Temporary Orange Contrast Markings Manual of Uniform Traffic Control Devices Experimentation

FHWA Ruling No. 6(09)-66 E	**Scott Davis Steve Haapala Fredrick Lintz Emily Nathan**	**October 2024**

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16. Abstract

From 2018 to 2022, Washington State highways averaged about four fatalities, 16 suspected serious injuries, and 256 suspected minor/possible injuries each year in work zones, with nearly 94% occurring to drivers. Motivated by its safety goals, the Washington Department of Transportation sought strategies to improve driver guidance and heighten awareness without disrupting lane marking expectations.

The introduction of lagging orange contrast supplemental markings is expected to enhance driver awareness and safety within work zones, aligning with the colors of existing construction signs and channelizing devices. This additional delineation aimed to reduce driver confusion during multi-stage traffic reconfigurations where shifted alignments left ghost lines.

To evaluate these goals, driver behavior, material performance, and safety data were examined. The experiment, conducted on Interstate 5 in Fife, near Tacoma, Washington, from February 2023 to January 2024. Despite some methodological limitations, no adverse effects of the orange contrast markings were observed. The experimental implementation of lagging orange pavement markings was deemed successful base on positive public perception, improved safety, and durability.

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1.0 INTRODUCTION

1.1 BACKGROUND

From 2018 to 2022, Washington State highways averaged about four fatalities, 16 suspected serious injuries, and 256 suspected minor/possible injuries each year in work zones, with nearly 94% occurring to drivers. The Washington State Department of Transportation has implemented many strategies to improve safety of workers and traveling public that range from schedule adjustments, Intelligent Transportation System-based solutions like smart work zones, and enhanced enforcement when applicable.

Though WSDOT has been able to implement many innovative safety strategies, one of the most basic elements of work zones that continues to pose challenges is when highway lanes are repositioned to accommodate roadway work. During long-term projects, work zones can be reconfigured many times over, which can result in "ghost" lines. These "ghost" lines can be quite conspicuous under certain lighting conditions, which when compounded by changing geometry, can confuse drivers navigating work zones. (Shaw J, 2017)

Washington state's safety goals has driven WSDOT's interest in pursuing strategies that would improve driver guidance and heighten awareness without disrupting lane marking expectations. One such strategy is offered in *NCHRP Report 574: Temporary Pavement Markings Placement and Removal Practices in Work Zones* – the use of supplemental orange pavement markings.

This report investigates conventional white broken lane lines with lagging orange contrast markings because of perceived cost-effectiveness and its similarity to black contrast lines, which have been implemented throughout the state.

There were several anticipated benefits. The first was that in comparison to ghost lines, orange lane stripes might better indicate which markings are active. The second was that orange striping might alert drivers to the fact they were driving through active work zones and exhibit greater attention. Improving driver awareness is anticipated to improve safety performance within the work zone.

Washington State's Strategic Highway Safety Plan Target Zero vision is zero deaths and serious injuries on Washington's roadways by 2030. Target Zero is built on the belief that not one death is acceptable on our state's roadways. This extends beyond just the traveling public and includes those working in and traveling through road construction sites.

Experiment objectives

Improve driver awareness

Improve safety performance

In October 2022, the Federal Highway Administration (FHWA) approved a WSODT request to evaluate the effectiveness of the supplemental lagging orange contrast markings during the Interstate 5 and State Route 167 Completion Project in Pierce County. This project on Interstate 5 underwent a major reconfiguration for work zone in February 2023 lending itself to an ideal location for experimentation.

1.2 LOCATION

The experiment location is situated on Interstate 5 in the city of Fife, near Tacoma, Washington. Fife is approximately midway between the state of Oregon and British Columbia, Canada, along the Interstate 5 corridor.

Route	Interstate 5, about 4 miles east of Tacoma				
Nearest city	City of Fife				
BMP	138.37	Latitude	47.24209830566689	Longitude	122.33772318420927
EMP	139.04	Latitude	47.25128589823643	Longitude	122.33261335420704

Vicinity Map

I-5 is an important interstate freeway for travel, including freight, commuter, and recreational traffic in south Puget Sound. It has four general purpose traffic lanes and one high occupancy vehicle lane in each direction, and a speed limit of 60 mph. I-5 is designated as an interstate freeway and is a part of the National Highway System. The experiment area includes a roughly half-mile stretch of I-5 between the 54th Avenue interchange and Porter Way Road overcrossing.

The experimental site falls within a construction project that is part of the broader Puget Sound Gateway Program. This program aims to improve regional mobility with new highway connections to Sea-Tac Airport and the Port of Tacoma and Seattle. Specifically, the site is associated with Stage 1B of the State Route 167 Completion Project in Pierce County. This project extends State Route 167 from the city of Puyallup to the Port of Tacoma and includes the construction of a new interchange on Interstate 5. Visual representations in the following figures provide additional context regarding the location of the experiment site within the overall project. The figure flow depicts the overall route of the State Route 167 Expressway.

The experimentation site was located on Interstate 5 near the city of Tacoma in what is locally known as the Fife curve.

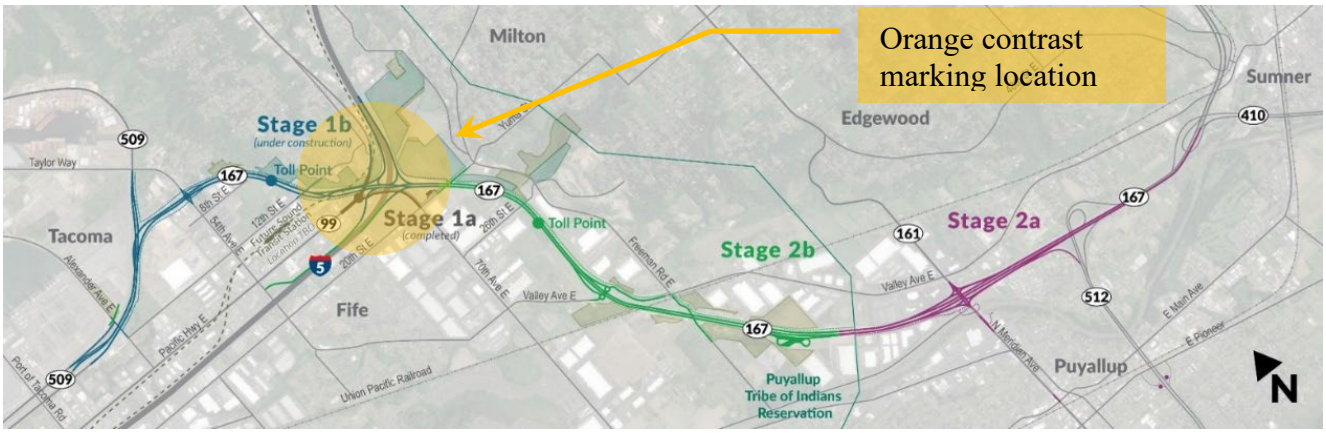
Interstate 5 within the experimentation site averaged close to 200,000 vehicles per day.

State Route 167 Expressway route

Orange contrast marking location

The next figure shows the different stages of the State Route 167 Expressway Project. Stage 1a is completed and now the Design Builder is working on Stage 1b. As noted earlier this stage includes a new system-to-system interchange at Interstate 5 and removal of fish barriers. To complete this work significant but temporary changes to Interstate 5 are necessary including geometric changes, lane shifting, and narrower lanes and shoulders.

1State Route 167 Expressway construction stages



1.3 RESEARCH FRAMEWORK

The lagging orange contrast markings were evaluated against conventional lane lines in a high-speed, high-volume work zone. Conventional white lane lines were implemented in the study work zone for approximately 3.5 months. The experimental orange contrast striping was then implemented in the same location for a similar duration. The roadway segment being used was in a temporary configuration for the duration of the experiment but otherwise remained unchanged. Data was collected by video, permanent traffic recorders, and driver surveys during and after the evaluation period. Crash and material data was collected, and the jobsite was observed by video for qualitative observation. The evaluation was broken into three broad categories: Driver Behavior, Materials, and Safety Information.

- Driver Behavior accessed by a motorist survey, speed evaluations, and targeted video observations of driver behavior by counting lane departures.

- Materials evaluated subjectively via in-person drive-through, video review, and photography. Paint materials information and retroreflectivity measurements were collected.

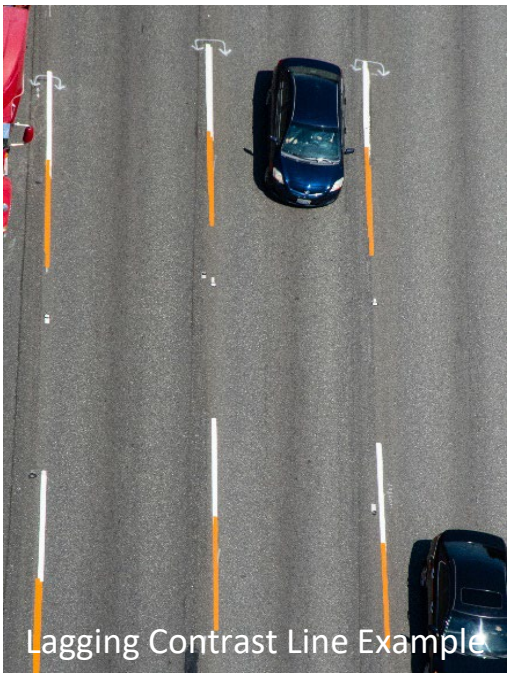
- Safety Information analyzes traditional reported collision information and documented un-reported incidents (incidents documented via inspections by the project office involving channelizing devices impacted but did not result in a collision report).

To support the research work, a technical advisory team was formed. This team's purpose was to offer expert guidance, ensure quality, solve problems and facilitate communication among internal stakeholders. It included members from the project office, regional traffic office and headquarters transportation operations division. The team met monthly from October 2022 to December 2023, guiding the development of the research plan, defining roles and responsibilities and reviewing materials as the experimentation progressed.

1.4 ORANGE MARKING APPROACH

One of the first steps was to determine how to incorporate orange markings into work zones. This process included a literature review of experiments conducted in Wisconsin, Kentucky and California. In Wisconsin and Kentucky, experiments involved replacing all work zone markings with orange. In contrast, California's experiment explored various methods of supplementing existing markings with orange versus replacing them. Caltrans' experiments included adding orange to existing lines, such as wide lines and lane lines, and tested several contrasting scenarios, including an orange stripe preceding the lane lines.

To minimize costs and maintain driver expectations, completely replacing work zone markings with orange was not considered. The goal was to retain the familiar white and yellow markings. WSDOT has previously used lagging black contrast markings on freeway lane lines for light-colored pavements in both permanent and temporary locations (including 1 mile south of the experimentation site) and believed that similar applications of orange in work zones would be worth testing. This approach ensures that all existing markings in the appropriate color remain in place, simplifying the temporary application of orange markings. WSDOT Standard Plans include details on lagging contrast markings, aiding in repeatability for future use. For these reasons, the team preferred supplementing lane lines with a lagging contrasting orange stripe.


Lagging Contrast Line Example

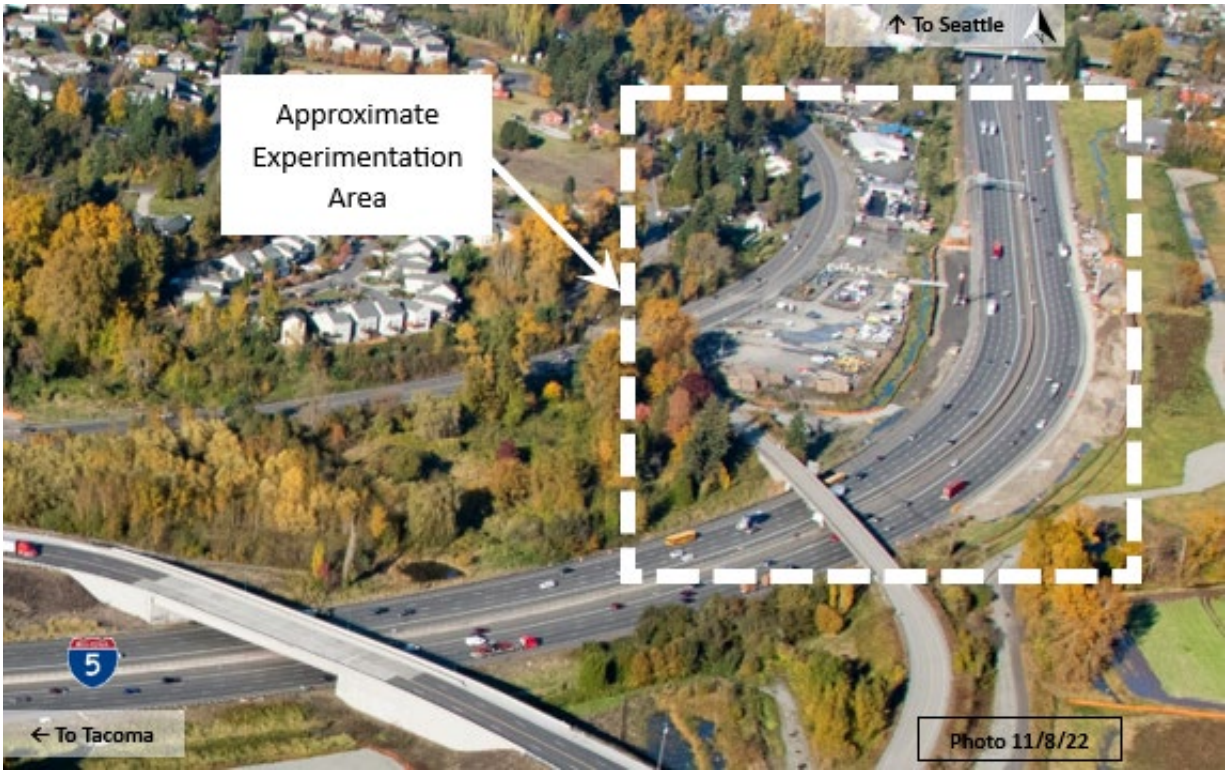
1.5 EXPERIMENT PHASES

Phase 0: Pre-Experiment – January 2023

This phase refers to the collection of base level vehicle speed data prior to the work zone staging configuration used during the lagging orange pavement marking experiment. Construction during this time occurred outside the paved area of the interstate in preparation for shifting travel lanes in the next phase. This phase did not include any major changes to the interstate geometry with existing 12 foot lanes maintained but shoulders were narrowed by a temporary barrier which separated work crews from traffic.

The existing 60-mph posted speed was maintained, but a 50-mph advisory speed warning sign was installed at the horizontal curve.

Phase 0 used conventional pavement marking consisting of 10 foot white broken lane lines with a solid white HOV lane line, yellow left edge line, and a white right edge line (all 4 inches in width). These will be referred to as "conventional markings."



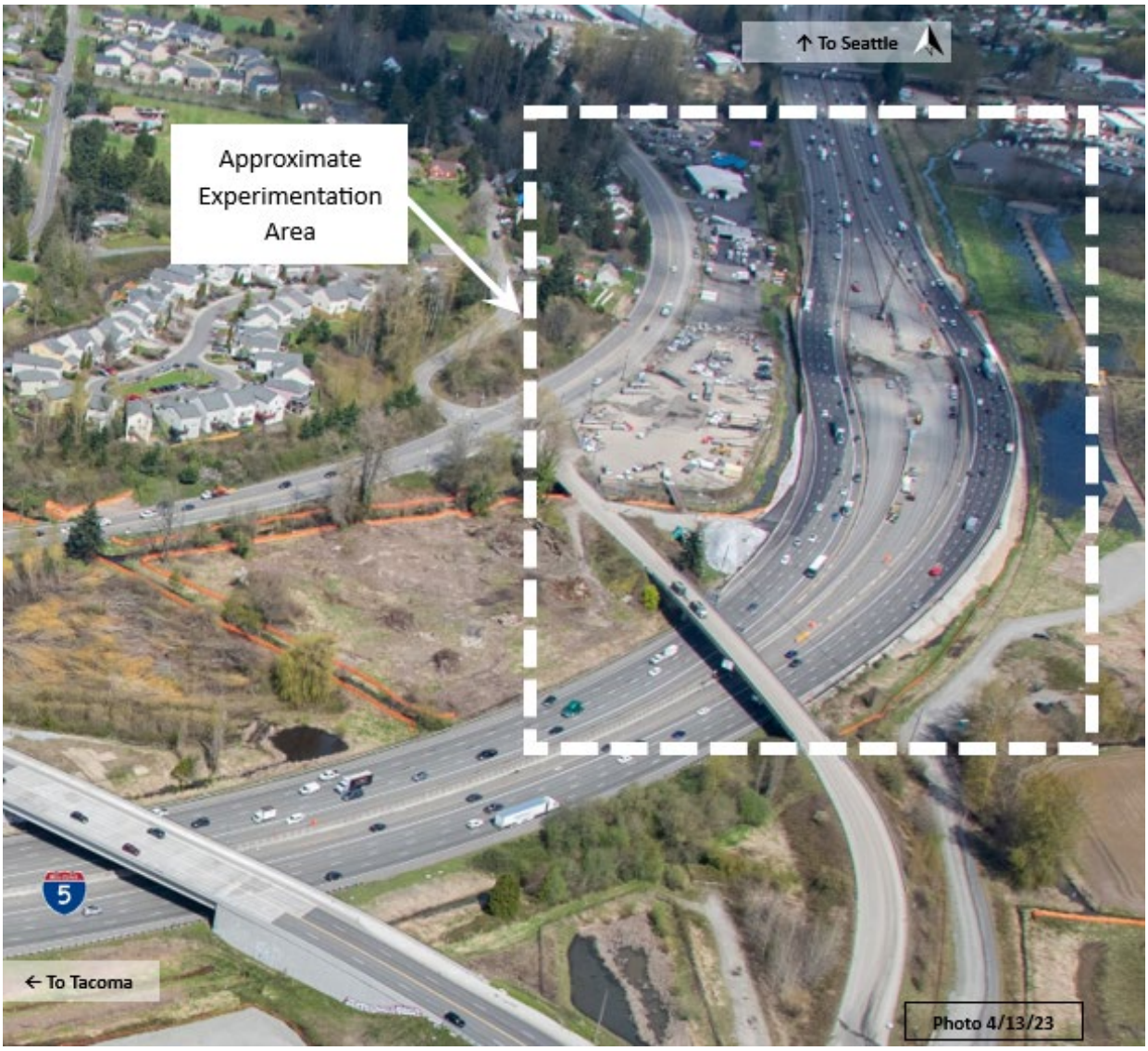
Phase 1: Conventional Pavement Markings – February 2023 to June 2023

In Phase 1, the I-5 staged traffic configuration was substantially changed from Phase 0. The southbound roadway was reconfigured to include an S-curve prior to the horizontal curve with a minor revision in the northbound alignment.

Northbound realignment occurred on Feb. 14, 2023, and southbound on Feb. 28, 2023. Conventional pavement markings were used without lagging orange contrast markings.

The staged traffic configuration narrowed lanes from 12 feet in width to 11 feet and further reduced the shoulders down to a minimum of 2 feet wide in both directions.

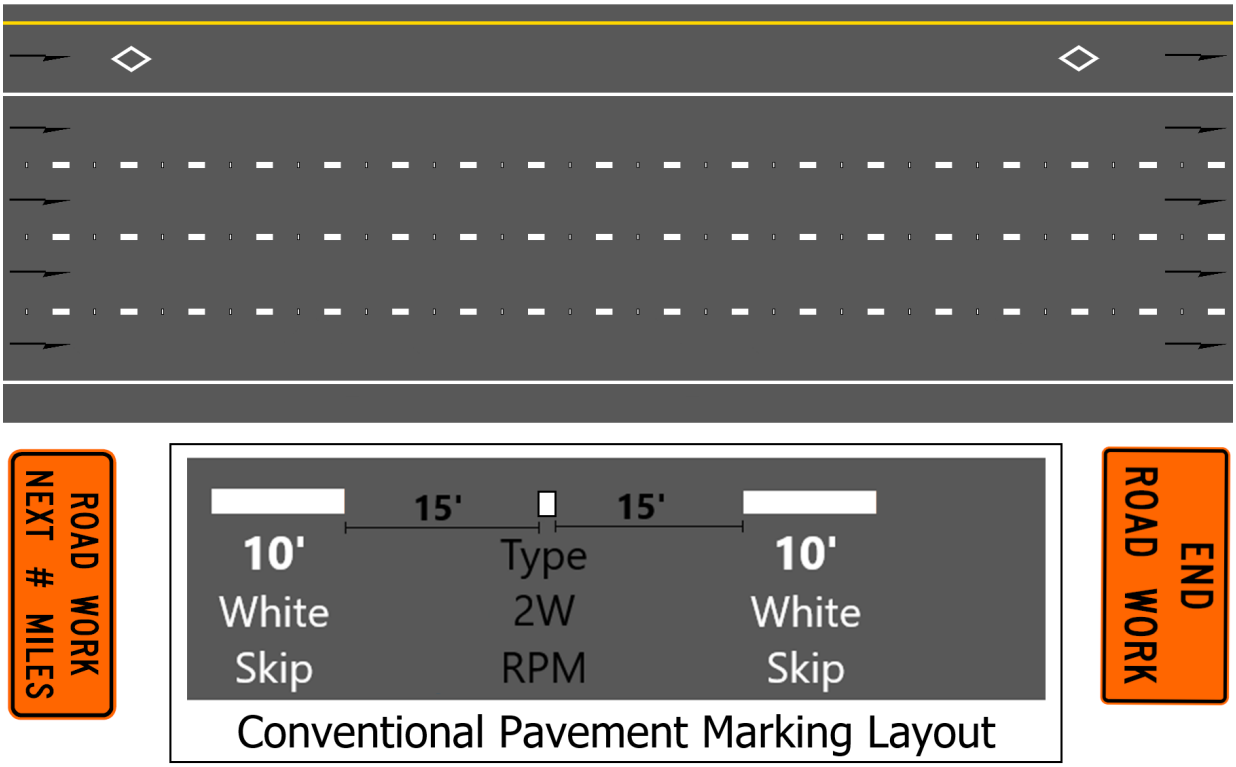
The regulatory speed limit was reduced from 60-mph to 50-mph. The northbound 50-mph reduction began about one-quarter mile prior to the reconfiguration and extended about three-quarters of a mile past the reconfiguration. The southbound 50-mph reduction began about three-



quarters of a mile prior to the reconfiguration and extended about one-half mile past the reconfiguration.

This phase included the collection of vehicle speed, safety data, video recordings, and marking retroreflective measurements.

Like Phase 0, Phase 1 used conventional pavement marking consisting of 10-foot-long white broken lane lines with a solid white HOV lane line, yellow left edge line, and a white right edge line (all 4 inches in width). These will be referred to as “conventional markings



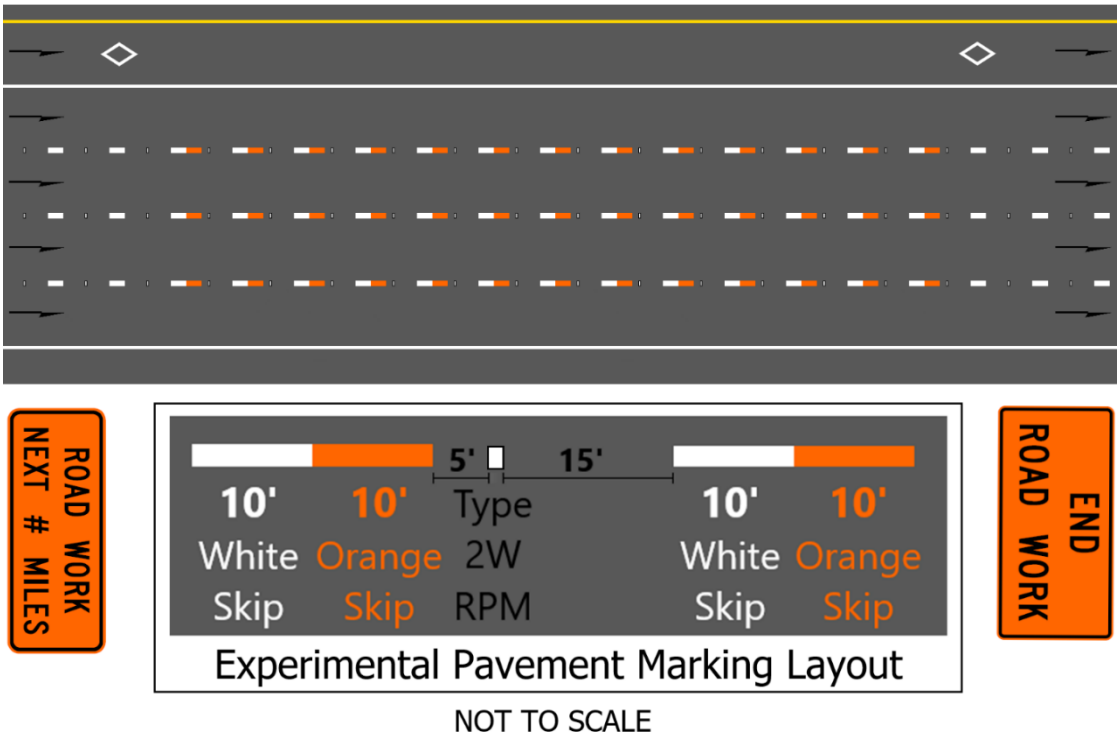
NOT TO SCALE

Phase 2: Experimental Orange Pavement Markings – June 2023 to September 2023

In Phase 2, the staged traffic configuration and regulatory speed limits were unchanged from Phase 1, but orange contrast markings were added in both directions on June 7, 2023. The white lane lines were also repainted.

This phase included the collection of vehicle speed, safety data, video recordings, and marking retroreflective measurements.

Phase 2 added an experimental 10-foot-long orange lagging contrast marking after the conventional white broken lane lines only where road geometry was being shifted around an existing highway, not throughout the entire project limits.



Phase 3: Experimental Orange Pavement Markings Ends – November 2023

Lane configuration did not change from Phase 2. Experimental markings remained in place. Data collection included video recordings and aerial photographs.

Phase 4: Staged Traffic Configuration Ends – January 2024

Phase 4 represents the end of the experimentation with the removal of the orange markings on Jan. 10, 2024.

The travel lanes shifted back to the inside on the new Hylebos Creek bridge, and the 60-mph posted speed was restored with a 50-mph advisory speed curve warning sign at the horizontal curve. This condition is expected to remain the same until Stage 1B of State Route 167 Completion Project is completed.

Picture below shows interstate configuration after orange markings were removed

2.0 DATA COLLECTION AND ANALYSIS

2.1 Driver Behavior

2.1.1 Driver Perception Survey

A multimethod public survey was conducted from May to August 2023 by PRR, a General Engineering Contractor. PRR is a communications, marketing, and community engagement company. The findings of the limited pre/post survey are summarized below. The full report is included in the Appendix.

A survey was designed to collect data regarding drivers' perceptions and experiences while navigating a work zone with orange contrast marking. Specifically, the data gathered aimed to provide insight into whether the use of the lagging orange contrast marking in construction work zones benefited drivers and enhanced worker safety by:

- Increasing work zone awareness.
- Reducing work zone incidents or intrusions.
- Maintaining work zone speed and variance.
- Improving lane discipline and driver behavior.

Over 900 survey responses

Over 20,000 survey invitations sent

Recruitment also included online outreach through WSDOT's social media accounts.

Nearly 87% drivers who noticed orange markings said they want to see orange used more in work zones.

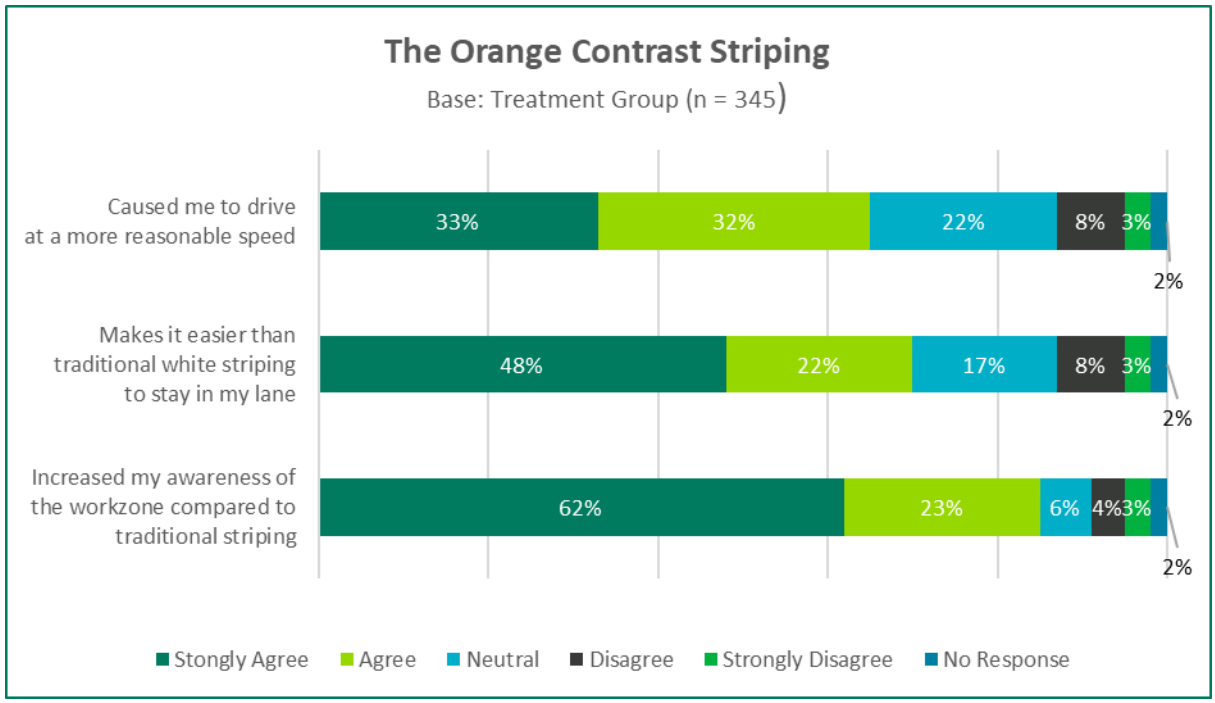
<u>Summary of findings</u>:

Overall, respondents who saw the orange contrast markings felt positively about their impact on safety, visibility and work zone awareness. Respondents generally wanted to see the orange contrast marking used more often.

From the group exposed to the orange markings (445 responses), over 80% noticed the orange markings. Of those who noticed the markings (345 responses), 70% agreed the markings made it easier to stay in their lane, and 65% agreed it made them drive slower or more reasonably in the

work zone. Additionally, more than 86% of those who saw the lagging orange contrast markings at night (43 responses) preferred it to only the conventional broken white lane markings

While the survey does not definitively reflect drivers' actual behaviors, it does show a consensus on the need for better driving practices in construction zones. The findings reveal that drivers recognize the benefits of improved driving habits and enhanced safety measures, and they view the orange contrast markings positively.



2.1.2 Driving Behavior Observations

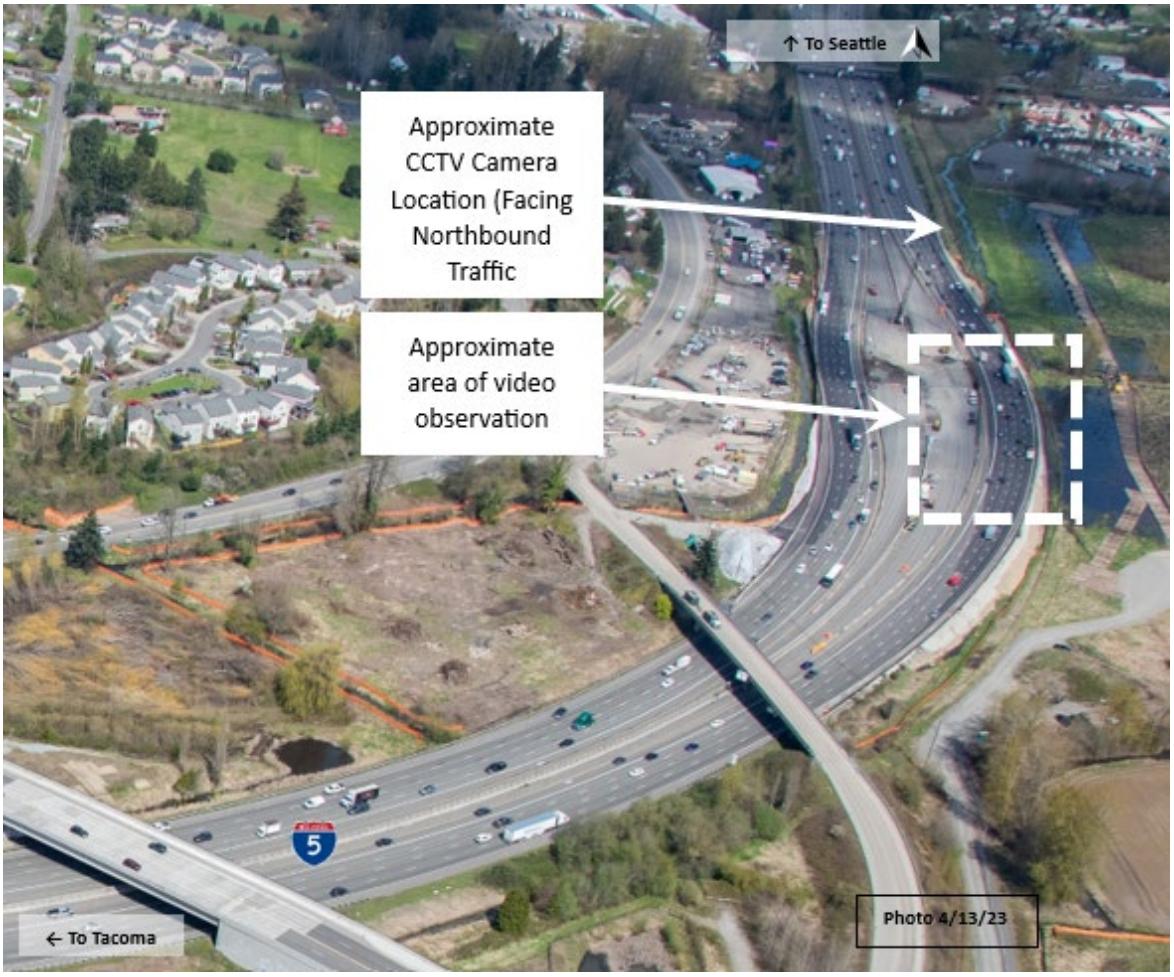
In addition to the motorist surveys, driver behavior in the study area was evaluated through reviewing six hours of video and a comprehensive speed analysis.

2.1.2.1 Driving Behavior

Lane discipline was evaluated in Phases 1 and 2 through review of CCTV camera footage. The CCTV camera captured footage of all five lanes of northbound traffic within the experimentation area. Three hours of late morning footage was observed for each phase to determine the number of lane departures, which was defined as any time a vehicle encroached on a lane line or adjacent lane without performing a complete lane change. Each northbound lane was observed individually for approximately 30 hours total observation time through both Phase 1 and 2.

Video footage during off-peak periods was used to allow vehicle behavior to be examined outside the influence of peak hour congestion. Note that lane changes were permitted throughout the work zone. The Phase 1 footage included approximately 16,000 vehicles over three hours, and the Phase 2 footage included approximately 17,000.

A summary of the video review is included in the Appendix.



The table below represents a summary of the lane intrusions and lane changes recorded during the video observation. When compared to the Phase 1, there were 105 fewer observed suspected lane departures in the Phase 2 footage representing about over a 25% reduction. While this video evaluation represents a small snapshot overall, it still is a notable reduction. The results also correlate with driver survey where 70% of the respondents said the orange lines made it easier to stay in their lane.

Driving behavior evaluation via video analysis (totals)				
	Phase 1 (Conventional)		Phase 2 (Orange contrast)	
	Tally	Percent of observed traffic	Tally	Percent of observed traffic
Suspected lane intrusion	413	2.5%	308	1.8%
Suspected lane change	379	2.3%	361	2.1%
Traffic volume observed	16,256		17,074	

The quality of the CCTV video, limited number of recordings, camera angle, and the limited viewing area likely impacted the observations. The footage showed pixelation at the edges, obscuring lane lines. The camera angle caused occlusions, making it difficult to determine if vehicles were within their lanes. The limited viewing area meant only a small part of the experimental zone was observed, and judging driver intent as vehicles left the frame required interpretation. For instance, it was challenging to discern whether a vehicle crossing a lane line was changing lanes or merely encroaching. This necessitated judgment in recording vehicle

observations and led to the inclusion of the word “suspected” as part of the tally description. Consequently, different or more video observations may have yielded different results. The resources available did not permit additional cameras, video reviews or inclusion of additional days or time periods.

Finally, the experiment itself did not control for improved driver familiarity over time. A significant portion of daily users in this section of I-5 are anticipated to be commuters. Because the geometric configuration of the study area did not change between Phases 1 and 2, it is likely that driver familiarity improved over the duration of the control period. Therefore, it is likely that part of the improved lane discipline can be attributed to driver familiarity rather than the paint. For example, the first two observations during Phase 1 averaged about 144 suspected lane intrusions for the one-hour observation period. During the last Phase 1 observation in May 2023 the recorded number of suspected lane intrusions dropped to 125 in a one-hour period, about a 13% reduction from earlier observations. Despite this change an overall reduction in suspected lane intrusions was observed in Phase 2 after the orange contrast markings were installed.

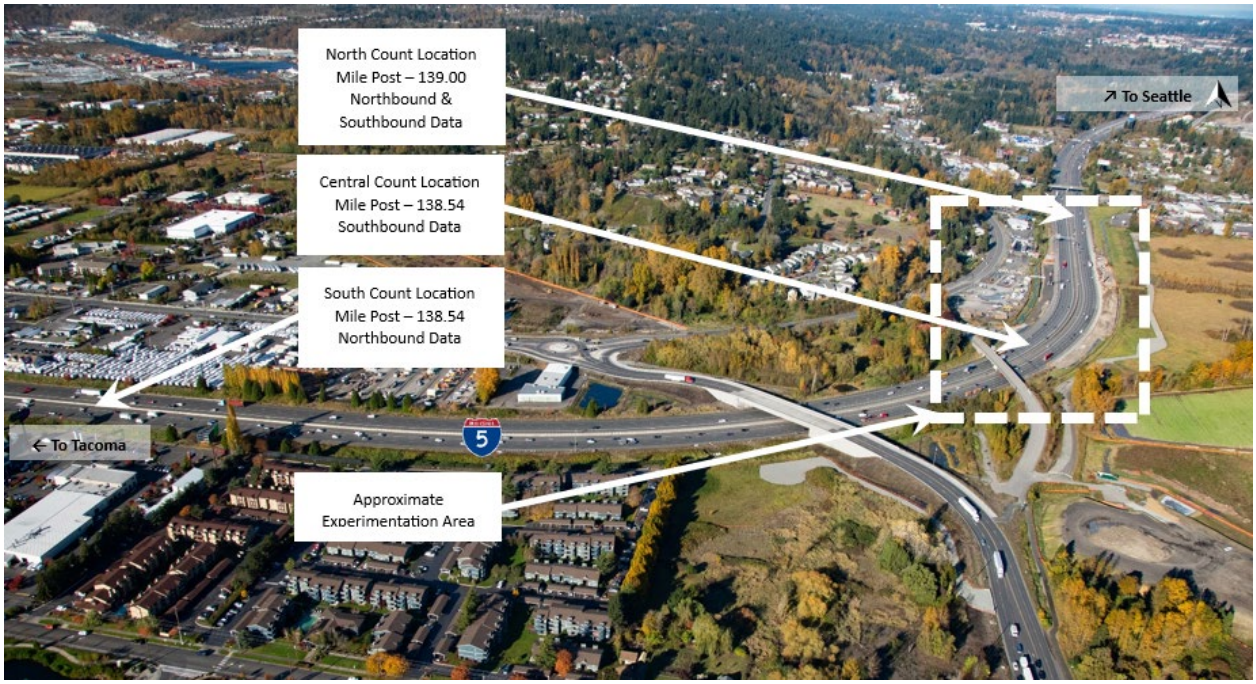
Despite these limitations, the impact of the orange markings of driver behavior appear to represent a positive change and correlate with the driver survey findings.

2.1.2.2 Vehicle Speeds

A speed analysis was completed at three locations within the work zone using three permanent traffic recording, or PTR, stations:

- **PTR @ MP 138.08 (traffic loops)**: Northbound only and about ¼ mile prior to the orange marking locations and roadway realignment but within 50-mph regulatory speed zone.
- **PTR @ MP 138.54 (side-fire radar)**: Southbound only. Within the middle of experimental orange marking locations and roadway realignment.
- **PTR @ MP 139.00 (traffic loops)**: Both directions. At northern limit of orange contrast marking locations, outside the roadway realignment, and ½ mile from northern limit of 50-mph zone.

Date range for speed analysis					
Phase	Direction of travel	Marking	Beginning	End	Duration (days)
1	Northbound	Conventional	2/14/23	6/8/23	114
2	Northbound	Contrast orange	6/8/23	9/30/23	114
1	Southbound	Conventional	2/28/23	6/8/23	100
2	Southbound	Contrast orange	6/8/23	9/16/23	100



The PTR speed data available was a 5-minute average in each lane. The intent of the speed analysis was to use free-flow speeds, 5-minute time periods with speeds less than 35 mph and

higher than 90 mph filtered during analysis. This filtered out the effects of reoccurring congestion or incidents that may impact the experiment area.

The speed data was aggregated along the 15th, 50th (median), 85th and 95th percentiles, along with a 10-mph pace speed for each day at each PTR. These values were calculated for each Pre-construction, Phase 0 (Pre-experiment), Phase 1 (conventional markings), and Phase 2 (contrast orange markings). See for table below for a summary of the speed analysis.

South count location	**I-5 northbound @ MP 138.08**					
Phase	Speed limit	15th percentile speed (mph)	Median speed (mph)	85th percentile speed (mph)	95th percentile speed (mph)	10 mph pace speed
Pre-construction	60	62.1	66.5	76.0	80.4	60.6 – 70.6
0 (Pre-experiment)	60	60.9	66.4	76.1	80.4	59.0 – 69.0
1 (Conventional)	50	60.9	66.4	73.2	77.1	60.8 – 70.8
2 (Contrast orange)	50	61.5	66.9	74.0	78.2	61.4 – 71.4

Central count location	**I-5 southbound @ MP 138.54 (Within S-curve reconfiguration)**					
Phase	Speed limit	15th percentile speed (mph)	Median speed (mph)	85th percentile speed (mph)	95th percentile speed (mph)	10 mph pace speed
Pre-construction	60	57.7	63.3	69.2	72.5	59.1 – 69.1
0 (Pre-experiment)	60	50.0	54.2	58.3	60.1	49.7 – 59.7
1 (Conventional)	50	52.3	57.2	61.2	64.2	52.3 – 62.3
2 (Contrast orange)	50	50.0	56.4	60.7	63.4	51.5 – 61.5

North count location	**I-5 northbound @ MP 139.00**					
Phase	Speed limit	15th percentile speed (mph)	Median speed (mph)	85th percentile speed (mph)	95th percentile speed (mph)	10 mph pace speed
Pre-construction	60	62.9	68.7	74.4	78.4	62.7 – 72.7
0 (Pre-experiment)	60	62.4	69.1	75.5	79.2	63.2 – 73.2
1 (Conventional)	50	60.9	66.9	72.9	76.8	61.8 – 71.8
2 (Contrast orange)	50	60.3	66.3	72.7	76.7	60.9 – 70.9

North count location	**I-5 southbound @ MP 139.00**					
Phase	Speed limit	15th percentile speed (mph)	Median speed (mph)	85th percentile speed (mph)	95th percentile speed (mph)	10 mph pace speed
Pre-construction	60	60.3	65.2	72.2	78.0	59.8 – 69.8
0 (Pre-experiment)	60	59.4	64.8	72.3	78.0	59.3 – 69.3
1 (Conventional)	50	54.8	61.3	68.3	72.5	56.1 – 66.1
2 (Contrast orange)	50	53.1	61.0	68.4	72.7	56.1 – 66.1

Significant speed reductions were observed at milepost 138.54 (central count location) for southbound traffic during the pre-construction Phase 0, compared to the pre-construction phase. The recorded 85th percentile speed decreased by over 15%, with similar reductions noted in other measured speeds. During Phase 0, preparations for Phase 1 (conventional markings) realignment included narrowing the shoulders and installing concrete barriers providing positive worker protection. Shoulders were narrowed from 10 feet to a minimum of 2 feet but varied throughout the work zone. These changes in road design, such as narrowing roadways and shoulders, likely contributed to the observed speed reductions. Therefore, it is probable that these recorded changes can be attributed to the roadway modifications including the s-curve alignment.

In Phase 1 of the experiment, which used conventional markings, the speed limit was reduced from 60 mph to 50 mph. Two permanent count recorders, unaffected by any changes to the roadway or geometry, noted a decrease in the 85th percentile speed by about 3.5% to 5.5% (2.5 mph to 4 mph) at the southern (MP 138.08) and northern (MP 139.00) locations. Similar reductions were seen in other recorded speeds. Speed feedback signs were placed on the shoulders for northbound traffic at the southern location (MP 138.08) and southbound traffic at the northern location (MP 139.00). Despite this modest reduction, observed speeds were still more than 18 mph over the posted 50 mph limit at these locations. Additionally, measured speeds for southbound traffic at the central count location (MP 138.54) increased between these two phases.

Orange contrast markings were not anticipated to influence traffic speeds, and the recorded speed data confirmed this, showing minimal change before and after their application between Phase 1 and Phase 2. The only exception was at the central count location at milepost 138.54, where southbound traffic speeds decreased by 0.8% to over 4%, depending on the metric. Comparing the speed measurements from Phase 1 and Phase 2 supports the expectation that the added contrast markings did not significantly affect driver speeds. This contrasts with the driver survey, where most respondents agreed that the orange markings prompted them to drive at a more reasonable speed.

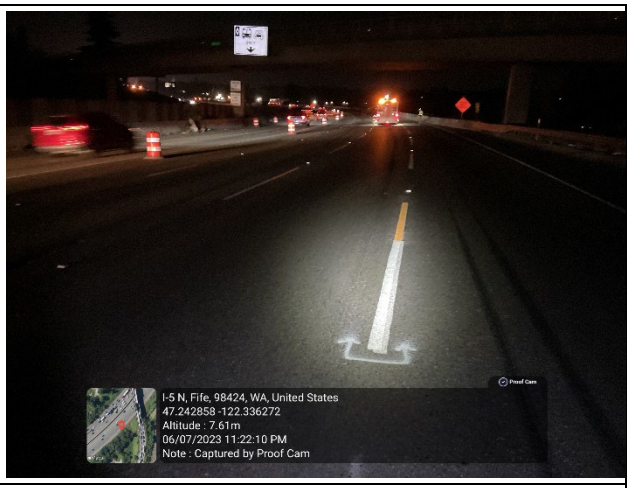
2.2 MATERIALS

2.2.1 Contrast Orange Marking Materials and Application

The work zone pavement markings for the experiment consisted of Sherwin Williams Hotline Fast Dry Latex Paint. Aerospace Material Specification Standard 595A for 22510 Orange was use for coloring match. The white lane lines were refreshed at the same time the orange markings were installed in June 2023. The installation included two coats of paint at 15 mils (microns) thickness, topped with AASHTO Type I reflective glass beads.

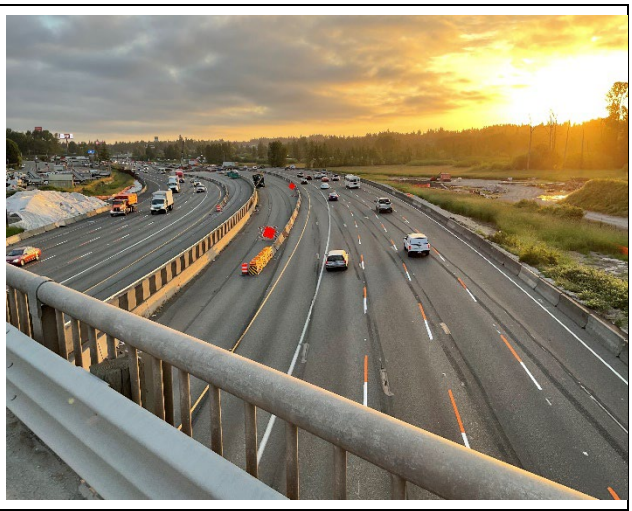
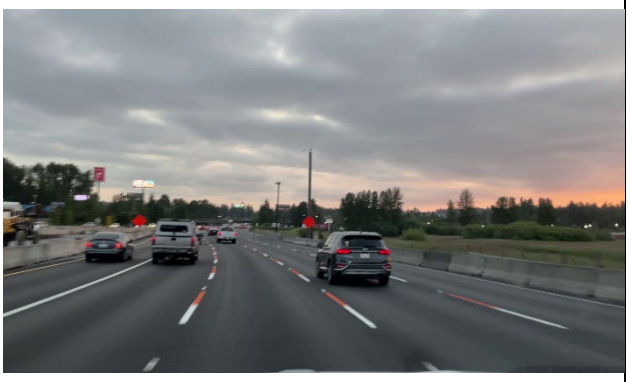
Pavement marking installation dates				
Date	Northbound conventional markings	Northbound orange contrast	Southbound conventional markings	Southbound orange contrast
2/14/2023	X	Not applicable	Not applicable	Not applicable
2/28/2023	Not applicable	Not applicable	X	Not applicable
6/7/2023	X	X	X	X

Sherwin Williams paint buckets



Northbound Interstate 5

Northbound Interstate 5 orange installation

	
Southbound I-5 view from 70th Ave. bridge	Northbound I-5 view from 70th Ave. bridge
	
Southbound I-5 dashboard view	Northbound I-5 dashboard view

2.2.2 Retroreflectivity Measurements

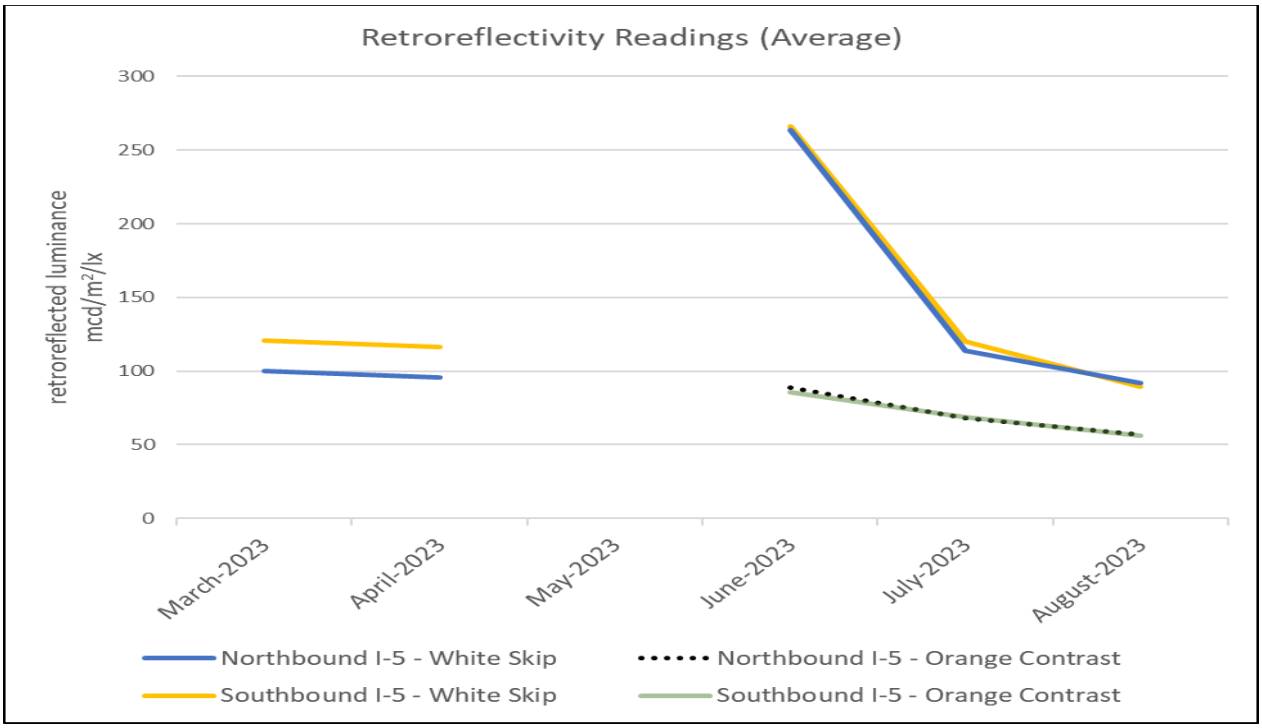
Measurements were performed by Specialized Pavement Marking (Portland, OR) with a portable reflectometer RoadVista Stripemaster (Model 70745), which collects the coefficient of retroreflected luminance, R_L. Retroreflectivity is important as it indicates how effective the markings are at reflecting light back to drivers. This is especially important during low light and hours of darkness. When retroreflectiveness reduces over time it can indicate the markings are becoming less effective.

R_L measurements were taken at night during temporary lane closures. The device has its own light source for nighttime measurements. The R_L measurements were taken at 10 separate reading locations in each direction and averaged to a single value for each collection date.

During Phase 1, measurements were conducted twice: once in March and once in April 2023. Following the installation of the orange markings in June 2023, three additional measurements were taken—one each in June, July, and August 2023.

For both directions, average measurements of the orange contrast marking were initially near 90 $mcd*m^2*lx^{-1}$ and dropping to the mid-50s $mcd*m^2*lx^{-1}$ after two months, seeing an average drop of 19% per month in retroreflective readings.

The white lane lines were refreshed on the same evening the contrast orange markings were installed. In both directions, the average retroreflectivity of the white lane markings was over 260 $mcd/m^2/lx$ in June, compared to 130 $mcd/m^2/lx$ in July, and around 90 $mcd/m^2/lx$ in August, two months later.



2.2.3 Observed Pavement Marking Performance

Durability:

Qualitative evaluations of the pavement markings were conducted through in-person drives, monthly aerial photographs and dashboard videos. Overall, the durability of the orange contrast markings was comparable to the white broken lane line markings from June to September 2023.

By the time the orange contrast enhancement was removed in January 2024, the wear was more pronounced for the orange markings compared to the white lane lines, especially in the southbound direction. The white lane line markings were initially installed in February 2023 and then refreshed in June 2023. This may have contributed to their greater durability compared to the orange contrast markings due to the increased paint thickness

Coloring or brightness:

The coloring was also observed qualitatively in the same manner as the durability.

Initially the orange pavement marking was both bright and appeared orange in color initially, but the brightness faded and the orange became darker as the lines aged.

2.2.3.1 Aerial View of Contrast Markings

Photo below from July 2023

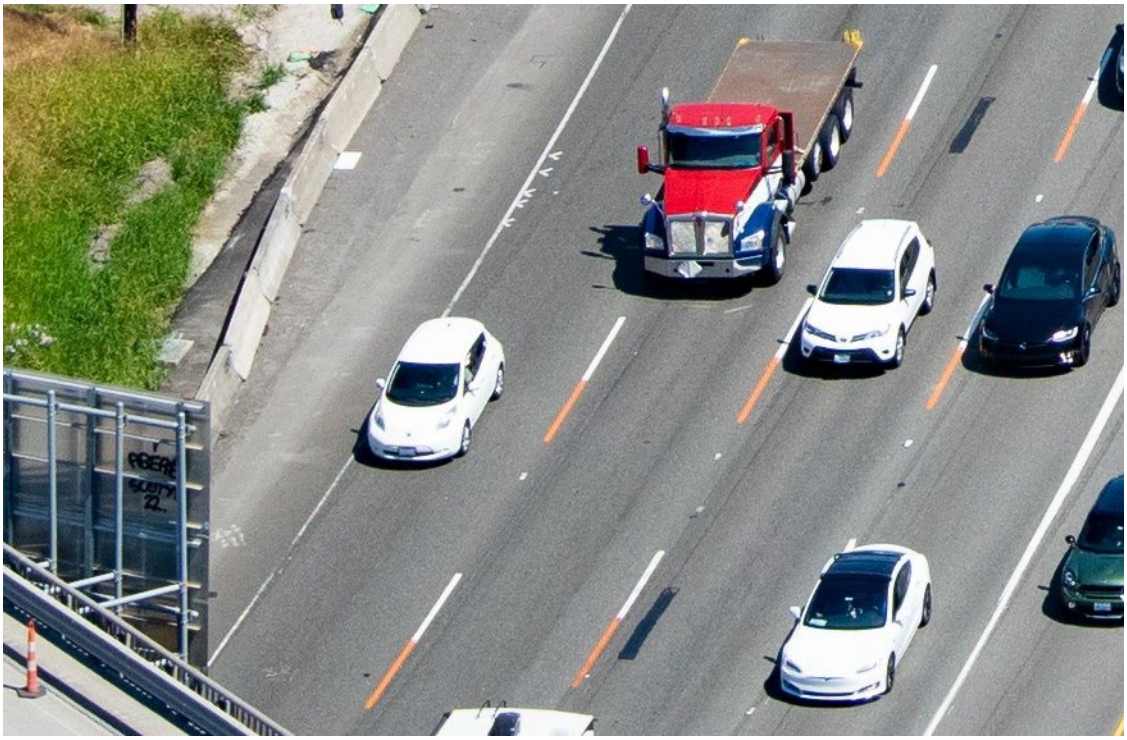


Photo below from September 2023

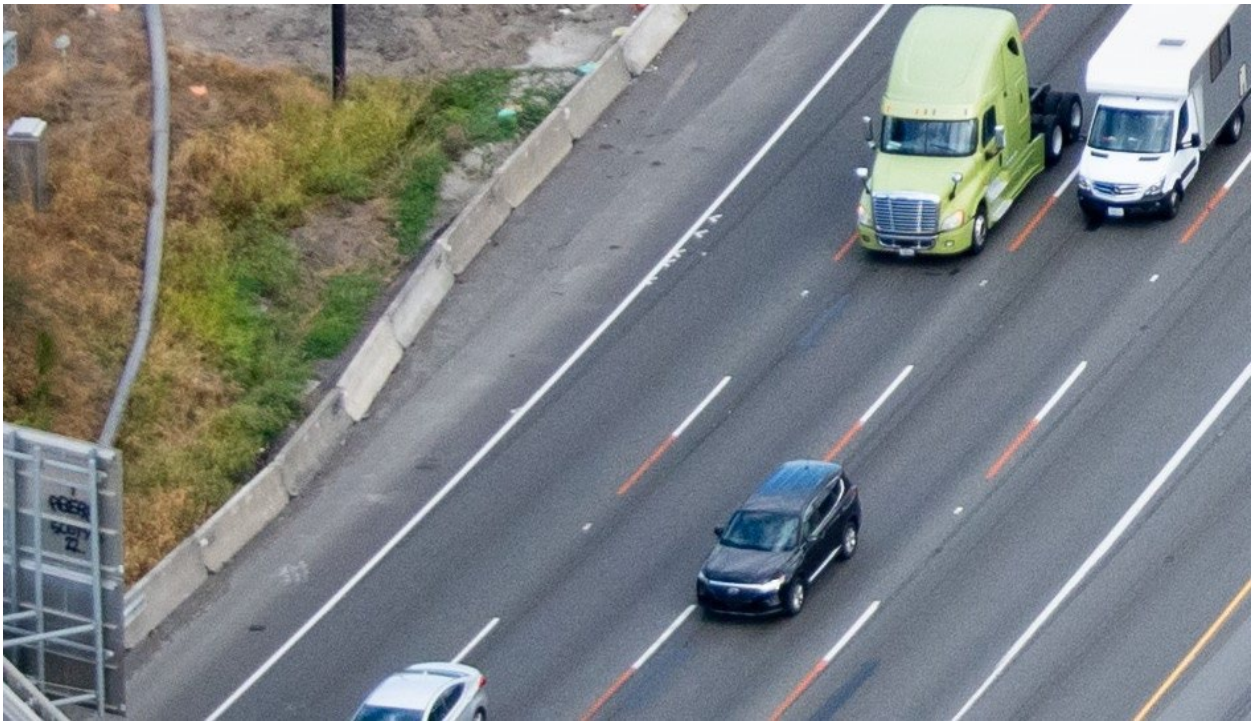


Photo below from October 2023

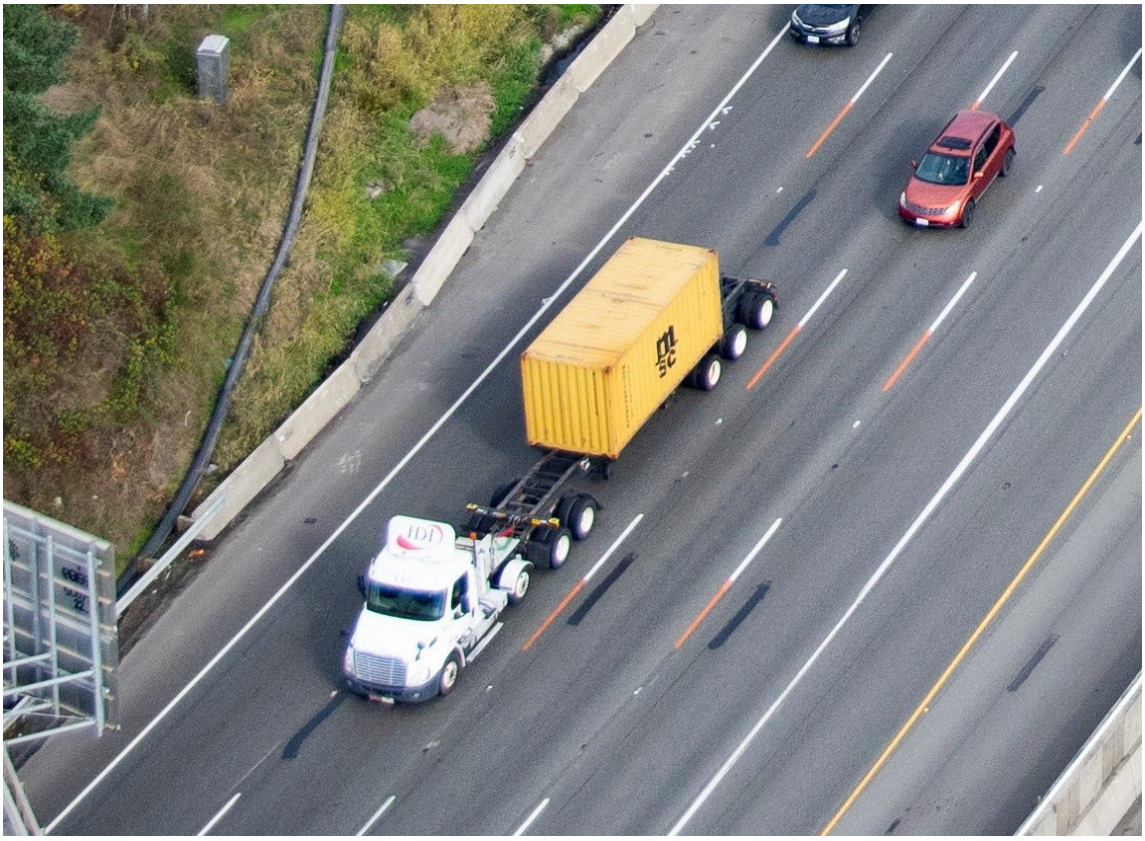


Photo below from November 2023

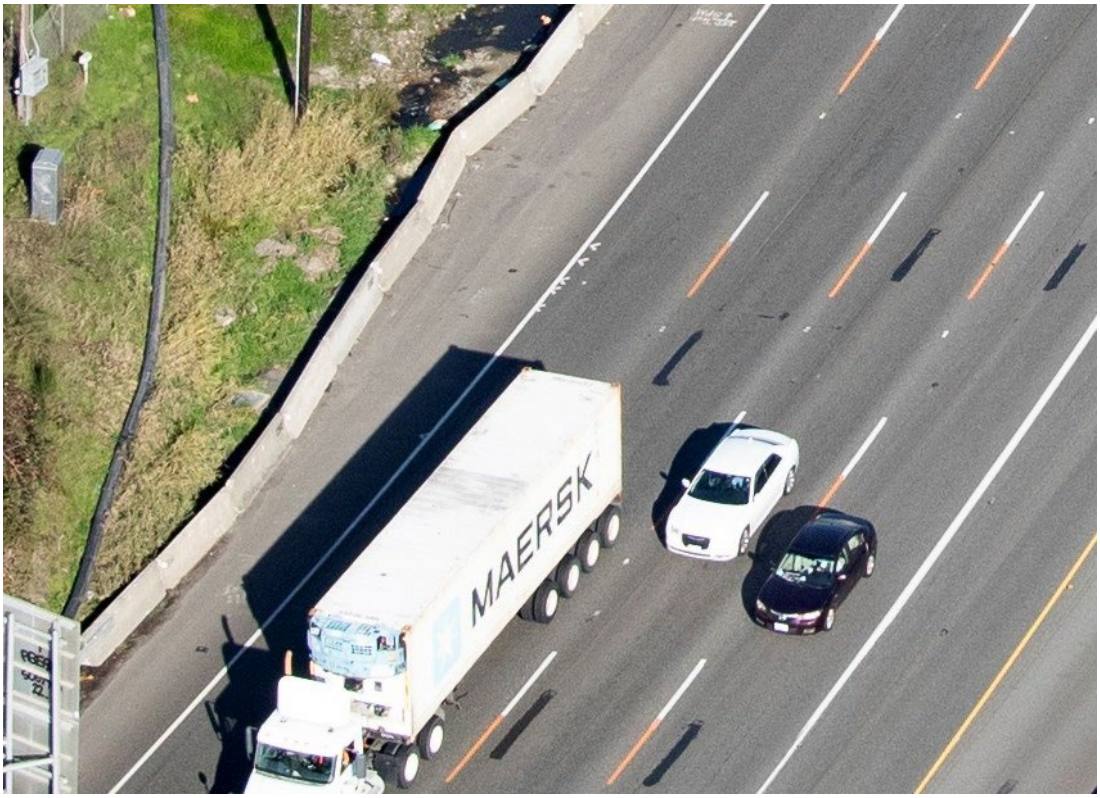


Photo below from December 2023

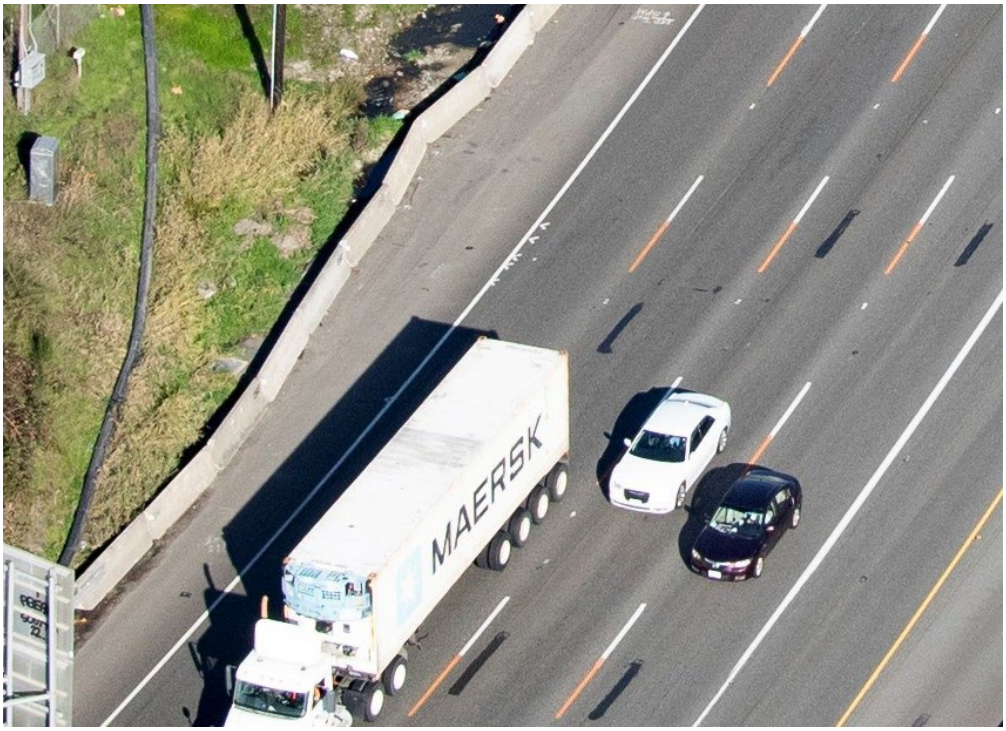
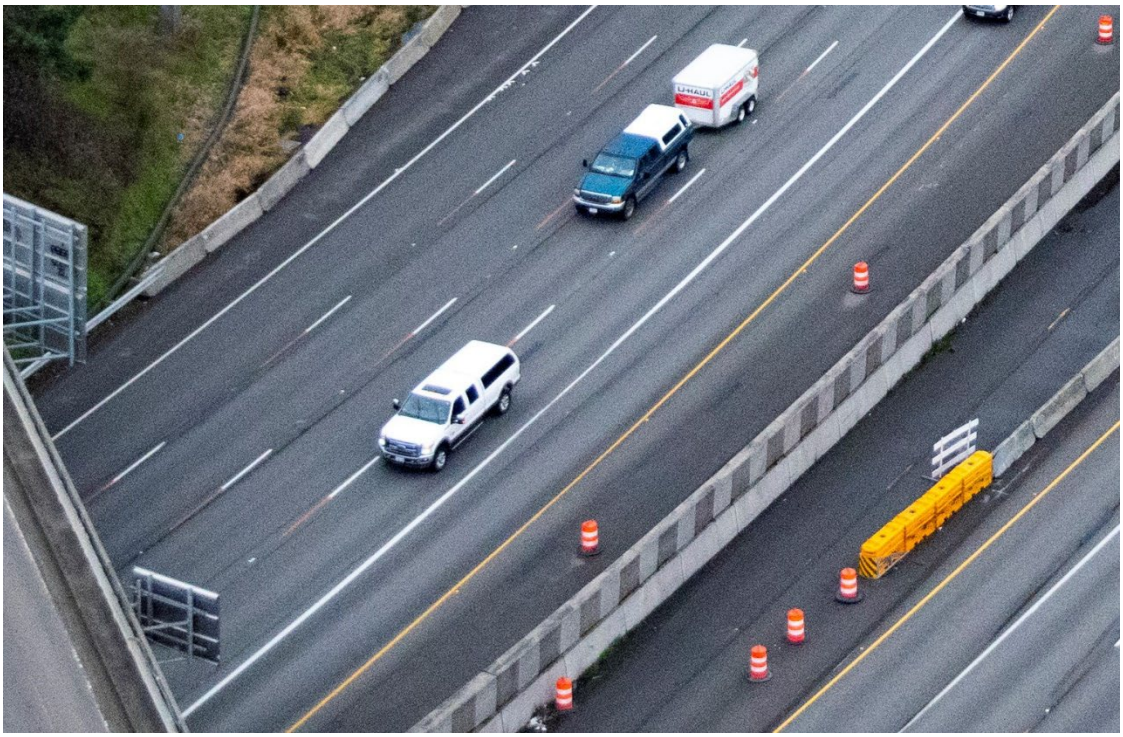


Photo below from January 2024

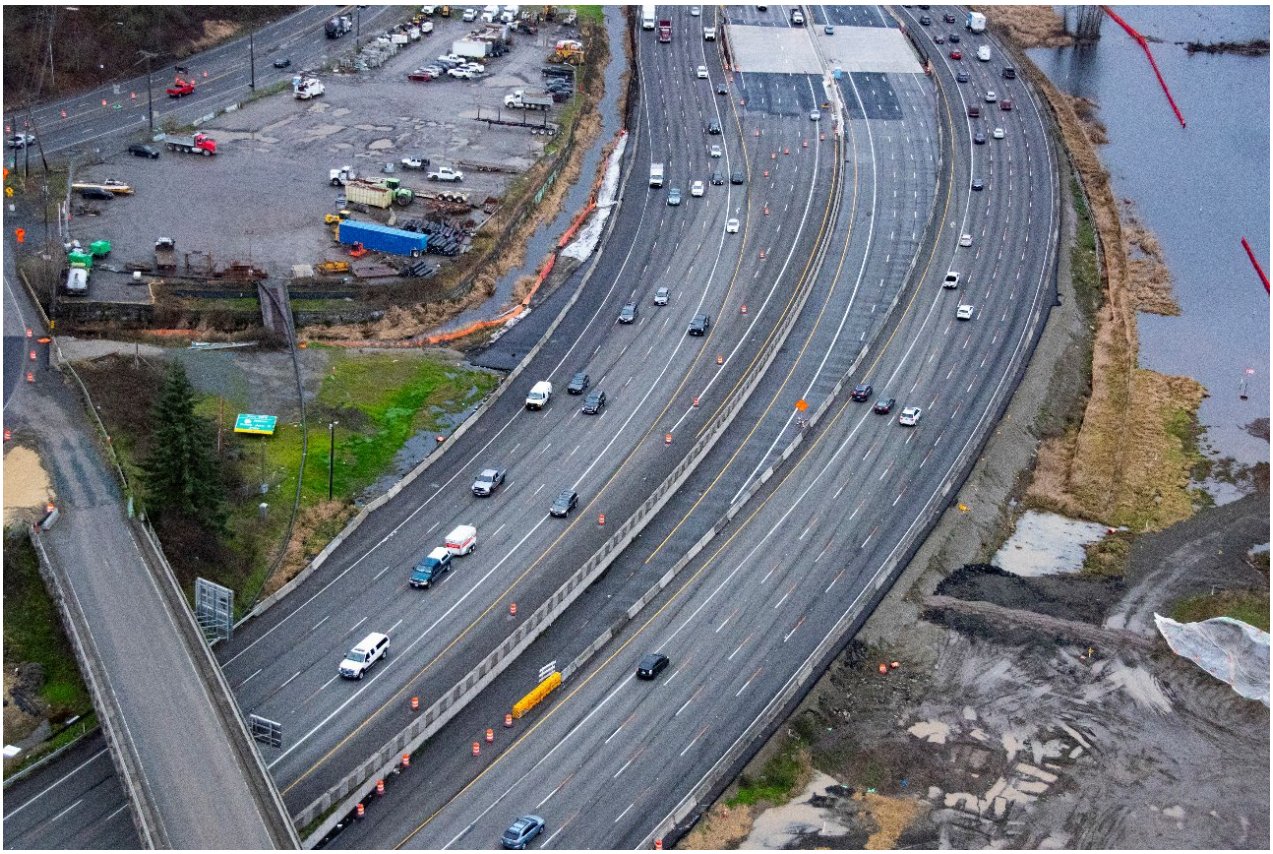


2.2.3.2 Overall work zone visual comparison

The next two photos provided a broader picture of the contrast markings within the work zone at two different time periods. The first photo is from July 2023 and was taken about a month after the orange markings were installed. The second photo is form January 2024 and was taken shortly before the orange markers were removed.

Photo below take July 2023

Photo below taken January 2024



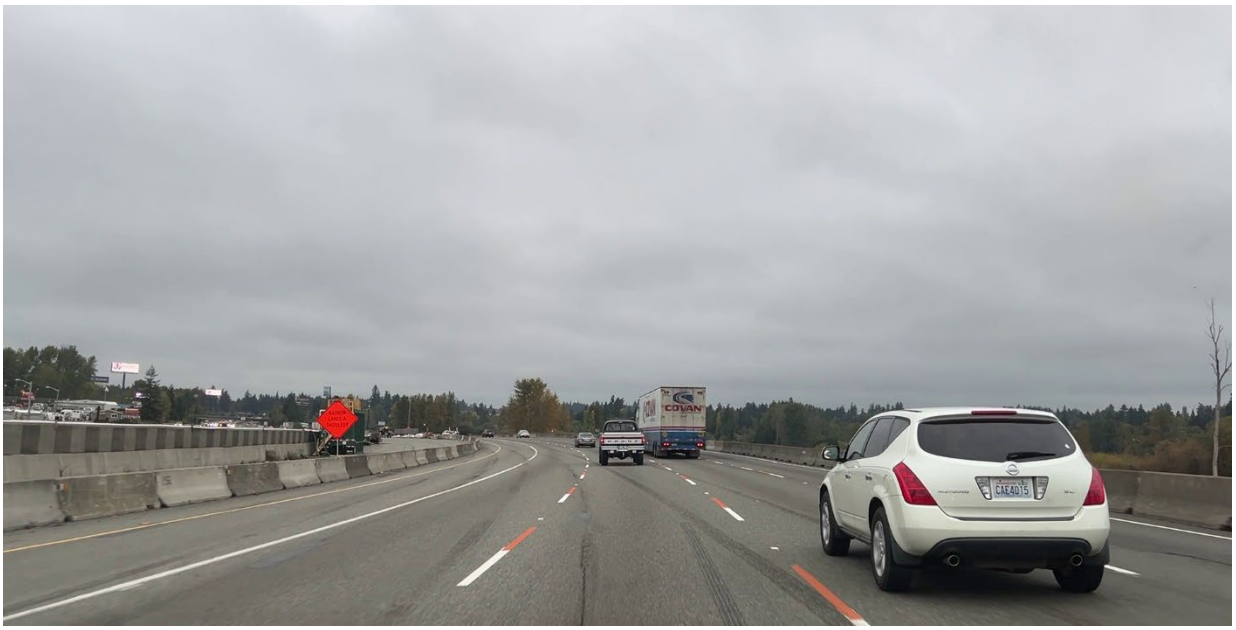
2.2.3.3 Dashboard View

Photo below taken on Jun. 8, 2023, northbound I-5

Photo below taken on Jun. 8, 2023, southbound I-5

Photo below taken Sept. 12, 2023, northbound I-5 HOV Lane

2Photo below taken Oct. 21, 2023, northbound I-5



2.3 Safety Information

Collision and non-reported incident data (temporary sign or channelizing devices impacts) was collected within the orange contrast markings limits from MP 138.37 to MP 139.04.

Date range for collison data					
Phase	Direction of travel	Marking	Beginning	End	Duration (days)
1	Northbound	Conventional	2/14/23	6/8/23	114
2	Northbound	Contrast orange	6/8/23	9/30/23	114
1	Southbound	Conventional	2/28/23	6/8/23	100
2	Southbound	Contrast orange	6/8/23	9/16/23	100

2.3.1 Traffic Volumes

Average daily traffic volumes were collected at the MP 139.00 permanent traffic recorder:

Northbound I-5 average daily traffic volumes							
Marking type	**Sun**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
Conventional	92,204	99,571	99,495	104,989	106,476	110,493	102,314
Contrast orange	102,857	106,427	106,851	109,740	113,345	117,269	108,088

Southbound I-5 average daily traffic volumes							
Marking type	**Sun**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
Conventional	97,493	106,489	110,219	113,589	115,721	120,794	113,615
Contrast orange	107,376	113,949	113,408	119,411	120,558	126,035	120,030

2.3.2 Reported Crashes

Collisions are crashes reported by Washington State Patrol within the orange contrast markings limits (MP 138.37-139.04). Collisions were totaled separately during the Phase 1 and Phase 2 time periods. They were compared to baseline averages taken from 2015 to 2019 at the corresponding locations for the same days of the year.

The higher historical (baseline) reported crashes for southbound I-5 are likely a result of significant daily congestion occurring in that location during the 2015-2019 period (60% of crashes were rear-end collisions). This congestion was reduced after the completion of an improvement project on I-5.

An important observation was the decrease in reported collisions after the orange contrast markings were added (25 to 16 total) even though the historical average increases (18 to 27.6 total) during the same calendar timeline.

Total WSP-reported collisions (total crashes)				
	Phase 1 (Conventional)		Phase 2 (Orange contrast)	
Direction of travel	Experiment	Baseline	Experiment	Baseline
Northbound	17	4.4	11	6
Southbound	8	13.6	5	21.6
Total	25	18	16	27.6

The collision data used was only those reported by Washington State Patrol to be within the milepost range of the experiment. Locational information on collision reports may not always be precise as mile posting and geospatial coordinates are often estimated using references (e.g., Wapato Way overpass) or other methods to determine the approximate location.

The experiment itself did not control for improved driver familiarity over time. A significant portion of daily users in this section of I-5 are anticipated to be commuters. Because the geometric configuration of the study area did not change between Phases 1 and 2, it is likely that driver familiarity improved over the duration of the control period. Therefore, it is likely that some of the reduced number of crashes can be attributed to driver familiarity rather than the paint.

Data collection spanned approximately six months. While longer evaluation periods are typically used for crash data analysis, the experiment area experienced an average of 220,000 vehicles per day, totaling over 47 million vehicles during this timeframe. Despite the short duration, the high vehicle count provided significant exposure, strengthening confidence in the safety data results

2.3.2.1 Fatalities and Injuries

There were no reported fatalities or suspected serious injury crashes in Phase 1 or Phase 2 of the experiment. Phase 1 and Phase 2 both had one suspected minor injury crash and four possible injury crashes reported. While Phase 1 experienced similar trends as the historical five-year average, Phase 2 of the experiment saw a small reduction in reported possible injury crashes.

Phase 1 – Conventional (crashes)						
	Experiment			Baseline		
Direction of travel	Fatal & suspected serious	Suspected minor injury	Possible injury	Fatal & suspected serious	Suspected minor injury	Possible injury
Northbound	0	1	2	0	0.2	1
Southbound	0	0	2	0.2	0.6	2.8
Total	0	1	4	0.2	0.8	3.8

Phase 2 – Orange contrast (crashes)						
	Experiment			Baseline		
Direction of travel	Fatal & suspected serious	Suspected minor injury	Possible injury	Fatal & suspected serious	Suspected minor Injury	Possible injury
Northbound	0	1	2	0	0	2.2
Southbound	0	0	2	0	.4	3.6
Total	0	1	4	0	0.4	5.8

2.3.2.2 Vehicles Involved in Collisions

The most significant change during this experiment came from the number of vehicles involved in reported collisions. After the orange pavement markings were implemented in Phase 2, there was a 48% reduction in collisions compared to Phase 1 while the historical (baseline) average typically increases 50%. This notable as the reduction is greater than the overall crash reduction and is a striking departure from historical trends on this portion of Interstate 5.

Vehicles involved in collisions		
Phase	No. vehicles	Historical average
1 - Conventional	66	40
2 - Orange contrast	34	61
Total	100	101

The number of vehicles involved in reported collisions reduced by almost 50% after orange contrast markings were installed.

2.3.3 Non-Reported Incidents

Non-reported incidents are those that did not lead to a documented collision report. These usually involved temporary signs or channelizing devices being knocked over and were recorded by the project office in daily inspector reports. Such incidents were generally linked to work conducted within the travel lanes of Interstate 5. This type of work often necessitates lane closures, reducing the number of lanes available for general traffic. Lane reductions are accompanied by of signage, channelization devices, and other equipment such as arrow boards and vehicle-mounted attenuators

Total non-reported incidents		
Direction of travel	Phase 1	Phase 2
Northbound	12	2
Southbound	3	4
Total	15	6

A 60% drop (from 15 to 6) in non-reported incidents was recorded between conventional pavement markings (Phase 1) and orange contrast markings (Phase 2) of the experiment. However, the project office noted there were more frequent nightly lane closures in Phase 1 versus Phase 2, which, along with longer days and better weather, may contribute to this difference.

The unreported incident data provided by the project team included incidents within and near the experiment limits but still within the larger work zone area. The information from the project team was reviewed and those that appeared to fall outside the experiment limits or were likely a reported crash were removed. About 80% of the data does not have precise locational information such as mileposts or geospatial coordinates. These uncertainties aside there was still a notable drop in unreported incidents.

3.0 CONCLUSIONS

Highlights

Experiment started in February 2023 and the orange markings were removed in January 2024.

A survey of the drivers who saw the orange contrast markings found 85% agreed it increased their awareness while 70% agreed it made it easier to stay in their lane.

A 25% percent reduction of suspected vehicles intruding into other lanes was observed

Negligible differences in vehicle speeds were observed

Total number of reported crashes fell 36%

The total number of vehicles reported being involved in collisions dropped almost 50%.

The study had certain limitations, such as a low number of reported crashes, a small survey response, and poor video quality, which hindered the ability to draw definitive conclusions about orange

The use of lagging orange contrast supplemental markings was anticipated to increase driver awareness and safety within work zones as it complements the color of existing work zone features such as construction signs and channelizing devices. The additional delineation was intended to reduce driver confusion during multiple staged traffic reconfigurations where shifted alignments leave behind ghost lines. These goals were tested by examining driver behavior, material performance, and safety information.

The driver survey elicited over 900 responses. From the group exposed to the orange markings (445 responses), over 80% noticed the orange markings. Of those who noticed the orange markings (345 responses), 85% agreed it increased their awareness of the work zone, 70% agreed it made it easier to stay in their lane, and 65% agreed it made them drive slower or more reasonably in the work zone. Additionally, more than 86% of those who saw the lagging orange contrast markings at night preferred it to only the conventional broken white lane markings.

Speeds were measured at three locations over ¾ mile on I-5 in the vicinity of the experimental striping. Speeds were not expected to change given that additional linear markings are not generally considered a traffic calming tool. The speed analysis demonstrated there was negligible change before or after the application of the orange contrast markings.

Based upon a qualitative review, the orange contrast markings appeared to be durable during the three months but did show considerable wear after six months. Given the traffic volumes, roadway geometry, and 11-foot lanes this was expected as motorists drive on the markings more frequently.

Reported collisions fell 36% (25 to 16) after orange contrast markings were installed.

Despite limitations to the methodology discussed previously, no adverse effects of the orange contrast markings were observed. The experimental lagging orange pavement markings are considered successful based on the following information:

- Positive public reception: Driver survey indicates the public understands the new marking application and would like to see it used more.
- Improved safety: The before and after review suggests improved safety performance and did not cause any adverse conditions.
- Durable application: The orange contrast markings met expectations based upon qualitative observation during the experimentation period.

"Hi, I love the orange and white highly visible lines down by Fife. I drove from Hood Canal to Whidbey this Sunday. The Fife lines made it very clear when the lanes are. The old seams, paint, rerouting, poor lighting, etc. can make it difficult to tell exactly where the new lane delineations are, especially with low sun in your eyes or rain. By contrast the construction zone north of Everett is much more difficult to see where the actual lanes move around because of the construction. Clear lane marking makes a huge contribution to safe driving!"

Susan Wagner, MPH
Island County Public Health Department

4.0 RECOMMENDATION

Based on these experimental findings, WSDOT should consider requesting continued interim approval from the Federal Highway Administration for the use of lagging orange contrast markings on broken lane lines. If interim approval is granted, WSDOT would then develop policies and guidelines on when and how this strategy could be applied to construction projects

5.0 REFERENCES

Brown, H., & Praveen, E. (2021). *NCHRP Synthesis 574 - Temporary Pavement Markings Placement and Removal Practices in Work Zones.* Transportation Research Board, National Cooperative Highway Research Program;. Washington DC: National Academies of Sciences, Engineering, and Medicine. Retrieved from https://nap.nationalacademies.org/catalog/26358/temporary-pavement-markings-placement-and-removal-practices-in-work-zones

Shaw J, C. M. (2017). Special-Color Pavement Markings for Highway Work Zones: Literature Review of International Practices. *Transportation Research Record, Transportation Research Board of the National Academies*, 78-86.

APPENDIX A

Orange striping pilot survey

January 2024

Prepared by:
Washington State Department of Transportation
Puget Sound Gateway Program

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Introduction

The orange striping pilot project, administered by the Washington State Department of Transportation, evaluates the effectiveness of using orange contrast lane striping to alert drivers to the presence of a construction work zone and to influence driving behaviors. This multimethod research study was conducted from May to August 2023 on a portion of Interstate 5 in Washington State that runs through the city of Fife at what is known as the “Fife curve.” Orange contrast striping was installed on both northbound and southbound lanes of a 1.5-mile section of I-5 that traveled around an active construction work zone of the SR 167, I-5 to SR 509 – New Expressway project.

This report summarizes the findings of a limited pre/post survey conducted as part of the larger orange striping pilot project. By collecting self-reported data using a standardized survey, the study team sought to better understand the perceptions, attitudes, and reported behaviors of area drivers both in the absence and presence of orange contrast striping. The survey allowed respondents to express their opinions of orange striping in the work zone and to self-report the perceived impact of orange striping on their driving behavior. This self-reported data proved particularly useful for capturing subjective measures such as awareness and perception (e.g., whether drivers recognized they were in a work zone), which can be useful for elaborating on and providing context to observed data collected by other means (e.g., number of crashes, average vehicle speed) as part of the larger study.

Approach and methods

Purpose and objectives

The Washington State Department of Transportation continues to observe traffic crashes and fatalities in work zones. As part of a pilot project studying the impact of adding orange contrast striping to roadways that pass through work zones, WSDOT conducted a community survey. This survey collected data on travel behaviors within work zones and gathered insights into public awareness and attitudes toward orange contrast striping.

The survey was designed to collect data offering insights into drivers' perceptions and experiences while navigating through a work zone with orange contrast striping. Specifically, the data gathered aimed to provide insight into whether the use of orange contrast striping in construction work zones benefits drivers and enhances worker safety by:

- Increasing work zone awareness
- Reducing work zone incidents or intrusions
- Maintaining work zone speed and reducing speed variability
- Improving lane discipline and driver behavior

Recruitment and fielding

To minimize any potential influence on responses and results, the project team used similar recruitment and fielding techniques for both phases of this study. Both surveys were open for approximately four weeks. Recruitment involved distributing post-cards to households in the project area and conducting outreach through social media, specifically on WSDOT's Facebook and X (Twitter) accounts. The surveys were accessible in five languages: English, Korean, Russian, Spanish and Vietnamese.

Geography	Pre-survey postcards	Post-survey postcards	Total
Within 2 mi. of project area	4,820	4,699	9,519
2-5 mi. of project area	5,216	5,312	10,528
Total	**10,036**	**10,011**	**20,047**

WSDOT conducted the pre-striping survey from May 1 to May 28, 2023. Pre-striping survey invitation postcards were mailed to 10,036 households within the project area. The post-striping survey was conducted from July 10 to Aug. 4, 2023. Post-striping survey invitation postcards were mailed to 10,011 households within the project area.

Segmentation and analysis

In total, 909 valid survey responses were received. The project team categorized responses into different research segments to meaningfully examine the differences between respondent groups.

The first level of segmentation divided all responses into two groups: a control group and an exposure group. The control group consisted of all respondents who were not exposed to orange striping. This group of 464 includes all respondents who took the pre-striping survey, as well as any post-striping survey respondents who indicated that the most recent time they drove through the project area was prior to the orange striping pilot period. The exposure group consisted of 445 respondents, all of whom completed the post-striping survey and indicated that they most recently drove through the project area during the period when the orange striping pilot was occurring.

Two additional levels of segmentation included the creation of a treatment group and segmentation of daytime and nighttime drivers. The treatment group is a subset of the exposure group, consisting of 345 respondents who indicated that they noticed orange striping when they drove through the project area. Finally, the treatment group was segmented by daytime and nighttime drivers to understand how drivers perceived orange striping in those separate conditions.

Following this segmentation, the project team compiled a topline report to display the initial results. The project team conducted further analysis using correlation and chi-square tests to determine the relationship between respondent characteristics (such as age, gender, driving frequency, etc.) and their survey responses (e.g., “Did the orange contrast striping increase your awareness of being in a construction work zone?”). To meet the standard for statistical significance, estimates must have a 0.05 significance level (a 95% confidence level). Correlations must have a coefficient above 0.15 or below -0.15. Unlike correlations, chi-square tests do not utilize coefficients. All statistically significant findings, indicating relationships unlikely to be due to random chance, are listed in Appendix B.

Survey respondents

Across both fielding periods, the survey instrument collected a total of 1,001 responses. Out of these, 92 responses were excluded through two filtering methods:

- The survey instrument automatically disqualified 43 responses for indicating that respondents had not driven on I-5 near the Fife curve in over a year.
- The project team manually excluded 49 responses for reasons such as incomplete or insufficient responses, duplicate entries, unreasonably rapid completion times or other clear indications of invalid responses.

Following this data cleaning process the pre-striping survey had a total of 414 valid responses - 412 in English, and one each in Spanish and Russian. There were 496 responses to the post-striping survey - 492 in English, two in Korean and one in Russian.

Respondents were able to select multiple options for demographic questions regarding racial identity and gender identity, resulting in some categories that total to more than 100 percent.

Control group respondents

The control group, consisting of 464 responses, included all 414 pre-survey responses and an additional 50 post-survey respondents who indicated that their most recent drive through the project area was before orange striping had been applied to the roadway. Among these respondents:

- Approximately 46 percent identified as male, while 37 percent identified as female. Over 2 percent identified as other genders, and 14.7 percent did not respond.
- Nearly 74 percent of respondents identified as White; 5.8 percent identified as Asian or Asian American; 5.2 percent identified as Hispanic or Latina/o/x; 2.8 percent identified as Black or African American; and 2.2 percent identified as American Indian or Alaska Native.
    - The total proportion of BIPOC respondents (that is, respondents identifying as race(s) other than White) was 13.9 percent.
- Almost 10 percent of respondents reported 2022 household incomes below $50,000, and 20.3 percent earned over $150,000. Just under 27 percent of respondents didn't respond or didn't know their 2022 income.
- Less than 5 percent of control group respondents were younger than 25; nearly a quarter (24 percent) were 35-44; and 13 percent were 65 or older (12.3 percent didn't respond).

Exposure group respondents

The exposure group, consisting of 445 responses, included all post-survey respondents who indicated that their most recent trip through the project area coincided with the orange striping pilot period. Among these respondents:

- Nearly 43 percent identified as male and 39 percent identified as female Just over 1 percent identified as other genders, and 17 percent did not respond.
- More than 68 percent of respondents identified as White; 4.7 percent identified as Asian or Asian American; 3.8 percent identified as Hispanic or Latina/o/x; 3.4 percent identified as Black or African American; 2.5 percent identified as other race(s) not listed here; and 2.2 percent identified as American Indian or Alaska Native.
    - The total number of BIPOC respondents identifying a race other than White was 14.9 percent.
- Over 8 percent of respondents reported 2022 household incomes below $50,000, and 21 percent earned over $150,000, while 27 percent didn't respond or didn't know their 2022 income.
- Nearly 2 percent of exposure group respondents were younger than 25; 18 percent were 35-44; another 18 percent were 55-64; and 13 percent were 65 or older (14.4 percent didn't respond).

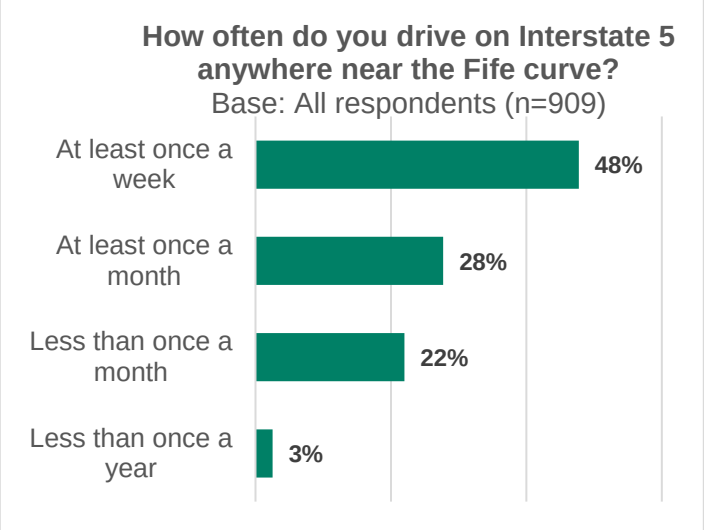
Findings

Travel behaviors

The survey asked respondents about their travel behaviors to understand the profile of the typical survey respondent, put context to respondents' awareness and perceptions of the Fife curve area construction zone, and to ensure that a relatively comparable sample was being heard from in both survey fielding periods. Respondents of both surveys, across all segmentation groups, answered questions about their driving frequency in the area, the recency of their travel through it during both day and night, the timing (day or night) of their most recent trip and their awareness of the construction work zone in the area. Additionally, this section of the survey featured a map highlighting the specific area, ensuring that respondents were correctly oriented to the segment of I-5 in question.

Frequency

The majority of all respondents in both the exposure group (76 percent) and the control group (75 percent) indicated that they drive on I-5 near the Fife curve at least once a month. Among these regular drivers, a slightly higher percentage in the control group (50 percent) reported driving near the Fife curve at least once a week, compared to 45 percent in the exposure group. Less than 3 percent of respondents said they drove near the Fife curve less than once a year.



Recent trips

The survey asked about the respondents' most recent trips on I-5 near the Fife curve, both during the day and at night. Over 90 percent of respondents reported that their most recent daytime trip had been within the past month. Within this group, 71 percent of respondents in the exposure group indicated they had driven near the Fife curve in the past week, while 62 percent of control group respondents reported the same.

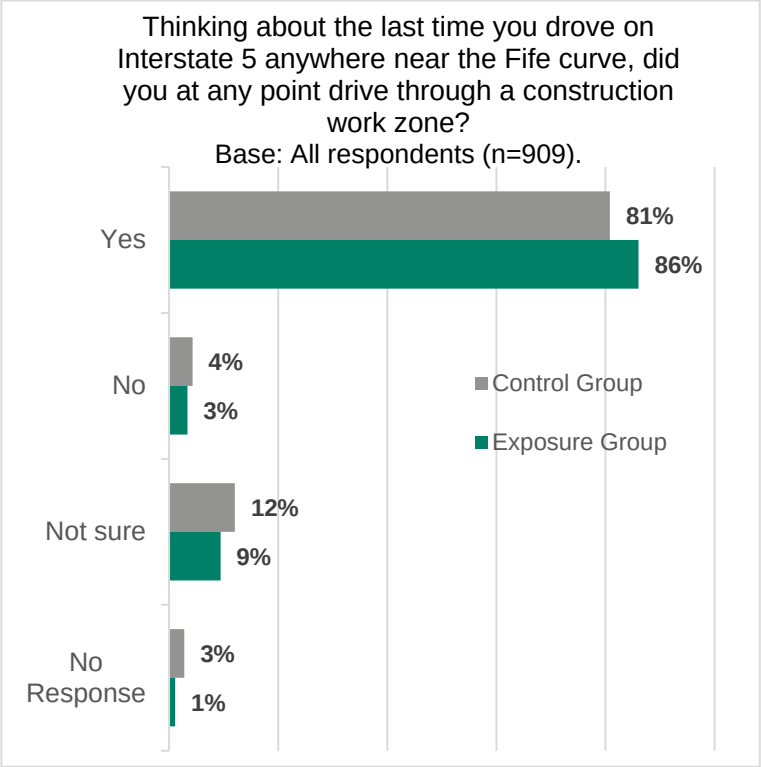
A smaller proportion reported recent nighttime trips, with 57 percent stating they had done so within the past month and nearly 14 percent indicating they had not taken such a trip in at least a year. These figures were similar across segments: 35 percent of control group and 33 percent of exposure group respondents reported a nighttime trip within the past week.

Respondents were also asked whether their most recent trip had been during the day or at night, and 81 percent of total respondents indicated that their most recent trip was during the day. A slightly higher percentage of control group respondents (17 percent) indicated that their most recent trip had been at night, compared to 14 percent of those in the exposure group. Notably, all subsequent questions asked respondents to answer based on their experience

during their most recent trip, so this question was used to segment respondents' later answers based on whether they were assessing a daytime or nighttime trip.

Construction zone awareness

When asked whether they drove through a construction work zone at any point during their most recent trip, 86 percent of exposure group respondents indicated that they had, compared to 81 percent of control group respondents. A similar percentage of exposure group respondents (3 percent) as control group respondents (4 percent) said they had not driven through a work zone, while 9 percent of those exposed and 12 percent of control group drivers said they were not sure.

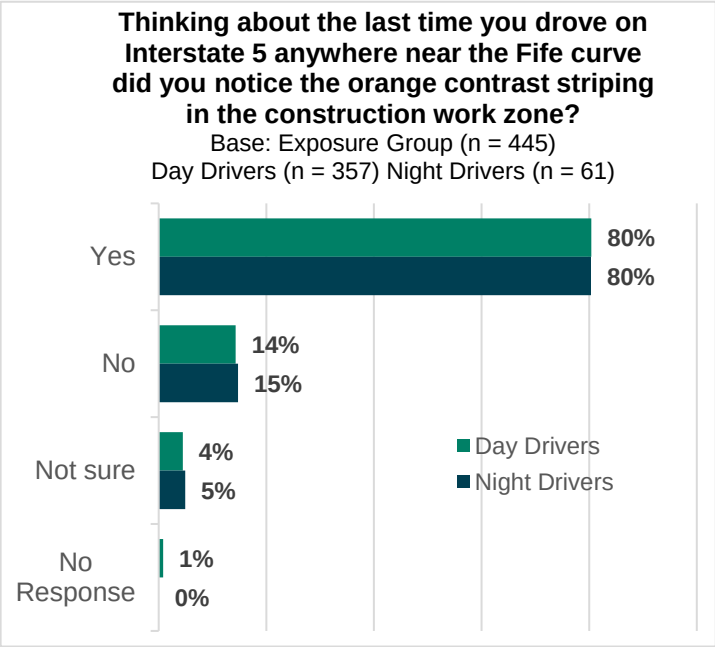


Orange striping

The second portion of the post-striping survey included questions specifically about the orange contrast striping. The questions covered a range of topics including whether respondents had noticed the striping, its impact on their awareness of being in a construction work zone and the effect it had on their driving behavior in terms of speed, lane keeping and overall awareness. Respondents were also asked about their perception of the orange striping at night and whether they would support its increased use. Reporting on these questions is primarily focused on the responses from the exposure group, consisting of those who drove through the project area while the striping was in place.

Noticing orange striping

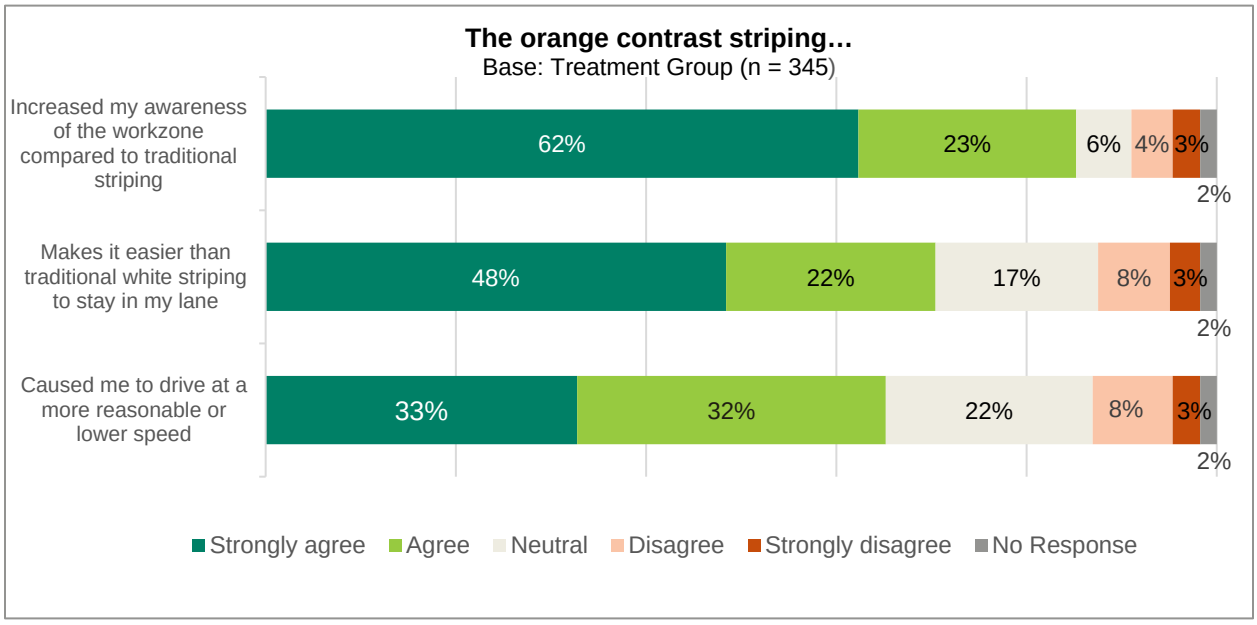
Among all respondents who completed the post-striping survey, only 20 percent indicated that they had prior knowledge of the orange striping pilot before driving through the work zone. Nevertheless, 78 percent of exposure group respondents noticed the orange striping while driving through the construction area. This observation was consistent among both day and night drivers, with equal percentages from each group acknowledging they had seen the striping.



Orange striping impact

Within the treatment group, 84 percent of drivers reported that the orange striping heightened their awareness of being in a work zone. Furthermore, when asked to what extent they agreed with the statement, “Orange contrast markings increased my awareness compared to traditional white stripes,” a notable 62 percent of respondents strongly agreed. An additional 23 percent agreed, while only 7 percent disagreed or strongly disagreed.

Respondents reported their perceptions of how orange striping influenced their lane keeping and speed, as detailed in the table below. More than 70 percent of respondents either agreed or strongly agreed that with the statement, “The orange striping makes it easier than traditional white striping to stay in my lane.” Given the statement, “The orange striping caused me to drive at a lower or more reasonable speed,” 65 percent agreed or strongly agreed.

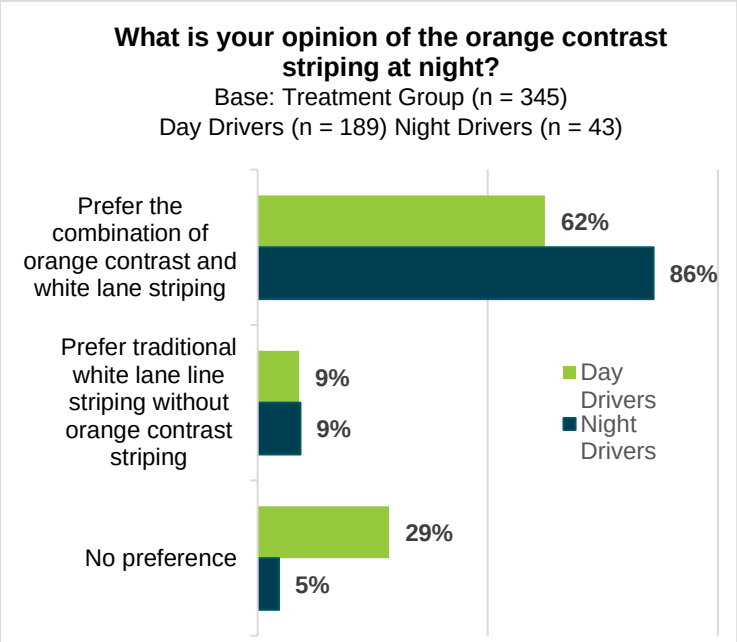


Orange striping opinions

Nearly 87 percent of drivers who noticed the orange striping said they want to see orange striping used in more road construction zones. When asked to provide their thoughts on the striping in an open-ended question, many drivers who wanted to see orange striping used more often noted that orange striping highlights changes in lane markings and traffic patterns intuitively, with some adding that they naturally associated the orange with construction and caution. Other drivers who favored the striping overall noted that orange striping on the roadway is easier to see, harder to miss, and less distracting than roadside signs. Drivers who did not want to see more orange striping worried about the additional cost of implementation or thought that orange striping would not change the behavior of other drivers.

Orange striping at night

Finally, drivers in the treatment group were asked about their opinions of the orange striping at night. The majority of these drivers preferred the orange striping over traditional white striping. Notably, those who had observed it at night expressed a much stronger preference (86 percent) for a combination of orange striping. Only a small fraction, 9 percent of respondents, indicated a preference for traditional white striping during nighttime. Among these, some drivers mentioned that they found the orange striping more challenging to see or distracting at night.



Conclusion

Overall, respondents who saw orange striping felt positively about the impact it had on safety, visibility and awareness in work zones, and wanted to see it used more often. Over 80 percent of drivers who passed through the work zone noticed the orange striping and 85 percent of those agreed that it increased their awareness; 70 percent agreed it made it easier to stay in their lane, and 65 percent agreed it made them drive slower or more reasonably. Additionally, more than 86 percent of those who saw orange striping at night preferred it to traditional white lane striping.

In total, 87 percent of all respondents wanted to see orange striping used more in work zones. This is a greater percentage than those who agreed with any of the individual attributes they were asked about. These results suggest that while drivers agreed that the orange striping had a positive impact on their behaviors, they felt even more strongly that the overall benefits were worthwhile. This is to say that respondents are not only receptive to, but are also hopeful for, increased safety and awareness measures in work zone, and believe that orange striping is a meaningful safety improvement. While these results cannot speak definitively to the actual

actions of drivers, they do suggest that among those drivers who responded, there is a recognition of a need for improved driving behavior in work zones, and a belief that orange striping could be a continual reminder to drivers to drive safely through the work zone. Therefore, while these results should be read in conjunction with observed traffic and speed data from the pilot area to best understand the impact orange striping has on actual driver behavior, these results on their own demonstrate that drivers recognize that better driving behaviors and increased safety features would be beneficial in work zones and believe that orange striping is a positive improvement in that direction.

Other public feedback

WSDOT used social media as a key communication tool for sharing updates and information about construction in this project area, educating the public about orange striping, and to promote the orange striping pilot survey. As part of this work, the project team also collected and tracked public comments and responses to project posts. These posts cannot be attributed to area residents or work zone drivers in the same way as survey responses, however, their content is still instructive as to how the public has reacted to orange striping both conceptually and as part of this project.

During the initial orange striping pilot and survey distribution phase, the project team noted more than 350 comments received on Facebook posts, X (Twitter) posts, and via email from individuals sharing feedback on the project. The sentiments of these responses were more evenly divided than those received in the survey, however, the underlying themes closely aligned. Posters with positive sentiments about the orange striping thought that it increased visibility and awareness, lowered speeds, and improved safety overall. Those with negative or neutral feelings offered concerns about the added costs, the color of the lines, and generally questioned whether the additional markings would have a significant impact on individuals who choose to speed or skirt safety precautions.

Almost six months after the initial striping occurred, WSDOT announced on social media that a new lane shift was coming to the project area and that orange stripes would be removed. The project team again tracked public comments and responses on the post. In the first 16 hours following the post, it received over 80 comments and replies, including 23 which discussed orange striping. All but one of these 23 comments expressed clear approval for the orange striping pilot, including the two comments which received the highest number of *likes* and positive reactions:

> *We liked the orange striping. It helped to determine the construction zone. It was bright enough to catch the eye. Good idea. Safety First.*

> *Appreciate the update. I commute through this area daily. Personally I liked the orange striping as it made it easier to clearly see the lanes. Sometimes during shifts it's really hard to tell if you are in a lane or not when it's dark & rainy.*

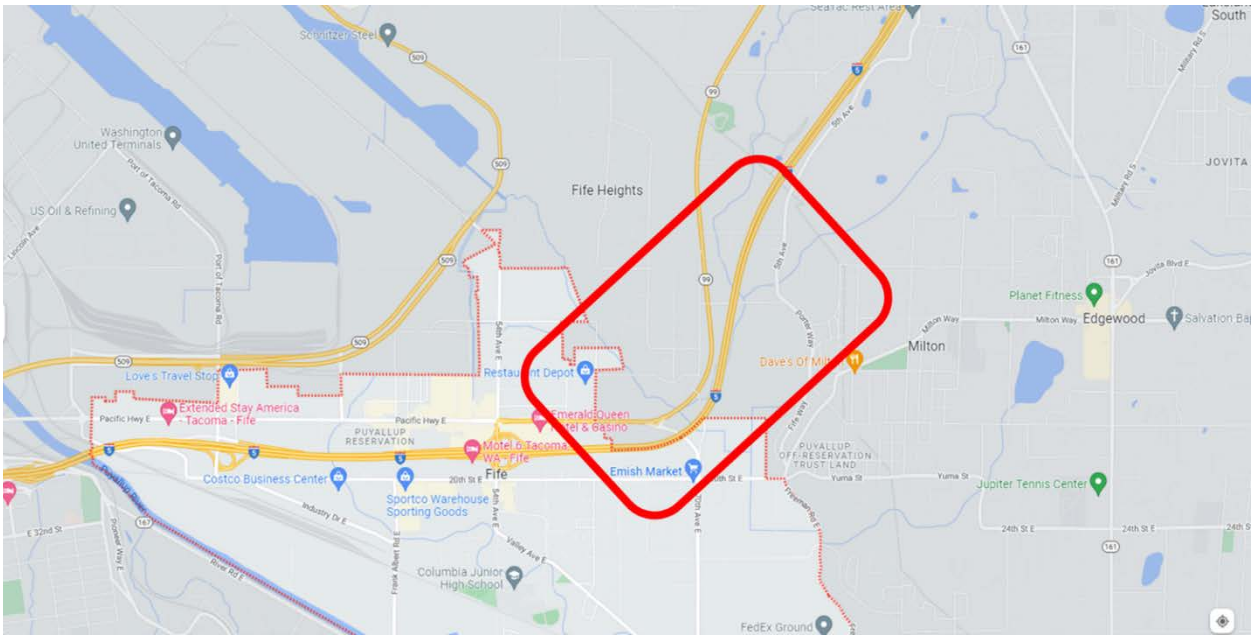
As noted above, tracking and quantifying social media responses present limitations; it is unknown whether posters live in or have traveled through the project area, or whether posts are written in good faith or from genuine respondents. However, while these limitations prevent direct comparison to survey or other data, they do reach a wide audience and provide broad insights into public mood and sentiment. For that reason, it is noteworthy that nearly all orange

striping related comments received at the end of the pilot period were positive and supportive of the orange striping, compared to the divided sentiments received on similar posts to the same platforms when the study began. Much like the survey data discussed above, these responses suggest public appreciation for the increased importance of safety in work zones, an appetite for changes which simplify awareness and visibility for drivers and indicate a perception that orange striping is a useful tool to help achieve these ends.

APPENDIX A: Survey instrument

I-5 Work Zone Safety Post-Survey

1) How often do you drive on Interstate 5 anywhere near the Fife curve (between the city of Federal Way and the Port of Tacoma)? See map below.



*

( ) At least once a week

( ) At least once a month

( ) Less than once a month

( ) Less than once a year

( ) Never

2) When was the last time you drove on Interstate 5 anywhere near the Fife curve (between city of Federal Way and the Port of Tacoma) **during the day**?

( ) Within the last week

( ) Within the last month

( ) More than one month ago but within the past year

( ) More than one year ago

---

3) When was the last time you drove on Interstate 5 anywhere near the Fife curve (between city of Federal Way and the Port of Tacoma) **during the night**?

( ) Within the last week

( ) Within the last month

( ) More than one month ago but within the past year

( ) More than one year ago

---

4) Thinking about the last time you drove on Interstate 5 anywhere near the Fife curve (between city of Federal Way and the Port of Tacoma), was it daytime or night?

( ) Daytime

( ) Night

---

5) Thinking about the last time you drove on Interstate 5 anywhere near the Fife curve (between city of Federal Way and the Port of Tacoma), did you at any point drive through a construction work zone?

( ) No

( ) Yes

( ) Not sure

---

6) Thinking about the last time you drove on Interstate 5 anywhere near the Fife curve (between city of Federal Way and the Port of Tacoma), did you notice the orange contrast striping in the construction work zone?*

( ) No

( ) Yes

( ) Not sure

---

7) Did the orange contrast striping increase your awareness of being in a road construction work zone?

( ) No

( ) Yes

---

8) How much do you agree or disagree with the following statements?

	Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
The orange contrast striping caused me to drive at a more reasonable or lower speed in the work zone.	( )	( )	( )	( )	( )
The orange contrast lane line striping makes it easier than traditional white lane line striping to stay in my lane.	( )	( )	( )	( )	( )
The orange contrast markings increased my awareness of the work zone compared to traditional white lane stripes.	( )	( )	( )	( )	( )

---

9) Did you have prior knowledge that the striping would be orange contrast before driving through the work zone? *

( ) Yes, I was aware of the orange contrasted striping on this section of I-5.

( ) No, I had no knowledge of the orange contrasted striping before entering the work zone.

---

10) Please tell us about how you became aware that the striping would be orange contrasted?

[ ] Radio

[ ] Television

[ ] Local and regional newspapers and blogs (please tell us more):
_____

[ ] Flyer mailed to my home

[ ] Social media (Twitter, Facebook, YouTube, etc.)

[ ] Friends, family, or word of mouth

[ ] Travel advisory

[ ] Online open house

[ ] Other (please tell us more): _____

[ ] I don't know

---

11) Would you like to see orange contrast striping used in more road construction zones?

( ) No

( ) Yes

12) Please tell us why or why not.

_____

_____

---

13) What is your opinion of the orange contrast striping **at night**?

( ) Prefer the combination of orange contrast and white lane striping

( ) Prefer traditional white lane line striping without orange contrast striping

( ) No preference

14) Please tell us why.

_____

_____

---

15) What is your home zip code?

_____

16) What is your age?

( ) Under 18

( ) 18-20

( ) 21-24

( ) 25-34

( ) 35-44

( ) 45-54

( ) 55-64

( ) 65-74

( ) 75 or older

17) What is your gender identity? Please choose all that apply.

[ ] Male

[ ] Female

[ ] Gender(s) not listed here

18) How do you identify? Please choose all that apply.

[ ] American Indian or Alaska Native

[ ] Asian or Asian American

[ ] Black or African American

[ ] Hispanic, Latino, or Spanish origin

[ ] Native Hawaiian or Pacific Islander

[ ] Middle Eastern or North African

[ ] White

[ ] Race(s) not listed here, please specify:

_____

19) What was your total household income for 2022 before taxes? Your best guess is fine.

( ) Less than $25,000

( ) $25,000 to $49,999

( ) $50,000 to $74,999

( ) $75,000 to $99,999

( ) $100,000 to $149,999

( ) $150,000 to $199,999

( ) More than $200,000

( ) Don’t know

20) Would you like to be notified with updates on the SR 167 Completion Project?

( ) Yes

( ) No

21) Please provide your contact information below in order to be notified of updates about the SR 167 Completion Project. The information you share here will only be used to contact you for the purpose(s) you just selected. It will not be connected to your previous survey answers.

First name: _____

Last name: _____

Email address: _____

Phone number (optional): _____

APPENDIX B: Statistical correlations

Those who drive I-5 near the Fife curve more often are also more likely to:

- Have driven the Fife curve recently during the day.
- Have driven the Fife curve recently at night.
- Identify as BIPOC.
- Be younger.

Those who drove the Fife curve more recently **during the day** are more likely to:

- Drive the Fife curve more frequently.
- Have also driven the Fife curve recently at night.
- Be older.

Those who drove the Fife curve more recently **at night** are more likely to:

- Identify as BIPOC.
- Drive the Fife curve more frequently.
- Have also driven the Fife curve recently during the day.
- Be older.

Those who noticed the work zone are more likely to:

- Drive the Fife curve more frequently.
- Drive the Fife curve more frequently at night.
- Have noticed orange striping when they last drove through.
- Think orange striping makes lane-keeping easier.
- Think orange striping increases work zone awareness compared to white stripes alone.
- Have heard about orange striping prior to seeing it.

Those who noticed the orange striping in the work zone were more likely to:

- Drive the Fife curve often.
- Have driven the Fife curve recently during the day.
- Have driven the Fife curve recently at night.
- Have noticed a work zone the last time they drove through Fife.
- Think orange striping causes lower or more reasonable speeds.
- Think orange striping makes lane keeping easier.
- Think orange striping is better for work zone awareness than white stripes alone.
- Have had prior knowledge of the work zone.
- Want to see orange striping used more.
- Prefer orange striping over white stripes alone at night.

Those who thought orange striping increased awareness in the work zone were more likely to:

- Think orange striping causes lower or more reasonable speeds.
- Think orange striping makes lane keeping easier.
- Think orange striping is better for work zone awareness than white stripes alone.
- Want to see orange striping used more.
- Prefer orange striping over white stripes alone at night.

Those who agreed that orange striping increased their awareness in the work zone compared to traditional striping were more likely to:

- Think orange striping increased work zone awareness overall.
- Think orange striping caused them to drive at slower or more reasonable speeds.
- Think orange striping makes lane keeping easier.
- Want to see more orange striping used.
- Prefer orange striping to white stripes alone at night.
- Be female.

Those who agreed that orange striping makes it easier than traditional striping to stay in my lane were more likely to:

- Think orange striping increased work zone awareness overall.
- Think orange striping increased awareness compared to white stripes alone.
- Think orange striping caused them to drive at slower or more reasonable speeds.
- Want to see more orange striping used.
- Prefer orange striping to white stripes alone at night.
- Be female.

Those who agreed that orange striping cause me to drive at a more reasonable or lower speed were more likely to:

- Think orange striping increased work zone awareness overall.
- Think orange striping increased awareness compared to white stripes alone.
- Think orange striping makes lane keeping easier.
- Want to see more orange striping used.
- Prefer orange striping to white stripes alone at night.
- Be female.

Those who wanted to see orange striping used in more road construction zones were more likely to:

- Think orange striping increased work zone awareness.
- Think orange striping caused them to drive slower or more reasonably.
- Think orange striping is better for work zone awareness compared to white stripes alone.
- Think orange striping helps with lane keeping.
- Prefer orange striping to white stripes alone at night.
- Be female.

Those who prefer the combination of orange and white striping at night were more likely to:

- Think orange striping increased work zone awareness.
- Think orange striping is better for work zone awareness compared to white stripes alone.
- Think orange striping helps with lane keeping.
- Want to see more orange striping used.
- Prefer orange striping to white stripes alone at night.
- Have driven at night when they saw orange striping.

Those who had prior knowledge of orange striping are more likely to:

- Be younger.
- Be male.

APPENDIX C: Respondent demographics

	Age	Total Count	Total Percent
What is your age?	Under 18	1	0.1%
	18-20	8	1%
	21-24	21	2%
	25-34	116	13%
	35-44	193	21%
	45-54	143	16%
	55-64	159	17%
	65-74	113	12%
	75 or older	34	4%
	No Response	121	13%
	Total	**909**	**100%**

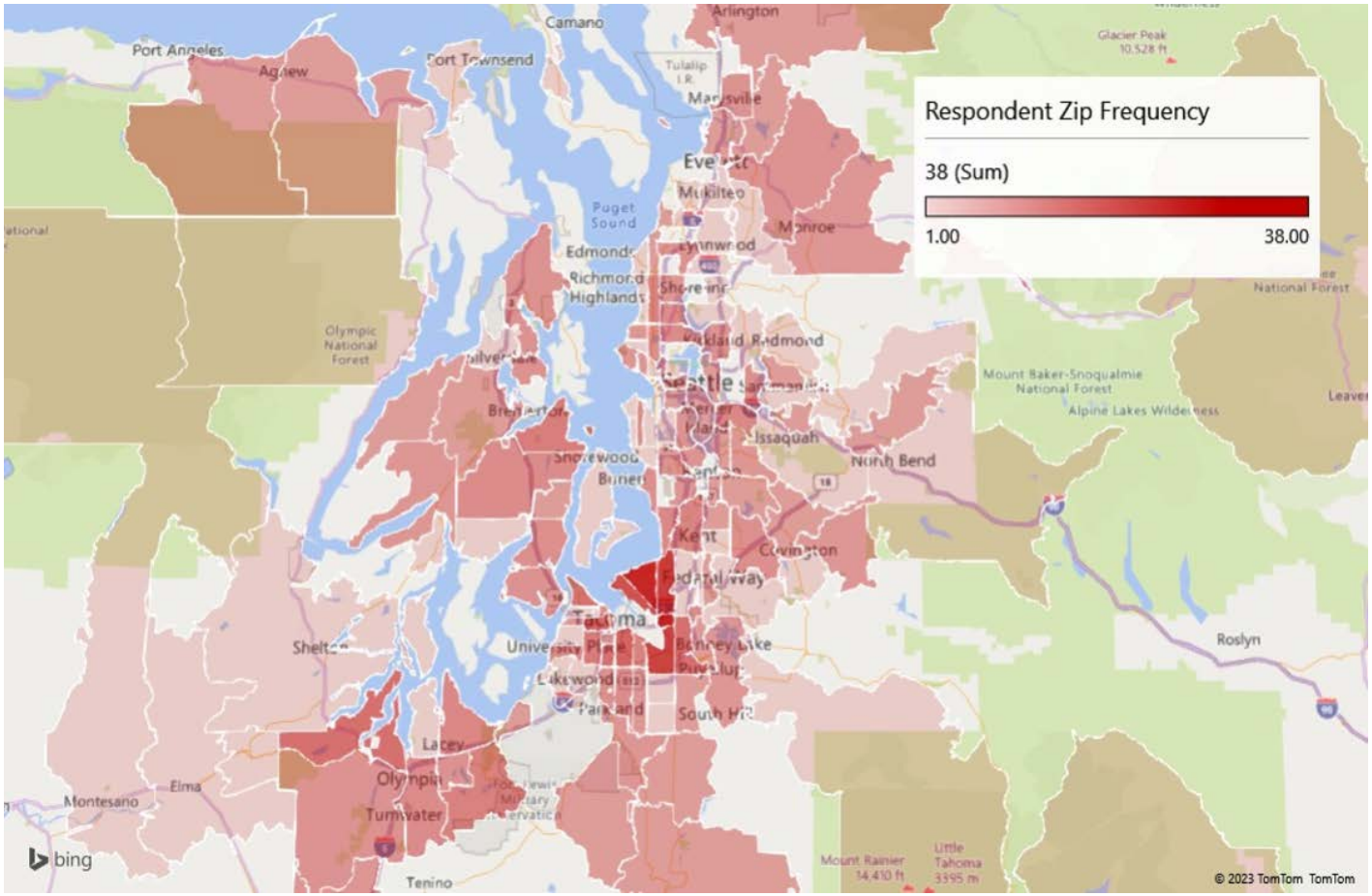
	Gender	Total count	Total percent
What is your gender identity? *Please choose all that apply.* (n = 909)	Female	345	38%
	Male	406	45%
	Gender(s) not listed here	18	2%
	No response	145	16%
	Total	**914**	**100%**

	Income	Total count	Total percent
What was your total household income for 2022 before taxes? Your best guess is fine.	Less than $25,000	15	2%
	$25,000 to $49,999	66	7%
	$50,000 to $74,999	92	10%
	$75,000 to $99,999	109	12%
	$100,000 to $149,999	167	18%
	$150,000 to $199,999	96	11%
	More than $200,000	92	10%

	Don't know	64	7%
	No response	208	15%
	Grand total	**909**	**100%**

	Race	**Total count**	**Total percent**
How do you identify? *Please choose all that apply.* (n = 909)	American Indian or Alaska Native	20	2%
	Asian or Asian American	48	5%
	Black or African American	28	3%
	Hispanic, Latino, or Spanish origin	41	5%
	Middle Eastern or North African	1	0%
	Native Hawaiian or Pacific Islander	10	1%
	White	644	71%
	Race(s) not listed here, please specify	12	1%
	No response	173	19%
	Total	**977**	**107%**

ZIP	Total percent
98424	4.2%
98354	4.2%
98023	4.1%
98003	3.3%
98371	3.1%
98001	2.6%
98422	2.5%
98405	2.0%
98404	2.0%
98502	1.5%
98408	1.5%
98372	1.5%
98407	1.4%
98409	1.2%
98466	1.1%
98366	1.1%



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APPENDIX B

March 25, 2024

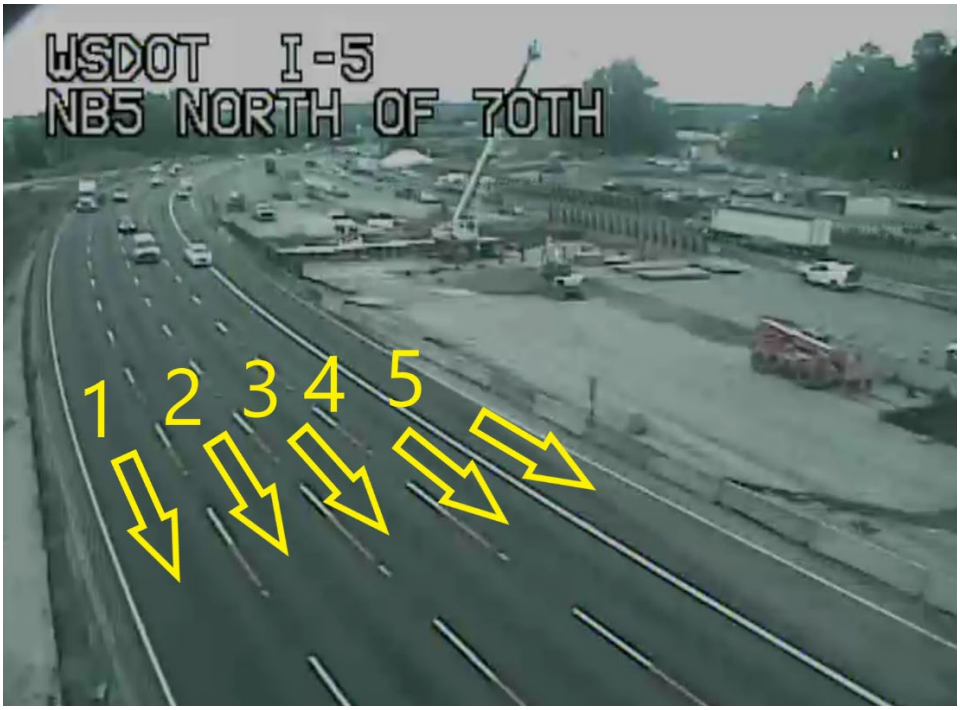
TO: Scott Davis, Transportation Operations Division (HQ)

FROM: Joshua Dohring, Transportation Technician 1, Olympic Region Traffic Office

SUBJECT: Orange Contrast Markings – Driver Observations

Review Methods

For this study, seven hours of video footage were gathered. Three hours were recorded in March, April, and May before the addition of orange markings, and four hours in June, July, and November following the addition of orange markings. For each hour-long video, the lanes were monitored one at a time, keeping record of how many times vehicles were suspected to have deviated from their lane. A separate tally was kept for suspected lane changes. The example below shows one of the lane deviations that were counted, where the vehicle is over the HOV lane line.



Lane numbers and travel direction

Lane Intrusion

Limitations

The camera resolution made it difficult to see the lane lines beyond a certain point, therefore nothing was counted until the lane lines were visible.

Camera angle did not allow for frontal view. This resulted in areas of occlusion where lines were not visible, or portions of vehicle path was not entirely visible.

Lane changes as vehicles moved off the view of the camera, as shown below, would be recorded as intentional lane changes by default.

Lane change as vehicle moves off camera

Pixelation and occlusion area

Data

Driving Behavior Evaluation via Video Analysis (Detailed)												
Phase	1 (Conventional)		1 (Conventional)		1 (Conventional)		2 (Orange Contrast)		2 (Orange Contrast)		2 (Orange Contrast)	
Route	I-5		I-5		I-5		I-5		I-5		I-5	
Vehicle Direction	North		North		North		North		North		North	
Camera Direction	South		South		South		South		South		South	
Date	March 21, 2023		April 11, 2023		May 9, 2023		June 13, 2023		July 7, 2023		November 7, 2023	
Time	10:00 a.m.		10:00 a.m.		10:00 a.m.		10:00 a.m.		10:00 a.m.		10:00 a.m.	
Duration	60 min		60 min		60 min		60 min		60 min		60 min	
	Suspected Lane Intrusion	Suspected Lane Change	Suspected Lane Intrusion	Suspected Lane Change	Suspected Lane Intrusion	Suspected Lane Change	Suspected Lane Intrusion	Suspected Lane Change	Suspected Lane Intrusion	Suspected Lane Change	Suspected Lane Intrusion	Suspected Lane Change
Lane 1	26	11	23	16	20	14	19	8	17	8	16	8
Lane 2	27	36	32	34	26	36	19	39	20	34	20	33
Lane 3	34	22	27	38	28	31	24	44	25	30	25	32
Lane 4	53	31	55	36	48	32	36	29	41	29	41	29
Lane 5 (HOV)	8	21	3	11	3	10	1	20	2	11	2	7
Total	148	121	140	135	125	123	99	140	105	112	104	109

Driving Behavior Evaluation via Video Analysis (Summary)					
	Suspected Lane Intrusion (Averaged by lane/hour)			Suspected Lane Change (Averaged by lane/hour)	
	Phase 1 (Conventional)	Phase 2 (Orange Contrast)		Phase 1 (Conventional)	Phase 2 (Orange Contrast)
Lane 1	23	17		14	8
Lane 2	28	20		35	35
Lane 3	30	25		30	35
Lane 4	52	39		33	29
Lane 5 (HOV)	5	2		14	13

Review Notes

A video from November 6th was recorded during a rainy day and featured heavier traffic than other videos reviewed. The traffic conditions sufficiently differed from other videos reviewed to consider this an outlier and is not recommended to be used for data comparison.

Footage from November 6th

Observations

Subjective observations based upon this small sample suggest that implementing orange contrast enhancement markings resulted in fewer suspected lane intrusions.