**Title**

# Final Noise and Smoothness Monitoring on Concrete Pilot Projects of Grind and Groove and Continuously Reinforced Concrete Pavements



**Authors**
Guada, Irwin
Harvey, John
Mateos, Angel

**Publication Date**
2025-04-01

**DOI**
10.7922/G2M32T4D

**December 2023**
**Technical Memorandum: UCPRC-RR-2023-07**

# Final Noise and Smoothness Monitoring on Concrete Pilot Projects of Grind and Groove on Existing Pavement and Current Texture Types on Continuously Reinforced Concrete Pavements

**Authors:**
Irwin Guada, John Harvey, and Angel Mateos

Partnered Pavement Research Center (PPRC) Strategic Plan Element Number 3.42:
Quieter Pavement Long-Term Monitoring (DRISI Task 3193)

**PREPARED FOR:**
California Department of Transportation
Division of Research, Innovation, and System Information
Office of Materials and Infrastructure

**PREPARED BY:**
University of California
Pavement Research Center
UC Davis, UC Berkeley

# TECHNICAL REPORT DOCUMENTATION PAGE

| 1. REPORT NUMBER<br>UCPRC-RR-2023-07 | 2. GOVERNMENT ASSOCIATION NUMBER | 3. RECIPIENT'S CATALOG NUMBER |
|---|---|---|
| 4. TITLE AND SUBTITLE<br>Final Noise and Smoothness Monitoring on Concrete Pilot Projects of Grind and Groove and Continuously Reinforced Concrete Pavements | | 5. REPORT PUBLICATION DATE<br>December 2023<br>6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S)<br>Irwin Guada (ORCID: 0000-0002-5100-2589)<br>John Harvey (ORCID: 0000-0002-8924-6212)<br>Angel Mateos (ORCID: 0000-0002-3614-2858) | | 8. PERFORMING ORGANIZATION REPORT NO.<br>UCPRC-TM-2023-07<br>UCD-ITS-RR-23-78 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>University of California Pavement Research Center<br>Department of Civil and Environmental Engineering, UC Davis<br>1 Shields Avenue<br>Davis, CA 95616 | | 10. WORK UNIT NUMBER<br>11. CONTRACT OR GRANT NUMBER<br>65A0628 |
| 12. SPONSORING AGENCY AND ADDRESS<br>California Department of Transportation<br>Division of Research, Innovation, and System Information<br>P.O. Box 942873<br>Sacramento, CA 94273-0001 | | 13. TYPE OF REPORT AND PERIOD COVERED<br>Technical Memorandum,<br>August 2018 to July 2020<br>14. SPONSORING AGENCY CODE |
| 15. SUPPLEMENTAL NOTES<br>DOI: 10.7922/G2M32T4D | | |

16. ABSTRACT
The goal of this report is to conclude the project titled "Quieter Pavement Long-term Monitoring" by completing the measuring of noise and smoothness on previously built jointed plain concrete pavements (JPCP), surfaced with conventional diamond grinding (CDG) or the new grind and groove (GnG), and on continuously reinforced concrete pavement (CRCP). Previous studies have initiated the investigation into both the noise properties of GnG and CRCP. This project gathered data in 2018 and again in 2020 on the performance of these concrete pavements in terms of noise and smoothness. These data were added to the noise database to further the development of specifications, guidelines, and standardized field test methods toward quieter pavements. The GnG technology on test sections in Caltrans pilot projects was evaluated in terms of measured tire/pavement 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. This report presents the results of four rounds of testing, two rounds completed in 2018 and 2020 on sections first tested in 2012 and 2013 and again in 2016 and 2017. Recommendations include continued monitoring of GnG, considering use of GnG on CRCP, and continued use of diamond grinding. These recommendations are based on functional performance and do not consider cost-effectiveness compared with other potential strategies.

| 17. KEY WORDS<br>noise, On-Board Sound Intensity (OBSI), International Roughness Index (IRI), smoothness, grind and groove (GnG), conventional diamond grinding (CDG), continuously reinforced concrete pavement (CRCP) | | 18. DISTRIBUTION STATEMENT<br>No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161 |
|---|---|---|
| 19. SECURITY CLASSIFICATION (of this report)<br>Unclassified | 20. NUMBER OF PAGES<br>180 | 21. PRICE<br>None |

Reproduction of completed page authorized

# UCPRC ADDITIONAL INFORMATION

| | |
|---|---|
| 1. DRAFT STAGE<br>Final | 2. VERSION NUMBER<br>1 |
| 3. PARTNERED PAVEMENT RESEARCH CENTER STRATEGIC PLAN ELEMENT NUMBER<br>3.42 | 4. DRISI TASK NUMBER<br>3193 |
| 5. CALTRANS TECHNICAL LEAD AND REVIEWER(S)<br>Kuo-Wei Lee | 6. FHWA NUMBER<br>CA223193 |

7. PROPOSALS FOR IMPLEMENTATION

No final recommendations for implementation. This is a final report.

8. RELATED DOCUMENTS

- Ongel, A., Harvey, J.T., Kohler, E., Lu, Q., and Steven, B.D. 2008. *Investigation of Noise, Durability, Permeability, and Friction Performance Trends for Asphaltic Pavement Surface Types: First- and Second-Year Results* (Research Report: UCPRC-RR-2007-03). Davis and Berkeley, CA: University of California Pavement Research Center.
- Ongel, A., Harvey, J.T., Kohler, E., Lu, Q., Steven, B.D., and Monismith, C.L. 2008. *Summary Report: Investigation of Noise, Durability, Permeability, and Friction Performance Trends for Asphalt Pavement Surface Types: First- and Second-Year Results* (Summary Report: UCPRC-SR-2008-01). Davis and Berkeley, CA: University of California Pavement Research Center.
- Kohler, E. and Harvey, J. 2011. *Quieter Pavement Research: Concrete Pavement Tire Noise* (Research Report: UCPRC-RR-2010-03). Davis and Berkeley, CA: University of California Pavement Research Center.
- Kohler, E. 2011. *Quiet Pavement Research: Bridge Deck Tire Noise Report* (Research Report: UCPRC-RR-2010-04). Davis and Berkeley, CA: University of California Pavement Research Center.
- Rezaei, A. and Harvey, J. 2012. *Concrete Pavement Tire Noise: Third-Year Results* (Research Report: UCPRC-RR-2012-03). Davis and Berkeley, CA: University of California Pavement Research Center.
- Rezaei, A. and Harvey, J. 2013. *Investigation of Tire/Pavement Noise for Concrete Pavement Surfaces: Summary of Four Years of Measurements* (Research Report: UCPRC-RR-2013-12). Davis and Berkeley, CA: University of California Pavement Research Center.
- Guada, I.M., Rezaei, A., Harvey, J.T., and Spinner, D. 2014. *Evaluation of Grind-and-Groove (Next Generation Concrete Surface) Pilot Projects in California* (Research Report: UCPRC-RR-2013-01). Davis and Berkeley, CA: University of California Pavement Research Center.
- Rezaei, A. and Harvey, J. 2014. *Investigation of Noise, Ride Quality and Macrotexture Trends for Asphalt Pavement Surfaces: Summary of Six Years of Measurements* (Research Report: UCPRC-RR-2013-11). Davis and Berkeley, CA: University of California Pavement Research Center.
- Guada, I. and Harvey, J. 2022. *Continued Noise and Smoothness Monitoring on Concrete Pilot Projects of Grind and Groove on Existing Pavement and Current Texture Types on Continuously Reinforced Concrete Pavements* (Technical Memorandum: UCPRC-TM-2021-04). Davis and Berkeley, CA: University of California Pavement Research Center.

9. LABORATORY ACCREDITATION

The UCPRC laboratory is accredited by AASHTO re:source and CCRL for the laboratory testing discussed in this report.

10. SIGNATURES

| | | | | | |
|---|---|---|---|---|---|
| I. Guada<br>**FIRST AUTHOR** | J.T. Harvey<br>**TECHNICAL REVIEW** | C. Fink<br>**EDITOR** | J.T. Harvey<br>**PRINCIPAL INVESTIGATOR** | K. Lee<br>**CALTRANS TECH. LEADS** | T.J. Holland<br>**CALTRANS CONTRACT MANAGER** |

# DISCLAIMER



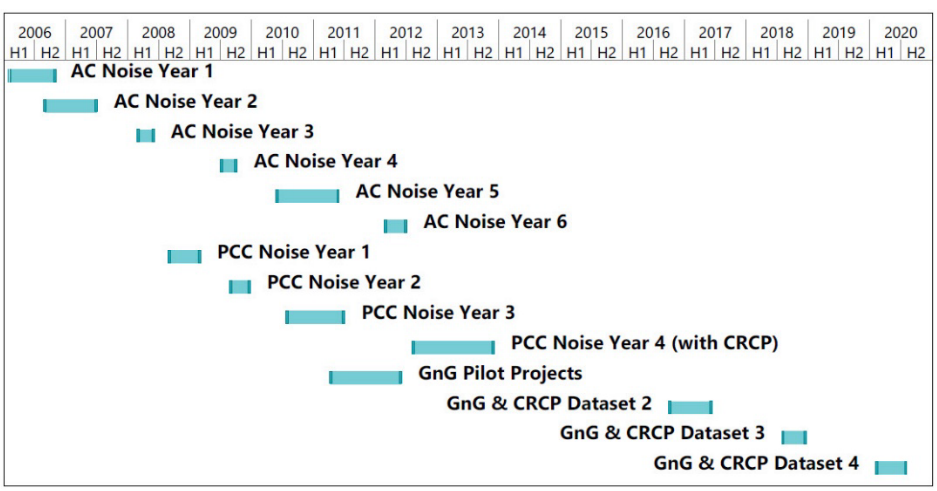
# ACKNOWLEDGMENTS

The authors would like to thank the technical lead, Linus Motumah (retired), and Reimond Garcia of the Caltrans Pavement Program, other members of the Caltrans Quieter Pavement Task Group, and T. Joe Holland (retired) of the Caltrans Division of Research, Innovation and System Information, for technical direction and advice. They would also like to thank Mark Hannum, who collected the noise and IRI data, and the UCPRC laboratory staff who assisted with the processing and management of the data.

# PROJECT OBJECTIVES

The goal of this project, Partnered Pavement Research Center Strategic Plan Element (PPRC SPE) 3.42, titled "Quieter Pavement Long-term Monitoring," is to complete measuring noise and smoothness of newer concrete pavement construction techniques. Previous studies have initiated the investigation into both the noise properties of continuously reinforced concrete pavements (CRCP) and the grind and groove (GnG) surfacing technology. This project aims to gather recent data on the performance of these concrete pavements in terms of noise and smoothness. The use of CRCP and GnG resurfacing technology is growing within the state, and this data will be added to the noise database to further the development of specifications, guidelines, and standardized field test methods toward quieter pavements. The goal of the study presented in this report, which is a part of PPRC SPE 3.42, is to evaluate the GnG technology used on test sections in Caltrans pilot projects in terms of noise, smoothness, and friction. The results of this study will 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 timeline below shows the Quieter Pavement noise studies conducted by the UCPRC, beginning in 2006 with research into asphalt pavements, and concluding with this report on GnG and CRCP pavements. This report presents the results of the third and fourth rounds of testing completed in 2018 and 2020, in addition to the results from the initial tests in 2012 and 2013 and the second round of testing in 2016 and 2017.




**Timeline of UCPRC Quieter Pavement research.**

# EXECUTIVE SUMMARY

The goal of this report is to conclude the project titled “Quieter Pavement Long-term Monitoring” by completing the measuring of noise and smoothness on previously built jointed plain concrete pavements (JPCP) surfaced with conventional diamond grinding (CDG) or the new grind and groove (GnG) treatment, and on continuously reinforced concrete pavements (CRCP) with longitudinal tined and CDG surfaces. Previous UCPRC projects have reported results from previous stages of this investigation into the noise properties of these pavement types. The results presented in this report are from the final project in the investigation that gathered data in 2018 and again in 2020 on the performance of these concrete pavements in terms of noise and smoothness. The results of this study are intended for use in decision-making regarding the incorporation of quieter pavement research into standard Caltrans practice and may serve as a basis for changes in quieter pavement policy and specifications.

The GnG technology, called the Next Generation Concrete Surface (NGCS) by the American Concrete Pavement Association, is a resurfacing technique intended to reduce tire/pavement noise. The GnG technology on Caltrans pilot projects was initially evaluated in terms of measured tire/pavement noise, smoothness, friction, and surface drainability. The CRCP sections, added to the concrete noise study as test sections became available in the state, were initially evaluated in terms of measured tire/pavement noise and smoothness.

The results presented in this research report show four rounds of tire/pavement noise data measured as the OBSI and smoothness data measured as the IRI on four concrete pavement types relatively new to California: (1) CRCP textured with longitudinal tining (LT), (2) CRCP textured with conventional diamond grinding (CDG), (3) JPCP textured with CDG, and (4) JPCP textured with the grind and groove (GnG) surface. Of the 52 test sections, six are CRCP, four with LT and two with CDG, and 46 are JPCP, 20 with CDG and 26 with GnG. The friction of these surfaces was not tested throughout this period. The results are from four rounds of testing, including two rounds completed in 2018 and 2020 on sections first tested in 2012 or 2013 and again in 2016 or 2017.

The GnG experiment was designed as a direct comparison between the GnG and CDG surface textures on JPCP. Seven pilot projects were included in the study to compare preconstruction noise and smoothness measurements with levels after CDG and after GnG. 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 test methods used to collect data on tire/pavement noise (on-board sound intensity [OBSI]) and smoothness (International Roughness Index [IRI]). Chapter 3 presents the project test results section by section. Chapter 4 presents an analysis of the noise and roughness data. Chapter 5 presents conclusions and recommendations. Appendices present details of the noise, smoothness, and traffic data.

**Conclusions**

The following are conclusions drawn from the results regarding tire-pavement noise in terms of OBSI and pavement smoothness in terms of IRI, from the four sets of data collected over eight years, from 2012 to 2020:

- OBSI levels on the concrete pavement test sections evaluated in this study originally (circa 2012) ranged from 100 to 112 dBA. The data from 2016 ranged from 101 to 112 dBA. In 2018, the range of OBSI was from 102 to 113 dBA, and the range of data in the final year of 2020 was from 102 to 114 dBA. This is consistent with the range of OBSI levels for concrete pavement textures measured in other similar studies.
- Among the four pavement types and textures, the CRCP with LT sections, on average, were the loudest, initially at 106 dBA and concluding at 107 dBA. The CRCP with CDG sections, on average (with two sections), were the next loudest, starting at 104 dBA and ending at 106 dBA. Overall, the annual change rate for the CRCP sections was 0.4 dBA/yr. However, excluding the Placer 80 section, which is affected by truck chain wear, the CRCP annual change rate is 0.2 dBA/year. The average OBSI change rate versus truck traffic is 0.5 dBA/mEAL versus 0.2 dBA/mEAL, respectively, when excluding Placer 80.
- The OBSI values for the JPCP sections with CDG initially ranged from 101 to 104 dBA, with an average of 103 dBA, and finally ranged from 102 to 107 dBA, with an average of 105 dBA. The

annual OBSI change rate for the CDG sections averaged 0.3 dBA/year. These values are within the range of values found in previous studies and are consistent with new and slightly aged diamond ground textures. The change rate versus truck traffic was 0.6 dBA/mEAL.

- The OBSI values for the JPCP sections with GnG initially ranged from 100 to 103 dBA, with an average of 101 dBA, and finally ranged from 102 to 107 dBA, with an average of 104 dBA. On average, the GnG sections were the quietest pavements in this study; however, GnG sections also had the highest OBSI change rate, at 0.4 dBA/year.
- The effect of truck traffic versus passenger car traffic on the OBSI change rate is indicated by the JPCP data, excluding the CRCP data. For the CDG sections, trucks increase the OBSI annual change rate from 0.2 to 0.3 dBA/year and the traffic-related change rate from 0.4 to 0.7 dBA/mEAL, when compared to passenger lanes. For the GnG sections, trucks increase the OBSI annual change rate from 0.4 to 0.5 dBA/year, and the traffic-related change rate from 0.7 to 0.8 dBA/mEAL.
- The JPCP sections included in this study were all on existing pavements with years of previous traffic that were resurfaced soon before the start of this study. The CRCP sections are on new pavements or pavements that had only a few years of traffic before the study was begun, and the last retexturing was their initial construction.
- IRI levels on the concrete pavements evaluated in this study originally ranged from 34 to 90 in./mi. The data from four years later ranged from 35 to 98 in./mi., with only one section, a JPCP section with CDG, that deteriorated from the “good” to the “acceptable” range of IRI values (95 to 170 in./mi.). The data from 2018 ranged from 42 to 104 in./mi., with a second JPCP with CDG section deteriorating to the acceptable range of IRI values. By 2020, the data ranged from 44 to 129 in./mi., and five of the sections had IRI values above 95 in./mi.
- Combining both LT and CDG surfaces, the six CRCP sections, on average, were initially the roughest, at 67 in./mi., and through 2020, showed a negligible increase in IRI to 68 in./mi. The annual IRI change rate for the period 2012 to 2020 was 0.2 in./mi./year. The traffic-related IRI change rate was 1.9 in./mi./mEAL.
- The IRI values for the JPCP with CDG sections initially ranged from 47 to 82 in./mi., with an average of 63 in./mi. There were continual increases throughout the study period, to 66 in./mi.

by 2016, 70 in./mi. by 2018, and 74 in./mi. with a range from 52 to 127 in./mi. by 2020. The annual IRI change rate for the JPCP with CDG sections averaged 1.5 in./mi./year, and the traffic-related IRI change rate was 2.1 in./mi./mEAL.

- On average, the GnG sections were the smoothest sections in this study. Initial IRI values for the JPCP with GnG sections ranged from 34 to 73 in./mi. and averaged 46 in./mi. These sections exhibited the highest change rates among the four types of sections with an annual IRI change rate of 2.5 in./mi./year and a traffic-related IRI change rate of 3.6 in./mi./mEAL. The final IRI values for the JPCP with GnG sections ranged from 44 to 129 in./mi. and averaged 65 in./mi.
- The effect of truck traffic versus passenger car traffic on the IRI change rate was indicated by the JPCP data. For JPCP with CDG sections, truck lanes showed an increase in the annual IRI change rate from 1.2 to 1.7 in./mi./year, but the traffic-related change rate decreased for truck lanes from 2.2 in./mi./mEAL to 1.9 in./mi./mEAL. For the JPCP with GnG sections, truck lanes exhibited a doubling of the IRI change rate from 1.7 to 3.4 in./mi./year, and more than doubling of the traffic-related change rate from 2.1 to 5.5 in./mi./mEAL.

**Recommendations**

Regarding development and implementation of quieter concrete pavement strategies in California, the results to date in this study lead to the following recommendations:

- Test the friction of aged GnG surfaces that still exist from this study.
- Continue the use of CDG.
- Continue the use and study of GnG, looking into performance beyond eight years. The GnG texture produced the best initial smoothness values.
- Continue the use and study of the GnG surface texture on CRCP pavement sections.

These recommendations are based on functional performance and do not consider cost-effectiveness compared with other potential strategies.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AADT | Average annual daily traffic |
| APCS | Automated Pavement Condition Survey |
| CDG | Conventional diamond grinding |
| CRCP | Continuously reinforced concrete pavement |
| EAL | Equivalent axle load |
| EB | Eastbound |
| GnG | Grind and groove |
| IRI | International Roughness Index |
| JPCP | Joint plain concrete pavement |
| LT | Longitudinal tining |
| mEAL | Million equivalent axle load |
| NB | Northbound |
| OBSI | On-Board Sound Intensity |
| PCC | Portland cement concrete |
| PM | Postmile |
| SB | Southbound |
| SRTT | Standard reference test tires |
| Std. Dev. | Standard deviation |
| WB | Westbound |

# SPECIFICATIONS USED IN THE REPORT

| | |
|---|---|
| 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 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 E1926 | Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements. American Society for Testing and Materials, 2010. |

| SI* (MODERN METRIC) CONVERSION FACTORS | | | | |
|---|---|---|---|---|
| **APPROXIMATE CONVERSIONS TO SI UNITS** | | | | |
| **Symbol** | **When You Know** | **Multiply By** | **To Find** | **Symbol** |
| **LENGTH** | | | | |
| in. | inches | 25.40 | millimeters | mm |
| ft. | feet | 0.3048 | meters | m |
| yd. | yards | 0.9144 | meters | m |
| mi. | miles | 1.609 | kilometers | km |
| **AREA** | | | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.09290 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8361 | square meters | $m^2$ |
| ac. | acres | 0.4047 | hectares | ha |
| $mi^2$ | square miles | 2.590 | square kilometers | $km^2$ |
| **VOLUME** | | | | |
| fl. oz. | fluid ounces | 29.57 | milliliters | mL |
| gal. | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.02832 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.7646 | cubic meters | $m^3$ |
| **MASS** | | | | |
| oz. | ounces | 28.35 | grams | g |
| lb. | pounds | 0.4536 | kilograms | kg |
| T | short tons (2000 pounds) | 0.9072 | metric tons | t |
| **TEMPERATURE (exact degrees)** | | | | |
| °F | Fahrenheit | (F-32)/1.8 | Celsius | °C |
| **FORCE and PRESSURE or STRESS** | | | | |
| lbf | pound-force | 4.448 | newtons | N |
| $lbf/in^2$ | pound-force per square inch | 6.895 | kilopascals | kPa |
| **APPROXIMATE CONVERSIONS FROM SI UNITS** | | | | |
| **Symbol** | **When You Know** | **Multiply By** | **To Find** | **Symbol** |
| **LENGTH** | | | | |
| mm | millimeters | 0.03937 | inches | in. |
| m | meters | 3.281 | feet | ft. |
| m | meters | 1.094 | yards | yd. |
| km | kilometers | 0.6214 | miles | mi. |
| **AREA** | | | | |
| $mm^2$ | square millimeters | 0.001550 | square inches | $in^2$ |
| $m^2$ | square meters | 10.76 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.196 | square yards | $yd^2$ |
| ha | hectares | 2.471 | acres | ac. |
| $km^2$ | square kilometers | 0.3861 | square miles | $mi^2$ |
| **VOLUME** | | | | |
| mL | milliliters | 0.03381 | fluid ounces | fl. oz. |
| L | liters | 0.2642 | gallons | gal. |
| $m^3$ | cubic meters | 35.31 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.308 | cubic yards | $yd^3$ |
| **MASS** | | | | |
| g | grams | 0.03527 | ounces | oz. |
| kg | kilograms | 2.205 | pounds | lb. |
| t | metric tons | 1.102 | short tons (2000 pounds) | T |
| **TEMPERATURE (exact degrees)** | | | | |
| °C | Celsius | 1.8C + 32 | Fahrenheit | °F |
| **FORCE and PRESSURE or STRESS** | | | | |
| N | newtons | 0.2248 | pound-force | lbf |
| kPa | kilopascals | 0.1450 | pound-force per square inch | $lbf/in^2$ |

*SI is the abbreviation for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised April 2021)

# 1 INTRODUCTION

## 1.1 Overview

In the early 2000s, the California Department of Transportation (Caltrans) identified a need for research on the noise-related performance properties of pavement surface textures used on the state highway network. In 2006 and 2008, research projects were initiated to evaluate the tire/pavement noise characteristics of existing asphalt and the performance properties of concrete pavements *(1,2,3)*. In the fourth and final year of data collection on jointed plain concrete pavement (JPCP) surface textures, a few continuously reinforced concrete pavements (CRCPs) were introduced to the dataset. CRCP is a type of concrete pavement that Caltrans has used with increasing frequency since the late 2000s.

In the early 2010s, Caltrans also began investigating a new concrete surfacing technique developed by the American Concrete Pavement Association, along with Purdue University, called the Next Generation Concrete Surface (NGCS) *(4)*. Caltrans refers to the version of this concrete surface texture used in California as grind and groove (GnG). Seven pilot projects were constructed to study the surface characteristics of the GnG surface, often in comparison to conventional diamond grinding (CDG) *(5)*.

A previous memorandum reports the second set of data collected on these sections in 2016, presented with the initial readings from approximately four years prior *(6)*. This document presents the results after approximately eight years of service, providing a midterm quantification of the long-term effects of traffic and age on noise and smoothness characteristics resulting from the use of continually reinforced pavements and from the use of the GnG texturing technique. The GnG technique is compared with the more typically used CDG technique for retexturing the surfaces of existing concrete pavements.

## 1.2 Problem Statement

Over the past few decades, awareness of the impacts of highway traffic noise has grown with increases in the number of vehicles and the populations either living close to highway corridors or conducting 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 the effect of pavement surface friction on safety and ride quality, but also because pavement surface characteristics contribute to noise generation through interaction with the vehicle's tires.

Vehicles contribute to highway noise from three sources: (1) mechanical, (2) exhaust, and (3) tire/pavement interaction. Tire/pavement interaction is the dominant source of noise at speeds above 30 mph for cars and 50 mph for trucks (*7)*. In addition to sound barriers, highway agencies have focused on tire/pavement noise because they can manage it through the selection and maintenance of pavement surfaces.

## 1.3 Structure of This Report

This report is organized as follows:

- Chapter 2 describes the test methods and test sections used in the study.
- Chapter 3 summarizes the test results collected on the evaluation sections.
- Chapter 4 presents an analysis of the test results.
- Chapter 5 presents conclusions and recommendations of this study.
- Appendix A, Appendix B, Appendix C, and Appendix D present the details of data collected in the study.

# 2 TEST SECTIONS AND TEST METHODS

## 2.1 Test Sections

This report provides an update on pavement sections previously measured in separate studies. CRCP pavements, surfaced with either longitudinal tining (LT) or CDG, were added to the last year of data collection of the portland cement concrete (PCC) noise study *(3)*. A separate report evaluated the GnG surfaces of several pilot projects of JPCP, often directly comparing the GnG sections with adjacent CDG pavements *(5)*. A recent technical memorandum presented the performance results after four years *(6)*.

### *2.1.1 Continuously Reinforced Concrete Pavement (CRCP) Sections*

For the fourth year of the concrete noise study in 2012, Caltrans added six CRCP projects to the list of sites, listed in Table 2.1. Only five of the sections were constructed before this evaluation in 2012, as the San Joaquin-5 project was accepted in March 2017. For each CRCP project, like the other noise study locations, a single 0.1-mile section was selected.

**Table 2.1: List of Continuously Reinforced Concrete Pavement Sections**

| Noise Section ID | Section County | Section Route | Section Direction | Section Lane | Section Start Postmile |
|---|---|---|---|---|---|
| ES 176 (QP 203) | Placer | 80 | East | Lane 1 | PM 56.45 |
| ES 177 | Siskiyou | 5 | North | Lane 2 | PM 57.0 |
| ES 178 | Kern | 5 | South | Lane 2 | PM 40.0 |
| ES 179 | San Joaquin | 5 | North | Lane 1 | PM 32.0 |
| ES 180 | Imperial | 78 | East | Lane 2 | PM R15.0 |
| ES 181 | Imperial | 86 | South | Lane 2 | PM R24.2 |

### *2.1.2 California Grind and Groove (GnG) Pilot Projects*

In 2010 and 2011, Caltrans selected seven concrete pavement preservation projects scheduled for CDG to pilot the GnG technology. Within each project’s limits, a one- to two-mile section was selected for the GnG construction, leaving CDG sections adjacent to GnG to be used for comparison of acoustical performance. The seven projects are listed in Table 2.2, along with the post-miles of the CDG and GnG evaluation test sections, which are approximately 0.4 to 2 miles long.

**Table 2.2: List of Grind and Groove (GnG) Pilot Projects**

| Project EA[a] | Project County | Project Route | Project Postmile Limits | CDG Evaluation Postmile Limits | GnG Evaluation Postmile Limits |
|---|---|---|---|---|---|
| 1F450[b] | Sacramento | 5 | PM 17.2/ PM 22.8 | PM 20.0 – 21.5 Southbound Lanes 1 and 4 | PM 20.0 – 21.5 Northbound Lanes 1 and 4 |
| 0F590[b] | Sacramento | 5 | PM 0.0/ PM 3.5 | PM 1.5 – 3.0 Southbound 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 | PM 13.0 – 14.0 Eastbound and Westbound Lanes 2 and 5 |
| 0A800[b] | Sacramento | 50 | PM R12.2/ PM R14.2 | PM R13.0 – R14.0 Eastbound Lanes 2 and 4 | PM R13.0 – R14.0 Westbound Lanes 2 and 4 |
| 0V870 | San Joaquin | 99 | PM 29.0/ PM 30.8 NB | n/a | PM 29.0 – 30.7 Northbound Lanes 1 and 2 |
| 2F050 | Yolo | 113 | PM R0.0/ PM R11.1 | PM R1.5 – R2.5 Northbound and PM R0.9 – R2.5 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 R35.8 – R36.3 PM R37.4 – R37.9 Northbound and Southbound Lanes 1 through 5 | PM R36.35 – R37.35 Northbound and Southbound Lanes 1 through 5 |

[a] EA: Expenditure Authorization serves as the Caltrans project identification number.
[b] Project had additional segments outside the reported project limits.

The initial evaluation involved measurements of noise and longitudinal profiles in the right wheelpaths before and after CDG and GnG construction. In this final study, the post-construction data collected between 2012 and 2013 (Round 1) were evaluated along with data collected in 2016 and 2017 (Round 2), 2018 (Round 3), and 2020 (Round 4).

### *2.1.3 List of Evaluation Test Sections*

Each CRCP location is a single section, and each GnG project has several sub-sections. The list of test sections is shown in Table 2.3. The location is shown along with the:

- Section length in miles.

- Pavement type, either CRCP or JPCP. The JPCP sections included in this study were all on existing pavements with years of previous traffic that were resurfaced soon before the start of this study. The CRCP sections are on new pavements or pavements that had only a few years of traffic before the study began, and the last retexturing was their initial construction.
- Surface texture of either longitudinal tining (LT), conventional diamond grinding (CDG), or grind and groove (GnG).
- Lane type, either passenger (P) or truck (T); truck lanes include:
    - Highways with one lane in each direction.
    - Right-most lane of highways with two or three lanes in one direction.
    - Two right-most lanes of roads with four or more lanes in one direction.
- Climate region.
- Date of the last retexturing.

**Table 2.3: List of Test Sections Evaluated**

| Test Section Location | Length (mi.) | Pavement Type[a] | Surface Texture[b] | Lane Type[c] | Climate Region | Last Retexturing |
|---|---|---|---|---|---|---|
| Pla80E1PM56.45 | 0.1 | CRCP | LT | P | High Mountain | 4/1/2012 |
| Sis5N2PM57.0 | 0.1 | CRCP | CDG | T | High Desert | 9/26/2007 |
| Ker5S2PM40.0 | 0.1 | CRCP | LT | T | Inland Valley | 8/23/2010 |
| SJ5N1PM32.0 | 0.1 | CRCP | CDG | P | Inland Valley | 1/26/2017 |
| Imp78E2PMR15.0 | 0.1 | CRCP | LT | T | Desert | 1/1/2012 |
| Imp86S2PMR24.2 | 0.1 | CRCP | LT | T | Desert | 1/2/2012 |
| Sac5N1PM20.0 | 1.5 | JPCP | GnG | P | Inland Valley | 7/1/2011 |
| Sac5N4PM20.0 | 1.5 | JPCP | GnG | T | Inland Valley | 7/1/2011 |
| Sac5S1PM21.5 | 1.5 | JPCP | CDG | P | Inland Valley | 7/1/2011 |
| Sac5S4PM21.5 | 1.5 | JPCP | CDG | T | Inland Valley | 7/1/2011 |
| Sac5N1PM1.5 | 1.5 | JPCP | GnG | P | Inland Valley | 12/1/2011 |
| Sac5N2PM1.5 | 1.5 | JPCP | GnG | T | Inland Valley | 12/1/2011 |
| Sac5S1PM3.0 | 1.5 | JPCP | CDG | P | Inland Valley | 12/1/2011 |
| Sac5S2PM3.0 | 1.5 | JPCP | CDG | T | Inland Valley | 12/1/2011 |
| Sac80E2PM13.0 | 1.0 | JPCP | GnG | P | Inland Valley | 5/1/2012 |
| Sac80E5PM13.0 | 1.0 | JPCP | GnG | T | Inland Valley | 5/1/2012 |
| Sac80W2PM14.0 | 1.0 | JPCP | GnG | P | Inland Valley | 5/1/2012 |
| Sac80W5PM14.0 | 1.0 | JPCP | GnG | T | Inland Valley | 5/1/2012 |
| Sac50E2PM13.0 | 1.0 | JPCP | CDG | P | Inland Valley | 6/1/2012 |
| Sac50E4PM13.0 | 1.0 | JPCP | CDG | T | Inland Valley | 6/1/2012 |
| Sac50W2PM14.0 | 1.0 | JPCP | GnG | P | Inland Valley | 6/1/2012 |
| Sac50W4PM14.0 | 1.0 | JPCP | GnG | T | Inland Valley | 6/1/2012 |
| SJ99N1PM29.0 | 1.7 | JPCP | GnG | P | Inland Valley | 7/1/2012 |
| SJ99N2PM29.0 | 1.7 | JPCP | GnG | T | Inland Valley | 7/1/2012 |

| Test Section Location | Length (mi.) | Pavement Type[a] | Surface Texture[b] | Lane Type[c] | Climate Region | Last Retexturing |
|---|---|---|---|---|---|---|
| Yol113N1PM0.5 | 1.0 | JPCP | GnG | P | Inland Valley | 4/1/2012 |
| Yol113N2PM0.5 | 1.0 | JPCP | GnG | T | Inland Valley | 4/1/2012 |
| Yol113S1PM0.9 | 0.5 | JPCP | GnG | P | Inland Valley | 4/1/2012 |
| Yol113S2PM0.9 | 0.5 | JPCP | GnG | T | Inland Valley | 4/1/2012 |
| Yol113N1PM1.5 | 1.0 | JPCP | CDG | P | Inland Valley | 4/1/2012 |
| Yol113N2PM1.5 | 1.0 | JPCP | CDG | T | Inland Valley | 4/1/2012 |
| Yol113S1PM2.5 | 1.5 | JPCP | CDG | P | Inland Valley | 4/1/2012 |
| Yol113S2PM2.5 | 1.5 | JPCP | CDG | T | Inland Valley | 4/1/2012 |
| SD5N1PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 |
| SD5N2PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 |
| SD5N3PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 |
| SD5N4PM36.4 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 |
| SD5N5PM36.4 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 |
| SD5S1PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 |
| SD5S2PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 |
| SD5S3PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 |
| SD5S4PM37.3 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 |
| SD5S5PM37.3 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 |
| SD5N1PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 |
| SD5N2PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 |
| SD5N3PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 |
| SD5N4PM35.8/37.4 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 |
| SD5N5PM35.8/37.4 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 |
| SD5S1PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 |
| SD5S2PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 |
| SD5S3PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 |
| SD5S4PM37.9/36.3 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 |
| SD5S5PM37.9/36.3 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 |

[a] CRCP is continuously reinforced concrete pavement, and JPCP is jointed plain concrete pavement.
[b] LT is longitudinally tined, CDG is conventional diamond grinding, and GnG is grind and groove.
[c] P is passenger lane, T is truck lane.

In summary, there are 46 JPCP sections, consisting of 20 JPCP sections with the CDG surface and 26 JPCP sections with the GnG surface, and there are six CRCP sections, consisting of two CRCP sections with the CDG surface and four CRCP sections with the LT surface. One of the two CRCP sections with the CDG surface, San Joaquin 5, was last retextured in 2017 and was inaccessible in 2020. Therefore, data exist only from round two (2016) and round three (2018), and some averages for CRCP with CDG are the result of only one test section.

## 2.2 Test Methods

Evaluation of these test sections was conducted with a single vehicle outfitted with equipment to measure both tire/pavement noise and pavement smoothness. The UCPRC test vehicle had microphones set up to measure noise at the passenger-side rear tire and smoothness in the right wheelpath (Figure 2.1).

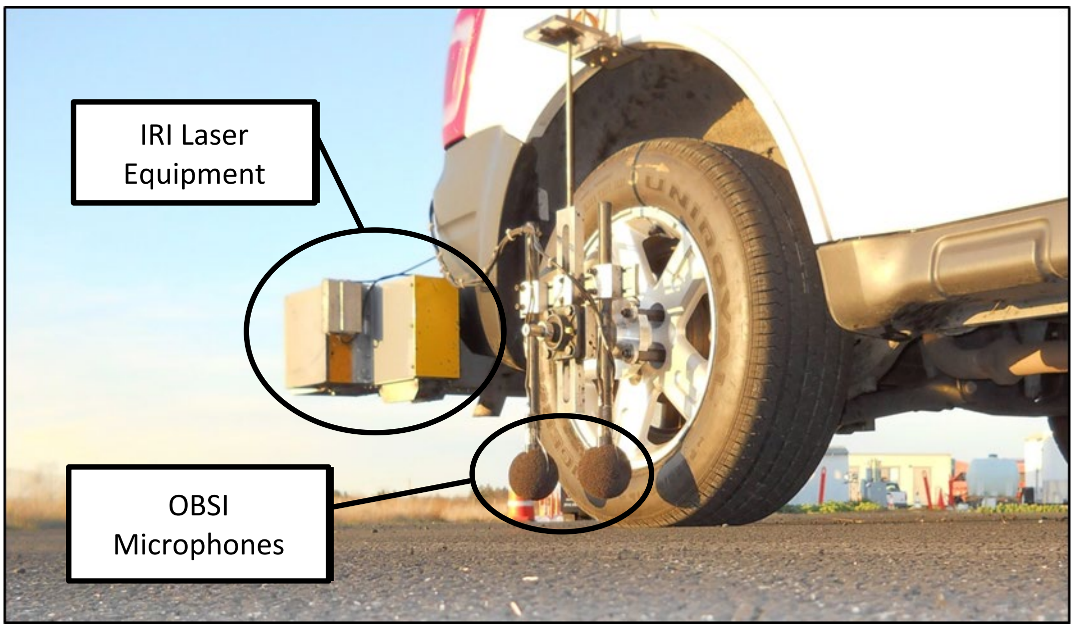



**Figure 2.1: The UCPRC OBSI and IRI test vehicle with mounted microphones and laser equipment.**

### *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." During data collection in 2016, AASHTO replaced the provisional AASHTO TP 76 with AASHTO T360. The UCPRC OBSI and International Roughness Index (IRI) test vehicle carried equipment for collecting OBSI data in accordance with AASHTO T360 and profile data in accordance with ASTM E950 (described in the following discussion). For OBSI measurement, the test vehicle usually operated at 60 mph and needed to maintain this speed (±1 mph) during the sampling period. Data were typically analyzed in 0.1-mile long pavement sections following standard OBSI procedures. The GnG test sections were 1 to 2 miles long.

The OBSI method measured 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 were obtained at the leading and trailing edges of the tire/pavement contact patch. Three replicate passes were 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) were used to obtain noise spectra, which were then used to calculate an overall sound intensity level—a single value that summarizes the overall tire/pavement noise. The sound intensity levels at the leading and trailing edges were averaged through the energy method *(8)*. The sound intensity was reported in dBA, with the A rating assigning greater weights to the frequencies that are perceived more by human hearing *(7)*.

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

The standard reference test tires (SRTT) used for noise measurements were maintained in a refrigerator to minimize aging. They were monitored for hardness before, during, and after each testing campaign. Before starting each campaign, the tires were calibrated to the first tire used in the study on a set of test calibration sections around Davis, California, and correction factors were developed to transform test results back to the test result for the first tire used in the study. The calibration procedures are described in previous research studies *(2,9)*.

In addition to the pavement texture, the OBSI levels presented in this report include the effects of joint slap, faulting, and sealant overbanding. CDG processes remove faulting and existing sealant overbanding from the surface, which removes their effects from CDG and GnG OBSI measurements; however, over time, these effects can recur. If present, joint slap, faulting, and sealant overbanding would increase the OBSI level above the level 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. The size of the joint will fluctuate throughout the day as daily temperature changes impact the slab. 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 *(10)*.

### *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 carried equipment for measuring inertial profiler equipment while OBSI was 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 (Roine) laser measuring at 3 kHz, both of which were attached to the rear of the test vehicle (Figure 2.1). All IRI data in this report are from the wide-spot laser.

# 3 TEST RESULTS

In this chapter, traffic and OBSI and IRI test results are presented for each section. The traffic counts are shown for the even years between 2012 and 2020, followed by the test results from OBSI and IRI data collected in 2012 (or 2013), 2016 (or 2017), 2018, and 2020. Following the traffic data is a table with the environmental conditions measured during sampling. As described in the previous discussion, the OBSI and IRI data are the average and standard deviation of three replicate passes. Noted in the tables within this chapter, some IRI values collected by the UCPRC fell outside the bounds of reasonableness and were replaced with data from the Caltrans Automated Pavement Condition Survey (APCS). The reason for the unreasonable values could not be determined but is potentially due to a periodic malfunction of the distance measuring device. The malfunction was random in occurrence during the final testing campaign. Appendix A presents figures of the OBSI over the length of each test section and displays figures of the IRI over the length of selected test sections.

Caltrans traffic data were selected from the closest intersection or interchange to the test section or on either side of the test section according to the postmile *(11)*. In the traffic count tables, the traffic leg indicates whether the counts are in the direction of increasing postmile numbers, A, or decreasing postmile numbers, B. Specific legs were selected based on the test section direction for the CRCP sections, and both directions are shown for the JPCP comparison sections when available. Also shown are the vehicle and truck counts, the truck percentage, and the two-way equivalent axle loads.

Because the traffic data and environmental conditions during sampling are the same for many JPCP test sections that are adjacent to each other, the section results are grouped. The CRCP sections show one set of traffic and environmental data for one test section. The JPCP sections are then shown, grouped by GnG pilot project, with one set of traffic and environmental data for several test sections where the traffic and sampling conditions are the same.

## 3.1 Continuously Reinforced Concrete Pavement (CRCP) Sections

### *3.1.1 Placer 80 EB Lane 1 – PM 56.45 – CRCP with Longitudinally Tined Surface*

The Pla80E1PM56.45 test section was mistakenly labeled as Nev80 E1PM56.45 in previous reports due to its meandering along the border between Placer County and Nevada County.

Table 3.1 presents the traffic and truck counts for the Placer 80 section for the even years between 2012 and 2020. The traffic counts are from the intersection with Route 174, at PM 33.131 in Colfax, and the intersection with Route 20, at PM R59.54, both in the eastbound direction. Like some other CRCP sections over this time period, the vehicle and truck counts increased by about 20% (19% and 24% for these separate locations) between 2012 and 2018 and then dropped in 2020. For PM 33.131, the drop in equivalent axle loads was negligible between 2018 and 2020, and for PM R59.54, the decline was 10%.

**Table 3.1: Traffic and Truck Counts on Placer 80 – PM 33.131 and PM R59.54**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 33.131 | A | 2012 | 25,000 | 4,738 | 19.0 | 1,169,000 |
| PM 33.131 | A | 2014 | 26,500 | 5,023 | 19.0 | 1,239,000 |
| PM 33.131 | A | 2016 | 29,800 | 5,647 | 19.0 | 1,393,000 |
| PM 33.131 | A | 2018 | 29,800 | 5,647 | 19.0 | 1,393,000 |
| PM 33.131 | A | 2020 | 29,500 | 5,590 | 19.0 | 1,379,000 |
| PM R59.54 | A | 2012 | 25,500 | 4,802 | 18.8 | 1,210,000 |
| PM R59.54 | A | 2014 | 27,000 | 5,085 | 18.8 | 1,281,000 |
| PM R59.54 | A | 2016 | 31,700 | 5,969 | 18.8 | 1,504,000 |
| PM R59.54 | A | 2018 | 31,700 | 5,969 | 18.8 | 1,504,000 |
| PM R59.54 | A | 2020 | 28,500 | 5,367 | 18.8 | 1,352,000 |

Table 3.2 summarizes the test results for this section, and Table 3.3 provides the environmental conditions during sampling. The pavement temperature for 2013 was not collected.

**Table 3.2: Summary of Test Results for Placer 80 EB Lane 1 – PM 56.45**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 11/14/2013 | 106.7 | 0.4 | 74.3 | 1.0 |
| 10/21/2016 | 109.1 | 0.6 | 80.8 | 1.4 |
| 10/24/2018 | 113.3 | 0.5 | 80.7 | 2.3 |
| 3/5/2020 | 113.5 | 0.5 | 84.3 (162.3)[a] | 9.3 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

**Table 3.3: Environmental Conditions While Sampling Placer 80 EB Lane 1 – PM 56.45**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 11/14/2013 | 15:12 | 59 | — | 34 | 30.06 |
| 10/21/2016 | 15:24 | 65 | 76 | 32 | 29.89 |
| 10/24/2018 | 11:54 | 61 | 71 | 27 | 30.04 |
| 3/5/2020 | 12:38 | 57 | 74 | 32 | 30.08 |

### *3.1.2 Siskiyou 5 NB Lane 2 – PM R57.0 – CRCP with Conventional Diamond Grind Surface*

Table 3.4 presents the traffic and truck counts for Siskiyou 5 for the even years between 2012 and 2020. The traffic counts are from the intersection with Route 3, at PM 48.239 in Yreka, and the intersection with Route 96 West, at PM R58.326. Like other CRCP sections between 2012 and 2016, the truck counts increased by approximately 20% (29% and 12% for the separate legs). Over 2018 and 2020, the location closer to the test section, PM R58.326, experienced count reductions of about 50%, while the other location had only a 5% reduction.

**Table 3.4: Traffic and Truck Counts on Siskiyou 5 – PM 48.239 and PM R58.326**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 48.239 | A | 2012 | 15,200 | 3,944 | 26.0 | 1,193,000 |
| PM 48.239 | A | 2014 | 13,400 | 4,035 | 30.1 | 1,291,000 |
| PM 48.239 | A | 2016 | 15,600 | 5,078 | 32.6 | 1,624,000 |
| PM 48.239 | A | 2018 | 15,800 | 5,143 | 32.6 | 1,655,000 |
| PM 48.239 | A | 2020 | 14,600 | 5,154 | 35.3 | 1,536,000 |
| PM R58.326 | A | 2012 | 15,800 | 4,196 | 26.6 | 1,269,000 |
| PM R58.326 | A | 2014 | 13,900 | 4,003 | 28.8 | 1,283,000 |
| PM R58.326 | A | 2016 | 16,800 | 4,692 | 27.9 | 1,485,000 |
| PM R58.326 | A | 2018 | 7,600 | 2,123 | 27.9 | 671,500 |
| PM R58.326 | A | 2020 | 7,000 | 2,452 | 35.0 | 732,000 |

Table 3.5 summarizes the test results for this section, and Table 3.6 provides the environmental conditions during sampling. The 2013 pavement temperature was not collected.

**Table 3.5: Summary of Test Results for Siskiyou 5 NB Lane 2 – PM R57.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 3/28/2013 | 104.3 | 0.4 | 64.8 | 2.5 |
| 10/20/2016 | 105.0 | 0.1 | 49.5 | 2.7 |
| 10/25/2018 | 108.0 | 0.8 | 54.3 | 6.2 |
| 3/4/2020 | 106.5 | 0.5 | 62.8 (110.8)[a] | 6.3 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

**Table 3.6: Environmental Conditions While Sampling Siskiyou 5 NB Lane 2 – PM R57.0**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 3/28/2013 | 9:41 | 48 | — | 91 | 30.02 |
| 10/20/2016 | 14:45 | 68 | 78 | 57 | 30.25 |
| 10/25/2018 | 12:56 | 63 | 74 | 49 | 30.26 |
| 3/4/2020 | 15:48 | 68 | 75 | 22 | 30.07 |

### *3.1.3 Kern 5 SB Lane 2 – PM 40.0 – CRCP with Longitudinally Tined Surface*

Table 3.7 presents the traffic and truck counts for Kern 5 for the even years between 2012 and 2020. The traffic counts are from the intersection with Route 43, at PM 41.193, and the intersection with Route 119, at PM 38.793, both in the southbound direction. Like some other CRCP sections, the truck counts increased by about 20% (21% and 15% for the separate legs) between 2012 and 2018. With little reduction in 2020, the increases in two-way equivalent axle loads were 19% and 22% between 2012 and 2020.

**Table 3.7: Traffic and Truck Counts on Kern 5 – PM 41.193 and PM 38.793**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 41.193 | B | 2012 | 30,500 | 8,561 | 28.1 | 2,233,000 |
| PM 41.193 | B | 2014 | 34,500 | 9,602 | 27.8 | 2,505,000 |
| PM 41.193 | B | 2016 | 38,000 | 10,260 | 27.0 | 2,722,000 |
| PM 41.193 | B | 2018 | 40,000 | 10,400 | 26.0 | 2,655,000 |
| PM 41.193 | B | 2020 | 38,500 | 10,010 | 26.0 | 2,655,000 |
| PM 38.793 | B | 2012 | 30,500 | 8,561 | 28.1 | 2,233,000 |
| PM 38.793 | B | 2014 | 34,000 | 9,400 | 27.7 | 2,453,000 |
| PM 38.793 | B | 2016 | 38,000 | 9,793 | 25.8 | 2,528,000 |
| PM 38.793 | B | 2018 | 38,500 | 9,854 | 25.6 | 2,801,000 |
| PM 38.793 | B | 2020 | 37,500 | 9,596 | 25.6 | 2,727,000 |

Table 3.8 summarizes the test results for this section, and Table 3.9 provides the environmental conditions during sampling.

**Table 3.8: Summary of Test Results for Kern 5 SB Lane 2 – PM 40.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 12/19/2012 | 111.6 | 0.2 | 89.5 | 1.2 |
| 11/18/2016 | 111.6 | 0.7 | 77.4 | 0.3 |
| 8/23/2018 | 110.0 | 0.3 | 70.5 | 2.8 |
| 7/21/2020 | 109.2 | 0.3 | 71.8 (123.7)[a] | 0.7 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

**Table 3.9: Environmental Conditions While Sampling Kern 5 SB Lane 2 – PM 40.0**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 12/19/2012 | 10:53 | 48 | 54 | 45 | 30.34 |
| 11/18/2016 | 13:59 | 73 | 78 | 21 | 29.98 |
| 8/23/2018 | 16:56 | 95 | 113 | 34 | 29.88 |
| 7/21/2020 | 16:14 | 100 | 113 | 18 | 29.71 |

### *3.1.4 San Joaquin 5 NB Lane 1 – PM 31.5/32.7 – CRCP with Conventional Diamond Grind Surface*

Table 3.10 presents the traffic and truck counts for San Joaquin 5 for the years 2016, 2018, and 2020, as the section was built between 2013 and 2017. The traffic counts are from the intersection with

March Lane, at PM 29.99, and the intersection with Hammer Lane, at PM 32.664, both in the northbound direction. Although there was no change in traffic counts during this period, these truck counts and equivalent axle loads are the largest in this study, about double the values from I-5 in Sacramento County.

**Table 3.10: Traffic and Truck Counts on San Joaquin 5 – PM 29.99 and PM 32.66**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 29.99 | A | 2016 | 106,000 | 24,381 | 23.0 | 6,929,000 |
| PM 29.99 | A | 2018 | 106,000 | 24,380 | 23.0 | 6,929,000 |
| PM 29.99 | A | 2020 | 106,000 | 24,380 | 23.0 | 6,929,000 |
| PM 32.664 | A | 2016 | 73,000 | 16,498 | 22.6 | 4,677,000 |
| PM 32.664 | A | 2018 | 73,000 | 16,498 | 22.6 | 4,677,000 |
| PM 32.664 | A | 2020 | 73,000 | 16,498 | 22.6 | 4,677,000 |

Table 3.11 summarizes the test results for this section and Table 3.12 provides the environmental conditions during sampling.

**Table 3.11: Summary of Test Results for San Joaquin 5 NB Lane 1 – PM 31.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| No Earlier Test | — | — | — | — |
| 6/6/2017 | 103.6 | 0.8 | 65.3 | 0.04 |
| 12/4/2018 | 105.2 | 0.6 | 66.0 | 0.2 |
| No Final Test | — | — | — | — |

**Table 3.12: Environmental Conditions While Sampling San Joaquin 5 NB Lane 1 – PM 31.5**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| No Earlier Test | — | — | — | — | — |
| 6/6/2017 | 11:55 | 86 | 103 | 27 | 29.88 |
| 12/4/2018 | 13:39 | 56 | 56 | 58% | 29.99 |
| No Final Test | — | — | — | — | — |

### *3.1.5 Imperial 78 EB Lane 2 – PM R15.0 – CRCP with Longitudinally Tined Surface*

Table 3.13 presents the traffic and truck counts for Imperial 78 for the even years between 2012 and 2020. The traffic counts are from the west junction of Route 78 with Route 115, at PM 18.651, in the eastbound direction; both directions of the east junction of Route 78 with Route 111, at PM 15.499; and from the west junction of Route 78 with Route 111, at PM R12.891, from within the interchange.

Unfortunately, traffic counts do not exist between 2011 and 2016 in the eastbound direction of Imperial 78 at the east junction with Route 111. However, there were data from 2010 from PM 15.03 that are presented to show the similar counts in 2012 and 2020; therefore, data from PM 18.651 in the eastbound direction, showing relatively similar traffic patterns, are used to estimate the equivalent axle loads for PM 15.499 in the eastbound direction.

The intersection of Imperial 78 and Route 111 was realigned in 2012, and since then, the traffic counts have increased more here than any other section sampled. The truck counts more than doubled in the westbound direction between 2012 and 2020 but stayed relatively steady in the eastbound direction at PM 18.651. The surprising increase likely arises from the realignment and its proximity to the international border at Calexico, 30 miles to the south.

**Table 3.13: Traffic and Truck Counts on Imperial 78 – PM 18.651, PM 15.499, and PM R12.891**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 18.651 | A | 2012 | 3,400 | 1,064 | 31.3 | 272,000 |
| PM 18.651 | A | 2014 | 3,200 | 1,001 | 31.3 | 256,000 |
| PM 18.651 | A | 2016 | 3,150 | 986 | 31.3 | 252,000 |
| PM 18.651 | A | 2018 | 3,550 | 1,111 | 31.3 | 252,000 |
| PM 18.651 | A | 2020 | 3,450 | 1,080 | 31.3 | 276,000 |
| PM 15.03[a] | A | 2012 | 4,200[a] | 1,915[a] | 45.6[a] | *327,000*[b] |
| PM 15.499 | A | 2014 | | | | *307,000*[b] |
| PM 15.499 | A | 2016 | | | | *303,000*[b] |
| PM 15.499 | A | 2018 | 4,400 | 2,318 | 52.68 | 311,000 |
| PM 15.499 | A | 2020 | 4,350 | 2,292 | 52.68 | 327,000 |
| PM 15.499 | B | 2012 | 2,600 | 598 | 23.0 | 88,000 |
| PM 15.499 | B | 2014 | 7,200 | 2,394 | 33.3 | 494,000 |
| PM 15.499 | B | 2016 | 9,400 | 4,261 | 45.3 | 601,000 |
| PM 15.499 | B | 2018 | 9,400 | 4,350 | 46.3 | 607,000 |
| PM 15.499 | B | 2020 | 11,800 | 5,461 | 46.3 | 762,000 |
| PM R12.891 | X | 2013 | 4,250 | 2,215 | 52.1 | 460,000 |
| PM R12.891 | X | 2014 | 4,250 | 2,995 | 70.5 | 516,000 |
| PM R12.891 | X | 2016 | 7,300 | 3,924 | 53.8 | 691,000 |
| PM R12.891 | X | 2018 | 8,450 | 5,141 | 60.8 | 760,000 |
| PM R12.891 | X | 2020 | 8,450 | 5,141 | 60.8 | 879,000 |

[a] Data from PM 15.03 is from year 2010.
[b] Values estimated using data from PM 18.651.

Table 3.14 summarizes the test results for this section, and Table 3.15 provides the environmental conditions during sampling.

**Table 3.14: Summary of Test Results for Imperial 78 EB Lane 2 – PM R15.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/12/2012 | 101.6 | 0.1 | 54.0 | 0.4 |
| 11/19/2016 | 101.8 | 0.8 | 70.0 | 4.1 |
| 8/24/2018 | 102.5 | 0.7 | 69.5 | 3.0 |
| 7/22/2020 | 102.6 | 0.7 | 67.1 | 4.1 |

**Table 3.15: Environmental Conditions While Sampling Imperial 78 EB Lane 2 – PM R15.0**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 8/12/2012 | 17:15 | 117 | 129 | 48 | 29.59 |
| 11/19/2016 | 12:19 | 71 | 85 | 30 | 30.06 |
| 8/24/2018 | 11:19 | 99 | 129 | 31 | 29.82 |
| 7/22/2020 | 12:21 | 101 | 129 | 32 | 29.83 |

### *3.1.6 Imperial 86 SB Lane 2 – PM R24.2 – CRCP with Longitudinally Tined Surface*

Table 3.16 presents the traffic and truck counts for Imperial 86 for the even years between 2012 and 2020. The traffic counts are from the junction with Imperial 78, at PM R24.057, and the intersection with Westmoreland Road and B Street, at PM R27.211, both in the southbound direction. The intersection of Imperial 78 and Route 111 was realigned in 2012, and there were no data for the junction with Imperial 78 that year. Therefore, 2013 data are presented instead.

The truck and traffic counts from both the intersection and junction show reductions between 2012 and 2018. Even with the 50% increase in counts between 2018 and 2020, the equivalent axle loads dropped by 25% between 2012 and 2020 at PM R24.057; whereas at PM R27.211, there is a 59% increase in equivalent axle loads over the same period. These two levels of traffic will be used later in the data analysis.

**Table 3.16: Traffic and Truck Counts on Imperial 86 – PM R24.057 and R27.211**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM R24.057 | B | 2013 | 6,200 | 1,116 | 18.0 | 240,000 |
| PM R24.057 | B | 2014 | 5,500 | 895 | 16.3 | 177,000 |
| PM R24.057 | B | 2016 | 5,400 | 764 | 14.2 | 135,000 |
| PM R24.057 | B | 2018 | 5,100 | 640 | 12.6 | 112,000 |
| PM R24.057 | B | 2020 | 8,700 | 1,092 | 12.6 | 180,000 |
| PM R27.211 | B | 2012 | 10,300 | 2,926 | 28.4 | 696,000 |
| PM R27.211 | B | 2014 | 9,600 | 2,726 | 28.4 | 648,000 |
| PM R27.211 | B | 2016 | 9,500 | 2,700 | 28.4 | 642,000 |
| PM R27.211 | B | 2018 | 9,500 | 2,699 | 28.4 | 656,000 |
| PM R27.211 | B | 2020 | 16,400 | 4,659 | 28.4 | 1,108,000 |

Table 3.17 summarizes the test results for this section, and Table 3.18 provides the environmental conditions during sampling.

**Table 3.17: Summary of Test Results for Imperial 86 SB Lane 2 – PM R24.2**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/12/2012 | 104.1 | 0.3 | 50.3 | 1.1 |
| 11/19/2016 | 103.6 | 0.8 | 51.2 | 1.2 |
| 8/24/2018 | 103.7 | 0.7 | 54.8 | 1.2 |
| 7/22/2020 | 103.6 | 0.6 | 52.7 | 2.4 |

**Table 3.18: Environmental Conditions While Sampling Imperial 86 SB Lane 2 – PM R24.2**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 8/12/2012 | 18:30 | 108 | 119 | 48 | 29.60 |
| 11/19/2016 | 12:19 | 71 | 85 | 30 | 30.06 |
| 8/24/2018 | 11:19 | 99 | 129 | 31 | 29.82 |
| 7/22/2020 | 12:21 | 101 | 129 | 32 | 29.83 |

## 3.2 Sacramento 5 – PM 20.0/21.5 – Grind and Groove versus Conventional Diamond Grind Surface

Table 3.19 presents the traffic and truck counts for Sacramento 5 for the even years between 2012 and 2020. The northbound traffic counts are from the intersection at Pocket Road and Meadowview Road, at PM 16.147, and the southbound traffic counts are from the intersection with Route 50, at PM R22.565. While the southbound vehicle counts, shown by the B leg, exceed the northbound counts by about 40%, the truck counts and two-way equivalent axle loads are very similar in both directions.

In 2012, the truck AADT was very similar on both legs. Between 2012 and 2018, the traffic and truck counts increased 14% in both directions. However, by 2020, truck counts decreased in both directions, enough in the northbound direction that the truck AADT was 6% lower than the 2012 truck count. In the southbound direction, the 2020 truck AADT was slightly higher (3.5%) than in 2012.

**Table 3.19: Traffic and Truck Counts on Sacramento 5 – PM 16.147 and PM 22.565**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 16.147 | A | 2012 | 101,000 | 13,342 | 13.2 | 3,475,000 |
| PM 16.147 | A | 2014 | 101,000 | 13,343 | 13.2 | 3,475,000 |
| PM 16.147 | A | 2016 | 111,700 | 14,756 | 13.2 | 3,844,000 |
| PM 16.147 | A | 2018 | 114,800 | 15,165 | 13.2 | 3,950,000 |
| PM 16.147 | A | 2020 | 95,000 | 12,550 | 13.2 | 3,269,000 |
| PM 22.565 | B | 2012 | 142,000 | 13,632 | 9.6 | 3,403,000 |
| PM 22.565 | B | 2014 | 142,000 | 13,631 | 9.6 | 3,403,000 |
| PM 22.565 | B | 2016 | 156,200 | 14,996 | 9.6 | 3,744,000 |
| PM 22.565 | B | 2018 | 161,500 | 15,504 | 9.6 | 3,871,000 |
| PM 22.565 | B | 2020 | 147,000 | 14,112 | 9.6 | 3,523,000 |

Table 3.20 provides the environmental conditions while sampling Sacramento 5 – PM 20.0/21.5.

**Table 3.20: Environmental Conditions While Sampling Sacramento 5 – PM 20.0/21.5**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 1/25/2012 | 12:21 | 61 | 66 | 68 | 30.38 |
| 1/25/2012 | 15:20 | 63 | 67 | 59 | 30.31 |
| 5/1/2017 | 11:45 | 79 | 85 | 41 | 29.92 |
| 5/1/2017 | 14:52 | 91 | 104 | 20 | 29.92 |
| 8/15/2018 | 12:57 | 80 | 105 | 45 | 29.91 |
| 2/28/2020 | 12:24 | 72 | 82 | 35 | 30.12 |
| 2/28/2020 | 13:50 | 75 | 84 | 37 | 30.08 |
| 2/28/2020 | 14:54 | 76 | 84 | 38 | 30.07 |

### *3.2.1 Sacramento 5 NB Lane 1 – PM 20.0 – JPCP with GnG*

Table 3.21 summarizes the test results for this section.

**Table 3.21: Summary of Test Results for Sacramento 5 NB Lane 1 – PM 20.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 1/25/2012 | 102.5 | 0.5 | 42.0 | 0.4 |
| 5/1/2017 | 103.5 | 0.6 | 45.9 | 0.5 |
| 8/15/2018 | 103.8 | 0.6 | 53.1 | 0.5 |
| 2/28/2020 | 104.2 | 0.7 | 106.2 | 5.7 |

### 3.2.2 Sacramento 5 NB Lane 4 – PM 20.0 – JPCP with GnG

Table 3.22 summarizes the test results for this section.

**Table 3.22: Summary of Test Results for Sacramento 5 NB Lane 4 – PM 20.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 1/25/2012 | 103.0 | 0.7 | 52.0 | 0.4 |
| 5/1/2017 | 105.2 | 1.5 | 62.7 | 1.0 |
| 8/15/2018 | 106.5 | 2.2 | 76.3 | 1.5 |
| 2/28/2020 | 106.7 | 1.9 | 129.2 | 11.3 |

### 3.2.3 Sacramento 5 SB Lane 1 – PM 21.5 – JPCP with CDG

Table 3.23 summarizes the test results for this section.

**Table 3.23: Summary of Test Results for Sacramento 5 SB Lane 1 – PM 21.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 1/25/2012 | 101.8 | 0.4 | 82.4 | 1.3 |
| 5/1/2017 | 103.2 | 0.5 | 77.9 | 0.8 |
| 8/15/2018 | 103.9 | 0.4 | 91.1 | 0.9 |
| 2/28/2020 | 103.8 | 0.5 | 118.6 | 19.3 |

### 3.2.4 Sacramento 5 SB Lane 4 – PM 21.5 – JPCP with CDG

Table 3.24 summarizes the test results for this section.

**Table 3.24: Summary of Test Results for Sacramento 5 SB Lane 4 – PM 21.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 1/25/2012 | 103.0 | 0.7 | 75.1 | 0.1 |
| 5/1/2017 | 104.9 | 0.7 | 98.2 | 0.9 |
| 8/15/2018 | 106.6 | 1.0 | 104.3 | 0.8 |
| 2/28/2020 | 106.7 | 1.0 | 126.7 | 3.4 |

## 3.3 Sacramento 5 – PM 1.5/3.0 – Grind and Groove versus Conventional Diamond Grind Surface

Table 3.25 presents the traffic and truck counts for Sacramento 5 for the even years between 2012 and 2020. The traffic counts are from the San Joaquin County Line, at PM 0.018, and the intersection with Pocket Road and Meadowview Road, at PM 16.147. The A traffic legs indicate both counts are northbound, and the values for two-way equivalent axle loads are assumed to be equivalent for both directions, as can be seen for Sacramento 5 – PM 20.0/21.5 in Table 3.19.

Between 2012 and 2018, the traffic and truck counts grew only 6% at the county line compared with 14% at the Pocket Road and Meadowview Road intersection. By 2014, the vehicle counts doubled between the county line and the Pocket Road and Meadowview Road intersection, and they increased another 40% by the junction with State Route 50. Still, through 2018, the truck counts were consistent and increased only 10% over these 22 miles. Most trucks that enter the county from San Joaquin County are heading north of State Route 50. Between 2018 and 2020, counts decreased 16% at the county line and 17% at the Pocket Road and Meadowview Road intersection.

**Table 3.25: Traffic and Truck Counts on Sacramento 5 – PM 0.018 and PM 16.147**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 0.018 | A | 2012 | 54,000 | 13,144 | 24.3 | 3,424,000 |
| PM 0.018 | A | 2014 | 50,000 | 12,170 | 24.3 | 3,170,000 |
| PM 0.018 | A | 2016 | 55,700 | 13,557 | 24.3 | 3,531,000 |
| PM 0.018 | A | 2018 | 57,400 | 13,971 | 24.3 | 3,639,000 |
| PM 0.018 | A | 2020 | 48,000 | 11,683 | 24.3 | 3,043,000 |
| PM 16.147 | A | 2012 | 101,000 | 13,342 | 13.2 | 3,475,000 |
| PM 16.147 | A | 2014 | 101,000 | 13,343 | 13.2 | 3,475,000 |
| PM 16.147 | A | 2016 | 111,700 | 14,756 | 13.2 | 3,844,000 |
| PM 16.147 | A | 2018 | 114,800 | 15,165 | 13.2 | 3,950,000 |
| PM 16.147 | A | 2020 | 95,000 | 12,550 | 13.2 | 3,269,000 |

Table 3.26 provides the environmental conditions while sampling Sacramento 5 – PM 1.5/3.0. The air temperature was not collected in 2012.

**Table 3.26: Environmental Conditions While Sampling Sacramento 5 – PM 1.5/3.0**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 2/6/2012 | 15:04 | — | 65 | 45 | 29.80 |
| 2/6/2012 | 15:42 | — | 68 | 36 | 29.80 |
| 5/2/2017 | 11:21 | 86 | 97 | 38 | 29.94 |
| 5/2/2017 | 12:44 | 90 | 101 | 39 | 29.94 |
| 6/6/2017 | 16:03 | 91 | 104 | 29 | 29.83 |
| 8/13/2018 | 13:30 | 88 | 112 | 52 | 29.91 |
| 2/27/2020 | 11:40 | 69 | 80 | 44 | 30.25 |
| 2/27/2020 | 12:22 | 73 | 84 | 43 | 30.23 |
| 2/27/2020 | 13:34 | 74 | 85 | 37 | 30.20 |

### *3.3.1 Sacramento 5 NB Lane 1 – PM 1.5 – JPCP with GnG*

Table 3.27 summarizes the test results for this section.

**Table 3.27: Summary of Test Results for Sacramento 5 NB Lane 1 – PM 1.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 2/6/2012 | 101.7 | 0.3 | 42.7 | 0.2 |
| 6/6/2017 | 103.9 | 0.8 | 46.7 | 0.3 |
| 8/13/2018 | 105.0 | 0.7 | 46.0 | 1.0 |
| 2/27/2020 | 106.2 | 0.7 | 49.2 (117.8)[a] | 16.7 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.3.2 Sacramento 5 NB Lane 2 – PM 1.5 – JPCP with GnG*

Table 3.28 summarizes the test results for this section. Unfortunately, the IRI data from the 2017 sample collection were inaccessible.

**Table 3.28: Summary of Test Results for Sacramento 5 NB Lane 2 – PM 1.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 2/6/2012 | 102.1 | 0.4 | 48.2 | 0.7 |
| 5/2/2017 | 105.1 | 0.8 | — | — |
| 8/13/2018 | 106.1 | 1.1 | 62.1 | 0.4 |
| 2/27/2020 | 107.3 | 1.1 | (113.4)[a] | 11.3 |

[a] Collected data unreasonable and no Automated Pavement Condition Survey data for this section; collected data shown in parentheses.

### 3.3.3 Sacramento 5 SB Lane 1 – PM 3.0 – JPCP with CDG

Table 3.29 summarizes the test results for this section.

**Table 3.29: Summary of Test Results for Sacramento 5 SB Lane 1 – PM 3.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 2/6/2012 | 103.4 | 0.4 | 62.8 | 0.2 |
| 6/6/2017 | 103.9 | 0.3 | 60.5 | 1.7 |
| 8/13/2018 | 104.6 | 0.4 | 62.1 | 2.3 |
| 2/27/2020 | 104.9 | 0.3 | 65.7 (154.9)[a] | 22.6 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### 3.3.4 Sacramento 5 SB Lane 2 – PM 3.0 – JPCP with CDG

Table 3.30 summarizes the test results for this section.

**Table 3.30: Summary of Test Results for Sacramento 5 SB Lane 2 – PM 3.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 2/6/2012 | 103.6 | 0.8 | 64.7 | 0.5 |
| 5/2/2017 | 104.4 | 0.7 | 60.7 | 1.4 |
| 8/13/2018 | 105.3 | 0.8 | 97.1 | 1.0 |
| 2/27/2020 | 105.9 | 0.6 | *(120.2) | 15.5 |

[a] Collected data unreasonable and no Automated Pavement Condition Survey data for this section; collected data shown in parentheses.

## 3.4 Sacramento 80 – PM 13.0/14.0 – Grind and Groove Surface Only

Table 3.31 presents the traffic and truck counts for Sacramento 80 for the even years between 2012 and 2020. The traffic counts are from both directions of the junction with Route 51, at PM R10.989, and the intersection with Greenback Lane, at PM 14.454, eastbound. In 2012, truck counts and equivalent axle loads were larger eastbound than westbound. However, in 2014, the westbound truck count increased by 22% while the eastbound count decreased by 8%. From 2012 through 2018, truck counts grew by less than 5%, and then declined between 2018 and 2020. In 2020, only the westbound direction saw a 23% increase in equivalent axle loads compared to 2012, while the eastbound direction showed no increase.

**Table 3.31: Traffic and Truck Counts on Sacramento 80 – PM R10.989 and PM 14.45**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM R10.989 | B | 2012 | 116,000 | 7,424 | 6.4 | 1,583,000 |
| PM R10.989 | B | 2014 | 142,000 | 9,089 | 6.4 | 1,938,000 |
| PM R10.989 | B | 2016 | 149,000 | 9,535 | 6.4 | 2,034,000 |
| PM R10.989 | B | 2018 | 149,000 | 9,536 | 6.4 | 2,034,000 |
| PM R10.989 | B | 2020 | 143,000 | 9,152 | 6.4 | 1,952,000 |
| PM R10.989 | A | 2012 | 211,000 | 8,208 | 3.9 | 1,871,000 |
| PM R10.989 | A | 2014 | 195,000 | 7,585 | 3.9 | 1,729,000 |
| PM R10.989 | A | 2016 | 220,500 | 8,578 | 3.9 | 1,955,000 |
| PM R10.989 | A | 2018 | 220,500 | 8,577 | 3.9 | 1,955,000 |
| PM R10.989 | A | 2020 | 211,000 | 8,208 | 3.9 | 1,871,000 |
| PM 14.454 | A | 2012 | 177,000 | 8,868 | 5.0 | 1,983,000 |
| PM 14.454 | A | 2014 | 177,000 | 8,144 | 4.6 | 1,895,000 |
| PM 14.454 | A | 2016 | 191,400 | 8,746 | 4.6 | 2,032,000 |
| PM 14.454 | A | 2018 | 191,400 | 8,747 | 4.6 | 2,032,000 |
| PM 14.454 | A | 2020 | 179,000 | 8,180 | 4.6 | 1,900,000 |

Table 3.32 provides the environmental conditions while sampling Sacramento 80 – PM 13.0/14.0. The pavement temperature and relative humidity were not collected in 2013.

**Table 3.32: Environmental Conditions While Sampling Sacramento 80 – PM 13.0/14.0**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 5/29/2012 | 14:48 | 84 | — | — | 29.98 |
| 11/10/2016 | 11:52 | 71 | 82 | 64 | 30.10 |
| 8/14/2018 | 11:51 | 78 | 98 | 54 | 29.91 |
| 2/25/2020 | 11:21 | 65 | 77 | 27 | 30.36 |
| 2/25/2020 | 12:27 | 70 | 81 | 25 | 30.34 |
| 2/25/2020 | 13:32 | 72 | 84 | 24 | 30.31 |

### *3.4.1 Sacramento 80 EB Lane 2 – PM 13.0 – JPCP with GnG*

Table 3.33 summarizes the test results for this section.

**Table 3.33: Summary of Test Results for Sacramento 80 EB Lane 2 – PM 13.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/29/2012 | 101.8 | 0.3 | 33.9 | 0.8 |
| 11/10/2016 | 103.7 | 0.3 | 35.2 | 1.5 |
| 8/14/2018 | 105.6 | 0.5 | 45.4 | 3.5 |
| 2/25/2020 | 106.1 | 0.5 | 58.8 | 5.2 |

### *3.4.2 Sacramento 80 EB Lane 5 – PM 13.0 – JPCP with GnG*

Table 3.34 summarizes the test results for this section.

**Table 3.34: Summary of Test Results for Sacramento 80 EB Lane 5 – PM 13.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/29/2012 | 101.8 | 0.3 | 41.6 | 0.8 |
| 11/10/2016 | 103.0 | 0.3 | 48.6 | 1.1 |
| 8/14/2018 | 103.9 | 0.4 | 57.7 | 1.6 |
| 2/25/2020 | 104.6 | 0.5 | 52.2 (173.7)[a] | 19.0 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.4.3 Sacramento 80 WB Lane 2 – PM 14.0 – JPCP with GnG*

Table 3.35 summarizes the test results for this section.

**Table 3.35: Summary of Test Results for Sacramento 80 WB Lane 2 – PM 14.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/29/2012 | 101.7 | 0.3 | 41.9 | 0.3 |
| 11/10/2016 | 103.1 | 0.4 | 45.8 | 0.6 |
| 8/14/2018 | 104.4 | 0.5 | 57.0 | 1.6 |
| 2/25/2020 | 105.1 | 0.6 | 47.6 | 0.9 |

### *3.4.4 Sacramento 80 WB Lane 5 – PM 14.0 – JPCP with GnG*

Table 3.36 summarizes the test results for this section.

**Table 3.36: Summary of Test Results for Sacramento 80 WB Lane 5 – PM 14.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/29/2012 | 102.0 | 0.4 | 47.7 | 0.7 |
| 11/10/2016 | 102.9 | 0.4 | 66.1 | 0.9 |
| 8/14/2018 | 103.5 | 0.5 | 73.7 | 1.5 |
| 2/25/2020 | 104.3 | 0.4 | 75.8 | 1.6 |

## 3.5 Sacramento 50 – PM 13.0/14.0 – Grind and Groove versus Conventional Diamond Grind Surface

Table 3.37 presents the traffic and truck counts for Sacramento 50 for the even years between 2012 and 2020. The traffic counts are from both directions of the Sunrise Boulevard intersection, at PM 12.496, and the intersection with Nimbus Road, at PM 15.759, eastbound. Like other JPCP sections, the vehicle and truck counts grew by more than 10% between 2012 and 2016. Counts barely grew in 2018 and fell in 2020, especially at the Sunrise Boulevard intersection, where truck counts fell 14%. The counts are consistent between the two intersections in the eastbound direction.

**Table 3.37: Traffic and Truck Counts on Sacramento 50 – PM 12.496 and PM 15.759**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 12.496 | B | 2012 | 141,000 | 7,811 | 5.5 | 1,077,000 |
| PM 12.496 | B | 2014 | 148,000 | 8,199 | 5.5 | 1,130,000 |
| PM 12.496 | B | 2016 | 156,000 | 8,641 | 5.5 | 1,191,000 |
| PM 12.496 | B | 2018 | 144,000 | 7,978 | 5.5 | 1,191,000 |
| PM 12.496 | B | 2020 | 124,000 | 6,870 | 5.5 | 947,000 |
| PM 12.496 | A | 2012 | 116,000 | 7,424 | 6.4 | 1,357,000 |
| PM 12.496 | A | 2014 | 116,000 | 7,425 | 6.4 | 1,357,000 |
| PM 12.496 | A | 2016 | 129,300 | 8,275 | 6.4 | 1,512,000 |
| PM 12.496 | A | 2018 | 130,600 | 8,358 | 6.4 | 1,512,000 |
| PM 12.496 | A | 2020 | 112,000 | 7,168 | 6.4 | 1,310,000 |
| PM 15.759 | A | 2012 | 110,000 | 6,930 | 6.3 | 1,248,000 |
| PM 15.759 | A | 2014 | 119,000 | 7,497 | 6.3 | 1,350,000 |
| PM 15.759 | A | 2016 | 126,300 | 7,957 | 6.3 | 1,433,000 |
| PM 15.759 | A | 2018 | 127,600 | 8,039 | 6.3 | 1,433,000 |
| PM 15.759 | A | 2020 | 119,000 | 7,497 | 6.3 | 1,350,000 |

Table 3.38 provides the environmental conditions while sampling Sacramento 50 – PM 13.0/14.0. The pavement temperature and relative humidity were not collected in 2013.

**Table 3.38: Environmental Conditions While Sampling Sacramento 50 – PM 13.0/14.0**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 5/30/2012 | 14:51 | 89 | — | — | 30.00 |
| 10/24/2016 | 14:55 | 70 | 81 | 59 | 29.94 |
| 8/16/2018 | 12:58 | 89 | 113 | 38 | 30.00 |
| 2/26/2020 | 11:00 | 74 | 81 | 67 | 30.42 |
| 2/26/2020 | 12:12 | 75 | 88 | 35 | 30.34 |

### *3.5.1 Sacramento 50 EB Lane 2 – PM 13.0 – JPCP with CDG*

Table 3.39 summarizes the test results for this section.

**Table 3.39: Summary of Test Results for Sacramento 50 EB Lane 2 – PM 13.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/30/2012 | 103.0 | 0.7 | 77.2 | 2.6 |
| 10/24/2016 | 103.9 | 0.9 | 77.9 | 1.0 |
| 8/16/2018 | 104.6 | 0.6 | 74.4 | 0.4 |
| 2/26/2020 | 104.9 | 0.6 | 64.8 (188.9)[a] | 14.4 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.5.2 Sacramento 50 EB Lane 4 – PM 13.0 – JPCP with CDG*

Table 3.40 summarizes the test results for this section. The initial data from May 2012 were not collected for this section, and the average value from Lane 2 is used for comparison since it was collected immediately after construction.

**Table 3.40: Summary of Test Results for Sacramento 50 EB Lane 4 – PM 13.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/30/2012 | 103.0 | 0.0 | 77.2 | 0.0 |
| 10/24/2016 | 105.5 | 0.5 | 70.0 | 1.8 |
| 8/16/2018 | 106.0 | 0.6 | 73.6 | 0.3 |
| 2/26/2020 | 106.3 | 0.6 | 76.3 (169.9)[a] | 7.6 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.5.3 Sacramento 50 WB Lane 2– PM 14.0 – JPCP with GnG*

Table 3.41 summarizes the test results for this section.

**Table 3.41: Summary of Test Results for Sacramento 50 WB Lane 2 – PM 14.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/30/2012 | 100.9 | 0.3 | 62.6 | 2.8 |
| 10/24/2016 | 102.7 | 1.1 | 63.3 | 0.5 |
| 8/16/2018 | 103.9 | 1.0 | 60.6 | 2.0 |
| 2/26/2020 | 104.8 | 0.9 | 63.2 | 0.7 |

### *3.5.4 Sacramento 50 WB Lane 4 – PM 14.0 – JPCP with GnG*

Table 3.42 summarizes the test results for this section.

**Table 3.42: Summary of Test Results for Sacramento 50 WB Lane 4 – PM 14.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 5/30/2012 | 101.8 | 0.3 | 52.3 | 0.2 |
| 10/24/2016 | 105.6 | 1.8 | 84.5 | 0.5 |
| 8/16/2018 | 106.6 | 1.5 | 91.6 | 0.3 |
| 2/26/2020 | 106.5 | 1.3 | 91.0 | 1.9 |

## 3.6 San Joaquin 99 – PM 29.0/30.7 – Grind and Groove Only

Table 3.43 presents the traffic and truck counts for San Joaquin 99 for the even years between 2012 and 2020. The traffic counts are from the junction with State Route 12 West, at PM 24.499, and the junction with State Route 12 East, at PM 30.974, both northbound only, since these test sections are northbound only. While the vehicle counts over this section were among the lowest of the GnG projects (only Yolo 113 and Sacramento 5 – PM 1.5/3.0 had lower AADT), the percentage of trucks (13.4%) was second only to Sacramento 5 – PM 1.5/3.0 (24.3%). The CRCP projects all have truck percentages in excess of 20%. This section was one of two that had increases in vehicle and truck AADT between 2018 and 2020; the Imperial 86 section was the other.

**Table 3.43: Traffic and Truck Counts on San Joaquin 99 – PM 29.499 and PM 30.974**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM 29.499 | A | 2012 | 65,000 | 8,710 | 13.4 | 1,875,000 |
| PM 29.499 | A | 2014 | 69,000 | 9,246 | 13.4 | 1,990,000 |
| PM 29.499 | A | 2016 | 76,000 | 10,184 | 13.4 | 2,192,000 |
| PM 29.499 | A | 2018 | 76,000 | 10,184 | 13.4 | 2,192,000 |
| PM 29.499 | A | 2020 | 94,000 | 12,596 | 13.4 | 2,711,000 |
| PM 30.974 | A | 2012 | 65,000 | 8,710 | 13.4 | 1,875,000 |
| PM 30.974 | A | 2014 | 69,000 | 9,246 | 13.4 | 1,990,000 |
| PM 30.974 | A | 2016 | 76,000 | 10,184 | 13.4 | 2,192,000 |
| PM 30.974 | A | 2018 | 76,000 | 10,184 | 13.4 | 2,192,000 |
| PM 30.974 | A | 2020 | 86,000 | 11,524 | 13.4 | 2,480,000 |

Table 3.44 provides the environmental conditions while sampling San Joaquin 99 – PM 29.0/30.7. The relative humidity was not collected in 2013.

**Table 3.44: Environmental Conditions While Sampling San Joaquin 99 – PM 29.0/30.7**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 9/14/2012 | 14:35 | 91 | 104 | — | 29.97 |
| 5/4/2017 | 11:06 | 88 | 104 | 41 | 29.88 |
| 12/4/2018 | 10:58 | 53 | 51 | 43 | 30.06 |
| 3/6/2020 | 12:05 | 67 | 73.5 | 48 | 29.98 |

### *3.6.1 San Joaquin 99 NB Lane 1 – PM 29.0 – JPCP with GnG*

Table 3.45 summarizes the test results for this section.

**Table 3.45: Summary of Test Results for San Joaquin 99 NB Lane 1 – PM 29.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 9/14/2012 | 100.7 | 0.8 | 44.3 | 1.9 |
| 5/4/2017 | 103.1 | 0.6 | 44.1 | 0.2 |
| 12/4/2018 | 105.2 | 0.6 | 44.9 | 0.2 |
| 3/6/2020 | 104.7 | 0.5 | 53.9 (130.7)[a] | 19.7 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.6.2 San Joaquin 99 NB Lane 2 – PM 29.0 – JPCP with GnG*

Table 3.46 summarizes the test results for this section.

**Table 3.46: Summary of Test Results for San Joaquin 99 NB Lane 2 – PM 29.0**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 9/14/2012 | 101.5 | 1.0 | 72.9 | 34.1 |
| 5/4/2017 | 104.5 | 0.9 | 80.1 | 2.1 |
| 12/4/2018 | 107.2 | 1.2 | 82.1 | 1.4 |
| 3/6/2020 | 106.6 | 0.9 | 88.2 (142.0)[a] | 26.6 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

## 3.7 Yolo 113 – PM R0.5/R2.5 – Grind and Groove Versus Conventional Diamond Grind Surface

Table 3.47 presents the traffic and truck counts for the project site for the even years from 2012 through 2020. The traffic counts are from both directions at the intersection with Russell Boulevard, at PM 1.082. This route had the lowest vehicular and truck counts of the JPCP sections evaluated. These counts increased about 10% between 2012 and 2016 or 2018, and then decreased enough by 2020 to fall below the 2012 counts. The southbound direction has about 5% to 10% more trucks, 15% to 20% more vehicles, and about 15% higher two-way equivalent axle loads than the northbound direction.

**Table 3.47: Traffic and Truck Counts on Yolo 113 – PM R1.082 and PM R4.105**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM R1.082 | B | 2012 | 37,000 | 1,991 | 5.4 | 428,000 |
| PM R1.082 | B | 2014 | 39,000 | 2,098 | 5.4 | 451,000 |
| PM R1.082 | B | 2016 | 41,200 | 2,217 | 5.4 | 477,000 |
| PM R1.082 | B | 2018 | 40,000 | 2,152 | 5.4 | 463,000 |
| PM R1.082 | B | 2020 | 34,500 | 1,856 | 5.4 | 399,000 |
| PM R1.082 | A | 2012 | 31,500 | 1,843 | 5.9 | 374,000 |
| PM R1.082 | A | 2014 | 32,500 | 1,900 | 5.9 | 386,000 |
| PM R1.082 | A | 2016 | 34,400 | 2,012 | 5.9 | 409,000 |
| PM R1.082 | A | 2018 | 34,700 | 2,030 | 5.9 | 412,000 |
| PM R1.082 | A | 2020 | 30,000 | 1,755 | 5.9 | 356,000 |

Table 3.48 provides the environmental conditions while sampling Yolo 113 – PM R0.5/R2.5. The 2013 pavement temperature was not collected.

**Table 3.48: Environmental Conditions While Sampling Yolo 113 – PM R0.5/R2.5**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 7/2/2013 | 16:30 | 104 | — | 25 | 29.78 |
| 7/2/2013 | 16:22 | 103 | — | 33 | 29.78 |
| 10/26/2016 | 14:31 | 76 | 80 | 51 | 30.00 |
| 10/26/2016 | 16:10 | 76 | 77 | 47 | 29.97 |
| 8/10/2018 | 10:35 | 80 | 112 | 5 | 29.95 |
| 2/20/2020 | 13:44 | 66 | 75 | 41 | 30.18 |

### 3.7.1 Yolo 113 NB Lane 1 – PM 0.5 – JPCP with GnG

Table 3.49 presents the data for this section.

**Table 3.49: Summary of Test Results for Yolo 113 NB Lane 1 – PM 0.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 100.6 | 0.3 | 53.1 | 3.9 |
| 10/26/2016 | 102.0 | 0.4 | 48.7 | 1.4 |
| 8/10/2018 | 101.9 | 0.5 | 45.5 | 2.1 |
| 2/20/2020 | 102.5 | 0.4 | 49.2 (122.2)[a] | 34.2 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### 3.7.2 Yolo 113 NB Lane 2 – PM 0.5 – JPCP with GnG

Table 3.50 summarizes the test results for this section.

**Table 3.50: Summary of Test Results for Yolo 113 NB Lane 2 – PM 0.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 100.4 | 0.4 | 47.6 | 2.5 |
| 10/26/2016 | 102.6 | 0.4 | 52.4 | 0.1 |
| 8/10/2018 | 102.8 | 0.6 | 46.8 | 0.6 |
| 2/20/2020 | 103.9 | 0.5 | 59.6 (129.9)[a] | 13.0 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### 3.7.3 Yolo 113 SB Lane 1 – PM 0.9 – JPCP with GnG

Table 3.51 summarizes the test results for this section.

**Table 3.51: Summary of Test Results for Yolo 113 SB Lane 1 – PM 0.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 100.6 | 0.2 | 59.0 | 0.2 |
| 10/26/2016 | 102.3 | 0.3 | 46.1 | 1.5 |
| 8/10/2018 | 102.1 | 0.4 | 45.9 | 2.7 |
| 2/20/2020 | 103.3 | 0.2 | 61.1 (89.1)[a] | 5.7 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.7.4 Yolo 113 SB Lane 2 – PM 0.9 – JPCP with GnG*

Table 3.52 summarizes the test results for this section.

**Table 3.52: Summary of Test Results for Yolo 113 SB Lane 2 – PM 0.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 100.2 | 0.2 | 53.5 | 0.7 |
| 10/26/2016 | 102.1 | 0.3 | 51.8 | 3.5 |
| 8/10/2018 | 102.4 | 0.3 | 59.9 | 1.5 |
| 2/20/2020 | 103.0 | 0.3 | 78.1 (143.8)[a] | 11.8 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.7.5 Yolo 113 NB Lane 1 – PM 1.5 – JPCP with CDG*

Table 3.53 summarizes the test results for this section.

**Table 3.53: Summary of Test Results for Yolo 113 NB Lane 1 – PM 1.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 102.3 | 0.4 | 50.2 | 1.6 |
| 10/26/2016 | 103.2 | 0.4 | 46.6 | 0.8 |
| 8/10/2018 | 103.1 | 0.4 | 45.6 | 0.5 |
| 2/20/2020 | 103.7 | 0.4 | 52.2 (101.2)[a] | 21.3 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.7.6 Yolo 113 NB Lane 2 – PM 1.5 – JPCP with CDG*

Table 3.54 summarizes the test results for this section.

**Table 3.54: Summary of Test Results for Yolo 113 NB Lane 2 – PM 1.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 101.2 | 0.3 | 46.7 | 0.1 |
| 10/26/2016 | 103.0 | 0.4 | 54.5 | 0.5 |
| 8/10/2018 | 103.4 | 0.5 | 54.5 | 1.5 |
| 2/20/2020 | 104.1 | 0.4 | 61.3 (116.1)[a] | 8.8 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.7.7 Yolo 113 SB Lane 1 – PM 2.5 – JPCP with CDG*

Table 3.55 summarizes the test results for this section.

**Table 3.55: Summary of Test Results for Yolo 113 SB Lane 1 – PM 2.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 101.4 | 0.8 | 50.5 | 0.4 |
| 10/26/2016 | 102.2 | 0.5 | 56.1 | 0.7 |
| 8/10/2018 | 101.9 | 0.5 | 56.3 | 0.5 |
| 2/20/2020 | 102.5 | 0.7 | 58.6 (128.9)[a] | 3.4 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.7.8 Yolo 113 SB Lane 2 – PM 2.5 – JPCP with CDG*

Table 3.56 summarizes the test results for this section.

**Table 3.56: Summary of Test Results for Yolo 113 SB Lane 2 – PM 2.5**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 7/2/2013 | 101.6 | 0.5 | 68.3 | 1.2 |
| 10/26/2016 | 102.9 | 0.4 | 74.9 | 1.7 |
| 8/10/2018 | 103.1 | 0.4 | 80.9 | 1.3 |
| 2/20/2020 | 103.8 | 0.4 | 58.4 (147.6)[a] | 5.3 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

## 3.8 San Diego 5 – PM 35.8/37.9 – Grind and Groove Versus Conventional Diamond Grind Surface

All the lanes in both directions of San Diego 5 were chosen for OBSI and IRI evaluation; originally, it was to be the only GnG pilot project. One mile of GnG surfacing between PM 36.35 and PM 37.35 served as the GnG sections, and the half mile of CDG surface both north and south of the GnG section, between PM R37.4 and PM R37.9 and between PM R35.8 and PM R36.3, was used for comparison. The pavement structure has PCC from three different construction periods: Lane 1 was constructed in the 2000s, Lanes 2 and 3 were constructed in the 1960s, and Lanes 4 and 5 were constructed in the 1970s.

Table 3.57 presents traffic and truck counts for the San Diego 5 project section for the even years from 2012 through 2020. The traffic counts are from the Route 805 North junction (at PM R30.682) and from the intersection of Encinitas Boulevard (at PM R41.509).

Between these two locations over this period, there were changes in the traffic counts. Prior to and into the start of this period in the northbound direction, the vehicle AADT was about 150,000 and the truck AADT was about 5,600. From the early 2000s through 2015, truck and vehicular traffic equated to over 1 million two-way equivalent axle loads. By 2020, the two-way equivalent axle loads dropped to 338,000, with truck AADT at less than 1,900 and vehicle AADT at 48,500, a two-thirds reduction of vehicular and truck traffic and equivalent axle loads.

Traffic counts in the southbound direction have always exceeded those in the northbound direction. But during this period, northbound traffic decreased while southbound traffic increased. In 2012, southbound vehicle AADT (205,000) was 37% higher than northbound vehicle AADT (150,000), and by 2020, the southbound vehicle AADT (175,000) was 3.5 times the northbound vehicle AADT (48,500).

The directional difference in traffic is more definite with truck counts. In 2012, southbound truck AADT (13,264) was 2.3 times the northbound truck AADT (5,700), and by 2020, the southbound truck AADT (14,490) was almost eight times the northbound truck AADT (1,843). This is reflected in the two-way equivalent axle load data, where southbound loads are almost six times the northbound loads in 2020.

**Table 3.57: Traffic and Truck Counts on San Diego 5 – PM R30.682 and PM R41.509**

| Postmile | Traffic Leg | Year | Vehicle AADT | Truck AADT | Trucks (%) | Two-Way Equivalent Axle Loads |
|---|---|---|---|---|---|---|
| PM R30.682 | A | 2012 | 150,000 | 5,700 | 3.8 | 1,045,000 |
| PM R30.682 | A | 2014 | 75,000 | 2,850 | 3.8 | 1,045,000 |
| PM R30.682 | A | 2016 | 150,000 | 2,850 | 3.8 | 522,000 |
| PM R30.682 | A | 2018 | 72,000 | 2,736 | 3.8 | 537,000 |
| PM R30.682 | A | 2020 | 48,500 | 1,843 | 3.8 | 338,000 |
| PM R41.509 | B | 2012 | 205,000 | 13,264 | 6.5 | 1,715,000 |
| PM R41.509 | B | 2014 | 212,000 | 14,581 | 6.9 | 1,802,000 |
| PM R41.509 | B | 2016 | 210,000 | 17,379 | 8.3 | 2,367,000 |
| PM R41.509 | B | 2018 | 217,000 | 17,968 | 8.3 | 2,447,000 |
| PM R41.509 | B | 2020 | 175,000 | 14,490 | 8.3 | 1,973,000 |

Table 3.58 provides the environmental conditions while sampling San Diego 5 – PM 35.8/37.9. The relative humidity in 2013 was not collected.

**Table 3.58: Environmental Conditions While Sampling San Diego 5 – PM 35.8/37.9**

| Date | Time (24 hr) | Air Temp. (°F) | Pavement Temp. (°F) | Relative Humidity (%) | Barometric Pressure (mm Hg) |
|---|---|---|---|---|---|
| 8/8/2012 | 11:45 | 79 | 101 | — | 29.88 |
| 8/8/2012 | 13:47 | 79 | 101 | — | 29.86 |
| 8/8/2012 | 14:00 | 77 | 100 | — | 29.87 |
| 11/21/2016 | 10:00 | 67 | 74 | 75 | 30.02 |
| 11/21/2016 | 12:06 | 66 | 76 | 86 | 29.97 |
| 11/21/2016 | 13:20 | 68 | 76 | 74 | 29.97 |
| 11/21/2016 | 14:27 | 66 | 75 | 85 | 29.95 |
| 8/25/2018 | 10:44 | 76 | 86 | 31 | 30.02 |
| 8/25/2018 | 10:56 | 76 | 86 | 30 | 29.96 |
| 8/25/2018 | 17:07 | 76 | 86 | 74 | 29.91 |
| 7/23/2020 | 10:40 | 71 | 91 | 62 | 29.93 |
| 7/23/2020 | 11:25 | 73 | 94 | 57 | 29.93 |
| 7/23/2020 | 13:03 | 75 | 96 | 56 | 29.92 |
| 7/23/2020 | 14:05 | 74 | 100 | 52 | 29.90 |

### *3.8.1 San Diego 5 NB Lane 1 – PM 36.4 – JPCP with GnG*

Table 3.59 summarizes the test results for this section.

**Table 3.59: Summary of Test Results for San Diego 5 NB Lane 1 – PM 36.4**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 100.2 | 0.6 | 41.2 | 0.6 |
| 11/20/2016 | 100.9 | 0.5 | 40.2 | 0.7 |
| 8/25/2018 | 101.7 | 0.5 | 41.9 | 0.9 |
| 7/23/2020 | 102.0 | 0.6 | 66.3 | 18.3 |

### *3.8.2 San Diego 5 NB Lane 2 – PM 36.4 – JPCP with GnG*

Table 3.60 summarizes the test results for this section.

**Table 3.60: Summary of Test Results for San Diego 5 NB Lane 2 – PM 36.4**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 100.9 | 0.3 | 43.9 | 0.7 |
| 11/20/2016 | 102.2 | 0.4 | 49.4 | 0.5 |
| 8/25/2018 | 103.3 | 0.5 | 55.0 | 0.8 |
| 7/23/2020 | 103.7 | 0.5 | 50.6 | 1.6 |

### *3.8.3 San Diego 5 NB Lane 3 – PM 36.4 – JPCP with GnG*

Table 3.61 summarizes the test results for this section.

**Table 3.61: Summary of Test Results for San Diego 5 NB Lane 3 – PM 36.4**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 100.7 | 0.4 | 37.7 | 0.4 |
| 11/20/2016 | 102.2 | 0.4 | 48.2 | 0.8 |
| 8/25/2018 | 103.3 | 0.4 | 45.5 | 0.2 |
| 7/23/2020 | 103.2 | 0.6 | 61.0 | 17.9 |

### *3.8.4 San Diego 5 NB Lane 4 – PM 36.4 – JPCP with GnG*

Table 3.62 summarizes the test results for this section.

**Table 3.62: Summary of Test Results for San Diego 5 NB Lane 4 – PM 36.4**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.3 | 0.3 | 39.1 | 0.6 |
| 11/20/2016 | 103.6 | 0.4 | 50.0 | 0.4 |
| 8/25/2018 | 104.9 | 0.6 | 52.9 | 2.2 |
| 7/23/2020 | 104.6 | 0.8 | 52.0 (81.1)[a] | 6.5 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.8.5 San Diego 5 NB Lane 5 – PM 36.4 – JPCP with GnG*

Table 3.63 summarizes the test results for this section.

**Table 3.63: Summary of Test Results for San Diego 5 NB Lane 5 – PM 36.4**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.2 | 0.3 | 37.7 | 1.1 |
| 11/20/2016 | 102.9 | 0.6 | 50.6 | 0.3 |
| 8/25/2018 | 104.1 | 0.8 | 59.6 | 1.1 |
| 7/23/2020 | 103.9 | 0.7 | 62.9 (114.8)[a] | 24.8 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.8.6 San Diego 5 SB Lane 1 – PM 37.3 – JPCP with GnG*

Table 3.64 summarizes the test results for this section.

**Table 3.64: Summary of Test Results for San Diego 5 SB Lane 1 – PM 37.3**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 100.4 | 0.7 | 37.3 | 0.9 |
| 11/20/2016 | 101.1 | 0.6 | 40.0 | 0.7 |
| 8/25/2018 | 101.9 | 0.6 | 44.0 | 0.7 |
| 7/23/2020 | 102.0 | 0.7 | 44.1 | 0.6 |

### *3.8.7 San Diego 5 SB Lane 2 – PM 37.3 – JPCP with GnG*

Table 3.65 summarizes the test results for this section.

**Table 3.65: Summary of Test Results for San Diego 5 SB Lane 2 – PM 37.3**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.2 | 0.5 | 36.1 | 1.1 |
| 11/20/2016 | 102.6 | 0.6 | 44.4 | 0.8 |
| 8/25/2018 | 103.6 | 0.8 | 45.9 | 1.0 |
| 7/23/2020 | 103.9 | 0.8 | 47.8 | 5.2 |

### *3.8.8 San Diego 5 SB Lane 3 – PM 37.3 – JPCP with GnG*

Table 3.66 summarizes the test results for this section.

**Table 3.66: Summary of Test Results for San Diego 5 SB Lane 3 – PM 37.3**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.0 | 0.3 | 41.0 | 0.7 |
| 11/20/2016 | 102.4 | 0.5 | 48.7 | 0.4 |
| 8/25/2018 | 103.3 | 0.3 | 50.5 | 0.3 |
| 7/23/2020 | 103.5 | 0.4 | 50.3 | 1.6 |

### *3.8.9 San Diego 5 SB Lane 4 – PM 37.3 – JPCP with GnG*

Table 3.67 summarizes the test results for this section.

**Table 3.67: Summary of Test Results for San Diego 5 SB Lane 4 – PM 37.3**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.5 | 0.3 | 38.4 | 1.2 |
| 11/20/2016 | 102.7 | 0.5 | 51.6 | 1.0 |
| 8/25/2018 | 103.8 | 0.6 | 57.2 | 1.3 |
| 7/23/2020 | 104.1 | 0.5 | 60.0 | 4.2 |

### *3.8.10 San Diego 5 SB Lane 5 – PM 37.3 – JPCP with GnG*

Table 3.68 summarizes the test results for this section.

**Table 3.68: Summary of Test Results for San Diego 5 SB Lane 5 – PM 37.3**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.0 | 0.4 | 45.1 | 1.1 |
| 11/20/2016 | 102.5 | 0.7 | 60.5 | 1.8 |
| 8/25/2018 | 103.7 | 0.7 | 76.0 | 0.6 |
| 7/23/2020 | 103.8 | 0.9 | 75.7 | 5.7 |

### *3.8.11 San Diego 5 NB Lane 1 – PM 35.8/37.4 – JPCP with CDG*

Table 3.69 summarizes the test results for this section.

**Table 3.69: Summary of Test Results for San Diego 5 NB Lane 1 – PM 35.8**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.9 | 0.9 | 57.4 | 0.4 |
| 11/20/2016 | 102.9 | 0.5 | 59.2 | 1.5 |
| 8/25/2018 | 103.9 | 0.9 | 59.6 | 0.7 |
| 7/23/2020 | 103.9 | 0.9 | 60.1 | 1.9 |

### *3.8.12 San Diego 5 NB Lane 2 – PM 35.8/37.4 – JPCP with CDG*

Table 3.70 summarizes the test results for this section.

**Table 3.70: Summary of Test Results for San Diego 5 NB Lane 2 – PM 35.8**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 102.9 | 0.8 | 62.5 | 2.3 |
| 11/20/2016 | 104.0 | 0.3 | 67.1 | 1.1 |
| 8/25/2018 | 105.3 | 0.8 | 71.1 | 2.8 |
| 7/23/2020 | 104.9 | 0.7 | 73.2 | 4.1 |

### *3.8.13 San Diego 5 NB Lane 3 – PM 35.8/37.4 – JPCP with CDG*

Table 3.71 summarizes the test results for this section.

**Table 3.71: Summary of Test Results for San Diego 5 NB Lane 3 – PM 35.8**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 102.5 | 1.1 | 60.6 | 1.9 |
| 11/20/2016 | 103.7 | 0.5 | 63.9 | 1.1 |
| 8/25/2018 | 105.0 | 1.0 | 63.2 | 0.6 |
| 7/23/2020 | 104.6 | 0.9 | 90.3 | 17.5 |

### *3.8.14 San Diego 5 NB Lane 4 – PM 35.8/37.4 – JPCP with CDG*

Table 3.72 summarizes the test results for this section.

**Table 3.72: Summary of Test Results for San Diego 5 NB Lane 4 – PM 35.8**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 103.7 | 0.7 | 57.3 | 1.8 |
| 11/20/2016 | 105.0 | 0.4 | 64.2 | 1.1 |
| 8/25/2018 | 106.4 | 0.7 | 66.5 | 1.5 |
| 7/23/2020 | 105.9 | 0.5 | 63.1 (110.8)[a] | 2.4 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.8.15 San Diego 5 NB Lane 5 – PM 35.8/37.4 – JPCP with CDG*

Table 3.73 summarizes the test results for this section.

**Table 3.73: Summary of Test Results for San Diego 5 NB Lane 5 – PM 35.8**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 103.3 | 0.6 | 60.5 | 0.5 |
| 11/20/2016 | 104.5 | 0.3 | 64.4 | 1.3 |
| 8/25/2018 | 105.8 | 0.7 | 67.3 | 0.6 |
| 7/23/2020 | 105.3 | 0.4 | 70.5 (102.3)[a] | 10.8 |

[a] Collected data replaced with data from the Automated Pavement Condition Survey; collected data shown in parentheses.

### *3.8.16 San Diego 5 SB Lane 1 – PM 37.9/36.3 – JPCP with CDG*

Table 3.74 summarizes the test results for this section.

**Table 3.74: Summary of Test Results for San Diego 5 SB Lane 1 – PM 37.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 101.8 | 1.3 | 60.5 | 0.8 |
| 11/20/2016 | 102.5 | 1.0 | 60.1 | 0.5 |
| 8/25/2018 | 103.3 | 1.2 | 65.1 | 1.9 |
| 7/23/2020 | 103.2 | 1.1 | 61.8 | 0.4 |

### *3.8.17 San Diego 5 SB Lane 2 – PM 37.9/36.3 – JPCP with CDG*

Table 3.75 summarizes the test results for this section.

**Table 3.75: Summary of Test Results for San Diego 5 SB Lane 2 – PM 37.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 102.8 | 1.0 | 57.6 | 0.4 |
| 11/20/2016 | 103.8 | 0.7 | 60.8 | 0.9 |
| 8/25/2018 | 104.7 | 1.2 | 66.1 | 0.3 |
| 7/23/2020 | 104.8 | 0.8 | 71.0 | 7.2 |

### *3.8.18 San Diego 5 SB Lane 3 – PM 37.9/36.3 – JPCP with CDG*

Table 3.76 summarizes the test results for this section.

**Table 3.76: Summary of Test Results for San Diego 5 SB Lane 3 – PM 37.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 102.6 | 0.9 | 62.7 | 0.8 |
| 11/20/2016 | 103.6 | 0.6 | 75.0 | 3.0 |
| 8/25/2018 | 104.8 | 0.9 | 72.7 | 0.6 |
| 7/23/2020 | 104.8 | 0.8 | 73.7 | 0.5 |

### *3.8.19 San Diego 5 SB Lane 4 – PM 37.9/36.3 – JPCP with CDG*

Table 3.77 summarizes the test results for this section.

**Table 3.77: Summary of Test Results for San Diego 5 SB Lane 4 – PM 37.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 103.5 | 0.7 | 61.3 | 0.9 |
| 11/20/2016 | 104.7 | 0.4 | 70.2 | 0.7 |
| 8/25/2018 | 105.8 | 0.7 | 69.4 | 1.0 |
| 7/23/2020 | 105.6 | 0.6 | 68.3 | 1.6 |

### *3.8.20 San Diego 5 SB Lane 5 – PM 37.9/36.3 – JPCP with CDG*

Table 3.78 summarizes the test results for this section.

**Table 3.78: Summary of Test Results for San Diego 5 SB Lane 5 – PM 37.9**

| Date | Average, OBSI (dBA) | Std. Dev., OBSI (dBA) | Average, IRI (in./mi.) | Std. Dev., IRI (in./mi.) |
|---|---|---|---|---|
| 8/8/2012 | 103.5 | 0.5 | 56.6 | 0.5 |
| 11/20/2016 | 104.8 | 0.5 | 62.2 | 0.6 |
| 8/25/2018 | 105.9 | 0.8 | 67.6 | 2.5 |
| 7/23/2020 | 104.7 | 1.4 | 63.9 | 3.1 |

# 4 ANALYSIS AND DISCUSSION

The results from the four rounds of testing are compared and analyzed in this chapter. Section 4.1 evaluates the OBSI values measured on these test sections, and Section **Error! Bookmark not defined.** compares the IRI values. Within each section, the measured data are first summarized over the study period from 2012 to 2020 and then evaluated versus time in years and versus traffic in millions of equivalent axle loads (mEALs).

Traffic calculations used two-way equivalent axle loads (EALs) estimated from Caltrans traffic and truck count data, like that shown with the test results in Chapter 3. The traffic was split according to direction and calculated for each interim period based on annual traffic counts and the dates of data collection. For the graphs, the EALs between the last retexturing and the first data collection were added, and they did not affect calculations of traffic change rates. Appendix D provides a discussion of the traffic estimates.

The analysis separates the data according to pavement and surface type, comparing the CRCP sections to the JPCP sections with CDG and the JPCP sections with GnG. Within each type, the data are then reviewed with respect to passenger car lanes and truck lanes.

## 4.1 On-Board Sound Intensity (OBSI) Data

Table 4.1 shows the OBSI data for all the sections following the initial section information from Table 2.3. The last column shows the difference between the first and final measurements. Table 4.2 presents the averages for the four pavement and surface types, for the two pavement types, and for the overall data set. Appendix A presents the longitudinal OBSI profile for each section.

Figure 4.1 presents the four OBSI data points for each section, with different marker types representing the pavement and surface types: triangles for the CRCP with LT sections, diamonds for the CRCP with CDG sections, squares for the JPCP with CDG sections, and circles for the JPCP with GnG sections. Figure 4.2 excludes two CRCP sections, Placer 80 and Kern 5, for a better view of the data and displays the center of the data for pavement and surface types.

**Table 4.1: OBSI Values for All Sections**

| Test Section Location | Length (mi.) | Pavement Type[a] | Surface Texture[b] | Lane Type[c] | Climate Region | Last Retexturing | 2012 OBSI (dBA) | 2016 OBSI (dBA) | 2018 OBSI (dBA) | 2020 OBSI (dBA) | OBSI Increase over 8 years[d] (dBA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pla80E1PM56.45 | 0.1 | CRCP | LT | P | High Mountain | 4/1/2012 | 106.7 | 109.1 | 113.3 | 113.5 | 6.8 |
| Sis5N2PM57.0 | 0.1 | CRCP | CDG | T | High Desert | 9/26/2007 | 104.3 | 105.0 | 108.0 | 106.5 | 2.1 |
| Ker5S2PM40.0 | 0.1 | CRCP | LT | T | Inland Valley | 8/23/2010 | 111.6 | 111.6 | 110.0 | 109.2 | -2.4 |
| SJ5N1PM32.0 | 0.1 | CRCP | CDG | P | Inland Valley | 1/26/2017 | | 103.6 | 105.2 | | 1.5 |
| Imp78E2PMR15.0 | 0.1 | CRCP | LT | T | Desert | 1/1/2012 | 101.6 | 101.8 | 102.5 | 102.6 | 1.0 |
| Imp86S2PMR24.2 | 0.1 | CRCP | LT | T | Desert | 1/2/2012 | 104.1 | 103.6 | 103.7 | 103.6 | -0.5 |
| Sac5N1PM20.0 | 1.5 | JPCP | GnG | P | Inland Valley | 7/1/2011 | 102.5 | 103.5 | 103.8 | 104.2 | 1.7 |
| Sac5N4PM20.0 | 1.5 | JPCP | GnG | T | Inland Valley | 7/1/2011 | 103.0 | 105.2 | 106.5 | 106.7 | 3.6 |
| Sac5S1PM21.5 | 1.5 | JPCP | CDG | P | Inland Valley | 7/1/2011 | 101.8 | 103.2 | 103.9 | 103.8 | 2.0 |
| Sac5S4PM21.5 | 1.5 | JPCP | CDG | T | Inland Valley | 7/1/2011 | 103.0 | 104.9 | 106.6 | 106.7 | 3.7 |
| Sac5N1PM1.5 | 1.5 | JPCP | GnG | P | Inland Valley | 12/1/2011 | 101.7 | 103.9 | 105.0 | 106.2 | 4.6 |
| Sac5N2PM1.5 | 1.5 | JPCP | GnG | T | Inland Valley | 12/1/2011 | 102.1 | 105.1 | 106.1 | 107.3 | 5.2 |
| Sac5S1PM3.0 | 1.5 | JPCP | CDG | P | Inland Valley | 12/1/2011 | 103.4 | 103.9 | 104.6 | 104.9 | 1.4 |
| Sac5S2PM3.0 | 1.5 | JPCP | CDG | T | Inland Valley | 12/1/2011 | 103.6 | 104.4 | 105.3 | 105.9 | 2.3 |
| Sac80E2PM13.0 | 1.0 | JPCP | GnG | P | Inland Valley | 5/1/2012 | 101.8 | 103.7 | 105.6 | 106.1 | 4.3 |
| Sac80E5PM13.0 | 1.0 | JPCP | GnG | T | Inland Valley | 5/1/2012 | 101.8 | 103.0 | 103.9 | 104.6 | 2.8 |
| Sac80W2PM14.0 | 1.0 | JPCP | GnG | P | Inland Valley | 5/1/2012 | 101.7 | 103.1 | 104.4 | 105.1 | 3.4 |
| Sac80W5PM14.0 | 1.0 | JPCP | GnG | T | Inland Valley | 5/1/2012 | 102.0 | 102.9 | 103.5 | 104.3 | 2.3 |
| Sac50E2PM13.0 | 1.0 | JPCP | CDG | P | Inland Valley | 6/1/2012 | 103.0 | 103.9 | 104.6 | 104.9 | 1.9 |
| Sac50E4PM13.0 | 1.0 | JPCP | CDG | T | Inland Valley | 6/1/2012 | 103.0 | 105.5 | 106.0 | 106.3 | 3.3 |
| Sac50W2PM14.0 | 1.0 | JPCP | GnG | P | Inland Valley | 6/1/2012 | 100.9 | 102.7 | 103.9 | 104.8 | 3.9 |
| Sac50W4PM14.0 | 1.0 | JPCP | GnG | T | Inland Valley | 6/1/2012 | 101.0 | 105.6 | 106.6 | 106.5 | 5.5 |
| SJ99N1PM29.0 | 1.7 | JPCP | GnG | P | Inland Valley | 7/1/2012 | 100.6 | 103.1 | 105.2 | 104.7 | 4.1 |
| SJ99N2PM29.0 | 1.7 | JPCP | GnG | T | Inland Valley | 7/1/2012 | 101.5 | 104.5 | 107.2 | 106.6 | 5.1 |
| Yol113N1PM0.5 | 1.0 | JPCP | GnG | P | Inland Valley | 4/1/2012 | 100.6 | 102.0 | 101.9 | 102.5 | 2.0 |
| Yol113N2PM0.5 | 1.0 | JPCP | GnG | T | Inland Valley | 4/1/2012 | 100.4 | 102.6 | 102.8 | 103.9 | 3.4 |
| Yol113S1PM0.9 | 0.5 | JPCP | GnG | P | Inland Valley | 4/1/2012 | 100.6 | 102.3 | 102.1 | 103.3 | 2.7 |
| Yol113S2PM0.9 | 0.5 | JPCP | GnG | T | Inland Valley | 4/1/2012 | 100.2 | 102.1 | 102.4 | 103.0 | 2.8 |
| Yol113N1PM1.5 | 1.0 | JPCP | CDG | P | Inland Valley | 4/1/2012 | 102.3 | 103.2 | 103.1 | 103.7 | 1.4 |
| Yol113N2PM1.5 | 1.0 | JPCP | CDG | T | Inland Valley | 4/1/2012 | 101.2 | 103.0 | 103.4 | 104.1 | 2.9 |

| Test Section Location | Length (mi.) | Pavement Type[a] | Surface Texture[b] | Lane Type[c] | Climate Region | Last Retexturing | 2012 OBSI (dBA) | 2016 OBSI (dBA) | 2018 OBSI (dBA) | 2020 OBSI (dBA) | OBSI Increase over 8 years[d] (dBA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yol113S1PM2.5 | 1.5 | JPCP | CDG | P | Inland Valley | 4/1/2012 | 101.4 | 102.2 | 101.9 | 102.5 | 1.1 |
| Yol113S2PM2.5 | 1.5 | JPCP | CDG | T | Inland Valley | 4/1/2012 | 101.6 | 102.9 | 103.1 | 103.8 | 2.2 |
| SD5N1PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 100.2 | 100.9 | 101.7 | 102.0 | 1.8 |
| SD5N2PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 100.9 | 102.2 | 103.3 | 103.7 | 2.8 |
| SD5N3PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 100.7 | 102.2 | 103.3 | 103.2 | 2.5 |
| SD5N4PM36.4 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 101.3 | 103.6 | 104.9 | 104.6 | 3.3 |
| SD5N5PM36.4 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 101.2 | 102.9 | 104.1 | 103.9 | 2.6 |
| SD5S1PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 100.4 | 101.1 | 101.9 | 102.0 | 1.6 |
| SD5S2PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 101.2 | 102.6 | 103.6 | 103.9 | 2.7 |
| SD5S3PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 101.0 | 102.4 | 103.3 | 103.5 | 2.5 |
| SD5S4PM37.3 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 101.5 | 102.7 | 103.8 | 104.1 | 2.7 |
| SD5S5PM37.3 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 101.0 | 102.5 | 103.7 | 103.8 | 2.8 |
| SD5N1PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 101.9 | 102.9 | 103.9 | 103.9 | 1.9 |
| SD5N2PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 102.9 | 104.0 | 105.3 | 104.9 | 2.0 |
| SD5N3PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 102.5 | 103.7 | 105.0 | 104.6 | 2.1 |
| SD5N4PM35.8/37.4 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 103.7 | 105.0 | 106.4 | 105.9 | 2.2 |
| SD5N5PM35.8/37.4 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 103.3 | 104.5 | 105.8 | 105.3 | 1.9 |
| SD5S1PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 101.8 | 102.5 | 103.3 | 103.2 | 1.5 |
| SD5S2PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 102.8 | 103.8 | 104.7 | 104.8 | 2.0 |
| SD5S3PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 102.6 | 103.6 | 104.8 | 104.8 | 2.2 |
| SD5S4PM37.9/36.3 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 103.5 | 104.7 | 105.8 | 105.6 | 2.1 |
| SD5S5PM37.9/36.3 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 103.5 | 104.8 | 105.9 | 104.7 | 1.1 |

[a] CRCP is continuously reinforced concrete pavement, and JPCP is jointed plain concrete pavement.
[b] LT is longitudinally tined, CDG is conventional diamond grinding, and GnG is grind and groove.
[c] Lane type is passenger (P) or truck (T).
[d] Apparent errors are due to rounding (i.e., for Sis5N2PM57.0, 106.47 – 104.34 = 2.13).

**Table 4.2: Average OBSI Values for Pavement Types and Surfaces**

| Pavement Types and Surfaces | 2012 OBSI (dBA) | 2016 OBSI (dBA) | 2018 OBSI (dBA) | 2020 OBSI (dBA) |
|---|---|---|---|---|
| **CRCP Sections** | **105.7** | **105.8** | **107.1** | **107.1** |
| w/ LT | 106.0 | 106.5 | 107.4 | 107.2 |
| w/ CDG | 104.3 | 104.3 | 106.6 | 106.5 |
| **JPCP Sections** | **101.8** | **103.4** | **104.3** | **104.5** |
| w/ CDG | 102.6 | 103.8 | 104.7 | 104.7 |
| w/ GnG | 101.2 | 103.1 | 104.0 | 104.4 |
| **All Sections Overall** | **102.2** | **103.6** | **104.6** | **104.8** |

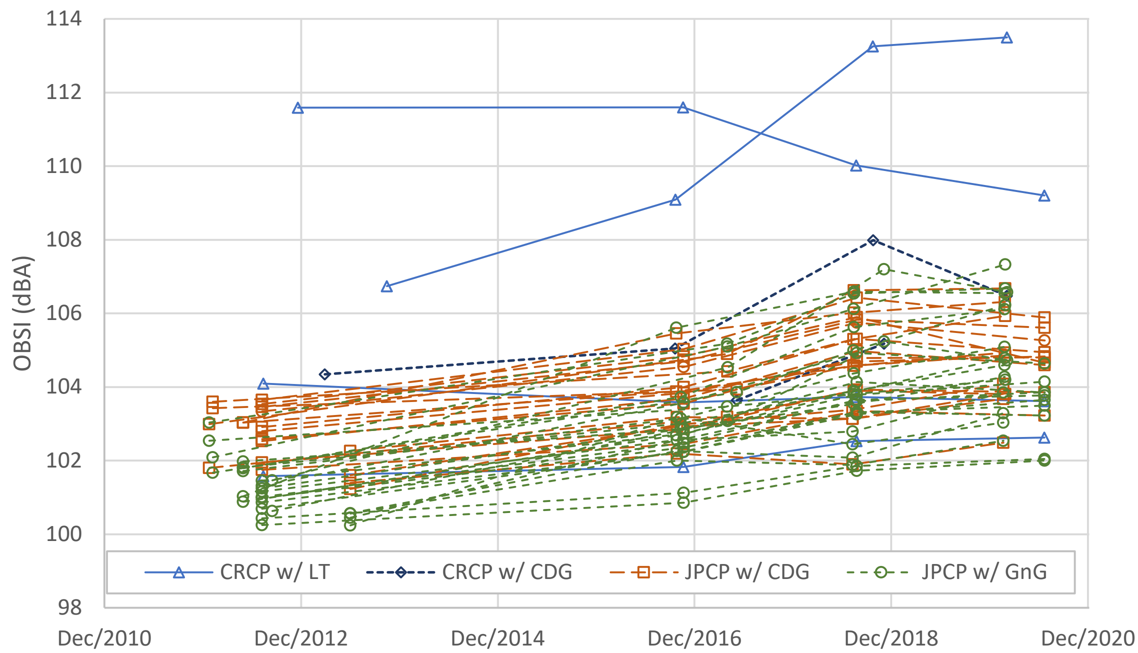



**Figure 4.1: OBSI measurements on all sections.**

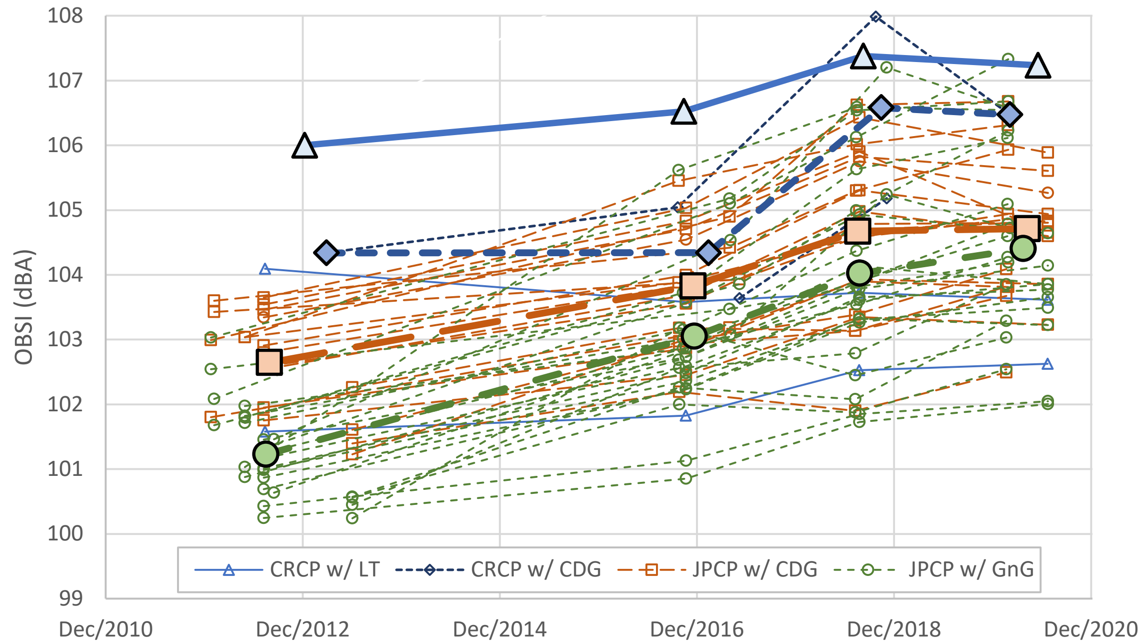



**Figure 4.2: OBSI measurements, except Placer 80 and Kern 5, with section type averages shown with heavy lines and large icons.**

The initial 2012 OBSI values range between 100.2 dBA and 111.6 dBA, and the final 2020 OBSI values range between 102.0 dBA and 113.5 dBA. Considering all sections and the first and last OBSI values, the OBSI change rate averaged 0.3 dBA/year and only exceeded 1.0 dBA/year on two CRCP sections, Placer 80 and San Joaquin 5. These are within the typical range of OBSI values for concrete pavement surfaces measured in similar studies *(3,12)*.

Figure 4.3 presents the four OBSI data points of each section like Figure 4.1 but with the OBSI graphed versus traffic. Figure 4.4 similarly presents the data of Figure 4.2, including the section type averages but with the OBSI versus traffic. With the OBSI values graphed versus cumulative traffic, the test sections with lower traffic counts appear to have higher rates of change of OBSI over the eight years between the first and last measurements. Yolo 113 and Imperial 78 each had less than two million EALs, and Placer 80 had less than six million EALs compared to the Sacramento 5 sections with 16 million EALs. Kern 5, with 12 million EALs, appears to get better with time and cumulative traffic.

Figure 4.5 simply presents the four rounds of average OBSI values for each pavement type and surface and the change rates, based on the time in years between the first and last data collections and the mEALs that occurred between the first and last data collections.

Overall, the CRCP sections exhibit higher OBSI values than the JPCP sections. From Table 4.1, all four rounds of testing resulted in average OBSI values above 103.0 dBA for each CRCP section, except for Imperial 78, which maintained OBSI values below 103.0 dBA throughout the four rounds of testing. Among the 52 sections, the only two sections that showed a decrease in the OBSI between the first and final rounds were CRCP sections, Kern 5 and Imperial 86.

From Figure 4.2 and Figure 4.5, one trend that can be seen is that the OBSI values for these pavement sections increased between 2012 and 2018 and leveled off between 2018 and 2020. The distinct outlier from Figure 4.1 is Kern 5, which starts as the test section with the highest OBSI, does not get any louder throughout the study, and concludes with an OBSI that is 2.4 dBA lower. Ultimately, Placer 80 ends up as the loudest test section in 2020. Another trend is that the CRCP with LT sections are louder than the CRCP with CDG sections; these sections are louder than the JPCP with CDG sections, which is louder than the JPCP with GnG sections. Figure 4.5 also shows the number of sections for each pavement type and surface; it should be noted that there are more JPCP sections than CRCP sections.

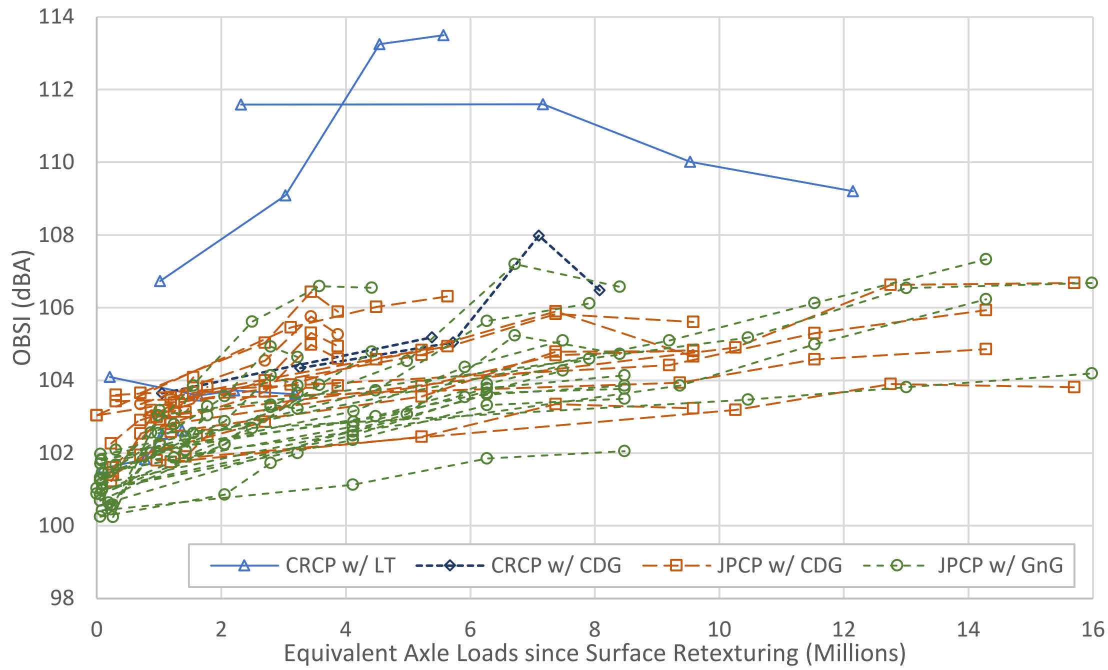



**Figure 4.3: OBSI Measurements versus traffic on all sections.**

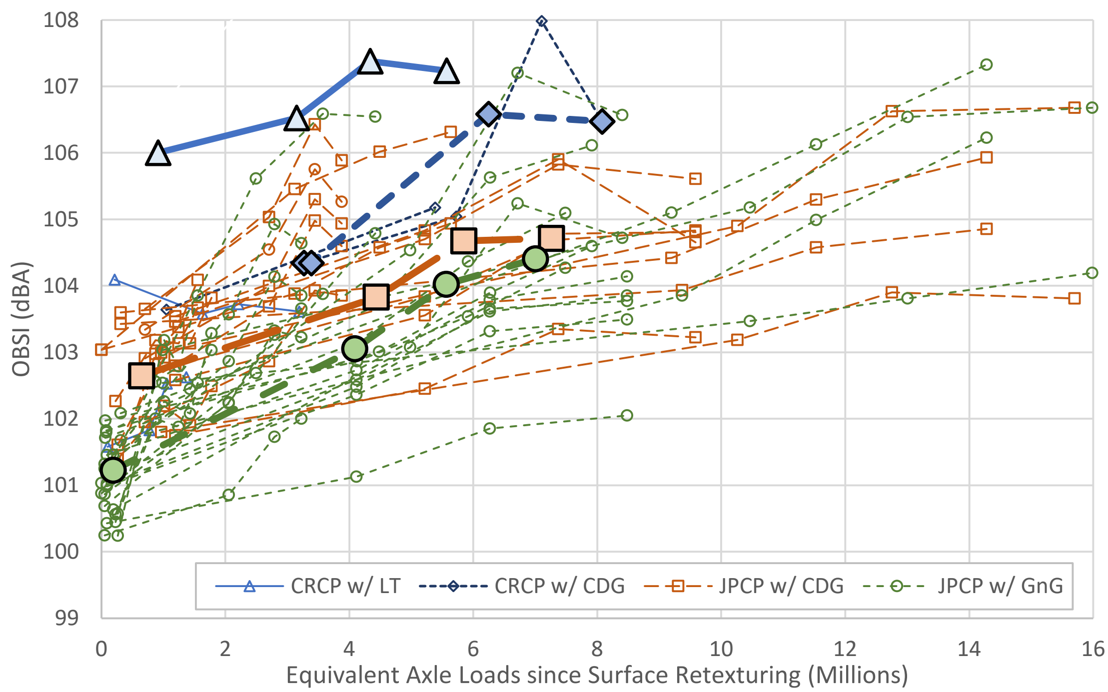
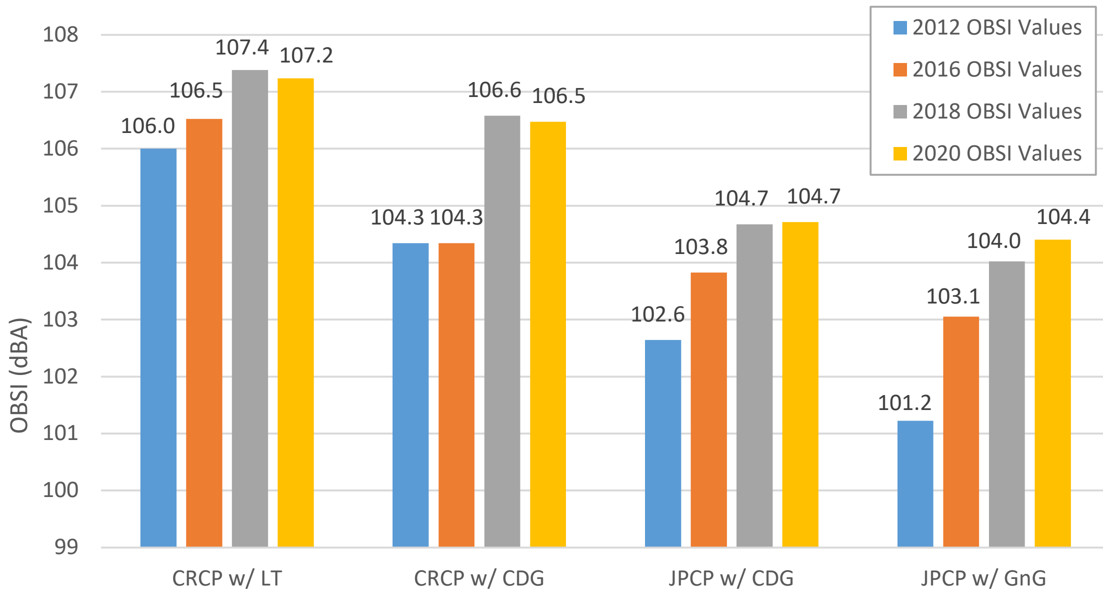



**Figure 4.4: OBSI versus traffic, except Placer 80 and Kern 5, with section type averages.**




| | CRCP w/ LT | CRCP w/ CDG | JPCP w/ CDG | JPCP w/ GnG |
|---|---|---|---|---|
| OBSI Annual Change Rate | 0.2 dBA/year | 0.7 dBA/year | 0.3 dBA/year | 0.4 dBA/year |
| OBSI Traffic Change Rate | 0.5 dBA/mEAL | 0.4 dBA/mEAL | 0.6 dBA/mEAL | 0.7 dBA/mEAL |
| Number of Sections | 4 | 2 | 20 | 26 |

**Figure 4.5: Average OBSI values and change rates for pavement types and surfaces.**

Table 4.3 shows the interim change rates for all the sections. The table is broken into three column sections: the first four columns show the changes in OBSI, the second four columns show the annual rate of change in dBA per year, and the last four columns show the traffic rate of change in dBA per millions of EALs. Within each set of four columns, the first three columns show the change from 2012 to 2016, 2016 to 2018, and 2018 to 2020; the fourth column shows the overall change between 2012 and 2020.

The annual rate of change is the difference in OBSI divided by the time difference in years between data collections. The traffic rate of change uses a calculation of millions of EALs associated with that section between data collections. Further discussion of the calculation of traffic loads can be found in Appendix D.

Table 4.4 presents the average values of the interim change rates for the four different pavement types and surfaces. The table also includes the averages of all the CRCP sections combined and all the JPCP sections combined, as well as the overall average for all sections in the bottom row. Between the first two rounds of data collection, from 2012 to 2016, the annual OBSI change rate was 0.19 dBA/year and 0.20 dBA/year for both CRCP surface types, with LT and CDG, respectively; 0.28 dBA/year for JPCP with CDG; and 0.41 dBA/year for JPCP with GnG.

The next interval, between 2016 and 2018, exhibited a 74% increase in the change rate for all sections, from 0.34 dBA/year to 0.59 dBA/year. The increase for the 46 JPCP sections was 62%, from 0.36 dBA/year to 0.58 dBA/year, and for the six CRCP sections, the increase was 368%, from 0.19 dBA/year to 0.69 dBA/year.

The change rates decreased for the last interval, between 2018 and 2020, and perhaps indicated some stability in the OBSI measurements. Reductions in the measured OBSI occurred on three of the six CRCP sections, and their average reduction in OBSI was 0.27 dBA/year. This compares to a 0.05 dBA/year increase for JPCP with CDG sections and a 0.24 dBA/year increase for the JPCP with GnG sections.

For sections overall and all four subgroups, the annual OBSI change rate between 2016 and 2018 was greatest, followed by the initial change rate from between 2012 and 2016; the final change rate from between 2018 and 2020 was the lowest. Considering the entire study period, the average annual OBSI change rate was 0.35 dBA/year for all the JPCP test sections. The rate of OBSI increase was higher for JPCP with GnG sections, at 0.41 dBA/year, compared with JPCP with CDG sections, at 0.27 dBA/year.

The two CRCP with CDG sections had an overall annual OBSI rate of 0.67 dBA/year, the highest rate among the four types of test sections; the four CRCP with LT sections had the lowest rate among the four types of test sections, at 0.21 dBA/year. The average of the six CRCP sections, at 0.36 dBA/year, was equivalent to that of the JPCP sections, at 0.35 dBA/year.

## Table 4.3: OBSI Interim Change Rates for All Sections

| Test Section Location | Interim Change in OBSI (dBA) | | | | Annual OBSI Change Rate (dBA/year) | | | | Traffic OBSI Change Rate (dBA/mEAL[a]) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-ALL (2012 – 2020) | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-ALL (2012 – 2020) | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-ALL (2012 – 2020) |
| Pla80E1PM56.45 | 2.4 | 4.2 | 0.2 | 6.8 | 0.8 | 2.1 | 0.2 | 1.1 | 1.2 | 2.8 | 0.2 | 1.5 |
| Sis5N2PM57.0 | 0.7 | 2.9 | -1.5 | 2.1 | 0.2 | 1.5 | -1.1 | 0.3 | 0.3 | 2.1 | -1.6 | 0.4 |
| Ker5S2PM40.0 | 0.0 | -1.6 | -0.8 | -2.4 | 0.0 | -0.9 | -0.4 | -0.3 | 0.0 | -0.7 | -0.3 | -0.2 |
| SJ5N1PM32.0 | | 1.5 | | 1.5 | | 1.0 | | 1.0 | | 0.4 | | 0.4 |
| Imp78E2PMR15.0 | 0.2 | 0.7 | 0.1 | 1.0 | 0.1 | 0.4 | 0.1 | 0.1 | 0.4 | 2.6 | 0.3 | 0.8 |
| Imp86S2PMR24.2 | -0.5 | 0.1 | -0.1 | -0.5 | -0.1 | 0.1 | -0.1 | -0.1 | -0.4 | 0.3 | -0.1 | -0.2 |
| Sac5N1PM20.0 | 0.9 | 0.3 | 0.4 | 1.7 | 0.2 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| Sac5N4PM20.0 | 2.1 | 1.4 | 0.1 | 3.6 | 0.4 | 1.1 | 0.1 | 0.4 | 0.2 | 0.5 | 0.0 | 0.2 |
| Sac5S1PM21.5 | 1.4 | 0.7 | -0.1 | 2.0 | 0.3 | 0.6 | -0.1 | 0.2 | 0.1 | 0.3 | 0.0 | 0.1 |
| Sac5S4PM21.5 | 1.9 | 1.7 | 0.1 | 3.7 | 0.4 | 1.3 | 0.0 | 0.4 | 0.2 | 0.7 | 0.0 | 0.2 |
| Sac5N1PM1.5 | 2.2 | 1.1 | 1.2 | 4.6 | 0.4 | 1.0 | 0.8 | 0.6 | 0.2 | 0.5 | 0.4 | 0.3 |
| Sac5N2PM1.5 | 3.0 | 1.0 | 1.2 | 5.2 | 0.6 | 0.8 | 0.8 | 0.6 | 0.3 | 0.4 | 0.4 | 0.4 |
| Sac5S1PM3.0 | 0.5 | 0.6 | 0.3 | 1.4 | 0.1 | 0.5 | 0.2 | 0.2 | 0.1 | 0.3 | 0.1 | 0.1 |
| Sac5S2PM3.0 | 0.8 | 0.9 | 0.6 | 2.3 | 0.2 | 0.7 | 0.4 | 0.3 | 0.1 | 0.4 | 0.2 | 0.2 |
| Sac80E2PM13.0 | 1.9 | 1.9 | 0.5 | 4.3 | 0.4 | 1.1 | 0.3 | 0.6 | 0.4 | 1.1 | 0.3 | 0.5 |
| Sac80E5PM13.0 | 1.2 | 0.9 | 0.7 | 2.8 | 0.3 | 0.5 | 0.5 | 0.4 | 0.3 | 0.5 | 0.4 | 0.4 |
| Sac80W2PM14.0 | 1.4 | 1.2 | 0.7 | 3.4 | 0.3 | 0.7 | 0.5 | 0.4 | 0.4 | 0.7 | 0.5 | 0.5 |
| Sac80W5PM14.0 | 0.9 | 0.7 | 0.7 | 2.3 | 0.2 | 0.4 | 0.5 | 0.3 | 0.2 | 0.4 | 0.5 | 0.3 |
| Sac50E2PM13.0 | 0.8 | 0.7 | 0.4 | 1.9 | 0.2 | 0.4 | 0.2 | 0.2 | 0.3 | 0.5 | 0.3 | 0.3 |
| Sac50E4PM13.0 | 2.4 | 0.6 | 0.3 | 3.3 | 0.5 | 0.3 | 0.2 | 0.4 | 0.8 | 0.4 | 0.3 | 0.6 |
| Sac50W2PM14.0 | 1.8 | 1.2 | 0.9 | 3.9 | 0.4 | 0.7 | 0.6 | 0.5 | 0.7 | 1.1 | 1.1 | 0.9 |
| Sac50W4PM14.0 | 4.6 | 1.0 | 0.0 | 5.5 | 1.0 | 0.5 | 0.0 | 0.7 | 1.8 | 0.9 | -0.1 | 1.2 |
| SJ99N1PM29.0 | 2.4 | 2.2 | -0.5 | 4.1 | 0.5 | 1.4 | -0.4 | 0.5 | 0.5 | 1.2 | -0.3 | 0.5 |
| SJ99N2PM29.0 | 3.1 | 2.7 | -0.6 | 5.1 | 0.7 | 1.7 | -0.5 | 0.7 | 0.6 | 1.5 | -0.4 | 0.6 |
| Yol113N1PM0.5 | 1.4 | -0.1 | 0.7 | 2.0 | 0.4 | -0.1 | 0.4 | 0.3 | 2.2 | -0.3 | 2.1 | 1.3 |
| Yol113N2PM0.5 | 2.1 | 0.2 | 1.1 | 3.4 | 0.6 | 0.1 | 0.7 | 0.4 | 3.3 | 0.6 | 3.4 | 2.2 |
| Yol113S1PM0.9 | 1.7 | -0.2 | 1.2 | 2.7 | 0.5 | -0.1 | 0.8 | 0.3 | 2.3 | -0.4 | 3.5 | 1.5 |
| Yol113S2PM0.9 | 1.8 | 0.4 | 0.6 | 2.8 | 0.6 | 0.2 | 0.4 | 0.4 | 2.5 | 0.9 | 1.7 | 1.6 |
| Yol113N1PM1.5 | 0.9 | 0.0 | 0.5 | 1.4 | 0.3 | 0.0 | 0.4 | 0.2 | 1.4 | -0.1 | 1.7 | 0.9 |
| Yol113N2PM1.5 | 1.7 | 0.4 | 0.7 | 2.9 | 0.5 | 0.2 | 0.5 | 0.4 | 2.7 | 1.1 | 2.3 | 1.8 |
| Yol113S1PM2.5 | 0.8 | -0.3 | 0.6 | 1.1 | 0.2 | -0.2 | 0.4 | 0.1 | 1.1 | -0.7 | 1.7 | 0.6 |

| Test Section Location | Interim Change in OBSI (dBA) | | | | Annual OBSI Change Rate (dBA/year) | | | | Traffic OBSI Change Rate (dBA/mEAL[a]) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-ALL (2012 – 2020) | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-ALL (2012 – 2020) | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-ALL (2012 – 2020) |
| Yol113S2PM2.5 | 1.3 | 0.2 | 0.7 | 2.2 | 0.4 | 0.1 | 0.4 | 0.3 | 1.8 | 0.5 | 2.0 | 1.2 |
| SD5N1PM36.4 | 0.6 | 0.9 | 0.3 | 1.8 | 0.1 | 0.5 | 0.1 | 0.2 | 0.3 | 1.2 | 0.6 | 0.5 |
| SD5N2PM36.4 | 1.4 | 1.0 | 0.4 | 2.8 | 0.3 | 0.6 | 0.2 | 0.3 | 0.7 | 1.4 | 0.9 | 0.9 |
| SD5N3PM36.4 | 1.6 | 1.1 | -0.1 | 2.5 | 0.4 | 0.6 | -0.1 | 0.3 | 0.8 | 1.5 | -0.2 | 0.8 |
| SD5N4PM36.4 | 2.2 | 1.4 | -0.3 | 3.3 | 0.5 | 0.8 | -0.1 | 0.4 | 1.1 | 1.8 | -0.7 | 1.0 |
| SD5N5PM36.4 | 1.6 | 1.3 | -0.3 | 2.6 | 0.4 | 0.7 | -0.1 | 0.3 | 0.8 | 1.7 | -0.7 | 0.8 |
| SD5S1PM37.3 | 0.7 | 0.7 | 0.2 | 1.6 | 0.2 | 0.4 | 0.1 | 0.2 | 0.2 | 0.3 | 0.1 | 0.2 |
| SD5S2PM37.3 | 1.4 | 1.0 | 0.2 | 2.7 | 0.3 | 0.6 | 0.1 | 0.3 | 0.4 | 0.5 | 0.1 | 0.3 |
| SD5S3PM37.3 | 1.4 | 1.0 | 0.2 | 2.5 | 0.3 | 0.5 | 0.1 | 0.3 | 0.3 | 0.4 | 0.1 | 0.3 |
| SD5S4PM37.3 | 1.3 | 1.1 | 0.4 | 2.7 | 0.3 | 0.6 | 0.2 | 0.3 | 0.3 | 0.5 | 0.2 | 0.3 |
| SD5S5PM37.3 | 1.5 | 1.2 | 0.1 | 2.8 | 0.3 | 0.7 | 0.1 | 0.3 | 0.4 | 0.5 | 0.1 | 0.3 |
| SD5N1PM35.8/37.4 | 0.9 | 1.1 | -0.1 | 1.9 | 0.2 | 0.6 | 0.0 | 0.2 | 0.5 | 1.4 | -0.2 | 0.5 |
| SD5N2PM35.8/37.4 | 1.1 | 1.3 | -0.4 | 2.0 | 0.3 | 0.7 | -0.2 | 0.2 | 0.5 | 1.8 | -0.8 | 0.5 |
| SD5N3PM35.8/37.4 | 1.2 | 1.3 | -0.4 | 2.1 | 0.3 | 0.7 | -0.2 | 0.2 | 0.6 | 1.7 | -0.9 | 0.5 |
| SD5N4PM35.8/37.4 | 1.4 | 1.4 | -0.5 | 2.2 | 0.3 | 0.8 | -0.3 | 0.2 | 0.7 | 1.9 | -1.3 | 0.6 |
| SD5N5PM35.8/37.4 | 1.2 | 1.2 | -0.5 | 1.9 | 0.3 | 0.7 | -0.3 | 0.2 | 0.6 | 1.6 | -1.1 | 0.5 |
| SD5S1PM37.9/36.3 | 0.7 | 0.9 | -0.1 | 1.5 | 0.2 | 0.5 | -0.1 | 0.2 | 0.2 | 0.4 | -0.1 | 0.2 |
| SD5S2PM37.9/36.3 | 1.0 | 0.8 | 0.1 | 2.0 | 0.2 | 0.5 | 0.1 | 0.2 | 0.3 | 0.4 | 0.1 | 0.2 |
| SD5S3PM37.9/36.3 | 1.0 | 1.2 | 0.0 | 2.2 | 0.2 | 0.7 | 0.0 | 0.2 | 0.2 | 0.6 | 0.0 | 0.2 |
| SD5S4PM37.9/36.3 | 1.2 | 1.1 | -0.2 | 2.1 | 0.3 | 0.6 | -0.1 | 0.2 | 0.3 | 0.5 | -0.1 | 0.2 |
| SD5S5PM37.9/36.3 | 1.3 | 1.1 | -1.2 | 1.1 | 0.3 | 0.6 | -0.7 | 0.1 | 0.3 | 0.5 | -0.6 | 0.1 |

[a] mEAL: millions of equivalent axle loads.

## Table 4.4: Average Interim OBSI Change Rates for Pavement Types and Surfaces

| Pavement Types and Surfaces | Interim Change in OBSI (dBA) | | | | | Annual OBSI Change Rate (dBA/year) | | | | | Traffic OBSI Change Rate (dBA/mEAL[a]) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-23 (2012 – 2018) | OBSI-ALL (2012 – 2020) | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-23 (2012 – 2018) | OBSI-ALL (2012 – 2020) | OBSI-2 (2012 – 2016) | OBSI-3 (2016 – 2018) | OBSI-4 (2018 – 2020) | OBSI-23 (2012 – 2018) | OBSI-ALL (2012 – 2020) |
| **CRCP** | **0.56** | **1.32** | **-0.42** | **1.78** | **1.44** | **0.19** | **0.69** | **-0.27** | **0.47** | **0.36** | **0.29** | **1.23** | **-0.29** | **0.63** | **0.45** |
| w/ LT | 0.52 | 0.86 | -0.14 | 1.38 | 1.24 | 0.19 | 0.41 | -0.06 | 0.28 | 0.21 | 0.29 | 1.22 | 0.03 | 0.61 | 0.48 |
| w/ CDG | 0.70 | 2.24 | -1.51 | 2.59 | 1.84 | 0.20 | 1.24 | -1.11 | 0.84 | 0.67 | 0.29 | 1.24 | -1.55 | 0.65 | 0.40 |
| **JPCP** | **1.52** | **0.94** | **0.23** | **2.46** | **2.70** | **0.36** | **0.58** | **0.15** | **0.41** | **0.35** | **0.74** | **0.74** | **0.39** | **0.71** | **0.66** |
| w/ CDG | 1.18 | 0.85 | 0.04 | 2.03 | 2.07 | 0.28 | 0.52 | 0.05 | 0.34 | 0.27 | 0.63 | 0.71 | 0.18 | 0.63 | 0.56 |
| w/ GnG | 1.78 | 1.01 | 0.38 | 2.80 | 3.18 | 0.41 | 0.62 | 0.24 | 0.46 | 0.41 | 0.82 | 0.76 | 0.55 | 0.77 | 0.74 |
| **Overall** | **1.43** | **0.99** | **0.17** | **2.38** | **2.55** | **0.34** | **0.59** | **0.11** | **0.41** | **0.35** | **0.70** | **0.79** | **0.32** | **0.70** | **0.64** |

[a] mEAL: millions of equivalent axle loads.

Looking at the OBSI change rates versus traffic in the last five columns of Table 4.4, the average over the entire study period is 0.64 dBA/million ESALs (mEAL) for all sections overall, 0.66 dBA/mEAL for JPCP sections, and 0.45 dBA/mEAL for CRCP sections. Using this metric, the JPCP with GnG sections had the highest traffic OBSI change rate at 0.74 dBA/mEAL, and the JPCP with CDG sections had a traffic OBSI change rate of 0.56 dBA/mEAL. The CRCP sections were lower, with 0.48 dBA/mEAL and 0.40 dBA/mEAL for CRCP sections with LT and CDG, respectively.

### *4.1.1 CRCP Sections*

Only five CRCP sections were tested in 2012 and 2013; four were surfaced with LT. Siskiyou 5 was the only CDG-textured section, as San Joaquin 5, the other CDG section, was still under construction. Four of the five CRCP sections tested in 2012 and 2013 are the only sections in this study with initial OBSI values over 104 dBA; the initial reading for Imperial 78 was 101.6 dBA. However, the CRCP sections performed very well.

The averages of all the 2012 and 2016 measurements on the CRCP sections were 105.7 dBA and 105.8 dBA, respectively, with a modest increase to 107.1 dBA for 2018 that held steady for 2020. Regardless of the surface texture, the average OBSI time change rate was 0.36 dBA/year, and the OBSI traffic change rate was 0.45 dBA/mEAL.

Two of the CRCP sections are noticeable in Figure 4.1; Kern 5 and Placer 80 both have data well above the rest. Although Kern 5 was the loudest section in the first two rounds at 111.6 dBA, there was a measured decrease in the OBSI to 109.2 dBA. Imperial 86 was the only other section that got quieter, by 0.5 dBA. Placer 80 started as the second loudest and concluded the study as the loudest section, increasing from 106.7 dBA to 113.5 dBA, with the largest increase in OBSI among all sections, 6.8 dBA.

While Placer 80 did show the largest time rate of increase at 1.1 dBA/year, it is located along a major trucking route in the High Mountain climate region where snow chains can be required. Exposure to chain wear may have also affected Siskiyou 5, located in the High Desert climate region, which showed the second highest change in OBSI among the CRCP sections at 2.1 dBA. The third largest increase of 1.5 dBA occurred on San Joaquin 5 over 18 months, resulting in the second largest time rate of 1.0 dBA/year.

Table 4.5 presents the first and last OBSI values and overall rate for the six CRCP sections and separates them according to surface texture (LT or CDG) and lane type (passenger or truck). Placer 80 and San Joaquin 5, with two instead of four rounds of data, are the only CRCP test section passenger lanes. Likewise, Siskiyou 5 and San Joaquin 5 are the only two CDG sections. With only two passenger lanes and two CRCP with CDG sections, it is difficult to make significant comparisons.

**Table 4.5: OBSI Summary Values for All CRCP Sections**

| Test Section Location | Passenger Lanes | | | | Truck Lanes | | | |
|---|---|---|---|---|---|---|---|---|
| | First OBSI (dBA) | Last OBSI (dBA) | Time Change Rate (dBA/yr) | Traffic Change Rate (dBA/mEAL) | First OBSI (dBA) | Last OBSI (dBA) | Time Change Rate (dBA/yr) | Traffic Change Rate (dBA/mEAL) |
| **CRCP w/ LT** | **106.7** | **113.5** | **1.1** | **1.5** | **105.8** | **105.1** | **-0.1** | **0.1** |
| Pla80E1PM56.45 | 106.7 | 113.5 | 1.1 | 1.5 | | | | |
| Ker5S2PM40.0 | | | | | 111.6 | 109.2 | -0.3 | -0.2 |
| Imp78E2PMR15.0 | | | | | 101.6 | 102.6 | 0.1 | 0.8 |
| Imp86S2PM24.2 | | | | | 104.1 | 103.6 | -0.1 | -0.2 |
| **CRCP w/ CDG** | **103.6** | **105.2** | **1.0** | **0.4** | **104.3** | **106.5** | **0.3** | **0.4** |
| Sis5N2PM57.0 | | | | | 104.3 | 106.5 | 0.3 | 0.4 |
| SJ5N1PM32.0[a] | 103.6 | 105.2 | 1.0 | 0.4 | | | | |

[a] For San Joaquin 5, the first OBSI was taken in 2017 and the last in 2018, for others the first is 2012 and the last is 2020.

Figure 4.5 shows that the CRCP with LT sections are the louder sections. However, with only two sections of CRCP with CDG, there is no clear difference between the noise values for the CRCP surface types.

The final OBSI measurements from the six CRCP sections are grouped into pairs. Placer 80 and Kern 5, two CRCP sections with LT surfaces, were the loudest at 113.5 dBA and 109.2 dBA, respectively; Siskiyou 5 and San Joaquin 5, two CRCP with CDG surfaces, are in the middle at 106.5 dBA and 105.2 dBA, respectively; and Imperial 86 and Imperial 78, the other two CRCP sections with LT surfaces, are the quietest at 103.6 dBA and 102.6 dBA, respectively.

### *4.1.2 JPCP Sections with CDG*

Five of the seven GnG pilot projects contain CDG surfaces as controls for comparison. Sacramento 80 and San Joaquin 99 only have the GnG surface. According to the data in Table 4.2, which shows the

JPCP section with CDG, and the findings from the earlier final concrete noise report,[1] the average 2012 OBSI value is 102.6 dBA. This value is lower than the 103.6 dBA average from the Year 1 data from the concrete noise study; however, both values fall within one standard deviation of each other. The 2016 average of 103.8 dBA is lower than the Year 4 data from the concrete noise study, 104.9 dBA, again within a standard deviation. The average after Year 6 and Year 8, 104.7 dBA for both 2018 and 2020, respectively, replicates the Year 4 data from the concrete noise study *(3)*. A difference may have been expected because the concrete noise study collected data on new and aged surfaces throughout the study, whereas the surfaces in this study are all new. However, the age of the pavement structure was not considered at this time.

Inclusion of new and aged surfaces may also explain the difference in the OBSI annual change rate. The OBSI annual change rate for CDG surfaces was reported as 0.8 dBA/year across the four-year study, much higher than the 0.3 dBA/year measured for this study after both Year 4 and Year 8.

Table 4.6 shows the OBSI values for all the JPCP sections with CDG surface textures as well as the OBSI time and traffic change rates, split between passenger and truck lanes. Figure 4.6 isolates the JPCP with CDG sections and distinguishes between the truck and passenger lanes, and Figure 4.7 shows the same OBSI data versus traffic. The OBSI values in the JPCP with CDG truck lanes are among the higher values measured throughout the study. Even the two truck lanes, Yol113N2 and Yol113S2, which have initial OBSI values below 102 dBA, conclude the study with values of 104 dBA.

While it is uncertain why these truck lanes started with lower OBSI values, there is much less truck traffic on these sections than on other sections in the study. The truck AADT for Yolo 113 remains around 2,000, whereas the Sacramento 5 and San Diego 5 sections have truck AADTs approaching 15,000 and 11,000, respectively. Possibly, the initial OBSI readings may be the result of recent construction and the "fins" from diamond grinding had not yet worn off. The 2 dBA plus increase in OBSI over the eight years occurs with less than 2 million equivalent axle loads.

[1] Table 5.1, Rezaei and Harvey (2013) *(3)*.

## Table 4.6: OBSI Values for All JPCP with CDG Sections

| Test Section Location | Passenger Lanes | | | | Truck Lanes | | | |
|---|---|---|---|---|---|---|---|---|
| | First OBSI (dBA) | Last OBSI (dBA) | Time Change Rate (dBA/yr.) | Traffic Change Rate (dBA/mEAL) | First OBSI (dBA) | Last OBSI (dBA) | Time Change Rate (dBA/yr.) | Traffic Change Rate (dBA/mEAL) |
| Sac5 S1 | 101.8 | 103.8 | 0.25 | 0.14 | | | | |
| Sac5 S4 | | | | | 103.0 | 106.7 | 0.46 | 0.25 |
| Sac5B S1 | 103.4 | 104.9 | 0.18 | 0.10 | | | | |
| Sac5B S2 | | | | | 103.6 | 105.9 | 0.29 | 0.17 |
| Sac50 E2 | 103.0 | 104.9 | 0.25 | 0.34 | | | | |
| Sac50 E4 | | | | | 103.0 | 106.3 | 0.42 | 0.58 |
| Yol113 N1 | 102.3 | 103.7 | 0.21 | 1.07 | | | | |
| Yol113 N2 | | | | | 101.2 | 104.1 | 0.43 | 2.16 |
| Yol113 S1 | 101.4 | 102.5 | 0.17 | 0.72 | | | | |
| Yol113 S2 | | | | | 101.6 | 103.8 | 0.33 | 1.46 |
| SD5 N1 | 101.9 | 103.9 | 0.24 | 0.60 | | | | |
| SD5 N2 | 102.9 | 104.9 | 0.26 | 0.64 | | | | |
| SD5 N3 | 102.5 | 104.6 | 0.26 | 0.65 | | | | |
| SD5 N4 | | | | | 103.7 | 105.9 | 0.28 | 0.70 |
| SD5 N5 | | | | | 103.3 | 105.3 | 0.24 | 0.61 |
| SD5 S1 | 101.8 | 103.2 | 0.19 | 0.18 | | | | |
| SD5 S2 | 102.8 | 104.8 | 0.26 | 0.24 | | | | |
| SD5 S3 | 102.6 | 104.8 | 0.28 | 0.26 | | | | |
| SD5 S4 | | | | | 103.5 | 105.6 | 0.27 | 0.26 |
| SD5 S5 | | | | | 103.5 | 104.7 | 0.14 | 0.13 |
| **Average** | **102.4** | **104.2** | **0.23** | **0.45** | **102.9** | **105.4** | **0.32** | **0.70** |

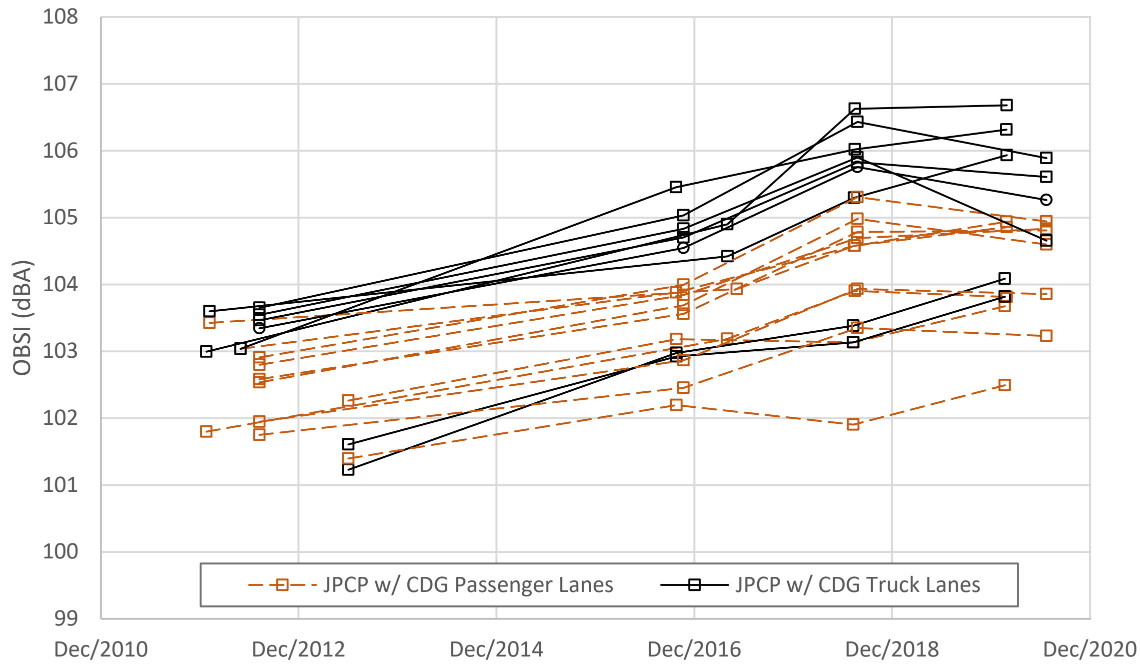



**Figure 4.6: OBSI on JPCP with CDG truck and passenger lanes.**

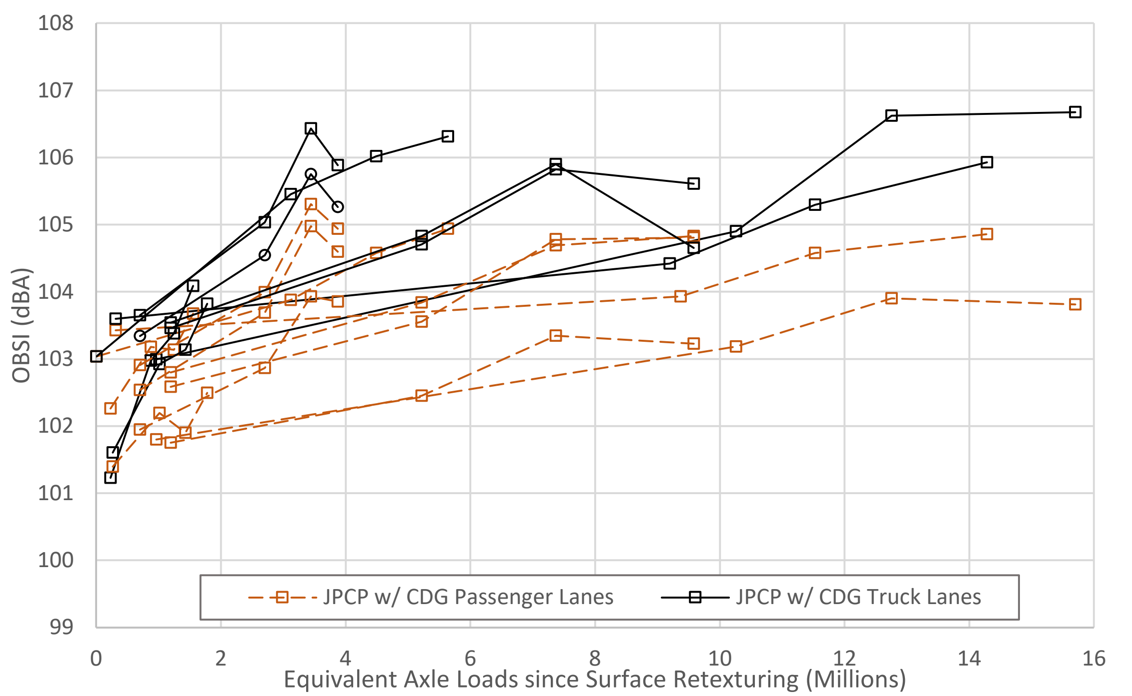



**Figure 4.7: OBSI versus traffic on JPCP with CDG truck and passenger lanes.**

Figure 4.8 presents the average OBSI values and change rates for passenger and truck lanes on JPCP with CDG sections. The averages show that the truck lanes' OBSI annual change rate is 39% greater than the annual change rate in the passenger lanes, at 0.23 dBA/year and 0.32 dBA/year, respectively. This may be an indication of the impact of truck traffic on concrete surface texture. Similarly, the OBSI traffic change rate is 56% greater than the traffic change rate in passenger lanes, at 0.45 dBA/mEAL and 0.70 dBA/mEAL, respectively.

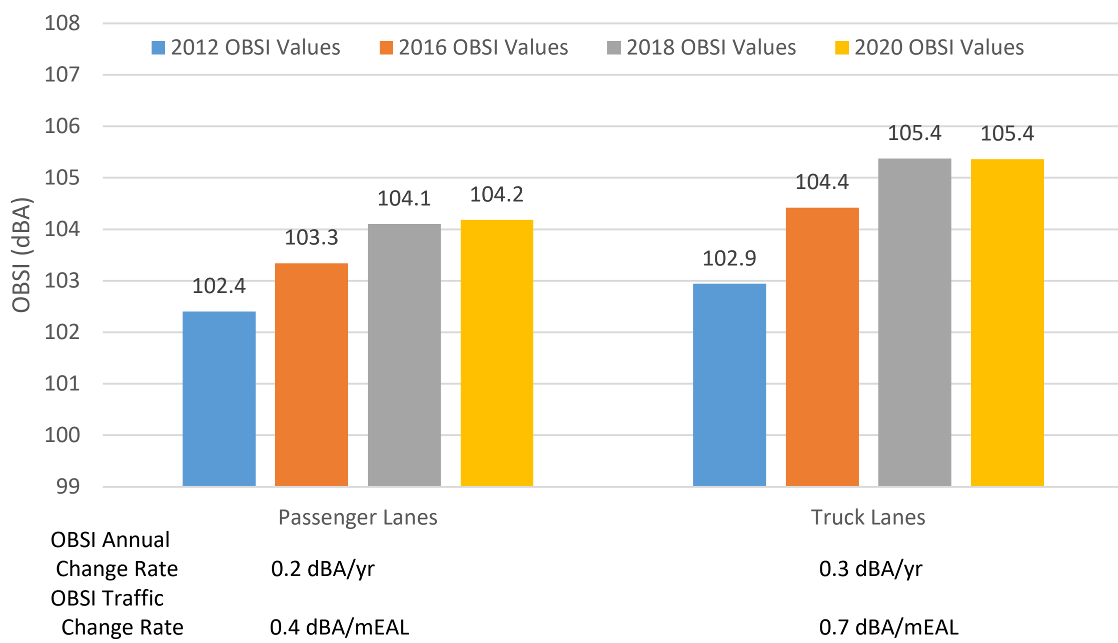



**Figure 4.8: Average OBSI and change rates for JPCP with CDG sections, passenger and truck lanes.**

### *4.1.3 JPCP Sections with GnG*

From Table 4.2, the average 2012 OBSI value of the JPCP with GnG sections, 101.2 dBA, is lower than the average from JPCP with CDG sections, 102.6 dBA, and the 2016 average of 103.1 dBA is lower than the average from JPCP with CDG sections, 103.8 dBA. The difference of 0.7 dBA was maintained in 2016, with values of 104.0 dBA to 104.7 dBA, and had reduced by the end of the study to 0.3 dBA, where JPCP with GnG sections averaged 104.4 dBA versus the JPCP with CDG sections, which had an average of 104.7 dBA. These average values fall within the range of values found outside the state *(4)*.

The differences between the averages of JPCP with LT and JPCP with CDG are less than humans can perceive *(13)*.

Comparing the OBSI time change rates from Table 4.4, the annual change rate for GnG sections is 0.41 dBA/year versus 0.28 dBA/year for CDG sections between the first two rounds of data. While these rates changed throughout the study, increasing between rounds two and three and falling more in the last interval, the overall annual change rate is identical to that reported after four years: 0.41 dBA/year for GnG sections versus 0.28 dBA/year for CDG sections.

Table 4.7 displays the OBSI values for all the JPCP sections with GnG surface textures, as well as the OBSI time and traffic change rates, split between passenger and truck lanes. Like the CDG sections after construction, there is little difference between the passenger and truck lanes of the GnG sections after construction, 101.1 dBA and 101.4 dBA, respectively.

Figure 4.9 isolates the JPCP with GnG sections and distinguishes between the truck and passenger lanes, and Figure 4.10 shows the same OBSI data versus traffic. Figure 4.11 shows the average OBSI values and change rates for passenger and truck lanes on JPCP with CDG sections.

By 2016, the difference between passenger and truck lanes grew to 1.1 dBA and stabilized for the remainder of the study. By 2020, the passenger lanes averaged 103.9 dBA while truck lanes averaged 104.9 dBA.

The effect of truck traffic may again be indicated by the difference in OBSI time change rates when comparing passenger lanes (0.38 dBA/year) to truck lanes (0.46 dBA/year). After the first two rounds of data and about four years of traffic, the average OBSI for GnG in the truck lanes is 103.5 dBA compared with 104.4 dBA for the CDG sections in this study. After eight years of traffic, the average OBSI for GnG in the truck lanes is 104.9 dBA compared with 105.4 dBA for the CDG sections in this study. This difference is less than humans can perceive *(12)*.

### Table 4.7: OBSI Values for All JPCP with GnG sections

| Test Section Location | Passenger Lanes | | | | Truck Lanes | | | |
|---|---|---|---|---|---|---|---|---|
| | First OBSI (dBA) | Last OBSI (dBA) | Time Change Rate (dBA/yr.) | Traffic Change Rate (dBA/mEAL) | First OBSI (dBA) | Last OBSI (dBA) | Time Change Rate (dBA/yr.) | Traffic Change Rate (dBA/mEAL) |
| Sac5 N1 | 102.5 | 104.2 | 0.20 | 0.11 | | | | |
| Sac5 N4 | | | | | 103.0 | 106.7 | 0.45 | 0.24 |
| Sac5B N1 | 101.7 | 106.2 | 0.57 | 0.33 | | | | |
| Sac5B N2 | | | | | 102.1 | 107.3 | 0.65 | 0.38 |
| Sac80 E2 | 101.8 | 106.1 | 0.56 | 0.55 | | | | |
| Sac80 E5 | | | | | 101.8 | 104.6 | 0.36 | 0.35 |
| Sac80 W2 | 101.7 | 105.1 | 0.44 | 0.46 | | | | |
| Sac80 W5 | | | | | 102.0 | 104.3 | 0.30 | 0.31 |
| Sac50 W2 | 100.9 | 104.8 | 0.50 | 0.88 | | | | |
| Sac50 W4 | | | | | 101.0 | 106.5 | 0.71 | 1.25 |
| SJ99 N1 | 100.6 | 104.7 | 0.55 | 0.50 | | | | |
| SJ99 N2 | | | | | 101.5 | 106.6 | 0.68 | 0.62 |
| Yol113 N1 | 100.6 | 102.5 | 0.30 | 1.50 | | | | |
| Yol113 N2 | | | | | 100.4 | 103.9 | 0.51 | 2.57 |
| Yol113 S1 | 100.6 | 103.3 | 0.41 | 1.79 | | | | |
| Yol113 S2 | | | | | 100.2 | 103.0 | 0.42 | 1.84 |
| SD5 N1 | 100.2 | 102.0 | 0.22 | 0.55 | | | | |
| SD5 N2 | 100.9 | 103.7 | 0.35 | 0.88 | | | | |
| SD5 N3 | 100.7 | 103.2 | 0.32 | 0.80 | | | | |
| SD5 N4 | | | | | 101.3 | 104.6 | 0.42 | 1.05 |
| SD5 N5 | | | | | 101.2 | 103.9 | 0.33 | 0.82 |
| SD5 S1 | 100.4 | 102.0 | 0.20 | 0.19 | | | | |
| SD5 S2 | 101.2 | 103.9 | 0.34 | 0.32 | | | | |
| SD5 S3 | 101.0 | 103.5 | 0.32 | 0.30 | | | | |
| SD5 S4 | | | | | 101.5 | 104.1 | 0.34 | 0.32 |
| SD5 S5 | | | | | 101.0 | 103.8 | 0.35 | 0.33 |
| **Average** | **101.1** | **103.9** | **0.38** | **0.65** | **101.4** | **104.9** | **0.46** | **0.84** |

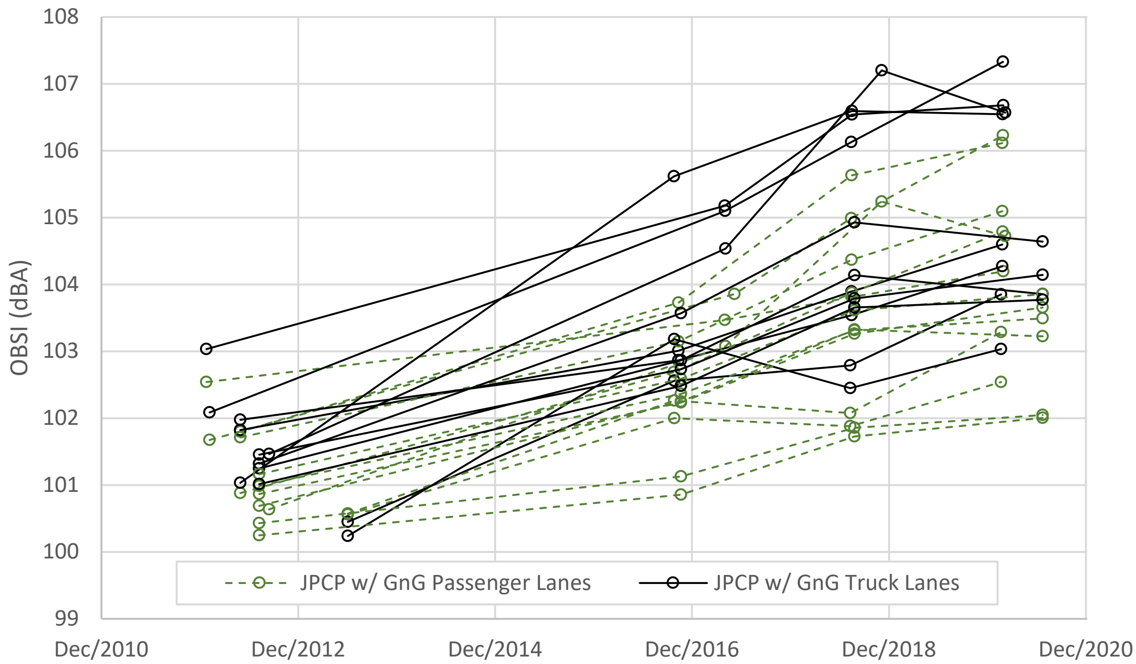



**Figure 4.9: OBSI on JPCP with GnG truck and passenger lanes.**

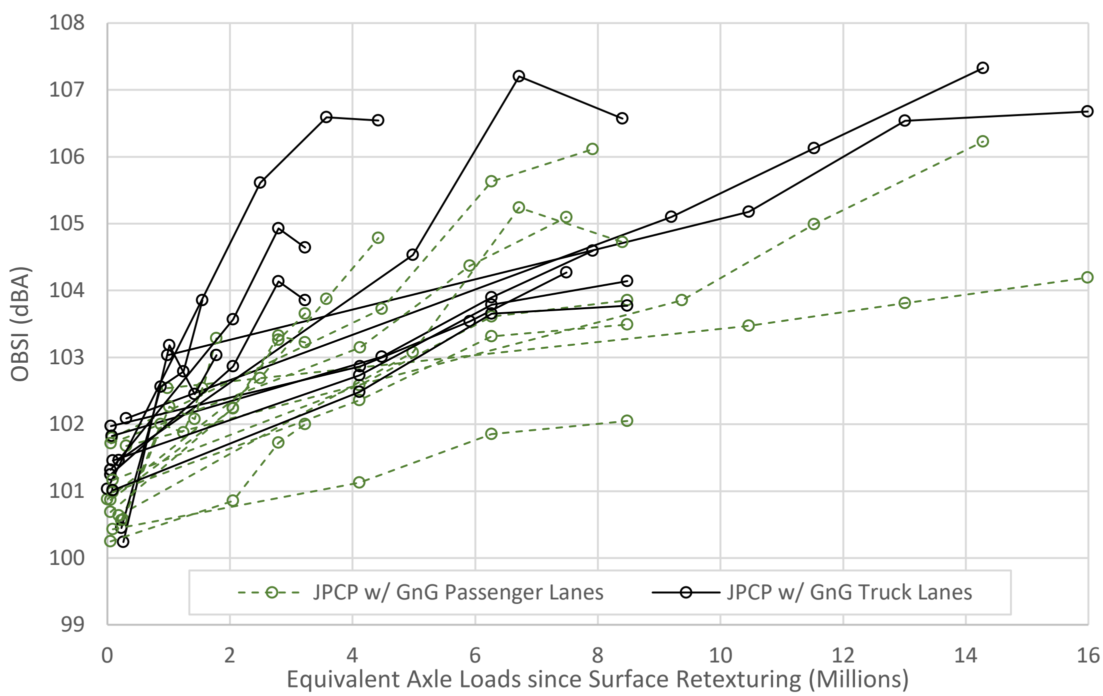



**Figure 4.10: OBSI versus traffic on JPCP with GnG truck and passenger lanes.**

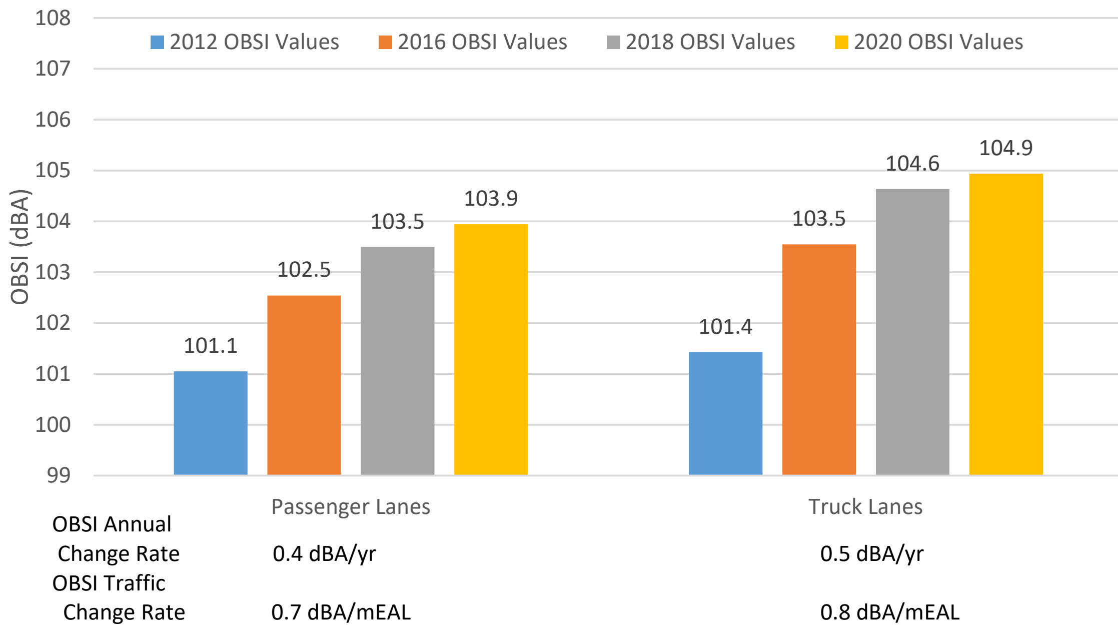



**Figure 4.11: Average OBSI and change rates for JPCP with GnG sections, passenger and truck lanes.**

## 4.2 International Roughness Index (IRI) Data

Table 4.8 shows the IRI data for all sections, along with the initial section information from Table 2.3. The last column shows the increase in IRI between the first and final IRI measurements. Some measurements taken during the 2020 data collection were unreasonably high and were replaced with data from the Automated Pavement Condition Survey, when available; these data are marked with asterisks. Table 4.9 presents the average IRI values for the four pavement and surface types, for the two pavement types, and the overall data set. Appendix A presents the figures of IRI data for selected sections.

It is known that concrete pavement roughness can vary depending on the time of day and season because of thermal gradients (daily) and drying shrinkage gradients (seasonal and after rain events), causing changes in the slab shape. While environmental conditions were recorded—including the time of day, air temperature, and pavement surface temperature—temperature gradients, which may affect daily and seasonal curling, were not considered in this report.

Table 4.10 shows the interim change rates for all the sections. The table is divided into three column sections: the first four columns show the changes in IRI, the second four columns show the annual rate of change in inches per mile per year, and the last four columns show the traffic rate of change in inches per mile per millions of EALs. Within each set of four columns, the first three columns show the change from 2012 to 2016, from 2016 to 2018, and from 2018 to 2020; the fourth column shows the overall change between 2012 and 2020.

The annual rate of change is the difference in IRI divided by the time difference in years between data collections. The traffic rate of change uses a calculation of millions of EALs associated with that section between data collections. Further discussion of the calculation of traffic can be found in Appendix D.

Table 4.11 presents the average values of the interim change rates for the four different pavement types and surfaces. The table also includes the averages of all the CRCP sections combined and all the JPCP sections combined, as well as the overall average for all sections in the bottom row.

## Table 4.8: IRI Values for All Sections

| Test Section Location | Length (mi.) | Pavement Type[a] | Surface Texture[b] | Lane Type[c] | Climate Region | Last Retexturing | 2012 IRI (in./mi.) | 2016 IRI (in./mi.) | 2018 IRI (in./mi.) | 2020 IRI[d] (in./mi.) | IRI Increase over 8 years[e] (in./mi.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pla80E1PM56.45 | 0.1 | CRCP | LT | P | High Mountain | 4/1/2012 | 74 | 81 | 81 | 84* | 10 |
| Sis5N2PM57.0 | 0.1 | CRCP | CDG | T | High Desert | 9/26/2007 | 65 | 50 | 54 | 63* | -2 |
| Ker5S2PM40.0 | 0.1 | CRCP | LT | T | Inland Valley | 8/23/2010 | 90 | 77 | 70 | 72* | -18 |
| SJ5N1PM32.0 | 0.1 | CRCP | CDG | P | Inland Valley | 1/26/2017 | | 65 | 66 | | 1 |
| Imp78E2PMR15.0 | 0.1 | CRCP | LT | T | Desert | 1/1/2012 | 54 | 70 | 70 | 67 | 13 |
| Imp86S2PMR24.2 | 0.1 | CRCP | LT | T | Desert | 1/2/2012 | 50 | 51 | 55 | 53 | 2 |
| Sac5N1PM20.0 | 1.5 | JPCP | GnG | P | Inland Valley | 7/1/2011 | 42 | 46 | 53 | 106 | 64 |
| Sac5N4PM20.0 | 1.5 | JPCP | GnG | T | Inland Valley | 7/1/2011 | 52 | 63 | 76 | 129 | 77 |
| Sac5S1PM21.5 | 1.5 | JPCP | CDG | P | Inland Valley | 7/1/2011 | 82 | 78 | 91 | 119 | 36 |
| Sac5S4PM21.5 | 1.5 | JPCP | CDG | T | Inland Valley | 7/1/2011 | 75 | 98 | 104 | 127 | 52 |
| Sac5N1PM1.5 | 1.5 | JPCP | GnG | P | Inland Valley | 12/1/2011 | 43 | 47 | 46 | 49* | 6 |
| Sac5N2PM1.5 | 1.5 | JPCP | GnG | T | Inland Valley | 12/1/2011 | 48 | | 62 | * | 14 |
| Sac5S1PM3.0 | 1.5 | JPCP | CDG | P | Inland Valley | 12/1/2011 | 63 | 61 | 62 | 66* | 3 |
| Sac5S2PM3.0 | 1.5 | JPCP | CDG | T | Inland Valley | 12/1/2011 | 65 | 61 | 97 | * | 32 |
| Sac80E2PM13.0 | 1.0 | JPCP | GnG | P | Inland Valley | 5/1/2012 | 34 | 35 | 45 | 59 | 25 |
| Sac80E5PM13.0 | 1.0 | JPCP | GnG | T | Inland Valley | 5/1/2012 | 42 | 49 | 58 | 52* | 11 |
| Sac80W2PM14.0 | 1.0 | JPCP | GnG | P | Inland Valley | 5/1/2012 | 42 | 46 | 57 | 48 | 6 |
| Sac80W5PM14.0 | 1.0 | JPCP | GnG | T | Inland Valley | 5/1/2012 | 48 | 66 | 74 | 76 | 28 |
| Sac50E2PM13.0 | 1.0 | JPCP | CDG | P | Inland Valley | 6/1/2012 | 77 | 78 | 74 | 65* | -12 |
| Sac50E4PM13.0 | 1.0 | JPCP | CDG | T | Inland Valley | 6/1/2012 | 77 | 70 | 74 | 76* | -1 |
| Sac50W2PM14.0 | 1.0 | JPCP | GnG | P | Inland Valley | 6/1/2012 | 63 | 63 | 61 | 63 | 1 |
| Sac50W4PM14.0 | 1.0 | JPCP | GnG | T | Inland Valley | 6/1/2012 | 52 | 85 | 92 | 91 | 39 |
| SJ99N1PM29.0 | 1.7 | JPCP | GnG | P | Inland Valley | 7/1/2012 | 44 | 44 | 45 | 54* | 10 |
| SJ99N2PM29.0 | 1.7 | JPCP | GnG | T | Inland Valley | 7/1/2012 | 73 | 80 | 82 | 88* | 15 |
| Yol113N1PM0.5 | 1.0 | JPCP | GnG | P | Inland Valley | 4/1/2012 | 53 | 49 | 46 | 49* | -4 |
| Yol113N2PM0.5 | 1.0 | JPCP | GnG | T | Inland Valley | 4/1/2012 | 48 | 52 | 47 | 60* | 12 |
| Yol113S1PM0.9 | 0.5 | JPCP | GnG | P | Inland Valley | 4/1/2012 | 59 | 46 | 46 | 61* | 2 |
| Yol113S2PM0.9 | 0.5 | JPCP | GnG | T | Inland Valley | 4/1/2012 | 54 | 52 | 60 | 78* | 25 |
| Yol113N1PM1.5 | 1.0 | JPCP | CDG | P | Inland Valley | 4/1/2012 | 50 | 47 | 46 | 52* | 2 |
| Yol113N2PM1.5 | 1.0 | JPCP | CDG | T | Inland Valley | 4/1/2012 | 47 | 55 | 55 | 61* | 15 |
| Yol113S1PM2.5 | 1.5 | JPCP | CDG | P | Inland Valley | 4/1/2012 | 50 | 56 | 56 | 59* | 8 |

| Test Section Location | Length (mi.) | Pavement Type[a] | Surface Texture[b] | Lane Type[c] | Climate Region | Last Retexturing | 2012 IRI (in./mi.) | 2016 IRI (in./mi.) | 2018 IRI (in./mi.) | 2020 IRI[d] (in./mi.) | IRI Increase over 8 years[e] (in./mi.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yol113S2PM2.5 | 1.5 | JPCP | CDG | T | Inland Valley | 4/1/2012 | 68 | 75 | 81 | 58* | -10 |
| SD5N1PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 41 | 40 | 42 | 66 | 25 |
| SD5N2PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 44 | 49 | 55 | 51 | 7 |
| SD5N3PM36.4 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 38 | 48 | 45 | 61 | 23 |
| SD5N4PM36.4 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 39 | 50 | 53 | 52* | 13 |
| SD5N5PM36.4 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 38 | 51 | 60 | 63* | 25 |
| SD5S1PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 37 | 40 | 44 | 44 | 7 |
| SD5S2PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 36 | 44 | 46 | 48 | 12 |
| SD5S3PM37.3 | 1.0 | JPCP | GnG | P | South Coast | 7/1/2012 | 41 | 49 | 50 | 50 | 9 |
| SD5S4PM37.3 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 38 | 52 | 57 | 60 | 22 |
| SD5S5PM37.3 | 1.0 | JPCP | GnG | T | South Coast | 7/1/2012 | 45 | 61 | 76 | 76 | 31 |
| SD5N1PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 57 | 59 | 60 | 60 | 3 |
| SD5N2PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 63 | 67 | 71 | 73 | 11 |
| SD5N3PM35.8/37.4 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 61 | 64 | 63 | 90 | 30 |
| SD5N4PM35.8/37.4 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 57 | 64 | 67 | 63* | 6 |
| SD5N5PM35.8/37.4 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 60 | 64 | 67 | 70* | 10 |
| SD5S1PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 61 | 60 | 65 | 62 | 1 |
| SD5S2PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 58 | 61 | 66 | 71 | 13 |
| SD5S3PM37.9/36.3 | 1.0 | JPCP | CDG | P | South Coast | 4/1/2011 | 63 | 75 | 73 | 74 | 11 |
| SD5S4PM37.9/36.3 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 61 | 70 | 69 | 68 | 7 |
| SD5S5PM37.9/36.3 | 1.0 | JPCP | CDG | T | South Coast | 4/1/2011 | 57 | 62 | 68 | 64 | 7 |

[a] CRCP is continuously reinforced concrete pavement, and JPCP is jointed plain concrete pavement.
[b] LT is longitudinally tined, CDG is conventional diamond grinding, and GnG is grind and groove.
[c] Lane Type is Passenger (P) or Truck (T).
[d] Collected data that was unreasonable are marked with an asterisk and were replaced with data from the Automated Pavement Condition Survey where available.
[e] Apparent errors are due to rounding (i.e., for Imp86S2PMR24.2, 50.3 – 52.7 = 2.4).

## Table 4.9: Average IRI Values for Pavement Types and Surfaces

| Pavement Types and Surfaces | 2012 IRI (inch/mile) | 2016 IRI (inch/mile) | 2018 IRI (inch/mile) | 2020 IRI (inch/mile) |
|---|---|---|---|---|
| **CRCP Sections** | **67** | **66** | **66** | **68** |
| w/ LT | 67 | 70 | 69 | 69 |
| w/ CDG | 65 | 57 | 60 | 63 |
| **JPCP Sections** | **53** | **58** | **63** | **68** |
| w/ CDG | 63 | 66 | 70 | 73 |
| w/ GnG | 46 | 52 | 57 | 65 |
| **All Sections Overall** | **54** | **59** | **63** | **68** |

## Table 4.10: IRI Interim Change Rates for All Sections

| Test Section Location | Interim Change in IRI (inch/mile) | | | | Annual IRI Change Rate (inch/mile/year) | | | | Traffic IRI Change Rate (inch/mile/mEAL[a]) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-ALL (2012 – 2020) | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-ALL (2012 – 2020) | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-ALL (2012 – 2020) |
| Pla80E1PM56.45 | 6 | 0 | 4 | 10 | 2.2 | -0.1 | 2.6 | 1.6 | 3.2 | -0.1 | 3.5 | 2.2 |
| Sis5N2PM57.0 | -15 | 5 | 9 | -2 | -4.3 | 2.4 | 6.3 | -0.3 | -6.2 | 3.5 | 8.8 | -0.4 |
| Ker5S2PM40.0 | -12 | -7 | 1 | -18 | -3.1 | -3.9 | 0.7 | -2.3 | -2.5 | -2.9 | 0.5 | -1.8 |
| SJ5N1PM32.0 | | 1 | | 1 | | 0.5 | | 0.5 | | 0.2 | | 0.2 |
| Imp78E2PMR15.0 | 16 | 0 | -2 | 13 | 3.8 | -0.3 | -1.3 | 1.6 | 23.7 | -1.7 | -7.7 | 10.3 |
| Imp86S2PMR24.2 | 1 | 4 | -2 | 2 | 0.2 | 2.0 | -1.1 | 0.3 | 0.6 | 6.2 | -2.1 | 0.8 |
| Sac5N1PM20.0 | 4 | 7 | 53 | 64 | 0.8 | 5.6 | 34.5 | 7.9 | 0.4 | 2.8 | 17.8 | 4.3 |
| Sac5N4PM20.0 | 11 | 14 | 53 | 77 | 2.0 | 10.6 | 34.4 | 9.5 | 1.1 | 5.4 | 17.7 | 5.1 |
| Sac5S1PM21.5 | -4 | 13 | 27 | 36 | -0.9 | 10.3 | 17.9 | 4.5 | -0.5 | 5.3 | 9.3 | 2.5 |
| Sac5S4PM21.5 | 23 | 6 | 22 | 52 | 4.4 | 4.7 | 14.6 | 6.4 | 2.5 | 2.4 | 7.6 | 3.5 |
| Sac5N1PM1.5 | 4 | -1 | 3 | 6 | 0.7 | -0.6 | 2.1 | 0.8 | 0.4 | -0.3 | 1.2 | 0.5 |
| Sac5N2PM1.5 | | | | 14 | | | | 2.1 | | | | 1.2 |
| Sac5S1PM3.0 | -2 | 2 | 4 | 3 | -0.4 | 1.4 | 2.3 | 0.4 | -0.3 | 0.8 | 1.3 | 0.2 |
| Sac5S2PM3.0 | -4 | 36 | 0 | 32 | -0.8 | 28.4 | 0.0 | 5.0 | -0.4 | 15.6 | 0.0 | 2.9 |
| Sac80E2PM13.0 | 1 | 10 | 13 | 25 | 0.3 | 5.8 | 8.8 | 3.2 | 0.3 | 5.7 | 8.2 | 3.2 |
| Sac80E5PM13.0 | 7 | 9 | -5 | 11 | 1.6 | 5.2 | -3.6 | 1.4 | 1.6 | 5.1 | -3.3 | 1.3 |
| Sac80W2PM14.0 | 4 | 11 | -9 | 6 | 0.9 | 6.4 | -6.2 | 0.7 | 1.0 | 6.3 | -6.0 | 0.8 |
| Sac80W5PM14.0 | 18 | 8 | 2 | 28 | 4.2 | 4.3 | 1.4 | 3.6 | 4.5 | 4.2 | 1.3 | 3.8 |
| Sac50E2PM13.0 | 1 | -3 | -10 | -12 | 0.2 | -1.9 | -6.3 | -1.6 | 0.2 | -2.5 | -8.4 | -2.2 |
| Sac50E4PM13.0 | -7 | 4 | 3 | -1 | -1.6 | 2.0 | 1.8 | -0.1 | -2.3 | 2.7 | 2.3 | -0.2 |

| Test Section Location | Interim Change in IRI (inch/mile) | | | | Annual IRI Change Rate (inch/mile/year) | | | | Traffic IRI Change Rate (inch/mile/mEAL[a]) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-ALL (2012 – 2020) | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-ALL (2012 – 2020) | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-ALL (2012 – 2020) |
| Sac50W2PM14.0 | 1 | -3 | 3 | 1 | 0.2 | -1.5 | 1.6 | 0.1 | 0.3 | -2.5 | 3.0 | 0.1 |
| Sac50W4PM14.0 | 32 | 7 | -1 | 39 | 7.3 | 3.9 | -0.4 | 5.0 | 12.9 | 6.6 | -0.7 | 8.8 |
| SJ99N1PM29.0 | 0 | 1 | 9 | 10 | 0.0 | 0.5 | 7.2 | 1.3 | 0.0 | 0.5 | 5.3 | 1.2 |
| SJ99N2PM29.0 | 7 | 2 | 6 | 15 | 1.6 | 1.3 | 4.8 | 2.0 | 1.5 | 1.2 | 3.6 | 1.9 |
| Yol113N1PM0.5 | -4 | -3 | 4 | -4 | -1.3 | -1.8 | 2.4 | -0.6 | -6.7 | -8.7 | 11.9 | -2.9 |
| Yol113N2PM0.5 | 5 | -6 | 13 | 12 | 1.5 | -3.2 | 8.4 | 1.8 | 7.5 | -15.4 | 41.5 | 9.1 |
| Yol113S1PM0.9 | -13 | 0 | 15 | 2 | -3.9 | -0.1 | 10.0 | 0.3 | -17.2 | -0.5 | 43.4 | 1.4 |
| Yol113S2PM0.9 | -2 | 8 | 18 | 25 | -0.5 | 4.5 | 12.0 | 3.7 | -2.3 | 19.3 | 52.2 | 16.2 |
| Yol113N1PM1.5 | -4 | -1 | 7 | 2 | -1.1 | -0.5 | 4.3 | 0.3 | -5.6 | -2.7 | 21.3 | 1.6 |
| Yol113N2PM1.5 | 8 | 0 | 7 | 15 | 2.4 | 0.0 | 4.4 | 2.2 | 12.2 | 0.0 | 21.8 | 11.0 |
| Yol113S1PM2.5 | 6 | 0 | 2 | 8 | 1.7 | 0.1 | 1.6 | 1.2 | 7.5 | 0.3 | 6.8 | 5.4 |
| Yol113S2PM2.5 | 7 | 6 | -23 | -10 | 2.0 | 3.3 | -14.7 | -1.5 | 8.9 | 14.4 | -64.3 | -6.5 |
| SD5N1PM36.4 | -1 | 2 | 24 | 25 | -0.2 | 1.0 | 12.8 | 3.2 | -0.5 | 2.3 | 56.4 | 7.9 |
| SD5N2PM36.4 | 6 | 6 | -4 | 7 | 1.3 | 3.1 | -2.3 | 0.8 | 2.8 | 7.5 | -10.1 | 2.1 |
| SD5N3PM36.4 | 10 | -3 | 16 | 23 | 2.4 | -1.5 | 8.1 | 2.9 | 5.2 | -3.6 | 35.9 | 7.3 |
| SD5N4PM36.4 | 11 | 3 | -1 | 13 | 2.6 | 1.6 | -0.4 | 1.6 | 5.5 | 3.9 | -1.9 | 4.1 |
| SD5N5PM36.4 | 13 | 9 | 3 | 25 | 3.0 | 5.1 | 1.8 | 3.2 | 6.4 | 12.1 | 7.7 | 7.9 |
| SD5S1PM37.3 | 3 | 4 | 0 | 7 | 0.6 | 2.3 | 0.0 | 0.8 | 0.7 | 1.9 | 0.0 | 0.8 |
| SD5S2PM37.3 | 8 | 2 | 2 | 12 | 1.9 | 0.9 | 1.0 | 1.5 | 2.0 | 0.7 | 0.9 | 1.4 |
| SD5S3PM37.3 | 8 | 2 | 0 | 9 | 1.8 | 1.0 | -0.1 | 1.2 | 1.9 | 0.8 | -0.1 | 1.1 |
| SD5S4PM37.3 | 13 | 6 | 3 | 22 | 3.1 | 3.2 | 1.5 | 2.7 | 3.3 | 2.6 | 1.3 | 2.6 |
| SD5S5PM37.3 | 15 | 15 | 0 | 31 | 3.6 | 8.8 | -0.2 | 3.8 | 3.8 | 7.2 | -0.2 | 3.6 |
| SD5N1PM35.8/37.4 | 2 | 0 | 1 | 3 | 0.4 | 0.2 | 0.3 | 0.3 | 0.9 | 0.5 | 1.2 | 0.8 |
| SD5N2PM35.8/37.4 | 5 | 4 | 2 | 11 | 1.1 | 2.3 | 1.1 | 1.3 | 2.3 | 5.4 | 4.8 | 3.3 |
| SD5N3PM35.8/37.4 | 3 | -1 | 27 | 30 | 0.8 | -0.4 | 14.2 | 3.7 | 1.7 | -0.9 | 62.6 | 9.4 |
| SD5N4PM35.8/37.4 | 7 | 2 | -3 | 6 | 1.6 | 1.3 | -1.8 | 0.7 | 3.4 | 3.2 | -7.9 | 1.8 |
| SD5N5PM35.8/37.4 | 4 | 3 | 3 | 10 | 0.9 | 1.7 | 1.7 | 1.3 | 1.9 | 3.9 | 7.4 | 3.1 |
| SD5S1PM37.9/36.3 | 0 | 5 | -3 | 1 | -0.1 | 2.9 | -1.7 | 0.2 | -0.1 | 2.3 | -1.5 | 0.2 |
| SD5S2PM37.9/36.3 | 3 | 5 | 5 | 13 | 0.7 | 3.0 | 2.6 | 1.7 | 0.8 | 2.5 | 2.2 | 1.6 |
| SD5S3PM37.9/36.3 | 12 | -2 | 1 | 11 | 2.9 | -1.3 | 0.5 | 1.4 | 3.1 | -1.1 | 0.4 | 1.3 |
| SD5S4PM37.9/36.3 | 9 | -1 | -1 | 7 | 2.1 | -0.5 | -0.6 | 0.9 | 2.2 | -0.4 | -0.5 | 0.8 |
| SD5S5PM37.9/36.3 | 6 | 5 | -4 | 7 | 1.3 | 3.0 | -1.9 | 0.9 | 1.4 | 2.5 | -1.7 | 0.9 |

[a] mEAL: millions of equivalent axle loads.

## Table 4.11: Average Interim IRI Change Rates for Pavement Types and Surfaces

| Pavement Types and Surfaces | Interim Change in IRI (inch/mile) | | | | | Annual IRI Change Rate (inch/mile/year) | | | | | Traffic IRI Change Rate (inch/mile/mEAL[a]) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-23 (2012 – 2018) | IRI-ALL (2012 – 2020) | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-23 (2012 – 2018) | IRI-ALL (2012 – 2020) | IRI-2 (2012 – 2016) | IRI-3 (2016 – 2018) | IRI-4 (2018 – 2020) | IRI-23 (2012 – 2018) | IRI-ALL (2012 – 2020) |
| **CRCP** | **-0.8** | **0.3** | **1.8** | **-0.4** | **1.1** | **-0.2** | **0.1** | **1.5** | **0.0** | **0.2** | **3.8** | **0.9** | **0.6** | **2.5** | **1.9** |
| w/ LT | 2.8 | -1.0 | 0.1 | 1.8 | 1.9 | 0.8 | -0.6 | 0.2 | 0.3 | 0.3 | 6.3 | 0.4 | -1.4 | 4.4 | 2.9 |
| w/ CDG | -15.3 | 2.8 | 8.5 | -4.9 | -0.6 | -4.3 | 1.4 | 6.3 | -0.7 | 0.1 | -6.2 | 1.8 | 8.8 | -1.3 | -0.1 |
| **JPCP** | **5.2** | **4.3** | **6.5** | **9.6** | **15.8** | **1.2** | **2.8** | **4.1** | **1.5** | **2.0** | **1.7** | **2.6** | **8.0** | **1.9** | **3.0** |
| w/ CDG | 3.6 | 4.2 | 3.5 | 7.8 | 11.2 | 0.9 | 3.0 | 2.1 | 1.3 | 1.5 | 2.0 | 2.7 | 3.4 | 2.1 | 2.1 |
| w/ GnG | 6.4 | 4.4 | 8.8 | 10.9 | 19.4 | 1.4 | 2.6 | 5.6 | 1.7 | 2.5 | 1.5 | 2.6 | 11.5 | 1.8 | 3.6 |
| **Overall** | **4.6** | **3.8** | **6.0** | **8.4** | **14.1** | **1.0** | **2.5** | **3.8** | **1.4** | **1.8** | **1.9** | **2.4** | **7.2** | **2.0** | **2.8** |

[a] mEAL: millions of equivalent axle loads.

The initial 2012 IRI values range between 34 in./mi. and 90 in./mi., with all sections considered in "good" condition, with IRI values between 60 and 94 in./mi., according to the Federal Highway Administration *(14)*. By 2016, only Sac5S4PM21.5 had moved from "good" condition to "acceptable" condition, with an IRI value between 95 and 170 in./mi. In 2018, Sac5S2PM3.0 also became "acceptable," with an IRI value of 97 in./mi. By 2020, the range of IRI values was between 44 in./mi. and 129 in./mi., with five of 52 sections having IRI values above 95, all four sections of Sacramento 5 – PM20.0/21.5 and Sac5S2PM3.0.

From Table 4.9, the average IRI values from the CRCP sections (67 in./mi.) are higher than those from the JPCP sections (53 in./mi.) initially, but the average final values are both 68 in./mi. The JPCP sections with the GnG surface have the lowest IRI (46 in./mi.) initially, display the highest change rates, and conclude with IRI values (65 in./mi.) similar to the CRCP sections (68 in./mi.) after eight years. It should be noted that the JPCP sections were mostly existing pavements that were resurfaced, while the CRCP sections were primarily new pavement or pavement that was only a few years old, and the last retexturing was during their initial construction.

From Table 4.11, the IRI on the CRCP sections on average did not change significantly for the first two intervals, decreasing negligibly by 0.8 in./mi., from 67 in./mi. to 66 in./mi., between 2012 and 2016, and increasing 0.3 in./mi. between 2016 and 2018. Between 2018 and 2020, an increase of 1.8 in./mi. resulted in a final measurement of 68 in./mi. The overall change from 67 in./mi. to 68 in./mi. represented an annual change rate of 0.2 in./mi./year and a traffic change rate of 1.9 in./mi./mEAL.

For the JPCP sections, on average, the IRI increased about 5 in./mi. between each testing interval: 5.2 in./mi. in the first interval, 4.5 in./mi. in the second interval, and 6.5 in./mi. in the final interval. For the JPCP sections, on average, the IRI increased from 53 in./mi. to 68 in./mi. over the eight years, representing an annual change rate of 2.0 in./mi. per year and a traffic change rate of 3.0 in./mi. per mEAL.

Considering the first and last IRI values for all sections, the average annual IRI change rate was 1.7 in./mi./year and 2.8 in./mi./mEAL. For the CRCP sections, the average annual IRI change rate was only 0.3 in./mi./year and 1.9 in./mi./mEAL, while for the JPCP sections, the average annual IRI change rate was 1.9 in./mi./year and 2.9 in./mi./mEAL. Again, it should be noted that the JPCP sections had mostly been constructed years before their resurfacing and the commencement of measurements for this study.

Figure 4.12 presents the four IRI data points of each section, with different marker types representing the pavement and surface types: triangles for the CRCP with LT sections, diamonds for the CRCP with CDG sections, squares for the JPCP with CDG sections, and circles for the JPCP with GnG sections. Figure 4.13 displays the IRI data versus millions of EALs. Figure 4.14 and Figure 4.15 both present the same data with the section type averages.

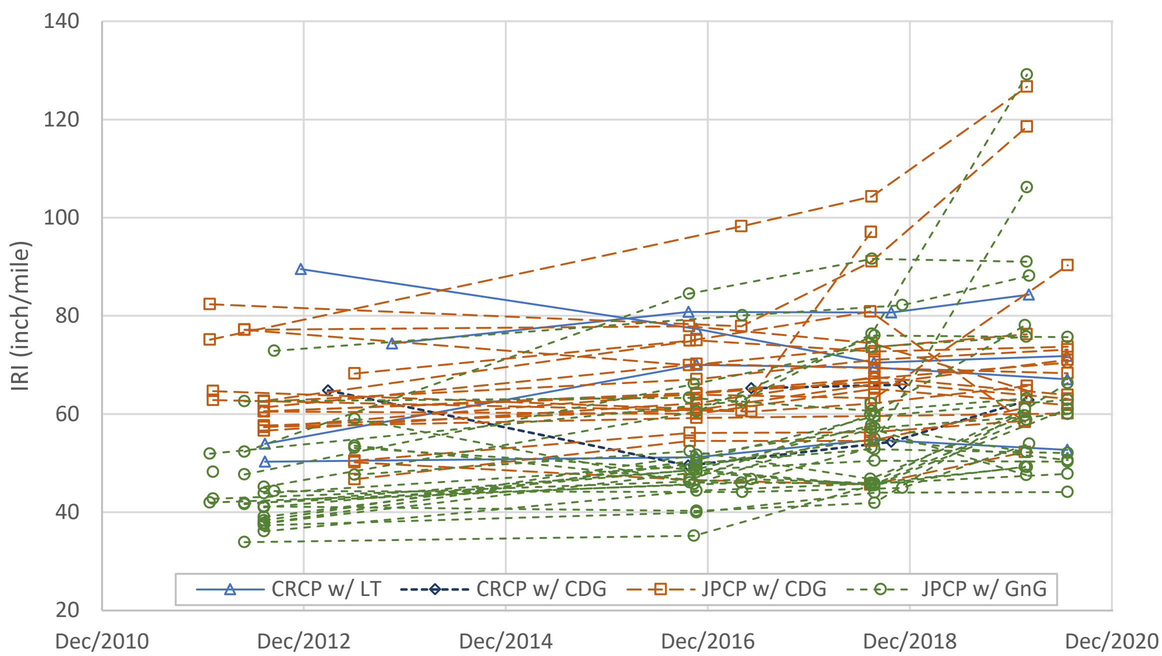



**Figure 4.12: IRI measurements on all sections.**

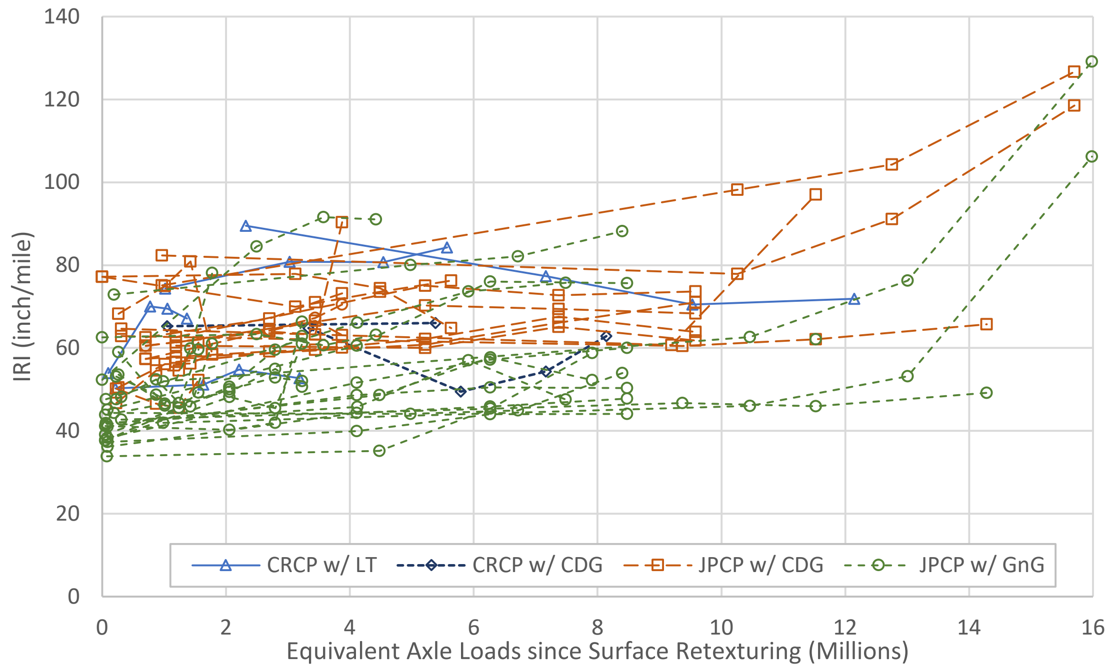



**Figure 4.13: IRI measurements versus traffic on all sections.**

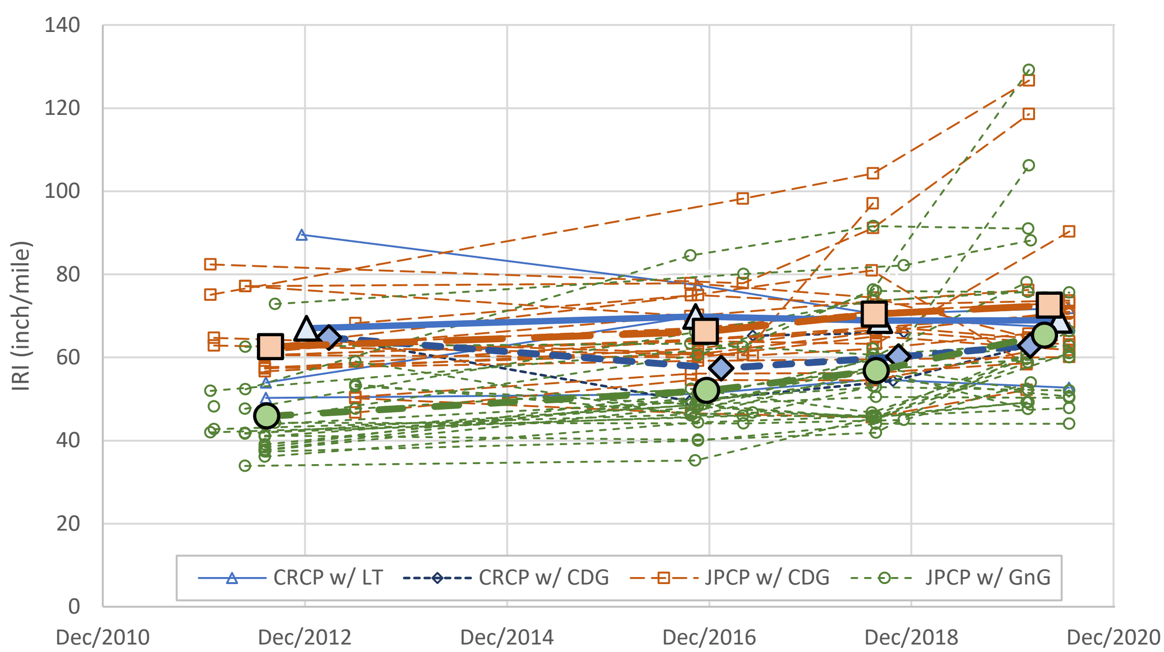



**Figure 4.14: IRI measurements with section type averages.**

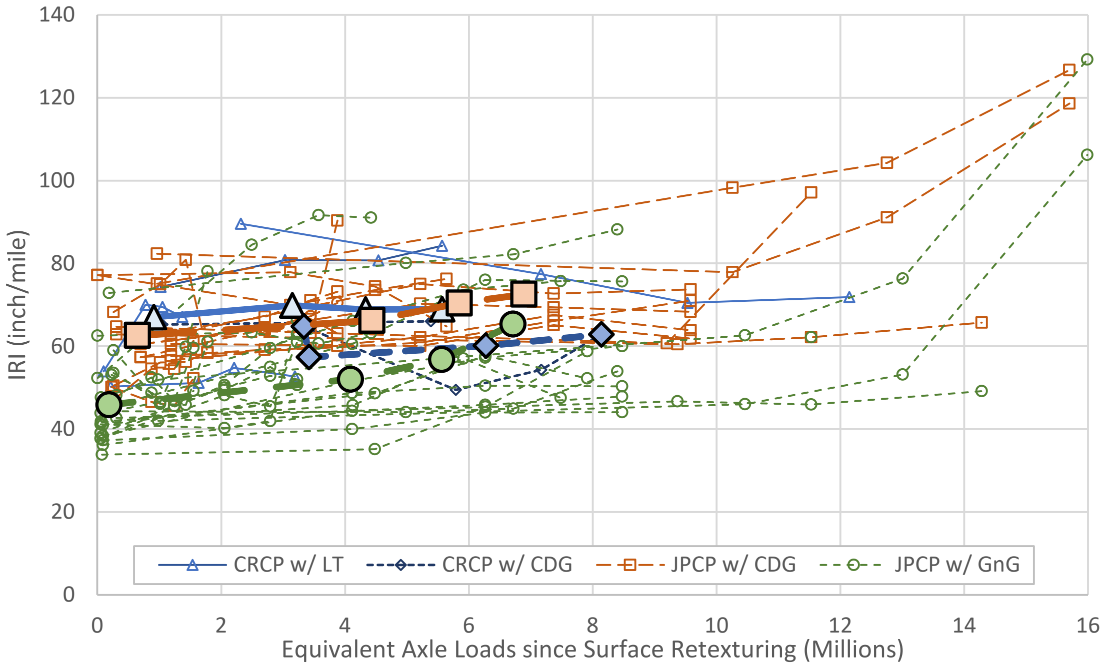



**Figure 4.15: IRI versus traffic with section type averages.**

Figure 4.16 presents the average IRI values for pavement types and surfaces and for time and traffic change rates, measured in in./mi./year and in./mi./mEAL, respectively.

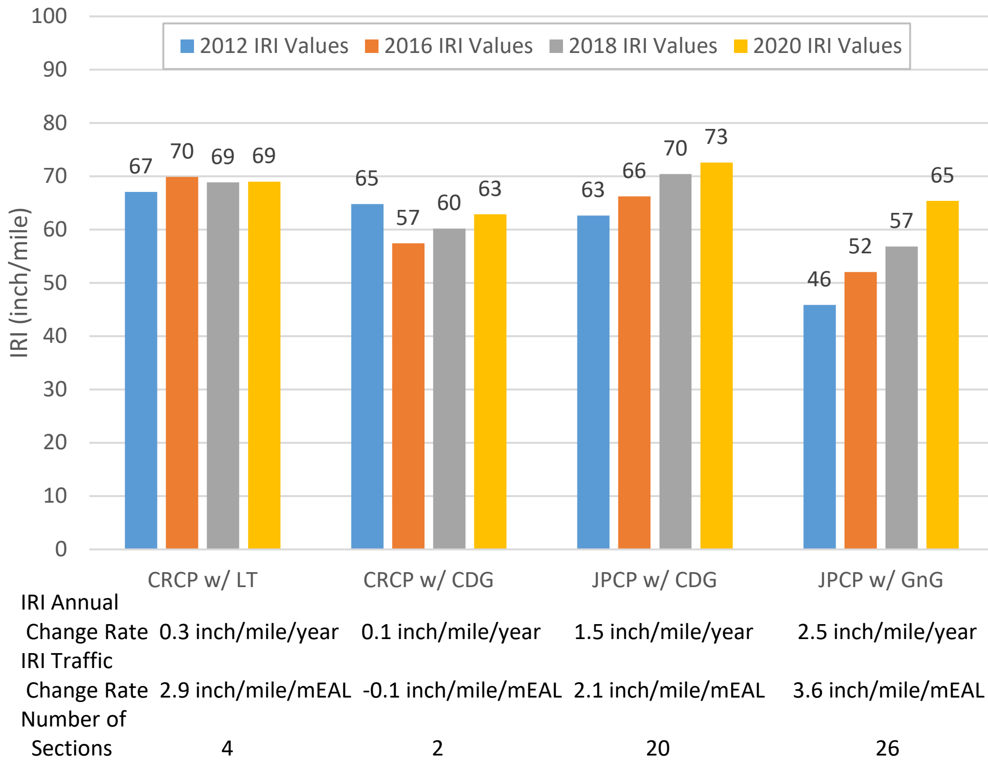



**Figure 4.16: Average IRI values for pavement types and surfaces.**

The JPCP with GnG sections had the lowest IRI for each round of the study and the highest change rates at 2.5 in./mi./year and 3.6 in./mi./mEAL. The CRCP with LT sections had the highest IRI for the first two rounds, 67 in./mi. in 2012 and 70 in./mi. in 2016, but displayed some durability with IRI values consistent for the remainder of the study at 69 in./mi. The JPCP with CDG sections concluded with the highest IRI in 2020, 73 in./mi., and the JPCP with GnG sections concluded with an average IRI value of 65 in./mi., just above the 63 in./mi. average IRI value for the CRCP with CDG sections.

### *4.2.1 CRCP Sections*

Table 4.12 displays the first and last IRI values for the CRCP sections, as well as the time and traffic change rates, separated by truck and passenger lanes. With only two passenger lanes and two CRCP with CDG sections, it is difficult to make significant comparisons. Overall, the CRCP sections performed very well in terms of smoothness. Only two of the six CRCP sections had any IRI values near 95 in./mi.: Kern 5 with an initial IRI value of 90 in./mi. and Placer 80 with a final IRI value of 84 in./mi.

The other four sections had final IRI values less than 70 in./mi., though this includes San Joaquin 5, whose first measurement was in 2016 and last measurement was in 2018. San Joaquin 5, after only two years of service, had negligible changes like the other sections after four and six years of service. The other sections with small increases between the first and last measurements were in Imperial and Siskiyou Counties. Imperial 78 and Imperial 86 both have very low traffic counts, especially when compared to Interstate 5 and Interstate 80, where the other CRCP sections are located.

**Table 4.12: IRI Summary Values for All CRCP Sections**

| Test Section Location | Passenger Lanes | | | | Truck Lanes | | | |
|---|---|---|---|---|---|---|---|---|
| | First IRI (in./mi.) | Last IRI (in./mi.) | Time Change Rate (in./mi./yr.) | Traffic Change Rate (in./mi./mEAL) | First IRI (in./mi.) | Last IRI (in./mi.) | Time Change Rate (in./mi./yr.) | Traffic Change Rate (in./mi./mEAL) |
| **CRCP w/ LT** | **74** | **84** | **1.6** | **2.2** | **65** | **64** | **-0.1** | **3.1** |
| Pla80E1PM56.45 | 74 | 84 | 1.6 | 2.2 | | | | |
| Ker5S2PM40.0 | | | | | 90 | 72 | -2.3 | -1.8 |
| Imp78E2PMR15.0 | | | | | 54 | 67 | 1.6 | 10.3 |
| Imp86S2PM24.2 | | | | | 50 | 53 | 0.3 | 0.8 |
| **CRCP w/ CDG** | **65** | **66** | **0.5** | **0.2** | **65** | **63** | **-0.3** | **-0.4** |
| Sis5N2PM57.0 | | | | | 65 | 63 | -0.3 | -0.4 |
| SJ5N1PM32.0[a] | 65 | 66 | 0.5 | 0.2 | | | | |

[a] For San Joaquin 5, the first IRI was taken in 2017 and the last in 2018, for others the first is 2012 and the last is 2020.

### *4.2.2 JPCP Sections with CDG*

Table 4.13 shows the IRI values for all the JPCP sections with CDG surface textures, along with the time and traffic IRI change rates, split between passenger and truck lanes. The average initial IRI values of 62 in./mi. and 63 in./mi. in the passenger and truck lanes indicate that the pavement surfaces started in a good and similar condition. These values correspond to values from the concrete noise study, where CDG surfaces measured 68 in./mi. *(3)*

**Table 4.13: IRI Values for All JPCP with CDG Sections**

| Test Section Location | Passenger Lanes | | | | Truck Lanes | | | |
|---|---|---|---|---|---|---|---|---|
| | First IRI (in./mi.) | Final IRI (in./mi.) | Time Change Rate (in./mi./yr.) | Traffic Change Rate (in./mi./mEAL) | First IRI (in./mi.) | Final IRI (in./mi.) | Time Change Rate (in./mi./yr.) | Traffic Change Rate (in./mi./mEAL) |
| Sac5 S1 | 82 | 119 | 4.5 | 2.5 | | | | |
| Sac5 S4 | | | | | 75 | 127 | 6.4 | 3.5 |
| Sac5B S1 | 63 | 66 | 0.4 | 0.2 | | | | |
| Sac5B S2 | | | | | 65 | 97 | 5.0 | 2.9 |
| Sac50 E2 | 77 | 65 | -1.6 | -2.2 | | | | |
| Sac50 E4 | | | | | 77 | 76 | -0.1 | -0.2 |
| Yol113 N1 | 50 | 52 | 0.3 | 1.6 | | | | |
| Yol113 N2 | | | | | 47 | 61 | 2.2 | 11.0 |
| Yol113 S1 | 50 | 59 | 1.2 | 5.4 | | | | |
| Yol113 S2 | | | | | 68 | 58 | -1.5 | -6.5 |
| SD5 N1 | 57 | 60 | 0.3 | 0.8 | | | | |
| SD5 N2 | 63 | 73 | 1.3 | 3.3 | | | | |
| SD5 N3 | 61 | 90 | 3.7 | 9.4 | | | | |
| SD5 N4 | | | | | 57 | 63 | 0.7 | 1.8 |
| SD5 N5 | | | | | 60 | 70 | 1.3 | 3.1 |
| SD5 S1 | 61 | 62 | 0.2 | 0.2 | | | | |
| SD5 S2 | 58 | 71 | 1.7 | 1.6 | | | | |
| SD5 S3 | 63 | 74 | 1.4 | 1.3 | | | | |
| SD5 S4 | | | | | 61 | 68 | 0.9 | 0.8 |
| SD5 S5 | | | | | 57 | 64 | 0.9 | 0.9 |
| **Average** | **62** | **72** | **1.2** | **2.2** | **63** | **76** | **1.7** | **1.9** |

The final values of 72 in./mi. for passenger lanes and 76 in./mi. for truck lanes may indicate the effect of truck traffic on the durability of IRI values. Similarly, the annual change rate is 43% higher in the truck lanes compared to the passenger lanes for JPCP sections with CDG. However, the traffic change rate is 11% lower in the truck lanes compared to the passenger lanes. Figure 4.17 shows the IRI data for the 20 JPCP with CDG sections, separated by truck and passenger lanes, while Figure 4.18 shows the same IRI data in relation to traffic rather than time.

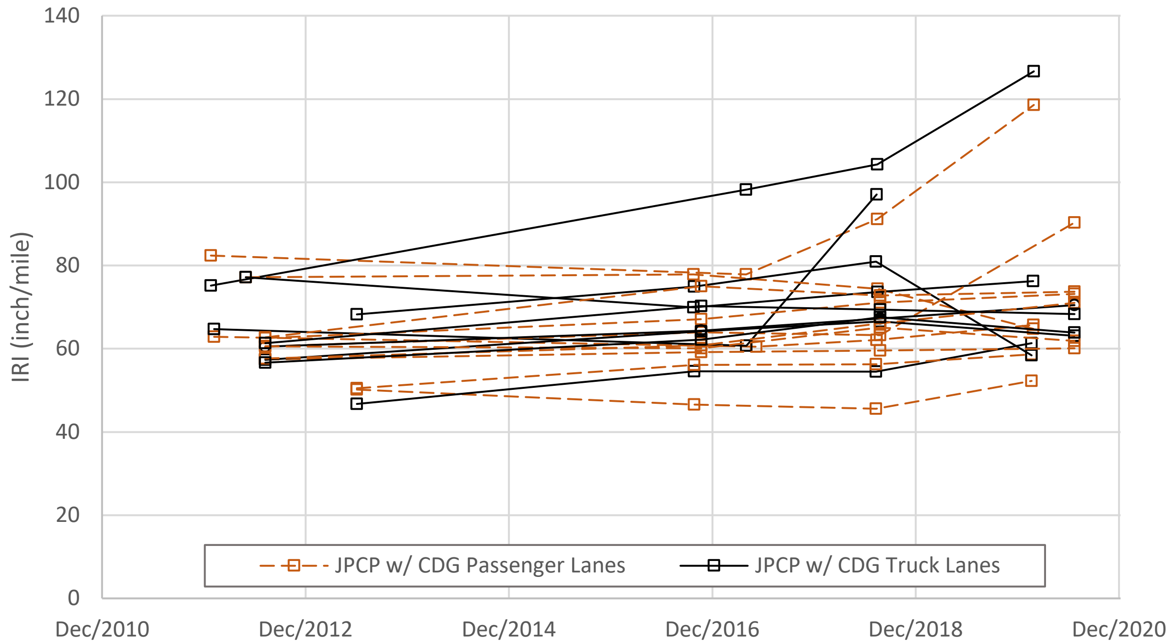



**Figure 4.17: IRI on JPCP with CDG truck and passenger lanes.**

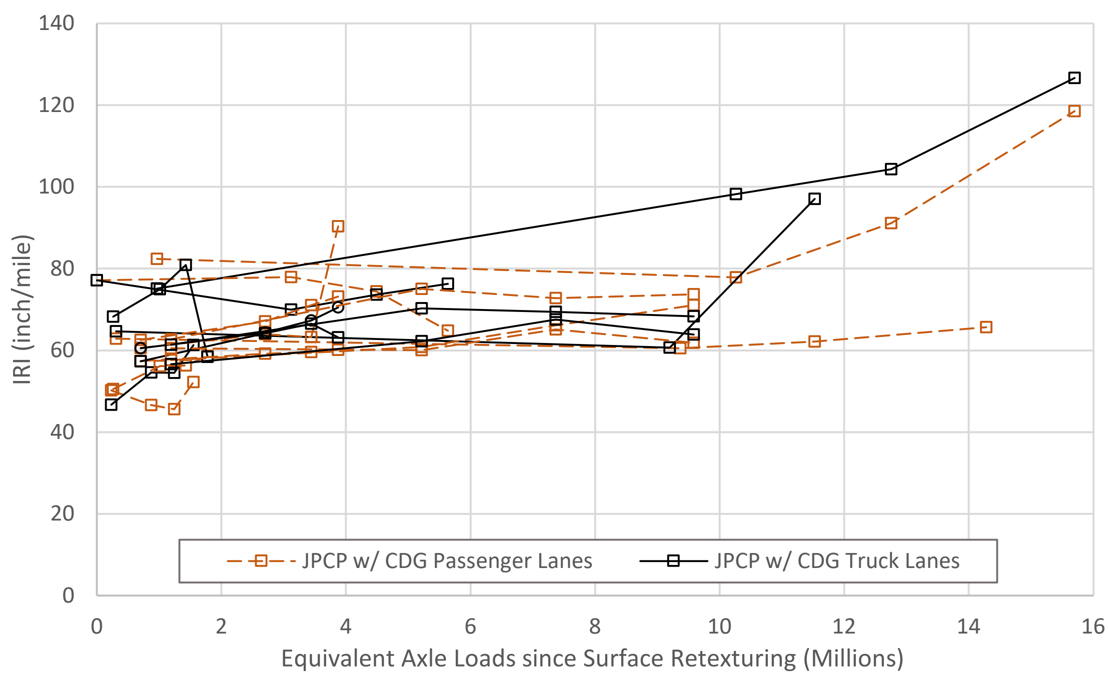



**Figure 4.18: IRI versus traffic on JPCP with CDG truck and passenger lanes.**

Although the truck lanes experience higher time change rates on average, these figures show that the passenger lanes can also have high IRI values. The two high values, one truck lane and one passenger lane, are from Sacramento 5 – PM 20.0/21.5.

Figure 4.19 shows the average IRI and change rates for JPCP with CDG sections for passenger and truck lanes. This figure shows how the negligible difference between passenger and truck lanes in 2012 grows to 5 in./mi. in 2016 and 10 in./mi. in 2018. The difference between passenger and truck lanes then shrinks back to 2 in./mi. by 2020, with passenger lanes continuing to exhibit growing IRI values over time, while the truck lanes level off after 2018.

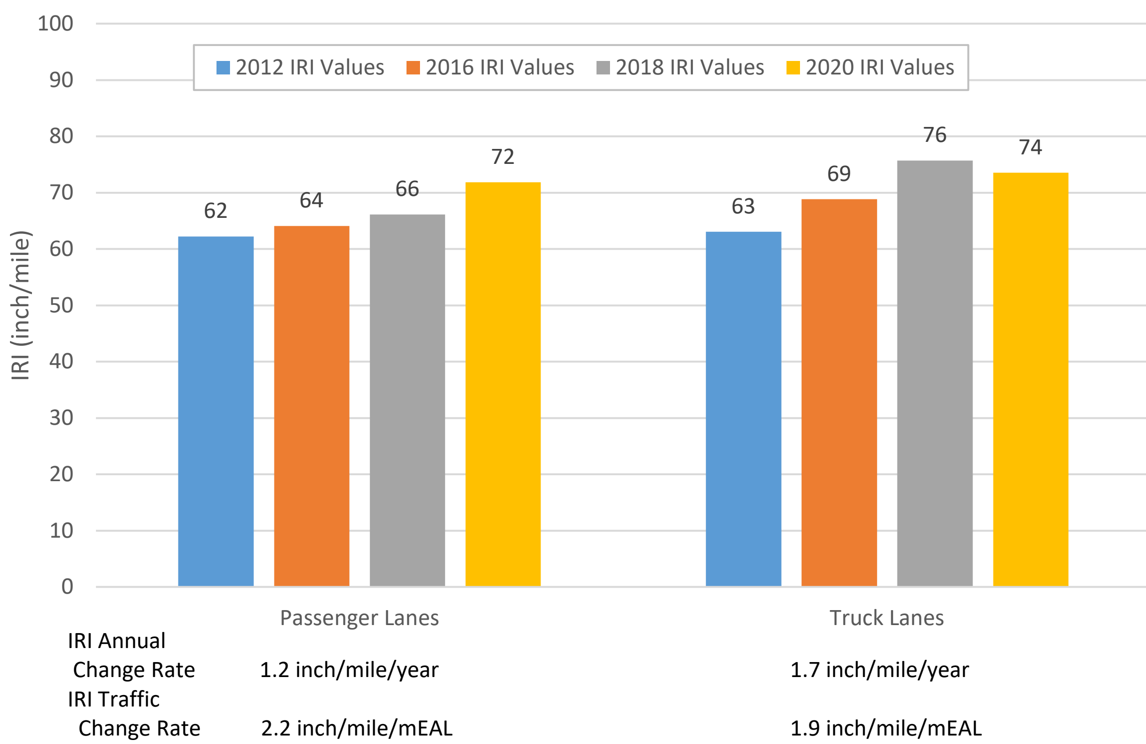



**Figure 4.19: Average IRI and change rates for JPCP with CDG sections, passenger and truck lanes.**

### *4.2.3 JPCP Sections with GnG*

Table 4.14 shows the first and final IRI values for all the JPCP sections with GnG surface textures, along with the IRI time and traffic change rates. Overall, these values show the GnG sections start in very good condition in terms of smoothness. However, even in 2012, these sections initially display a small difference between truck lanes, at 48 in./mi., and passenger lanes, at 44 in./mi.

**Table 4.14: IRI Values for All JPCP with GnG Sections**

| Test Section Location | Passenger Lanes | | | | Truck Lanes | | | |
|---|---|---|---|---|---|---|---|---|
| | First IRI (in./mi.) | Final IRI (in./mi.) | Time Change Rate (in./mi./yr.) | Traffic Change Rate (in./mi./ mEAL) | First IRI (in./mi.) | Final IRI (in./mi.) | Time Change Rate (in./mi./yr.) | Traffic Change Rate (in./mi./ mEAL) |
| Sac5 N1 | 42 | 106 | 7.9 | 4.3 | | | | |
| Sac5 N4 | | | | | 52 | 129 | 9.5 | 5.1 |
| Sac5B N1 | 43 | 49 | 0.8 | 0.5 | | | | |
| Sac5B N2 | | | | | 48 | 62 | 2.1 | 1.2 |
| Sac80 E2 | 34 | 59 | 3.2 | 3.2 | | | | |
| Sac80 E5 | | | | | 42 | 52 | 1.4 | 1.3 |
| Sac80 W2 | 42 | 48 | 0.7 | 0.8 | | | | |
| Sac80 W5 | | | | | 48 | 76 | 3.6 | 3.8 |
| Sac50 W2 | 63 | 63 | 0.1 | 0.1 | | | | |
| Sac50 W4 | | | | | 52 | 91 | 5.0 | 8.8 |
| SJ99 N1 | 44 | 54 | 1.3 | 1.2 | | | | |
| SJ99 N2 | | | | | 73 | 88 | 2.0 | 1.9 |
| Yol113 N1 | 53 | 49 | -0.6 | -2.9 | | | | |
| Yol113 N2 | | | | | 48 | 60 | 1.8 | 9.1 |
| Yol113 S1 | 59 | 61 | 0.3 | 1.4 | | | | |
| Yol113 S2 | | | | | 54 | 78 | 1.7 | 16.2 |
| SD5 N1 | 41 | 66 | 3.2 | 7.9 | | | | |
| SD5 N2 | 44 | 51 | 0.8 | 2.1 | | | | |
| SD5 N3 | 38 | 61 | 2.9 | 7.3 | | | | |
| SD5 N4 | | | | | 39 | 52 | 1.6 | 4.1 |
| SD5 N5 | | | | | 38 | 63 | 3.2 | 7.9 |
| SD5 S1 | 37 | 44 | 0.8 | 0.8 | | | | |
| SD5 S2 | 36 | 48 | 1.5 | 1.4 | | | | |
| SD5 S3 | 41 | 50 | 1.2 | 1.1 | | | | |
| SD5 S4 | | | | | 38 | 60 | 2.7 | 2.6 |
| SD5 S5 | | | | | 45 | 76 | 3.8 | 3.6 |
| **Average** | **44** | **58** | **1.7** | **2.1** | **48** | **74** | **3.4** | **5.5** |

By 2020, the difference between truck lanes, at 74 in./mi., and passenger lanes, at 58 in./mi., is 16 in./mi. The ratio of time change rates between truck lanes (3.4 in./mi./year) and passenger lanes (1.7 in./mi/year) is two to one, and for the traffic change rate, the ratio is over two and one-half: 5.5 in./mi./year for truck lanes and 2.2 in./mi./year for passenger lanes.

Again, the data table is split between passenger lanes and truck lanes, as are the data shown in Figure 4.20, which presents the IRI data on JPCP with GnG in truck and passenger lanes, and Figure 4.21, which shows the same IRI data on JPCP with GnG but versus traffic instead of time. Figure 4.22 shows the average IRI and change rates for JPCP with GnG sections, passenger lanes, and truck lanes.

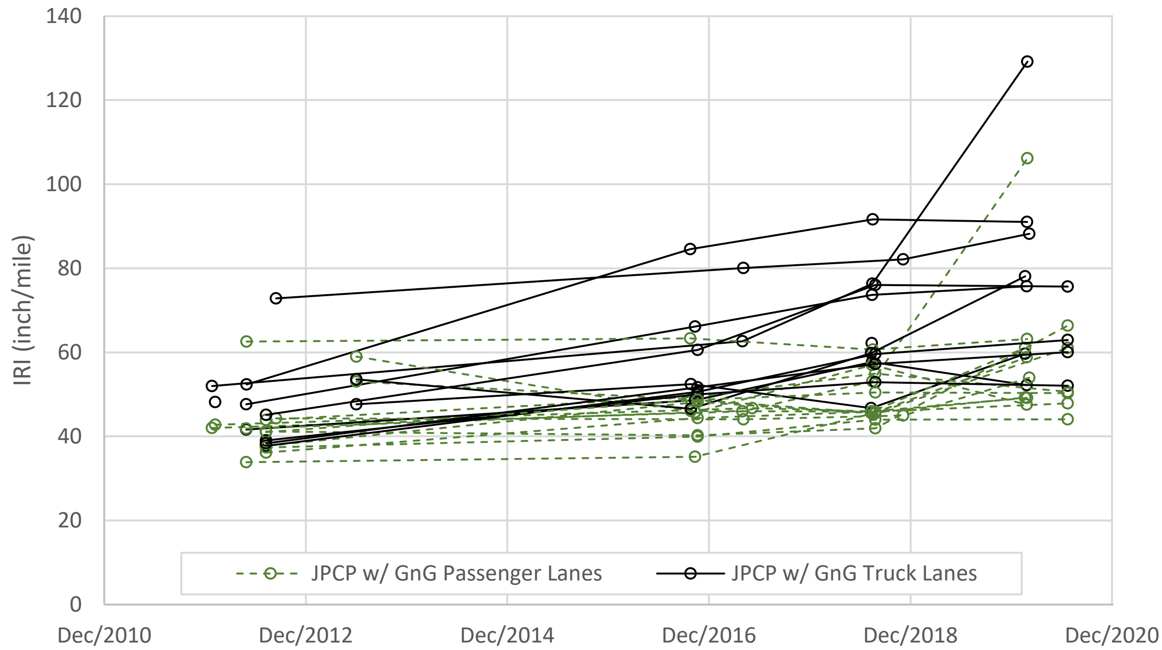



**Figure 4.20: IRI on JPCP with GnG truck and passenger lanes.**

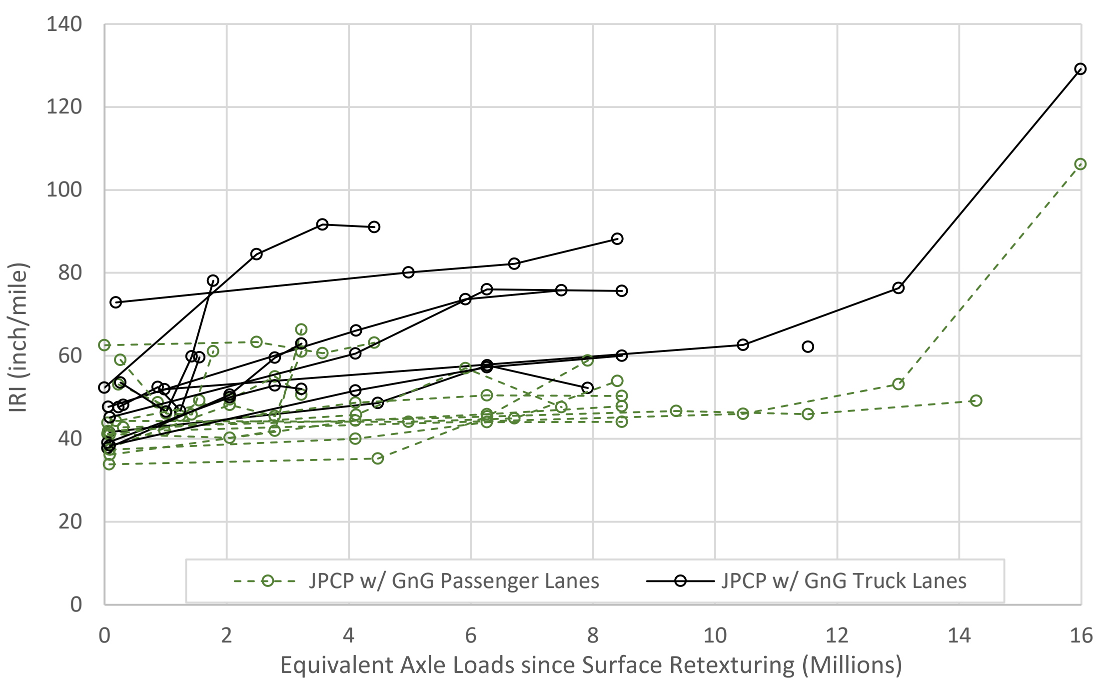



**Figure 4.21: IRI versus traffic on JPCP with GnG truck and passenger lanes.**

JPCP with GnG passenger lanes and truck lanes start with average IRI values of 44 in./mi. and 48 in./mi., respectively. These are significantly lower than JPCP with CDG sections, with 62 in./mi. for passenger lanes and 63 in./mi. for truck lanes. After eight years, the JPCP with GnG passenger lanes show some loss of smoothness, with the IRI increasing to 58 in./mi., still in very good condition, and the truck lanes increasing to 74 in./mi., still in good condition, where the acceptable condition is between 96 and 170 in./mi.

The annual IRI change rate for JPCP with GnG sections in truck lanes is the highest when compared to the JPCP with CDG sections, at 3.4 in./mi./year versus 1.7 in./mi./year, respectively, and CRCP sections at -0.2 in./mi./year. Similarly, for the passenger lanes, the JPCP with GnG sections have a higher annual change rate than the JPCP with CDG sections, at 1.7 in./mi./year versus 1.2 in./mi./year, respectively, while the two CRCP sections that are passenger lanes have an average annual change rate of 1.0 in./mi./year.

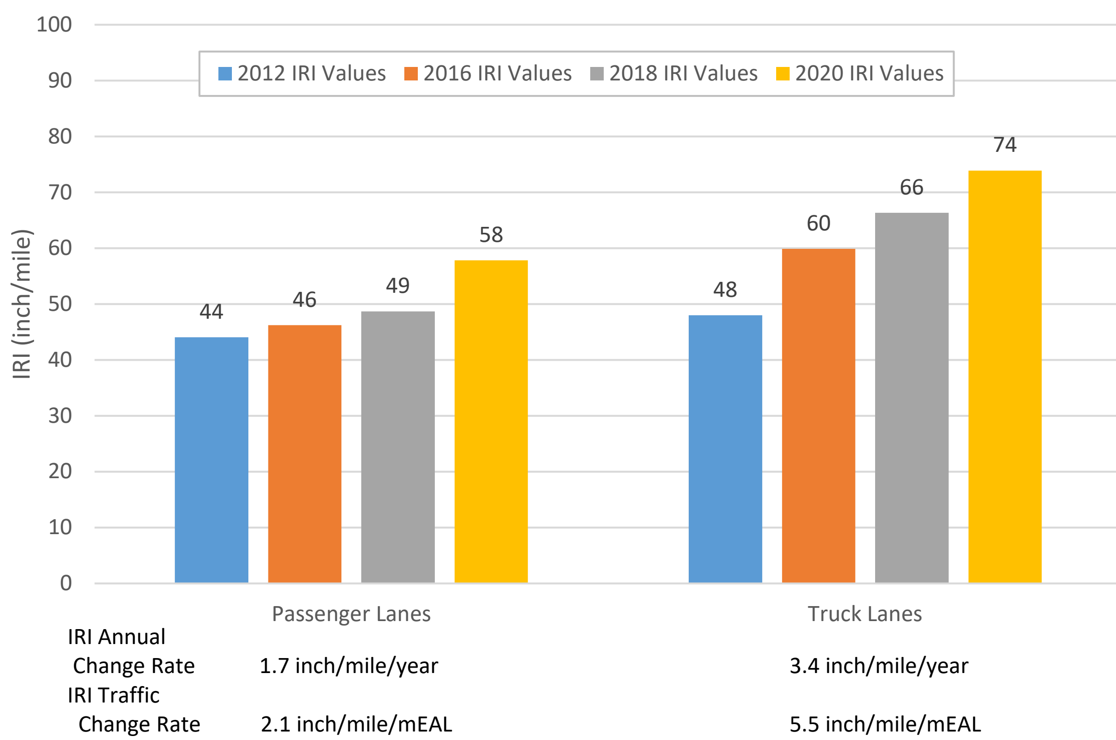



**Figure 4.22: Average IRI and change rates for JPCP with GnG sections, passenger and truck lanes.**

# 5 CONCLUSIONS AND RECOMMENDATIONS

The results presented in this research report show four rounds of tire/pavement noise data measured as the OBSI and smoothness data measured as the IRI on four concrete pavement types relatively new to California: (1) CRCP textured with longitudinal tining (LT), (2) CRCP textured with conventional diamond grinding (CDG), (3) JPCP textured with CDG, and (4) JPCP textured with the grind and groove (GnG) surface. Of the 52 test sections, six are CRCP, four with LT and two with CDG, and 46 are JPCP, 20 with CDG and 26 with GnG. The friction of these surfaces was not tested during this time period.

The following are conclusions regarding tire-pavement noise in terms of OBSI and pavement smoothness in terms of IRI, from the four sets of data collected over eight years, from 2012 to 2020:

- OBSI levels on the concrete pavement test sections evaluated in this study originally (circa 2012) ranged from 100 to 112 dBA. The data from 2016 ranged from 101 to 112 dBA. In 2018, the range of OBSI was from 102 to 113 dBA, and the range of data in the final year of 2020 was from 102 to 114 dBA. This is consistent with the range of OBSI levels for concrete pavement textures measured in other similar studies.
- Among the four pavement types and textures, the CRCP with LT sections on average were the loudest, initially at 106 dBA and concluding at 107 dBA. The CRCP with CDG sections on average (with two sections) were the next loudest, starting at 104 dBA and ending at 106 dBA. Overall, the annual change rate for the CRCP sections was 0.4 dBA/yr. However, excluding the Placer 80 section, which is affected by truck chain wear, the CRCP annual change rate is 0.2 dBA/year. The average OBSI change rate versus truck traffic is 0.5 dBA/mEAL versus 0.2 dBA/mEAL, respectively, when excluding Placer 80.
- The OBSI values for the JPCP sections with CDG initially ranged from 101 to 104 dBA, with an average of 103 dBA, and finally ranged from 102 to 107 dBA, with an average of 105 dBA. The annual OBSI change rate for the CDG sections averaged 0.3 dBA/year. These values are within the range of values found in previous studies and are consistent with new and slightly aged diamond ground textures. The change rate versus truck traffic was 0.6 dBA/mEAL.

- The OBSI values for the JPCP sections with GnG initially ranged from 100 to 103 dBA, with an average of 101 dBA, and finally ranged from 102 to 107 dBA, with an average of 104 dBA. On average, the GnG sections were the quietest pavements in this study; however, GnG sections also had the highest OBSI change rate, at 0.4 dBA/year.
- The effect of truck traffic versus passenger car traffic on the OBSI change rate is indicated by the JPCP data, excluding the CRCP data. For the CDG sections, trucks increase the OBSI annual change rate from 0.2 to 0.3 dBA/year and the traffic-related change rate from 0.4 to 0.7 dBA/mEAL, when compared to passenger lanes. For the GnG sections, trucks increase the OBSI annual change rate from 0.4 to 0.5 dBA/year, and the traffic-related change rate from 0.7 to 0.8 dBA/mEAL.
- The JPCP sections included in this study were all on existing pavements with years of previous traffic that were resurfaced soon before the start of this study. The CRCP sections are on new pavements or pavements that had only a few years of traffic before the study was begun, and the last retexturing was their initial construction.
- IRI levels on the concrete pavements evaluated in this study originally ranged from 34 to 90 in./mi. The data from four years later ranged from 35 to 98 in./mi., with only one section, a JPCP section with CDG, that deteriorated from the "good" to the "acceptable" range of IRI values (95 to 170 in./mi.). The data from 2018 ranged from 42 to 104 in./mi., with a second JPCP with CDG section deteriorating to the acceptable range of IRI values. By 2020, the data ranged from 44 to 129 in./mi., and five of the sections had IRI values above 95 in./mi.
- Combining both LT and CDG surfaces, the six CRCP sections, on average, were initially the roughest, at 67 in./mi., and through 2020, showed a negligible increase in IRI to 68 in./mi. The annual IRI change rate for the period 2012 to 2020 was 0.2 in./mi./year. The traffic-related IRI change rate was 1.9 in./mi./mEAL.
- The IRI values for the JPCP with CDG sections initially ranged from 47 to 82 in./mi., with an average of 63 in./mi. There were continual increases throughout the study period, to 66 in./mi. by 2016, 70 in./mi. by 2018, and 74 in./mi. with a range from 52 to 127 in./mi. by 2020. The annual IRI change rate for the JPCP with CDG sections averaged 1.5 in./mi./year, and the traffic-related IRI change rate was 2.1 in./mi./mEAL.

- On average, the GnG sections were the smoothest sections in this study. Initial IRI values for the JPCP with GnG sections ranged from 34 to 73 in./mi. and averaged 46 in./mi. These sections exhibited the highest change rates among the four types of sections, with an annual IRI change rate of 2.5 in./mi./year and a traffic-related IRI change rate of 3.6 in./mi./mEAL. The final IRI values for the JPCP with GnG sections ranged from 44 to 129 in./mi. and averaged 65 in./mi.
- The effect of truck traffic versus passenger car traffic on the IRI change rate was indicated by the JPCP data. For JPCP with CDG sections, truck lanes showed an increase in the annual IRI change rate from 1.2 to 1.7 in./mi./year, but the traffic-related change rate decreased for truck lanes from 2.2 in./mi./mEAL to 1.9 in./mi./mEAL. For the JPCP with GnG sections, truck lanes exhibited a doubling of the IRI change rate from 1.7 to 3.4 in./mi./year, and more than doubling of the traffic-related change rate from 2.1 to 5.5 in./mi./mEAL.

Regarding the development and implementation of quieter concrete pavement strategies in California, the results to date in this study suggest the following preliminary recommendations:

- Test the friction of aged GnG surfaces that still exist from this study.
- Continue the use of CDG.
- Continue the use and study of GnG, looking into performance beyond eight years. The GnG texture produced the best initial smoothness values.
- Continue the use and study of the GnG surface texture on CRCP pavement sections.

# REFERENCES


1. Ongel, A., Harvey, J.T., Kohler, E., Lu, Q., and Steven, B.D. 2008. *Summary Report: Investigation of Noise, Durability, Permeability, and Friction Performance Trends for Asphaltic Pavement Surface Types: First- and Second-Year Results* ( Summary Report: UCPRC-SR-2008-01). Davis and Berkeley, CA: University of California Pavement Research Center. https://escholarship.org/uc/item/96v7p9j9.
2. Rezaei, A., and Harvey, J. 2013. *Investigation of Noise, Ride Quality and Macrotexture Trends for Asphalt Pavement Surfaces: Summary of Six Years of Measurements* (Research Report: UCPRC-RR-2013-11). Davis and Berkeley, CA: University of California Pavement Research Center. https://escholarship.org/uc/item/21w7n8sn.
3. Rezaei, A., and Harvey, J. 2013. *Investigation of Tire/Pavement Noise for Concrete Pavement Surfaces: Summary of Four Years of Measurements* (Research Report: UCPRC-RR-2013-12). Davis and Berkeley, CA: University of California Pavement Research Center. https://escholarship.org/uc/item/99h8c6gp.
4. Scofield, L. 2012. *Development and Implementation of the Next Generation Concrete Surface*. Rosemont, IL: American Concrete Pavement Association, and West Coxsackie, NY: International Grooving and Grinding Association.
5. Guada, I., Rezaei, A., Harvey, J.T., and Spinner, D. 2012. *Evaluation of Grind and Groove (Next Generation Concrete Surface) Pilot Projects in California* (Research Report: UCPRC-RR-2013-01). Davis and Berkeley, CA: University of California Pavement Research Center. https://escholarship.org/uc/item/72d3q2h4.
6. Guada, I., and Harvey, J. 2022. *Continued Noise and Smoothness Monitoring on Concrete Pilot Projects of Grind and Groove on Existing Pavement and Current Texture Types on Continuously Reinforced Concrete Pavements* (Technical Memorandum: UCPRC-TM-2021-04). Davis and Berkeley, CA: University of California Pavement Research Center. https://doi.org/10.7922/G22N50K0

7. Rasmussen, R.O., Bernhard, R., Sandberg, U., and Mun, E.P. 2007. *The Little Book of Quieter Pavements*. Washington, DC: Federal Highway Administration. https://rosap.ntl.bts.gov/view/dot/41905
8. Rezaei, A., and Harvey, J. 2011. *Concrete Pavement Tire Noise: Third-Year Results* (Research Report: UCPRC-RR-2012-03). Davis and Berkeley, CA: University of California Pavement Research Center. https://escholarship.org/uc/item/6xj7n7cb.
9. Lu, Q., Wu, R., and Harvey, J. 2011. "Calibration of On-Board Sound Intensity for Test Tire, Speed, Pavement Temperature, and Analyzer Equipment." In *TRB 91st Annual Meeting Compendium of Papers*. Washington, DC, January 22-26, 2012.
10. Donavan, P. 2010. "Acoustic Radiation from Pavement Joint Grooves Between Concrete Slabs." *Transportation Research Record* 2158, no. 1: 129–137. https://doi.org/10.3141/2158-16.
11. California Department of Transportation. n.d. "Traffic Census Program." Accessed September 20, 2020. https://dot.ca.gov/programs/traffic-operations/census.
12. Rasmussen, R.O., Wiegand, P.D., Fick, G.J., and Harrington, D.S. 2012. *How to Reduce Tire-Pavement Noise: Better Practices for Constructing and Texturing Concrete Pavement Surfaces* (Report Number: DTFH61-06-H-00011 Work Plan 7, TPF-5(139)). Ames, IA: National Concrete Pavement Technology Center. https://publications.iowa.gov/14942/1/IA_DOT_TPF-5%28139%29_InTrans_tire-pavement_noise_2012.pdf.
13. Van Dam, T.J., Harvey, J.T., Muench, S.T., Smith, K.D., Snyder, M.B., Al-Qadi, I.L., Ozer, H., Meijer, J., Ram, P.V., Roesler, J.R., and Kendall, A. 2015. *Towards Sustainable Pavement Systems: A Reference Document* (FHWA-HIF-15-002). Washington, DC: Federal Highway Administration. https://rosap.ntl.bts.gov/view/dot/38541.
14. Federal Highway Administration. 1990. *Highway Performance Monitoring System, Field Manual*. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/page00.cfm

# APPENDIX A OBSI LONGITUDINAL PROFILES

Longitudinal profiles of OBSI for all the sections are presented in the following figures. Each profile is an individual lane, with a direction and lane number indicated in the figure header. The figure legend provides the month and year of the four sampling periods, as some project data were collected over multiple days.

After the CRCP profiles in Section A.1, the JPCP profiles were paired by direction for each project in Section A.2 through Section A.8. For example, the Sac 5 – PM 20.0/21.5 charts for northbound Lane 1 and northbound Lane 4 are paired on opposing pages and southbound Lane 1 and southbound Lane 4 are paired on the following pages of Section A.2. With different lanes in the same direction paired, the effect of truck traffic versus passenger car traffic may be evident.

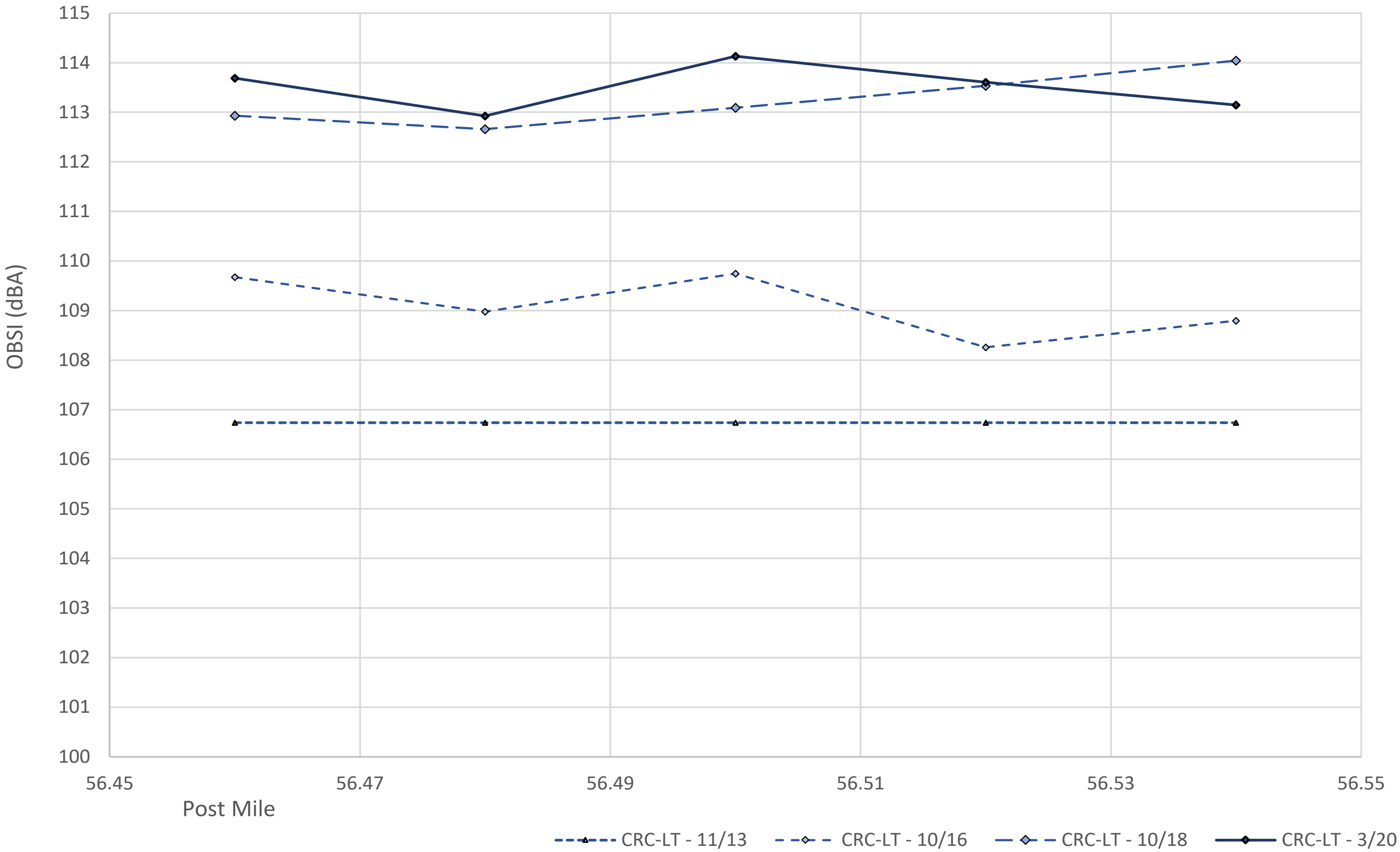
The average OBSI value and standard deviation OBSI values (in parentheses) for the longitudinal profiles are shown under the legend.

The following notations are used in the following figures:

- Empty very small markers with dotted lines represent the oldest data from 2012.
- Lightly filled small markers with dashed lines represent the data from 2016.
- Moderately filled markers with long dashed lines represent the data from 2018.
- Black-filled markers with solid lines represent the newest data from 2020.

The section location is found in the figure caption, indicating the county and highway number, followed by the direction and lane number, concluding with the starting postmile (PM). For example, Imp86S2PMR24.2 is located in Imperial County on Highway 86 in the southbound direction of Lane 2, starting at PM R24.2.

## A.1 CRC Pavement Sections




OBSI Average (Std. Dev.), dBA 106.7 (0.4) 109.1 (0.6) 113.3 (0.5) 113.5 (0.5)

**Figure A.1: OBSI on Pla80E1PM56.45.**

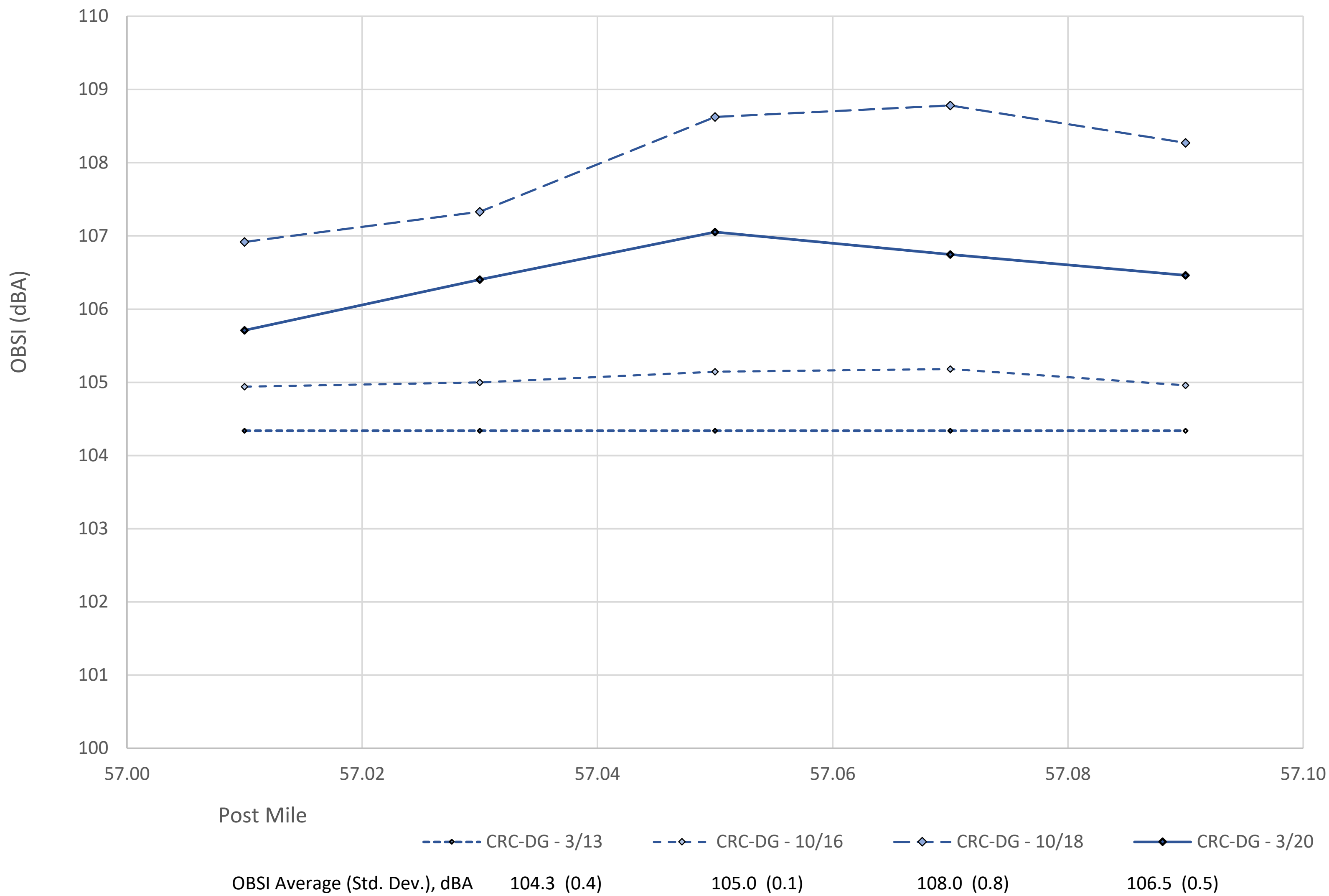



**Figure A.2: OBSI on Sis5N2PM57.0.**

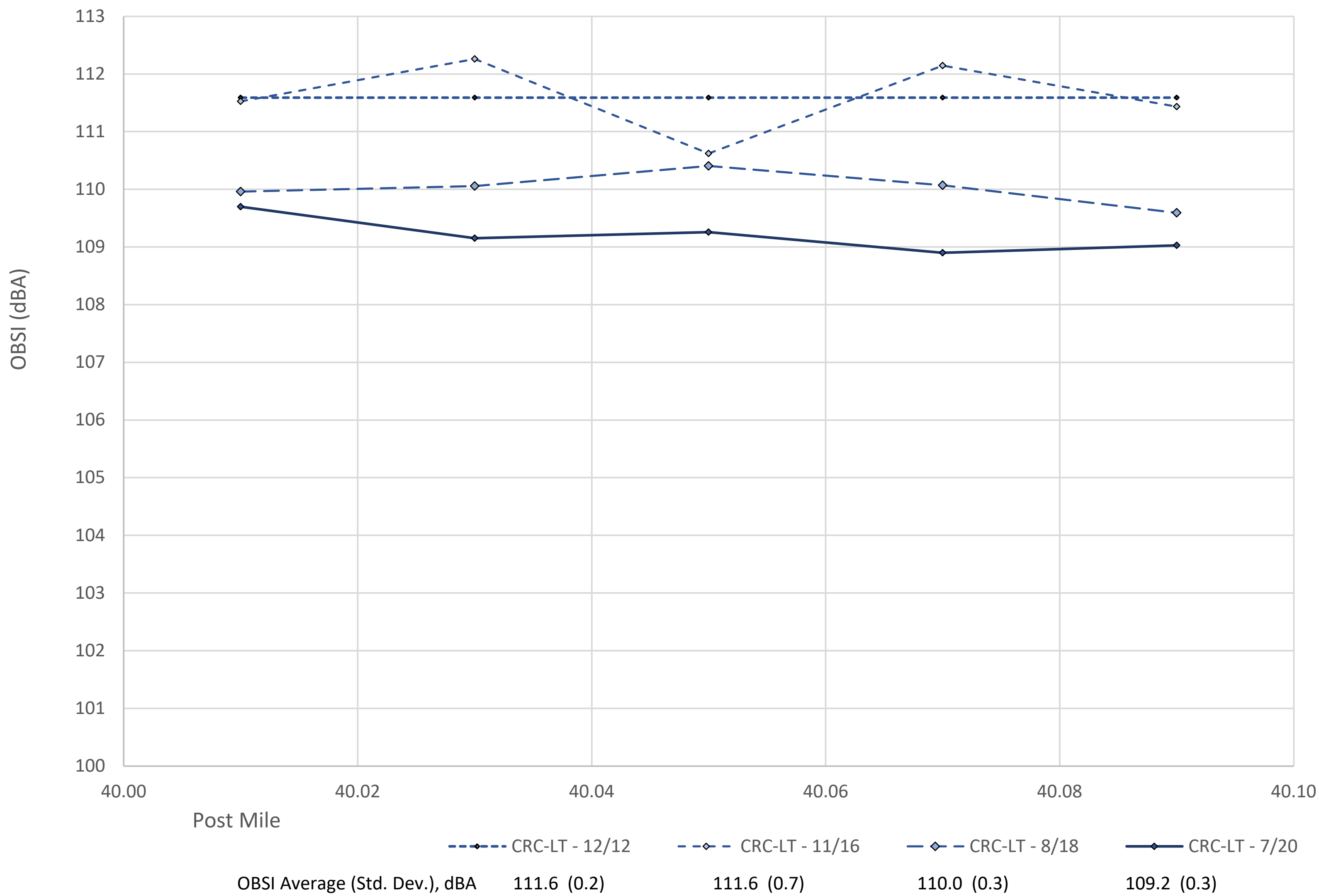
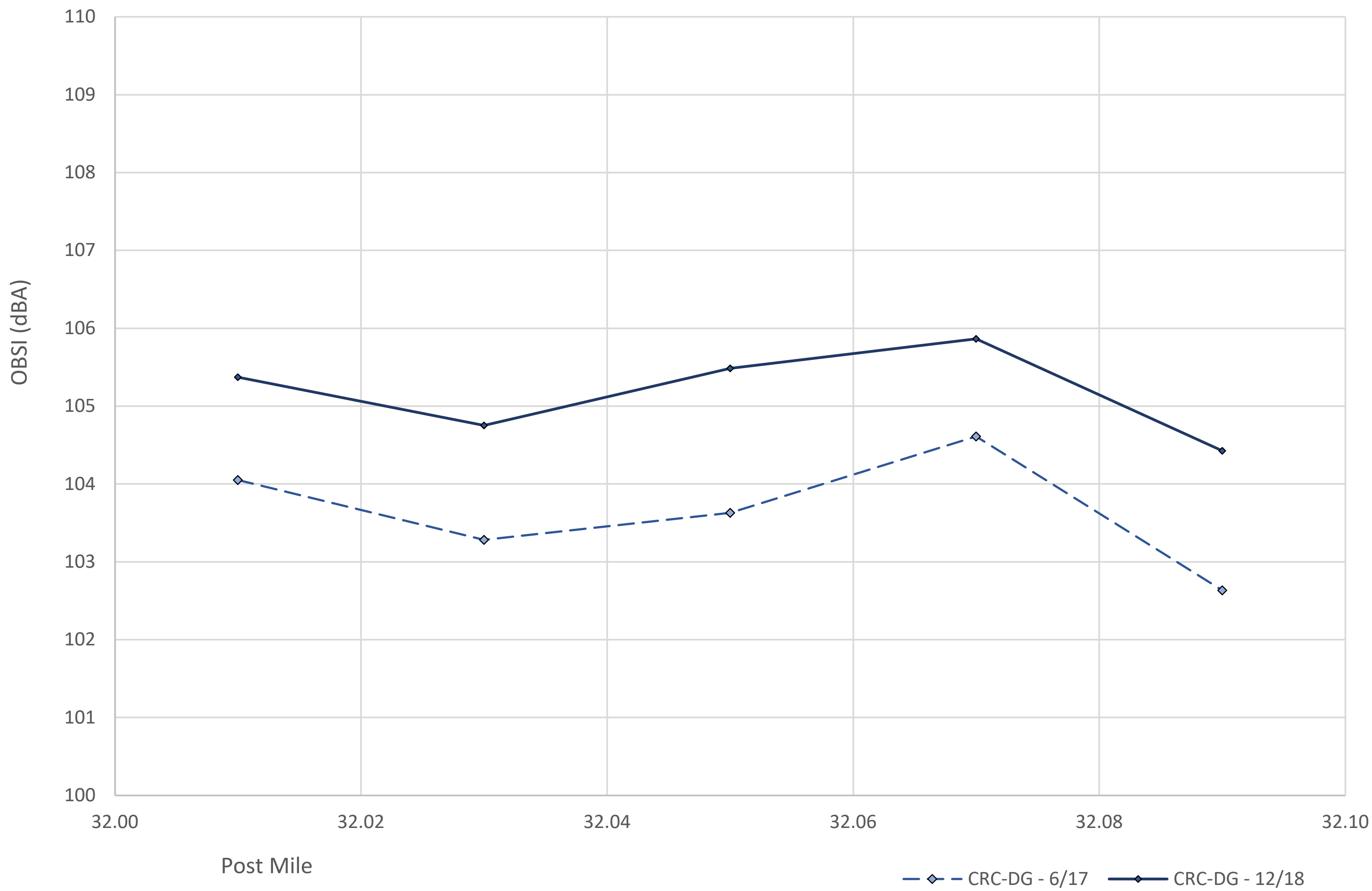
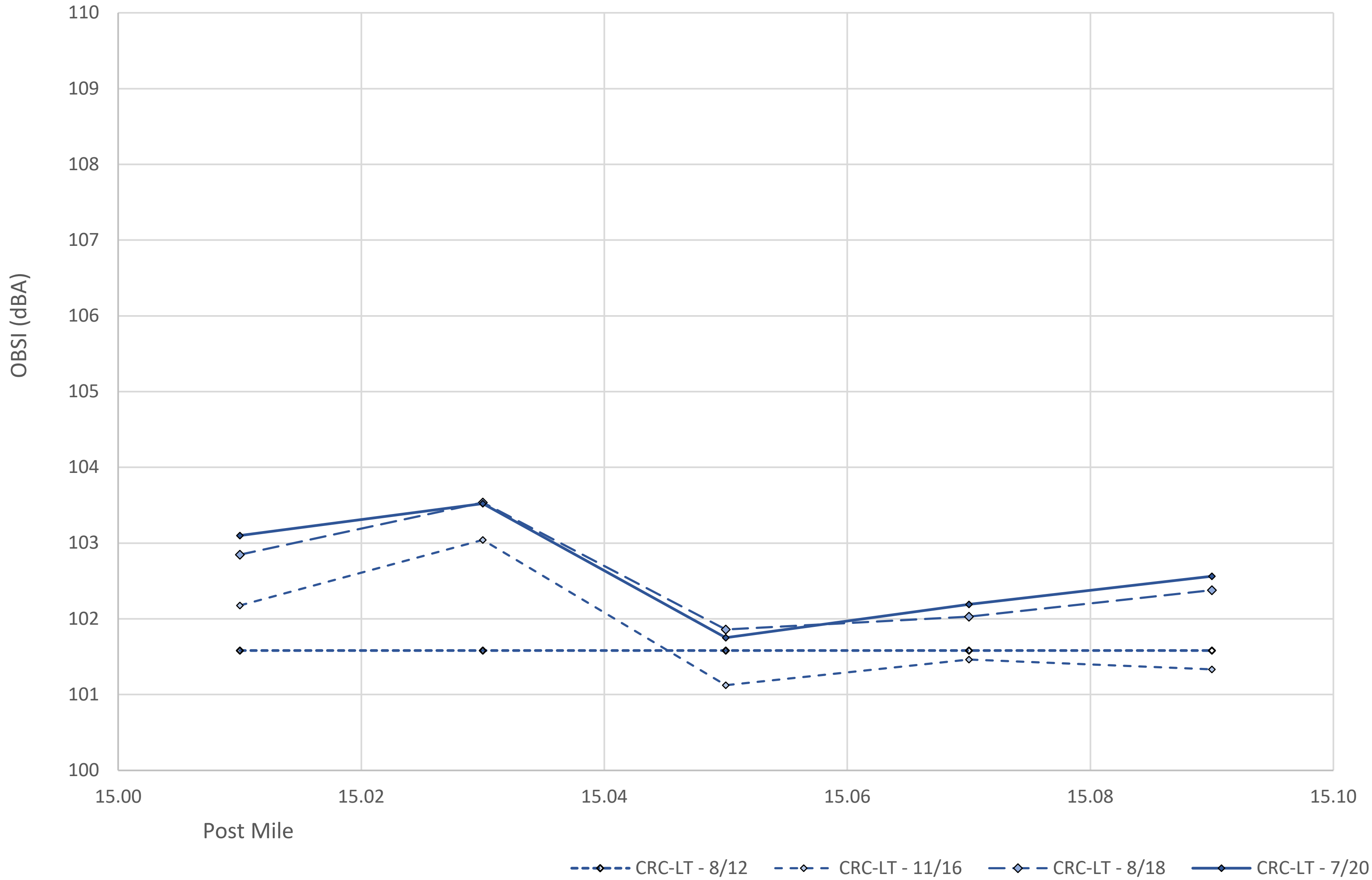



**Figure A.3: OBSI on Ker5S2PM40.0.**



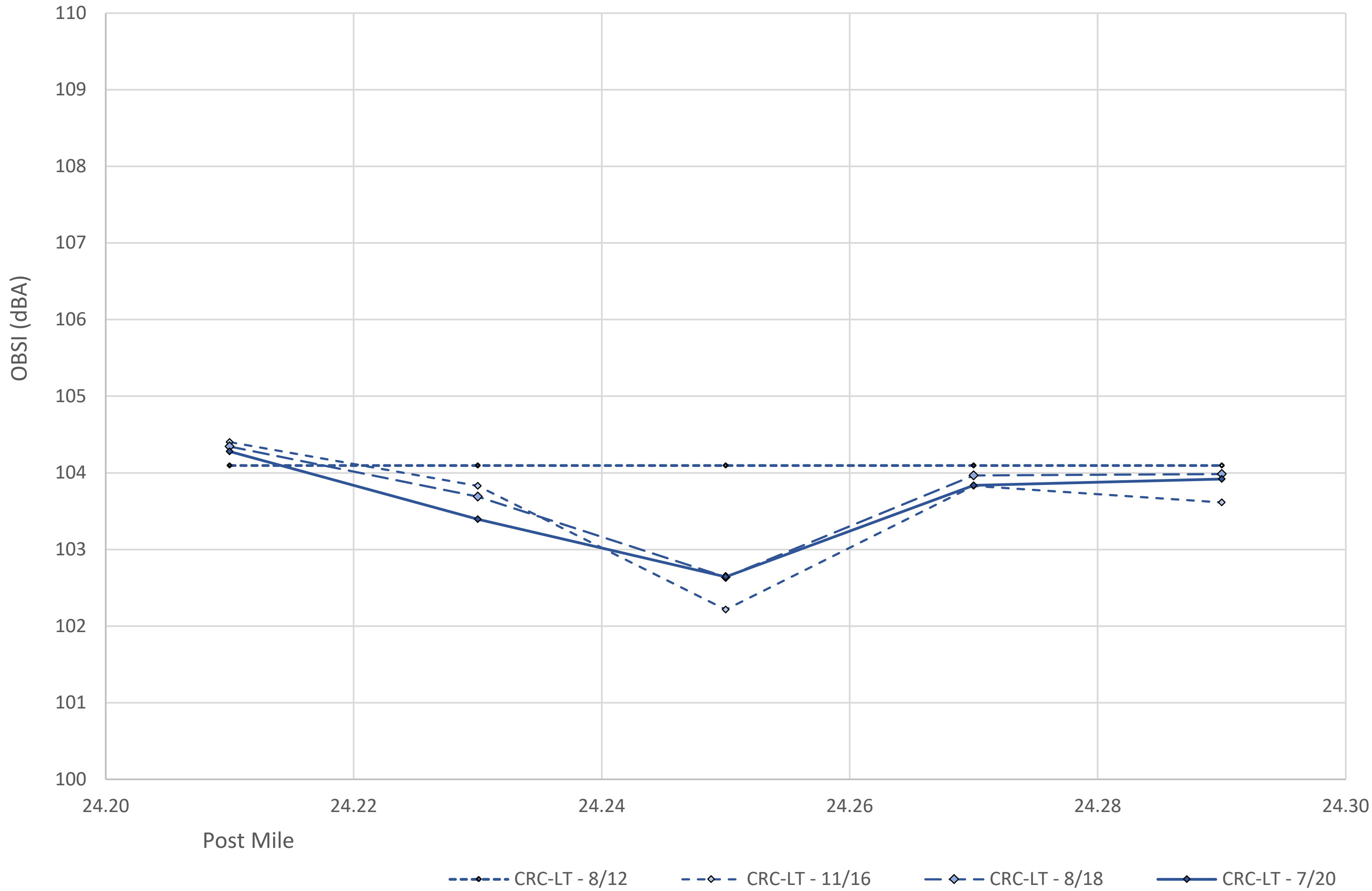

| OBSI Average (Std. Dev.), dBA | 103.6 (0.8) | 105.2 (0.6) |
|---|---|---|

**Figure A.4: OBSI on SJ5N1PM32.0.**




| OBSI Average (Std. Dev.), dBA | 101.6 (0.1) | 101.8 (0.8) | 102.5 (0.7) | 102.6 (0.7) |
|---|---|---|---|---|

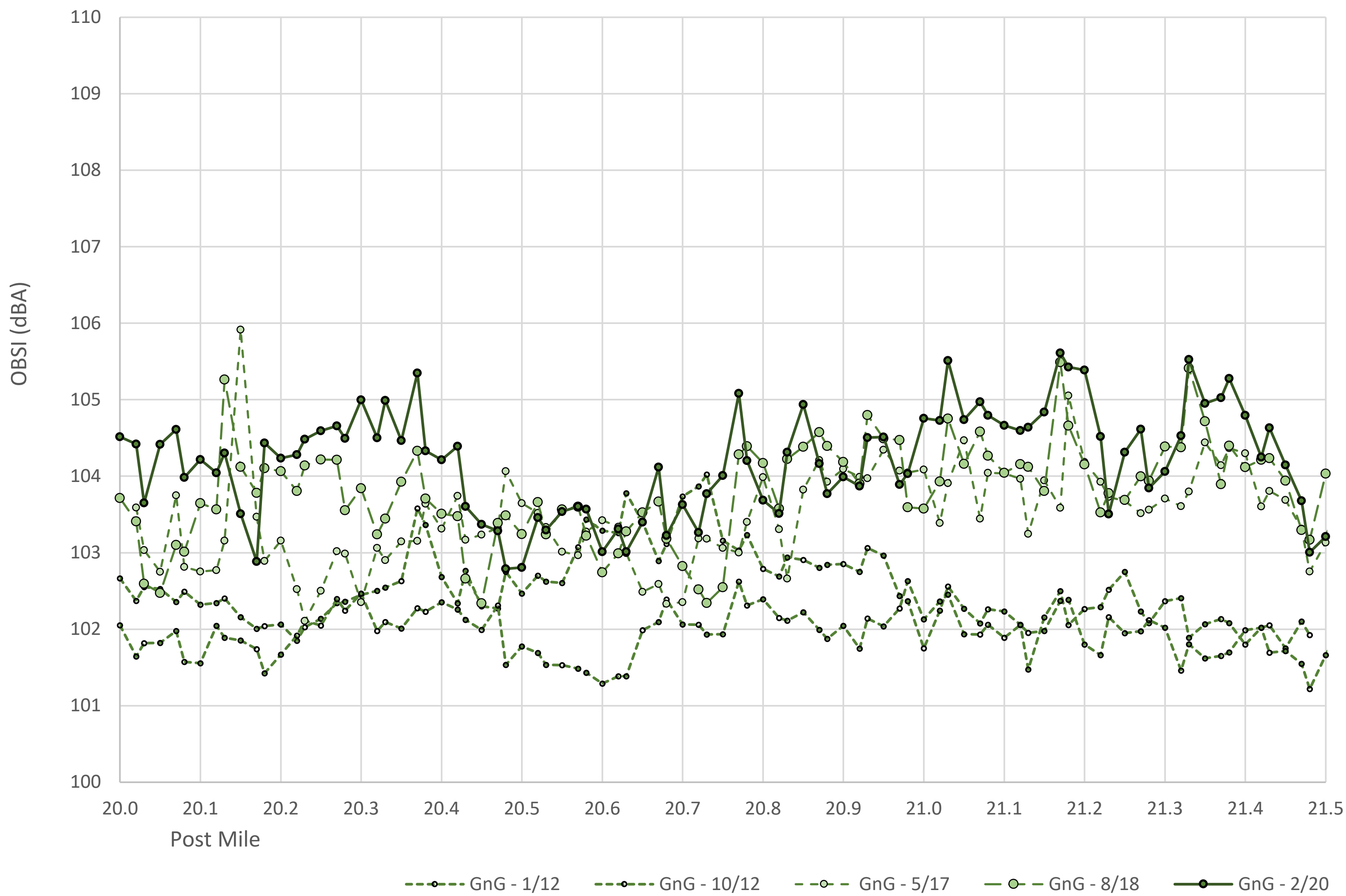
**Figure A.5: OBSI on Imp78E2PMR15.0.**




| | | | | |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 104.1 (0.3) | 103.6 (0.8) | 103.7 (0.7) | 103.6 (0.6) |

**Figure A.6: OBSI on Imp86S2PMR24.2.**

## A.2 Sacramento 5 – PM20.0/21.5




| OBSI Average (Std. Dev.), dBA | 102.5 (0.5) | 101.9 (0.3) | 103.5 (0.6) | 103.8 (0.6) | 104.2 (0.7) |
|---|---|---|---|---|---|

**Figure A.7: OBSI on Sac5N1-PM20.0/21.5.**

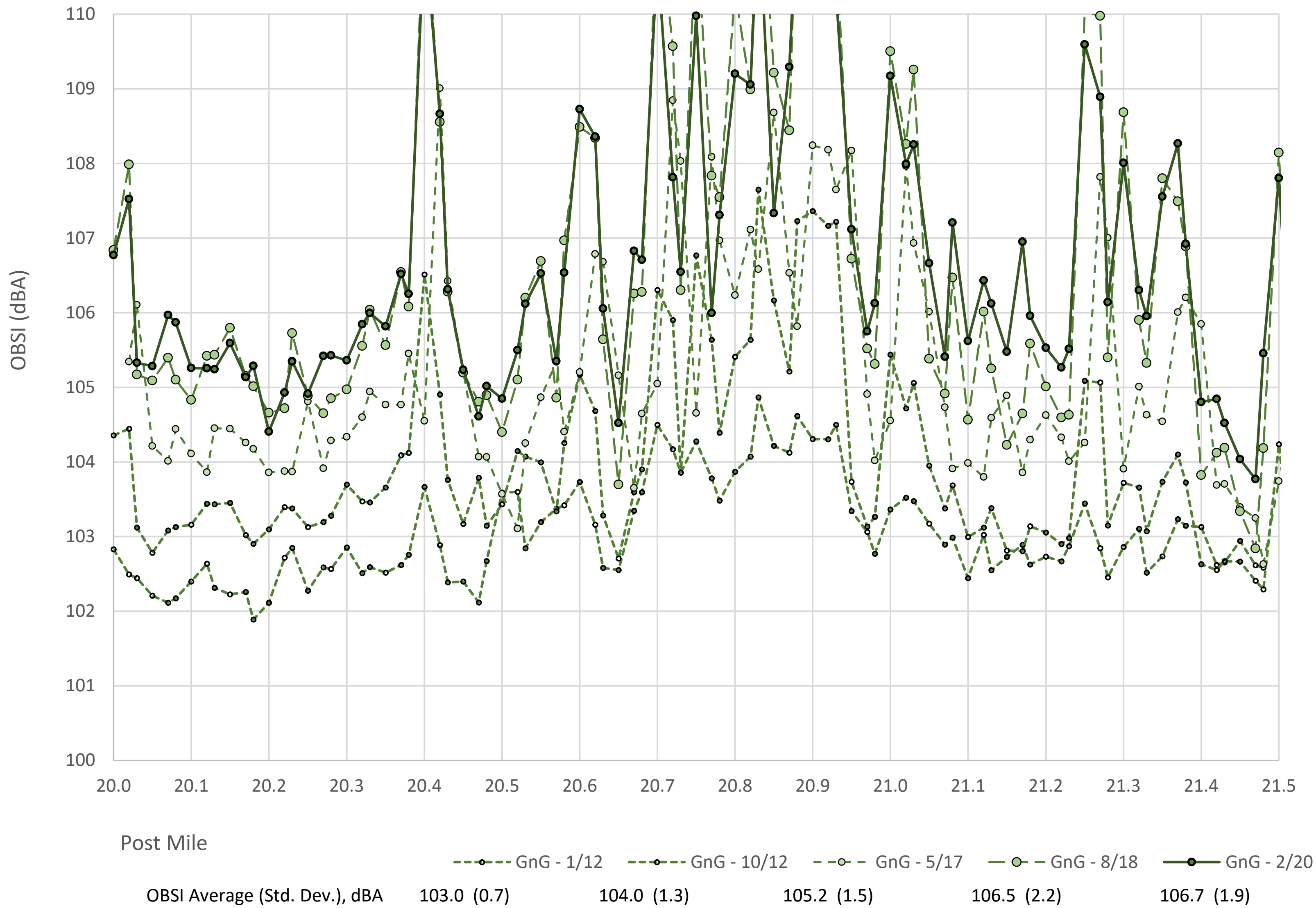
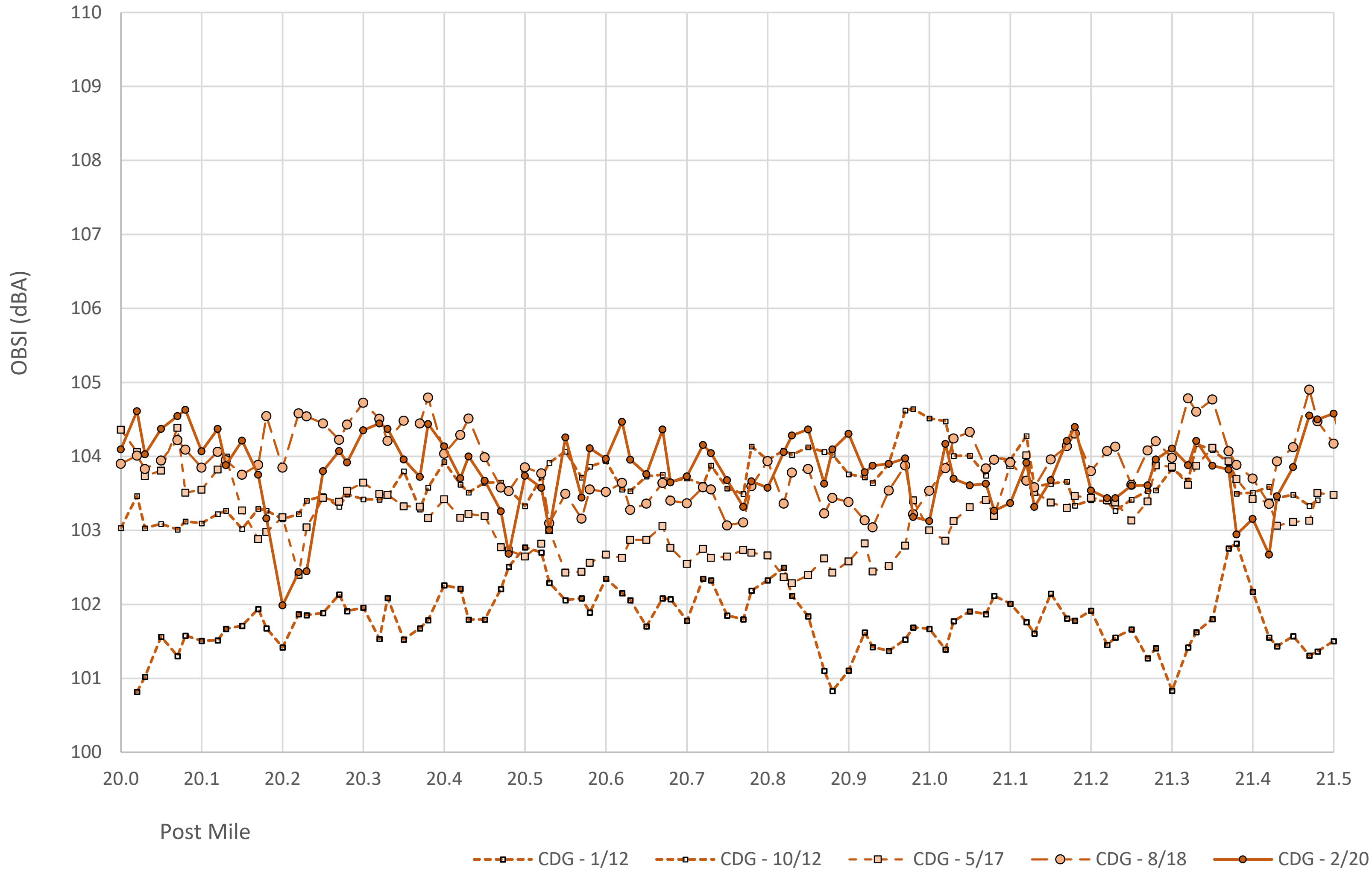



**Figure A.8: OBSI on Sac5N4 – PM20.0-/21.5.**




| | | | | | |
|---|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 101.8 (0.4) | 103.6 (0.4) | 103.2 (0.5) | 103.9 (0.4) | 103.8 (0.5) |

**Figure A.9: OBSI on Sac5S1 - PM20.0/21.5.**

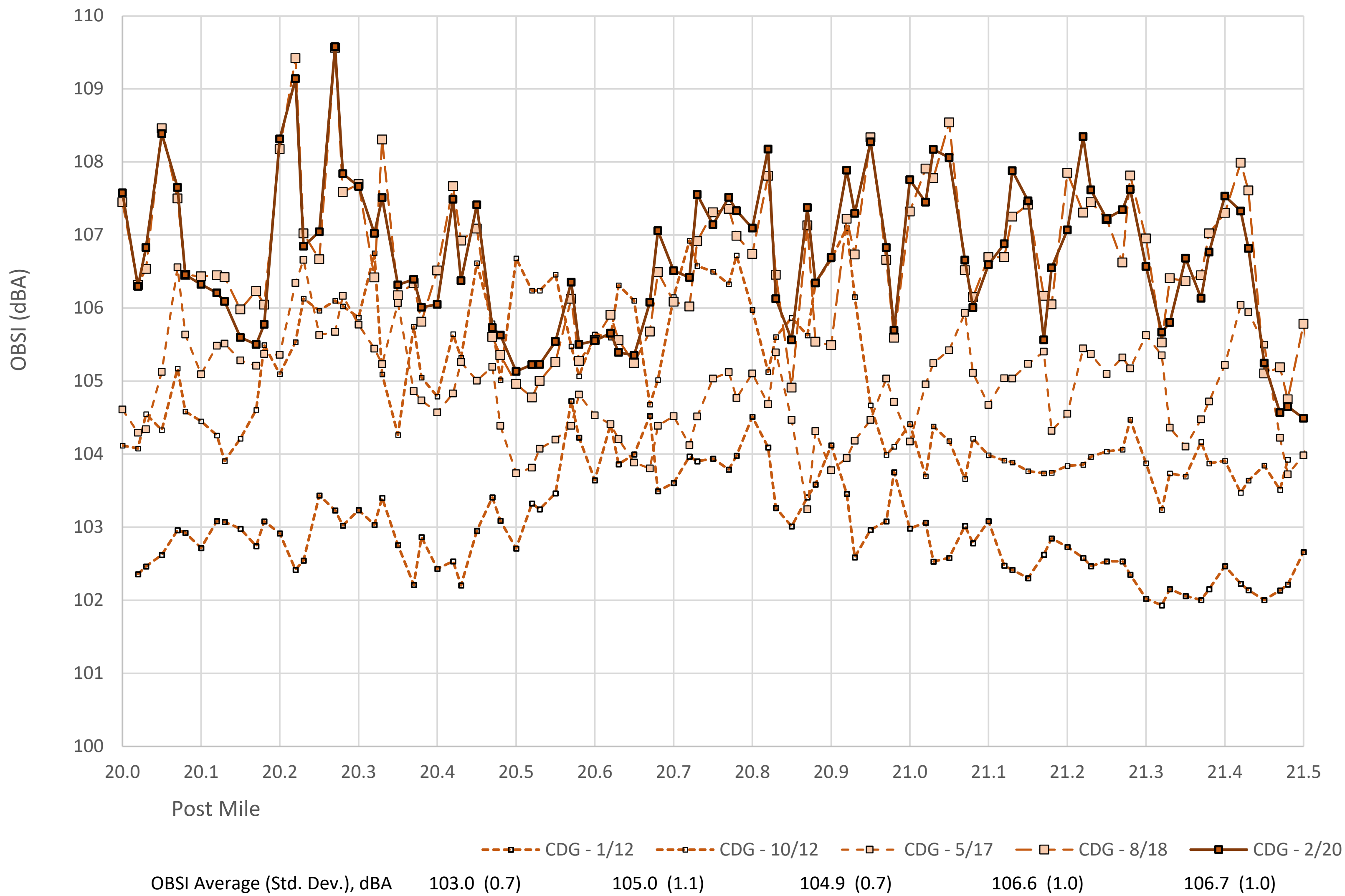



**Figure A.10: OBSI on Sac5S4 - PM20.0/21.5.**

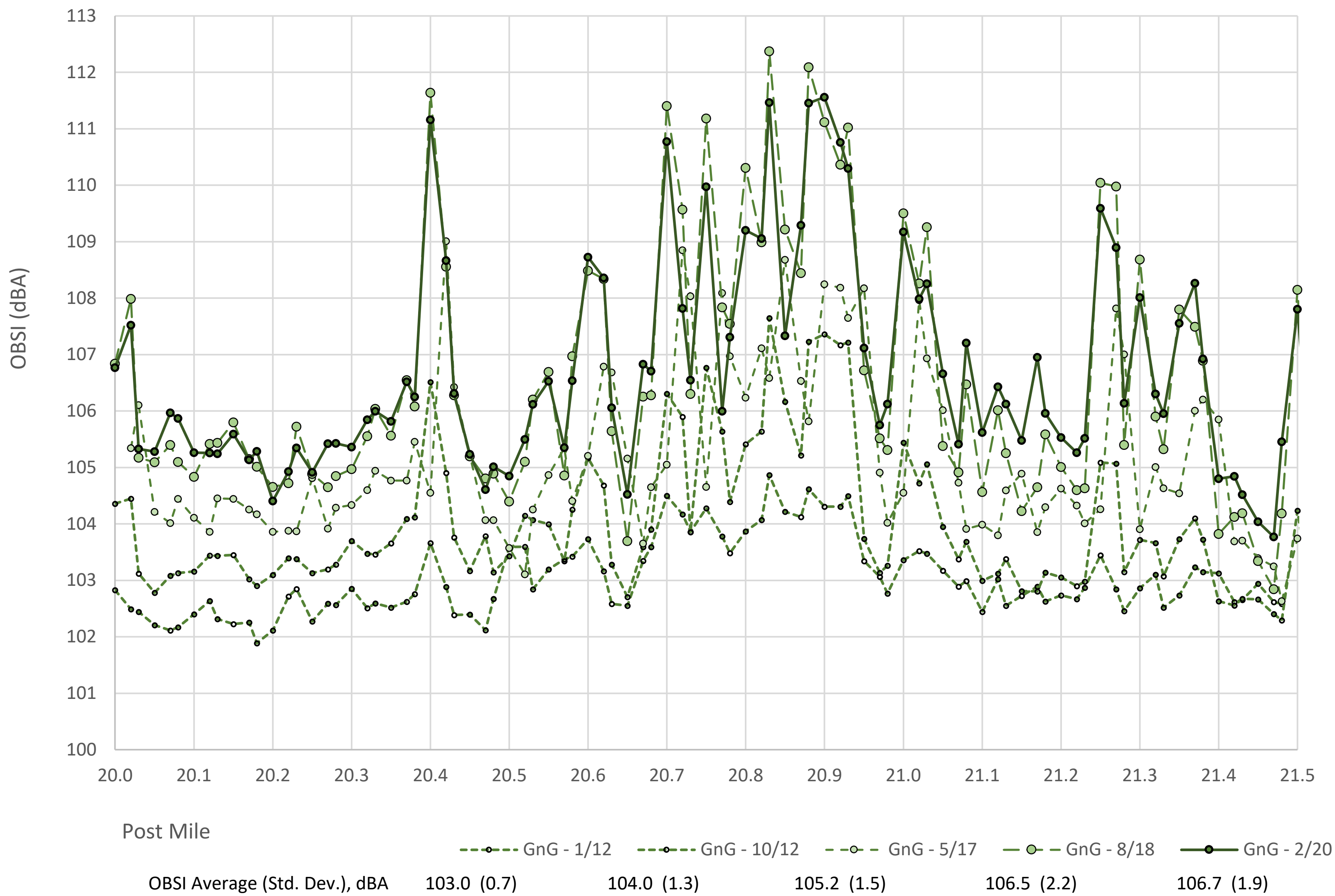



**Figure A.11: OBSI on Sac5N4 - PM20.0/21.5 (larger scale).**

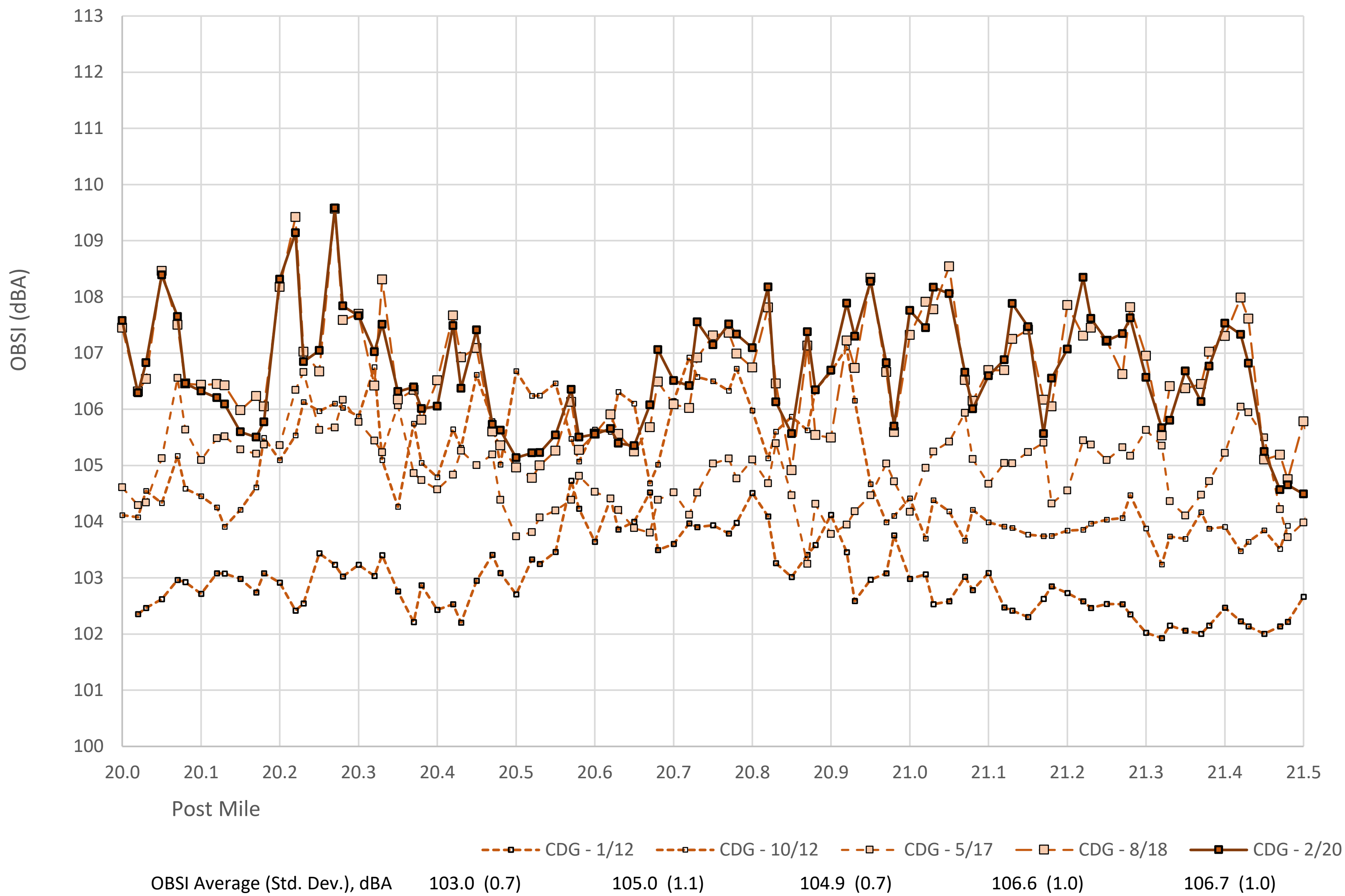
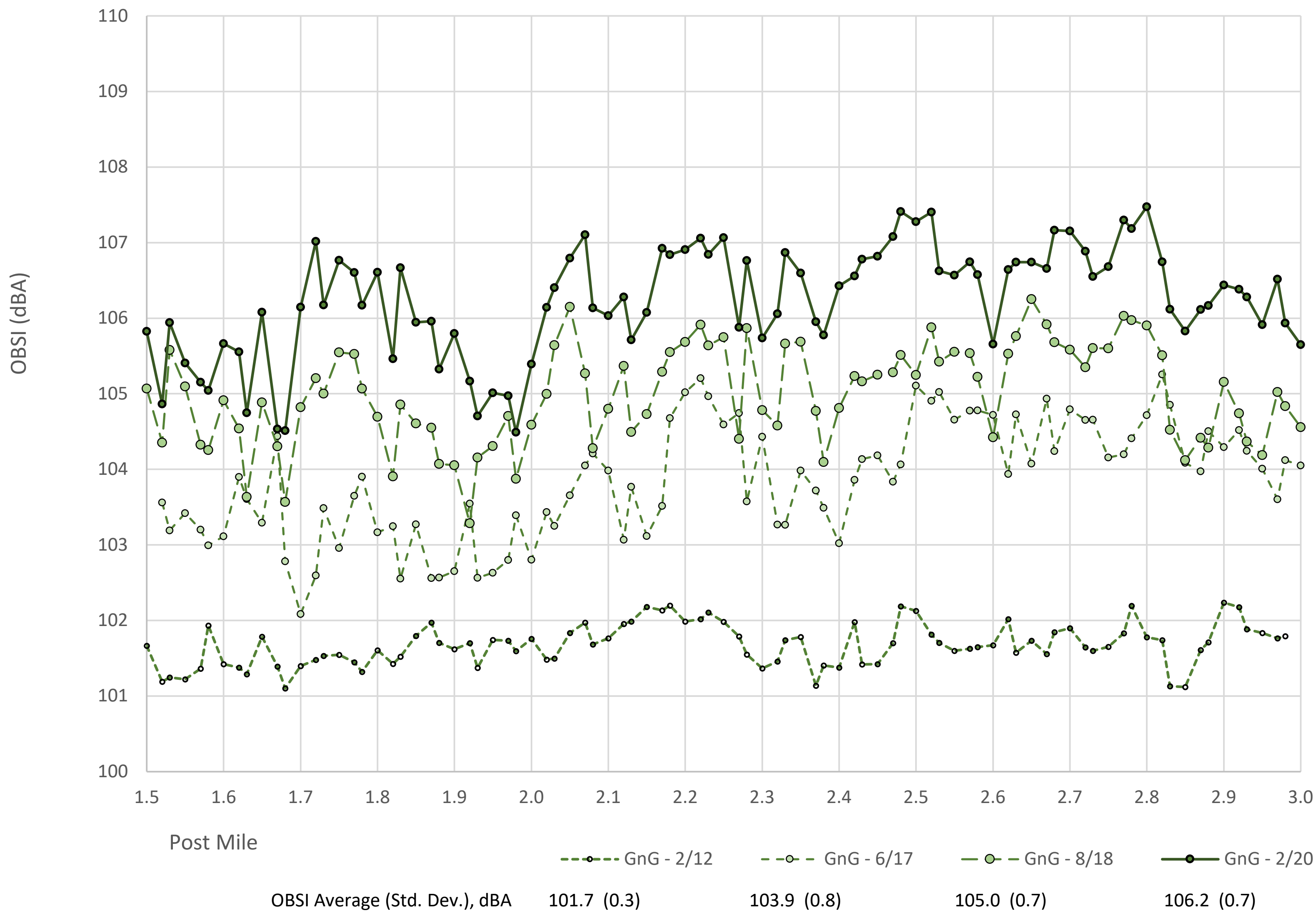



**Figure A.12: OBSI on Sac5S4 - PM20.0/21.5 (larger scale).**

## A.3 Sacramento 5 – PM1.5/3.0




| OBSI Average (Std. Dev.), dBA | 101.7 (0.3) | 103.9 (0.8) | 105.0 (0.7) | 106.2 (0.7) |
|---|---|---|---|---|

**Figure A.13: OBSI on Sac5N1 - PM1.5/3.0.**

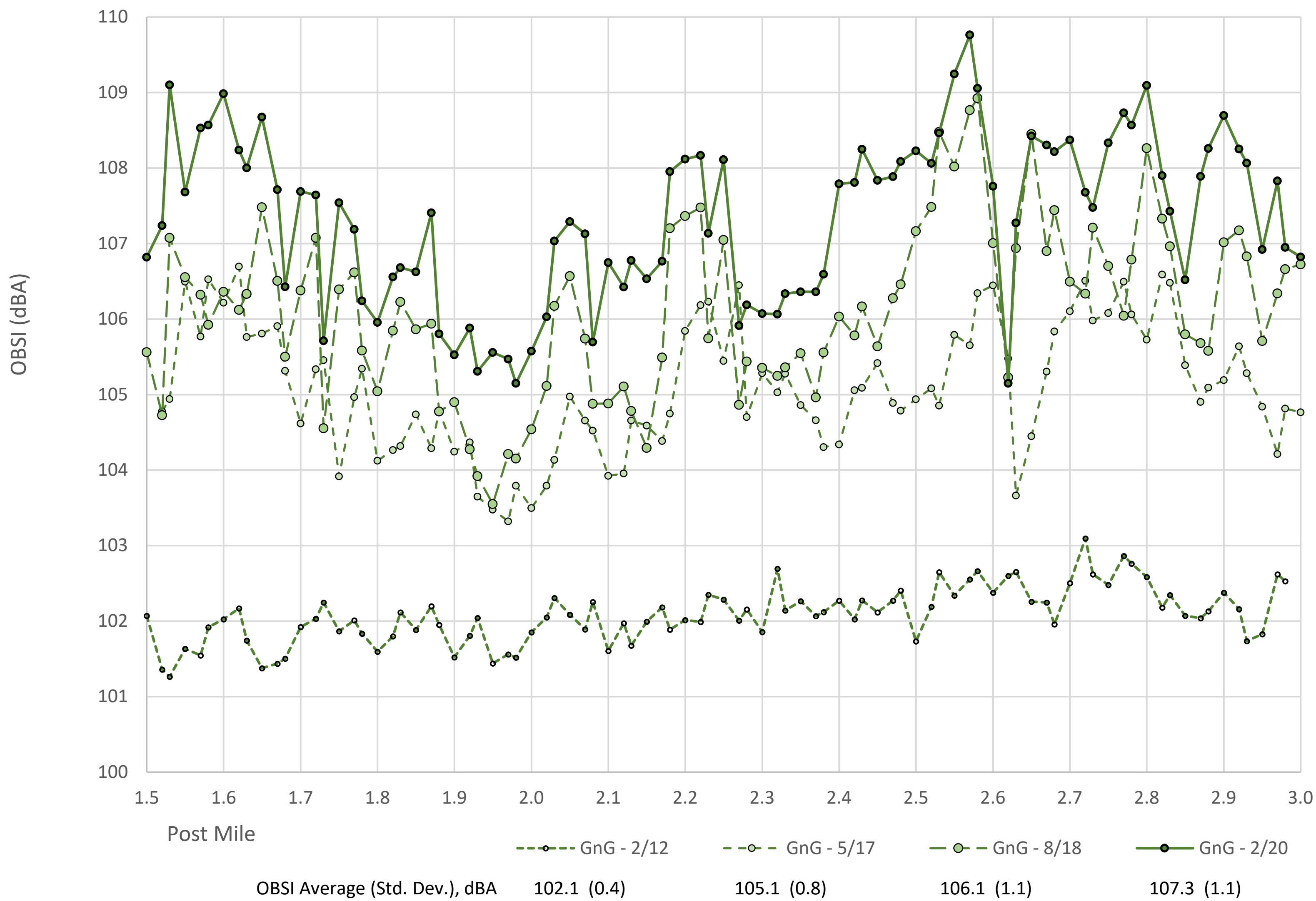
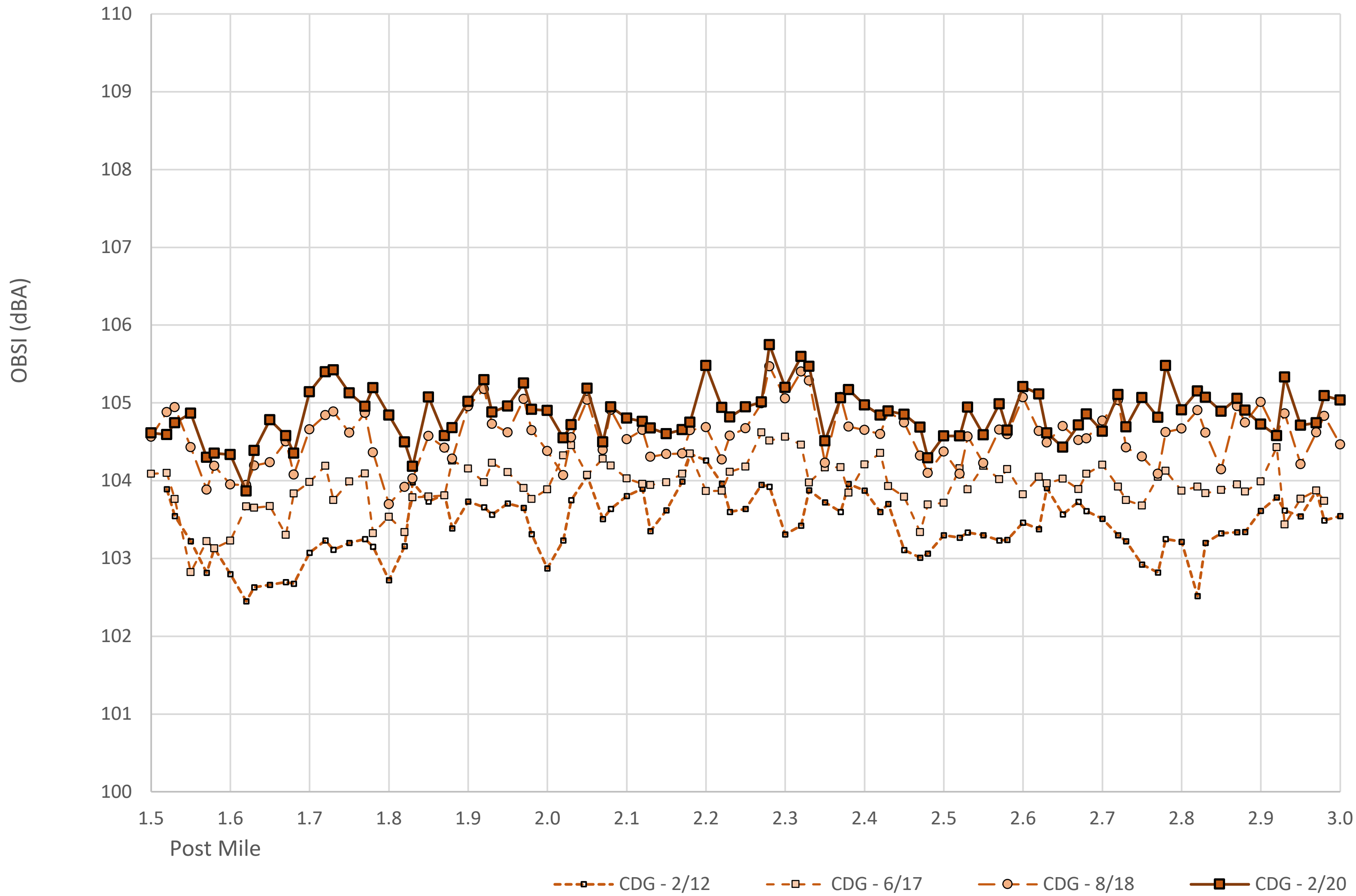



**Figure A.14: OBSI on Sac5N2 - PM1.5/3.0.**




| | | | | |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 103.4 (0.4) | 103.9 (0.3) | 104.6 (0.4) | 104.9 (0.3) |

**Figure A.15: OBSI on Sac5S1 - PM1.5/3.0.**

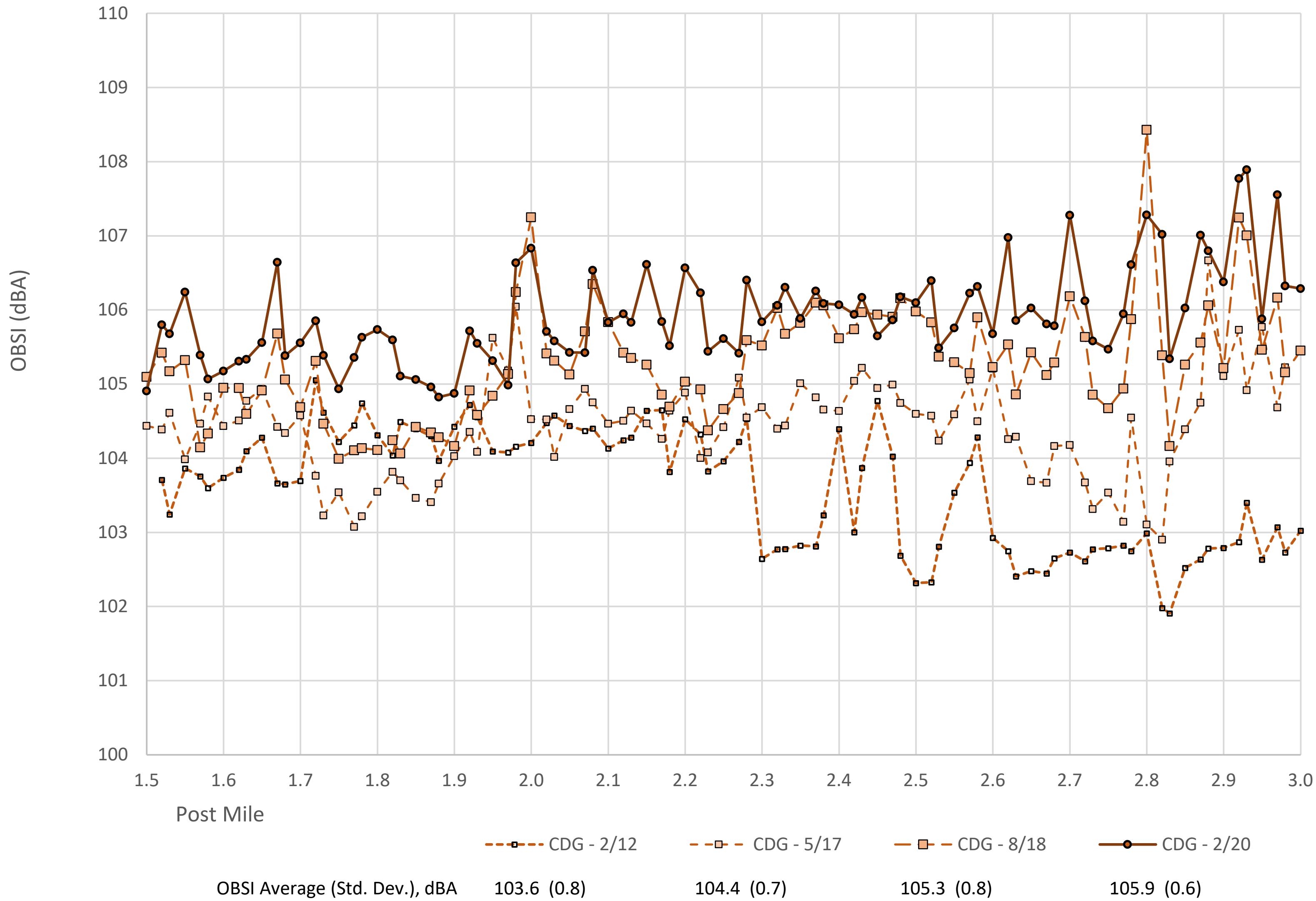



**Figure A.16: OBSI on Sac5S2 - PM 1.5/3.0.**

## A.4 Sacramento 80 – PM13.0/14.0

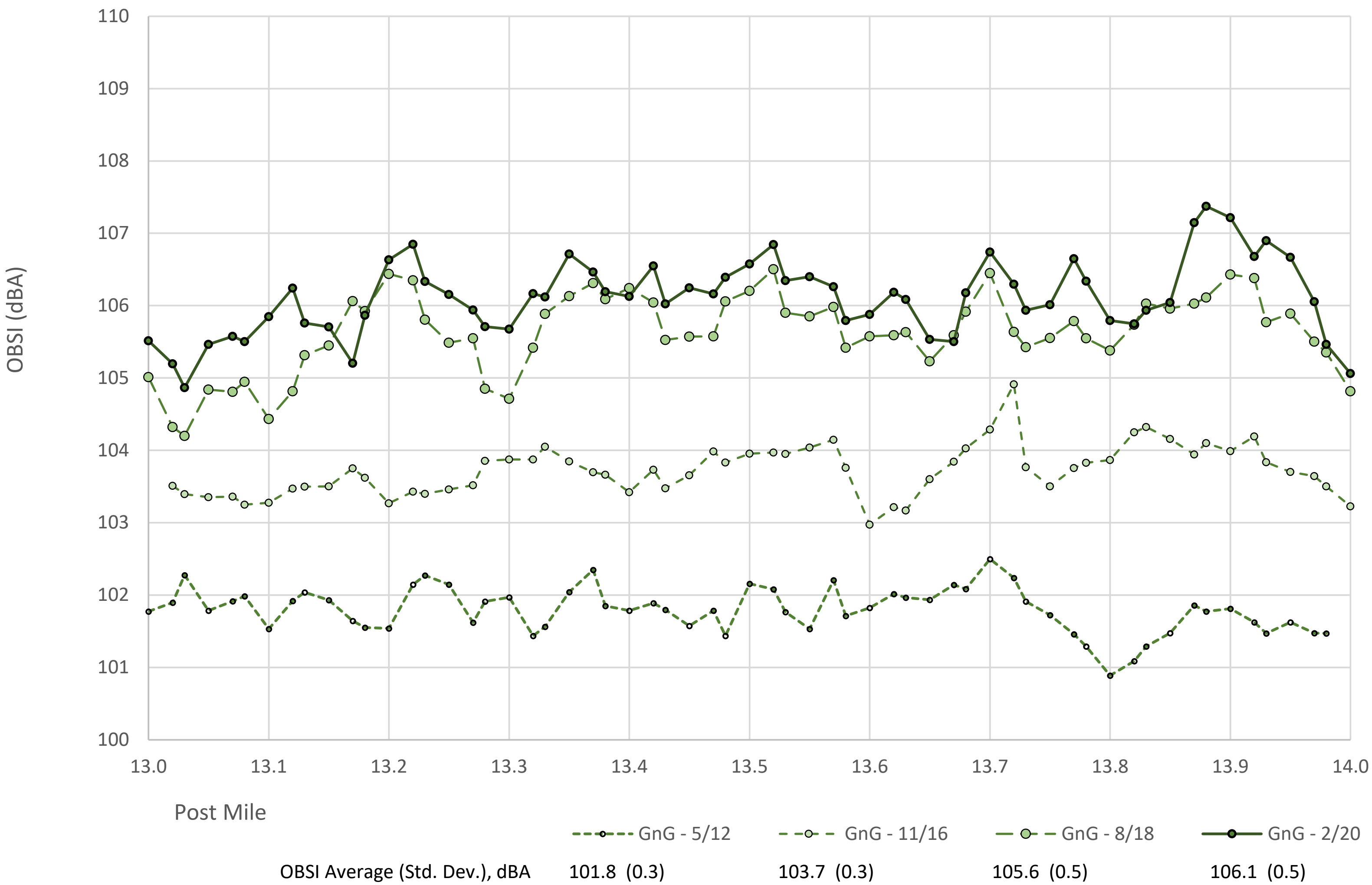



**Figure A.17: OBSI on Sac80E2 - PM13.0/14.0.**

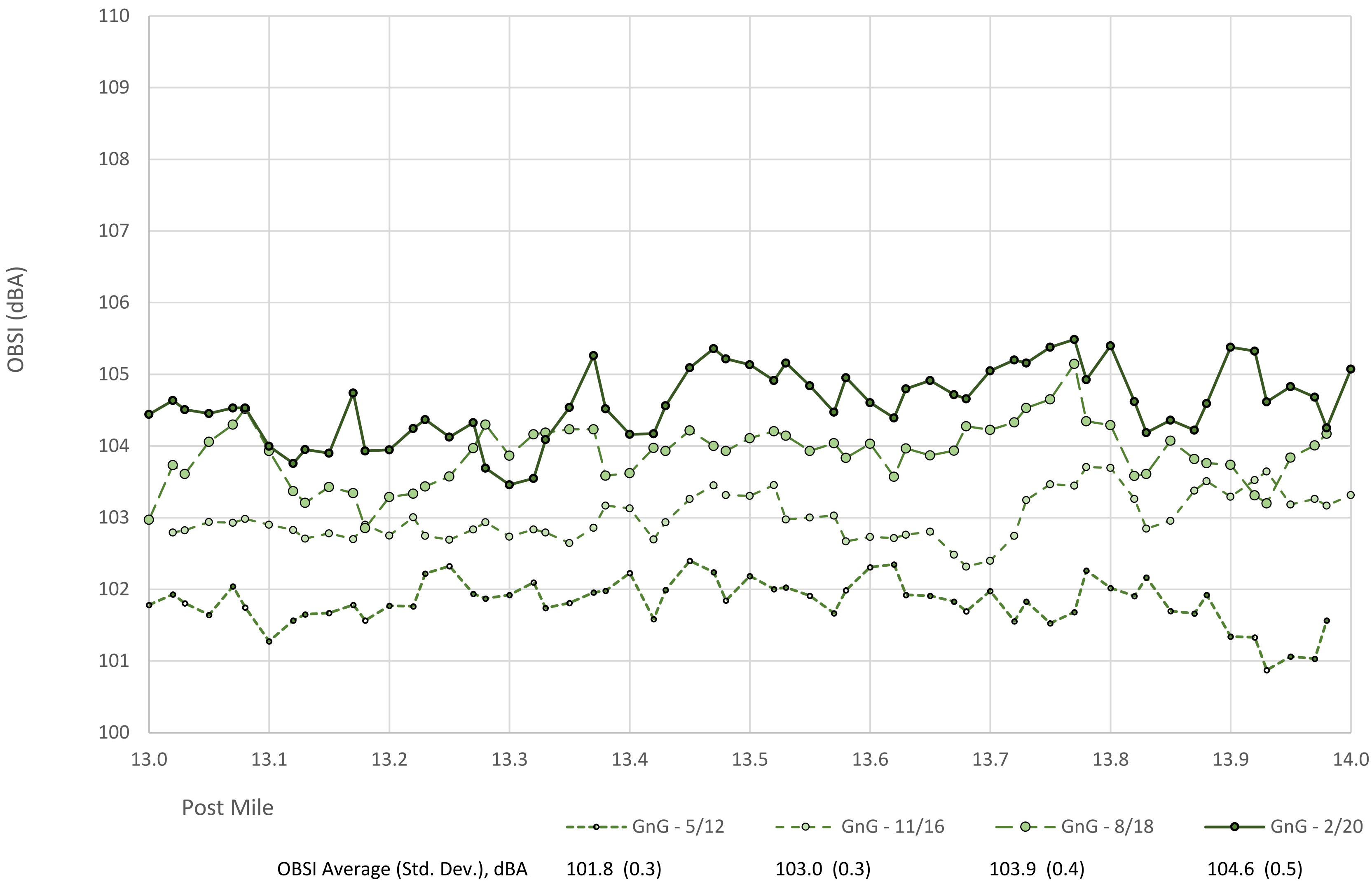



**Figure A.18: OBSI on Sac80E5 - PM13.0/14.0.**

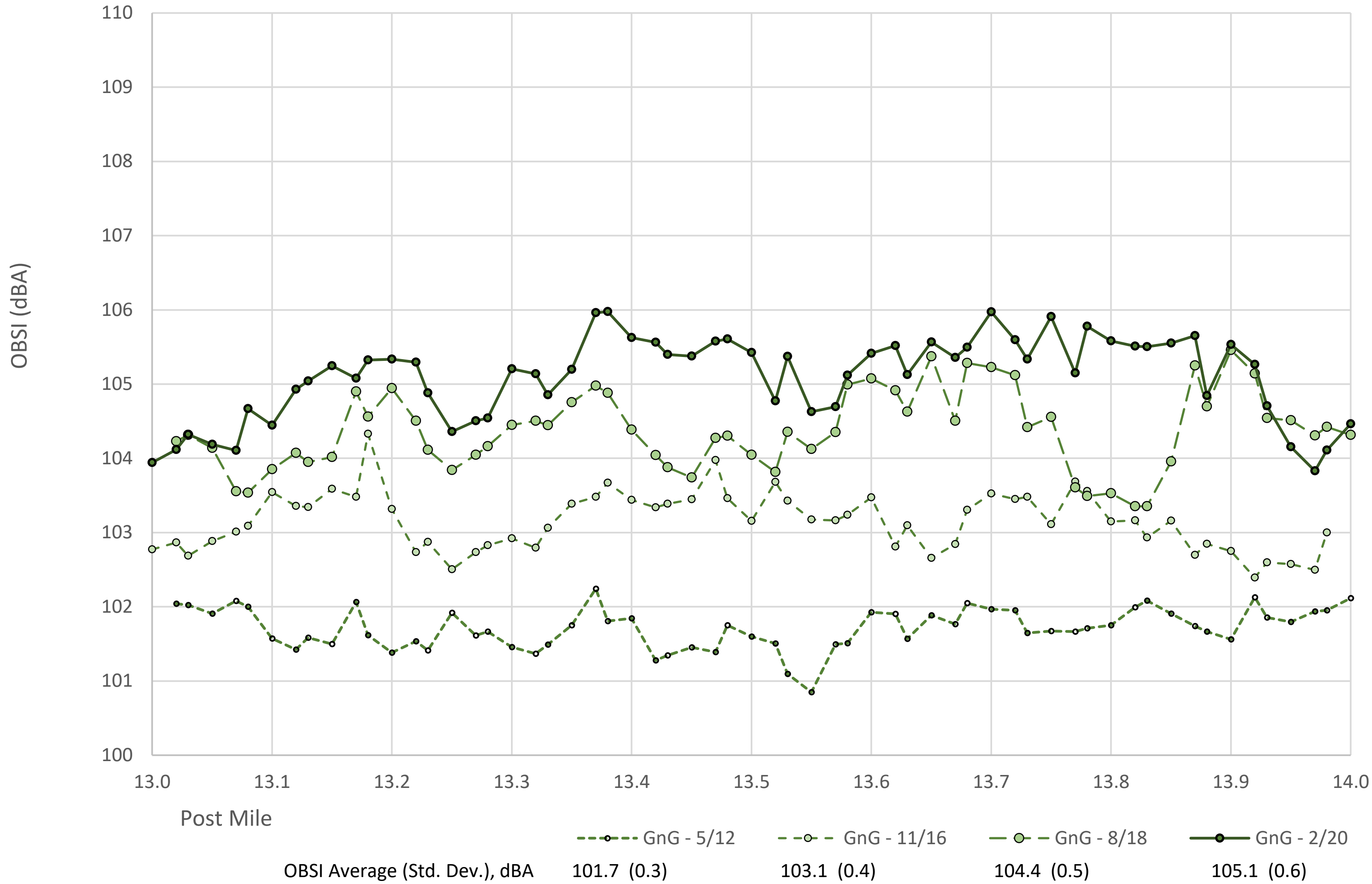



**Figure A.19: OBSI on Sac80W2 - PM13.0/14.0.**

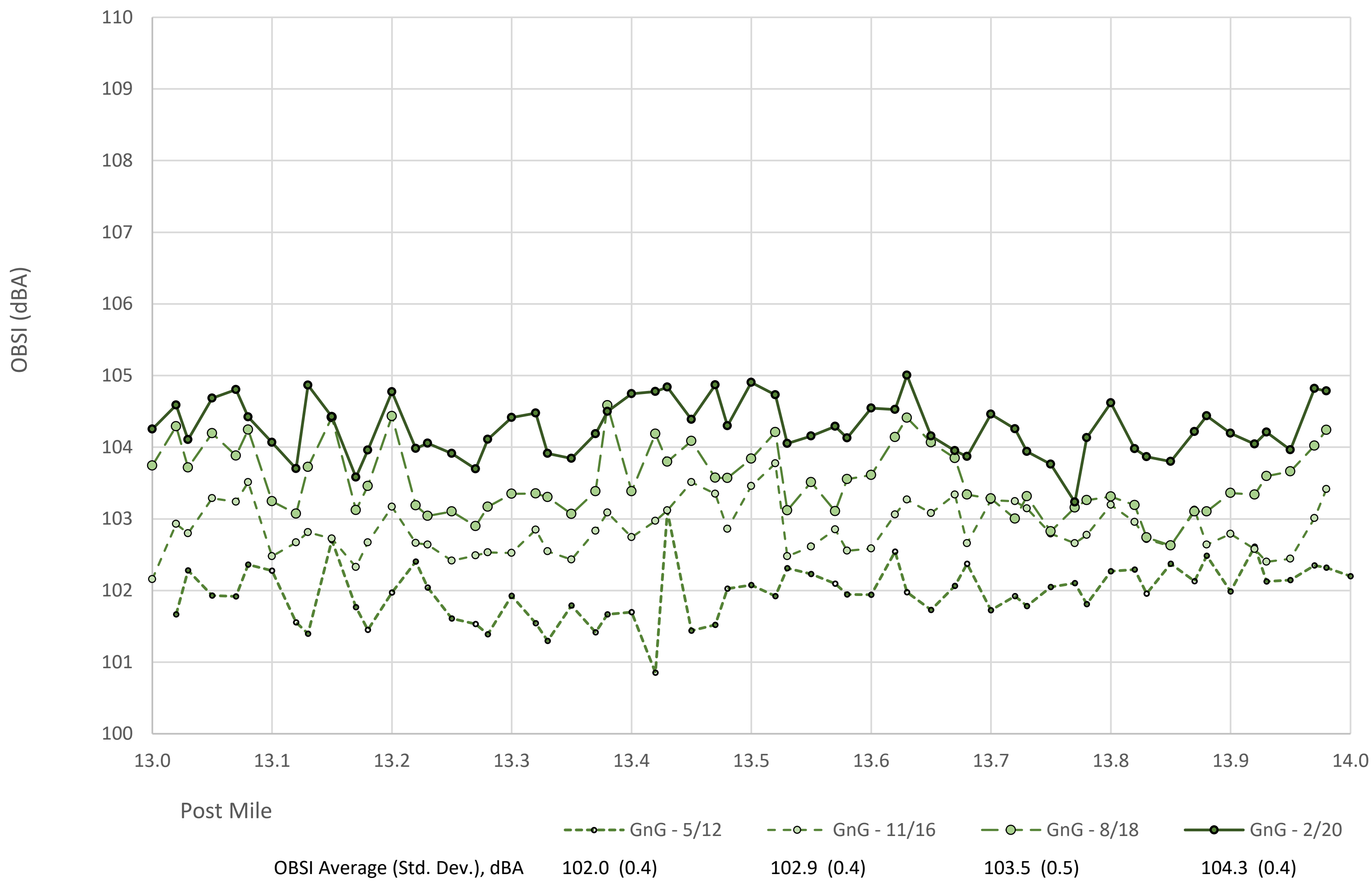



**Figure A.20: OBSI on Sac80W5 - PM13.0/14.0.**

## A.5 Sacramento 50 – PMR13.0/R14.0

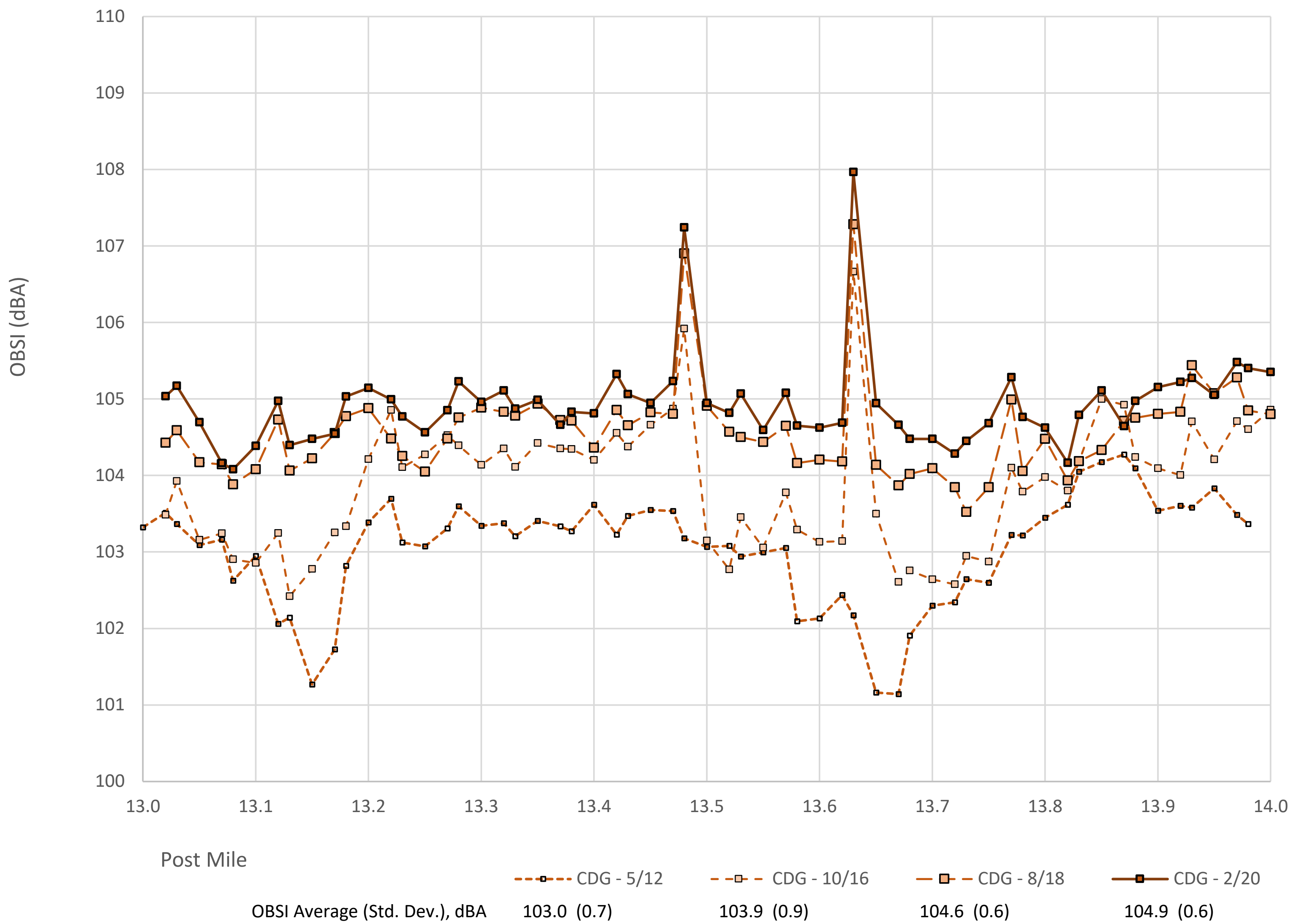



**Figure A.21: OBSI on Sac50E2 - PMR13.0/R14.0.**

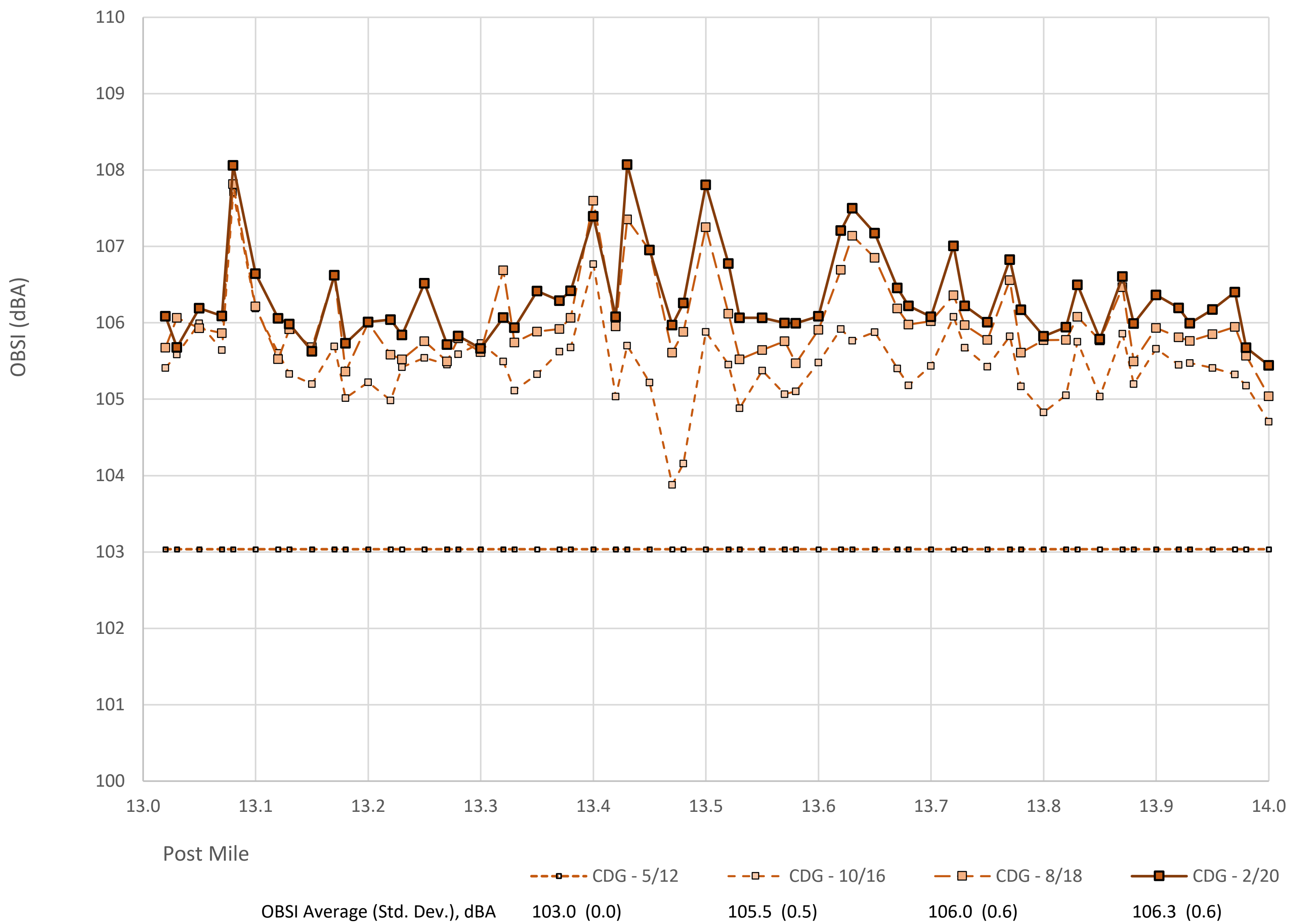



**Figure A.22: OBSI on Sac50E4 - PMR13.0/R14.0.**

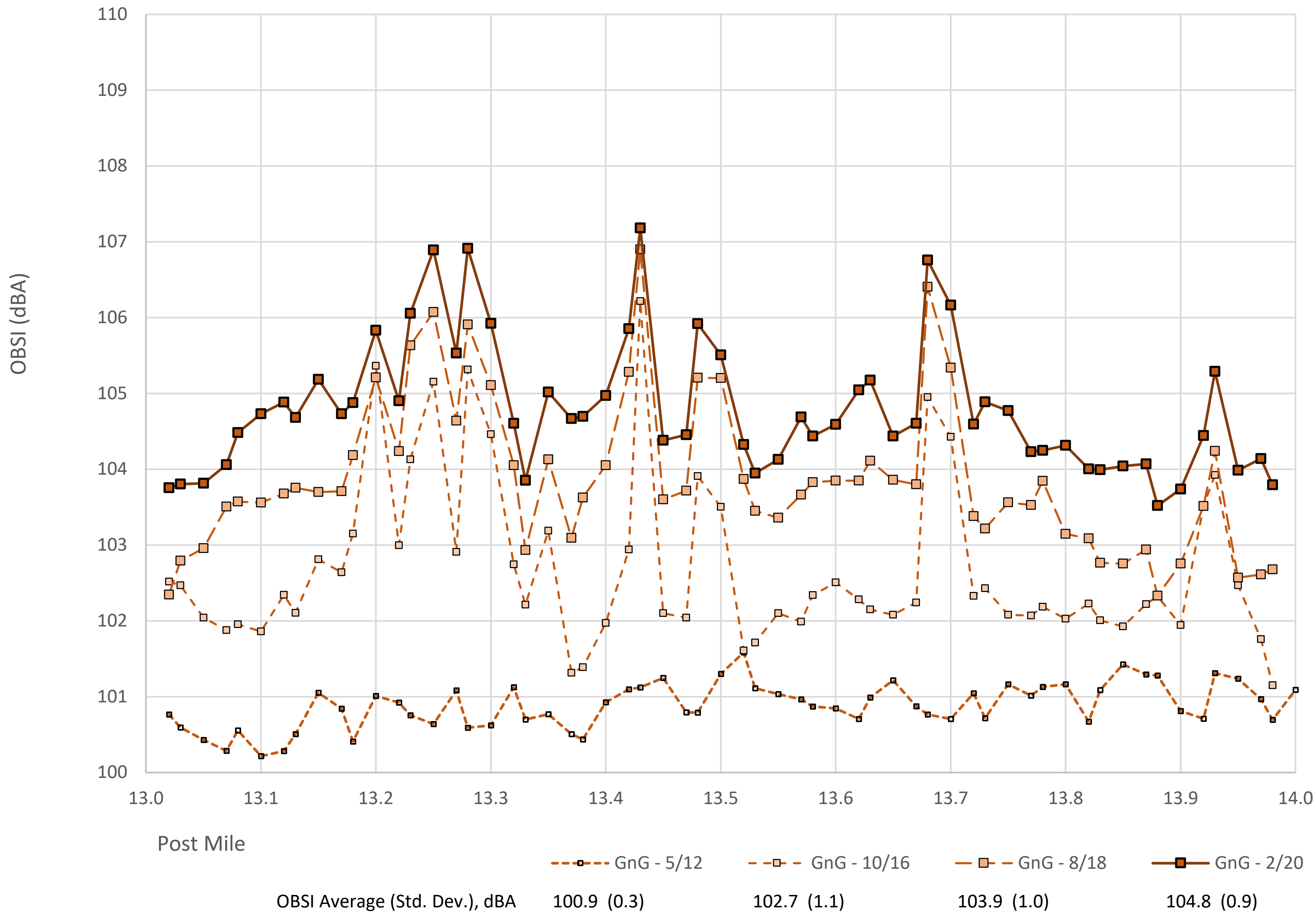



**Figure A.23: OBSI on Sac50W2 - PMR13.0/R14.0.**

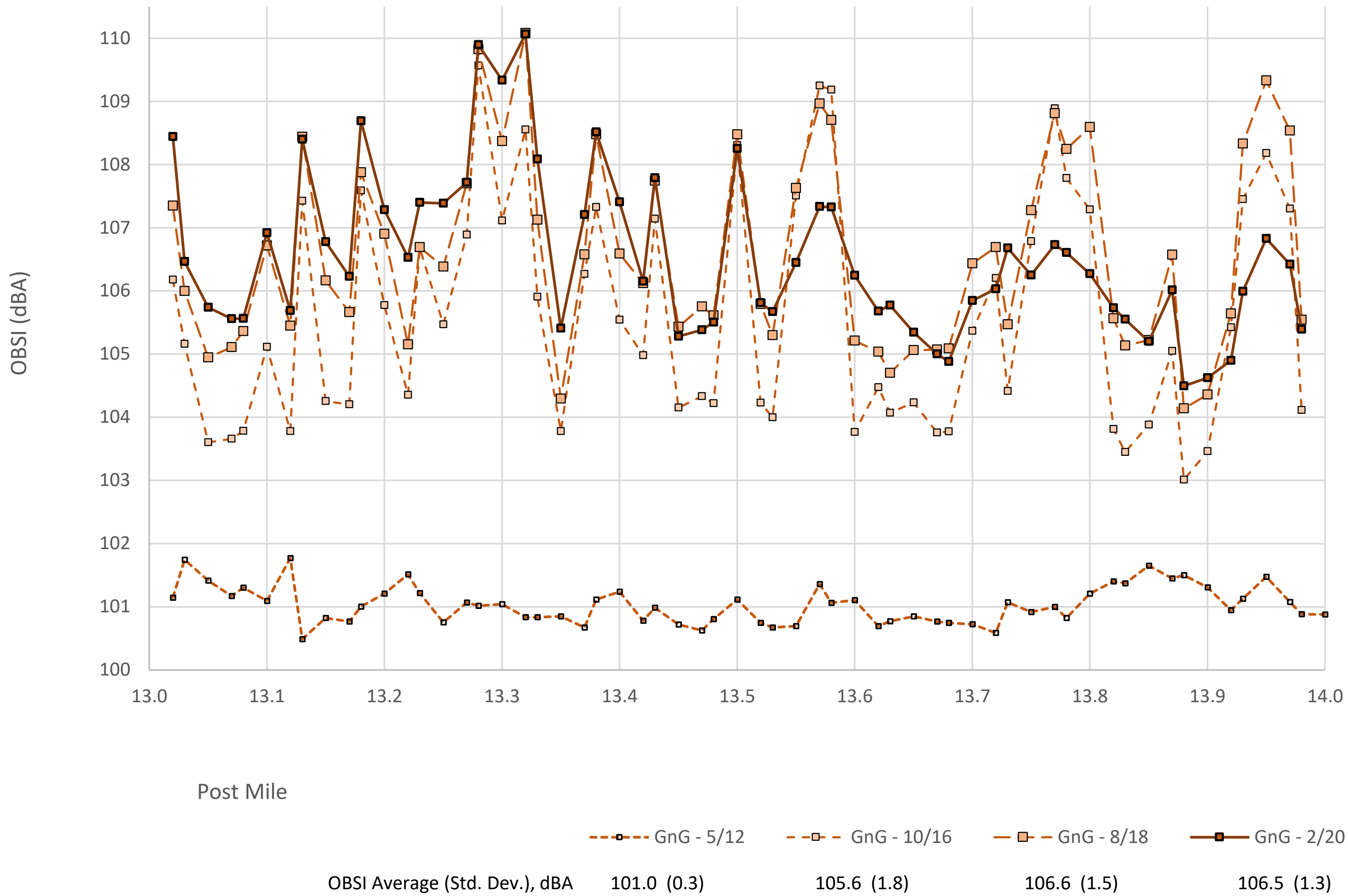



**Figure A.24: OBSI on Sac50W4 - PMR13.0/R14.0.**

## A.6 San Joaquin 99 – PM29.0/30.7

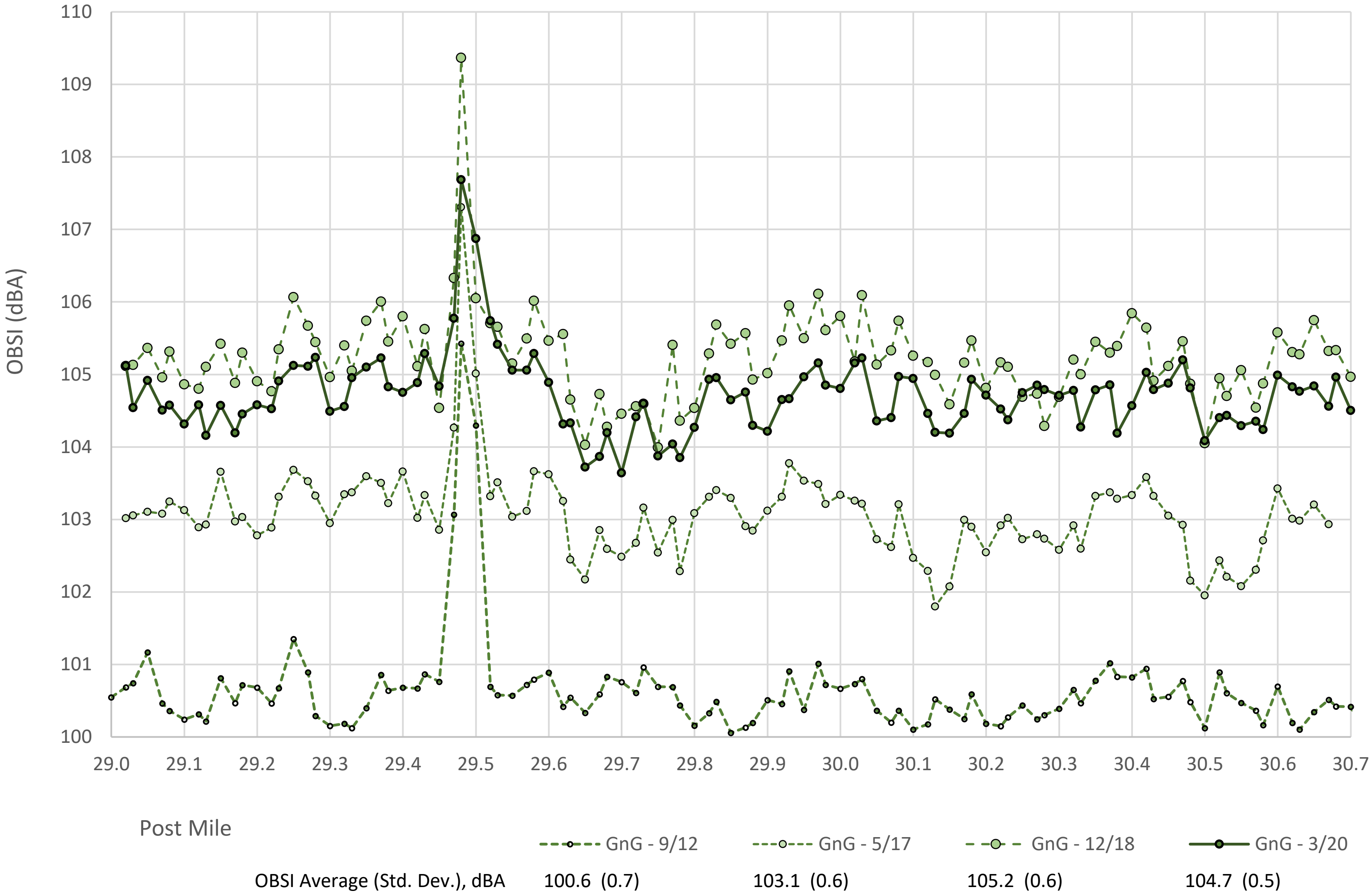
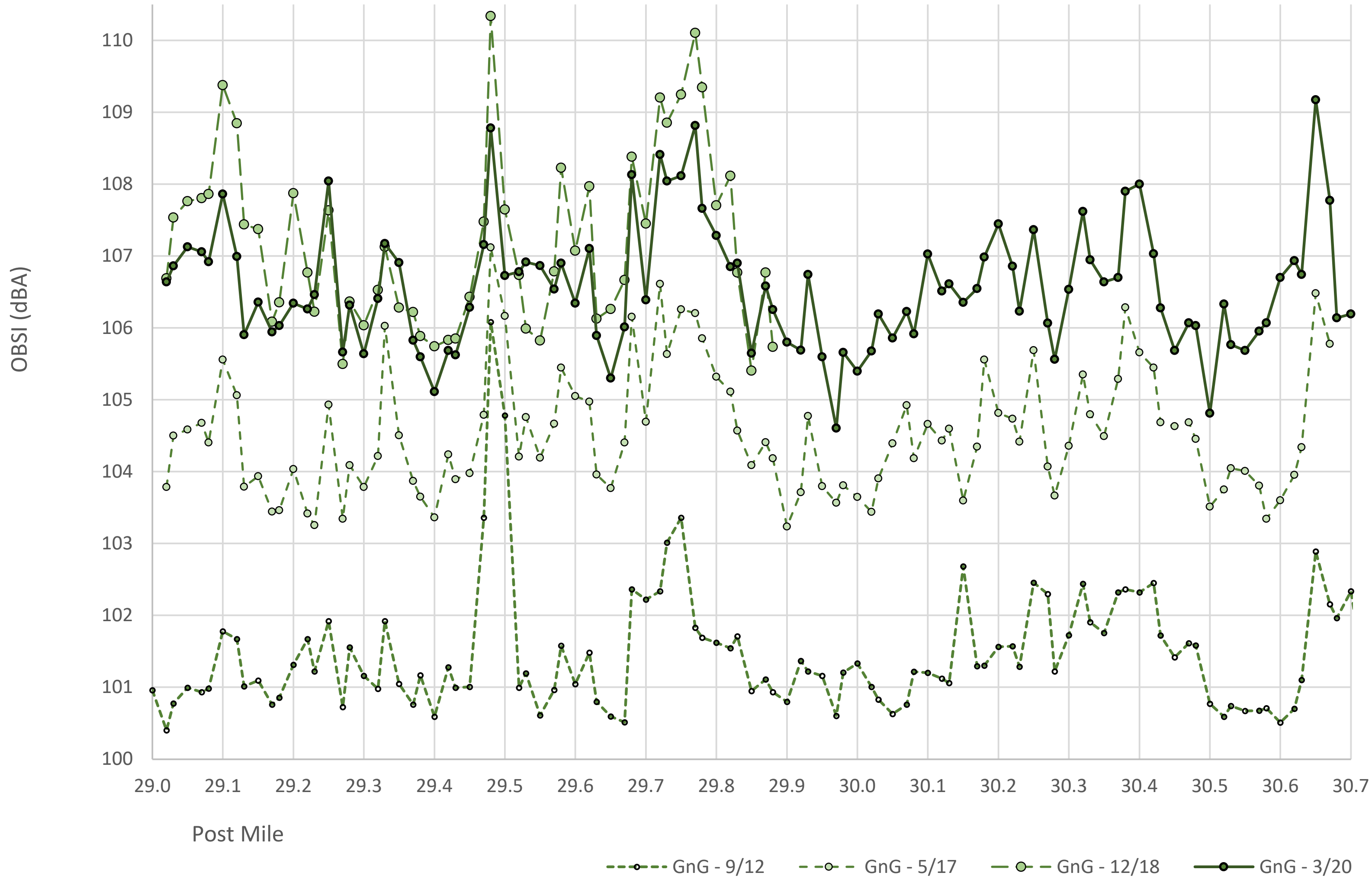



**Figure A.25: OBSI on SJ99N1 - PM29.0/30.7.**




| OBSI Average (Std. Dev.), dBA | 101.5 (0.9) | 104.5 (0.9) | 107.2 (1.2) | 106.6 (0.9) |
|---|---|---|---|---|

**Figure A.26: OBSI on SJ99N2 - PM29.0/30.7.**

## A.7 Yolo 113 – PMR0.5/R2.5

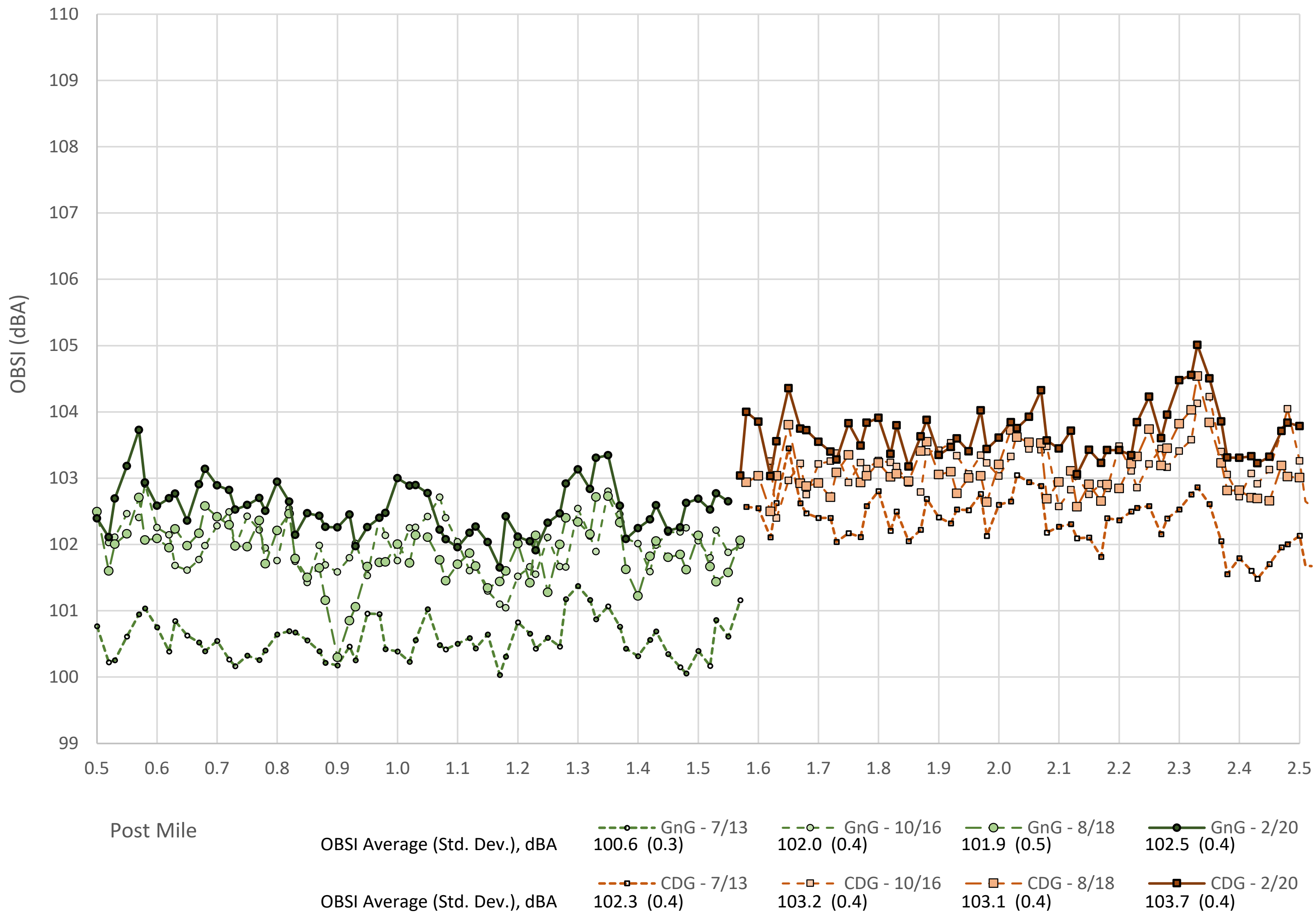



**Figure A.27: OBSI on Yol113N1 - PMR0.5/R2.5.**

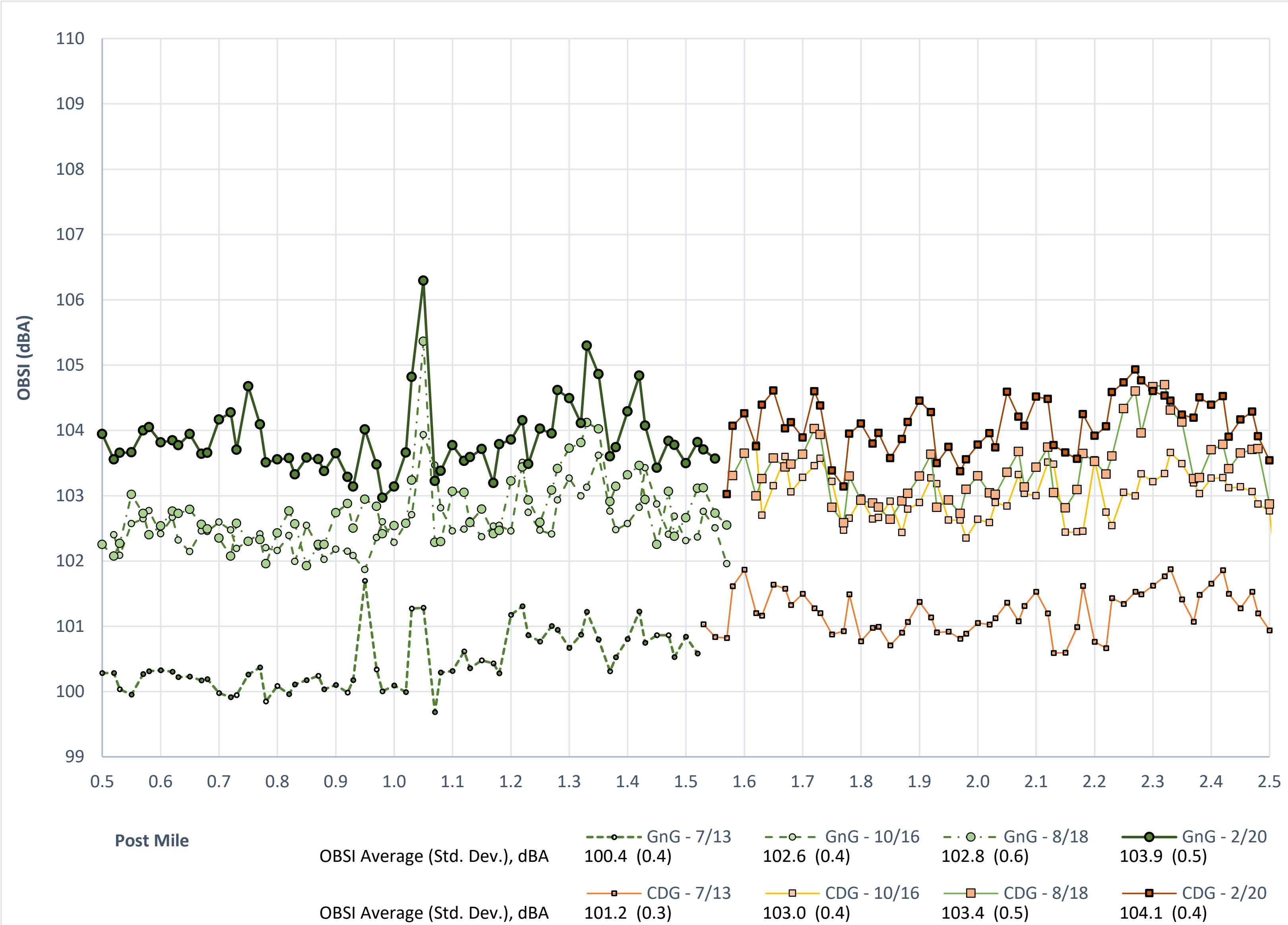



**Figure A.28: OBSI on Yol113N2 - PMR0.5/R2.5.**

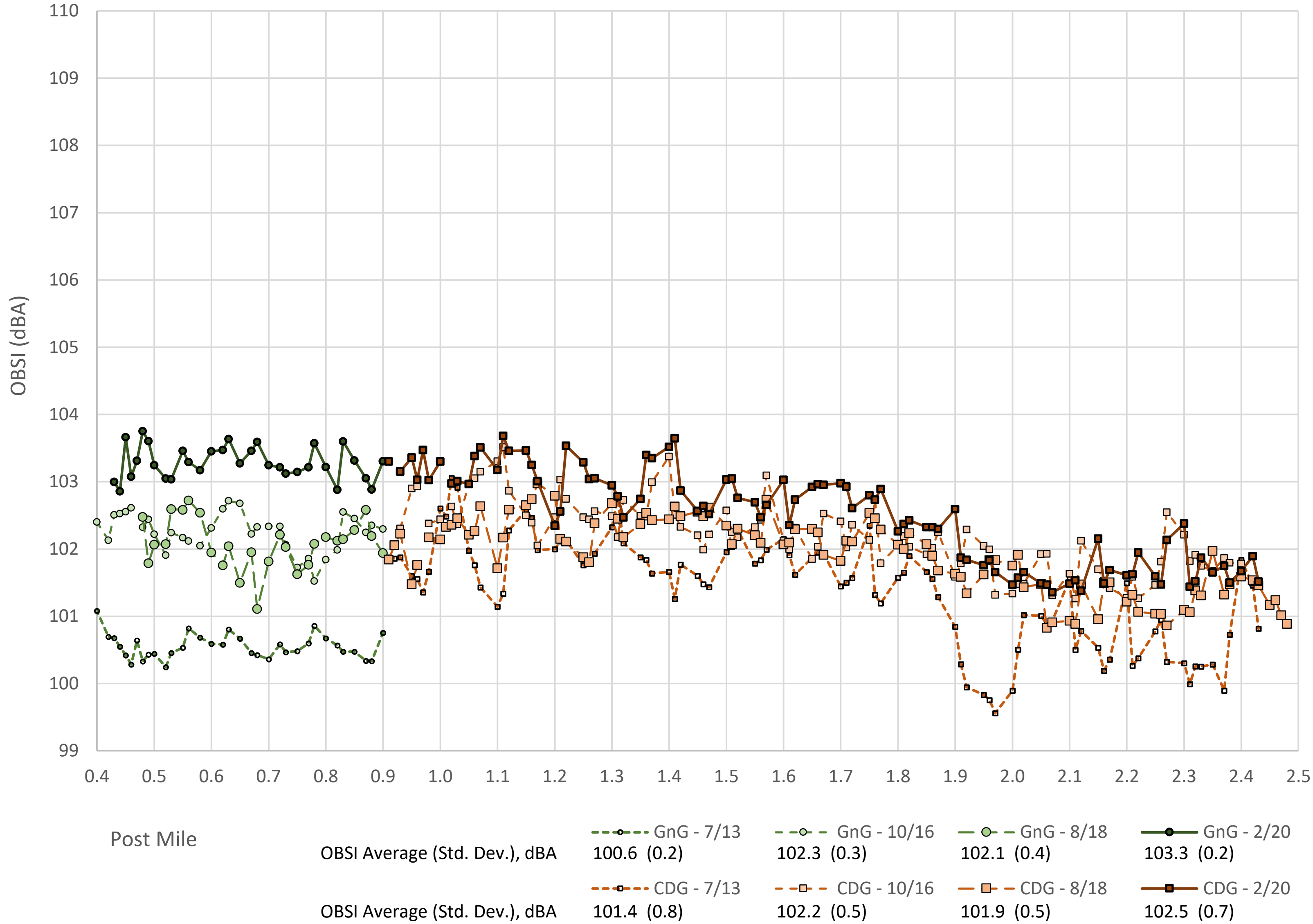



**Figure A.29: OBSI on Yol113S1 - PMR0.5/R2.5.**

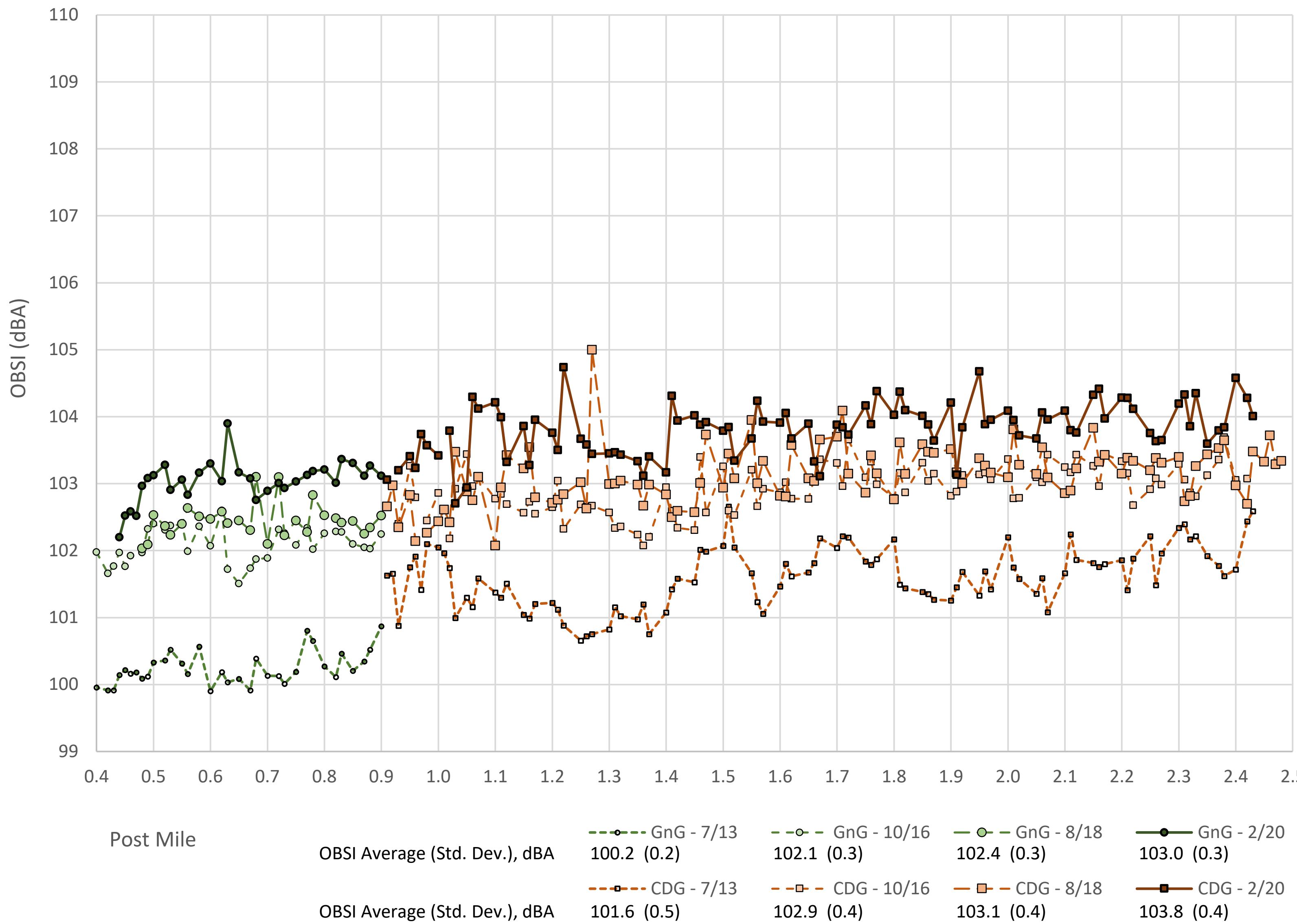



**Figure A.30: OBSI on Yol113S2 - PMR0.5/R2.5.**

## A.8 San Diego 5 – PM35.8/37.9

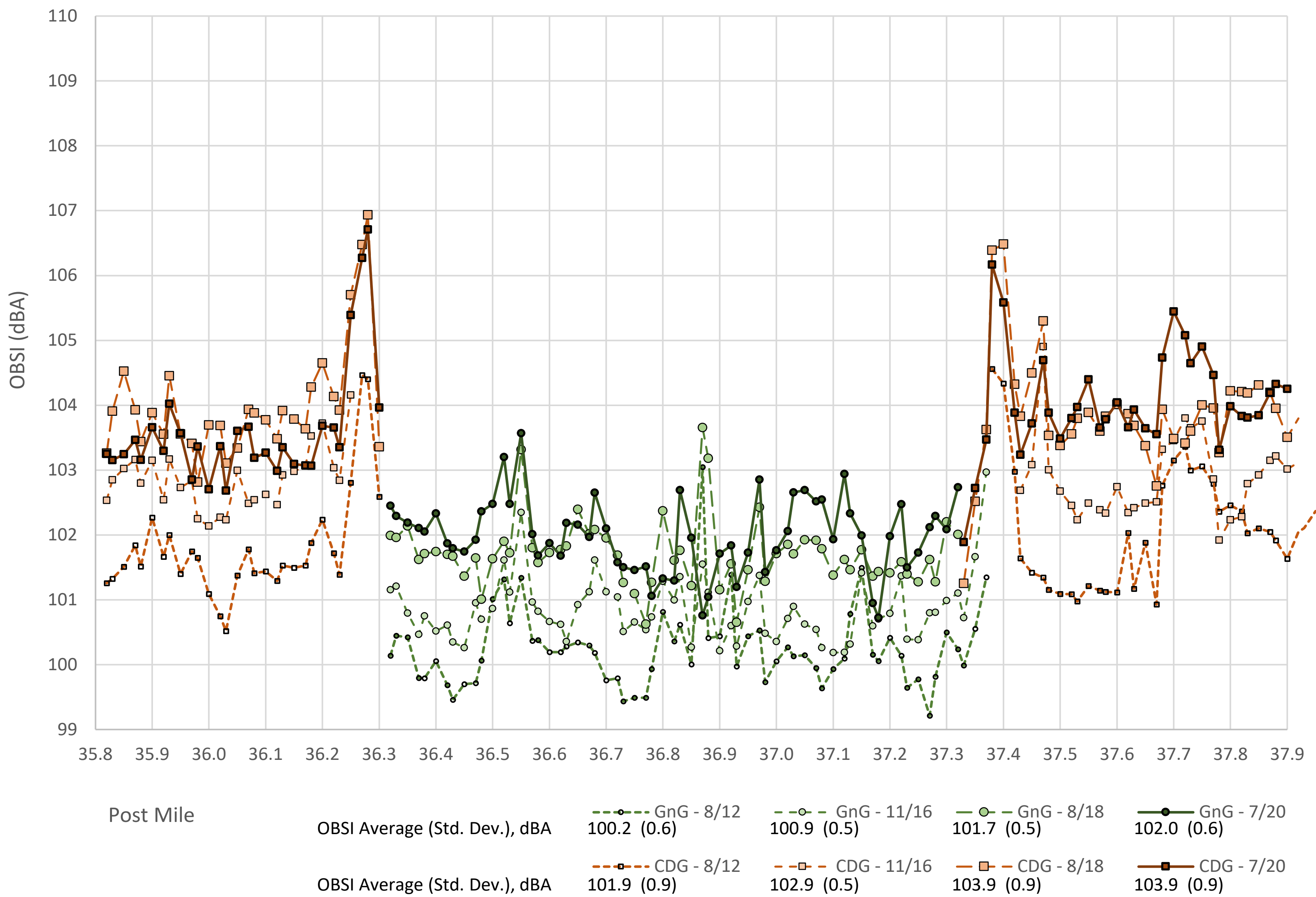



**Figure A.31: OBSI on SD5N1 - PM35.8/37.9.**

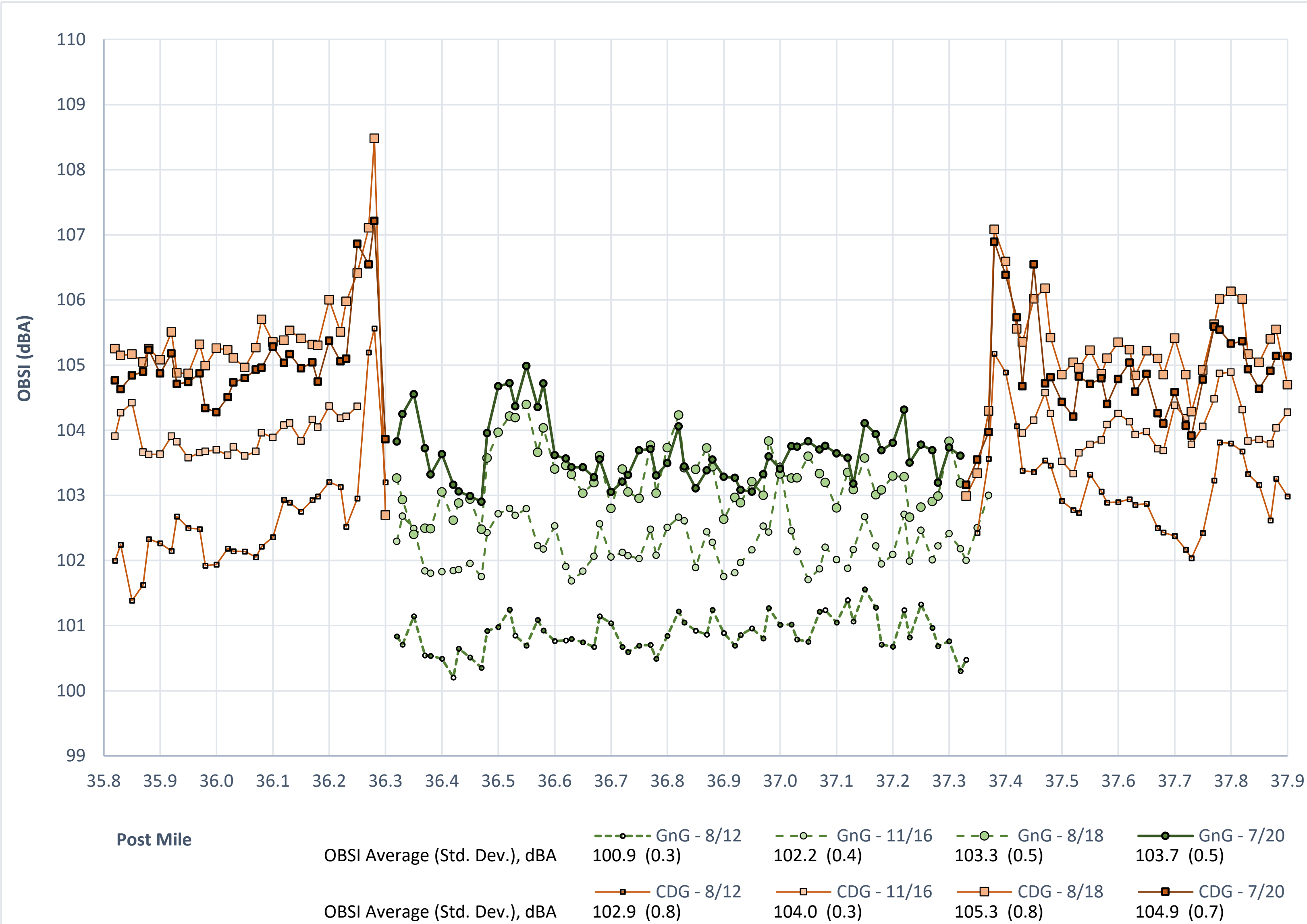



**Figure A.32: OBSI on SD5N2 - PM35.8/37.9.**

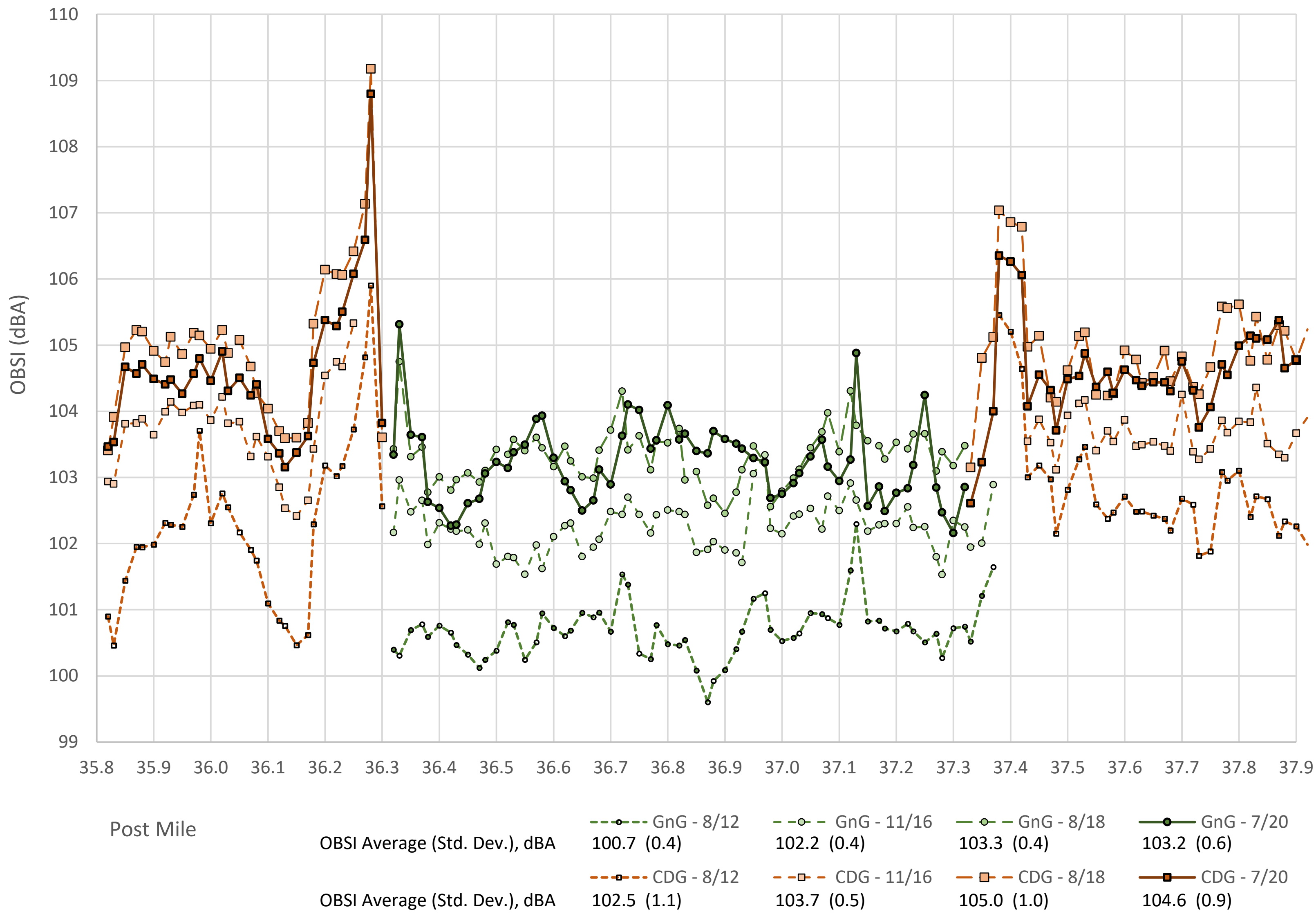
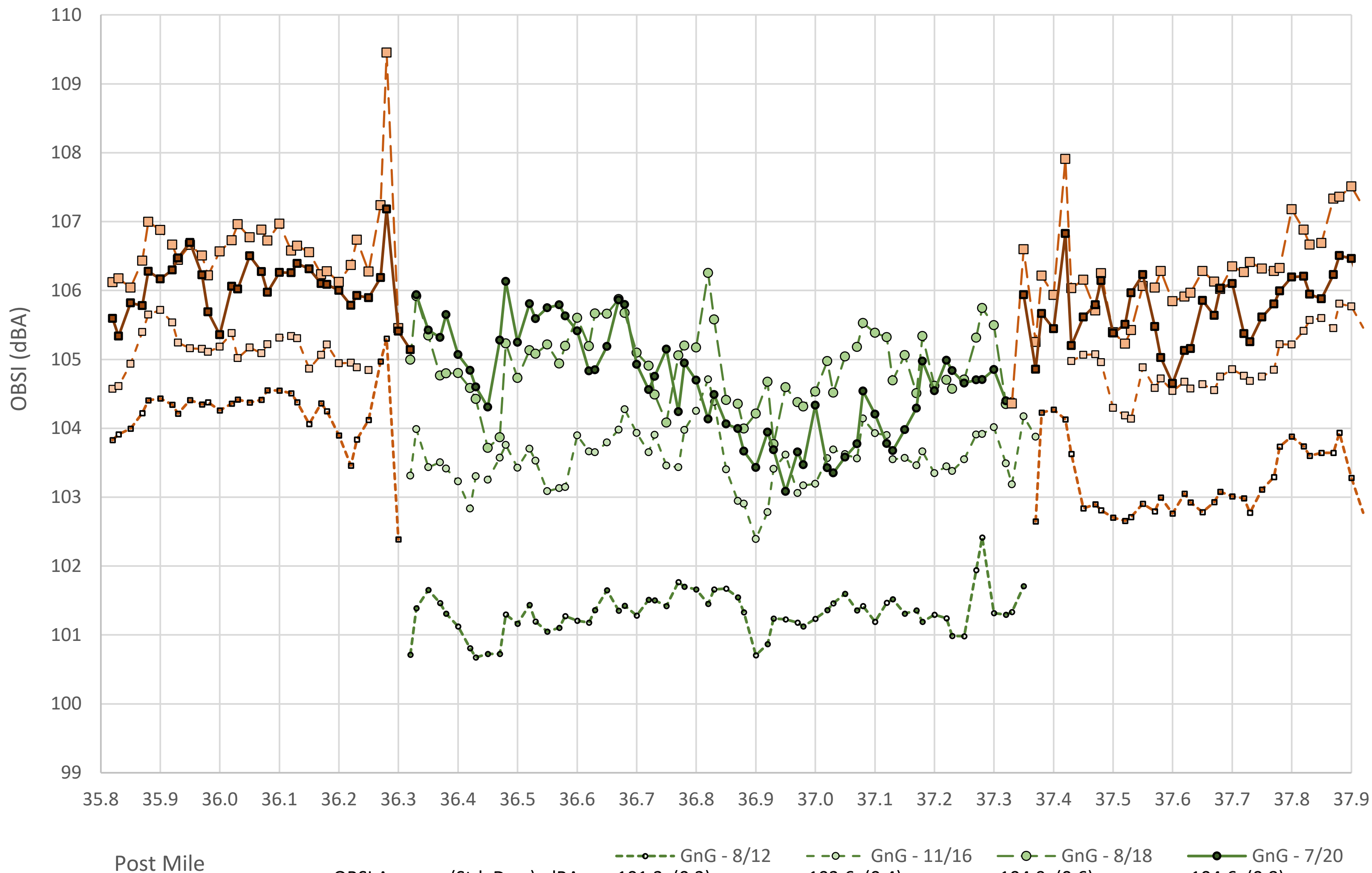



**Figure A.33: OBSI on SD5N3 - PM35.8/37.9.**




| | GnG - 8/12 | GnG - 11/16 | GnG - 8/18 | GnG - 7/20 |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 101.3 (0.3) | 103.6 (0.4) | 104.9 (0.6) | 104.6 (0.8) |

| | CDG - 8/12 | CDG - 11/16 | CDG - 8/18 | CDG - 7/20 |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 103.7 (0.7) | 105.0 (0.4) | 106.4 (0.7) | 105.9 (0.5) |

**Figure A.34: OBSI on SD5N4 - PM35.8/37.9.**

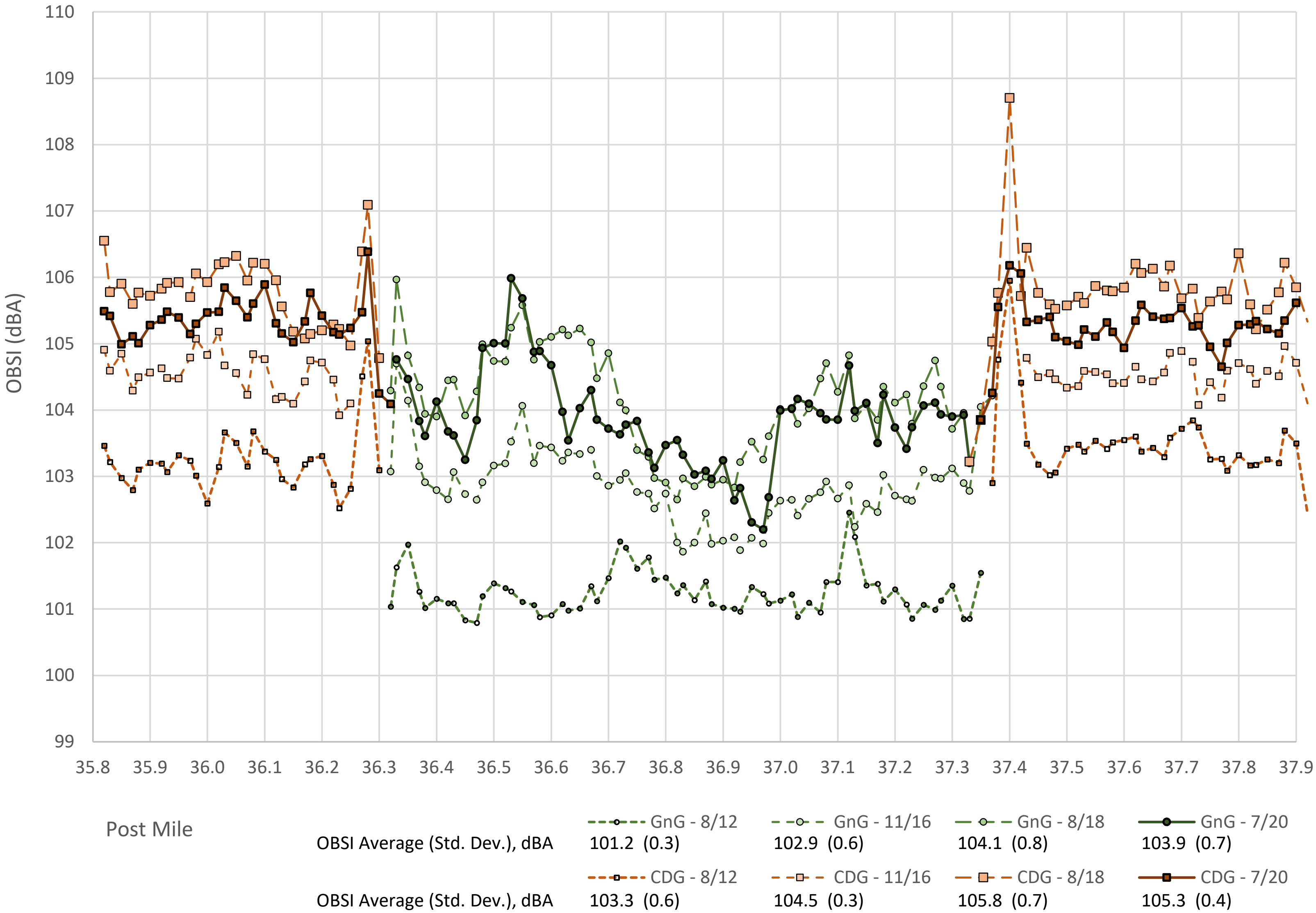
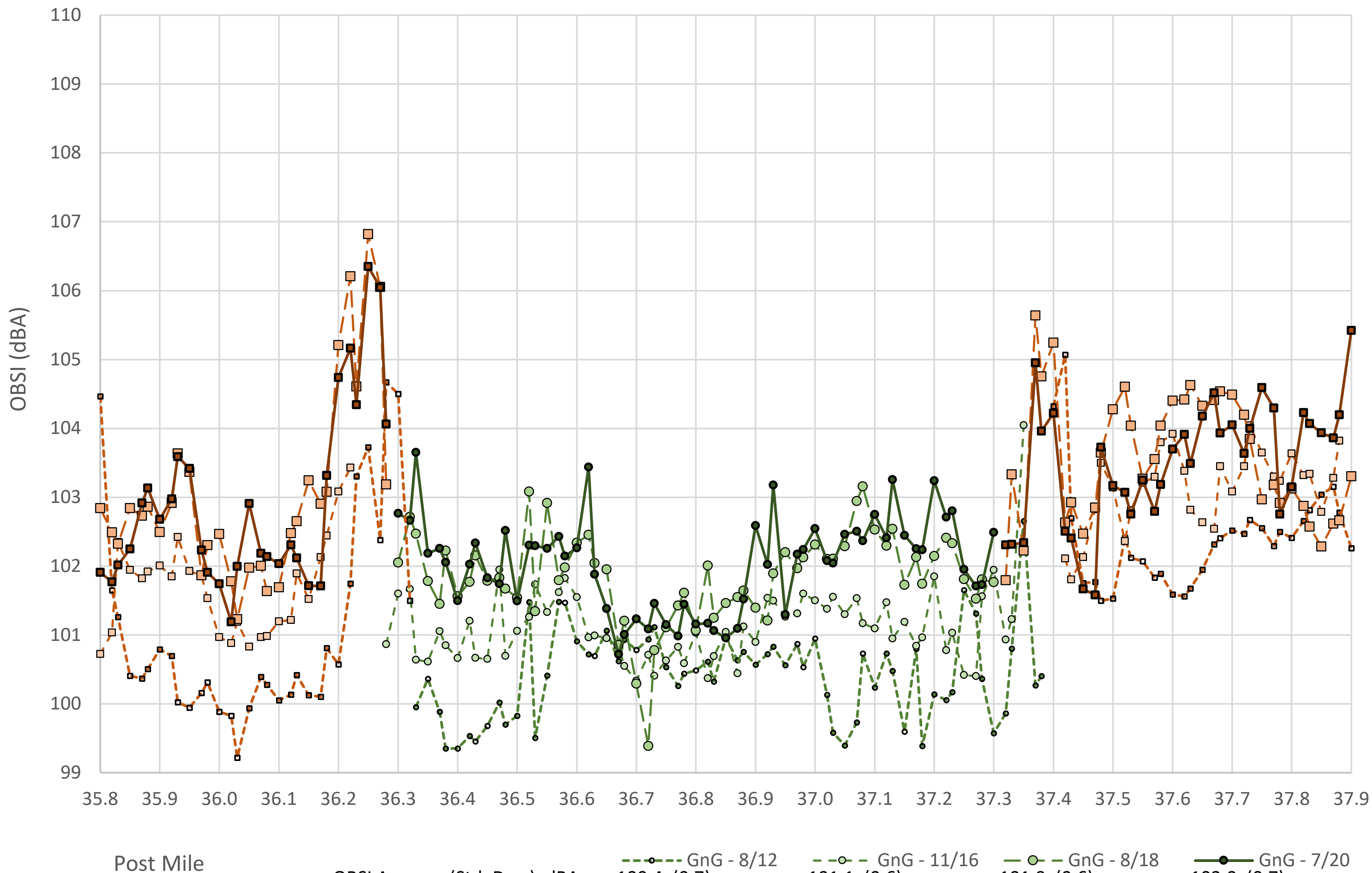



**Figure A.35: OBSI on SD5N5 - PM35.8/37.9.**




| | GnG - 8/12 | GnG - 11/16 | GnG - 8/18 | GnG - 7/20 |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 100.4 (0.7) | 101.1 (0.6) | 101.9 (0.6) | 102.0 (0.7) |

| | CDG - 8/12 | CDG - 11/16 | CDG - 8/18 | CDG - 7/20 |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 101.8 (1.3) | 102.5 (1.0) | 103.3 (1.2) | 103.2 (1.1) |

**Figure A.36: OBSI on SD5S1 - PM35.8/37.9.**

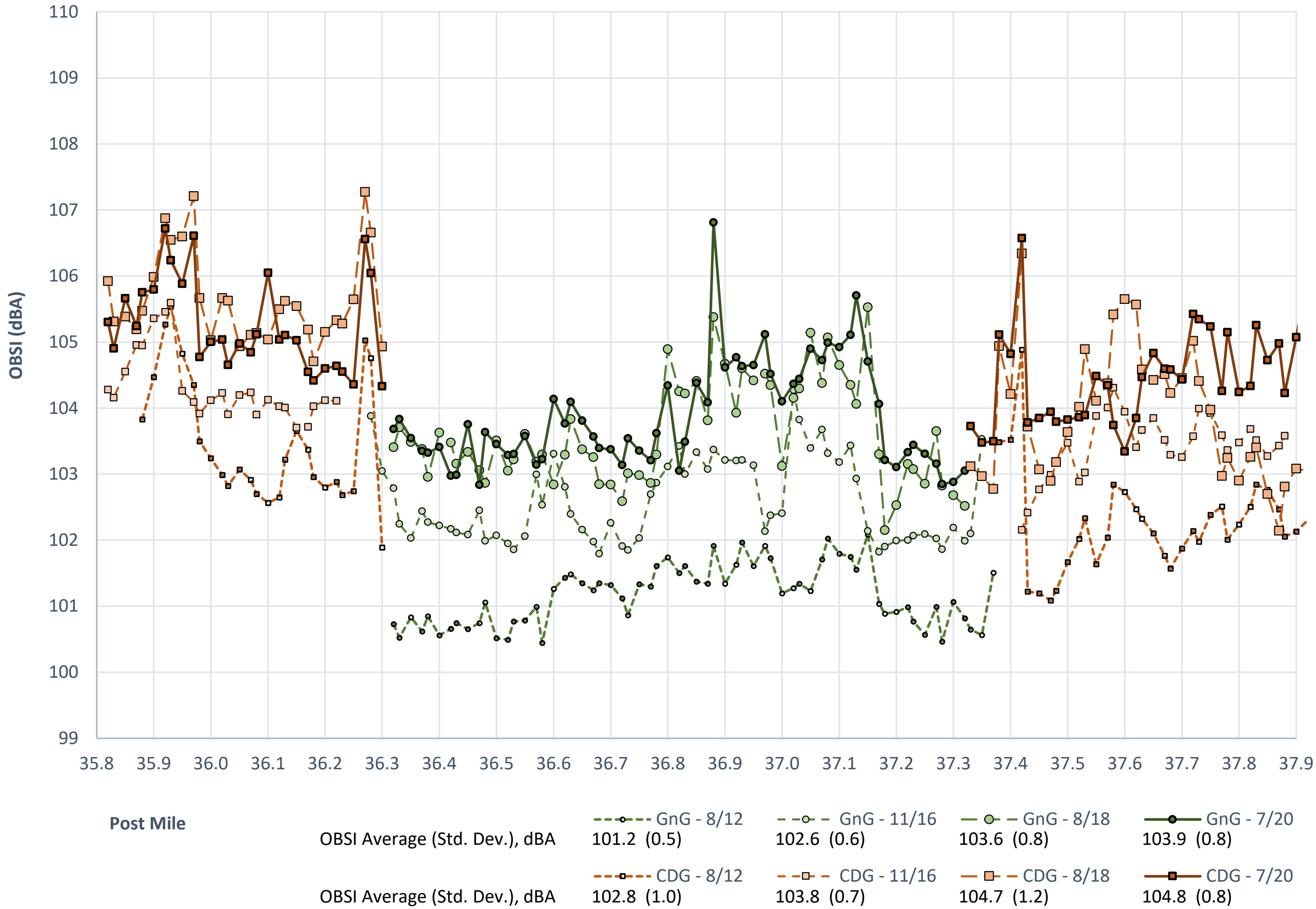



**Figure A.37: OBSI on SD5S2 - PM35.8/37.9.**

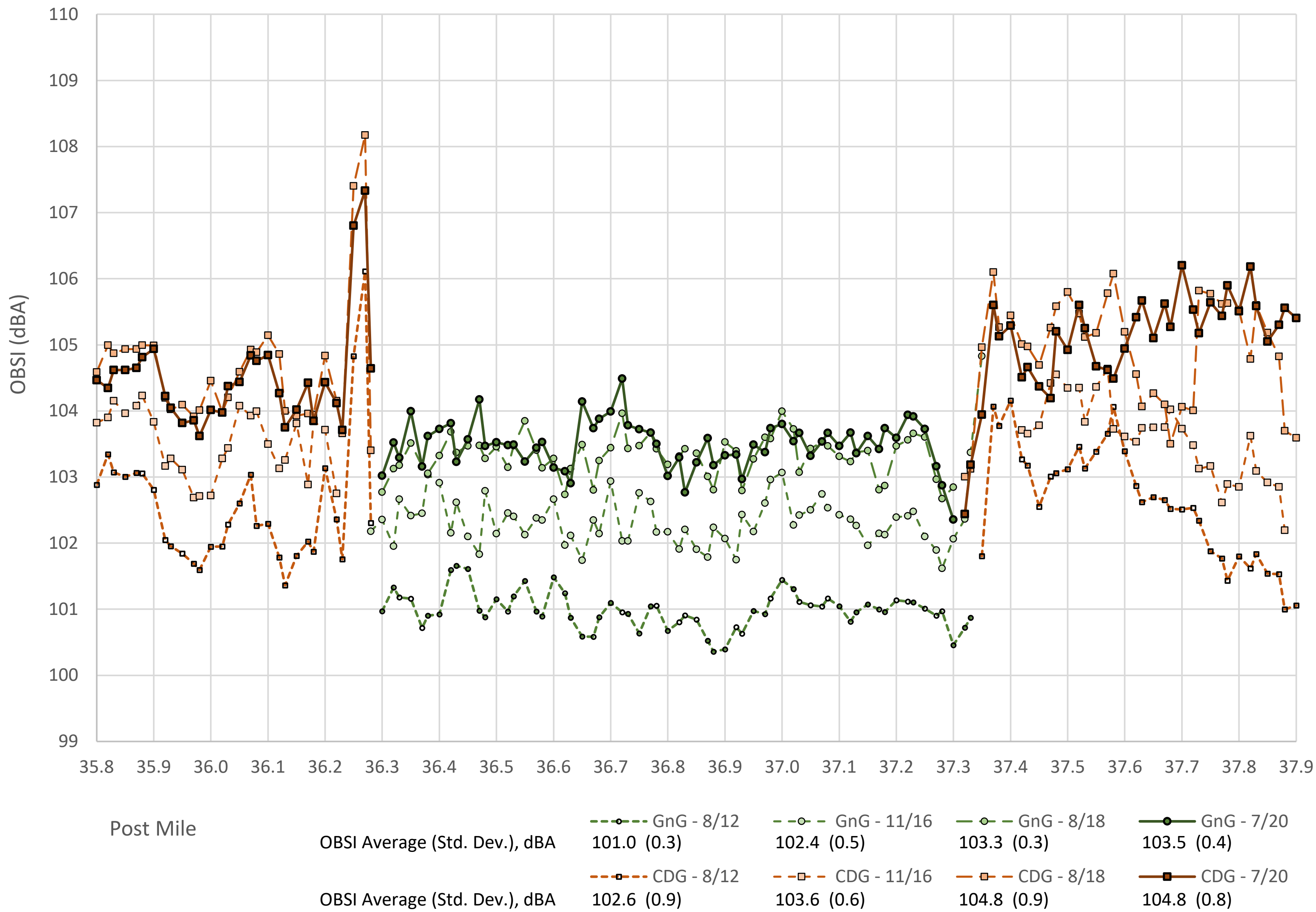
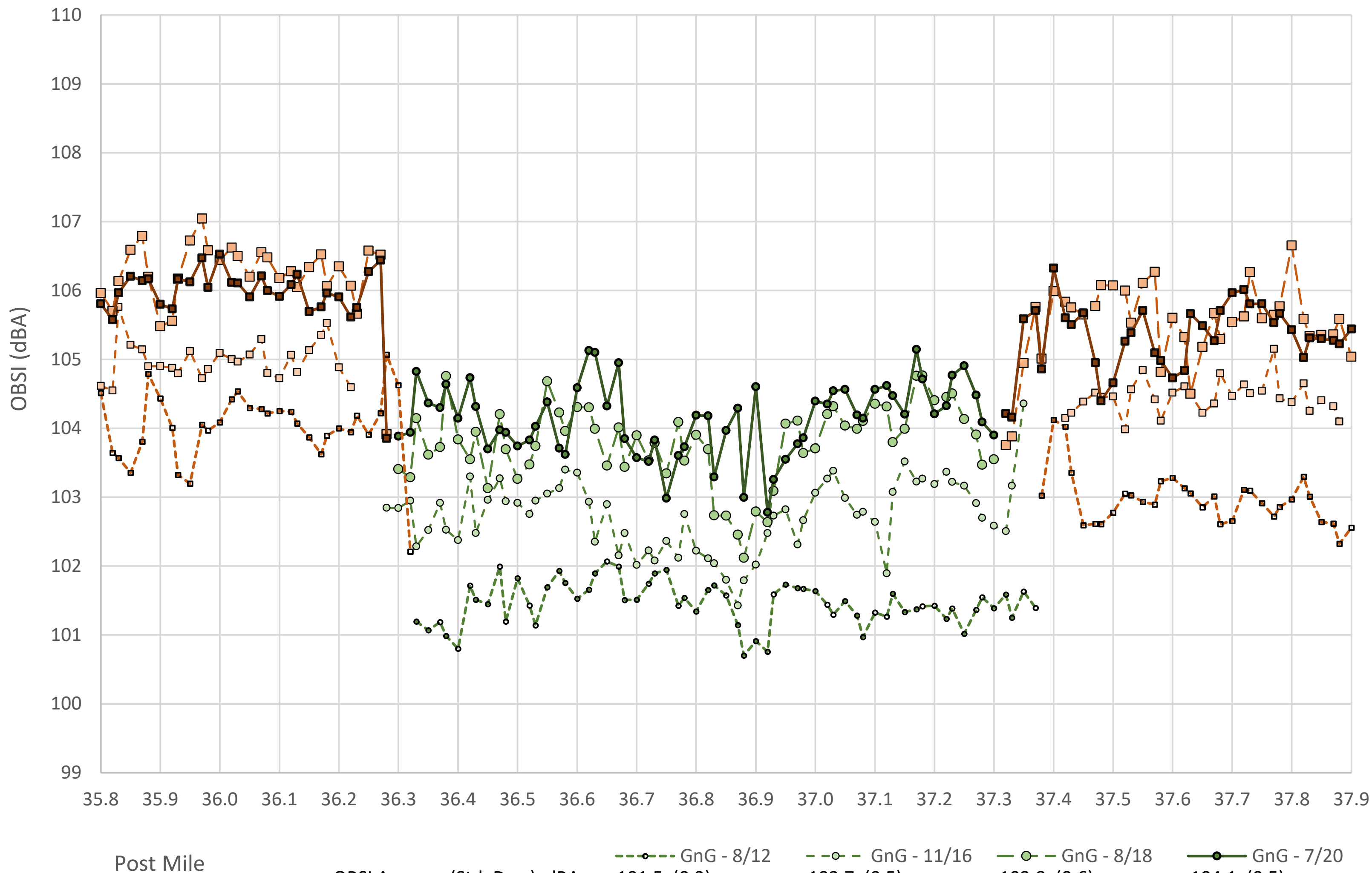



**Figure A.38: OBSI on SD5S3 - PM35.8/37.9.**




| | GnG - 8/12 | GnG - 11/16 | GnG - 8/18 | GnG - 7/20 |
|---|---|---|---|---|
| OBSI Average (Std. Dev.), dBA | 101.5 (0.3) | 102.7 (0.5) | 103.8 (0.6) | 104.1 (0.5) |
| | CDG - 8/12 | CDG - 11/16 | CDG - 8/18 | CDG - 7/20 |
| OBSI Average (Std. Dev.), dBA | 103.5 (0.7) | 104.7 (0.4) | 105.8 (0.7) | 105.6 (0.6) |

**Figure A.39: OBSI on SD5S4 - PM35.8/37.9.**

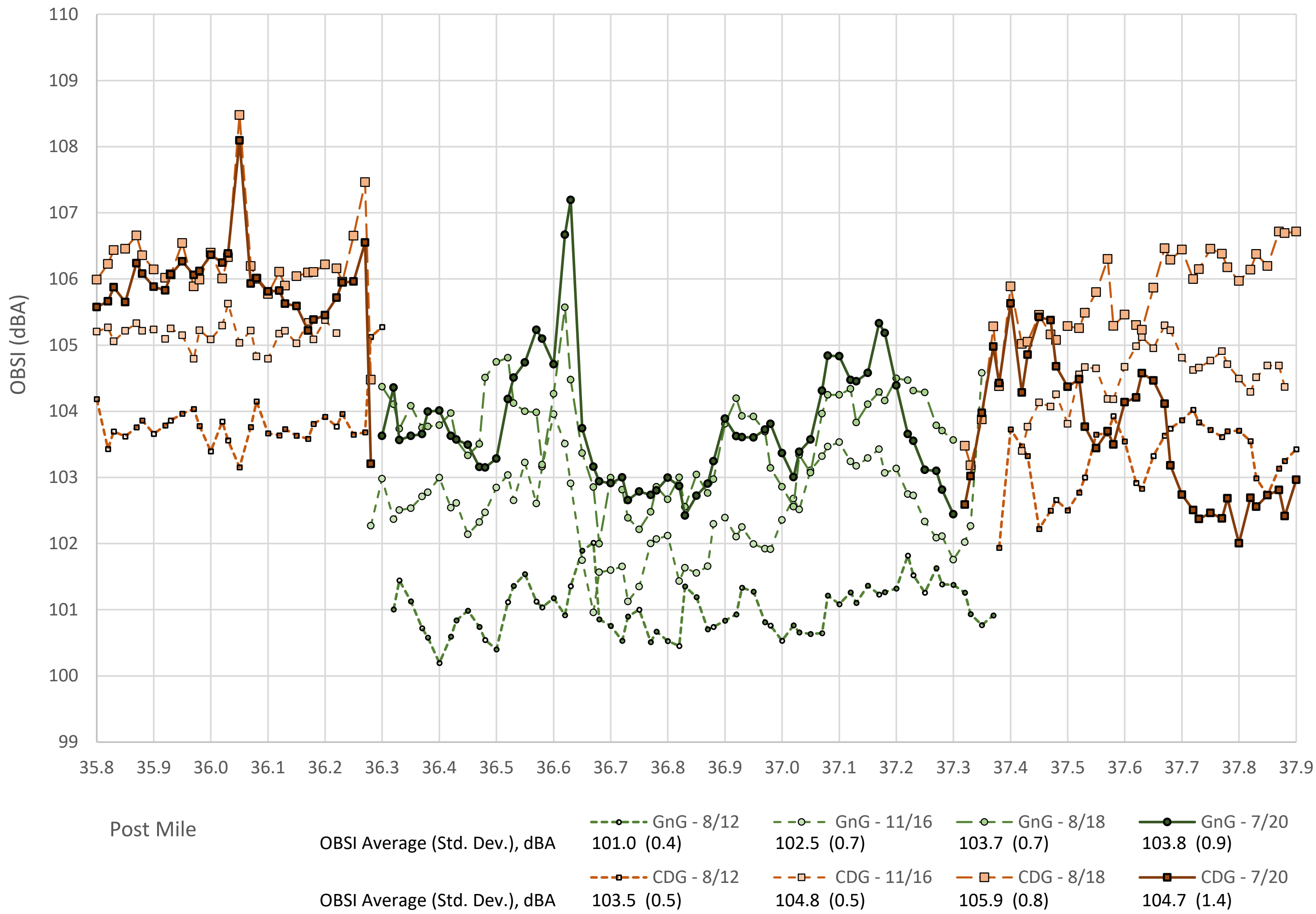



**Figure A.40: OBSI on SD5S5 - PM35.8/37.9.**

# APPENDIX B IRI LONGITUDINAL PROFILES

Longitudinal profiles of IRI for selected sections are presented in the following figures. Each profile is an individual lane, with a direction and lane number indicated in the figure header. The figure legend provides the month and year of the four sampling periods.

The JPCP profiles from Yol113 and SD5 follow the CRCP profiles in Section B.1. Both JPCP projects have longitudinal profiles that show the transition between the GnG and CDG textures. The Yol113 profiles are paired by direction for each project in Section B.2. For example, the Yol113 charts for northbound Lane 1 and northbound Lane 2 are on consecutive pages, as are southbound Lane 1 and southbound Lane 2. With different lanes in the same direction paired, the effect of truck traffic versus passenger car traffic may be evident.

The average IRI value and standard deviation IRI values for the longitudinal profiles are shown below the legend. Profiles were not kept for some sections in the first measurement campaign in 2012 and 2013. Those are shown as a continuous value in the figures. The standard deviation values were kept, and those are shown in the captions even where the profiles are not shown. Some Year 8 IRI data were replaced with data from Caltrans Automated Pavement Condition Survey data. These data are also shown as a continuous value with “avg. ACPS” shown in parentheses.

The following notations are used in the following figures:

- Empty very small markers with dotted lines represent the oldest data from 2012.
- Lightly filled small markers with dashed lines represent the data from 2016.
- Moderately filled markers with long dashed lines represent the data from 2018.
- Black-filled markers with solid lines represent the newest data from 2020.

The section location is found in the figure caption, indicating the county and highway number, followed by the direction and lane number, concluding with the starting postmile (PM). For example, Plac80E1PM56.45 is located in Placer County on Highway 80 in the eastbound direction of Lane 1, starting at PM 56.45.

## B.1 CRCP Sections

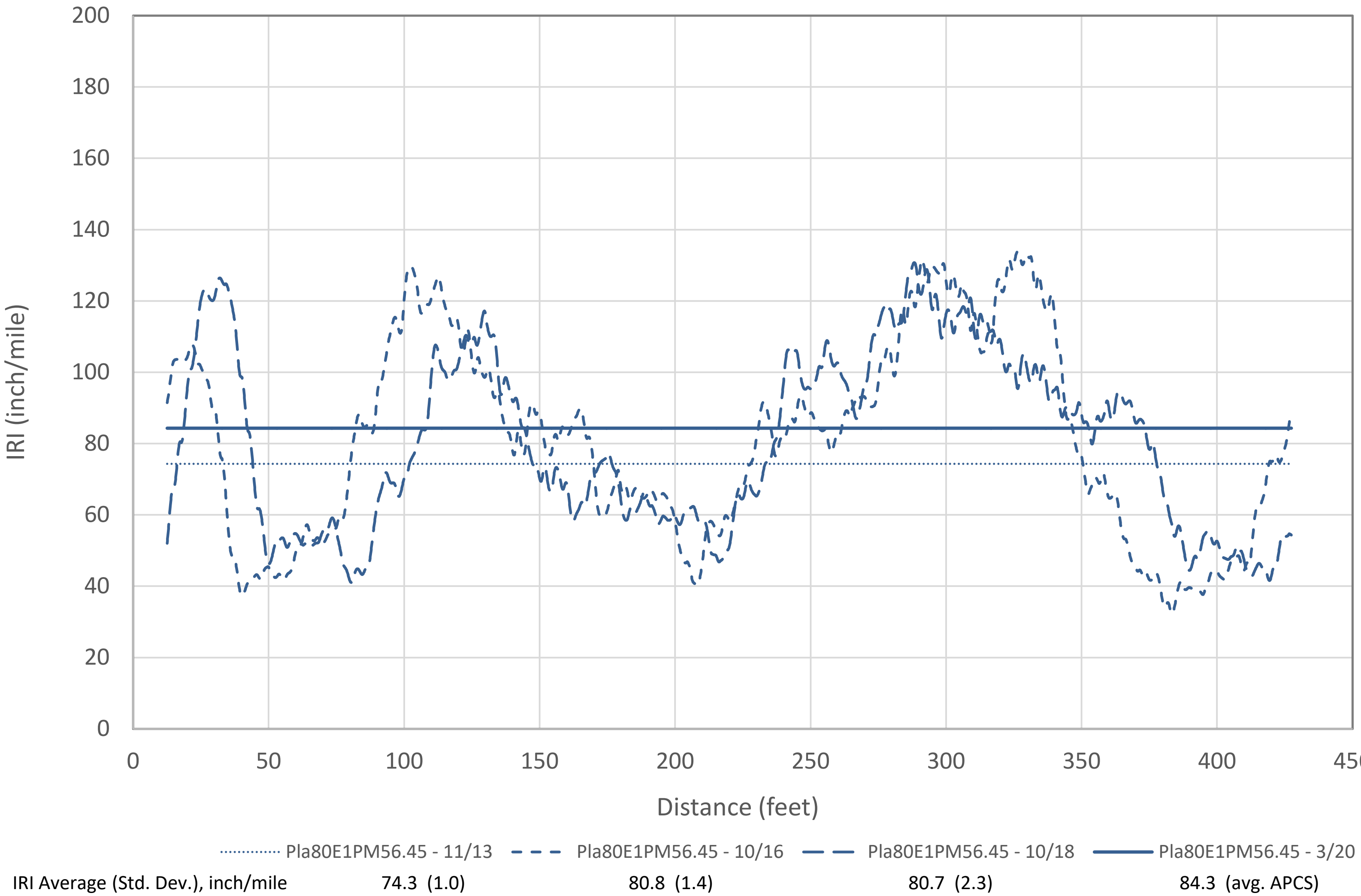



**Figure B.1: IRI on Pla80E1PM56.45.**

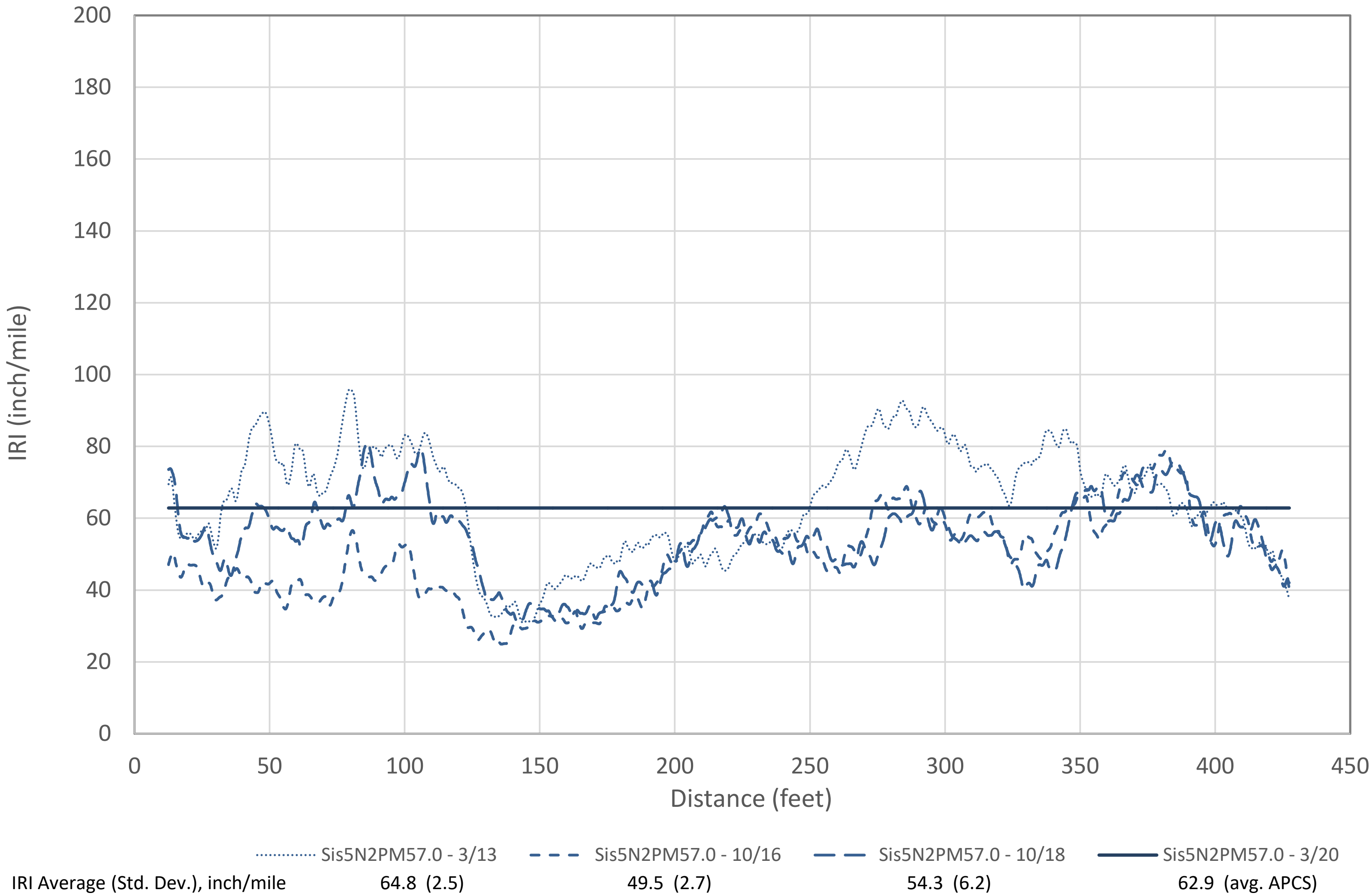



**Figure B.2: IRI on Sis5N2PM57.0.**

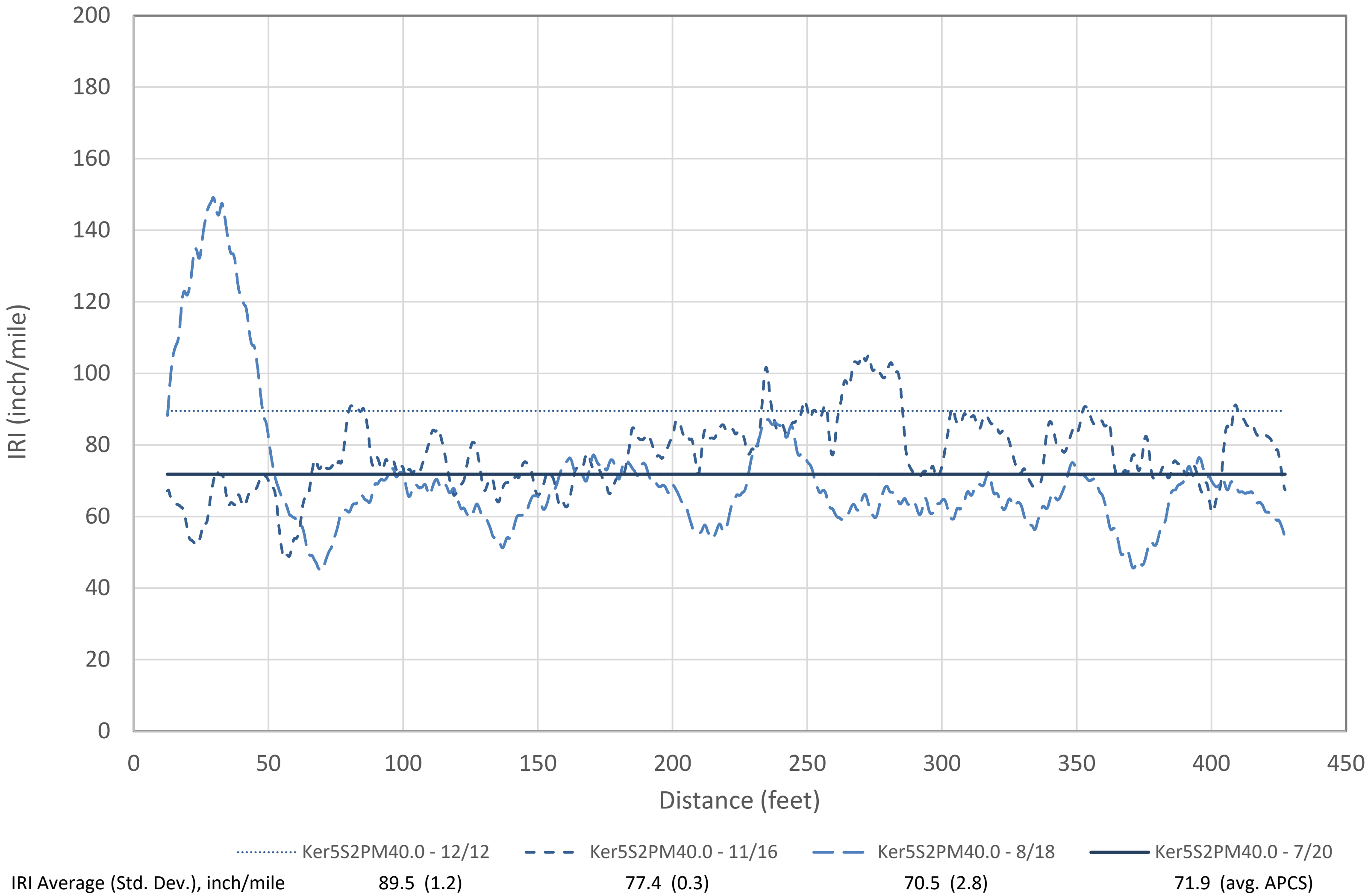
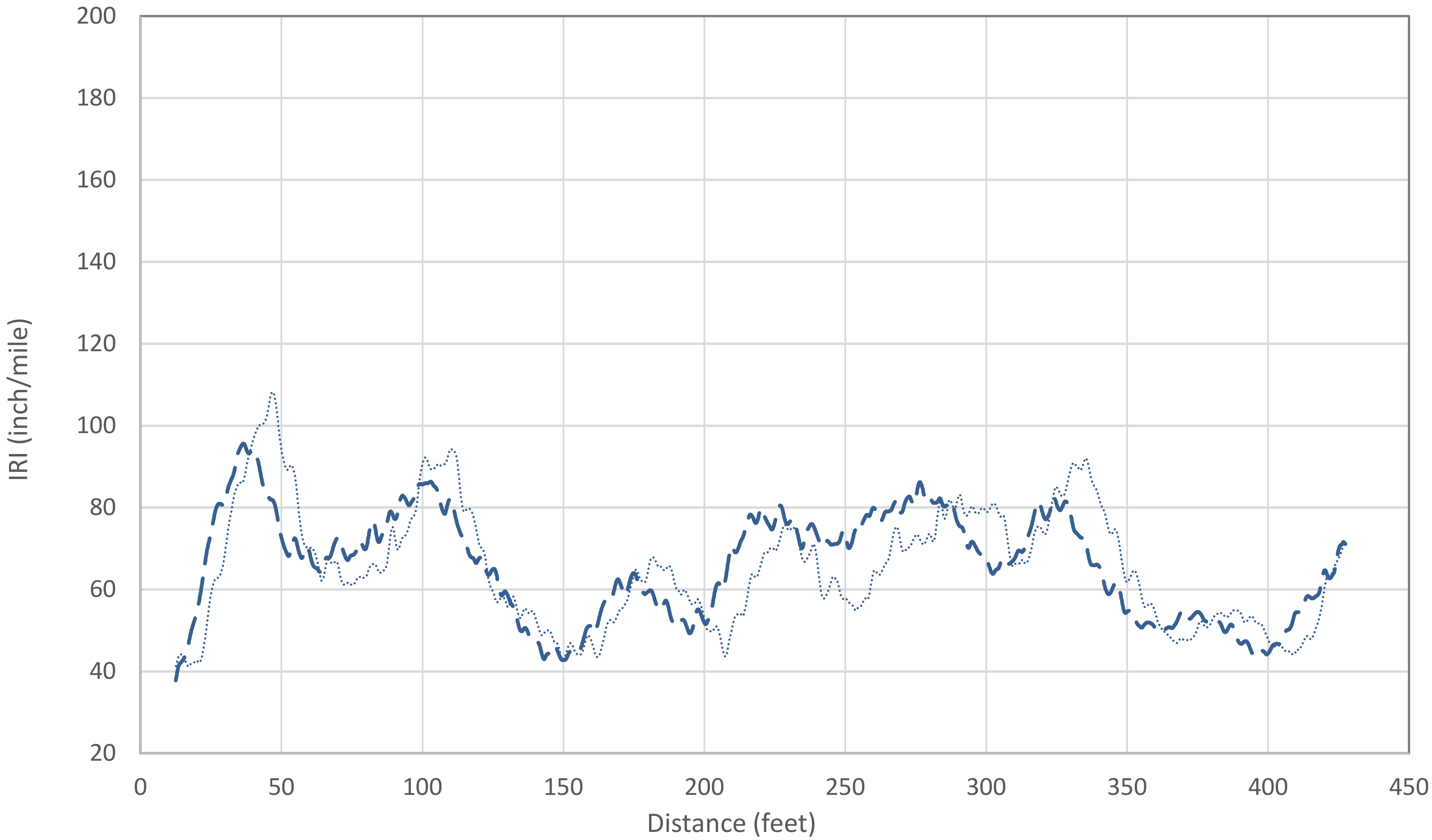



**Figure B.3: IRI on Ker5S2PM40.0.**




| | Constructed 2017 | SJ5N1PM32.0 - 6/17 | SJ5N1PM32.0 - 12/18 | No Data - 2020 |
|---|---|---|---|---|
| IRI Average (Std. Dev.), inch/mile | 0.0 (0.0) | 65.3 (0.0) | 66.0 (0.2) | |

**Figure B.4: IRI on SJ5N1PM32.0.**

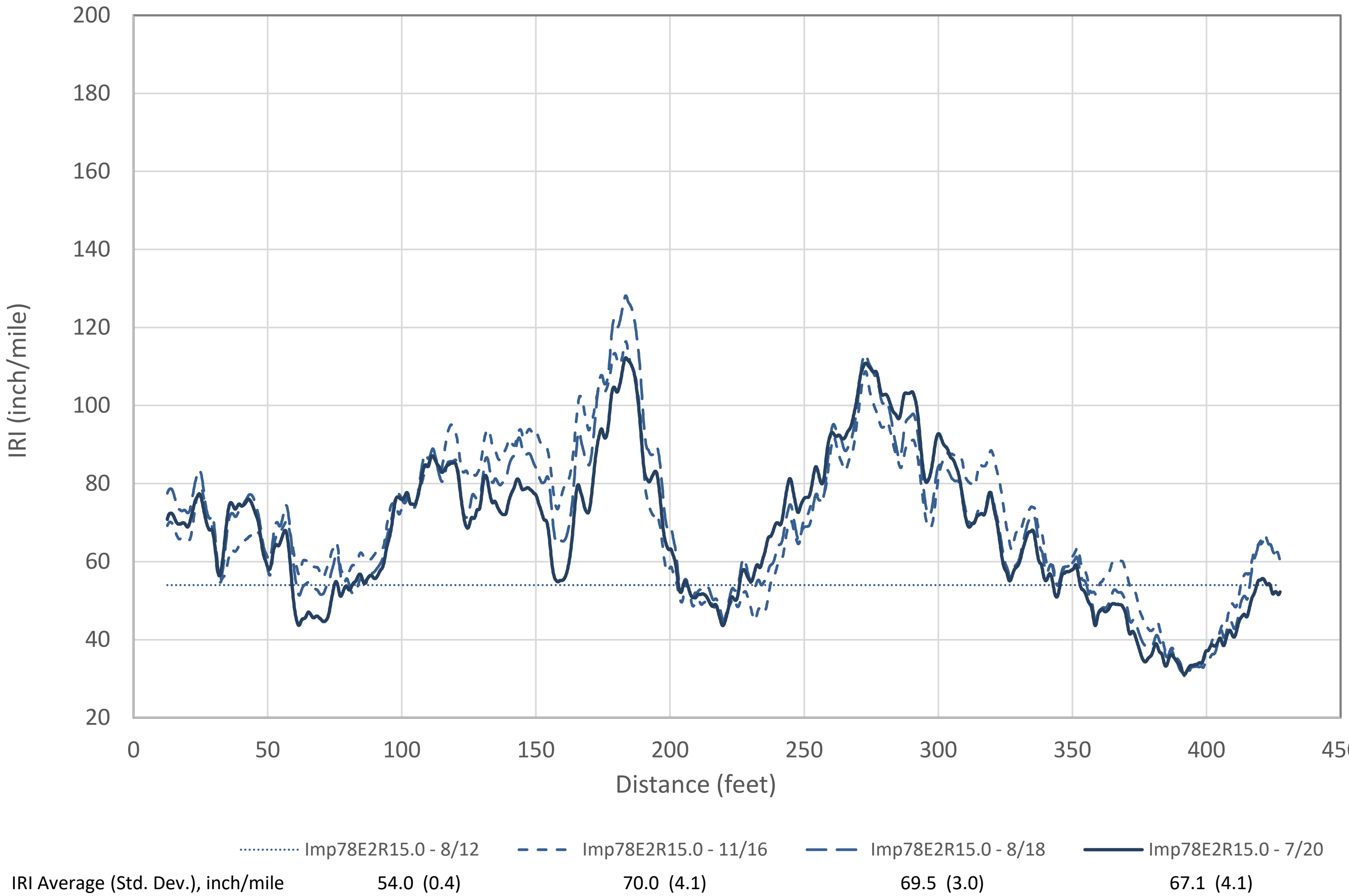
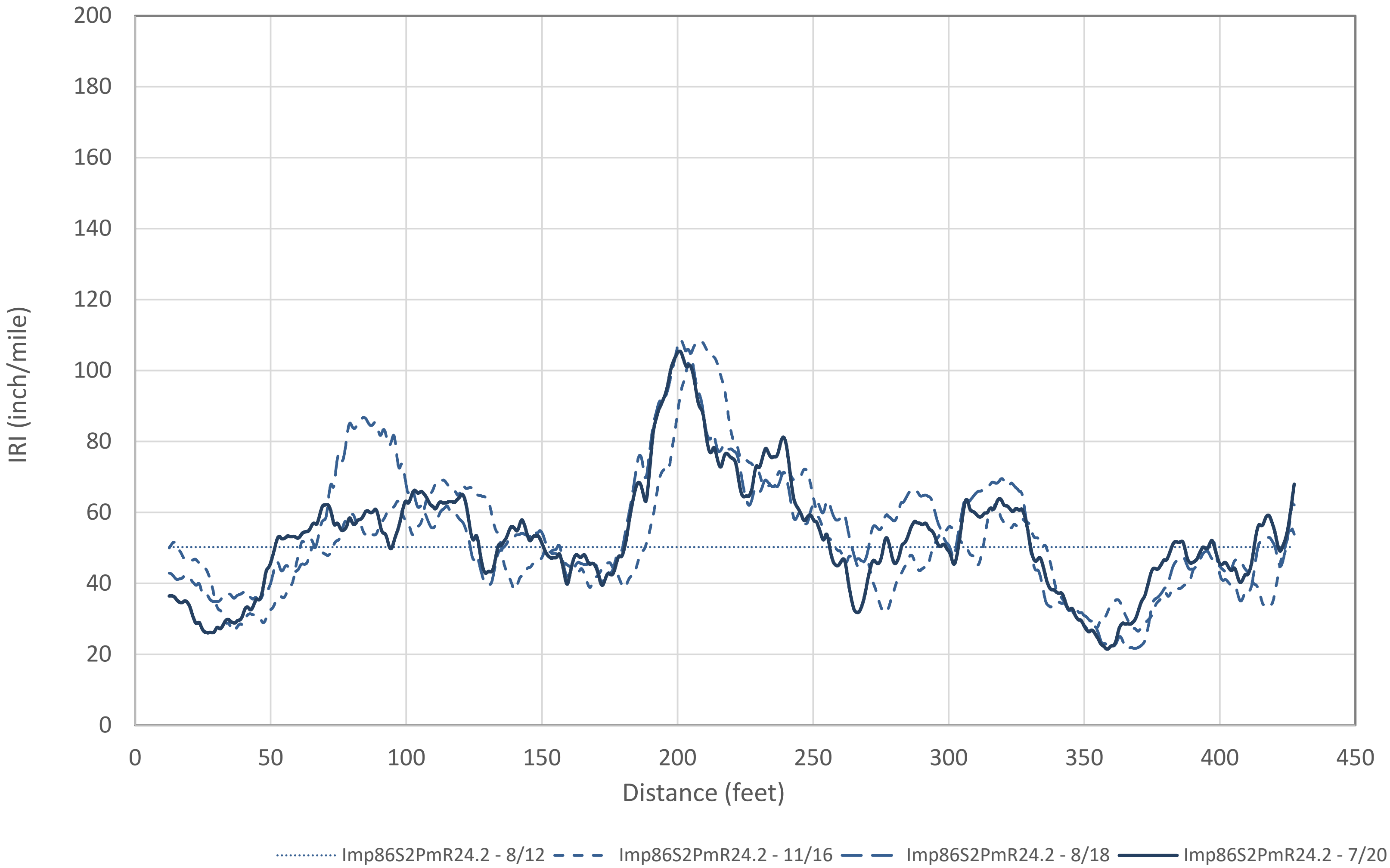


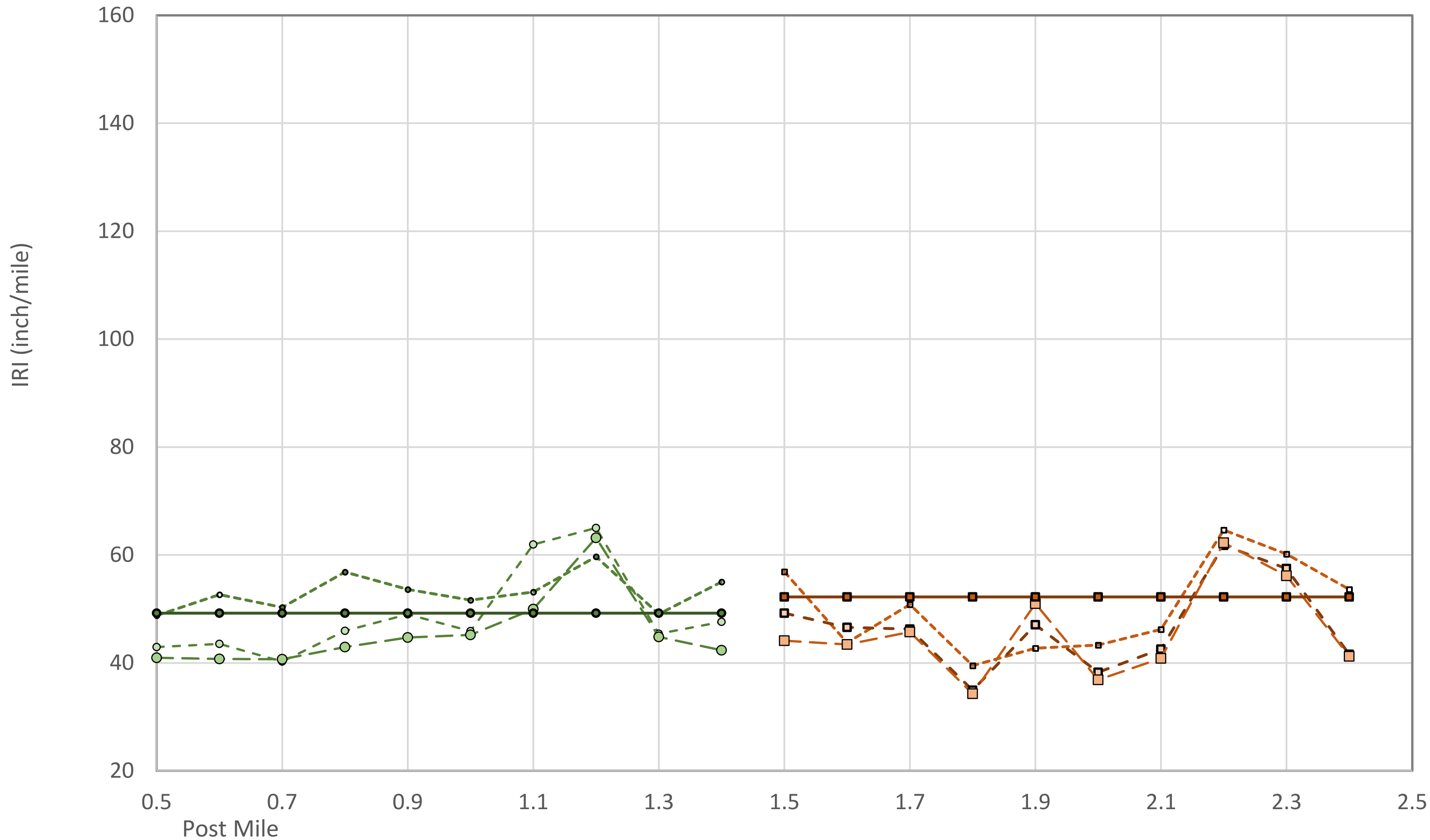

**Figure B.5: IRI on Imp78E2PM15.0.**




| | | | | |
|---|---|---|---|---|
| IRI Average (Std. Dev.), inch/mile | 50.3 (1.1) | 51.2 (1.2) | 54.8 (1.2) | 52.7 (2.4) |

**Figure B.6: IRI on Imp86S2PM24.2.**

## B.2 Yolo 113 – PM 0.5/2.5




| | GnG - 7/13 | GnG - 10/16 | GnG - 8/18 | GnG - 2/20 |
|---|---|---|---|---|
| IRI Average (Std. Dev.), inch/mile | 53.1 (3.9) | 48.7 (1.4) | 45.5 (2.1) | 53.5 (avg. APCS) |
| | CDG - 7/13 | CDG - 10/16 | CDG - 8/18 | CDG - 2/20 |
| IRI Average (Std. Dev.), inch/mile | 50.2 (1.6) | 46.6 (0.8) | 45.6 (0.5) | 50.4 (avg. APCS) |

**Figure B.7: IRI on Yol113N1.**

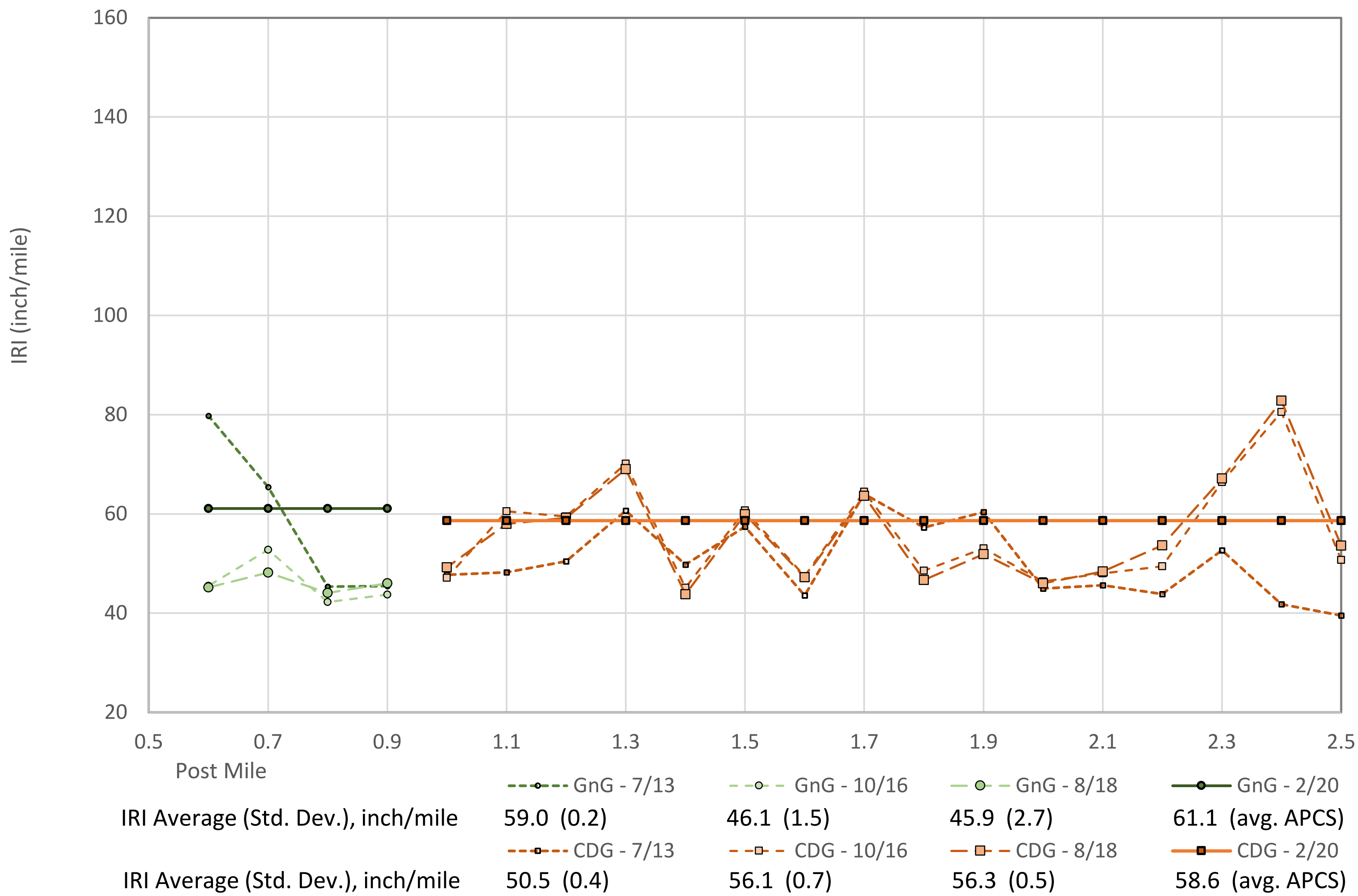
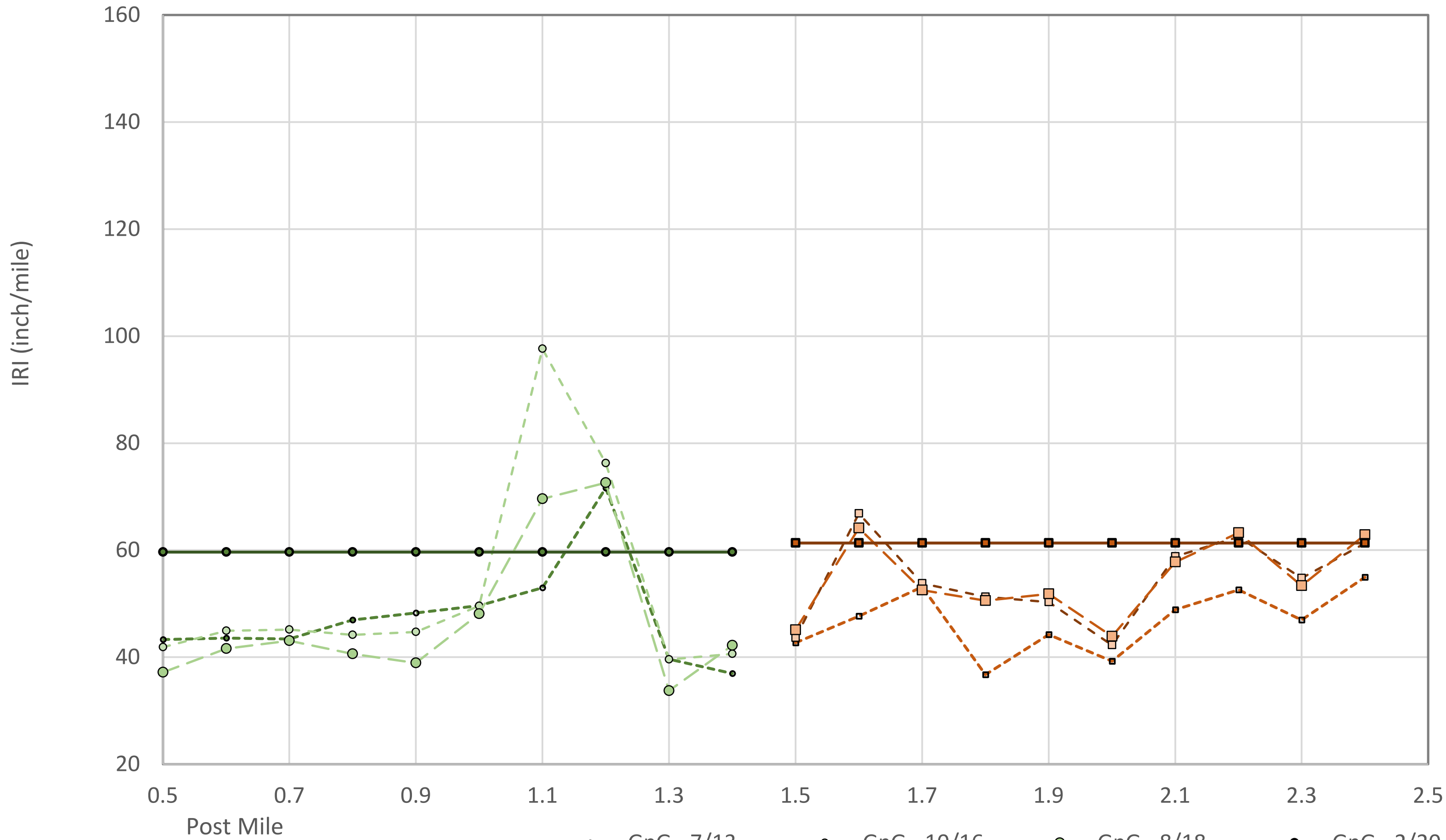



**Figure B.8: IRI on Yol113S1.**




| | GnG - 7/13 | GnG - 10/16 | GnG - 8/18 | GnG - 2/20 |
|---|---|---|---|---|
| IRI Average (Std. Dev.), inch/mile | 47.6 (2.5) | 52.4 (0.1) | 46.8 (0.6) | 59.6 (avg. APCS) |
| | CDG - 7/13 | CDG - 10/16 | CDG - 8/18 | CDG - 2/20 |
| IRI Average (Std. Dev.), inch/mile | 46.7 (0.1) | 54.5 (0.5) | 54.5 (1.5) | 61.3 (avg. APCS) |

**Figure B.9: IRI on Yol113N2.**

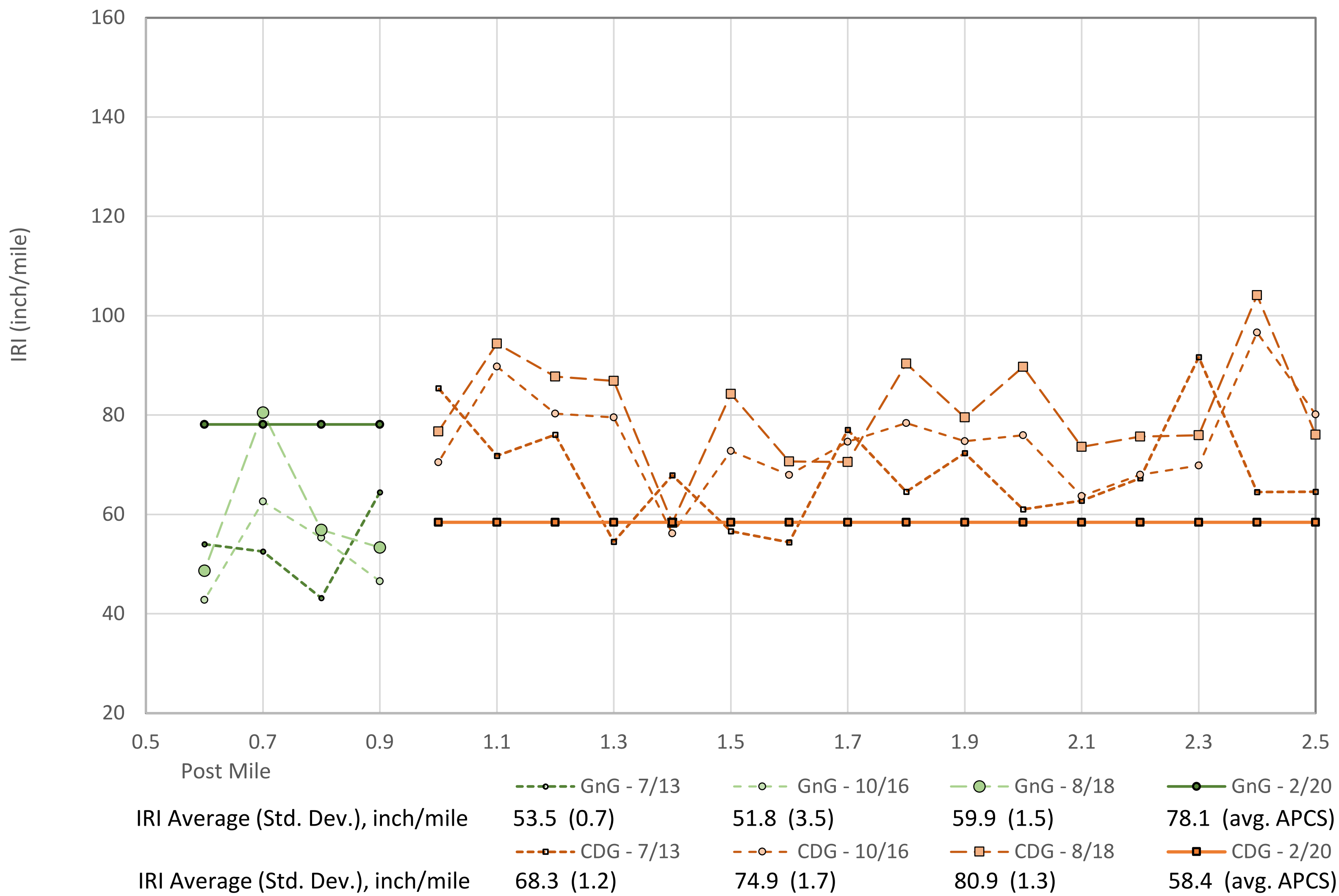



**Figure B.10: IRI on Yol113S2.**

## B.3 San Diego 5 – PM 35.8/37.9

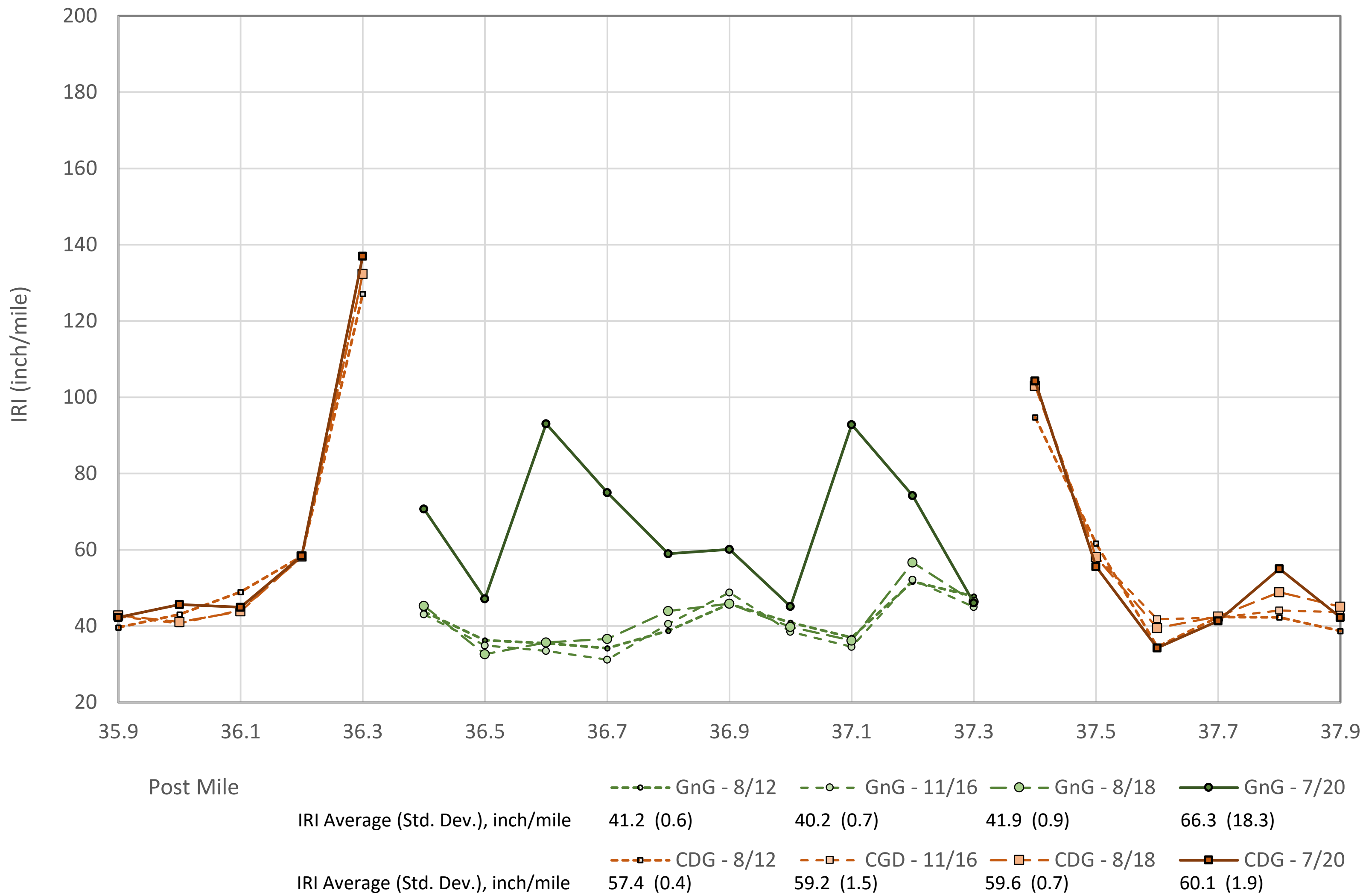



**Figure B.11: IRI on SD5N1.**

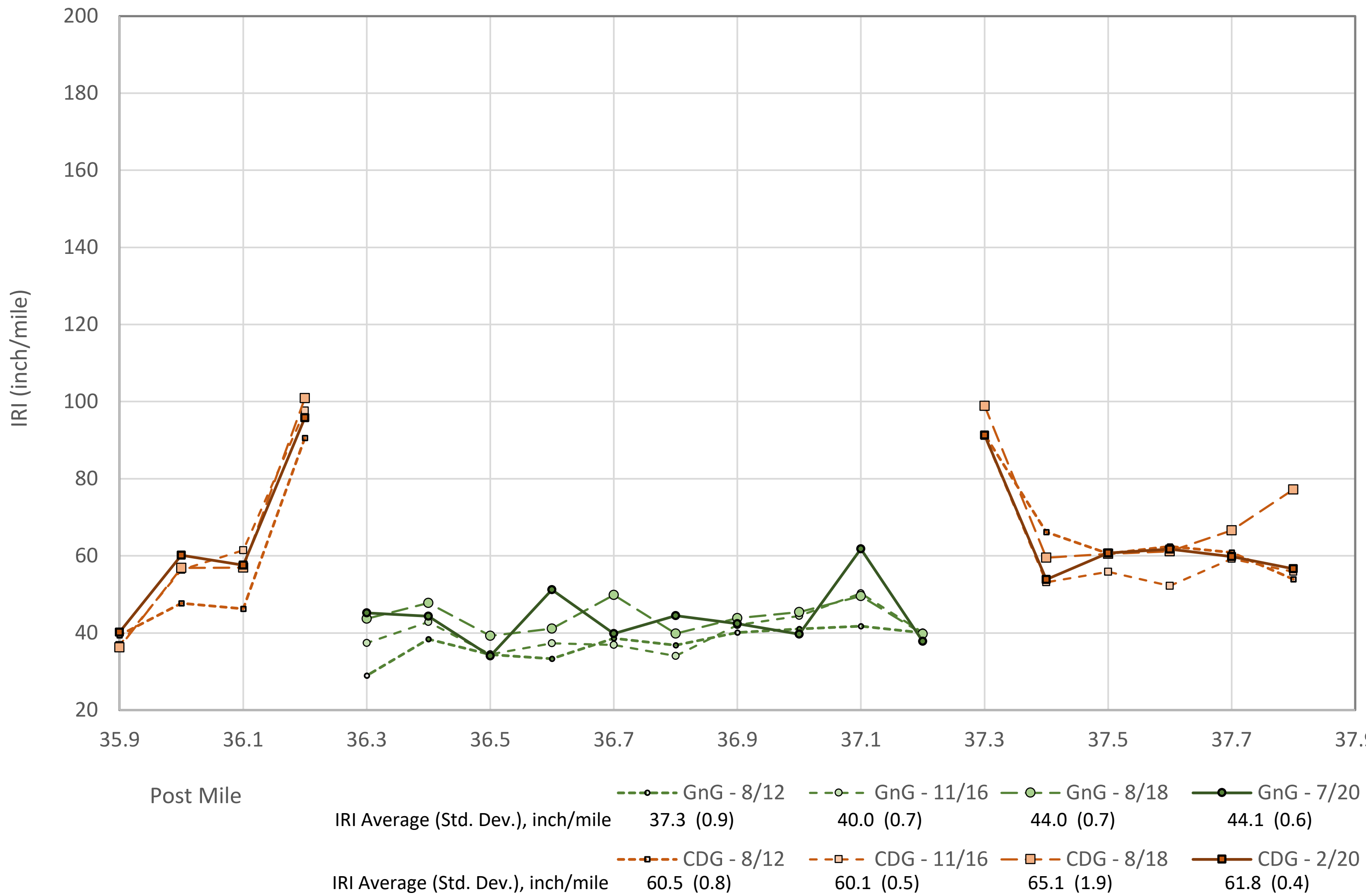



**Figure B.12: IRI on SD5S1.**

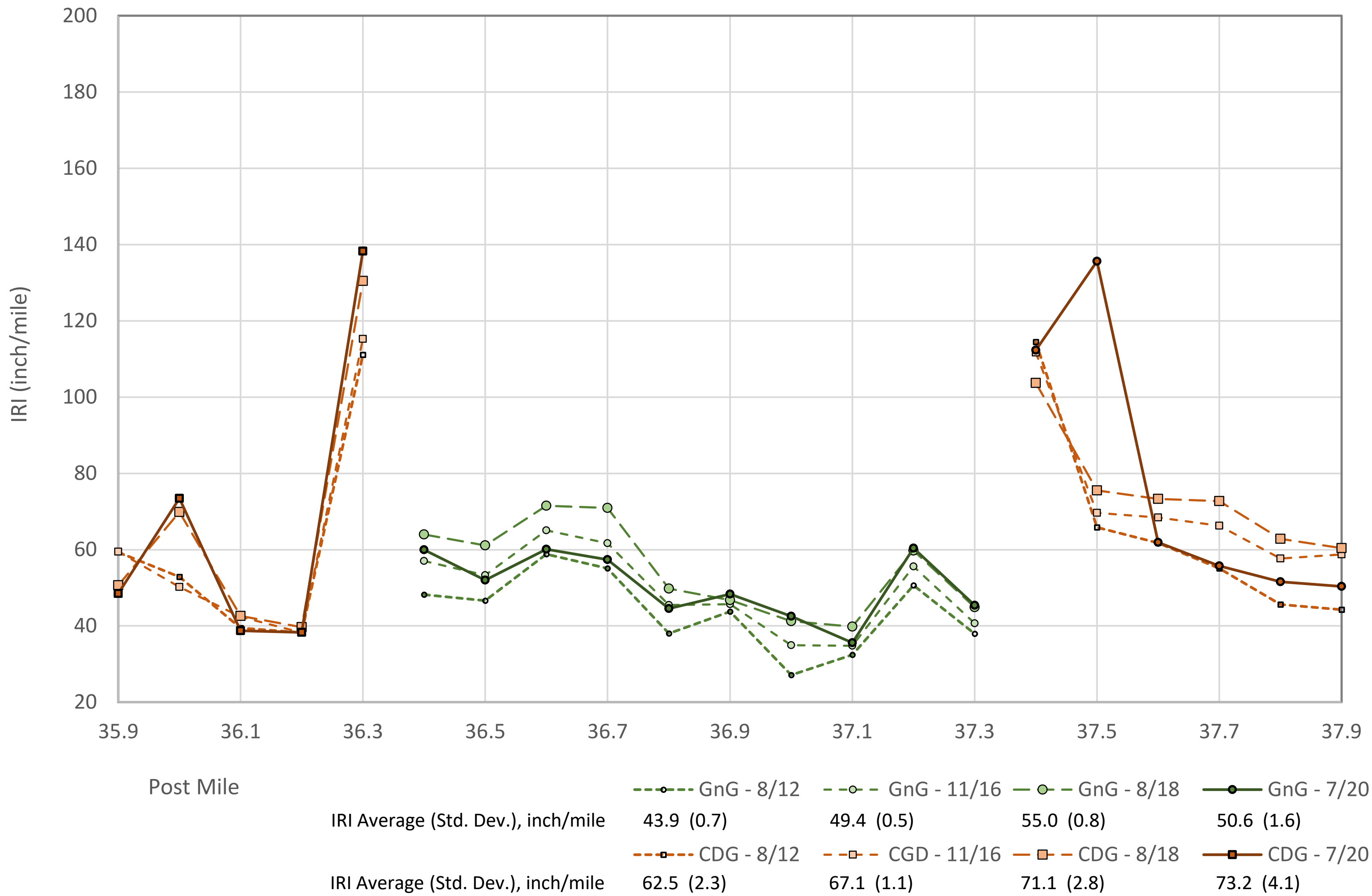



**Figure B.13: IRI on SD5N2.**

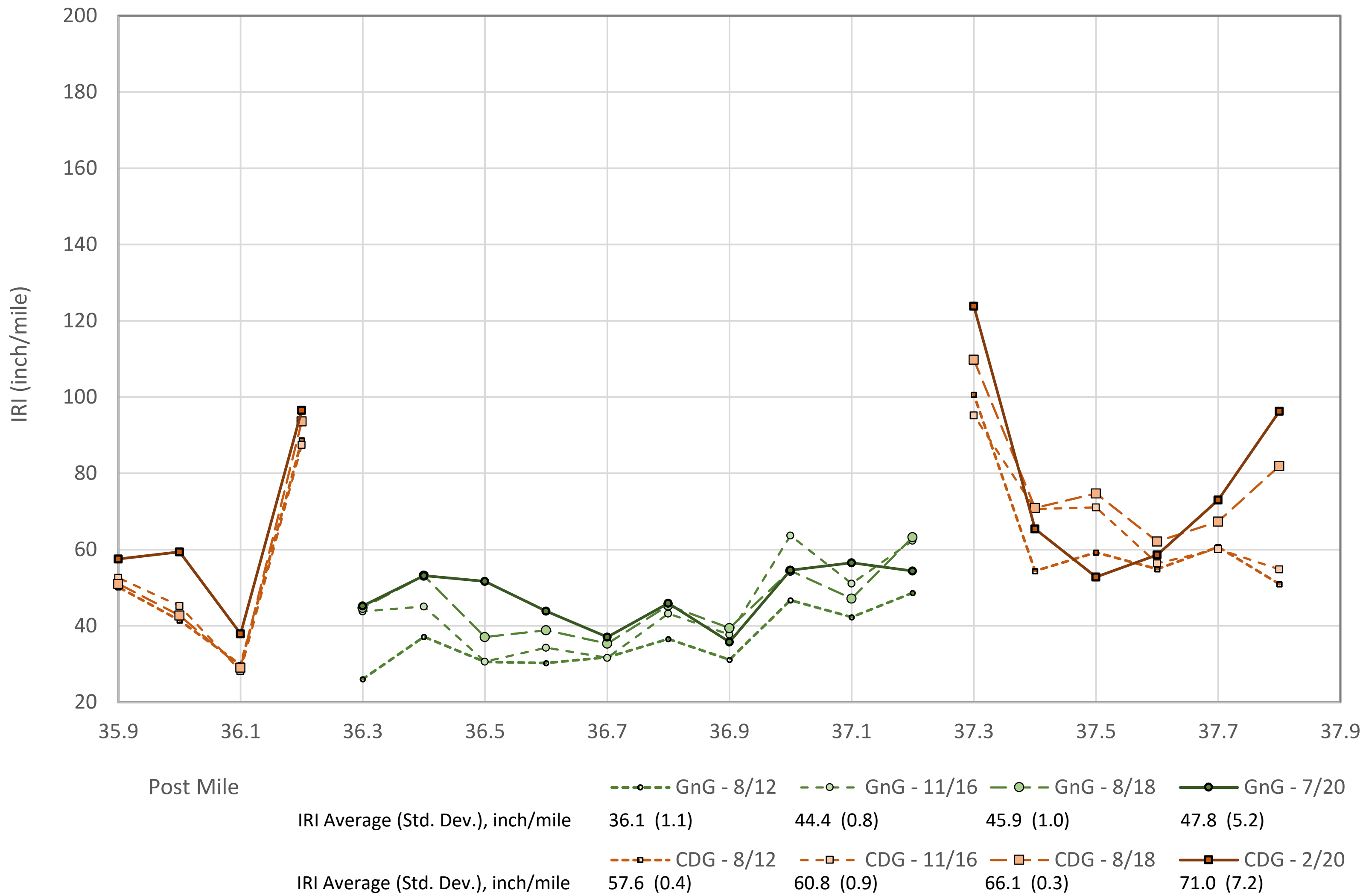



**Figure B.14: IRI on SD5S2.**

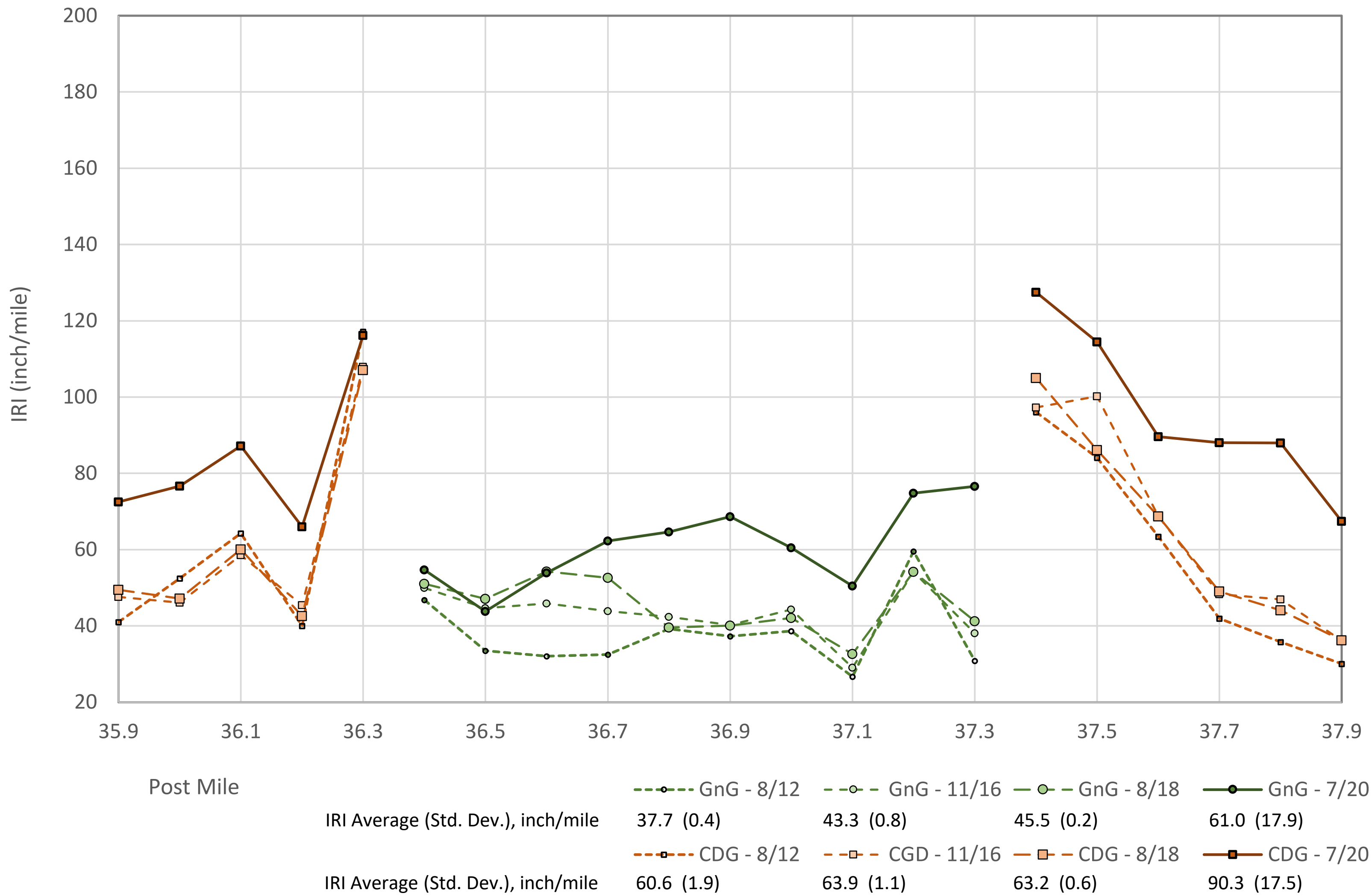



**Figure B.15: IRI on SD5N3.**

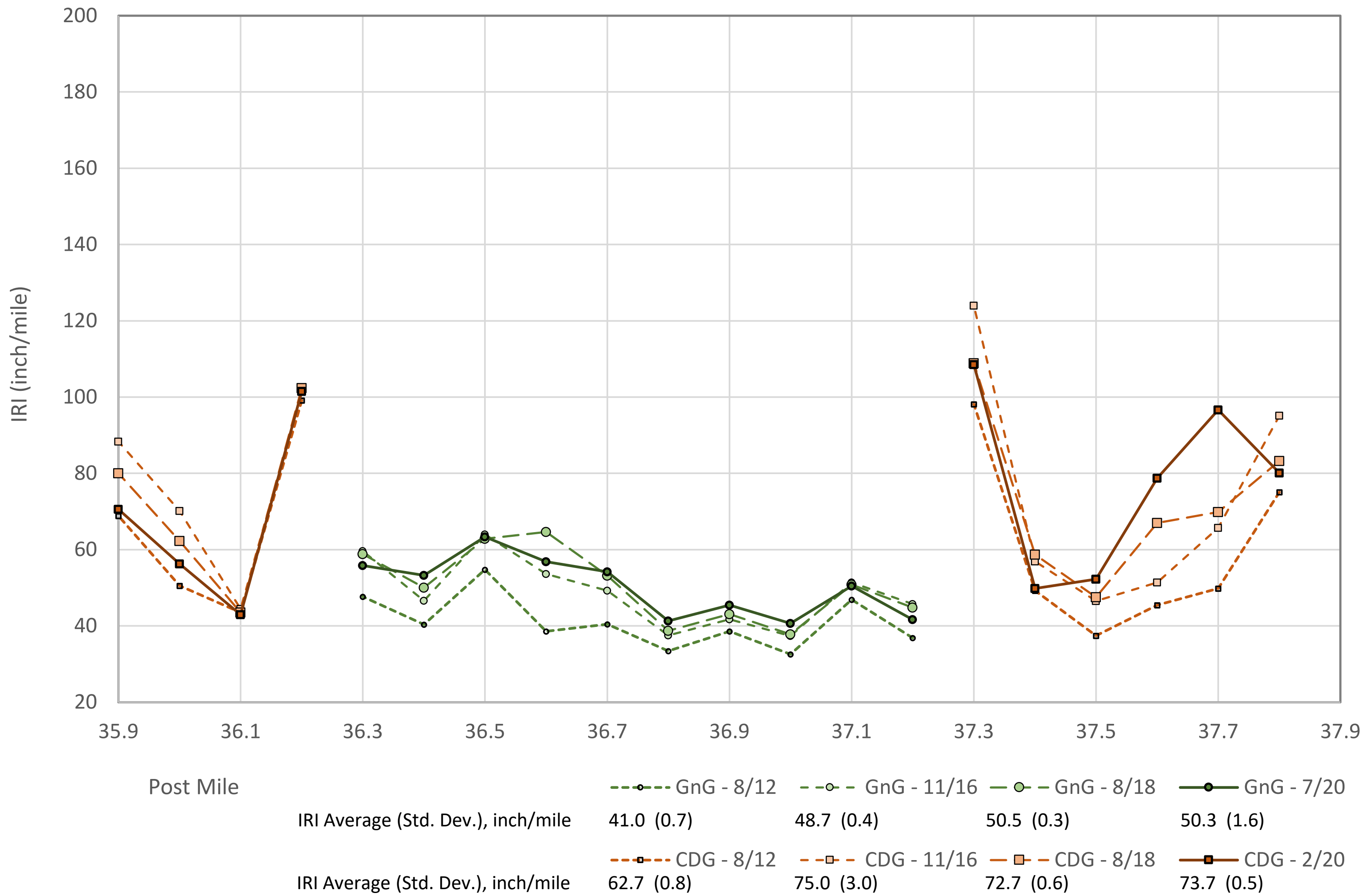



**Figure B.16: IRI on SD5S3.**

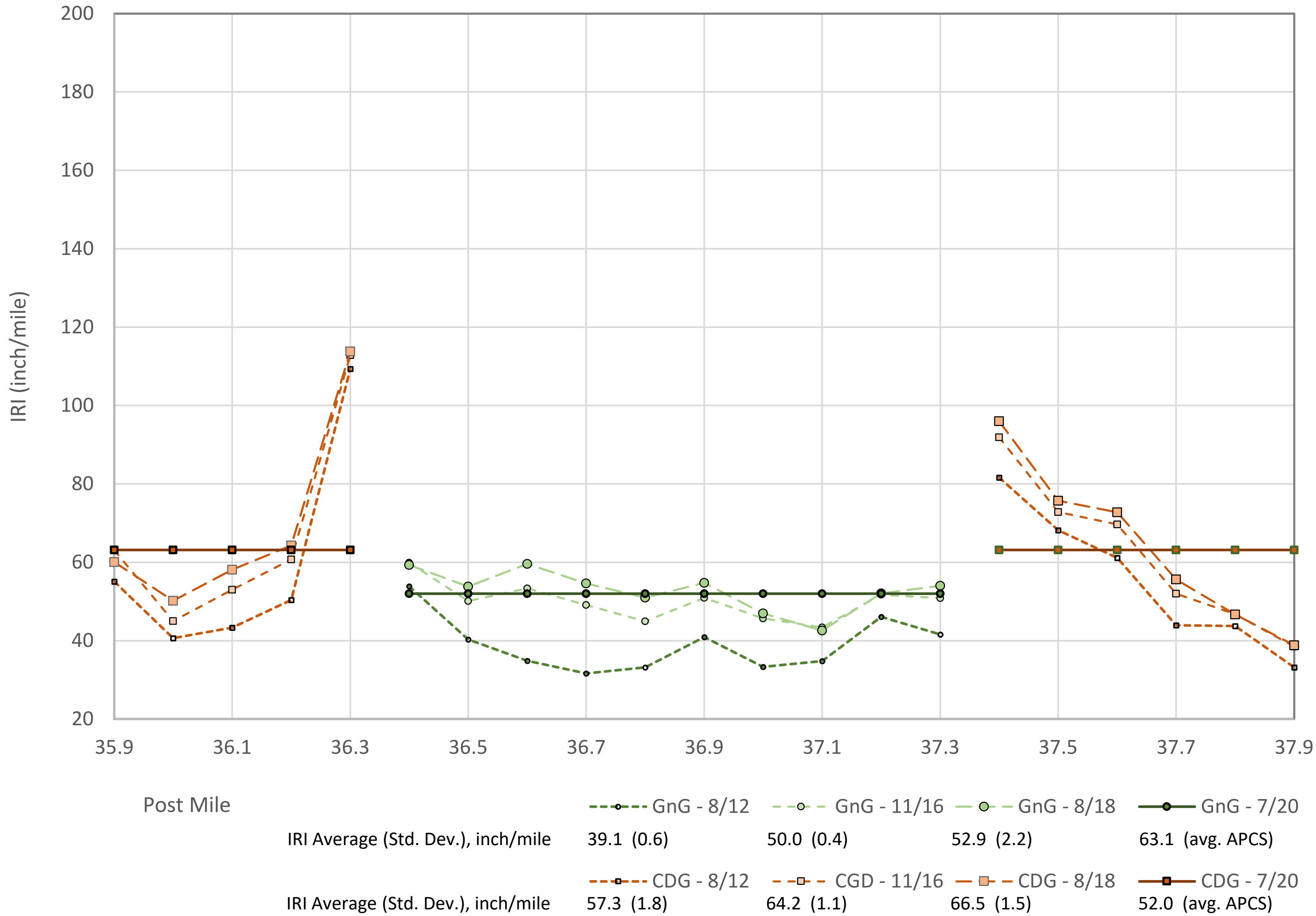



**Figure B.17: IRI on SD5N4.**

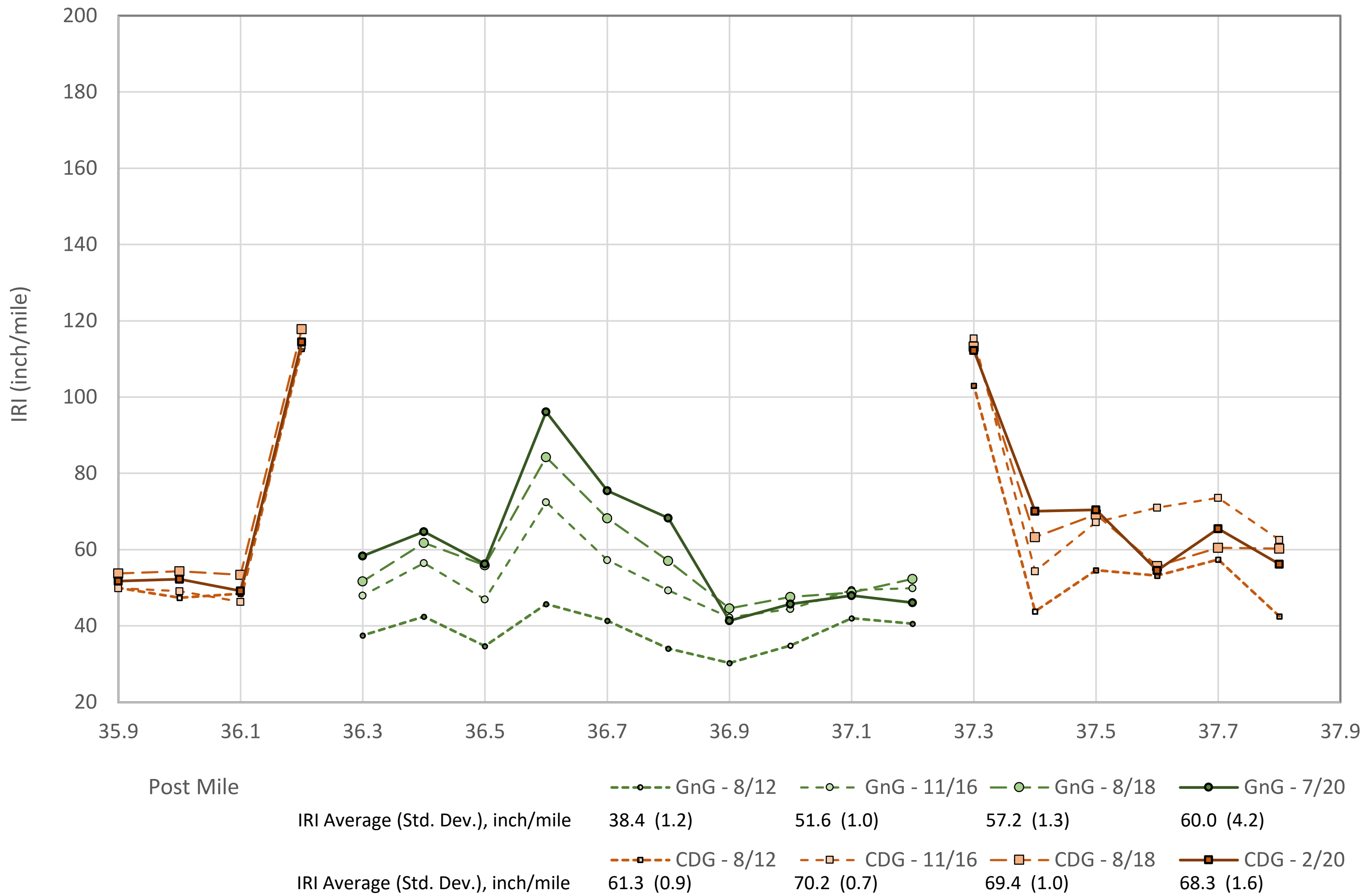



**Figure B.18: IRI on IRI on SD5S4.**

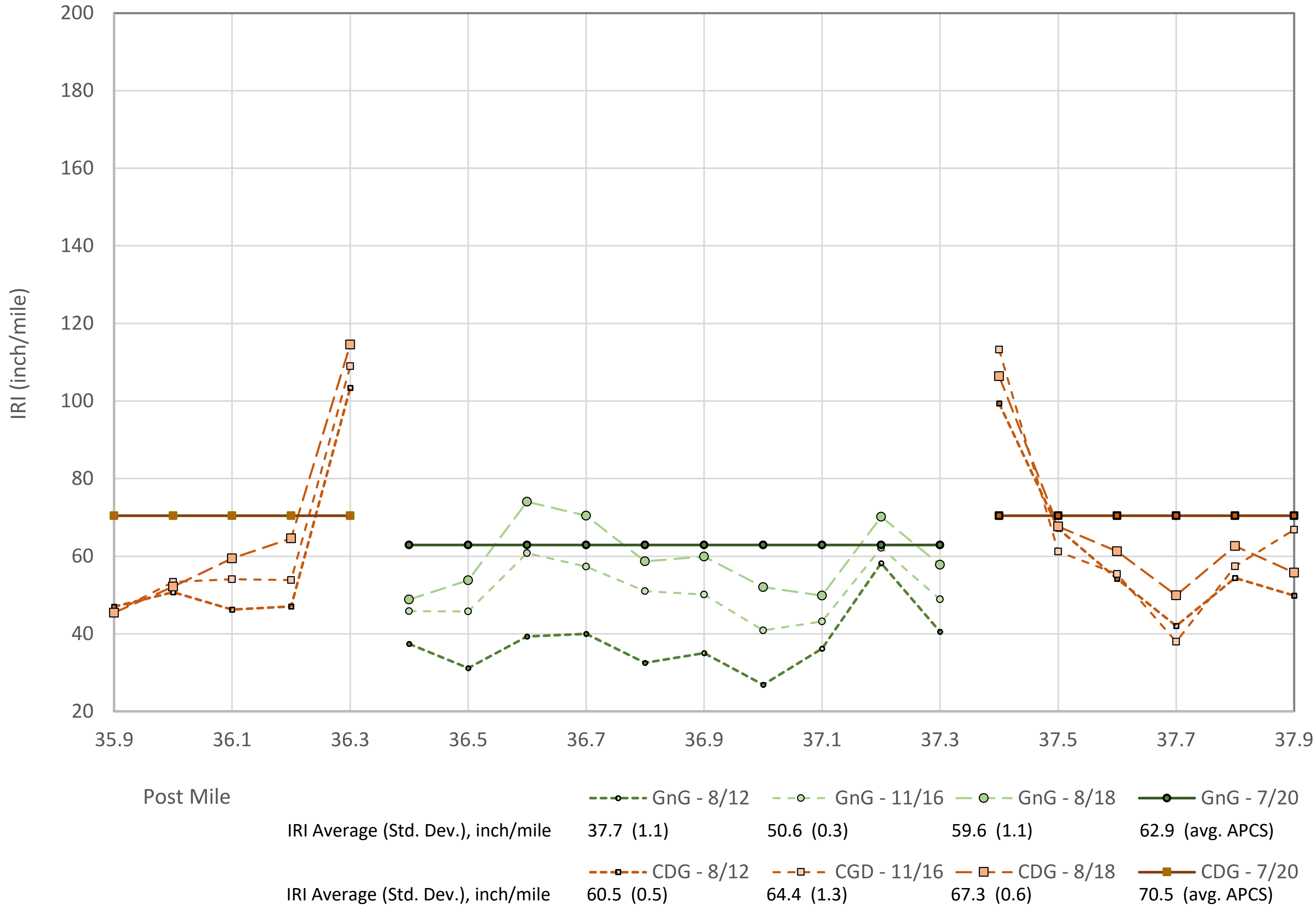



**Figure B.19: IRI on SD5N5.**

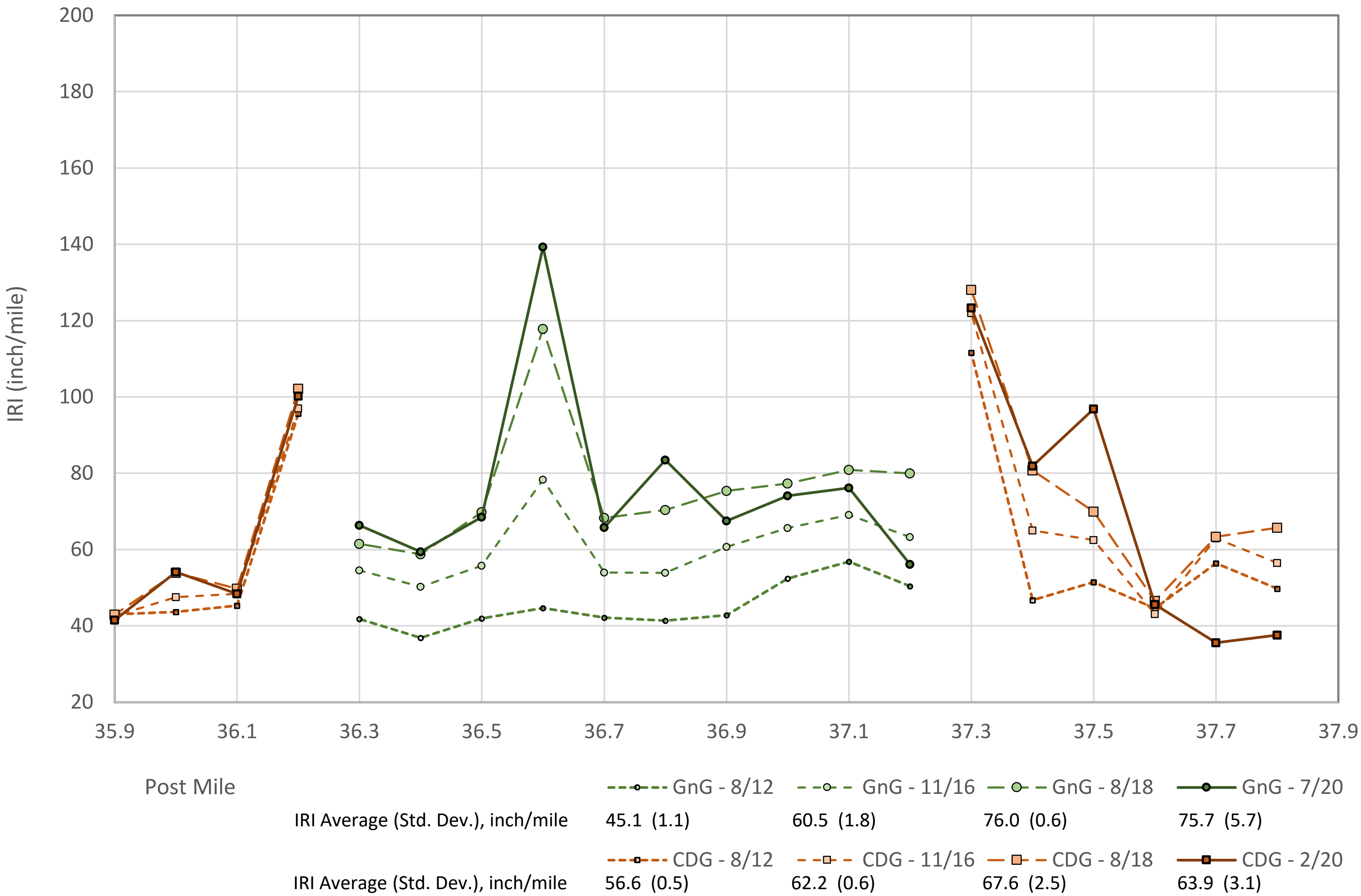



**Figure B.20: IRI on SD5S5.**

# APPENDIX C OBSI DATA CORRECTION: TIRE AND AIR DENSITY

Over the years that the on-board sound intensity measurement technology has been used by the UCPRC, there have been improvements to the process of OBSI data collection. As with the research performed in previous years, adjustments to the OBSI data have been made to normalize the results and make them consistent with other OBSI results from prior years. In the past, these adjustments included vehicle speed, sound analyzer, air density, and tire corrections. The vehicle speed is now strictly regulated, and the sound analyzer is now standardized, so adjustments are only required for air density and the test tire.

## C.1 Tire Conversion Procedure

The UCPRC monitors the test tires, standard reference test tires (SRTTs), used on the noise test vehicle and replaces the tires between testing phases. The criteria proposed by Donavan and Lodico *(1)* to determine when the test tire should be replaced are as follows:

- Tire age should not exceed four 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).

In November 2011, SRTT#5 was installed on the vehicle for the noise study. The sampling for this project began in 2012 and used SRTT#5 throughout the 2012 and 2013 data collection period. For the data collected in 2016 and 2017, SRTT#6 was installed on the noise vehicle.

While the tires used in both sets of data collection are SRTTs, different SRTTs can influence the data collected. Therefore, linear transformation equations are developed using only concrete test sections to adjust the results to the Year 1 SRTT. The sections used to compare the SRTTs are shown in Table C.1. Use of a common reference tire (SRTT#1) allows the eventual comparison of all noise measurements. The conversions were applied by frequency, and the overall sound intensity was calculated from the summation of the adjusted spectra values.

Table C.1 also shows the conversion process. Data are collected by both tires on the same section, and a linear approximation is used, shown in Figure C.1. This process is repeated for each frequency: 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, and 5,000 Hz. Finally, Table C.2 shows the conversion parameters for both the SRTT#5 and SRTT#6 tires to the SRTT#1 tire for each frequency.

**Table C.1: Tire Conversion Sections with Data Used in the Conversion Process**

| Section | SRTT#6 | SRTT#1 | Difference |
|---|---|---|---|
| Yolo113N2Pm3.0 | 102.68 | 102.30 | 0.38 |
| Yolo113N2Pm6.0 | 103.42 | 103.39 | 0.03 |
| Yolo113S2Pm5.5 | 103.04 | 102.59 | 0.44 |
| Yolo32aE | 106.54 | 107.58 | -1.04 |
| Yolo32aW1 | 105.73 | 106.56 | -0.84 |
| Yolo32aW2 | 105.15 | 106.07 | -0.92 |
| Yolo505S2Pm13.0 | 103.58 | 103.67 | -0.09 |

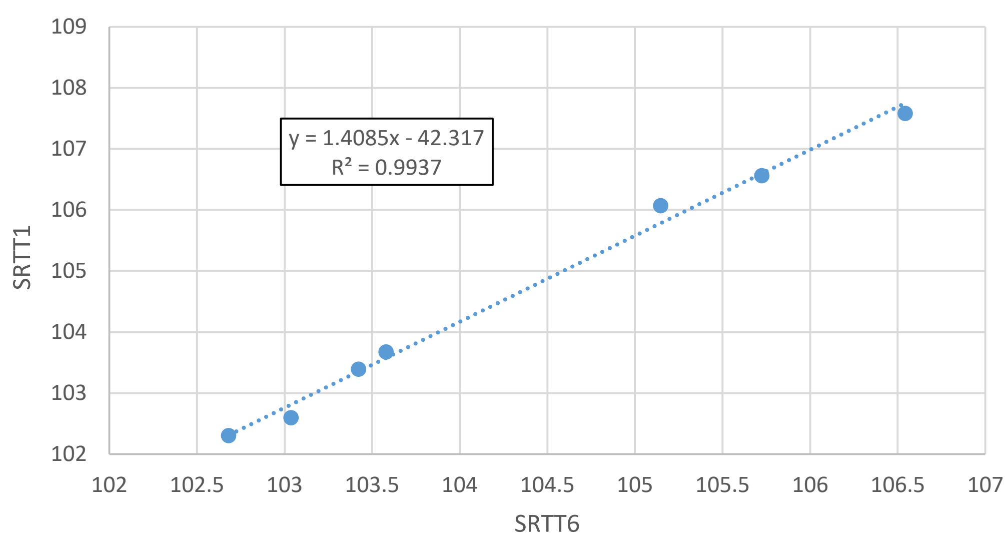



**Figure C.1: Tire conversion parameters from compared data.**

**Table C.2: Tire Conversion Parameters**

| One-Third Octave Band | SRTT#5 to SRTT#1 | | | SRTT#6 to SRTT#1 | | |
|---|---|---|---|---|---|---|
| | Slope | Intercept | R2 | Slope | Intercept | R2 |
| 400 | 0.694 | 26.514 | 0.648 | 1.193 | -17.014 | 0.944 |
| 500 | 0.902 | 8.664 | 0.838 | 1.208 | -18.084 | 0.993 |
| 630 | 0.914 | 7.402 | 0.848 | 1.154 | -13.577 | 0.996 |
| 800 | 1.087 | -8.839 | 0.909 | 1.304 | -29.783 | 0.996 |
| 1,000 | 0.886 | 10.735 | 0.721 | 2.132 | -112.150 | 0.939 |
| 1,250 | 0.893 | 10.446 | 0.718 | 1.609 | -57.848 | 0.917 |
| 1,600 | 0.842 | 15.161 | 0.886 | 0.923 | 8.324 | 0.855 |
| 2,000 | 1.027 | -2.399 | 0.754 | 1.024 | -0.775 | 0.884 |
| 2,500 | 0.956 | 3.742 | 0.572 | 1.859 | -75.312 | 0.660 |
| 3,150 | 1.033 | -2.929 | 0.867 | 0.679 | 26.710 | 0.269 |
| 4,000 | 0.757 | 19.485 | 0.751 | 0.669 | 27.215 | 0.664 |
| 5,000 | 0.807 | 14.596 | 0.656 | 0.847 | 12.641 | 0.786 |
| SumA | 1.029 | -3.032 | 0.905 | 1.408 | -42.317 | 0.994 |

## C.2 Air Density Correction

Air density corrections were applied at each frequency level. The following are the air density correction equations:

Mskg = 3.884266 + 10 ^ ((7.5 x Tc)/(237.7 + Tc))

Mkg = Mskg x Humidity%/100

Tvc = ((1 + 1.609 x Mkg)/(1 + Mkg)) x Tc

Baro = Bmb x exp (-Am/7000)

AirDensity = (Baro x 100)/((Tvc + 273) x 287))

OBSI Correction = 10 x ($Log_{10}$(ReferenceAirDensity) – $Log_{10}$(AirDensity))

Where:

Mskg = factor used in the humidity correction,

Tc = temperature (°C),

Mkg = adjustment for humidity,

Baro = adjustment of pressure for altitude,

Bmb = calculation of pressure in mbars,

Am = calculation of altitude in meters,

Tvc = application of the correction to temperature using the humidity adjustment, and

ReferenceAirDensity = 1.21

## References


1. Donavan, P. and Lodico, D. 2012. "Variation in On-Board Sound Intensity Levels Created by Different ASTM Standard Reference Test Tires." Presented at Transportation Research Board Annual Meeting, Washington, DC, January 22–26, 2012.

# APPENDIX D TRAFFIC COUNTS AND EQUIVALENT SINGLE-AXLE LOADS

Annual traffic data comes from Caltrans Traffic Operations and includes Average Annual Daily Traffic, Total Trucks, and Total Truck Percent, with additional columns showing the number and percent of two-, three-, four-, and five-axle trucks *(1)*. Beginning in 2011, the data have included thousands of equivalent axle loads (EAL, 1000s) representing two-way travel along each segment. Because the number of EALs included are for two-way traffic, they are halved to convert to one-way traffic for individual section calculations.

The annual EAL data were used to calculate the total number of EALs for each section for four intervals, from the time of last retexturing through the first data collection and the three intervals between the four data collections. When calculating the number of EALs, the annual data are assumed to be evenly distributed throughout the year. Therefore, the number of EALs in a given year is proportional to the number of days of the year from or to the date of data collection.

All dates of retexturing were in or after 2011, except for two sections: Kern 5 was retextured in 2010 and Siskiyou 5 was retextured in 2007. For Kern 5, the vehicle and truck counts were identical in 2010 and 2011, so the EAL from 2011 was used for 2010. For Siskiyou 5, the vehicle and truck counts were also identical in 2010 and 2011. For the years 2007 and 2009, the EALs were estimated to be proportional to the truck AADT in 2010. There were no data from 2008, so the average of the adjacent years was used as the estimate of EALs for 2008. Table D.1 shows the one-way annual EALs between 2011 and 2020.

Table D.2 shows the time and number of EALs accumulated between sampling trips, except for sampling interval 1. Sampling Interval 1 is the time between the date of last retexturing and the first sampling date. Sampling Interval 2 is the time between the first two samplings, Sampling Interval 3 is the time between the second and third sampling, and Sampling Interval 4 is the time between the third and final sampling.

These times and EALs are used to determine the time rate of change and the traffic rate of change. EALs for the sampling interval are given in the thousands, but the final column shows the EALs in the millions. The final column shows the total number of EALs between the first and final samplings, which is the sum of Sampling Intervals 2, 3, and 4.

## Table D.1: One-Way Annual Equivalent Axle Loads, 2011 – 2020

| Section | EALs 2011 | EALs 2012 | EALs 2013 | EALs 2014 | EALs 2015 | EALs 2016 | EALs 2017 | EALs 2018 | EALs 2019 | EALs 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pla80E1 | 605 | 605 | 650 | 641 | 679 | 752 | 752 | 752 | 769 | 676 |
| Sis5N2[a] | 568 | 616 | 594 | 644 | 736 | 777 | 750 | 582 | 767 | 567 |
| Ker5S2[b] | 913 | 1117 | 1163 | 1240 | 1252 | 1313 | 1330 | 1364 | 1381 | 1346 |
| SJ5N1 | 3482 | 3160 | 3700 | 2902 | 2902 | 2902 | 2902 | 2902 | 2902 | 2902 |
| Imp78E2 | 156 | 164 | 166 | 154 | 159 | 152 | 156 | 156 | 171 | 164 |
| Imp86S2 | 362 | 348 | 365 | 324 | 314 | 321 | 328 | 328 | 554 | 554 |
| Sac5-NB | 1738 | 1738 | 1738 | 1738 | 1798 | 1922 | 1975 | 1975 | 1975 | 1635 |
| Sac5-SB | 1702 | 1702 | 1702 | 1702 | 1786 | 1872 | 1935 | 1936 | 1936 | 1762 |
| Sac5b-NB | 1712 | 1712 | 1712 | 1585 | 1668 | 1766 | 1820 | 1820 | 1820 | 1522 |
| Sac5b-SB | 1712 | 1712 | 1712 | 1585 | 1668 | 1766 | 1820 | 1820 | 1820 | 1522 |
| Sac80-EB | 992 | 992 | 1003 | 948 | 996 | 1016 | 1016 | 1016 | 1115 | 950 |
| Sac80-WB | 792 | 792 | 785 | 969 | 969 | 1017 | 1017 | 1017 | 1038 | 976 |
| Sac50-EB | 679 | 679 | 679 | 679 | 749 | 756 | 756 | 756 | 764 | 655 |
| Sac50-WB | 539 | 539 | 539 | 565 | 590 | 596 | 596 | 596 | 550 | 474 |
| SJ99-NB | 952 | 938 | 952 | 995 | 1096 | 1096 | 1096 | 1096 | 1356 | 1356 |
| Yol113-NB | 190 | 187 | 178 | 193 | 195 | 205 | 206 | 206 | 206 | 178 |
| Yol113-SB | 214 | 214 | 203 | 226 | 228 | 239 | 231 | 232 | 232 | 200 |
| SD5-NB | 516 | 523 | 516 | 523 | 523 | 261 | 536 | 268 | 244 | 169 |
| SD5-SB | 901 | 858 | 833 | 901 | 901 | 1184 | 1223 | 1224 | 1229 | 987 |

[a] Annual EALs for Sis5N2 in 2007 (633), 2008 (635), 2009 (638), and 2010 (568).

[b] Annual EALs for Ker5S2 in 2010 (913).

**Table D.2: Time and Traffic During Four Intervals of Sampling**

| Test Section | Sampling Interval 1 | | Sampling Interval 2 | | Sampling Interval 3 | | Sampling Interval 4 | | Total Test EALs (x1000000) |
|---|---|---|---|---|---|---|---|---|---|
| | Time 1 (years) | EALs 1 (x1000) | Time 2 (years) | EALs 2 (x1000) | Time 3 (years) | EALs 3 (x1000) | Time 4 (years) | EALs 4 (x1000) | |
| Pla80E1PM56.45 | 1.6 | 1019 | 2.9 | 2011 | 2.0 | 1510 | 1.4 | 1029 | 4.55 |
| Sis5N2PM57.0 | 5.5 | 3335 | 3.6 | 2454 | 2.0 | 1379 | 1.4 | 973 | 4.81 |
| Ker5S2PM40.0 | 2.3 | 2317 | 3.9 | 4848 | 1.8 | 2366 | 1.9 | 2614 | 9.83 |
| SJ5N1PM32.0 | 0.4 | 1048 | | | 1.5 | 4337 | | | 4.34 |
| Imp78E2PMR15.0 | 0.6 | 101 | 4.3 | 677 | 1.8 | 275 | 1.9 | 318 | 1.27 |
| Imp86S2PMR24.2 | 0.6 | 213 | 4.3 | 1421 | 1.8 | 578 | 1.9 | 979 | 2.98 |
| Sac5 NB | 0.6 | 985 | 5.3 | 9476 | 1.3 | 2546 | 1.5 | 2980 | 15.00 |
| Sac5 SB | 0.6 | 964 | 5.3 | 9296 | 1.3 | 2495 | 1.5 | 2946 | 14.74 |
| Sac5b NB | 0.2 | 309 | 5.3 | 9060 | 1.2 | 2159 | 1.5 | 2754 | 13.97 |
| Sac5b SB | 0.2 | 309 | 5.2 | 8888 | 1.3 | 2331 | 1.5 | 2754 | 13.97 |
| Sac80 EB | 0.1 | 77 | 4.4 | 4403 | 1.8 | 1789 | 1.5 | 1644 | 7.84 |
| Sac80 WB | 0.1 | 62 | 4.4 | 4062 | 1.8 | 1791 | 1.5 | 1571 | 7.42 |
| Sac50 EB | 0.0 | 2 | 4.4 | 3118 | 1.8 | 1369 | 1.5 | 1148 | 5.64 |
| Sac50 WB | 0.0 | 1 | 4.4 | 2493 | 1.8 | 1079 | 1.5 | 846 | 4.42 |
| SJ99 NB | 0.2 | 190 | 4.6 | 4792 | 1.6 | 1735 | 1.3 | 1683 | 8.21 |
| Yol113 NB | 1.3 | 230 | 3.3 | 644 | 1.8 | 368 | 1.5 | 311 | 1.32 |
| Yol113 SB | 1.3 | 263 | 3.3 | 751 | 1.8 | 415 | 1.5 | 350 | 1.52 |
| SD5 NB – GnG[a] | 0.1 | 54 | 4.3 | 2001 | 1.8 | 740 | 1.9 | 433 | 3.17 |
| SD5 SB – GnG[a] | 0.1 | 88 | 4.3 | 4025 | 1.8 | 2153 | 1.9 | 2211 | 8.39 |
| SD5 NB – CDG[a] | 1.4 | 702 | 4.3 | 2001 | 1.8 | 740 | 1.9 | 433 | 3.17 |
| SD5 SB – CDG[a] | 1.4 | 1193 | 4.3 | 4025 | 1.8 | 2153 | 1.9 | 2211 | 8.39 |

[a] The GnG and CDG surfaces were constructed at different times for San Diego 5 sections.

## References


1. California Department of Transportation. n.d. "Traffic Census Program." Traffic Operations. Accessed January 6, 2021. https://dot.ca.gov/programs/traffic-operations/census.