The Pennsylvania State University

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COMPARATIVE ANALYSIS OF COMMONLY USED AGGREGATE MATERIALS AND PLACEMENT METHODS FOR A SURFACE WEARING COURSE ON LOW-VOLUME ROADS IN PENNSYLVANIA

A Thesis in

Environmental Pollution Control

by

Steven M. Bloser

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The thesis of Steven M. Bloser was reviewed and approved* by the following:

Barry E. Scheetz
Professor of Material, Civil, and Nuclear Engineering
Thesis Advisor

Ghassan R. Chehab
Assistant Professor of Civil Engineering

Mian C. Wang
Professor of Civil Engineering

Raymond W. Regan
Professor of Environmental Engineering
Program Chair for Environmental Pollution Control

*Signatures are on file in the Graduate School.

ABSTRACT

Aggregate surfaced roads are a viable component of the transportation network that provide significant increases in stability over earthen surfaced roads, while avoiding the high placement and maintenance costs associated with pavements. The use of higher quality, more stable aggregates will make significant reductions to both the cost of maintaining gravel roads, and the environmental concerns related to unpaved road runoff. The objective of this thesis is to provide a better understanding of wearing coarse aggregates by describing a comparative analysis experiment done through Pennsylvania's Dirt and Gravel Road Maintenance Program. Three commonly used aggregates in Pennsylvania were placed side-by-side using two different placement methods as part of a three year study to compare their long-term durability and cost effectiveness. The two placement methods tested were the "dump and spread" method known as tailgating, and the application of aggregate through a paver. Cross-sectional surveys were conducted on each aggregate section for three years following placement to determine elevation changes in the road surfaces. Throughout the study, there was no significant difference in performance between aggregate sections placed with a paver when compared to the same aggregate placed by tailgating. Driving Surface Aggregate (DSA), a product developed for use as a wearing course for unpaved roads in Pennsylvania, was the only aggregate of the three tested that did not show a statistically significant change in road elevation over the three year course of study. The DSA in this study also had the lowest overall degree of rutting of the aggregates tested. The results of this study emphasize the importance of selecting a properly graded aggregate for use as surface aggregate on low-volume roads to reduce maintenance costs and sediment pollution. The study also identifies several aspects of unpaved road aggregate selection where additional research is needed.

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Chapter 1. INTRODUCTION

Unpaved roads continue to make up an important part of the worldwide transportation network, even in developed nations such as the United States. As of the year 2000, approximately 39.3% of the 3,900,000 miles (6,300,000 km) of publicly owned road in the United States were unpaved (Forman, 2003). Uncounted additional miles of unpaved private driveways, access roads, and farm/ranch lanes are also scattered across the country. One of the most visible and expensive practices done to improve unpaved roads, both public and private, is the addition of a crushed rock aggregate as a driving surface. Surface aggregate refers to a size-specific mixture of crushed rock that is applied several inches thick to the surface of unpaved roads. The continual placement of surface aggregate on unpaved road has serious environmental and economic implications. The purpose of this research is to evaluate several of Pennsylvania's commonly used surface aggregates and placement methods to determine the most economic and environmentally sensitive strategies for surfacing unpaved roads.

1.1 Background

Choosing an appropriate road aggregate must take into consideration both economic and environmental factors. Those factors are summarized below, along with a detailed discussion of the Driving Surface Aggregate (DSA) specification that has been developed by the Center for Dirt and Gravel Roads at Penn State University.

1.1.1 Environmental and Economic Implications

As of the year 2000, 78% of the 1,500,000 miles (2,400,00 km) of public unpaved roads in the United States were surfaced with some type of stone or gravel (Forman, 2003). The Commonwealth of Pennsylvania, despite several large metropolitan areas, currently has over 20,000 miles (32,206 km) of publicly owned unpaved roads, most of which are also surfaced with some type of crushed rock aggregate. These low-volume roads serve as a major part of the infrastructure for Pennsylvania's four largest industries of tourism, agriculture, mining, and timber harvesting (PennDOT, 2000). Placement of aggregate on unpaved roads has been practiced for decades throughout Pennsylvania and other states. A crushed rock aggregate provides a more durable road surface for heavy vehicles, and is less prone to failure than native surfaces. Aggregate roads also provide advantages over asphalt roads because they are cheaper and easier to create and maintain. Aggregate is typically applied to roads every couple of years as conditions warrant and local road maintenance budgets allow. There are extremely high costs, economic and environmental, associated with this practice of spreading aggregate over thousands of miles of roadway each year.

To often in today's society, environmental issues are at odd with economic pressures. Many times in these situations, potential environmental benefits are not realized until they become economically feasible. Fortunately, in the case of unpaved road surfaces, environmental and economic benefits are one in the same. The goal of good road aggregate is to provide long term durability and resist erosion.

The economic benefits of longer lasting, more durable aggregates are substantial. Although statistics on surface aggregate spending are not readily available, it is likely that millions of dollars are spent annually to maintain and resurface the unpaved road network in Pennsylvania alone. The use of a longer lasting surface aggregate will reduce the amount of maintenance required on a road for several years after placement (Foltz, 1995). Aggregate maintenance, usually involving the cutting and reworking of aggregate with a motor-grader to re-establish crown, is costly in terms of manpower and equipment time. In addition to lengthening the maintenance cycle for unpaved roads, better aggregates will also provide the road with a longer total lifespan. Long term economic benefits can be realized when aggregate application cycles are lengthened due to the use of more durable materials.

Although well documented, the environmental impacts of unpaved road runoff are often overlooked by road maintenance professionals. Unfortunately, the majority of aggregate spread on unpaved roads each year is eventually carried away from the road in the form sediment in rainfall runoff (Forman, 2003). Erosion of the road surface occurs due to traffic pressures, maintenance activities, raindrop impacts, and water movement.

Any loose material generated from the road surface is mobilized in runoff during rain events. Runoff containing eroded aggregate from the road surface is usually collected in ditches that run parallel to the road. These ditches collect and concentrate road drainage until they leave the road area, either through a cut in the road bank or a culvert (cross-drain or crosspipe) under the road. Many times, these ditches and crosspipes drain water directly into adjacent streams, lakes, and wetlands. Figure 1 illustrates a road ditch as it empties road sediment into a stream at a typical crossing in Pennsylvania during a moderate rain event. To gain a more complete perspective on the pollution potential of unpaved road runoff, the ditch pictured in Figure 1 needs to be multiplied by four, in order to account for the other three ditches not pictured at this single bridge. The four ditches at this one stream crossing then need to be multiplied by the tens of thousands of stream crossings that exist on Pennsylvania's 20,000 miles of unpaved public roads. As they wear down and wash away, many of these roads are continually being surfaced with some form of surface aggregate. Any improvement in the durability and erosion resistance of surface aggregates will achieve extensive reductions in the amount of sediment pollution generated by unpaved roads.

Figure 1. Ditches from the unpaved road in the background dump sediment into a High Quality stream at a bridge crossing near Clarion, PA.

The infusion of large quantities of road sediment can have many negative ecological impacts on the aquatic ecosystem. In general, excessive sediment loading will cause the deterioration or destruction of aquatic habitat in the receiving waters (Novotny, 2003). Sediment can coat the bottom of streams and rivers as it settles out of the water in slow moving areas. This can cause the loss of habitat for aquatic plants as well as the loss of fish spawning areas. Increased sediment loads will also increase the turbidity of the water and lower the total energy available to the aquatic system. Chronic sedimentation also has direct negative effects on fish and other aquatic organisms due to the abrasion of the suspended sediments. Sediment particles are often host to many other pathogens such as excess nutrients, heavy metals, and road oils or salts. Additionally to the ecological effects describe above, the effect of excessive sedimentation on lake and wetland ecosystems can result algae blooms, eutrophication, and the rapid loss of storage capacity. Excessive sedimentation can effectively fill in lakes and choke wetlands shut. (Novotny, 2003)

Additionally to the direct erosion resistant properties of better aggregates, other environmental benefits are achieved by lengthening the maintenance cycle for unpaved roads as previously discussed under economic implications. Every time a motor-grader is used to reshape a road, it loosens the road material and makes it more available for erosion and transport into nearby waterways (Coe, 2006). Grading also has detrimental environmental effects when ditches and road banks are inadvertently or intentionally scrapped or “cleaned” as part of road grading. A better surface aggregate will result in several less grading cycles, and therefore less erosion, over the life of the aggregate. Both environmental impacts and maintenance costs for unpaved roads can be reduced by using durable surface aggregates that resist erosion and lengthen maintenance cycles.

1.1.2 Driving Surface Aggregate

The environmental effects of dust and sediment pollution from unpaved roads have been well documented. A summary of these effects can be found in the literature review. These environmental impacts have resulted in the creation of the Dirt and Gravel

Road Maintenance Program (Program) in Pennsylvania. The State's Dirt and Gravel Road Maintenance Program has allocated more than $45,000,000 over the past decade to local municipalities in order to reduce sediment pollution from unpaved roads. The Program funds road improvement projects that focus on long-term reductions of erosion, maintenance, and pollution associated with publicly owned unpaved roads. The Program also funds an "Environmentally Sensitive Maintenance for Dirt and Gravel Roads" training to educate local road owning entities about reducing the environmental impact and maintenance costs of their roads. Penn State University's Center for Dirt and Gravel Road Studies (Center) has worked closely with Pennsylvania's Dirt and Gravel Road Maintenance Program over the past decade. The Center's mission includes development and delivery of the "Environmentally Sensitive Maintenance for Dirt and Gravel Roads" training. The Center also provides research, documentation, and technical assistance on environmental issues relating to unpaved road maintenance.

One of the early problems identified by the Center was a lack of proper aggregate for use on unpaved roads. Many local road-owning entities throughout Pennsylvania have been surfacing roads with available aggregates that were never designed or intended to be used as a wearing course on roadways. Upon its founding in 1999, the Center immediately began working with aggregate producers and industry experts to develop an aggregate specification designed for use as a wearing course on unpaved surfaces. The resulting product, called Driving Surface Aggregate (DSA), has been increasing in use and acceptance throughout the state since its development in 1999. DSA was approved by the Pennsylvania Department of Transportation, Bureau of Municipal Services, in 2007 and is available throughout the Commonwealth. DSA is designed for maximum compaction density and abrasion resistance to provide a more durable road surface with less erosion and maintenance (Penn State, 2006). The Center recommends that DSA is to be placed at optimum moisture through a paver to minimize aggregate segregation by size (Penn State, 2006). While DSA is increasing in use and popularity in Pennsylvania, no quantitative studies have been completed on the effectiveness or longevity of this aggregate in the field. One goal of this research is to provide a better understanding of wearing coarse aggregates by describing a comparative aggregate study that includes

DSA and several other commonly used aggregate gradations. DSA was placed side-by-side with two traditionally used aggregates in a three-year cost and performance study in cooperation with the Pennsylvania Bureau of Forestry. The purpose of this research is to evaluate several of Pennsylvania's commonly used surface aggregates and placement methods to determine the most economical and environmental sensitive strategies for unpaved roads.

1.2 Study Variables

Three different road aggregates were compared in this study. Each aggregate was placed using two different methods, for a total of six distinct test sections of approximately 1,000 feet (305 m) each. This study represents the most common type of surface aggregate placements that occur on a regular basis throughout Pennsylvania. Although not a requirement of any of the specifications, the parent material for all of the aggregates used in this study is limestone. Table 1 lists the size gradation ranges, along with the actual tested gradations of the aggregates used in this study. Each aggregate was made by the same quarry from the same source in order to reduce all potential variations outside of size gradations.

AGGREGATE	**SPECIFICATION - Total Percent Passing**								
	2"	**1.5"**	**3/4"**	**3/8"**	**#4**	**#8**	**#16**	**#100**	**#200**
DSA	-	100	65-90	-	30-65	-	15-30	-	10-20
2A	100	-	52-100	36-70	24-50	16-38	10-30	-	0-10
2RC	100	-	-	-	15-60	-	-	0-30	-
AGGREGATE	**ACTUAL - Total Percent Passing**								
	2"	**1.5"**	**3/4"**	**3/8"**	**#4**	**#8**	**#16**	**#100**	**#200**
DSA	-	100	89	-	44	-	20	-	15.4
2A	100	-	85	55	34	24	14	-	9
2RC	100	-	-	-	56	-	-	-	20

Table 1. Specified gradation ranges and actual gradation of the three tested aggregates.

1.2.1 Aggregates

"DSA", or Driving Surface Aggregate, is a specification developed by the Center for Dirt and Gravel Road Studies at Penn State University in 1999. It is designed to achieve maximum compaction density and is intended to be used as a wearing course for unpaved roads. DSA has a max-size of 1.5 inches (38 mm), a nominal max-size of ¾ inch, and a larger percentage of fine material (10-20% passing #200 sieve) when compared to the other aggregates. Another important consideration of the DSA specification is the strict limitations on clay or soil content. At least 98% of the fines passing the # 200 sieve must be crushed native rock. No silt, soil, or clay may be added (Penn State, 2006) (Table 1). It should be noted that the specification for the DSA gradation range was changed in 2006, after this study. More details on this change are provided in the discussion.

"2A" is an aggregate specification used by the Pennsylvania Department of Transportation as a base to be placed under asphalt. Although not designed as a wearing course, it is the most commonly used aggregate for surfacing unpaved roads in Pennsylvania. 2A has a max-size of 2 inches (51 mm) and has relatively little fine material (0-10% passing #200 sieve) compared to the other two aggregates. (Table 1)

"2RC" is a "dirty" aggregate that has many uses as fill material and as a base for asphalts. As shown in Table 1, the specification range for 2RC is fairly broad. 2RC allows soil and clay fines to be included in the aggregate. Aggregates with clay or soil fines such as this are often used by the PA Bureau of Forestry and other road maintenance professionals around Pennsylvania. The specific 2RC used in this study was created by adding 5% by weight of clay to the DSA aggregate.

1.2.2 Aggregate Placement Methods

Tailgating is the traditional method of placing aggregate throughout most of Pennsylvania and is commonly practiced by the PA Bureau of Forestry and most municipalities. Tailgating, shown in Figure 2A, involves dumping aggregate out of trucks directly onto a road and spreading it with equipment such as a bulldozer or motor-grader to achieve the final road shape. Compaction is accomplished by the movement of successive loaded aggregate trucks over aggregate that has already been placed. The continued grading and movement of aggregate into place may result in aggregate segregation by size, which will create a less stable road surface. The quality of a tailgated aggregate placement is highly dependent on the skill of the motor-grader operator to distribute the aggregate as evenly as possible over the entire roadway.

Paver placement of aggregate, shown in Figure 2B, is done to prevent segregation of aggregate by size, and to control the depth and shape of placement. The paver is the same equipment used to place asphalt. Aggregate is dumped out of trucks directly into the paver which places it onto the road in a single lift at the desired depth and shape. No asphalt or other bonding agents are used. A roller is then used to achieve proper compaction of the placed aggregate.

Each of the three aggregates in this study were placed using both placement methods described above for a total of 6 distinct test sections as follows: 1) 2RC - tailgated; 2) 2A - tailgated; 3) DSA - tailgated; 4) 2RC - paver-placed; 5) 2A – paver-placed; and 6) DSA - paver-placed. The six sections were located adjacent to one another to make up over 6,000 feet (1830 m) of continuous aggregate placement.

Figure 2. **Photo "A"** on the left illustrates the process of tailgating aggregate. A windrow of aggregate has just been dumped out of the truck. A motor-grader waits to spread the material and shape the road. **Photo "B"** on the right illustrates the placement of aggregate through a paver. The truck is dumping aggregate directly into the paver which uses an auger to minimize segregation as it places material on the road.

Chapter 2. LITERATURE REVIEW

The effect of road-born sediment on streams has been well documented. In many forested watersheds, unpaved road have been determined to be the dominant source of surface erosion and stream pollution (Megahan and Kidd, 1972; Reid and Dunne, 1984; Bilby et al. 1989; Luce and Black, 1999). Road-born sediment is generated by the entire road prism including the banks, ditches, and driving surface. Road-derived sediment has been shown to have many detrimental effects to aquatic systems. Sediment influxes from unpaved roads can alter the morphological characteristics of stream systems including turbidity, suspended sediment concentrations, temperature, dissolved oxygen, and channel substrate composition (Bernard, 2006; Bilby et al., 1989; Forman, R. T. T. and L. E. Alexander., 1998). Biological effects follow these morphological changes including habitat alteration and loss, fluctuations in peak flow, and alterations in food source composition in the aquatic food web (Bernard, 2006; Bilby et al., 1989; Forman, R. T. T. and L. E. Alexander, 1998; Coe, 2006; Waters, 1995).

One of the most important factors in determining the amount of sediment that is generated by a segment of road is the availability of erodable material, which is largely dependant on the choice of material used as a driving surface (Swift, 1984; Bernard, 2006; Ziegler, 2000; Ziegler, 2001). In examining the sediment generation and transport process on unpaved road surfaces, it is useful to divide the erosion process into raindrop impact erosion and hydraulic erosion caused by flowing water (Ziegler et al., 2000; MacDonald et al., 2001).

In addition to water, traffic and maintenance are the major destructive agents acting upon the surface material. The action of tires against the road surface will grind and dislocate particles into smaller units that can eventually be carried away by other agents like water and wind. Some researches consider traffic to be the single most essential factor influencing sediment generation, capable of increasing sediment amounts by one order of magnitude or more (Damian, 2003; Reid and Dunne, 1984). Frequent road surface maintenance operations also increase sediment generation from the road surface. Coe (2006) reported that recently-graded roads produced more than twice as much sediment as ungraded roads. A reduction in the frequency of grading will decrease the supply of easily erodable sediment.

Several studies have been completed on the sediment reduction benefits of using some type of crushed stone aggregate instead of native material for road surfaces. All of the studies indicate that a significant sediment reduction is achieved by using some kind of crushed stone aggregate instead of native earth materials. The level of sediment reduction is dependent on the native material being covered and the type of aggregate being used. Coe (2006) determined that sediment production rates from native surface roads were 12-25 times greater than from aggregate surfaced, or "rocked" roads. "Rocking" (aggregate placement) decreases rainsplash erosion, increases the critical shear stress necessary for erosion, and reduces the supply of easily erodable sediment (Coe, 2006). Foltz and Truebe (1995) reported a 92% reduction in sediment generation after aggregate application. These results are similar to the 95% reduction given by equations relating ground cover to sediment production by Burroughs and King (1989), and Foltz and Truebe (1995).

Beyond simply comparing aggregate to native surface roads, several studies have attempted to compare the sediment production of "good" and "marginal" quality aggregates. Foltz (1998) reported on the sediment production difference between good and marginal quality aggregates over a four year field study. During a simulated timber sale, a section of road with marginal quality aggregate produced 3.7 to 17.3 times as much sediment as a similar section with good-quality aggregate (Foltz, 1998). Lower quality aggregate also results in increased flow pathways on the road surface in the form of ruts. More frequent surface maintenance is required to remove rutting (Foltz, 2003; Foltz, 1998; Provencher, 1995). As discussed earlier, more frequent maintenance results in increased sediment production and road degradation. In several past studies about aggregate quality, the major difference between good and marginal aggregate was the hardness and durability of the aggregate, especially of the fines. Marginal durability aggregates tend to break down and produce excessive fines easily (Foltz and Truebe, 1995). While much data exists for asphalt mixes, very little research has been done on the effect of aggregate gradation on durability for unpaved road surfaces.

Chapter 3. METHODS

3.1 Site Selection

Many factors were taken into consideration when choosing an appropriate road to place the aggregates for this test. In order to eliminate outside influences on aggregate performance, the chosen road had to be relatively uniform in terms of road slope, width, aspect, vegetative cover, and traffic. Working closely with the Pennsylvania Bureau of Forestry, the Center chose Crowfield Road, located in rural Centre County, Pennsylvania to conduct this study (Figure 3). With a width that ranges from 13 to 15 feet (4.0 to 4.6 m), Crowfield Road was characterized by a single driving lane with two well defined

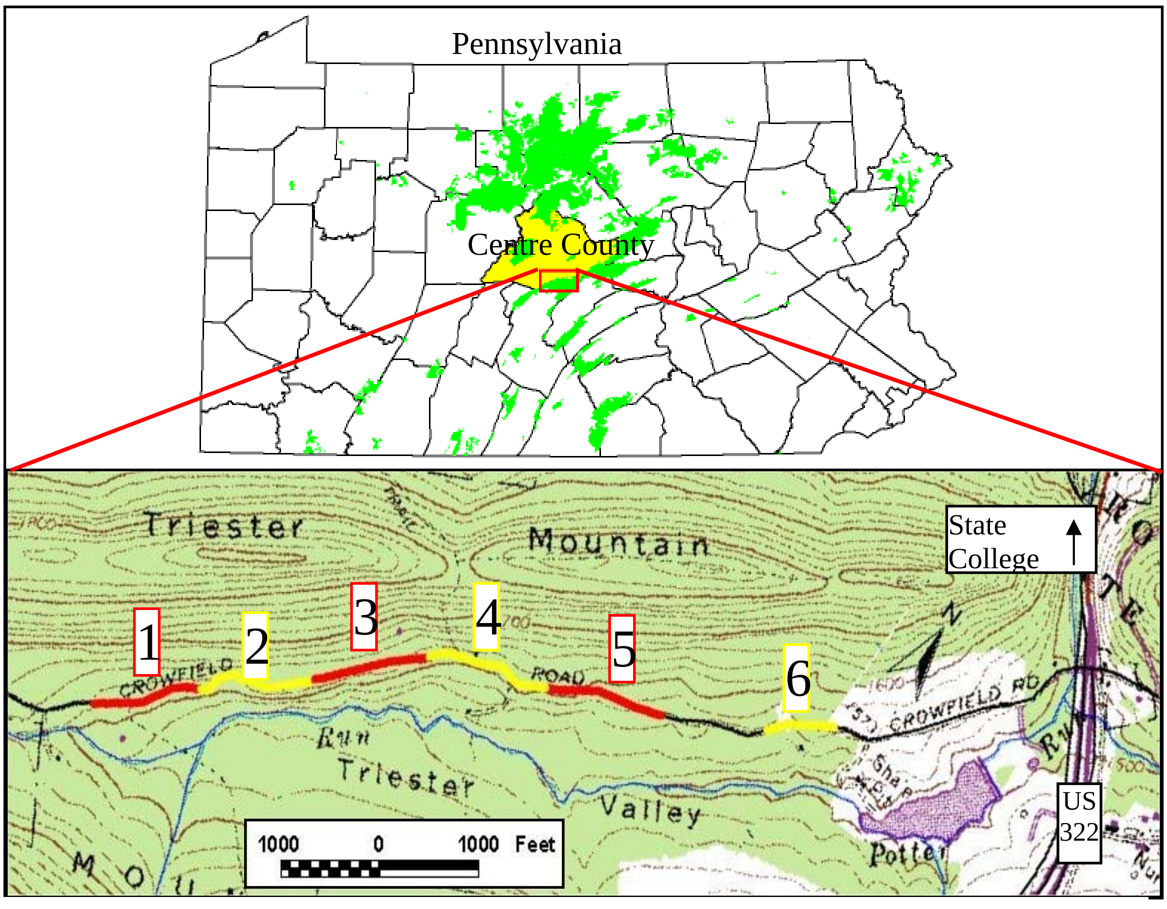

Figure 3. Maps illustrating both the location of Crowfield Road in Pennsylvania, above, and the site layout of the aggregate test sections, below. Numbered aggregate placements represent: 1) 2RC - tailgated, 2) 2A - tailgated; 3) DSA - tailgated; 4) 2RC – paver-placed; 5) 2A – paver-placed; and 6) DSA – paver-placed.

wheel tracks. The road is owned and maintained by the PA Bureau of Forestry's Rothrock State Forest District (Forestry), who also maintains the surrounding forest using sustainable forestry practices. The entire two-mile section of road used for this study has a grade of 0-3% and is partially shaded by the surrounding northeastern deciduous forest. To insure equal traffic over the 6,000 feet (1,830 m) of test aggregate, no road intersections were included within the study area. The average daily traffic (ADT) on Crowfield Road was measured at approximately 48 cars per day as measured from August through November of 2003 (see Appendix A for traffic Data). The road is open year-round, but receives no winter maintenance and is typically under snowpack for most of the winter. The composition of the existing road consisted of a native soil that had mixed with numerous previous aggregate placements over time.

3.2 Site Layout

The six test sections of aggregate were placed in sequence as shown in Figure 3. The sections were placed end-to-end with no gaps between placements. The length of the aggregate placements was based on available funding for the project. Placement lengths averaged just over 1,000 feet in length. Wooden signs were used to mark section boundaries for future reference.

3.3 Aggregate Placement

All six aggregate placements occurred in the fall of 2002. Before aggregates were placed on the road, the road base was prepared using a motor-grader. The existing road was graded for several important reasons. First, it is important to eliminate any existing potholes, wash boarding, or wheel ruts so these undesirable features are not reflected in the surface of the new aggregates. Second, it is important to establish crown in both the surface and base of a roadway, especially in unpaved roads. Crown is the practice of elevating the center of the road higher than the shoulders in order to force water to drain laterally off the roadway. The level of crown established in the existing road was between ½ and ¾ inches of fall per linear foot of distance across the road (42 to 62 millimeter per meter, or 4-8%). A third reason for grading the road was to roughen the existing surface to provide better contact with the new aggregate to be placed on top. Finally, the most important reason for grading the existing road was to obtain a uniform base on which to place the six aggregate placements being studied. The same motor-grader and operator from the PA Bureau of Forestry were used to prepare all six sections in order to maintain consistent conditions throughout the road. Aggregate for all six sections of the study was made and delivered by the same quarry to maintain consistency. The same parent material was used for all aggregated to insure comparable hardness, density, and composition. Only the size gradations of the aggregate were changed. For the 2RC aggregate, an additional 5% (by weight) of clay fines was added to the DSA size gradation. This was done to approximate 2RC aggregates typically used by forestry which have a clay component. The Center worked closely with the quarry to explain the study and insure the accuracy and consistency of delivered aggregates.

The six sections of aggregate were placed in the fall of 2002. The three tailgated aggregates, sections 1-3, were placed on October 23 and 24, 2002. The aggregates were delivered to the site by the quarry in 23-ton capacity tri-axel dump trucks. Once on site, the aggregate was dumped out of a moving truck to form a windrow down the center of the roadway. This windrow of aggregate was then spread across the road surface using a motor-grader operated by the Bureau of Forestry. Repeated passes of the motor-grader were used to distribute the aggregate and shape the final road surface. Compaction of the 3 tailgated sections was accomplished by the movement of successive loaded aggregate trucks over aggregate that had already been placed. Trucks are driven in a staggered fashion across the width of the roadway to achieve compaction across the entire road profile and avoid forming ruts. Finished aggregate thickness is typically about 4 inches (101 mm) after compaction. Figure 2A illustrates the tailgating process.

The three paver-placed aggregates, sections 4-6, were placed on November 18, 2002. These aggregates were generated and delivered to the site by the same quarry as the tailgated aggregate. The trucks then dumped the aggregate directly into a tracked paver. The paver was operated by a contracted professional crew. The paver was used to place a uniform layer of aggregate approximately 8 inches (203 mm) thick in a single lift onto the prepared road base. The 8 inches of placed aggregate was then compacted to approximately 6 inches (154 mm) using a 10 ton (9072 kg) vibratory roller. Compaction continued for several passes until the drum of the roller no longer left an indentation in the road surface. Figure 2B illustrates the paver placement process.

3.4 Cost Tracking

In order to determine the cost of initial placement, many factors dealing with aggregate placement were documented in addition to the purchased aggregate price. Several people were stationed throughout the jobsite to record the length of time for individual events in the aggregate placement process. Information such as motor-grader activity, truck waiting time, idle paver time, and labor time were recorded so that the actual costs of aggregate placements could be determined. Throughout the three year study, all maintenance time and costs were documented so that the overall long-term costs of the aggregates could be determined.

3.5 Aggregate Performance Monitoring

Over time, road surface aggregate is both mobilized and compacted by wind, water, traffic, and maintenance activity. Surface elevation changes occur in both the upward and downward directions through traffic wear, compaction, freeze/thaw cycles, and erosion. Aggregate performance in this study was based on changes and deformations in the surface elevation of the six aggregates. Elevation changes across the road surface were quantified using detailed cross-sectional surveys repeated over a three year period. Three cross-sectional survey locations were identified on each of the six aggregate placement sites. Each of the total 18 cross-sectional survey locations was permanently identified using a 36” (0.9 m) length of ½” diameter steel rebar driven into the ground on either side of the road, just outside the right-of-way. The rebar along the road served to permanently identify the ends of each cross-section, and to establish a reference elevation for measuring changes in the road surface elevation. 36 inch (0.9m) long rebars were used to insure frost heaving did not cause changes in rebar elevation (DeGaetano, 1994). Each cross-section was surveyed from rebar to rebar across the road profile using a Topcon GPT-2003 Total Station. Using the top of the rebars as reference elevations, changes in surface elevation and shape over time can then be calculated. Figure 4 illustrates the results of a typical paver-placed cross-sectional survey over the three year study. This cross-sectional survey methodology was adapted from practices commonly used to survey cross-sections of streams (Moglan, 2001; Harrelson, 1994). Cross-sectional surveys on all six aggregates were located in topographically similar areas with approximately 1% slope. On each aggregate placement site, the three cross-sections were located approximately 50-75 feet (15-23 m) apart. The actual mechanisms contributing to changes in surface elevation were not a component of this study.

The first cross-sectional surveys were conducted approximately one week prior to aggregate placements in order to establish the existing road elevation profile. A second survey was done after each section was graded, just before aggregate placement. These first two surveys can be seen as the lower lines in Figure 4. When compared with surveys of the finished aggregate, the initial surveys will allow the calculation of aggregate volume and depth. Surveys were conducted the day following aggregate placement in order to obtain an "as-placed" road profile measurement for each cross-

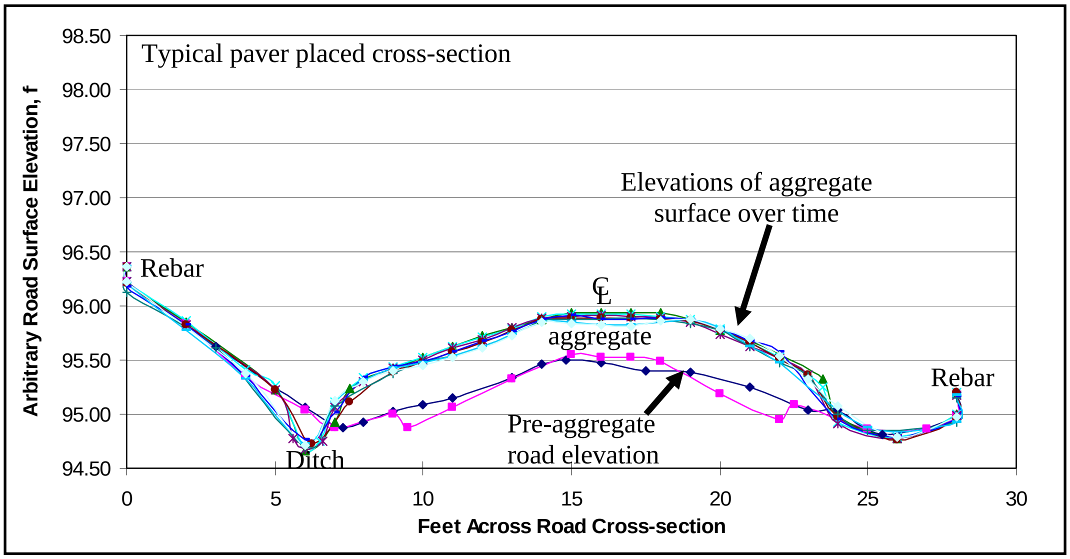

Figure 4. Repeated surveys of a single cross-section for a paver placed aggregate are illustrated here.

section. Successive cross-sectional surveys were conducted at time intervals of 1 month, 4 months, 6 months, 8 months, 12 months, 16 months, 2 years, 2 ½ years, and 3 years from aggregate placement. In conjunction with each survey that was conducted, pictures and notes were taken for each of the six aggregate sites. Pictures were standardized to allow for direct comparisons of road surfaces over time. The surveyed profiles of aggregate will be used to determine and compare both bulk aggregate loss and surface deformations (rutting) over the three years of study.

3.5.1 Bulk Aggregate Loss

The aggregate cross-sectional profiles will be used to determine if each cross-section has a statistically significant change in the average road elevation over the duration of the study. A paired t-test will be used with a p-value of 0.05 to determine the 95% confidence interval for elevation change (Kutner, 2005; Jaisingh, 2006). This test will indicate whether there was a statistically significant change in road surface elevation during the study. A ten foot width of road surface, centered on the road centerline, will be used in this analysis. Figure 5

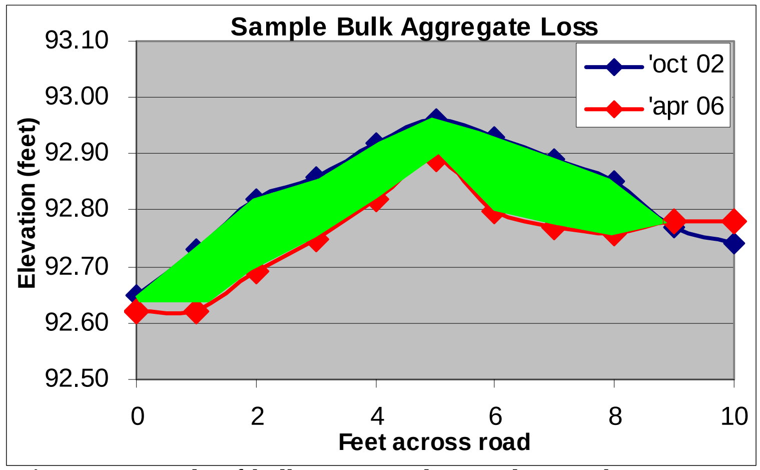

Figure 5. Sample of bulk aggregate loss analysis. The average difference between 2002 elevations (top line) and 2006 elevations (bottom line) will approximate the aggregate loss (green area) over time for the cross-section.

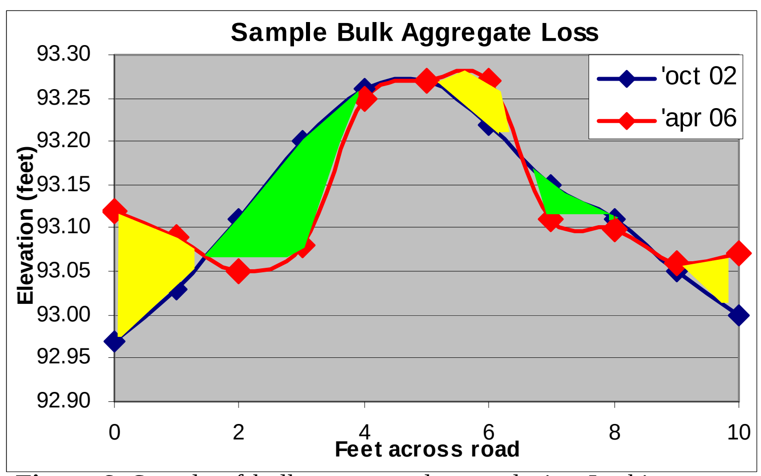

Figure 6. Sample of bulk aggregate loss analysis. In this case, simply comparing the average elevation change would make this cross-section look stable since elevation loss (shaded green) is nullified by elevation gain (shaded yellow).

illustrates the aggregate loss in a typical cross-section. It is important to note that a paired t-test will determine if there is a significant difference in the "average" elevations across the road profile. Because the paired t-test compares the average elevation change, it is possible that rutting of the road surface will not be reflected. If a particular cross-section becomes rutted, as in Figure 6, the paired t-test could return indicating that there was no change in average road elevation. This is because elevation was gained in some locations that would negate the elevation loss in others. In order to account for rutted sections of road as illustrated in Figure 6, a test for the degree of rutting of the aggregate is needed.

3.5.2 Degree of Rutting

The cross-sectional profiles will also be used to quantify the degree of rutting in each of the aggregates. Two methods will be used to measure the degree of rutting; a rut volume and depth calculation, and a goodness of fit test.

Maximum rut depth and rut volumes are often used to quantify the degree of rutting across a road's surface (Bennett, 2002; FHWA, 2001). Both rut depth and volume are determined by use of a "straight-edge" placed over each wheel track. The greatest vertical distance from the straight-edge to the road surface is measured and recorded as the rut depth. Rut volumes are similarly calculated by measuring the

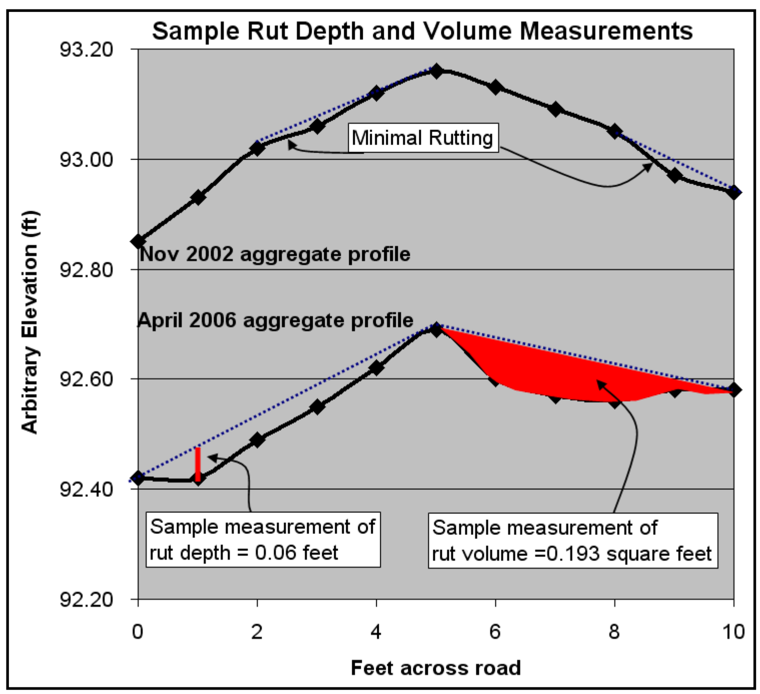

Figure 7 Sample of rut depth and volume measurement. Road cross-section 5.2 is shown here from November of 2002 and April of 2006. A "straight-edge" to determine rutting is indicated by the dotted lines. The vertical red line in the left wheel track indicates rut depth. The red area in the right wheel track indicates rut volume.

volume between the straight-edge and the road surface (Bennett, 2002; FHWA, 2001). Two wheel ruts are averaged to obtain the average rut depth and volume for each cross-section. Figure 7 illustrates the measurement of rut depth and volume for cross-section 5.2 on the 2A paver-placed aggregate.

The degree of rutting can be further quantified by comparing the goodness of fit of the points on each cross-section with the ideal cross-sectional shape. The ideal cross-section shape can be approximated by determining the trendline for each road profile. It was determined that a third-order polynomial trendline provided the best approximation of the ideal cross-sectional shape since it was the lowest order trendline that fit the newly placed aggregate profiles with an average R^2 of over 95%. A third-order polynomial provided an average of 97% goodness of fit for the surveys of newly placed aggregate. Figure 8 illustrates the value of using R^2 to quantify rutting by illustrating several cross-sections along with their trendlines and corresponding R^2 value. By comparing the R^2 value of newly placed aggregate to the surveys completed in April, 2006, it is possible to further quantify the increase in rutting over the course of the study. This test is confirmed by comparison with rut depth and volume calculations, and by visual correlations with field and survey observations. An R^2 value of 100% would indicate no rutting, while a R^2 value of below 85% would indicate significant rutting, and an a R^2 value of below 70% would indicate severe rutting.

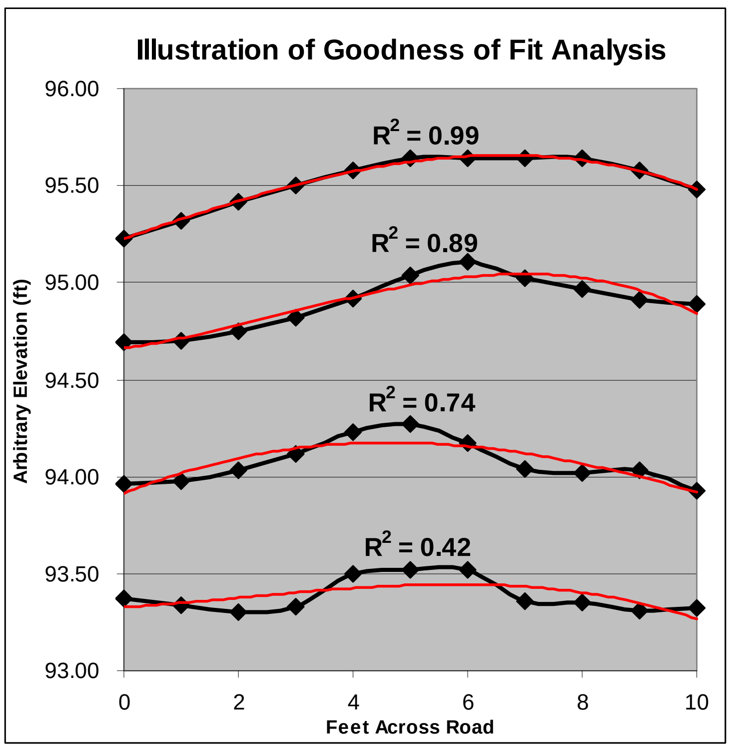

Figure 8. Sample of goodness of fit rutting analysis. The data points on each cross-section (shown in black) are fitted to their third order polynomial trendlines (shown in red). The resulting R^2 value is a quantification of the rutting with R^2=1 indicating an ideal surface. Actual cross-sections are illustrated (cross-section IDs from top = 5.3, 1.3, 3.2 ,4.3). Elevation baseline is arbitrary; Figure is for R-squared comparative purposes.

Chapter 4. RESULTS

4.1 Cost Analysis

The first component of this study was to compare the placement methods of tailgating and placing aggregate through a paver. Placement of aggregate with a paver requires delivery trucks to approach the paver backwards, dumping the aggregate into the paver as it slowly advances. This sequence of motions requires extra effort in backing aggregate trucks into the paver and requires additional truck time as the load is delivered to the working paver. Trucks delivering aggregate for tailgated sections drove in forward, dumped the aggregate, and then continued on while the motor-grader worked to spread the aggregate. The average placement rates were 127 tons/hour for paver-placed sections, and 169 tons/hour for tailgated sections. Paver-placed sections were applied approximately 50% deeper than tailgated sections. The slightly slower rate of paver placement, along with the greater placement depth resulted in tailgated aggregates being placed at twice the rate as paver-placed aggregates in terms of road distance per unit time. The average initial cost of aggregate placement for paver-placed sections was $13.50 per ton. This price included the placement and compaction of the aggregate by a contracted crew. The average initial cost of aggregate placement for tailgated sections was $6.60 per ton. This price included trucking only. The aggregate was then spread using Bureau of Forestry grader and operator.

The depth and distribution of aggregate placements can be determined by comparing the cross–sectional surveys before and after aggregate placement. The three sections that were placed using a paver were uniformly distributed across the road surface with an average depth of 6 inches (154 mm) (Figure 4). The sections of aggregate that were placed by tailgating had a much greater variation in placement depth across the road. Tailgated aggregates tend to be placed at a greater depth at the centerline and tapered off on either side of the road. Road centerline depths for tailgated sections averaged approximately 5 inches (128 mm). The average depth of aggregate across the entire road profile for the tailgated sections was just less than 4 inches (101 mm).

Overall, tailgated aggregate was placed at a rate of 1/3 less per linear foot of road when compared to paver placement. This results in an initial cost saving up front because less aggregate is used. Maintenance requirements over the three years of study did not differ based on placement methods. A longer term of study is needed to determine if the long term benefits of using more aggregate will outweigh the higher up-front costs of paver-placed aggregate at a greater depth.

4.2 Maintenance Requirements

Each of the six aggregate sections was monitored for a three year period beginning with placement in the fall of 2002. Two of the aggregate placements, "Section 1: 2RC, tailgated", and "Section 4: 2RC, paver", showed significant rutting after the first winter and had to be graded to re-establish their shape. Both of these rutted sections consisted of the 2RC aggregate which contained clay fines. "Section 4: 2RC, paver" was virtually impassable to cars over the first winter due to 4-6 inch (102-154 mm) ruts which formed in the wheel tracks (Figure 9). "Section 1: 2RC, tailgated" showed less severe rutting, but was also graded in the spring of 2003. After these 2 sections were graded, they were compacted using a 4 ton rubber tire roller. The grading effort was successful, and both sections soon dried and hardened. This was the only aggregate maintenance required on these sections. No maintenance was done on any of the other four aggregate placements throughout the three years of study.

Figure 9. Severe rutting occurred on both of the 2RC aggregates over the first winter. The severe rutting on "Section 4: 2RC, Paver" is illustrated here.

4.3 Cross-Sectional Surveys

Data from the cross-sectional surveys done during this study was used to determine the bulk aggregate loss and degree of rutting as describe in section 3.5. The full results from all 180 surveyed cross-sections can be found in Appendix E.

4.3.1 Bulk Aggregate Loss

The results of the paired t-test for surface elevation change are summarized in Table 2. It is important to consider that both of the 2RC sections rutted severely during the first winter and had to be graded in April of 2003. For this reason, changes in surface elevations would be expected for these aggregates due to aggregate loss or incorporation of road edge material into the road while grading. Because these aggregates were graded, three time periods are summarized in Table 2; the whole study (2002-2006), prior to grading (2002 - 2003 ungraded), and after grading (2003 graded – 2006).

The results of the paired t-test indicate that DSA placed by tailgating was the only aggregate that did not show a significant change in surface elevation over the entire length of the study (not including 2RC which was graded). Two out of the three cross-sections for DSA Tailgated did not show a statistically significant elevation change. The

		Whole Study 2002-2006		Before Grading 2002-2003 ungraded		After Grading 2003 graded-2006		
	Cross Section	Avg Elevation Change (ft)	P- Value	Avg Elevation Change (ft)	P- Value	Avg Elevation Change (ft)	P- Value	
2RC tailgated ***graded**	1.1	-0.12	-	-0.02	0.017	-0.09	0.006	2RC tailgated
	1.2	-0.04	0.049	0.00	0.603	-0.04	0.116	
	1.3	-0.02	0.556	0.00	1.000	0.00	0.858	
2A tailgated	2.1	-0.06	0.010	0.01	0.617	-0.07	0.003	2A tailgated
	2.2	-0.11	0.001	-0.03	0.012	-0.07	0.003	
	2.3	-0.09	-	-0.02	0.111	-0.07	-	
DSA tailgated	3.1	-0.04	0.053	-0.01	0.087	-0.03	0.083	DSA tailgated
	3.2	-0.04	0.035	-0.02	-	-0.03	0.061	
	3.3	-0.02	0.188	0.01	0.127	-0.05	0.006	
2RC paver ***graded**	4.1	-0.04	0.184	0.00	0.890	0.00	0.898	2RC paver
	4.2	-0.04	0.148	0.03	0.060	-0.03	0.164	
	4.3	0.01	0.686	0.07	0.018	-0.01	0.752	
2A paver	5.1	-0.08	0.001	0.02	0.030	-0.06	0.002	2A paver
	5.2	-0.10	-	0.01	0.109	-0.08	-	
	5.3	-0.06	0.003	-0.01	0.096	-0.03	0.073	
DSA paver	6.1	-0.11	-	0.00	0.796	-0.11	-	DSA paver
	6.2	-0.11	-	0.00	0.640	-0.09	-	
	6.3	-0.06	0.004	-0.02	0.011	-0.03	0.059	

Shaded blocks indicate NO significant change in elevation (P>0.05)

Table 2. Results of paired t-test on surface elevation change. Average elevation change for each cross-section is listed. A P-value above 0.05 (shaded) indicates that there was NO statistically significant change in the aggregate surface elevations. Note that cross-sections 1.1, 1.2, 1.3, 4.1, 4.2, and 4.3 were graded in April of 2003.

results also showed that all of the aggregates did fairly well from placement in Fall 2002 through Spring 2003 before the two 2RC sections were graded in April. Each of the six aggregate sections had two of their three cross-sections indicate that there was no significant change in surface elevation during the first winter of the study. The analysis of bulk aggregate loss also showed that after the two sections of 2RC were graded, they performed very well having 5 out of 6 cross-sections show no significant elevation change from May of 2003 through 2006.

4.3.2 Degree of Rutting

In order to quantify the degree of rutting, a third-order polynomial was fitted to each cross-section. The goodness of fit of the surveyed points was then compared to the trendline for each cross-section. The results of the degree of rutting analysis are shown in Table 3. Because the 2RC aggregates were graded in April 2003, three time periods are summarized in Table 3 for those aggregates; the whole study (2002-2006), prior to grading (2002 - 2003 ungraded), and after grading (2003 graded – 2006).

The results of the goodness of fit rutting analysis showed that DSA placed using a paver had the least degree of rutting of any of the aggregates. 2RC placed using a paver

R-Squared for fit of trendline								
Aggregate	**Cross-Section**	**2002 as placed R2**	**March 2003 Ungraded**	**May 2003 Graded R2**	**2006 Final R2**	**2002-2006 % change**	**Average % change**	**Aggregate**
2RC tailgated ***graded**	1.1	0.97	0.98	0.92	0.96	-1%		2RC tailgated ***graded**
	1.2	0.98	0.96	0.96	0.82	-15%	-9%	
	1.3	0.99	0.99	0.96	0.89	-10%		
2A tailgated	2.1	0.97			0.87	-9%		2A tailgated
	2.2	0.97			0.86	-11%	-9%	
	2.3	0.97			0.91	-6%		
DSA tailgated	3.1	0.94			0.88	-6%		DSA tailgated
	3.2	0.91			0.82	-9%	-5%	
	3.3	0.95			0.95	-1%		
2RC paver ***graded**	4.1	0.97	0.73	0.97	0.54	-43%		2RC paver ***graded**
	4.2	0.98	0.96	0.95	0.52	-46%	-47%	
	4.3	0.94	0.70	0.97	0.42	-52%		
2A paver	5.1	0.97			0.77	-19%		2A paver
	5.2	0.96			0.69	-28%	-17%	
	5.3	1.00			0.96	-4%		
DSA paver	6.1	0.99			0.96	-3%		DSA paver
	6.2	0.99			0.97	-2%	-2%	
	6.3	0.98			0.97	-1%		

Table 3. Results of "goodness of fit" tests for rutting. R^2 values near 1.0 indicate no rutting. R^2 values below 0.80 indicate substantial rutting. Because both 2RC sections were graded in April 2003, additional timeframes are included in the Table for those aggregates to capture the period before and after grading.

had the highest degree of rutting. This is also the section that rutted severely immediately after placement and had to be graded in April 2003.

Further quantification of the degree of rutting was done by measuring the depth and volume of the ruts on each cross-section as outlined in Figure 7. The results of the rutting measurements were averaged for the three cross-sections on each aggregate placement. Results of the rut depth and volume measurements are summarized in Figure 10 (full results in Appendix D). For comparison, the R^2 values obtained from the goodness of fit analysis are included in Figure 10. The results of the rut depth and volume measurements show a strong correlation with the goodness of fit analysis previously discussed. Once again, the two sections of DSA aggregate showed the least amount of rutting, with section 4, 2RC paver-placed, showing the most rutting.

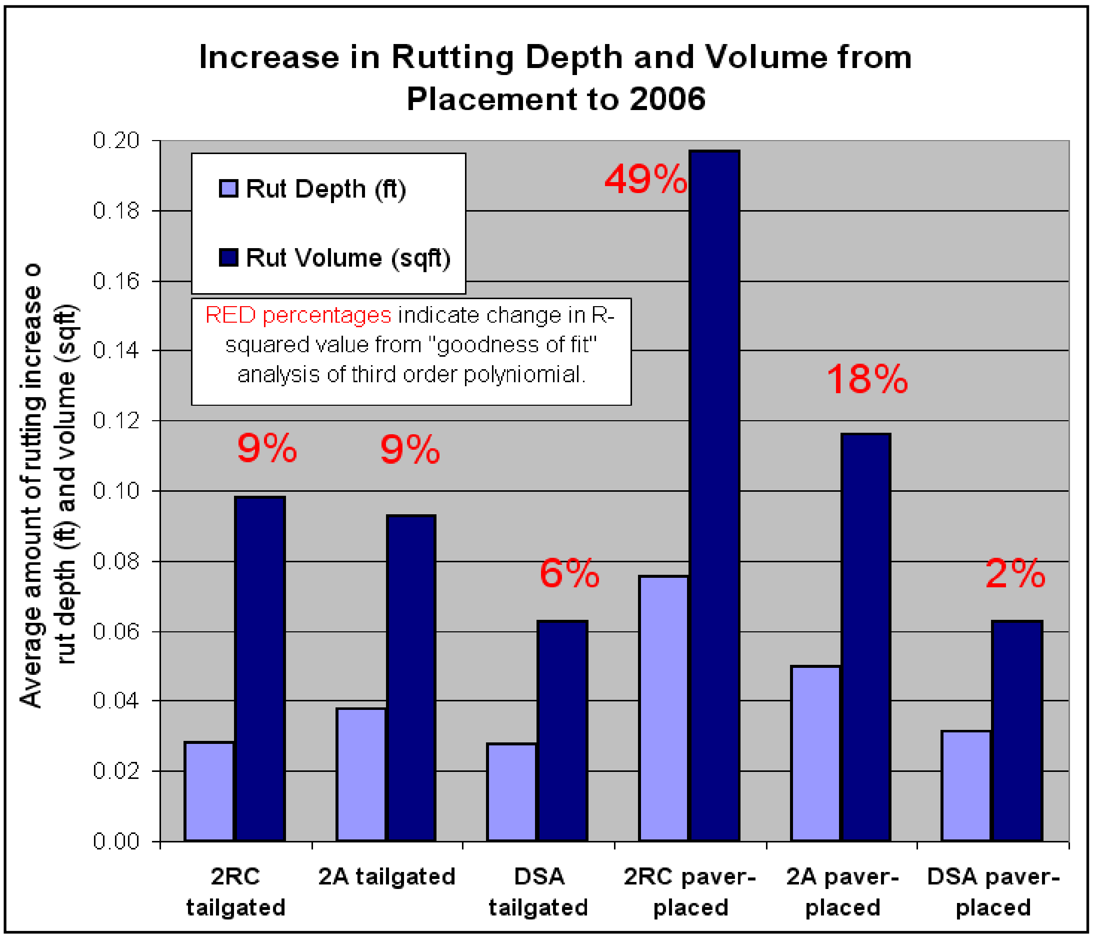

Figure 10. Rut depth and volume were measured for each cross-section. Three cross-sections for each aggregate placement were then averaged. This Figure represents the average increase in rut depth (ft) and rut volume (ft^2) over the course of the study. Red percentages indicate change in R^2 value from goodness of fit analysis for comparison.

Chapter 5. DISCUSSION

5.1 Individual aggregates

What follows is a discussion of each of the six individual aggregate placements, including two pictures taken in 2006 for each section. Comprehensive pictures of each aggregate section over the entire three years of study can be found in Appendix C. The performance of each of the 6 aggregate sections will first be discussed individually in this section. Comparisons will then be made in performances among placement methods and aggregates.

5.1.1 Section 1, 2RC Tailgated

Figure 11. Section 1, 2RC Tailgated, shown in April of 2006. More pictures located in Appendix C.

Section 1 was graded in April 2003 because the surface was soft and slightly rutted. Field observations repeatedly found that the two sections of 2RC had a significantly smoother surface texture than the other two aggregates. The high amount of fines along with the presence of clay made the surface of this aggregate relatively soft and almost "soil-like" in appearance and feel. In general, the 2RC sections showed the least amount of loose stone both on the surface of the roadway and along the road edge.

Bulk aggregate loss analysis showed little signs of an overall drop in aggregate surface elevation in the time periods before or after grading in 2003. A moderate degree of rutting (average 9% drop in R^2 value) was found in this aggregate placement.

5.1.2 Section 2, 2A Tailgated

Figure 12. Section 2, 2A Tailgated, shown in April of 2006. More pictures located in Appendix C.

Field observations found that this section of 2A Tailgated consistently had a large amount of large loose stone between and beside the wheel tracks. The loose stone was typically several inches deep and could easily be moved with light foot pressure. The wheel tracks themselves were typically hard-packed. The 2A sections had the largest amount of large stone visible as part of the road surface. The large stone can be seen to in the picture to the right in Figure 12.

Bulk aggregate loss analysis showed a significant drop in surface elevation over the three years of study. A moderate degree of rutting (average 9% drop in R^2 value) was found in this aggregate placement.

5.1.3 Section 3, DSA Tailgated

Figure 13. Section 3, DSA Tailgated, shown in April of 2006. More pictures located in Appendix C.

Field observations found that this section of DSA Tailgated had some loose stone between and beside the wheel tracks. The wheel tracks were typically hard packed with some exposed large stone (~1”) embedded in the driving surface. Road crown was more pronounced in this section than most others.

Bulk aggregate loss analysis showed that two of the three cross-sections did not have a statistically significant drop in elevation. This was the only un-graded aggregate placement to show no significant change in surface elevation. A low degree of rutting (average 5% drop in R^2 value) was found in this aggregate placement.

5.1.4 Section 4, 2RC Paver-placed

Figure 14. Section 4, 2RC paver-placed, shown in April of 2006. More pictures located in Appendix C.

Field observations found that this section of paver-placed 2RC was consistently the softest and most rutted of the aggregates. This section was graded in April of 2003 because 4-6 inch ruts had formed in the aggregate which made the road impassable to low-clearance vehicles. The surface of the aggregate was typically smooth with very little loose stone. During dry weather, dust was more noticeable on this section than any of the others.

Bulk aggregate loss analysis showed little signs of an overall drop in road surface elevation in the time periods before or after grading in 2003. An extremely high degree of rutting (average 47% drop in R^2 value) was found in this aggregate placement both before and after grading. This corresponded to the observations of rutting as shown in Figure 9.

5.1.5 Section 5, 2A Paver-placed

Figure 15. Section 5, 2A paver-placed, shown in April of 2006. More pictures located in Appendix C.

Field observations found that this section of 2A paver-placed consistently had the largest amount of large loose stone between and beside the wheel tracks. The loose stone was typically several inches deep and could easily be moved with light foot pressure. The wheel tracks themselves were typically hard-packed. This section showed the largest degree of elevation difference between the lowered wheel tracks and the piles of loose aggregate.

Bulk aggregate loss analysis showed a significant drop in average road surface elevation through the three year study. A high degree of rutting (average 17% drop in R^2 value) was found in this aggregate placement.

5.1.6 Section 6, DSA Paver-placed

Figure 16. Section 6, DSA paver-placed, shown in April of 2006. More pictures located in Appendix C.

Field observations found that this section of paver-placed DSA had minor amounts of loose stone between and beside the wheel tracks. The entire surface of this section was hard packed and uniform with no visible rutting.

Bulk aggregate loss analysis showed a significant drop in average road surface elevation through the three year study. The lowest degree of rutting (average 2% drop in R^2 value) was found in this aggregate placement.

5.2 Placement Method Comparisons

One of the goals of this study was to compare the performance of aggregates that have been paver-placed against the same aggregates that has been tailgated. Since three identical aggregates were used in this study, three comparisons can be made between the placement methods. Before comparing placement methods, it is important to take into consideration the factors that differed between paver-placed and tailgated aggregates. First, paver-placed aggregates were applied approximately 50% thicker than tailgated aggregates. Paver-placed aggregates were placed in a uniform lift of eight inches (201 mm) and compacted to six inches (152 mm). Tailgated aggregates were placed at an average compacted depth of 4 inches (101 mm), but had a relatively high degree of depth variability between and within cross-sections. The thickness and final shape of the tailgated aggregates is largely dependant on the ability of the equipment operator shaping the aggregate. Second, paver-placed aggregates were compacted using a 10-ton vibratory roller, while tailgated aggregates were compacted using loaded aggregate trucks.

Both the tailgated and paver-placed sections of 2RC aggregate were graded in April 2003. As documented in the field and supported by the degree of rutting analysis, the paver-placed section of 2RC experienced a great deal more rutting than the tailgated section. There are several factors in the paver placement process that could have caused this difference. First, the paver-placed 2RC aggregate was approximately 50% thicker than the tailgated aggregate. This thicker placement means that more aggregate is available for displacement in the form of rutting. It also means that the aggregate would have been slower to dry or cure after placement. Another possible influence on the rutting of the paver-placed 2RC is the fact that a vibratory roller was used to compact the aggregate. The forces from the vibratory roller could have saturated the clay in the aggregate by pumping moisture up out of the ground. The third potential influence on rutting in the paver-placed section was the surrounding tree cover. Although efforts were made to survey identical sites on each aggregate, section 4, paver-placed 2RC, had the highest degree of shading of any of the sections.

Both of the 2A sections of aggregate performed similarly. While field observations noted slightly more loose stone on the paver-placed sections, analysis of bulk aggregate movement was virtually identical for these two aggregate. Both sections showed a statistically significant reduction in surface elevation over the study. The degree of rutting analysis showed a more uneven surface in the paver-placed aggregate compared to the tailgated aggregate over the study period (17% and 9% R^2 reductions respectively). Again in this situation, the thicker placement of the paver-placed sections could explain why more material was available for rutting deformations. It appears from visual observations that much of the rutting for the 2A aggregate was caused by the detachment and transport of large stones. This contrasts to the rutting in the 2RC aggregate where few loose stones were present and rutting appeared to be due "in-place" plastic deformations.

The two DSA aggregate placements were also very similar in performance. Field observations noted that both sections had little rutting and some loose stone on the road surface. Analysis of bulk aggregate movement over the study indicated that the tailgated section of DSA performed better than the paver-placed section. Two of the three DSA tailgated cross-sections were the only ones out of the 18 that were not graded and did not show a significant elevation loss. Both of these aggregates performed exceptionally well in degree of rutting analysis, which matched field observations of minimal visible rutting. The tailgated section performed better in bulk aggregate movement analysis, while the paver-placed section had slightly less rutting.

The goal of this section of the study was to determine if the added cost of placing aggregate through a paver would be justified by improved aggregate performance. The theoretical benefits of paver placement are the reduced segregation of aggregate by size, and the placement of a thicker, more uniform lift of material. The results of this section of the study indicate that there was no significant change in aggregate performance between paver-placed and tailgated aggregates over the first three years. Another reason for placement of a thicker lift of aggregate through a paver is to provide sufficient material to re-establish the road in future years through grading. Since the term of this study was limited to three years and did not include regular grading, potential benefits of using a paver to place aggregate may not have been realized.

5.3 Aggregate Comparisons

The major goal of this study was to compare the durability and performance of three commonly used materials as road surface aggregates. Several factors about the aggregate gradations need to be taken into consideration before aggregate performance can be compared. The most significant factor to consider is that the aggregates used in this study represent a specific gradation within a range of gradations for each specification. For example, it is possible to get a gradation of 2A aggregate with 1% fine material (passing #200 sieve). Such a coarsely graded 2A would undoubtedly perform differently that the 2A used in this study, which had 9% fine material, but was still within the specification. The 2RC specification, which has a fine (passing #100 sieve) range of 0-30% would be expected to allow for even greater variations of aggregate within such a wide specification. In fact, the DSA used in this study would also qualify as acceptable 2RC aggregate. For this reason, this study is only comparing the specific aggregate gradations used, and generalizations about one entire aggregate specification performing better than another would be unfounded. Specific gradations of tested aggregates, along with gradation ranges for each specification are listed in Table 1 of this thesis.

5.3.1 Aggregate Discussion: 2RC

The 2RC aggregates in this study had approximately 20% fine material (passing #200 sieve). Approximately 5% clay fines were added to DSA in order to obtain the 2RC aggregate. The use of clay material in road surface aggregate is often a point of contention among road maintenance professionals. In a survey of "surface aggregate" specifications in the United States, only 5 out of 12 aggregates had a plasticity limitation which relates to the allowable amount of clay (Table 5). Nationwide, guidance is mixed as to whether the incorporation of a small amount of clay is beneficial or detrimental to aggregate performance. Those who recommend some clay in surface aggregate typically believe that the material will retain water which will reduce dust and facilitate the re-working or grading of the road surface. Those who discourage the incorporation of clay in surface aggregate typically believe that clay will cause the road surface to be softer and rut more easily. Clay is also believed to be more readily available for detachment in the form of dust and sediment runoff due to its hydroscopic and platy properties.

The clay contained in both sections of 2RC aggregate had some obvious effects in this study. The surface of the 2RC material was by far the smoothest and softest of the aggregates. As discussed previously, the 2RC aggregates had to be graded due to severe rutting in April of 2003. Even after this grading, the softness of the 2RC aggregate made it more susceptible to rutting as shown in the degree of rutting analysis. The rutting observed in the 2RC aggregate appeared to be cause by displacement and plastic deformations. This contrasts to rutting in the other aggregate that appeared to be due to the unraveling of the road surface.

In addition to rutting, several observations during the course of this study support the idea that the clay in the 2RC aggregate is more available to detachment. First, the 2RC sections of aggregate consistently had more dust that other aggregates by visual

Figure 17. This culvert is located at the boundary of two aggregate placements. Clear runoff on the left of the image is runoff from "Section 5: 2A, Paver." The sediment-laden water on the right of the image is runoff from the clay containing aggregate on "Section 4: 2RC, Paver."

observations. The dust that was generated also was more persistent, meaning that it traveled higher and took a longer time to dissipate. These observations are similar to other dust quantification studies that have been performed by the Center for Dirt and Gravel Roads (Bloser, 2003). A second notable effect of the clay in the 2RC sections was the increased amount of sediment in road runoff compared to the other sections. Figure 17 shows a culvert inlet that is located at the boundary of the 2A and 2RC paver-placed sections. It is clear in Figure 17 that the runoff coming to the culvert from the 2RC sections contains significantly more sediment that the runoff coming from the 2A section. The increased amount of sediment in runoff from the 2RC sites was also evident by staining at culvert outlets. Culverts that were located on 2RC sections of the roadway had outlets that were noticeably stained with sediment (Figure 18). Grayish-brown sediment covered leaves and vegetation over 50 feet (15 m) from some culvert outlets. In comparison, outlet staining associated with DSA and 2A was minimal and confined to within 10 feet (3 m) of the roadway.

It is clear that the 2RC aggregate used in this study had a softer surface, was more susceptible to rutting, and had a higher level of dust and sediment generation. It should be noted that before attributing these differences solely to the existence of clay in the aggregate, that there was a higher level of total fines (-#200 sieve) in the aggregate. The 2RC aggregate had approximately 20% fine material compared to 15.4% for DSA, and 9% for 2A. The existence of these excess fines could have caused this aggregate to perform this way even if the fines were not clay. In order to determine the effect of clay in aggregates, it would be necessary to compare two identical

Figure 18. This culvert outlet located on "Section 4: 2RC, Paver" is visibly stained with sediment from runoff. Other aggregate sections had minimal visible sediment or outlet staining.

gradations, one with rock fines, and one with clay fines.

5.3.2 Aggregate Discussion: 2A

It is important to take into consideration that the 2A aggregate used in this study had approximately 9% fine material (passing #200 sieve). This is at the upper end of the range of 0-10% fines in the 2A aggregate specification. The 2A aggregate used in this study was almost within the range of the DSA specification (10-20% fines).

The 2A aggregate used in this study performed relatively well. While the aggregate elevation dropped across the road profile for all cross-sections, the aggregate did not need to be graded for the duration of the study. Degree of rutting analysis showed that moderate rutting occurred in both 2A placements. On average, the rutting was less severe than 2RC aggregates, and slightly more severe than the DSA aggregates. Unlike rutting in the 2RC sections which was caused by displacement of soft aggregate, rutting in the 2A sections appeared to be caused by large stones being separated from the road surface and accumulating in windrows along the roadway. This is clearly evident in the form of wide and deep piles

Figure 19. **"**Section 2: 2A, Tailgated" illustrates the outward migration of larger size aggregate. Larger stones are mobilized and windrowed on the centerline and shoulders of the roadway.

of loose stone that line the edges of the 2A placement sections (Figure 19).

One of the major differences between the specifications for 2A and DSA is the range of fines (passing #200 sieve). The range of fine material for 2A is 0-10% of the aggregate weight, whereas the range for DSA is 10-20% of the aggregate weight. Because the specific 2A gradation used in this study had a fine content of 9%, it can be expected to behave more like DSA. A more ideal comparison could be accomplished by comparing "midline" specifications for each aggregate.

5.3.3 Aggregate Discussion: DSA

The Driving Surface Aggregate used in this study had a fine (passing #200 sieve) content of 15.4% of the total aggregate weight. This is approximately in the middle of the DSA specification range for fine material of 10-20%. Since this study began in 2002, the Center for Dirt and Gravel Roads and the Dirt and Gravel Road Maintenance Program have slightly modified the DSA gradation specification. Both the past and current DSA specifications are listed in Table 4. The most significant change in the specification was a reduction in the range for material passing the #200 sieve from 10-20% to 10-15%. This was done based on many aggregate placement jobs throughout Pennsylvania that

AGGREGATE	**SPECIFICATION - Total Percent Passing**								
	2"	**1.5"**	**3/4"**	**3/8"**	**#4**	**#8**	**#16**	**#100**	**#200**
DSA - 2002	-	100	65-90	-	30-65	-	15-30	-	10-20
DSA - current	-	100	65-95	-	30-65	-	15-30	-	10-15
2A	100	-	52-100	36-70	24-50	16-38	10-30	-	0-10
2RC	100	-	-	-	15-60	-	-	0-30	-
AGGREGATE	**ACTUAL - Total Percent Passing**								
	2"	**1.5"**	**3/4"**	**3/8"**	**#4**	**#8**	**#16**	**#100**	**#200**
DSA	-	100	89	-	44	-	20	-	15.4
2A	100	-	85	55	34	24	14	-	9
2RC	100	-	-	-	56	-	-	-	20

Table 4. Specification ranges and actual gradations for the aggregates used in this study. DSA specification was modified in 2005.

experienced problems when fines approached 20%. The reduction of the percent passing in the DSA specification was made in 2005. The DSA used in this study had a fine content of 15.4%, which met the specification in 2002, but would fall just outside of the new limits. The DSA on Crowfield Road performed well over the course of this study. DSA tailgated showed the least amount of bulk aggregate loss, and the second lowest degree of rutting. The paver-placed DSA showed a uniform drop in surface elevation across the road profile and had the least rutting of any of the aggregate placements.

Chapter 6. CONCLUSIONS

6.1 Placement Methods

Paver placement of road aggregates resulted in a much more uniform and controllable aggregate thickness. The quality and thickness of tailgated aggregates will be highly dependant on the skill and experience of motor-grader or bull-dozer operator who determines the final road shape. Placing aggregate using a paver costs approximately 4-5 dollars per ton more than tailgating the same aggregate. This three-year study found no significant differences in the performance of aggregates that can be attributed to the method of placement. It is likely that any potential differences caused by the two placement methods may arise after this three year study has been completed. Longer-term monitoring of the aggregate is suggested to determine if the extra cost of using a paver to place aggregate will result in long-term cost and maintenance reductions.

6.2 Aggregates

The gradation of aggregates used for road surfacing is a key factor in determining the longevity of the driving surface and the amount of sediment that will be generated. The 2RC aggregate used in this study suffered because of the presence of clay fines, an overabundance of fines, or a combination of both factors. The resulting road is soft and prone to rutting deformations. The clay in the 2RC aggregate does retain water and make the aggregate easier to grade back into shape when rutting occurs. Although quantitative measurements were not part of this study, field observations indicated that dust and sediment runoff was much higher for the 2RC aggregates. The 2A aggregate used in this study was most prone to the windrowing of large loose stone along the road edge. The DSA used in this study exhibited the least amount of aggregate degradation and deformation. It is important to remember, as discussed earlier, that these results are for the specific aggregate gradations used in this study, and no generalizations about one entire aggregate specification performing better than another can be implied.

6.3 The Importance of Aggregate Gradation

While attention is usually given to the hardness or quality of material used for unpaved road aggregates, the importance of selecting the proper size gradation for the aggregate is often overlooked. Several studies have been done to compare the performance of “good quality” aggregates to “poor quality” aggregates. Virtually all of these studies, however, focus on the quality of the parent material of the aggregate and the durability of the fine material (Bilby, 1989; Foltz, 1995; Foltz, 2003). In an effort to illustrate this knowledge gap, it is useful to compare the gradation ranges in aggregates that have been specified for use as a wearing course on unpaved roads. Table 5 summarizes the gradation ranges for “unbound surface aggregate” specifications that exist throughout the United States. It is clear from the variation in the specifications in Table 5 that there is no standard gradation for “surface aggregate”. While aggregate specifications vary nationwide, some useful information can be summarized from Table 5. One thing that all the aggregates have in common is a specification for fine material passing the #200 sieve. Fine percentages range from a low of 4% to a high of 21% with an average percent passing range of 6.2-15.3%. Table 5 also indicates that only half of the specifications have a plasticity limit to address the amount of clay in the aggregate fines. For those aggregates with a defined plasticity limit, the average range of plasticity indexes is 4-10.

Surface aggregate is typically the most costly component of unpaved road maintenance. An aggregate with insufficient fine material will ravel apart, and an aggregate with to much fine material will lack structural support and generate excessive

Pasing Sieve Size	mm	50	38	25	19	12	9.5	4.75	2.36	1.18	0.600	0.420	0.150	0.075	Plasticity Index
	in	2	1.5	1	0.75	0.5	0.375	#4	#8	#16	#30	#40	#100	#200	
Driving Surface Aggregate			100		65-75			30-65		15-30				10-15	
PennDOT 2RC		100						15-60					0-30		
PennDOT 2A		100			52-100		36-70	24-50	16-38	10-30				0-10	
S. Dakota "Gravel Surfacing" (1)					100			50-78	37-67		13-35	13-35		4-15	4-12
"Gradation D" (2)				100	60-90			30-55			11-27	11-27		6-15	
Surface Coarse Aggregate (3)				100			66-100	50-76	40-60	32-50	22-36	22-36		9-21	2-10
"Gradation F" (4)				100	97-100			41-71			12-18	12-18		5-16	
Ohio "411" spec (5)			100	75-100	60-100		35-75	30-60			7-30			3-13	<6 on -#40
Maine Surface Aggregate (6)		100												7-12	
AASHTO Class A&B (7)				100	95-100	70-90		30-55	15-40					6-16	4-9
AASHTO Class C (7)					100			50-80	25-60					>6	4-9
Wisconson DOT (8)					100			20-60						8-15	

(1) Skorseth, 2000, (2) Foltz and truebe, 2003, (3) Keller and Shearer, 2003, (4) FHWA, 1996, (5) Ohio DOT webpage, (6) Maine DEP, (7) AASHTO website

Table 5. Size gradations for “unbound surfacing aggregates” from around the United States are summarized. The first three gradations (shaded) are the ones used in this study

sediment. With billions of dollars being spent each year to surface gravel roads worldwide, more research is need to determine the optimum gradation for surface aggregates. Better aggregate gradations will lead to improvements in unpaved road durability with minimal increased cost since existing aggregate sources can used more effectively. Using a better gradation of aggregate as a driving surface will lead to lower maintenance cost, longer lasting roads, and reduced sediment pollution.

Chapter 7. STUDY INFLUENCING FACTORS

An important component of any research project is to define any factors that may have influenced the study results. Identifying potential study improvements not only enhances the understanding of the subject, but provides guidance to anyone doing similar research in the future.

Several factors about the aggregate placement study could have influenced the results. Since one of the goals of the project was to compare tailgated aggregate against paver-placed aggregate, both sections of aggregate should have been identical. Due to weather problems and contractor schedule conflicts, approximately one month of time elapsed between the tailgated placements in October and the paver placements in November of 2002. While the aggregates were taken off the same pile at the same quarry, a month of outdoor exposure could have caused some changes in aggregate composition.

In order to properly compare placement methods, both aggregates should also have been placed at the same thickness. The paver-placed aggregates were placed according to the Center's specifications at eight inches and compacted to six inches. The depth of the tailgated sections were placed according to the PA Bureau of Forestry's procedures and averaged approximately four inches after compaction. The method of compaction also differed between the placement techniques, with a roller being used to compact the paver-placed aggregates. Since placement depth and compaction were different between the aggregate placements, any changes cannot be directly attributed to the "paver-vs-tailgated" placement methods. In reality, the placement study compared two entirely different philosophies about aggregate placement. The amount of variability inherent to tailgating aggregate could have also influenced the study. Final road shape and the degree of aggregate segregation in tailgated placements is highly dependant on the skill of the truck and grader operator.

The study of the aggregates themselves could have also been improved. As detailed in the discussion, each aggregate that was placed in this study represented one sample in a range of gradations for each aggregate specification. Ideally, the "midline" or average gradation should have been used for each aggregate. This was not done, and as a result, the 2A aggregate is very close to meeting the specification for DSA. However, even if the midline gradations would have been used for each aggregate, it would be impossible to compare complete aggregate specifications based on one data point for each aggregate. The field testing of the aggregate gradations should also have been more rigorous. One sample from the aggregates was taken and used as a basis for that entire aggregate placement. Because variation in gradations can be expected, taking several samples from each aggregate would have given a better approximation of the average gradation of each aggregate.

The cross-sectional survey methods used to measure elevation changes in this study were adapted from methods developed to quantify changes in streambed elevations. Initially, surveys were done on a bi-monthly basis because it was unclear exactly how fast surface elevation changes would occur. It would have been more beneficial to survey more cross-sections less frequently. More cross-sections spread throughout each aggregate would have given a better indication of aggregate performance. Additional testing techniques should have been used to supplement the cross-sectional surveys. Runoff sampling from rain events would have given a quantification of the amount of sediment leaving the road area. More technically advanced equipment used for real-time measurement of pavement roughness could have been adapted for use on the unpaved road surface. These data would have supplemented the cross-sectional data and aided in aggregate comparisons. The cross-sections themselves worked to quantify elevation changes of the road surface, but are very labor intensive. In addition, the mechanisms that led to surface elevation changes were not part of this study. For this reason, it is possible that failures in the road base could be reflected in the road surface and misinterpreted as aggregate failures. Any future studies should attempt to determine (to the greatest extent possible) if aggregate deformations and loss are due to erosion, compaction, lateral movement, or subsurface deformations.

Other variables in the study could also have affected the results. Although Crowfield Road was chosen for its uniformity, small variations existed in the topography, canopy cover, road width, average travel speed, road slope, and cross-sectional shape of the aggregate placements. These variations could have caused some of the performance differences that were seen between the aggregates.

Chapter 8. FUTURE RESEARCH

Unpaved roads have long been the orphan of the modern transportation system. As pavement and concrete consume both road budgets and research efforts, unpaved roads are often forgotten. Maintenance standards for unpaved roads are often non-existent or improperly adapted from highway standards. Unpaved roads are often surfaced with the cheapest or most readily available material with little regard to aggregate performance. Poor surface aggregates result in excessive sediment runoff and increased road maintenance costs. While much research exists concerning aggregates for asphalt pavement mixes, research regarding unbound aggregate gradations for surfacing unpaved roads is minimal. Unpaved roads are more than just roads waiting to be paved. They will continue to be a viable part of the transportation network for decades to come. Table 5 lists aggregate gradations from throughout the United States that are specifically designed as a driving surface for unpaved roads. The limited number of aggregates and the wide range in gradations in Table 5 indicate that much more research is needed concerning surface aggregate gradations for unpaved roads.

The most obvious avenue for future research is to determine the optimum gradation for surface aggregates. While an optimum gradation may be somewhat source dependant, determining the optimum gradation range that will work for most “hard” aggregate sources will lead to longer lasting, more environmentally sensitive unpaved road surfaces. Of particular interest is the amount of fine material (passing #200 sieve) that should be contained in the aggregate. It is a delicate balance since the aggregate will not bind together with insufficient fines, but excessive fines will be more available for erosion. Future research in this area should focus on testing and improving the few surface aggregate gradations that have already been developed. Because of the high costs of aggregate placement, future research should begin in the lab before moving to full scale field tests.

The inclusion of clay fines in aggregate is also an area for future research. The unique properties of clay will have a large effect on the behavior of surface aggregates. While clay can retain water and act as a binder, it can also become more readily available for erosion as dust or sediment. The DSA specification developed by the Center does not allow for the addition of clay or silt fines. The 10-15% by weight of material passing the #200 sieve must me made entirely of crushed rock. Significant further research opportunities exist in determining the benefits and pitfalls of clay fines versus rock fines for unpaved road aggregates.

The use of a paver to place aggregate is another subject where more research is needed. Although anecdotal observations indicate that paver-placed aggregate performs better, no quantitative studies have demonstrated the effectiveness of using a paver to place unbound road aggregates. Paver-placement increases aggregate costs by approximately $4-5 per ton. More research is needed to determine if paver-placement provides benefits to justify this additional cost.

Unpaved roads will continue to be an important part of the transportation infrastructure in the United States and Worldwide. Many research opportunities exists regarding aggregates specifically designed as surface wearing courses for unpaved roads. Any improvements in the durability of surface aggregates will result in lower maintenance costs and reduced sediment pollution wherever they are used.

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Appendix A. Stationing of Crowfield Road

Distance (ft)	Points	Aggregate
0	end of nursery fence to South	
255	Begin section 6-DSA Paver	6 - DSA_paver
325	Driveway	
375	cross-section 6.3	
445	cross-section 6.2	
487	cross-section 6.1	
658	culvert	
900	Trail to North	
948	End section 6-DSA Paver	
2,010	Begin section 5	5 - 2A_paver
2,188	culvert	
2,820	culvert	
2,946	cross-section 5.3	
3,008	cross-section 5.2	
3,062	cross-section 5.1	
3,096	culvert	
3,239	End 5- Begin 4	4 - 2R _paver
3,394	culvert	
3,700	Driveway	
3,928	culvert	
4,171	cross-section 4.1	
4,227	cross-section 4.2	
4,269	cross-section 4.3	
4,471	culvert	
4,489	End 4 begin 3	3 - DSA_tail
5,063	side road	
5,154	culvert	
5,320	cross-section 3.3	
5,380	cross-section 3.2	
5,441	cross-section 3.1	
5,570	culvert	
5,577	End 3-Start2	2 - 2A_tail
5,945	culvert	
6,388	culvert	
6,432	cross-section 2.3	
6,472	cross-section 2.2	
6,521	cross-section 2.1	
6,605	culvert	
6,773	End 2 Start 1	1 - 2RC_tail
6,883	culvert	
7,221	culvert	
7,323	cross-section 1.3	
7,367	cross-section 1.2	
7,422	cross-section 1.1	
7,531	culvert	
7,855	culvert-End of Section 1	

Appendix B. Traffic Counts for Crowfield Road

Fall 2003

weekends shaded

Counter located at east end of road near nursery fence

DATE	COUNT	NOTE
5-Aug	30	
6-Aug	46	
7-Aug	22	
8-Aug	26	
9-Aug	38	
10-Aug	59	
11-Aug	40	
12-Aug	53	
13-Aug	40	
14-Aug	44	
15-Aug	46	
16-Aug	55	
17-Aug	59	
18-Aug	32	
19-Aug	38	
20-Aug	28	
21-Aug	23	
22-Aug	28	
23-Aug	46	
24-Aug	48	
25-Aug	23	
26-Aug	15	
27-Aug	25	
28-Aug	39	
29-Aug	62	
30-Aug	49	
31-Aug	57	
1-Sep	20	
2-Sep	20	
3-Sep	8	
4-Sep	38	
5-Sep	35	
6-Sep	34	
7-Sep	52	
8-Sep	23	
9-Sep	24	
10-Sep	31	
11-Sep	40	
12-Sep	35	
13-Sep	39	
14-Sep	34	
15-Sep	20	

Traffic Counters recharged and replaced

DATE	COUNT	NOTE
2-Oct	29	
3-Oct	77	
4-Oct	109	*Archery
5-Oct	96	Season
6-Oct	52	Begins
7-Oct	49	
8-Oct	23	
9-Oct	40	
10-Oct	62	
11-Oct	157	
12-Oct	89	
13-Oct	46	
14-Oct	32	
15-Oct	23	
16-Oct	29	
17-Oct	60	
18-Oct	147	
19-Oct	83	
20-Oct	48	
21-Oct	48	
22-Oct	49	
23-Oct	85	
24-Oct	97	
25-Oct	136	
26-Oct	88	
27-Oct	7	
28-Oct	20	
29-Oct	31	
30-Oct	26	
31-Oct	45	
1-Nov	78	
2-Nov	101	
3-Nov	53	
4-Nov	39	
5-Nov	33	
6-Nov	57	
7-Nov	55	
8-Nov	72	
9-Nov	48	
10-Nov	36	
11-Nov	22	
12-Nov	33	
13-Nov	25	
14-Nov	39	

cont…..

DATE	COUNT	NOTE
15-Nov	59	***Archery
16-Nov	31	Season
17-Nov	24	Ends
18-Nov	30	
19-Nov	10	
20-Nov	34	
21-Nov	30	
22-Nov	71	
23-Nov	72	
24-Nov	140	Bear Season
25-Nov	95	Bear Season
26-Nov	90	Bear Season
27-Nov	50	Thanksgiving
28-Nov	88	
29-Nov	137	
30-Nov	173	
1-Dec	165	***Deer
2-Dec	141	Season
3-Dec	113	Begins
4-Dec	57	
5-Dec	41	
6-Dec	61	
7-Dec	9	Significent snows
8-Dec	43	may have affected
9-Dec	31	readings
10-Dec	26	
11-Dec	35	
12-Dec	78	
13-Dec	76	***Deer
14-Dec	24	Season
15-Dec	31	Ends
16-Dec	4	
17-Dec	1	
18-Dec	10	
19-Dec	6	
20-Dec	20	
21-Dec	19	
22-Dec	3	
23-Dec	9	
24-Dec	1	
25-Dec	5	
26-Dec	39	
27-Dec	85	
28-Dec	18	

DATE	COUNT	NOTE
29-Dec	31	
30-Dec	21	
31-Dec	25	
1-Jan	29	2004
2-Jan	35	
3-Jan	38	
4-Jan	16	

Winter pack snow reduced reading to zero
Air tube broke over winter

Total Count	6,578
Average Weekday	40
Average Weekend	68
Average Daily	**48**

Appendix C: Pictures of Aggregate Placement Sections

Before Placement – 10 / 2002

After Placement: 10 / 2002

3 / 2003

5 / 2004

4 / 2006

4 / 2006 Aggregate Surface

Aggregate Section 1: 2RC Tailgated


Before Placement – 10 / 2002


After Placement: 10 / 2002

3 / 2003


5 / 2004

4 / 2006

4 / 2006 Aggregate Surface

Aggregate Section 2: 2A Tailgated

Before Placement – 10 / 2002

After Placement: 10 / 2002

3 / 2003

5 / 2004

4 / 2006

4 / 2006 Aggregate Surface

Aggregate Section 3: DSA Tailgated

Before Placement – 10 / 2002

After Placement: 10 / 2002

3 / 2003


5 / 2004

4 / 2006

4 / 2006 Aggregate Surface

Aggregate Section 4: 2RC Paver Placed

Before Placement – 10 / 2002

After Placement: 10 / 2002

3 / 2003

5 / 2004

4 / 2006

4 / 2006 Aggregate Surface

Aggregate Section 5: 2A Paver Placed

Before Placement – 10 / 2002

After Placement: 10 / 2002

3 / 2003

5 / 2004

4 / 2006

4 / 2006 Aggregate Surface

Aggregate Section 6: DSA Paver Placed

Appendix D. Rutting Depth and Volume Measurements

FT / SQFT		Rut DEPTH (ft)				Rut VOL (sqft)			
		2002	2002	2006	2006	2002	2002	2006	2006
2RC tailgated	1.1	0.059	0.027	0.043	0.013	0.126	0.017	0.076	0.005
	1.2	0.030	0.024	0.105	0.061	0.025	0.008	0.338	0.100
	1.3	0.046	0.006	0.094	0.045	0.131	0.003	0.284	0.096
2A tailgated	2.1	0.016	0.013	0.056	0.083	0.008	0.004	0.098	0.160
	2.2	0.032	0.026	0.053	0.048	0.035	0.017	0.126	0.085
	2.3	0.013	0.024	0.058	0.053	0.008	0.010	0.092	0.077
DSA tailgated	3.1	0.038	0.014	0.037	0.058	0.057	0.003	0.045	0.102
	3.2	0.032	0.034	0.072	0.072	0.027	0.025	0.119	0.161
	3.3	0.059	0.014	0.065	0.054	0.111	0.011	0.117	0.066
2RC paver	4.1	0.035	0.005	0.139	0.000	0.024	0.002	0.379	0.000
	4.2	0.026	0.024	0.161	0.032	0.032	0.022	0.346	0.033
	4.3	0.042	0.016	0.155	0.112	0.033	0.007	0.326	0.218
2A paver	5.1	0.016	0.026	0.059	0.080	0.003	0.008	0.129	0.193
	5.2	0.008	0.018	0.043	0.105	0.002	0.003	0.037	0.244
	5.3	0.000	0.008	0.048	0.038	0.000	0.002	0.058	0.053
DSA paver	6.1	0.021	0.032	0.089	0.054	0.003	0.018	0.158	0.067
	6.2	0.019	0.016	0.067	0.029	0.007	0.016	0.078	0.019
	6.3	0.014	0.021	0.061	0.011	0.001	0.002	0.099	0.003

Appendix E. Cross-sectional Survey Data

Data for each of the 18 cross-sections is listed in this appendix. The data is presented in the order listed below. "X" coordinates represents the distance across the road from the upslope rebar. "Y" coordinates represents the elevation of each point.

Cross-section 1.1 – 1.3	2RC Tailgated
Cross-section 2.1 – 2.3	2A Tailgated
Cross-section 3.1 – 4.3	DSA Tailgated
Cross-section 4.1 – 4.3	2RC Paver Placed
Cross-section 5.1 – 5.3	2A Paver Placed
Cross-section 6.1 – 6.3	DSA Paver Placed

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10	-	96.10
-	95.90	-	95.94	-	95.89	-	95.89	-	95.91	-	95.87	-	95.94	-	95.87	-	95.89	-	95.92	-	95.88	-	95.88
3	95.40	2	95.67	1	95.74	2	95.60	3	95.41	3	95.36	3	95.44	3	95.40	2	95.61	2	95.57	4	95.27	2	95.61
6	95.19	4	95.33	2	95.60	5	95.23	5	95.23	5	95.24	6	95.03	6	94.94	4	95.29	5	95.19	6	95.04	4	95.33
6	94.78	7	94.69	4	95.31	6	94.94	6	94.94	6	94.95	7	95.02	7	95.00	6	95.01	6	95.00	7	95.15	6	95.01
7	94.72	9	94.89	5	95.25	7	95.08	7	95.01	7	95.02	8	95.15	8	95.16	7	95.09	7	95.10	8	95.18	7	95.17
7	94.75	11	95.07	6	94.83	8	95.12	7	95.16	8	95.15	9	95.26	9	95.23	8	95.18	8	95.17	9	95.24	8	95.20
8	94.85	13	95.38	7	95.12	9	95.21	8	95.13	9	95.30	10	95.39	10	95.35	9	95.25	9	95.21	10	95.32	9	95.21
9	94.89	14	95.38	8	95.13	10	95.45	9	95.23	10	95.42	11	95.51	11	95.48	10	95.33	10	95.30	11	95.46	10	95.30
11	95.01	15	95.44	8	95.05	11	95.58	10	95.43	11	95.52	12	95.66	12	95.62	11	95.49	11	95.46	12	95.59	11	95.41
12	95.16	17	95.37	9	95.31	12	95.67	11	95.59	12	95.66	13	95.83	13	95.80	12	95.62	12	95.58	13	95.72	12	95.55
13	95.31	19	95.26	10	95.44	13	95.78	12	95.66	13	95.87	14	95.92	14	95.83	13	95.81	13	95.73	14	95.77	13	95.70
14	95.37	21	95.13	11	95.58	14	95.87	13	95.79	14	95.91	15	95.85	15	95.80	14	95.83	14	95.75	15	95.73	14	95.71
15	95.42	23	95.09	12	95.67	15	95.89	14	95.87	15	95.85	16	95.78	16	95.74	15	95.75	15	95.72	16	95.70	15	95.69
16	95.43	25	94.97	13	95.78	16	95.81	15	95.88	16	95.77	17	95.71	17	95.68	16	95.75	16	95.69	17	95.66	16	95.67
17	95.38	27	94.95	14	95.90	17	95.74	16	95.81	17	95.68	18	95.62	18	95.63	17	95.69	17	95.68	18	95.66	17	95.66
18	95.37	28	94.79	15	95.90	18	95.67	17	95.74	18	95.63	19	95.55	19	95.54	18	95.63	18	95.65	19	95.58	18	95.65
20	95.27	28	95.14	16	95.83	19	95.60	18	95.67	19	95.55	20	95.47	20	95.45	19	95.59	19	95.53	20	95.46	19	95.63
22	95.11	-	-	17	95.76	20	95.50	19	95.59	20	95.47	21	95.37	21	95.27	20	95.47	20	95.44	21	95.39	20	95.48
24	94.99	-	-	18	95.70	21	95.32	20	95.50	21	95.30	22	95.23	24	94.97	22	95.36	21	95.39	23	95.08	21	95.40
26	94.98	-	-	19	95.62	22	95.13	21	95.30	22	95.19	23	95.06	28	94.79	23	95.08	22	95.24	25	94.94	22	95.26
28	94.80	-	-	20	95.53	24	94.99	23	95.06	24	94.98	25	94.93	28	95.08	25	94.93	24	94.98	28	94.82	23	95.08
28	95.12	-	-	21	95.37	26	94.97	25	94.93	26	94.94	28	94.78	-	-	27	94.83	26	94.96	28	95.11	24	95.00
-	-	-	-	22	95.15	28	94.79	28	94.83	28	94.80	28	95.07	-	-	27	95.10	28	94.79	-	-	26	94.98
-	-	-	-	23	95.05	28	95.10	28	95.08	28	95.07	-	-	-	-	-	-	28	95.07	-	-	28	94.79
-	-	-	-	24	95.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	95.05
-	-	-	-	26	94.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	94.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	94.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	95.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 1-1 2RC Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51	-	94.51
-	94.28	-	94.28	-	94.27	-	94.26	-	94.26	-	94.25	-	94.27	-	94.21	-	94.29	-	94.26	-	94.33	-	94.31
5	93.72	2	94.12	1	94.22	3	93.93	3	93.97	3	93.84	3	93.95	3	93.89	2	94.08	3	93.95	4	93.84	2	94.11
6	93.56	4	93.83	3	93.95	5	93.71	6	93.56	6	93.51	6	93.53	6	93.42	4	93.83	5	93.74	7	93.37	4	93.83
7	93.27	6	93.54	5	93.73	7	93.27	7	93.31	7	93.26	7	93.26	7	93.22	6	93.55	7	93.31	8	93.51	6	93.51
8	93.27	7	93.25	6	93.47	8	93.33	8	93.39	8	93.36	9	93.44	9	93.44	7	93.33	8	93.45	9	93.64	7	93.30
9	93.36	9	93.41	7	93.28	9	93.50	9	93.56	9	93.50	10	93.63	9	93.50	8	93.42	9	93.60	10	93.69	8	93.45
10	93.45	11	93.55	8	93.33	10	93.64	10	93.67	10	93.62	11	93.73	10	93.61	9	93.56	10	93.63	11	93.74	9	93.63
11	93.52	13	93.80	9	93.52	11	93.78	11	93.77	11	93.73	12	93.83	11	93.66	10	93.63	11	93.70	12	93.83	10	93.61
12	93.61	14	93.83	10	93.66	12	93.85	12	93.88	12	93.83	13	93.97	12	93.78	11	93.72	12	93.82	13	93.95	11	93.70
13	93.69	15	93.80	11	93.81	13	93.92	13	93.92	13	93.98	14	94.10	13	93.91	12	93.82	13	93.92	14	94.06	12	93.76
14	93.80	17	93.69	12	93.88	14	94.02	14	94.04	14	94.09	15	94.06	14	94.04	13	93.93	14	94.03	15	94.08	13	93.88
15	93.81	19	93.59	13	93.94	15	93.99	15	94.01	15	94.05	16	93.99	15	94.01	14	94.08	15	94.03	16	94.01	14	93.99
16	93.78	21	93.39	14	94.03	16	93.94	16	93.95	16	93.97	17	93.92	16	93.92	15	94.06	16	93.95	17	93.92	15	93.99
17	93.69	22	93.32	14	94.04	17	93.88	17	93.89	17	93.93	18	93.83	17	93.85	16	93.96	17	93.86	18	93.86	16	93.89
19	93.61	23	93.26	15	93.99	18	93.81	18	93.82	18	93.83	19	93.74	18	93.78	17	93.88	18	93.81	19	93.85	17	93.83
20	93.54	25	92.95	16	93.95	19	93.76	19	93.76	19	93.73	20	93.66	19	93.69	18	93.83	19	93.78	20	93.77	18	93.79
22	93.38	27	92.87	17	93.90	20	93.66	20	93.68	20	93.66	21	93.57	20	93.63	19	93.78	20	93.70	21	93.74	19	93.78
23	93.22	28	92.53	18	93.83	21	93.55	21	93.56	21	93.57	22	93.46	21	93.53	20	93.70	21	93.58	22	93.58	20	93.76
24	93.22	28	92.75	19	93.79	22	93.34	22	93.37	22	93.45	24	93.18	24	93.13	21	93.60	22	93.47	24	93.22	21	93.63
26	92.99	-	-	20	93.66	23	93.24	24	93.17	23	93.28	26	92.99	27	92.77	22	93.48	24	93.17	26	93.07	22	93.47
28	92.43	-	-	21	93.54	26	92.99	26	93.00	25	93.04	28	92.48	28	92.38	24	93.21	26	93.00	28	92.59	23	93.31
28	92.74	-	-	22	93.37	28	92.52	28	92.55	27	92.85	28	92.73	28	92.70	26	93.01	28	92.56	28	92.80	25	93.72
-	-	-	-	23	93.24	28	92.74	28	92.79	28	92.54	-	-	-	-	28	92.62	28	92.75	-	-	28	92.54
-	-	-	-	24	93.19	-	-	-	-	28	92.74	-	-	-	-	28	92.76	-	-	-	-	28	92.74
-	-	-	-	25	93.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	26	92.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	92.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	92.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	92.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 1-2 2RC Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95	-	93.95
-	93.72	-	93.72	-	93.71	-	93.70	-	93.70	-	93.67	-	93.69	-	93.66	-	93.72	-	93.72	-	93.70	-	93.74
3	93.20	2	93.36	2	93.35	3	93.14	2	93.31	2	93.30	3	93.14	3	93.12	2	93.35	3	93.11	4	92.96	2	93.39
6	92.82	4	92.96	4	92.96	6	92.82	4	92.98	5	92.85	5	92.85	6	92.79	4	93.00	5	92.87	6	92.82	4	92.97
7	92.74	6	92.84	6	92.82	8	92.83	6	92.81	7	92.71	7	92.72	7	92.75	6	92.82	7	92.77	8	92.92	6	92.87
9	92.87	7	92.76	7	92.74	9	93.02	8	92.77	8	92.85	9	92.97	8	92.89	8	92.85	8	92.88	9	93.18	7	92.83
10	92.95	9	92.91	8	92.79	10	93.13	8	92.87	9	93.05	10	93.11	9	92.99	9	93.05	9	93.08	10	93.18	8	93.00
11	92.99	11	93.01	9	92.92	11	93.26	9	93.03	10	93.16	11	93.21	10	93.11	10	93.13	10	93.16	11	93.23	9	93.19
12	93.05	13	93.25	9	93.01	12	93.34	10	93.15	11	93.25	12	93.29	11	93.19	11	93.20	11	93.23	12	93.28	10	93.20
13	93.12	15	93.27	10	93.11	13	93.49	11	93.29	12	93.35	13	93.40	12	93.29	12	93.27	12	93.23	13	93.40	11	93.25
14	93.20	17	93.18	11	93.26	14	93.59	12	93.38	13	93.45	14	93.58	13	93.39	13	93.37	13	93.38	14	93.51	12	93.32
14	93.28	19	93.05	12	93.38	15	93.64	13	93.49	14	93.63	15	93.65	14	93.56	14	93.55	14	93.52	15	93.58	13	93.42
15	93.27	21	92.90	13	93.46	16	93.62	14	93.58	15	93.64	16	93.56	15	93.60	15	93.63	15	93.58	16	93.53	14	93.54
16	93.21	23	92.88	14	93.59	17	93.54	15	93.63	16	93.58	17	93.49	16	93.55	16	93.56	16	93.53	17	93.44	15	93.61
17	93.16	25	92.51	15	93.62	18	93.46	16	93.61	17	93.52	18	93.39	17	93.49	17	93.46	17	93.45	18	93.37	16	93.52
19	93.10	27	92.00	16	93.63	19	93.38	17	93.53	18	93.41	19	93.33	18	93.41	18	93.42	18	93.38	19	93.35	17	93.47
20	93.08	29	91.42	17	93.56	20	93.29	18	93.44	19	93.32	20	93.23	19	93.33	19	93.34	19	93.35	20	93.29	18	93.41
21	92.99	29	91.67	18	93.48	21	93.25	19	93.36	20	93.21	21	93.13	20	93.25	20	93.27	20	93.27	21	93.20	19	93.39
22	92.91	-	-	19	93.39	22	93.10	20	93.28	21	93.13	22	93.03	21	93.14	21	93.19	21	93.19	22	93.08	20	93.36
24	92.73	-	-	20	93.33	23	92.90	21	93.24	22	93.05	23	92.95	23	92.99	22	93.06	22	93.05	23	92.99	21	93.24
27	91.92	-	-	21	93.25	24	92.79	22	93.11	23	92.94	24	92.77	26	92.29	23	92.97	24	92.80	25	92.49	22	93.13
29	91.43	-	-	22	93.11	25	92.51	23	92.93	26	92.24	27	91.99	29	91.38	24	92.84	26	92.28	-	-	23	93.02
29	91.66	-	-	23	92.90	27	91.93	24	92.74	29	91.43	29	91.39	29	91.65	26	92.30	29	91.44	-	-	24	92.86
-	-	-	-	24	92.78	29	91.41	26	92.25	29	91.66	29	91.63	-	-	28	91.66	29	91.65	-	-	25	92.58
-	-	-	-	25	92.53	29	91.67	28	91.60	-	-	-	-	-	-	29	91.42	-	-	-	-	26	92.25
-	-	-	-	26	92.28	-	-	29	91.43	-	-	-	-	-	-	29	91.65	-	-	-	-	27	92.04
-	-	-	-	27	92.01	-	-	29	91.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	91.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	29	91.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	29	91.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 1-3 2RC Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80	-	91.80
-	91.61	-	91.61	-	91.60	-	91.60	-	91.59	-	91.57	-	91.56	-	91.58	-	91.57	-	91.57	-	91.56	-	91.63
2	90.92	1	91.30	1	91.25	2	90.94	3	90.51	2	90.98	2	90.91	3	90.47	2	90.90	2	90.99	2	90.95	2	91.02
3	90.45	2	91.02	2	90.89	4	90.07	4	90.09	4	90.08	4	90.06	4	90.04	4	90.07	3	90.47	3	90.09	4	90.09
4	90.06	3	90.58	3	90.33	5	90.09	5	90.05	5	90.12	5	90.17	5	90.05	5	90.19	4	90.10	5	90.27	5	90.21
5	90.01	4	90.06	4	90.07	6	90.30	6	90.33	6	90.27	6	90.35	6	90.27	6	90.38	5	90.32	6	90.34	6	90.41
5	90.12	5	89.91	5	89.97	7	90.50	7	90.49	7	90.47	7	90.50	7	90.43	7	90.49	6	90.35	7	90.43	7	90.44
7	90.16	7	90.13	5	90.08	8	90.59	8	90.57	8	90.59	8	90.60	8	90.53	8	90.60	7	90.41	8	90.48	8	90.48
8	90.24	9	90.25	6	90.29	9	90.68	9	90.67	9	90.69	9	90.70	9	90.61	9	90.68	8	90.51	9	90.59	9	90.58
10	90.35	11	90.46	7	90.49	10	90.77	10	90.75	10	90.73	10	90.76	10	90.69	10	90.76	9	90.60	10	90.70	10	90.70
11	90.53	13	90.58	8	90.60	11	90.90	11	90.87	11	90.86	11	90.87	11	90.83	11	90.87	10	90.75	11	90.82	11	90.82
12	90.58	15	90.48	9	90.68	12	90.95	12	90.96	12	90.96	12	90.95	12	90.93	12	90.91	11	90.86	12	90.89	12	90.87
13	90.54	17	90.38	10	90.78	13	90.92	13	90.91	13	90.92	13	90.91	13	90.86	13	90.89	12	90.88	13	90.78	13	90.76
15	90.50	19	90.25	11	90.88	14	90.85	14	90.85	14	90.85	14	90.85	14	90.79	14	90.88	13	90.78	14	90.74	14	90.74
16	90.48	21	90.11	12	90.95	15	90.80	15	90.82	15	90.81	15	90.78	15	90.75	15	90.75	14	90.73	15	90.72	15	90.74
17	90.45	23	89.94	13	90.91	16	90.74	16	90.75	16	90.75	16	90.72	16	90.71	16	90.72	15	90.73	16	90.73	16	90.74
19	90.31	25	89.71	14	90.85	17	90.69	17	90.72	17	90.69	17	90.66	17	90.64	17	90.66	16	90.73	17	90.68	17	90.72
21	90.08	27	89.44	15	90.80	18	90.57	18	90.63	18	90.58	18	90.61	18	90.62	18	90.68	17	90.67	18	90.65	18	90.72
22	90.03	27	89.69	16	90.74	19	90.49	19	90.51	19	90.52	19	90.52	19	90.48	19	90.53	18	90.60	19	90.54	19	90.59
27	89.47	-	-	17	90.62	20	90.37	20	90.43	20	90.41	20	90.38	20	90.34	20	90.47	19	90.49	20	90.36	20	90.38
27	89.72	-	-	18	90.53	21	90.24	21	90.36	21	90.34	21	90.32	21	90.17	21	90.28	20	90.36	21	90.25	21	90.32
-	-	-	-	19	90.45	22	90.11	22	90.17	22	90.18	24	89.76	24	89.72	22	90.12	21	90.27	23	89.93	22	90.19
-	-	-	-	20	90.41	24	89.74	23	90.00	24	89.75	27	89.46	27	89.41	24	89.75	23	89.89	25	89.71	23	89.96
-	-	-	-	21	90.23	27	89.44	25	89.69	27	89.44	27	89.71	27	89.68	26	89.52	25	89.67	27	89.44	24	89.75
-	-	-	-	22	90.10	27	89.71	27	89.45	27	89.72	-	-	-	-	27	89.45	27	89.45	27	89.70	27	89.47
-	-	-	-	23	89.88	-	-	27	89.70	-	-	-	-	-	-	27	89.71	27	89.71	-	-	27	89.73
-	-	-	-	24	89.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	25	89.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	26	89.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	89.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	89.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 2-1 2A Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92	-	93.92
-	93.70	-	93.76	-	93.72	-	93.71	-	93.72	-	93.68	-	93.70	-	93.69	-	93.74	-	93.69	-	93.70	-	93.73
3	92.82	2	93.29	1	93.47	2	93.28	2	93.17	2	93.24	2	93.22	3	92.71	2	93.24	2	93.19	2	93.20	2	93.16
4	92.50	4	92.07	2	93.19	4	92.48	4	92.46	3	92.75	4	92.44	4	92.45	4	92.49	3	92.77	3	92.59	4	92.54
5	92.60	5	92.61	3	92.78	5	92.71	5	92.71	4	92.47	6	92.75	5	92.56	5	92.79	4	92.56	5	92.88	5	92.89
6	92.69	7	92.76	4	92.49	6	92.93	6	92.96	5	92.72	7	93.10	6	92.91	6	93.07	5	92.81	6	93.01	6	93.03
6	92.71	9	92.89	5	92.76	7	93.11	7	93.07	6	92.90	8	93.22	7	93.11	7	93.15	6	93.01	7	93.09	7	93.11
8	92.80	11	92.97	6	92.96	8	93.25	8	93.25	7	93.08	9	93.32	8	93.20	8	93.25	7	93.10	8	93.16	8	93.17
9	92.87	13	93.10	7	93.08	9	93.31	9	93.37	8	93.23	10	93.40	9	93.28	9	93.31	8	93.17	9	93.28	9	93.22
10	92.89	15	92.94	8	93.28	10	93.45	10	93.43	9	93.32	11	93.54	10	93.37	10	93.41	9	93.25	10	93.36	10	93.31
11	92.97	17	92.85	9	93.39	11	93.57	11	93.57	10	93.41	12	93.55	11	93.45	11	93.50	10	93.36	11	93.47	11	93.40
12	93.07	19	92.72	10	93.50	12	93.64	12	93.61	11	93.56	13	93.54	12	93.57	12	93.60	11	93.45	12	93.55	12	93.52
13	93.07	20	92.64	11	93.65	13	93.58	13	93.58	12	93.61	14	93.45	13	93.51	13	93.55	12	93.58	13	93.49	13	93.47
14	92.99	21	92.54	12	93.64	14	93.47	14	93.49	13	93.59	15	93.35	14	93.41	14	93.44	13	93.50	14	93.38	14	93.36
15	92.93	23	92.20	13	93.59	15	93.40	15	93.39	14	93.50	16	93.25	15	93.32	15	93.35	14	93.39	15	93.33	15	93.31
16	92.90	25	91.49	14	93.50	16	93.29	16	93.29	15	93.37	17	93.15	16	93.24	16	93.26	15	93.32	16	93.28	16	93.25
18	92.86	26	91.08	15	93.40	17	93.21	17	93.22	16	93.27	18	93.06	17	93.18	17	93.21	16	93.27	17	93.21	17	93.21
19	92.75	26	91.26	16	93.34	18	93.11	18	93.14	17	93.19	19	92.95	18	93.08	18	93.15	17	93.21	18	93.11	18	93.12
20	92.62	-	-	17	93.20	19	92.96	19	92.99	18	93.07	20	92.80	19	93.08	20	92.86	18	93.05	19	92.93	19	92.95
21	92.54	-	-	18	93.13	20	92.82	20	92.84	19	92.97	23	92.15	21	92.68	22	92.45	19	92.92	21	92.57	20	92.83
22	92.49	-	-	19	93.00	21	92.61	21	92.69	20	92.85	26	91.05	23	92.19	24	91.82	20	92.85	24	91.86	21	92.65
26	91.01	-	-	20	92.86	22	92.45	23	92.14	21	92.62	26	91.25	26	91.05	26	91.07	22	92.40	26	91.04	22	92.43
26	91.21	-	-	21	92.65	24	91.86	24	91.88	24	91.83	-	-	26	91.23	26	91.27	24	91.79	26	91.28	24	91.88
-	-	-	-	22	92.46	26	91.03	26	91.09	26	91.11	-	-	-	-	-	-	26	91.07	-	-	26	91.02
-	-	-	-	23	92.22	26	91.25	26	91.26	26	91.26	-	-	-	-	-	-	26	91.26	-	-	26	91.26
-	-	-	-	24	91.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	25	91.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	26	91.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	26	91.28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 2-2 2A Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	96.09	-	95.97
-	95.80	-	95.82	-	95.82	-	95.79	-	95.76	-	95.78	-	95.76	-	95.75	-	95.77	-	95.70	-	95.71	-	95.75
-	-	1	95.38	1	95.47	2	94.91	2	94.94	2	94.74	2	94.88	3	94.43	2	94.96	2	94.93	2	94.89	2	94.90
3	94.51	2	94.99	2	94.94	3	94.48	3	94.48	3	94.45	4	94.48	6	94.71	4	94.63	3	94.50	3	94.46	4	94.61
4	94.54	3	94.47	3	94.50	5	94.64	4	94.55	5	94.63	6	94.78	7	94.89	6	94.83	4	94.59	5	94.68	5	94.67
5	94.62	4	94.56	4	94.55	6	94.76	5	94.63	6	94.79	7	94.94	8	95.10	7	94.97	5	94.65	6	94.88	6	94.94
7	94.78	5	94.64	5	94.65	7	94.89	6	94.78	7	94.99	8	95.11	9	95.09	8	95.09	6	94.80	7	94.98	7	95.03
8	94.88	7	94.76	6	94.74	8	95.04	7	94.93	8	95.10	9	95.10	10	95.13	9	95.14	7	94.99	8	95.00	8	95.07
9	94.90	9	94.86	6	94.82	9	95.12	8	95.12	9	95.11	10	95.14	11	95.16	10	95.15	8	95.06	9	95.06	9	95.09
10	94.88	11	94.93	7	94.90	10	95.19	9	95.13	10	95.15	11	95.18	12	95.21	11	95.18	9	95.05	10	95.04	10	95.08
12	94.90	13	94.95	8	95.06	11	95.20	10	95.14	11	95.20	12	95.21	13	95.17	12	95.20	10	95.07	11	95.06	11	95.09
14	94.93	15	94.82	9	95.13	12	95.26	11	95.20	12	95.25	13	95.21	14	95.16	13	95.20	11	95.10	12	95.14	12	95.15
16	94.76	17	94.65	10	95.19	13	95.28	12	95.24	13	95.25	14	95.22	15	95.05	14	95.18	12	95.16	13	95.16	13	95.19
18	94.59	19	94.69	11	95.26	14	95.21	13	95.30	14	95.20	15	95.08	16	94.95	15	95.09	13	95.21	14	95.07	14	95.13
20	94.47	21	94.31	12	95.33	15	95.11	14	95.20	15	95.07	16	94.99	17	94.86	16	94.95	14	95.14	15	95.00	15	95.03
21	94.32	23	94.17	13	95.30	16	95.05	15	95.10	16	95.01	17	94.88	18	94.79	17	94.86	15	95.00	16	94.88	16	94.91
22	94.36	25	93.82	14	95.20	17	94.92	16	95.00	17	94.90	18	94.80	19	94.72	18	94.78	16	94.87	17	94.77	17	94.82
25	93.82	27	93.14	15	95.14	18	94.82	17	94.89	18	94.82	19	94.76	20	94.67	19	94.76	17	94.79	18	94.71	18	94.78
27	93.07	27	93.31	16	95.02	19	94.75	18	94.82	19	94.73	20	94.66	21	94.47	20	94.70	18	94.75	19	94.71	19	94.72
27	93.30	-	-	17	94.94	20	94.65	19	94.77	20	94.61	21	94.54	24	93.99	22	94.35	19	94.67	20	94.57	20	94.68
-	-	-	-	18	94.81	21	94.51	20	94.67	21	94.50	24	94.02	27	93.07	24	93.98	20	94.58	22	94.30	21	94.49
-	-	-	-	19	94.75	22	94.34	21	94.55	22	94.31	27	93.08	27	93.29	26	93.54	21	94.43	24	93.89	23	94.25
-	-	-	-	20	94.67	24	94.01	22	94.38	24	93.99	27	93.68	-	-	27	93.14	23	94.24	27	93.08	27	93.13
-	-	-	-	21	94.51	27	93.11	24	94.00	27	93.11	-	-	-	-	27	93.29	25	93.74	27	93.22	27	93.30
-	-	-	-	22	94.36	27	93.30	27	93.12	27	93.30	-	-	-	-	-	-	27	93.05	-	-	-	-
-	-	-	-	23	94.19	-	-	27	93.31	-	-	-	-	-	-	-	-	27	93.28	-	-	-	-
-	-	-	-	24	94.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	25	93.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	26	93.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	93.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	93.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 2-3 2A Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02	-	91.02
-	90.72	-	90.73	-	90.78	-	90.78	-	90.77	-	90.76	-	90.77	-	90.70	-	90.69	-	90.68	-	90.77	-	90.82
4	89.52	2	90.16	2	90.21	2	90.19	2	90.28	2	90.23	2	90.24	3	89.77	2	90.18	2	90.24	3	89.80	2	90.23
4	89.37	4	89.39	3	89.80	4	89.43	5	89.33	4	89.47	4	89.40	4	89.36	4	89.40	4	89.42	5	89.55	4	89.45
5	89.33	5	89.35	4	89.42	5	89.43	5	89.42	5	89.43	5	89.50	5	89.50	5	89.52	6	89.75	6	89.79	5	89.56
6	89.49	7	89.51	5	89.44	6	89.73	6	89.69	6	89.68	6	89.74	7	89.83	6	89.75	7	89.82	7	89.81	6	89.78
8	89.64	9	89.62	6	89.62	7	89.87	7	89.88	7	89.85	7	89.88	8	89.92	7	89.85	8	89.86	8	89.86	7	89.84
10	89.76	11	89.80	6	89.76	8	89.95	8	89.94	8	89.93	8	89.95	9	89.95	8	89.92	9	89.92	9	89.94	8	89.83
12	89.88	13	89.98	7	89.88	9	89.97	9	89.97	9	89.95	9	89.98	10	90.00	9	89.96	10	90.03	10	90.03	9	89.90
13	89.92	15	89.83	8	89.96	10	90.03	10	90.03	10	90.02	10	90.05	11	90.12	10	90.05	11	90.14	11	90.13	10	89.98
14	89.91	17	89.77	9	89.99	11	90.12	11	90.13	11	90.11	11	90.14	12	90.17	11	90.12	12	90.16	12	90.17	11	90.07
16	89.87	19	89.64	10	90.04	12	90.22	12	90.17	12	90.19	12	90.21	13	90.16	12	90.15	13	90.13	13	90.10	12	90.14
18	89.82	21	89.54	11	90.12	13	90.19	13	90.19	13	90.19	13	90.18	14	90.11	13	90.13	14	90.07	14	90.05	13	90.06
20	89.70	23	89.11	12	90.20	14	90.16	14	90.15	14	90.15	14	90.15	15	90.08	14	90.09	15	90.03	15	90.06	14	90.04
23	89.21	25	88.60	13	90.20	15	90.11	15	90.11	15	90.09	15	90.10	16	90.08	15	90.08	16	90.12	16	90.07	15	90.04
28	87.37	27	87.93	14	90.15	16	90.06	16	90.05	16	90.07	16	90.09	17	90.03	16	90.09	17	89.99	17	90.05	16	90.09
28	87.65	28	87.31	15	90.11	17	89.96	17	89.97	17	89.96	17	89.98	18	89.91	17	90.01	18	89.86	18	89.91	17	90.01
-	-	28	87.59	16	90.06	18	89.86	18	89.89	18	89.90	18	89.91	19	89.79	18	89.85	19	89.80	19	89.82	18	89.95
-	-	-	-	17	89.97	19	89.79	19	89.81	19	89.80	19	89.77	21	89.69	20	89.65	20	89.70	21	89.59	19	89.81
-	-	-	-	18	89.88	20	89.65	20	89.67	20	89.67	20	89.65	24	89.00	22	89.35	22	89.43	23	89.19	20	89.71
-	-	-	-	19	89.79	22	89.39	23	89.15	22	89.41	23	89.17	28	87.37	24	88.90	24	88.98	25	88.70	21	89.59
-	-	-	-	20	89.72	25	88.62	25	88.65	25	88.61	26	88.33	28	87.64	26	88.23	26	88.33	28	87.37	23	89.16
-	-	-	-	20	89.67	28	87.35	28	87.33	28	87.36	28	87.38	-	-	28	87.33	28	87.31	28	87.64	26	88.30
-	-	-	-	21	89.57	28	87.65	28	87.63	28	87.63	28	87.64	-	-	28	87.62	28	87.63	-	-	28	87.33
-	-	-	-	22	89.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	87.65
-	-	-	-	23	89.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	25	88.64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	26	88.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	87.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	87.36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	87.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 3-1 DSA Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54	-	92.54
-	92.36	-	92.39	-	92.32	-	92.36	-	92.33	-	92.34	-	92.33	-	92.33	-	92.31	-	92.34	-	92.33	-	92.32
4	91.07	1	92.12	2	91.67	2	91.65	3	91.30	2	91.71	2	91.65	3	91.29	2	91.69	2	91.74	2	91.68	2	91.70
5	90.99	2	91.72	3	91.27	4	91.02	4	91.00	4	91.06	4	91.01	4	91.02	4	91.07	4	91.08	4	91.01	4	91.06
6	91.05	3	91.33	4	91.03	5	91.05	5	91.03	5	91.06	5	91.09	5	91.08	5	91.18	5	91.16	6	91.36	5	91.10
6	91.11	4	91.04	5	91.08	6	91.34	6	91.32	6	91.34	6	91.28	6	91.29	6	91.39	6	91.44	7	91.45	6	91.43
8	91.19	5	91.03	6	91.34	7	91.47	7	91.44	7	91.44	7	91.45	7	91.39	7	91.48	7	91.44	8	91.48	7	91.46
9	91.21	7	91.16	7	91.46	8	91.53	8	91.54	8	91.56	8	91.51	8	91.49	8	91.53	8	91.48	9	91.53	8	91.48
10	91.25	9	91.20	8	91.55	9	91.60	9	91.58	9	91.59	9	91.57	9	91.54	9	91.59	9	91.54	10	91.64	9	91.53
11	91.31	11	91.31	9	91.60	10	91.67	10	91.68	10	91.67	10	91.66	10	91.61	10	91.68	10	91.66	11	91.74	10	91.62
12	91.33	13	91.30	10	91.69	11	91.78	11	91.77	11	91.78	11	91.75	11	91.73	11	91.80	11	91.78	12	91.77	11	91.73
14	91.25	15	91.20	11	91.79	12	91.81	12	91.82	12	91.83	12	91.80	12	91.80	12	91.82	12	91.79	13	91.66	12	91.77
14	91.18	17	91.07	12	91.83	13	91.74	13	91.76	13	91.76	13	91.71	13	91.72	13	91.71	13	91.70	14	91.59	13	91.67
16	91.15	19	90.87	13	91.78	14	91.61	14	91.62	14	91.62	14	91.59	14	91.60	14	91.62	14	91.58	15	91.44	14	91.54
16	91.15	20	90.87	14	91.64	15	91.52	15	91.54	15	91.55	15	91.51	15	91.52	15	91.54	15	91.52	16	91.49	15	91.52
18	91.00	21	90.64	15	91.57	16	91.44	16	91.46	16	91.48	16	91.45	16	91.47	16	91.50	16	91.51	17	91.36	16	91.53
20	90.80	23	90.28	16	91.47	17	91.32	17	91.35	17	91.37	17	91.33	17	91.36	17	91.37	17	91.38	18	91.21	17	91.43
24	90.03	25	90.11	17	91.37	18	91.14	18	91.17	18	91.22	18	91.15	18	91.15	18	91.25	18	91.26	20	90.82	18	91.32
28	88.74	27	89.40	18	91.17	19	90.95	19	91.01	19	91.01	19	91.00	19	90.98	20	90.78	19	91.05	24	90.09	19	91.06
28	88.94	28	88.72	19	90.97	20	90.77	20	90.73	20	90.85	20	90.77	21	90.61	22	90.47	22	90.42	28	88.72	20	90.85
-	-	28	88.94	20	90.80	22	90.42	22	90.44	22	90.44	23	90.20	25	90.00	24	90.15	25	89.96	28	88.92	21	90.62
-	-	-	-	21	90.58	25	90.00	25	90.02	25	90.07	26	89.68	28	88.75	26	89.67	27	88.66	-	-	24	90.13
-	-	-	-	23	90.24	28	88.71	28	88.71	28	88.77	28	88.73	28	88.92	28	88.77	27	88.91	-	-	28	88.66
-	-	-	-	25	90.03	28	88.93	28	88.91	28	88.93	28	88.93	-	-	28	88.95	-	-	-	-	28	88.94
-	-	-	-	26	89.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	27	89.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	88.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	28	88.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 3-2 DSA Tailgated

Before		Graded		Oct-02		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53	-	96.53
-	96.32	-	96.47	-	96.27	-	96.25	-	96.34	-	96.29	-	96.30	-	96.29	-	96.44	-	96.30	-	96.27	-	96.33
2	95.48	1	95.87	1	95.87	2	95.47	2	95.48	1	95.85	2	95.48	2	95.53	2	95.47	2	95.58	3	94.84	2	95.46
3	94.85	2	95.46	3	95.12	4	93.69	4	93.67	3	94.98	3	94.92	5	93.42	3	94.98	4	94.00	4	94.06	4	93.93
4	93.58	3	95.34	4	93.81	5	93.40	6	93.56	4	93.82	5	93.42	7	93.70	4	93.76	5	93.48	6	93.48	6	93.50
5	93.40	3	94.91	5	93.46	6	93.51	7	93.86	5	93.44	7	93.79	8	93.89	6	93.57	7	93.79	8	93.90	7	93.69
6	93.54	4	93.85	6	93.52	7	93.77	8	93.94	6	93.52	8	93.89	9	93.93	8	93.91	9	93.98	9	94.02	8	93.88
7	93.67	5	93.52	7	93.81	8	93.87	9	93.99	7	93.82	9	93.95	10	94.00	9	94.00	10	94.06	10	94.04	9	93.99
9	93.73	7	93.66	8	93.88	9	93.93	10	94.06	8	93.92	10	94.02	11	94.03	10	94.04	11	94.04	11	94.05	10	94.06
11	93.74	9	93.72	9	93.93	10	94.01	11	94.04	9	93.98	11	94.03	12	94.04	11	94.04	12	94.04	12	94.03	11	94.05
12	93.71	11	93.72	10	94.02	11	94.01	12	94.06	10	94.06	12	94.03	13	94.06	12	94.04	13	94.06	13	94.04	12	94.02
14	93.66	13	93.70	11	94.03	12	94.02	13	94.11	11	94.06	13	94.09	14	94.10	13	94.09	14	94.10	14	94.08	13	94.02
15	93.66	15	93.70	12	94.05	13	94.08	14	94.15	12	94.04	14	94.13	15	94.10	14	94.12	15	94.12	15	94.09	14	94.05
16	93.56	17	93.47	13	94.10	14	94.13	15	94.09	13	94.10	15	94.07	16	93.98	15	94.10	16	94.01	16	93.98	15	94.07
18	93.39	19	93.35	14	94.19	15	94.08	16	94.00	14	94.18	16	94.01	17	93.87	16	94.00	17	93.85	17	93.82	16	93.98
20	93.23	21	93.09	15	94.08	16	93.99	17	93.87	15	94.10	17	93.87	18	93.75	17	93.88	18	93.70	18	93.69	17	93.82
22	93.08	23	93.00	16	93.98	17	93.87	18	93.77	16	94.02	18	93.77	19	93.62	18	93.76	19	93.62	19	93.60	18	93.69
24	92.81	25	92.48	17	93.88	18	93.75	19	93.63	17	93.90	19	93.65	20	93.50	19	93.64	20	93.58	20	93.54	19	93.61
27	91.81	27	91.77	18	93.75	19	93.62	20	93.51	18	93.78	20	93.52	21	93.33	20	93.52	21	93.45	21	93.39	20	93.56
32	90.22	29	90.94	19	93.62	20	93.48	21	93.35	19	93.64	21	93.35	22	93.16	21	93.42	22	93.21	22	93.23	21	93.54
32	90.35	32	90.21	20	93.47	21	93.32	22	93.14	20	93.52	22	93.15	23	93.01	23	93.04	24	92.88	24	92.79	22	93.27
-	-	32	90.35	21	93.24	22	93.11	24	92.81	21	93.34	23	93.00	24	92.82	25	92.59	26	92.14	26	92.15	23	93.08
-	-	-	-	22	93.08	24	92.80	26	92.14	22	93.12	26	92.08	26	92.10	27	91.76	28	91.42	30	90.82	25	92.50
-	-	-	-	23	92.96	27	91.78	29	90.91	23	93.04	29	90.93	29	90.91	29	90.94	32	90.19	32	90.21	29	90.89
-	-	-	-	24	92.80	30	90.65	32	90.19	24	92.90	32	90.18	32	90.16	32	90.20	32	90.36	32	90.30	32	90.14
-	-	-	-	26	92.02	32	90.18	32	90.35	26	92.10	32	90.34	32	90.34	32	90.39	-	-	-	-	32	90.34
-	-	-	-	28	91.09	32	90.34	-	-	29	90.98	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	30	90.53	-	-	-	-	32	90.16	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	32	90.16	-	-	-	-	32	90.37	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	32	90.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 3-3 DSA Tailgated

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	96.70	-	96.70	-	96.70	-	96.70	-	96.70	-	96.70	-	96.70	-	96.70	-	96.70	-	96.70	-	96.70
-	96.53	-	96.49	-	96.51	-	96.49	-	96.50	-	96.55	-	96.47	-	96.49	-	96.49	-	96.59	2	96.56
2	95.65	1	96.14	2	95.60	2	95.62	2	95.62	2	95.66	2	95.62	1	96.12	2	95.79	2	95.74	3	95.76
2	95.52	2	95.58	3	95.82	3	95.80	3	95.88	3	95.92	3	95.80	2	95.70	4	96.06	4	96.04	4	96.11
3	95.54	3	95.52	4	95.97	3	95.89	4	95.97	4	96.00	5	96.04	3	95.90	5	96.20	5	96.19	5	96.18
4	95.63	4	95.69	5	96.07	4	96.01	5	96.02	5	96.06	6	96.05	4	95.98	6	96.16	6	96.16	6	96.15
5	95.70	5	95.49	6	96.13	5	96.04	6	96.07	6	96.10	7	96.08	5	96.08	7	96.12	7	96.11	7	96.08
6	95.78	6	95.61	7	96.14	6	96.19	7	96.12	7	96.15	8	96.10	6	96.12	8	96.14	8	96.11	8	96.08
8	95.81	8	95.83	8	96.26	7	96.15	8	96.14	8	96.16	9	96.17	7	96.12	9	96.22	9	96.20	9	96.13
9	95.82	10	96.02	9	96.26	8	96.06	9	96.22	9	96.26	10	96.23	8	96.12	10	96.32	10	96.28	10	96.23
10	95.90	12	95.95	10	96.27	8	96.05	10	96.25	10	96.30	11	96.25	9	96.17	11	96.29	11	96.27	11	96.25
11	95.91	14	95.69	11	96.29	9	96.24	11	96.25	11	96.28	12	96.17	10	96.24	12	96.20	12	96.19	12	96.15
13	95.77	17	95.37	12	96.25	10	96.30	12	96.17	12	96.24	13	96.08	11	96.25	13	96.07	13	96.07	13	96.02
15	95.63	17	95.50	13	96.15	11	96.34	13	96.09	13	96.12	14	96.02	12	96.20	14	96.04	14	96.03	14	96.00
16	95.58	19	95.30	14	96.15	12	96.35	14	96.03	14	96.10	15	95.96	13	96.08	15	96.02	15	96.00	15	95.96
18	95.41	21	94.62	15	96.04	12	96.09	15	95.96	15	96.02	16	95.90	14	96.03	16	95.95	16	95.94	16	95.95
19	95.32	22	94.24	16	96.00	13	96.03	16	95.88	16	95.94	17	95.81	15	95.98	17	95.88	17	95.88	17	95.89
22	94.24	22	94.41	17	95.89	14	96.14	17	95.80	17	95.85	18	95.62	16	95.92	20	94.99	19	95.38	18	95.65
22	94.43	-	-	18	95.83	15	96.10	18	95.66	18	95.64	22	94.31	17	95.85	22	94.29	22	94.37	19	95.28
-	-	-	-	19	95.36	16	96.03	19	95.29	20	94.96	22	94.41	18	95.70	22	94.50	22	94.47	22	94.28
-	-	-	-	20	94.99	17	95.92	20	94.95	22	94.24	-	-	20	95.00	-	-	-	-	22	94.42
-	-	-	-	22	94.26	18	95.41	22	94.24	22	94.44	-	-	22	94.33	-	-	-	-	-	-
-	-	-	-	22	94.43	20	94.92	22	94.40	-	-	-	-	22	94.43	-	-	-	-	-	-
-	-	-	-	-	-	22	94.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	22	94.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 4-1 2RC Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	95.95	-	95.95	-	95.95	-	95.95	-	95.95	-	95.95	-	95.95	-	95.95	-	95.95	-	95.95	-	95.95
-	95.82	-	95.83	-	95.83	-	95.84	-	95.81	-	95.83	-	95.75	-	95.79	-	95.78	-	95.77	-	95.76
2	94.87	1	95.49	2	94.84	1	95.49	1	95.43	2	94.85	3	94.68	1	95.42	2	94.90	2	94.81	2	94.87
3	94.47	2	94.92	3	94.77	2	94.84	2	94.86	3	94.75	4	94.81	2	94.82	3	94.78	3	94.84	3	94.80
3	94.44	3	94.47	4	94.82	3	94.75	2	94.82	3	94.77	5	94.86	3	94.72	4	94.90	4	94.89	4	94.94
4	94.51	4	94.50	5	94.85	4	94.80	3	94.72	4	94.85	6	94.90	4	94.86	5	94.91	5	94.93	5	94.94
5	94.59	4	94.26	6	94.91	5	94.88	4	94.88	5	94.95	7	94.94	5	94.91	6	94.91	6	94.89	6	94.86
7	94.64	6	94.49	7	94.99	6	94.93	5	94.91	6	94.97	8	95.00	6	94.93	7	94.91	7	94.92	7	94.86
9	94.71	8	94.75	8	95.04	7	94.93	6	94.95	7	94.99	9	95.03	7	94.91	8	95.03	8	95.01	8	94.97
10	94.80	10	94.89	9	95.09	8	95.06	7	94.99	8	95.07	10	95.05	8	95.02	9	95.07	9	95.08	9	95.06
11	94.75	11	94.88	10	95.12	8	95.05	8	95.05	9	95.10	11	95.00	9	95.06	10	95.06	10	95.06	10	95.04
12	94.70	12	94.75	11	95.06	9	95.14	9	95.04	10	95.10	12	94.96	10	95.05	11	94.98	11	94.96	11	94.95
14	94.62	14	94.53	12	95.01	10	95.20	10	95.07	11	95.01	13	94.89	11	94.99	12	94.90	12	94.89	12	94.90
16	94.52	16	94.35	13	94.96	11	95.16	11	95.02	12	95.00	14	94.83	12	94.91	13	94.88	13	94.90	13	94.86
18	94.40	16	94.51	14	94.91	11	95.08	12	94.97	13	94.93	15	94.75	13	94.90	14	94.87	14	94.88	14	94.87
20	93.87	18	94.27	15	94.82	12	95.05	13	94.92	14	94.87	17	94.62	14	94.85	15	94.81	15	94.80	15	94.82
20	94.04	20	93.86	16	94.77	13	95.09	14	94.85	15	94.83	20	93.81	15	94.79	16	94.72	16	94.72	16	94.70
-	-	20	94.03	17	94.61	14	95.03	15	94.81	16	94.75	20	93.90	16	94.70	17	94.64	18	94.21	17	94.62
-	-	-	-	18	94.26	15	94.97	16	94.70	17	94.71	-	-	17	94.62	20	93.85	20	93.83	18	94.21
-	-	-	-	20	93.84	16	94.86	17	94.64	18	94.73	-	-	18	94.22	20	93.90	20	93.89	20	93.79
-	-	-	-	20	93.91	17	94.68	18	94.25	19	94.05	-	-	20	93.81	-	-	-	-	20	93.87
-	-	-	-	-	-	18	94.28	19	94.01	20	93.85	-	-	20	93.89	-	-	-	-	-	-
-	-	-	-	-	-	20	93.94	20	93.86	20	93.93	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	20	93.88	20	93.91	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 4-2 2RC Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	93.73	-	93.73	-	93.73	-	93.73	-	93.73	-	93.73	-	93.73	-	93.73	-	93.73	-	93.73	-	93.73
-	93.62	-	93.61	-	93.60	-	93.61	-	93.64	-	93.62	-	93.56	-	93.62	-	93.60	-	93.66	-	93.65
1	92.92	1	93.00	1	92.90	1	92.96	2	92.78	2	92.90	2	92.92	1	93.07	2	92.92	1	93.04	2	92.95
2	92.48	2	92.51	2	92.85	2	92.83	2	92.82	2	92.85	3	92.91	2	92.92	3	93.00	3	93.05	3	93.03
3	92.54	3	92.62	3	92.92	2	92.84	3	92.95	3	92.95	4	93.05	3	92.95	4	93.08	4	93.12	4	93.12
5	92.67	4	92.40	4	92.97	3	92.92	4	93.03	4	93.04	5	93.08	4	93.04	5	93.09	5	93.13	5	93.09
7	92.75	5	92.62	5	93.03	4	92.96	5	93.09	5	93.06	6	93.13	5	93.10	6	93.07	6	93.06	6	93.05
8	92.80	7	92.88	6	93.11	5	93.09	6	93.12	6	93.12	7	93.15	6	93.06	7	93.13	7	93.13	7	93.08
9	92.92	9	93.04	7	93.20	6	93.17	7	93.23	7	93.22	8	93.23	7	93.13	8	93.23	8	93.23	8	93.25
11	92.82	10	93.03	8	93.26	6	93.03	8	93.23	8	93.25	9	93.30	8	93.23	9	93.27	9	93.28	9	93.27
13	92.77	12	92.83	9	93.27	7	93.06	9	93.25	9	93.27	10	93.22	9	93.27	10	93.20	10	93.23	10	93.27
14	92.77	14	92.65	10	93.22	7	93.20	10	93.22	10	93.24	11	93.19	10	93.23	11	93.14	11	93.15	11	93.11
15	92.68	15	92.52	11	93.15	8	93.25	11	93.19	11	93.20	12	93.14	11	93.15	12	93.11	12	93.11	12	93.10
16	92.61	16	92.64	12	93.11	9	93.29	12	93.15	12	93.15	13	93.10	12	93.11	13	93.07	13	93.08	13	93.06
17	92.63	18	92.54	13	93.05	10	93.26	13	93.06	13	93.09	14	93.06	13	93.07	14	93.06	14	93.07	14	93.07
19	92.40	20	92.23	14	93.00	11	93.33	14	92.98	14	93.02	15	92.97	14	93.02	15	92.99	15	92.99	15	93.02
21	91.80	21	91.85	15	92.94	11	93.15	15	92.91	15	92.94	16	92.84	15	92.95	16	92.84	16	92.86	16	92.87
21	92.01	21	92.02	16	92.85	12	93.16	16	92.80	16	92.83	17	92.65	17	92.65	18	92.54	18	92.57	17	92.59
-	-	-	-	17	92.61	12	93.23	17	92.62	17	92.65	18	92.57	19	92.37	21	91.76	21	91.80	18	92.59
-	-	-	-	18	92.44	13	93.14	19	92.36	19	92.34	21	91.75	21	91.77	21	91.93	21	91.92	21	91.77
-	-	-	-	21	91.82	14	93.12	21	91.67	21	91.77	21	91.97	21	91.93	-	-	-	-	21	91.90
-	-	-	-	21	92.00	15	93.01	21	91.98	21	91.97	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	16	92.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	17	92.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	17	92.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	19	92.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	21	91.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	21	92.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 4-3 2RC Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	93.12	-	93.12	-	93.12	-	93.12	-	93.12	-	93.12	-	93.12	-	93.12	-	93.12	-	93.12	-	93.12
-	93.03	-	93.03	-	93.03	-	93.04	-	93.03	-	93.03	-	92.98	-	92.96	-	93.03	-	92.97	-	92.98
5	92.03	2	92.51	2	92.50	3	92.44	3	92.41	3	92.36	3	92.40	2	92.53	3	92.44	4	92.19	3	92.39
6	91.85	4	92.14	5	92.04	5	92.10	6	91.90	5	92.04	7	91.75	4	92.14	6	91.90	6	92.16	6	91.87
7	91.73	6	91.80	7	91.69	8	91.74	7	91.74	7	91.76	8	91.94	6	91.80	8	92.27	7	91.76	7	91.78
7	91.70	7	91.69	8	92.29	9	92.40	8	92.28	8	92.29	9	92.43	7	91.75	9	92.52	8	92.27	8	92.21
8	91.82	9	91.98	9	92.48	9	92.46	9	92.43	9	92.50	10	92.56	8	92.16	10	92.61	9	92.50	9	92.43
9	91.94	10	91.81	10	92.57	10	92.59	10	92.57	10	92.61	11	92.64	9	92.47	11	92.65	10	92.59	10	92.63
10	92.05	11	91.98	11	92.65	11	92.68	11	92.60	11	92.62	12	92.65	10	92.62	12	92.64	11	92.62	11	92.62
11	92.11	13	92.27	12	92.73	12	92.75	12	92.68	12	92.69	13	92.73	11	92.63	13	92.73	12	92.63	12	92.62
12	92.15	15	92.45	13	92.82	13	92.79	13	92.76	13	92.77	14	92.78	12	92.63	14	92.80	13	92.67	13	92.69
13	92.20	16	92.51	14	92.86	14	92.85	14	92.83	14	92.81	15	92.88	13	92.72	15	92.89	14	92.74	14	92.75
15	92.38	17	92.53	15	92.92	15	92.92	15	92.89	15	92.90	16	92.94	14	92.79	16	92.94	15	92.83	15	92.82
16	92.43	18	92.50	16	92.96	16	92.97	16	92.97	16	92.95	17	92.90	15	92.88	17	92.88	16	92.89	16	92.89
17	92.38	20	92.23	17	92.93	17	92.97	17	92.92	17	92.92	18	92.84	16	92.95	18	92.79	17	92.85	17	92.80
19	92.29	22	91.95	18	92.89	18	92.91	18	92.89	18	92.86	19	92.79	17	92.90	19	92.78	18	92.77	18	92.77
20	92.27	22	92.10	19	92.85	19	92.88	19	92.85	19	92.82	20	92.78	18	92.83	20	92.80	19	92.75	19	92.76
21	92.22	24	91.95	20	92.77	20	92.84	20	92.79	20	92.75	21	92.73	19	92.77	21	92.80	20	92.76	20	92.78
22	92.14	26	91.63	21	92.74	21	92.81	21	92.76	21	92.76	22	92.73	20	92.77	22	92.71	21	92.77	21	92.78
23	92.03	28	91.44	22	92.67	22	92.74	22	92.68	22	92.70	23	92.51	21	92.75	23	92.62	22	92.69	22	92.77
25	91.97	28	91.80	23	92.56	23	92.64	23	92.57	23	92.55	24	92.12	22	92.70	26	91.66	23	92.50	23	92.61
28	91.45	-	-	24	91.98	24	92.52	24	92.34	24	92.06	25	91.95	23	92.59	28	91.44	24	92.11	24	92.26
28	91.81	-	-	26	91.68	25	92.02	25	91.97	26	91.66	28	91.45	25	91.99	28	91.83	26	91.71	26	91.75
-	-	-	-	28	91.44	26	91.75	28	91.44	28	91.43	28	91.83	27	91.55	-	-	28	91.45	28	91.43
-	-	-	-	28	91.82	28	91.54	28	91.79	28	91.80	-	-	28	91.48	-	-	28	91.81	28	91.74
-	-	-	-	-	-	28	91.84	-	-	-	-	-	-	28	91.80	-	-	-	-	-	-
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Cross-section 5-1 2A Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	94.89	-	94.89	-	94.89	-	94.89	-	94.89	-	94.89	-	94.89	-	94.89	-	94.89	-	94.89	-	94.89
-	94.79	-	94.82	-	94.81	-	94.80	-	94.78	-	94.88	-	94.75	-	94.76	-	94.81	-	94.79	-	94.77
2	94.22	2	94.24	2	94.23	2	94.24	2	94.23	2	94.23	3	94.03	2	94.21	3	94.09	4	94.01	3	94.02
6	93.70	4	93.96	4	93.99	4	94.00	5	94.02	5	93.64	6	93.58	4	94.04	6	93.68	5	93.74	5	93.71
7	93.63	6	93.75	5	93.69	5	93.70	5	93.70	6	93.59	7	93.81	6	93.68	8	94.14	6	93.67	7	93.91
8	93.75	7	93.71	7	93.64	6	93.61	7	93.81	8	94.08	8	94.09	8	94.19	9	94.29	7	93.99	8	94.15
9	93.83	9	93.91	7	94.05	7	93.83	8	94.13	9	94.28	9	94.23	9	94.28	10	94.33	8	94.20	9	94.30
10	93.87	10	93.75	9	94.26	8	94.14	9	94.25	10	94.39	10	94.30	10	94.32	11	94.32	9	94.32	10	94.31
11	93.89	11	93.84	10	94.33	9	94.25	10	94.32	11	94.35	11	94.30	11	94.36	12	94.36	10	94.30	11	94.30
13	93.96	13	94.04	11	94.38	10	94.33	11	94.37	12	94.40	12	94.36	12	94.36	13	94.41	11	94.34	12	94.31
15	94.02	15	94.13	12	94.44	11	94.40	12	94.40	13	94.49	13	94.41	13	94.42	14	94.48	12	94.33	13	94.38
15	94.06	16	94.16	13	94.49	12	94.43	13	94.47	14	94.51	14	94.48	14	94.51	15	94.56	13	94.38	14	94.44
16	94.04	17	94.14	14	94.56	13	94.52	14	94.55	15	94.57	15	94.56	15	94.55	16	94.51	14	94.45	15	94.50
17	93.94	19	93.92	15	94.61	14	94.56	15	94.61	16	94.52	16	94.51	16	94.49	17	94.38	15	94.51	16	94.46
18	93.84	21	93.63	16	94.57	15	94.61	16	94.57	17	94.46	17	94.44	17	94.42	18	94.34	16	94.48	17	94.34
19	93.80	22	93.48	17	94.52	16	94.60	17	94.47	18	94.43	18	94.38	18	94.36	19	94.32	17	94.34	18	94.30
20	93.79	23	93.61	18	94.47	17	94.49	18	94.43	19	94.34	19	94.33	19	94.33	20	94.37	18	94.31	19	94.31
21	93.73	24	93.63	19	94.40	18	94.47	19	94.38	20	94.33	20	94.33	20	94.34	21	94.33	19	94.30	20	94.33
22	93.66	25	93.84	20	94.35	19	94.42	20	94.35	21	94.33	21	94.33	21	94.27	22	94.20	20	94.32	21	94.31
23	93.53	26	93.91	21	94.27	20	94.37	21	94.30	22	94.21	22	94.17	23	93.97	25	93.89	21	94.28	22	94.24
24	93.54	28	93.61	22	94.18	21	94.32	22	94.21	23	94.12	23	93.96	25	93.86	28	93.50	22	94.24	23	94.11
25	93.80	30	92.94	23	94.07	22	94.25	23	94.03	24	93.67	24	93.55	27	93.77	31	92.70	23	94.00	24	93.63
27	93.80	31	92.66	24	93.46	23	94.26	24	93.53	25	93.83	31	92.57	29	93.04	31	93.10	26	93.78	27	93.66
31	92.61	31	92.78	25	93.86	24	93.53	25	93.82	29	93.07	31	92.77	31	92.59	-	-	28	93.56	29	93.06
31	92.74	-	-	28	93.54	25	93.76	27	93.80	31	92.63	-	-	31	92.75	-	-	31	92.53	30	92.61
-	-	-	-	31	92.64	27	93.71	29	93.24	31	92.76	-	-	-	-	-	-	31	92.75	30	92.76
-	-	-	-	31	92.78	29	93.10	31	92.61	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	31	92.65	31	92.79	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	31	92.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Cross-section 5-2 2A Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	96.36	-	96.36	-	96.36	-	96.36	-	96.36	-	96.36	-	96.36	-	96.36	-	96.36	-	96.36	-	96.36
-	96.22	-	96.23	-	96.22	-	96.23	-	96.22	-	96.21	-	96.13	-	96.17	-	96.21	-	96.23	-	96.23
3	95.63	2	95.84	2	95.85	2	95.86	2	95.83	2	95.83	3	95.61	2	95.83	2	95.78	4	95.38	4	95.43
6	95.06	4	95.35	5	95.23	4	95.41	5	95.23	5	95.22	6	94.70	4	95.35	4	95.32	6	94.71	5	95.30
7	94.89	6	95.04	6	94.66	5	95.26	6	94.77	6	94.73	7	95.07	6	94.76	6	94.73	7	95.12	6	94.73
7	94.88	7	94.87	7	94.92	6	94.68	6	94.68	8	95.11	9	95.38	7	95.01	7	95.11	8	95.30	7	95.06
8	94.92	9	95.00	8	95.24	7	94.75	7	94.75	9	95.39	10	95.49	8	95.34	8	95.31	9	95.40	8	95.33
9	95.02	10	94.87	9	95.42	7	95.11	7	95.06	10	95.48	11	95.54	9	95.44	9	95.43	10	95.45	9	95.45
10	95.09	11	95.06	10	95.53	8	95.34	8	95.30	11	95.58	12	95.63	10	95.49	10	95.47	11	95.53	10	95.49
11	95.15	13	95.33	11	95.62	9	95.44	9	95.43	12	95.66	13	95.74	11	95.57	11	95.54	12	95.61	11	95.54
13	95.34	15	95.55	12	95.72	10	95.52	10	95.50	13	95.77	14	95.86	12	95.67	12	95.63	13	95.72	12	95.63
14	95.46	16	95.52	13	95.80	11	95.62	11	95.61	14	95.87	15	95.88	13	95.76	13	95.74	14	95.85	13	95.74
15	95.50	17	95.53	14	95.88	12	95.71	12	95.69	15	95.89	16	95.87	14	95.88	14	95.85	15	95.84	14	95.84
16	95.48	18	95.49	15	95.94	13	95.79	13	95.80	16	95.89	17	95.89	15	95.91	15	95.85	16	95.82	15	95.86
18	95.40	20	95.19	16	95.94	14	95.90	14	95.89	17	95.89	18	95.88	16	95.87	16	95.83	17	95.81	16	95.83
19	95.39	22	94.95	17	95.94	15	95.92	15	95.90	18	95.88	19	95.84	17	95.88	17	95.82	18	95.86	17	95.83
21	95.25	23	95.09	18	95.94	16	95.92	16	95.91	19	95.86	20	95.78	18	95.89	18	95.85	19	95.87	18	95.86
23	95.04	25	94.86	19	95.88	17	95.92	17	95.90	20	95.77	21	95.63	19	95.87	19	95.87	20	95.79	19	95.87
24	95.04	27	94.86	20	95.78	18	95.90	18	95.89	21	95.66	22	95.48	20	95.79	20	95.80	21	95.70	20	95.84
26	94.81	28	94.99	21	95.67	19	95.88	19	95.85	22	95.51	23	95.35	21	95.67	21	95.63	22	95.54	21	95.72
28	94.98	28	95.18	22	95.55	20	95.79	20	95.74	23	95.36	24	95.00	22	95.57	22	95.48	23	95.32	22	95.55
28	95.20	-	-	24	95.32	21	95.66	21	95.63	24	94.97	25	94.85	24	94.95	25	94.87	24	95.08	23	95.37
-	-	-	-	24	94.99	22	95.53	22	95.51	26	94.76	28	94.93	26	94.79	28	94.93	26	94.79	25	94.90
-	-	-	-	26	94.78	23	95.36	23	95.36	28	94.96	28	95.15	28	94.96	28	95.18	28	94.98	28	94.97
-	-	-	-	28	95.00	24	95.25	24	94.91	28	95.20	-	-	28	95.16	-	-	28	95.18	28	95.15
-	-	-	-	28	95.20	24	94.93	26	94.78	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	26	94.79	28	94.99	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	28	95.00	28	95.18	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	28	95.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 5-3 2A Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	93.04	-	93.04	-	93.04	-	93.04	-	93.04	-	93.04	-	93.04	-	93.04	-	93.04	-	93.04	-	93.04
-	92.94	-	92.95	-	92.95	-	92.94	-	92.94	-	92.94	-	92.88	-	92.91	-	92.91	-	92.94	-	92.93
1	92.84	2	92.65	2	92.69	3	92.46	2	92.66	1	92.83	3	92.42	4	92.16	3	92.49	4	92.25	3	92.46
5	91.98	4	92.25	5	92.02	6	91.66	5	92.00	4	92.27	6	91.62	7	91.22	6	91.75	7	91.32	5	91.97
10	90.11	6	91.69	8	90.92	9	90.44	8	90.87	7	91.26	9	90.45	11	89.86	9	90.52	10	90.21	9	90.42
11	89.85	8	90.81	11	90.05	11	89.89	11	90.07	9	90.47	12	89.67	12	89.74	11	89.96	12	89.79	11	89.87
12	89.87	10	90.09	12	89.60	12	89.64	12	89.68	11	89.86	13	89.95	13	90.12	12	89.73	13	90.14	12	89.98
12	89.66	11	89.87	13	90.00	13	89.93	13	89.94	12	89.67	14	90.18	14	90.35	13	90.02	14	90.37	13	90.17
13	89.69	12	89.70	14	90.20	13	90.09	13	90.07	13	90.06	15	90.34	15	90.37	14	90.33	15	90.42	14	90.37
15	89.93	13	89.75	15	90.35	14	90.26	14	90.18	14	90.22	16	90.39	16	90.44	15	90.42	16	90.42	15	90.38
16	89.96	14	89.67	16	90.47	15	90.33	15	90.35	15	90.32	17	90.52	17	90.53	16	90.39	17	90.48	16	90.38
17	90.10	15	89.91	17	90.58	16	90.51	16	90.47	16	90.43	18	90.59	18	90.67	17	90.50	18	90.63	17	90.46
19	90.30	17	90.14	18	90.71	17	90.61	17	90.59	17	90.57	19	90.72	19	90.77	18	90.58	19	90.79	18	90.53
21	90.37	19	90.44	19	90.82	18	90.74	18	90.72	18	90.67	20	90.84	20	90.91	19	90.72	20	90.87	19	90.70
22	90.56	20	90.56	20	90.96	19	90.83	19	90.82	19	90.82	21	90.89	21	90.95	20	90.86	21	90.90	20	90.87
24	90.48	21	90.57	21	91.01	20	90.95	20	90.93	20	90.91	22	90.93	22	90.99	21	90.95	22	90.89	21	90.90
26	90.42	22	90.59	22	91.04	21	91.00	21	90.98	21	90.96	23	90.98	23	90.99	22	90.94	23	90.95	22	90.89
28	90.38	24	90.56	23	91.06	22	91.03	22	91.02	22	91.01	24	91.03	24	91.03	23	90.95	24	91.00	23	90.90
30	90.19	26	90.35	24	91.07	23	91.05	23	91.04	23	91.03	25	91.02	25	91.03	24	91.02	25	91.02	24	90.96
30	90.28	28	90.12	25	91.12	24	91.07	24	91.11	24	91.04	26	90.94	26	90.95	25	91.03	26	90.94	25	90.97
31	90.28	29	90.28	26	91.02	25	91.09	25	91.10	25	91.07	27	90.83	27	90.84	26	90.98	27	90.84	26	90.93
33	90.04	30	90.24	27	90.89	26	90.99	26	91.00	26	90.97	28	90.68	28	90.74	27	90.89	28	90.72	27	90.84
36	89.96	32	90.14	28	90.74	27	90.88	27	90.88	27	90.87	29	90.37	29	90.41	28	90.80	29	90.42	28	90.71
39	89.10	34	89.98	29	90.59	28	90.73	28	90.74	28	90.71	33	90.01	31	90.18	29	90.58	32	90.16	29	90.47
41	88.90	36	89.97	30	90.23	29	90.58	29	90.58	29	90.64	36	89.93	33	90.03	30	90.23	35	89.94	30	90.23
41	89.16	38	89.39	32	90.15	30	90.28	30	90.26	30	90.27	39	89.04	36	89.96	33	90.05	39	88.95	33	89.99
-	-	39	89.03	35	89.98	31	90.21	33	90.05	31	90.24	41	88.81	38	89.37	36	89.98	41	88.90	36	89.96
-	-	41	88.89	38	89.49	33	90.01	36	89.97	34	89.94	41	89.10	41	88.92	39	89.09	41	89.16	41	88.89
-	-	41	89.15	41	88.89	36	89.97	41	88.90	38	89.80	-	-	41	89.16	41	88.89	-	-	41	89.14
-	-	-	-	41	89.17	38	89.44	41	89.17	41	88.86	-	-	-	-	41	89.16	-	-	-	-
-	-	-	-	-	-	40	89.03	-	-	41	89.17	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	41	88.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	41	89.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 6-1 DSA Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	94.03	-	94.03	-	94.03	-	94.03	-	94.03	-	94.03	-	94.03	-	94.03	-	94.03	-	94.03	-	94.03
-	93.90	-	93.92	-	93.91	-	93.93	-	93.91	-	93.96	-	93.89	-	93.93	-	93.94	-	90.94	-	93.92
3	93.18	2	93.47	2	93.47	3	93.18	2	93.47	2	93.46	3	93.15	3	93.20	2	93.42	3	93.22	3	93.15
7	91.83	4	92.84	5	92.52	6	92.20	4	92.82	4	92.85	6	92.10	7	91.86	5	92.45	8	91.56	6	92.13
10	91.18	6	92.16	8	91.60	9	91.39	6	92.18	7	91.84	9	91.32	10	91.22	8	91.58	10	91.20	9	91.37
12	90.98	8	91.58	10	91.23	11	91.19	8	91.55	10	91.24	12	90.88	12	91.10	11	91.20	11	91.21	11	91.21
13	91.07	10	91.19	11	91.22	12	90.94	10	91.17	12	91.18	13	91.09	13	91.49	12	90.98	12	91.08	12	91.27
14	91.24	12	91.00	12	90.89	13	91.35	12	91.30	12	91.00	14	91.55	14	91.68	13	91.52	13	91.52	13	91.52
15	91.33	13	91.15	13	91.50	13	91.46	12	90.94	13	91.49	15	91.71	15	91.76	14	91.73	14	91.72	14	91.73
16	91.38	14	91.03	14	91.63	14	91.61	13	91.29	14	91.68	16	91.75	16	91.83	15	91.79	15	91.76	15	91.77
18	91.50	16	91.38	15	91.75	15	91.74	13	91.43	15	91.74	17	91.83	17	91.91	16	91.81	16	91.78	16	91.75
20	91.70	18	91.65	16	91.86	16	91.86	14	91.60	16	91.86	18	91.95	18	92.02	17	91.85	17	91.82	17	91.80
20	91.83	20	91.85	17	91.96	17	91.95	15	91.73	17	91.96	19	92.07	19	92.15	18	91.97	18	91.94	18	91.94
22	91.85	21	91.92	18	92.07	18	92.06	16	91.85	18	92.06	20	92.17	20	92.20	19	92.13	19	92.10	19	92.08
24	91.79	23	91.95	19	92.19	19	92.18	17	91.94	19	92.16	21	92.21	21	92.27	20	92.23	20	92.21	20	92.19
26	91.72	24	91.92	20	92.28	20	92.27	18	92.06	20	92.26	22	92.23	22	92.28	21	92.27	21	92.24	21	92.23
28	91.56	25	91.79	21	92.30	21	92.30	19	92.17	21	92.28	23	92.27	23	92.30	22	92.28	22	92.23	22	92.21
30	91.42	26	91.55	22	92.33	22	92.32	20	92.24	22	92.30	24	92.26	24	92.35	23	92.29	23	92.24	23	92.22
30	91.48	27	91.35	23	92.35	23	92.35	21	92.29	23	92.34	25	92.23	25	92.26	24	92.27	24	92.25	24	92.24
31	91.43	28	91.58	24	92.38	24	92.37	22	92.31	24	92.36	26	92.15	26	92.19	25	92.27	25	92.23	25	92.23
35	90.89	30	91.50	25	92.31	25	92.34	23	92.33	25	92.30	27	92.03	27	92.09	26	92.19	26	92.14	26	92.16
39	89.89	32	91.26	26	92.20	26	92.21	24	92.35	26	92.19	28	91.90	28	91.90	27	92.07	27	92.06	27	92.07
41	89.74	34	91.12	27	92.08	27	92.09	25	92.29	27	92.07	29	91.53	30	91.49	28	91.93	28	91.93	28	91.90
41	89.92	36	90.32	28	91.93	28	91.96	26	92.18	28	91.94	32	91.22	33	91.27	29	91.70	29	91.61	29	91.62
-	-	39	89.84	29	91.86	29	91.89	27	92.07	29	91.86	35	90.82	36	90.58	31	91.44	31	91.45	30	91.50
-	-	41	89.74	29	91.47	30	91.42	28	91.97	30	91.50	38	89.86	41	89.76	33	91.23	33	91.23	32	91.24
-	-	41	89.93	31	91.44	31	91.48	29	91.67	31	91.47	41	89.67	41	89.94	35	90.87	36	90.63	34	91.10
-	-	-	-	34	91.10	33	91.24	30	91.48	33	91.27	41	89.90	-	-	37	90.36	41	89.72	38	89.95
-	-	-	-	37	90.32	36	90.65	32	91.33	36	90.66	-	-	-	-	41	89.72	41	89.91	41	89.72
-	-	-	-	41	89.75	39	89.92	35	90.91	39	89.89	-	-	-	-	41	89.92	-	-	41	89.91
-	-	-	-	41	89.93	41	89.75	38	89.94	41	89.76	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	41	89.94	41	89.76	41	89.95	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	41	89.94	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 6-2 DSA Paver Placed

Before		Graded		Nov-02		Mar-03		May-03		Jul-03		Nov-03		May-04		Nov-04		May-05		Apr-06	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-	97.12	-	97.12	-	97.12	-	97.12	-	97.12	-	97.12	-	97.12	-	97.12	-	97.12	-	97.12	-	97.12
-	96.97	-	96.97	-	96.97	-	96.97	-	96.96	-	96.98	-	96.95	-	96.93	2	96.57	-	97.00	-	97.01
3	96.34	2	96.61	2	96.59	3	96.34	2	96.58	2	96.58	3	96.29	4	96.01	4	96.07	4	96.03	2	96.59
6	95.33	4	96.02	4	96.01	6	95.42	5	95.76	5	95.76	6	95.35	7	94.93	6	95.44	7	94.99	5	95.78
9	94.26	6	95.39	6	95.41	9	94.32	8	94.62	8	94.64	9	94.29	10	93.88	8	94.79	10	93.88	8	94.64
11	93.63	8	94.60	8	94.62	11	93.69	10	93.87	11	93.73	11	93.61	11	93.76	10	93.97	11	93.75	10	93.99
12	93.47	10	93.93	10	93.90	12	93.54	11	93.72	12	93.67	12	93.74	13	93.87	12	93.72	12	93.73	11	93.74
13	93.54	12	93.52	11	93.74	12	93.82	12	93.58	13	93.81	14	94.01	14	94.03	13	93.95	13	94.06	12	93.75
15	93.72	14	93.59	12	93.47	13	93.93	12	93.76	14	94.03	15	94.08	15	94.14	14	94.16	14	94.10	13	94.02
16	93.80	14	93.50	12	93.81	14	94.01	13	93.91	15	94.11	16	94.14	16	94.16	15	94.20	15	94.17	14	94.11
17	93.85	16	93.79	13	93.93	15	94.09	14	94.02	16	94.17	17	94.23	17	94.25	16	94.19	16	94.16	15	94.22
19	93.96	18	93.95	14	94.01	16	94.18	15	94.09	17	94.26	18	94.31	18	94.33	17	94.29	17	94.23	16	94.19
20	94.14	20	94.13	15	94.11	17	94.29	16	94.19	18	94.35	19	94.39	19	94.42	18	94.35	18	94.30	17	94.21
21	94.17	21	94.23	16	94.19	18	94.39	17	94.28	19	94.46	20	94.50	20	94.51	19	94.44	19	94.42	18	94.31
22	94.16	22	94.20	17	94.30	19	94.45	18	94.37	20	94.53	21	94.54	21	94.56	20	94.56	20	94.56	19	94.40
24	94.10	23	94.25	18	94.40	20	94.54	19	94.45	21	94.58	22	94.56	22	94.56	21	94.58	21	94.57	20	94.50
26	94.02	25	94.09	19	94.51	21	94.59	20	94.56	22	94.57	23	94.57	23	94.59	22	94.59	22	94.57	21	94.53
28	93.94	28	93.76	20	94.56	22	94.59	21	94.56	23	94.61	24	94.57	24	94.60	23	94.60	23	94.57	22	94.54
29	93.84	28	94.16	21	94.59	23	94.62	22	94.58	24	94.61	25	94.50	25	94.50	24	94.59	24	94.56	23	94.57
30	93.84	30	93.92	22	94.61	24	94.62	23	94.61	25	94.55	26	94.39	26	94.44	25	94.56	25	94.53	24	94.54
30	93.92	32	93.77	23	94.64	25	94.55	24	94.61	26	94.43	27	94.27	27	94.29	26	94.48	26	94.45	25	94.52
32	93.77	34	94.26	24	94.66	26	94.43	25	94.52	27	94.27	28	93.92	28	94.00	27	94.33	27	94.30	26	94.49
33	94.11	35	94.74	25	94.55	27	94.29	26	94.40	28	94.03	31	93.83	30	93.87	28	94.11	28	94.01	27	94.33
35	94.76	35	94.99	26	94.43	28	94.22	27	94.27	29	93.87	33	94.02	32	93.78	29	93.95	30	93.95	28	94.08
35	94.99	-	-	27	94.27	28	94.01	28	93.95	31	93.82	35	94.68	34	94.26	32	93.84	32	93.81	29	93.95
-	-	-	-	28	94.17	29	93.88	30	93.92	33	93.94	35	94.97	35	94.69	35	94.70	35	94.73	31	93.85
-	-	-	-	28	93.95	30	93.88	32	93.80	35	94.71	-	-	35	94.99	35	95.02	37	95.00	33	93.96
-	-	-	-	30	93.92	32	93.82	34	94.26	35	94.99	-	-	-	-	-	-	-	-	35	94.71
-	-	-	-	32	93.83	34	94.31	35	94.68	-	-	-	-	-	-	-	-	-	-	35	95.02
-	-	-	-	34	94.30	35	94.69	35	94.96	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	35	94.77	35	94.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	35	94.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cross-section 6-3 DSA Paver Placed