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Interim Report – 2009 Testing

TIRE/PAVEMENT AND ENVIRONMENTAL TRAFFIC NOISE RESEARCH STUDY

Robert Otto Rasmussen

January 2011

COLORADO DEPARTMENT OF TRANSPORTATION
DTD APPLIED RESEARCH AND INNOVATION BRANCH

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16. Abstract

This research study is being conducted in response to CDOT's interest in traffic noise in general, and the tire/pavement interaction in particular. Following a rigid set of testing protocols, data is being collected on highway traffic noise characteristics along with safety and durability aspects of the associated pavements. The overall goal of this research project is to develop and execute a comprehensive, long-term study to determine if a particular pavement surface type and/or texture can be successfully used in Colorado to help satisfy FHWA noise mitigation requirements. The study is needed to accomplish the following:

- Determine the noise generation/reduction characteristics of pavements as functions of pavement type, pavement texture, age, time, traffic loading, and distance away from the pavement;
- Determine a correlation between source measurements using on-board sound intensity (OBSI), and statistical pass-by (SPB) and time-averaged wayside measurements; and
- Accumulate information that can be used for validation and verification of the accuracy of the FHWA Traffic Noise Model (TNM) to use on future Colorado highway projects.

Implementation:

The information included in this report highlights the third in a series of four measurements to be collected over a five-year period. While some of this information can be used immediately for decisions related to pavement design and specification, it is recommended that caution be exercised as the results from future testing will help further define the long-term acoustical durability of these pavement surfaces.

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EXECUTIVE SUMMARY

This report summarizes interim results of a field-testing program to evaluate tire-pavement and environmental noise of representative pavements throughout the State of Colorado. To date, tire-pavement noise has been measured using two unique technologies: close-proximity (CPX) and on-board sound intensity (OBSI). In recent years, testing has focused on the latter technique since it has become the standard in the USA (AASHTO TP 76). Environmental noise was measured using wayside (roadside) microphones that capture traffic noise in a manner that is more relevant to the potential impacts to highway abutters. The test results provided in this interim report are from 2009. Comparisons are also given to the results from testing conducted in 2006 and 2007. Combined, the testing represents the first four years of a multi-year effort, with a final round of testing scheduled for 2011 in order to further assess the long-term acoustical durability of the various pavements being evaluated.

Implementation Statement

The information included in this report highlights the third in a series of four measurements to be collected over a five-year period. While some of this information can be used immediately for decisions related to pavement design and specification, it is recommended that caution be exercised as the results from future testing will help further define the long-term acoustical durability of these pavement surfaces, which is sometimes (often unintentionally) overlooked as an important variable.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Background

Traffic noise pollution has become a growing concern to residents worldwide. This is particularly true in urban areas where the population density near major thoroughfares is much higher, and there is a greater volume of commuter traffic. To mitigate the noise – at least for residences directly adjacent to the highway – engineers at the Colorado Department of Transportation (CDOT) and elsewhere commonly resort to costly noise barriers. Although arguably the psychology of a noise wall is a factor, noise barriers including walls have not been shown to be an ideal solution for minimizing noise pollution in all cases. Sound tends to diffract over the top and around the ends of barriers, thus proving ineffective on arterial streets since the openings in the barrier required for side streets and driveways effectively defeat the benefits provided by the barrier. Furthermore, the mountainous terrain commonly found in the State of Colorado can further challenge the effectiveness of barriers.

In recent years, alternative solutions to noise barriers have been advanced – ones that may be able to mitigate noise for drivers, adjacent residences, and even for citizens farther from the highway. Driven in large part by public outcry, national policy, and eventually directives to reduce noise, engineers in the European Union and elsewhere have developed alternative pavement types and surfaces that reduce noise generated at the tire-pavement interface.

The noise produced from tire-pavement interaction is just one of several types of traffic noise. However, for many roads with low truck volumes, it becomes the primary source of traffic noise for vehicular speeds over 30 mph. While not a cure-all, certain pavement type and texture options have led to improvements in noise levels; in some cases, reducing the need for or height of noise walls and improving the quality of life.

For a more thorough discussion on these topics, one of the better sources is the FHWA *Little Book of Quieter Pavements*, which can be downloaded from the website http://www.tcpsc.com/LittleBookQuieterPavements.pdf .

As a matter of federal policy (23 CFR 772), pavement type or texture cannot be considered as traffic noise abatement in projects receiving federal funding. For pavement effects to be considered in determining impacts or as a mitigation technique, a so-called Quiet Pavement Pilot Program (QPPP) must be approved and in place. Under a QPPP, a commitment must be made by the State Highway Agency to guarantee, in perpetuity, noise mitigation through use of a specified pavement type and/or texture. To date, Arizona is the only state that has accepted this challenge, opting for an asphalt-rubber friction course (ARFC) as the pavement (surface) of choice. A lot has been learned since 2003 when ARFC resurfacing began under the QPPP. However, any state that is interested in asphalt-rubber or any other specific pavement type should first evaluate its noise reducing capabilities under local conditions.

Every state has unique conditions, with differences in characteristics and issues such as climate, traffic, materials availability, and maintenance. Choosing a "quiet pavement" alternative that is best for any state must account for all of these factors along with durability, cost, and safety. Currently, the factors that CDOT considers in pavement selection emphasize safety and durability. Life cycle cost analyses are performed to determine the most appropriate pavement type and/or rehabilitation technique for a given project. While noise is not currently a factor that is considered in CDOT pavement type selection process, it may eventually be used as a secondary consideration in environmentally sensitive areas and in cases where no significant differences in cost among alternatives have been determined.

Given the inherent issues with a QPPP, most states have instead opted to conduct Quiet Pavement Research (QPR). While the data that is collected under a QPPP and QPR is the same, no policy changes are made that would allow for a mitigation contribution from the pavements under investigation. Instead, if research is being conducted on a project that requires abatement, conventional means will need to be used until a QPPP is in place.

To meet the requirements of a Federal Highway Administration (FHWA) QPR program, the research should have an intended purpose, include a Data Acquisition Plan (DAP), and possess a reporting schedule frequent enough to demonstrate the various changes in the properties of the

pavements under study over time. Within this research project, CDOT has drafted a DAP, which contains the various data collection, analysis, and reporting elements described in the FHWA model which, in turn, is based on that developed and implemented by the State of Arizona under their QPPP.

Within the current DAP, data are to be collected on tire-pavement and wayside noise, along with pavement, traffic, safety, and meteorological data. These data will be analyzed and reported in a fashion suitable to derive acoustic properties of various pavement types – by season, over time (and cumulative traffic), and correlated to the physical characteristics of the pavement and texture. Additionally, the data will be used to relate various noise measures to one another, particularly as standardization of these measures – at least, in the US – is an ongoing task within the industry.

Scope

This project is about examining current pavements in Colorado to determine their tire-pavement noise characteristics over a long period. In recent years, the FHWA has supported this through establishment of both a QPPP and guidelines for a QPR. For now, CDOT's emphasis will be on the latter, but the intent is to prepare for the possibility of entering the QPPP, depending on the results of the project.

The scope of this project is to assist CDOT with the collection of tire-pavement surface and environmental (wayside) noise data. This data is then organized and reported in such a manner to help fulfill the Department's mission of conducting a proper Quiet Pavement Research program.

Project Objectives

The primary objective of this study is to provide CDOT with tire-pavement and environmental traffic data that are reliable, accurate, and representative given the sheer variety of conditions within the State of Colorado – from both traffic and climatic perspectives. Supporting data on traffic and climate are collected simultaneously with noise measurements. Ultimately, these will

be compiled along with numerous other data being collected by CDOT, and interpreted and reported accordingly. The goal is to fulfill the overall QPR requirements as well as the desire of CDOT to learn what various pavement types and/or textures might do to address or supplement overall noise mitigation requirements.

To meet this objective, a specialized database has been developed. It has been populated by data collected from 34 select pavement sections, as described in a QPPP/QPR Data Acquisition Plan (DAP). Along with noise (and related) data collected by Transtec, a variety of other information about the pavement sections will continue to populate this database, including items related to design, materials construction, climate, traffic, and maintenance.

As additional data are collected in subsequent years, the database will be used to fulfill at least three specific objectives, as follows:

1. To establish relationships between the various noise measures, their change over time, and the variables that may be contributors to both.

2. To establish relationships between and within the various noise measurement techniques – near field (e.g., Close Proximity, CPX and On-Board Sound Intensity, OBSI), wayside (e.g., Statistical Pass-By Index, SPBI), and environmental (e.g., "SPBI+").

3. To assist in providing information suitable for validating and verifying the accuracy of the FHWA Traffic Noise Model (TNM) based on the pavements and other conditions unique to the State of Colorado.

DATA COLLECTION

So far under this project, data have been collected in 2006, 2007, and 2009. Additional repeat measurements are planned for 2011. Thirty-four unique pavement sections are being evaluated, representing the vast array of pavement types and surface treatment textures that are currently used by CDOT. These are listed in Table 1 along with some additional identifying information.

Table 1. Site Location Information.

Site ID	Road	Direction	Location	Nearest City	Zip Code
1	SH 83	NB	Between. CR-14 & Hess Rd.	Parker	80134
2	I-70	EB	Between Evergreen Pkwy. & CR-65	Golden	80439
3	I-70	WB	Between Federal Blvd. & Pecos St.	Denver	80221
4	US 50	WB	Between 35 6/10 Rd. and Bridgeport Rd.	Grand Junction	81527
5	SH 74	EB	Between Bergen Pkwy. & Lewis Ridge Rd.	Evergreen	80439
6	US 50	EB	Between 35 6/10 Rd. and Bridgeport Rd.	Grand Junction	81527
7	US 85	SB	Between Daniels Park Rd. & Happy Canyon Rd.	Sedalia	80135
8	I-70	EB	Between US 6 & Herman Gulch Rd.	Bakerville (E.Dillon)	80444
9	C-470	WB (N)	Between US 285 & Morrison Rd.	Morrison	80465
10	US 287	SB	Between Bonner Spring Ranch Rd. & SH 14	Laporte	80535
11	SH 82	EB	Between Hunter Logan & Lower River Rd.	Basalt	81654
12	SH 58	WB	Between McIntyre St. & 44th Ave.	Golden	80403
13	I-25	SB	Between CR-12 and CR-10	Erie	80516
14	US 285	NB	Between Surrey Dr. & Goddard Ranch Ct.	Indian Hills	80465
15	I-25	NB	Between Fontanero St. & Fillmore St.	Colorado Springs	80907
16	SH 121	NB	Between Chatfield Ave. & Ken Caryl Ave.	Littleton	80128
17	I-70	WB	Between SH 13 and US 6/24	Rifle	81650
18	US 285	NB	Between Turkey Creek Rd. & Chamberlain Rd.	Indian Hills	80465
19	I-70	WB	Between Camino Dorado Rd. & Trail Gulch Rd.	Gypsum	81637
20	US 40	WB	Between CR-8 & SH 94	Kit Carson	80862
21	US 285	SB	Between Kipling Pkwy. & C-470	Morrison	80227
22	US 160	WB	Between CR-103 & Threemile Rd.	Alamosa	81101
23	I-70	EB	Between 23 Rd. & 24 Rd.	Grand Junction	81505
24	I-76	WB	Between CR-49 & SH 52	Hudson	80642
25	I-76	EB	Between 88th Ave. & 96th Ave.	Henderson	80640
26	I-25	SB	Between SH 105 & Higby Rd.	Monument	80132
27	C-470	WB (N)	Between Morrison Rd. & Alameda Pkwy.	Morrison	80228
28	Powers Blvd.	NB (W)	Between Union Blvd. & Old Ranch Rd.	Colorado Springs	80908
29	Powers Blvd.	SB (E)	Btw. Old Ranch Rd. & Union Blvd.	Colorado Springs	80908
30	US 85	NB	Btw. Daniels Park Rd. & SH 67	Sedalia	80135
31	I-70	EB	Btw. 15th St. & US 40	Georgetown	80444
32	US 34	EB	Btw. 71st Ave. & 65th Ave.	Greeley	80634
33	US 34	EB	Btw. 65th Ave. & 59th Ave.	Greeley	80634
34	US 34	EB	Btw. 47th Ave. & 35th Ave.	Greeley	80634

Testing to date under this effort has been conducted by Robert Whirledge, Eric Mun, R.P. Watson, and Robert Light of Transtec. In 2009, the following measurements were made depending on the type of site:

1. **On-Board Sound Intensity (OBSI)** – a near-field technique that measures tire-pavement noise in close proximity to the source. Instead of measuring levels via sound pressure from a single microphone (as the ISO 11819-2 or "CPX" method does), OBSI measures tire-pavement noise using a phase-matched pair of microphones that are positioned in such a way to isolate sound generated near the tire-pavement contact patch. The OBSI technique was originally developed by Dr. Paul Donavan of Illingworth & Rodkin while employed by General Motors. It was subsequently refined under sponsorship of Caltrans, and is now standardized nationally as AASHTO TP 76. The current standard tire for OBSI measurements is the ASTM F 2493 Standard Reference Test Tire (SRTT) (P225/60R16). The Goodyear Aquatred III (P205/70R15) tire has also been used for both OBSI and CPX testing in the past (2006 and 2007 testing). However, it has been dropped from the test program since it is no longer in production and the test results between the two tires have been found to be highly correlated. The standard test speed used in OBSI measurements is typically 60 mph (although in 2006 and 2007, two of the test sections were tested at 55 mph due to concerns with testing above the posted speed limit).

2. **Statistical Pass-By (SPB) and Time-Averaged (TA) Wayside** – these measurements are made using a tripod-mounted microphone located at a fixed position (50 ft. from and 5 ft. higher than the center of the outside lane). In 2009, additional measurements were made at a 50 ft. offset and 12 ft. height; and at a 25 ft. offset and a 5 ft. height. In order to normalize for the traffic present during the measurements, there is a simultaneous collection of vehicle counts, classifications, and speeds. The SPB measurements collected in this effort have been made by adopting components of the ISO 11819-1 standard and the recently developed AASHTO draft provisional standards, SIP (Statistical Isolated Pass-By Method) and CTIM (Continuous-Flow Traffic Time-Integrated Method). To assist in developing Reference Energy Mean Emission Level (REMEL) type data for the various pavements under study, provisions of the FHWA

"Measurement of Highway-Related Noise" have also been adopted, particularly those related to site selection, microphone positioning, data processing, and reporting (e.g., third-octave).

3. **Environmental Wayside** – these measurements are collected in the same manner as SPB/TA wayside measurements. They have been referred to as "SPBI+" by CDOT. The measurements are made with additional microphone positions at 100 and 200 ft. from the center of the outside lane. The reason that this information is desired is to attempt to characterize if the noise characteristics are significant at these distances, which would correspond to locations of residences in these areas. Conducting these tests so far has been very difficult due to the inability to obtain the proper clearances for adjacent land access and/or contamination from other sound sources. There has also been issues raised from industry experts about the accuracy and usefulness of these type of measurements; at least, those 200 ft. and greater. In 2009, one SPBI+ location was evaluated.

4. **Supporting Data** – this includes climatic data via an on-site weather station, photographs and digital video, and site surveys to benchmark the begin/end points for each section along with the location of any wayside microphone positions.

Photographs of some of the test equipment can be found in Appendix A. Additional details for each site, along with the types of measurements collected are listed in Table 2.

RESULTS OF 2009 EVALUATION

The work conducted so far under this project has resulted in a large database of information. In addition to the various site reference information, such as that contained in Tables 1 and 2, it contains as-built plans and construction records for many of the 34 sites.

The noise data collected thus far have also been organized into the database and are classified in a hierarchical folder structure for ready access. Appendix B contains a detailed summary of the data collected in 2009 from each of the sites. This includes general information on the sites, followed by details of both the environmental and tire-pavement noise measurements.

A summary of the OBSI data (A-weighted Sound Intensity Level (SIL) in dB ref 1 pW/m^2) is given in Table 3. OBSI levels reported from the 2006 and 2007 testing are also included, along with calculated changes in level.

Table 4 contains a summary of the SPB wayside testing including levels for both automobiles and heavy trucks. The results from 2006 and 2007 are included here as well for comparison purposes.

Figure 1 includes a chart of measured OBSI levels. The rank order sorted by nominal pavement type (color) is based on the levels measured in 2009 (solid bars). The striped bars represent levels measured in 2006 and 2007.

Table 2. Additional Site Information.

Site ID	Surface Type	Construction Accepted [1]	CPX [2]	OBSI	SPB	TA	Approx. Lat.	Approx. Lon.	Approx. Elev. (ft.)	Section Length (ft.)	Wayside Mic Pos. from Begin (ft.)
1	SMA (3/4")	2004	✓	✓		✓ [2,3]	39.4883	104.7591	5960	1558	769
2	SMA (3/4")	1/2004	✓	✓		✓	39.7084	105.3511	7490	5308	4116
3	SMA (3/4")	10/2003	✓	✓			39.7841	105.0186	5330	3575	n/a
4	SMA (1/2")	8/2002	✓	✓	✓		38.8147	108.3385	5110	4847	1422
5	SMA (3/8")	7/2004	✓	✓			39.2861	107.1376	7680	3488	n/a
6	Asphalt (SX, 1/2")	8/2002	✓	✓	✓		38.8994	108.3666	5010	5333	1048
7	Asphalt (SX, 1/2")	2006	✓ [6]	✓ [6]	✓ [2,3]	✓ [4]	39.4288	104.9111	6000	2686	1864
8	Asphalt (SX, 1/2")	2005 [3]	✓	✓			39.6976	105.8703	10470	3535	n/a
9	SMA (1/2")	6/2006	✓	✓		✓	39.6410	105.1723	5760	3033	2460
10	Asphalt (S, 3/4")	10/2003	✓	✓	✓ [2,4]		40.7113	105.1730	5470	3380	2649
11	NovaChip	10/2000	✓	✓			39.3389	106.9989	6880	3228	n/a
12	NovaChip	6/2003	✓	✓		✓	39.7706	105.1895	5600	3082 [2,3] 1010 [4,7]	653
13	Concrete (Long. Tining)	10/2005	✓	✓		✓	40.0667	104.9809	5060	3389	1054
14	Concrete (Long. Tining)	10/1999	✓	✓			39.5838	105.2258	7130	1613	n/a
15	Concrete (Lon. Groov.)	11/2001	✓	✓ [2]			38.8672	104.8340	6130	4485	n/a
16	Concrete (Carpet Drag)	8/2001	✓	✓		✓	39.5741	105.0837	5580	2422	1323
17	Concrete (Dia. Grinding)	11/2005	✓	✓		✓	39.5205	107.8229	5290	6368	1177
18	Concrete (Dia. Grinding)	10/1999	✓	✓			39.5980	105.2255	7050	2069	n/a
19	SMA	8/1996	✓	✓	✓		39.6528	106.8823	6630	3122	443
20	Concrete	4/2002	✓	✓	✓ [2,4]	✓ [3]	38.8328	103.0540	4520	5241	2668
21	Asphalt (S, 3/4")	11/2003	✓	✓		✓	39.6438	105.1318	5700	3599	1451
22	Asphalt	10/1999	✓	✓	✓		37.5177	105.9948	7610	2930	796
23	Asphalt	10/2004	✓	✓			39.1138	108.6193	4560	3623	n/a
24	Concrete	3/2001	✓	✓			40.0942	104.6143	4940	3345	n/a
25	Concrete	11/2002	✓	✓			39.8655	104.9059	5120	2495	n/a
26	Concrete	10/1996	✓	✓			39.0862	104.8614	7010	1493	n/a
27	Concrete	1/2001	✓	✓			39.6759	105.1869	5890	7873	n/a
28	Concrete (Drag)	12/2004	✓	✓			38.9796	104.7574	7010	1804	n/a
29	SMA	9/2005	✓	✓			38.9790	104.7575	7010	1724	n/a
30	Concrete (Burlap Drag)	2003 [5]	✓ [6]	✓ [6]		✓ [3,4]	39.4365	104.9514	5870	3019	2657
31	SMA (3/4")	10/2006	✓				39.7286	105.6919	8560	5529	n/a
32	Asphalt (PG 64-28)	8/2009		✓ [4]			40.3921	104.7904	4900	440	n/a
33	Asphalt (CRM, Wet Proc)	8/2009		✓ [4]			40.3921	104.7772	4890	440	n/a
34	Asphalt (CRM, Terminal)	8/2009		✓ [4]			40.3921	104.7483	4870	440	n/a

Notes: [1] Traffic loading may have begun prior to construction acceptance date; [2] 2006 testing; [3] 2007 testing; [4] 2009 testing; [5] To be confirmed; [6] Testing conducted at 55 mph 2006-2007; all others at 60 mph; [7] Same point of begin.

Table 3. Unadjusted OBSI Test Summary A-weighted SIL (dB ref 1pW/m²).

Site	2006	2007	2009	Change ('07-'06)	Change ('09-'07)	Change ('09-'06)
1	102.7	102.0	102.8	–0.7	+0.8	+0.1
2	102.9	105.5	104.9	+2.6	-0.6	+2.0
3	104.0	105.1	104.5	+1.1	-0.5	+0.5
4	101.4	102.4	102.0	+1.0	-0.5	+0.6
5	102.3	102.7	102.8	+0.4	+0.1	+0.4
6	101.6	102.7	102.3	+1.1	-0.5	+0.7
7**	104.8	104.3	104.3	–0.6	+0.1	-0.5
8	104.0	106.0	104.6	+2.0	-1.3	+0.7
9	100.6	101.7	102.4	+1.1	+0.7	+1.8
10	102.5	102.9	102.5	+0.4	-0.4	0.0
11	104.3	104.6	103.5	+0.3	-1.0	-0.7
12	101.8	101.7	100.9	–0.2	-0.8	-0.9
13	101.8	101.5	101.4	–0.3	-0.2	-0.5
14	104.3	104.8	105.1	+0.5	+0.3	+0.8
15	102.4		102.8			+0.4
16	102.8	103.3	103.3	+0.6	-0.1	+0.5
17	101.6	103.5	103.6	+2.0	+0.1	+2.0
18	104.5	104.7	104.5	+0.1	-0.1	0.0
19	104.7	105.0	104.2	+0.3	-0.8	-0.6
20	101.9	102.1	101.3	+0.1	-0.8	-0.6
21	104.7	105.1	104.8	+0.4	-0.3	+0.2
22	103.4	103.2	102.0	–0.2	-1.2	-1.5
23	101.6	103.2	102.7	+1.6	-0.5	+1.1
24	102.2	101.0	101.6	–1.2	+0.6	-0.6
25	102.2	102.2	102.2	0.0	0.0	0.0
26	102.1	101.8	102.8	–0.3	+1.0	+0.7
27	102.4	103.5	103.1	+1.1	-0.4	+0.7
28	101.4	101.9	102.2	+0.5	+0.3	+0.8
29	101.4	102.3	103.2	+0.9	+0.9	+1.8
30**	102.4	102.8	102.5	+0.4	-0.3	0.0
31		104.9	105.3		+0.4	
32			100.5			
33			100.4			
34			99.3			

** Note: As needed, results normalized to standard test speed of 60 mph.

Table 4. SPB (50×5 mic) Test Summary A-weighted SPL (dB ref 20 µPa).

	SPB 2006		SPB 2007		SPB 2009		Change ('07-'06)		Change ('09-'07)		Change ('09-'06)	
	Car	Hvy. Truck	Car	Hvy. Truck	Car	Hvy. Truck	Car	Hvy. Truck	Car	Hvy. Truck	Car	Hvy. Truck
4	74.1	80.8	75.3	80.8	73.1	79.6	+1.2	0.0	–2.2	–1.2	–1.0	–1.2
6	74.4	83.0	75.0	82.2	74.6	83.0	+0.6	–0.8	–0.4	+0.8	+0.2	0.0
10	74.8	83.7			74.0	82.2					–0.8	–1.5
19	76.0	83.0	76.5	82.2	76.3	82.8	+0.5	–0.8	–0.2	+0.6	+0.3	–0.2
20	73.8	82.8			72.0	80.7					–1.8	–2.1
22	74.5	81.9	73.8	81.6	73.6	81.0	–0.7	–0.3	–0.2	–0.6	–0.9	–0.9

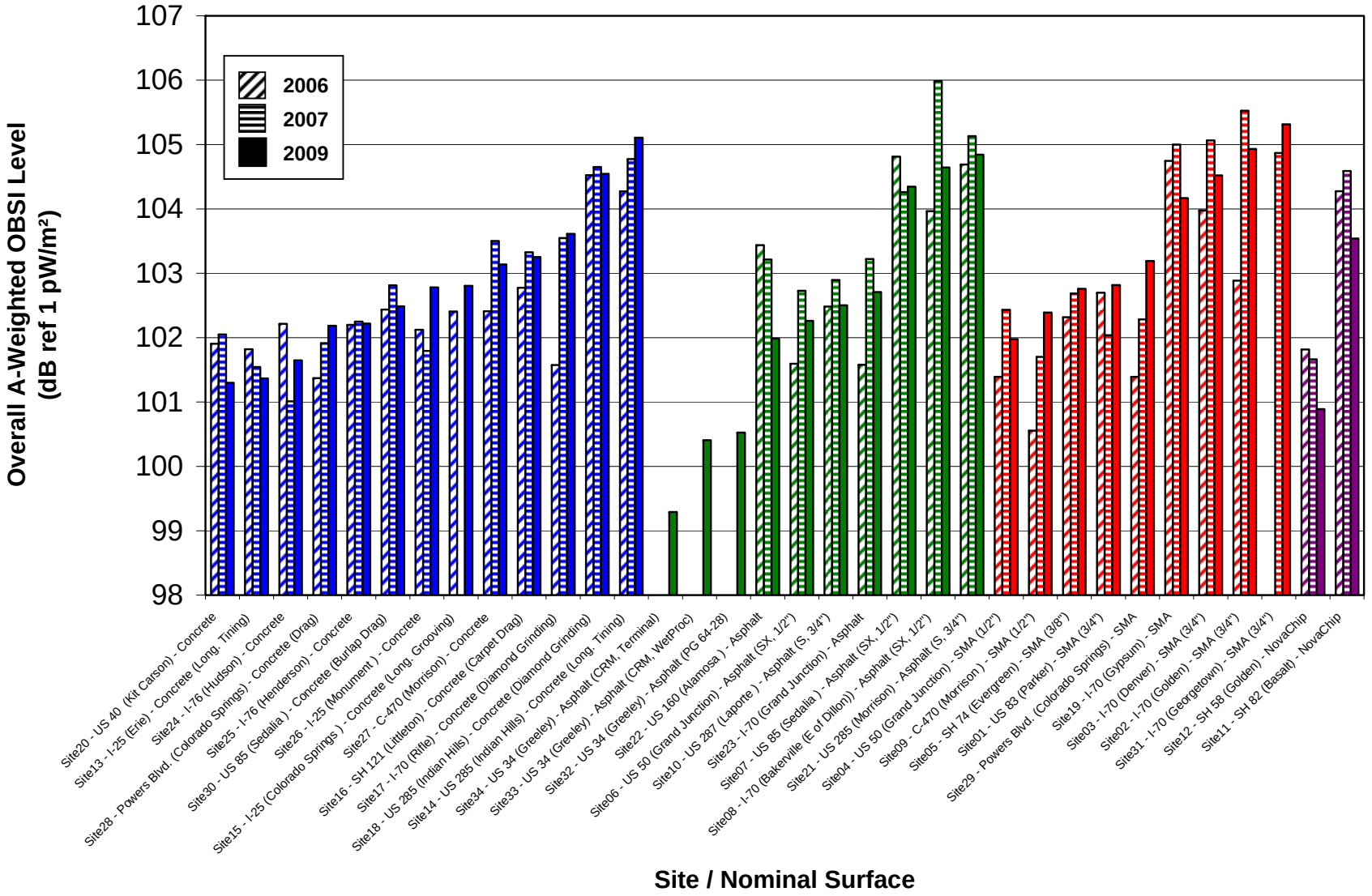

Figure 1. Summary of Unadjusted Overall OBSI Levels.

Relationship between OBSI and SPB Tests

On six of the sites in 2009, SPB data were collected, which permitted the estimate of an "average" car at 60 mph. This average is reported as an index level, as summarized in Table 4.

A comparison was made of the SPBI levels for cars and the corresponding average overall OBSI levels. This is shown in Figure 2. When using a best-fit 1:1 slope, the offset is 28.4 dBA, which is nearly identical to the offset of 28.5 dBA reported by Dr. Paul Donavan of Illingworth & Rodkin as part of the NCHRP 1-44 project (NCHRP Report 630).

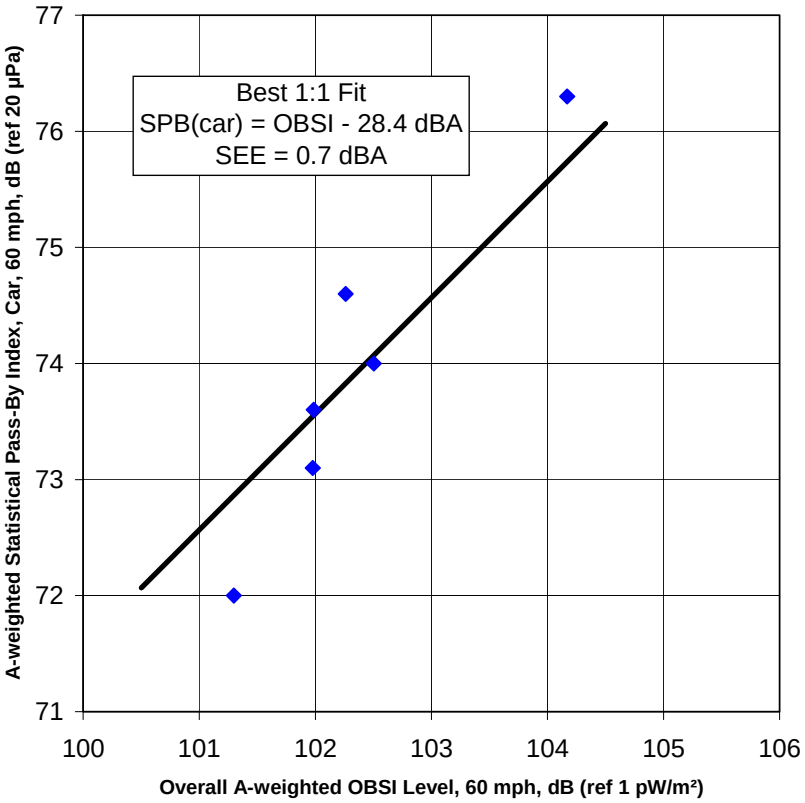

Figure 2. Comparison of OBSI and SPBI Sound Levels.

Further Comparison of 2006, 2007, and 2009 Tests

In 2006, the CDOT QPR testing was conducted during the fall, from mid-September to early November. In 2007, testing occurred largely during the summer months, and in 2009, testing was conducted in May-June, and again in September. Coinciding with this were average

ambient air temperatures during OBSI testing of 63°F in 2006, 82°F in 2007, and 69°F in 2009. While temperatures during testing fell within the range of both specification and good practice, the difference was large enough to warrant further investigation of any influence this might have on the measured levels.

To approach this, plots comparing changes in OBSI level versus the corresponding changes in ambient air temperature were made between paired years. Figures 3 and 4 show these relationships for all of the test sections, divided into concrete and flexible pavements, respectively. From these plots, an average sensitivity of 0.011 dBA/°F was calculated for concrete, and 0.040 dBA/°F for flexible pavements. This sensitivity can be interpreted as a preliminary form of correction factor for OBSI level as a function of temperature.

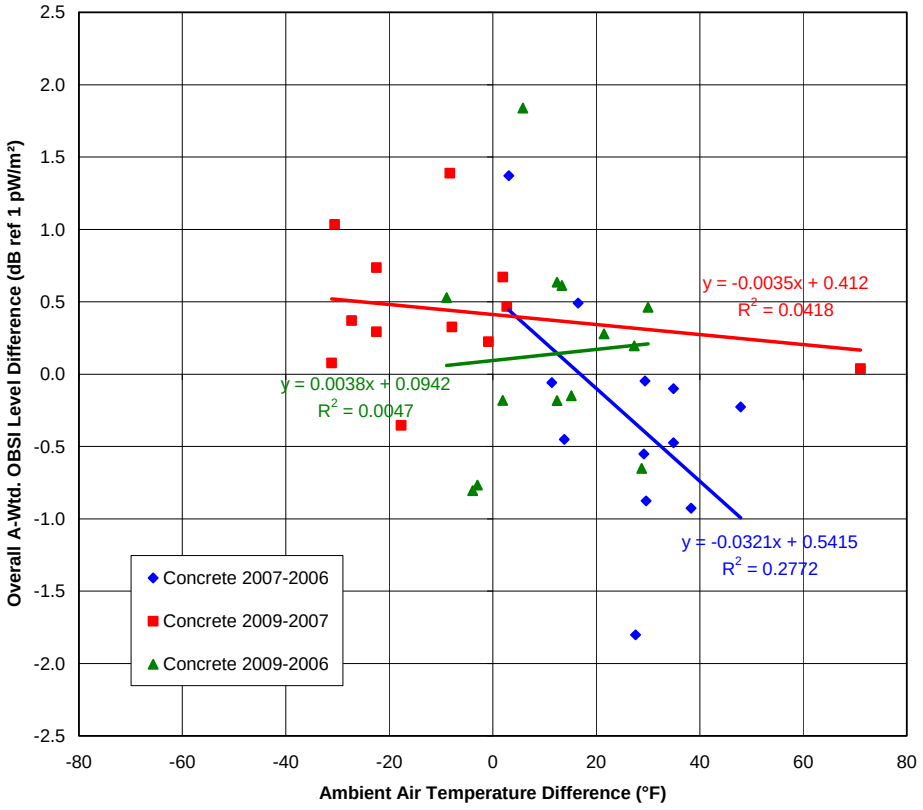

Figure 3. Concrete Pavement OBSI Level vs. Air Temperature Differences.

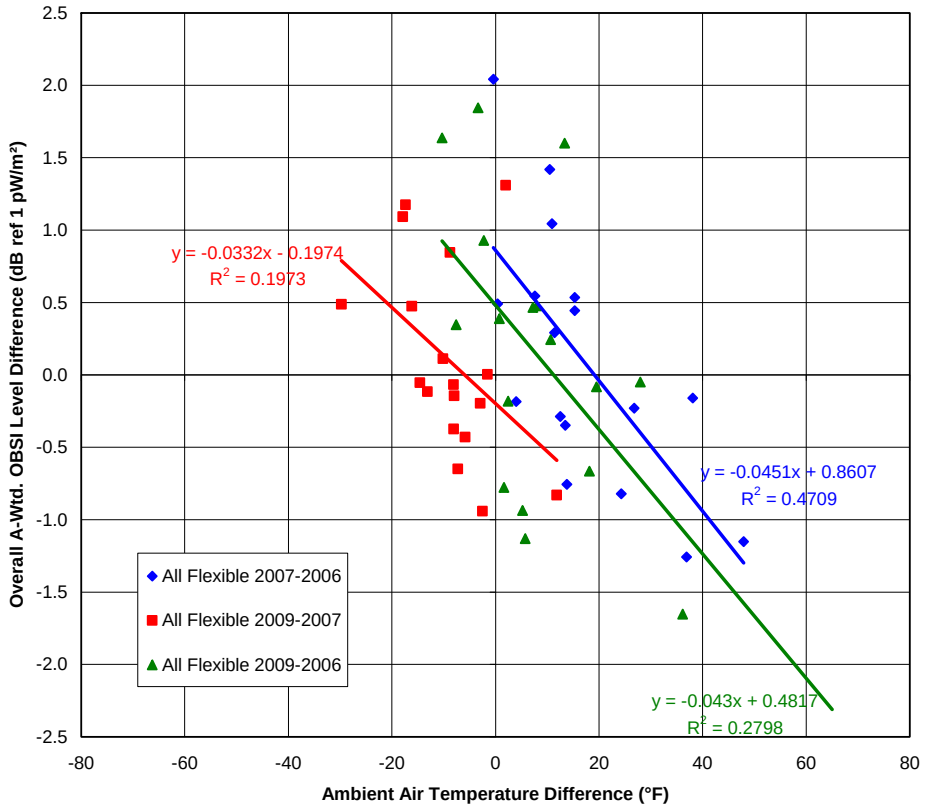

Figure 4. Flexible Pavement OBSI Level vs. Air Temperature Differences.

It can be reasonably hypothesized that OBSI levels will increase to some degree with decreased temperature regardless of pavement type. For example, the tire hardness will increase with decreasing temperature, which will in turn affect the measurement to some degree. An effect of temperature on the dynamic modulus of asphalt will also likely be present, with a level increase resulting from colder, stiffer pavements. Concrete pavement joints will open as temperatures decrease, which will in turn increase the overall level due to an increased contribution of "joint slap" noise. It is reasonable that all of these effects (and others) will vary from pavement to pavement.

Using the trends (slopes) in Figures 3 and 4 (for rigid and flexible pavements, respectively), the measured OBSI levels were adjusted in order to more directly compare them to each other. An additional adjustment was applied to account for changes in test tire hardness and tread wear

between measurement periods. The resulting overall level calculations are tabulated in Table 5 and illustrated in Figure 5.

Table 5. Temperature Adjusted OBSI Summary A-weighted SIL (dB ref 1pW/m²).

Site	Unadjusted	Adjusted	Change
1	102.8	102.6	-0.2
2	104.9	104.7	-0.2
3	104.5	104.2	-0.3
4	102.0	102.1	+0.1
5	102.8	102.5	-0.2
6	102.3	102.7	+0.4
7	104.3	103.7	-0.6
8	104.6	104.2	-0.5
9	102.4	102.4	0.0
10	102.5	102.9	+0.4
11	103.5	103.8	+0.2
12	100.9	101.2	+0.3
13	101.4	101.6	+0.2
14	105.1	105.1	-0.1
15	102.8	103.0	+0.2
16	103.3	103.4	+0.1
17	103.6	103.7	+0.1
18	104.5	104.5	-0.1
19	104.2	104.0	-0.2
20	101.3	101.3	0.0
21	104.8	105.2	+0.3
22	102.0	102.3	+0.3
23	102.7	102.9	+0.2
24	101.6	101.6	-0.1
25	102.2	102.2	0.0
26	102.8	102.9	+0.1
27	103.1	103.2	0.0
28	102.2	102.2	0.0
29	103.2	103.1	-0.1
30	102.5	102.3	-0.2
31	105.3	105.2	-0.1
32	100.5	100.0	-0.6
33	100.4	99.8	-0.6
34	99.3	98.7	-0.6

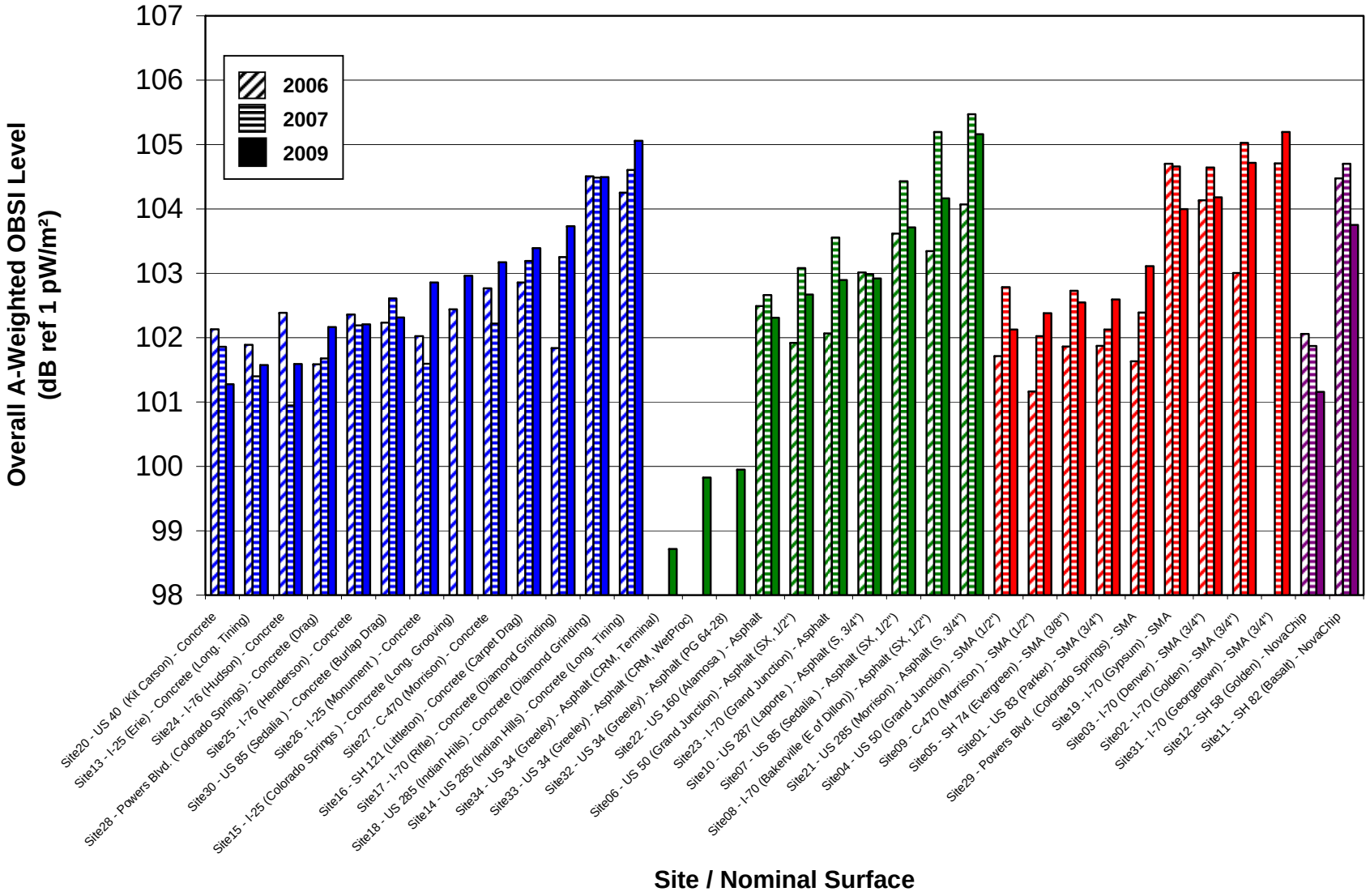

Figure 5. Summary of Temperature-Corrected Overall OBSI Levels.

Relationship between Environmental Tests

In 2009, Statistical Pass-By testing was conducted on six sites, and time-averaged measurements on an additional nine sites. The methodology for these tests was described previously. However, of particular importance are two methods that are being balloted by the AASHTO Subcommittee on Materials as possible provisional methods of test. Termed SIP and CTIM for SPB and TA measurements, respectively, both test methods describe additional microphone positions beyond the conventional 50 ft. offset / 5 ft. height that has been used to date. So that CDOT is prepared for possible adoption of these new methods, two additional mic positions were used on most of the sites, namely a 50 ft. offset with a 12 ft. height, and a 25 ft. offset with a 4 ft. height. Tables 6 and 7 include results from the SPB and TA measurements at the various microphone positions, and further calculate delta SPL values at these positions. The difference between the average Heavy Truck and Car levels are also given for the SPB measurements.

Table 6. SPB Test Summary A-weighted SPL (dB ref 20 µPa).

Site	SPB 50×5		SPB 25×4		SPB 50×12		Hvy.Truck–Car			(25×4) – (50×5)		(50×12) – (50×5)	
	Car	Hvy. Trk.	Car	Hvy. Trk.	Car	Hvy. Trk.	50×5	25×4	50×12	Car	Hvy. Trk.	Car	Hvy. Trk.
4	73.1	79.6	81.0	87.8			6.5	6.8		7.9	8.2		
6	74.6	83.0	80.8	89.1	75.3	83.4	8.4	8.3	8.1	6.2	6.1	0.7	0.4
10	74.0	82.2	80.6	88.7	75.0	83.4	8.2	8.1	8.4	6.6	6.5	1.0	1.2
19	76.3	82.8	82.7	89.5			6.5	6.8		6.4	6.7		
20	72.0	80.7	79.7	88.5	73.1	82.5	8.7	8.8	9.4	7.7	7.8	1.1	1.8
22	73.6	81.0	80.1	87.6	73.9	81.6	7.4	7.5	7.7	6.5	6.6	0.3	0.6
Avg							7.6	7.7	8.4	6.9	7.0	0.8	1.0

Table 7. TA Test Summary A-weighted SPL (dB ref 20 µPa).

Site	SPB 50×5	SPB 25×4	SPB 50×12	(25×4) – (50×5)	(50×12) – (50×5)
2	76.9		76.8		-0.1
7	72.4	76	73.1	3.6	0.7
9	75.5	79.6		4.1	
12	67.7	72.6	69.9	4.9	2.2
13	78.6	82.1	79.4	3.5	0.8
16	70.7	75.4	72.7	4.7	2.0
17	74.2	79.2	75.6	5.0	1.4
21	74	77.9	74.7	3.9	0.7
30	68.1	71.8	69.7	3.7	1.6
Avg,				4.2	1.2

As can be seen from these tables, the levels measured at the new "high" microphone position at the 50 ft. offset are approximately 1.0 dBA higher than the existing standard height of 5 ft. Furthermore, the closer microphone at 25 ft. measures 7.0 dBA higher for the SPB measurements, and 4.2 dBA higher for the time-averaged measurements, with the difference largely attributed to the idealized source type (point versus line).

The average heavy truck was found to be 7.6 to 8.4 dB higher in level than the average car. This is nearly identical to the 2006 and 2007 testing that found an offset of 8.1 and 7.7 dBA, respectively.

In the vicinity of Site 21, there was an opportunity to conduct SPB+ testing in 2009. At this location, three 5-ft. high microphone positions were used with offsets of 50, 100, and 200 ft. Table 8 shows the results of these tests, with calculated time-averaged levels and the differences between each position.

Table 8. SPB+ Test Summary A-weighted SPL (dB ref 20 µPa).

Mic Position (ft) Distance × Height	**SPL**
50 × 5	74.4
100 × 5	70.9
200 × 5	65.7
Differences in Level	**SPL Difference**
(100×5) – (50×5)	–3.5
(200×5) – (100×5)	–5.2
(200×5) – (50×5)	–8.7

Figure 6 illustrates calculated SPB+ levels as a function of distance, with the level at 25 ft estimated based on the level differences for Site 21 reported in Table 7. From this figure, an average level change of -4.2 dBA per doubling of distance (DD) is calculated. This value is to be expected considering that a theoretical point source (e.g., an idealized single vehicle pass by) would have a change of -6 dBA/DD and a theoretical line source (e.g., an idealized traffic lane with dense traffic) would have a change of -3 dBA/DD. The traffic flow on this section during measurement was somewhere in between these theoretical extremes, with approximately 1200 vehicles per hour (total for 5 lanes, including both directions) and an average speed of 64 mph.

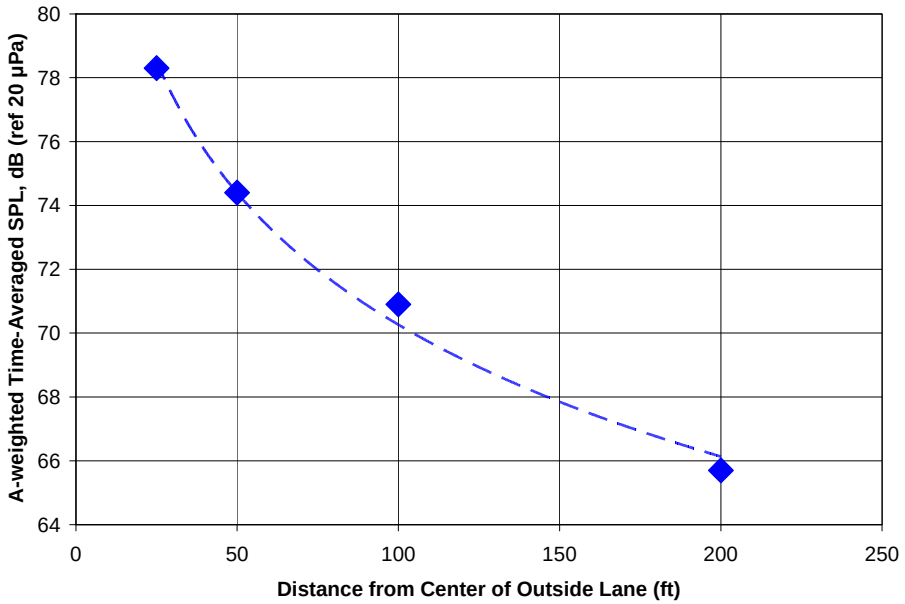

Figure 6. Relationship of Time-Averaged SPL and Distance for SPB+ site.

CONCLUSIONS AND RECOMMENDATIONS

From the measurements, it can be concluded that no single pavement type can be considered definitively quieter. Each pavement type has a demonstrated range of noise levels that largely overlap. It is anticipated that as the final set of measurements are taken in 2011, these levels will change by different amounts, making the conclusion of a single definitive quieter pavement type even less likely.

Preliminary trends of acoustical durability have been illustrated herein. From these data, it appears that the pavements are increasing in level at an average of approximately 0.1 dB per year, but with some sections increasing at a rate approaching 0.6 dB per year. The rates of these changes are not easily determined given the numerous other variables likely at play including temperature effects and incremental changes in the test equipment over time. It is anticipated that more refined estimates can be made following collection of the 2011 data.

From these data, it is possible to identify a few sites that may be of interest for a more detailed investigation. For example, the longitudinally tined concrete pavement on I-25 (Site 13) is among the quietest pavements in this study, and furthermore, appears stable in terms of its acoustical durability. On Site 17, however, the diamond ground surface has experienced a more modest increase in noise level, which is likely due to the heavy use of chains. The HMA at Site 21 (on US 285) experienced a similar degradation in acoustical performance, as did the SMA on Sites 9 and 29. However, the SMA at Site 4 and the Novachip at Site 12 are both quieter, have appeared to performed well, and thus might also be worth investigating further. Such an investigation has the possibility of leading to interim changes in materials specifications (e.g., recommended gradations) that can lead to the potential for quieter pavements with improved acoustical durability.

Based on the testing conducted to date, the following operational recommendations can be made:

1. The necessity and validity of temperature corrections remains a question, and the conclusions that are drawn from this program should attempt to further quantify this

variable. Controlled testing can also be conducted to assist in this. For example, two sets of measurements can be collected at varying times of day, or immediately before and after a cold front. Such a temperature change without accumulated traffic could be used to validate this effect. Furthermore, relevant national-level research on this topic is expected in the near future, with application of those findings possible in this study.

2. All subsequent testing should continue to be conducted at both the source and wayside. Both measurements have been of value to the CDOT program.
3. Accompanying pavement texture measurements should be considered during the remaining noise testing period (in 2011). These data can potentially be used to evaluate the hypotheses of the pavement surface condition affecting the resulting noise levels (and their spectra).

To date, a wealth of information has been collected concerning the tire-pavement noise and environmental noise on various pavements in Colorado. Thirty-four unique pavement surfaces have been evaluated, and the information reported herein furthers the development of acoustical durability relationships. Additional testing is currently scheduled to occur in 2011. In the interim, these and other relevant findings and recommendations will be discussed with the project panel in order to ensure the greatest value from this research program.

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APPENDIX A – PHOTOGRAPHS

Figure A.1. OBSI Measurement Bracket Configuration.

Figure A.2. Test Tires – ASTM F 2493 SRTT and Goodyear Aquatred III.

Figure A.3. Wayside Measurement Configuration.

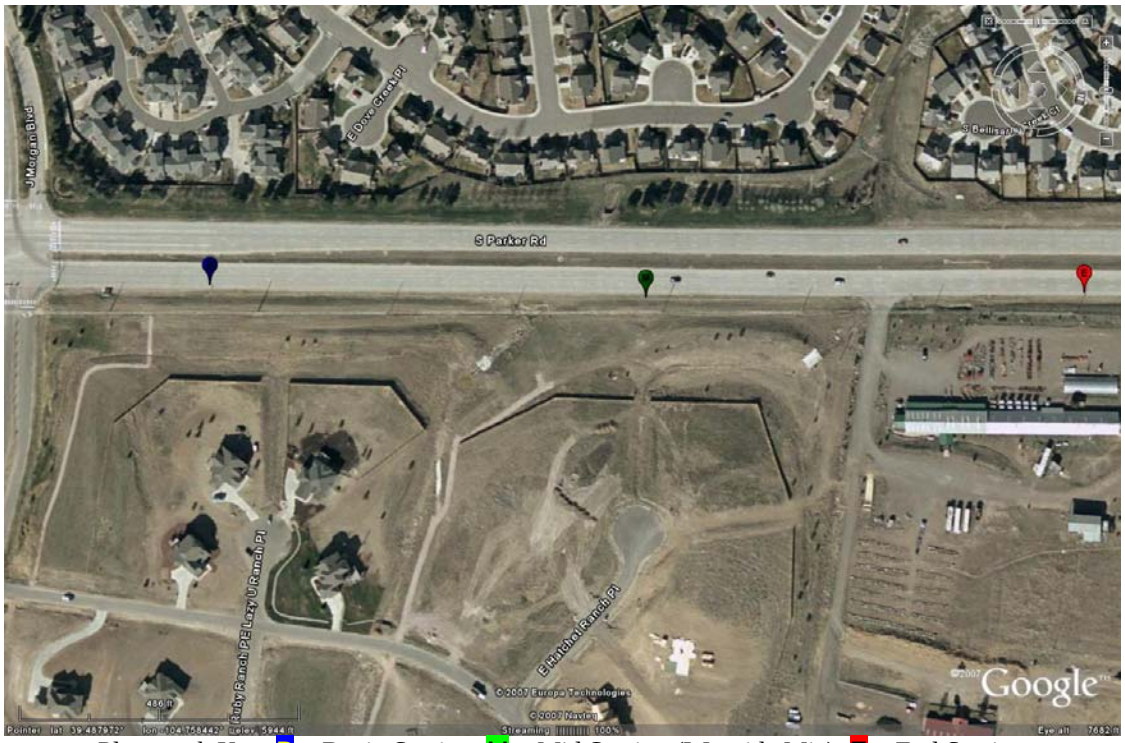
APPENDIX B – DETAILED SITE DATA

Site: 01
General Information

Highway: US Highway 83, Northbound
Location: Between CR-14 & Hess Rd., Parker (80134)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.4883 / 104.7591 / 5960

Nominal Surface: SMA (3/4") **Construction Accepted:** 2004

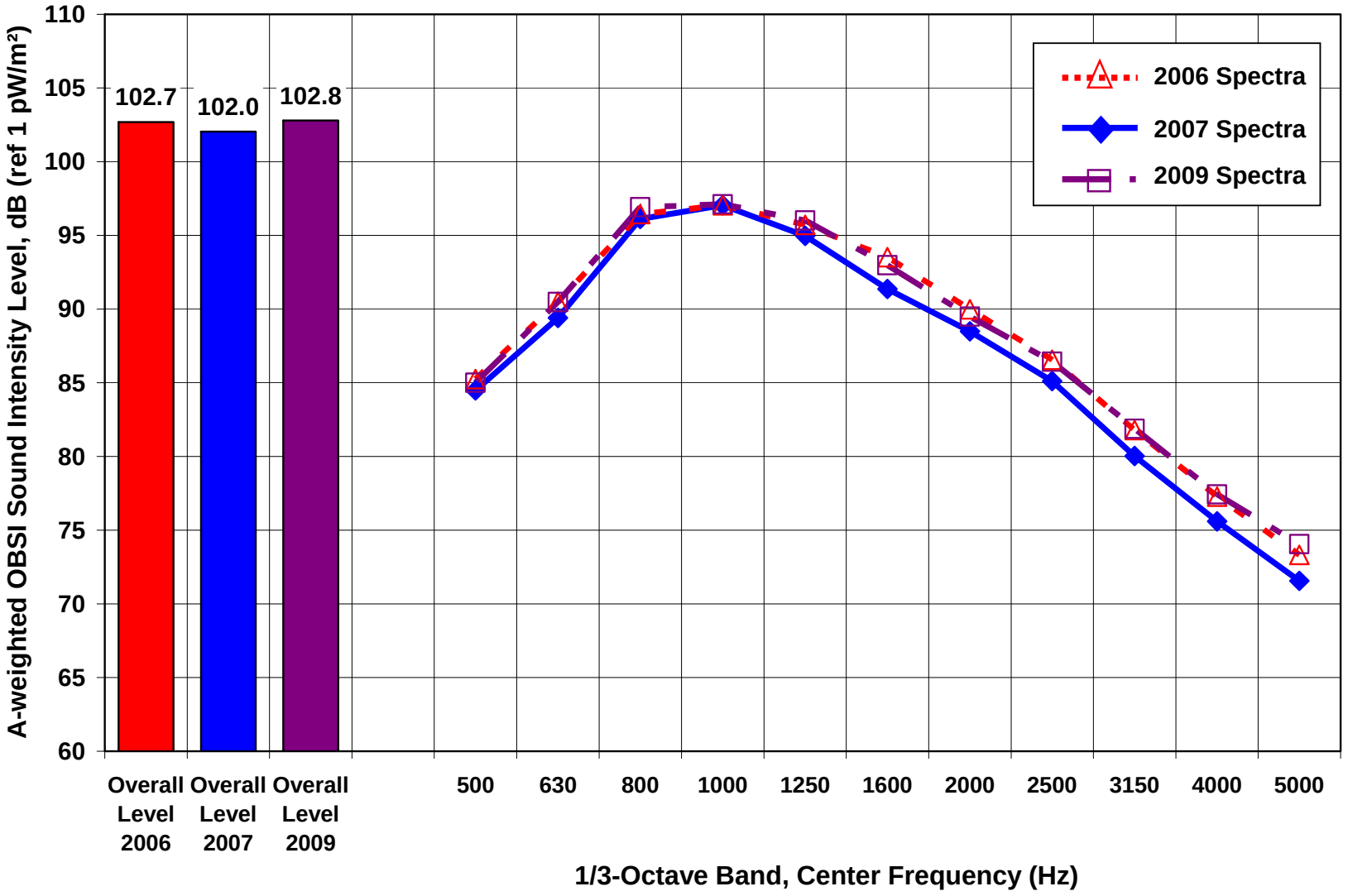
OBSI?: Yes (9/24/09) **SPB?:** No **TA?:** No
Total Section Length: 1558 ft.
Distance from Begin to Wayside Microphone: n/a



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 01

OBSI (SRTT) Test Information



Site: 02
General Information

Highway: Interstate 70, Eastbound
Location: Between Evergreen Pkwy. & CR-65, Golden (80439)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.7084 / 105.3511 / 7490

Nominal Surface: SMA (3/4") **Construction Accepted:** 1/2004

OBSI?: Yes (6/4/09) **SPB?:** No **TA?:** Yes
Total Section Length: 5308 ft.
Distance from Begin to Wayside Microphone: 4116 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 02
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (10:00 am to 11:30 am, 6/5/09)

Traffic Volumes and Speeds during Sample Period

	EB Lane 3 (Outside)	EB Lane 2	EB Lane 1 (Inside)	WB Lane 1 (Inside)	WB Lane 2	WB Lane 3 (Outside)
Distance from Mic (ft.)*	50	62	74	131	143	155
Average Speed (mph)	71			72		
Automobile	347	1394	606	278	777	363
Heavy Truck	115	25	11	0	13	93
Medium Truck	35	19	3	6	18	24
Bus	9	10	2	0	3	3
Motorcycle	3	6	5	1	7	3
Auto + 1-Axle Trlr.	10	16	1	1	9	3
Auto + 2-Axle Trlr.	12	7	4	0	2	6
M. Trk. + 1-Axle Trlr.	1	1	1	0	1	1
M. Trk. + 2-Axle Trlr.	16	10	0	3	3	9

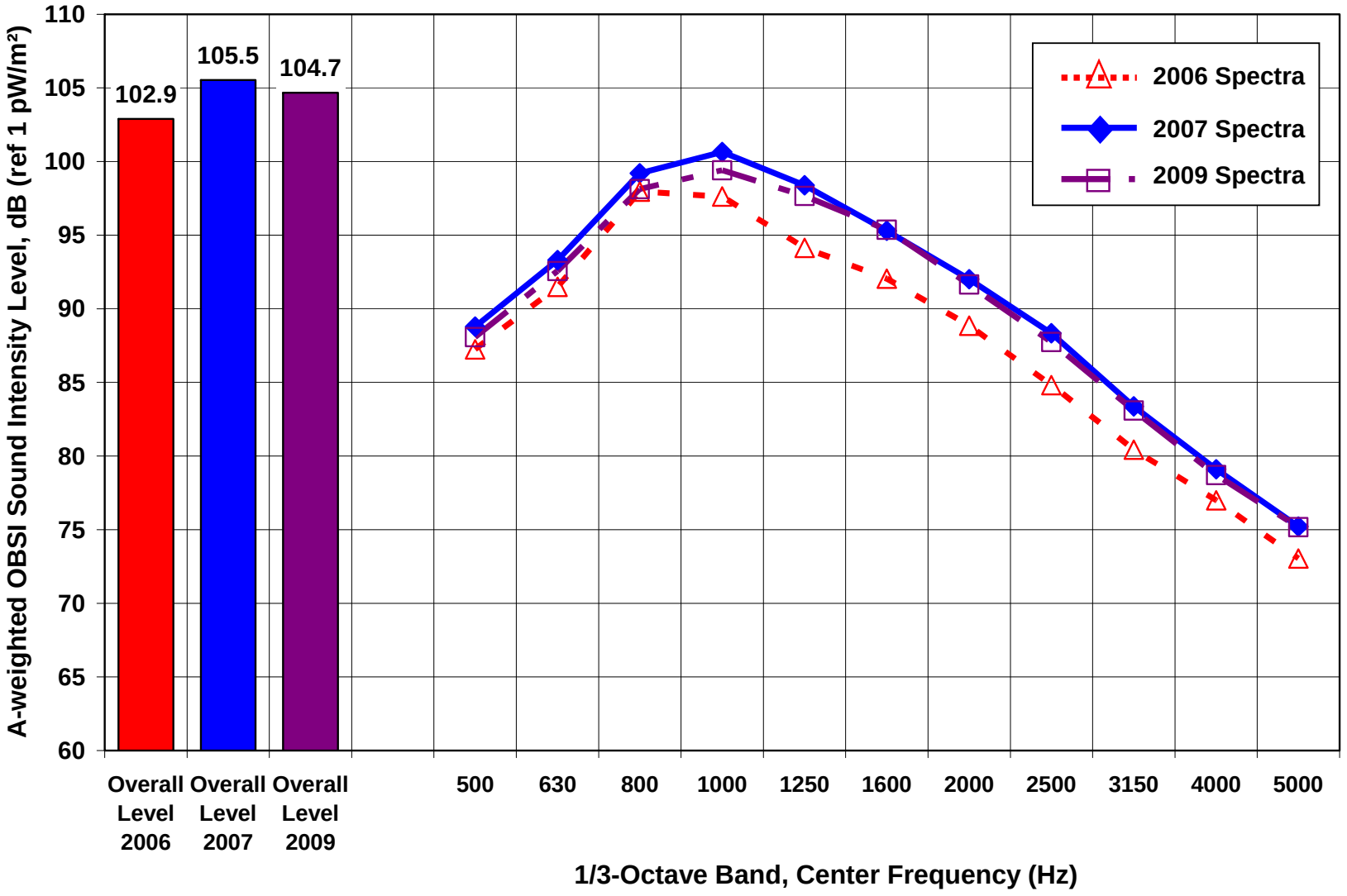
** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	76.8	76.6	77.0	76.8	77.6	76.8	**76.9**
50 × 12	76.8	76.4	76.7	76.6	77.4	76.6	**76.8**

Site: 02

OBSI (SRTT) Test Information

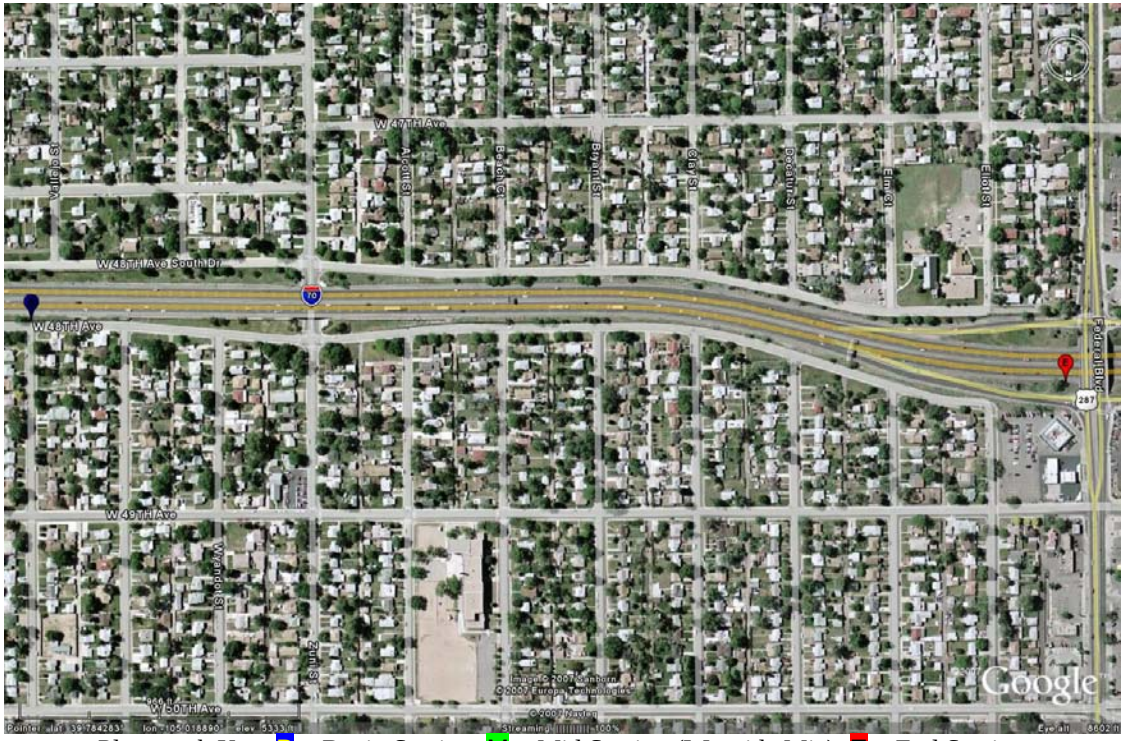


Site: 03
General Information

Highway: Interstate 70, Westbound
Location: Between Federal Blvd. & Pecos St., Denver (80221)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.7841 / 105.0186 / 5330

Nominal Surface: SMA (3/4") **Construction Accepted:** 10/2003

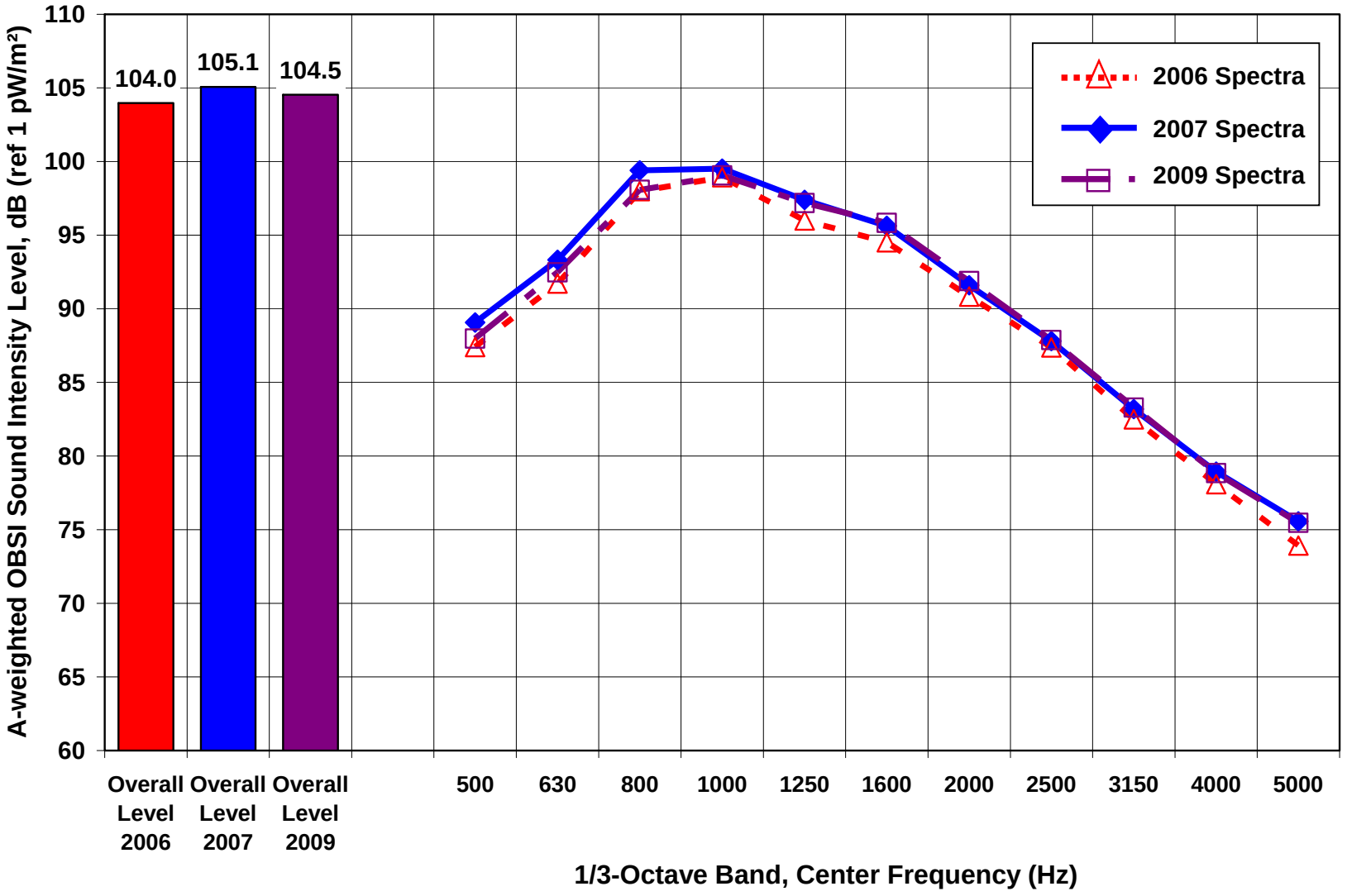
OBSI?: Yes (5/23/09) **SPB?:** No **TA?:** No
Total Section Length: 3575 ft.
Distance from Begin to Wayside Microphone: n/a



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 03

OBSI (SRTT) Test Information

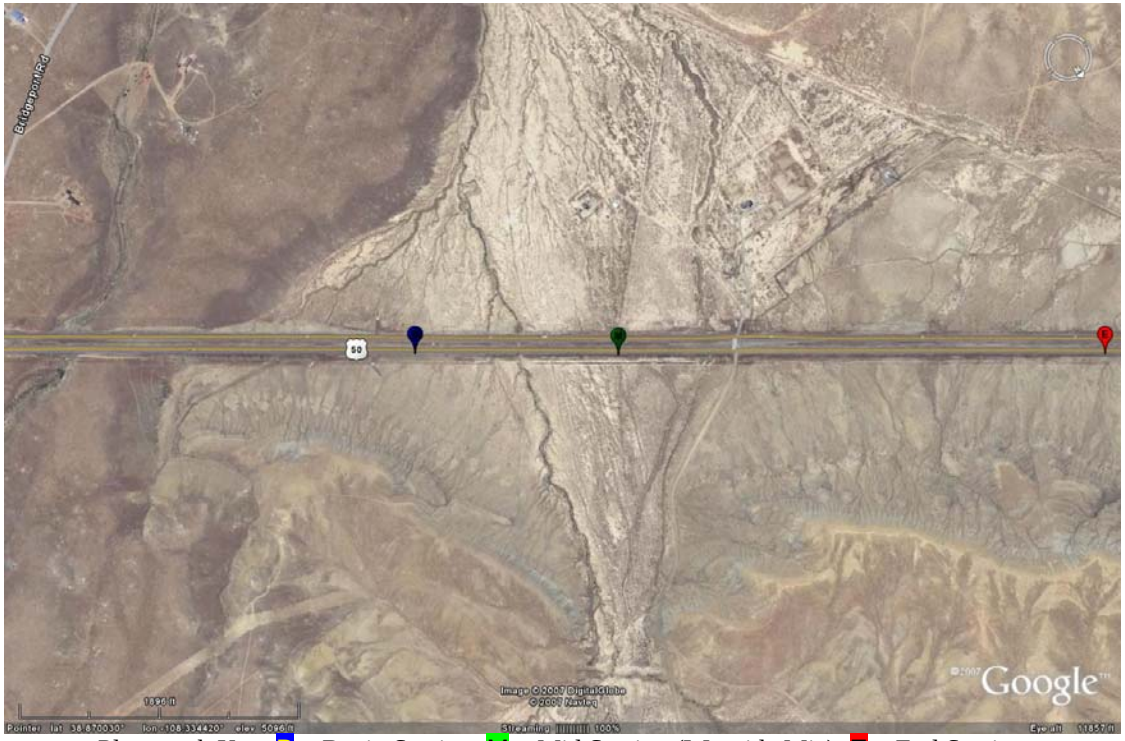


Site: 04
General Information

Highway: US Highway 50, Westbound
Location: Between 35 6/10 Rd. & Bridgeport Rd., Grand Junction (81527)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 38.8147 / 108.3385 / 5110

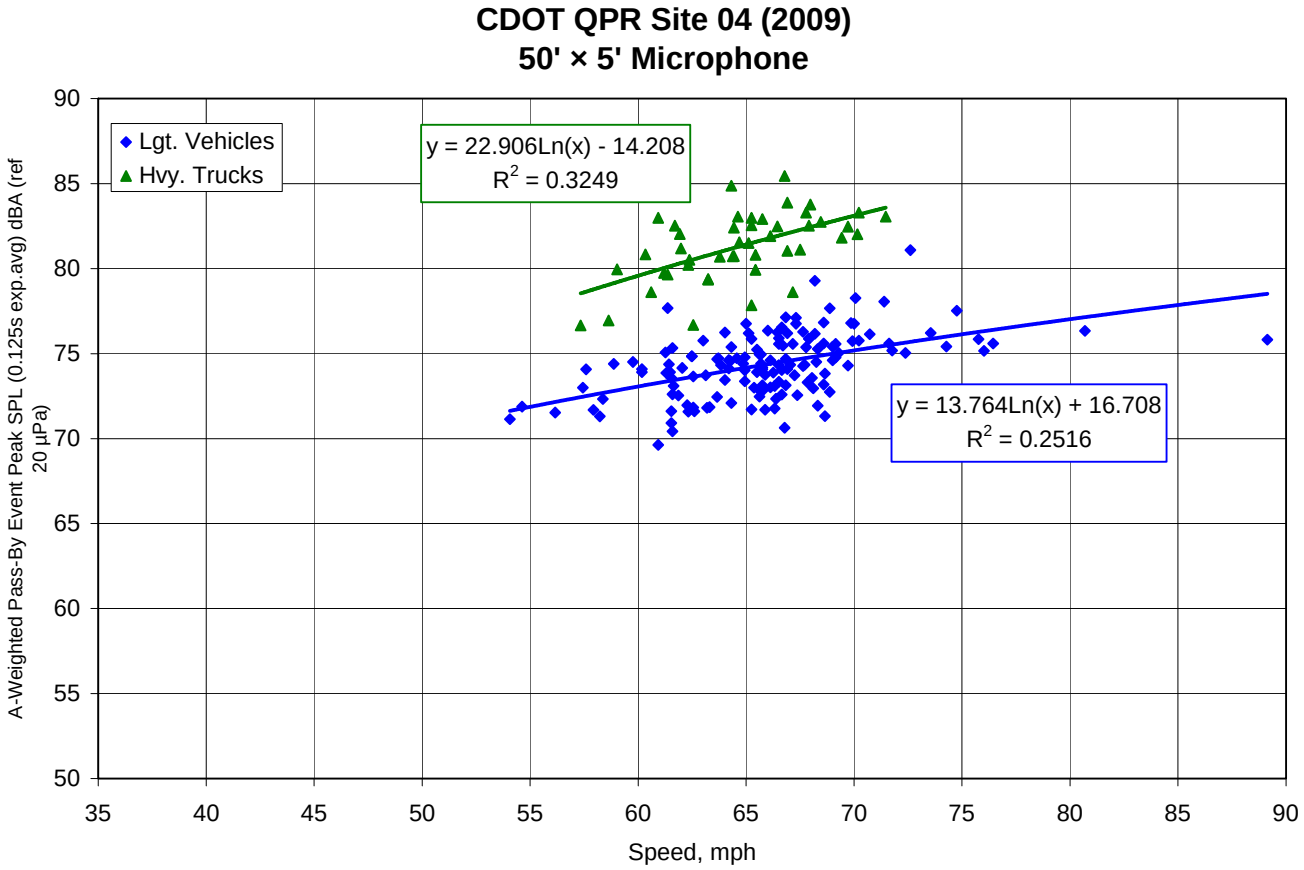
Nominal Surface: SMA (1/2") **Construction Accepted:** 8/2002

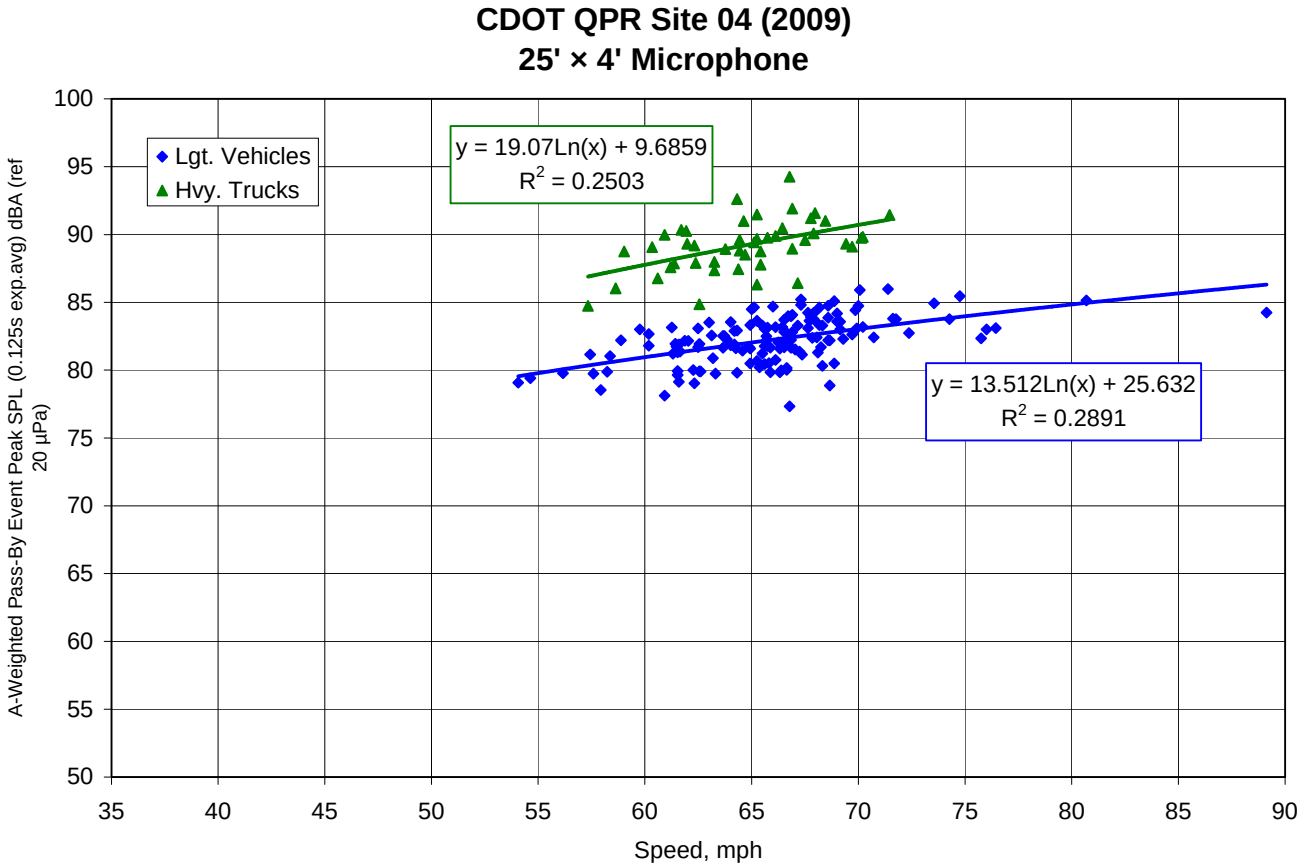
OBSI?: Yes (6/10/09) **SPB?:** Yes **TA?:** No
Total Section Length: 4847 ft.
Distance from Begin to Wayside Microphone: 1422 ft.



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 04
SPB Wayside Test Information

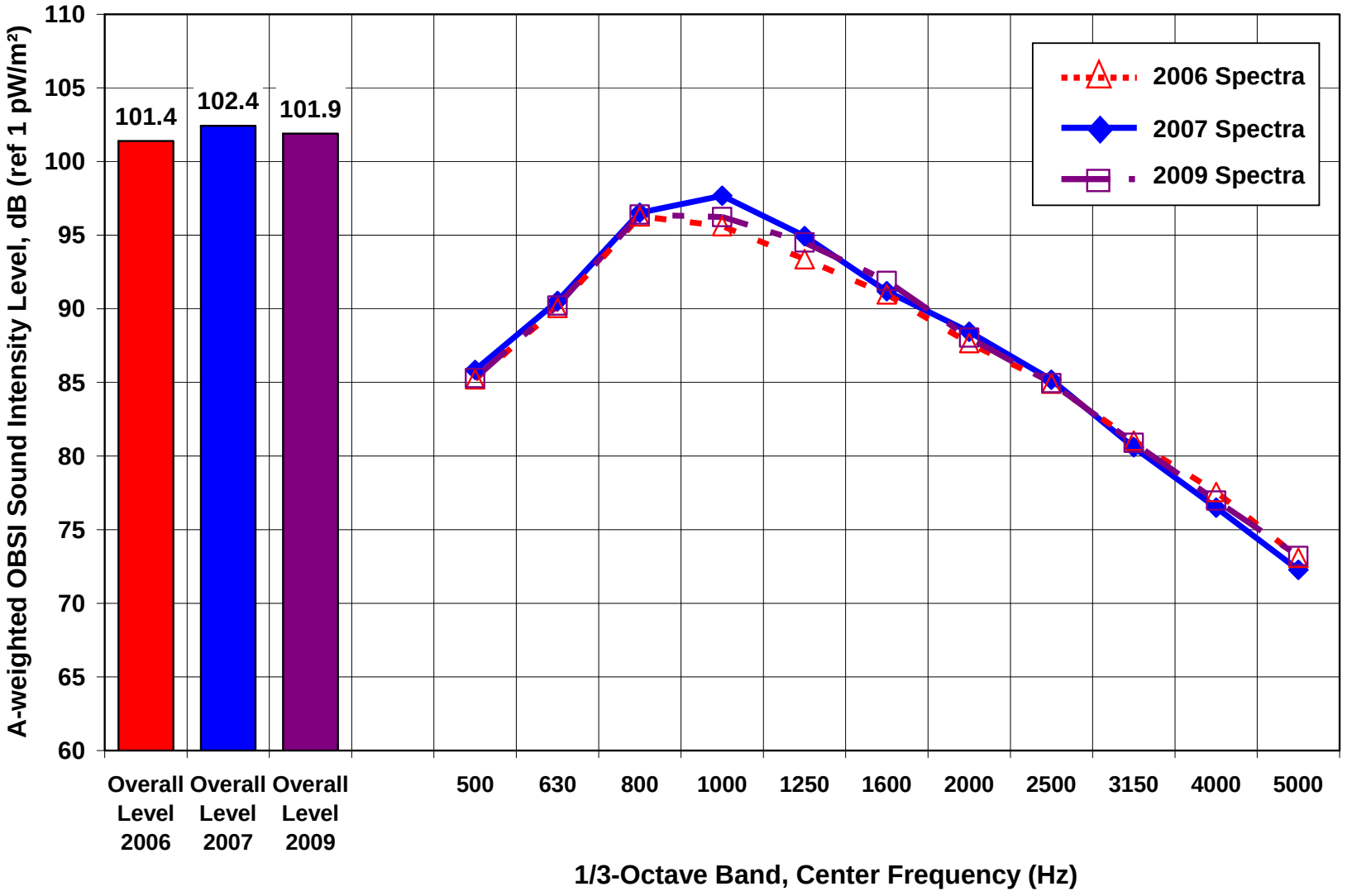




Average A-weighted SPB Level at 60 mph (dB ref 20 µPa), SPBI

Vehicle	50×5 microphone	25×4 microphone
Lgt. Vehicle (Car)	**73.1**	**81.0**
Hvy. Truck	**79.6**	**87.8**

Site: 04
OBSI (SRTT) Test Information



Site: 05
General Information

Highway: State Highway 74, Eastbound
Location: Between Bergen Pkwy. & Lewis Ridge Rd., Evergreen (80439)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.2861 / 107.1376 / 7680

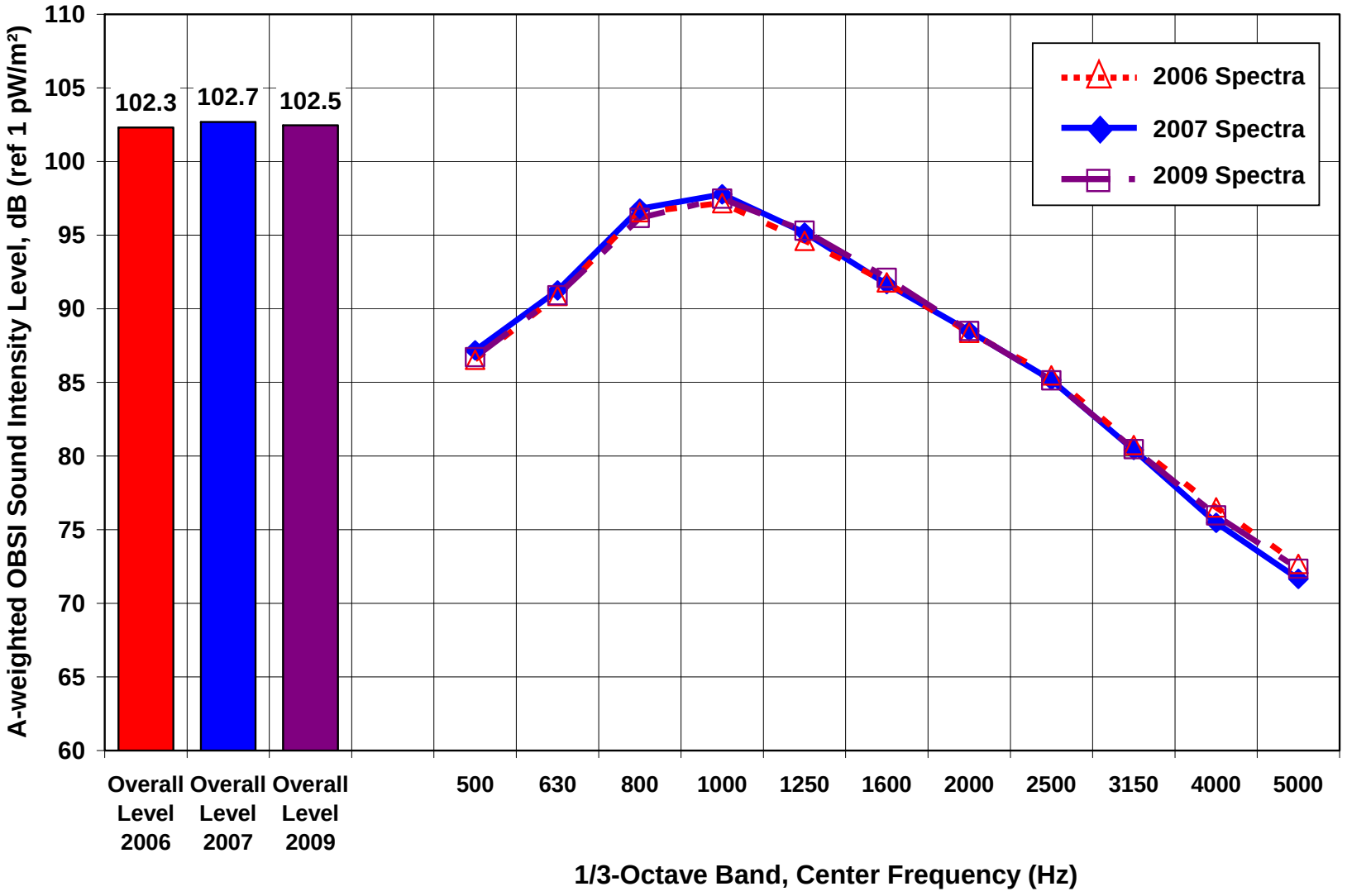
Nominal Surface: SMA (3/8") **Construction Accepted:** 7/2004

OBSI?: Yes (6/4/09) **SPB?:** No **TA?:** No
Total Section Length: 3488 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 05

OBSI (SRTT) Test Information

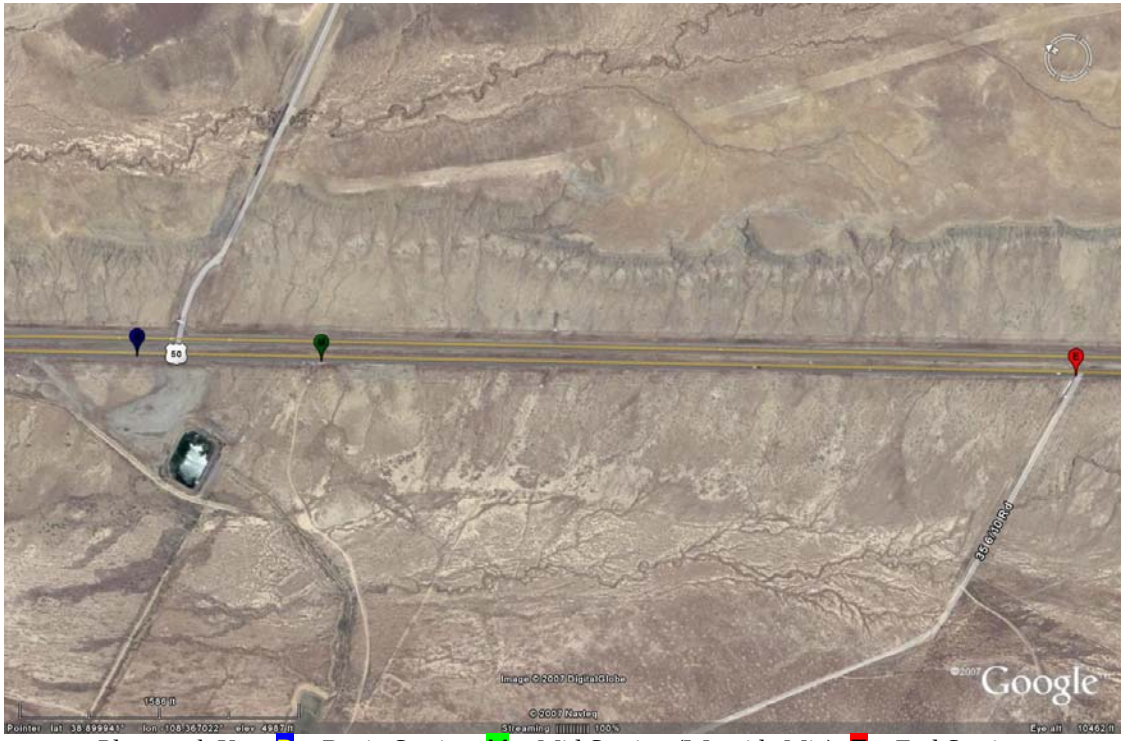


Site: 06
General Information

Highway: US Highway 50, Eastbound
Location: Between 35 6/10 Rd. & Bridgeport Rd., Grand Junction (81527)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 38.8994 / 108.3666 / 5010

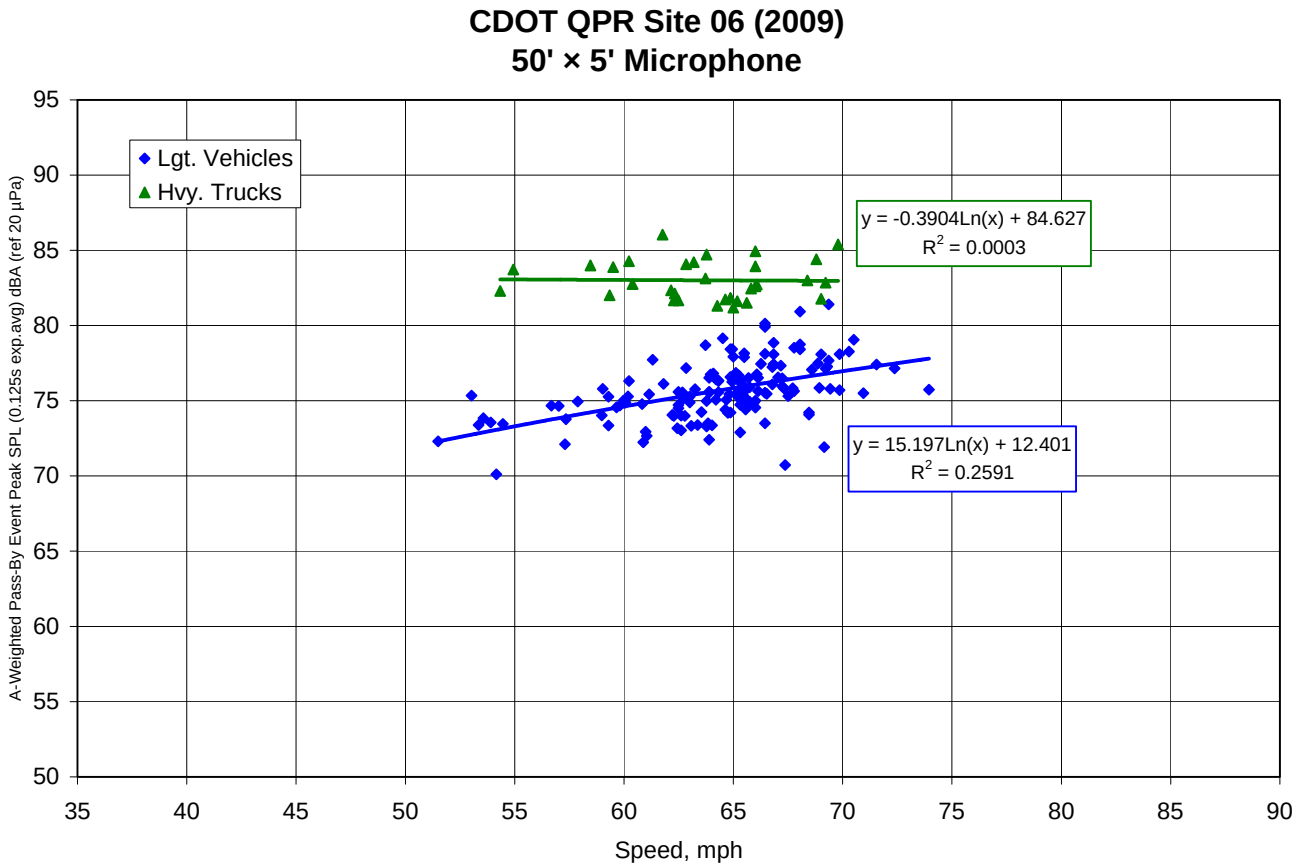
Nominal Surface: Asphalt (SX, 1/2") **Construction Accepted:** 8/2002

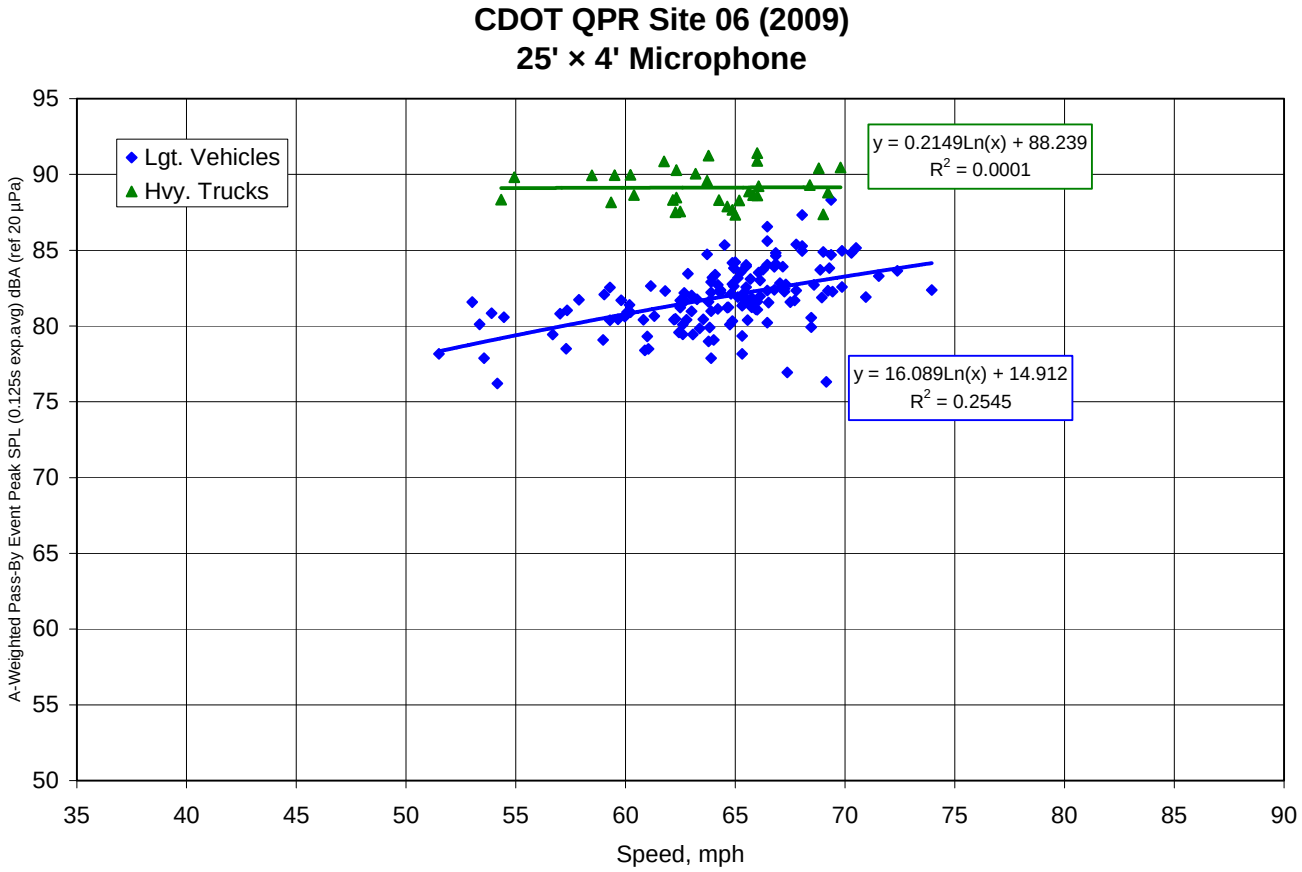
OBSI?: Yes (6/13/09) **SPB?:** Yes **TA?:** No
Total Section Length: 5333 ft.
Distance from Begin to Wayside Microphone: 1048 ft.

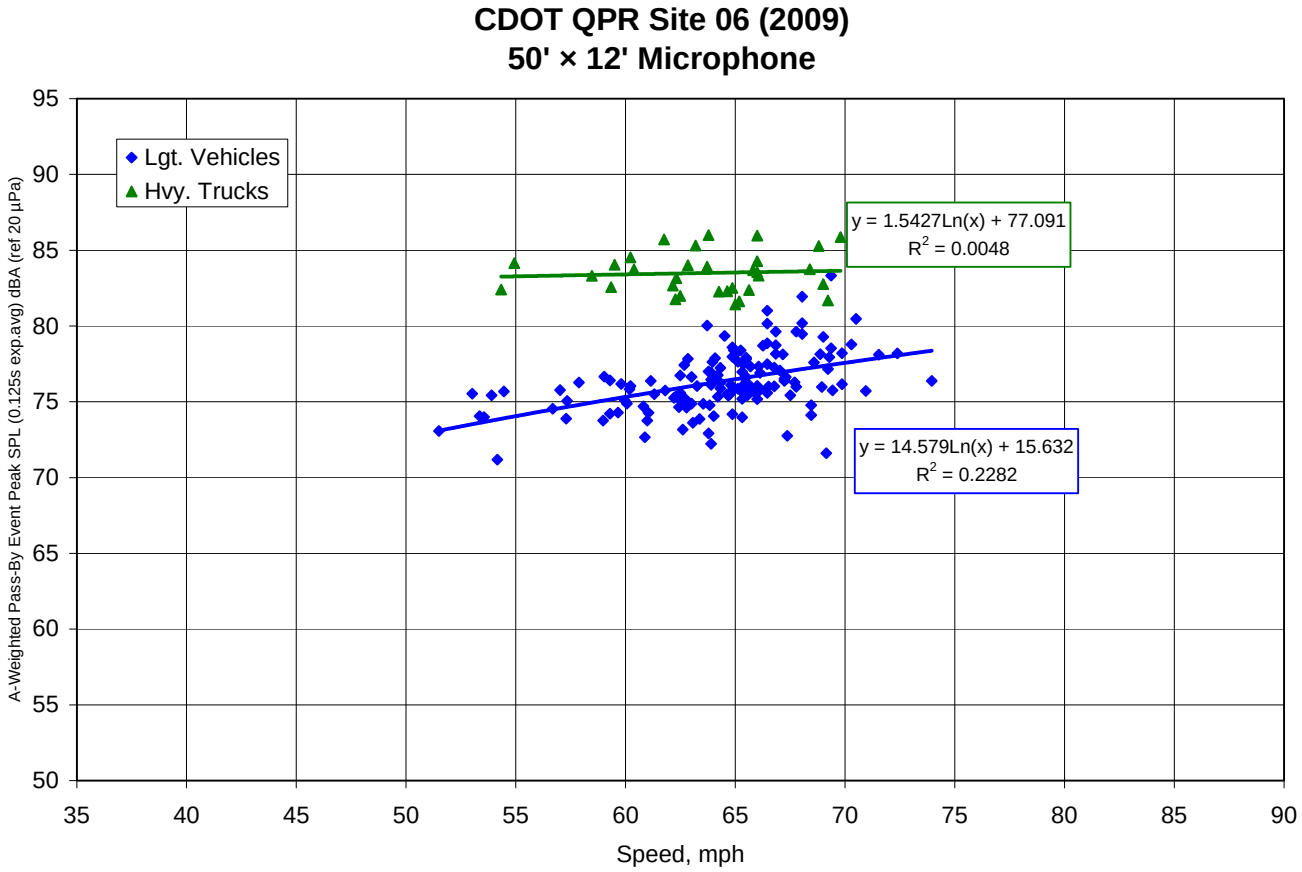


Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 06
SPB Wayside Test Information




CDOT QPR Site 06 (2009)
25' × 4' Microphone
Lgt. Vehicles
Hvy. Trucks
y = 0.2149Ln(x) + 88.239
R2 = 0.0001
y = 16.089Ln(x) + 14.912
R2 = 0.2545
A-Weighted Pass-By Event Peak SPL (0.125s exp.avg) dBA (ref 20 µPa)
Speed, mph
95
90
85
80
75
70
65
60
55
50
35
40
45
50
55
60
65
70
75
80
85
90

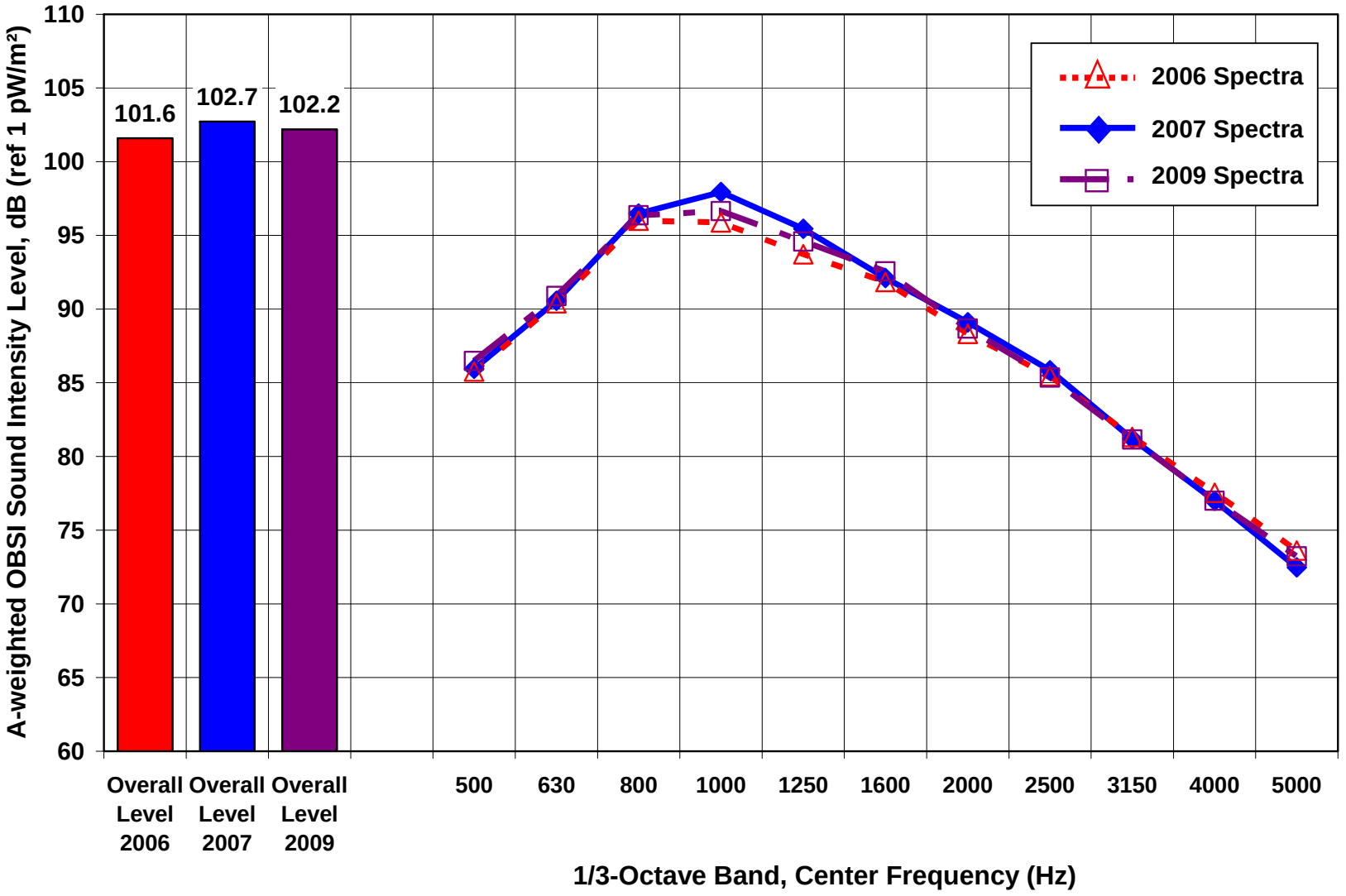


Average A-weighted SPB Level at 60 mph (dB ref 20 µPa), SPBI

Vehicle	50×5 microphone	25×4 microphone	50×12 microphone
Lgt. Vehicle (Car)	**74.6**	**80.8**	**75.3**
Hvy. Truck	**83.0**	**89.1**	**83.4**

Site: 06

OBSI (SRTT) Test Information



Site: 07
General Information

Highway: US Highway 85, Southbound
Location: Between Daniels Park Rd. & Happy Canyon Rd., Sedalia (80135)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.4288 / 104.9111 / 6000

Nominal Surface: Asphalt (SX, 1/2") **Construction Accepted:** 2006

OBSI?: Yes (9/22/09) **SPB?:** No **TA?:** Yes
Total Section Length: 2686 ft.
Distance from Begin to Wayside Microphone: 1864 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 07
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (10:00 am to 11:30 am, 6/5/09)

Traffic Volumes and Speeds during Sample Period

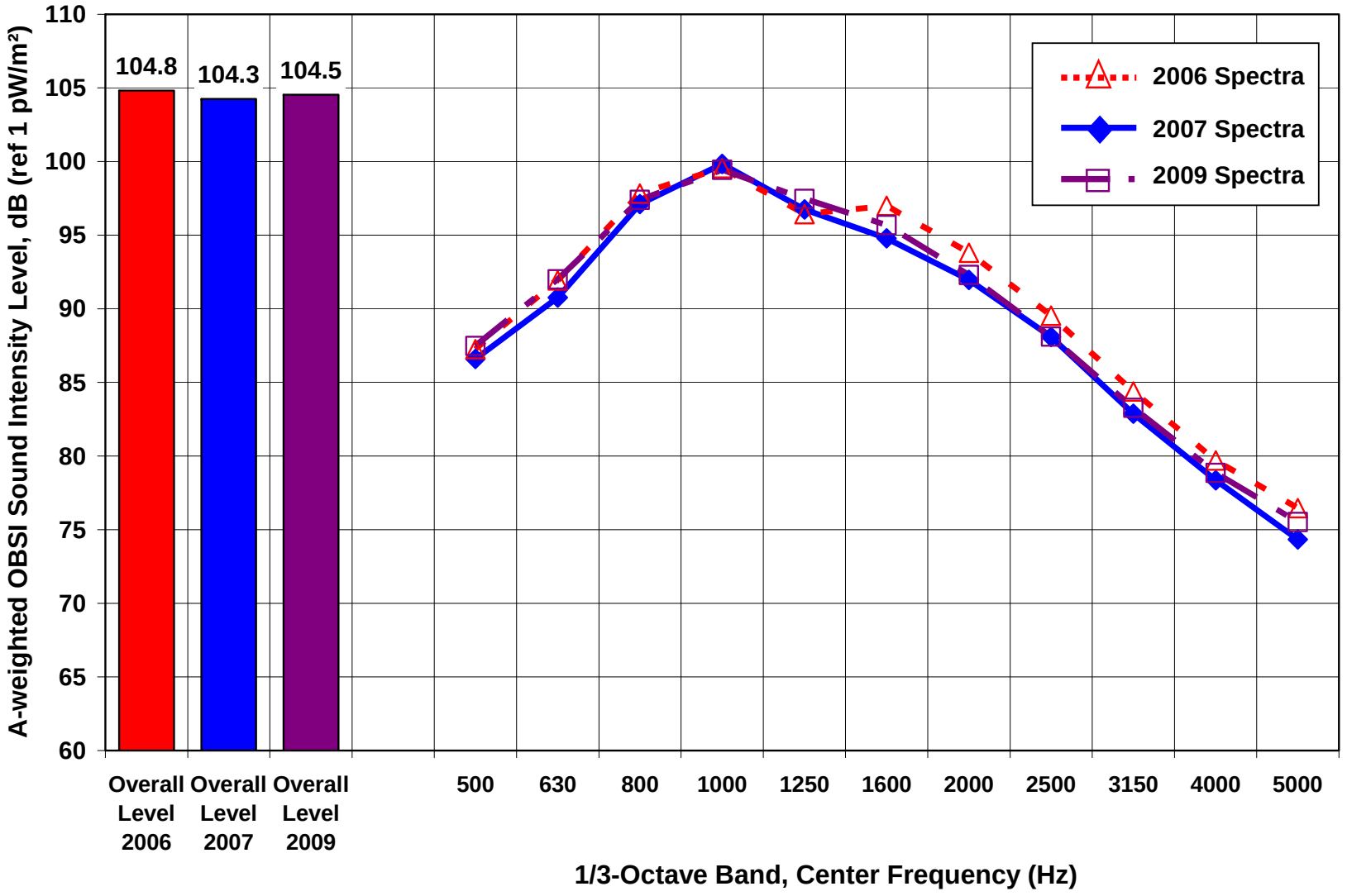
	SB Lane 1	NB Lane 1
Distance from Mic (ft.)*	50	62
Average Speed (mph)	54	53
Automobile	866	831
Heavy Truck	17	17
Medium Truck	31	27
Bus	0	0
Motorcycle	11	4
Auto + 1-Axle Trlr.	8	8
Auto + 2-Axle Trlr.	16	15
M. Trk. + 1-Axle Trlr.	0	0
M. Trk. + 2-Axle Trlr.	1	4

** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	72.6	71.9	72.1	72.6	72.6	72.4	**72.4**
25 × 4	76.1	75.6	75.7	76.2	76.2	76.2	**76.0**
50 × 12	73.2	72.8	72.8	73.3	73.3	73.3	**73.1**

Site: 07
OBSI (SRTT) Test Information



Site: 08
General Information

Highway: Interstate 70, Eastbound
Location: Between US 6 & Herman Gulch Rd., Bakerville (E of Dillon) (80444)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.6976 / 105.8703 / 10470

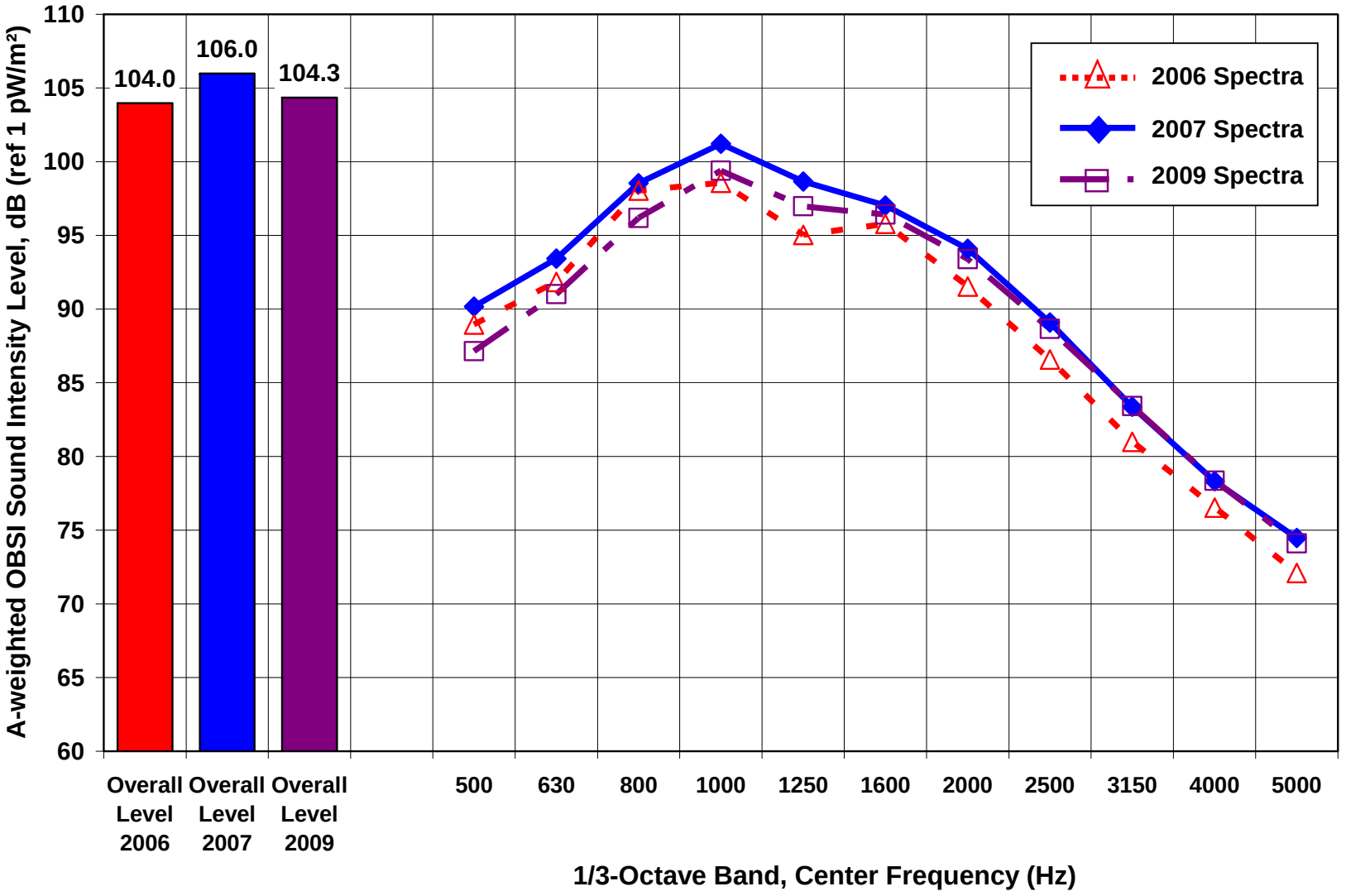
Nominal Surface: Asphalt (SX, 1/2") **Construction Accepted:** 2005

OBSI?: Yes (6/6/09) **SPB?:** No **TA?:** No
Total Section Length: 3535 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 08

OBSI (SRTT) Test Information



Site: 09
General Information

Highway: Highway C-470, Westbound (Northbound)
Location: Between US 285 & Morrison Rd., Morrison (80465)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.641 / 105.1723 / 5760

Nominal Surface: SMA (1/2") **Construction Accepted:** 6/2006

OBSI?: Yes (5/23/09) **SPB?:** No **TA?:** Yes
Total Section Length: 3033 ft.
Distance from Begin to Wayside Microphone: 2460 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 09
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (1:00 pm to 2:30 pm, 5/27/09)

Traffic Volumes and Speeds during Sample Period

	WB Lane 3 (Outside)	WB Lane 2	WB Lane 1 (Inside)	EB Lane 1 (Inside)	EB Lane 2	EB Lane 3 (Outside)
Distance from Mic (ft.)	50	62	74	121	133	145
Average Speed (mph)	67			66		
Automobile	505	1574	1109	1096	1686	398
Heavy Truck	4	64	9	11	35	13
Medium Truck	15	108	11	11	139	20
Bus	4	6	1	4	8	10
Motorcycle	13	14	13	12	14	4
Auto + 1-Axle Trlr.	4	14	3	5	8	7
Auto + 2-Axle Trlr.	4	12	3	5	10	5
M. Trk. + 1-Axle Trlr.	0	2	0	1	2	1
M. Trk. + 2-Axle Trlr.	2	7	2	4	11	2

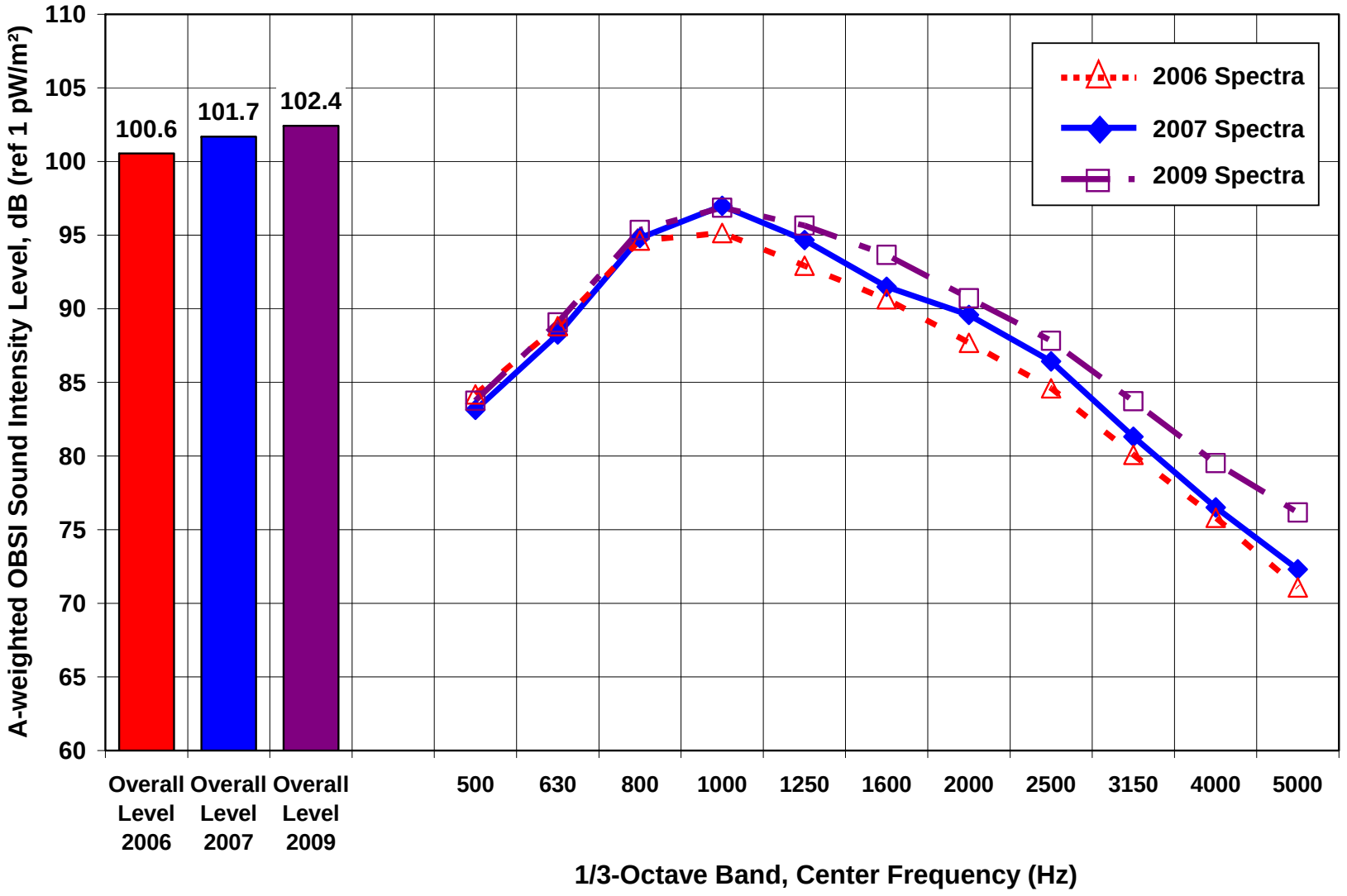
** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	75.8	75.6	75.7	75.3	75.4	75.5	**75.5**
25 × 4	80.0	79.8	79.5	79.6	79.2	79.8	**79.6**

Site: 09

OBSI (SRTT) Test Information

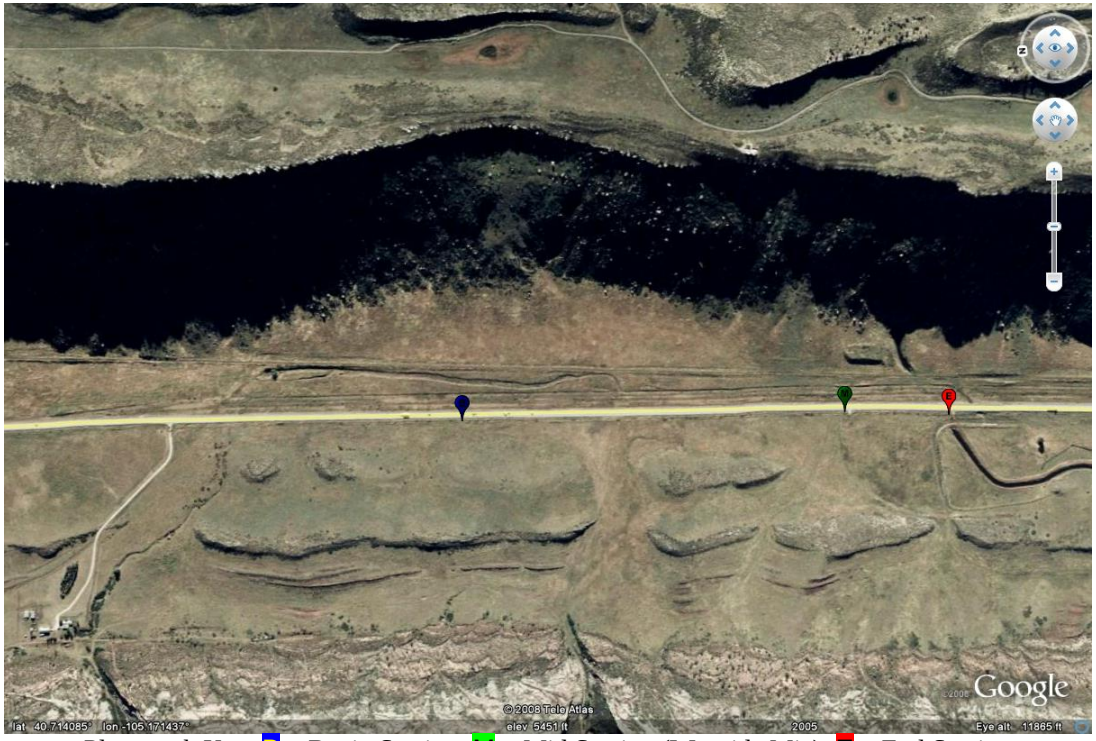


Site: 10
General Information

Highway: US Highway 287, Southbound
Location: Between Bonner Spring Ranch Rd. & SH 14, Laporte (80535)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 40.7113 / 105.173 / 5470

Nominal Surface: Asphalt (S, 3/4") **Construction Accepted:** 10/2003

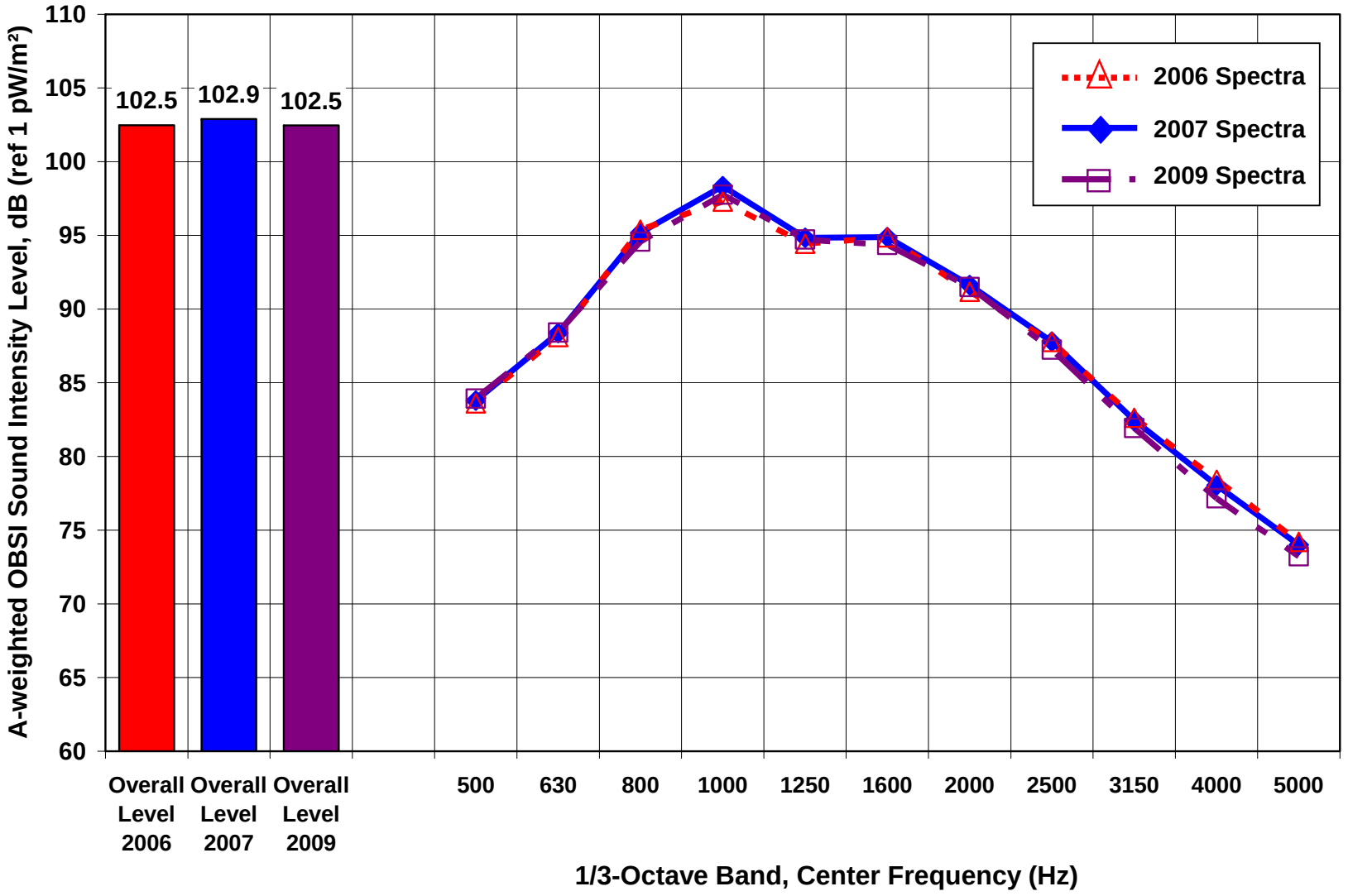
OBSI?: Yes (5/12/09) **SPB?:** Yes **TA?:** No
Total Section Length: 3380 ft.
Distance from Begin to Wayside Microphone: 2649 ft.



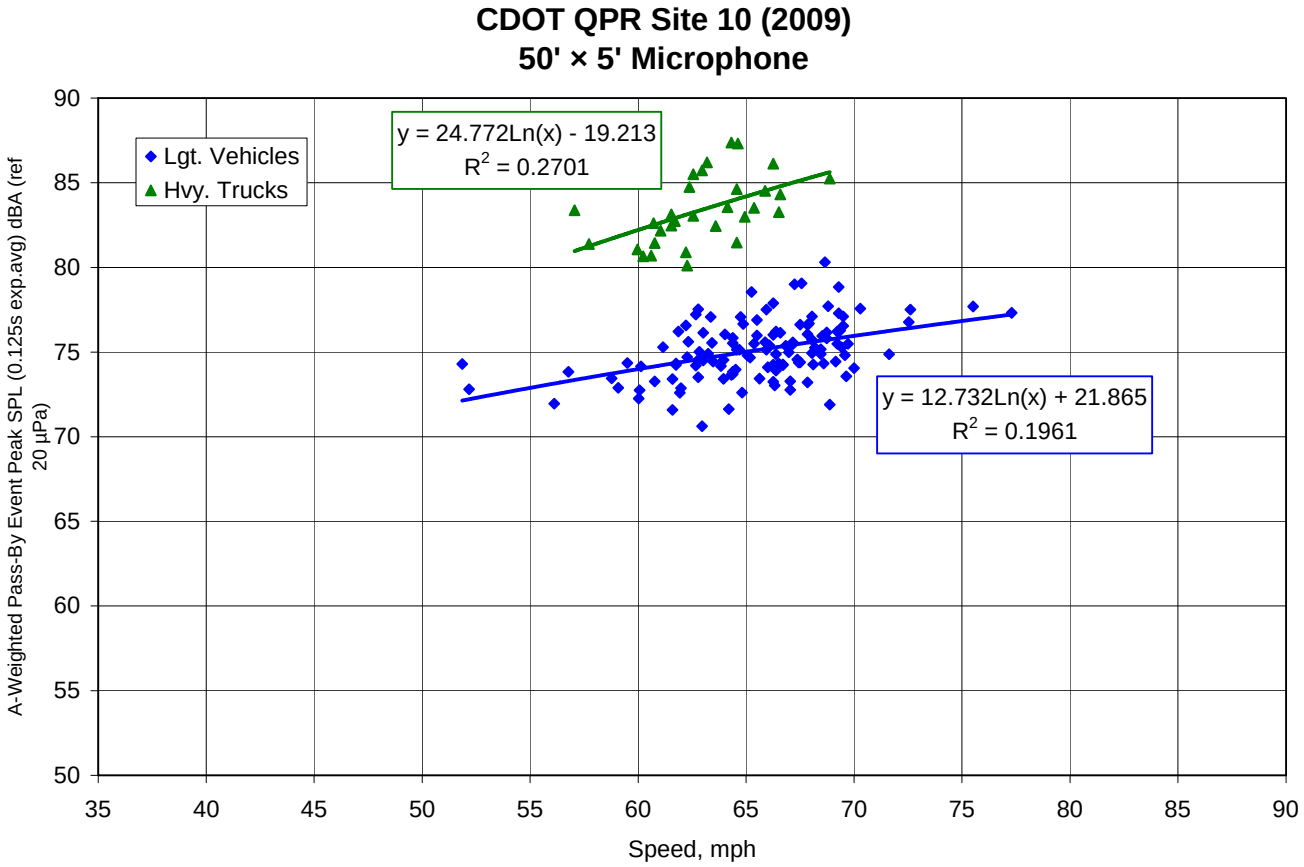
Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

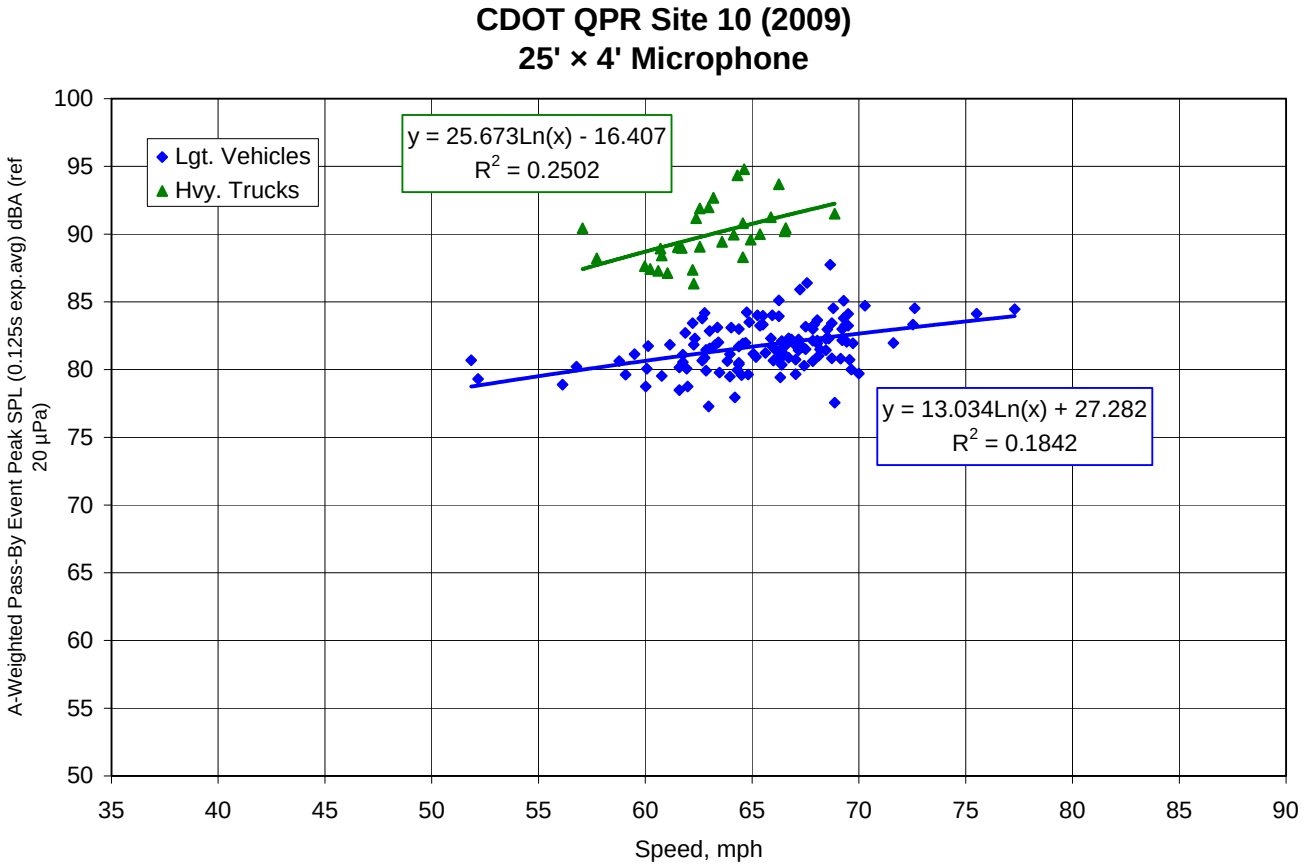
Site: 10

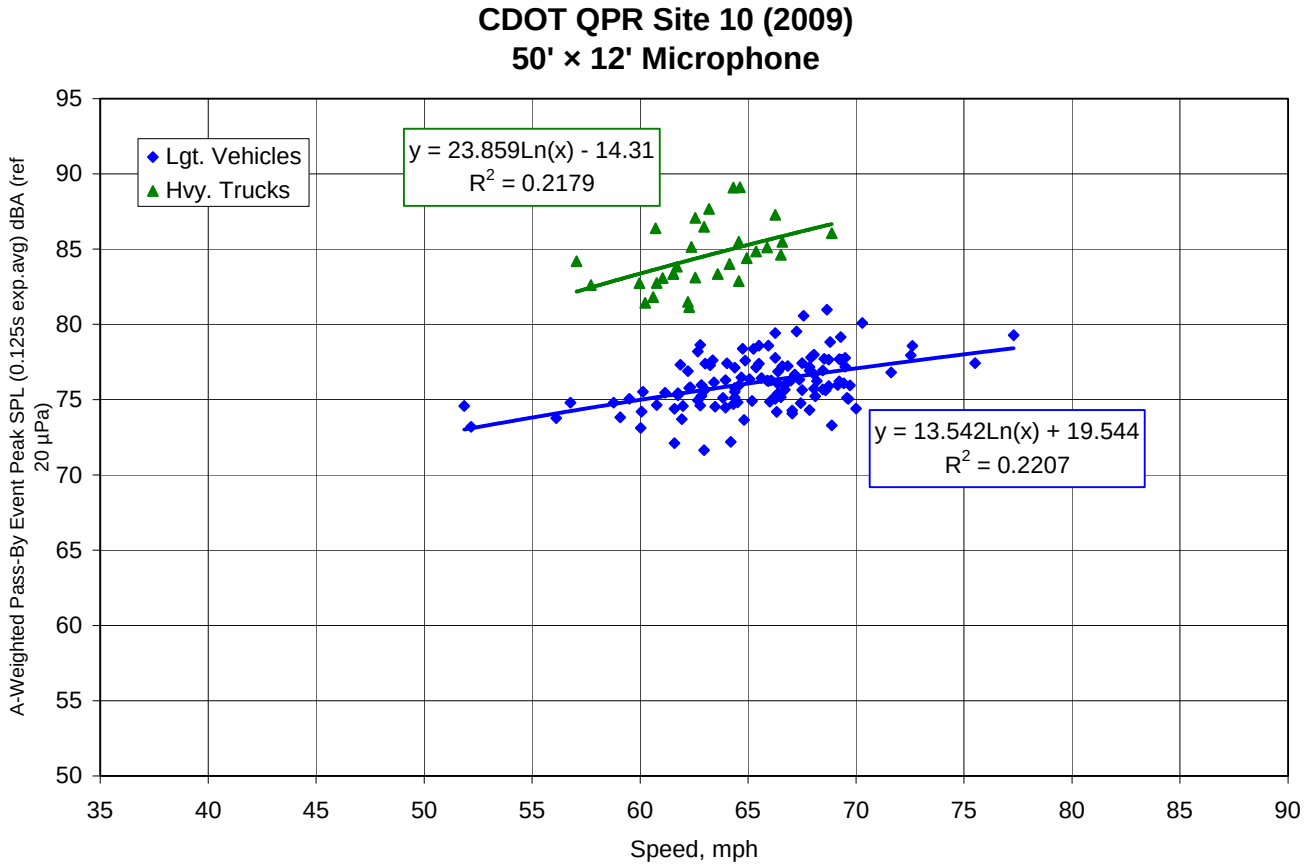
OBSI (SRTT) Test Information



Site: 10
SPB Wayside Test Information




CDOT QPR Site 10 (2009)
25' × 4' Microphone
A-Weighted Pass-By Event Peak SPL (0.125s exp.avg) dBA (ref 20 µPa)
Speed, mph
Lgt. Vehicles
Hvy. Trucks
y = 25.673Ln(x) - 16.407
R2 = 0.2502
y = 13.034Ln(x) + 27.282
R2 = 0.1842
100
95
90
85
80
75
70
65
60
55
50
35
40
45
50
55
60
65
70
75
80
85
90



Average A-weighted SPB Level at 60 mph (dB ref 20 µPa), SPBI

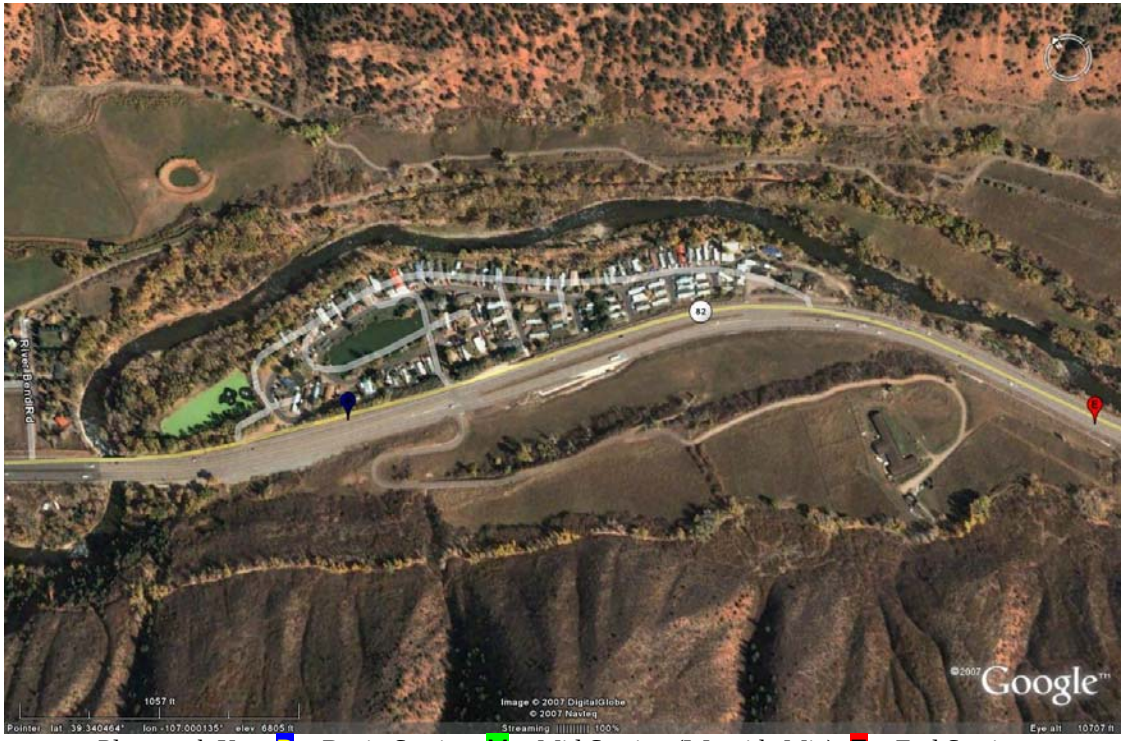
Vehicle	50×5 microphone	25×4 microphone	50×12 microphone
Lgt. Vehicle (Car)	**74.0**	**80.6**	**75.0**
Hvy. Truck	**82.2**	**88.7**	**83.4**

Site: 11
General Information

Highway: State Highway 82, Eastbound
Location: Between Hunter Logan & Lower River Rd., Basalt (81654)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.3389 / 106.9989 / 6880

Nominal Surface: NovaChip **Construction Accepted:** 10/2000

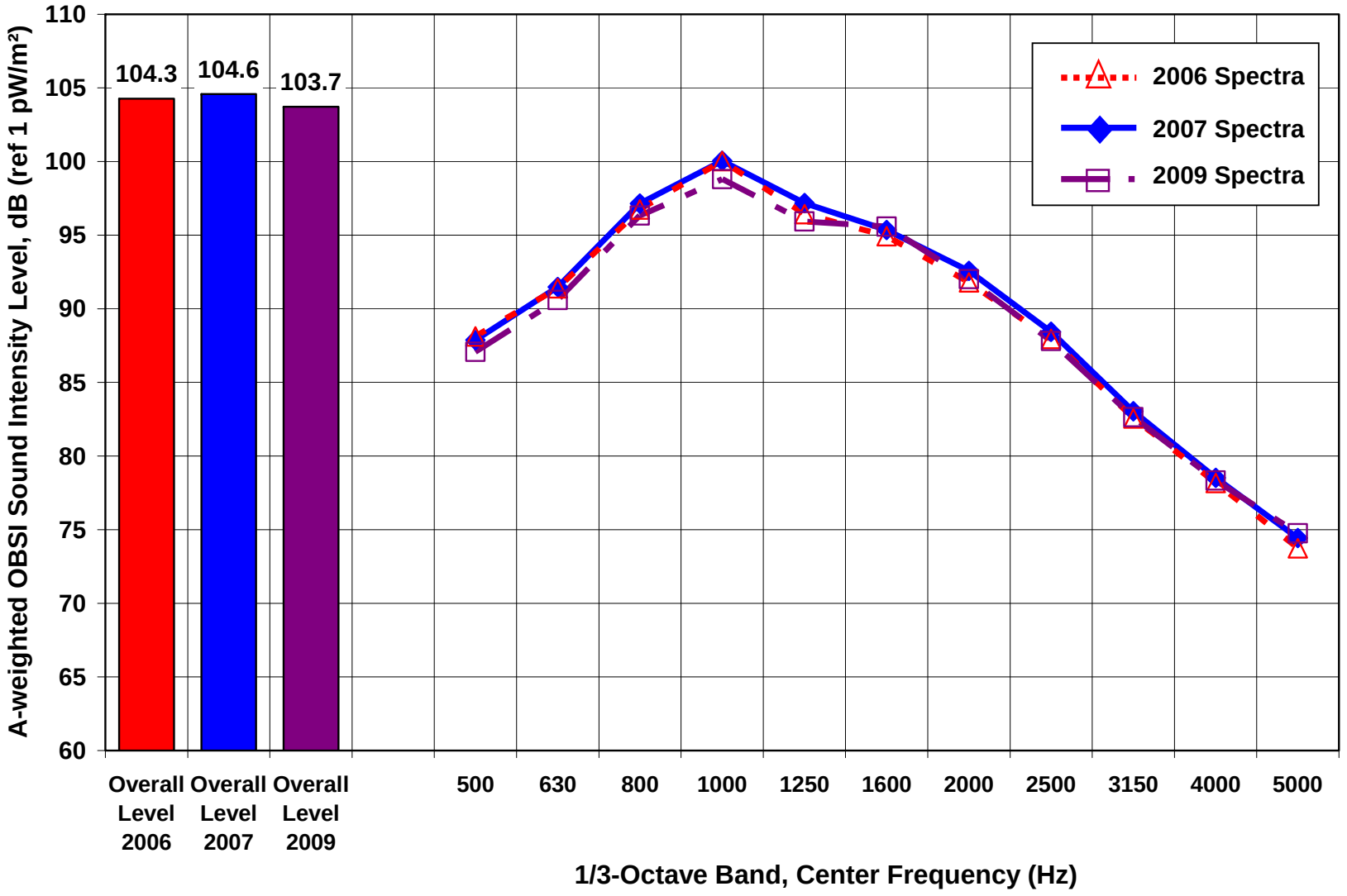
OBSI?: Yes (6/15/09) **SPB?:** No **TA?:** No
Total Section Length: 3228 ft.
Distance from Begin to Wayside Microphone: n/a



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 11

OBSI (SRTT) Test Information

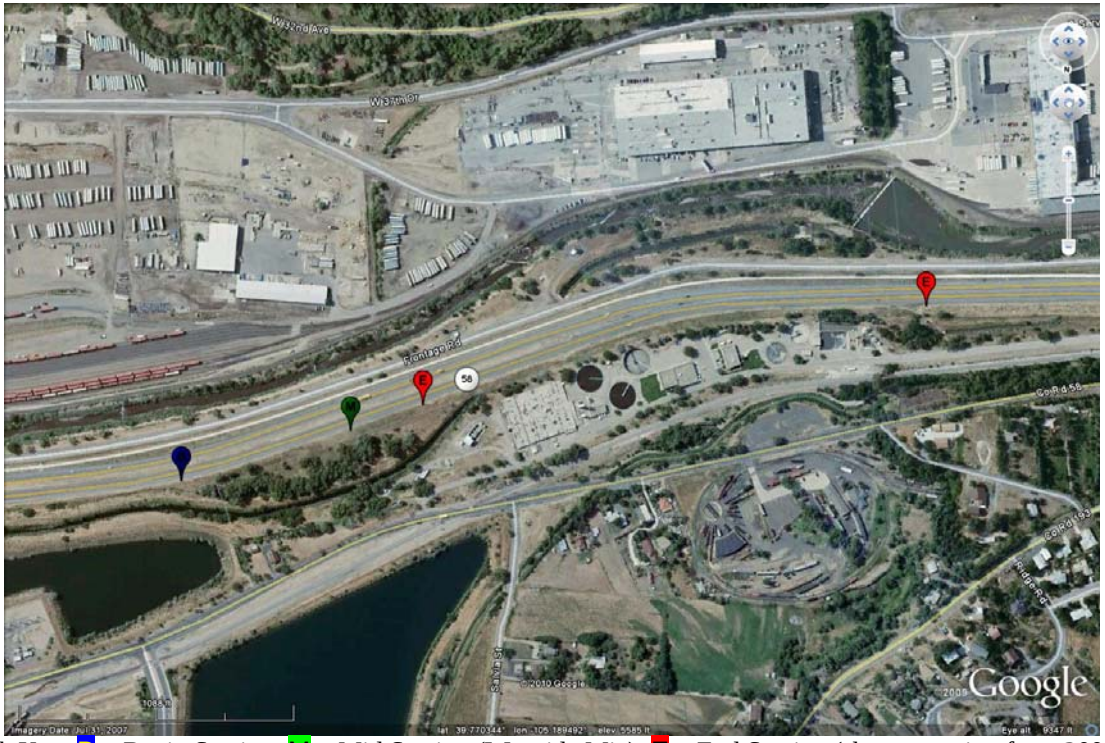


Site: 12
General Information

Highway: State Highway 58, Westbound
Location: Between McIntyre St. & 44th Ave., Golden (80403)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.7706 / 105.1895 / 5600

Nominal Surface: NovaChip **Construction Accepted:** 6/2003

OBSI?: Yes (5/22/09) **SPB?:** No **TA?:** Yes
Total Section Length: 1010 ft. (same point of begin as previous 3082 ft. section)
Distance from Begin to Wayside Microphone: 653 ft.



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section (shorter section from 2009 and on)

Site: 12
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (9:50 am to 11:20 am, 5/28/09)

Traffic Volumes and Speeds during Sample Period

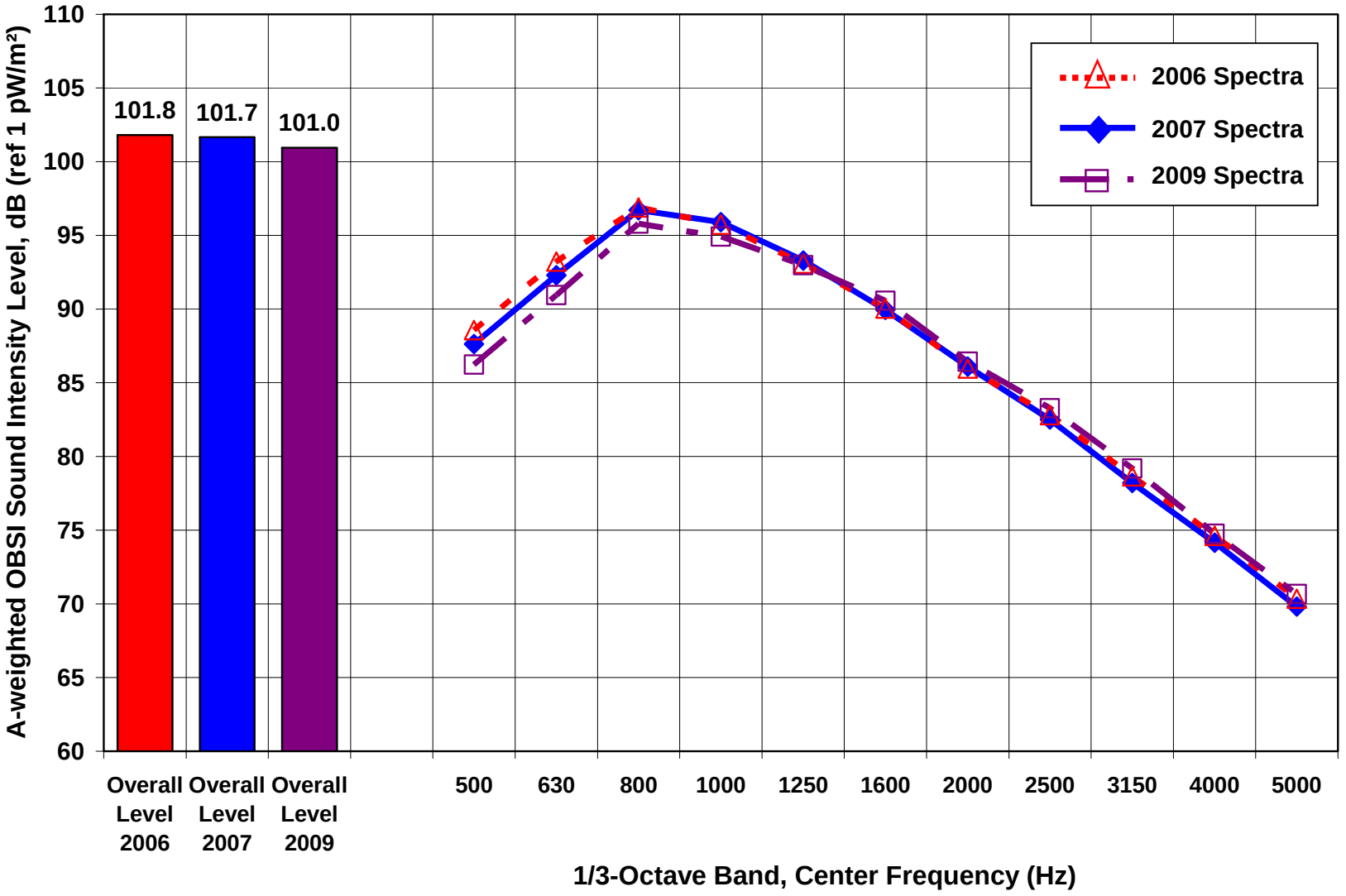
	WB Lane 2 (Outside)	WB Lane 1 (Inside)	EB Lane 1 (Inside)	EB Lane 2 (Outside)
Distance from Mic (ft.)	50	62	111	123
Average Speed (mph)	57		59	
Automobile	571	183	238	398
Heavy Truck	7	0	27	21
Medium Truck	18	3	13	18
Bus	4	1	4	4
Motorcycle	9	1	5	4
Auto + 1-Axle Trlr.	2	0	2	1
Auto + 2-Axle Trlr.	5	1	0	5
M. Trk. + 1-Axle Trlr.	0	0	0	0
M. Trk. + 2-Axle Trlr.	1	0	1	2

** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	67.0	67.2	67.2	68.3	68.0	68.1	**67.7**
25 × 4	72.1	71.9	72.3	73.2	73.0	73.1	**72.6**
50 × 12	69.3	69.3	69.4	70.5	70.3	70.4	**69.9**

Site: 12
OBSI (SRTT) Test Information



Site: 13
General Information

Highway: Interstate 25, Southbound
Location: Between CR-12 & CR-10, Erie (80516)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 40.0667 / 104.9809 / 5060

Nominal Surface: Concrete (Long. Tining) **Construction Accepted:** 10/2005

OBSI?: Yes (5/20/09) **SPB?:** No **TA?:** Yes
Total Section Length: 3389 ft.
Distance from Begin to Wayside Microphone: 1054 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 13
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (12:00 pm to 1:30 pm, 5/16/09)

Traffic Volumes and Speeds during Sample Period

	SB Lane 3 (Outside)	SB Lane 2	SB Lane 1 (Inside)	NB Lane 1 (Inside)	NB Lane 2	NB Lane 3 (Outside)
Distance from Mic (ft.)	50	62	74	145	157	169
Average Speed (mph)	72			74		
Automobile	888	2052	1875	1514	1873	676
Heavy Truck	112	73	7	8	62	123
Medium Truck	31	23	10	4	23	26
Bus	2	11	0	2	1	2
Motorcycle	8	8	7	22	15	12
Auto + 1-Axle Trlr.	13	12	7	8	26	22
Auto + 2-Axle Trlr.	17	18	7	10	23	17
M. Trk. + 1-Axle Trlr.	1	0	0	0	1	1
M. Trk. + 2-Axle Trlr.	4	4	2	0	5	6

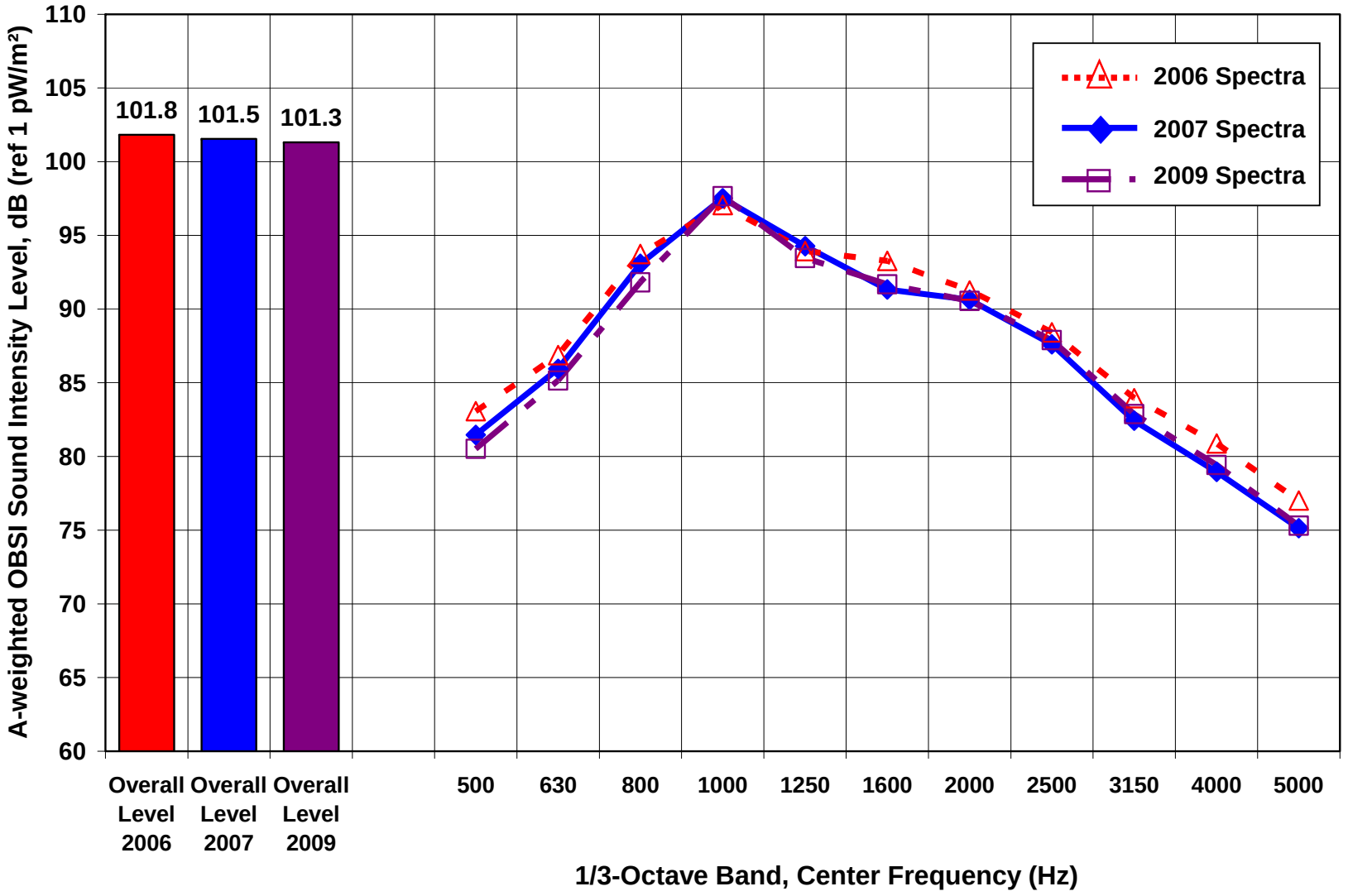
** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	79.3	77.4	79.3	78.7	78.8	78.2	**78.6**
25 × 4	82.6	81.1	82.7	82.0	82.3	81.7	**82.1**
50 × 12	79.7	78.2	80.0	79.6	79.7	79.1	**79.4**

Site: 13

OBSI (SRTT) Test Information



Site: 14
General Information

Highway: US Highway 285, Northbound
Location: Between Surrey Dr. & Goddard Ranch Ct., Indian Hills (80465)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.5838 / 105.2258 / 7130

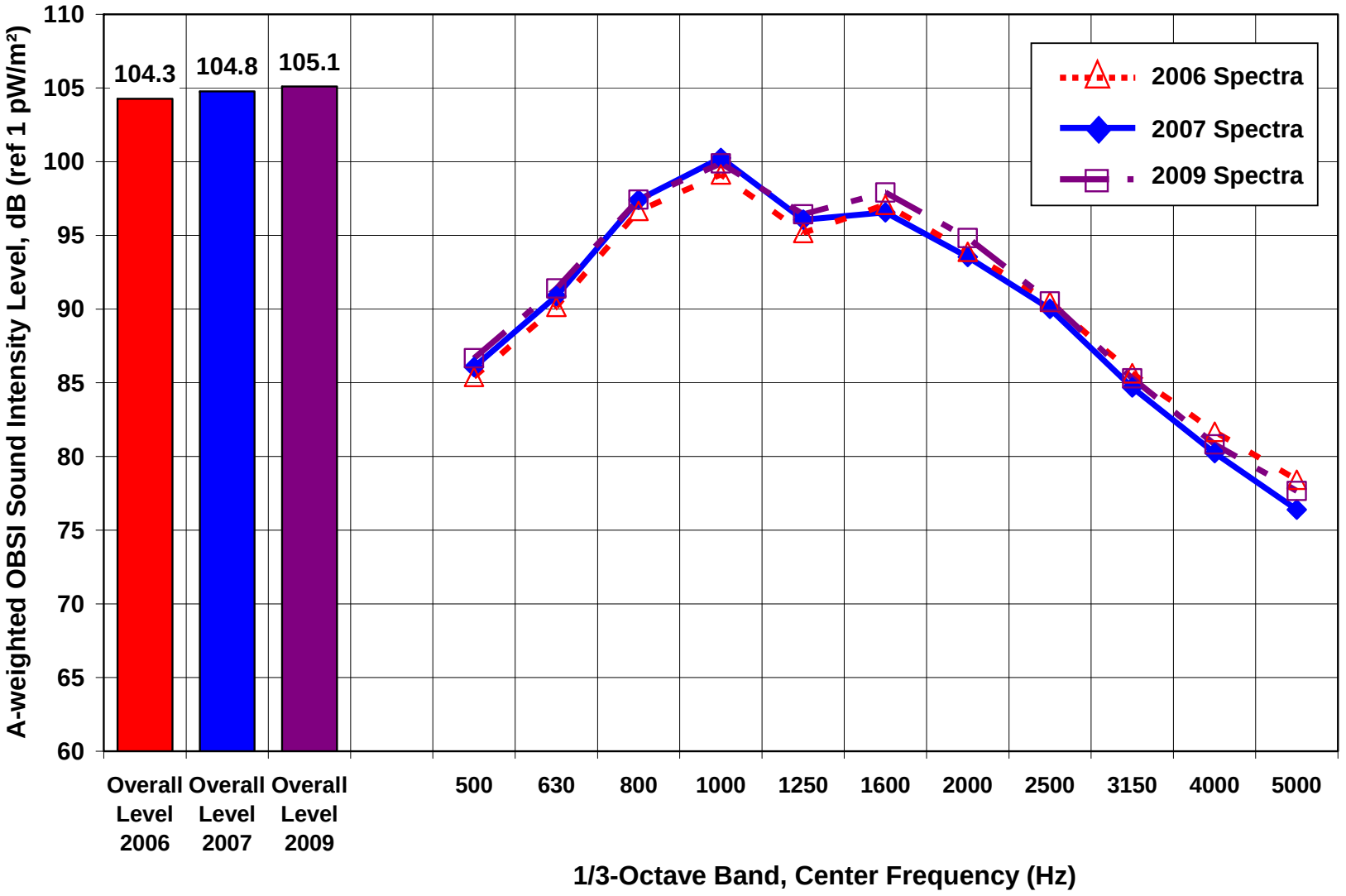
Nominal Surface: Concrete (Long. Tining) **Construction Accepted:** 10/1999

OBSI?: Yes (5/25/09) **SPB?:** No **TA?:** No
Total Section Length: 1613 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 14

OBSI (SRTT) Test Information

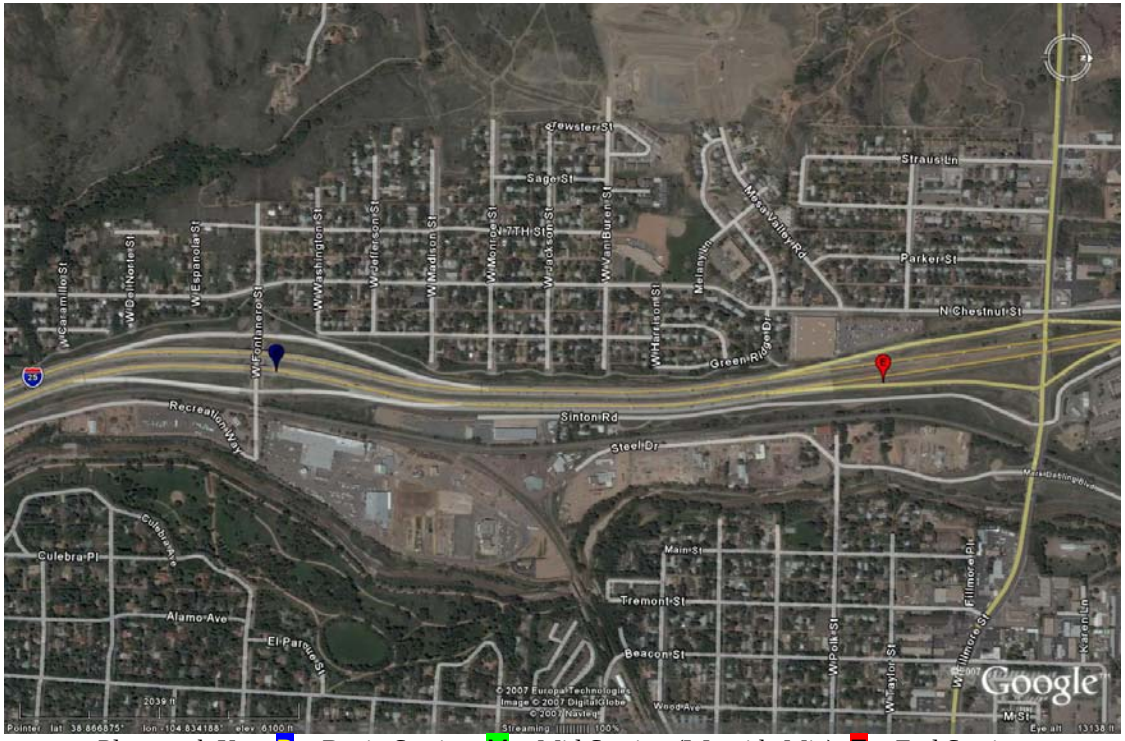


Site: 15
General Information

Highway: Interstate 25, Northbound
Location: Between Fontanero St. & Fillmore St., Colorado Springs (80907)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 38.8672 / 104.834 / 6130

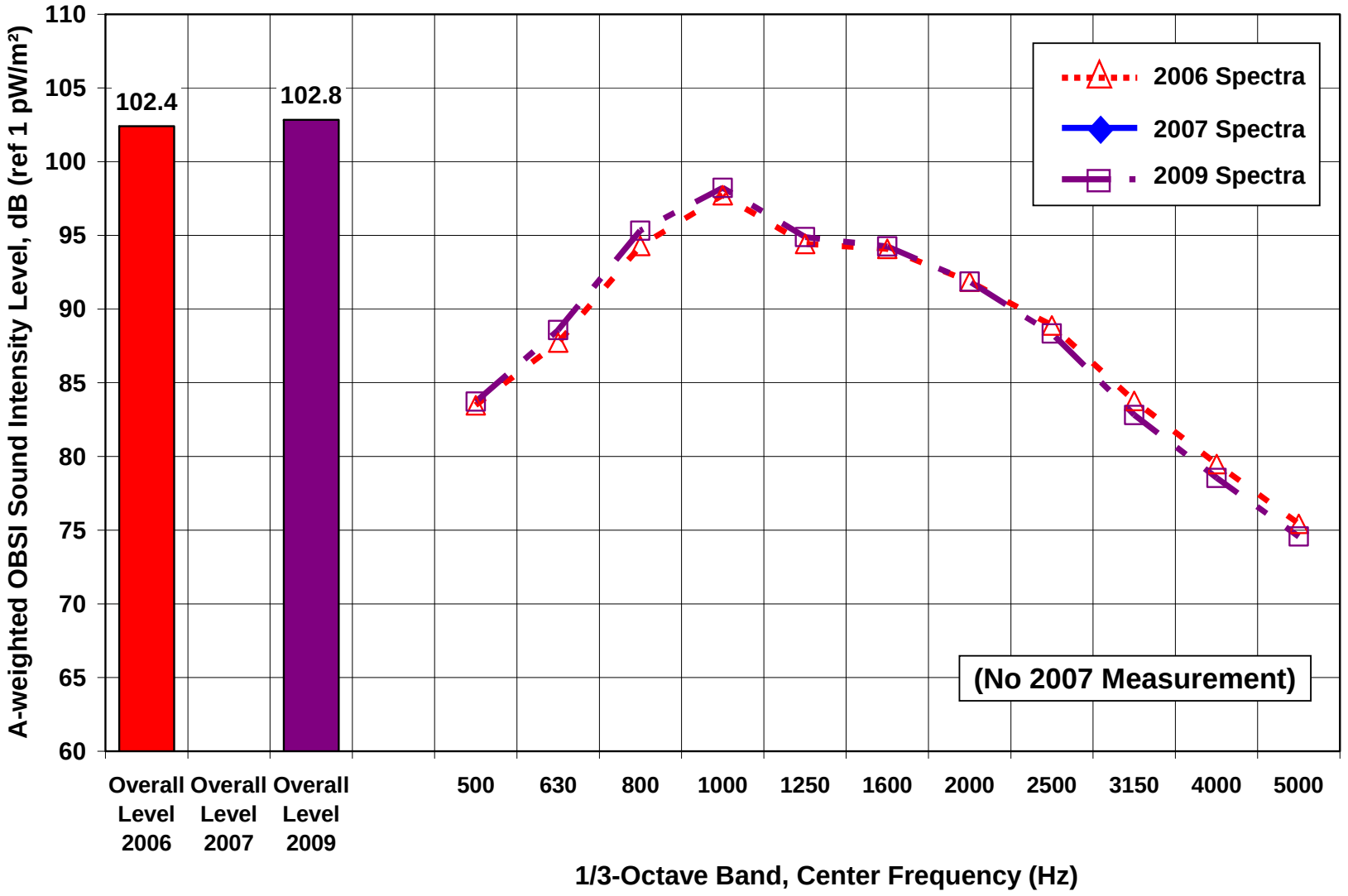
Nominal Surface: Concrete (Long. Grooving) **Construction Accepted:** 11/2001

OBSI?: Yes (6/18/09) **SPB?:** No **TA?:** No
Total Section Length: 4485 ft.
Distance from Begin to Wayside Microphone: n/a



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 15
OBSI (SRTT) Test Information

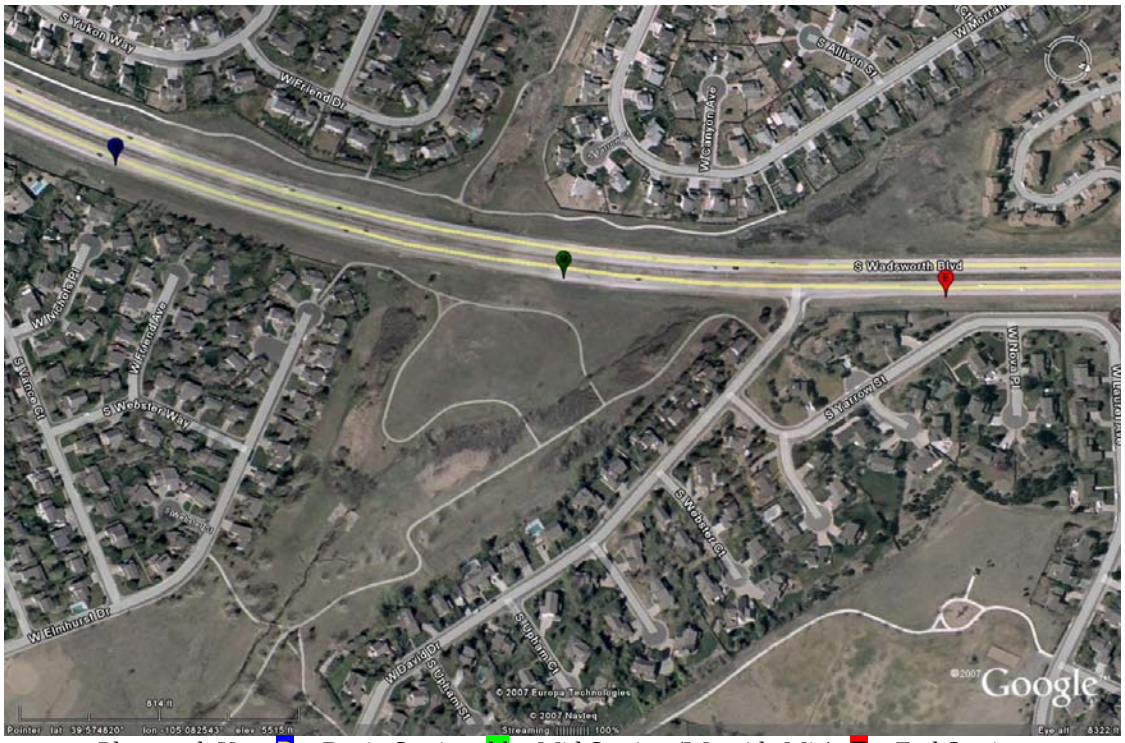


Site: 16
General Information

Highway: State Highway 121, Northbound
Location: Between Chatfield Ave. & Ken Caryl Ave., Littleton (80128)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.5741 / 105.0837 / 5580

Nominal Surface: Concrete (Carpet Drag) **Construction Accepted:** 8/2001

OBSI?: Yes (5/24/09) **SPB?:** No **TA?:** Yes
Total Section Length: 2422 ft.
Distance from Begin to Wayside Microphone: 1323 ft.



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 16
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (2:00 pm to 3:30 pm, 5/26/09)

Traffic Volumes and Speeds during Sample Period

	NB Lane 2 (Outside)	NB Lane 1 (Inside)	SB Lane 1 (Inside)	SB Lane 2 (Outside)
Distance from Mic (ft.)	50	62	104	116
Average Speed (mph)	58		65	
Automobile	640	666	614	490
Heavy Truck	4	0	3	2
Medium Truck	14	3	3	9
Bus	2	2	0	4
Motorcycle	3	0	1	0
Auto + 1-Axle Trlr.	4	2	3	1
Auto + 2-Axle Trlr.	1	2	1	0
M. Trk. + 1-Axle Trlr.	0	0	1	0
M. Trk. + 2-Axle Trlr.	0	0	0	0

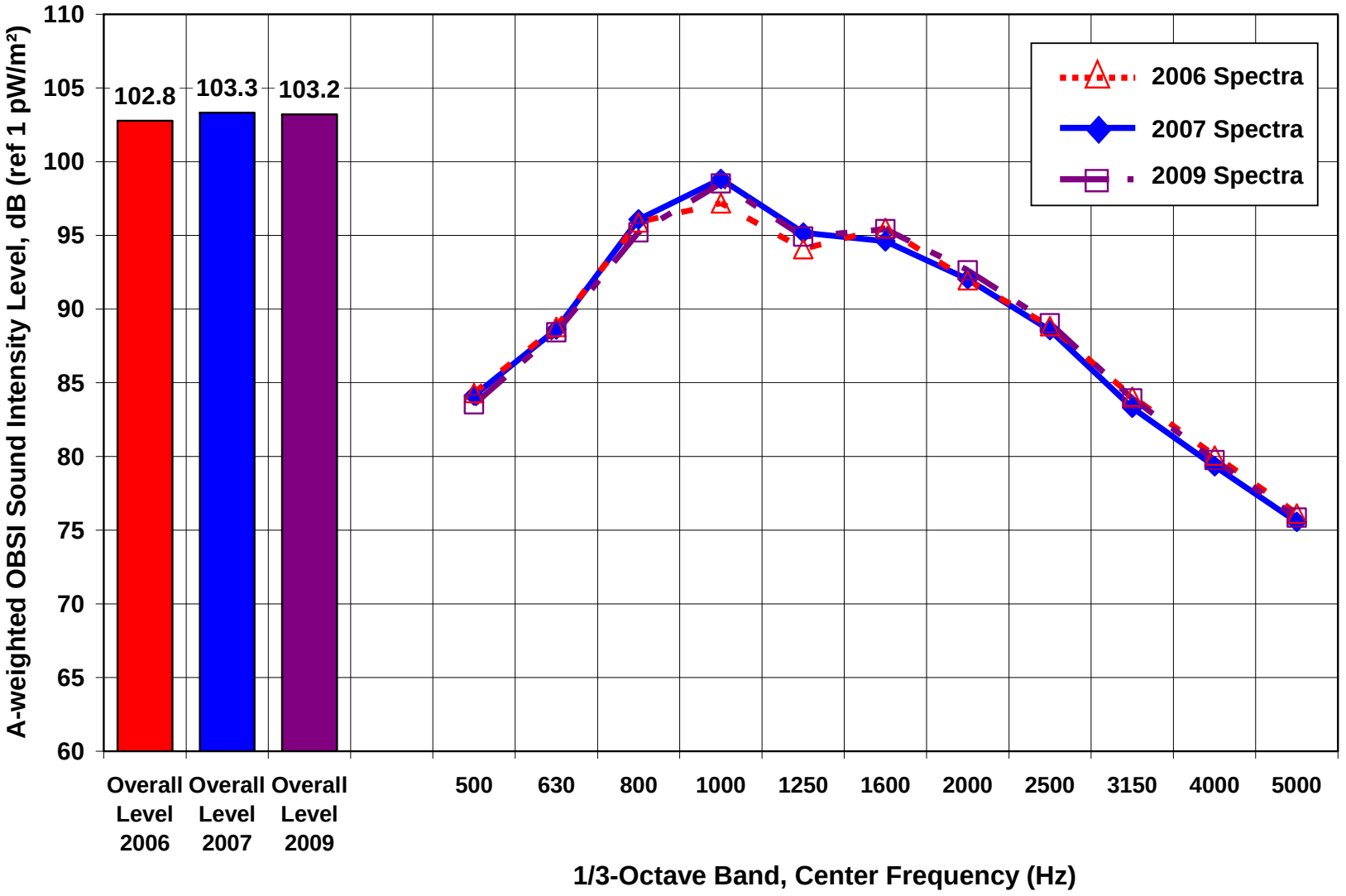
** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	70.2	70.0	70.5	71.1	71.3	70.8	**70.7**
25 × 4	75.1	74.8	75.5	75.9	76.0	75.3	**75.4**
50 × 12	72.4	72.4	72.8	73.2	73.1	72.4	**72.7**

Site: 16

OBSI (SRTT) Test Information



Site: 17
General Information

Highway: Interstate 70, Westbound
Location: Between SH 13 & US 6/24, Rifle (81650)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.5205 / 107.8229 / 5290

Nominal Surface: Concrete (Diamond Grinding) **Construction Accepted:** 11/2005

OBSI?: Yes (6/13/09) **SPB?:** No **TA?:** Yes
Total Section Length: 6368 ft.
Distance from Begin to Wayside Microphone: 1177 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 17
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (11:00 am to 12:30 pm, 6/14/09)

Traffic Volumes and Speeds during Sample Period

	WB Lane 2 (Outside)	WB Lane 1 (Inside)	EB Lane 1 (Inside)	EB Lane2 (Outside)
Distance from Mic (ft.)	50	62	174	186
Average Speed (mph)	76		75	
Automobile	543	224	281	549
Heavy Truck	68	5	9	84
Medium Truck	19	5	0	13
Bus	5	1	0	0
Motorcycle	5	6	1	11
Auto + 1-Axle Trlr.	18	2	3	24
Auto + 2-Axle Trlr.	17	3	7	26
M. Trk. + 1-Axle Trlr.	0	0	0	0
M. Trk. + 2-Axle Trlr.	9	0	1	10

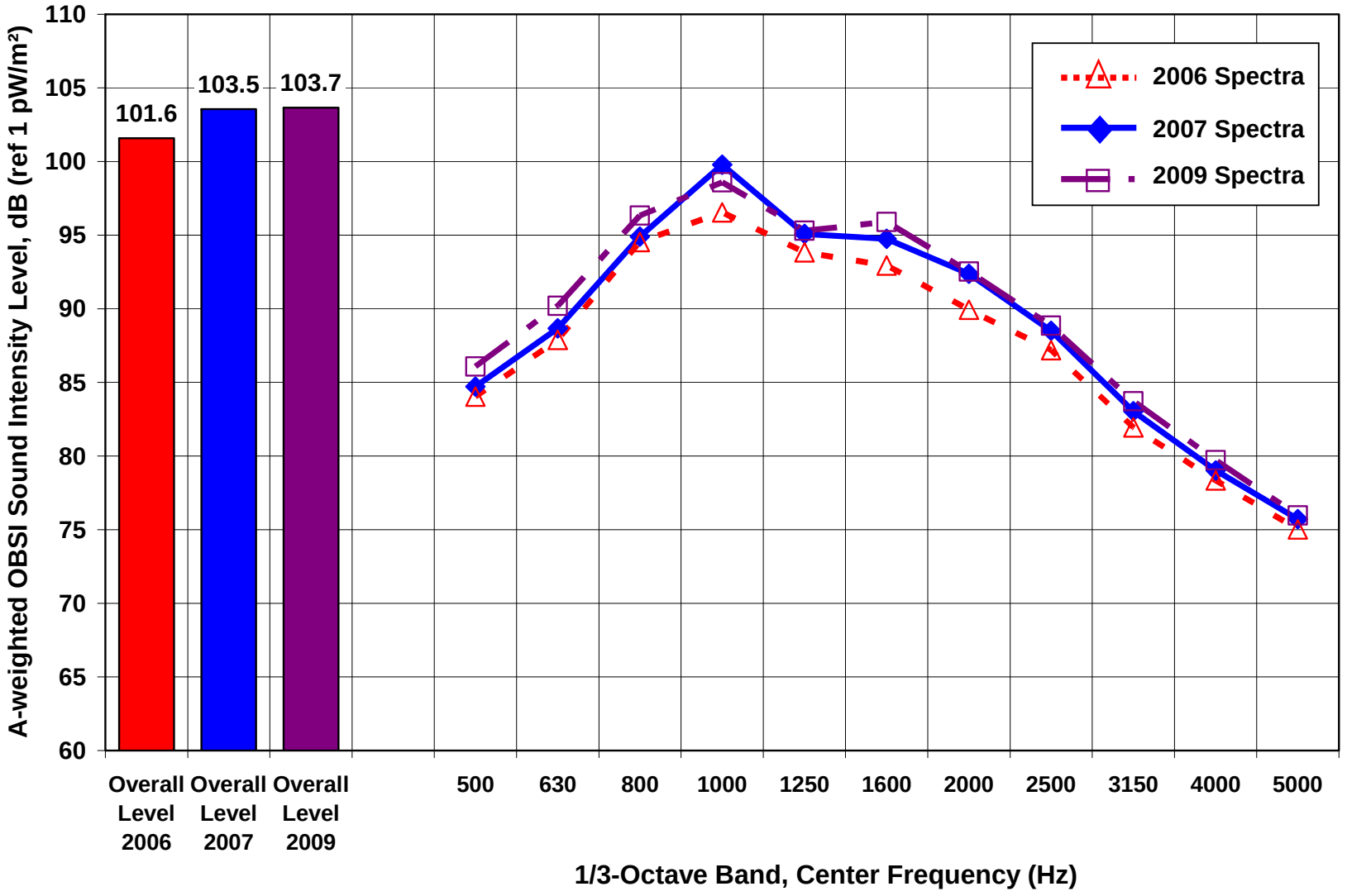
** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	74.7	74.5	73.4	74.2	73.5	74.8	**74.2**
25 × 4	79.5	79.4	78.3	79.3	78.6	79.8	**79.2**
50 × 12	76.1	75.8	74.8	75.7	75.0	76.2	**75.6**

Site: 17

OBSI (SRTT) Test Information



Site: 18
General Information

Highway: US Highway 285, Northbound
Location: Between Turkey Creek Rd. & Chamberlain Rd., Indian Hills (80465)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.598 / 105.2255 / 7050

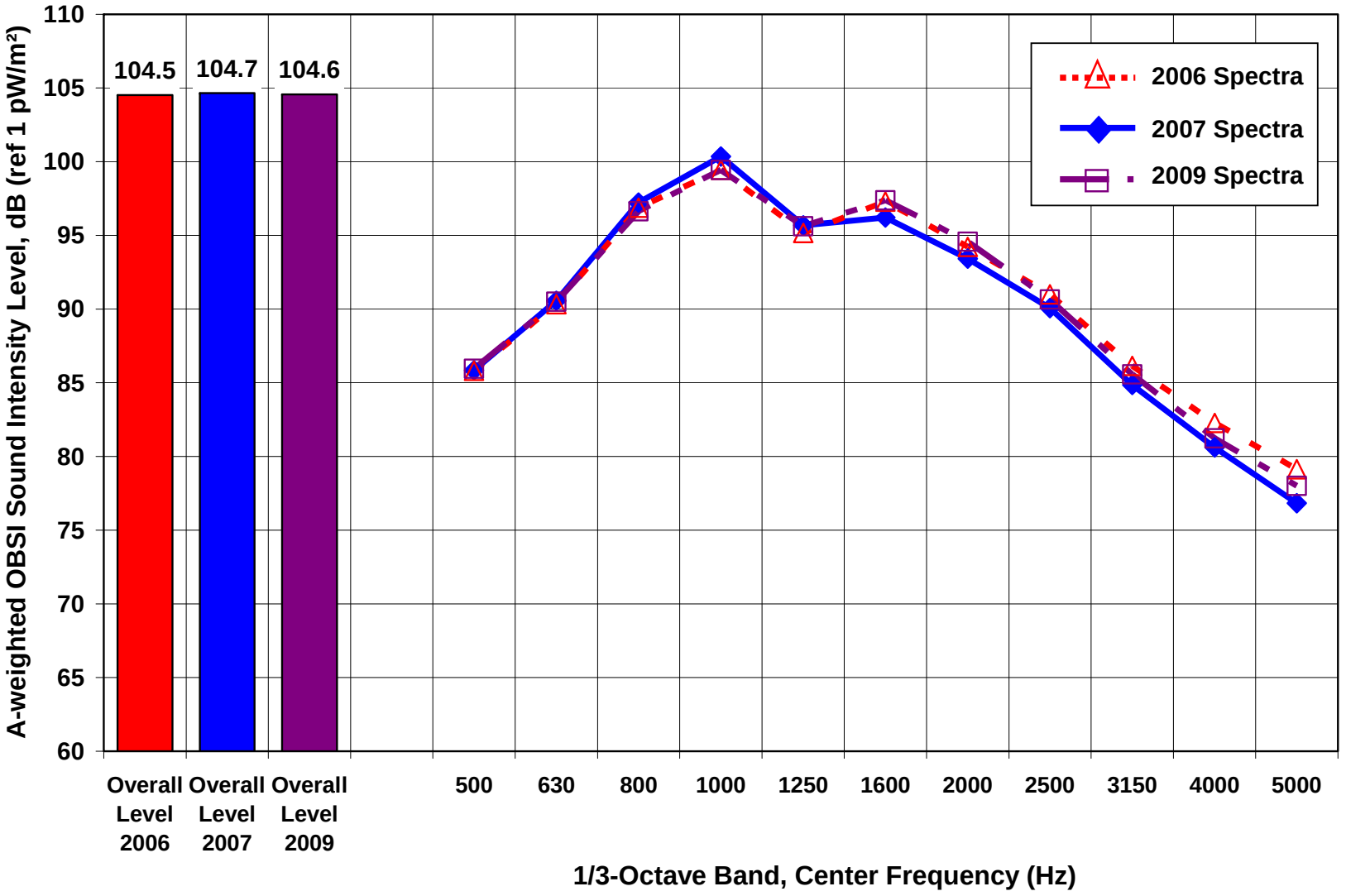
Nominal Surface: Concrete (Diamond Grinding) **Construction Accepted:** 10/1999

OBSI?: Yes (5/25/09) **SPB?:** No **TA?:** No
Total Section Length: 2069 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 18

OBSI (SRTT) Test Information



Site: 19
General Information

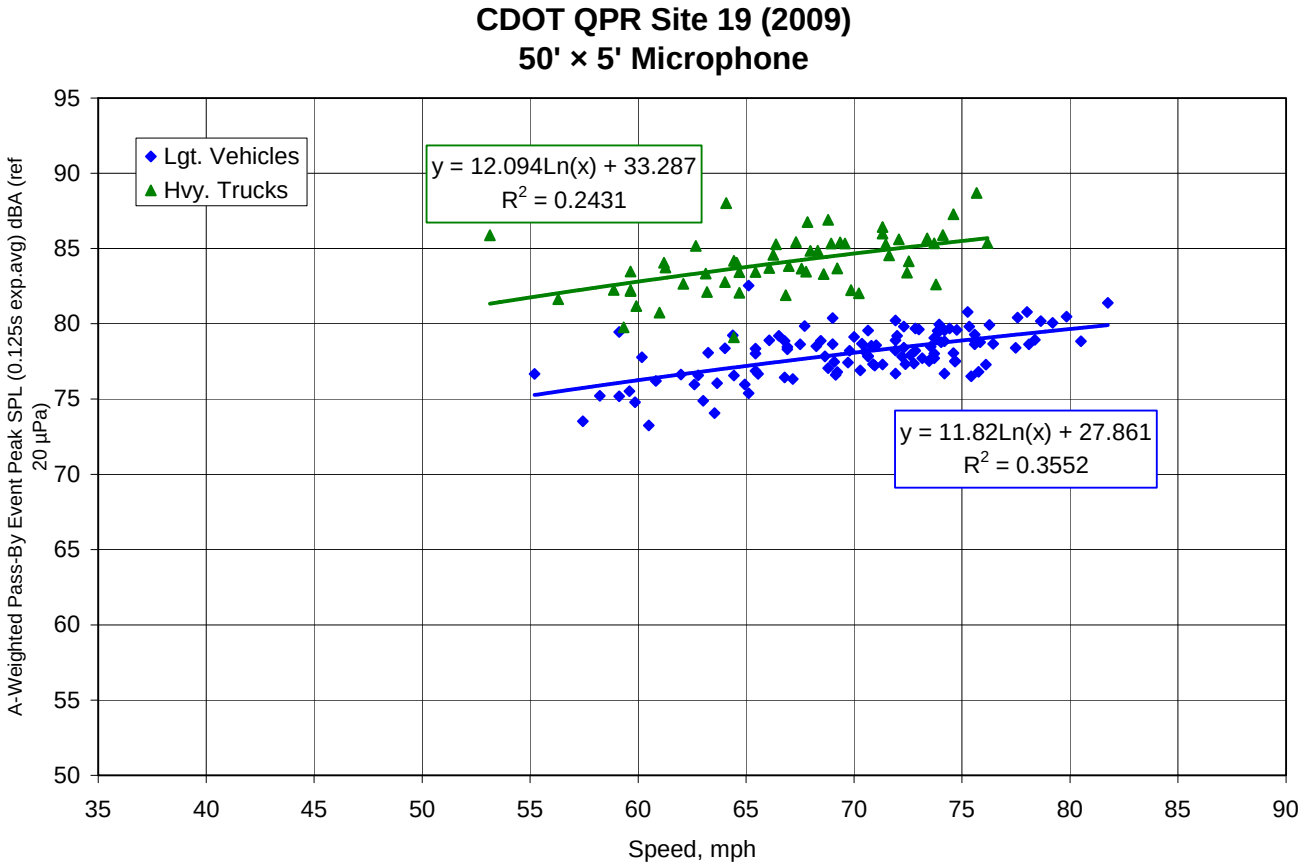
Highway: Interstate 70, Westbound
Location: Between Camino Dorado Rd. & Trail Gulch Rd., Gypsum (81637)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.6528 / 106.8823 / 6630

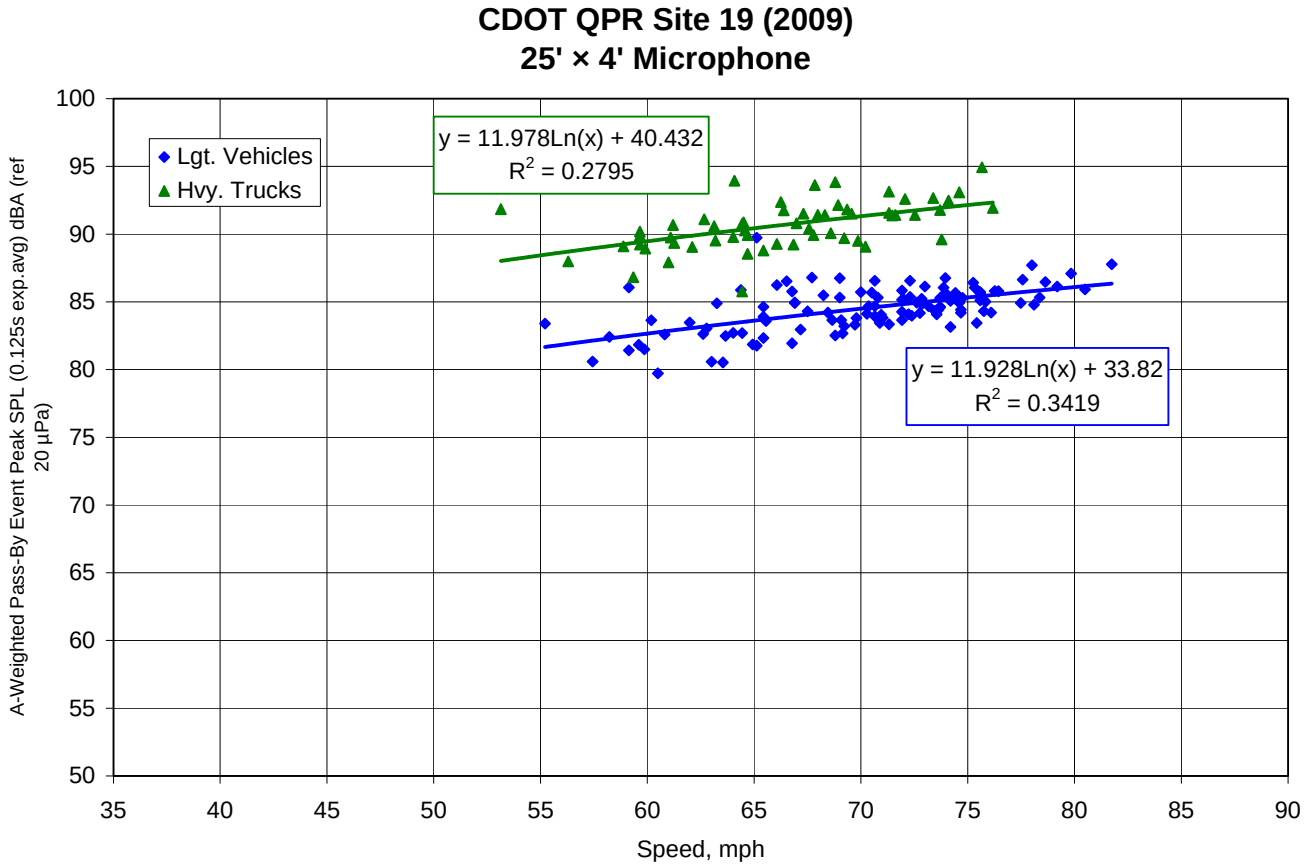
Nominal Surface: SMA **Construction Accepted:** 8/1996

OBSI?: Yes (6/8/09) **SPB?:** Yes **TA?:** No
Total Section Length: 3122 ft.
Distance from Begin to Wayside Microphone: 443 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 19
SPB Wayside Test Information

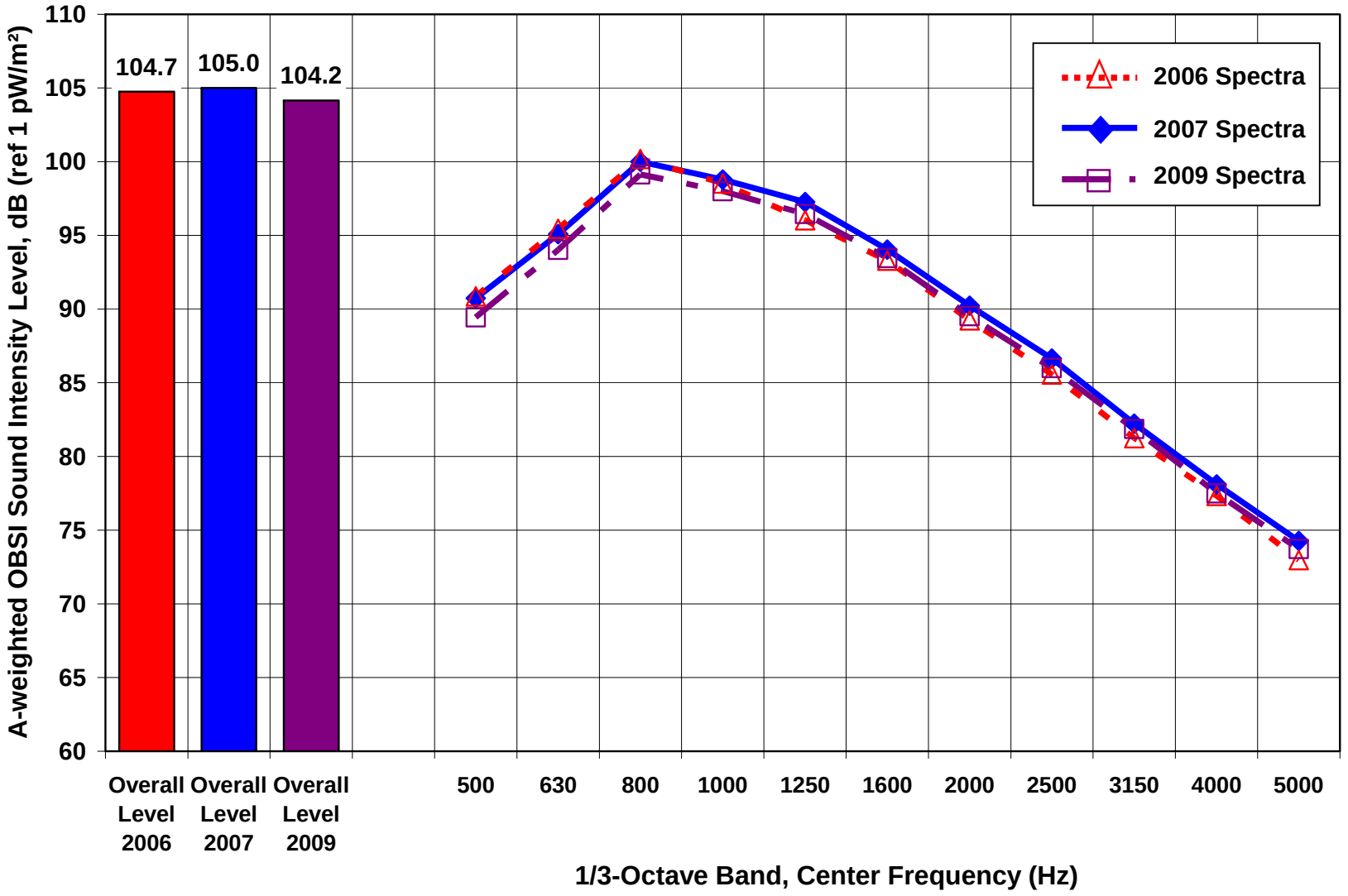




Average A-weighted SPB Level at 60 mph (dB ref 20 µPa), SPBI

Vehicle	50×5 microphone	25×4 microphone
Lgt. Vehicle (Car)	**76.3**	**82.7**
Hvy. Truck	**82.8**	**89.5**

Site: 19
OBSI (SRTT) Test Information



Site: 20
General Information

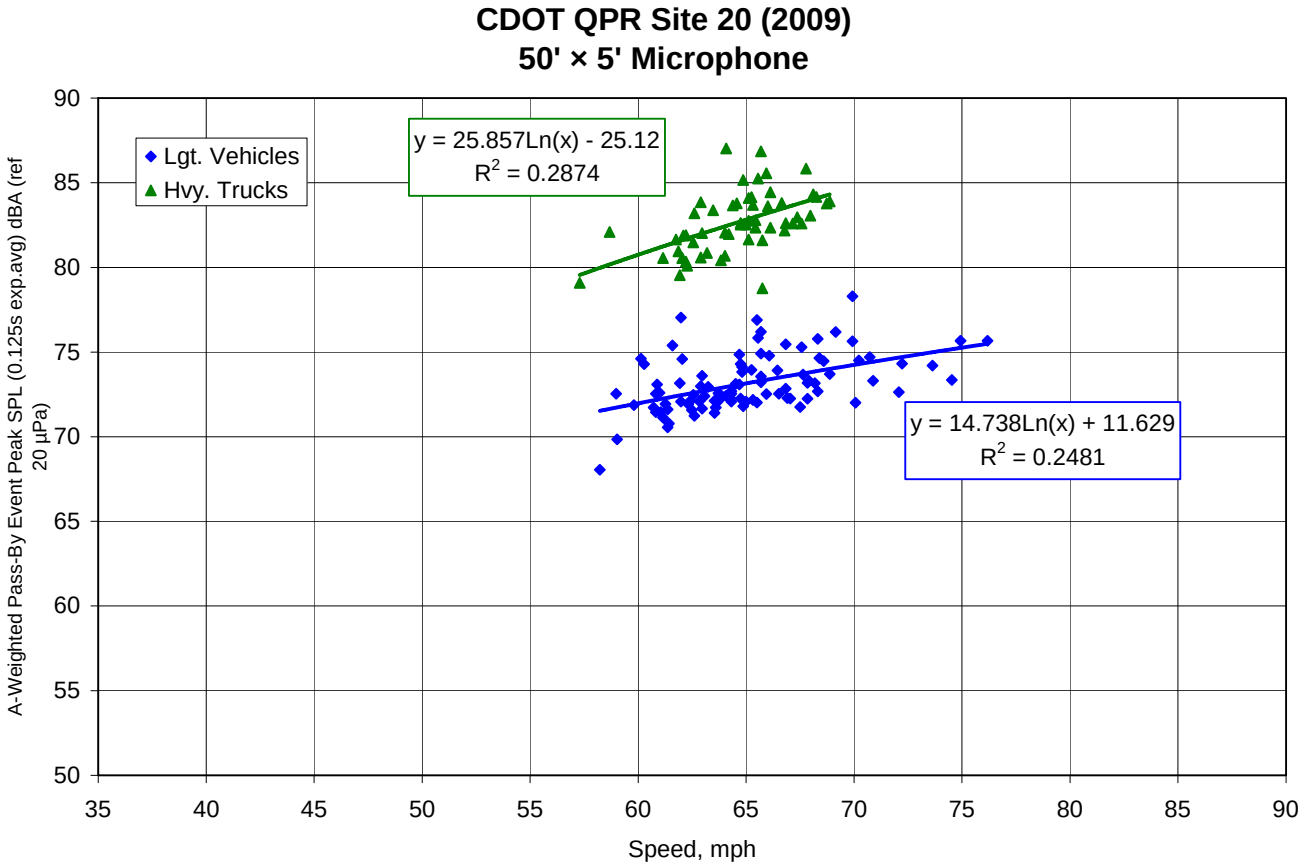
Highway: US Highway 40, Westbound
Location: Between CR-8 & SH 94, Kit Carson (80862)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 38.8328 / 103.054 / 4520

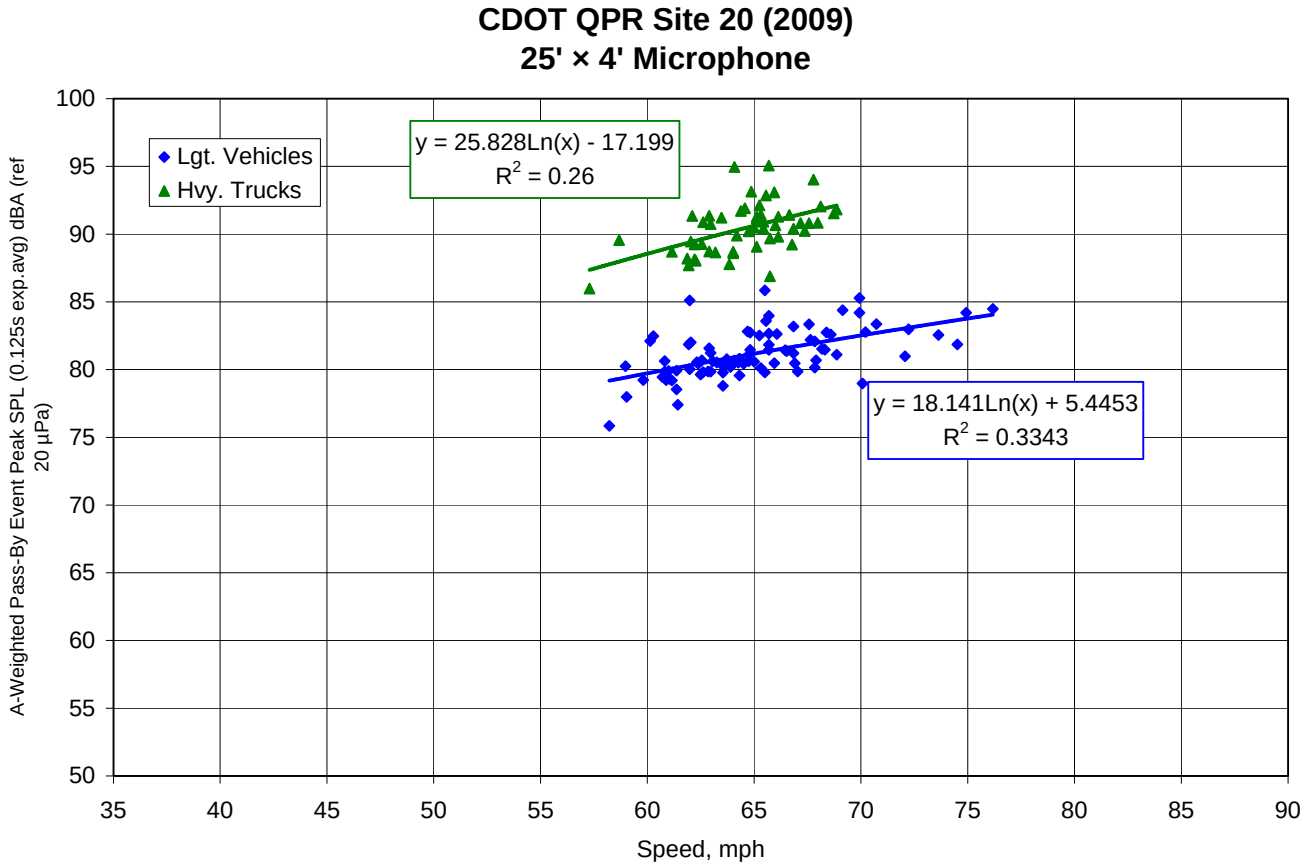
Nominal Surface: Concrete **Construction Accepted:** 4/2002

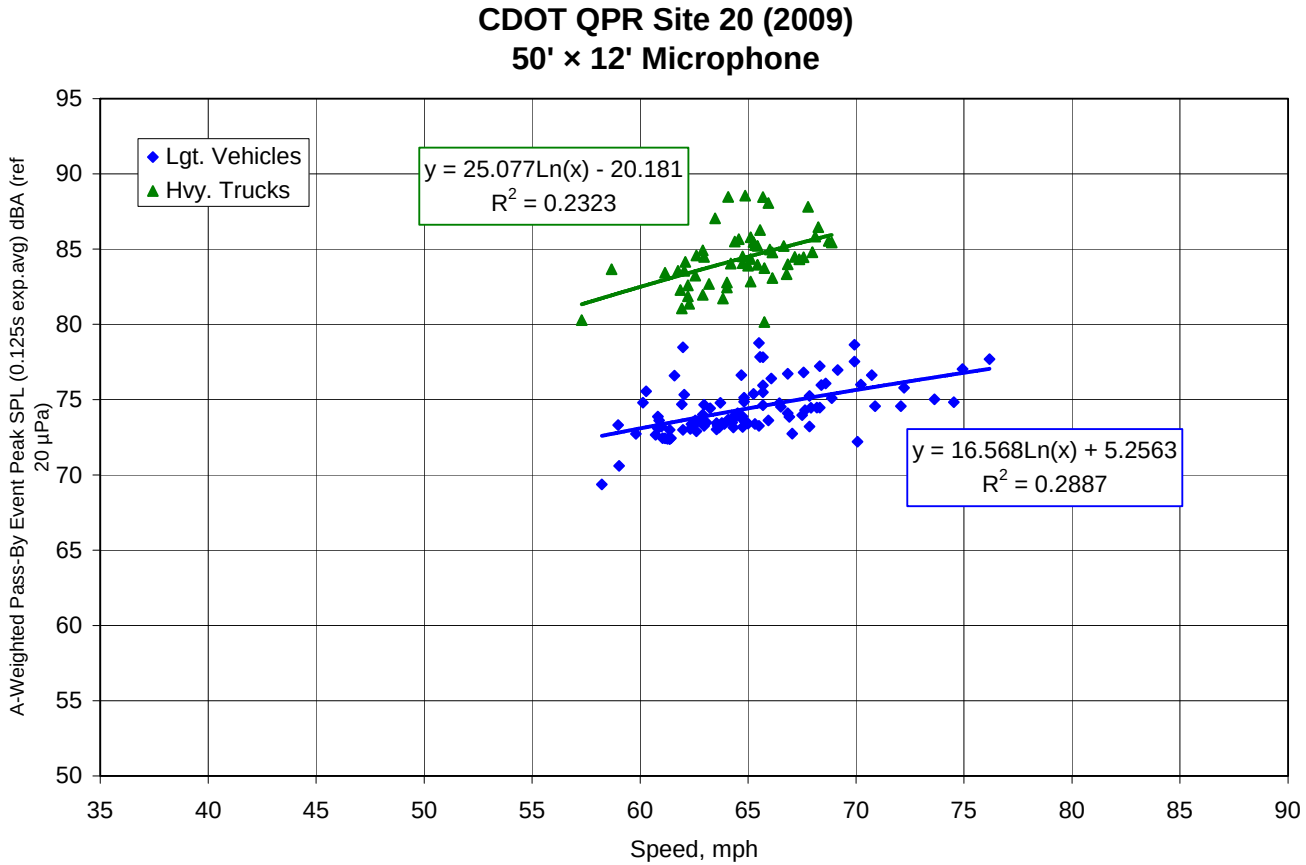
OBSI?: Yes (5/8/09) **SPB?:** Yes **TA?:** No
Total Section Length: 5241 ft.
Distance from Begin to Wayside Microphone: 2668 ft.

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 20
SPB Wayside Test Information




CDOT QPR Site 20 (2009)
25' × 4' Microphone
Lgt. Vehicles
Hvy. Trucks
y = 25.828Ln(x) - 17.199
R2 = 0.26
y = 18.141Ln(x) + 5.4453
R2 = 0.3343
A-Weighted Pass-By Event Peak SPL (0.125s exp.avg) dBA (ref 20 µPa)
Speed, mph
100
95
90
85
80
75
70
65
60
55
50
35
40
45
50
55
60
65
70
75
80
85
90

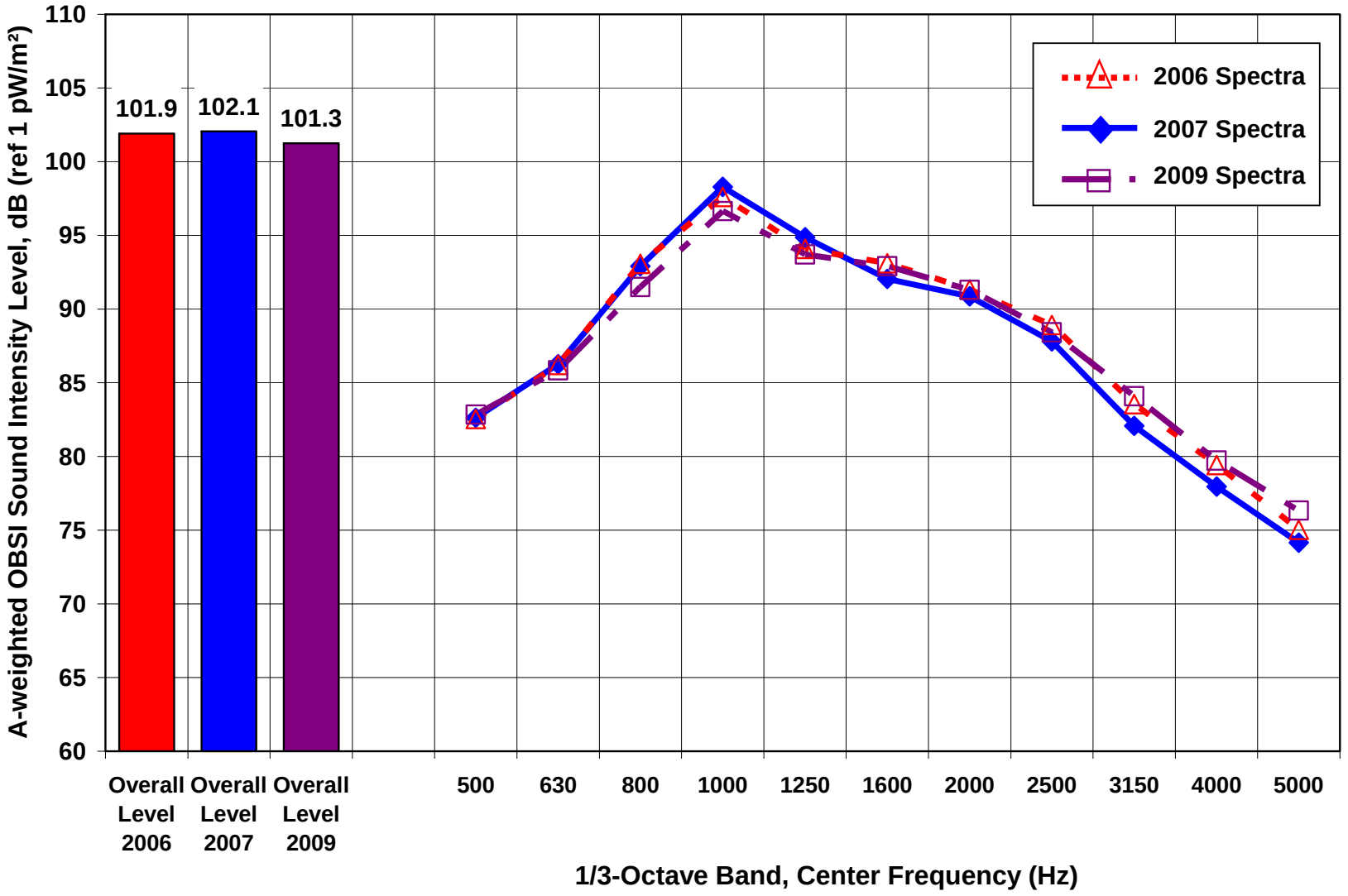


Average A-weighted SPB Level at 60 mph (dB ref 20 µPa), SPBI

Vehicle	50×5 microphone	25×4 microphone	50×12 microphone
Lgt. Vehicle (Car)	**72.0**	**79.7**	**73.1**
Hvy. Truck	**80.7**	**88.5**	**82.5**

Site: 20

OBSI (SRTT) Test Information

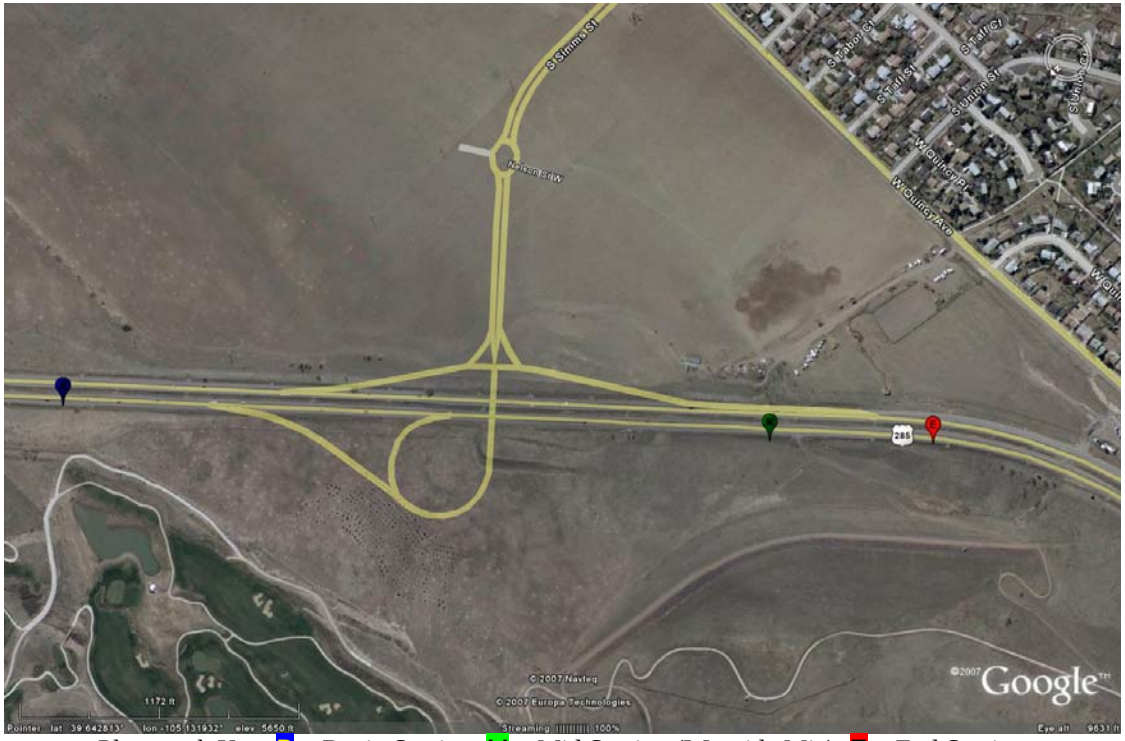


Site: 21
General Information

Highway: US Highway 285, Southbound
Location: Between Kipling Pkwy. & C-470, Morrison (80227)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.6438 / 105.1318 / 5700

Nominal Surface: Asphalt (S, 3/4") **Construction Accepted:** 11/2003

OBSI?: Yes (5/24/09) **SPB?:** No **TA?:** Yes
Total Section Length: 3599 ft.
Distance from Begin to Wayside Microphone: 1451 ft.



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 21
Time-Averaged Wayside Test Information

Sampling Periods: 2 (TA and SPB+)

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (9:50 am to 11:20 am, 5/27/09)

Traffic Volumes and Speeds during Sample Period

	SB Lane 2 (Outside)	SB Lane 1 (Inside)	NB Lane 1 (Inside)	NB Lane2 (Outside)
Distance from Mic (ft.)	50	62	110	122
Average Speed (mph)	63		65	
Automobile	705	214	265	719
Heavy Truck	17	0	3	16
Medium Truck	24	3	4	34
Bus	1	0	0	0
Motorcycle	3	1	0	9
Auto + 1-Axle Trlr.	4	0	2	9
Auto + 2-Axle Trlr.	2	1	1	4
M. Trk. + 1-Axle Trlr.	0	0	0	1
M. Trk. + 2-Axle Trlr.	0	0	0	2

** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	74.5	74.4	74.4	74.2	73.5	73.3	**74.0**
25 × 4	78.2	78.2	78.2	78.1	77.5	77.3	**77.9**
50 × 12	74.9	74.8	74.9	74.9	74.5	74.4	**74.7**

Sample Period 2 (SPB +) – 5 Blocks @ 15 min ea. = 75 min. (9:10 am to 10:25 am, 10/15/09)

Traffic Volumes and Speeds during Sample Period

	SB Lane 2 (Outside)	SB Lane 1 (Inside)	NB Lane 1 (Inside)	NB Lane2 (Outside)
Distance from Mic (ft.)	50	62	110	122
Average Speed (mph)	63		66	
Automobile	578	266	258	594
Heavy Truck	13	0	3	23
Medium Truck	23	4	2	24
Bus	3	0	1	4
Motorcycle	3	0	2	4
Auto + 1-Axle Trlr.	2	0	0	8
Auto + 2-Axle Trlr.	3	0	2	5
M. Trk. + 1-Axle Trlr.	0	0	0	0
M. Trk. + 2-Axle Trlr.	1	0	0	1

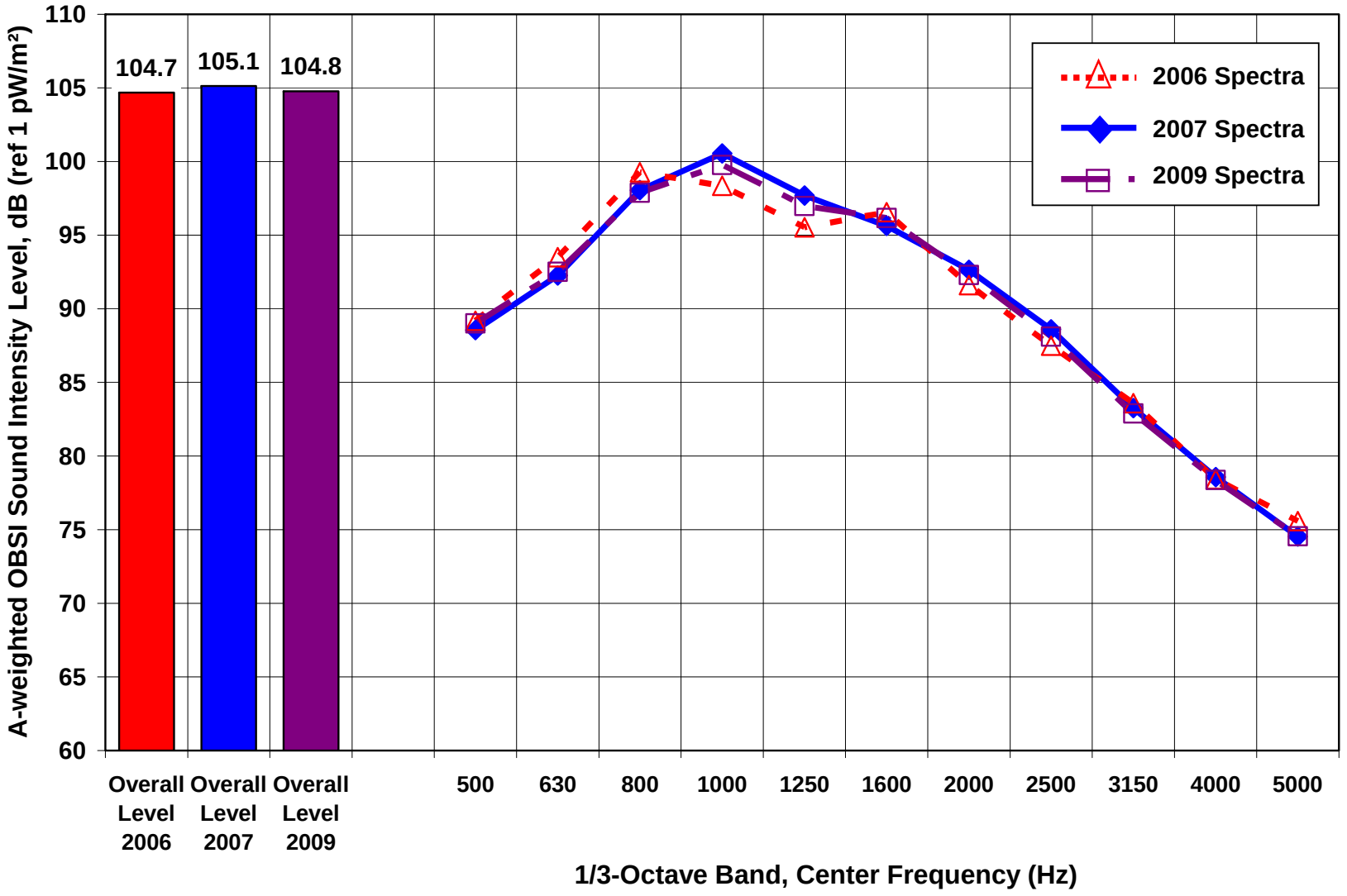
** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	74.4	75.4	74.4	74.7	74.3	74.7	**74.4**
100 × 5	70.9	71.4	70.2	70.6	69.9	70.6	**70.9**
200 × 5	65.7	64.5	63.8	64.5	63.4	64.4	**65.7**

Site: 21

OBSI (SRTT) Test Information

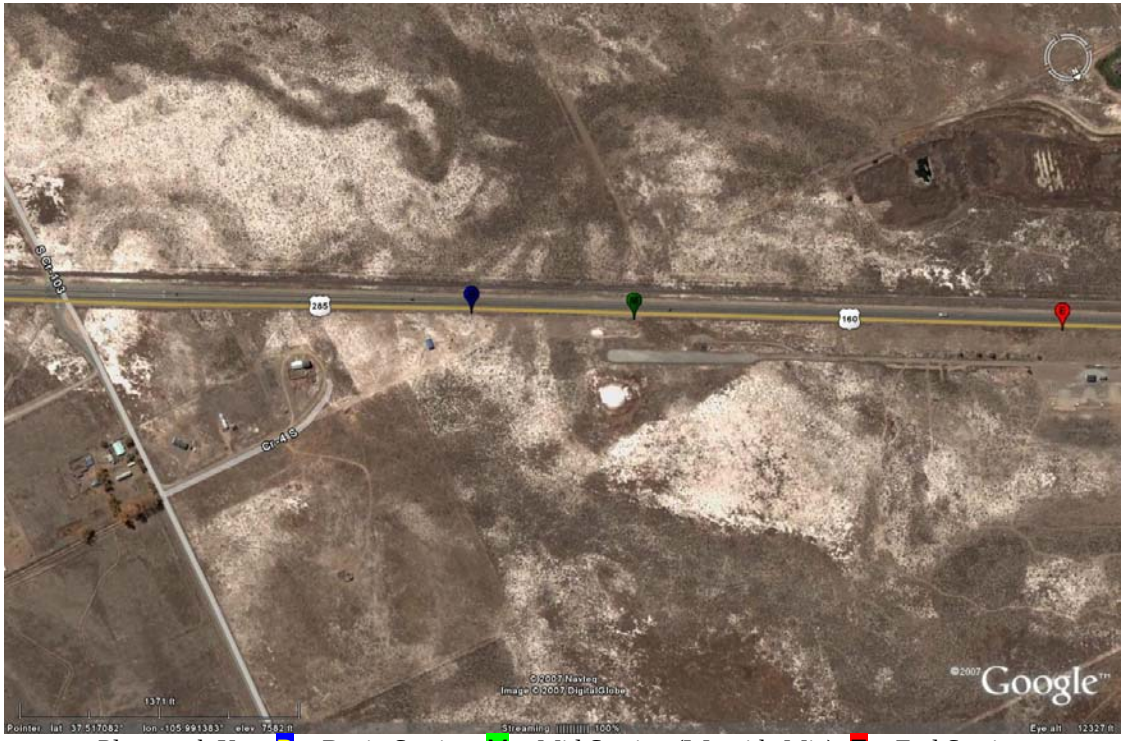


Site: 22
General Information

Highway: US Highway 160, Westbound
Location: Between CR-103 & Threemile Rd., Alamosa (81101)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 37.5177 / 105.9948 / 7610

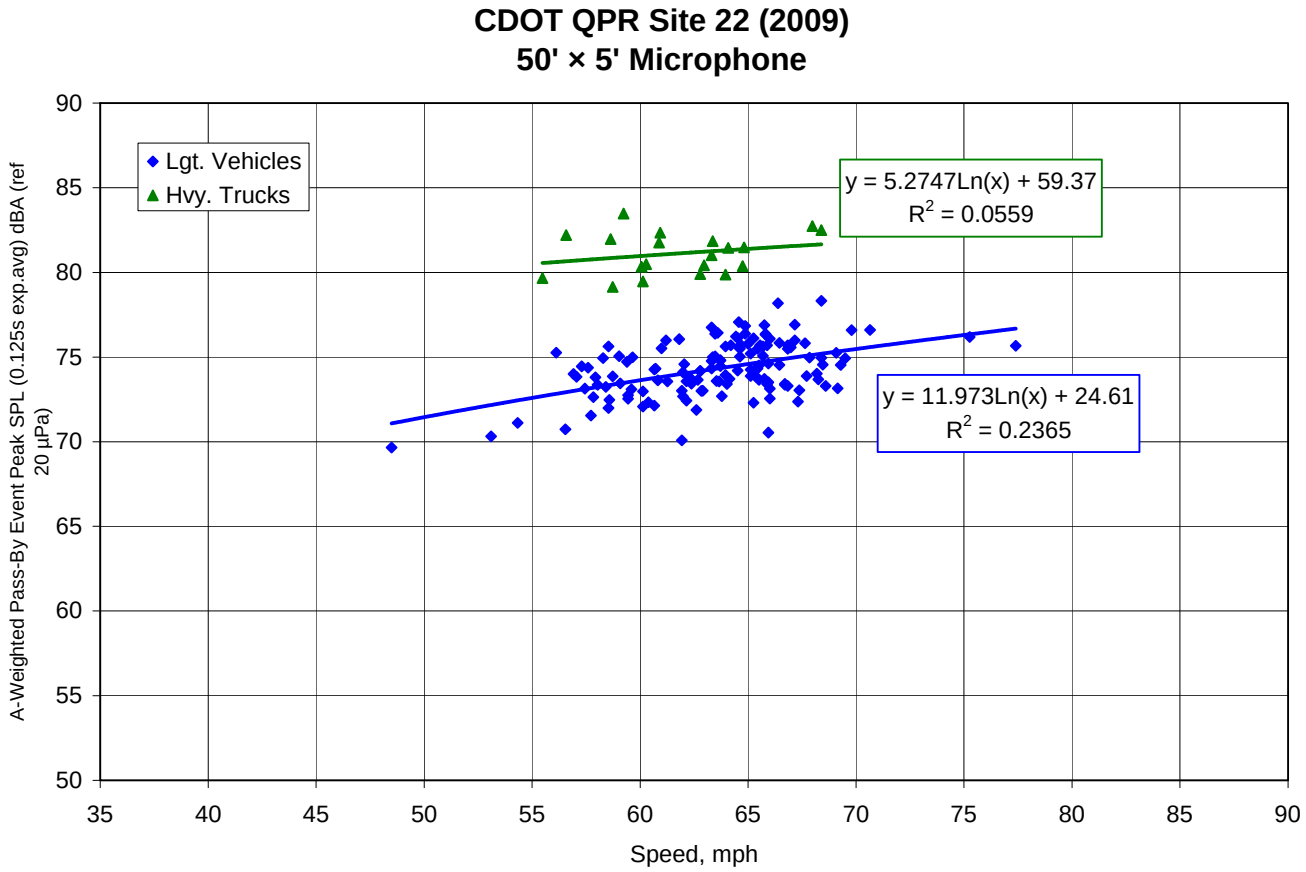
Nominal Surface: Asphalt **Construction Accepted:** 10/1999

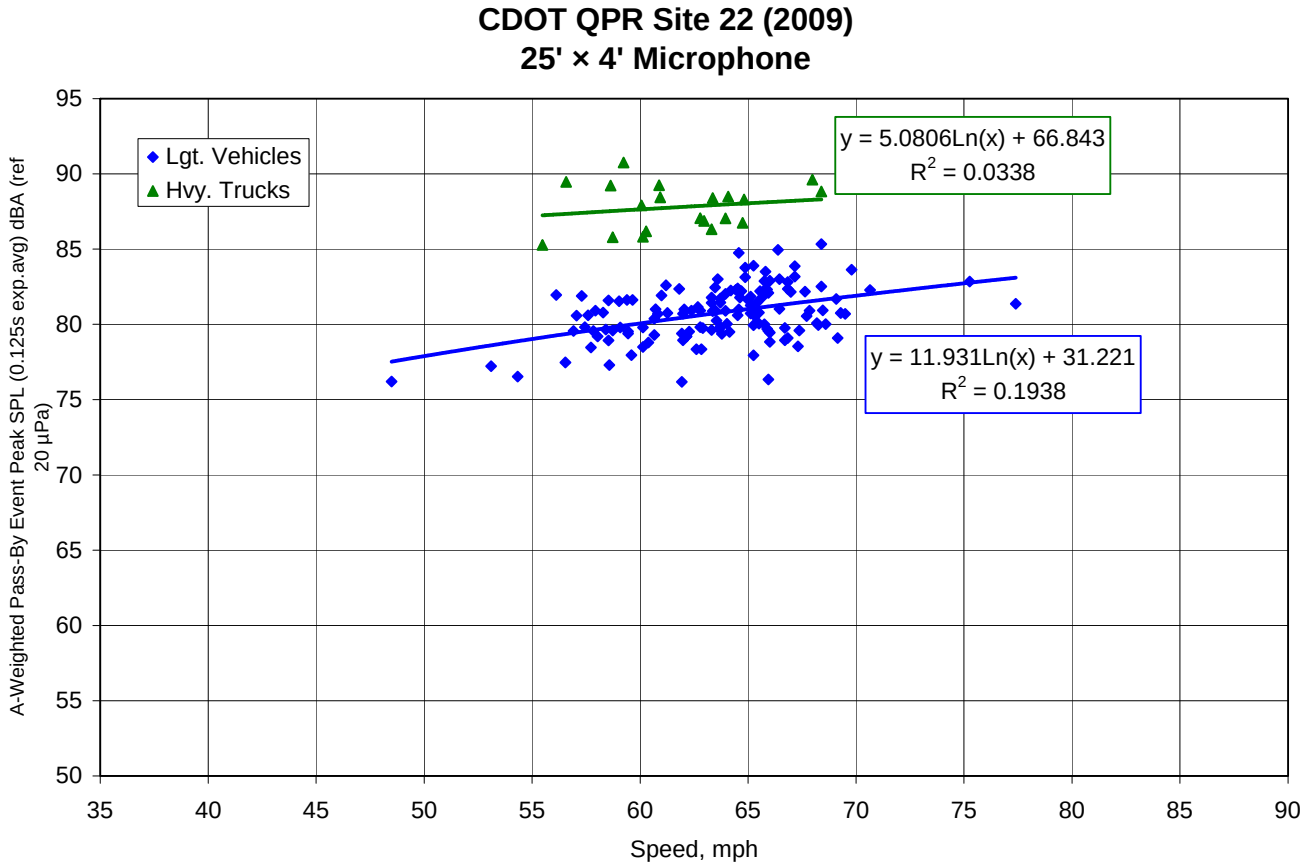
OBSI?: Yes (6/17/09) **SPB?:** Yes **TA?:** No
Total Section Length: 2930 ft.
Distance from Begin to Wayside Microphone: 796 ft.

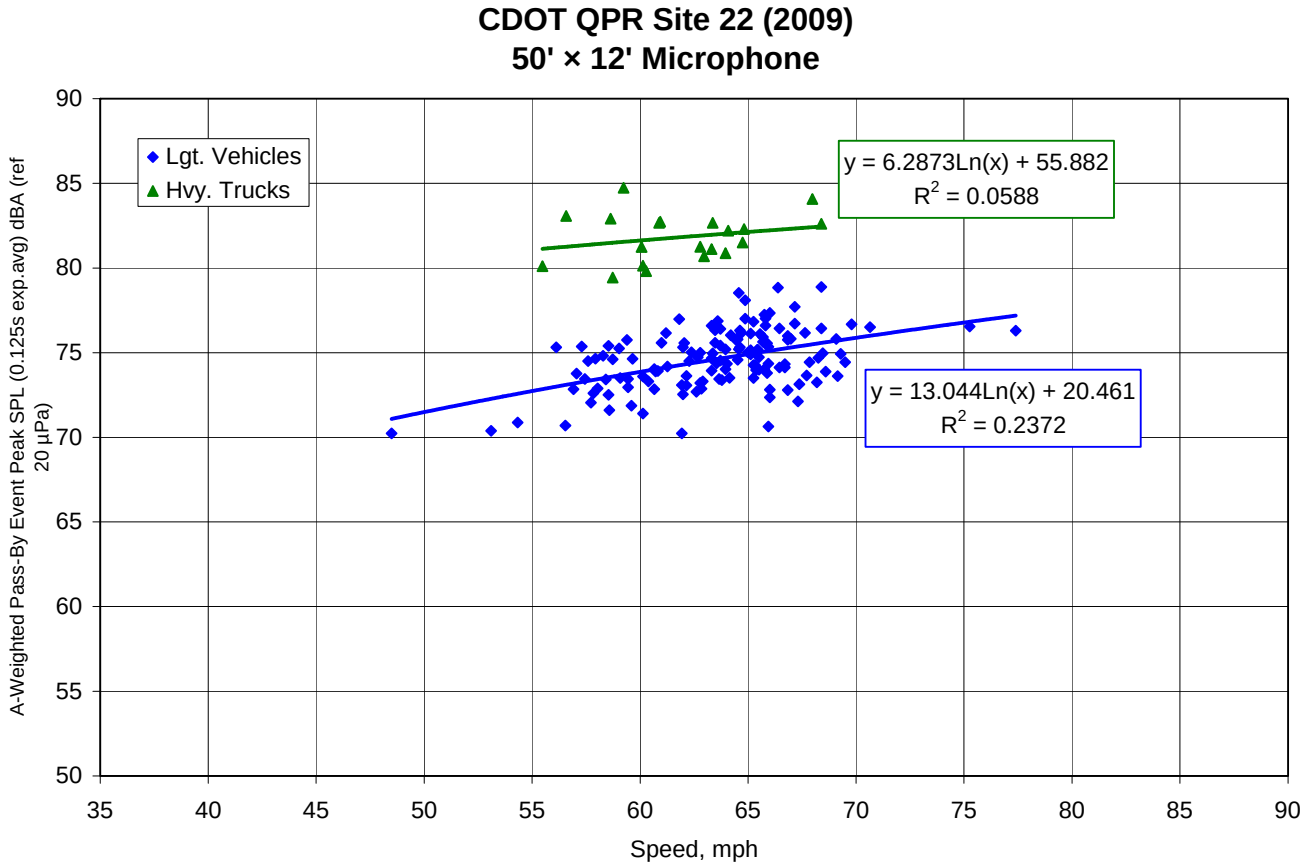


Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 22
SPB Wayside Test Information




CDOT QPR Site 22 (2009)
25' × 4' Microphone
Lgt. Vehicles
Hvy. Trucks
y = 5.0806Ln(x) + 66.843
R2 = 0.0338
y = 11.931Ln(x) + 31.221
R2 = 0.1938
A-Weighted Pass-By Event Peak SPL (0.125s exp.avg) dBA (ref 20 µPa)
Speed, mph
95
90
85
80
75
70
65
60
55
50
35
40
45
50
55
60
65
70
75
80
85
90

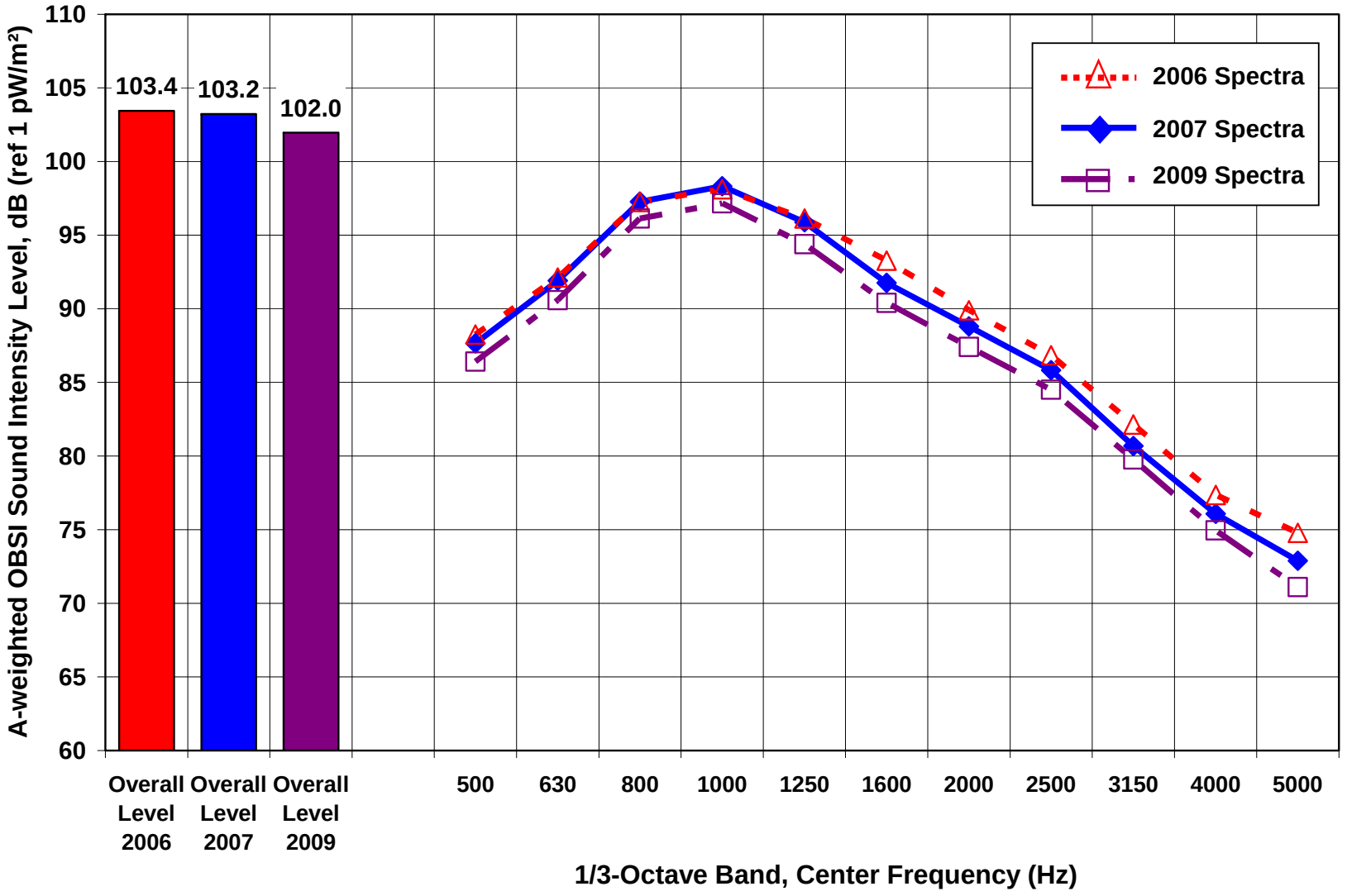


Average A-weighted SPB Level at 60 mph (dB ref 20 µPa), SPBI

Vehicle	50×5 microphone	25×4 microphone	50×12 microphone
Lgt. Vehicle (Car)	**73.6**	**80.1**	**73.9**
Hvy. Truck	**81.0**	**87.6**	**81.6**

Site: 22

OBSI (SRTT) Test Information



Site: 23
General Information

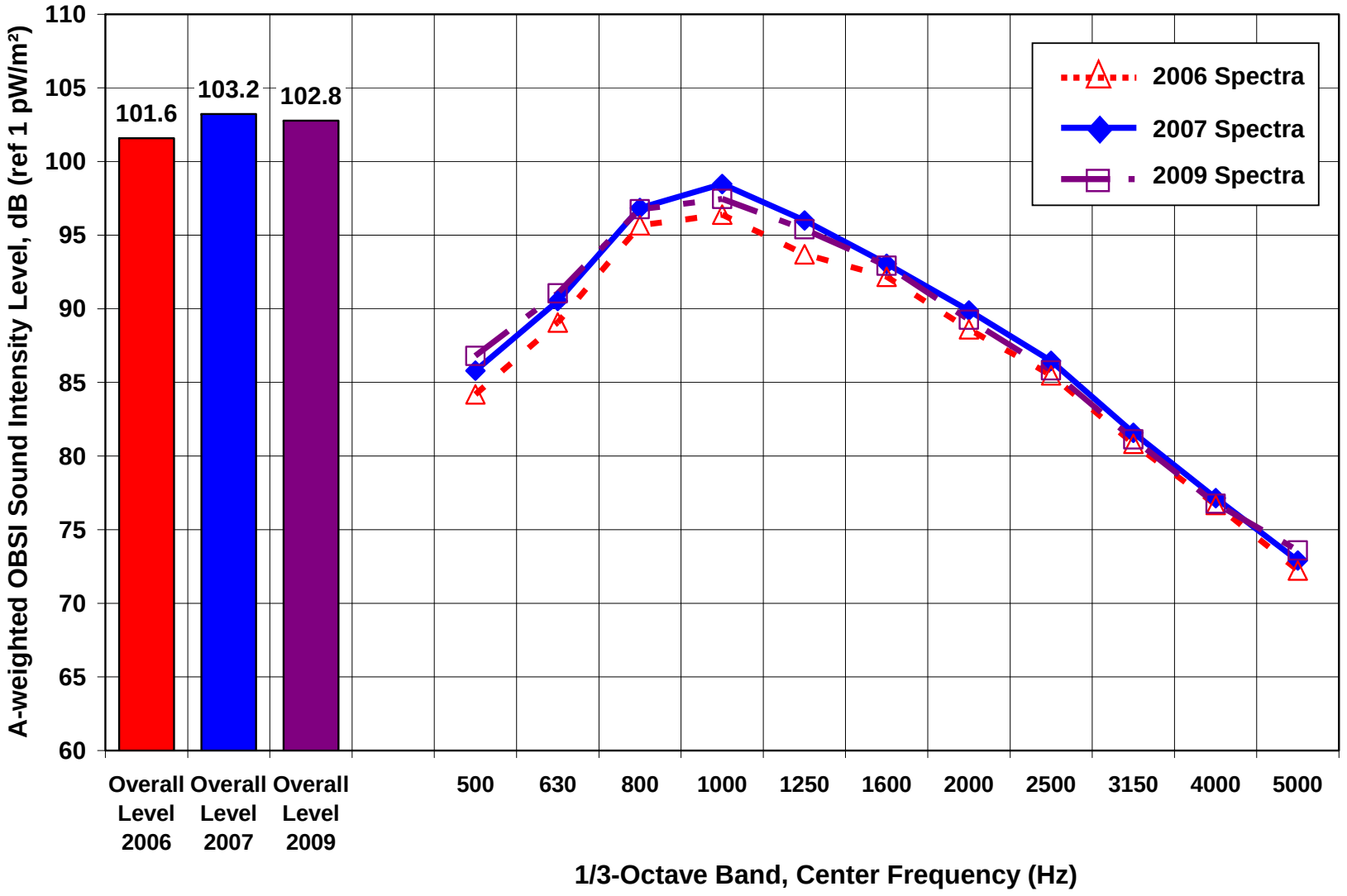
Highway: Interstate 70, Eastbound
Location: Between 23 Rd. & 24 Rd., Grand Junction (81505)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.1138 / 108.6193 / 4560

Nominal Surface: Asphalt **Construction Accepted:** 10/2004

OBSI?: Yes (6/10/09) **SPB?:** No **TA?:** No
Total Section Length: 3623 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 23
OBSI (SRTT) Test Information



Site: 24
General Information

Highway: Interstate 76, Westbound
Location: Between CR-49 & SH 52, Hudson (80642)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 40.0942 / 104.6143 / 4940

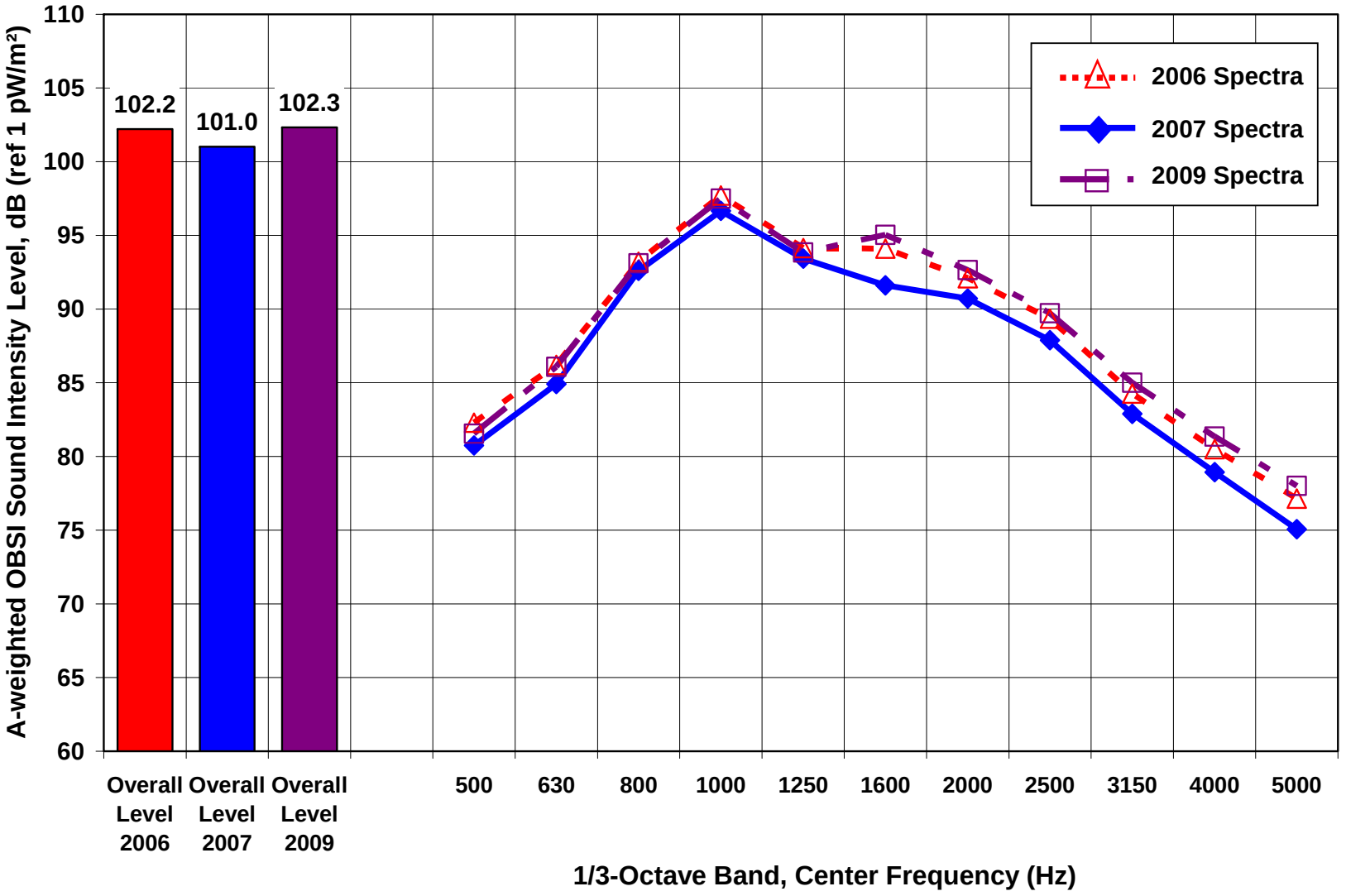
Nominal Surface: Concrete **Construction Accepted:** 3/2001

OBSI?: Yes (5/21/09) **SPB?:** No **TA?:** No
Total Section Length: 3345 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 24

OBSI (SRTT) Test Information



Site: 25
General Information

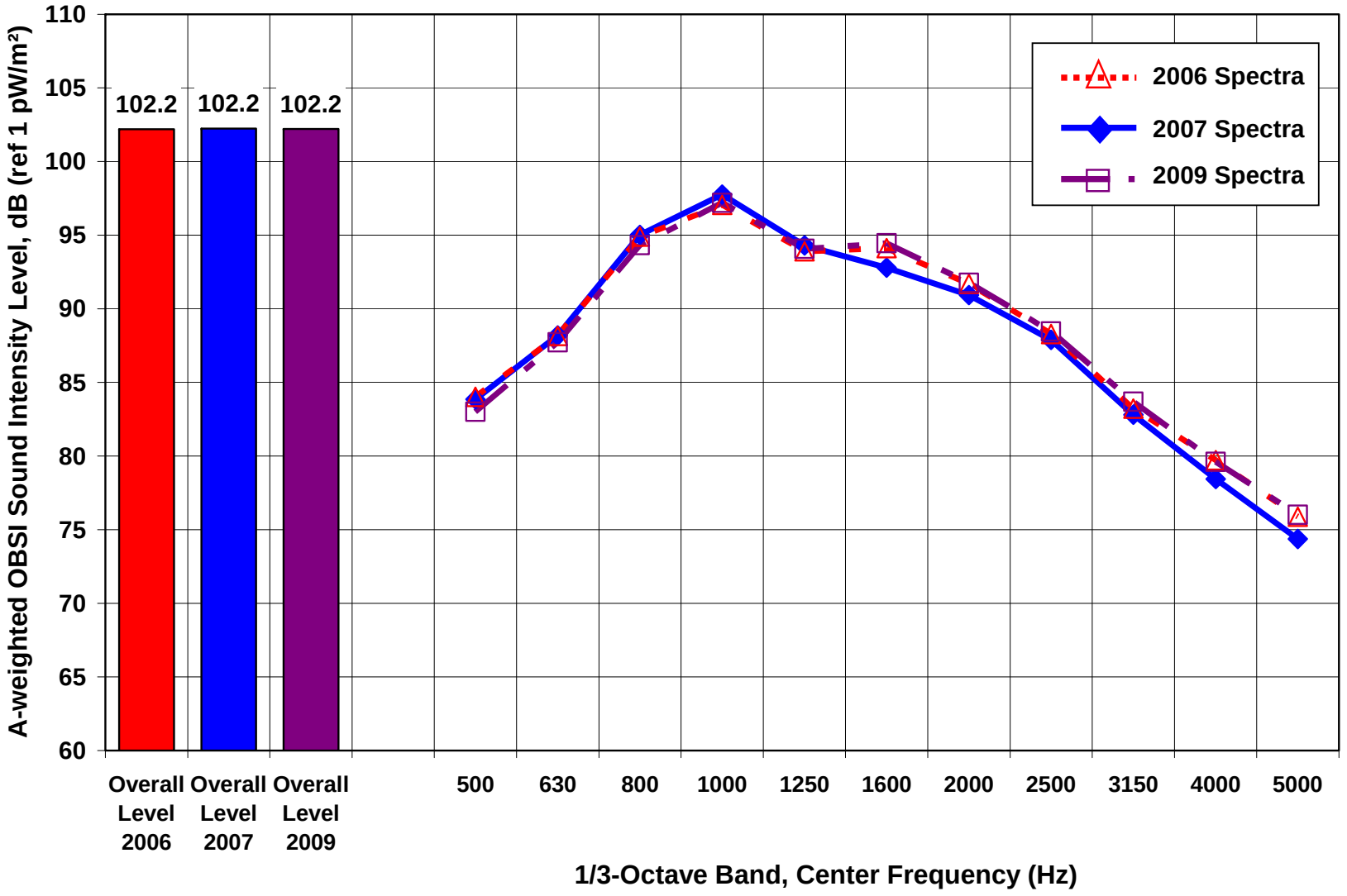
Highway: Interstate 76, Eastbound
Location: Between 88th Ave. & 96th Ave., Henderson (80640)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.8655 / 104.9059 / 5120

Nominal Surface: Concrete **Construction Accepted:** 11/2002

OBSI?: Yes (5/22/09) **SPB?:** No **TA?:** No
Total Section Length: 2495 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 25
OBSI (SRTT) Test Information



Site: 26
General Information

Highway: Interstate 25, Southbound
Location: Between SH 105 & Higby Rd., Monument (80132)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.0862 / 104.8614 / 7010

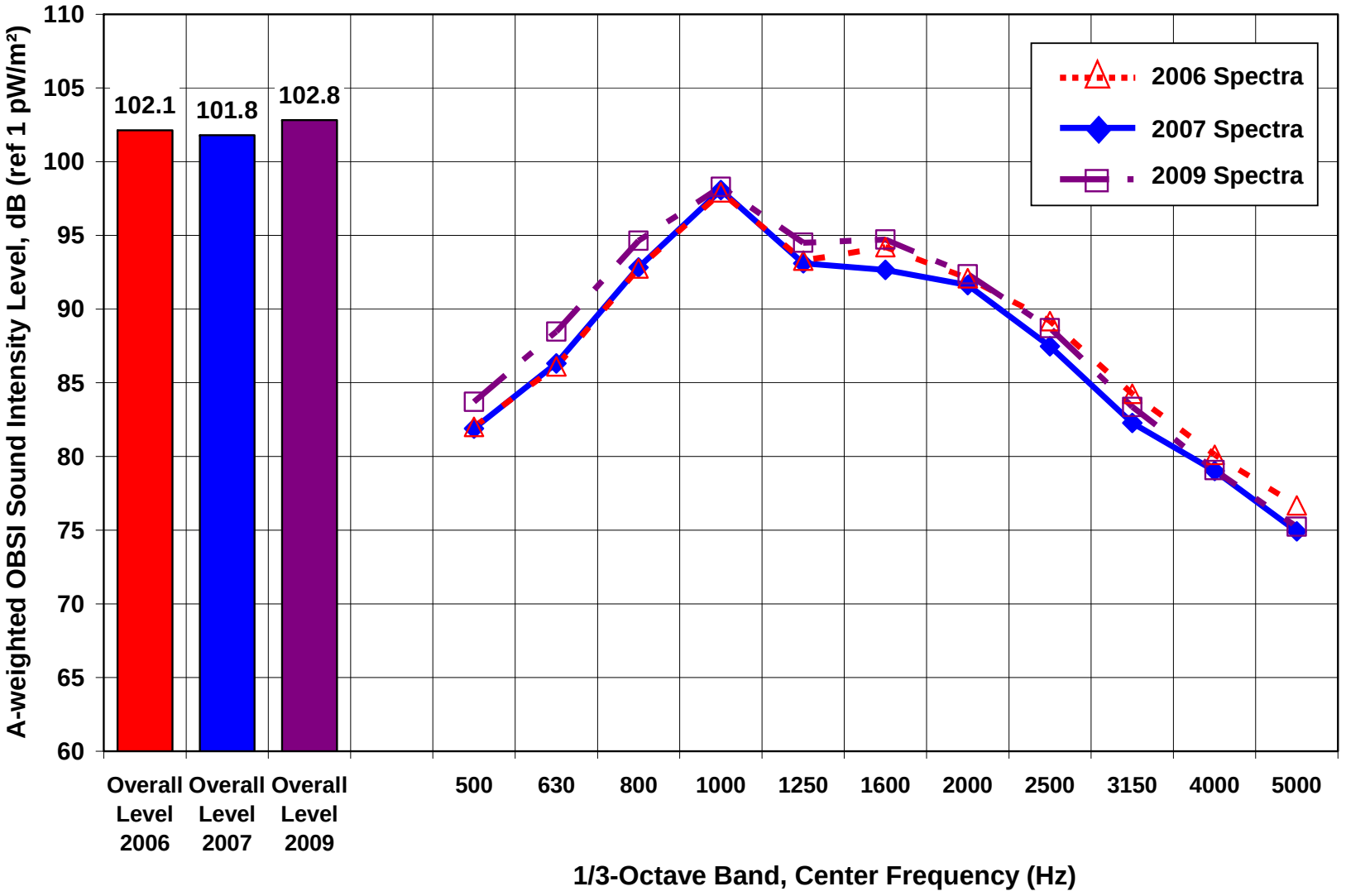
Nominal Surface: Concrete **Construction Accepted:** 10/1996

OBSI?: Yes (6/19/09) **SPB?:** No **TA?:** No
Total Section Length: 1493 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 26

OBSI (SRTT) Test Information



Site: 27
General Information

Highway: Highway C-470, Westbound (Northbound)
Location: Between Morrison Rd.& Alameda Pkwy., Morrison (80228)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.6759 / 105.1869 / 5890

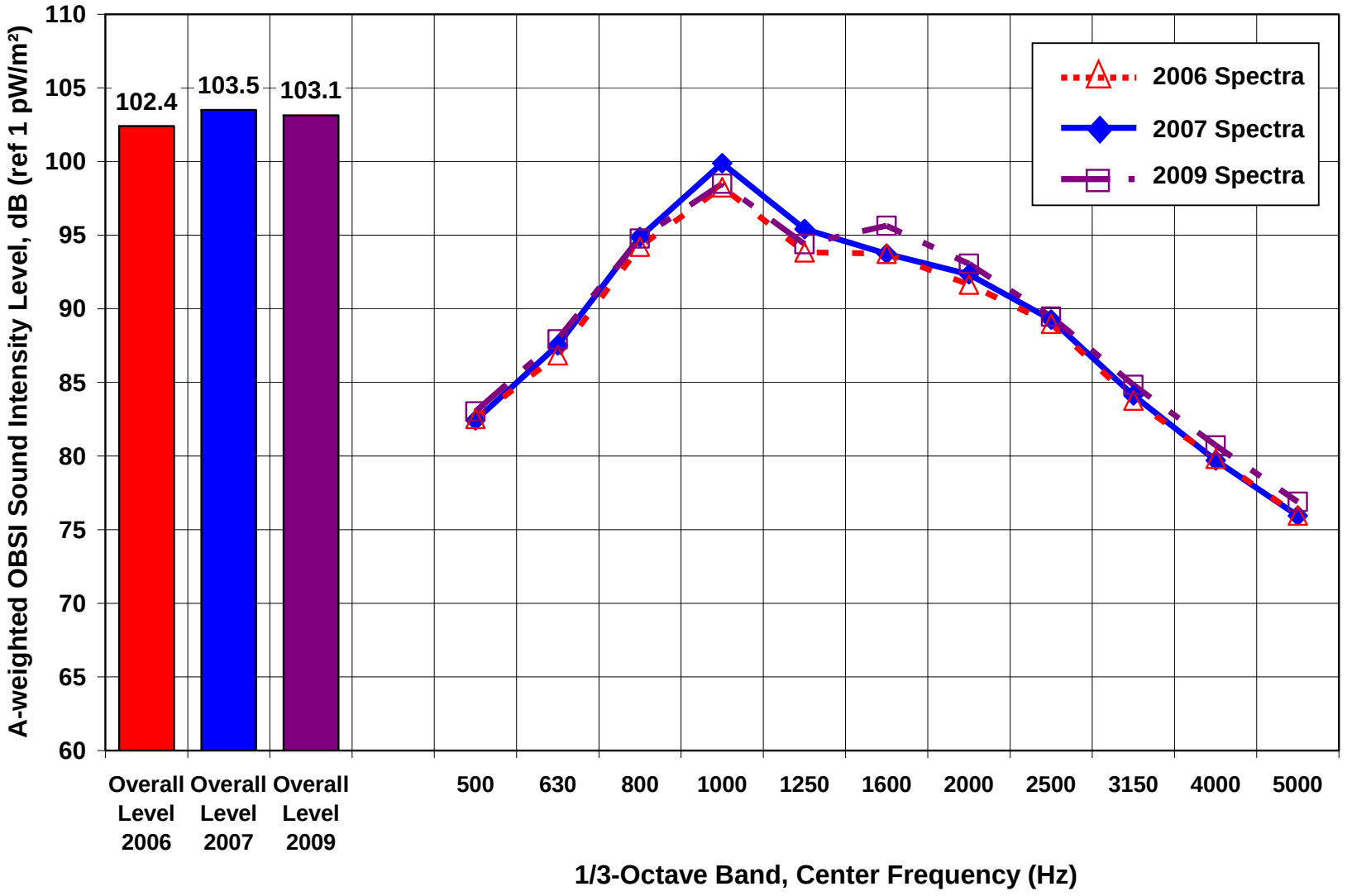
Nominal Surface: Concrete **Construction Accepted:** 1/2001

OBSI?: Yes (5/23/09) **SPB?:** No **TA?:** No
Total Section Length: 7873 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 27

OBSI (SRTT) Test Information

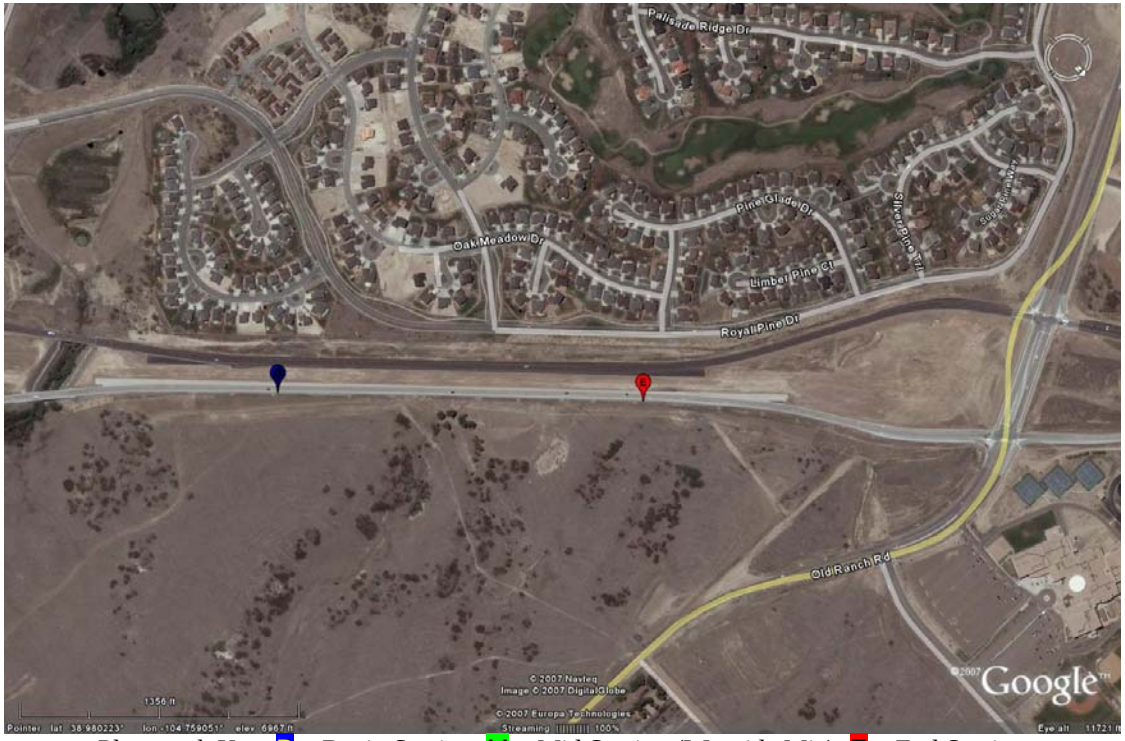


Site: 28
General Information

Highway: Powers Blvd., Northbound (Westbound)
Location: Between Union Blvd. & Old Ranch Rd., Colorado Springs (80908)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 38.9796 / 104.7574 / 7030

Nominal Surface: Concrete (Drag) **Construction Accepted:** 12/2004

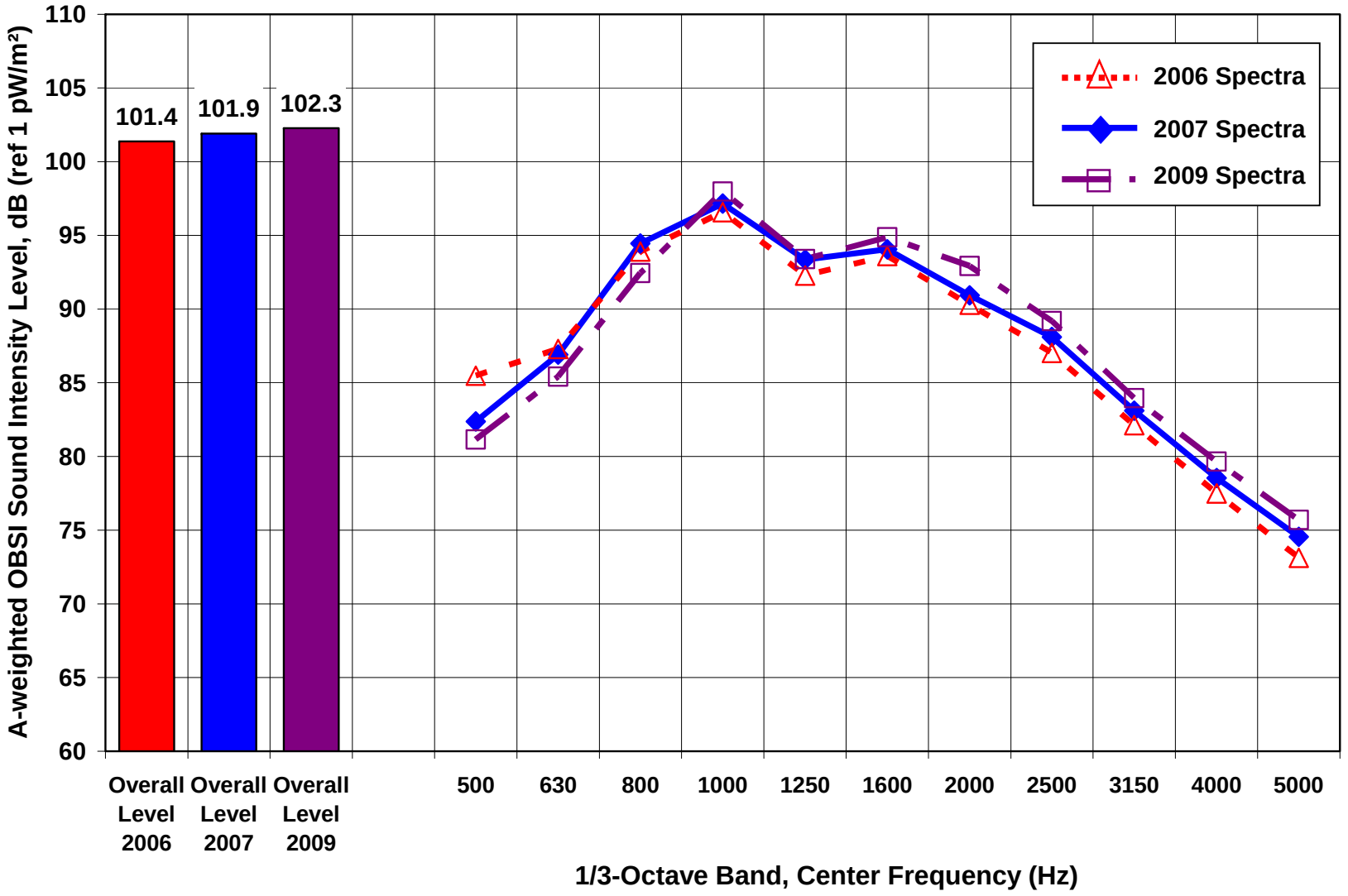
OBSI?: Yes (6/19/09) **SPB?:** No **TA?:** No
Total Section Length: 1804 ft.
Distance from Begin to Wayside Microphone: n/a



Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 28

OBSI (SRTT) Test Information



Site: 29
General Information

Highway: Powers Blvd., Southbound (Eastbound)
Location: Between Old Ranch Rd. & Union Blvd., Colorado Springs (80920)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 38.979 / 104.7575 / 6990

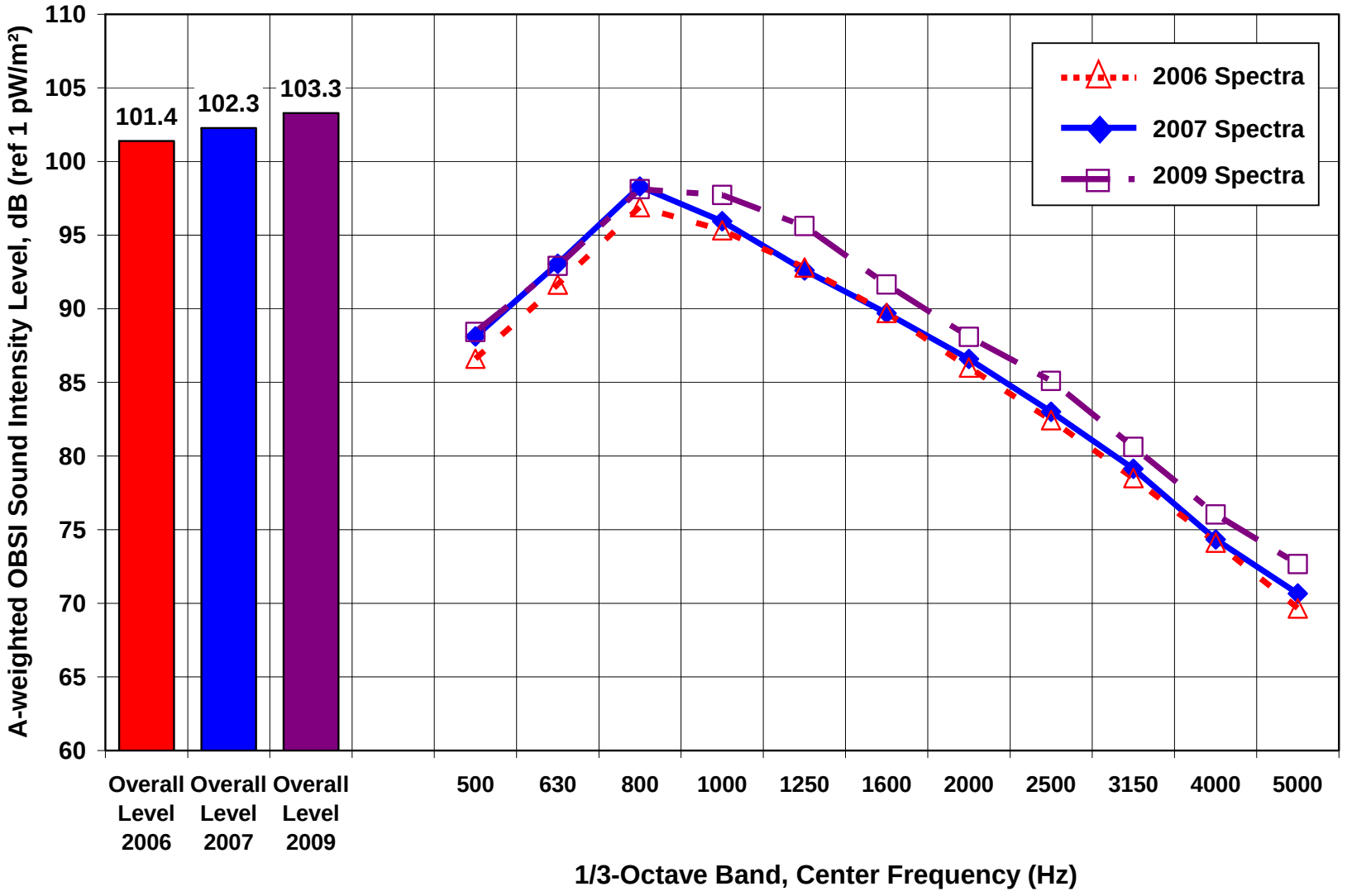
Nominal Surface: SMA **Construction Accepted:** 9/2005

OBSI?: Yes (6/19/09) **SPB?:** No **TA?:** No
Total Section Length: 1724 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 29

OBSI (SRTT) Test Information



Site: 30
General Information

Highway: US Highway 85, Northbound
Location: Between Daniels Park Rd. & SH 67, Sedalia (80135)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.4365 / 104.9514 / 5870

Nominal Surface: Concrete (Burlap Drag) **Construction Accepted:** 2003

OBSI?: Yes (9/22/09) **SPB?:** No **TA?:** Yes
Total Section Length: 3019 ft.
Distance from Begin to Wayside Microphone: 2657

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 30
Time-Averaged Wayside Test Information

Sampling Periods: 1

Sample Period 1 – 6 Blocks @ 15 min ea. = 90 min. (10:35 am to 12:05 pm, 9/25/09)

Traffic Volumes and Speeds during Sample Period

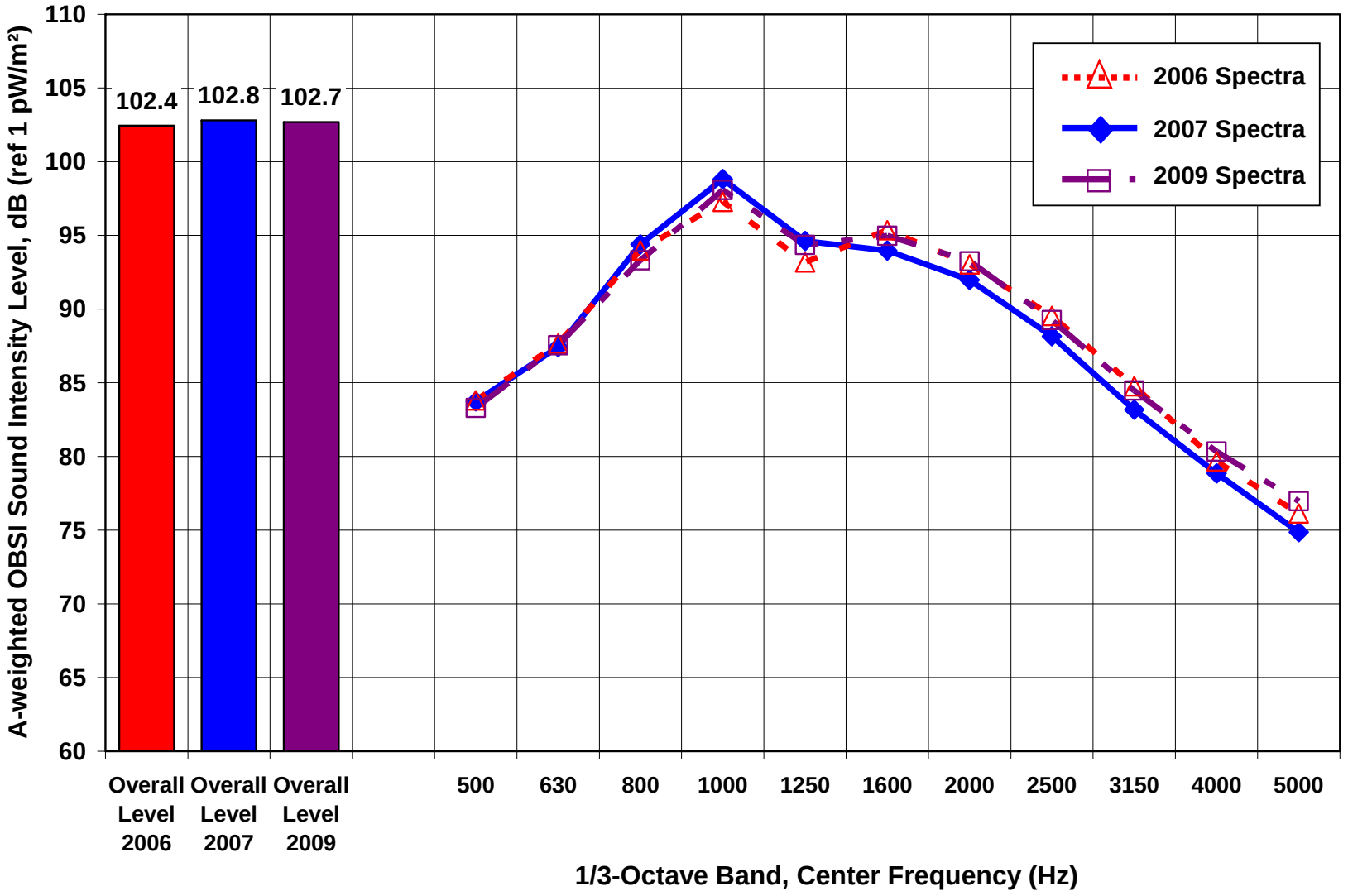
	NB Lane 2 (Outside)	NB Lane 1 (Inside)	SB Lane 1 (Inside)	SB Lane2 (Outside)
Distance from Mic (ft.)	50	62	90	102
Average Speed (mph)	52		57	
Automobile	276	331	265	345
Heavy Truck	17	3	4	21
Medium Truck	21	9	4	27
Bus	0	0	0	1
Motorcycle	3	5	1	2
Auto + 1-Axle Trlr.	3	3	2	5
Auto + 2-Axle Trlr.	6	3	2	14
M. Trk. + 1-Axle Trlr.	1	0	1	0
M. Trk. + 2-Axle Trlr.	3	0	0	6

** Note: for 50 ft mic positions*

A-Weighted Time Averaged Sound Pressure Levels during Sample Period (dB ref 20 µPa)

Mic Position (ft) Distance × Height	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Average
50 × 5	68.1	68.8	68.6	68.1	66.4	68.3	**68.1**
25 × 4	71.8	72.6	72.2	71.9	70.4	72.0	**71.8**
50 × 12	69.4	70.2	70.1	69.7	68.9	70.0	**69.7**

Site: 30
OBSI (SRTT) Test Information



Site: 31
General Information

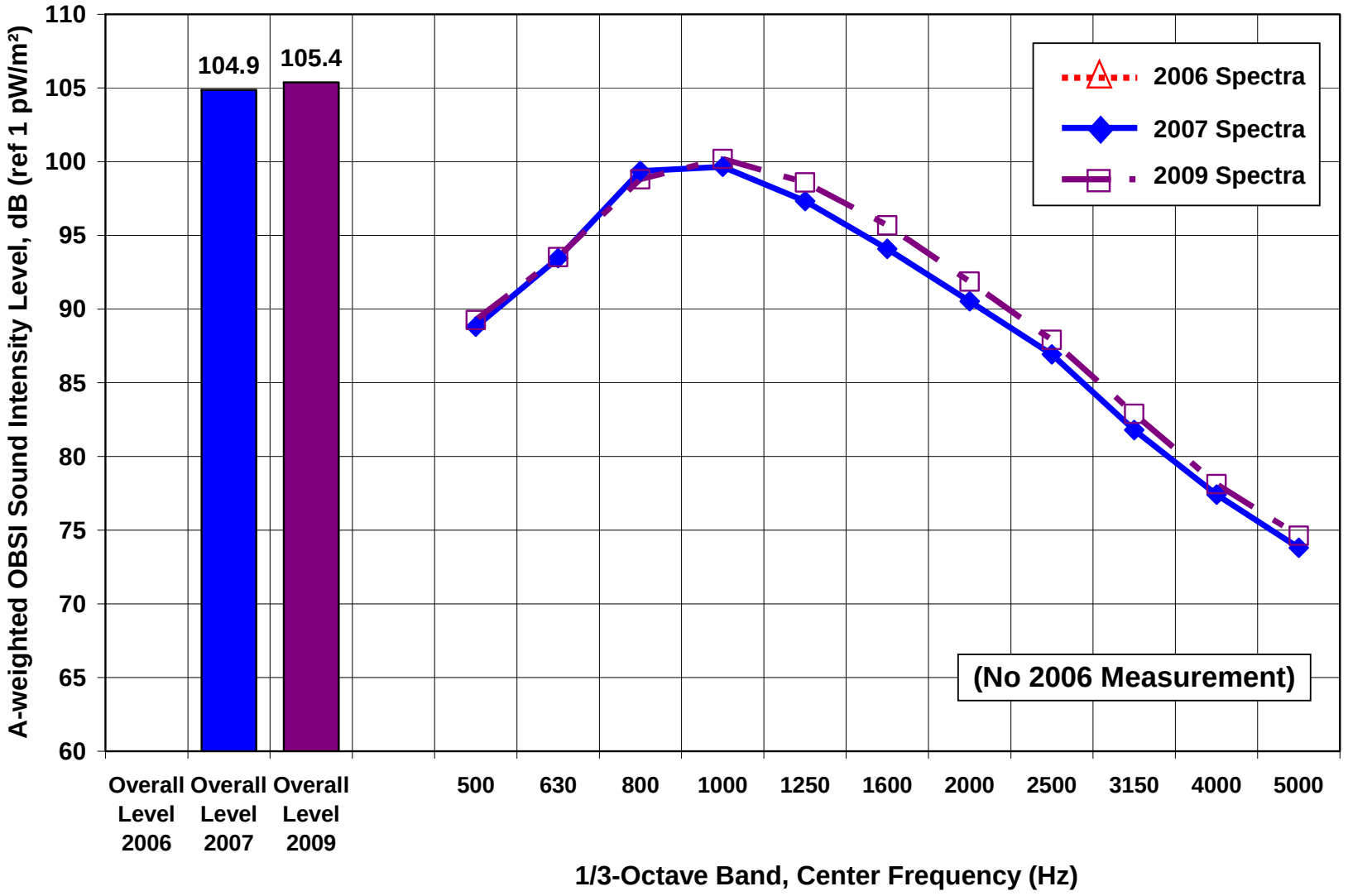
Highway: Interstate 70, Eastbound
Location: Between 15th St. & US 40, Georgetown (80444)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 39.7286 / 105.6919 / 8560

Nominal Surface: SMA (3/4") **Construction Accepted:** 10/2006

OBSI?: Yes (6/6/09) **SPB?:** No **TA?:** No
Total Section Length: 5529 ft.
Distance from Begin to Wayside Microphone: n/a

Placemark Key: B = Begin Section; M = Mid Section (Wayside Mic); E = End Section

Site: 31
OBSI (SRTT) Test Information



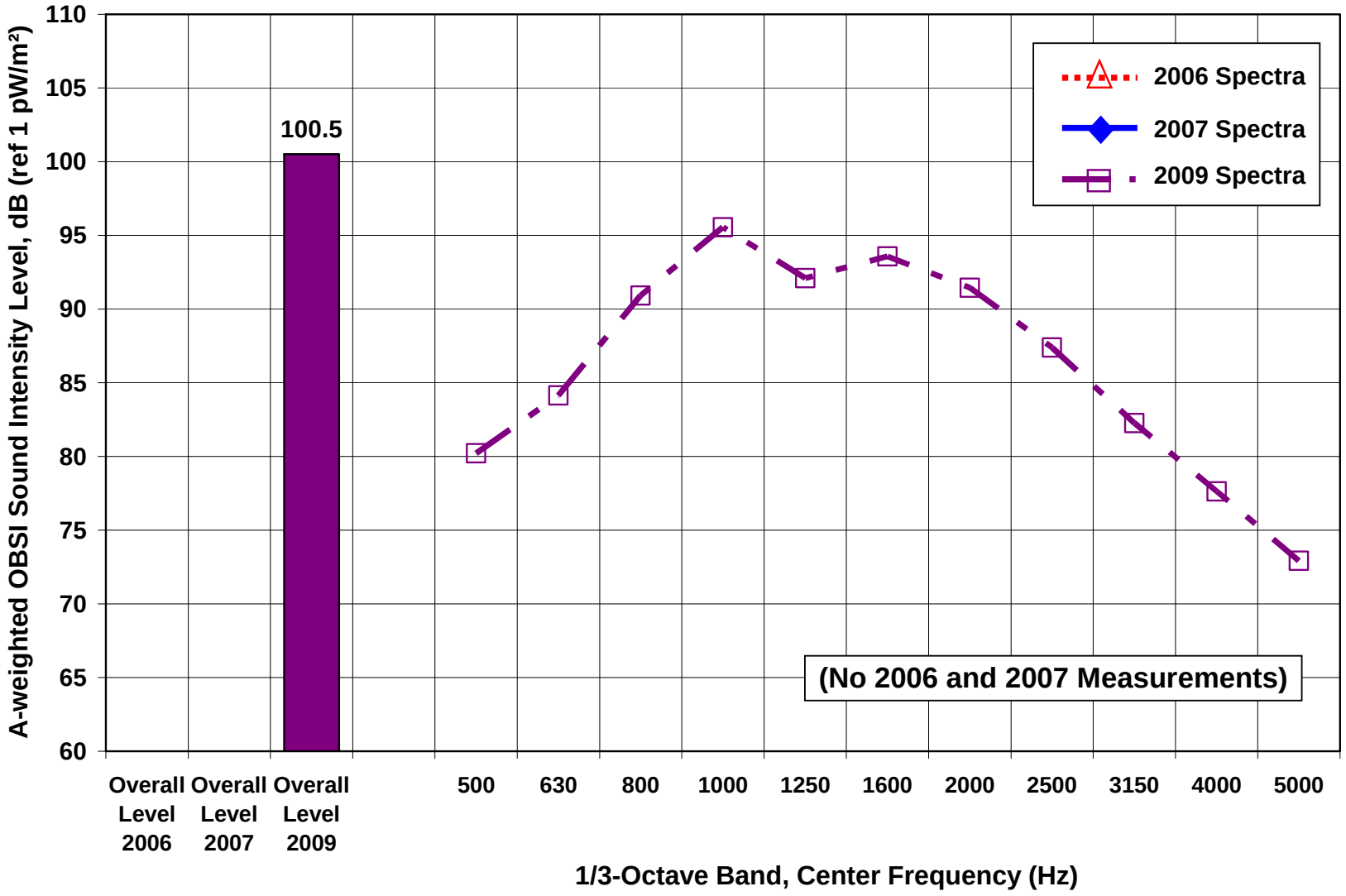
Site: 32
General Information

Highway: US Highway 34, Eastbound
Location: Between 71st Ave. & 65th Ave., Greeley (80634)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 40.3921 / 104.7904 / 4900

Nominal Surface: Asphalt (PG 64-28) **Construction Accepted:** 8/2009

OBSI?: Yes (9/24/09) **SPB?:** No **TA?:** No
Total Section Length: 440 ft.
Distance from Begin to Wayside Microphone: n/a

Site: 32
OBSI (SRTT) Test Information



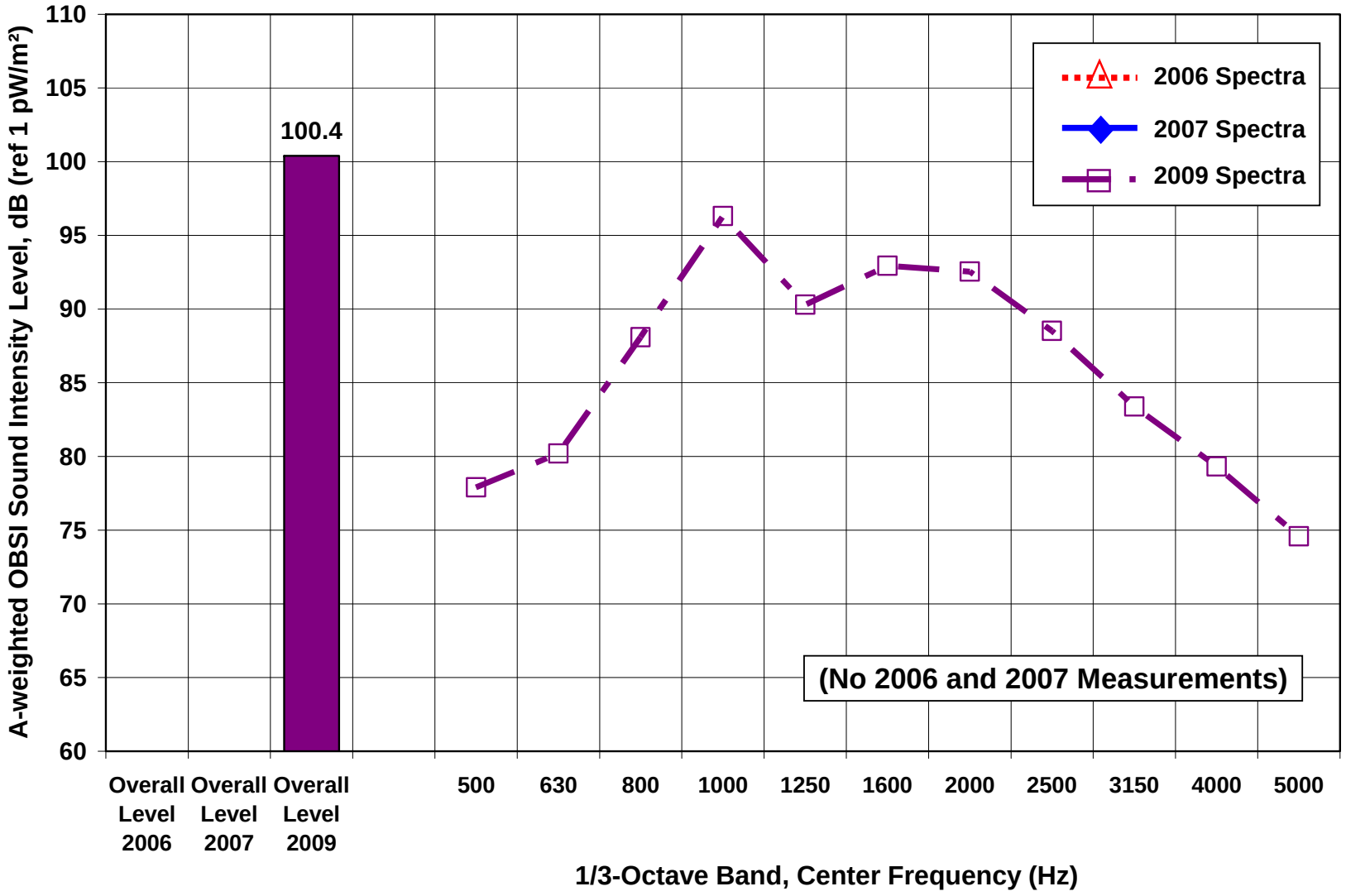
Site: 33
General Information

Highway: US Highway 34, Eastbound
Location: Between 65th Ave. & 59th Ave., Greeley (80634)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 40.3921 / 104.7772 / 4890

Nominal Surface: Asphalt (CRM, Wet Proc) **Construction Accepted:** 8/2009

OBSI?: Yes (9/24/09) **SPB?:** No **TA?:** No
Total Section Length: 440 ft.
Distance from Begin to Wayside Microphone: n/a

Site: 33
OBSI (SRTT) Test Information



Site: 34
General Information

Highway: US Highway 34, Eastbound
Location: Between 47th Ave. & 35th Ave., Greeley (80634)
Approx. Latitude (°N) / Longitude (°W) / Elevation (ft.): 40.3921 / 104.7483 / 4870

Nominal Surface: Asphalt (CRM Term. Blend) **Construction Accepted:** 8/2009

OBSI?: Yes (9/24/09) **SPB?:** No **TA?:** No
Total Section Length: 440 ft.
Distance from Begin to Wayside Microphone: n/a

Site: 34
OBSI (SRTT) Test Information