FHWA/WSDOT PAVEMENT MARKING REMOVAL ISSUES AND SOLUTIONS JOINT REVIEW

FINAL REPORT

SEPTEMBER 2006

Photo 1. Ghost striping on Interstate 5.

Executive Summary

Rehabilitation and reconstruction of major highways in Washington State, as well as the addition of new capacity lanes, is leading to more multi-staged projects and traffic lane shifts. An important component of multi-staging details is pavement stripe removal, both permanent and temporary. If the former pavement stripe, whether white or yellow, is not completely removed it can lead to confusion by drivers about which lane to be used through the work zone. The driver may follow the old stripe, leading to near misses and/or traffic accidents. Often, when the old pavement markings are removed there is a "ghost stripe", an image of the former stripe, adding to driver confusion.

Pavement markings are perhaps the most important item on the roadway for guidance to drivers. Pavement markings offer a large return on their investment when comparing the safety benefits to the cost. It is good business for WSDOT and FHWA to ensure that pavement markings are present and clearly seen, as well as the complete removal of old markings in work zones. Ideally, efforts should be made to minimize temporary striping through work zones. This may be the best way to reduce ghost striping.

In order to look more closely at these issues, which include finding possible ways to improve work zone pavement marking removal, and ways to reduce ghost striping, a joint FHWA and WSDOT team was formed.

Conclusion and Recommendations

There is no easy or inexpensive way to reduce ghost striping on WSDOT projects. This review team found no silver bullet to eliminate ghost striping, however, the team has provided some ways to reduce and mitigate ghost striping. The report also offers recommendations on other pavement marking issues; it should help designers choose which method of pavement marking removal is best for their project. This information should be beneficial to construction inspectors, design staff and ultimately, the driving public. Some of this information needs to be entered into the WSDOT Lessons Learned Database. The review team ultimately came up with six recommendations; please see the full recommendations in the report for more details.

1. **Increase the Use of Removable Preformed Tape**
   By increasing the use of temporary tape during multi-stage projects, there will be less ghost striping. Temporary tape has the advantage of being removed without leaving any markings or ghost striping. Although not suitable for every project, it's use should be considered for more multi-staged projects. It typically costs 10-15 times the cost of temporary pavement markings.
   Action: Inform regional designers through annual design and construction conferences and other venues. Guidance will be developed in the future on this topic.
   Responsible Parties: WSDOT HQ Program Management, Design, and the Traffic Offices followed by Regional support.

2. **Reduce the cure time associated with applying MMA over new HMA.**

When MMA is placed over a new asphalt pavement, there is a 21 day cure period as required by the WSDOT Standard Specifications, 8-22.3(2). Ennis Paint, the manufacturer of Duraset pavement markings (MMA), has indicated that there is flexibility in this minimum time. The WSDOT Standard Specification could then be amended to reflect a shortened time frame.
Action: Work with industry to determine if the cure time can be reduced.
Responsible Party: HQ Traffic, Construction and HQ Materials Lab Offices followed by Regional support.

3. Enhance the WSDOT Specifications

- Create a series of GSPs for Pavement Marking Removal

Standardized GSPs give designers more flexibility for specifying pavement marking removal. The hydroblaster is a good tool, but traditional forms of pavement marking removal may be preferable in some situations. This team has provided a starting point. See Appendix B for the proposed GSPs.
Action: Develop GSPs.
Responsible Party: HQ Construction Office followed by Regional support.

- Separate Bid Items for Installation and Maintenance of Temporary Pavement Marking

Create a separate bid item for the installation of temporary pavement markings and maintenance of temporary pavement markings. The current specification combines these two items. Very often the driving public encounters faded lane lines because the subcontractor has not adequately maintained the pavement markings.
Action: Develop GSPs.
Responsible Party: HQ Construction Office followed by Regional support.

4. Solid White Lane Line Markings

WSDOT should encourage the solid white stripes for lane lines in transition areas and other alignments where a higher level of delineation is needed. The Manual on Uniform Traffic Control Devices (MUTCD) provides for this in 3B.04 "Wide solid lane line markings may be used for greater emphasis", and 6F.72. The use of the solid white line has been effective, by anecdotal evidence from several project offices. It provides better delineation to drivers through work zones, particularly through transition areas.
Action: Inform WSDOT designers and field personnel through annual design/construction conferences and other venues.
Responsible Parties: HQ Construction and HQ Traffic Offices followed by Regional support.

5. Preplanning during Construction

WSDOT PEOs must outline their expectations for lane reconfigurations and traffic switches to the contractor at activity meetings, particularly for multi-staged projects; these expectations must be in the contract documents. Institute better communication with the contractor and all parties involved prior to shifting traffic

Action: Share at winter design/construction conferences; add more guidance to the construction manual.
Responsible Party: HQ Traffic and Construction Offices followed by Regional support.

6. Project Development Phase

WSDOT should expect temporary channelization plans to be identified early. In the past not enough thought has gone into developing traffic control plans for staged construction. The stages are too loosely defined and may result in wide lanes. Traffic control plans need to address all stages. Additionally, more plan review will improve the plans and may catch plan errors such as incorrect pavement markings currently existing in the field.
Action: Change Design Manual to include maximum lane width for work zone traffic control. Inform WSDOT designers and project development staff through annual design/construction conferences and other venues. Encourage WSDOT PEOs to carefully review and comment on project plans before contract goes to ad. Share the Guidelines Matrix that was developed, See Appendix A.
Responsible Parties: HQ Design and Traffic Offices followed by Regional support.

Introduction to Issues Concerning Pavement Marking Removal through Work Zones

Rehabilitation and reconstruction of major highways in Washington State, as well as the addition of new capacity lanes, is leading to more multi-staged projects and traffic lane shifts. An important component of multi-staging details is pavement stripe removal, both permanent and temporary. Incomplete removal of pavement markings, both white and yellow, can lead to confusion by drivers about which lane to be used through the work zone. The driver may follow the old stripe, leading to near misses and/or traffic accidents. Often, when the old pavement markings are removed there is a "ghost stripe", an image of the former stripe, adding to driver confusion.

Pavement markings are perhaps the most important item on the roadway for guidance to drivers. Pavement markings offer a large return on their investment when comparing the safety benefits to the cost. It is good business for WSDOT and FHWA to ensure that pavement markings are present and clearly seen, as well as the complete removal of old markings in work zones. Ideally, efforts should be made to minimize temporary striping through work zones. This may be the best way to reduce ghost striping because temporary paint does not have to be removed then.

Photo 2. Ghost striping in gore area on I-5 in Bellingham area.

In order to look more closely at these issues, which include finding possible ways to improve work zone pavement marking removal, and ways to reduce ghost striping, a joint FHWA and WSDOT team was formed. WSDOT team members were Jim Spaid, WSDOT Roadway Construction Engineer; Larry Eik, Assistant Roadway Construction Engineer; Phil Fordyce, Regional Construction and Traffic Engineer; Robert Blegen, Assistant Project Engineer; Frank Newboles, State Work Zone Safety and Mobility Manager, Marty Weed, State Work Zone Traffic Control Engineer; and Ed Lagergren, Traffic Design Standards & Materials Engineer. FHWA team members were Cathy Nicholas, Construction & Materials Engineer; and Bryan Dillon, Area Engineer. This report was a collaborative effort among the team members.

Objectives, Scope & Methodology of the Review

The objectives of this review were to determine ways to improve pavement marking removal, ways to mitigate ghost striping, evaluate different pavement marking removal procedures and make recommendations for the best practices. Other methods of delineation and construction management of the work zone were focused on as well.

This review focused on visiting WSDOT field offices to get a sampling of the state of the practice on pavement marking removal and ghost striping. A striping subcontractor and

the US Air Force McChord Airfield were contacted during the review. Lastly, a brief literature search was conducted.

Background on Stripe Removal Methods

A brief background on pavement marking removals is essential to this report. There are several methods of pavement markings removal available to the highway industry. These include grinding, hydroblasting (water blasting), and shot/sand blasting.

Grinding[1]

There are generally two types of grinding machines-rotary and drum. Grinding machines range in size from small walk behind to large truck mounted systems. The drum machines usually provide more efficient production over the rotary type. Grinding machines are efficient at removing any type of line or marking. The machines work on both concrete and asphalt roadways. However, they can leave an indentation on the surface or a ghost stripe. Vendor literature states that large quantity jobs can see production of up to 25,000 lineal feet per hour on machines with multiple heads.

Photo 3. Typical walk behind grinder.

Hydroblasting (Water blasting)[1]

Water blasting is a process that uses high pressure water, typically between 34,000 and 40,000 psi to clean the surface, remove old coatings, prep a surface for a new application and remove rubber from runways. Hydroblasting has been used in the past to remove bridge decks of delaminated concrete before an overlay. Hydroblasting can remove any type of pavement markings, including thermoplastic and tape. It can be used on both concrete and asphalt roadways. Hydroblasting equipment is available in various sizes, from walk behind units to truck mounted units. Additionally, vacuum recovery units collect residual water, paint and debris for disposal.

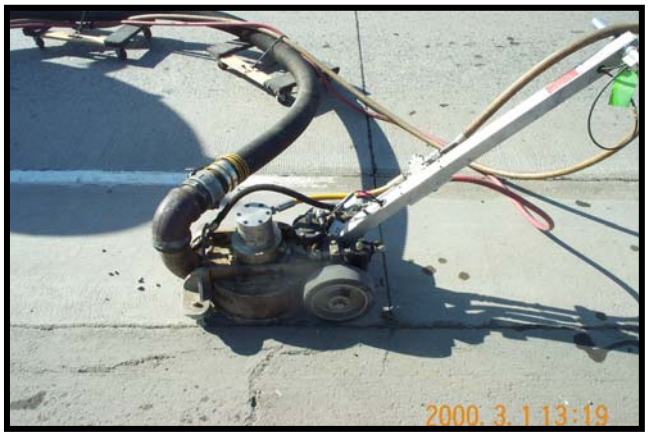


Photo 4. Hydroblaster used in the Eastern Region.

The advantage of hydroblasting is that the surface is left clean, nearly dry and ready for restriping almost immediately. Water blasting may do the least amount of damage to the surface of the pavement compared with grinding or shot/sand blasting. Vendor literature states that hydroblasting to remove paint can remove up to 7,500 lineal feet per hour.

Shot Blasting[1]

Shot blasting is similar to sand blasting. They will be used interchangeably in this report. Small metal beads, or shot, are propelled at the surface of the roadway at high speed to remove the pavement marking. The process does remove a small portion of the top surface on the asphalt roadway. The process can be used on both concrete and asphalt roadways. Shot blasters typically are self contained because the shot has to be vacuumed up immediately after it hits the pavement. Shot blasting machines come in walk-behind sizes to large ride-on versions.

Shot blasting should not be used on wet surfaces and it is not effective in removing tapes or thermoplastics. Shot blasting a new asphalt surface may cause the machine to gum up due to the oil and heat created by the shot blasting process. Vendor literature states that a typical production is about 1,400 lineal feet of paint stripe per hour.

State of the Practice: Field Reviews

Table 1 lists WSDOT projects selected for a field review. Criteria for project selection included mult-staging, heavy traffic, and use of multiple bid items for pavement marking removal. A variety of pavement marking removal methods used.

Table 1. Projects Sampled for this Review

WSDOT Contract Number	Project Name	Region/PEO
#7108	Spokane Viaduct Bridge Deck Rut Repair	Eastern Darrel McCallum
#6801	I-5, NE 175th to NE 205th ST NB Auxiliary Lane	Northwest Amir Ahmadi
#6620	I-90, Argonne to Sullivan***	Eastern Darrel McCallum
#6610	I-5, Salmon Creek Widening	South West Casey Liles
#6759	I-5, North of Lakeway I/C Phase 1A	Northwest Chris Damitio
#6757	I-5/Federal Way-317th St HOV Direct Access	Northwest John Chi
#6932	Totem Lake/NE 128th St HOV Direct Access/Freeway Station ***	Northwest Doug Haight
#6958	I-5, 48th St to Pacific	Olympic Howard Diep
#6473	I-5, 36th U/C to Vic SR 542, Phase 1	Northwest Chris Damitio
#6933	SR 24, I-82 to Keys Road***	South Central Paul Gonseth
#7216	Chehalis Western Trail Pedestrian Bridge***	Olympic Neil Uhlmeyer

***These projects were not visited; however anecdotal information and data from these projects have been used in this report.

The team developed a questionnaire (see Appendix C) for use in discussions with each project visited. Appendix D lists project information.

Other Sources of Information

McChord Airfield and Fort Lewis Army Base personnel were contacted for their pavement marking removal specifications. The team believed these agencies might offer some new insight into these issues. Their paint removal applications typically remove old paint and replace new paint in the same place and do not include a multistage workzone on a runway. Hydroblasting and grinding are the predominant means of paint and rubber removal from military airfields. Apparently, chemical removers are allowed but viewed as less effective, perhaps for environmental reasons. The pertinent details of the Air Force specification (being used in current rubber and paint removal contracts) states:

> The equipment used in the removal process shall be mounted on pneumatic tires and shall remove deposits of rubber and paint without causing damage to pavement surfaces, joints, or joint and crack seal material.
>
> Paint shall be removed by high pressure water. The contractor may inject sand as an abrasive into the high pressure water system. The use of environmentally acceptable chemical agents of high velocity impact removal shall be considered on a case-by-case basis.

Other Air Force specifications give a percentage of paint or rubber removal. For PCCP and ACP it is 85% of the paint buildup from 100% of the runway. A note to designers says to not specify 100% as this will result in excessive exposure of pavement aggregates. The paint removal rate is specified as 1,000 square feet per hour. Additionally, there is a quality assurance component that includes a test section prior to commencing work and continual sampling of the pavement during production by randomly sampling locations and using a grid tool to verify 85 of 100 squares have had the paint properly removed

The Air Force specifications offer some new information for highway application, such as the use of a test section and performance criteria. These concepts will be referred to later in the Specifications section of this report.

Factors Affecting Production

Production rates between different pavement marking removal methods can vary tremendously. Vendors may give best case scenarios for removing markings. In reality, production rates are influenced by pavement type, weather, surface condition and machine dependability. Each method has advantages and disadvantages. Some of these considerations will be given here as well as data from recent WSDOT projects.

Pavement type can have an important impact on production. In Washington State, Hot Mix Asphalt (HMA) pavement is a softer material than Portland Cement Concrete

Pavement (PCCP) because Washington State's concretes are so strong and durable. Pavement marking removal is generally faster on HMA than on PCCP when grinding. However, when using hydroblasting the production rates on HMA and PCCP are very similar, as reported by the I-5/NE 175 project staff. To elaborate further, Caltrans has reported that removal speed was 1000 L.F./hr for removal of thermoplastic from an open graded rubberized asphalt by hydroblasting. Caltrans also reported removal from concrete or dense asphalt is typically about 3,000 L.F./hr for hydroblasting. Marking removal from porous asphalt will take longer, i.e. slower production than removing from dense graded asphalt. This also supports the concept that hydroblaster production rates are similar between HMA (dense graded) and PCCP. To summarize, the grinding process cuts through the pavement, resulting in slower production for more durable pavements such as concrete. Conversely, with the hydroblasting process, the surface area of the pavement affects the production. Thus pavement markings on porous asphalt will take longer to remove than on dense graded asphalt.

Rainy or wet weather precludes the use of the shot blaster because the filter gets gummed up with paint chips in wet conditions. On the I-90/Argonne to Sullivan Road project, significant delays were experienced waiting for weather in which the shot blaster could be used. Lastly, pavement surface condition also influences the removal rate. It is more difficult to completely remove pavement markings on rough surfaces such as polished concrete and diamond grind, due to the increase in surface area. Usually, any type of machine must run at a slower pace to do a better job of removal.

Machine dependability is hard to quantify, however it should be noted. Inspector's experience and subsequent diaries provide most of the insight into this aspect of removal. The hydroblaster machine is a large and complex machine, compared to a shot blaster or grinder. It will be more susceptible to mechanical problems. As reported by the project teams associated with the Spokane Street Viaduct and the NE 175th projects, the hydroblaster can have problems that force it to stop work or need maintenance. For example, on the Spokane Street Viaduct project, the hydroblaster had mechanical difficulties and the shot blaster had to be brought in to take over due to the tight time frame for pavement marking removal work.

Table 2 presents actual field production numbers from some of the projects visited. It is clear that each project is unique. Stripe or marking removal depends on the condition of the roadway and pavement type. Because hydroblasting has only been used on a few WSDOT projects, there is not much history of production rates. Grinding has been used extensively, throughout the state, but a big variation can still be seen in the rates because of different pavement types.

Table 2. Actual Field Pavement Marking Removal Production Rates in Linear Feet/Hour (L.F./hr)

Project Location	Grinding	Shot Blasting/Sand Blasting	Hydroblasting
Literature data	25,000 [(1)] (HMA)	1,400 [(1)] (HMA)	2,400 [(2)] (HMA)
CalTrans Project (thermoplastic over open graded rubberized asphalt)			1,000 (open graded HMA) 3,000 (PCCP or dense graded HMA)
317th Project (removing same 4" solid temp line)		1109 (PCCP)	597 (PCCP)
48th to Pacific	1200-1300 (PCCP)		250 (PCCP)
Spokane Viaduct Rut Repair		1900 (PCCP)	1200 for paint over MMA (PCCP). Approx 12,000 for paint only (PCCP)
I-5, NE 175th	2243 for wide temp stripe (walk behind grinder) (PCCP)	7300 for temp stripe (PCCP)	7300 for temp stripe (PCCP)(1)
Chehalis Western Trail Pedestrian Bridge	2400 for removing profiled plastic and paint (distance includes gap in skip stripe) (HMA)		

(1) The hydroblasted areas had to be gone over twice to get good removal. This figure is for one pass.

Cost Information for Hydroblasting

Table 3 lists the cost data gathered during field visits. Hydroblasting is more expensive than grinding. Other projects that used hydroblasting experimentally, such as the 175th project, added this work by change order at a lump sum cost. This made it difficult to determine the hydroblasting costs. However a cost comparison between grinding and hydroblasting, at least on PCCP, can be made. The Spokane Viaduct Rut Repair project was the first real project, with a significant quantity (48,220 L.F.), to specify pavement marking removal with the hydroblaster. As a comparison, the 48th to Pacific project in Tacoma primarily used grinding (80,175 L.F.**)**. Both of these projects primarily consisted of pavement marking removal on concrete pavement. The bid costs were only 15% higher than grinding costs from the 48th to Pacific project. However, the Spokane Viaduct project costs were higher because the plans indicated the wrong pavement markings for removal. The actual costs were higher due to the marking being paint over MMA. A more accurate comparison may be that the hydroblasting cost 2.5 times more than the grinding ($0.70 vs. $0.27). It is difficult to determine what a true comparison cost would be, had the plans been correct.

These costs include all costs associated with removing the pavement markings, including wastewater treatment and disposal of water used in the removal process. Lastly, as expected, the unit costs for pavement marking removal decrease for larger quantities.

Table 3. Cost Data from Field Visits

Project Location	Removal Method	Cost information
48th to Pacific	Grinding	$0.27/L.F
	Hydroblasting (Change Order cost)	$1.15/L.F.
Spokane Viaduct Rut Repair	Hydroblasting Paint Stripe (bid amount)	$0.32/L.F.
	Hydroblasting MMA (actual field condition)	$0.70/L/.F. (Change order cost)
Chehalis Western Trail Pedestrian Bridge	Hydroblaster specified, but change ordered to grinding (1)	L.S.

(1) This was later change ordered to grinding because the permanent stripe being removed was raised profile plastic line and the contractor brought out inadequate hydroblasting equipment to remove it.

Specifications

The current WSDOT Specifications are very general and do not specify a removal method.

> 8-22.3(6) Removal of Pavement Markings
> Pavement markings to be removed shall be obliterated until blemishes caused by the pavement marking removal conform to the coloration of the adjacent pavement. If, in the opinion of the Engineer, the pavement is materially damaged by pavement marking removal, such damage shall be repaired by the contractor in accordance with Section 1-07.13(1). Sand or other material deposited on the pavement as a result of removing lines and markings shall be removed as the work progresses to avoid hazardous conditions. Accumulation of sand or other material which might interfere with drainage will not be permitted.

The team considered a General Special Provision (GSP) that would specify the exclusive use of one type of pavement marking removal. The exclusive use of the hydroblaster has been used on one recent project, as already noted. The Chehalis Western Trail Project also specified that all pavement markings were to be removed with hydroblasting. For more on this topic see Observations 2 and 7.

Another proposed specification that had support from the team was to exclude the use of the shot blaster, due to its weather sensitivity. This is not specifically detailed in Appendix B, but should be considered by the WSDOT/AGC Roadway Team when moving forward with these specifications. A project in the Eastern Region was substantially delayed last year waiting for weather in which the shot blaster could be used.

Performance is a very important component that could go into a specification. If a rate were specified, by a GSP (General Special Provision), then WSDOT inspectors would have more authority or reason to remove underperforming equipment, similar to what happened on the Chehalis Western Trail Pedestrian Bridge Project. A test section before full production could also ensure that the proper equipment was brought to the job. Production rates as well as quality of removal could be checked then. Maybe use the test section to establish which method of pavement marking removal to use. Water collection is an important environmental consideration that may need to be addressed more specifically in the future.

Please see Appendix B for suggested GSP. The team envisioned that GSP approval would move forward through the WSDOT/AGC Roadway team.

Designers need to be aware of all the implications of using a specification that excludes one type of equipment or limits the removal to one type of method. This information needs to be captured in the lessons learned database. Several project offices can offer some lessons learned.

The Spokane Viaduct Rut Repair contract specified the hydroblaster, in an effort to exclude the shot blaster. Stripe removal occurred during a critical part of the project time line-at the beginning and end of the project. The public was notified that the Viaduct was shut down for a certain time period, by using the hydroblaster the Spokane PEO felt that they could meet those commitments. (Ironically, a shot blaster had to be used because of mechanical problems that occurred with the hydroblaster during the staging to reopen the viaduct). Excluding the shot blaster takes WSDOT out of the debate of non-workable days due to critical path activity for stripe removal. If WSDOT just specifies pavement marking removal and the contractor has a shot blaster in his inventory, the contractor will make the case that he has been delayed due to his inability to use that equipment. Because the standard specification does not exclude shot blasting, the contractor's case must be considered, in addition to the delay to the project while waiting for drier weather.

Another point to consider before using a GSP is the cost associated with a more prescriptive specification. Initially establish costs for each pavement marking removal method and pavement type during project development. A more expensive pavement marking removal method may not be cost effective if float is available in the schedule. It may be satisfactory to let the contractor use a slower method of marking removal. Additionally, user delay costs must be factored into the decision. A project in an urban area with significant delay costs may realize the monetary benefits of using a more expensive removal method sooner than a rural project with lower user costs. However, as stated in the costs section above, hydroblasting may only be 15% higher than grinding. The designer is urged to check quantities and recent regional production factors and costs.

Environmental Considerations

There are several environmental considerations when choosing a pavement marking removal method. The grinding process can leave grinding teeth, small metal bits, behind on the pavement surface. There will likely be dust associated with a fresh ground pavement marking, even after sweeping. The hydroblasting process involves the water being collected immediately after it hits the pavement. In general, because this water contains heavy metals and other contaminants it can be reused or recycled in the process.

Observations

Many noteworthy observations came from discussions with the field offices. This information may be useful to project designers on future projects. The recommendations are summarized in a separate section.

1. Temporary Removable & Contrast Tape

   Temporary removable tape has the potential to alleviate many of the ghost striping issues and should be considered by more designers. Temporary tape has the potential to eliminate the need for applying temporary paint and then the grinding or hydroblasting to remove it. The traffic control associated with this pavement removal should be less because the tape can be pulled or scraped off, versus grinding or hydroblasting. The cost of eliminating ghost striping is hard to quantify, but there are real safety benefits associated with not having ghost striping.

   Some common thoughts, or misconceptions, of the removable tape are that it is all the same, it does not stick, and it does not go down in a straight line. Many offices have had poor performance with the foil backed tape. The removable preformed tape is not the same material; it is more durable and should withstand the elements in many cases. Two people are needed to install the tape and guidelines are critical. There are installation devices that allow the user to push a cart along and apply the tape properly and in a straight line. Other techniques for getting a more durable stripe on HMA include rolling the tape with the finish roller. WSDOT has had quite a bit of experience with removable preformed tape. Much of the Olympia freeway work utilized this type of tape, with good success.

   Gathering some cost data from January 2, 2002 to August 2006, from the WSDOT Bid-Inventory Analysis, shows that removable preformed tape was specified four times at a cost of $2.00/L.F. for 1,100 L.F. to $1.10 for 46,000 L.F. Temporary pavement marking blackout tape was also specified four times in that time frame with costs from $1.50 to $1.70 L.F. Compare this to the cost of installing and maintaining temporary pavement marking for this same time frame. The statewide average low bid was $0.14 L.F. The Northwest Region averaged $0.22/L.F. and the least expensive costs were in the North Central Region at $0.08/L.F. From these figures, **removable preformed tape costs about 10-15 times more than paint pavement markings**. These costs are for installing and maintaining the marking. Removal or traffic control costs are not included. A

direct cost comparison between the removable tape and temporary pavement markings is not easy; traffic control will still be required for removal of both, but the extent may vary. However, with more use, the costs for preformed tape should come down.

Photo 5. I-90, Snoqualmie pass area, blackout tape.

Photo 6. Snoqualmie pass area, same blackout tape as in Photo 5. Different lighing coditions.

Additionally, on the January 2006 Qualified Products List (QPL), there is one temporary removable tape that can be used to mask existing pavement markings. Per the WSDOT Standard Specifications, 9-34.5, pavement masking tape shall be black, non-retroreflective and non-glaring. This black mask tape has been used effectively throughout the state, most recently on an I-82 project in the SCR Region and on a slope stabilization project on I-90 at Snoqualmie Pass. The tape was used to cover the centerline skip line. There was no ghost stripe from grinding out the permanent skip line. The tape is being used for about 4-6 summer months. One drawback to the black masking tape is that it can appear almost white in some lighting conditions. See Photos 5 and 6.

Some instances where temporary tape may not be suitable are on those projects where the tape would be expected to perform during the winter months. Most temporary tape will not withstand repeated snowplowing. There are tapes where the manufacturer claims they can be used in winter driving conditions, but WSDOT has had limited experience with projects subjected to severe winter weather. The tape should perform well in multi-staged projects on the Westside with each stage being one season, etc.

Because temporary tape is an expensive item, it must be accounted for in the scoping and project development phases so that adequate funds are included. The team recommends that more projects utilize temporary tape. The QPL (Specification Reference 9-34.5) contains many different types of temporary tape; removable, removable wet reflective and non-removable. Most of the types have

multiple suppliers, so there should not be an issue with specifying a proprietary product. These products have already been pre-approved for use on WSDOT projects.

2. Hydroblaster Use Becoming more Common

   The use of the hydroblaster is becoming more common. Overall it does a very good job of removing the pavement markings. In the few cases where it was used, it appeared to be better than grinding at removing the pavement markings. Several recent contracts, specifically the Chehalis Western Trail Pedestrian Trail and Spokane Viaduct, used a special provision that only allows for the use of the hydroblaster. In several other cases, the use of a hydroblaster has been change ordered into the contract, such as 48th to Pacific, NE 175th, and the Everett Design Build Project, for a specific purpose such as a test case. This team recommends that a GSP be developed to ensure statewide uniformity in the specification.

   However, its use is not suitable for every application; grinding may be preferable. WSDOT typical plastic pavement markings and profiled plastic pavement markings can be 60, 90, 125 mils with profiles of 500 mils. It is not reasonable to require a contractor to hydroblast these off. Hydroblasting will most likely damage the pavement in these cases. See Observation 7 concerning HMA and the hydroblaster.

3. Solid White Line through Transition Zone

   A solid white lane line marking through the work zone transition area or all the way through the work zone appears to be effective. The I-5,48th to Pacific project, in the Tacoma area, used this technique in the transition zones. The Spokane Viaduct project and the Chehalis Western Trail Ped Bridge project used it throughout the entire workzone, similar to a no-passing zone. The white line, usually placed with paint, appears to be effective because it clearly defines the path for the driver to follow. It is effective (in 2 of these cases) because it is solid lines over concrete pavement that has a mix of concrete longitudinal joints and ghost patches from the old raised pavement markers (RPMs) present. As long as the solid white stripe is maintained, it provides positive reinforcement to drivers through the work zone. Additionally, the Spokane Viaduct project used large white arrows in the transition zone and text on the lanes such as “EXIT LANE ONLY”. These measures were very effective. From the local camera network, it was possible to

Photo 7. Spokane Viaduct Project, solid white lines and arrows.

see that the "near-misses" significantly reduced once the arrows and text were placed. The 48th to Pacific project reported reduced complaints once the solid white line was installed.

4. Widened Lanes

Oftentimes, in very busy urban areas, there are very limited nighttime working hours and long stretches of roadway that must be shifted to a new lane configuration, including removal of old stripe and installation of new striping. In the interest of getting the road open on time, a less than optimal lane configuration may be used for a few days and nights. For example, a wide lane (12-16 feet) may show up for a few days until the whole traffic switch can be completed. A lane this wide this lane can lead to increased confusion for drivers. If possible, it should be avoided through better upfront planning with WSDOT and the subcontractor.

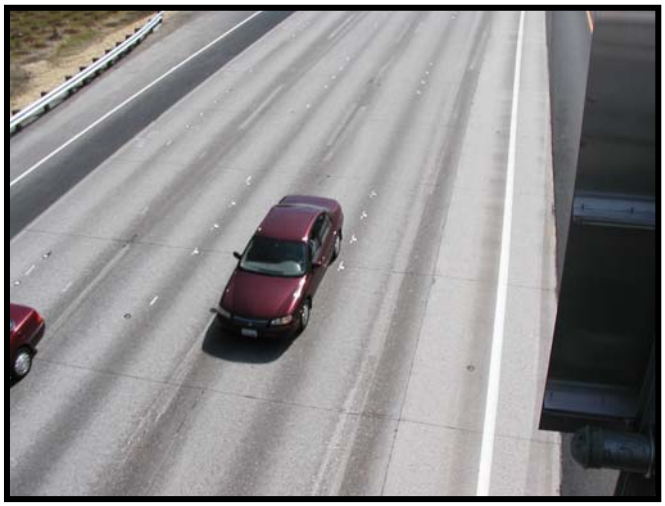


Photo 8. I-5, 175th project vicinity, note highly visible wheel paths on aging concrete.

5. Good coordination with Subcontractor

A way to prevent these wide lanes is another submittal process. It was suggested by one office that approval of a submittal that clearly detailed all aspects of the lane shifting could be required of the contractor. In later discussions with other offices and the WSDOT Construction Office it was thought a better method is to hold weekly contractor and subcontractor meetings, such as what they do on the 48th to Pacific project and the Spokane Viaduct project. The Spokane Viaduct project personnel developed a "D-Day Plan" for every stage of traffic shifting. See Number One in Best Practices and Appendix F for some good examples. Another formal submittal process, with required apoproval, would be an administrative burden on all involved. It is not being supported by this team.

Photo 9. Spokane Viaduct project, hydroblaster removed permanent striping.

6. Concrete Pavements and the Hydroblaster

Older, polished concrete often has very noticeable wheel paths. For example, in the Seattle metro area, in the NE 175th vicinity, the wheel paths are very noticeable due to years of oil and grime accumulation in the non-wheelpath areas. These noticeable wheelpaths make it very hard for drivers, if the lanes are shifted half a lane or some other portion, to focus on new pavement markings. It is natural for drivers to gravitate to the established wheelpaths. On the NE 175th project, an attempt was made to clean up some of the oil and grime by hydroblasting one entire lane for a short distance. However, this was not successful. There was no significant difference in the pavement before and after the hydroblasting. It may be that it is not possible to remove years of grime that has probably been embedded deeper than the hydroblaster can take off in the normal pavement marking removal mode.

Photo 11. Hydroblasting on the I-90/Argonne to Sullivan project. Note circular pattern left by the hydroblaster as well as minimal amount of paste removed and cracking where perm. stripe was.

In Washington State, there are some very aged and polished concrete pavements. Discussions with the 317th project field office and vendors indicate that it is difficult to remove the stripe from this highly polished surface. This office indicated that the ghost striping that was produced by hydroblasting is not as shiny at night as the ghost stripes that were produced from grinding. The grinding seems to give more of a glare at night, perhaps because the aggregate is polished and more of the polished surface is intact with grinding. The NE 175th Project staff also agreed that grinding gives a more polished surface, very noticeable during the day and at night. They also noted that the trough created during grinding can collect water, further accentuating the removed marking. The 317th project reported that hydroblasting on brand new concrete pavement left a ghost line that looks "black", or darker, than the older concrete. This may be because it took off some of the curing compound.

Photo 10. A small amount of fines removed from the ACP due to hydroblasting.

One last interesting thing to note with the use of the hydroblaster

presented itself on the I-90/Argonne to Sullivan project. The hydroblaster took off a small amount of cement paste and also caused some minimal cracking to the concrete under the stripe that was removed. See Photo 10 for this cracking.

7. HMA and the Hydroblaster

Using the hydroblaster on HMA can lead to pavement damage if Methyl Methacrylate (MMA), raised profile plastic markings, or thermoplastic markings are being removed. On the Spokane Viaduct Rut Repair project, it was assumed in design that the entire pavement striping to be removed was paint. However, during the removal process, it turned out there was a lot of degraded MMA under the paint stripe. See Photo 12. Production dropped from 200 feet per minute for paint to 20 feet per minute for the paint over MMA removal. The contractor had to put more powerful nozzles on the machine for the MMA removal (10 ksi to 40 ksi). When the hydroblaster removed MMA from HMA it blasted off some of the fines because the hydroblaster head was wider than the stripe. Because the MMA is much thicker it takes longer for the hydroblaster to remove it, thus taking fines and oil from the adjacent HMA.

Photo 12. Permanent paint stripe over unanticipated MMA pavement markings on the Spokane Viaduct project.

One solution proposed by industry to grind off the durable stripe or paint/durable stripe combination is the grind off the durable stripe down to the surface of the ACP and then go back over the stripe and remove it with the hydroblaster. The paving marking removal subcontractor on this project said that the costs for removal would not necessarily increase. There would be a stripe removal train with a small grinder and a hydroblaster, but production should be faster than two separate operations.

8. WSDOT Specifications-GSPs

There was considerable discussion at many offices on specifications. Some offices want to have specifications that only allow the use of the hydroblaster. However, it's use is not for universal application, see Observations 6 and 7 above. Some offices like the current specification the way it is, let the contractor decide which marking removal method to use. This review team recommended several alternatives for specification changes earlier in the report. See Appendix B for proposed General Special Provisions recommended by the team. The team also recommends a GSP to disallow the use of a shot/sand blaster.

9. Painting Over Pavement Markings

   Paint has been used to effectively mask the skip line on several different projects. Due to the very tight time frame in which these traffic switches must take place, timeliness becomes critical. Two offices used a gray paint to match the PCCP and actually mask the white line. In the Eastern Region where the MMA is inset, the hydroblaster is not ideal for removing this stripe because it takes so much pressure and as a result the concrete comes up along the edge and does not leave a smooth edge. It was found that grinding it out is better. Due to time constraints with grinding these slots, it was decided to stripe over these inset locations in gray paint. However, the MUTCD, 6F.71, states "Painting over existing pavement markings with black paint or spraying with asphalt shall not be accepted as a substitute for removal or obliteration". So this practice should be on a very limited basis.

10. Maintaining Temporary Stripe

    Currently, the temporary pavement marking bid item includes installation and maintenance of the striping. In some cases this gets to be an administrative burden on the part of WSDOT. The temporary paint striping gets placed and then it may be 6 months through a winter, that the temp stripe is expected to perform well. If the stripe does not perform well the contactor has to come back and repaint. This gets to be difficult in bad weather, when a certain temperature or surface condition is needed to reapply the paint. Additionally, contractors may be busy elsewhere and can not immediately respond to a WSDOT request for restriping the next day or week. A good practice on the I-90/ Argonne to Sullivan project was to direct the contractor to put down two coats of paint, so that it would perform better over the winter.

    Recommendation No.3 suggests a separate specification for installation and maintenance of temporary markings. This specification could even go as far as stating every 30 or 60 days, etc the temporary stripe must be refreshed. (Project scopers and designer would need to ensure sufficient funds were available if this were included in a GSP). This would allow the contractor to plan and budget for this repainting. It would reduce the amount of discussion between WSDOT and the contractor about maintenance of the temporary paint stripe if this were spelled out in the contract.

11. MMA Cure Time

    When MMA is placed over a brand new asphalt pavement, there is a 21 day cure period as required by the WSDOT Standard Specifications, 8-22.3(2). The Specifications also state that MMA applied on PCCP requires a cure period of 28 days. (The Specifications actually state Type D material requires these cure times. Section 9-34.1 defines Type D as liquid cold applied methyl Methacrylate). A common complaint from many project offices was that waiting for the 21 day cure period for HMA to lapse can lead to some projects wintering over because the permanent striping can not be placed until decent weather is

available after the 21 day cure has elapsed. The 28 day cure period for concrete is likely not as critical because PCCP is paved less frequently than HMA.

Ennis Paint, the manufacturer of Duraset pavement markings, requires that the roadway have at least 7 days of traffic flow, per their Application Guidelines. The local representative of Ennis relayed to the team that they are willing to be flexible on the 21 day cure for HMA. They typically come to the project and do a test section, then they come back in 24 hours and see how well the MMA has adhered to the pavement. They would be willing to work with WSDOT to shorten the time frame and the optimal cure time for each project.

The WSDOT Standard Specification could be amended to "a pavement cure period of 21 days, or less, as determined by the Project Engineer". Overall, the team recommends that an effort be made to work with the manufacturer and industry to determine if this time period can be shortened.

12. Foil Tape

    Foil tape is being used and its performance is less than satisfactory in most cases, particularly on major traffic routes. The standard specifications do not exclude the use of this type of temporary pavement marking. The foil backed tape does not stay affixed to the pavement, usually HMA, for the length of time it needs to, resulting in poor performance. It is suggested that the Standard Specifications be amended to exclude the use of this tape for high volume roadways. Foil backed tape is less expensive than the removable preformed tape, it may have limited application on some low volume roadways with a short term duration of use.

13. Subcontractor's Issues

    In speaking with the stripe removal subcontractors, they need time to gear up if many more projects are going to be exclusively marking removal with the hydroblaster. On several of the projects where the use of the hydroblaster was used on an experimental basis, the subcontractor was not immediately receptive to the idea. This equipment is expensive and in constant demand. The pump and the vacuum system is $200,000 and the truck is another $100,000. It is difficult for the subcontractor to drop everything on current projects and mobilize the equipment in for a test section. This will be reflected in the costs. Another concern that the subcontractors' have is the vacuum collected water issue. Some Regions may require treating the water, other Regions may not. In the past, one vendor, Apply-A-Line could not recycle their water; they had to have new water for the entire production. This needs to be known to the bidders.

14. Hydroblaster and Noise

    The hydroblaster was less noisy than a grinder on the I-5 317th Project. Although no direct sound readings were taken, this was the consensus of the project office. As construction noise becomes more of an issue on WSDOT projects. this aspect may studied more by WSDOT.

15. Using the Shotblaster

The SW Region and others offices are routinely using the shot blaster or other abrasive blasting. They report less of a ghost line by using a shot blaster than with a grinder. The grinder is generally only allowed on a temporary or final lift. Good production figures can be achieved with the use of a shot blaster. For example, for the Spokane Viaduct Replacement Project, the shotblaster was brought in as an emergency because the hydroblaster broke down. The production achieved for this work, removing one coat of temporary paint on PCCP, was approximately 1900 L.F./hr. Whereas the hydroblaster removal rate, same conditions, was 1700 L.F./hr. The office reported very good removal results and a clean surface. See Photo 13 for a comparison of hydroblasting and shotblasting on old latex PCCP on the viaduct. Because the shotblaster is so weather dependent, it is very important to anticipate and determine the risk that weather may have on the pavement marking removal production process. This

Photo 13. Hydroblasting on the left and shotblasting on the right on aged latex PCCP.

Best Practices

Throughout this review, the team participated in many good discussions and observed good practices in virtually all projects. A few of these good practices result in a project that runs very smoothly and produces a work zone that functions well and should be shared as best practices.

1. Weekly meeting with the contractor and subcontractor. On several projects WSDOT, the prime contractor, and all the pertinent subcontractors meet every week to discuss the future work activities. When it comes time for a traffic switch or lane reconfiguration, everyone meets and discusses the entire production of the lane shift. From the set up of the traffic control to the stripe removal to the ending traffic control setup, every detail is discussed. See Appendix F for examples of these plans. Diagrams are reviewed in order to provide the safest possible work environment. This is excellent work and should be encouraged throughout all project offices for large multi-stage projects. See Recommendation 5.

2. Complete removal of the adhesive that holds down the Type 1 and 2 pavement markers. On a few of the projects the team visited, the inspectors insisted that there be complete removal of the Type 1 and 2 marker adhesive. This really minimizes confusion to the driving public, because it removes the black spots from the roadway. On concrete pavement, the black adhesive is more noticeable than it is on ACP, but it can be very visible on aged ACP as well, if left in place.

3. Experienced staff is essential for safety; it can ultimately save money and produce a better product. Many offices were adamant that traffic switches may be the most dangerous aspect of these multi-staged projects. WSDOT needs to utilize their most experienced inspectors for this work. WSDOT was already doing this on many projects.

4. Removal of only the skip stripe versus the removal of a continuous line that includes a skip stripe. When only the skip stripe is removed there is less damage to the pavement. At least one project office directed the contractor to remove only the centerline skip stripe markings and not cause additional pavement damage by grinding the roadway between the skip stripes. This does require more effort on the contractor's part to set up the pavement marking removal equipment at each stripe, but it does less damage to the roadway.

Conclusion and Recommendations

There is no easy or inexpensive way to reduce ghost striping on WSDOT projects. This review team found no silver bullet to eliminate ghost striping, however, the team has provided some ways to reduce and mitigate ghost striping. The report also offers recommendations on other pavement marking issues; it should help designers choose which method of pavement marking removal is best for their project. This information should be beneficial to construction inspectors, design staff and ultimately the driving public.

Photo 14. I-82 in Yakima area, black out tape used over the summer months.

Due to the complexity of these pavement marking removal issues there were many discussions concerning how to mitigate ghost striping, reconfigure lanes and other ways to improve the work zone pavement markings and their removal. Some of this information needs to be entered into the WSDOT Lessons Learned Database. The review team ultimately came up with six recommendations for statewide consideration and implementation.

1. **Increase the Use of Removable Preformed Tape**
   By increasing the use of temporary tape during multi-stage projects, there will be less ghost striping. Temporary tape has the advantage of being removed without leaving any markings or ghost striping. It is not suitable for every project, but its use should be considered for more multi-staged projects. It typically costs 10-15 times the cost of temporary pavement markings. These costs are material costs and do not include removal or traffic control costs.

Action: Inform regional designers through annual WSDOT Design and Construction Conferences and other venues. Guidance will be developed in the future on this topic.
Responsible Parties: WSDOT HQ Program Management, Design, and the Traffic Offices followed by Regional support.

2. Reduce the cure time associated with MMA application over HMA.

When MMA is placed over a brand new asphalt pavement, there is a 21 day cure period as required by the WSDOT Standard Specifications, 8-22.3(2).
Ennis Paint, the manufacturer of Duraset pavement markings, requires that the roadway have at least 7 days of traffic flow, per their Application Guidelines.
Ennis Paint indicated that they are willing to be flexible on the 21 day cure.
The WSDOT Standard Specification could be amended to "a pavement cure period of 21 days, or less, as determined by the Manufacturer" or some other similar language.
Action: Work with industry to determine if the cure time can be reduced.
Responsible Party: HQ Traffic, Construction and Materials Lab Offices followed by Regional support.

3. Enhance the WSDOT Specifications

- Create a series of GSPs for Pavement Marking Removal

Standardized GSPs can give designers more flexibility for specifying pavement marking removal. The hydroblaster is a good tool, but traditional forms of pavement marking removal, such as grinding or shot blasting, may be preferable in some situations. This team has provided a starting point with a proposed GSP in Appendix B. The team envisioned taking these proposed GSPs to the WSDOT/AGC Roadway Team to get industry input. Additionally, a GSP to disallow the use of the shotblaster is recommended.
Action: Develop GSPs.
Responsible Party: HQ Construction Office followed by Regional support.

- Separate Bid Items for Installation and Maintenance of Temporary Pavement Marking

Create a separate bid item for the installation of temporary pavement markings and maintenance of temporary pavement markings. The current specification combines these two items. Very often the driving public encounters faded lane lines because the subcontractor has not adequately maintained the pavement markings. This often becomes an administrative burden for WSDOT to get the subcontractor to come back and maintain the markings. The team suggests this specification be developed in conjunction with the WSDOT/AGC Roadway Team to get industry input and final specification preparation.
Action: Develop GSPs.
Responsible Party: HQ Construction Office, followed by Regional support.

4. **Solid White Lane Line Markings**
   WSDOT should encourage the use of the solid white stripes for lane lines in transition areas and other alignments where a higher level of delineation is needed. The Manual on Uniform Traffic Control Devices (MUTCD) provides for this in 3B.04 "Wide solid lane line markings may be used for greater emphasis", and 6F.72. The use of the solid white line has been effective, by anecdotal evidence from several project offices. It provides better delineation to drivers through work zones, particularly through transition areas.
   Action: Inform WSDOT designers and field personnel through annual design/construction conferences and other venues.
   Responsible Parties: HQ Construction and HQ Traffic Offices followed by Regional support.

5. **Preplanning during Construction**
   WSDOT PEOs must outline their expectations for lane reconfigurations and traffic switches to the contractor at activity meetings particularly for multi-staged projects; these expectations must be in the contract documents. Institute better communication with the contractor and all involved prior to shifting traffic. Emphasize that wide lanes are not acceptable; diagrams may be helpful, etc. More upfront planning may eliminate ghost striping.
   Action: Share at winter design/construction conferences; add more guidance to the construction manual.
   Responsible Party: HQ Traffic and Construction Offices followed by Regional support.

6. **Project Development Phase**
   WSDOT should expect temporary channelization plans to be identified early. In the past not enough thought has gone into developing traffic control plans for staged construction. The stages are too loosely defined and may result in wide lanes. Traffic control plans need to address all of the stages. Additionally, more plan review will improve the plans and may catch plan errors such as incorrect pavement markings currently existing in the field.
   Action: Change Design Manual to include maximum lane width for work zone traffic control. Inform WSDOT designers and project development staff through annual design/construction conferences and other venues. Encourage WSDOT PEOs to carefully review and comment on project plans before contract goes to ad. Share Matrix that was developed, See Appendix A**.**
   Responsible Parties: HQ Design and Traffic Offices followed by Regional support.

APPENDIX A

Pavement Marking Removal Method Guidelines Matrix

Details such as pavement type, weather, surface condition of the pavement, and contractor's equipment all have an impact on the production rate and cost of pavement marking removal. These guidelines were established from an FHWA/WSDOT Joint Review conducted in 2006.

H = Hydroblasting S = Shotblaster or Sandblaster G = Grinder

	Hot Mix Asphalt (HMA)		Portland Cement Concrete Pavement (PCCP)
Pavement Marking Type	Dense graded	Open Graded	
Paint or Temporary Paint	H,S,G (2)(4)(6)	H,S,G (2)(4) (7)	H, S, G(1)(2)(4)(8)
Thermo-plastic-Type A or B	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)
Preformed Tape-Type C	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)
MMA-Type D	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)
Paint over MMA or Thermo plastic	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)
Epoxy from RPMs(3)	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)	G followed by H or S (2) (4) (5)

Notes

(1) May be an increase in glare when grinding on older polished concrete, especially at night, as compared to hydroblasting.

(2) Shot blasting should not be used during wet weather or on wet pavement. The filter system on the equipment can plug up with paint chips. This can result in reduced production.

(3) Raised Pavement Markings

(4) None of the methods should remove the pavement deeper than 10 mils because it will cause pavement damage.

(5) For best results, plastic, MMA, and profiled plastic pavement markings should be removed by grinding to the pavement surface with the final removal done by sandblasting, steel shot blasting or hydroblasting to minimize ghost striping.

(6) For dense graded HMA, the production rates may be similar for all three removal methods. The sealed up surface of the dense graded HMA should allow the hydroblaster and the shot blaster to readily clean the surface, while the grinder should be able to cut through HMA relatively easily.

(7) For open graded asphalt, the production rates may be higher for grinding versus hydroblasting and shot blasting because the hydroblaster and shot blaster have to clean the open graded surface rather than cut through it.

(8) For PCCP, the production rates for hydroblasting may be higher than for grinding because the grinder has to cut through the pavement, whereas the hydroblaster and shotblaster are cleaning the surface. This can vary depending on what type of equipment is used and how hard the PCCP is.

APPENDIX B

Proposed General Standard Specifications (GSPs)

Draft A – alternative to minimize shadow stripes by specifying only hydroblasting, shot blasting or sand blasting.

Section 8-22.3(6), Removal of Pavement Markings, shall be supplemented as follows:

> Sandblasting, steel shot blasting or hydroblasting shall be used for removing pavement markings. Vacuum shrouded equipment, or other equally effective means, shall be used to contain and collect all pavement marking debris, water, or spent abrasive. Collected debris shall be disposed of off the project site and in accordance with Department of Ecology or other federal, state or local regulations.

Draft B – alternative to minimize shadow stripes by not allowing the use of grinders.

Section 8-22.3(6), Removal of Pavement Markings, shall be supplemented as follows:

> Use of a grinder to remove pavement markings will not be allowed.

Draft C – alternate to minimize shadow stripes by requiring hydroblasting as the only option.

Section 8-22.3(6), Removal of Pavement Markings, shall be supplemented as follows:

> Only hydroblasting equipment will be allowed for removal of pavement markings. Vacuum shrouded equipment, or other equally effective means, shall be used to contain and collect all pavement marking debris and excess water. Collected water and debris shall be disposed of off the project site in accordance with Department of Ecology or other federal, state or local regulations.

APPENDIX C

PAVEMENT MARKING REMOVAL PROCESS QUESTIONNAIRE

Date of Review _____

Names of Reviewers _____

Project Name _____

Project Location _____

Project Engineer _____

1. Did the project have a bid item for pavement marking removal?

2. What pavement marking materials were removed?

    a. Paint

    b. Thermoplastic: transverse and symbol markings, longitudinal line, longitudinal line profiled
    c. MMA, Transverse and symbols, longitudinal line, longitudinal line profiled

3. When were the pavement markings removed/different stages?

4. What method of pavement marking removal was used?

5. Were the quantities enough to complete the work? Did the contract adequately provide for the pavement marking removal?

6. How well were the pavement markings removed? What was the production rate for the type of material and the method of removal?

7. Did the same marking have to be removed more than once?

8. Ghost stripes or residual stripe?

9. Any pavement damage?

10. If grinding, shot blasting, or sand blasting was used to remove the pavement markings, was the debris collected and disposed of properly?

11. Was this work done at night? What was the average production of the stripe removal?

12. What were the costs for the pavement marking removal?

13. Was there a specific plan to detail the markings to be removed, new/temp marking replacement, reference to a TCP during removal, temp. channelization plan and pavement marking detail?

14. Was the marking removal and replacement work adequately addressed with consideration of production rates, equipment or material restrictions, environmental or site issues, conflicting or otherwise hazardous traffic condition as a result of marking removal?

15. Were any specifications other than 8-22 & 23 included?

16. Results.....successful or not? Would be interesting to know of any innovations or pitfalls.

APPENDIX D

Field Review Summaries

WSDOT Contract Number	Project Name	Region	Site Visit Date	Project Engineer	People Involved in Review
#7108	Spokane Viaduct Bridge Deck Rut Repair	Eastern	May 15, 2006	Darrel McCallum (509) 324-6244	Robert Blegen , Darrel McCallum, Steve Saxton, Cathy Nicholas
#6801	I-5, NE 175th	Northwest	May 4, 2006	Amir Ahmadi (425) 225-8700	Sherry Felke, Phil Fordyce, Amir Ahmadi, Farshid Namiranian, Chuck Smith, Cathy Nicholas (Follow-up discussions with Robert Wofford)
#6610	I-5, Salmon Creek Widening	South West	May 16, 2006	Casey Liles (360) 905-1537	Chris Edwards, Steve Saxton Cathy Nicholas
#6759	I-5, North of Lakeway I/C Phase 1A	Northwest	May 3, 2006	Chris Damitio (360) 788-7403	Larry Eik, Brian West, Patrick Fuller, Phil Fordyce, Cathy Nicholas
#6757	I-5/Federal Way-317th St HOV Direct Access	Northwest	May 2, 2006	John Chi (206) 768-9002	Phil Fordyce, Jim Spaid, Bryan Dillon, Chad Brown, Kevin Hepler Cathy Nicholas
#6958	I-5, 48th St to Pacific	Olympic	May 25, 2006	Howard Diep (253) 589-6100	Larry Eik, Troy Watts, Howard Diep, John Diffenbacher, Cathy Nicholas
#6473	I-5, 36th U/C to Vic SR 542, Phase 1	Northwest	May 3, 2006	Chris Damitio (360) 788-7403	Patrick Fuller, Jeff Petersen, Brian West, Larry Eik, Cathy Nicholas

(Information from the completed questionnaires may be obtained from Cathy Nicholas at FHWA.)

APPENDIX E

References

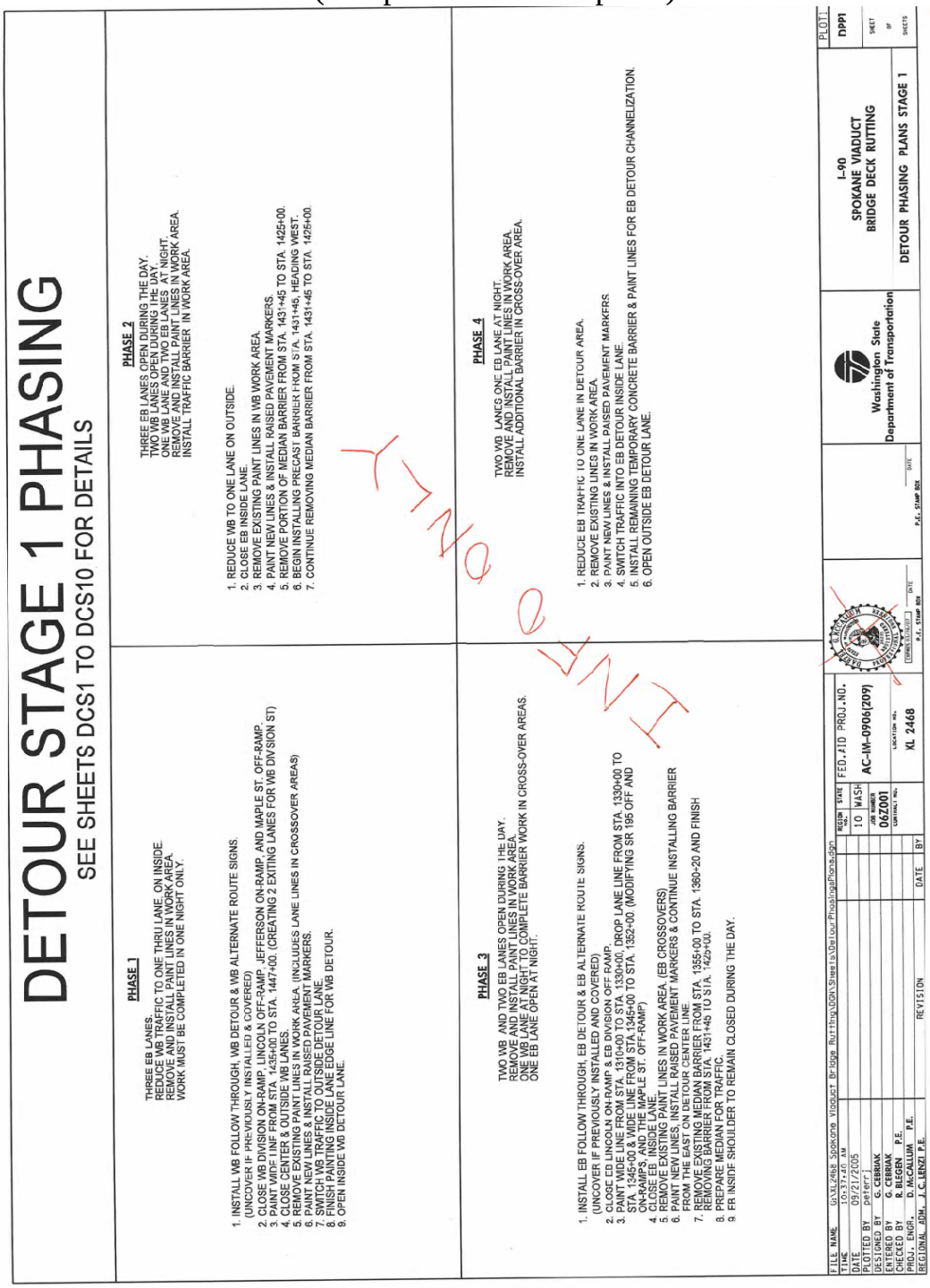
(1)Taking it Off, Pavement Maintenance & Reconstruction, May 2005, Becky Wasieleski, pages 12-13
(2) Waterblasting Technologies Report to Pavement Marking Removal Work Team, January 27, 2006.

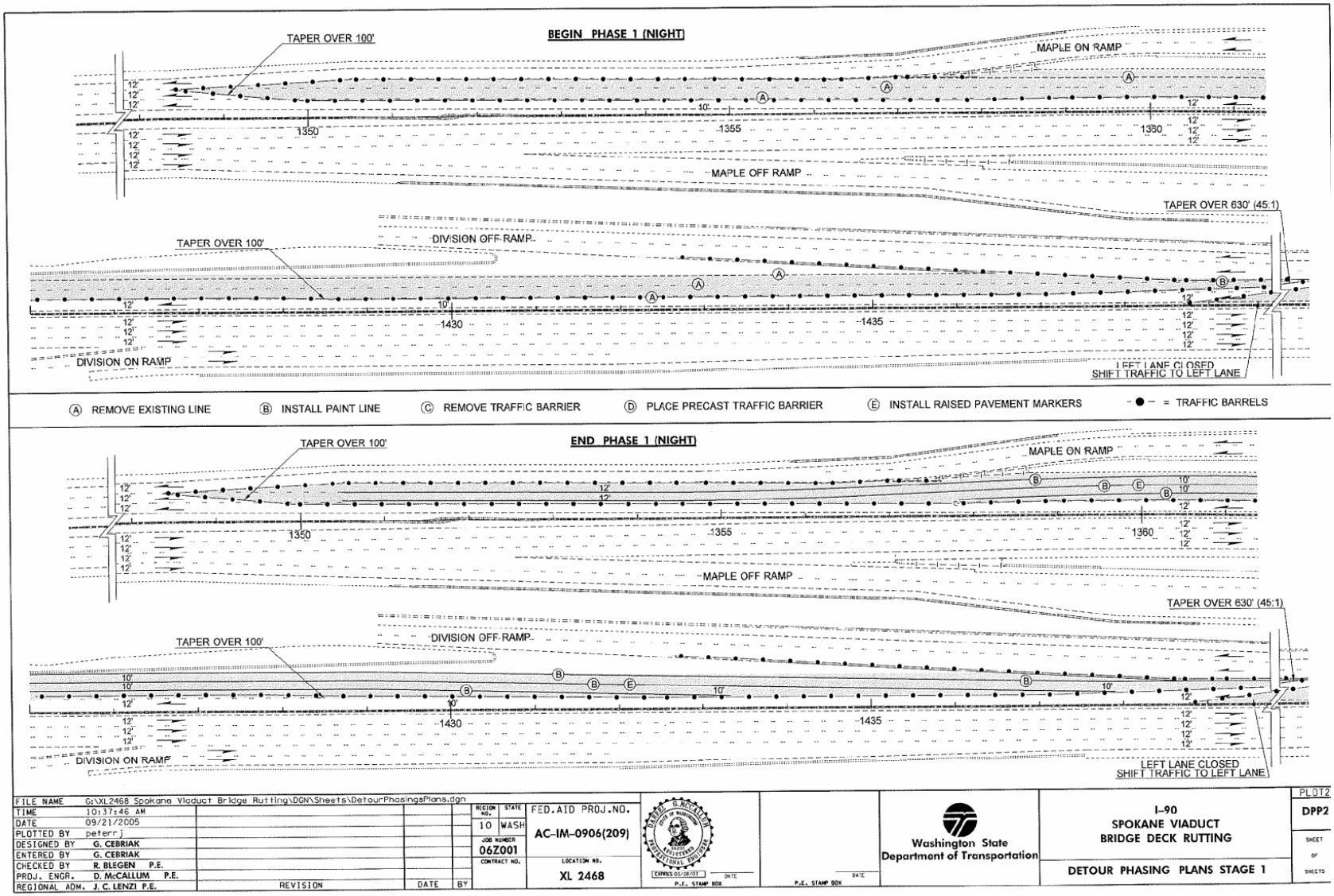
APPENDIX F

Spokane Viaduct Bridge Deck Rutting

Stage 1 Phasing- Conceptual plans to demonstrate a way to walk into and out of the detour safely while maintaining traffic.

(Not part of contract plans)





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DESIGNED BY	G. CEBRIAK
ENTERED BY	G. CEBRIAK
CHECKED BY	R. BLEGEN P.E.
PROJ. ENGR.	D. McCALLUM P.E.
REGIONAL ADM.	J. C. LENZI P.E.

REVISION	DATE	BY

REGION NO.	STATE
10	WASH

JOB NUMBER 06Z001
CONTRACT NO.

FED.AID PROJ.NO. AC-IM-0906(209)
LOCATION NO. XL 2468

EXPIRES 03/28/07 DATE
P.E. STAMP BOX

DATE
P.E. STAMP BOX

Washington State Department of Transportation

I-90
SPOKANE VIADUCT
BRIDGE DECK RUTTING

DETOUR PHASING PLANS STAGE 1

PLOT2 DPP2
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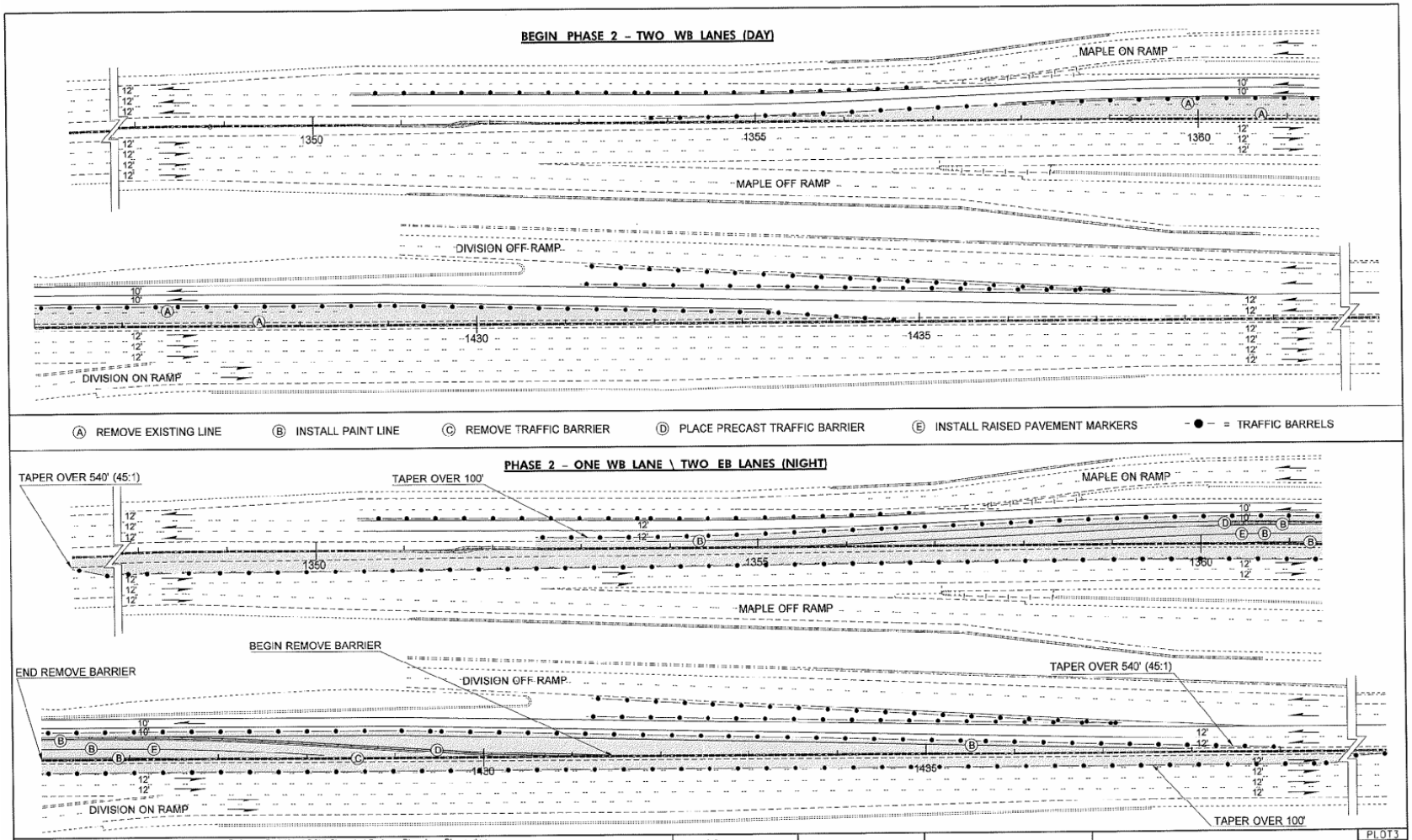

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REGIONAL ADM.	J. C. LENZI P.E.

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | JOB NUMBER 06Z001 | CONTRACT NO.

FED. AID PROJ. NO. AC-IM-0906(209)

LOCATION NO. XL 2468

EXPIRES 03/26/07 DATE P.E. STAMP BOX

DATE P.E. STAMP BOX

Washington State Department of Transportation

I-90
SPOKANE VIADUCT
BRIDGE DECK RUTTING

DETOUR PHASING PLANS STAGE 1

PLOT3 DPP3

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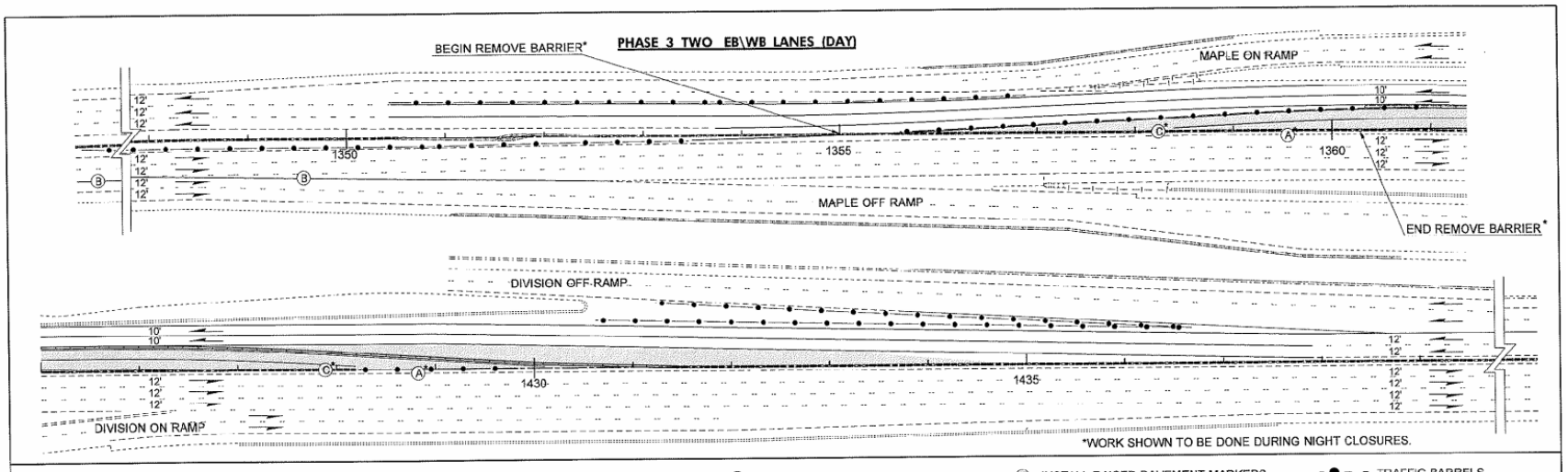

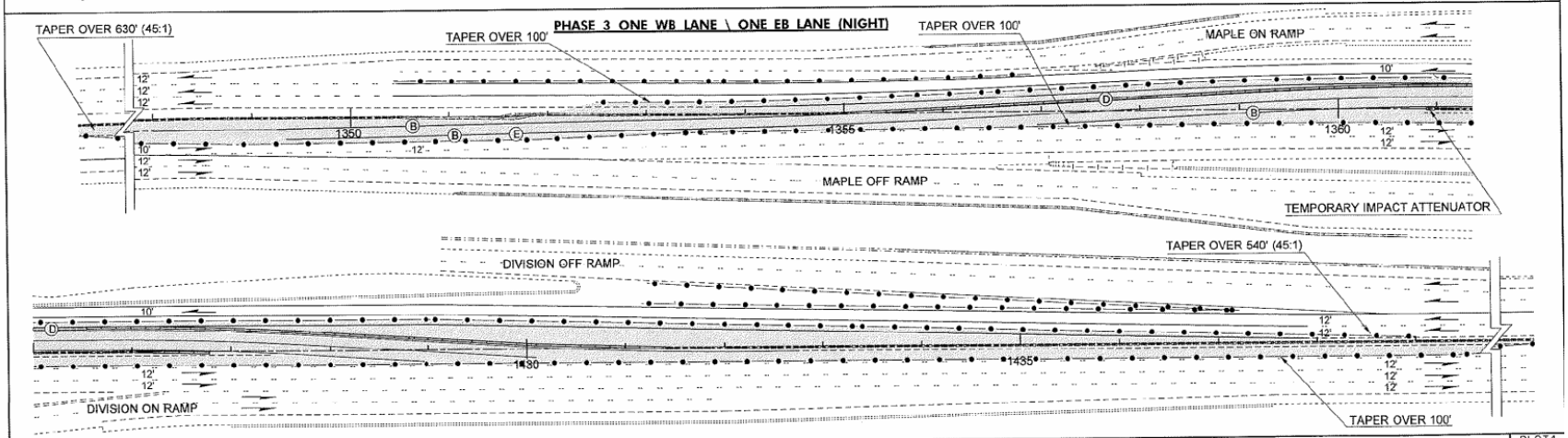

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CHECKED BY	R. BLEGEN P.E.						
PROJ. ENGR.	D. McCALLUM P.E.						
REGIONAL ADM.	J. C. LENZI P.E.	REVISION	DATE	BY			

EXPIRES 03/09/07 — DATE — P.E. STAMP BOX

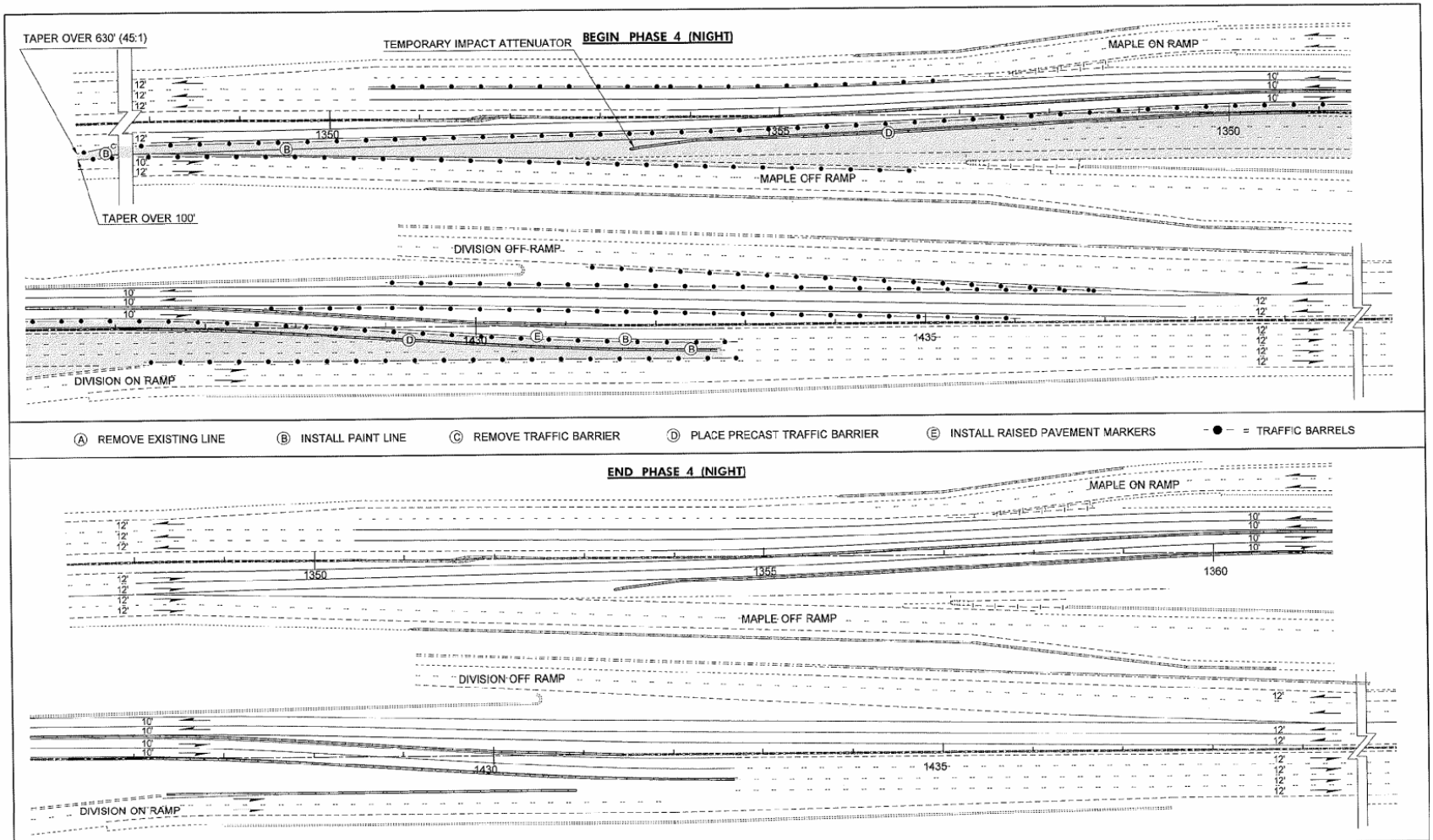
DATE — P.E. STAMP BOX

Washington State Department of Transportation

I-90
SPOKANE VIADUCT
BRIDGE DECK RUTTING

DETOUR PHASING PLANS STAGE 1

SHEET OF SHEETS



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TIME	10:38:02 AM
DATE	09/21/2005
PLOTTED BY	peterrj
DESIGNED BY	G. CEBRIAK
ENTERED BY	G. CEBRIAK
CHECKED BY	R. BLEGEN P.E.
PROJ. ENGR.	D. McCALLUM P.E.
REGIONAL ADM.	J. C. LENZI P.E.

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | JOB NUMBER 06Z001 | CONTRACT NO.

FED.AID PROJ.NO. AC-IM-0906(209)

LOCATION NO. XL 2468

EXPIRES 03/26/07 DATE P.E. STAMP BOX

DATE P.E. STAMP BOX

Washington State Department of Transportation

I-90
SPOKANE VIADUCT
BRIDGE DECK RUTTING

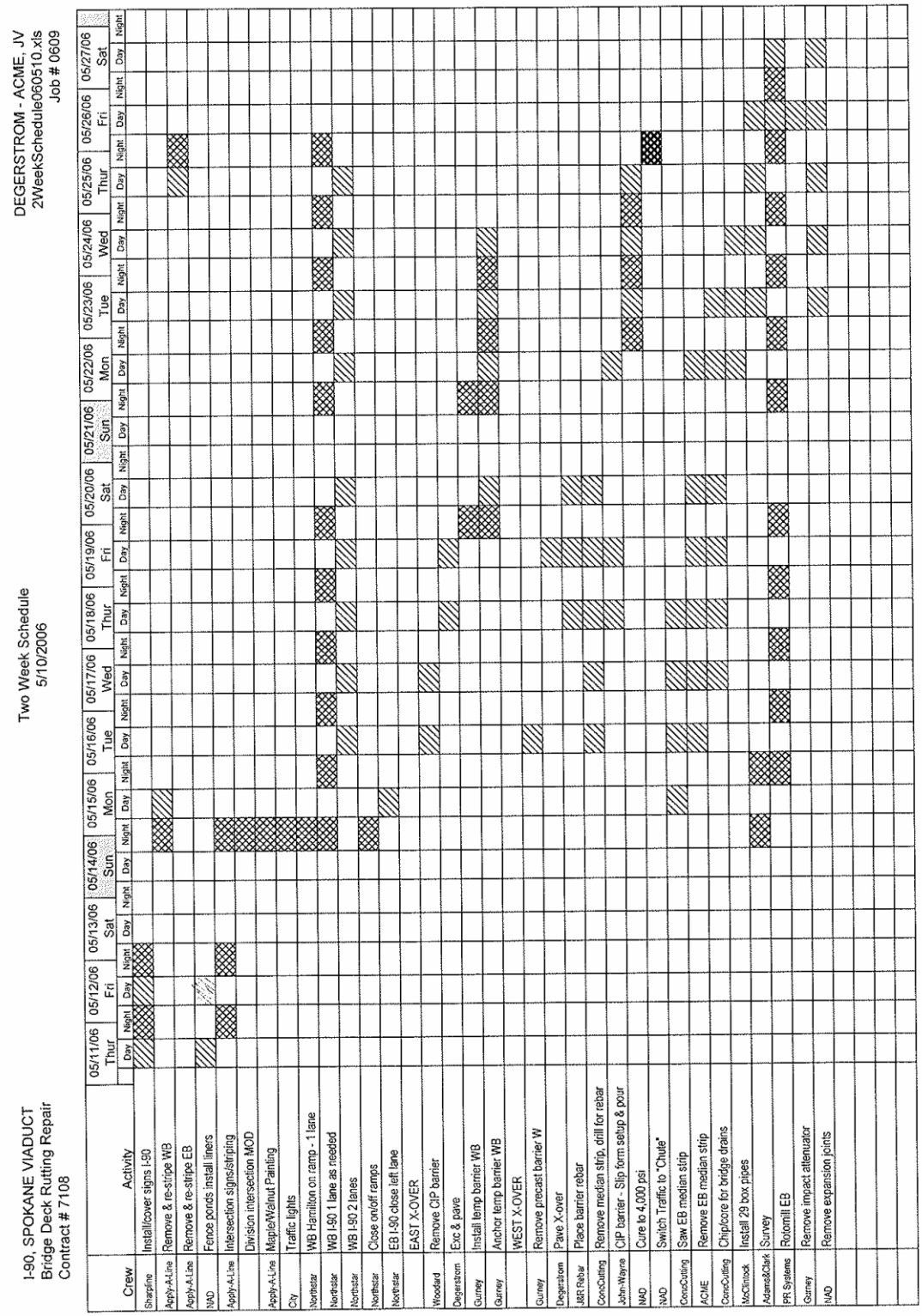
DETOUR PHASING PLANS STAGE 1

PLOTS DPP5 | SHEET OF SHEETS

Appendix F Continued

Spokane Viaduct Bridge Deck Rutting

Timeline of Workzone activities during Stage 1 Phasing work



Interstate 90/Downtown Spokane

Tentative Schedule

Note: Lane restriping REQUIRES dry weather. This schedule is subject to change.

Now

- Work Underway
  - Contractor has placed informational portable variable message signs at various locations on I-90 announcing the work.
  - Placement of alternate route directional signing is underway. Signs are placed and covered until needed.
- Traffic Impacts
  - Some night freeway restrictions may be possible at times.
  - Possible brief city street restrictions at sign placement locations.

Sunday Evening-May 14, 2006 into Monday morning-May 15, 2006 until 6:00 a.m.

- Work Underway
  - Freeway signage put into place, uncover alternate route signs on surface streets.
  - Lane stripe removal and painting.
- Traffic Impacts
  - The following ramp closures go into effect at various times during these hours as work progresses.
    - Eastbound Maple/Walnut On Ramp-Closed
    - Eastbound Monroe On Ramp-Closed
    - Eastbound Division Off Ramp-Closed
    - Westbound Browne On Ramp-Closed
    - Westbound Lincoln Off Ramp-Closed
    - Westbound Monroe/Jefferson On Ramp-Closed
  - I-90 reduced to two lanes in each direction
    - (one lane possible during evening and night hours)
    - Lane widths may vary
    - Traffic will remain on existing sides
- Speed Limits (in effect until mid September
  - Eastbound speed limit reduced to 55 mph from top of Sunset Hill to US 195.
  - Eastbound speed limit reduced to 45 mph from US 195 to Hamilton until mid-September
  - Westbound speed limit reduced to 45 mph from Hamilton to US 195

Monday morning-May 15, 2006, 6:00 a.m. for up to 10 days.

- Work Underway

- Pavement stripe removal and painting
- Concrete pavement grinding
- Concrete barrier placement
- Drainage modifications
- Minor paving

- Speed Limits
  - Same as above
- Traffic Impacts
  - Same ramp closures as above now in effect until mid-September.
  - Westbound I-90 through traffic lanes now 10 ½ feet wide and no shoulders.
    - Will be in a "chute" with concrete barrier and barrels as barrier placement proceeds.
  - Westbound lanes have solid center stripe-NO LANE CHANGES ALLOWED IN CONSTRUCTION ZONE.
  - I-90 reduced to two lanes in each direction
    - (one lane possible during evening and night hours)
    - Eastbound lane widths may vary

Sometime during the week of May 22-26 during overnight hours (depending on weather and the contractors progress).

- Work Underway
  - Traffic shift
- Speed Limits
  - Same as above
- Traffic Impacts
  - Eastbound traffic will be shifted into the "chute" with 10 ½ foot lanes and no shoulder
  - Eastbound lanes now have solid center stripe-NO LANE CHANGES ALLOWED IN CONSTRUCTION ZONE.
  - Ramp closures same as above
  - Westbound same as above

Following the eastbound traffic switch, the following will be in place until mid-September, 2006:

- Work Underway
  - Removal of existing concrete surface,
  - Repair underlying deck,
  - Repair drainage,
  - Install new expansion joints,
  - Place new concrete surface on the south half of the downtown freeway..

- Traffic Impacts
  - The following ramp closures go into effect at various times during these hours as work progresses.

        - Eastbound Maple/Walnut On Ramp-Closed
        - Eastbound Monroe On Ramp-Closed
        - Eastbound Division Off Ramp-Closed
        - Westbound Browne On Ramp-Closed
        - Westbound Lincoln Off Ramp-Closed
        - Westbound Monroe/Jefferson On Ramp-Closed
    - I-90 reduced to two lanes in each direction
        - (one lane possible during evening and night hours)
        - Eastbound and Westbound lane widths – 10 ½ feet with no shoulders.
    - Eastbound and Westbound lanes now have solid center stripe
        - NO LANE CHANGES ALLOWED IN CONSTRUCTION ZONE.
- <u>Speed Limits (in effect until mid September</u>
    - Eastbound speed limit reduced to 55 mph from top of Sunset Hill to US 195.
    - Eastbound speed limit reduced to 45 mph from US 195 to Hamilton until mid-September
    - Westbound speed limit reduced to 45 mph from Hamilton to US 195