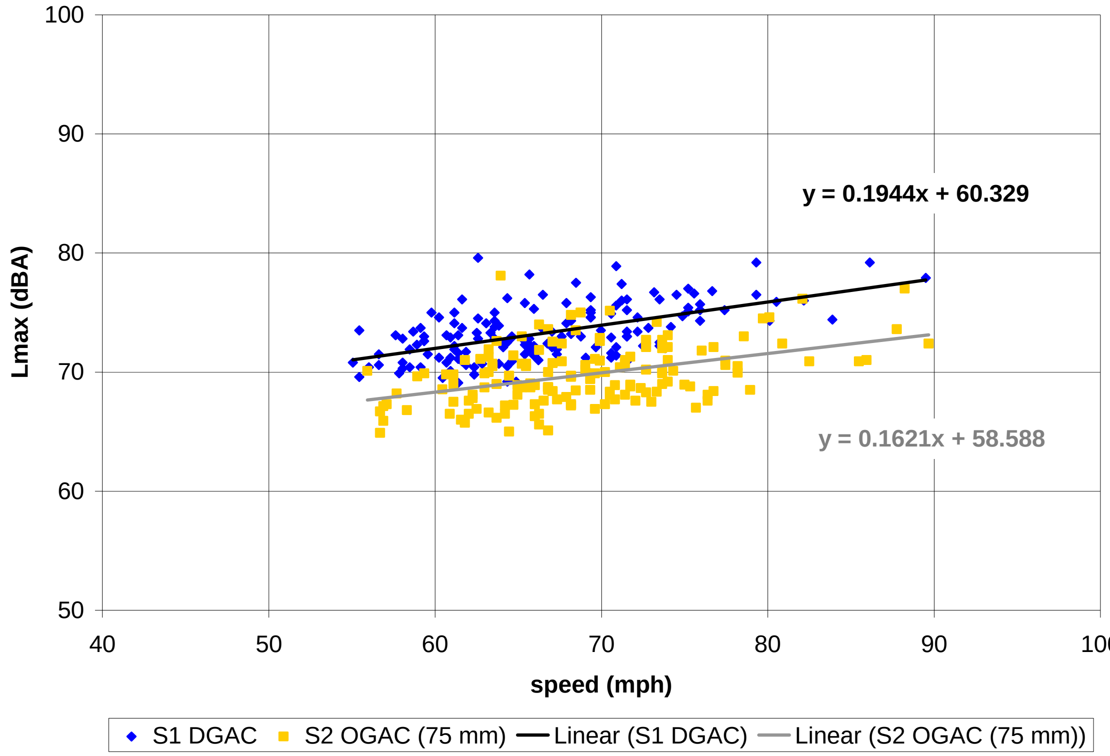
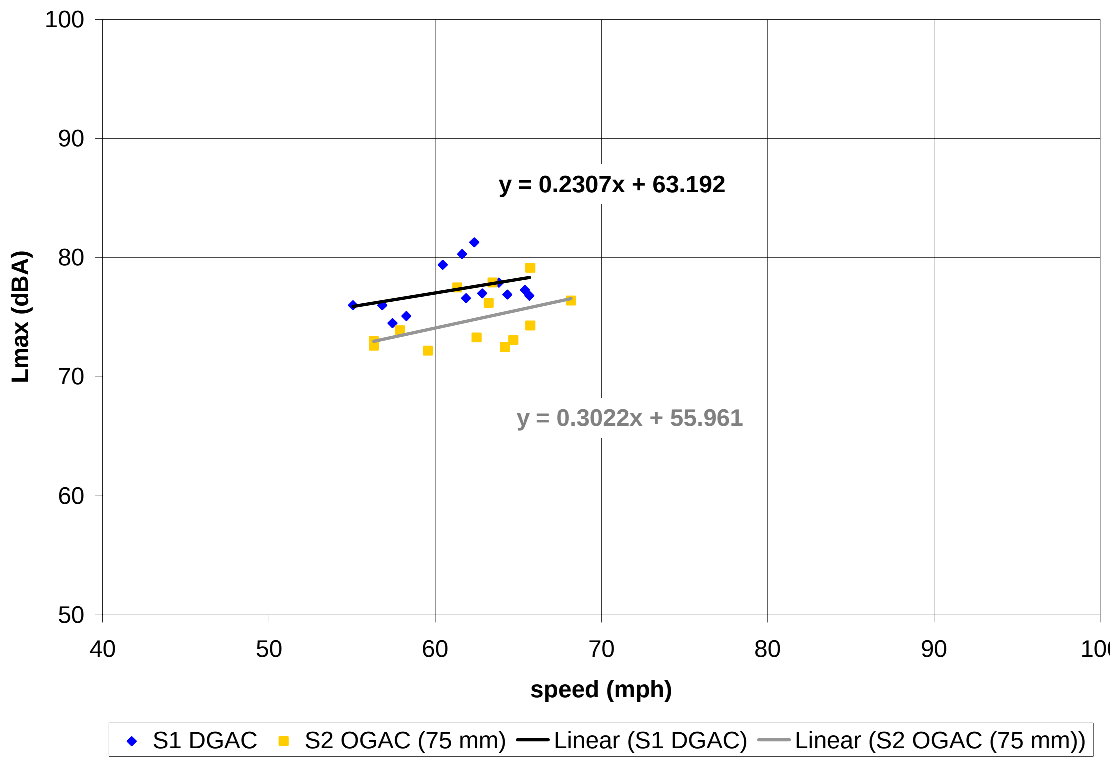


Figure C-14. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1944x + 60.329
y = 0.1621x + 58.588
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2307x + 63.192
y = 0.3022x + 55.961
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

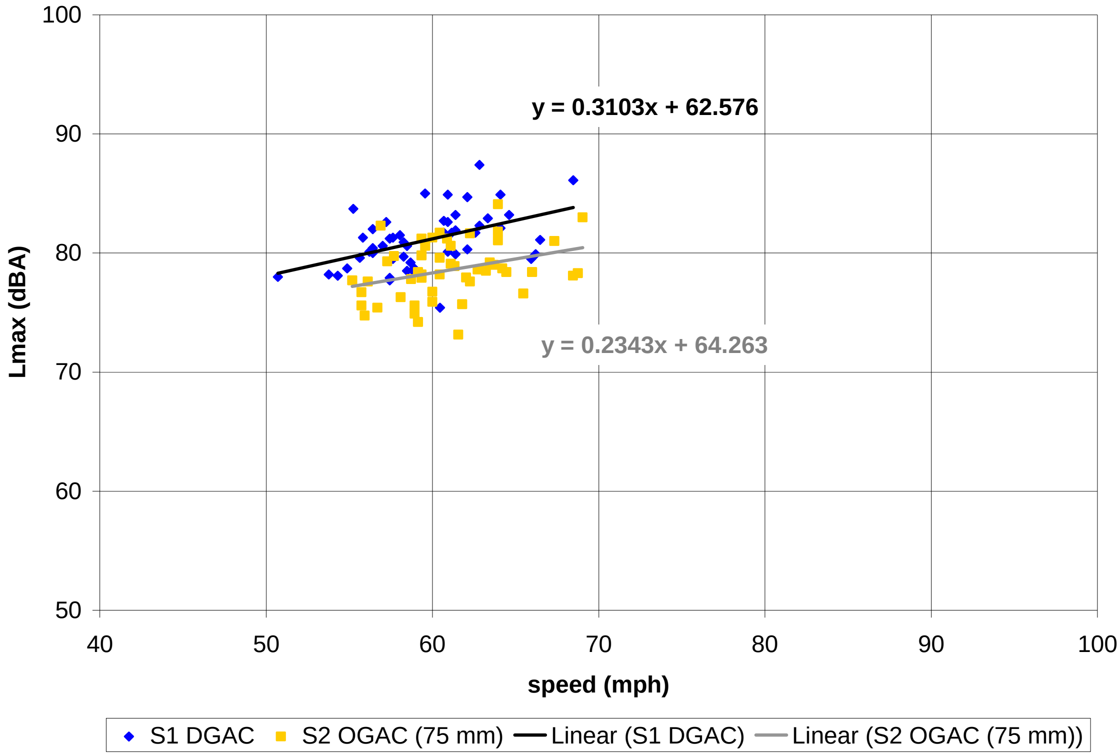
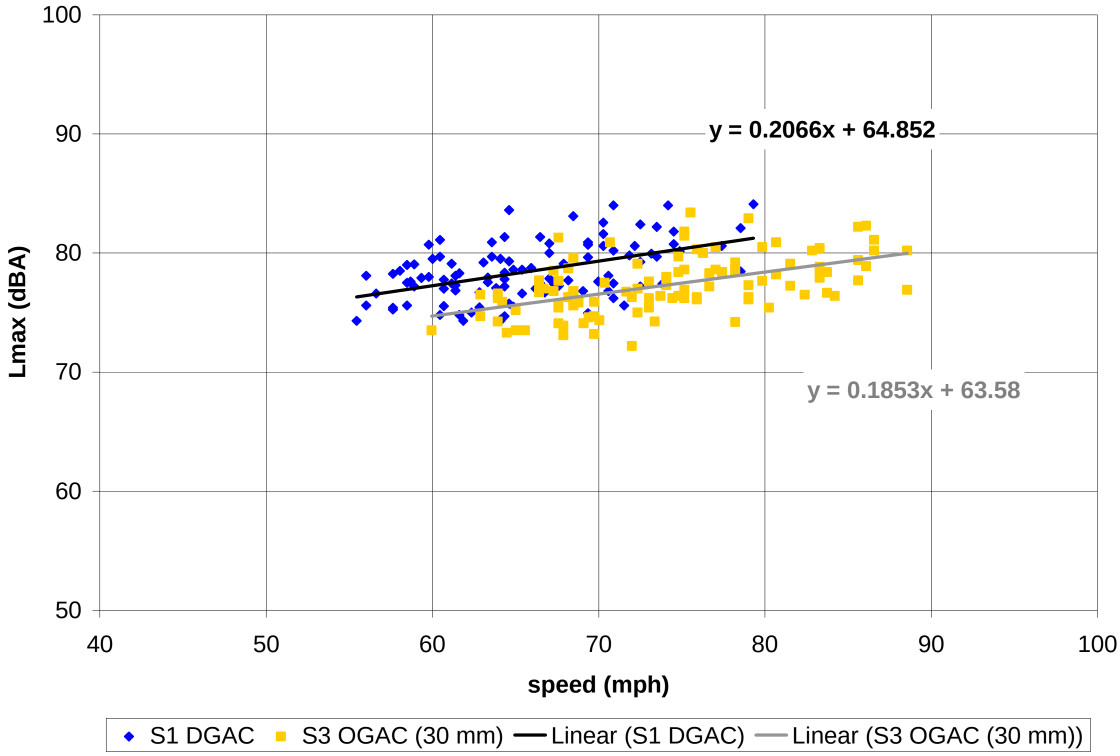
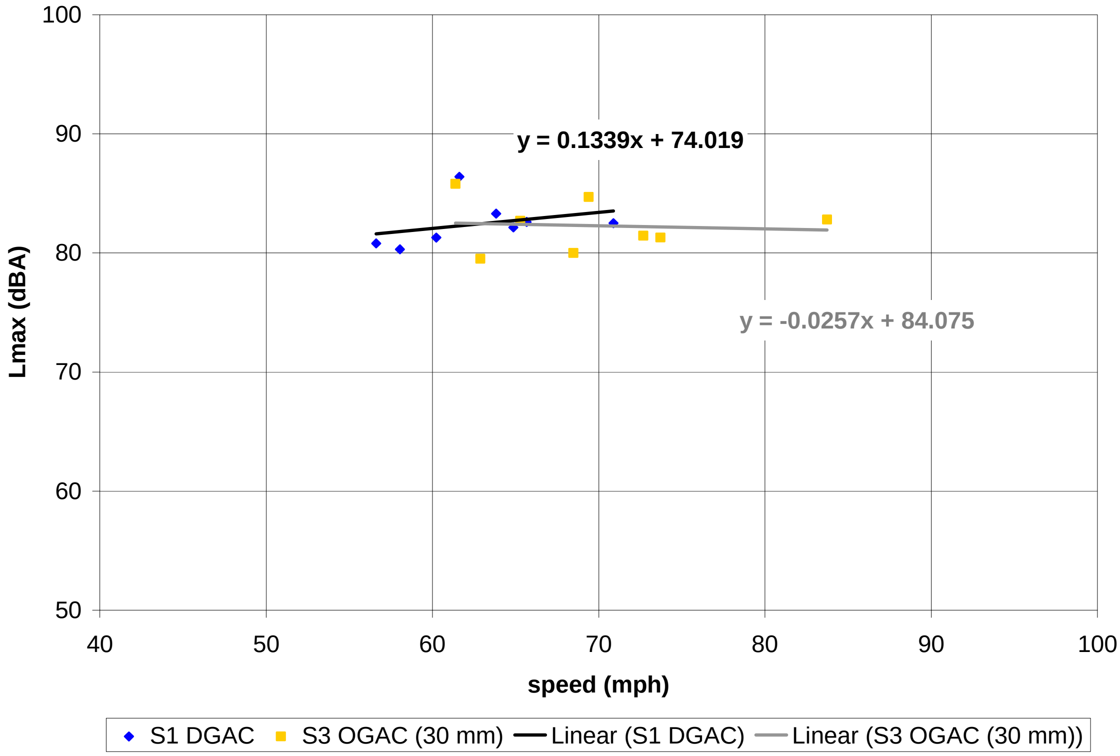


Figure C-15. Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2066x + 64.852
y = 0.1853x + 63.58
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1339x + 74.019
y = -0.0257x + 84.075
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

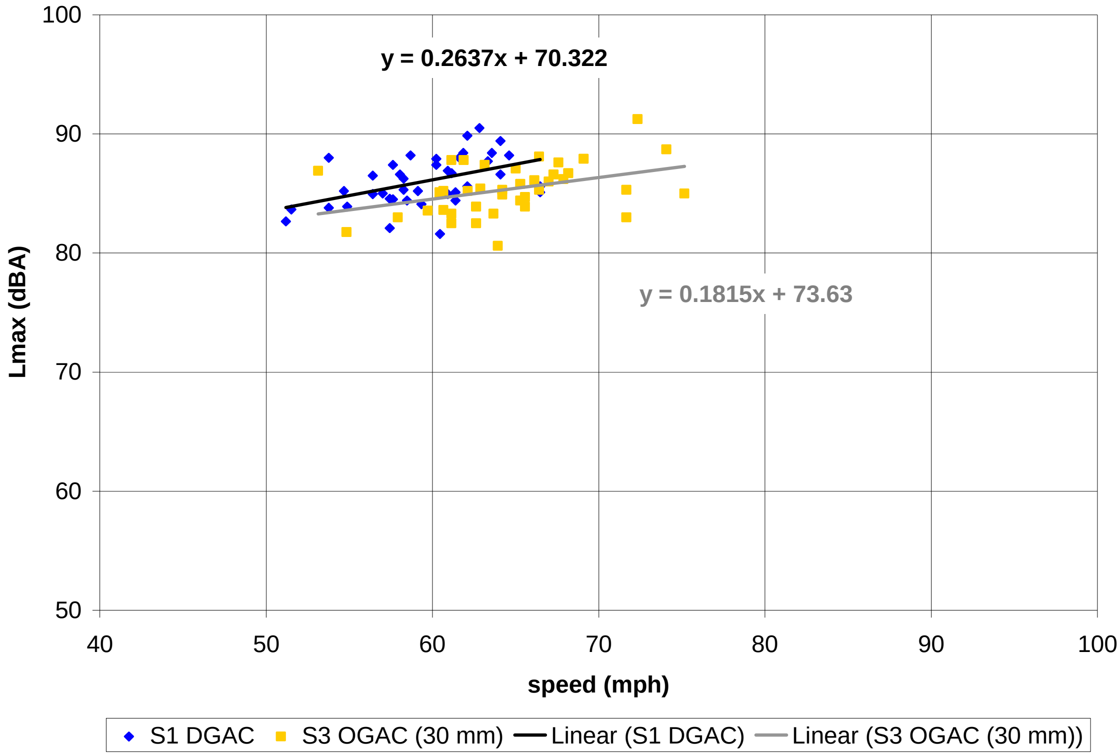
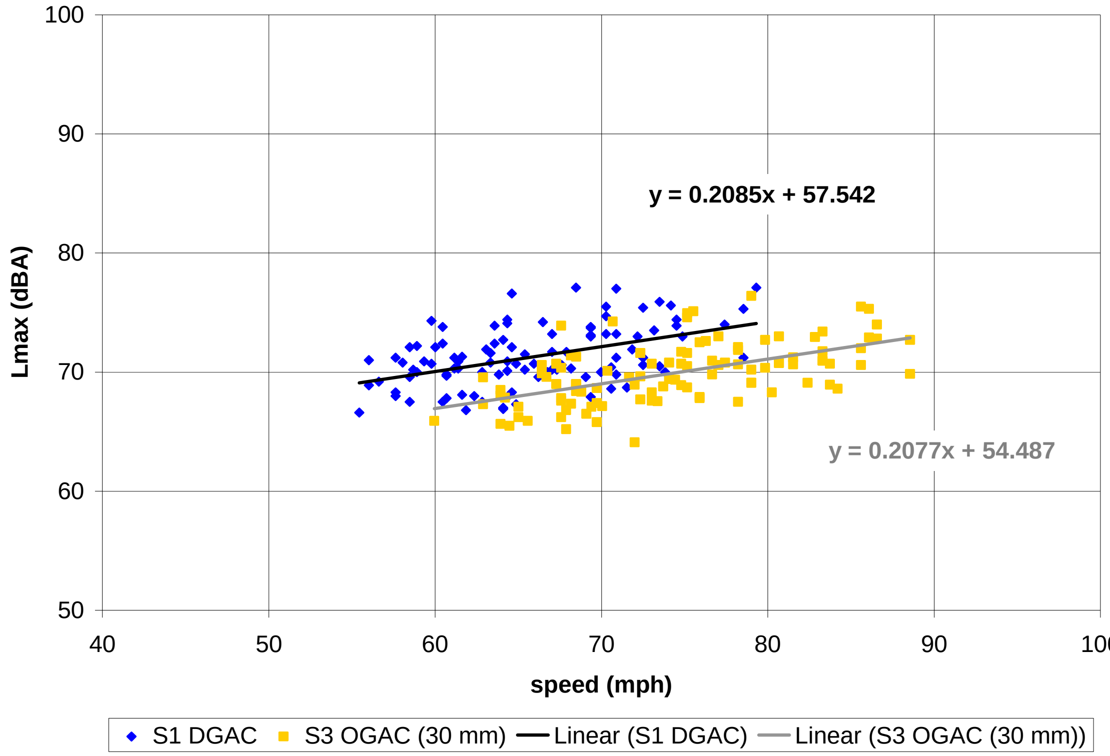
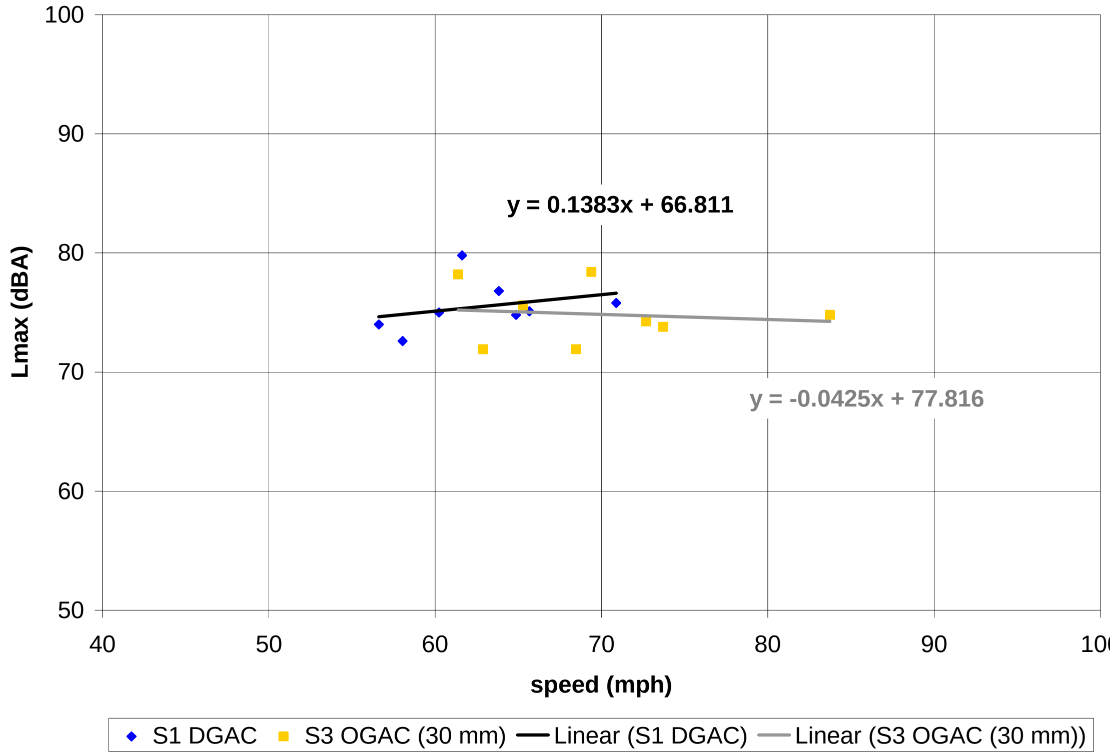


Figure C-16. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2085x + 57.542
y = 0.2077x + 54.487
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1383x + 66.811
y = -0.0425x + 77.816
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

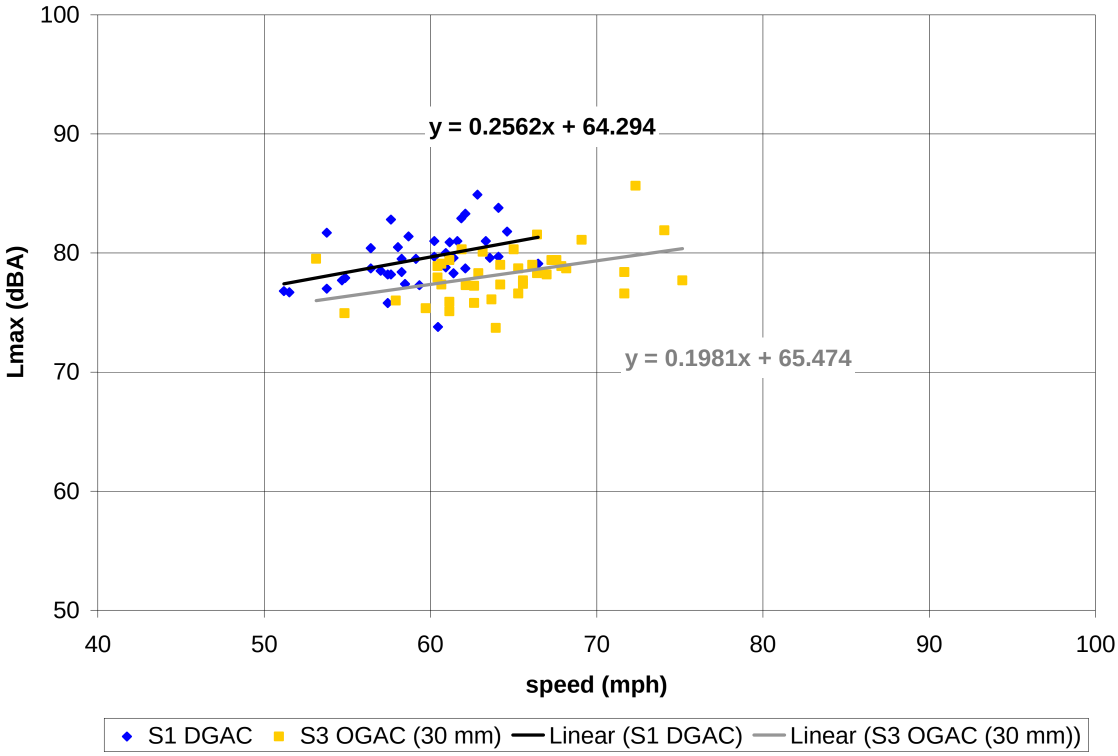
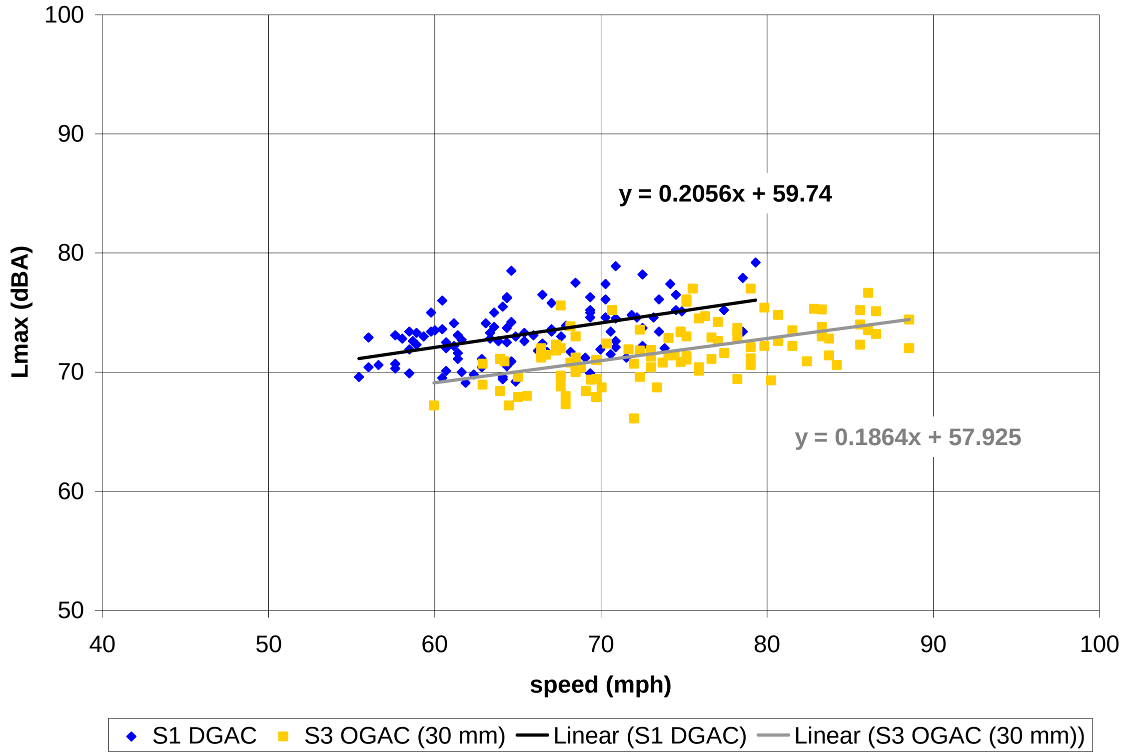
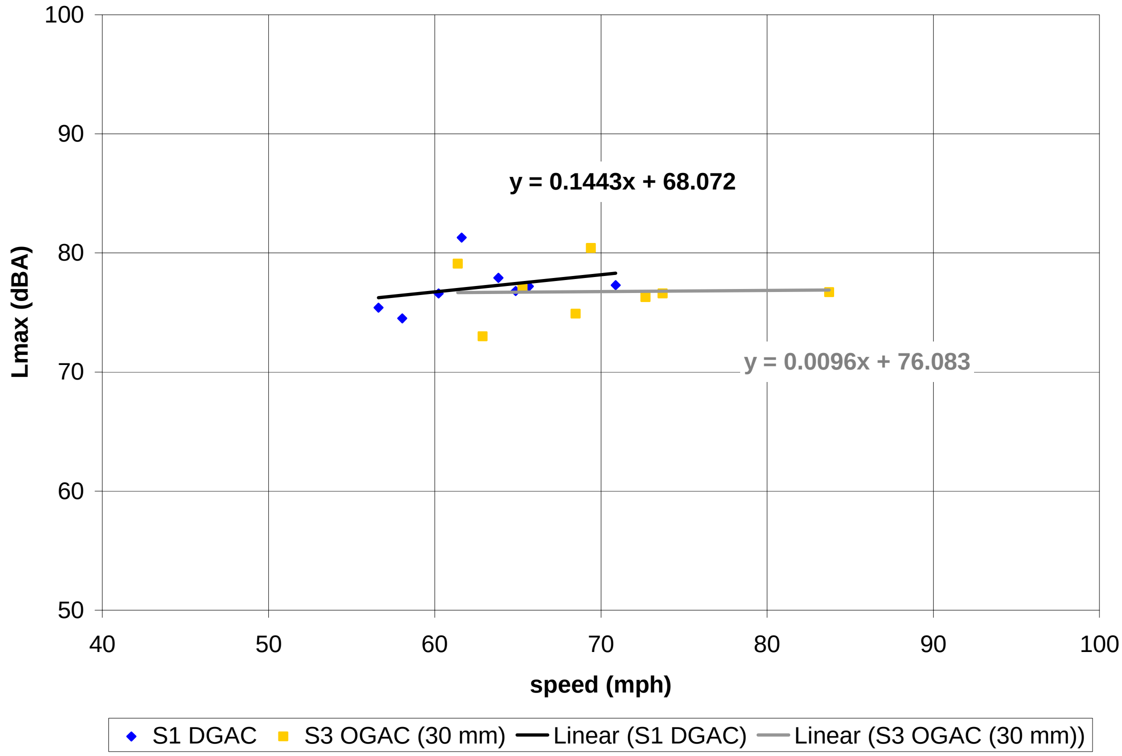


Figure C-17. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2056x + 59.74
y = 0.1864x + 57.925
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1443x + 68.072
y = 0.0096x + 76.083
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

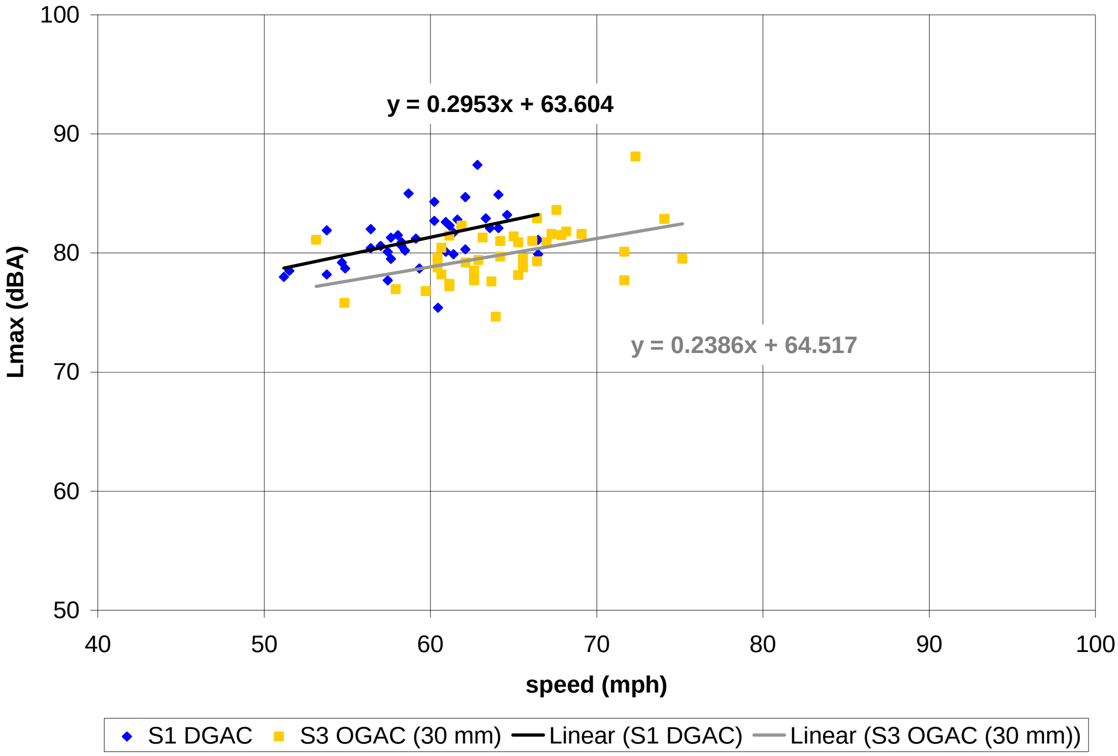
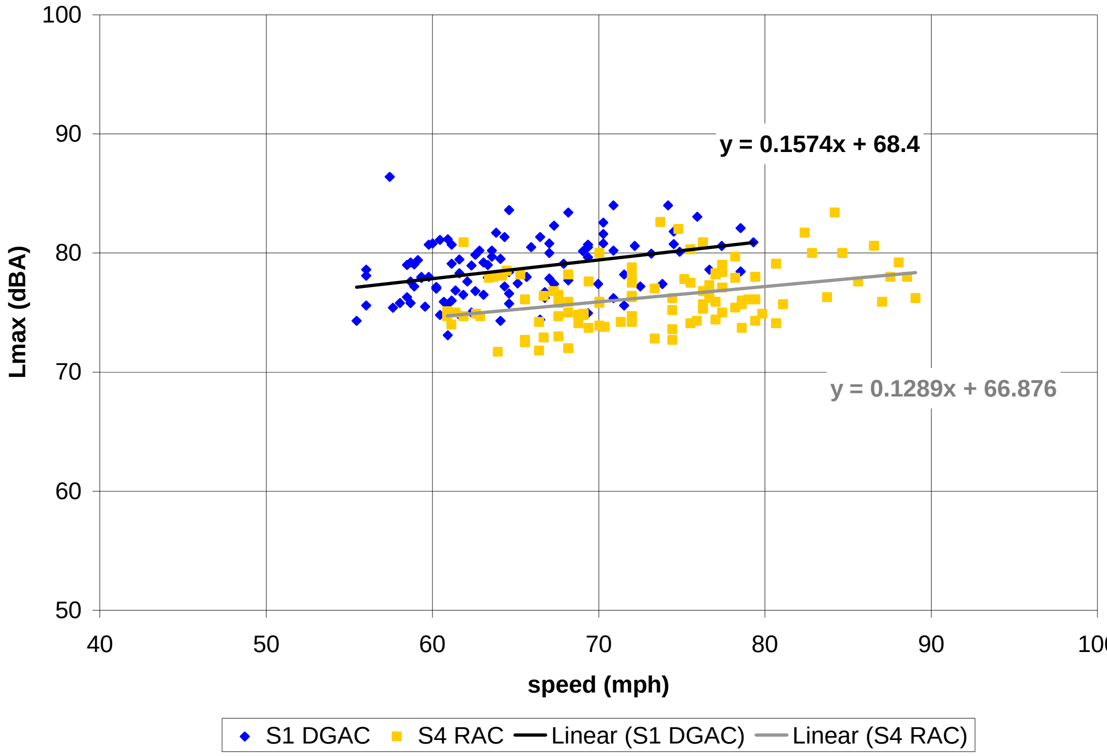
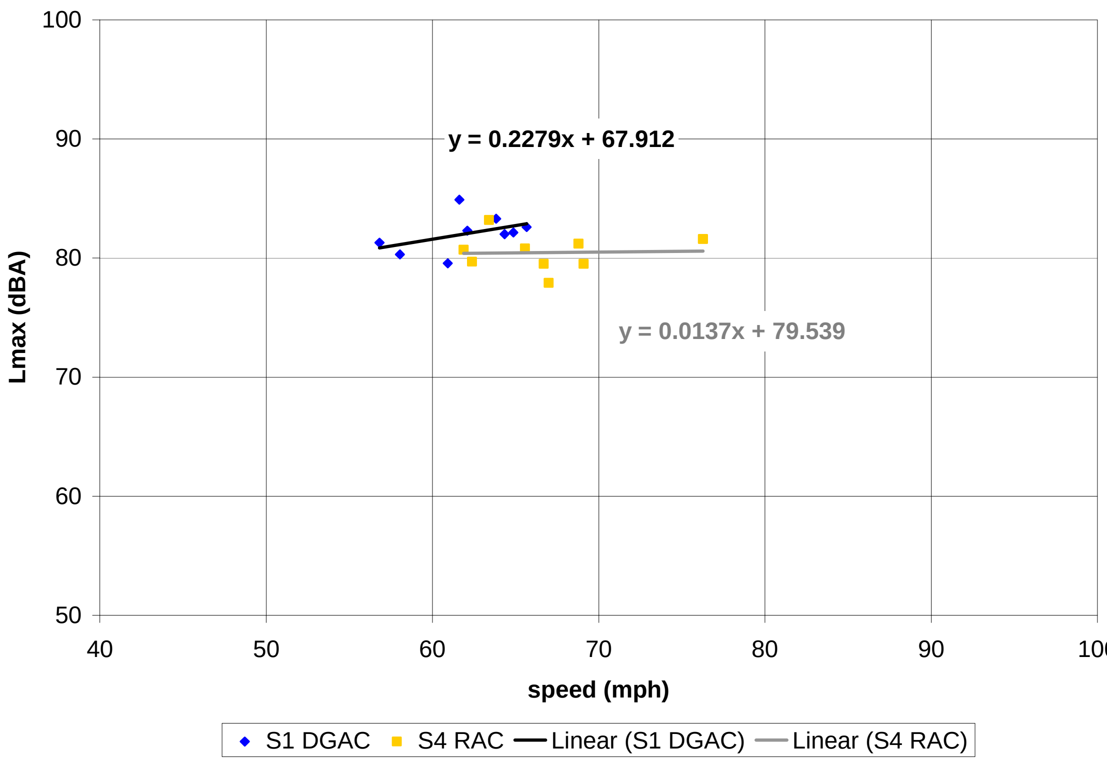


Figure C-18. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1574x + 68.4
y = 0.1289x + 66.876
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2279x + 67.912
y = 0.0137x + 79.539
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

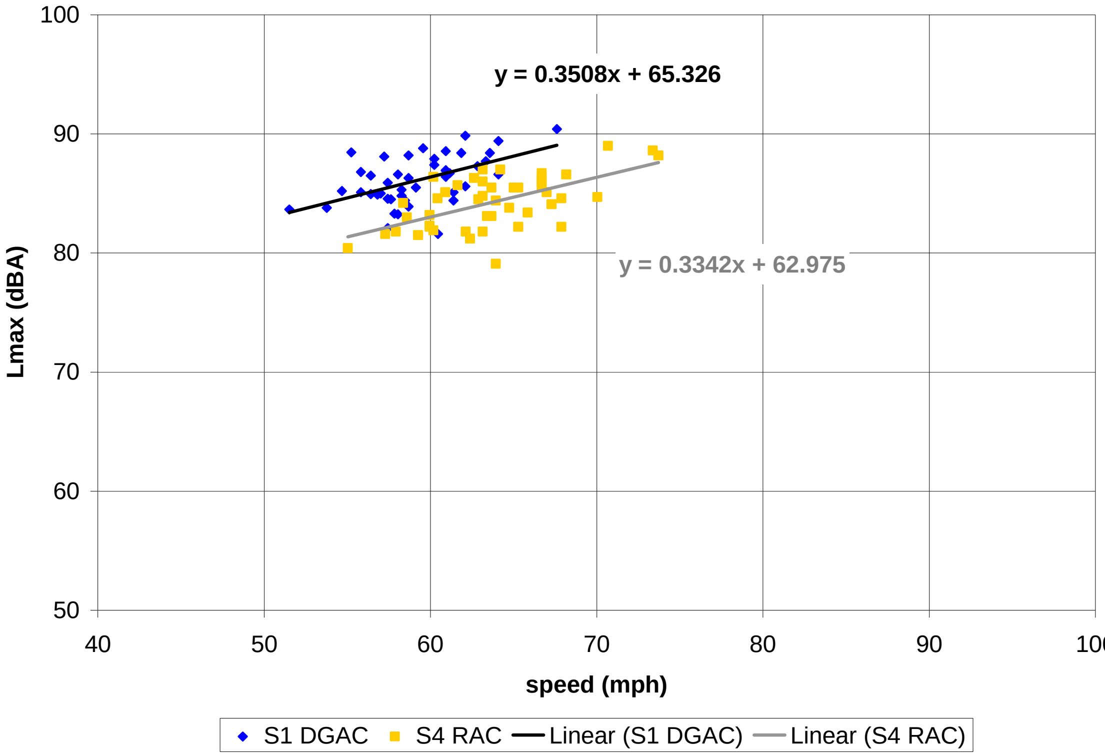
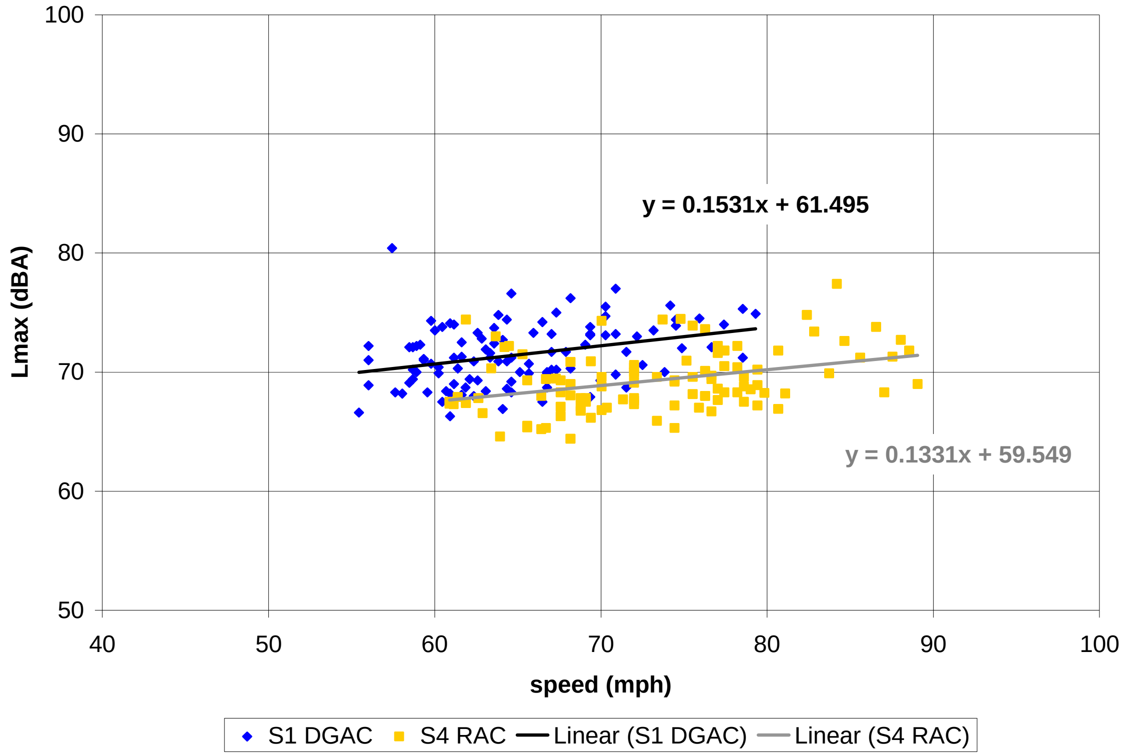
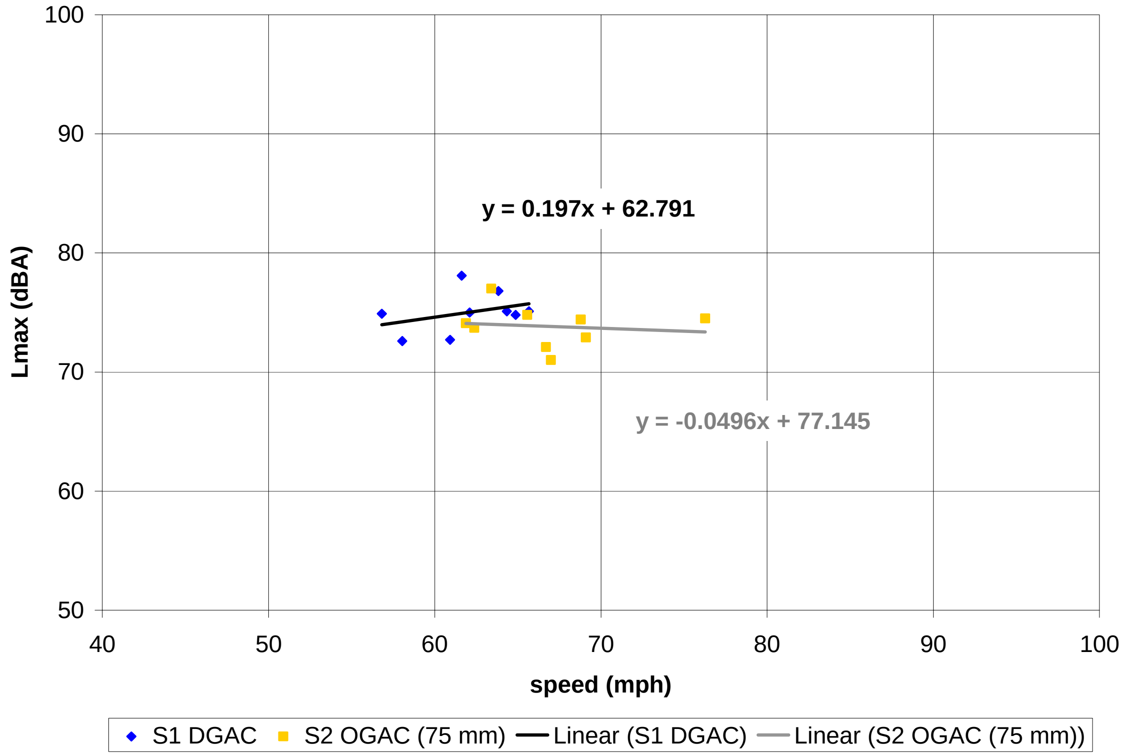


Figure C-19. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



y = 0.1531x + 61.495
y = 0.1331x + 59.549
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



y = 0.197x + 62.791
y = -0.0496x + 77.145
Lmax (dBA)
speed (mph)
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

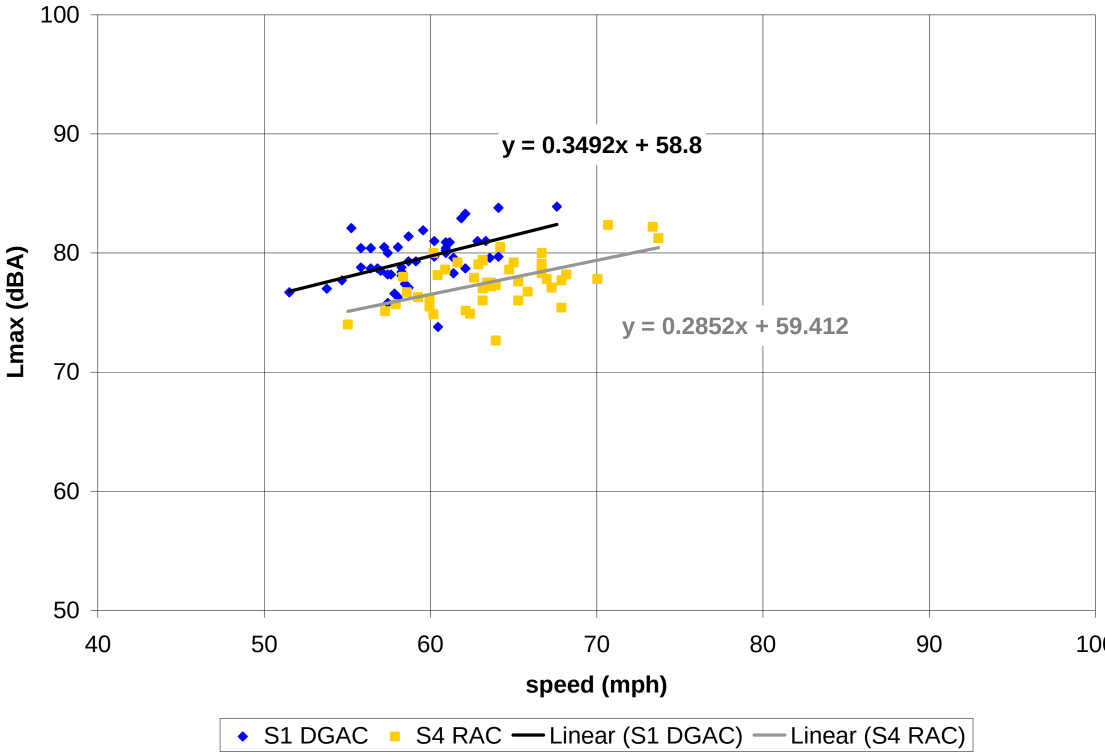
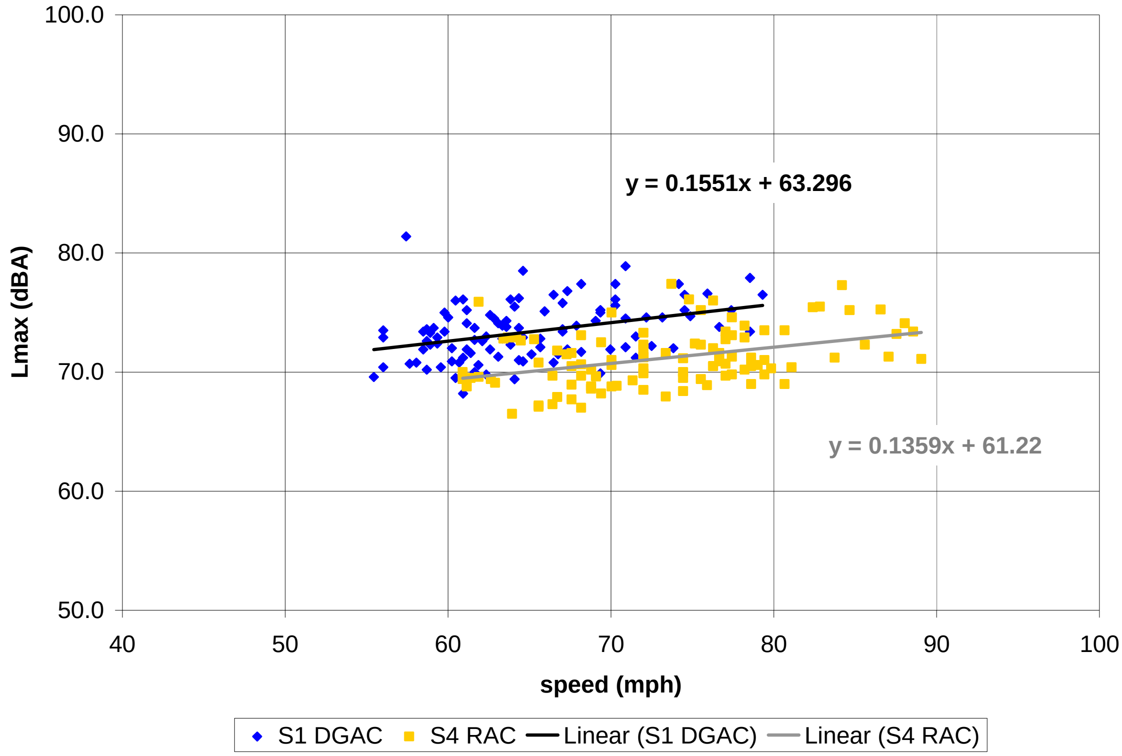
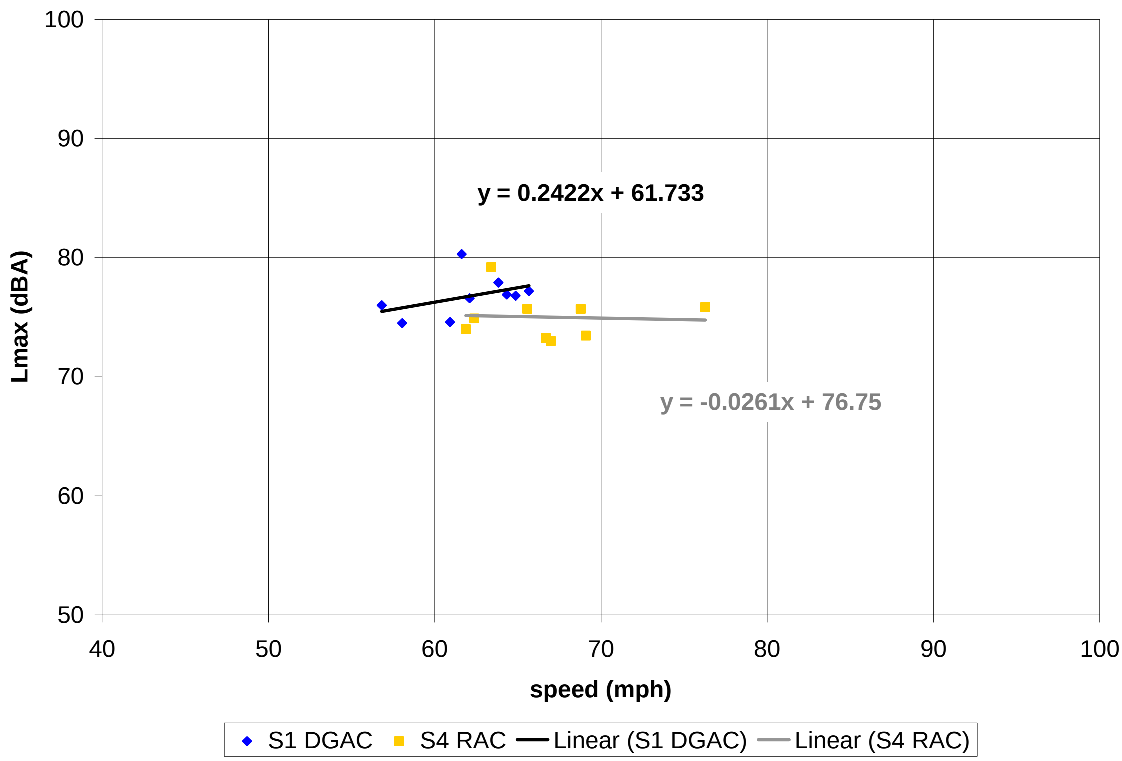


Figure C-20. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



y = 0.1551x + 63.296
y = 0.1359x + 61.22
Lmax (dBA)
100.0
90.0
80.0
70.0
60.0
50.0
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



y = 0.2422x + 61.733
y = -0.0261x + 76.75
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

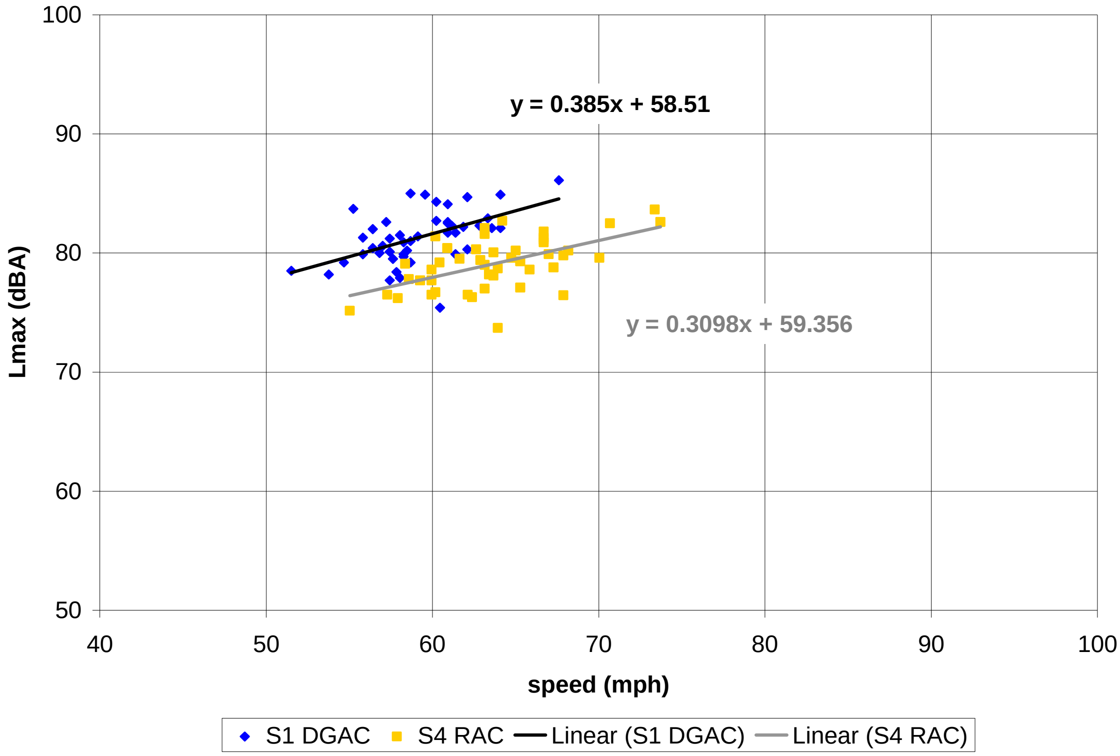
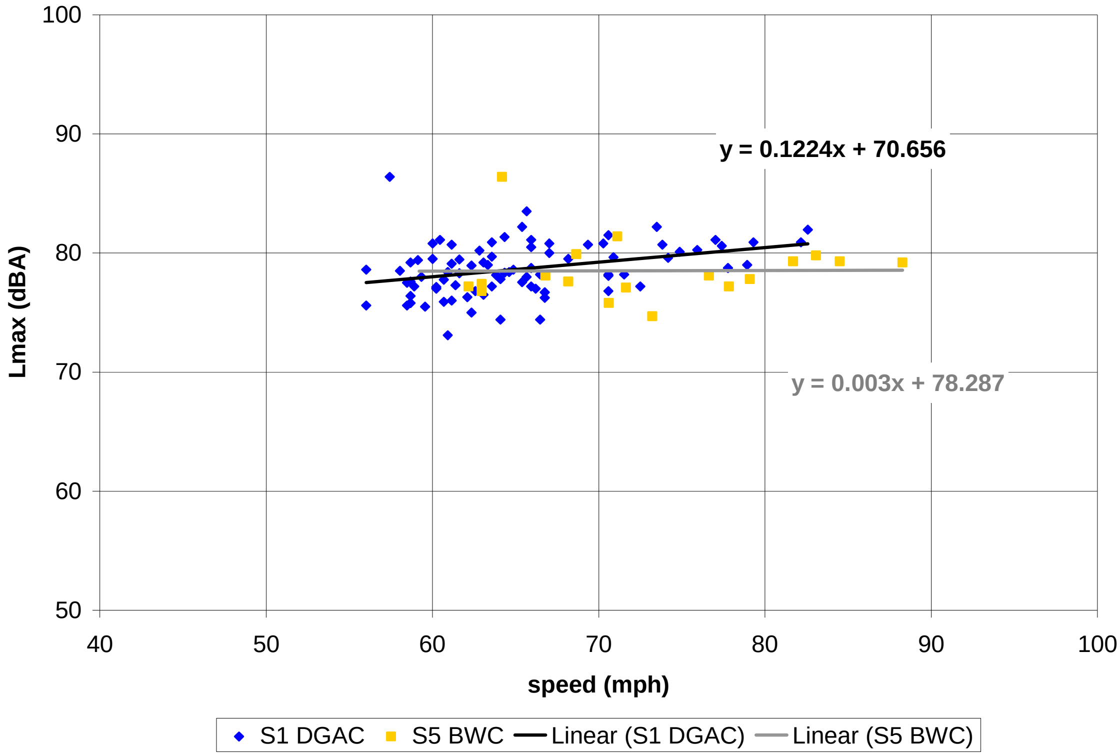
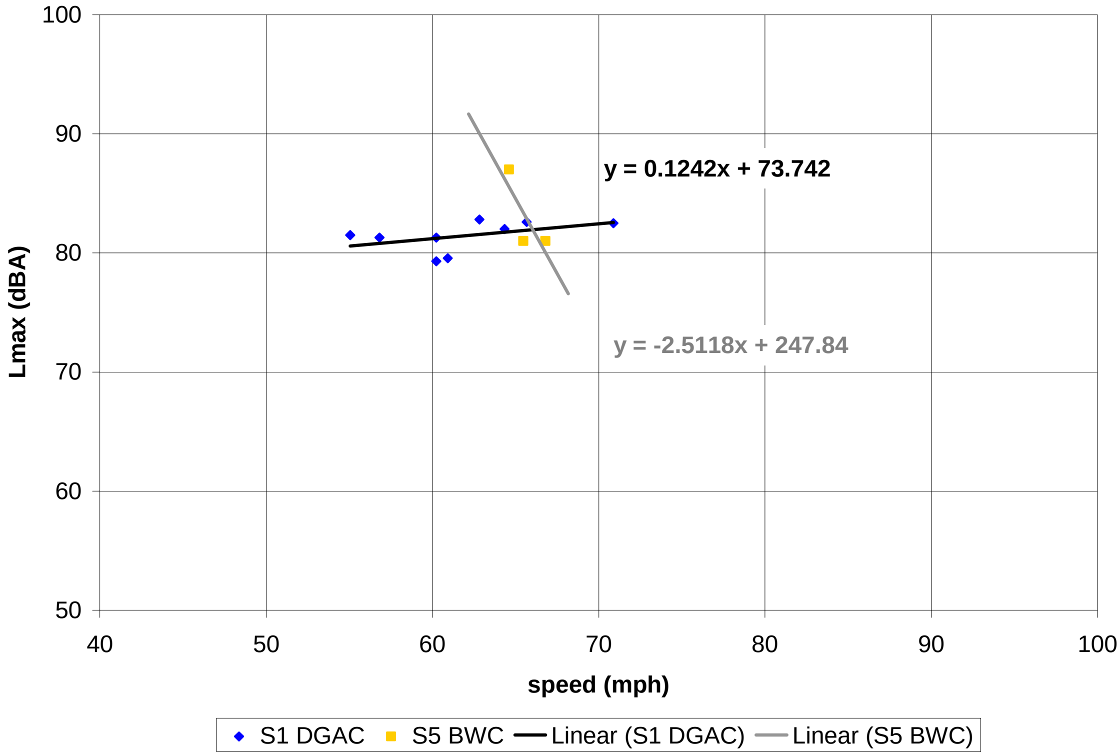


Figure C-21. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1224x + 70.656
y = 0.003x + 78.287
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1242x + 73.742
y = -2.5118x + 247.84
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

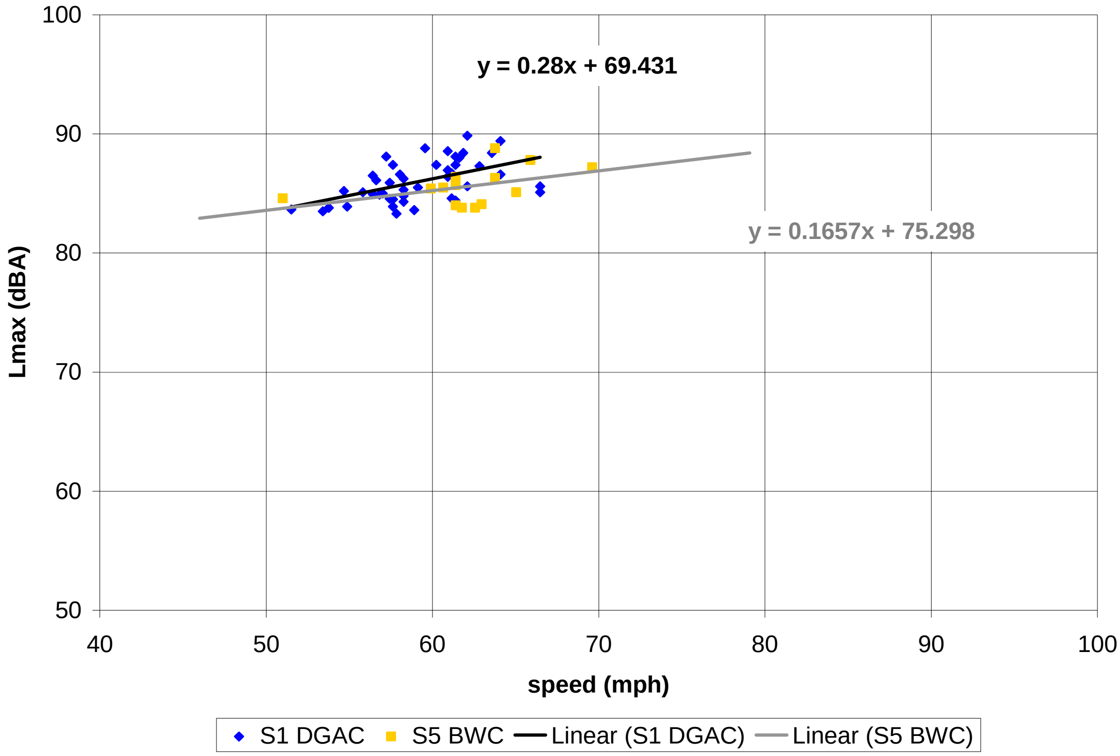
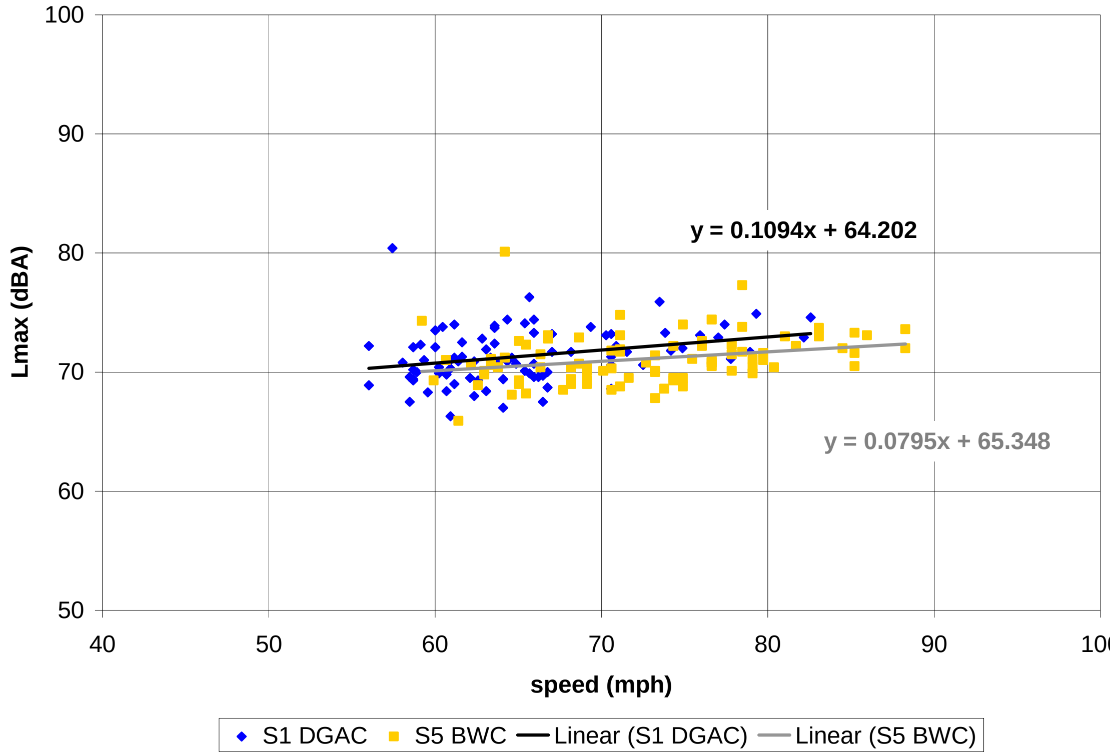
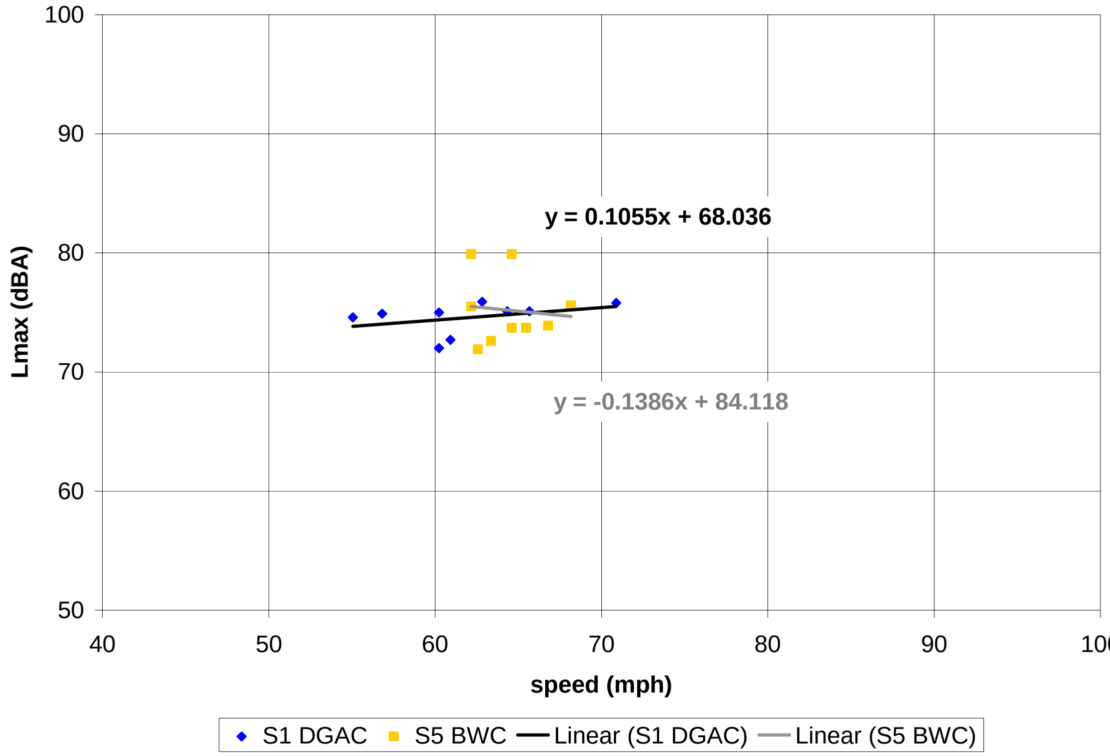


Figure C-22. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1094x + 64.202
y = 0.0795x + 65.348
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1055x + 68.036
y = -0.1386x + 84.118
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

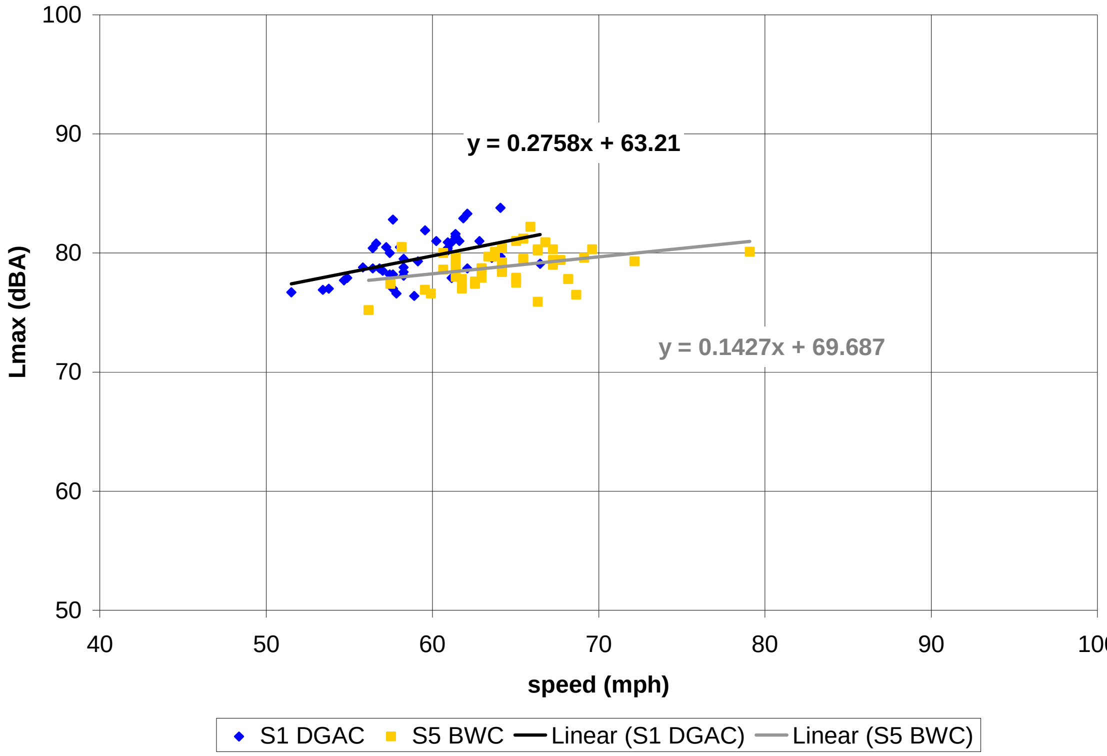
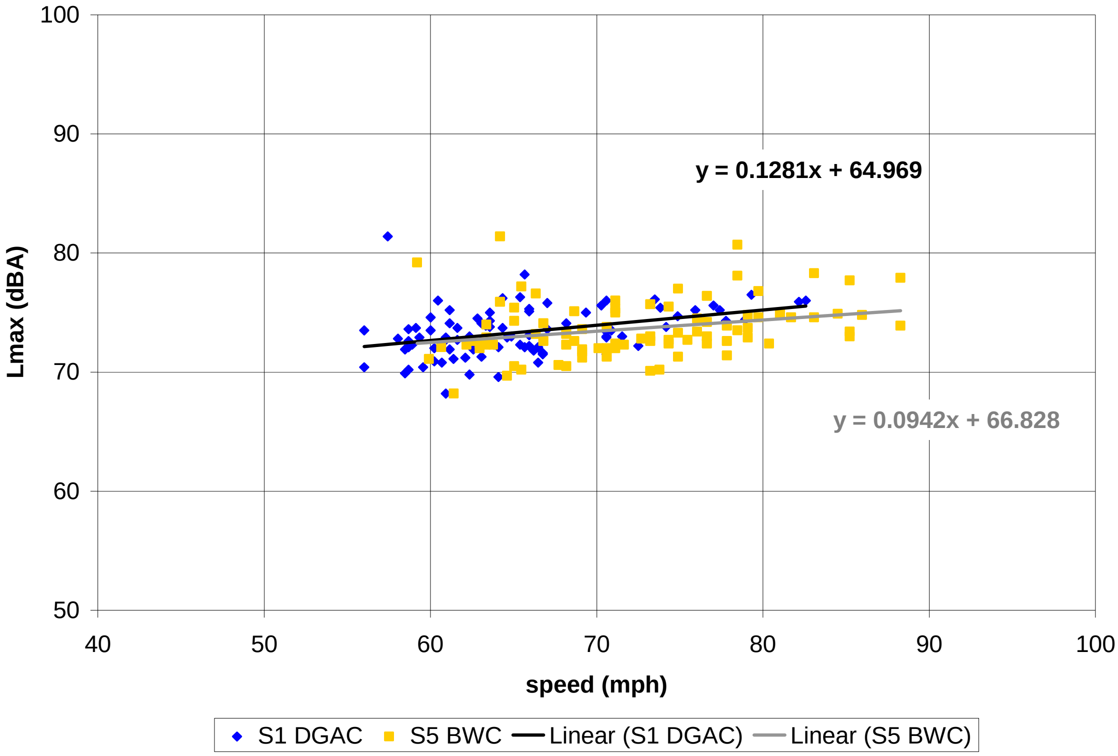
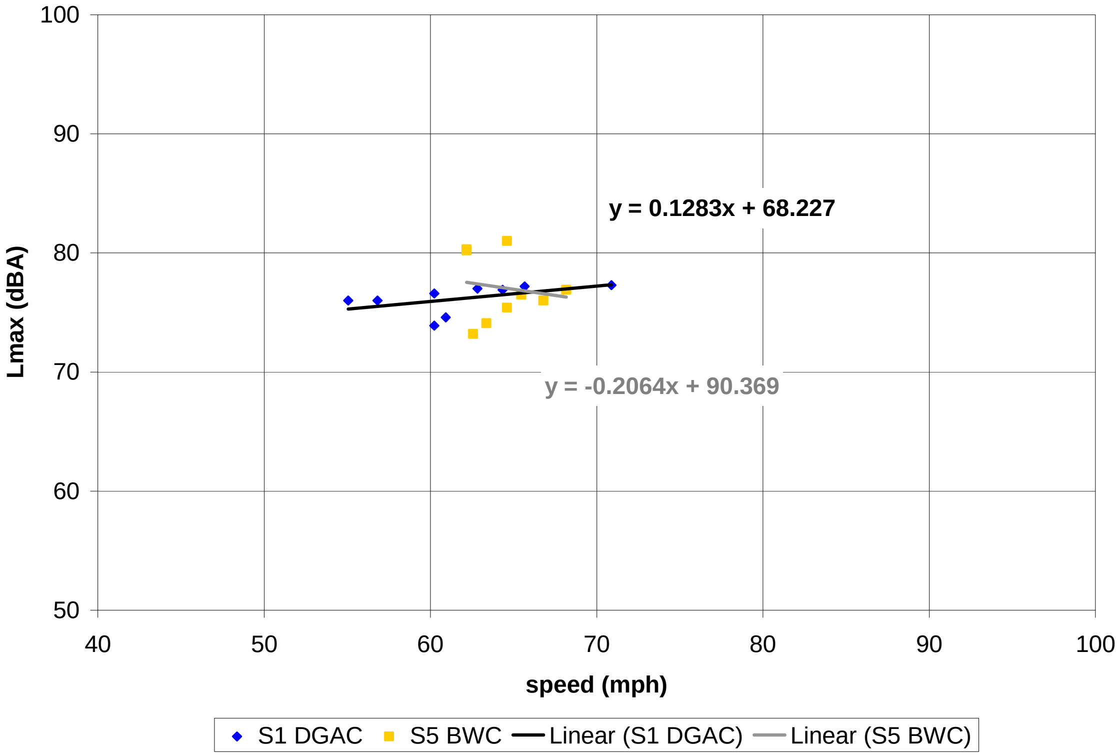


Figure C-23. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


y = 0.1281x + 64.969
y = 0.0942x + 66.828
Lmax (dBA)
speed (mph)
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


y = 0.1283x + 68.227
y = -0.2064x + 90.369
Lmax (dBA)
speed (mph)
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

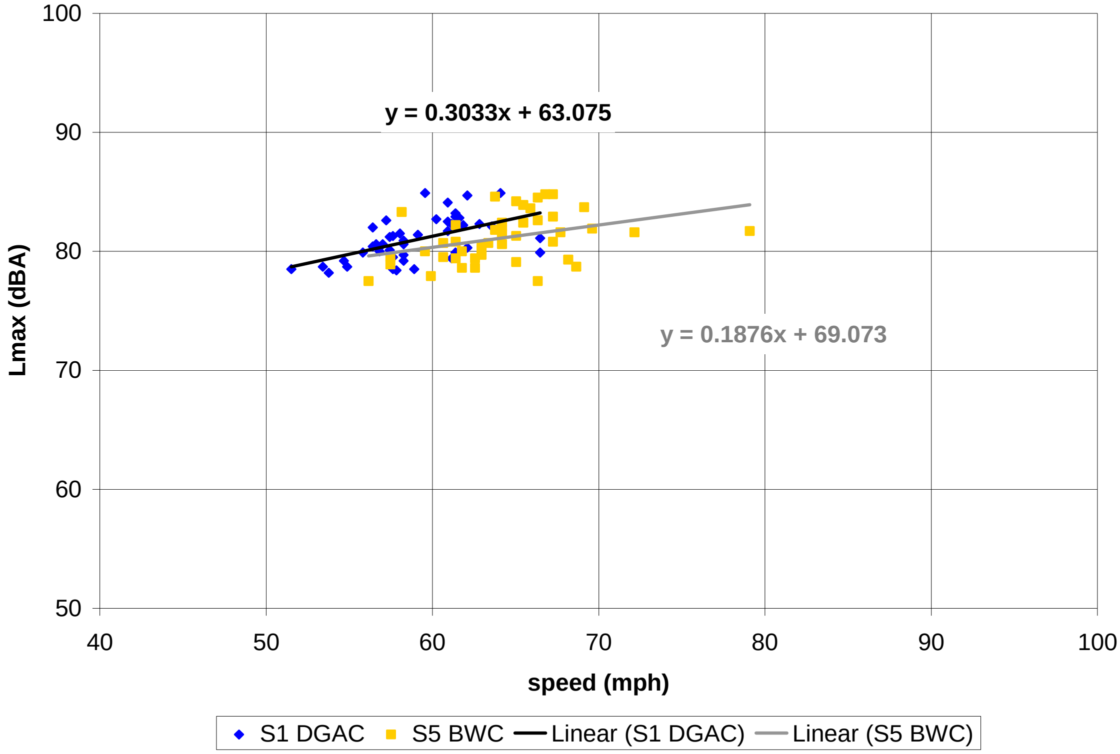
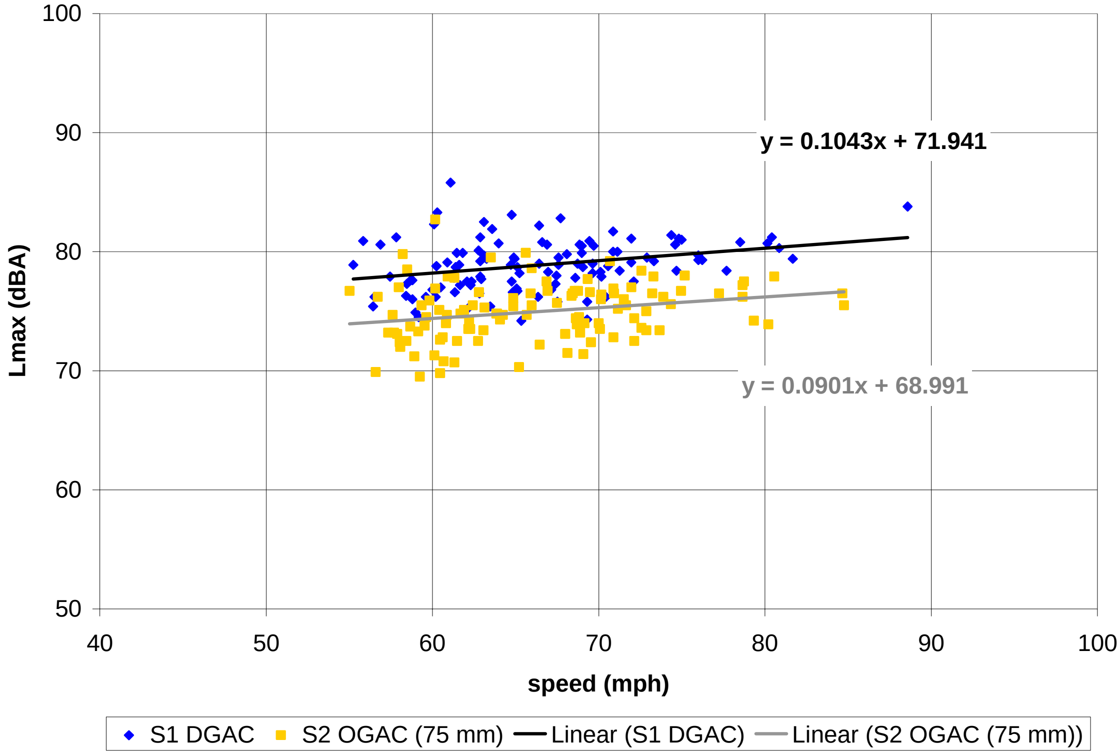
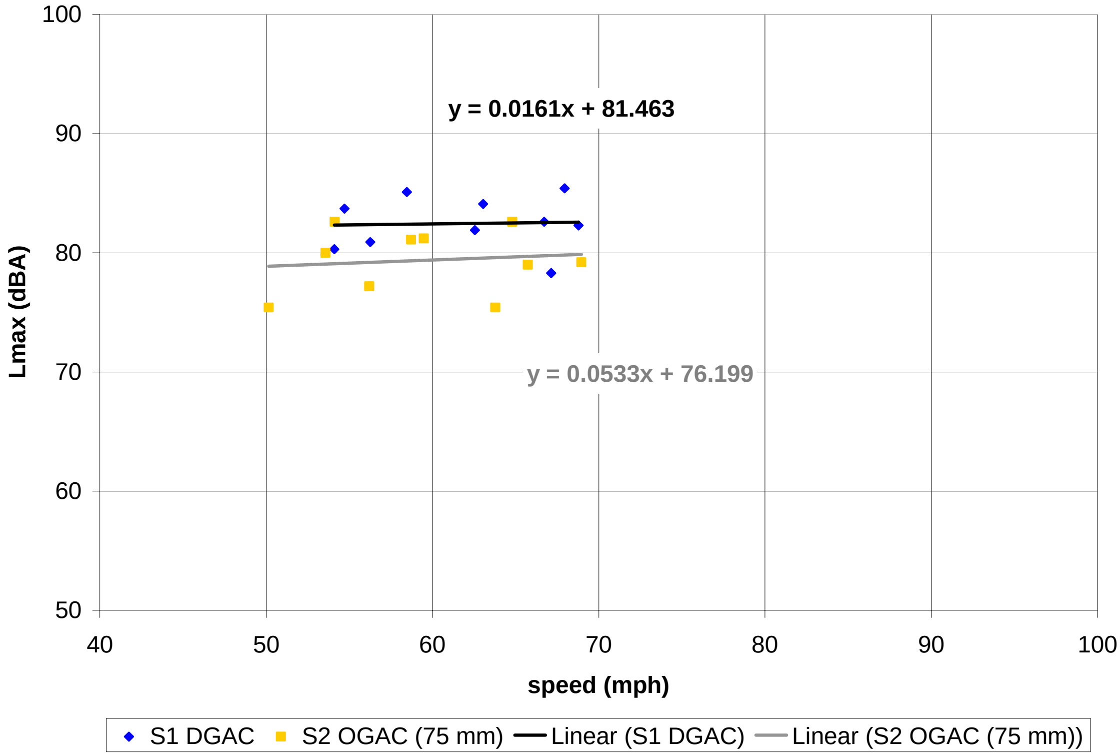


Figure C-24. (this and previous page) Vehicle pass-by data, post-overlay, 4 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.4 Post-Overlay – Pavement Age: 10 months





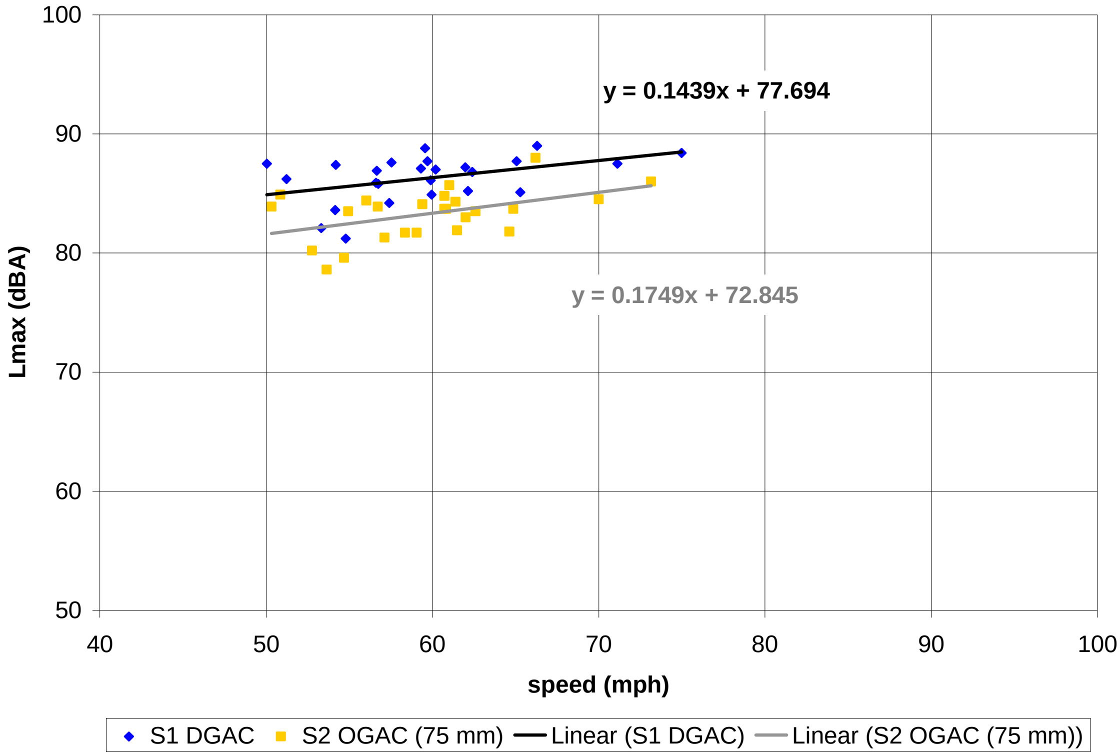
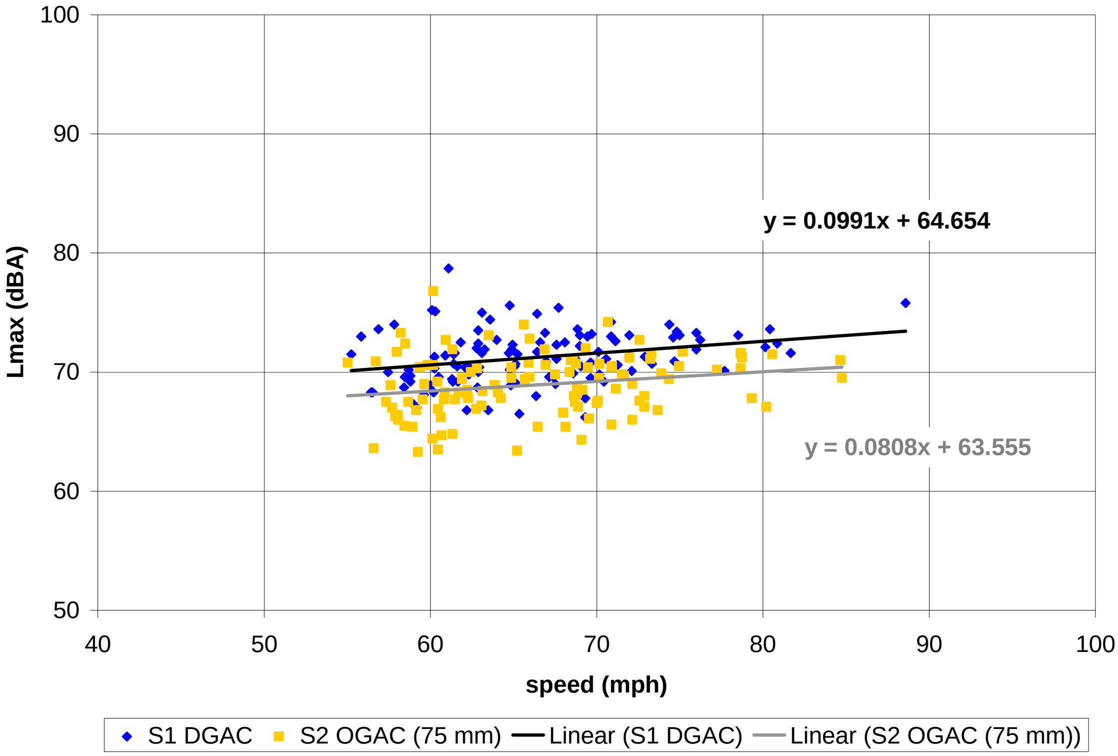
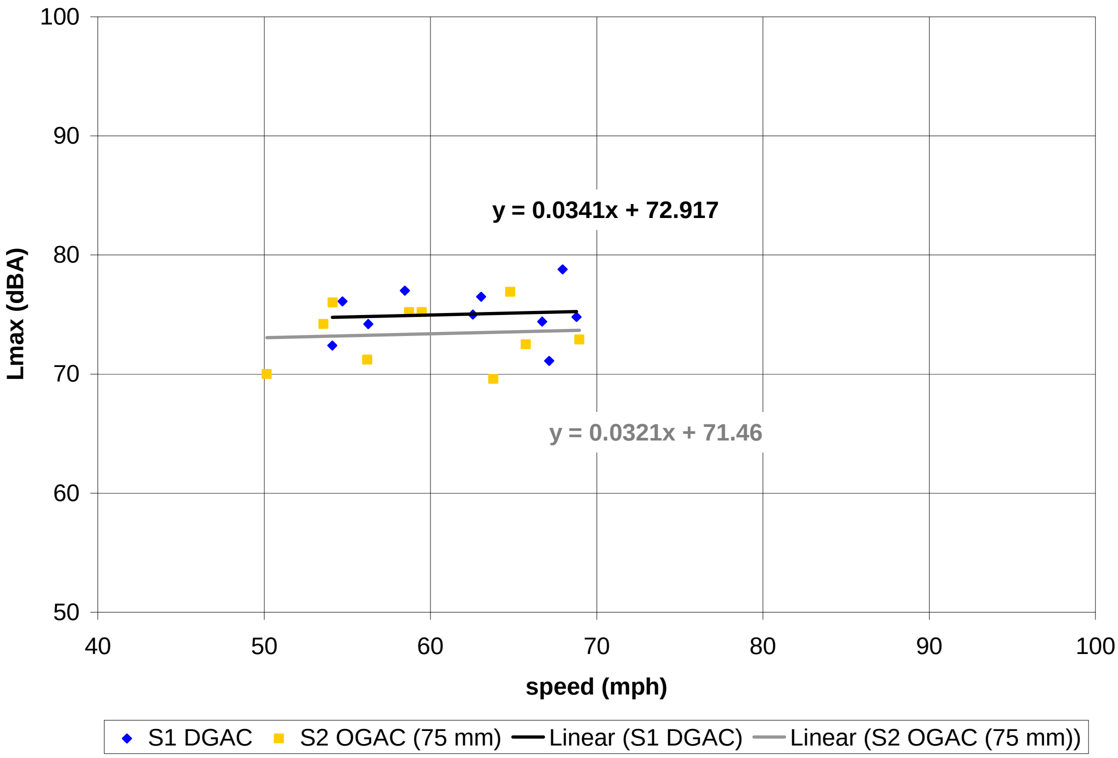


Figure C-25. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0991x + 64.654
y = 0.0808x + 63.555
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0341x + 72.917
y = 0.0321x + 71.46
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

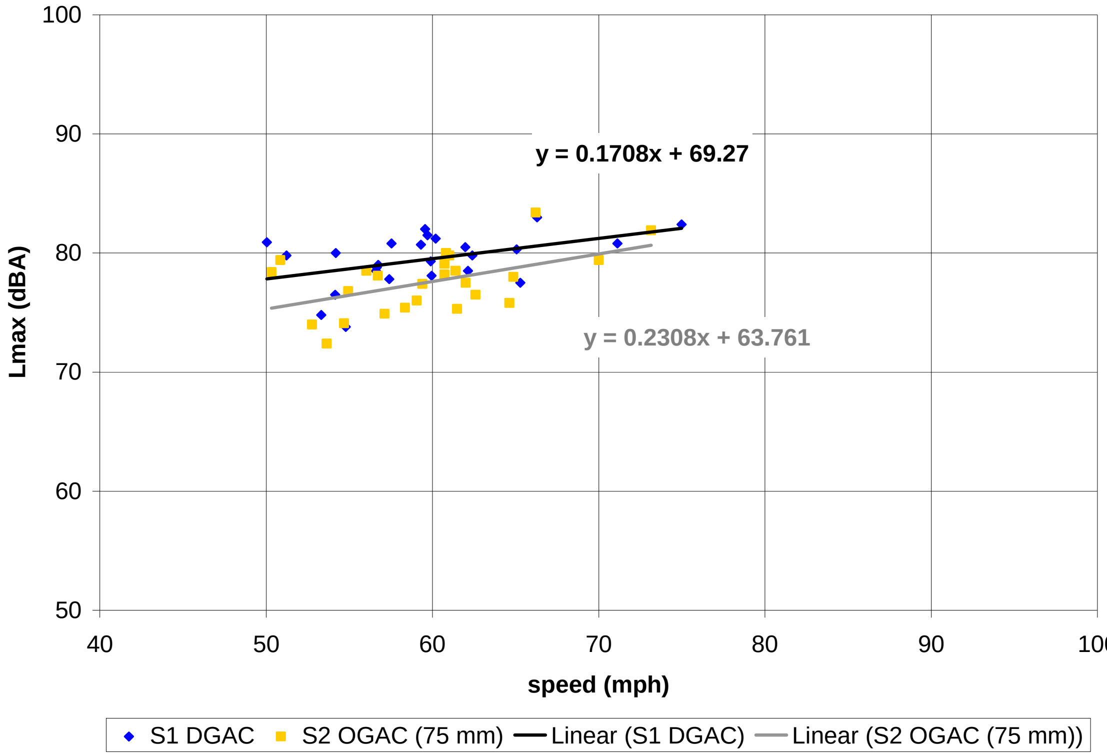
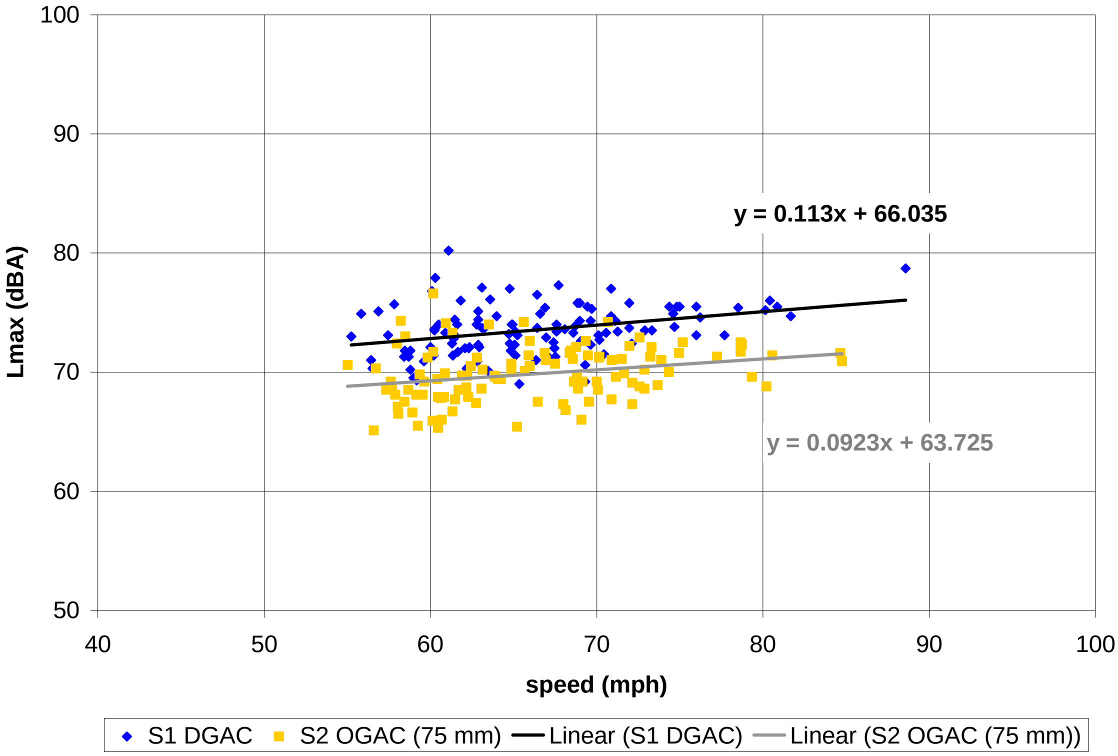
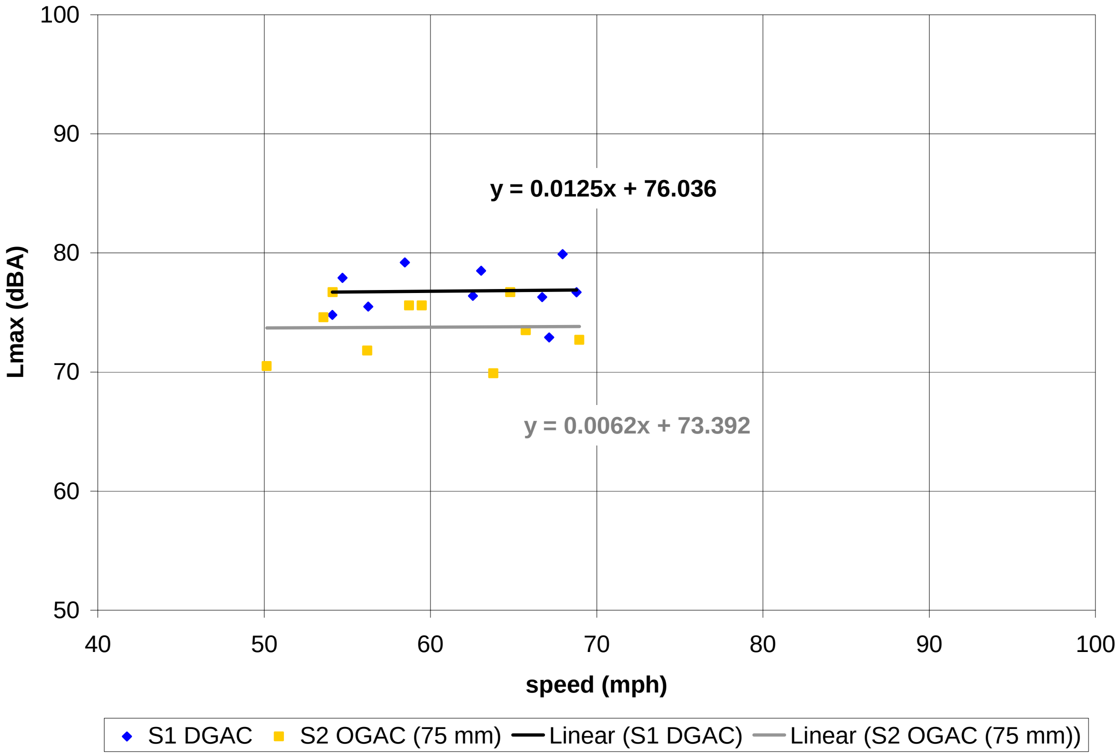


Figure C-26. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.113x + 66.035
y = 0.0923x + 63.725
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0125x + 76.036
y = 0.0062x + 73.392
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

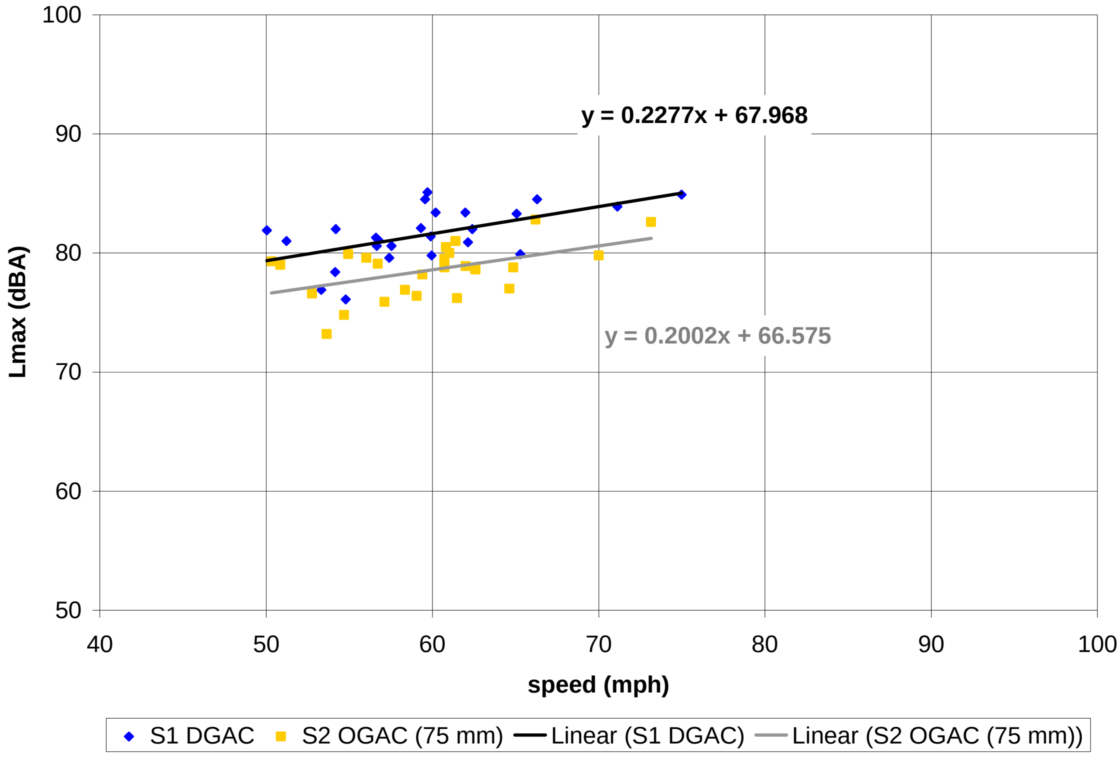
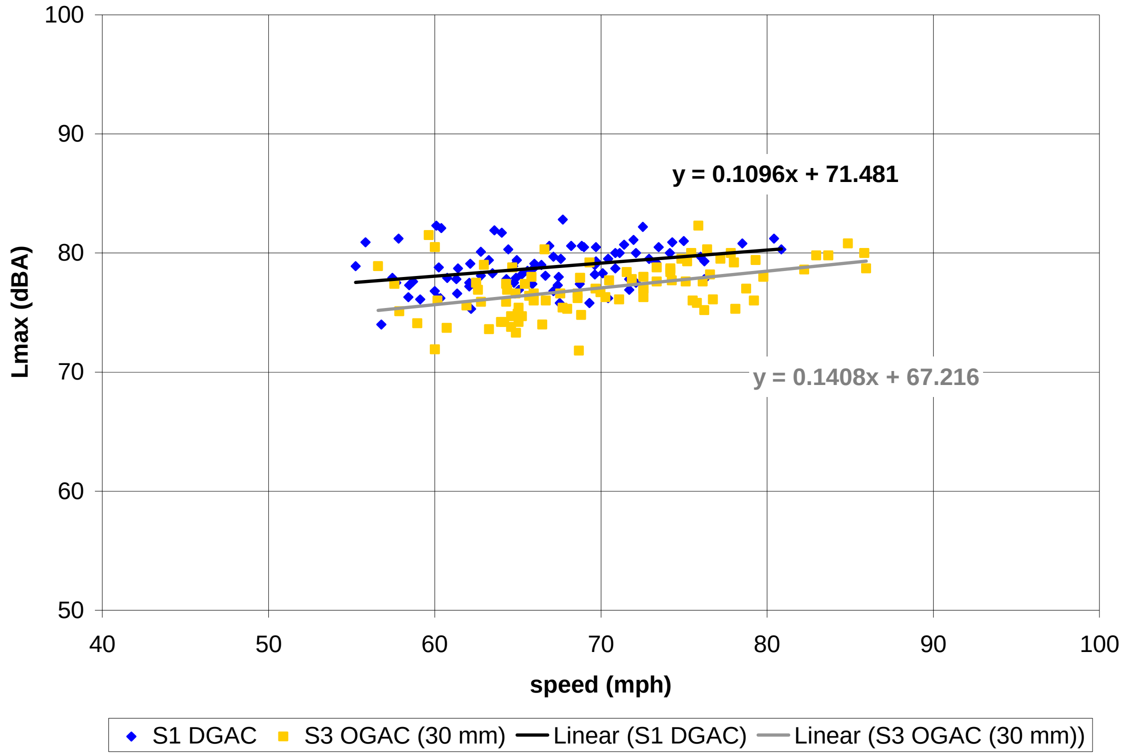
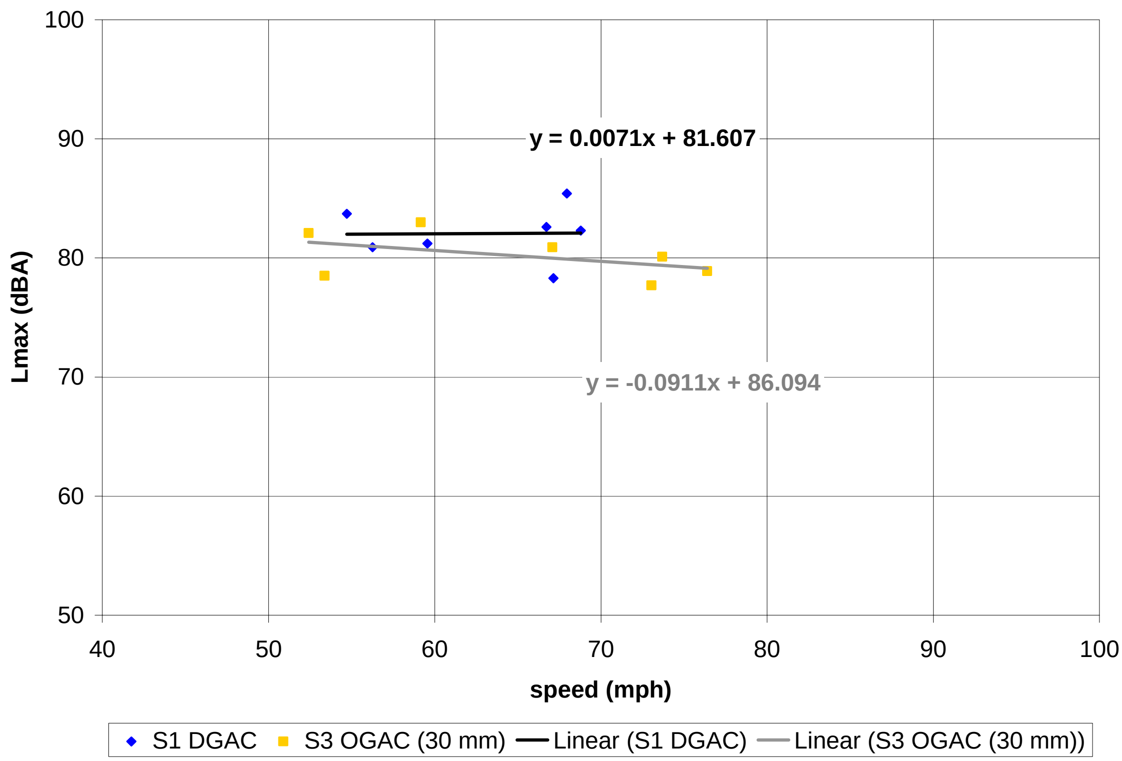


Figure C-27. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1096x + 71.481
y = 0.1408x + 67.216
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.0071x + 81.607
y = -0.0911x + 86.094
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

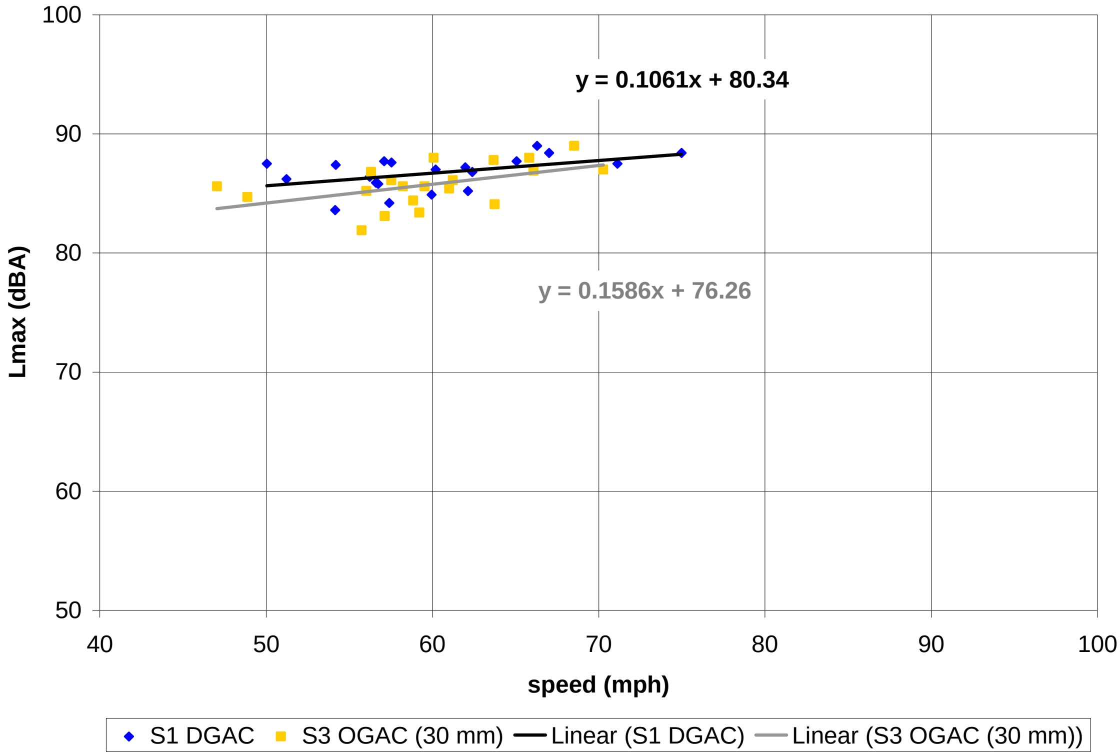
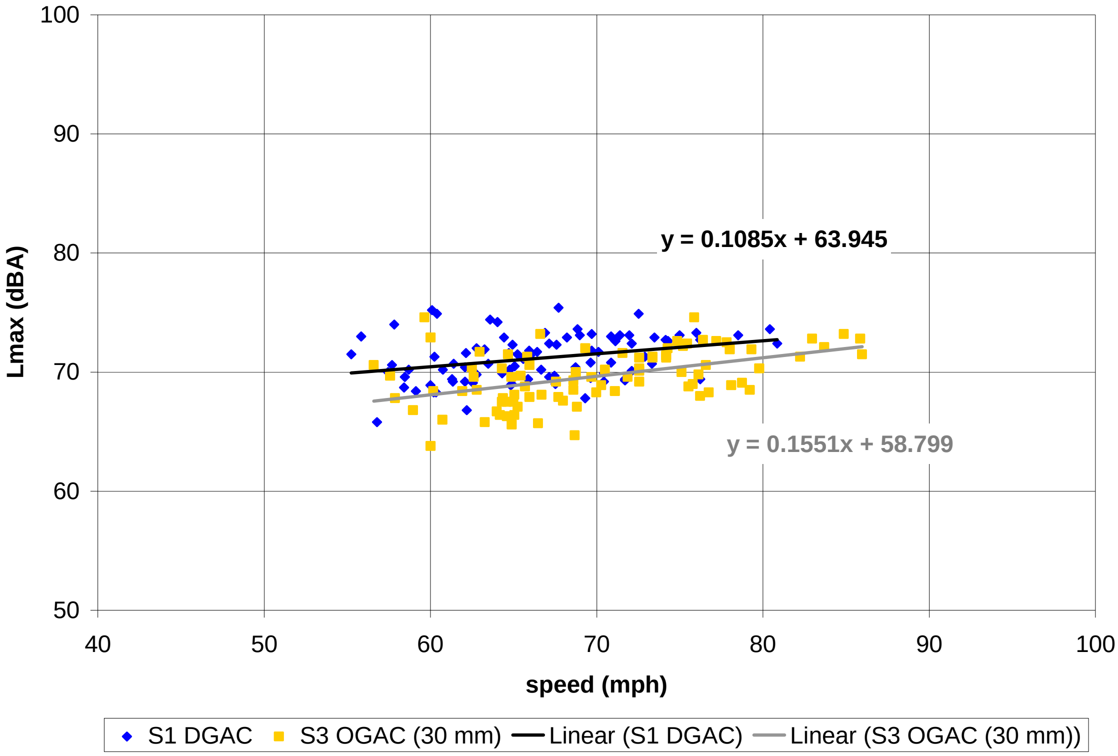
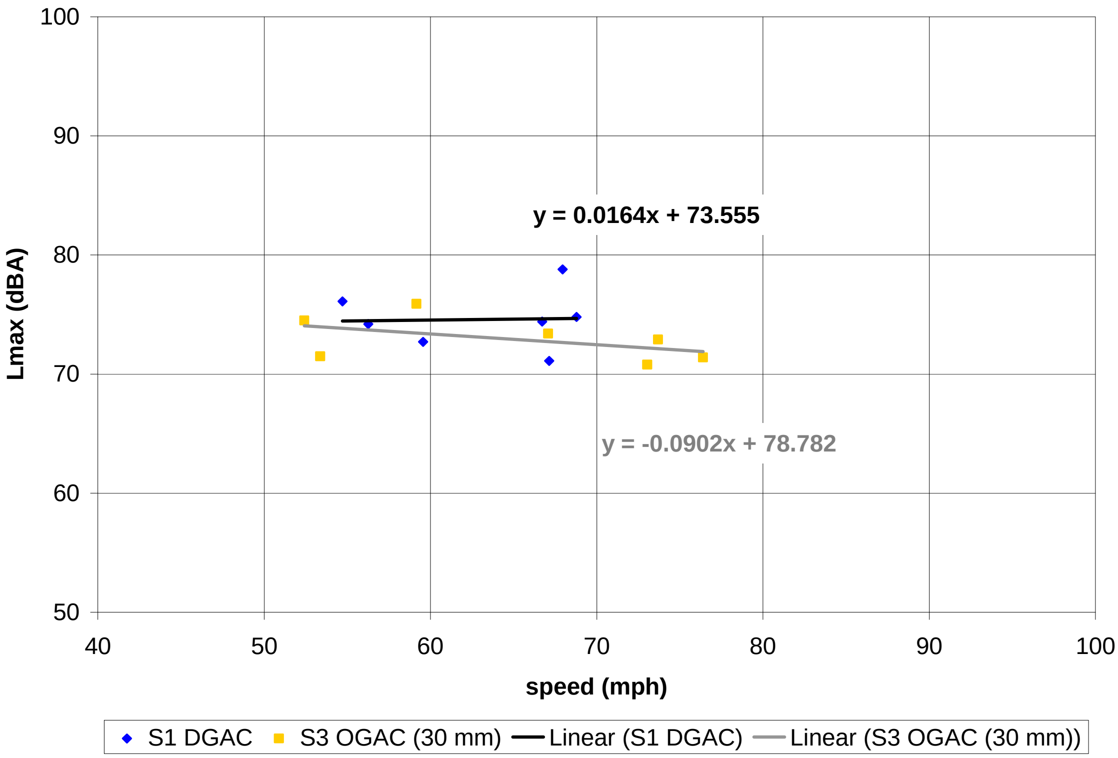


Figure C-28. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1085x + 63.945
y = 0.1551x + 58.799
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0164x + 73.555
y = -0.0902x + 78.782
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

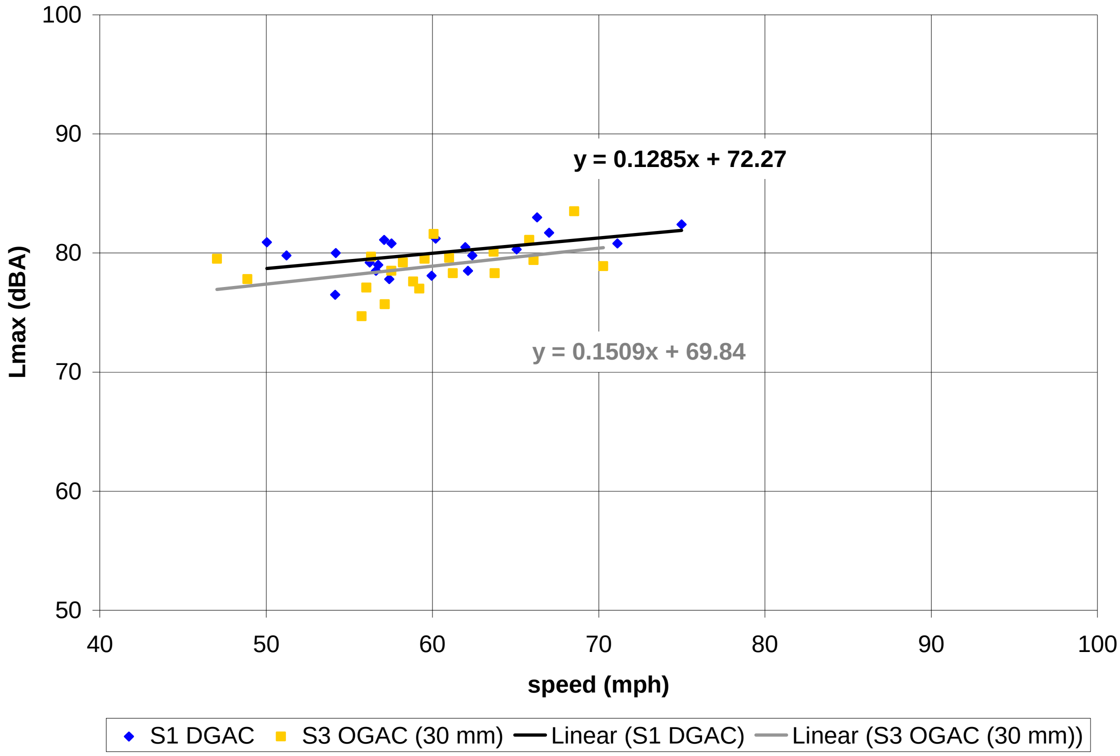
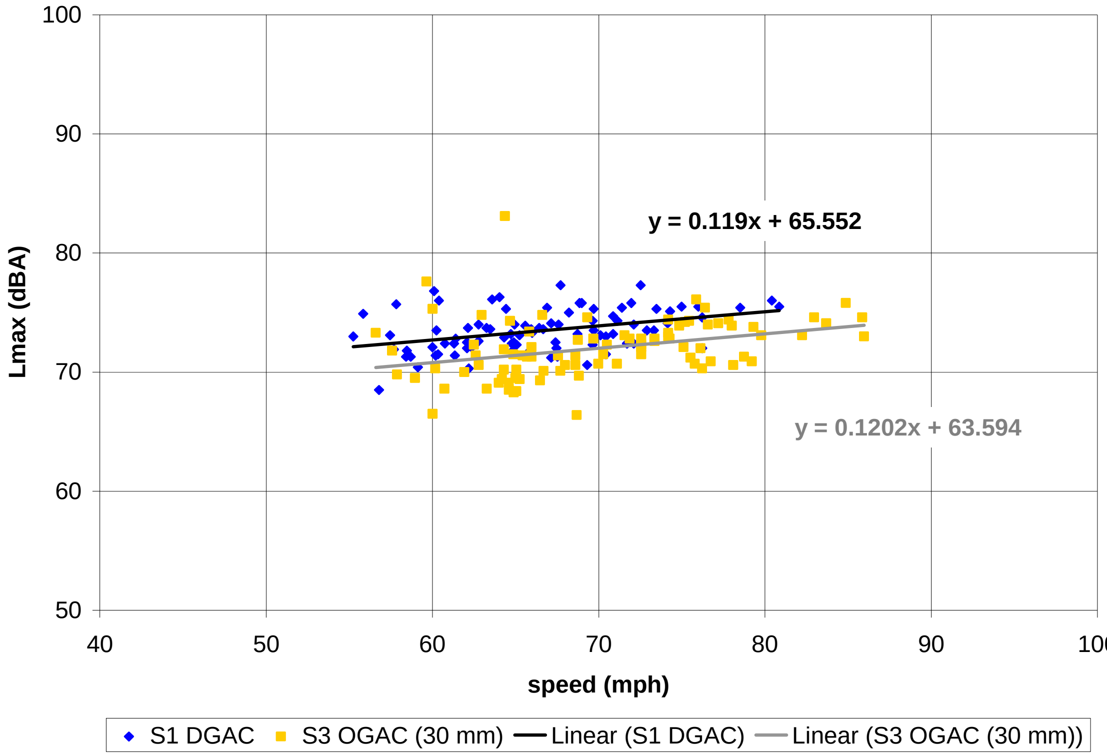
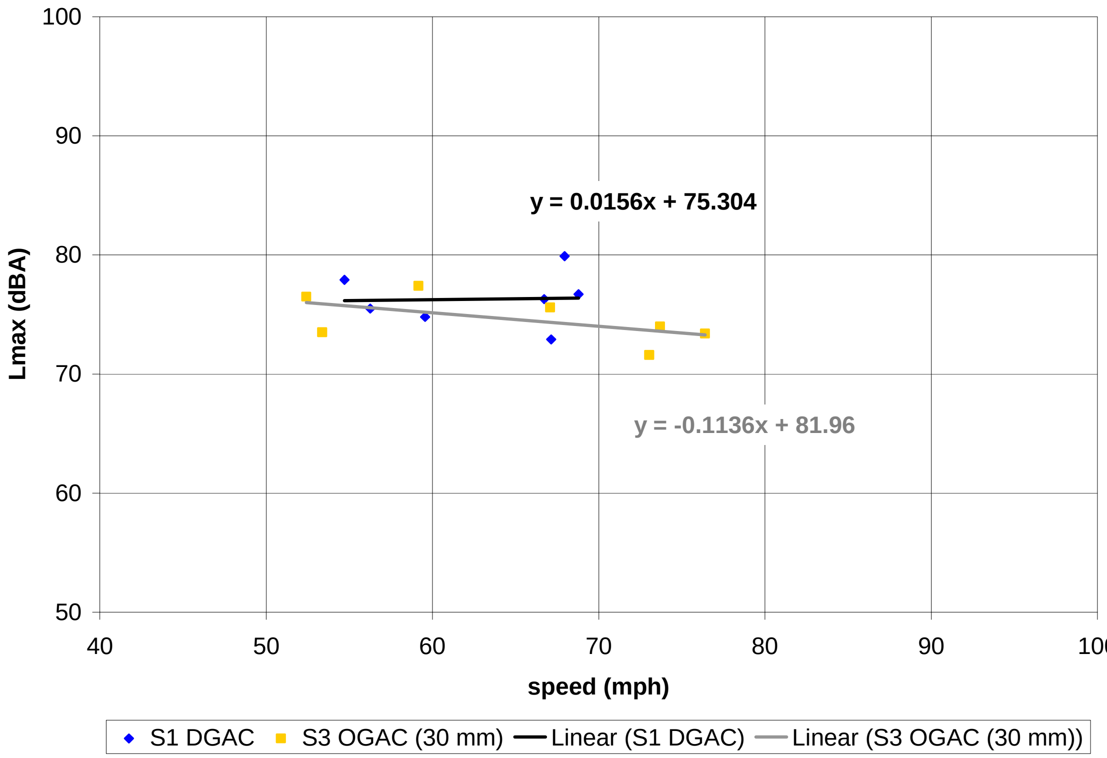


Figure C-29. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



y = 0.119x + 65.552
y = 0.1202x + 63.594
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



y = 0.0156x + 75.304
y = -0.1136x + 81.96
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

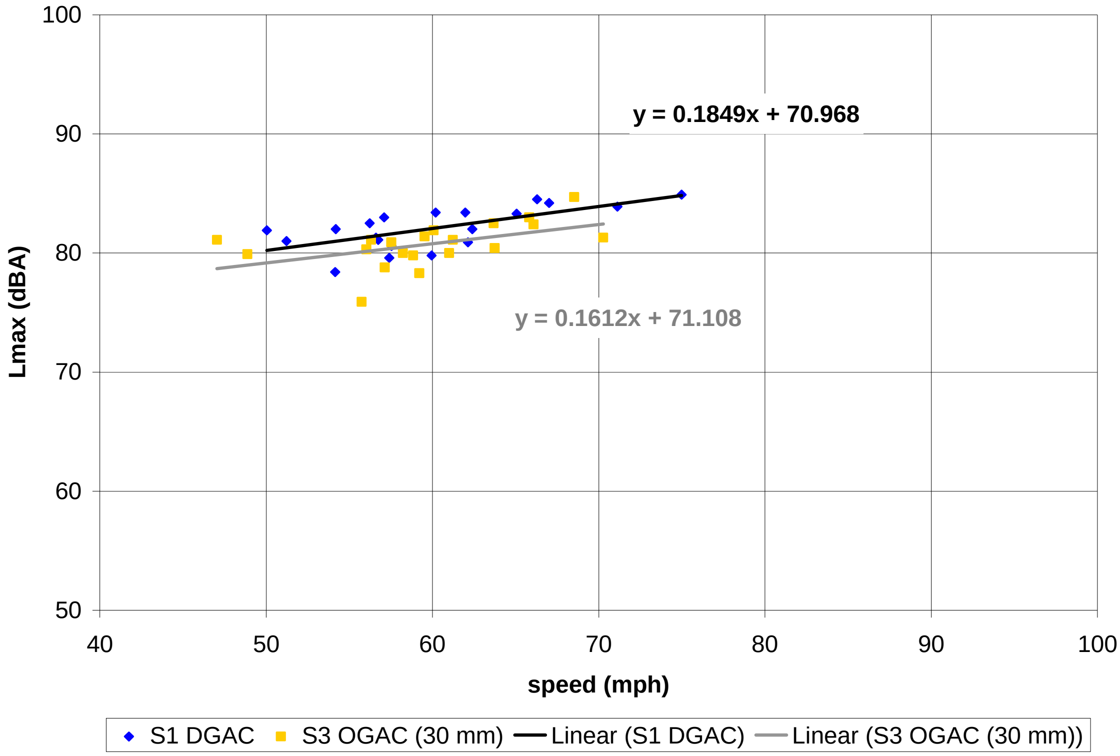
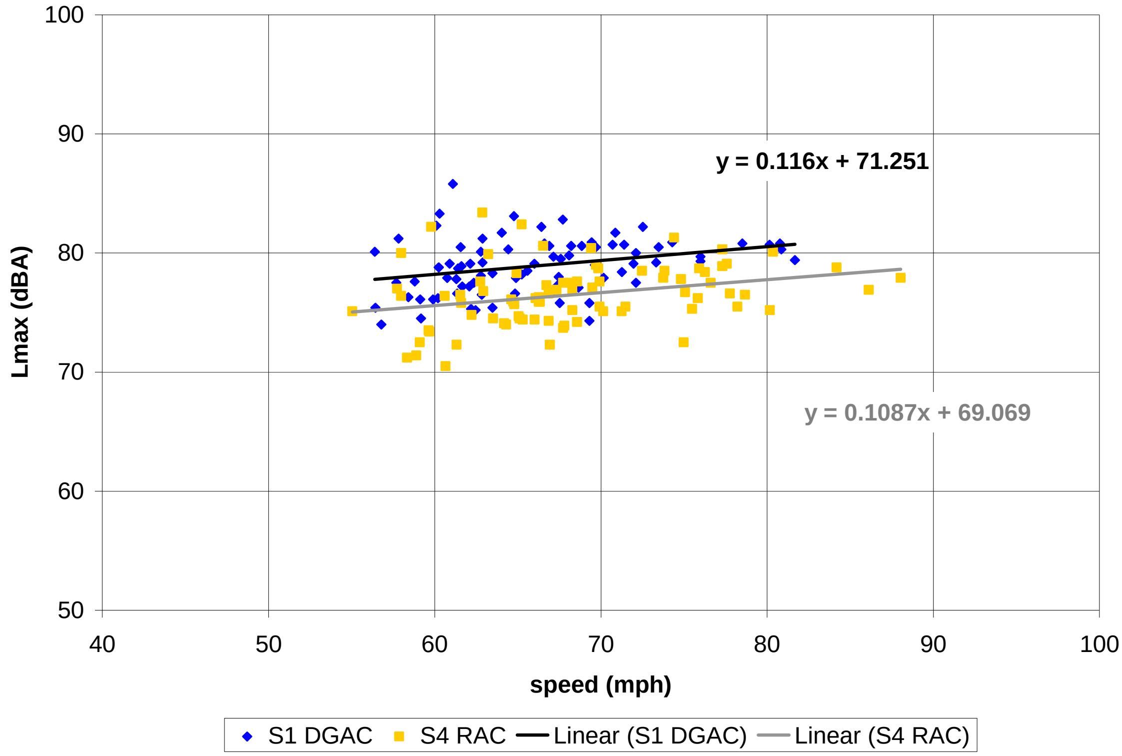
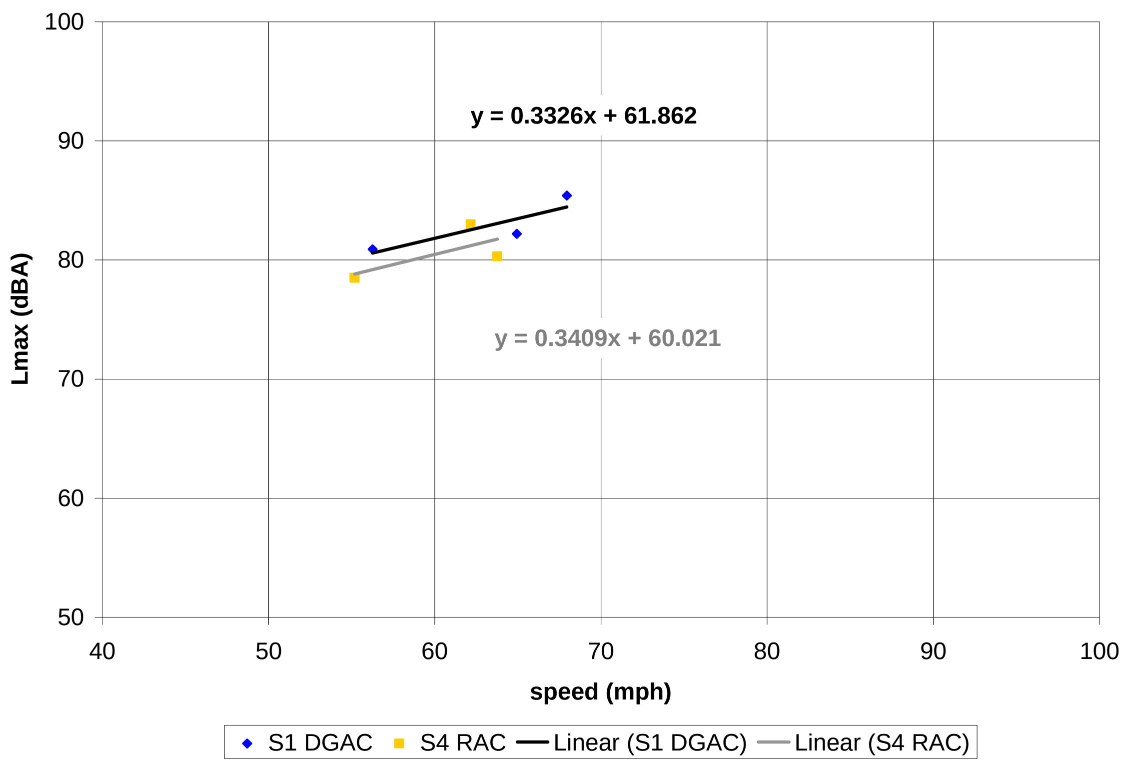


Figure C-30. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



y = 0.116x + 71.251
y = 0.1087x + 69.069
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



y = 0.3326x + 61.862
y = 0.3409x + 60.021
Lmax (dBA)
100
90
80
70
60
50
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

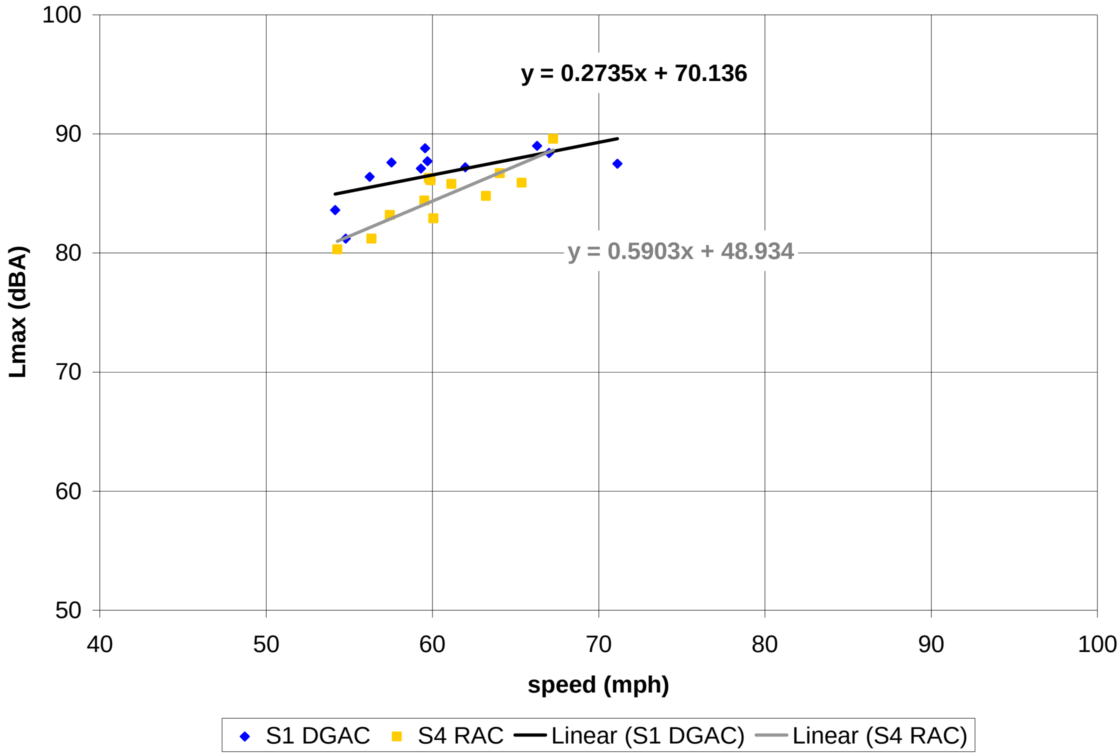
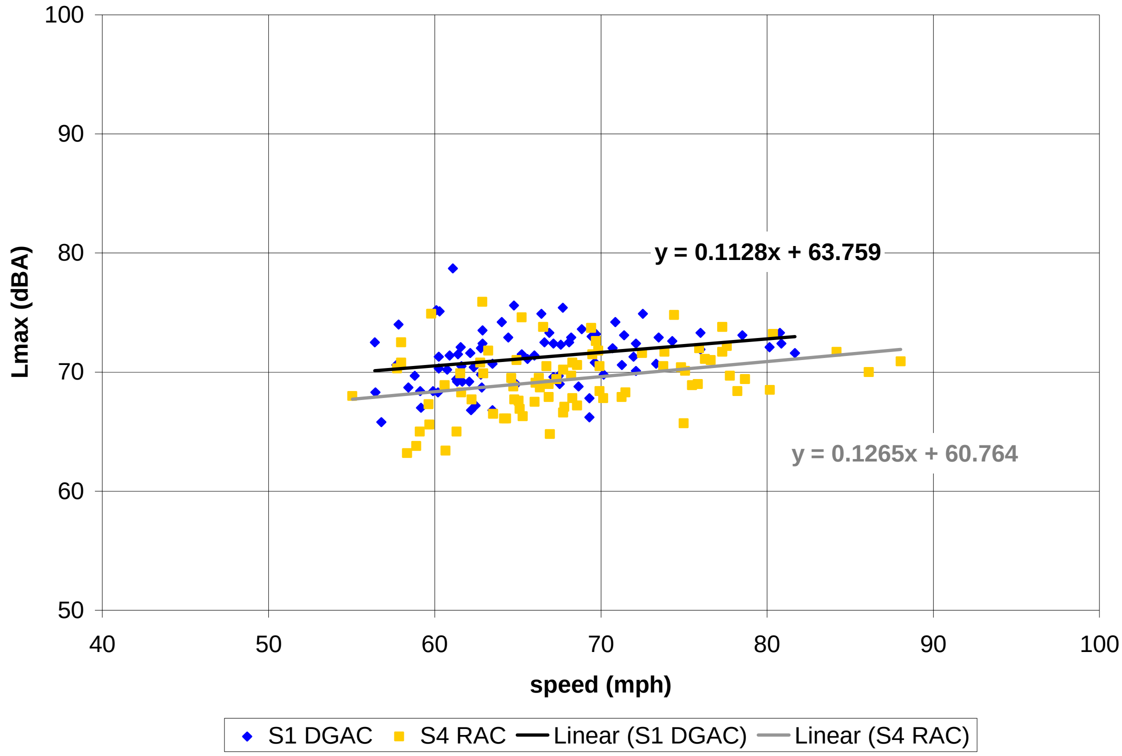
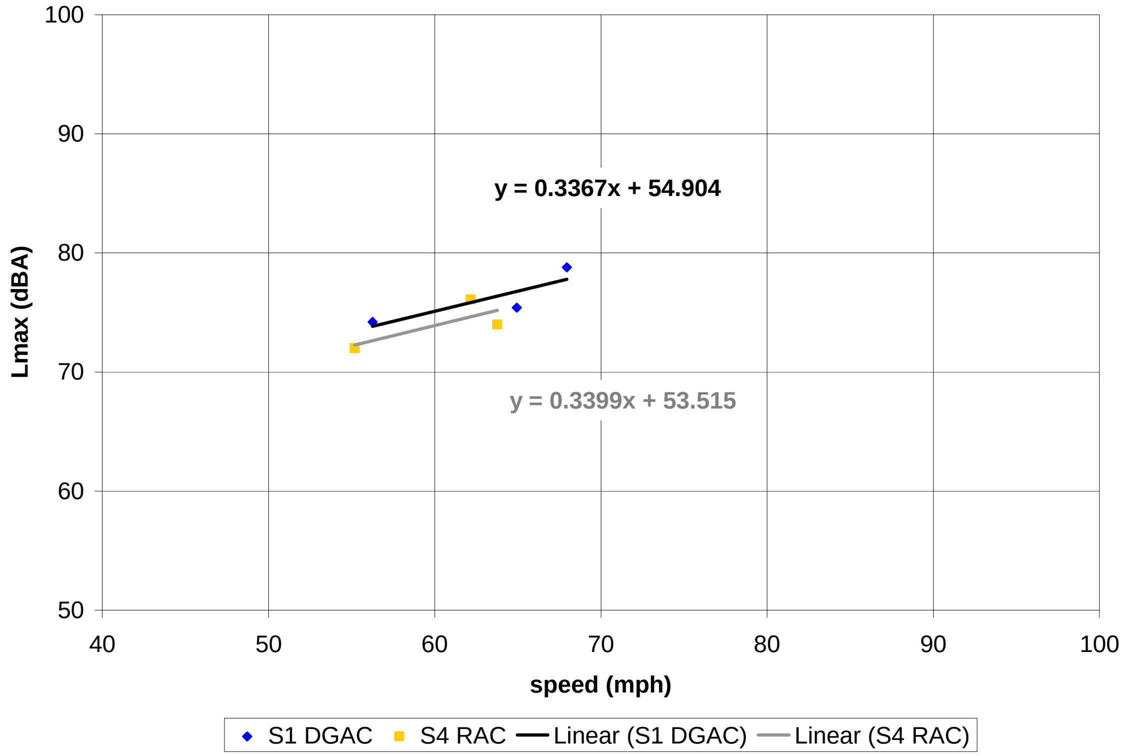


Figure C-31. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
y = 0.1128x + 63.759
y = 0.1265x + 60.764
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
Lmax (dBA)
y = 0.3367x + 54.904
y = 0.3399x + 53.515
40
50
60
70
80
90
100
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

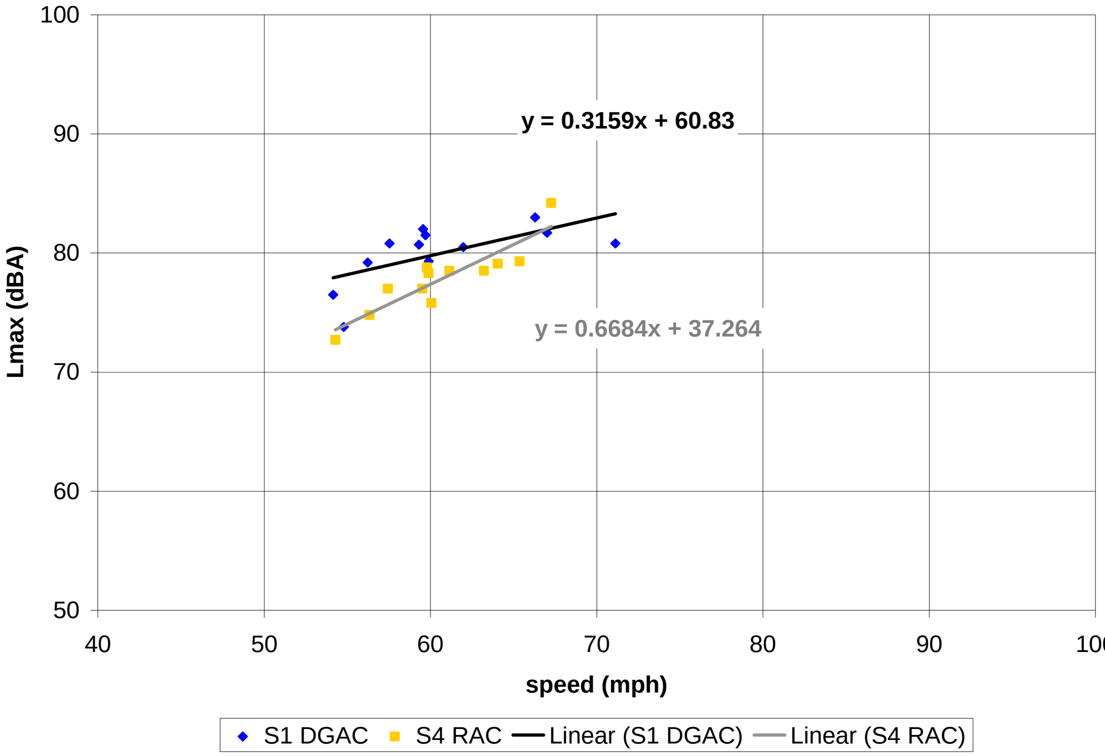
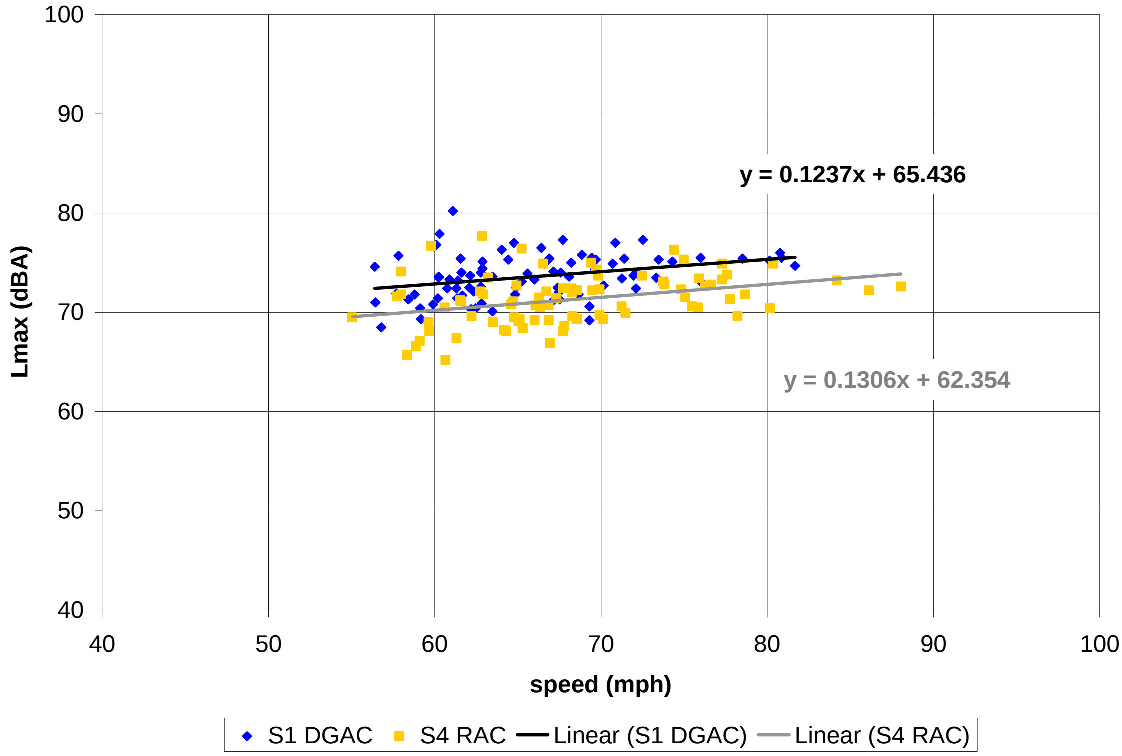
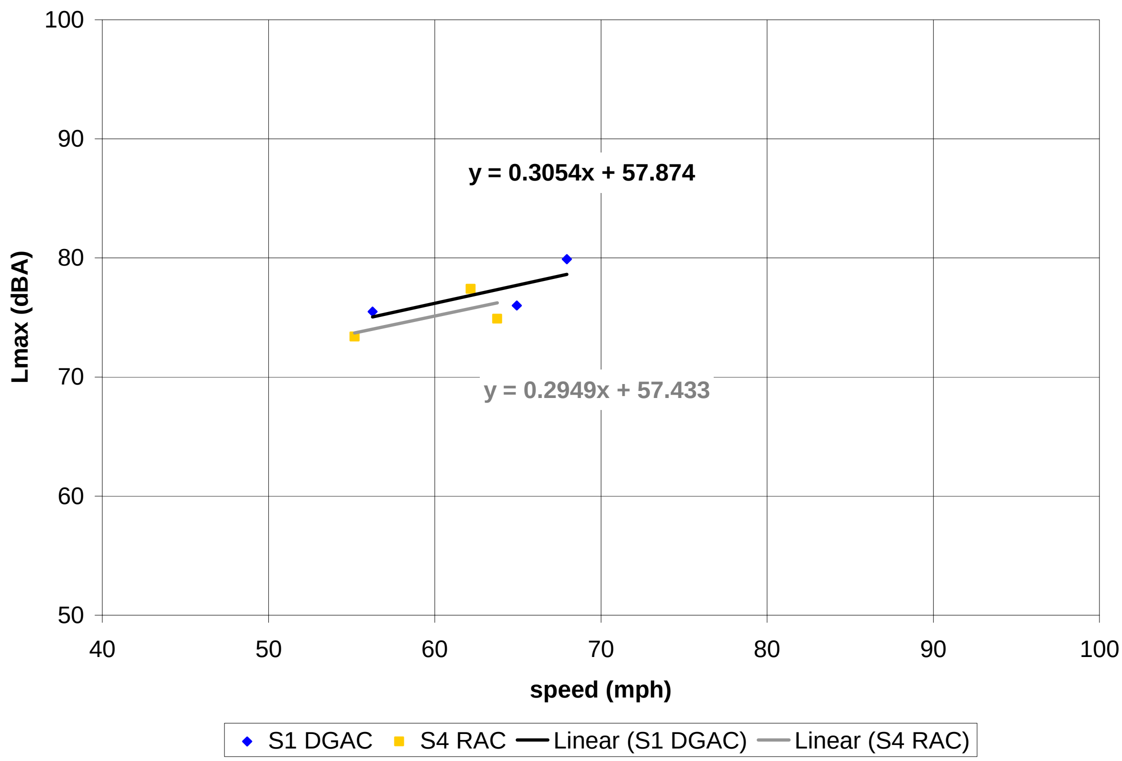


Figure C-32. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



y = 0.1237x + 65.436
y = 0.1306x + 62.354
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



y = 0.3054x + 57.874
y = 0.2949x + 57.433
Lmax (dBA)
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

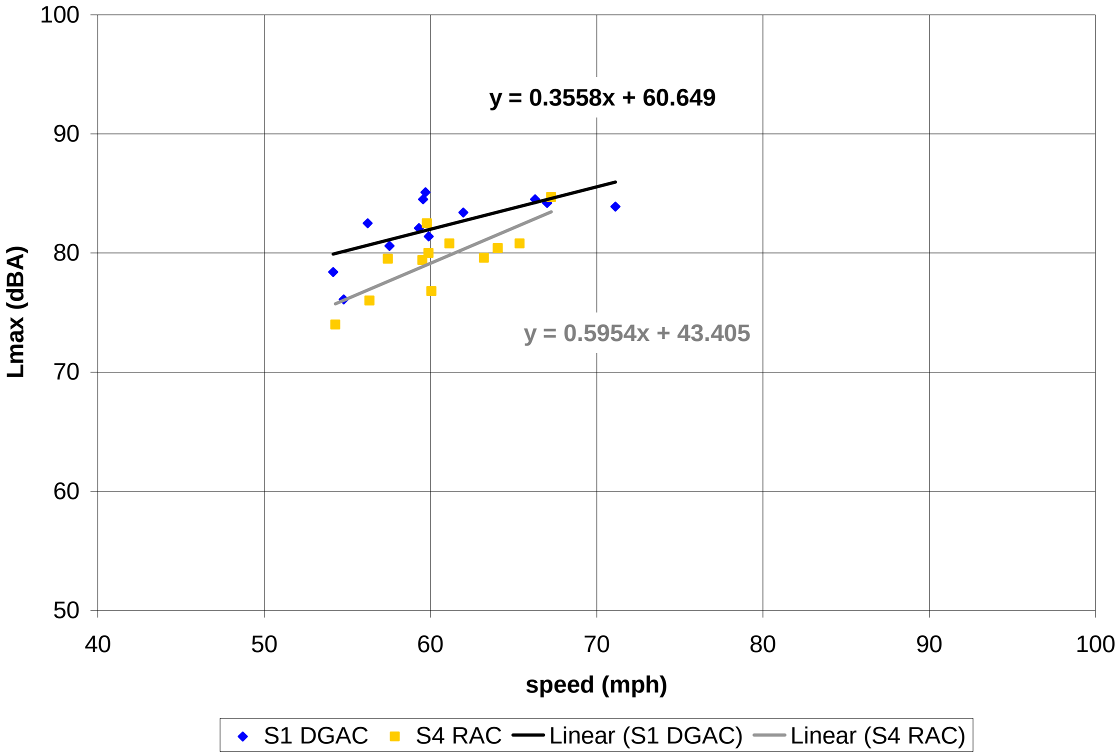
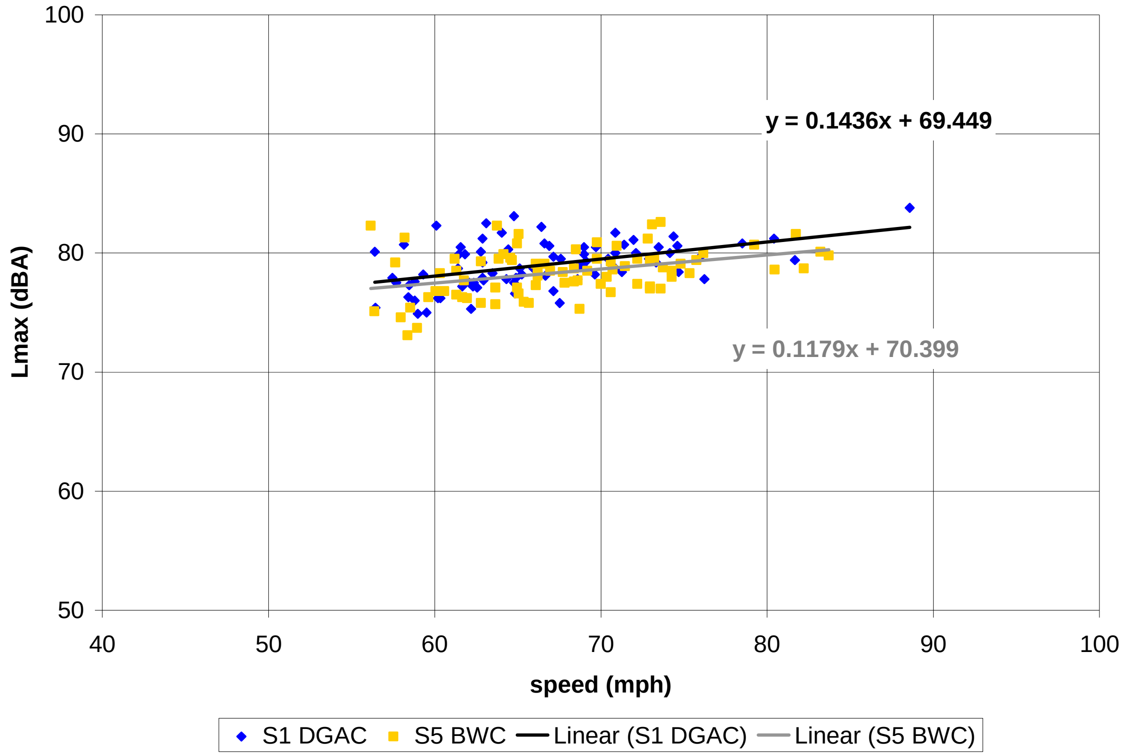
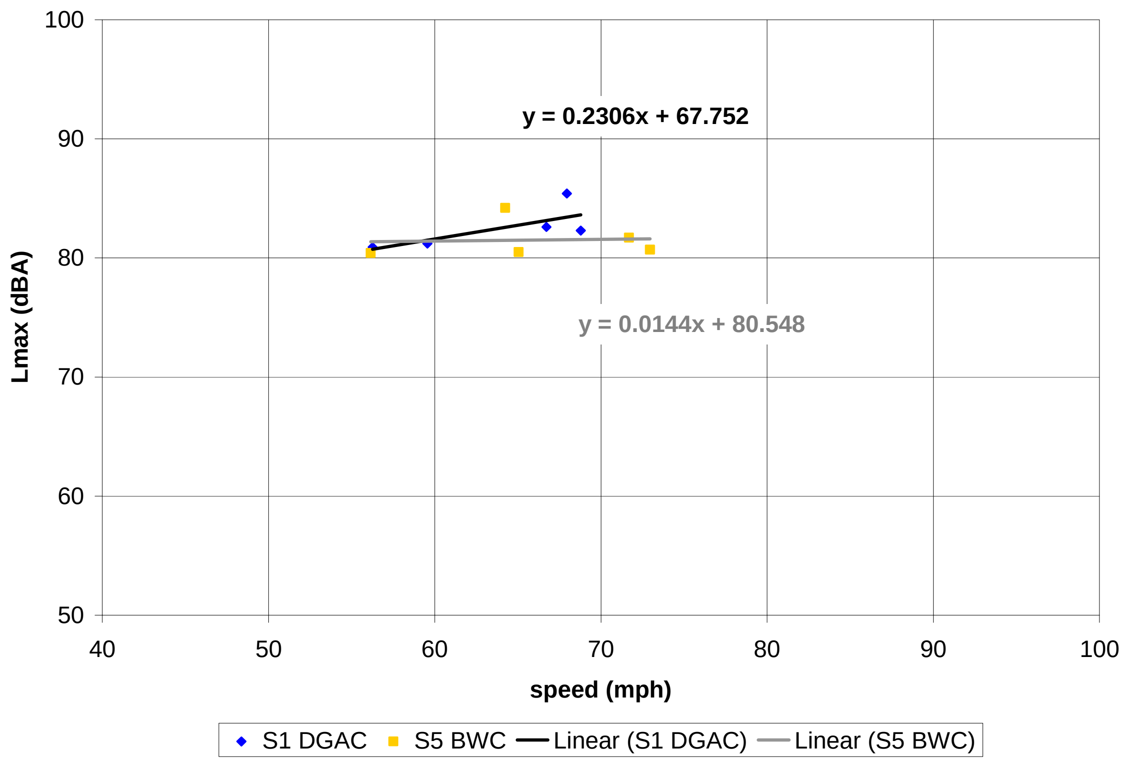


Figure C-33. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



y = 0.1436x + 69.449
y = 0.1179x + 70.399
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



y = 0.2306x + 67.752
y = 0.0144x + 80.548
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

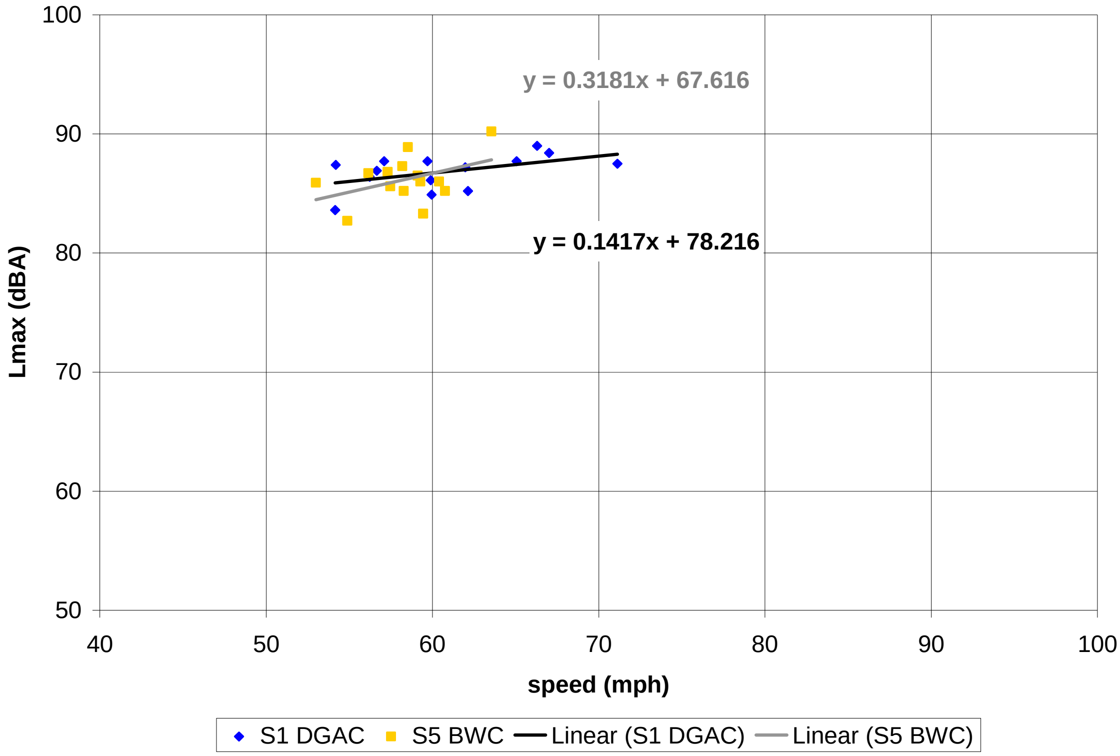
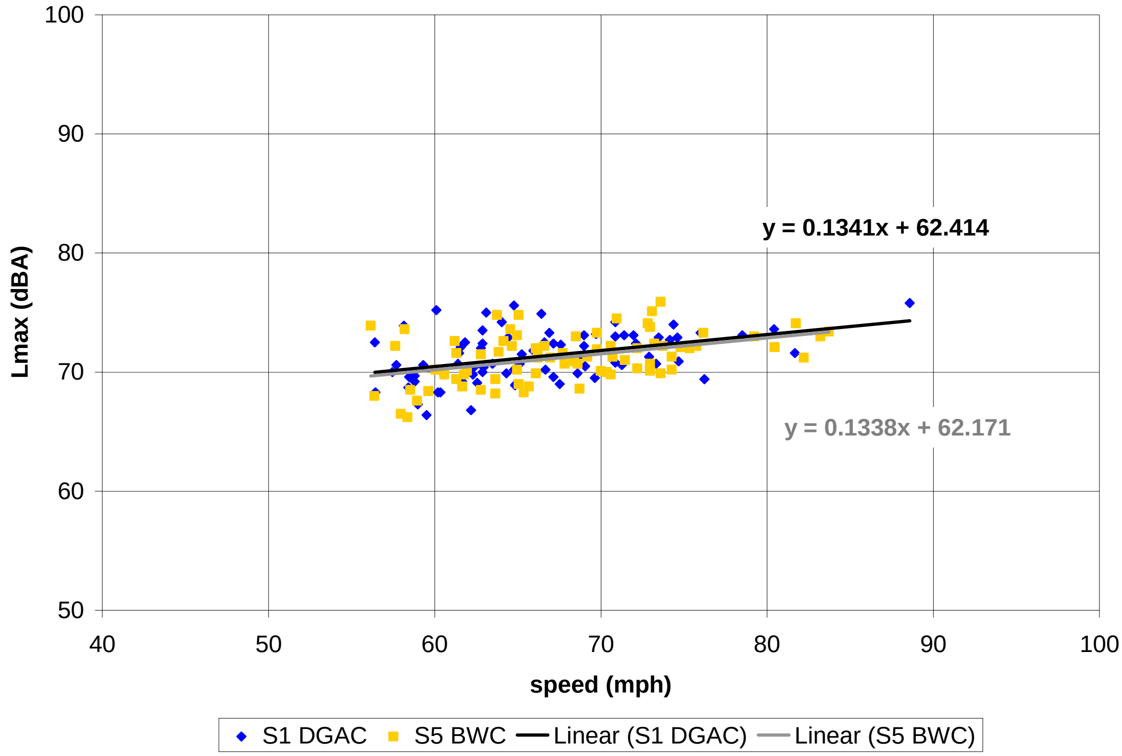
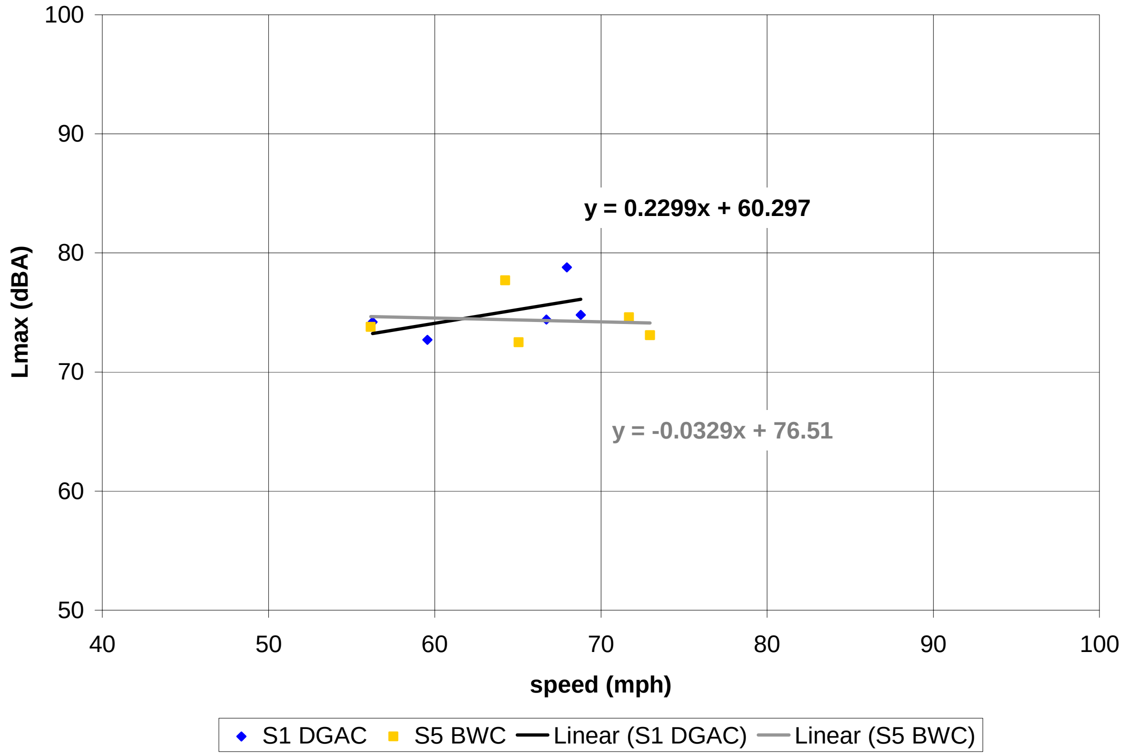


Figure C-34. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1341x + 62.414
y = 0.1338x + 62.171
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2299x + 60.297
y = -0.0329x + 76.51
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

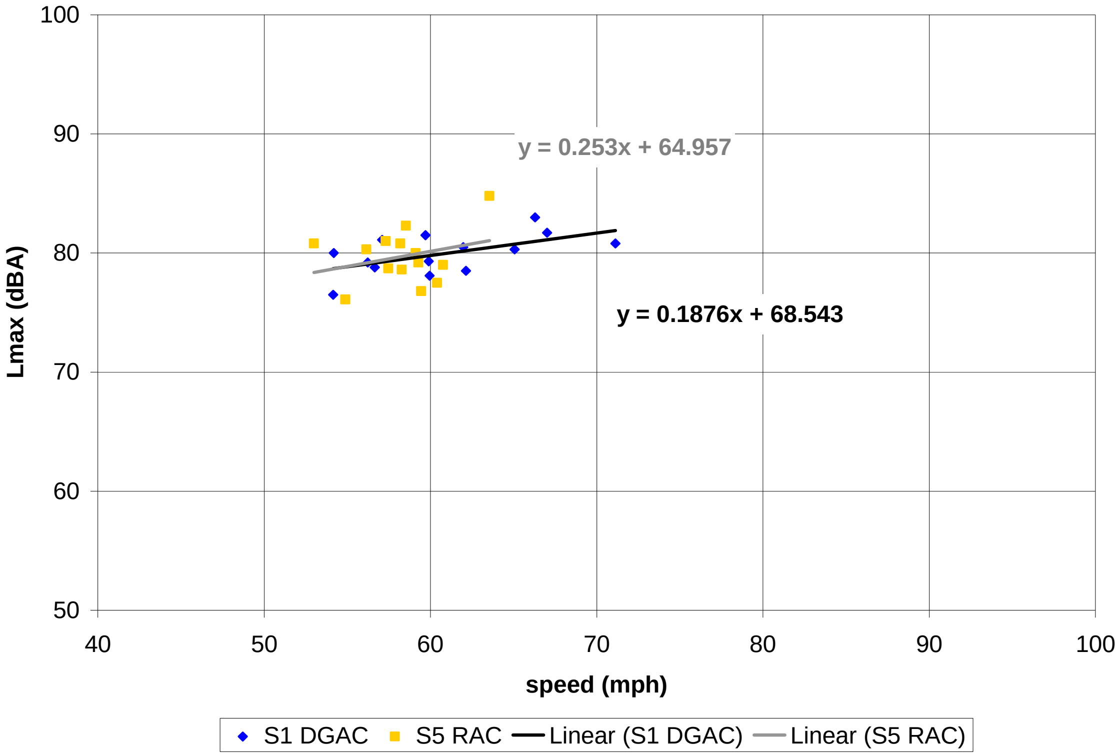
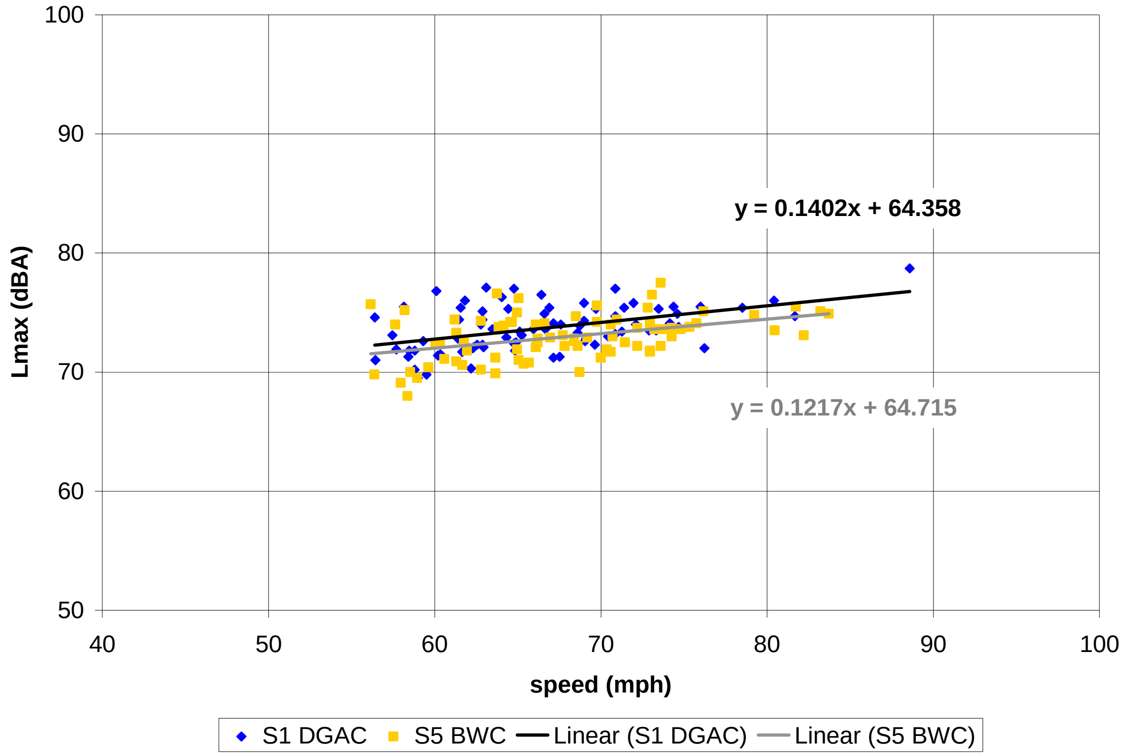
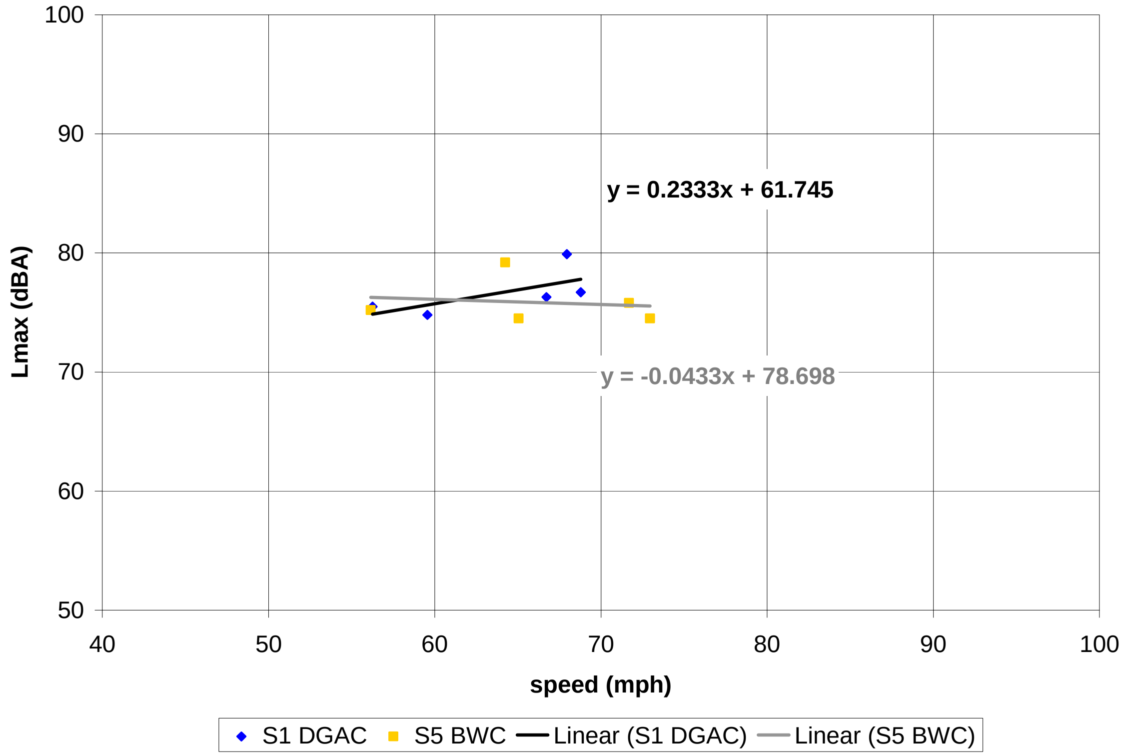


Figure C-35. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1402x + 64.358
y = 0.1217x + 64.715
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2333x + 61.745
y = -0.0433x + 78.698
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

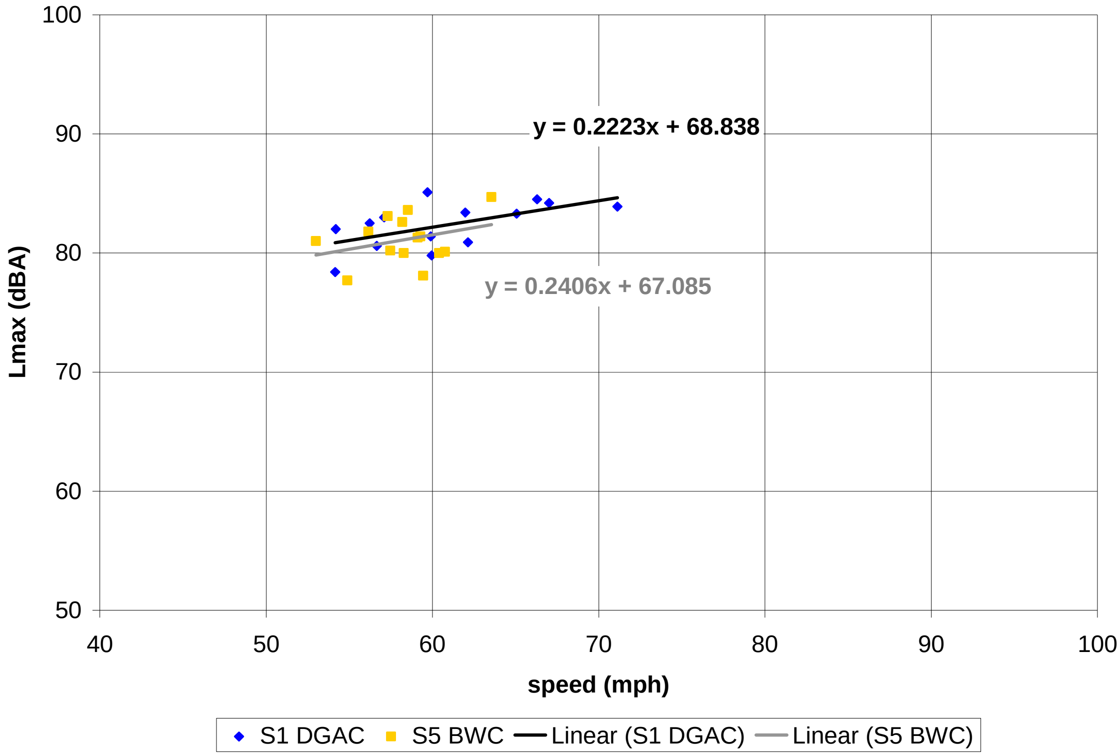
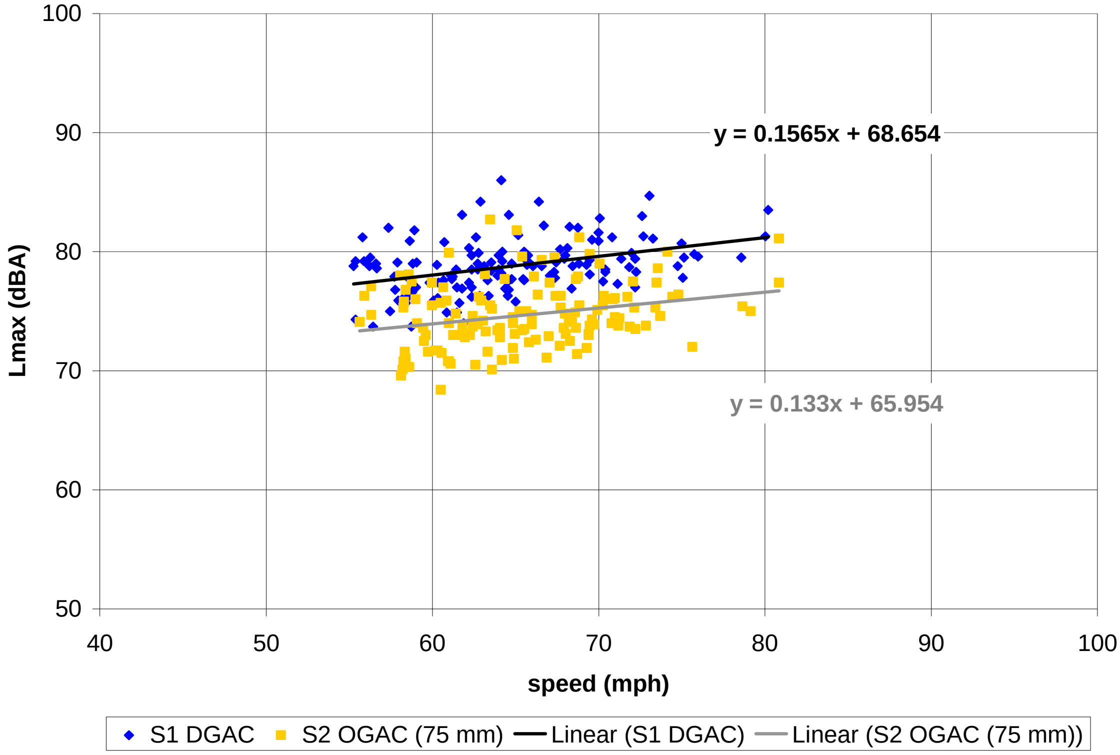
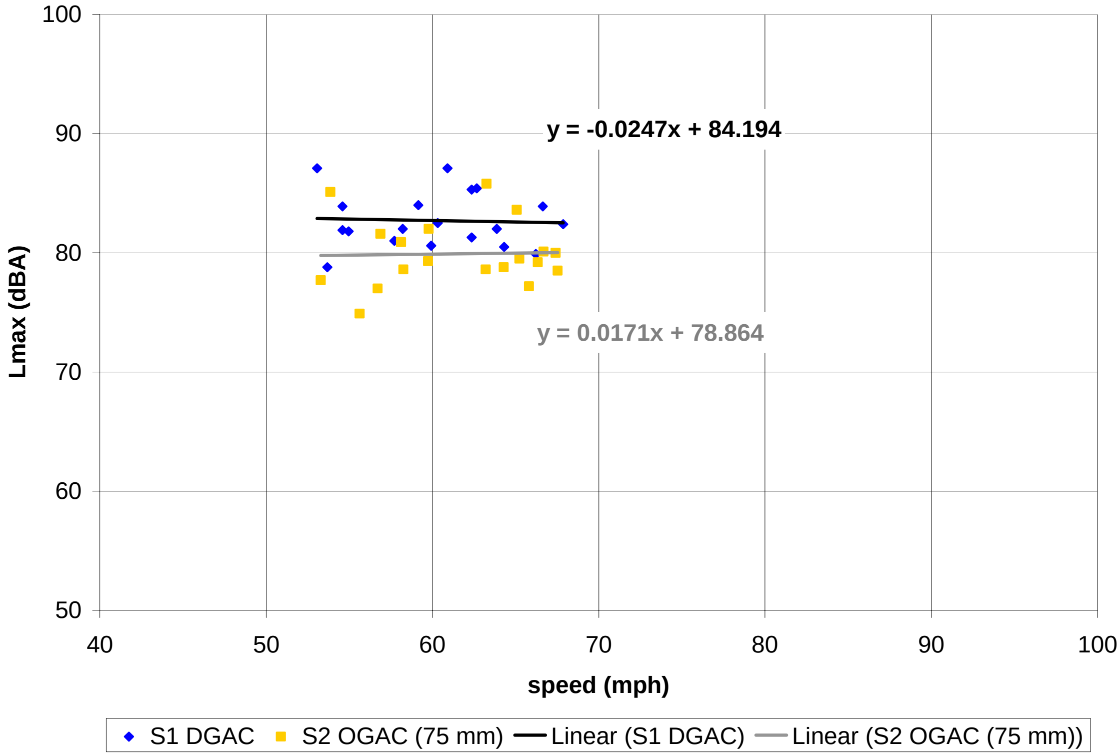


Figure C-36. (this and previous page) Vehicle pass-by data, post-overlay, 10 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.5 Post-Overlay – Pavement Age: 16 months





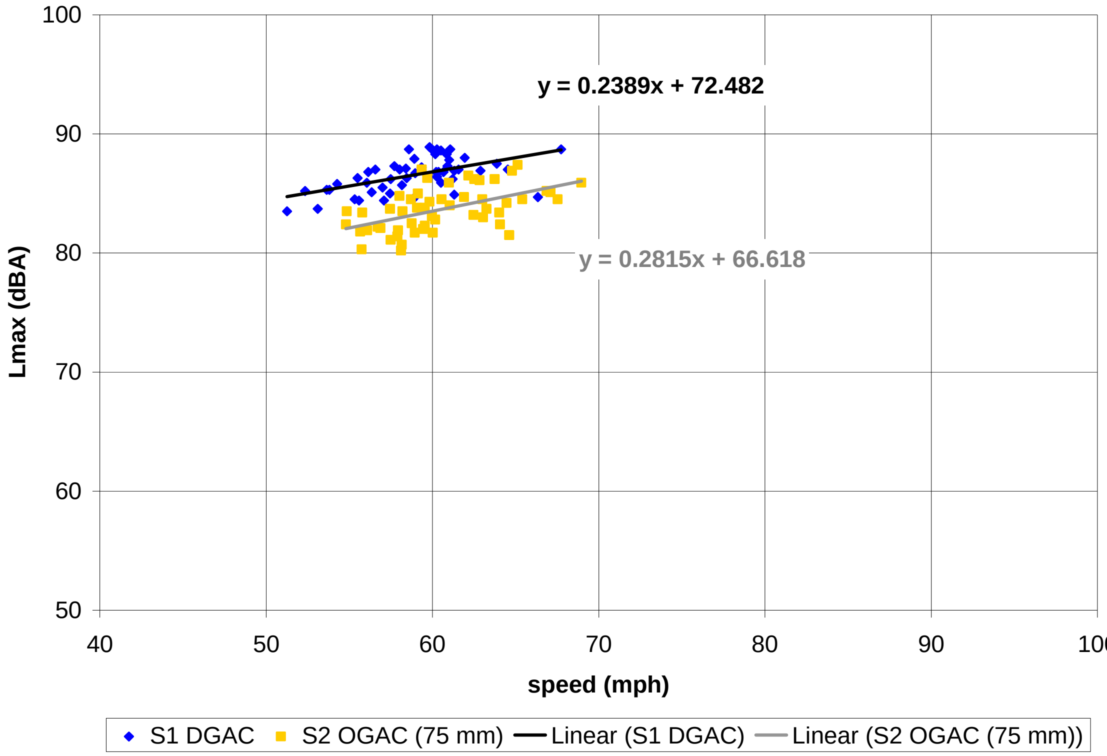
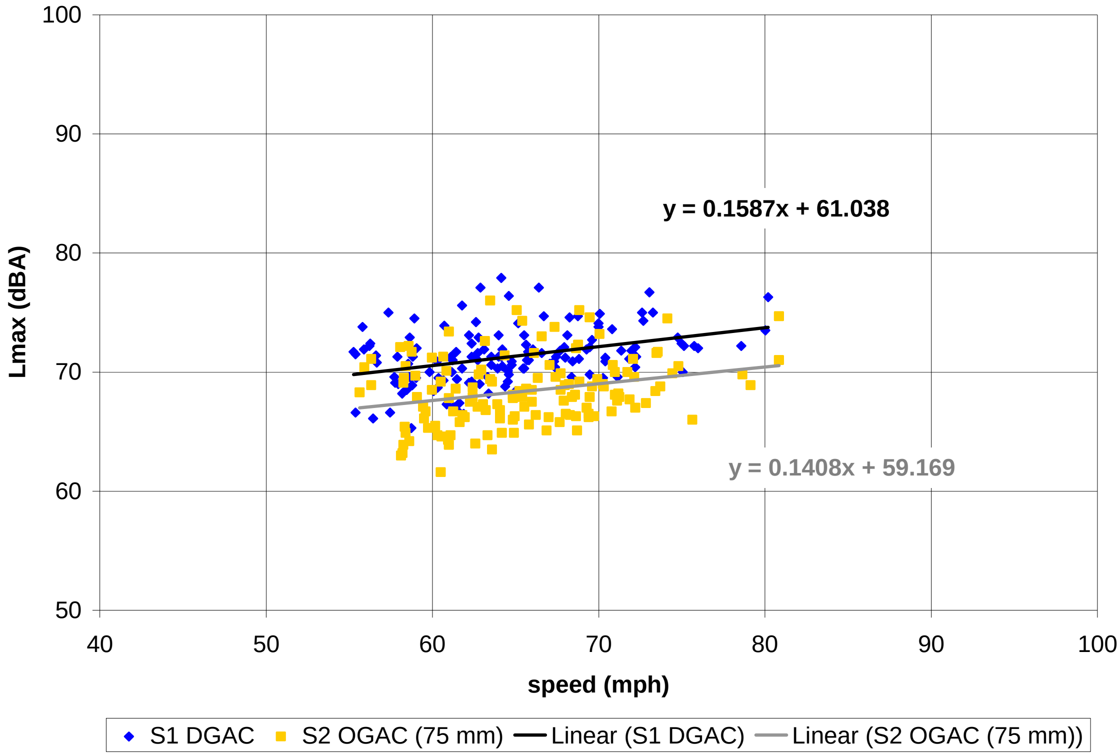
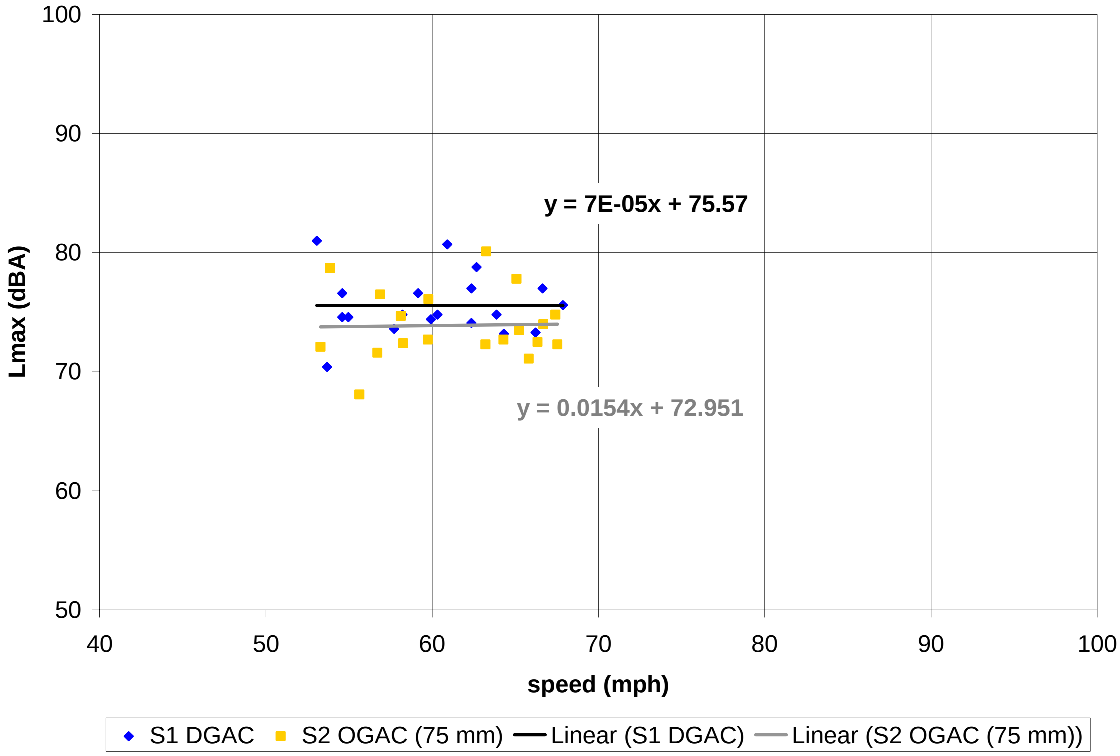


Figure C-37. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1587x + 61.038
y = 0.1408x + 59.169
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 7E-05x + 75.57
y = 0.0154x + 72.951
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

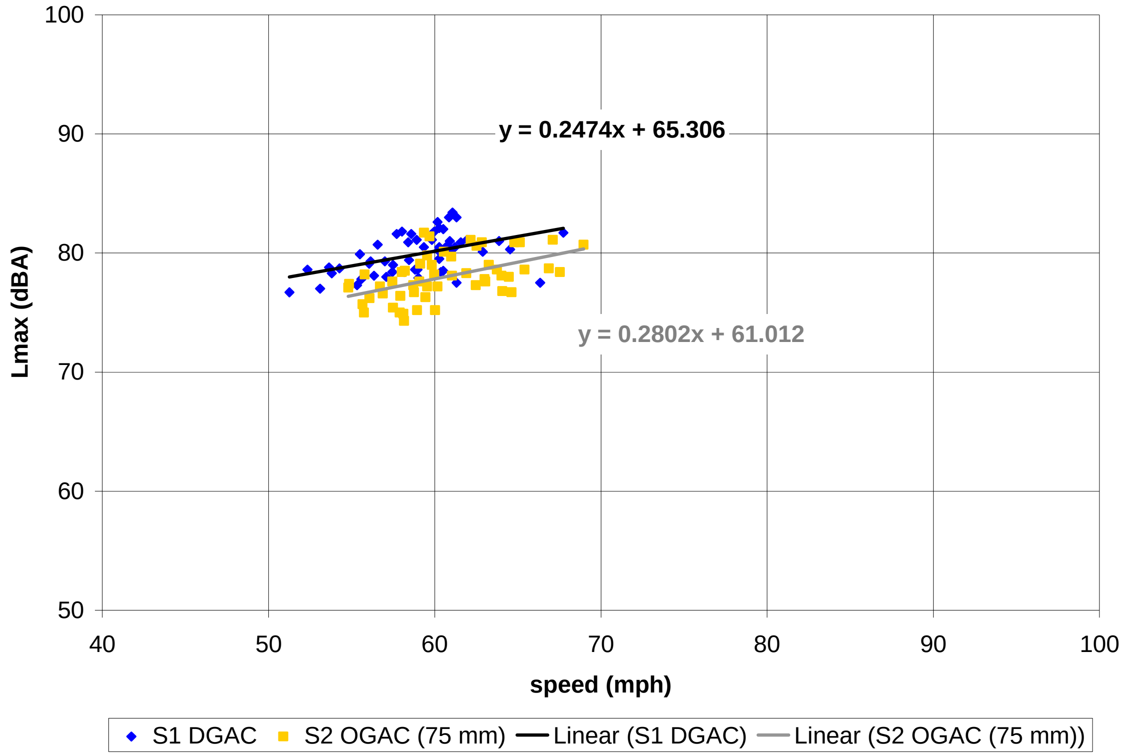
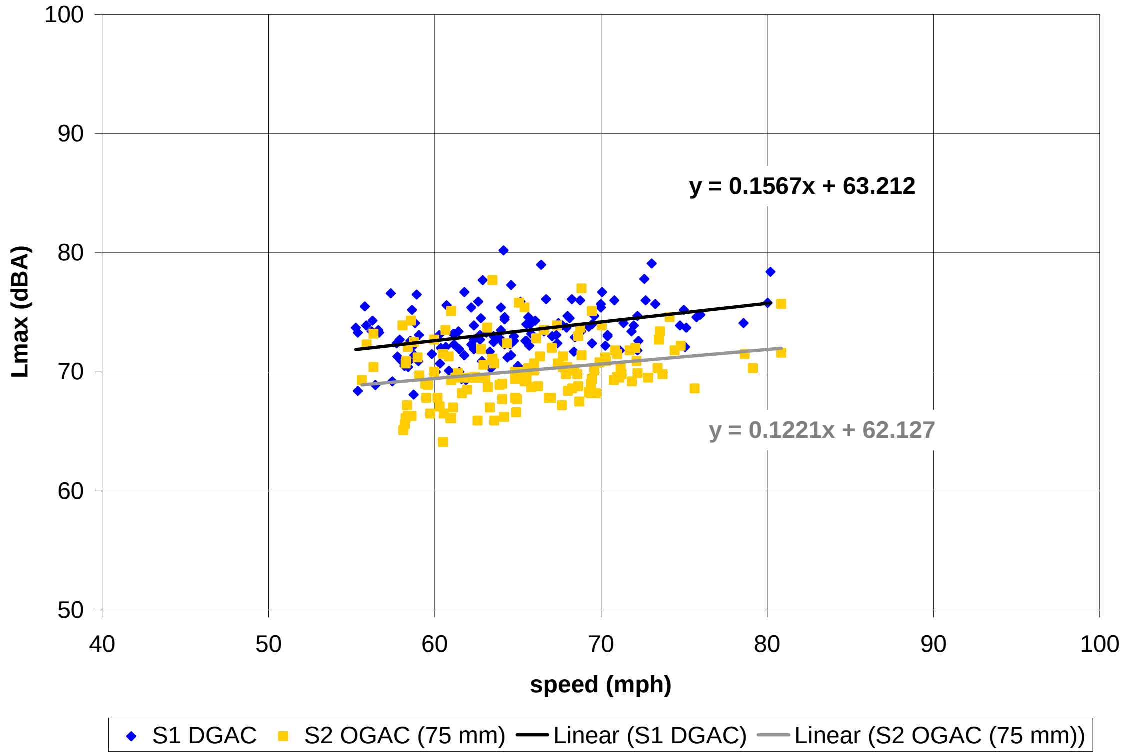
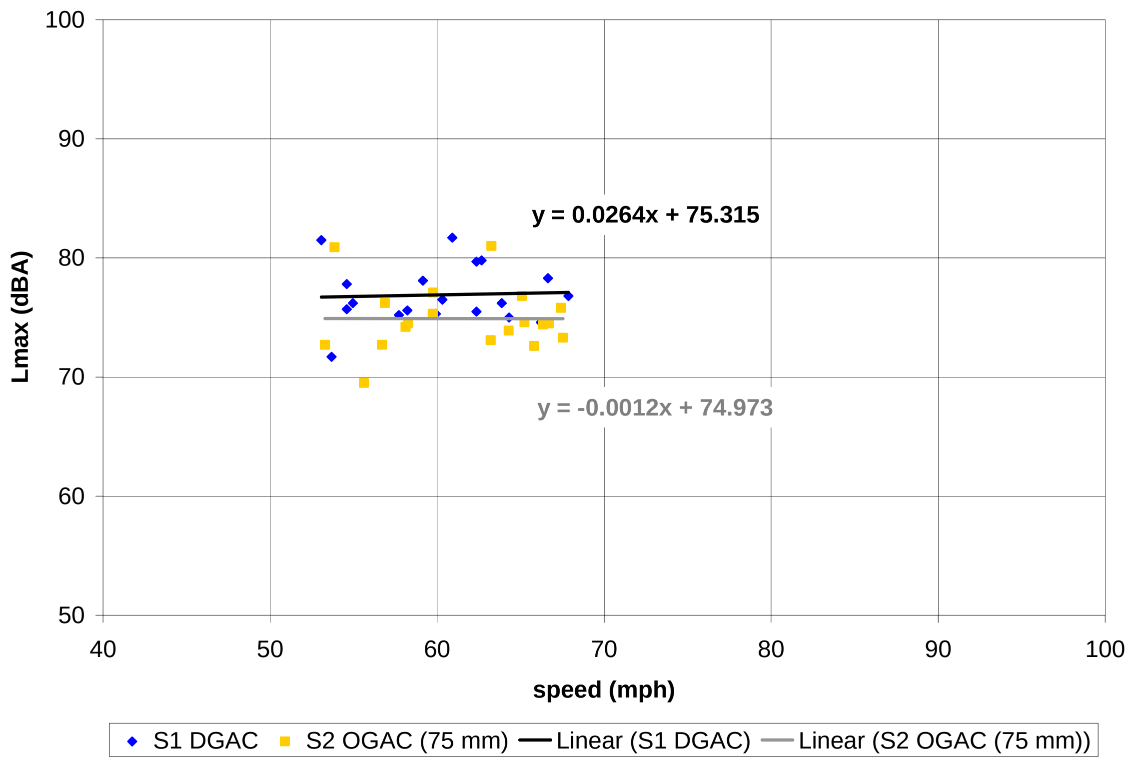


Figure C-38. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1567x + 63.212
y = 0.1221x + 62.127
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0264x + 75.315
y = -0.0012x + 74.973
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

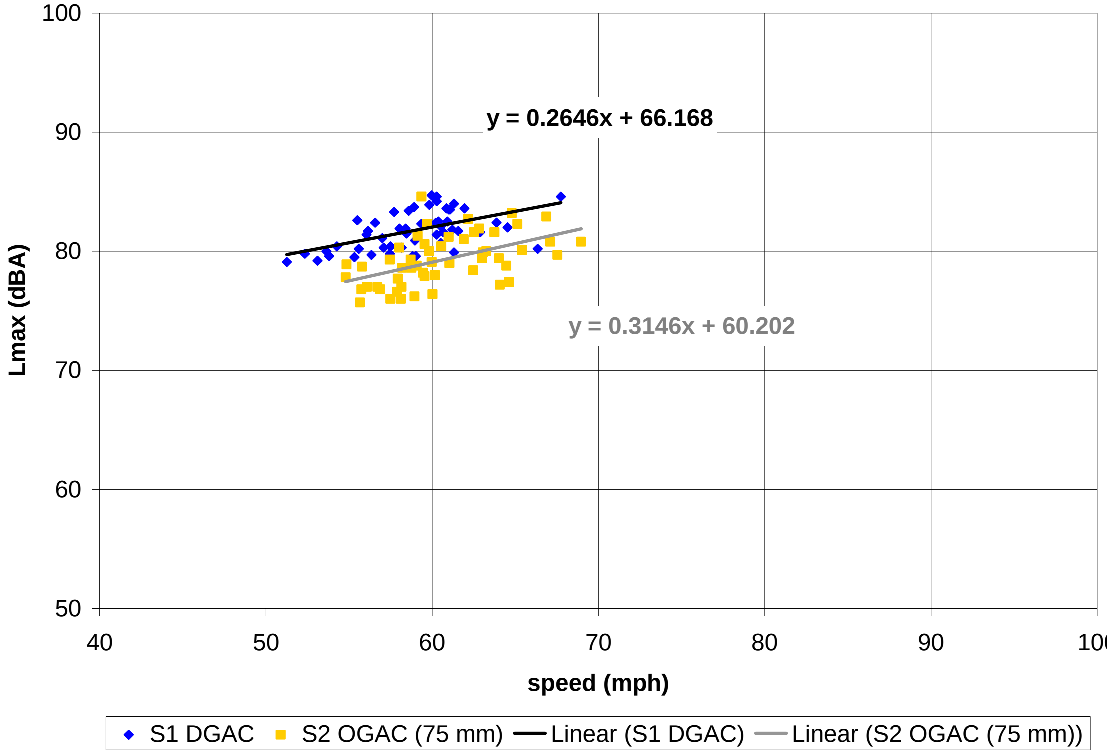
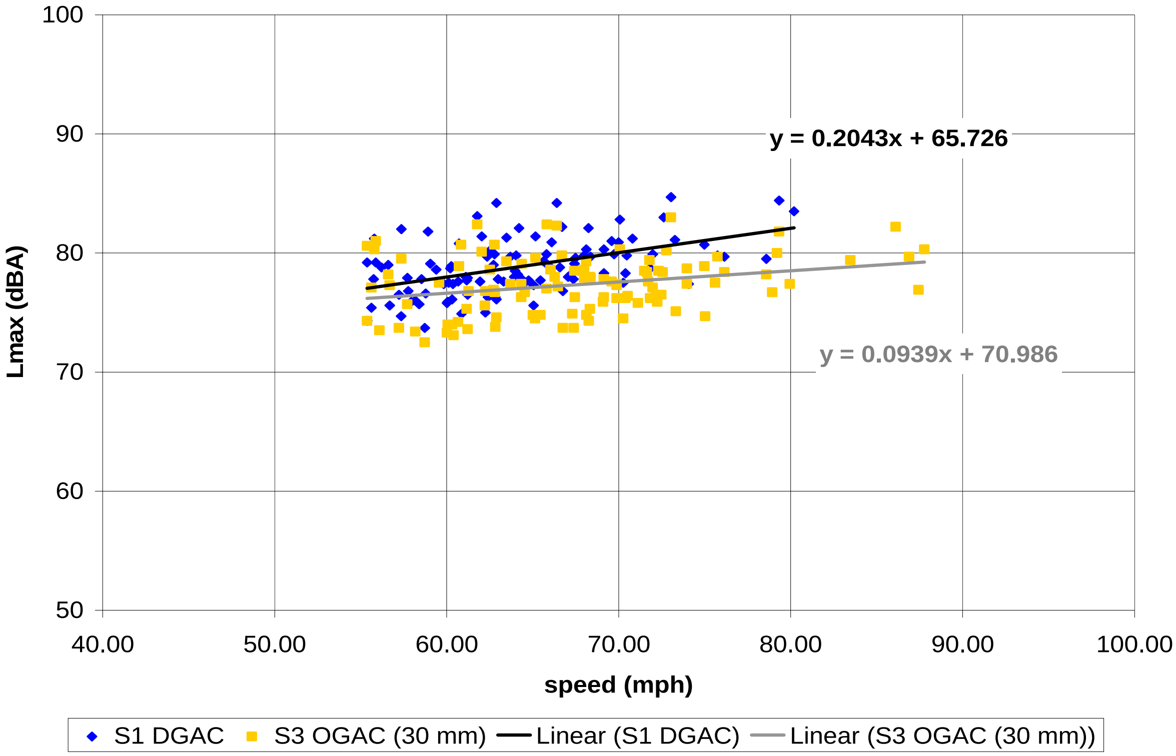
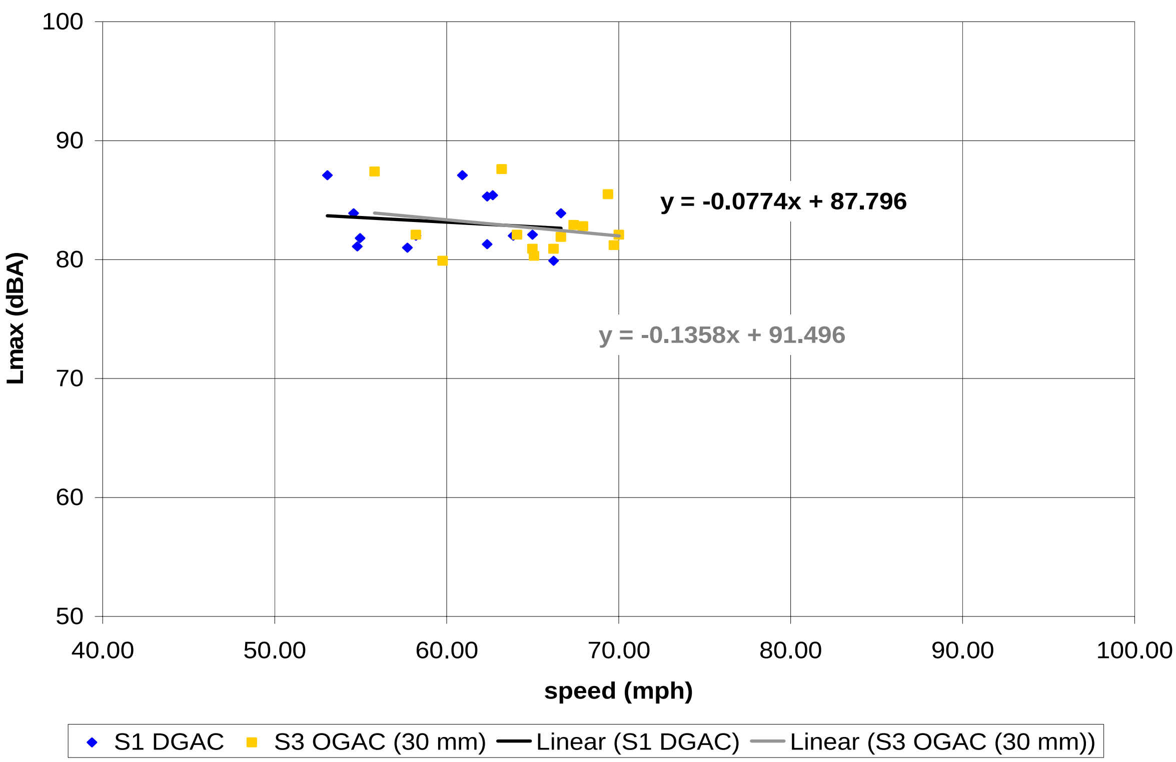


Figure C-39. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
Lmax (dBA)
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
y = 0.2043x + 65.726
y = 0.0939x + 70.986
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
Lmax (dBA)
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
y = -0.0774x + 87.796
y = -0.1358x + 91.496
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

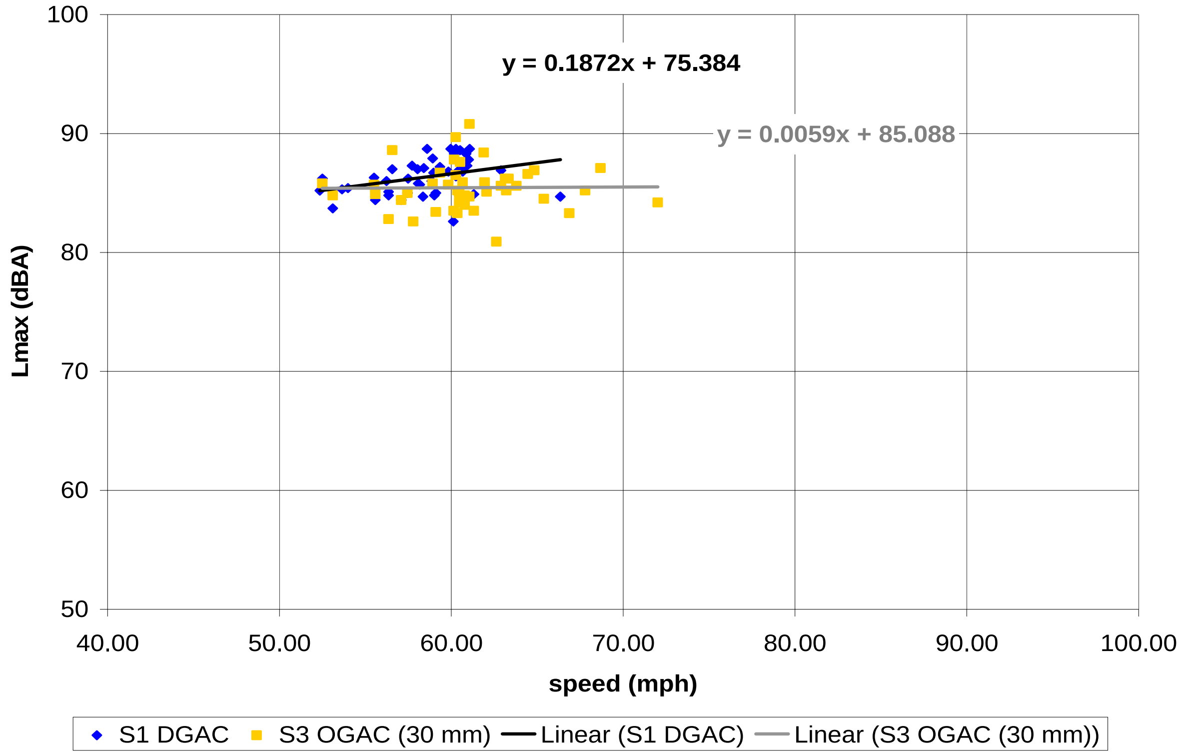
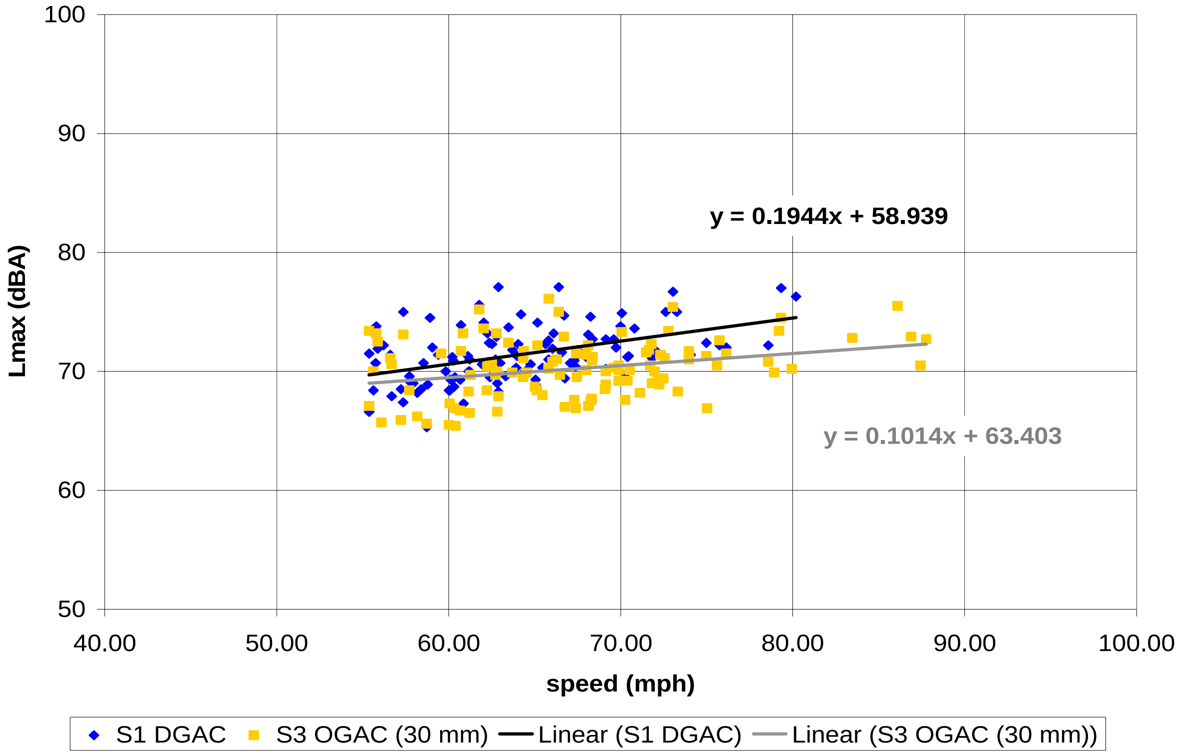
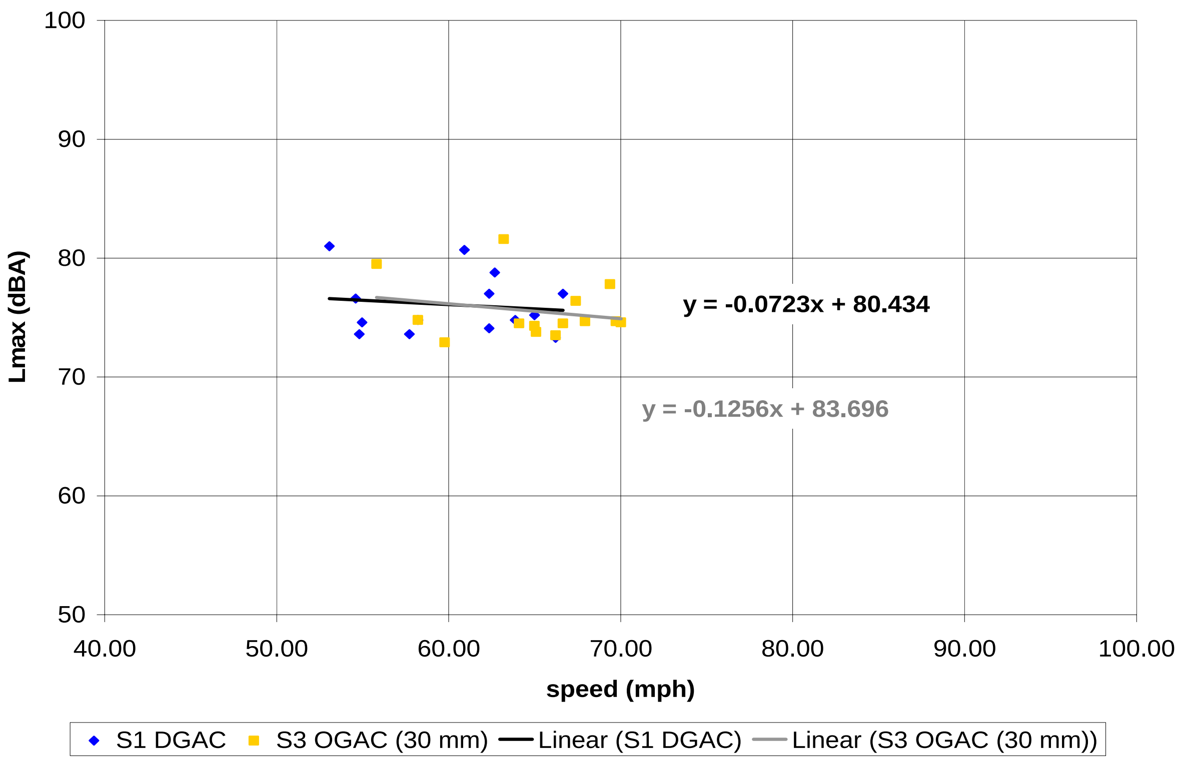


Figure C-40. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1944x + 58.939
y = 0.1014x + 63.403
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
Lmax (dBA)
y = -0.0723x + 80.434
y = -0.1256x + 83.696
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

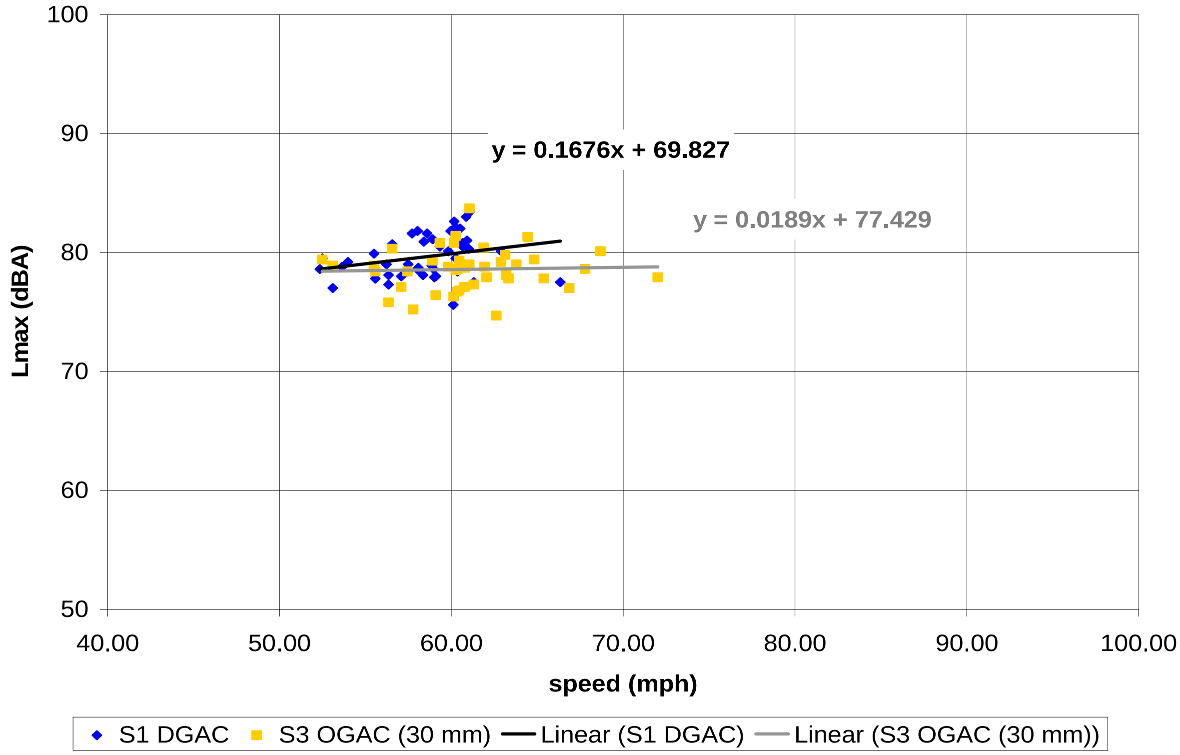
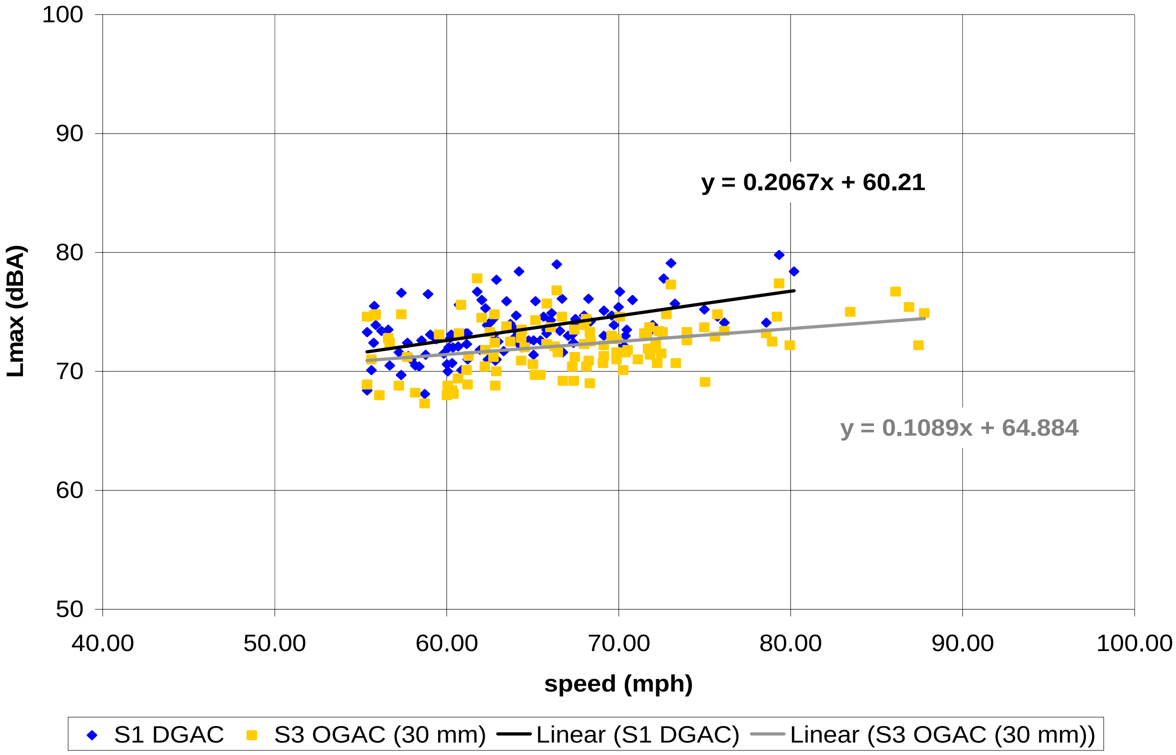
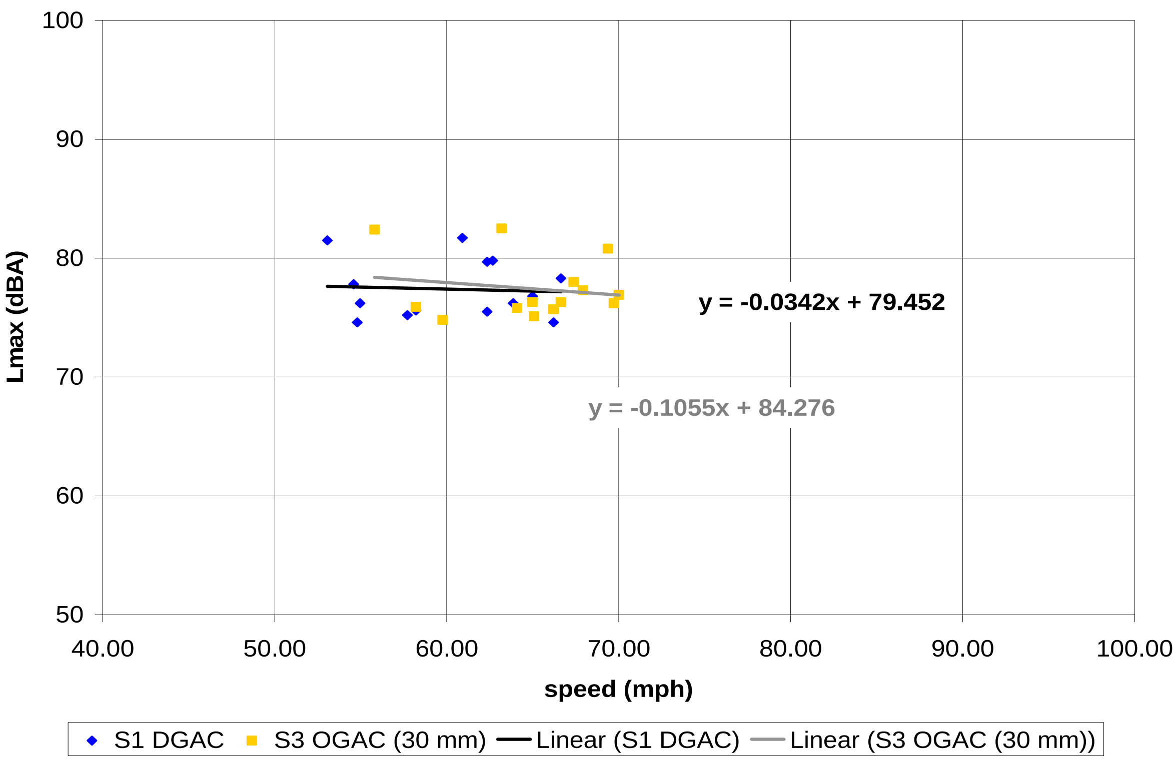


Figure C-41. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
y = 0.2067x + 60.21
y = 0.1089x + 64.884
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
Lmax (dBA)
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
y = -0.0342x + 79.452
y = -0.1055x + 84.276
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

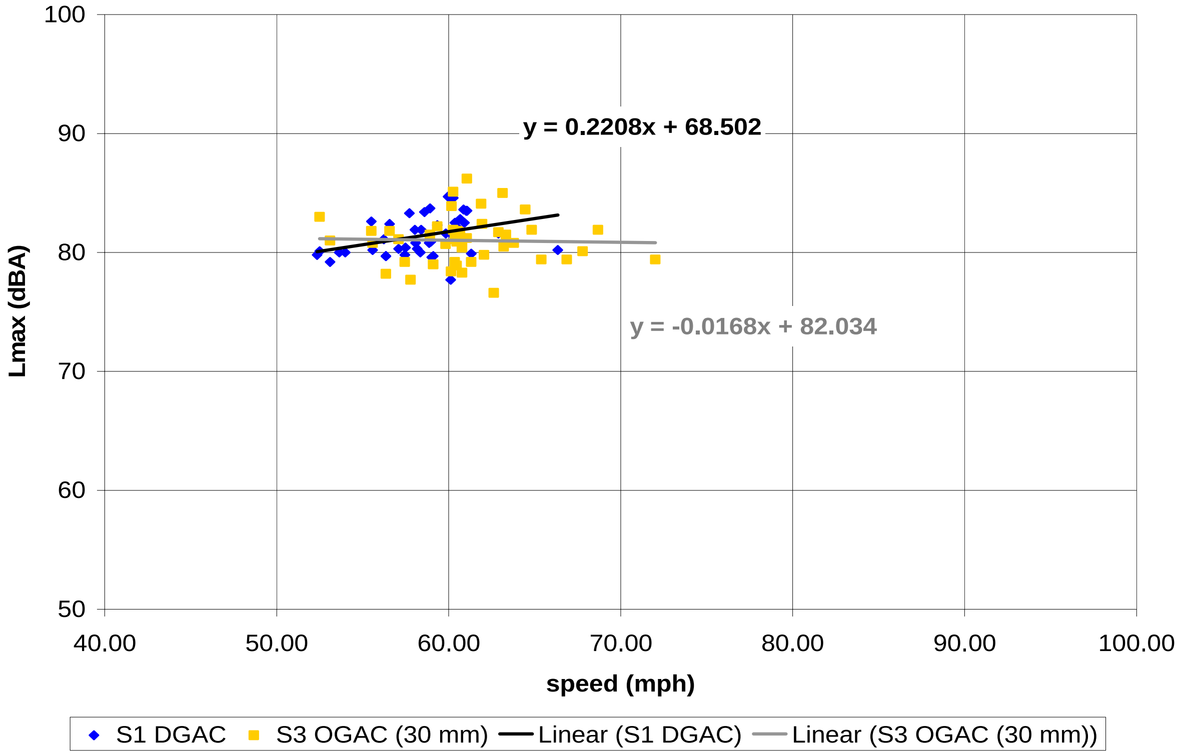
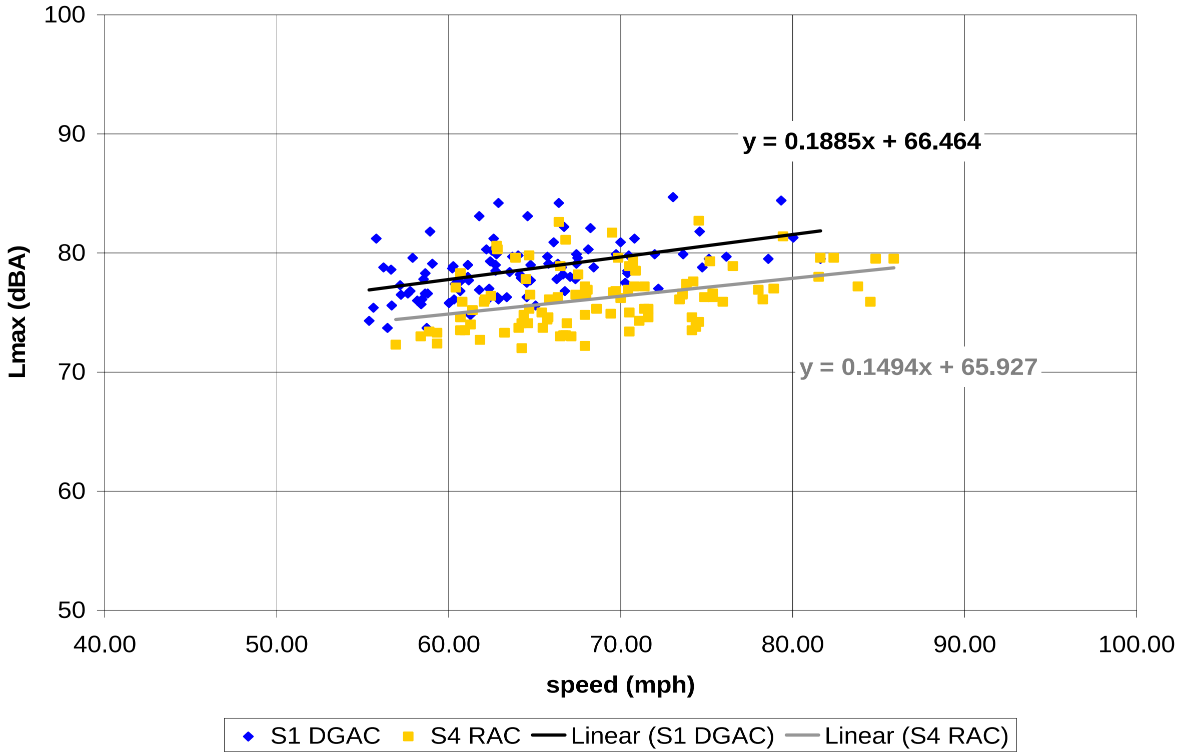
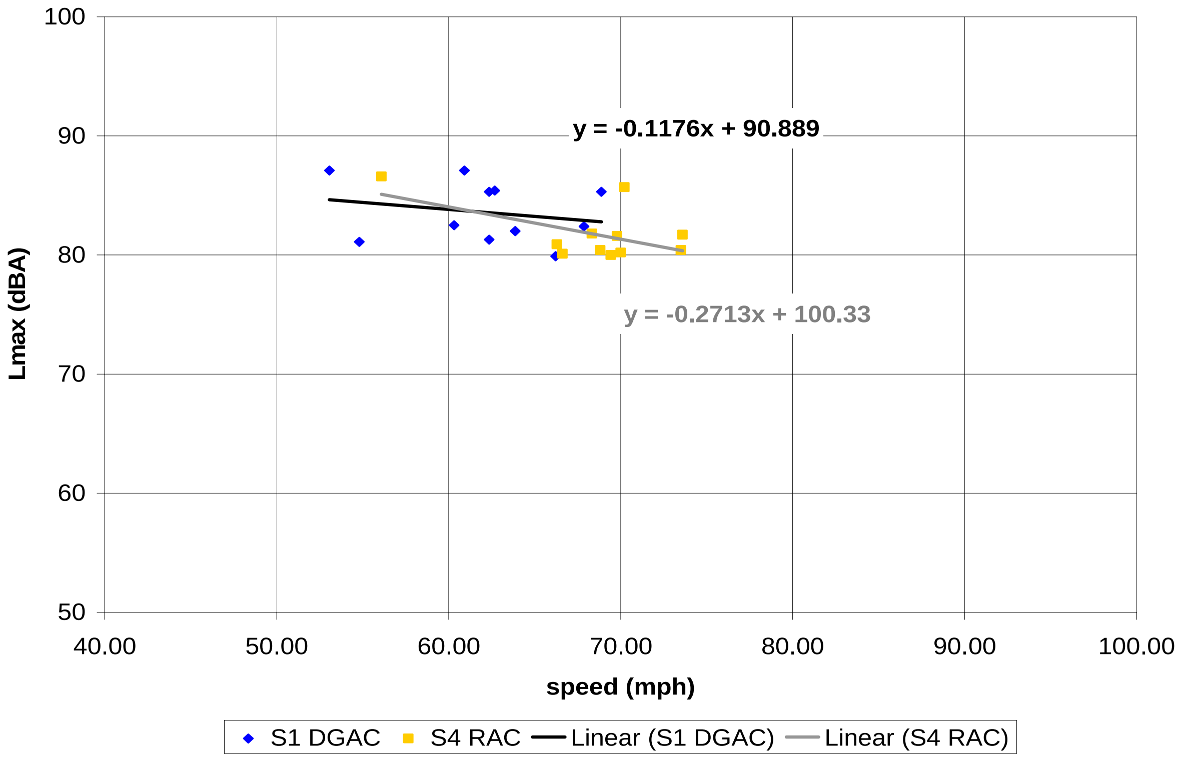


Figure C-42. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


y = 0.1885x + 66.464
y = 0.1494x + 65.927
Lmax (dBA)
100
90
80
70
60
50
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


y = -0.1176x + 90.889
y = -0.2713x + 100.33
Lmax (dBA)
100
90
80
70
60
50
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

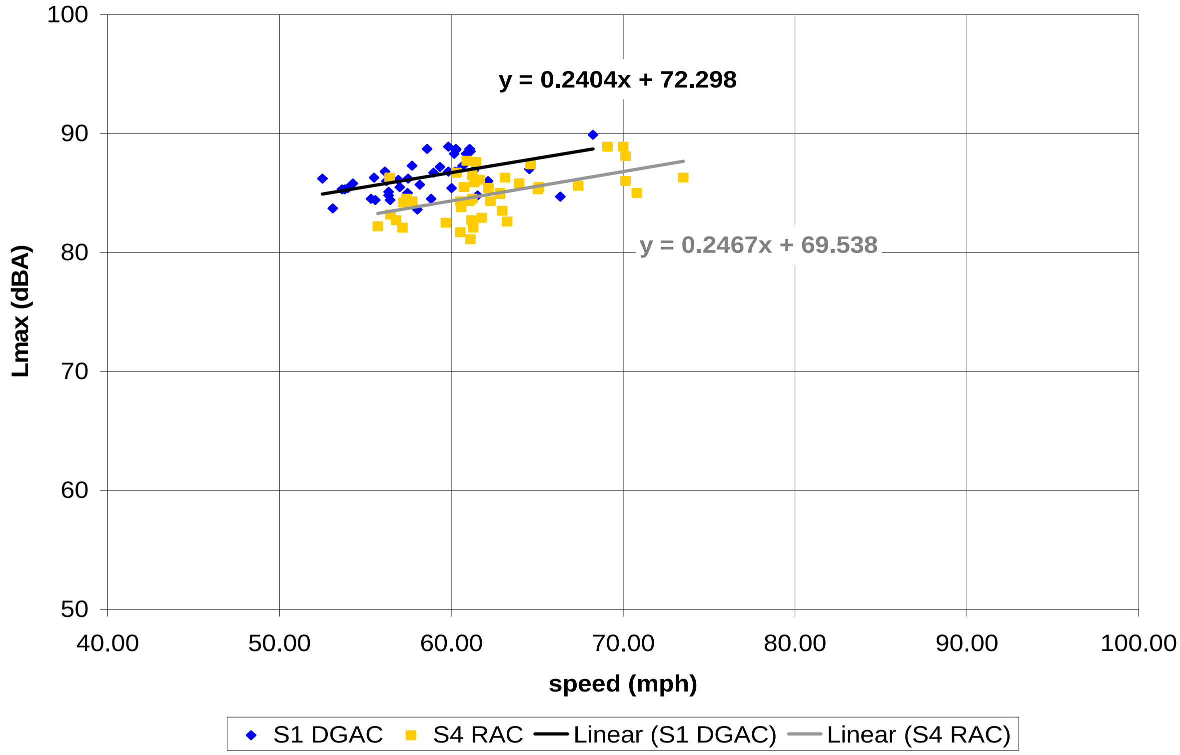
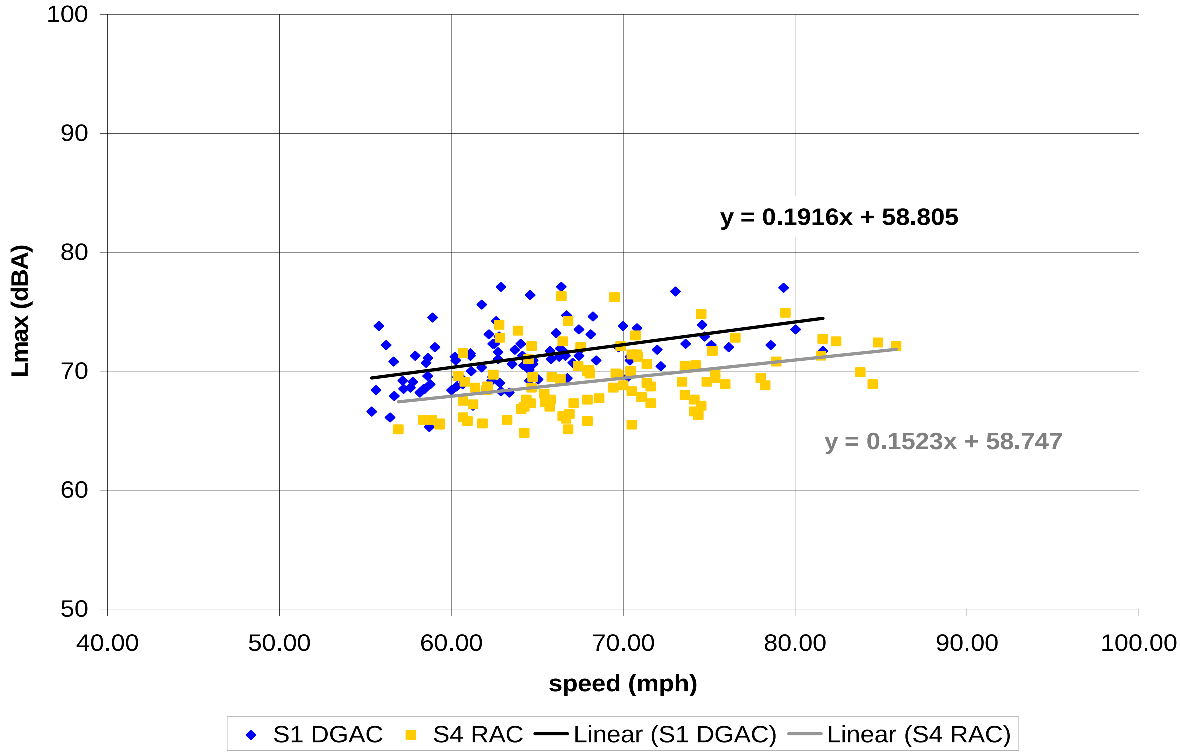
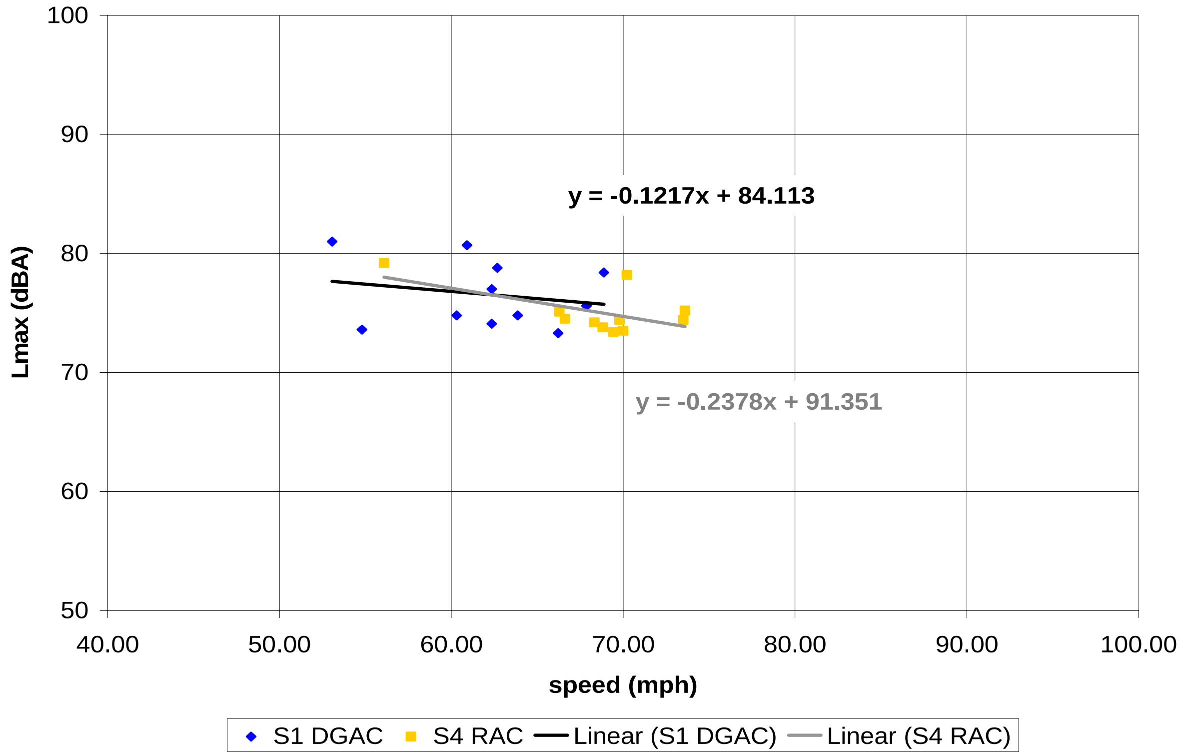


Figure C-43. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
y = 0.1916x + 58.805
y = 0.1523x + 58.747
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
Lmax (dBA)
y = -0.1217x + 84.113
y = -0.2378x + 91.351
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

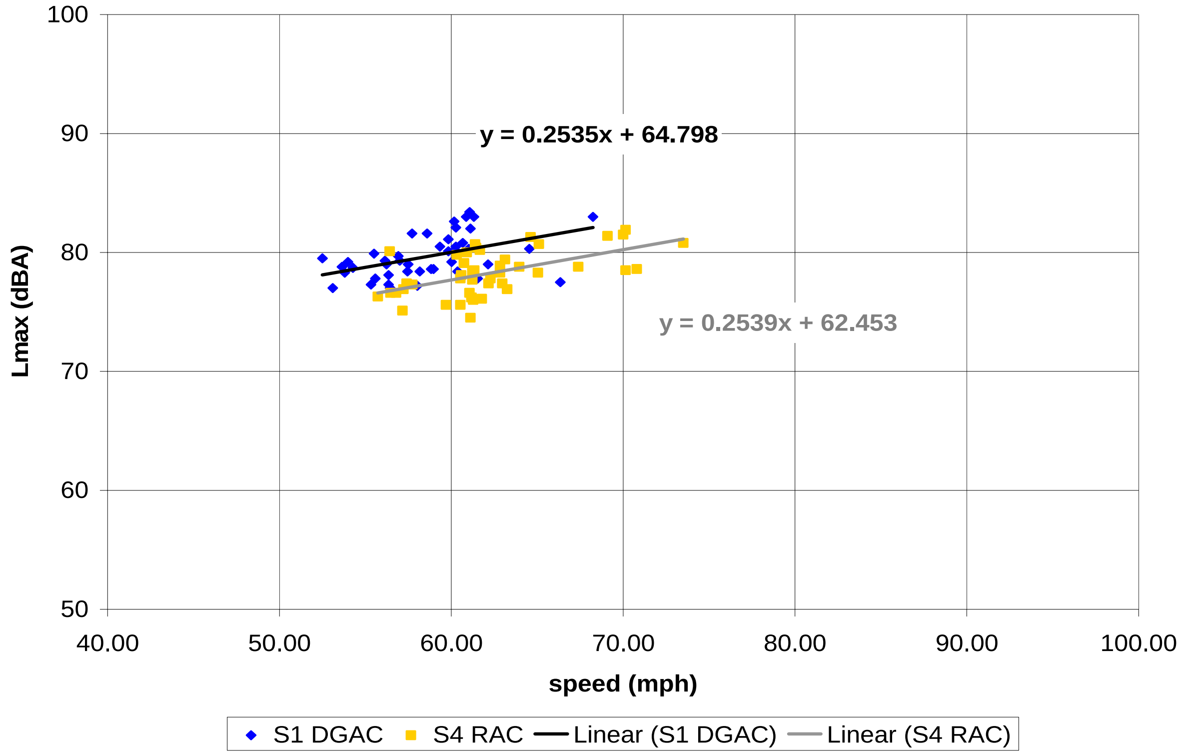
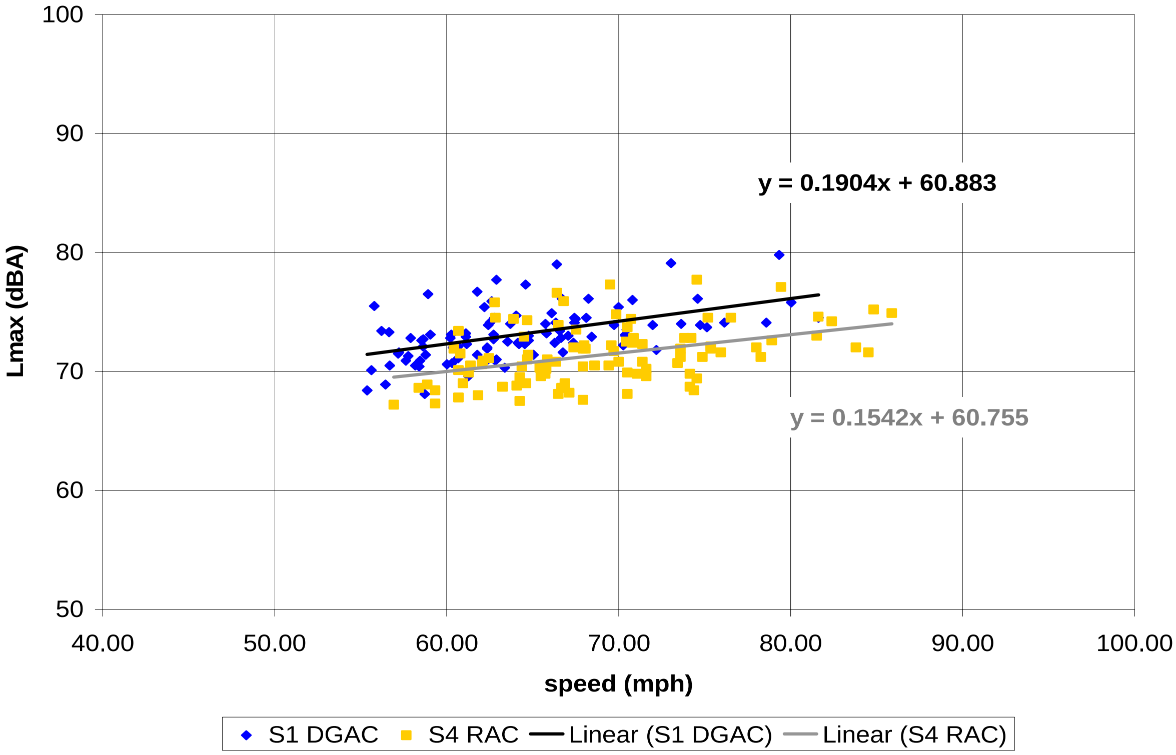
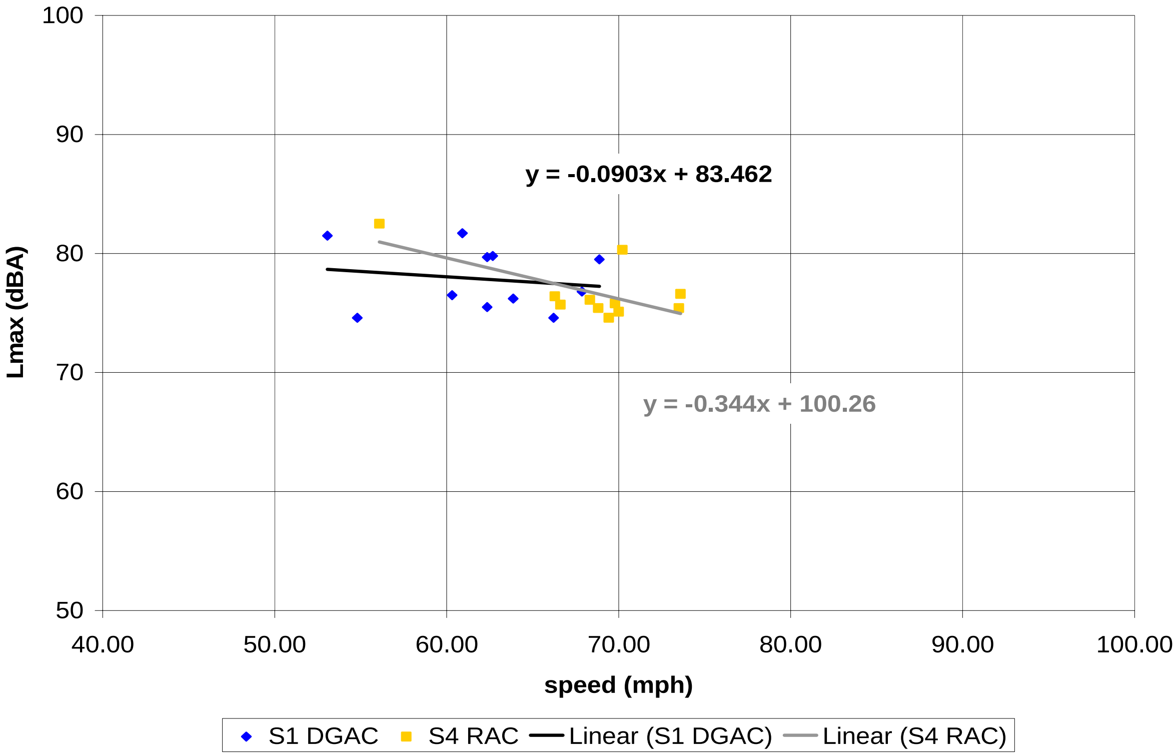


Figure C-44. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
y = 0.1904x + 60.883
y = 0.1542x + 60.755
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
Lmax (dBA)
y = -0.0903x + 83.462
y = -0.344x + 100.26
40.00
50.00
60.00
70.00
80.00
90.00
100.00
speed (mph)
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

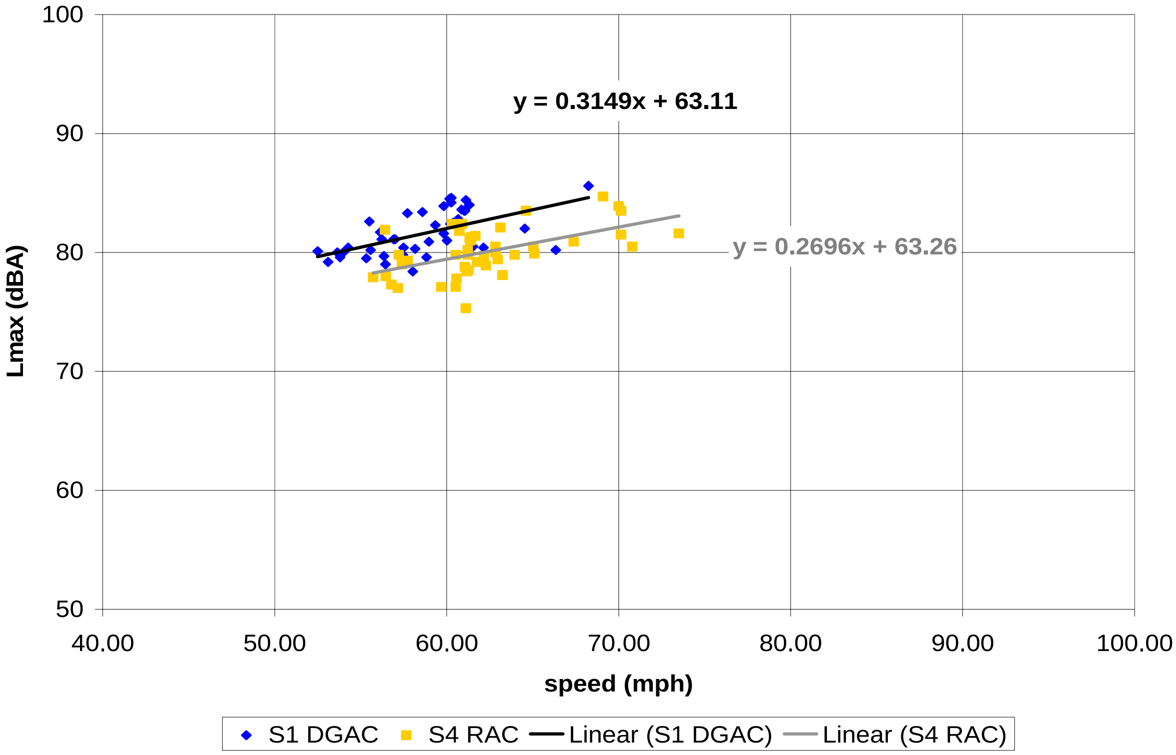
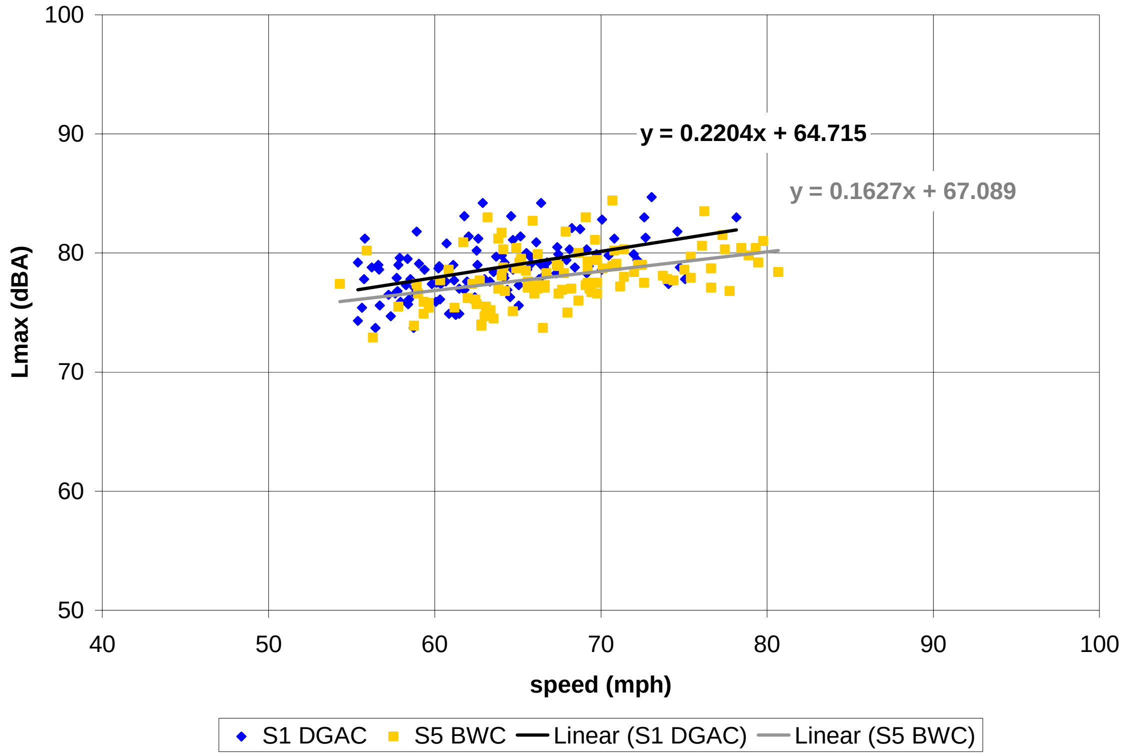
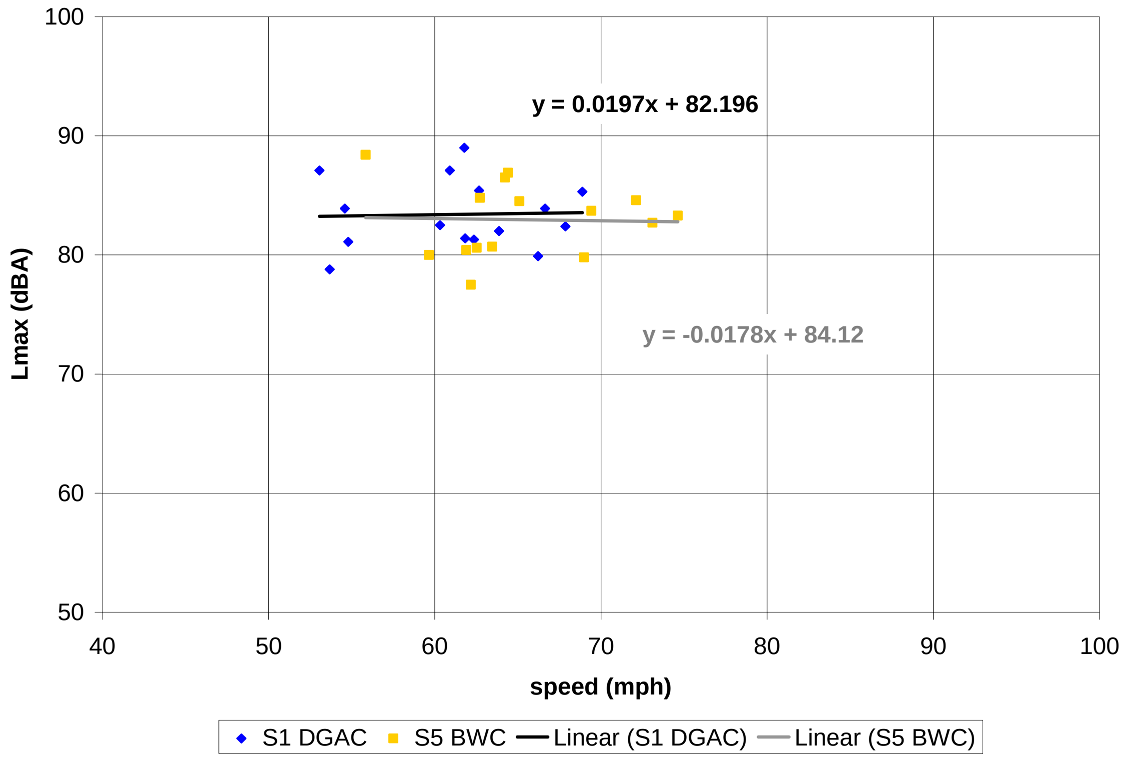


Figure C-45. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.


y = 0.2204x + 64.715
y = 0.1627x + 67.089
Lmax (dBA)
speed (mph)
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)


y = 0.0197x + 82.196
y = -0.0178x + 84.12
Lmax (dBA)
speed (mph)
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

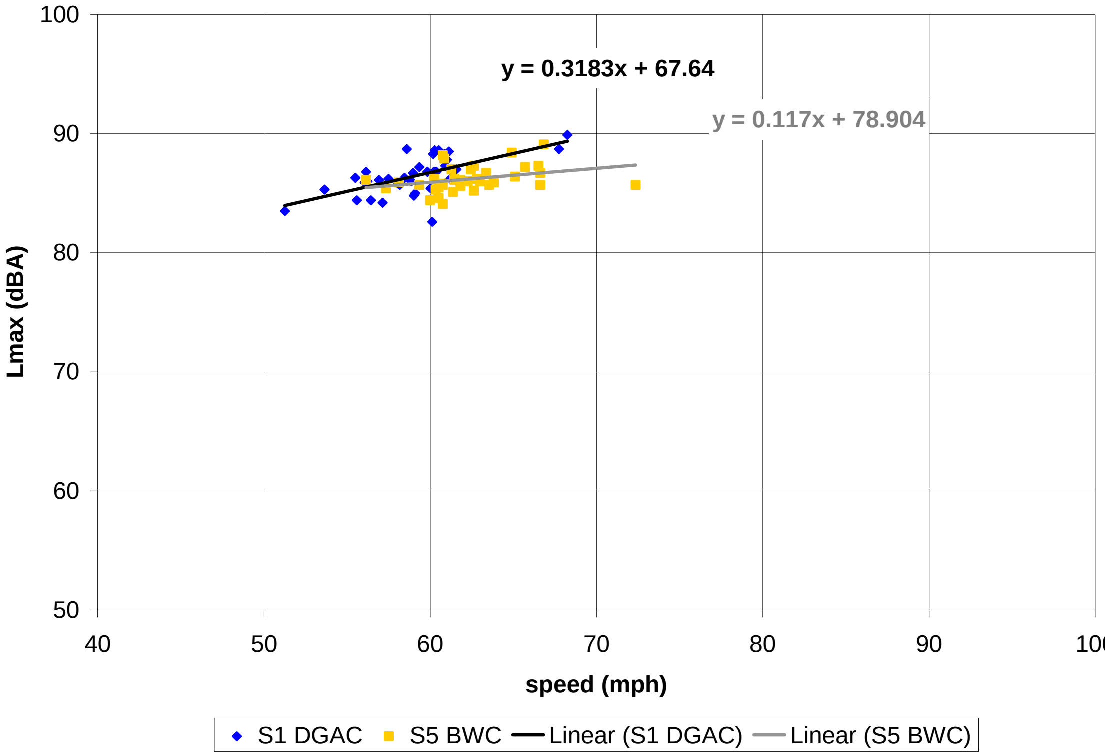
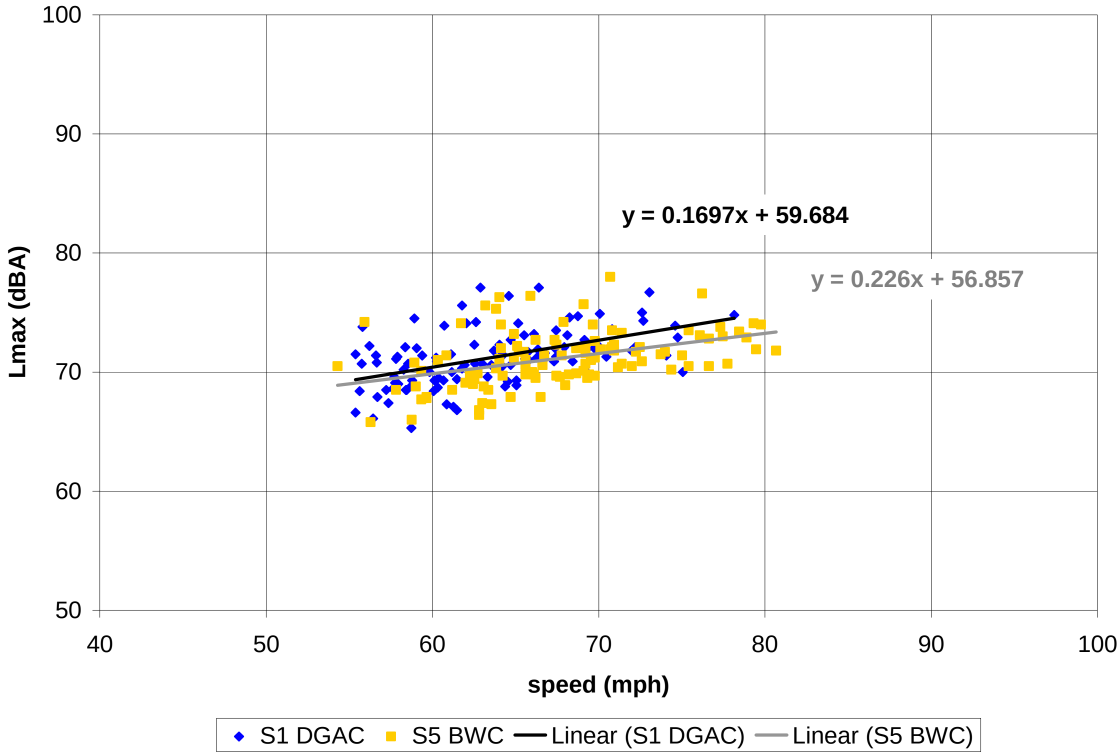
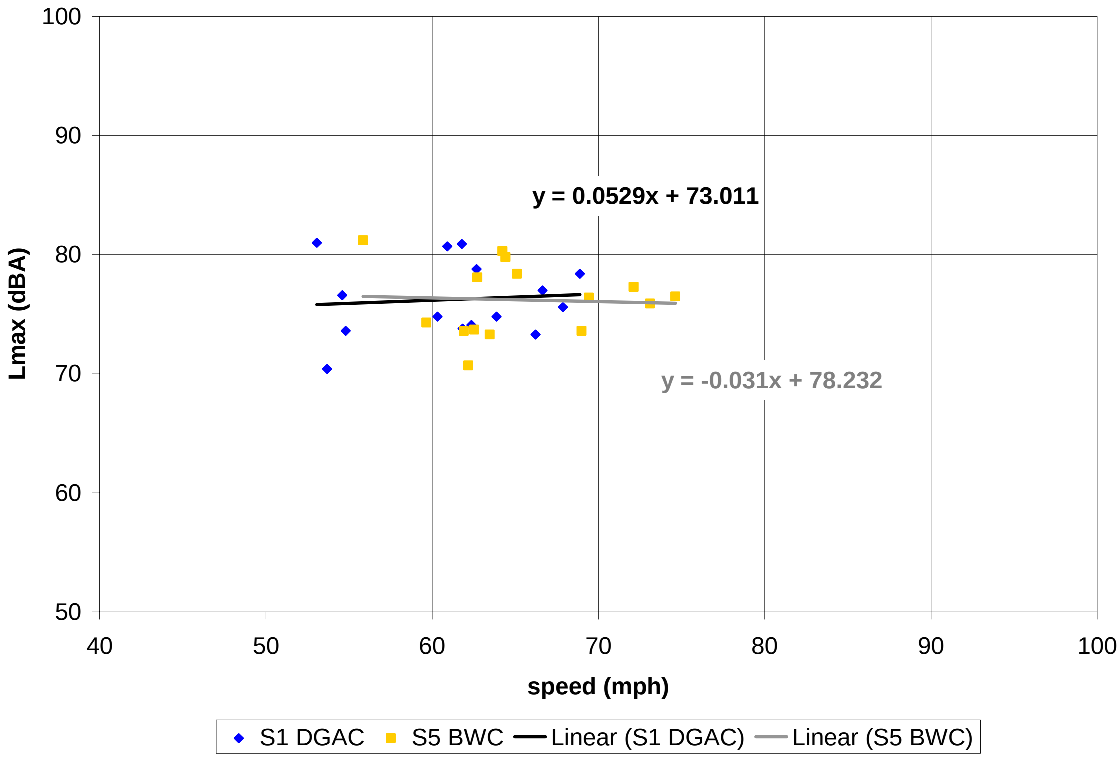


Figure C-46. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1697x + 59.684
y = 0.226x + 56.857
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0529x + 73.011
y = -0.031x + 78.232
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

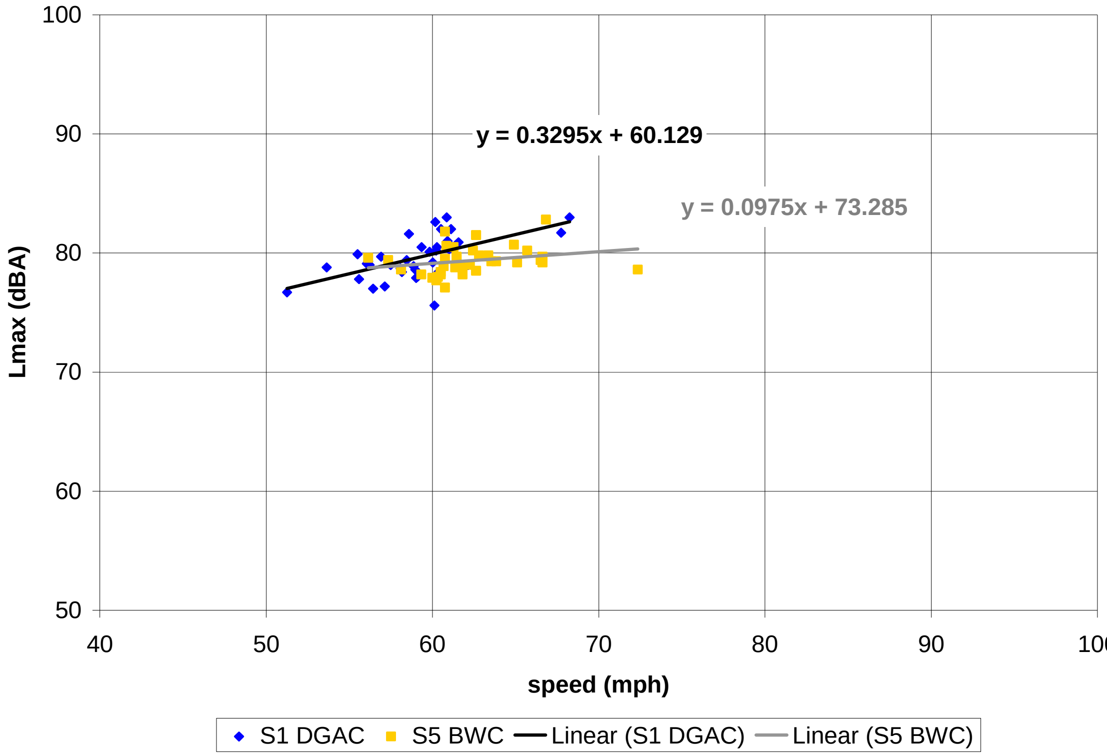
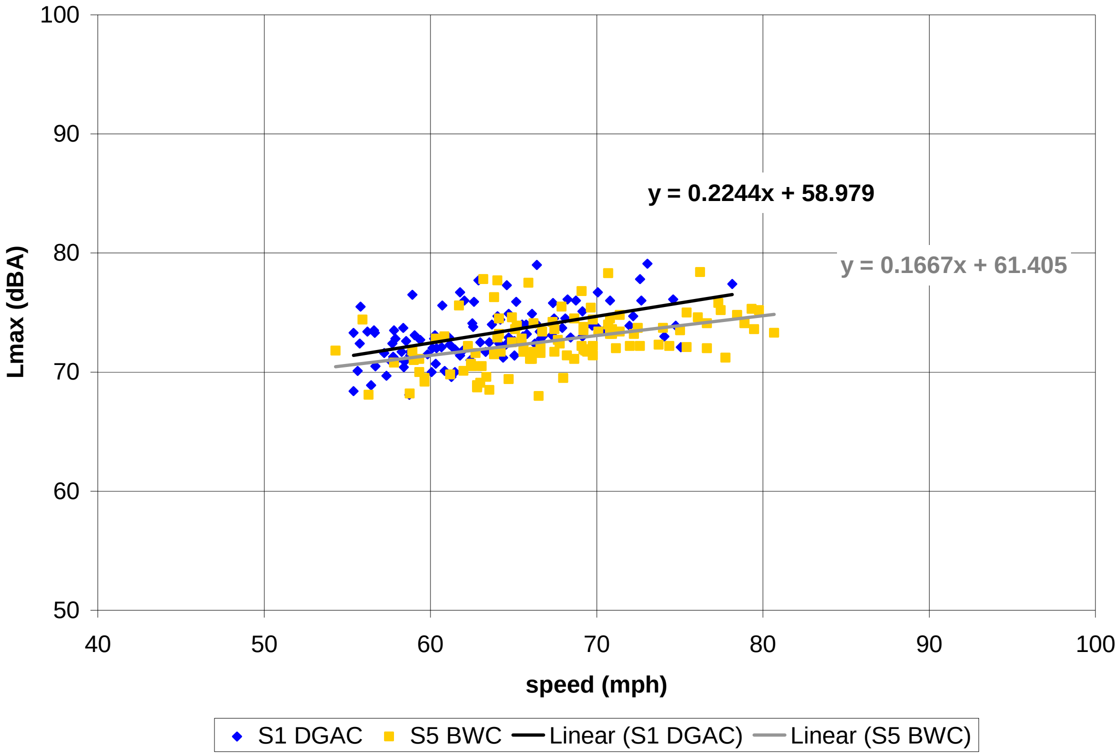
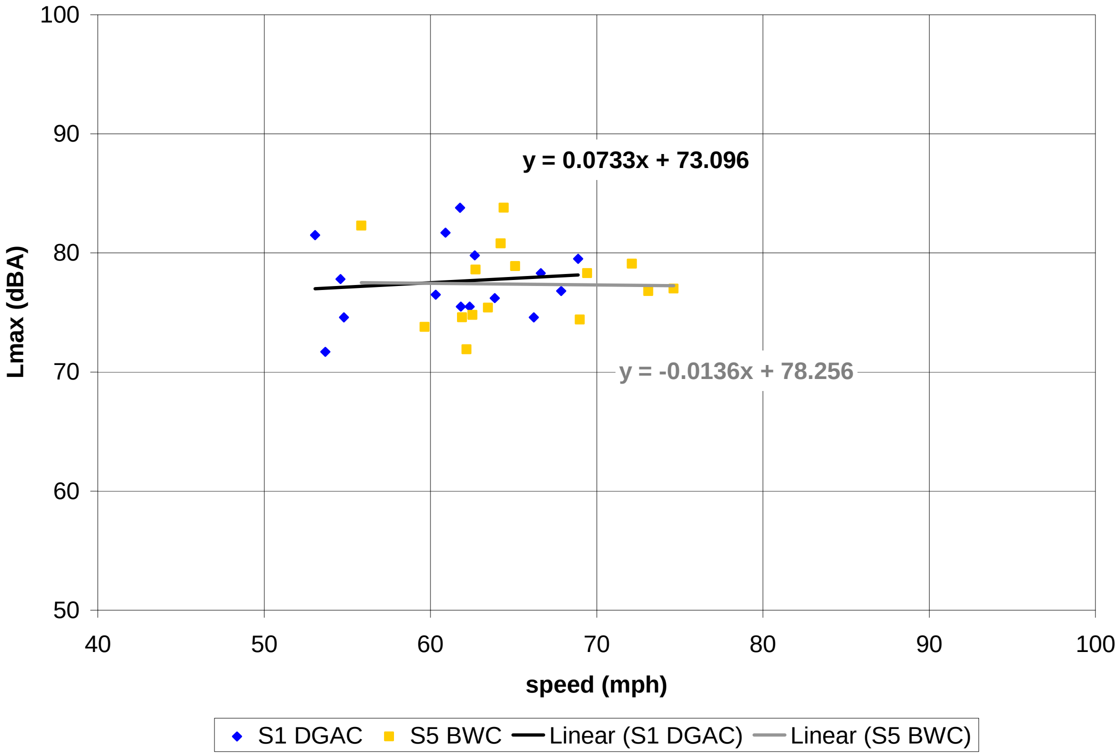


Figure C-47. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2244x + 58.979
y = 0.1667x + 61.405
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)



100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.0733x + 73.096
y = -0.0136x + 78.256
S1 DGAC
S5 BWC
Linear (S1 DGAC)
Linear (S5 BWC)

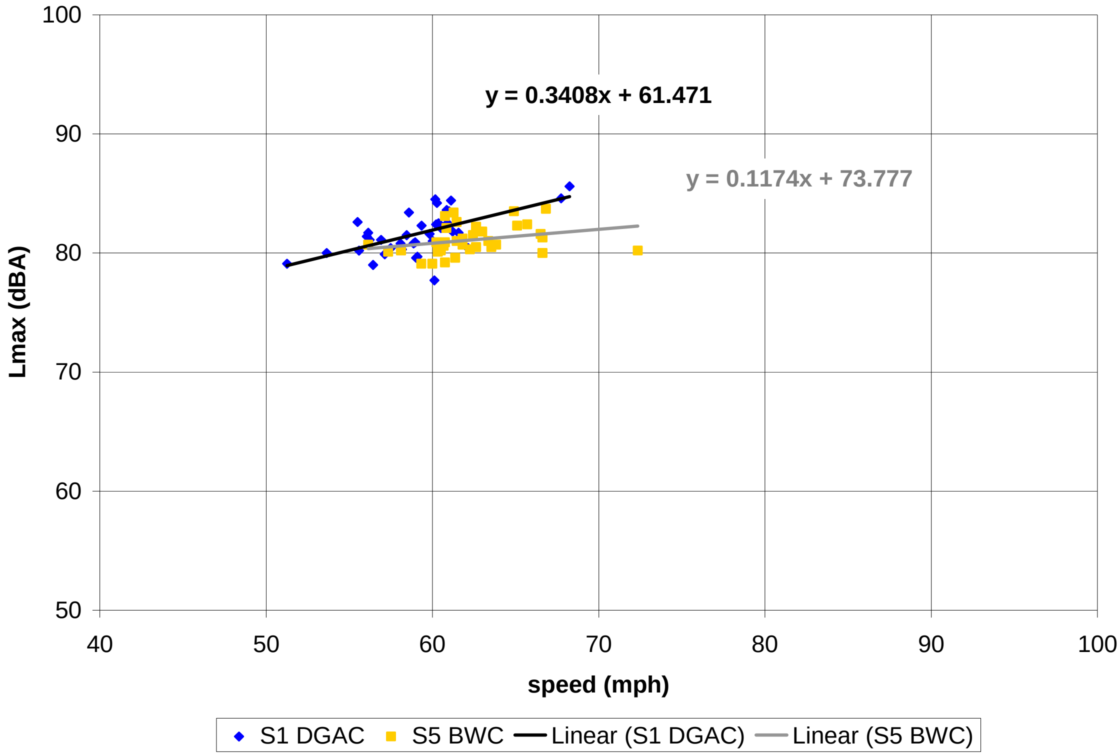
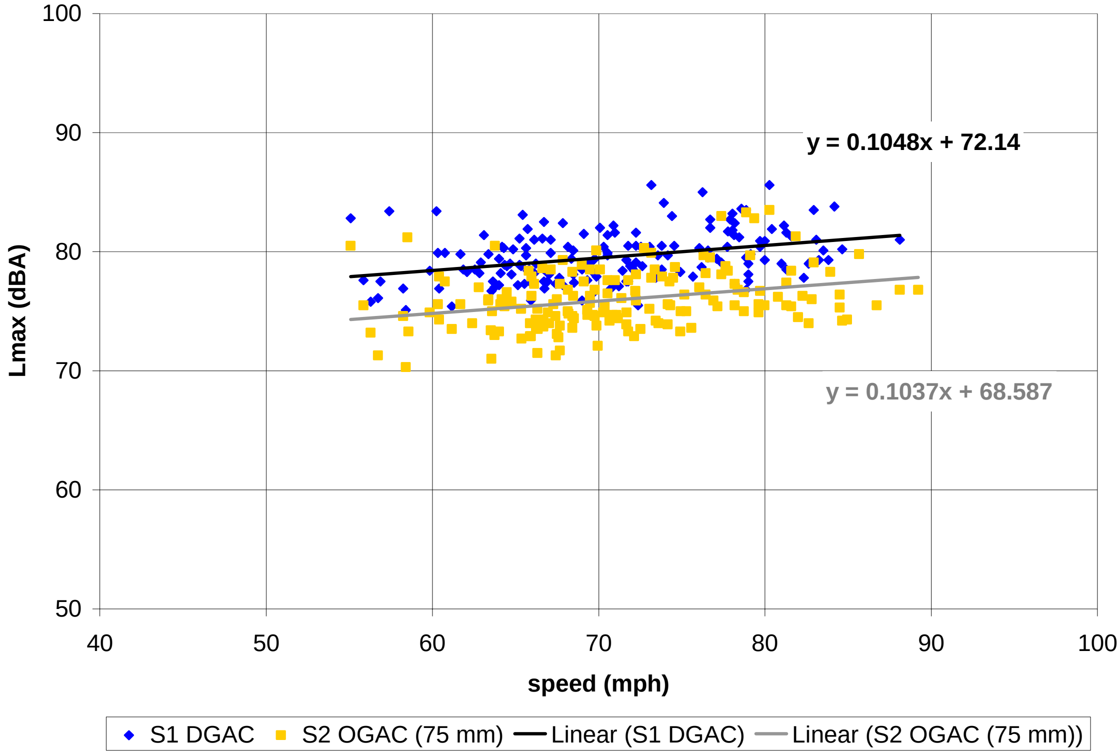
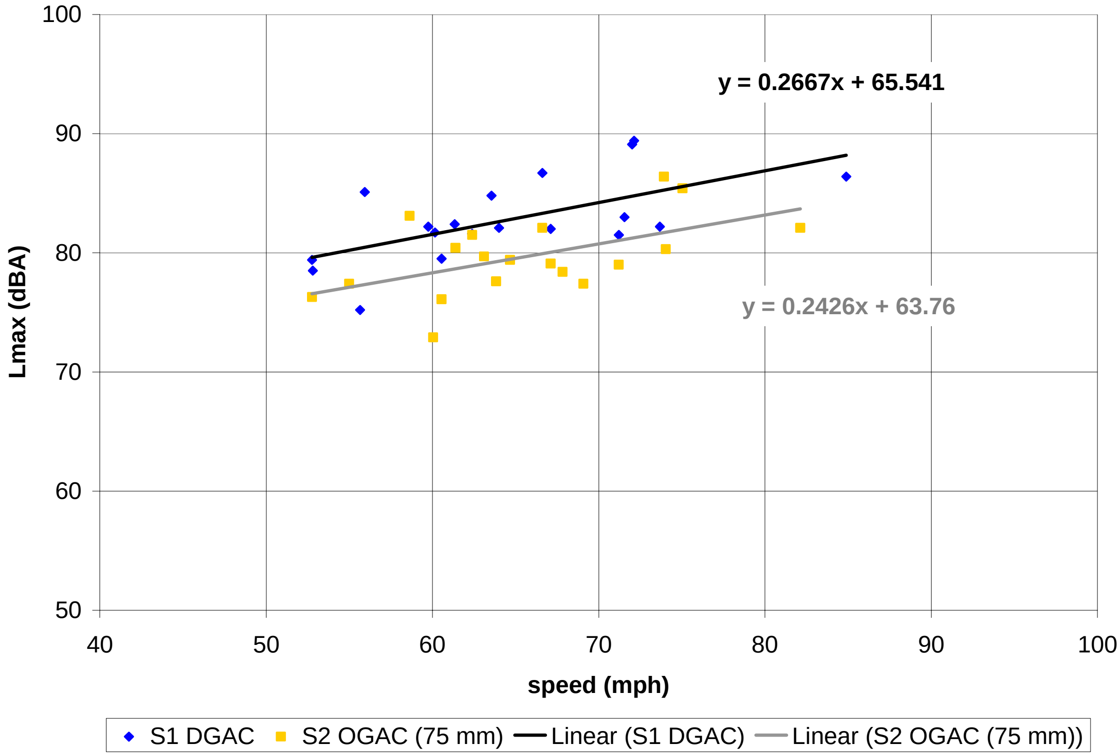


Figure C-48. (this and previous page) Vehicle pass-by data, post-overlay, 16 months age; Site 1 (DGAC 30mm), Site 5 (BWC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

C.6 Post-Overlay – Pavement Age: 52 months





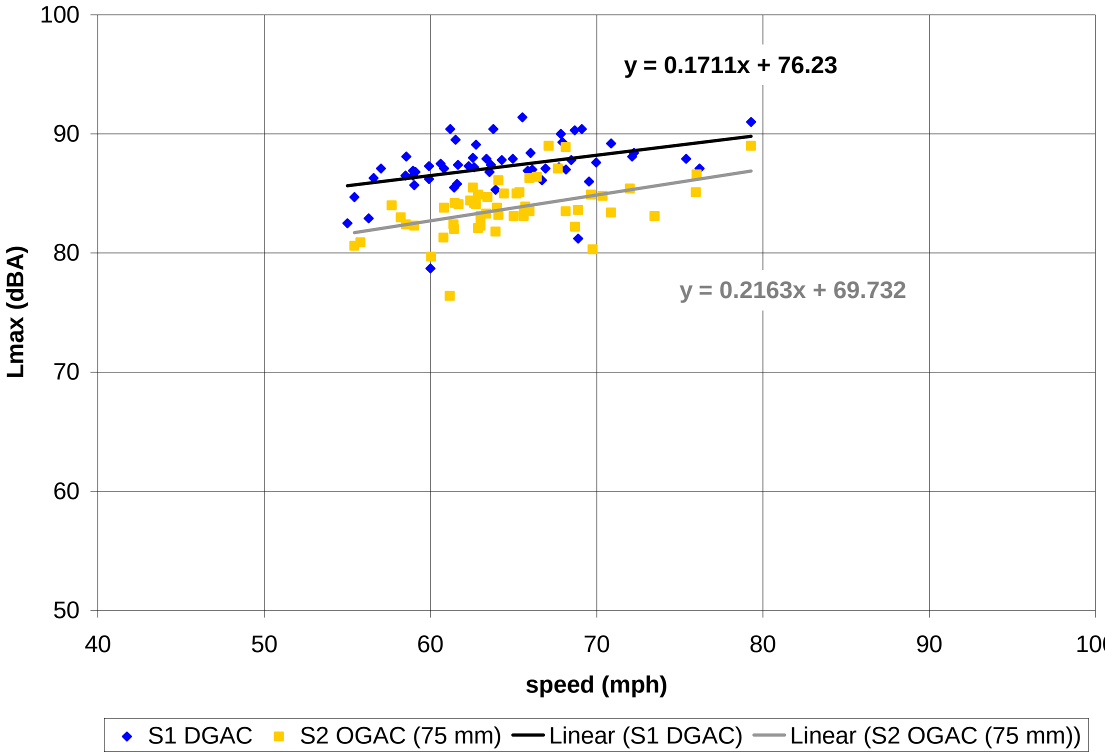
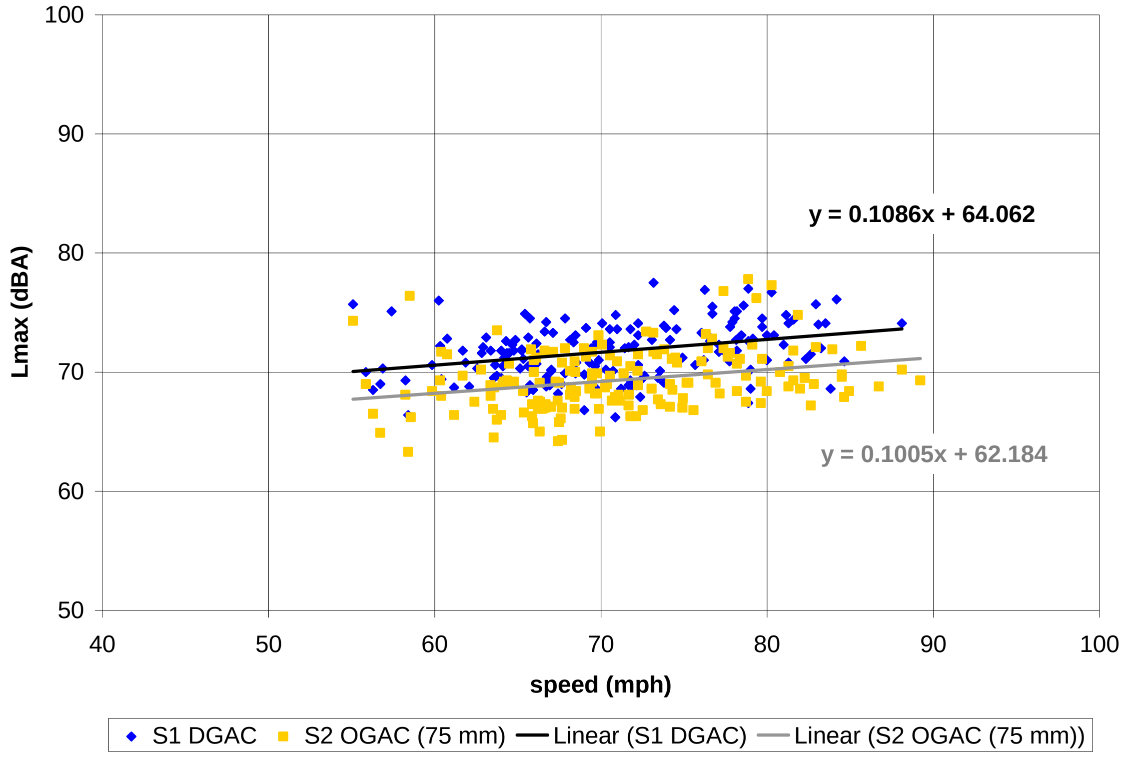
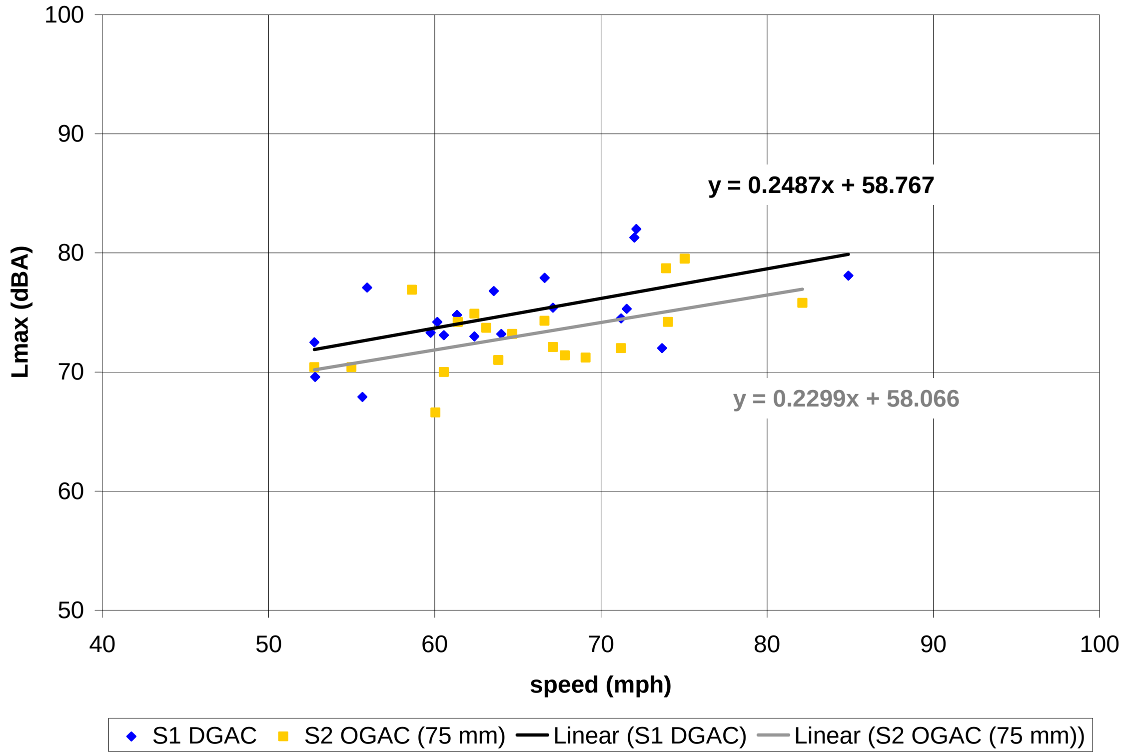


Figure C-49. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


y = 0.1086x + 64.062
y = 0.1005x + 62.184
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


y = 0.2487x + 58.767
y = 0.2299x + 58.066
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

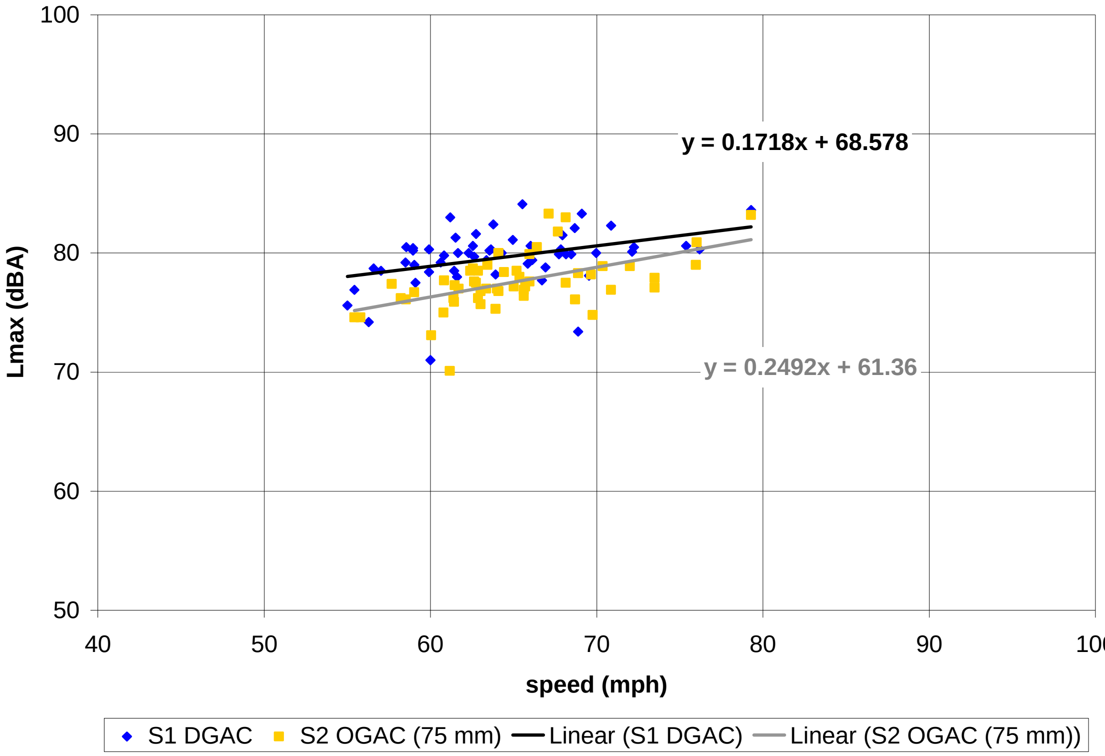
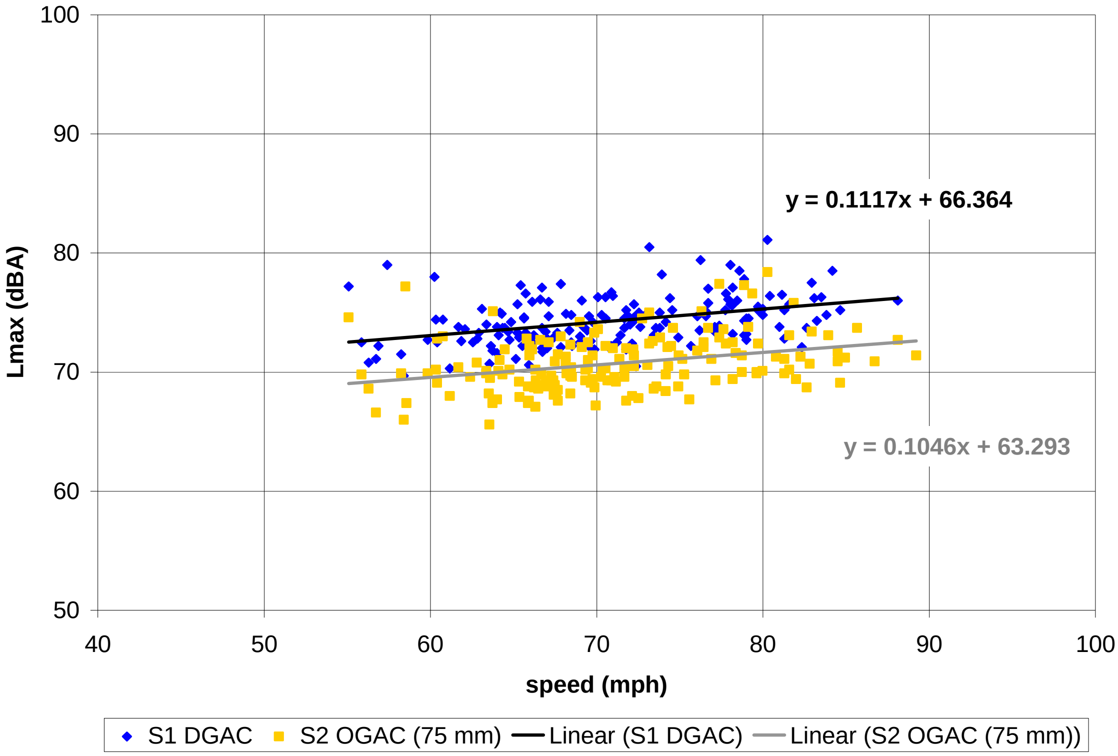
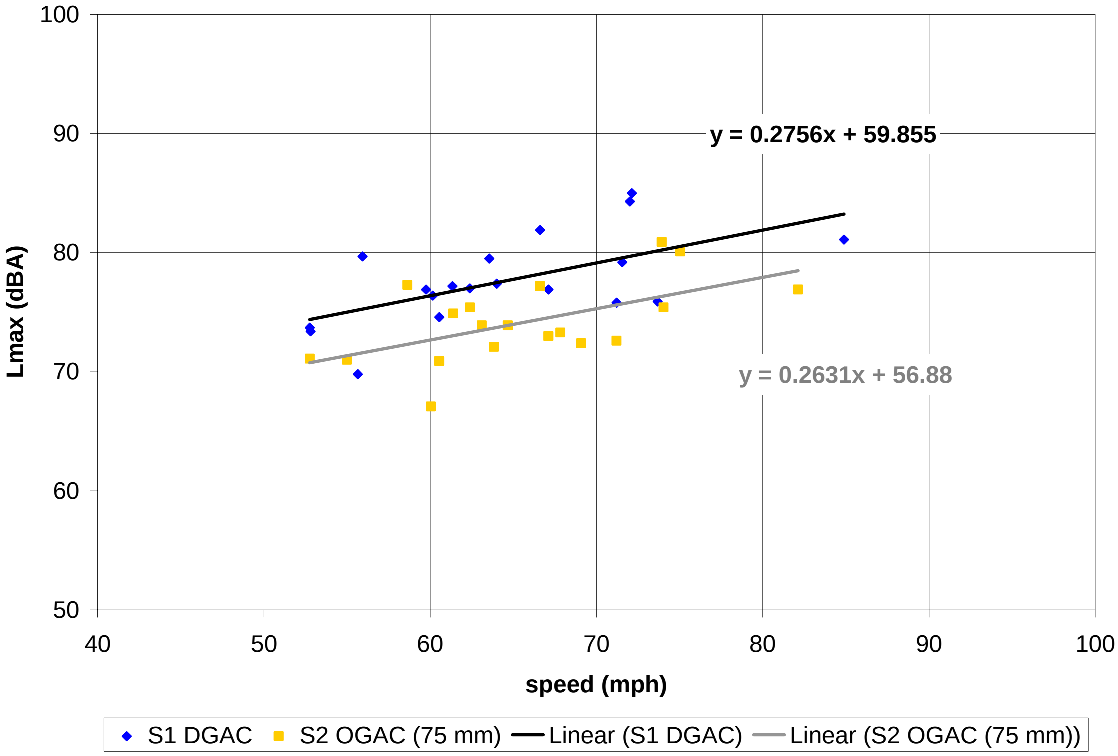


Figure C-50. Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.1117x + 66.364
y = 0.1046x + 63.293
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))


100
90
80
70
60
50
Lmax (dBA)
40
50
60
70
80
90
100
speed (mph)
y = 0.2756x + 59.855
y = 0.2631x + 56.88
S1 DGAC
S2 OGAC (75 mm)
Linear (S1 DGAC)
Linear (S2 OGAC (75 mm))

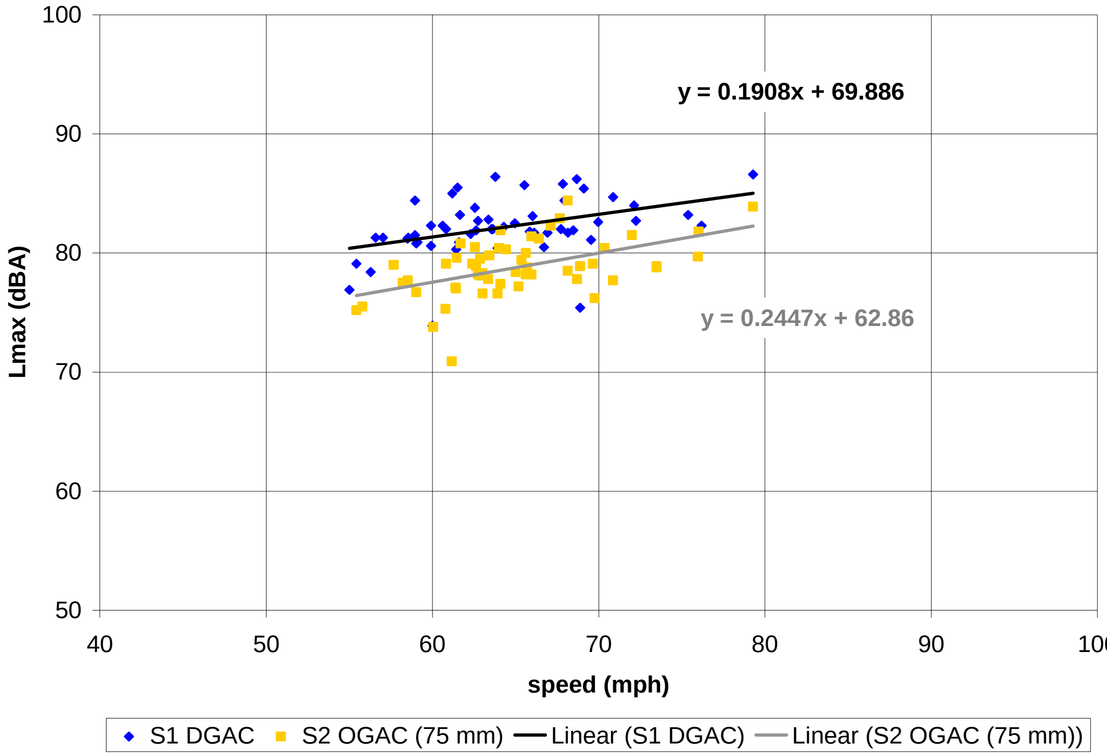
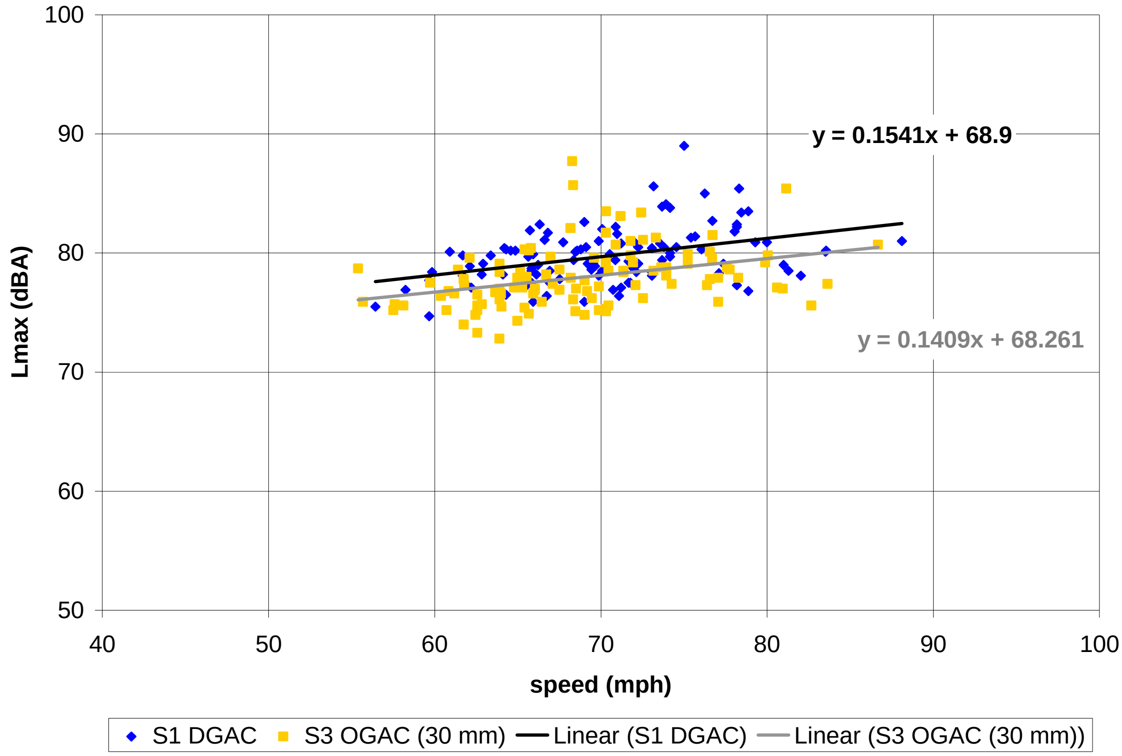
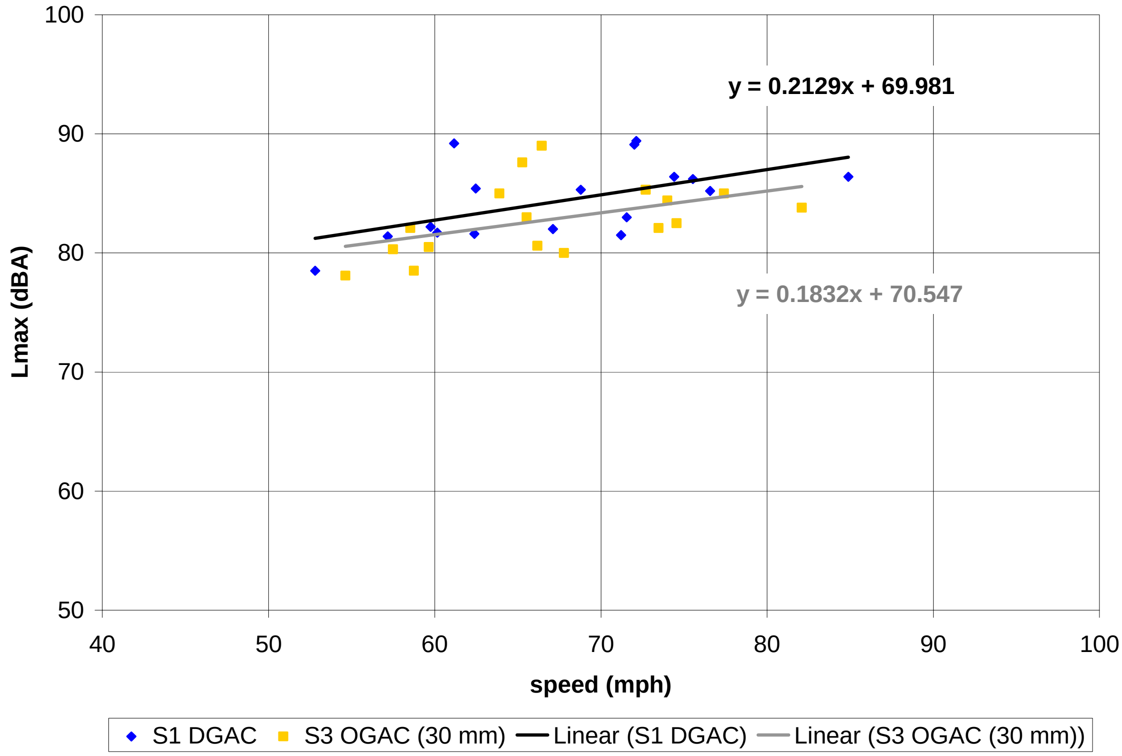


Figure C-51. Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 2 (OGAC 75mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1541x + 68.9
y = 0.1409x + 68.261
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.2129x + 69.981
y = 0.1832x + 70.547
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

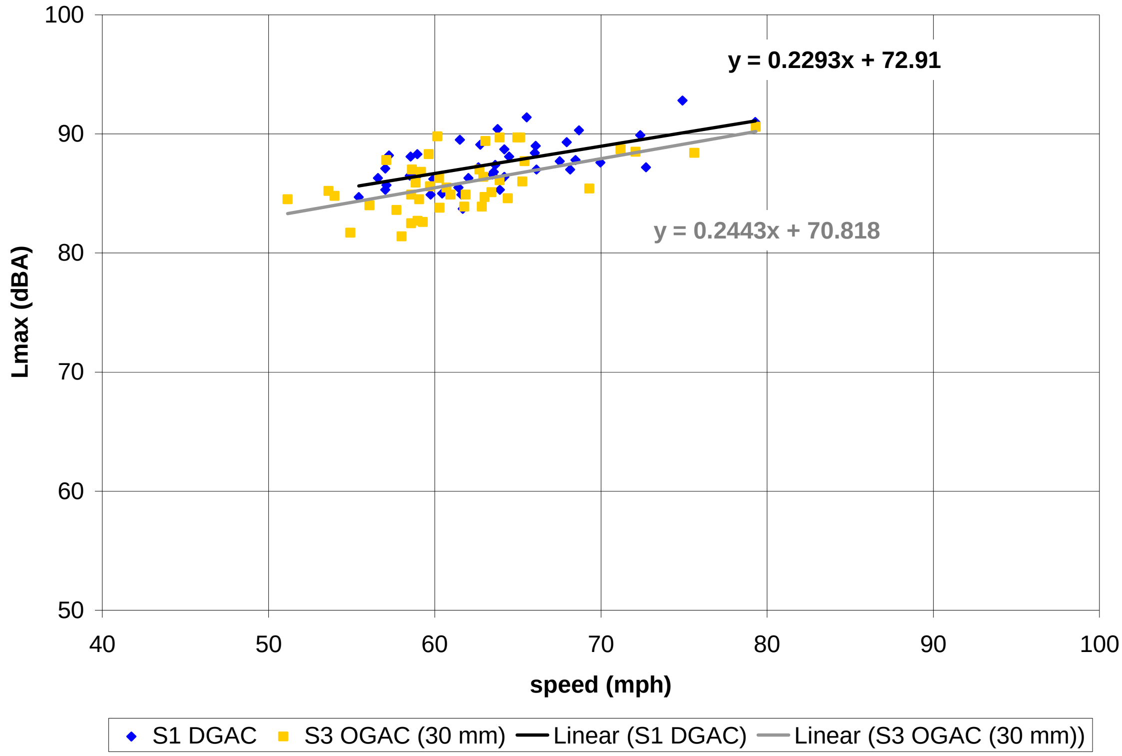
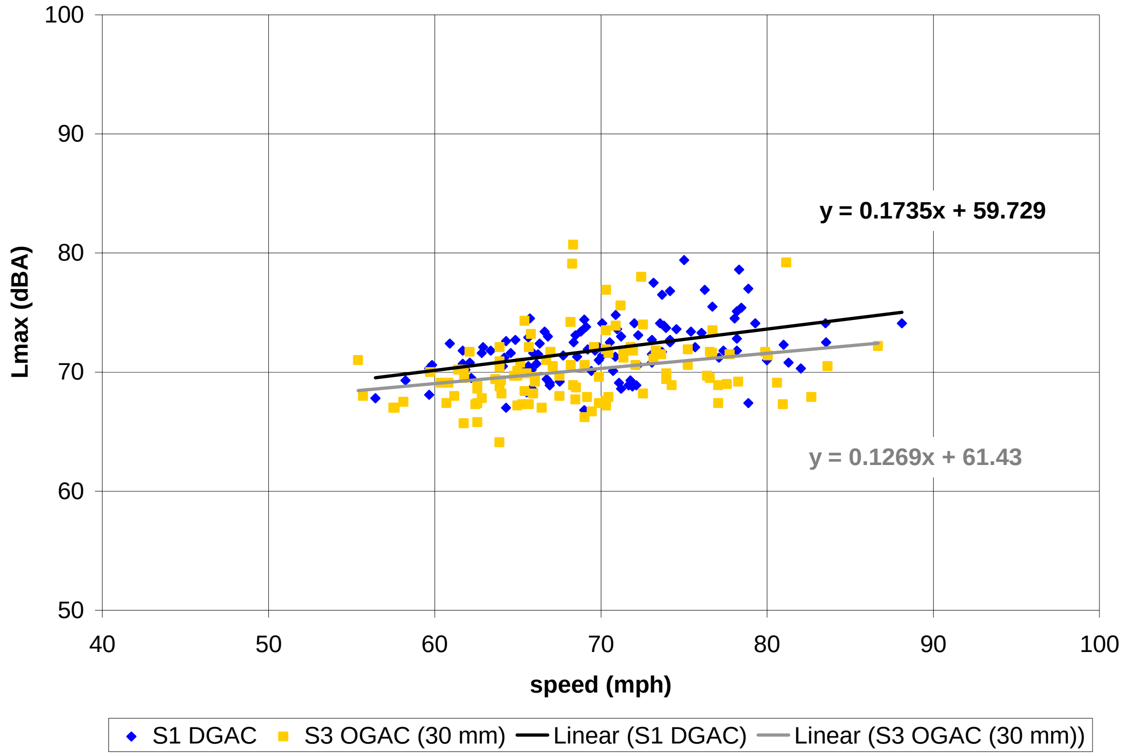
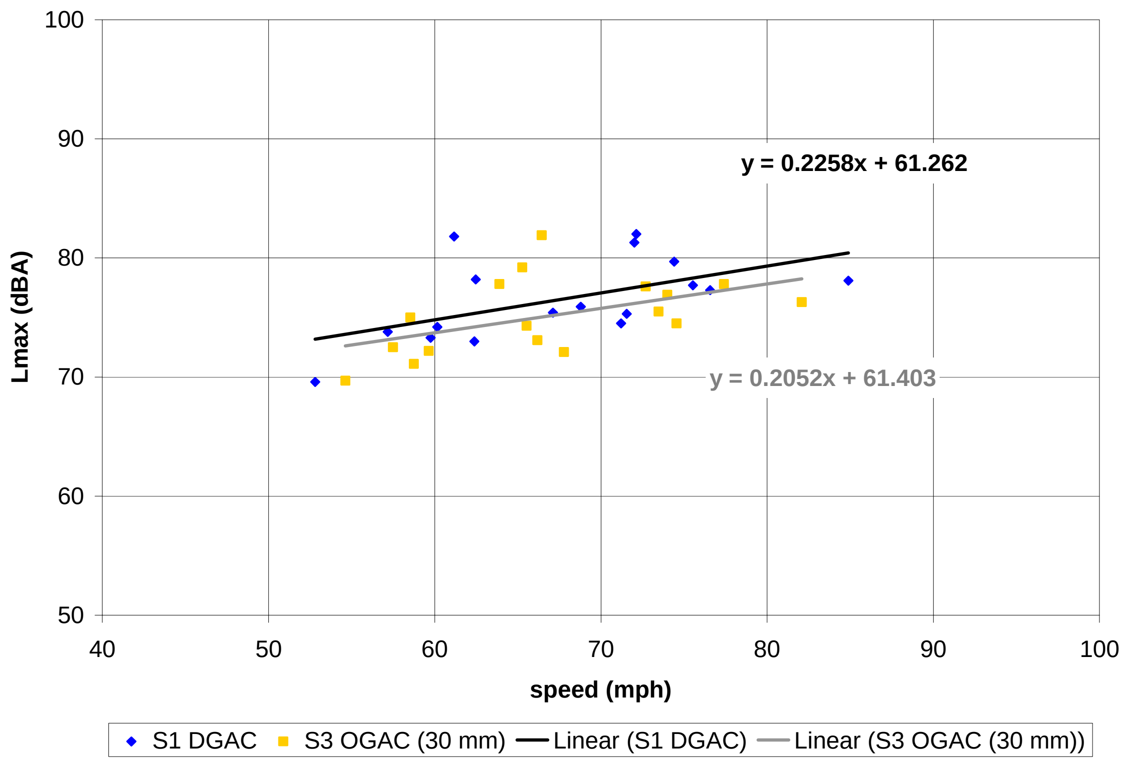


Figure C-52. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.



Lmax (dBA)
speed (mph)
y = 0.1735x + 59.729
y = 0.1269x + 61.43
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))



Lmax (dBA)
speed (mph)
y = 0.2258x + 61.262
y = 0.2052x + 61.403
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

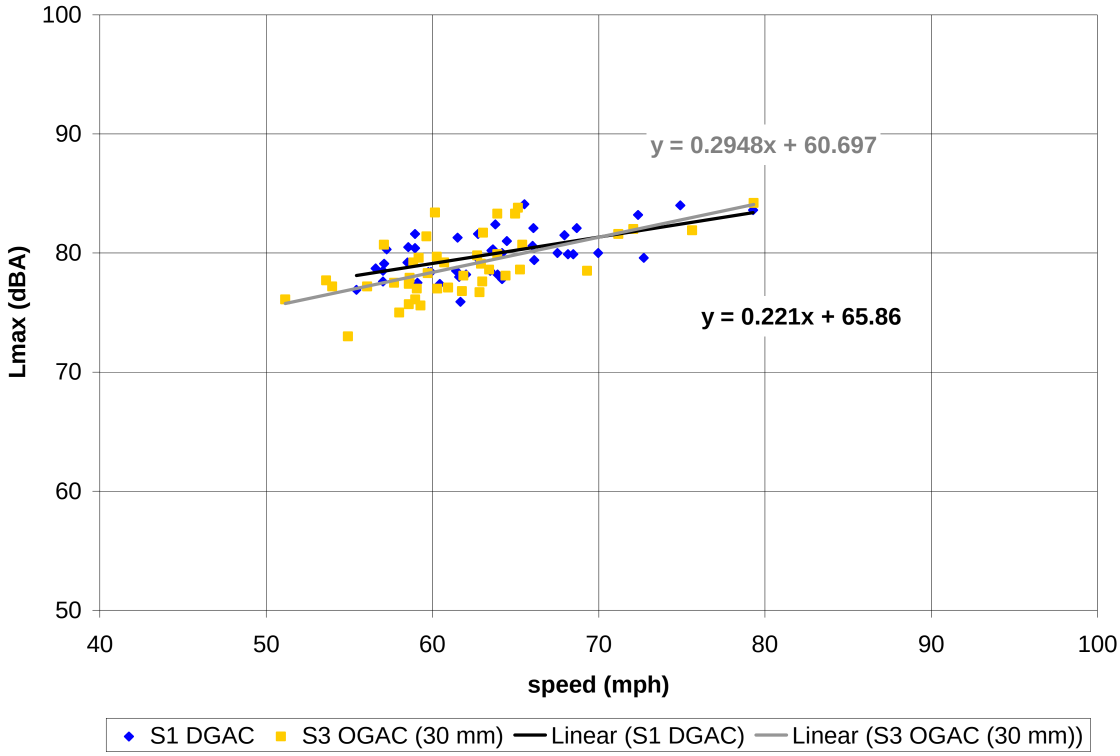
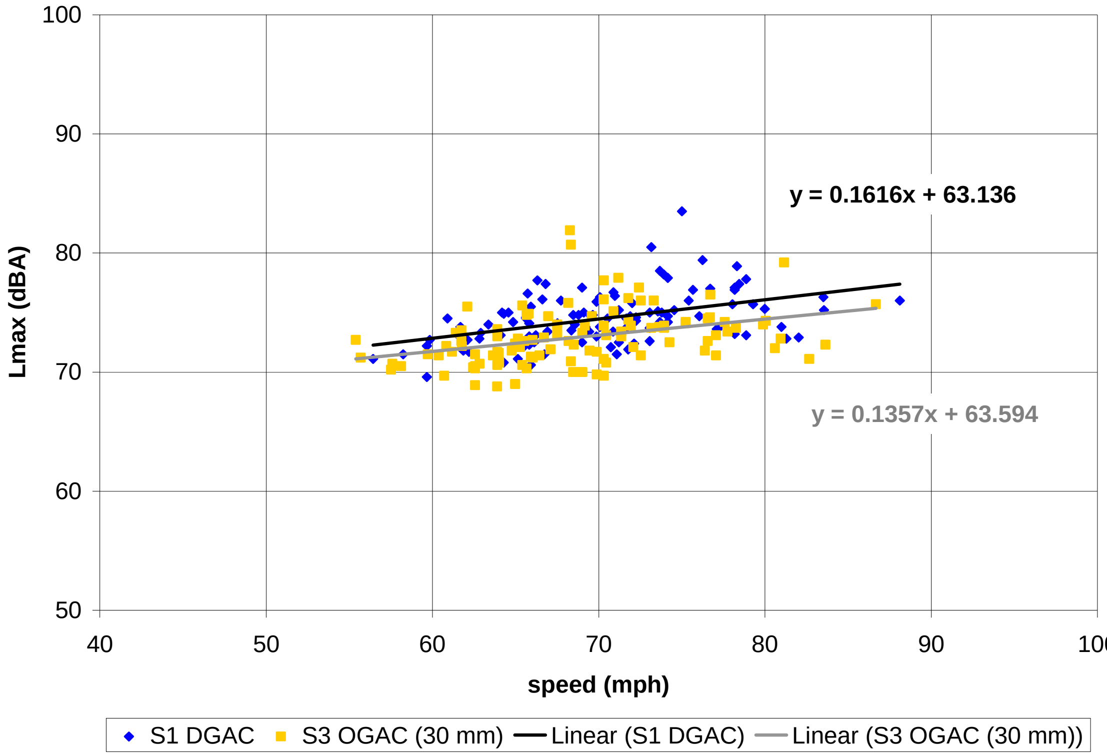
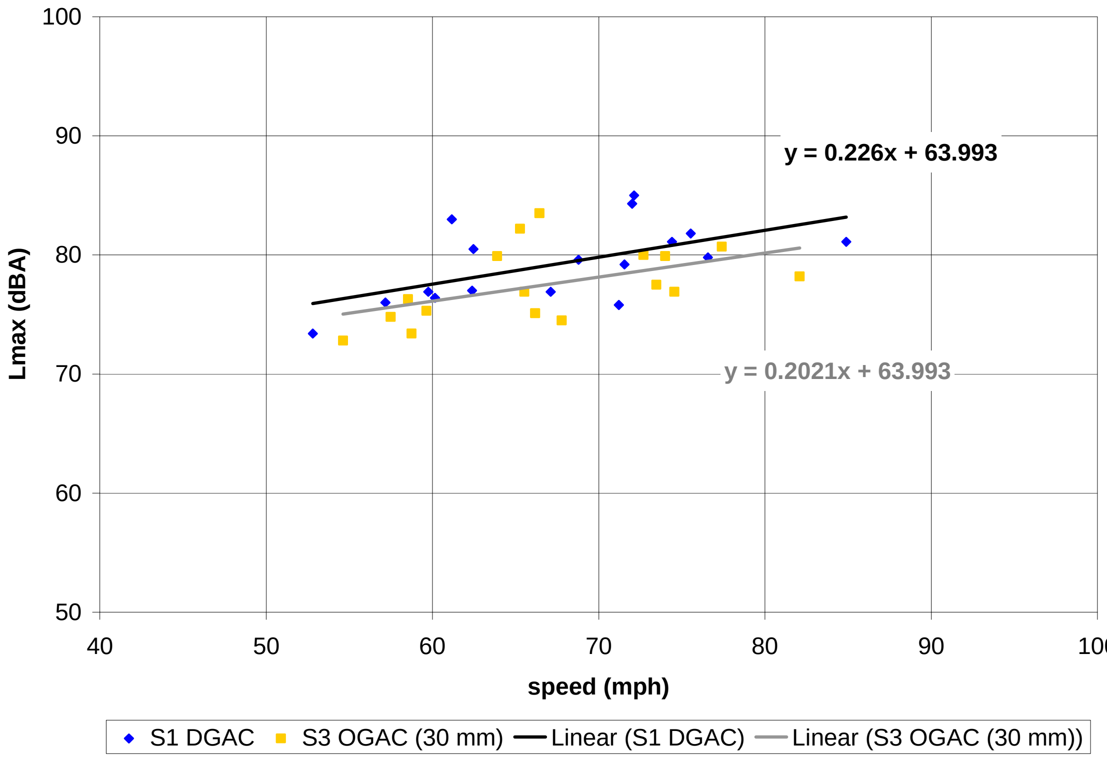


Figure C-53. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1616x + 63.136
y = 0.1357x + 63.594
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.226x + 63.993
y = 0.2021x + 63.993
S1 DGAC
S3 OGAC (30 mm)
Linear (S1 DGAC)
Linear (S3 OGAC (30 mm))

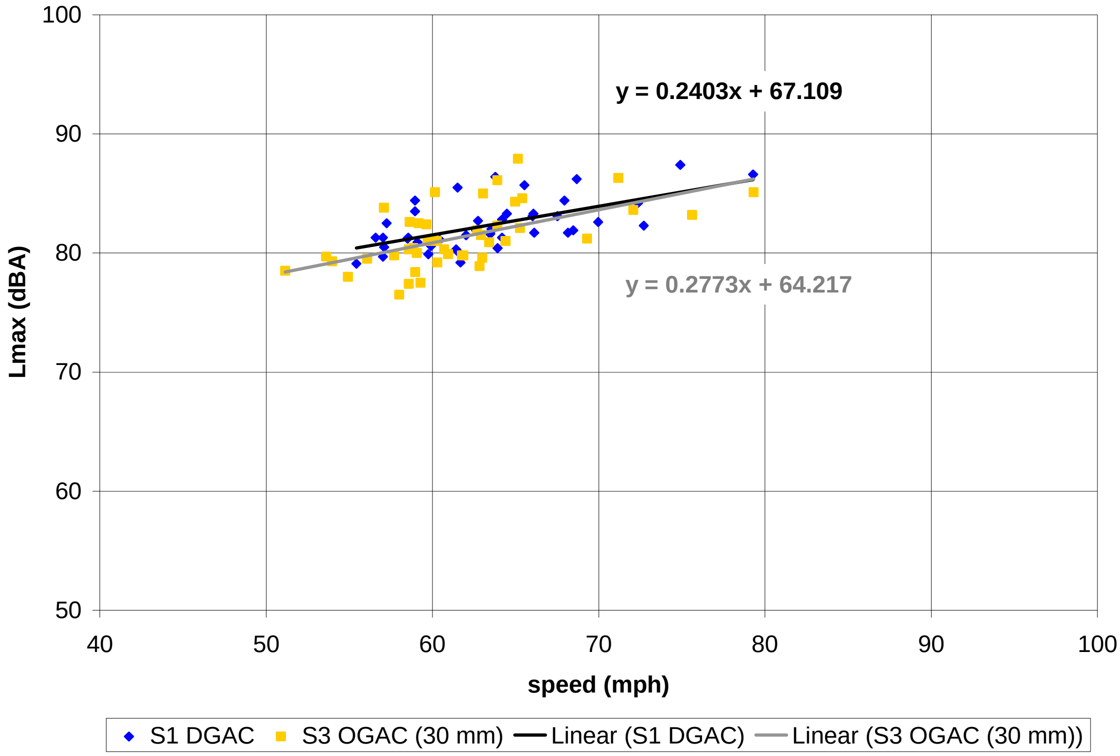
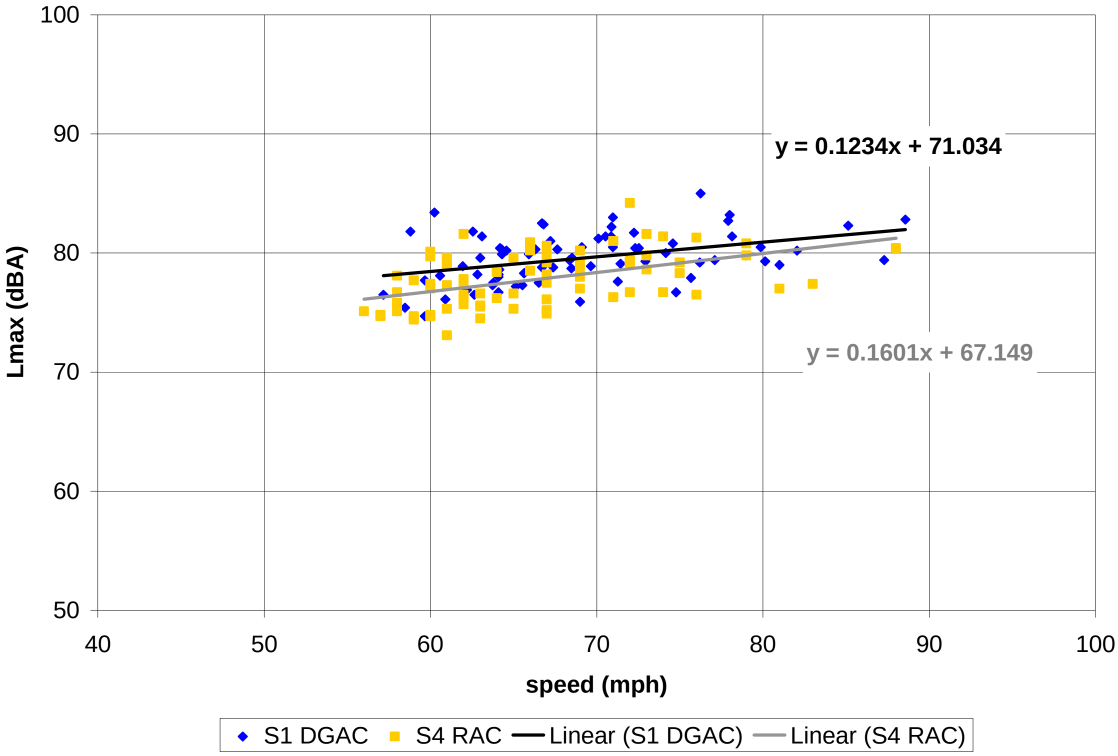
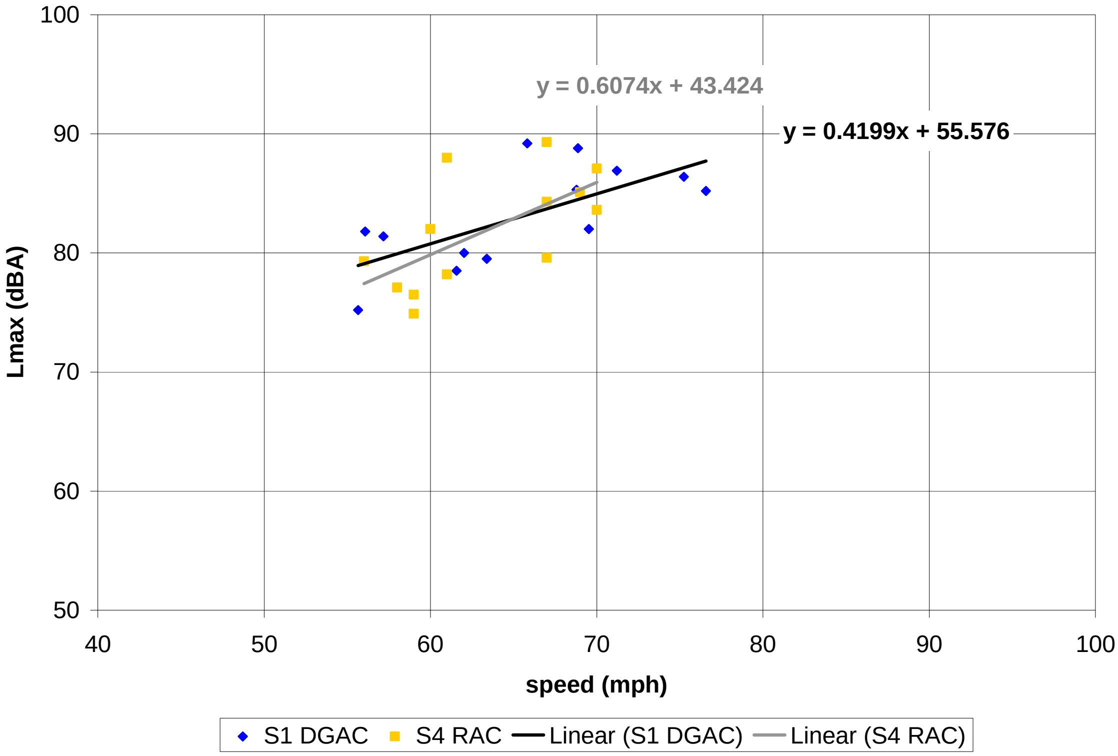


Figure C-54. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 3 (OGAC 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1234x + 71.034
y = 0.1601x + 67.149
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)



100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.6074x + 43.424
y = 0.4199x + 55.576
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

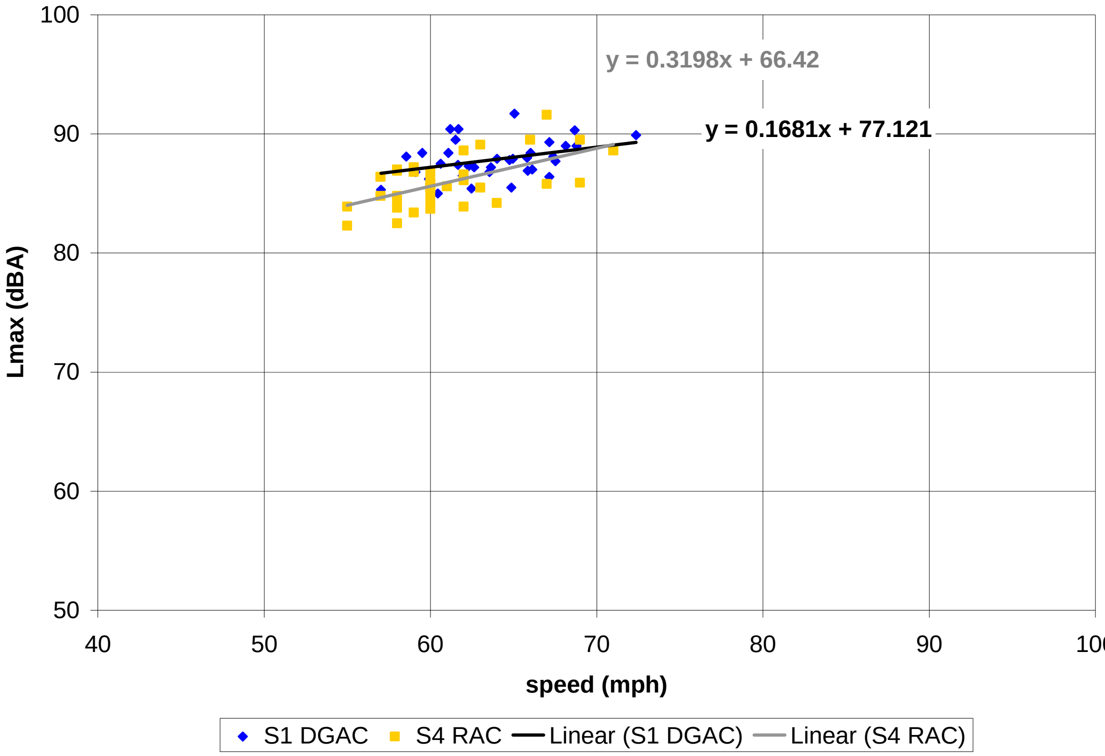
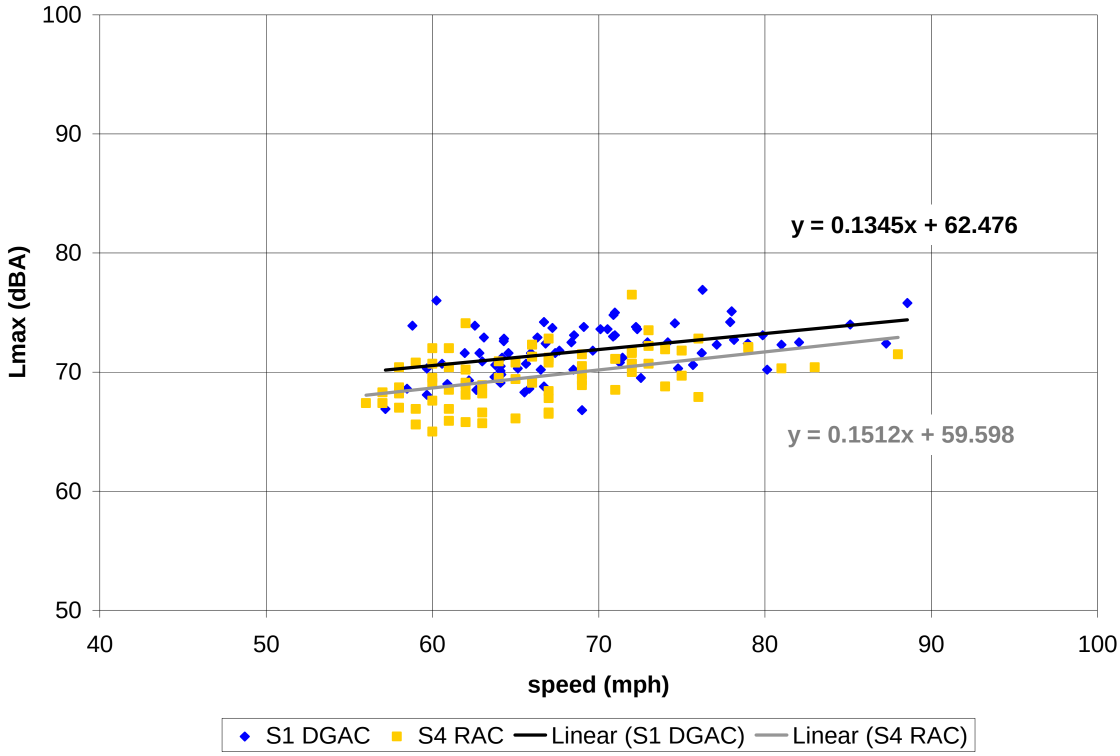
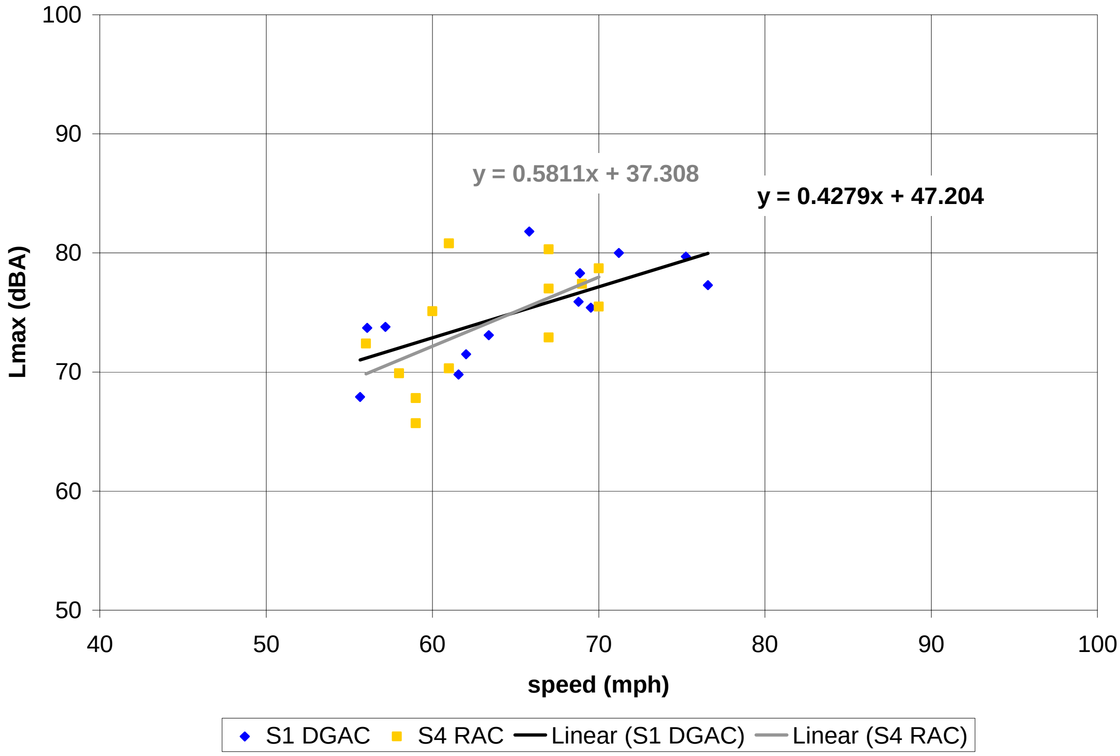


Figure C-55. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 25 ft, height 5 ft.


y = 0.1345x + 62.476
y = 0.1512x + 59.598
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


y = 0.5811x + 37.308
y = 0.4279x + 47.204
Lmax (dBA)
speed (mph)
100
90
80
70
60
50
40
50
60
70
80
90
100
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

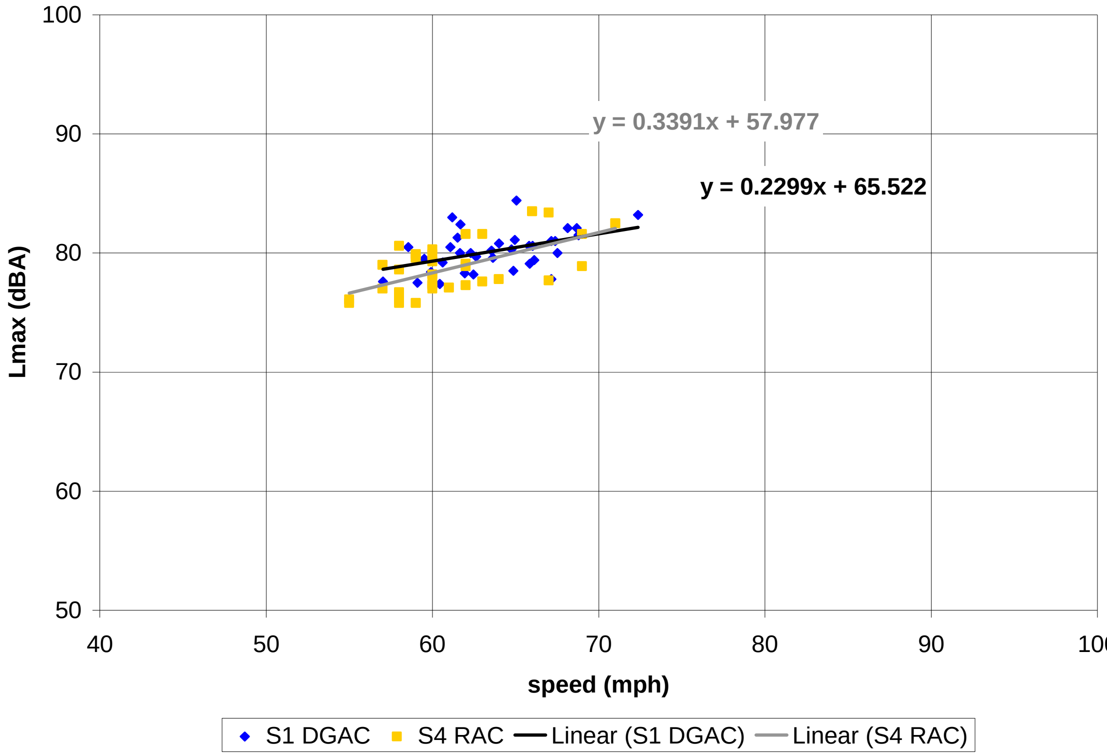
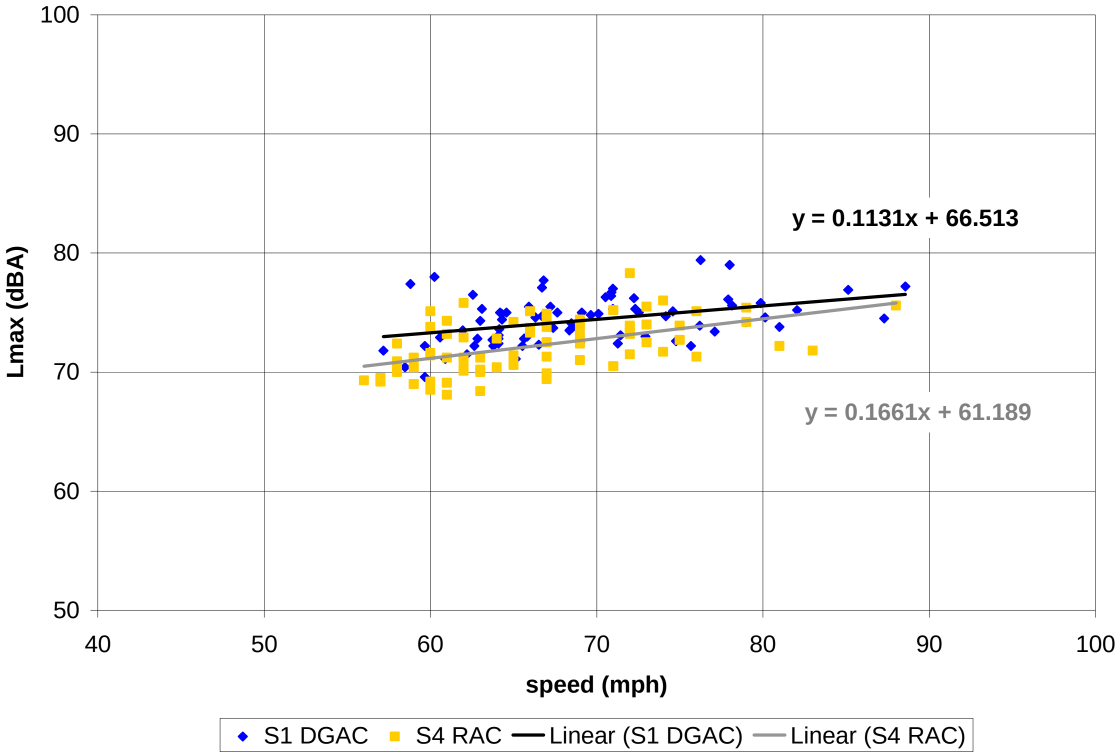
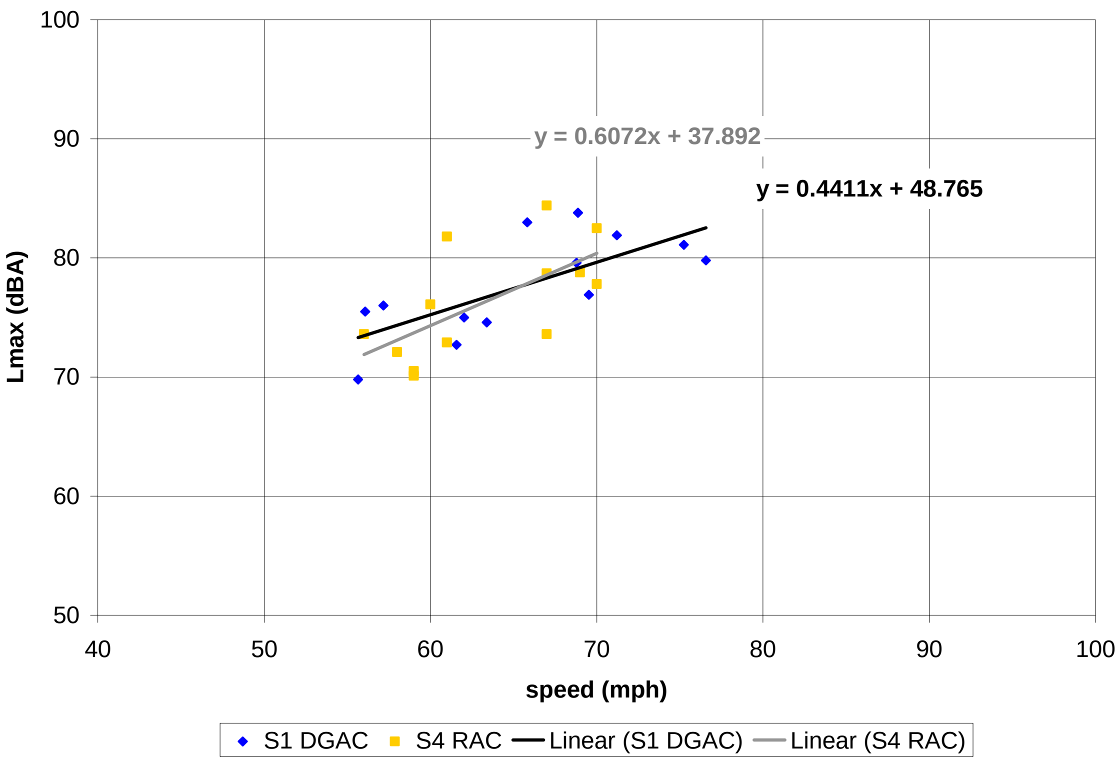


Figure C-56. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 5 ft.


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.1131x + 66.513
y = 0.1661x + 61.189
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)


100
90
80
70
60
50
40
50
60
70
80
90
100
Lmax (dBA)
speed (mph)
y = 0.6072x + 37.892
y = 0.4411x + 48.765
S1 DGAC
S4 RAC
Linear (S1 DGAC)
Linear (S4 RAC)

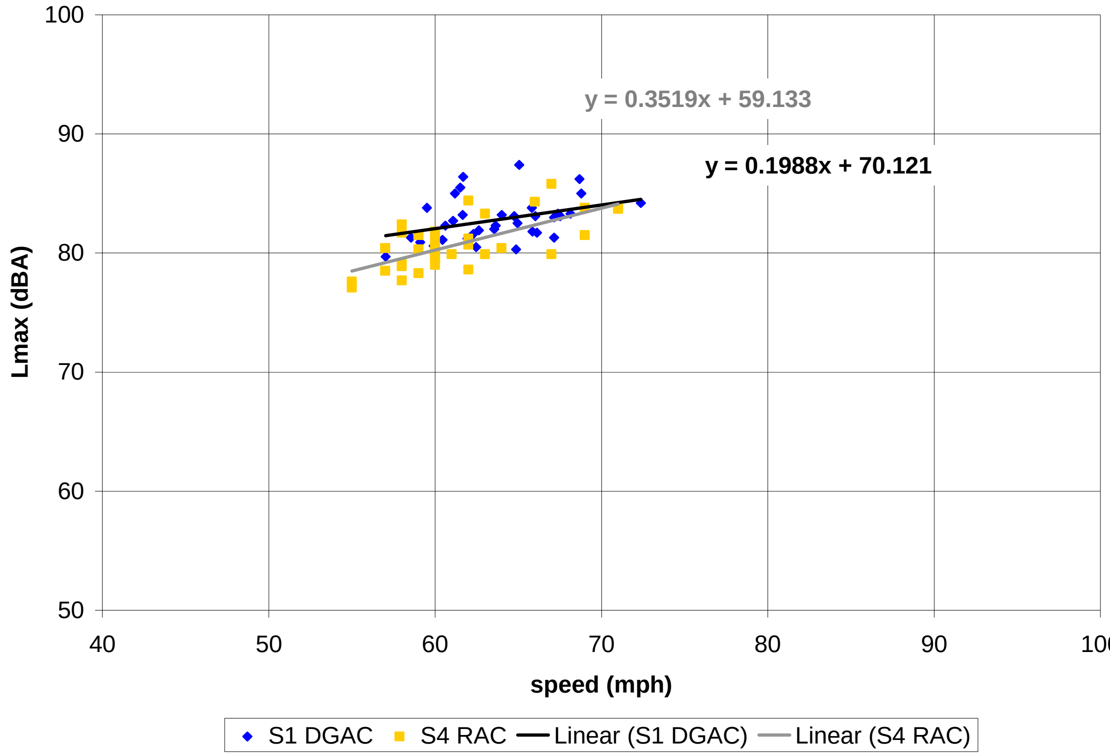


Figure C-57. (this and previous page) Vehicle pass-by data, post-overlay, 52 months age; Site 1 (DGAC 30mm), Site 4 (RAC Type O 30mm). Automobiles (top), medium trucks (middle), and heavy trucks (bottom). Microphone location: distance 50 ft, height 15 ft.

APPENDIX D. OVERALL PAVEMENT PERFORMANCE

This appendix shows the following:

- tables and plots of the modified SPBI **values** for each pavement pair, age, and microphone position;
- tables and plots of the modified SPBI **deltas** (comparing each of the other pavements to DGAC) for each pavement pair, age, and microphone position; and
- tables and discussion of the site bias decibel adjustment values.

D.1 SPBI Values

Tables show values with and without site bias being removed. All plots show only values with the site bias removed.

Table D-1. Post-overlay measurements: sound levels for each pavement type (SPBI*) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months. Site bias removed.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* (dBA)							
		Site 1 (DGAC, 30 mm)	Site 2 (OGAC, 75 mm)	Site 1 (DGAC, 30 mm)	Site 3 (OGAC, 30 mm)	Site 1 (DGAC, 30 mm)	Site 4 (RAC Type O, 30 mm)	Site 1 (DGAC, 30 mm)	Site 5 (BWC, 30 mm)
baseline	7.5 m (25 ft) low	80.1	80.1	79.8	79.8	79.3	79.3	80.1	80.1
	15m (50 ft) low	73.3	73.3	72.9	72.9	72.4	72.4	73.2	73.2
	15m (50 ft) high	73.5	73.5	72.9	72.9	74.3	74.3	77.7	77.7
4 months	7.5 m (25 ft) low	82.1	78.9	82.0	80.6	82.1	79.7	na	na
	15m (50 ft) low	75.3	72.7	75.3	73.6	75.3	72.7	75.3	75.5
	15m (50 ft) high	77.1	73.8	77.1	75.4	77.2	75.1	76.9	76.2
10 months	7.5 m (25 ft) low	82.3	78.7	82.6	80.6	82.7	80.0	82.7	80.6
	15m (50 ft) low	75.2	72.4	75.5	73.8	75.7	72.9	75.6	76.0
	15m (50 ft) high	77.4	73.7	77.7	75.8	77.8	75.4	77.9	75.9
16 months	7.5 m (25 ft) low	82.5	79.0	82.4	80.7	82.4	80.2	82.5	80.7
	15m (50 ft) low	75.6	72.6	75.5	73.9	75.5	73.3	75.4	75.9
	15m (50 ft) high	77.5	74.4	77.3	76.2	77.3	75.9	77.4	75.9
52 months	7.5 m (25 ft) low	83.2	79.4	83.5	81.2	83.6	81.3	na	na
	15m (50 ft) low	75.5	72.5	75.9	74.1	75.9	73.6	na	na
	15m (50 ft) high	78.0	74.2	78.4	76.7	78.5	76.5	na	na

Table D-2. Post-overlay measurements: sound levels for each pavement type (SPBI*) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	SPBI* (dBA)							
		Site 1 (DGAC, 30 mm)	Site 2 (OGAC, 75 mm)	Site 1 (DGAC, 30 mm)	Site 3 (OGAC, 30 mm)	Site 1 (DGAC, 30 mm)	Site 4 (RAC Type O, 30 mm)	Site 1 (DGAC, 30 mm)	Site 5 (BWC, 30 mm)
baseline	7.5 m (25 ft) low	80.1	80.5	79.8	80.6	79.3	79.8	80.1	81.6
	15m (50 ft) low	73.3	74.1	72.9	73.4	72.4	73.0	73.2	72.6
	15m (50 ft) high	73.5	73.9	72.9	73.4	74.3	74.2	77.7	78.6
4 months	7.5 m (25 ft) low	82.1	79.3	82.0	81.3	82.1	80.2	na	na
	15m (50 ft) low	75.3	73.6	75.3	74.1	75.3	73.4	75.3	74.8
	15m (50 ft) high	77.1	74.3	77.1	75.8	77.2	75.0	76.9	77.2
10 months	7.5 m (25 ft) low	82.3	79.1	82.6	81.3	82.7	80.6	82.7	82.1
	15m (50 ft) low	75.2	73.2	75.5	74.3	75.7	73.6	75.6	75.4
	15m (50 ft) high	77.4	74.2	77.7	76.3	77.8	75.3	77.9	76.9
16 months	7.5 m (25 ft) low	82.5	79.3	82.4	81.4	82.4	80.7	82.5	82.1
	15m (50 ft) low	75.6	73.5	75.5	74.5	75.5	74.0	75.4	75.3
	15m (50 ft) high	77.5	74.8	77.3	76.7	77.3	75.8	77.4	76.9
52 months	7.5 m (25 ft) low	83.2	79.7	83.5	81.9	83.6	81.8	na	na
	15m (50 ft) low	75.5	73.3	75.9	74.6	75.9	74.2	na	na
	15m (50 ft) high	78.0	74.6	78.4	77.1	78.5	76.4	na	na

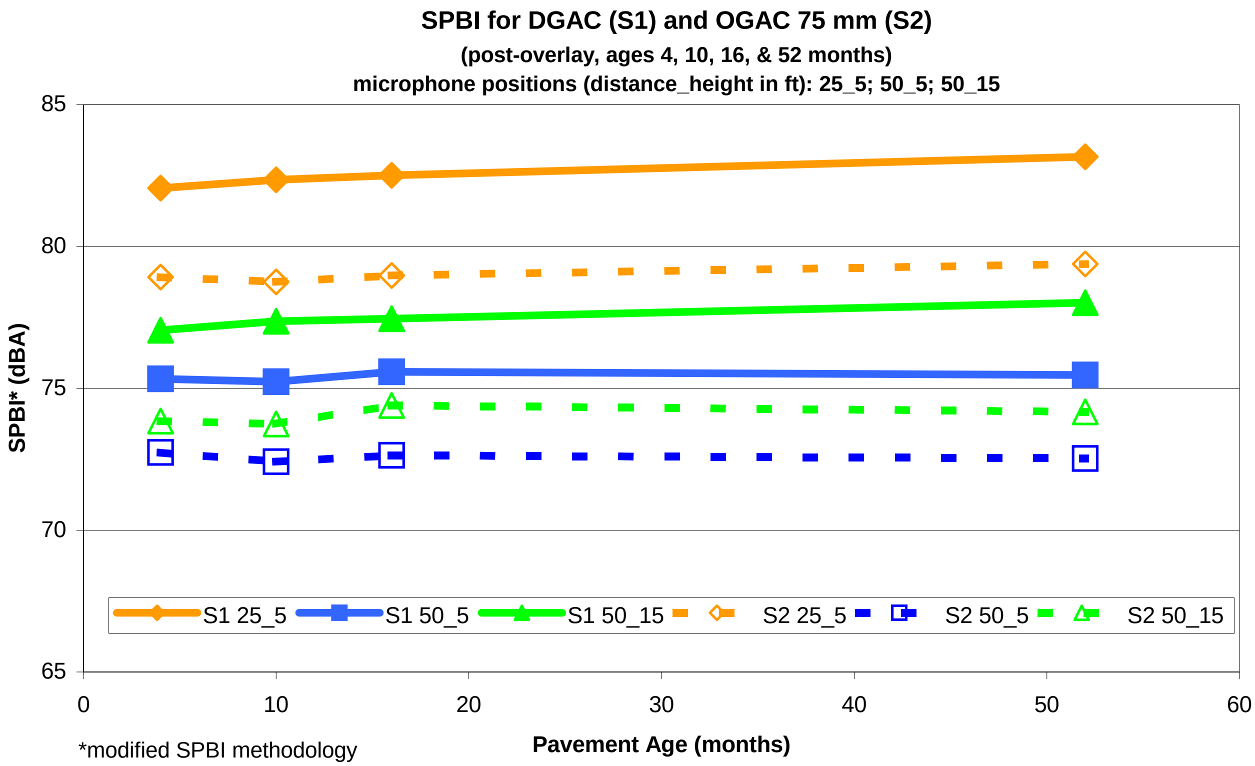


Figure D-1. SPBI* values over time for pavement pair DGAC 30mm (S1) and OGAC 75mm (S2). Overlay pavements aged 4, 10, 16, and 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

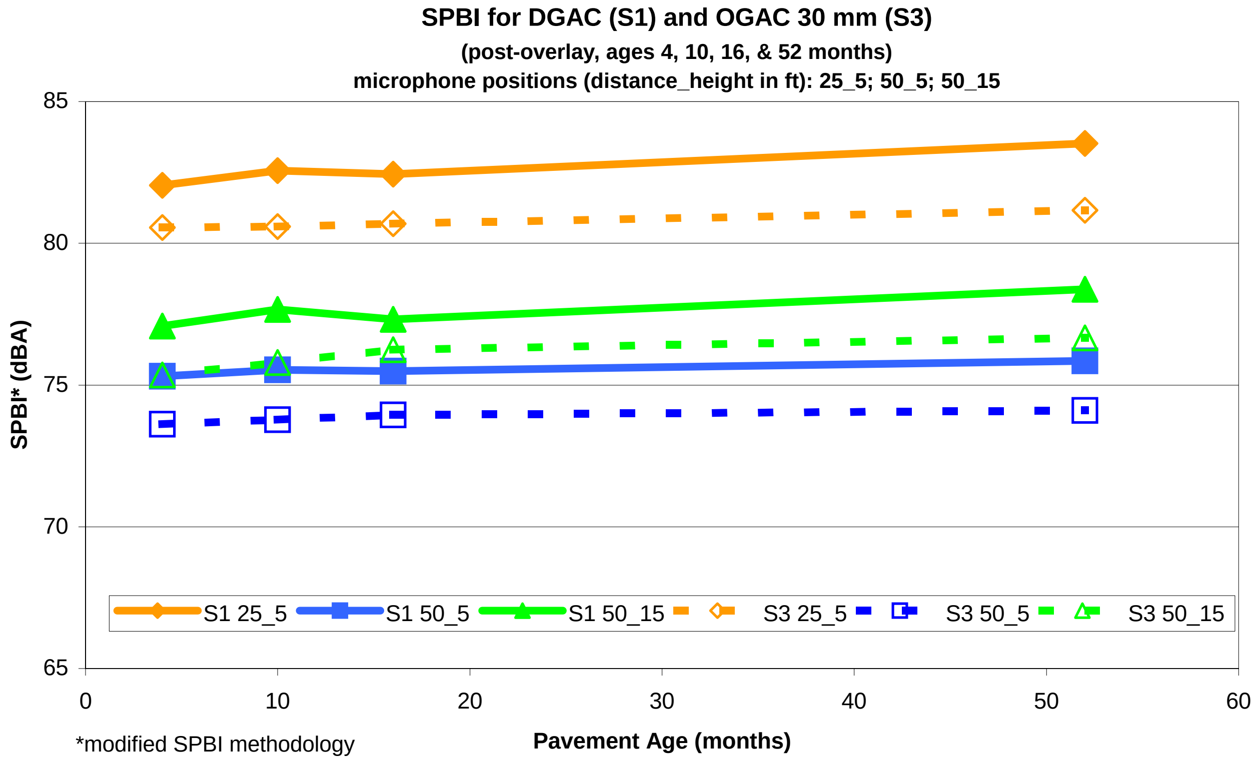


Figure D-2. SPBI* values over time for pavement pair DGAC 30mm (S1) and OGAC 30mm (S3). Overlay pavements aged 4, 10, 16, and 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

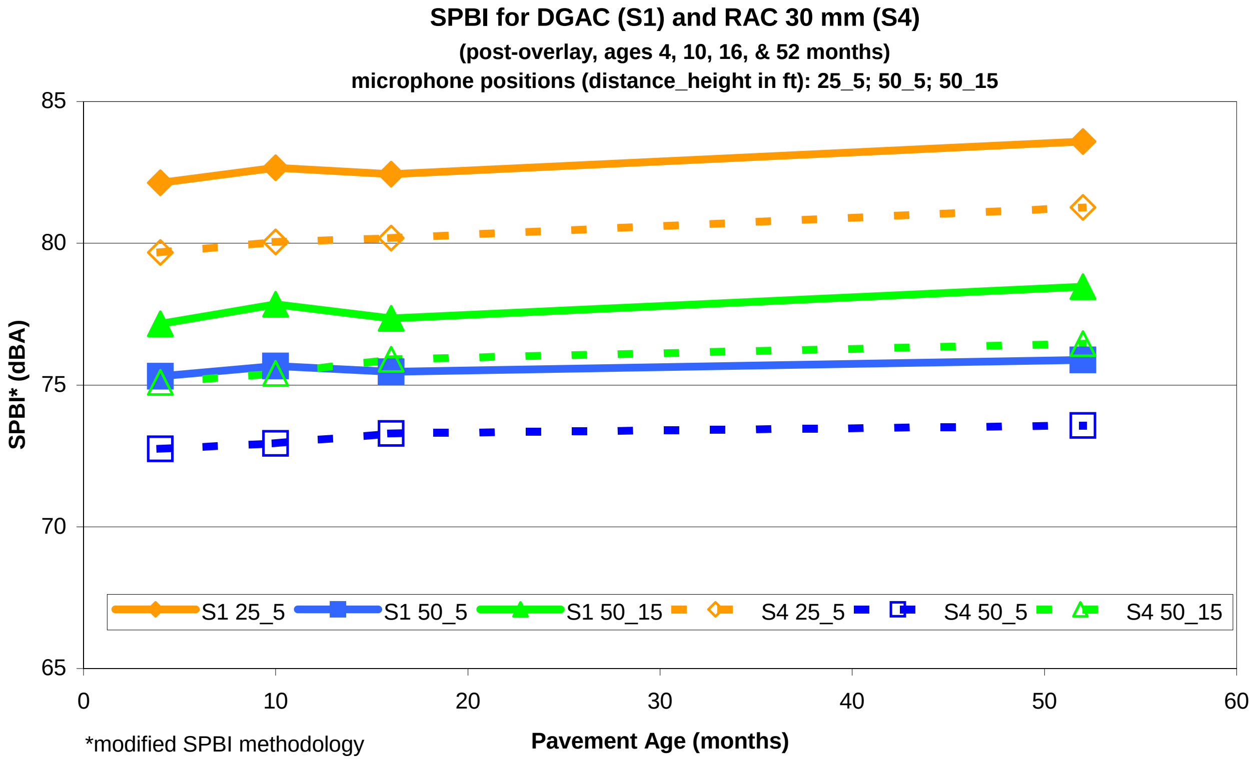


Figure D-3. SPBI* values over time for pavement pair DGAC 30mm (S1) and RAC Type O 30mm (S4). Overlay pavements aged 4, 10, 16, and 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

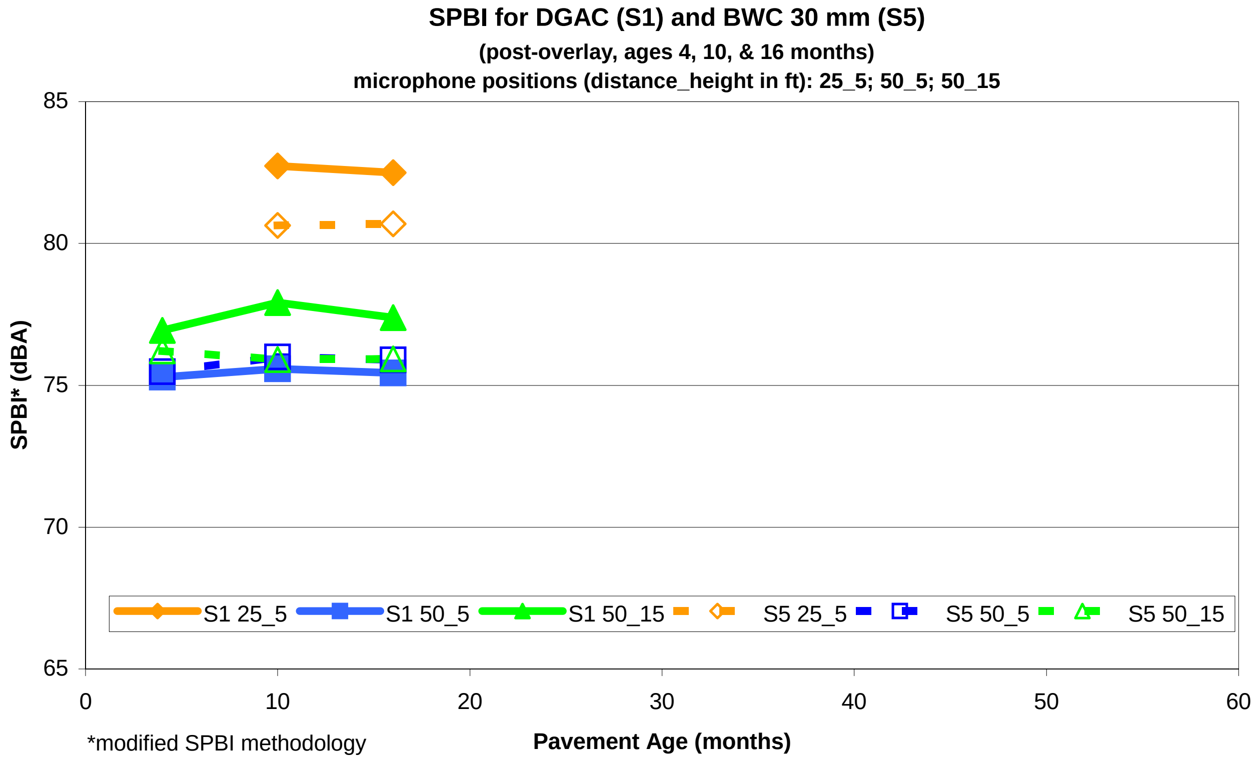


Figure D-4. SPBI* values over time for pavement pair DGAC 30mm (S1) and BWC 30mm (S5). Overlay pavements aged 4, 10, and 16 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

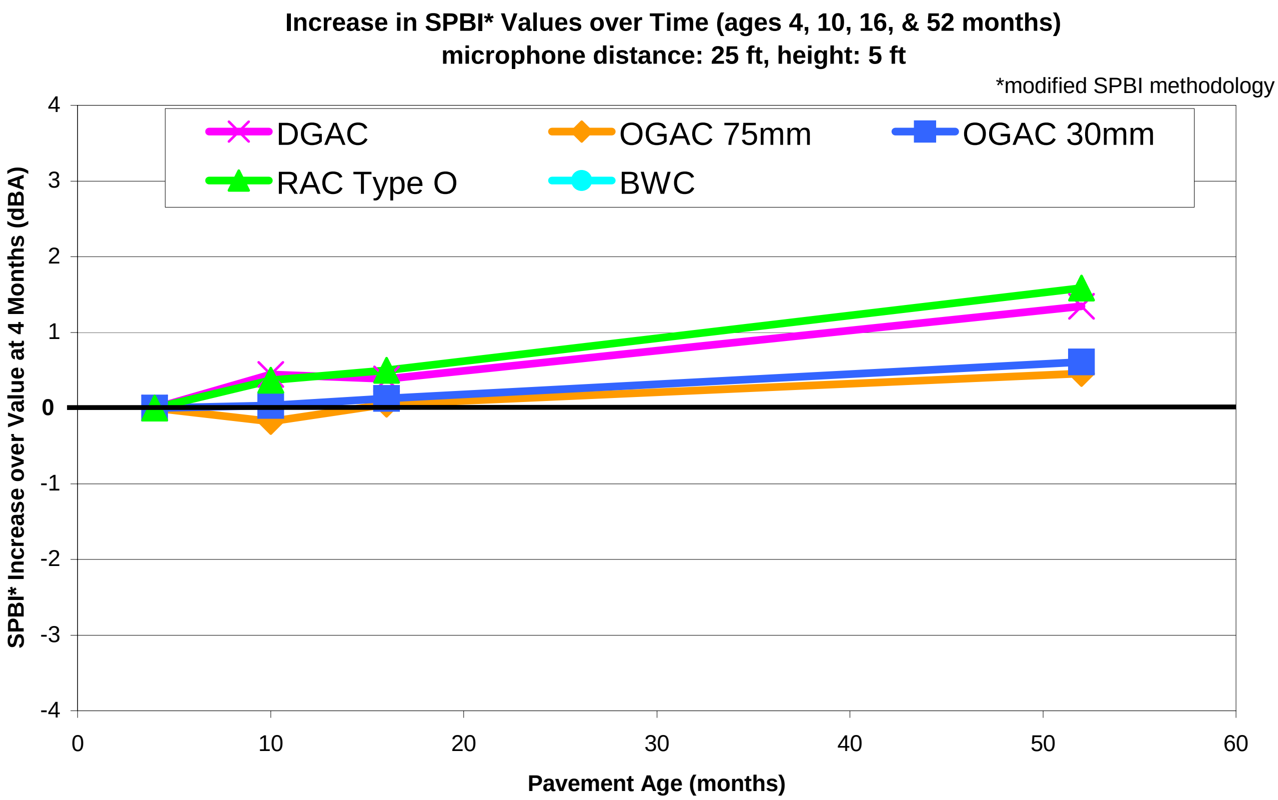


Figure D-5. Increase in SPBI* values over time, as compared to values at 4 months. Post-overlay results, all pavements (except BWC – no data available), including DGAC, aged 4, 10, 16, and 52 months. Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

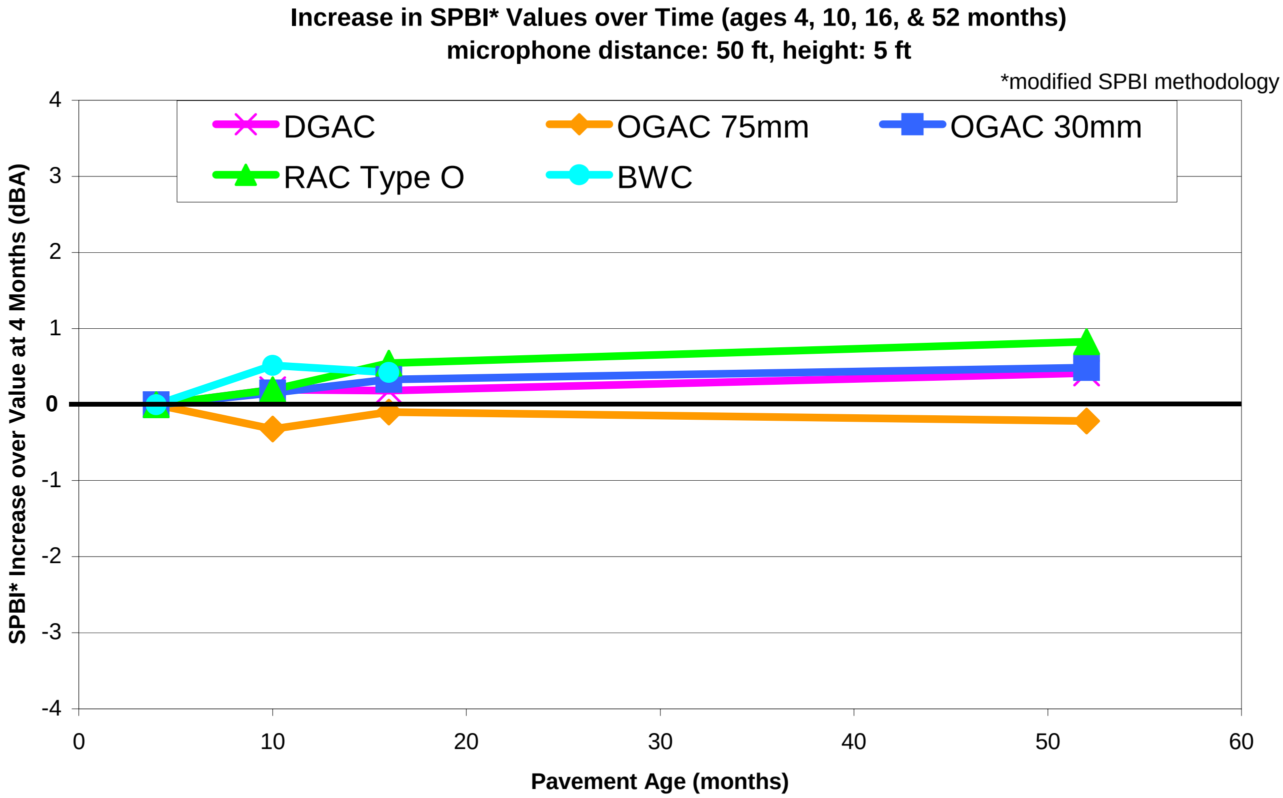


Figure D-6. Increase in SPBI* values over time, as compared to values at 4 months. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 1.5 m (5 ft).

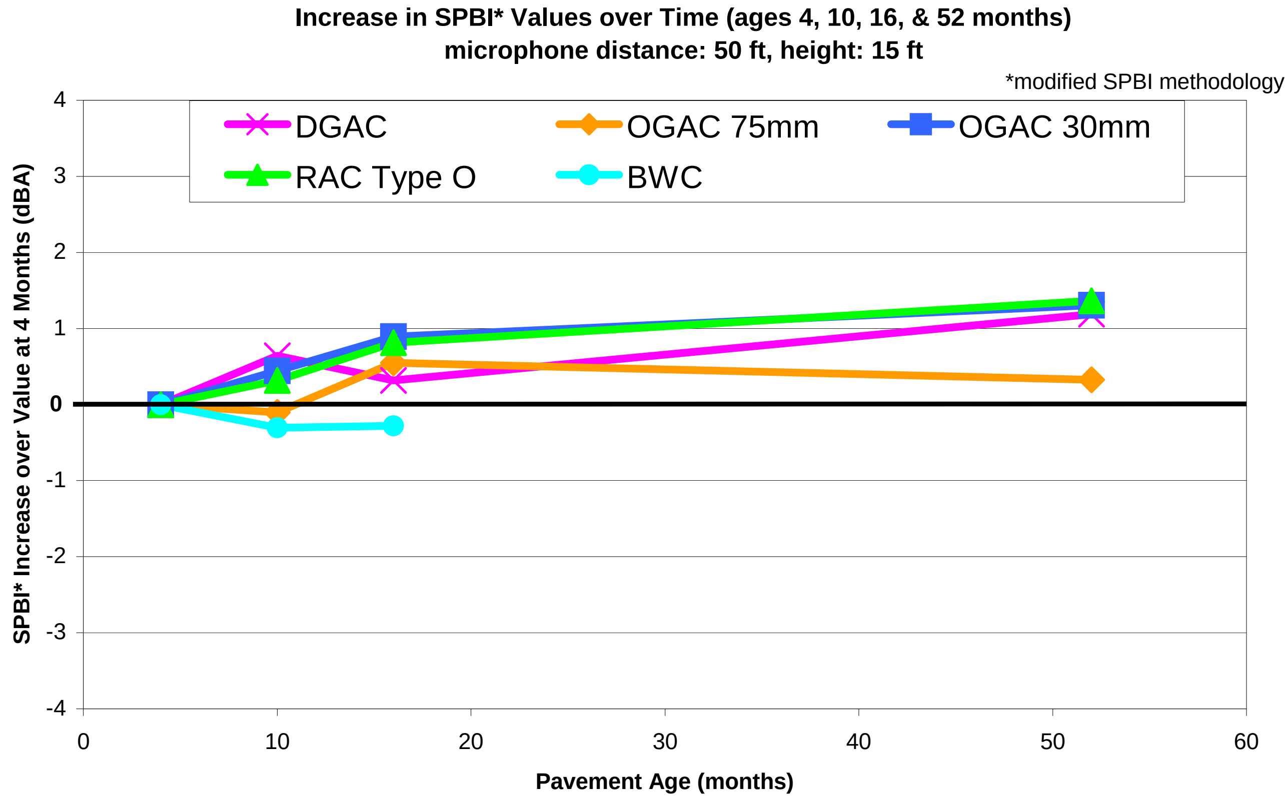


Figure D-7. Increase in SPBI* values over time, as compared to values at 4 months. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 4.5 m (15 ft).

D.2 SPBI Deltas

Tables show values with and without site bias being removed. All plots show only values with the site bias removed.

Table D-3. Post-overlay measurements: site differences due to type of pavement (SPBI* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months. Site bias removed.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	SPBI* delta (dBA)			
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)	Site 3 – Site 1 (OGAC, 30 mm – DGAC)	Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)	Site 5 – Site 1 (BWC, 30 mm – DGAC)
baseline	7.5 m (25 ft) low	0.0	0.0	0.0	0.0
	15m (50 ft) low	0.0	0.0	0.0	0.0
	15m (50 ft) high	0.0	0.0	0.0	0.0
4 months	7.5 m (25 ft) low	-3.1	-1.5	-2.5	na
	15m (50 ft) low	-2.6	-1.7	-2.6	0.2
	15m (50 ft) high	-3.2	-1.7	-2.1	-0.7
10 months	7.5 m (25 ft) low	-3.6	-2.0	-2.6	-2.1
	15m (50 ft) low	-2.8	-1.8	-2.7	0.4
	15m (50 ft) high	-3.6	-1.9	-2.4	-2.0
16 months	7.5 m (25 ft) low	-3.5	-1.7	-2.3	-1.8
	15m (50 ft) low	-2.9	-1.5	-2.2	0.5
	15m (50 ft) high	-3.1	-1.1	-1.4	-1.5
52 months	7.5 m (25 ft) low	-3.8	-2.4	-2.3	na
	15m (50 ft) low	-3.0	-1.7	-2.3	na
	15m (50 ft) high	-3.8	-1.7	-2.0	na

Table D-4. Post-overlay measurements: site differences due to type of pavement (SPBI* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	SPBI* delta (dBA)			
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)	Site 3 – Site 1 (OGAC, 30 mm – DGAC)	Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)	Site 5 – Site 1 (BWC, 30 mm – DGAC)
baseline	7.5 m (25 ft) low	0.3	0.7	0.5	1.4
	15m (50 ft) low	0.8	0.5	0.7	-0.6
	15m (50 ft) high	0.4	0.5	-0.1	1.0
4 months	7.5 m (25 ft) low	-2.8	-0.8	-1.9	na
	15m (50 ft) low	-1.8	-1.2	-1.9	-0.4
	15m (50 ft) high	-2.8	-1.3	-2.2	0.2
10 months	7.5 m (25 ft) low	-3.3	-1.2	-2.1	-0.7
	15m (50 ft) low	-2.0	-1.3	-2.1	-0.2
	15m (50 ft) high	-3.2	-1.4	-2.5	-1.1
16 months	7.5 m (25 ft) low	-3.2	-1.0	-1.7	-0.4
	15m (50 ft) low	-2.1	-1.0	-1.5	-0.2
	15m (50 ft) high	-2.6	-0.6	-1.5	-0.5
52 months	7.5 m (25 ft) low	-3.4	-1.6	-1.8	na
	15m (50 ft) low	-2.1	-1.2	-1.6	na
	15m (50 ft) high	-3.4	-1.2	-2.1	na

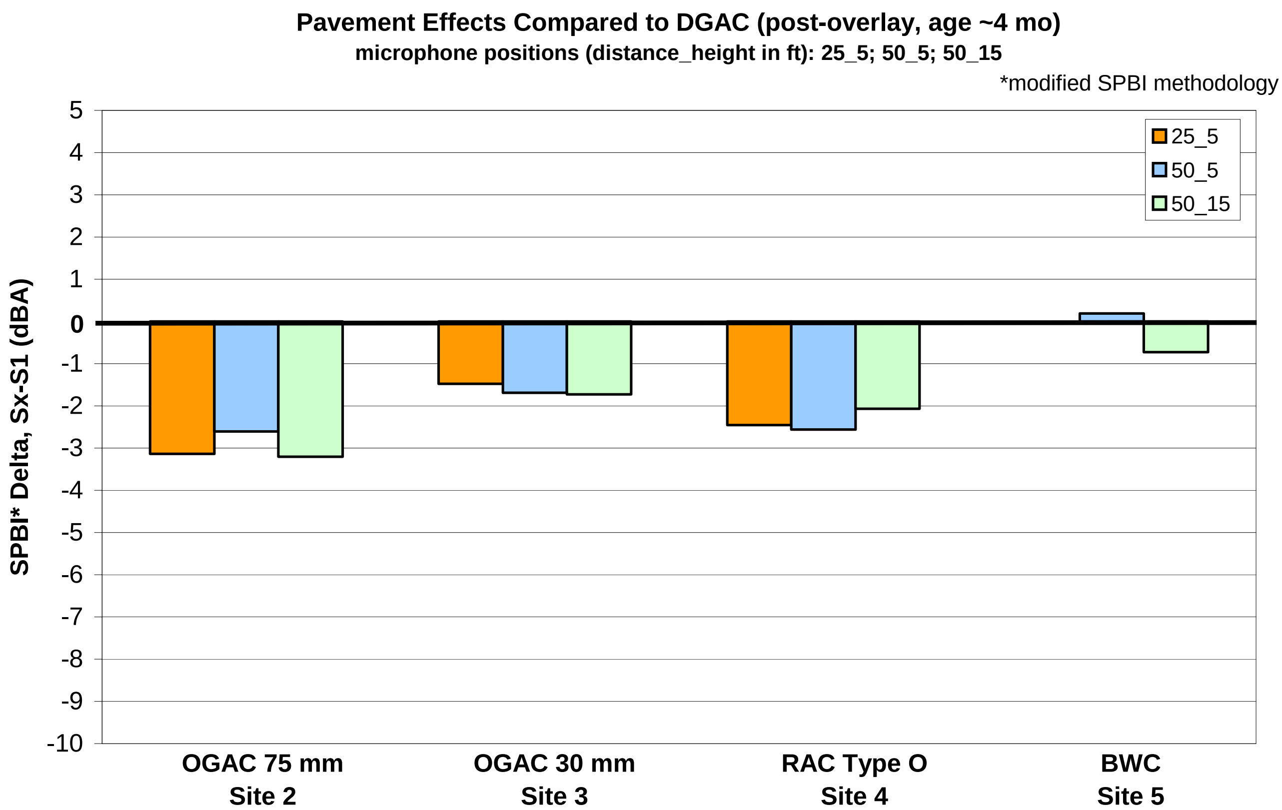


Figure D-8. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

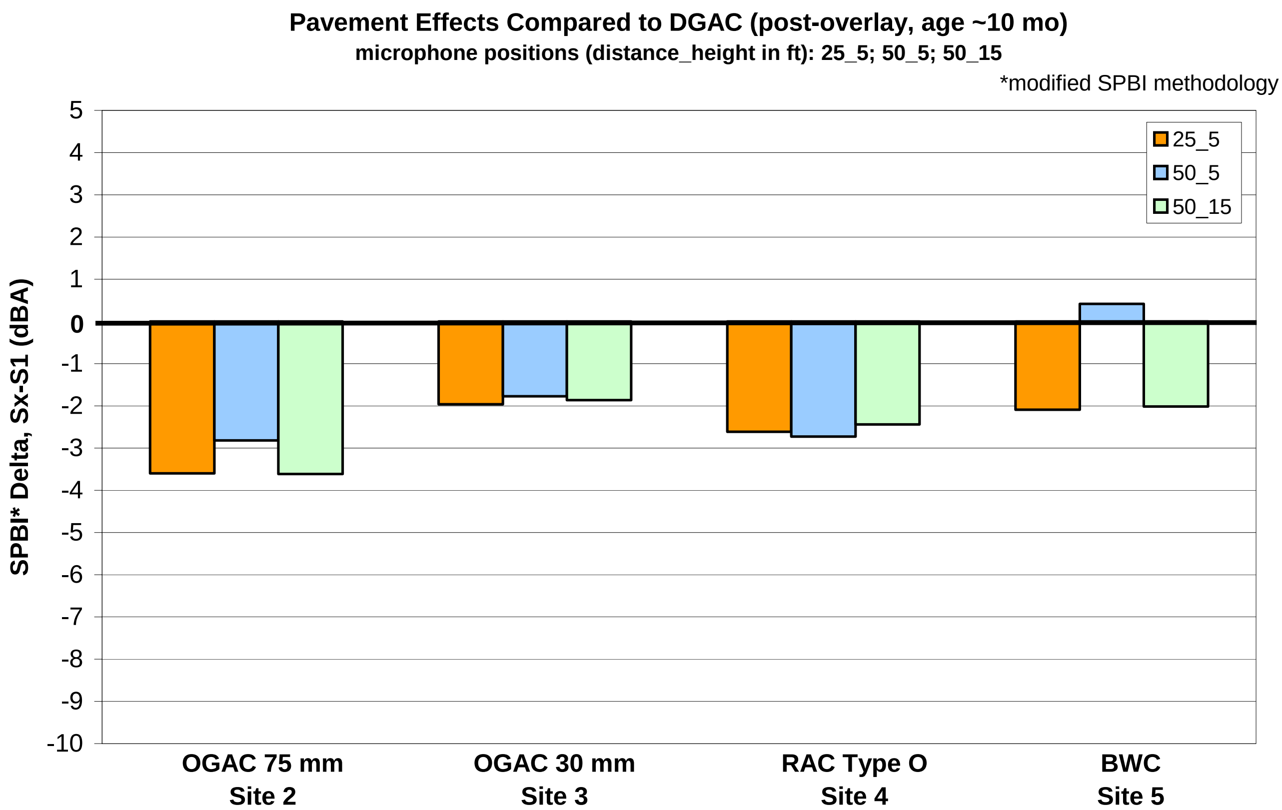


Figure D-9. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 10 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

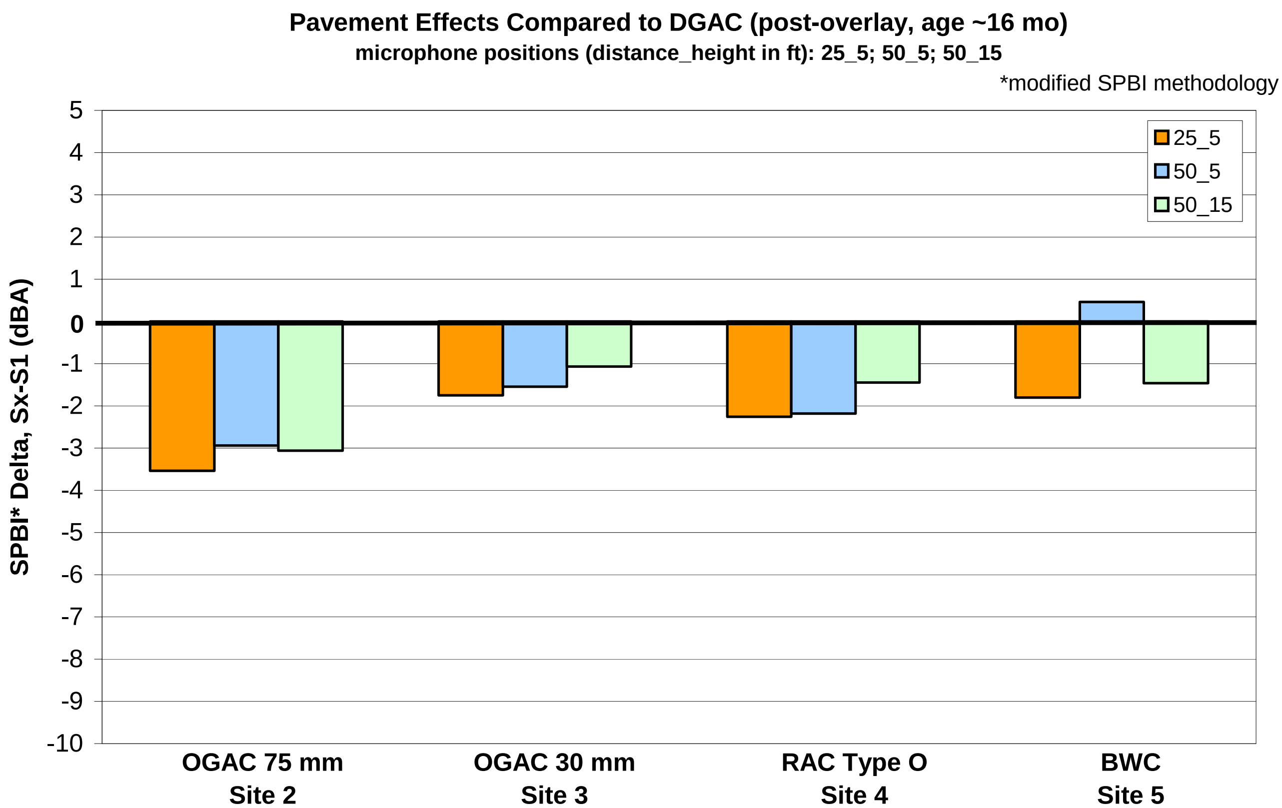


Figure D-10. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 16 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

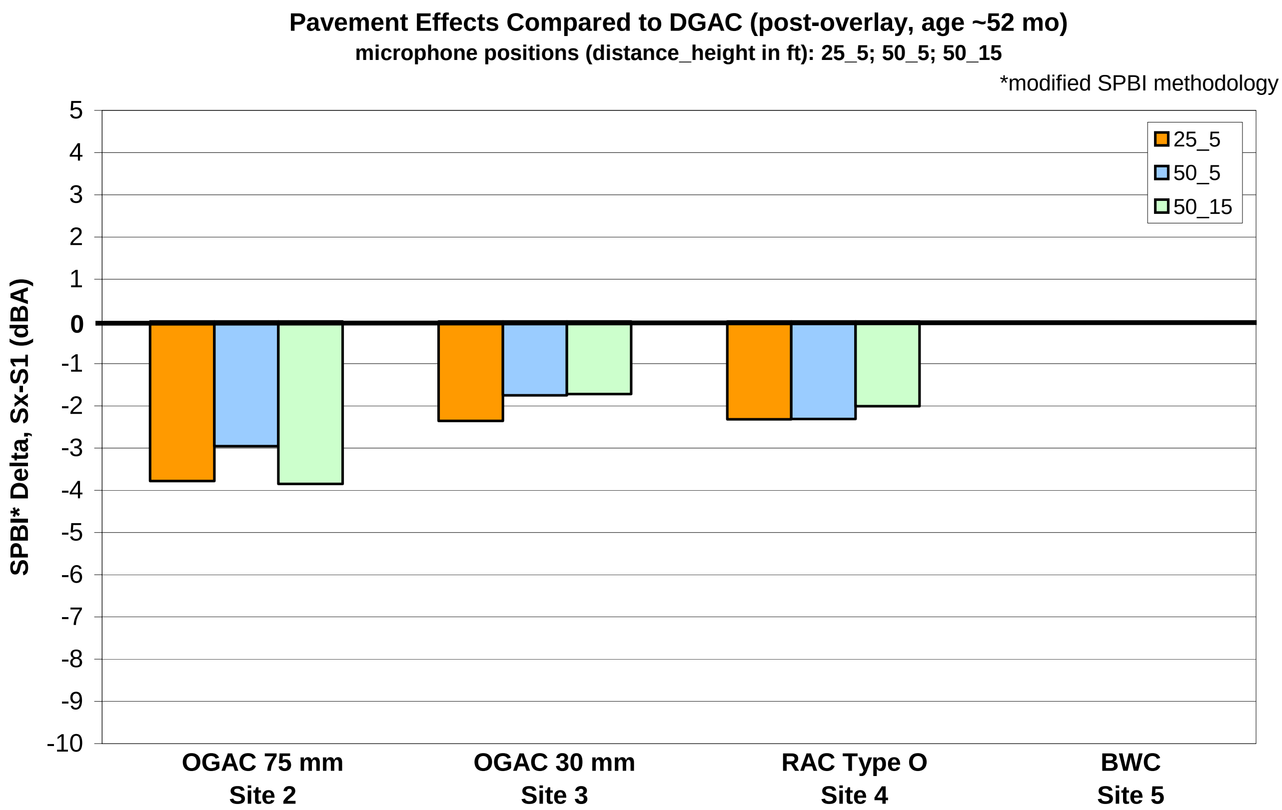


Figure D-11. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 52 months. Microphone locations: distance 7.5 m (25 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 1.5 m (5 ft); distance 15 m (50 ft), height 4.5 m (15 ft).

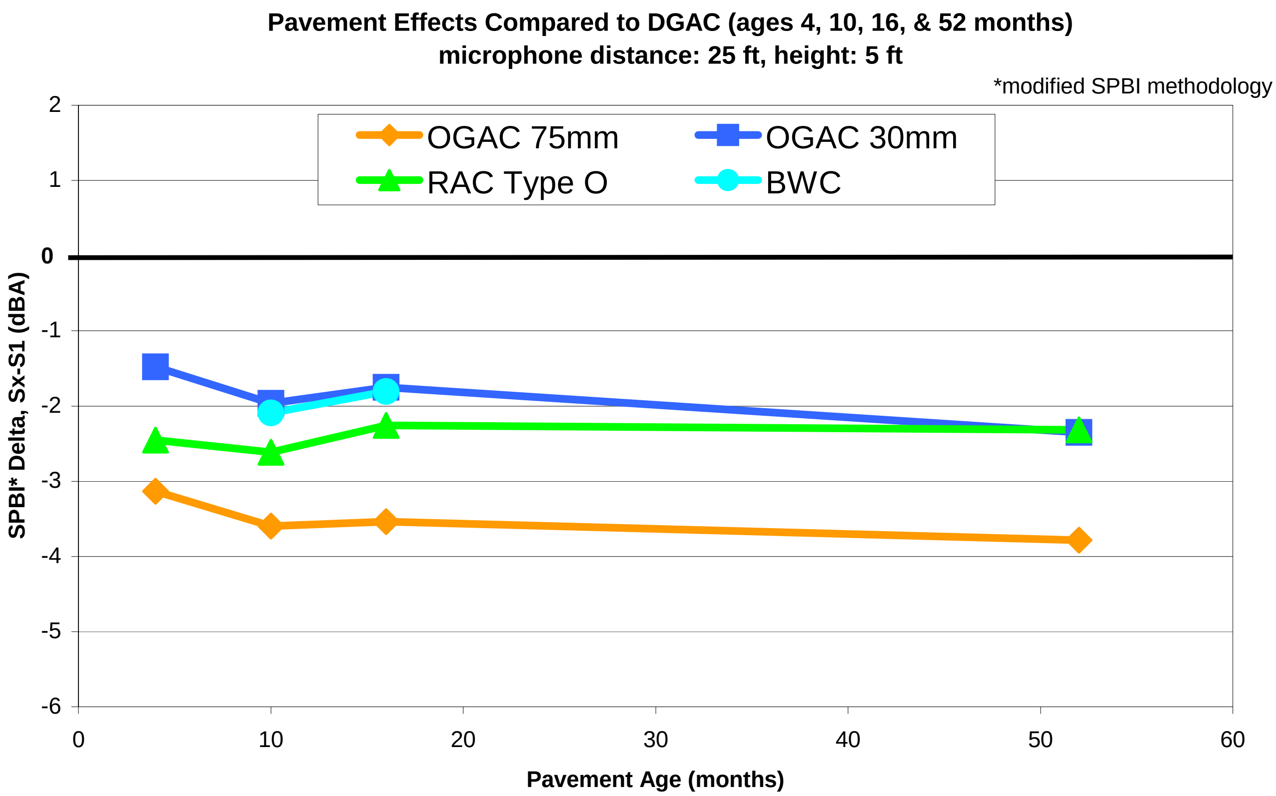


Figure D-12. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

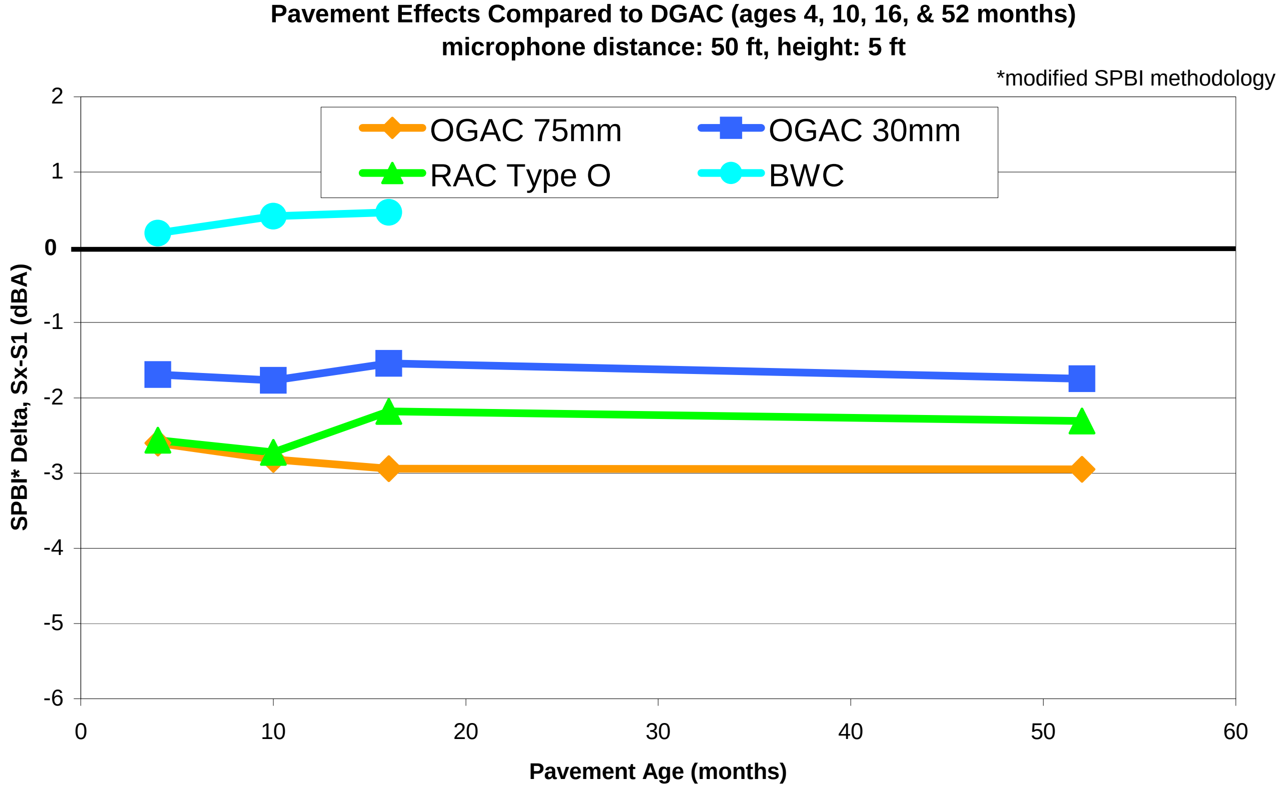


Figure D-13. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 1.5 m (5 ft).

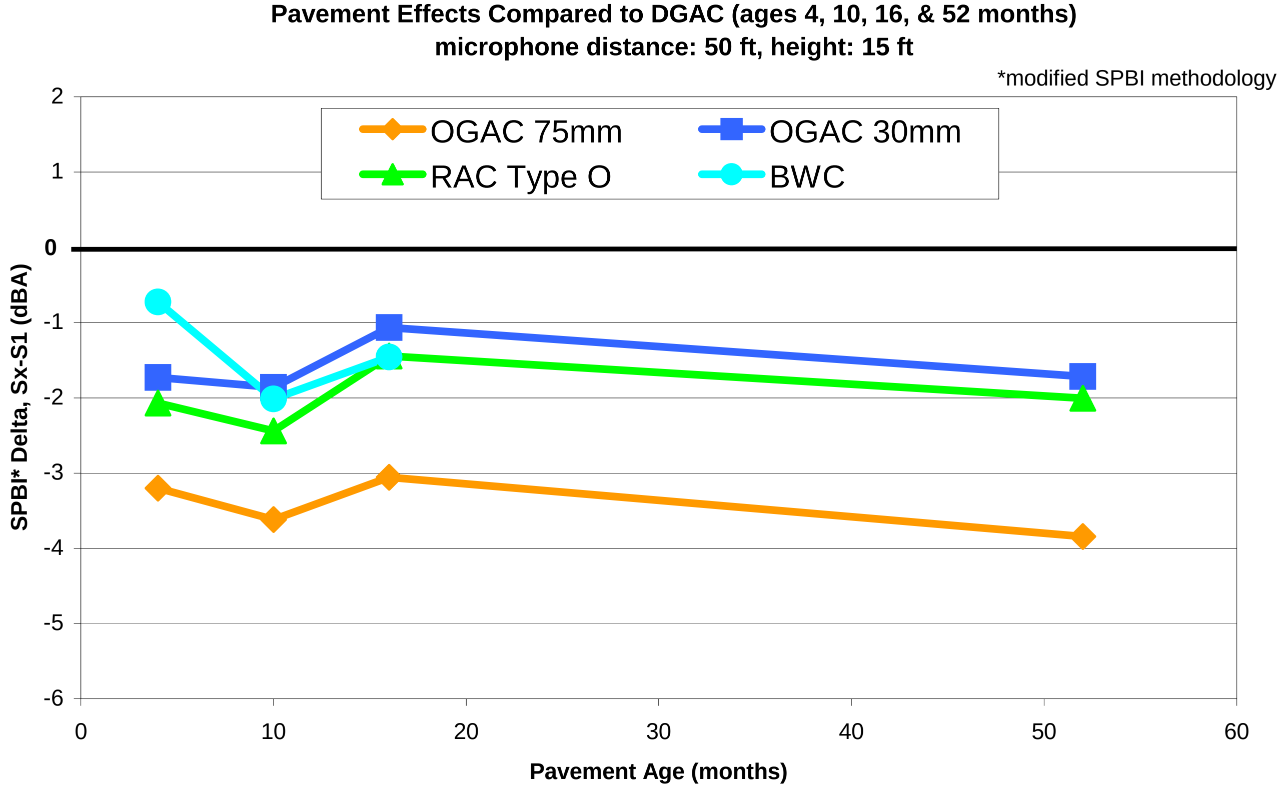


Figure D-14. Pavement effects compared to DGAC (Site x minus Site 1) using modified SPBI. Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 4.5 m (15 ft).

D.3 Site Bias Decibel Adjustment Values

The baseline data collected in March 2002, with pavement at all sites being new DGAC, allow for the determination of site differences unrelated to the type of pavement. Data from Sites 2-5 are compared to data from Site 1. Because the terrain is not identical for each site, some differences are found. These differences are applied after the pavement overlays are in place in order to remove site bias (calibrate to Site 1).

The differences (Site x minus Site 1) range from -0.6 to 1.4 dB(A) and can be seen in Table 1; these differences are applied directly to (subtracted from) the SPBI results for post-overlay measurements for each Site x.

Table D-5. Baseline measurements: Site differences unrelated to type of pavement (SPBI* deltas).

*modified SPB methodology

	SPBI delta (dB(A))			
Microphone location	Site 2 – Site 1 (DGAC)	Site 3 – Site 1 (DGAC)	Site 4 – Site 1 (DGAC)	Site 5 – Site 1 (DGAC)
25 ft (7.5 m) low	0.3	0.7	0.5	1.4
50 ft (15 m) low	0.8	0.5	0.7	-0.6
50 ft (15 m) high	0.4	0.5	-0.1	1.0

APPENDIX E. PAVEMENT PERFORMANCE BY VEHICLE TYPE

This appendix shows the following:

- tables and plots of the modified-SPB Lveh **values** for each pavement pair, age, and microphone position;
- tables and plots of the modified-SPB Lveh **deltas** (comparing each of the other pavements to DGAC) for each pavement pair, age, and microphone position; and
- plots of spectral data averaged over several vehicle pass-by events, shown with varying parameter configurations.

E.1 Lveh Values

Tables show only values with site bias.

Table E-1. Post-overlay measurements: sound levels for each pavement type (Lveh*) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	Modified Lveh (or average L_{AFmx}) (dBA)																							
		Site 1 (DGAC, 30 mm)			Site 2 (OGAC, 75 mm)			Site 1 (DGAC, 30 mm)			Site 3 (OGAC, 30 mm)			Site 1 (DGAC, 30 mm)			Site 4 (RAC Type O, 30 mm)			Site 1 (DGAC, 30 mm)			Site 5 (BWC, 30 mm)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
baseline	7.5 m (25 ft) low	76.5	83.6	83.4	76.5	83.9	84.0	76.4	81.0	83.6	77.5	81.6	84.1	76.6	81.9	82.2	77.8	82.3	82.1	76.4	81.3	84.0	77.5	81.9	85.7
	15m (50 ft) low	69.3	76.4	76.9	70.0	77.3	77.7	69.1	74.4	76.8	70.1	74.3	77.2	69.4	75.0	75.5	71.2	76.2	74.9	69.2	74.9	77.2	68.5	74.5	76.5
	15m (50 ft) high	71.1	78.0	75.1	71.6	78.9	75.1	71.0	75.7	75.1	72.1	75.9	74.7	71.3	77.1	77.4	72.4	77.0	76.3	71.3	74.8	82.8	71.5	75.4	83.9
4 months	7.5 m (25 ft) low	78.6	82.8	85.9	74.8	80.2	83.5	78.4	82.4	86.0	77.3	82.3	85.3	78.6	82.0	86.1	76.3	80.5	84.3	na	na	na	na	na	na
	15m (50 ft) low	71.2	75.9	79.5	68.9	74.5	77.9	71.3	75.5	79.5	69.9	74.9	78.3	71.5	75.0	79.5	69.3	73.8	77.6	71.4	74.6	79.5	71.1	75.2	78.9
	15m (50 ft) high	73.3	77.3	81.1	69.8	74.8	78.6	73.3	77.1	81.2	71.8	76.8	79.9	73.4	76.8	81.3	71.2	75.0	79.1	73.4	76.2	81	73.7	77.1	81.1
10 months	7.5 m (25 ft) low	78.9	82.5	86.3	75	79.4	83.3	78.8	82.1	86.7	77.1	80.2	85.7	78.9	82.8	86.7	76.5	80.6	84.8	79	82.5	86.8	78.4	81.5	86.2
	15m (50 ft) low	71.2	75	79.5	68.9	73.4	77.6	71.2	74.6	80	69.7	72.9	78.9	71.2	76.1	80.0	69.4	74.0	77.8	71.3	75.0	80.0	71.2	74.3	79.7
	15m (50 ft) high	73.5	76.8	81.5	69.9	73.8	78.5	73.5	76.3	82.1	72	74.6	80.7	73.6	77.1	82.2	71.3	75.2	79.5	73.7	76.6	82.4	73.0	75.8	81.1
16 months	7.5 m (25 ft) low	78.8	82.7	86.6	74.7	79.9	83.7	78.9	83.1	86.3	77.3	82.7	85.4	78.6	83.6	86.4	76.2	81.8	84.9	78.7	83.4	86.5	78.1	83.0	86.2
	15m (50 ft) low	71.3	75.6	79.9	68.4	73.9	78.0	71.4	76.1	79.6	70.2	75.5	78.6	71.2	76.6	79.6	69.3	75.1	78.3	71.2	76.3	79.6	71.2	76.2	79.4
	15m (50 ft) high	73.3	76.9	81.8	70.1	74.9	79.3	73.5	77.4	81.4	72.2	77.4	81.0	73.2	77.9	81.6	71.4	76.7	80.1	73.2	77.6	81.6	72.7	77.4	81.1
52 months	7.5 m (25 ft) low	79.6	82.8	87.2	76.0	79.7	83.8	79.7	84.4	87.5	78.0	82.8	85.9	79.6	83.1	87.8	77.8	81.9	85.9	na	na	na	na	na	na
	15m (50 ft) low	71.7	74.8	79.6	69.3	73.2	77.6	71.9	76.5	79.9	70.2	75.1	78.9	71.8	75.2	80.2	69.7	74.1	78.7	na	na	na	na	na	na
	15m (50 ft) high	74.3	77.7	82.1	70.7	74.2	78.8	74.5	79.3	82.4	72.9	77.5	81.4	74.3	77.7	82.8	72.2	76.4	80.6	na	na	na	na	na	na

E.2 Lveh Deltas

Tables show values with and without site bias being removed. All plots show only values with the site bias removed.

Table E-2. Post-overlay measurements: for each vehicle type, site differences due to type of pavement (Lveh* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months. Site bias removed.**

*modified SPB methodology
other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements)

Pavement age	Microphone location	Modified Lveh* (or average L_{AFmx}) delta (dBA)											
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)			Site 3 – Site 1 (OGAC, 30 mm – DGAC)			Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)			Site 5 – Site 1 (BWC, 30 mm – DGAC)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
baseline	25 ft (7.5 m) low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 ft (15 m) low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	50 ft (15 m) high	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 months	25 ft (7.5 m) low	-3.7	-2.9	-3.0	-2.2	-0.6	-1.2	-3.5	-2.0	-1.7	na	na	na
	50 ft (15 m) low	-3.1	-2.4	-2.4	-2.3	-0.5	-1.6	-4.0	-2.3	-1.3	0.5	1.0	0.0
	50 ft (15 m) high	-4.0	-3.4	-2.5	-2.7	-0.6	-0.9	-3.3	-1.7	-1.1	0.0	0.4	-1.0
10 months	25 ft (7.5 m) low	-3.9	-3.3	-3.6	-2.8	-2.4	-1.5	-3.6	-2.6	-1.8	-1.7	-1.6	-2.3
	50 ft (15 m) low	-3.0	-2.6	-2.7	-2.4	-1.6	-1.5	-3.6	-3.2	-1.6	0.7	-0.3	0.4
	50 ft (15 m) high	-4.2	-3.9	-3.0	-2.6	-2.0	-0.9	-3.4	-1.8	-1.6	-0.9	-1.3	-2.3
16 months	25 ft (7.5 m) low	-4.1	-3.0	-3.4	-2.7	-1.0	-1.4	-3.6	-2.2	-1.4	-1.8	-1.1	-1.9
	50 ft (15 m) low	-3.6	-2.7	-2.7	-2.1	-0.4	-1.4	-3.7	-2.6	-0.8	0.7	0.3	0.4
	50 ft (15 m) high	-3.7	-2.9	-2.5	-2.4	-0.2	0.0	-2.8	-1.0	-0.4	-0.8	-0.8	-1.6
52 months	25 ft (7.5 m) low	-3.6	-3.3	-4.0	-2.9	-2.1	-2.1	-3.0	-1.6	-1.8	na	na	na
	50 ft (15 m) low	-3.1	-2.6	-2.9	-2.7	-1.3	-1.4	-3.9	-2.2	-1.0	na	na	na
	50 ft (15 m) high	-4.0	-4.4	-3.4	-2.8	-2.0	-0.6	-3.1	-1.2	-1.1	na	na	na

Table 3. Post-overlay measurements: for each vehicle type, site differences due to type of pavement (Lveh* deltas) by site pairs with identical vehicle sets. Post-overlay pavements, including DGAC, aged 4, 10, 16, and 52 months.**

*modified SPB methodology
other sites ***not* **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pavement age	Microphone location	Modified Lveh* (or average L_{AFmx}) delta (dBA)											
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)			Site 3 – Site 1 (OGAC, 30 mm – DGAC)			Site 4 – Site 1 (RAC Type O, 30 mm – DGAC)			Site 5 – Site 1 (BWC, 30 mm – DGAC)		
		auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck	auto	med truck	hvy truck
baseline	25 ft (7.5 m) low	0.0	0.3	0.6	1.1	0.5	0.5	1.2	0.4	-0.1	1.2	0.6	1.7
	50 ft (15 m) low	0.7	1.0	0.8	0.9	-0.1	0.4	1.8	1.1	-0.5	-0.7	-0.3	-0.7
	50 ft (15 m) high	0.5	0.9	0.0	1.2	0.3	-0.4	1.0	-0.1	-1.1	0.3	0.5	1.1
4 months	25 ft (7.5 m) low	-3.7	-2.6	-2.4	-1.1	-0.1	-0.7	-2.3	-1.6	-1.8	na	na	na
	50 ft (15 m) low	-2.4	-1.4	-1.6	-1.3	-0.6	-1.2	-2.2	-1.2	-1.9	-0.3	0.6	-0.7
	50 ft (15 m) high	-3.5	-2.5	-2.5	-1.5	-0.3	-1.3	-2.2	-1.8	-2.2	0.3	0.9	0.1
10 months	25 ft (7.5 m) low	-3.9	-3.1	-3.0	-1.7	-1.9	-1.0	-2.4	-2.2	-1.9	-0.6	-1.0	-0.7
	50 ft (15 m) low	-2.3	-1.7	-1.9	-1.5	-1.7	-1.1	-1.8	-2.1	-2.2	-0.1	-0.6	-0.2
	50 ft (15 m) high	-3.7	-3.1	-3.0	-1.5	-1.7	-1.3	-2.3	-1.9	-2.7	-0.7	-0.8	-1.2
16 months	25 ft (7.5 m) low	-4.1	-2.8	-2.9	-1.5	-0.4	-0.9	-2.4	-1.8	-1.5	-0.6	-0.4	-0.3
	50 ft (15 m) low	-2.9	-1.7	-1.9	-1.2	-0.5	-1.0	-1.9	-1.5	-1.4	-0.1	0.0	-0.2
	50 ft (15 m) high	-3.2	-2.0	-2.5	-1.3	0.0	-0.4	-1.8	-1.1	-1.5	-0.6	-0.2	-0.5
52 months	25 ft (7.5 m) low	-3.6	-3.1	-3.4	-1.8	-1.6	-1.6	-1.8	-1.2	-1.9	na	na	na
	50 ft (15 m) low	-2.4	-1.7	-2.0	-1.8	-1.4	-1.0	-2.1	-1.1	-1.5	na	na	na
	50 ft (15 m) high	-3.5	-3.5	-3.4	-1.6	-1.8	-1.0	-2.1	-1.3	-2.2	na	na	na

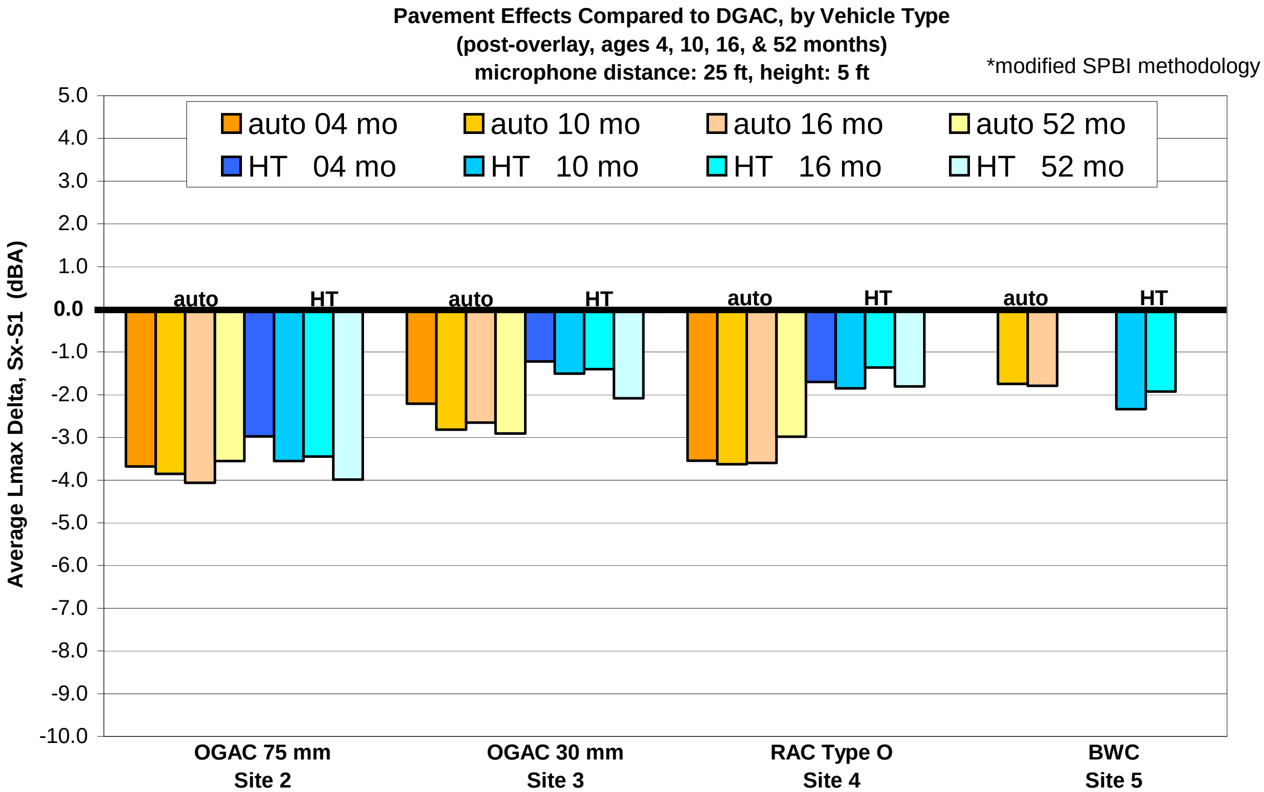


Figure E-1. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 7.5 m (25 ft), height 1.5 m (5 ft).

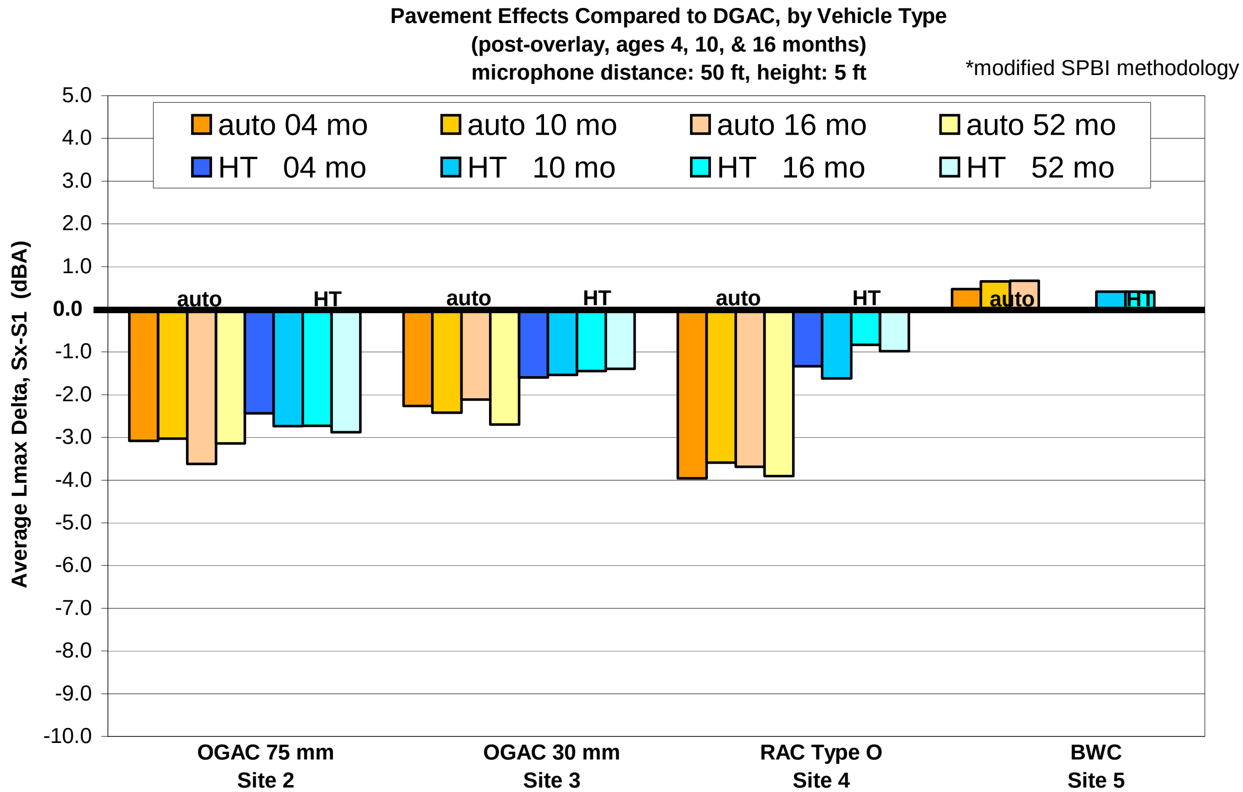


Figure E-2. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 1.5 m (5 ft).

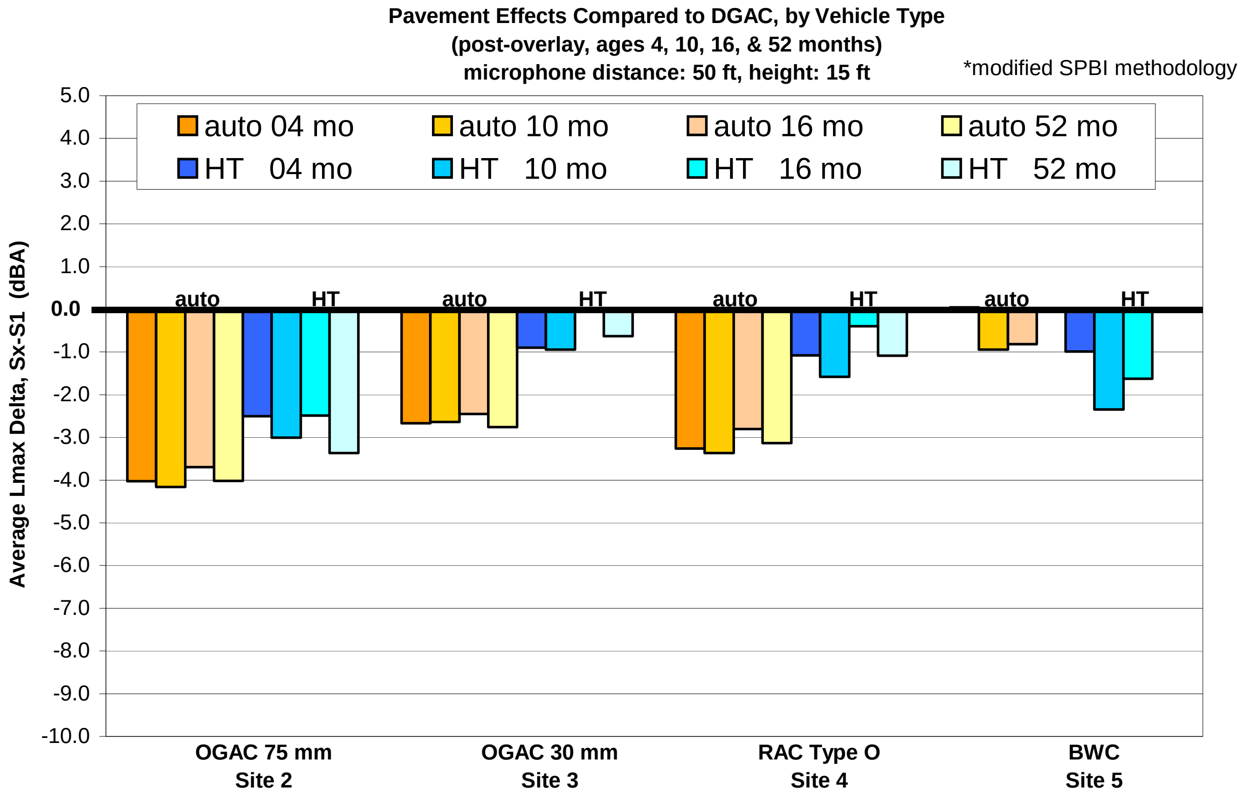


Figure E-3. Pavement effects compared to DGAC (Site x minus Site 1) for autos and heavy trucks using modified SPBI.* Post-overlay results, all pavements, including DGAC, aged 4, 10, 16, and 52 months (limited data for BWC). Microphone location: distance 15 m (50 ft), height 4.5 m (15 ft).

E.3 Spectral Results

All plots show values where site bias has not been removed. Results are shown for various combinations of parameters:

- Figures E-4 through E-18 compare results for the different pavements for one age and a single microphone location; this includes results for both automobiles and heavy trucks. These plots highlight the spectral differences among pavements.
- Figures E-19 through E-23 compare results for different ages of a single pavement for a single microphone location; this includes results for automobiles only (heavy truck results show no trends). These plots highlight the age-related spectral differences among microphone locations.
- Figures E-24 through E-28 compare results for different microphone locations for a single pavement for one age (16 months only); this includes results for both automobiles and heavy trucks. These plots highlight the spectral differences among microphone locations.

Note: Data are not available for some data sets in Figures 4-28; results shown are those available.

As a reminder …

Site Information	
site name	pavement type
Site 1 (S1)	DGAC 30 mm
Site 2 (S2)	OGAC 75 mm
Site 3 (S3)	OGAC 30 mm
Site 4 (S4)	RAC Type O 30 mm
Site 5 (S5)	BWC 30 mm

Microphone Locations	
distance (ft)	height (ft)
25	5
50	5
50	15
200	5

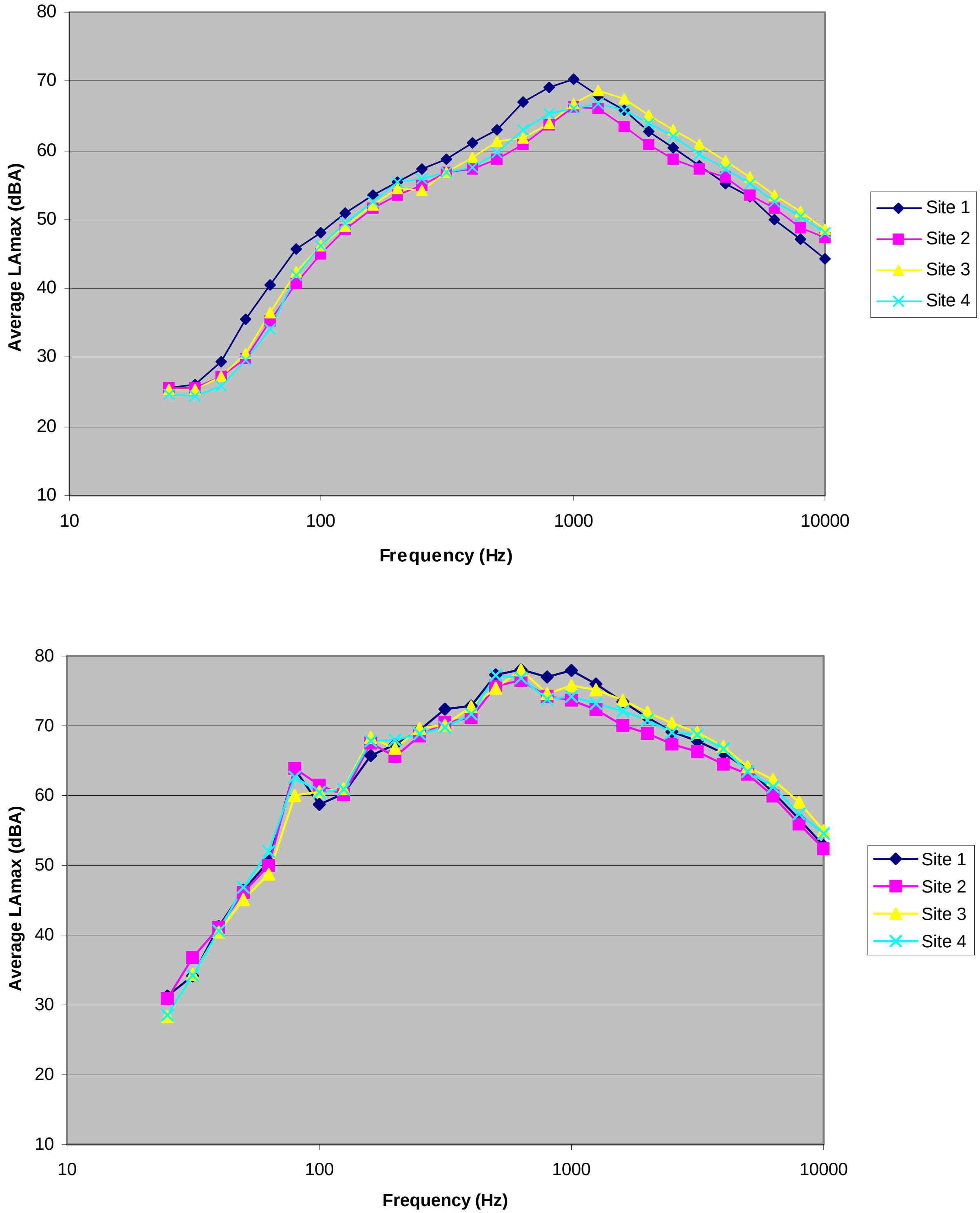


Figure E-4. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 25 ft, height 5 ft.

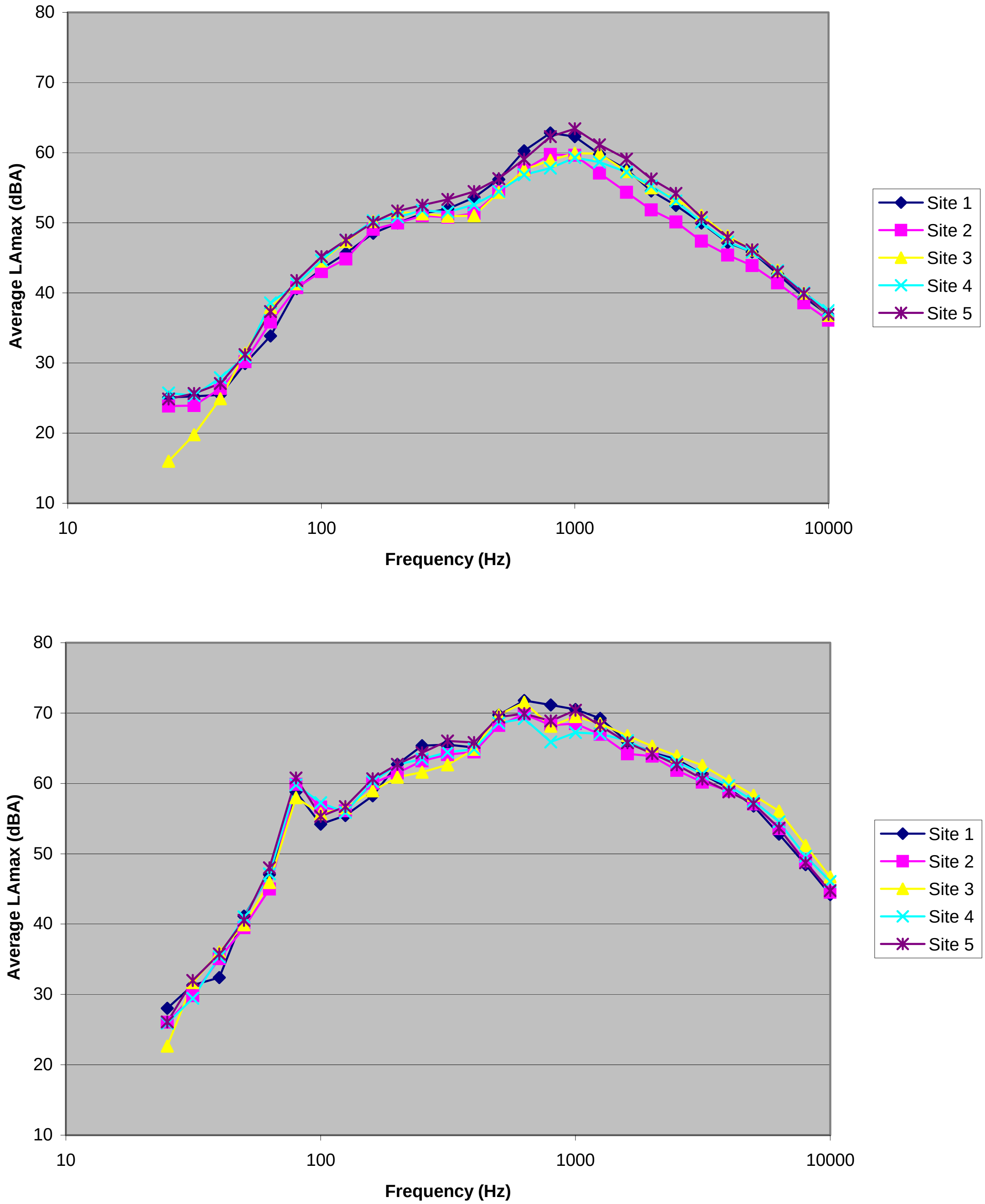
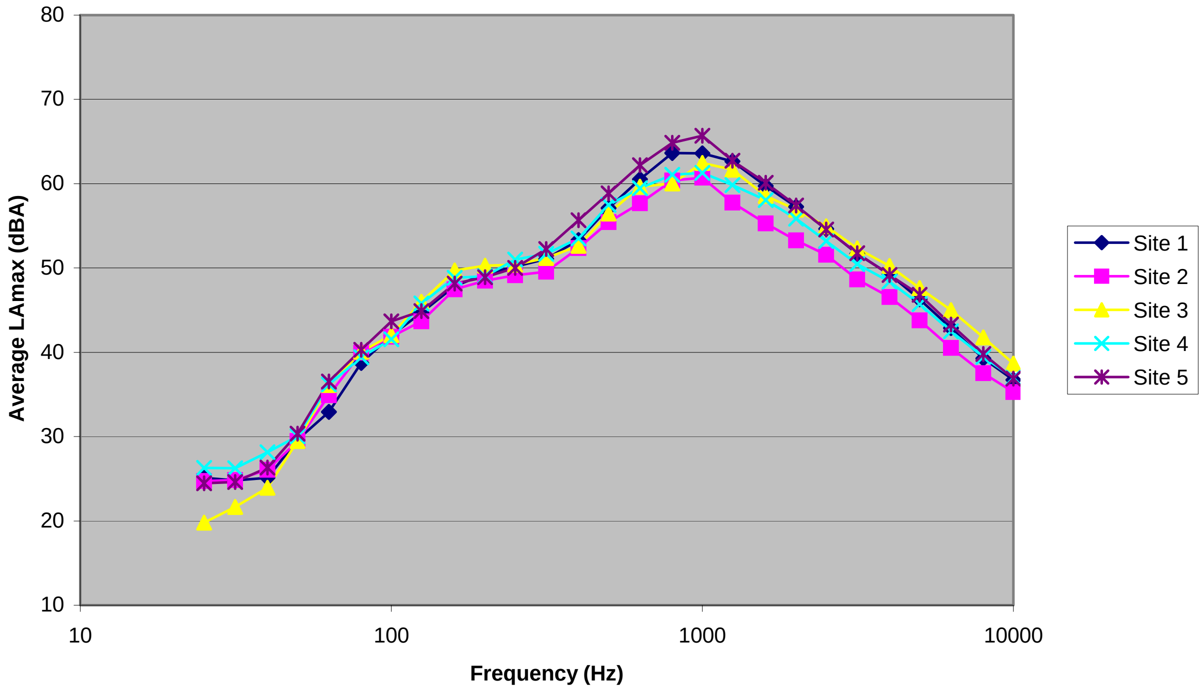


Figure E-5. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 50 ft, height 5 ft.



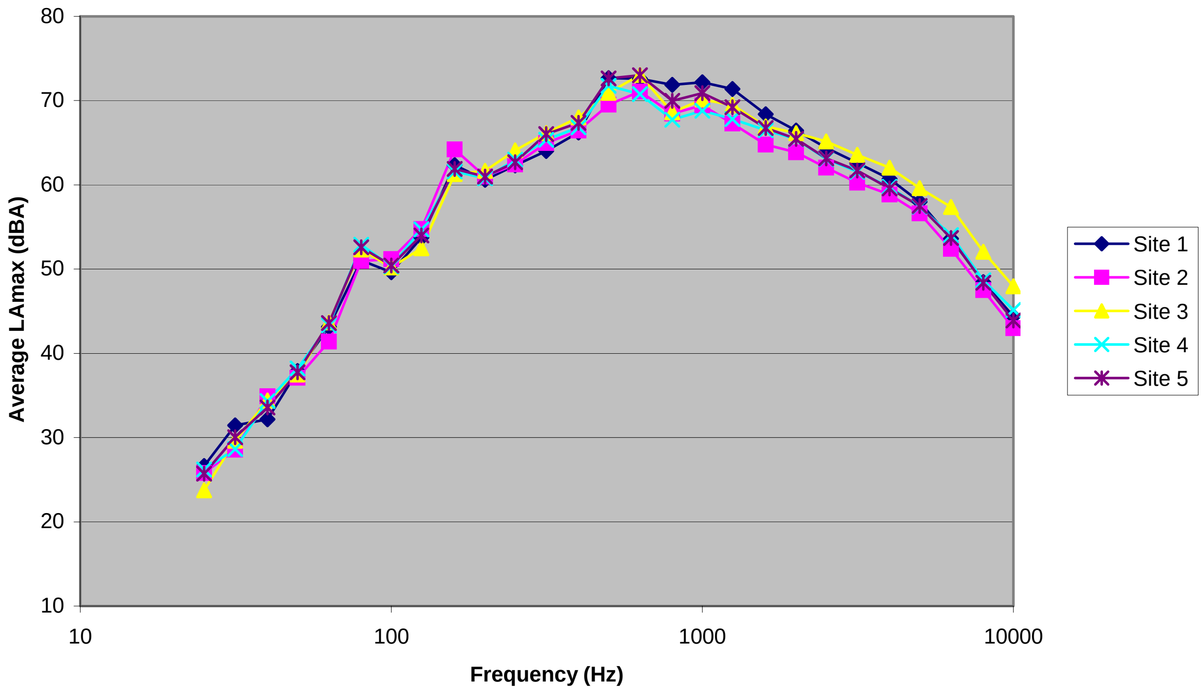
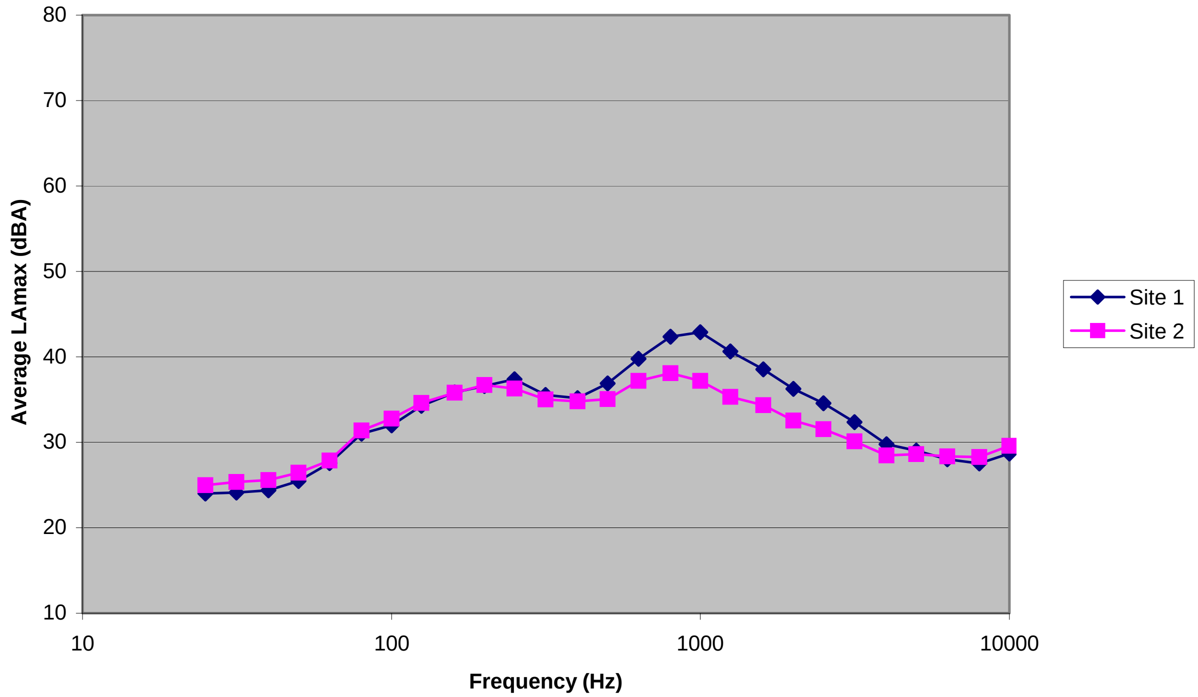


Figure E-6. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 50 ft, height 15 ft.



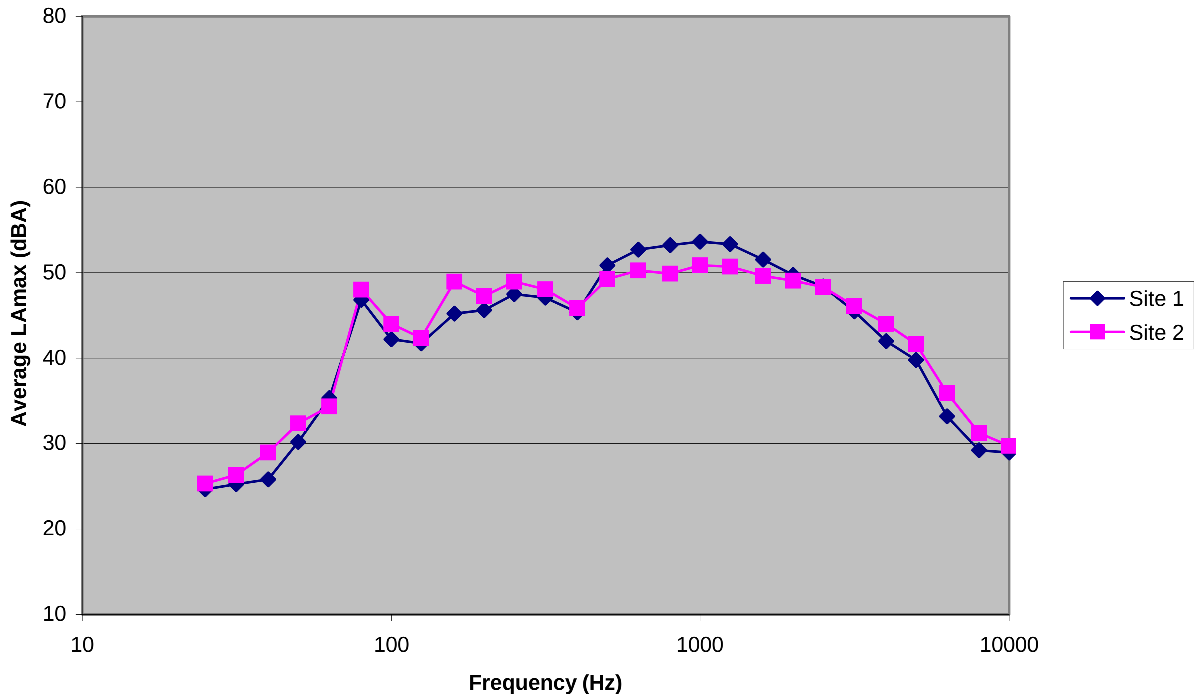
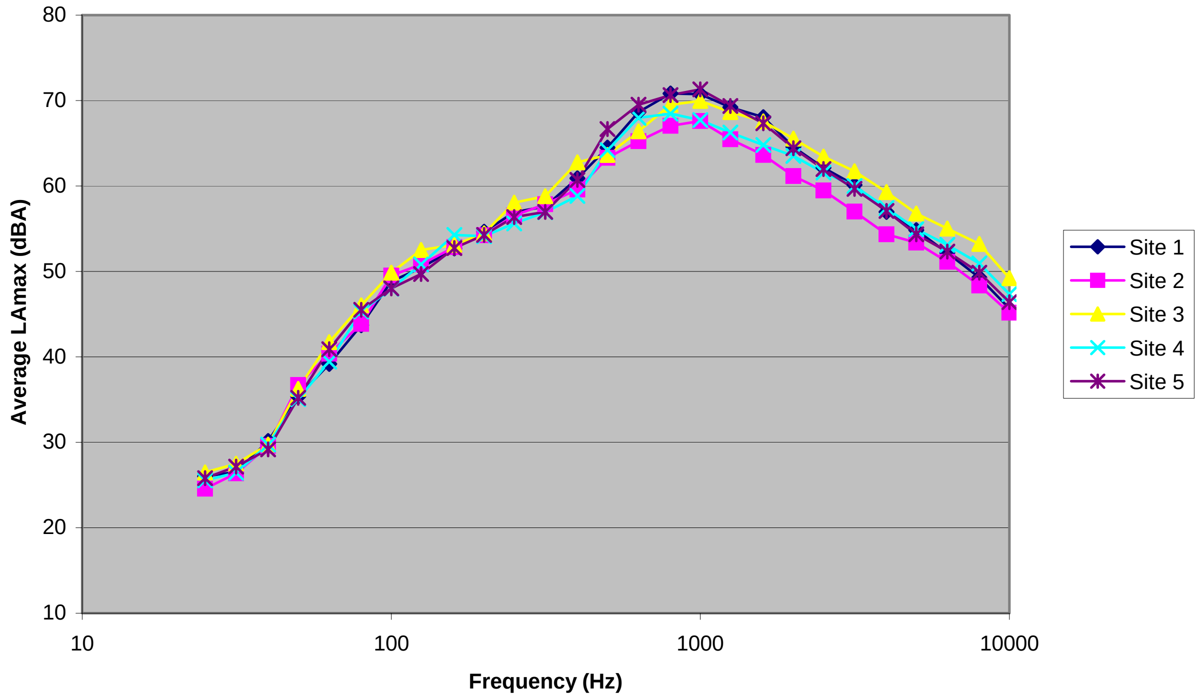


Figure E-7. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 4 months. Microphone location: distance 200 ft, height 5 ft.



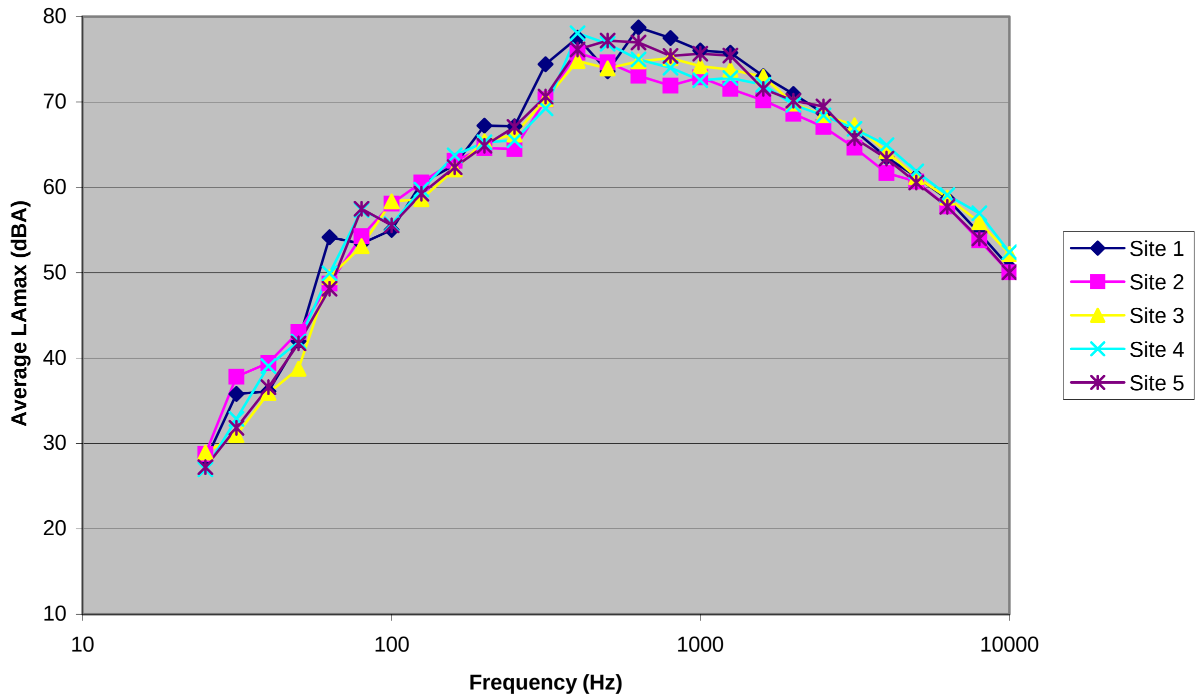
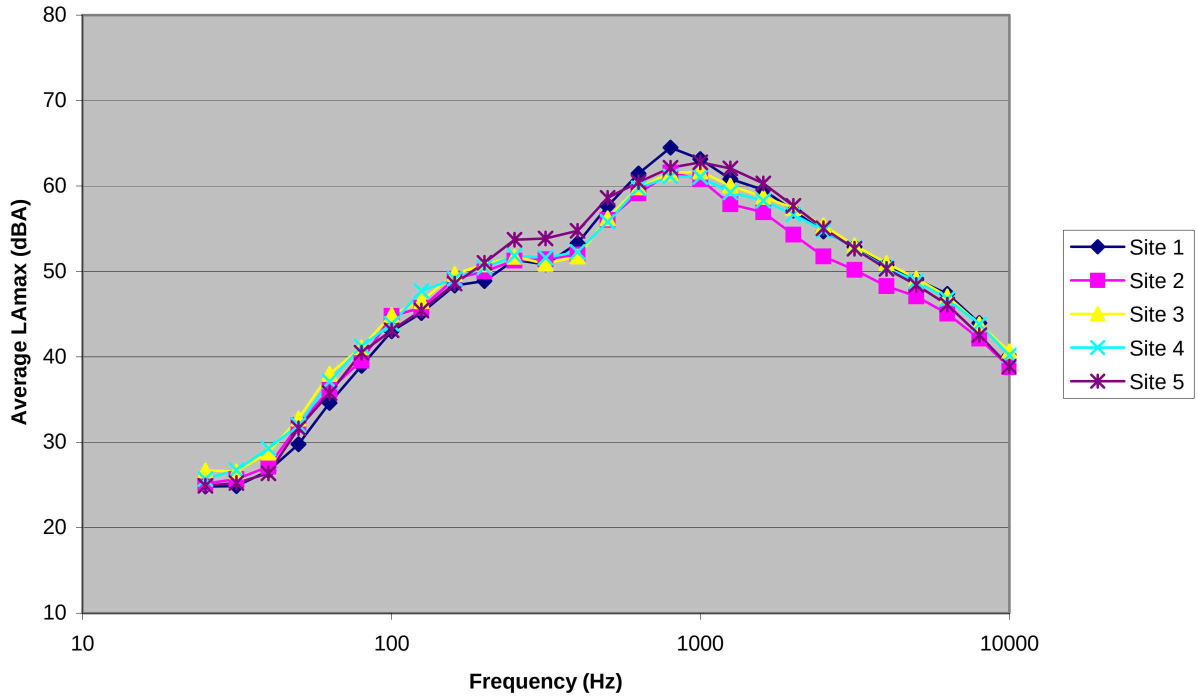


Figure E-8. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10 months. Microphone location: distance 25 ft, height 5 ft.



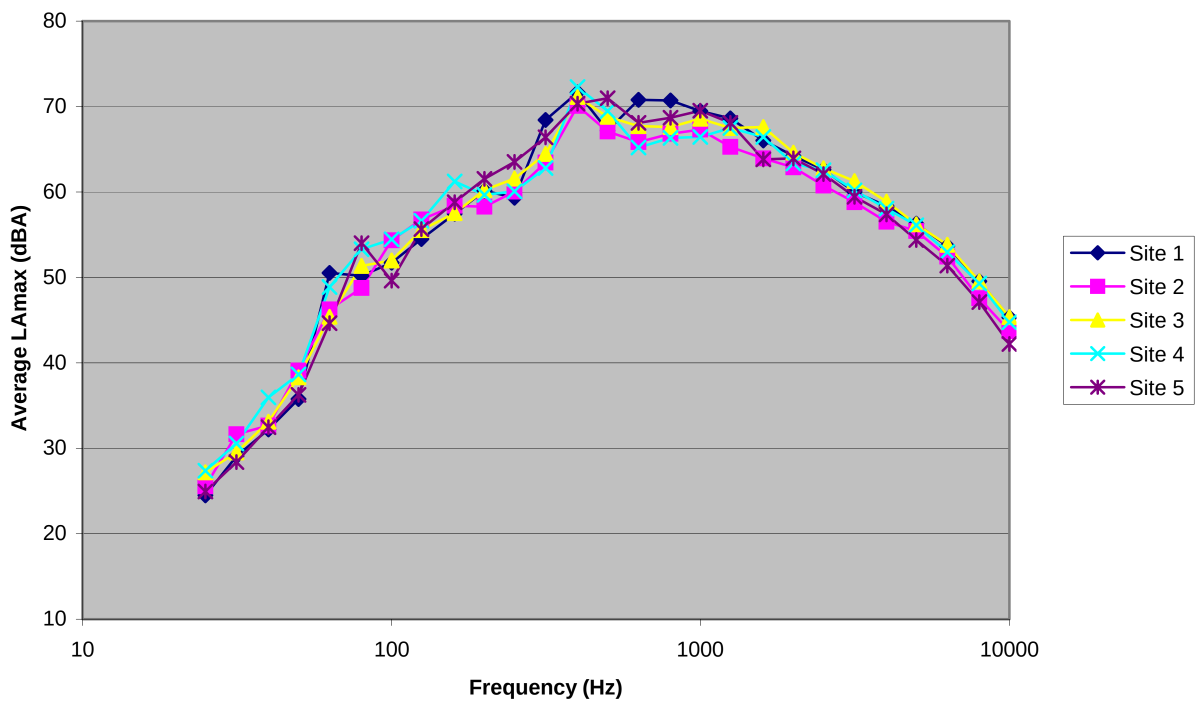
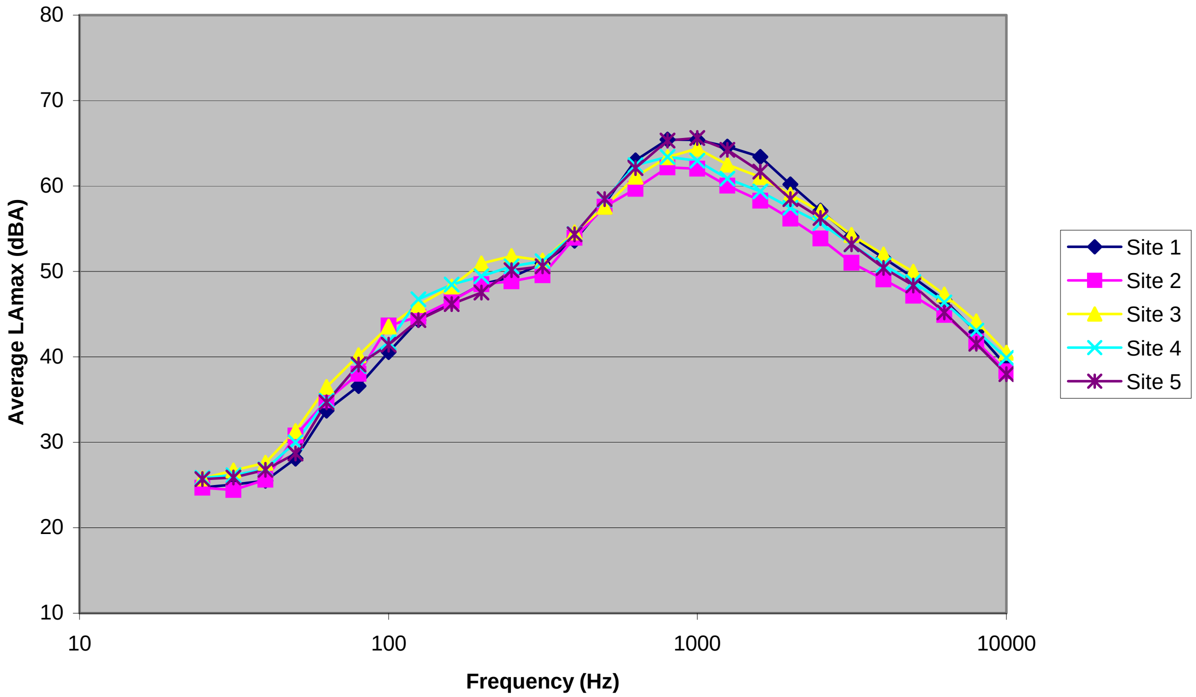


Figure E-9. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10 months. Microphone location: distance 50 ft, height 5 ft.



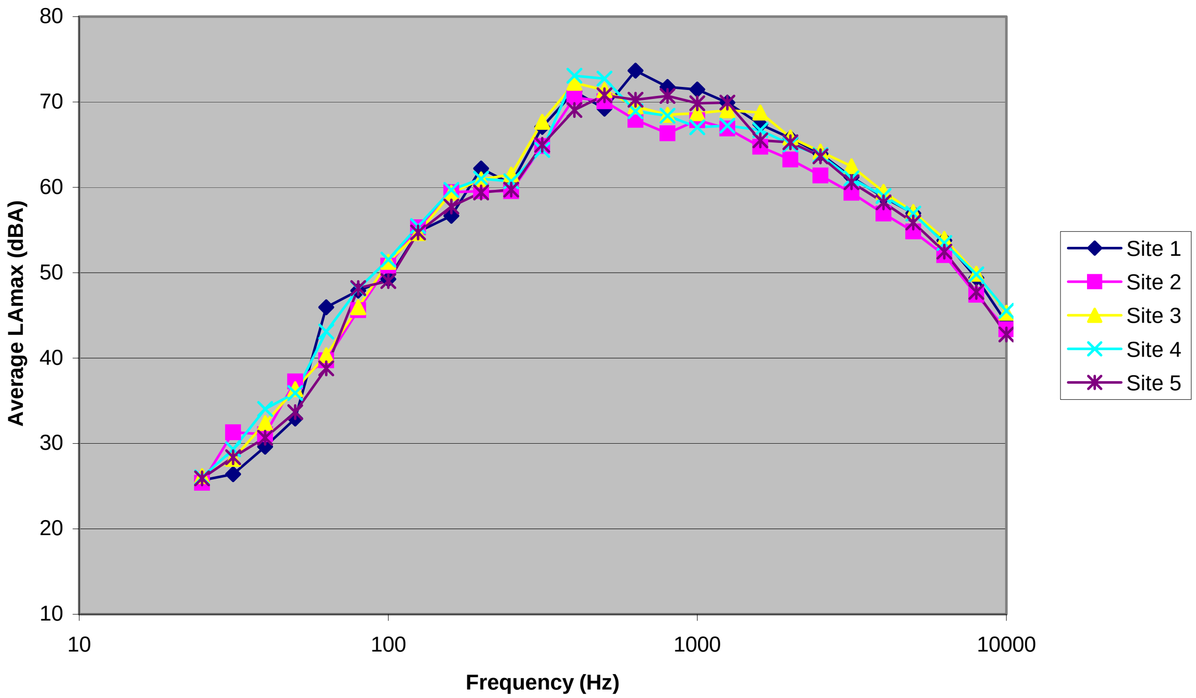


Figure E-10. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10 months. Microphone location: distance 50 ft, height 15 ft.

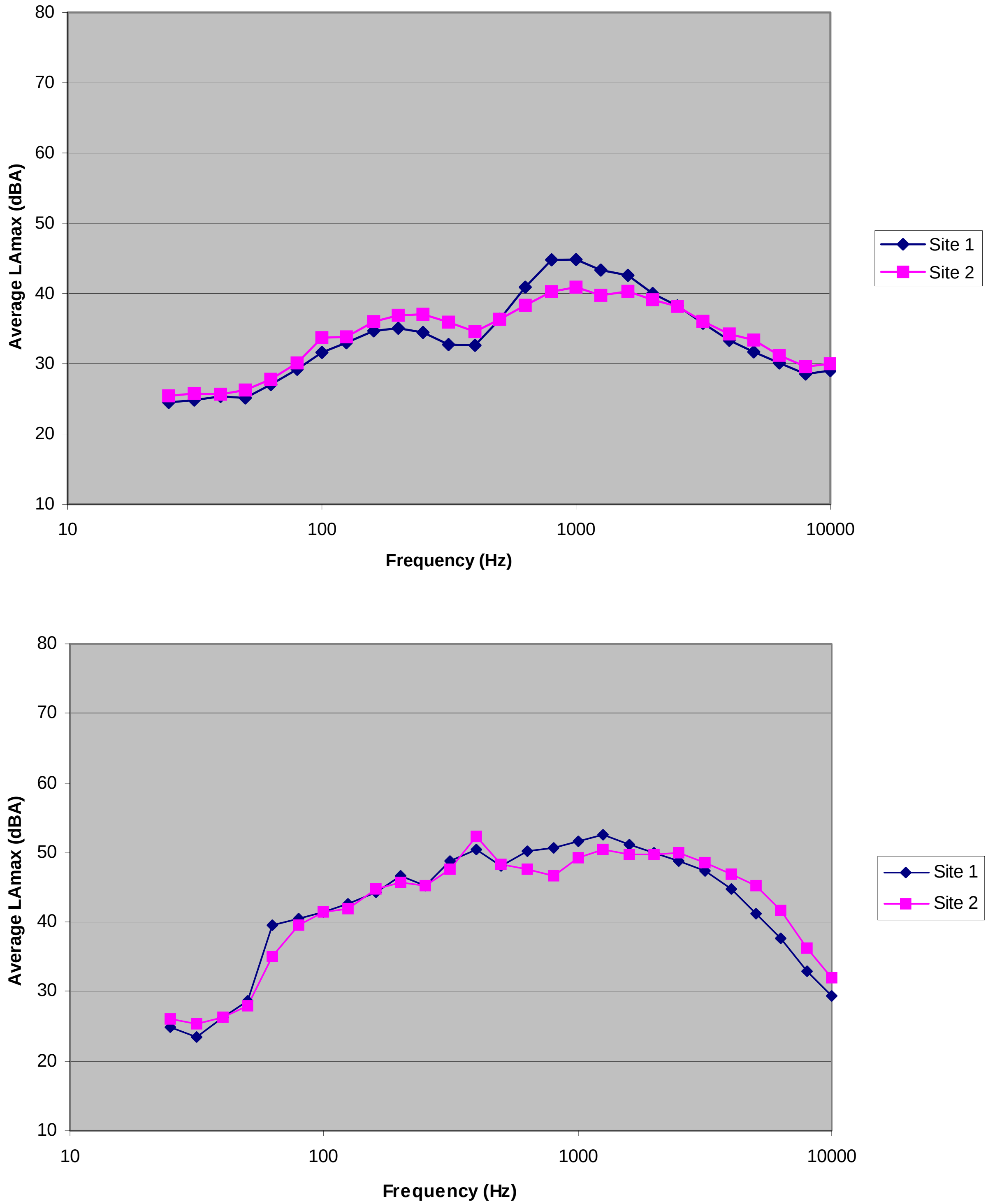
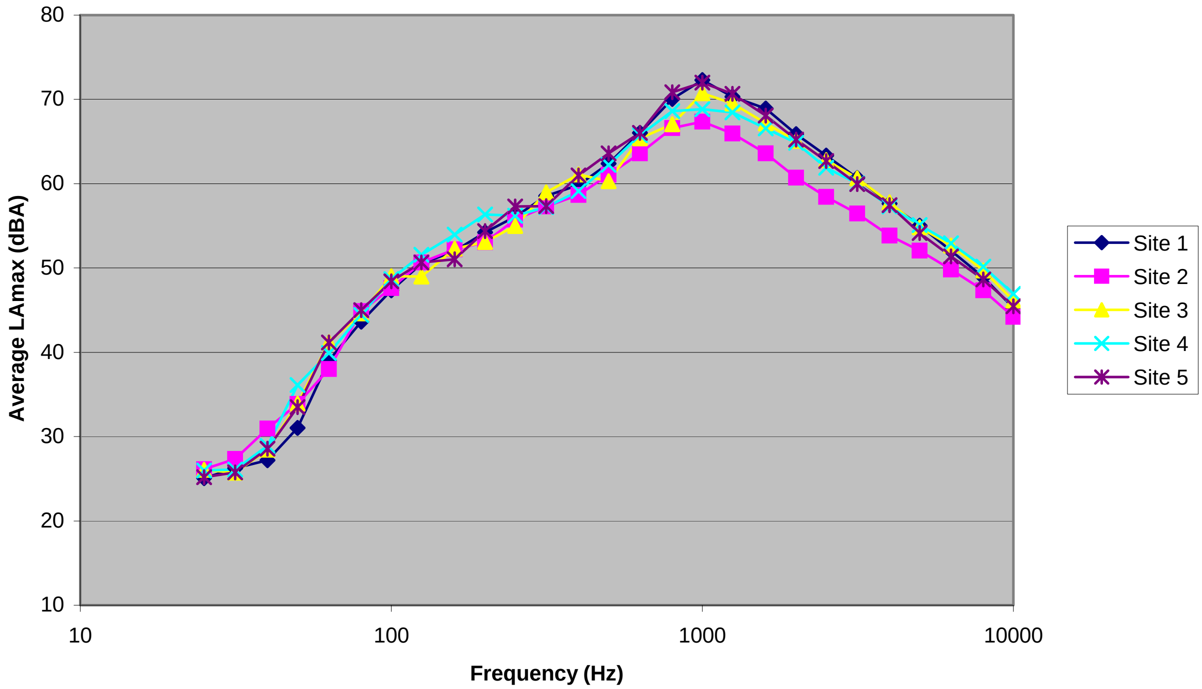


Figure E-11. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 10months. Microphone location: distance 200 ft, height 5 ft.



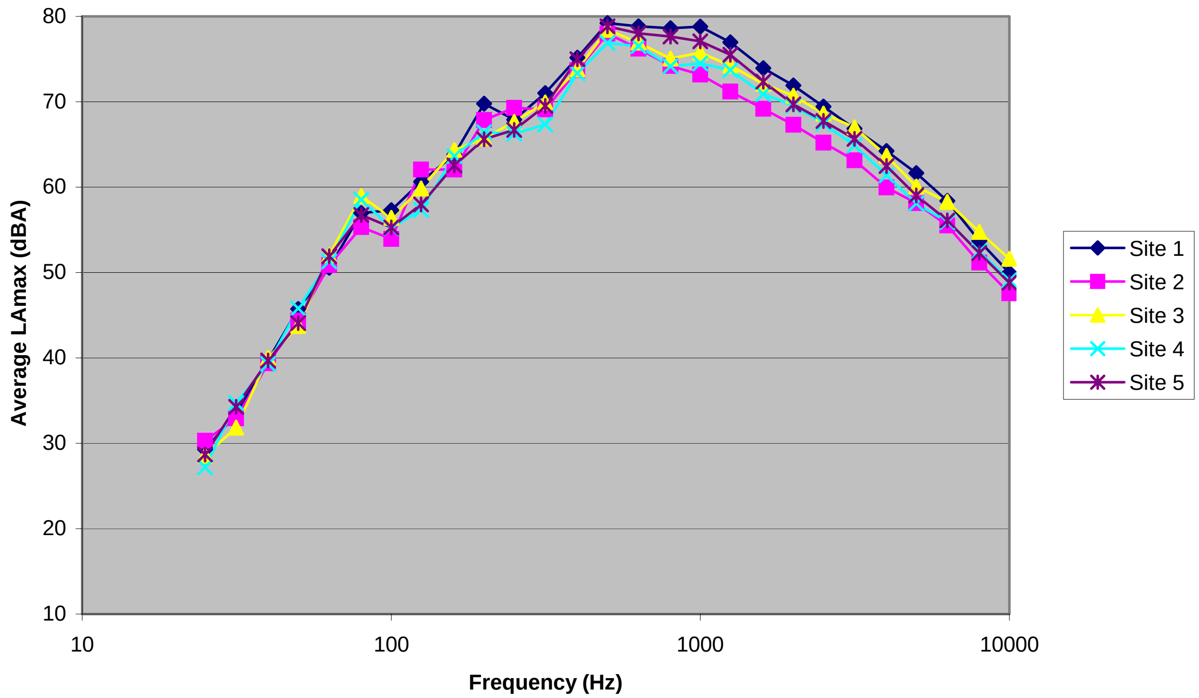
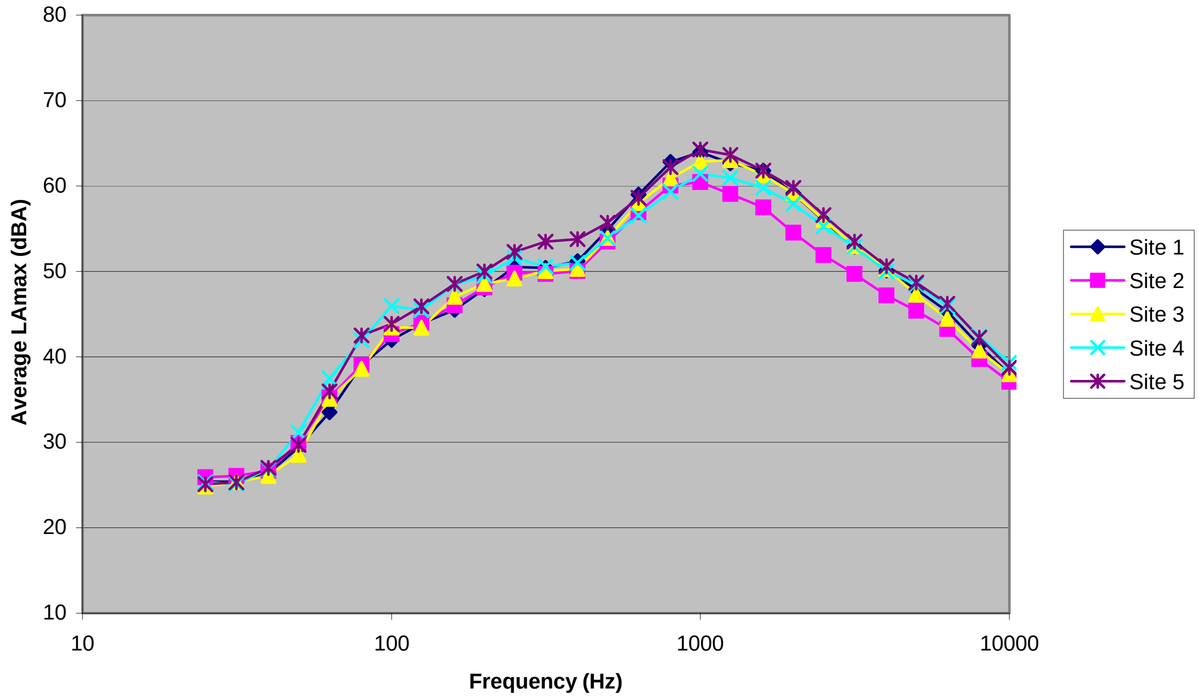


Figure E-12. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 25 ft, height 5 ft.



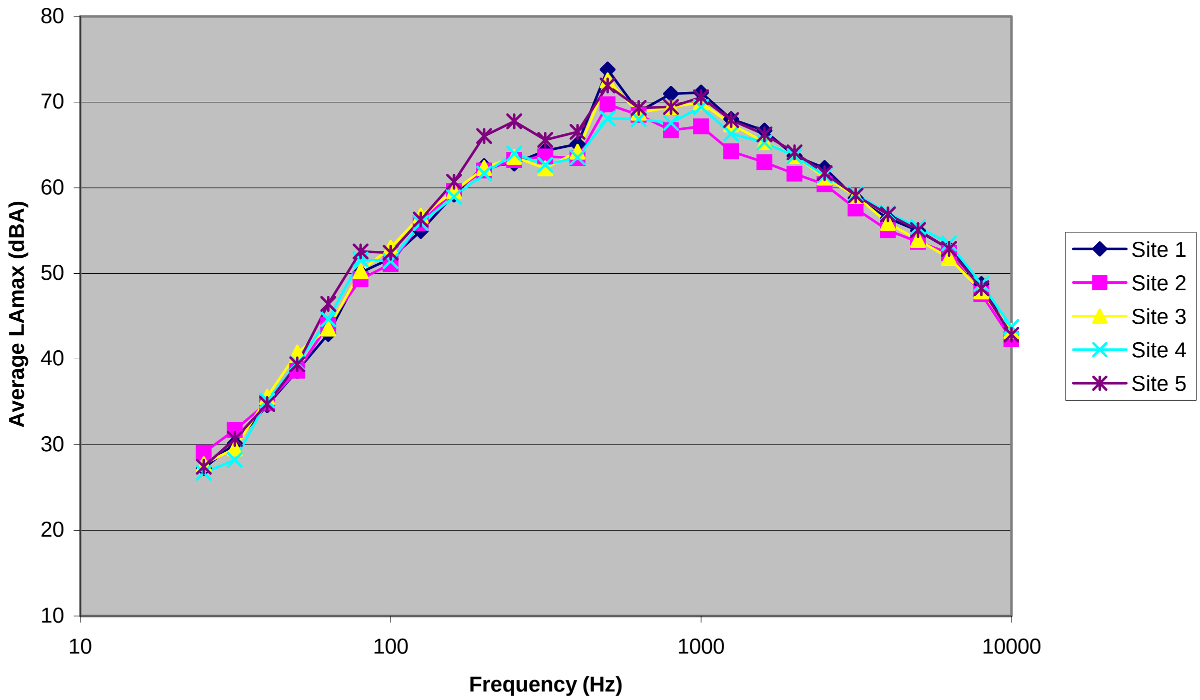
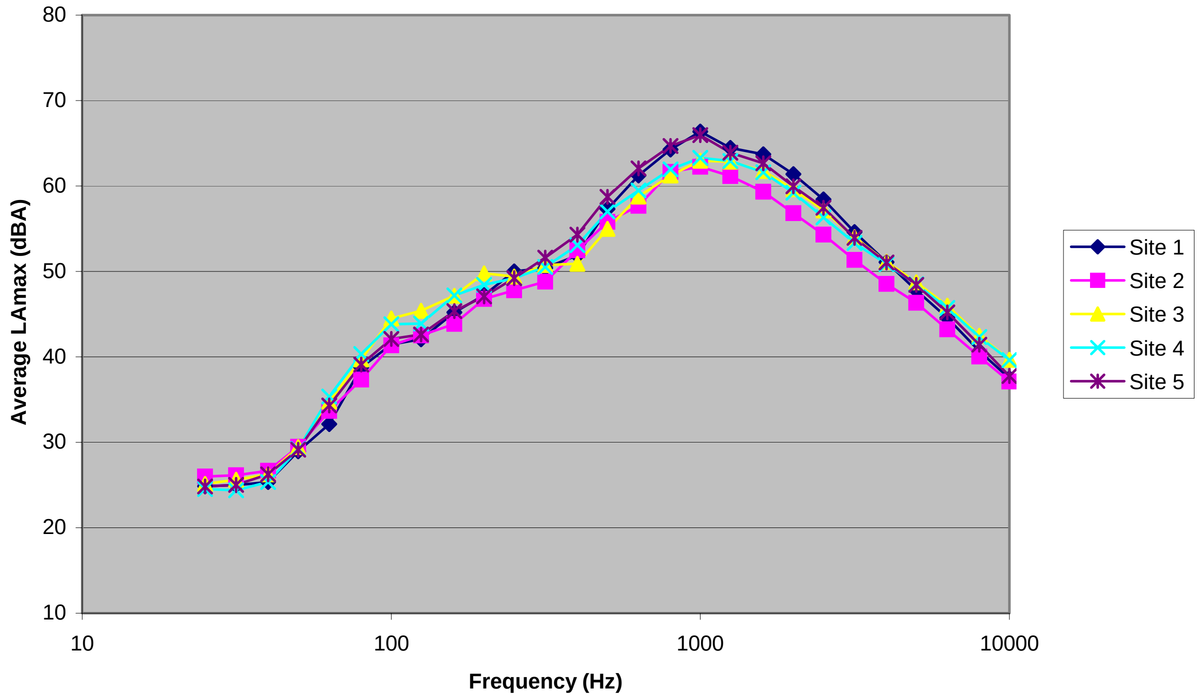


Figure E-13. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 50 ft, height 5 ft.



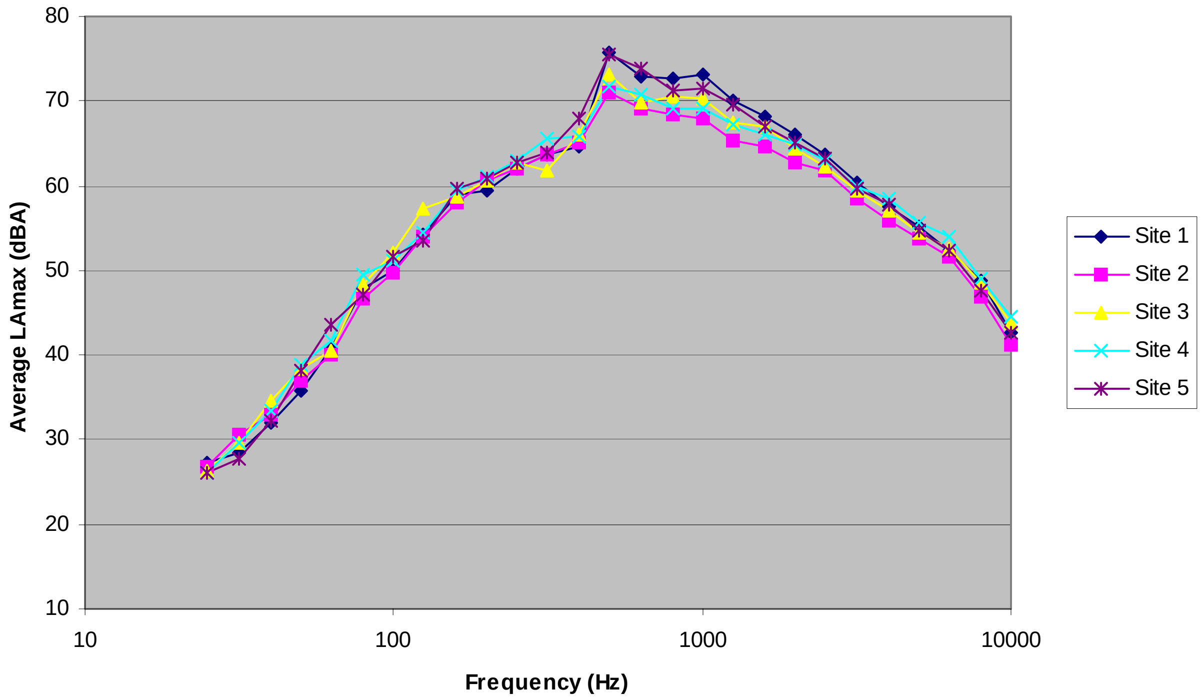
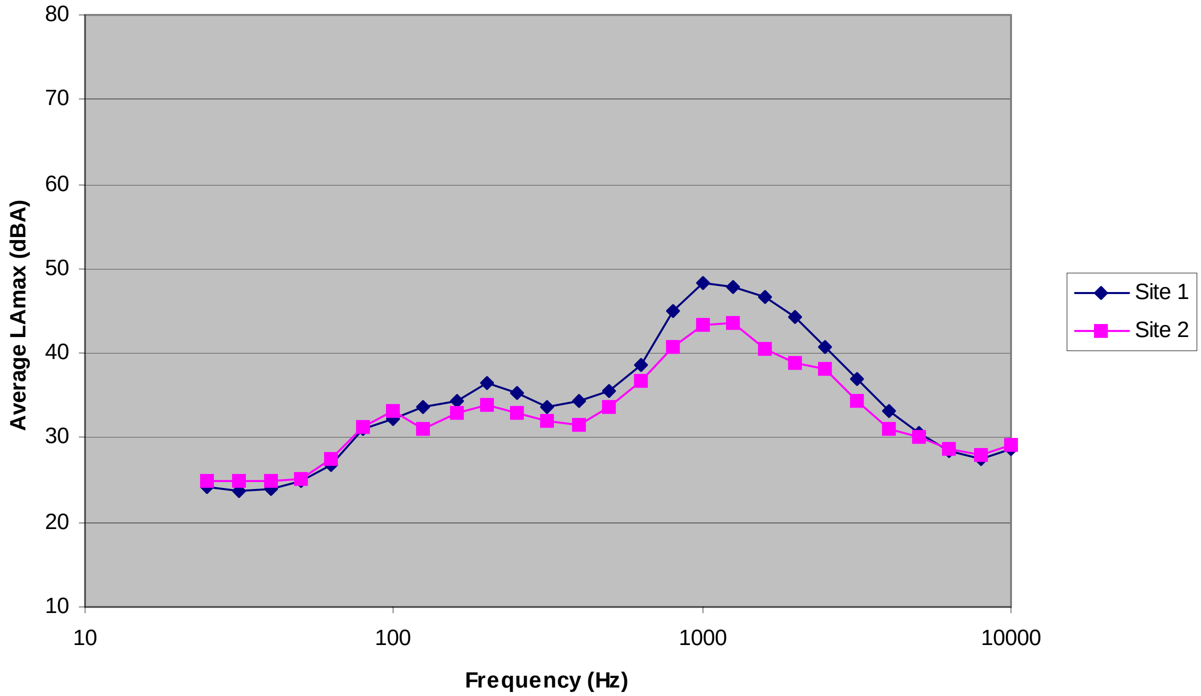


Figure E-14. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 50 ft, height 15 ft.



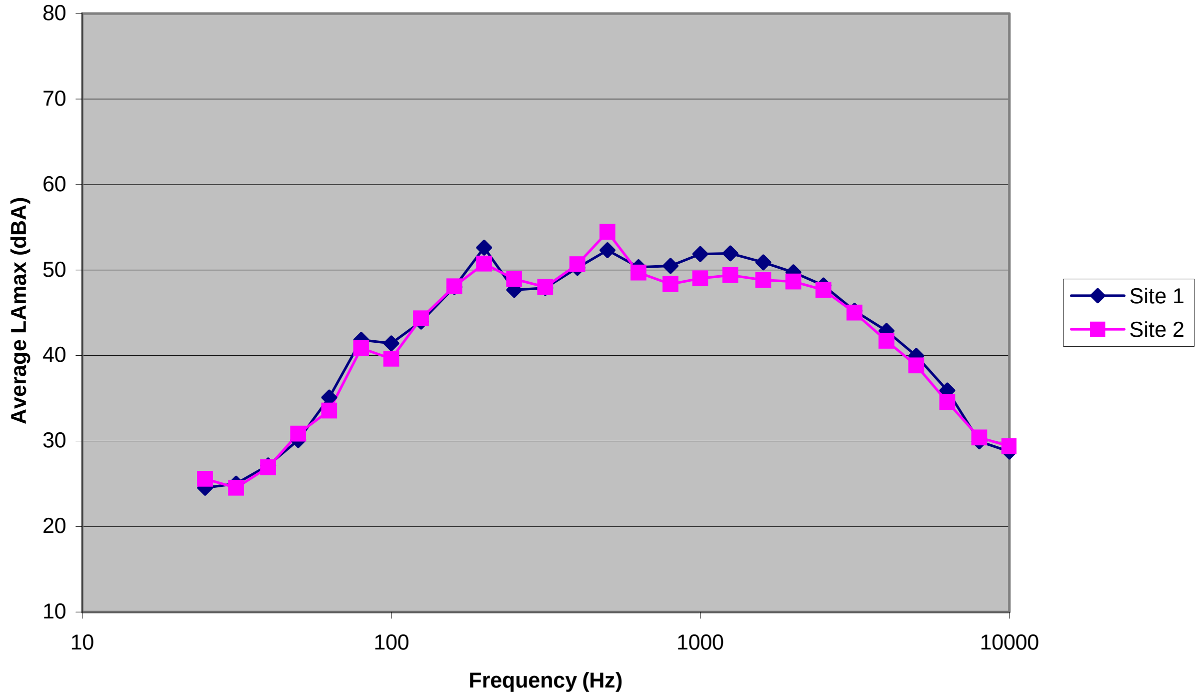
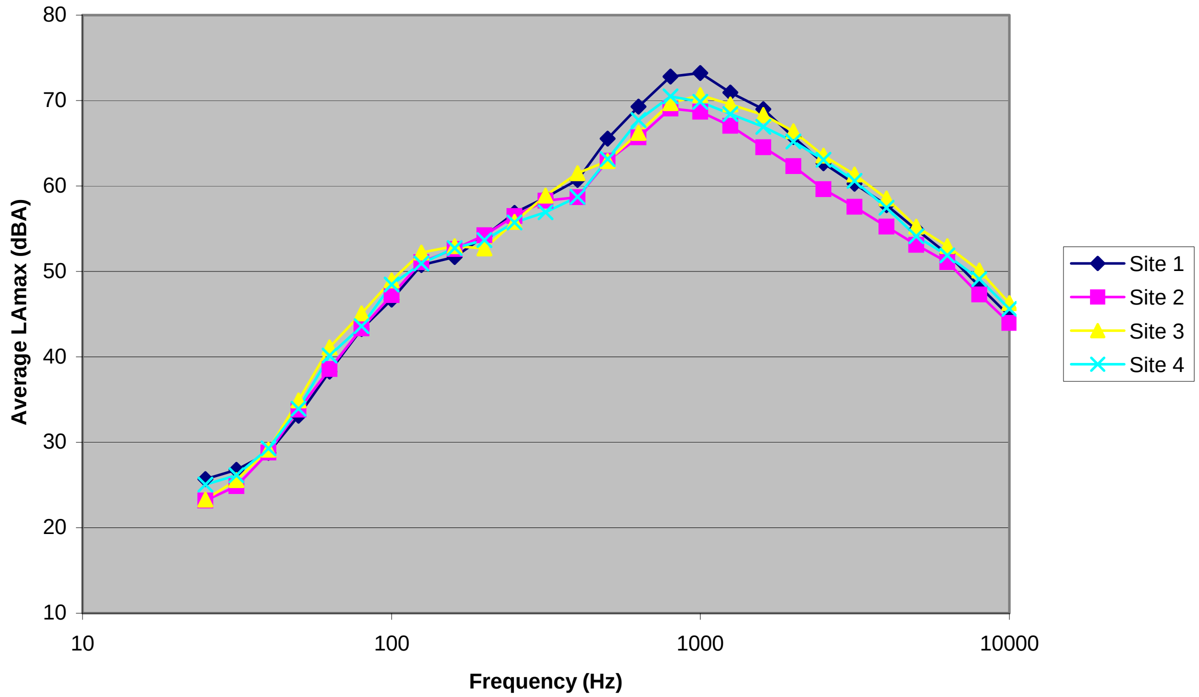


Figure E-15. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 16 months. Microphone location: distance 200 ft, height 5 ft.



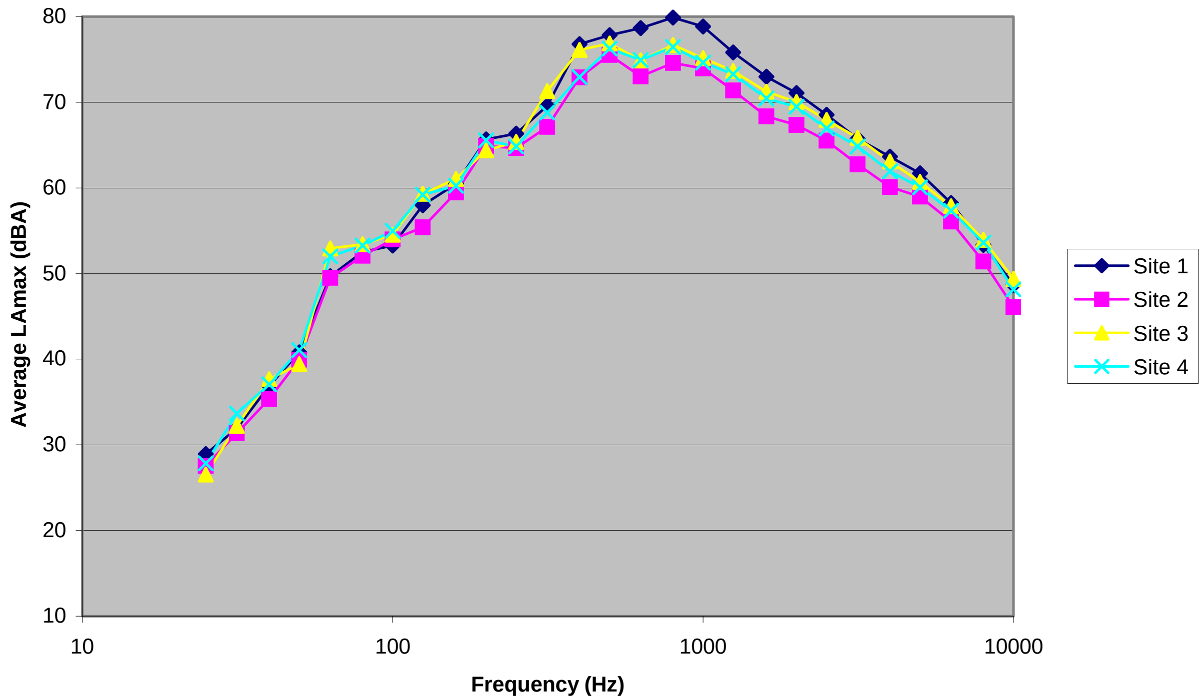
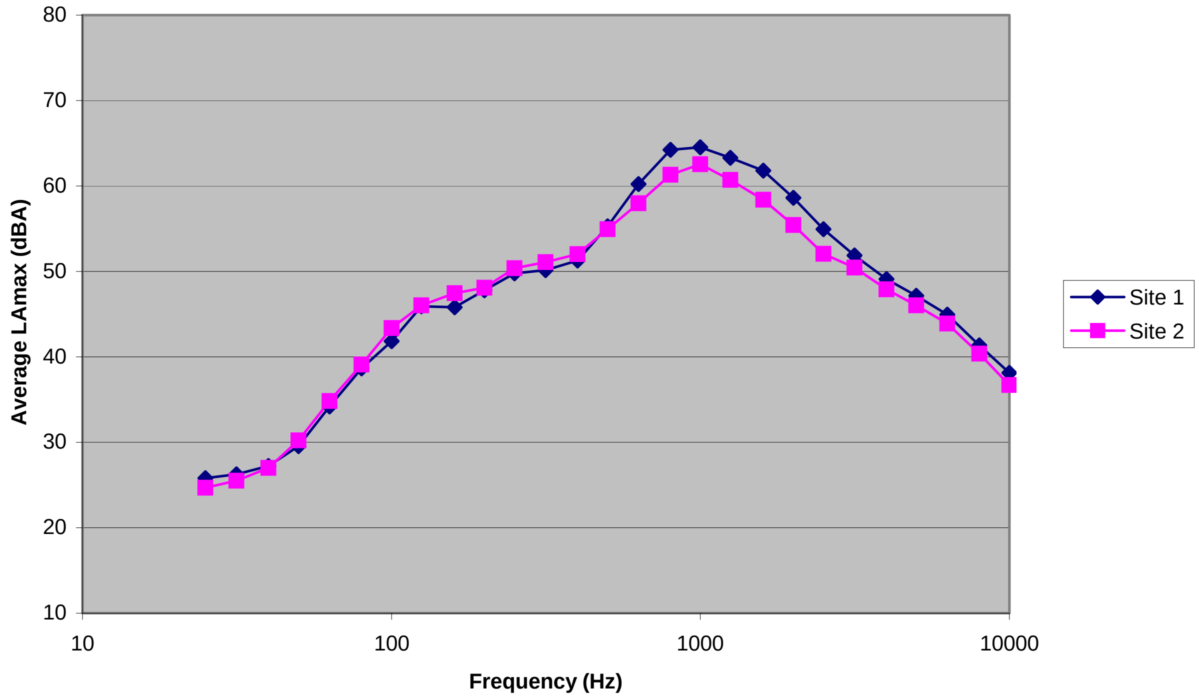


Figure E-16. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 52 months. Microphone location: distance 25 ft, height 5 ft.



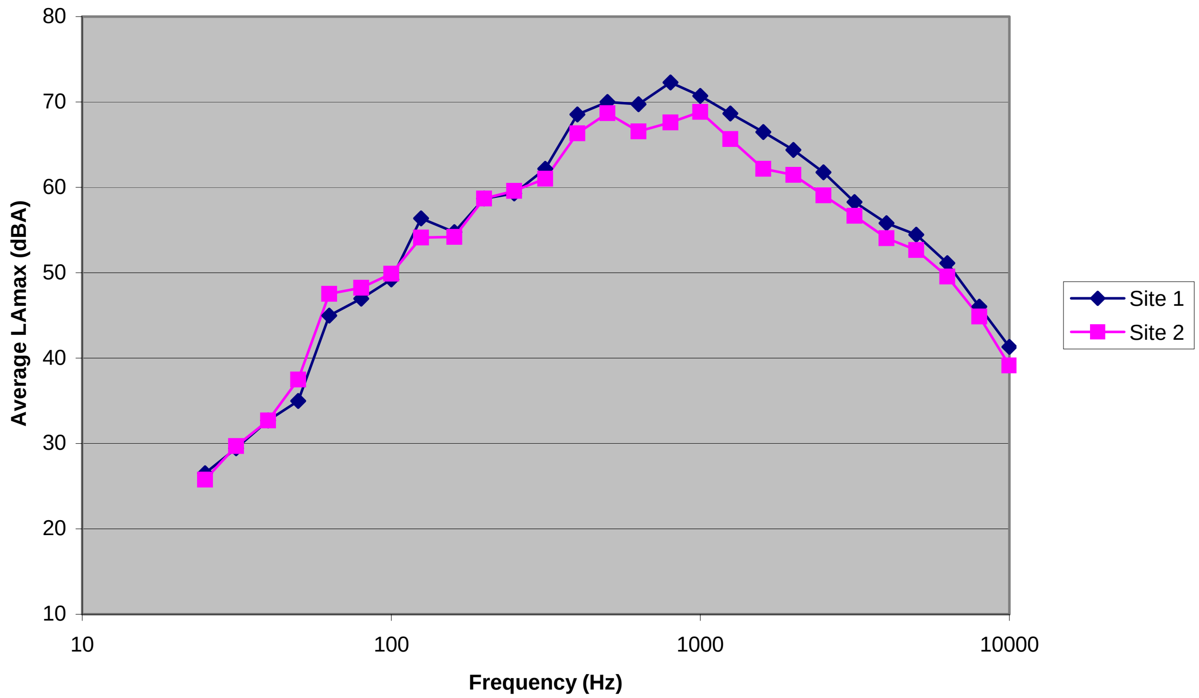
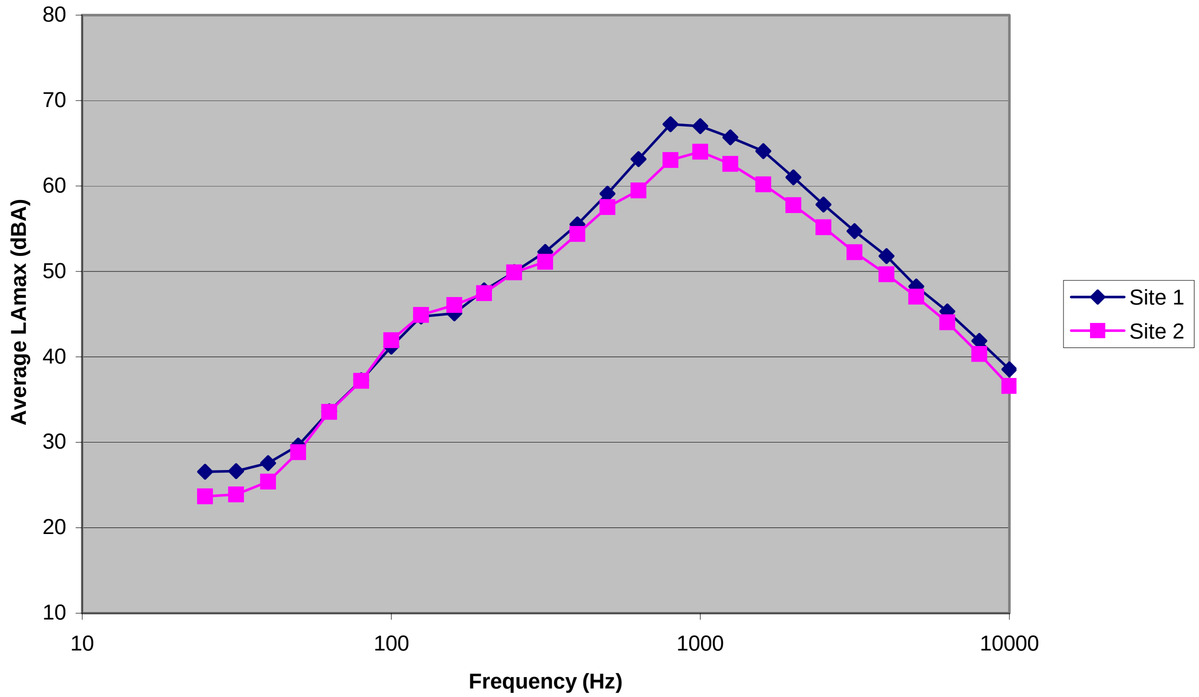


Figure E-17. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 52 months. Microphone location: distance 50 ft, height 5 ft.



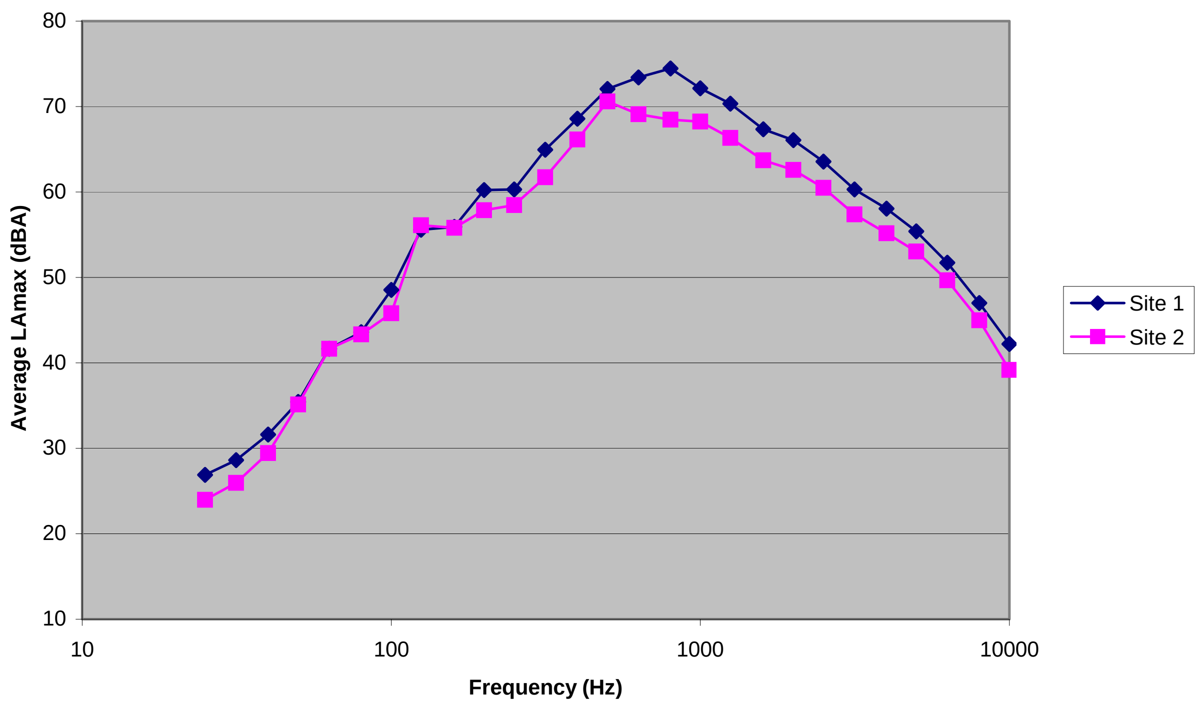


Figure E-18. Spectral data for automobiles (top) and heavy trucks (bottom) on four different pavement types. Post-overlay results, all pavements aged 52 months. Microphone location: distance 50 ft, height 15 ft.

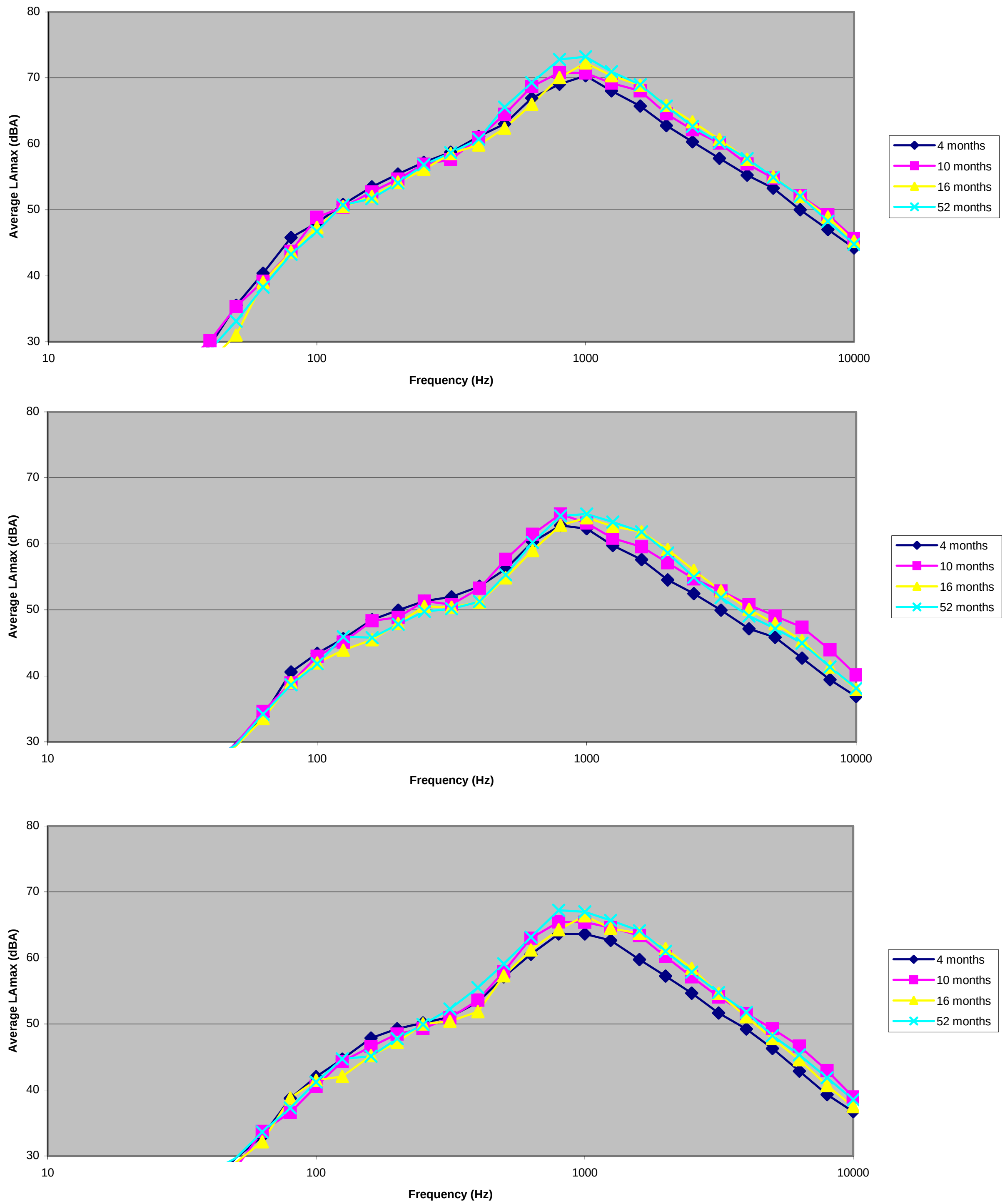
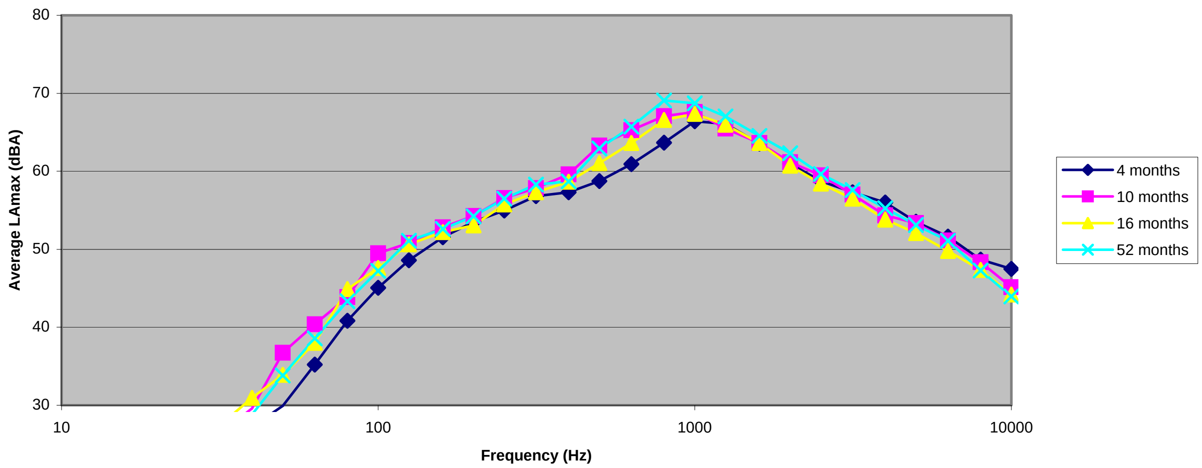
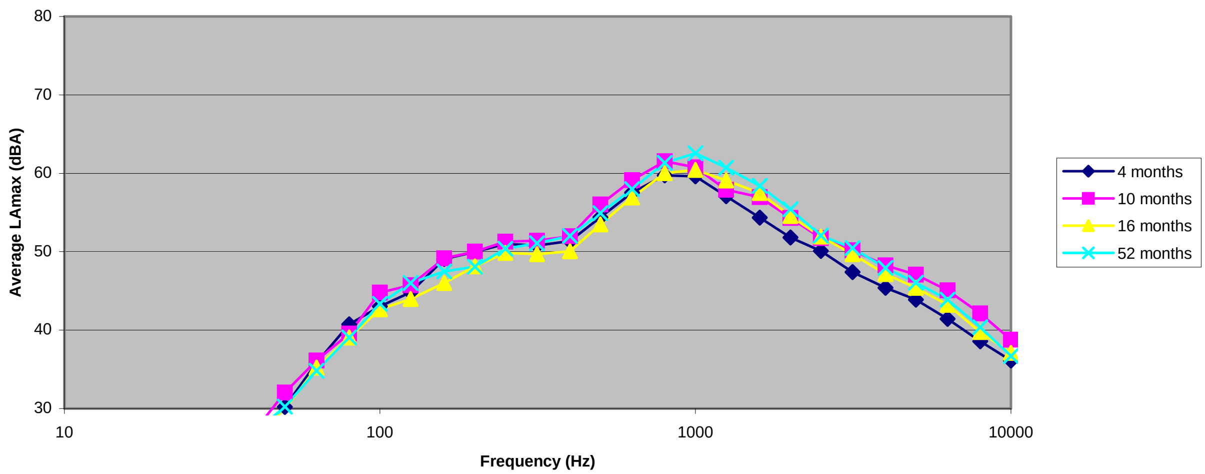


Figure E-19. Spectral data for automobiles; post-overlay results for Site 1 (DGAC 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).





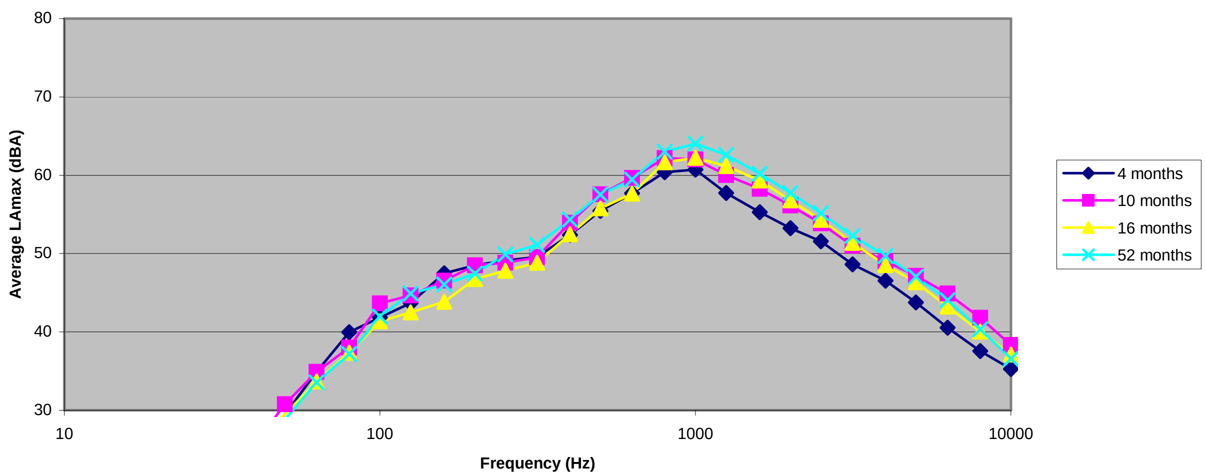


Figure E-20. Spectral data for automobiles; post-overlay results for Site 2 (OGAC 75 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).

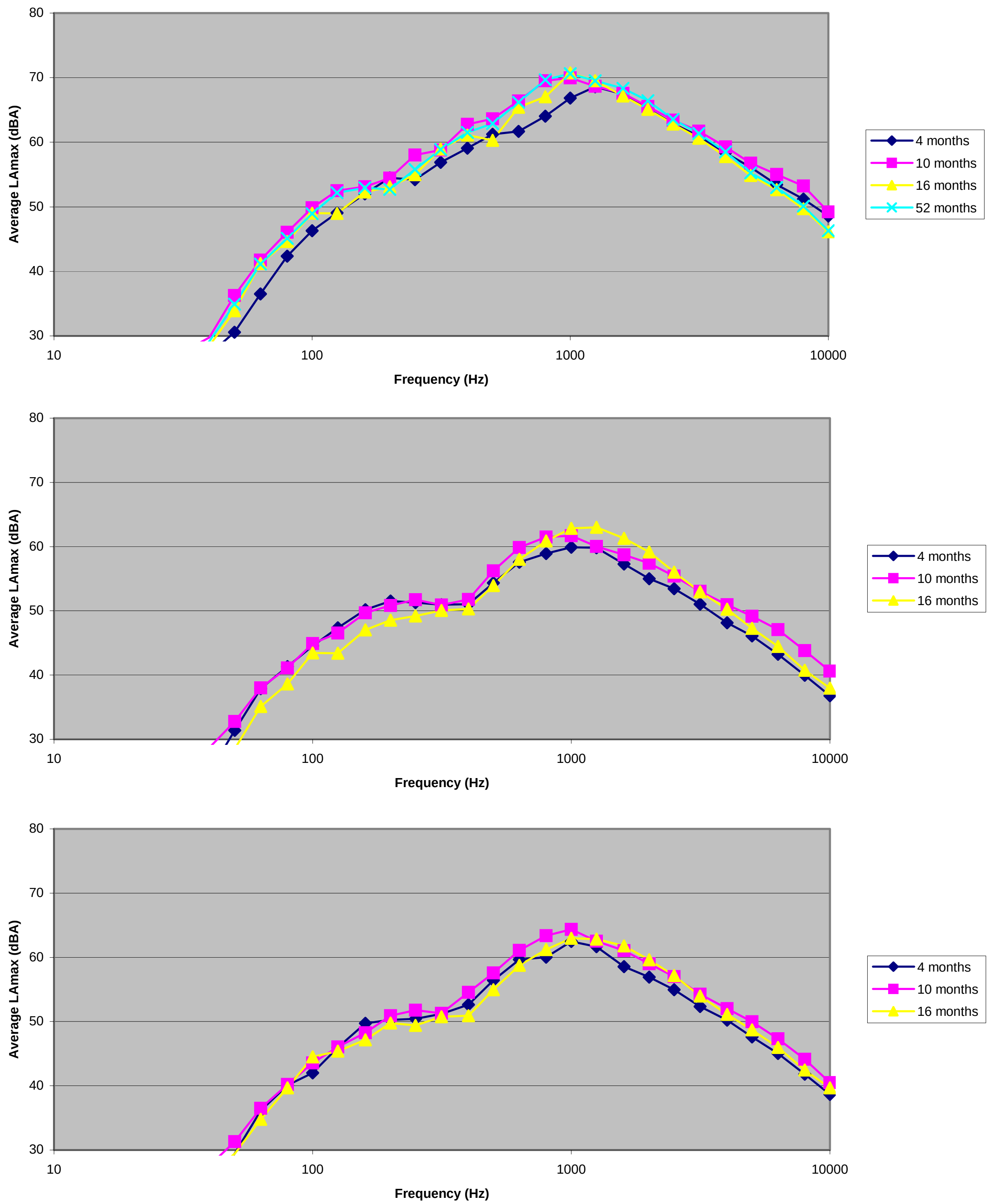


Figure E-21. Spectral data for automobiles; post-overlay results for Site 3 (OGAC 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).

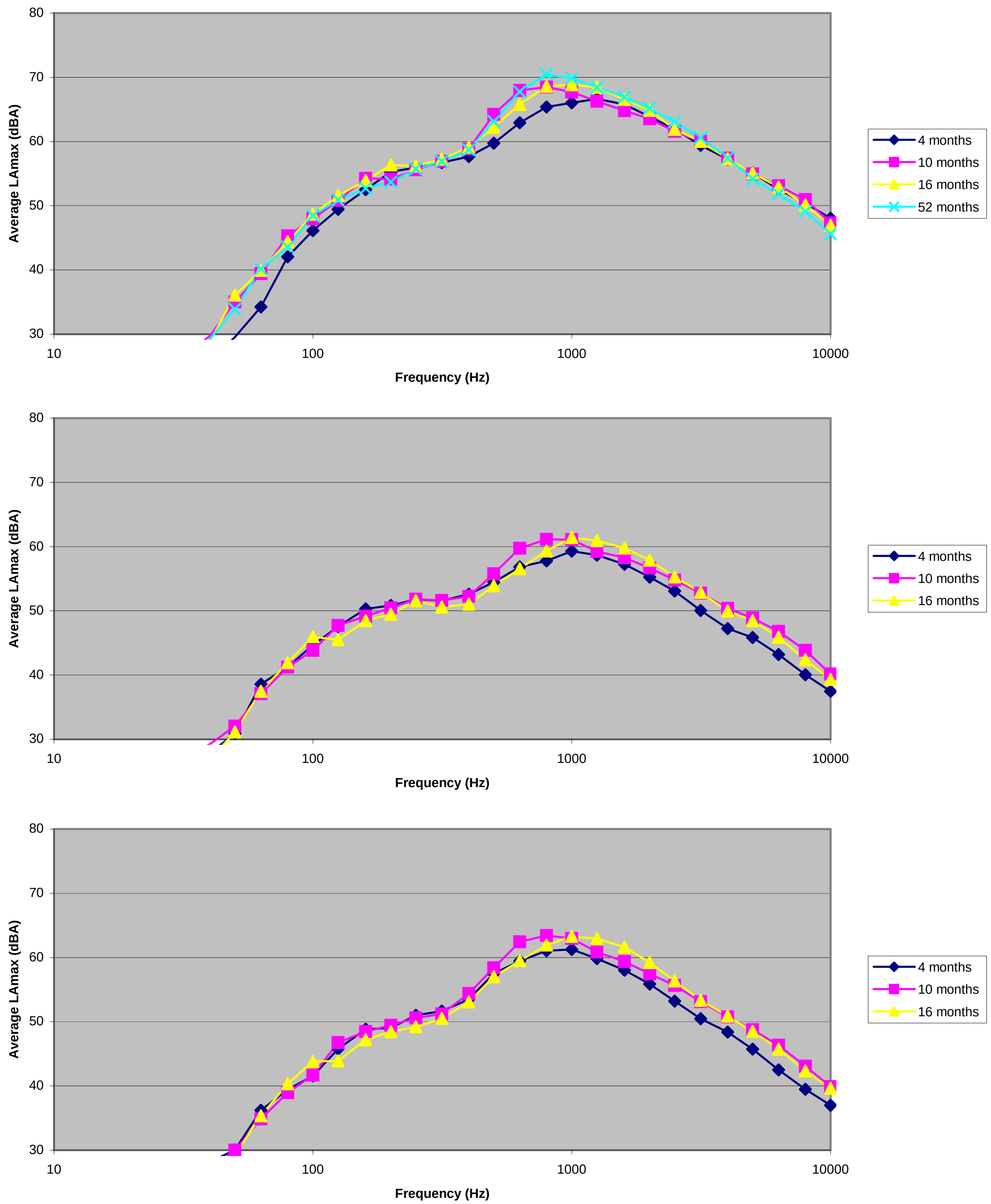


Figure E-22. Spectral data for automobiles; post-overlay results for Site 4 (RAC Type O 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).

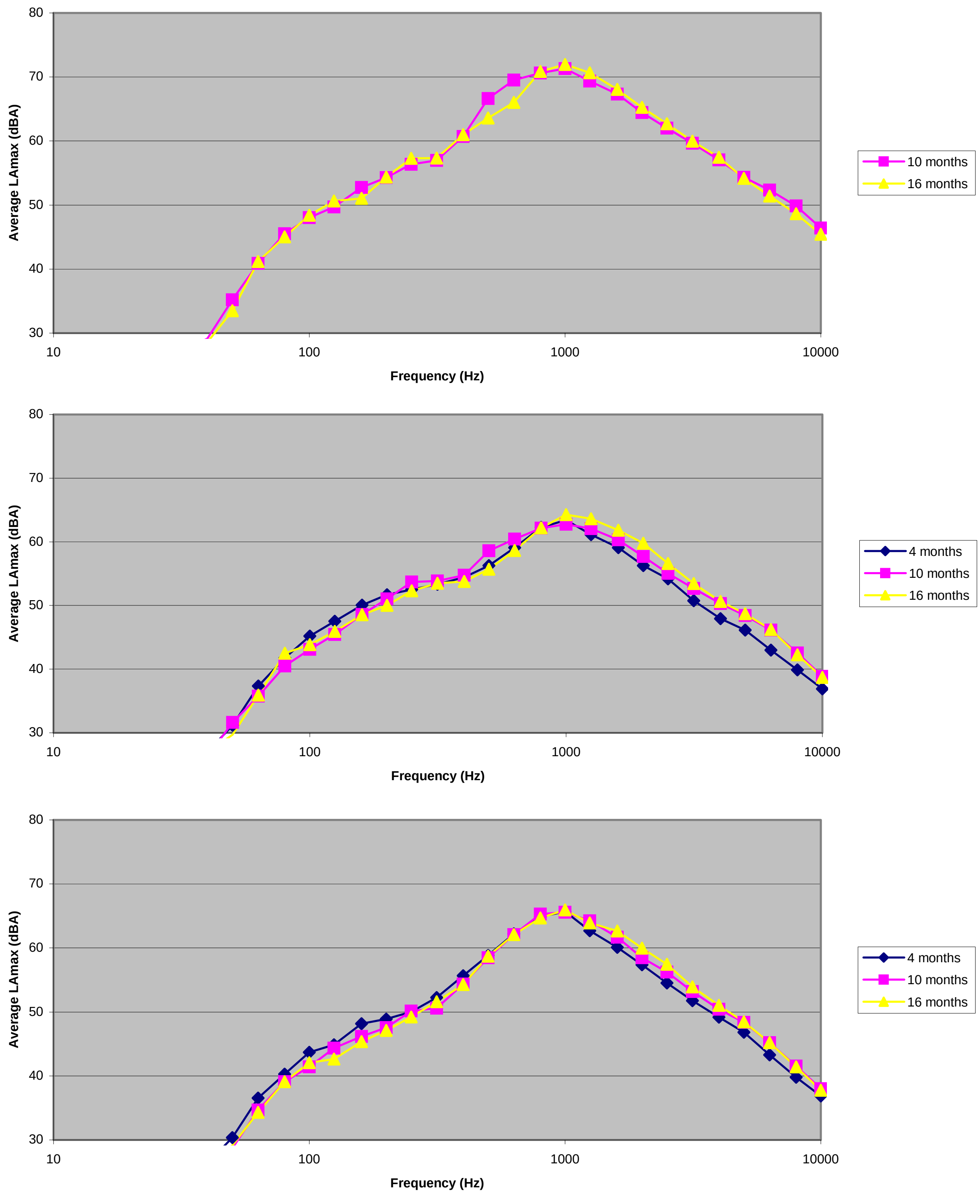
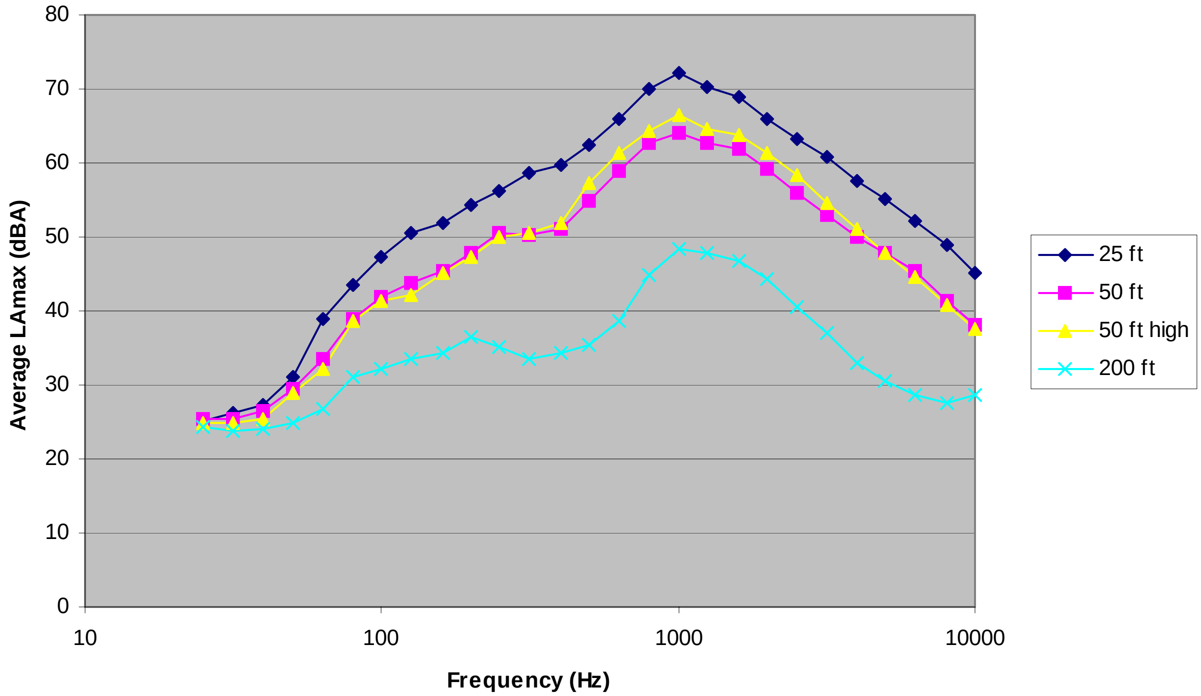


Figure E-23. Spectral data for automobiles; post-overlay results for Site 5 (BWC 30 mm); all ages measured. Microphone location: distance 25 ft, height 5 ft (top); microphone location: distance 50 ft, height 5 ft (middle); microphone location: distance 50 ft, height 15 ft (bottom).



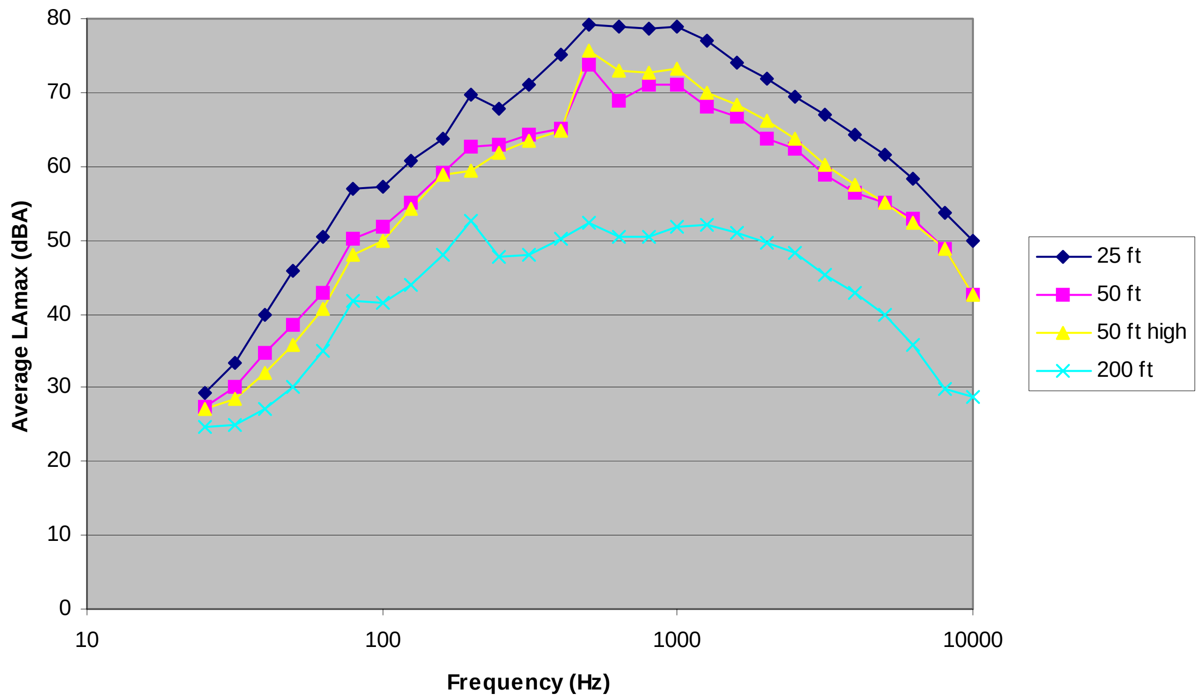


Figure E-24. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 1 (DGAC 30 mm) aged 16 months; all microphone positions.

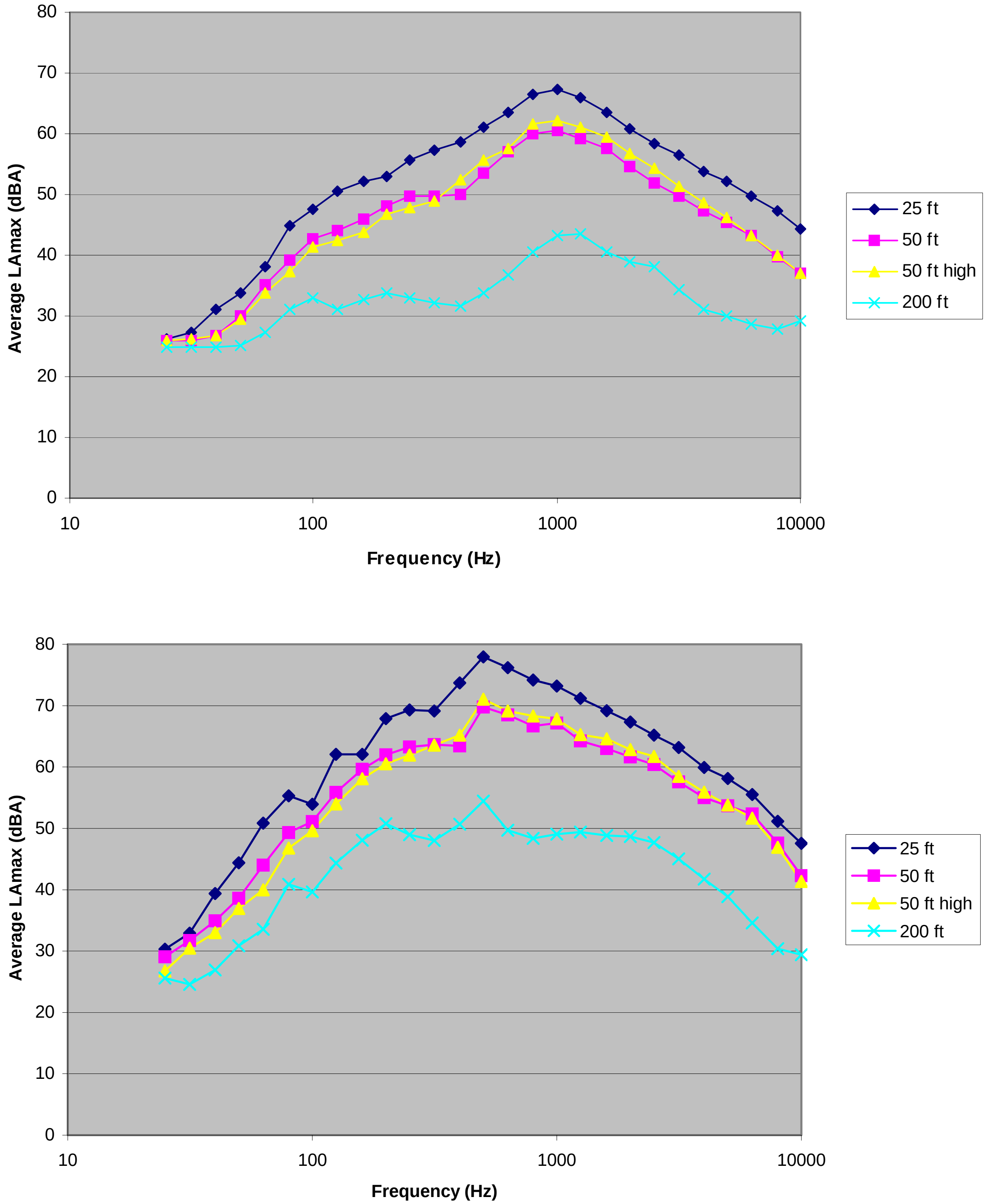
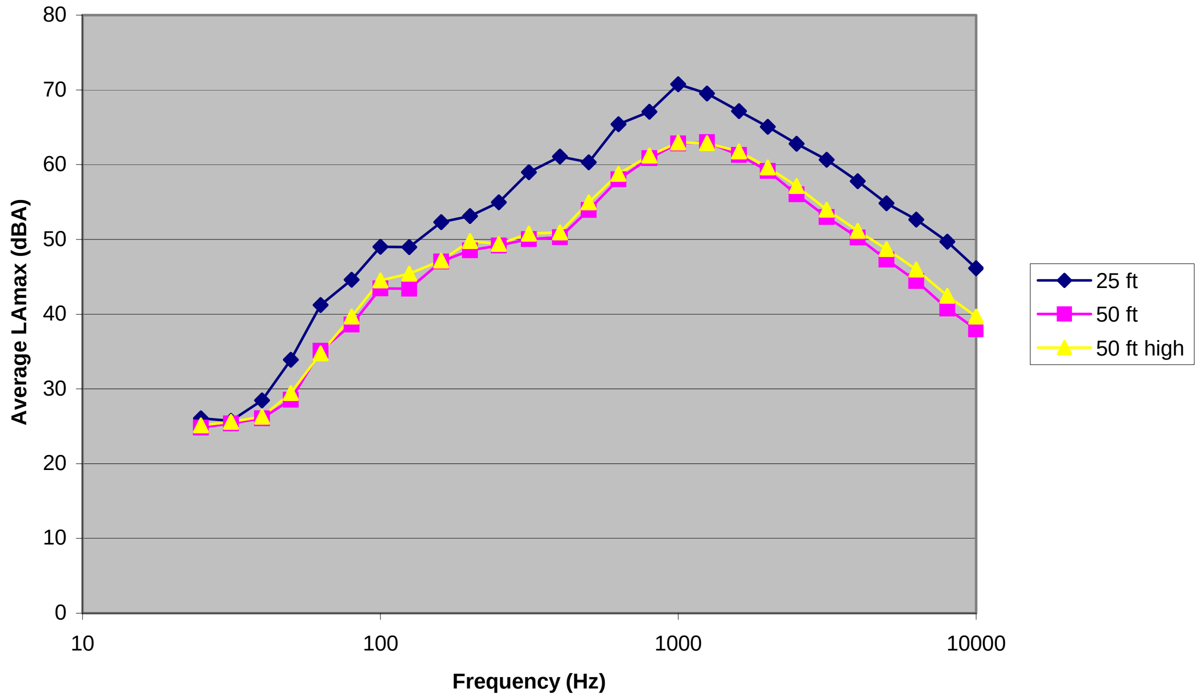


Figure E-25. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 2 (OGAC 75 mm) aged 16 months; all microphone positions.



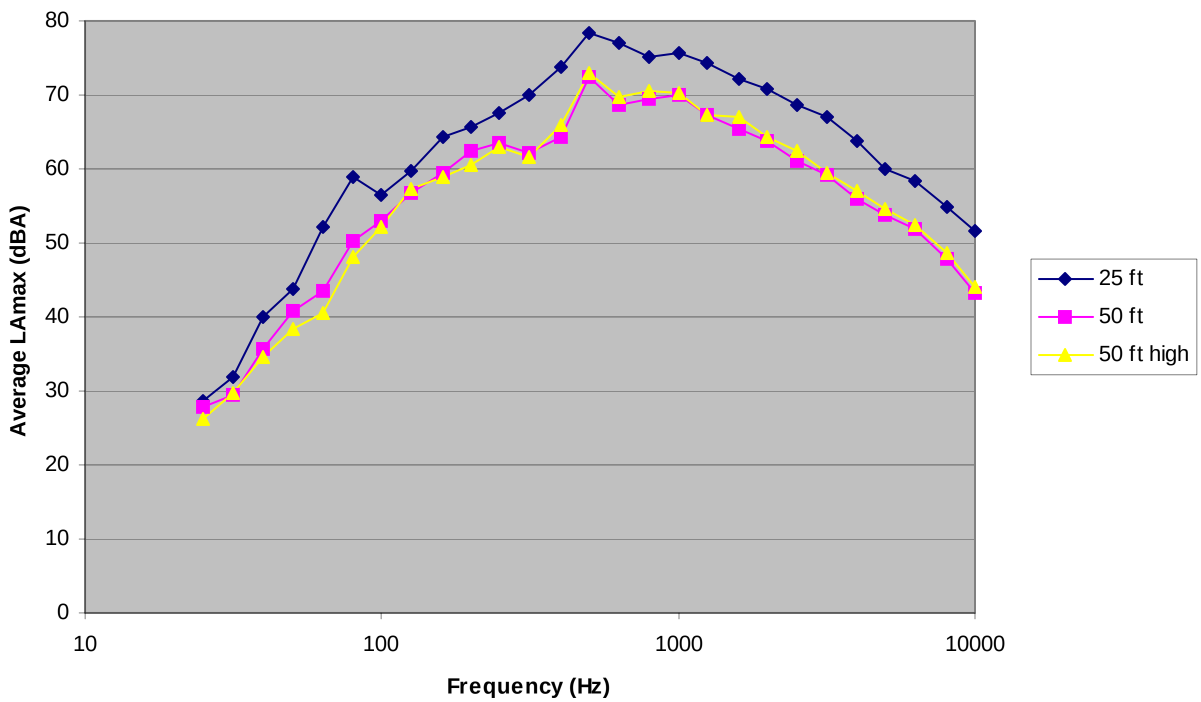
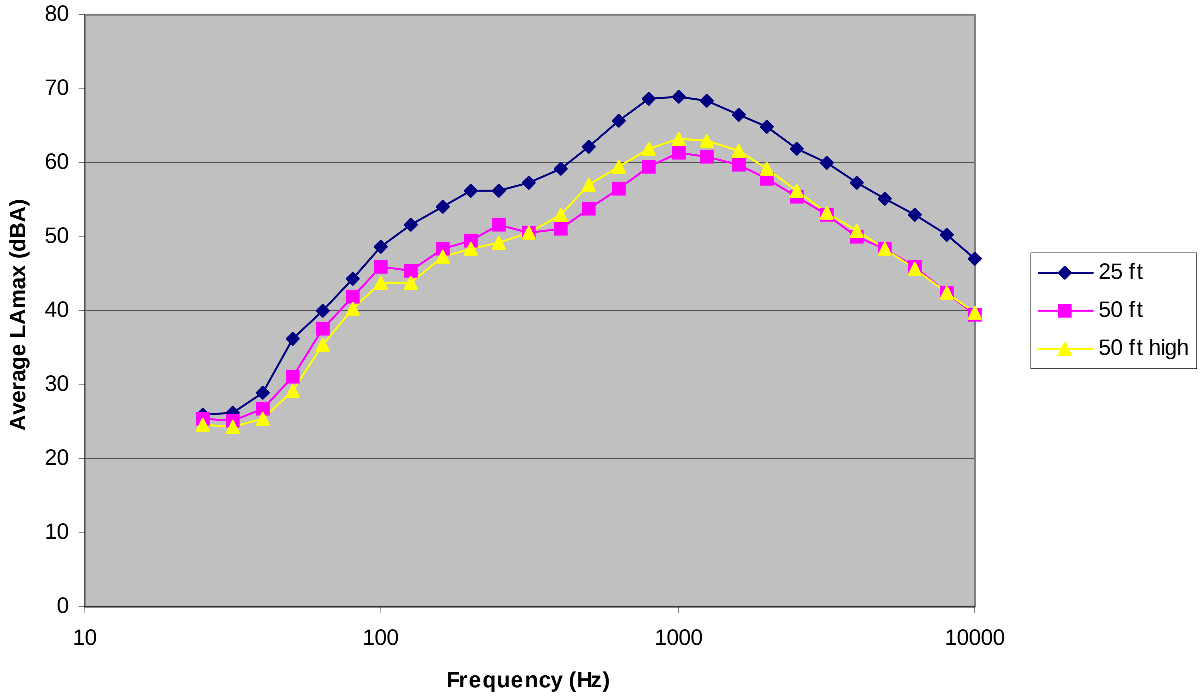


Figure E-26. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 3 (OGAC 30 mm) aged 16 months; all microphone positions.



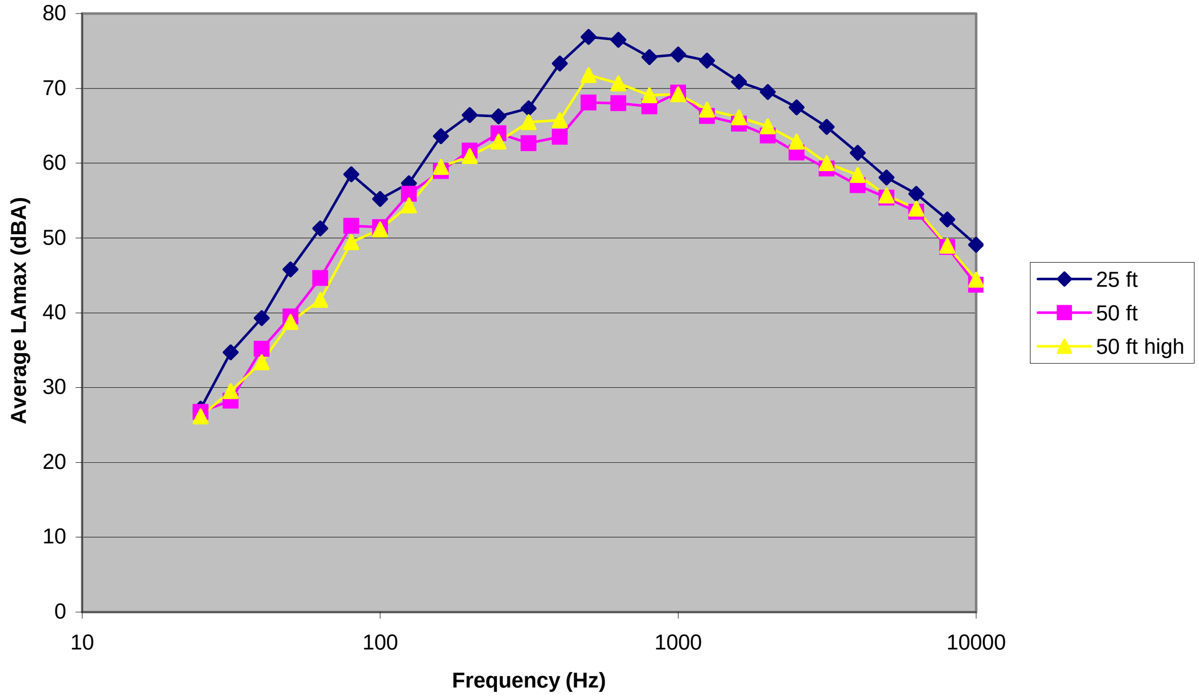
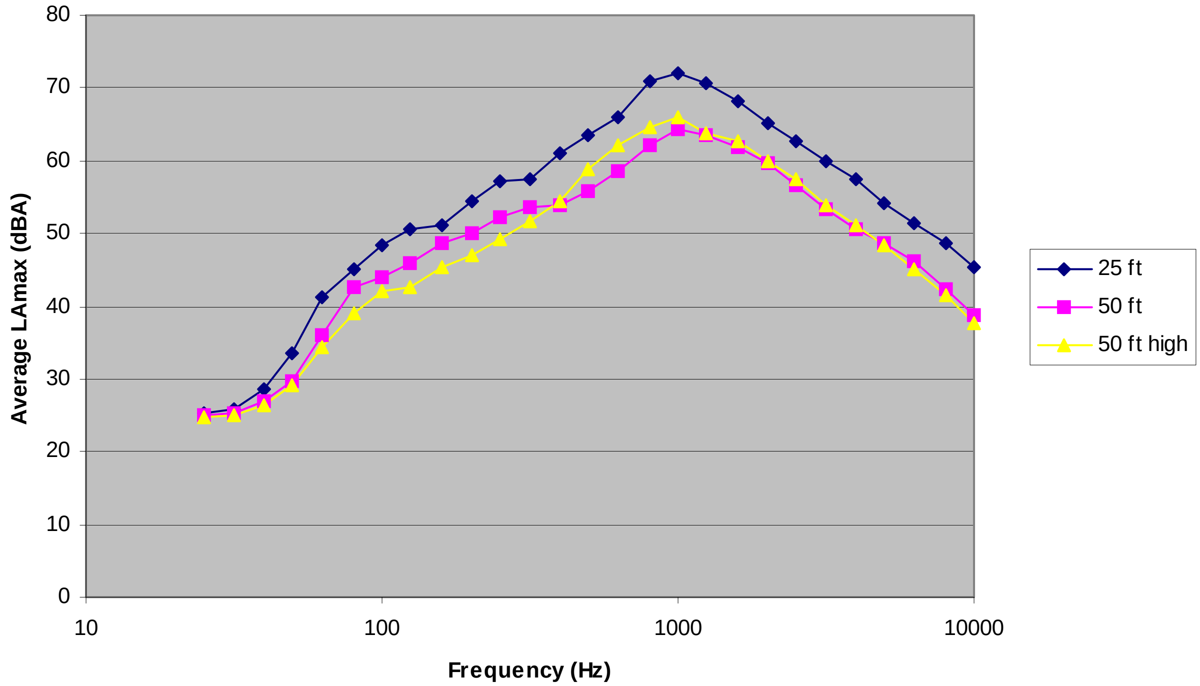


Figure E-27. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 4 (RAC Type O 30 mm) aged 16 months; all microphone positions.



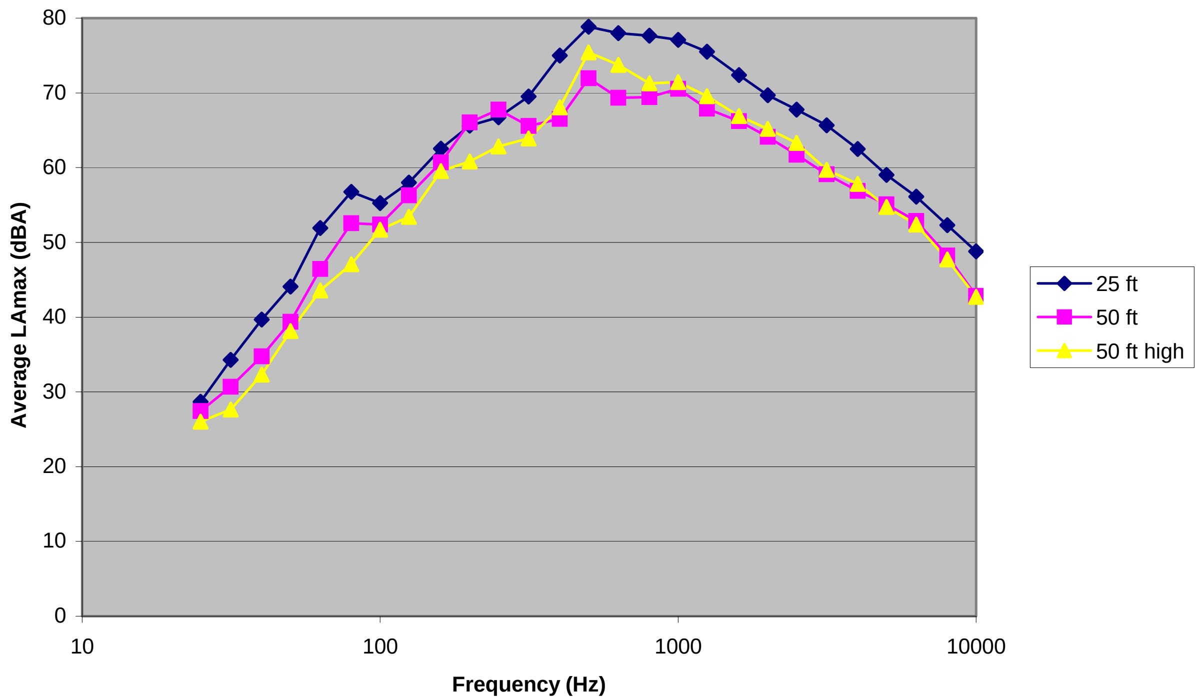


Figure E-28. Spectral data for automobiles (top) and heavy trucks (bottom); post-overlay results for Site 5 (BWC 30 mm) aged 16 months; all microphone positions.

APPENDIX F. TEST VEHICLE RESULTS

This appendix shows the following:

- tables and plots of the average L_{AFmx} values for the test vehicle for each pavement, age (except 52 months), and microphone position; and
- tables and plots of the average L_{AFmx} deltas (comparing each of the other pavements to DGAC) for each pavement pair, age (except 52 months), and microphone position**.**

F.1 Average L_{AFmx} for Test Vehicle

Table F-1 shows the average L_{AFmx} for the test vehicle with site bias removed and Table F-2 shows the values with site bias not removed. The figures following the tables show plots of the site-bias-removed data (each plot shows multiple vehicle speeds and represents a different pavement age and microphone position).

Table F-1. Post-overlay measurements: sound levels for each pavement type (average L_{AFmx} for test vehicle). Post-overlay pavements, including DGAC, aged 4, 10, and 16 months. Site bias removed.*

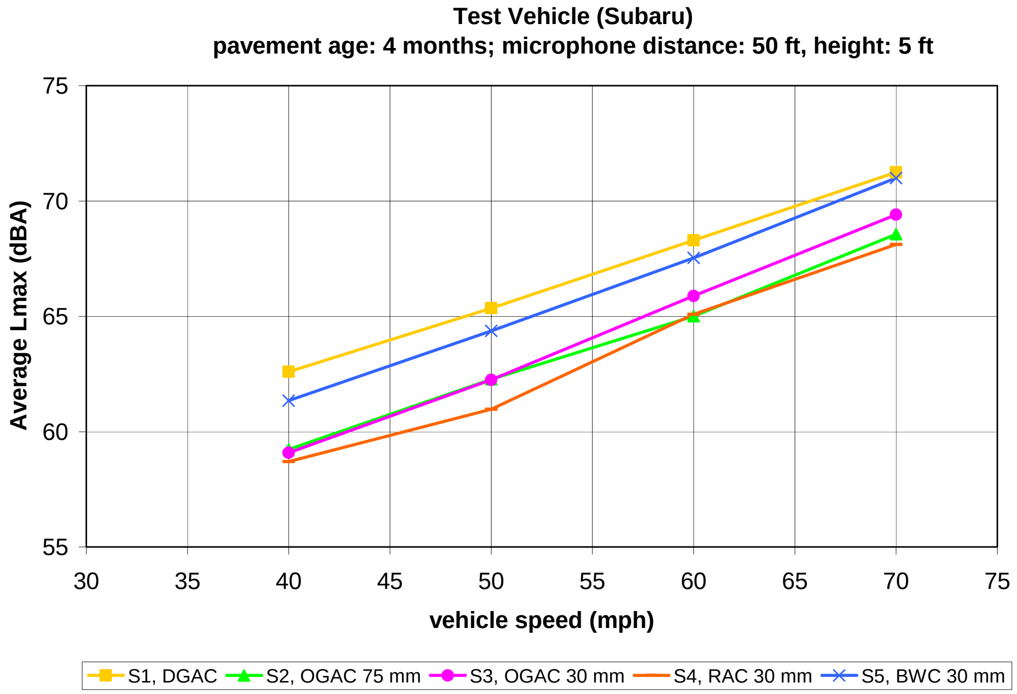
*other sites **calibrated to Site 1 to remove site bias** unrelated to pavement type (based on baseline measurements of test vehicle)

Pave-ment age	Microphone location	Test vehicle Average L_{AFmx} (dBA)																			
		Site 1 (DGAC)				Site 2 (OGAC, 75 mm)				Site 3 (OGAC, 30 mm)				Site 4 (RAC type O, 30 mm)				Site 5 (BWC, 30 mm)			
		Speed (mph)																			
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
4 months	50 ft (15 m) low	62.6	65.4	68.3	71.3	59.2	62.3	65.0	68.6	59.1	62.3	65.9	69.4	58.7	61.0	65.1	68.1	61.4	64.4	67.5	71.0
	50 ft (15 m) high	64.1	67.2	70.2	72.8	60.5	63.3	65.4	68.6	61.6	65	67.3	71	60.1	63.8	66.2	68.8	63.2	66.6	69.4	72.6
10 months	50 ft (15 m) low	62.3	66.0	68.0	71.0	58.9	62.5	64.4	67.4	59.9	63.1	66.9	69.2	59.5	61.8	65.5	67.7	61.0	64.6	67.7	70.9
	50 ft (15 m) high	65.1	68.3	70.5	73.6	61.4	63.8	65.8	68.7	63.1	65.9	68.7	70.8	61.1	64.8	67.0	68.6	63.7	67.5	69.8	72.8
16 months	50 ft (15 m) low	62.2	65.7	68.5	71.3	58.0	61.3	64.6	67.5	59.9	63.6	66.8	69.5	59.1	62.5	65.4	68.1	62.2	65.5	67.4	71.5
	50 ft (15 m) high	64.6	67.9	70.5	73.2	60.9	63.4	66.0	68.9	62.8	65.9	68.3	71.2	60.8	65.2	66.7	68.8	64.0	68.0	69.0	72.7

Table F-2. Post-overlay measurements: sound levels for each pavement type (average L_{AFmx} for test vehicle). Post-overlay pavements, including DGAC, aged 4, 10, and 16 months.*

*other sites ***not*** **calibrated to Site 1 to remove site bias** unrelated to pavement type

Pave-ment age	Microphone location	Test vehicle Average L_{AFmx} (dBA)																			
		Site 1 (DGAC)				Site 2 (OGAC, 75 mm)				Site 3 (OGAC, 30 mm)				Site 4 (RAC type O, 30 mm)				Site 5 (BWC, 30 mm)			
		Speed (mph)																			
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
Base-line	50 ft (15 m) low	60.3	63.7	67.0	69.9	60.8	63.7	67.4	69.6	60.5	63.9	66.8	69.5	60.7	64.8	67.1	70.1	61.2	64.7	67.6	69.3
	50 ft (15 m) high	62.5	65.9	68.7	71.0	62.5	66.0	69.4	71.2	62.4	65.8	68.9	71.0	63.4	66.1	69.3	71.9	62.8	66.0	68.8	70.3
4 months	50 ft (15 m) low	62.6	65.4	68.3	71.3	59.7	62.3	65.4	68.3	59.3	62.5	65.7	69.1	59.1	62.1	65.1	68.3	62.3	65.5	68.1	70.4
	50 ft (15 m) high	64.1	67.2	70.2	72.8	60.5	63.4	66.1	68.8	61.5	64.9	67.5	71.0	61.0	64.0	66.8	69.7	63.5	66.7	69.5	71.9
10 months	50 ft (15 m) low	62.3	66.0	68.0	71.0	59.4	62.5	64.8	67.1	60.1	63.3	66.7	68.9	59.9	62.9	65.5	67.9	61.9	65.7	68.3	70.3
	50 ft (15 m) high	65.1	68.3	70.5	73.6	61.4	63.9	66.5	68.9	63.0	65.8	68.9	70.8	62.0	65.0	67.6	69.5	64.0	67.6	69.9	72.1
16 months	50 ft (15 m) low	62.2	65.7	68.5	71.3	58.5	61.3	65.0	67.2	60.1	63.8	66.6	69.2	59.5	63.6	65.4	68.3	63.1	66.6	68.0	70.9
	50 ft (15 m) high	64.6	67.9	70.5	73.2	60.9	63.5	66.7	69.1	62.7	65.8	68.5	71.2	61.7	65.4	67.3	69.7	64.3	68.1	69.1	72.0



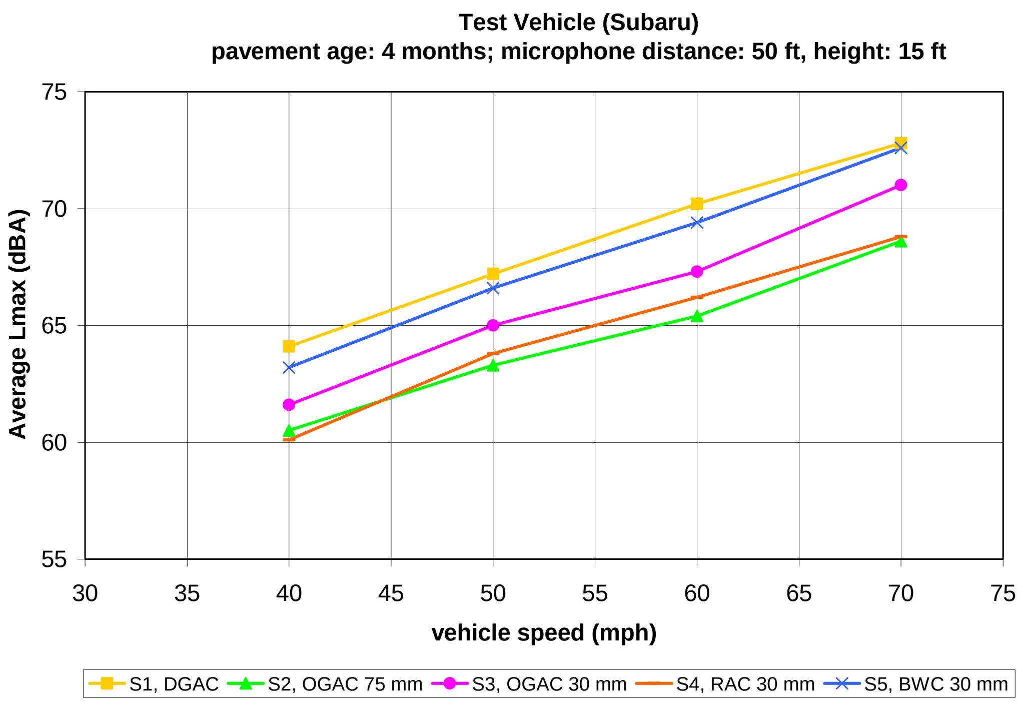
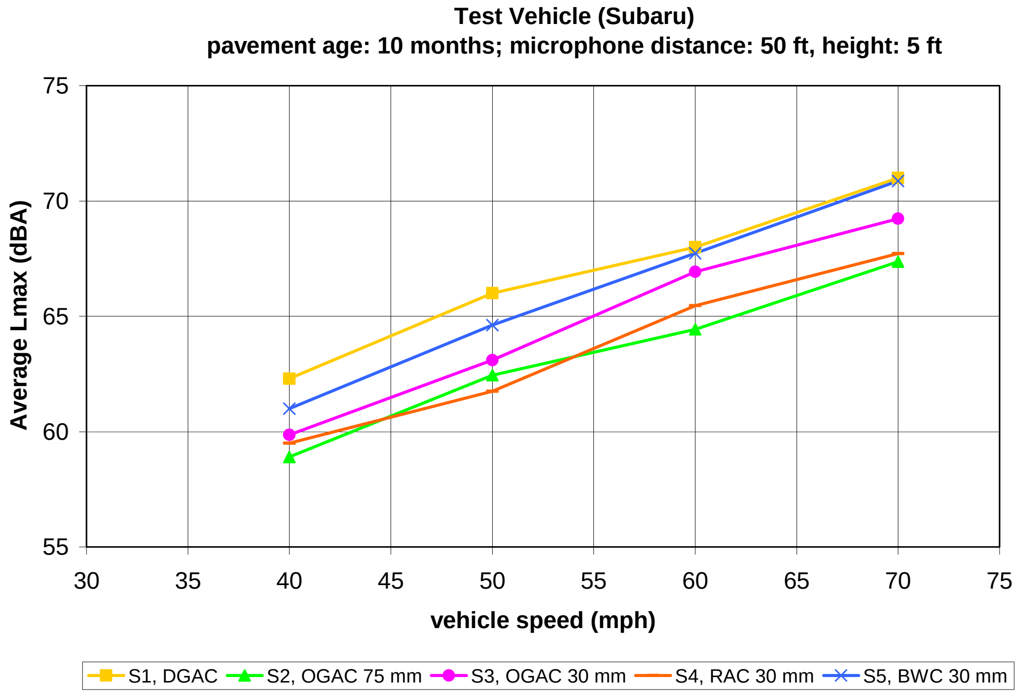


Figure F-1. Test vehicle average L_{AFmx} values for pavement aged 4 months, multiple speeds. Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.



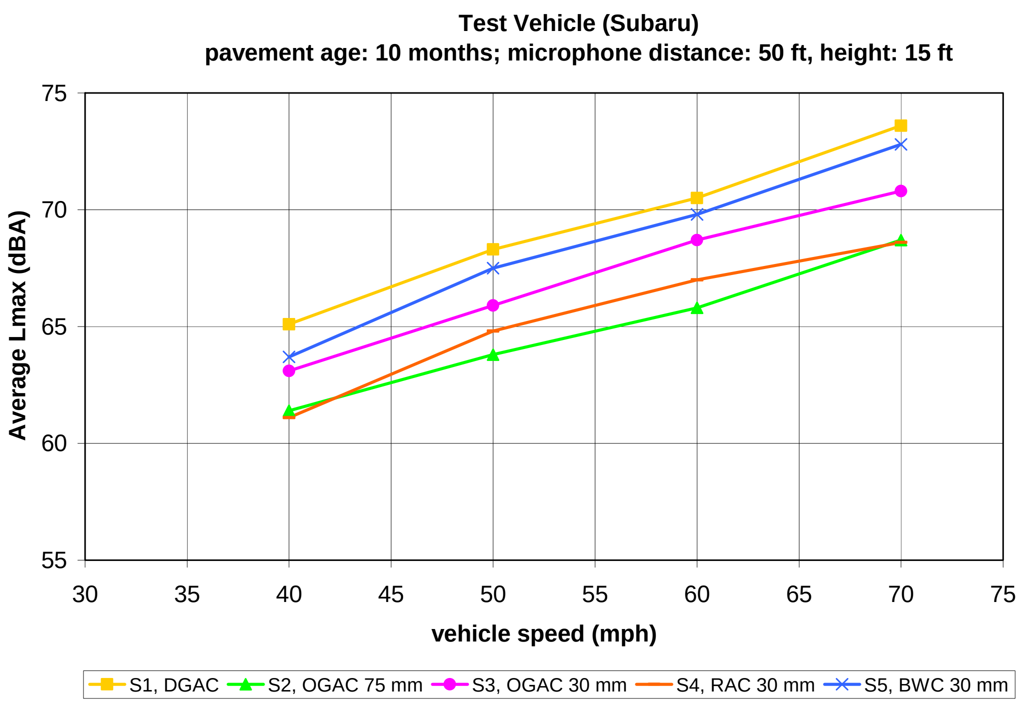
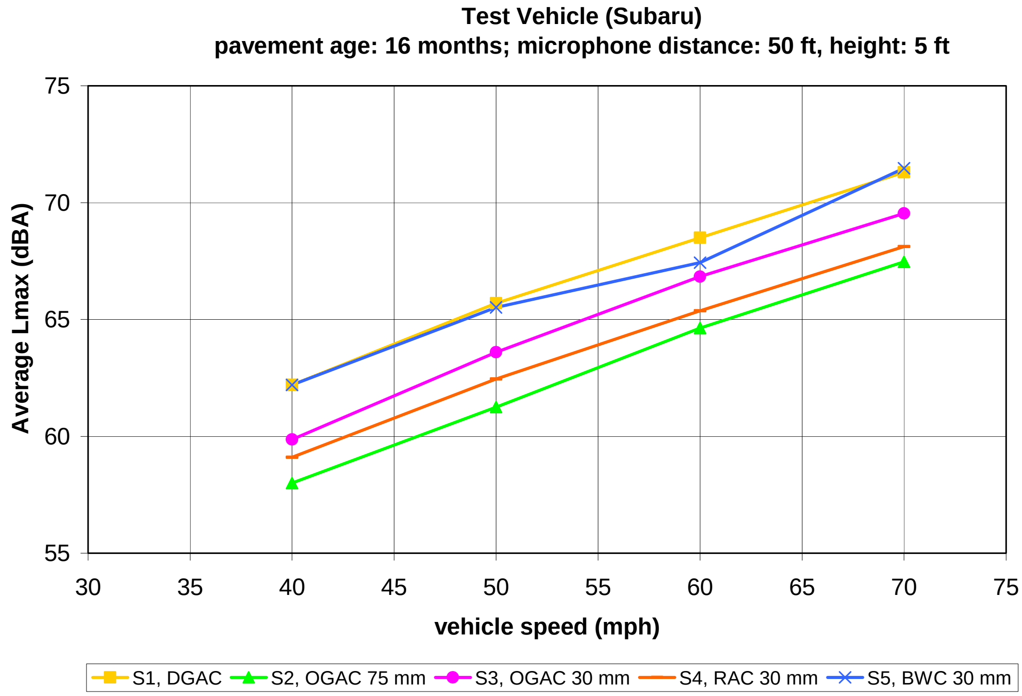


Figure F-2. Test vehicle average L_{AFmx} values for pavement aged 10 months, multiple speeds. Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.



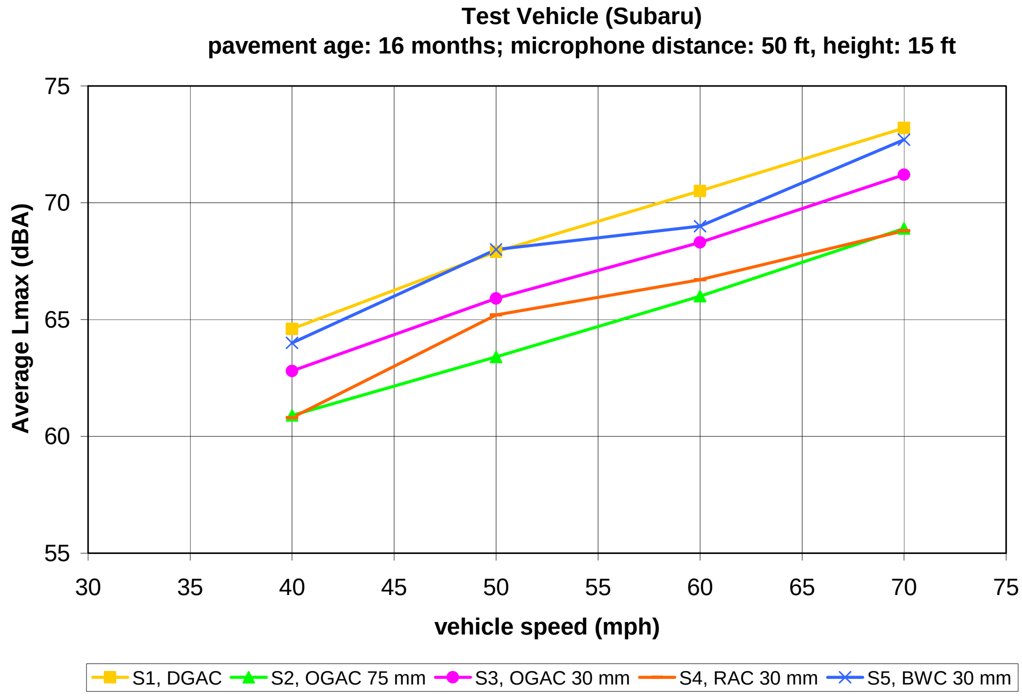


Figure F-3. Test vehicle average L_{AFmx} values for pavement aged 16 months, multiple speeds. Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.

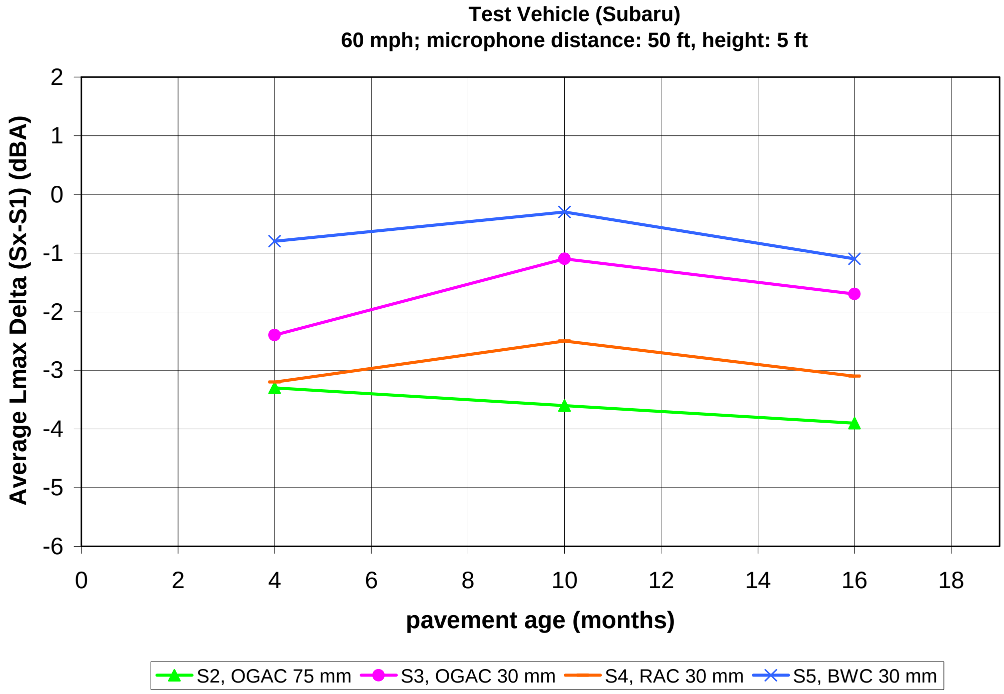
F.2 Average L_{AFmx} Deltas for Test Vehicle

Table F-3 shows the average L_{AFmx} deltas (Site 1 minus Site x) for the test vehicle with site bias removed. The figures following the tables show plots of the data (each plot representing a different microphone position for a single vehicle speed).

Table F-3. Post-overlay measurements: for the test vehicle, site differences due to type of pavement (average L_{AFmx} deltas). Post-overlay pavements, including DGAC, aged 4, 10, and 16 months. Site bias removed.*

other sites **calibrated to Site 1 to remove site bias unrelated to pavement type (based on baseline measurements of test vehicle)

Pave-ment age	Micro-phone location	Average L_{AFmx} delta (dBA)															
		Site 2 – Site 1 (OGAC, 75 mm – DGAC)				Site 3 – Site 1 (OGAC, 30 mm – DGAC)				Site 4 – Site 1 (RAC type O, 30 mm – DGAC)				Site 5 – Site 1 (BWC, 30 mm – DGAC)			
		Speed (mph)															
		40	50	60	70	40	50	60	70	40	50	60	70	40	50	60	70
base-line	50 ft (15 m) low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	50 ft (15 m) high	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 months	50 ft (15 m) low	-3.4	-3.1	-3.3	-2.7	-3.5	-3.1	-2.4	-1.8	-3.9	-4.4	-3.2	-3.1	-1.3	-1.0	-0.8	-0.3
	50 ft (15 m) high	-3.6	-3.9	-4.8	-4.2	-2.5	-2.2	-2.9	-1.8	-4.0	-3.4	-4.0	-4.0	-0.9	-0.6	-0.8	-0.2
10 months	50 ft (15 m) low	-3.4	-3.6	-3.6	-3.6	-2.4	-2.9	-1.1	-1.8	-2.8	-4.3	-2.5	-3.3	-1.3	-1.4	-0.3	-0.1
	50 ft (15 m) high	-3.7	-4.5	-4.7	-4.9	-2.0	-2.4	-1.8	-2.8	-4.0	-3.5	-3.5	-5	-1.4	-0.8	-0.7	-0.8
16 months	50 ft (15 m) low	-4.2	-4.5	-3.9	-3.8	-2.3	-2.1	-1.7	-1.8	-3.1	-3.3	-3.1	-3.2	0.0	-0.2	-1.1	0.2
	50 ft (15 m) high	-3.7	-4.5	-4.5	-4.3	-1.8	-2.0	-2.2	-2.0	-3.8	-2.7	-3.8	-4.4	-0.6	0.1	-1.5	-0.5
Average (both locations, all time)		-3.7	-4.0	-4.1	-3.9	-2.4	-2.5	-2.0	-2.0	-3.6	-3.6	-3.4	-3.8	-0.9	-0.7	-0.9	-0.3
Average (both locations, all time, all speeds)		-3.9				-2.2				-3.6				-0.7			



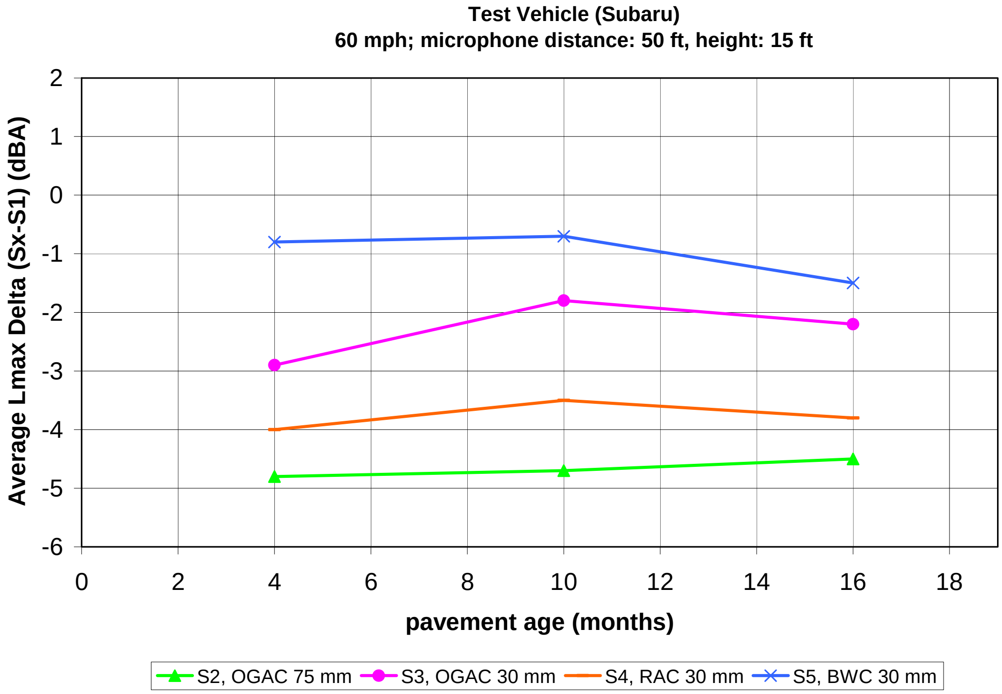


Figure F-4. Test vehicle average L_{AFmx} deltas (Site x minus Site 1) for pavement ages 4 months, 10 months, and 16 months, 100 km/h (60 mph). Microphone position: (top) distance 15 m (50 ft), height 1.5 m (5 ft); (bottom) distance 15 m (50 ft), height 4.5 m (15 ft). Site bias removed.