RockSol Consulting Group, Inc.

October 26, 2015

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Attention: Mr. Gaurav Vasisht, PE, PTOE

Subject: Pavement Design Report, US 50 West – Westbound Preliminary Design, Purcell Boulevard to Wills Boulevard, CDOT Project No. STA 0503-088 (Project Code 20448), Task Order No. 7, Pueblo County, Colorado, RockSol Project Number 302.02

Dear Mr. Vasisht:

RockSol Consulting Group, Inc. (RockSol) has performed a geotechnical investigation for the US 50 West Westbound Preliminary Design Project in Pueblo County, Colorado (See Figure 1, Site Vicinity Map). This Pavement Design Report presents pavement design and construction recommendations for US 50 West – Westbound Preliminary Design.

This report presents information on the subsurface soil, groundwater, and bedrock conditions obtained from soil borings performed within the project limits from Purcell Boulevard (western project limit) to Wills Boulevard (eastern project limit). A brief discussion of local geologic conditions and the subsurface conditions encountered are presented in this report. Also presented is a summary of the lab testing performed on recovered soil and bedrock samples recovered from the project site. RockSol performed a geotechnical evaluation for eastbound US 50 within the project limits in 2013 that included Falling Weight Deflectometer (FWD) testing along WB US50. Results of the 2013 geotechnical evaluation for eastbound US 50 are presented in the Foundation Investigation, Pavement Design, and Soil Investigation Reports dated July 31, 2014.

Surface and groundwater hydrology, hydraulic engineering, and environmental studies including contaminant characterization were not included in RockSol's scope of work.

Project Description

Project descriptions are based on information provided in the Colorado Department of Transportation (CDOT) *Scope of Work Task Order 7* Memorandum dated September 24, 2014, *U.S. 50 Westbound Wills to Purcell WB Realignment (20448)* plan sheets dated March 5, 2015 and April 8, 2015, provided by J.F.Sato and Associates (J.F. Sato) and discussions with JF Sato.

The purpose of Task Order No. 7 is to develop a conceptual level of design for the US 50 Planned Environmental Linkage (PEL) Preferred Alternative between Wills Boulevard and Purcell Boulevard, including grade separation at Pueblo Boulevard and preliminary level design for the improvement projects identified in the US 50 PEL Preferred Alternative Implementation Plan. Based on the information provided in the *CDOT Scope of Work Task Order No. 7*, these improvements include:

- Widening westbound US 50 from 2 to 3 lanes from Wills Boulevard to approximately 1,500 ft west of Purcell Boulevard.
- Realigning westbound US 50 to be parallel to the eastbound lanes in the vicinity of Pueblo Blvd. (Approximately 3,000 feet to the east and west of Pueblo Boulevard).
- Modifying the existing eastbound and westbound US50 and Pueblo Boulevard intersections.

- Widening Pueblo Boulevard south of US 50 to accommodate additional turn lanes.
- Modifying the intersections at US 50 and Purcell Boulevard and US 50 and Wills Boulevard.
- Constructing a westbound US 50 acceleration lane between Wills Boulevard and the Burlington Northern Santa Fe (BNSF) railroad bridge.
- Replacing the existing WB US 50 bridge over Wild Horse Dry Creek.
- Adding a temporary connection lane between the new westbound US 50 lanes and the existing US 50 westbound lanes.
- Modifying the slope paving, adjacent to the westbound US 50 lanes, at the BNSF underpass to accommodate the additional westbound US 50 through lane.
- Extending the Williams Creek Box Culvert (CBC) under US 50 to accommodate US 50 widening.
- Analyzing the Williams Creek CBC under Pueblo Blvd with regards to future grade separation at the US 50 and Pueblo Boulevard intersection.
- Providing a bike/pedestrian trail between Wills Boulevard and Pueblo Boulevard.
- Providing pedestrian access along the west side of Purcell Boulevard between Haley Lane and Kimble Drive.
- Extending the CBC under Purcell Boulevard to accommodate the proposed bike/pedestrian trail as well as future widening of US 50.

The new westbound US 50 bridge over Wild Horse Creek is proposed as a three span structure with approximate 60 foot to 70 foot span lengths and will be a multi-lane bridge approximately 60 feet in width. Construction for the new westbound US 50 bridge over Wild Horse Creek will also include placement of approximately 2 feet to 8 feet of embankment fill material within the existing center median area to match the existing eastbound US 50 roadway elevation.

Existing Site Conditions

Undeveloped land and a mix of commercial and residential development borders the project area and includes a CDOT maintenance facility located near the northwest corner of westbound US 50 and Pueblo Boulevard and a wastewater treatment plant located south of US 50, between Pueblo Boulevard and Purcell Boulevard. Topography at the site generally consists of flat to mild slopes with a general trend of decreasing elevation toward Wild Horse Creek and Williams Creek. Moderate to steep bank slopes were noted along both Wild Horse Creek and Williams Creek. Low water flow conditions were noted within both Wild Horse Creek and Williams Creek during our field work.

The current alignment of westbound US 50 was the original route for both eastbound and westbound US 50 until two new lanes were constructed for eastbound US 50 in the mid 1970's, diverging from westbound US 50 approximately 3,000 feet to the east and west of Pueblo Boulevard. The existing eastbound US 50 bridge over Wild Horse Creek is a three span structure consisting of a continuous concrete girder and slab (poured in place) with two continuous concrete wall center piers. The existing bridge carries two lanes of traffic over Wild Horse Creek and is approximately 42 feet in width. The eastbound bridge is being widened at this time to accommodate 3 lanes of traffic. The existing approach embankments (fill placement) are approximately 16 to 18 feet in height at the EB and WB bridge abutments. Rip-rap is present at each abutment with embankment side slopes approximately 2H:1V.

The existing Williams Creek CBC structure beneath Pueblo Boulevard is duel celled and approximately 21 feet in width and 320 feet in length with approximately 12 feet of embankment cover material above it. The existing CBC structure beneath Purcell Boulevard, located south of US 50, is a single cell CBC approximately 108 feet in length and 15 feet wide.

Geologic Conditions

The project area lies between the High Plains and the Colorado Piedmont, east of the eastern foothills of the Front Range of the Southern Rocky Mountains. The eastern project site limit is located approximately two miles west of the geologic floodplain of the Arkansas River. The western project site limit is located approximately twelve miles east of the Front Range foothills. Based on the 1964 USGS *Geology Map of the Northwest and Northeast Pueblo Quadrangles, Colorado* by Glenn R. Scott (See Figure 2, Site Geology Map), the site is underlain by surficial soils and sedimentary bedrock.

The surficial soils encountered and mapped within the project generally consist of sandy clay and silty to clayey sand fill material with gravel associated with US 50 roadway construction and native soils consisting of Piney Creek Alluvium (Qp), Slocum Alluvium (Qs), Broadway Alluvium (Qb) deposits of generally consisting of silt, clay and sand with pebbles and limestone fragments, gravel and cobbles in parts. Colluvium (Qc) deposits are also mapped within the project limits and generally consist of silt and clay with pebbles and blocks of limestone and sandstone in parts. The surficial soils at the project comprise a relatively thin cover, typically less than 20 feet, over bedrock.

Bedrock of the Pierre Shale (Kpt) Formation and the seven members of the Niobrara (Ksus, Ksuc, Ksmc, Ksll, Ksls, Kssl, and Kf) Formation (both formations are Upper Cretaceous in age) are mapped at or near the surface within portions of the project limits. The Pierre Shale Formation generally consists of shale, siltstone sandstone and claystone and appears to be located near the eastern limits of the project. The Niobrara Formation generally consists of silty to chalky shale and chalky to fossiliferous limestone and appears to be under the majority of the project. Bentonite lenses within the bedrock formations have potential for swelling which can pose a risk to structures, roadways and utilities.

The sedimentary bedrock contained calcareous and/or gypsum minerals/crystals in parts. A slight hydrocarbon odor was also noted within the shale bedrock during RockSol's 2013 drilling operations/investigation. This odor is believed to be from a naturally occurring process associated with the organic content of the shale, primarily comprised of marine organisms, algae, and plant material deposited millions of years ago in an inland seaway.

Subsurface Investigation

RockSol drilled 18 boreholes to evaluate the subsurface conditions for the US 50 West – Westbound Preliminary Design, Purcell Boulevard to Wills Boulevard Improvements Project. The borehole locations are identified as BR-1, BR-2, CBC-1, CBC-2, WC-1, WC-2 and PV-1 through PV-12, as shown on Figures 3A through 3G, Borehole Location Plans. RockSol also obtained four pavement cores at borehole locations PV-3, PV-5, PV-10, and PV-11. The boreholes drilled for RockSol's 2013 investigation are also shown on the Borehole Location Plans.

Boreholes BR-1 and BR-2 were drilled at the approximate location of a future grade separation at the US 50 and Pueblo Boulevard intersection. Boreholes WC-1 and WC-2 were drilled at the approximate location of the proposed culvert extension at Williams Creek for the future widening of Pueblo Boulevard, between the current alignment of westbound and eastbound US 50. Boreholes CBC-1 and CBC-2 were drilled to assist with the proposed extension of the CBC under Purcell Boulevard to accommodate a proposed bike/pedestrian trail as well as future widening of US 50. Boreholes PV-1 through PV-12 were drilled to assist with pavement thickness recommendations for westbound US 50 and a temporary connection lane between the new westbound US 50 lanes and the existing US 50 westbound lanes. After drilling operations, the boreholes were located by field survey provided by CDOT. Horizontal and vertical locations were then provided to RockSol for inclusion on the Borehole Location Plan and on the borehole logs.

A truck mounted CME-45 drill rig was used for drilling and sampling. The boreholes were advanced using 4-inch and 6-inch outside diameter solid stem augers to maximum depths ranging from approximately 5 feet to 30 feet below existing grades. The boreholes were logged in the field by a representative of RockSol then backfilled at the completion of drilling and groundwater level checks. Boreholes drilled within existing pavement were patched with an asphalt patch mix.

Subsurface materials were sampled using modified California barrel and standard split spoon samplers. The modified California barrel sampler has an outside diameter of approximately 2.5 inches and an inside diameter of 2 inches. The standard split spoon sampler used had an outside diameter of 2 inches and an inside diameter of 1⅜-inches. Brass tube liners are used with the modified California barrel sampler to retain samples for density, swell, and unconfined compressive strength testing. Sample retaining liners are not used with the standard split spoon sampler.

Penetration Tests were performed at selected intervals using an automatic lift system with a hammer weighing 140 pounds and falling 30 inches. The standard split spoon sampling method is the Standard Penetration Test (SPT) described by ASTM Method D-1586. Penetration Tests were performed using the modified California barrel sampler with a standard hammer weighing 140 pounds falling 30 inches per ASTM D3550.The modified California Barrel sampling method is similar to the SPT test with the difference being the sampler dimensions and the number of 6-inch intervals driven with the hammer. Correlation of blow counts obtained from a modified California sampler to blow counts obtained from a standard split spoon sampler is not available. However, it is RockSol's experience that blow counts obtained with the modified California sampler tend to be slightly greater than a standard split spoon sampler. Penetration resistance values (blow counts) were recorded for each sampling event. Blow counts, when properly evaluated, indicate the relative density or consistency of the soils. Depths at which the samples were taken, the type of sampler used, and the blow counts that were obtained are shown on the Boring Logs for each borehole. Borehole logs are presented in Appendix A.

Laboratory Testing

Soil samples retrieved from the borehole locations were examined by the project geotechnical engineer in the RockSol laboratory. Selected samples were tested and classified according to the Unified Soil Classification System (USCS). The following laboratory tests were performed in accordance with the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), and current local practices:

- Natural Moisture Content (ASTM D-2216)
- Percent Passing No. 200 Sieve (ASTM D-1140)
- Liquid and Plastic Limits (ASTM D-4318)
- Dry Density (ASTM D-2937)
- Gradation (ASTM D6913)
- Water Soluble Sulfates (CDOT CP-L 2103)
- Soil Classification (ASTM D-2487, ASTM D-2488, and AASHTO M145)
- Swell Test (ASTM D-4546)

- Water Soluble Chloride Content (AASHTO T291-91)
- Standard Test Method for pH of Soils (ASTM D4972-01 and AASHTO T289)
- Soil Resistivity (ASTM G187 - Soil Box)
- Resistance Value (CP-L 3101)

Resistance Value (R-Value) tests were performed by Cesare, Inc. Water Soluble Chloride Ion Content tests were performed by Colorado Analytical Laboratories. All other laboratory tests were performed by RockSol. Laboratory test results are presented in Appendix B and are also summarized on the Borehole Logs presented in Appendix A.

Surface and Subsurface Conditions

Topsoil was encountered at the ground surface at nine borehole locations. The topsoil encountered was generally lightly organic silty to clayey sand and sandy clay which supported a sparse covering of grasses and weeds. A topsoil thickness of approximately 6 inches was estimated based on field observations. Beneath the pavement and topsoil, subsurface conditions encountered generally consisted of fill material, native soils, and sedimentary bedrock.

Fill material was encountered in eleven of the boreholes to approximate depths ranging from 2.5 feet to 13 feet below existing grades. The fill material is associated with roadway embankment and culvert backfill for the construction of US 50 and Purcell Boulevard. The fill material encountered generally consisted of loose to dense silty to clayey sand with gravel and sandy clay (reworked shale) in parts, medium stiff to very stiff sandy clay with gravel in parts, and medium dense slightly silty to gravelly sand.

Native soils encountered below the fill material or ground surface generally included medium stiff to very stiff sandy clay with silty to clayey sand and gravel in parts, loose to dense silty to clayey sand and gravelly sand. The native soils extended to depths ranging from 3 feet 18 feet below existing grades. The majority of the fill and native soils tested were classified as sandy clay and clayey sand soils (AASHTO A-6) with an average Plasticity Index of 14. AASHTO A-2-4, A-2-6, and A-4 soils were also encountered within the project limits.

Sedimentary bedrock was encountered beneath the fill material and native soils at depths varying from approximately 3 feet to 18 feet below existing grades. Sedimentary bedrock consisting of hard to very hard claystone, sandstone and shale was encountered in Boreholes BR-1, BR-2, WC-1 and WC-2 (US 50 and Pueblo Boulevard) at elevations ranging from 4,800 feet to 4,824 feet (approximate depths ranging from 3 feet to 18 feet below existing grades) during drilling operations.

The bedrock generally consisted of very hard silty to clayey shale. Very hard shale was also encountered in Boreholes CBC-1 and CBC-2 (Purcell Boulevard and US 50) at an approximate elevation of 4,968 feet (approximate depths of 8 feet and 12 feet below existing grades). Sedimentary bedrock consisting of very hard claystone and shale was also encountered in Boreholes PV-2, PV-7, PV-8, and PV-10 at elevations of 4,784 feet to 4,957 feet (approximate depths of 3 feet to 9 feet below existing grades) between Purcell Boulevard and Wills Boulevard along the existing and proposed westbound US 50 alignment.

Groundwater was encountered in four of the boreholes at elevations ranging from 4,804 feet to 4,971 feet (approximate depths ranging from 7 feet to 23 feet below existing grades) and is perched above the shale and claystone bedrock. Groundwater generally appears to be at an elevation consistent with the water elevations of Williams Creek and the drainage at the Purcell

Boulevard CBC structure. However, it should be noted that groundwater elevations are subject to change depending on climatic conditions, stream stages, local irrigation practices, changes in local topography, and changes in surface storm water management.

A summary of the bedrock and groundwater elevations encountered in RockSol's 2015 evaluation is presented in Table 1. In addition, a summary of the bedrock and groundwater elevations encountered in RockSol's 2013 evaluation is presented in References 1 through 3. The approximate groundwater and bedrock elevations are rounded to the nearest foot and are based on the depth to groundwater and bedrock noted during drilling and sampling operations and the ground surface elevations provided by the project surveyor.

Table 1 – Approximate Groundwater and Bedrock Elevations

Borehole	Ground Elevation (feet)	Groundwater Elevation (feet)	Bedrock Elevation (feet)
BR-1	4,827	4,804	4,824
BR-2	4,827	NE	4,824
CBC-1	4,980	4,971	4,968
CBC-2	4,976	4,969	4,968
PV-2	4,965	NE	4,957
PV-7	4,864	NE	4,861
PV-8	4,834	NE	4,825
PV-10	4,792	NE	4,784
WC-1	4,823	4,806	4,805
WC-2	4,814	NE	4,800

Note: NE indicates not encountered.

Individual logs are included in Appendix A. A summary of laboratory test results is presented in Appendix B.

Expansive Soil Discussion

Swell potential in the subgrade soils obtained within the upper 5 feet below existing grades ranged from -1.0 percent (consolidation) to 7.5 percent (swell), when tested with a 200 pound per square foot (psf) surcharge. The average swell potential in the subgrade soils obtained within the upper 5 feet below existing grades is 1.3 percent and the average consolidation potential is 0.6 percent, based on the samples tested. One sample (Borehole PV-7 at 2 feet below existing grade) exhibited a swell potential (7.5 percent) greater than two percent, when tested with a 200-psf surcharge. Six samples of the subgrade soils and bedrock material obtained within the upper 15 feet below existing grades exhibited an average swell potential of 0.7 percent when tested with a 500-psf or 1,000 psf surcharge.

Thirteen samples obtained within the upper 5 feet below existing grades were tested for plasticity (Atterberg Limits) and all but one sample (PV-2) resulted in a plasticity index (PI) of less than 20, with an average PI of 13.

Based on the swell test data and plasticity index test data, the majority of the subgrade soils appear to possess low swell potential and low consolidation potential. Based on the PI data and swell test results, RockSol recommends the upper 2 feet of roadway subgrade for new roadway construction be considered for excavation and recompaction with moisture and density control, or replacement with non-expansive soil.

Cement Type Discussion

Cementitious material requirements for concrete in contact with site soils or groundwater are based on the percentage of water soluble sulfate in either soil or groundwater that will be in contact with concrete constructed for this project. Mix design requirements for concrete exposed to water soluble sulfates in soils or water is considered by CDOT as shown in Table 2 and in the Standard Specifications for Road and Bridge Construction, dated 2011 (CDOT Table 601-2).

Table 2 - Requirements to Protect Against Damage to Concrete by Sulfate Attack from External Sources of Sulfate

Severity of sulfate exposure	Water-soluble sulfate (SO_4), in dry soil, percent	Sulfate (SO_4), in water, ppm	Water Cementitious Ratio, maximum	Cementitious Material Requirements
Class 0	0.00 to 0.10	0 to 150	0.45	Class 0
Class 1	0.11 to 0.20	151 to 1,500	0.45	Class 1
Class 2	0.21 to 2.0	1,500 to 10,000	0.45	Class 2
Class 3	2.01 or greater	10,001 or greater	0.40	Class 3

The average concentration of water soluble sulfates measured in 21 soil samples obtained from RockSol's exploratory boreholes was 0.39 percent by weight. The water soluble sulfate concentrations ranged from 0.00 percent by weight to 1.72 percent by weight. Only one test result exceeded 1 percent (1.72 percent at Borehole PV-10). Based on the results of the water soluble sulfate testing, Exposure Class 2 is considered appropriate for concrete in contact with subgrade materials for this project. Additional testing is recommended for future phases of the ultimate design. Based on the water soluble sulfate test results, stabilization of subgrade soils through the use of lime, cement, or calcium-rich flyash is discouraged.

Subgrade Support Testing

In order to test subgrade support characteristics, an R-Value laboratory test was performed on a composite bulk sample obtained within the upper 5 feet below the top of existing grade from Boreholes PV-3, PV-4, PV-8 and PV-10, which were classified as AASHTO A-6 material. The R-Value test for the composite bulk sample indicated an R-Value of 17. The result of the R-Value laboratory test is presented in Appendix B.

Based on the results of the R-Value testing for the westbound US 50 alignment and considering the R-Value test results obtained for the eastbound phase, RockSol recommends using a design R-Value for the existing subgrade materials of 5. Based on equation 4.1 of the CDOT 2016 M-E Pavement Design Manual, the R-Value of 5 correlates to a resilient modulus of 5,356 psi.

Corrosion Resistance Discussion

Water soluble chloride content, pH and electrical resistivity tests were performed on 12 bulk samples obtained from Boreholes PV-1 through PV-12 and are summarized in Table 3.

Table 3 – Corrosivity Test Results

Borehole Location	Sample Depth (ft)	Water Soluble Chloride (%)	Saturated Resistivity (ohm-cm) at Moisture content (%)	Water Soluble Sulfate (% by weight)	pH	CR Level
PV-1	0.91 – 5	0.0111	1,150 @ 19.5	0.03	6.9	CR 0
PV-2	0.83 – 5	**0.1455**	385 @ 19.5	0.06	7.3	CR 2
PV-3	0.83 – 5	0.0081	900 @ 19.3	**0.20**	8.0	CR 2
PV-4	0.91 – 5	0.0179	860 @ 20.5	**0.67**	7.1	CR 4
PV-5	0.875 – 5	0.0132	920 @ 17.9	**0.62**	7.5	CR 4
PV-6	0 – 5	0.0012	1,800 @ 16.8	**0.18**	7.6	CR 2
PV-7	0 – 5	0.0029	880 @ 25.7	**0.14**	7.8	CR 2
PV-8	0 – 5	0.0462	610 @ 21.6	**0.08**	7.3	CR 1
PV-9	0 – 5	0.0044	1,300 @ 18.6	0.02	8.0	CR 0
PV-10	0.5 – 5	0.0130	770 @ 22.5	**1.72**	8.0	CR 4
PV-11	0.7 – 5	0.0226	890 @ 19.8	**0.56**	7.3	CR 4
PV-12	0 – 5	0.0023	1,200 @ 16.0	**0.38**	6.7	CR 3

Comparison of the test results of the sulfate, chloride, and pH testing performed with *Table 1 - Guidelines for Selection of Corrosion Resistance Levels as presented in the CDOT Pipe Materials Selection Guide,* dated April 30, 2015, suggests corrosion resistance (CR) levels of CR 0, CR 2, CR 3 and CR 4 are present within the project limits.

Of the three variables (water soluble sulfate, water soluble chloride, and pH) that are used in determining the CR level, the water soluble sulfate content appears to be the predominant component affecting the CR level selection. One water soluble chloride test indicated elevated chloride level at 0.01455 percent. The pH tests are all within the 6.0 to 8.5 range. Tests that result in a CR Level greater than CR 0 are bolded in Table 3.

In addition, electrical resistivity analyses were performed in the RockSol laboratory using the soil box method (ASTM G-187). Comparison of the results of the electrical resistivity testing performed with *Table 2 – Minimum Pipe Thickness For Metal Pipes Based On The Resistivity And pH Of The Adjacent Soil* as presented in the *CDOT Pipe Materials Selection Guide,* effective April 30, 2015, suggests the minimum required gauge thickness for metal pipe material, if used, for this project is *0.052 inches (18 Gauge) Polymer Coated*.

Existing Pavement Structure

As-built pavement thicknesses for portions of US 50 within the project limits were also provided in plan sheets from three previous CDOT projects: 1) Federal Aid Project No. RS 0045(5), dated 11-2-73, completed 7-31-74; 2) Federal Aid Project No. RF050-3(6), dated 4-4-74, completed 11-14-74; and 3) Federal Aid Project No. STA 0451-003, dated 1992 to 1995, completed 1996. Based on the plans provided, the pavement structure for the original alignment of EB US 50, as constructed in 1974, consisted of 3.5 inches of hot mix asphalt (HMA) over 4 inches to 6 inches of aggregate base course (ABC).

The existing shoulders of WB US 50 roadway was also widened in 1974 with a pavement structure consisting of 3.5 inches of HMA over 6 inches of ABC with 2 feet of R-value 43 embankment material beneath the new widened areas. An HMA overlay of US 50 extending from 210 feet west to 1,370 east of Pueblo Boulevard was performed in 1996 and consisted of 5 inches (2.5 inch lifts) for the drive lanes and shoulders and new 9 inch HMA pavement sections for the acceleration, deceleration and connections ramps at Pueblo Boulevard.

Existing pavement was encountered by RockSol for this investigation at seven locations along WB US 50. Where flexible HMA roadway pavement was encountered in our boreholes along westbound US 50 between Purcell Boulevard and the western edge of where US 50 diverges (approximately 3,200 feet west of Pueblo Boulevard), the pavement section thickness generally averaged 10.5 inches of HMA. Approximately 6 inches of aggregate base course (ABC) was noted beneath the HMA at Boreholes PV-1 and PV-5 within this area. Where HMA roadway pavement was encountered along westbound US 50 between Wills Boulevard and the eastern edge of where US 50 diverges (approximately 3,000 feet east of Pueblo Boulevard), the pavement section thickness generally averaged 7.25 inches of HMA. Approximately 6 inches of aggregate base course (ABC) was noted beneath the HMA at Borehole PV-10 within this area. A summary of the existing pavement structure measurements is presented in Table 4.

Table 4 – Existing Pavement Structure Measurements

Borehole	Approximate WB Station No.	Westbound US50 Location	HMA Thickness (Inches)	ABC Thickness (Inches)
PV-1	277+40	Outside Turn Lane to Purcell Blvd	11.0	6.0
PV-2	256+80	Lane 2	10.0	NE
PV-3	236+50	Lane 2	10.0	NE
		Outside Shoulder (pavement core)	10.0	NM
PV-4	216+80	Lane 1	11.0	NE
PV-5	196+80	Lane 1 (pavement core)	10.5	NM
		Inside Shoulder	10.5	6.0
PV-10	128+00	Center Median (pavement core)	6.0	6.0
PV-11	109+50	Outside Turn Lane to Business (pavement core)	8.5	NE

NE=Not Encountered; NM=Not Measured (core thickness only, aggregate base course not measured).
HMA = Hot Mix Asphalt, ABC = Aggregate Base Course

Pavement thicknesses were obtained by either direct measurement of the pavement section during drilling operations or measurement of a recovered pavement core. A summary of the pavement thickness measured from recovered cores is presented in Appendix C, Pavement Core Log Summary. Included in the core logs are photographs of the recovered core sections and RockSol's general assessment of the condition of each core.

A limited pavement distress survey was performed on WB US 50 between Mile Marker (MM) 313.14 (Wills Boulevard) to MM 312.63 (WB/EB Diverge Point) and MM 311.45 (WB/EB Merge Point) to MM 309.75 (Purcell Boulevard).

In general, the pavement distresses typically noted between MM 312.99 to MM 312.63 (EB/WB US 50 diverge point) included moderate to severe fatigue cracking in the wheel paths of Lane 2, longitudinal joint cracks within the wheel path and non-wheel path of Lanes 1 and 2 and the outside shoulder ranging in severity from low to moderate, transverse cracks ranging in severity from low to high across both lanes and the outside shoulder, and block cracking ranging in severity from low to high at some areas where the longitudinal and transverse cracks intersected. Several low severity potholes were also noted where transverse and longitudinal cracks intersected with Lane 2 within this area.

In general, the pavement distresses typically noted between MM 311.45 (EB/WB merge point) to MM 309.75 (Purcell Blvd.) included reoccurring transverse cracks ranging in severity from low to high every 20 feet to 50 feet throughout the length of the project limits. The transverse cracks typically extend across the shoulders and Lanes 1 and 2 and longitudinal joint cracks within the wheel path and non-wheel path ranging in severity from low to moderate. Fatigue cracking and block cracking ranging in severity from low to high was noted near the intersection of Purcell Boulevard and WB US 50.

The causes of the distress types appear to be load associated and climate/environment related. The majority of the fatigue and block cracking appears to be load associated. Some of the longitudinal cracks appear to be associated with utility cuts within the existing pavement. Small potholes noted also appear to be load and climate associated. The general severity rating for WB US 50 is low to moderate, with high severity noted near the intersection of WB US 50 and Purcell Boulevard and between the proposed WB US50 bridge over Wild Horse Creek (east of Pueblo Boulevard) and Wills Boulevard (between MM 312.63 and MM 313.14).

Falling Weight Deflectometer Testing

Falling Weight Deflectometer (FWD) testing was performed on the pavement within the project limits for EB US 50 and WB US 50 (except where EB/WB US 50 diverges) in June, 2013. The FWD testing was conducted by Kumar & Associates. Results of the FWD testing are included in Appendix D.

Results of the FWD testing indicate an average in-situ subgrade resilient modulus (M_R) of 7,227 psi for the inside lane of WB US 50 between Mile Marker (MM) 313.14 (Wills Boulevard) to MM 312.63 (WB/EB Diverge Point). For the inside lane from MM 311.45 (WB/EB Merge Point) to MM 309.75 (Purcell Boulevard) an average in-situ M_R of 7,042 psi is indicated.

Results of the FWD testing indicate an average in-situ subgrade resilient modulus (M_R) of 6,655 psi for the outside lane of WB US 50 between Mile Marker (MM) 313.14 (Wills Boulevard) to MM 312.63 (WB/EB Diverge Point). For the outside lane from MM 311.45 (WB/EB Merge Point) to MM 309.75 (Purcell Boulevard) an average in-situ M_R of 5,360 psi is indicated. This resilient modulus value was used by RockSol as the design subgrade M_R value for this project.

The differences in the in-situ subgrade resilient modulus FWD results between the inside and outside lanes along WB US 50 may be attributed to the long term loading conditions from truck traffic.

Based on the results of the FWD testing, approximate remaining life (ESAL's) from Wills Boulevard to the existing EB/WB diverge point (where new alignment is proposed) indicates the existing pavement structure is reaching the end of its service life. Based on the FWD results, RockSol recommends full reconstruction of Westbound US 50, east of Pueblo Boulevard.

Pavement Thickness Recommendations for New Construction

Design of new pavement was performed by RockSol using design criteria presented in the Colorado Department of Transportation (CDOT) 2016 M-E Pavement Design Manual. RockSol also utilized the AASHTOWare M-E Pavement Design software, Version 2.2.

Average annual daily traffic (AADT) for US 50 was based on information obtained from the PEL for No Action (NA) and the Preferred Alternative (Pref. Alt) demands and from the CDOT Division of Transportation Development (DTD) Online Transportation Information System (OTIS). A summary of the traffic data provided to RockSol is outlined in Table 4.

Table 4 - US 50 Future Traffic Demand Estimates

Location	2012 AADT (vpd)	Truck (%)	2035 AADT (vpd)		
			DTD	PEL (NA)	PEL (Pref. Alt)
Wills Blvd to Pueblo Blvd	47,000	4.70	101,050	80,471	64,713
Pueblo Blvd to Purcell Blvd	38,000	6.40	85,633	86,416	80,731

Percent trucks for US 50 between Wills Boulevard and Pueblo Boulevard accounted for approximately 4.7 percent of the traffic volume with an estimated single unit truck and combination truck percentage of approximately 2.35 percent, based on information provided by CDOT OTIS. Percent trucks for US 50 between Pueblo Boulevard and Purcell Boulevard accounted for approximately 6.4 percent of the traffic volume with an estimated single unit truck percentage of 3.73 and 2.67 percent for combination trucks, based on information provided by CDOT OTIS. Based on the AADT and the truck percentages provided, the section of WB US 50 from Pueblo Boulevard to Purcell Boulevard has the highest volume of truck traffic and the highest growth rate. Therefore, the traffic data for the section from Pueblo Boulevard to Purcell Boulevard was used as the basis for pavement design of US 50 Westbound for this project.

Based on the traffic data provided and shown in Table 4, RockSol used a growth rate of 3.65 for the project roadway, and a 2017 Average Annual Daily Truck Traffic (AADTT) of 2,900. Truck traffic for the M-E design model was based on Cluster 3 Vehicle Class. US 50 is classified by CDOT as a Principal Arterial (Freeway and Expressway). RockSol used an opening year of 2017 as the basis for design life total truck traffic. For new construction, design lives of ten and twenty years were used for flexible pavement and a design life of thirty years was used for rigid pavement. The ten year design life is to help evaluate the required thickness of a thinner outside shoulder option.

All flexible pavements will be Hot Mix Asphalt (HMA) using CDOT approved mix designs. RockSol recommends using Grade SX or SMA mix for the surface layer and Grade S mix for the lower (intermediate and base) layers. The flexible pavement layer thicknesses must conform to the minimum and maximum layer thicknesses presented in the CDOT Pavement Design Manual designated at the time of bidding. For this report suggested layer thickness are based on requirements presented in the 2016 M-E Pavement Design Manual. Pavement Design Parameter Sheets are included in Appendix F.

18kip Equivalent Single Axle Load's (ESALs) presented in this report were based on information presented in CDOT OTIS. With M-E pavement design, the 18k ESAL information is used as the basis for HMA binder section. A gyratory design revolution (Ndes) of 100 is recommended. Performance Grade Binder of PG 76-28 is recommended for the surface layer (Grade SX or SMA mix). Performance Grade Binder of PG 64-22 is recommended for the intermediate and base layers (Grade S mix). Summary sheets of the LTPPBind PG Binder Selection Report are presented in Appendix G.

Based on R-Value testing a design subgrade R-Value of 5 is considered appropriate for pavement design. Using equation 4-1 in the 2016 CDOT M-E Pavement Design Manual, a resilient modulus value of 5,356 psi was used for existing subgrade. A resilient modulus of 9,500 psi was used for the 24 inches of improved subgrade (R-Value of 40, or greater). With the 24 inches of improved subgrade a resilient modulus of 20,000 psi was assigned to the aggregate base layer.

A summary of new construction pavement sections of flexible and rigid pavement types for Westbound US 50 is presented in Table 5A and Table 5B.

Table 5A - New Construction Pavement Section Summary

Westbound US 50	Flexible Pavement Alternative (20-Year Design Life)			Rigid Pavement Alternative (30-Year Design Life)		
	HMA (inches)	ABC (inches)	Improved Subgrade (inches)	PCCP (inches)	ABC (inches)	Improved Subgrade (inches)
Mainline	8.0	6	24	10.0	6	24
Interim Off Ramp to Pueblo Boulevard	7.0	6	24	----	----	----

HMA = Hot Mix Asphalt Pavement with top 2-inches comprised of Stone Matrix Asphalt (SMA) or SX (100) PG 76-28.
ABC = CDOT Class 6 Aggregate Base Course; PCCP = Portland Cement Concrete Pavement
Improved Subgrade = Replacement of existing subgrade or placement of embankment with A-2-4 soil, or better, with a minimum R-Value of 40.

Table 5B - New Construction Outside Shoulder Pavement Section (10-Year Design Life)

Westbound US 50	Flexible Pavement		
	HMA (inches)	ABC (inches)	Improved Subgrade (inches)
Mainline Shoulder	6.0	6	24

HMA = Hot Mix Asphalt Pavement with top 2-inches comprised of Stone Matrix Asphalt (SMA) or SX (100) PG 76-28.
ABC = CDOT Class 6 Aggregate Base Course
Improved Subgrade = Replacement of existing subgrade or placement of embankment with A-2-4 soil, or better, with a minimum R-Value of 40.

Electronic copies of M-E Pavement Design files will be forwarded to CDOT Region 2 Materials for their review.

Pavement Rehabilitation

The limited pavement distress evaluation performed on WB US 50 indicates both functional and structural deficiencies. Severe distress was noted within the WB US 50 project limits, east of Wild Horse Creek. Due to the results of the FWD testing and the distress noted in the pavement evaluation, full pavement reconstruction is recommended for WB US 50 between Pueblo Boulevard and Wills Boulevard.

Based on the FWD test data and the existing pavement section thicknesses and lift thicknesses measured, a 3 inch mill and fill operation is feasible along WB US 50 between Pueblo Boulevard and Purcell Boulevard for a design life of 10 years.

Subgrade Preparation (New Pavement)

During construction all landscape material, topsoil, trash, and debris shall be removed from the pavement subgrade limits. Moisture treatment of the existing subgrade material to a minimum depth of 6 inches is recommended prior to construction. For all new pavement areas, proof rolling with pneumatic tire equipment shall be performed using a minimum axle load of 18 kips per axle after specified subgrade compaction has been obtained. Areas found to be weak and those areas which exhibit soft spots, non-uniform deflection or excessive deflection as determined by the project engineer shall be ripped, scarified, wetted or dried if necessary, and re-compacted to the requirements for density and moisture. Complete coverage of the proof roller will be required.

All pavement subgrade preparation, pavement materials, and pavement construction shall conform to CDOT Standard Specifications for Road and Bridge Construction (2011). At a minimum, subgrade moisture conditioning and compaction should meet the compaction specifications outlined in Table 6.

Table 6 –Compaction Specifications

AASHTO Classification	Minimum Relative Compaction (Percentage of MDD), %	Moisture Content (Deviation from OMC)
A-1, A-2-4, A-2-5, A-3,	95% of AASHTO T99	-2 to +2
A-2-6, A-2-7, A-4, A-5, A-6 and A-7	95% of AASHTO T99	0 to +3

Embankment Construction

The ground surface underlying all fills should be carefully prepared by removing all organic matter (topsoil), scarification to a minimum depth of 6 inches and recompacting to at least 95 percent of the maximum dry density (AASHTO T-99/ASTM D698) prior to fill placement. Materials used to construct embankments, including slopes, should meet requirements for soil embankment constructed with moisture density control as required in Section 203.07 (and subsequent revisions) of the CDOT Standard Specifications for Road and Bridge Construction.

Where fill material is to be placed on existing slopes steeper than 4 (H):1 (V), benching must be performed to tie the new fill into the existing slope. Benching into the native ground shall be sufficient to allow sufficient bench width to accommodate placing and compaction equipment to operate in a horizontal orientation.

Claystone and shale materials are not recommended for construction of permanent fill slopes steeper than 4 horizontal (H) to 1 vertical (V).

Material Specifications

The following material specifications are presented for earthwork on the project. The project geotechnical engineer should approve all fill used on the site prior to placement in order to determine its suitability.

1. Soil Embankment: Material shall be soil predominately of materials smaller than No. 4 sieve in diameter. Soil embankment shall be constructed with moisture and density control. RockSol recommends that soil embankment consist of non-swelling material with an R-Value of at least 40.

2. Aggregate Base Course: Material shall be crushed stone, crushed slag, crushed gravel or natural gravel which conforms to the Colorado State Department of Transportation (CDOT) for Class 6 aggregate base course.

3. Utility Trench Backfill: Material excavated from the utility trenches may be used for backfill provided it does not contain unsuitable material (see Item 5) or particles larger than 4 inches.

5. Unsuitable Material: Vegetation, brush, sod, trash, and other deleterious substances shall not be placed in embankment, excavation backfill, or structural backfill. A geotechnical engineer should approve all fill utilized on the site prior to placement to determine its suitability.

Limitations

This geotechnical investigation was conducted in general accordance with the scope of work and was performed to provide preliminary design level information. Additional geotechnical investigations are recommended for future design phases associated with the ultimate build-out for US 50. The geotechnical practices are similar to that used in the Colorado Front Range area with similar soil conditions and our understanding of the proposed work. This report has been prepared by RockSol for use by J. F. Sato Associates, FHU and CDOT. The information presented is based on our exploratory boreholes and does not take into account variations in the subsurface conditions that may exist between boreholes. Additional investigation is required to address such variation. RockSol is not responsible for liability associated with interpretation of subsurface data by others.

Prepared by RockSol Consulting Group, Inc.:

COLORADO REGISTERED PROFESSIONAL ENGINEER
DONALD GORDON HUNT
4-13-16
35249

Ryan Lepro
Geological Engineer

Donald G. Hunt, P.E.
Senior Geotechnical Engineer

Attachments:

Figure 1 - Site Vicinity Map
Figure 2 – Site Geology Map
Figure 3 - Borehole Location Figure Index
Figures 3A – 3G – Borehole Location Plans

Appendix A – Legend and Individual Borehole Logs
Appendix B – Laboratory Test Results
Appendix C – Pavement Core Log Summary
Appendix D – Falling Weight Deflectometer Test Results
Appendix E – Flexible and Rigid Pavement Thickness Calculation Sheets (AASHTO M-E, V2.2)
Appendix F – Pavement Parameter Sheets
Appendix G – LTPPBind PG Binder Selection Report Sheets

IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY, NORTHWEST PUEBLO, COLORADO QUADRANGLE, 2010

Print Date: 7/28/2015 File Name: 20448_F1 Site Vicinity.dgn Horiz. Scale: 1:1	US 50 WEST PURCELL BLVD. TO WILLIS BLVD. SITE VICINITY MAP	Project No./Code STA 0503-088
RockSol Consulting Group, Inc. 6510 W 91st Ave, Ste 130 Westminster, CO 80031	0 2000 4000 6000 (FEET) Designer: R. Lepro Detailer: D. Knight Sheet Subset:	20448 Figure 1

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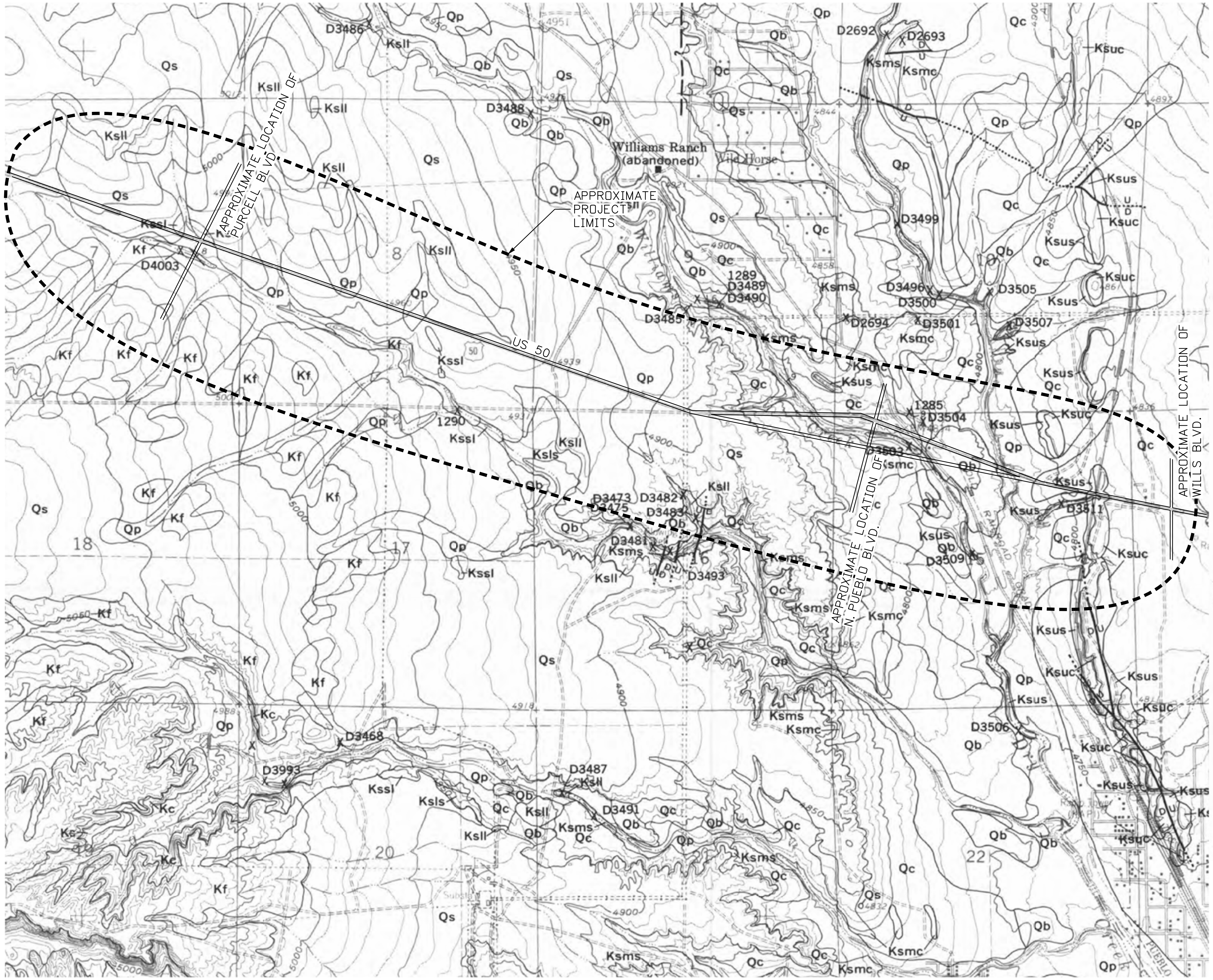
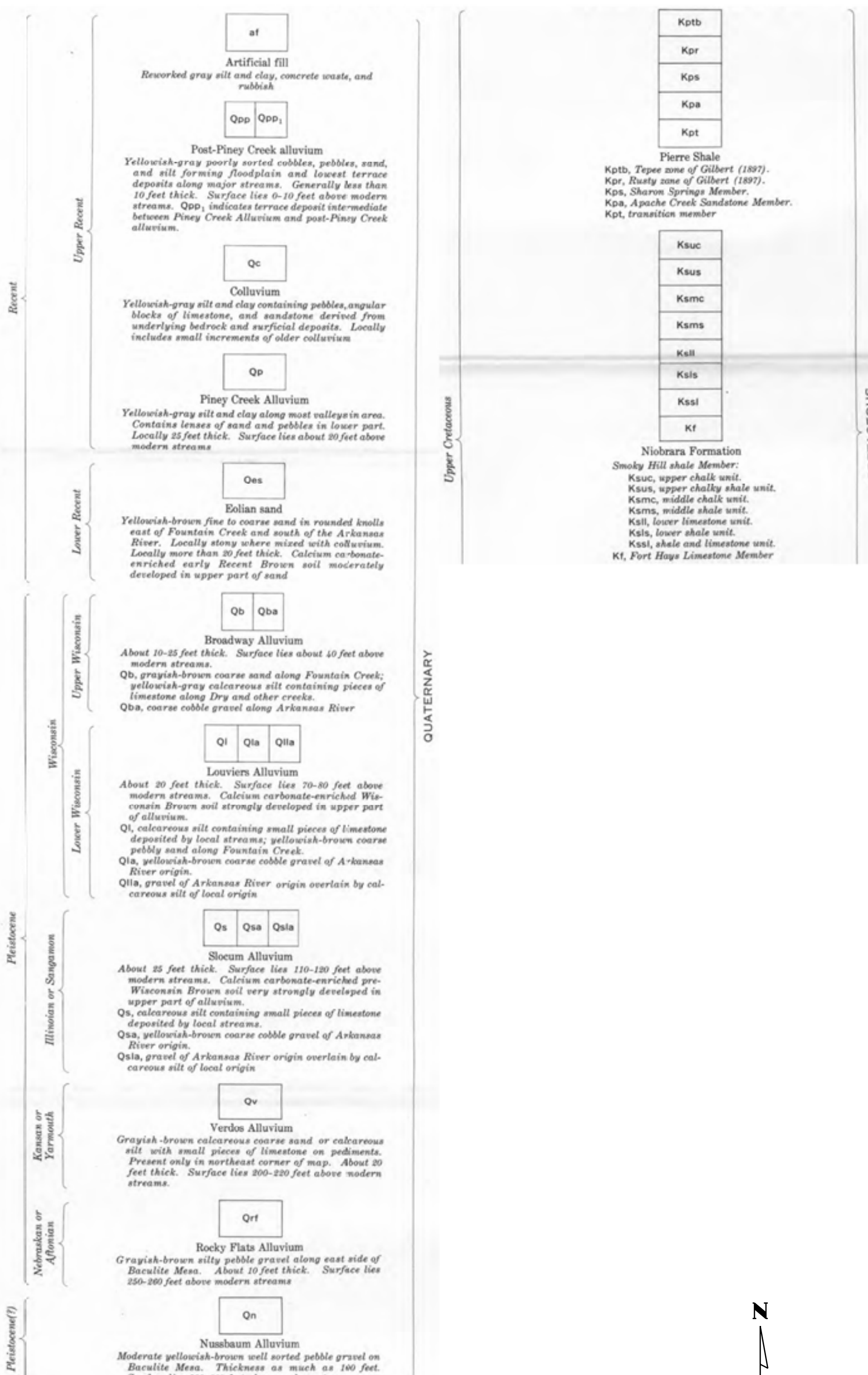


EXPLANATION



GEOLOGY MAP COMPILED FROM THE USGS GEOLOGY OF THE NORTHWEST AND NORTHEAST PUEBLO QUADRANGLES, COLORADO BY GLENN R. SCOTT, DATED 1964 AND MODIFIED BY ROCKSOL

Print Date: 7/28/2015	
File Name: 20448GEO_F2 Site Geology.dgn	
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US 50 WEST
PURCELL BLVD. TO WILLS BLVD
SITE GEOLOGY MAP

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Subset Sheets: of

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Figure

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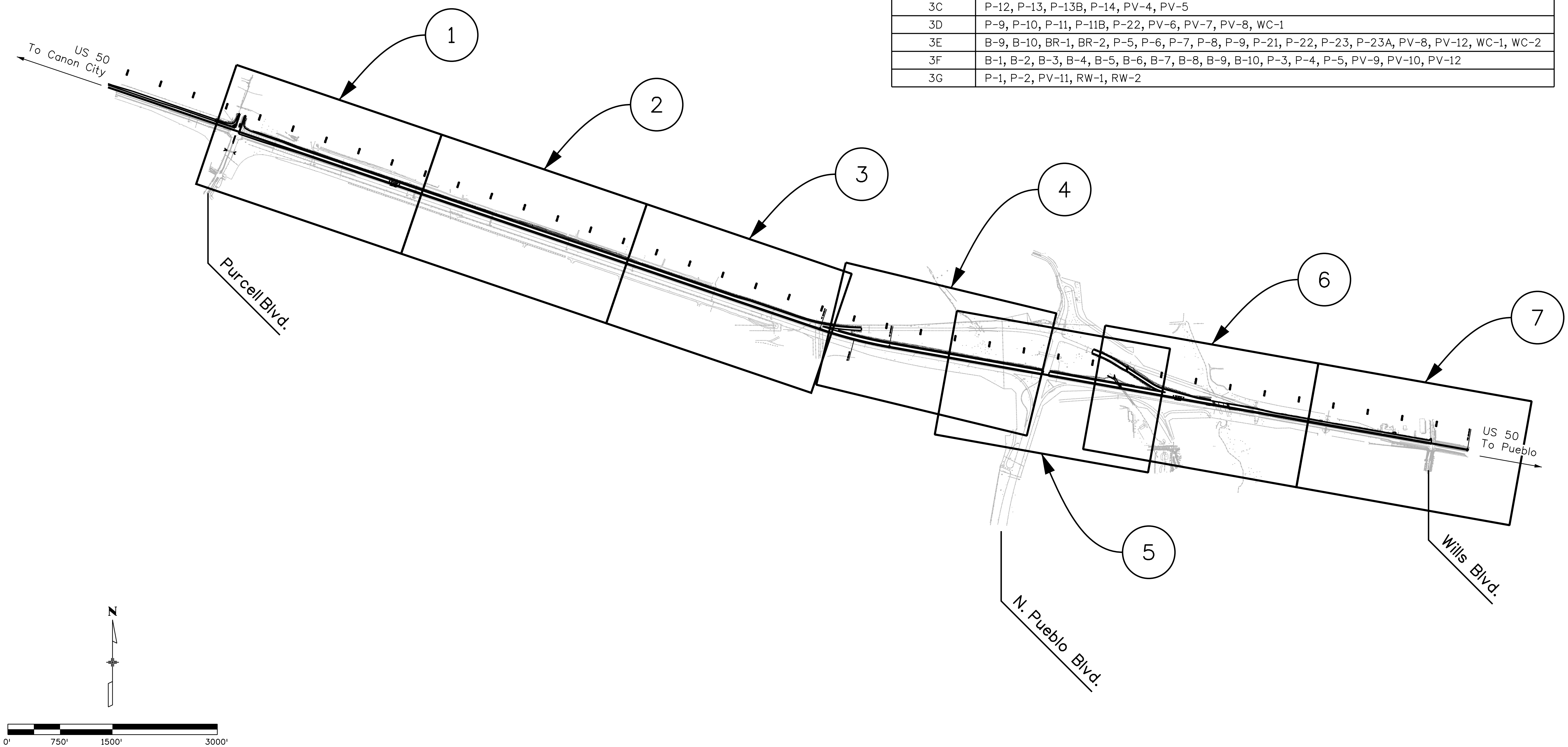
FIGURE NO.	BOREHOLES
3A	CBC-1, CBC-2, P-18, P-19, P-20, PV-1, PV-2
3B	P-15, P-16, P-17, PV-3
3C	P-12, P-13, P-13B, P-14, PV-4, PV-5
3D	P-9, P-10, P-11, P-11B, P-22, PV-6, PV-7, PV-8, WC-1
3E	B-9, B-10, BR-1, BR-2, P-5, P-6, P-7, P-8, P-9, P-21, P-22, P-23, P-23A, PV-8, PV-12, WC-1, WC-2
3F	B-1, B-2, B-3, B-4, B-5, B-6, B-7, B-8, B-9, B-10, P-3, P-4, P-5, PV-9, PV-10, PV-12
3G	P-1, P-2, PV-11, RW-1, RW-2



LEGEND:

(1) Indicates Borehole Location Plan Sheet

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As Constructed	US 50 WEST PURCELL BLVD. TO WILLS BLVD BOREHOLE LOCATION - KEY PLAN	Project No./Code
No Revisions:	Designer: R. Lepro	STA 0503-088
Revised:	Detailer: D. Knight	20448
Void:	Structure Numbers	
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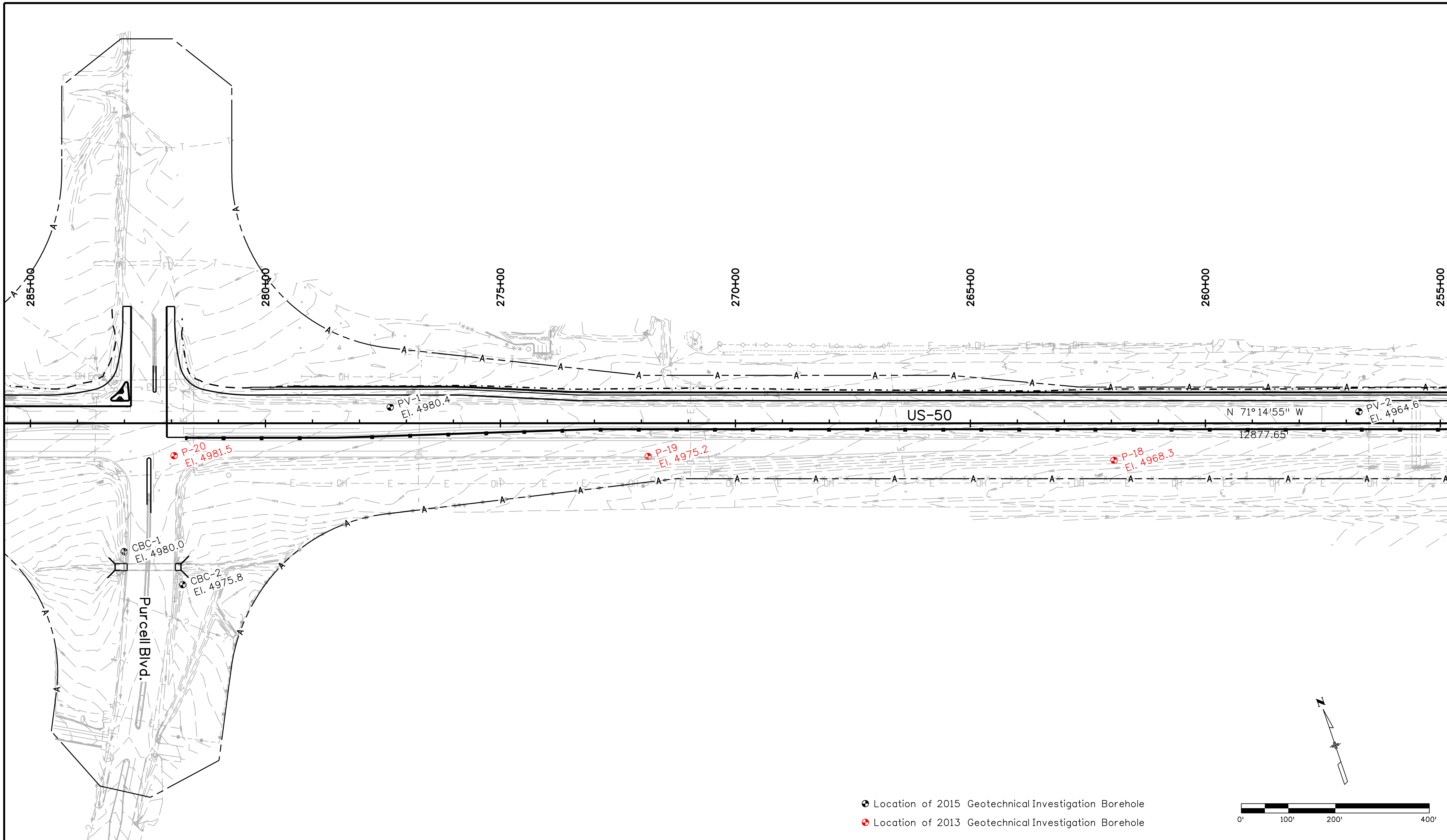

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US 50 WEST
PURCELL BLVD. TO WILLS BLVD
BOREHOLE LOCATION PLAN (1 OF 7)

Designer: R. Lepro	Structure Numbers		
Detailer: D. Knight			
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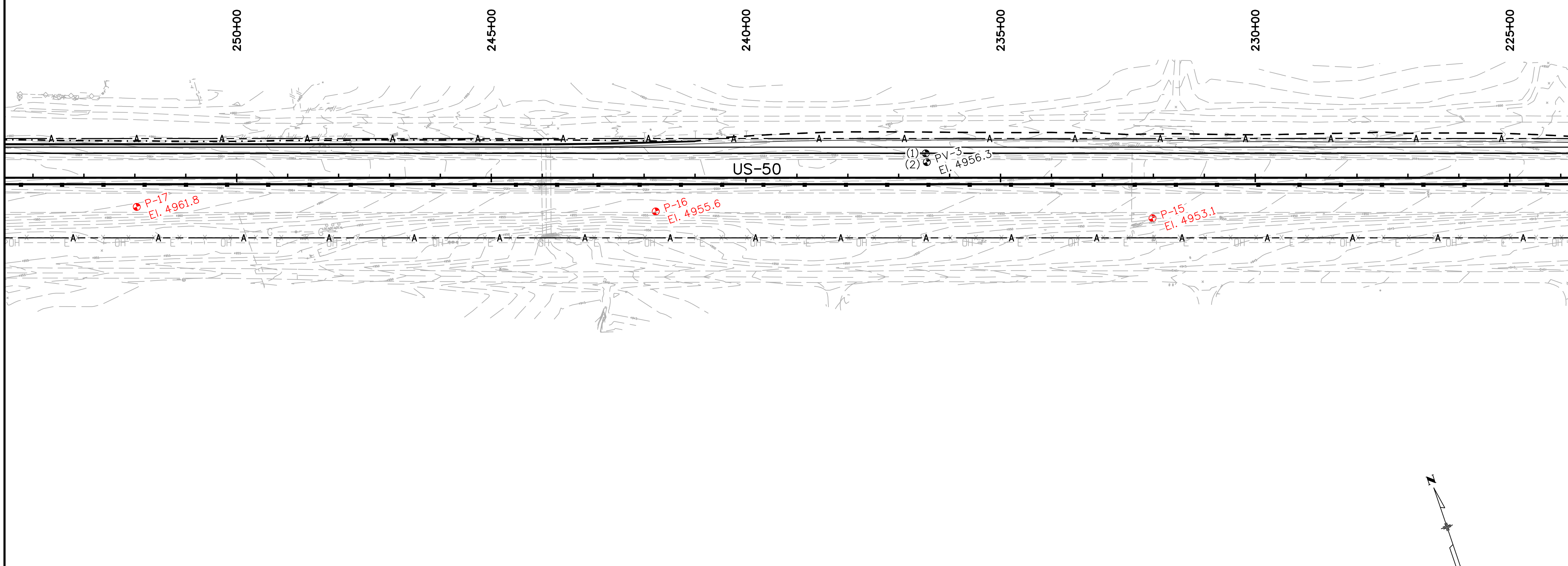
Project No./Code	
STA 0503-088	
20448	
Figure	3A



PV-3 Note:
(1) - Shoulder Corehole
(2) - Existing Lane Borehole

Location of 2015 Geotechnical Investigation Borehole
Location of 2013 Geotechnical Investigation Borehole

0' 100' 200' 400'

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US 50 WEST
PURCELL BLVD. TO WILLS BLVD
BOREHOLE LOCATION PLAN (2 OF 7)

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Detailer: D. Knight
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Figure 3B

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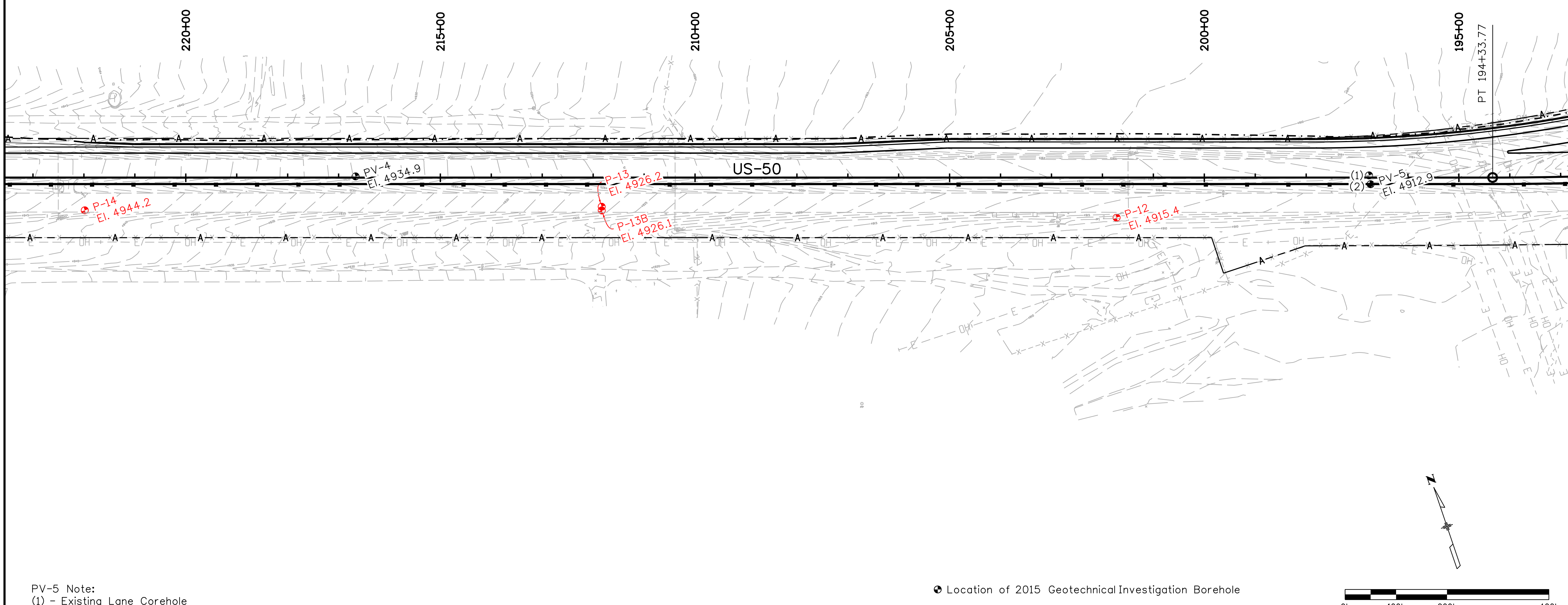

PV-5 Note:
(1) - Existing Lane Corehole
(2) - Median Borehole

Location of 2015 Geotechnical Investigation Borehole
Location of 2013 Geotechnical Investigation Borehole

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US 50 WEST
PURCELL BLVD. TO WILLS BLVD
BOREHOLE LOCATION PLAN (3 OF 7)

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Detailer: D. Knight
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Figure 3C

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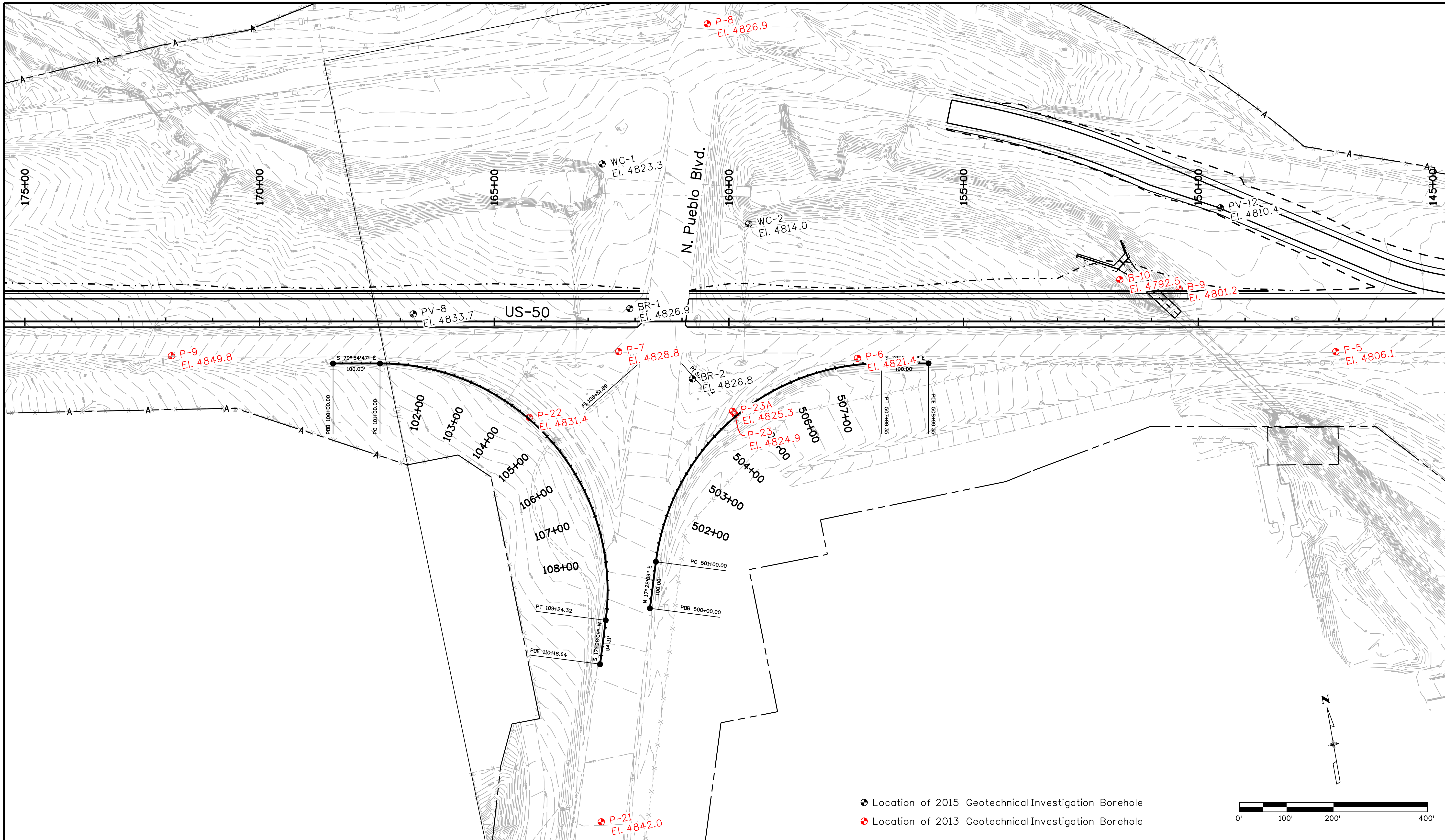

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US 50 WEST
PURCELL BLVD. TO WILLS BLVD
BOREHOLE LOCATION PLAN (5 OF 7)

Designer:	R. Lepro	Structure Numbers	
Detailer:	D. Knight		
Subset:		Subset Sheets:	of

Project No./Code
STA 0503-088
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Figure 3E

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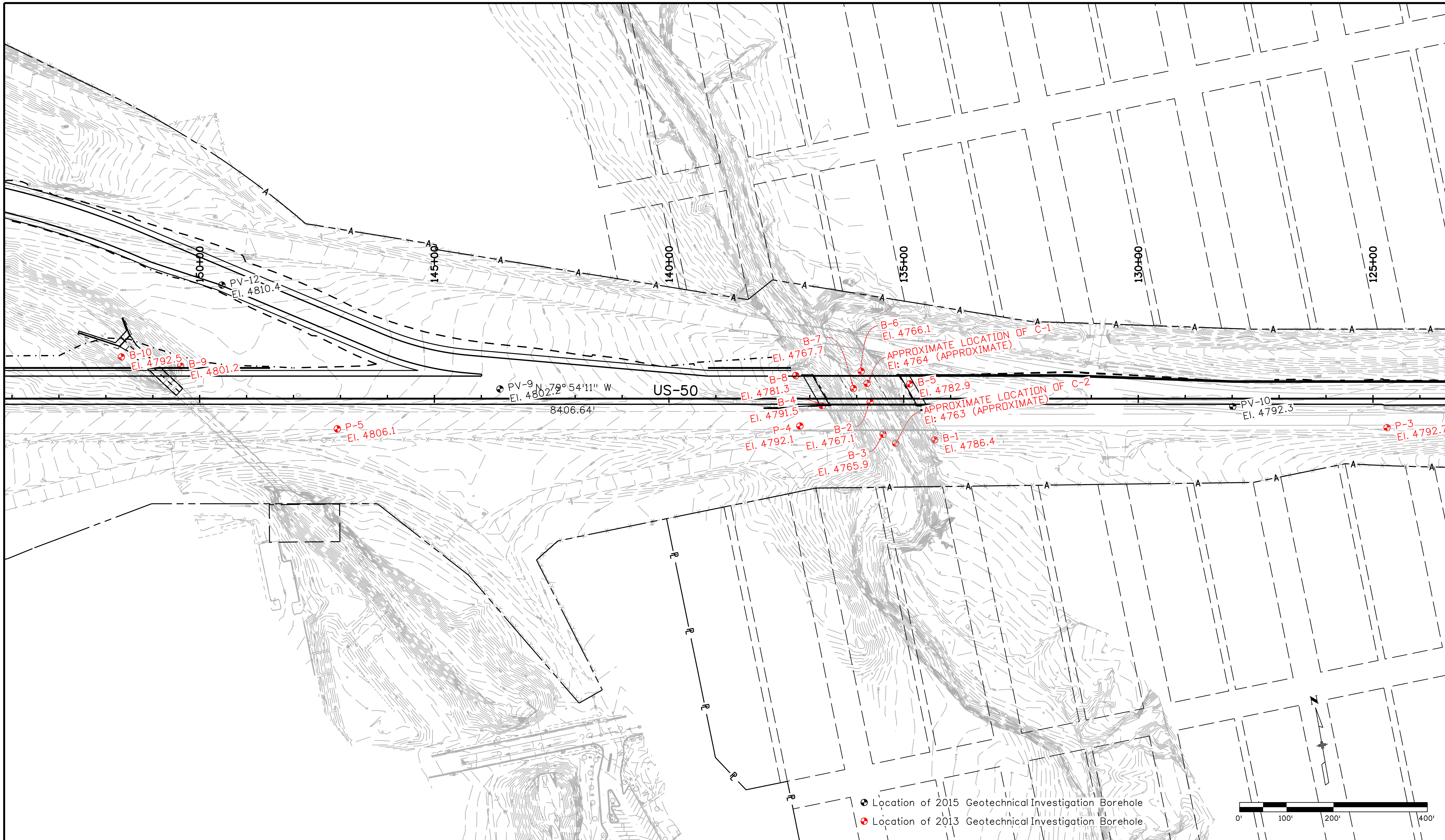

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US 50 WEST
PURCELL BLVD. TO WILLS BLVD
BOREHOLE LOCATION PLAN (6 OF 7)

Designer: R. Lepro
Detailer: D. Knight
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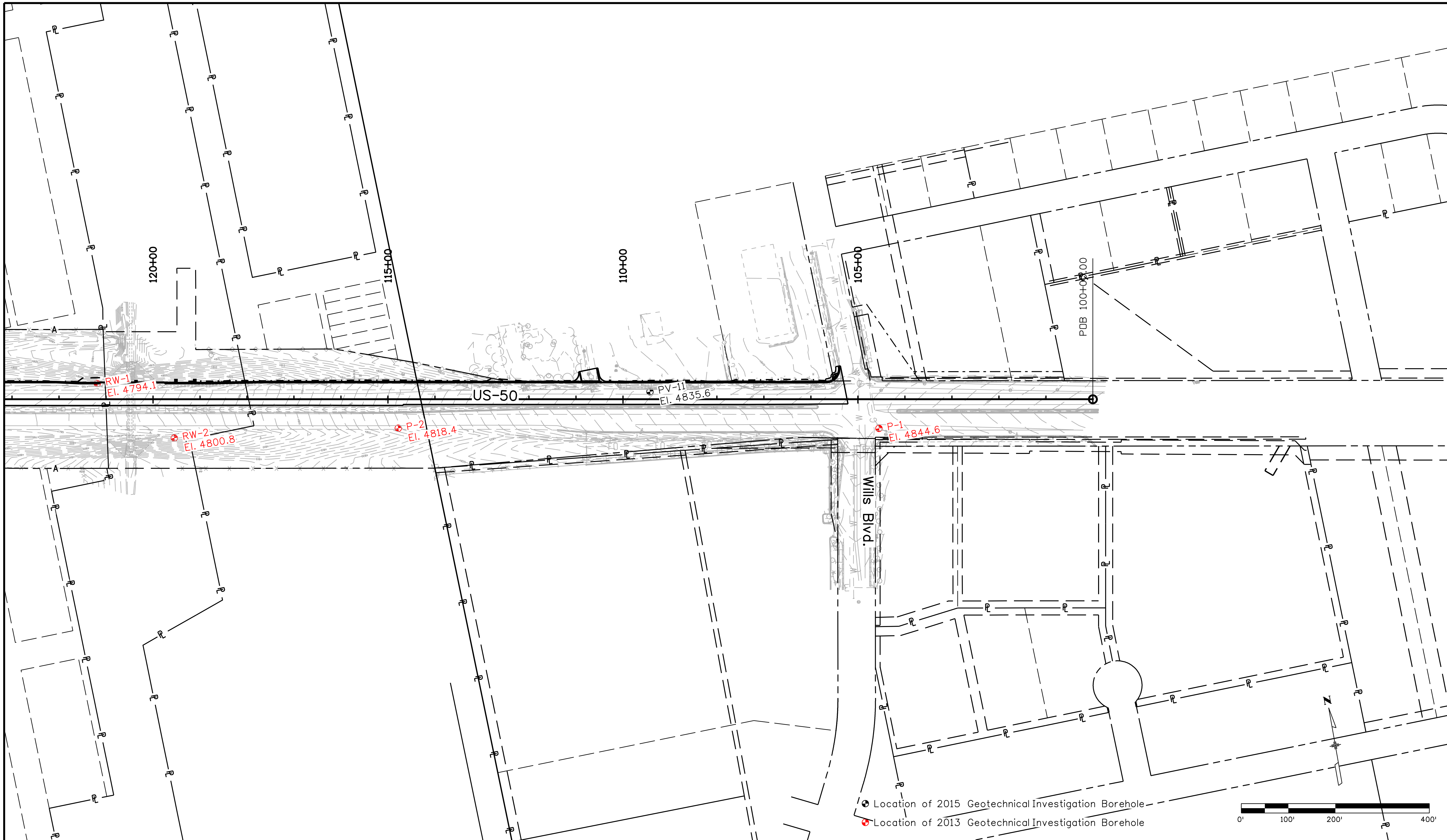
Structure Numbers
Subset Sheets: of

Project No./Code
STA 0503-088
20448
Figure 3F



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No Revisions:		STA 0503-088
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	Detailer: D. Knight	
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APPENDIX A

LEGEND
AND
INDIVIDUAL BOREHOLE LOGS

BR-1, BR-2, CBC-1, CBC-2, PV-1 through PV-12, WC-1, and WC-2
(Westbound US 50 Alignment Boreholes)

CLIENT J.F. Sato

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

LITHOLOGY

- **Asphalt Pavement**
- **Fill - CLAY**
- **Fill - SAND**
- **TOPSOIL**
- **Native - SAND, gravelly**
- **Native - CLAY**
- **Native - CLAY, sandy**
- **Bedrock - CLAYSTONE**
- **Bedrock - SHALE**
- **Fill - Aggregate Base Course**
- **Fill - SAND**
- **Fill - CLAY**
- **Native - SAND, silty**
- **Native - SAND, clayey**
- **Native - CLAY, gravelly**
- **Native - GRAVEL, silty**
- **Bedrock - SANDSTONE**

SAMPLE TYPE

- Auger Cuttings
- MODIFIED CALIFORNIA SAMPLER
2.5" O.D. AND 2" I.D.
WITH BRASS LINERS INCLUDED
- SPLIT SPOON SAMPLER
2" O.D. AND 1 3/8" I.D.
NO LINERS

15/12 Indicates 15 blows of a 140 pound hammer falling 30 inches was required to drive the sampler 12 inches.

50/11 Indicates 50 blows of a 140 pound hammer falling 30 inches was required to drive the sampler 11 inches.

5,5,5 Indicates 5 blows, 5 blows, 5 blows of a 140 pound hammer falling 30 inches was required to drive the sampler 18 inches.

▼ GROUND WATER LEVEL NOTED AT THE TIME OF DRILLING

RockSol Consulting Group, Inc.

BORING : BR-1

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4826.9 ft **STATION NO.** 162+00
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601426.1 **EAST** 241437.8
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: NW corner, EB US50 & Pueblo Blvd.
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
▼ **WATER DEPTH** 23.0 ft on 5/12/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
4827	0		(Fill) SAND, gravel, moist, light brown, hard, approximately 2" in depth										
			(Native) SAND, silty to clayey, slightly moist to moist, light brown, medium dense to dense										
			(Bedrock) SANDSTONE, clayey (interbedded claystone), slightly moist, light brown, hard										
4822	5			MC	50/11		0.73	112.9	9.9	30	18	12	43.5
			(Bedrock) SANDSTONE, clayey, slightly moist, light brown, very hard										
4817	10			MC	50/6	0.1		123.1	10.2				
4812	15			MC	50/3			123.4	9.7				
			(Bedrock) CLAYSTONE, sandy, slightly moist, light brown, very hard										
4807	20			SS	50/6		0.77		10.7	33	17	16	85.5
		▼	(Bedrock) SHALE, silty to clayey, moist to wet, dark gray, very hard										
4802	25			MC	50/1								
			Bottom of hole at 29.1 feet.	SS	100/1								

RockSol Consulting Group, Inc.

BORING : BR-2

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4826.8 ft **STATION NO.** 160+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601255.1 **EAST** 241543.1
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: SE corner, EB US50 & Pueblo Blvd.
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 5/12/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4827	0		(Fill) SAND, gravel, very moist, light brown, loose, approximately 6" in thickness										
			(Fill) CLAY, sandy, moist, light brown, medium stiff										
			(Bedrock) CLAYSTONE, sandy, moist, light brown, hard to very hard										
4822	5			MC	50/12	1.6	0.70	126.4	12.7				
4817	10			MC	50/4			127.6	10.0	27	18	9	60.1
4812	15			MC	50/6		0.26	114.9	11.6	31	14	17	74.0
4807	20			SS	50/4								
			(Bedrock) SHALE, silty to clayey, slightly moist to moist, gray, very hard										
4802	25			SS	50/1								
			Bottom of hole at 28.0 feet.										

BORING : CBC-1

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4980.0 ft **STATION NO.** 283+00
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 604631.0 **EAST** 229793.8
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: West of Purcell Blvd north of culvert
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES S of US50
WATER DEPTH 9.5 ft on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
4980	0		TOPSOIL, clay, sandy, approximately 6 inches in thickness	BULK			0.03			27	15	12	63.9
			(Fill) CLAY, sandy, slightly moist to moist, brown, very stiff										
4975	5			MC	21/12			117.8	14.8				
			(Fill) CLAY, (reworked shale), very moist to wet, light brown, medium stiffness										
4970	10			MC	5/12			131.1	7.9				17.4
			(Bedrock) SHALE, slightly moist, light brown, very hard										
			Bottom of hole at 13.5 feet.	SS	50/0.75								

Approximate Bulk Depth 0-5
Liquid Limit= 27
Plastic Limit= 15
Plasticity Index= 12
Fines Content= ERROR
Sulfate= 0.03

BORING : CBC-2

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4975.8 ft **STATION NO.** 281+70
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 604524.5 **EAST** 229889.2
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: East side of Purcell Blvd, South side of culvert
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES S of US50
WATER DEPTH 7.0 ft on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4976	0		TOPSOIL, clay, sandy, approximately 6 inches in thickness, moist, brown, stiff to very stiff	BULK			0.77			27	14	13	49.4
			(Fill) SAND, clayey, sandy clay in parts (reworked shale), slightly moist to wet, light brown to brown, medium dense										
4971	5			MC	25/12			127.8	8.9				
			(Bedrock) SHALE, slightly silty, slightly moist to moist, brownish gray, very hard, iron oxide staining	MC	50/4.5		0.10	134.4	7.9				
4966	10												
			Bottom of hole at 11.5 feet.	SS	50/0.5								

Approximate Bulk Depth 0-5
Liquid Limit= 27
Plastic Limit= 14
Plasticity Index= 13
Fines Content= ERROR
Sulfate= 0.77

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NUMBER 302.02
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4980.4 ft **STATION NO.** 277+40
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 604740.3 **EAST** 230428.8
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: WB US50, E of Purcell St.
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
WATER DEPTH None Encountered on 5/12/15
NOTES Right turn lane

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4980	0		Asphalt Pavement, approximately 11" in thickness										
			Aggregate Base Course, approximately 6" in thickness	BULK			0.03						34.1
			(Native) SAND, clayey, very moist, light brown, loose to medium dense	MC	6/12	-0.1		108.7	15.7				
4975	5			MC	9/12			111.1	17.0				
4970	10			MC	12/12			113.4	16.8				

Bottom of hole at 10.0 feet.

Approximate Bulk Depth 0.91-5
Liquid Limit=
Plastic Limit=
Plasticity Index=
Fines Content= ERROR
Sulfate= 0.03

RockSol Consulting Group, Inc.

BORING : PV-2

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4964.6 ft **STATION NO.** 256+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 604068.4 **EAST** 232377.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: WB US50
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
WATER DEPTH None Encountered on 5/12/12
NOTES Lane 2

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
4965	0		Asphalt Pavement, approximately 10" in thickness										
			(Fill) SAND, clayey moist, light brown, loose	BULK			0.06			37	13	24	33.6
				MC	9/12	0.0		108.3	18.0				
			(Native) SAND, clayey, moist, light brown, loose										
4960	5			MC	6/12			106.2	17.9				
			(Bedrock) SHALE, silty to clayey, slightly moist to moist, dark gray, very hard										
			Bottom of hole at 9.0 feet.	MC	SR								

Approximate Bulk Depth 0.83-5
Liquid Limit= 37
Plastic Limit= 13
Plasticity Index= 24
Fines Content= ERROR
Sulfate= 0.06

BORING : PV-3

RockSol Consulting Group, Inc.

CLIENT J.F. Sato

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

DATE STARTED 5/12/15 **COMPLETED** 5/12/15

GROUND ELEVATION 4956.3 ft **STATION NO.** 236+50

DRILLING CONTRACTOR Old Dirt Drilling

NORTH 603422.2 **EAST** 234300.1

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"

BORING LOCATION: WB US50

LOGGED BY J. Biller **HAMMER TYPE** Automatic

GROUND WATER LEVELS:

WATER DEPTH None Encountered on 5/12/15

NOTES Lane 2, core in shoulder

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
4956	0		Asphalt Pavement, approximately 10" in thickness										
			(Native) CLAY, sandy, moist, light brown, medium stiff	BULK			0.20			30	14	16	51.7
				MC	7/12	0.1		104.9	18.4				
4951	5			MC	6/12			106.7	17.0				
			(Native) CLAY, sandy, moist, light brown, very stiff										
4946	10			MC	20/12			118.3	12.1				

Bottom of hole at 10.0 feet.

Approximate Bulk Depth 0.83-5
Liquid Limit= 30
Plastic Limit= 14
Plasticity Index= 16
Fines Content= ERROR
Sulfate= 0.20

BORING : PV-4

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4934.9 ft **STATION NO.** 216+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 602759.4 **EAST** 236164.2
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: WB US50
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
WATER DEPTH None Encountered on 5/12/15
NOTES Lane 1

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4935	0		Asphalt Pavement, approximately 11" in thickness										
			(Fill) SAND, clayey to silty, moist, light brown to brown, loose	BULK			0.67			27	14	13	49.5
				MC	7/12	0.0		102.6	20.5				
4930	5			MC	6/12			105.8	18.0				
			(Native) CLAY, sandy, moist, light brown, very stiff										
4925	10			MC	17/12			105.3	21.1				
			Bottom of hole at 10.0 feet.										

Approximate Bulk Depth 0.91-5
Liquid Limit= 27
Plastic Limit= 14
Plasticity Index= 13
Fines Content= ERROR
Sulfate= 0.67

BORING : PV-5

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4912.9 ft **STATION NO.** 196+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 602121.5 **EAST** 238049.4
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: WB US50
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Inside shoulder, core in Lane 1
WATER DEPTH None Encountered on 5/12/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
4913	0		Asphalt Pavement, approximately 10.5" in thickness										
			Aggregate Base Course, approximately 6" in thickness	BULK			0.62			22	14	8	36.1
			(Fill) SAND, clayey with gravel, moist, light brown, medium dense	MC	27/12	0.9		122.7	12.5				
4908	5		(Native) CLAY, sandy with gravel in parts, moist, light brown, stiff	MC	13/12			110.3	14.5				
4903	10			MC	10/12			123.2	10.5				

Bottom of hole at 10.0 feet.

Approximate Bulk Depth 0.875-5
Liquid Limit= 22
Plastic Limit= 14
Plasticity Index= 8
Fines Content= ERROR
Sulfate= 0.62

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4889.1 ft **STATION NO.** 186+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601850.4 **EAST** 239018.7
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Median EB/WB Hwy 50
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES N side of EB US50, ~2500' W of Pueblo Blvd
WATER DEPTH None Encountered on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
4889	0		(Topsoil) SAND, clayey, moist, brown, medium dense, approximately 6" in thickness	BULK			0.18			20	15	5	24.6
			(Fill) SAND silty to clayey with gravel, slightly moist to moist, light brown, dense	MC	33/12	-1.0		123.1	4.8				
4884	5		(Native) SAND, silty, slightly moist to moist, brown, medium dense	MC	29/12			128.7	5.2				
4879	10			MC	22/12			115.8	12.1				

Bottom of hole at 10.0 feet.

Approximate Bulk Depth 0-5
Liquid Limit= 20
Plastic Limit= 15
Plasticity Index= 5
Fines Content= ERROR
Sulfate= 0.18

RockSol Consulting Group, Inc.

BORING : PV-7

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4863.8 ft **STATION NO.** 176+90
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601665.3 **EAST** 239987.9
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Median, Hwy 50
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES N side of EB US50, approx 1500' E of Pueblo Blvd
WATER DEPTH None Encountered on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4864	0		(Topsoil) CLAY, sandy, moist, brown, stiff to very stiff, approximately 6" in thickness	BULK			0.14			32	14	18	79.0
			(Native) CLAY, sandy, slightly moist, light brown, very stiff	MC	41/12	7.5		124.0	9.9				
			(Bedrock) CLAYSTONE, slightly moist to moist, light brown, very hard	MC	50/10			129.8	9.6				
4859	5												
				MC	50/7			130.1	9.1				

Bottom of hole at 9.6 feet.

<u>Approximate Bulk Depth 0-5</u>
Liquid Limit= 32
Plastic Limit= 14
Plasticity Index= 18
Fines Content= ERROR
Sulfate= 0.14

RockSol Consulting Group, Inc.

BORING : PV-8

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4833.7 ft **STATION NO.** 166+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601495.6 **EAST** 240981.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Median EB & WB US50
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES N side of EB US50, approx 500' W of Pueblo Blvd
WATER DEPTH None Encountered on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4834	0		(Topsoil) CLAY, sandy, moist, brown, stiff to very stiff, approximately 6" in thickness	BULK			0.08			28	16	12	60.1
			(Native) CLAY, sandy, slightly moist to moist, light brown, stiff to very stiff	MC	13/12	0.8		99.7	5.9				
4829	5			MC	21/12			112.9	6.6				
			(Bedrock) SHALE, slightly silty to sandy, slightly moist to moist, light brown, very hard	MC	50/6			128.9	8.4				

Bottom of hole at 9.5 feet.

Approximate Bulk Depth 0-5
Liquid Limit= 28
Plastic Limit= 16
Plasticity Index= 12
Fines Content= ERROR
Sulfate= 0.08

RockSol Consulting Group, Inc.

BORING : PV-9

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4802.2 ft **STATION NO.** 143+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601094.8 **EAST** 243259.0
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Median WB/EB Hwy 50
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES N side of EB US50, approx 1700' E of Pueblo Blvd
WATER DEPTH None Encountered on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4802	0		(Topsoil) SAND, silty to clayey, moist, brown, medium dense, approximately 6" in thickness	BULK			0.02			23	17	6	43.3
			(Native) SAND, silty to clayey with gravel in parts, slightly moist to moist, light brown, medium dense	MC	15/12	1.2		99.6	3.9				
4797	5			MC	10/12			103.7	3.9				
			(Native) CLAY, silty to sandy, slightly moist, light brown, stiff										
4792	10			MC	16/12			107.4	6.2				

Bottom of hole at 10.0 feet.

Approximate Bulk Depth 0-5
Liquid Limit= 23
Plastic Limit= 17
Plasticity Index= 6
Fines Content= ERROR
Sulfate= 0.02

BORING : PV-10

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4792.3 ft **STATION NO.** 128+00
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 600784.3 **EAST** 244789.9
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: WB US50
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Center median
WATER DEPTH None Encountered on 5/12/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4792	0		Asphalt Pavement, approximately 6" in thickness										
			Aggregate Base Course, approximately 6" in thickness	BULK			1.72			33	15	18	51.1
			(Native) CLAY, sandy, slightly moist to moist, light brown, very stiff to hard	MC	17/12	0.0		114.1	16.3				
4787	5			MC	41/12			105.0	19.2				
			(Bedrock) CLAYSTONE, sandy, slightly moist, light brown, very hard	MC	50/11			113.6	17.1				
			Bottom of hole at 10.0 feet.										

Approximate Bulk Depth 0.5-5
Liquid Limit= 33
Plastic Limit= 15
Plasticity Index= 18
Fines Content= ERROR
Sulfate= 1.72

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/12/15 **COMPLETED** 5/12/15
GROUND ELEVATION 4835.6 ft **STATION NO.** 109+50
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 600491.1 **EAST** 246623.1
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: US50 W of Wills Blvd.
LOGGED BY J. Biller **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Right turn lane
WATER DEPTH None Encountered on 5/12/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4836	0		Asphalt Pavement, approximately 8.5" in thickness										
			(Fill) SAND, slightly silty to gravelly, moist, brown, medium dense	BULK			0.56			26	13	13	34.7
			(Native) CLAY, sandy to silty, moist, brown, stiff	MC	15/12	0.8		112.9	16.1				
4831	5			MC	12/12	0.1		104.6	20.5				

Bottom of hole at 5.0 feet.

Approximate Bulk Depth 0.7-5
Liquid Limit= 26
Plastic Limit= 13
Plasticity Index= 13
Fines Content= ERROR
Sulfate= 0.56

BORING : PV-12

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4810.4 ft **STATION NO.** 149+50
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601416.6 **EAST** 242714.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Median EB/WB Hwy 50
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES S side of WB US 50, approx 1000' E of Pueblo Blvd
WATER DEPTH None Encountered on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4810	0		(Topsoil) SAND, silty, slightly moist, light brown, loose to medium dense, approximately 6 inches in thickness	BULK			0.38			23	14	9	31.0
			(Native) SAND, slightly clayey to silty with gravel, slightly moist, light brown to brown, medium dense	MC	17/12			113.8	2.5				
4805	5			MC	18/12			113.8	2.9				
4800	10			MC	23/12			115.5	3.0				

Bottom of hole at 10.0 feet.

Approximate Bulk Depth 0-5
Liquid Limit= 23
Plastic Limit= 14
Plasticity Index= 9
Fines Content= ERROR
Sulfate= 0.38

LOG - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

BORING : RW-1

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/13 **COMPLETED** 5/15/13
GROUND ELEVATION **STATION NO.** 268+00
DRILLING CONTRACTOR Old Dirt Drilling
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Proposed Retaining Wall EB US50
LOGGED BY R. Lepro **HAMMER TYPE** Automatic Hammer
E. Side of RR Bridge 60' E. on Cut Slope
GROUND WATER LEVELS:
NOTES 5/15/2013
WATER DEPTH 14.0 ft on 5/15/13

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
	0		Topsoil, SAND, silty to clayey, slightly moist to moist, brown, loose to medium dense, approximately 3" thick										
			(Native) SAND, clayey, slightly moist to moist, brown, medium dense	MC	44/12		1.44						
			(Bedrock) SHALE, silty to clayey, slightly moist to moist, brown and grey, hard to very hard										
	5			MC	50/7	0.1							
	10			MC	40/12								
	15			MC	46/12								
			Bottom of hole at 15.0 feet.										

BORING : RW-2

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/13 **COMPLETED** 5/15/13
GROUND ELEVATION **STATION NO.** 262+00
DRILLING CONTRACTOR Old Dirt Drilling
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Proposed Retaining Wall WB US50 W. Side of RR Bridge 60' W. in Drainage Ditch
LOGGED BY R. Lepro **HAMMER TYPE** Automatic Hammer
GROUND WATER LEVELS:
NOTES 5/15/2013
▼ **WATER DEPTH** 9.0 ft on 5/15/13

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
	0		(Fill) SAND, silty with gravel, cobbles/boulders in parts, loose to medium dense, brown, moist				0.16						
			(Native) SAND, clayey (weathered bedrock), moist, brown, medium dense, calcareous/gypsum crystals in parts										
	5			MC	22/12	1.1	1.40						
			(Bedrock) SANDSTONE, clayey, silty in parts, moist, brown, hard										
		▼											
	10			MC	34/12								
			(Bedrock) SHALE, silty to clayey, slightly moist to moist, dark grey, very hard										
				MC	50/0.5								
			Bottom of hole at 14.1 feet.										

Approximate Bulk Depth 0-4
Liquid Limit=
Plastic Limit=
Plasticity Index=
Fines Content= ERROR
Sulfate= 0.16

RockSol Consulting Group, Inc.

BORING : WC-1

CLIENT J.F. Sato

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

DATE STARTED 5/12/15 **COMPLETED** 5/12/15

GROUND ELEVATION 4823.3 ft **STATION NO.** 163+00

DRILLING CONTRACTOR Old Dirt Drilling

NORTH 601739.7 **EAST** 241433.8

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"

BORING LOCATION: W side of Pueblo Blvd. at Williams Creek

LOGGED BY J. Biller **HAMMER TYPE** Automatic

GROUND WATER LEVELS:

NOTES North side of culvert

▼ **WATER DEPTH** 17.0 ft on 5/12/15

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4823	0	(Topsoil) SAND, silty to gravelly, wet, brown, loose, approximately 6" in thickness										
		(Fill) SAND, clayey, moist, light brown, dense										
4818	5		MC	48/12			127.9	10.1				
4813	10		MC	49/12			121.2	11.9	29	16	13	43.4
		(Native) CLAY, sandy with gravel and silty sand, very moist to wet, brown, medium stiff										
4808	15		MC	7/12	-0.5	0.00	111.5	15.9				
		(Bedrock) CLAYSTONE, sandy, moist, brown, very hard										
4803	20		MC	50/7			119.6	14.6				
		(Bedrock) SHALE, very moist to wet, dark gray, very hard										
4798	25		SS	100/1				16.0				31.2
			SS	50/1				13.2				
		Bottom of hole at 29.1 feet.										

BORING : WC-2

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado
DATE STARTED 5/15/15 **COMPLETED** 5/15/15
GROUND ELEVATION 4814.0 ft **STATION NO.** 159+80
DRILLING CONTRACTOR Old Dirt Drilling
NORTH 601559.5 **EAST** 241719.2
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Median between WB & EB US50
LOGGED BY H. Ochoa **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES E side of Pueblo Blvd @ Williams Creek, South side of culvert
WATER DEPTH None Encountered on 5/15/15

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
4814	0		(Topsoil) CLAY, sandy with gravel, slightly moist, light brown, approximately 6" in thickness	BULK									
			(Fill) CLAY, sandy with gravel, slightly moist to moist, brown, stiff to very stiff										
			(Native) CLAY with sand to sandy, gravel in parts, slightly moist to moist, light brown, stiff to very stiff										
4809	5			MC	15/12			112.1	6.5				
4804	10			MC	13/12	0.7	0.14	115.9	13.8				
			(Native) GRAVEL, sandy, wet, light brown, medium dense to dense										
4799	15		(Bedrock) SHALE, moist, light brown, very hard	MC	50/4	0.8		132.6	11.4				
			(Bedrock) SHALE, slightly moist, dark gray, very hard										
4794	20			MC	50/1				7.3				

Bottom of hole at 20.1 feet.

Approximate Bulk Depth 0-5
Liquid Limit=
Plastic Limit=
Plasticity Index=
Fines Content= ERROR

APPENDIX B

LABORATORY TEST RESULT SUMMARY

RockSol Consulting Group, Inc.

SUMMARY OF PHYSICAL & CHEMICAL TEST RESULTS

CLIENT J.F. Sato

PROJECT NUMBER 302.02

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

Borehole	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	Swell Potential (%)	%<#200 Sieve	Classification		Water Content (%)	Dry Density (pcf)	Unconfined Compressive Strength (psi)	Sulfate (%)	Resistivity (ohm-cm)	pH	Chlorides (%)	Proctor S=Standard M=Modified		
							USCS	AASHTO								MDD	OMC	S/M
BR-1	4	30	18	12		44	SC	A-6 (2)	9.9	112.9		0.73						
BR-1	9				0.1				10.2	123.1								
BR-1	14								9.7	123.4								
BR-1	19	33	17	16		85	CL	A-6 (12)	10.7			0.77						
BR-2	4				1.6				12.7	126.4		0.70						
BR-2	9	27	18	9		60	CL	A-4 (3)	10.0	127.6								
BR-2	14	31	14	17		74	CL	A-6 (10)	11.6	114.9		0.26						
CBC-1	0-5	27	15	12		64	CL	A-6 (5)				0.03						
CBC-1	4								14.8	117.8								
CBC-1	9					17			7.9	131.1								
CBC-2	0-5	27	14	13		49	SC	A-6 (3)				0.77						
CBC-2	4								8.9	127.8								
CBC-2	9								7.9	134.4		0.10						
PV-1	0.91-5					34						0.03	1150 ohms-cm @ 19.5@	6.9	0.0111			
PV-1	0.92																	
PV-1	2				-0.1				15.7	108.7								
PV-1	4								17.0	111.1								
PV-1	9								16.8	113.4								
PV-2	0.83-5	37	13	24		34	SC	A-2-6 (3)				0.06	385 ohms-cm @ 19.5%	7.3	0.1455			
PV-2	2				0.0				18.0	108.3								
PV-2	4								17.9	106.2								
PV-3	0.83-5	30	14	16		52	CL	A-6 (5)				0.20	900 ohms-cm @ 19.3%	8.0	0.0081			
PV-3	2				0.1				18.4	104.9								
PV-3	4								17.0	106.7								
PV-3	9								12.1	118.3								
PV-4	0.91-5	27	14	13		49	SC	A-6 (3)				0.67	860 ohms-cm @ 20.5%	7.1	0.0179			
PV-4	2				0.0				20.5	102.6								
PV-4	4								18.0	105.8								
PV-4	9								21.1	105.3								
PV-5	0.875-5	22	14	8		36	SC	A-4 (0)				0.62	920 ohms-cm @ 17.9%	7.5	0.0132			

RockSol Consulting Group, Inc.

CLIENT J.F. Sato

PROJECT NUMBER 302.02

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

Borehole	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	Swell Potential (%)	%<#200 Sieve	Classification		Water Content (%)	Dry Density (pcf)	Unconfined Compressive Strength (psi)	Sulfate (%)	Resistivity (ohm-cm)	pH	Chlorides (%)	Proctor S=Standard M=Modified		
							USCS	AASHTO								MDD	OMC	S/M
PV-5	2				0.9				12.5	122.7								
PV-5	4								14.5	110.3								
PV-5	9								10.5	123.2								
PV-6	0-5	20	15	5		25	SC-SM	A-2-4 (0)				0.18	1800 ohms-cm @ 16.8%	7.6	0.0012			
PV-6	2				-1.0				4.8	123.1								
PV-6	4								5.2	128.7								
PV-6	9								12.1	115.8								
PV-7	0-5	32	14	18		79	CL	A-6 (12)				0.14	880 ohms-cm@25.7%	7.8	0.0029			
PV-7	2				7.5				9.9	124.0								
PV-7	4								9.6	129.8								
PV-7	9								9.1	130.1								
PV-8	0-5	28	16	12		60	CL	A-6 (4)				0.08	610 ohms-cm @ 21.6%	7.3	0.0462			
PV-8	2				0.8				5.9	99.7								
PV-8	4								6.6	112.9								
PV-8	9								8.4	128.9								
PV-9	0-5	23	17	6		43	SC-SM	A-4 (0)				0.02	1300 ohms-cm @ 18.6%	8.0	0.0044			
PV-9	2				1.2				3.9	99.6								
PV-9	4								3.9	103.7								
PV-9	9								6.2	107.4								
PV-10	0.5-5	33	15	18		51	CL	A-6 (6)				1.72	770 ohms-cm @ 22.5%	8.0	0.0130			
PV-10	2				0.0				16.3	114.1								
PV-10	4								19.2	105.0								
PV-10	9								17.1	113.6								
PV-11	0.7-5	26	13	13		35	SC	A-2-6 (1)				0.56	890 ohms-cm @ 19.8%	7.3	0.0226			
PV-11	2				0.8				16.1	112.9								
PV-11	4				0.1				20.5	104.6								
PV-12	0-5	23	14	9		31	SC	A-2-4 (0)				0.38	1200 ohms-cm @ 16.0%	6.7	0.0023			
PV-12	2								2.5	113.8								
PV-12	4								2.9	113.8								
PV-12	9								3.0	115.5								

RockSol Consulting Group, Inc.

CLIENT J.F. Sato

PROJECT NUMBER 302.02

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

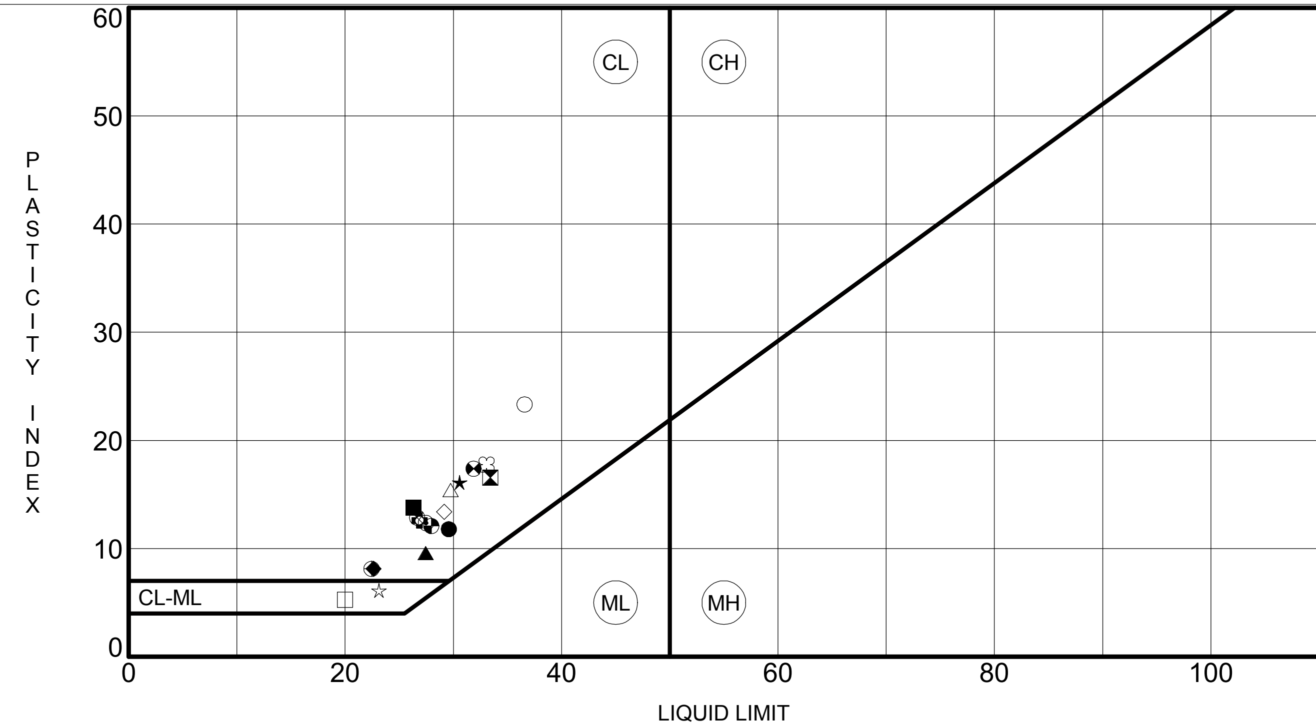
Borehole	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	Swell Potential (%)	%<#200 Sieve	Classification		Water Content (%)	Dry Density (pcf)	Unconfined Compressive Strength (psi)	Sulfate (%)	Resistivity (ohm-cm)	pH	Chlorides (%)	Proctor S=Standard M=Modified		
							USCS	AASHTO								MDD	OMC	S/M
WC-1	4								10.1	127.9								
WC-1	9	29	16	13		43	SC	A-6 (2)	11.9	121.2								
WC-1	14				-0.5				15.9	111.5		0.00						
WC-1	19								14.6	119.6								
WC-1	24					31			16.0									
WC-1	29								13.2									
WC-2	-5																	
WC-2	4								6.5	112.1								
WC-2	9				0.7				13.8	115.9		0.14						
WC-2	14				0.8				11.4	132.6								
WC-2	19								7.3									

ATTERBERG LIMITS RESULTS
ASTM D4318 Method A

RockSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



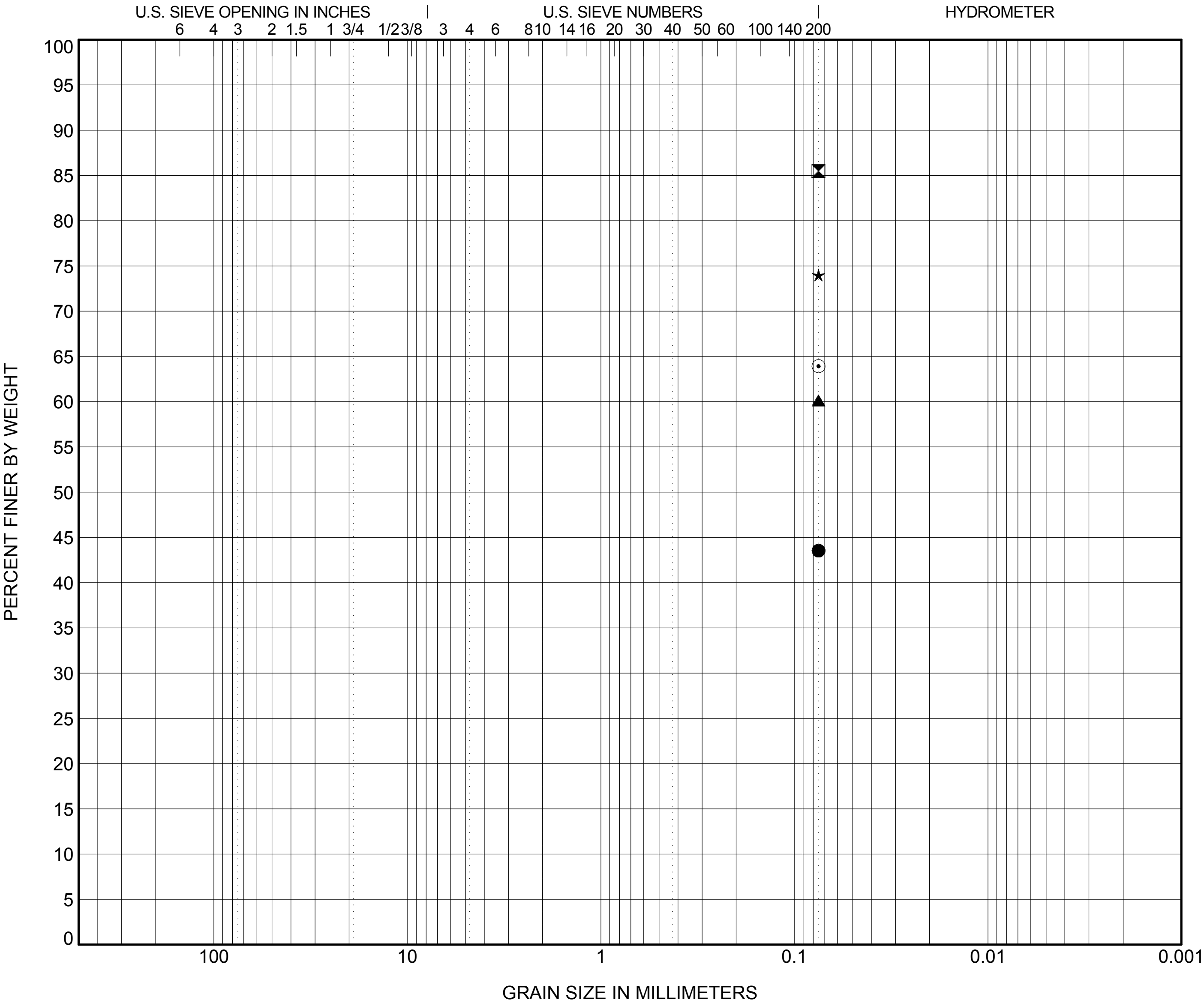
	Specimen Identification		LL	PL	PI	Fines	Classification
●	BR-1	4.0	30	18	12	43.5	(Bedrock) SANDSTONE, clayey (SC) (A-6)
⧗	BR-1	19.0	33	17	16	85.5	(Bedrock) CLAYSTONE, sandy (CL) (A-6)
▲	BR-2	9.0	27	18	9	60.1	(Bedrock) SANDY CLAYSTONE (CL) (A-4)
★	BR-2	14.0	31	14	17	74.0	(Bedrock) CLAYSTONE with SAND (CL) (A-6)
⊙	CBC-1	0.0-5.0	27	15	12	63.9	SANDY LEAN CLAY (CL) (A-6)
✿	CBC-2	0.0-5.0	27	14	13	49.4	CLAYEY SAND (SC) (A-6)
○	PV-2	0.8-5.0	37	13	24	33.6	CLAYEY SAND with GRAVEL (SC) (A-2-6)
△	PV-3	0.8-5.0	30	14	16	51.7	SANDY LEAN CLAY (CL) (A-6)
⊗	PV-4	0.9-5.0	27	14	13	49.5	CLAYEY SAND (SC) (A-6)
⊕	PV-5	0.9-5.0	22	14	8	36.1	CLAYEY SAND with GRAVEL (SC) (A-4)
□	PV-6	0.0-5.0	20	15	5	24.6	SILTY, CLAYEY SAND (SC-SM) (A-2-4)
◍	PV-7	0.0-5.0	32	14	18	79.0	LEAN CLAY with SAND (CL) (A-6)
◕	PV-8	0.0-5.0	28	16	12	60.1	SANDY LEAN CLAY (CL) (A-6)
☆	PV-9	0.0-5.0	23	17	6	43.3	SILTY, CLAYEY SAND (SC-SM) (A-4)
✤	PV-10	0.5-5.0	33	15	18	51.1	SANDY LEAN CLAY (CL) (A-6)
■	PV-11	0.7-5.0	26	13	13	34.7	CLAYEY SAND with GRAVEL (SC) (A-2-6)
◆	PV-12	0.0-5.0	23	14	9	31.0	CLAYEY SAND with GRAVEL (SC) (A-2-4)
◇	WC-1	9.0	29	16	13	43.4	CLAYEY SAND (SC) (A-6)

ATTERBERG LIMITS - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

GRAIN SIZE DISTRIBUTION

RockSol Consulting

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

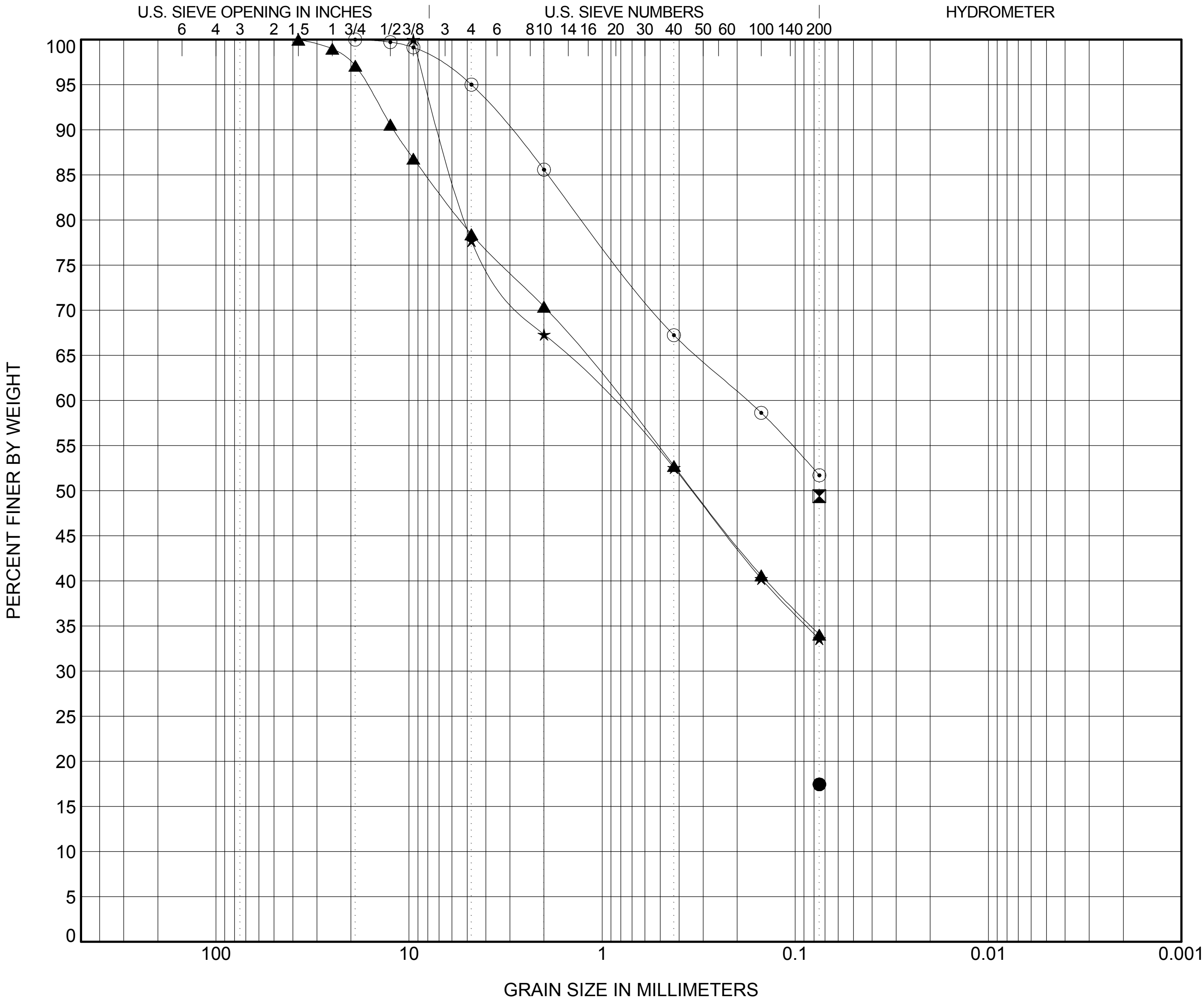
Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● BR-1	4.0	**(Bedrock) SANDSTONE, clayey (SC) (A-6)**	30	18	12		
⧗ BR-1	19.0	**(Bedrock) CLAYSTONE, sandy (CL) (A-6)**	33	17	16		
▲ BR-2	9.0	**(Bedrock) SANDY CLAYSTONE (CL) (A-4)**	27	18	9		
★ BR-2	14.0	**(Bedrock) CLAYSTONE with SAND (CL) (A-6)**	31	14	17		
⊙ CBC-1	0.0-5.0	**SANDY LEAN CLAY (CL) (A-6)**	27	15	12		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BR-1	4.0	0.075						43.5	
⧗ BR-1	19.0	0.075						85.5	
▲ BR-2	9.0	0.075						60.1	
★ BR-2	14.0	0.075						74.0	
⊙ CBC-1	0.0-5.0	0.075						63.9	

GRAIN SIZE DISTRIBUTION

RockSol Consulting

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

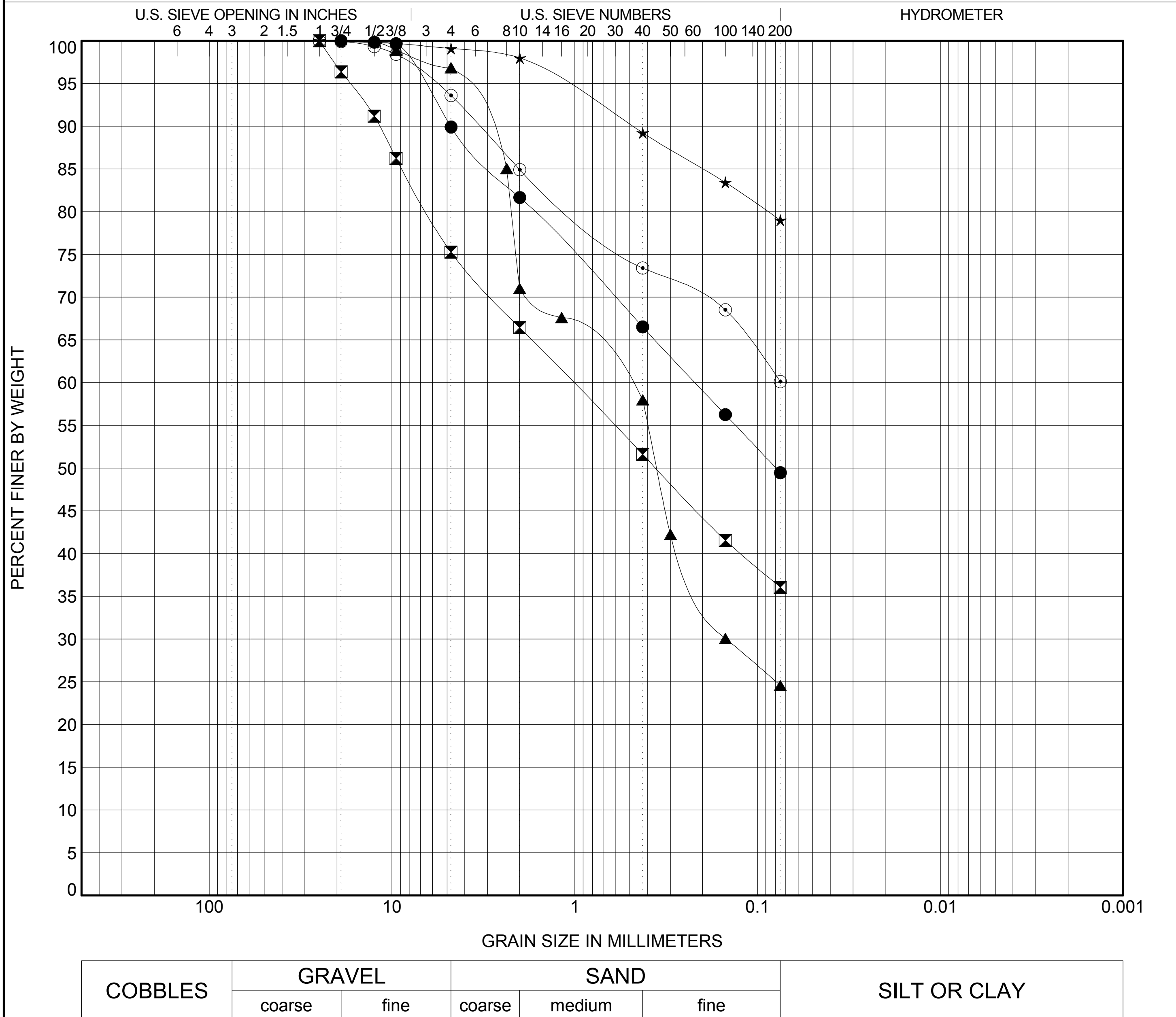
Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● CBC-1	9.0	**(Fill) CLAY-Reworked Shale**					
⧗ CBC-2	0.0-5.0	**CLAYEY SAND (SC) (A-6)**	27	14	13		
▲ PV-1	0.9-5.0	**SAND, clayey**					
★ PV-2	0.8-5.0	**CLAYEY SAND with GRAVEL (SC) (A-2-6)**	37	13	24		
⊙ PV-3	0.8-5.0	**SANDY LEAN CLAY (CL) (A-6)**	30	14	16		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● CBC-1	9.0	0.075						17.4	
⧗ CBC-2	0.0-5.0	0.075						49.4	
▲ PV-1	0.9-5.0	37.5	0.803			21.6	44.4	34.1	
★ PV-2	0.8-5.0	9.5	0.929			22.3	44.1	33.6	
⊙ PV-3	0.8-5.0	19	0.177			5.0	43.3	51.7	

GRAIN SIZE DISTRIBUTION

RockSol Consulting

CLIENT	J.F. Sato	**PROJECT NAME**	US 50 West, WB Preliminary Design
PROJECT NUMBER	302.02	**PROJECT LOCATION**	Wills Blvd. to Purcell Blvd., Pueblo, Colorado



Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● **PV-4**	**0.9-5.0**	**CLAYEY SAND (SC) (A-6)**	**27**	**14**	**13**		
⧗ **PV-5**	**0.9-5.0**	**CLAYEY SAND with GRAVEL (SC) (A-4)**	**22**	**14**	**8**		
▲ **PV-6**	**0.0-5.0**	**SILTY, CLAYEY SAND (SC-SM) (A-2-4)**	**20**	**15**	**5**		
★ **PV-7**	**0.0-5.0**	**LEAN CLAY with SAND (CL) (A-6)**	**32**	**14**	**18**		
⊙ **PV-8**	**0.0-5.0**	**SANDY LEAN CLAY (CL) (A-6)**	**28**	**16**	**12**		

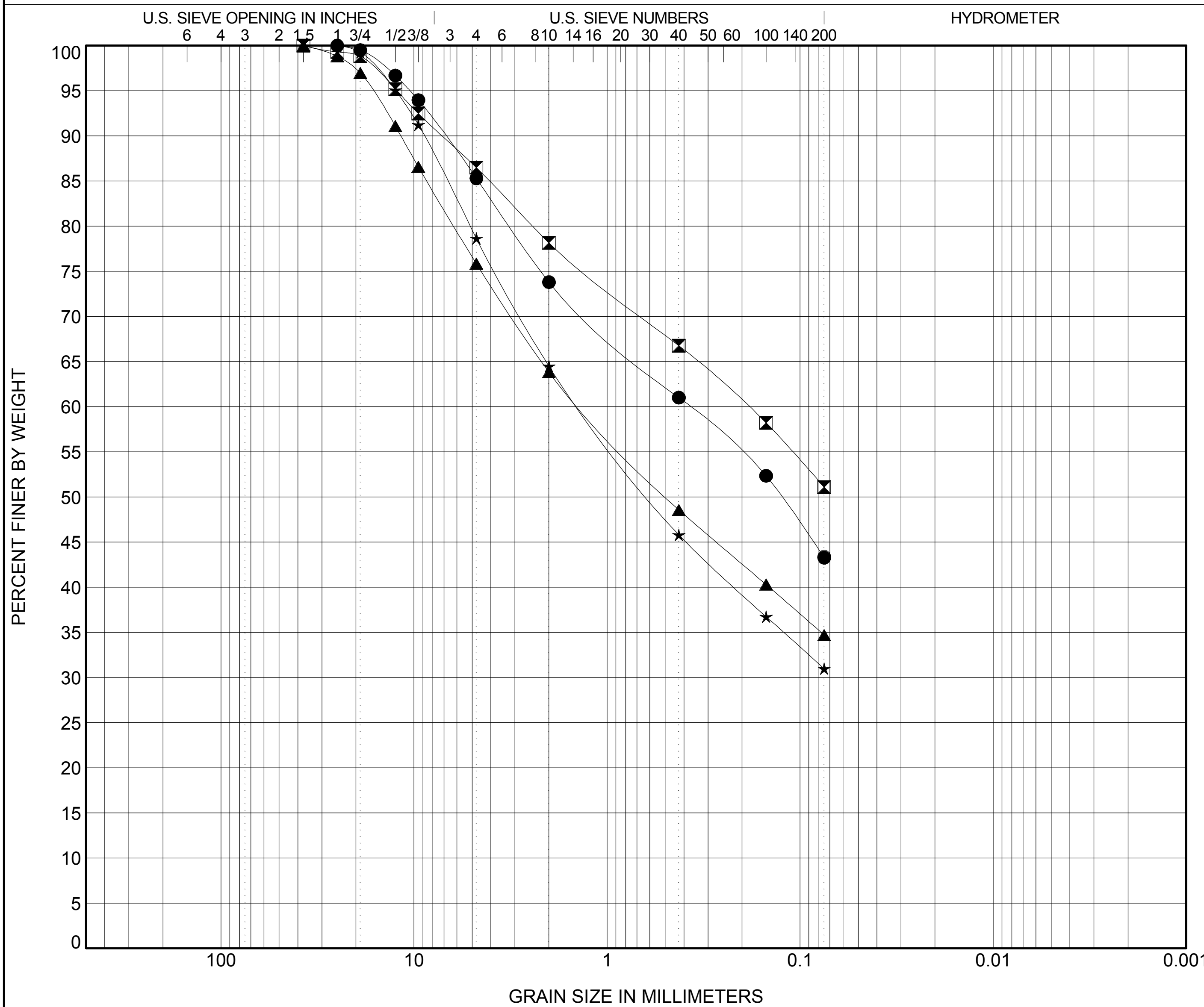
Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **PV-4**	**0.9-5.0**	**19**	**0.219**			**10.1**	**40.4**	**49.5**	
⧗ **PV-5**	**0.9-5.0**	**25**	**1.022**			**24.7**	**39.2**	**36.1**	
▲ **PV-6**	**0.0-5.0**	**12.5**	**0.526**	**0.149**		**3.2**	**72.3**	**24.6**	
★ **PV-7**	**0.0-5.0**	**25**				**0.9**	**20.1**	**79.0**	
⊙ **PV-8**	**0.0-5.0**	**25**				**6.4**	**33.5**	**60.1**	

GRAIN SIZE DISTRIBUTION

RockSol Consulting

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● PV-9	0.0-5.0	**SILTY, CLAYEY SAND (SC-SM) (A-4)**	23	17	6		
⧗ PV-10	0.5-5.0	**SANDY LEAN CLAY (CL) (A-6)**	33	15	18		
▲ PV-11	0.7-5.0	**CLAYEY SAND with GRAVEL (SC) (A-2-6)**	26	13	13		
★ PV-12	0.0-5.0	**CLAYEY SAND with GRAVEL (SC) (A-2-4)**	23	14	9		
⊙ WC-1	9.0	**CLAYEY SAND (SC) (A-6)**	29	16	13		

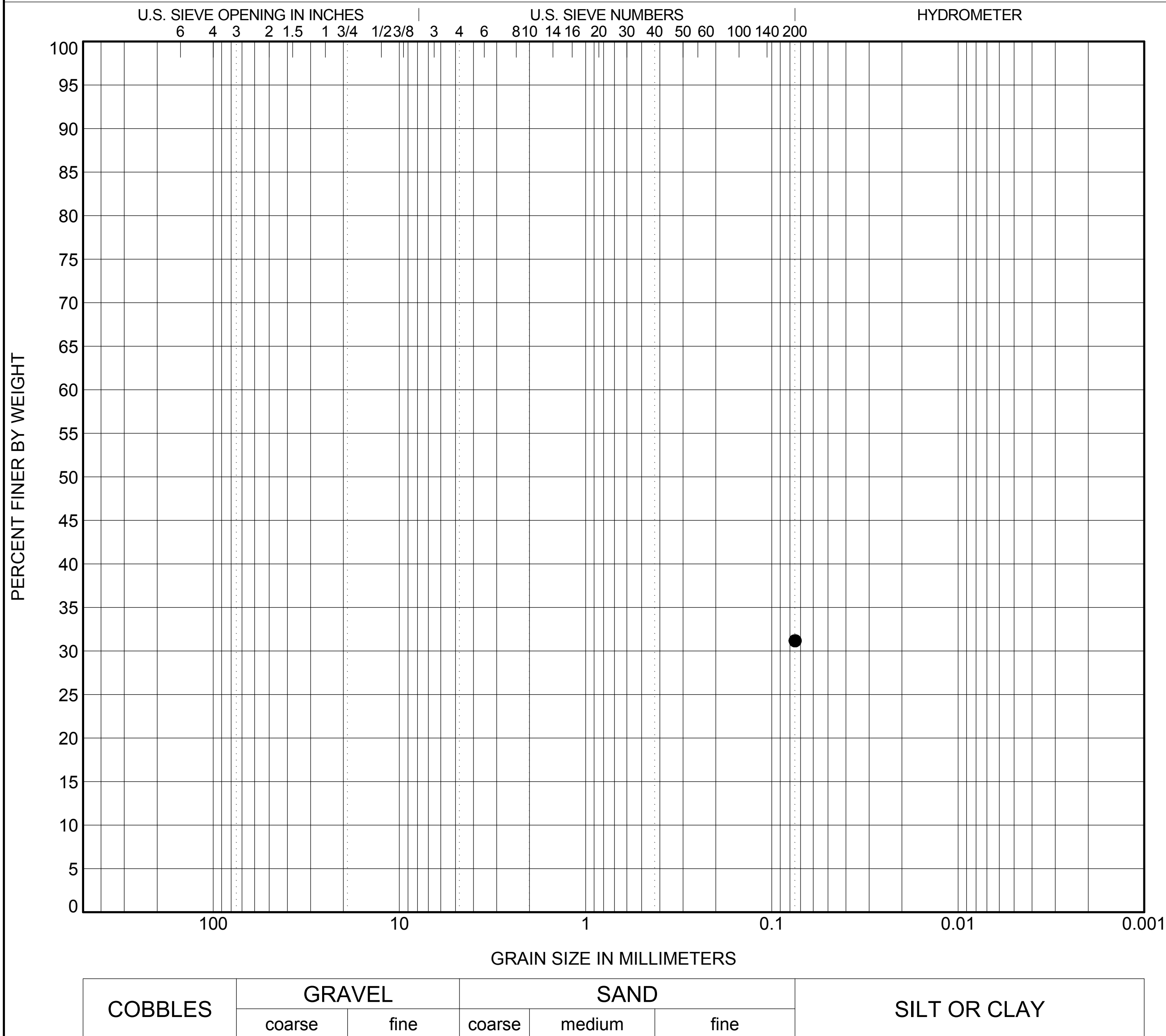
Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● PV-9	0.0-5.0	25	0.377			14.7	42.0	43.3	
⧗ PV-10	0.5-5.0	37.5	0.186			13.5	35.4	51.1	
▲ PV-11	0.7-5.0	37.5	1.358			24.2	41.1	34.7	
★ PV-12	0.0-5.0	25	1.379			21.4	47.7	31.0	
⊙ WC-1	9.0	0.075						43.4	

GRAIN SIZE DISTRIBUTION

RockSol Consulting

CLIENT J.F. Sato | **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 | **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● **WC-1**	**24.0**	**(Bedrock) SHALE**					

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **WC-1**	**24.0**	**0.075**						**31.2**	

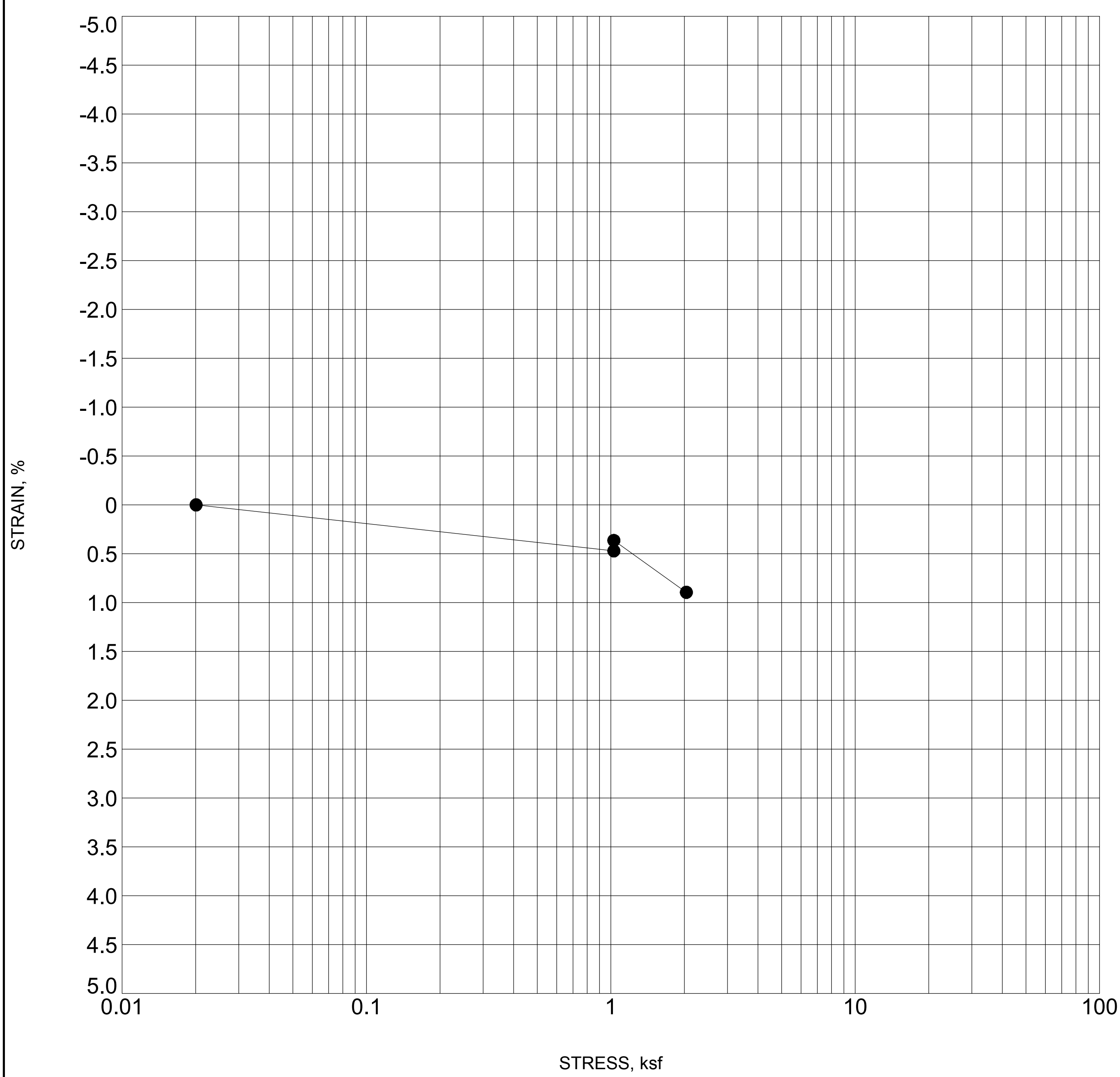
GRADATION - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

SWELL - CONSOLIDATION TEST

RocksSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



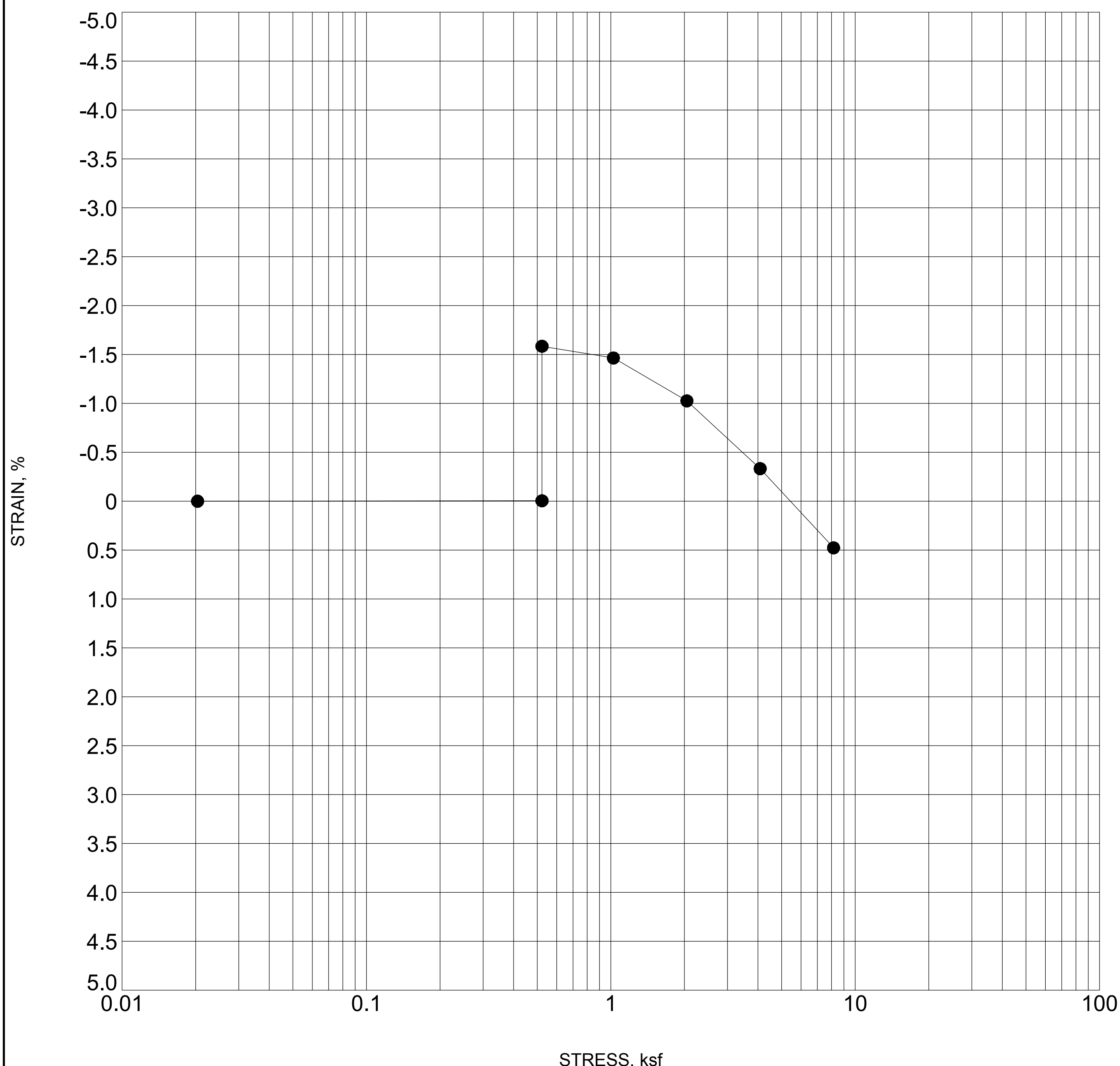
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **BR-1**	**9**	**(Bedrock) SANDSTONE, clayey**	**0.1**	**123.1**	**10.2**

SWELL - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



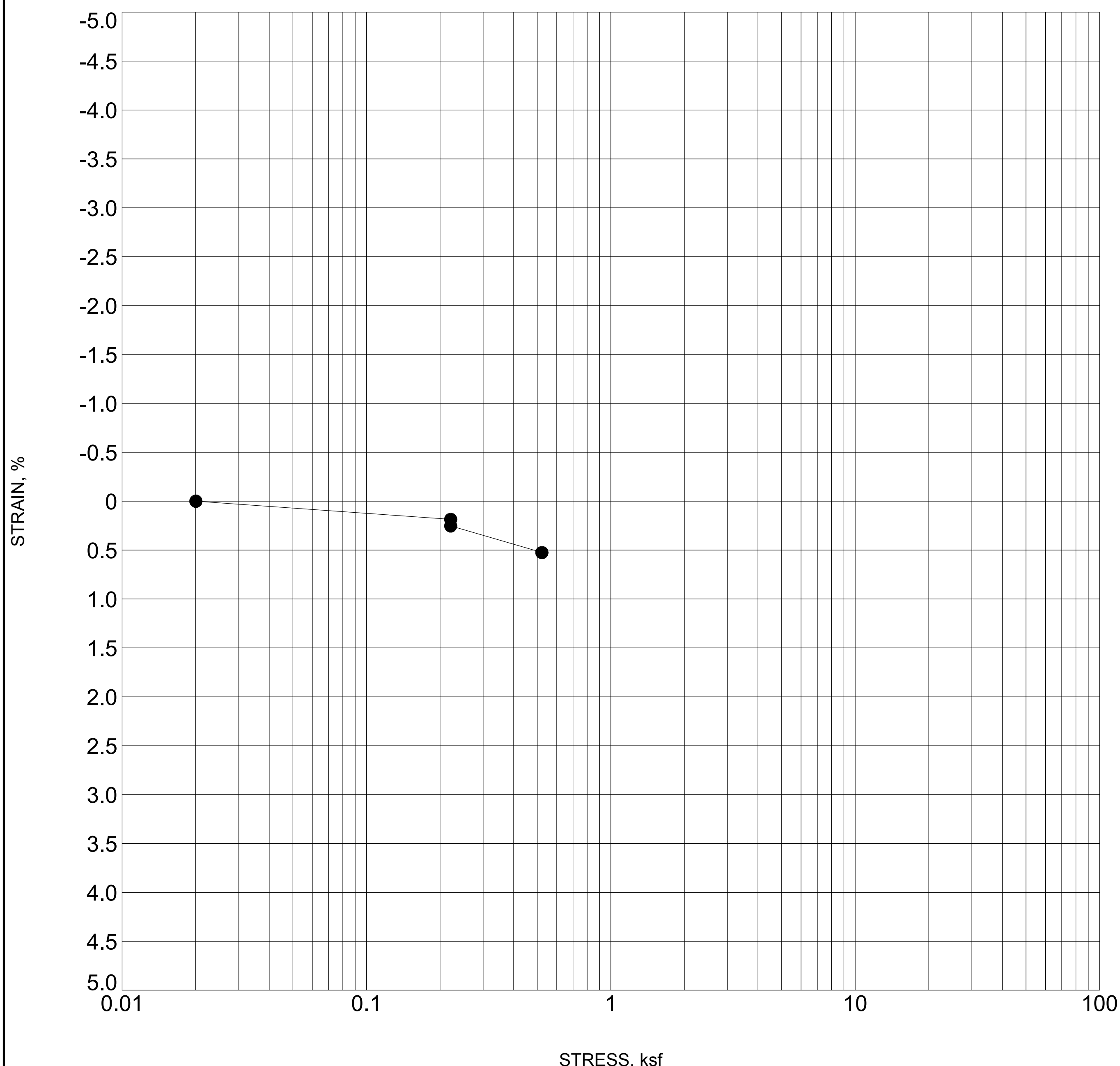
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● BR-2	4	(Bedrock) CLAYSTONE, sandy	1.6	126.4	12.7

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato | **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 | **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado

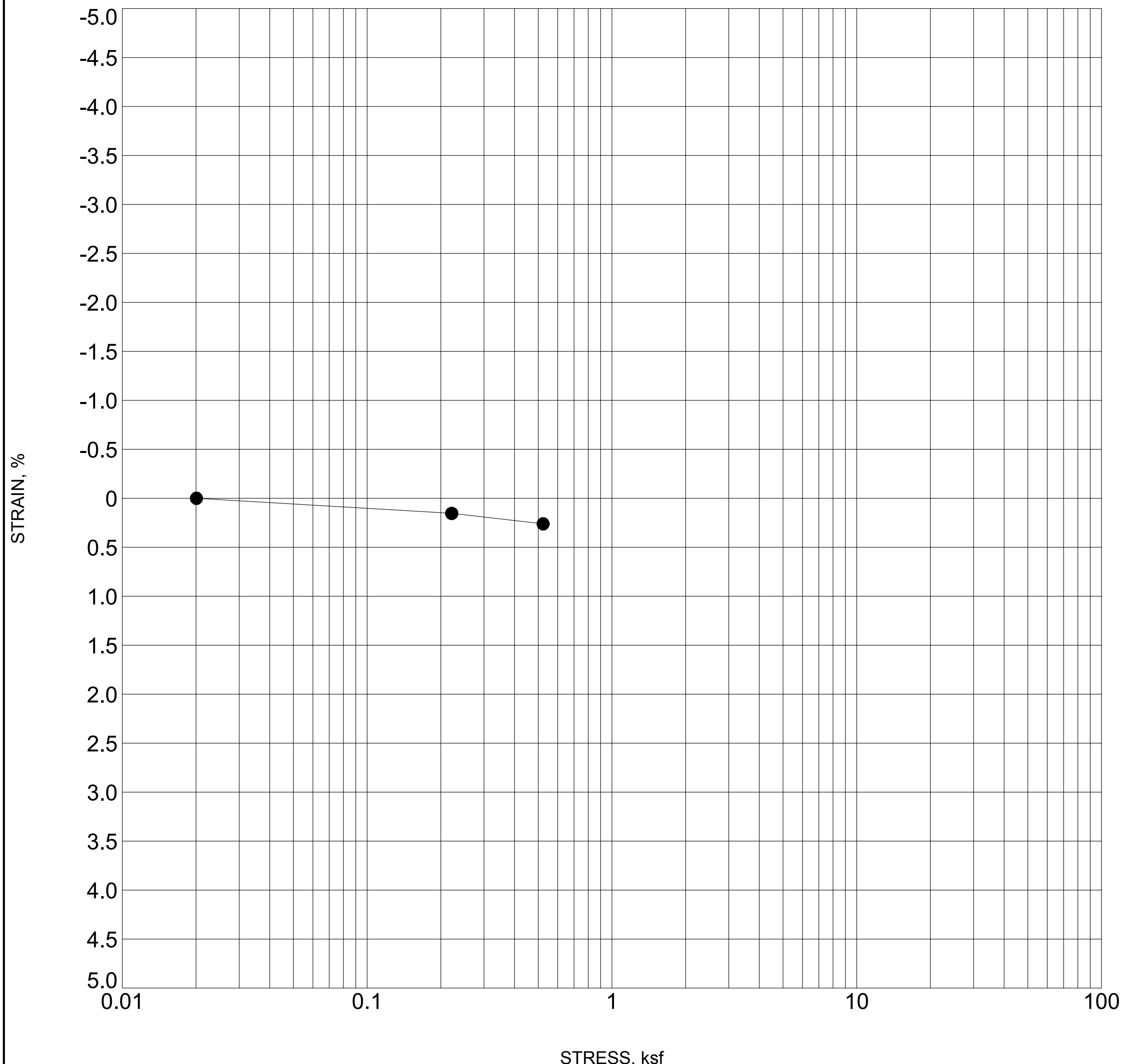


Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● PV-1	2	SAND, clayey	-0.1	108.7	15.7

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



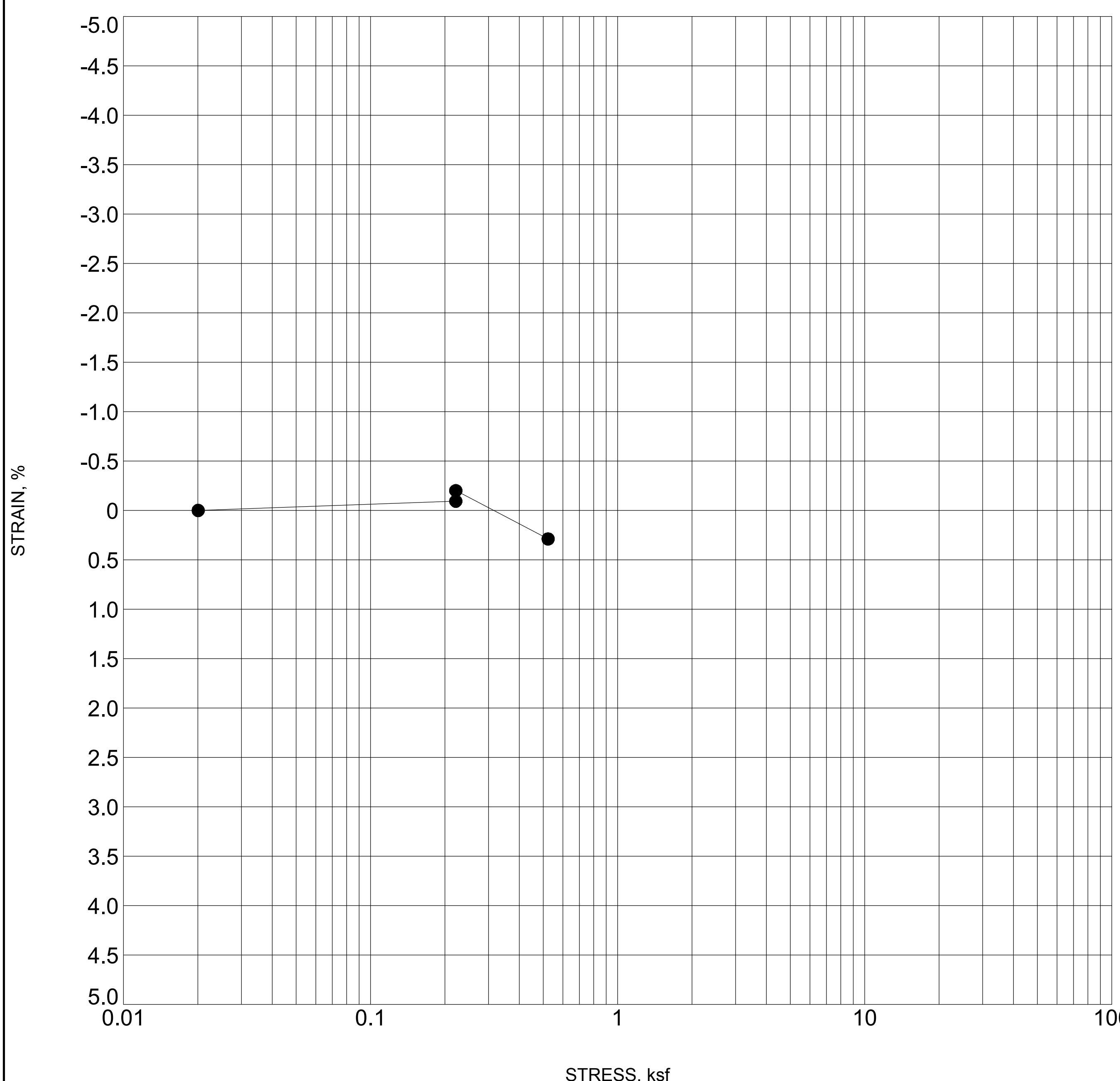
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-2**	**2**	**(Fill) SAND, clayey**	**0.0**	**108.3**	**18.0**

SWELL - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

RocksSol Consulting Group, Inc.

SWELL - CONSOLIDATION TEST

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



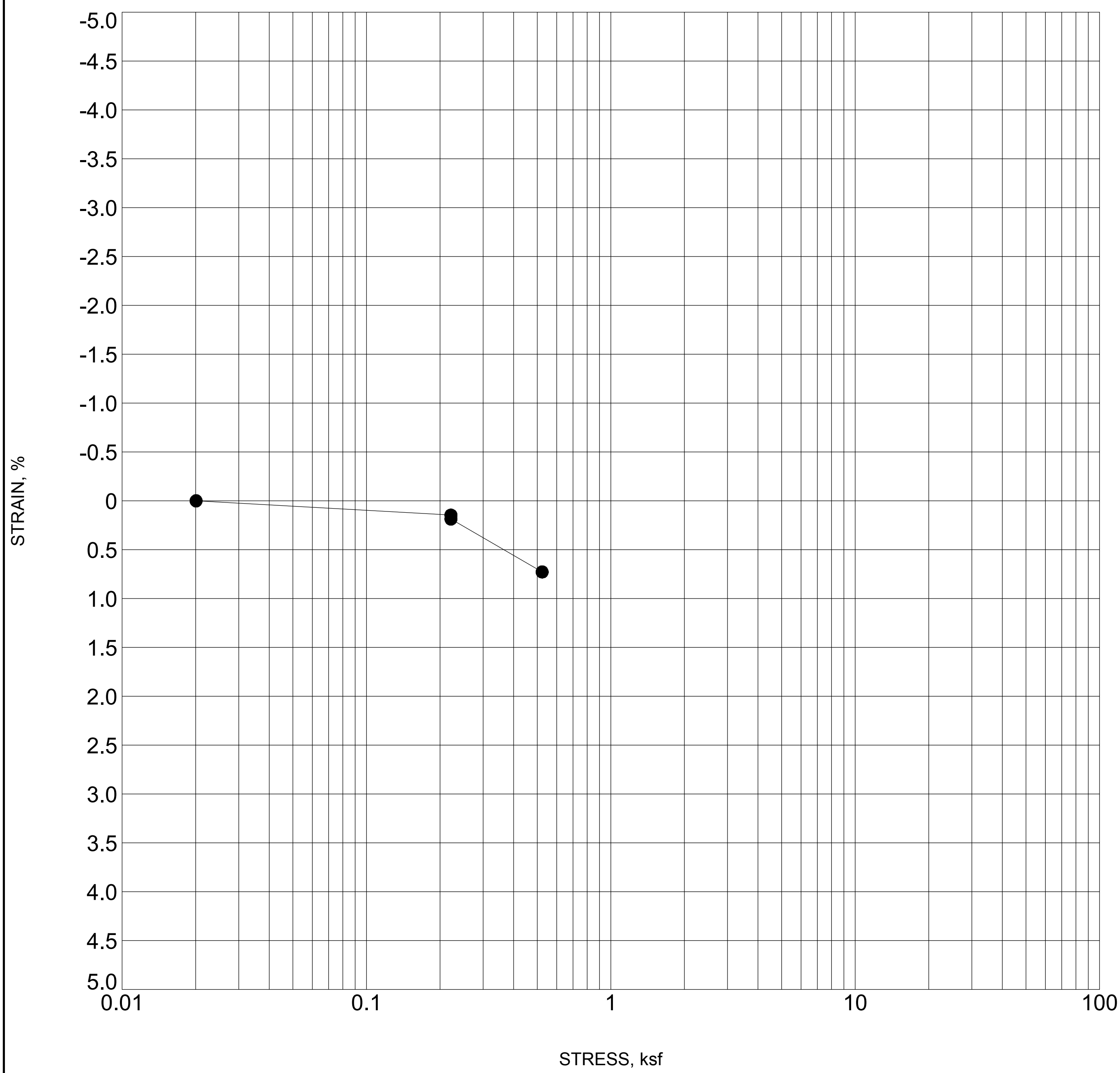
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-3**	**2**	**(Native) CLAY, sandy**	**0.1**	**104.9**	**18.4**

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato | **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 | **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-4**	**2**	**(Fill) SAND, clayey**	**0.0**	**102.6**	**20.5**

SWELL - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

SWELL - CONSOLIDATION TEST

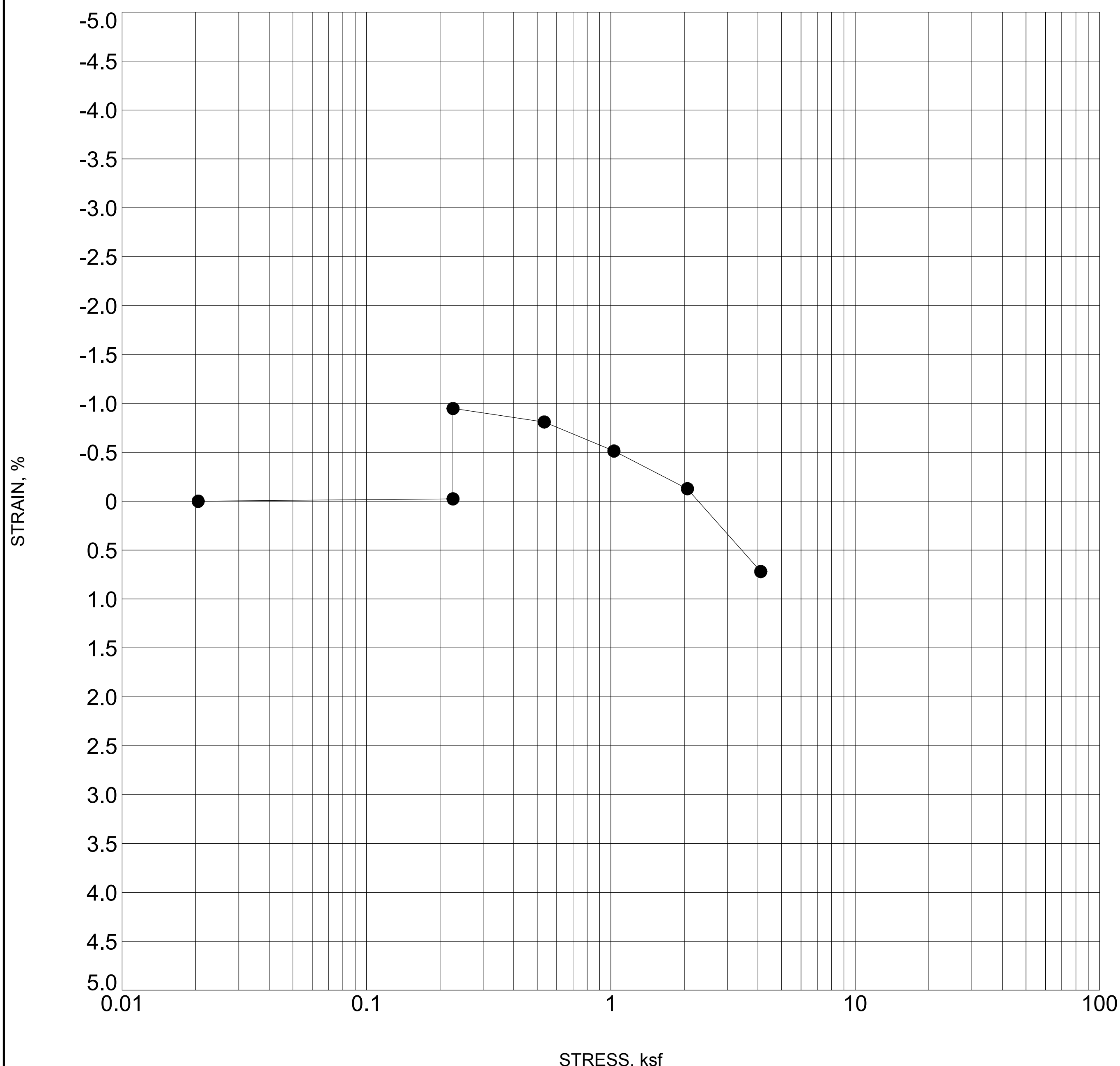
RockSol Consulting Group, Inc.

CLIENT J.F. Sato

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



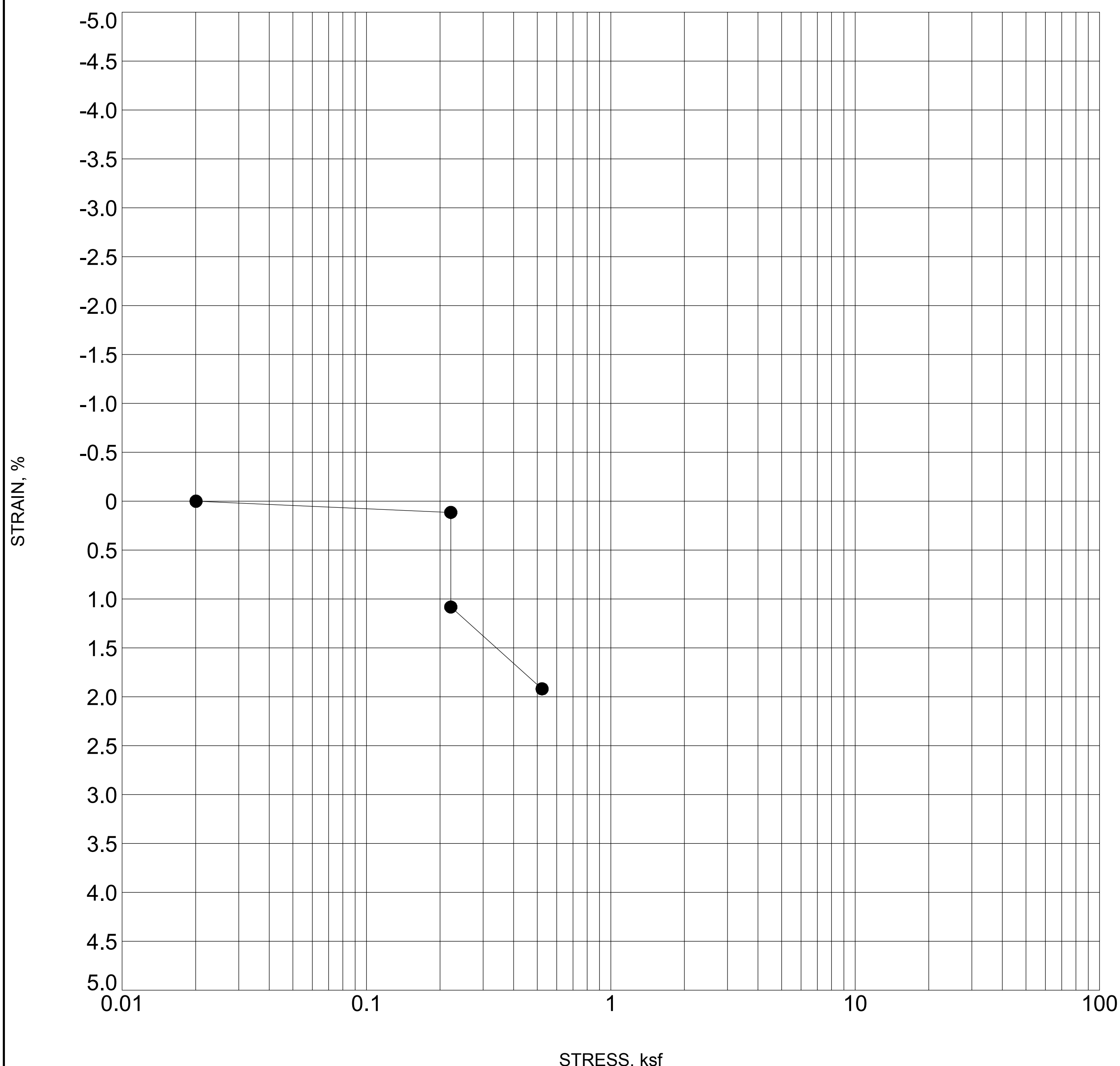
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-5**	**2**	**(Fill) SAND, clayey with gravel**	**0.9**	**122.7**	**12.5**

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-6**	**2**	**(Fill) SAND, silty to clayey with gravel**	**-1.0**	**123.1**	**4.8**

RockSol Consulting Group, Inc.

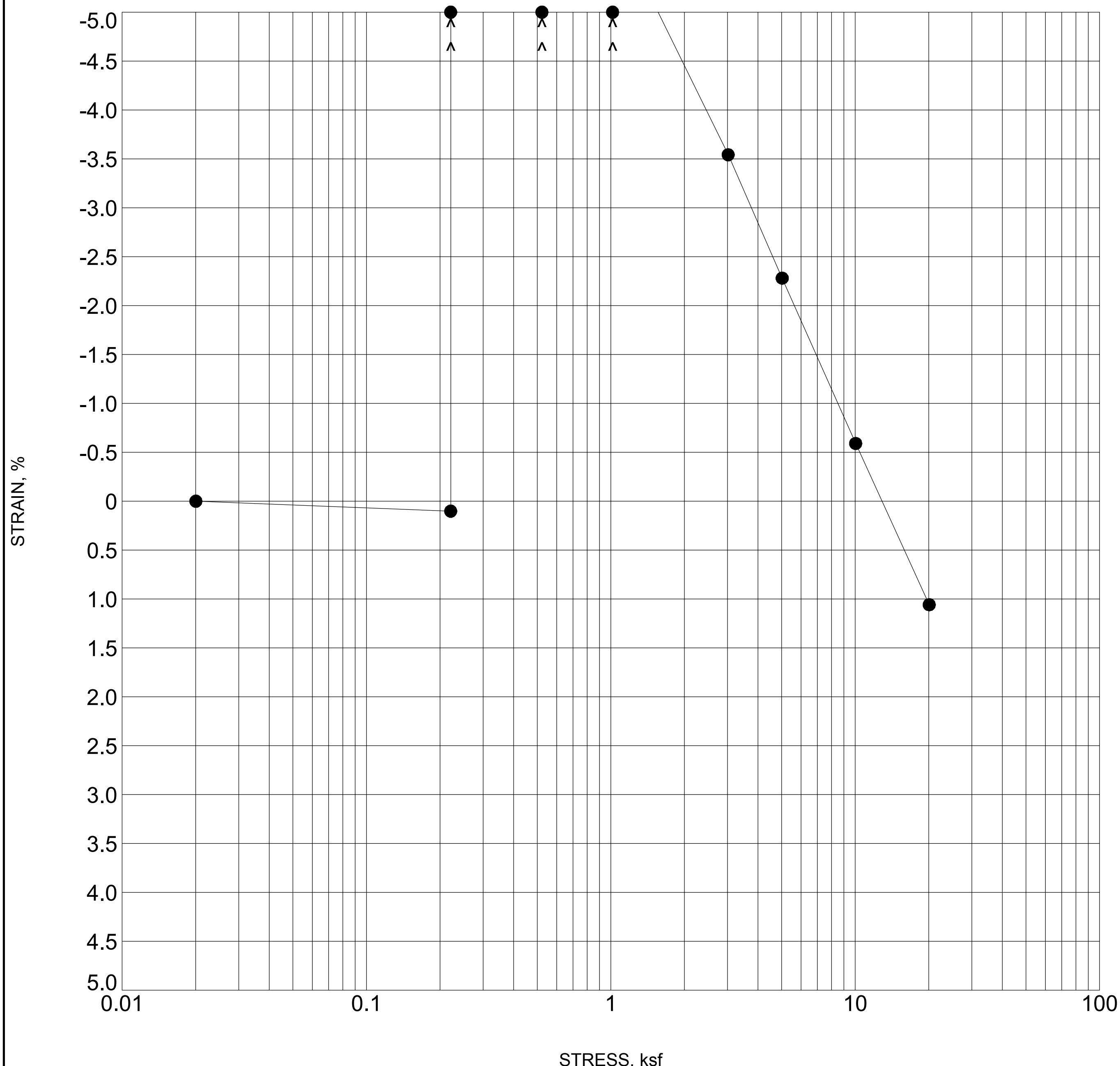
SWELL - CONSOLIDATION TEST

CLIENT J.F. Sato

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



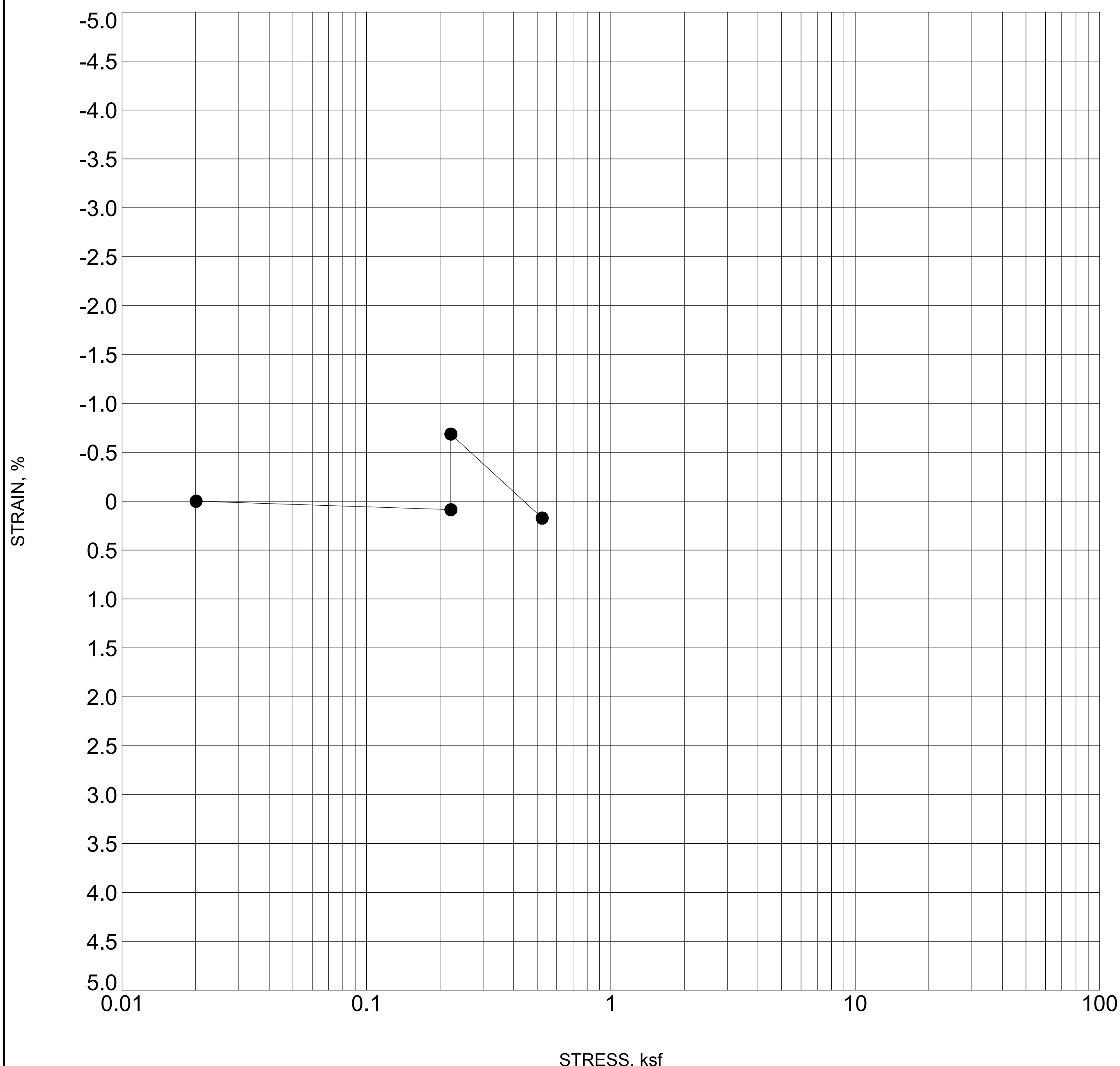
Specimen Identification	Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-7** **2**	**CLAY**	**7.5**	**124.0**	**9.9**

SWELL - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

RockSol Consulting Group, Inc.

SWELL - CONSOLIDATION TEST

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● PV-8	2	CLAY, sandy	0.8	99.7	5.9

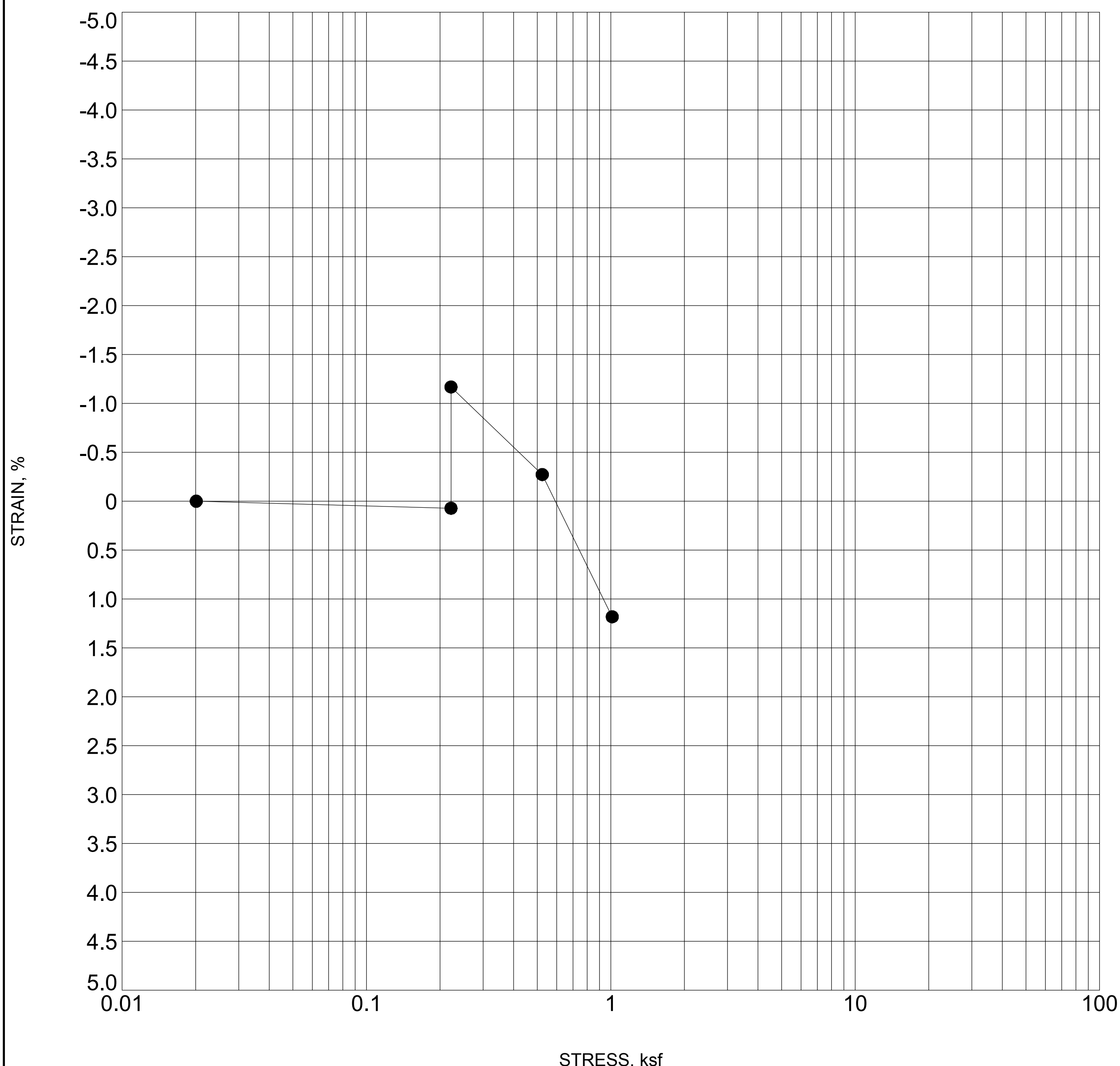
SWELL - STANDARD 302.02 US 50 WEST.GPJ ROCKSOL TEMPLATE.GDT 7/28/15

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



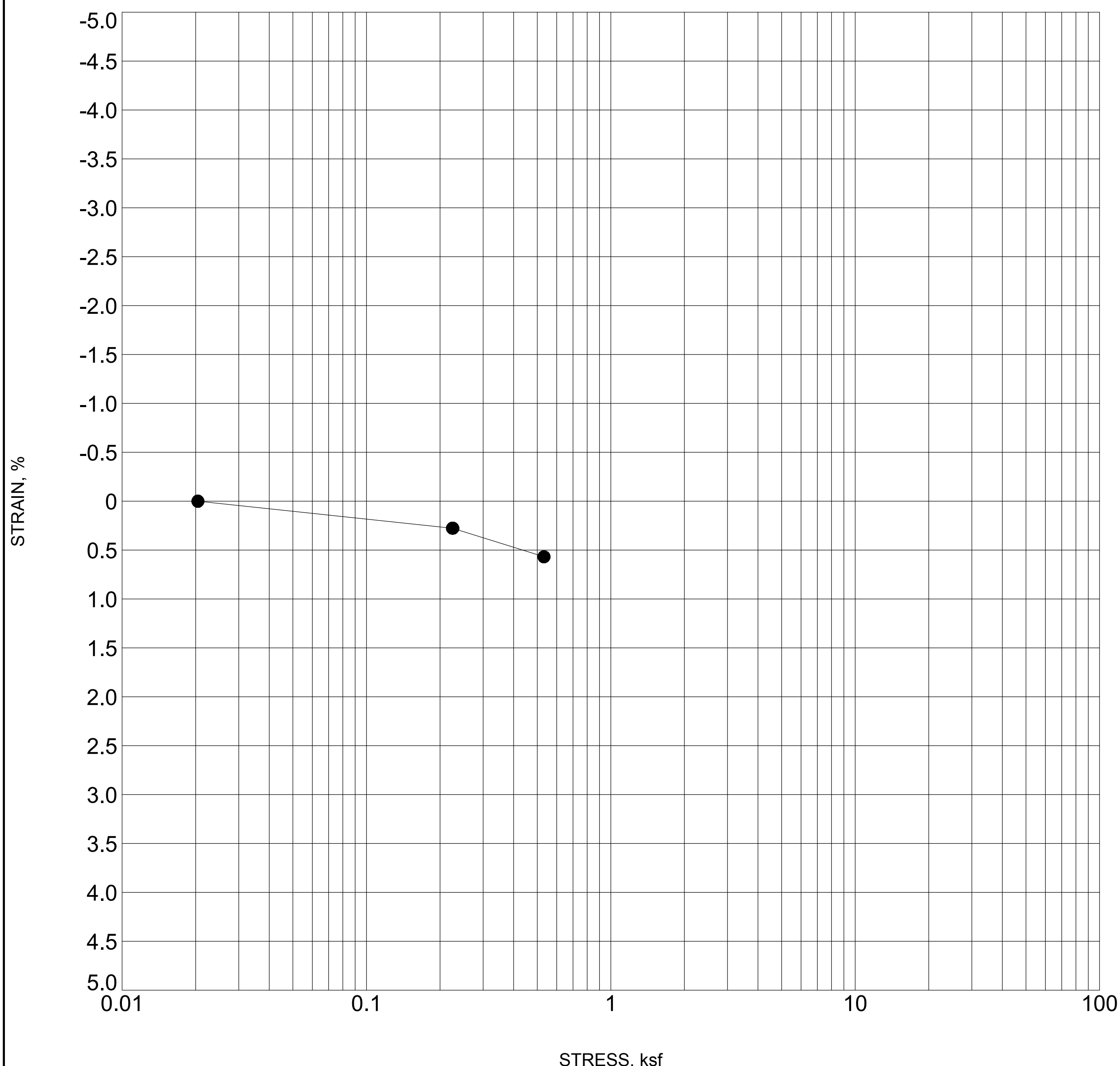
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-9**	**2**	**SAND, silty to clayey**	**1.2**	**99.6**	**3.9**

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato | **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 | **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



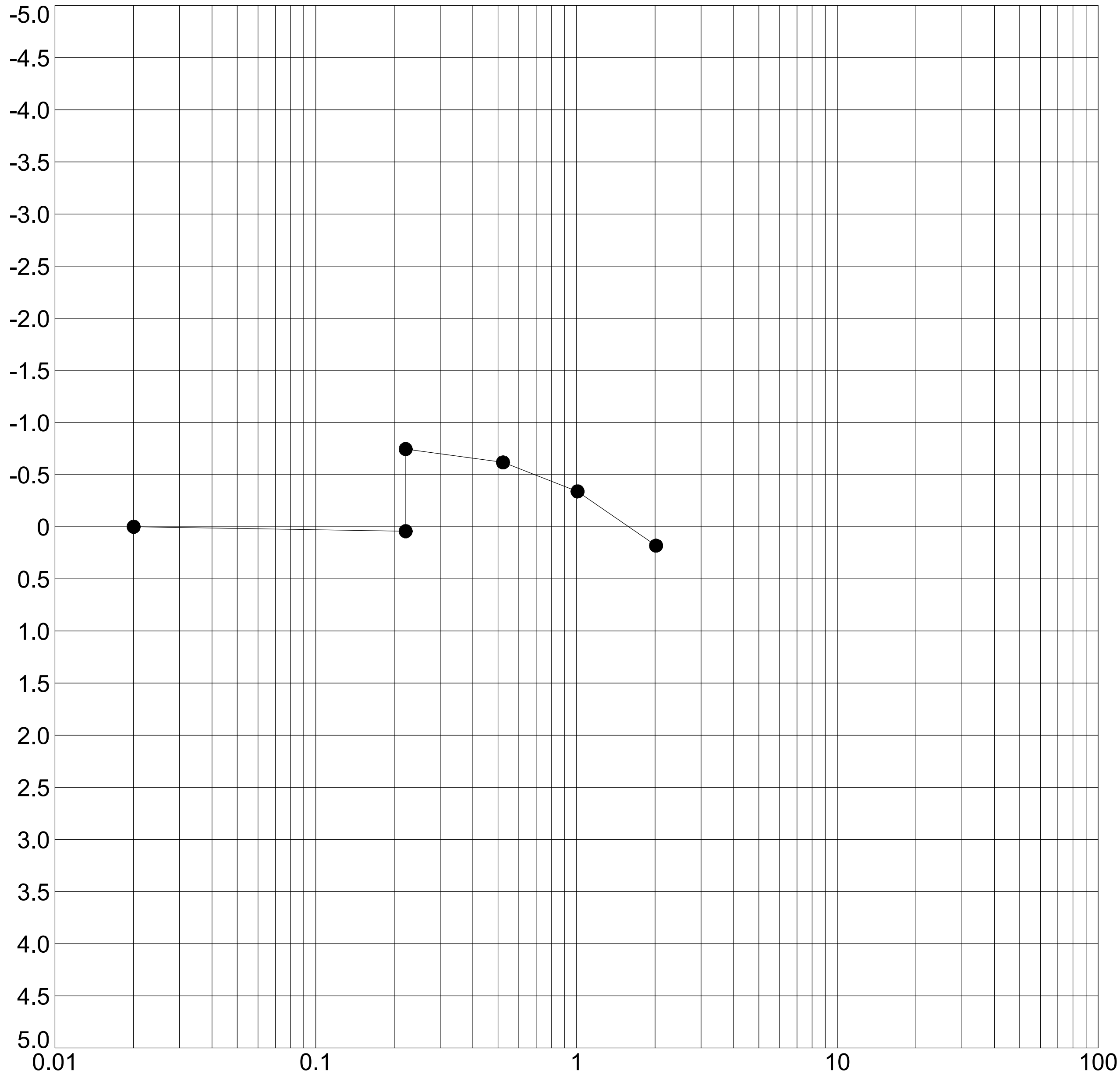
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● PV-10	2	(Native) CLAY, sandy	0.0	114.1	16.3

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



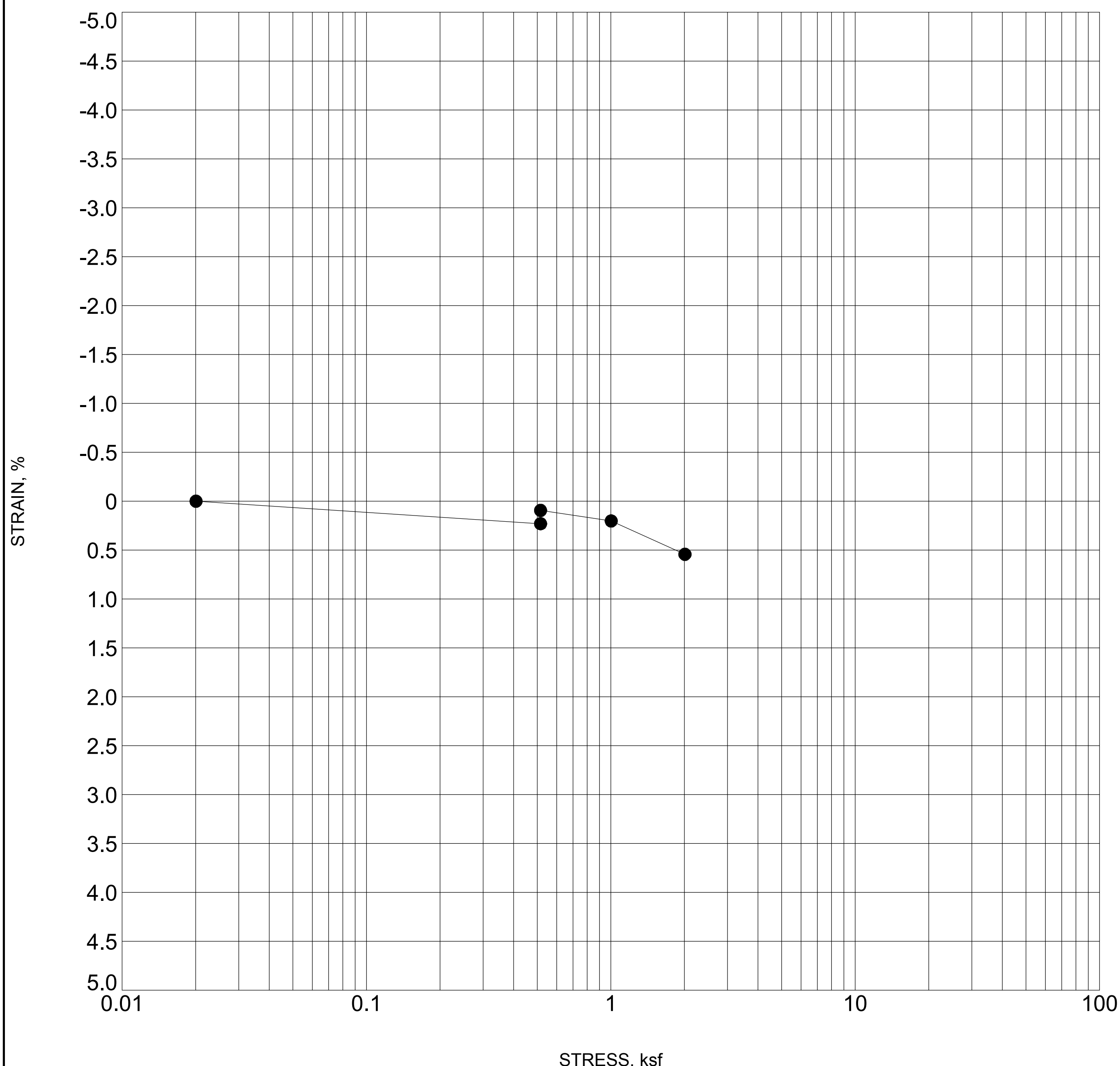
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● PV-11	2	**SANDY CLAY**	**0.8**	**112.9**	**16.1**

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **PV-11**	**4**	**SANDY CLAY**	**0.1**	**104.6**	**20.5**

SWELL - CONSOLIDATION TEST

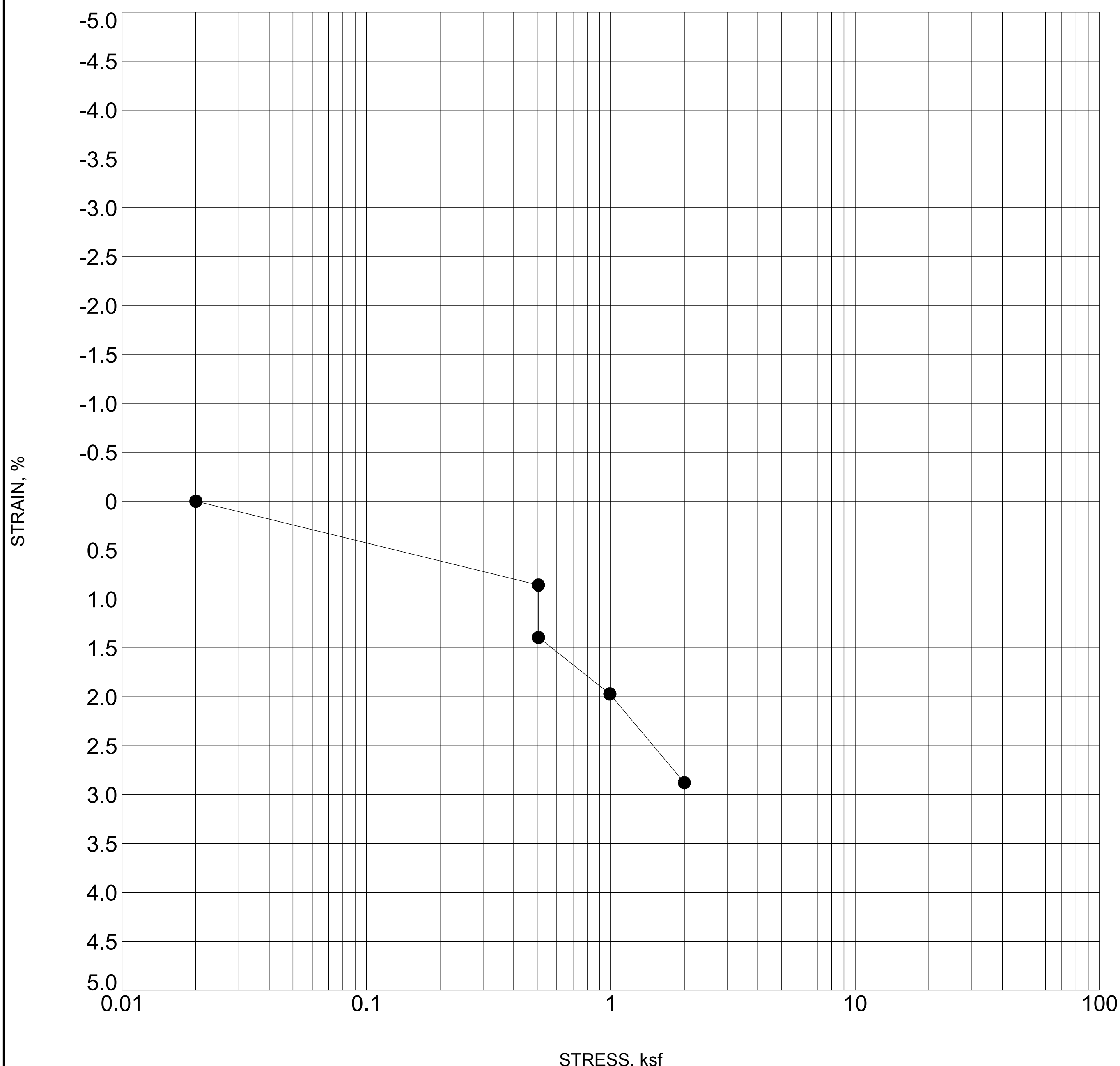
RockSol Consulting Group, Inc.

CLIENT J.F. Sato

PROJECT NAME US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02

PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado



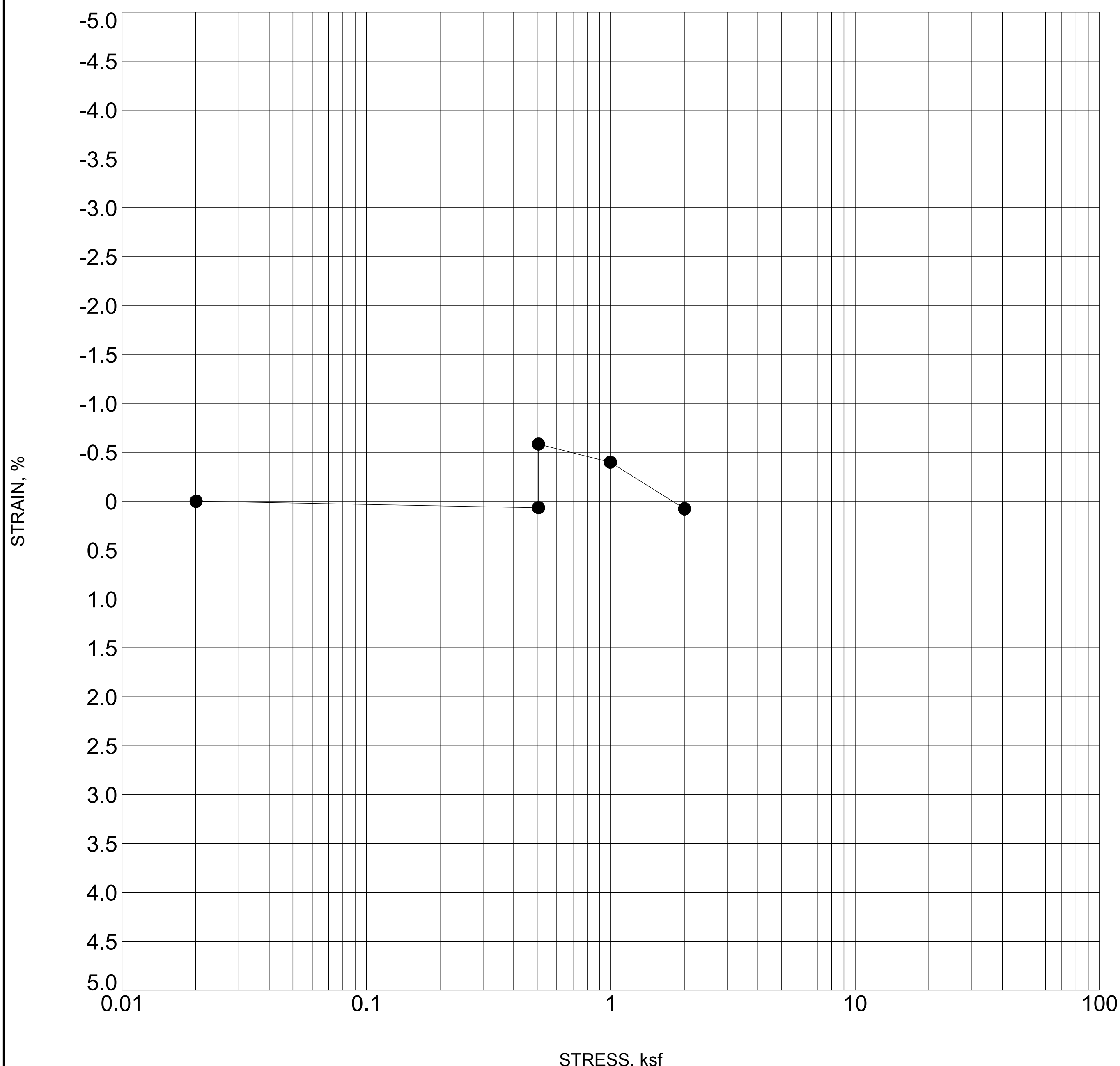
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **WC-1**	**14**	**(Native) CLAY, sandy with gravel**	**-0.5**	**111.5**	**15.9**

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato **PROJECT NAME** US 50 West, WB Preliminary Design

PROJECT NUMBER 302.02 **PROJECT LOCATION** Wills Blvd. to Purcell Blvd., Pueblo, Colorado

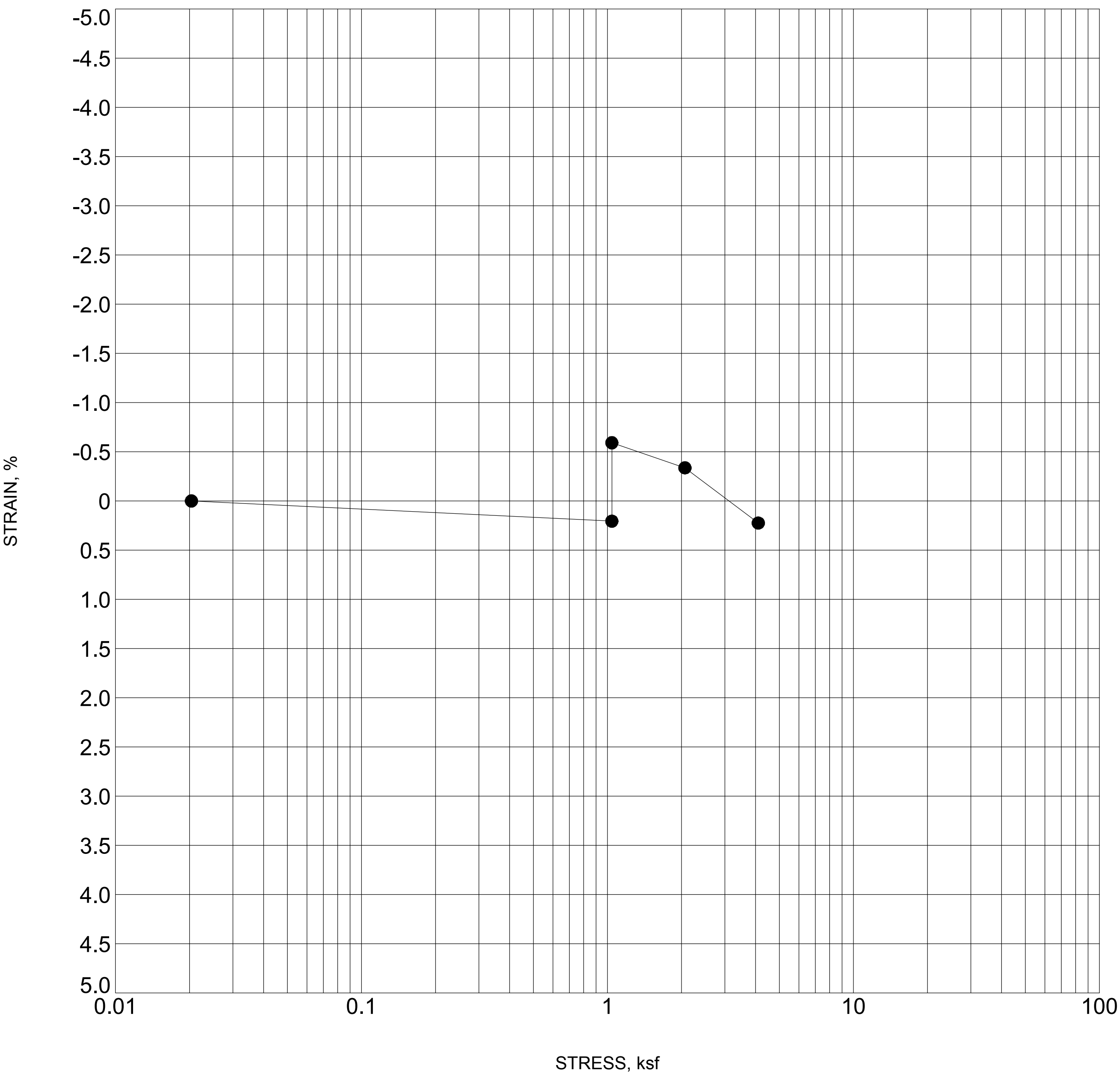


Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● WC-2	9	CLAY, sandy	0.7	115.9	13.8

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT J.F. Sato
PROJECT NAME US 50 West, WB Preliminary Design
PROJECT NUMBER 302.02
PROJECT LOCATION Wills Blvd. to Purcell Blvd., Pueblo, Colorado

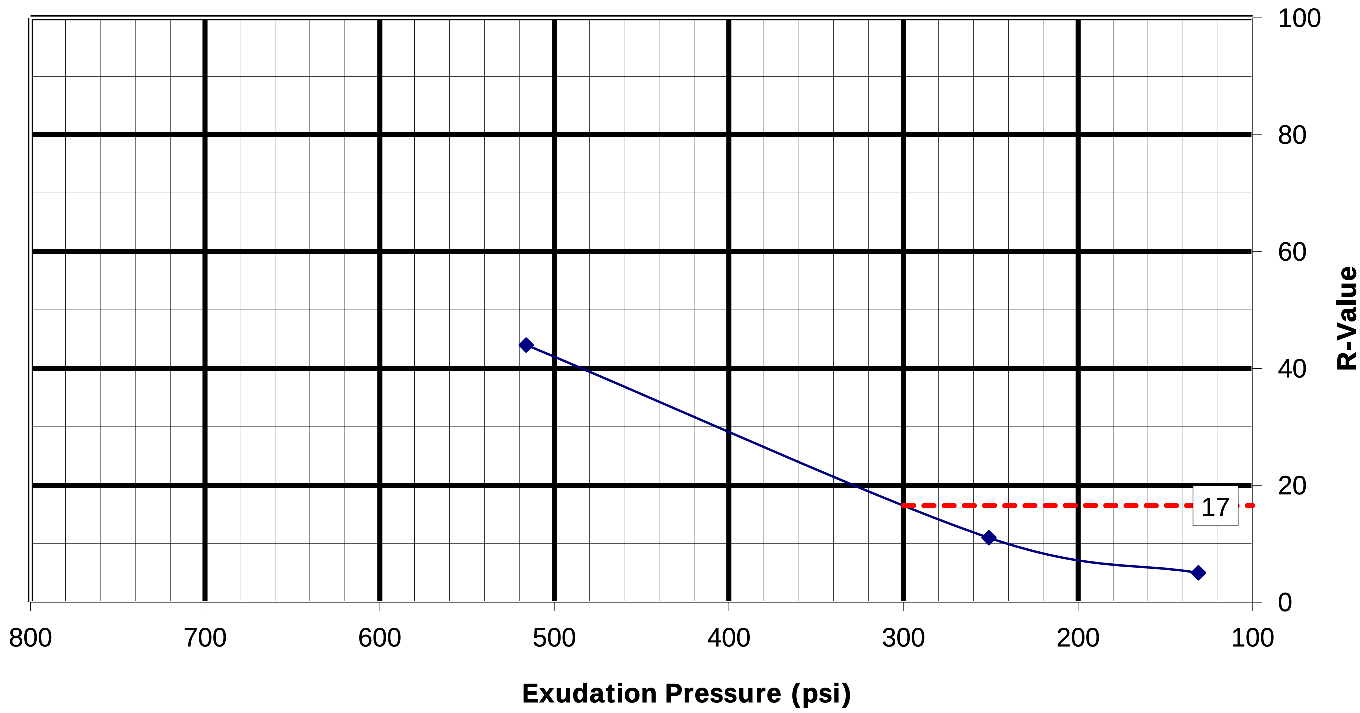


Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **WC-2**	**14**	**(Bedrock) SHALE**	**0.8**	**132.6**	**11.4**

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

R-Value Test Graph (AASHTO T-190 / Colorado Procedure CP-L 3101)

Project Number:	15.024, Rocksol Consulting Group, LLC	Date:	29-Jun-15
Project Name:	US 50 W, Task order #5 (RockSol Project No. 302.02)	Technician:	DGB
Lab ID Number:	1521297	Reviewer:	RAZ
Sample Location:	WB US 50 - Composite sample PV-3, 4, 8, 10 at 1' to 5'		
Visual Description:	SAND, clayey, brown		



R-Value @ Exudation Pressure 300 psi:	**17**
Specification:	

CDOT Pavement Design Manual, 2011.
Eq. 2.1 & 2.2, page 2-3.

$S_1 = [(R-5)/11.29]+3$ **S_1 = 4.02**

$M_R = 10^{[(S_1+18.72)/6.24]}$ **M_R = 4,406**

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	10.7	12.6	15.8
Expansion Pressure, psi:	1.06	0.33	-0.30
Dry Density, pcf:	119.8	115.5	108.7
R-Value:	44	11	5
Exudation Pressure, psi:	516	251	131

Note: The R-Value is measured; the M_R is an approximation from correlation formulas.

APPENDIX C

PAVEMENT CORE LOG SUMMARY

CORE ID: PV-3 **General Location: WB US 50, Lane 2 ≈ Sta No. 236+50**

Recovered Core Thickness: 10½ inches

Number of Identifiable Asphalt layers: 4

1. 1 ¾ inches
2. 4 ½ inches
3. 2 ½ inches
4. 1 ¾ inches

Condition of Asphalt: Good to Fair

Comments: Some signs of raveling at layer 3-4 interface.

CORE ID: PV-5 **General Location: WB US 50, Inside Shoulder ≈ Sta No. 196+80**

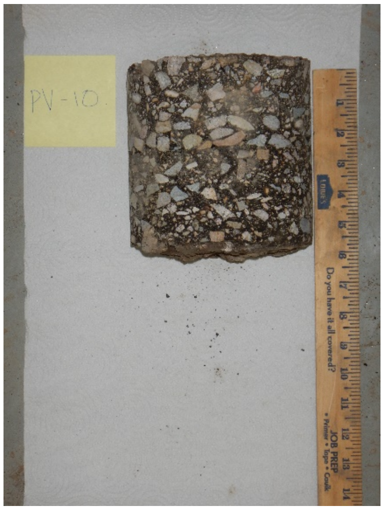
Thickness of Asphalt Pavement: 11 inches

Number of Identifiable Asphalt layers: 5

1. 2 ¼ inches
2. 2 ½ inches
3. 1 ¾ inches
4. 2 inches
5. 2 ½ inches

Condition of Asphalt: Good to Fair

Comments: Slight sign of raveling at bottom layer interfaces. Minor loss of fines in lower layers.

CORE ID: PV-10	**General Location: Center Median Between WB and EB US 50 ≈ Sta No. 128+00**
	Thickness of Asphalt Pavement: 6 inches Number of Identifiable Asphalt layers: 2 1. 2 ¾ inches 2. 3 ¼ inches Condition of Asphalt: Good to Fair Comments: Slight signs of raveling on bottom. Minor loss of fines at layer 1-2 interface.

CORE ID: PV-11	**General Location: WB US 50, Outside Turn Lane ≈ Sta No. 109+40**
	Thickness of Asphalt Pavement: 8 ¾ inches Number of Identifiable Asphalt layers: 5 1. ¾ inches 2. 1 ½ inches 3. 2 ½ inches 4. 2 ¼ inches 5. 1 ¾ inches Condition of Asphalt: Good Comments: Slight sign of raveling on bottom.

APPENDIX D

2013 FALLING WEIGHT DEFLECTOMETER TEST RESULTS
(KUMAR & ASSOCIATES, INC.)

Kumar & Associates, Inc.
Geotechnical and Materials Engineers
and Environmental Scientists

ACEC MEMBER

2390 South Lipan Street
Denver, CO 80223
phone: (303) 742-9700
fax: (303) 742-9666
email: kadenver@kumarusa.com
www.kumarusa.com

Office Locations: Denver (HQ), Colorado Springs, Fort Collins, and Frisco, Colorado

July 29, 2013

Mr. Ryan Lepro
RockSol Consulting Group
6510 West 91st Avenue, Suite 130
Westminster, Colorado 80031

Subject: Nondestructive Deflection Testing Results and Pavement Structural Evaluation, U.S. Highway 50 from Purcell Boulevard to Wills Boulevard, Pueblo, Colorado.

Project No. 13-1-286

Dear Mr. Lepro:

This letter presents the results of a nondestructive, falling weight deflectometer (FWD) deflection testing program and pavement structural evaluation program performed for approximately 11 lane miles of U.S. Highway 50 between Purcell Boulevard and Wills Boulevard in Pueblo, Colorado. The study was conducted in general accordance with the scope of work in our Proposal No. P-13-330 to RockSol Consulting dated April 23, 2013.

Scope of Work: Based on stationing provided by RockSol Consulting, FWD testing was performed in the eastbound travel lanes from the approximate Station 98+12 to Station 272+50, and in the westbound travel lanes from the approximate Station 98+49 to Station 274+00. Based on conversations with the client, we understand that an approximate1.1 mile segment of the westbound lanes between Station 185+00 and Station 248+00 was not under consideration for rehabilitation at the time, and therefore did not require FWD testing.

The FWD testing was performed using a JILS 20 Falling Weight Deflectometer (FWD). The JILS 20 FWD has the capability of imposing an impact load of up to 20,000 pounds on the pavement surface. The FWD applies a predetermined load to the pavement surface and measures the resultant pavement deflection with seven velocity transducers at offsets from the load source of 0, 8, 12, 18, 24, 36 and 60 inches. Testing was performed at spaced intervals of approximately 300 feet per lane with an approximate offset of 150 feet between adjacent lanes. At the completion of the FWD testing, the results were analyzed to determine the structural characteristics of the pavement section and underlying subgrade materials using the AASHTO DARWin™ computer software program. The existing pavement section type and thicknesses for the roadway were provided by RockSol Consulting, and were used in the data analysis.

Project Understanding: At the onset of this study, we were requested by the client to perform testing on Highway 50 between the limits of Purcell Boulevard on the west and Wills Boulevard on the east. At this time, we understand that the Colorado Department of Transportation (CDOT) is primarily focused on widening the eastbound portion of the highway between Purcell Boulevard and Wildhorse Creek (approximate Station 245+00). The roadway widening may consist of either an asphalt overlay, or a complete reconstruction of the existing shoulder. Potential mill and overlay operations of the eastbound travel lanes within that segment are being evaluated at this time.

Existing Site: At the time of testing, the majority U.S. 50 consisted of a 4-lane arterial highway with small inside shoulders, and wider outside shoulders. The roadway configuration also consisted of various turn and merge lane configurations. Signalized intersections were located at Purcell Boulevard, Pueblo Boulevard, and Wills Boulevard.

The pavement type and thicknesses provided for U.S. Highway 50 consisted of hot mix asphalt (HMA) overlying base course material. Thicknesses of the HMA encountered in the exploratory borings drilled by RockSol varied from approximately 8.5 to 10.0 inches, while the base course encountered ranged in thickness from approximately 6 to 14.5 inches.

Results: The structural characteristics of the pavement section and underlying subgrade determined for the project from the DARWin™ computer software included the effective pavement modulus and subgrade resilient modulus. Results from FWD testing were also used to evaluate the existing structural capacity as it relates to remaining 18-kip equivalent single axle loadings (ESAL) and performance with respect to the intended 20-year design life of the pavement.

In analyzing flexible pavements, the FWD tests can be evaluated where the combined stiffness influence of the various pavement layer moduli (asphalt and aggregate base layer) represents the overall structural capacity of the pavement. The structural capacity obtained from this procedure is generally a function of the maximum deflection determined at the load center as well as the subgrade resilient modulus. The maximum measured deflection obtained at the load center is used to predict the effective pavement modulus of the combined pavement layers. The effective pavement modulus of the combined pavement layers and the known pavement thickness were correlated to an overall existing structural number of the pavement section at each test location. The existing structural number for the tested locations ranged from 2.83 to 6.04 with an average structural number of 4.56. The existing structural numbers are a function of the pavement modulus, and existing pavement thickness assumed at each test location.

In general, the deflection sensors located at a greater distance from the load source are used to determine the subgrade resilient modulus. When the deflection basin is measured using the FWD, the outer readings of the deflection basin under the imposed load represent the in-situ resilient modulus of the subgrade soil. The subgrade resilient modulus is the value that represents the pavement support condition. The subgrade resilient modulus determined from the FWD testing was also variable, ranging from approximately 2,345 psi to 19,797 psi with an average value of 7,442 psi.

The remaining service life of the roadway was determined by backcalculating the remaining ESALs with respect to the intended 20-year design life of the pavement. The existing structural numbers and resilient modulus values obtained from the FWD testing were used to backcalculate the remaining ESALs.

The subgrade resilient modulus, effective pavement modulus, correlated existing structural number, and remaining ESALs of the roadway segments determined at each of the FWD test locations are provided in Tables 1 through 4.

Limitations: This study has been conducted in accordance with generally accepted pavement engineering practices in this area. The results and conclusions provided in this report are based upon the data obtained from the FWD tests taken at the approximate locations summarized in Tables 1 through 4, and the asphalt pavement section thicknesses provided. Kumar & Associates, Inc. is not responsible for liability associated with interpretation of the data by others.

Sincerely,
KUMAR & ASSOCIATES, INC.

By: ______________________
Ryan R. Kumar, Staff Engineer

Reviewed By:
James A. Noll, P.E.

COLORADO REGISTERED
JAMES A. NOLL
27051
7-29-2013
PROFESSIONAL ENGINEER

RRK/jw
Attachments
cc: File, book

TABLE 1
PAVEMENT ANALYSIS RESULTS
U.S. HIGHWAY 50
EASTBOUND OUTSIDE LANE

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
98+12	9,319	128,296	3.97	1,804,482
101+00	6,981	91,222	3.55	360,875
104+12	7,854	137,966	4.07	1,569,785
107+01	9,904	129,082	3.98	2,108,062
110+00	9,695	129,272	3.98	2,006,290
113+01	11,960	115,614	3.84	2,106,926
116+02	8,027	201,737	4.62	4,073,541
119+00	8,365	150,537	4.19	2,417,703
122+01	7,260	211,760	4.69	3,559,047
125+12	7,236	189,352	4.52	2,780,727
128+03	6,714	167,393	4.34	1,806,459
131+02	8,625	180,262	4.45	3,782,848
134+19	6,587	186,637	4.50	2,173,438
137+02	8,312	178,439	4.43	3,374,088
140+22	7,956	196,777	5.76	>10M
143+02	9,285	228,720	4.82	>10M
146+09	9,159	230,813	4.83	>10M
149+03	8,743	174,853	4.40	3,634,259
152+00	9,529	218,224	4.74	7,170,918
155+01	10,209	217,102	4.73	>10M
158+20	7,236	120,606	3.89	796,570
161+10	8,870	168,527	4.35	3,496,927
164+04	7,123	221,748	4.77	3,805,666
167+00	8,381	198,918	4.60	4,377,691
170+23	7,549	238,032	4.88	6,982,804
173+06	10,282	221,073	4.76	>10M
176+01	10,442	208,837	4.67	>10M
179+01	11,169	192,486	4.55	>10M
182+02	8,622	70,411	3.25	231,632
185+01	7,088	202,714	4.63	3,095,421
188+03	7,052	189,943	4.53	2,656,819
191+01	9,530	217,923	4.74	9,099,722
194+11	7,044	220,720	4.76	4,644,820
197+01	9,919	153,084	4.21	3,696,960
200+03	11,141	210,560	4.68	>10M
203+00	11,415	321,530	4.62	>10M
206+02	11,343	302,469	4.53	8,993,829
206+11	8,437	212,363	5.91	>10M
209+03	9,369	313,089	4.58	6,203,545

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
212+00	6,841	387,652	4.92	5,451,064
215+00	8,303	236,648	4.87	7,959,491
217+00	18,688	218,021	5.96	>10M
221+01	13,922	205,116	5.84	>10M
224+01	8,736	151,423	4.20	2,713,375
227+00	5,304	60,824	3.10	440,471
230+00	4,612	79,476	3.39	62,987
233+01	2,982	68,782	3.23	14,530
236+02	4,756	56,279	3.02	24,984
239+01	6,203	173,879	4.40	1,639,078
242+02	3,393	78,605	3.37	30,266
245+17	3,022	65,184	3.17	12,694
248+08	3,018	46,572	2.83	7,410
251+01	3,782	60,141	3.09	15,444
254+08	6,834	76,536	3.34	148,853
257+02	19,797	155,080	4.23	>10M
260+08	4,029	61,244	3.10	23,272
263+01	6,250	122,292	3.91	655,476
266+08	3,653	72,573	3.28	27,089
269+00	4,076	90,889	3.54	102,175
271+33	2,345	23,704	2.26	1,296

TABLE 2
PAVEMENT ANALYSIS RESULTS
U.S .HIGHWAY 50
EASTBOUND INSIDE LANE

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
98+49	9,403	173,015	4.39	4,745,498
98+50	8,328	178,216	4.43	3,796,970
101+53	8,604	194,171	4.56	4,946,553
104+51	12,363	212,637	4.70	>10M
107+51	12,444	156,792	4.25	8,172,216
110+51	8,790	185,460	4.49	4,697,184
113+51	7,940	216,244	4.73	5,872,972
116+51	5,769	81,805	3.42	172,304
119+50	9,268	361,433	4.81	9,430,890
122+64	8,202	196,030	5.75	>10M
125+50	8,365	210,003	5.88	>10M
128+51	8,035	175,425	4.41	3,393,323
131+51	6,791	227,488	6.04	>10M

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
134+52	8,786	217,315	5.95	>10M
137+52	9,037	180,763	4.45	4,725,575
140+52	8,258	216,371	5.94	>10M
143+51	9,494	210,736	5.89	>10M
146+55	9,435	211,345	5.90	>10M
149+50	10,096	221,111	4.76	>10M
152+60	8,504	200,986	5.80	>10M
155+51	7,319	365,944	4.83	5,611,410
158+71	8,272	207,075	5.86	>10M
161+52	9,546	362,124	4.81	>10M
164+50	12,619	219,985	5.98	>10M
167+72	10,172	164,144	3.70	1,196,586
170+50	10,908	341,070	4.72	>10M
173+58	9,850	197,000	5.76	>10M
179+51	5,438	125,249	3.94	440,035
182+84	9,209	131,687	4.01	1,644,492
185+94	7,347	209,866	4.68	4,563,026
188+53	8,743	203,995	4.64	6,445,906
191+54	9,642	217,592	4.74	934,957
194+50	9,864	295,918	4.50	5,906,901
197+52	12,446	383,348	4.90	>10M
200+50	8,314	194,552	3.91	1,130,325
203+52	11,815	388,943	4.93	>10M
206+50	10,011	350,062	4.76	>10M
209+53	5,744	203,248	5.82	>10M
212+53	13,254	256,320	4.29	8,139,721
215+58	6,552	209,437	5.88	>10M
218+51	17,430	320,135	4.62	>10M
221+50	8,650	196,654	5.76	>10M
224+51	7,416	164,874	4.32	2,210,343
227+50	2,692	67,524	3.21	18,484
230+60	4,606	96,576	3.61	149,041
233+50	5,343	90,470	3.54	191,453
236+52	4,308	60,171	3.09	26,939
239+51	6,872	46,502	2.83	71,481
241+90	8,756	96,311	3.61	661,520
245+57	4,892	104,855	3.71	221,989
248+50	3,062	56,128	3.02	18,224
251+50	6,234	116,370	3.84	464,699
254+51	12,385	124,267	3.93	2,584,716
257+51	9,557	127,427	3.96	1,673,368
260+51	4,686	136,519	4.05	410,158
263+50	4,061	90,427	3.53	99,942
266+51	4,224	102,923	3.69	153,627
269+50	4,069	72,019	3.28	5,626

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
272+50	3,195	46,436	2.83	12,093
274+00	4,059	145,330	4.14	419,548

TABLE 3
PAVEMENT ANALYSIS RESULTS
U.S. HIGHWAY 50
WESTBOUND OUTSIDE LANE

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
273+50	3,642	63,366	3.14	19,073
270+50	5,488	153,105	4.21	936,440
267+50	5,897	123,246	3.92	516,564
264+47	10,236	116,347	3.84	1,661,102
261+27	9,283	136,153	4.05	2,247,170
258+50	10,285	108,333	3.75	1,396,332
255+49	5,171	117,032	3.85	345,512
252+50	5,712	190,383	4.53	1,629,394
249+50	4,183	87,280	3.49	89,559
246+48	5,711	241,677	4.20	1,012,131
243+80	6,594	149,015	4.18	1,371,883
240+27	3,884	197,284	5.76	3,989,232
182+49	7,763	181,130	5.60	>10M
179+49	5,014	300,814	4.52	3,846,098
176+49	5,873	170,583	5.49	7,355,858
173+40	4,302	215,122	5.93	7,184,476
170+36	3,869	213,812	5.92	3,546,210
167+50	4,663	333,232	4.68	1,589,210
164+50	6,286	152,960	5.29	5,755,058
161+50	5,039	222,373	5.49	4,477,796
158+50	5,718	130,936	5.03	2,840,457
155+50	3,773	150,923	5.75	3,194,633
152+48	4,780	155,205	5.32	3,171,722
149+46	5,123	177,249	5.56	5,856,090
146+50	4,114	85,156	3.46	93,589
143+49	7,420	144,695	5.67	>10M
140+50	7,865	201,075	5.80	>10M
137+50	6,306	368,397	4.84	4,028,676
134+48	4,774	193,514	4.55	1,243,191
131+49	5,749	216,335	5.94	>10M
125+49	5,468	220,522	5.98	>10M
122+50	6,507	263,851	4.33	1,655,753
119+48	4,404	151,513	4.20	553,848

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
116+49	4,025	193,465	4.55	836,734
113+49	5,464	236,752	4.87	3,014,983
110+48	5,377	197,156	5.76	9,696,619
107+50	5,236	221,478	4.76	2,334,034
104+50	4,860	226,812	4.80	2,079,369
101+48	4,945	205,059	4.64	1,718,294

TABLE 4
PAVEMENT ANALYSIS RESULTS
U.S. HIGHWAY 50
WESTBOUND INSIDE LANE

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
270+77	6,025	133,348	4.02	583,682
267+99	4,766	156,469	4.24	705,399
265+00	12,811	87,545	3.50	1,217,474
261+89	8,877	190,570	4.53	5,092,763
258+76	12,481	178,057	4.43	9,706,916
256+00	2,701	101,726	3.68	53,696
252+98	4,681	80,982	3.41	104,710
249+65	5,476	190,868	5.70	8,195,124
182+78	6,991	342,739	4.72	3,841,498
180+00	6,266	355,095	4.78	3,643,458
177+00	5,742	353,336	4.77	2,932,863
173+99	4,298	206,715	5.85	6,474,310
171+98	8,651	332,972	4.68	6,666,895
167+99	6,484	203,058	5.82	>10M
165+00	11,502	139,943	4.09	3,915,811
161+91	6,043	193,324	5.72	>10M
158+83	8,607	194,517	5.74	>10M
156+00	5,846	175,208	5.54	7,749,539
153+00	5,968	397,879	4.96	4,201,478
150+00	7,828	212,391	5.91	>10M
147+00	3,832	168,592	5.47	2,653,484
144+00	5,497	321,454	4.62	1,907,000
141+00	4,907	179,964	4.45	1,145,966
137+99	10,711	167,544	3.72	1,557,455
135+00	5,685	196,596	5.76	9,654,643
131+98	9,606	320,215	4.62	6,962,382
129+00	6,280	315,901	4.60	2,523,859
125+99	7,328	156,816	5.34	8,774,664
122+97	6,686	289,590	4.47	2,155,938

Station	M_R (psi)	Effective Pavement Modulus (psi)	Existing SN	Approx. Remaining Life (ESAL)
120+00	9,351	313,588	4.59	6,265,406
117+00	10,806	324,179	4.64	9,414,468
113+95	5,532	211,869	4.69	2,396,544
110+99	5,276	170,995	5.49	5,720,616
107+99	5,206	242,953	4.91	2,852,056
104+99	10,275	196,254	4.58	8,587,720
101+94	6,493	216,642	5.95	>10M
98+96	6,511	220,928	5.98	>10M

M_R – Subgrade Resilient Modulus
SN – Existing Structural Number

APPENDIX E

FLEXIBLE AND RIGID PAVEMENT SECTION SUMMARY SHEETS
AASHTO M-E PAVEMENT DESIGN (VERSION 2.2)

US50 Westbound - Flexible - R-5 Subgrade

File Name: E:\ME Design\302.02 - US50\US50 Westbound - Flexible - R-5 Subgrade.dgpx

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2017
Pavement construction: June, 2017
Traffic opening: August, 2017

Climate Data Sources (Lat/Lon): 38.29, -104.498

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 SMA	2.0
Flexible	R1 Level 1 S(100) PG 64-22	5.5
NonStabilized	CDOT Class 6 ABC (Mr-20000)	6.0
Subgrade	A-2-4 (R-40)	24.0
Subgrade	A-6 (R-5)	8.0
Subgrade	A-6 (Native)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	12.2
Air voids (%)	4.7

Traffic

Age (year)	Heavy Trucks (cumulative)
2017 (initial)	2,900
2027 (10 years)	3,753,800
2037 (20 years)	9,126,150

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	171.58	95.00	99.41	Pass
Permanent deformation - total pavement (in)	0.65	0.64	95.00	96.22	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	17.18	95.00	99.32	Pass
AC thermal cracking (ft/mile)	1500.00	1166.92	95.00	99.97	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	340.42	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.48	95.00	96.94	Pass

US50 Westbound - Flexible - R-5 Subgrade

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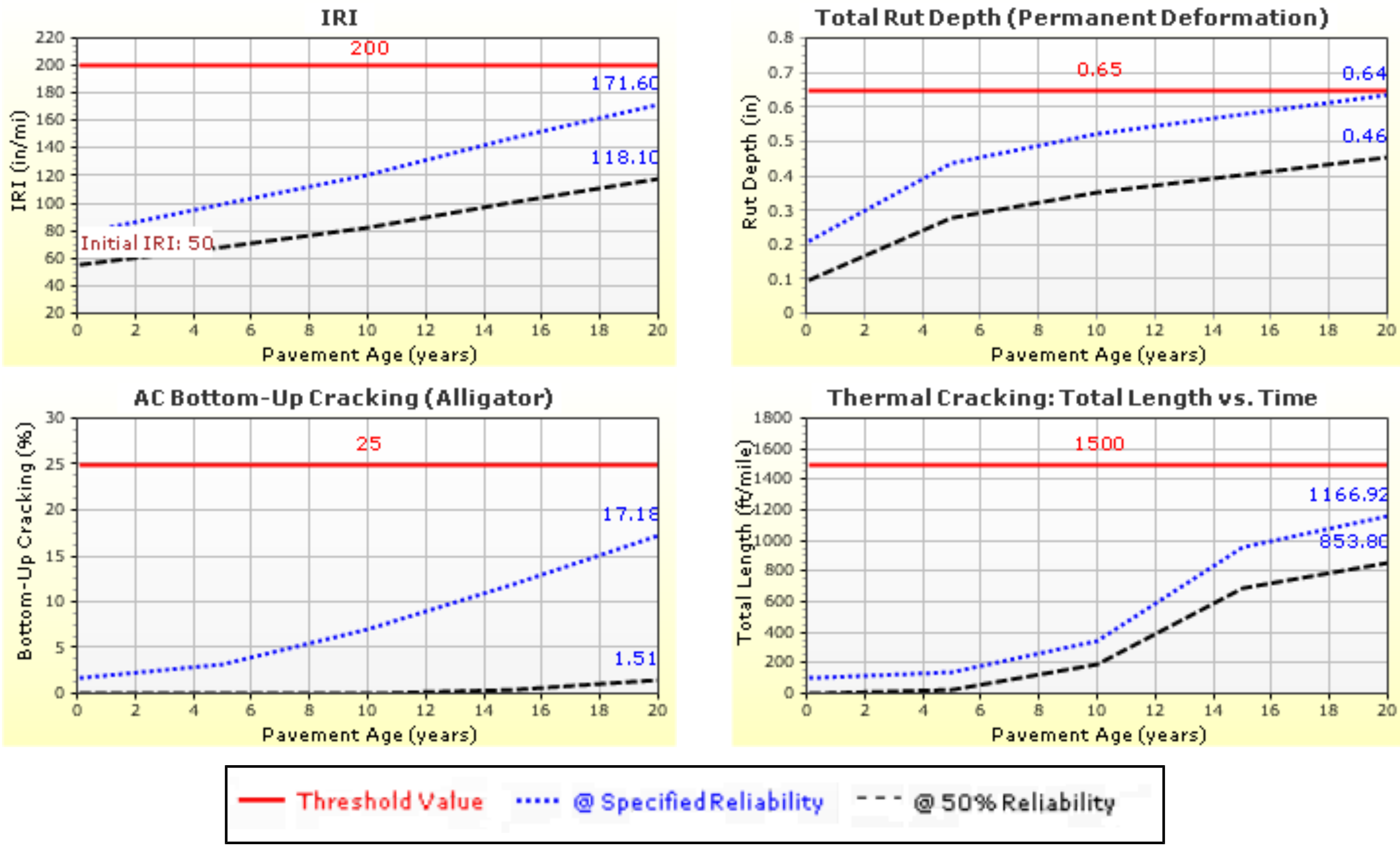
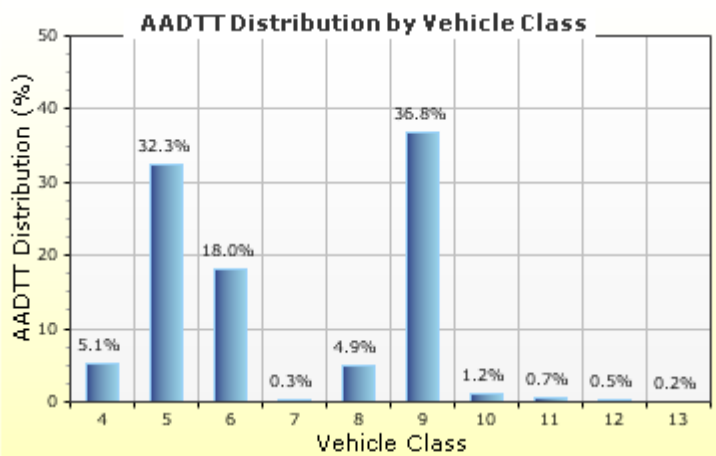
Distress Charts

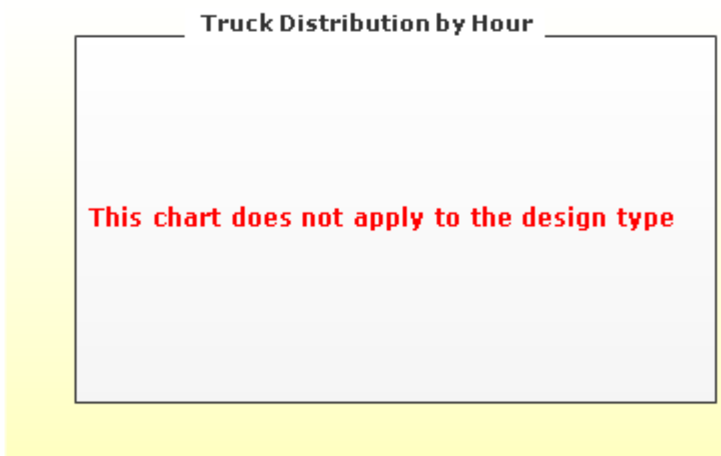


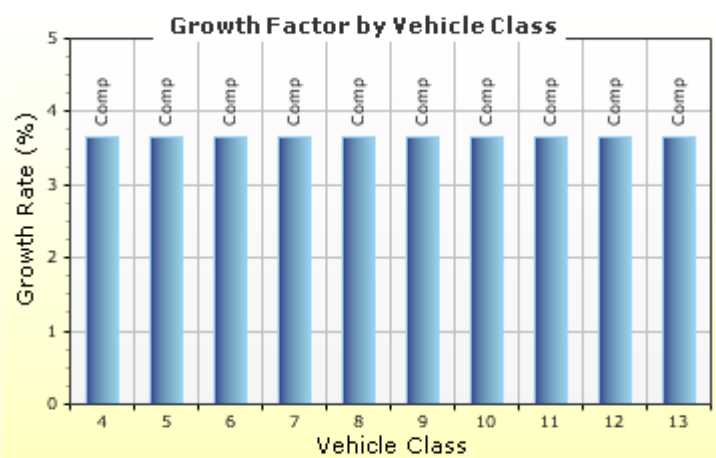
Traffic Inputs

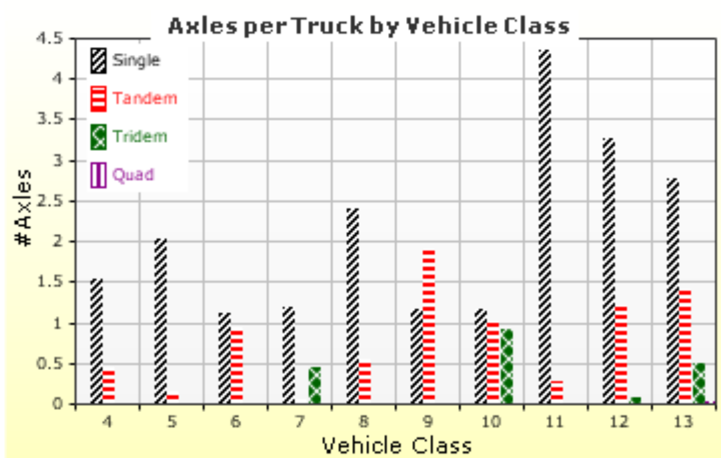
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,900	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	6	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	55.0

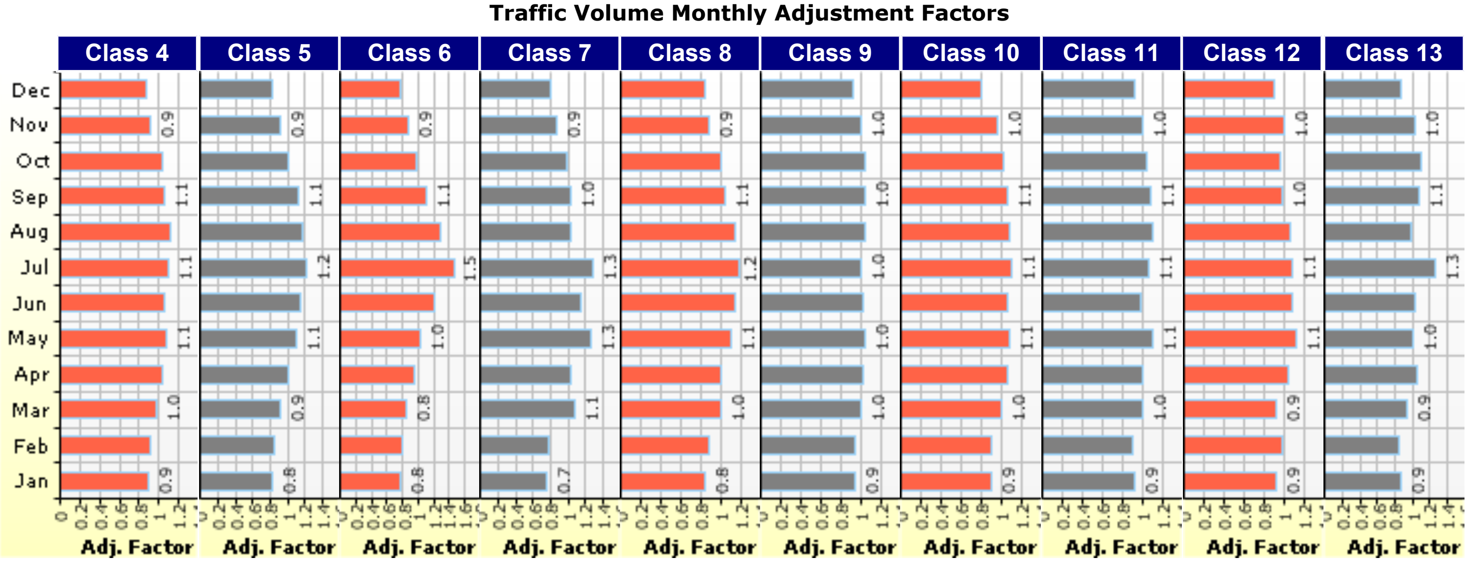








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3.65%	Compound
Class 5	32.3%	3.65%	Compound
Class 6	18%	3.65%	Compound
Class 7	0.3%	3.65%	Compound
Class 8	4.9%	3.65%	Compound
Class 9	36.8%	3.65%	Compound
Class 10	1.2%	3.65%	Compound
Class 11	0.7%	3.65%	Compound
Class 12	0.5%	3.65%	Compound
Class 13	0.2%	3.65%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

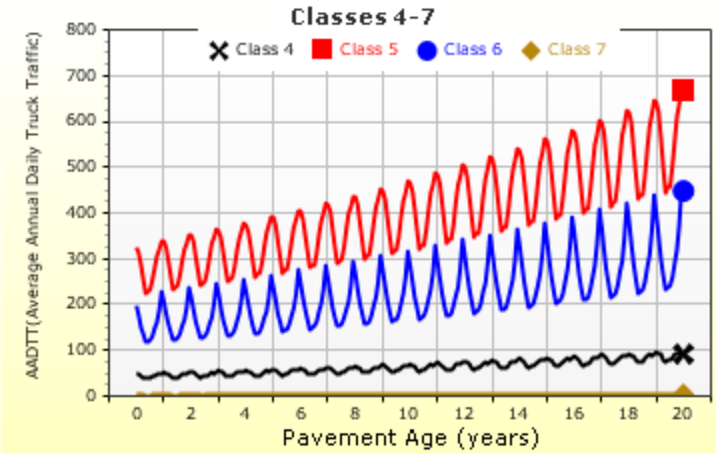
Wheelbase does not apply

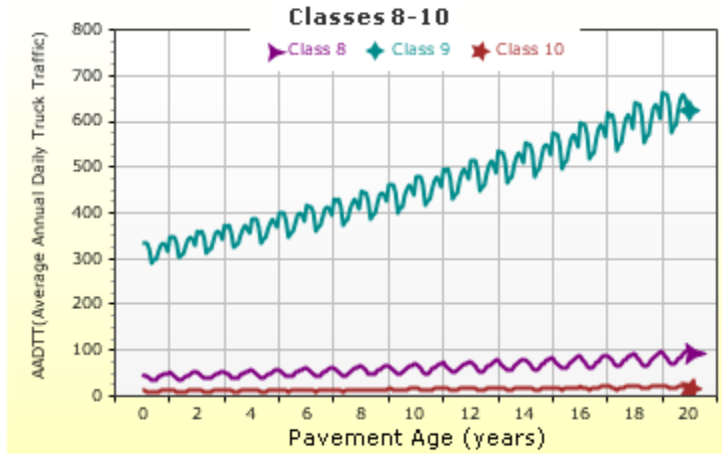
Number of Axles per Truck

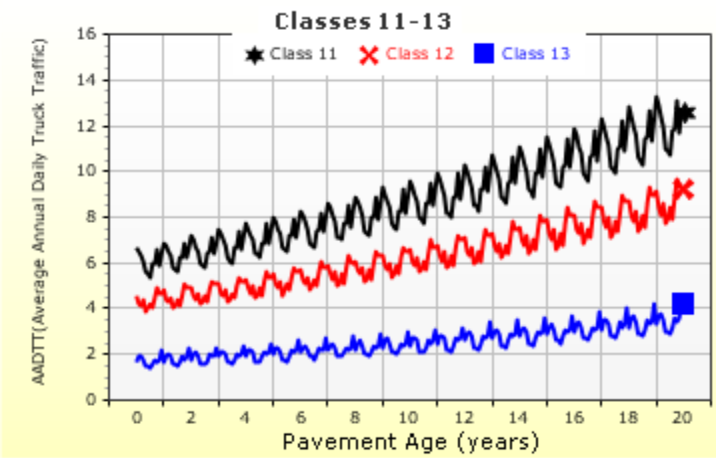
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.94	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.9	0.01	0
Class 10	1.15	1.01	0.93	0.02
Class 11	4.35	0.29	0.02	0
Class 12	3.27	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

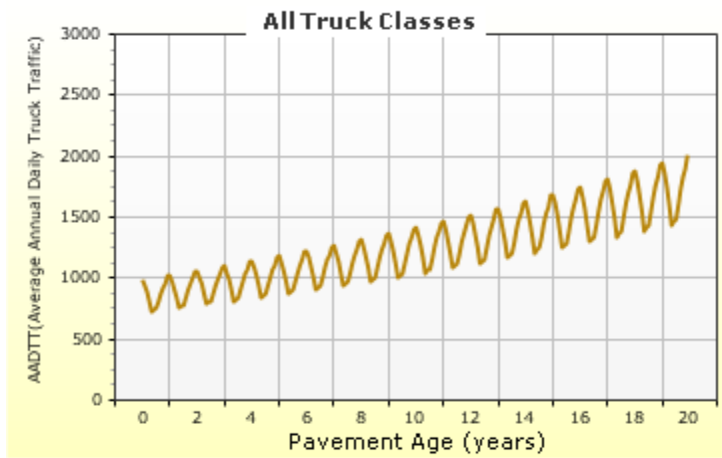
AADTT (Average Annual Daily Truck Traffic) Growth

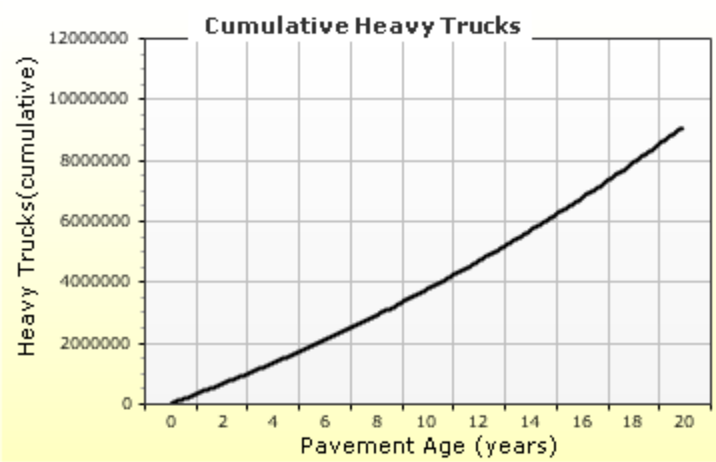
*** Traffic cap is not enforced**











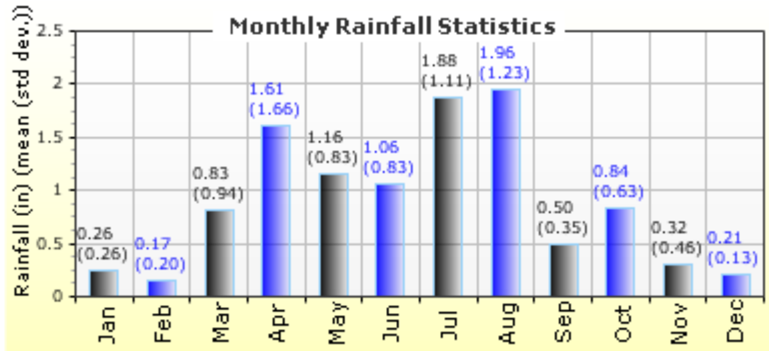
Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
PUEBLO, CO	38.29000 -104.49800 4720

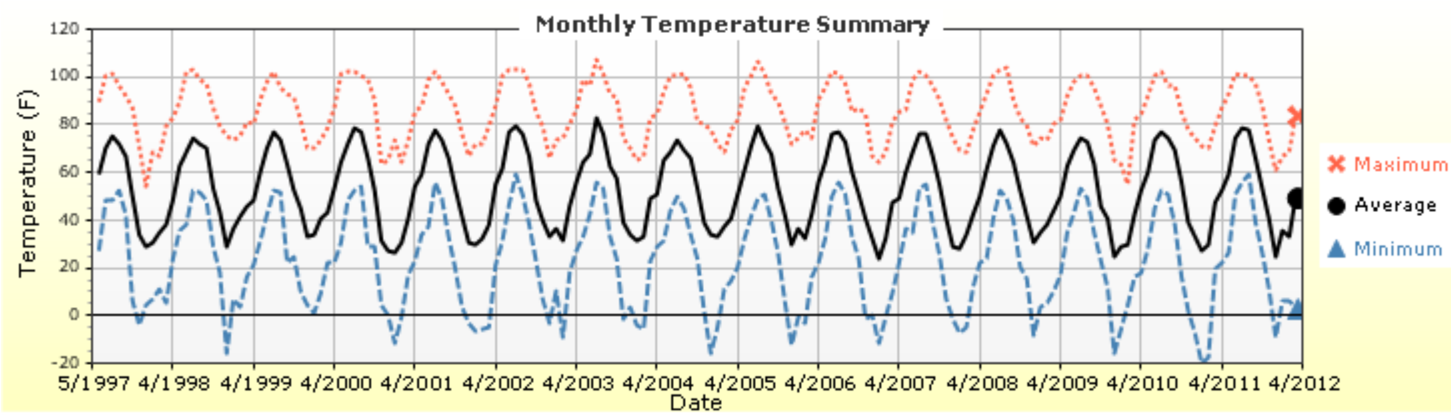
Annual Statistics:

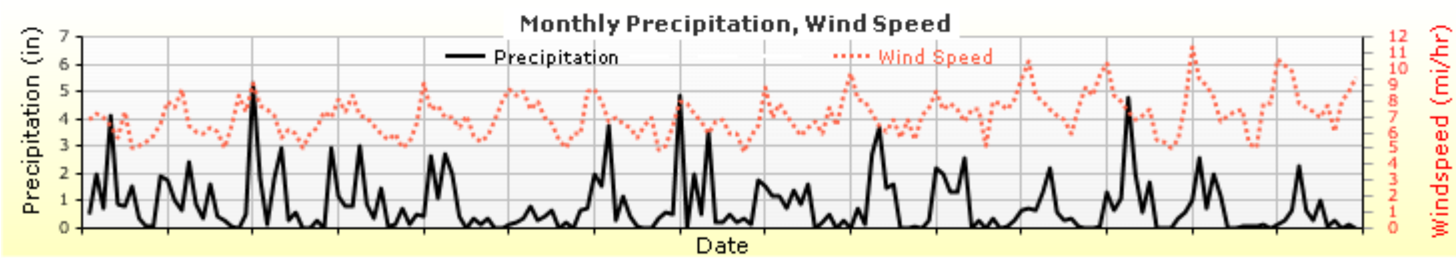
Mean annual air temperature (ºF)	52.95
Mean annual precipitation (in)	10.91
Freezing index (ºF - days)	377.71
Average annual number of freeze/thaw cycles:	142.23

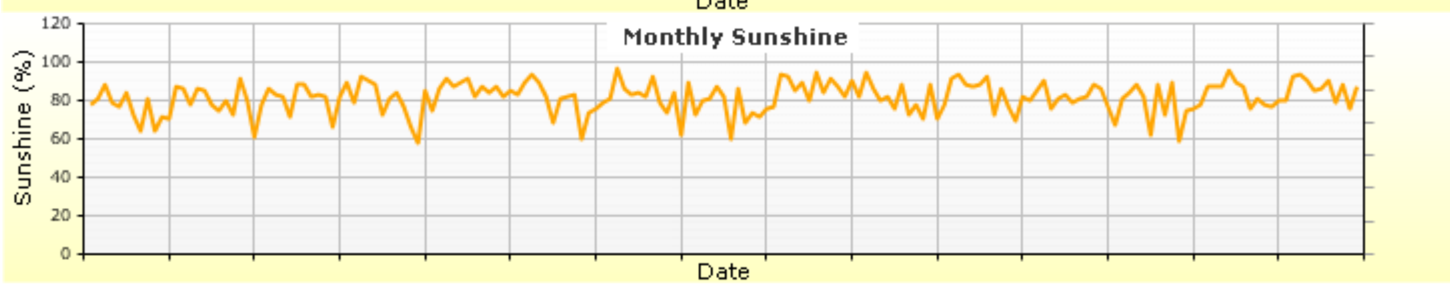


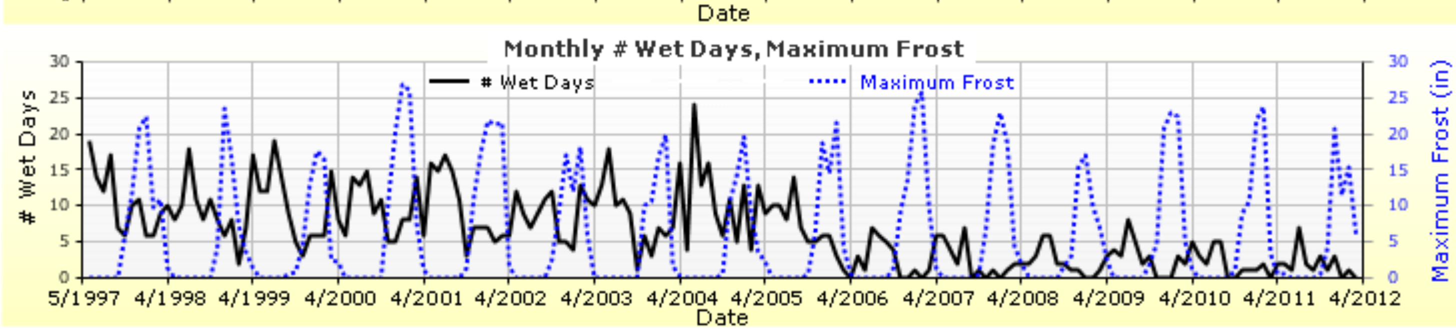
Water table depth (ft)	10.00

Monthly Climate Summary:









US50 Westbound - Flexible - R-5 Subgrade

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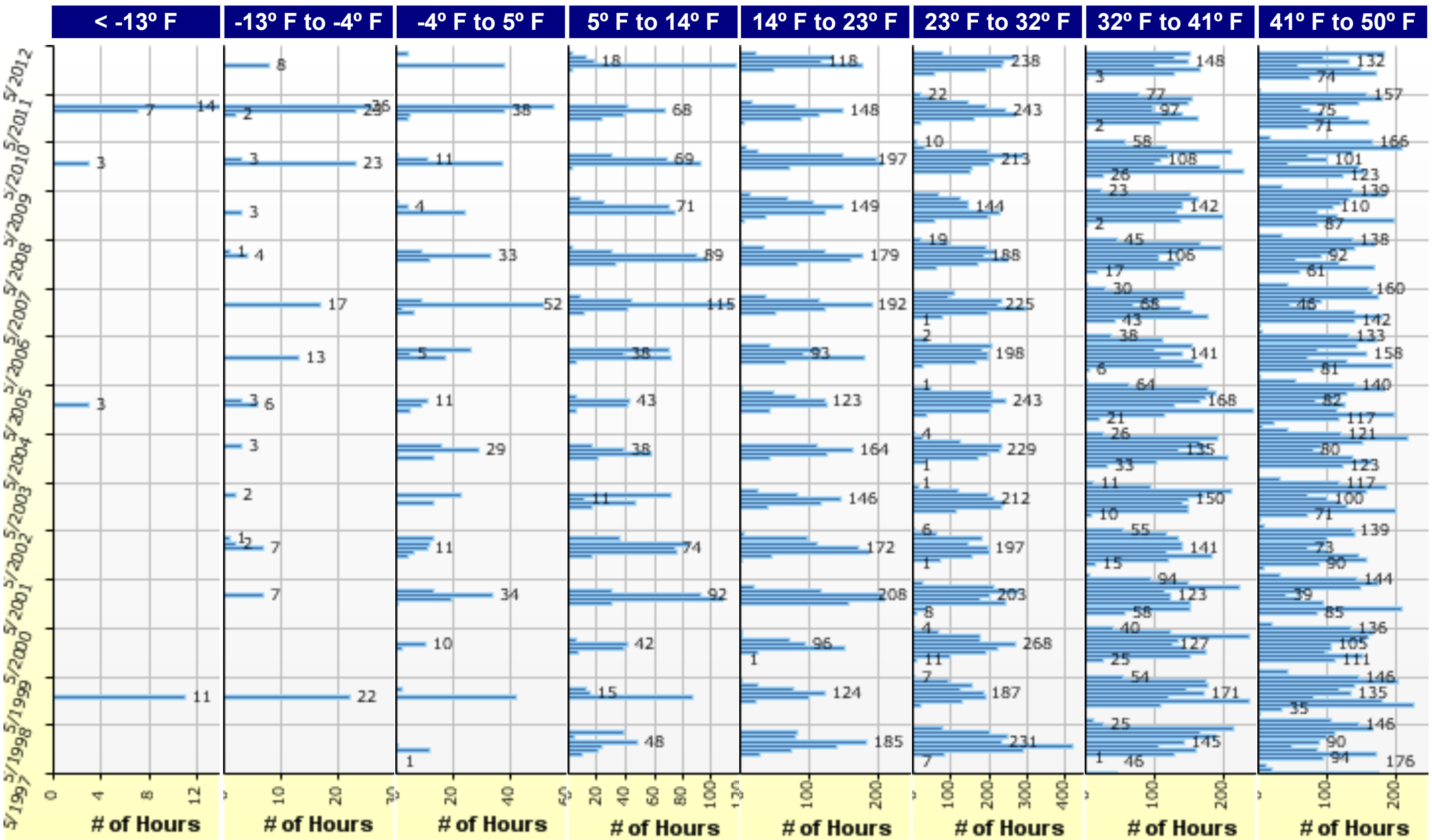
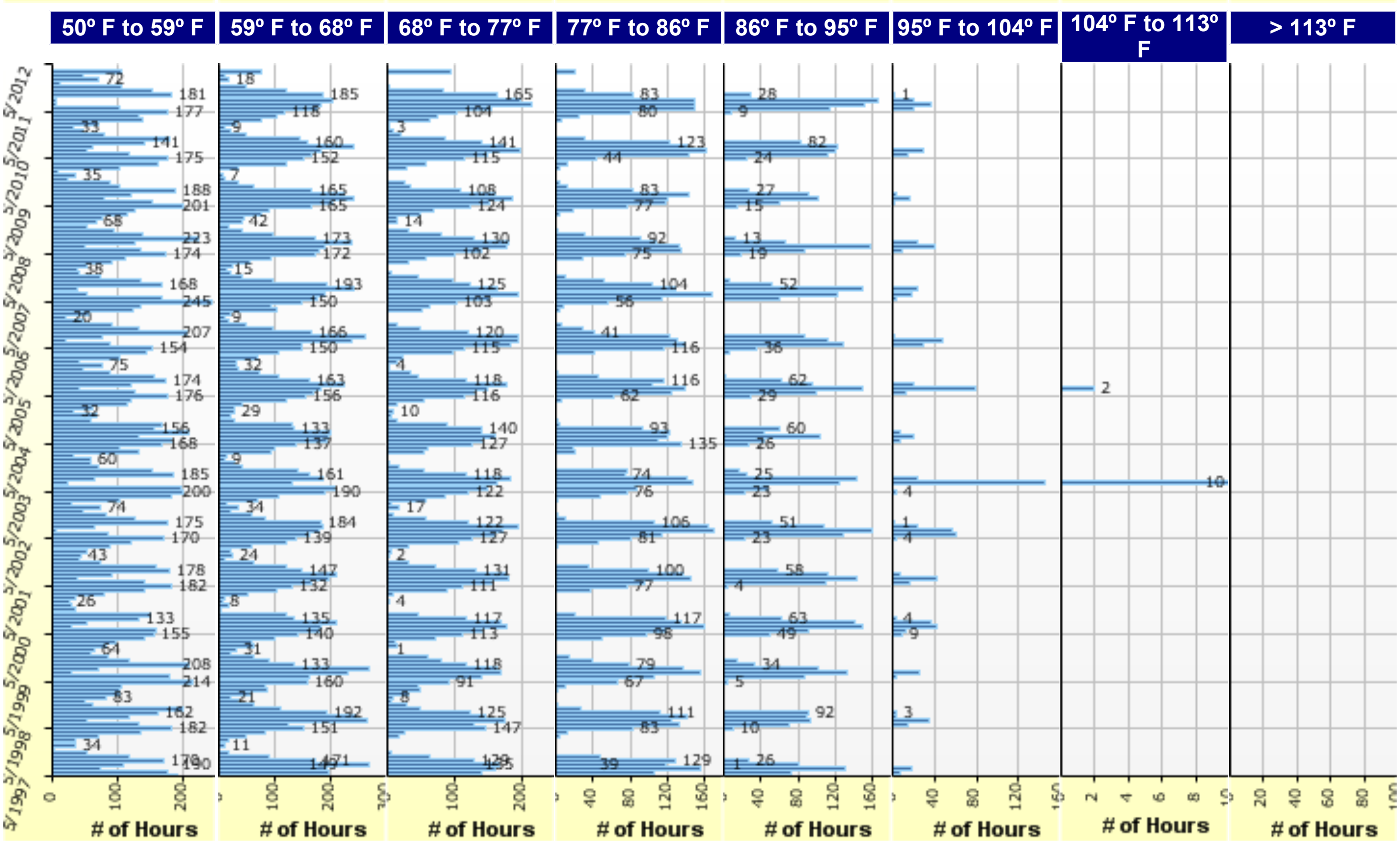
Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	True
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

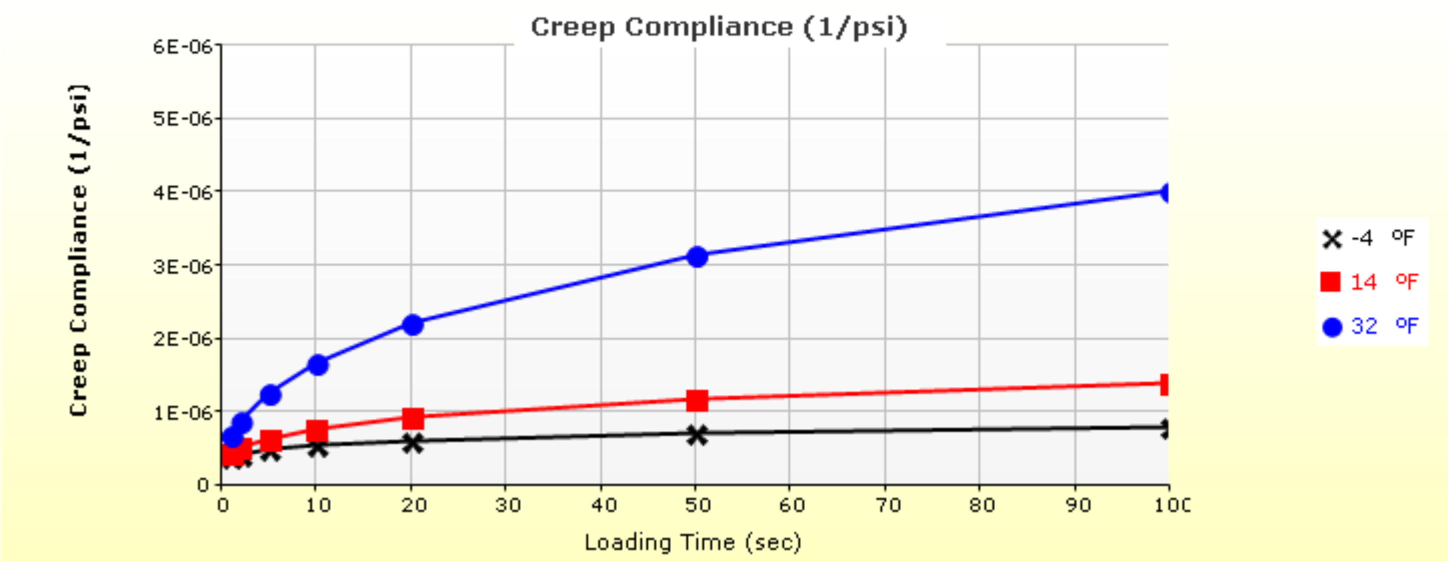
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 SMA	Flexible (1)	1.00
Layer 2 Flexible : R1 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : CDOT Class 6 ABC (Mr-20000)	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-2-4 (R-40)	Subgrade (5)	1.00
Layer 5 Subgrade : A-6 (R-5)	Subgrade (5)	1.00
Layer 6 Subgrade : A-6 (Native)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

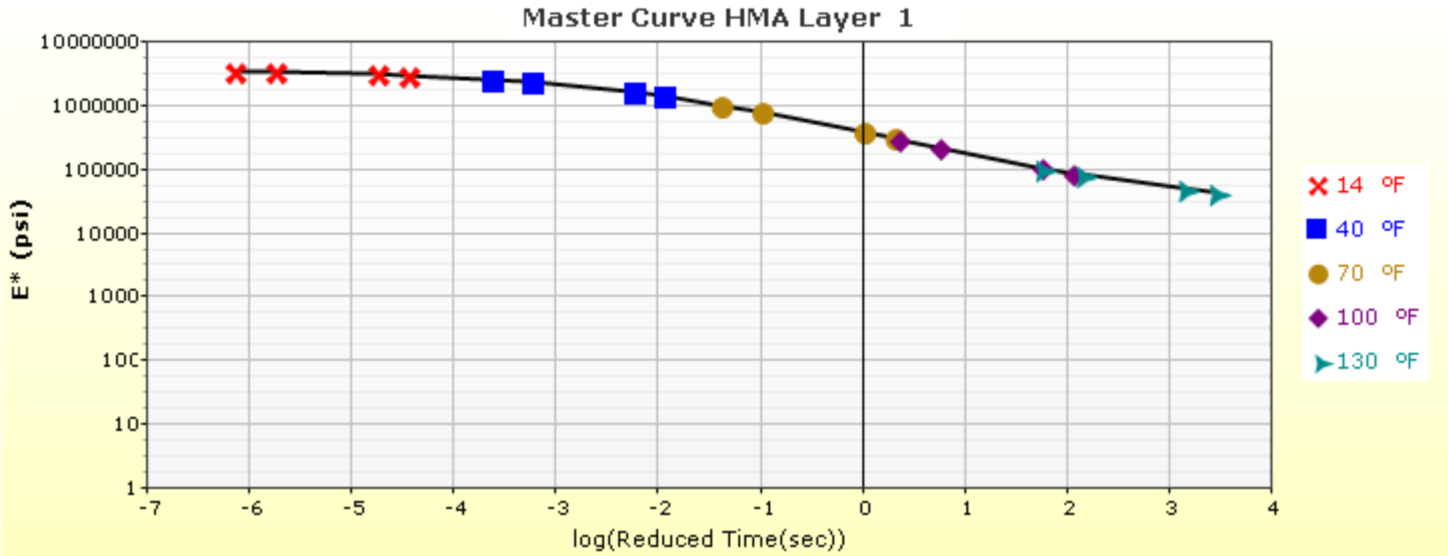
Indirect tensile strength at 14 ºF (psi)	515.00

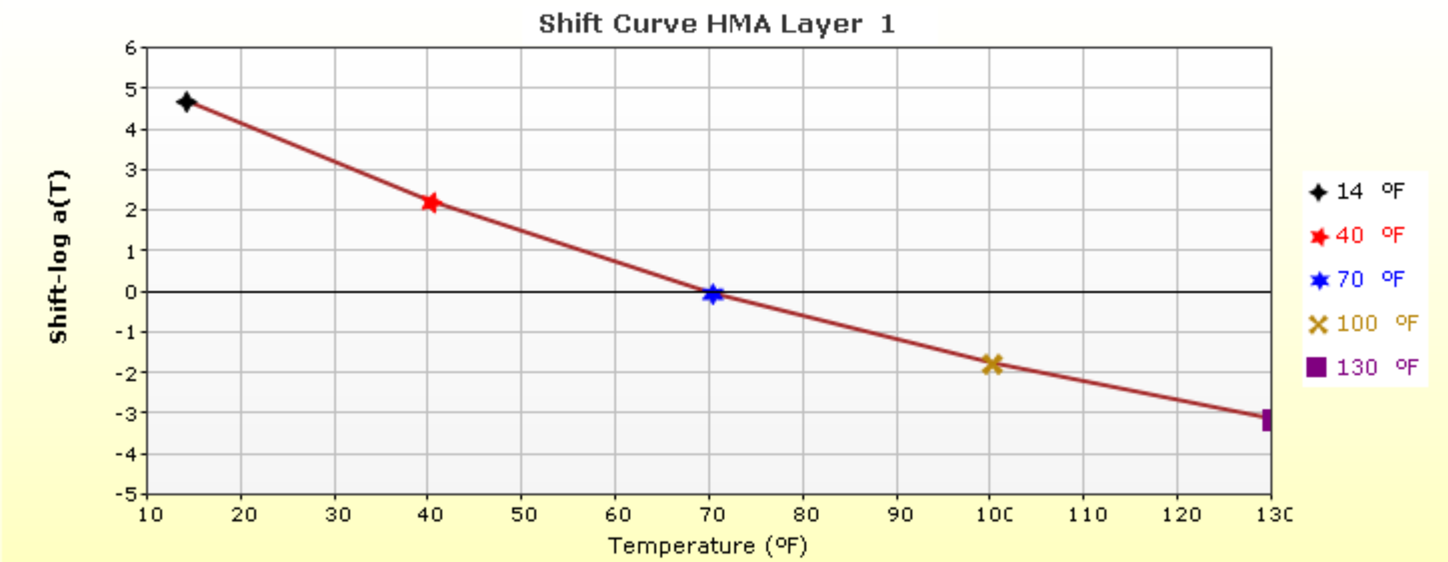
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.9

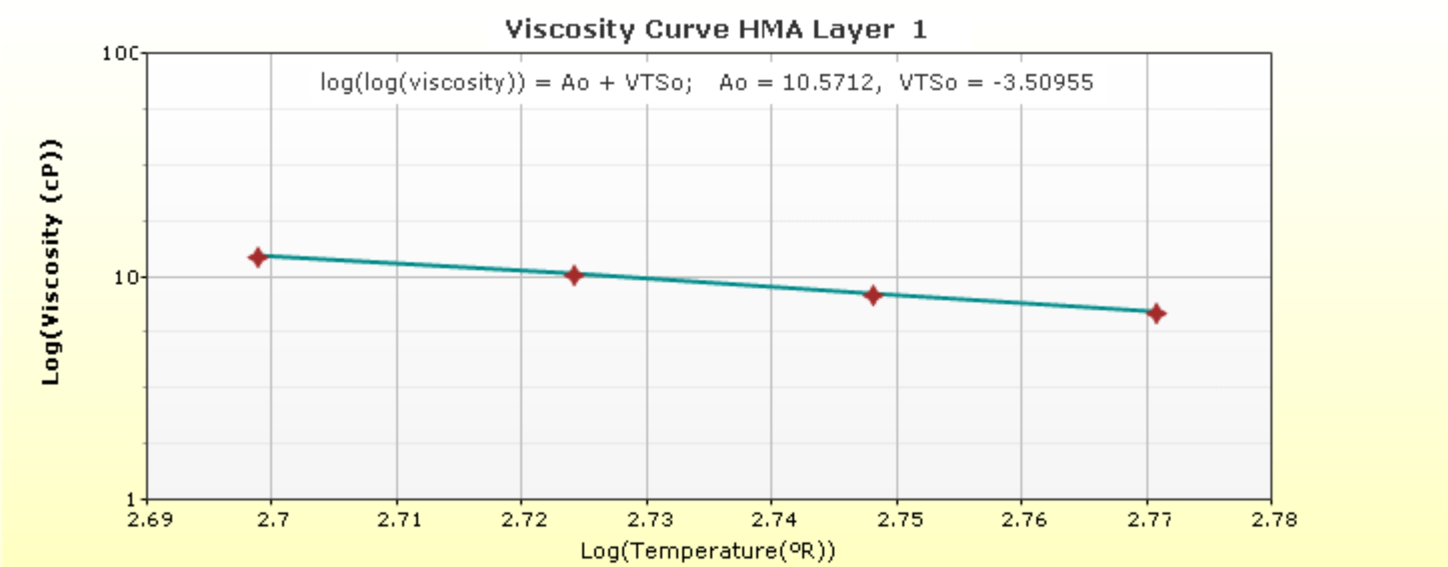
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.01e-007	4.45e-007	6.88e-007
2	4.28e-007	5.41e-007	8.96e-007
5	4.98e-007	6.37e-007	1.27e-006
10	5.51e-007	7.85e-007	1.69e-006
20	6.17e-007	9.33e-007	2.23e-006
50	7.19e-007	1.18e-006	3.14e-006
100	7.96e-007	1.39e-006	4.01e-006



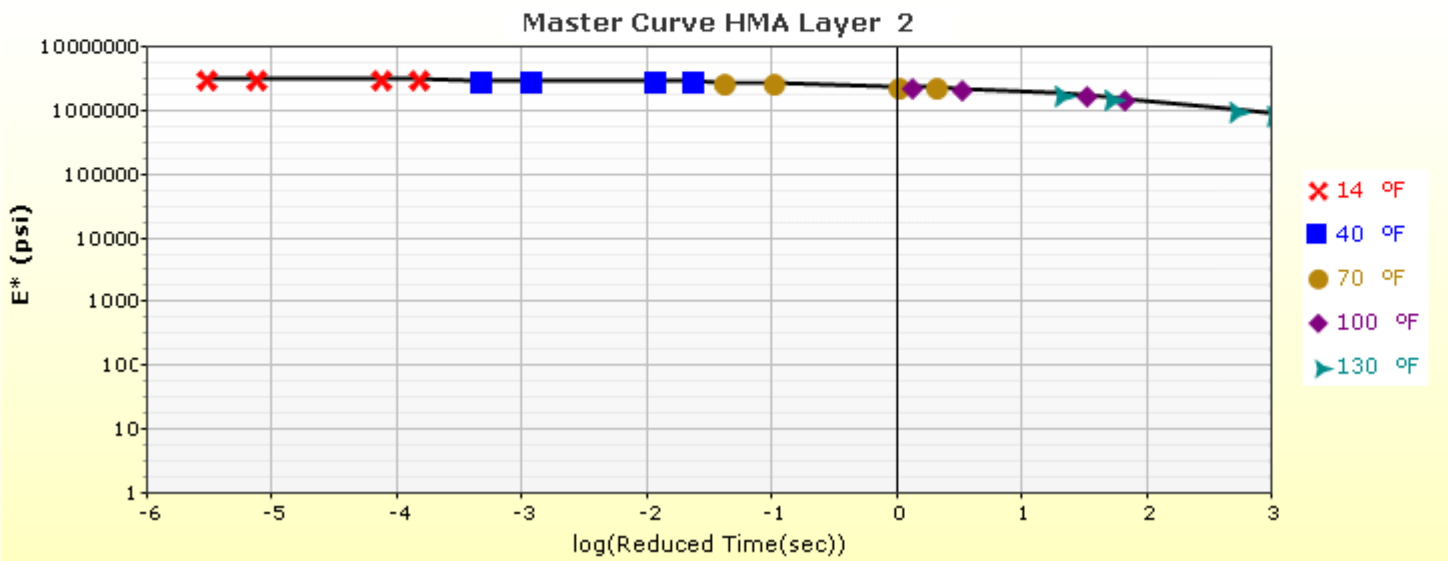
HMA Layer 1: Layer 1 Flexible : R2 SMA

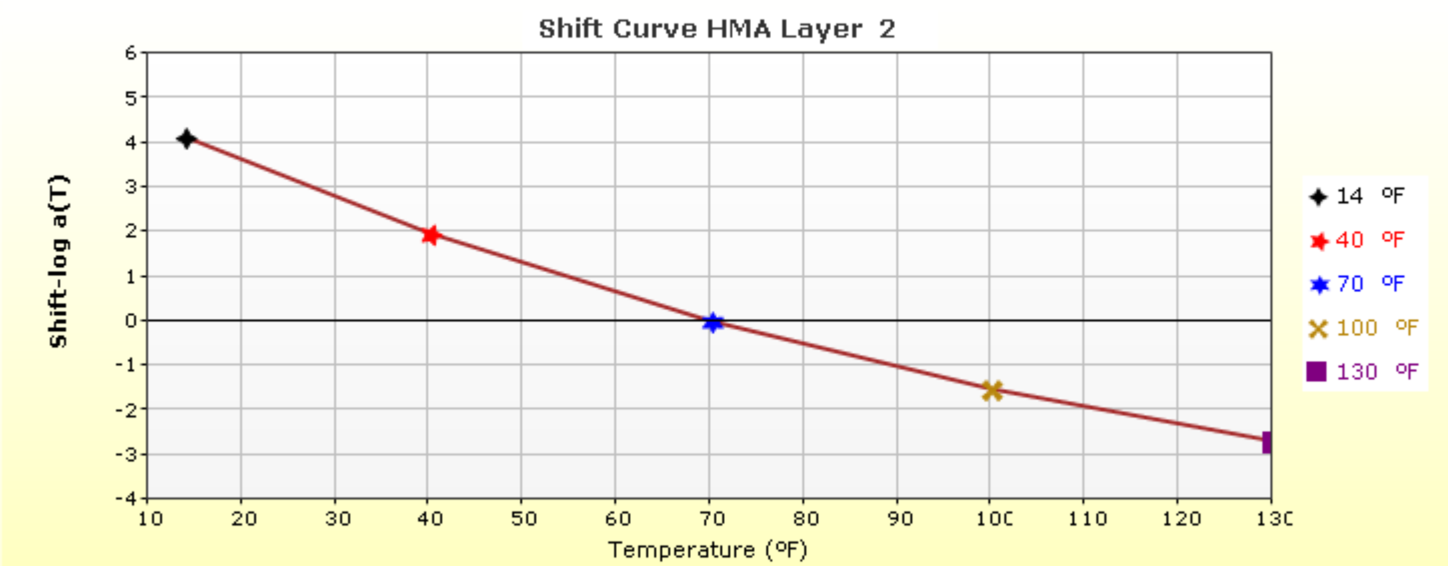


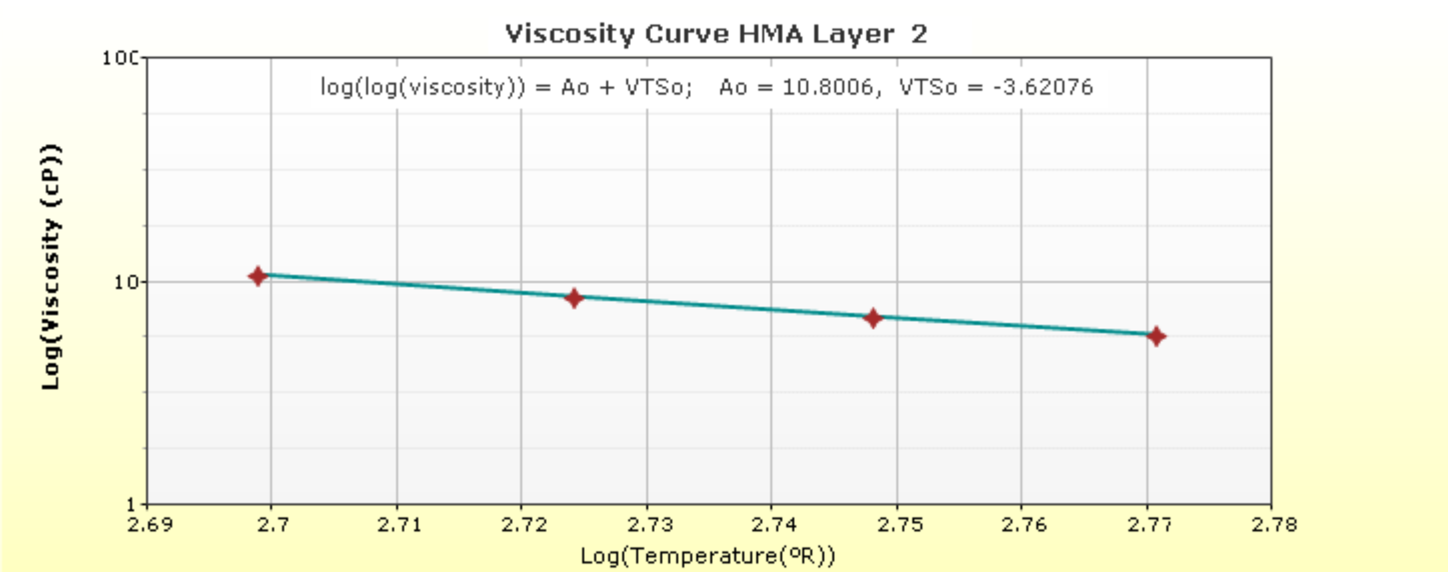




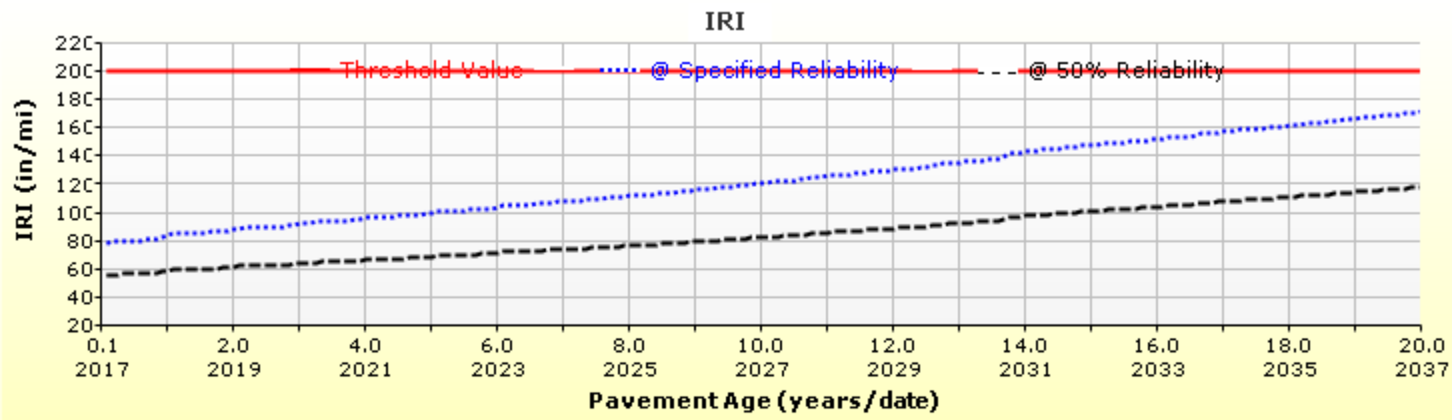
HMA Layer 2: Layer 2 Flexible : R1 Level 1 S(100) PG 64-22

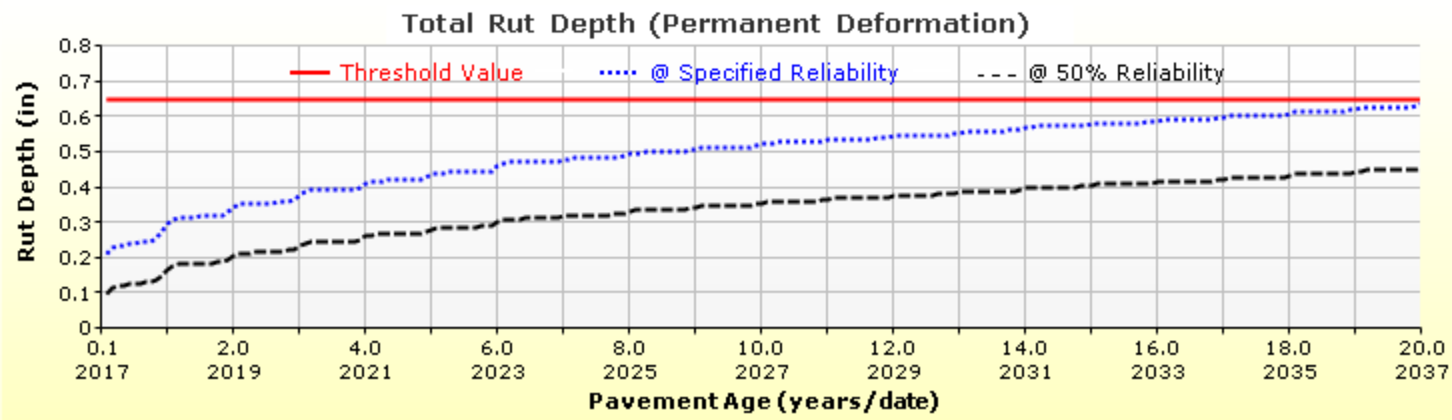


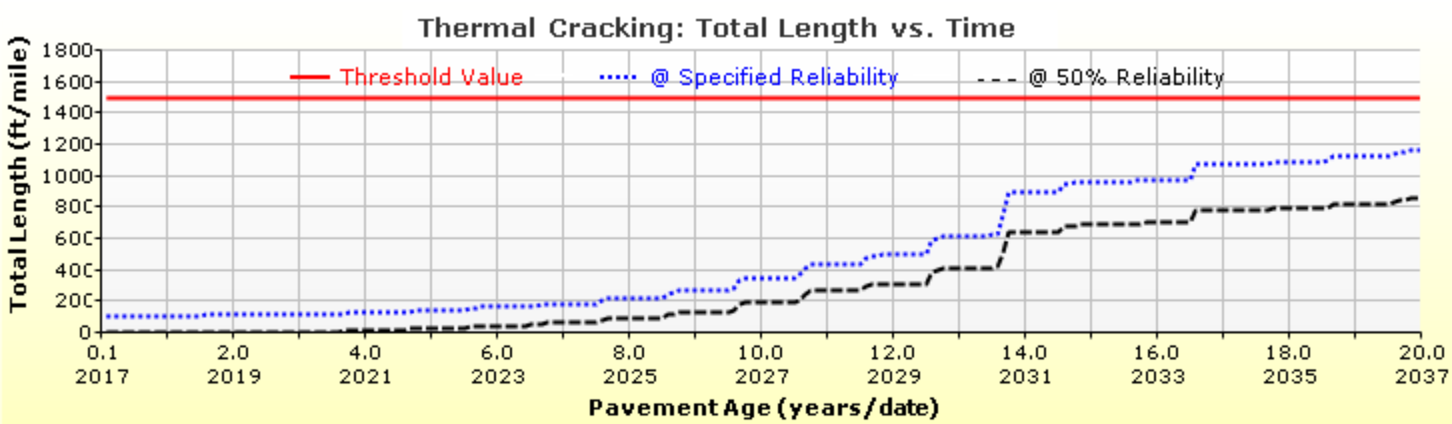


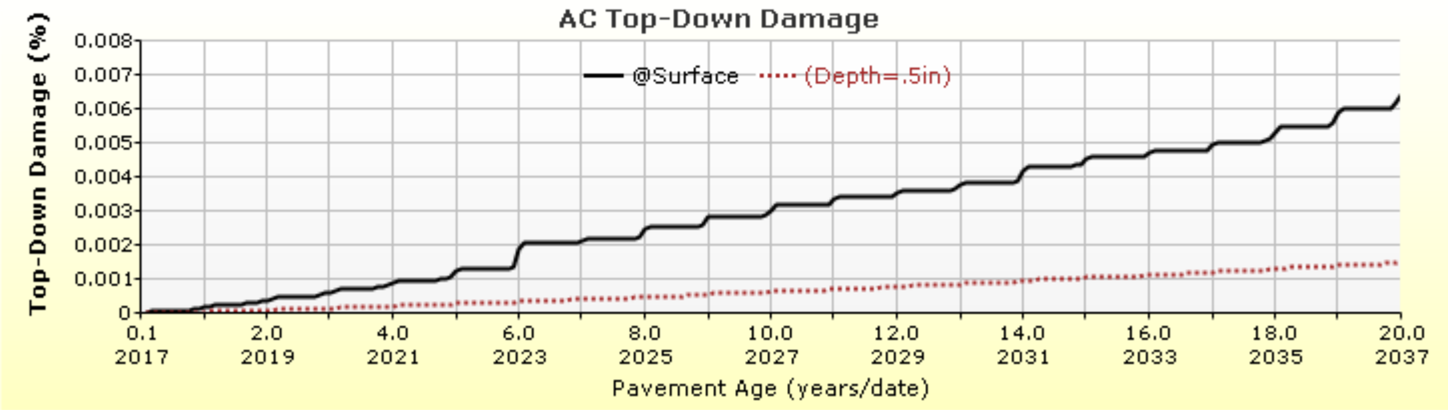


Analysis Output Charts

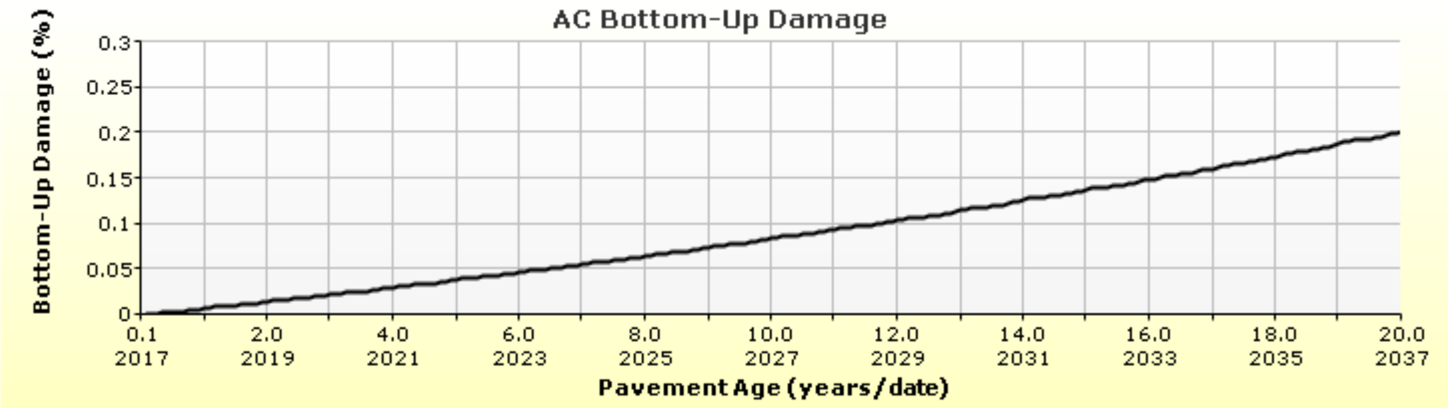




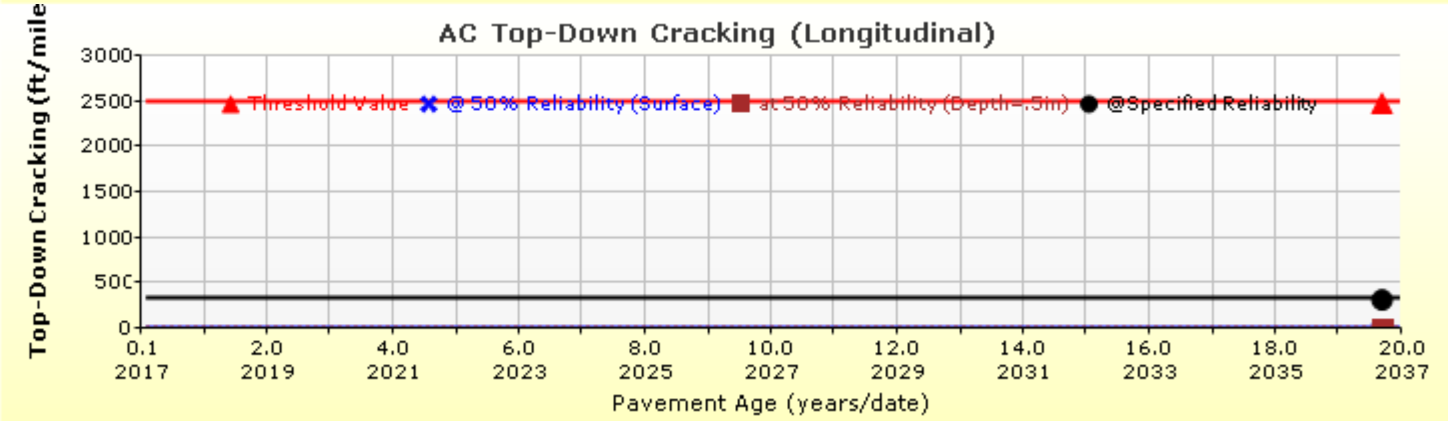




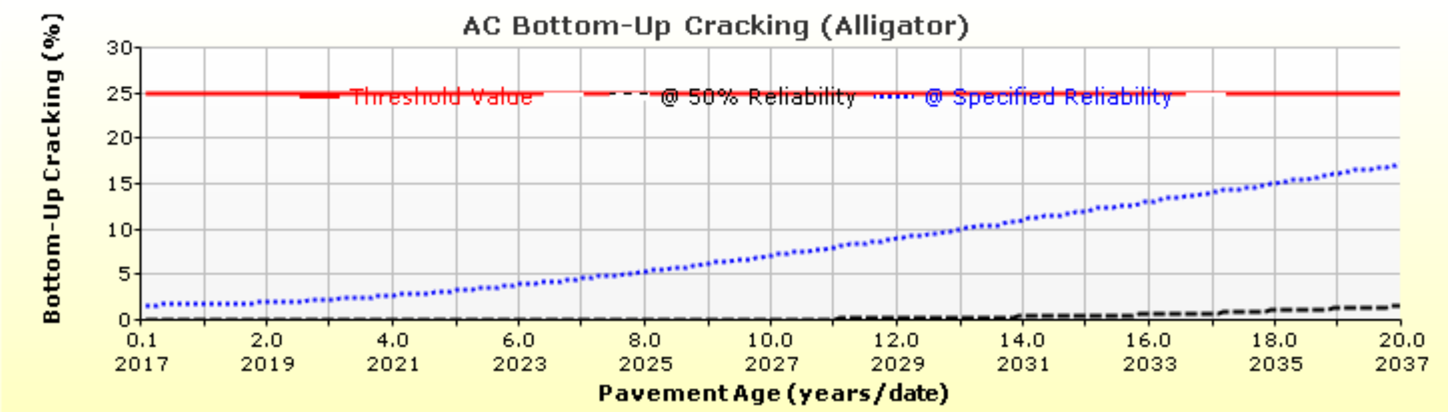
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



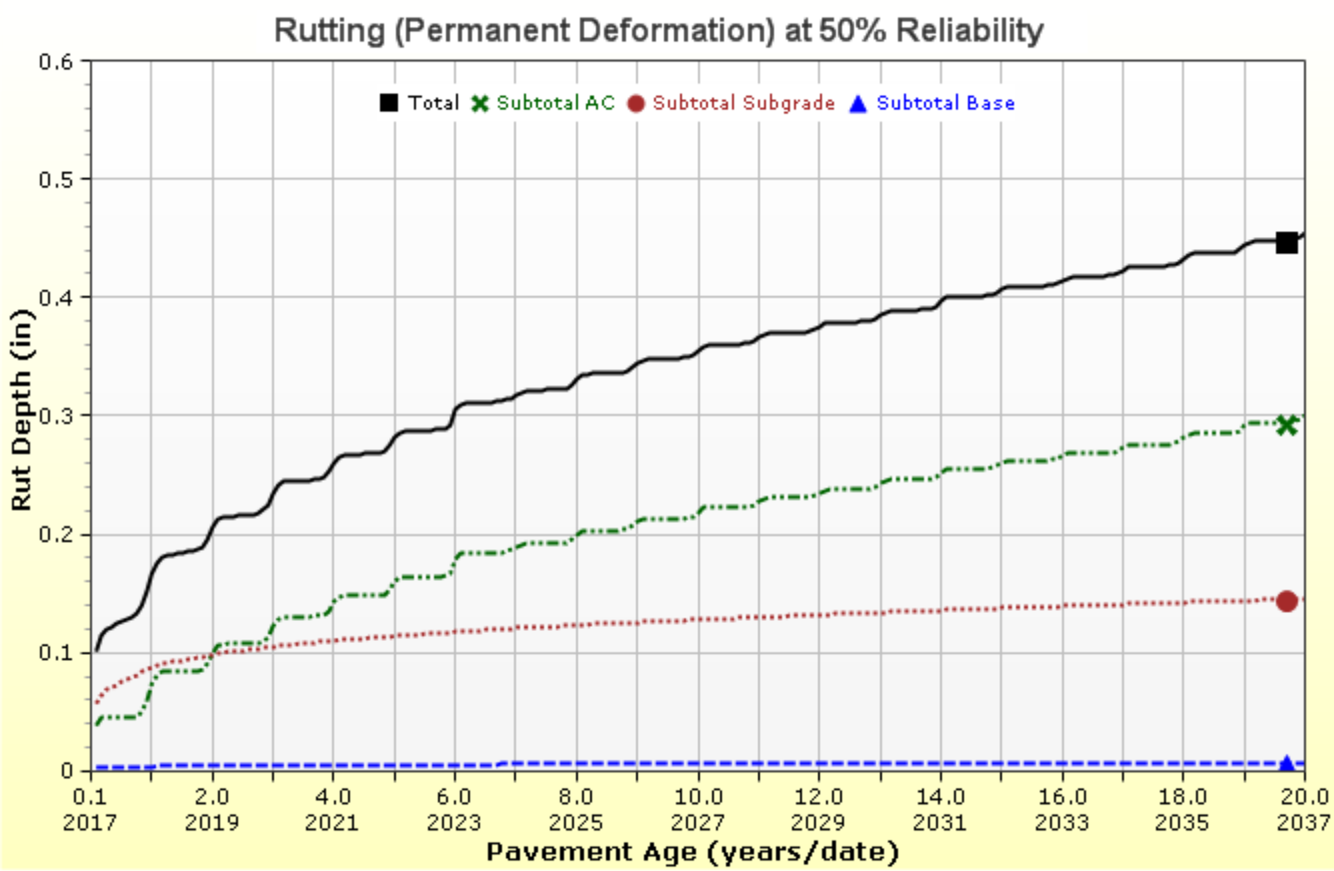
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



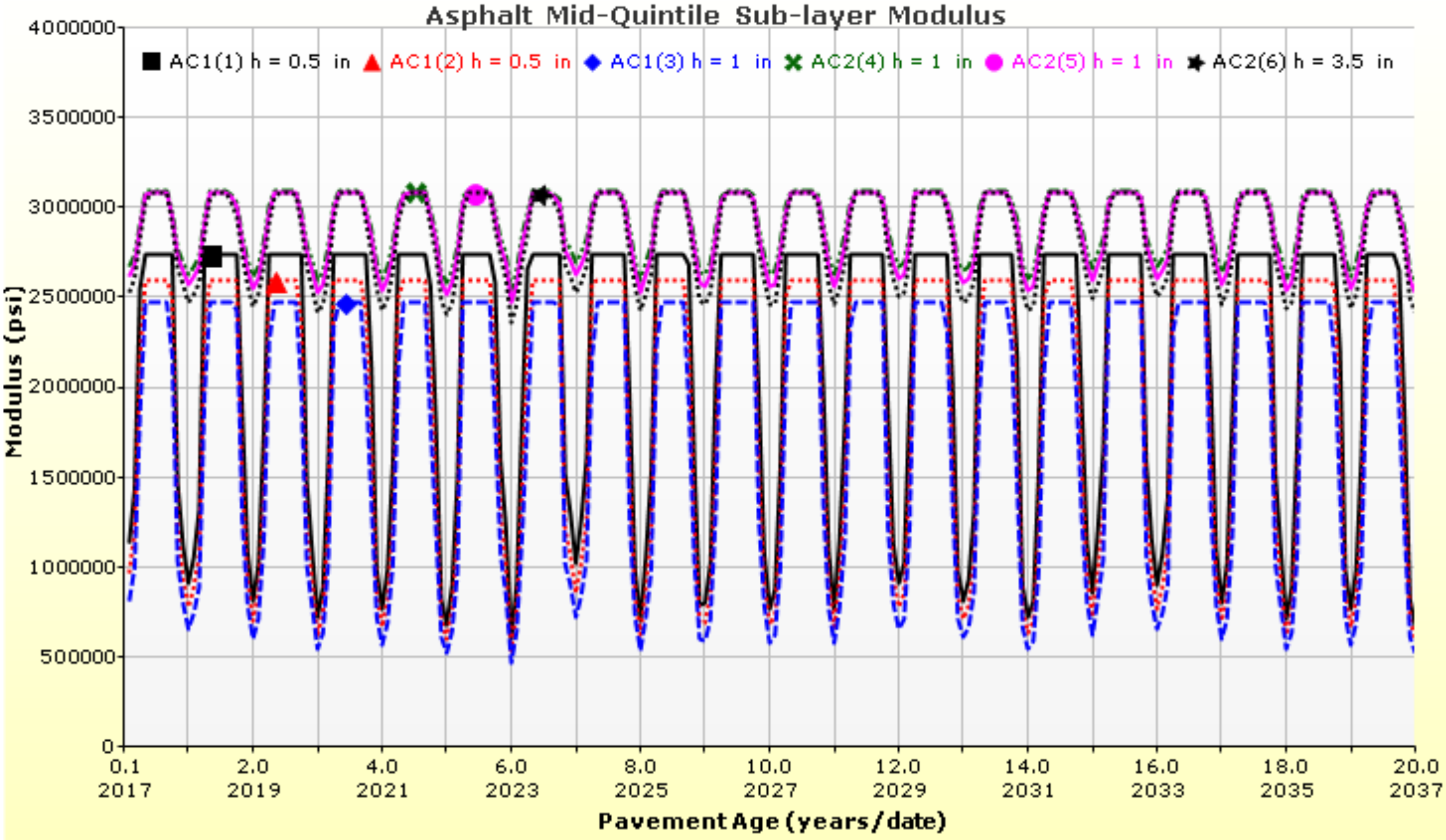
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)



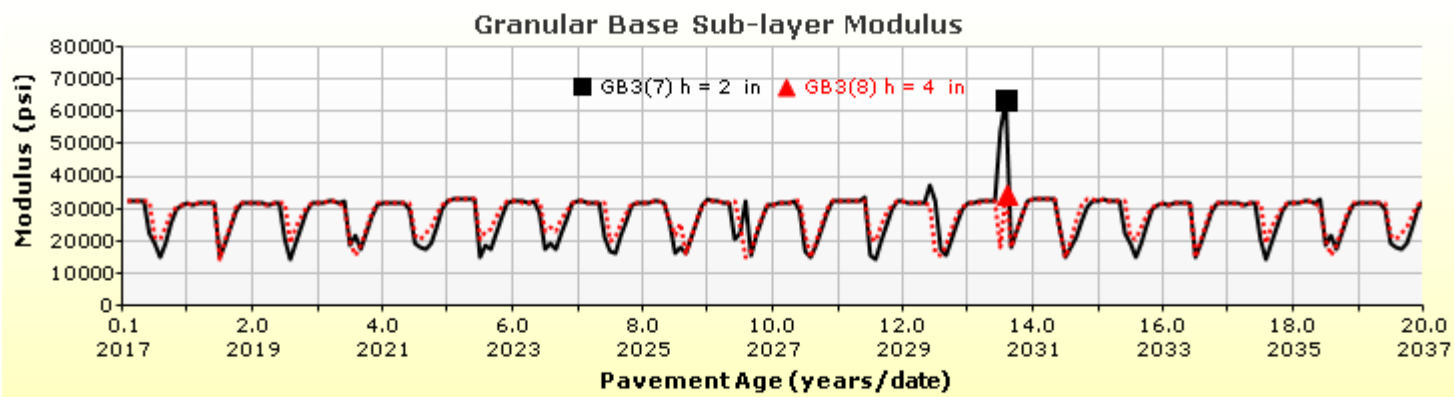
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



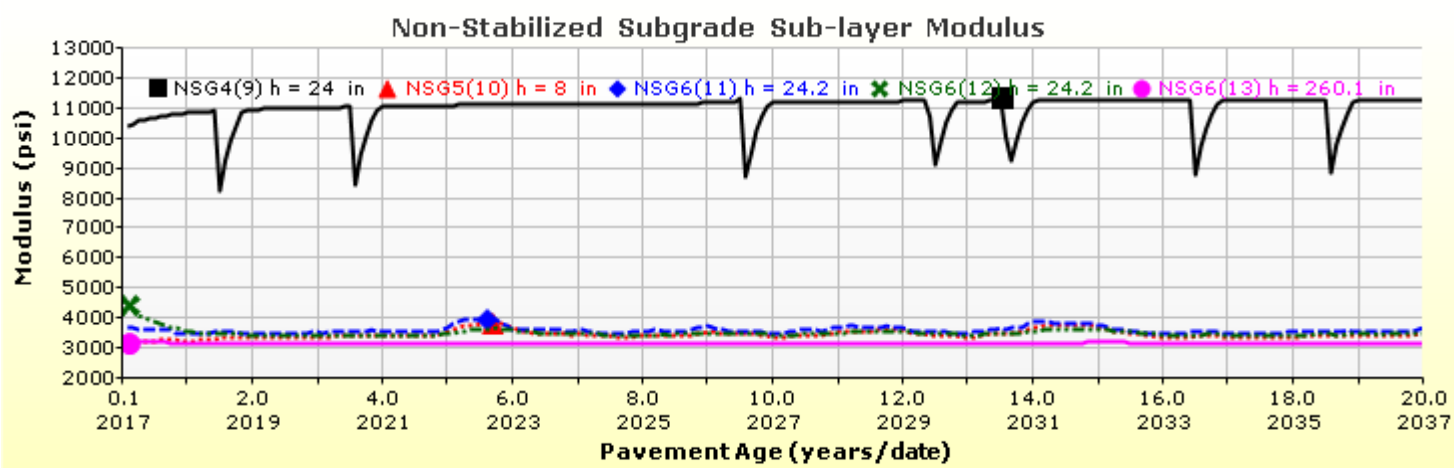
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 3.5 in
Modulus (psi)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 4 in
Modulus (psi)
80000
70000
60000
50000
40000
30000
20000
10000
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG4(9) h = 24 in
NSG5(10) h = 8 in
NSG6(11) h = 24.2 in
NSG6(12) h = 24.2 in
NSG6(13) h = 260.1 in
Modulus (psi)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 SMA

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1875400	2299039	2624309	2726019
40	846575	1309050	1799540	1983379
70	230100	427271	753122	918360
100	76296	127286	231357	296468
130	40803	55308	84229	102895

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	9836	57
158	4538	59
168.8	2220	61

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	12.2
Air voids (%)	4.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 SMA
Description of object	Mix ID # FS1919-2
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Flexible : R1 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	5.5	
Unit weight (pcf)	152.6	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1875400	2299039	2624309	2726019		
40	846575	1309050	1799540	1983379		
70	230100	427271	753122	918360		
100	76296	127286	231357	296468		
130	40803	55308	84229	102895		

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	9836	57
158	4538	59
168.8	2220	61

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.48
Air voids (%)	4.9
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R1 Level 1 S(100) PG 64-22
Description of object	Mix ID # FS29326
Author	CDOT
Date Created	2/11/2015 12:00:00 AM
Approver	CDOT
Date approved	2/11/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : CDOT Class 6 ABC (Mr-20000)

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	CDOT Class 6 ABC (Mr-20000)
Description of object	Aggregate Base Course (ABC)
Author	RockSol JBiller
Date Created	12/31/2014 12:00:00 AM
Approver	JBiller
Date approved	12/31/2014 12:00:00 AM
State	Colorado
District	
County	United States
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	A-1-a
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 4 Subgrade : A-2-4 (R-40)

Unbound	
Layer thickness (in)	24.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-2-4 (R-40)
Description of object	Improved Subgrade
Author	RockSol JBiller
Date Created	1/1/2011 12:00:00 AM
Approver	JBiller
Date approved	1/1/2011 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	14.0
Plasticity Index	2.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124
Saturated hydraulic conductivity (ft/hr)	False	5.854e-04
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	9

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	9.5043
bf	0.6439
cf	3.0636
hr	189.6000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 5 Subgrade : A-6 (R-5)

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (R-5)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 6 Subgrade : A-6 (Native)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (Native)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	20.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	106.2
Saturated hydraulic conductivity (ft/hr)	False	2.543e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	18.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	115.7360
bf	0.6334
cf	0.1681
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Calibration Coefficients

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting (using Multilayer Calibration)		
$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(°F)$ $N = number\ of\ load\ repetitions$	
AC Rutting Standard Deviation	0.1414*Pow(RUT,0.25)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture	
$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$ $\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = refression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_M = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
Level 1 K: 6.3	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue			
$N_f = 10^{\left(\frac{k_1 \beta_{c1}\left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$	$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$ $\sigma_s = Tensile\ stress(psi)$ $M_r = modulus\ of\ rupture(psi)$		
k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

δ_a = permanent deformation for the layer
N = number of repetitions
ε_v = average veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104*Pow(BASERUT,0.67)+0.001		Standard Deviation (BASERUT) 0.0663*Pow(SUBRUT,0.5)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D*100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	c3: 6000
AC Cracking Top Standard Deviation				**AC Cracking Bottom Standard Deviation**		
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))				1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))		

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation			
CTB*1			

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02

302.02 - US50 Westbound - Rigid - R-5 Subgrade

File Name: E:\ME Design\302.02 - US50\302.02 - US50 Westbound - Rigid - R-5 Subgrade.dgpx

Design Inputs

Design Life: 30 years
Design Type: Jointed Plain Concrete Pavement (JPCP)

Existing construction: -
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 38.29, -104.498

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.5
NonStabilized	CDOT Class 6 ABC (Mr-20000)	6.0
Subgrade	A-2-4 (R-40)	24.0
Subgrade	A-6 (R-5)	8.0
Subgrade	A-6 (Native)	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

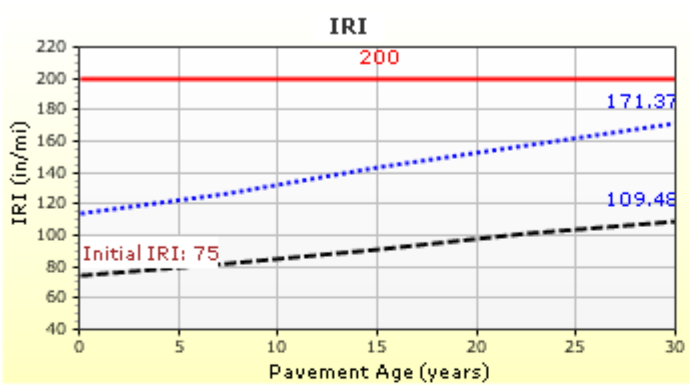
Age (year)	Heavy Trucks (cumulative)
2017 (initial)	2,900
2032 (15 years)	5,984,360
2047 (30 years)	14,578,400

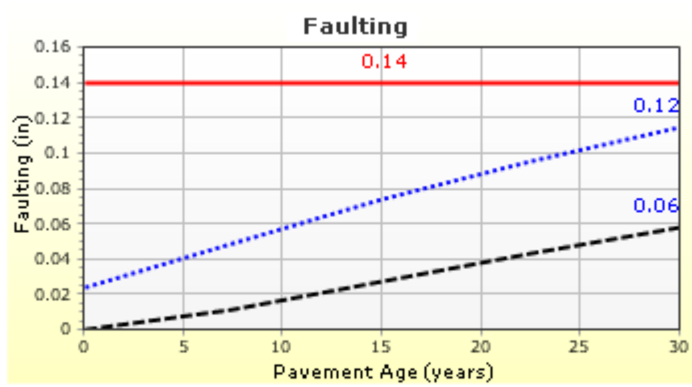
Design Outputs

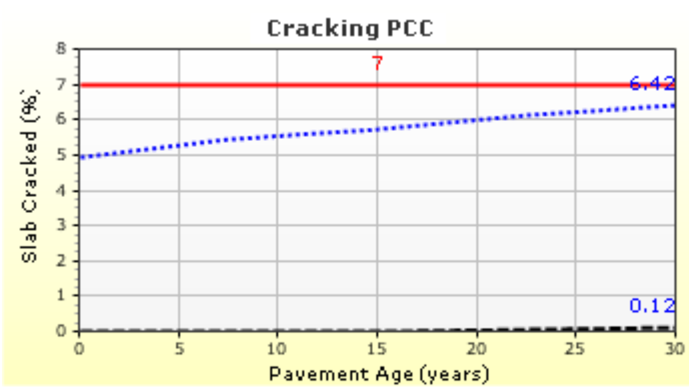
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	171.37	95.00	99.19	Pass
Mean joint faulting (in)	0.14	0.12	95.00	99.07	Pass
JPCP transverse cracking (percent slabs)	7.00	6.42	95.00	96.38	Pass

Distress Charts



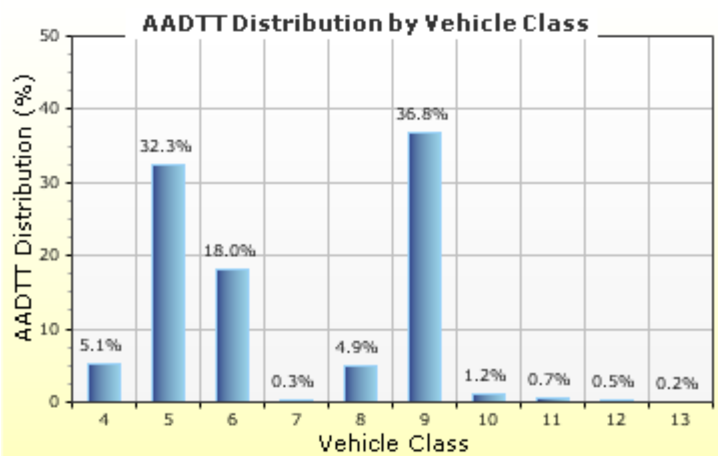


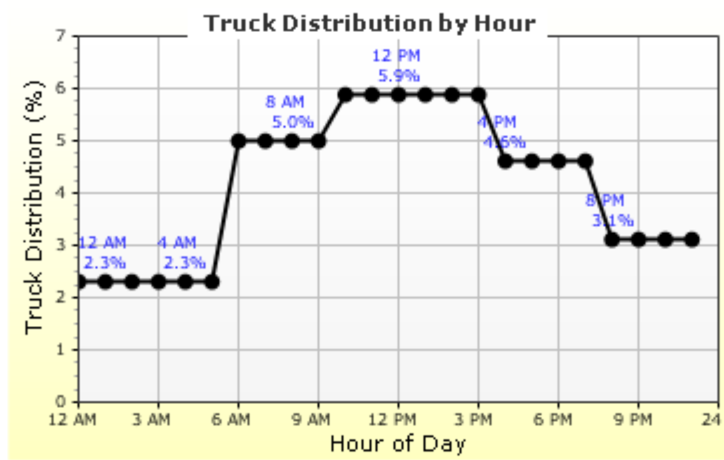


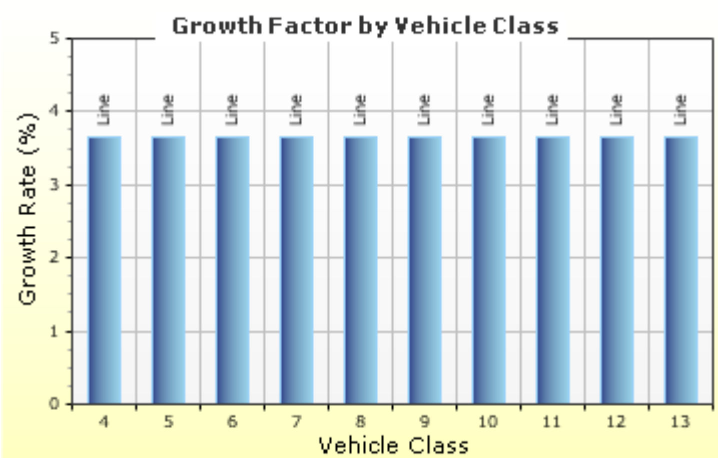
Traffic Inputs

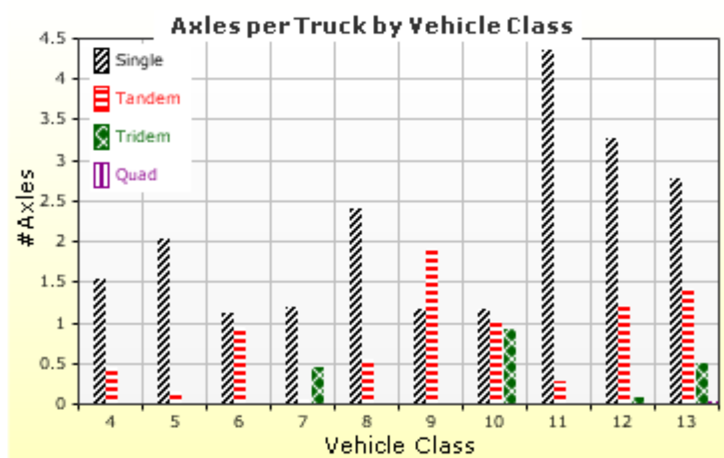
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,900	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	6	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	55.0

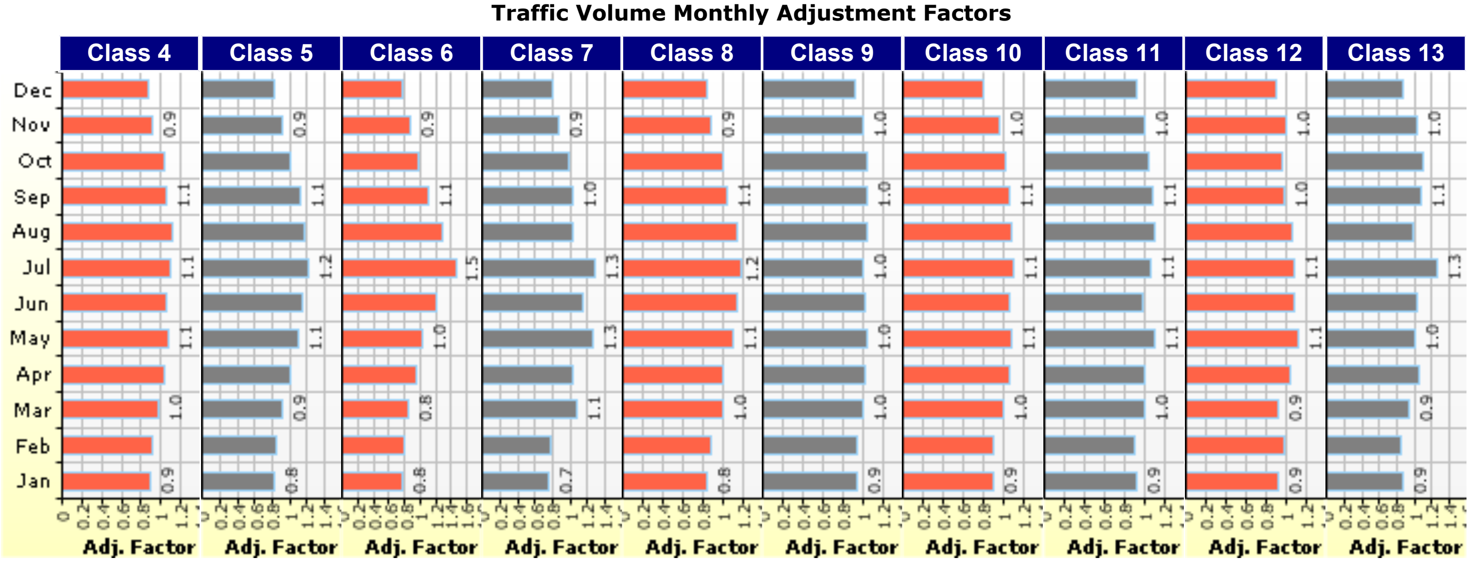








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3.65%	Linear
Class 5	32.3%	3.65%	Linear
Class 6	18%	3.65%	Linear
Class 7	0.3%	3.65%	Linear
Class 8	4.9%	3.65%	Linear
Class 9	36.8%	3.65%	Linear
Class 10	1.2%	3.65%	Linear
Class 11	0.7%	3.65%	Linear
Class 12	0.5%	3.65%	Linear
Class 13	0.2%	3.65%	Linear

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	2.3%	12 PM	5.9%
1 AM	2.3%	1 PM	5.9%
2 AM	2.3%	2 PM	5.9%
3 AM	2.3%	3 PM	5.9%
4 AM	2.3%	4 PM	4.6%
5 AM	2.3%	5 PM	4.6%
6 AM	5%	6 PM	4.6%
7 AM	5%	7 PM	4.6%
8 AM	5%	8 PM	3.1%
9 AM	5%	9 PM	3.1%
10 AM	5.9%	10 PM	3.1%
11 AM	5.9%	11 PM	3.1%
		Total	100%

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

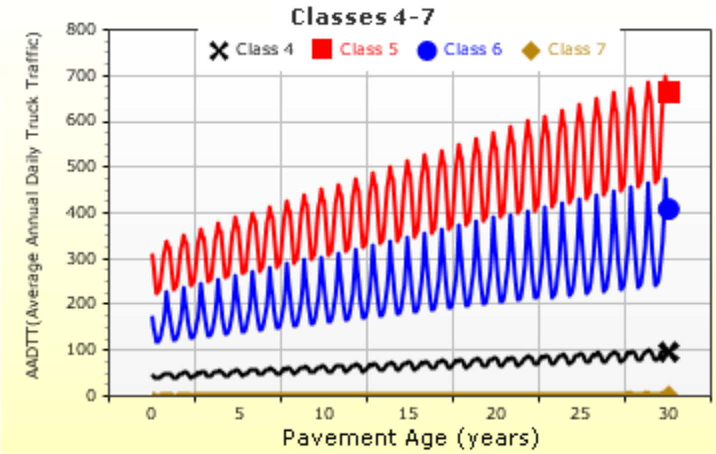
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

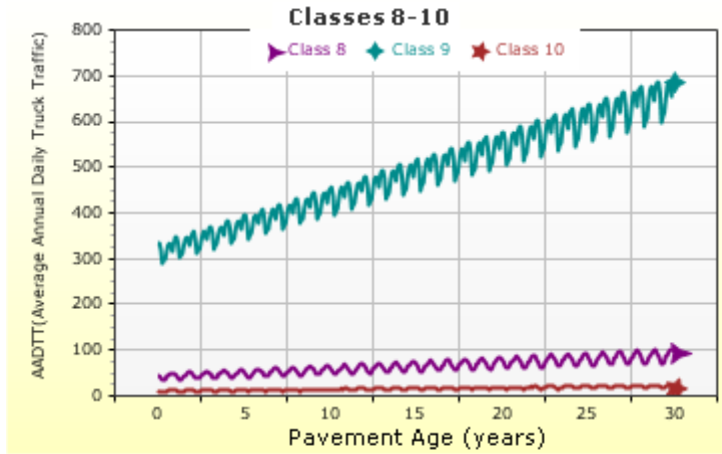
Number of Axles per Truck

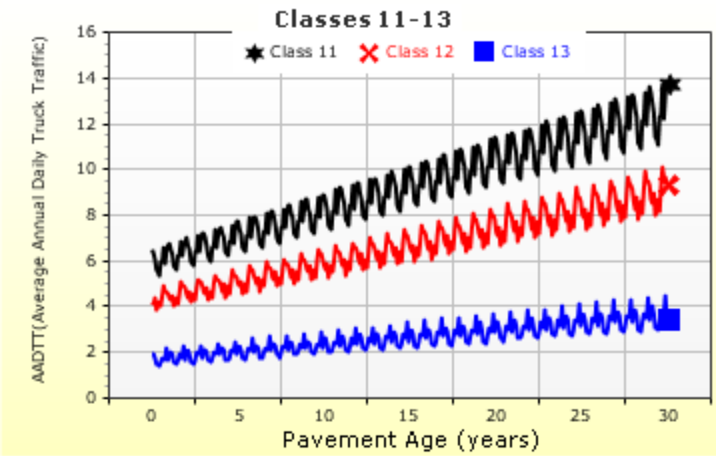
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.94	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.9	0.01	0
Class 10	1.15	1.01	0.93	0.02
Class 11	4.35	0.29	0.02	0
Class 12	3.27	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

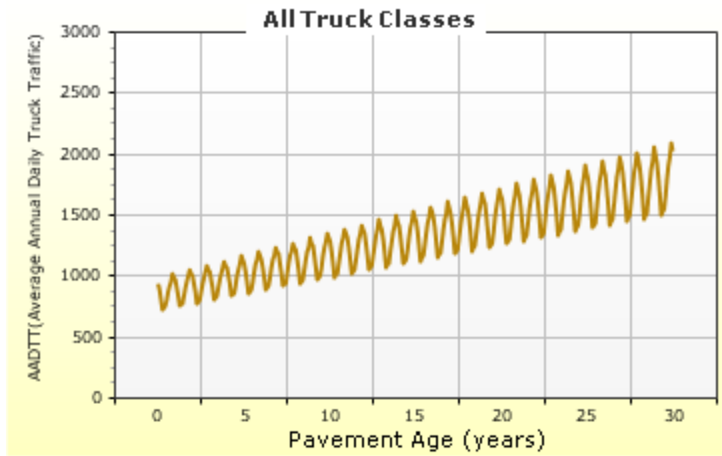
AADTT (Average Annual Daily Truck Traffic) Growth

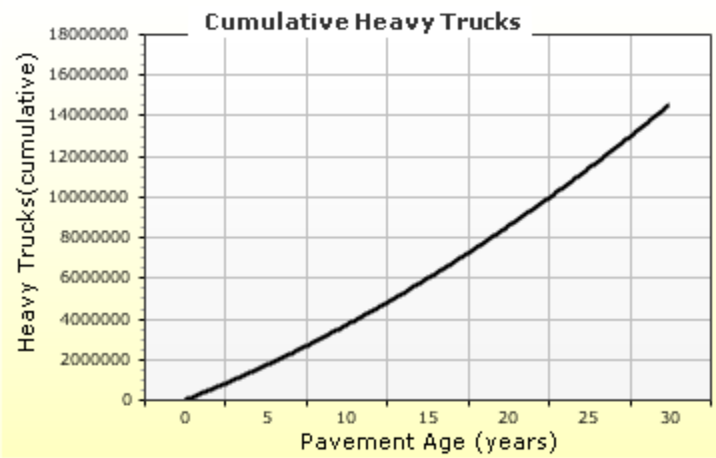
*** Traffic cap is not enforced**







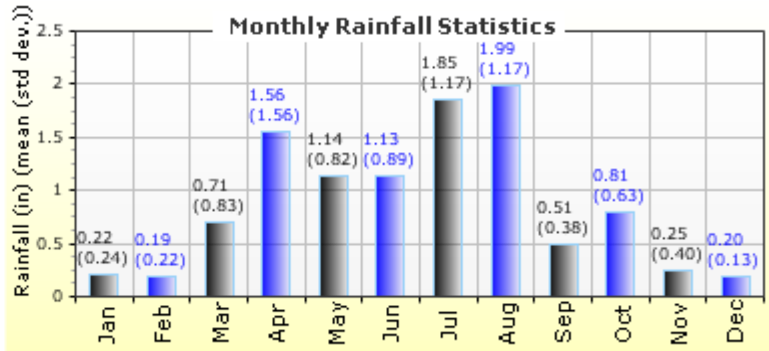




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
PUEBLO, CO	38.29000 -104.49800 4720

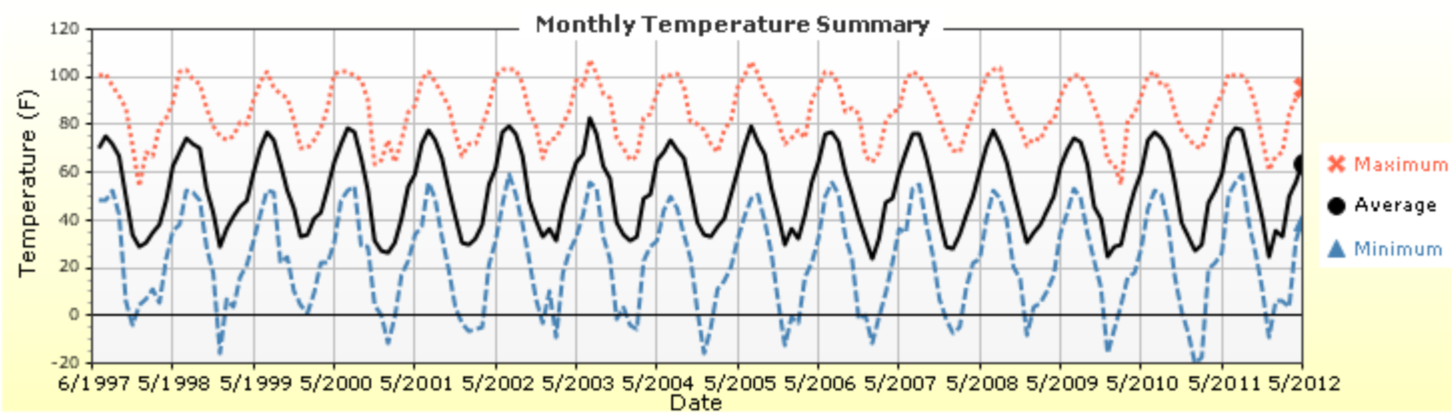


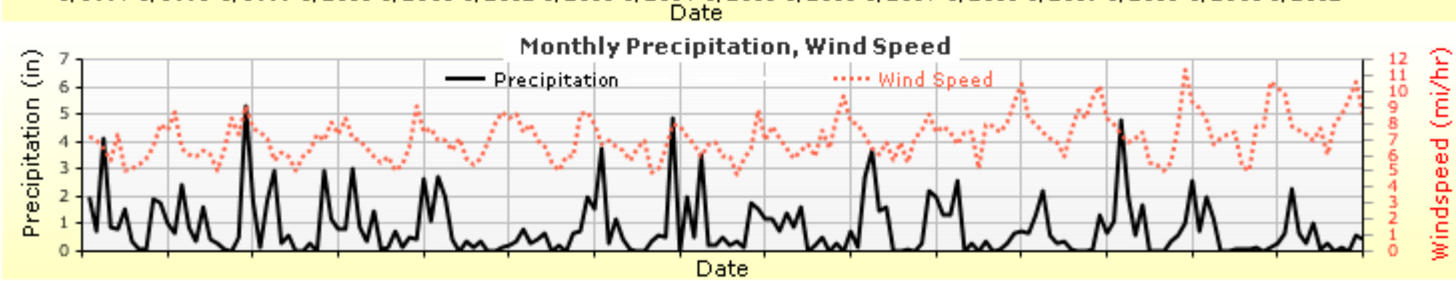
Annual Statistics:

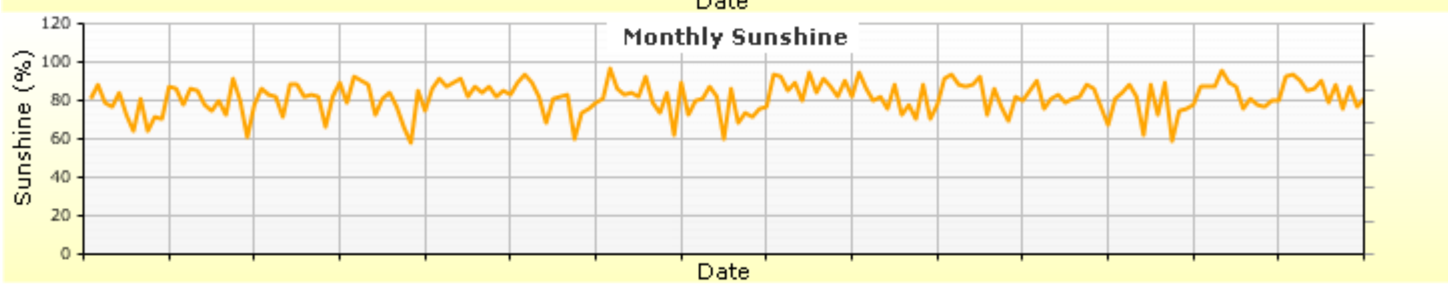
Mean annual air temperature (ºF)	52.71
Mean annual precipitation (in)	10.55
Freezing index (ºF - days)	390.7
Average annual number of freeze/thaw cycles:	142.17

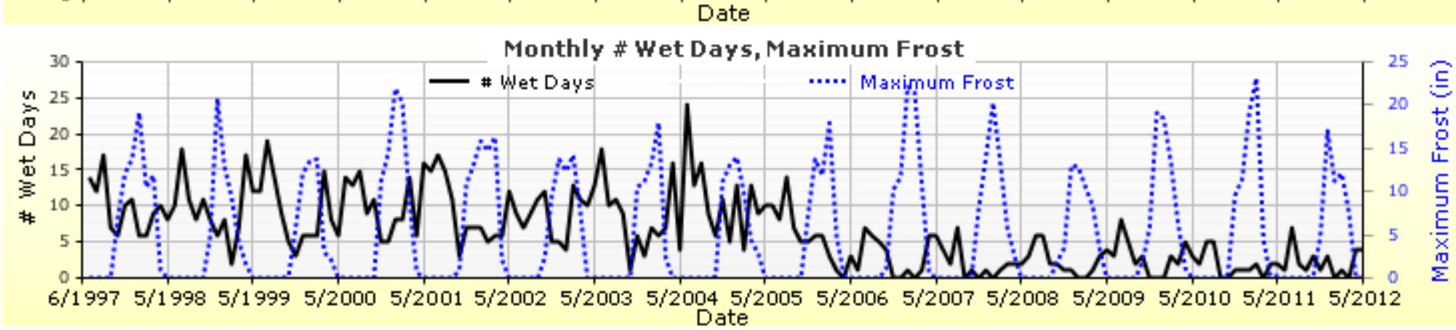
Water table depth (ft)	10.00

Monthly Climate Summary:

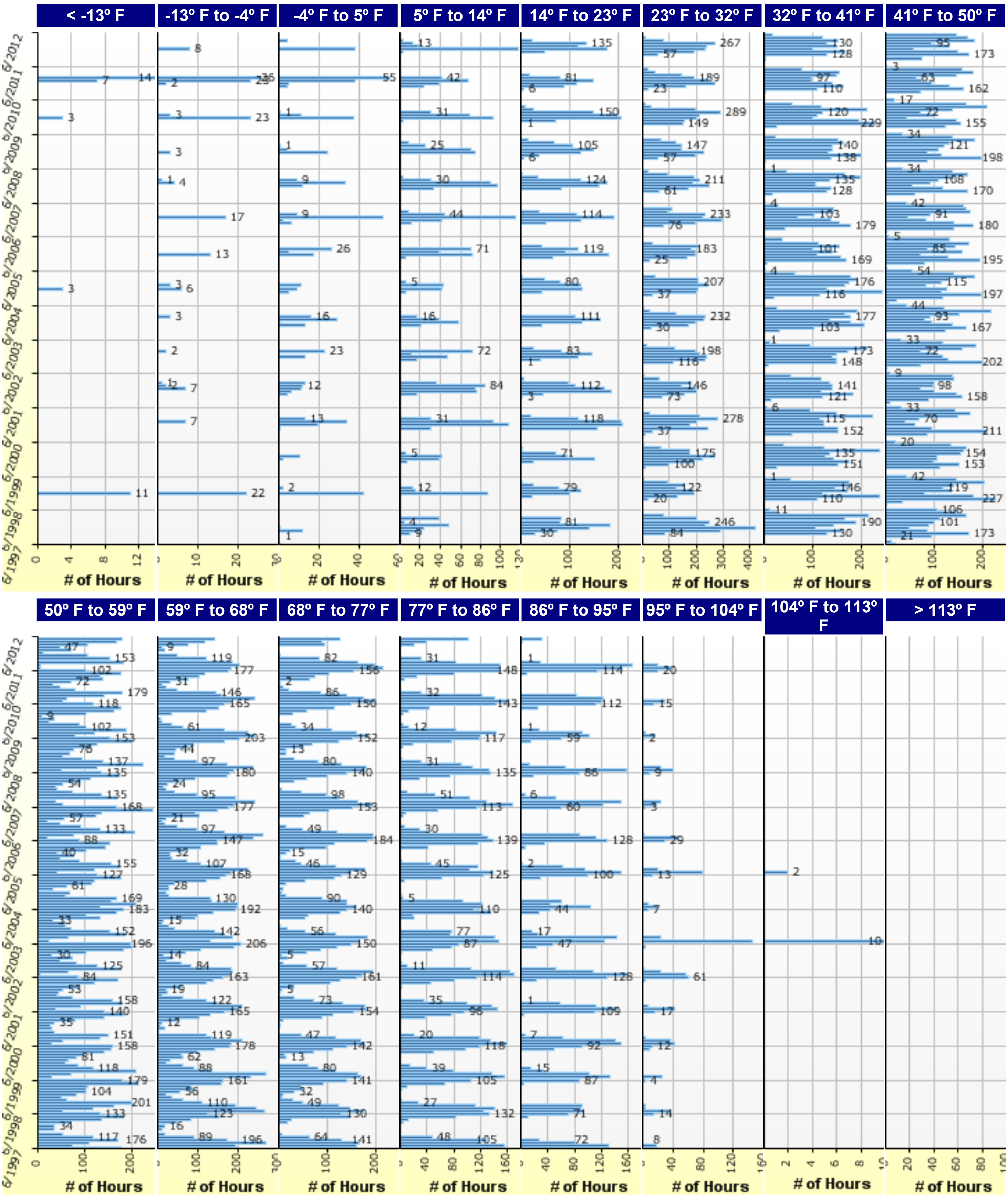








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in)	1.25
Dowel spacing (in)	12.00

Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	40.00

PCC joint spacing (ft)	
Is joint spacing random ?	False
Joint spacing (ft)	15.00

Widened Slab	
Is slab widened ?	False
Slab width (ft)	12.00

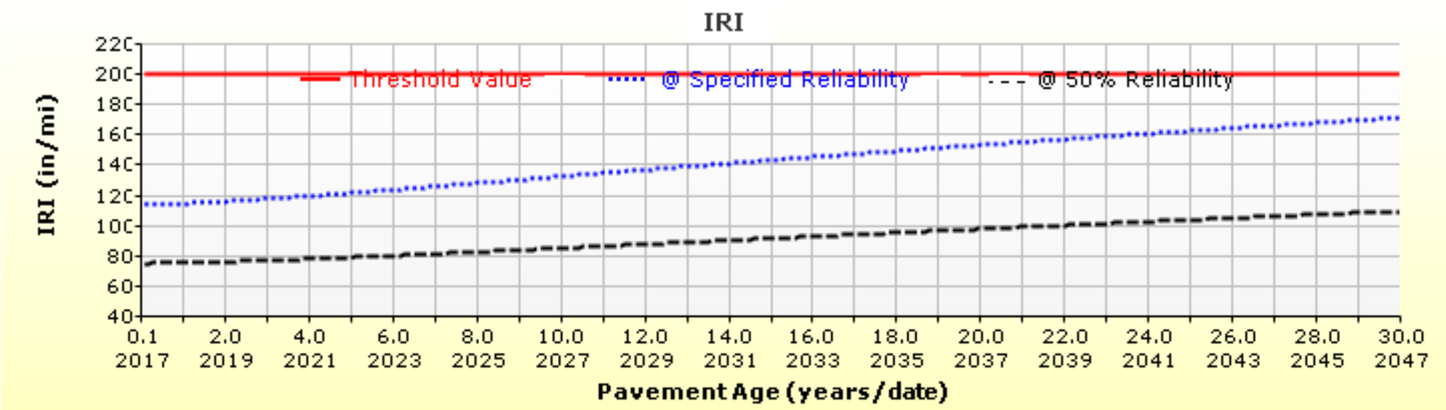
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	240.00

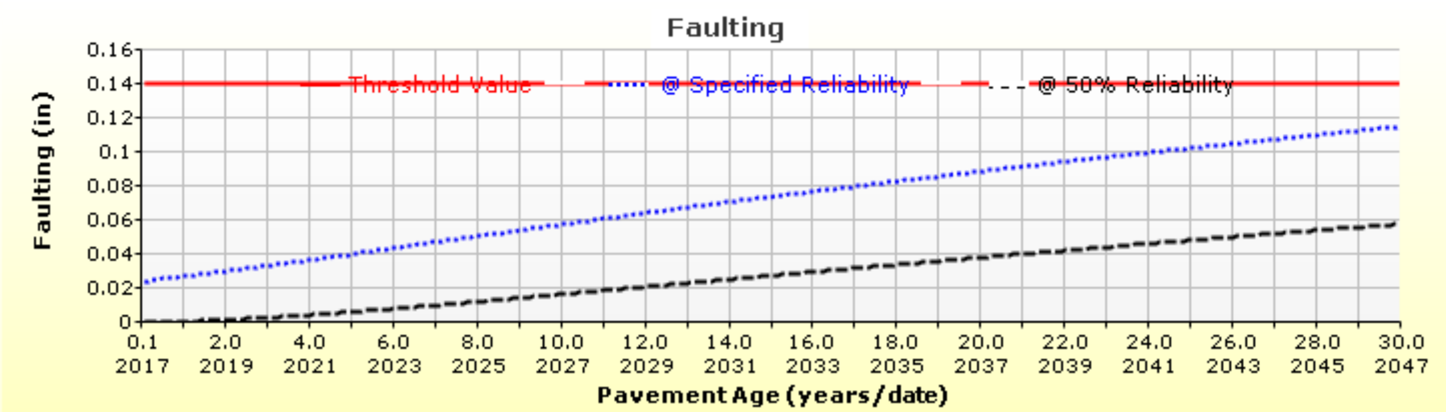
Sealant type	Preformed

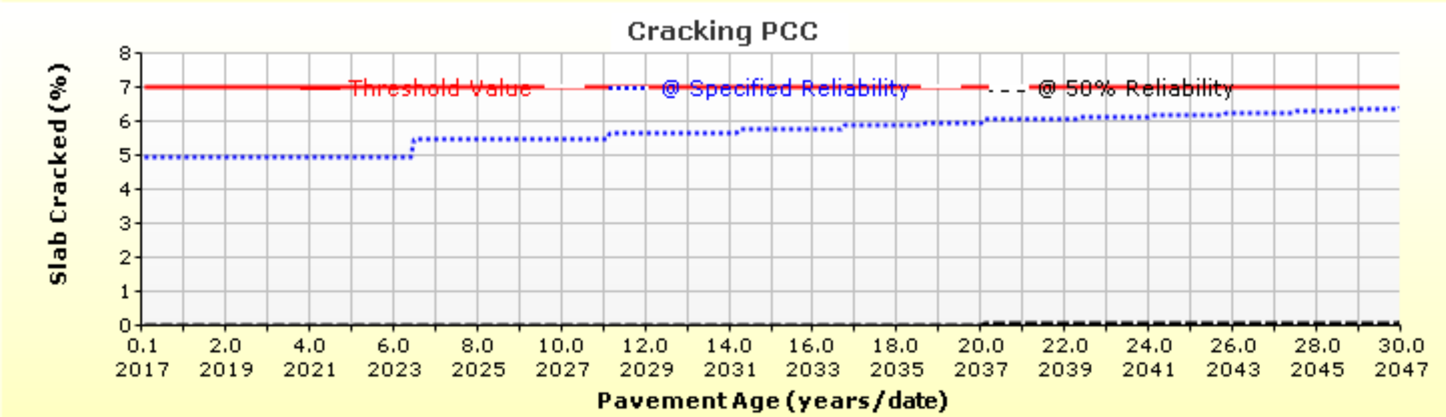
Erodibility index	4

Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

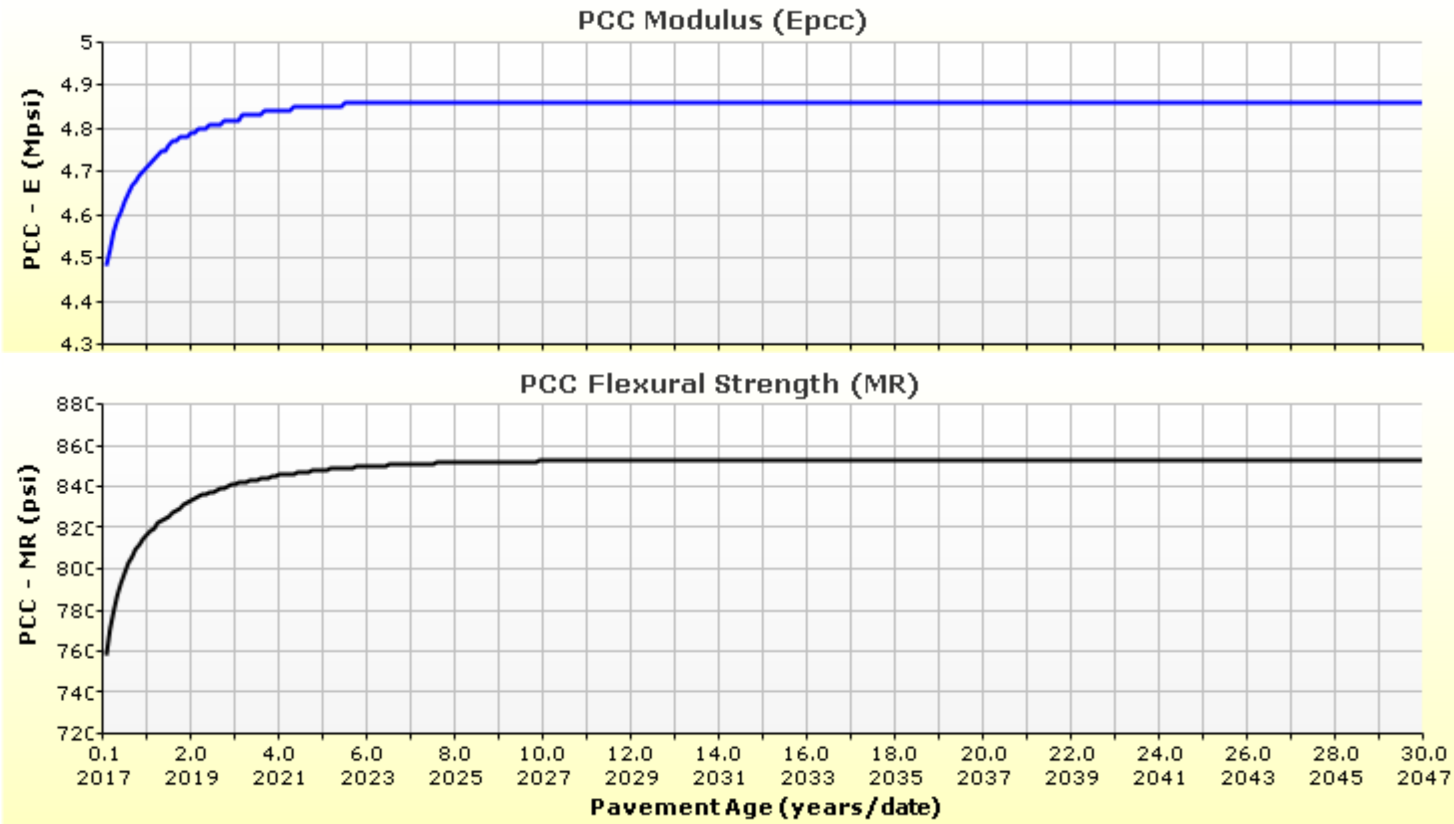


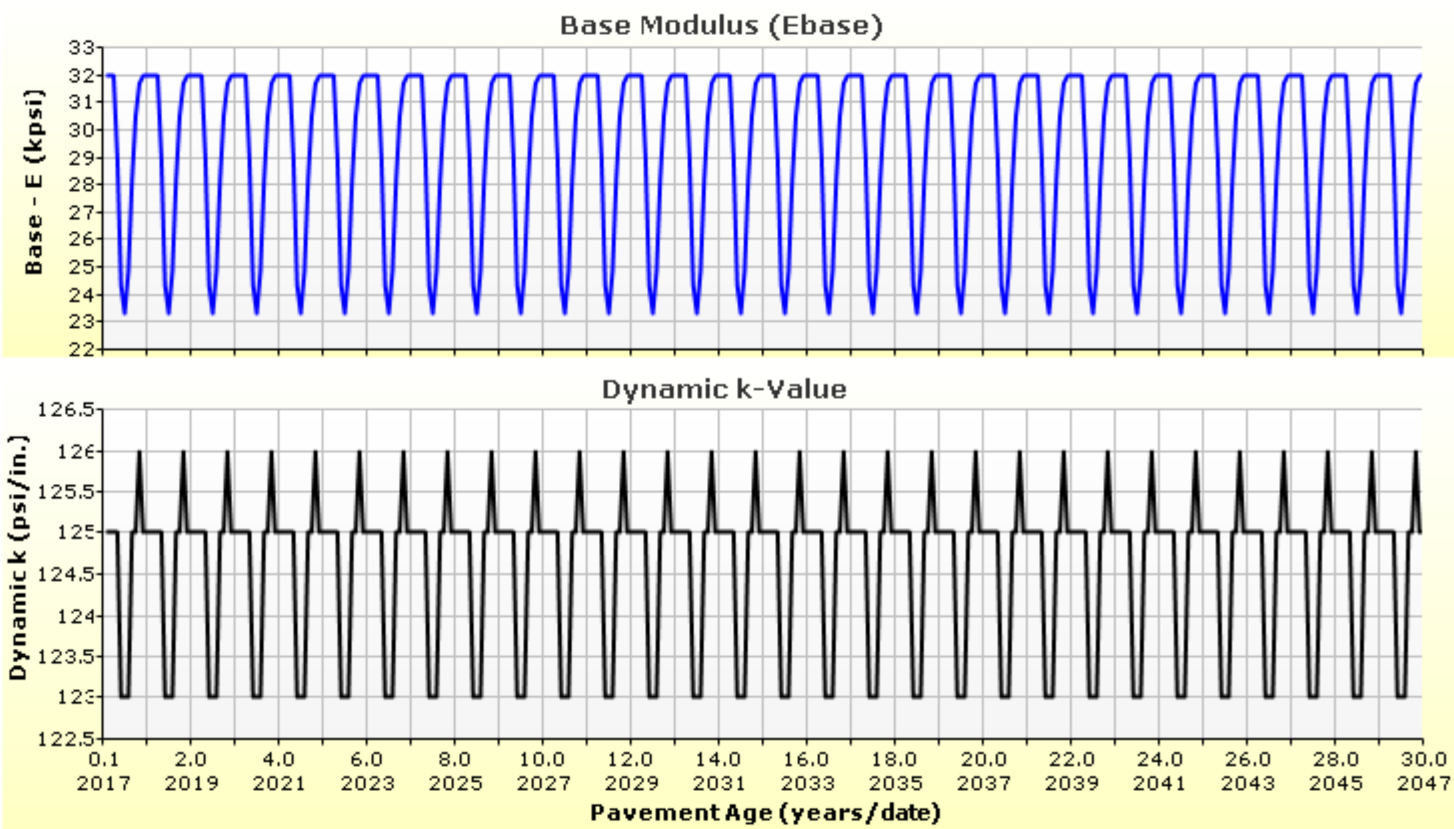


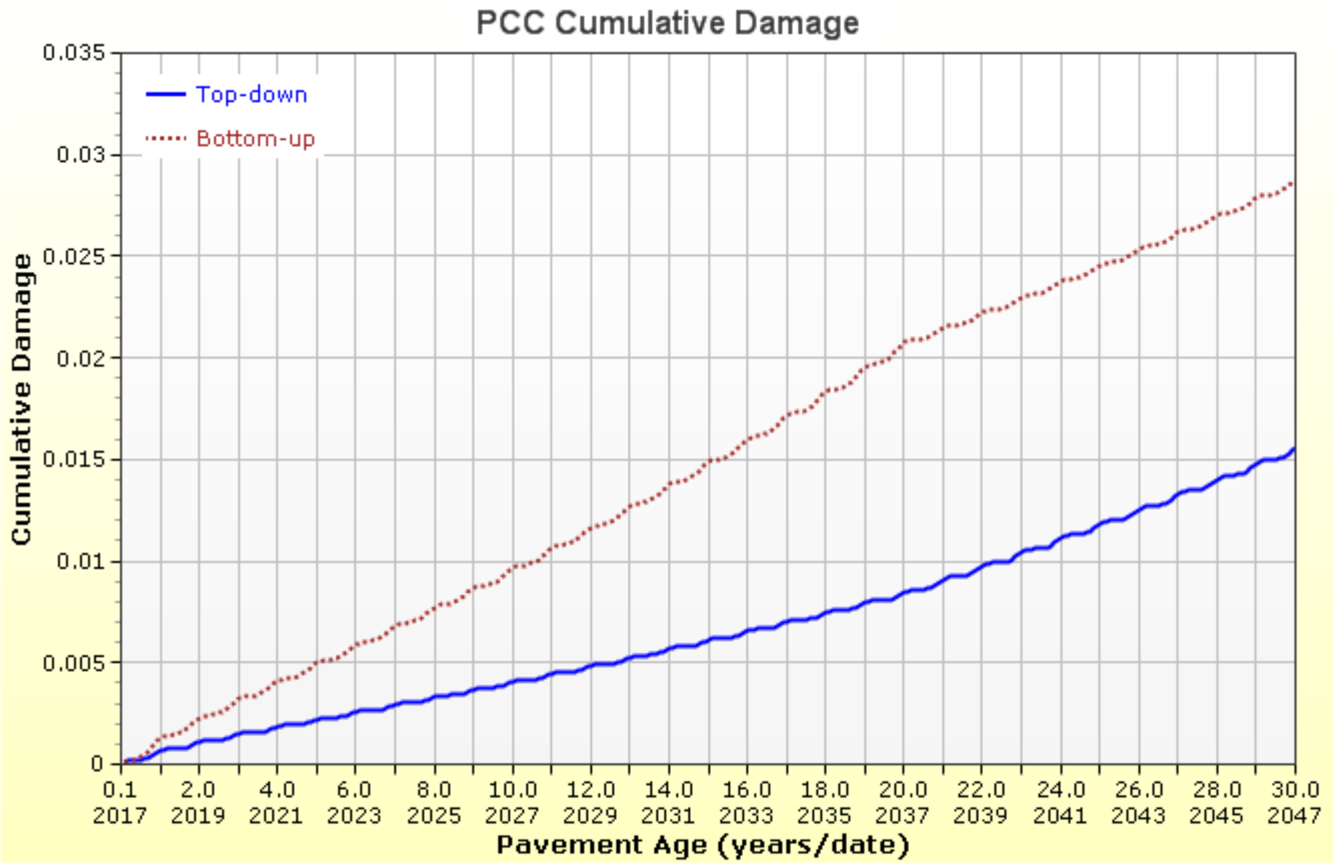


302.02 - US50 Westbound - Rigid - R-5 Subgrade

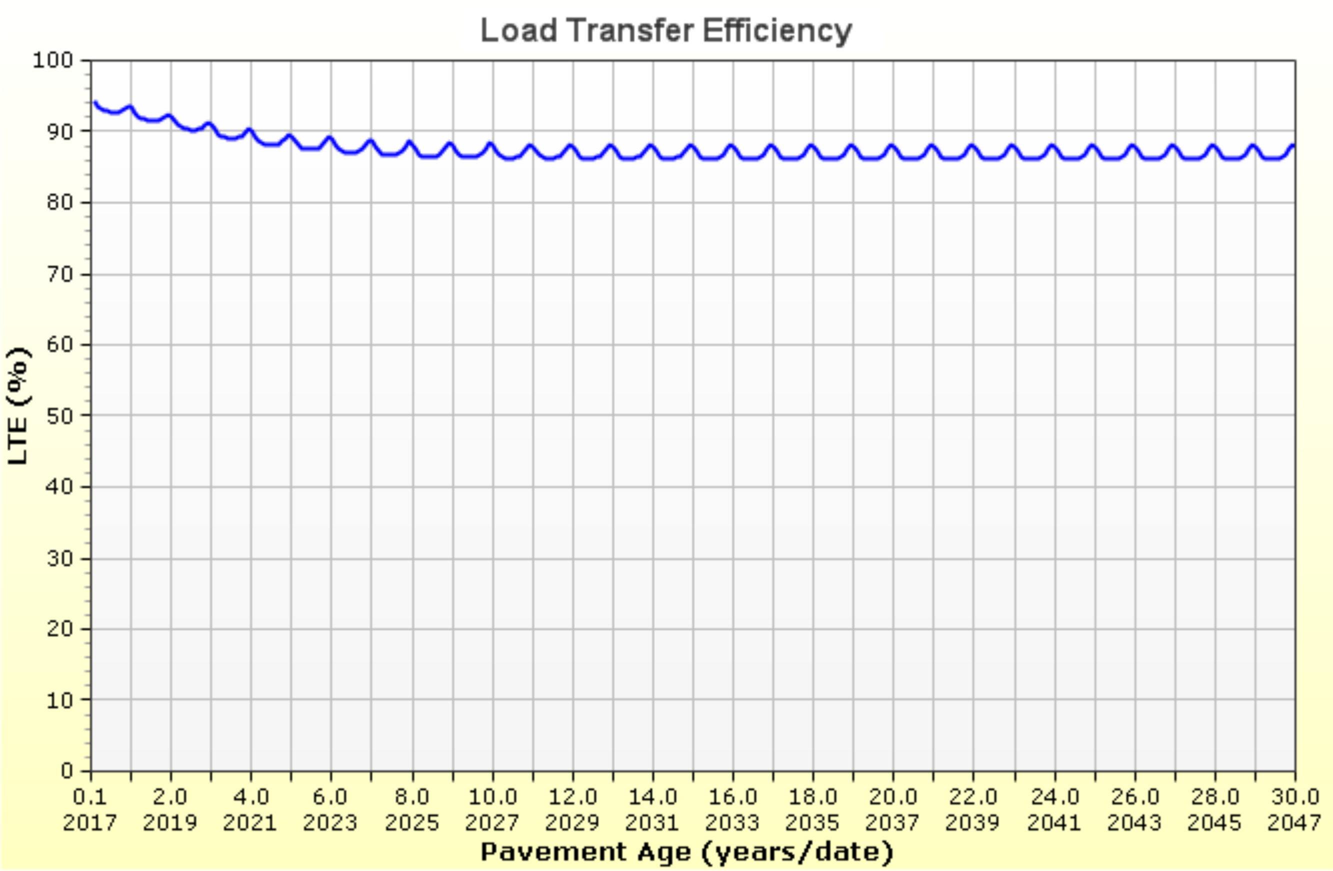
File Name: E:\ME Design\302.02 - US50\302.02 - US50 Westbound - Rigid - R-5 Subgrade.dgpx







PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
22.0 2039
24.0 2041
26.0 2043
28.0 2045
30.0 2047
Pavement Age (years/date)



Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
22.0 2039
24.0 2041
26.0 2043
28.0 2045
30.0 2047
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.5
Unit weight (pcf)	140.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.86
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		563
Water to cement ratio		0.36
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	101.5
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	516.0
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	560	3230000
14-day	620	3500000
28-day	710	4030000
90-day	730	4240000
20-year/28-day	1.2	1.2

Identifiers

Field	Value
Display name/identifier	R4 Level 1 Lawson
Description of object	Mix ID # 2009105
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : CDOT Class 6 ABC (Mr-20000)

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	CDOT Class 6 ABC (Mr-20000)
Description of object	Aggregate Base Course (ABC)
Author	RockSol JBiller
Date Created	12/31/2014 12:00:00 AM
Approver	JBiller
Date approved	12/31/2014 12:00:00 AM
State	Colorado
District	
County	United States
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	A-1-a
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 3 Subgrade : A-2-4 (R-40)

Unbound	
Layer thickness (in)	24.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-2-4 (R-40)
Description of object	Improved Subgrade (Mr=9500)
Author	RockSol JBiller
Date Created	1/1/2011 12:00:00 AM
Approver	JBiller
Date approved	1/1/2011 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	14.0
Plasticity Index	2.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124
Saturated hydraulic conductivity (ft/hr)	False	5.854e-04
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	9

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	9.5043
bf	0.6439
cf	3.0636
hr	189.6000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 4 Subgrade : A-6 (R-5)

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (R-5)
Description of object	Disturbed Native Material (Mr=5356)
Author	Jacob Biller Rocksol
Date Created	7/20/2015 12:00:00 AM
Approver	JBiller
Date approved	7/20/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 5 Subgrade : A-6 (Native)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (Native)
Description of object	Undisturbed Native Material (Mr=5356)
Author	RockSol Consulting Group Inc.
Date Created	7/20/2015 12:00:00 AM
Approver	JBiller
Date approved	7/20/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Calibration Coefficients

PCC Faulting

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$

$$C_{34} = C_3 + (C_4 * FR^{0.25})$$

$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_s}\right)\right]^{C_6}$$

$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$

$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$

$$C_8 = DowelDeterioration$$

C1: 1.0184	C2: 0.91656	C3: 0.0021848	C4: 0.000883739
C5: 250	C6: 0.4	C7: 1.83312	C8: 400

PCC Reliability Faulting Standard Deviation

Pow(0.0097*FAULT,0.5178)+0.014

IRI-jpcp

C1 - Cracking	C1: 0.8203	C2: 0.4417
C2 - Spalling	C3: 1.4929	C4: 25.24
C3 - Faulting	**Reliability Standard Deviation**	
C4 - Site Factor	5.4	

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$

$$CRK = \frac{100}{1 + C4\ FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 1	C5: -1.98

PCC Reliability Cracking Standard Deviation

Pow(5.3116*CRACK,0.3903) + 2.99

US50 Westbound - Flexible - R-5 Subgrade 10 year

File Name: E:\ME Design\302.02 - US50\US50 Westbound - Flexible - R-5 Subgrade 10 year.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: May, 2017
Pavement construction: June, 2017
Traffic opening: August, 2017

Climate Data Sources (Lat/Lon): 38.29, -104.498

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 SMA	2.0
Flexible	R1 Level 1 S(100) PG 64-22	4.0
NonStabilized	CDOT Class 6 ABC (Mr-20000)	6.0
Subgrade	A-2-4 (R-40)	24.0
Subgrade	A-6 (R-5)	8.0
Subgrade	A-6 (Native)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	12.2
Air voids (%)	4.7

Traffic

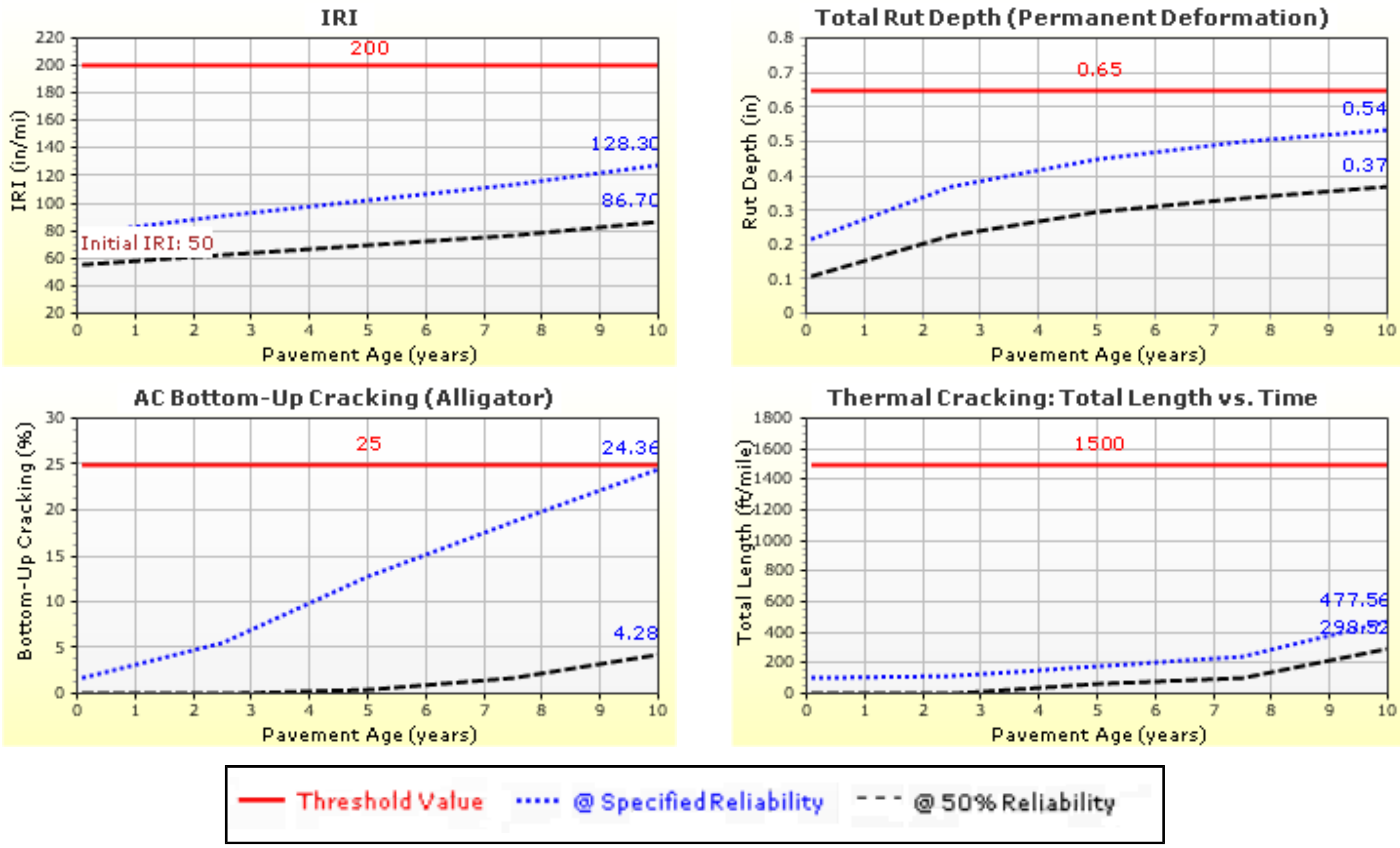
Age (year)	Heavy Trucks (cumulative)
2017 (initial)	2,900
2022 (5 years)	1,709,130
2027 (10 years)	3,753,800

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	128.35	95.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.54	95.00	99.71	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	24.36	95.00	95.51	Pass
AC thermal cracking (ft/mile)	1500.00	477.56	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	455.18	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.37	95.00	99.85	Pass

Distress Charts



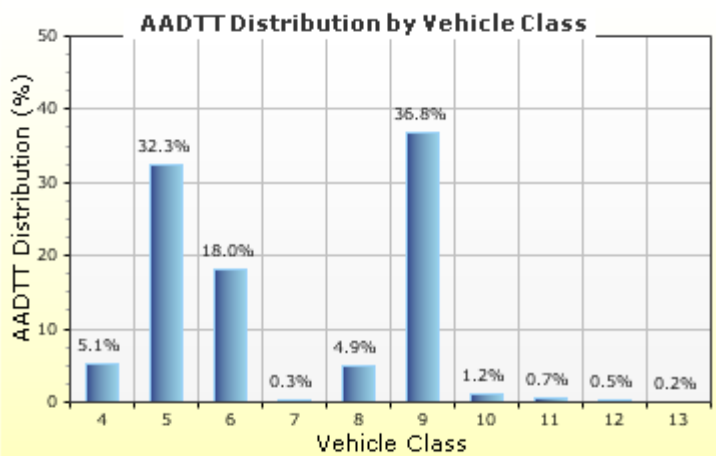
US50 Westbound - Flexible - R-5 Subgrade 10 year

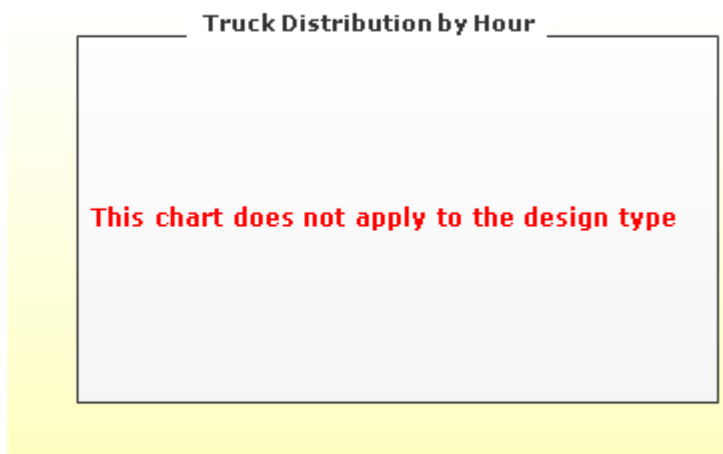
File Name: E:\ME Design\302.02 - US50\US50 Westbound - Flexible - R-5 Subgrade 10 year.dgpx

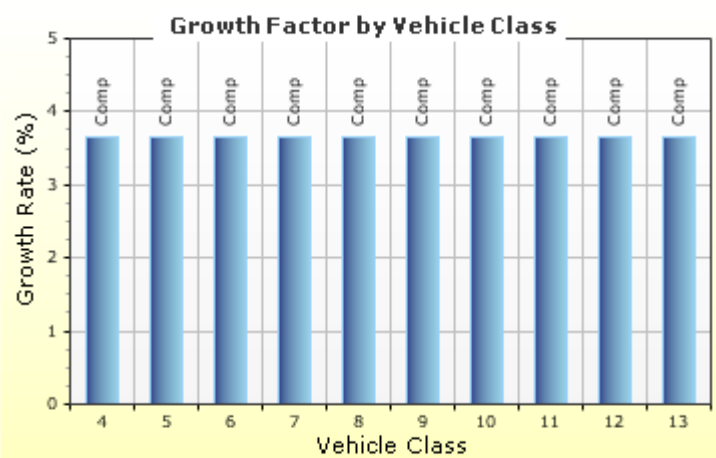
Traffic Inputs

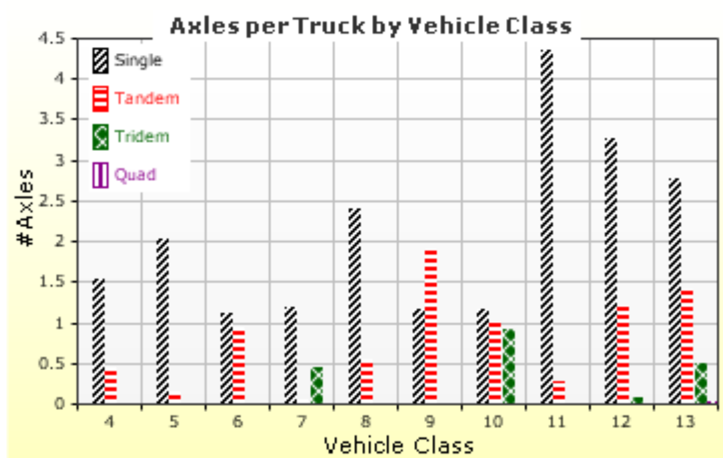
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,900	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	6	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	55.0

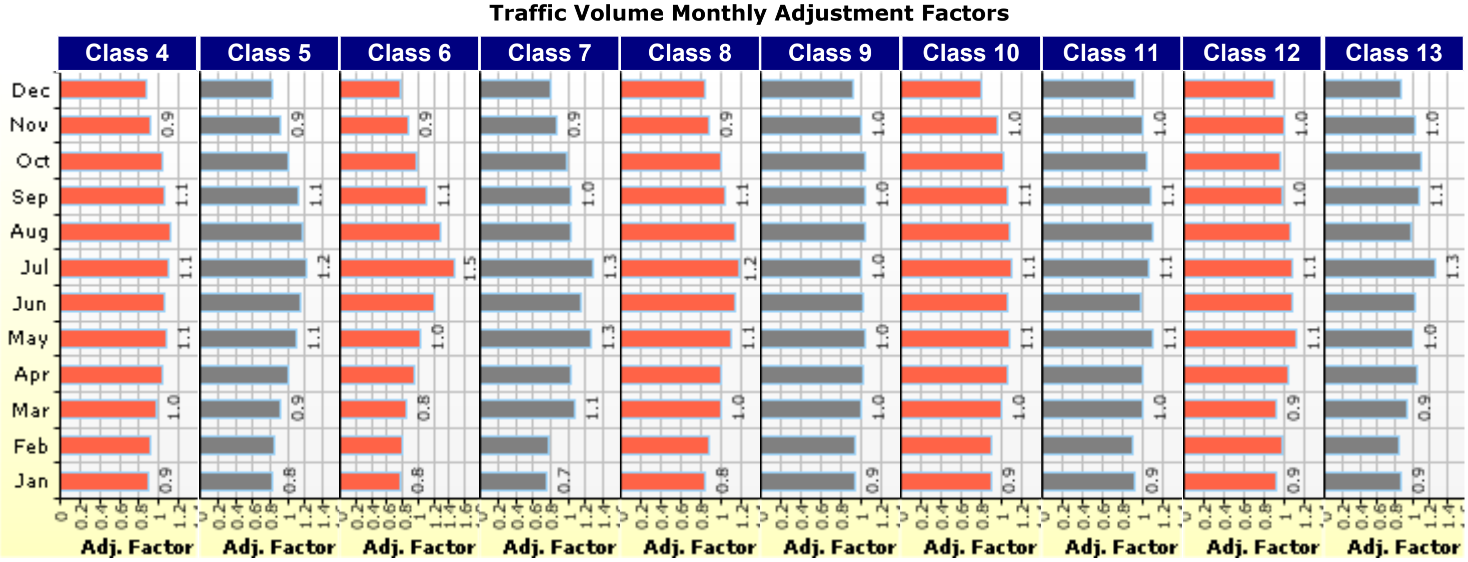








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3.65%	Compound
Class 5	32.3%	3.65%	Compound
Class 6	18%	3.65%	Compound
Class 7	0.3%	3.65%	Compound
Class 8	4.9%	3.65%	Compound
Class 9	36.8%	3.65%	Compound
Class 10	1.2%	3.65%	Compound
Class 11	0.7%	3.65%	Compound
Class 12	0.5%	3.65%	Compound
Class 13	0.2%	3.65%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

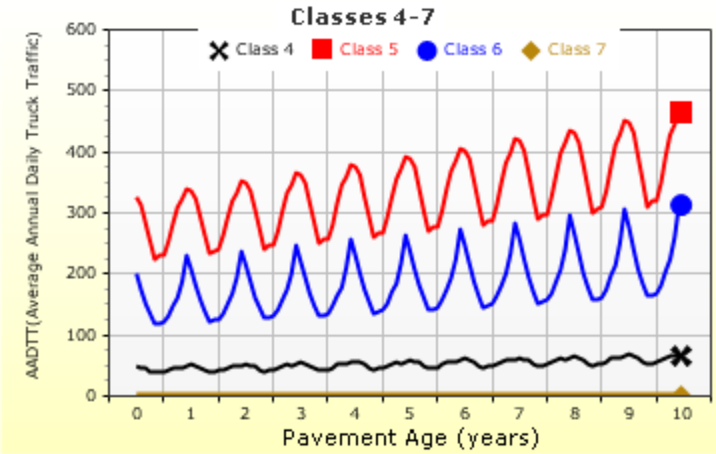
Wheelbase does not apply

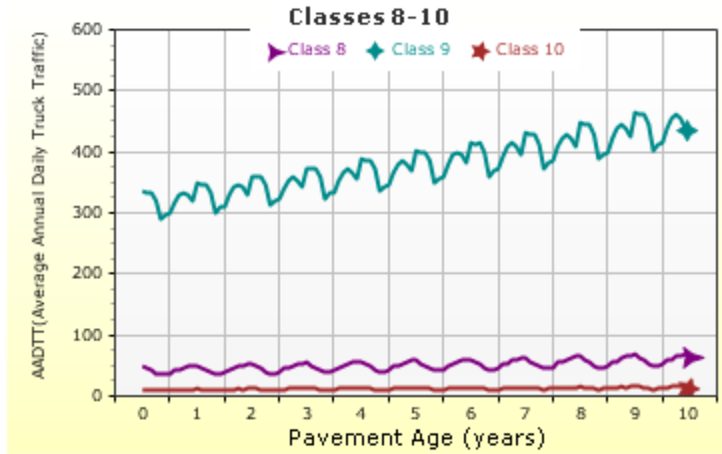
Number of Axles per Truck

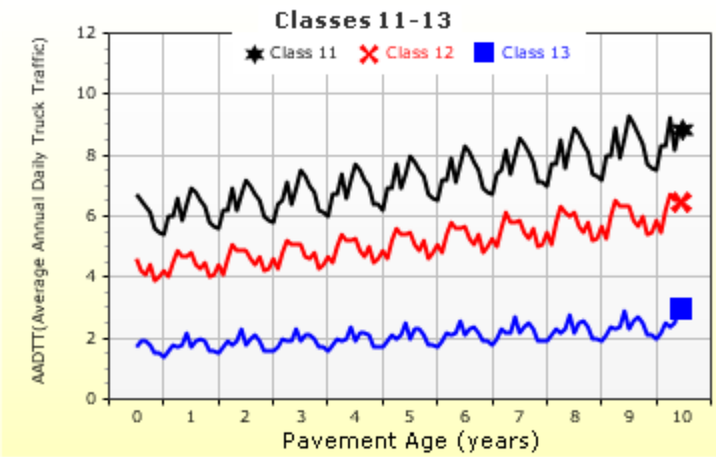
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.94	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.9	0.01	0
Class 10	1.15	1.01	0.93	0.02
Class 11	4.35	0.29	0.02	0
Class 12	3.27	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

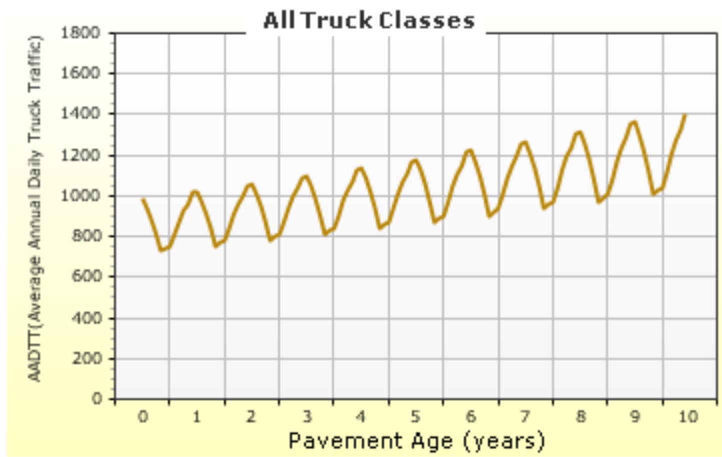
AADTT (Average Annual Daily Truck Traffic) Growth

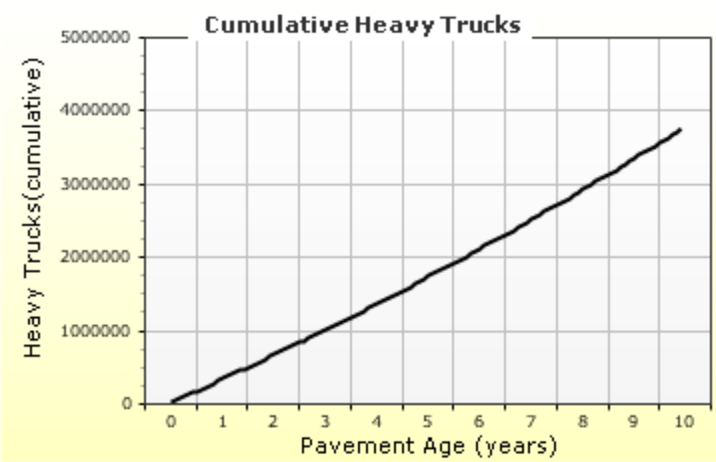
*** Traffic cap is not enforced**







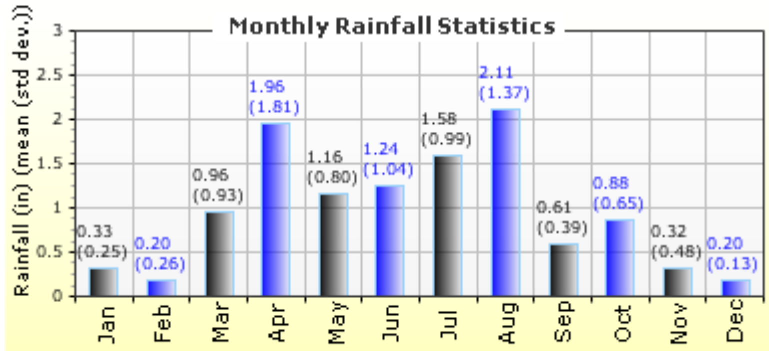




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
PUEBLO, CO	38.29000 -104.49800 4720

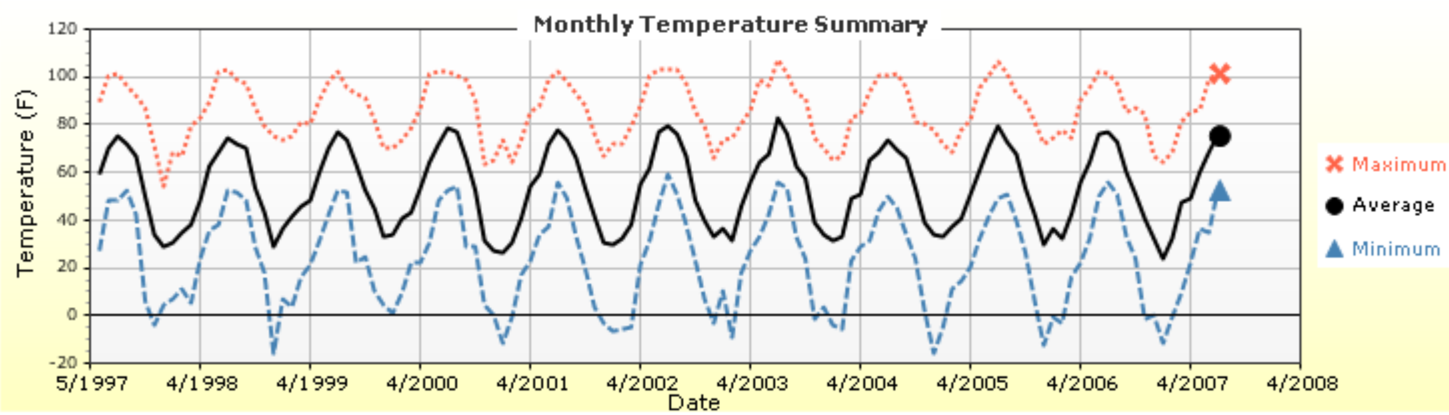


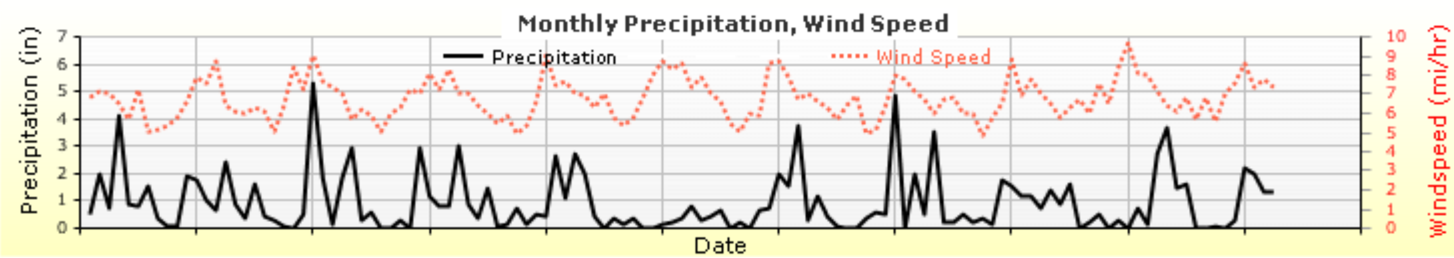
Annual Statistics:

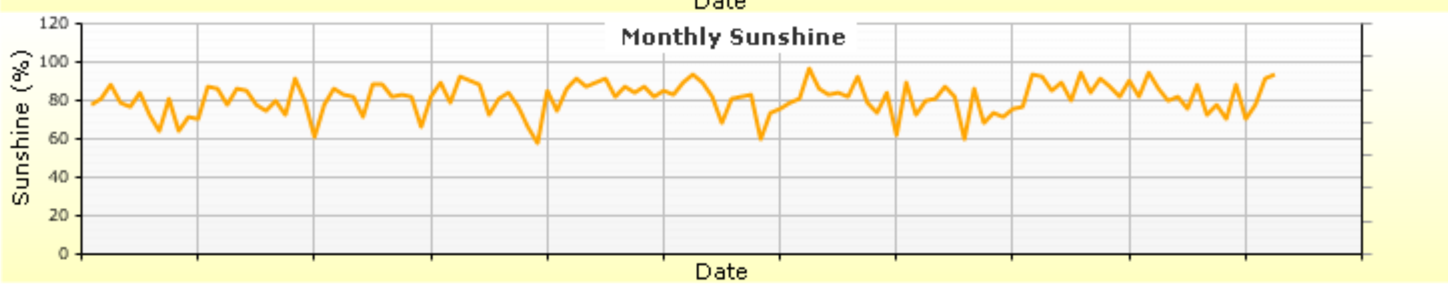
Mean annual air temperature (ºF)	53.33
Mean annual precipitation (in)	11.81
Freezing index (ºF - days)	354.62
Average annual number of freeze/thaw cycles:	142.23

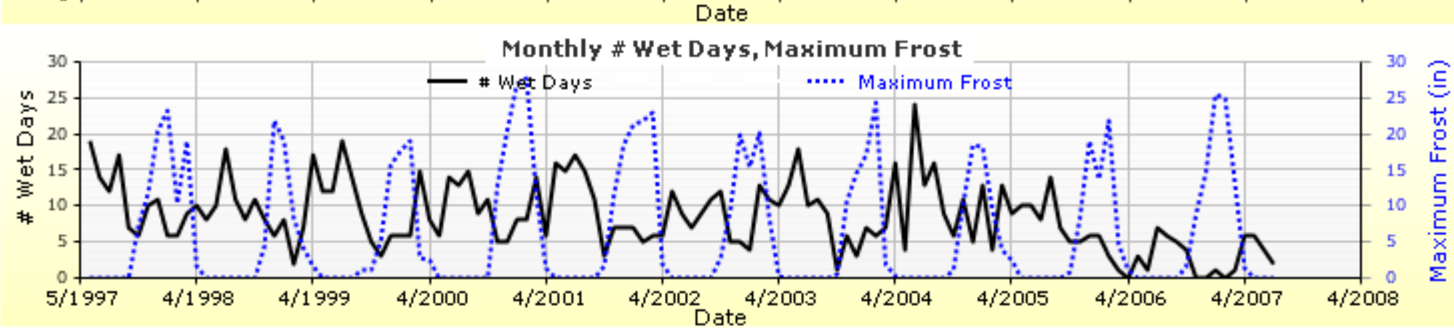
Water table depth (ft) 10.00

Monthly Climate Summary:

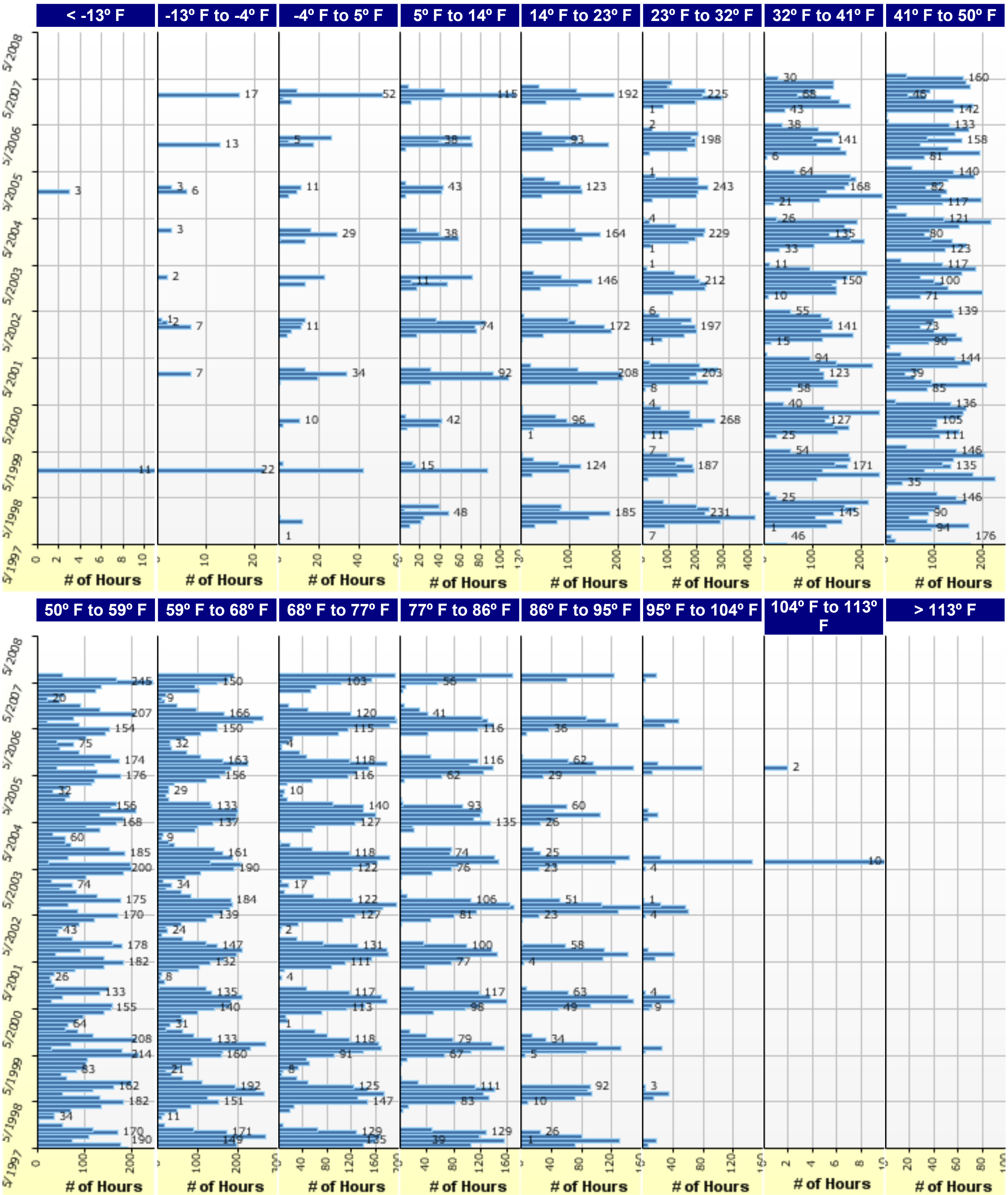








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	True
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

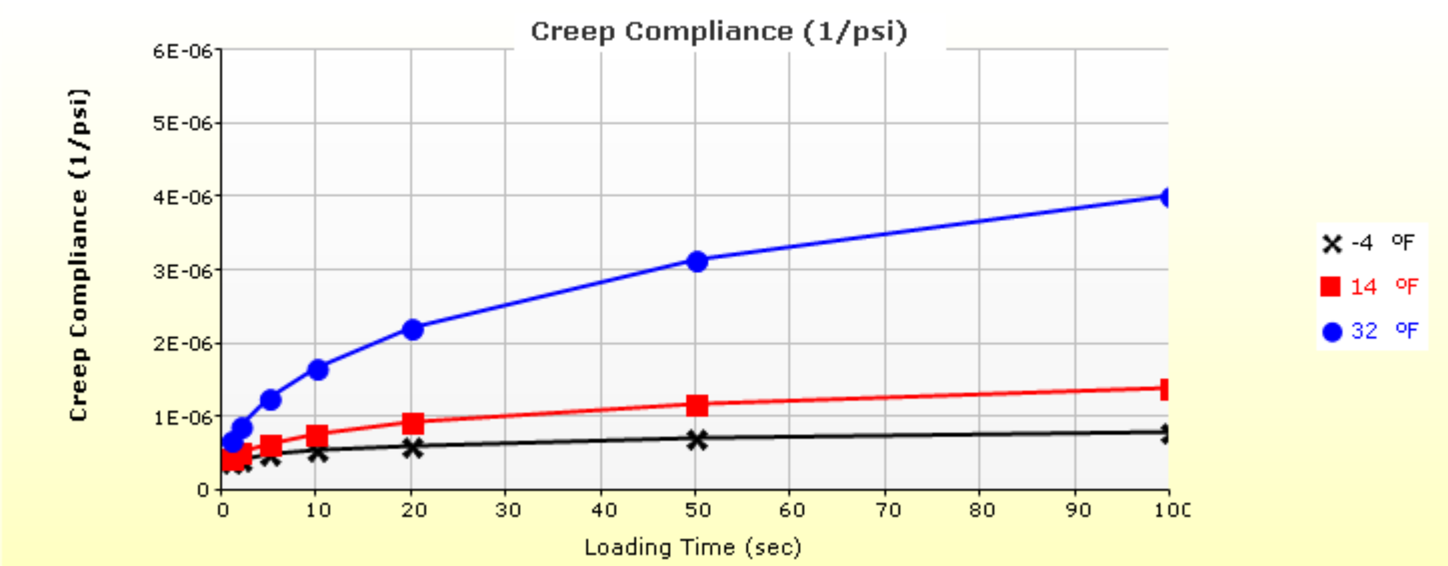
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 SMA	Flexible (1)	1.00
Layer 2 Flexible : R1 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : CDOT Class 6 ABC (Mr-20000)	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-2-4 (R-40)	Subgrade (5)	1.00
Layer 5 Subgrade : A-6 (R-5)	Subgrade (5)	1.00
Layer 6 Subgrade : A-6 (Native)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

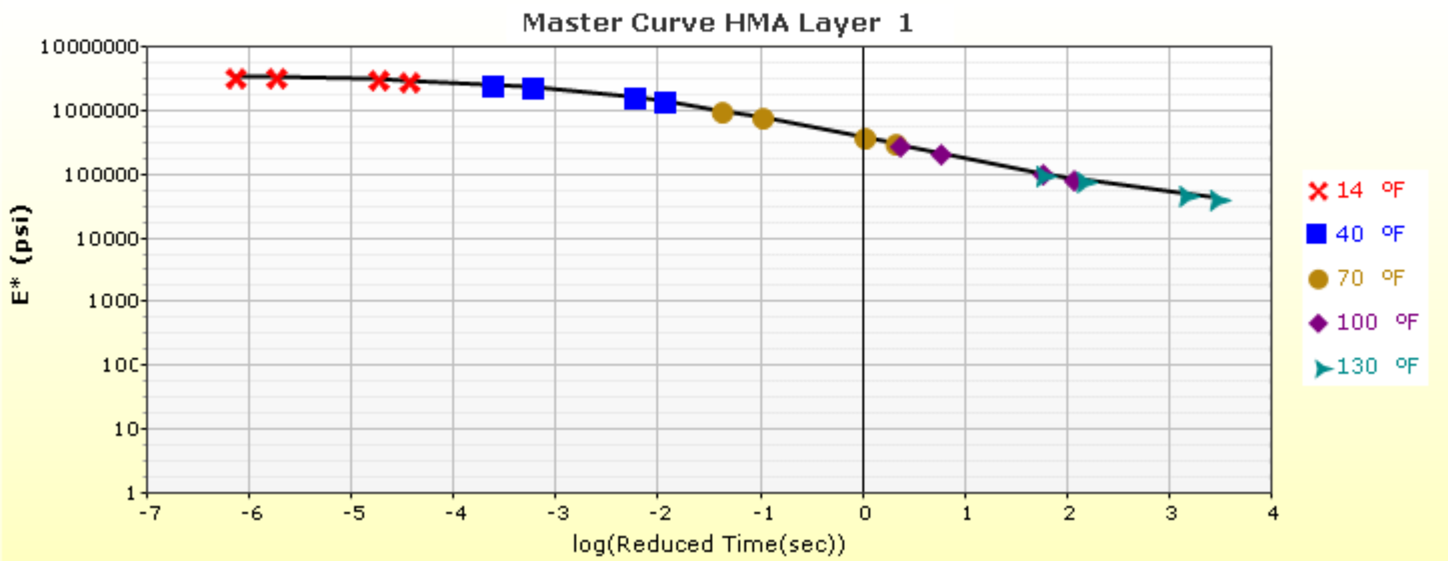
Indirect tensile strength at 14 ºF (psi)	515.00

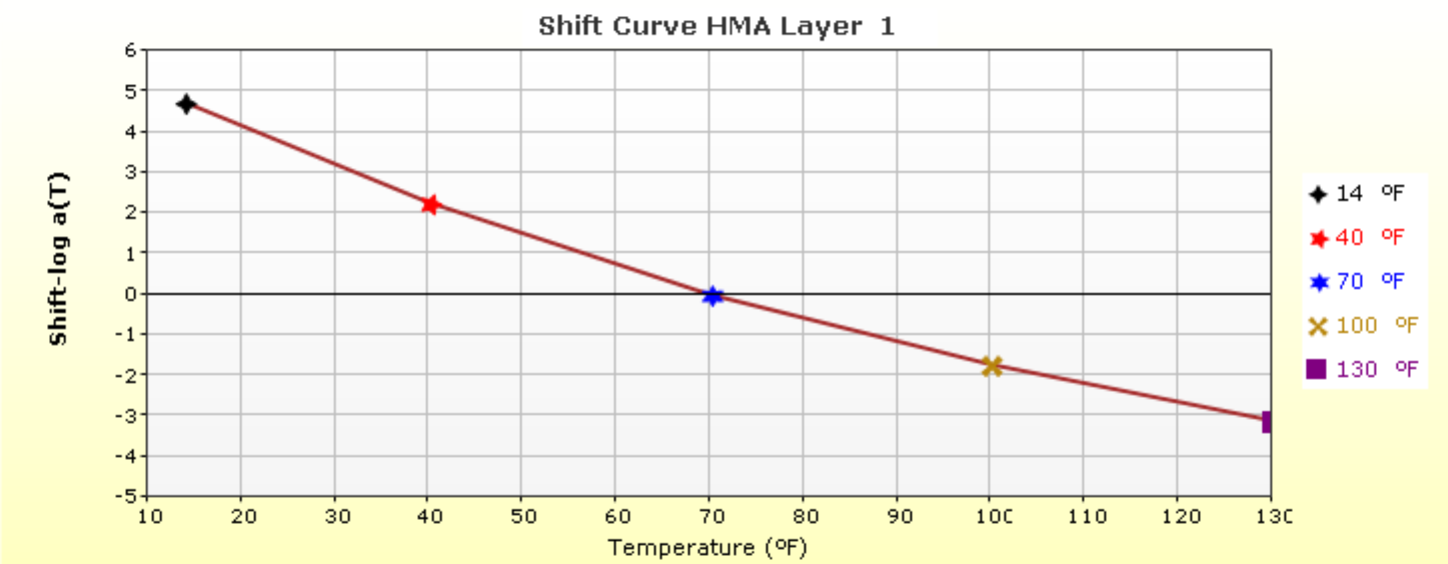
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.9

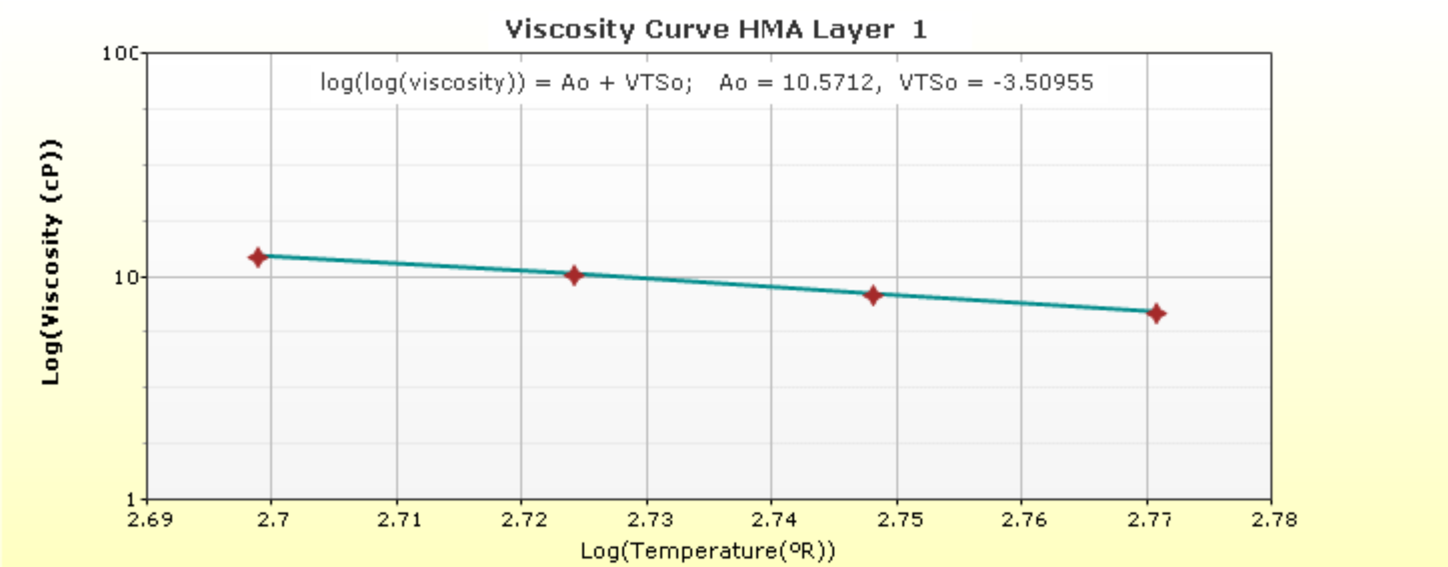
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.01e-007	4.45e-007	6.88e-007
2	4.28e-007	5.41e-007	8.96e-007
5	4.98e-007	6.37e-007	1.27e-006
10	5.51e-007	7.85e-007	1.69e-006
20	6.17e-007	9.33e-007	2.23e-006
50	7.19e-007	1.18e-006	3.14e-006
100	7.96e-007	1.39e-006	4.01e-006



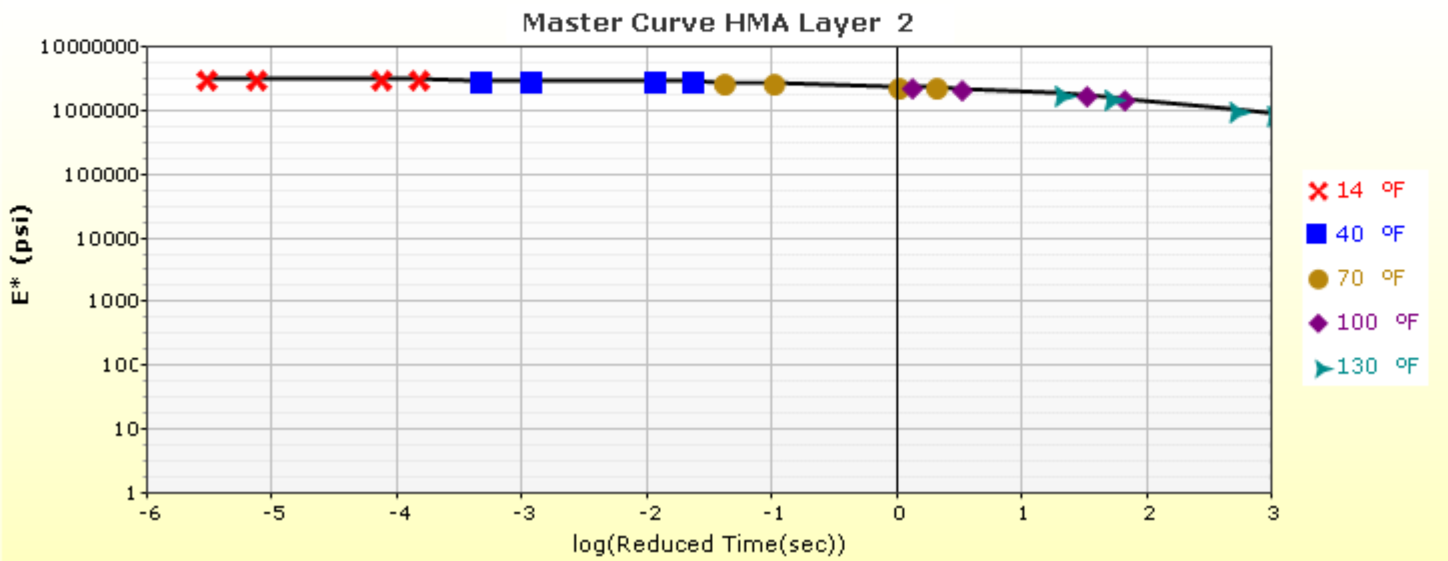
HMA Layer 1: Layer 1 Flexible : R2 SMA

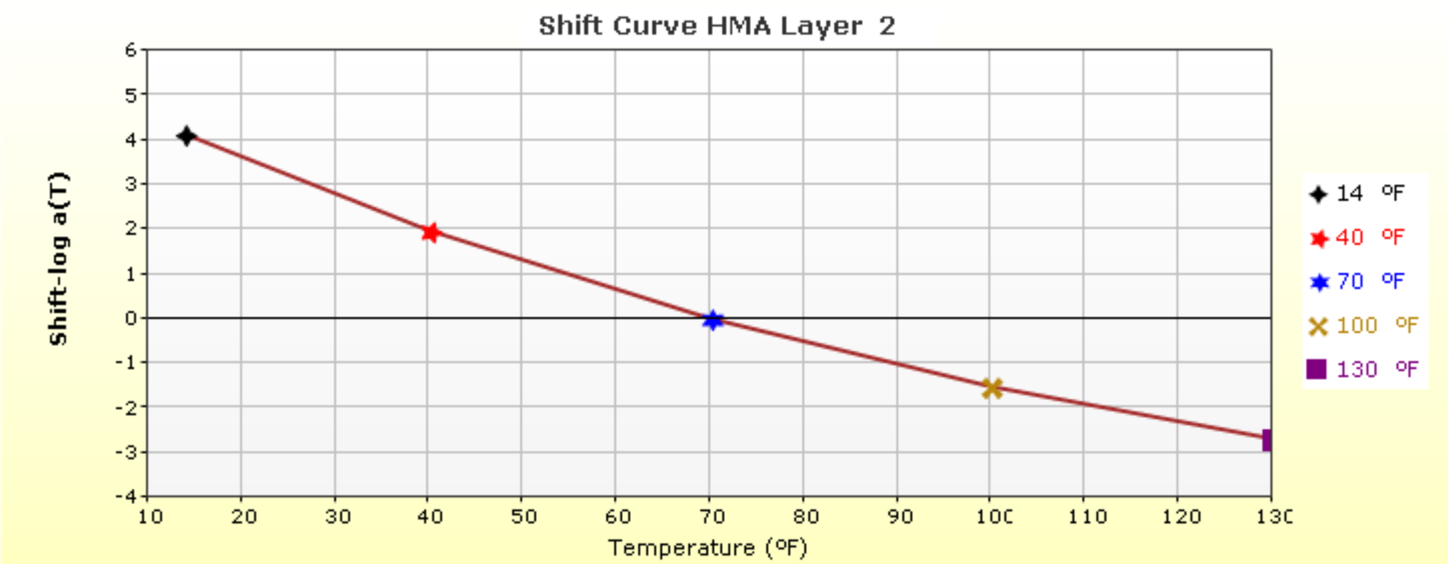


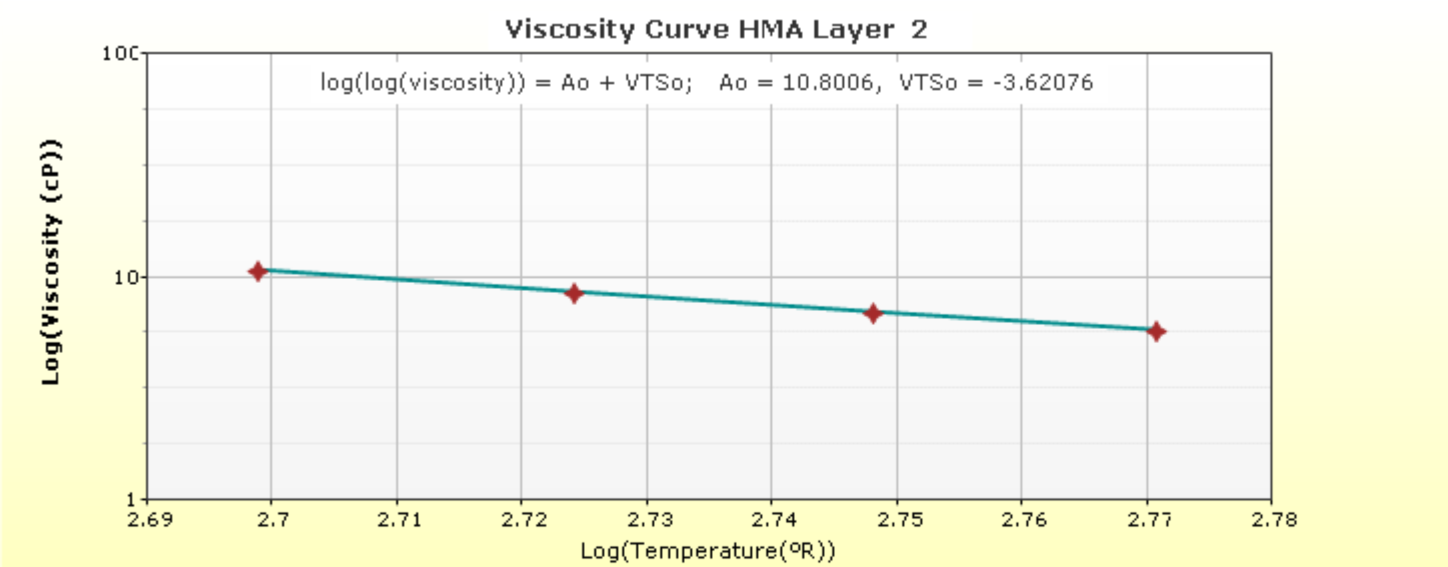




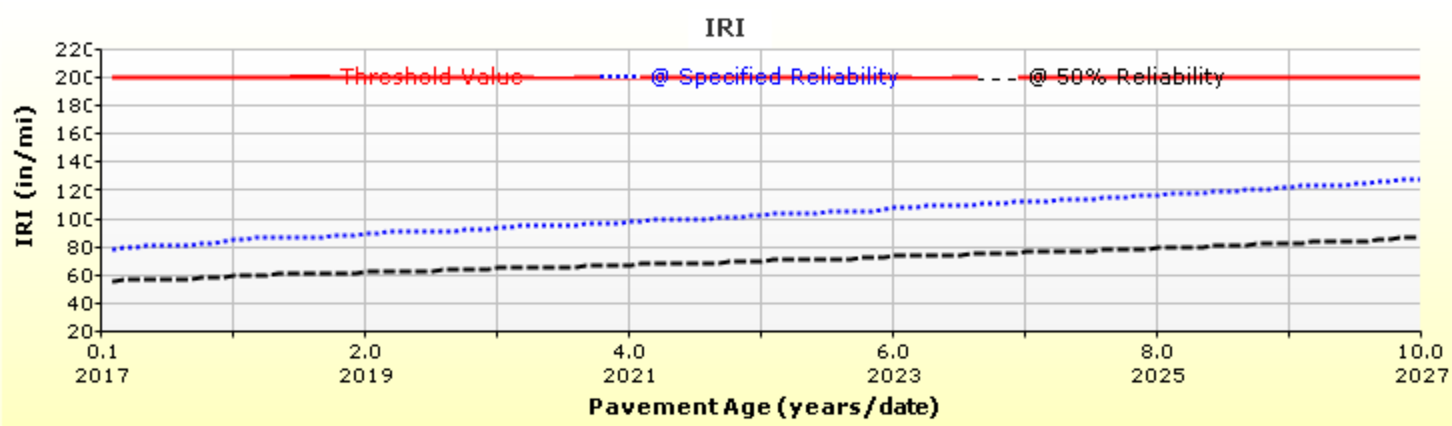
HMA Layer 2: Layer 2 Flexible : R1 Level 1 S(100) PG 64-22

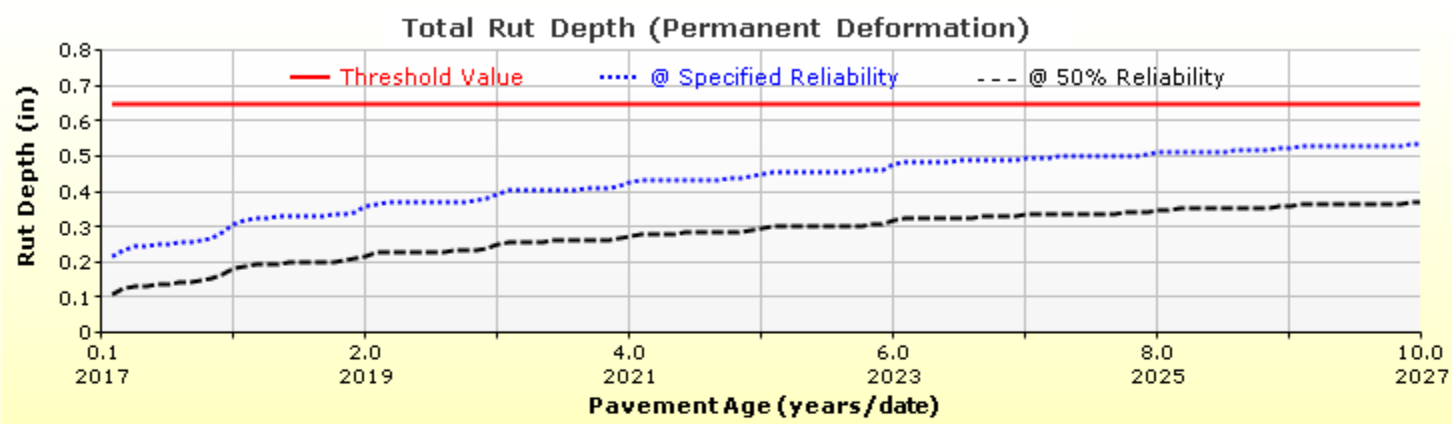


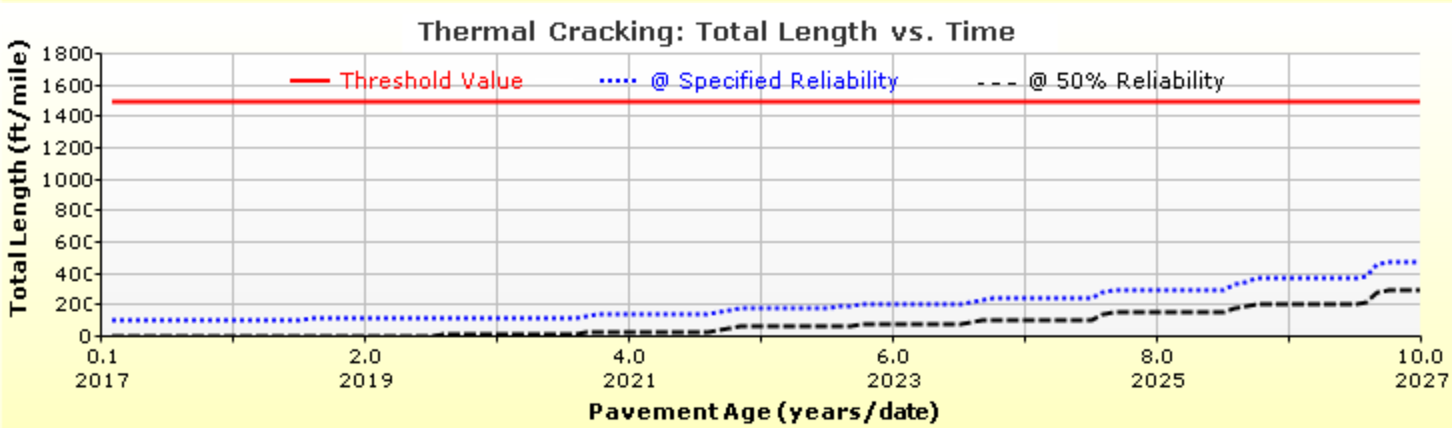


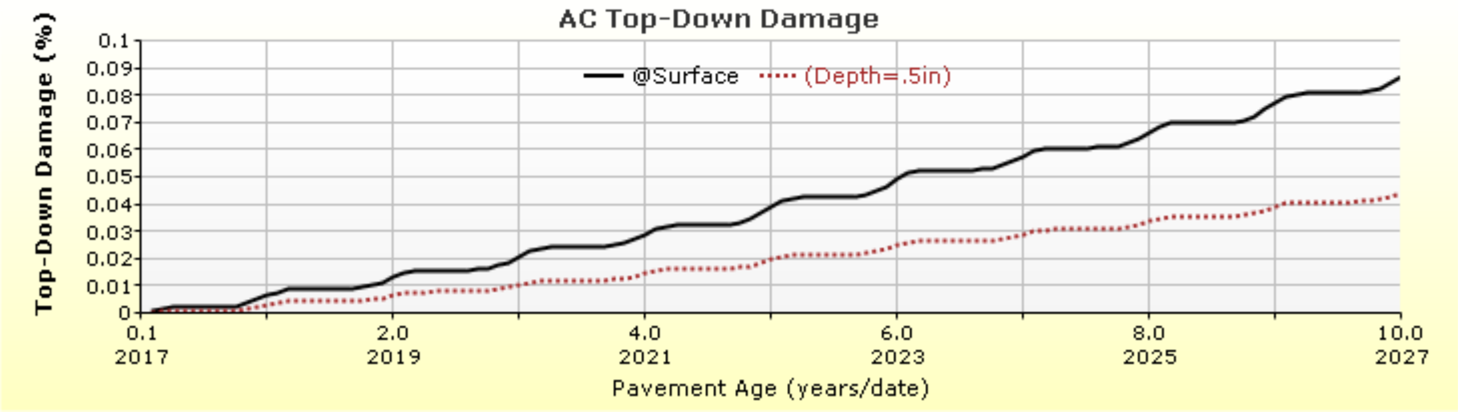


Analysis Output Charts

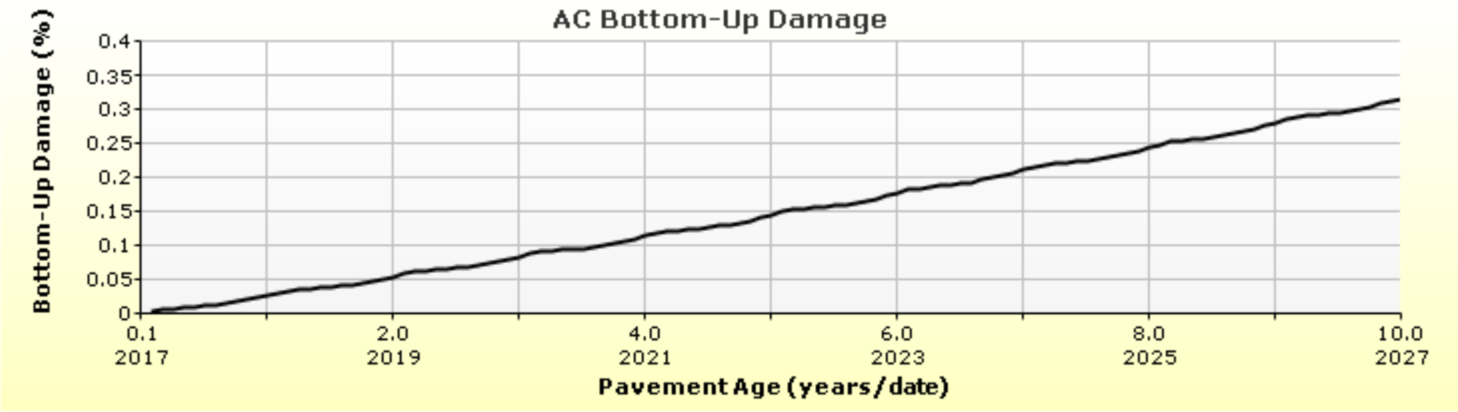




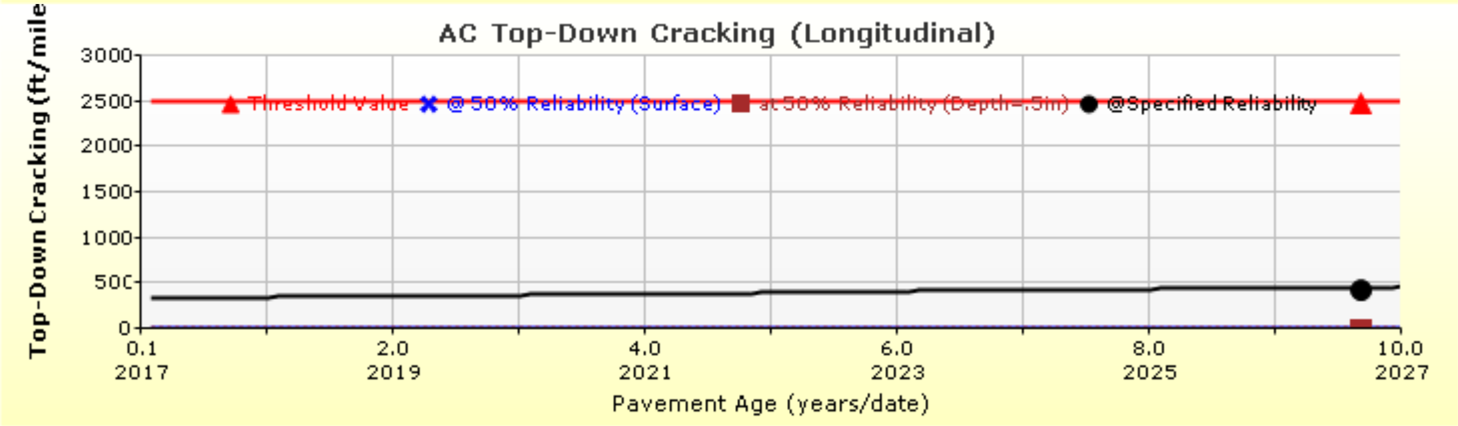




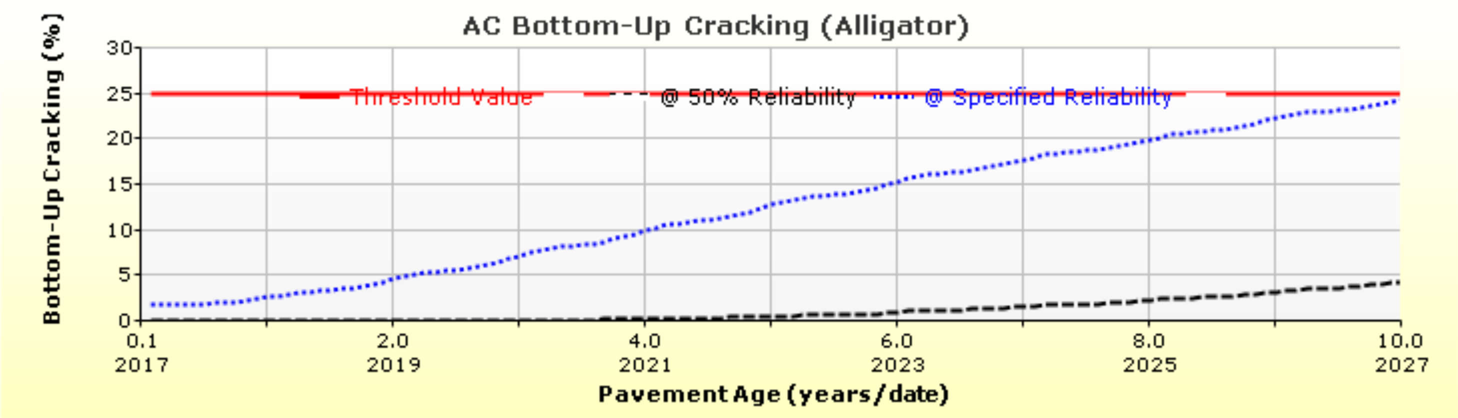
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



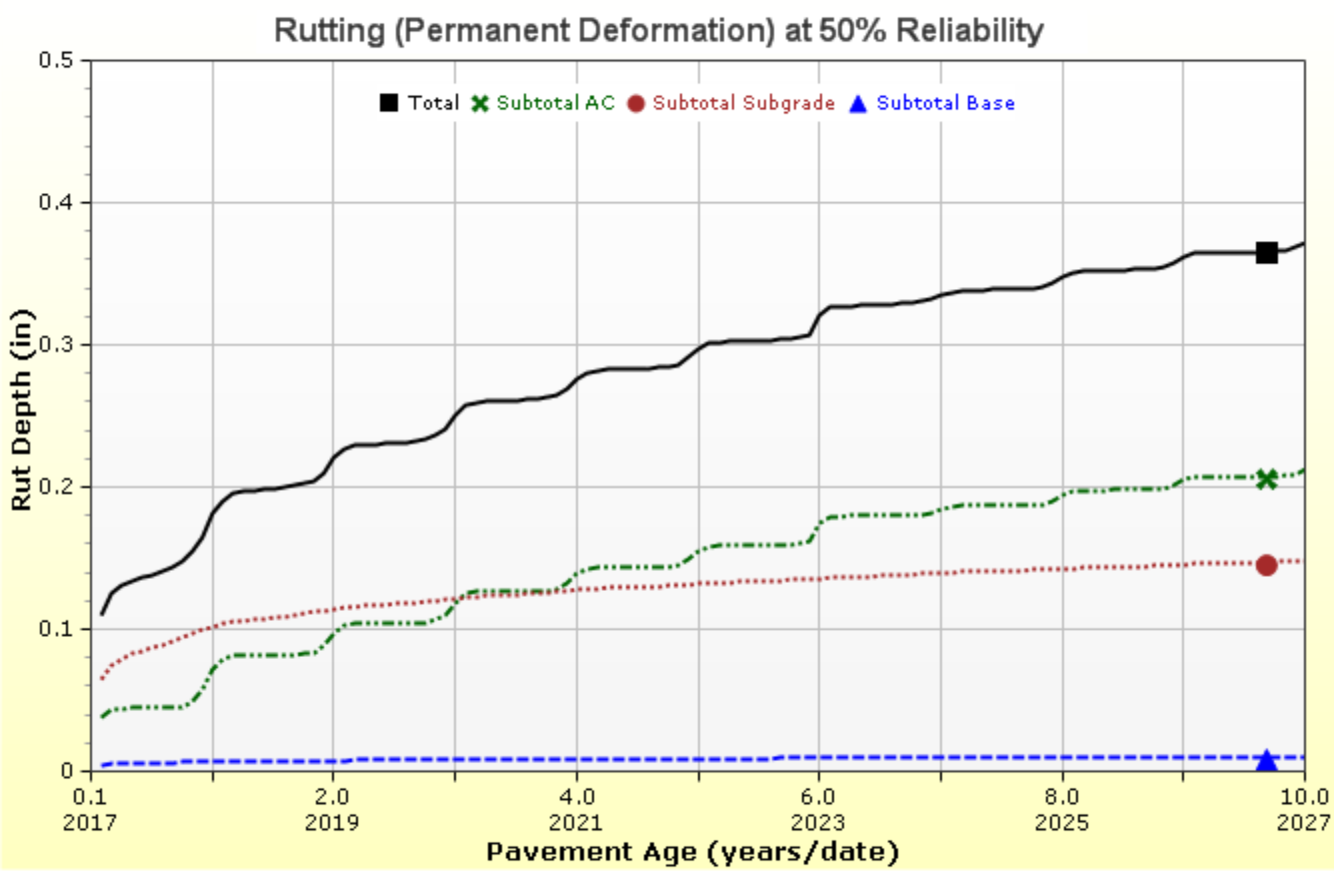
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

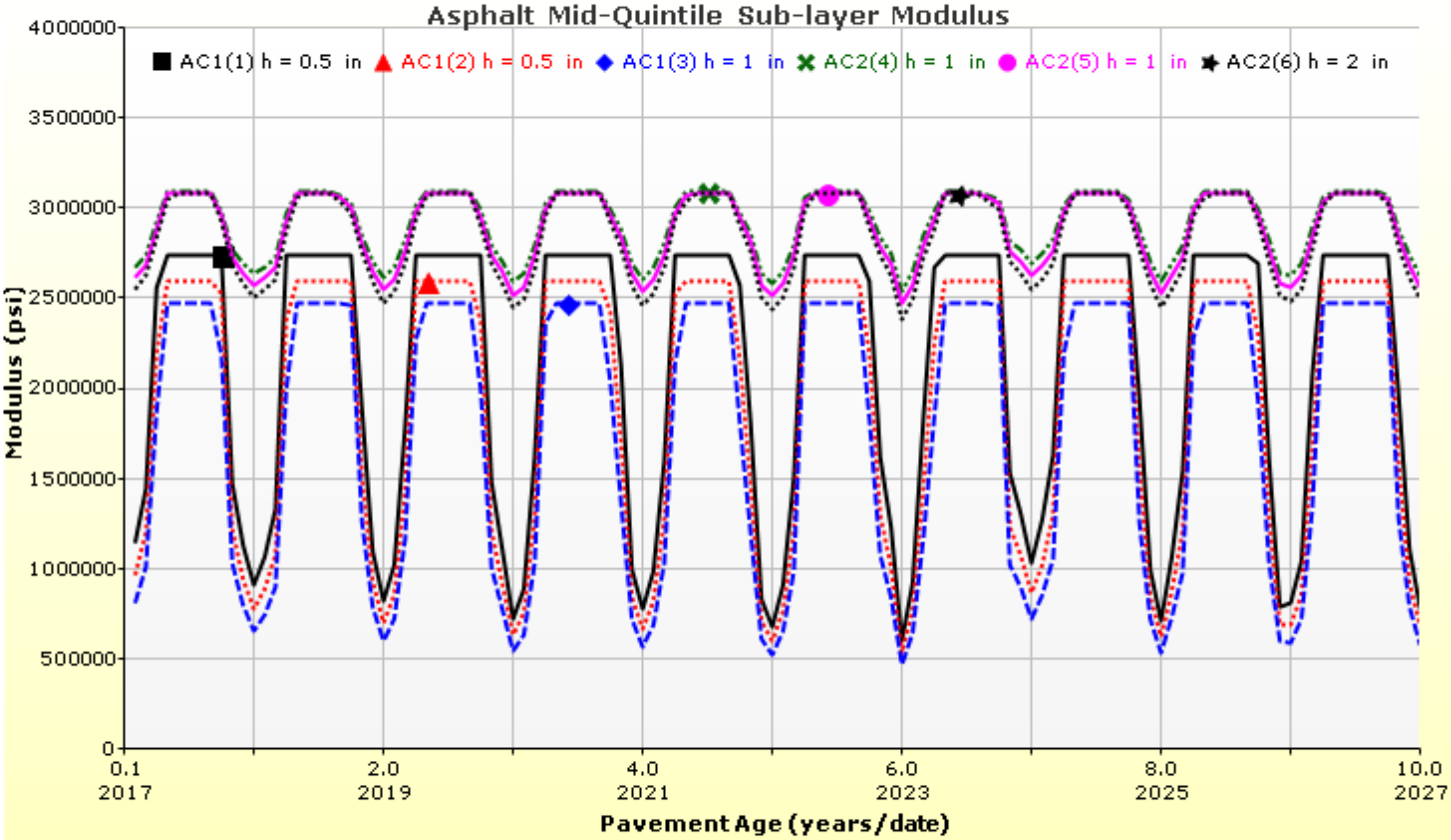


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)

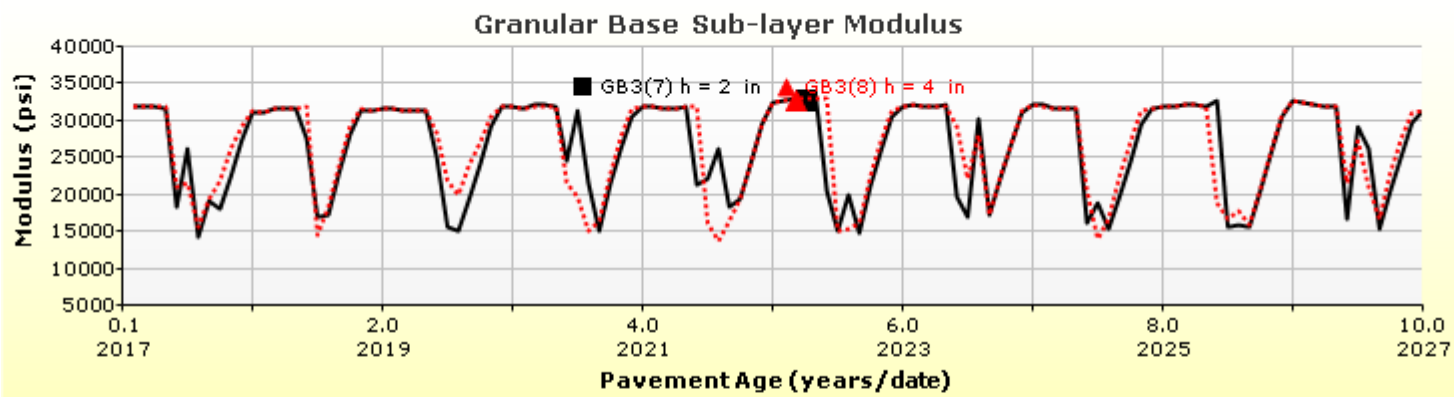


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

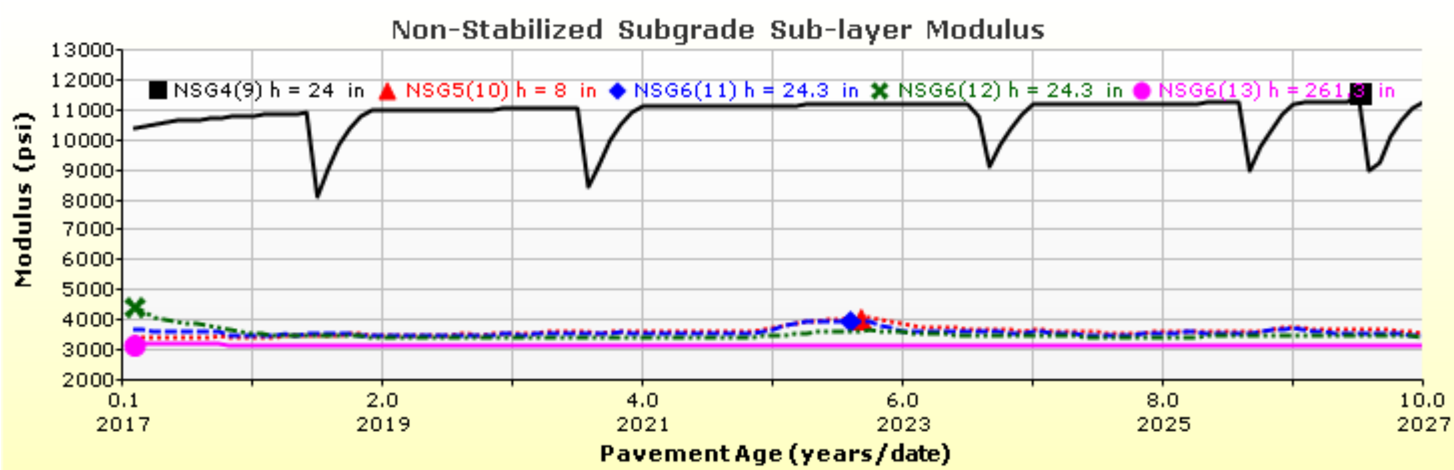

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1
2017
2.0
2019
4.0
2021
6.0
2023
8.0
2025
10.0
2027
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 2 in
Modulus (psi)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 4 in
Modulus (psi)
40000
35000
30000
25000
20000
15000
10000
5000
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG4(9) h = 24 in
NSG5(10) h = 8 in
NSG6(11) h = 24.3 in
NSG6(12) h = 24.3 in
NSG6(13) h = 261 in
Modulus (psi)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 SMA

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1875400	2299039	2624309	2726019
40	846575	1309050	1799540	1983379
70	230100	427271	753122	918360
100	76296	127286	231357	296468
130	40803	55308	84229	102895

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	9836	57
158	4538	59
168.8	2220	61

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	12.2
Air voids (%)	4.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 SMA
Description of object	Mix ID # FS1919-2
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Flexible : R1 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	152.6	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1875400	2299039	2624309	2726019		
40	846575	1309050	1799540	1983379		
70	230100	427271	753122	918360		
100	76296	127286	231357	296468		
130	40803	55308	84229	102895		

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	9836	57
158	4538	59
168.8	2220	61

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.48
Air voids (%)	4.9
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R1 Level 1 S(100) PG 64-22
Description of object	Mix ID # FS29326
Author	CDOT
Date Created	2/11/2015 12:00:00 AM
Approver	CDOT
Date approved	2/11/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : CDOT Class 6 ABC (Mr-20000)

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	CDOT Class 6 ABC (Mr-20000)
Description of object	Aggregate Base Course (ABC)
Author	RockSol JBiller
Date Created	12/31/2014 12:00:00 AM
Approver	JBiller
Date approved	12/31/2014 12:00:00 AM
State	Colorado
District	
County	United States
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	A-1-a
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 4 Subgrade : A-2-4 (R-40)

Unbound	
Layer thickness (in)	24.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-2-4 (R-40)
Description of object	Improved Subgrade (Mr=9500)
Author	RockSol JBiller
Date Created	1/1/2011 12:00:00 AM
Approver	JBiller
Date approved	1/1/2011 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	14.0
Plasticity Index	2.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124
Saturated hydraulic conductivity (ft/hr)	False	5.854e-04
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	9

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	9.5043
bf	0.6439
cf	3.0636
hr	189.6000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 5 Subgrade : A-6 (R-5)

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (R-5)
Description of object	Default material (Mr=5356)
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 6 Subgrade : A-6 (Native)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
20000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (Native)
Description of object	Default material (Mr=5356)
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	20.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	106.2
Saturated hydraulic conductivity (ft/hr)	False	2.543e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	18.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	115.7360
bf	0.6334
cf	0.1681
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	k2: 3.9492
k3: 1.281	Bf1: 130.3674
Bf2: 1	Bf3: 1.217799

AC Rutting (using Multilayer Calibration)

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

AC Rutting Standard Deviation	0.1414*Pow(RUT,0.25)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
C = crack depth(in)
h_{ac} = thickness of asphalt layer(in)
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the asphalt mixture
E = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 6.3	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1}\left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress(psi)
M_r = modulus of rupture(psi)

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

δ_a = permanent deformation for the layer
N = number of repetitions
ε_v = average veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104*Pow(BASERUT,0.67)+0.001		Standard Deviation (BASERUT) 0.0663*Pow(SUBRUT,0.5)+0.001	

AC Cracking

AC Top Down Cracking				AC Bottom Up Cracking		
$FC_{top} = \left(\frac{C_4}{1+e^{(C_1 - C_2 * \log_{10}(Damage))}}\right) * 10.56$				$FC = \left(\frac{6000}{1+e^{(C_1 * C_1' + C_2 * C_2' \log_{10}(D*100))}}\right) * \left(\frac{1}{60}\right)$ $C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C_1' = -2 * C_2'$		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	c3: 6000
AC Cracking Top Standard Deviation				**AC Cracking Bottom Standard Deviation**		
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))				1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))		

CSM Cracking				IRI Flexible Pavements			
$FC_{ctb} = C_1 + \frac{C_2}{1+e^{C_3 - C_4(Damage)}}$				C1 - Rutting C2 - Fatigue Crack		C3 - Transverse Crack C4 - Site Factors	
C1: 1	C2: 1	C3: 0	C4: 1000	C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02
CSM Standard Deviation							
CTB*1							

US50 Westbound - Flexible - Exit Ramp R-5 Subgrade

File Name: E:\ME Design\302.02 - US50\US50 Westbound - Flexible - Exit Ramp R-5 Subgrade.dgpx

Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement

Base construction: May, 2017
Pavement construction: June, 2017
Traffic opening: August, 2017

Climate Data Sources (Lat/Lon): 38.29, -104.498

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R6 SX(100) PG 76-28	2.0
Flexible	R1 Level 1 S(100) PG 64-22	5.0
NonStabilized	CDOT Class 6 ABC (Mr-15000)	6.0
Subgrade	A-2-4 (R-40)	24.0
Subgrade	A-6 (R-5)	8.0
Subgrade	A-6 (Native)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.1
Air voids (%)	5.2

Traffic

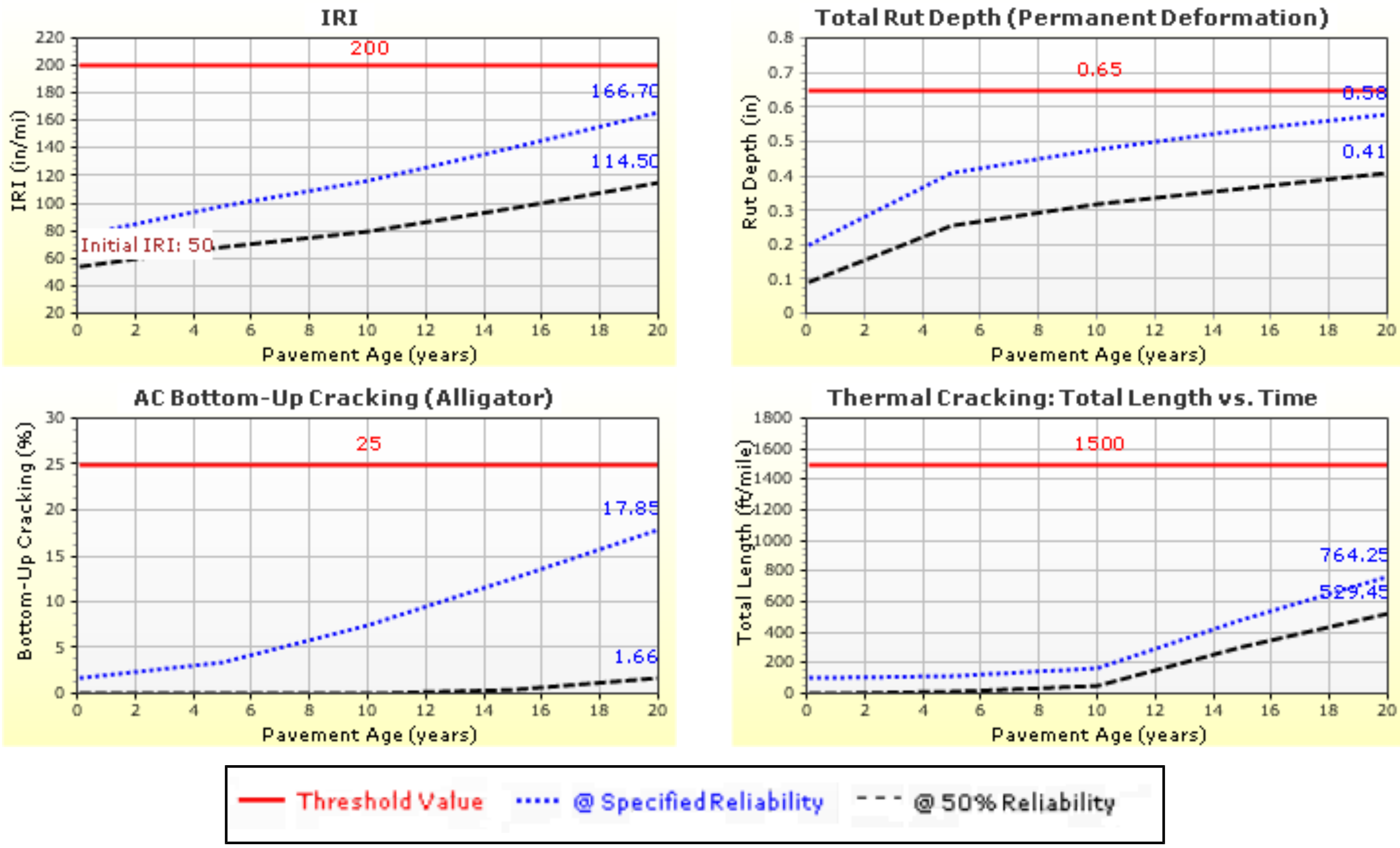
Age (year)	Heavy Trucks (cumulative)
2017 (initial)	500
2027 (10 years)	2,157,360
2037 (20 years)	5,244,910

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	166.71	95.00	99.65	Pass
Permanent deformation - total pavement (in)	0.65	0.58	95.00	98.90	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	17.85	95.00	99.11	Pass
AC thermal cracking (ft/mile)	1500.00	764.25	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	359.44	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.50	0.42	95.00	99.29	Pass

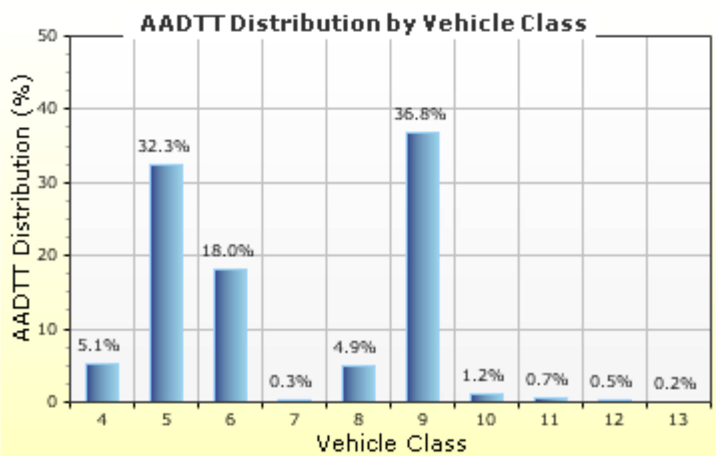
Distress Charts

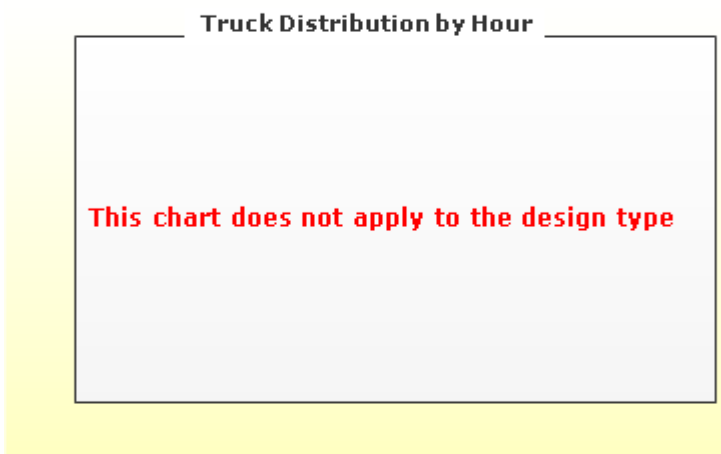


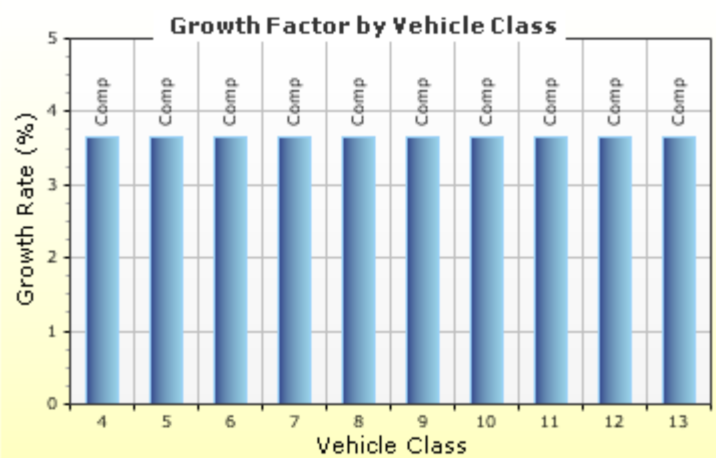
Traffic Inputs

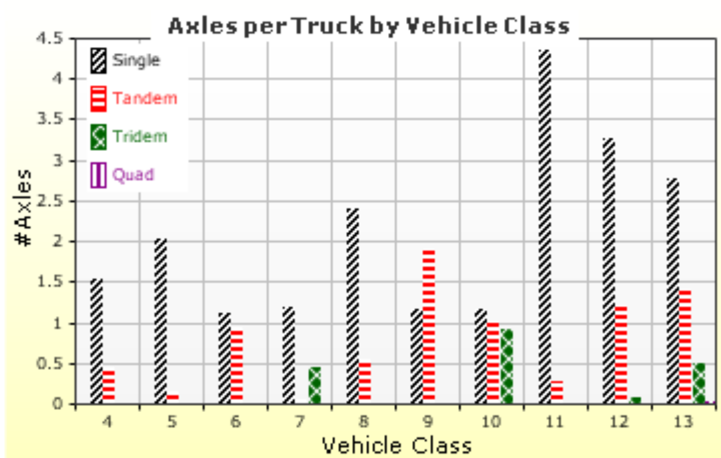
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	500	Percent of trucks in design direction (%):	100.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	45.0

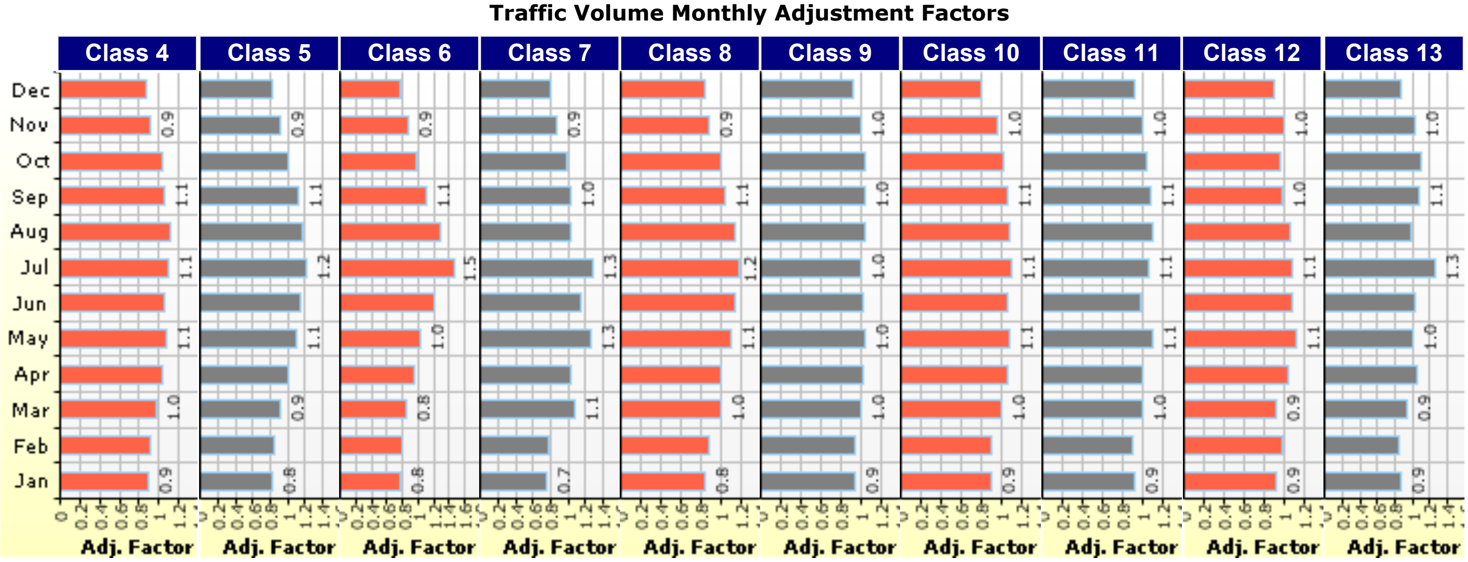








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3.65%	Compound
Class 5	32.3%	3.65%	Compound
Class 6	18%	3.65%	Compound
Class 7	0.3%	3.65%	Compound
Class 8	4.9%	3.65%	Compound
Class 9	36.8%	3.65%	Compound
Class 10	1.2%	3.65%	Compound
Class 11	0.7%	3.65%	Compound
Class 12	0.5%	3.65%	Compound
Class 13	0.2%	3.65%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

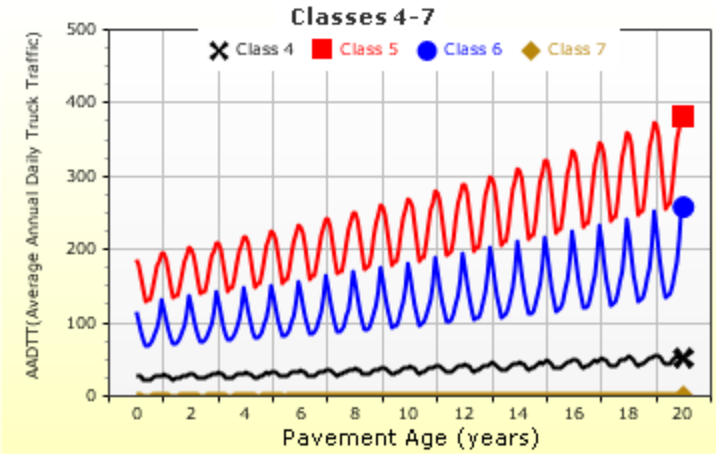
Wheelbase does not apply

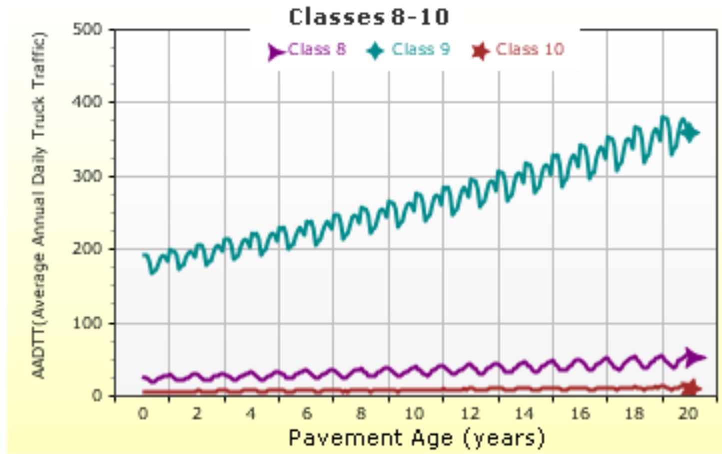
Number of Axles per Truck

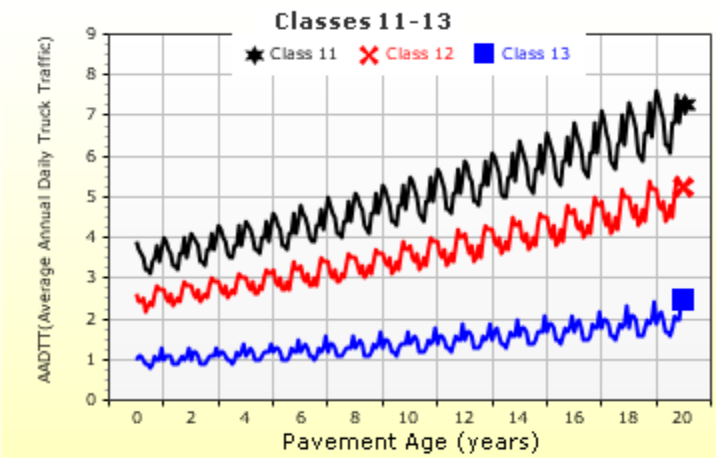
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.94	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.9	0.01	0
Class 10	1.15	1.01	0.93	0.02
Class 11	4.35	0.29	0.02	0
Class 12	3.27	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

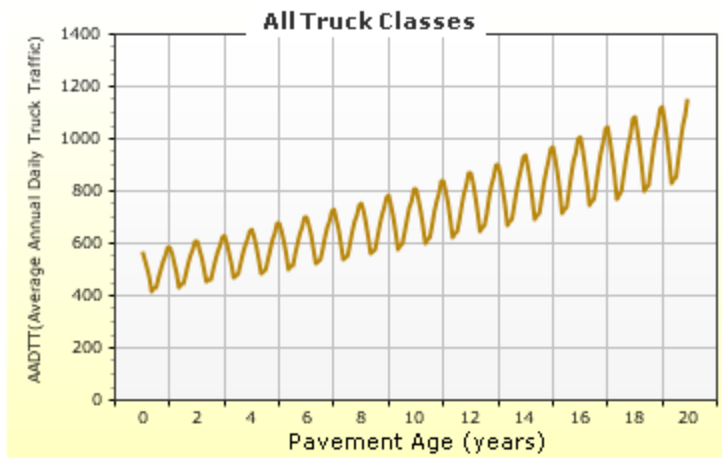
AADTT (Average Annual Daily Truck Traffic) Growth

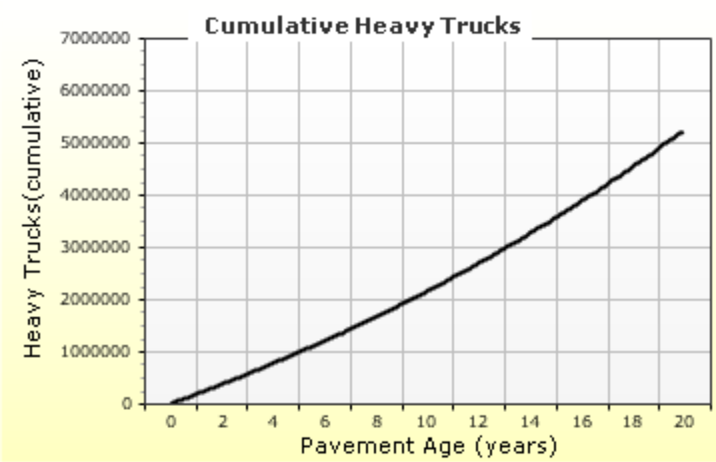
*** Traffic cap is not enforced**







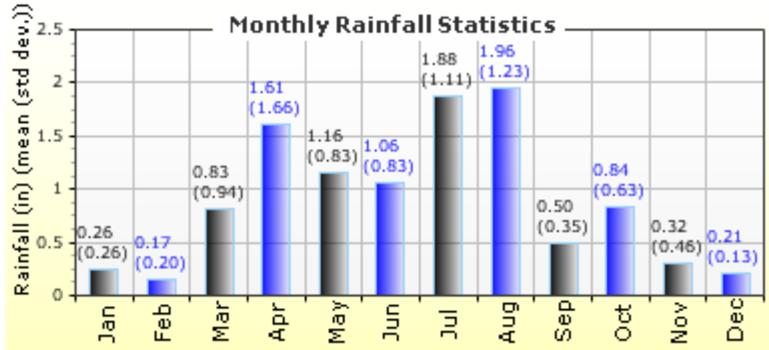




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
PUEBLO, CO	38.29000 -104.49800 4720

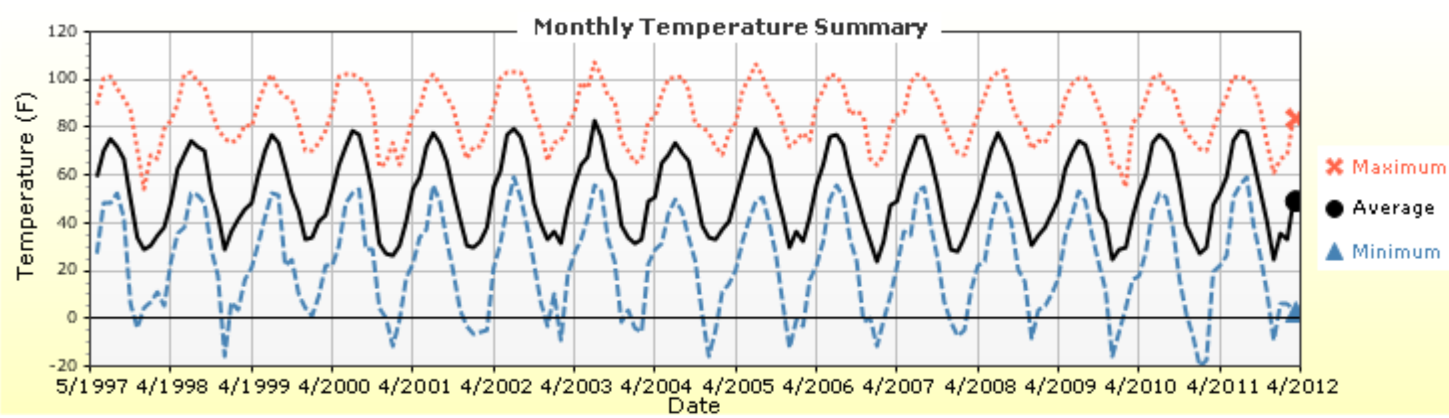


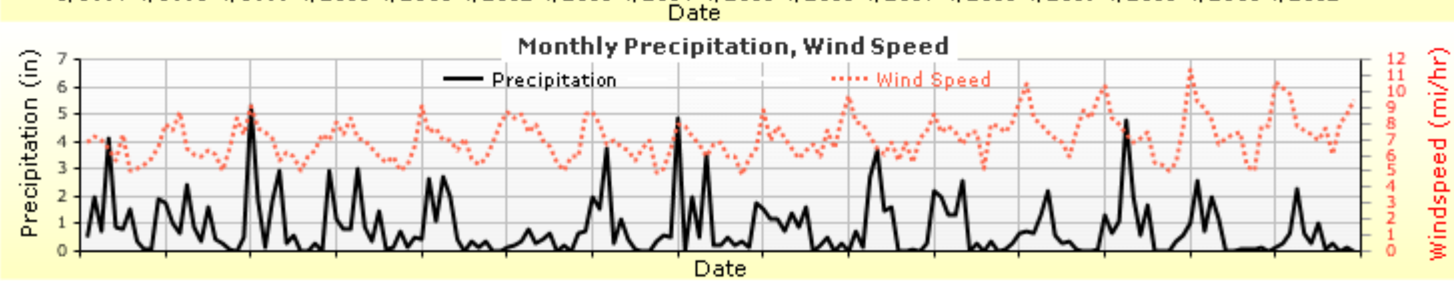
Annual Statistics:

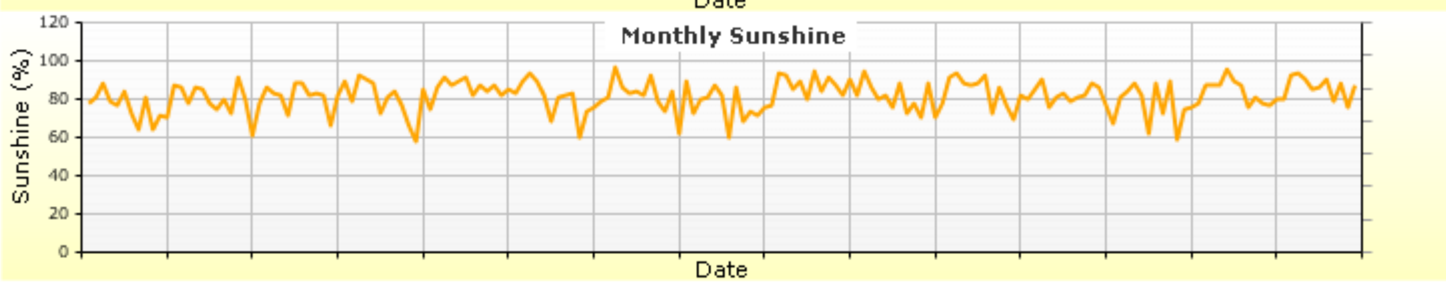
Mean annual air temperature (ºF)	52.95
Mean annual precipitation (in)	10.91
Freezing index (ºF - days)	377.71
Average annual number of freeze/thaw cycles:	142.23

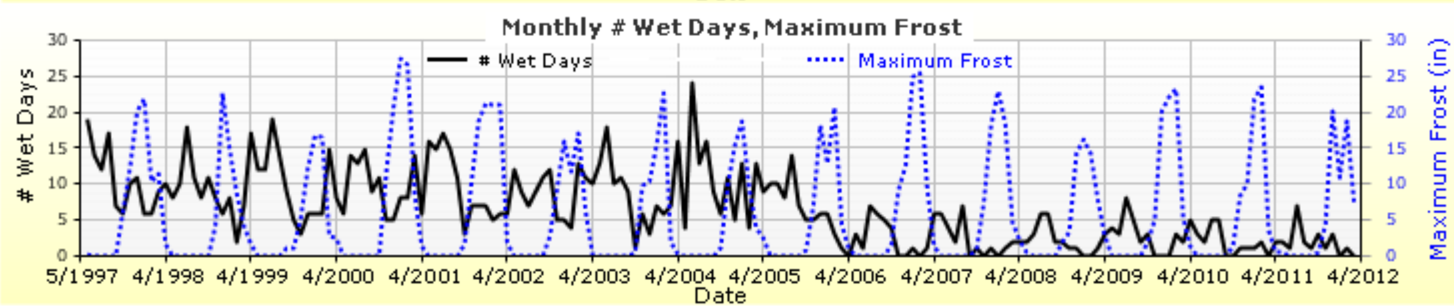
Water table depth (ft) 10.00

Monthly Climate Summary:

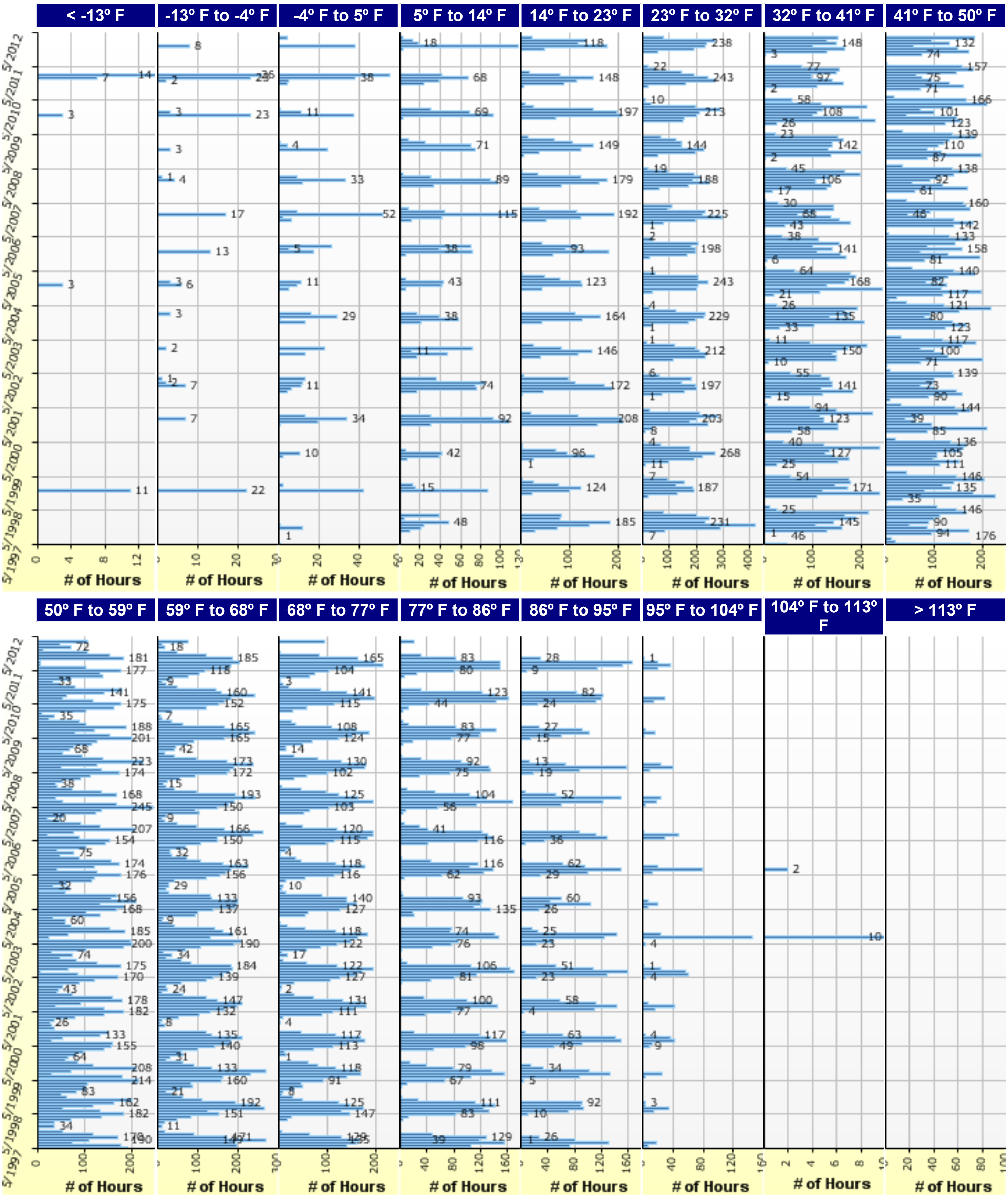








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	True
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

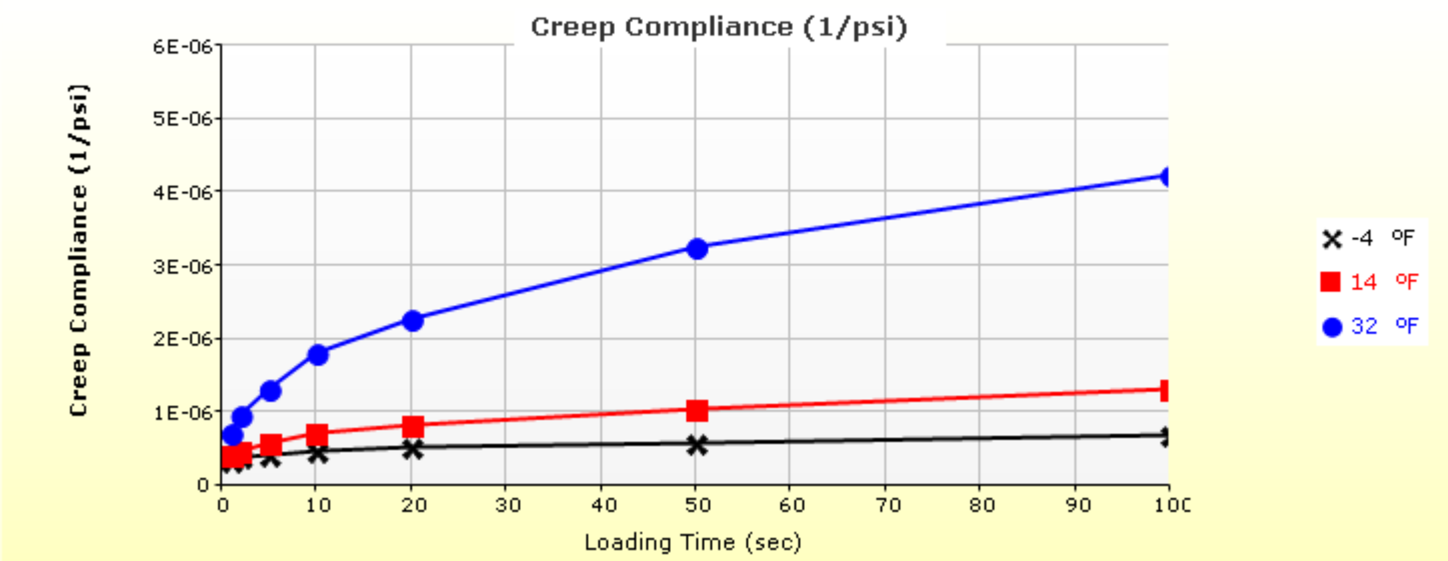
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R6 SX(100) PG 76-28	Flexible (1)	1.00
Layer 2 Flexible : R1 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : CDOT Class 6 ABC (Mr-15000)	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-2-4 (R-40)	Subgrade (5)	1.00
Layer 5 Subgrade : A-6 (R-5)	Subgrade (5)	1.00
Layer 6 Subgrade : A-6 (Native)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

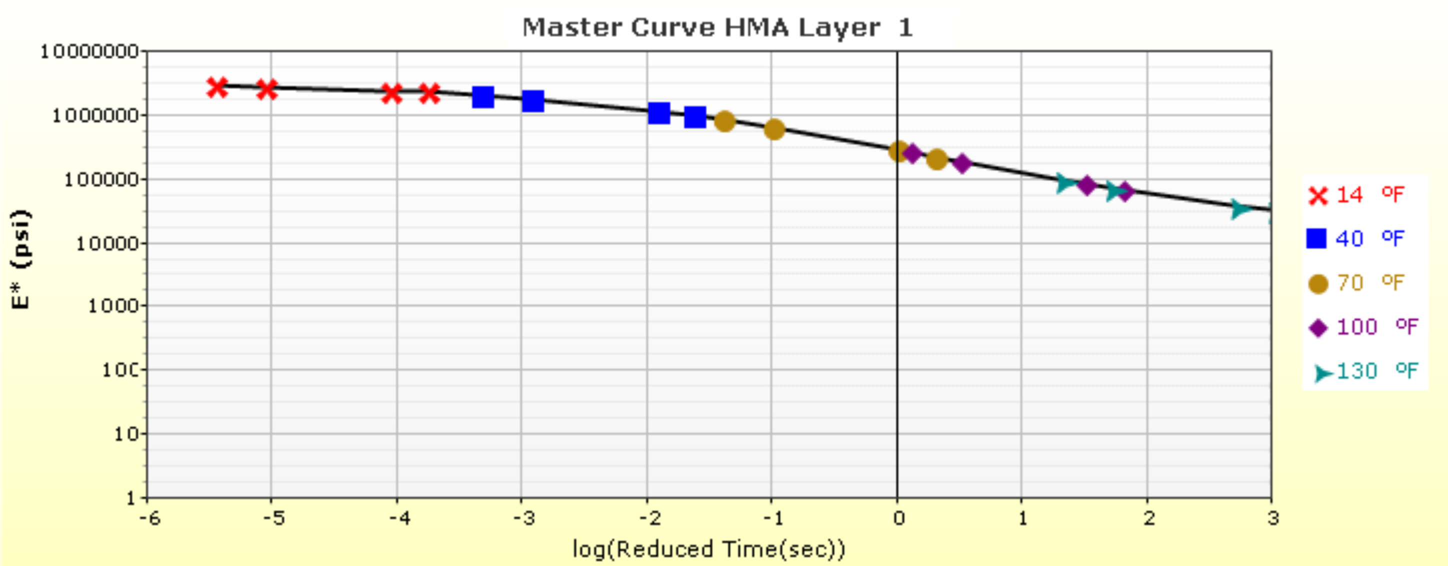
Indirect tensile strength at 14 ºF (psi)	595.00

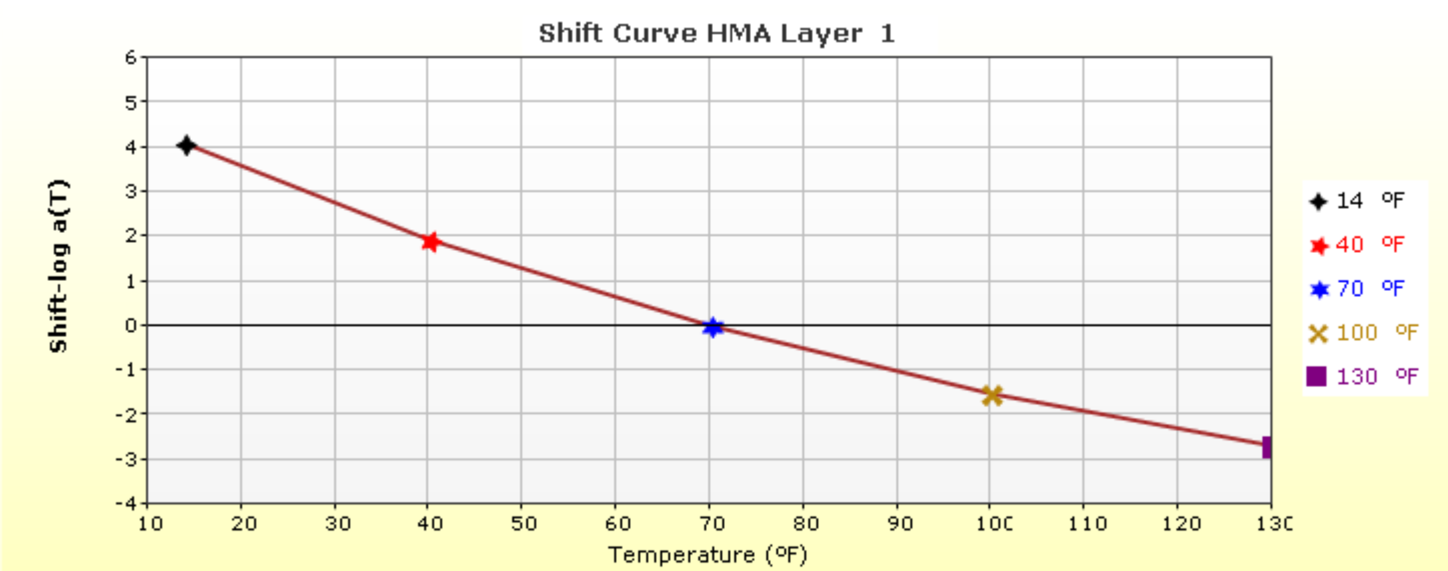
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	11.1

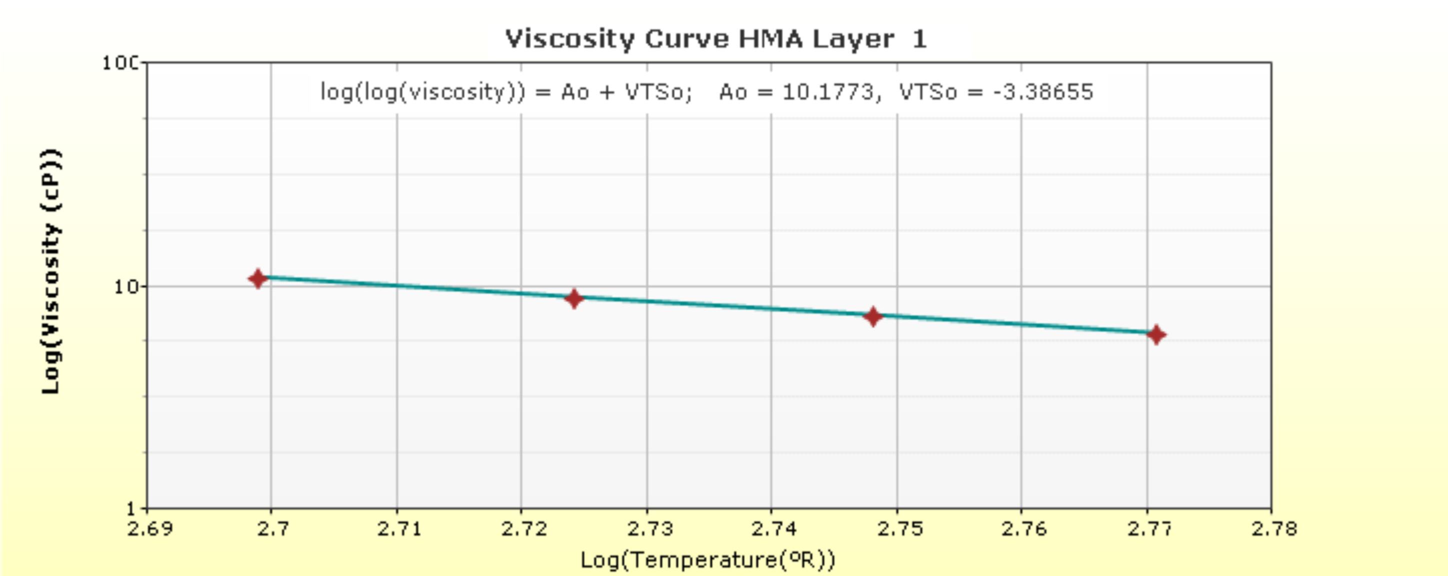
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.46e-007	4.12e-007	7.13e-007
2	3.83e-007	4.76e-007	9.57e-007
5	4.34e-007	5.97e-007	1.33e-006
10	4.85e-007	7.25e-007	1.80e-006
20	5.29e-007	8.45e-007	2.29e-006
50	5.99e-007	1.05e-006	3.25e-006
100	6.87e-007	1.32e-006	4.24e-006



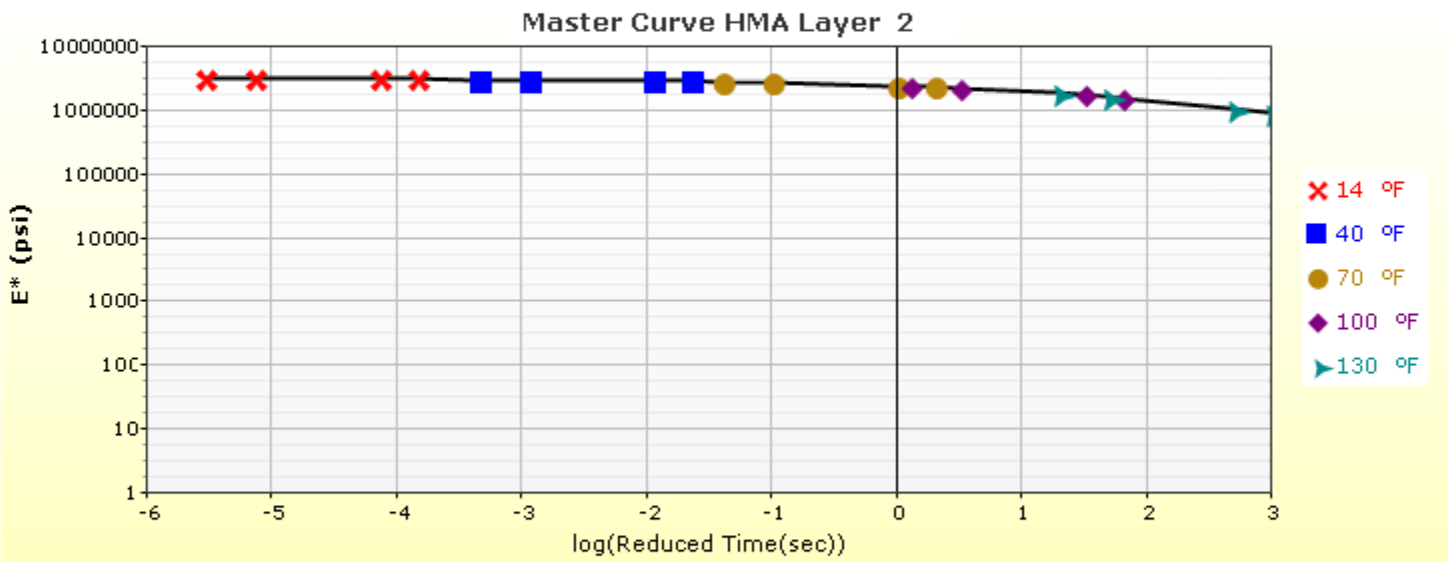
HMA Layer 1: Layer 1 Flexible : R6 SX(100) PG 76-28

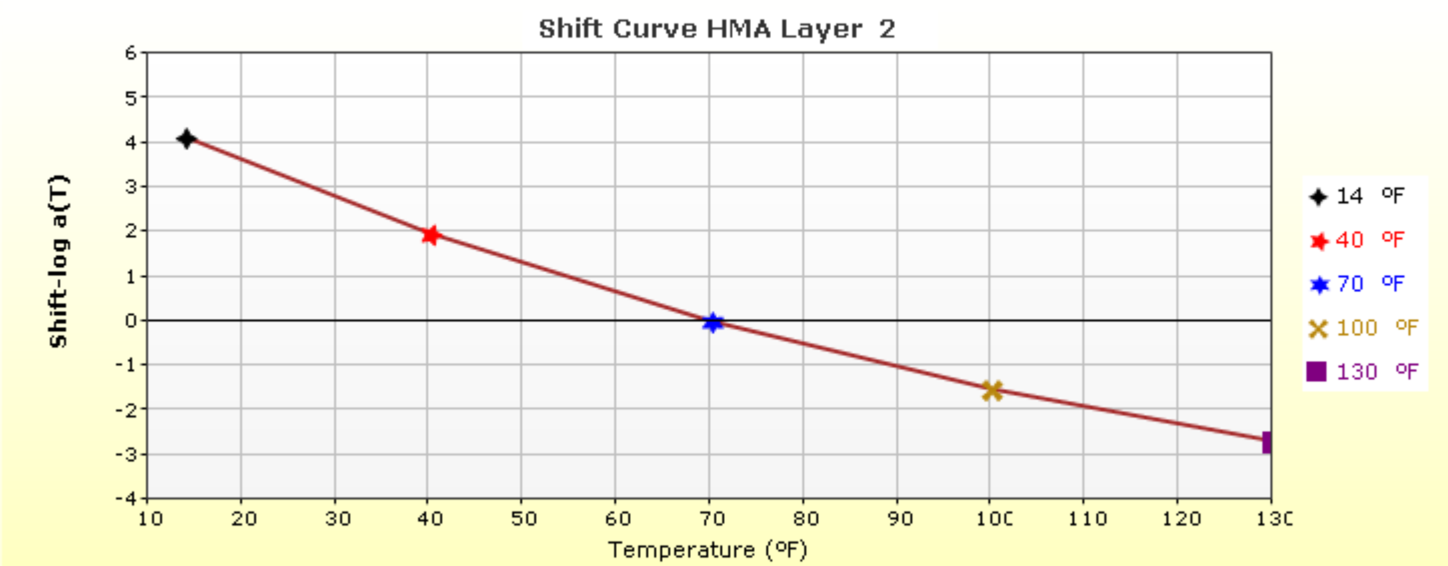


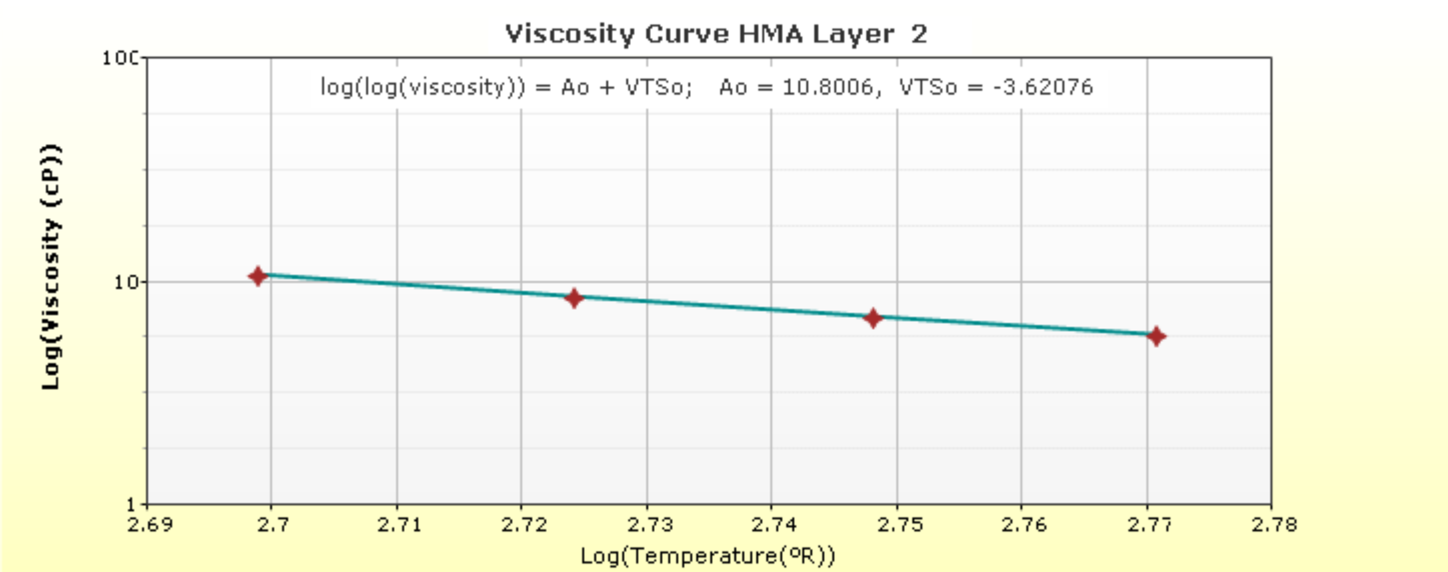




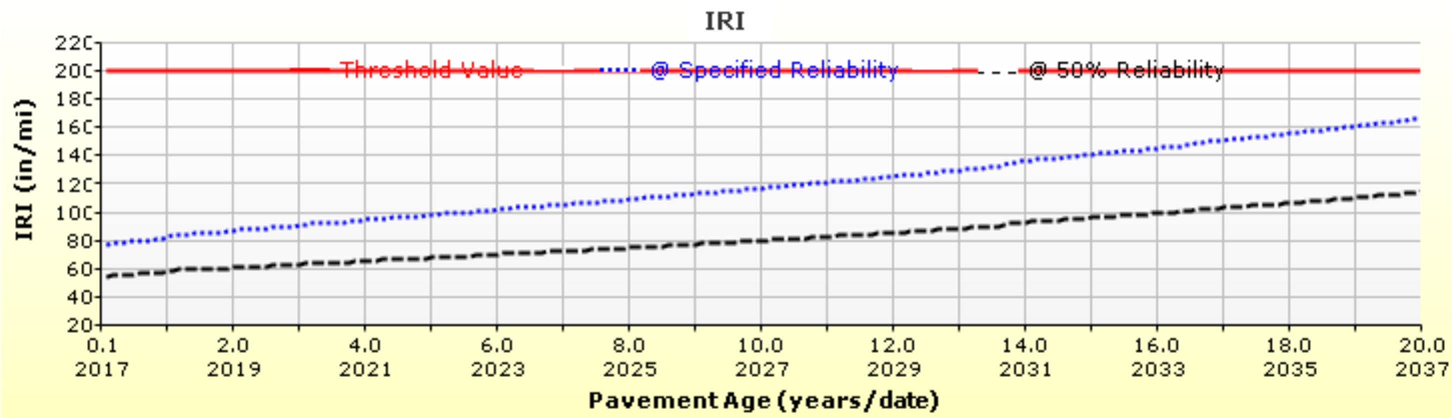
HMA Layer 2: Layer 2 Flexible : R1 Level 1 S(100) PG 64-22

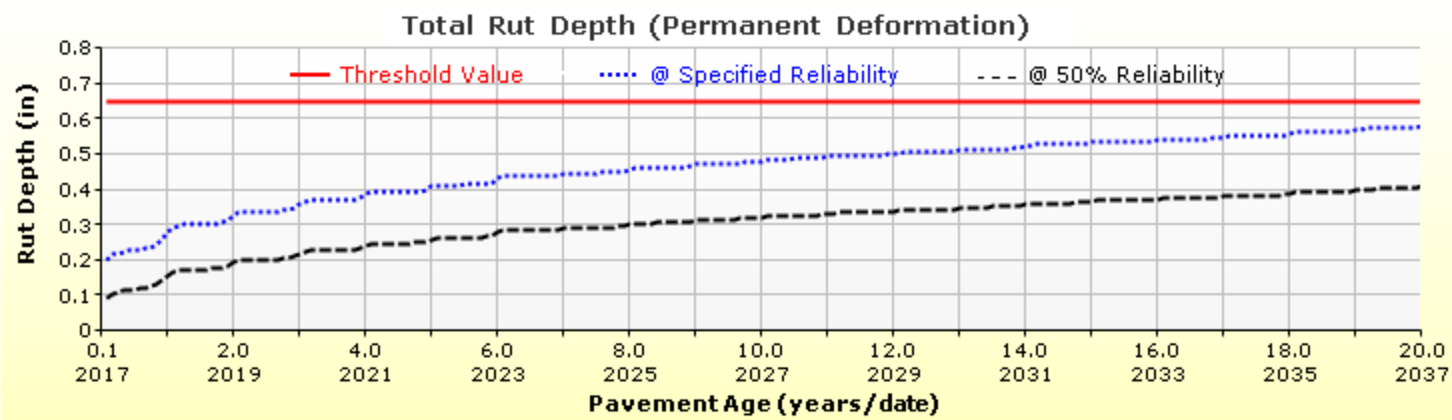


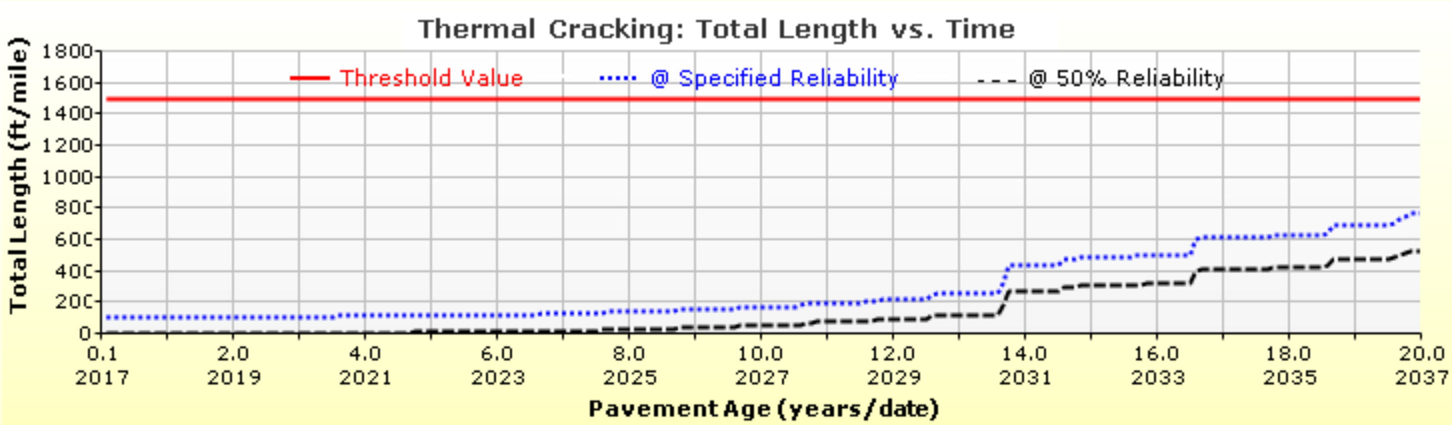


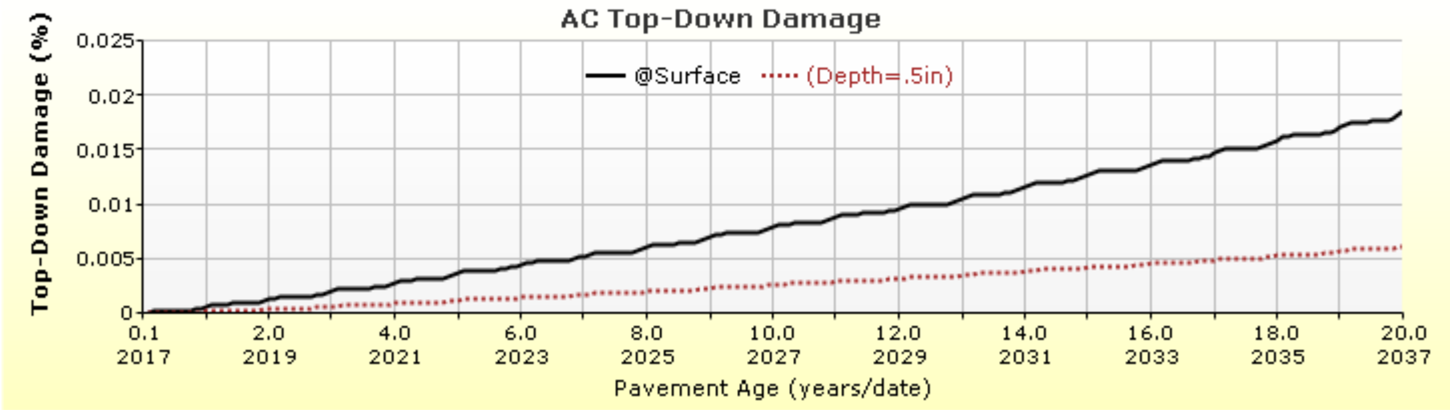


Analysis Output Charts

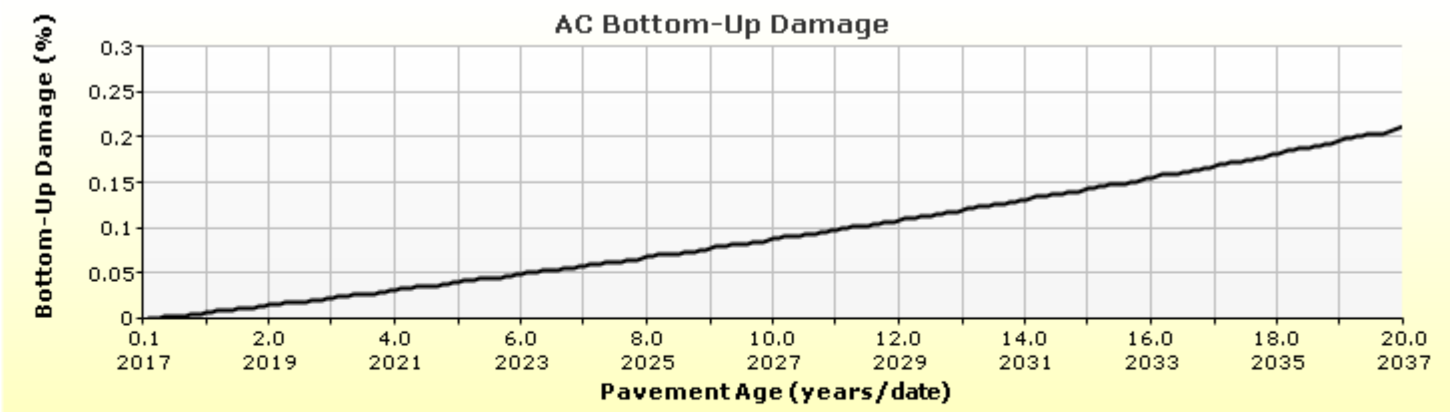




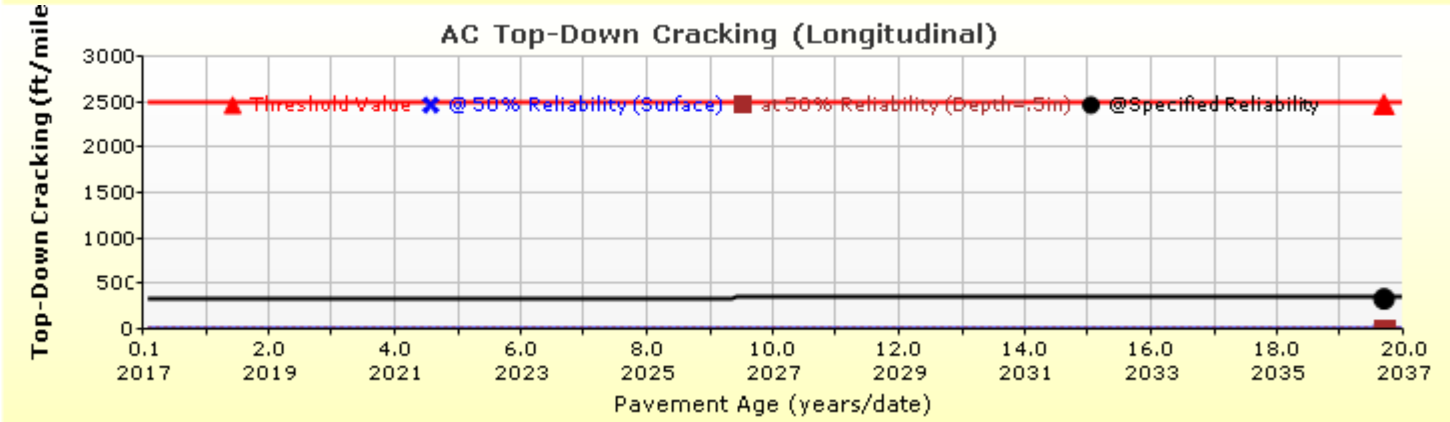




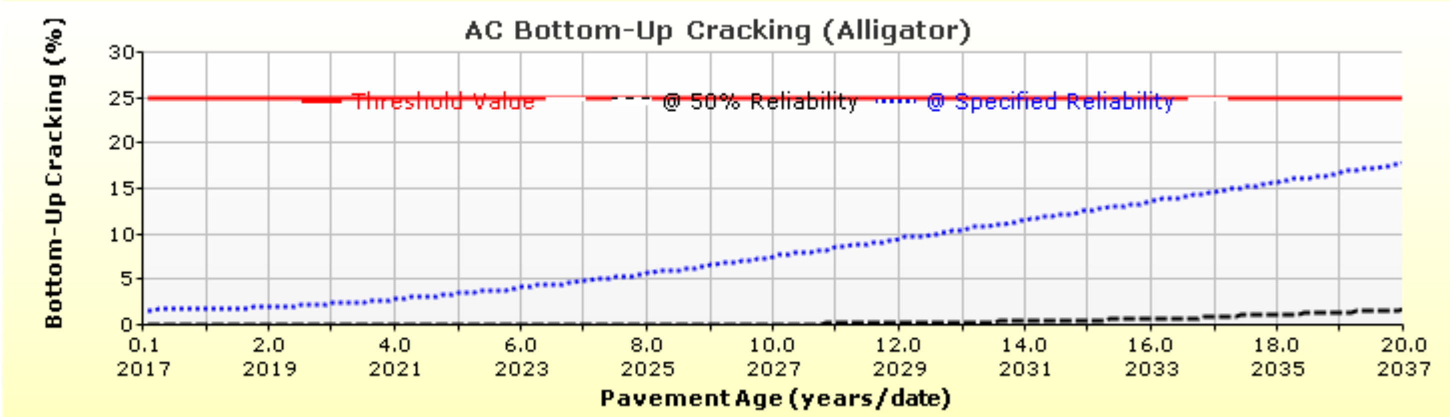
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.025
0.02
0.015
0.01
0.005
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)



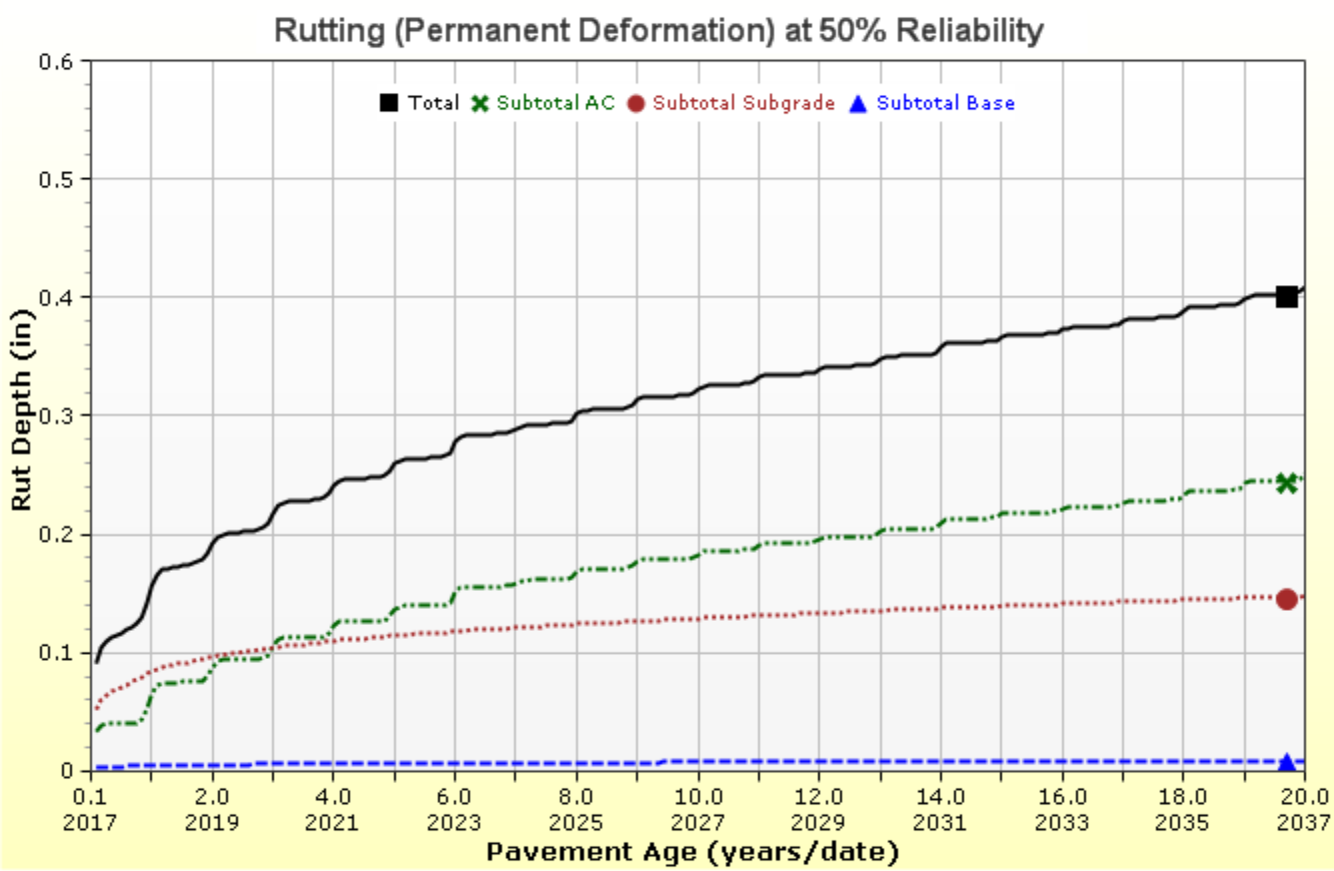
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)



AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3000
2500
2000
1500
1000
500
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)



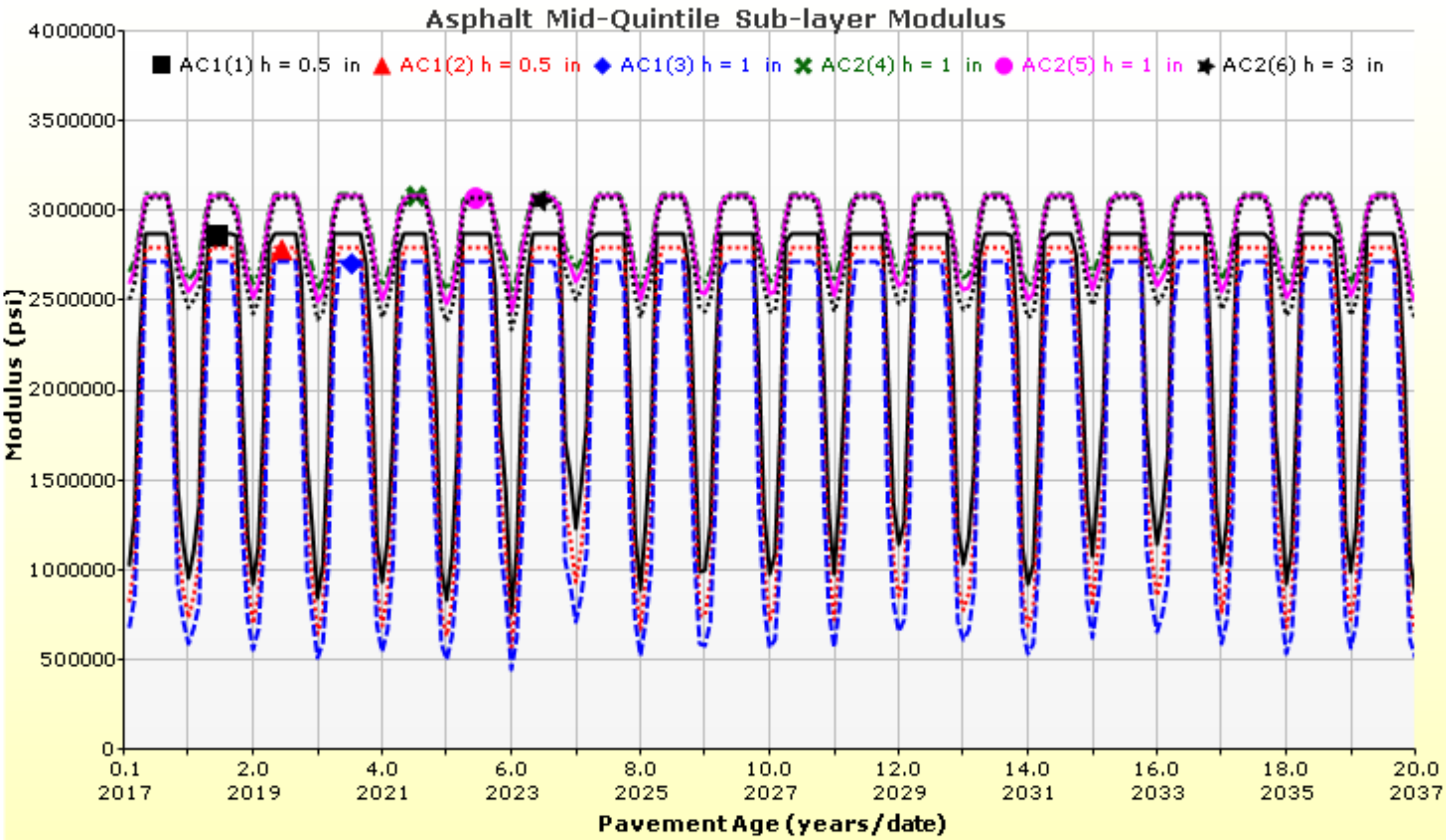
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)

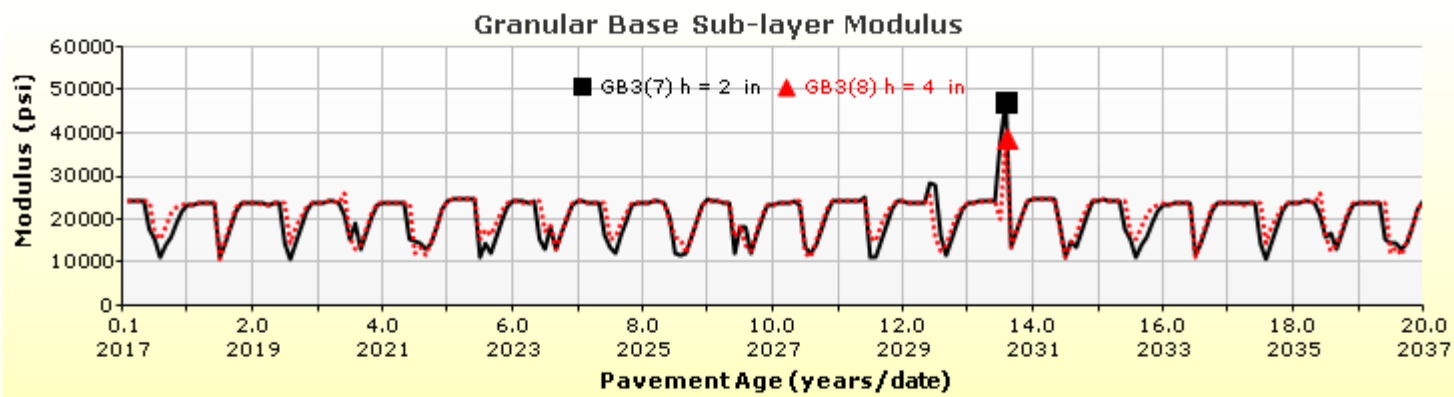


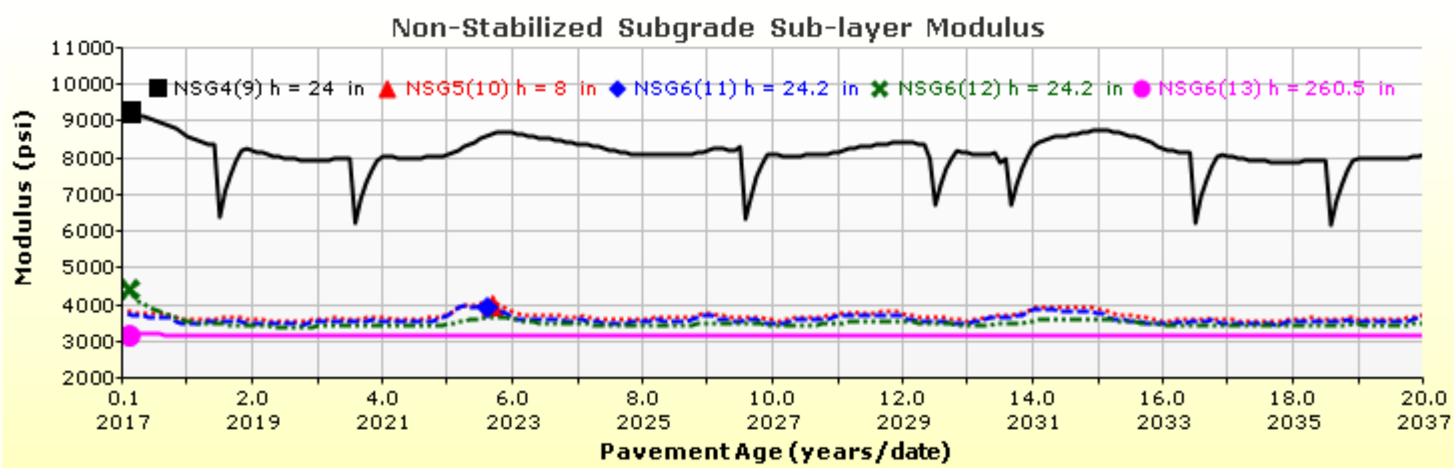
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
12.0 2029
14.0 2031
16.0 2033
18.0 2035
20.0 2037
Pavement Age (years/date)

US50 Westbound - Flexible - Exit Ramp R-5 Subgrade

File Name: E:\ME Design\302.02 - US50\US50 Westbound - Flexible - Exit Ramp R-5 Subgrade.dgpx







Layer Information

Layer 1 Flexible : R6 SX(100) PG 76-28

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.1
Air voids (%)	5.2
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1821960	2284749	2635719	2743629
40	761414	1245330	1773800	1972669
70	186328	368894	694551	866370
100	59960	102426	195476	256712
130	32727	44234	68258	84345

Identifiers

Field	Value
Display name/identifier	R6 SX(100) PG 76-28
Description of object	Mix ID # FS1939-5
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	4213	81
158	2029	83
168.8	1027	85

Layer 2 Flexible : R1 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	5.0	
Unit weight (pcf)	152.6	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1821960	2284749	2635719	2743629		
40	761414	1245330	1773800	1972669		
70	186328	368894	694551	866370		
100	59960	102426	195476	256712		
130	32727	44234	68258	84345		

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	4213	81
158	2029	83
168.8	1027	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.48
Air voids (%)	4.9
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R1 Level 1 S(100) PG 64-22
Description of object	Mix ID # FS29326
Author	CDOT
Date Created	2/11/2015 12:00:00 AM
Approver	CDOT
Date approved	2/11/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : CDOT Class 6 ABC (Mr-15000)

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
15000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	CDOT Class 6 ABC (Mr-15000)
Description of object	Aggregate Base Course (ABC)
Author	RockSol JBiller
Date Created	12/31/2014 12:00:00 AM
Approver	JBiller
Date approved	12/31/2014 12:00:00 AM
State	Colorado
District	
County	United States
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	A-1-a
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 4 Subgrade : A-2-4 (R-40)

Unbound	
Layer thickness (in)	24.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
15000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-2-4 (R-40)
Description of object	Improved Subgrade
Author	RockSol JBiller
Date Created	1/1/2011 12:00:00 AM
Approver	JBiller
Date approved	1/1/2011 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	25.0
Plasticity Index	9.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.6
Saturated hydraulic conductivity (ft/hr)	False	9.054e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	True	12

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	55.4591
bf	1.1366
cf	0.5635
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 5 Subgrade : A-6 (R-5)

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
15000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (R-5)
Description of object	Default material (Mr=5356)
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Layer 6 Subgrade : A-6 (Native)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
15000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (Native)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	20.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	106.2
Saturated hydraulic conductivity (ft/hr)	False	2.543e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	18.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	115.7360
bf	0.6334
cf	0.1681
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	7.5
#100	
#80	
#60	
#50	
#40	
#30	
#20	
#16	
#10	
#8	40.0
#4	47.5
3/8-in.	
1/2-in.	
3/4-in.	100.0
1-in.	
1 1/2-in.	
2-in.	
2 1/2-in.	
3-in.	
3 1/2-in.	

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting (using Multilayer Calibration)

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$
$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$
$$C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$$
$$C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$$

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

AC Rutting Standard Deviation	0.1414*Pow(RUT,0.25)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$
$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$
$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
C = crack depth(in)
h_{ac} = thickness of asphalt layer(in)
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the asphalt mixture
E = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 6.3	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress(psi)
M_r = modulus of rupture(psi)

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

δ_a = permanent deformation for the layer
N = number of repetitions
ε_v = average veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104*Pow(BASERUT,0.67)+0.001		Standard Deviation (BASERUT) 0.0663*Pow(SUBRUT,0.5)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Top Standard Deviation	AC Cracking Bottom Standard Deviation
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))	1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02

Design Inputs

Design Life: 10 years
Design Type: AC over AC

Existing construction: May, 1996
Pavement construction: June, 2017
Traffic opening: September, 2017

Climate Data Sources (Lat/Lon): 39.57, -104.849

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R4 SMA	3.0
Flexible (existing)	Existing Asphalt	7.0
Subgrade	A-6 (R-5)	8.0
Subgrade	A-6 (Native)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	13.1
Air voids (%)	4.0

Traffic

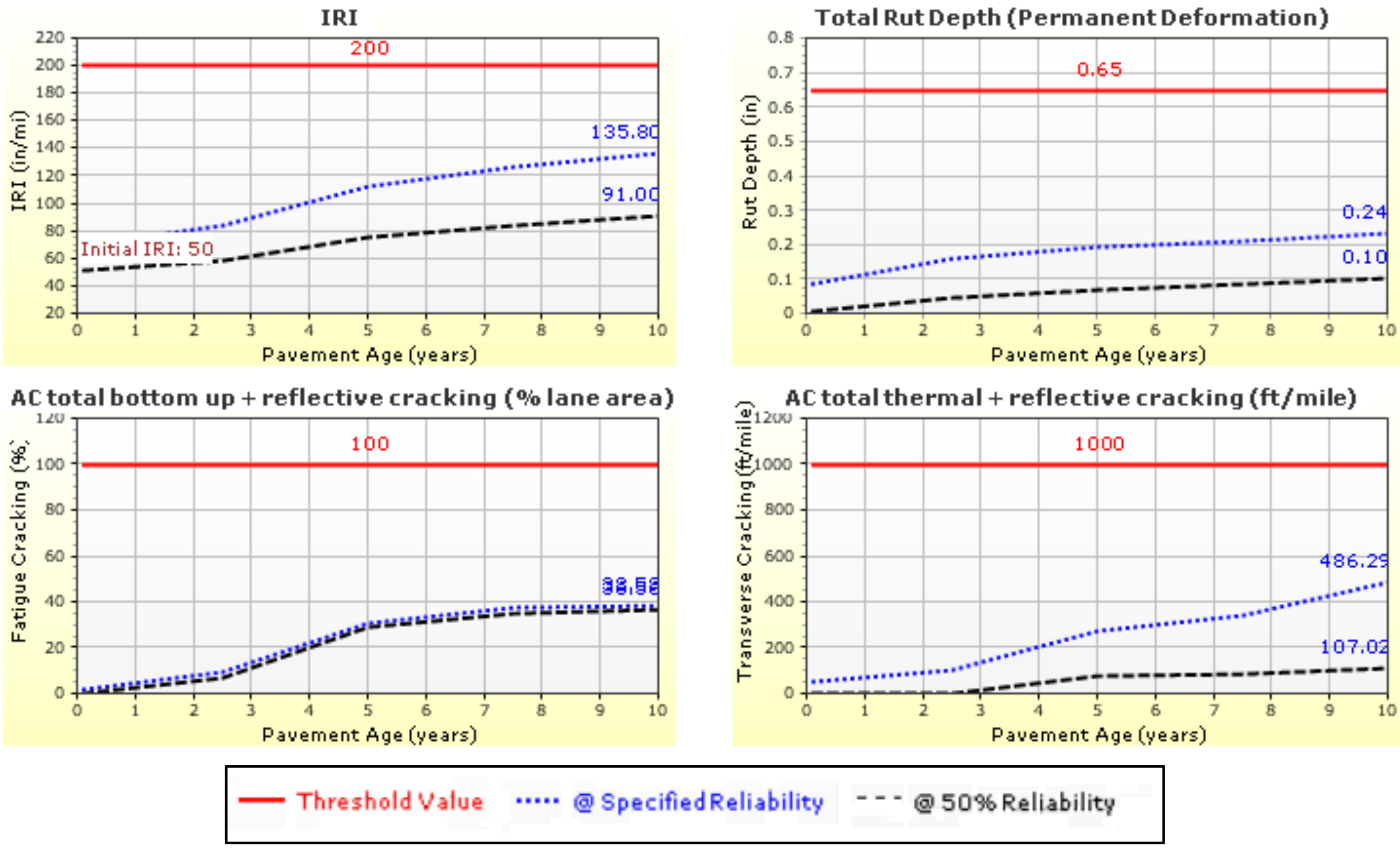
Age (year)	Heavy Trucks (cumulative)
2017 (initial)	2,900
2022 (5 years)	1,709,130
2027 (10 years)	3,753,800

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	135.81	95.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.24	95.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	100.00	38.59	95.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	1000.00	486.29	95.00	99.99	Pass
Permanent deformation - AC only (in)	0.50	0.24	95.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	32.06	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	358.53	95.00	100.00	Pass

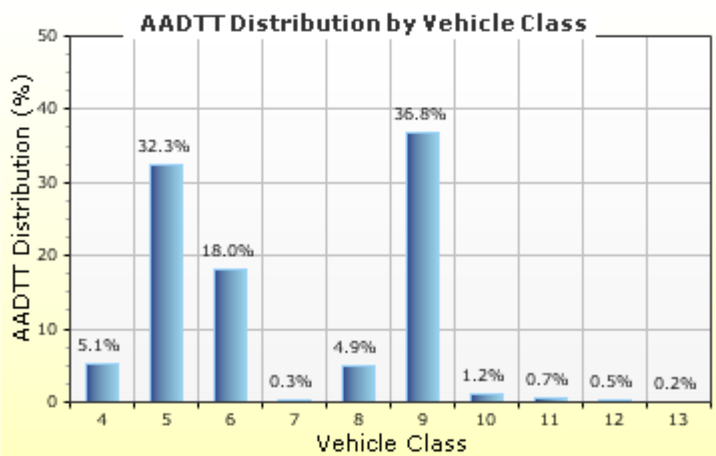
Distress Charts

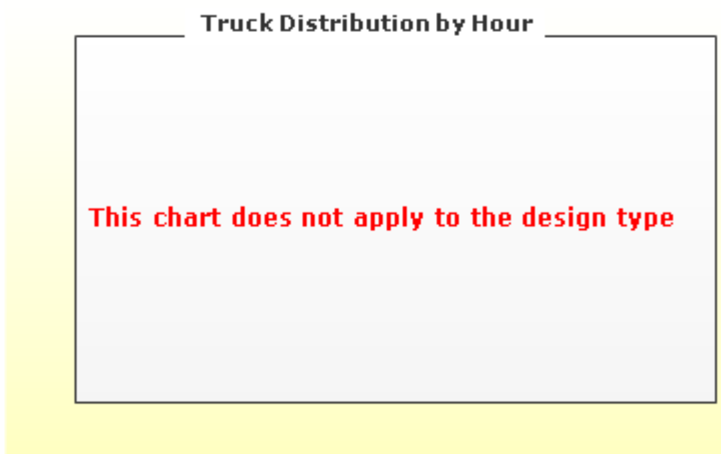


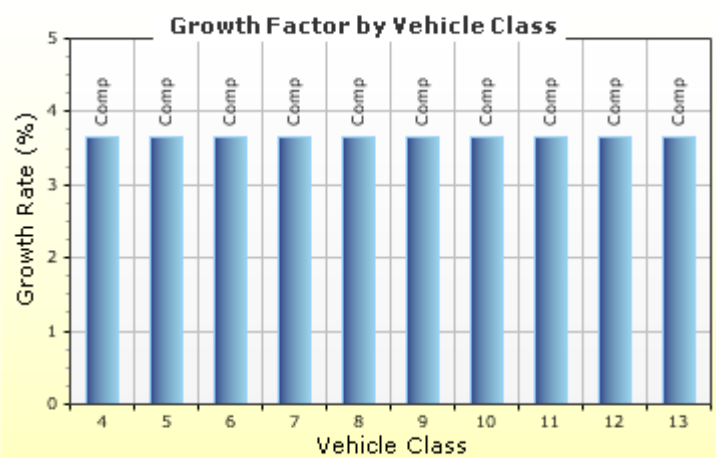
Traffic Inputs

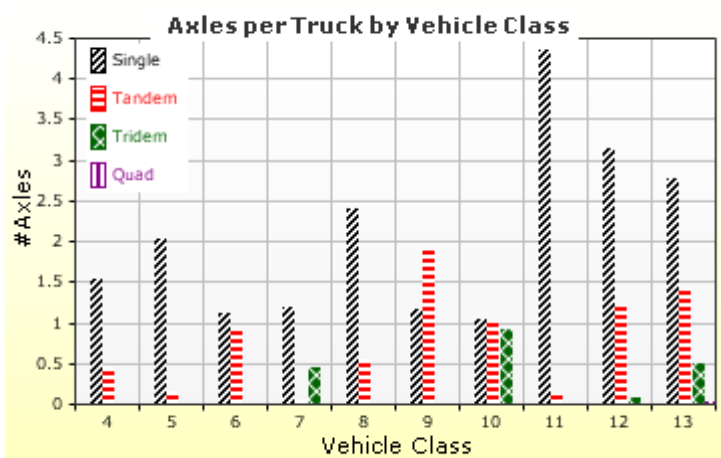
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,900	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	6	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	40.0

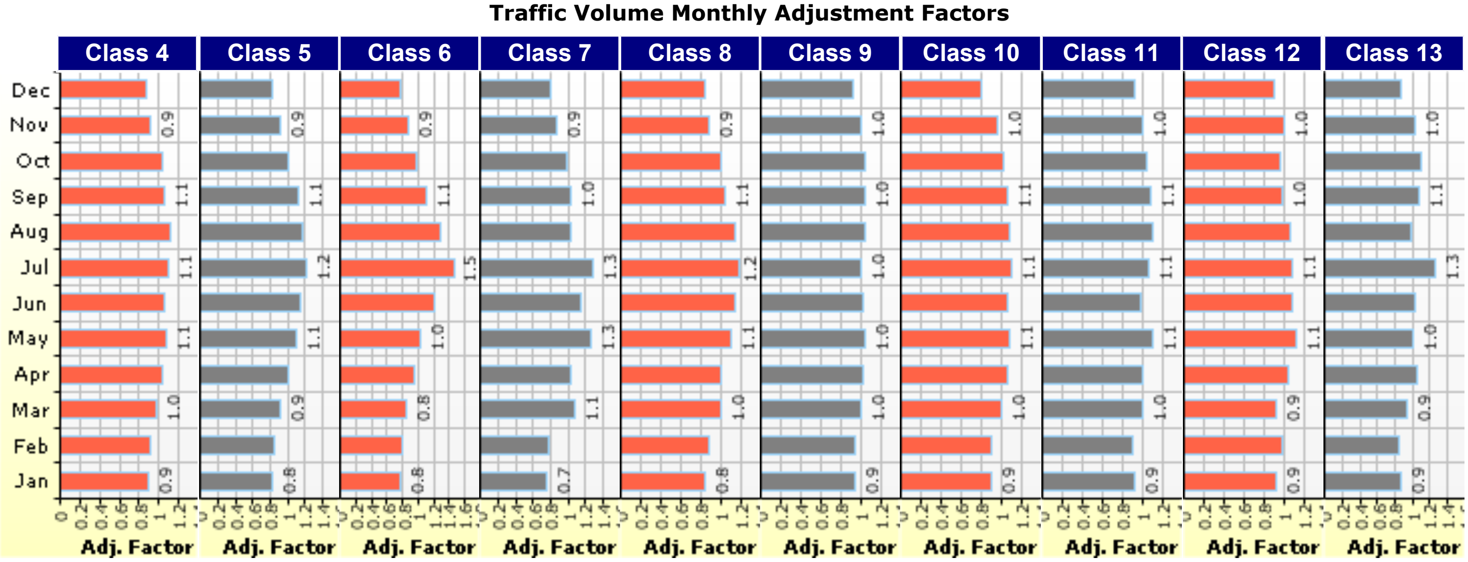








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3.65%	Compound
Class 5	32.3%	3.65%	Compound
Class 6	18%	3.65%	Compound
Class 7	0.3%	3.65%	Compound
Class 8	4.9%	3.65%	Compound
Class 9	36.8%	3.65%	Compound
Class 10	1.2%	3.65%	Compound
Class 11	0.7%	3.65%	Compound
Class 12	0.5%	3.65%	Compound
Class 13	0.2%	3.65%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

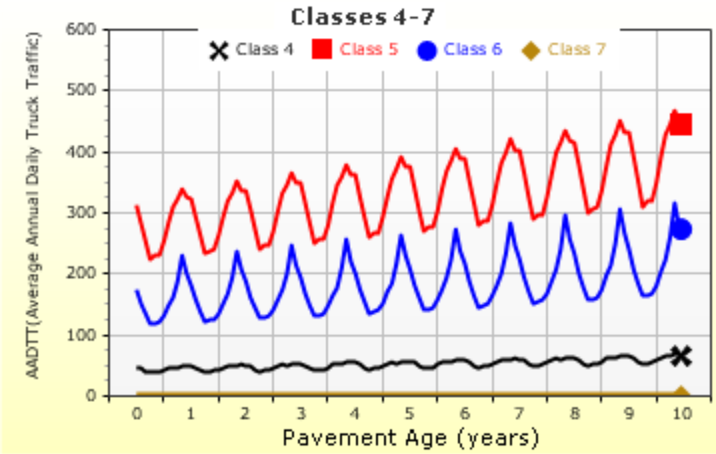
Wheelbase does not apply

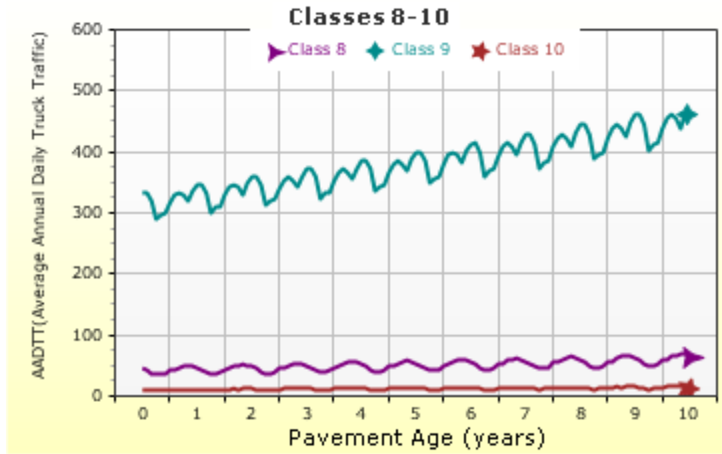
Number of Axles per Truck

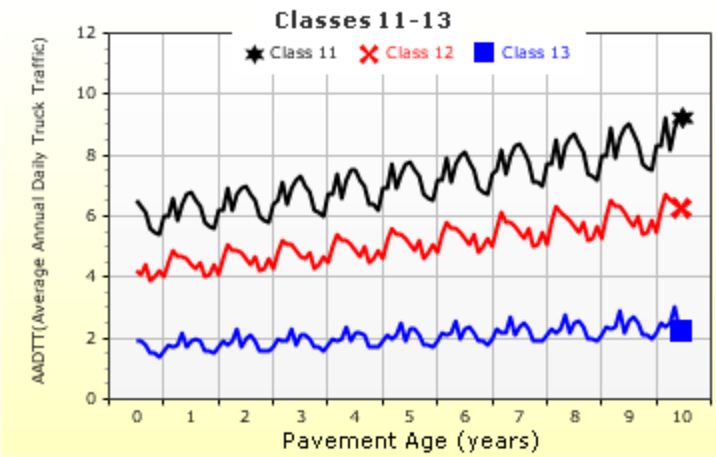
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

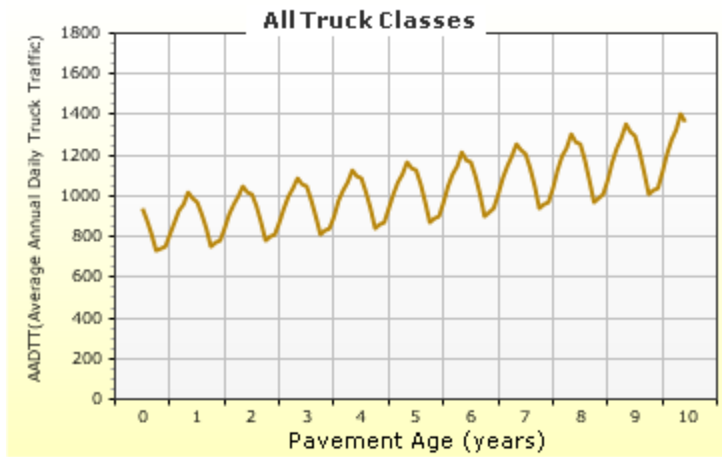
AADTT (Average Annual Daily Truck Traffic) Growth

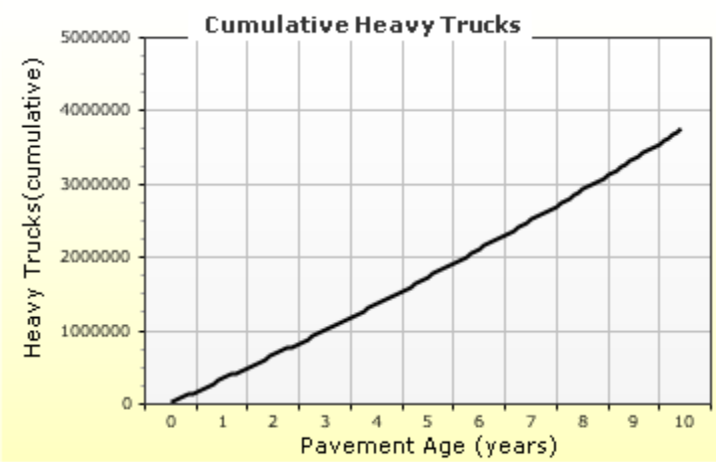
*** Traffic cap is not enforced**







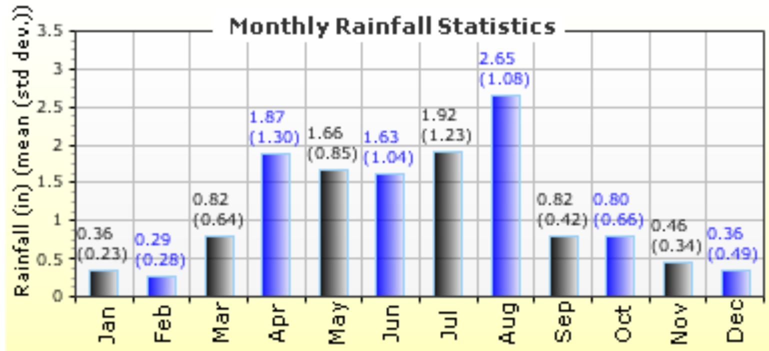




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
CENTENNIAL, CO	39.57000 -104.84900 5828

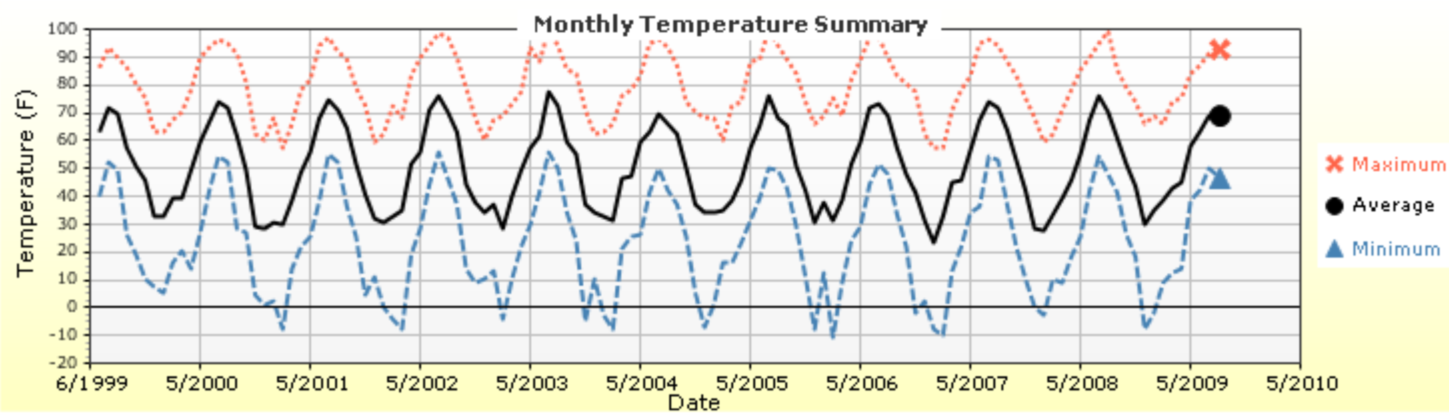


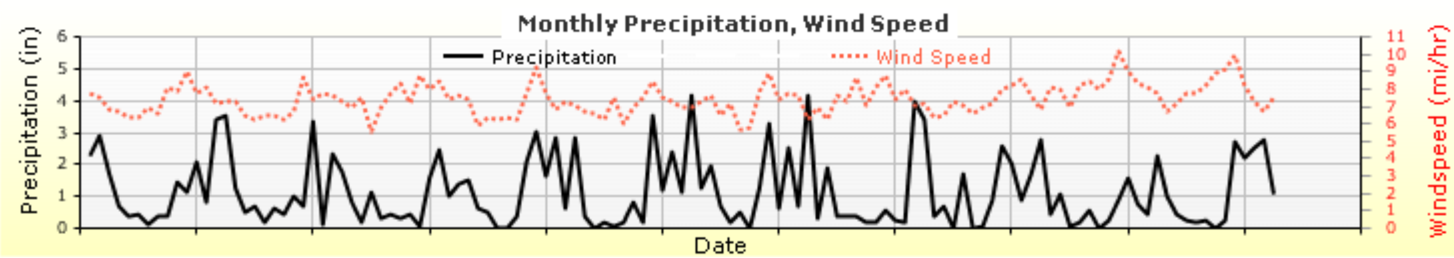
Annual Statistics:

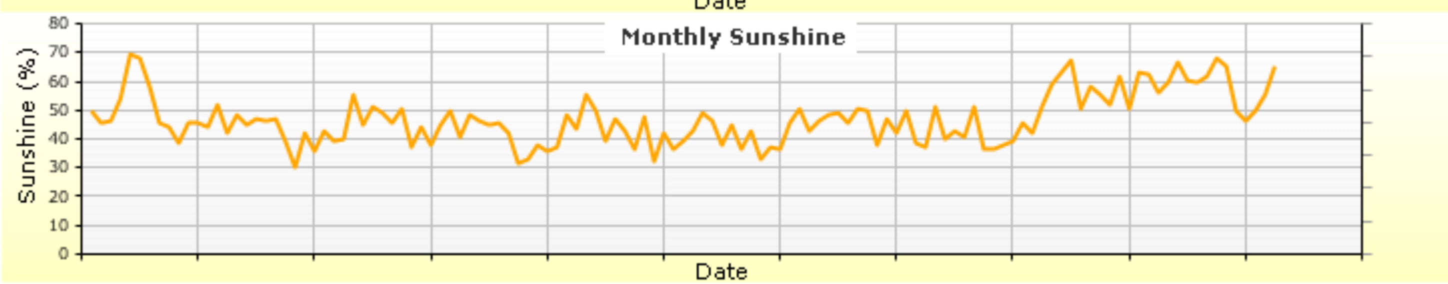
Mean annual air temperature (ºF)	50.82
Mean annual precipitation (in)	14.00
Freezing index (ºF - days)	444.05
Average annual number of freeze/thaw cycles:	123.95

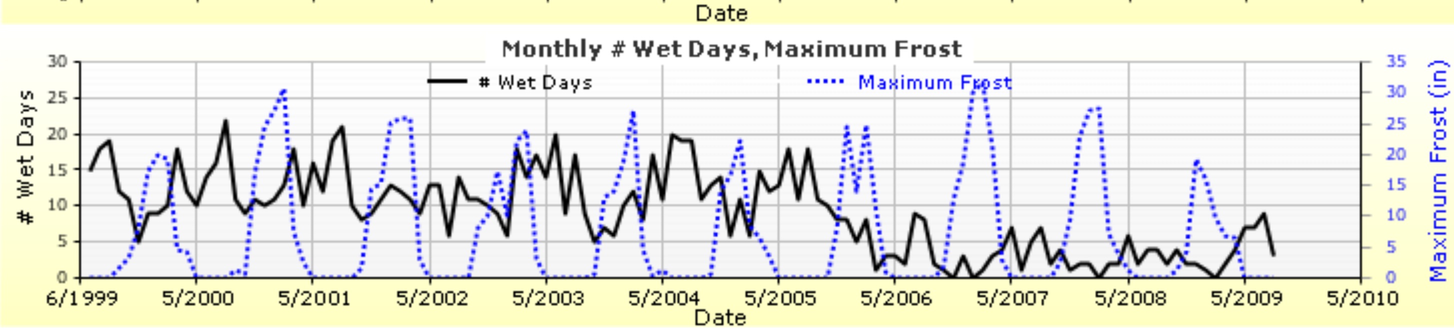
Water table depth (ft)	10.00

Monthly Climate Summary:

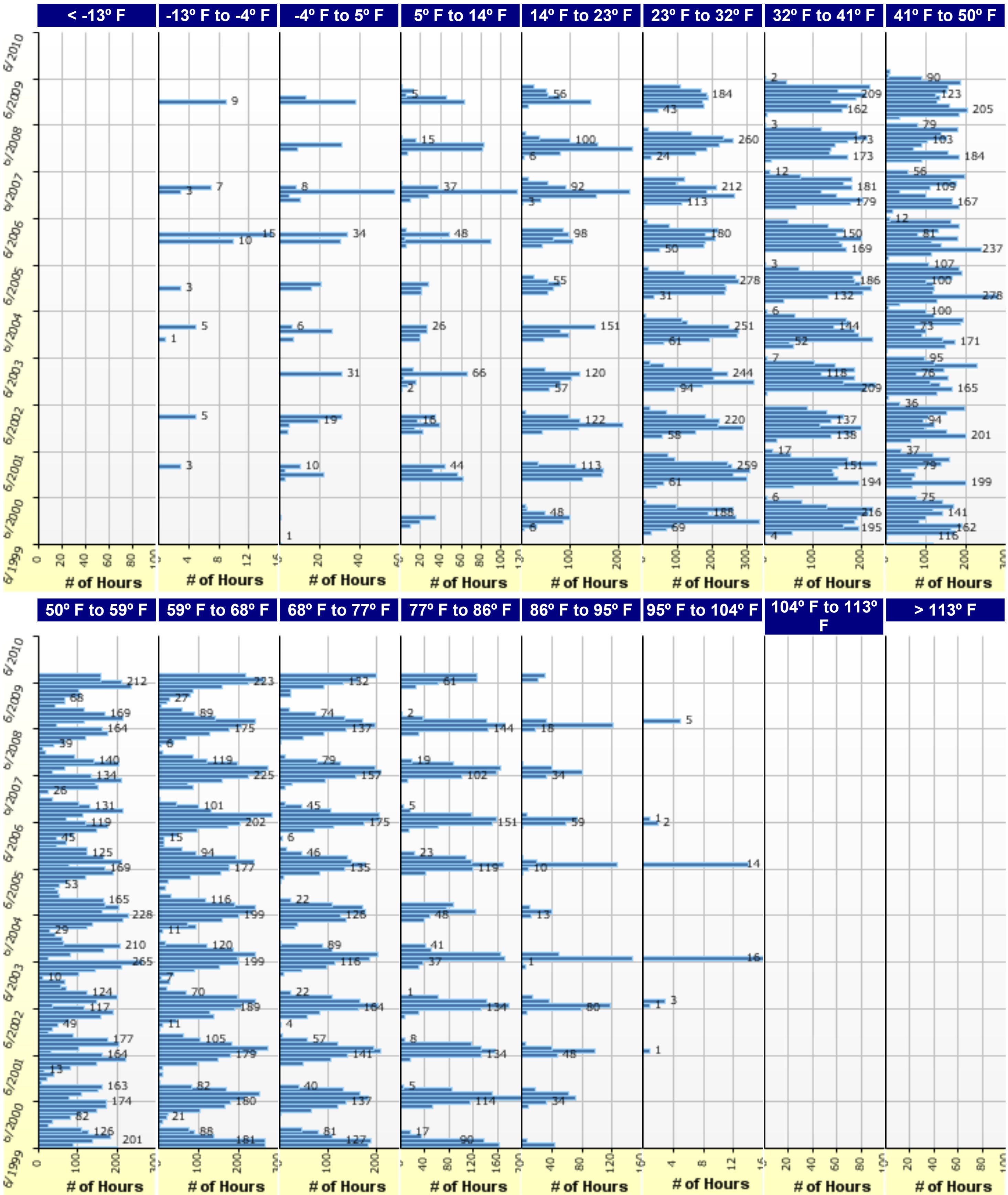








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R4 SMA	Flexible (1)	1.00
Layer 2 Flexible : Existing Asphalt (existing)	Flexible (1)	1.00
Layer 3 Subgrade : A-6 (R-5)	Subgrade (5)	1.00
Layer 4 Subgrade : A-6 (Native)	Subgrade (5)	-

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

HMA Rehabilitation (Input Level: 3)

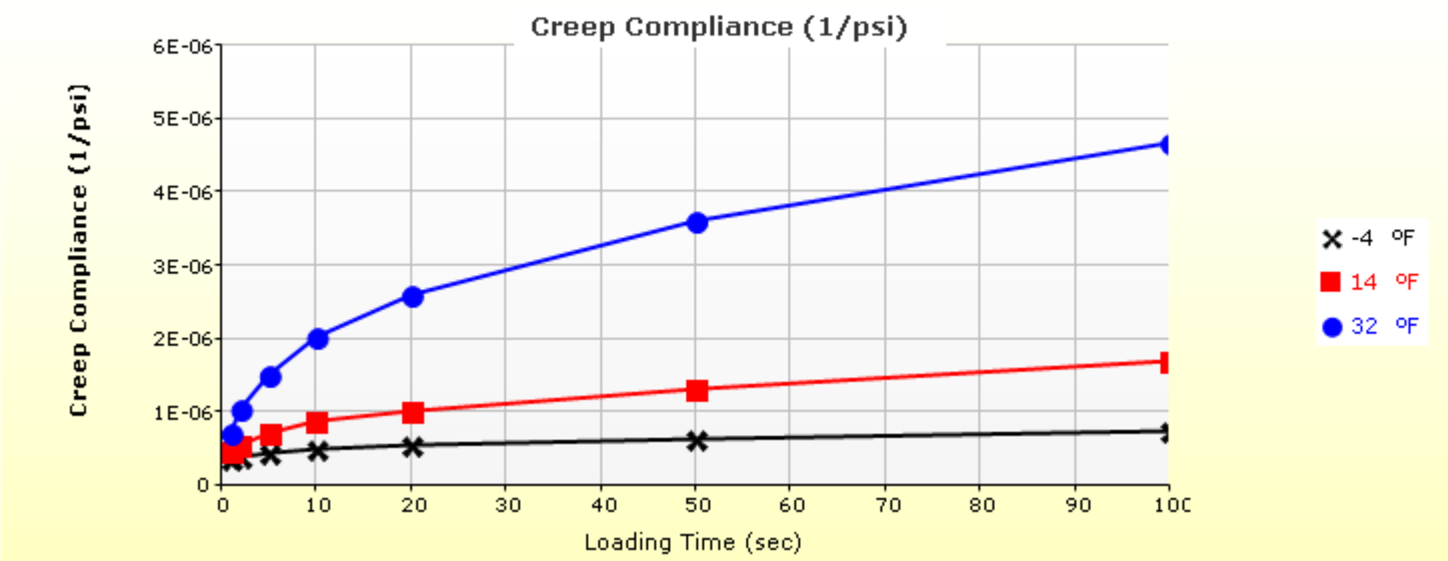
Milled thickness (in)	3.00
Structural rating	Fair
Environmental rating	Good
Total rut depth (in)	0.50

Thermal Cracking (Input Level: 1)

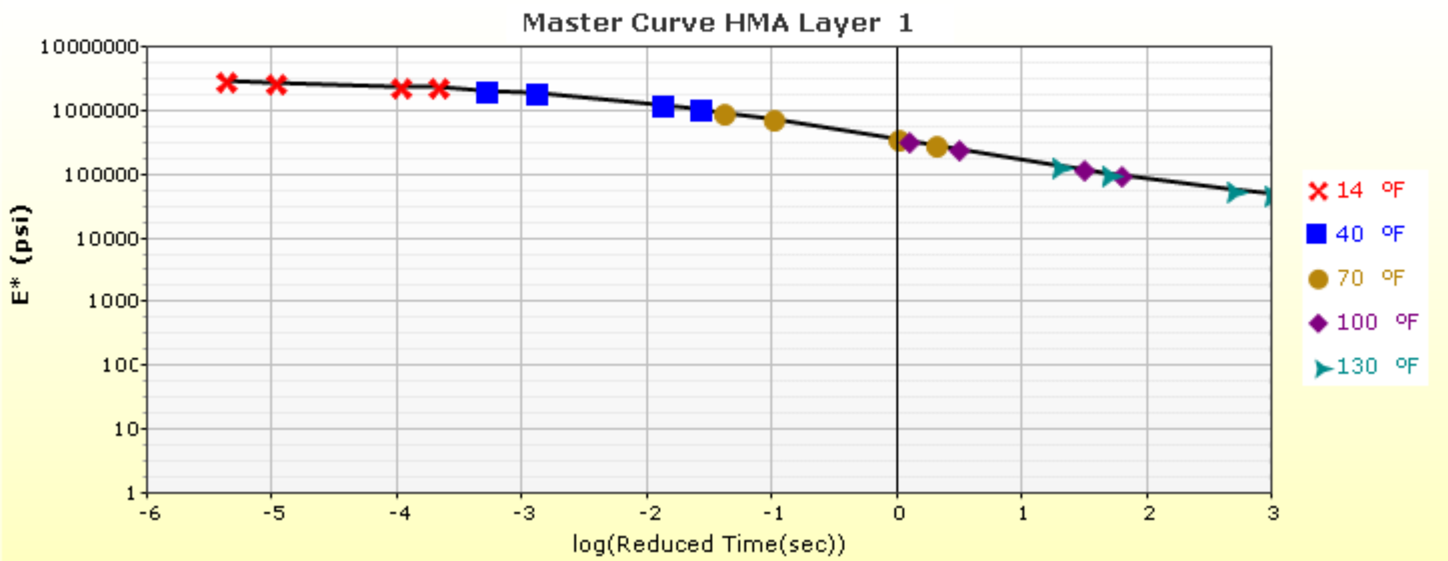
Indirect tensile strength at 14 ºF (psi)	566.00

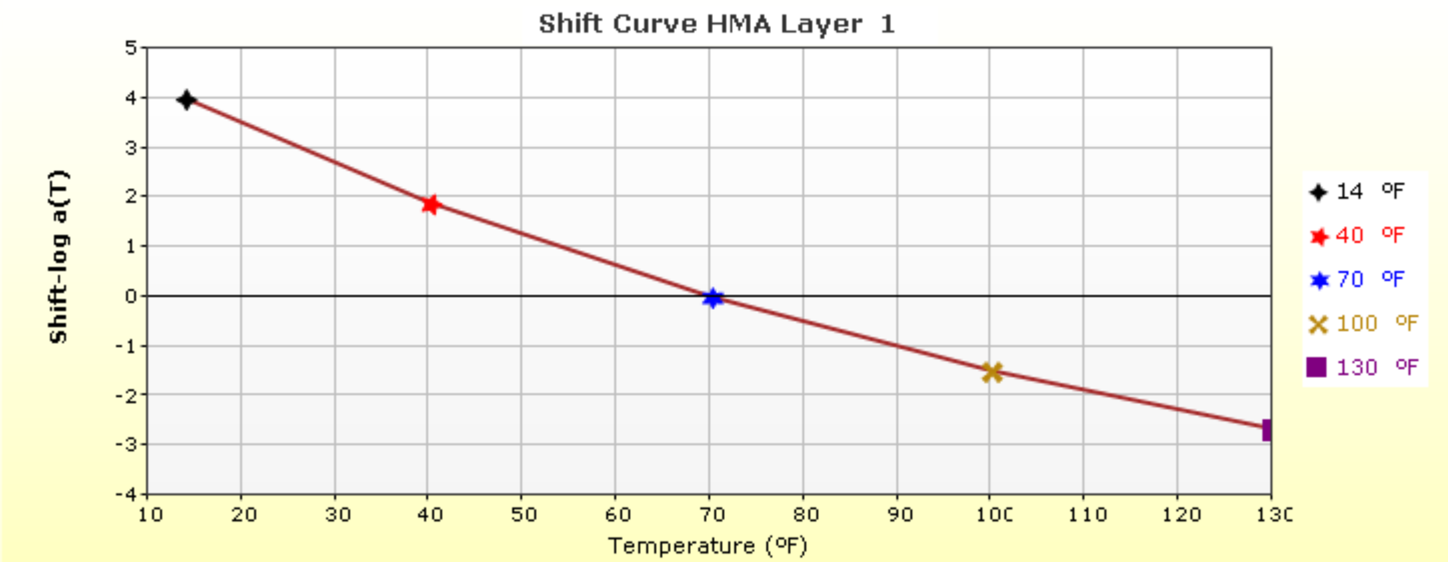
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	17.1

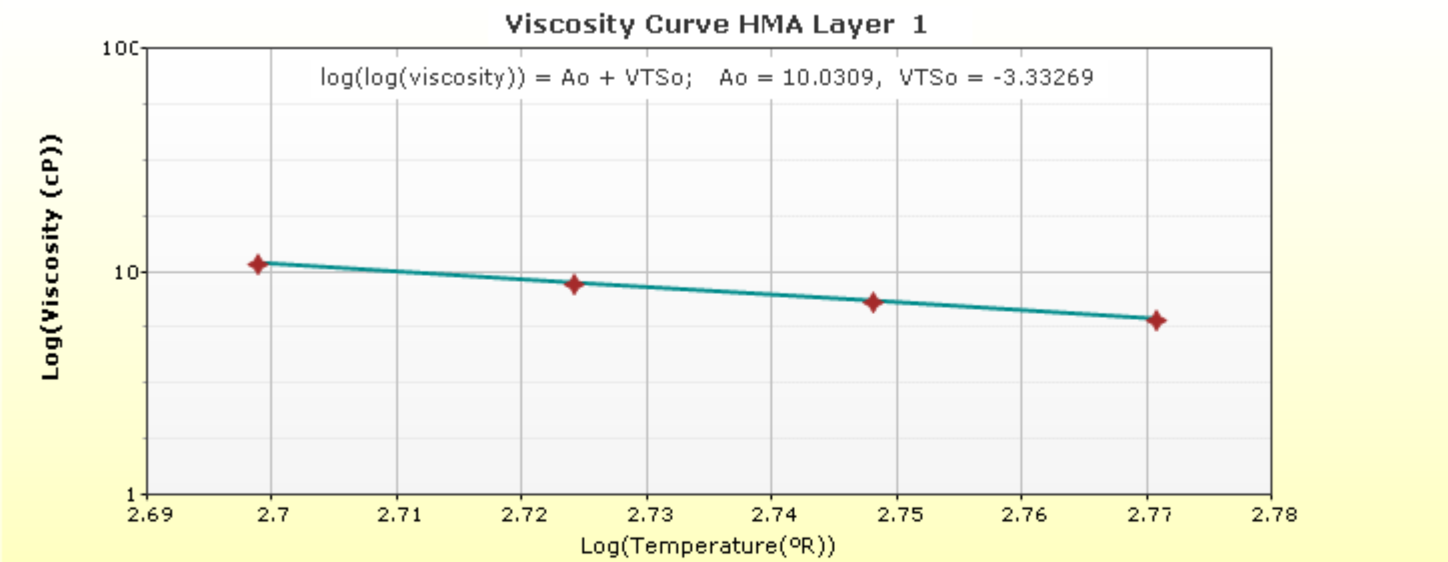
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.64e-007	4.64e-007	7.35e-007
2	4.05e-007	5.70e-007	1.04e-006
5	4.43e-007	7.15e-007	1.51e-006
10	5.06e-007	8.79e-007	2.04e-006
20	5.48e-007	1.03e-006	2.61e-006
50	6.40e-007	1.31e-006	3.61e-006
100	7.44e-007	1.70e-006	4.69e-006



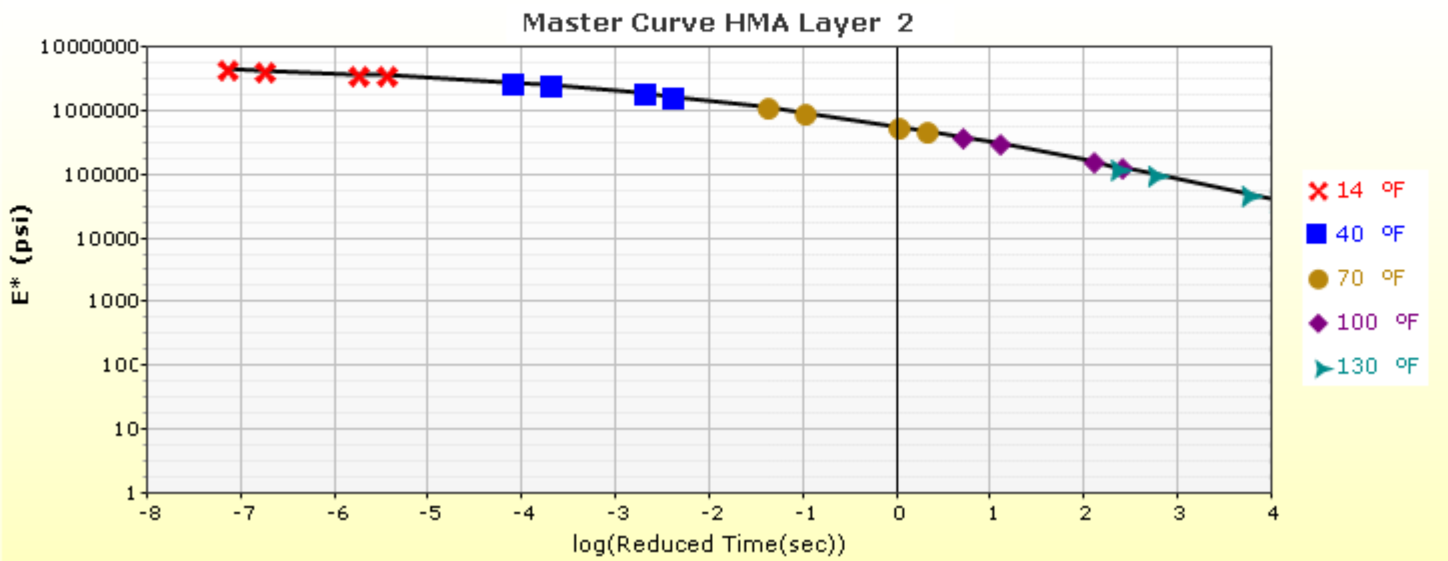
HMA Layer 1: Layer 1 Flexible : R4 SMA

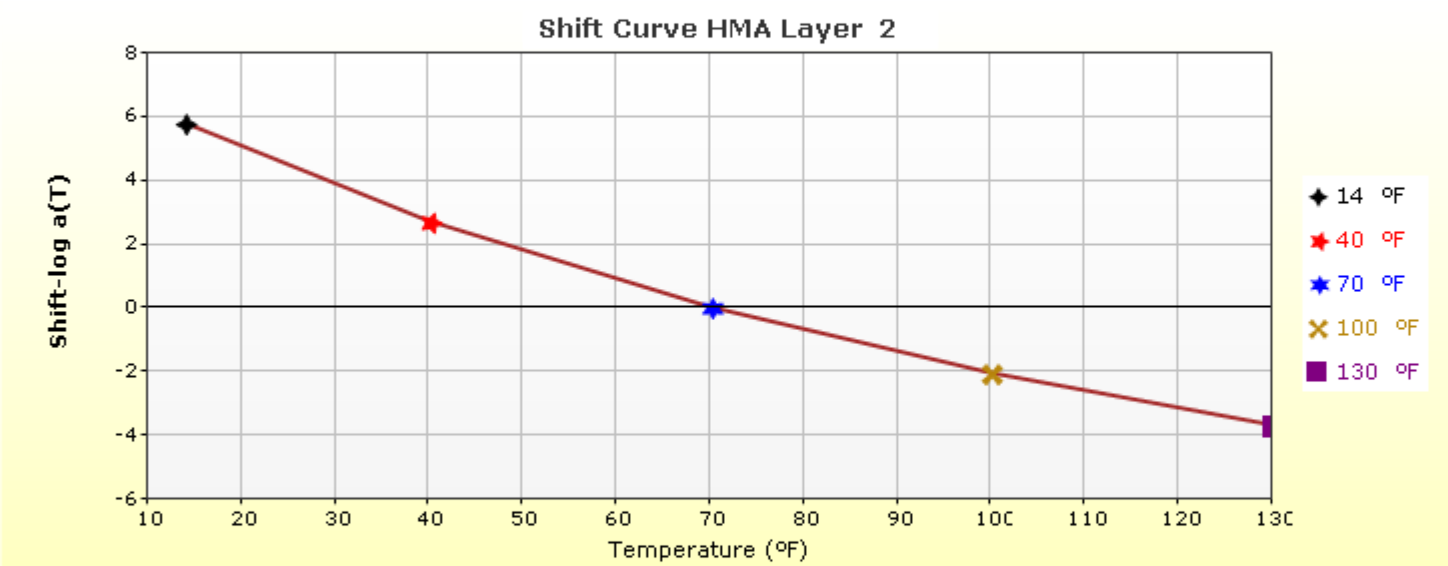


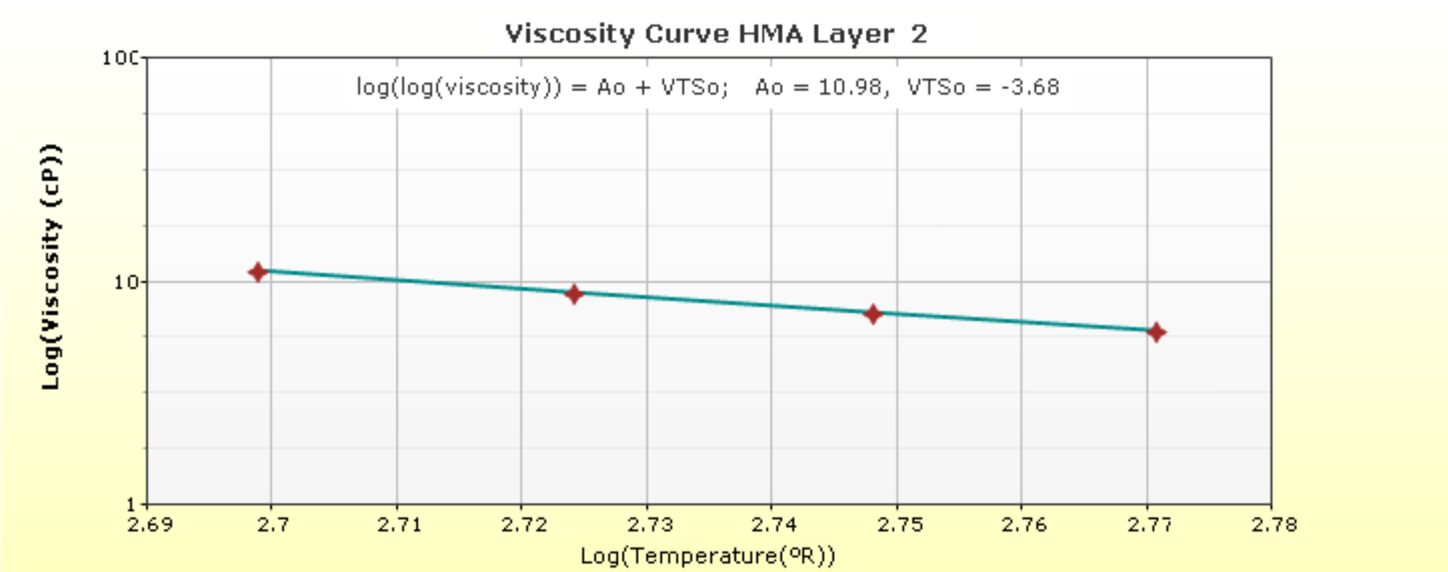




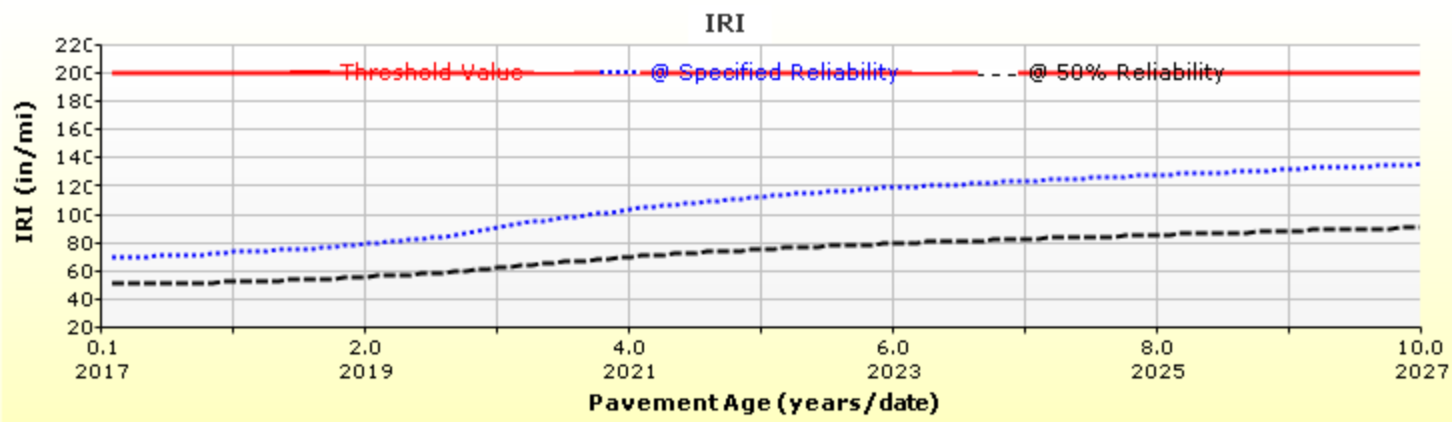
HMA Layer 2: Layer 2 Flexible : Existing Asphalt(existing)

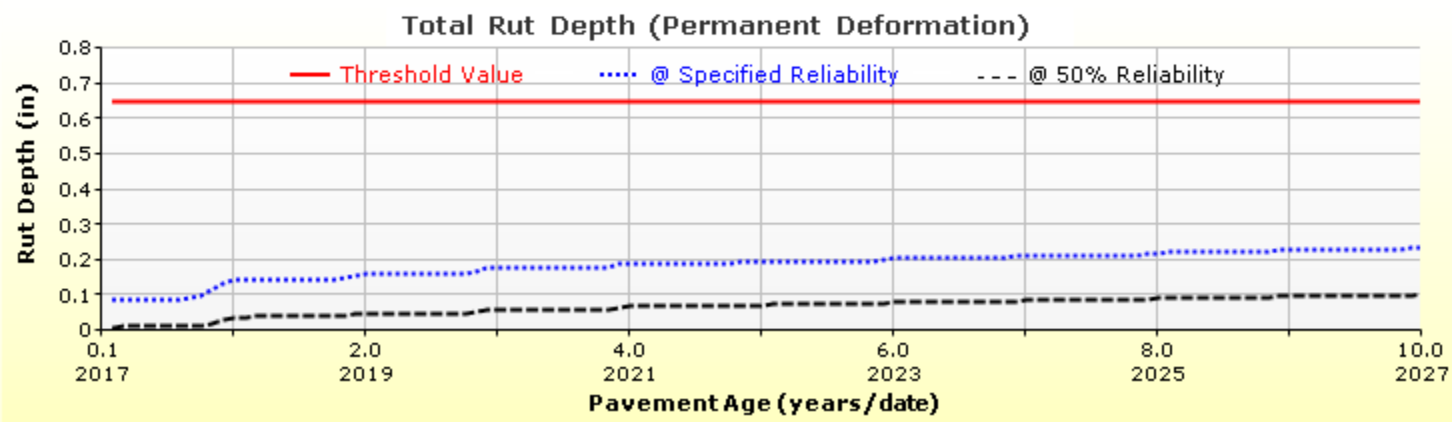


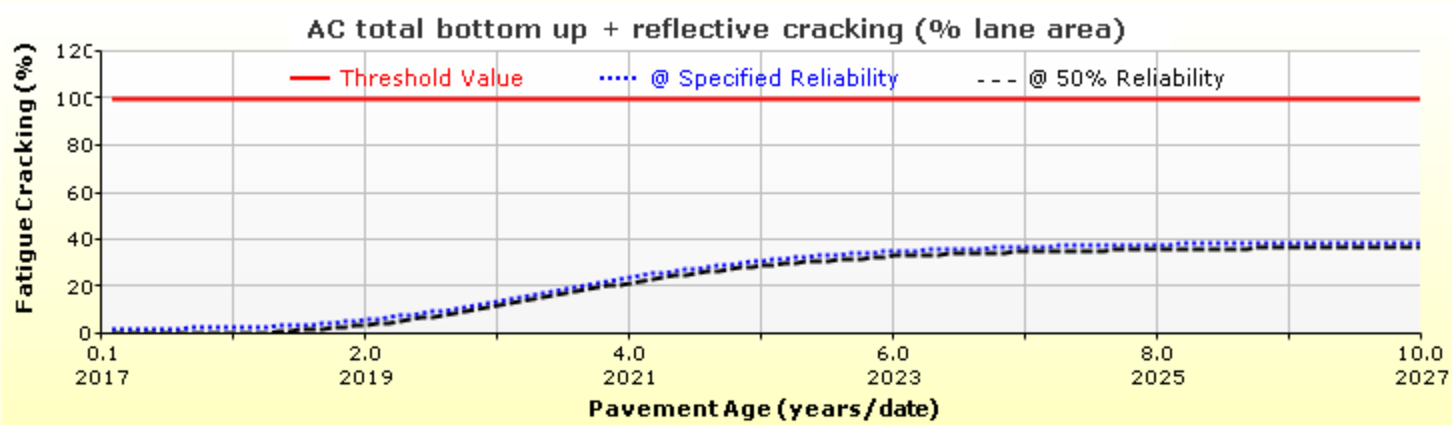


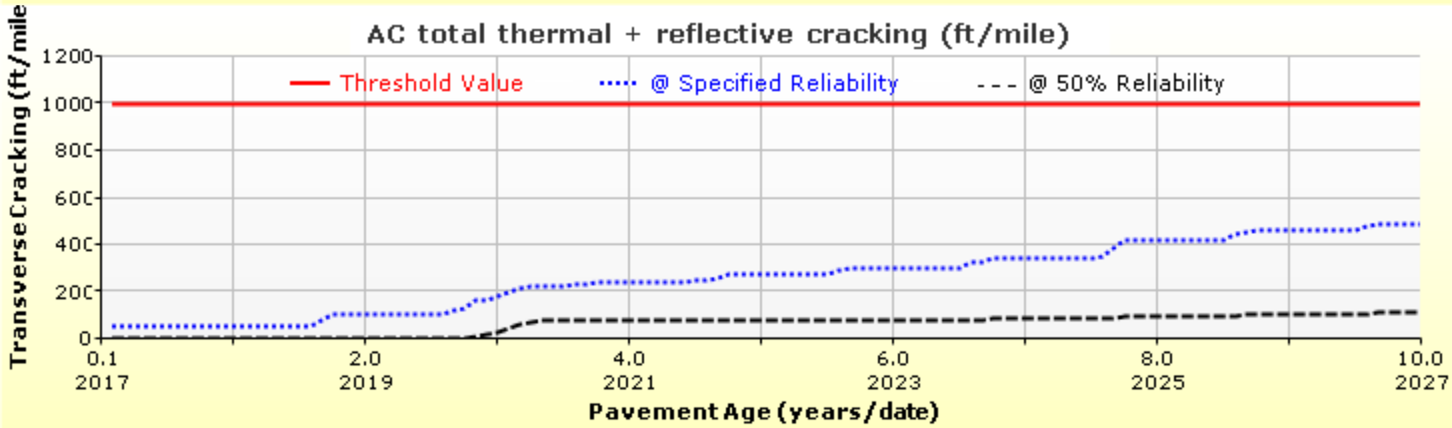


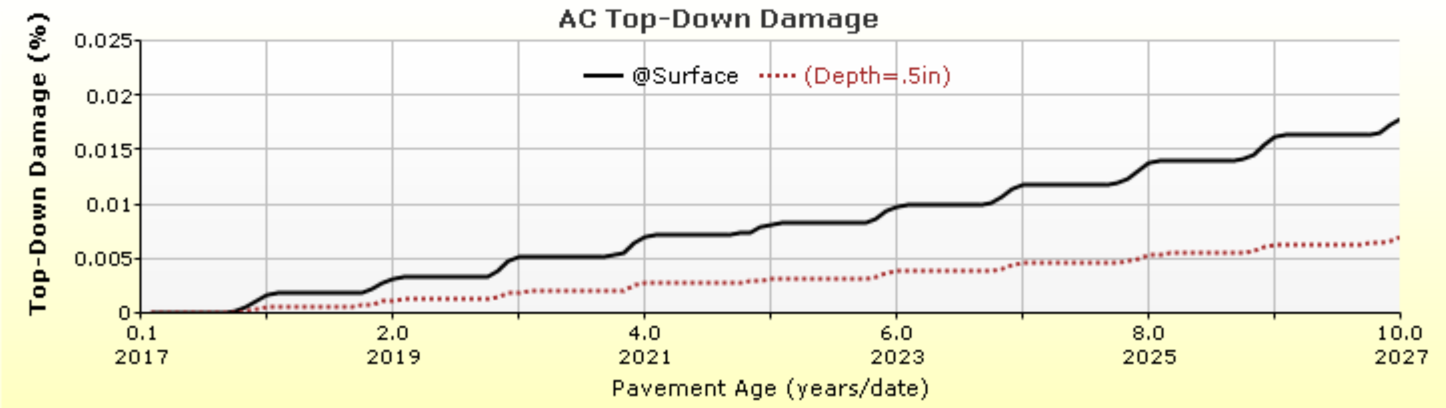
Analysis Output Charts



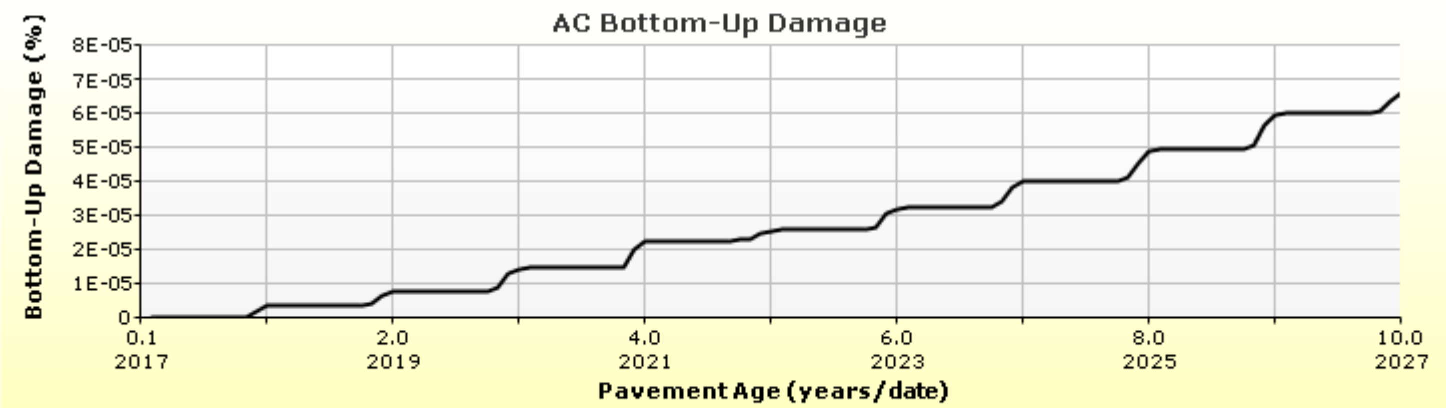




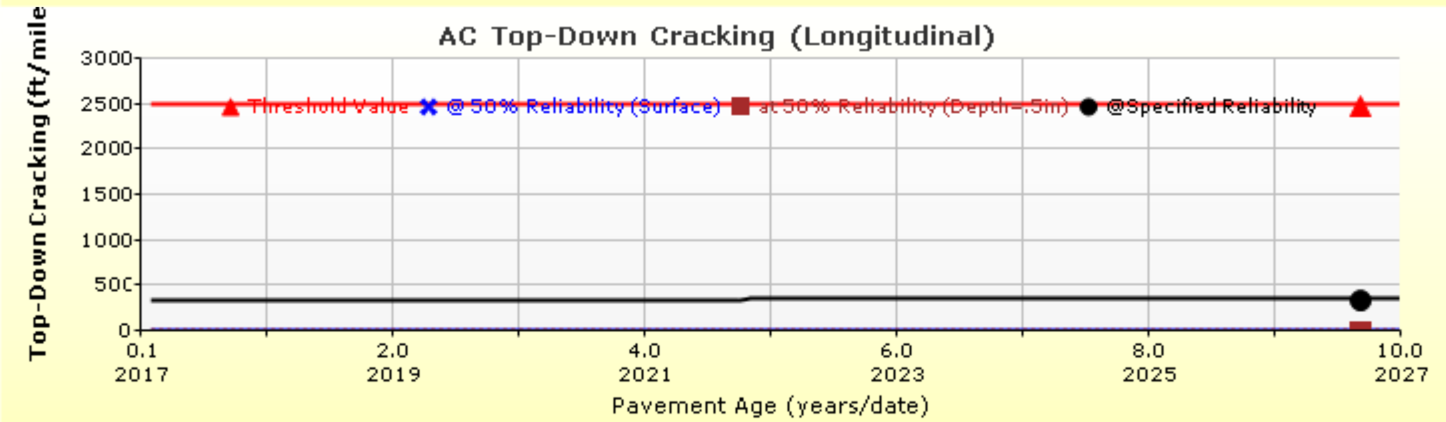




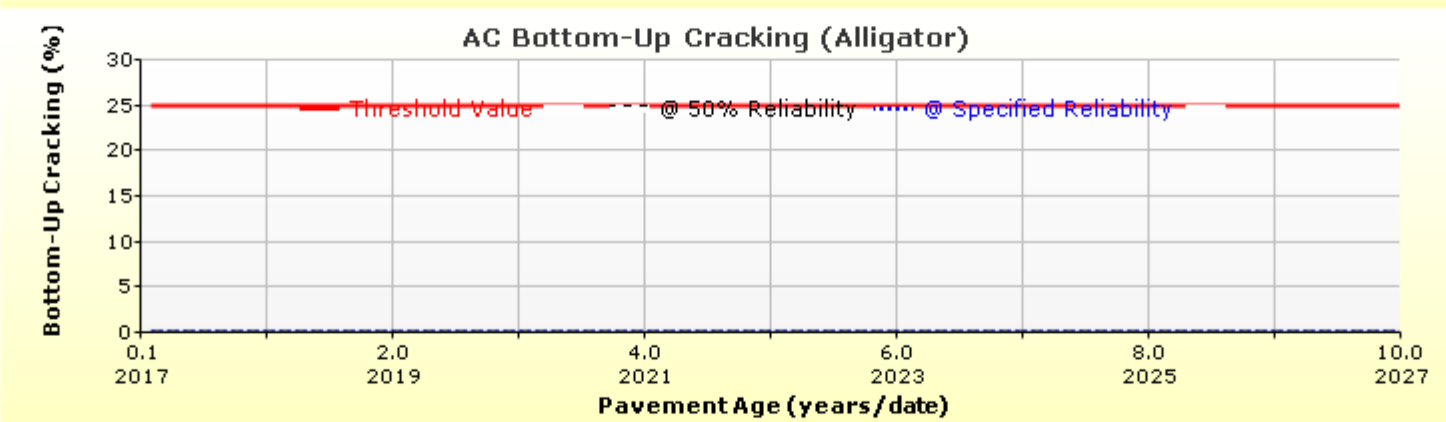
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.025
0.02
0.015
0.01
0.005
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



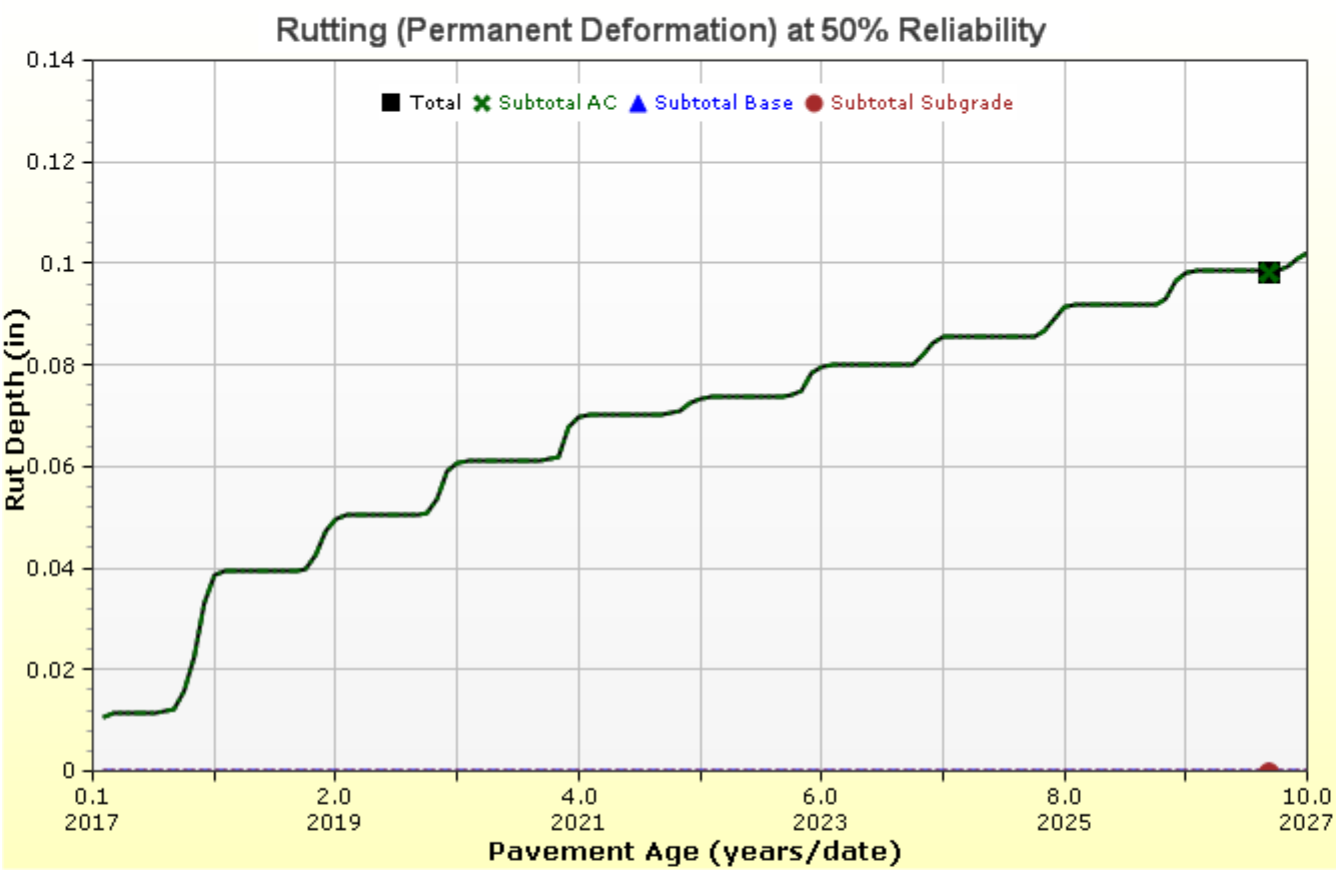
AC Bottom-Up Damage
Bottom-Up Damage (%)
8E-05
7E-05
6E-05
5E-05
4E-05
3E-05
2E-05
1E-05
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



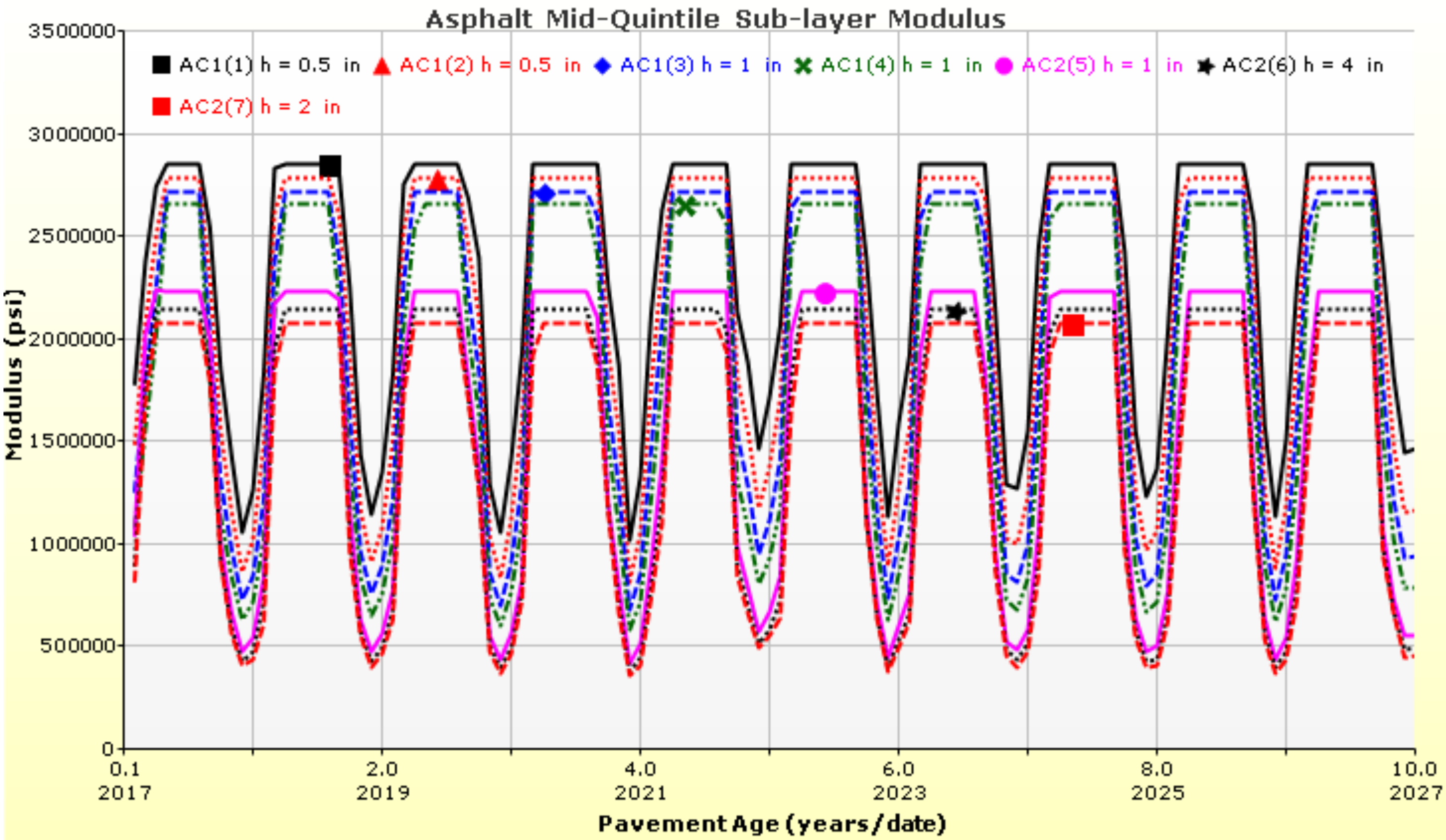
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3000
2500
2000
1500
1000
500
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



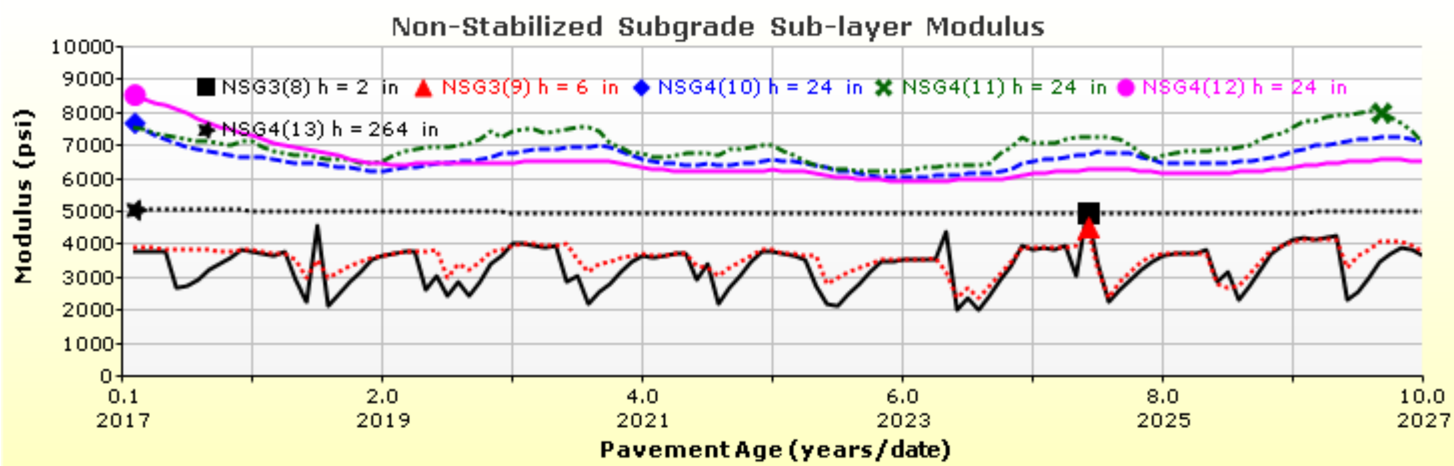
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (in)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC1(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
AC2(7) h = 2 in
Modulus (psi)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG3(8) h = 2 in
NSG3(9) h = 6 in
NSG4(10) h = 24 in
NSG4(11) h = 24 in
NSG4(12) h = 24 in
NSG4(13) h = 264 in
Modulus (psi)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.1 2017
2.0 2019
4.0 2021
6.0 2023
8.0 2025
10.0 2027
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R4 SMA

Asphalt		
Thickness (in)	3.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	13.1
Air voids (%)	4
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1860030	2300499	2637329	2741889
40	850728	1324800	1828840	2017009
70	246113	453444	796133	969276
100	88308	145258	261320	333687
130	49660	66719	100905	123005

Identifiers

Field	Value
Display name/identifier	R4 SMA
Description of object	Mix ID # FS 1960-2
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	4682	81
158	2268	83
168.8	1153	85

Layer 2 Flexible : Existing Asphalt(existing)

Asphalt		
Thickness (in)	7.0	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
14	1860030
40	850728
70	246113
100	88308
130	49660

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	4
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Existing Asphalt
Description of object	
Author	
Date Created	10/29/2010 11:00:00 PM
Approver	
Date approved	10/29/2010 11:00:00 PM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Subgrade : A-6 (R-5)

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
5356.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (R-5)
Description of object	Disturbed Native Material
Author	Jacob Biller Rocksol
Date Created	7/20/2015 12:00:00 AM
Approver	JBiller
Date approved	7/20/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

Layer 4 Subgrade : A-6 (Native)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
5356.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	A-6 (Native)
Description of object	Undisturbed Native Material (Mr=9000)
Author	RockSol Consulting Group Inc.
Date Created	7/20/2015 12:00:00 AM
Approver	JBiller
Date approved	7/20/2015 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	Native material Mr derived from
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k1: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 130.3674
	Bf2: 1
	Bf3: 1.217799

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

AC Rutting Standard Deviation	0.1414*Pow(RUT,0.25)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
C = crack depth(in)
h_{ac} = thickness of asphalt layer(in)
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the asphalt mixture
E = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 6.3	
Level 2 K: 0.5	
Level 3 K: 6.3	

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress(psi)
M_r = modulus of rupture(psi)

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104*Pow(BASERUT,0.67)+0.001		Standard Deviation (BASERUT) 0.0663*Pow(SUBRUT,0.5)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Top Standard Deviation	AC Cracking Bottom Standard Deviation
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))	1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation
CTB*11

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC	=	Crack length increment, in
ΔD	=	Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$	=	Calibration factors (local and global)
$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$	=	Crack length increments caused by bending, shearing, and thermal loading
A, n	=	HMA material fracture properties
N	=	Total number of days
$(SIF)_B, (SIF)_S, (SIF)_T$	=	Stress intensity factors caused by bending, shearing, and thermal loading
D	=	Damage ratio
h_{OL}	=	Overlay thickness, in
RCR	=	Cracks in the underlying layers reflected, %
EX_CRK	=	Transverse cracking in underlying pavement layers, ft/mile (transverse cracking) Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

APPENDIX F

PAVEMENT DESIGN PARAMETER SUMMARY SHEETS

US 50 West – Westbound Preliminary Design, STA 0503-088 (20448), Task Order No. 7		
US 50 Westbound (with subgrade improvement)		
Design Parameter	**Design Value (Flexible)**	**Design Value (Rigid)**
Roadway Classification:	Principal Arterial (Freeway and Expressway)	
Number of Lanes (Total All Directions):	6	
[Initial Year] and Design Life (years) See Note 1:	[2017] - 20	[2017] - 30
Initial Year Heavy Truck (AADTT):	2900	
Growth Rate, %:	3.65	
Approximate Design Life 18k ESAL's:	3 to 10 million	10 to 15 million
Design Life Cumulative Truck Traffic:	9,126,150	14,578,400
% Reliability:	95	
AC Bottom-up Fatigue Cracking (%):	25	----
AC Thermal Cracking (ft/mile):	1,500	----
Permanent Deformation, Total (in):	0.65	----
Permanent Deformation, AC only (in):	0.50	----
AC Top-down Fatigue Cracking (ft/mile):	2,500	----
Terminal IRI (in/mile):	200	200
Mean Joint Faulting (in):	----	0.15
JPCP Transverse Cracking (% slabs):	----	7.0
Semi-Infinite Subgrade Layer Resilient Modulus (psi):	6,482	6,482
Intermediate Subgrade Layer Resilient Modulus (psi):	9,494	9,494
Base Layer Resilient Modulus (psi):	25,000	25,000
Pavement Section Component	**HMA**	**PCCP**
Pavement Type and Total Thickness (in):	HMA – 8	PCCP – 10.0
Aggregate Base Thickness (in):	6	6
Intermediate Subgrade Layer Thickness (in):	24 (Note 2)	24 (Note 2)
Overlay Thickness (in):	----	----
Milling Thickness (in):	----	----
HMA Grading (Lower Lifts):	S(100) PG 64-22	----
Lower Lift Thicknesses – Lifts from Bottom Up:	(Bot) 3" – 3"	----
HMA Grading (Top Lift):	SMA (Fibers)(Asphalt) or, SX(100) PG 76-28	----
Top Lift Thickness (in):	2	----

Note 1: Initial Year is first year open to general traffic
Note 2: Improved subgrade, A-2-4(0), or better, with R-Value = 40 or greater

US 50 West – Westbound Preliminary Design, STA 0503-088 (20448), Task Order No. 7		
US 50 Westbound Interim Ramp Connection at Pueblo Blvd (with subgrade improvement)		
Design Parameter	**Design Value (Flexible)**	**Design Value (Rigid)**
Roadway Classification:	Principal Arterial (Freeway and Expressway)	
Number of Lanes (Total All Directions):	6	
[Initial Year] and Design Life (years) See Note 1:	[2017] - 20	----
Initial Year Heavy Truck (AADTT):	500	
Growth Rate, %:	3.65	
Approximate Design Life 18k ESAL's:	3 to 10 million	----
Design Life Cumulative Truck Traffic:	5,244,910	----
% Reliability:	95	
AC Bottom-up Fatigue Cracking (%):	25	----
AC Thermal Cracking (ft/mile):	1,500	----
Permanent Deformation, Total (in):	0.65	----
Permanent Deformation, AC only (in):	0.50	----
AC Top-down Fatigue Cracking (ft/mile):	2,500	----
Terminal IRI (in/mile):	200	----
Mean Joint Faulting (in):	----	----
JPCP Transverse Cracking (% slabs):	----	----
Semi-Infinite Subgrade Layer Resilient Modulus (psi):	6,482	----
Intermediate Subgrade Layer Resilient Modulus (psi):	9,494	----
Base Layer Resilient Modulus (psi):	25,000	----
Pavement Section Component	**HMA**	**PCCP**
Pavement Type and Total Thickness (in):	HMA – 7	----
Aggregate Base Thickness (in):	6	----
Intermediate Subgrade Layer Thickness (in):	24 (Note 2)	----
Overlay Thickness (in):	----	----
Milling Thickness (in):	----	----
HMA Grading (Lower Lifts):	S(100) PG 64-22	----
Lower Lift Thicknesses – Lifts from Bottom Up:	(Bot) 2.5" – 2.5"	----
HMA Grading (Top Lift):	SMA (Fibers)(Asphalt) or, SX(100) PG 76-28	----
Top Lift Thickness (in):	2	----

Note 1: Initial Year is first year open to general traffic
Note 2: Improved subgrade, A-2-4(0), or better, with R-Value = 40 or greater

US 50 West – Westbound Preliminary Design, STA 0503-088 (20448), Task Order No. 7		
US 50 Westbound (with subgrade improvement)		
Design Parameter	**Design Value (Flexible)**	**Design Value (Rigid)**
Roadway Classification:	Principal Arterial (Freeway and Expressway)	
Number of Lanes (Total All Directions):	6	
[Initial Year] and Design Life (years) See Note 1:	[2017] - 10	
Initial Year Heavy Truck (AADTT):	2900	
Growth Rate, %:	3.65	
Approximate Design Life 18k ESAL's:	3 to 10 million	----
Design Life Cumulative Truck Traffic:	3,753,800	----
% Reliability:	95	
AC Bottom-up Fatigue Cracking (%):	25	----
AC Thermal Cracking (ft/mile):	1,500	----
Permanent Deformation, Total (in):	0.65	----
Permanent Deformation, AC only (in):	0.50	----
AC Top-down Fatigue Cracking (ft/mile):	2,500	----
Terminal IRI (in/mile):	200	----
Mean Joint Faulting (in):	----	----
JPCP Transverse Cracking (% slabs):	----	----
Semi-Infinite Subgrade Layer Resilient Modulus (psi):	6,482	----
Intermediate Subgrade Layer Resilient Modulus (psi):	9,494	----
Base Layer Resilient Modulus (psi):	25,000	----
Pavement Section Component	**HMA**	**PCCP**
Pavement Type and Total Thickness (in):	HMA – 6	----
Aggregate Base Thickness (in):	6	----
Intermediate Subgrade Layer Thickness (in):	24 (Note 2)	----
Overlay Thickness (in):	----	----
Milling Thickness (in):	----	----
HMA Grading (Lower Lifts):	S(100) PG 64-22	----
Lower Lift Thicknesses – Lifts from Bottom Up:	(Bot) 3"	----
HMA Grading (Top Lift):	SMA (Fibers)(Asphalt) or, SX(100) PG 76-28	----
Top Lift Thickness (in):	3	----

Note 1: Initial Year is first year open to general traffic
Note 2: Improved subgrade, A-2-4(0), or better, with R-Value = 40 or greater

APPENDIX G

LTPPBIND BINDER SELECTION REPORT SHEETS

Five Closest Weather Stations For Latitude/Longitude= 38.178/104.728

General	A=7 km	B=11 km	C=23 km	D=35 km	E=51 km
Station ID	✓ CO6767	✓ CO6765	✓ CO6740	✗ CO7315	✗ CO1294
County/District	pueblo	pueblo	pueblo	pueblo	fremont
Weather Station	pueblo 6 ssw	pueblo reservo	pueblo memoria	rye	canon city
Elevation, m	1392	1375	1327	1940	1510
Latitude, Longitude	38.18 ,104.65	38.27 ,104.72	38.28 ,104.5	37.92 ,104.93	38.42 ,105.23
Last Year Data Available	1984	1997	1997	1989	1997

Air Temperature	Mean (Std, N)	Mean (Std, N)	Mean (Std, N)	Mean (Std, N)	Mean (Std, N)
High Temperature	35.3 (8,12)	36.7 (13,21)	37.2 (12,35)	31.8 (19,24)	34.7 (12,31)
Low Temperature	-27.3 (41,13)	-23.7 (41,20)	-25.3 (40,34)	-27.5 (32,24)	-22.4 (38,28)
Low Temperature Drop	34 (31,13)	32.9 (26,20)	31.5 (32,34)	31.7 (26,24)	31.8 (35,28)
Degree-Days > 10C	3145 (179,12)	3356 (183,21)	3425 (162,35)	2495 (376,24)	3086 (154,31)

PG	High Low Rel.	High Low Rel.	High Low Rel.	High Low Rel.	High Low Rel.
Pavement Temperature, C	57.7 -18.3	59.4 -15.7	59.9 -16.9	52.2 -18.4	57.3 -14.8
50% Reliability PG	58-22 (62,84)	64-16 (98,53)	64-22 (98,92)	58-22 (98,88)	58-16 (77,63)
>50% Reliability PG	64-22 (98,84)	64-22 (98,95)	64-28 (98,98)	58-28 (98,98)	58-22 (77,98)
=	64-28 (98,98)	64-28 (98,98)			64-22 (98,98)
=					
=					
=					

PG Binder Selection

Parameter	A=7 km	B=11 km	C=23 km	D=35 km	E=51 km
Station ID	✓ CO6767	✓ CO6765	✓ CO6740	✗ CO7315	✗ CO1294
Elevation, m	4565	4510	4351	6362	4951
Degree-Days >10 C	3145	3356	3425	2495	3086
Low Air Temperature, C	-27.3	-23.7	-25.3	-27.5	-22.4
Low Air Temp. Std Dev	4.1	4.1	4	3.2	3.8

Input Data

Latitude, Degree: 38.18

Lowest Yearly Air Temperature, C: -25.4

Yearly Degree-Days>10 Deg.C: 3309

Low Air Temp. Standard Dev., Deg: 4.1

Temperature Adjustments

Base HT PG: 64

Desired Reliability, %: 98

Depth of Layer, mm: 0

Traffic Adjustments for HT

Traffic Loading	Traffic Speed: Fast	Slow
Up to 3 M. ESAL	0.0	2.6
3 to 10 M. ESAL	6.5	8.8
10 to 30 M. ESAL	11.3	13.5
Above 30 M. ESAL	13.4	15.5

PG Temperature	HIGH	LOW
PG Temp. at 50% Reliability	59.0	-16.9
PG Temp. at Desired Reliability	61.1	-24.4
Adjustments for Traffic	6.5	
Adjustments for Depth	0.0	0.0
Adjusted PG Temperature	67.6	-24.4
Selected PG Binder Grade	70	-28

? Recalculate PG Save Cancel

PG Binder Selection

Parameter	A=7 km	B=11 km	C=23 km	D=35 km	E=51 km
Station ID	✓ CO6767	✓ CO6765	✓ CO6740	✗ CO7315	✗ CO1294
Elevation, m	4565	4510	4351	6362	4951
Degree-Days >10 C	3145	3356	3425	2495	3086
Low Air Temperature, C	-27.3	-23.7	-25.3	-27.5	-22.4
Low Air Temp. Std Dev	4.1	4.1	4	3.2	3.8

Input Data

Latitude, Degree: 38.18

Lowest Yearly Air Temperature, C: -25.4

Yearly Degree-Days>10 Deg.C: 3309

Low Air Temp. Standard Dev., Deg C: 4.1

Temperature Adjustments

Base HT PG: 64

Desired Reliability, %: 98

Depth of Layer, mm: 50

Traffic Adjustments for HT

	Traffic Speed	
Traffic Loading	Fast	Slow
Up to 3 M. ESAL	0.0	2.6
3 to 10 M. ESAL	6.5	8.8
10 to 30 M. ESAL	11.3	13.5
Above 30 M. ESAL	13.4	15.5

PG Temperature	HIGH	LOW
PG Temp. at 50% Reliability	59.0	-16.9
PG Temp. at Desired Reliability	61.1	-24.4
Adjustments for Traffic	6.5	
Adjustments for Depth	-4.9	3.0
Adjusted PG Temperature	62.7	-21.4
Selected PG Binder Grade	64	-22

? Recalculate PG Save Cancel