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Evaluation of Grind and Groove (Next Generation Concrete Surface) Pilot Projects in California

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Part of Partnered Pavement Research Program (PPRC) Strategic Plan Element 3.21:
Implementation of New Quieter Pavement Research

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Abstract:

This research report presents the results of tire/pavement noise, friction, drainability, and profile measurements performed on conventional diamond grind (CDG) and grind and groove (GnG) concrete pavement surface textures as a part of the California Department of Transportation (Caltrans) Quieter Pavement Research (QPR) study to investigate tire/pavement noise on concrete pavements. The On-board Sound Intensity (OBSI) method (AASHTO TP 76) was used to measure tire/pavement noise. Longitudinal profile data were collected at the same time as the OBSI data using an inertial profiler (ASTM E950) and were used to calculate the International Roughness Index (IRI). Friction was measured using the Towed Skid Trailer (ASTM E274) and the California Portable Skid Tester (CT 342), and estimated using the Circular Track Meter (ASTM E2157) and Dynamic Friction Tester (ASTM E1911). Drainability was measured using the Outflow Meter (ASTM E2380).

Seven pilot projects scheduled for CDG were selected for this research study. They include one each in San Diego, San Joaquin, and Yolo counties, and four in Sacramento County. At these seven sites, measurements were made before and after construction, and in between construction phases when possible.

The GnG surface texture was found to be quieter than the CDG, with lane average OBSI values on the GnG texture ranging from 99.5 dBA to 101.7 dBA, with an average of 100.8 dBA, compared with a range of 100.6 dBA to 104.7 dBA, and an average of 102.8 dBA measured on the CDG surface texture. The average OBSI level for all GnG sections was 100.8 dBA compared with an average of 102.8 for all CDG sections. OBSI values on the CDG texture on the San Diego 5 project decreased by 0.5 dBA over 1.3 years where OBSI was measured several times after initial construction. This reduction was attributed to flattening of the “fins” produced by CDG during construction. The average OBSI for all sections prior to treatment was 104.4 dBA, although not all sections had measurements of both CDG and GnG.

The IRI measurements showed that both CDG and GnG texturing treatments improved smoothness substantially compared with the pre-treatment values. The average IRI was reduced from 142 in./mi for the preconstruction surface textures to 64 in./mi on average after the CDG treatment and to 49 in./mi on average after the GnG texture treatment.

Both the OBSI and IRI are improved by CDG and even more so by the GnG texturing. Both CDG and GnG remove sealant overbanding and reduce or eliminate faulting at joints and cracks. Both processes also remove imperfections in the slabs caused by curling, warping, and most of whatever roughness was introduced during initial construction. All of these changes that result from CDG and GnG are likely to contribute to reductions in both noise and roughness. In this study, however, the individual contributions of removal of faulting and overbanding to noise and roughness reductions were not measured.

The few friction measurements on the GnG texture using CT 342 were not sufficient to draw conclusions, indicating that further attention should be given to use of this test on this texture if Caltrans continues to use the test. The skid tests using ASTM E 274 indicated that both the CDG and GnG textures passed specifications used by most state highway departments.

Keywords: tire noise, on-board sound intensity, friction, grind and groove, next generation concrete surface, diamond grinding, concrete pavements, surface texture, drainability, roughness, wide spot laser

Proposals for Implementation: Based on the relative cost-effectiveness of GnG versus CDG in reducing noise levels (reducing OBSI) and improving ride quality (reducing IRI), this study recommends use of GnG in noise-sensitive areas and CDG texturing where improving ride quality is the primary goal. Consider a larger experiment to investigate the potential use of the E274 Towed Skid Trailer in lieu of the CT 342 Portable Skid Tester for testing the friction characteristics of pavement surfaces.

Related Documents:

- Ongel, A., J. Harvey, E. Kohler, Q. Lu, and B. D. Steven. (2008) Investigation of Noise, Durability, Permeability, and Friction Performance Trends for Asphaltic Pavement Surface Types: First- and Second-Year Results. (UCPRC-RR-2007-03)
- Arash Rezaei, A. and J.T. Harvey. (2013) Investigation of Noise, Ride Quality and Macrotexture Trends for Asphalt Pavement Surfaces: Summary of Six Years of Measurements. (UCPRC-RR-2013-11)
- Kohler, E., and J. Harvey. (2011) Quieter Pavement Research: Concrete Pavement Tire Noise. (UCPRC-RR-2010-03)
- Rezaei, A., and J. Harvey. (2012) Quieter Pavement Research: Concrete Pavement Tire Noise: Third-Year Results Report (UCPRC-RR-2012-03)
- Rezaei, A., and J. Harvey. (2013) Concrete Pavement Tire Noise: Fourth-Year Results (UCPRC-RR-2013-12)

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PROJECT OBJECTIVES

The goal of this project, Partnered Pavement Research Center Strategic Plan Element (PPRC SPE) 3.21, titled “Implementation of New Quieter Pavement Research,” is to continue support for the development of specifications, guidelines, and standardized laboratory and field test methods toward quieter pavements. The goal of the study presented in this report, which is a part of PPRC SPE 3.21, is to evaluate the Grind and Groove (GnG) technology as used on test sections in Caltrans pilot projects in terms of noise, smoothness, friction, and surface drainability. The results of this study are to be used to further incorporate quieter pavement research into standard Caltrans practice, and may serve as a basis for changes in Quieter Pavement policy and specifications.

The evaluation of the GnG technology was achieved through the following tasks:

- Quantifying the effect of the GnG technology on tire/pavement noise levels by measuring OBSI before and after construction.
- Comparing the OBSI of the GnG texture to that of conventional diamond grinding (CDG), where there were adjacent test sections.
- Investigating the effect of the GnG technology on pavement surface skid resistance by measuring the coefficient of friction before and after construction.
- Investigating the effect of the GnG technology on pavement profile, or smoothness, by measuring International Roughness Index (IRI) before and after construction.

This report presents the results of these tasks.

EXECUTIVE SUMMARY

The grind and groove (GnG) texturing of concrete pavement surfaces is a new resurfacing technique intended to reduce tire/pavement noise. The American Concrete Pavement Association refers to this surface as the Next Generation Concrete Surface (NGCS). The goal of the study presented in this report is to evaluate the Grind and Groove (GnG) technology as used on test sections in Caltrans pilot projects in terms of noise, smoothness, friction, and surface drainability. The results of this study are to be used to further incorporate quieter pavement research into standard Caltrans practice, and may serve as a basis for changes in Quieter Pavement policy and specifications.

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The experiment was designed as a direct comparison between the GnG and CDG surface textures. Seven pilot projects were included in the study to compare preconstruction noise measurements with levels after CDG and after grinding and grooving (GnG) for individual lanes. The same comparison was conducted for roughness and friction. Two of the seven project sites had no adjacent CDG and GnG surface textures, and the data collected on them could only be compared to earlier measurements taken on an interim surface.

Chapter 2 of this report summarizes the differences between the CDG and GnG textures and how they are constructed. This chapter also summarizes the test methods used to collect data on tire/pavement noise (on-board sound intensity [OBSI]), roughness (International Roughness Index [IRI]), and friction. Two methods were used for friction, the Caltrans Test 342 Portable Skid Tester and the ASTM E274 Towed Skid Trailer. A drainability test, and the Circular Texture Meter and Dynamic Friction Tester were also used on some sections. Chapter 3 presents the project results section by section. Chapter 4 presents analysis of the noise, roughness and friction data. Chapter 5 summarizes all results and presents a cost/benefit comparison of noise reduction and roughness reduction for the CDG and GnG surface textures. Chapter 6 presents conclusions and recommendations. Appendixes present details of the data, comparisons of the friction test methods, and details of statistical analyses of results.

Conclusions

Based on the results obtained from this study, the following conclusions can be made regarding surface characteristics and the relative benefits of the CDG and GnG grinding procedures:

1. Concrete pavements in California that are scheduled for Capital Preventive Maintenance (CaPM) projects can be expected to have OBSI noise levels ranging from about 100 to 110 dBA, and ride quality (smoothness, in terms of IRI) of about 120 to 160 in./mi.
2. After CDG and GnG texturing, OBSI noise levels for the CDG sections reduced to between 98.5 to 107.9 dBA, while those for GnG test sections reduced to between 98.2 and 106.8 dBA. Ride quality improved to IRI values ranging from 48 to 79 in./mi for CDG; and 40 to 64 in./mi for GnG sections.
3. GnG construction was approximately two to three times as effective in reducing noise levels as CDG construction, with OBSI reductions of 3.1 to 4.5 dBA for GnG versus 1.0 to 2.0 dBA for CDG. Overall, average noise reduction for GnG was 3.6 dBA versus 1.6 dBA for CDG.
4. On average, the CDG texture shifted the OBSI spectrum down across all frequencies while the GnG texture tended to reduce noise in the frequencies of 1,000 Hz and below more than in the higher frequencies, which shifted the peak noise to a higher frequency. As a result of these changes in the noise spectrum, the GnG texture caused both a reduction in total noise and a change in the tonality of the noise to slightly higher pitches.
5. The GnG was typically about 20 to 35 percent more effective in improving ride quality than CDG, with IRI reductions of 74 to 119 in./mi for GnG versus 55 to 99 in./mi for CDG. On average, GnG improved ride quality by 93 in./mi while the average improvement for CDG sections was 78 in./mi.
6. The average unit cost for GnG construction was nearly three times that for CDG: $11.71/sqyd for GnG versus $4.18/sqyd for CDG. The size of this difference is attributed in part to the fact that GnG is a new procedure, while CDG is widely used in California, and because the average quantities for the CDG projects in this study were almost three times those for the GnG sections (237,000 sqyd for the CDG versus 85,000 sqyd for the GnG).
7. Although GnG textures produced two to three times as much noise reduction as CDG textures, due to the higher unit costs for GnG texturing, the cost-effectiveness of noise reduction for GnG was on average only about 20 percent greater than for CDG: $2.77/dBA for GnG and $3.36/dBA for CDG. The additional noise reduction benefits of the GnG procedure over CDG would on average cost about $4/sqyd for every additional dBA reduction.
8. The cost-effectiveness of the CDG construction in improving ride quality (IRI reduction) was approximately two to two-and-half times that for GnG. On average, for every $1/sqyd, CDG reduced IRI by 19 in./mi versus 8 in./mi for GnG. The additional $7.53/sqyd unit cost of GnG over CDG produced a benefit of only 2 in./mi reduction in IRI for every additional $1/sqyd.

9. The CDG texture met the state-required 0.30 coefficient of friction using the California Test 342 (Portable Skid Tester) on all lanes tested; however, the CT 342 test measurements on three of the seven pilot projects produced inconclusive results on the friction characteristics of GnG texturing, suggesting that further study may be needed to evaluate the friction characteristics of GnG using this test. On the other hand, skid resistance tests conducted on six of the seven pilot projects using the towed skid trailer test (ASTM E 274) showed that both CDG and GnG textures met skid resistance standards specified in many other states using this test.
10. The single NGL texture test section on Sacramento 5 had similar noise and friction characteristics as the control CDG texture.

Recommendations

The results of this study led to the following recommendations to further evaluate the performance of the CDG and GnG grinding procedures in terms of their long-term benefits and surface characteristics:

1. Conduct annual measurements to monitor the long-term acoustical, friction, and ride quality (IRI) performance of the GnG surface textures and adjacent control CDG textures.
2. Perform a comprehensive literature review to examine the frictional properties of GnG surfaces that have been constructed in other states versus coefficients of friction obtained on GnG sections in California tested using CT 342.
3. Undertake a larger field study to determine the feasibility of replacing the CT 342 Portable Skid Tester with the E274 Towed Skid Trailer for testing friction on pavements in California.
4. Based on the relative cost-effectiveness of GnG versus CDG in reducing noise levels (reducing OBSI) and improving ride quality (reducing IRI), this study recommends use of GnG in noise-sensitive areas and CDG texturing where improving ride quality is the primary goal.

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LIST OF ABBREVIATIONS USED IN THE REPORT

AASHTO	American Association of State Highway and Transportation Officials
ACPA	American Concrete Pavement Association
ASTM	American Society for Testing and Materials
Avg.	Average
BWP	Between wheelpaths
Caltrans	California Department of Transportation
CDG	Conventional Diamond Grind
CT	California Test
CTM	Circular Track Meter
DFT	Dynamic Friction Tester
EA	Expenditure Authorization
EB	Eastbound
GnG	Grind and Groove
HMA	Hot-mix asphalt
IRI	International Roughness Index
LWP	Left wheelpath
NB	Northbound
NGCS	Next Generation Concrete Surface
NGL	Next Generation Lite
OBSI	On-board Sound Intensity
RWP	Right wheelpath
Std. Dev.	Standard Deviation
SB	Southbound
SN	Skid Number
TPTA	Tire Pavement Test Apparatus
WB	Westbound

LIST OF SPECIFICATIONS CITED IN THE REPORT

CT 342	California Department of Transportation (Caltrans), Method of Test for Surface Skid Resistance with the California Portable Skid Tester. California Test 342, 1995.
AASHTO TP 76	Standard Method of Test for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method. American Association of State Highway and Transportation Officials, 2009.
ASTM E274	Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire. American Society for Testing and Materials, 2010.
ASTM E501	Standard Specification for Standard Rib Tire for Pavement Skid-Resistance Tests. American Society for Testing and Materials, 2010.
ASTM E524	Standard Specification for Standard Smooth Tire for Pavement Skid-Resistance Tests. American Society for Testing and Materials, 2010.
ASTM E950	Standard Test Method for Measuring the Longitudinal Profiles of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference. American Society for Testing and Materials, 2010.
ASTM E1845	Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth. American Society for Testing and Materials, 2010.
ASTM E1911	Standard Test Method for Measuring Paved Surface Frictional Properties Using the Dynamic Friction Tester. American Society for Testing and Materials, 2010.
ASTM E1926	Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements. American Society for Testing and Materials, 2010.
ASTM E2157	Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter. American Society for Testing and Materials, 2010.
ASTM E2380	Standard Test Method for Measuring Pavement Texture Drainage Using an Outflow Meter. American Society for Testing and Materials, 2010.

1 INTRODUCTION

1.1 Overview

The grind and groove (GnG) texturing of concrete pavement surfaces is a new resurfacing technique also known as the Next Generation Concrete Surface (NGCS), and it is intended to reduce tire/pavement noise. In 2005, the American Concrete Pavement Association (ACPA) worked with Purdue University to investigate tire/pavement interaction using the university's Tire Pavement Test Apparatus (TPTA) (*1*). The research looked at the effects of grinding depth, blade width, and spacer width, with the result that variability of the fin profile was found to be the most important factor affecting noise (*2*). Blade types and configurations were tested, and ultimately a pavement surface was created that measured about 3 dBA less than a conventionally ground pavement (*1*). The new surface texture was produced two ways, which were referred to as the *double pass* and *single pass* methods. The double pass method refers to grinding followed by longitudinal grooving. The single pass method uses a combined grinding and grooving head that contains two types of cutting blades, one type that textures the riding surface and another that has a diameter large enough to produce longitudinal grooves. The single and double pass methods both produce the same final surface texture. Proof of concept and field validation were performed in Minnesota and Illinois in 2007.

The ACPA refers to this surface the *Next Generation Concrete Surface (NGCS)* (*1*). The Caltrans version of the specification is referred to as Grind and Groove (GnG).

Evaluations of NGCS have been performed by the state transportation department in both Washington State (2011) and Minnesota (2010). The Washington State project evaluated construction, costs, and initial friction, and tire/pavement noise. The latter was evaluated using the on-board sound intensity (OBSI) for the existing pavement, conventional diamond grind (CDG), and the NGCS on several sections on I-82 (*3*). The Minnesota project included measurement of surface characteristics (noise, friction, texture, and ride) immediately prior to and after each step of the grinding operation that produces the NGCS (*4*). Both states report that they will be performing long-term monitoring. A number of evaluations of test sections in other states have been reported by the ACPA (*5, 6, 7, 8, 9, 10, 11, 12*).

This research report presents the results of a study to quantify any potential noise reduction benefits and effects on friction and smoothness resulting from use of the GnG technique based on evaluation of a small set of pilot projects in California, and includes one short section where an alternative called the Next Generation Lite (NGL) texture was placed. This work was conducted as part of the Partnered Pavement Research Center Strategic Plan Element (PPRC SPE) 3.21, titled *Implementation of New Quieter Pavement Research* (*13*). The goal of PPRC SPE 3.21 is to continue to support the development of specifications, guidelines, and standardized laboratory and field test methods toward quieter pavements. This evaluation, as part of the SPE 3.21 project, follows the quieter pavement research initiated by the California Department of Transportation (Caltrans) for flexible pavements in 2006 and rigid pavements in 2008.

1.2 Problem Statement

Awareness of the impacts of highway traffic noise has grown with increases in highway users and the populations either living close to highway corridors or conducting their activities near them. In response, many departments of transportation have recognized the need to better understand the surface characteristics of pavements, not only because of how pavement surface friction affects safety and ride quality, but also because pavement surface characteristics contribute to noise generation. A better understanding of pavement surface characteristics may lead to techniques that not only improve safety and ride quality but also minimize highway noise.

Vehicles contribute to highway noise from three sources: propulsion, which includes the engine, power train, and exhaust; aerodynamics; and tire/pavement interaction (*14*). Highway agencies have focused on the latter because they can manage their states' pavements (unlike the other two noise sources, which are governed by characteristics of the vehicle fleet). In addition, since tire/pavement noise becomes the dominant source of vehicle noise at speeds above 30 mph for cars and 50 mph for trucks (*14*), an increasing number of agencies have adopted reducing tire/pavement noise at the source as a new objective.

Having been successfully constructed in other states since 2007, Caltrans is now evaluating the use of the GnG surfacing technique to minimize the levels of traffic noise experienced by highway users as well as by residents and businesses adjacent to state highways.

1.3 Study Objectives

The goal of this study is to evaluate the GnG technology as used on test sections in Caltrans pilot projects in terms of noise, smoothness, and friction and surface drainability. The results of this study are to be used to further incorporate quieter pavement research into standard Caltrans practice, and may serve as a basis for changes in Quieter Pavement policy and specifications.

The evaluation of the GnG technology was achieved through the following tasks:

- Quantifying the effect of the GnG technology on tire/pavement noise levels by measuring OBSI before and after construction.

- Comparing the OBSI of the GnG texture to that of CDG, where there are adjacent test sections.
- Investigating the effect of the GnG technology on pavement surface skid resistance by measuring the coefficient of friction before and after construction.
- Investigating the effect of the GnG technology on pavement profile, or smoothness, by measuring International Roughness Index (IRI) before and after construction.

This report presents the results of these tasks.

1.4 Structure of This Report

This report is organized as follows:

- Chapter 2 summarizes the grinding and grooving construction methods, presents the experiment design, and describes the test methods used in the study.
- Chapter 3 summarizes the test results collected on the evaluation sections.
- Chapter 4 presents an analysis of the results.
- Chapter 5 contains a discussion of cost data and benefit cost analysis of the CDG and GnG processes.
- Chapter 6 presents conclusions and recommendations of this study.
- Appendices present the details of data collected in the study.

2 CONSTRUCTION METHODS, EXPERIMENT DESIGN, AND TEST METHODS

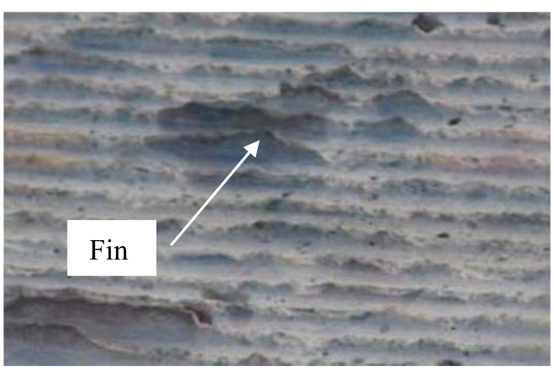
2.1 Construction Methods

Three different grinding methods are discussed in this report: conventional diamond grinding (CDG), NGCS grinding, and the combined CDG and NGCS process that constitutes the GnG method that was used for California's pilot projects. CDG and NGCS are shown in Figure 2.1. As mentioned, conventional diamond grinding has variability in blade spacing, and in width and cutting depth. Because no national standard has been established yet, the NGCS construction method can show project-to-project variability in the final product (*1*). As detailed below, California's construction method varied slightly from other NGCS projects.

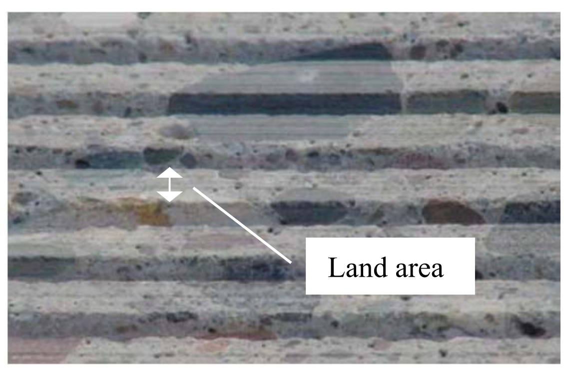
2.1.1 Conventional Diamond Grinding

The conventional diamond grinding (CDG) process uses stacked saw blades of a single diameter interspersed at regular intervals with smaller diameter spacers. The spacers aid cutting as they provide a location for residual slurry to exit the cutting surface area and allow ventilation at the cutting surface to reduce the heat developed by friction. The spacer locations leave an exposed *fin* (see Figure 2.1a) that sticks upward from the pavement surface; this is known as positive texture.

For CDG, the spacing and thickness of the blades varies depending on the aggregate type, concrete mixture, and pavement condition. With a challenging pavement, one with a rough profile or hard aggregates, the CDG process may require more than one pass of the grinding unit. However, it is often completed in a single pass, requiring regrinding only in limited areas which don't meet specified profile requirements.



(a)



(b)

Figure 2.1: Conventional diamond-ground surface after trafficking (a) and with the Next Generation Concrete Surface (b). (*1*)

2.1.2 Next Generation Concrete Surface

The Next Generation Concrete Surface (single pass) process intersperses one or two large-diameter blades between three or four small-diameter blades. The small-diameter blades grind the final surface and provide microtexture, while the large-diameter blades cut longitudinal grooves. The textured surface between the grooves, referred to as the *land area* (see Figure 2.1b), is more stable and durable while the grooves provide a path for excess water to exit and allow better tire/pavement interaction (*1*).

During development at Purdue and field testing at MnROAD, both the single pass and double pass methods were used to construct the NGCS surface texture. However, on the majority of projects to date, contractors have generally constructed the NGCS surface by the double pass method, first completing a flush grind (sometimes referred to as a "profile grind") and then installing the longitudinal grooves afterward because of the potential for excessive wear on the grinding equipment.

2.1.3 California Grind and Groove

In California, the NGCS texture has been termed *Grind and Groove* (GnG) in Caltrans' specifications. For the projects built to date, it was required that the GnG surface be constructed using the double pass method after the completion of CDG. In the double pass method to construct the GnG surface, a contractor first completes a flush grind using a grinding head with no spacers to remove the positive texture and improve ride quality (measured in terms of IRI). *(Note: in the results presented in this report the flush grind is referred to as "pre-GnG.")* Once the flush grind is completed, the contractor installs longitudinal grooves. Figure 2.2 shows the surface after the flush grind (left) and after grooving (right). Caltrans specifies that groove depths be between 0.125 in. and 0.187 in. (3.2 mm and 4.8 mm), and be spaced every 0.50 in. (12.7 mm) to 0.625 in. (15.9 mm) on center. For the seven pilot projects evaluated in this research study, neither the configuration of the grinding head nor the name of the grinding contractor was recorded.

Figure 2.2: Concrete surface after flush grind only (left) and after grooving (right).

Because these grooves are cut into the pavement surface, they are considered negative texture, reducing the positive texture of fins. Reducing the degree of positive texture is considered one component of producing noise-reducing pavement surfaces (*1, 2*). The increased width of the land area relative to the fin profile makes the riding surface more stable (see Figure 2.1); however, the stability of the land area surface profile is affected by aggregate loss, which in turn increases with time and traffic. Aggregate loss was visually observed in some sections of the GnG immediately after construction.

2.2 Test Methods

2.2.1 Tire/Pavement Noise Test Method

Tire/pavement noise measurements were collected following AASHTO TP 76: "Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method." The UCPRC OBSI and IRI test vehicle carries equipment for collecting OBSI data in accordance with AASHTO TP 76 and profile data in accordance with ASTM E950 (described below). For OBSI measurement, the test vehicle usually operates at 60 mph and must maintain this speed (±1 mph) during the sampling period. In standard OBSI measurements, 0.1 mile long pavement sections are used. However, for this research the test sections were one to two miles long. The UCPRC test vehicle has the microphones set up to measure noise at the passenger-side rear tire (shown in Figure 2.3).

The OBSI method measures sound intensity levels in one-third octave bands, from the frequency centered at 400 Hz to the frequency centered at 5,000 Hz. These values are obtained at the leading and the trailing edges of the tire/pavement contact patch. Three replicate passes are conducted at each test section to account for lateral variability and speed deviations from the 60 mph (96 km/h) specification. Measurements from the three passes at the two probe locations (leading and trailing) are used to obtain noise spectra, which are in turn used to calculate an overall sound intensity level, the single value that summarizes the overall tire/pavement noise. The sound intensity levels at the leading and trailing edges are averaged through the energy method (*15*). The sound intensity is reported in dBA, the A rating assigning greater weights to the frequencies that are perceived more by human hearing (*14*).

An air density correction was applied to the overall sound intensity level to take into account the effect of air density on the speed of sound, which is calculated from atmospheric data collected during testing, including air temperature, barometric pressure, and relative humidity, as well as the altitude of the section.

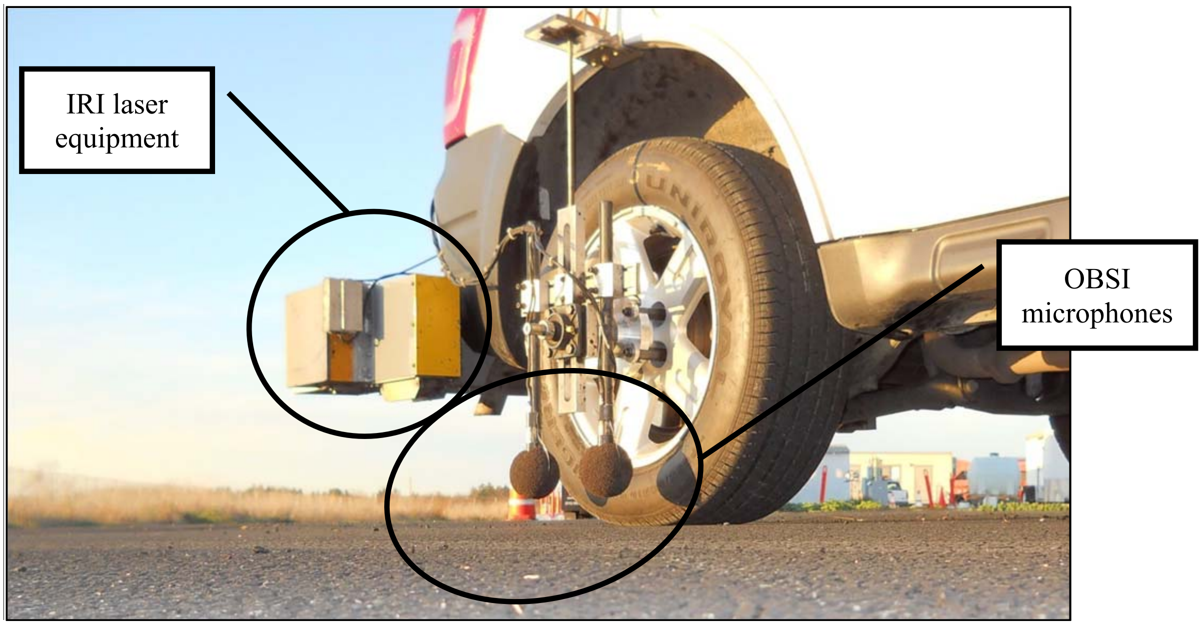


Figure 2.3: The UCPRC OBSI and IRI test vehicle with mounted microphones and laser equipment.

In addition to the pavement texture, the OBSI levels presented in this report *include* the effects of joint slap, faulting, and sealant overbanding. If present, joint slap, faulting, and sealant overbanding would increase the OBSI level above that caused by the texture alone. Joint slap is primarily a function of the empty cross-sectional area of the joint below the surface amplifying the sound of the tire passing over the joint. Similarly, faulting causes noise as the tire passes over a fault. Sealant overbanding is the presence of joint sealant above the surface of a joint, which creates positive texture that results in noise increase from tire vibration (*16*). The effects of joint slap, faulting, and sealant overbanding will be present in the measurements on the existing pavement (pre-CDG).

Both conventional and flush grinding processes remove faulting and existing sealant overbanding from the surface, which removes their effects from CDG and GnG OBSI measurements.

2.2.2 Roughness Test Method

Roughness measurements were calculated following ASTM E1926: "Computing International Roughness Index of Roads from Longitudinal Profile Measurements". The UCPRC test vehicle carries equipment for measuring inertial profiler equipment at the same time that OBSI is being measured, with the longitudinal profiles used for IRI collected in accordance with ASTM E950: "Measuring the Longitudinal Profiles of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference." The IRI was measured in the right wheelpath with a high-speed point laser measuring at 60 kHz and a wide-spot (Roline™) laser measuring at 3 kHz, both of which were attached to the rear of the test vehicle (Figure 2.3).

Because of the longitudinal orientation of surface texturing—tining, grinding, grooving—a wide-spot laser with a 100 mm wide line yields a different profile than a point laser. A point laser may travel across longitudinal tining or grinding, or in and out of grooving, to produce a larger IRI value than would have otherwise been measured. Some early pre-CDG IRI measurements were conducted using the point laser before the wide-spot laser was installed in December 2011. Those test sections were subjected to grinding before the wide-spot laser was installed. On the US 50 site in Sacramento pre-CDG measurements were taken with both the point and wide-spot lasers and the difference can be seen in the results for that section. All IRI results from point laser measurements are noted in this report.

2.2.3 Skid, Texture, Friction and Surface Drainage Test Methods

The test methods described in this section were conducted under a stationary lane closure, except for the Towed Skid Trailer test (ASTM E274) which was conducted at freeway speeds or with a moving lane closure when traffic speeds exceeded the testing speed by 10 mph.

2.2.3.1 <u>California Test 342: "Method of Test for Surface Skid Resistance with the California Portable Skid Tester"</u>

The Caltrans standard test for surface friction is California Test (CT) 342. In CT 342, the Portable Skid Tester (Figure 2.4) is used to directly measure the coefficient of friction. This test method requires (a) five tests spaced every 25 feet (7.5 m) conducted over a 100 foot (30 m) section, and (b) that the testing be performed at zero degrees relative to the direction of traffic. UCPRC testing for this study varied from the standard procedure in that CT 342 was conducted in and between wheelpaths at angles of 0, 15, and 45 degrees with respect to the direction of traffic. Testing was conducted at different angles to determine the effects of the enhanced lateral control that is required when the wheel is not parallel to the direction of traffic, as occurs when a vehicle changes lanes or when a driver loses vehicle control.

Figure 2.4: Caltrans Portable Skid Tester used for California Test 342.

2.2.3.2 ASTM E274: "Skid Resistance of Paved Surfaces Using a Full-Scale Tire"

This test method was conducted using both ASTM E524 smooth and E501 ribbed tires. The Skid Trailer measures average locked wheel (skid) and peak incipient (slip) friction characteristics on paved surfaces. Figure 2.5 shows the Caltrans skid trailer, which consists of a fully instrumented tow vehicle and test trailer that use a force transducer to provide dynamic vertical load and horizontal tractive force measurements. This test is used by many states as a standard test method for friction (*17*).

Per protocol, ASTM E274 was conducted in the left wheelpath at 40 mph. When traffic conditions and available time made it possible, additional tests were run at speeds of 50 and 60 mph. The test length was between 200 and 250 feet depending on the vehicle speed.

The skid number determined with the ribbed tire is predominantly influenced by the microtexture of the pavement, whereas the skid number with the smooth tire is influenced to a greater extent by pavement macrotexture and any water film thickness within the tire–pavement contact area (*18*). The grooves of the ribbed tire provide channels for water to discharge from the tire–pavement contact area, resulting in a higher skid number.

Figure 2.5: Towed Skid Trailer.

2.2.3.3 ASTM E2380: "Standard Test Method for Measuring Pavement Texture Drainage Using an Outflow Meter"

The Outflow Meter (OFM) measures the relative ability of pavement surfaces to drain water. Shown in Figure 2.6, the OFM is a transparent vertical cylinder that rests on a rubber annulus placed on the pavement.

Water is allowed to flow from the cylinder into the pavement, and the time it takes the water level to drop from one marker to another is recorded. Five repetitions is the standard; however, large drainage times constrained the number of replicate measurements on slow-draining surfaces, where three to five measurements were averaged as the outflow time.

The outflow time provides a measure of the ability of the pavement surface to remove water from under the tire: the higher the outflow time, the smoother, or flatter, the surface. Increasing numbers imply a reduced ability to drain water from the surface. The mechanics of the test do not apply forces or pressures to the pavement surface that are similar to those of a vehicle tire; however, the device is a quick, simple method to investigate the ability of the surface texture to drain water off the surface.

Figure 2.6: The Outflow Meter.

2.2.3.4 ASTM E2157: "Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter"

Shown in Figure 2.7, the Circular Track Meter (CTM, sometimes also referred to as the Circular Texture Meter) consists of a charge-coupled device laser-displacement sensor mounted on an arm that rotates such that the sensor follows a circular track having a diameter of 284 mm. Using the laser profile, the device measures the Mean Profile Depth (MPD) according to ASTM E1845, "Practice for Calculating Pavement Macrotexture Mean Profile Depth." In this study, these tests were often conducted immediately behind active grinding equipment and the operators dried the surface before testing. CTM testing was performed on a few sections before the equipment was returned to the FHWA.

2.2.3.5 ASTM E1911: "Standard Test Method for Measuring Paved Surface Frictional Properties Using the Dynamic Friction Tester"

Shown in Figure 2.8, the Dynamic Friction Tester (DFT) consists of a horizontal spinning disk fitted with three spring-loaded rubber sliders that contact the paved surface as the disk rotational speed decreases due to the friction generated between the sliders and the paved surface. A water supply unit delivers water to the paved surface being tested. The torque generated by the slider forces measured during the spin down is then used to calculate friction as a function of speed. DFT testing was performed on a few sections before the equipment was returned to the FHWA.

The DFT measures the same circular track that is measured by the CTM. For this study, the device was accelerated to 60 km/h (37.5 mph) before the disk was released to contact the surface. Data was recorded at 20, 40, and 60 km/h (12.4, 24.9, and 37.5 mph), and extrapolated for the dynamic friction at 0 km/h.

Figure 2.7: Circular Track Meter (CTM).

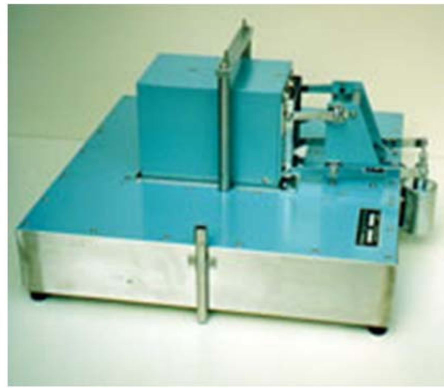


Figure 2.8: Dynamic Friction Tester (DFT).

Results from the CTM and DFT are used to estimate the skid number generated from the Towed Skid Trailer used in ASTM E274. This estimation is based on research work that resulted in the International Friction Index (IFI), which was developed to normalize friction and texture measurements by different test methods (*20, 21, 21*).

2.2.4 Condition Survey

Condition surveys were performed on those sections where lighting conditions and traffic closure time windows permitted. The condition surveys consisted of counting the number of slabs within the evaluation sections with transverse, longitudinal and corner cracking, as well as spalling and scaling.

2.3 Experiment Design and Testing Overview

Caltrans selected seven concrete pavement preservation projects scheduled for conventional diamond grinding (CDG) to pilot the GnG technology. Within each project's limits, a one- to two-mile subsection was selected for the GnG construction. This process left CDG sections either in the opposite direction or adjacent to GnG available as control sections for comparative measurements.

Field evaluations involved measurements of noise, friction, and longitudinal profiles in the wheelpaths before and after CDG and GnG construction. Where GnG sections were adjacent to CDG sections, the results were first compared to the preconstruction data and then compared against each other.

2.3.1 Evaluation Section Locations

Table 2.1 lists the seven pilot project sites with their project limits, CDG and Grind and Groove post mile limits, noise and roughness evaluation post mile limits, and locations of the texture and friction testing. Figure 2.9 shows the locations of six projects in Sacramento, San Joaquin, and Yolo counties. The San Diego County project location is shown in Figure 2.10. Three sites, the two on Sacramento 5 and the Sacramento 50 project, had GnG in one direction and CDG that could be used for comparison in the other. Another three sites had GnG placed in both directions—Sacramento 80, Yolo 113, and San Diego 5. For the latter two, the conventional diamond-ground surfaces upstream and/or downstream were used for comparison. Two sites, Sacramento 80 and San Joaquin 99, had no other rigid surface texture for comparison nearby.

Table 2.1: Grind and Groove Pilot Projects

Project Description				Conventional Diamond Grind (CDG) Post Mile Limits		Grind and Groove (GnG) Post Mile Limits	
EA[1]	County	Route	Post Mile Limits	Construction	Evaluation	Construction	Evaluation
1F450[2]	Sacramento	5	PM 17.2/ PM 22.8	PM 17.2 – PM 22.8 Northbound and Southbound Lanes 1 – 4	PM 20.0 – 21.5 Southbound Lanes 1 and 4	PM 18.7 – 22.4 Northbound Lanes 1 – 4	PM 20.0 – 21.5 Northbound Lanes 1 and 4
0F590[2]	Sacramento	5	PM 0.0/ PM 3.5	PM 0.0 – 3.5 Northbound and Southbound Lanes 1 and 2	PM 1.5 – 3.0 Southbound Lanes 1 and 2	PM 1.0 – 3.1 Northbound Lanes 1 and 2	PM 1.5 – 3.0 Northbound Lanes 1 and 2
2F040	Sacramento	80	PM 12.4/ PM 18.0	N/A	N/A	PM 12.8 – 17.6 Eastbound and PM 12.9 – 18.0 Westbound Lanes 2 – 5	PM 13.0 – 14.0 Eastbound and Westbound Lanes 2 and 5
0A800[2]	Sacramento	50	PM R12.2/ PM R14.2	PM R12.8 – R14.2 Eastbound Lanes 2 – 4	PM R13.0 – R14.0 Eastbound Lanes 2 and 4	PM R12.8 – R14.2 Westbound Lanes 2 – 4	PM R13.0 – R14.0 Westbound Lanes 2 and 4
0V870	San Joaquin	99	PM 29.0/ PM 30.8 NB	N/A	N/A	PM 29.0 – 30.8 Northbound	PM 29.0 – 30.7 Northbound Lanes 1 and 2
2F050	Yolo	113	PM R0.0/ PM R11.1	PM R1.5 – R11.1 Northbound and PM R0.9 – R11.1 Southbound Lanes 1 and 2	PM R1.5 – R2.5 Northbound and PM R0.9 – R2.5 Southbound Lanes 1 and 2	PM R0.2 - R1.5 Northbound and PM R0.25 – R0.9 Southbound Lanes 1 and 2	PM R0.5 - R1.5 Northbound and PM R0.5 – R0.9 Southbound Lanes 1 and 2
07760 and 07980	San Diego	5	PM R36.3/ PM R37.4	PM R32.7 – R42.9 Northbound and Southbound Lanes 1 through 5	PM R35.8 – R36.3 PM R37.4 – R37.9 Northbound and Southbound Lanes 1, 2 and 5	PM R36.3 – R37.4 Northbound and Southbound Lanes 1 through 5	PM R36.35 – R37.35 Northbound and Southbound Lanes 1, 2 and 5

Notes:
1. EA - Expenditure Authorization serves as Caltrans project identification number.
2. Project has additional segments outside the reported project limits.

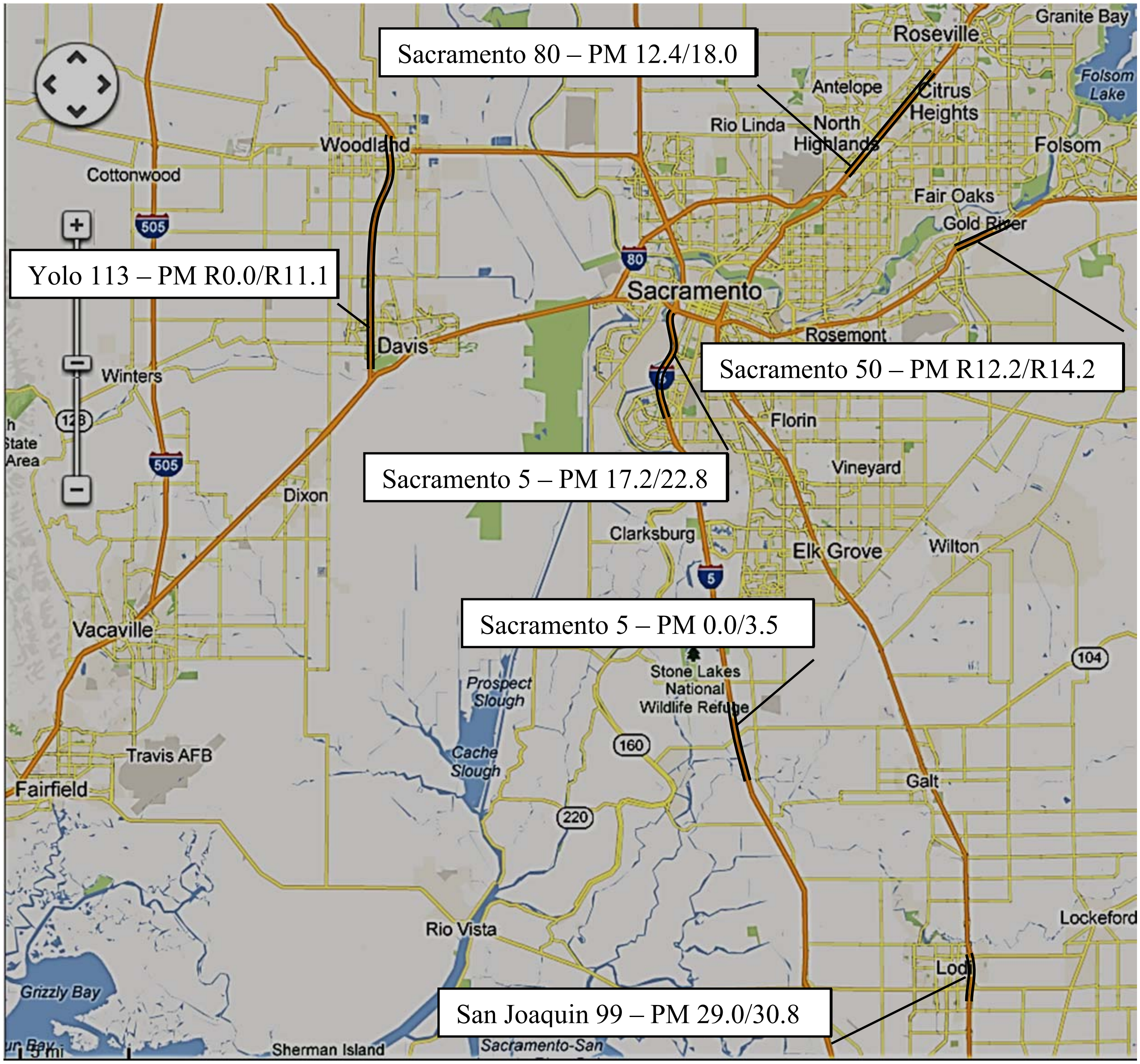


Figure 2.9: Project limits for the six pilot projects in Sacramento, San Joaquin, and Yolo counties.

Figure 2.10: Project Limits on San Diego 5 – PM R32.7/R42.9

Caltrans and UCPRC personnel coordinated selection of the evaluation locations, which were subject to the approval of the Resident Engineer. The intent was to perform tests on each of the seven pilot projects before and after construction to characterize the following textures:

- Before construction: pre-CDG
- After conventional diamond grind: CDG
- After the flush (i.e., secondary) grind: pre-GnG
- After grooving: GnG

The abbreviations shown above have been used throughout this report.

OBSI and IRI data were collected before construction (pre-CDG), after the conventional diamond grind (CDG) (whenever possible), and after the Grind and Groove surface texture construction (GnG). The texture, friction, and drainability tests were also conducted on pre-CDG, CDG, and GnG surfaces as well as after the flush grind (pre-GnG). Significant effort was spent to avoid slowing the pace of construction, and data was sometimes not collected because of tight construction schedules, such as when contractors conducted consecutive grinding operations within the same work shift. For textures that were tested more than once, a number and a letter were added to one of the codes above to represent the number of years after construction or initial characterization, e.g., CDG1.1y represents a CDG surface texture tested approximately 1.1 years after construction or initial characterization.

2.3.2 *Typical Test Location Layout*

The typical layout of test locations within each site is shown in Figure 2.11.

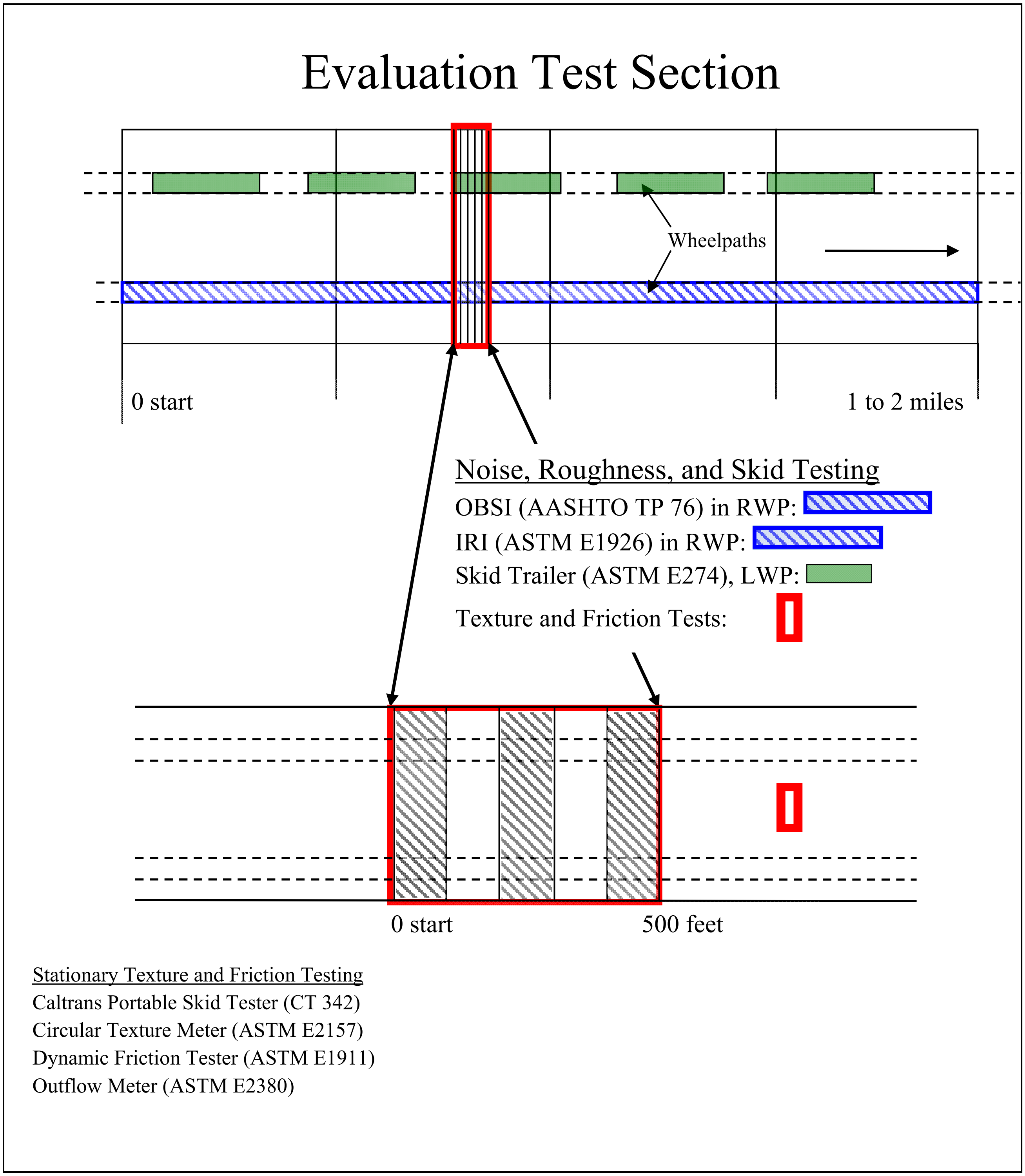


Figure 2.11: Overview of evaluation testing layout on project section.

3 TEST RESULTS

3.1 Sacramento 5 – PM 20.0/21.5 Evaluation Section

3.1.1 Location and Traffic

The first Sacramento 5 grind project (EA#1F450) consisted of two segments: from PM 17.2 (at Florin Road) to PM 22.8 as shown in Figure 3.1. This pilot project included grinding of all lanes in both directions, with the GnG surface in the northbound lanes between PM 18.7 (north edge of the 43rd Avenue overcrossing) and PM 22.4.

The noise and skid measurements at highway speeds were conducted in Lanes 1 and 4 between PM 20.0 and PM 21.5 in both directions. The stationary friction and other tests were conducted in northbound Lane 1 at PM 18.7.

Table 3.1 presents the traffic and truck volumes for Sacramento 5 for the years 2007, 2009, and 2011. The traffic counts are from the intersection at Pocket and Meadowview Roads (at PM 16.147) and the intersection with Route 50 (at PM 22.565). Between these two post mile locations, the total vehicle traffic increased about 40 percent while the truck traffic increased less than 5 percent. This data, along with similar data from Table 3.2 in the following section, shows the large number of trucks—two-thirds with five or more axles—that travel this segment of I-5.

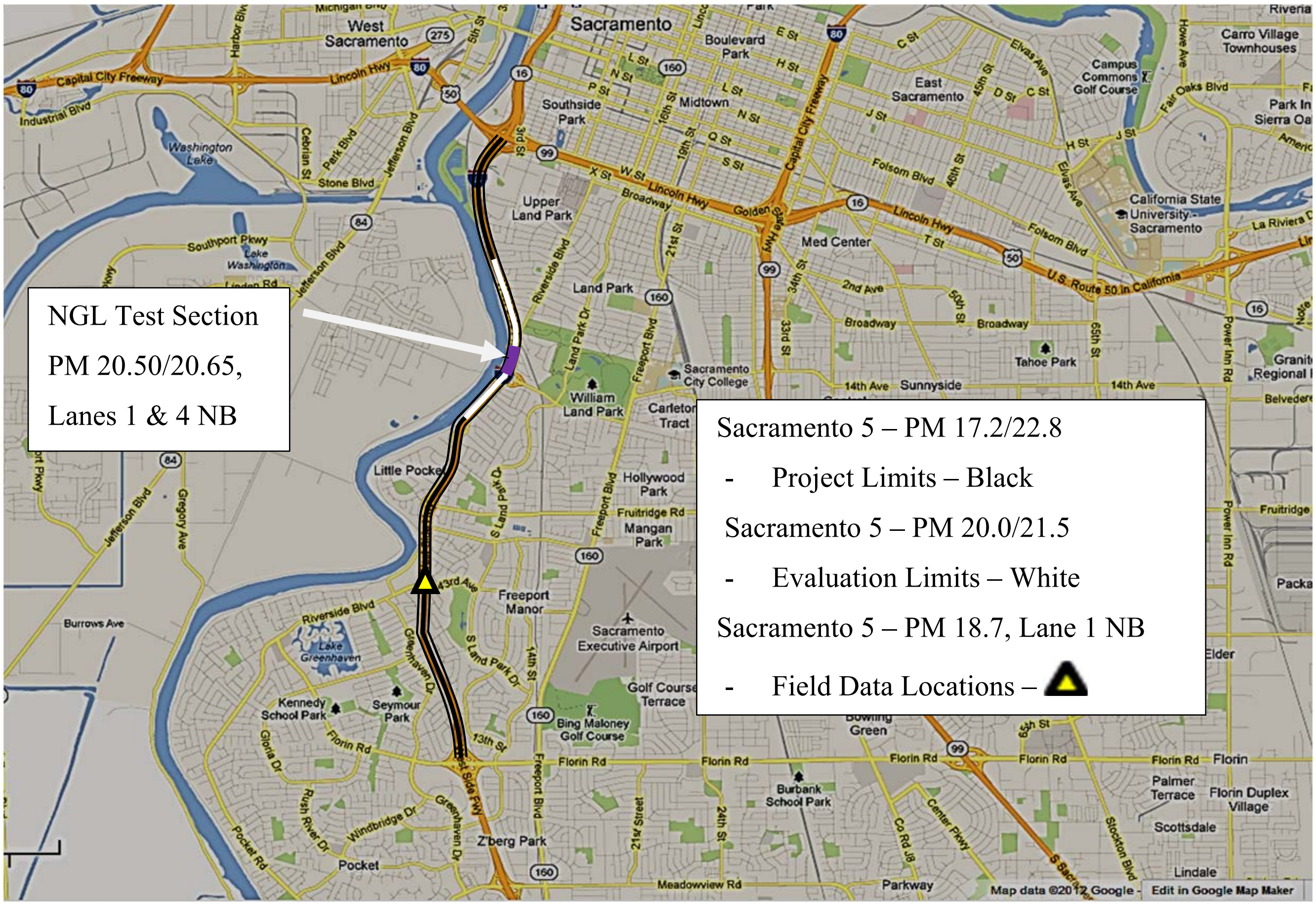


Figure 3.1: Noise and friction evaluation limits on Sacramento 5 – PM 20.0/21.5, including location of Next Generation Lite section.

Table 3.1: AADT and Truck Counts on Sacramento 5 - PM 16.147 and 22.565

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Trucks		2	3	4	5+
PM 16.147	A	2007	108,000	14,267	13.2	3,316	521	234	10,197
		2009	102,000	13,474	13.2	3,131	492	221	9,630
		2011	101,000	13,342	13.2	3,101	487	219	9,536
PM 22.565	B	2007	156,000	14,976	9.6	3,654	884	359	10,079
		2009	144,000	13,824	9.6	3,373	816	332	9,304
		2011	142,000	13,632	9.6	3,326	804	327	9,174

Note: Traffic Leg A traffic counts are from north of the intersection and Leg B traffic counts are from south of the intersection.

3.1.2 Testing and Construction Sequence

Table 3.2 shows the testing and construction evaluation sequence for this project, including testing and construction of the Next Generation Lite surface texture within this project (described in Section 3.2).

Table 3.2: Testing and Construction Sequence for Sacramento 5 – PM 20.0/21.5 Evaluation

Date	Texture Condition*	Testing or Activity	Comment
5/19/2011	Pre-CDG	OBSI and IRI testing	Tests in both directions, only point laser
5/26/2011	Pre-CDG	Friction E274 testing	Tests in Lanes 1 and 4 in both directions
6/2/2011	Pre-CDG	Outflow Drainage testing	Tests were conducted starting at northbound Lane 1 PM 18.7 + 0, 50, 100, 200, 250, and 300 feet.
6/2/2011	CDG	Outflow Drainage testing	
6/6/2011	CDG	Friction CT 342 testing	
6/6/2011	Pre-GnG	Friction CT 342 testing	Tests were conducted starting at northbound Lane 1 PM 18.7 + 100, 150, 200, 300, 350, and 400 feet.
6/9/2011	Pre-GnG	Outflow Drainage testing	
6/9/2011	GnG	Friction CT 342 testing	
6/9/2011	GnG	Outflow Drainage testing	
6/2011 – 8/2011		Resurfacing of Evaluation Area	EA 1F450
7/2011 – 8/2011		NGL Resurfacing	Northbound Lanes 1 and 4, PM 20.5/20.7
7/20/2011	NGL	Outflow Drainage testing, Lane 1	Tests were conducted starting at northbound Lane 1 PM 20.5 + 200, 225, 250, 275, 300, 400, 425, 450, 475, 500, 700, 725, 750, 775, and 800 feet.
7/25/2011	NGL	Friction CT 342 testing, Lane 1	
8/3/2011	NGL	Outflow Drainage testing, Lane 4	
10/11/2011	CDG	OBSI and IRI	Tests southbound, only point laser
	GnG	OBSI and IRI	Tests northbound, only point laser
1/25/2012	CDG0.3y	OBSI and IRI	Tests southbound, with wide spot laser
	GnG0.3y	OBSI and IRI	Tests northbound, with wide spot laser
2/15/2012	CDG & GnG	Friction E274 testing	Tests in Lane 4 northbound

* Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, Pre-GnG = after flush grinding, GnG = after longitudinal grooving, CDGX.Xy = X.X years after conventional diamond grinding, GnGX.Xy = X.X years after longitudinal grooving, NGL = after next generation lite grinding

3.1.3 Test Results

The test results for Sacramento 5 – PM 20.0/21.5 are shown in Table 3.3. The condition survey results are shown in Table 3.4.

Table 3.3: Summary of Test Results for Sac-5-PM 20.0/21.5

Evaluation Test Section			OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40}) CT 342		Friction & Skid Test Results (Coefficient of Friction or SN_{40}) E274		Drainability Test Results (Avg. time in seconds)		
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**
NB	LN 1	20.0/21.5	103.9		100.3	125.3		42.0	0.39	0.35			7.2	3.8	3.4
NB	LN 4	20.0/21.5	105.1		101.7	164.7		52.0			42 48[1]	43 48[1]			
SB	LN 1	20.0/21.5	104.1	102.0		135.3	84.2								
SB	LN 4	20.0/21.5	104.6	102.9		153.9	75.1								
NB Average Values			**104.5**		**101.0**	**147.8**		**47.0**	**0.39**	**0.35**	**42**	**43**	**7.2**	**3.8**	**3.4**
SB Average Values			**104.4**	**102.5**		**144.6**	**79.3**								
Project Average Values			**104.4**	**102.5**	**101.0**	**146.3**	**79.3**	**47.0**	**0.39**	**0.35**	**42**	**43**	**7.2**	**3.8**	**3.4**
Standard Deviation			0.9	1.0	1.1										

Note:
[1] Ribbed tire test results, not included in averages

Table 3.4: Condition Survey Results for Sac-5-PM 20.0/21.5

Location: Project	Location: Lane, Direction, and Post Mile	Number of Observed Slabs	Transverse Cracking	Longitudinal Cracking	Corner Cracking	Minor Spalling	Major Spalling	Scaling
			Percentage (Number) of Observed Slabs with Distress					
Sac 5 – PM20.0/21.5	Lane 1 NB PM18.6/18.7	35	14% (5)		11% (4)	31% (11)	9% (3)	
Sac 5 – PM20.0/21.5	Lane 1 NB PM20.5/20.6	40	5% (2)			68% (27)	18% (7)	

3.2 Sacramento 5 – PM 20.5/20.7 Evaluation Section (Next Generation Lite)

3.2.1 Location and Traffic

This section was constructed for the evaluation of a new grinding texture termed the "Next Generation Lite" (NGL) grind. The NGL construction was funded as part of a conventional diamond-grinding project on Interstate 5 in Sacramento County between Florin Road (PM 17.2) and the US-50 South connector (PM 24.8). A literature survey found no evidence that the NGL surface has been tested or evaluated by any agency.

Two 1,000 foot test strips located at PM 20.5 (at the Sutterville Avenue overcrossing) in northbound Lanes 1 and 4 were textured with NGL after CDG. The NGL test strips were constructed after CDG instead of installing the flush grind (Pre-GnG) or groove (GnG) textures.

The NGL process uses a proprietary combination of blades without spacers to produce a continuous cutting head that leaves a sinusoidal wave like that shown in Figure 3.2. The wave's peak-to-peak amplitude is approximately 2 millimeters (< 1/8 inch).

Traffic data shown in Table 3.7 is applicable to this section as well. The evaluation section location is indicated in Figure 3.1.

Figure 3.2: Concrete surface after the Next Generation Lite (NGL) grind.

3.2.2 Testing and Construction Sequence

Table 3.2 shows the testing and construction evaluation sequence for this project.

3.2.3 Test Results

The test results for Sacramento 5 – PM 20.5/20.7 NGL evaluation section are shown in Table 3.5.

Table 3.5: Summary of Test Results for Sacramento-5-PM 20.5/20.7 NGL

Evaluation Test Section			OBSI Test Results (dBA)			Friction & Skid Test Results (Coefficient of Friction or SN_{40})				Drainability Test Results (Avg. time in seconds)		
						CT 342		E274				
Direction	**Lane**	**Post Mile**	**PreCDG**	**NGL**	**GnG**	**NGL**	**GnG**	**NGL**	**GnG**	**PreCDG**	**NGL**	**GnG**
NB	LN 1	20.5/20.7	103.9	99.3	100.3	0.39	0.35			7.2	11.5	3.5
	LN 4	20.5/20.7	105.1	101.7	101.7			33 49[1]	43 48[1]			
NB Average Values			**104.5**	**100.5**	**101.0**	**0.39**	**0.35**	**33**	**43**	**7.2**	**11.5**	**3.5**
Project Average Values			**104.4**	**100.5**	**101.0**	**0.39**	**0.35**	**33**	**43**	**7.2**	**11.5**	**3.5**
Standard Deviation			0.9	0.7	1.1							

Note:
[1] Ribbed Tire test results, not included in averages

3.3 Sacramento 5 – PM 1.5/3.0 Evaluation Section

3.3.1 Location and Traffic

As shown in Figure 3.3, this grind project (EA#0F590) included grinding of both lanes in both directions of Sacramento 5 from PM 0.0 (at the San Joaquin County Line) to PM 3.5 (north of Dierssen Road). The GnG surface was constructed between PM 1.04 (north edge of the Lost Slough overcrossing) and PM 3.14 (south of Dierssen Road) in the northbound direction on both lanes; the CDG surface in the southbound direction was used for comparison.

The noise and skid measurements at highway speeds were performed in Lanes 1 and 2 between PM 1.5 and PM 3.0, in both directions. The stationary friction and other tests were conducted in northbound Lane 1 at PM 2.9.

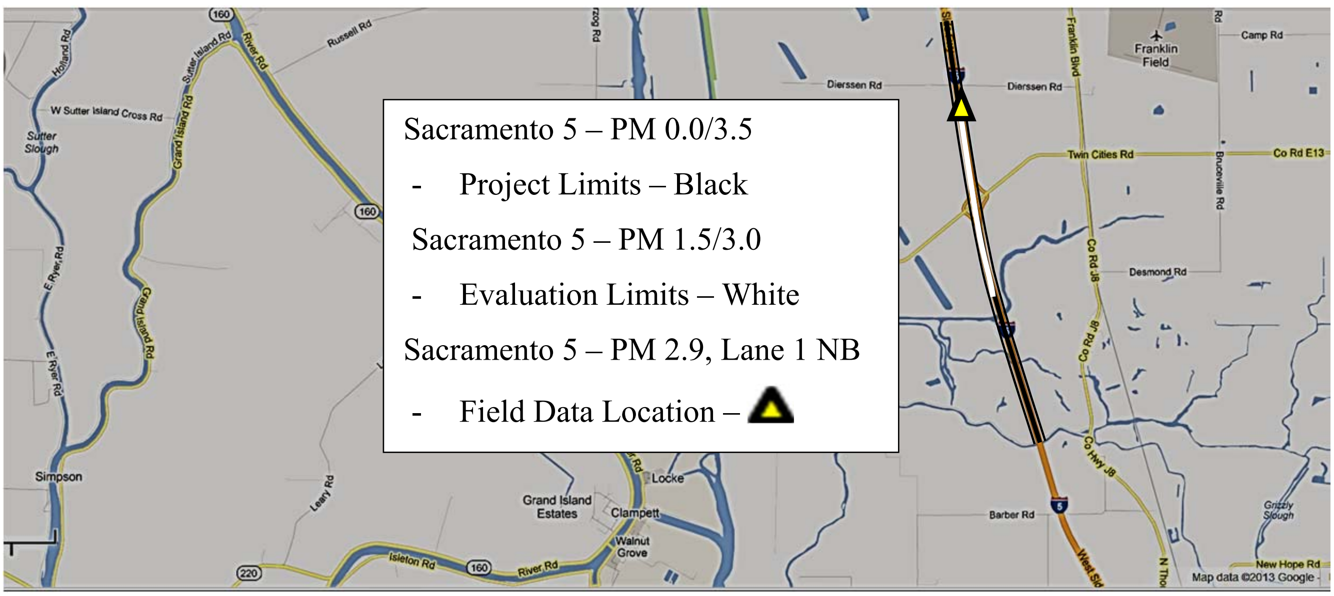


Figure 3.3: Noise and Friction Evaluation Limits on Sacramento 5 – PM 1.5/3.0.

Table 3.6 presents the traffic and truck volumes for the project site from 2007 through 2011. The traffic counts are from the San Joaquin County Line (at PM 0.018) to the intersection with Pocket and Meadowview Roads (at PM 16.147). In the table, traffic leg A indicates that the volumes are in the direction of increasing post mile numbers, and are moving toward the evaluation section at PM 1.5/3.0 for the counts taken at PM 0.018.

This section of Sacramento 5 had the highest percentage of trucks of all the projects: 24 percent. It contained the second highest truck volumes of all the projects (within 5 percent of those moving upstream toward Sacramento 5 – PM 20.0/21.5) and the second lowest total vehicular traffic (behind only Yolo 113).

Table 3.6: Traffic and Truck Counts on Sacramento 5 - PM 0.018 and 16.147

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Truck		2	3	4	5+
PM 0.018	A	2007	57,000	13,874	24.3	3,224	506	228	9,916
		2009	53,000	12,900	24.3	2,998	471	212	9,220
		2011	54,000	13,144	24.3	3,055	480	216	9,394
PM 16.147	A	2007	108,000	14,267	13.2	3,316	521	234	10,197
		2009	102,000	13,474	13.2	3,131	492	221	9,630
		2011	101,000	13,342	13.2	3,101	487	219	9,536

Note: Traffic Leg A traffic counts are from north of the intersection.

3.3.2 Testing and Construction Sequence

Table 3.7 shows the testing and construction evaluation sequence for this project.

Table 3.7: Testing and Construction Sequence for Sacramento 5 – PM 1.5/3.0 Evaluation

Date	Texture Condition*	Testing or Activity	Comment
6/22/2011	Pre-CDG	OBSI and IRI testing	Tests in both directions, only point laser
12/12/2011	Pre-CDG	Outflow Drainage testing	Tests were conducted starting at northbound Lane 1 PM 2.9 + 0, 25, 50, 75, 100, 200, 225, 250, 275, 300, 400, 425, 450, 475, and 500 feet.
1/12/2012	Pre-GnG	Outflow Drainage testing	
1/16/2012	GnG	Outflow Drainage testing	
8/2011 – 1/2012		Resurfacing of Evaluation Area	EA 0F590
12/14/2011	CDG	OBSI and IRI testing	Tests in both directions, only point laser
2/6/12	CDG0.2y	OBSI and IRI testing	Tests southbound, with wide spot laser
2/6/12	GnG		Tests northbound, with wide spot laser

*Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, Pre-GnG = after flush grinding, GnG = after longitudinal grooving, CDGX.Xy = X.X years after conventional diamond grinding

3.3.3 Test Results

The test results for Sacramento 5 – PM 1.5/3.0 are shown in Table 3.8. Condition survey results are shown in Table 3.9.

Table 3.8: Summary of Test Results for Sac-5-PM 1.5/3.0

Evaluation Test Section			OBSI Test Results (dBA)				IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40}) CT 342		Friction & Skid Test Results (Coefficient of Friction or SN_{40}) E274		Drainability Test Results (Avg. time in seconds)		
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG 0.0y**	**CDG 0.2y**	**GnG**	**PreCDG**	**CDG**	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**
NB	LN 1	1.5/3.0	104.1	103.9		101.3	112.9		42.7					3.1		5.0
	LN 2	1.5/3.0	105.8	104.4		101.7	113.3		48.2							
SB	LN 1	1.5/3.0	103.8	103.9	103.1		121.1	62.8								
	LN 2	1.5/3.0	104.5	103.8	103.3		128.9	64.7								
NB Average Values			**104.9**	**104.1**			**113.1**		**45.5**					**3.1**		**5.0**
SB Average Values			**104.2**	**103.8**	**103.2**	**103.2**	**125.0**	**63.8**								
Project Average Values			**104.6**	**104.0**	**103.2**	**103.2**	**119.1**	**63.8**	**45.5**					**3.1**		**5.0**
Standard Deviation			1.1	0.8	0.7	0.7										

Table 3.9: Condition Survey Results for Sacramento 5 – PM 1.5/3.0.

Location		Number of Observed Slabs	Percentage (Number) of Observed Slabs with Distress					
Project	**Lane, Direction, and Post Mile**		**Transverse Cracking**	**Longitudinal Cracking**	**Corner Cracking**	**Minor Spalling**	**Major Spalling**	**Scaling**
Sac 5 – PM1.5/3.0	Lane 1 NB PM2.9/3.0	22		9% (2)		36% (8)	5% (1)	

3.4 Sacramento 80 – PM 13.0/14.0 Evaluation Section

3.4.1 Location and Traffic

This grind project (EA#2F040) included constructing the GnG surface on all PCC lanes of Sacramento 80, Lane 2 through Lane 5 (Lane 1 is hot-mix asphalt [HMA]), in both directions between PM 12.8 (east of Madison Avenue overcrossing) and PM 18.0 (at the Placer County Line) as shown in Figure 3.4. No CDG surface was located nearby for comparison.

The noise and skid measurements at highway speeds were conducted in Lanes 2 and 5 between PM 13.0 and PM 14.0 in both directions. The stationary friction and other tests were conducted in eastbound Lane 2 at PM 13.5.

Table 3.10 presents the traffic and truck volumes for the evaluation site between 2007 and 2011. The traffic counts are from the Route 51 junction (at PM R10.989) and the intersection with Greenback Lane (at PM 14.454). In the table, traffic leg A indicates that the volumes are in the direction of increasing post mile numbers, moving toward the evaluation section at PM 13.0/14.0 for the traffic count at PM R10.989. In 2011, this section carried the most vehicular traffic of all the pilot projects, approximately 211,000 vehicles per day and 8,200 trucks per day.

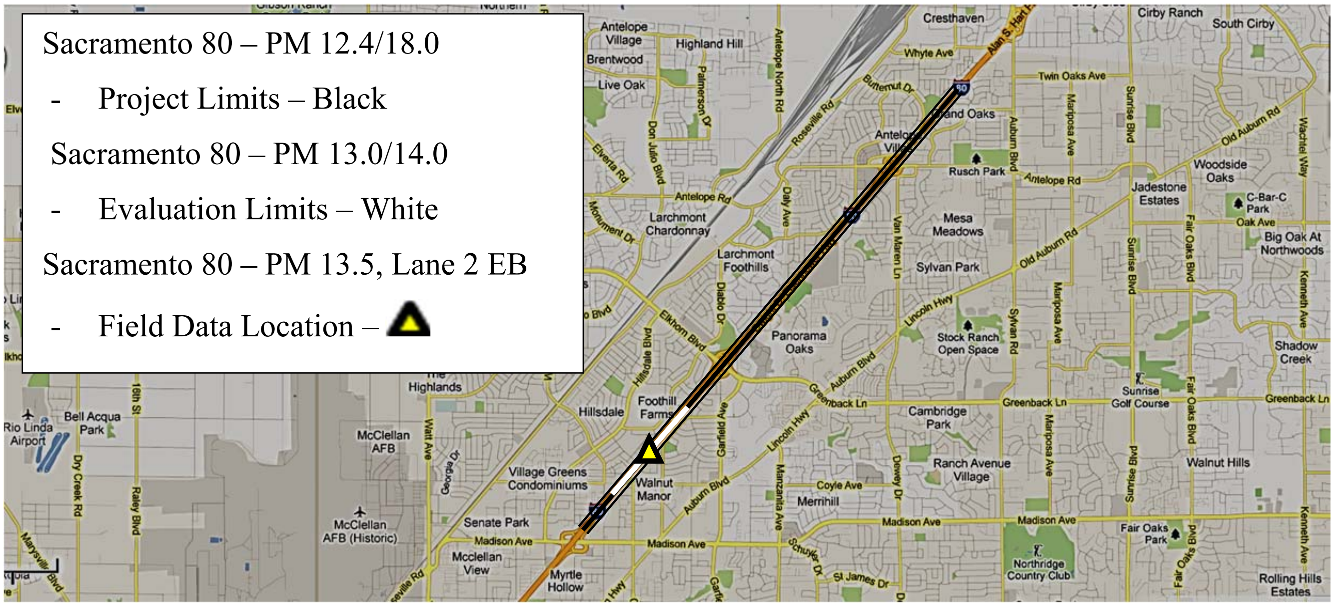


Figure 3.4: Noise and Friction Evaluation Limits on Sacramento 80 – PM 13.0/14.0.

Table 3.10: Traffic and Truck Counts on Sacramento 80 - PM R10.989 and 14.454

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Trucks		2	3	4	5+
R10.989	A	2007	232,000	9,025	3.9	2,698	650	280	5,397
		2009	224,000	8,714	3.9	2,605	627	270	5,211
		2011	211,000	8,208	3.9	2,454	591	254	4,908
14.454	A	2007	185,000	9,269	5.0	2,966	603	272	5,429
		2009	178,000	8,918	5.0	2,854	581	261	5,223
		2011	178,000	8,918	5.0	2,854	581	261	5,223

Note: Traffic Leg A traffic counts are from north of the intersection.

3.4.2 Testing and Construction Schedule

Table 3.11 shows the testing and construction evaluation sequence for this project.

Table 3.11: Testing and Construction Sequence for Sacramento 80 – PM 13.0/14.0 Evaluation

<table>
<tr><th>Date</th><th>Texture Condition*</th><th>Testing or Activity</th><th>Comment</th></tr>
<tr><td>2/3/2012</td><td>Pre-CDG</td><td>OBSI and IRI testing</td><td>Tests in both directions</td></tr>
<tr><td>2/15/2012</td><td>Pre-CDG</td><td>Outflow Drainage testing</td><td rowspan="7">Tests were conducted starting at eastbound Lane 2 PM 13.5 + 0, 25, 50, 75, 100, 200, 225, 250, 275, 300, 400, 425, 450, 475, and 500 feet.</td></tr>
<tr><td>2/15/2012</td><td>Pre-CDG</td><td>Friction CT 342 testing</td></tr>
<tr><td>2/16/2012</td><td>CDG</td><td>Outflow Drainage testing</td></tr>
<tr><td>3/5/2012</td><td>CDG</td><td>Friction CT 342 testing</td></tr>
<tr><td>3/19/2012</td><td>Pre-GnG</td><td>Outflow Drainage testing</td></tr>
<tr><td>3/26/2012</td><td>GnG</td><td>Friction CT 342 testing</td></tr>
<tr><td>3/26/2012</td><td>GnG</td><td>Outflow Drainage testing</td></tr>
<tr><td colspan="2">2/2012 – 5/2012</td><td>Resurfacing of Evaluation Area</td><td>EA 2F040</td></tr>
<tr><td>3/12/2012</td><td>CDG</td><td>OBSI and IRI testing</td><td>Tests in both directions, Lane 2 only</td></tr>
<tr><td>5/29/2012</td><td>GnG</td><td>OBSI and IRI testing</td><td>Tests in both directions</td></tr>
<tr><td>4/22/2013</td><td>GnG</td><td>Friction E274 testing</td><td>Tests in Lane 4 both directions</td></tr>
</table>

*Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, Pre-GnG = after flush grinding, GnG = after longitudinal grooving

3.4.3 Test Results

The test results for Sacramento 5 – PM 13.0/14.0 are shown in Table 3.12. Condition survey results are shown in Table 3.13.

Table 3.12: Summary of Test Results for Sac-80-PM 13.0/14.0

Evaluation Test Section			OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40})				Drainability Test Results (Avg. time in seconds)		
									CT 342 [2]		E 274				
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**
EB	LN 2	13.0/14.0	105.2	102.7	101.3	125.4	42.7	33.9	0.39 0.39	0.30 0.28			14.3	2.7	8.3
	LN 5	13.0/14.0	105.1		101.4	137.1		41.6				39 48[1]			
WB	LN 2	13.0/14.0	104.9	103.5	101.2	134.0	54.4	41.9							
	LN 5	13.0/14.0	105.2		101.5	147.6		47.7				29 37[1]			
EB Average Values			**105.2**	**102.7**	**101.4**	**131.3**	**42.7**	**37.8**	**0.39**	**0.29**		**39**	**14.3**	**2.7**	**8.3**
WB Average Values			**105.0**	**103.5**	**101.4**	**140.8**	**54.4**	**44.8**				**29**			
Project Average Values			**105.1**	**103.1**	**101.4**	**136.0**	**47.7**	**41.3**	**0.39**	**0.29**		**33**	**14.3**	**2.7**	**8.3**
Standard Deviation			0.5	0.8	0.5										

Notes:
[1] Ribbed Tire test results, not included in averages
[2] Left wheelpath results above right wheelpath results

Table 3.13: Condition Survey Results for Sac-80-PM 13.0/14.0

Location		Number of Observed Slabs	Percentage (Number) of Observed Slabs with Distress					
Project	**Lane, Direction, and Post Mile**		**Transverse Cracking**	**Longitudinal Cracking**	**Corner Cracking**	**Minor Spalling**	**Major Spalling**	**Scaling**
Sac 80 – PM13.0/14.0	Lane 2 EB PM13.5/13.6	22		9% (2)				2% (4)

3.5 Sacramento 50 – PM R13.0/R14.0 Evaluation Section

3.5.1 Location and Traffic

This grind project (EA#0A800) included grinding all lanes in both directions of Sacramento 50 from PM R12.2 (west of the Sunrise overcrossing) to PM R14.2 (between Sunrise Boulevard and Hazel Avenue) as shown in Figure 3.5. By special provision, the GnG surface was placed between PM R12.8 and PM R14.2 in all the westbound lanes; the CDG surface in the eastbound direction was used for comparison.

The noise and skid measurements at highway speeds for the GnG texture were conducted in Lanes 2 and 4 between PM R13.0 and PM R14.0 in both directions, and the stationary friction and other tests were conducted in westbound Lane 4 at PM R13.5. Lane 1 was not used because the surface in both directions is asphalt concrete.

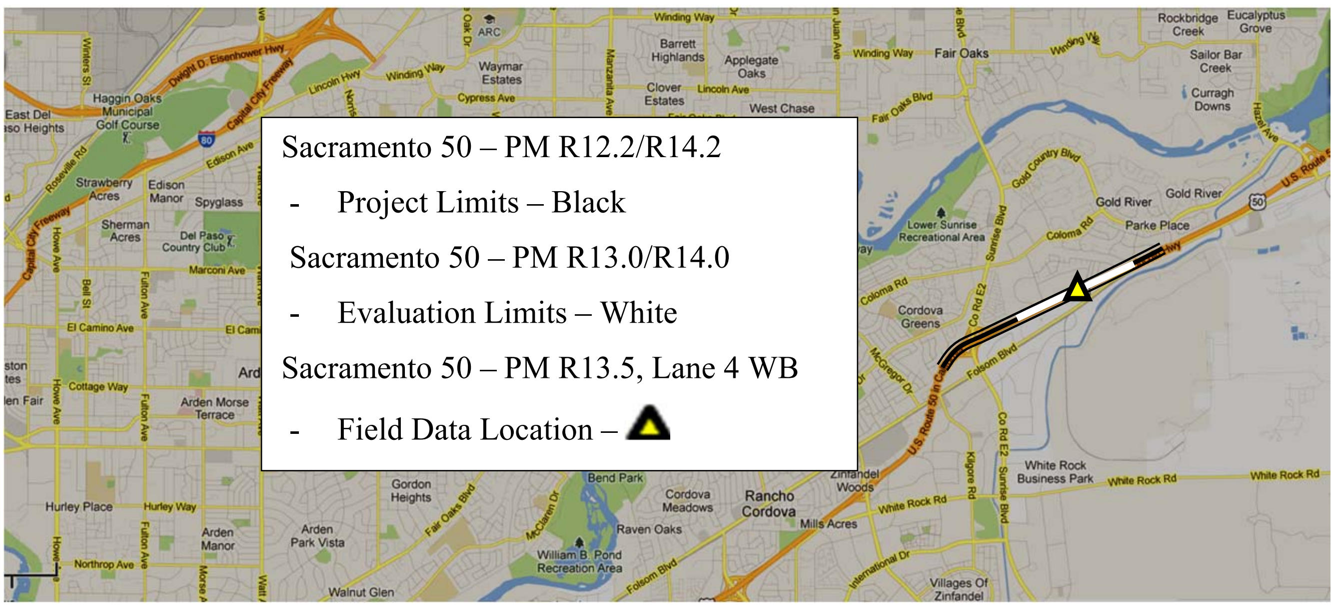


Figure 3.5: Noise and Friction Evaluation Limits on Sacramento 50 – PM R13.0/R14.0.

Table 3.14 presents the traffic and truck volumes for the project site from 2007 through 2011. The traffic counts are from the intersection of Sunrise Boulevard (at PM 12.496) and the intersection of Nimbus Road (at PM 15.759). In the table, traffic leg A indicates that the volumes are in the direction of increasing post mile numbers, moving toward the evaluation section at PM 13.0/14.0 for the volumes counted at PM 12.496.

Table 3.14: Traffic and Truck Counts on Sacramento 50 - PM 12.496 and 15.759

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Trucks		2	3	4	5+
12.496	A	2007	125,000	8,000	6.4	3,200	960	320	3,520
		2009	121,000	7,744	6.4	3,098	929	310	3,407
		2011	117,000	7,488	6.4	2,995	899	300	3,295
15.759	A	2007	118,000	7,434	6.3	3,078	900	223	3,234
		2009	115,000	7,245	6.3	2,999	877	217	3,152
		2011	111,000	6,993	6.3	2,895	846	210	3,042

Note: Traffic Leg A traffic counts are from north of the intersection.

3.5.2 Testing and Construction Schedule

Table 3.15 shows the testing and construction evaluation sequence for this project.

Table 3.15: Testing and Construction Sequence for Sac 50 – PM R13.0/R14.0 Evaluation

Date	Texture Condition*	Testing or Activity	Comment
8/12/2010	Pre-CDG	OBSI and IRI testing	Data from tests conducted in eastbound lanes as part of the UCPRC PCC Noise Study QP106
1/8/2011	Pre-CDG	Outflow Drainage testing	
4/2012 – 6/2012		Resurfacing of Evaluation Area	EA 0A800
5/30/2012	CDG	OBSI and IRI testing	Tests in Lane 1 in both directions
5/30/2012	GnG	OBSI and IRI testing	Tests in both directions
8/2/2012	GnG	Outflow Drainage testing	Tests were conducted starting at westbound Lane 4 PM R13.5 + 0, 25, 50, 75, 100, 200, 225, 250, 275, 300, 400, 425, 450, 475, and 500 feet.
4/22/2013	GnG	Friction E274 testing	Tests in Lane 4 in both directions

*Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, Pre-GnG = after flush grinding, GnG = after longitudinal grooving

3.5.3 Test Results

The test results for Sacramento 50 – PM R13.0/R14.0 are shown in Table 3.16. No condition survey was performed on this section.

Table 3.16: Summary of Test Results for Sac-50 – PM R13.0/R14.0

Evaluation Test Section			OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40})				Drainability Test Results (Avg. time in seconds)		
									CT 342		E 274				
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**
EB	LN 1	13.0/14.0	103.4	102.9		135.2	77.2								
	LN 4	13.0/14.0	104.4			171.9						39	9.4		
WB	LN 1	13.0/14.0			100.6			62.6							
	LN 4	13.0/14.0			100.8			52.3				40 46[1]			12.0
EB Average Values			**103.9**	**102.9**		**153.5**	**77.2**					**39**	**9.4**		
WB Average Values					**100.7**			**57.5**				**40**			**12.0**
Project Average Values			**103.9**	**102.9**	**100.7**	**153.5**	**77.2**	**57.5**				**39**	**9.4**		**12.0**
Standard Deviation [2]			0.6	1.1	0.7										

[1] Ribbed Tire test results, not included in averages

3.6 San Joaquin 99 – PM 29.0/30.7 Evaluation Section

3.6.1 Location and Traffic

As shown in Figure 3.6, this project (EA#0V870) included grinding both lanes in the northbound direction of San Joaquin 99, from PM 29.0 (South of Kettleman Lane) to PM 30.8 (north of the East Pine Street overcrossing). The GnG surface was constructed on the entire project. There was no CDG texturing on this pilot project as the southbound direction and all adjacent pavement surfacing is hot-mix asphalt.

The noise and skid measurements at highway speeds were performed in Lanes 1 and 2 between PM 29.0 and PM 30.7, while the stationary tests were conducted in Lane 1 at PM 30.5.

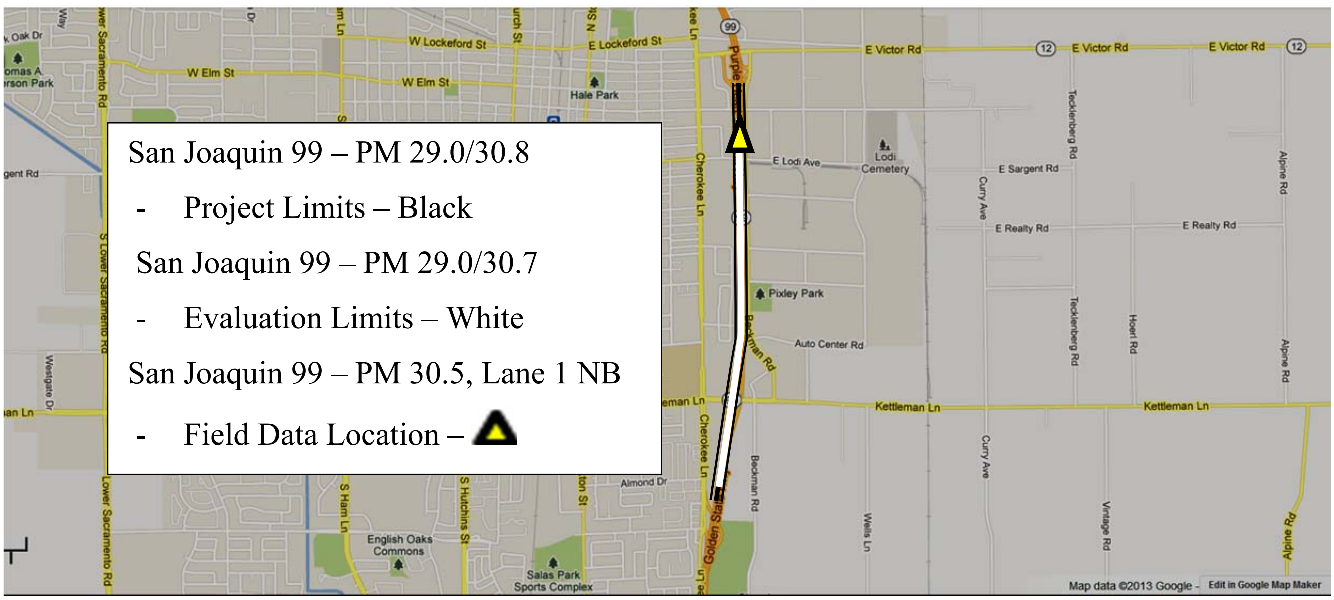


Figure 3.6: Noise and Friction Evaluation Limits on San Joaquin 99 Northbound – PM 29.0/30.7.

Table 3.17 presents the traffic and truck volumes for the project site from 2007 through 2011. The traffic counts are from the Route 12 West Junction (at PM 24.499) and the Route 12 East Junction (at PM 30.974). In the table, the traffic leg entry indicates whether the volumes are in the direction of increasing post mile numbers, A, or decreasing post mile numbers, B. While the vehicle counts over this section were among the lowest of the pilot projects (only Yolo 113 and Sacramento 5 – PM 1.5/3.0 had lower AADT), the percent trucks (13.4 percent) were second only to Sacramento 5 – PM 1.5/3.0 (24.3 percent).

Table 3.17: Traffic and Truck Counts on San Joaquin 99 - PM 29.499 and 30.974

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Trucks		2	3	4	5+
29.499	B	2007	67,000	8,911	13.3	2,673	713	356	5,168
		2009	59,000	7,847	13.3	2,354	628	314	4,551
		2011	58,000	7,714	13.3	2,314	617	309	4,474
29.499	A	2007	65,000	8,710	13.4	3,026	540	281	4,863
		2009	65,000	8,710	13.4	3,026	540	281	4,863
		2011	65,000	8,710	13.4	3,026	540	281	4,863
30.974	A	2007	64,000	8,576	13.4	2,979	532	277	4,788
		2009	65,000	8,710	13.4	3,026	540	281	4,863
		2011	65,000	8,710	13.4	3,026	540	281	4,863

Note: Traffic Leg A traffic counts are from north of the intersection and Leg B traffic counts are from south of the intersection.

3.6.2 Testing and Construction Schedule

Table 3.18 shows the testing and construction evaluation sequence for this project.

Table 3.18: Testing and Construction Sequence for SJ 99 – PM 29.0/30.7 Evaluation

Date	Texture Condition*	Testing or Activity	Comment
6/25/2012	Pre-CDG	OBSI and IRI testing	Tests northbound only
6/26/2012	Pre-CDG	Outflow Drainage testing	Tests were conducted starting at northbound Lane 2 PM 30.5 + 0, 25, 50, 75, 100, 200, 225, 250, 275, 300, 400, 425, 450, 475, and 500 feet.
6/27/2012	CDG	Outflow Drainage testing	
7/11/2012	GnG	Outflow Drainage testing	
6/2012 – 7/2012		Resurfacing of Evaluation Area	EA 0V870
7/18/2012		Friction E274 testing	Tests northbound only
9/14/2012	GnG	OBSI and IRI testing	Tests northbound only
4/22/2013	GnG	Friction E274 testing	Tests northbound only

*Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, Pre-GnG = after flush grinding, GnG = after longitudinal grooving

3.6.3 Test Results

The test results for San Joaquin 99 – PM 29.0/30.7 are shown in Table 3.19. No condition survey was performed on this section.

Table 3.19: Summary of Test Results for San Joaquin 99 – PM 29.0/30.7

Evaluation Test Section			OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40})				Drainability Test Results (Avg. time in seconds)		
									CT 342		E274				
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**
NB	LN 1	29.0/30.7	104.0		100.2	126.1		44.3					6.5	4.3	4.5
	LN 2	29.0/30.7	104.6		101.1	178.5		72.9				36 44[1]			
NB Average Values			**104.3**		**100.7**	**152.3**		**64.3**				**36**	**6.5**	**4.3**	**4.5**
Project Average Values			**104.3**		**100.7**	**152.3**		**64.3**				**36**	**6.5**	**4.3**	**4.5**
Standard Deviation [2]			0.7		1.1										

Note:
[1] Ribbed Tire test results, not included in averages

3.7 Yolo 113 – PM R0.0/R11.1 Evaluation Section

3.7.1 Location and Traffic

This project (EA#2F050) included grinding of all lanes in both directions of Yolo 113 from PM R0.0 (at the Solano County line) to PM R11.1 (at the I-5 interchange) as shown in Figure 3.7. The GnG texture was constructed on all the lanes between PM R0.2 (south of Hutchinson Drive) and PM R1.5 (north of Russell Boulevard) northbound and between PM R0.25 and PM R0.9 (south of Russell Boulevard) southbound. The CDG surface north of the GnG sections up to PM R2.5 (north of Covell Road) was used for comparison.

Adjacent sections up through PM R2.5 were planned for construction but the initial data revealed differences in the Pre-CDG textures before construction in Lane 1, with the OBSI readings from the section of pavement scheduled for GnG treatment found to be 1 dBA different from the section that was to receive the CDG surface.

The noise and friction evaluations were conducted at highway speed in Lanes 1 and 2 between PM R0.5 and R2.5 in both directions. The stationary tests were conducted in southbound Lane 1 at PM R0.5. Initially, the evaluation point was southbound Lane 1 at PM R1.0, within the original GnG limits of PM R0.25 to PM R1.5 southbound. The GnG limits southbound were shortened to between PM R0.25 and PM R0.90, and the preconstruction texture and friction evaluation was conducted again at PM R0.5. In order to collect more data to compensate for the reduced section size, post-GnG construction measurements of the OBSI southbound were extended from PM 0.5 to PM 0.4.

Table 3.20 presents the traffic and truck volumes for the project site from 2007 through 2011. The traffic counts are from the intersection with Russell Boulevard (at PM 1.082) and the intersection with County Road 29 (at PM 4.105). In the table, the traffic leg indicates whether the volumes are in the direction of increasing post mile numbers, A, or decreasing post mile numbers, B. This route had the lowest vehicular and truck volumes of the seven pilot projects.

Table 3.20: Traffic and Truck Counts on Yolo 113 - PM R1.082 and R4.105

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Trucks		2	3	4	5+
R1.082	B	2007	41,000	2,206	5.4	715	196	77	1,218
		2009	37,500	2,018	5.4	654	180	71	1,114
		2011	37,100	1,996	5.4	647	178	70	1,102
R1.082	A	2007	33,000	1,931	5.9	660	180	120	971
		2009	32,500	1,901	5.9	650	177	118	955
		2011	32,000	1,872	5.9	640	175	116	941
R4.105	A	2007	25,000	1,930	7.7	660	180	120	970
		2009	24,600	1,899	7.7	649	177	118	954
		2011	24,100	1,861	7.7	636	174	116	935

Note: Traffic Leg A traffic counts are from north of the intersection and Leg B traffic counts are from south of the intersection.

3.7.2 Testing and Construction Schedule

Table 3.21 shows the testing and construction evaluation sequence for this project.

Table 3.21: Testing and Construction Sequence for Yolo 99 – PM R0.5/R2.5 Evaluation

Date	Texture Condition*	Testing or Activity	Comment
6/25/2012	Pre-CDG	OBSI and IRI testing	Tested in both directions
7/13/2012	Pre-CDG	Outflow Drainage testing	Tests were conducted starting at southbound Lane 1 PM R1.0, outside revised GnG limits.
10/31/2012	Pre-CDG	Outflow Drainage testing	Tests were conducted starting at southbound Lane 1 PM R0.5 + 0, 25, 50, 75, 100, 200, 225, 250, 275, 300, 400, 425, 450, 475, and 500 feet.
11/27/2012	GnG	Outflow Drainage testing	
2/2012 – 5/2012		Resurfacing of Evaluation Area	EA 2F050
3/12/2012	CDG	OBSI and IRI testing	Tests in both directions, Lane 2 only
5/29/12	GnG	OBSI and IRI testing	Tests in both directions
7/12/2012	GnG	Friction E274	Tests in Lane 1 southbound
4/23/2013	GnG	Friction E274	Tests in both lanes in both directions

*Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, Pre-GnG = after flush grinding, GnG = after longitudinal grooving.

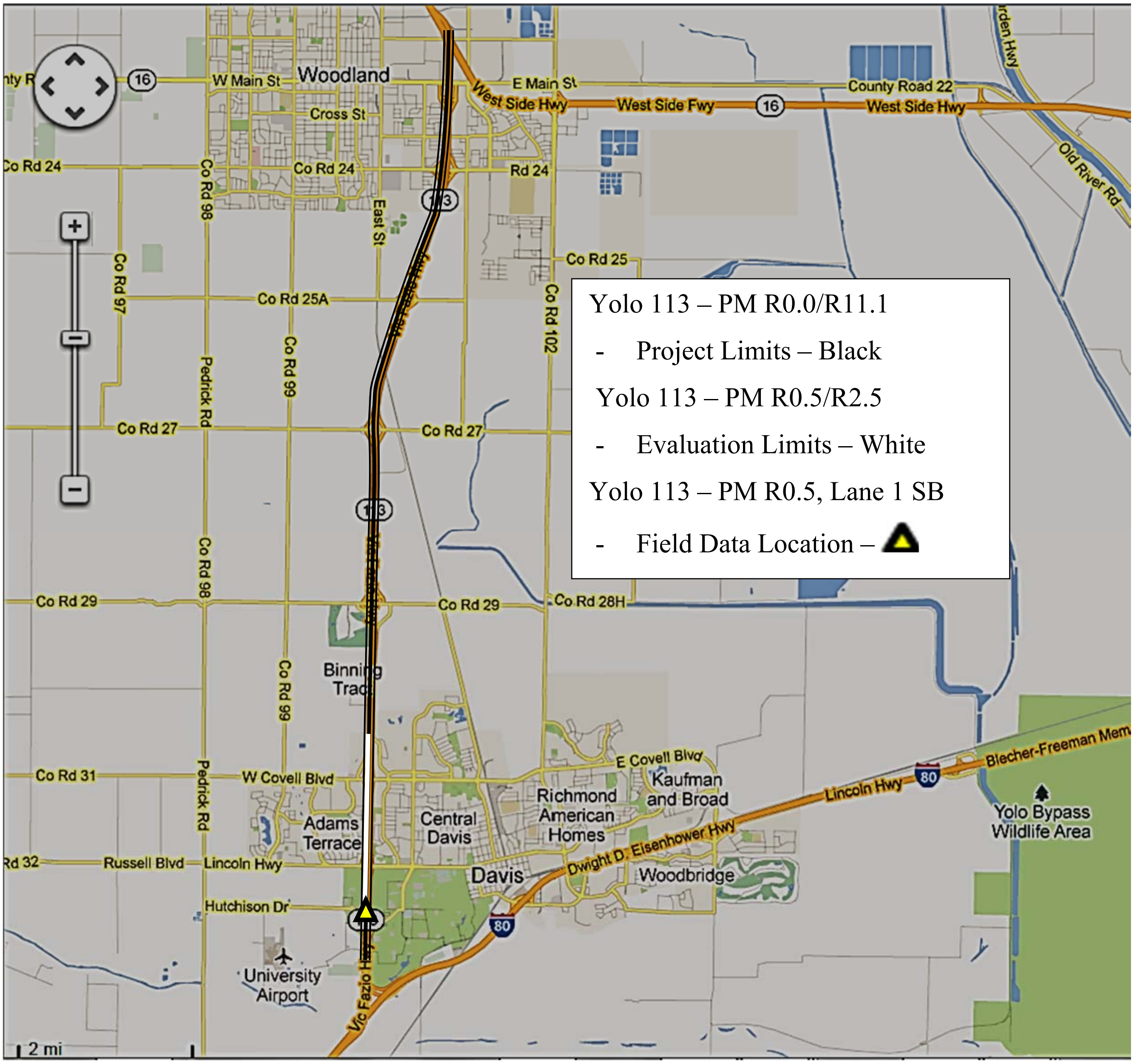


Figure 3.7: Noise and Friction Evaluation Limits on Yolo 113 – PM R0.5/R2.5.

3.7.3 Test Results

The test results for Yolo 113 – PM R0.5/R2.5 are shown in Table 3.22. No condition survey was performed on this section.

Table 3.22: Summary of Test Results for Yol-113-PM 0.5/2.5

Evaluation Test Section			OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40})				Drainability Test Results (Avg. time in seconds)		
									CT 342		E274				
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**PreCDG**	**CDG**	**GnG**
NB	LN 1	0.5/1.5	102.7		99.9	116.7		53.1							
		1.5/2.5	103.6	101.8		106.8	49.2								
	LN 2	0.5/1.5	103.6		99.7	132.3		47.6				45 50[1]			
		1.5/2.5	103.8	100.6		119.5	45.4				44				
SB	LN 1	0.4/0.9	103.2		99.9	151.1		44.7					18.6		4.8
		0.9/2.5	102.1	100.8		126.3	54.1				54[1]				
	LN 2	0.4/0.9	102.9		99.5	138.6		49.3				41 45[1]			
		0.9/2.5	103.1	101.0		134.7	68.0				41 52[1]				
NB Average Values			**103.4**	**101.2**	**99.8**	**118.5**	**47.3**	**50.3**			**44**	**45**			
SB Average Values			**102.8**	**100.9**	**99.8**	**133.9**	**61.5**	**47.0**			**41**	**41**	**18.6**		**4.8**
Project Average Values			**103.0**	**101.0**	**99.8**	**126.1**	**55.4**	**49.1**			**43**	**43**	**18.6**		**4.8**
Standard Deviation [2]			1.1	0.7	0.4										

Note:
[1] Ribbed Tire test results, not included in averages

3.8 San Diego 5 – PM R35.8/R37.9 Evaluation Section

3.8.1 Location and Traffic

The grinding of both directions of San Diego 5 near Solana Beach included two construction contracts, one for the conventional diamond grind (EA#07980) between PM R32.7 (south of the SR 56 interchange) and PM R42.9 (north of Leucadia Ave.), and the other for the grind and groove (EA #07760) from PM R36.3 (at the Via de la Valle overcrossing) to PM R37.4 (at the Lomas Sante Fe overcrossing) (see Table 2.1 and Figure 3.8).

At the conclusion of the first contract for the CDG, a 2,000 foot test strip was constructed to evaluate the surface friction of the interim and final surfaces of the GnG texture. Once it was determined that the final texture satisfied the state friction requirement, approval was given to proceed with construction of the one mile long GnG section.

In the original plan for this study, San Diego 5 was going to be the only GnG pilot project. As a result, more comprehensive testing was conducted on it than on any of the other projects. Because the pavement structure has PCC from three different construction periods, three lanes were chosen for evaluation in both directions: Lane 1, which was constructed in the 2000s; Lane 2, which was constructed in the 1960s; and Lane 5, which was constructed in the 1970s. The half-mile of CDG surface both north and south of the GnG section, between PMs R37.4 and R37.9 and PMs R35.8 and R36.3, were used for comparison.

The highway speed noise and friction evaluation limits for the GnG and control CDG sections were set as Lane 1, Lane 2, and Lane 5 between PM R35.8 and PM R37.9 in both directions (Figure 3.8). The stationary tests were conducted in Lanes 1, 2, and 5 in both directions at the post miles shown in (Figure 3.9).

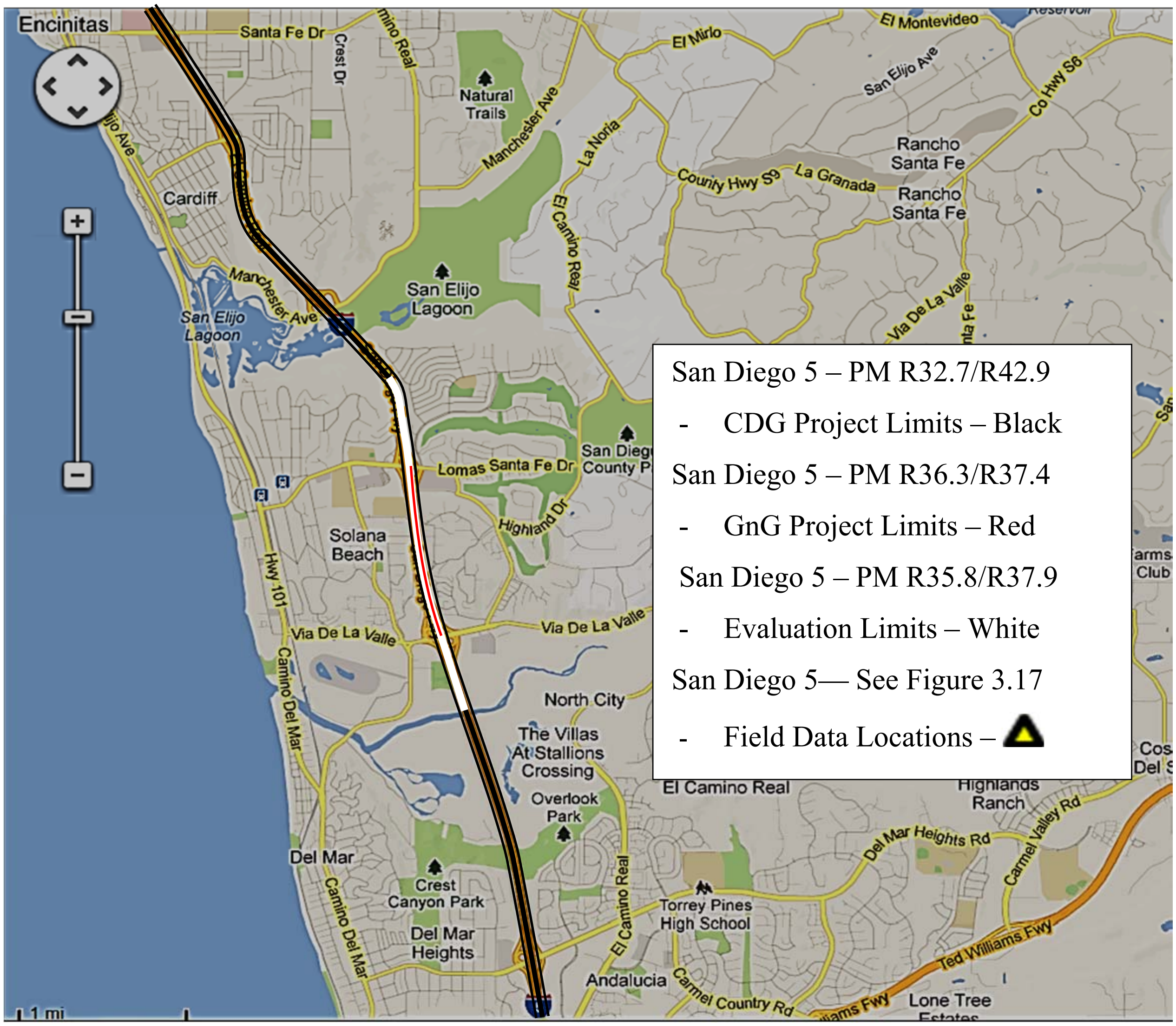


Figure 3.8: Noise and friction evaluation limits on San Diego 5 – PM R35.8/R37.9.

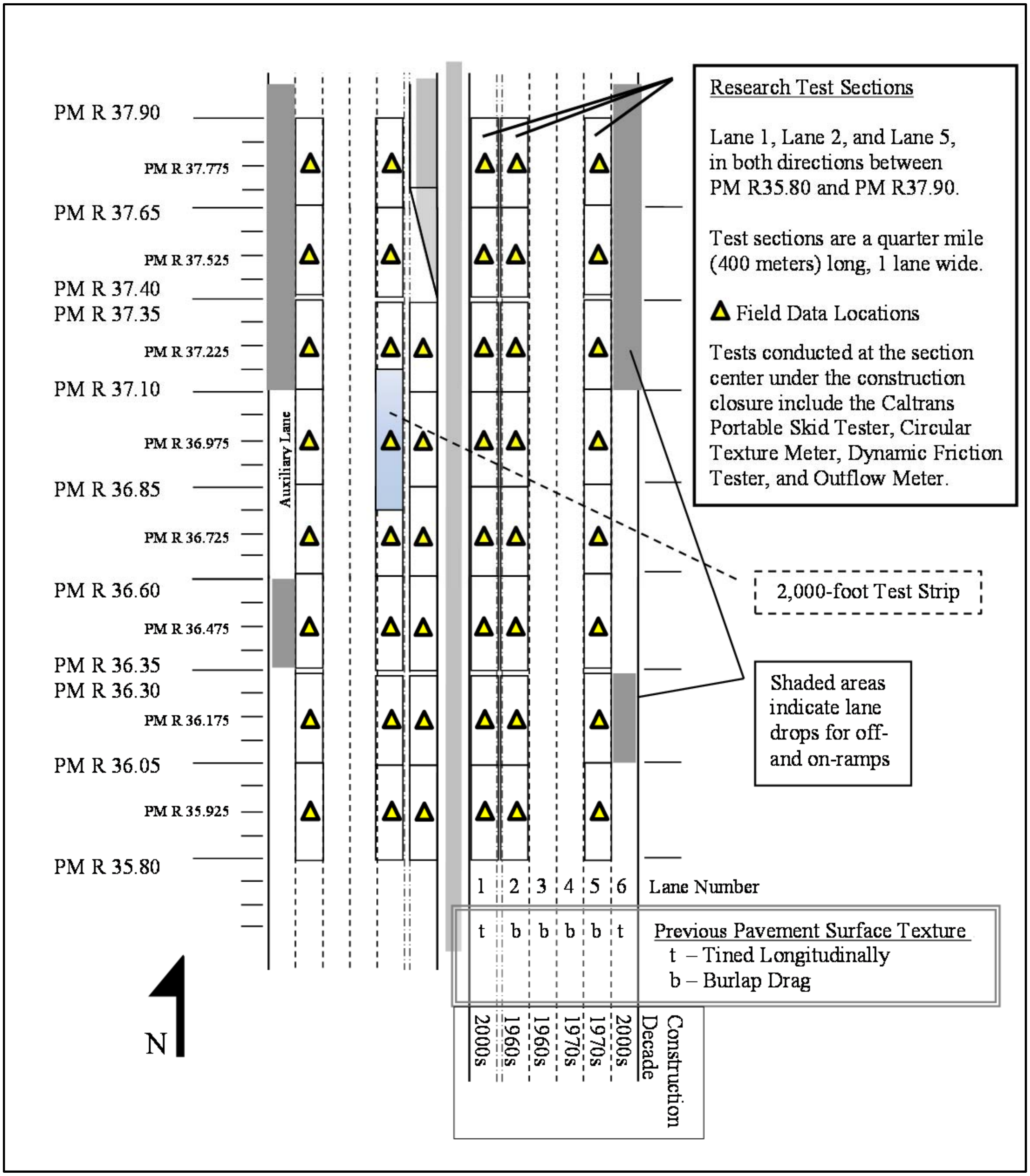


Figure 3.9: Texture and friction evaluation locations on San Diego 5 – PM R35.8/R37.9.

Table 3.23 presents the traffic and truck volumes for the project site from 2007 through 2011. The traffic counts are from the Route 805 North junction (at PM R30.682) and from the intersection of Leucadia Boulevard (at PM R42.712). In the table, traffic leg A indicates that the volumes are in the direction of increasing post mile numbers, toward the evaluation section at PM R35.8/R37.9, for the volumes counted at PM R30.682. Between these two traffic count locations, there was a 35 percent increase in vehicular traffic as well as a 60 percent increase in truck traffic. The GnG construction began at PM R36.3.

Table 3.23: Traffic and Truck Counts on San Diego 5 - PM R30.682 and R42.712

Post Mile	Traffic Leg	Year	Annual Average Daily Traffic (AADT)		Percent Trucks	Truck AADT Total (by Axle)			
			All Vehicles	Trucks		2	3	4	5+
R30.682	A	2007	145,000	5,510	3.8	2,424	413	176	2,496
		2009	148,000	5,624	3.8	2,474	422	180	2,548
		2011	148,000	5,624	3.8	2,475	422	180	2,548
R42.712	B	2007	201,000	10,030	5.0	4,007	793	350	4,881
		2009	202,000	9,145	4.4	3,717	739	345	4,344
		2011	205,000	9,020	4.4	3,710	667	292	4,349

Note: Traffic Leg A traffic counts are from north of the intersection and Leg B traffic counts are from south of the intersection.

3.8.2 Testing and Construction Schedule

Table 3.24 shows the testing and construction evaluation sequence for this project. Only OBSI testing was conducted immediately after CDG, so there are no CDG0.0y measurements for texture. Texture measurements were made 0.7 years after CDG (CDG0.7y), while the GnG was scheduled for early 2011. With project delays, another trip was made in May 2012 (CDG1.1y) to capture the texture immediately before the GnG construction.

Table 3.24: Testing and Construction Sequence for San Diego 5 – PM R35.8/R37.9 Evaluation

Date	Texture Condition*	Testing or Activity	Comment
12/2010 – 3/2011	Pre-CDG	Friction CT 342	Tests were conducted in both directions, Lane 1, Lane 2, and Lane 5 at the following post miles: R35.925, R36.175, R36.475, R36.725, R36.975, R37.225, R37.525, R37.775.
12/2010 – 3/2011	Pre-CDG	Outflow Drainage testing	
12/15/2010	Pre-CDG	OBSI and IRI testing	Tests in Lanes 1 – 5 in both directions
1/12/2011	Pre-CDG	Friction E274 testing	Tests in Lanes 1 – 5 in both directions
12/2010 – 4/2011		Conventional Diamond Grind	EA 07980, PM32.7/42.7
4/13/2011	CDG	OBSI and IRI testing	Tests in Lanes 1 – 5 in both directions
4/21/2011	CDG	Friction E274 testing	Tests in Lanes 1, 2 and 5 in both directions
4/21/2011	CDG	Friction CT 342 testing	Test Strip located on Lane 2 Southbound at PM R37.15/R36.80
4/27/2011	Pre-GnG	Friction CT 342 testing	
4/27/2011		GnG 2,000-ft Test Strip Construction	
4/28/2011	GnG-2k	Friction CT 342 testing	
5/6/2011	GnG-2k	OBSI and IRI testing	
12/10/2011	CDG0.7y	OBSI and IRI testing	Tests in Lanes 1 – 5 in both directions
5/10/2012	CDG1.1y	OBSI and IRI testing	Tests in Lanes 1 – 5 in both directions
5/10/2012	CDG1.1y	Outflow Drainage testing	Tests were conducted in both directions, Lane 1, Lane 2, and Lane 5 at the following post miles: R35.925, R36.175, R36.475, R36.725, R36.975, R37.225, R37.525, R37.775.
7/17/2012	GnG & CDG1.3y	Friction CT 342 and Outflow Drainage testing	
5/2012 – 7/2012		Grind and Groove Construction	EA 07760, PM36.3/37.4
8/10/2012	GnG & CDG1.3y	OBSI and IRI testing	Tests in Lanes 1 – 5 in both directions
4/20/2013	GnG & CDG1.3y	Friction E274	Tests in Lane 5 in both directions, and Lane 2 northbound

*Texture Condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDG = after conventional diamond grinding, GnG-2k = after construction of 2,000 foot test strip, CDGX.Xy = X.X years after conventional diamond grinding, GnG = after longitudinal grooving

3.8.3 Test Results

The test results for SD-5-PM 35.8/37.9 are shown in Table 3.25. Condition survey results are shown in Table 3.26.

Table 3.25: Summary of Test Results for SD-5-PM 35.8/37.9

Evaluation Test Section			OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40}) CT 342		E274		Drainability Test Results (Avg. time in seconds)		
Direction	**Lane**	**Post Mile**	**PreCDG**	**CDG[1]**	**GnG**	**PreCDG**	**CDG[1]**	**GnG**	**CDG[1]**	**GnG**	**CDG[1]**	**GnG**	**PreCDG**	**CDG[1]**	**GnG**
NB	LN 1	35.8/37.9	105.0	102.3	99.9	127.3	57.4	41.2	0.33	0.33			7.9	2.1	4.8
	LN 2	35.8/37.9	104.9	103.1	100.6	175.3	62.5	43.9	0.33	0.30	49[2]	46[2]	8.0	2.6	5.8
	LN 3	35.8/37.9	105.7	102.9	100.4	178.9	60.6	37.7							
	LN 4	35.8/37.9	106.3	104.7	101.1	164.0	57.3	39.1							
	LN 5	35.8/37.9	104.8	103.7	101.0	155.3	59.8	37.7	0.33	0.23	42 49[2]	36 42[2]		4.4	5.4
SB	LN 1	35.8/37.9	103.7	101.9	100.1	126.0	60.5	37.3	0.34	0.28			7.8		5.7
	LN 2	35.8/37.9	104.6	103.1	100.9	158.8	60.5	36.1					6.0	6.4	4.7
	LN 3	35.8/37.9	105.6	102.6	100.7	177.0	57.6	41.0							
	LN 4	35.8/37.9	106.2	104.2	101.2	164.1	62.7	38.4							
	LN 5	35.8/37.9	105.2	103.6	100.8	156.0	61.3	45.1	0.47	0.29	43 47[2]	42 45[2]	7.4	3.7	4.4
NB Average Values			**105.3**	**103.3**	**100.6**	**160.4**	**59.5**	**39.9**			**42**	**36**	**8.0**	**3.6**	**5.3**
SB Average Values			**105.1**	**103.1**	**100.7**	**155.8**	**59.8**	**39.6**			**43**	**42**	**7.2**	**5.0**	**4.9**
Project Average Values			**105.2**	**103.2**	**100.7**	**158.3**	**59.6**	**39.8**			**42**	**39**	**7.5**	**4.0**	**5.1**
Standard Deviation [2]															

Notes:
[1] OBSI and IRI tests on CDG conducted immediately after grinding (CDG0.0y). Friction and drainability tests conducted after grinding and grooving (CDG1.3y).
[2] Ribbed tire test results, not included in average.

Table 3.26: Condition Survey Results for SD-5-PM 35.8/37.9.

Location		Number of Observed Slabs	Percentage (Number) of Observed Slabs with Distress					
Project	Lane, Direction, and Post Mile		Transverse Cracking	Longitudinal Cracking	Corner Cracking	Minor Spalling	Major Spalling	Scaling
SD 5 – PM35.8/37.9	Lane 1 NB PM35.9/37.8	247	1% (3)		1% (2)	54% (133)	4% (10)	
SD 5 – PM35.8/37.9	Lane 2 NB PM35.9/37.8	226	4% (8)	1% (3)	4% (8)	55% (125)	4% (10)	3% (6)
SD 5 – PM35.8/37.9	Lane 1 SB PM35.9/37.8	185	1% (1)		2% (3)	37% (69)		
SD 5 – PM35.8/37.9	Lane 2 SB PM35.9/37.8	206				54% (111)		

4 ANALYSIS AND DISCUSSION

Results of the evaluations are compared and analyzed in this chapter.

- Section 4.1 presents analysis of the OBSI data in terms of overall sound intensity, changes in sound intensity, and changes in the sound frequency spectra of the pilot projects.
- Section 4.3 presents analysis of the friction data obtained with both the California Test 342 (Portable Skid Tester) and ASTM E274 (Towed Skid Trailer), and surface drainability (related to texture) data obtained using the Outflow Meter (ASTM E2380).
- Section 4.4 presents IRI data analysis.

4.1 On-Board Sound Intensity (OBSI) Data

OBSI data were analyzed for both overall sound intensity and frequency spectra at one-third octave bands. The overall sound intensity allows comparison of sound intensity as perceived by humans.

4.1.1 Sound Intensity Data Analysis Process

OBSI data from each project were evaluated following the steps below:

1. Using the OBSI longitudinal profile for each lane tested (see Appendix A for all figures), average OBSI values for each texture type, lane, and direction were determined for each project. These averages were used to compare the differences in OBSI between the lanes and directions for the various textures. A detailed set of statistical comparisons can be found in Appendix I.
2. The OBSI data were combined for all lanes and directions for each project to produce a project average for each texture type.
3. Differences among the project averages for each texture type were then calculated to show the relative change in OBSI from pre-CDG to CDG, from pre-CDG to GnG, and from CDG to GnG.

In Section 4.1.2 through Section 4.1.9, the first figure shows the overall OBSI measured on the different textures for the individual lanes within each project. After a discussion of the sampled lanes and the change in overall OBSI for the different textures, the project averages for each texture are presented and the difference in overall OBSI between textures is shown. Section 4.1.9.1 summarizes the frequency content of OBSI data for all the pilot projects.

4.1.2 Sound Intensity Review of Sacramento 5 – PM 20.0/21.5

Figure 4.1 shows the overall OBSIs for the individual lanes on the Sacramento 5 – PM 20.0/21.5 project.

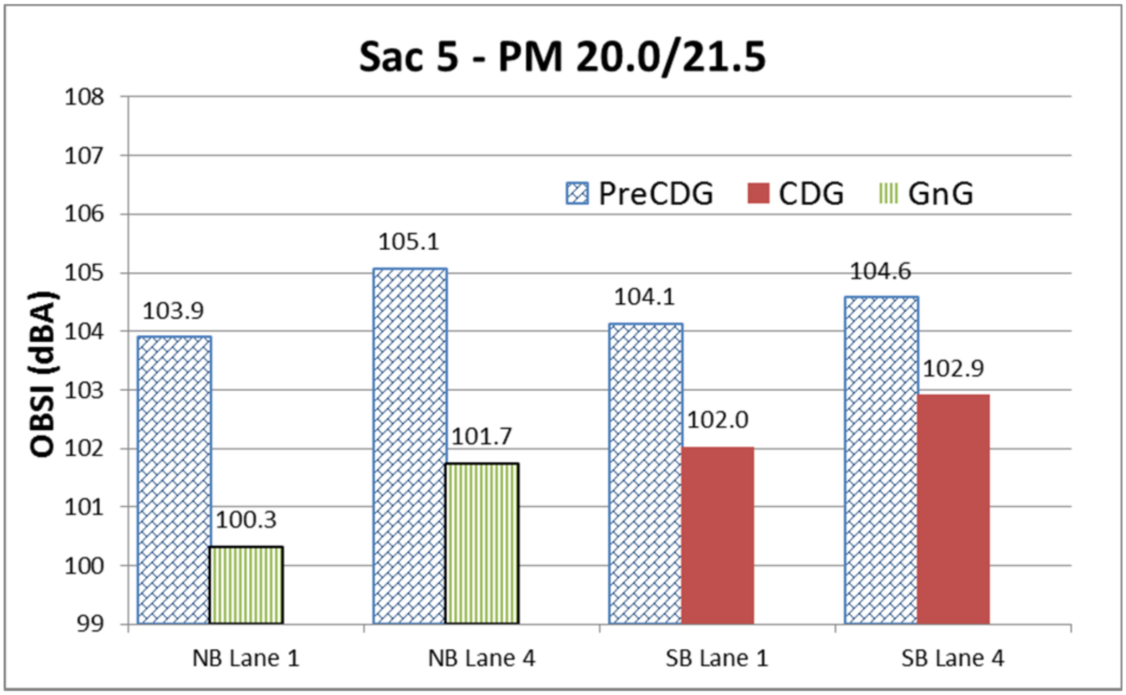


Figure 4.1: OBSI summary by lane for Sacramento 5 – PM 20.0/21.5.

Looking at the individual lanes on the Sacramento 5 – PM 20.0/21.5 project shown in Figure 4.1, it can be seen that the OBSI for the pre-CDG texture was much higher than those of the CDG and GnG textures. A statistical comparison of the lanes and textures appears in Table I.1. The GnG texture was quieter than the CDG texture on both Lane 1 and Lane 4. For each direction and surface texture, Lane 4 was louder than Lane 1 both before and after treatment. The pre-CDG difference in noise between the lanes is most likely due to traffic-related damage, namely faulting, which caused the higher IRI in the truck lanes (Table 3.3). The section had almost no cracking, and minor spalling on a large number of joints (Table 3.4). Joint width should not have been affected by grinding or grooving, although any refilling of joints with sealant would have reduced the joint cross-sectional area and the measured OBSI. The joints were not sealed before measurements were made after grinding and grooving.

Northbound, the reduction in OBSI from pre-CDG to GnG was 3.6 dBA for Lane 1 and 3.3 dBA for Lane 4. Southbound, the reduction in OBSI from pre-CDG to CDG was 2.1 dBA for Lane 1 and 1.7 dBA for Lane 4.

Figure 4.2 shows that on average across all lanes the CDG texture lowered the OBSI by 1.9 dBA, and the GnG texture produced an additional 1.4 dBA reduction (102.47 dBA to 101.03 dBA).

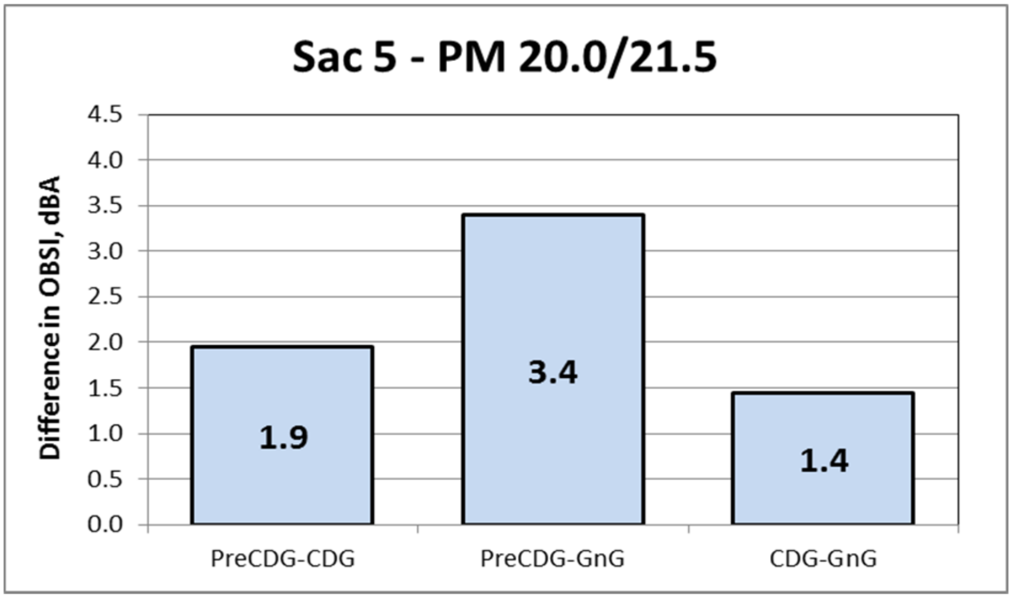


Figure 4.2: Overall difference in OBSI between different textures for Sacramento 5 – PM 20.0/21.5.

4.1.3 Sound Intensity Comparison of NGL and GnG on Sacramento-5-PM 20.5/20.7 NGL

The sound intensity data for the GnG and NGL textures are compared in Table 4.1.

Table 4.1: OBSI Data Comparison for GnG and NGL on Sacramento 5 – PM 20.0/21.5

Texture	Lane	OBSI, Average	OBSI, Standard Deviation
NGL	L1	99.3	0.2
GnG		100.4	0.5
NGL	L4	101.7	0.6
GnG		101.7	0.9

The OBSI difference between the GnG and NGL textures seen in Lane 1 does not exist in Lane 4, as can be seen in Table 4.1 and in Figure A.3 and Figure A.4 in Appendix A. The reason why the NGL was noisier in Lane 1 than Lane 4 is unknown.

4.1.4 Sound Intensity Review of Sacramento 5 – PM 1.5/3.0

For the Sacramento 5 – PM 1.5/3.0 project, shown in Figure 4.3, OBSI measurements were taken after the CDG construction in both directions and before GnG construction northbound. Two months later, OBSI measurements were taken in both directions after the GnG texture was constructed northbound. The measurements in the southbound direction were repeat measurements of the CDG texture and showed a decrease from the readings taken two months prior, with the decrease due to the reduction in positive texture from the breaking off of the fins caused by grinding. These second measurements of CDG texture have been used for direct comparison to the GnG texture measured at the same time.

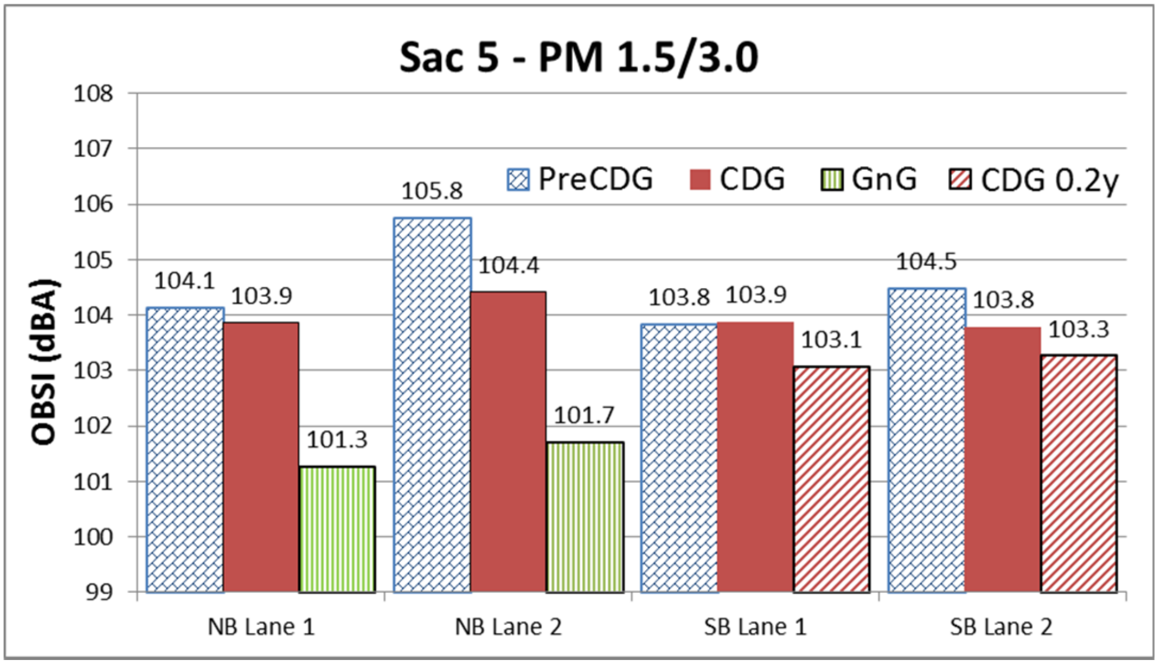


Figure 4.3: OBSI summary by lane for Sacramento 5 – PM 1.5/3.0.

The figure shows that in Lane 1 there was little to no reduction in the OBSI from pre-CDG to CDG. (A statistical comparison of lanes and textures can be seen in Table I.3.) The pre-CDG and CDG measurements (103.8 dBA and 103.9 dBA, respectively) in southbound Lane 1 are statistically equivalent, while those in the northbound direction (104.1 dBA and 103.9 dBA) are statistically different (Table I.4). For Lane 2, the reduction from pre-CDG to CDG was less than expected, 1.4 dBA northbound and 0.7 dBA southbound.

The noise reduction from the pre-CDG texture to the CDG texture may have been masked by a tire change from SRTT#4 to SRTT#5 between the pre-CDG and CDG evaluations. As discussed in Appendix C, the data sets are not adjusted for this comparison.

The pre-CDG data indicates that Lane 1 had less noise than Lane 2 for each direction. The reason for this is not certain, and is most likely not caused by a difference in faulting, as can be seen by the pre-CDG IRI values (Table 3.8). The data also indicate that for each lane the northbound direction had more noise than the southbound direction, which again probably cannot be attributed to differences in faulting since both directions have similar IRI values.

For Lane 1 in each direction, the CDG construction may have been less beneficial because the pavement condition was better before construction. The condition survey indicates that Lane 1 had a small amount of longitudinal cracking and some minor spalling at the joints (Table 3.9).

Figure 4.4 shows a reduction in the overall sound intensity for both the CDG and GnG constructions on the Sacramento 5 – PM 1.5/3.0 project. The CDG texture lowered the OBSI by 1.4 dBA, and the GnG texture produced an additional 1.7 dBA reduction.

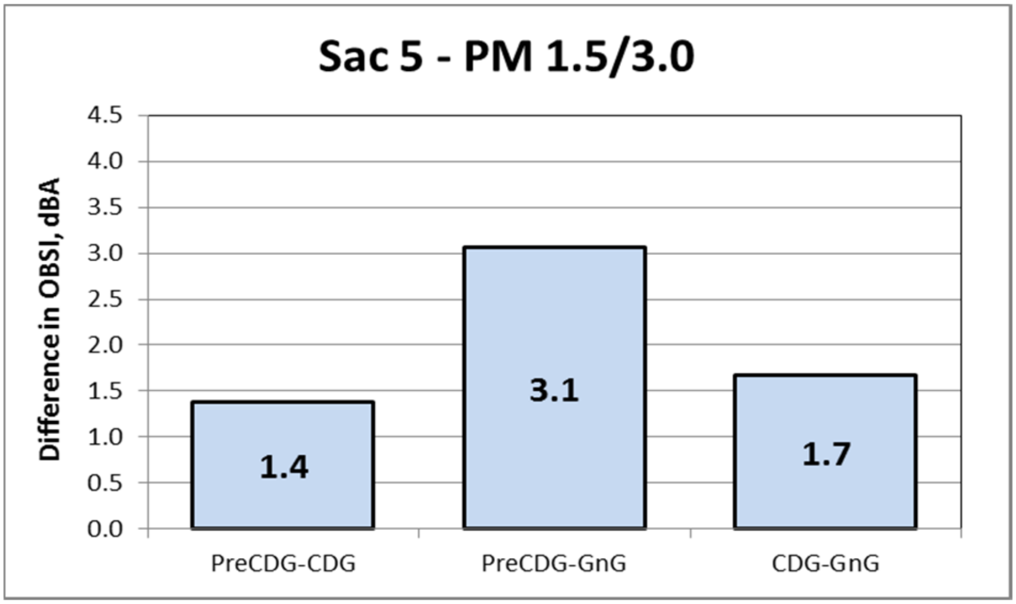


Figure 4.4: Difference in OBSI between different textures for Sacramento 5 – PM 1.5/3.0.

4.1.5 Sound Intensity Review of Sacramento 80 – PM 13.0/14.0

Figure 4.5 shows the overall OBSI measured on the individual lanes of Sacramento 80 – PM 13.0/14.0. Lane 1 was not included because it is surfaced with asphalt concrete. The CDG texture, measured only in Lane 2 because Lane 5 was inaccessible due to construction, was an interim surface. There is no CDG surface for future comparisons of noise levels on CDG versus GnG textures.

For the pre-CDG and GnG textures, the OBSI values are generally similar across the directions and lanes (Table I.5). The CDG in eastbound Lane 2 produced a 2.5 dBA reduction while the reduction was 1.4 dBA in westbound Lane 2. The condition survey on eastbound Lane 2 indicates that there was a small amount of longitudinal cracking and a small amount of minor spalling, which should not have contributed to noise (Table 3.13).

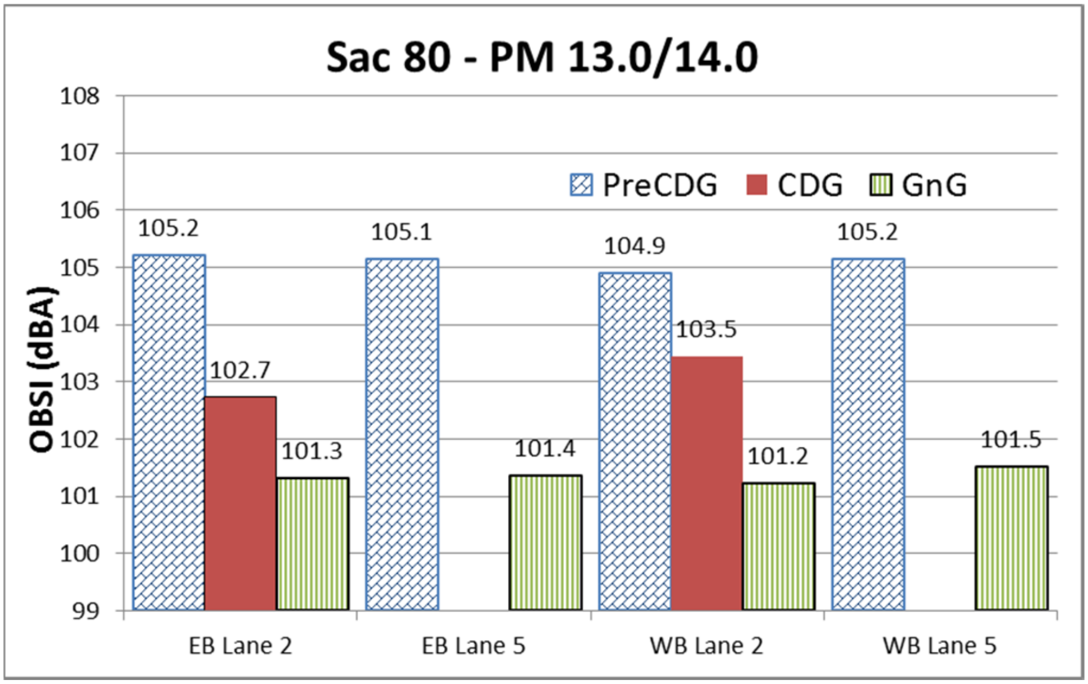


Figure 4.5: OBSI summary by lane for Sacramento 80 – PM 13.0/14.0.

Figure 4.6 shows the average reduction in overall sound intensity for both the CDG and GnG textures on the Sacramento 80 – PM 13.0/14.0 project. The CDG texture lowered the OBSI by 2.0 dBA, and the GnG texture produced an additional 1.7 dBA reduction.

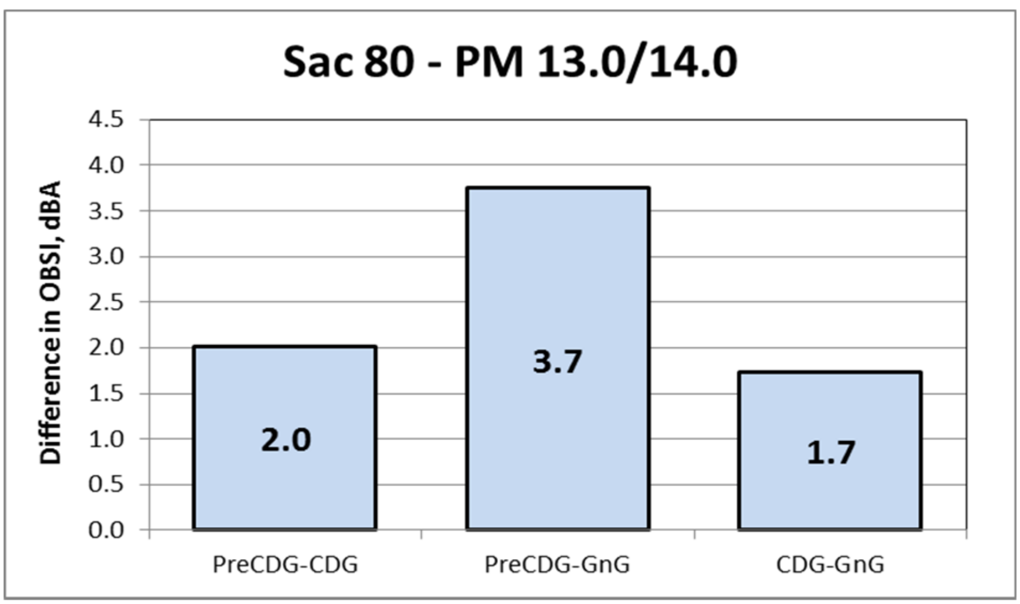


Figure 4.6: OBSI summary by lane for Sacramento 80 – PM 13.0/14.0.

4.1.6 Sound Intensity Review of Sacramento 50 – PM R13.0/R14.0

Figure 4.7 shows the overall OBSI measured on the lanes of the Sacramento 50 – PM R13.0/R14.0 project. The pre-CDG value was obtained from Sacramento 50 at PM R10.0 in the eastbound direction, as part of the PCC Noise Study (*15*). Lane 4 was inaccessible when the CDG evaluation was conducted.

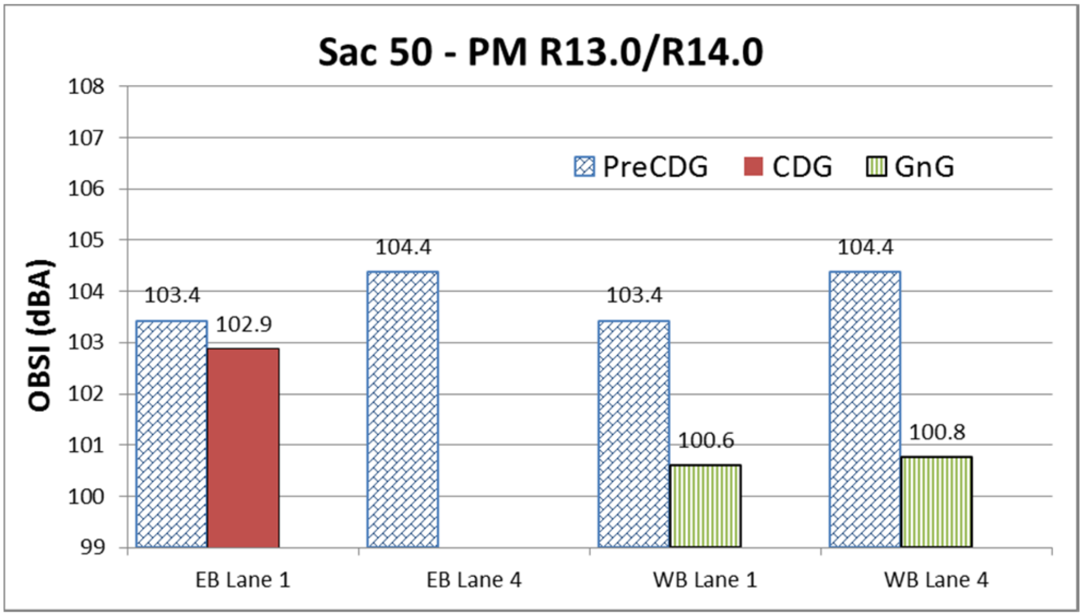


Figure 4.7: OBSI summary by lane for Sacramento 50 – PM R13.0/R14.0.

The Lane 4 pre-CDG values are higher, most likely due to faulting as evidenced by the higher IRI in Lane 4 of the westbound direction compared with Lane 1 (Table 3.16). For the GnG data, the overall OBSIs in Lane 1 and Lane 4 are close, with a difference of 0.2 dBA, although they are statistically distinct with a p-value of 0.004 (Table I.6) indicating that there was little variance within each lane.

Figure 4.8 shows that the CDG texture lowered the OBSI by 1.0 dBA compared with the pre-CDG texture, and the GnG texture produced an additional 2.2 dBA reduction.

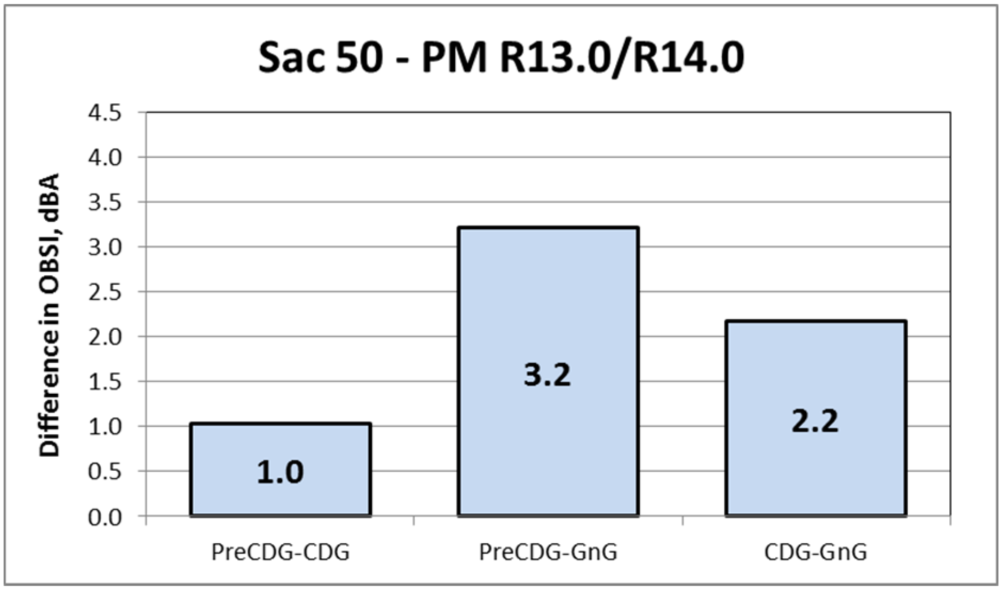


Figure 4.8: Differences in OBSI between different textures for Sacramento 50 – PM R13.0/R14.0.

4.1.7 Sound Intensity Review of San Joaquin 99 – PM 29.0/30.7

Figure 4.9 shows the overall OBSI measured on the individual lanes of San Joaquin 99 – PM 29.0/30.7 northbound; the southbound direction is asphalt concrete so no measurements were taken there. For both the pre-CDG and GnG textures, OBSI levels in Lane 2 were greater than in Lane 1 (Table I.7), although the IRI values in Lane 2 are much higher than those in Lane 1 (Table 3.19).

The GnG texture lowered the OBSI compared to the pre-existing (pre-CDG) condition by 3.8 dBA in Lane 1 and by 3.5 dBA in Lane 2. No CDG surface was available for comparison.

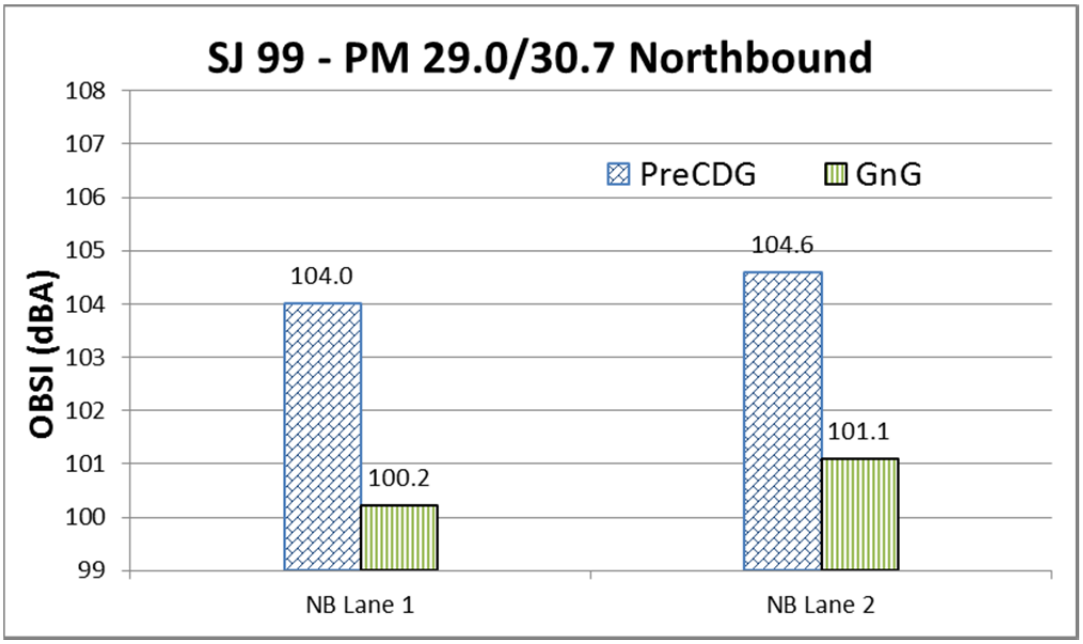


Figure 4.9: OBSI summary by lane for San Joaquin 99 – PM 29.0/30.7.

4.1.8 Sound Intensity Review of Yolo 113 – PM R0.5/R2.5

A summary of the OBSI measured on the Yolo 113 – PM R0.5/R2.5 subsections is given in Figure 4.10. As mentioned, the GnG texture was constructed from PM R0.2 to PM R1.5 northbound and PM R0.25 to PM R0.9 southbound. Figure 4.10 shows the overall OBSI measured on the lanes of the Yolo 113 – PM R0.5/R2.5 project.

Before construction, the average OBSI in Lane 2 was somewhat greater than that in Lane 1 in both directions. And for both Lane 1 and Lane 2, the northbound lanes were louder than the southbound lanes, although the IRI was generally lower in the northbound direction than in the southbound direction (Table 3.22).

The CDG texture reduced the OBSI of Lane 1 by 1.8 dBA northbound and by 1.3 dBA southbound. The OBSI in Lane 2 was reduced by 3.2 dBA northbound and by 2.0 dBA southbound. After CDG construction, the OBSI in northbound Lane 1 was 0.8 dBA to 1.2 dBA louder than the other lanes. After GnG construction, the OBSI levels in both the northbound and southbound Lane 1, at 99.9 dBA, were louder than those of Lane 2. It is not known why these differences occurred.

Figure 4.11 shows a reduction in the overall sound intensity for both the CDG and GnG construction on the Yolo 113 – PM R0.5/R2.5 project. The CDG texture lowered the OBSI by 2.0 dBA, and the GnG texture produced an additional 1.3 dBA reduction.

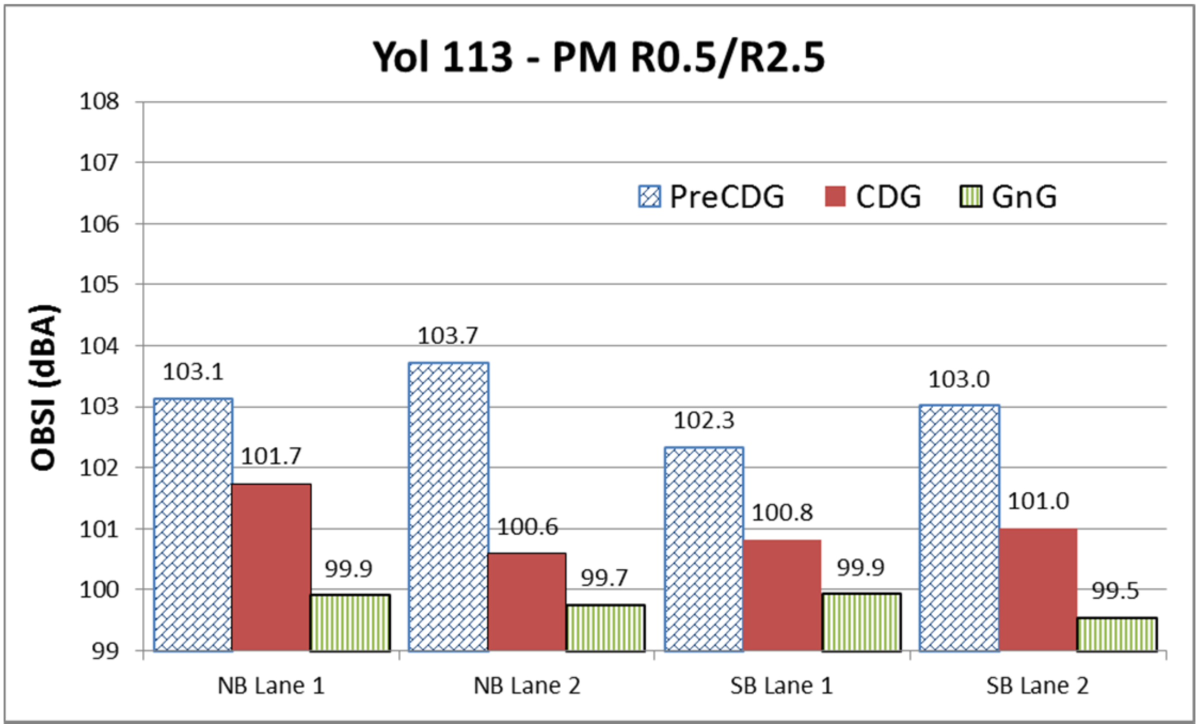


Figure 4.10: OBSI summary by lane for Yolo 113 – PM R0.5/R2.5.

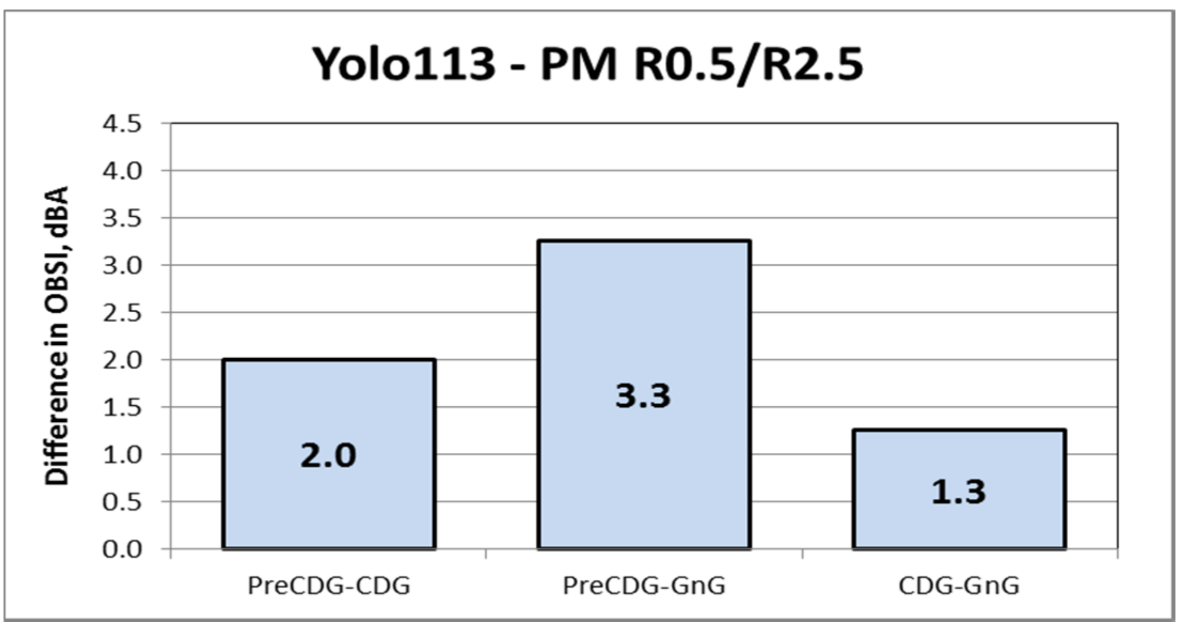


Figure 4.11: Difference in OBSI between different textures for Yolo 113 – PM R0.5/R2.5.

4.1.9 Sound Intensity Review of San Diego 5 – PM R35.8/R37.9

Table 4.2 provides a lane and texture summary of all of the testing on the San Diego 5 project. Multiple measurements were taken on the CDG texture: immediately after CDG construction (CDG0.0y), after equipment recalibration eight months later (CDG0.7y), before the GnG construction (CDG1.1y), and after GnG construction (CDG1.3y). Of the CDG data collected, the CDG0.0y is shown in Figure 4.12 and Figure 4.13, which compare the pre-CDG, CDG, and GnG textures for each lane of the San Diego 5 – PM R35.8/R37.9 project northbound and southbound, respectively. Figure 4.14 shows a comparison of the pre-CDG and measurements at different times after construction for the CDG texture. It can be seen that in addition to the reduction in OBSI caused by the initial CDG, the first seven months of trafficking resulted in an additional reduction in OBSI but not much reduction in the variability of OBSI. It can also be seen that there was little further reduction in OBSI on the CDG after the initial seven months. Figure 4.14 also shows that in addition to the reduction in OBSI caused by the GnG treatment, the variability of OBSI was also reduced.

The condition survey data (Table 3.26) indicates that there was a small amount of transverse and corner cracking on Lanes 1 and 2 in both directions, which should not have made much contribution to noise.

Table 4.2: OBSI Data from San Diego 5–PM R35.8/R37.9 Pilot Project

Texture[1]	Pre-CDG[1,2]		CDG0.0y[1,2]		CDG0.7y		CDG1.1y		CDG1.3y		GnG	
Date	**12/15/2010**		**4/13/2011**		**12/10/2011**		**5/10/2012**		**8/10/2012**		**8/10/2012**	
Lane	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
NB Lane 1	105.0	1.1	102.3	0.9	102.2	0.9	102.1	0.8	101.7	1.1	99.9	0.8
NB Lane 2	104.9	0.7	103.1	1.1	103.2	0.9	103.2	0.8	102.7	1.0	100.6	0.4
NB Lane 3	105.7	0.7	102.9	1.8	103.1	1.2	103.3	1.1	102.3	1.4	100.4	0.7
NB Lane 4	106.3	0.9	104.7	1.2	103.9	0.9	103.9	0.7	103.5	0.9	101.1	0.5
NB Lane 5	104.8	0.9	103.7	1.1	103.4	0.9	103.3	0.7	103.2	0.7	101.0	0.5
NB Average	105.3	1.0	103.3	1.5	103.1	1.1	103.2	1.0	102.7	1.2	100.6	0.7
SB Lane 1	103.7	1.2	101.9	1.0	101.7	1.2	101.6	1.1	101.5	1.5	100.1	0.9
SB Lane 2	104.6	0.9	103.1	1.3	102.7	1.2	102.8	1.0	102.6	1.2	100.9	0.6
SB Lane 3	105.6	0.8	102.6	1.5	102.9	1.0	103.0	0.9	102.4	1.0	100.7	0.5
SB Lane 4	106.2	0.8	104.2	1.2	103.5	0.8	103.5	0.7	103.3	0.8	101.2	0.5
SB Lane 5	105.2	0.9	103.6	1.2	103.5	0.9	103.4	0.8	103.4	0.7	100.8	0.5
SB Average	105.1	1.3	103.1	1.5	102.8	1.2	102.9	1.1	102.6	1.3	100.7	0.7
Average	**105.2**	**1.2**	**103.2**	**1.5**	**103.0**	1.2	**103.0**	1.1	**102.7**	**1.3**	**100.7**	0.7

Notes:

1. Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDGX.Xy = X.X years after flush grinding, GnG-2k = after construction of 2,000 foot test strip, GnG = after longitudinal grooving.
2. Data collected with the SRTT#4 test tire, otherwise data collected with the SRTT#5 test tire.

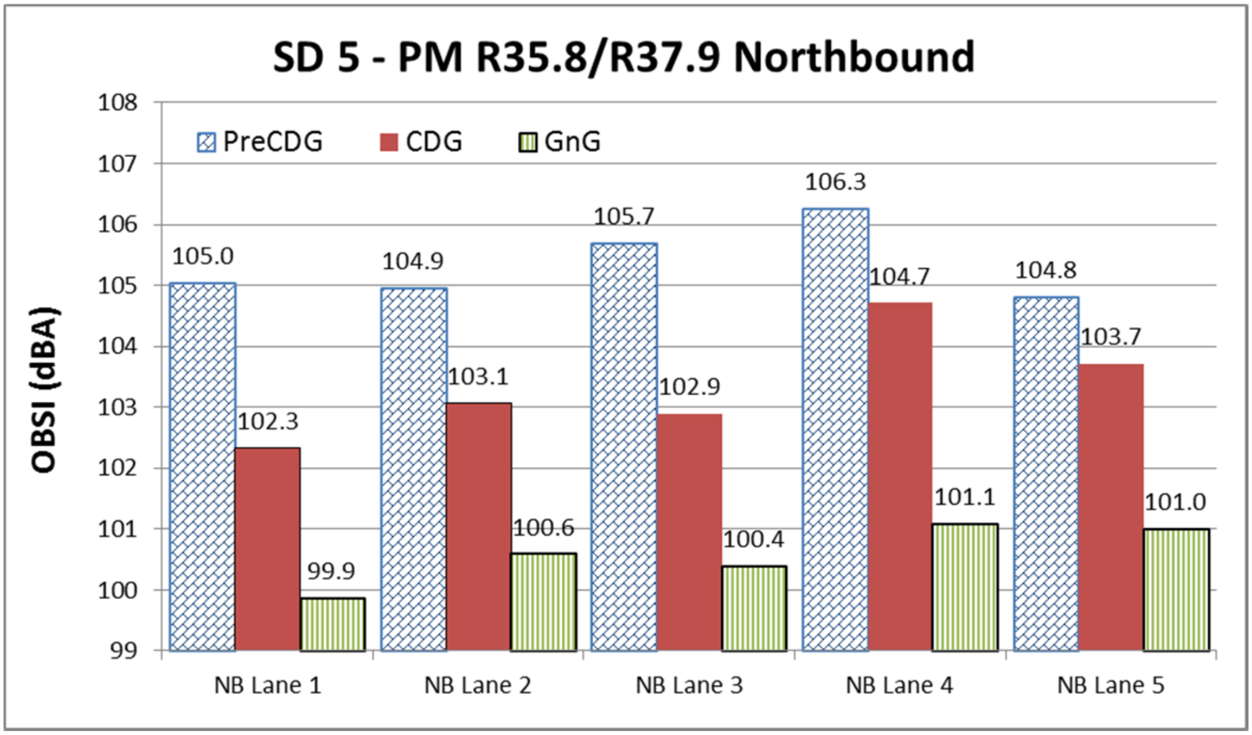


Figure 4.12: OBSI summary by lane for San Diego 5 – PM R35.8/R37.9 northbound.

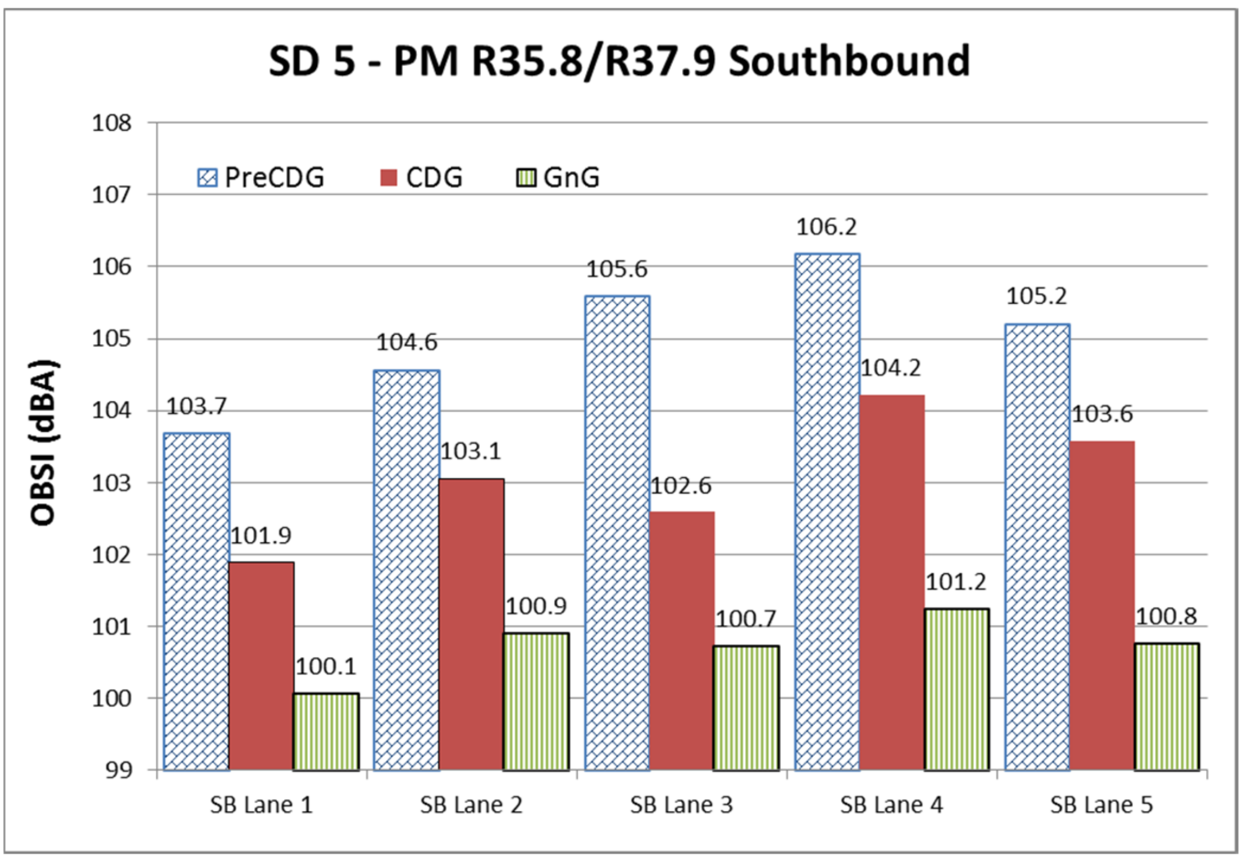


Figure 4.13: OBSI summary by lane for San Diego 5 – PM R35.8/R37.9 southbound.

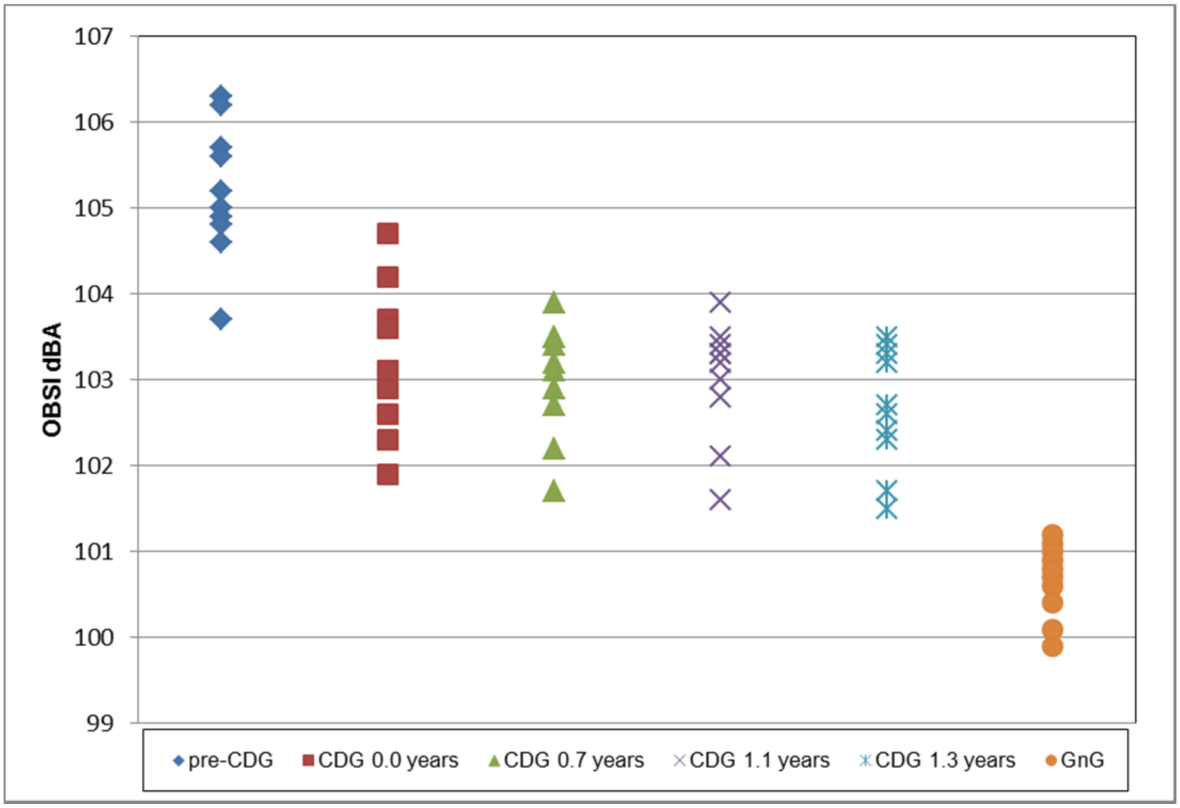


Figure 4.14: OBSI for all lanes on San Diego 5 – PM R35.8/R37.9 over time.

From Table 4.2 it can be seen that there are only small differences in the OBSI readings between CDG0.0y and CDG0.7y, except for Lane 4 in both directions (Table I.11).

Lane 4 was louder than any other lane for both directions and for each surface texture, while Lane 1 was the quietest. Lane 1 was also the newest lane, built after 2000, while Lanes 2 and 3 were 50 years old. Lanes 4 and 5 were constructed in between.

The results on the CDG surface show consistent or slightly diminished noise levels over the 1.3 years between the CDG data collections in April 2011 and in August 2012.

Figure 4.15, which combines data from all five lanes in both directions, shows that the CDG texture lowered the OBSI by 2.0 dBA, and the GnG texture produced an additional 2.5 dBA reduction.

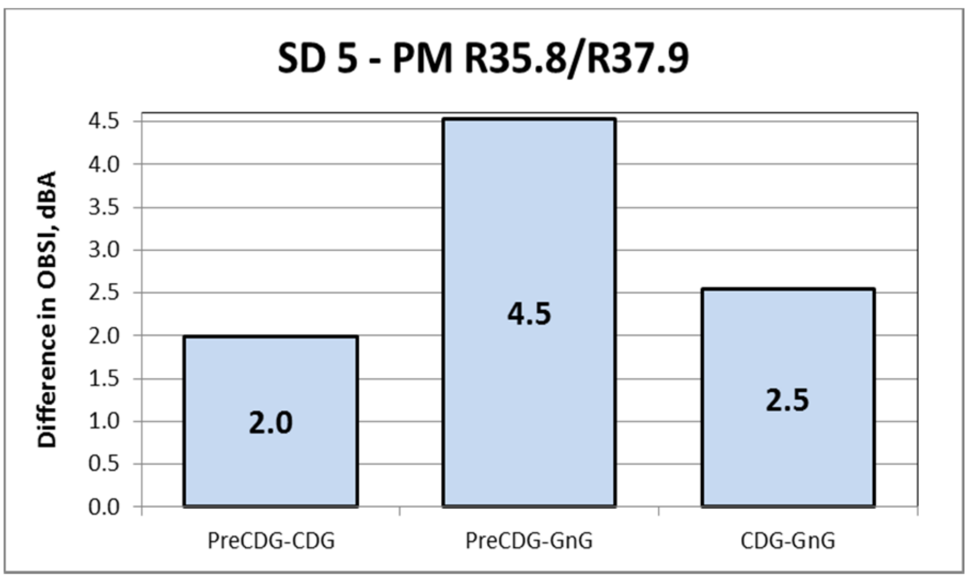


Figure 4.15: Difference in OBSI between different textures for San Diego 5 – PM R35.8/R37.9.

4.1.9.1 <u>Sound Intensity Review of Pilot Projects</u>

The overall OBSI data averaged across the seven pilot projects is shown in Figure 4.16 and Figure 4.17 shows the average differences in OBSI values between the different textures for all of the projects. Figure 4.17 shows that for these pilot projects the CDG texture produced an average 1.6 dBA reduction in OBSI and the GnG texture produced an average 3.6 dBA reduction in OBSI when these measurements were compared with those taken on the pre-existing (pre-CDG) texture. The figure also shows that the GnG texture produced an average 2.0 dBA OBSI reduction when compared to the CDG texture.

The average OBSI measurement on each lane/direction for each texture from all of the pilot projects is shown in Figure 4.18. The overall trend of noise reduction from pre-CDG to CDG to GnG can be seen in the plot. The results show that those projects that were quieter or noisier prior to treatment generally remained among the quietest or noisiest after CDG and GnG treatment. This indicates that the noise reduction from each treatment was relatively consistent across all sections and that variables other than texture continued to contribute to the noise after treatment. The distribution of pre-CDG, CDG, and GnG OBSI measurements is shown in Figure 4.19, using the average value from each lane/direction on all projects. The results in both figures show that the OBSI values remain consistently higher in the truck lanes compared with the nontruck lanes (referred to as "traffic lanes" in the figures). The results also show that GnG texture had a smaller range of OBSI values than did the CDG or pre-CDG textures. This indicates that the GnG texture appears to be more consistent with respect to noise levels than does the CDG texture, for this small set of pilot projects.

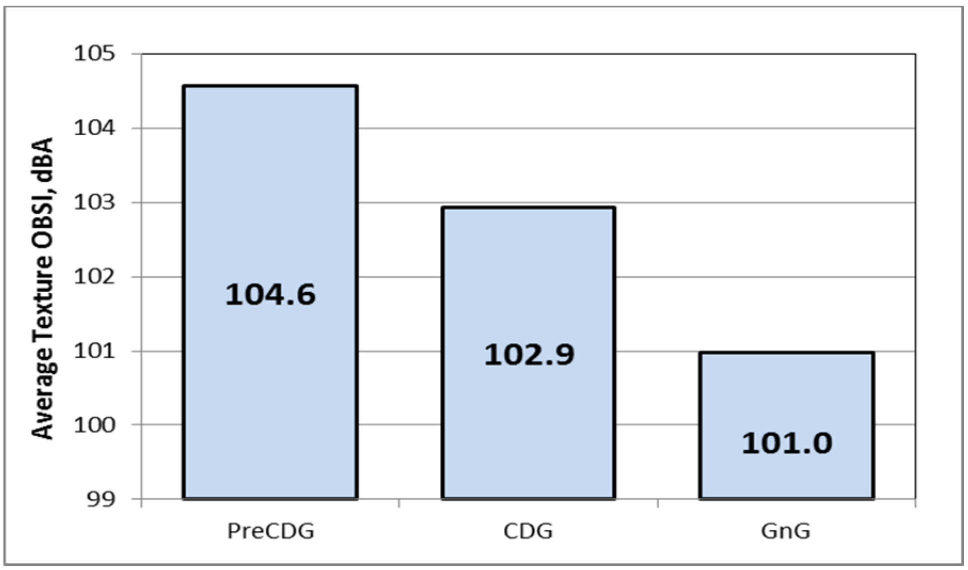


Figure 4.16: Average OBSI for textures from all pilot projects.

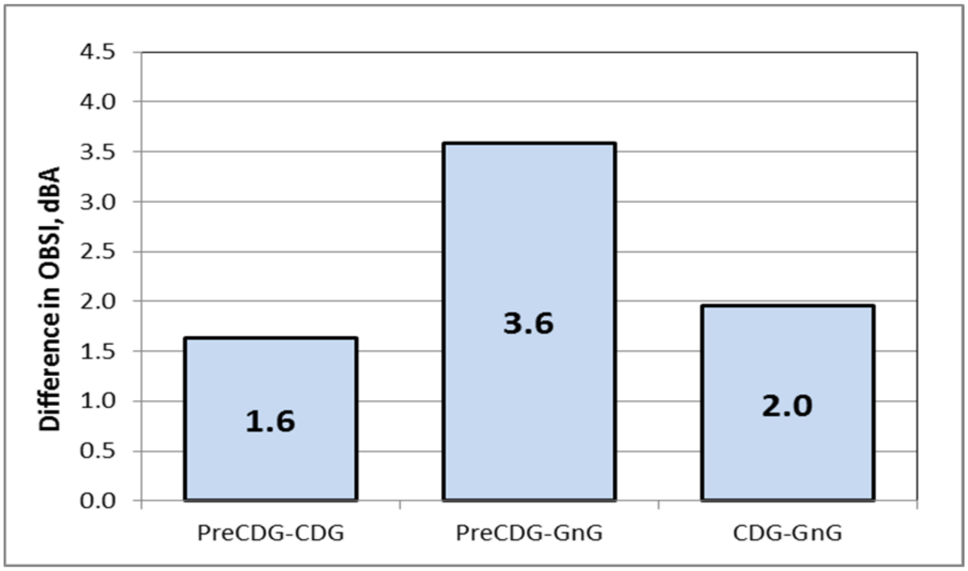


Figure 4.17: Differences in OBSI between different textures from all pilot projects.

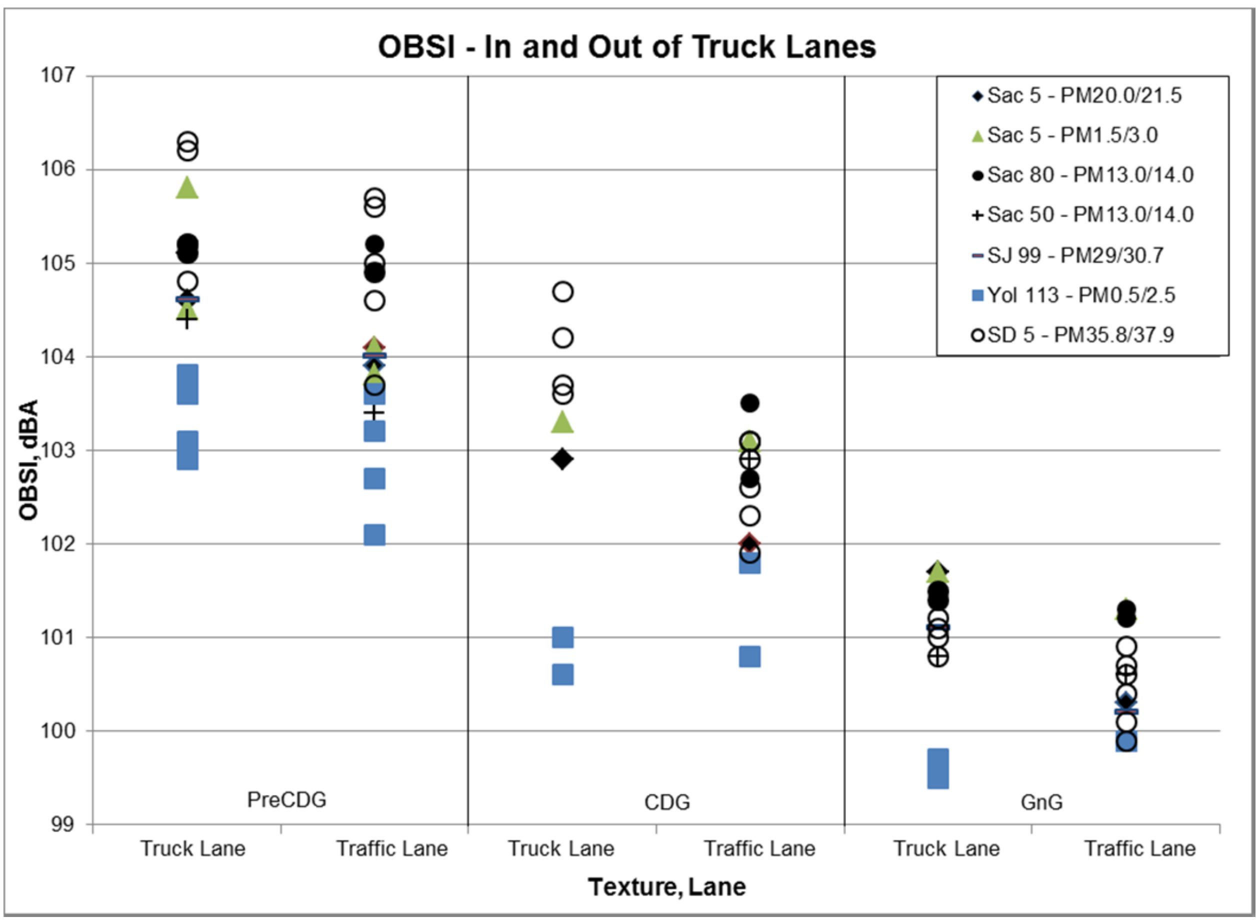


Figure 4.18: Summary of OBSI measurements for each texture across all pilot projects.

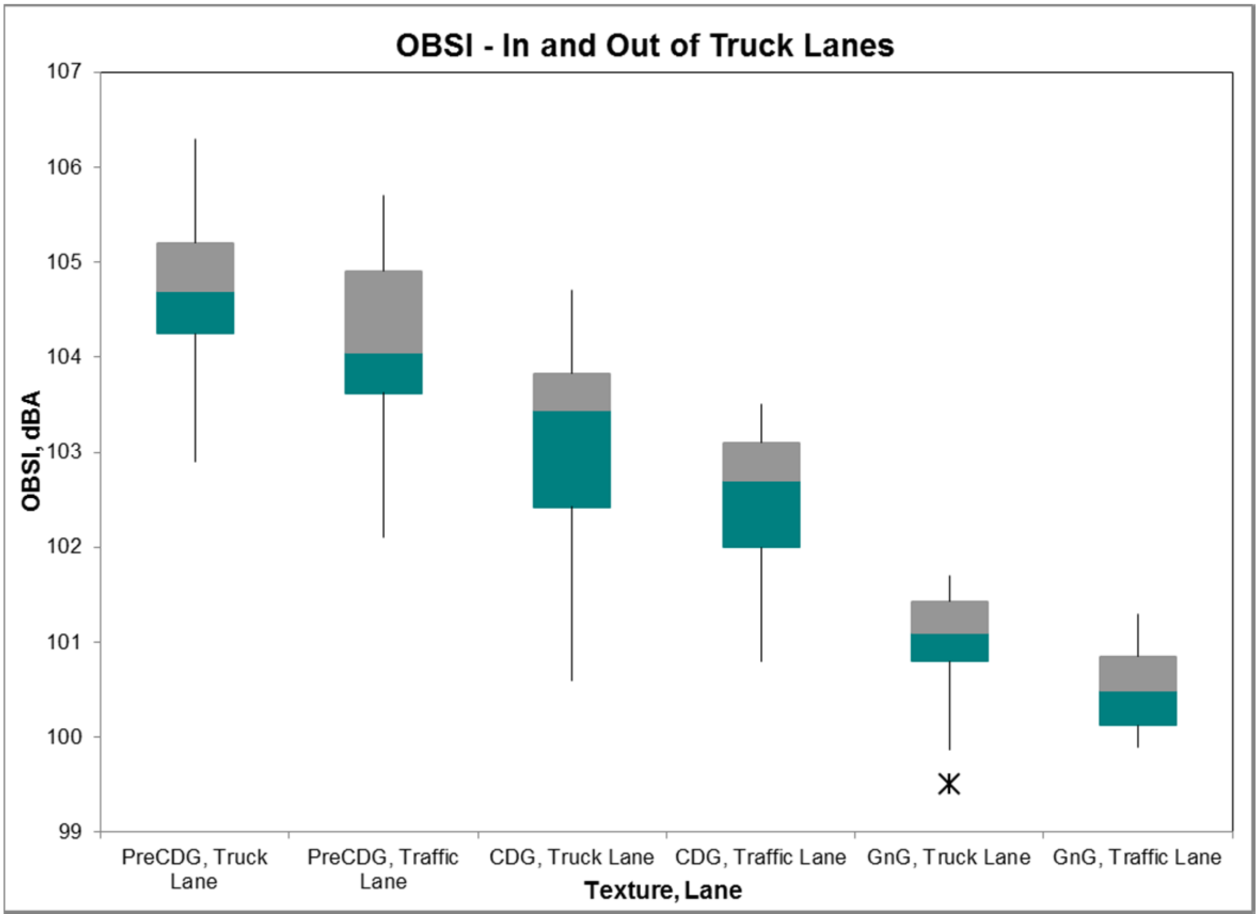


Figure 4.19: Box plot of OBSI measurements for each texture across all pilot projects.

Plots of the change in OBSI from pre-CDG to CDG, from pre-CDG to GnG, and from CDG to GnG are included in Appendix K. Also shown in the appendix are regression equations relating pre-CDG to CDG and GnG textures, and CDG to GnG. Both plots and equations are in terms of both reduction in OBSI as a function of pre-CDG OBSI and percent reduction. These equations can be used to provide an indication of the expected reduction in OBSI for each treatment given a current OBSI. The OBSI results indicate that pre-CDG OBSI has a positive correlation with CDG and GnG noise levels, most likely because the contribution of joints and cracks may remain after treatment.

4.2 OBSI Frequency Spectra Summary

Figure 4.20 through Figure 4.27 show the frequency spectra results from the OBSI data with one-third octave bands for each project. Each figure represents a combination of lanes and directions, providing an overview of the sound intensity at several frequencies for the different textures. The frequency spectra with one-third octave bands from the individual lanes in each project are shown in Appendix B.

Overall, the pre-CDG surface texture produced the greatest sound intensity at all frequencies, with these exceptions: at 4,000 Hz, where it was sometimes exceeded by the GnG surface; on Yolo 113, where the sound intensity of the GnG texture above 3,000 Hz exceeded the pre-CDG or CDG textures; and on Sacramento 5 – PM 1.5/3.0, where the immediate post-CDG (CDG0.0y) surface produced the highest sound intensity values below 800 Hz—although within three months the sound intensity at these frequencies matched the pre-CDG values.

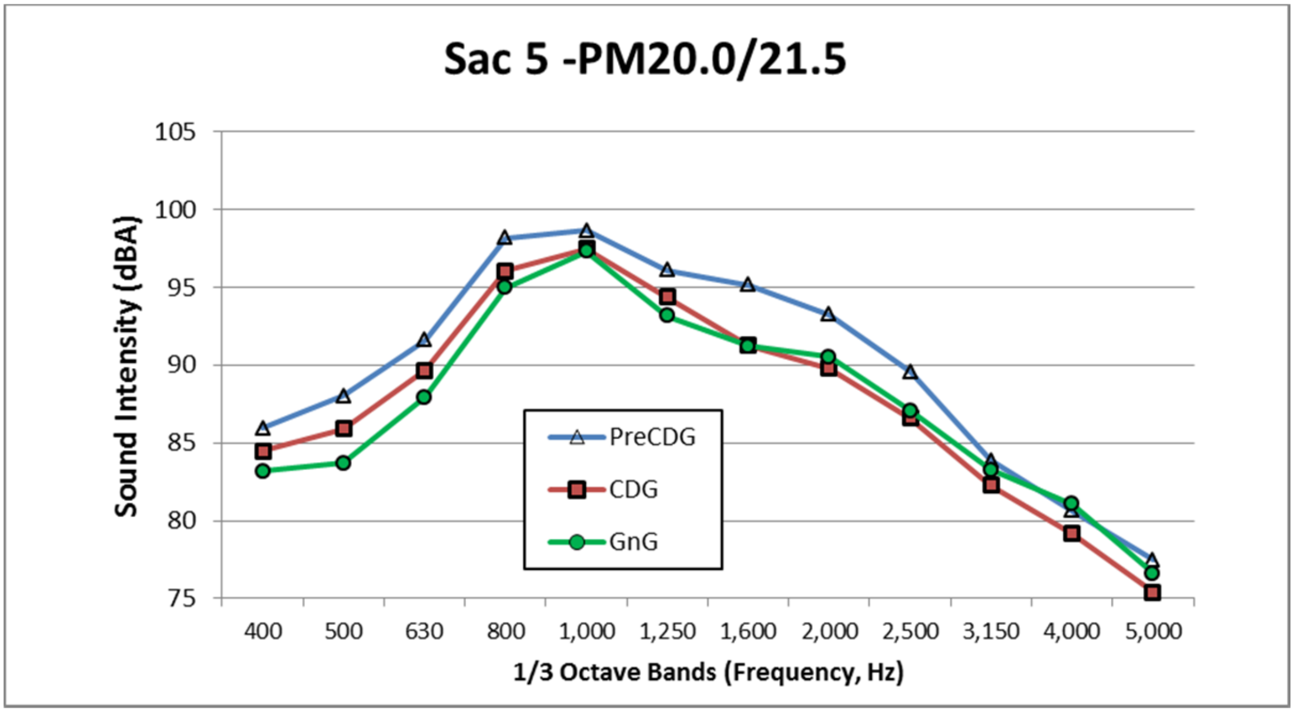


Figure 4.20: Frequency spectra project overview for Sacramento 5 – PM 20.0/21.5.

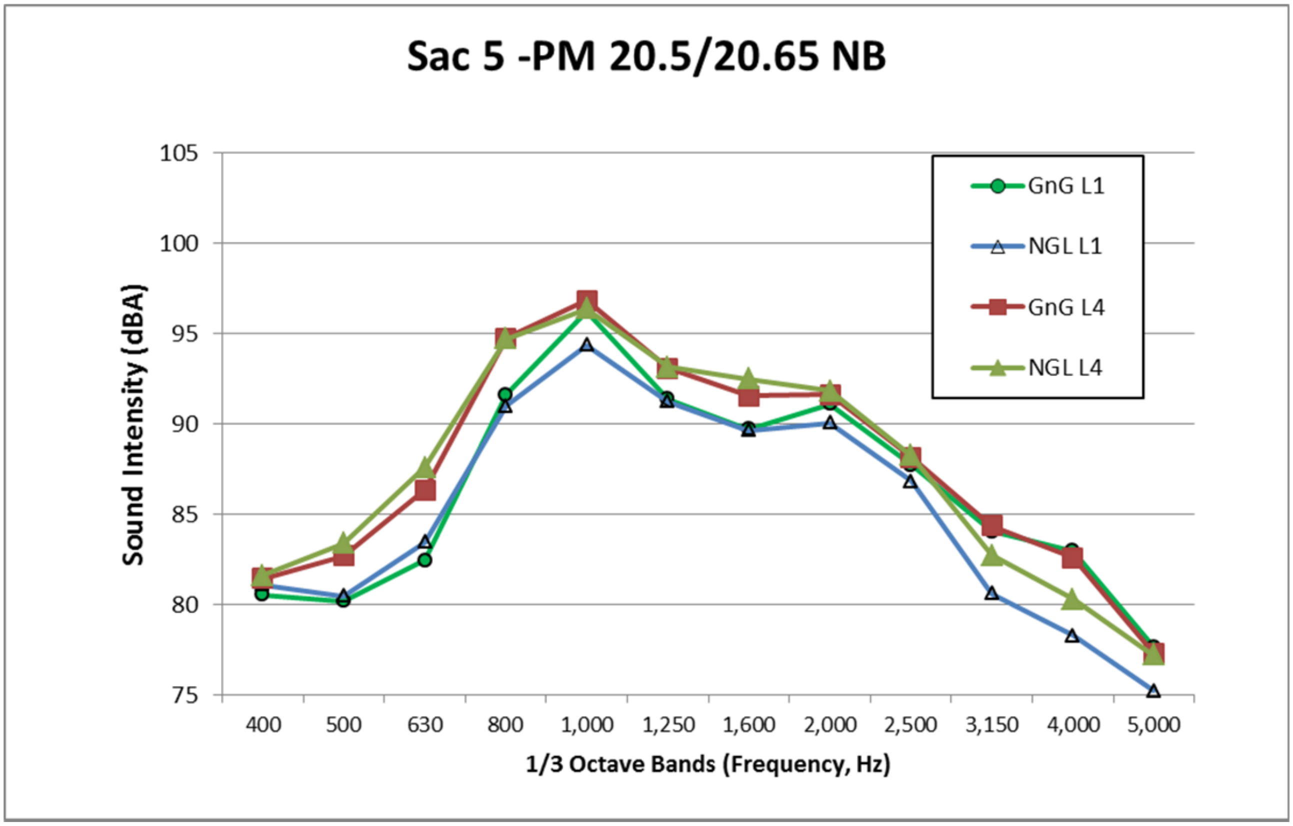


Figure 4.21:Frequency spectra for NGL and GnG on Sacramento 5 – PM 20.5/20.65.

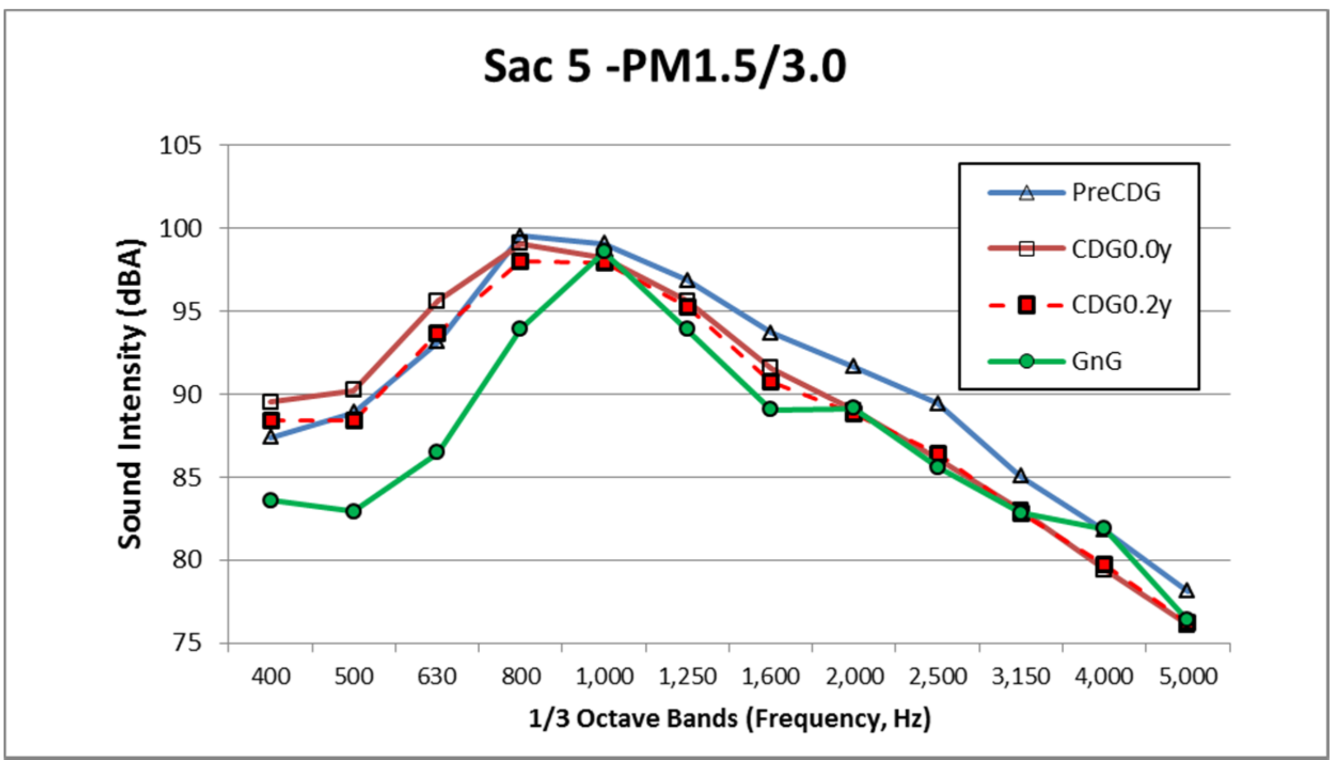


Figure 4.22: Frequency spectra project overview for Sacramento 5 – PM 1.5/3.0.

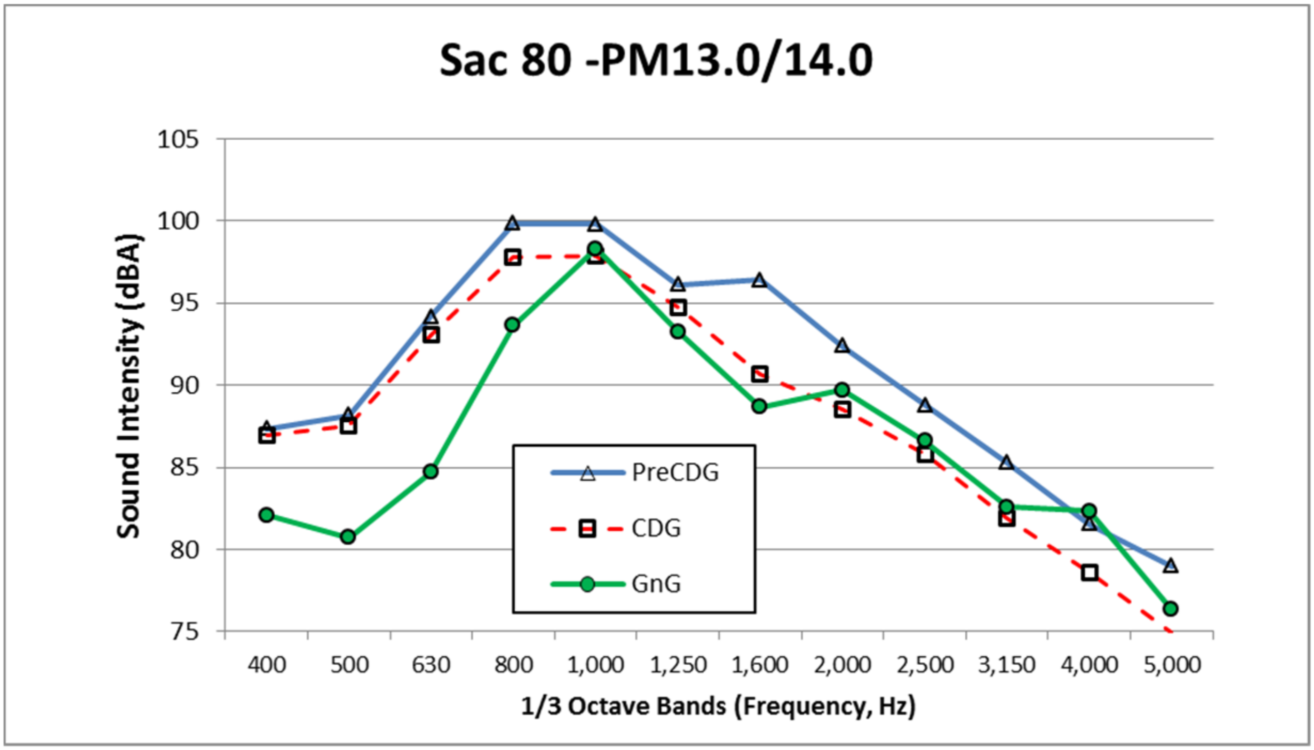


Figure 4.23: Frequency spectra project overview for Sacramento 80 – PM 13.0/14.0.

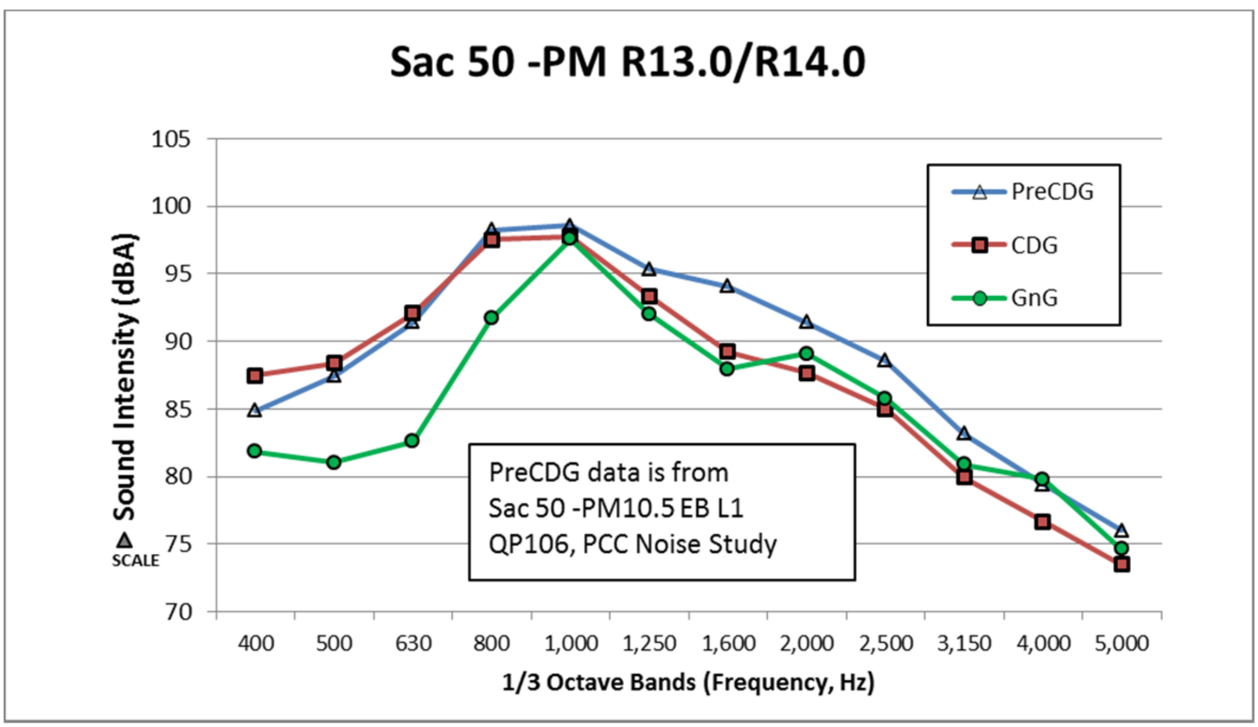


Figure 4.24: Frequency spectra project overview for Sacramento 50 – PM R13.0/R14.0.
***(Note:* The ordinate scale depicted in this figure is 5 dBA larger than in the surrounding figures.)**

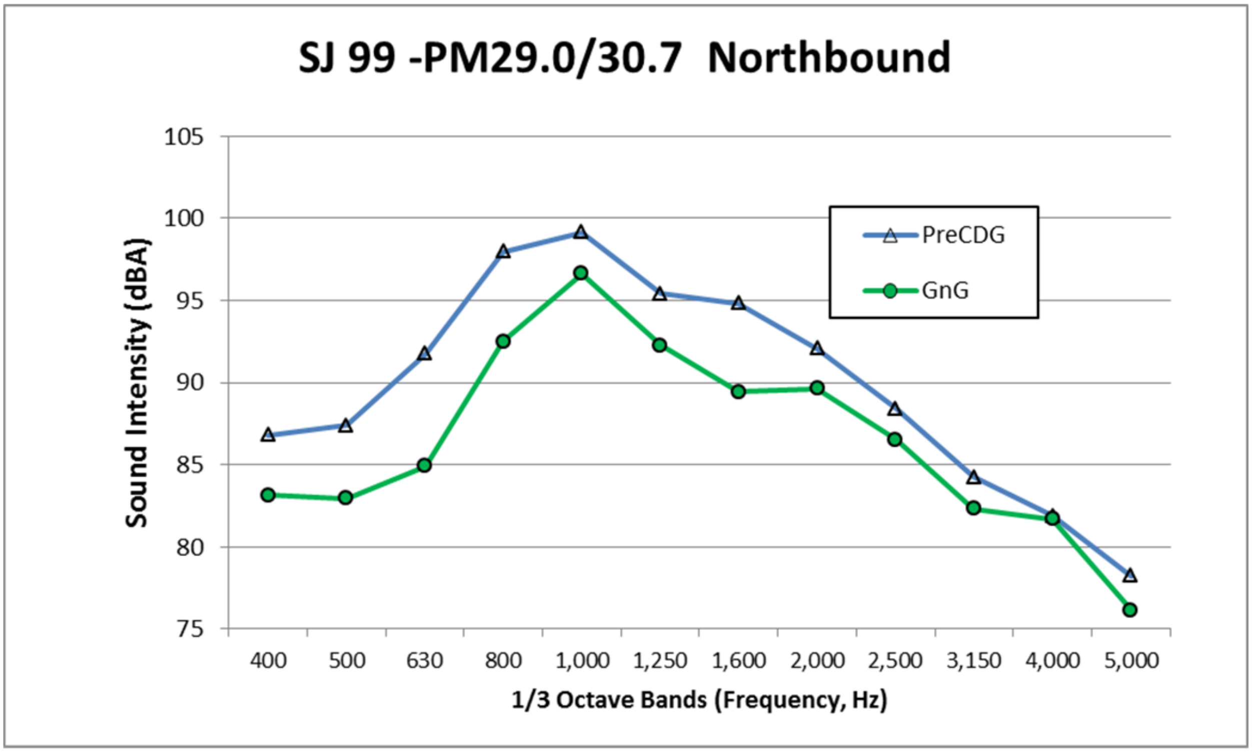


Figure 4.25: Frequency spectra project overview for San Joaquin 99 – PM 29.0/30.7, northbound.

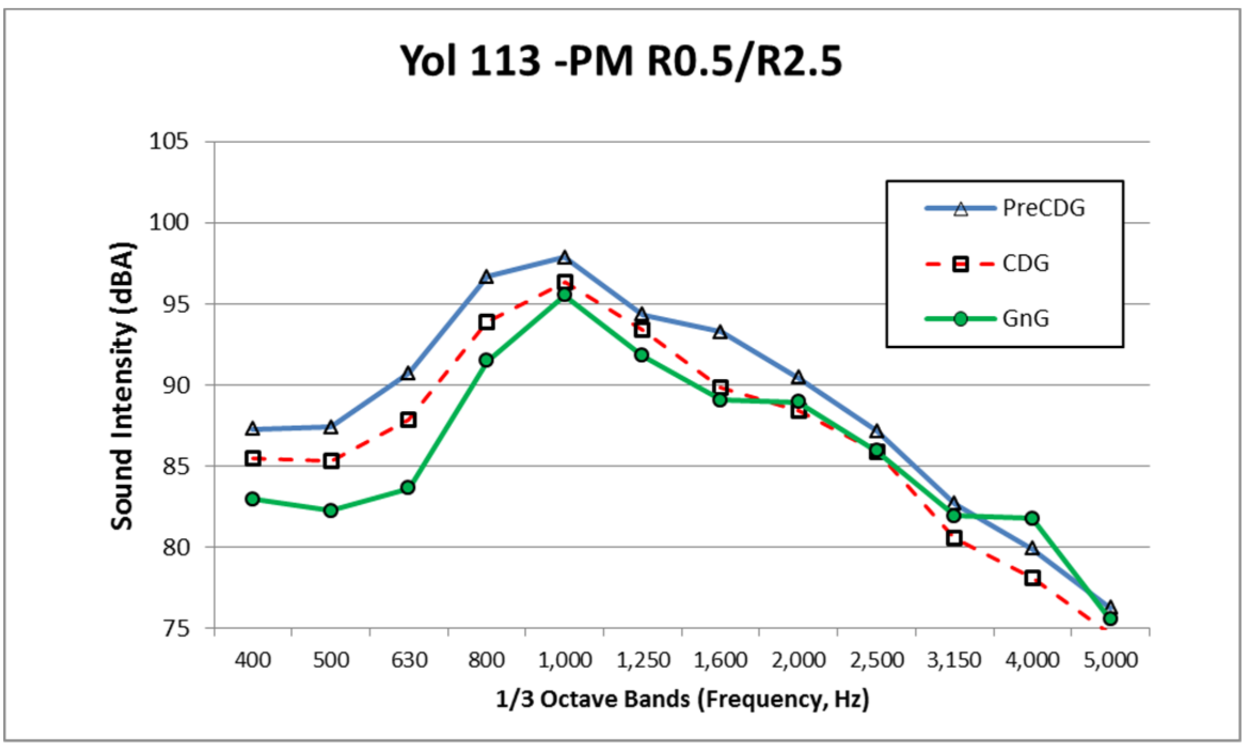


Figure 4.26: Frequency spectra project overview for Yolo 113 – PM R0.5/R2.5.

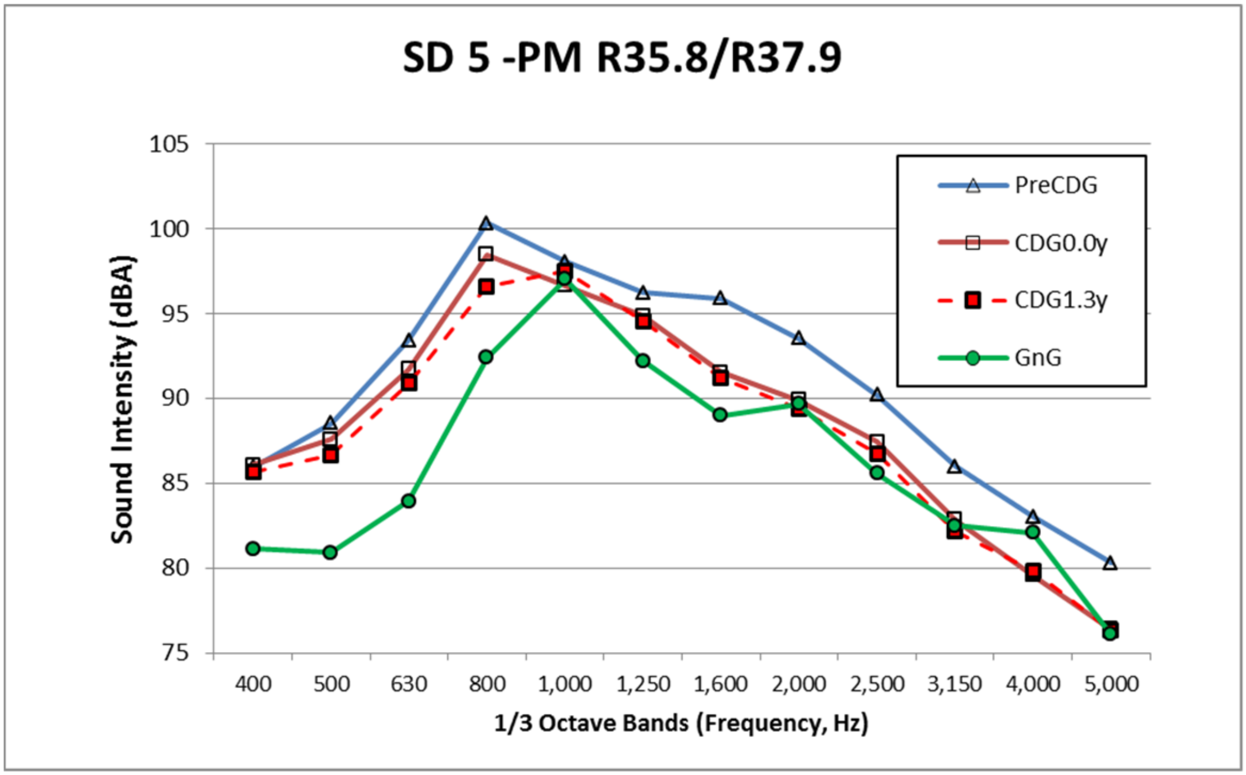


Figure 4.27: Frequency spectra project overview for San Diego 5 – PM R35.8/R37.9.

Table 4.3 presents the average sound intensities at the one-third band octave frequencies for the pre-CDG, CDG, and GnG textures. It can be seen in the plots of these data in Figure 4.20 through Figure 4.27 that the CDG textures generally shifted the OBSI spectrum down across all frequencies. The GnG texture tended to shift the frequencies of 1,000 Hz and lower more than the higher frequencies, and often reduced the 800 Hz noise so much that 1,000 Hz became the new peak frequency. The effect of these changes in the noise spectrum is to not only reduce total noise but also change the tonality of the noise to slightly higher pitches. Higher frequency noises attenuate quickly, while the lower frequency noise travels further before diminishing. This combination would therefore reduce the "noise footprint."

Table 4.3: Frequency Spectra Summary of Textures

Project	Texture	400 Hz	500 Hz	630 Hz	800 Hz	1,000 Hz	1,250 Hz	1,600 Hz	2,000 Hz	2,500 Hz	3,150 Hz	4,000 Hz	5,000 Hz	OBSI
SAC 5 – PM20.0 / PM21.5	Pre-CDG	85.9	88.0	91.6	98.2	98.6	96.1	95.2	93.2	89.6	83.9	80.6	77.5	104.4
	CDG	83.5	86.7	90.0	96.4	96.6	95.4	91.5	89.4	87.0	81.3	77.5	74.7	102.5
	GnG	81.0	81.5	84.5	93.1	96.4	92.2	90.7	91.3	87.9	84.0	82.5	77.4	101.0
SAC 5 – PM1.5 / PM3.0	Pre-CDG	87.4	88.9	93.2	99.5	99.1	96.9	93.7	91.6	89.5	85.1	81.8	78.1	104.6
	CDG	88.4	88.4	93.6	98.0	97.9	95.3	90.8	88.8	86.4	82.9	79.7	76.2	103.2
	GnG	83.6	82.9	86.5	94.0	98.6	93.9	89.1	89.1	85.6	82.8	81.9	76.4	101.5
SAC 80 – PM13.0 / PM14.0	Pre-CDG	87.3	88.2	94.2	99.9	99.8	96.1	96.4	92.4	88.8	85.3	81.5	79.0	105.1
	CDG	87.0	87.5	93.1	97.8	97.9	94.8	90.7	88.6	85.8	81.9	78.5	74.9	103.1
	GnG	82.1	80.7	84.7	93.7	98.3	93.3	88.7	89.7	86.6	82.6	82.3	76.3	101.4
Sac 50 – PM13.0 / PM14.0	Pre-CDG	84.9	87.4	91.4	98.2	98.6	95.4	94.1	91.4	88.6	83.2	79.4	76.0	103.9
	CDG	87.5	88.4	92.1	97.5	97.8	93.4	89.3	87.7	85.0	80.0	76.7	73.5	102.9
	GnG	81.9	81.1	82.6	91.7	97.6	92.1	87.9	89.1	85.8	80.9	79.8	74.6	100.7
SJ 99 – PM29.0 / PM30.7	Pre-CDG	86.8	87.4	91.8	98.0	99.2	95.4	94.8	92.1	88.4	84.3	81.9	78.2	104.3
	GnG	83.2	83.0	84.9	92.5	96.6	92.3	89.4	89.6	86.6	82.3	81.7	76.1	100.7
Yol 113 – PM0.5 / PM2.5	Pre-CDG	87.3	87.4	90.7	96.7	97.9	94.3	93.3	90.5	87.2	82.7	79.9	76.3	103.0
	CDG	85.5	85.3	87.9	93.8	96.3	93.4	89.8	88.4	85.9	80.6	78.1	74.6	101.0
	GnG	83.0	82.3	83.7	91.5	95.5	91.8	89.1	88.9	85.9	81.9	81.8	75.6	99.8
SD 5 – PM35.8 / PM37.9	Pre-CDG	85.9	88.5	93.4	100.3	98.1	96.2	95.9	93.5	90.2	86.0	83.0	80.3	105.2
	CDG	86.1	87.6	91.7	98.5	96.6	94.9	91.5	89.9	87.4	82.8	79.6	76.4	103.2
	GnG	81.1	80.9	83.9	92.4	97.0	92.2	89.0	89.7	85.6	82.5	82.1	76.1	100.7

4.3 Friction Data

The results of friction testing are presented in Section 4.3.1 for the California Test 342 (Portable Skid Tester), Section 4.3.3 for ASTM E274 (Towed Skid Trailer), and Section 4.3.4 for the Outflow Meter Test (ASTM E2380) that was used to assess the drainability of the surface texture. Friction tests were not run on every project.

4.3.1 California Test 342 (Portable Skid Tester) Data

Following are results from the Portable Skid Tester for three of the projects: Sacramento 5 – PM 20.0/21.5, Sacramento 80 – PM 13.0/14.0, and San Diego 5 – PM R35.8/R37.9. Portable skid tests were conducted with traffic control at the locations discussed in Section 2.3.2, and do not represent the entire project area. The state-required minimum value for the coefficient of friction is 0.30 (*22*), based on the average of five measurements per section between the wheelpaths at a zero degree test angle. In the tables below that present the Portable Skid Tester results, friction values lower than the state required value of 0.30 are shaded with a gray background.

4.3.1.1 Sacramento 5 – PM 20.0/21.5

Table 4.4 includes the data from Sacramento 5 – PM 18.7 after CDG construction (CDG), after the flush grind (pre-GnG), and after the GnG construction (GnG). The data show that the surface friction resulting from the GnG texturing is lower than the friction resulting from the CDG texturing but that the GnG value still meets the state requirement. It can be seen that the pre-GnG texture produced very low friction values, indicating that it produced a very smooth surface with little texture.

Table 4.4: CT 342 Data from Sacramento 5 – PM 18.7, Lane 1, NB, Left Wheelpath: Averaged Values

	CDG		Pre-GnG		GnG	
	6/6/2011		6/6/2011		6/9/2011	
Test Angle	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
0 degrees	0.39	0.03	0.24	0.03	0.35	0.02
15 degrees	0.40	0.03	0.25	0.03	0.42	0.03
45 degrees	0.43	0.05	0.29	0.01	0.38	0.03

Note: Values in shaded table cells do not meet the state required minimum of 0.30.

At this location, both the CDG and GnG surfaces showed sufficient friction, with the CDG surface producing greater friction than the GnG surface. However, this is the only location where the pre-GnG texture (flush grind) showed such low values (as low as 0.24) and failed to meet the state-required minimum. The large decrease in friction from the CDG texture to the pre-GnG texture most likely indicates that the pre-GnG treatment removed most of the positive texture from the fins made by the CDG treatment.

Zero degrees is the reference angle for the test and the other angles of testing were included to identify whether a tire sliding at other angles had higher or lower friction. The data averages support the notion of increased friction in the test angles, as the tire engages more of the longitudinally oriented texture.

4.3.1.2 Sacramento 5 – PM 20.5/20.7 NGL

Table 4.5 presents the friction data from CT 342. The data in the CDG, pre-GnG, and GnG columns, which have been taken from Table 4.4, appear alongside data from the NGL surface.

Table 4.5: CT 342 Data Comparison from Sacramento 5 – PM 18.7 and PM 20.5

Surface Texture	CDG		Pre-GnG		GnG		NGL	
Test Date	6/6/2011		6/6/2011		6/9/2011		7/25/2011	
Test Angle	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
0 degrees	0.39	0.03	0.24	0.03	0.35	0.02	0.39	0.01
15 degrees	0.40	0.03	0.25	0.03	0.42	0.03	0.39	0.02
45 degrees	0.43	0.05	0.29	0.01	0.38	0.03	0.39	0.02

The test results show that the NGL has greater friction than GnG at 0 and 45 degrees; the difference between them at 0 degrees is more pronounced than at 45 degrees, where it is statistically insignificant (Table I.12). There are no clear differences between the friction measured on the NGL and CDG surfaces (Table 4.5 and Table I.12). It is assumed that installation of the longitudinal grooves with GnG reduced the surface area and limited friction. Perhaps the NGL surface, like the CDG surface, had greater contact with the test tire because it does not have the grooves of the GnG surface, and may therefore produce additional friction.

4.3.1.3 Sacramento 80 – PM 13.0/14.0

The data from Sacramento 80 – PM 13.5 before construction (pre-CDG), after CDG construction (CDG), and after GnG construction (GnG) are shown in Table 4.6. The data show that the CDG surface friction met the state requirement in both wheelpaths. One GnG surface friction value indicates that the state-required minimum was met in the left wheelpath but not in the right wheelpath. Although the sample size is small, the pooled data from both wheelpaths presented in Table I.13 indicate that the surface friction difference between the pre-CDG texture and the GnG texture is significant. There is no strong trend supporting the notion of increased friction with increased test angles.

Table 4.6: CT 342 Data from Sacramento 80 – PM 13.5, Lane 2, EB

		Pre-CDG		CDG		GnG	
		2/15/2012		3/5/2012		3/26/2012	
Wheelpath	**Test Angle**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Left	0 degrees			0.39	0.02	0.30	0.03
Right	0 degrees	0.32	0.04	0.39	0.02	0.28	0.03
Right	15 degrees	0.29	0.03	0.42	0.03	0.24	0.02
Right	45 degrees	0.34	0.04	0.47	0.02	0.29	0.02

Note: Values in shaded table cells do not meet the state required minimum of 0.30.

4.3.1.4 San Diego 5 – PM R35.8/R37.9

The data from San Diego 5 – PM R35.8/R37.9 are presented in two tables: Table 4.7 summarizes testing on the 2,000 foot test strip constructed in April 2011, and Table 4.8 presents results for the locations shown in Figure 3.9 within the two-mile evaluation section tested in July 2013 after GnG construction. The pre-CDG data were collected before CDG construction at PM R36.975.

Table 4.7: CT 342 Data from San Diego 5 - PM R37.15, Lane 2, Left Wheelpath (2,000 Foot Test Strip)

	Pre-CDG[1]		CDG		Pre-GnG		GnG	
	1/6/2011		4/21/2011		4/27/2011		4/28/2011	
Test Angle	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
0 degrees	0.40	0.02	0.43	0.02	0.43	0.03	0.41	0.02
5 degrees	0.36	0.0	0.43	0.02	0.45	0.02	0.42	0.02
15 degrees	0.38	0.02	0.44	0.04	0.46	0.03	0.43	0.02
30 degrees	0.36	0.03	0.46	0.03	0.47	0.03	0.44	0.02
45 degrees	0.34	0.01	0.47	0.03	0.49	0.02	0.46	0.02

Note:
1. Pre-CDG data come from testing at PM R36.975 in Southbound Lane 2.

The test strip data in Table 4.7 show that the surface friction that resulted from the GnG texture was slightly lower than that from the CDG texture, although the GnG value still exceeded the state required 0.30 (*22*). The table also shows that at this site both the pre-CDG and pre-GnG textures produced surface friction values that met the state requirement.

The comparable friction values for CDG and pre-GnG textures may be the result of the similar grinding microtextures, whereas on the Sacramento 5 project the pre-GnG texture had considerably lower friction values than the CDG texture. This difference may be due to differences in the grinding heads used for the pre-GnG flush grinds on the two projects. On the other hand, on the Sacramento 5 project, the GnG grooving restored the friction values. This casts some suspicion on the pre-GnG friction values on the Sacramento 5 project.

The pre-CDG surface texture does not indicate an increase in friction with testing angle. The directional treatments (CDG, pre-GnG, GnG) also do not show a consistent increase in friction with testing angle.

Before proceeding to the comparison of the data in Table 4.8, it should be noted that the CDG data at 1.3 years and the GnG data were collected from different locations in the evaluation area (see Figure 3.9) due to the application of the GnG surface between PMs R36.3 and R37.4. The data for CDG at 1.3 years were measured between PMs R35.8 and R36.3 and between PMs R37.4 and R37.9. The GnG data were collected between PMs R36.35 and R37.35.

The data show that the surface friction on the GnG texture was significantly lower than the friction on the CDG texture and below the state requirement at several locations in northbound Lane 5 (Table 4.8 and Table I.14). The CDG texture measurements in northbound Lane 5 show sufficient friction. The same operator and equipment was used for all of the tests on this pilot project. Two possible explanations for these results are that the GnG texture was different on this section, although there was no apparent difference noted by visual observation compared with other sections, or that there was a problem with the test results. Considering that each test result shown is the average of five measurements, and that similar results were found in two directions and different locations in the lanes (right and left wheelpaths, between wheelpaths), the first explanation is considered more likely.

Table 4.8: Detailed CT 342 Data from Two-Mile Evaluation Section at San Diego 5 PM R35.8/R37.9

		Pre-CDG				CDG1.3y[1]				GnG[2]			
	Direction	**NB**		**SB**		**NB**		**SB**		**NB**		**SB**	
		12/2010-3/2011				**7/19-26/2012**				**7/19-26/2012**			
		Avg.	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Direction Average[3]		**0.40**	**0.05**	**0.37**	**0.05**	**0.33**	**0.05**	**0.39**	**0.06**	**0.29**	**0.03**	**0.31**	**0.03**
Lane 1 Average[3]		*0.43*	*0.05*	*0.40*	*0.04*	*0.37*	*0.06*	*0.34*	*0.01*	*0.32*	*0.03*	*0.30*	*0.04*
Location	**Test Angle**												
Left Wheelpath	0 degrees	0.43	0.05	0.41	0.05	0.33	0.04	0.34	0.01	0.33	0.02	0.28	0.03
	15 degrees	0.42	0.05	0.39	0.04	0.35	0.02	0.32	0.0	0.32	0.02	0.27	0.02
	45 degrees	0.40	0.04	0.35	0.03	0.38	0.06	0.39	0.03	0.33	0.02	0.30	0.02
Between Wheelpaths	0 degrees	0.42	0.04	0.39	0.04	0.44	–	0.34	0.01	0.30	0.03	0.32	0.03
	15 degrees	0.42	0.05	0.40	0.04	0.46	–	0.41	0.05	0.31	0.02	0.31	0.05
	45 degrees	0.40	0.05	0.36	0.04	0.39	–	0.41	0.06	0.33	0.02	0.30	0.03
Right Wheelpath	0 degrees					0.38	–						
	15 degrees					0.37	–						
	45 degrees					0.37	–						
Lane 2 Average[3]		*0.38*	*0.05*	*0.37*	*0.04*	*0.31*	*0.03*			*0.30*	*0.01*		
Left Wheelpath	0 degrees	0.38	0.05	0.38	0.05	0.33	0.01			0.30	0.01		
	15 degrees	0.37	0.04	0.34	0.04	0.35	0.01			0.31	0.02		
	45 degrees	0.37	0.04	0.34	0.04	0.35	0.02			0.30	0.04		
Between Wheelpaths	0 degrees	0.39	0.04	0.37	0.03								
	15 degrees	0.38	0.04	0.35	0.05								
	45 degrees	0.37	0.04	0.33	0.03								
Right Wheelpath	0 degrees					0.30	0.05			0.31	0.02		
	15 degrees					0.31	0.09			0.31	0.02		
	45 degrees					0.34	0.04			0.32	0.02		
Lane 5 Average[3]				*0.34*	*0.05*	*0.33*	*0.02*	*0.44*	*0.05*	*0.26*	0.02	*0.31*	*0.03*
Left Wheelpath	0 degrees			0.37	0.05	0.33	0.03	0.47	0.04	0.23	-	0.29	0.02
	15 degrees			0.33	0.04	0.32	0.01	0.46	0.02	0.24	-	0.30	0.02
	45 degrees			0.34	0.07	0.36	0.02	0.45	0.01	0.25	-	0.28	0.03
Between Wheelpaths	0 degrees			0.32	0.04			0.41	0.02	0.26	0.02	0.33	0.02
	15 degrees			0.31	0.06			0.41	0.01	0.26	0.01	0.33	0.02
	45 degrees			0.33	0.06			0.44	0.01	0.25	0.04	0.29	0.02
Right Wheelpath	0 degrees					0.32	0.01			0.26	0.02		
	15 degrees					0.37	0.01			0.23	0.02		
	45 degrees					0.35	0.06			0.25	0.03		

Notes:

1. Texture condition at time of the activity: pre-CDG = before conventional diamond grinding, CDG1.3y = 1.3 years after conventional diamond grinding, GnG = after grind and groove.
2. Values shaded with light gray do not meet the state required minimum coefficient of friction of 0.30.
3. Directional averages in bold and lane averages in italics are for tests conducted at the zero degree test angle only.

4.3.2 Summary of CT 342 Data Across All Pilot Projects

The average CT 342 measurement on each lane/direction for each texture (wheelpaths only) from the small subset of all of the pilot projects on which CT 342 tests were performed is shown in Figure 4.28. As can be seen, most of the measurements were taken on the San Diego 5 project. The few results show similar texture for the pre-CDG and CDG textures, and the lower values for the GnG texture.

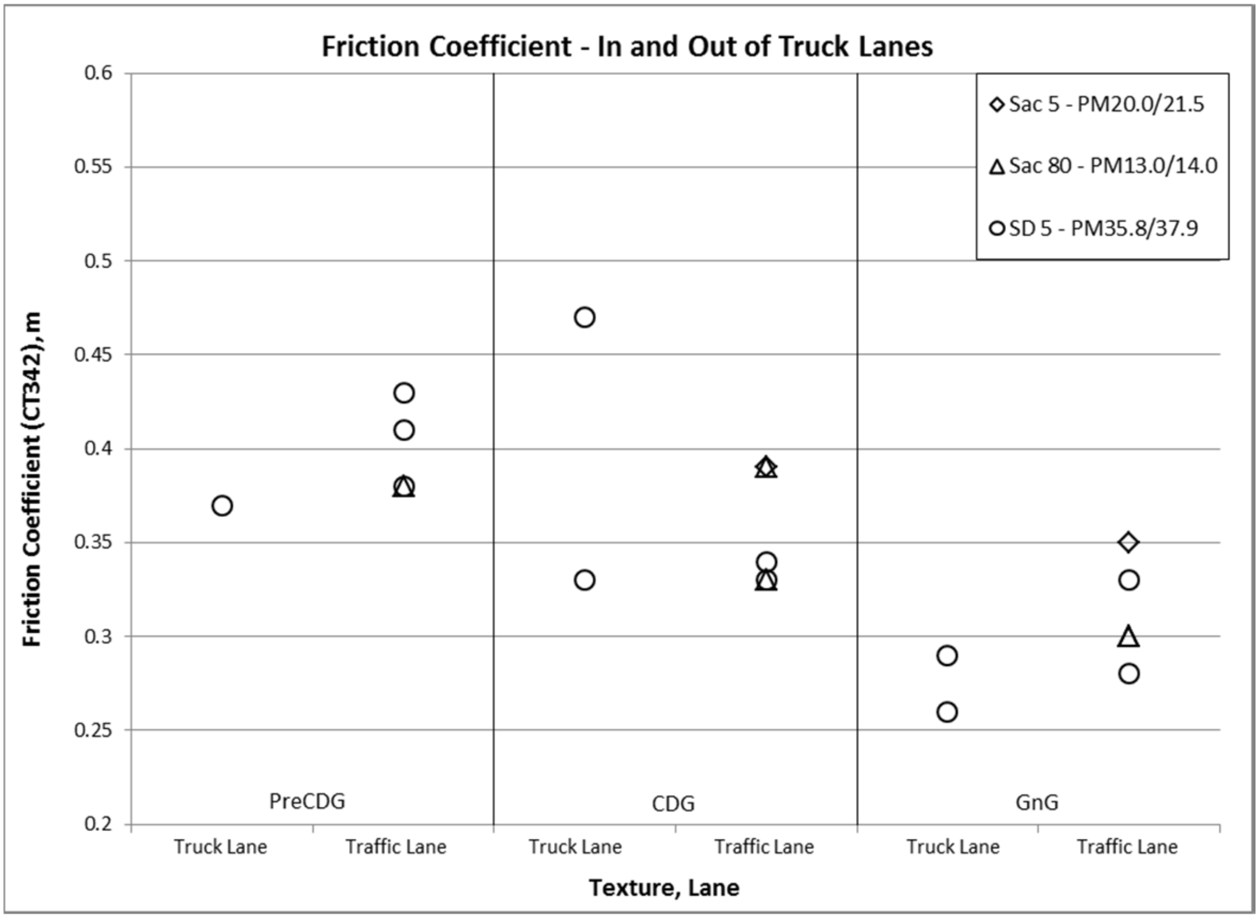


Figure 4.28: Summary of CT 342 measurements for each texture across all pilot projects, in truck and traffic lanes, wheelpath measurements only.

4.3.3 ASTM E274 (Towed Skid Trailer) Data

Towed Skid Trailer testing was conducted on all the projects except Sacramento 5 – PM 1.5/3.0. These tests were conducted over distances ranging between 0.3 miles and 0.6 miles. There is no state requirement associated with this test because ASTM E274 is not used as a compliance test in California. However, skid numbers lower than 30 have been considered typical of the threshold at which pavement surface corrections must be made. In the tables that follow, results at or below the threshold value of 30 have been shaded. It should also be noted that skid numbers higher than 35 are considered suitable for heavily trafficked roads (*23*).

4.3.3.1 Sacramento 5 – PM 20.0/21.5

Data were collected by Caltrans on Sacramento 5 – PM 20.0/21.5 in May 2011 before construction, and in February 2012 after both CDG and GnG construction. Postconstruction data was also collected by the International Grinding and Grooving Association (IGGA) in April 2013. Table 4.9 presents average results from the Caltrans sampling before construction (pre-CDG) and after construction in the northbound (GnG) and southbound (CDG) directions. Table 4.10 presents the IGGA data from April 2013 along with earlier Caltrans data from tests conducted under similar conditions.

Any comparison of the ribbed tire data in the left wheelpath from Table 4.9 should take into account that the pre-CDG values for both directions are statistically similar for every test speed and lane number except for the 60 mph testing in Lane 4 north, which had a p-value of 0.03 (Table I.15). All of the right wheelpath pre-CDG data for Lane 1 in each direction are also statistically similar, whereas the data for Lane 4 northbound and southbound are not (Table I.16).

The ribbed tire data from Caltrans show that the CDG texture substantially increased the friction over the pre-CDG texture on this section, raising the skid number approximately 16 units for both wheelpaths. The GnG texture also increased the friction relative to the pre-existing condition by approximately 8 units, a large change even if not to the level of that resulting from the change to the CDG texture. The ribbed tire data averages indicate that Lane 1 had more friction than Lane 4 but that the difference was not statistically significant. The ribbed tire data show that both lanes exhibited satisfactory friction, meeting the standard for heavy traffic of 35 (*23*).

The average skid numbers (SN_{40}) using the ribbed tire in the left wheelpath for the various textures are as follows:

- Pre-CDG – 44
- CDG – 60
- GnG – 51

Table 4.9: Towed Skid Trailer Detailed Results From Caltrans on Sacramento 5 – PM 20.0/21.5

Testing by Caltrans				Average SN_{40} (and Standard Deviation)											
				Left Wheelpath						Right Wheelpath					
				Pre-CDG		CDG		GnG		Pre-CDG		CDG		GnG	
Tire Type	Lane	Test Speed	Direction	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Ribbed	1	*Lane 1 Averages*		*45*	*3*	*62*	*3*	*53*	*5*	*44*	*2*	*63*	*3*	*53*	*4*
		40 MPH	North	47	3			54	6	43	2			55	4
			South	48	1	64	2			43	2	65	3		
		50 MPH	North					53	5					52	3
			South			62	2					62	3		
		60 MPH	North	43	2			51	5	44	2			51	4
			South	44	2	60	2			45	2	60	2		
	4	*Lane 4 Averages*		*42*	*4*	*58*	*3*	*50*	*4*	*40*	*4*	*59*	*3*	*51*	*3*
		40 MPH	North	43	5			50	5	43	4			52	3
			South	42	2	58	2			39	2	59	3		
		50 MPH	North					49	4					51	2
			South			57	3					59	3		
		60 MPH	North	42	4			49	3	39	3			51	4
			South	40	2	58	3			37	2	59	3		
	Ribbed Tire Averages			**44**	**4**	**60**	**4**	**51**	**5**	**42**	**4**	**61**	**4**	**52**	**4**
Smooth	1	*Lane 1 Averages*		*33*	*3*	*56*	*4*	*51*	*7*	*28*	*3*	*54*	*4*	*51*	*4*
		40 MPH	North	33	2			51	7	28	3			51	4
			South	35	3	56	4			29	3	54	4		
		60 MPH	North	30	3					26	3				
			South	33	3					28	2				
	4	*Lane 4 Averages*		*28*	*5*	*49*	*5*	*45*	*6*	*24*	*5*	*52*	*5*	*51*	*5*
		40 MPH	North	29	7			45	6	25	6			51	5
			South	26	2	49	5			20	2	52	5		
		60 MPH	North	30	6					28	5				
			South	26	2					22	2				
	Smooth Tire Averages			30	5	53	6	48	7	26	**5**	**53**	**4**	**51**	**5**

Note: Lane averages are in italics, tire averages are in bold, and values less than 30 are shaded, indicating an unacceptable level of friction.

The smooth tire data show that the surface friction before construction was near or below the threshold for treatment, and both the CDG and GnG showed a significant improvement over the pre-CDG texture. Again, the average friction for the CDG texture was greater than that for the GnG texture, but the difference between them was not significant (Table I.17).

For the GnG texture, the results between the ribbed and smooth tire are statistically similar. A Student's *t*-test comparison of the ribbed tire (SN_{40} = 51) and the smooth tire (SN_{40} = 48) yielded p-values of 0.07 for the left wheelpath data and 0.13 for the right wheelpath data (Table I.18).

Table 4.10 presents the average skid numbers determined from tests conducted by IGGA and Caltrans at 40 mph in the left wheelpath. It should be noted that the sampling dates differ by over one year and that the sampling locations do not coincide. The IGGA CDG data come from a section south of the GnG evaluation section, in the northbound direction. IGGA data was collected between PMs 18.1 and 18.6 for the CDG texture, and between PMs 19.0 and 19.7 for the GnG texture. Caltrans data was collected between PMs 20.0 and 21.5 southbound for the CDG texture and northbound for the GnG texture.

Table 4.10: Towed Skid Trailer Results on GnG Texture from the Sacramento 5 – PM 20.0/21.5 Project from Caltrans and IGGA

			Average SN_{40} and Standard Deviation			
			CDG		GnG	
Tire Type	Operator	Location	Avg.	Std. Dev.	Avg.	Std. Dev.
Ribbed	IGGA	NB Lane 4	48	2	48	1
	Caltrans	NB Lane 4			51	5
		SB Lane 4	58	2		
Smooth	IGGA	NB Lane 4	42	3	43	2
	Caltrans	NB Lane 4			45	6
		SB Lane 4	49	5		

Note: test speed = 40 mph; left wheelpath

The IGGA data show no difference between the CDG and GnG textures, regardless of the tire type (Table I.19). Even with the location and timing differences in data collection by Caltrans and IGGA, there is still no statistical difference between the means of the data collected by each of the operators on the GnG surface, independent of the tire type, with a p-value of 0.14 (Table I.20).

4.3.3.2 Sacramento-5-PM 20.5/20.7 NGL

Table 4.11 shows test result averages on the NGL section alongside the data collected from the CDG and GnG sections. The ribbed tire results are satisfactory, individually and in comparison to the other two textures. For the smooth tire test results, the difference between the NGL and the CDG and the GnG is 10 points.

Table 4.11: Towed Skid Trailer Testing on the Sacramento 5 – PM 20.0/21.5 Project

	Average SN_{40} and Standard Deviation					
Texture	**CDG**		**GnG**		**NGL**	
Tire Type	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Ribbed	48	2	48	1	49	1
Smooth	42	3	43	2	33	3

4.3.3.3 Sacramento 80 – PM13.0/14.0

A summary of the IGGA postconstruction data from Sacramento 80 – PM 13.0/14.0, Lane 4, tested April 22, 2013, appears in Table 4.12. This testing was conducted in both directions; as noted earlier, there was no comparable CDG texture for this section.

Table 4.12: Towed Skid Trailer Results on GnG Texture from Sacramento 80 – PM 13.0/14.0, Lane 4

			Average SN_{40} and Standard Deviation	
Tire Type	**Direction**	**PM Range**	**Avg.**	**Std. Dev.**
Ribbed	East	13.0 / 13.5	48	2
	West	13.5 / 14.0	37	2
Smooth	East	13.0 / 13.5	39	2
	West	13.8 / 14.2	29	2

Notes:
Test speed = 40 mph; left wheelpath
Value in shaded table cell does not meet the state required minimum of 0.30.

An unexpected finding appeared in the westbound direction test results: for the smooth tire the skid number result was less than 30 and for the ribbed tire the result was close to 35. Skid numbers under 35 may represent an area unsuitable for heavy traffic (*23*), and it is unclear why this difference between the eastbound and westbound test results occurred. It may have been due to the traffic in the westbound direction, which, as shown in Table 3.10, handles up to 20 percent more traffic.

4.3.3.4 Sacramento 50 – PM R13.0/R14.0

The postconstruction test data from Sacramento 50 – PM R13.0/R14.0, Lane 4, collected on April 22, 2013, are shown in Table 4.13. This testing was conducted in both directions, and there was no comparable CDG texture for this section.

Table 4.13: Towed Trailer Skid Numbers on GnG from Sacramento 50 – PM R13.0/R14.0, Lane 4

			Average SN_{40} and Standard Deviation	
Tire Type	**Direction**	**PM Range**	**Avg.**	**Std. Dev.**
Ribbed	East			
	West	13.8 / 14.0	46	3
Smooth	East	11.2 / 11.5	39	2
	West	13.8 / 14.0	40	5

Note: test speed = 40 mph; left wheelpath

The data from Sacramento 50 followed a more expected pattern than those from Sacramento 80 in that the smooth tire results for both directions were similar. The eastbound direction was not tested with the ribbed tire. The higher values for the smooth tire (approximately 40) and for the ribbed tire (approximately 50) were similar to those for eastbound Sacramento 80.

4.3.3.5 San Joaquin 99 – PM 29.0/30.7

Data was collected by Caltrans on San Joaquin 99 between post miles 30.5 and 30.65 in Lane 1 northbound on July 18, 2012, after construction. Postconstruction data was also collected by the IGGA in April 22, 2013, between PMs 30.4 and 30.7 in Lane 2. Table 4.14 presents the averaged results from both Caltrans and IGGA. Testing was conducted northbound only.

Table 4.14: Towed Trailer Skid Numbers on GnG from San Joaquin 99 – PM 29.0/30.7

			Average SN_{40} and Standard Deviation	
Tire Type	**Operator**	**PM Range**	**Avg.**	**Std. Dev.**
Ribbed	Caltrans	30.5 / 30.65	46	1
	IGGA	30.4 / 30.7	44	3
Smooth	IGGA	30.4 / 30.7	36	4

Note: test speed = 40 mph; left wheelpath.

With the differences in the location and timing of the data collection by Caltrans and IGGA, there is no statistical difference between the means of the data collected by the two operators on the GnG surface, as shown in Table I.21 (with a p-value of 0.055). The average skid number (SN_{40}) is 45 using the ribbed tire in the left wheelpath for the GnG textures.

4.3.3.6 Yolo 113 – PM R0.5/R2.5

In July 2012, Caltrans collected data on Yolo 113 – PM R0.5/R2.5 after construction southbound between PM R1.2 and PM R1.0. The IGGA also collected postconstruction data in April 2013. Table 4.15 presents the averaged after-construction results from both the Caltrans and IGGA sampling. The project had GnG and CDG textures in both directions.

The IGGA data show a distinction between the tire types. But even with differences in the location and timing of the two sets of data collected, no statistical difference between their means on the southbound CDG surface was found, with a p-value of 0.13 (Table I.22).

The ribbed tire data show that the CDG texture produced higher friction values, with an average SN of 53, compared to the GnG texture, which produced an average SN of 48. However, the data show that for the smooth tire, no statistical distinction exists between the CDG and GnG textures, as both showed an average SN of 43 (Table I.23).

Table 4.15: Comparison of Towed Skid Trailer Results from Yolo 113 – PM R0.5/R2.5

				Average SN_{40} and Standard Deviation			
				CDG		GnG	
Tire Type	**Operator**	**Location**	**PM Range[1]**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Ribbed	IGGA	NB Lane 2	R0.2 / R0.5			50	2
		SB Lane 2	R0.3 / R0.5			45	1
		SB Lane 2	R1.3 / R1.6	52	3		
	Caltrans	SB Lane 1	R1.0 / R1.2	54	5		
Smooth	IGGA	NB Lane 2	R0.2 / R0.5			45	3
		SB Lane 2	R0.3 / R0.5			41	3
		NB Lane 2	R1.6 / R1.9	44	2		
		SB Lane 2	R1.3 / R1.6	41	3		

Note: test speed = 40 mph; left wheelpath.
[1] PM Range for IGGA data is approximated from operator notes.

4.3.3.7 San Diego 5 – PM R35.8/R37.9

Construction on the San Diego 5 project included a ten mile CDG section, a 2,000 foot test strip, and a one mile GnG section, as noted in Section 3.8. Caltrans, Dynatest Consulting Inc., and the IGGA all collected data on the San Diego 5 project.

Pre-CDG testing was performed by Dynatest on December 14 and 15, 2010, at speeds of 40 and 60 mph using both ribbed and smooth tires. Caltrans performed pre-CDG testing with a ribbed tire at 50 mph on January 11 and 12, 2011. Dynatest did not conduct tests at 50 mph. A comparison of the Caltrans and Dynatest test vehicles can be seen in Appendix D: Comparison of Two Towed Skid Trailers.

Caltrans conducted CDG testing between April 12 and 14 and between April 20 and 21, 2011 on the two mile evaluation section, and GnG testing on the 2,000 foot test strip between May 4 and 6, 2011. Both sets of tests were conducted with ribbed and smooth tires at three test speeds: 40, 50, and 60 mph. This was the last Caltrans testing performed on this project. On April 20, 2013, the IGGA conducted tests on the CDG and GnG textures on the San Diego 5 project two mile evaluation section.

A review of the test results from the 2,000 foot test strip, San Diego 5 – PM R36.80/R37.15, Lane 2 southbound, which was constructed April 2011, appears in Section 4.3.3.7.1. Results from tests on the two-mile evaluation area of the San Diego 5 – PM R35.8/R37.9 project, completed in July 2012, are presented in Section 4.3.3.7.2 for the Pre-CDG, CDG, and GnG textures.

4.3.3.7.1 Two-Thousand Foot Test Strip

Caltrans and Dynatest both carried out Towed Skid Trailer testing on the Pre-CDG, CDG, and GnG textures of the San Diego 5 project's 2,000 foot test strip, and the combined test results appear in Table 4.16. It should be noted that the Pre-CDG and CDG data in this section are subsets of the data gathered during evaluation of the larger two-mile area to be discussed in Section 4.3.3.7.2. The GnG texture testing was performed solely to acquire data on the test strip texture located in southbound Lane 2 PM 37.15/36.80.

While some of the already existing surface textures produced skid numbers (SN_{40}) less than 30, results obtained from textures constructed by all the grinding methods yielded skid numbers greater than 40. Statistical comparisons of the skid number results for the different textures and speeds are provided in Table I.24.

Table 4.16: Combined Results by Tire Type of Towed Skid Trailer Testing on the San Diego 5 2,000 Foot Test Strip

		Average SN_{40} and Standard Deviation					
		Pre-CDG[1]		CDG		GnG	
Tire Type	**Test Speed**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Ribbed	40 MPH	51	5	50	2	48	2
	50 MPH	49	4	49	1	51	1
	60 MPH	41	3	53	0	47	2
Smooth	40 MPH	43	2	50	1	45	2
	50 MPH	-	-	47	2	47	2
	60 MPH	<u>29</u>	1	45	1	44	2

Note: Testing in the left wheelpath.
[1] Pre-CDG testing at 40 and 60 mph conducted by Dynatest Consulting.

For the ribbed tire, the data at 40 mph show a statistically insignificant decrease in the skid numbers between the pre-CDG and CDG surface textures. Testing at 60 mph showed a significant increase between the pre-CDG and CDG textures and a significant decrease between the CDG and GnG textures. The differences in the test results at 40 mph and 50 mph were not statistically significant for the change from CDG to GnG.

For the smooth tire, the data show that the skid number increased after the transition from a pre-CDG to a CDG surface, with a prominent increase at 60 mph. The distinction between the skid numbers for the CDG and GnG textures is significant only for skid testing at 40 mph. Results from tests at 50 mph and 60 mph showed no difference between the two constructed textures.

4.3.3.7.2 Two-Mile Evaluation Area

The combined results of Towed Skid Trailer testing conducted by Caltrans and Dynatest to evaluate the two-mile section of San Diego 5 – PM R35.8/R37.9 are presented in Table 4.17. Appendix I.4.4 contains the p-value results of statistical *t*-tests that compare the data for entire project.

In order make a valid comparison of the CDG and GnG surface textures using Towed Skid Trailer testing results it was necessary to determine whether the sections were uniform, both before and after CDG construction. Table I.25 summarizes the preconstruction test results for all lanes of the two mile evaluation section, and Table I.26 and Table I.27 display the p-values of the statistical *t*-tests resulting from the comparison. The statistical test results show strong similarities among the lanes and directions before construction.

There were three exceptions each, however, for the ribbed tire tests and the smooth tire tests. For the ribbed tire tests the exceptions were northbound Lane 5, southbound Lane 4, and southbound Lane 5. In this case, the section at PM R35.8/R36.3 was not similar to the one at PM R36.3/R37.4. For the smooth tire tests, the three exceptions were northbound Lane 2, southbound Lane 1, and southbound Lane 5. Here, the section at PM R37.4/R37.9 was not similar to the section at PM R36.3/R37.4. These differences were likely eliminated since these sections were resurfaced with the CDG texture.

After CDG texturing was completed on the San Diego 5 – PM R35.8/R37.9 project, Caltrans and Dynatest conducted Towed Skid Trailer testing, with the results presented in Table 4.17. Table I.28 and Table I.29 contain the results of statistical *t*-tests for ribbed and smooth tires, respectively, that show a strong similarity in the sections after CDG construction. This similarity is exhibited across Lanes 1, 2, and 5, and testing speeds of 40, 50, and 60 mph.

Thus, before the GnG construction, the Towed Skid Trailer test results showed a strong similarity among all the sections of this project: the CDG surface south of the future GnG sections (PM R35.8/R36.3), the CDG surface north of the future GnG sections (PM R37.4/R37.9), and the CDG surface that would eventually become the GnG surface (PM R36.3/37.4).

After CDG construction ended, the IGGA conducted Towed Skid Trailer testing on the San Diego 5 project. The results are summarized in Table 4.18 and the results of Student's *t*-tests on ribbed and smooth tires, respectively, appear in Table I.30 and Table I.31. Three of the five test locations had skid number results within 1 on the CDG lanes north and south of the GnG section. Only in northbound Lane 5, which was tested with the ribbed tire, are the CDG results from each side of the GnG not statistically similar.

When the data from the CDG sections north and south of the GnG section are combined before comparison with the GnG, only the smooth tire testing of southbound Lane 5 showed no statistical difference between the CDG and GnG textures (Table I.32). Overall, the difference between the friction results from the two textures was significant, although both textures produced acceptable friction values.

Table 4.17: Towed Skid Trailer Results by Caltrans and Dynatest on the San Diego 5 - PM R35.8/R37.9 Two Mile Evaluation Area

				Average SN_{40} (and Standard Deviation)							
				Left Wheelpath				Right Wheelpath			
				Pre-CDG[1]		CDG		Pre-CDG		CDG	
Tire Type	Lane	Test Speed	Direction	Avg.	Std. Dev.	Avg.	S.D	Avg.	Std. Dev.	Avg.	Std. Dev.
Ribbed	1	*Lane 1 Averages*		*53*	*5*	*50*	*4*	*45*	*10*	*51*	*4*
		40 MPH	North	54	3	51	3			51	3
			South	56	4	48	4			49	4
		50 MPH	North	54	3	52	3	48	10	53	3
			South	57	6	49	3	42	10	50	4
		60 MPH	North	46	4	52	4			53	4
			South	47	5	50	3			49	4
	2	*Lane 2 Averages*		*47*	*6*	*46*	*4*	*43*	*9*	*45*	*3*
		40 MPH	North	48	4	47	3			46	2
			South	50	5	46	4			46	3
		50 MPH	North	50	2	47	3	43	9	47	2
			South	51	4	44	3	43	9	46	3
		60 MPH	North	40	5	46	4			44	3
			South	41	4	46	4			44	4
	5	*Lane 5 Averages*		*40*	*6*	*47*	*3*	*38*	*9*		
		40 MPH	North	40	3	46	4				
			South	40	3	47	3				
		50 MPH	North	42	3	47	3	35	12		
			South	48	4	48	3	42	4		
		60 MPH	North	33	2	46	3				
			South	33	5	48	2				
	Ribbed Tire Averages			**47**	**8**	**48**	**4**	**42**	**10**	**48**	**4**
Smooth	1	*Lane 1 Averages*		*43*	*8*	*45*	*4*			*45*	*5*
		40 MPH	North	47	5	46	3			51	4
			South	51	6	44	5			47	3
		50 MPH	North			47	2			44	3
			South			44	5			42	4
		60 MPH	North	37	5	46	4			42	3
			South	38	5	43	5			41	4
	2	*Lane 2 Averages*				*43*	*3*			*43*	*4*
		40 MPH	North	34	10	44	2			45	3
			South	42	9	43	3			45	4
		50 MPH	North			43	3			41	3
			South			42	4			41	4
		60 MPH	North	<u>23</u>	7	42	3			41	2
			South	31	6	41	3			41	4
	5	*Lane 5 Averages*		*<u>27</u>*	*8*						
		40 MPH	North	31	7						
			South	34	5						
		60 MPH	North	<u>20</u>	6						
			South	<u>24</u>	5						
	Smooth Tire Averages			**34**	**11**	**44**	**4**			**44**	**4**

Note: Lane averages are in italics, tire averages are in bold, and values less than 30 are underlined.

[1] Pre-CDG testing at 40 and 60 mph conducted by Dynatest; Pre-CDG testing at 50 mph conducted by Caltrans.

Table 4.18: Towed Skid Trailer Results by IGGA from San Diego 5 Project

			Average SN_{40} and Standard Deviation					
			CDG South of GnG		GnG		CDG North of GnG	
Tire Type	Location	PM Range[1]	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Ribbed	NB Lane 2	R0.2 / R0.5	49	1	46	2	50	2
	NB Lane 5	R0.3 / R0.5	46	2	42	2	50	2
	SB Lane 5	R1.0 / R1.2	47	1	45	1	47	1
	Ribbed Tire Average[2]		**47**	**2**	**44**	**2**	**49**	**2**
Smooth	SB Lane 5	R0.2 / R0.5	43	2	42	3	42	3
	NB Lane 5	R1.3 / R1.6	40	2	36	2	44	3
	Smooth Tire Average[2]		**42**	**2**	**39**	**4**	**43**	**3**

Note: testing speed = 40 mph, left wheelpath
1. PM for IGGA data is estimated from operator notes.
2. Tire averages are in bold.

4.3.3.8 Towed Skid Trailer Review of Pilot Projects

Table 4.19 contains a summary of the Towed Skid Trailer data collected by the IGGA for six of the seven pilot projects (Sacramento 5 – PM 1.5/3.0 was not tested). The results show that the GnG surface texture produced sufficient friction for use on *most* heavy volume roads (that is, a test result of 40 or greater). Only the Sacramento 80 and San Diego projects produced Towed Skid Trailer test results below 30 on textured surfaces.

Under ribbed tire testing, the CDG texture produced an average skid number of 49 versus an average of 45 for the GnG texture. Smooth tire testing resulted in an average of 43 on the CDG texture and 39 on the GnG texture.

The differences in the results between the CDG and GnG textures for both tire types is statistically significant, whether the texture data are analyzed individually or as project summaries (Table I.38). Seen from the perspective of the project summaries, the CDG texture provided about 9 percent more friction than the GnG texture for both ribbed and smooth tires.

The average ASTM E274 measurement on each lane/direction for each texture from the small subset of all of the pilot projects on which towed skid trailer tests were performed is shown in Figure 4.29. As can be seen, most of the measurements were taken on the San Diego 5 project. The few results show lower values for the pre-CDG texture and similar values for the CDG and GnG textures. Figure 4.30 shows the distributions of ASTM E274 results for all of the projects, again showing that the skid trailer indicates that the GnG and CDG treatments produce better friction, while the pre-CDG texture produces lower values, in contrast to the values seen with the CT 342 results.

Table 4.19: Average Skid Numbers for CDG and GnG Surfaces Using Ribbed and Smooth Tires, Tested by IGGA

	Tire Type	Ribbed Tire				Smooth Tire			
	Texture	CDG		GnG		CDG		GnG	
Project	Test Location	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Sac 5 – PM20.0/21.5	NB	48.4	1.5	48.3	1.4	41.9	3.3	42.6	1.6
Sac 80 – PM13.0/14.0	EB			47.7	2.2			38.8	2.4
	WB			36.6	1.9			28.8	1.9
Sac 50 – PMR13.0/R14.0	EB							39.3	2.1
	WB			46.4	2.6			39.6	4.6
SJ 99 – PM29.0/30.7	NB			43.6	2.9			35.9	3.9
Yol 113 – PMR0.5/R2.5	NB			50.2	1.9	44.1	1.8	45.3	3.1
	SB	51.6	2.6	45.5	1.4	41.5	3.4	41.1	2.7
SD 5 – PMR35.8/R37.9	NB	48.8	2.2	44.1	2.8	42.3	3.0	35.8	2.3
	SB	47.3	0.7	44.7	1.1	42.7	2.2	42.4	2.8
Project Averages		49.0		45.2		42.5		39.0	

Note: test speed = 40 mph; left wheelpath

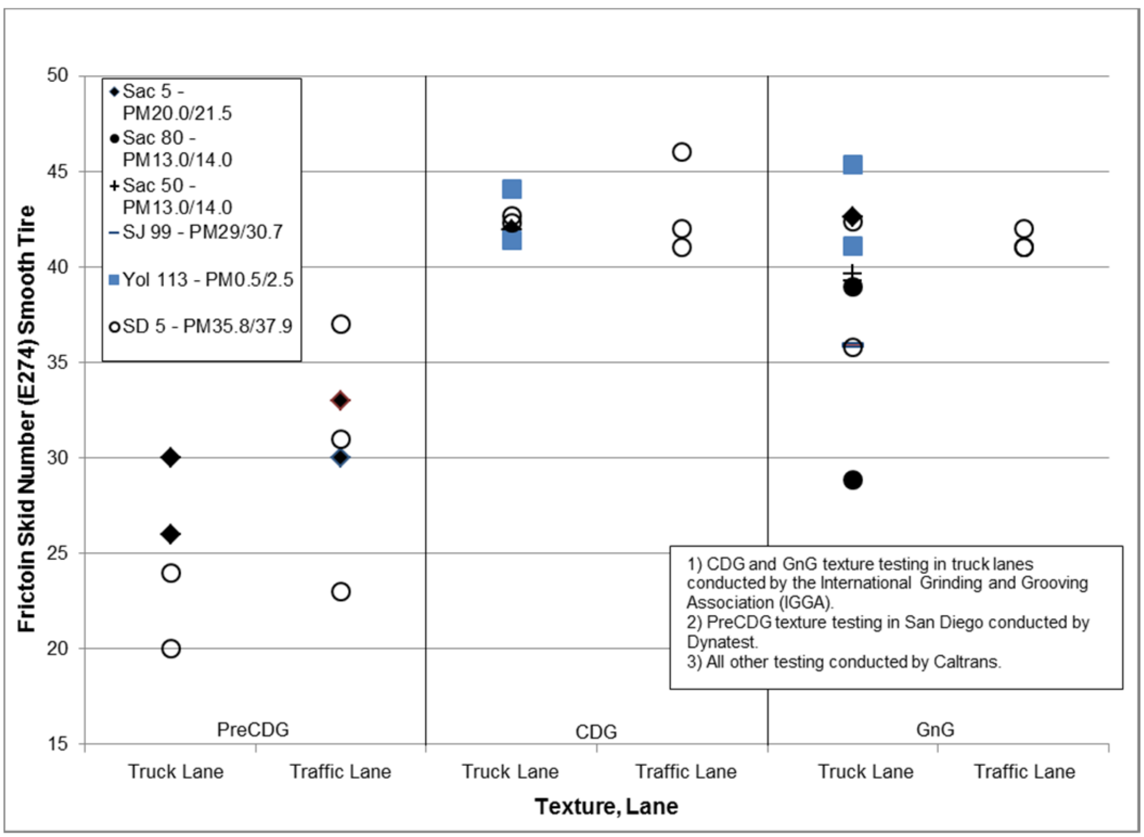


Figure 4.29: Summary of towed skid trailer measurements (ASTM E274) for the smooth tire for each texture across all pilot projects, truck and traffic lanes.

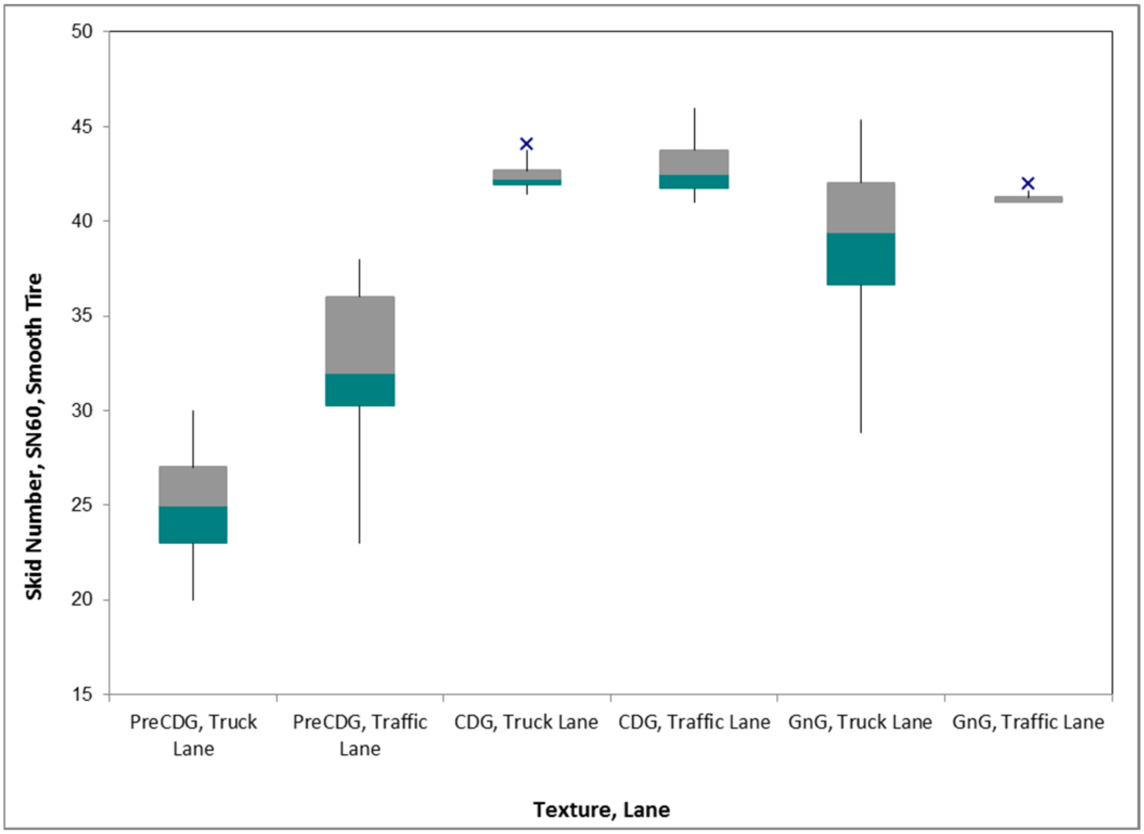


Figure 4.30: Box plot of towed skid trailer measurements for ASTM E274 smooth tire for each texture across all pilot projects, truck and traffic lanes.

4.3.3.9 Comparisons of Towed Skid Trailer Data with California Portable Skid Tester Data and Estimated Skid Numbers from CTM and DFT

As noted in Section 2.2.3.2, the Towed Skid Trailer (ASTM E274) is a common national standard for friction testing. Four appendices discuss and review comparisons of this friction test. Appendix E presents a comparison of the Towed Skid Trailer results to the California standard Portable Skid Tester (CT 342) on three projects, Sacramento 5 – PM 20.0/21.5, Sacramento 80, and San Diego 5. A discussion of the skid number estimated from Circular Texture Meter and Dynamic Friction Tester data is found in Appendix F, followed by presentation of the calculated skid numbers in Appendix G. This latter appendix also compares estimated skid numbers to actual Towed Skid Trailer data.

The results of the analysis presented in Appendix E show similarities between the towed skid trailer and the California portable skid tester for the CDG texture, but not for the GnG texture. For the GnG texture, the portable skid tester generally, but not always, shows lower values for the GnG texture than does the towed skid trailer. This finding is based on a limited comparison, with just a few sections and surface textures sampled. It is recommended that a larger experiment be undertaken to address the potential use of the E274 Towed Skid Trailer in lieu of the CT 342 Portable Skid Tester for testing the friction characteristics of pavement surfaces.

4.3.4 ASTM E2380 (Outflow Meter) Data

The results from the Outflow Meter Test are presented in Appendix J.

4.3.5 Comparison of Drainability and Skid Resistance for CDG, GnG, and NGL on Sacramento-5-PM 20.5/20.7 NGL

4.3.5.1 Drainability

The results from the Outflow Meter tests for the one project that it was used on are presented in Table 4.20. A low Outflow Meter time indicates a pavement that is able to move water out from under a tire faster, reducing the likelihood of hydroplaning. The results indicate that the CDG texture had a faster drain time than did the pre-CDG texture, and that the GnG texture further reduced the drain time. The NGL texture had the longest drain time of any of the final textures (CDG, GnG), and the only texture with a longer drain time was the flush grind intermediate texture (pre-GnG) occurring during construction of the GnG texture.

Table 4.20: Outflow Meter Times from Sacramento 5 – PM 18.7 and PM 20.5

Location	Between Wheelpaths		Left Wheelpath	
Texture	Avg. (sec.)	Std. Dev.	Avg. (sec.)	Std. Dev.
Pre-CDG	8.0	2.4	6.5	1.4
CDG	4.9	0.7	2.7	0.6
Pre-GnG	19.2	4.0	24.5	4.9
GnG	3.2	0.5	3.7	0.3
Pre-NGL	5.1	1.5	3.2	0.9
NGL	11.6	1.6	11.4	1.4

4.3.5.2 Skid Number from CTM and DFT Data

As discussed in Appendix G, the skid number (SN_{40}) can be estimated using the International Friction Index (IFI). Table 4.21 presents a comparison of the estimated skid numbers for the surfaces in Lane 1.

Table 4.21: Skid Number Calculated with CTM and DFT Data on the Surfaces from Sacramento 5

	Pre-CDG	CDG	Pre-GnG	GnG	NGL
Calculated SN_{40} Ribbed Tire	47.28	74.37	36.99	52.15	50.24
Calculated SN_{40} Smooth Tire	30.27	53.94	20.67	37.91	31.29

The skid numbers estimated for the NGL are lower than those for the GnG surface. Numbers below 30 indicate an area that requires improvement, which only occurred for the Pre-GnG texture. Heavily traveled roads with skid numbers between 30 and 35 should be monitored frequently (Table 4.22). The smooth tire results for the NGL texture imply an area of concern with regard to wet weather conditions.

Table 4.22: Typical Skid Numbers (*23*)

Skid Number	Comments
< 30	Take measures to correct
≥ 30	Acceptable for low volume roads
31 – 34	Monitor pavement frequently
≥ 35	Acceptable for heavily traveled roads

4.4 IRI Data

4.4.1 Sacramento 5 – PM 20.0/21.5

As noted in Chapter 2, prior to December 2011, IRI was collected with a point laser. A wide-spot laser (a Roline laser) was later installed because a point laser cannot accurately characterize longitudinally oriented, deeply textured surfaces. On Sacramento 5 – PM 20.0/21.5, the CDG and GnG IRI data were first measured with a point laser but were later retested with the wide-spot laser.

Table 4.23 shows data collected with the point and wide-spot lasers between PM 20.0 and PM 21.5. The averaged results from data collected with the point laser differ significantly from the wide-spot laser data for both the CDG and GnG textures. The difference between the laser results for the CDG texture is 10 to 20 percent; however, IRI for the GnG texture measured with the point laser is four to five times larger than that reported using the wide-base laser.

Table 4.23: Comparison of IRI Data Collected with Point and Wide-Base Lasers

Sac 5-PM 20.0/21.5		Point Laser on Pre-CDG (in./mi)		Point Laser on Treatment Texture (in./mi)		Wide-Spot Laser on Treatment Texture (in./mi)	
Final Texture	Location	5/19/2011		10/11/2011		1/25/2012	
		Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
GnG	NB Lane 1	125.3	0.8	209.1	5.3	42.0	0.4
	NB Lane 4	164.7	2.0	229.9	2.2	52.0	0.4
CDG	SB Lane 1	135.3	1.7	91.7	1.4	82.4	1.3
	SB Lane 4	153.9	0.5	93.0	0.3	75.1	0.1

Assuming that the point laser provided reasonable results for the pre-CDG treatment, the measurements indicate that the CDG treatment reduced the IRI by approximately 50 to 75 in./mi, and the GnG treatment further reduced the IRI by approximately another 25 to 40 in./mi. The final GnG IRI values are very low.

4.4.2 Sacramento 5 – PM 1.5/3.0

Table 4.24 shows IRI data from the Sacramento 5 – PM 1.5/3.0 project, and includes data collected on the CDG texture in both directions before the GnG construction. Before construction the two directions were statistically different, with the IRI measured on the southbound lanes 10 percent higher than that on the northbound lanes.

The CDG construction produced a significant reduction in IRI for all lanes, and the GnG construction again reduced the IRI. Northbound Lane 1 and Lane 2 were statistically similar for both the pre-CDG and CDG measurements, but no other similarities existed between other measurements of the same texture in Lane 1 and Lane 2 (Table I.34). Only the December 14, 2011, measurement of CDG showed greater roughness in Lane 1 than Lane 2. The IRI was measured twice on the CDG southbound, with no statistical difference appearing in the means when the data from both Lane 1 and Lane 2 (Table I.35) were combined. The IRI on the CDG texture on December 14, 2011, averaged 62.8 in./mi and the IRI on the CDG0.3y texture on February 6, 2012, averaged 63.8 in./mi.

Overall, the CDG treatment reduced the IRI by approximately 60 to 70 in./mi and the GnG treatment reduced IRI by approximately 10 to 20 more in./mi, resulting in very low IRI values.

Table 4.24: IRI Data from Sacramento 5 – PM 1.5/3.0 Pilot Project

Sac5-PM 1.5/3.0	Pre-CDG (in./mi)		CDG (in./mi)		CDG0.3y (in./mi)		GnG (in./mi)	
	6/22/2011		12/14/2011		2/6/2012		2/6/2012	
Project	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
NB Lane 1	112.9	0.7	60.4	1.2			42.7	0.2
NB Lane 2	113.3	1.0	60.6	0.7			48.2	0.7
SB Lane 1	121.1	0.6	65.7	0.1	62.8	0.2		
SB Lane 2	128.9	1.3	60.0	0.6	64.7	0.5		

4.4.3 Sacramento 80 – PM 13.0/14.0

Preconstruction IRI on the westbound lanes of Sacramento 80 – PM 13.0/14.0 was greater than on the eastbound lanes, by 10 in./mi on Lane 5 and by 8 in./mi on Lane 2 (Table 4.25). This 8 in./mi difference in the IRI of Lane 2 between directions remained consistent throughout the testing of the different textures and may be a result of heavier traffic westbound.

The CDG texture measured in Lane 2 was resurfaced with the GnG texture. The CDG texture showed a reduction of about 80 to 90 in./mi (a 63 percent reduction) from the pre-CDG texture, while the GnG texture showed a reduction of an additional 2 to 10 in./mi, which is a 70 percent reduction over the pre-CDG texture. Eastbound Lane 2 was consistently smoother than westbound Lane 2 for the pre-CDG, CDG, and GnG textures, and it had the lowest recorded IRI of all the pilot projects.

Table 4.25: IRI Data from Sacramento 80 PM 13.0/14.0 Pilot Project

	Pre-CDG (in./mi)		CDG (in./mi)		GnG (in./mi)	
	Avg.	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
EB Lane 2	125.4	1.7	42.7	2.8	33.9	0.8
EB Lane 5	137.1	1.6			41.6	0.8
WB Lane 2	134.0	0.1	54.4	1.3	41.9	0.3
WB Lane 5	147.6	0.9			47.7	0.7

4.4.4 Sacramento 50 – PM R13.0/R14.0

On this project, the IRIs measured in Lane 1 and Lane 4 in both directions are different both before and after construction. Preconstruction IRI on eastbound Lane 4 was one of the highest recorded of the pilot projects (Table 4.26).

Table 4.26: IRI Data from Sacramento 50 PM R13.0/R14.0 Pilot Project

	Pre-CDG (in./mi)		CDG (in./mi)		GnG (in./mi)	
	Avg.	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
EB Lane 1	135.2	1.1	77.2	2.6		
EB Lane 4	171.9	3.0				
WB Lane 1					62.6	2.8
WB Lane 4					52.3	0.2

4.4.5 San Joaquin 99 – PM 29.0/30.7

The pre-CDG IRI for these two lanes were dissimilar, and the IRI result obtained on northbound Lane 2 was the highest value obtained from among all the lanes tested in the project. After GnG texturing, however, the difference in IRI between Lanes 1 and 2 fell to 30 in./mi from a pre-CDG difference of 50 in./mi (Table 4.27). Overall the GnG treatment reduced IRI by approximately 80 to 100 in./mi.

Table 4.27: IRI Data from San Joaquin 99 PM 29.0/30.7 Pilot Project

	Pre-CDG (in./mi)		GnG (in./mi)	
	Avg.	**Std. Dev.**	**Avg.**	**Std. Dev.**
NB Lane 1	126.1	0.9	44.3	1.9
NB Lane 2	178.5	1.0	72.9	34.1

4.4.6 *Yolo 113 – PM R0.5/R2.5*

IRI data for the entire section are shown in Appendix H. Table 4.28 shows a detailed breakdown of the project averages. To compute differences between the textures, the evaluation section was divided along the north edge of GnG construction, PM 1.5 northbound and PM 0.9 southbound. The statistical comparisons (Table I.31, Parts A and B) show that only southbound Lane 2 PM 0.5/0.9 and PM 0.9/2.5 are statistically similar (p-value of 0.1), although for northbound Lane 2, the lanes are not wholly dissimilar between PM 0.5/1.5 and PM 1.5/2.5 (the p-value is 0.02).

Table 4.28: IRI Data from Yolo 113 Pilot Project

			Pre-CDG (in./mi)		CDG (in./mi)		GnG (in./mi)	
Dir.	**Lane**	**Post Mile**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
NB	1	0.5 – 1.5	116.7	7.9			53.1	5.4
		1.5 – 2.5	106.8	21.3	49.2	9.0		
	2	0.5 – 1.5	132.3	26.0			47.6	9.8
		1.5 – 2.5	119.5	22.0	45.4	6.1		
SB	1	0.5 – 0.9	151.1	3.5			44.7	4.9
		0.9 – 2.5	126.3	14.5	54.1	9.5		
	2	0.5 – 0.9	138.6	10.1			46.2	6.4
		0.9 – 2.5	134.7	15.6	68.0	10.3		

4.4.7 *San Diego 5 – PM R35.8/37.9*

IRI data for the entire section are shown in Appendix H. Table 4.29 below is the IRI data summary for the San Diego 5 project. As with the OBSI testing, the IRI of the CDG texture at 1.3 years was measured on about half as many sections on which the CDG texture at 0.7 or 1.1 years were measured. The CDG texture at 0.7 and 1.1 years was measured between PMs R35.8 and R37.9, before the GnG texture was constructed. The CDG texture at 1.3 years and the GnG texture data were measured at different locations in the evaluation area after GnG construction: the CDG texture at 1.3 years was measured between PMs R35.8 and R36.3 and between PMs R37.4 and R37.9, and the GnG texture was measured between PMs R36.35 and R37.35 (Figure 3.9).

Table 4.29: IRI Data (in./mi) from the San Diego 5 – PM R35.8/R37.9 Pilot Project

Texture[1]	Pre-CDG [2]		CDG0.7y		CDG1.1y		CDG1.3y		GnG	
	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Project Average	**158.3**	**18.3**	**57.5**	**20.6**	**57.6**	**19.4**	**59.6**	**22.8**	**39.8**	**7.7**
NB Lane 1	127.3	4.0	56.0	23.7	60.1	20.6	57.4	27.8	41.2	5.9
NB Lane 2	175.3	2.9	54.3	24.3	58.5	23.6	62.5	25.8	43.9	9.8
NB Lane 3	178.9	0.9	54.1	22.3	54.6	20.8	60.6	27.3	37.7	9.3
NB Lane 4	164.0	6.1	56.7	17.1	53.7	17.3	57.3	22.1	39.1	7.0
NB Lane 5	155.3	1.8	59.9	20.2	58.2	17.7	59.8	21.1	37.7	8.4
SB Lane 1	126.0	3.8	57.3	13.7	60.0	14.0	60.5	16.8	37.3	4.3
SB Lane 2	158.8	1.3	51.1	21.9	51.1	19.6	57.6	19.9	36.1	7.7
SB Lane 3	177.0	1.2	59.6	18.2	60.2	17.8	62.7	21.0	41.0	6.9
SB Lane 4	164.1	7.4	61.6	19.0	58.6	19.0	61.3	23.1	38.4	5.3
SB Lane 5	156.0	0.3	64.1	21.2	60.8	20.5	56.6	23.4	45.1	6.1

Notes:
1. Texture condition at time of the activity: pre-CDG = before conventional diamond grinding, CDGX.Xy = X.X years after flush grinding, GnG = after longitudinal grooving.
2. IRI data collected with point laser, not the wide-base (Roline) laser.

These data show a drop of approximately 100 in./mi between the IRI measured on the pre-CDG texture and on any of the three subsequent CDG textures. A difference of 20 in./mi was measured between the IRI of the CDG after 1.3 years and the IRI of the GnG. The IRI reduction between the pre-CDG texture and the CDG texture was 62 percent, while the reduction from the pre-CDG to the GnG texture was 75 percent.

4.4.8 Review of IRI on Pilot Projects

Results of the IRI evaluation for all the pilot projects, by lane, are summarized in Table 4.30. Data for each lane of all projects are shown from treatment to treatment in Figure 4.31, and the distributions of IRI for each treatment are shown in Figure 4.32. Overall, the pre-CDG IRI for all the projects averaged 140 in./mi and ranged between 75 in./mi to 205 in./mi. IRI values after CDG construction ranged between 30 in./mi and 140 in./mi, with average of 60 in./mi, which indicates a 55 percent reduction from the pre-CDG to the CDG texture. This reduction is most likely from the grinding operation of the CDG treatment removing faulting at the transverse joints. IRI values after GnG construction ranged between the very smooth value of 35 in./mi to 120 in./mi., with an average of 45 in./mi, which indicates a 65 percent reduction from the pre-CDG to the GnG texture. It can be seen in Figure 4.31 and Figure 4.32 that CDG grinding results in consistently low IRI values, which are reduced a little more by the GnG treatment.

Table 4.30: Summary of IRI Data of the Pilot Projects by Lane (Note: Project averages appear in bold.)

	Pre-CDG[1] (in./mi)		CDG[2] (in./mi)		GnG (in./mi)		Percent Reduction from Pre-CDG	
Project	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**To CDG**	**To GnG**
Sac5-PM 20.0/21.5	**146.3**		**79.3**		**47.0**			
NB Lane 1	125.3	0.8			42.0	0.4		66
NB Lane 4	164.7	2.0			52.0	0.4		68
SB Lane 1	135.3	1.7	82.4	1.3			39	
SB Lane 4	153.9	0.5	75.1	0.1			51	
Sac5-PM 1.5/3.0	**119.1**		**63.8**		**45.5**			
NB Lane 1	112.9	0.7			42.7	0.2		62
NB Lane 2	113.3	1.0			48.2	0.7		57
SB Lane 1	121.1	0.6	62.8	0.2			48	
SB Lane 2	128.9	1.3	64.7	0.5			50	
Sac 80-PM 13.0/14.0	**136.0**		**47.7**		**41.3**			
EB Lane 2	125.4	1.7	42.7	2.8	33.9	0.8	66	73
EB Lane 5	137.1	1.6			41.6	0.8		70
WB Lane 2	134.0	0.1	54.4	1.3	41.9	0.3	59	69
WB Lane 5	147.6	0.9			47.7	0.7		68
Sac 50-PM R13.0/R14.0	**153.5**		**77.2**		**57.5**			
EB Lane 1	135.2	1.1	77.2	2.6			43	
EB Lane 4	171.9	3.0						
WB Lane 1					62.6	2.8		
WB Lane 4					52.3	0.2		
SJ 99-PM 29.0/30.7	**152.3**				**64.3**			
NB Lane 1	126.1	0.9			44.3	1.9		65
NB Lane 2	178.5	1.0			72.9	34.1		59
Yolo 113-PM R0.5/R2.5	**126.1**		**55.4**		**48.7**			
NB Lane 1	111.4	17.0	49.2	9.0	53.1	5.4	56	52
NB Lane 2	125.5	24.6	45.4	6.1	47.6	9.8	64	62
SB Lane 1	132.2	16.6	54.1	9.5	44.7	4.9	59	66
SB Lane 2	135.6	14.5	68.0	10.3	46.2	6.4	50	66
San Diego 5-PMR35.8/37.9	**158.3**		**59.6**		**39.8**			
NB Lane 1	127.3	4.0	57.4	27.8	41.2	5.9	55	68
NB Lane 2	175.3	2.9	62.5	25.8	43.9	9.8	64	75
NB Lane 3	178.9	0.9	60.6	27.3	37.7	9.3	66	79
NB Lane 4	164.0	6.1	57.3	22.1	39.1	7.0	65	76
NB Lane 5	155.3	1.8	59.8	21.1	37.7	8.4	61	76
SB Lane 1	126.0	3.8	60.5	16.8	37.3	4.3	52	70
SB Lane 2	158.8	1.3	57.6	19.9	36.1	7.7	64	77
SB Lane 3	177.0	1.2	62.7	21.0	41.0	6.9	65	77
SB Lane 4	164.1	7.4	61.3	23.1	38.4	5.3	63	77
SB Lane 5	156.0	0.3	56.6	23.4	45.1	6.1	64	71

Notes:

1. Pre-CDG IRI data collected with point laser, not the wide-base (Roline) laser.
2. CDG data collected on interim surface that had been retextured.

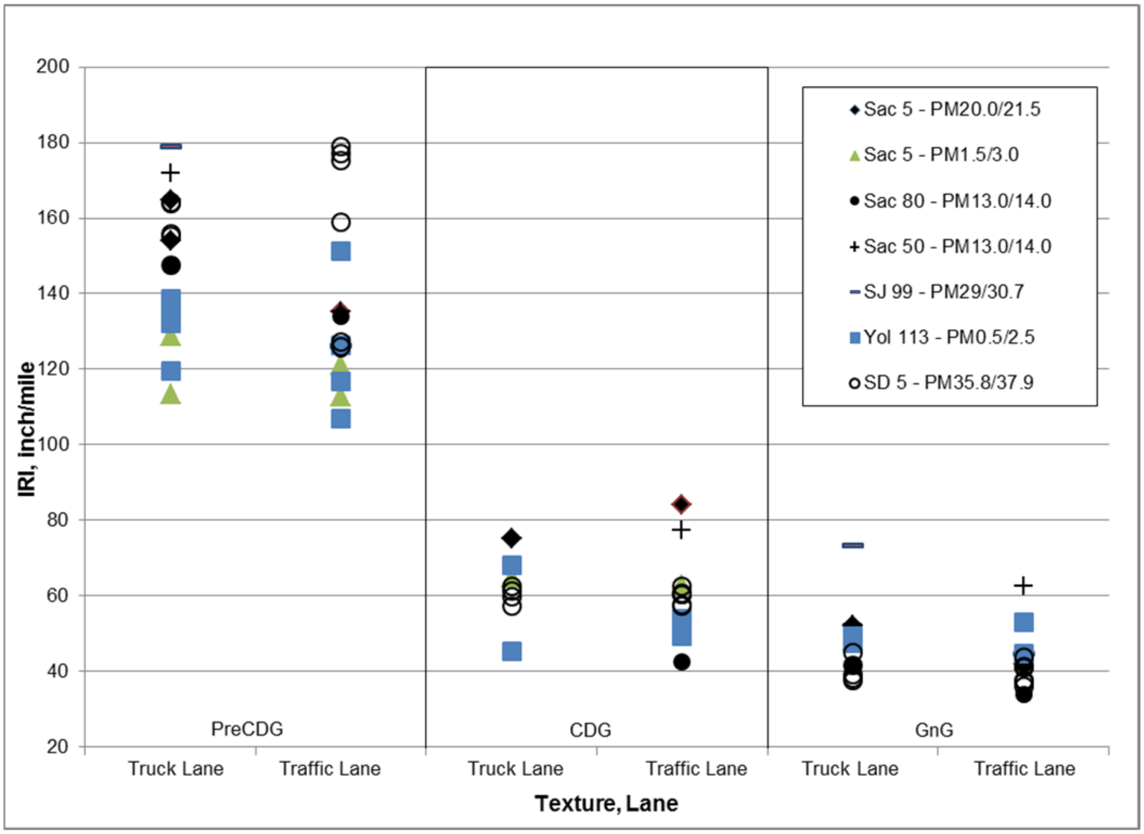


Figure 4.31: Summary of IRI measurements for each texture across all pilot projects, truck and traffic lanes.

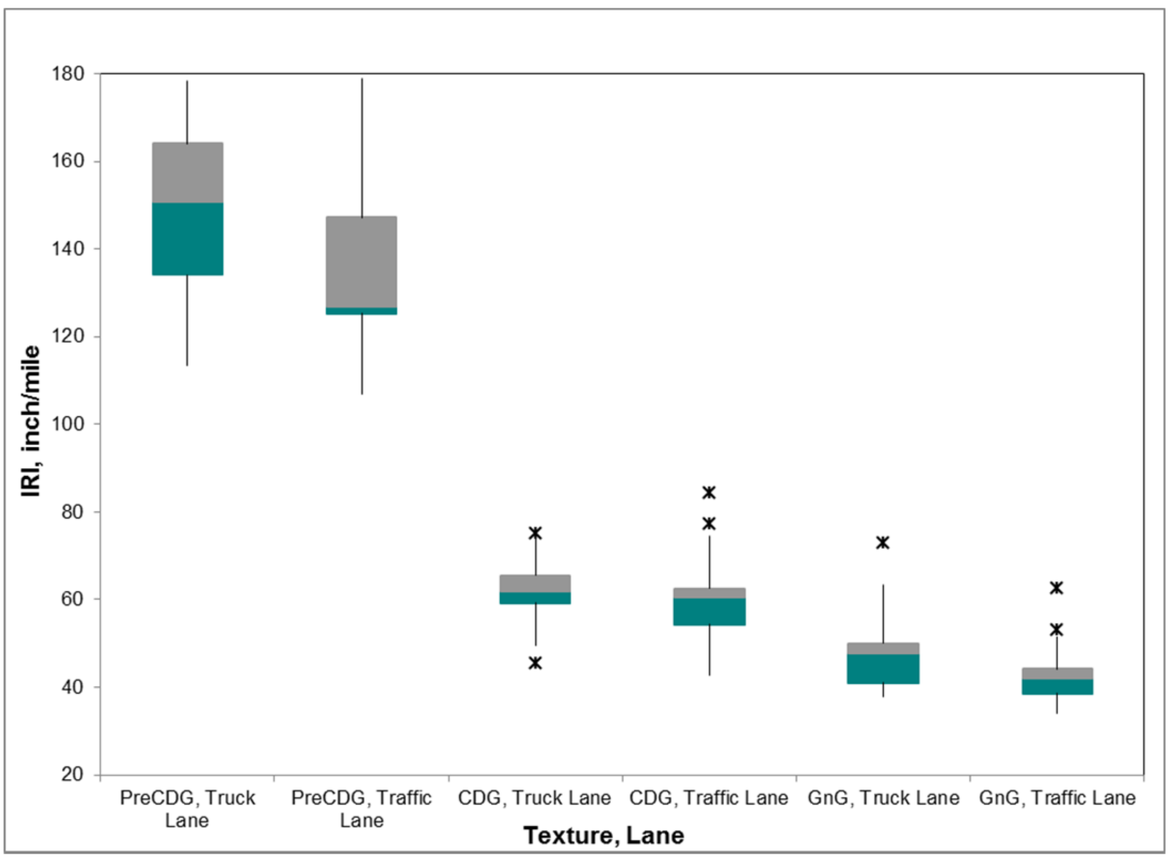


Figure 4.32: Box plot of IRI measurements for each texture across all pilot projects, truck and traffic lanes.

Plots of the change in IRI from pre-CDG to CDG, pre-CDG to GnG and CDG to GnG are included in Appendix K. Also shown in the appendix are regression equations relating pre-CDG to CDG and GnG textures and CDG to GnG. Both plots and equations are in terms of both reduction in IRI as a function of pre-CDG OBSI and percent reduction. These equations can be used to provide an indication of expected reduction in IRI for each treatment given a current IRI. The OBSI results indicate that although pre-CDG OBSI has a positive trend, with CDG and GnG roughness levels the correlation is very weak, indicating that existing IRI has little impact on the final IRI from either treatment for the ranges of existing IRI in this study.

5 COST DATA

Table 5.1 presents the unit costs and quantities of CDG and GnG construction for the seven pilot projects. The conventional grinding ranged from 49,200 to 613,000 square yards, and the GnG construction from 25,300 to 280,000 square yards. The unit prices per square yard ranged from $2.50 to $6.00 for CDG, and from $5.50 to $9.75 for the GnG (flush grind and grooving).

Table 5.1: Cost and Quantity Data from the Seven Pilot Projects

Project	Contract Number	Item Description	Quantity (sq. yd.)		Unit Price ($/sq. yd)	
			CDG	GnG	CDG	GnG
Sac 5 PM 20.0/21.5	03-1F450	Grind and Groove		111,000		5.50
	03-1F450	Conventional Grind	170,000		4.50	
Sac 5 PM 1.5/3.0	03-0F590	Grind and Groove		25,300		7.50
	03-0F590	Conventional Grind	76,600		5.50	
Sac 80 PM 13.0 /14.0	03-2F040	Grind and Groove		280,000		7.60
	03-2F040	Conventional Grind	49,200		2.50	
Sac 50 PM R13.0/R14.0	03-0A800	Grind and Groove		29,100		7.00
	03-0A800	Conventional Grind	185,500		6.00	
SJ 99 PM 29.0/30.7	10-0V870	Grind and Groove		27,000		9.75
	10-0M800	Conventional Grind	243,000		4.00	
Yol 113 PM R0.5/R2.5	03-2F050	Grind and Groove		35,000		8.65
	03-2F050	Conventional Grind	324,000		3.10	
SD 5 PM R35.8/R37.9	11-07760	Grind and Groove		87,200		7.75
	11-07980	Conventional Grind	613,000		3.63	
		Median	185,500	35,000	4.00	7.60
		Average	237,000	85,000	4.18	7.36
		Standard Deviation			1.26	1.32

The quantities of work of each texture type likely affected the construction unit costs shown in Figure 5.1, and it is reasonable to assume that larger quantities would lower the unit costs for GnG construction further. The project in Minnesota referred to in Section 1.1 (and in Reference [*4*]) constructed 104,000 square yards at a price of $4.60 per square yard, values comparable those for the Sacramento 5 – PM 20.0/21.5 project.

In this study, GnG was applied to pavements that were retextured with CDG, making them more likely to already meet smoothness specification. That retexturing lessened the extent of the flush grind required for the GnG to obtain the correct profile.

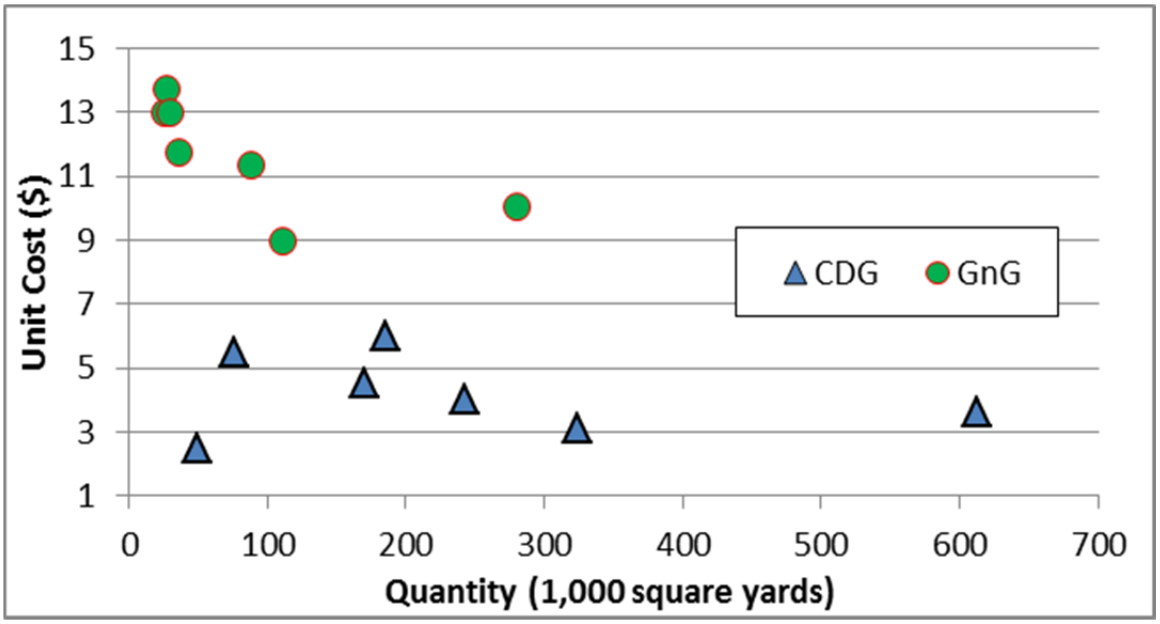


Figure 5.1: Quantity versus unit costs for CDG and GnG construction.

Table 5.2 shows costs and all performance measurements (OBSI, IRI, friction, drainability) for all projects. Table 5.3 and Table 5.4 show cost to benefit calculations for OBSI reduction and IRI reduction, respectively for all projects. The cost/benefit calculations for OBSI in terms of $/dBA reduction indicate that from the pre-CDG condition, overall GnG generally has slightly higher cost to benefit than does CDG. The cost/benefit calculations for IRI in terms of $/(inches/mile) reduction indicate that from the pre-CDG condition, CDG costs about half as much per inch/mile reduction in IRI as does GnG. There is considerable variability in the cost/benefit calculations, however, the overall conclusion is that GnG has a similar cost-effectiveness as CDG in reducing noise and results in lower noise, while GnG is not cost-effective in terms of reducing roughness compared to CDG alone and provides a small additional decrease in roughness.

Table 5.2: Summary of Test Results and Costs for All Pilot Projects

Project Location (County-Rte-PM)	Evaluation Test Section (PM)		Quantity (SQYD x1,000)		Unit Costs ($/SQYD)		OBSI Test Results (dBA)			IRI Test Results (in./mi)			Friction & Skid Test Results (Coefficient of Friction or SN_{40})				Drainability Test Results (Average times in seconds)		
													CT 342[3]		E274[3]				
	CDG	GnG	CDG	GnG	CDG	GnG	Pre-CDG	CDG	GnG	Pre-CDG[6]	CDG[7]	GnG[7]	CDG	GnG	CDG	GnG	Pre-CDG[13]	CDG	GnG
SAC-05-17.2/22.8	20.0/21.5 S	20.0/21.5 N	170	111	$4.50	$9.00	104.4	102.5	101.0	130 159	82 75	42 52	0.39N	0.35N	53S	49N	7.2 N	3.8	3.4
SAC-05-0.0/3.5	1.5/3.0 S	1.5/3.0 N	77	25	$5.50	$13.00	104.6	103.2	101.5	117 121	63 65	43 48					3.1 N		5.0
SAC-80-12.4/18.0	N/A	13.0/14.0 E & W	49[1]	280	$2.50[1]	$10.10	105.1	N/A	101.4	130 142		38[8] 45[8]	0.39E	0.29E		39E 29W	14.3 E	2.7	8.3
SAC-50-12.2/14.2	13.0/14.0 E	13.0/14.0 W	186	29	$6.00	$13.00	103.9	102.9	100.7	135[9] 172[9]	77[9]	63[10] 52[10]				39E 40W	9.4 E		12.0
SJ-99-29.0/30.8	N/A	29.0/30.7 N	243[1]	27	$4.00	$13.75	104.3	N/A	100.7	126[11] 179[11]		44[11] 73[11]				36N[4]	6.5 N	4.3	4.5
YOL-113-0.0/11.1	1.5/2.5 N 0.9/2.5 S	0.5/1.5 N 0.5/0.9 S	324	35	$3.10	$11.75	103.0	101.0	99.8	125 131	52 57	49 47			44N[4] 41S[4]	45N[4] 41S[4]	18.6 S		4.8
SD-05-32.7/42.9	35.8/36.3 & 37.4/37.9	36.3/37.3 N & S	613	87	$3.63	11.38[2]	105.2	103.2	100.7	160[12] 156[12]	56[12] 59[12]	40[12] 40[12]	0.33N 0.39S	0.29N 0.31S	44[5]	44[5]	8.0[14] 7.2[14]	3.5[14] 4.3[14]	5.3[14] 4.9[14]
WEIGHTED AVERAGE UNIT COST ($/SQYD					**$3.99**	**$10.61**													
AVERAGE FOR ALL TEST SECTIONS			**237**	**85**	**$4.18**	**$11.71**	**104.4**	**102.8**	**100.8**	**142**	**65**	**48**	**0.38**	**0.31**	**45.5**	**40.2**	**9.3**	**3.7**	**6.0**
LOWEST FOR ALL TEST SECTIONS			49	25	$2.50	$9.00	103.0	101.0	99.8	117	52	38	0.33	0.29	41	29	3.1	2.7	3.4
HIGHEST FOR ALL TEST SECTIONS			613	280	$6.00	$13.75	105.2	103.2	101.5	179	82	73	0.39	0.35	53	49	18.6	4.3	12.0

1. Quantity and unit cost data for a comparable CDG project in the same vicinity.
2. Unit cost for SD-05 GnG includes $3.63/SQYD for CDG constructed in an earlier contract.
3. E, W, N and S denote direction of traffic flow (eastbound, westbound, northbound, and southbound).
4. From IGGA towed trailer skid test results
5. Average for SD-05 PM 35.8/37.9 Lanes 1 and 2 in both directions and all test speeds (40, 50 and 60 mph)
6. Unless otherwise stated, first value is average IRI for Lane 1 in both directions and second value is average for the rightmost lanes in both directions.
7. Unless otherwise stated, first value is for Lane 1 and second value is for rightmost lane.
8. First value is average IRI for Lane 2 in both directions and second value is average for Lanes 5 in both directions.
9. First value is IRI for WB Lane 1 and second value is for WB Lane 4.
10. First value is IRI for EB Lane1 and second value is for EB Lane 4.
11. First value is IRI for NB Lane1 and second value is for NB Lane 2.
12. First value is average IRI for all NB lanes (1 to 5) and second value is average for all SB lanes (1 to 5).
13. Indicates average drainability for the direction and lanes tested.
14. First value is average for NB lanes 1, 2, and 5 and second value is average for SB lanes 1, 2, and 5.

Table 5.3: OBSI Cost Benefit Summary for All Pilot Projects

Project Location (County-Rte-PM)	Evaluation Test Section (PM)		Quantity (SQYD x1,000)		Unit Costs ($/SQYD)		OBSI Test Results (dBA)			Change in OBSI (dBA)			Cost Benefit Ratio ($/dBA)		
	CDG	GnG	CDG	GnG	CDG	GnG	Pre-CDG	CDG	GnG	Pre-CDG – CDG	Pre-CDG – GnG	CDG – GnG	CDG	GnG	GnG – CDG
SAC-05-17.2/22.8	20.0/21.5 SB	20.0/21.5 NB	170	111	$4.50	$9.00	104.4	102.5	101.0	1.9	3.4	1.5	2.31	2.65	3.11
SAC-05-0.0/3.5	1.5/3.0 SB	1.5/3.0 NB	77	25	$5.50	$13.00	104.6	103.2	101.5	1.4	3.1	1.7	3.97	4.25	4.48
SAC-80-12.4/18.0	N/A	13.0/14.0 EB & WB	49[1]	280	$2.50[1]	$10.10	105.1	N/A	101.4	2.0	3.7	1.7	1.24	2.70	4.38
SAC-50-12.2/14.2	13.0/14.0 EB	13.0/14.0 WB	186	29	$6.00	$13.00	103.9	102.9	100.7	1.0	3.2	2.2	5.76	4.04	3.21
SJ-99-29.0/30.8	N/A	29.0/30.7 NB	243[1]	27	$4.00	$13.75	104.3	N/A	100.7		3.6			3.77	
YOL-113-0.0/11.1	1.5/2.5 NB 0.9/2.5 SB	0.5/1.5 NB 0.5/0.9 SB	324	35	$3.10	$11.75	103.0	101.0	99.8	2.0	3.3	1.2	1.52	3.61	7.10
SD-05-32.7/42.9	35.8/36.3 & 37.4/37.9	36.3/37.3 NB & SB	613	87	$3.63	11.38[2]	105.2	103.2	100.7	2.0	4.5	2.5	1.82	2.51	3.05
QUANTITY-WEIGHTED AVERAGE					**$3.99**	**$10.61**							**2.42**	**2.89**	**3.65**
AVERAGE FOR ALL TEST SECTIONS			**237**	**85**	**$4.18**	**$11.71**	**104.4**	**102.8**	**100.8**	**1.7**	**3.6**	**1.8**	**2.77**	**3.36**	**4.22**
LOWEST FOR ALL TEST SECTIONS			49	25	$2.50	$9.00	103.0	101.0	99.8	1.0	3.1	1.2	1.24	2.51	3.05
HIGHEST FOR ALL TEST SECTIONS			613	280	$6.00	$13.75	105.2	104.2	101.5	2.0	4.5	2.5	5.76	4.25	7.10

1. Quantity and unit cost data for a comparable CDG project in the same vicinity
2. Unit cost for SD-05 GnG includes $3.63/SQYD for CDG constructed in an earlier contract.
3. E, W, N and S denote direction of traffic flow (EB, WB, NB and SB).

Table 5.4: IRI Cost Benefit Summary for All Pilot Projects

Project Location (County-Rte-PM)	Evaluation Test Section (PM)		Quantity (SQYD x1,000)		Unit Costs ($/SQYD)		IRI Test Results (in./mi)			Change in IRI (in./mi)			Cost Benefit Ratio ($/[in./mi])		
	CDG	**GnG**	**CDG**	**GnG**	**CDG**	**GnG**	**Pre-CDG**	**CDG**	**GnG**	**Pre-CDG – CDG**	**Pre-CDG – GnG**	**CDG – GnG**	**CDG**	**GnG**	**GnG – CDG**
SAC-05-17.2/22.8	20.0/21.5 SB	20.0/21.5 NB	170	111	$4.50	$9.00	146.3	79.3	47.0	67.0	99.3	32.3	0.067	0.091	0.139
SAC-05-0.0/3.5	1.5/3.0 SB	1.5/3.0 NB	77	25	$5.50	$13.00	119.1	63.8	45.5	55.3	73.6	18.3	0.100	0.177	0.409
SAC-80-12.4/18.0	N/A	13.0/14.0 EB & WB	49[1]	280	$2.50[1]	$10.10	136.0	47.7	41.3	88.3	94.8	6.5	0.028	0.107	1.176
SAC-50-12.2/14.2	13.0/14.0 EB	13.0/14.0 WB	186	29	$6.00	$13.00	153.5	77.2	57.5	76.4	96.1	19.7	0.079	0.135	0.355
SJ-99-29.0/30.8	N/A	29.0/30.7 NB	243[1]	27	$4.00	$13.75	152.3		64.3		88.0			0.156	
YOL-113-0.0/11.1	1.5/2.5 NB 0.9/2.5 SB	0.5/1.5 NB 0.5/0.9 SB	324	35	$3.10	$11.75	126.1	55.4	48.7	70.8	77.4	6.7	0.044	0.152	1.301
SD-05-32.7/42.9	35.8/36.3 & 37.4/37.9	36.3/37.3 NB & SB	613	87	$3.63	11.38[2]	158.3	59.6	39.8	98.7	118.5	19.8	0.037	0.096	0.390
QUANTITY-WEIGHTED AVERAGE					**$3.99**	**$10.61**							**0.051**	**0.111**	**0.613**
AVERAGE FOR ALL TEST SECTIONS			**237**	**85**	**$4.18**	**$11.71**	**141.7**	**63.8**	**49.1**	**77.8**	**92.5**	**14.7**	**0.059**	**0.130**	**0.628**
LOWEST FOR ALL TEST SECTIONS			49	25	$2.50	$9.00	119.1	47.7	39.8	55.3	73.6	6.5	0.028	0.091	0.355
HIGHEST FOR ALL TEST SECTIONS			613	280	$6.00	$13.75	158.3	79.3	64.3	98.7	118.5	32.3	0.100	0.177	1.301

1. Quantity and unit cost data for a comparable CDG project in the same vicinity
2. Unit cost for SD-05 GnG includes $3.63/SQYD for CDG constructed in an earlier contract
3. E, W, N and S denote direction of traffic flow (EB, WB, NB and SB)

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results obtained from this study, the following conclusions can be made regarding surface characteristics and the relative benefits of the CDG and GnG grinding procedures:

1. Concrete pavements in California that are scheduled for Capital Preventive Maintenance (CaPM) projects can be expected to have OBSI noise levels ranging from about 100 to 110 dBA, and ride quality (smoothness, in terms of IRI) of about 120 to 160 in./mi.
2. After CDG and GnG texturing, OBSI noise levels for the CDG sections reduced to between 98.5 to 107.9 dBA, while those for GnG test sections reduced to between 98.2 and 106.8 dBA. Ride quality improved to IRI values ranging from 48 to 79 in./mi for CDG; and 40 to 64 in./mi for GnG sections.
3. GnG construction was approximately two to three times as effective in reducing noise levels as CDG construction, with OBSI reductions of 3.1 to 4.5 dBA for GnG versus 1.0 to 2.0 dBA for CDG. Overall, average noise reduction for GnG was 3.6 dBA versus 1.6 dBA for CDG.
4. On average, the CDG texture shifted the OBSI spectrum down across all frequencies while the GnG texture tended to reduce noise in the frequencies of 1,000 Hz and below more than in the higher frequencies, which shifted the peak noise to a higher frequency. As a result of these changes in the noise spectrum, the GnG texture caused both a reduction in total noise and a change in the tonality of the noise to slightly higher pitches.
5. The GnG was typically about 20 to 35 percent more effective in improving ride quality than CDG, with IRI reductions of 74 to 119 in./mi for GnG versus 55 to 99 in./mi for CDG. On average, GnG improved ride quality by 93 in./mi while the average improvement for CDG sections was 78 in./mi.
6. The average unit cost for GnG construction was nearly three times that for CDG: \$11.71/sqyd for GnG versus \$4.18/sqyd for CDG. The size of this difference is attributed in part to the fact that GnG is a new procedure, while CDG is widely used in California, and because the average quantities for the CDG projects in this study were almost three times those for the GnG sections (237,000 sqyd for the CDG versus 85,000 sqyd for the GnG).
7. Although GnG textures produced two to three times as much noise reduction as CDG textures, due to the higher unit costs for GnG texturing, the cost-effectiveness of noise reduction for GnG was on average only about 20 percent greater than for CDG: \$2.77/dBA for GnG and \$3.36/dBA for CDG. The additional noise reduction benefits of the GnG procedure over CDG would on average cost about \$4/sqyd for every additional dBA reduction.
8. The cost-effectiveness of the CDG construction in improving ride quality (IRI reduction) was approximately two to two-and-half times that for GnG. On average, for every \$1/sqyd, CDG reduced IRI by 19 in./mi versus 8 in./mi for GnG. The additional \$7.53/sqyd unit cost of GnG over CDG produced a benefit of only 2 in./mi reduction in IRI for every additional \$1/sqyd.

9. The CDG texture met the state-required 0.30 coefficient of friction using the California Test 342 (Portable Skid Tester) on all lanes tested; however, the CT 342 test measurements on three of the seven pilot projects produced inconclusive results on friction characteristics of GnG texturing, suggesting that further study may be needed to evaluate the friction characteristics of GnG using this test. On the other hand, skid resistance tests conducted on six of the seven pilot projects using the towed skid trailer test (ASTM E 274) showed that both CDG and GnG textures met skid resistance standards specified in many other states using this test.
10. The single NGL texture test section on Sacramento 5 had similar noise and friction characteristics as the control CDG texture.

6.2 Recommendations

The results of this study led to the following recommendations to further evaluate the performance of the CDG and GnG grinding procedures in terms of their long-term benefits and surface characteristics:

1. Conduct annual measurements to monitor the long-term acoustical, friction, and ride quality (IRI) performance of the GnG surface textures and adjacent control CDG textures.
2. Perform a comprehensive literature review to examine the frictional properties of GnG surfaces that have been constructed in other states versus coefficients of friction obtained on GnG sections in California tested using CT 342.
3. Undertake a larger field study to determine the feasibility of replacing the CT 342 Portable Skid Tester with the E274 Towed Skid Trailer for testing friction on pavements in California.
4. Based on the relative cost-effectiveness of GnG versus CDG in reducing noise levels (reducing OBSI) and improving ride quality (reducing IRI), this study recommends use of GnG in noise-sensitive areas and CDG texturing where improving ride quality is the primary goal.

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APPENDIX A: OBSI LONGITUDINAL PROFILES

Longitudinal profiles of OBSI for all the pilot projects are presented in the following figures. Each profile is an individual lane, with a direction and lane number indicated in the figure header. The profiles are paired by direction for each lane. For example, the Sac 5 – PM 20.0/21.5 charts for northbound Lane 1 and southbound Lane 1 are paired in Figure A.1, as are northbound and southbound Lane 4 in Figure A.2.

The figure legend provides an approximate sampling date since some data were collected over multiple days. The text box within each figure provides the average and standard deviation OBSI values for the longitudinal profiles shown.

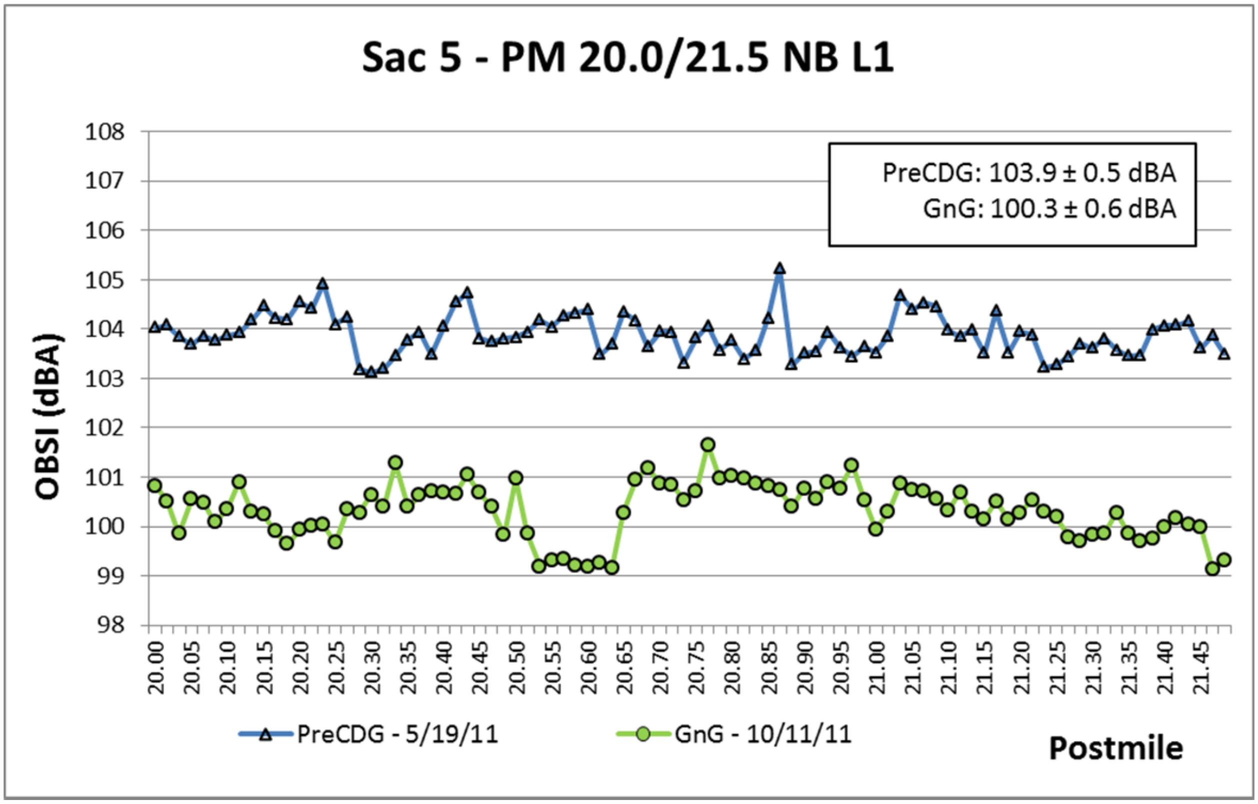
Discrete bumps in the measured OBSI represent transverse bridge joints. These bumps were used to adjust the location data that were included in the conventional diamond grind (CDG) data.

The following markers and notations are used in all figures:

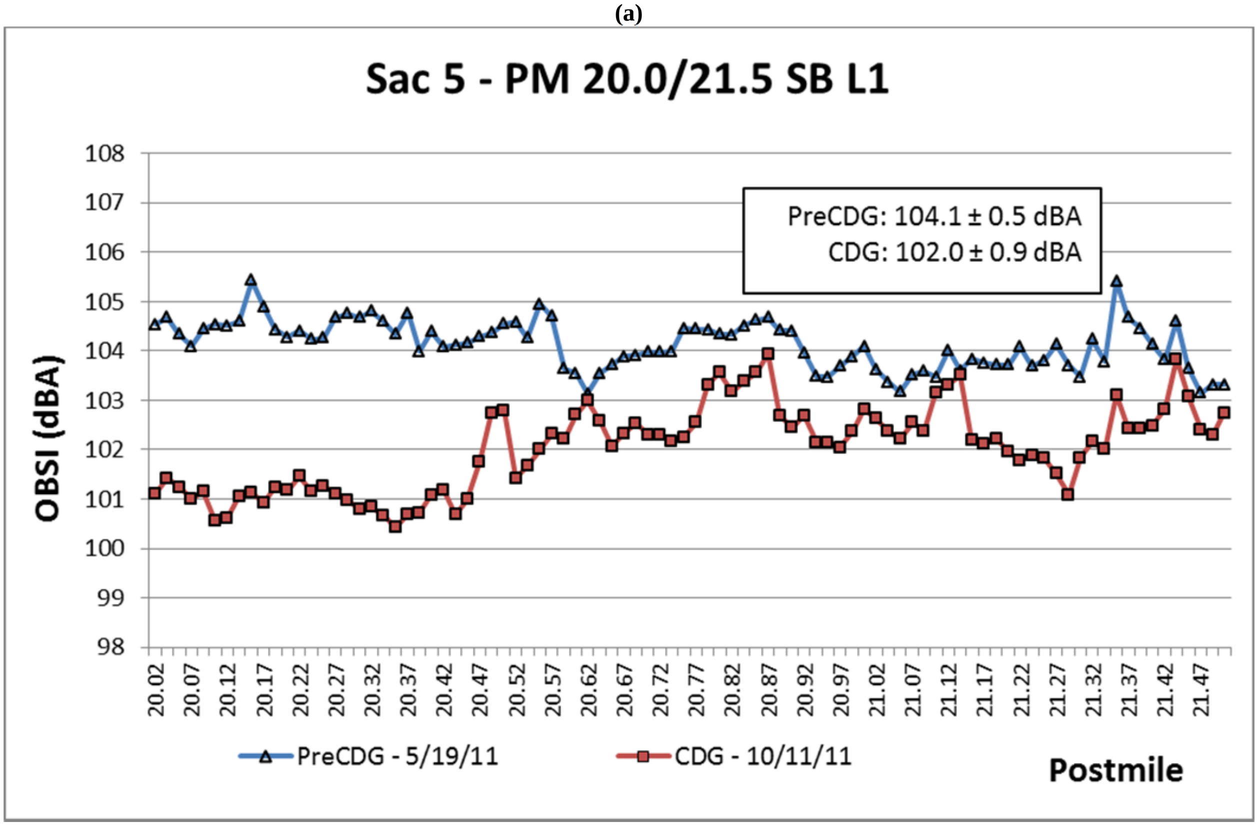
- Pre-CDG: Blue line and triangle marker
- CDG: Brown line and square marker
- CDGX.Xy: Red dashed line and square marker
- GnG: Green line and circle marker
- If a marker is filled with a color, it represents the current surface texture; if a marker is not filled with a color, it represents a surface texture that has been replaced.
- X.Xy represents the number of years since data were first collected. For instance, CDG0.3y represents the CDG surface texture 0.3 years after the first CDG measurement.

Individual lane graphs use the following abbreviations:

- PM = Post mile
- L = Lane (e.g., L1 = Lane 1)
- NB = Northbound
- SB = Southbound
- WB = Westbound
- EB = Eastbound

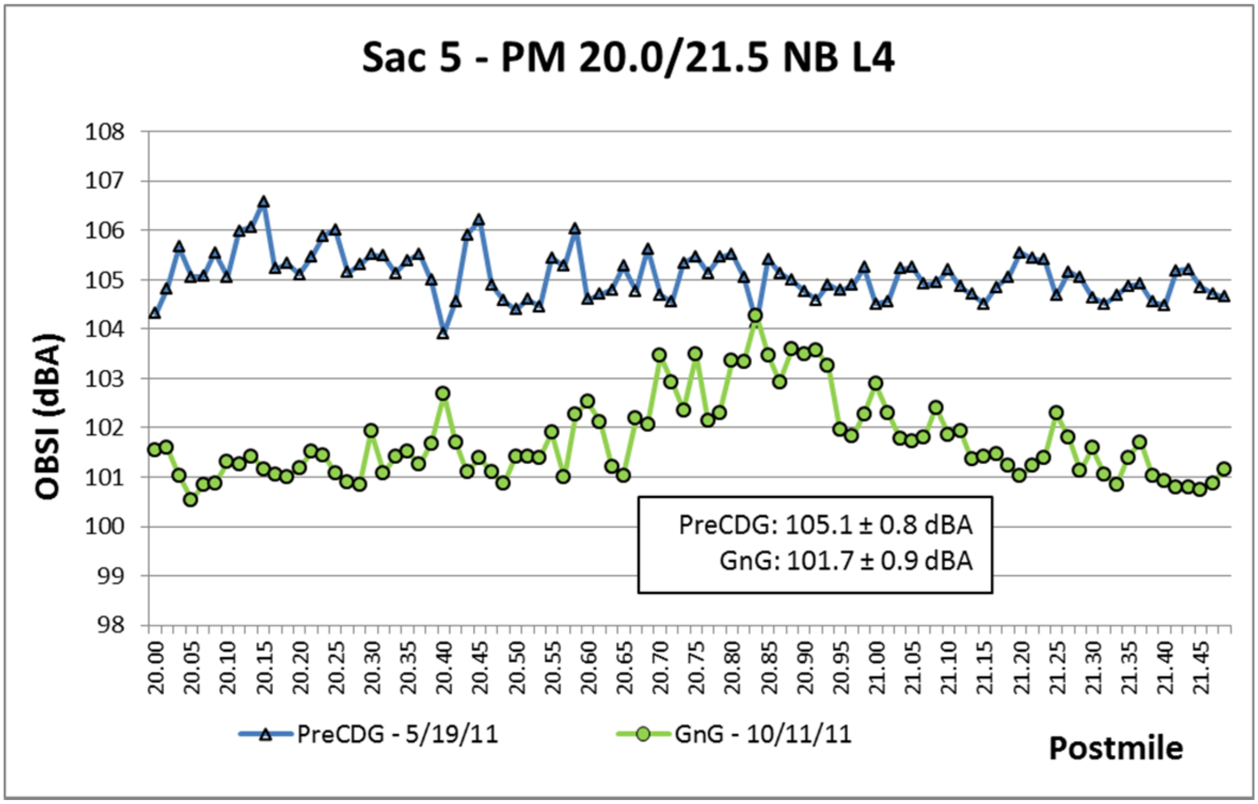


(a)

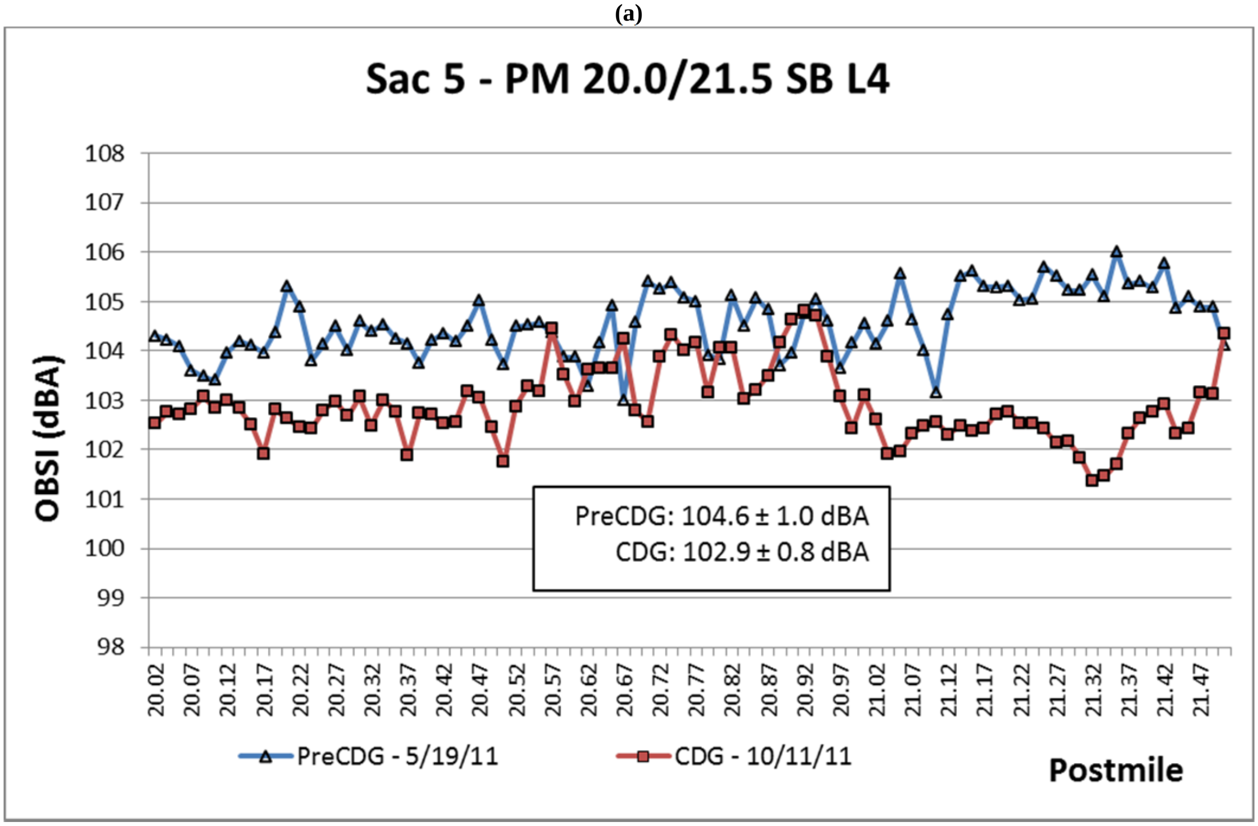


(b)

Figure A.1: Sacramento 5 – PM 20.0/21.5, Lane 1, (a) northbound and (b) southbound.



(a)



(b)

Figure A.2: Sacramento 5 – PM 20.0/21.5, Lane 4, (a) northbound and (b) southbound.

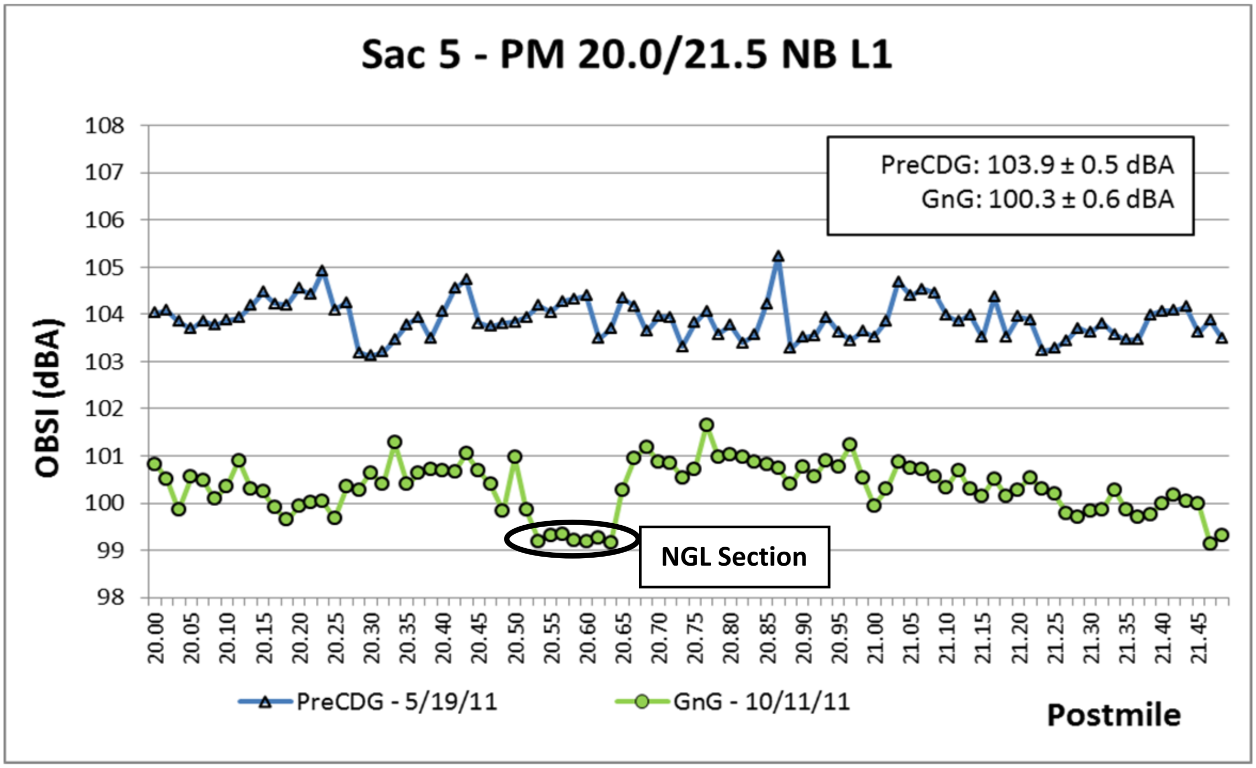


Figure A.3: OBSI profile for northbound Sacramento 5 – PM 20.0/2.15, Lane 1.

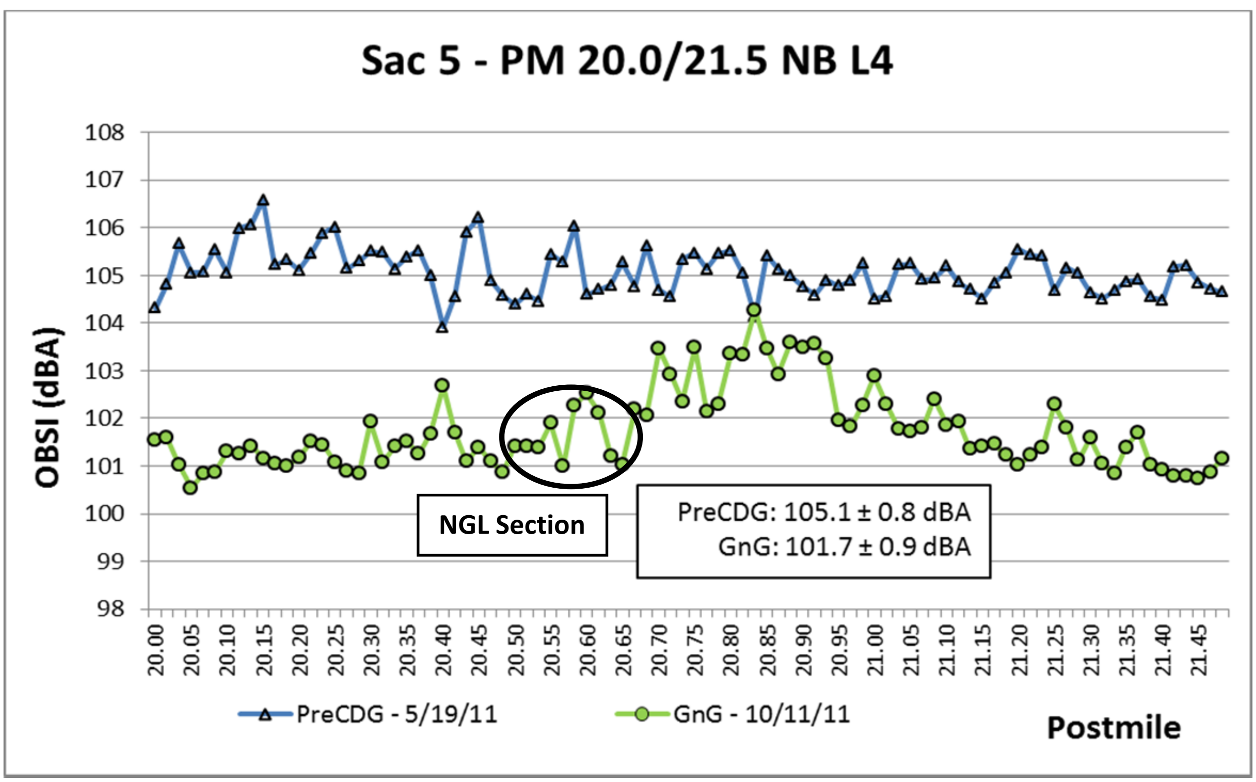
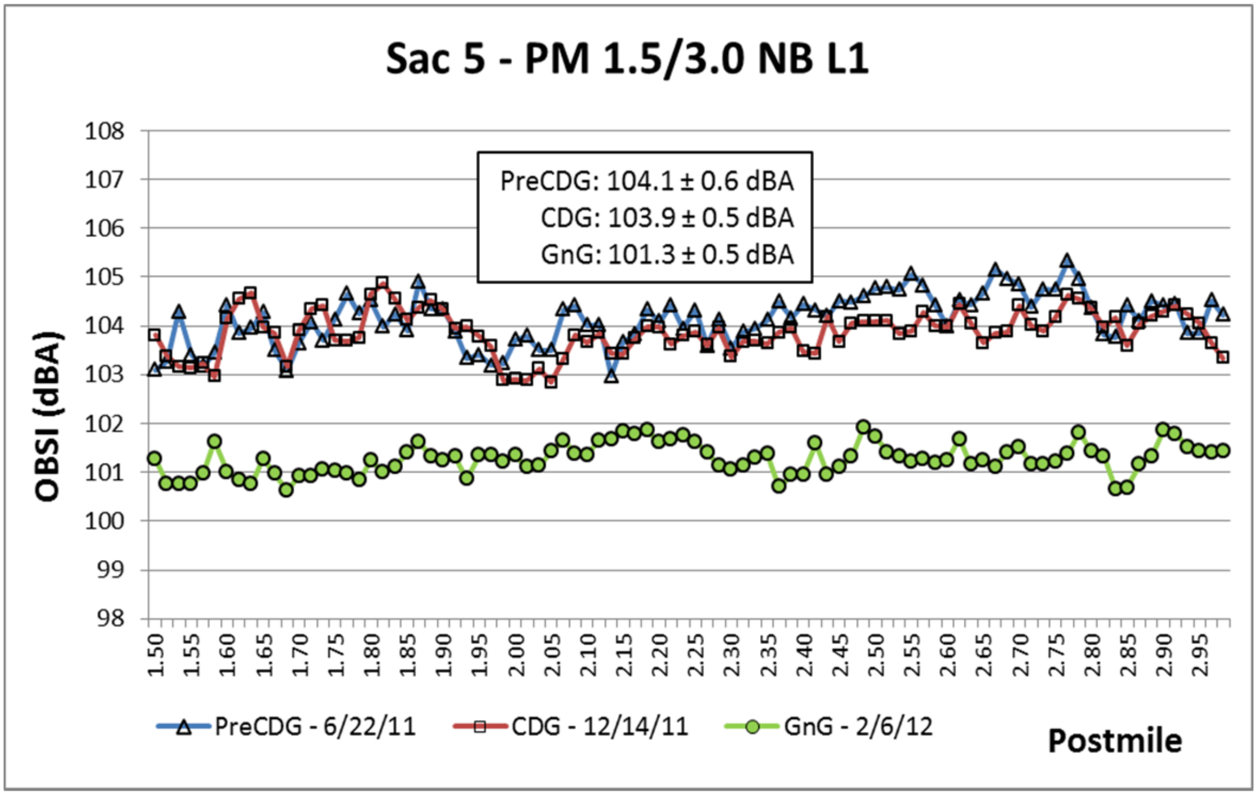


Figure A.4: OBSI profile for northbound Sacramento 5 – PM 20.0/2.15, Lane 4.



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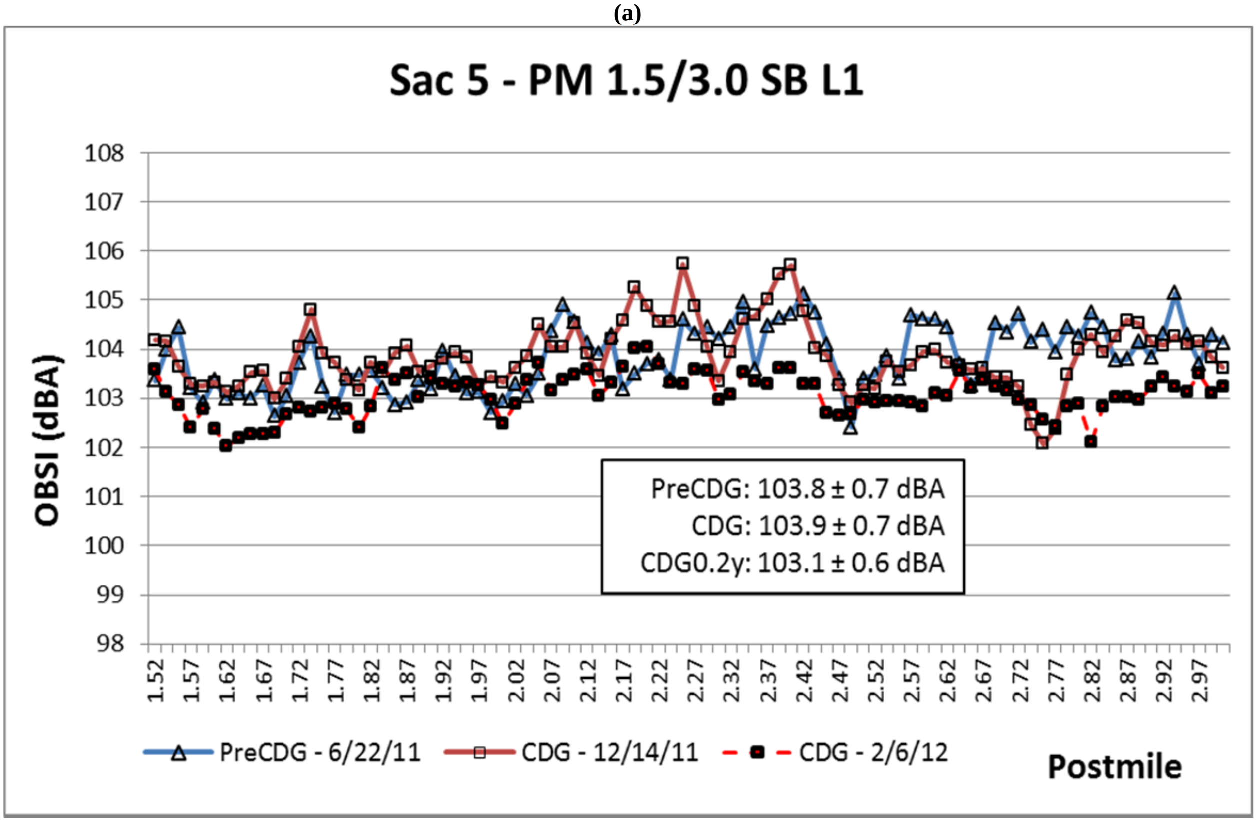
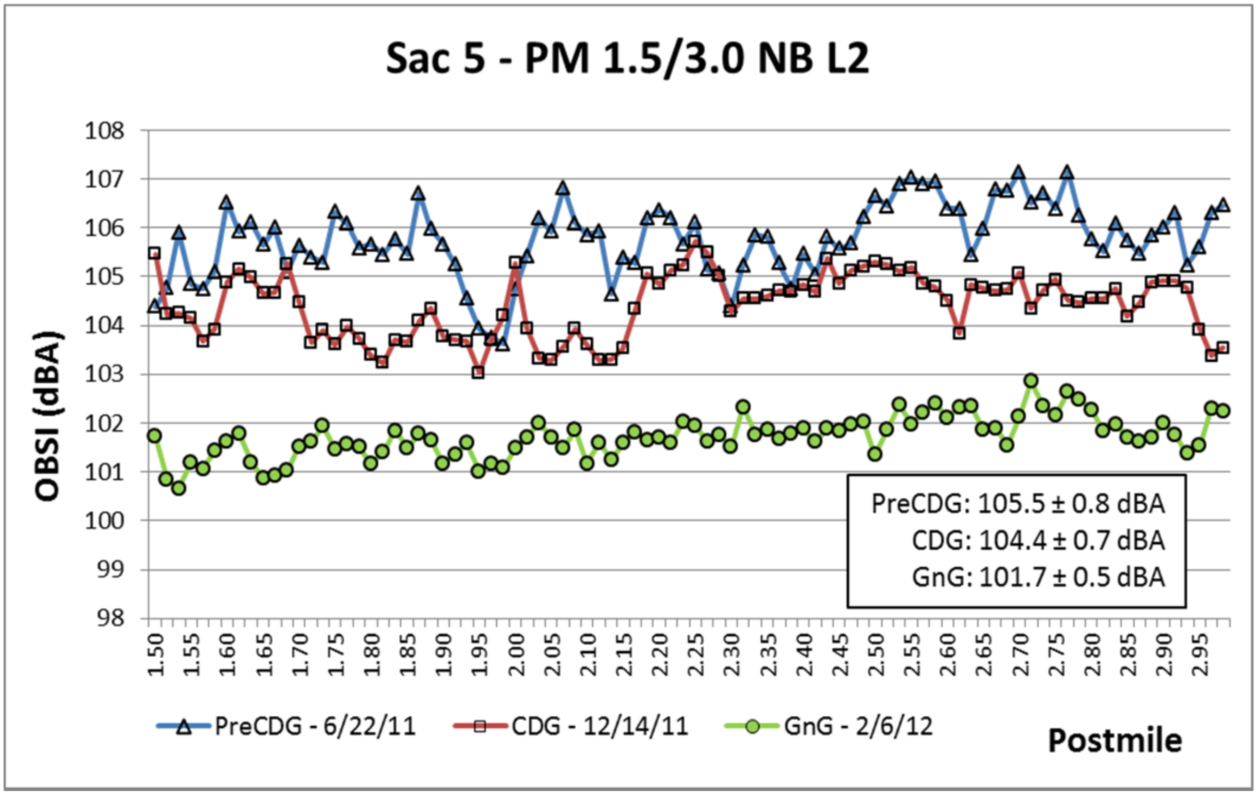
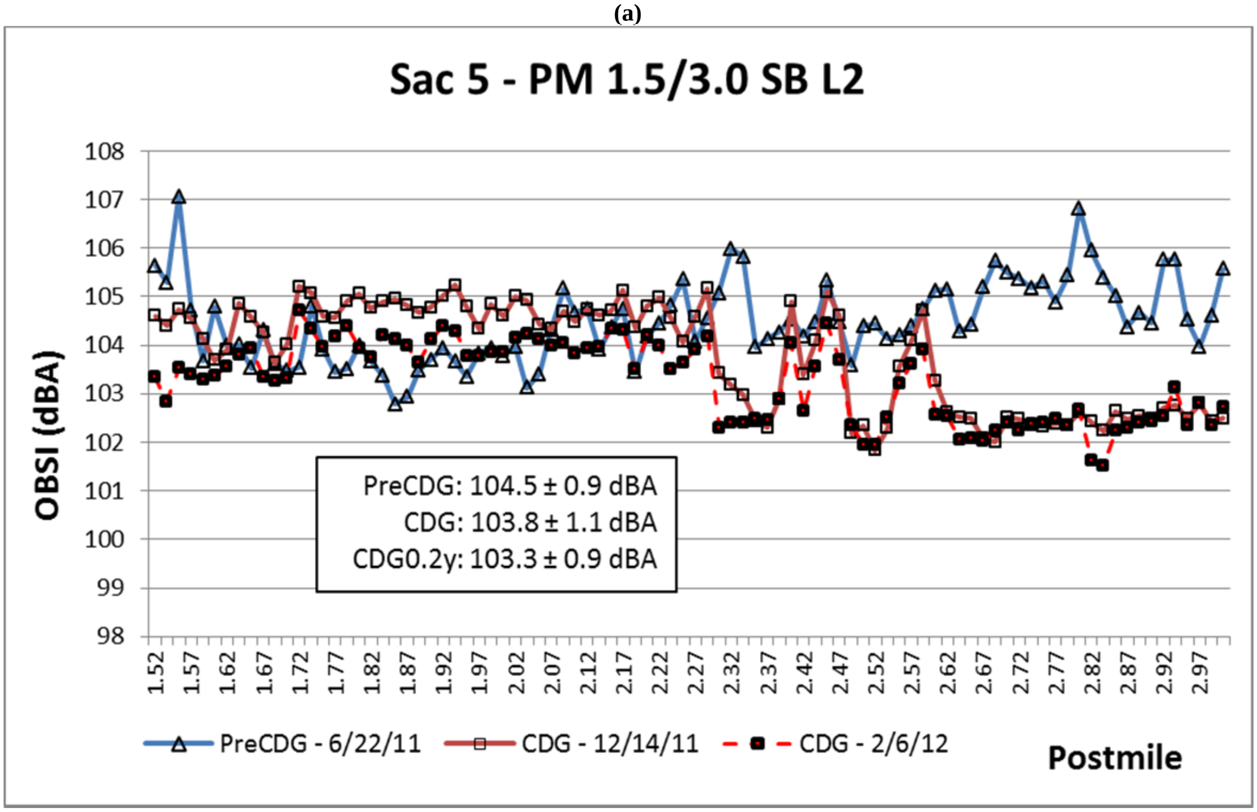


(b)

Figure A.5: Sacramento 5 – PM 1.5/3.0, Lane 1, (a) northbound and (b) southbound.

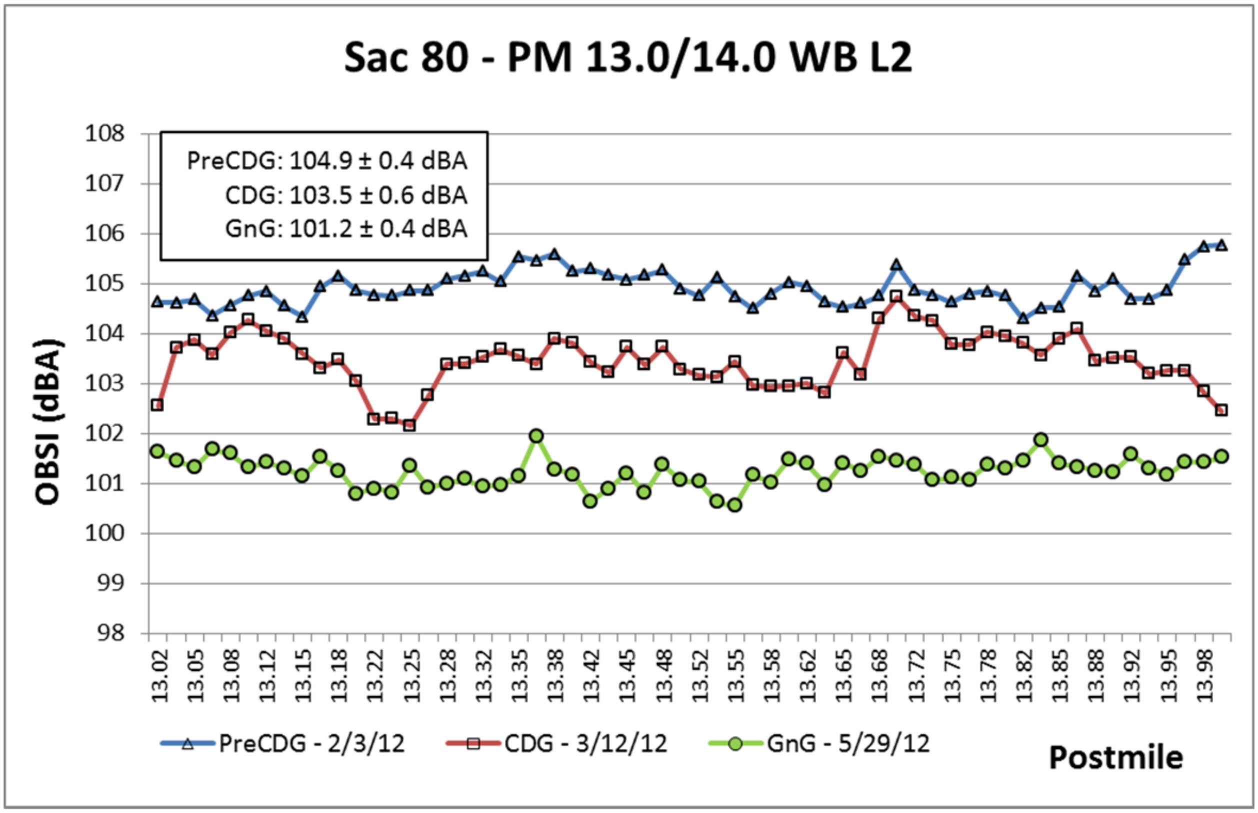


(a)

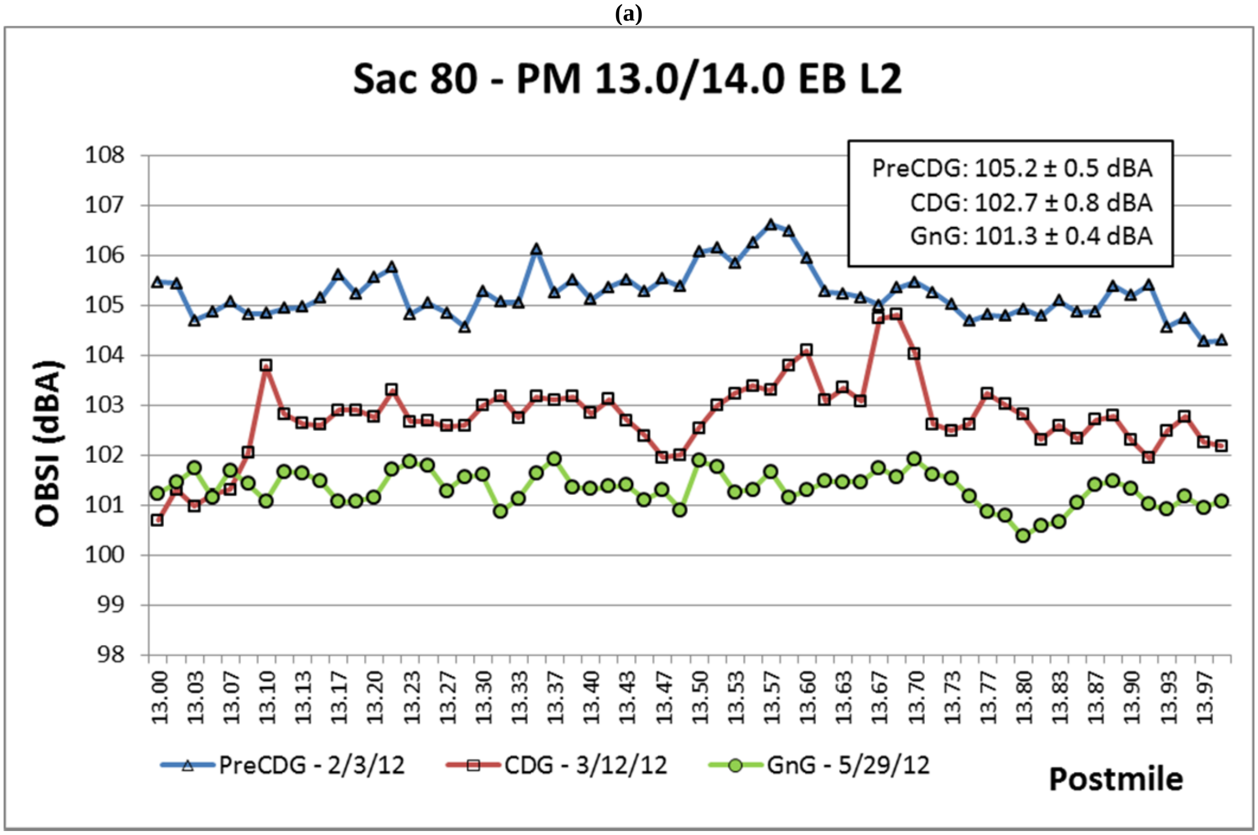


(b)

Figure A.6: Sacramento 5 – PM 1.5/3.0, Lane 2, (a) northbound and (b) southbound.

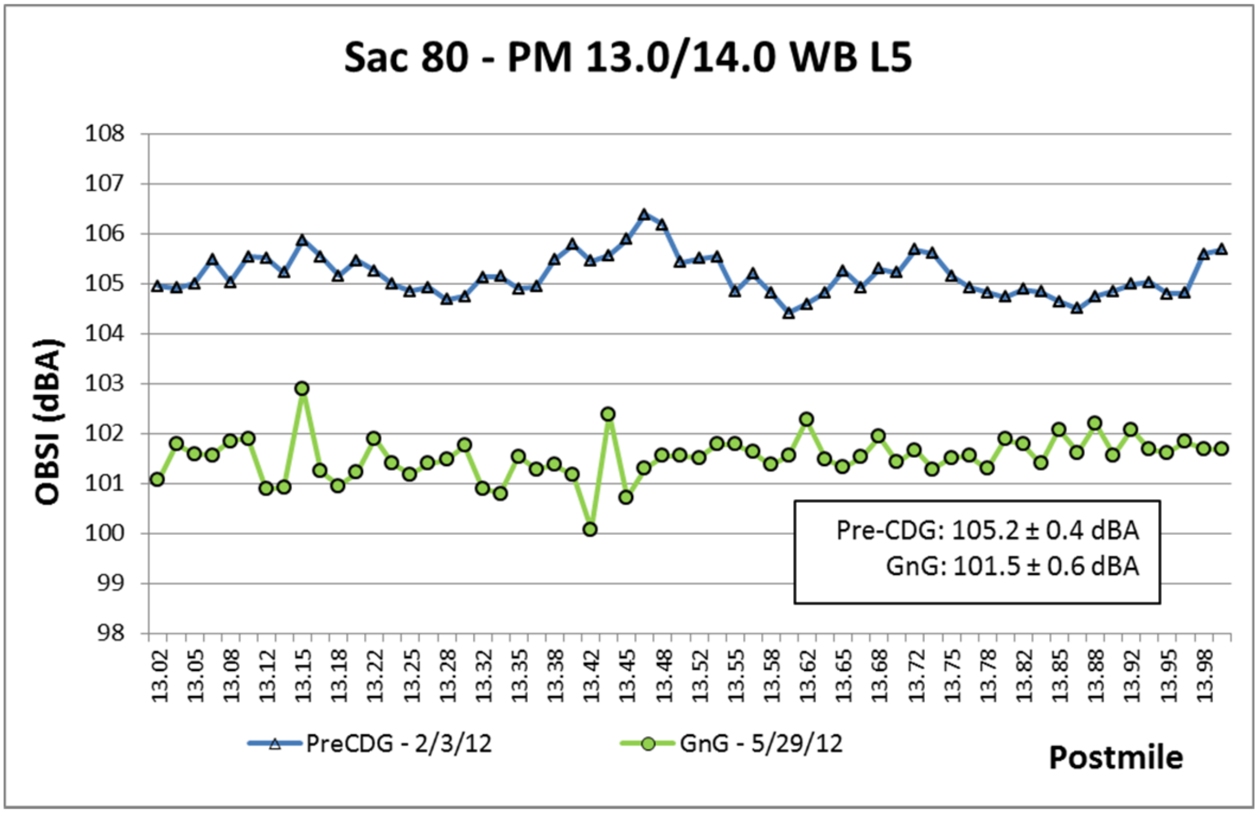


(a)

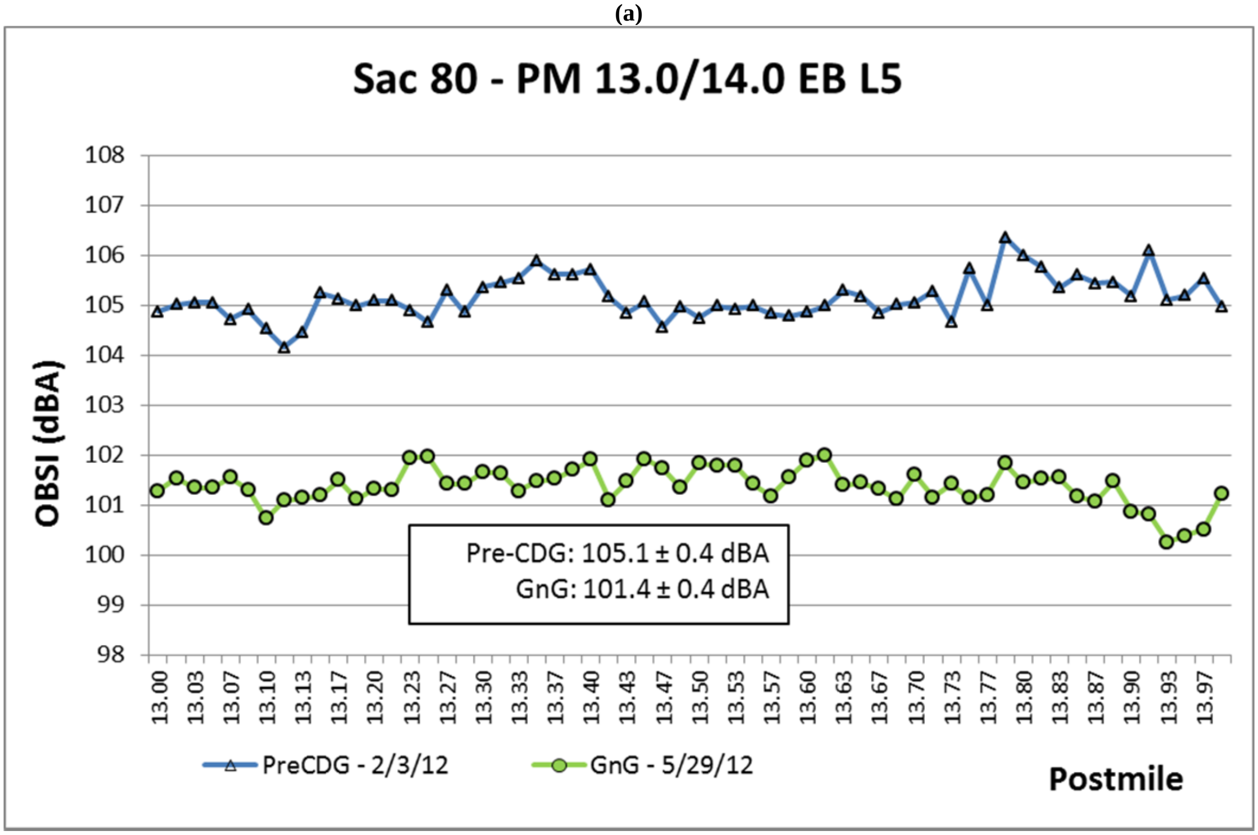


(b)

Figure A.7: Sacramento 80 – PM 13.0/14.0, Lane 2, (a) westbound and (b) eastbound.

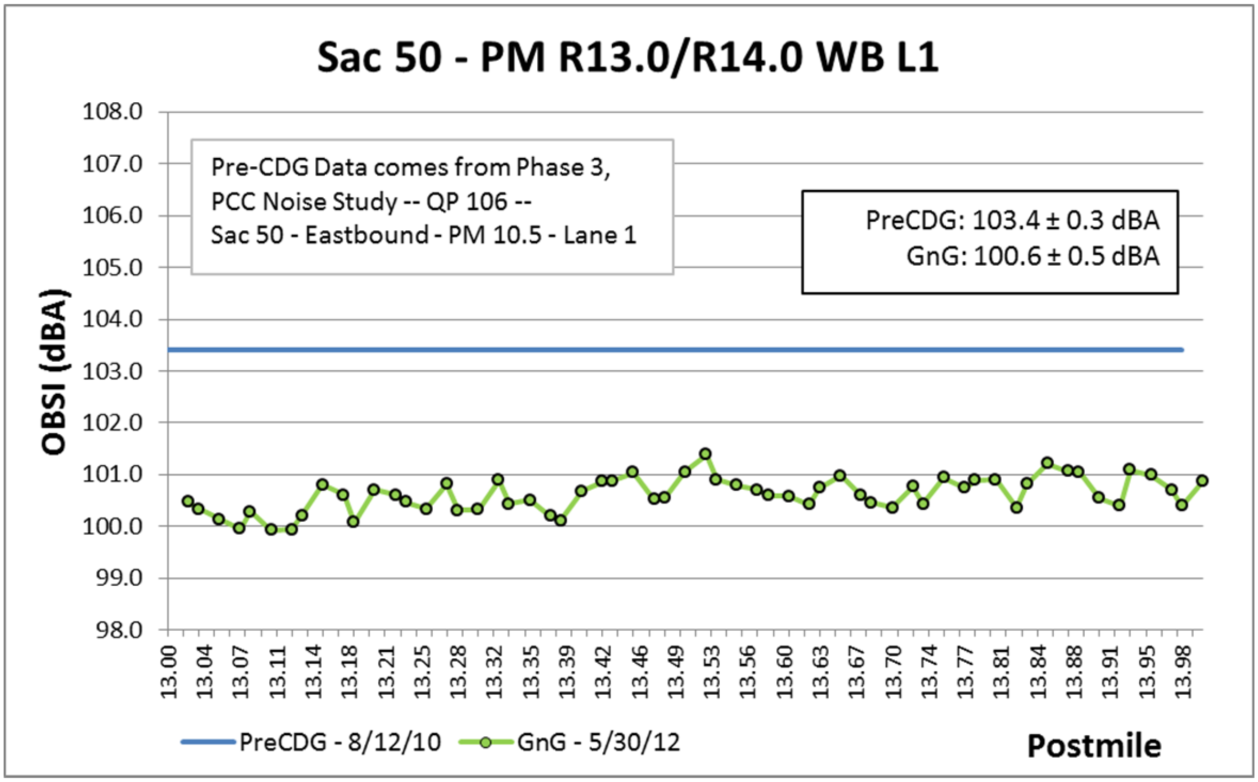


(a)

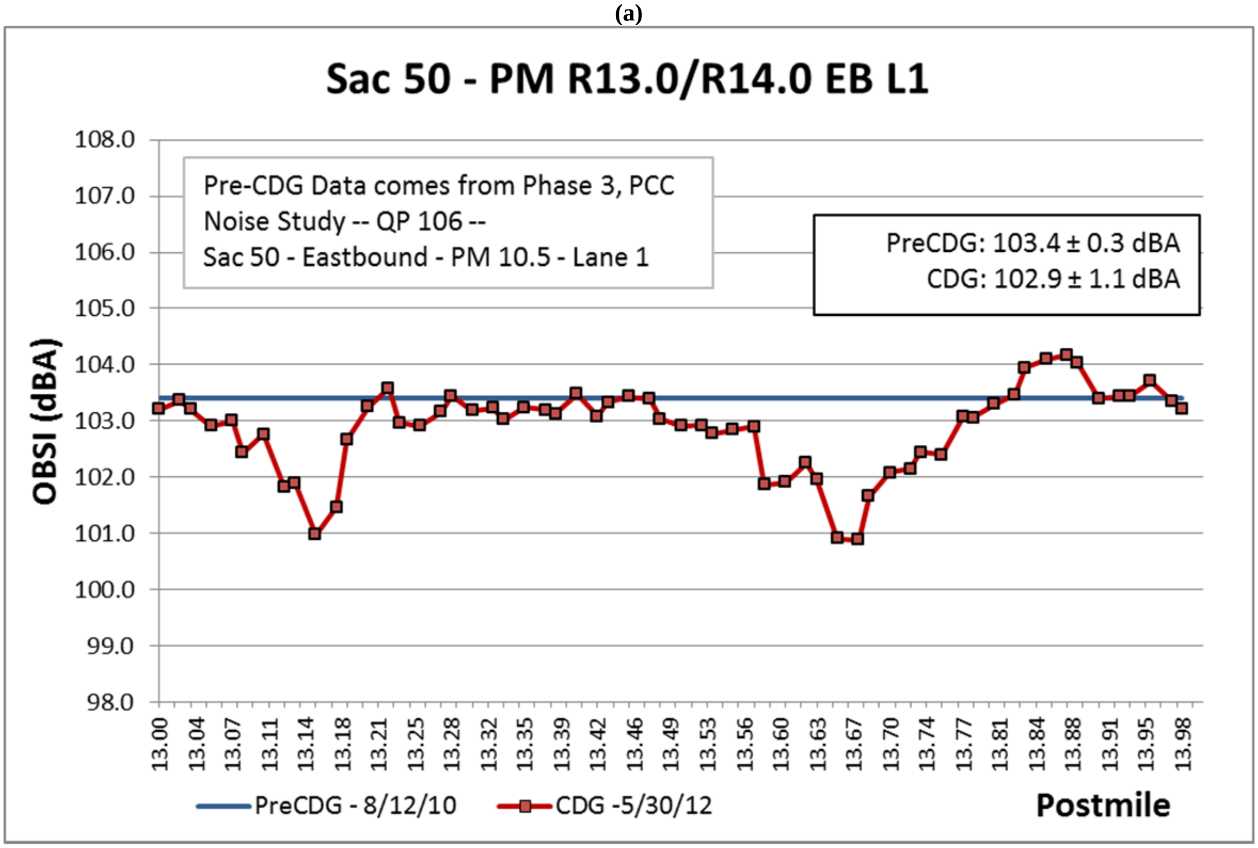


(b)

Figure A.8: Sacramento 80 – PM 13.0/14.0, Lane 5, (a) westbound and (b) eastbound.



(a)



(b)

Figure A.9: Sacramento 50 – PM R13.0/R14.0, Lane 1, (a) westbound and (b) eastbound.
(Note: the blue line indicates average pre-CDG OBSI level for the section collected in previous project.)

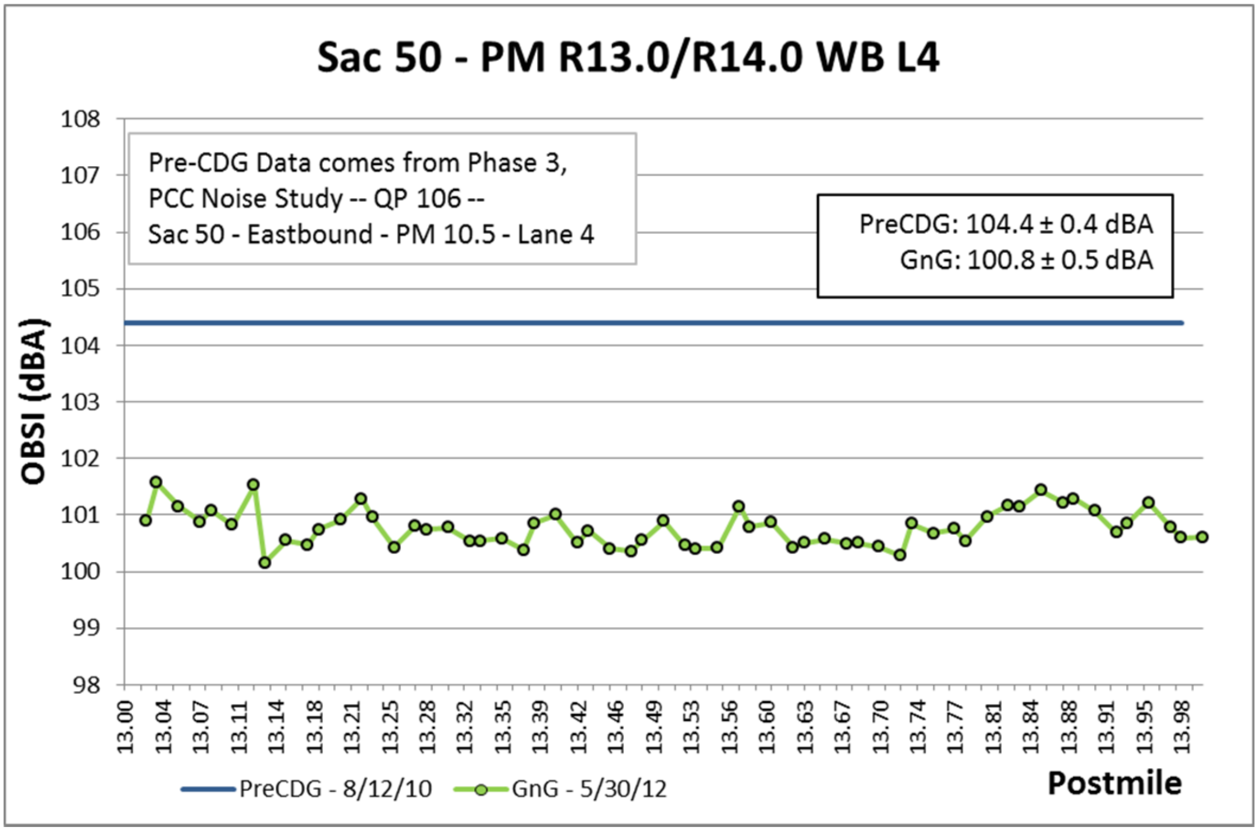
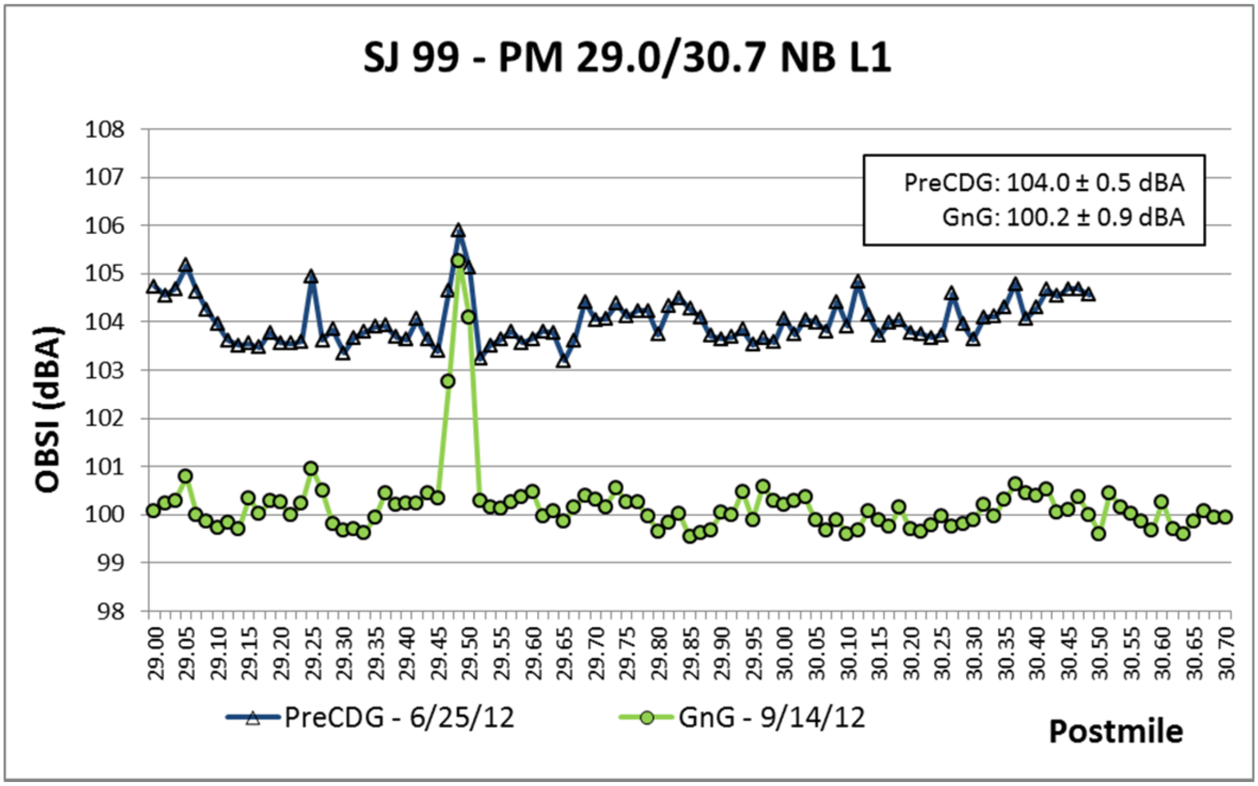
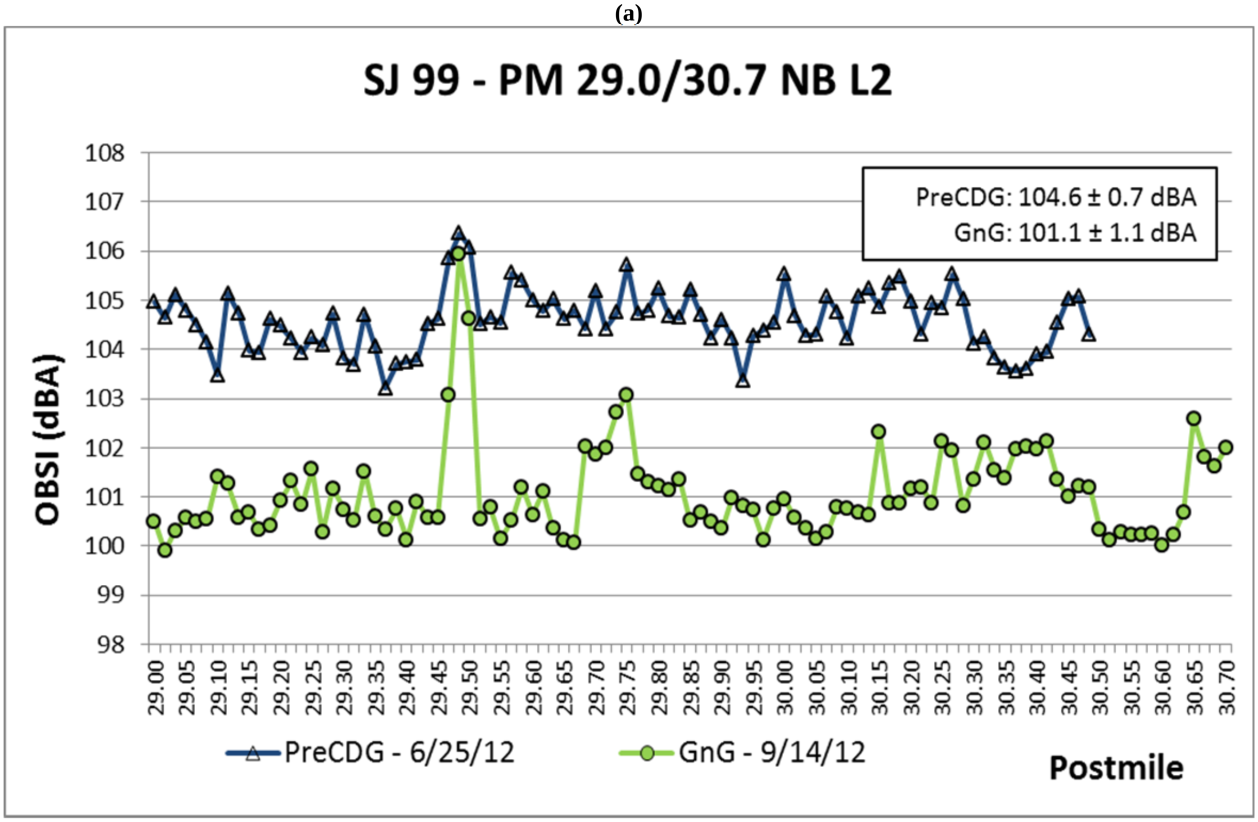


Figure A.10:Sacramento 50 – PM R13.0/R14.0, Lane 4, westbound.
(Note: the blue line indicates average pre-CDG OBSI level for the section collected in previous project.)

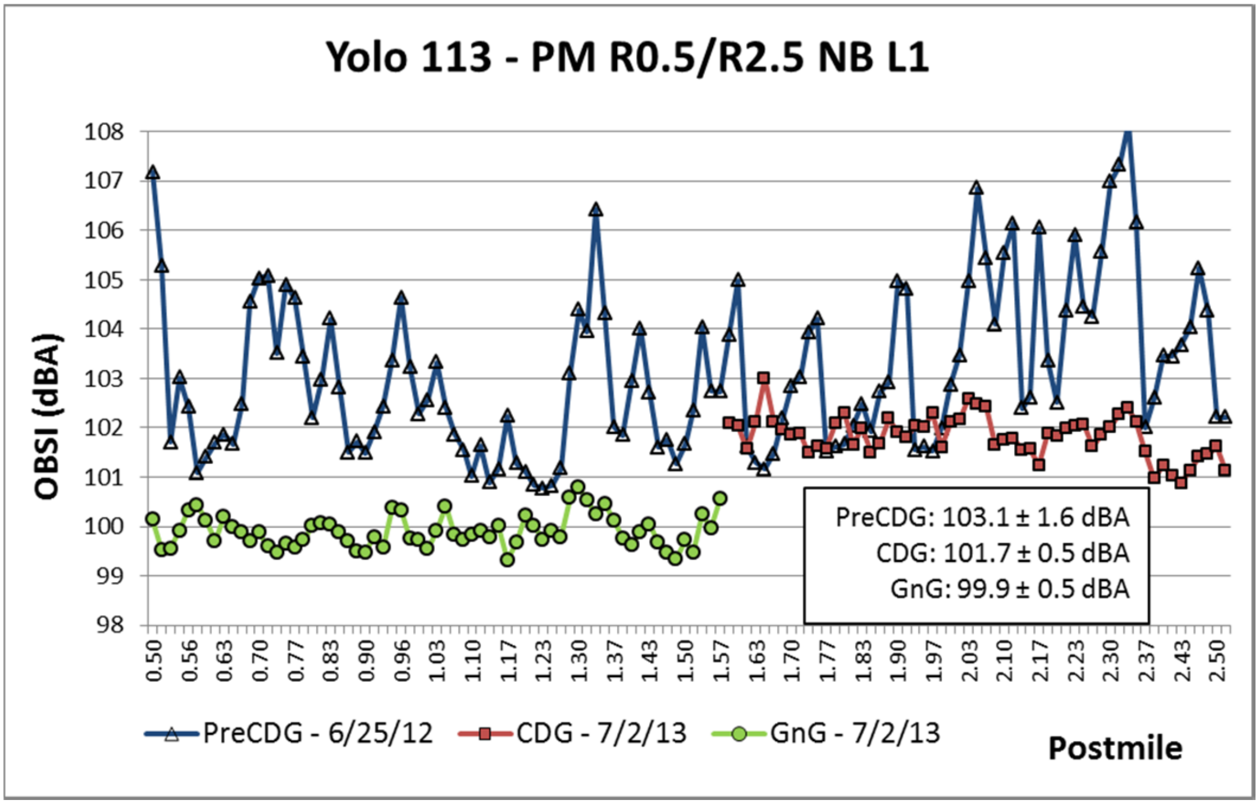


(a)



(b)

Figure A.11: San Joaquin 99 – PM 29.0/30.7, northbound, Lanes 1 (a) and 2 (b). (Note: San Joaquin 99 – PM 29.0/30.7, southbound, has an asphalt concrete surface and could not be used for comparison.)



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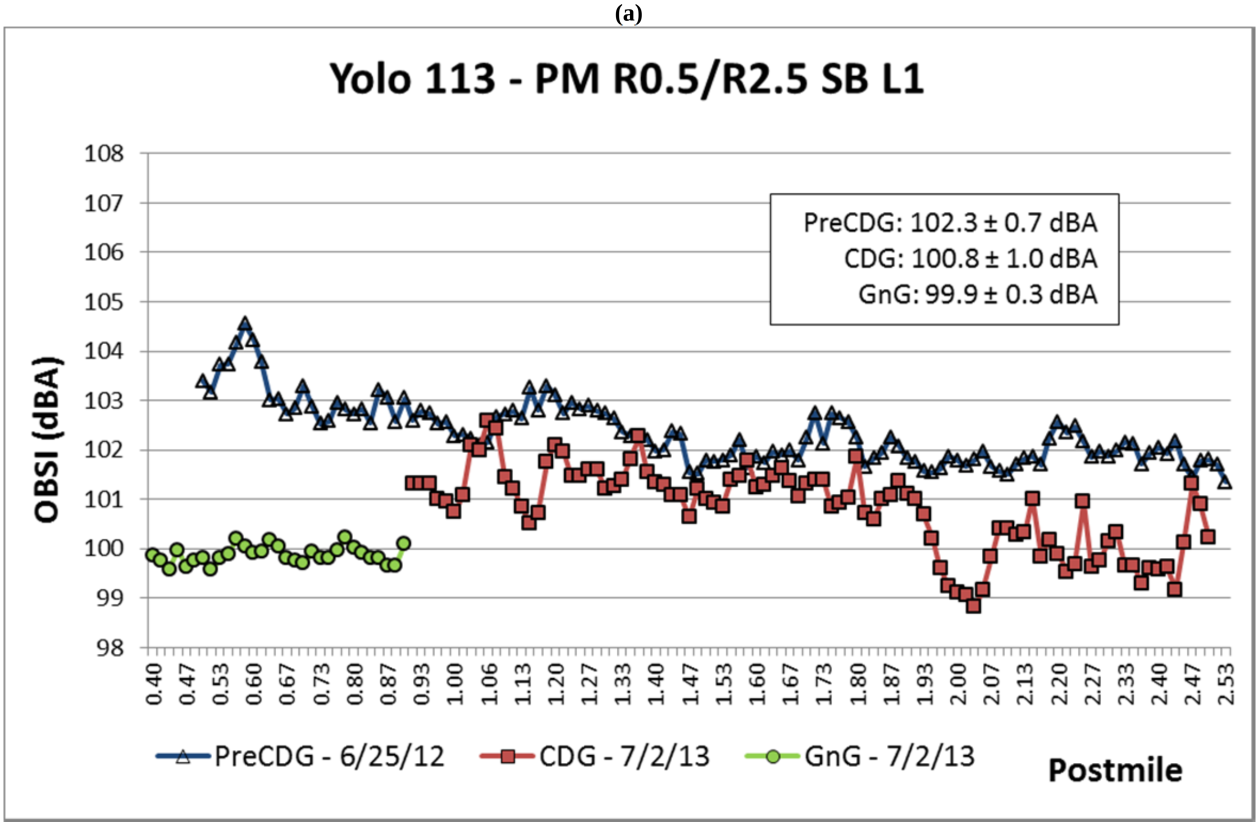
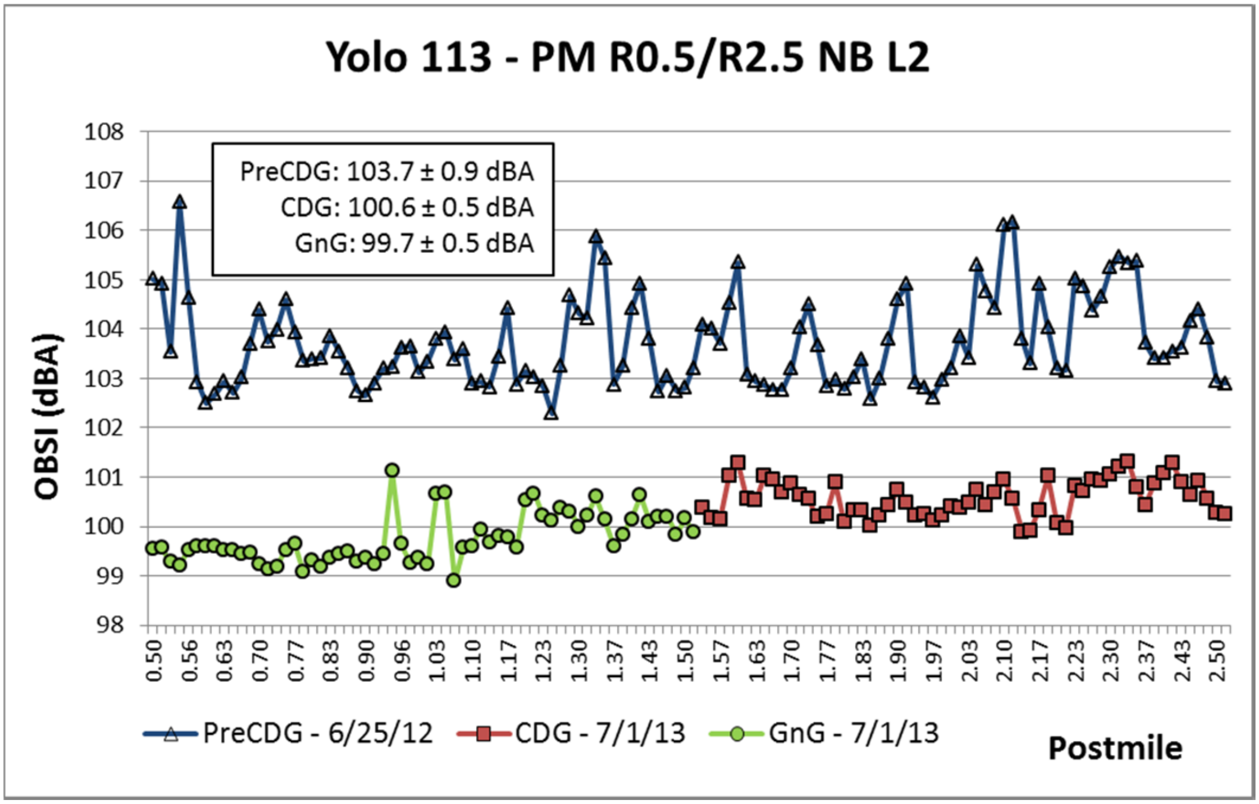


(b)

Figure A.12: Yolo 113 – PM R0.5/R2.5, Lane 1, (a) northbound and (b) southbound.



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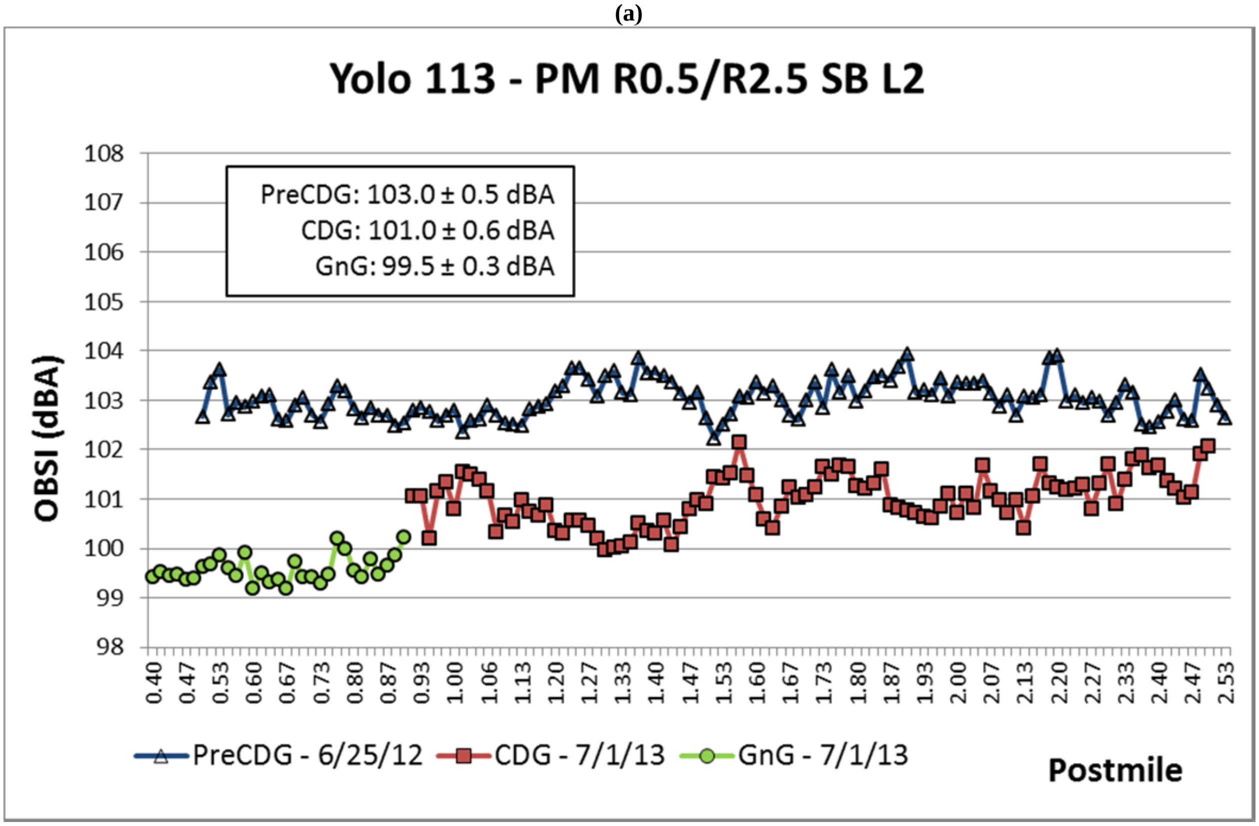

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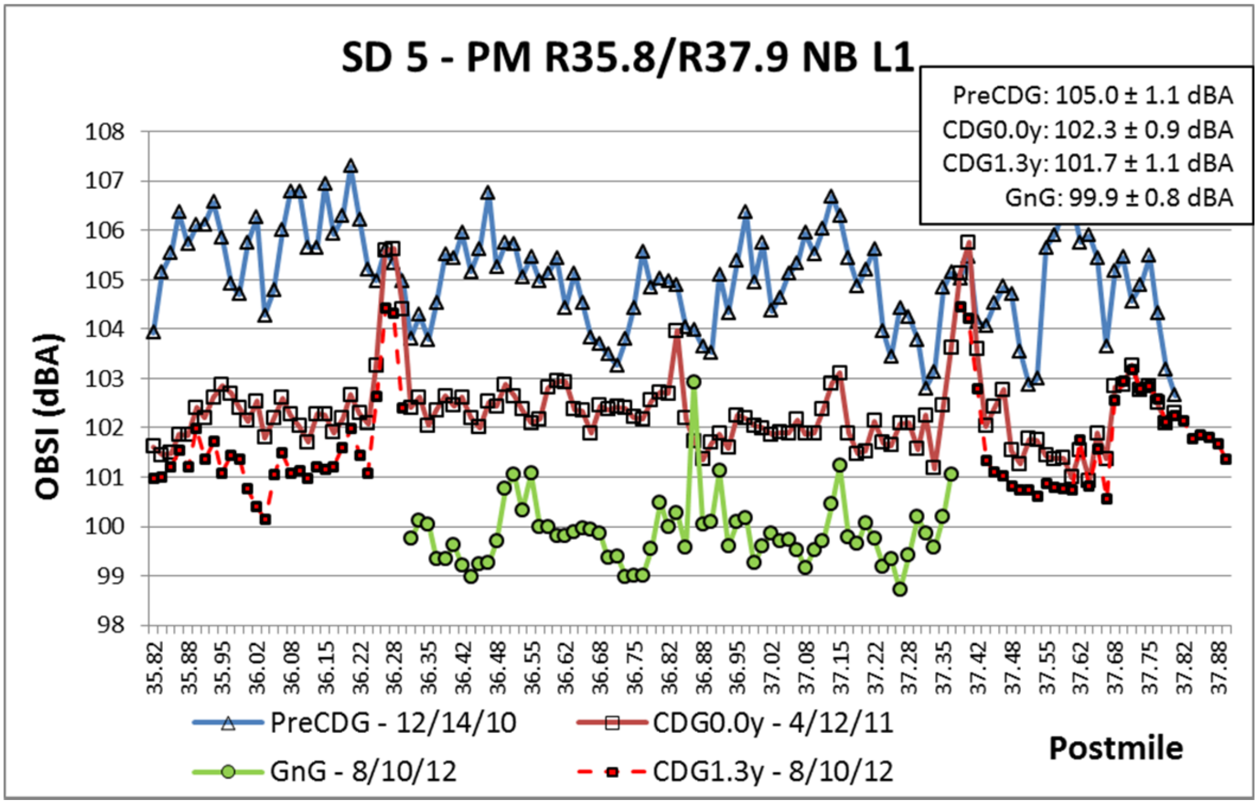
Figure A.13: Yolo 113 – PM R0.5/R2.5, Lane 2, (a) northbound and (b) southbound.



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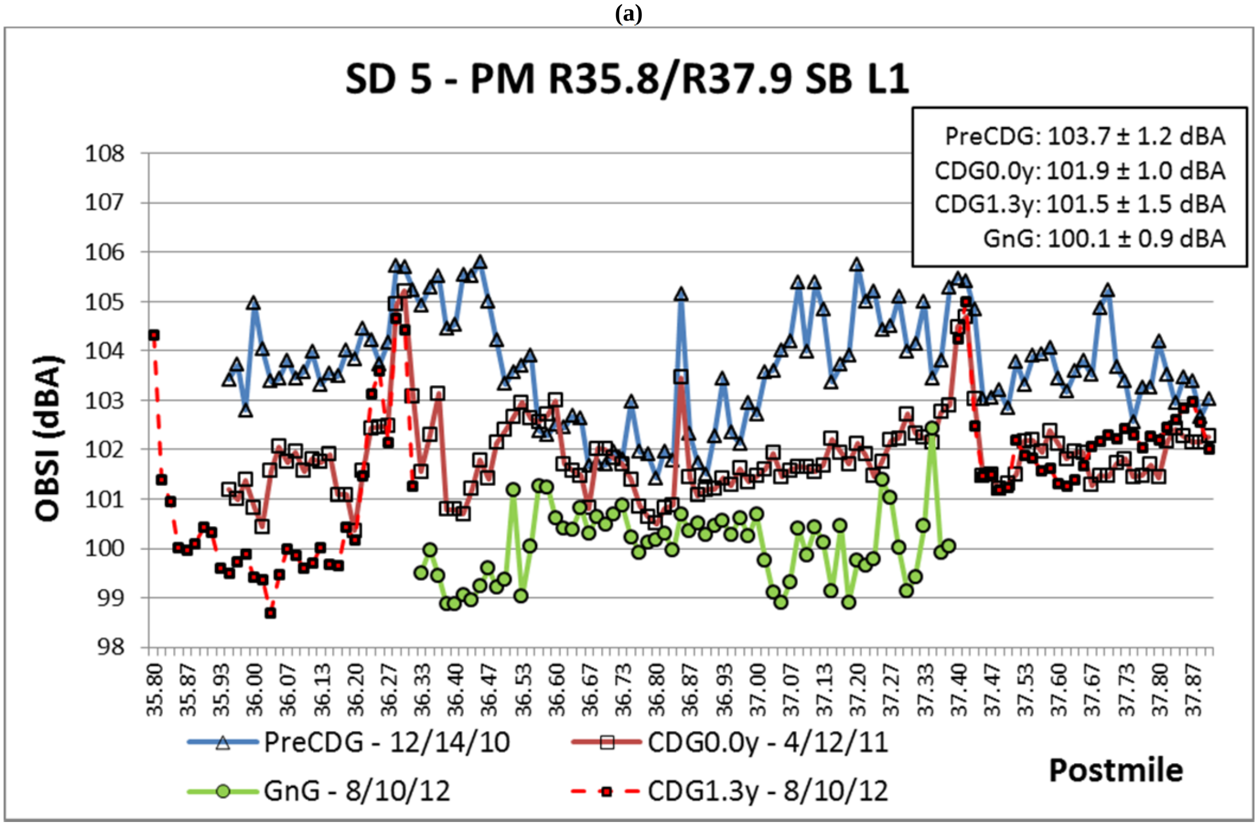
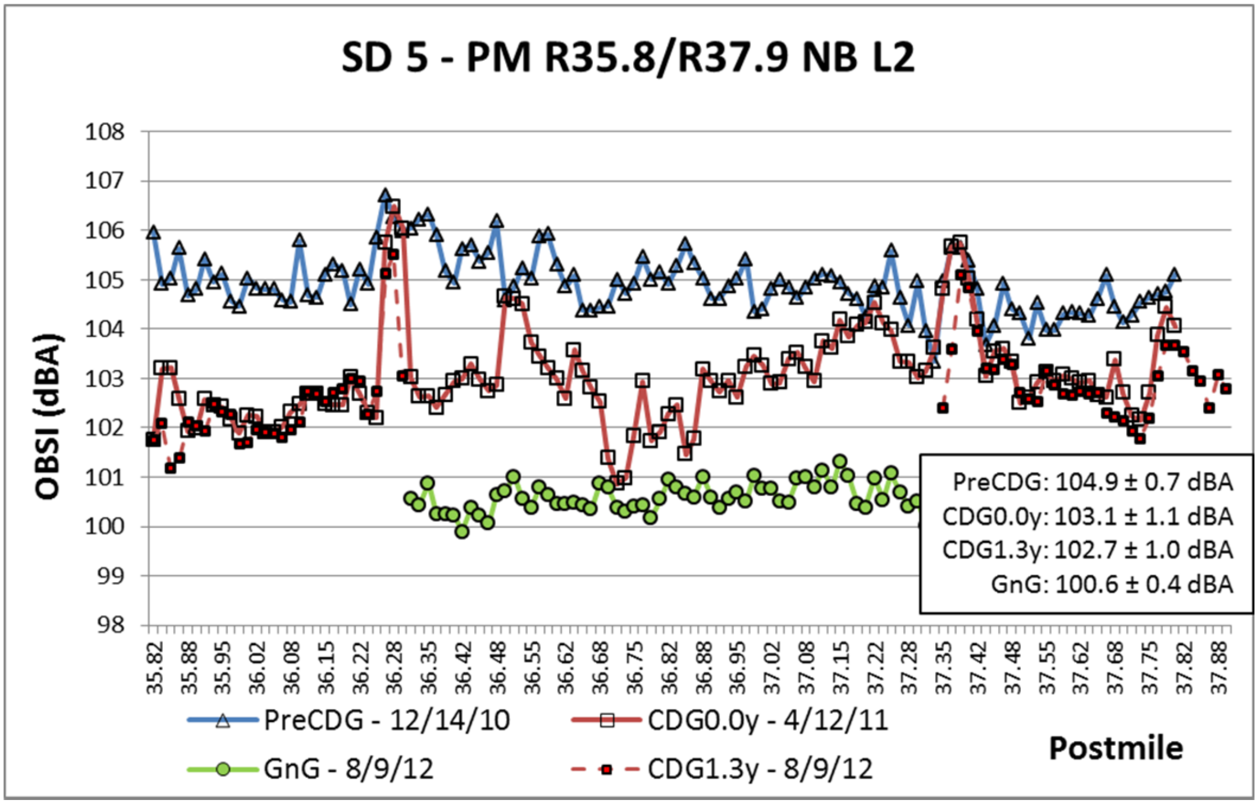
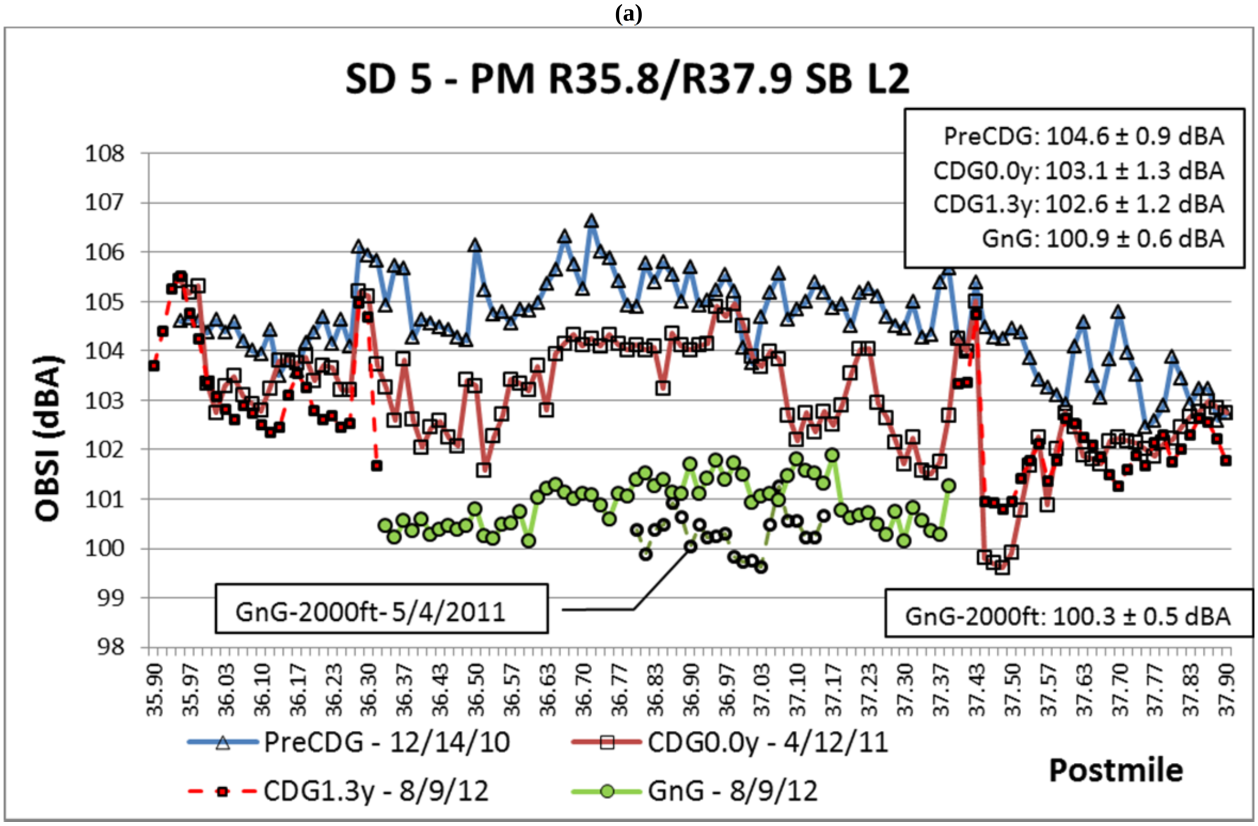


(b)

Figure A.14: San Diego 5 – PM R35.8/R37.9, Lane 1, (a) northbound and (b) southbound.

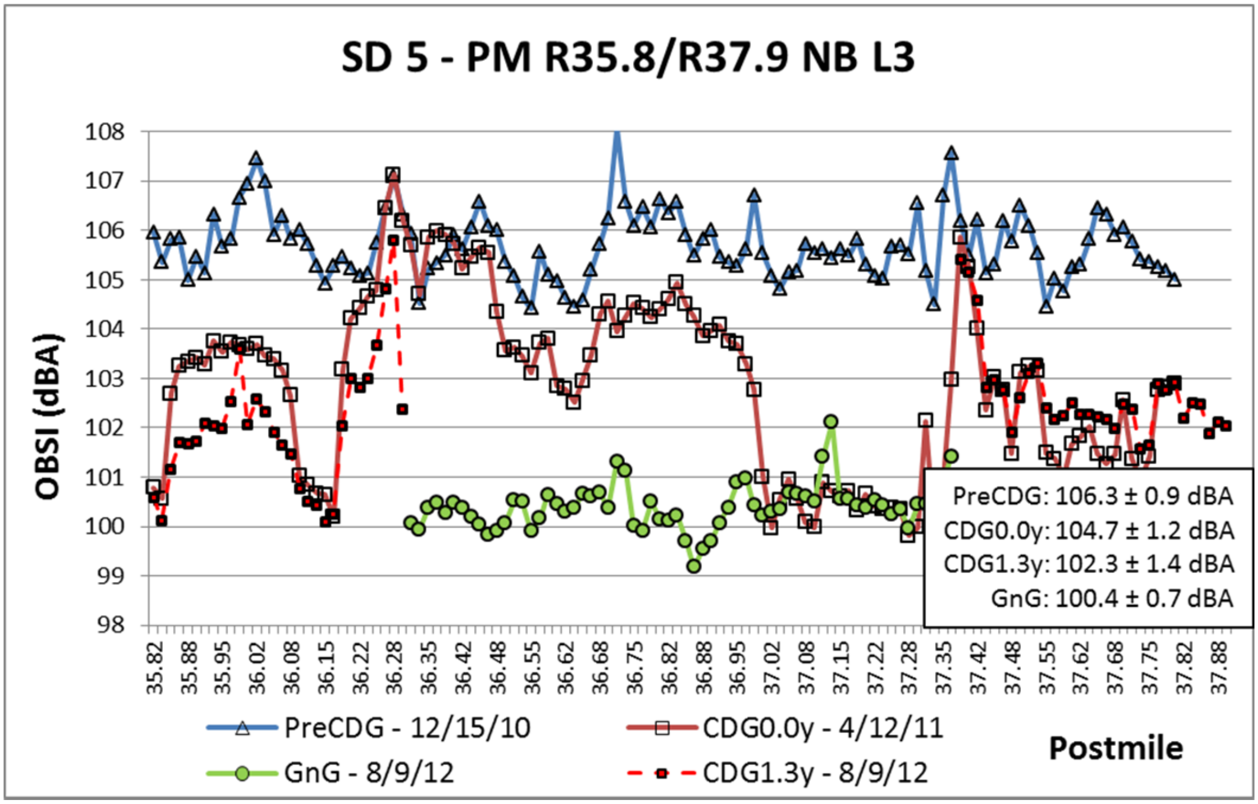


(a)



(b)

Figure A.15: San Diego 5 – PM R35.8/R37.9, Lane 2, (a) northbound and (b) southbound.



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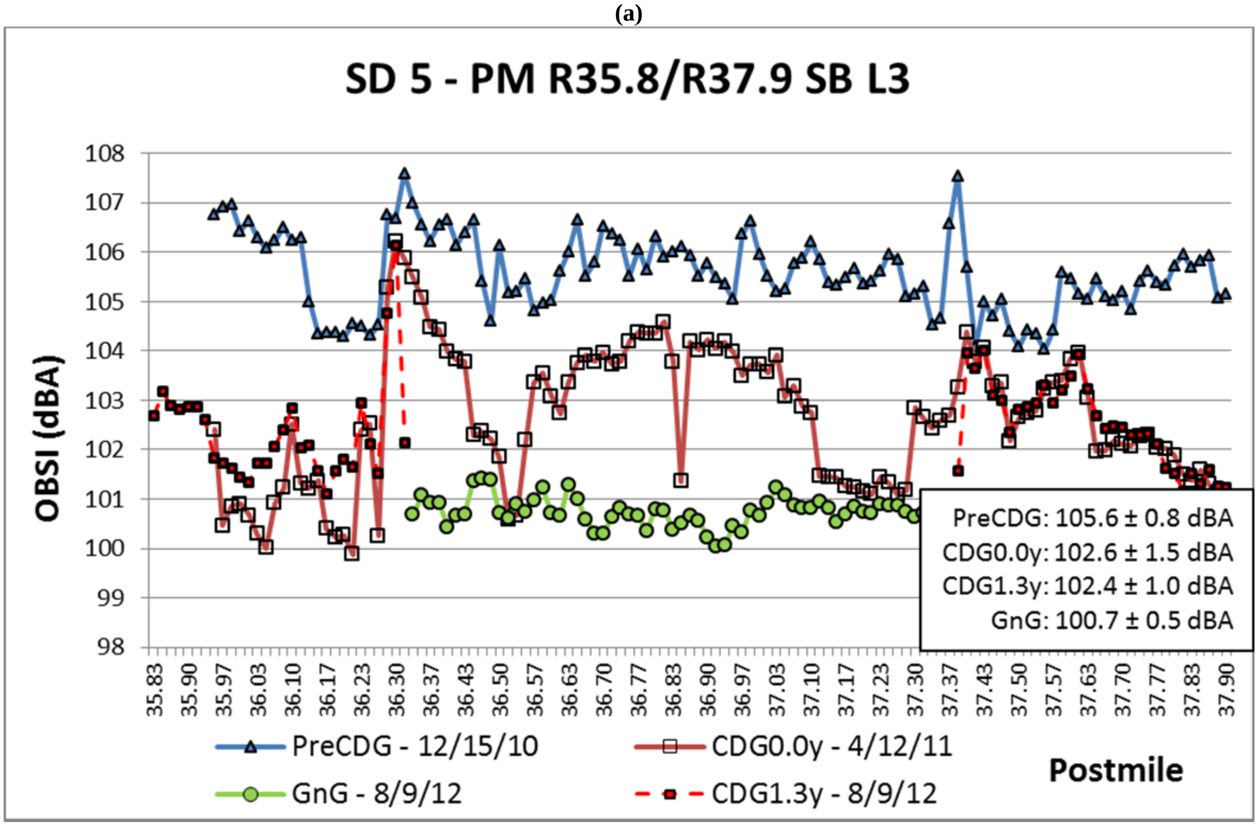
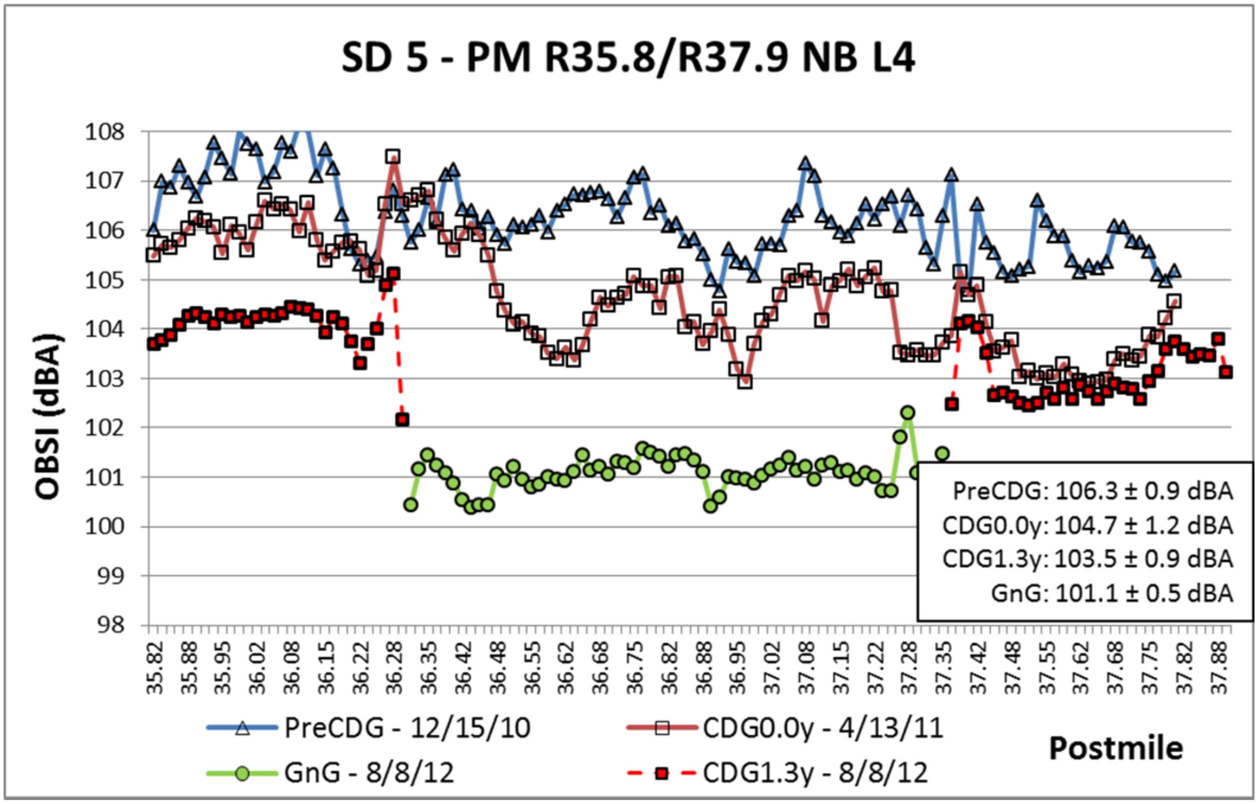


(b)

Figure A.16: San Diego 5 – PM R35.8/R37.9, Lane 3, (a) northbound and (b) southbound.



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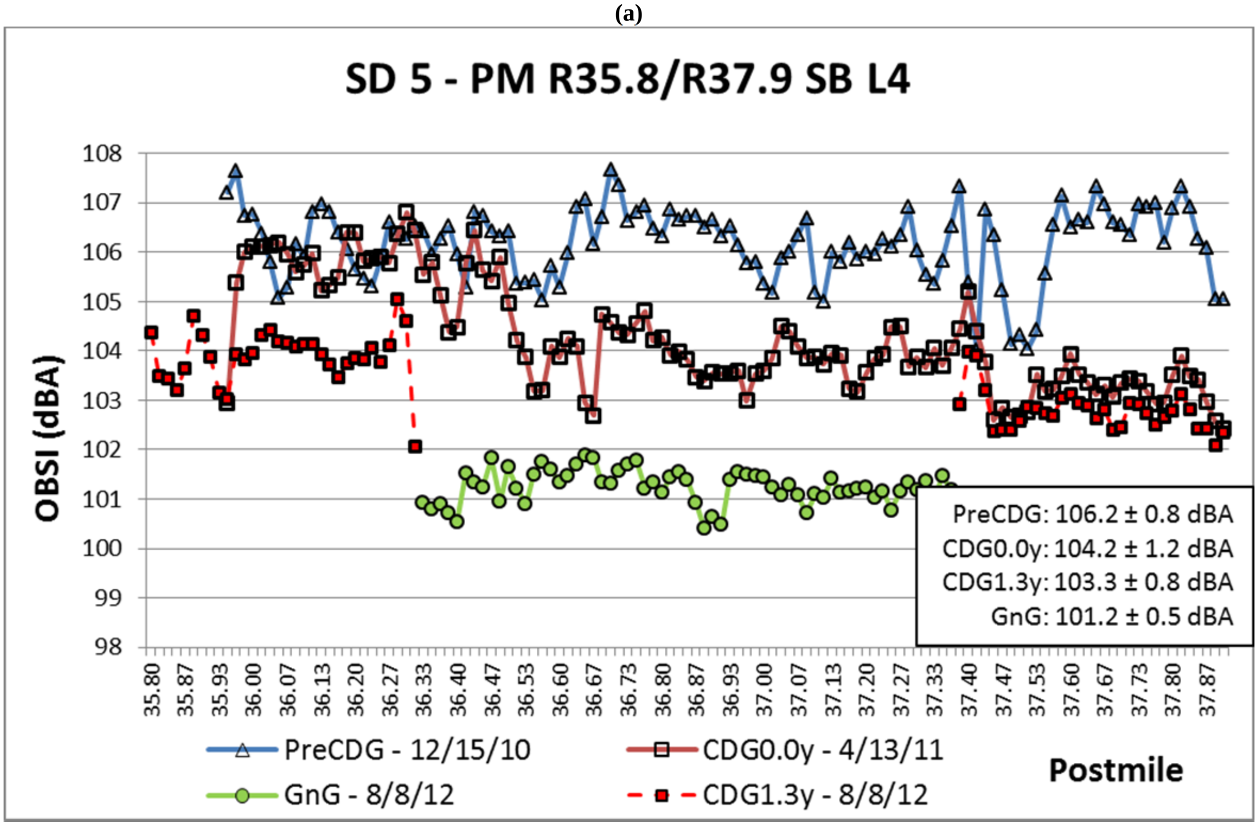
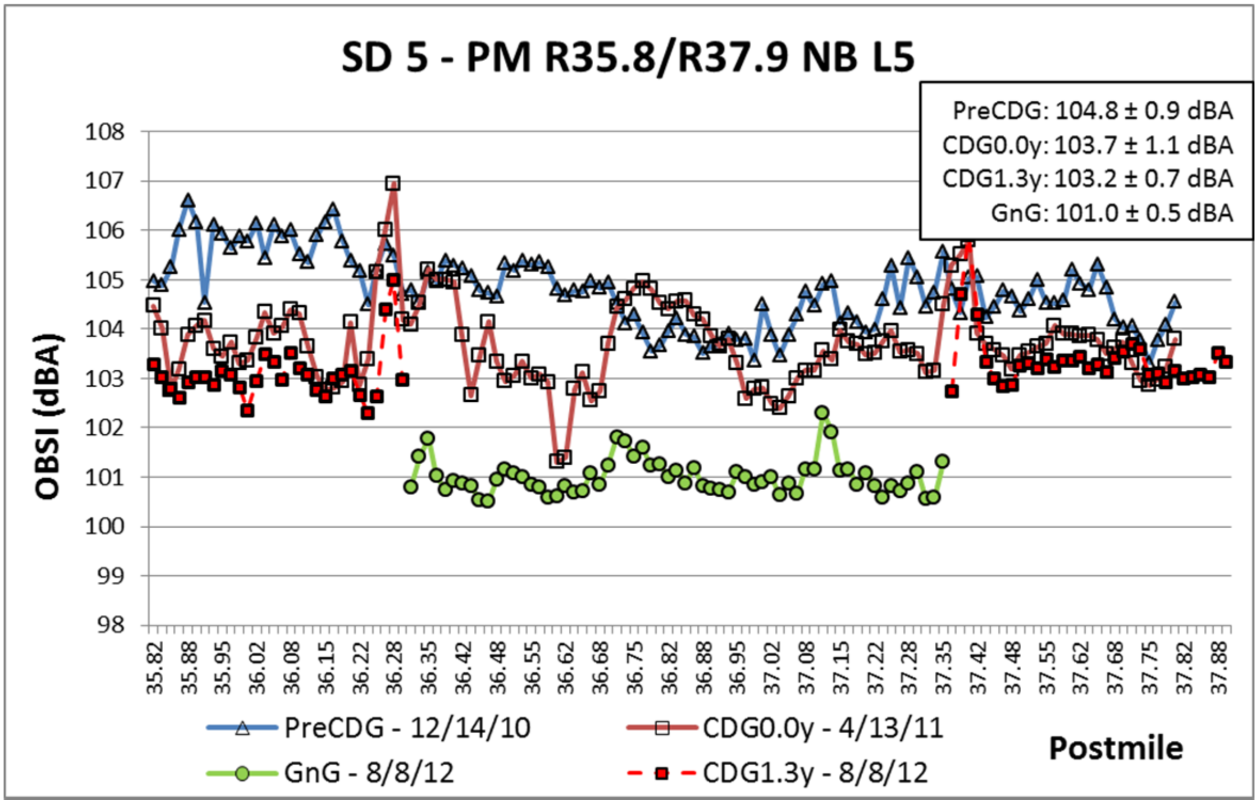
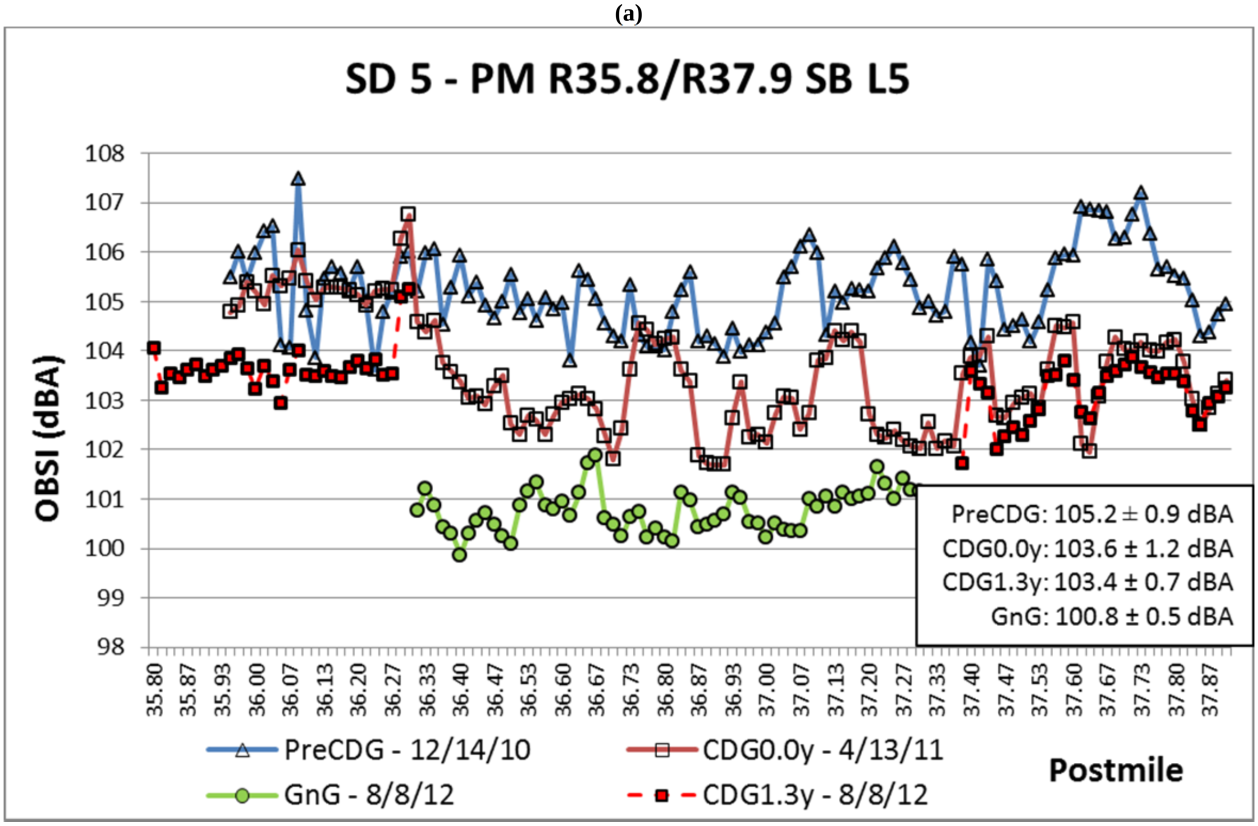


(b)

Figure A.17: San Diego 5 – PM R35.8/R37.9, Lane 4, (a) northbound and (b) southbound.



(a)



(b)

Figure A.18: San Diego 5 – PM R35.8/R37.9, Lane 5, (a) northbound and (b) southbound.

APPENDIX B: OBSI FREQUENCY SPECTRA PLOTS

The OBSI frequency spectra in one-third octave bands are presented in the following figures for all the pilot projects. The figures present the lane-by-lane OBSI frequency spectra for the data averaged for each section presented in Section 4.2. Direction and lane number are indicated in the figures' headers. The profiles are paired by direction for each lane. For example, the Sac 5 – PM 20.0/21.5 charts for northbound Lane 1 and southbound Lane 1 are paired in Figure B.1, as are northbound and southbound Lane 4 in Figure B.2.

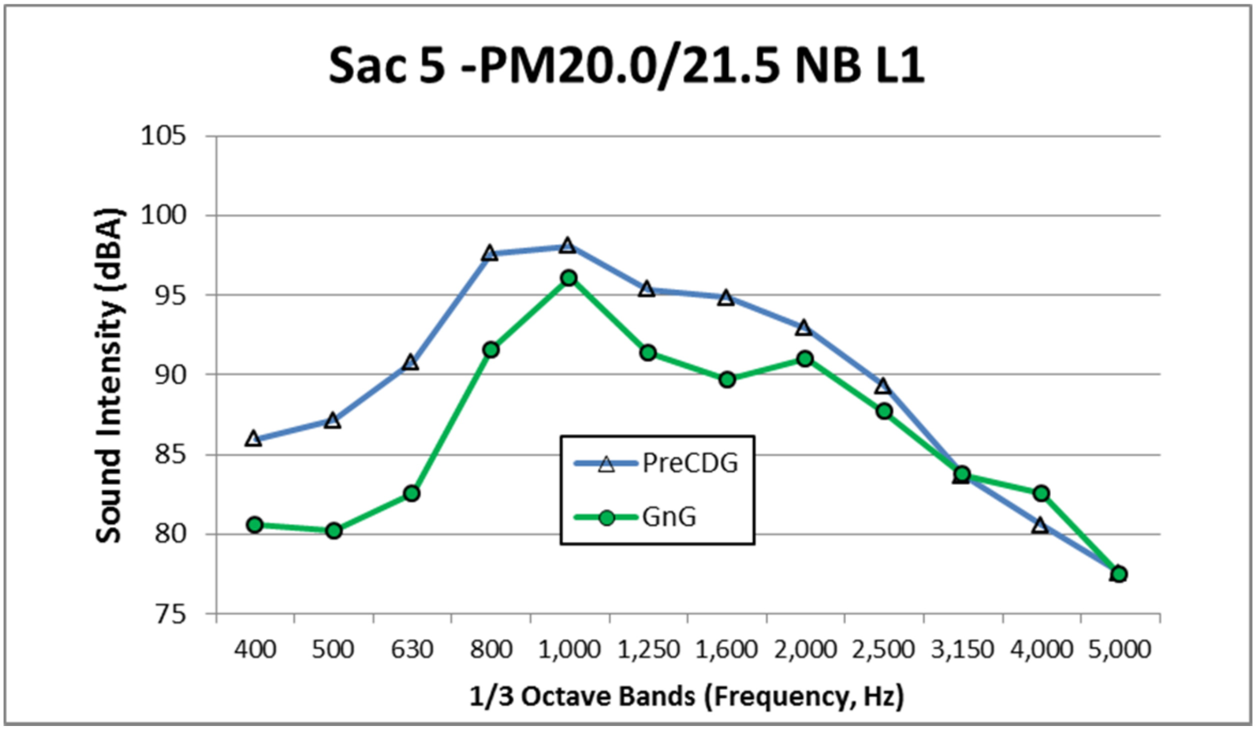
The following markers and notation are used in all plots:

- Pre-CDG: Blue line and triangle marker
- CDG: Brown line and square marker
- CDGX.Xy: Red dashed line and square marker
- GnG: Green line and circle marker
- If a marker is filled with a color, it represents the current surface texture; if a marker is not filled with a color, it represents a surface texture that has been replaced.
- The X.Xy represents the number of years since data were first collected. For instance, CDG0.3y represents the CDG surface texture 0.3 years after the first CDG measurement.

Individual lane graphs use the following abbreviations.

- PM = Post mile
- L = Lane (e.g., L1 = Lane 1)
- NB = Northbound
- SB = Southbound
- WB = Westbound
- EB = Eastbound

Note: The OBSI spectra for Sacramento 50 eastbound Lane 4 is not presented because the CDG data were not collected.



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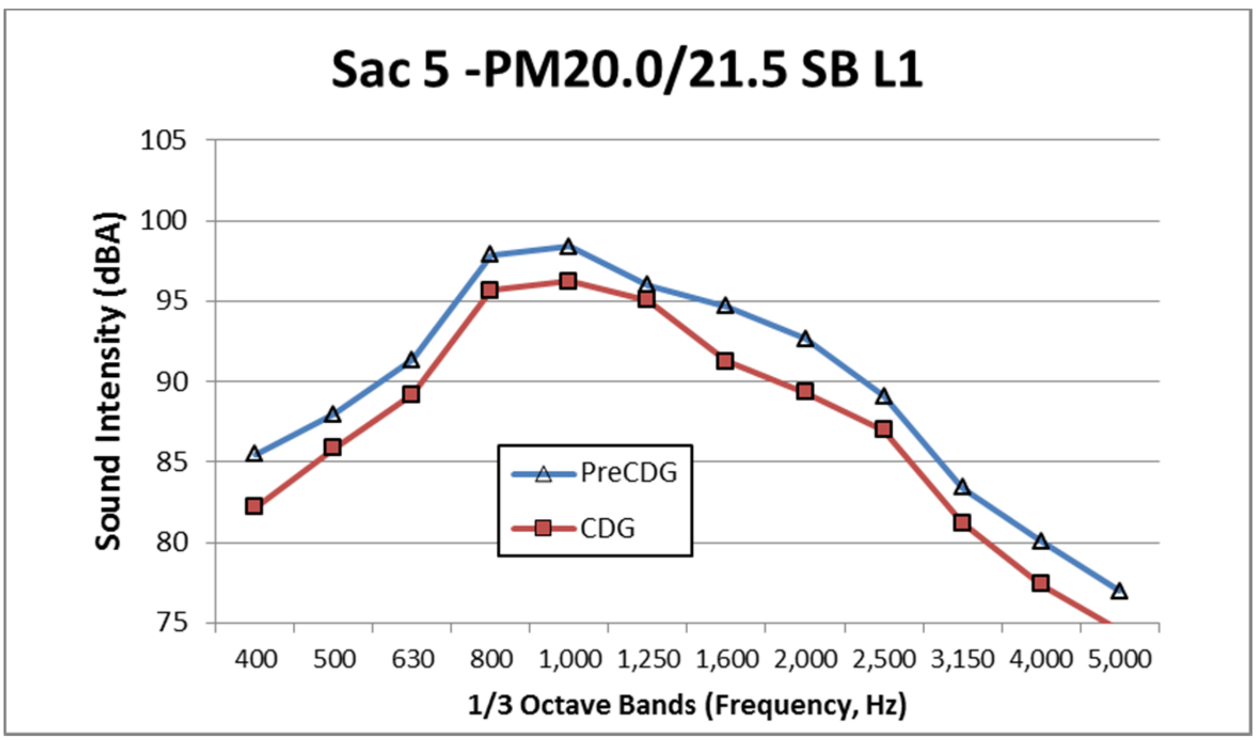
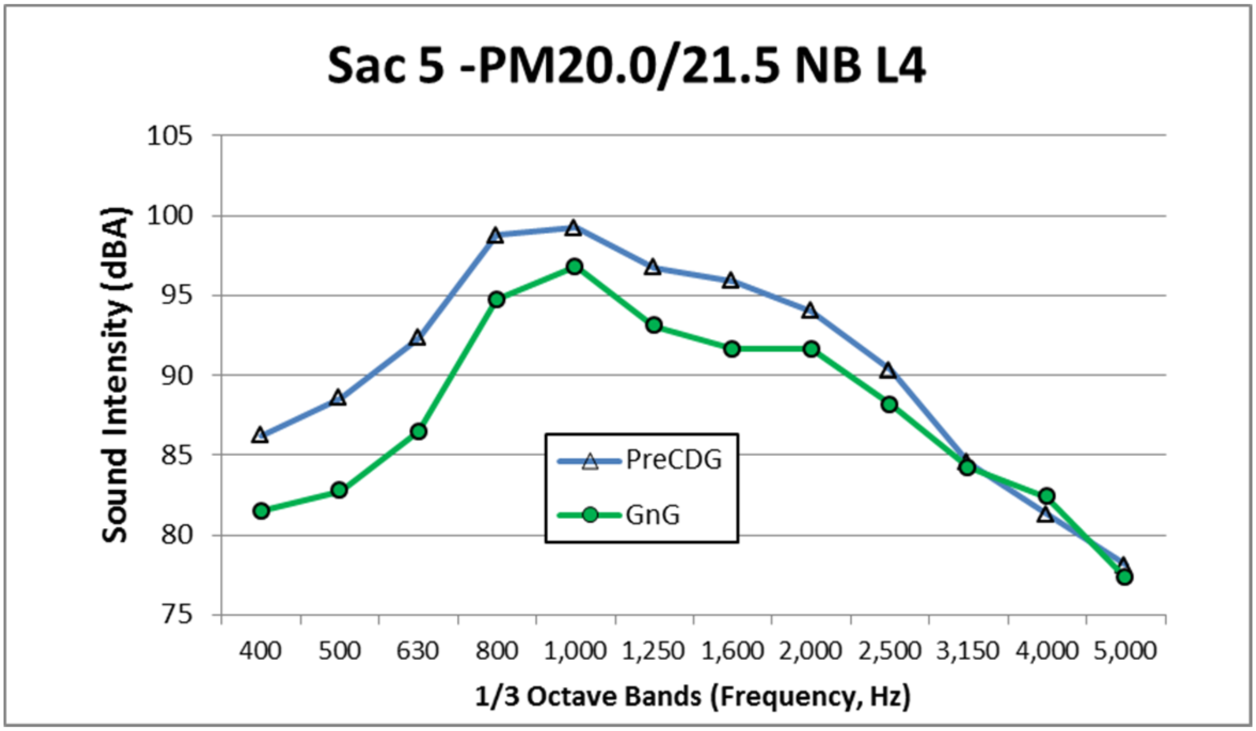


(b)

Figure B.1: OBSI noise spectra for Sacramento 5 – PM 20.0/21.5, Lane 1, (a) northbound and (b) southbound.



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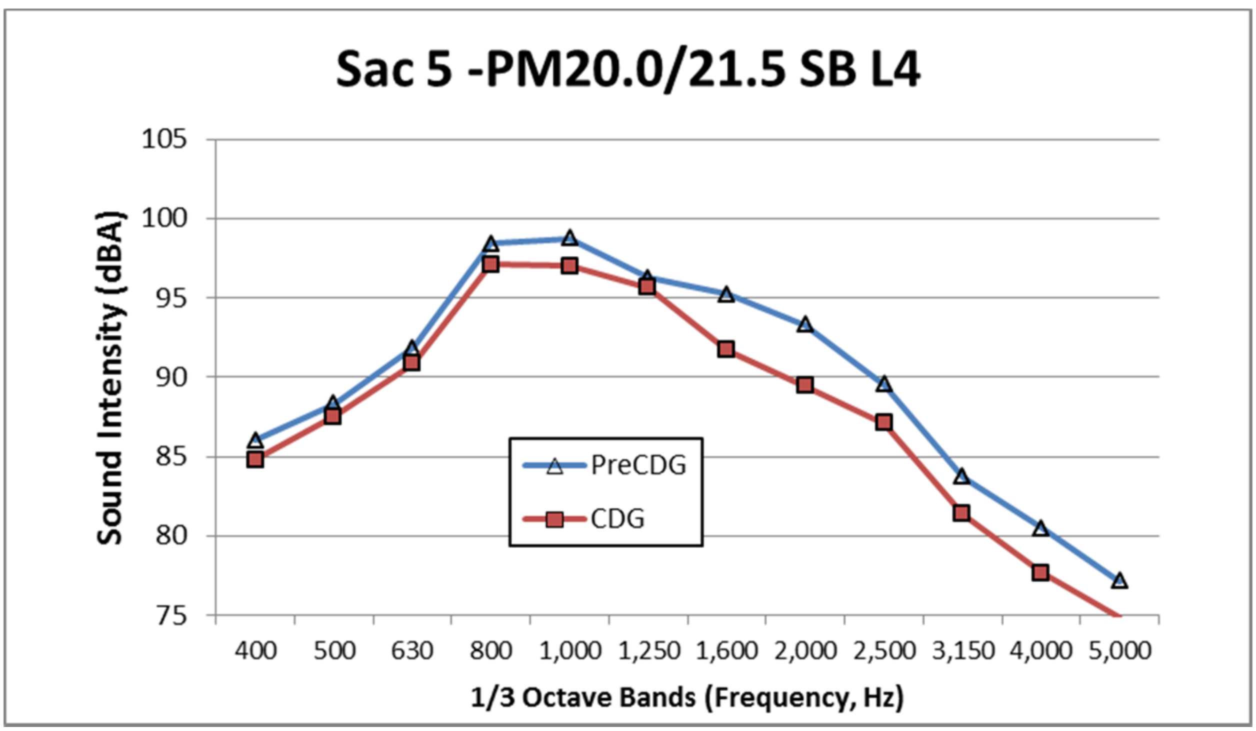
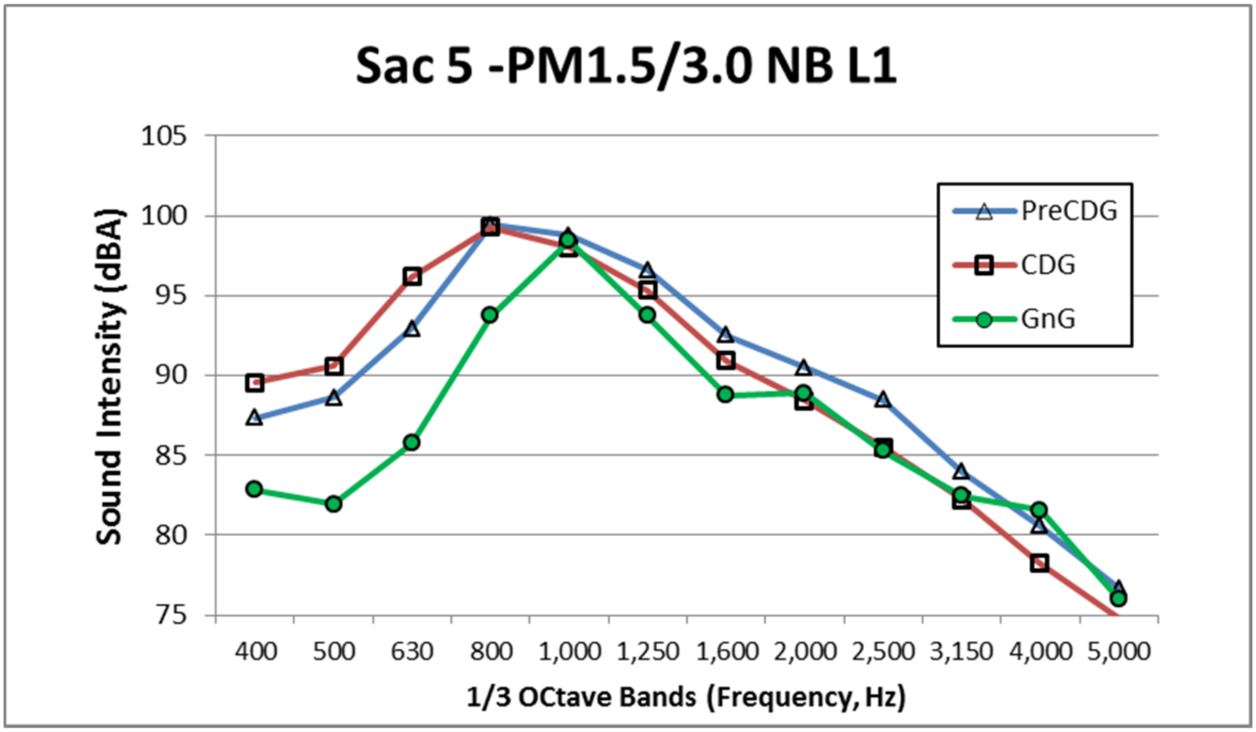


(b)

Figure B.2: OBSI noise spectra for Sacramento 5 – PM 20.0/21.5, Lane 4, (a) northbound and (b) southbound.



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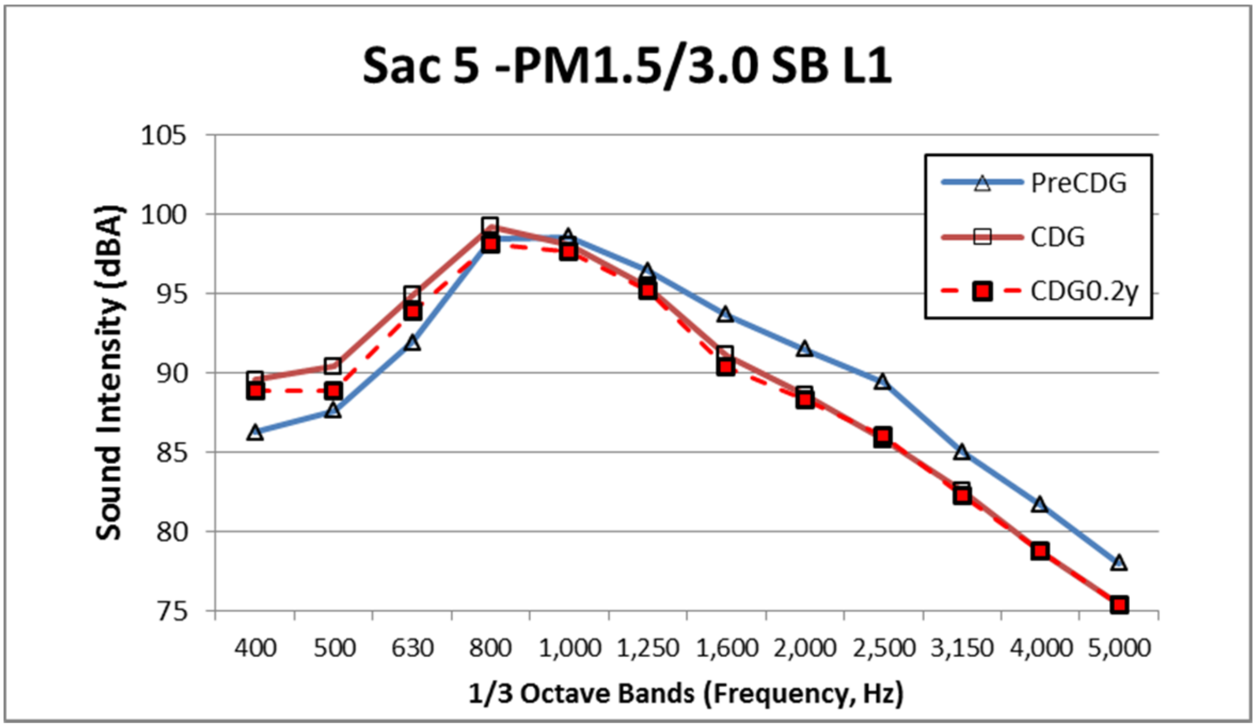
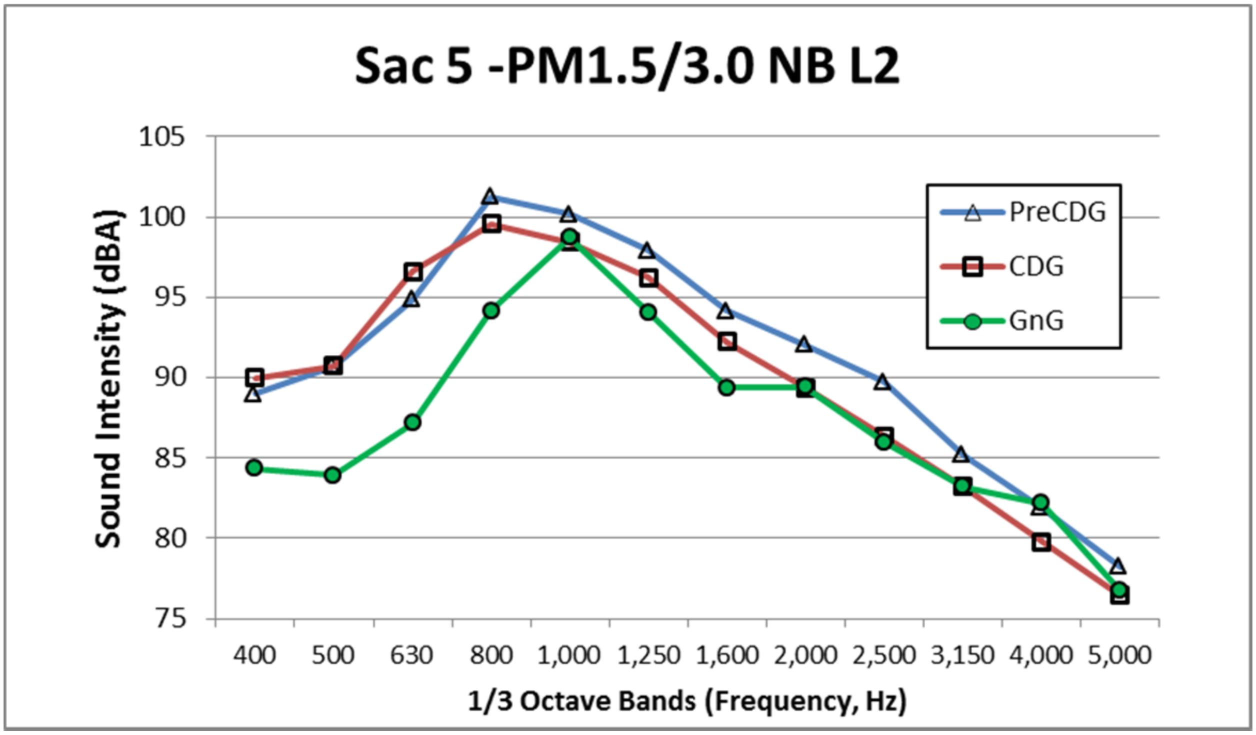


(b)

Figure B.3: OBSI noise spectra for Sacramento 5 – PM 1.5/3.0, Lane 1, (a) northbound and (b) southbound.



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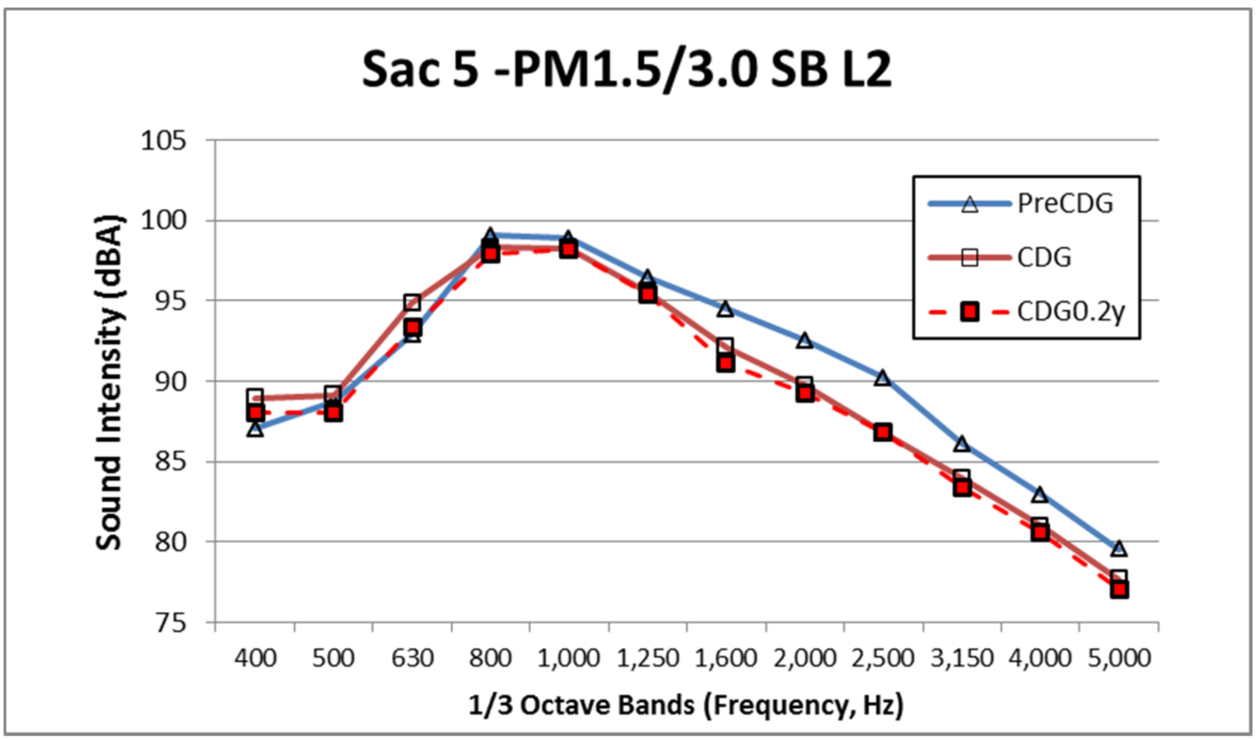
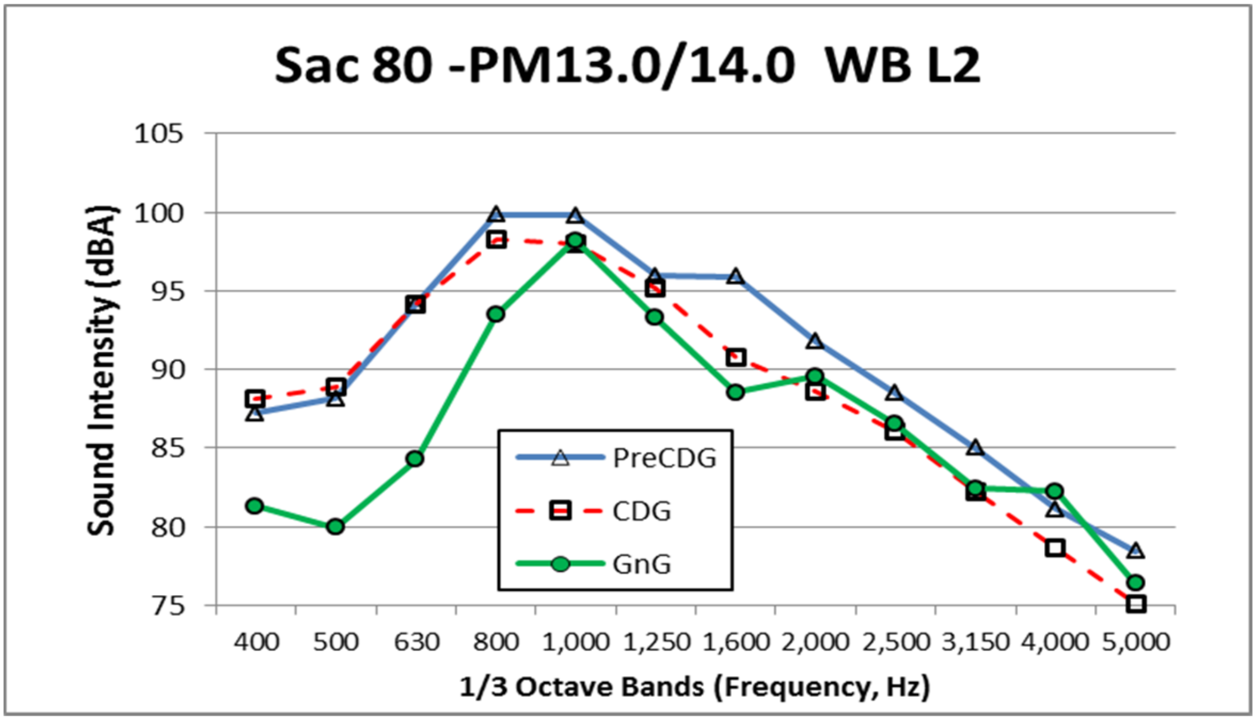


(b)

Figure B.4: OBSI noise spectra for Sacramento 5 – PM 1.5/3.0, Lane 2, (a) northbound and (b) southbound.



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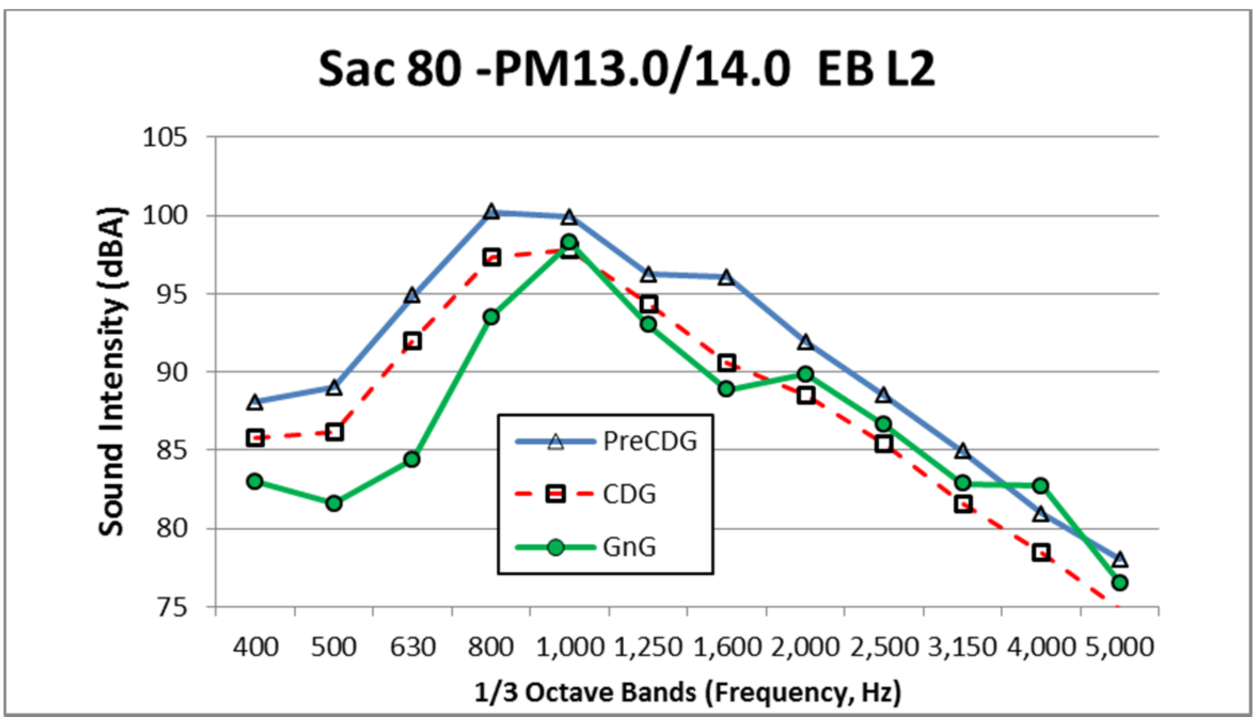
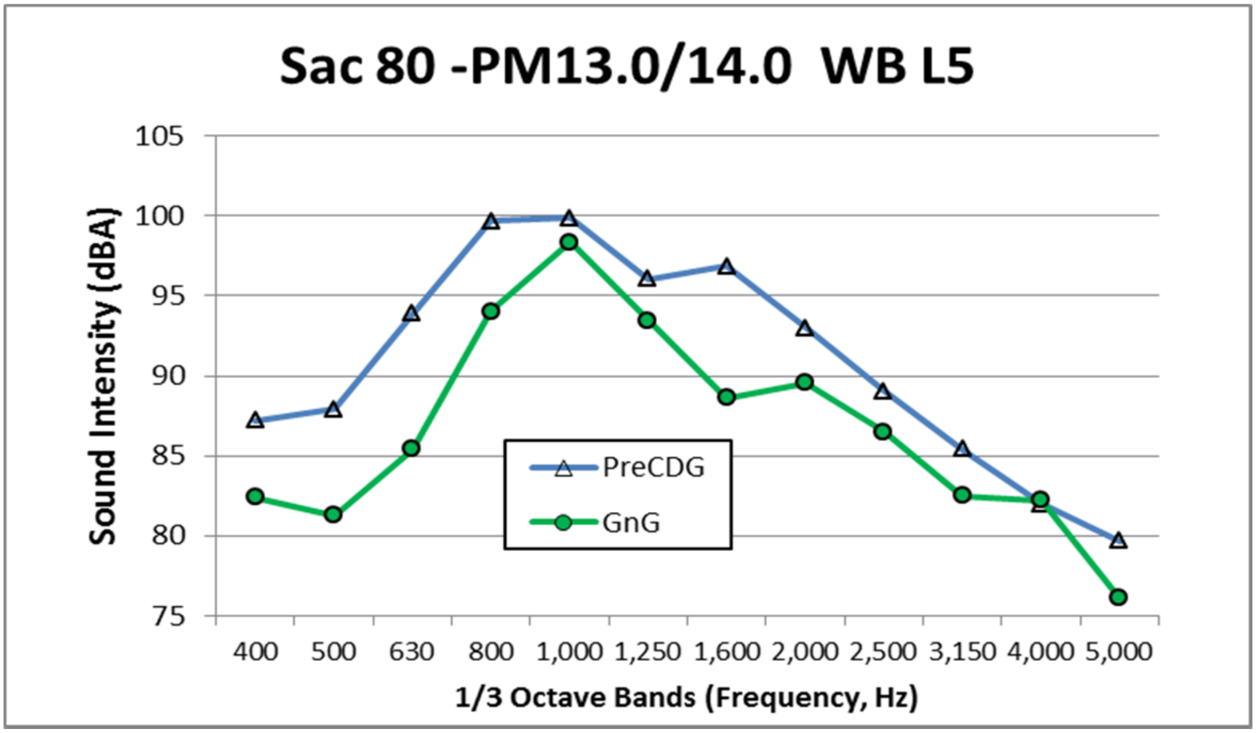
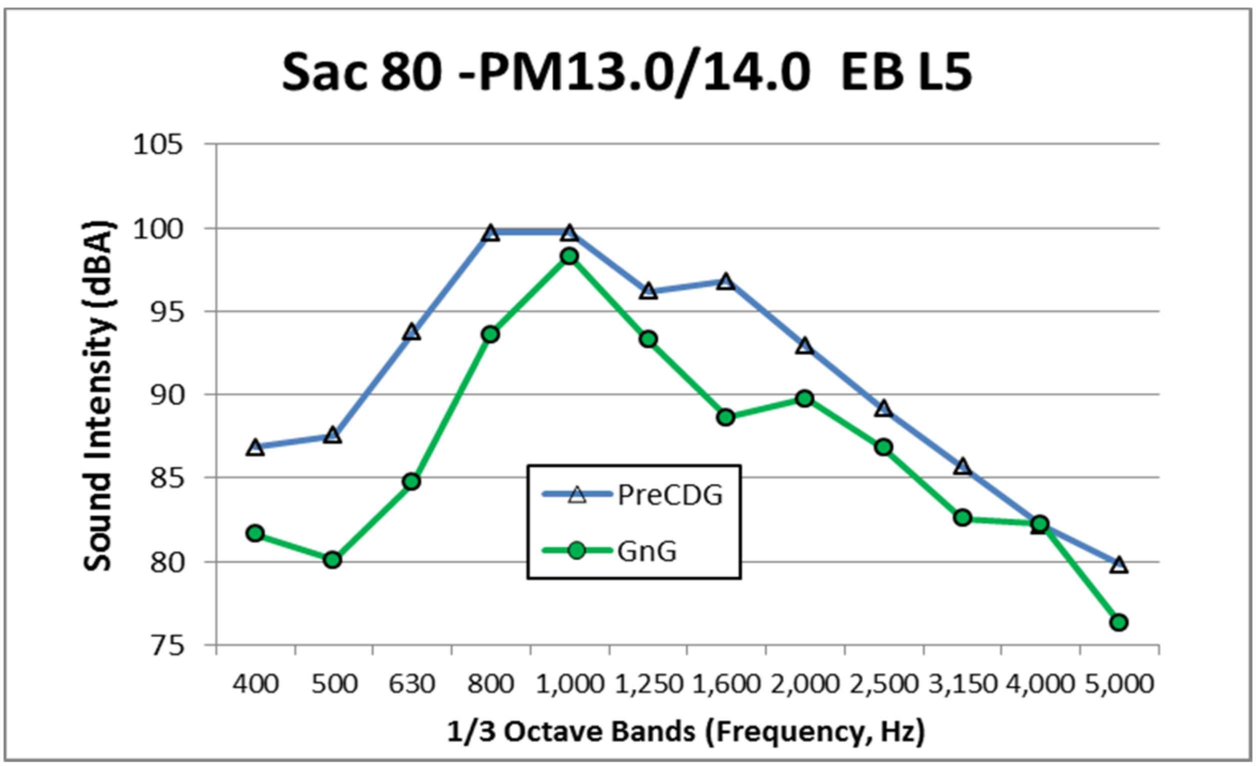


(b)

Figure B.5: OBSI noise spectra for Sacramento 80 – PM R13.0/R14.0, Lane 2, (a) westbound and (b) eastbound.

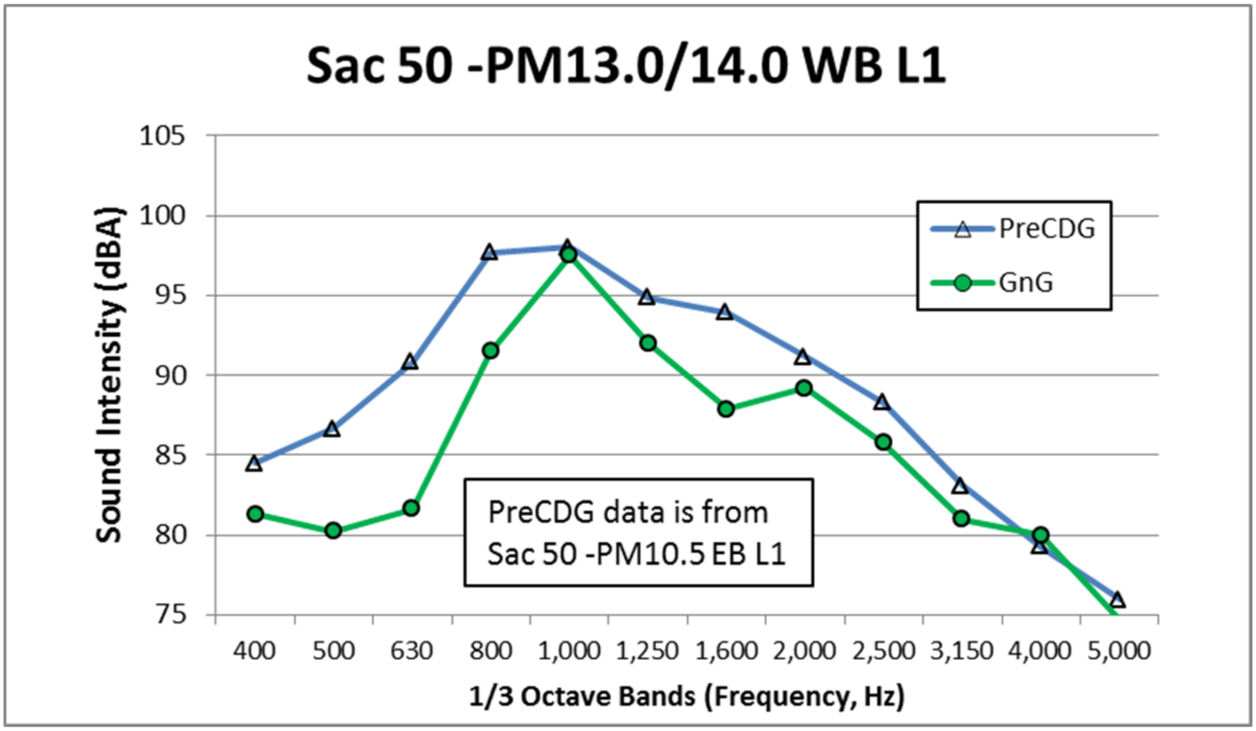


(a)



(b)

Figure B.6: OBSI noise spectra for Sacramento 80 – PM 13.0/14.0, Lane 5, (a) westbound and (b) eastbound.



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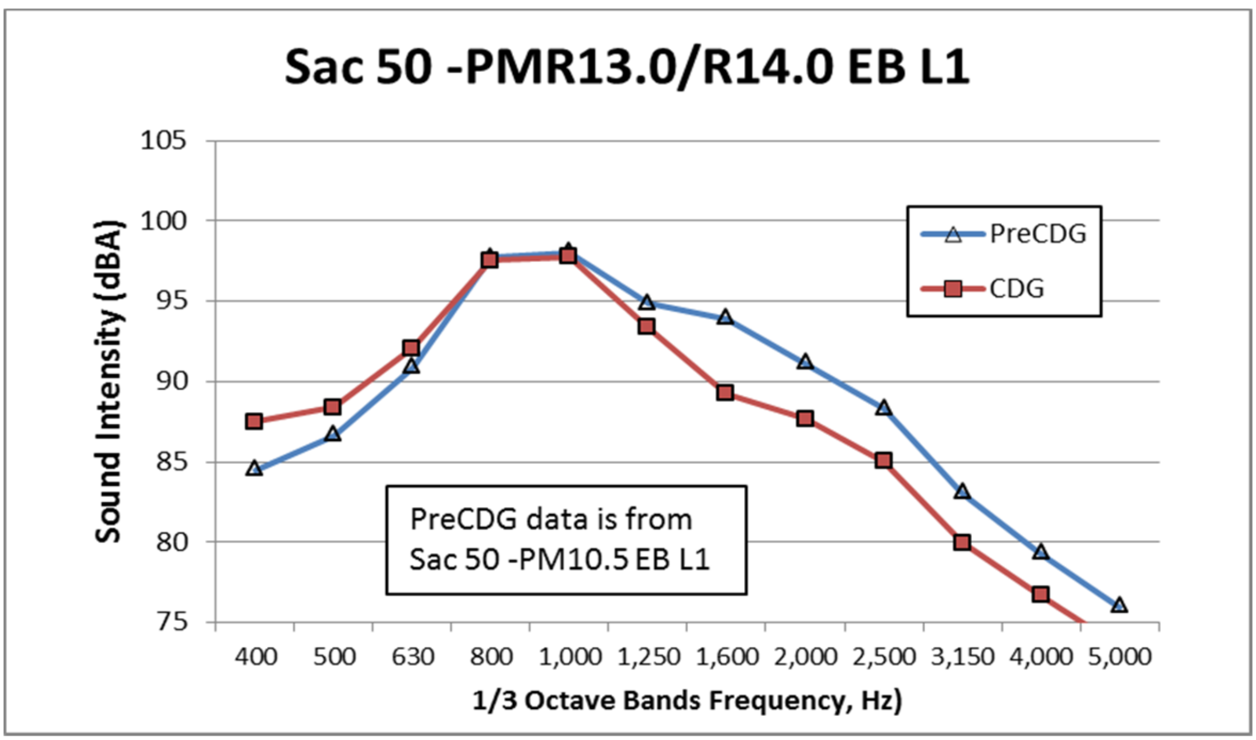


(b)

Figure B.7: OBSI noise spectra for Sacramento 50 – PM R13.0/R14.0, Lane 1, (a) westbound and (b) eastbound.

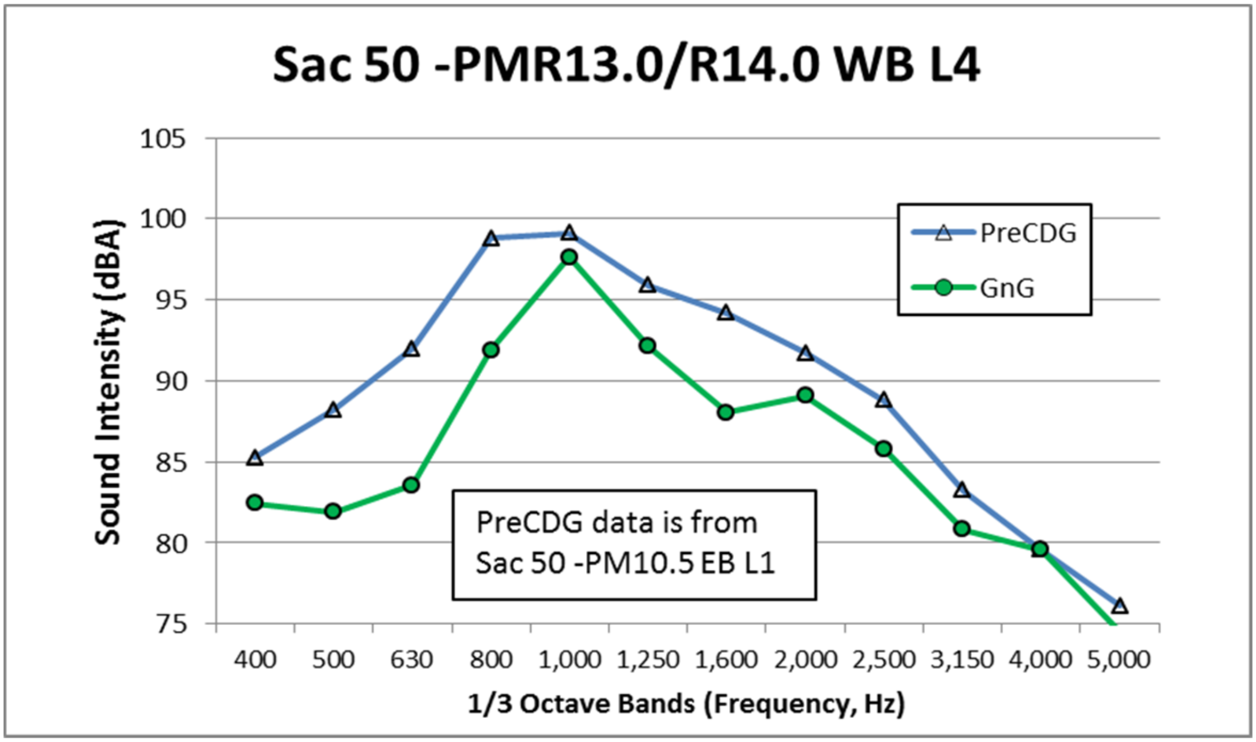
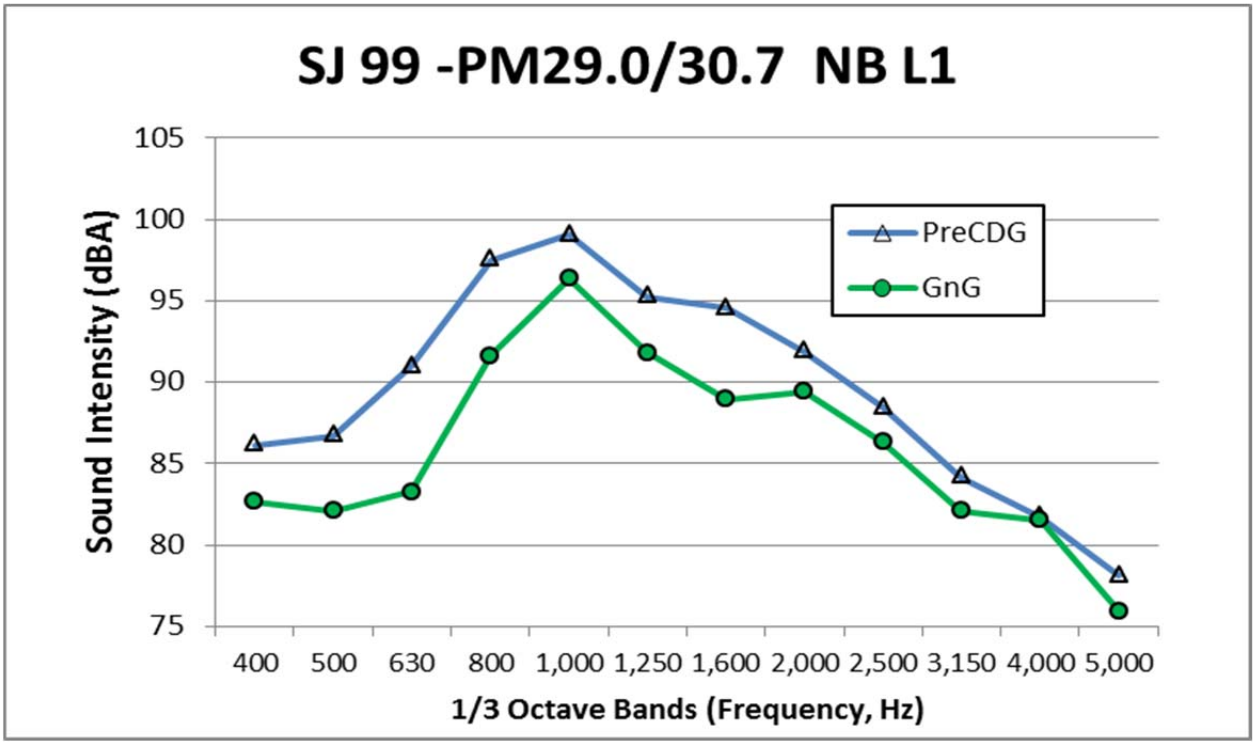
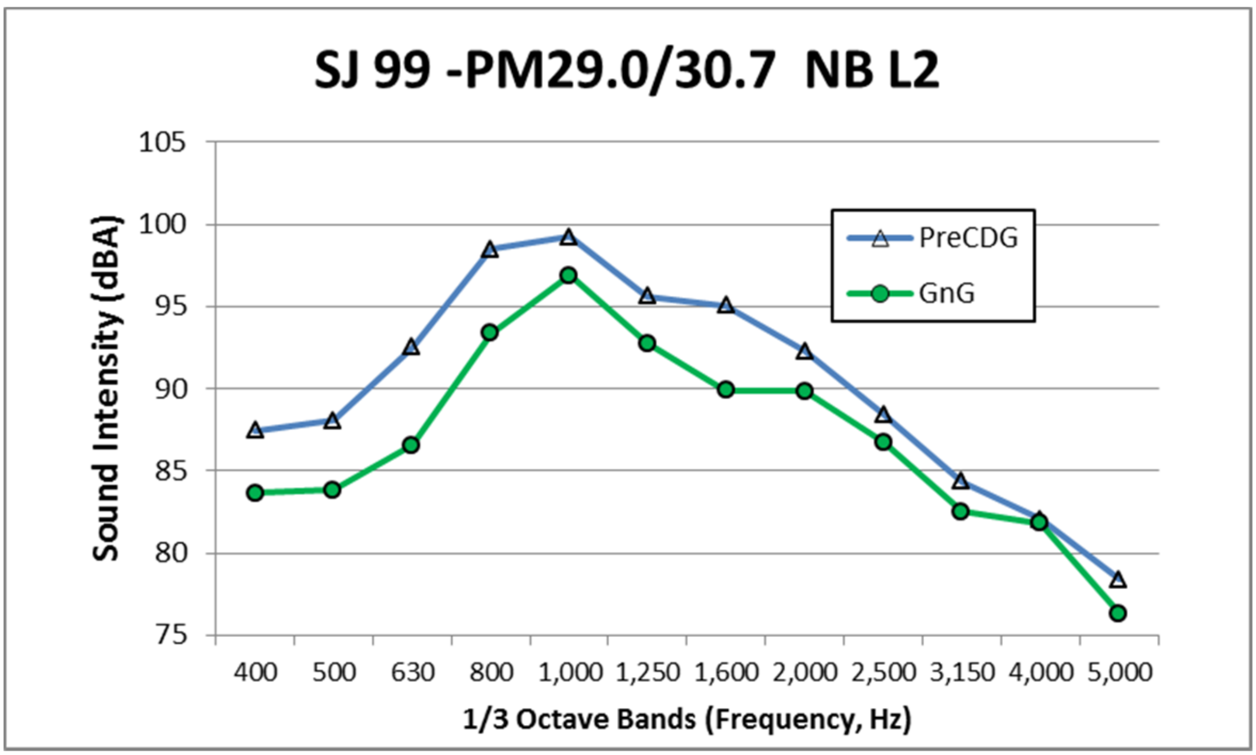


Figure B.8: OBSI noise spectra for Sacramento 50 – PM R13.0/R14.0, Lane 4, westbound.

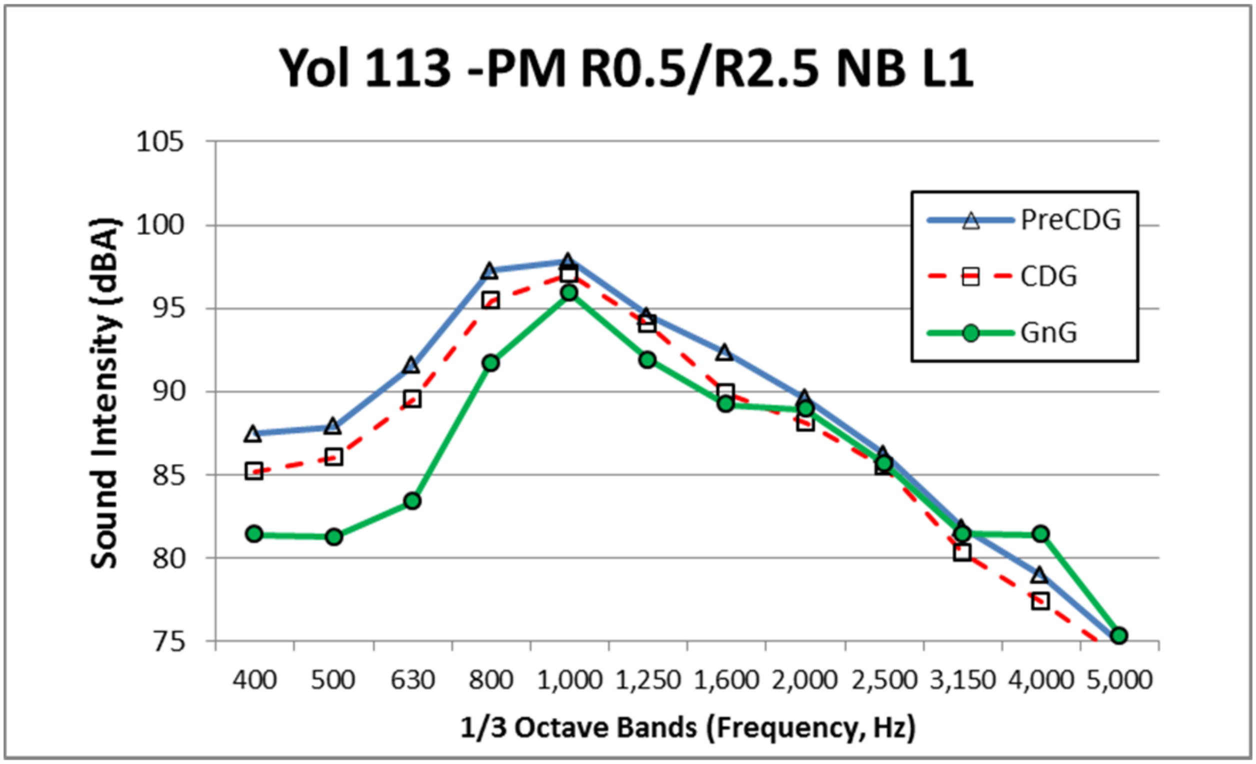


(a)

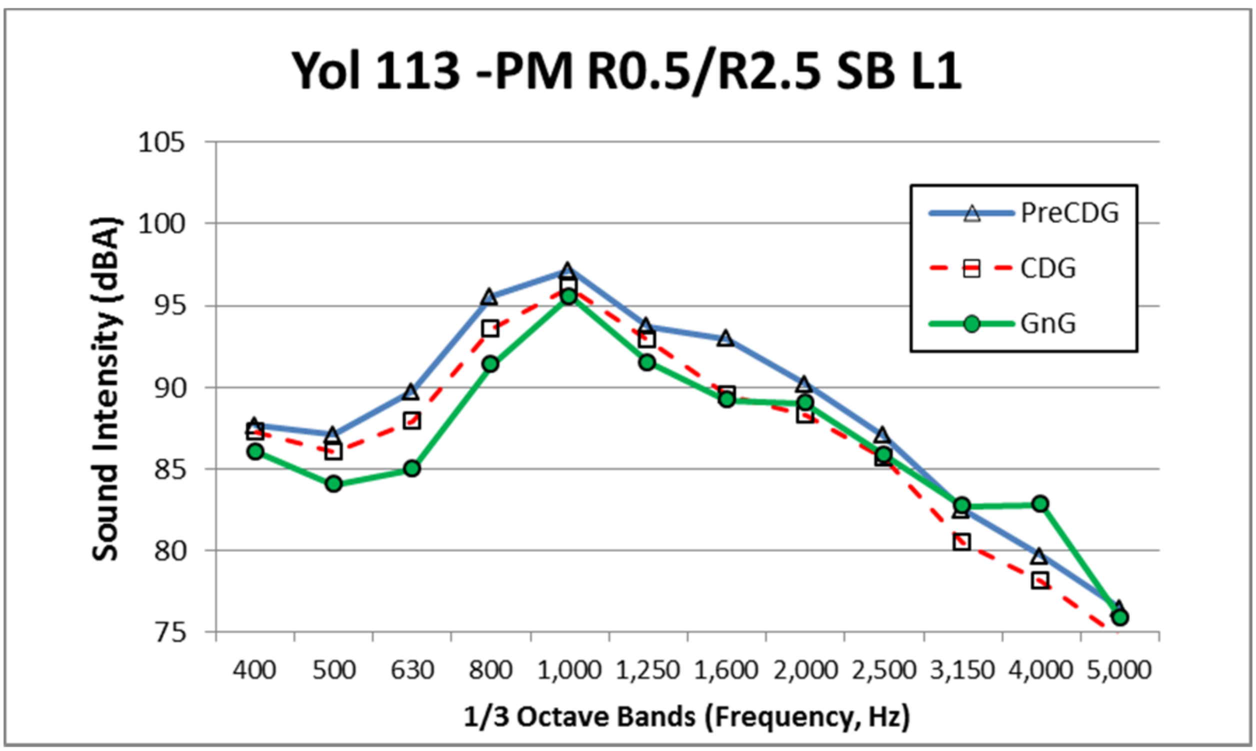


(b)

Figure B.9: OBSI noise spectra for San Joaquin 99 – PM 29.0/30.7, lanes 1 (a) and 2 (b), northbound.

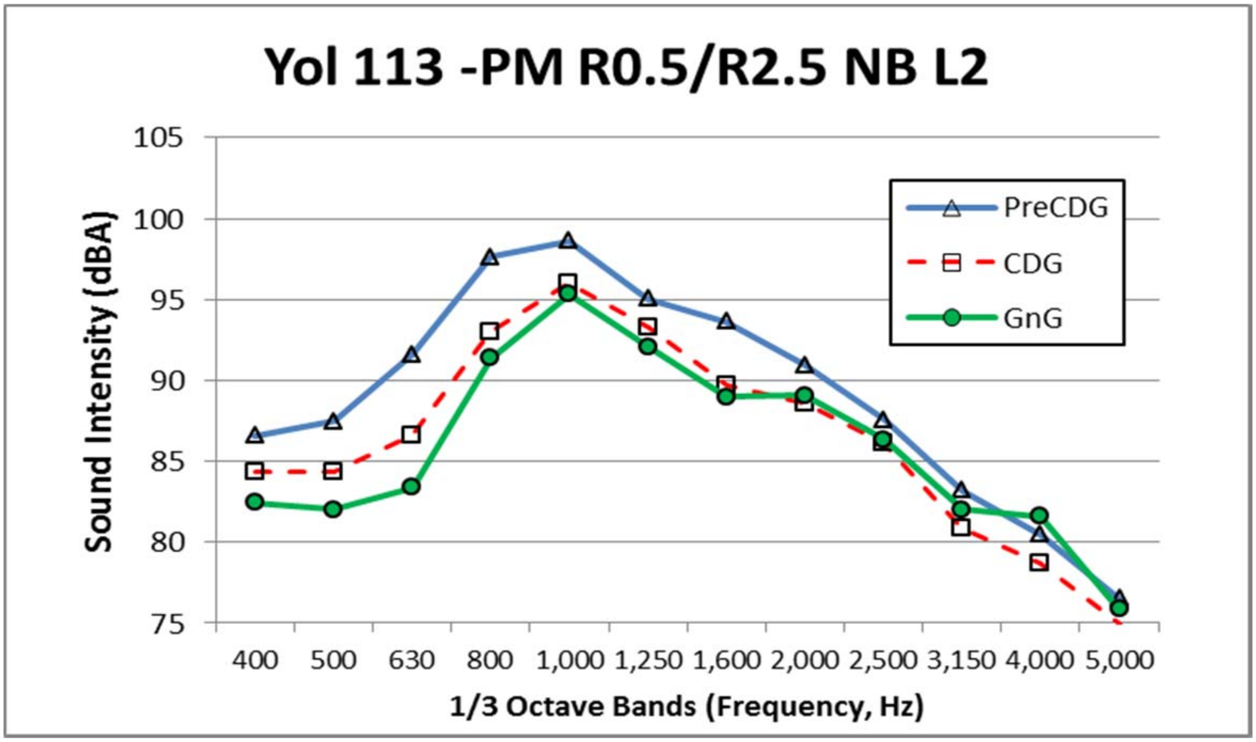


(a)

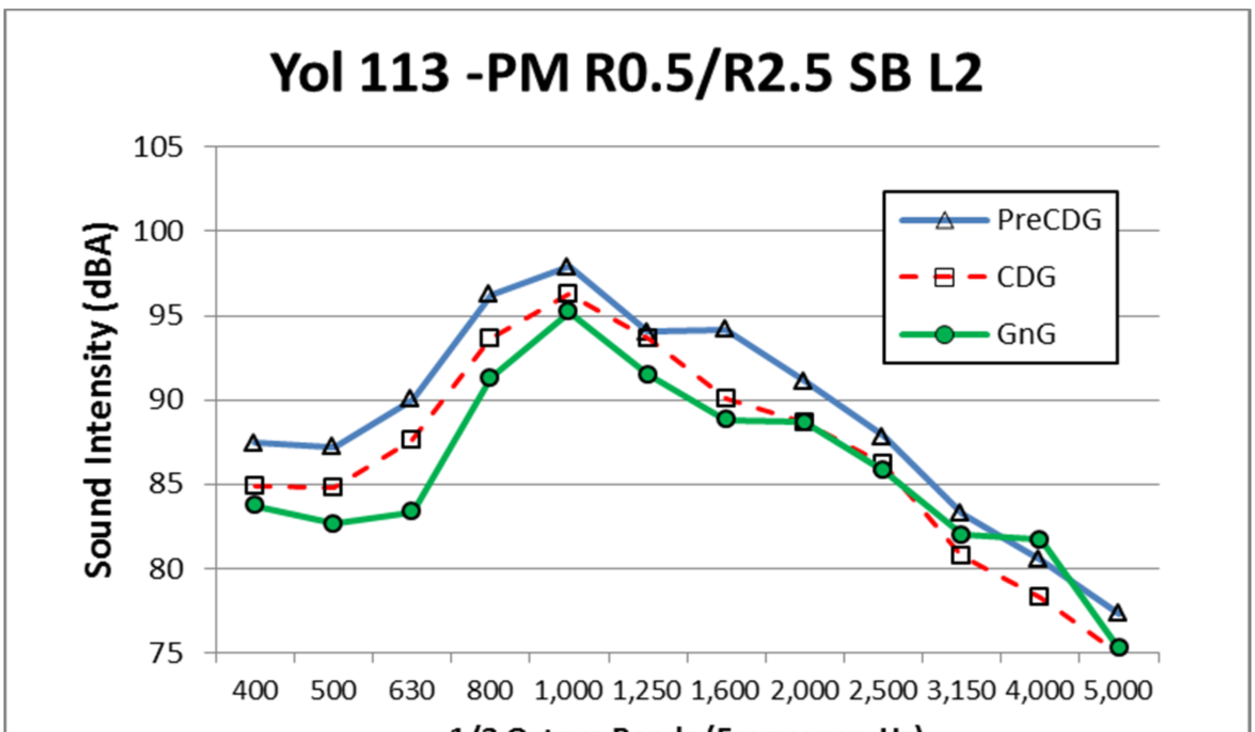


(b)

Figure B.10: OBSI noise spectra for Yolo 113 – PM R0.5/R2.5, Lane 1, (a) northbound and (b) southbound.

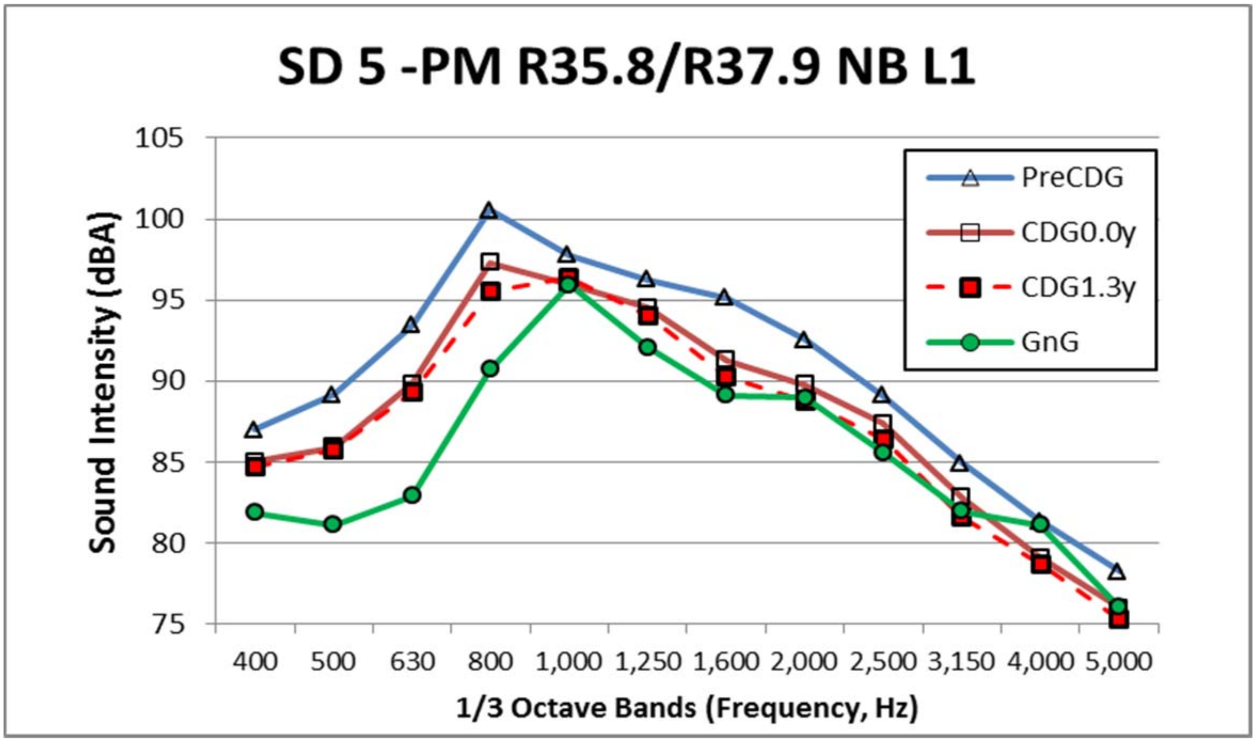


(a)

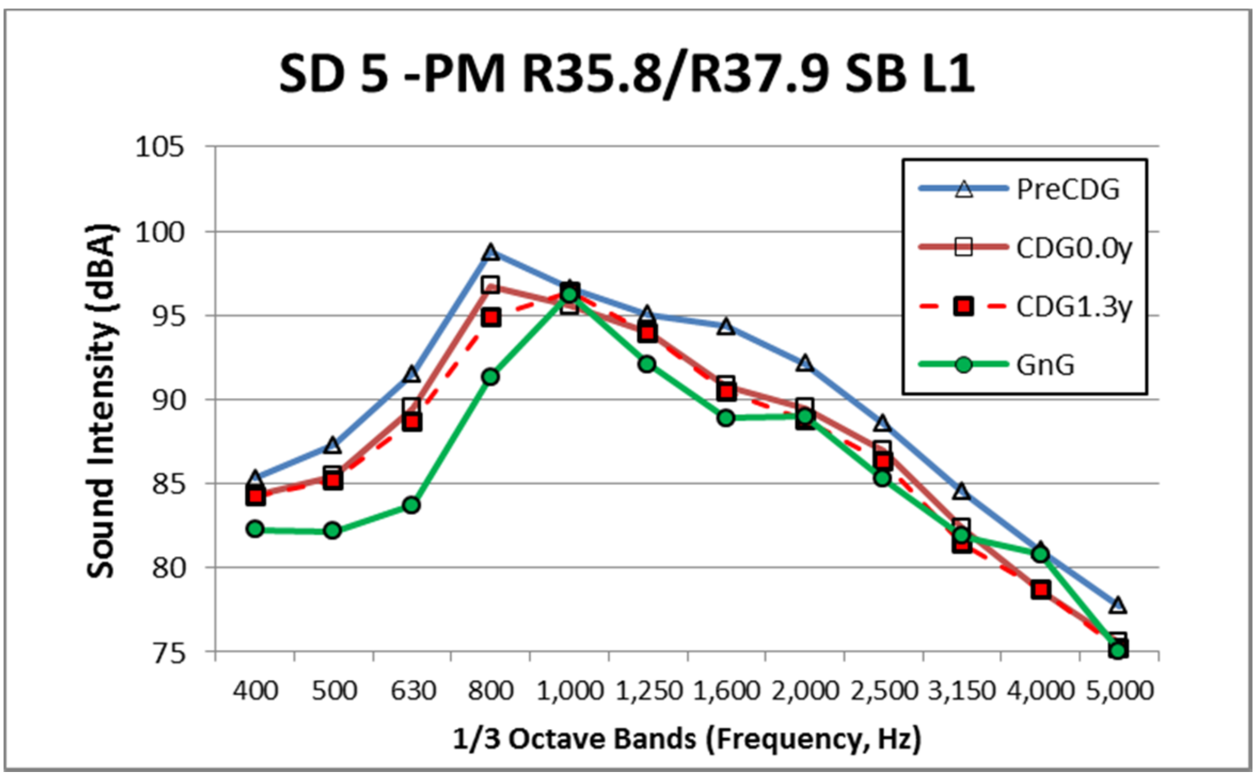


(b)

Figure B.11: OBSI noise spectra for Yolo 113 – PM R0.5/R2.5, Lane 2, (a) northbound and (b) southbound.

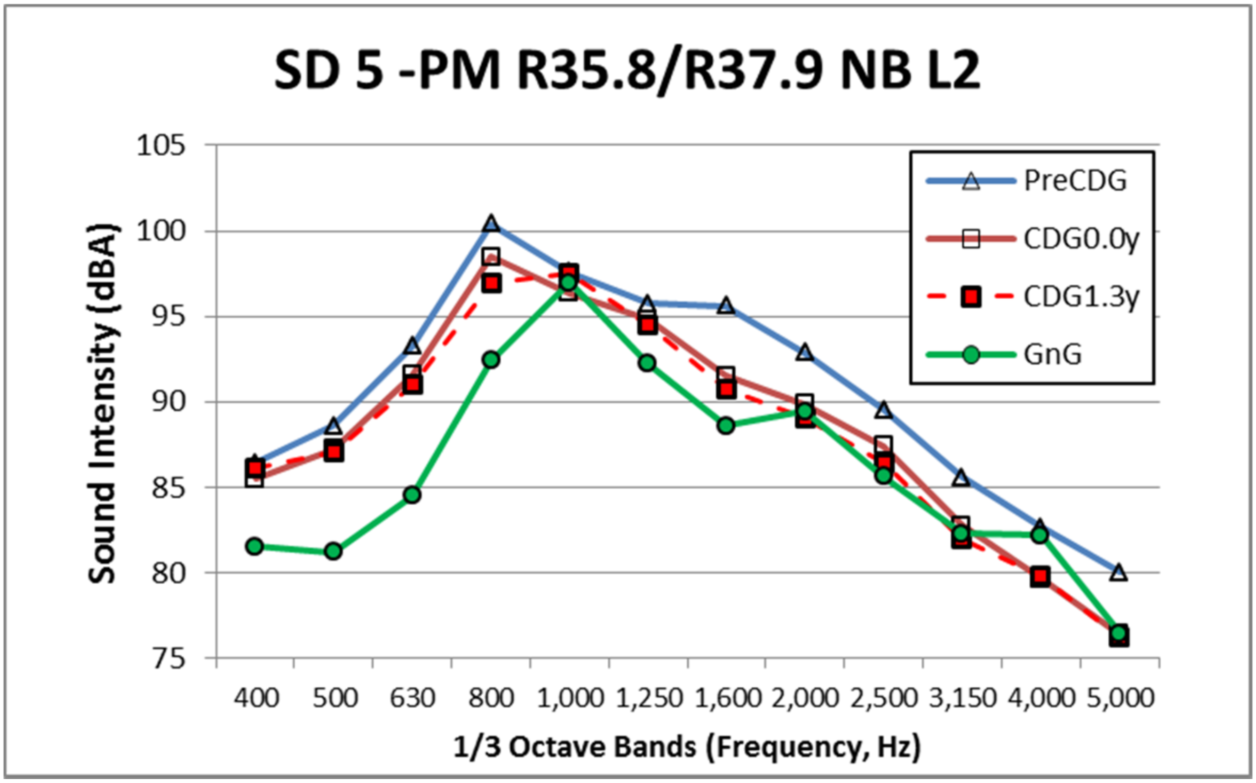


(a)

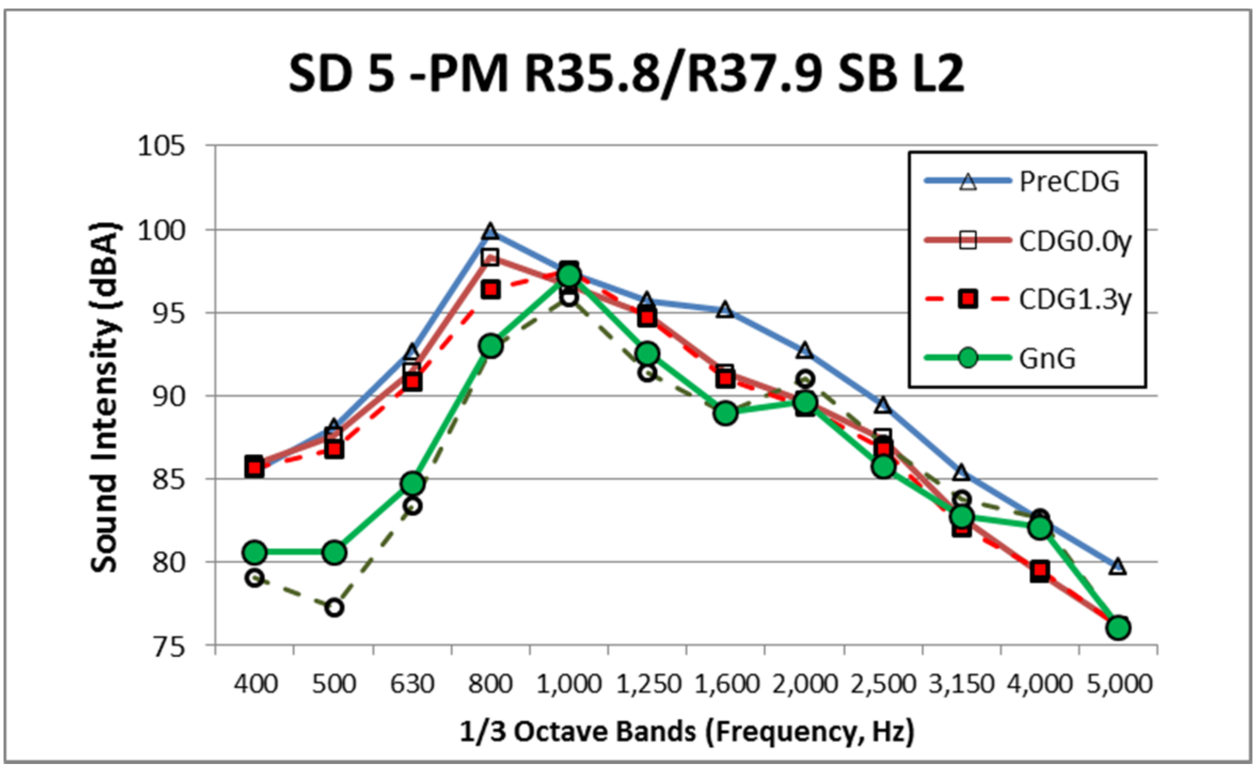


(b)

Figure B.12: OBSI noise spectra for San Diego 5 – PM R35.8/R37.9, Lane 1, (a) northbound and (b) southbound.

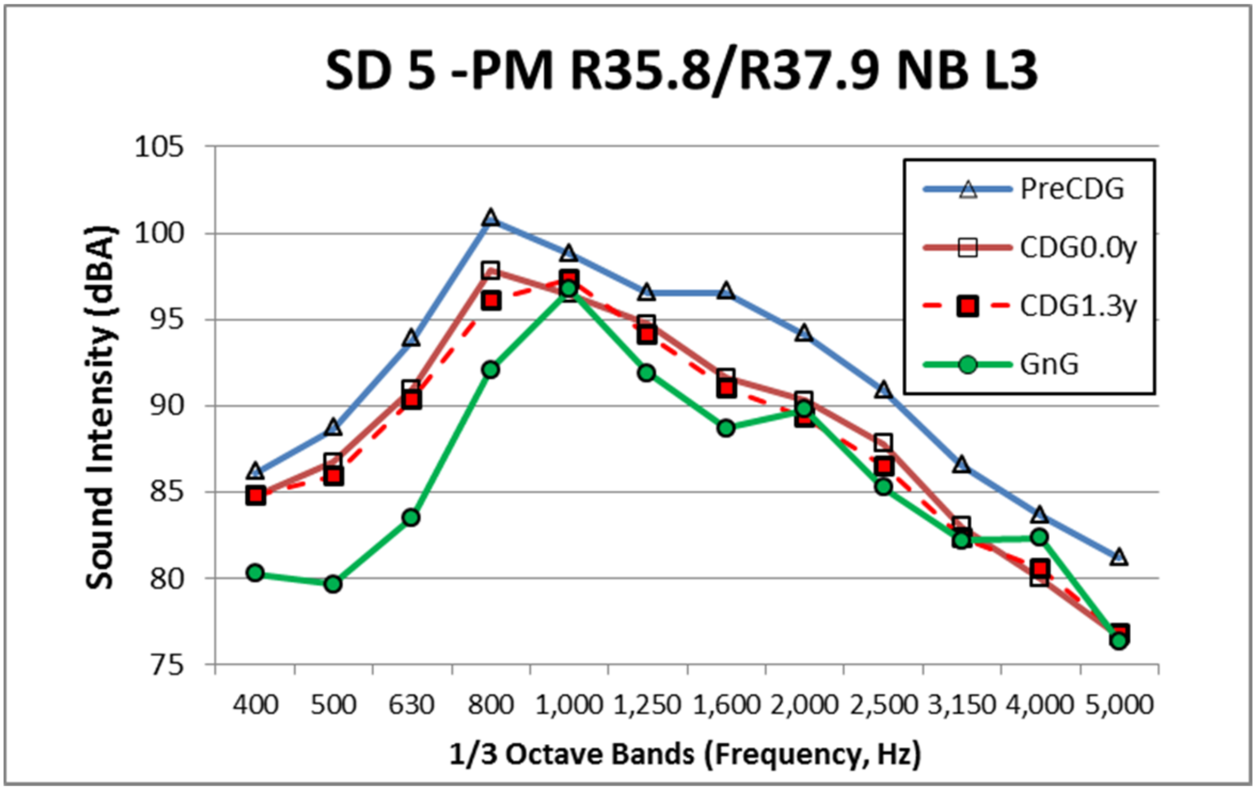


(a)

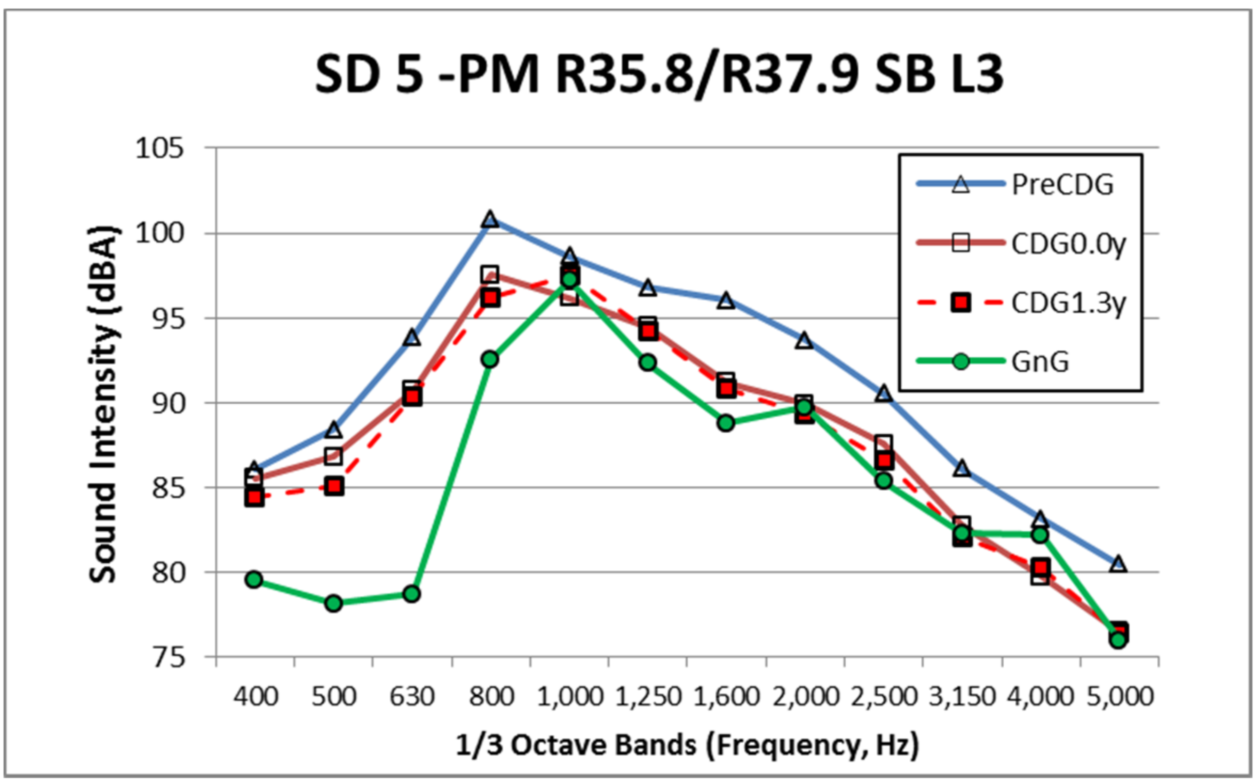


(b)

Figure B.13: OBSI noise spectra for San Diego 5 – PM R35.8/R37.9, Lane 2, (a) northbound and (b) southbound.

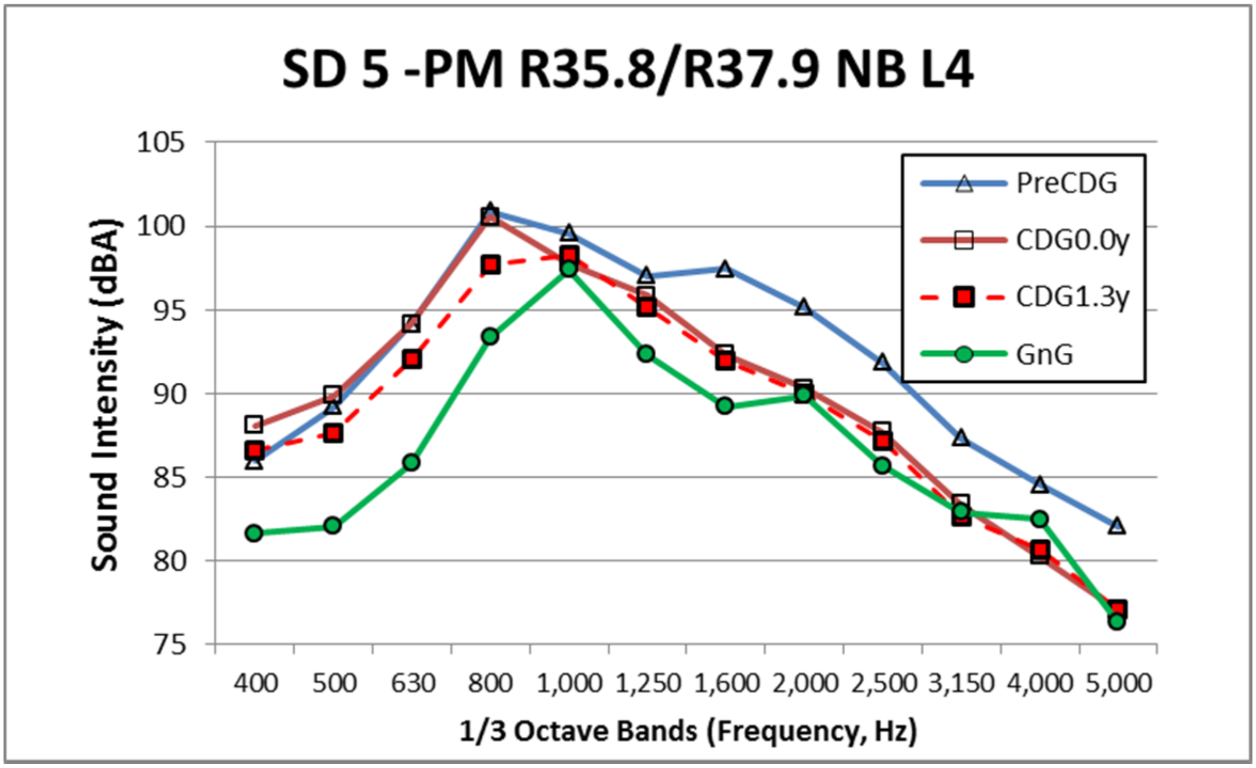


(a)

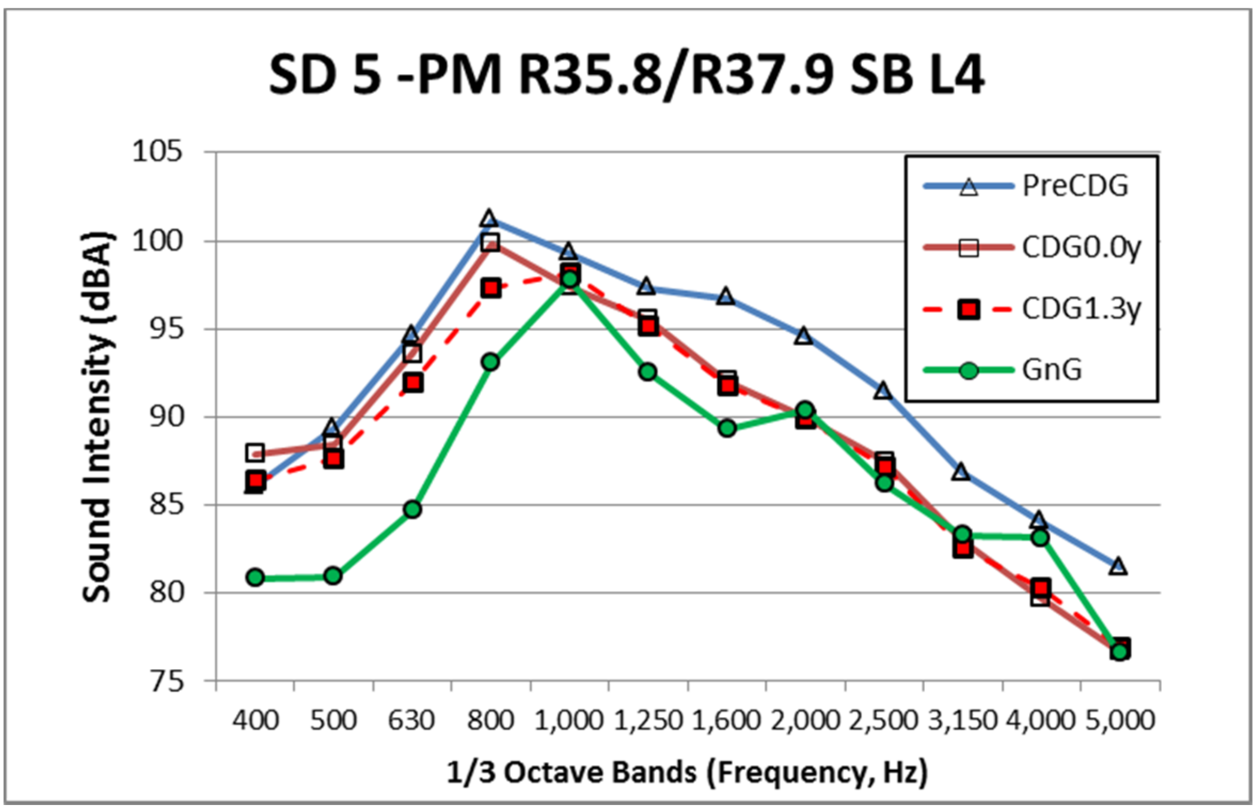


(b)

Figure B.14: OBSI noise spectra for San Diego 5 – PM R35.8/R37.9, Lane 3, (a) northbound and (b) southbound.

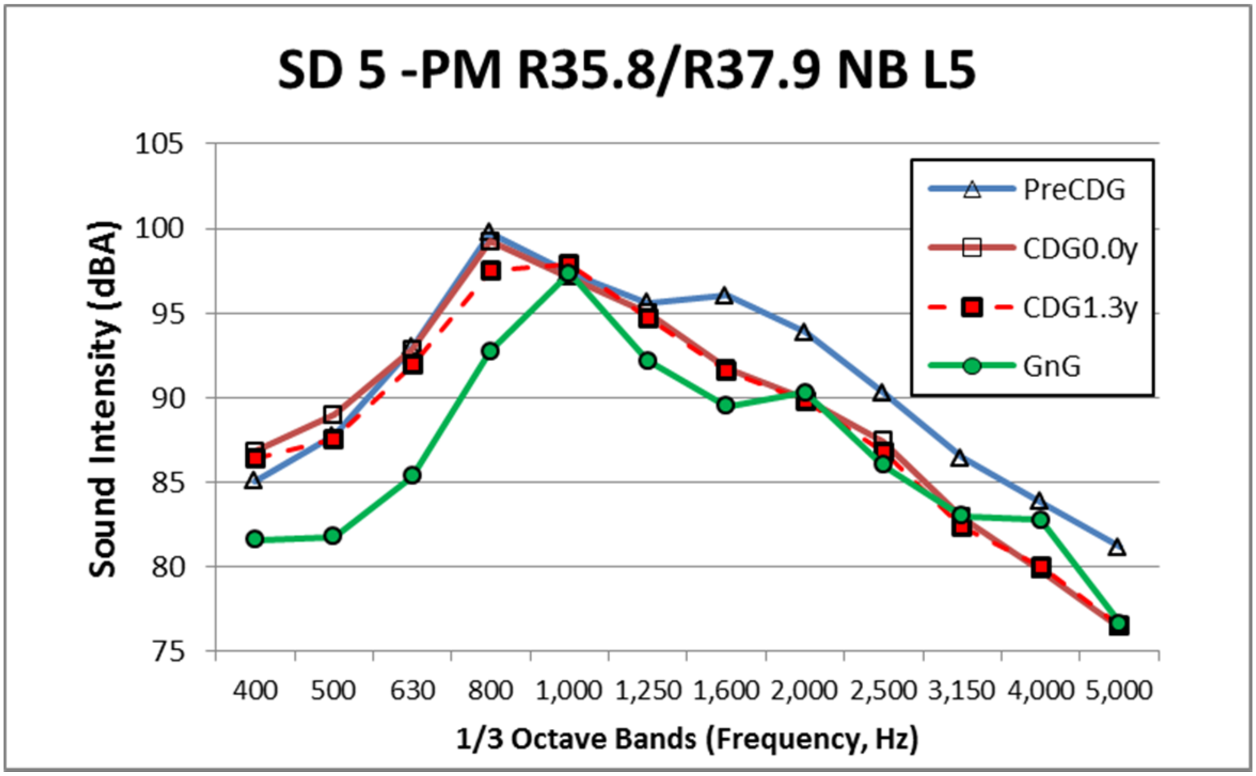


(a)

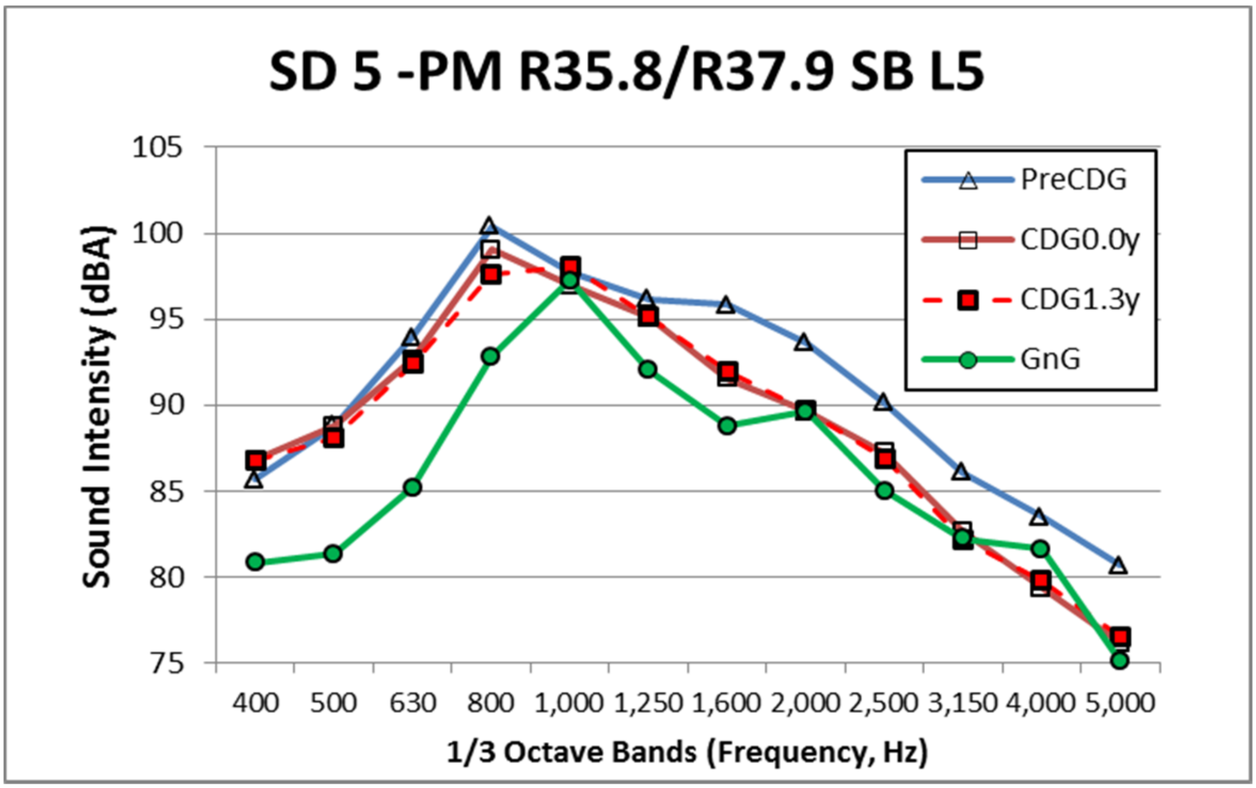


(b)

Figure B.15: OBSI noise spectra for San Diego 5 – PM R35.8/R37.9, Lane 4, (a) northbound and (b) southbound.



(a)



(b)

Figure B.16: OBSI noise spectra for San Diego 5 – PM R35.8/R37.9, Lane 5, (a) northbound and (b) southbound.

APPENDIX C: COMPARISON OF OBSI MEASURED WITH SRTT#4 AND SRTT#5 TIRES

The UCPRC monitors the test tires used on its noise and roughness test vehicle, and replaces the tires between testing phases, which are approximately one year long. These other tire replacement criteria related to tire characteristics have been proposed by Donavan and Lodico (*C1*):

- Tire age should not exceed 4 years.
- Tire mileage should not exceed 11,000 miles.
- Tire hardness should not exceed a durometer reading of 68 duro.
- Tire tread should be greater than 0.28 in. (7.2 mm).

The sampling for this project began in 2010, when the noise and roughness testing vehicle used Standard Reference Test Tire Number 4 (SRTT#4). In November 2011, SRTT#5 was installed on the vehicle for the subsequent year of sampling for the noise study.

About one-third of the data reported here were collected using SRTT#4 and the remainder were collected using SRTT#5. The projects (and textures, in parentheses) that were evaluated using SRTT#4 are Sacramento 5 – PM20.0/21.5 (Pre-CDG, CDG, and GnG), San Diego 5 (Pre-CDG, CDG0.0y, and the 2,000 foot GnG test strip), Sacramento 50 (Pre-CDG), and Sacramento 5 – PM1.5/30 (Pre-CDG).

An investigation was performed to determine whether the differences in measured OBSI between the two tires were significant enough to warrant development of a tire conversion factor before pooling the data from the two tires. The test sections listed in Table C.0.1were used for the comparison.

Table C.0.1: List of Sections for Comparing SRTT#4 and SRTT#5 Tires

	Direction and Texture Types
Sacramento 5 - PM 20.0/21.5 (Lane 1 and Lane 4)	Northbound, GnG Southbound, CDG
Sacramento 50 - PM R13.0/R14.0 (Lane 2)	Eastbound, GnG Westbound, CDG
Sacramento 80 - PM 13.0/14.0 (Lane 2)	Eastbound and Westbound, GnG
Yolo 113 - PM R0.5/R2.5 (Lane 1 and Lane 2)	Northbound PM R0.5 – R1.5, GnG Northbound PM R1.5 – R2.5, CDG Southbound PM R0.5 – R0.9, GnG Southbound PM R0.9 – R2.5, CDG

In this study, as with all the tire/pavement noise studies conducted by the UCPRC, both tires were correlated with SRTT#1. SRTT#1 conversion values will be used in future reports to compare data from the GnG sections shown in this report with the data collected over the years on other noise test sections.

The differences among the tires in each of the four project sections are shown in Figure C.1 through Figure C.4, and are discussed following each figure.

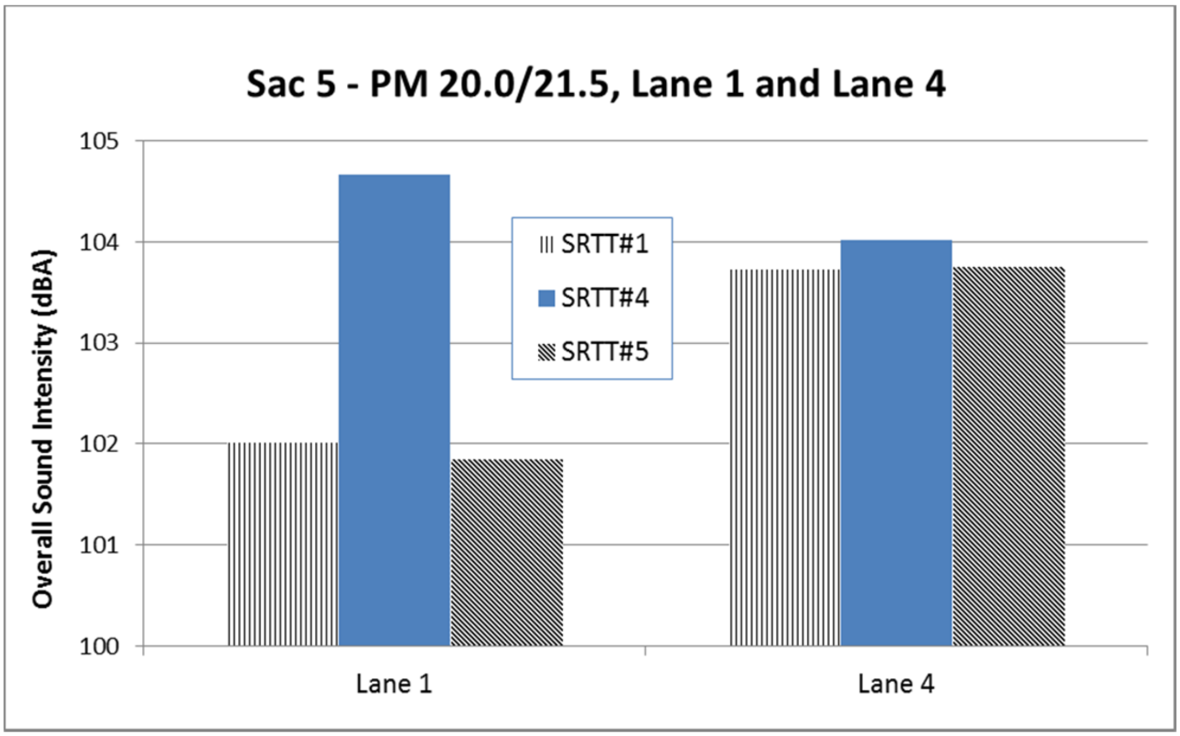


Figure C.1: Overview of OBSI from three tires on Sacramento 5 – PM 20.0/21.5, lanes 1 and 4.

Figure C.1 shows that on the Sacramento 5 – PM 20.0/21.5 section, SRTT#4 was louder than SRTT#5, by 2.8 dBA in Lane 1 and by 0.3 dBA in Lane 4.

Table C.2: Comparison of SRTTs #1, #4, and #5 on Sacramento 5 – PM 20.0/21.5

Tires for Comparison		Lane 1			Lane 4		
Tire A	Tire B	Mean Difference (A-B)	Std. Error	Sig. Level	Mean Difference (A-B)	Std. Error	Sig. Level
SRTT#1	SRTT#4	-2.65	.06	.00	-.30	.11	.02
	SRTT#5	.16	.04	.00	-.03	.10	.99
SRTT#4	SRTT#1	2.65	.06	.00	.30	.11	.02
	SRTT#5	2.81	.06	.00	.27	.11	.04
SRTT#5	SRTT#1	-.16	.04	.00	.03	.10	.99
	SRTT#4	-2.81	.06	.00	-.27	.11	.04

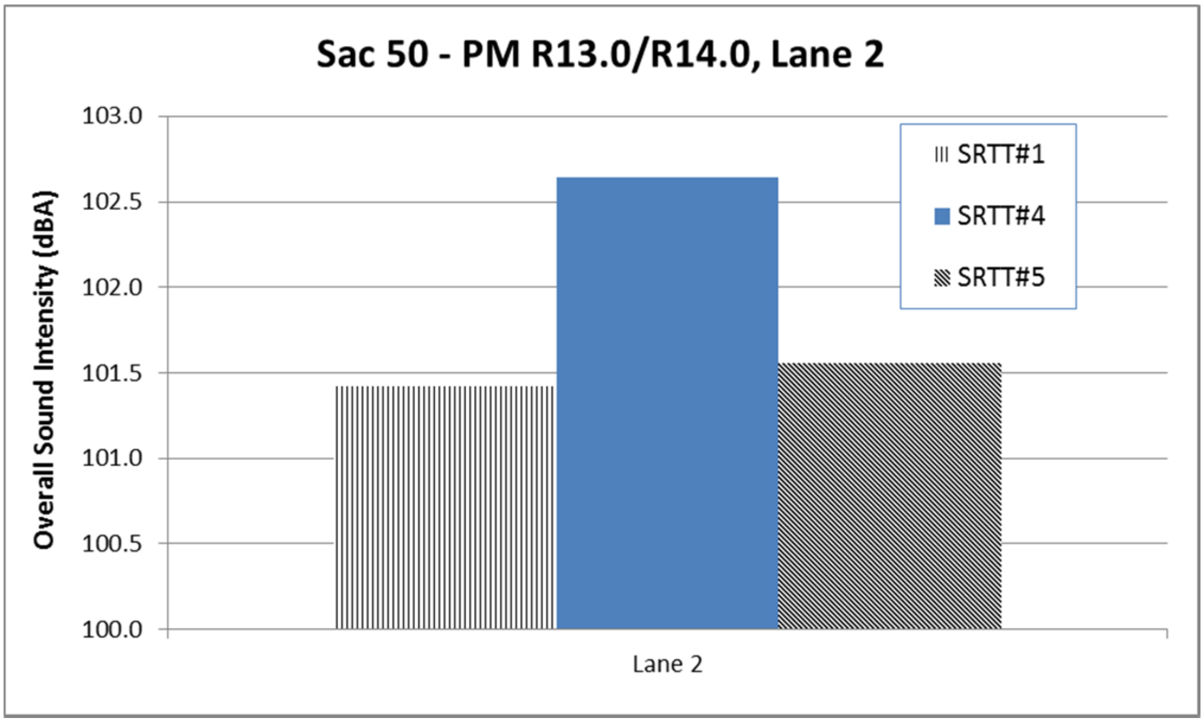


Figure C.2: Overview of OBSI from three tires on Sacramento 50 – PM R13.0/R14.0. Lane 2.

Figure C.2 shows that on the Sacramento 50 – PM R13.0/R14.0 section, SRTT#4 was 1.2 dBA louder than SRTT#5 in Lane 2.

Table C.3: Comparison of SRTTs #1, #4, and #5 for Sacramento 50 – PM R13.0/R14.0, Lane 2

Tires for Comparison		Mean Difference (A-B)	Std. Error	Sig. Level
(A) Tire	(B) Tire			
SRTT#1	SRTT#4	-1.23	.10	.00
	SRTT#5	-.14	.07	.13
SRTT#4	SRTT#1	1.23	.10	.00
	SRTT#5	1.09	.10	.00
SRTT#5	SRTT#1	.14	.07	.13
	SRTT#4	-1.09	.10	.00

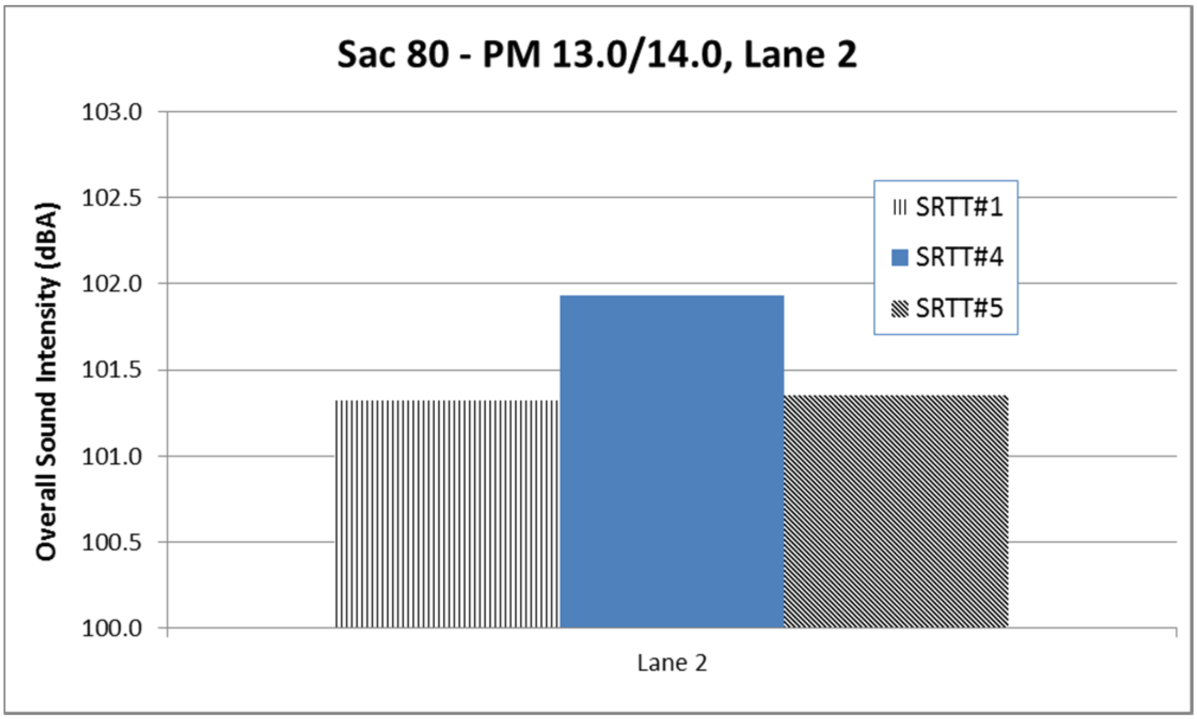


Figure C.3: Overview of OBSI from tires on Sacramento 80 – PM 13.0/14.0. Lane 2.

Figure C.3 shows that on the Sacramento 80 – PM 13.0/14.0 section, SRTT#4 was 0.6 dBA louder than SRTT#5 in Lane 2.

Table C.4: Comparisons of SRTTs #1, #2, and #5 for Sacramento 80 – PM 13.0/14.0, Lane 2

Tires for Comparison		Mean Difference (A-B)	Std. Error	Sig. Level
Tire A	Tire B			
SRTT#1	SRTT#4	-.61	.04	.00
	SRTT#5	-.03	.04	.40
SRTT#4	SRTT#1	.61	.04	.00
	SRTT#5	.58	.04	.00
SRTT#5	SRTT#1	.03	.04	.40
	SRTT#4	-.58	.04	.00

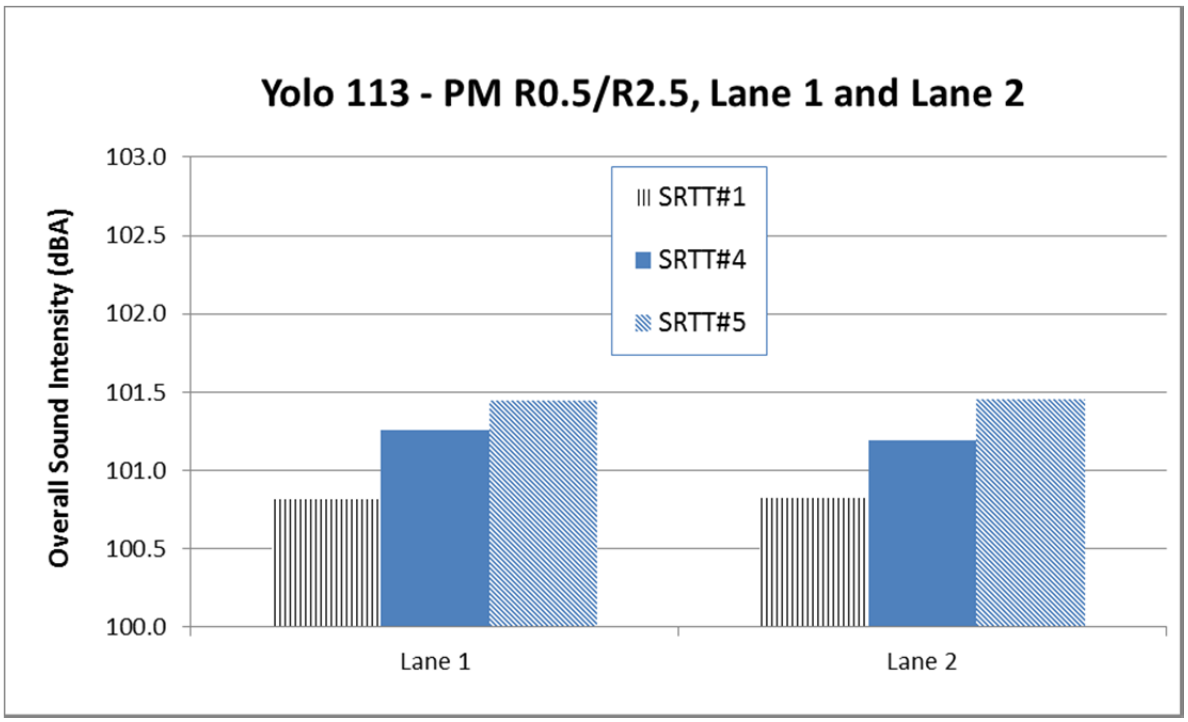


Figure C.4: Overview of OBSI from three tires on Yolo 113 – PM R0.5/R2.5, lanes 1 and 2.

Figure C.4 shows that on the Yolo 113 – PM R0.5/R2.5 section, SRTT#5 was 0.2 dBA louder than SRTT#4 in Lane 1 and 0.3 dBA louder in Lane 2.

Table C.5: Comparisons of SRTTs #1, #2, and #5 for Yolo 113 – PM R0.5/R2.5

Tires for Comparison		Lane 1			Lane 2		
Tire A	**Tire B**	**Mean Difference (A-B)**	**Std. Error**	**Sig. Level**	**Mean Difference (A-B)**	**Std. Error**	**Sig. Level**
SRTT#1	SRTT#4	-.44	.06	.00	-.37	.06	.00
	SRTT#5	-.63	.06	.00	-.63	.06	.00
SRTT#4	SRTT#1	.44	.06	.00	.37	.06	.00
	SRTT#5	-.19	.06	.00	-.26	.06	.00
SRTT#5	SRTT#1	.63	.06	.00	.63	.06	.00
	SRTT#4	.19	.06	.00	.26	.06	.00

Figure C.5 through Figure C.18 are plots of sound intensity differences for individual frequencies and show that there is a difference between the tires for the one-third octave bands, but they also show no apparent bias consistent across all frequencies. The average difference for overall OBSI was 0.2 dBA. Since this difference is within the standard error of the OBSI measurements, a decision was made to pool the data for overall OBSI and all frequencies without first applying a tire conversion factor.

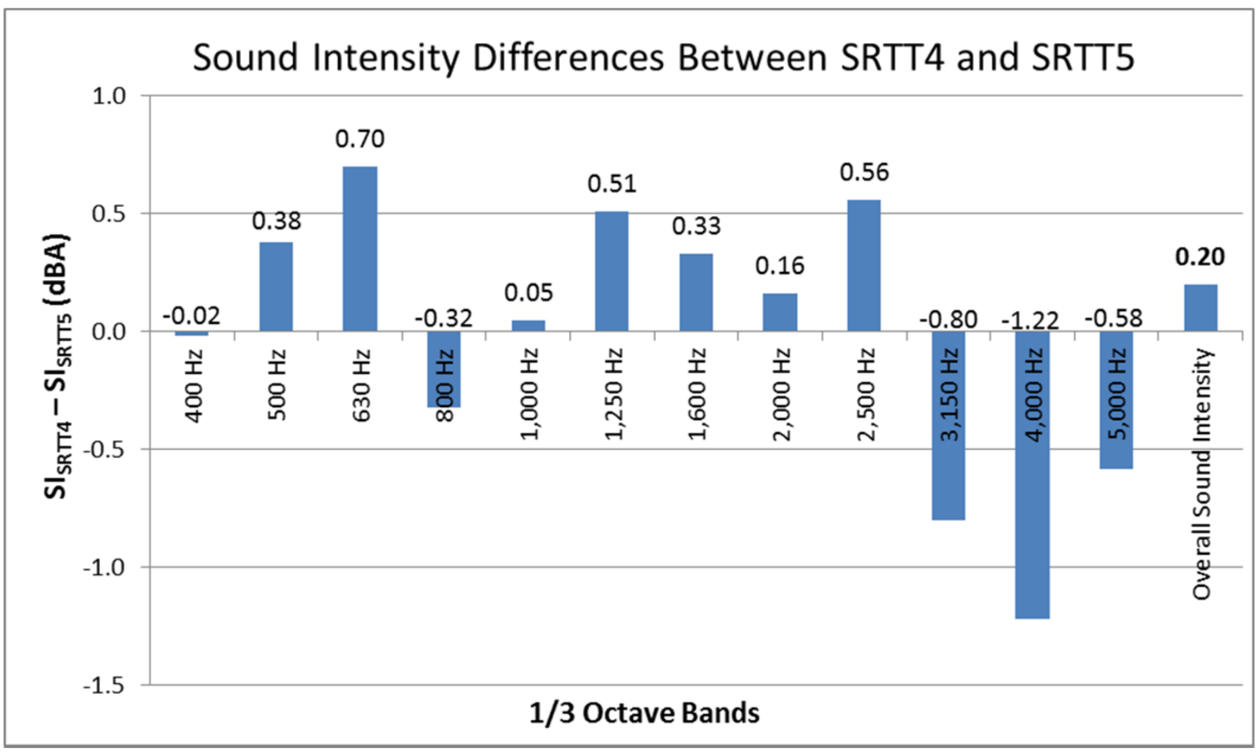


Figure C.5: Sound intensity differences measured with SRTT#4 and SRTT#5, at one-third octave bands.

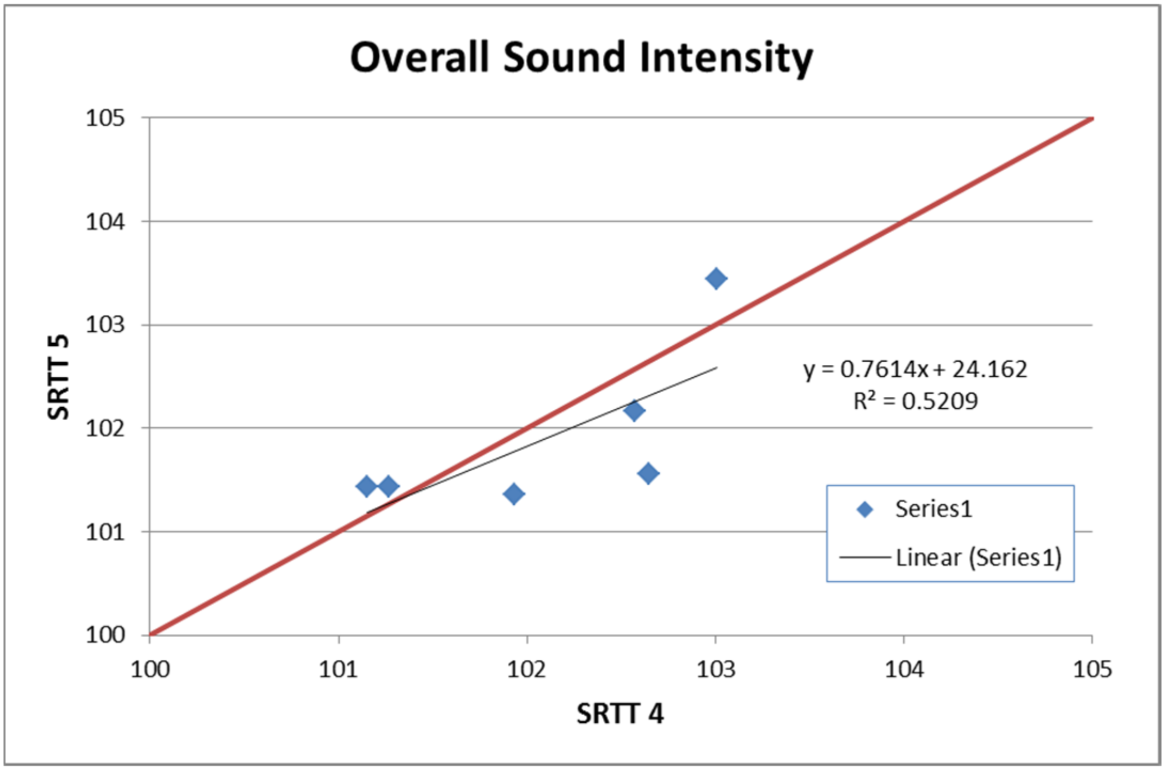


Figure C.6: Overall sound intensity difference measured with SRTT#4 and SRTT#5.

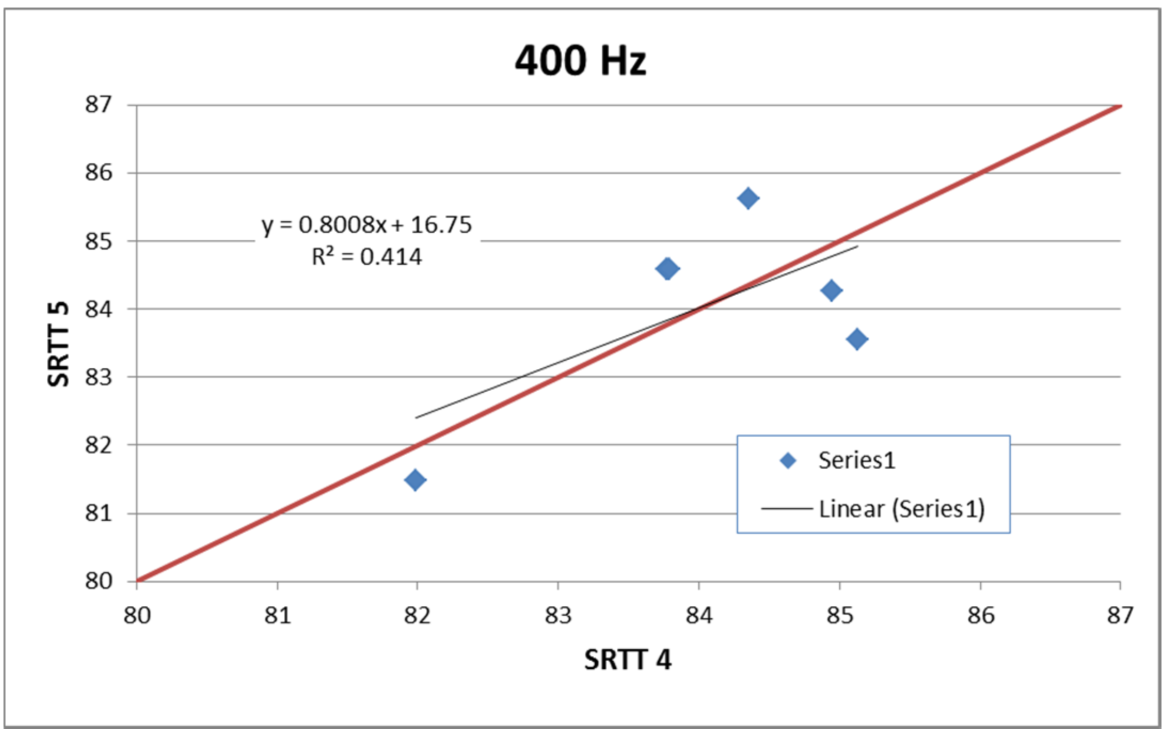


Figure C.7: OBSI at 400 Hz measured with SRTT#4 and SRTT#5.

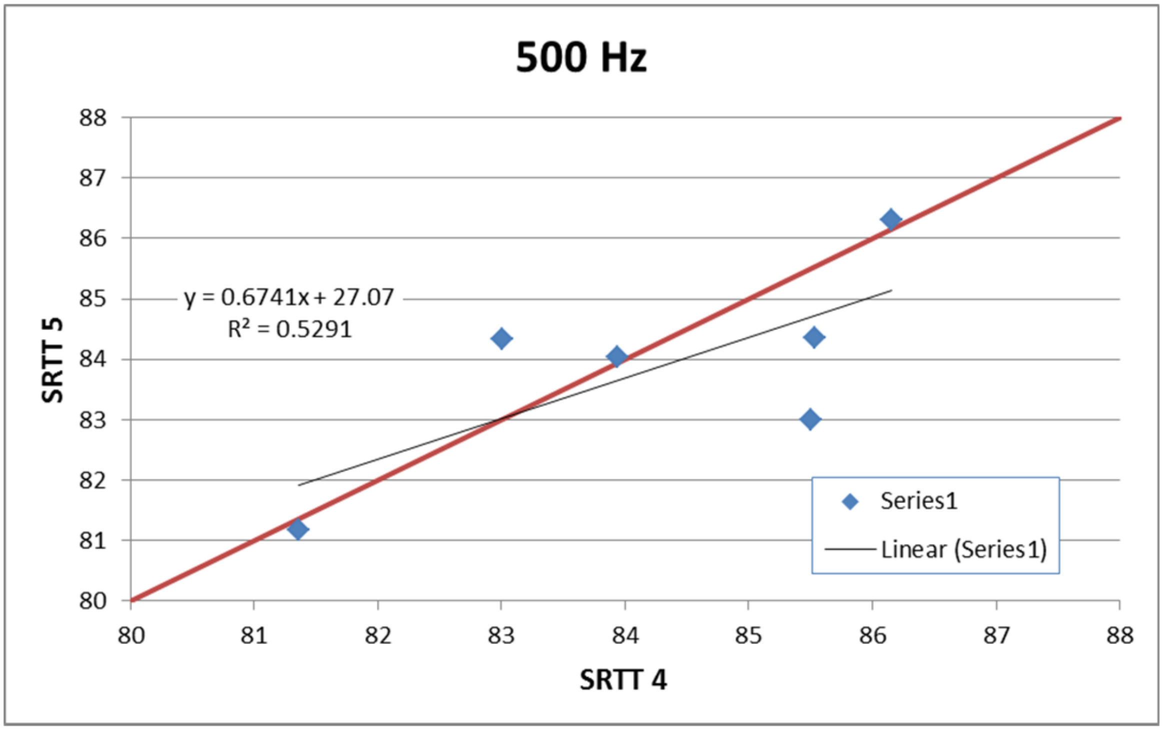


Figure C.8: OBSI at 500 Hz measured with SRTT#4 and SRTT#5.

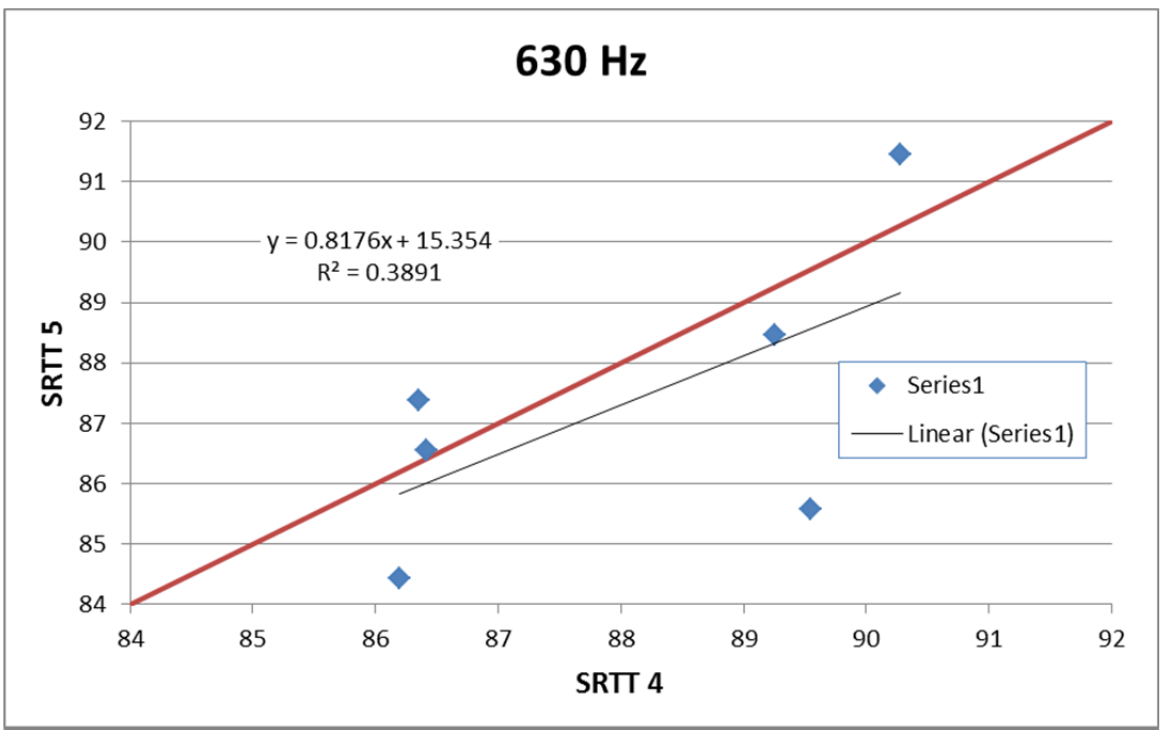


Figure C.9: OBSI at 630 Hz measured with SRTT#4 and SRTT#5.

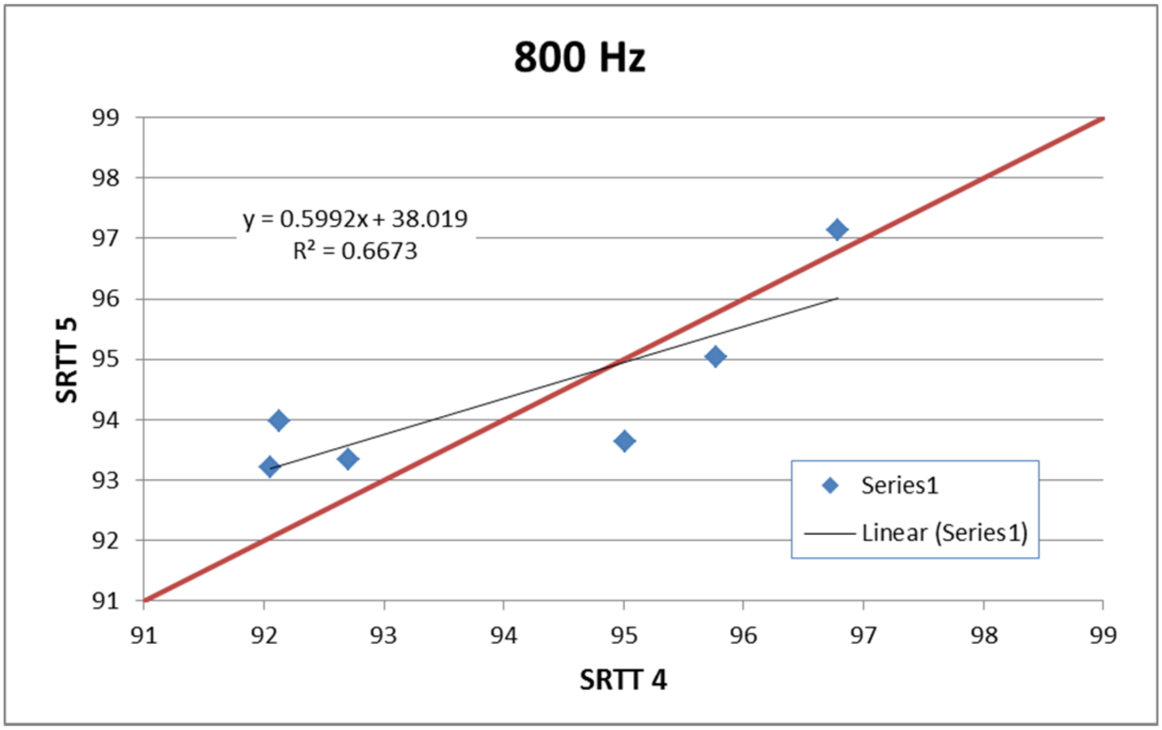


Figure C.10: OBSI at 800 Hz measured with SRTT#4 and SRTT#5.

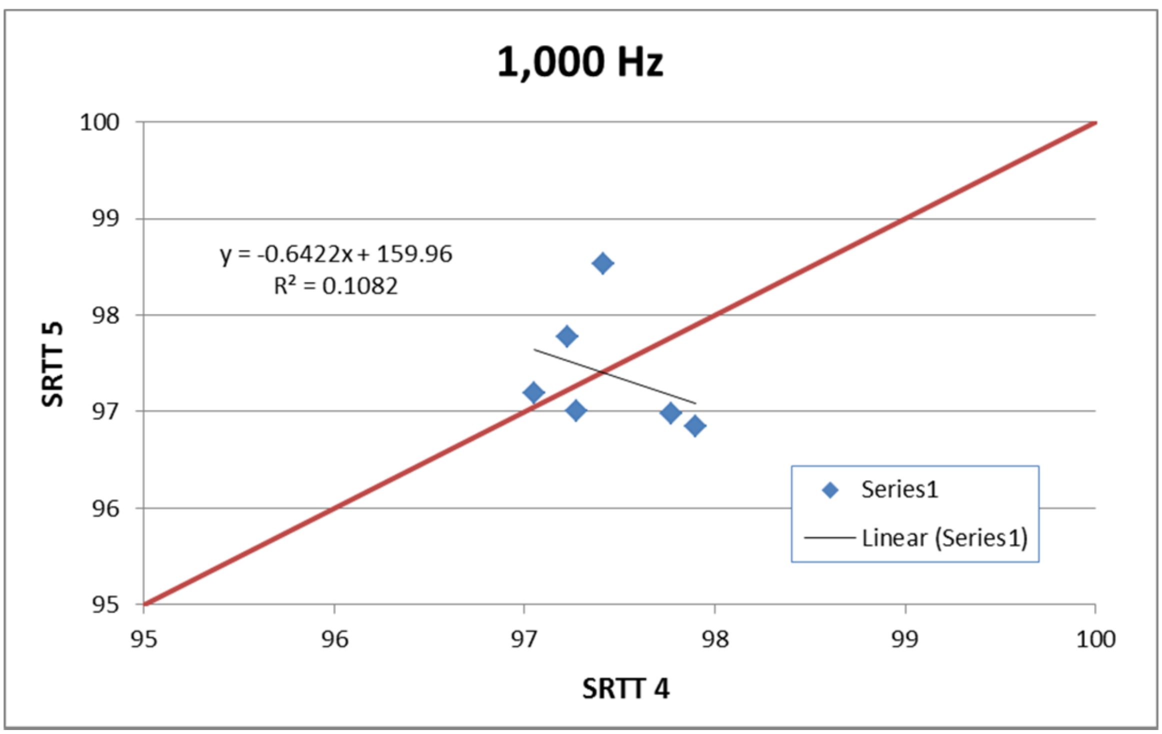


Figure C.11: OBSI at 1,000 Hz measured with SRTT#4 and SRTT#5.

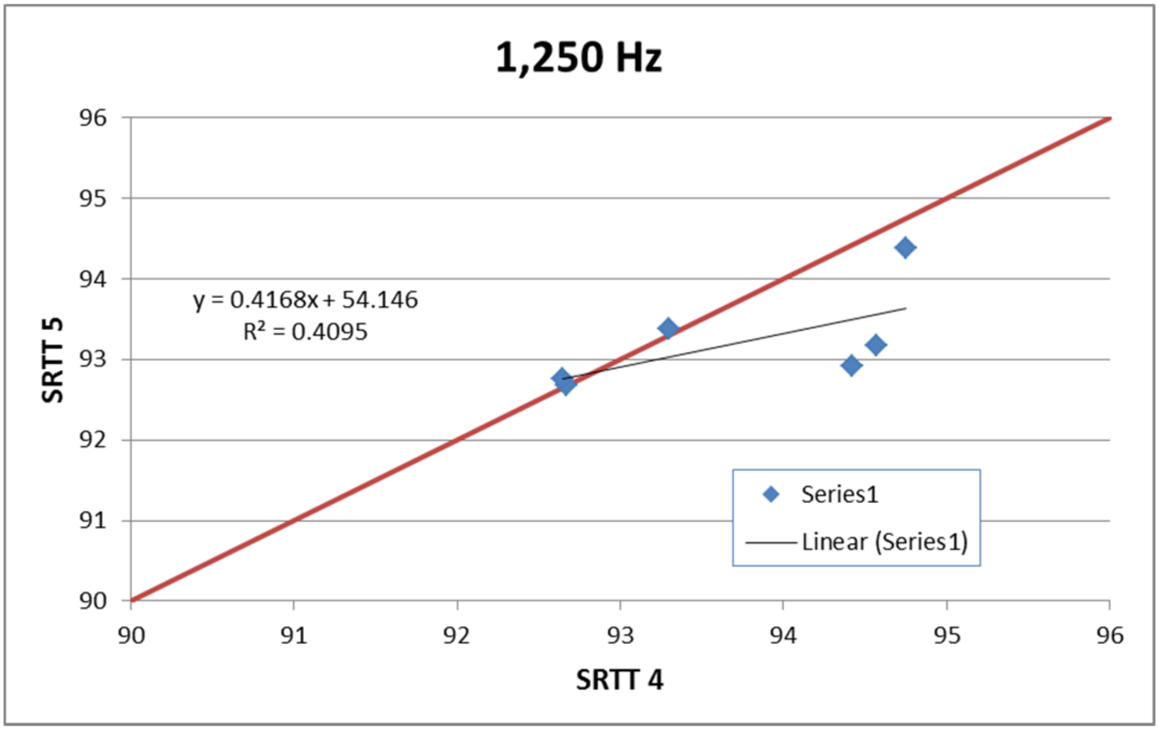


Figure C.12: OBSI at 1,250 Hz measured with SRTT#4 and SRTT#5.

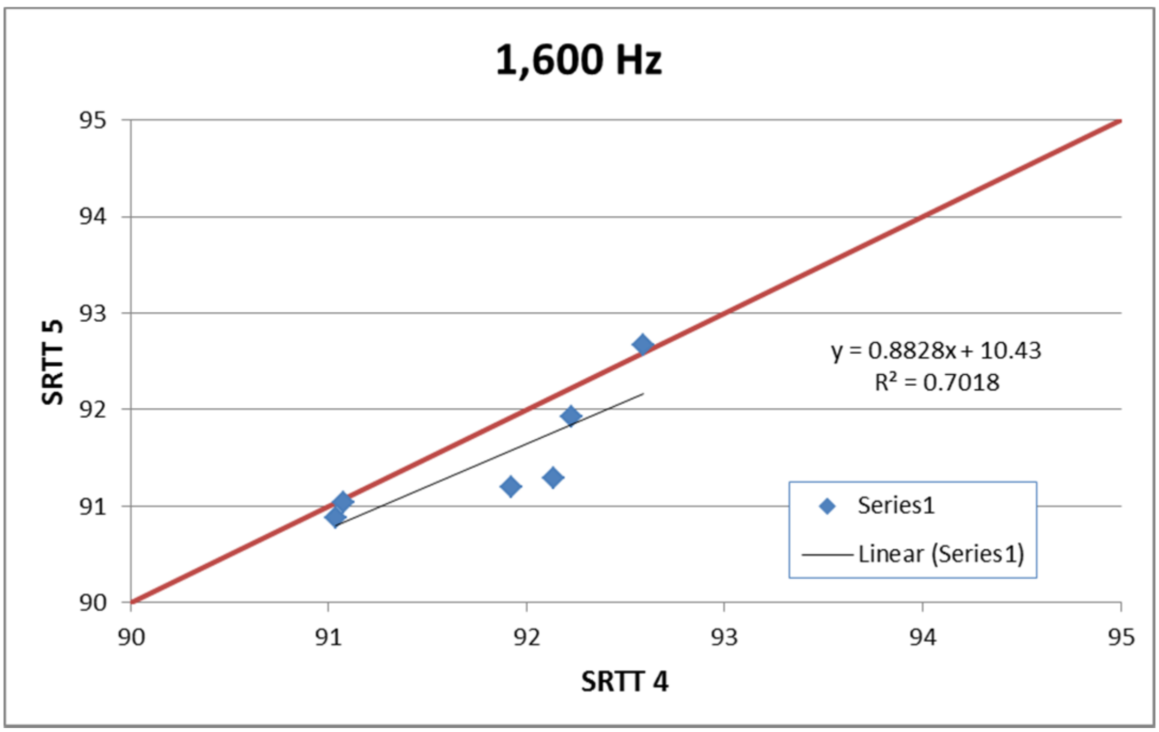


Figure C.13: OBSI at 1,600 Hz measured with SRTT#4 and SRTT#5.

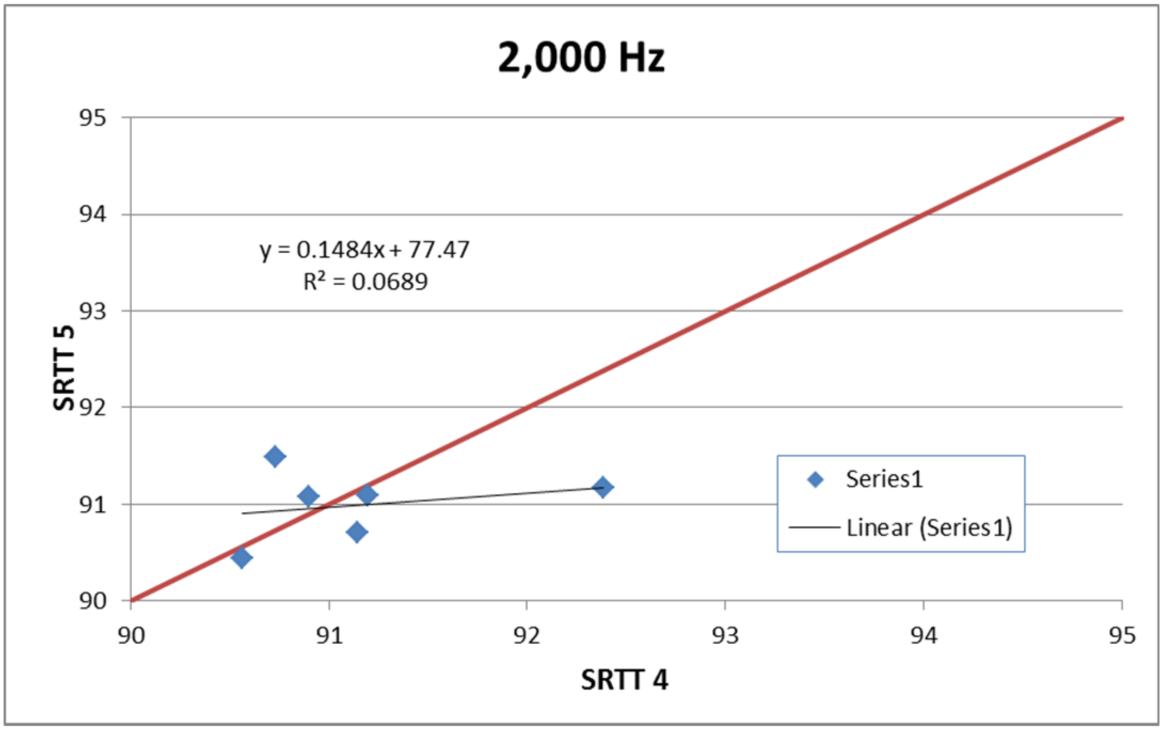


Figure C.14: OBSI at 2,000 Hz measured with SRTT#4 and SRTT#5.

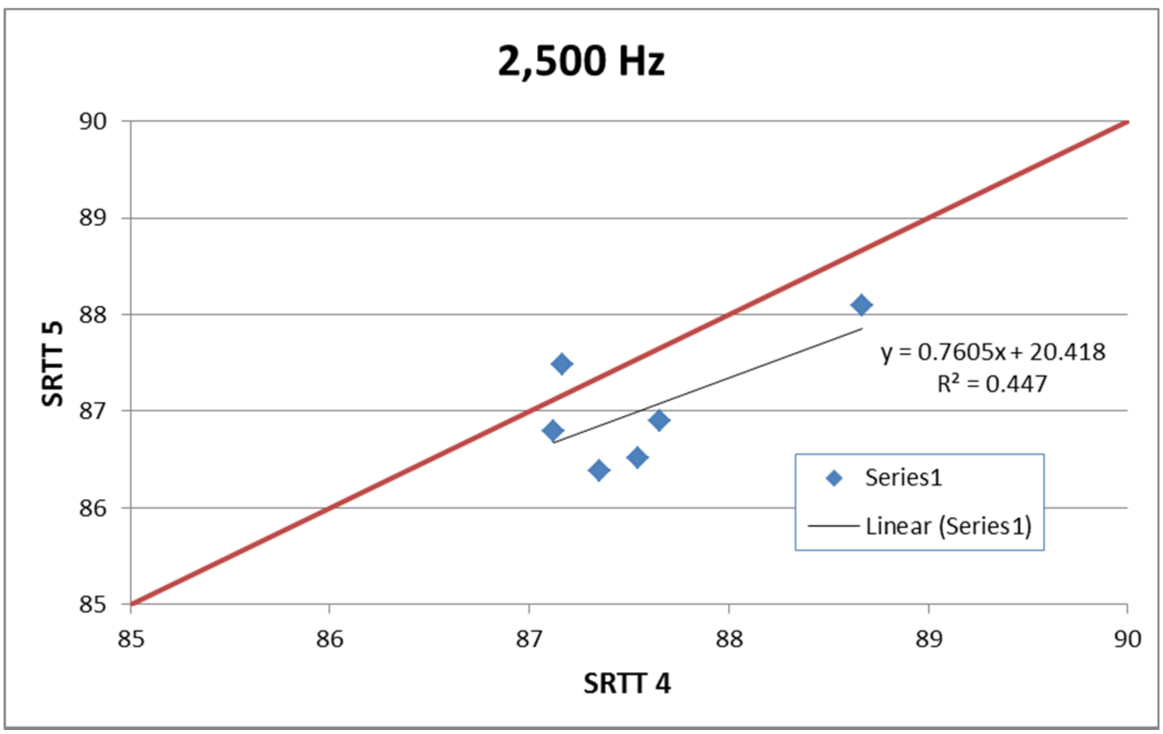


Figure C.15: OBSI at 2,500 Hz measured with SRTT#4 and SRTT#5.

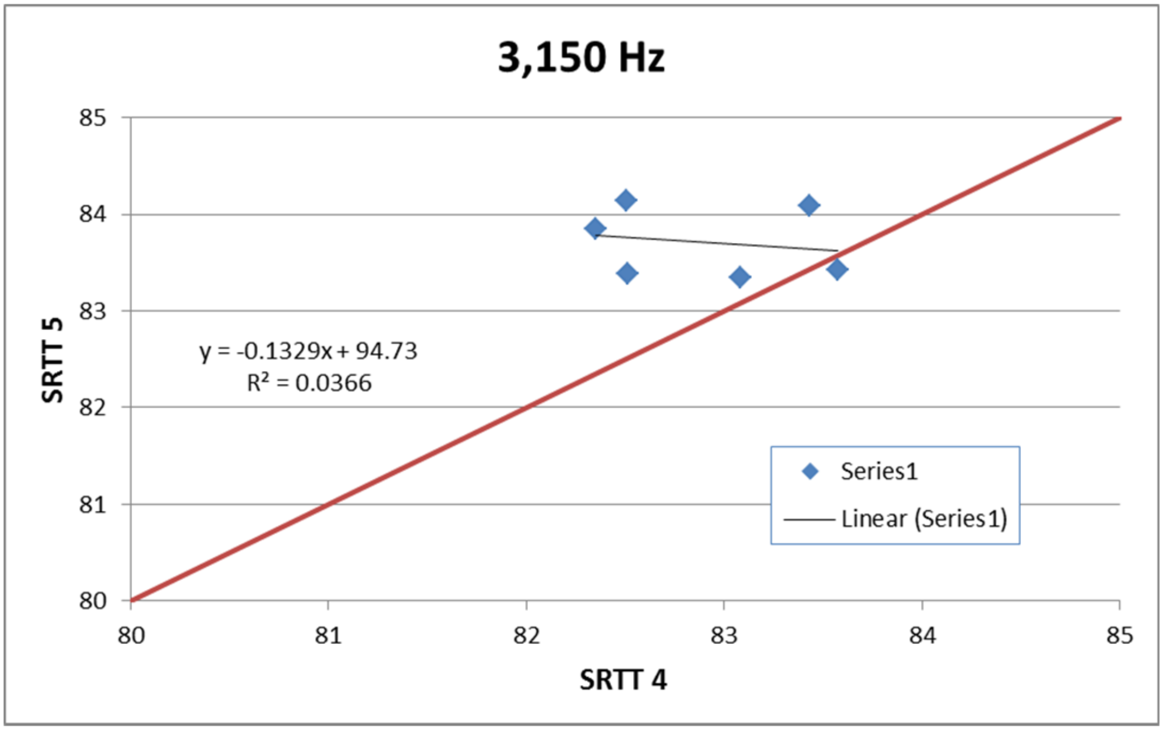


Figure C.16: OBSI at 3,150 Hz measured with SRTT#4 and SRTT#5.

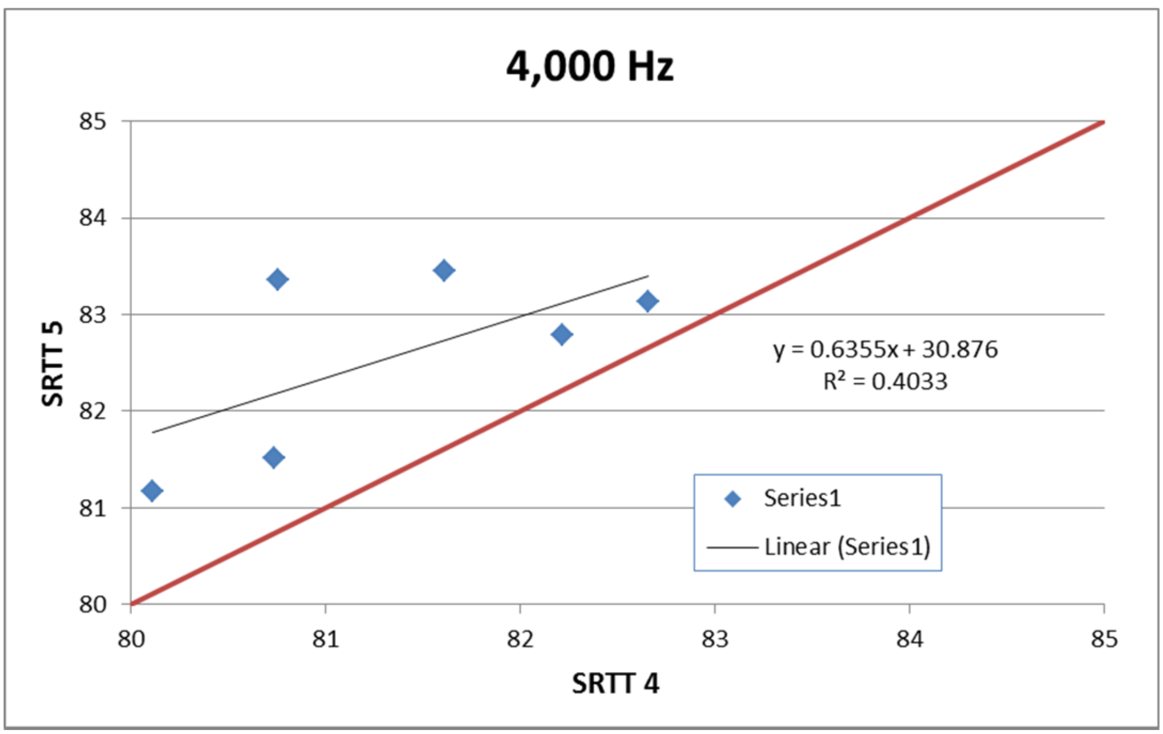


Figure C.17: OBSI at 4,000 Hz measured with SRTT#4 and SRTT#5.

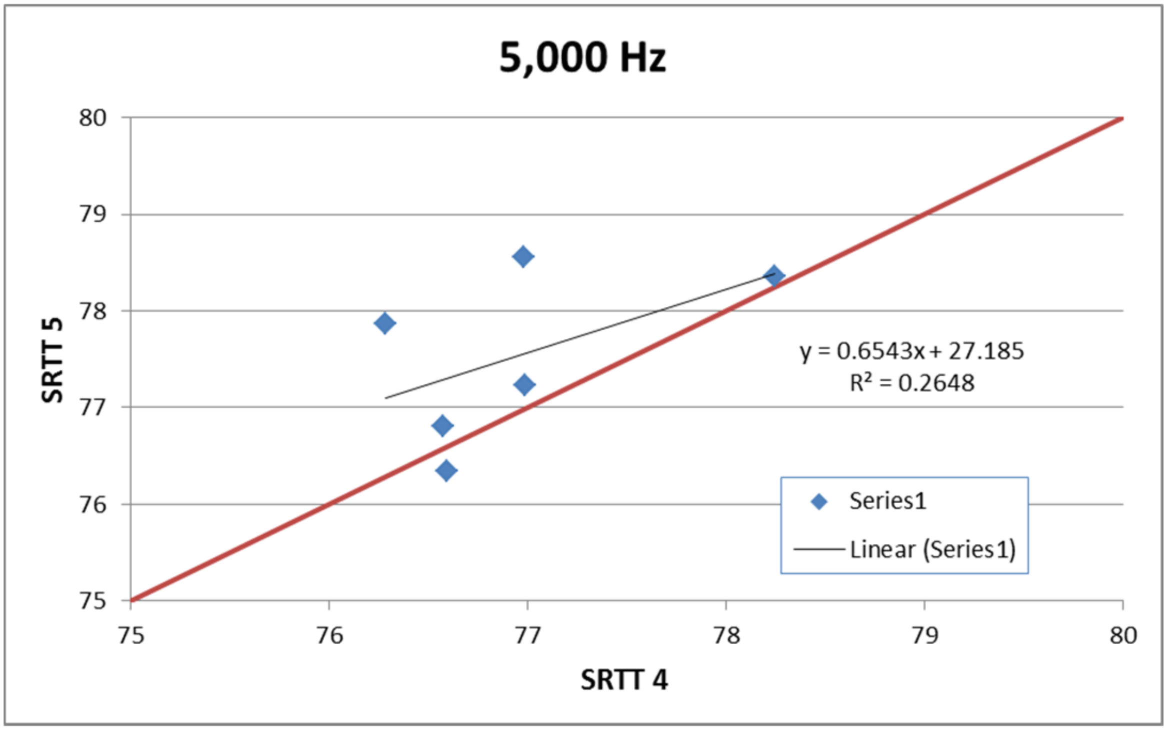


Figure C.18: OBSI at 5,000 Hz measured with SRTT#4 and SRTT#5.

Reference for Appendix C

1. Donavan, P., and D. Lodico. "Measuring Tire-Pavement Noise at the Source: Precision and Bias," Draft Final Report to the National Cooperative Highway Research Program (NCHRP) on Project 1-44 (1), July 14, 2011.

APPENDIX D: COMPARISON OF TWO TOWED SKID TRAILERS

As noted in Section 4.3.3, the ASTM E274 Skid Trailer testing was conducted with two different test vehicles. Although Caltrans alone performed the CDG and GnG testing, the pre-CDG testing was first conducted with one vehicle by Dynatest Consulting Inc. in December 2010 and then by Caltrans with a different vehicle—with a ribbed tire at 50 mph—in January 2011. Appendix D contains a comparison of the results measured by the two vehicles covering the two-mile test area on San Diego 5 between PM R35.8 and PM R37.9, and including the 2,000 foot test strip between southbound PM R37.15 and R36.80 in Lane 2.

Pre-CDG evaluations by Dynatest consisted of testing a single location per section with two or three replicate passes. The Caltrans pre-CDG evaluation tested each quarter-mile section two or three times with a single replicate. Table D.1 and Figure D.1 show the results of Skid Trailer testing by both Caltrans and Dynatest using ASTM E274.

Table D.1: ASTM E274 Skid Numbers on San Diego 5 with Ribbed Tire at 60 mph Using Different Test Operators

Direction	Lane	Test Trailer/ Operator	Station (miles) [Station 0 = PM R35.85]								Statistical *t*-test (p-value)
			0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	
North-bound	L1	Caltrans	52.0	49.3	54.7	52.5	54.7	57.0	54.3	52.0	0.5288
		Dynatest	53.1	54.6	55.1	55.1	57.9	56.1	50.0	53.1	
	L2	Caltrans	52.0	51.7	52.0	51.0	51.0	48.7	49.3	52.0	0.2795
		Dynatest	40.6	50.0	46.1	51.7	49.4	47.1	48.9	52.2	
	L5	Caltrans	36.7	37.0	41.0	41.0	44.0	43.7	40.5	41.0	0.2109
		Dynatest	38.3	40.5	37.0	41.7	40.5	38.9	42.2	43.0	
South-bound	L1	Caltrans	56.0	48.7	62.0	61.3	59.0	59.3	54.3	57.3	0.9664
		Dynatest	52.9	61.2	60.8	58.4	59.2	54.5	51.0	53.6	
	L2	Caltrans	51.5	47.5	48.3	49.3	50.0	55.3	54.3	54.0	0.4965
		Dynatest	56.1	52.4	52.0	54.1	48.0	50.4	44.9	44.3	
	L5	Caltrans	42.5	48.0	45.8	48.8	46.5	45.0	-	37.0	0.0002
		Dynatest	40.4	45.0	42.3	40.9	42.1	40.0	36.3	36.8	

These data show that there is some similarity between the two test vehicles over most of the lanes. Only Lane 5 southbound shows a statistical p-value less than 0.05, indicating a statistical difference between the skid resistance data measured by the two operators. Looking at all the data, the measured skid numbers differ by 3.5 points on average with neither operator always higher than the other. The tests in southbound Lane 2 show statistically similar averages, but the measured skid numbers differ by 5.5 points over all the stations with neither operator always higher than the other. Between PM R35.8 to PM R36.7, or Stations 0.0 and 0.9 in the charts, the Dynatest skid numbers are about 5 points higher than the Caltrans numbers. After approximately PM R36.7, or Station 0.9, the Caltrans numbers are several points higher than the Dynatest numbers. Based on these data, and considering that measurements were not performed at the exact same locations, the results were determined to be statistically similar and no adjustments were made to the data presented in Table 4.17 of Section 4.3.3.

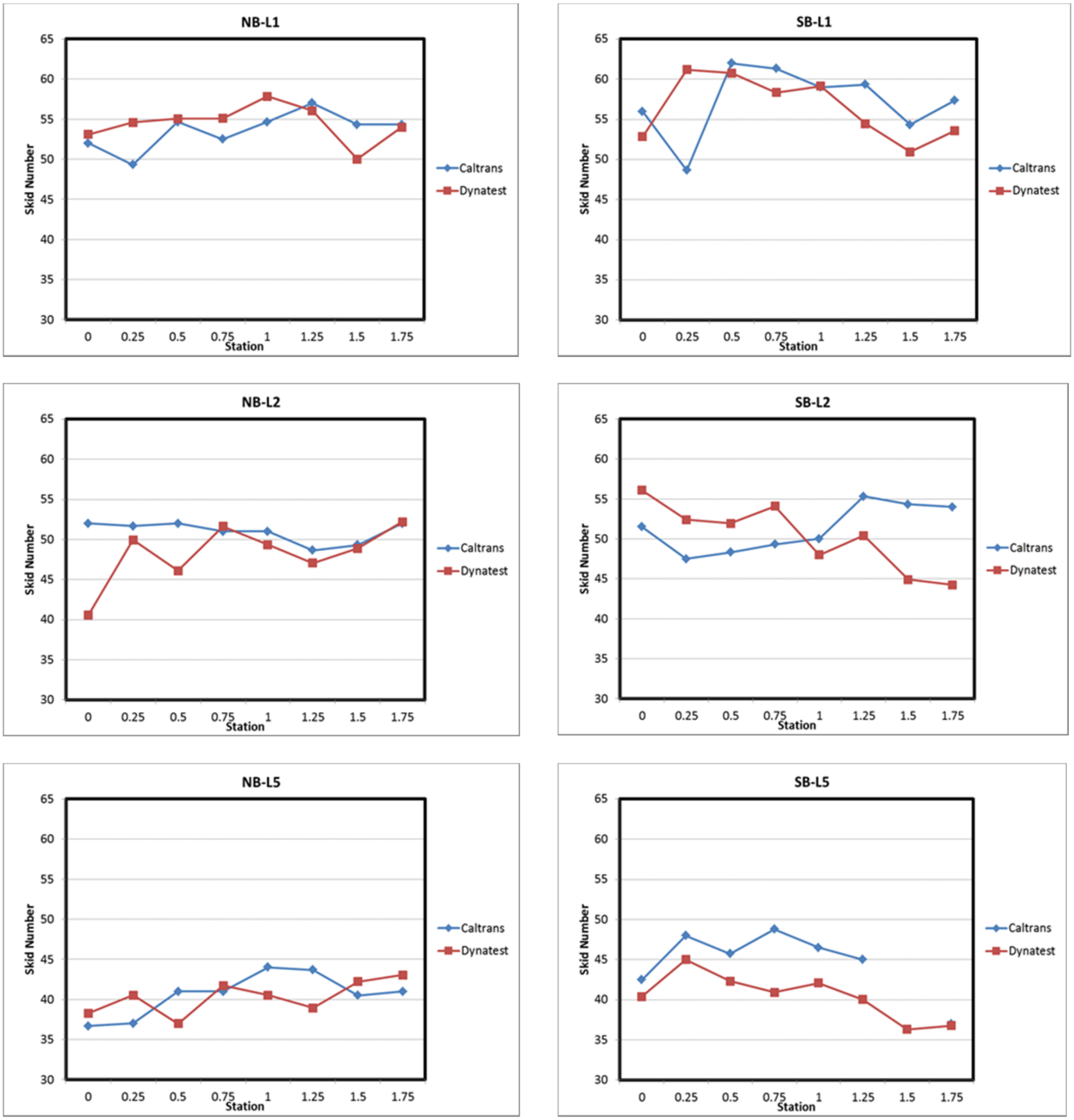


Figure D.1: Skid testing over two miles by Caltrans and Dynatest on San Diego 5, PM R35.8/R37.9. (Note: each station covers 0.25 miles, Station 0 equals PM R35.85, and Station 2.0 equals PM R37.85.) (NB = northbound, L5 = Lane 5)

APPENDIX E: COMPARISON OF TOWED SKID TRAILER AND PORTABLE SKID TESTER DATA

As discussed in Section 4.3, on three of the seven sections, both Towed Skid Trailer (ASTM E274) and Portable Skid Tester (CT 342) tests were conducted: Sacramento 5 – PM 20.0/21.5, Sacramento 80 – PM 13.0/14.0, and San Diego 5 – PM R35.8/R37.9. The Portable Skid Tester requires traffic control and covers a standard one hundred foot test area. The Towed Skid Trailer does not require traffic control and can sample large areas, testing every 200 to 300 feet depending on speed.

Because the accepted minimum criteria for the Towed Skid Trailer is 30 (*E1*) and 0.30 for the Portable Skid Tester (*E2*), *the Portable Skid Tester data presented here has been multiplied by 100 for the comparison*.

The Towed Skid Trailer data reported by IGGA were used for comparison with Portable Skid Tester data collected by Caltrans. The wheel used on the California device was smooth (following ASTM E1551), and the IGGA smooth-tire data collected at 40 mph was used for comparison. Only Portable Skid Tester data in the left wheelpath parallel to the direction of traffic, at zero degrees, were used for comparison.

In Section E.1 through Section E.3, plots of Towed Skid Trailer and Portable Skid Tester data precede discussion of the results. Section E.4 summarizes the comparison of Towed Skid Trailer and Portable Skid Tester testing.

E.1 Sacramento 5 – PM 20.0/21.5

The Towed Skid Trailer and Portable Skid Tester data from Sacramento 5 – PM 20.0/21.5 are shown in Table E.1. All the testing was conducted in the northbound direction. The E274 CDG data came from an area just south of the GnG evaluation area, and the CT 342 CDG data came from an interim surface. As noted in Section 3.1, the GnG construction began northbound at PM 18.7. Also included are results from another surface, termed Next Generation Lite (NGL), which was constructed as part of the Sacramento 5 project. (Further information regarding the NGL texture can be found in Section 3.2.) Statistics regarding the following discussion are located in Table I.39.

Table E.1: Friction Test Results from Sacramento 5 – PM 20.0/21.5 Northbound

CDG PM 18.1/18.8				GnG PM 18.7/19.3				NG LITE PM 20.5/20.7			
ASTM E274		CT 342		ASTM E 274		CT 342		ASTM E 274		CT 342	
PM[1]	**SN_{40}**	**PM**	**μ (x100)**	**PM**[1]	**SN_{40}**	**PM**	**μ (x100)**	**PM**[1]	**SN_{40}**	**PM**	**μ (x100)**
18.10	44	18.719	39	19.00	42	18.719	36	20.50	31	20.538	39
18.17	38	18.724	40	19.06	41	18.724	37	20.56	33	20.543	37
18.23	39	18.728	36	19.11	45	18.728	32	20.61	31	20.547	41
18.28	45	18.733	37	19.17	43	18.733	32	20.66	37	20.552	40
18.35	44	18.738	43	19.24	42	18.738	36			20.557	37
						18.757	36			20.576	37
						18.762	39			20.580	41
						18.766	35			20.585	39
						18.771	33			20.590	38
						18.776	34			20.595	40
										20.633	38
										20.637	39
										20.642	39
										20.647	40
										20.652	38
Avg.	**41.9**	**Avg.**	**39.0**	**Avg.**	**42.6**	**Avg.**	**35.0**	**Avg.**	**33.1**	**Avg.**	**38.9**
Std. Dev.	**3.3**	**Std. Dev.**	**2.7**	**Std. Dev.**	**1.6**	**Std. Dev.**	**2.3**	**Std. Dev.**	**2.7**	**Std. Dev.**	**1.4**

Note:
[1] PM for IGGA data is estimated from operator notes.

The data show that the friction measured on the CDG texture by both tests were equivalent. This was not the case for the GnG texture where the E274 test showed a negligible increase in friction from the CDG to the GnG texture (41.9 to 42.6), but the CT 342 test showed a significant decrease in the friction from CDG to GnG (39.0 to 35.0).

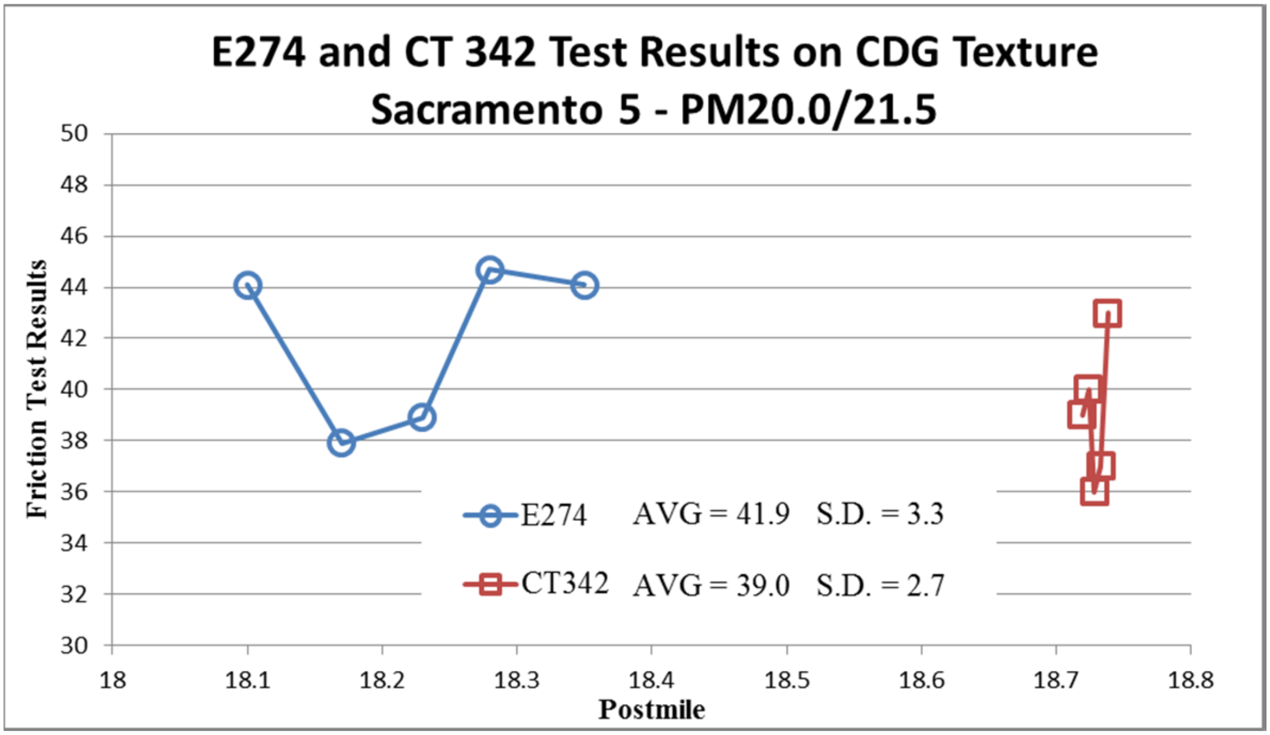


Figure E.1: ASTM E274 and CT 342 data on the CDG texture from the Sacramento 5 – PM 20.0/21.5 Project.

Figure E.1 above shows both the E274 and CT 342 data on the CDG texture. These two tests yielded similar results, although the E274 test sampled 0.25 miles and the CT 342 test sampled 0.02 miles.

Figure E.2 below shows both the E274 and CT 342 data on the GnG texture. The two tests yielded dissimilar results in this case, with the E274 test reporting greater friction on the texture than the CT 342 test. This time, the E274 test sampled 0.25 miles while the CT 342 test covered 0.06 miles.

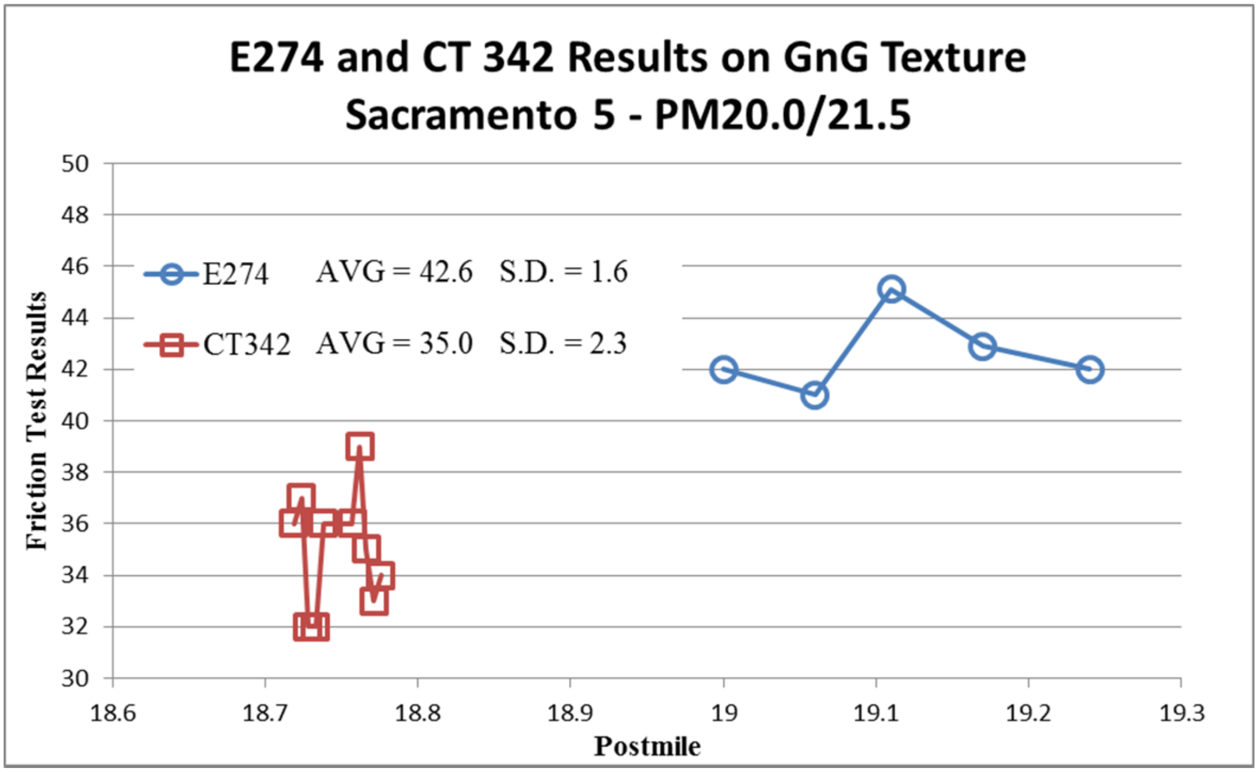


Figure E.2: ASTM E274 and CT 342 data on the GnG texture from Sacramento 5 – PM 20.0/21.5 Project.

Figure E.3 shows both the E274 and CT 342 data on the NGL texture. These two tests did not yield similar results on the GnG texture, with the CT 342 test reporting more friction than the E274 test. Here, the E274 test sampled 0.16 miles while the CT 342 test covered 0.11 miles.

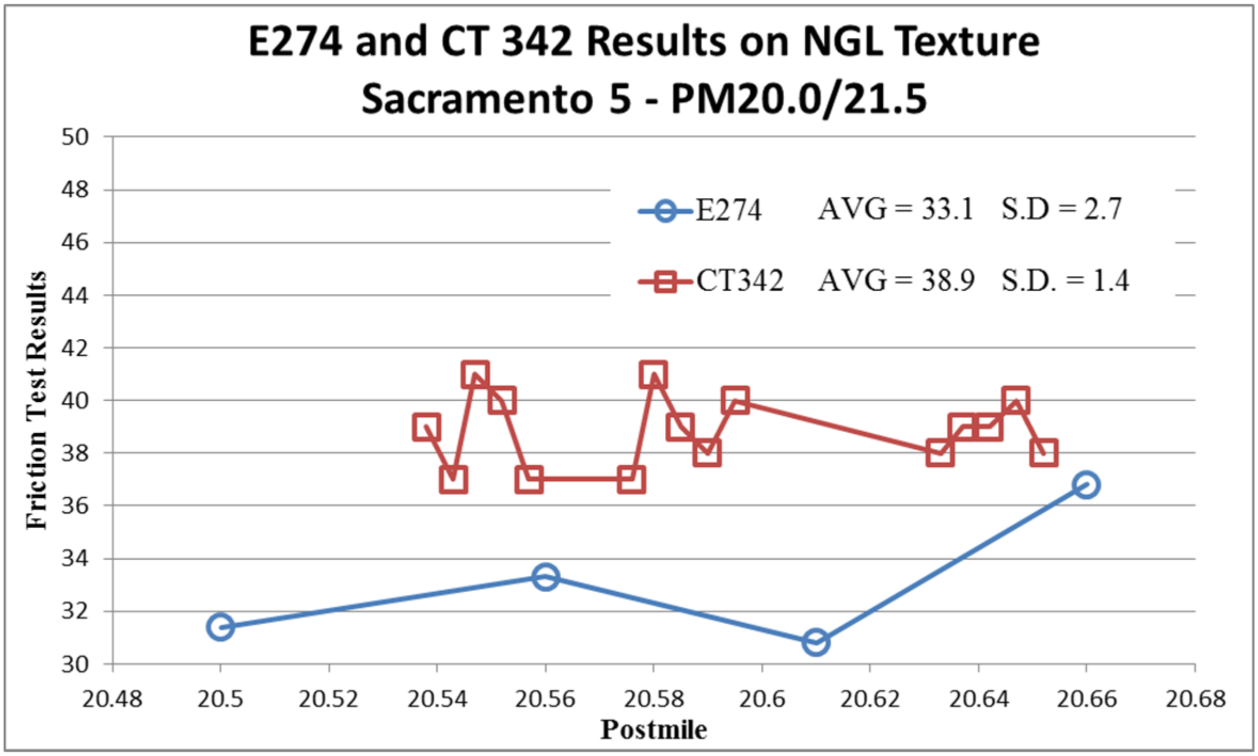


Figure E.3: ASTM E274 and CT 342 data on the NGL texture from Sacramento 5 – PM 20.0/21.5 Project.

E.2 Sacramento 80 – PM13.0/14.0

The Towed Skid Trailer and Portable Skid Tester data from Sacramento 80 – PM 13.0/14.0 are shown in Table E.2. Testing was conducted in both directions and, as noted, there was no comparable CDG texture for this section. Statistics regarding the following discussion are located in Table I.40.

Table E.2: Friction Test Results on the GnG Texture from the Sacramento 80 – PM 13.0/14.0 Project

GnG – PM 13.8/14.2 Westbound		GnG – PM 13.0/13.5 Eastbound			
E274		E274		CT 342	
PM[1]	SN_{40}	PM[1]	SN_{40}	PM	μ (x100)
14.29	30	13.05	43	13.500	32
14.21	29	13.13	41	13.505	35
14.14	33	13.22	36	13.509	31
14.09	27	13.29	37	13.514	30
14.03	27	13.37	39	13.519	29
13.96	29	13.44	38	13.538	24
13.89	28			13.543	26
13.80	28			13.547	27
				13.552	30
				13.557	30
				13.576	30
				13.580	29
				13.585	29
				13.590	31
				13.595	34
Avg.	**28.8**	**Avg.**	**39.0**	**Avg.**	**29.8**
Std. Dev.	**1.9**	**Std. Dev.**	**2.4**	**Std. Dev.**	**2.8**

[1] PM for IGGA data was estimated from operator notes.

The E274 test sampled 0.4 miles eastbound and the CT 342 test sampled 0.1 miles eastbound. Figure E.4 shows the E274 and CT 342 data on the GnG texture. The data from these two tests are statistically dissimilar. The data show that the friction measured on the GnG texture from both tests in the eastbound direction was *not* equivalent. That was not the case for the E274 results on the westbound GnG texture. The westbound E274 data was equivalent to the eastbound CT 342 data. This is the site where the two results show friction less than the recommended minimum (*E1, E2*).

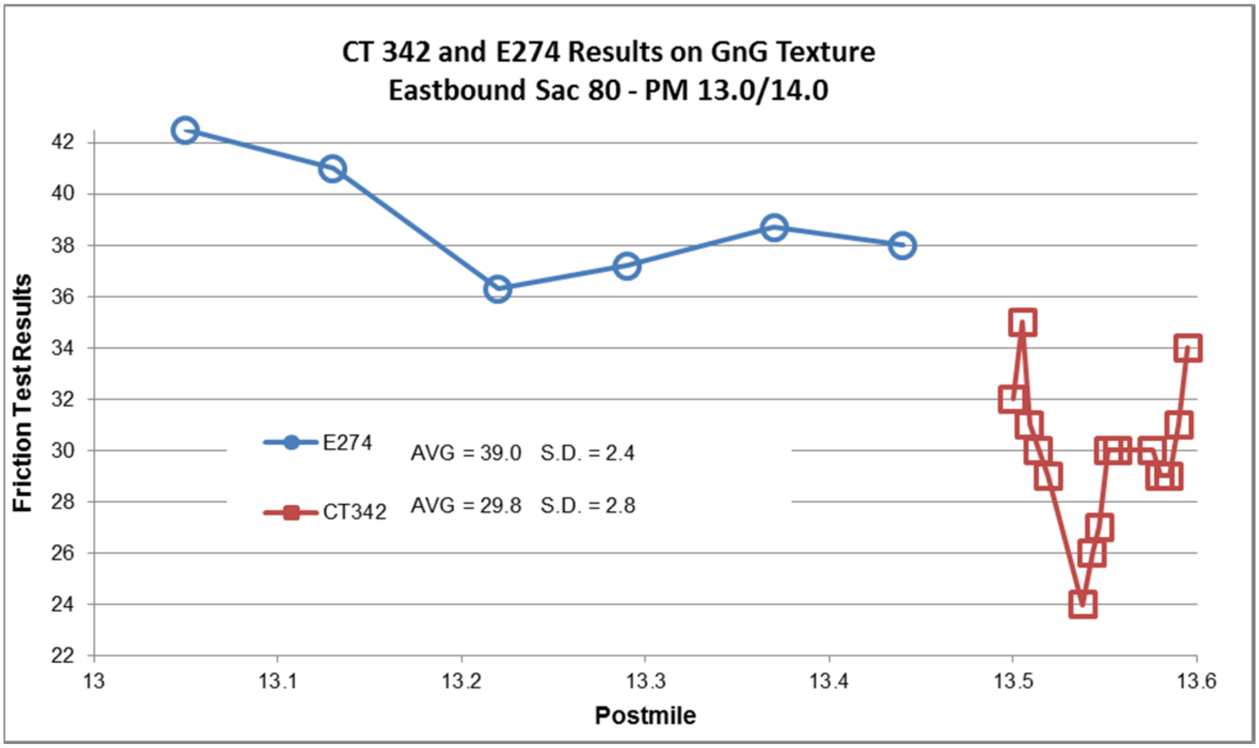


Figure E.4: ASTM E274 and CT 342 data on the GnG texture from Sacramento 80 – PM 13.0/14.0 Project.

E.3 San Diego 5 – PM R35.8/R37.9

The Towed Skid Trailer and Portable Skid Tester data from the San Diego 5 project are shown in Table E.3. Testing was conducted in both directions, but only three sections of this project were available for comparison. The comparison sections are the CDG south of the GnG section in northbound Lane 5 (PM R35.3/R36.2), the CDG north of the GnG section in southbound Lane 5 (PM R37.5/R37.9), and the GnG section in southbound Lane 5 (PM R36.4/R37.4). Statistics regarding the comparisons of those locations are located in Table I.41.

Table E.3: Friction Test Results from the San Diego 5 Project, Lane 5

	CDG South of GnG Section PM R35.3/R36.2				GnG Section PM R36.4/R37.4				CDG North of GnG Section PM R37.5/R37.9			
	E274		CT 342		E274		CT 342		E274		CT 342	
	PM	SN_{40}	PM	μ (x100)	PM	SN_{40}	PM	μ (x100)	PM	SN_{40}	PM	μ (x100)
Northbound Lane 5	35.30	38	35.80	31	36.40	33			37.60	41		
	35.37	39	36.05	35	36.46	33			37.65	46		
	35.44	41			36.53	38			37.72	45		
	35.49	43			36.58	37			37.78	42		
	35.56	40			36.64	38			37.85	47		
					36.75	36						
	Ave	**40.4**	**Ave**	**33.0**	**Ave**	**35.8**			**Ave**	**44.2**		
	Std. Dev.	**1.9**	**Std. Dev.**	**2.8**	**Std. Dev.**	**2.3**			**Std. Dev.**	**2.7**		
	CDG South of GnG Section PM R35.3/R36.2				**GnG Section PM R36.4/R37.4**				**CDG North of GnG Section PM R37.5/R37.9**			
	E274		**CT 342**		**E274**		**CT 342**		**E274**		**CT 342**	
	PM	**SN_{40}**	**PM**	**μ (x100)**	**PM**	**SN_{40}**	**PM**	**μ (x100)**	**PM**	**SN_{40}**	**PM**	**μ (x100)**
Southbound Lane 5	35.85	40			37.01	42	36.35	33	37.49	39	37.65	50
	35.91	44			37.08	40	36.60	29	37.55	44	37.90	44
	35.96	42			37.15	43	36.85	28	37.61	46		
	36.03	44			37.21	43	36.85	29	37.69	41		
	36.09	44			37.28	39	37.10	28	37.76	42		
					37.36	47						
	Avg.	**42.9**			**Avg.**	**42.4**	**Ave**	**29.4**	**Avg.**	**42.4**	**Avg.**	**47.0**
	Std. Dev.	**1.8**			**Std. Dev.**	**2.8**	**Std. Dev.**	**2.1**	**Std. Dev.**	**2.8**	**Std. Dev.**	**4.2**

Note:
[1] PM for IGGA data is estimated from operator notes.

The data in Table E.3 (statistical comparison in Table I.41) show that the friction measured on the CDG textures from both tests is similar but this statistical similarity is questionable because of the scant data. ASTM E274 reported greater friction south of the GnG section while CT 342 reported greater friction north of it. The two tests were also statistically dissimiliar for the GnG texture: CT 342 measured substandard friction (29) but the E274 reported sufficient friction (42).

E.4 Summary of E274 and CT 342 Comparison

Table E.4 shows the averaged values of data from the three sections where the Portable Skid Tester and Towed Skid Trailer testing were compared. The results show similarities among the data sets for the CDG texture, but not for the GnG texture. Since this finding was discovered in such a limited comparison, with just a few sections and surface textures sampled, it is suggested that a larger experiment be undertaken to address the potential use of the E274 Towed Skid Trailer in lieu of the CT 342 Portable Skid Tester for testing the friction characteristics of pavement surfaces.

Table E.4: Average Skid Number for CDG and GnG Surfaces Using Smooth Tires

		CDG				GnG			
		E274		CT 342		E274		CT 342	
Project	**Test Location**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Sac 5 – PM20.0/21.5	NB	42	3	39	3	43	2	35	2
Sac 80 – PM13.0/14.0	EB					39	2	30	3
	WB					29	2		
SD 5 – PMR35.8/R37.9	NB	42	3	33	3	36	2		
	SB	43	2	47	2	42	3	29	2

E.5 References for Appendix E

1. Jayawickrama, P. W., R. Prassana, and S. P. Senadheera. "Survey of State Practices to Control Skid Resistance on Hot-mix Asphalt Concrete Pavements." Transportation Research Record 1536, Transportation Research Board, National Research Council, Washington, D.C., 1996, p. 52-58.
2. Fog Seal Guidelines. State of California, Department of Transportation, Office of Pavement Preservation, Sacramento, California, October 2003.

APPENDIX F: COMPARISON OF SKID NUMBERS CALCULATED WITH CIRCULAR TEXTURE METER AND DYNAMIC FRICTION TESTER DATA

Data from the Circular Texture Meter (CTM) and the Dynamic Friction Tester (DFT) can be used to estimate skid numbers produced by the Towed Skid Trailer test, ASTM E274. The mean profile depth (MPD) data from the CTM and the friction coefficient at 20 km/h from the DFT are used.

As Figure F.1 shows, the circular track measured by the CTM can be partitioned into eight segments. Segments A and E provide measurements that are parallel to the direction of traffic, Segments C and G provide measurements that are perpendicular to the direction of traffic, and the remaining four segments, B, D, F, and H, provide measurements at 45 degrees to the direction of traffic. To investigate whether the longitudinal orientation of the pre-CDG, CDG, pre-GnG, and GnG surfaces can be identified, the results from these directional measurements are presented.

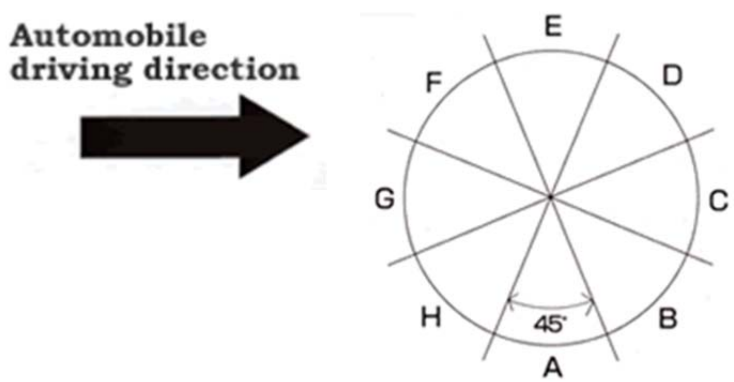


Figure F.1: Circular Track Meter arc segments.

The following eight tables show the estimated skid numbers for all seven projects using the following MPD values: the average of all the segments (All), the parallel segments (Parallel), the segment at 45 degrees (45-deg), and the perpendicular segments (Perpendicular). Table F.1 through Table F.4 cover six of the seven projects, and Table F.5 through Table F.8 cover the San Diego 5 project. (As noted earlier, CDG measures for San Diego 5 were not taken.) Each table shows a different surface texture.

While there are differences in the estimated values, there is no consistent difference between the measurements using all the segments, the parallel segments, the perpendicular segments, or the segments at 45 degrees. With this data, no conclusive distinction has been drawn in regard to the use of the CTM and DFT to estimate skid numbers according to ASTM E274.

Table F.1: Skid Numbers Calculated with CTM and DFT Data on the Pre-CDG Surface

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
SAC5-PM18.7-NB-L1	31	31	31	26	49	49	49	43
BWP	32	32	32	22	51	50	51	38
LWP	30	31	30	31	47	48	47	47
SAC5-PM2.9-NB-L1	47	46	48	45	64	64	65	62
BWP	53	47	53	46	71	66	70	63
LWP	40	45	44	43	57	63	60	60
SAC80-PMR13.5-EB-L2	25	29	28	27	43	47	46	44
BWP	27	27	28	23	46	46	46	41
LWP	24	30	29	30	40	48	46	48
SJ99-PM30.5-NB-L1	32	31	33	33	48	47	49	49
BWP	31	30	33	33	48	47	50	50
LWP	33	33	33	34	48	48	48	48
YOL113-PMR1.06-SB-L1	23	27	25	24	37	42	40	40
BWP	26	27	25	22	41	43	40	37
LWP	19	26	25	27	34	42	40	43

Table F.2: Skid Numbers Calculated with CTM and DFT Data on the CDG Surface

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
SAC5-PM18.7-NB-L1	49.6	42.8	43.0	44.7	70.6	63.9	62.3	65.2
BWP	45.4	43.2	39.6	44.5	66.9	65.0	59.6	66.2
LWP	53.8	42.5	46.3	45.0	74.4	62.7	65.1	64.2
SAC80-PM13.5-EB-L2	44.1	43.8	46.3	45.9	60.9	62.1	62.3	62.4
BWP	44.5	45.8	48.5	44.3	61.2	64.1	64.1	61.0
LWP	43.7	41.8	44.1	47.4	60.6	60.1	60.6	63.7
SJ99-PM30.5-NB-L1	38.6	37.4	40.0	40.9	55.1	54.5	56.5	57.6
BWP	44.6	43.2	45.0	44.6	61.2	60.5	61.1	61.1
LWP	32.6	31.6	35.0	37.1	49.1	48.5	51.9	54.2

Table F.3: Skid Numbers Calculated with CTM and DFT Data on the Pre-GnG Surface

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
SAC5-PM18.7-NB-L1	18.8	18.2	22.2	22.7	34.7	34.2	39.1	39.6
BWP	18.9	18.5	22.4	23.7	34.8	34.6	39.3	40.8
LWP	18.7	17.8	22.1	21.6	34.6	33.8	38.9	38.4
SAC5-PM2.9-NB-L1	15.1	17.3	17.9	18.4	30.0	33.2	33.9	34.6
BWP	12.8	17.3	18.0	18.4	26.9	33.3	34.2	34.8
LWP	17.4	17.3	17.8	18.5	33.1	33.0	33.6	34.5
SAC80-PM13.5-EB-L2	19.3	15.1	18.9	21.5	36.2	30.4	35.6	39.0
BWP	20.0	16.2	21.0	20.3	37.2	32.0	38.5	37.5
LWP	18.7	14.1	17.0	22.6	35.2	28.9	32.9	40.4

Table F.4: Skid Numbers Calculated with CTM and DFT Data on the GnG Surface

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
SAC5-PM18.7-NB-L1	38.3	31.2	35.6	33.9	51.5	45.3	48.7	45.7
BWP	39.3	31.9	33.4	34.2	51.7	45.9	46.0	45.8
LWP	37.3	30.5	37.7	33.6	51.3	44.8	51.3	45.5
SAC5-PM2.9-NB-L1	28.7	23.8	27.0	29.8	40.8	37.7	38.9	41.9
BWP	29.9	27.8	34.1	31.8	43.2	42.2	47.6	45.0
LWP	27.6	20.1	20.3	27.9	38.6	33.5	30.8	39.0
SAC80-PM13.5-EB-L2	26.4	26.9	27.1	30.7	42.4	43.3	43.2	47.0
BWP	28.4	30.3	30.5	33.1	43.8	46.5	46.0	48.7
LWP	24.4	23.6	23.8	28.4	41.0	40.0	40.4	45.3
SAC50-PMR13.5-WB-L4	21.1	19.6	20.6	21.3	34.7	33.0	34.0	35.1
BWP	20.4	19.4	19.2	21.4	34.1	33.2	32.5	35.3
RWP	21.8	19.9	22.0	21.2	35.3	32.8	35.5	34.9
SJ99-PM30.5-NB-L1	36.2	36.1	37.5	39.1	51.1	51.1	52.6	54.1
BWP	32.3	37.4	39.6	40.1	47.1	52.5	55.3	55.4
LWP	40.3	34.8	35.2	38.0	55.5	49.5	49.6	52.6

Table F.5: Skid Numbers Calculated with CTM and DFT Data on the San Diego 5 Pre-CDG Surface
(Note: average for each direction appears in bold.)

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
NB Avg.	**29.3**	**28.3**	**30.9**	**30.2**	**44.6**	**44.1**	**46.4**	**45.7**
Lane 1	36.4	33.2	38.2	35.2	52.9	50.0	55.0	51.1
BWP	42.8	35.6	42.8	40.2	60.4	53.6	60.8	56.2
LWP	38.1	37.0	38.6	32.1	54.9	54.1	55.3	48.5
RWP	28.4	27.1	33.4	33.3	43.5	42.4	48.9	48.6
Lane 2	22.2	23.3	23.6	25.3	36.3	38.3	37.8	40.3
BWP	23.6	25.4	27.4	29.9	38.5	41.0	42.8	45.9
LWP	18.6	25.1	18.6	22.3	32.3	40.5	32.3	37.0
RWP	24.2	19.5	24.7	23.6	38.2	33.2	38.4	37.8
Lane 5								
BWP								
LWP								
RWP								
SB Avg.	**33.0**	**30.6**	**33.6**	**31.4**	**50.4**	**47.7**	**51.1**	**48.3**
Lane 1	37.8	36.2	37.9	34.0	56.7	54.9	57.0	52.5
BWP	34.0	39.6	39.1	38.1	52.3	58.8	58.4	57.7
LWP	39.5	32.9	35.2	34.8	58.5	51.5	53.3	52.8
RWP	39.8	36.0	39.5	28.9	59.4	54.4	59.2	46.9
Lane 2	32.9	31.8	35.1	34.0	50.3	49.5	52.9	51.2
BWP	31.1	30.5	37.5	38.4	48.5	48.1	56.0	56.7
LWP	38.8	31.4	39.4	35.0	56.4	48.5	56.7	51.1
RWP	28.7	33.6	28.5	28.7	46.0	52.0	45.8	45.9
Lane 5	28.2	23.9	28.0	26.5	43.8	38.8	43.6	41.8
BWP	31.1	22.1	30.3	26.1	47.8	37.3	47.4	41.8
LWP	24.4	24.0	24.5	27.5	38.8	38.3	38.7	42.3
RWP	29.4	25.8	29.4	25.9	45.0	41.0	44.9	41.1

Table F.6: Skid Numbers Calculated with CTM and DFT Data on the San Diego 5 CDG Surface After 1.1 Years
(Note: average for each direction appears in bold.)

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
NB Avg.	**39.1**	**35.5**	**38.5**	**37.6**	**52.5**	**50.3**	**51.6**	**50.4**
Lane 1	44.6	40.4	44.6	43.5	59.3	56.5	59.1	56.8
BWP	52.8	39.7	52.6	48.3	67.7	54.8	67.2	61.7
LWP	39.4	40.7	43.9	45.6	51.7	56.6	56.5	55.7
RWP	41.7	40.7	37.3	36.5	58.5	58.0	53.5	52.9
Lane 2	36.0	34.4	35.0	33.7	49.5	49.4	48.4	47.2
BWP	41.6	34.8	35.5	35.7	55.4	50.5	49.5	49.7
LWP	31.2	30.0	34.6	31.6	43.5	43.4	46.8	43.5
RWP	35.1	38.5	34.8	33.8	49.5	54.2	49.0	48.3
Lane 5	36.6	31.6	35.8	35.5	48.8	45.1	47.5	47.1
BWP	37.7	32.2	37.9	38.0	47.8	43.3	48.0	47.4
LWP	39.1	31.9	39.7	39.5	51.4	45.7	51.2	51.1
RWP	32.8	30.8	29.9	29.0	47.1	46.3	43.2	42.9
SB Avg.	**35.5**	**35.4**	**36.5**	**35.9**	**49.7**	**50.5**	**50.6**	**49.3**
Lane 1	37.2	36.6	39.7	35.6	54.0	53.6	57.0	51.7
BWP	39.1	37.9	46.9	39.3	56.0	55.5	64.8	56.0
LWP	40.0	36.1	39.8	32.9	56.4	51.0	56.5	48.6
RWP	32.4	35.8	32.5	34.6	49.7	54.5	49.7	50.5
Lane 2	35.4	35.4	34.3	35.2	48.7	49.9	47.1	47.6
BWP	44.9	42.3	39.9	40.1	59.5	59.4	54.2	52.7
LWP	30.3	28.9	30.7	34.6	42.2	41.7	42.1	45.8
RWP	31.0	34.9	32.3	30.9	44.3	48.6	44.9	44.3
Lane 5	34.4	34.4	36.4	36.9	47.6	48.7	49.3	49.3
BWP	27.5	30.9	32.9	38.3	40.4	45.0	45.7	50.2
LWP	37.6	36.7	37.8	33.7	51.1	50.5	51.1	46.8
RWP	38.0	35.6	38.4	38.6	51.3	50.6	51.2	51.0

Table F.7: Skid Numbers Calculated with CTM and DFT Data on the San Diego 5 CDG Surface After 1.3 Years
(Note: average for each direction appears in bold.)

Location/ Segments	Smooth				Ribbed			
	All	Parallel	45-deg	Perpendicular	All	Parallel	45-deg	Perpendicular
NB Avg.	**34.3**	**33.2**	**36.8**	**35.1**	**44.2**	**44.1**	**46.4**	**45.4**
Lane 1	33.7	32.2	38.6	38.2	44.2	43.7	49.3	49.8
BWP	36.0	35.5	51.8	50.5	45.9	46.4	61.8	62.3
LWP	40.0	28.9	28.9	38.4	49.3	37.4	37.4	49.4
RWP	25.2	32.1	35.2	25.8	37.6	47.3	48.7	37.6
Lane 2	36.6	36.0	36.7	32.7	48.0	48.1	47.9	43.4
BWP	44.3	43.4	43.9	45.8	57.7	57.8	57.7	57.1
LWP	34.2	33.5	34.7	33.7	43.7	43.9	43.5	44.0
RWP	31.2	31.1	31.4	18.6	42.7	42.7	42.7	29.0
Lane 5	32.3	31.2	32.9	31.9	38.3	39.1	37.4	38.7
BWP	35.3	35.2	35.9	33.8	40.8	41.6	39.3	42.2
LWP								
RWP	29.4	27.2	29.8	30.0	35.8	36.6	35.4	35.1
SB Avg.	**32.9**	**31.7**	**35.0**	**33.4**	**46.7**	**46.3**	**48.9**	**46.6**
Lane 1								
BWP								
LWP								
RWP								
Lane 2	33.5	32.2	33.7	34.0	49.5	48.7	49.7	49.5
BWP	37.2	34.8	37.2	39.1	54.6	52.9	55.0	54.5
LWP	30.8	30.4	30.3	32.0	46.0	45.8	45.6	46.7
RWP	32.5	31.4	33.6	31.0	48.0	47.3	48.5	47.1
Lane 5	32.3	31.2	36.3	32.9	43.9	44.0	48.1	43.7
BWP	43.1	40.8	43.5	44.0	55.2	55.4	55.0	54.7
LWP	33.7	33.2	33.5	34.4	45.9	45.8	45.9	45.8
RWP	20.1	19.8	31.8	20.1	30.6	30.7	43.4	30.6

Table F.8: Skid Numbers Calculated with CTM and DFT Data on the San Diego 5 GnG Surface
(Note: average for each direction appears in bold.)

Location/ Segments	Smooth				Ribbed			
	All	**Parallel**	**45-deg**	**Perpendicular**	**All**	**Parallel**	**45-deg**	**Perpendicular**
NB Avg.	**26.8**	**23.7**	**30.3**	**27.3**	**38.6**	**36.2**	**41.7**	**38.8**
Lane 1	26.9	23.0	32.1	27.2	39.2	35.5	44.1	39.6
BWP	17.2	25.8	32.7	25.8	29.7	38.0	44.9	37.6
LWP	31.5	19.1	31.8	25.1	42.7	32.2	42.4	36.3
RWP	31.9	24.1	31.8	30.9	45.2	36.4	45.2	44.9
Lane 2	31.1	28.2	31.9	31.4	44.2	42.2	44.2	44.2
BWP	30.9	31.1	31.0	30.5	43.7	43.8	43.6	43.7
LWP	31.4	29.1	32.3	31.3	43.6	43.0	43.6	43.6
RWP	31.1	24.3	32.4	32.3	45.3	39.9	45.5	45.3
Lane 5	23.4	21.2	26.5	24.5	33.5	32.8	36.1	33.4
BWP	22.9	21.7	28.5	29.3	33.6	33.4	38.9	38.6
LWP								
RWP	23.9	20.7	24.5	19.7	33.4	32.3	33.4	28.2
SB Avg.	**27.9**	**31.3**	**30.2**	**31.5**	**41.0**	**45.1**	**43.2**	**44.6**
Lane 1	30.3	35.9	30.4	37.0	45.3	51.1	44.8	51.9
BWP	29.0	38.3	28.5	37.3	43.8	53.1	43.6	52.8
LWP	34.3	32.4	26.6	35.7	50.3	48.6	40.9	51.1
RWP	26.6	37.3	38.0	38.3	40.5	51.5	51.8	51.8
Lane 2	27.7	32.4	32.1	29.9	40.6	45.7	45.1	42.9
BWP	29.2	31.8	35.3	37.0	42.7	46.1	49.5	49.8
LWP	28.1	35.6	35.4	27.3	41.0	48.1	47.8	40.9
RWP	25.6	29.7	25.5	25.2	38.1	42.8	37.9	38.0
Lane 5	26.1	26.2	28.0	28.2	37.6	39.0	39.7	39.6
BWP	23.9	29.3	23.8	24.2	36.7	42.8	36.7	36.8
LWP	24.6	29.4	30.7	30.5	35.8	41.7	42.0	41.7
RWP	29.6	19.7	29.5	30.0	40.2	32.5	40.4	40.2

APPENDIX G: MEASURED ASTM E274 SKID NUMBER VERSUS ESTIMATES USING CTM AND DFT

The International Friction Index (IFI) was recently developed to harmonize friction and texture measurements by different test methods (*G1, G2*). The index was developed through collection of a wide range of friction data measured by several test methods on different pavement surfaces, mainly in Spain and Belgium, for a study by the Permanent International Association of Road Congresses (PIARC). In this study, a model originated by Pennsylvania State University researchers was used (*G3*). Two important factors affecting pavement skid resistance, speed and friction, were considered in the model. The original model has the following form:

$$F_{\mu}(s) = F_0 . e^{\frac{-s}{s_P}}$$

where

S is slip speed,

F_{μ} is friction,

F_0 is a constant that relates to microtexture, and

S_P is a constant that relates to macrotexture.

During the PIARC study, a curve relating slip speed to friction was established for each pavement section. This so-called "golden curve" showed the friction experienced by a driver during emergency braking. Then, by using calibration factors, various friction test equipment was able to predict the golden curve. It is worthwhile noting that the friction reported for each test section was at a speed of 60 km/h (37.5 mph). The IFI is composed of two numbers, F60 and S_p, which are calculated in the following ways:

The Speed constant (S_p) parameter is calculated based on texture measurements:

$S_p = a + b\ T_x$

where "a" and "b" are calibration factors and are different for each measuring device, and T_x is a measure of pavement texture.

The friction measurement at a slip speed FR(S) is then converted to a measurement at 60 km/h, FR(60):

$$FR(60) = FR(S) \times e^{\left(\frac{S-60}{S_P}\right)}$$

Finally, the F(60) is recalculated by the application of a speed-adjusted friction value FR(60) using the following equation:

$F(60) = A + B\ FR(60) + C\ T_x$

where "A," "B," and "C" are calibration constants for a selected friction device. These values have been standardized for each measuring device in ASTM E1960.

Two parameters used in the IFI calibrated model, wet friction at 60 km/h, F(60), and the speed constant of wet pavement friction, SP, are indications of the average wet coefficient of friction experienced by a driver during a locked-wheel slide at a speed of 60 km/h and the dependence of the wet-pavement friction on the sliding speed, respectively.

Based on ASTM E1960, the calibration factors for the Circular Texture Meter are a = 14.23 and b = 89.72, and for the Dynamic Friction Tester they are A = 0.081 and B = 0.732. Thus, the IFI and Sp can be calculated as:

$$IFI = 0.081 + 0.732 DF_{20}\, e^{\frac{-40}{S_P}}$$

$$S_P = 14.2 + 89.7 MPD$$

where:

DF_{20} = wet friction number measured by Dynamic Friction Tester at the speed of 20 km/h,

MPD = MPD measured by Circular Texture Meter (mm).

The IFI values for the locked-wheel friction trailer using a smooth tire (A = 0.04461, B = 0.92549, and C = 0.097589) and a ribbed tire (A = -0.02283, B = 0.60682, and C = 0.097589) at desired speeds are:

$$IFI = 0.045 + 0.925 \times 0.01 \times SN(40)S.e^{\frac{4}{S_P}} \qquad For\ Smooth Tire$$

$$IFI = -0.023 + 0.607 \times 0.01 \times SN(40)R.e^{\frac{4}{S_P}} + 0.098 \times MPD \quad For\ Ribbed\ Tire$$

where SN_{40} is the skid number measured at test speed of 40 mph using a smooth or ribbed tire divided by 100.

Based on the equation above, predicted SN_{40} values were calculated. Generally, the predicted SN_{40} values for a smooth tire are less than for a ribbed tire (see Reference [*G3*]). According to several research studies, the ribbed tire test is predominantly influenced by the microtexture of the pavement, whereas the smooth tire test is influenced to a greater extent by the pavement macrotexture and water film thickness in the tire pavement contact area. The grooves in the ribbed tire provide larger channels than those provided by pavement macrotexture for water to escape from the tire/pavement contact area; therefore, higher skid numbers should result from ribbed tire tests versus smooth tire tests.

The data presented in this appendix is used to compare estimated skid numbers to actual skid numbers measured according to ASTM E274. As is discussed above, estimated skid numbers are calculated through the International Friction Index, which uses mean profile depth (MPD) data from the Circular Texture Meter (CTM) along with friction data from the Dynamic Friction Tester (DFT). Testing equipment is discussed in Section 2.2.3.

To investigate how well the estimated skid numbers compared to the measured skid numbers, a Kolmogorov-Smirnov nonparametric test was performed to compare the two samples' distributions. This test is performed by computing the maximum distance between the cumulative distributions of the two samples.

Of particular interest is the approximate p-value results from the test: a p-value greater than or equal to 0.05 indicates there is not a statistically significant difference between the two distributions at the 95.0% confidence level. A p-value less than 0.05 indicates that two samples are statistically different.

In Section G.1 through Section G.5, the data labelled UCPRC are the averages of estimated skid numbers, and the data labelled IGGA and Caltrans are averages of skid numbers measured during E274 testing. Following each of the tables below, where the average values are presented, is a table that shows and discusses the statistical summary.

G.1 Sacramento 5 – PM 20.0/21.5

Table G.1 reviews the averages from ribbed and smooth testing on the Sacramento 5 – PM 20.0/21.5 project, and Table G.2 displays the results of the statistical comparison.

Table G.1: Estimated and Actual Skid Numbers on Different Textures on Sacramento 5 – PM 20.0/21.5

Average SN_{40} – Ribbed Tire			
Texture	**UCPRC**	**IGGA**	**Caltrans**
CDG	52.7	48.4	
GnG	51.5	48.3	51.7
NGL	50.2	48.5	
Average SN_{40} – Smooth Tire			
Texture	**UCPRC**	**IGGA**	**Caltrans**
CDG	34.2	41.9	
GnG	38.3	42.6	49.2
NGL	30.6	33.1	

Table G.2: Results of Statistical Test on Friction Values on Sacramento 5 – PM 20.0/21.5

		alpha = 0.05	UCPRC	IGGA	CALTRANS
RIBBED TIRE	CDG	UCPRC	1.0	0.18	
		IGGA	0.18	1.0	
	GnG	UCPRC	1.0	0.03	0.25
		IGGA	0.03	1.0	0.11
		CALTRANS	0.25	0.11	1.0
	NGL	UCPRC	1.0	0.15	
		IGGA	0.15	1.0	
SMOOTH TIRE		**alpha = 0.05**	**UCPRC**	**IGGA**	**CALTRANS**
	CDG	UCPRC	1.0	0.25	
		IGGA	0.25	1.0	
	GnG	UCPRC	1.0	0.00	0.00
		IGGA	0.00	1.0	0.01
		CALTRANS	0.00	0.01	1.0
	NGL	UCPRC	1.0	0.57	
		IGGA	0.57	1.0	

On the CDG texture and the NGL texture, the friction data for both the UCPRC estimated and IGGA measured are statistically similar for both ribbed and smooth tires.

On the GnG texture the opposite is true: the UCPRC and IGGA numbers are statistically different. The Caltrans data has a statistical resemblance to both the UCPRC estimated and IGGA measured results for the ribbed tire testing, but not for the smooth tire testing.

G.2 Sacramento 80 – PM 13.0/14.0

Table G.3 reviews the averages from ribbed and smooth testing on the Sacramento 80 – PM 13.0/14.0 project, and Table G.4 displays the results of the statistical comparison.

Table G.3: Estimated and Actual Skid Numbers on the GnG Texture on Sacramento 80 – PM 13.0/14.0

	Average SN_{40} – Ribbed Tire	
GnG Texture	UCPRC	IGGA
	42.4	47.7
	Average SN_{40} – Smooth Tire	
	UCPRC	IGGA
	26.4	38.8

Table G.4: Results of Statistical Test on Friction Values on Sacramento 80 – PM 13.0/14.0

		UCPRC	IGGA
Ribbed	UCPRC	1.0	0.12
	IGGA	0.12	1.0
Smooth		UCPRC	IGGA
	UCPRC	1.0	0.000
	IGGA	0.000	1.0

On the GnG texture, the UCPRC and IGGA numbers are statistically similar for the ribbed tire testing but not for the smooth tire testing.

G.3 Sacramento 50 – PM R13.0/R14.0

Table G.5 reviews the averages from ribbed and smooth testing on the Sacramento 50 – PM R13.0/R14.0 project, and Table G.6 displays the results of the statistical comparison. On the GnG texture, the UCPRC and IGGA data are statistically dissimilar for both ribbed and smooth tire testing.

Table G.5: Estimated and Actual Skid Numbers on the GnG Texture on Sacramento 50 – PM R13.0/R14.0

	Average SN_{40} – Ribbed Tire	
GnG Texture	UCPRC	IGGA
	34.7	46.4
	Average SN_{40} – Smooth Tire	
	UCPRC	IGGA
	21.1	39.6

Table G.6: Results of Statistical Test on Friction Values on Sacramento 50 – PM R13.0/R14.0

		UCPRC	IGGA
Ribbed	UCPRC	1.0	0.0004
	IGGA	0.0004	1.0
Smooth		**UCPRC**	**IGGA**
	UCPRC	1.0	0.0004
	IGGA	0.0004	1.0

G.4 San Joaquin 99 – PM 29.0/30.7

Table G.7 reviews the averages from ribbed and smooth testing on the San Joaquin 99 – PM 29.0/30.7 project, and Table G.8 displays the results of the statistical comparison.

Table G.7: Estimated and Actual Skid Numbers on GnG Texture of San Joaquin 99 – PM 29.0/30.7

GnG Texture	Average SN_{40} – Ribbed Tire		
	UCPRC	**IGGA**	**Caltrans**
	51.8	43.6	46.2
	Average SN_{40} – Smooth Tire		
	UCPRC	**IGGA**	**Caltrans**
	37.3	35.9	

Table G.8: Results of Statistical Test on GnG Texture of San Joaquin 99 – PM 29.0/30.7

	alpha = 0.05	UCPRC	IGGA	CALTRANS
Ribbed	UCPRC	1.0	0.002	0.00
	IGGA	0.002	1.0	0.20
	CALTRANS	0.00	0.20	1.0
Smooth	**alpha = 0.05**	**UCPRC**	**IGGA**	
	UCPRC	1.0	0.008	
	IGGA	0.008	1.0	

On the GnG texture on San Joaquin 99, the estimated skid numbers are not statistically similar to the measured skid numbers for ribbed or for smooth tires. There is a similarity between the two sets of measured E274 data collected by IGGA and Caltrans.

G.5 San Diego 5 – PM R35.8/R37.9

Table G.9 reviews the averaged results from ribbed and smooth tire testing on the San Diego 5 project, and Table G.10 displays the results of the statistical comparison.

The averages show consistency between the measured data from IGGA and Caltrans for both CDG and GnG textures tested with both tire types. The comparison tests also show the same result, with a statistical similarity between IGGA and Caltrans testing for both tire types and textures.

Table G.9: Estimated and Actual Skid Numbers on Different Textures on San Diego 5 – PM R35.8/R37.9

		Northbound			Southbound		
Ribbed	**Texture**	**UCPRC**	**IGGA**	**Caltrans**	**UCPRC**	**IGGA**	**Caltrans**
	CDG	51.4	48.4	48.4	49.3	47.3	47.2
	GnG	41.1	44.1		41.0	44.7	41.0
Smooth	**Texture**	**UCPRC**	**IGGA**	**Caltrans**	**UCPRC**	**IGGA**	**Caltrans**
	CDG	38.8	42.3	44.5	35.1	42.7	42.9
	GnG	28.1	35.8		27.9	42.4	44.6

Among the UCPRC-estimated and IGGA-measured skid numbers on the CDG texture, similarities only appeared between the smooth tire tests in the northbound direction. Statistical tests on the GnG texture results revealed a similarity between the UCPRC-estimated and IGGA-measured skid numbers under testing with the ribbed tire in both directions and the smooth tire in the northbound direction.

Table G.10: Results of Statistical Test on Friction Values on San Diego 5 – PM R35.8/R37.9

			Northbound			Southbound		
			UCPRC	IGGA	Caltrans	UCPRC	IGGA	Caltrans
Ribbed Tire	CDG	UCPRC	1.0	0.00	0.00	1.0	0.00	0.00
		IGGA	0.00	1.0	0.05	0.00	1.0	0.06
		Caltrans	0.00	0.05	1.0	0.00	0.06	1.0
	GnG	UCPRC	1.0	0.52		1.0	0.30	0.03
		IGGA	0.52	1.0		0.30	1.0	0.14
		Caltrans				0.03	0.14	1.0
Smooth Tire	CDG	UCPRC	1.0	0.25		1.0	0.03	0.00
		IGGA	0.25	1.0		0.03	1.0	0.49
		Caltrans				0.00	0.49	1.0
	GnG	UCPRC	1.0	0.17	0.00	1.0	0.00	0.00
		IGGA	0.17	1.0	0.29	0.00	1.0	0.27
		Caltrans	0.00	0.29	1.0	0.00	0.27	1.0

G.6 Conclusions Based on Estimated Versus Measured Skid Numbers

Statistical analysis shows the following in comparing estimated and actual skid numbers over five project sites on CDG and GnG textures.

- *For ribbed tire tests on CDG textures*: the Sacramento 5 – PM 20.0/21.5 project showed a similarity between estimated and actual skid numbers. However, there is a statistical difference between the estimated and actual skid numbers for both directions of the San Diego project.
- *For smooth tire tests on CDG textures:* the Sacramento 5 – PM 20.0/21.5 project and the northbound lanes of the San Diego project show similarities between estimated and actual skid numbers. For the southbound lanes of the San Diego project, the estimated skid numbers underestimate the actual numbers.
- *For ribbed tire tests on GnG textures:* the Sacramento 80 project and both directions of the San Diego 5 project show similarities between estimated and actual skid numbers. There is a statistical difference between those measurements for the Sacramento 5 – PM 20.0/21.5, Sacramento 50, and San Joaquin 99 projects. The estimated values did not follow a uniform pattern, sometimes overestimating or underestimating values measured according to E274.
- *For smooth tire tests on GnG textures:* no project sites showed similarities between estimated and actual skid numbers.

Based on these results, it can be concluded that estimated skid numbers based on the IFI are not a reliable predictor for textured concrete surfaces. More research is needed to construct a reliable relationship between skid numbers measured according to E274 and those estimated according to the International Friction Index.

References for Appendix G

1. Wambold, J. C., C. E. Antle, J. J. Henry, and Z. Rado. *International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurement*, PIARC (Permanent International Association of Road Congresses) Report, C-1 PIARC Technical Committee on Surface Characteristics, France, 1995.
2. Henry J. J. Overview of the International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements: The International Friction Index. *Proceedings of the 3rd International Symposium on Pavement Surface Characteristics,* Christchurch, New Zealand, September 1996.
3. Hall, J. W., L T. Glover, K. L. Smith, L. D. Evans, J.C. Wambold, T. J. Yager, and Z. Rado. "Guide for Pavement Friction." *Project No. 1-43*, Final Guide, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., 2006.

APPENDIX H: IRI LONGITUDINAL PROFILES

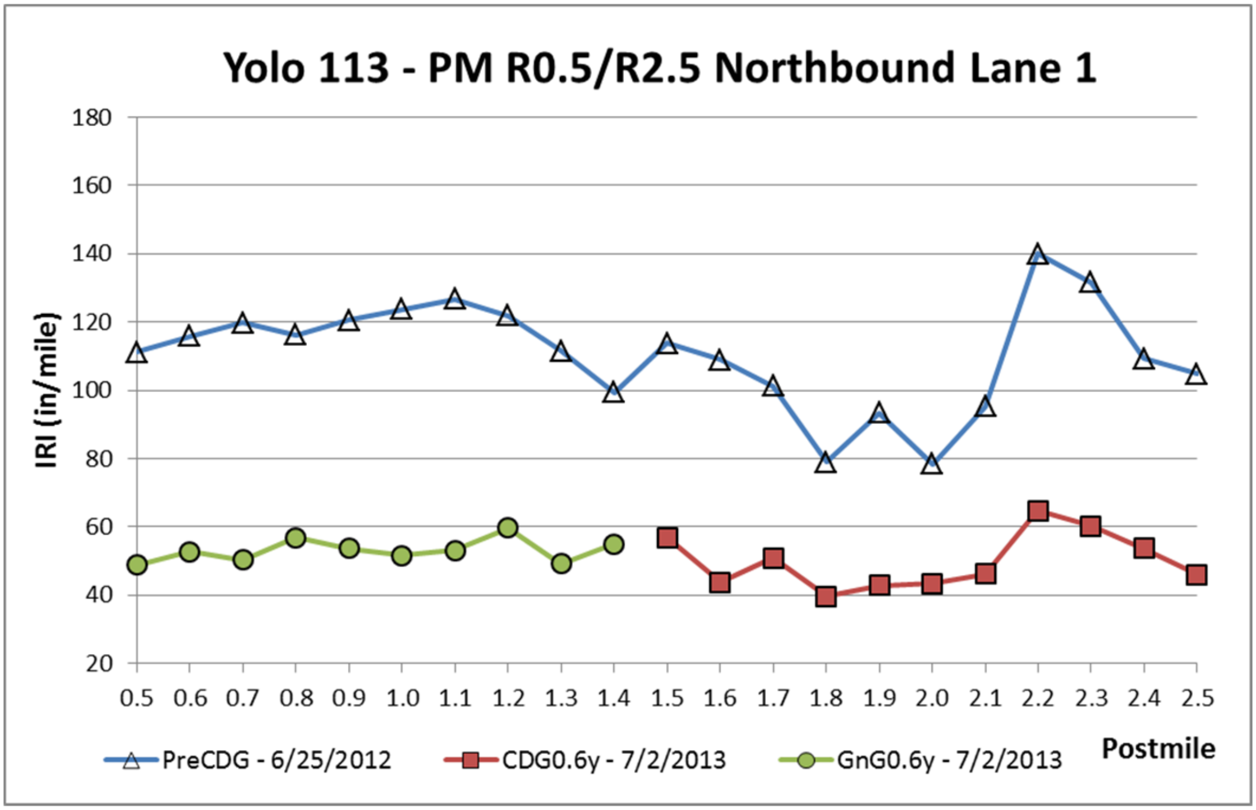
Longitudinal profiles of IRI are presented in the following figures for the Yolo 113 and San Diego 5 projects. All the textured data were collected with a wide-base (Roline) laser; the pre-CDG data were collected with a point laser.

The figures that follow present data from individual lanes and directions, and are grouped by lane number. For example, Figure H.1 has two plots, one showing IRI for northbound Lane 1 of Yolo 113 and one showing southbound Lane 1. Figure H.2 shows the same information for Lane 2 of Yolo 113. Figure H.3 through Figure H.7 present the data for five San Diego project northbound and southbound lanes, and Figure H.8 is a composite of all the project's lanes for each direction.

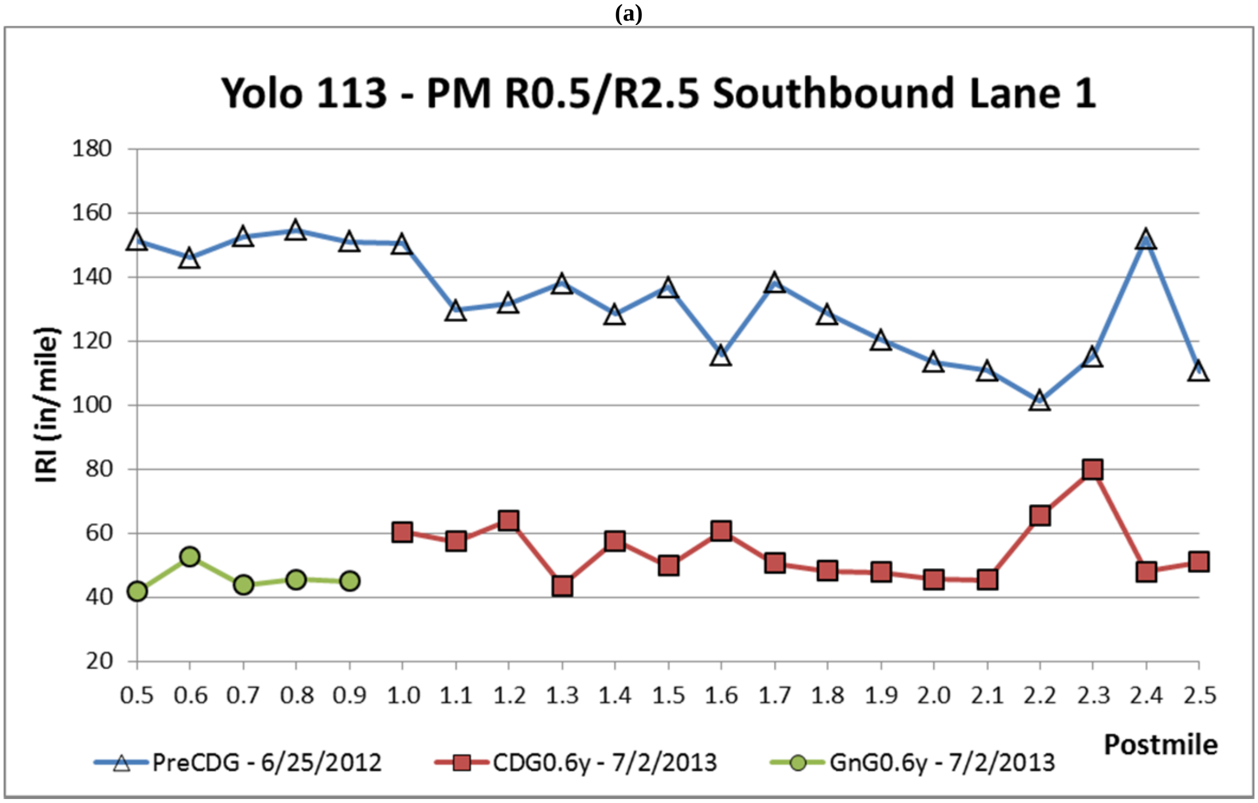
Note that in the figures for the San Diego 5 project, the plots contain large spikes at PM R36.3 and PM R37.4 that indicate the locations of bridge joints.

The following markers and notations are used in the figures:

- Pre-CDG: ▲ Solid line and triangle marker
- CDG0.0y: □ Solid line and square marker
- CDG1.3y: ■ Red dashed line and square marker
- GnG: ● Green solid line and circle marker
- If a marker is filled with a color, it represents the current surface texture; if a marker is not filled with a color, it represents a surface texture that has been replaced.
- The X.Xy represents the number of years since data were first collected. For instance, CDG1.3y represents the CDG surface texture 1.3 years after the CDG measurement.

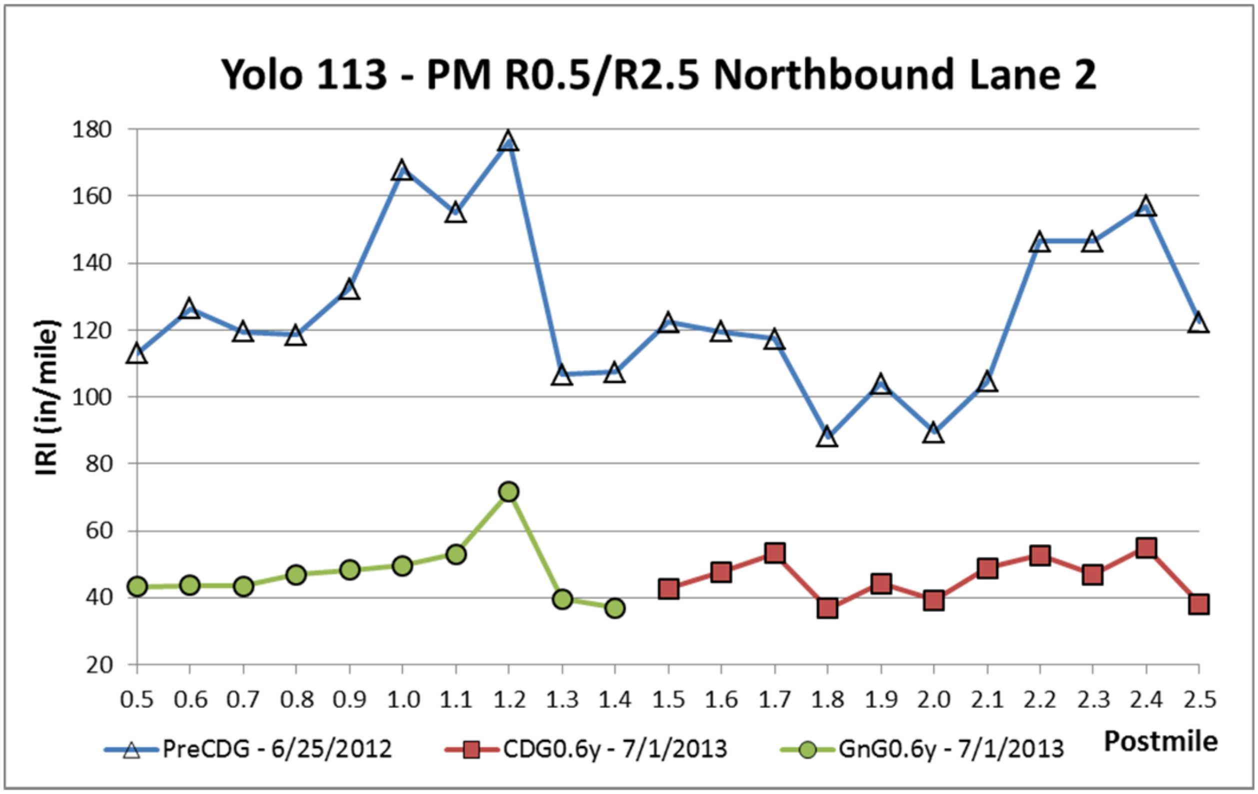


(a)

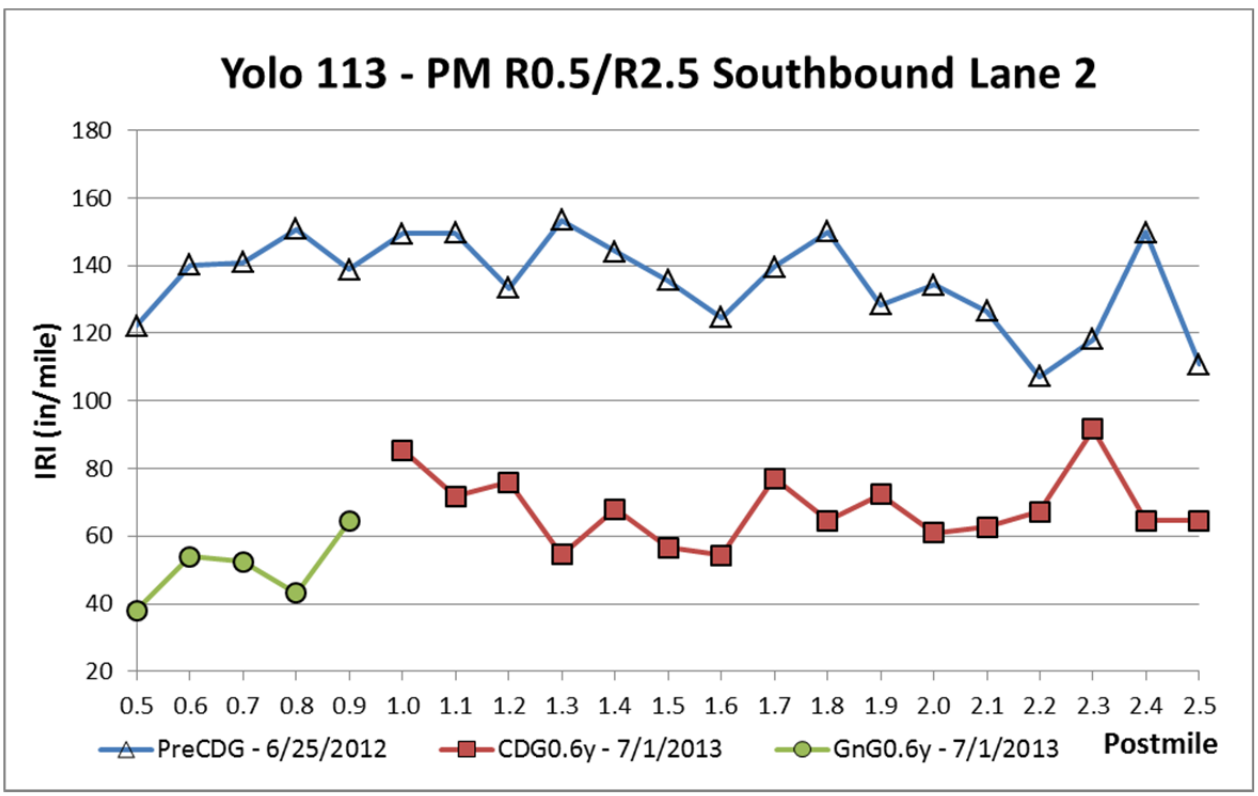


(b)

Figure H.1: Yolo 113 – PM R0.5/R2.5, Lane 1, (a) northbound and (b) southbound.

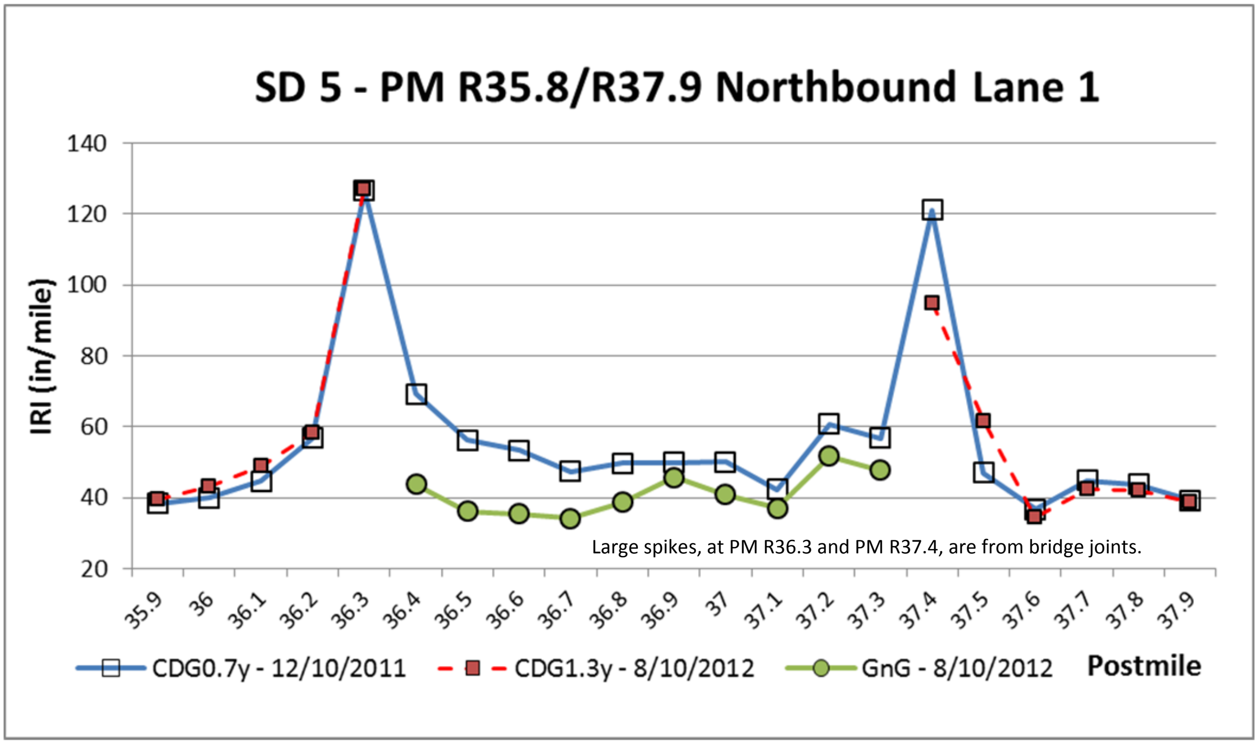


(a)

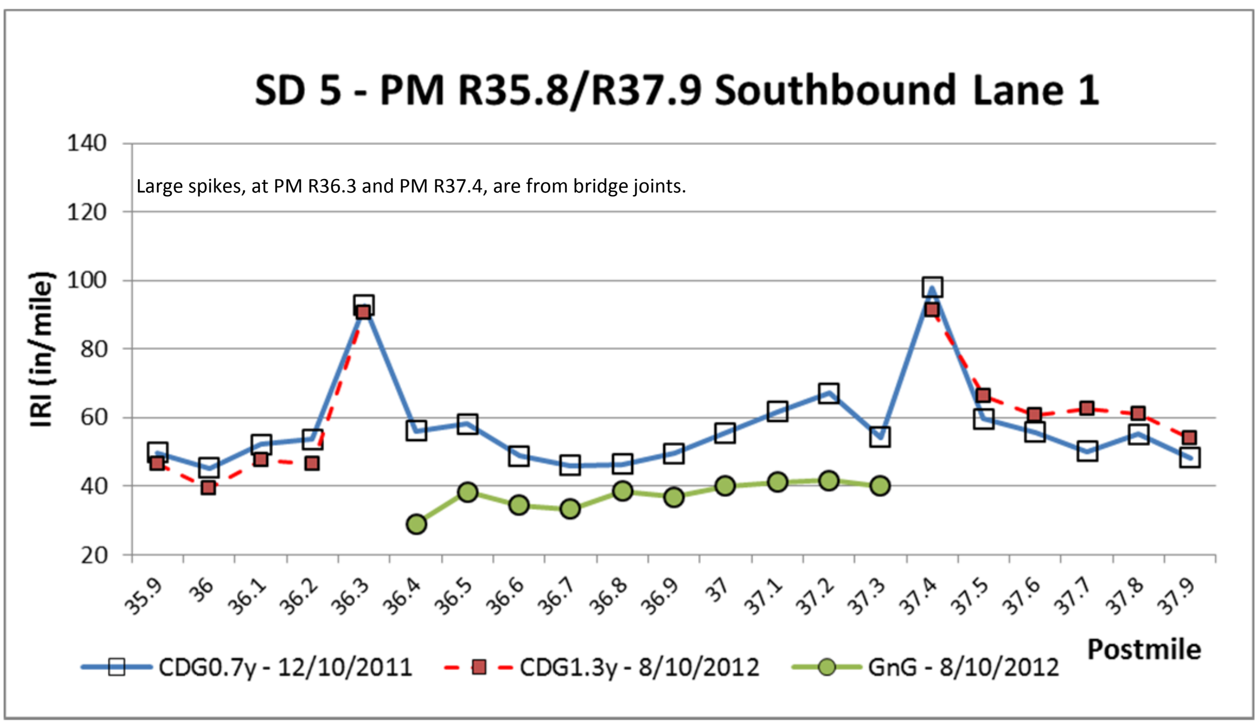


(b)

Figure H.2: Yolo 113 – PM R0.5/R2.5, Lane 2, (a) northbound and (b) southbound.

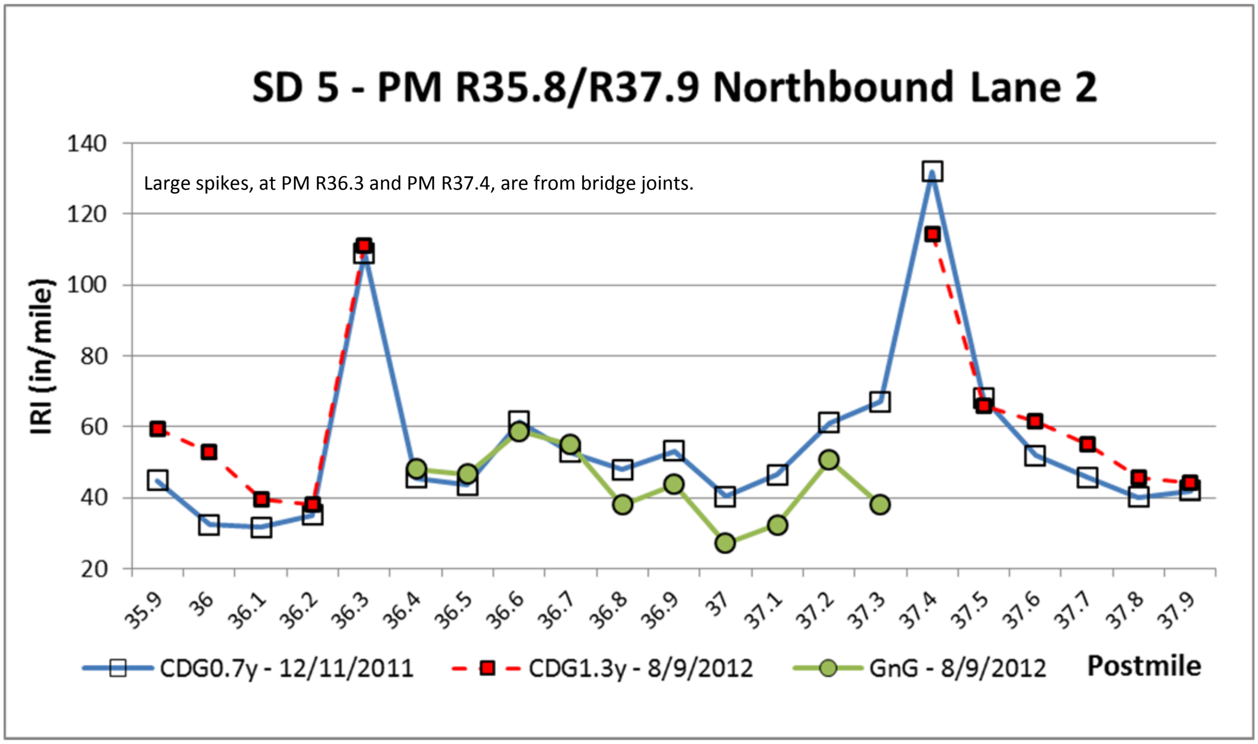


(a)

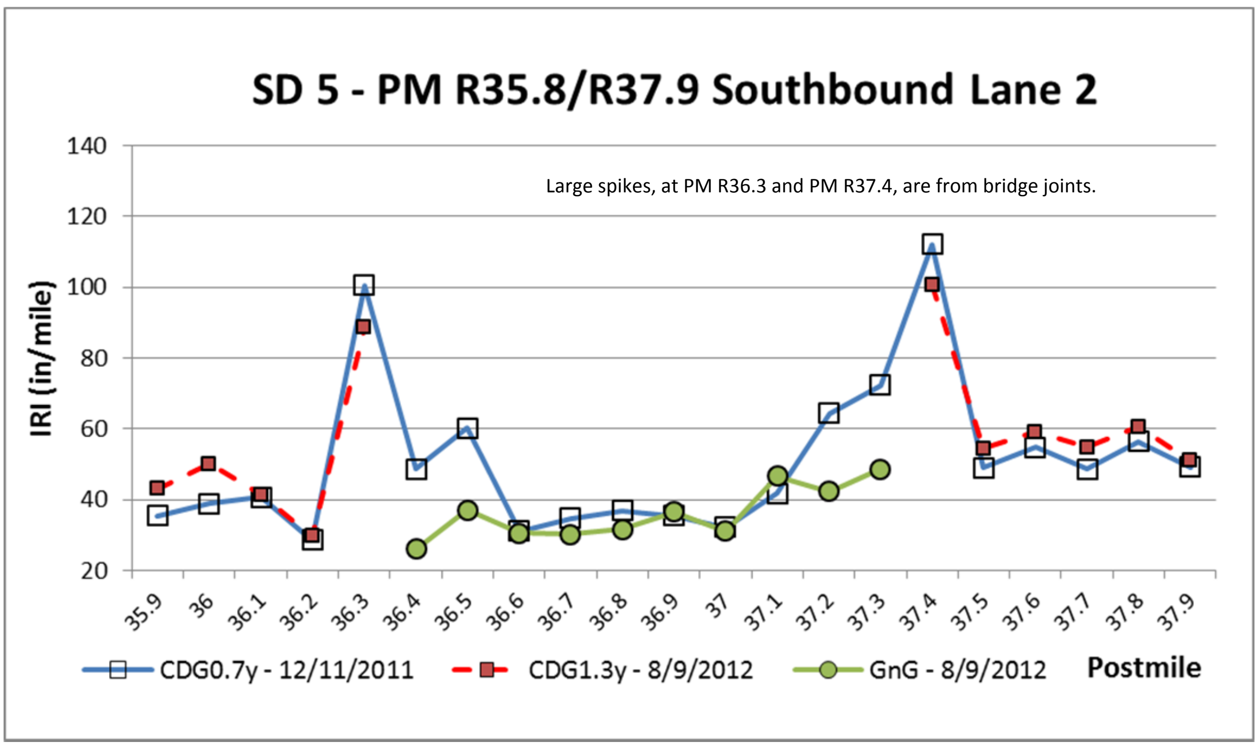


(b)

Figure H.3: San Diego 5 – PM R35.8/R37.9, Lane 1, (a) northbound and (b) southbound.

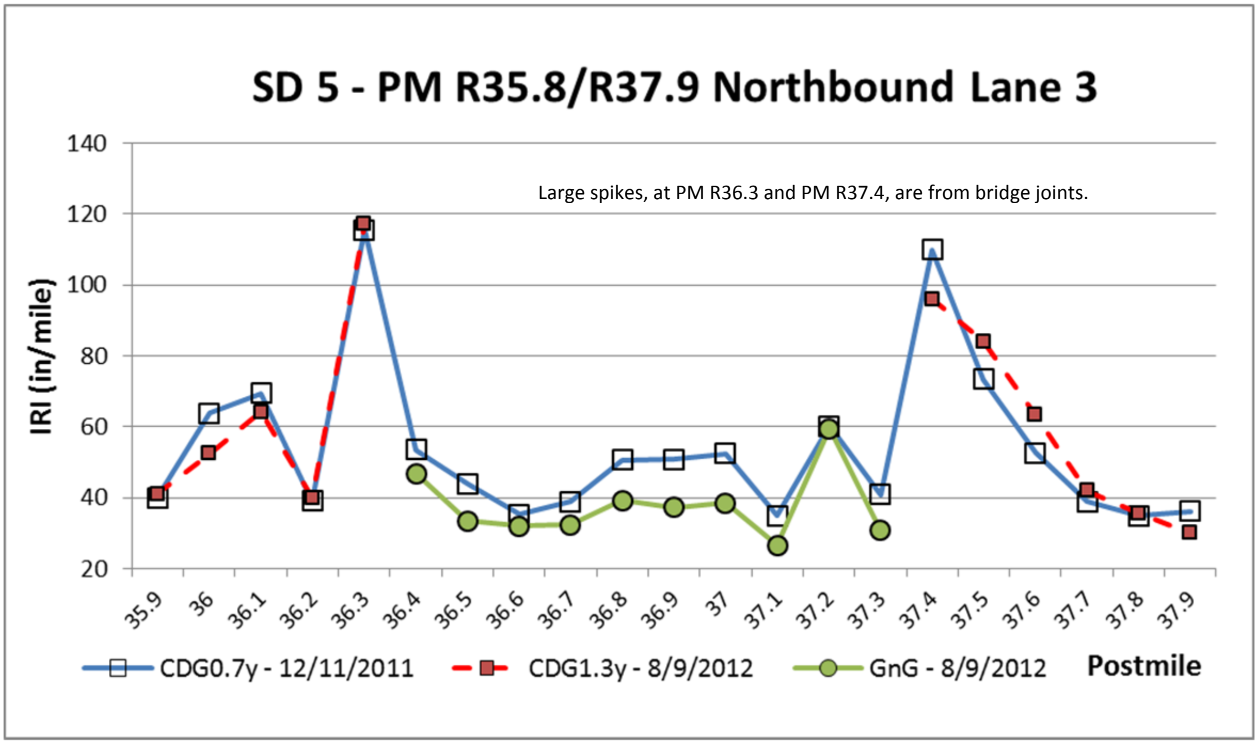


(a)

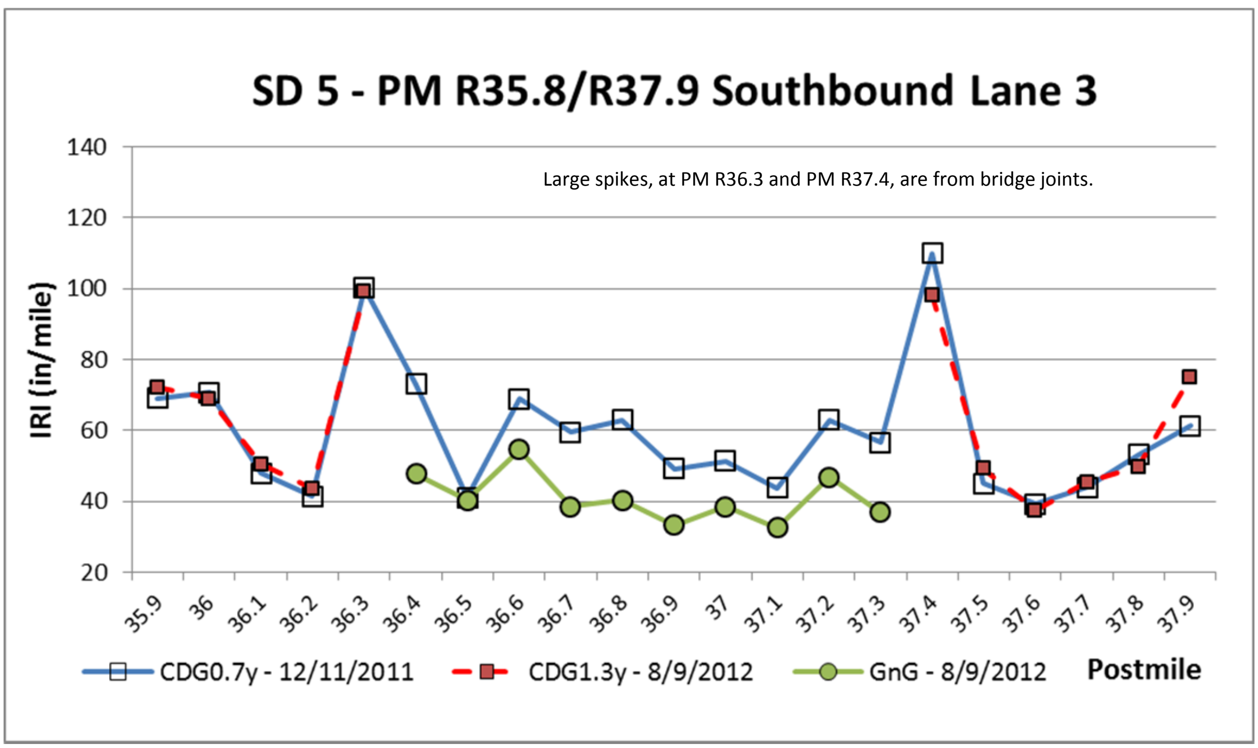


(b)

Figure H.4: San Diego 5 – PM R35.8/R37.9, Lane 2, (a) northbound and (b) southbound.

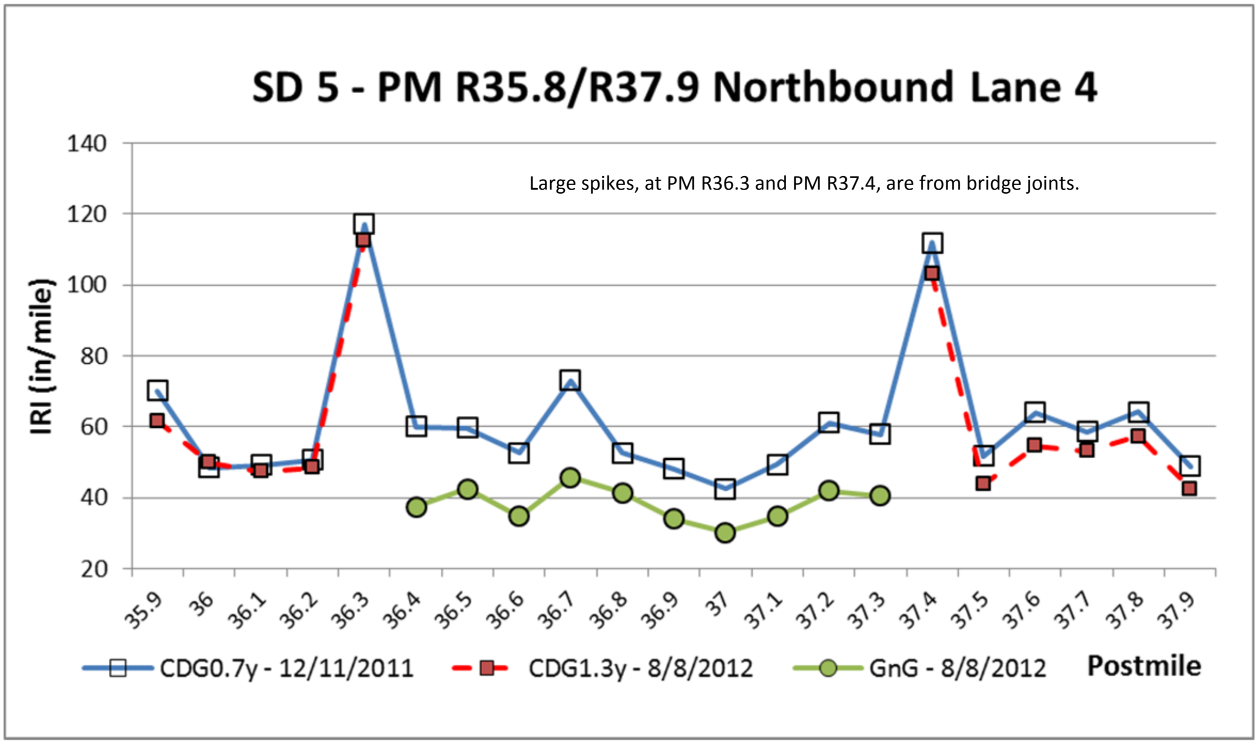


(a)

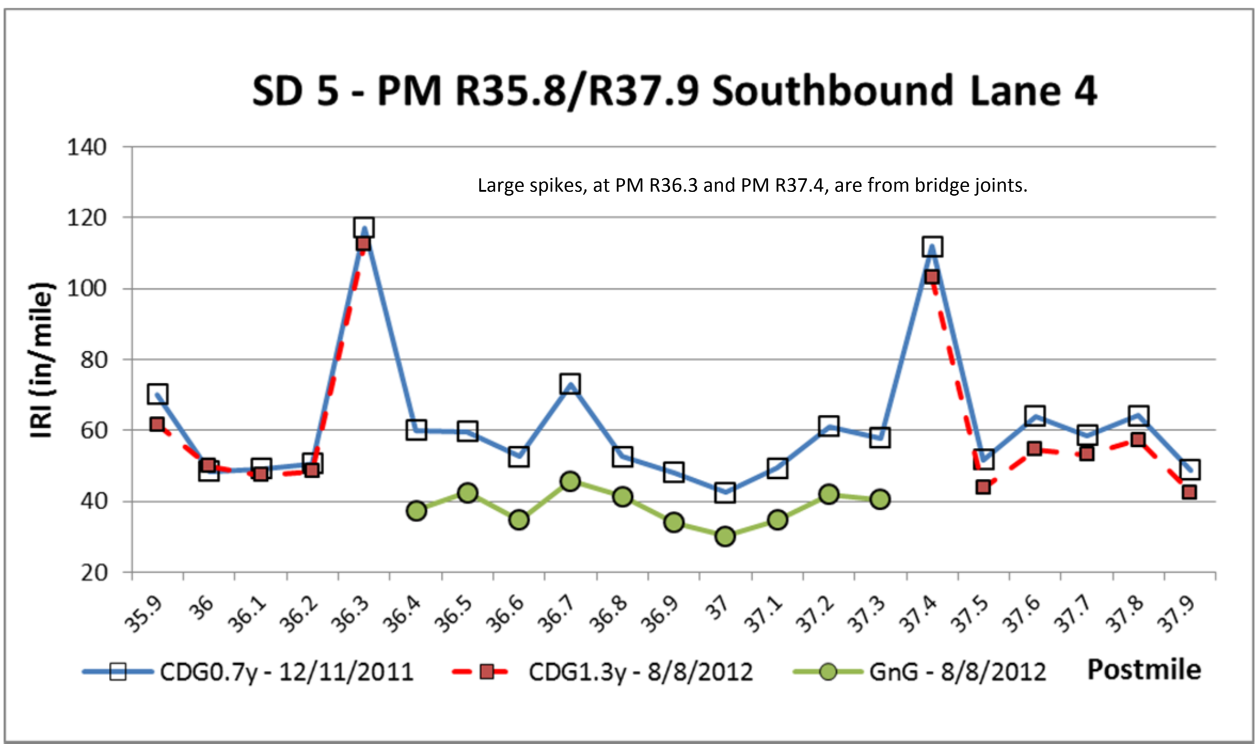


(b)

Figure H.5: San Diego 5 – PM R35.8/R37.9, Lane 3, (a) northbound and (b) southbound.

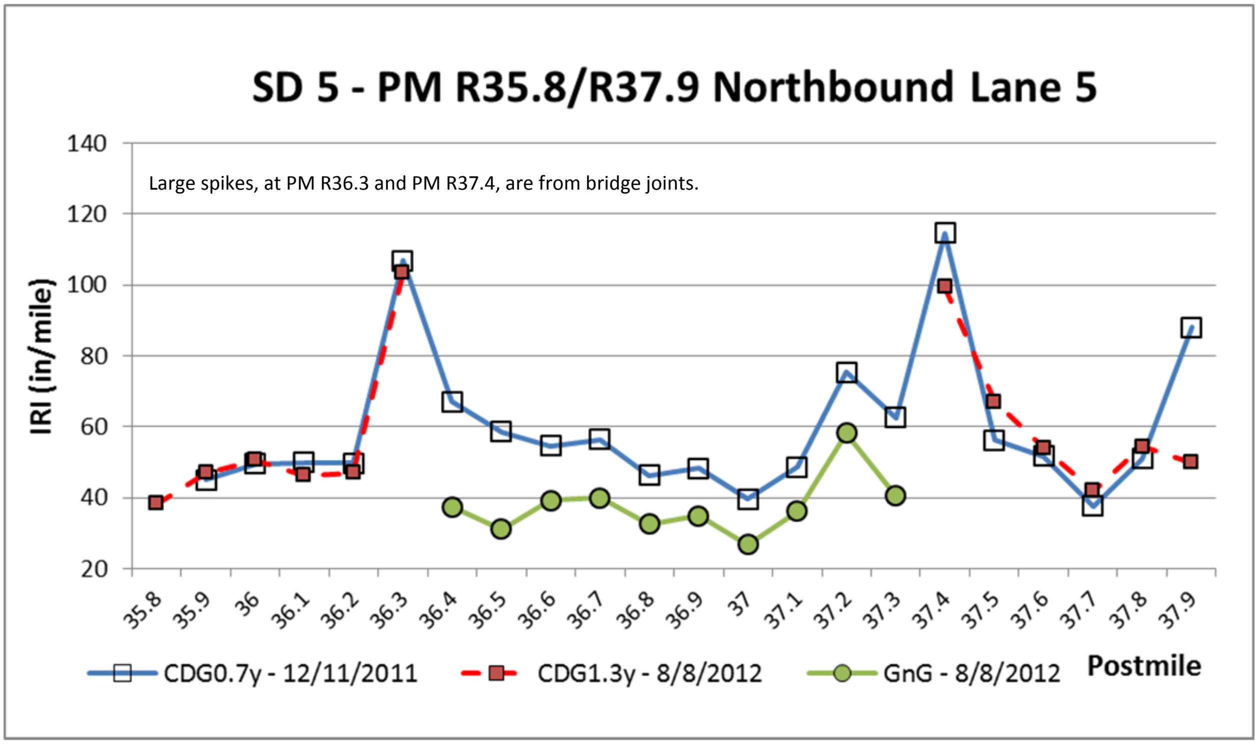


(a)

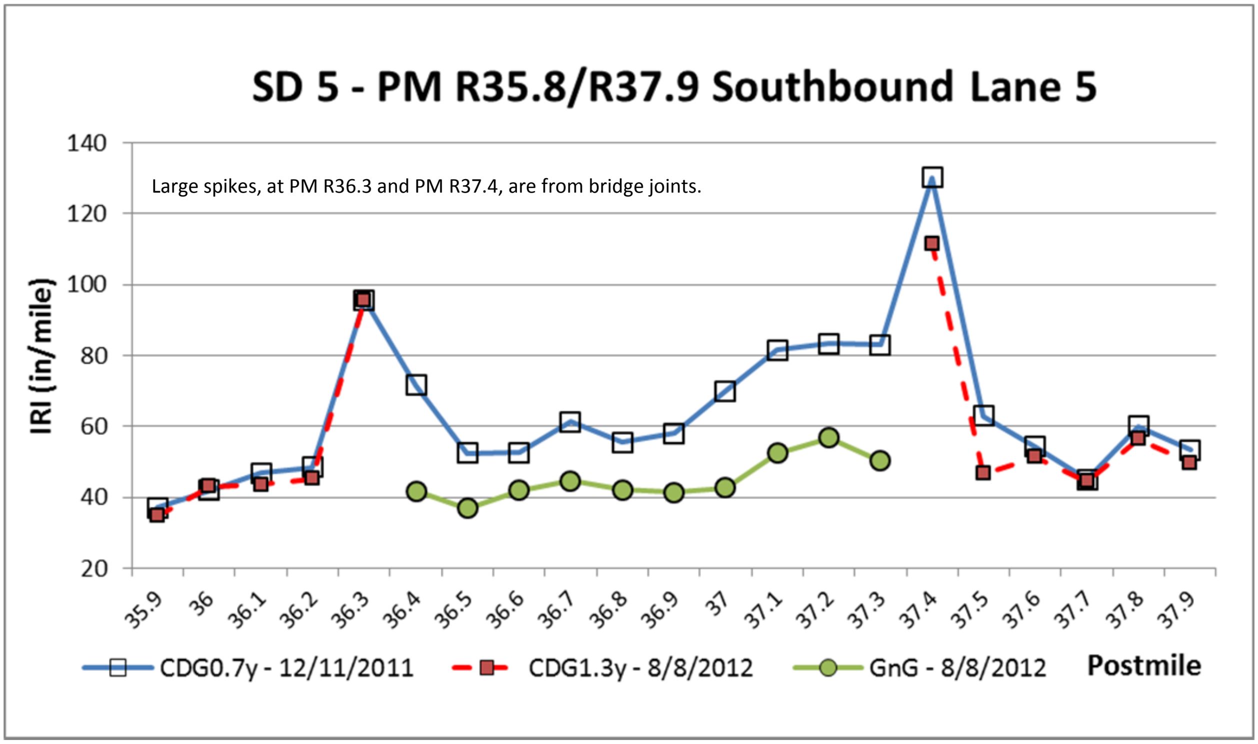


(b)

Figure H.6: San Diego 5 – PM R35.8/R37.9, Lane 4, (a) northbound and (b) southbound.

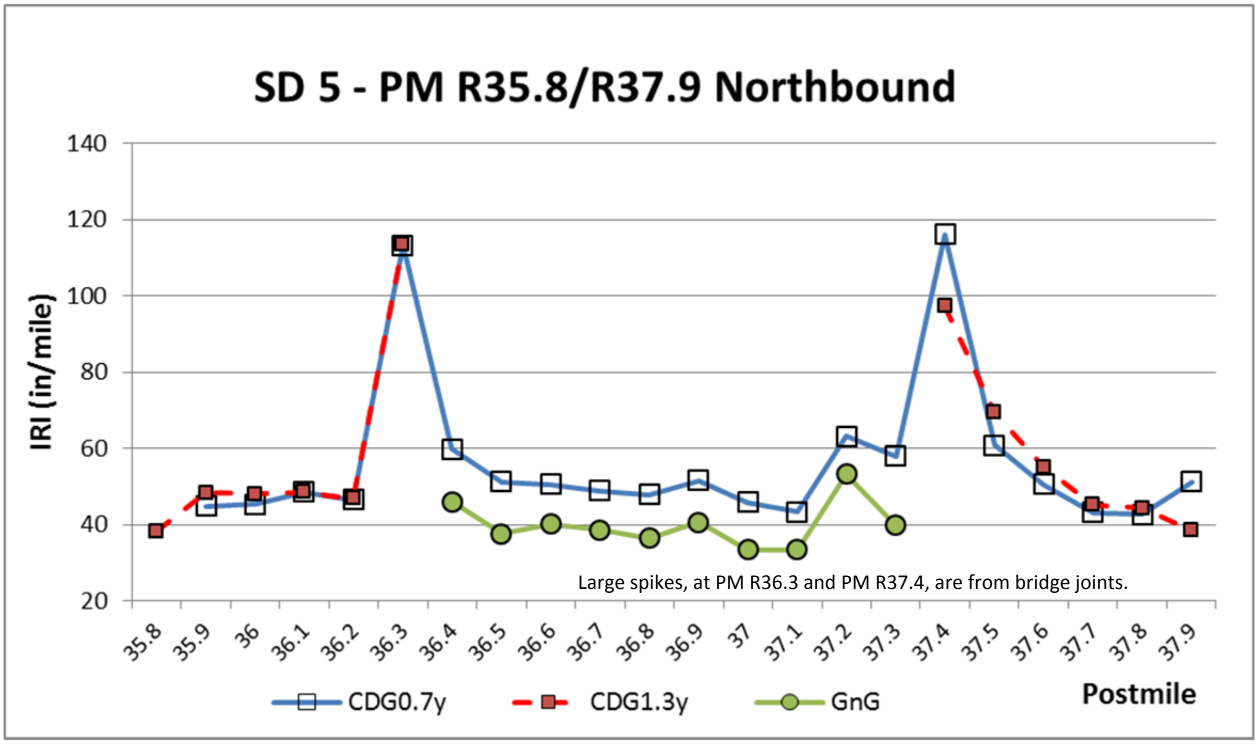


(a)

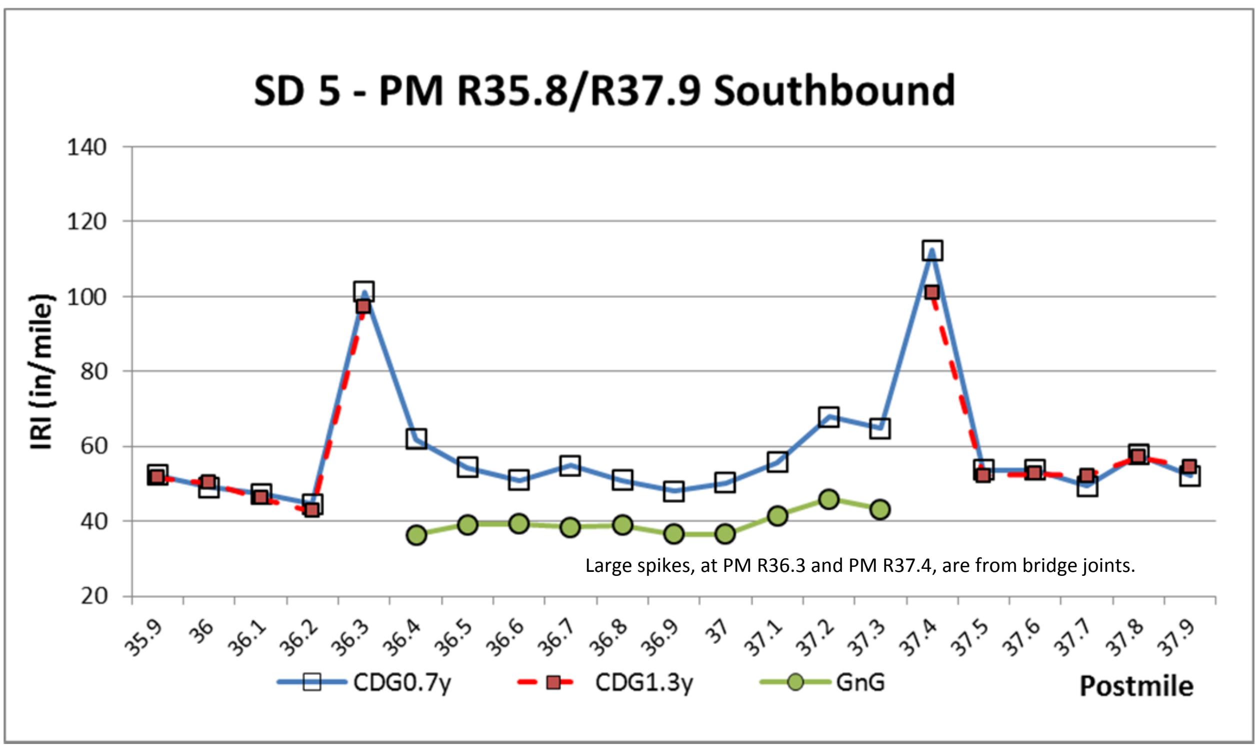


(b)

Figure H.7: San Diego 5 – PM R35.8/R37.9, Lane 5, (a) northbound and (b) southbound.



(a)



(b)

Figure H.8: San Diego 5 – PM R35.8/R37.9, all lanes, (a) northbound and (b) southbound.

APPENDIX I: SUMMARY OF STATISTICAL T-TESTS

I.1 Introduction

Student's *t*-tests were conducted to determine if differences in the data collected on the various textures in specific lanes were statistically significant. Primarily, this type of test was run to see if the constructed textures made a significant change in a variable (overall OBSI or friction), but they were also run to see whether any effect from traffic could be seen between the innermost and outermost lanes. Single tail *t*-tests were run with an alpha value of 0.05 and the variances assumed unequal.

P-value results are presented for each project in tables that compare the salient variables. P-values are bolded if the result was greater than 0.01 (1.E-02), indicating statistical similarity at the 99% confidence level. Results greater than 0.05 indicate statistical similarity at the 95% confidence level.

The analyses in Appendix I follow the order presented in the evaluation of results in Chapter 4.

Section I.2 presents the *t*-test results from OBSI comparisons of each pilot project. The first table in each subsection lays out a matrix of p-values resulting from *t*-tests comparing each lane and texture combination for that project. Additional tables may follow the p-value matrix if further comparisons, such as one by direction, were warranted.

Similarly, Section I.3 and Section I.4 present the *t*-test results from Portable Skid Tester and Towed Skid Trailer testing, respectively. Section I.5 contains the IRI statistics and Section I.6 provides the statistical results that support Appendix E.

The datasets are coded according to the texture, direction, and lane number. Specifically, one of three textures is indicated (PreCDG, CDG, or GnG) first, then the lane direction (N, S, E, or W), and then the lane number. For example, PreCDG-N4 stands for the PreCDG texture in northbound Lane 4. When more than one measurement was taken on a single texture, a number was appended to the texture code; this number indicates the number of years since the completion of the texturing. For example, CDG0.7y-S3 stands for the CDG texture 0.7 years after construction in southbound Lane 3.

I.2 OBSI Statistics

I.2.1 Sacramento 5 – PM 20.0/21.5

Table I.1: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on Sacramento 5 – PM 20.0/21.5

alpha = 5.E-02	PreCDG-N1	PreCDG-N4	PreCDG-S1	PreCDG-S4	GnG-N1	GnG-N4	CDG-S1	CDG-S4	GnG1.0-N1	GnG1.0-N4	CDG1.0-S1	CDG1.0-S4
PreCDG-N1	0.5	1.E-40	3.E-04	4.E-14	8.E-101	7.E-46	2.E-38	5.E-21	1.E-78	5.E-02	3.E-16	1.E-27
PreCDG-N4	1.E-40	0.5	1.E-27	2.E-08	1.E-120	1.E-68	4.E-62	3.E-52	4.E-99	1.E-09	1.E-57	5.E-01
PreCDG-S1	3.E-04	1.E-27	0.5	6.E-07	1.E-104	2.E-51	7.E-44	5.E-27	3.E-75	5.E-01	2.E-23	1.E-19
PreCDG-S4	4.E-14	2.E-08	6.E-07	0.5	1.E-100	1.E-59	3.E-52	4.E-36	1.E-66	2.E-03	2.E-32	9.E-07
GnG-N1	8.E-101	1.E-120	1.E-104	1.E-100	0.5	3.E-28	1.E-34	7.E-62	6.E-54	3.E-51	7.E-85	2.E-102
GnG-N4	7.E-46	1.E-68	2.E-51	1.E-59	3.E-28	0.5	1.E-02	5.E-19	6.E-03	2.E-31	7.E-31	2.E-68
CDG-S1	2.E-38	4.E-62	7.E-44	3.E-52	1.E-34	**1.E-02**	0.5	4.E-12	3.E-01	2.E-26	1.E-22	1.E-61
CDG-S4	5.E-21	3.E-52	5.E-27	4.E-36	7.E-62	5.E-19	4.E-12	0.5	5.E-20	7.E-13	2.E-04	2.E-47
GnG1.0-N1	2.E-78	5.E-99	4.E-75	1.E-66	5.E-54	6.E-03	**3.E-01**	7.E-20	0.5	2.E-28	7.E-43	4.E-70
GnG1.0-N4	**5.E-02**	1.E-09	**5.E-01**	2.E-03	3.E-51	2.E-31	2.E-26	7.E-13	3.E-28	0.5	2.E-08	4.E-09
CDG1.0-S1	3.E-16	1.E-57	2.E-23	2.E-32	7.E-85	7.E-31	1.E-22	2.E-04	1.E-42	2.E-08	0.5	2.E-44
CDG1.0-S4	1.E-27	**5.E-01**	1.E-19	9.E-07	2.E-102	2.E-68	1.E-61	2.E-47	4.E-70	7.E-09	3.E-44	0.5

Table I.2: Comparison of Northbound and Southbound Pre-CDG Texture

Ho: PreCDG NB L1&4 = PreCDG SB L1&4		
H1: PreCDG NB L1&4 ≠ PreCDG SB L1&4		
alpha = 0.05	PreCDG NB	PreCDG SB
Mean	104.488	104.357
Variance	0.5506	0.3849
Observations	180	180
df	347	
t Stat	1.82183	
P(T<=t) two-tail	**0.06934**	**Accept null**
t Critical two-tail	1.96682	

I.2.2 Sacramento 5 – PM 1.5/3.0

Table I.3: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on Sacramento 5 – PM 1.5/3.0

alpha = 5.E-02	PreCDG-N1	PreCDG-N2	PreCDG-S1	PreCDG-S2	CDG-N1	CDG-N2	CDG-S1	CDG-S2	GnG-N1	GnG-N2	CDG0.2y-S1	CDG0.2y-S2
PreCDG-N1	0.5	2.E-37	3.E-04	5.E-04	1.E-04	1.E-03	2.E-03	3.E-03	1.E-87	5.E-79	1.E-33	6.E-15
PreCDG-N2	2.E-37	0.5	4.E-43	2.E-21	4.E-45	2.E-27	1.E-41	3.E-30	1.E-84	3.E-85	1.E-62	5.E-51
PreCDG-S1	3.E-04	4.E-43	0.5	1.E-08	3.E-01	5.E-09	3.E-01	4.E-01	1.E-65	6.E-58	7.E-17	4.E-07
PreCDG-S2	5.E-04	2.E-21	1.E-08	0.5	4.E-09	3.E-01	1.E-07	2.E-06	8.E-62	1.E-57	6.E-29	6.E-19
CDG-N1	1.E-04	4.E-45	3.E-01	4.E-09	0.5	4.E-10	5.E-01	3.E-01	9.E-93	2.E-78	6.E-26	4.E-09
CDG-N2	1.E-03	2.E-27	5.E-09	**3.E-01**	4.E-10	0.5	7.E-08	3.E-06	2.E-76	6.E-72	5.E-36	3.E-20
CDG-S1	2.E-03	1.E-41	**3.E-01**	1.E-07	**5.E-01**	7.E-08	0.5	2.E-01	1.E-65	2.E-58	4.E-18	6.E-08
CDG-S2	3.E-03	3.E-30	**4.E-01**	2.E-06	**3.E-01**	3.E-06	**2.E-01**	0.5	2.E-39	3.E-33	3.E-08	2.E-04
GnG-N1	1.E-87	1.E-84	1.E-65	8.E-62	9.E-93	2.E-76	1.E-65	2.E-39	0.5	2.E-13	2.E-73	2.E-42
GnG-N2	5.E-79	3.E-85	6.E-58	1.E-57	2.E-78	6.E-72	2.E-58	3.E-33	2.E-13	0.5	1.E-51	5.E-33
CDG0.2y-S1	1.E-33	1.E-62	7.E-17	6.E-29	6.E-26	5.E-36	4.E-18	3.E-08	2.E-73	1.E-51	0.5	2.E-02
CDG0.2y-S2	6.E-15	5.E-51	4.E-07	6.E-19	4.E-09	3.E-20	6.E-08	2.E-04	2.E-42	5.E-33	**2.E-02**	0.5

Table I.4: Comparison of OBSI on Pre-CDG and CDG Textures on Sacramento 5 – PM 1.5/3.0 Northbound and Southbound Lane 1

Northbound Lane 1			Southbound Lane 1		
Ho: PreCDG NB L1 = CDG NB L1			Ho: PreCDG SB L1 = CDG SB L1		
H1: PreCDG NB L1 > CDG NB L1			H1: PreCDG SB L1 > CDG SB L1		
alpha = 0.05	PreCDG-N1	CDG-N1	alpha = 0.05	PreCDG-S1	CDG-S1
Mean	104.1380	103.8698	Mean	103.8295	103.8783
Variance	0.2694	0.20137	Variance	0.4251	0.4370
Observations	90	90	Observations	90	90
df	174		df	178	
t Stat	3.7082		t Stat	-0.4987	
P(T<=t) one-tail	0.00014	Reject Null	P(T<=t) one-tail	0.3093	Accept Null
t Critical one-tail	1.65366		t Critical one-tail	1.65346	

I.2.3 Sacramento 80 – PM 13.0/14.0

Table I.5: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on Sacramento 80 – PM 13.0/14.0

alpha = 5 E-02	PreCDG-E2	PreCDG-E5	PreCDG-W2	PreCDG-W5	CDG-E2	CDG-W2	GnG-E2	GnG-E5	GnG-W2	GnG-W5
PreCDG-E2	0.5	2 E-01	4 E-05	2 E-01	5 E-39	1 E-37	2 E-75	9 E-76	3 E-73	5 E-74
PreCDG-E5	**2 E-01**	0.5	4 E-04	4 E-01	2 E-37	9 E-38	3 E-84	2 E-83	2 E-83	5 E-78
PreCDG-W2	4 E-05	4 E-04	0.5	2 E-04	2 E-33	4 E-33	3 E-88	1 E-85	5 E-92	5 E-76
PreCDG-W5	**2 E-01**	**4 E-01**	2 E-04	0.5	1 E-37	4 E-38	2 E-84	2 E-83	1 E-83	3 E-78
CDG-E2	5 E-39	2 E-37	2 E-33	1 E-37	0.5	2 E-08	5 E-22	4 E-21	2 E-23	3 E-18
CDG-W2	1 E-37	9 E-38	4 E-33	4 E-38	2 E-08	0.5	1 E-46	6 E-46	4 E-47	2 E-42
GnG-E2	2 E-75	3 E-84	3 E-88	2 E-84	5 E-22	1 E-46	0.5	2 E-01	5 E-02	4 E-03
GnG-E5	9 E-76	2 E-83	1 E-85	2 E-83	4 E-21	6 E-46	**2 E-01**	0.5	1 E-02	2 E-02
GnG-W2	3 E-73	2 E-83	5 E-92	1 E-83	2 E-23	4 E-47	**5 E-02**	**1 E-02**	0.5	2 E-05
GnG-W5	5 E-74	5 E-78	5 E-76	3 E-78	3 E-18	2 E-42	4 E-03	**2 E-02**	2 E-05	0.5

I.2.4 Sacramento 50 – PM R13.0/R14.0

Table I.6: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on Sacramento 50 – PM R13.0/R14.0

alpha = 5 E-02	PreCDG-E1	PreCDG-E4	CDG-E1	GnG-W1	GnG-W4
PreCDG-E1	0.5	2.4 E-09	1.6 E-06	6.5 E-30	1.0 E-28
PreCDG-E4	2.4 E-09	0.5	7.4 E-16	6.0 E-21	2.1 E-20
CDG-E1	1.6 E-06	7.4 E-16	0.5	3.9 E-35	6.4 E-33
GnG-W1	6.5 E-30	6.0 E-21	3.9 E-35	0.5	4.4 E-03
GnG-W4	1.0 E-28	2.1 E-20	6.4 E-33	4.4 E-03	0.5

I.2.5 San Joaquin 99 – PM 29.0/30.7

Table I.7: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on San Joaquin 99 – PM 29.0/30.7

alpha = 5 E-02	PreCDG-N1	PreCDG-N2	GnG-N1	GnG-N2
PreCDG-N1	0.5	5.4 E-11	5.1 E-95	2.9 E-64
PreCDG-N2	5.4 E-11	0.5	3.7 E-103	2.2 E-75
GnG-N1	5.1 E-95	3.7 E-103	0.5	1.2 E-12
GnG-N2	2.9 E-64	2.2 E-75	1.2 E-12	0.5

I.2.6 Yolo 113 – PM R0.5/R2.5

The Yolo 113 project was broken into subsections in both directions and the labels applied to each of those subsections appears in Table I.8. The statistical data for Yolo 113 – PM R0.5/R2.5 is presented in two tables, Table I.9, Parts A and B. The first column shows all the lane texture combinations and is repeated in both parts of the table. The first table reports the p-values for the northbound lanes and the second one reports them for the southbound lanes. For both parts of the table, the PreGnG abbreviation represents a PreCDG texture at locations that later were surfaced with the GnG texture, as labeled in Table I.8.

Table I.8: Abbreviations for Pre-CDG Test Subsections

Direction	Lane	Post Mile	Abbreviations for Table I.9
NB	LN 1	0.5 – 1.5	PreGnG-N1
		1.5 – 2.5	PreCDG-N1
	LN 2	0.5 – 1.5	PreGnG-N2
		1.5 – 2.5	PreCDG-N2
SB	LN 1	0.5 – 0.9	PreGnG-S1
		0.9 – 2.5	PreCDG-S1
	LN 2	0.5 – 0.9	PreGnG-S2
		0.9 – 2.5	PreCDG-S2

Table I.9: P-Values from One Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on Yolo 113 – PM R0.5/R2.5, Northbound (Part A)

alpha = 2 E-02	PreGnG-N1	PreCDG-N1	PreGnG-N2	PreCDG-N2	GnG-N1	CDG-N1	GnG-N2	CDG-N2
PreGnG-N1	0.5	9 E-04	2 E-05	2 E-07	3 E-24	4 E-06	5 E-26	3 E-18
PreCDG-N1	9 E-04	0.5	5 E-01	1 E-01	2 E-25	1 E-11	7 E-27	5 E-21
PreGnG-N2	2 E-05	**5 E-01**	0.5	5 E-02	2 E-46	5 E-26	1 E-51	8 E-41
PreCDG-N2	2 E-07	**1 E-01**	**5 E-02**	0.5	2 E-46	6 E-28	2 E-51	4 E-41
GnG-N1	3 E-24	2 E-25	2 E-46	2 E-46	0.5	3 E-52	2 E-02	3 E-20
CDG-N1	4 E-06	1 E-11	5 E-26	6 E-28	3 E-52	0.5	5 E-49	4 E-34
GnG-N2	5 E-26	7 E-27	1 E-51	2 E-51	**2 E-02**	5 E-49	0.5	3 E-19
CDG-N2	3 E-18	5 E-21	8 E-41	4 E-41	3 E-20	4 E-34	3 E-19	0.5
PreGnG-S1	**1 E-02**	**5 E-02**	6 E-03	5 E-05	2 E-23	1 E-13	3 E-27	6 E-21
PreCDG-S1	2 E-03	5 E-09	9 E-21	4 E-23	5 E-80	3 E-06	5 E-60	8 E-56
PreGnG-S2	**2 E-01**	1 E-03	7 E-08	4 E-11	4 E-41	2 E-21	2 E-49	4 E-37
PreCDG-S2	**2 E-02**	9 E-03	8 E-06	5 E-09	9 E-103	1 E-37	1 E-71	8 E-83
GnG-S1	6 E-24	3 E-25	6 E-45	5 E-45	**4 E-01**	4 E-48	9 E-03	9 E-20
CDG-S1	2.E-15	1.E-19	2.E-41	2.E-42	6.E-17	4.E-17	8.E-19	6.E-03
GnG-S2	6.E-27	1.E-27	4.E-49	3.E-49	4.E-05	1.E-38	**4.E-02**	3.E-19
CDG-S2	7 E-14	6 E-18	7 E-37	1 E-37	2 E-37	2 E-19	3 E-32	6 E-10

Table I.9: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on Yolo 113 – PM R0.5/R2.5, Southbound (Part B)

alpha = 2 E-02	PreGnG-S1	PreCDG-S1	PreGnG-S2	PreCDG-S2	GnG-S1	CDG-S1	GnG-S2	CDG-S2
PreGnG-N1	1 E-02	2 E-03	2 E-01	2 E-02	6 E-24	2.E-15	6.E-27	7 E-14
PreCDG-N1	5 E-02	5 E-09	1 E-03	9 E-03	3 E-25	1.E-19	1.E-27	6 E-18
PreGnG-N2	6 E-03	9 E-21	7 E-08	8 E-06	6 E-45	2.E-41	4.E-49	7 E-37
PreCDG-N2	5 E-05	4 E-23	4 E-11	5 E-09	5 E-45	2.E-42	3.E-49	1 E-37
GnG-N1	2 E-23	5 E-80	4 E-41	9 E-103	4 E-01	6.E-17	4.E-05	2 E-37
CDG-N1	1 E-13	3 E-06	2 E-21	1 E-37	4 E-48	4.E-17	1.E-38	2 E-19
GnG-N2	3 E-27	5 E-60	2 E-49	1 E-71	9 E-03	8.E-19	4.E-02	3 E-32
CDG-N2	6 E-21	8 E-56	4 E-37	8 E-83	9 E-20	6.E-03	3.E-19	6 E-10
PreGnG-S1	0.5	3 E-10	1 E-02	1 E-01	1 E-22	1.E-23	2.E-26	4 E-19
PreCDG-S1	3 E-10	0.5	5 E-15	2 E-37	2 E-71	3.E-27	7.E-41	1 E-38
PreGnG-S2	**1 E-02**	5 E-15	0.5	7 E-03	7 E-37	1.E-38	4.E-39	4 E-35
PreCDG-S2	**1 E-01**	2 E-37	7 E-03	0.5	4 E-86	3.E-49	3.E-43	1 E-76
GnG-S1	1 E-22	2 E-71	7 E-37	4 E-86	0.5	3.E-17	4.E-05	7 E-36
CDG-S1	1.E-23	3.E-27	1.E-38	3.E-49	3.E-17	0.5	2.E-21	3.E-02
GnG-S2	2.E-26	7.E-41	4.E-39	3.E-43	4.E-05	2.E-21	0.5	3.E-28
CDG-S2	4 E-19	1 E-38	4 E-35	1 E-76	7 E-36	**3.E-02**	3.E-28	0.5

Table I.10: Comparison of OBSI on Pre-CDG Textures on Yolo 113 – PM R0.5/R2.5 Northbound and Southbound Lane 2

Northbound Lane 2			Southbound Lane 2		
Ho: PreCDG NB L2 = PreGnG NB L2			Ho: PreCDG SB L2 = PreGnG SB L2		
H1: PreCDG NB L2 ≠ PreGnG NB L2			H1: PreCDG SB L2 ≠ PreGnG SB L2		
alpha = 0.05	PreGnG-N2	PreCDG-N2	alpha = 0.05	PreGnG-S2	PreCDG-S2
Mean	103.5821005	103.8428709	Mean	102.8737573	103.050284
Variance	0.738724928	0.86385441	Variance	0.082017719	0.144316753
Observations	62	63	Observations	25	102
df	123		df	47	
t Stat	1.628959371		t Stat	2.576117793	
P(T<=t) two-tail	0.105880204	Accept Null	P(T<=t) two-tail	0.013194803	Reject Null
t Critical two-tail	1.979438685		t Critical two-tail	2.011740514	

I.2.7 San Diego 5 – PM R35.8/R37.9

Table I.11: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on San Diego 5 – PM R35.8/R37.9 (Part A, South of the GnG Section)

CDG Section South of the GnG Section, PM R35.8/R36.3											
	Direction	Northbound					Southbound				
Lane	Texture	PreCDG	CDG0.0y	CDG0.7y	CDG1.1y	CDG1.3y	PreCDG	CDG0.0y	CDG0.7y	CDG1.1y	CDG1.3y
Lane 1	PreCDG	0.5	2E-19	6E-22	2E-23	2E-26	0.5	1E-08	1E-13	4E-13	2E-13
	CDG0.0y	2E-19	0.5	4E-01	2E-01	1E-04	1E-08	0.5	9E-03	1E-02	1E-03
	CDG0.7y	6E-22	**4E-01**	0.5	3E-01	2E-04	1E-13	9E-03	0.5	4E-01	2E-01
	CDG1.1y	2E-23	**2E-01**	**3E-01**	0.5	7E-04	4E-13	**1E-02**	**4E-01**	0.5	2E-01
	CDG1.3y	2E-26	1E-04	2E-04	7E-04	0.5	2E-13	1E-03	**2E-01**	**2E-01**	0.5
Lane 2	PreCDG	0.5	8E-13	5E-15	1E-15	1E-18	0.5	2E-03	5E-04	7E-07	2E-05
	CDG0.0y	8E-13	0.5	2E-01	3E-01	1E-01	2E-03	0.5	4E-01	3E-02	5E-02
	CDG0.7y	5E-15	**2E-01**	0.5	4E-01	1E-02	5E-04	**4E-01**	0.5	4E-02	8E-02
	CDG1.1y	1E-15	**3E-01**	**4E-01**	0.5	2E-02	7E-07	**3E-02**	**4E-02**	0.5	5E-01
	CDG1.3y	1E-18	**1E-01**	**1E-02**	**2E-02**	0.5	2E-05	**5E-02**	**8E-02**	**5E-01**	0.5
Lane 3	PreCDG	0.5	1E-09	1E-12	4E-14	4E-18	0.5	2E-11	3E-13	1E-12	2E-15
	CDG0.0y	1E-09	0.5	4E-01	5E-01	2E-03	2E-11	0.5	8E-03	2E-03	5E-02
	CDG0.7y	1E-12	**4E-01**	0.5	4E-01	1E-04	3E-13	8E-03	0.5	2E-01	8E-02
	CDG1.1y	4E-14	**5E-01**	**4E-01**	0.5	2E-04	1E-12	2E-03	**2E-01**	0.5	1E-02
	CDG1.3y	4E-18	2E-03	1E-04	2E-04	0.5	2E-15	**5E-02**	**8E-02**	**1E-02**	0.5
Lane 4	PreCDG	0.5	5E-07	4E-16	2E-19	8E-22	0.5	2E-02	2E-15	7E-15	6E-18
	CDG0.0y	5E-07	0.5	6E-13	1E-17	3E-21	**2E-02**	0.5	1E-10	2E-10	3E-13
	CDG0.7y	4E-16	6E-13	0.5	1E-04	2E-09	2E-15	1E-10	0.5	2E-01	2E-02
	CDG1.1y	2E-19	1E-17	1E-04	0.5	4E-03	7E-15	2E-10	**2E-01**	0.5	7E-04
	CDG1.3y	8E-22	3E-21	2E-09	4E-03	0.5	6E-18	3E-13	**2E-02**	7E-04	0.5
Lane 5	PreCDG	0.5	8E-12	2E-14	2E-22	4E-26	0.5	5E-01	1E-05	1E-05	8E-09
	CDG0.0y	8E-12	0.5	1E-01	8E-03	6E-05	**5E-01**	0.5	1E-10	6E-11	4E-17
	CDG0.7y	2E-14	**1E-01**	0.5	1E-01	2E-03	1E-05	1E-10	0.5	5E-01	3E-06
	CDG1.1y	2E-22	8E-03	**1E-01**	0.5	1E-02	1E-05	6E-11	**5E-01**	0.5	2E-07
	CDG1.3y	4E-26	6E-05	2E-03	**1E-02**	0.5	8E-09	4E-17	3E-06	2E-07	0.5

Table I.11: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on San Diego 5 – PM R35.8/R37.9 (Part B, North of the GnG Section)

CDG Section North of the GnG Section, PM R37.4/R37.9											
	Direction	Northbound					Southbound				
Lane	Texture	PreCDG	CDG0.0y	CDG0.7y	CDG1.1y	CDG1.3y	PreCDG	CDG0.0y	CDG0.7y	CDG1.1y	CDG1.3y
Lane 1	PreCDG	0.5	3E-10	2E-14	2E-13	6E-15	0.5	3E-12	1E-09	2E-11	3E-11
	CDG0.0y	3E-10	0.5	7E-02	2E-01	4E-02	3E-12	0.5	6E-02	2E-01	3E-01
	CDG0.7y	2E-14	**7E-02**	0.5	2E-01	4E-01	1E-09	**6E-02**	0.5	2E-01	2E-01
	CDG1.1y	2E-13	**2E-01**	**2E-01**	0.5	1E-01	2E-11	**2E-01**	**2E-01**	0.5	4E-01
	CDG1.3y	6E-15	**4E-02**	**4E-01**	**1E-01**	0.5	3E-11	**3E-01**	**2E-01**	**4E-01**	0.5
Lane 2	PreCDG	0.5	1E-06	5E-11	3E-13	4E-16	0.5	3E-08	5E-10	9E-11	6E-13
	CDG0.0y	1E-06	0.5	4E-01	2E-01	2E-02	3E-08	0.5	3E-01	1E-01	4E-01
	CDG0.7y	5E-11	**4E-01**	0.5	3E-01	2E-02	5E-10	**3E-01**	0.5	2E-01	1E-01
	CDG1.1y	3E-13	**2E-01**	**3E-01**	0.5	3E-02	9E-11	**1E-01**	**2E-01**	0.5	2E-02
	CDG1.3y	4E-16	**2E-02**	**2E-02**	**3E-02**	0.5	6E-13	**4E-01**	**1E-01**	**2E-02**	0.5
Lane 3	PreCDG	0.5	4E-14	2E-23	2E-22	1E-23	0.5	5E-18	3E-22	9E-22	6E-21
	CDG0.0y	4E-14	0.5	1E-01	1E-02	3E-01	5E-18	0.5	4E-01	9E-02	5E-01
	CDG0.7y	2E-23	**1E-01**	0.5	5E-02	2E-01	3E-22	**4E-01**	0.5	1E-01	4E-01
	CDG1.1y	2E-22	**1E-02**	**5E-02**	0.5	1E-02	9E-22	**9E-02**	**1E-01**	0.5	8E-02
	CDG1.3y	1E-23	**3E-01**	**2E-01**	**1E-02**	0.5	6E-21	**5E-01**	**4E-01**	**8E-02**	0.5
Lane 4	PreCDG	0.5	1E-16	2E-23	4E-21	3E-25	0.5	8E-20	2E-20	1E-19	6E-22
	CDG0.0y	1E-16	0.5	9E-03	2E-01	1E-04	8E-20	0.5	2E-01	4E-01	5E-05
	CDG0.7y	2E-23	9E-03	0.5	5E-02	5E-02	2E-20	**2E-01**	0.5	2E-01	5E-04
	CDG1.1y	4E-21	**2E-01**	**5E-02**	0.5	5E-04	1E-19	**4E-01**	**2E-01**	0.5	8E-06
	CDG1.3y	3E-25	1E-04	**5E-02**	5E-04	0.5	6E-22	5E-05	5E-04	8E-06	0.5
Lane 5	PreCDG	0.5	3E-05	3E-09	1E-11	3E-12	0.5	8E-15	3E-15	1E-16	2E-18
	CDG0.0y	3E-05	0.5	2E-02	1E-02	2E-03	8E-15	0.5	5E-01	1E-01	5E-03
	CDG0.7y	3E-09	**2E-02**	0.5	4E-01	3E-01	3E-15	**5E-01**	0.5	1E-01	4E-03
	CDG1.1y	1E-11	**1E-02**	**4E-01**	0.5	2E-01	1E-16	**1E-01**	**1E-01**	0.5	5E-02
	CDG1.3y	3E-12	2E-03	**3E-01**	**2E-01**	0.5	2E-18	5E-03	4E-03	**5E-02**	0.5

Table I.11: P-Values from One-Sided Student's *t*-Tests on OBSI Results for Individual Lanes and Textures on San Diego 5 – PM R35.8/R37.9 (Part C, the GnG Section)

GnG Section, PM R36.3/R37.4											
	Direction	Northbound					Southbound				
Lane	Texture	PreCDG	CDG0.0y	CDG0.7y	CDG1.1y	GnG	PreCDG	CDG0.0y	CDG0.7y	CDG1.1y	GnG
Lane 1	PreCDG	0.5	6E-37	2E-37	5E-39	1E-64	0.5	5E-16	1E-17	5E-18	5E-34
	CDG0.0y	6E-37	0.5	2E-01	4E-02	9E-45	5E-16	0.5	9E-02	6E-02	4E-27
	CDG0.7y	2E-37	**2E-01**	0.5	2E-01	8E-44	1E-17	**9E-02**	0.5	4E-01	3E-22
	CDG1.1y	5E-39	**4E-02**	**2E-01**	0.5	5E-42	5E-18	**6E-02**	**4E-01**	0.5	4E-21
	GnG	1E-64	9E-45	8E-44	5E-42	0.5	5E-34	4E-27	3E-22	4E-21	0.5
Lane 2	PreCDG	0.5	2E-29	7E-31	2E-34	8E-72	0.5	2E-24	2E-40	1E-34	2E-77
	CDG0.0y	2E-29	0.5	2E-01	4E-02	5E-35	2E-24	0.5	1E-07	1E-04	3E-33
	CDG0.7y	7E-31	**2E-01**	0.5	2E-01	2E-40	2E-40	1E-07	0.5	5E-02	8E-23
	CDG1.1y	2E-34	**4E-02**	**2E-01**	0.5	1E-52	1E-34	1E-04	**5E-02**	0.5	2E-25
	GnG	8E-72	5E-35	2E-40	1E-52	0.5	2E-77	3E-33	8E-23	2E-25	0.5
Lane 3	PreCDG	0.5	1E-16	8E-25	1E-25	5E-76	0.5	5E-28	1E-39	1E-41	6E-78
	CDG0.0y	1E-16	0.5	2E-01	7E-02	1E-15	5E-28	0.5	2E-01	1E-01	4E-23
	CDG0.7y	8E-25	**2E-01**	0.5	2E-01	1E-27	1E-39	**2E-01**	0.5	3E-01	1E-35
	CDG1.1y	1E-25	**7E-02**	**2E-01**	0.5	1E-33	1E-41	**1E-01**	**3E-01**	0.5	1E-39
	GnG	5E-76	1E-15	1E-27	1E-33	0.5	6E-78	4E-23	1E-35	1E-39	0.5
Lane 4	PreCDG	0.5	8E-22	8E-50	4E-51	2E-84	0.5	5E-33	4E-55	2E-57	2E-78
	CDG0.0y	8E-22	0.5	4E-07	5E-08	1E-43	5E-33	0.5	7E-10	1E-11	3E-44
	CDG0.7y	8E-50	4E-07	0.5	3E-01	1E-63	4E-55	7E-10	0.5	2E-01	2E-46
	CDG1.1y	4E-51	5E-08	**3E-01**	0.5	2E-63	2E-57	1E-11	**2E-01**	0.5	1E-47
	GnG	2E-84	1E-43	1E-63	2E-63	0.5	2E-78	3E-44	2E-46	1E-47	0.5
Lane 5	PreCDG	0.5	6E-11	7E-20	1E-22	3E-64	0.5	7E-29	1E-32	7E-35	7E-70
	CDG0.0y	6E-11	0.5	1E-02	7E-03	3E-37	7E-29	0.5	5E-01	5E-01	1E-33
	CDG0.7y	7E-20	**1E-02**	0.5	5E-01	2E-41	1E-32	**5E-01**	0.5	5E-01	3E-39
	CDG1.1y	1E-22	7E-03	**5E-01**	0.5	4E-48	7E-35	**5E-01**	**5E-01**	0.5	8E-44
	GnG	3E-64	3E-37	2E-41	4E-48	0.5	7E-70	1E-33	3E-39	8E-44	0.5

I.3 Portable Skid Tester (CT 342) Statistics

I.3.1 Sacramento 5 – PM 20.0/21.5

Table I.12: P-Values from One-Sided Student's *t*-Tests on CT 342 Results for Testing on Sacramento 5 – PM 20.0/21.5 Project, Including NGL

	CDG-0deg	PreGnG-0deg	GnG-0deg	NGL-0deg	CDG-15deg	PreGnG-15deg	GnG-15deg	NGL-15deg	CDG-45deg	PreGnG-45deg	GnG-45deg	NGL-45deg
CDG-0deg	0.5	2 E-05	1 E-02	4 E-01	2 E-01	3 E-05	6 E-02	5 E-01	7 E-02	2 E-04	4 E-01	4 E-01
PreGnG-0deg	2 E-05	0.5	2 E-04	1 E-04	1 E-05	2 E-01	3 E-06	9 E-05	7 E-05	1 E-02	2 E-05	4 E-05
GnG-0deg	**1 E-02**	2 E-04	0.5	2 E-04	4 E-03	3 E-04	1 E-05	1 E-04	8 E-03	8 E-06	5 E-03	4 E-04
NGL-0deg	**4 E-01**	1 E-04	2 E-04	0.5	1 E-01	2 E-04	8 E-03	4 E-01	6 E-02	6 E-07	3 E-01	5 E-01
CDG-15deg	**2 E-01**	1 E-05	4 E-03	**1 E-01**	0.5	2 E-05	2 E-01	2 E-01	2 E-01	1 E-04	1 E-01	2 E-01
PreGnG-15deg	3 E-05	**2 E-01**	3 E-04	2 E-04	2 E-05	0.5	5 E-06	1 E-04	1 E-04	3 E-02	3 E-05	6 E-05
GnG-15deg	**6 E-02**	3 E-06	1 E-05	8 E-03	**2 E-01**	5 E-06	0.5	1 E-02	3 E-01	1 E-08	1 E-02	1 E-02
NGL-15deg	**5 E-01**	9 E-05	1 E-04	**4 E-01**	**2 E-01**	1 E-04	**1 E-02**	0.5	6 E-02	1 E-07	3 E-01	4 E-01
CDG-45deg	**7 E-02**	7 E-05	8 E-03	**6 E-02**	**2 E-01**	1 E-04	**3 E-01**	**6 E-02**	0.5	8 E-04	5 E-02	6 E-02
PreGnG-45deg	2 E-04	**1 E-02**	8 E-06	6 E-07	1 E-04	**3 E-02**	1 E-08	1 E-07	8 E-04	0.5	3 E-07	1 E-08
GnG-45deg	**4 E-01**	2 E-05	5 E-03	**3 E-01**	**1 E-01**	3 E-05	**1 E-02**	**3 E-01**	**5 E-02**	3 E-07	0.5	4 E-01
NGL-45deg	**4 E-01**	4 E-05	4 E-04	**5 E-01**	**2 E-01**	6 E-05	**1 E-02**	**4 E-01**	**6 E-02**	1 E-08	**4 E-01**	0.5

I.3.2 Sacramento 80 – PM 13.0/14.0

Table I.13: P-Values from One-Sided Student's *t*-Tests on CT 342 Results for Testing on Sacramento 80 – PM 13.0/14.0 Project

	PreCDG-0deg	CDG-0deg	GnG-0deg	PreCDG-15deg	CDG-15deg	GnG-15deg	PreCDG-45deg	CDG-45deg	GnG-45deg
PreCDG-0deg	0.5	9 E-07	6 E-03	3 E-02	4 E-08	1 E-06	1 E-01	2 E-12	7 E-03
CDG-0deg	9 E-07	0.5	2 E-14	4 E-12	1 E-02	5 E-18	2 E-05	1 E-08	2 E-14
GnG-0deg	6 E-03	2 E-14	0.5	2 E-01	2 E-10	3 E-07	7 E-05	6 E-15	5 E-01
PreCDG-15deg	**3 E-02**	4 E-12	**2 E-01**	0.5	6 E-11	4 E-06	5 E-04	3 E-16	2 E-01
CDG-15deg	4 E-08	**1 E-02**	2 E-10	6 E-11	0.5	3 E-13	7 E-07	2 E-04	5 E-11
GnG-15deg	1 E-06	5 E-18	3 E-07	4 E-06	3 E-13	0.5	1 E-08	3 E-18	2 E-06
PreCDG-45deg	**1 E-01**	2 E-05	7 E-05	5 E-04	7 E-07	1 E-08	0.5	1 E-11	8 E-05
CDG-45deg	2 E-12	1 E-08	6 E-15	3 E-16	2 E-04	3 E-18	1 E-11	0.5	3 E-16
GnG-45deg	7 E-03	2 E-14	**5 E-01**	**2 E-01**	5 E-11	2 E-06	8 E-05	3 E-16	0.5

I.3.3 San Diego 5 – PM R35.8/R37.9

Table I.14: P-Values from One-Sided Student's *t*-Tests on CT 342 Results for Testing on San Diego 5 – PM R35.8/R37.9 Project (Part A)

	CDG -0 deg	Pre-GnG -0 deg	GnG -0 deg	PreCDG -5 deg	CDG -5 deg	Pre-GnG -5 deg	GnG -5 deg	PreCDG -15 deg	CDG - 15 deg
CDG-0 deg	0.5	**3 E-01**	1 E-02	1 E-08	**3 E-01**	3 E-03	**5 E-02**	**7 E-02**	**1 E-01**
PreGnG-0 deg	**3 E-01**	0.5	1 E-03	4 E-14	**4 E-01**	5 E-03	1 E-02	**7 E-02**	**2 E-01**
GnG-0 deg	1 E-02	1 E-03	0.5	3 E-16	2 E-03	8 E-10	**2 E-01**	**1 E-01**	3 E-03
PreCDG-5 deg	1 E-08	4 E-14	3 E-16	0.5	7 E-09	2 E-19	3 E-15	3 E-01	3 E-07
CDG-5 deg	**3 E-01**	**4 E-01**	2 E-03	7 E-09	0.5	**2 E-02**	1 E-02	**6 E-02**	**2 E-01**
PreGnG-5 deg	3 E-03	5 E-03	8 E-10	2 E-19	**2 E-02**	0.5	1 E-07	**5 E-02**	**2 E-01**
GnG-5 deg	**5 E-02**	1 E-02	**2 E-01**	3 E-15	1 E-02	1 E-07	0.5	**1 E-01**	1 E-02
PreCDG-15 deg	**7 E-02**	**7 E-02**	**1 E-01**	**3 E-01**	**6 E-02**	**5 E-02**	**1 E-01**	0.5	**3 E-02**
CDG-15 deg	**1 E-01**	**2 E-01**	3 E-03	3 E-07	**2 E-01**	**2 E-01**	1 E-02	**3 E-02**	0.5
PreGnG-15 deg	6 E-05	6 E-05	2 E-10	2 E-17	5 E-04	3 E-02	5 E-09	**4 E-02**	**3 E-02**
GnG-15 deg	**3 E-01**	**4 E-01**	3 E-06	9 E-22	**4 E-01**	7 E-04	6 E-04	**8 E-02**	**2 E-01**
PreCDG-30 deg	**8 E-02**	**8 E-02**	**1 E-01**	**5 E-01**	**7 E-02**	6 E-02	**1 E-01**	**3 E-01**	**5 E-02**
CDG-30 deg	2 E-03	3 E-03	1 E-05	6 E-09	6 E-03	**1 E-01**	4 E-05	**2 E-02**	**5 E-02**
PreGnG-30 deg	8 E-07	1 E-07	3 E-15	5 E-21	9 E-06	2 E-04	2 E-13	**4 E-02**	3 E-03
GnG-30 deg	**7 E-02**	**1 E-01**	2 E-07	8 E-20	**2 E-01**	**3 E-02**	3 E-05	6 E-02	**4 E-01**
PreCDG-45 deg	**1 E-02**	1 E-02	**3 E-02**	**1 E-01**	9 E-03	**1 E-02**	**3 E-02**	**1 E-01**	2 E-03
CDG-45 deg	1 E-04	2 E-04	4 E-07	3 E-10	7 E-04	**2 E-02**	1 E-06	**3 E-02**	**2 E-02**
PreGnG-45 deg	6 E-09	6 E-12	1 E-23	2 E-26	7 E-08	3 E-09	2 E-20	**4 E-02**	1 E-04
GnG-45 deg	3 E-05	1 E-05	3 E-14	2 E-21	3 E-04	1 E-02	7 E-12	**4 E-02**	**2 E-02**

Table I.14: P-Values from One-Sided Student's *t*-Tests on CT 342 Results for Testing on San Diego 5 – PM 35.8/37.9 Project (Part B)

	PreGnG-15 deg	GnG-15 deg	PreCDG-30 deg	CDG-30 deg	PreGnG-30 deg	GnG-30 deg	PreCDG-45 deg	CDG-45 45 deg	PreGnG-45 deg	GnG-45 deg
CDG-0 deg	6 E-05	**3 E-01**	**8 E-02**	2 E-03	8 E-07	**7 E-02**	**1 E-02**	1 E-04	6 E-09	3 E-05
PreGnG-0 deg	6 E-05	**4 E-01**	**8 E-02**	3 E-03	1 E-07	**1 E-01**	1 E-02	2 E-04	6 E-12	1 E-05
GnG-0 deg	2 E-10	3 E-06	**1 E-01**	1 E-05	3 E-15	2 E-07	**3 E-02**	4 E-07	1 E-23	3 E-14
PreCDG-5 deg	2 E-17	9 E-22	**5 E-01**	6 E-09	5 E-21	8 E-20	**1 E-01**	3 E-10	2 E-26	2 E-21
CDG-5 deg	5 E-04	**4 E-01**	**7 E-02**	6 E-03	9 E-06	**2 E-01**	9 E-03	7 E-04	7 E-08	3 E-04
PreGnG-5 deg	**3 E-02**	7 E-04	6 E-02	**1 E-01**	2 E-04	**3 E-02**	1 E-02	**2 E-02**	3 E-09	1 E-02
GnG-5 deg	5 E-09	6 E-04	**1 E-01**	4 E-05	2 E-13	3 E-05	**3 E-02**	1 E-06	2 E-20	7 E-12
PreCDG-15 deg	**4 E-02**	**8 E-02**	**3 E-01**	**2 E-02**	**4 E-02**	**6 E-02**	**1 E-01**	**3 E-02**	**4 E-02**	**4 E-02**
CDG-15 deg	**3 E-02**	**2 E-01**	**5 E-02**	**5 E-02**	3 E-03	**4 E-01**	2 E-03	**2 E-02**	1 E-04	**2 E-02**
PreGnG-15 deg	0.5	8 E-06	**5 E-02**	**4 E-01**	**1 E-01**	3 E-04	6 E-03	**4 E-01**	6 E-04	**4 E-01**
GnG-15 deg	8 E-06	0.5	**8 E-02**	2 E-03	7 E-10	**8 E-02**	**3 E-02**	1 E-04	4 E-18	6 E-08
PreCDG-30 deg	**5 E-02**	**8 E-02**	0.5	**4 E-02**	**5 E-02**	**7 E-02**	**2 E-01**	**4 E-02**	**5 E-02**	**6 E-02**
CDG-30 deg	**4 E-01**	2 E-03	**4 E-02**	0.5	**1 E-01**	1 E-02	1 E-03	**3 E-01**	8 E-03	**5 E-01**
PreGnG-30 deg	**1 E-01**	7 E-10	**5 E-02**	**1 E-01**	0.5	2 E-07	9 E-03	**2 E-01**	1 E-02	**5 E-02**
GnG-30 deg	3 E-04	**8 E-02**	**7 E-02**	**1 E-02**	2 E-07	0.5	**2 E-02**	1 E-03	4 E-14	3 E-05
PreCDG-45 deg	6 E-03	**3 E-02**	**2 E-01**	1 E-03	9 E-03	**2 E-02**	0.5	3 E-03	1 E-02	1 E-02
CDG-45 deg	**4 E-01**	**1 E-04**	**4 E-02**	**3 E-01**	**2 E-01**	1 E-03	3 E-03	0.5	1 E-02	**3 E-01**
PreGnG-45 deg	6 E-04	4 E-18	**5 E-02**	8 E-03	1 E-02	4 E-14	1 E-02	1 E-02	0.5	1 E-05
GnG-45 deg	**4 E-01**	6 E-08	**6 E-02**	**5 E-01**	**5 E-02**	3 E-05	1 E-02	**3 E-01**	1 E-05	0.5

I.4 Towed Skid Trailer (ASTM E274) Statistics

I.4.1 Sacramento 5 – PM 20.0/21.5

Table I.15: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Ribbed Results for Caltrans Testing on Sacramento 5 – PM 20.0/21.5 Project, Left Wheelpath (Part A)

	PreCDG-N1-40	PreCDG-N4-40	PreCDG-S1-40	PreCDG-S4-40	CDG-S1-40	CDG-S4-40	GnG-N1-40	GnG-N4-40	CDG-S1-50	CDG-S4-50
PreCDG-N1-40	0.5	1 E-04	2 E-01	7 E-14	2 E-11	9 E-09	9 E-03	6 E-02	4 E-13	2 E-06
PreCDG-N4-40	1 E-04	0.5	1 E-05	6 E-02	2 E-17	2 E-13	5 E-04	2 E-03	4 E-19	1 E-09
PreCDG-S1-40	**2 E-01**	1 E-05	0.5	1 E-18	1 E-09	1 E-07	1 E-02	9 E-02	2 E-10	6 E-06
PreCDG-S4-40	7 E-14	**6 E-02**	1 E-18	0.5	3 E-12	2 E-10	3 E-04	5 E-04	4 E-14	4 E-08
CDG-S1-40	2 E-11	2 E-17	1 E-09	3 E-12	0.5	4 E-05	6 E-04	1 E-05	5 E-02	9 E-05
CDG-S4-40	9 E-09	2 E-13	1 E-07	2 E-10	4 E-05	0.5	3 E-02	7 E-04	6 E-04	3 E-01
GnG-N1-40	9 E-03	5 E-04	**1 E-02**	3 E-04	6 E-04	**3 E-02**	0.5	1 E-01	2 E-03	7 E-02
GnG-N4-40	**6 E-02**	2 E-03	**9 E-02**	5 E-04	1 E-05	7 E-04	**1 E-01**	0.5	4 E-05	2 E-03
CDG-S1-50	4 E-13	4 E-19	2 E-10	4 E-14	**5 E-02**	6 E-04	2 E-03	4 E-05	0.5	1 E-03
CDG-S4-50	2 E-06	1 E-09	6 E-06	4 E-08	9 E-05	**3 E-01**	**7 E-02**	2 E-03	1 E-03	0.5
GnG-N1-50	6 E-03	2 E-04	8 E-03	1 E-04	2 E-04	**2 E-02**	**5 E-01**	**1 E-01**	8 E-04	**4 E-02**
GnG-N4-50	**1 E-01**	3 E-03	**2 E-01**	7 E-04	2 E-06	2 E-04	**6 E-02**	**3 E-01**	1 E-05	4 E-04
PreCDG-N1-60	2 E-09	**4 E-01**	1 E-14	6 E-04	3 E-11	2 E-09	8 E-04	2 E-03	1 E-12	2 E-07
PreCDG-N4-60	9 E-10	**9 E-02**	3 E-11	**5 E-01**	1 E-15	8 E-13	3 E-04	5 E-04	1 E-18	3 E-09
PreCDG-S1-60	2 E-08	**3 E-01**	1 E-13	3 E-05	6 E-11	3 E-09	1 E-03	3 E-03	3 E-12	3 E-07
PreCDG-S4-60	1 E-17	3 E-03	7 E-23	9 E-03	2 E-12	1 E-10	2 E-04	2 E-04	3 E-14	2 E-08
CDG-S1-60	2 E-15	2 E-19	8 E-12	4 E-17	5 E-04	**3 E-02**	8 E-03	2 E-04	**1 E-02**	**2 E-02**
CDG-S4-60	1 E-06	7 E-10	4 E-06	3 E-08	9 E-05	**3 E-01**	**6 E-02**	2 E-03	1 E-03	**5 E-01**
GnG-N1-60	**3 E-02**	9 E-04	**4 E-02**	4 E-04	4 E-05	3 E-03	**2 E-01**	**3 E-01**	2 E-04	8 E-03
GnG-N4-60	**5 E-02**	2 E-04	**8 E-02**	5 E-05	4 E-08	1 E-05	**5 E-02**	**4 E-01**	3 E-07	7 E-05

Table I.15: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Ribbed Results for Caltrans Testing on Sacramento 5 – PM 20.0/21.5 Project, Left Wheelpath (Part B)

	GnG-N1-50	GnG-N4-50	PreCDG-N1-60	PreCDG-N4-60	PreCDG-S1-60	PreCDG-S4-60	CDG-S1-60	CDG-S4-60	GnG-N1-60	GnG-N4-60
PreCDG-N1-40	6 E-03	1 E-01	2 E-09	9 E-10	2 E-08	1 E-17	2 E-15	1 E-06	3 E-02	5 E-02
PreCDG-N4-40	2 E-04	3 E-03	4 E-01	9 E-02	3 E-01	3 E-03	2 E-19	7 E-10	9 E-04	2 E-04
PreCDG-S1-40	8 E-03	2 E-01	1 E-14	3 E-11	1 E-13	7 E-23	8 E-12	4 E-06	4 E-02	8 E-02
PreCDG-S4-40	1 E-04	7 E-04	6 E-04	5 E-01	3 E-05	9 E-03	4 E-17	3 E-08	4 E-04	5 E-05
CDG-S1-40	2 E-04	2 E-06	3 E-11	1 E-15	6 E-11	2 E-12	5 E-04	9 E-05	4 E-05	4 E-08
CDG-S4-40	2 E-02	2 E-04	2 E-09	8 E-13	3 E-09	1 E-10	3 E-02	3 E-01	3 E-03	1 E-05
GnG-N1-40	5 E-01	6 E-02	8 E-04	3 E-04	1 E-03	2 E-04	8 E-03	6 E-02	2 E-01	5 E-02
GnG-N4-40	1 E-01	3 E-01	2 E-03	5 E-04	3 E-03	2 E-04	2 E-04	2 E-03	3 E-01	4 E-01
CDG-S1-50	8 E-04	1 E-05	1 E-12	1 E-18	3 E-12	3 E-14	1 E-02	1 E-03	2 E-04	3 E-07
CDG-S4-50	4 E-02	4 E-04	2 E-07	3 E-09	3 E-07	2 E-08	2 E-02	5 E-01	8 E-03	7 E-05
GnG-N1-50	0.5	5 E-02	4 E-04	1 E-04	5 E-04	7 E-05	4 E-03	4 E-02	2 E-01	4 E-02
GnG-N4-50	**5 E-02**	0.5	3 E-03	6 E-04	4 E-03	3 E-04	5 E-05	3 E-04	2 E-01	5 E-01
PreCDG-N1-60	4 E-04	3 E-03	0.5	1 E-02	2 E-01	4 E-08	5 E-15	1 E-07	1 E-03	3 E-04
PreCDG-N4-60	1 E-04	6 E-04	**1 E-02**	0.5	3 E-03	3 E-02	1 E-21	2 E-09	3 E-04	3 E-05
PreCDG-S1-60	5 E-04	4 E-03	**2 E-01**	3 E-03	0.5	9 E-10	2 E-14	2 E-07	2 E-03	6 E-04
PreCDG-S4-60	7 E-05	3 E-04	4 E-08	**3 E-02**	9 E-10	0.5	3 E-17	1 E-08	2 E-04	2 E-05
CDG-S1-60	4 E-03	5 E-05	5 E-15	1 E-21	2 E-14	3 E-17	0.5	2 E-02	8 E-04	3 E-06
CDG-S4-60	**4 E-02**	3 E-04	1 E-07	2 E-09	2 E-07	1 E-08	**2 E-02**	0.5	7 E-03	5 E-05
GnG-N1-60	**2 E-01**	**2 E-01**	1 E-03	3 E-04	2 E-03	2 E-04	8 E-04	7 E-03	0.5	2 E-01
GnG-N4-60	**4 E-02**	**5 E-01**	3 E-04	3 E-05	6 E-04	2 E-05	3 E-06	5 E-05	**2 E-01**	0.5

Table I.16: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Ribbed Results for Caltrans Testing on Sacramento 5 – PM 20.0/21.5 Project, Right Wheelpath (Part A)

	PreCDG-N1-40	PreCDG-N4-40	PreCDG-S1-40	PreCDG-S4-40	CDG-S1-40	CDG-S4-40	GnG-N1-40	GnG-N4-40	CDG-S1-50	CDG-S4-50
PreCDG-N1-40	0.5	4 E-01	2 E-01	1 E-08	2 E-09	2 E-08	2 E-05	1 E-05	2 E-10	6 E-10
PreCDG-N4-40	**4 E-01**	0.5	5 E-01	7 E-05	5 E-11	6 E-10	7 E-06	3 E-06	5 E-13	3 E-12
PreCDG-S1-40	**2 E-01**	**5 E-01**	0.5	6 E-09	7 E-09	4 E-08	2 E-05	2 E-05	1 E-09	3 E-09
PreCDG-S4-40	1 E-08	7 E-05	6 E-09	0.5	9 E-10	4 E-09	3 E-06	1 E-06	7 E-11	1 E-10
CDG-S1-40	2 E-09	5 E-11	7 E-09	9 E-10	0.5	5 E-04	4 E-05	4 E-07	5 E-02	4 E-04
CDG-S4-40	2 E-08	6 E-10	4 E-08	4 E-09	5 E-04	0.5	2 E-02	3 E-04	9 E-03	5 E-01
GnG-N1-40	2 E-05	7 E-06	2 E-05	3 E-06	4 E-05	**2 E-02**	0.5	8 E-02	4 E-04	2 E-02
GnG-N4-40	1 E-05	3 E-06	2 E-05	1 E-06	4 E-07	3 E-04	**8 E-02**	0.5	2 E-06	2 E-04
CDG-S1-50	2 E-10	5 E-13	1 E-09	7 E-11	**5 E-02**	9 E-03	4 E-04	2 E-06	0.5	6 E-03
CDG-S4-50	6 E-10	3 E-12	3 E-09	1 E-10	4 E-04	**5 E-01**	**2 E-02**	2 E-04	6 E-03	0.5
GnG-N1-50	3 E-05	9 E-06	3 E-05	3 E-06	1 E-06	7 E-04	**1 E-01**	**4 E-01**	7 E-06	4 E-04
GnG-N4-50	3 E-06	5 E-07	5 E-06	1 E-07	6 E-08	2 E-05	**2 E-02**	**2 E-01**	9 E-08	5 E-06
PreCDG-N1-60	**6 E-02**	**8 E-02**	6 E-03	3 E-12	7 E-09	6 E-08	4 E-05	4 E-05	8 E-10	3 E-09
PreCDG-N4-60	1 E-06	2 E-04	2 E-06	**5 E-01**	1 E-10	6 E-10	2 E-06	4 E-07	3 E-12	6 E-12
PreCDG-S1-60	4 E-03	**2 E-02**	8 E-05	8 E-15	1 E-08	1 E-07	7 E-05	7 E-05	2 E-09	8 E-09
PreCDG-S4-60	6 E-15	3 E-09	1 E-15	3 E-05	2 E-10	6 E-10	8 E-07	2 E-07	7 E-12	1 E-11
CDG-S1-60	2 E-11	2 E-14	2 E-10	6 E-12	2 E-03	**1 E-01**	4 E-03	2 E-05	**4 E-02**	**1 E-01**
CDG-S4-60	1 E-07	4 E-09	2 E-07	3 E-08	7 E-04	**5 E-01**	**3 E-02**	4 E-04	**1 E-02**	**5 E-01**
GnG-N1-60	3 E-04	2 E-04	2 E-04	2 E-05	1 E-06	4 E-04	**5 E-02**	**3 E-01**	1 E-05	3 E-04
GnG-N4-60	3 E-04	2 E-04	3 E-04	3 E-05	2 E-06	6 E-04	**5 E-02**	**3 E-01**	2 E-05	5 E-04

Table I.16: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Ribbed Results for Caltrans Testing on Sacramento 5 – PM 20.0/21.5 Project, Right Wheelpath (Part B)

	GnG-N1-50	GnG-N4-50	PreCDG-N1-60	PreCDG-N4-60	PreCDG-S1-60	PreCDG-S4-60	CDG-S1-60	CDG-S4-60	GnG-N1-60	GnG-N4-60
PreCDG-N1-40	3 E-05	3 E-06	6 E-02	1 E-06	4 E-03	6 E-15	2 E-11	1 E-07	3 E-04	3 E-04
PreCDG-N4-40	9 E-06	5 E-07	8 E-02	2 E-04	2 E-02	3 E-09	2 E-14	4 E-09	2 E-04	2 E-04
PreCDG-S1-40	3 E-05	5 E-06	6 E-03	2 E-06	8 E-05	1 E-15	2 E-10	2 E-07	2 E-04	3 E-04
PreCDG-S4-40	3 E-06	1 E-07	3 E-12	5 E-01	8 E-15	3 E-05	6 E-12	3 E-08	2 E-05	3 E-05
CDG-S1-40	1 E-06	6 E-08	7 E-09	1 E-10	1 E-08	2 E-10	2 E-03	7 E-04	1 E-06	2 E-06
CDG-S4-40	7 E-04	2 E-05	6 E-08	6 E-10	1 E-07	6 E-10	1 E-01	5 E-01	4 E-04	6 E-04
GnG-N1-40	1 E-01	2 E-02	4 E-05	2 E-06	7 E-05	8 E-07	4 E-03	3 E-02	5 E-02	5 E-02
GnG-N4-40	4 E-01	2 E-01	4 E-05	4 E-07	7 E-05	2 E-07	2 E-05	4 E-04	3 E-01	3 E-01
CDG-S1-50	7 E-06	9 E-08	8 E-10	3 E-12	2 E-09	7 E-12	4 E-02	1 E-02	1 E-05	2 E-05
CDG-S4-50	4 E-04	5 E-06	3 E-09	6 E-12	8 E-09	1 E-11	1 E-01	5 E-01	3 E-04	5 E-04
GnG-N1-50	0.5	2 E-01	7 E-05	1 E-06	1 E-04	5 E-07	7 E-05	8 E-04	3 E-01	3 E-01
GnG-N4-50	**2 E-01**	0.5	1 E-05	3 E-08	3 E-05	1 E-08	6 E-07	4 E-05	5 E-01	4 E-01
PreCDG-N1-60	7 E-05	1 E-05	0.5	3 E-09	1 E-01	2 E-18	2 E-10	3 E-07	6 E-04	8 E-04
PreCDG-N4-60	1 E-06	3 E-08	3 E-09	0.5	5 E-11	2 E-04	8 E-14	5 E-09	2 E-05	2 E-05
PreCDG-S1-60	1 E-04	3 E-05	**1 E-01**	5 E-11	0.5	2 E-20	5 E-10	5 E-07	1 E-03	1 E-03
PreCDG-S4-60	5 E-07	1 E-08	2 E-18	2 E-04	2 E-20	0.5	3 E-13	5 E-09	5 E-06	7 E-06
CDG-S1-60	7 E-05	6 E-07	2 E-10	8 E-14	5 E-10	3 E-13	0.5	1 E-01	9 E-05	1 E-04
CDG-S4-60	8 E-04	4 E-05	3 E-07	5 E-09	5 E-07	5 E-09	**1 E-01**	0.5	5 E-04	7 E-04
GnG-N1-60	**3 E-01**	**5 E-01**	6 E-04	2 E-05	1 E-03	5 E-06	9 E-05	5 E-04	0.5	5 E-01
GnG-N4-60	**3 E-01**	**4 E-01**	8 E-04	2 E-05	1 E-03	7 E-06	1 E-04	7 E-04	**5 E-01**	0.5

Table I.17: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Smooth Results for Caltrans Testing on Sacramento 5 – PM 20.0/21.5 Project

		PreCDG-N1-40	PreCDG-N4-40	PreCDG-S1-40	PreCDG-S4-40	CDG-S1-40	CDG-S4-40	GnG-S1-40	GnG-S4-40
Left Wheelpath	PreCDG-N1-40	0.5	5 E-03	1 E-02	2 E-20	4 E-08	3 E-05	6 E-05	3 E-04
	PreCDG-N4-40	5 E-03	0.5	3 E-04	2 E-03	1 E-12	3 E-07	2 E-06	1 E-05
	PreCDG-S1-40	1 E-02	3 E-04	0.5	5 E-19	2 E-08	4 E-05	9 E-05	6 E-04
	PreCDG-S4-40	2 E-20	2 E-03	5 E-19	0.5	2 E-09	1 E-06	4 E-06	9 E-06
	CDG-S1-40	4 E-08	1 E-12	2 E-08	2 E-09	0.5	6 E-03	3 E-02	2 E-04
	CDG-S4-40	3 E-05	3 E-07	4 E-05	1 E-06	6 E-03	0.5	3 E-01	7 E-02
	GnG-S1-40	6 E-05	2 E-06	9 E-05	4 E-06	3 E-02	3 E-01	0.5	4 E-02
	GnG-S4-40	3 E-04	1 E-05	6 E-04	9 E-06	2 E-04	7 E-02	4 E-02	0.5
Right Wheelpath	PreCDG-N1-40	0.5	5 E-02	4 E-02	1 E-17	8 E-10	4 E-08	1 E-07	2 E-06
	PreCDG-N4-40	5 E-02	0.5	6 E-03	6 E-05	1 E-14	6 E-11	1 E-10	5 E-08
	PreCDG-S1-40	4 E-02	6 E-03	0.5	1 E-19	1 E-09	6 E-08	2 E-07	3 E-06
	PreCDG-S4-40	1 E-17	6 E-05	1 E-19	0.5	1 E-10	4 E-09	1 E-08	3 E-07
	CDG-S1-40	8 E-10	1 E-14	1 E-09	1 E-10	0.5	2 E-01	4 E-02	8 E-02
	CDG-S4-40	4 E-08	6 E-11	6 E-08	4 E-09	2 E-01	0.5	2 E-01	3 E-01
	GnG-S1-40	1 E-07	1 E-10	2 E-07	1 E-08	4 E-02	2 E-01	0.5	5 E-01
	GnG-S4-40	2 E-06	5 E-08	3 E-06	3 E-07	8 E-02	3 E-01	5 E-01	0.5

Table I.18: Student's *t*-Tests for Equivalence of Smooth and Ribbed Tire Testing on GnG Texture

Left Wheelpath			Right Wheelpath		
Ho: GnG L1&4 Smooth = GnG L1&4 Ribbed			Ho: GnG L1&4 Smooth = GnG L1&4 Ribbed		
H1: GnG L1&4 Smooth ≠ GnG L1&4 Ribbed			H1: GnG L1&4 Smooth ≠ GnG L1&4 Ribbed		
alpha = 0.05	GnG-Smooth	GnG-Ribbed	alpha = 0.05	GnG-Smooth	GnG-Ribbed
Mean	47.794	51.252	Mean	50.656	52.154
Variance	43.271	24.174	Variance	21.943	13.508
Observations	16	48	Observations	16	48
df	21	Accept Null	df	21	Accept Null
t Stat	1.9308		t Stat	1.1651	
P(T<=t) two-tail	0.0671		P(T<=t) two-tail	0.1285	
t Critical two-tail	2.0796		t Critical two-tail	1.7207	

Table I.19: Student's *t*-Tests on ASTM E274 Results for IGGA Testing on Sacramento 5 – PM 20.0/21.5 Project

Ribbed Tire			Smooth Tire		
Ho: CDG = GnG			Ho: CDG = GnG		
H1: CDG > GnG			H1: CDG > GnG		
alpha = 0.05	CDG	GnG	alpha = 0.05	CDG	GnG
Mean	48.35	48.28	Mean	41.94	42.6
Variance	2.379	1.977	Variance	10.628	2.405
Observations	6	5	Observations	5	5
df	9		df	6	
t Stat	0.0787		t Stat	0.4088	
P(T<=t) one-tail	0.4695	Accept Null	P(T<=t) one-tail	0.34844	Accept Null
t Critical one-tail	1.8331		t Critical one-tail	1.94318	

Table I.20: Student's *t*-Tests on Caltrans and IGGA Data on GnG Texture on Sacramento 5 – PM 20.0/21.5

alpha = 0.05	NB L4 Caltrans	NB L4 IGGA
Mean	50.98	48.28
Variance	28.05	1.98
Observations	6	5
df	6	
t Stat	1.2001	
P(T<=t) one-tail	0.1376	Accept Null
t Critical one-tail	1.9432	

Testing with a ribbed tire at 40 mph in the left wheelpath on GnG texture

I.4.2 San Joaquin 99 – PM 29.0/30.7

Table I.21: Results of Student's *t*-Test Comparing Caltrans and IGGA Data on San Joaquin 99 – PM 29.0/30.7

Ribbed Tire on GnG, NB Lane 2		
alpha = 0.05	Caltrans	IGGA
Mean	46.22	43.58
Variance	1.94	8.20
Observations	9	5
df	5	
t Stat	1.939	
P(T<=t) one-tail	0.055	Accept Null
t Critical one-tail	2.015	

I.4.3 Yolo 113 – PM R0.5/R2.5

Table I.22: Results of Student's *t*-Test Comparing Caltrans and IGGA data on Yolo 113 - PM R0.5/R2.5 Project

Ribbed Tire on CDG Southbound		
alpha = 0.05	Caltrans	IGGA
Mean	53.533	51.56
Variance	20.409	6.873
Observations	15	5
df	12	
t Stat	1.1932	
P(T<=t) one-tail	0.1279	Accept Null
t Critical one-tail	1.7823	

Table I.23: Results of Student's *t*-Test Comparing CDG and GnG Data on Yolo 113 – PM R0.5/R2.5 Project

Ribbed Tire			Smooth Tire		
alpha = 0.05	CDG	GnG	alpha = 0.05	CDG	GnG
Mean	53.04	48.31	Mean	42.622	43.409
Variance	17.254	8.754	Variance	8.884	12.693
Observations	20	10	Observations	9	11
df	24		df	18	
t Stat	3.5877		t Stat	-0.5378	
P(T<=t) one-tail	0.0007	Reject Null	P(T<=t) one-tail	0.2987	Accept Null
t Critical one-tail	1.7109		t Critical one-tail	1.7341	

I.4.4 San Diego 5 – PM R35.8/R37.9

The CDG texture south of the GnG section, between PM R35.5/R36.3, was designated CDG(S). The CDG texture north of the GnG section, between PM R37.4/R38.4, was designated CDG(N).

Table I.24: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Ribbed Test Results by Caltrans for San Diego 5 Test Strip

Tire Type	Texture		PreCDG			CDG			GnG		
	Speed		**40**	**50**	**60**	**40**	**50**	**60**	**40**	**50**	**60**
Ribbed Tire	**PreCDG**	**40**	0.5	3E-1	8E-3	4E-1	2E-1	3E-1	1E-1	4E-1	9E-2
		50	**3E-1**	0.5	7E-2	4E-1	5E-1	2E-1	3E-1	3E-1	3E-1
		60	8E-3	**7E-2**	0.5	4E-3	5E-3	2E-3	7E-3	3E-3	1E-2
	CDG	**40**	**4E-1**	**4E-1**	4E-3	0.5	2E-1	1E-1	1E-1	4E-1	6E-2
		50	**2E-1**	**5E-1**	5E-3	**2E-1**	0.5	8E-2	2E-1	1E-1	9E-2
		60	**3E-1**	**2E-1**	2E-3	**1E-1**	**8E-2**	0.5	1E-7	7E-4	1E-6
	GnG	**40**	**1E-1**	**3E-1**	7E-3	**1E-1**	**2E-1**	1E-7	0.5	3E-5	1E-1
		50	**4E-1**	**3E-1**	3E-3	**4E-1**	**1E-1**	7E-4	3E-5	0.5	3E-5
		60	**9E-2**	**3E-1**	**1E-2**	**6E-2**	**9E-2**	1E-6	**1E-1**	3E-5	0.5
Smooth Tire	**PreCDG**	**40**	0.5	2E-7	1E-3	7E-2	1E-1	1E-1	7E-3	2E-1	5E-1
		50	2E-7	0.5	1E-4	9E-3	1E-4	1E-12	1E-13	5E-12	2E-7
		60	1E-3	1E-4	0.5	1E-1	2E-2	6E-3	2E-2	3E-3	1E-3
	CDG	**40**	**7E-2**	9E-3	**1E-1**	0.5	2E-1	1E-1	4E-1	1E-1	7E-2
		50	**1E-1**	1E-4	**2E-2**	**2E-1**	0.5	4E-1	4E-2	3E-1	1E-1
		60	**1E-1**	1E-12	6E-3	**1E-1**	**4E-1**	0.5	1E-2	3E-1	1E-1
	GnG	**40**	7E-3	1E-13	**2E-2**	**4E-1**	**4E-2**	**1E-2**	0.5	6E-3	7E-3
		50	**2E-1**	5E-12	3E-3	**1E-1**	**3E-1**	**3E-1**	6E-3	0.5	2E-1
		60	**5E-1**	2E-7	1E-3	**7E-2**	**1E-1**	**1E-1**	7E-3	**2E-1**	0.5

Table I.25: Towed Skid Trailer Results on Pre-CDG by Caltrans on San Diego 5 – PM R35.8/37.9, All Lanes

		Left Wheelpath		Right Wheelpath	
Lane	**Direction**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
1	North	54	3	48	10
	South	57	6	42	10
2	North	50	2	43	9
	South	51	4	43	9
3	North	46	3	41	10
	South	46	3	45	6
4	North	45	7	38	9
	South	43	4	27	6
5	North	42	3	35	12
	South	48	4	42	4
6	North	55	3	54	5
	South	52	4	52	3
Grand Total		**48**	**6**	**41**	**10**

Note: tests at 50 mph with ribbed tire

Table I.26: P-Values from One-Sided Student's *t*-Test on San Diego E274 Ribbed Tests by Caltrans at 50 mph on Pre-CDG Texture, Left Wheelpath

Texture		CDG South of GnG - PM35.8/36.3										CDG North of GnG - PM37.4/37.9										CDG before GnG PM36.3/37.4											
Lane		N1	N2	N3	N4	N5	S1	S2	S3	S4	S5	N1	N2	N3	N4	N5	S1	S2	S3	S4	S5	N1	N2	N3	N4	N5	N6	S1	S2	S3	S4	S5	S6
CDG South of GnG - PM36.3/37.4	N1	0.5	4E-1	3E-1	4E-1	2E-2	5E-2	9E-2	2E-2	2E-3	1E-2	4E-2	1E-1	4E-2	6E-3	2E-2	4E-1	2E-1	1E-2	3E-1	3E-1	4E-2	5E-1	2E-2	4E-3	3E-3	1E-2	9E-4	4E-1	9E-2	5E-3	1E-1	3E-1
	N2	4E-1	0.5	3E-1	4E-1	6E-3	7E-2	8E-2	2E-2	9E-4	1E-2	4E-2	1E-1	5E-2	9E-3	1E-3	4E-1	2E-1	2E-2	3E-1	4E-1	2E-2	5E-1	2E-3	2E-3	4E-5	6E-3	7E-4	4E-1	3E-2	3E-3	5E-2	2E-1
	N3	3E-1	3E-1	0.5	3E-1	1E-1	1E-1	2E-1	3E-1	2E-1	3E-1	1E-1	4E-1	4E-1	2E-1	2E-1	2E-1	4E-1	3E-1	5E-1	3E-1	2E-1	3E-1	5E-1	3E-1	3E-1	1E-1	8E-2	2E-1	4E-1	3E-1	4E-1	2E-1
	N4	4E-1	4E-1	3E-1	0.5	2E-1	5E-1	5E-1	2E-1	2E-1	2E-1	5E-1	3E-1	3E-1	2E-1	2E-1	4E-1	3E-1	3E-1	3E-1	3E-1	5E-1	4E-1	3E-1	2E-1	2E-1	5E-1	3E-1	4E-1	3E-1	2E-1	3E-1	4E-1
	N5	2E-2	6E-3	1E-1	2E-1	0.5	2E-2	4E-3	3E-2	2E-1	5E-2	5E-3	2E-2	3E-2	1E-1	3E-2	3E-2	5E-2	2E-2	2E-1	3E-2	3E-5	5E-5	4E-5	2E-3	5E-4	2E-4	4E-5	4E-3	5E-5	3E-3	9E-6	1E-2
	S1	5E-2	7E-2	1E-1	5E-1	2E-2	0.5	2E-1	6E-3	7E-3	1E-2	5E-1	3E-2	9E-3	3E-3	2E-2	2E-1	4E-2	8E-3	2E-1	8E-2	2E-1	5E-2	2E-2	5E-3	1E-2	5E-1	4E-2	1E-1	3E-2	4E-3	3E-2	1E-1
	S2	9E-2	8E-2	2E-1	5E-1	4E-3	2E-1	0.5	5E-3	1E-3	5E-3	2E-1	3E-2	1E-2	2E-3	5E-3	3E-1	6E-2	5E-3	2E-1	1E-1	4E-1	8E-2	1E-2	3E-3	3E-3	1E-1	8E-3	3E-1	3E-2	3E-3	3E-2	3E-1
	S3	2E-2	2E-2	3E-1	2E-1	3E-2	6E-3	5E-3	0.5	3E-2	2E-1	3E-3	4E-2	3E-1	1E-1	8E-2	8E-2	9E-2	4E-1	4E-1	1E-1	2E-3	1E-2	1E-1	4E-1	3E-1	2E-3	2E-4	3E-2	3E-2	4E-1	3E-2	2E-2
	S4	2E-3	9E-4	2E-1	2E-1	2E-1	7E-3	1E-3	3E-2	0.5	2E-2	2E-3	3E-3	2E-2	2E-1	8E-2	3E-2	4E-2	1E-2	2E-1	4E-2	1E-5	6E-5	4E-4	4E-3	6E-3	3E-5	7E-6	4E-3	2E-4	6E-3	7E-5	7E-3
	S5	1E-2	1E-2	3E-1	2E-1	5E-2	1E-2	5E-3	2E-1	2E-2	0.5	5E-3	2E-2	1E-1	2E-1	9E-2	6E-2	7E-2	1E-1	3E-1	8E-2	1E-4	1E-3	1E-2	1E-1	3E-1	3E-4	4E-5	1E-2	4E-3	1E-1	2E-3	2E-2
CDG North of GnG - PM37.4/37.9	N1	4E-2	4E-2	1E-1	5E-1	5E-3	5E-1	2E-1	3E-3	2E-3	5E-3	0.5	2E-2	6E-3	1E-3	5E-3	2E-1	3E-2	4E-3	1E-1	8E-2	2E-1	3E-2	1E-2	3E-3	4E-3	5E-1	4E-2	1E-1	2E-2	2E-3	2E-2	1E-1
	N2	1E-1	1E-1	4E-1	3E-1	2E-2	3E-2	3E-2	4E-2	3E-3	2E-2	2E-2	0.5	1E-1	1E-2	2E-2	2E-1	5E-1	4E-2	4E-1	4E-1	8E-3	1E-1	1E-1	2E-2	8E-3	4E-3	4E-4	2E-1	5E-1	2E-2	4E-1	1E-1
	N3	4E-2	5E-2	4E-1	3E-1	3E-2	9E-3	1E-2	3E-1	2E-2	1E-1	6E-3	1E-1	0.5	5E-2	5E-2	1E-1	2E-1	4E-1	4E-1	2E-1	7E-3	4E-2	3E-1	3E-1	2E-1	5E-3	7E-4	5E-2	1E-1	3E-1	9E-2	3E-2
	N4	6E-3	9E-3	2E-1	2E-1	1E-1	3E-3	2E-3	1E-1	2E-1	2E-1	1E-3	1E-2	5E-2	0.5	5E-1	4E-2	3E-2	6E-2	2E-1	5E-2	6E-4	4E-3	2E-2	7E-2	1E-1	7E-4	8E-5	7E-3	1E-2	7E-2	7E-3	7E-3
	N5	2E-2	1E-3	2E-1	2E-1	3E-2	2E-2	5E-3	8E-2	8E-2	9E-2	5E-3	2E-2	5E-2	5E-1	0.5	5E-2	7E-2	4E-2	2E-1	5E-2	4E-5	7E-5	2E-4	2E-2	1E-2	2E-4	4E-5	8E-3	8E-5	2E-2	3E-5	1E-2
	S1	4E-1	4E-1	2E-1	4E-1	3E-2	2E-1	3E-1	8E-2	3E-2	6E-2	2E-1	2E-1	1E-1	4E-2	5E-2	0.5	2E-1	9E-2	2E-1	3E-1	3E-1	4E-1	1E-1	8E-2	7E-2	2E-1	6E-2	5E-1	2E-1	8E-2	2E-1	4E-1
	S2	2E-1	2E-1	4E-1	3E-1	5E-2	4E-2	6E-2	9E-2	4E-2	7E-2	3E-2	5E-1	2E-1	3E-2	7E-2	2E-1	0.5	1E-1	4E-1	4E-1	5E-2	2E-1	3E-1	9E-2	8E-2	4E-2	9E-3	2E-1	5E-1	1E-1	4E-1	1E-1
	S3	1E-2	2E-2	3E-1	3E-1	2E-2	8E-3	5E-3	4E-1	1E-2	1E-1	4E-3	4E-2	4E-1	6E-2	4E-2	9E-2	1E-1	0.5	4E-1	1E-1	1E-3	9E-3	1E-1	4E-1	2E-1	8E-4	8E-5	3E-2	3E-2	5E-1	3E-2	2E-2
	S4	3E-1	3E-1	5E-1	3E-1	2E-1	2E-1	2E-1	4E-1	2E-1	3E-1	1E-1	4E-1	4E-1	2E-1	2E-1	2E-1	4E-1	4E-1	0.5	3E-1	2E-1	3E-1	5E-1	4E-1	3E-1	2E-1	1E-1	3E-1	4E-1	4E-1	4E-1	2E-1
	S5	3E-1	4E-1	3E-1	3E-1	3E-2	8E-2	1E-1	1E-1	4E-2	8E-2	8E-2	4E-1	2E-1	5E-2	5E-2	3E-1	4E-1	1E-1	3E-1	0.5	1E-1	4E-1	2E-1	1E-1	9E-2	8E-2	2E-2	3E-1	4E-1	1E-1	4E-1	2E-1
CDG before GnG PM36.3/37.4	N1	4E-2	2E-2	2E-1	5E-1	3E-5	2E-1	4E-1	2E-3	1E-5	1E-4	2E-1	8E-3	7E-3	6E-4	4E-5	3E-1	5E-2	1E-3	2E-1	1E-1	0.5	3E-2	5E-4	1E-4	2E-5	1E-1	3E-3	2E-1	3E-3	2E-4	4E-3	3E-1
	N2	5E-1	5E-1	3E-1	4E-1	5E-5	5E-2	8E-2	1E-2	6E-5	1E-3	3E-2	1E-1	4E-2	4E-3	7E-5	4E-1	2E-1	9E-3	3E-1	4E-1	3E-2	0.5	4E-3	1E-3	5E-5	4E-3	3E-4	4E-1	5E-2	2E-3	8E-2	2E-1
	N3	2E-2	2E-3	5E-1	3E-1	4E-5	2E-2	1E-2	1E-1	4E-4	1E-2	1E-2	1E-1	3E-1	2E-2	2E-4	1E-1	3E-1	1E-1	5E-1	2E-1	5E-4	4E-3	0.5	7E-2	5E-3	2E-4	5E-5	8E-2	5E-2	9E-2	5E-2	5E-2
	N4	4E-3	2E-3	3E-1	2E-1	2E-3	5E-3	3E-3	4E-1	4E-3	1E-1	3E-3	2E-2	3E-1	7E-2	2E-2	8E-2	9E-2	4E-1	4E-1	1E-1	1E-4	1E-3	7E-2	0.5	2E-1	5E-5	7E-6	3E-2	8E-3	5E-1	7E-3	2E-2
	N5	3E-3	4E-5	3E-1	2E-1	5E-4	1E-2	3E-3	3E-1	6E-3	3E-1	4E-3	8E-3	2E-1	1E-1	1E-2	7E-2	8E-2	2E-1	3E-1	9E-2	2E-5	5E-5	5E-3	2E-1	0.5	2E-5	8E-6	2E-2	3E-4	2E-1	3E-4	2E-2
	N6	1E-2	6E-3	1E-1	5E-1	2E-4	5E-1	1E-1	2E-3	3E-5	3E-4	5E-1	4E-3	5E-3	7E-4	2E-4	2E-1	4E-2	8E-4	2E-1	8E-2	1E-1	4E-3	2E-4	5E-5	2E-5	0.5	1E-2	1E-1	9E-4	8E-5	7E-4	1E-1
	S1	9E-4	7E-4	8E-2	3E-1	4E-5	4E-2	8E-3	2E-4	7E-6	4E-5	4E-2	4E-4	7E-4	8E-5	4E-5	6E-2	9E-3	8E-5	1E-1	2E-2	3E-3	3E-4	5E-5	7E-6	8E-6	1E-2	0.5	1E-2	1E-4	9E-6	8E-5	1E-2
	S2	4E-1	4E-1	2E-1	4E-1	4E-3	1E-1	3E-1	3E-2	4E-3	1E-2	1E-1	2E-1	5E-2	7E-3	8E-3	5E-1	2E-1	3E-2	3E-1	3E-1	2E-1	4E-1	8E-2	3E-2	2E-2	1E-1	1E-2	0.5	2E-1	3E-2	2E-1	4E-1
	S3	9E-2	3E-2	4E-1	3E-1	5E-5	3E-2	3E-2	3E-2	2E-4	4E-3	2E-2	5E-1	1E-1	1E-2	8E-5	2E-1	5E-1	3E-2	4E-1	4E-1	3E-3	5E-2	5E-2	8E-3	3E-4	9E-4	1E-4	2E-1	0.5	1E-2	4E-1	1E-1
	S4	5E-3	3E-3	3E-1	2E-1	3E-3	4E-3	3E-3	4E-1	6E-3	1E-1	2E-3	2E-2	3E-1	7E-2	2E-2	8E-2	1E-1	5E-1	4E-1	1E-1	2E-4	2E-3	9E-2	5E-1	2E-1	8E-5	9E-6	3E-2	1E-2	0.5	1E-2	2E-2
	S5	1E-1	5E-2	4E-1	3E-1	9E-6	3E-2	3E-2	3E-2	7E-5	2E-3	2E-2	4E-1	9E-2	7E-3	3E-5	2E-1	4E-1	3E-2	4E-1	4E-1	4E-3	8E-2	5E-2	7E-3	3E-4	7E-4	8E-5	2E-1	4E-1	1E-2	0.5	1E-1
	S6	3E-1	2E-1	2E-1	4E-1	1E-2	1E-1	3E-1	2E-2	7E-3	2E-2	1E-1	1E-1	3E-2	7E-3	1E-2	4E-1	1E-1	2E-2	2E-1	2E-1	3E-1	2E-1	5E-2	2E-2	2E-2	1E-1	1E-2	4E-1	1E-1	2E-2	1E-1	0.5

Table I.27: P-Values from One-Sided Student's *t*-Tests on San Diego E274 Ribbed Tests by Caltrans at 50 mph on Pre-CDG Texture, Right Wheelpath

Texture		CDG South of GnG - PM35.8/36.3										CDG North of GnG - PM37.4/37.9										CDG Before GnG - PM36.3/37.4											
Lane		N2	N3	N4	N5	S1	S2	S3	S4	S5	S6	N1	N2	N3	N4	N5	S1	S2	S3	S4	S5	N1	N2	N3	N4	N5	N6	S1	S2	S3	S4	S5	S6
CDG South of GnG - PM36.3/37.4	N2	0.5	5E-1	5E-1	1E-1	4E-1	3E-1	4E-1	1E-1	3E-1	3E-1	5E-1	2E-1	3E-1	4E-1	4E-1	2E-1	3E-1	4E-1	2E-1	4E-1	2E-1	4E-1	4E-1	3E-1	3E-1	2E-1	4E-1	5E-1	4E-1	2E-1	5E-1	2E-1
	N3	5E-1	0.5	5E-1	6E-2	3E-1	2E-1	3E-1	3E-2	2E-1	2E-1	4E-1	1E-1	3E-1	4E-1	4E-1	1E-1	2E-1	4E-1	6E-2	4E-1	7E-2	3E-1	4E-1	2E-1	3E-1	8E-2	2E-1	4E-1	3E-1	7E-2	4E-1	1E-1
	N4	5E-1	5E-1	0.5	6E-2	1E-1	2E-2	5E-2	9E-3	2E-1	6E-2	4E-1	5E-4	3E-1	2E-2	2E-2	3E-2	1E-1	4E-1	1E-2	4E-2	7E-3	7E-2	3E-1	6E-2	1E-1	5E-3	1E-1	5E-1	1E-2	7E-3	3E-1	3E-2
	N5	1E-1	6E-2	6E-2	0.5	7E-2	1E-1	4E-2	5E-1	1E-1	3E-2	5E-2	1E-1	1E-1	7E-2	7E-2	2E-1	3E-2	8E-2	3E-1	7E-2	2E-2	4E-2	6E-2	1E-1	8E-2	2E-2	3E-2	4E-2	4E-2	2E-1	5E-2	3E-2
	S1	4E-1	3E-1	1E-1	7E-2	0.5	6E-2	2E-2	8E-3	3E-1	1E-2	3E-1	5E-2	4E-1	4E-1	2E-1	5E-2	6E-2	5E-1	1E-2	4E-1	2E-3	1E-2	4E-1	2E-1	4E-1	2E-3	5E-2	2E-1	1E-2	2E-2	4E-2	6E-3
	S2	3E-1	2E-1	2E-2	1E-1	6E-2	0.5	1E-3	2E-2	4E-1	1E-2	2E-1	7E-2	4E-1	5E-3	3E-3	2E-1	5E-2	3E-1	4E-2	1E-2	1E-3	1E-3	1E-1	5E-1	2E-1	9E-4	1E-2	4E-2	4E-5	8E-2	4E-5	8E-3
	S3	4E-1	3E-1	5E-2	4E-2	2E-2	1E-3	0.5	4E-3	1E-1	8E-2	5E-1	3E-3	2E-1	5E-3	1E-2	1E-2	2E-1	2E-1	5E-3	6E-3	4E-3	3E-1	2E-1	3E-2	5E-2	9E-3	3E-1	3E-1	4E-1	3E-3	7E-2	1E-2
	S4	1E-1	3E-2	9E-3	5E-1	8E-3	2E-2	4E-3	0.5	7E-2	3E-3	5E-2	3E-2	8E-2	1E-2	1E-2	3E-2	5E-3	6E-2	1E-1	1E-2	7E-4	6E-4	5E-3	3E-2	9E-3	4E-4	9E-4	2E-3	3E-3	1E-1	5E-3	2E-3
	S5	3E-1	2E-1	2E-1	1E-1	3E-1	4E-1	1E-1	7E-2	0.5	9E-2	2E-1	3E-1	4E-1	3E-1	2E-1	3E-1	7E-2	3E-1	1E-1	3E-1	5E-2	9E-2	2E-1	4E-1	4E-1	5E-2	7E-2	1E-1	1E-1	2E-1	2E-1	7E-2
	S6	3E-1	2E-1	6E-2	3E-2	1E-2	1E-2	8E-2	3E-3	9E-2	0.5	3E-1	2E-2	1E-1	2E-2	3E-2	8E-3	4E-1	2E-1	3E-3	2E-2	2E-2	2E-1	6E-2	1E-2	2E-2	4E-2	4E-1	1E-1	1E-1	2E-3	2E-2	4E-2
CDG North of GnG - PM37.4/37.9	N1	5E-1	4E-1	4E-1	5E-2	3E-1	2E-1	5E-1	5E-2	2E-1	3E-1	0.5	1E-1	3E-1	3E-1	3E-1	1E-1	3E-1	3E-1	8E-2	3E-1	1E-1	4E-1	3E-1	2E-1	2E-1	2E-1	4E-1	4E-1	4E-1	8E-2	4E-1	2E-1
	N2	2E-1	1E-1	5E-4	1E-1	5E-2	7E-2	3E-3	3E-2	3E-1	2E-2	1E-1	0.5	3E-1	4E-3	1E-3	4E-1	5E-2	2E-1	8E-2	2E-2	2E-3	8E-4	6E-2	3E-1	1E-1	9E-4	9E-3	2E-2	3E-5	2E-1	8E-6	2E-2
	N3	3E-1	3E-1	3E-1	1E-1	4E-1	4E-1	2E-1	8E-2	4E-1	1E-1	3E-1	3E-1	0.5	4E-1	4E-1	3E-1	1E-1	4E-1	1E-1	4E-1	6E-2	2E-1	4E-1	4E-1	5E-1	7E-2	2E-1	3E-1	2E-1	2E-1	3E-1	8E-2
	N4	4E-1	4E-1	2E-2	7E-2	4E-1	5E-3	5E-3	1E-2	3E-1	2E-2	3E-1	4E-3	4E-1	0.5	2E-1	5E-2	8E-2	5E-1	1E-2	4E-1	2E-3	1E-2	4E-1	1E-1	3E-1	2E-3	5E-2	2E-1	8E-4	2E-2	1E-2	6E-3
	N5	4E-1	4E-1	2E-2	7E-2	2E-1	3E-3	1E-2	1E-2	2E-1	3E-2	3E-1	1E-3	4E-1	2E-1	0.5	4E-2	9E-2	5E-1	2E-2	1E-1	3E-3	2E-2	5E-1	1E-1	3E-1	3E-3	7E-2	3E-1	1E-3	1E-2	2E-2	1E-2
	S1	2E-1	1E-1	3E-2	2E-1	5E-2	2E-1	1E-2	3E-2	3E-1	8E-3	1E-1	4E-1	3E-1	5E-2	4E-2	0.5	1E-2	2E-1	1E-1	5E-2	2E-3	4E-3	7E-2	3E-1	1E-1	1E-3	8E-3	2E-2	1E-2	2E-1	2E-2	4E-3
	S2	3E-1	2E-1	1E-1	3E-2	6E-2	5E-2	2E-1	5E-3	7E-2	4E-1	3E-1	5E-2	1E-1	8E-2	9E-2	1E-2	0.5	1E-1	8E-3	8E-2	1E-1	2E-1	7E-2	2E-2	3E-2	2E-1	3E-1	1E-1	2E-1	4E-3	1E-1	2E-1
	S3	4E-1	4E-1	4E-1	8E-2	5E-1	3E-1	2E-1	6E-2	3E-1	2E-1	3E-1	2E-1	4E-1	5E-1	5E-1	2E-1	1E-1	0.5	1E-1	5E-1	7E-2	2E-1	5E-1	3E-1	4E-1	8E-2	2E-1	4E-1	2E-1	1E-1	3E-1	9E-2
	S4	2E-1	6E-2	1E-2	3E-1	1E-2	4E-2	5E-3	1E-1	1E-1	3E-3	8E-2	8E-2	1E-1	1E-2	2E-2	1E-1	8E-3	1E-1	0.5	2E-2	7E-4	9E-4	2E-2	1E-1	3E-2	4E-4	2E-3	5E-3	4E-3	4E-1	6E-3	2E-3
	S5	4E-1	4E-1	4E-2	7E-2	4E-1	1E-2	6E-3	1E-2	3E-1	2E-2	3E-1	2E-2	4E-1	4E-1	1E-1	5E-2	8E-2	5E-1	2E-2	0.5	3E-3	1E-2	4E-1	2E-1	3E-1	2E-3	5E-2	2E-1	7E-4	2E-2	6E-3	1E-2
CDG before GnG - PM36.3/37.4	N1	2E-1	7E-2	7E-3	2E-2	2E-3	1E-3	4E-3	7E-4	5E-2	2E-2	1E-1	2E-3	6E-2	2E-3	3E-3	2E-3	1E-1	7E-2	7E-4	3E-3	0.5	6E-3	7E-3	2E-3	2E-3	3E-1	5E-2	9E-3	3E-3	3E-4	1E-3	1E-1
	N2	4E-1	3E-1	7E-2	4E-2	1E-2	1E-3	3E-1	6E-4	9E-2	2E-1	4E-1	8E-4	2E-1	1E-2	2E-2	4E-3	2E-1	2E-1	9E-4	1E-2	6E-3	0.5	1E-1	2E-2	4E-2	2E-2	4E-1	2E-1	4E-1	2E-3	1E-1	2E-2
	N3	4E-1	4E-1	3E-1	6E-2	4E-1	1E-1	2E-1	5E-3	2E-1	6E-2	3E-1	6E-2	4E-1	4E-1	5E-1	7E-2	7E-2	5E-1	2E-2	4E-1	7E-3	1E-1	0.5	2E-1	3E-1	1E-2	1E-1	3E-1	1E-1	3E-2	3E-1	1E-2
	N4	3E-1	2E-1	6E-2	1E-1	2E-1	5E-1	3E-2	3E-2	4E-1	1E-2	2E-1	3E-1	4E-1	1E-1	1E-1	3E-1	2E-2	3E-1	1E-1	2E-1	2E-3	2E-2	2E-1	0.5	3E-1	3E-3	3E-2	9E-2	2E-2	2E-1	5E-2	4E-3
	N5	3E-1	3E-1	1E-1	8E-2	4E-1	2E-1	5E-2	9E-3	4E-1	2E-2	2E-1	1E-1	5E-1	3E-1	3E-1	1E-1	3E-2	4E-1	3E-2	3E-1	2E-3	4E-2	3E-1	3E-1	0.5	4E-3	5E-2	2E-1	5E-2	6E-2	1E-1	5E-3
	N6	2E-1	8E-2	5E-3	2E-2	2E-3	9E-4	9E-3	4E-4	5E-2	4E-2	2E-1	9E-4	7E-2	2E-3	3E-3	1E-3	2E-1	8E-2	4E-4	2E-3	3E-1	2E-2	1E-2	3E-3	4E-3	0.5	9E-2	2E-2	9E-3	3E-4	3E-3	4E-1
	S1	4E-1	2E-1	1E-1	3E-2	5E-2	1E-2	3E-1	9E-4	7E-2	4E-1	4E-1	9E-3	2E-1	5E-2	7E-2	8E-3	3E-1	2E-1	2E-3	5E-2	5E-2	4E-1	1E-1	3E-2	5E-2	9E-2	0.5	2E-1	4E-1	3E-3	2E-1	1E-1
	S2	5E-1	4E-1	5E-1	4E-2	2E-1	4E-2	3E-1	2E-3	1E-1	1E-1	4E-1	2E-2	3E-1	2E-1	3E-1	2E-2	1E-1	4E-1	5E-3	2E-1	9E-3	2E-1	3E-1	9E-2	2E-1	2E-2	2E-1	0.5	2E-1	1E-2	5E-1	2E-2
	S3	4E-1	3E-1	1E-2	4E-2	1E-2	4E-5	4E-1	3E-3	1E-1	1E-1	4E-1	3E-5	2E-1	8E-4	1E-3	1E-2	2E-1	2E-1	4E-3	7E-4	3E-3	4E-1	1E-1	2E-2	5E-2	9E-3	4E-1	2E-1	0.5	3E-3	4E-2	7E-3
	S4	2E-1	7E-2	7E-3	2E-1	2E-2	8E-2	3E-3	1E-1	2E-1	2E-3	8E-2	2E-1	2E-1	2E-2	1E-2	2E-1	4E-3	1E-1	4E-1	2E-2	3E-4	2E-3	3E-2	2E-1	6E-2	3E-4	3E-3	1E-2	3E-3	0.5	6E-3	7E-4
	S5	5E-1	4E-1	3E-1	5E-2	4E-2	4E-5	7E-2	5E-3	2E-1	2E-2	4E-1	8E-6	3E-1	1E-2	2E-2	2E-2	1E-1	3E-1	6E-3	6E-3	1E-3	1E-1	3E-1	5E-2	1E-1	3E-3	2E-1	5E-1	4E-2	6E-3	0.5	3E-3
	S6	2E-1	1E-1	3E-2	3E-2	6E-3	8E-3	1E-2	2E-3	7E-2	4E-2	2E-1	2E-2	8E-2	6E-3	1E-2	4E-3	2E-1	9E-2	2E-3	1E-2	1E-1	2E-2	1E-2	4E-3	5E-3	4E-1	1E-1	2E-2	7E-3	7E-4	3E-3	0.5

Table I.28: P-Values from One-Sided Student's *t*-Tests by Caltrans on San Diego E274 Ribbed Tests on CDG Texture, Left Wheelpath

Texture			CDG South of GnG – PM R35.8/R36.3																		CDG North of GnG – PM R37.4/R37.9																	
Speed			**40 MPH**						**50 MPH**						**60 MPH**						**40 MPH**						**50 MPH**						**60 MPH**					
Lane			**N1**	**N2**	**N5**	**S1**	**S2**	**S5**	**N1**	**N2**	**N5**	**S1**	**S2**	**S5**	**N1**	**N2**	**N5**	**S1**	**S2**	**S5**	**N1**	**N2**	**N5**	**S1**	**S2**	**S5**	**N1**	**N2**	**N5**	**S1**	**S2**	**S5**	**N1**	**N2**	**N5**	**S1**	**S2**	**S5**
CDG South of GnG – PM R35.8/R36.3	**40 MPH**	**N1**	0.5	1E-1	2E-1	1E-2	6E-2	7E-2	4E-1	5E-2	7E-2	3E-2	4E-3	1E-1	1E-1	7E-2	2E-2	3E-2	1E-2	4E-2	1E-2	4E-3	4E-3	4E-2	3E-3	2E-2	4E-2	1E-3	6E-3	5E-2	7E-4	2E-2	1E-2	2E-3	1E-3	1E-1	1E-3	1E-2
		N2	1E-1	0.5	4E-1	1E-1	2E-1	5E-1	8E-2	4E-1	4E-1	3E-1	2E-2	4E-1	2E-2	3E-1	2E-1	3E-1	8E-2	3E-1	9E-2	5E-2	3E-2	1E-1	3E-2	2E-1	4E-1	2E-2	5E-2	2E-1	8E-3	2E-1	2E-1	2E-2	2E-2	4E-1	1E-2	1E-1
		N5	2E-1	4E-1	0.5	2E-1	2E-1	4E-1	1E-1	4E-1	4E-1	3E-1	4E-2	3E-1	6E-2	3E-1	2E-1	3E-1	1E-1	3E-1	1E-1	9E-2	6E-2	1E-1	5E-2	2E-1	4E-1	4E-2	1E-1	2E-1	3E-2	2E-1	2E-1	4E-2	4E-2	3E-1	3E-2	2E-1
		S1	1E-2	1E-1	2E-1	0.5	4E-1	9E-2	3E-2	8E-2	2E-1	2E-1	6E-2	4E-1	3E-3	4E-1	4E-1	2E-1	2E-1	2E-1	3E-1	1E-1	9E-2	2E-1	7E-2	5E-1	9E-2	2E-2	1E-1	4E-1	7E-3	4E-1	4E-1	2E-2	2E-2	3E-1	3E-2	5E-1
		S2	6E-2	2E-1	2E-1	4E-1	0.5	2E-1	5E-2	2E-1	2E-1	2E-1	2E-1	3E-1	3E-2	3E-1	3E-1	2E-1	4E-1	2E-1	4E-1	4E-1	3E-1	4E-1	3E-1	4E-1	2E-1	3E-1	5E-1	4E-1	2E-1	3E-1	3E-1	2E-1	3E-1	3E-1	2E-1	4E-1
		S5	7E-2	5E-1	4E-1	9E-2	2E-1	0.5	7E-2	4E-1	4E-1	2E-1	2E-2	4E-1	4E-3	3E-1	2E-1	2E-1	7E-2	3E-1	4E-2	1E-2	2E-2	1E-1	2E-2	1E-1	4E-1	2E-3	2E-2	2E-1	1E-3	8E-2	8E-2	5E-3	3E-3	4E-1	6E-3	9E-2
	50 MPH	**N1**	4E-1	8E-2	1E-1	3E-2	5E-2	7E-2	0.5	6E-2	6E-2	5E-2	6E-3	9E-2	2E-1	5E-2	3E-2	5E-2	1E-2	5E-2	3E-2	2E-2	9E-3	3E-2	6E-3	2E-2	6E-2	9E-3	2E-2	4E-2	6E-3	4E-2	4E-2	1E-2	8E-3	7E-2	5E-3	2E-2
		N2	5E-2	4E-1	4E-1	8E-2	2E-1	4E-1	6E-2	0.5	4E-1	2E-1	2E-2	4E-1	5E-4	3E-1	2E-1	2E-1	7E-2	3E-1	2E-2	8E-3	2E-2	1E-1	2E-2	1E-1	4E-1	8E-4	7E-3	2E-1	5E-4	6E-2	6E-2	1E-3	2E-3	4E-1	6E-3	8E-2
		N5	7E-2	4E-1	4E-1	2E-1	2E-1	4E-1	6E-2	4E-1	0.5	4E-1	3E-2	4E-1	2E-2	4E-1	3E-1	4E-1	1E-1	5E-1	2E-1	8E-2	5E-2	1E-1	4E-2	2E-1	5E-1	3E-2	9E-2	2E-1	1E-2	3E-1	2E-1	3E-2	3E-2	4E-1	2E-2	2E-1
		S1	3E-2	3E-1	3E-1	2E-1	2E-1	2E-1	5E-2	2E-1	4E-1	0.5	3E-2	5E-1	2E-5	4E-1	3E-1	5E-1	1E-1	4E-1	2E-2	2E-2	4E-2	2E-1	3E-2	2E-1	2E-1	1E-3	7E-3	3E-1	1E-3	7E-2	1E-1	5E-4	4E-3	5E-1	1E-2	2E-1
		S2	4E-3	2E-2	4E-2	6E-2	2E-1	2E-2	6E-3	2E-2	3E-2	3E-2	0.5	9E-2	4E-3	8E-2	5E-2	3E-2	3E-1	3E-2	8E-2	1E-1	3E-1	3E-1	4E-1	7E-2	3E-2	4E-1	1E-1	1E-1	4E-1	5E-2	5E-2	4E-1	4E-1	7E-2	5E-1	6E-2
		S5	1E-1	4E-1	3E-1	4E-1	3E-1	4E-1	9E-2	4E-1	4E-1	5E-1	9E-2	0.5	4E-2	5E-1	4E-1	5E-1	2E-1	4E-1	3E-1	2E-1	1E-1	2E-1	1E-1	4E-1	4E-1	1E-1	2E-1	3E-1	6E-2	4E-1	4E-1	9E-2	1E-1	5E-1	8E-2	4E-1
	60 MPH	**N1**	1E-1	2E-2	6E-2	3E-3	3E-2	4E-3	2E-1	5E-4	2E-2	2E-5	4E-3	4E-2	0.5	2E-2	4E-3	1E-5	8E-3	1E-3	8E-5	5E-4	6E-3	2E-2	2E-3	4E-3	4E-6	1E-5	2E-4	2E-2	9E-5	4E-5	8E-4	8E-6	2E-4	3E-2	1E-3	1E-3
		N2	7E-2	3E-1	3E-1	4E-1	3E-1	3E-1	5E-2	3E-1	4E-1	4E-1	8E-2	5E-1	2E-2	0.5	5E-1	4E-1	2E-1	4E-1	3E-1	2E-1	1E-1	2E-1	1E-1	4E-1	3E-1	9E-2	2E-1	4E-1	5E-2	5E-1	4E-1	7E-2	9E-2	4E-1	7E-2	4E-1
		N5	2E-2	2E-1	2E-1	4E-1	3E-1	2E-1	3E-2	2E-1	3E-1	3E-1	5E-2	4E-1	4E-3	5E-1	0.5	3E-1	2E-1	3E-1	3E-1	1E-1	8E-2	2E-1	7E-2	4E-1	2E-1	3E-2	1E-1	4E-1	1E-2	5E-1	5E-1	3E-2	3E-2	4E-1	3E-2	4E-1
		S1	3E-2	3E-1	3E-1	2E-1	2E-1	2E-1	5E-2	2E-1	4E-1	5E-1	3E-2	5E-1	1E-5	4E-1	3E-1	0.5	1E-1	4E-1	1E-2	2E-2	4E-2	2E-1	3E-2	2E-1	2E-1	1E-3	8E-3	3E-1	2E-3	7E-2	1E-1	3E-4	5E-3	5E-1	1E-2	2E-1
		S2	1E-2	8E-2	1E-1	2E-1	4E-1	7E-2	1E-2	7E-2	1E-1	1E-1	3E-1	2E-1	8E-3	2E-1	2E-1	1E-1	0.5	1E-1	3E-1	4E-1	4E-1	5E-1	3E-1	2E-1	8E-2	3E-1	4E-1	3E-1	2E-1	2E-1	2E-1	2E-1	3E-1	2E-1	2E-1	2E-1
		S5	4E-2	3E-1	3E-1	2E-1	2E-1	3E-1	5E-2	3E-1	5E-1	4E-1	3E-2	4E-1	1E-3	4E-1	3E-1	4E-1	1E-1	0.5	6E-2	2E-2	3E-2	1E-1	3E-2	2E-1	4E-1	3E-3	2E-2	2E-1	1E-3	2E-1	1E-1	5E-3	5E-3	5E-1	1E-2	2E-1
CDG North of GnG – PM R37.4/R37.9	**40 MPH**	**N1**	1E-2	9E-2	1E-1	3E-1	4E-1	4E-2	3E-2	2E-2	2E-1	2E-2	8E-2	3E-1	8E-5	3E-1	3E-1	1E-2	3E-1	6E-2	0.5	1E-1	1E-1	3E-1	9E-2	4E-1	2E-3	1E-2	1E-1	5E-1	9E-3	4E-2	2E-1	8E-3	3E-2	3E-1	4E-2	3E-1
		N2	4E-3	5E-2	9E-2	1E-1	4E-1	1E-2	2E-2	8E-3	8E-2	2E-2	1E-1	2E-1	5E-4	2E-1	1E-1	2E-2	4E-1	2E-2	1E-1	0.5	3E-1	4E-1	2E-1	2E-1	1E-2	7E-2	4E-1	3E-1	2E-2	5E-2	5E-2	4E-2	9E-2	2E-1	9E-2	1E-1
		N5	4E-3	3E-2	6E-2	9E-2	3E-1	2E-2	9E-3	2E-2	5E-2	4E-2	3E-1	1E-1	6E-3	1E-1	8E-2	4E-2	4E-1	3E-2	1E-1	3E-1	0.5	5E-1	4E-1	1E-1	4E-2	3E-1	2E-1	2E-1	2E-1	8E-2	8E-2	3E-1	3E-1	1E-1	3E-1	9E-2
		S1	4E-2	1E-1	1E-1	2E-1	4E-1	1E-1	3E-2	1E-1	1E-1	2E-1	3E-1	2E-1	2E-2	2E-1	2E-1	2E-1	5E-1	1E-1	3E-1	4E-1	5E-1	0.5	4E-1	2E-1	1E-1	4E-1	4E-1	3E-1	3E-1	2E-1	2E-1	3E-1	4E-1	2E-1	3E-1	2E-1
		S2	3E-3	3E-2	5E-2	7E-2	3E-1	2E-2	6E-3	2E-2	4E-2	3E-2	4E-1	1E-1	2E-3	1E-1	7E-2	3E-2	3E-1	3E-2	9E-2	2E-1	4E-1	4E-1	0.5	9E-2	2E-2	5E-1	2E-1	2E-1	2E-1	6E-2	6E-2	4E-1	5E-1	9E-2	4E-1	7E-2
		S5	2E-2	2E-1	2E-1	5E-1	4E-1	1E-1	2E-2	1E-1	2E-1	2E-1	7E-2	4E-1	4E-3	4E-1	4E-1	2E-1	2E-1	2E-1	4E-1	2E-1	1E-1	2E-1	9E-2	0.5	1E-1	4E-2	2E-1	4E-1	2E-2	4E-1	4E-1	3E-2	4E-2	3E-1	4E-2	5E-1
	50 MPH	**N1**	4E-2	4E-1	4E-1	9E-2	2E-1	4E-1	6E-2	4E-1	5E-1	2E-1	3E-2	4E-1	4E-6	3E-1	2E-1	2E-1	8E-2	4E-1	2E-3	1E-2	4E-2	1E-1	2E-2	1E-1	0.5	7E-4	4E-3	2E-1	1E-3	8E-3	4E-2	2E-5	3E-3	4E-1	1E-2	9E-2
		N2	1E-3	2E-2	4E-2	2E-2	3E-1	2E-3	9E-3	8E-4	3E-2	1E-3	4E-1	1E-1	1E-5	9E-2	3E-2	1E-3	3E-1	3E-3	1E-2	7E-2	3E-1	4E-1	5E-1	4E-2	7E-4	0.5	4E-2	2E-1	2E-1	5E-3	5E-3	3E-1	5E-1	8E-2	3E-1	2E-2
		N5	6E-3	5E-2	1E-1	1E-1	5E-1	2E-2	2E-2	7E-3	9E-2	7E-3	1E-1	2E-1	2E-4	2E-1	1E-1	8E-3	4E-1	2E-2	1E-1	4E-1	2E-1	4E-1	2E-1	2E-1	4E-3	4E-2	0.5	4E-1	1E-2	5E-2	5E-2	3E-2	6E-2	2E-1	7E-2	1E-1
		S1	5E-2	2E-1	2E-1	4E-1	4E-1	2E-1	4E-2	2E-1	2E-1	3E-1	1E-1	3E-1	2E-2	4E-1	4E-1	3E-1	3E-1	2E-1	5E-1	3E-1	2E-1	3E-1	2E-1	4E-1	2E-1	2E-1	4E-1	0.5	1E-1	4E-1	4E-1	1E-1	2E-1	3E-1	1E-1	4E-1
		S2	7E-4	8E-3	3E-2	7E-3	2E-1	1E-3	6E-3	5E-4	1E-2	1E-3	4E-1	6E-2	9E-5	5E-2	1E-2	2E-3	2E-1	1E-3	9E-3	2E-2	2E-1	3E-1	2E-1	2E-2	1E-3	2E-1	1E-2	1E-1	0.5	5E-3	4E-3	2E-1	2E-1	5E-2	4E-1	7E-3
		S5	2E-2	2E-1	2E-1	4E-1	3E-1	8E-2	4E-2	6E-2	3E-1	7E-2	5E-2	4E-1	4E-5	5E-1	5E-1	7E-2	2E-1	2E-1	4E-2	5E-2	8E-2	2E-1	6E-2	4E-1	8E-3	5E-3	5E-2	4E-1	5E-3	0.5	4E-1	1E-3	1E-2	4E-1	2E-2	4E-1
	60 MPH	**N1**	1E-2	2E-1	2E-1	4E-1	3E-1	8E-2	4E-2	6E-2	2E-1	1E-1	5E-2	4E-1	8E-4	4E-1	5E-1	1E-1	2E-1	1E-1	2E-1	5E-2	8E-2	2E-1	6E-2	4E-1	4E-2	5E-3	5E-2	4E-1	4E-3	4E-1	0.5	2E-2	1E-2	4E-1	2E-2	4E-1
		N2	2E-3	2E-2	4E-2	2E-2	2E-1	5E-3	1E-2	1E-3	3E-2	5E-4	4E-1	9E-2	8E-6	7E-2	3E-2	3E-4	2E-1	5E-3	8E-3	4E-2	3E-1	3E-1	4E-1	3E-2	2E-5	3E-1	3E-2	1E-1	2E-1	1E-3	2E-2	0.5	4E-1	7E-2	4E-1	2E-2
		N5	1E-3	2E-2	4E-2	2E-2	3E-1	3E-3	8E-3	2E-3	3E-2	4E-3	4E-1	1E-1	2E-4	9E-2	3E-2	5E-3	3E-1	5E-3	3E-2	9E-2	3E-1	4E-1	5E-1	4E-2	3E-3	5E-1	6E-2	2E-1	2E-1	1E-2	1E-2	4E-1	0.5	8E-2	3E-1	2E-2
		S1	1E-1	4E-1	3E-1	3E-1	3E-1	4E-1	7E-2	4E-1	4E-1	5E-1	7E-2	5E-1	3E-2	4E-1	4E-1	5E-1	2E-1	5E-1	3E-1	2E-1	1E-1	2E-1	9E-2	3E-1	4E-1	8E-2	2E-1	3E-1	5E-2	4E-1	4E-1	7E-2	8E-2	0.5	6E-2	3E-1
		S2	1E-3	1E-2	3E-2	3E-2	2E-1	6E-3	5E-3	6E-3	2E-2	1E-2	5E-1	8E-2	1E-3	7E-2	3E-2	1E-2	2E-1	1E-2	4E-2	9E-2	3E-1	3E-1	4E-1	4E-2	1E-2	3E-1	7E-2	1E-1	4E-1	2E-2	2E-2	4E-1	3E-1	6E-2	0.5	3E-2
		S5	1E-2	1E-1	2E-1	5E-1	4E-1	9E-2	2E-2	8E-2	2E-1	2E-1	6E-2	4E-1	1E-3	4E-1	4E-1	2E-1	2E-1	2E-1	3E-1	1E-1	9E-2	2E-1	7E-2	5E-1	9E-2	2E-2	1E-1	4E-1	7E-3	4E-1	4E-1	2E-2	2E-2	3E-1	3E-2	0.5

Table I.29: P-Values from One-Sided Student's *t*-Tests on San Diego E274 Smooth Tests by Caltrans on CDG Texture, Left Wheelpath

Texture			CDG South of GnG - PM35.8/36.3												CDG North of GnG - PM37.4/37.9												CDG before GnG - PM36.3/37.4											
Speed			40 MPH				50 MPH				60 MPH				40 MPH				50 MPH				60 MPH				40 MPH				50 MPH				60 MPH			
Lane			N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2	N1	N2	S1	S2
CDG South of GnG - PM35.8/36.3	40 MPH	N1	0.5	1E-1	2E-1	6E-2	4E-1	9E-2	6E-2	1E-2	5E-1	3E-2	5E-2	5E-2	9E-2	2E-2	2E-1	1E-2	3E-1	4E-2	8E-2	6E-2	5E-2	9E-3	9E-2	7E-3	5E-1	8E-2	1E-1	1E-1	3E-1	4E-2	3E-1	5E-2	5E-1	5E-2	9E-2	1E-2
		N2	1E-1	0.5	4E-1	3E-1	7E-2	3E-1	3E-1	5E-2	3E-1	1E-1	2E-1	1E-1	4E-1	1E-1	4E-1	4E-2	2E-1	2E-1	2E-1	1E-1	2E-1	2E-2	2E-1	2E-2	9E-2	4E-1	5E-1	4E-1	5E-2	2E-1	2E-1	2E-1	8E-2	2E-1	4E-1	5E-2
		S1	2E-1	4E-1	0.5	8E-2	5E-2	2E-1	8E-2	2E-2	3E-1	1E-2	4E-2	1E-1	2E-1	3E-2	3E-1	8E-3	8E-2	7E-2	1E-1	1E-1	7E-2	3E-3	1E-1	1E-2	3E-2	2E-1	4E-1	3E-1	9E-3	5E-2	3E-1	9E-2	2E-2	8E-2	2E-1	7E-3
		S2	6E-2	3E-1	8E-2	0.5	1E-2	5E-1	5E-1	6E-2	2E-1	2E-1	3E-1	2E-1	4E-1	1E-1	4E-1	4E-2	2E-2	3E-1	2E-1	2E-1	3E-1	1E-2	2E-1	3E-2	5E-3	4E-1	2E-1	4E-1	2E-3	3E-1	6E-2	3E-1	4E-3	3E-1	5E-1	5E-2
	50 MPH	N1	4E-1	7E-2	5E-2	1E-2	0.5	5E-2	1E-2	4E-3	4E-1	4E-3	7E-3	3E-2	4E-2	6E-3	2E-1	2E-3	1E-1	1E-2	7E-2	5E-2	1E-2	1E-3	8E-2	2E-3	4E-1	2E-2	4E-2	5E-2	4E-1	6E-3	2E-1	1E-2	4E-1	1E-2	4E-2	1E-3
		N2	9E-2	3E-1	2E-1	5E-1	5E-2	0.5	5E-1	1E-1	2E-1	3E-1	5E-1	3E-1	4E-1	3E-1	4E-1	1E-1	1E-1	4E-1	2E-1	2E-1	4E-1	8E-2	2E-1	7E-2	6E-2	4E-1	3E-1	4E-1	4E-2	4E-1	1E-1	4E-1	5E-2	4E-1	4E-1	1E-1
		S1	6E-2	3E-1	8E-2	5E-1	1E-2	5E-1	0.5	6E-2	2E-1	2E-1	4E-1	2E-1	4E-1	1E-1	4E-1	4E-2	2E-2	3E-1	2E-1	2E-1	4E-1	1E-2	2E-1	3E-2	5E-3	4E-1	2E-1	3E-1	2E-3	3E-1	6E-2	3E-1	4E-3	4E-1	4E-1	6E-2
		S2	1E-2	5E-2	2E-2	6E-2	4E-3	1E-1	6E-2	0.5	8E-2	1E-1	8E-2	4E-1	7E-2	2E-1	3E-1	5E-1	1E-2	2E-1	4E-1	5E-1	1E-1	4E-1	4E-1	3E-1	5E-3	5E-2	3E-2	5E-2	3E-3	1E-1	1E-2	2E-1	4E-3	1E-1	8E-2	4E-1
	60 MPH	N1	5E-1	3E-1	3E-1	2E-1	4E-1	2E-1	2E-1	8E-2	0.5	1E-1	2E-1	1E-1	2E-1	1E-1	2E-1	8E-2	4E-1	1E-1	1E-1	1E-1	2E-1	6E-2	1E-1	5E-2	5E-1	2E-1	3E-1	2E-1	4E-1	1E-1	4E-1	2E-1	5E-1	2E-1	2E-1	8E-2
		N2	3E-2	1E-1	1E-2	2E-1	4E-3	3E-1	2E-1	1E-1	1E-1	0.5	3E-1	3E-1	2E-1	3E-1	5E-1	1E-1	4E-3	5E-1	3E-1	3E-1	3E-1	3E-2	3E-1	6E-2	8E-4	2E-1	5E-2	2E-1	4E-4	4E-1	2E-2	4E-1	6E-4	4E-1	2E-1	2E-1
		S1	5E-2	2E-1	4E-2	3E-1	7E-3	5E-1	4E-1	8E-2	2E-1	3E-1	0.5	3E-1	3E-1	2E-1	5E-1	6E-2	8E-3	4E-1	2E-1	2E-1	5E-1	2E-2	2E-1	4E-2	2E-3	3E-1	1E-1	3E-1	9E-4	4E-1	4E-2	4E-1	2E-3	4E-1	4E-1	8E-2
		S2	5E-2	1E-1	1E-1	2E-1	3E-2	3E-1	2E-1	4E-1	1E-1	3E-1	3E-1	0.5	2E-1	4E-1	4E-1	4E-1	6E-2	3E-1	3E-1	4E-1	3E-1	3E-1	4E-1	2E-1	4E-2	2E-1	1E-1	2E-1	3E-2	3E-1	7E-2	3E-1	3E-2	3E-1	2E-1	4E-1
CDG North of GnG - PM37.4/37.9	40 MPH	N1	9E-2	4E-1	2E-1	4E-1	4E-2	4E-1	4E-1	7E-2	2E-1	2E-1	3E-1	2E-1	0.5	2E-1	4E-1	7E-2	1E-1	3E-1	2E-1	2E-1	3E-1	4E-2	2E-1	3E-2	5E-2	5E-1	3E-1	4E-1	3E-2	3E-1	1E-1	3E-1	4E-2	3E-1	5E-1	8E-2
		N2	2E-2	1E-1	3E-2	1E-1	6E-3	3E-1	1E-1	2E-1	1E-1	3E-1	2E-1	4E-1	2E-1	0.5	4E-1	2E-1	2E-2	3E-1	3E-1	3E-1	2E-1	1E-1	3E-1	1E-1	5E-3	1E-1	4E-2	1E-1	2E-3	3E-1	2E-2	3E-1	4E-3	3E-1	2E-1	3E-1
		S1	2E-1	4E-1	3E-1	4E-1	2E-1	4E-1	4E-1	3E-1	2E-1	5E-1	5E-1	4E-1	4E-1	4E-1	0.5	4E-1	2E-1	5E-1	3E-1	3E-1	5E-1	3E-1	3E-1	3E-1	2E-1	4E-1	3E-1	4E-1	2E-1	5E-1	3E-1	5E-1	2E-1	5E-1	4E-1	4E-1
		S2	1E-2	4E-2	8E-3	4E-2	2E-3	1E-1	4E-2	5E-1	8E-2	1E-1	6E-2	4E-1	7E-2	2E-1	4E-1	0.5	4E-3	2E-1	4E-1	4E-1	8E-2	3E-1	4E-1	2E-1	1E-3	3E-2	1E-2	4E-2	5E-4	1E-1	4E-3	2E-1	9E-4	1E-1	7E-2	5E-1
	50 MPH	N1	3E-1	2E-1	8E-2	2E-2	1E-1	1E-1	2E-2	1E-2	4E-1	4E-3	8E-3	6E-2	1E-1	2E-2	2E-1	4E-3	0.5	3E-2	1E-1	8E-2	2E-2	2E-3	1E-1	7E-3	2E-1	4E-2	1E-1	1E-1	5E-2	1E-2	4E-1	3E-2	1E-1	2E-2	9E-2	2E-3
		N2	4E-2	2E-1	7E-2	3E-1	1E-2	4E-1	3E-1	2E-1	1E-1	5E-1	4E-1	3E-1	3E-1	3E-1	5E-1	2E-1	3E-2	0.5	3E-1	3E-1	4E-1	7E-2	3E-1	7E-2	1E-2	2E-1	1E-1	2E-1	5E-3	5E-1	4E-2	5E-1	9E-3	4E-1	3E-1	2E-1
		S1	8E-2	2E-1	1E-1	2E-1	7E-2	2E-1	2E-1	4E-1	1E-1	3E-1	2E-1	3E-1	2E-1	3E-1	3E-1	4E-1	1E-1	3E-1	0.5	4E-1	2E-1	4E-1	5E-1	5E-1	8E-2	2E-1	2E-1	2E-1	7E-2	2E-1	1E-1	2E-1	8E-2	2E-1	2E-1	4E-1
		S2	6E-2	1E-1	1E-1	2E-1	5E-2	2E-1	2E-1	5E-1	1E-1	3E-1	2E-1	4E-1	2E-1	3E-1	3E-1	4E-1	8E-2	3E-1	4E-1	0.5	2E-1	5E-1	5E-1	4E-1	6E-2	2E-1	1E-1	2E-1	4E-2	3E-1	8E-2	3E-1	5E-2	2E-1	2E-1	4E-1
	60 MPH	N1	5E-2	2E-1	7E-2	3E-1	1E-2	4E-1	4E-1	1E-1	2E-1	3E-1	5E-1	3E-1	3E-1	2E-1	5E-1	8E-2	2E-2	4E-1	2E-1	2E-1	0.5	3E-2	2E-1	4E-2	8E-3	3E-1	1E-1	3E-1	4E-3	4E-1	5E-2	4E-1	7E-3	5E-1	4E-1	1E-1
		N2	9E-3	2E-2	3E-3	1E-2	1E-3	8E-2	1E-2	4E-1	6E-2	3E-2	2E-2	3E-1	4E-2	1E-1	3E-1	3E-1	2E-3	7E-2	4E-1	5E-1	3E-2	0.5	5E-1	4E-1	1E-4	9E-3	2E-3	2E-2	8E-5	5E-2	1E-3	7E-2	1E-4	4E-2	3E-2	3E-1
		S1	9E-2	2E-1	1E-1	2E-1	8E-2	2E-1	2E-1	4E-1	1E-1	3E-1	2E-1	4E-1	2E-1	3E-1	3E-1	4E-1	1E-1	3E-1	5E-1	5E-1	2E-1	5E-1	0.5	5E-1	9E-2	2E-1	2E-1	2E-1	7E-2	3E-1	1E-1	3E-1	9E-2	3E-1	2E-1	4E-1
		S2	7E-3	2E-2	1E-2	3E-2	2E-3	7E-2	3E-2	3E-1	5E-2	6E-2	4E-2	2E-1	3E-2	1E-1	3E-1	2E-1	7E-3	7E-2	5E-1	4E-1	4E-2	4E-1	5E-1	0.5	3E-3	2E-2	1E-2	2E-2	2E-3	6E-2	5E-3	7E-2	3E-3	5E-2	4E-2	2E-1
CDG before GnG - PM36.3/37.4	40 MPH	N1	5E-1	9E-2	3E-2	5E-3	4E-1	6E-2	5E-3	5E-3	5E-1	8E-4	2E-3	4E-2	5E-2	5E-3	2E-1	1E-3	2E-1	1E-2	8E-2	6E-2	8E-3	1E-4	9E-2	3E-3	0.5	1E-2	4E-2	6E-2	2E-1	5E-3	2E-1	1E-2	4E-1	9E-3	4E-2	8E-4
		N2	8E-2	4E-1	2E-1	4E-1	2E-2	4E-1	4E-1	5E-2	2E-1	2E-1	3E-1	2E-1	5E-1	1E-1	4E-1	3E-2	4E-2	2E-1	2E-1	2E-1	3E-1	9E-3	2E-1	2E-2	1E-2	0.5	3E-1	4E-1	5E-3	2E-1	1E-1	3E-1	9E-3	3E-1	5E-1	5E-2
		S1	1E-1	5E-1	4E-1	2E-1	4E-2	3E-1	2E-1	3E-2	3E-1	5E-2	1E-1	1E-1	3E-1	4E-2	3E-1	1E-2	1E-1	1E-1	2E-1	1E-1	1E-1	2E-3	2E-1	1E-2	4E-2	3E-1	0.5	4E-1	1E-2	1E-1	2E-1	1E-1	2E-2	1E-1	3E-1	2E-2
		S2	1E-1	4E-1	3E-1	4E-1	5E-2	4E-1	3E-1	5E-2	2E-1	2E-1	3E-1	2E-1	4E-1	1E-1	4E-1	4E-2	1E-1	2E-1	2E-1	2E-1	3E-1	2E-2	2E-1	2E-2	6E-2	4E-1	4E-1	0.5	3E-2	2E-1	2E-1	2E-1	5E-2	3E-1	4E-1	6E-2
	50 MPH	N1	3E-1	5E-2	9E-3	2E-3	4E-1	4E-2	2E-3	3E-3	4E-1	4E-4	9E-4	3E-2	3E-2	2E-3	2E-1	5E-4	5E-2	5E-3	7E-2	4E-2	4E-3	8E-5	7E-2	2E-3	2E-1	5E-3	1E-2	3E-2	0.5	2E-3	8E-2	6E-3	3E-1	4E-3	2E-2	3E-4
		N2	4E-2	2E-1	5E-2	3E-1	6E-3	4E-1	3E-1	1E-1	1E-1	4E-1	4E-1	3E-1	3E-1	3E-1	5E-1	1E-1	1E-2	5E-1	2E-1	3E-1	4E-1	5E-2	3E-1	6E-2	5E-3	2E-1	1E-1	2E-1	2E-3	0.5	4E-2	5E-1	4E-3	4E-1	3E-1	2E-1
		S1	3E-1	2E-1	3E-1	6E-2	2E-1	1E-1	6E-2	1E-2	4E-1	2E-2	4E-2	7E-2	1E-1	2E-2	3E-1	4E-3	4E-1	4E-2	1E-1	8E-2	5E-2	1E-3	1E-1	5E-3	2E-1	1E-1	2E-1	2E-1	8E-2	4E-2	0.5	6E-2	2E-1	6E-2	2E-1	6E-3
		S2	5E-2	2E-1	9E-2	3E-1	1E-2	4E-1	3E-1	2E-1	2E-1	4E-1	4E-1	3E-1	3E-1	3E-1	5E-1	2E-1	3E-2	5E-1	2E-1	3E-1	4E-1	7E-2	3E-1	7E-2	1E-2	3E-1	1E-1	2E-1	6E-3	5E-1	6E-2	0.5	1E-2	5E-1	3E-1	2E-1
	60 MPH	N1	5E-1	8E-2	2E-2	4E-3	4E-1	5E-2	4E-3	4E-3	5E-1	6E-4	2E-3	3E-2	4E-2	4E-3	2E-1	9E-4	1E-1	9E-3	8E-2	5E-2	7E-3	1E-4	9E-2	3E-3	4E-1	9E-3	2E-2	5E-2	3E-1	4E-3	2E-1	1E-2	0.5	7E-3	4E-2	6E-4
		N2	5E-2	2E-1	8E-2	3E-1	1E-2	4E-1	4E-1	1E-1	2E-1	4E-1	4E-1	3E-1	3E-1	3E-1	5E-1	1E-1	2E-2	4E-1	2E-1	2E-1	5E-1	4E-2	3E-1	5E-2	9E-3	3E-1	1E-1	3E-1	4E-3	4E-1	6E-2	5E-1	7E-3	0.5	3E-1	1E-1
		S1	9E-2	4E-1	2E-1	5E-1	4E-2	4E-1	4E-1	8E-2	2E-1	2E-1	4E-1	2E-1	5E-1	2E-1	4E-1	7E-2	9E-2	3E-1	2E-1	2E-1	4E-1	3E-2	2E-1	4E-2	4E-2	5E-1	3E-1	4E-1	2E-2	3E-1	2E-1	3E-1	4E-2	3E-1	0.5	9E-2
		S2	1E-2	5E-2	7E-3	5E-2	1E-3	1E-1	6E-2	4E-1	8E-2	2E-1	8E-2	4E-1	8E-2	3E-1	4E-1	5E-1	2E-3	2E-1	4E-1	4E-1	1E-1	3E-1	4E-1	2E-1	8E-4	5E-2	2E-2	6E-2	3E-4	2E-1	6E-3	2E-1	6E-4	1E-1	9E-2	0.5

Table I.30: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Ribbed Tire Results for IGGA Testing on San Diego 5 Project

	CDG(S)-N2	GNG-N2	CDG(N)-N2	CDG(S)-N5	GNG-N5	CDG(N)-N5	CDG(S)-S5	GNG-S5	CDG(N)-S5
CDG(S)-N2	0.5	2 E-02	9 E-02	6 E-02	4 E-05	2 E-02	2 E-02	4 E-05	7 E-03
GNG-N2	**2 E-02**	0.5	6 E-03	4 E-01	4 E-03	2 E-03	1 E-01	1 E-01	1 E-01
CDG(N)-N2	**9 E-02**	6 E-03	0.5	2 E-02	1 E-05	2 E-01	1 E-02	2 E-04	1 E-02
CDG(S)-N5	**6 E-02**	**4 E-01**	**2 E-02**	0.5	5 E-03	7 E-03	2 E-01	9 E-02	2 E-01
GNG-N5	4 E-05	4 E-03	1 E-05	5 E-03	0.5	4 E-06	9 E-05	6 E-03	1 E-04
CDG(N)-N5	**2 E-02**	2 E-03	**2 E-01**	7 E-03	4 E-06	0.5	3 E-03	7 E-05	3 E-03
CDG(S)-S5	**2 E-02**	**1 E-01**	**1 E-02**	**2 E-01**	9 E-05	3 E-03	0.5	5 E-04	4 E-01
GNG-S5	4 E-05	**1 E-01**	2 E-04	**9 E-02**	6 E-03	7 E-05	5 E-04	0.5	6 E-04
CDG(N)-S5	7 E-03	**1 E-01**	**1 E-02**	**2 E-01**	1 E-04	3 E-03	**4 E-01**	6 E-04	0.5

Table I.31: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Smooth Tire Results for IGGA Testing on San Diego 5 Project

	CDG(S)-S5	GNG-S5	CDG(N)-S5	CDG(S)-N5	GNG-N5	CDG(N)-N5
CDG(S)-S5	0.5	4 E-01	4 E-01	3 E-02	1 E-04	2 E-01
GnG-S5	**4 E-01**	0.5	5 E-01	1 E-01	7 E-04	1 E-01
CDG(N)-S5	**4 E-01**	**5 E-01**	0.5	1 E-01	2 E-03	2 E-01
CDG(S)-N5	**3 E-02**	**1 E-01**	**1 E-01**	0.5	3 E-03	2 E-02
GNG-N5	1 E-04	7 E-04	2 E-03	3 E-03	0.5	3 E-04
CDG(N)-N5	**2 E-01**	**1 E-01**	**2 E-01**	**2 E-02**	3 E-04	0.5

Table I.32: P-Values from One-Sided Student's *t*-Tests on ASTM E274 Texture Results for IGGA Testing on San Diego 5 Project

	R-C-N2	R-G-N2	R-C-N5	R-G-N5	R-C-S5	R-G-S5	S-CS-S5	S-G-S5	S-CS-N5	S-G-N5
RIBBED –CDG - North Lane 2	0.5	1 E-02	3 E-01	7 E-06	8 E-04	5 E-06	8 E-07	6 E-04	1 E-05	2 E-06
RIBBED –GnG - North Lane 2	**1 E-02**	0.5	3 E-02	4 E-03	1 E-01	1 E-01	8 E-03	2 E-02	7 E-03	7 E-06
RIBBED –CDG - North Lane 5	**3 E-01**	**3 E-02**	0.5	1 E-05	8 E-02	6 E-04	2 E-05	6 E-04	4 E-05	1 E-07
RIBBED –GnG - North Lane 5	7 E-06	4 E-03	1 E-05	0.5	2 E-04	6 E-03	3 E-01	4 E-01	4 E-01	2 E-04
RIBBED –CDG - South Lane 5	8 E-04	**1 E-01**	**8 E-02**	2 E-04	0.5	5 E-04	4 E-05	3 E-03	2 E-04	2 E-05
RIBBED –GnG - South Lane 5	5 E-06	**1 E-01**	6 E-04	6 E-03	5 E-04	0.5	2 E-02	5 E-02	2 E-02	3 E-05
SMOOTH –CDG - South Lane 5	8 E-07	8 E-03	2 E-05	**3 E-01**	4 E-05	**2 E-02**	0.5	4 E-01	4 E-01	7 E-05
SMOOTH –GnG - South Lane 5	6 E-04	**2 E-02**	6 E-04	**4 E-01**	3 E-03	**5 E-02**	**4 E-01**	0.5	5 E-01	7 E-04
SMOOTH –CDG - North Lane 5	1 E-05	7 E-03	4 E-05	**4 E-01**	2 E-04	**2 E-02**	**4 E-01**	**5 E-01**	0.5	2 E-04
SMOOTH –GnG - North Lane 5	2 E-06	7 E-06	1 E-07	2 E-04	2 E-05	3 E-05	7 E-05	7 E-04	2 E-04	0.5

I.5 IRI Statistics

I.5.1 Sacramento 5 – PM 20.0/21.5

Table I.33: One-Sided Student's *t*-Tests on IRI Results for Northbound and Southbound Pre-CDG Texture on Sacramento 5 – PM 20.0/21.5

	PreCDG-NB	PreCDG-SB
Mean	130.37997	129.04696
Variance	277.69345	21.80677
Observations	7	6
Df	7	
t Stat	0.20257	
P(T<=t) one-tail	0.42262	Accept Null
t Critical one-tail	1.89458	

I.5.2 Sacramento 5 – PM 1.5/3.0

Table I.34: P-Values from One-Sided Student's *t*-Tests on IRI Results for Individual Lanes and Textures on Sacramento 5 – PM 1.5/3.0

	PreCDG-N1	PreCDG-N2	PreCDG-S1	PreCDG-S2	CDG-N1	CDG-N2	CDG-S1	CDG-S2	GnG-N1	GnG-N2	CDG0.3y-S1	CDG0.3y-S2
PreCDG-N1	0.5	3 E-01	7 E-05	2 E-04	2 E-06	5 E-08	2 E-05	6 E-08	4 E-06	2 E-08	2 E-05	2 E-07
PreCDG-N2	**3 E-01**	0.5	5 E-04	7 E-05	4 E-07	3 E-07	6 E-05	1 E-06	2 E-05	2 E-07	5 E-05	3 E-06
PreCDG-S1	7 E-05	5 E-04	0.5	2 E-03	3 E-06	4 E-08	9 E-06	1 E-08	1 E-06	1 E-08	5 E-06	2 E-08
PreCDG-S2	2 E-04	7 E-05	2 E-03	0.5	2 E-07	2 E-06	7 E-05	5 E-06	3 E-05	1 E-06	6 E-05	1 E-05
CDG-N1	2 E-06	4 E-07	3 E-06	2 E-07	0.5	4 E-01	8 E-03	3 E-01	6 E-04	2 E-04	3 E-02	7 E-03
CDG-N2	5 E-08	3 E-07	4 E-08	2 E-06	**4 E-01**	0.5	3 E-03	2 E-01	1 E-04	2 E-05	1 E-02	1 E-03
CDG-S1	2 E-05	6 E-05	9 E-06	7 E-05	8 E-03	3 E-03	0.5	1 E-03	9 E-08	2 E-04	2 E-05	4 E-02
CDG-S2	6 E-08	1 E-06	1 E-08	5 E-06	**3 E-01**	**2 E-01**	1 E-03	0.5	4 E-05	1 E-05	5 E-03	3 E-04
GnG-N1	4 E-06	2 E-05	1 E-06	3 E-05	6 E-04	1 E-04	9 E-08	4 E-05	0.5	1 E-03	3 E-08	1 E-05
GnG-N2	2 E-08	2 E-07	1 E-08	1 E-06	2 E-04	2 E-05	2 E-04	1 E-05	1 E-03	0.5	2 E-04	5 E-06
CDG0.3y-S1	2 E-05	5 E-05	5 E-06	6 E-05	**3 E-02**	**1 E-02**	2 E-05	5 E-03	3 E-08	2 E-04	0.5	9 E-03
CDG0.3y-S2	2 E-07	3 E-06	2 E-08	1 E-05	7 E-03	1 E-03	**4 E-02**	3 E-04	1 E-05	5 E-06	9 E-03	0.5

Table I.35: P-Values from One-Sided Student's t-Tests on IRI Results for Combined Lanes and Individual Textures on Sacramento 5 – PM 1.5/3.0

	PreCDG-NB	PreCDG-SB	CDG-NB	CDG-SB	GnG-NB	CDG0.3y-SB
PreCDG-NB	0.5	5E-04	1E-16	2E-08	3E-09	2E-15
PreCDG-SB	5E-04	0.5	6E-08	2E-10	3E-11	6E-08
CDG-NB	1E-16	6E-08	0.5	6E-02	1E-05	1E-04
CDG-SB	2E-08	2E-10	**6E-02**	0.5	1E-06	3E-01
GnG-NB	3E-09	3E-11	1E-05	1E-06	0.5	3E-06
CDG0.3y-SB	2E-15	6E-08	1E-04	**3E-01**	3E-06	0.5

I.5.3 San Joaquin 99 – PM 29.0/30.7

Table I.36: P-Values from One-Sided Student's *t*-Tests on IRI Results for Individual Lanes and Textures on San Joaquin 99 – PM 29.0/30.7

	PreCDG-N1	PreCDG-N2	GnG-N1	GnG-N2
PreCDG-N1	0.5	2 E-07	6 E-06	3 E-03
PreCDG-N2	2 E-07	0.5	6 E-07	9 E-05
GnG-N1	6 E-06	6 E-07	0.5	3 E-02
GnG-N2	3 E-03	9 E-05	3 E-02	0.5

I.5.4 Yolo 113 – PM R0.5/R2.5

The statistical data for Yolo 113 – PM R0.5/R2.5 is presented in two tables, Table I.37, Parts A and B. The first column, which shows all the lane texture combinations, is repeated in both tables. The first table reports the p-values for the preconstruction texture and the second table reports the p-values for the postconstruction textures. In these two tables, the PreGnG abbreviation represents the pre-CDG texture at locations that later were surfaced with the GnG texture, as shown in Table I.8.

Table I.37: P-Values from One-Sided Student's *t*-Tests on IRI Data from Yolo 113 – PM 0.5/2.5 Project, Preconstruction Textures (Part A)

	PreGnG-N1	PreCDG-N1	PreGnG-N2	PreCDG-N2	PreGnG-S1	PreCDG-S1	PreGnG-S2	PreCDG-S2
PreGnG-N1	0.5	8 E-03	2 E-03	2 E-01	7 E-24	1 E-04	9 E-08	1 E-09
PreCDG-N1	8 E-03	0.5	4 E-05	9 E-03	2 E-14	1 E-05	3 E-09	1 E-08
PreGnG-N2	2 E-03	4 E-05	0.5	2 E-02	2 E-04	1 E-01	1 E-01	3 E-01
PreCDG-N2	**2 E-01**	9 E-03	**2 E-02**	0.5	5 E-10	6 E-02	6 E-05	5 E-04
PreGnG-S1	7 E-24	2 E-14	2 E-04	5 E-10	0.5	4 E-16	1 E-04	4 E-09
PreCDG-S1	1 E-04	1 E-05	**1 E-01**	**6 E-02**	4 E-16	0.5	4 E-04	4 E-03
PreGnG-S2	9 E-08	3 E-09	**1 E-01**	6 E-05	1 E-04	4 E-04	0.5	1 E-01
PreCDG-S2	1 E-09	1 E-08	**3 E-01**	5 E-04	4 E-09	4 E-03	**1 E-01**	0.5
GnG-N1	1 E-38	5 E-17	3 E-17	2 E-19	9 E-45	1 E-41	2 E-17	7 E-42
CDG-N1	1 E-41	9 E-19	2 E-18	2 E-21	4 E-47	2 E-45	1 E-20	3 E-46
GnG-N2	2 E-36	2 E-19	4 E-19	3 E-22	1 E-38	1 E-42	3 E-22	2 E-44
CDG-N2	2 E-42	5 E-19	2 E-18	3 E-21	2 E-49	6 E-45	3 E-18	6 E-45
GnG-S1	1 E-33	2 E-19	8 E-19	1 E-21	2 E-30	5 E-41	3 E-19	3 E-42
CDG-S1	8 E-44	3 E-17	2 E-17	6 E-20	2 E-56	8 E-45	3 E-19	3 E-45
GnG-S2	2 E-27	3 E-19	5 E-19	8 E-22	4 E-25	1 E-35	1 E-20	5 E-38
CDG-S2	1 E-36	5 E-13	4 E-15	2 E-16	5 E-52	2 E-38	4 E-18	5 E-40

Table I.37: P-Values from One-Sided Student's *t*-Tests on IRI Data from Testing on Yolo 113 – PM 0.5/2.5 Project, Postconstruction Textures
(Part B)

	GnG-N1	CDG-N1	GnG-N2	CDG-N2	GnG-S1	CDG-S1	GnG-S2	CDG-S2
PreGnG-N1	1 E-38	1 E-41	2 E-36	2 E-42	1 E-33	8 E-44	2 E-27	1 E-36
PreCDG-N1	5 E-17	9 E-19	2 E-19	5 E-19	2 E-19	3 E-17	3 E-19	5 E-13
PreGnG-N2	3 E-17	2 E-18	4 E-19	2 E-18	8 E-19	2 E-17	5 E-19	4 E-15
PreCDG-N2	2 E-19	2 E-21	3 E-22	3 E-21	1 E-21	6 E-20	8 E-22	2 E-16
PreGnG-S1	9 E-45	4 E-47	1 E-38	2 E-49	2 E-30	2 E-56	4 E-25	5 E-52
PreCDG-S1	1 E-41	2 E-45	1 E-42	6 E-45	5 E-41	8 E-45	1 E-35	2 E-38
PreGnG-S2	2 E-17	1 E-20	3 E-22	3 E-18	3 E-19	3 E-19	1 E-20	4 E-18
PreCDG-S2	7 E-42	3 E-46	2 E-44	6 E-45	3 E-42	3 E-45	5 E-38	5 E-40
GnG-N1	0.5	2 E-02	5 E-03	5 E-07	5 E-06	3 E-01	7 E-04	4 E-13
CDG-N1	**2 E-02**	0.5	2 E-01	2 E-02	1 E-02	9 E-03	9 E-02	4 E-14
GnG-N2	5 E-03	**2 E-01**	0.5	1 E-01	9 E-02	3 E-03	3 E-01	5 E-13
CDG-N2	5 E-07	**2 E-02**	**1 E-01**	0.5	3 E-01	7 E-07	3 E-01	1 E-21
GnG-S1	5 E-06	**1 E-02**	**9 E-02**	**3 E-01**	0.5	3 E-06	2 E-01	6 E-17
CDG-S1	**3 E-01**	9 E-03	3 E-03	7 E-07	3 E-06	0.5	4 E-04	9 E-11
GnG-S2	7 E-04	**9 E-02**	**3 E-01**	**3 E-01**	**2 E-01**	4 E-04	0.5	2 E-12
CDG-S2	4 E-13	4 E-14	5 E-13	1 E-21	6 E-17	9 E-11	2 E-12	0.5

I.5.5 Project Summary

Table I.38: Student's *t*-Tests on E274 Project Summary Data, Left Wheelpath

	Ribbed			Smooth		
Project Averages	Ho: CDG = GnG			Ho: CDG = GnG		
	H1: CDG > GnG			H1: CDG > GnG		
	alpha = 0.05	CDG	GnG	alpha = 0.05	CDG	GnG
	Mean	49.015	45.2296	Mean	42.487	38.9633
	Variance	3.2809	15.0627	Variance	1.0003	21.4897
	Observations	4	9	Observations	5	10
	df	11		df	11	
	t Stat	2.3970		t Stat	2.2991	
	P(T<=t) one-tail	0.01771	**Reject Null**	P(T<=t) one-tail	0.02105	**Reject Null**
	t Critical one-tail	1.7959		t Critical one-tail	1.7959	
	Ribbed			Smooth		
All Data Averages	Ho: CDG = GnG			Ho: CDG = GnG		
	H1: CDG > GnG			H1: CDG > GnG		
	alpha = 0.05	CDG	GnG	alpha = 0.05	CDG	GnG
	Mean	49.94828	44.8929	Mean	42.43529	38.5368
	Variance	13.17552	18.3454	Variance	7.274474	30.2563
	Observations	58	56	Observations	34	57
	df	108		df	86	
	t Stat	6.7874		t Stat	4.5173	
	P(T<=t) one-tail	3.2E-10	**Reject Null**	P(T<=t) one-tail	9.91E-06	**Reject Null**
	t Critical one-tail	1.6591		t Critical one-tail	1.66278	

I.6 Statistics Supporting Appendix E

Table I.39: Comparison of E274 and CT 342 Friction Results on Sacramento 5 – PM 20.0/21.5 Project

CDG			GnG			NGL		
Ho: E274 = CT342			Ho: E274 = CT342			Ho: E274 = CT342		
H1: E274 ≠ CT342			H1: E274 ≠ CT342			H1: E274 ≠ CT342		
alpha = 0.05	E274	CT 342	alpha = 0.05	E274	CT 342	alpha = 0.05	E274	CT 342
Mean	41.94	39	Mean	42.6	35	Mean	33.075	38.867
Variance	10.628	7.5	Variance	2.405	5.111	Variance	7.3025	1.838
Observations	5	5	Observations	5	10	Observations	4	15
df	8		df	11		df	3	
t Stat	1.544		t Stat	7.630		t Stat	-4.149	
P(T<=t) two-tail	0.161	**Accept Null**	P(T<=t) two-tail	1.0E-5	**Reject Null**	P(T<=t) two-tail	0.0254	**Reject Null**
t Critical two-tail	2.306		t Critical two-tail	2.201		t Critical two-tail	3.1824	

Note: CT324 results are multiplied by 100 for comparison to E274 results.

Table I.40: Comparison of E274 and CT 342 Friction Results on Sacramento 80 – PM 13.0/14.0 Project

WB E274 vs EB CT 342			EB E274 vs EB CT 342		
Ho: WB E274 = EB CT342			Ho: EB E274 = EB CT342		
H1: WB E274 ≠ EB CT342			H1: EB E274 ≠ EB CT342		
alpha = 0.05	WB E274	EB CT 342	alpha = 0.05	EB E274	EB CT 342
Mean	28.825	29.8	Mean	38.95	29.8
Variance	3.525	7.8857	Variance	5.571	7.8857
Observations	8	15	Observations	6	15
df	20		df	11	
t Stat	-0.99184		t Stat	7.587643	
P(T<=t) two-tail	0.333127	**Accept Null**	P(T<=t) two-tail	1.08E-05	**Reject Null**
t Critical two-tail	2.085963		t Critical two-tail	2.200985	

Note: CT324 results are multiplied by 100 for comparison to E274 results.

Table I.41: Comparison of E274 and CT 342 Friction Results on San Diego 5 – PM R35.8/R37.9 Project

CDG South of GnG Section – NB L5			CDG North of GnG Section – SB L5			GnG Section – SB L5		
Ho: E274 = CT342			Ho: E274 = CT342			Ho: E274 = CT342		
H1: E274 ≠ CT342			H1: E274 ≠ CT342			H1: E274 ≠ CT342		
alpha = 0.05	E274	CT342	alpha = 0.05	E274	CT342	alpha = 0.05	E274	CT342
Mean	40.38	33	Mean	42.44	47	Mean	35.8167	29.4
Variance	3.512	8	Variance	8.083	18	Variance	5.2417	4.3
Observations	5	2	Observations	5	2	Observations	6	5
df	1		df	1		df	9	
t Stat	3.4033		t Stat	-1.399497		t Stat	4.8734	
P(T<=t) two-tail	0.1819	**Accept Null**	P(T<=t) two-tail	0.39497	**Accept Null**	P(T<=t) two-tail	0.00088	**Reject Null**
t Critical two-tail	12.7062		t Critical two-tail	12.7062		t Critical two-tail	2.26216	

Note: CT 324 results are multiplied by 100 for comparison to E274 results.

APPENDIX J: OUTFLOW METER DATA

Table J.1 shows outflow meter data for six of the seven projects and Table J.2 shows the same data for the San Diego project. Note that the higher the number shown, the longer the time required to drain the water. When comparing Outflow Meter Test results, increases may indicate a smoother, less textured surface that is more prone to high-speed hydroplaning.

The data show that the Pre-CDG time was always greater than the time required for either the CDG or GnG surface, indicating that the existing surface was more polished with less texture than the newly constructed CDG or GnG surfaces. For each project where drainability was measured, the Pre-GnG surface was the least drainable (highest times), showing the smoothing effect of the flush grind.

When comparing the data in Table J.2 for the San Diego 5 project, note that the CDG at 1.1 years was measured between PMs R35.8 and R37.9, before the GnG was constructed. The CDG at 1.3 years and the GnG data come from different locations in the evaluation area: the data for CDG at 1.3 years were collected between PMs R35.8 and R36.3 and between PMs R37.4 and R37.9, while the GnG data were collected between PMs R36.35 and R37.35 (see Figure 3.9).

Table J.1: Average Outflow Meter Time from Pilot Projects, Excluding San Diego 5
(Note: Bold numbers are project averages for each texture condition.)

	Pre-CDG (sec)		CDG (sec)		Pre-GnG (sec)		GnG (sec)	
	Avg.	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Sac 5 – PM 18.7	6/2/2011		6/2/2011		6/9/2011		6/9/2011	
NB Lane 1*	**7.2**	**2.0**	**3.8**	**1.3**	**22.1**	**4.6**	**3.4**	**0.5**
BWP	7.9	2.3	4.9	0.7	19.2	4.0	3.1	0.2
LWP	6.4	1.4	2.7	0.6	25.6	2.5	3.7	0.3
Sac 5 – PM 2.9	12/12/2011				1/12/2012		1/16/2012	
NB Lane 1*	**3.1**	**0.6**			**51.5**	**7.6**	**5.0**	**0.6**
BWP	2.7	0.6			51.2	0.1	5.0	0.7
LWP	3.4	0.4			51.7	7.4	4.9	0.4
Sac 80 – PM 13.5	2/15/2012				3/19/2012		3/26/2012	
EB Lane 2*	**14.3**	**7.7.**	**2.7**	**0.8**	**92.0**	**25.0**	**8.3**	**1.1**
BWP	21.1	3.9	2.2	0.5	107.3	26.5	7.9	1.3
LWP	8.9	5.1	3.3	0.7	77.9	12.6	8.7	0.7
Sac 50 – PM R13.5	1/8/2011		7/16/2012					
EB Lane 4*	**9.4**	**8.3**						
BWP	19.8	5.3						
LWP	5.4	1.1						
RWP	2.9	0.8						
WB Lane 4*							**12.0**	**3.1**
BWP							10.8	3.4
RWP							13.6	1.7
SJ 99 – PM 30.51	6/26/2012		6/27/2012				7/11/2012	
NB Lane 1*	**6.5**	**1.6**	**4.3**	**1.3**			**4.5**	**0.7**
BWP	7.2	1.9	3.1	0.5			4.6	0.3
LWP	5.7	0.6	5.4	0.5			4.5	0.9
Yol 113 – PM R0.5	10/31/2012						11/27/2012	
SB Lane 1*	**18.6**	**10.2**					**4.8**	**0.9**
BWP	13.6	3.0					5.4	0.6
LWP	23.3	12.3					4.2	0.7

Note:
* BWP = between wheelpaths, LWP = left wheelpath, RWP = right wheelpath

Table J.2: Average Outflow Meter Times from San Diego 5 – PM R35.8/R37.9 Pilot Project

Texture[1]	Pre-CDG (sec)		CDG1.1y (sec)		CDG1.3y (sec)		GnG (sec)	
	12/2010 – 3/2011		5/7-15/2012		7/18-25/2012		7/18-25/2012	
	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.	Avg.	Std. Dev.
Project Average	**7.5**	**5.3**	**3.8**	**2.3**	**4.0**	**1.7**	**5.1**	**1.1**
NB Average	**8.0**	**5.9**	**3.5**	**2.0**	**3.6**	**1.4**	**5.3**	**0.8**
SB Average	**7.2**	**4.7**	**4.2**	**2.6**	**5.0**	**1.9**	**4.9**	**1.3**
NB Lane 1	7.9	7.3	3.0	1.3	2.1	0.7	4.8	1.3
BWP[2]	6.9	4.1	2.4	1.1	1.8	0.4	5.4	0.2
LWP[2]	8.7	11.8	2.4	0.8	2.5	0.8	4.2	1.9
RWP[2]	8.3	3.6	4.4	0.8				
NB Lane 2	8.0	4.2	3.2	0.8	2.6	1.0	5.8	0.6
BWP	8.0	4.0	3.0	0.5	2.5	0.0	6.0	1.0
LWP	9.4	3.6	2.7	0.4	2.7	1.7	5.6	0.3
RWP	6.4	5.2	4.0	0.8				
NB Lane 5			4.1	2.9	4.4	1.2	5.4	0.4
BWP			2.7	0.8	4.1	0.9	5.1	0.1
LWP			4.3	1.1	5.4	0.9		
RWP			5.3	4.6	3.0	0.2	5.6	0.5
SB Lane 1	7.8	3.4	4.9	3.8			5.7	0.8
BWP	8.0	1.3	3.2	0.8			5.2	0.3
LWP	6.9	1.6	5.5	3.4			6.3	0.6
RWP	8.4	5.6	6.0	5.7				
SB Lane 2	6.0	2.1	3.8	2.0	6.4	1.5	4.7	1.6
BWP	7.6	1.8	3.2	2.6	6.5	1.9	5.2	2.2
LWP	4.8	1.7	3.6	1.0	6.3	1.8	4.1	0.2
RWP	5.4	2.0	4.8	1.8				
SB Lane 5	7.4	6.7	4.0	1.3	3.7	1.2	4.4	0.9
BWP	11.8	10.6	2.7	0.6	2.8	1.0	4.8	0.4
LWP	5.5	1.6	4.6	0.3	4.6	0.0	4.1	1.0
RWP	5.1	2.7	5.0	1.0				

[1] Texture condition at time of the activity: Pre-CDG = before conventional diamond grinding, CDGX.Xy = X.X years after flush grinding, GnG = after longitudinal grooving.
[2] BWP = between wheelpaths, LWP = left wheelpath, RWP = right wheelpath

A comparison of the data from the CDG and GnG surfaces for all the projects shows that the CDG surface appears to be more drainable, although this may be a consequence of the test device. With the CDG surface, the positive texture (fins) that stick upward support the Outflow Meter device during the test, and produce a gap between the bottom of the device and the pavement surface. The effect on the test results would then vary with the height of the gap, which varies with the grinding depth and material stiffness. The negative texture resulting from the GnG surface would allow the meter to sit directly on the pavement surface, where the only drainage path is through the longitudinal grooves.

Table J.3: Outflow Meter Times from Sacramento 5 – PM 18.7 and PM 20.5

Location	**Between Wheelpaths**		**Left Wheelpath**		**Between and Left Wheelpaths, Combined**	
Texture	**Avg. (sec.)**	**Std. Dev.**	**Avg. (sec.)**	**Std. Dev.**	**Avg. (sec.)**	**Std. Dev.**
Pre-CDG	8.0	2.4	6.5	1.4	7.2	2.0
CDG	4.9	0.7	2.7	0.6	3.8	1.3
Pre-GnG	19.2	4.0	24.5	4.9	21.9	5.1
GnG	3.2	0.5	3.7	0.3	3.5	0.4
Pre-NGL	5.1	1.5	3.2	0.9	4.1	1.5
NGL	11.6	1.6	11.4	1.4	11.5	1.5

APPENDIX K: PLOTS AND REGRESSION EQUATIONS FOR OBSI AND IRI AS A FUNCTION OF PRE-TREATMENT VALUES

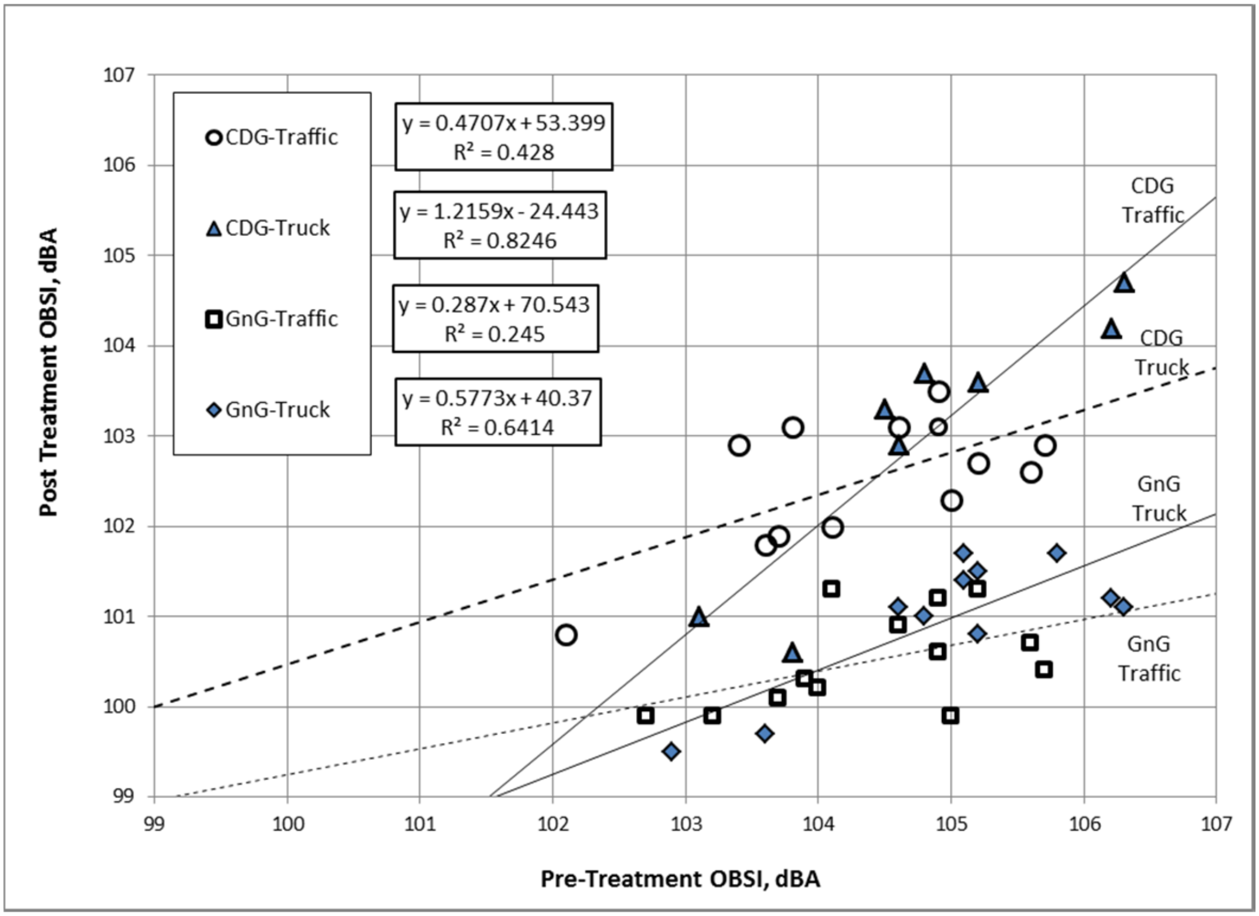


Figure K.1: OBSI trends for CDG and GnG surface treatments in truck and traffic lanes.

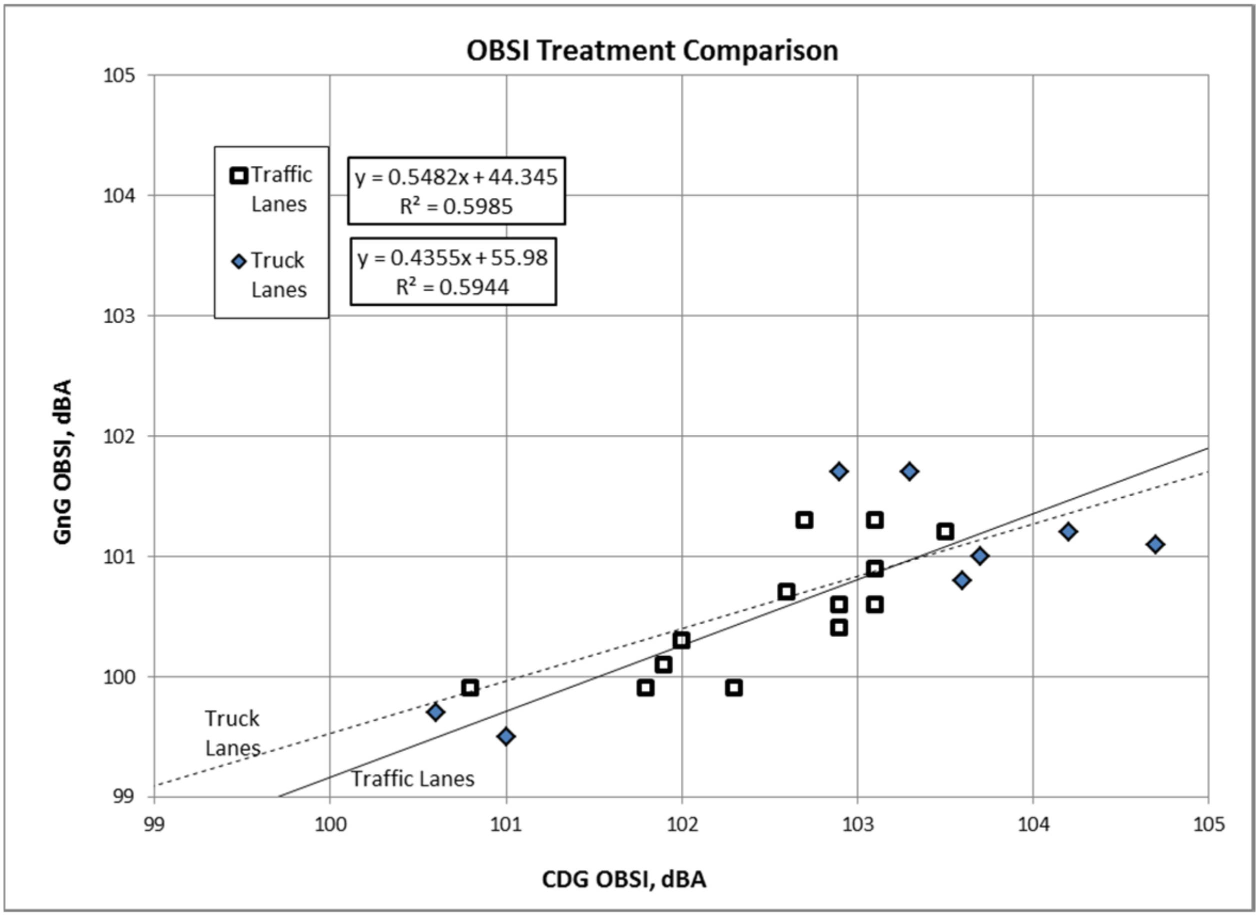


Figure K.2: Comparison of OBSI from CDG and GnG treatments in traffic and truck lanes.

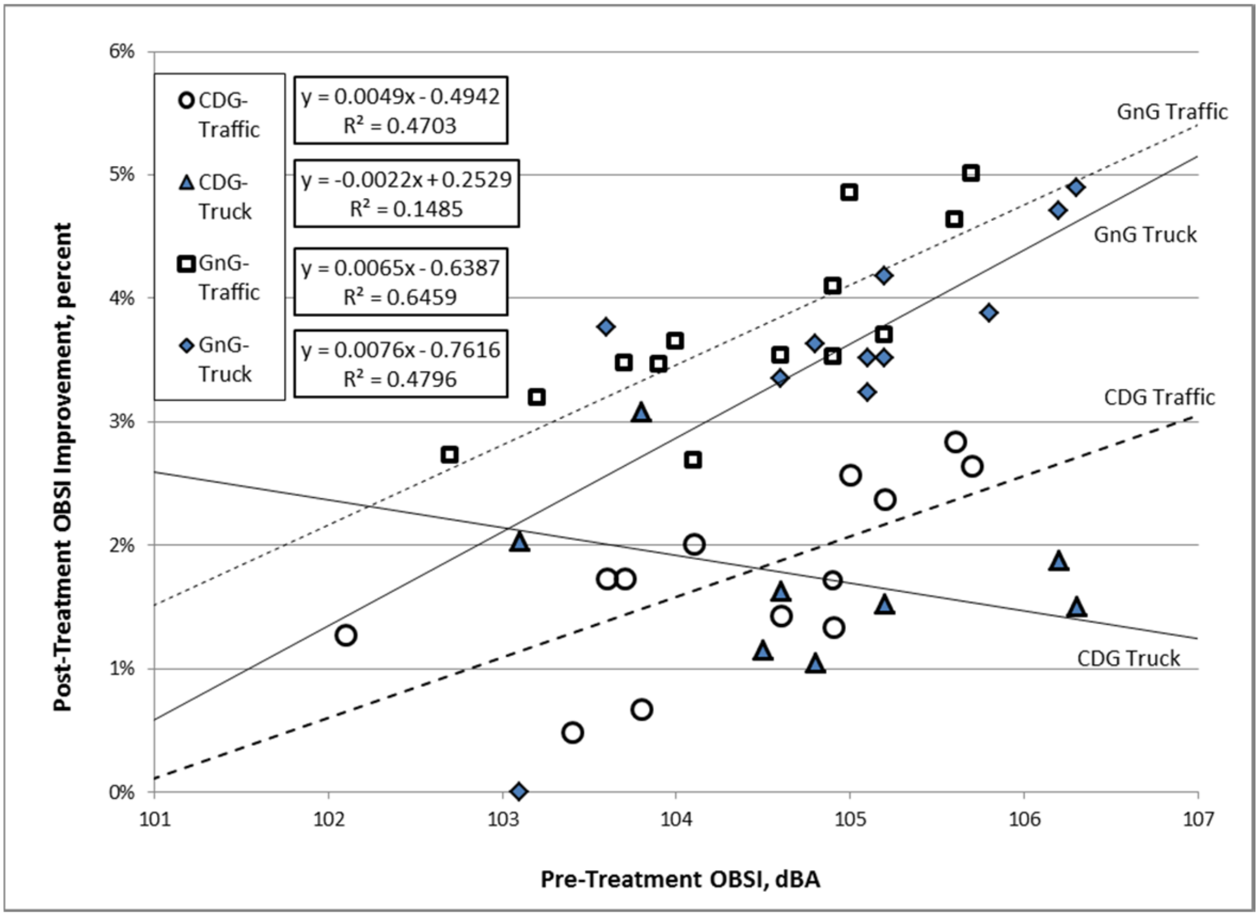


Figure K.3: OBSI percent improvement from CDG and GnG treatments in traffic and truck lanes.

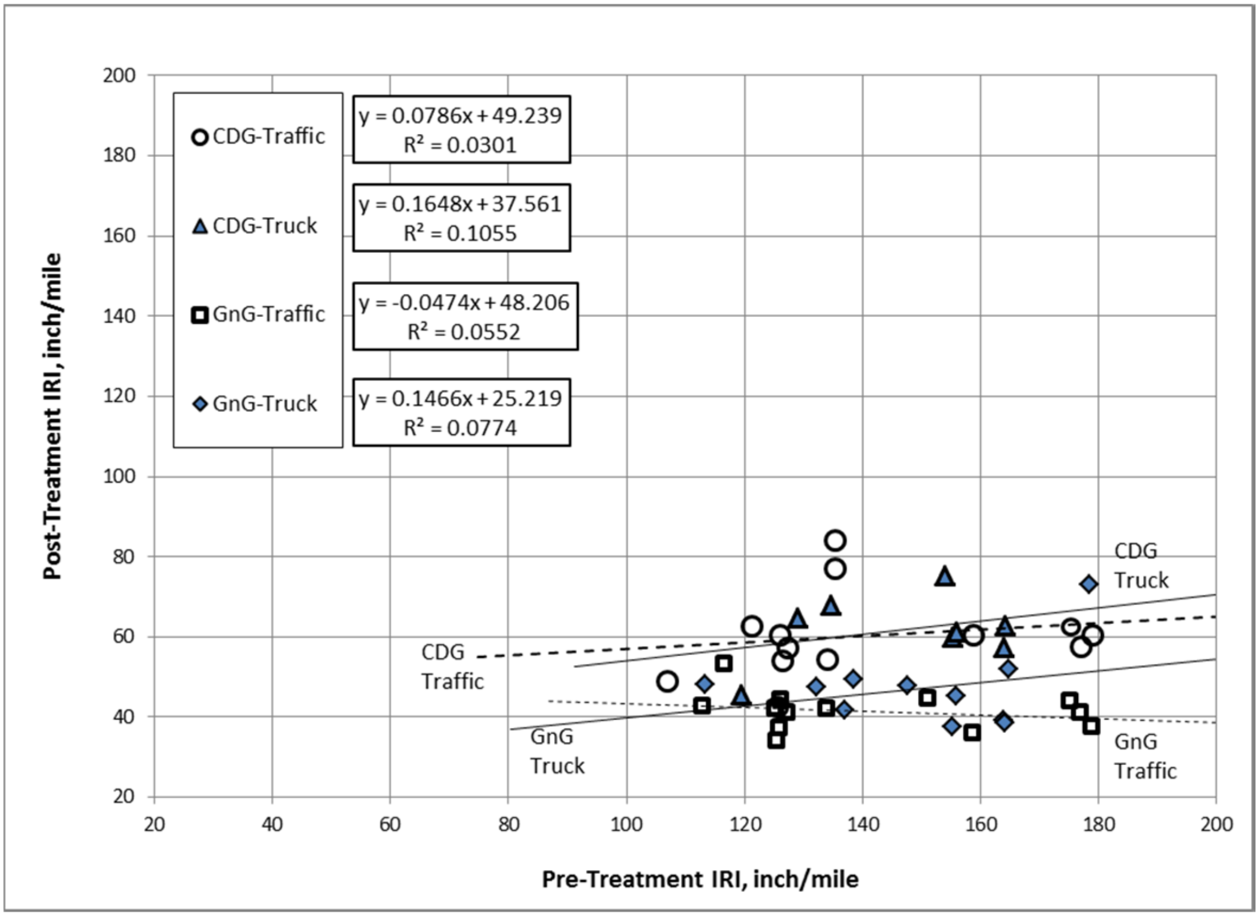


Figure K.4: IRI trends for CDG and GnG surface treatments in truck and traffic lanes.

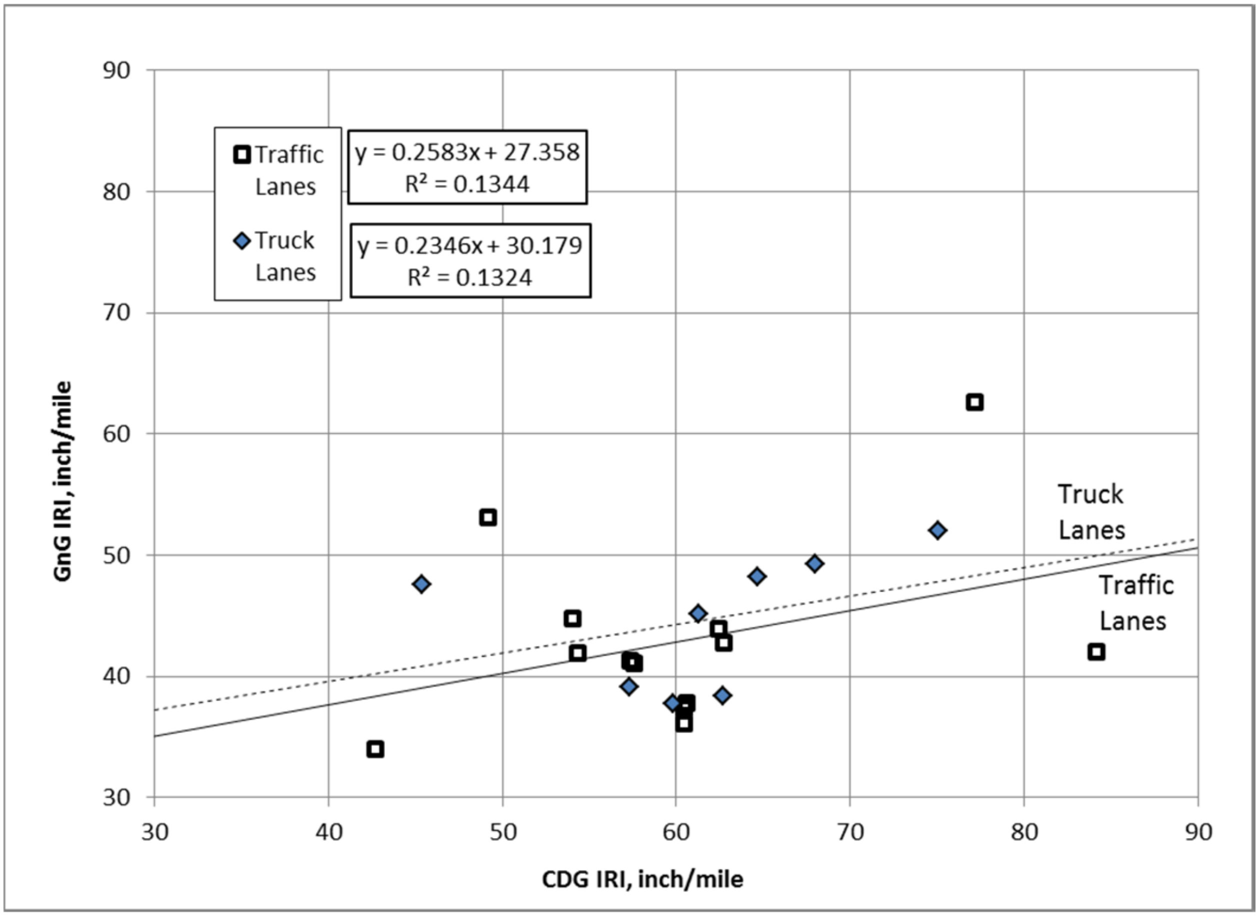


Figure K.5: Comparison of IRI from CDG and GnG treatments in traffic and truck lanes.

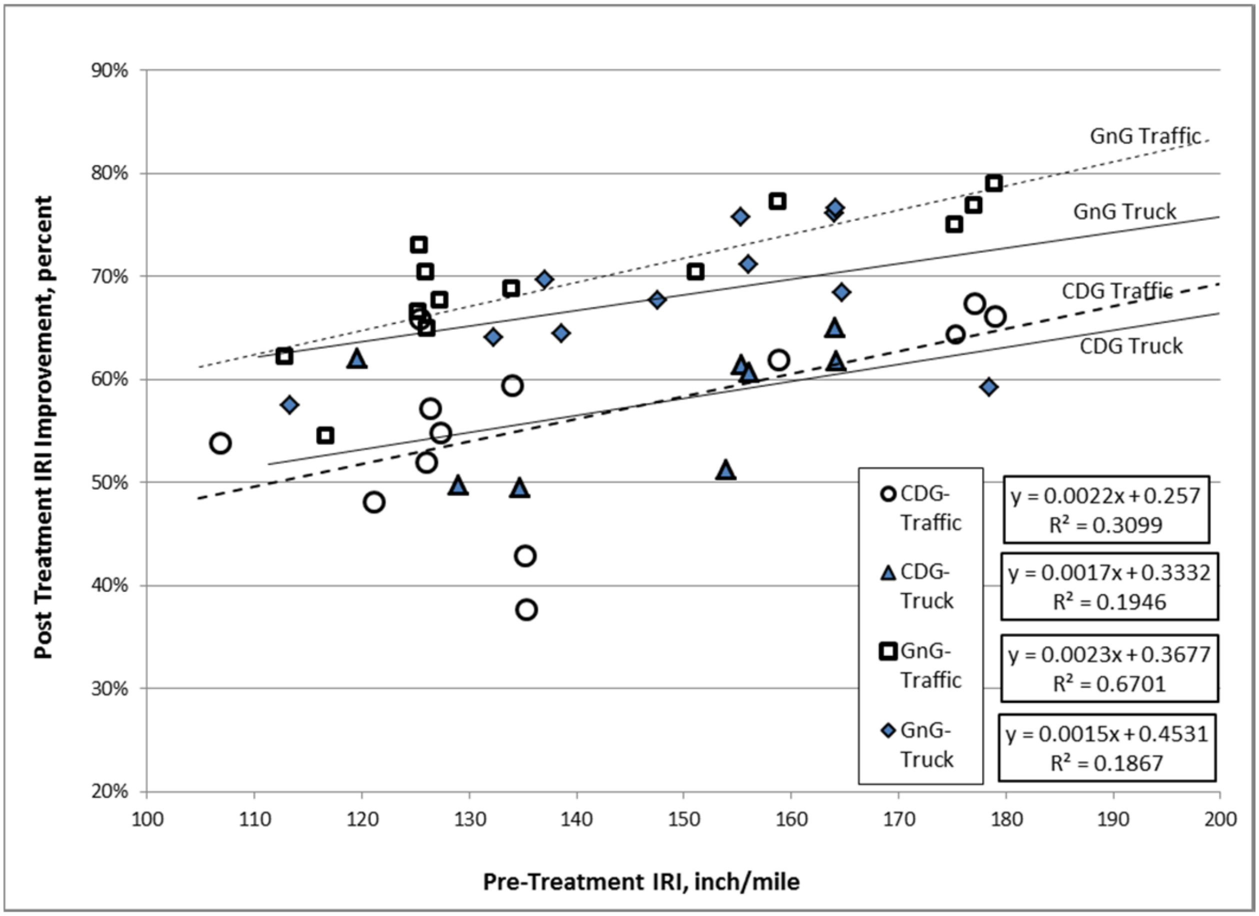


Figure K.6: IRI percent improvement from CDG and GnG treatments in traffic and truck lanes.

Table K.1: Regression Equations to Estimate Final Treatment OBSI from Pre-Treatment OBSI

Treatment, Location	Y axis	Equation	R-squared
CDG-Traffic Lanes	Final OBSI	y=0.471x+53.4	0.428
CDG-Truck Lanes		y=1.216x+24.4	0.825
GnG-Traffic Lanes		y=0.287x+70.5	0.245
GnG-Truck Lanes		y=0.577x+40.4	0.641
CDG-Traffic Lanes	Percent Improvement	y=0.0049x-0.494	0.470
CDG-Truck Lanes		y=-0.0022x+0.253	0.149
GnG-Traffic Lanes		y=0.0065x-0.639	0.646
GnG-Truck Lanes		y=0.0076x-0.762	0.480

Note: y is the treated value and x is the pre-treatment value.

Table K.2: Regression Equations to Estimate Final Treatment IRI from Pre-Treatment IRI

Treatment, Location	Y axis	Equation	R-squared
CDG-Traffic Lanes	Final IRI	y=0.079x+49.2	0.030
CDG-Truck Lanes		y=0.165x+37.6	0.106
GnG-Traffic Lanes		y=-0.047x+48.2	0.055
GnG-Truck Lanes		y=0.147x+25.2	0.077
CDG-Traffic Lanes	Percent Improvement	y=0.0022x+0.257	0.301
CDG-Truck Lanes		y=0.0017x+0.333	0.195
GnG-Traffic Lanes		y=0.0023x+0.368	0.670
GnG-Truck Lanes		y=0.0015x+0.453	0.187

Note: y is the treated value and x is the pre-treatment value.