Chelaque Estates

Roadway Assessment and Repair Plan

University of Tennessee
Tickle College of Engineering
Department of Civil and Environmental Engineering
Senior Design Course Experience
CE399S – CE400
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Mission Statement

The Knoxx Engineering team is committed to the goals put forth by the National Academy of Engineering (NAE) Grand Challenges and the American Society of Civil Engineers Body of Knowledge (ASCE BOK). Specifically, the team is focused on balancing the NAE Grand Challenge of restoring and improving urban infrastructure with the ASCE BOK professional responsibility of public safety. Knoxx Engineering is also committed to producing designs that consider the global, social, cultural, environmental, and economical (GSCEE) factors that impact a project. The team achieves these goals by taking a comprehensive approach to their design projects and exhausting all effort in the pursuit of a brighter future.

Acknowledgements

Knoxx Engineering would like to acknowledge everyone who contributed to the success of this project. The Chelaque Road Assessment Project would not have been possible without the advice, assistance, and support provided by the following people. Shap Stiles and Patrick Fiveash, transportation engineers at Gresham Smith, served as technical mentors for the team. We would like to thank them for providing technical support and professional assistance throughout this project. Dave and Jody Howells were our direct point of contact with the community of Chelaque Estates. We would like to thank the Howells for providing the team with quality information regarding the existing site conditions and for facilitating our communications with the community. Dr. Retherford serves as the team's faculty mentor and was responsible for the professional review of the project. We would like to thank Dr. Retherford for her guidance and support as we completed our first engineering design. Dave Margozzi serves as president of the Chelaque Homeowner Association and representative for the HOA. We would like to thank Dave for his feedback throughout our project, which helped us provide a report that Chelaque Estates can easily use to accomplish their goals for the community's roadways. We would also like to thank Dr. Sarah Mobley for her guidance and support with the process of completing field sampling for and testing of soils.

Disclaimer

The following report and construction documents were prepared by students as part of the University of Tennessee's Senior Design Project coursework. The University of Tennessee and the individuals involved in this project assume no liability for services, construction, or designs attached in this report. All work for this project must be reviewed and approved by a professional engineer in its entirety before the implementation of any recommendations contained within the student documentation. The documents of this project should not be considered for construction.

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Introduction

The Homeowner's Association (HOA) of Chelaque Estates contracted Knoxx Engineering to assess the current state of their roadways and produce a multi-year roadway repair plan. Chelaque Estates is a private community located on Cherokee Lake in Mooresburg, Tennessee, and the HOA dues allow the community to have an average annual budget of $100,000 to maintain their 12 miles of roadway. The Chelaque community has experienced unsafe driving conditions due to the degradation of their roadways, many of which were not laid on top of a suitable foundation. The community is continuing to grow, with an average of four new houses under construction every year, which has accelerated the degradation of the roadways. The roadway assessment and repair plan are required to fortify the roadways to withstand heavy construction loads and to improve the overall resilience of the roadway network, which required efforts in geotechnical, transportation, water resources, and construction engineering.

Background

Roadway conditions within Chelaque Estates are a growing problem for the community, and the homeowner's association is responsible for providing solutions to remedy the compromised infrastructure. There are visible signs of damage and distress along the twelve miles of roadways that have resulted as a consequence of the poor construction methods used when the roads were initially built. All roads were built before Chelaque Estates was established as a residential subdivision, meaning the current use case was not considered when the roads were designed. Currently, the community is approximately halfway built-out, and new homes are being built at a rate of four per year. The resulting increase in both residential and construction traffic has led to increasing rates of deterioration for the roadways. In response to these evolving conditions, the Chelaque Homeowner's Association seeks engineering services to provide safe and sustainable solutions to address the current needs and prepare for future infrastructure improvements anticipated as Chelaque Estates continues to be developed.

Existing Site Conditions

The twelve miles of roadway throughout the Chelaque Estates community show signs of damage caused by poor pavement design, inadequate or clogged stormwater infrastructure, excessive construction loads, and loss of soil on the adjacent slopes. The roadways do not have a consistent design, and the original specification of any road is unknown; however, the main road, Chelaque Way, is 22 feet wide and consists of three layers that are shown below in **Figure 1**. The road appears to consist of a surface asphalt layer three inches thick, atop four inches of gravel-sized aggregate, atop a twelve-inch layer of large rip-rap-sized aggregate. The side roads appear to mostly consist of a layer of asphalt over an approximately 3-inch thick layer of gravel-sized aggregate. In some areas, the roadways are a layer of asphalt with varying thickness, lain directly on top of the soil. The site contains many areas of stagnant stormwater due to the steep terrain, which contributes to the deterioration of the roadbed, for example, due to undercutting. As new homes are built, contractors must haul in heavy equipment which exceeds the maximum allowable load of the roadways and causes fatigue ("alligator") cracking. Due to a loss of vegetation, several of the roadways have lost their shoulders to erosion of the nearby slopes, which also causes erosion of the roadway. Some of the damages caused by these factors were recently repaired in 2019 but are already showing signs of deterioration, indicating an overall poor lifecycle of the roadways within Chelaque Estates and reinforcing the need for a roadway specification and repair plan.

Figure 1: Cross-Sectional View of Chelaque Way

Team Members

Knoxx Engineering is comprised of four civil engineering students at the University of Tennessee at Knoxville, shown in **Figure 2**. Braden completed an internship experience with transportation projects. Ashley has been an Undergraduate Research Assistant in the field of transportation since 2020 and recently published an award-winning study on fare policy. Bryce has four summers of internship experience with stormwater management from Site Engineering Consultants in Murfreesboro, TN. Ben completed an internship experience with construction fieldwork from Blalock Companies. The wide range of technical knowledge allows the team to take a multidisciplinary approach to the project. The organizational roles, shown in **Figure 3**, are: Braden Boyd, geotechnical; Ashley Hightower, transportation; Bryce Lott, water resources; and Ben Tran, construction. The student team works in conjunction with several mentors and professional engineers, shown in **Table 1**. Patrick Fiveash and Shap Stiles work for Gresham Smith Engineering in Knoxville and have each worked in the civil engineering field for over 20 years. In addition to our engineering mentors, the student team works closely with the client team from Chelaque Estates, comprised of Dave Howells, Jody Howells, and Dave Margozzi. Dave Howells is the former Road Chairmen of Chelaque Estates and served in the role for five years. Jody Howells is the former President of the Chelaque Estates Homeowner’s Association (HOA). Dave Margozzi is the current President of the HOA.

Figure 2: Team Members

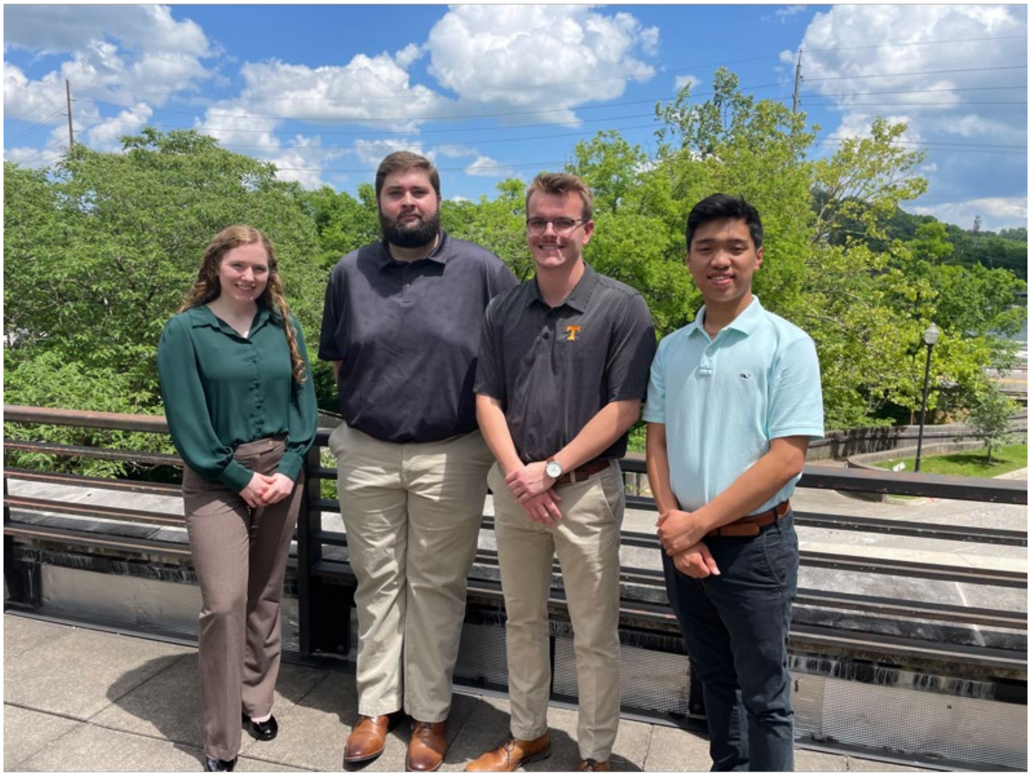

Figure 3: Organizational Roles

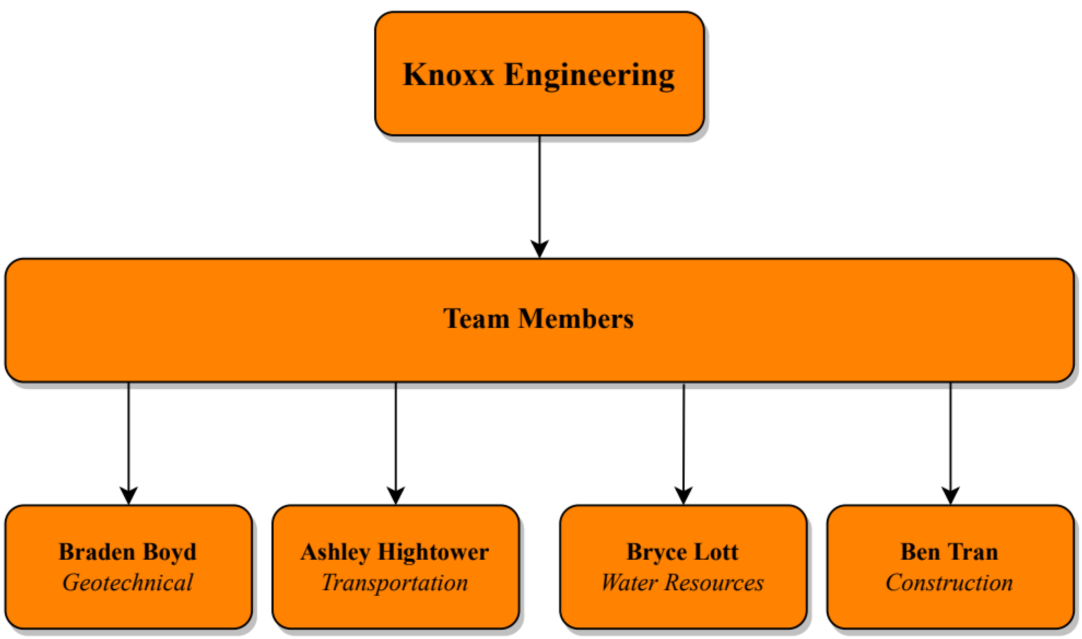

Table 1: Overview of Team Members, Clients, and Mentors

Name	Affiliation	Role	Contact
Braden Boyd	Knoxx Engineering	Geotechnical	bboyd16@vols.utk.edu
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Technical Scope of Work

The Knoxx Engineering team is tasked with performing a roadway assessment of the twelve miles of roadways within Chelaque Estates and providing a multi-year repair plan for the homeowner's association. A prioritized inventory of the twenty-five worst damage locations was developed to inform the necessary design work. Analysis of the existing soils was required in order to provide solutions for stabilizing unsafe slopes. Traffic calming devices and a site-specific pavement design were recommended in order to improve the safety and resilience of the roadways. A stormwater analysis was required to determine the effectiveness of the existing stormwater infrastructure, and recommendations were proposed in order to improve this infrastructure. The cost and scheduling will be determined for each of the repair types to produce the multi-year repair plan.

Roadway Assessment

A roadway assessment was performed using the Federal Highway Administration's (FHWA) Practical Guide for Quality Management of Pavement Condition Data Collection, and a roadway assessment guide was developed. The assessment was developed to determine the worst areas of roadway damage and to allow Chelaque Estates to self-assess roadway damage in the future. The damages were inventoried and characterized to determine the type of damage and repair solution.

A roadway assessment guide for a residential neighborhood was made, which was developed using the Chelaque HOA's existing roadway assessment process and the Federal Highway Administration's Practical Guide for Quality Management of Pavement Condition Data Collection (US DOT Federal Highway Administration 2013). The guide, shown in **Figure 4**, may be used by Chelaque Estates to self-assess future roadway damages. The steps to complete the roadway assessment are as follows. First, a roadway damage inventory was taken on Microsoft Excel using a route-lots and route-telephone pole numbers reference system. The inventory was gathered using visual inspection during a site visit and a community survey through Google Forms. Next, the damages were classified according to failure type and root cause. Then, the damages were categorized according to severity, and the severity of the roadway damage was determined using factors including the size of the area affected and the urgency of the repair (e.g., if damage was caused to vehicles or if the road would be rendered unpassable without repair). Other factors contributing to the ranking of roadway inventory are the difficulty of the repair solution (30%), the level of safety (25%) and the accessibility of the roadway for users (15%). The level of severity for each category was ranked from 1 to 4 following the guidelines found in Appendix A.

Figure 4: Roadway Assessment Flowchart

The roadway damages were inventoried with the finalized priority list, listed in **Table 2**, with observation notes found in Appendix A. The inventory was plotted on Google MyMaps to group together similar damages, shown below in **Figure 5**. The categories for the damages were defined as hill instability, fatigue cracking, standing water, and safety. The soil was tested to determine the soil's strength characteristics in order to specify the necessary retaining wall design. The design of the existing roadways was analyzed to determine if the pavement layer thicknesses were in compliant with the AASHTO and TDOT Pavement Design Guidelines (AASHTO 1993; TDOT 2019a). Further investigations were made to determine if the deterioration of the pavement support is due to stormwater seeping beneath the road. Repair types for each category of damage was specified, and a schedule and cost estimate for all repairs were determined.

Figure 5: Inventory of Damages

Table 2: Ranked Inventory List

Rank	Point	Route-Lots / Telephone Pole	Failure Type
1	D	Keetoowah Dr - L21 to L23	FC/HS
2	N	Chelaque Way - L65	FC
3	R	Chelaque Way - L25	SW
4	E	Keetoowah Dr - L39 to L40	FC
5	F	Keetoowah Dr - L52 to L53	HS/FC
6	G	Wilderness Dr - L40	FC
7	L	Kahiti Ct - L122	FC/HS
8	W	Wilderness Dr - L43	HS/SW
9	A	Chelaque Way L2, TP 59 to TP60	FC
10	U	Keetoowah Dr. + Nowata Ct	S-GR
11	S	Muskogee Dr L147 to L150	S-GR
12	V	Nowata Ct - L6 to L7	FC
13	C	Keetoowah Dr - (TVA)	FC
14	B	Keetoowah Dr - L13 to L14	FC/HS
15	I	Lakeview Dr - L87 to L89	HS
16	K	Chelaque Way - L116 to L118	FC
17	M	Chelaque Way - L101	FC
18	O	Sequoyah Dr - L82 to L83	SW
19	T	Chelaque Way - L167	S-SS
20	Y	Keetoowah Dr	S-RW
21	Q	Chelaque Way - L26	HS/FC
22	X	Kahiti Ct	S-RW
23	H	Muskogee + Channel Point Dr	SW
24	J	Channel Point Dr - L77 near TP8	S-RW
25	P	Chelaque Way - L43 to L44	HS/FC

Route-Lot Number can be found in Property Map.
L#: Lot Number, TP#: Telephone Pole Number, +: Intersection
FC: Fatigue Cracking, HS: Hill Shearing, SW: Standing Water,
S-GR: Safety- Guard Rail, S-RW: Safety- Retaining Wall, S-SS: Safety- Steep Slope

Geotechnical Design

Geotechnical Services performed for the Chelaque property included the determination of the soil's strength parameters as well as the design of two retaining wall options for locations identified in the roadway assessment as having evidence of hill shearing and instability. A sampling plan was developed to collect two soil samples from each of three unique locations anticipated to offer differing soil conditions provided by the US Soils Map. Each sample was tested to determine the particle size distribution, Liquid Limit, Plastic Limit, Plasticity Index, and classification using the Unified Soil Classification System (USCS). Mechanically Stabilized Earth (MSE) retaining walls were analyzed and designed. according to geotechnical and structural criteria. The AISC Steel Manual and geotechnical analysis of soil stability were used in the design of soldier pile retaining wall.

A sampling plan was developed to collect soil samples from the community in reference to the US Soils Map. The locations were chosen representative of three soil types represented in the US Soils Map (United States Department of Agriculture N.D.). Two soil samples were collected from each region of the US Soils Map for the community, with each region representing a different soil type. After finalizing locations for sampling and mapping underground utilities, six total samples were collected using a hand-auger and bagged to test at the University of Tennessee.

The six soil samples were tested and classified to determine the strength parameters of the soil on site. The Grain Size Distribution of each soil was determined using a Hydrometer Test in accordance with ASTM D422 to find the Grain Size Distribution of each soil. The Liquid Limit, Plastic Limit, and Plasticity Index of each soil were determined through the Atterberg Limits Test in accordance with ASTM D4318. Each soil was then classified using the Unified Soil Classification System, ASTM D2487. The expected soil type from the US Soils Map and the lab determined Soil Type using USCS are summarized below in **Table 3**. The hand-auger collected soil samples at a depth up to four-feet, compared to the US Soils Map which represents the expected soil at a deeper depth.

Table 3: Soil Types at Sampling Locations

Location	US Soils Map Soil Type	Liquid Limit	Plastic Limit	Plasticity Index	Determined Soil Type
Keetoowah Dr at Light Pole 18	Loam	26	21.7	4.3	Silt
Intersection of Chelaque Way and Keetoowah Dr	Loam	32.5	23.6	8.9	Silt
Chelaque Pavilion	Silt Loam	32.5	25.5	7	Silt
Chelaque Marina	Silt Loam	33.5	26.8	6.7	Silt with Sand
Chelaque Way at Lot 65	Silt Loam	41	32.4	8.6	Silt
Tahlequah Lane at Light Pole 6	Silt Loam	26	23.1	2.9	Silt with Sand

Each soil sample was classified as either Silt or Sandy Silt using the Unified Soil Classification System. Silt and Sandy Silt resemble characteristics of Loamy soils, due to Loam consisting of a mixture of silt, sand, and clay. The US Soils Map classification compared to the determined classification indicated that there are silts and sands near the ground surface and clays mixed at lower depths. The soil classification informs the strength parameters of the soil at the sample location. Silt and Sandy Silt are similar and have the following strength parameters: Cohesion of 459.5 psf, Maximum Bearing Capacity of 1560 psf, Compacted Unit Weight of 146.5 pcf, and Internal Friction Angle of 35° (Geotech Data N.D.).

Mechanically Stabilized Earth (MSE) retaining walls were designed and stability calculations were performed for the installation of walls at locations experiencing hill instability. Tennessee Department of Transportation (TDOT) Typical Drawings for MSE walls were used as the basis for design (TDOT 2015a). All MSE walls are designed with one-foot depth, two-foot width concrete wall footing along the wall length, placed at a minimum of one-foot below the surface of the lower ground level. Installation of the wall includes segmented blocks creating the wall face, with Silty Sand soil backfilled at a maximum 1:1 slope from the bottom of the wall footing. For walls exceeding five-foot in height, geotextile matting will be placed between the block layers of the wall and act as soil reinforcement. The upper ground level includes a ditch of minimum 12-inch depth for rainfall drainage. Roadway Pavement acts as a surcharge load in pressure calculations and is included in stability calculations of the wall. The Rankine Theory and Meyerhoff's Pressure Distribution were used to determine the resultant forces acting on the wall. Stability calculations were performed with and without the pavement surcharge load and can be found in Appendix B. The Factor of Safety against Sliding and Overturning proved the design requires pavement to be a minimum of the wall height in length from the back of the wall.

Soldier Pile retaining walls were designed and stability calculations were performed as well. TDOT Soldier Pile wall typical drawings were used as the basis for design (TDOT 2015b). Installation of Soldier Pile walls includes W10x39 Steel Beams piled to a depth of twice the wall face height and Timber Lagging of maximum 8-inches thickness. In consistency with MSE walls, Silty Sand soils and a 12-inch drainage ditch is included in designs. The Rankine Theory was used to determine the resultant forces from the backfilled soil. The resulting forces were used to determine the resulting moment at the base of the wall face to check against overturning. The W10x39 beams were checked against bending from the resulting soil forces. The timber lagging was checked against failure acting as a simply supported beam. A pavement surcharge load was excluded in designs, meaning the wall and edge of pavement must be at least the length of the beam apart.

Transportation Design

Pavement design, design speed, and safety considerations were determined in order to improve the user comfort of the roadways. The pavement layer thicknesses were calculated according to TDOT and AASHTO standards, and the Structural Number method was applied to the design to confirm that the layer thicknesses were appropriate for the site conditions. The design speed limit of the road network in Chelaque Estates was determined using the TDOT standards. Safety recommendations proposing new striping and signage were developed according to the Manual on Uniform Traffic Control Devices (MUTCD).

A pavement design was developed using TDOT's Pavement Design Guidelines and AASHTO's Guide for Design of Pavement Structures, and the suitability of the existing pavement section of Chelaque Way was analyzed according to the same standards (AASHTO 1993; TDOT 2019a). The recommended construction materials and necessary "a" coefficients were identified using the TDOT Pavement Design Manual in order to determine the layer thickness using the Structural Number (SN) method (see **Table 4**). PG 64-22 was selected as the recommended performance grade binder (TDOT 2019a). The SN required for the pavement was determined using AASHTO's Guide for Design of Pavement Structures. Based on the U.S. Climactic Region and the relative quality of the roadbed soil, the effective roadbed soil resilient modulus was estimated to be 5,500 psi. The lifecycle of the roadways was predicted to be 20 years, and the equivalent single axle loads (ESALs) were assumed to be "high" (AASHTO 1993); all assumptions, calculations, and AASHTO tables relevant to the design solution are shown in Appendix C. A pavement reliability of 90% was selected to inform the value of the SN (TDOT 2019a). The recommended SN for 90% reliability was extrapolated from the AASHTO 50% and 75% pavement reliability and found to range from 3.2 to 3.4 (AASHTO 1993). The pavement thickness for each layer was calculated using the SN; the recommended minimum design thickness is summarized in **Table 4**. The recommended design was designed in compliance with the TDOT recommended maximum thickness for the surface and binder layers, and the base layer was designed to be thicker than the TDOT recommendation in order for the design's SN to be within the 90% reliability range. The existing pavement section of Chelaque Way was analyzed and found to have a SN of 3.12, which is within the 75% reliability range; the calculation to determine the SN of Chelaque Way is documented in Appendix C.

Table 4: Pavement Layers, Coefficients, and Layer Thicknesses

Layer	Material Selection	"a" Layer Coefficient or Modulus of Resilience M_R	Thickness (in)
Surface Layer	Grading D	a_1 = 0.40	1.5
Binder Layer	B-Mod-2	a_2 = 0.40	2.75
Base Layer	Mineral Aggregate Base Grading D	a_3 = 0.12	12.5
Subgrade	Existing Subgrade	M_R = 5,000 psi	Not Applicable

The design speed was proposed based on the Tennessee Department of Transportation (TDOT) standards, the current operating speed, and a community survey; several traffic calming recommendations are proposed. The minimum design speed was determined using the TDOT Design Standards for Low-Volume Roads; for a rural road with mountainous terrain, TDOT recommends a minimum speed of 20 miles per hour (TDOT 2019b). The current operating speed of the road is 25 miles per hour. Based on the findings from the community survey, lane departure due to excessive speeds is common among construction vehicles on the upper half of Chelaque Way (Station 0+00 through Station 55+00). Additionally, a somewhat serious collision involving a construction vehicle and lane departure happened near the entrance of Chelaque Estates which resulted in hospitalization and surgery for a Chelaque Estates community member. Therefore, although the operating speed of the road is 25 miles per hour, the conditions on the road may require a lower speed limit. Because the minimum allowable speed limit designated by TDOT is 20 miles per hour, one solution aimed at reducing speed would be to lower the speed limit from 25 to 20 miles per hour; this solution aligns with the community's desires to minimize signage. However, the preferred solution recommended by Knoxx Engineering is to keep the operating speed at 25 miles per hour and introduce advisory speed limits. The TDOT standard drawings shown in Appendix C tabulate the maximum speeds for a given turn radius; the turn radii in the Chelaque roadway network were measured using Civil 3D and are shown in the appendix. Advisory speed limits were suggested in compliance with the TDOT standard drawings and the MUTCD's requirements (TDOT 2019b). According to the standards set forth by the MUTCD, where the advisory speed limit is at least 10 mph lower than the speed limit, advisory speed plaques and "turn ahead" signs are required (Federal Highway Administration 2009). In some locations, there already exist signs to warn drivers of an approaching turn (see **Figure 6**) which are recommended to be replaced with reflective, MUTCD-compliant signs, documented in Appendix C and in the drawings. In order to avoid excessive signage, advisory speed limits and turn ahead signs were only recommended on the two major roads with the most traffic, Chelaque Way and Keetoowah Drive. All required signage, signage height and dimensions, and placement are show in the drawings.

Figure 6: Existing Turn Warning Sign on Chelaque Way

The need for safety improvements was informed by the neighborhood residents via a community survey, and several recommendations for safety improvements are proposed. The results of the survey revealed that lane departure is common on the upper half of Chelaque Way, especially by construction vehicles on steep slopes and in sharp turns. The existing roadways were measured and found to have a width of 22 feet, which meets the TDOT design standard of a minimum of 18 feet (TDOT 2019b). A centerline already exists, and each lane is approximately 11 feet wide. Raised line striping is recommended to be added in order to delineate the shoulder of the road, up to two feet on either side. A two-foot shoulder would reduce the lane width from 11 feet to 9 feet, which is compliant with the TDOT standard. With the appearance of a narrower road, drivers may be more likely to drive slower through the neighborhood, reducing lane departure. Additionally, raised line striping is more visible under nighttime or foggy conditions. Other tools to reduce lane departure should be considered, such as adding rumble strips in the centerline and adding speed humps in advance of sharp turns. However, speed humps may be an unpopular interference to driving for community members, and noise pollution would be produced by rumble strips. Such measures should be considered with the community's input. In addition to delineating the shoulders, Knoxx Engineering recommends chevrons to be placed in the sharpest and steepest turns in order to improve the safety of nighttime and foggy driving conditions. According to the MUTCD, chevrons (18 in x 24 in) are required where the advisory speed is at least 15 mph lower than the speed limit (Federal Highway Administration 2009). According to the TDOT standard drawings (shown in Appendix C), turns with a radius less than 38 ft require an advisory speed limit of 10 mph, which is at least 15 mph lower than the speed limit and therefore require chevrons to be placed at intervals of 40 ft, starting 100 ft before the turn (Federal Highway Administration 2009; TDOT 2019b). However, in order to avoid excessive signage which would result in drivers ignoring the signage, chevrons were only recommended for the sharpest and steepest turns with a radius less than 38 ft and with the most traffic. Additional chevrons may be added in more locations as the community sees fit. All required signage, signage height and dimensions, and placement are show in the drawings.

Water Resources Design

A drainage analysis was performed for each of the three areas identified in the roadway assessment to determine the effectiveness of the existing stormwater infrastructure. Runoff for the entire site was calculated in accordance with Chapter 4 of the TDOT Drainage Manual to determine the community's stormwater capacity. Flow values were calculated for the individual problem areas using the Rational Method as specified in Chapter 4 of the TDOT Drainage Manual, and the depth of flow in the existing pipes downstream from the pooling locations was determined using the Federal Highway Administration's Hydraulic Toolbox software to determine the effectiveness of the existing pipes (Federal Highway Administration N.D.; TDOT 2021). As a result of the existing pipes being shown to be adequate for the calculated flow values, a new ditch cross-section was generated to improve the drainage conditions in the pooling areas. A long-term maintenance plan was developed to keep the stormwater infrastructure operating at adequate drainage performance levels.

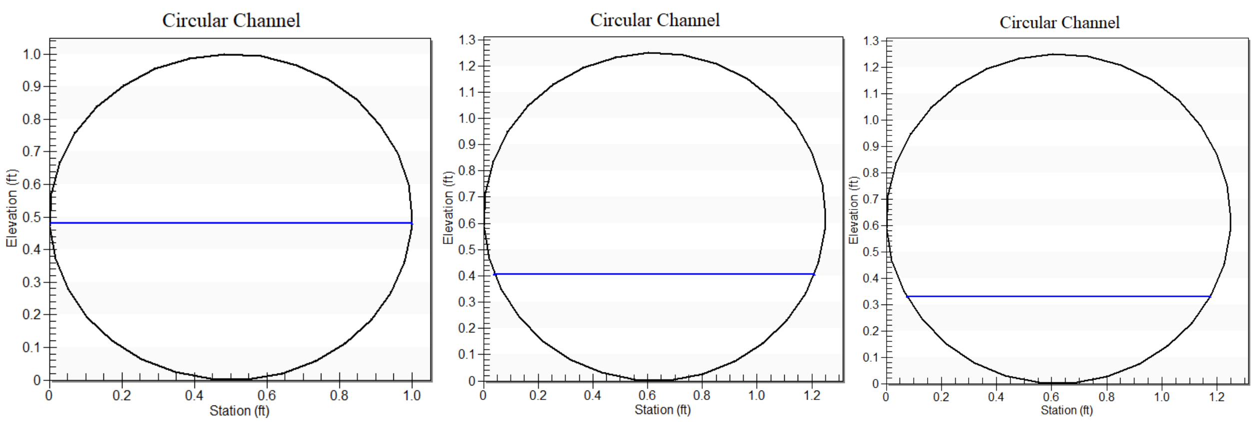
The initial step of the water resources design work was to determine whether the community has sufficient stormwater capacity based on the hydrologic analysis of the soils located on the site. Soil data was acquired from the United States Department of Agriculture (USDA) Web Soil Survey (United States Department of Agriculture N.D.). **Table 5** shows that Chelaque Estates' soils primarily consist of A rated soils with an approximately equal amount of B and C soils. The weighted curve number of the soil was calculated using the Tennessee Department of Transportation (TDOT) Drainage Manual (TDOT 2021). The cover type was determined to be woods. Using the soil ratings, amounts, and cover type, the weighted curve number was calculated to be 50. The curve number was used to determine the amount of water retention capacity of the soil in the form of the initial abstraction. The initial abstraction was calculated to be two inches. The initial abstraction was greater than the amount of precipitation for all of the recorded rainfall events. The soils within the community were determined to be capable of providing capacity for all of the recorded rainfall events. The existence of pooling shows that the full capacity of the soil is not being utilized.

Table 5: Hydrologic Soil Data

Hydrologic Soil Type	Rating	CN	Percentage
Lehew channery loam	A	45	82%
Decatur silt loam and Dewey silt loam	B	66	10%
Litz shaly silt loam	C	77	8%

The initial step of the individual drainage analysis for each location was to use the Rational Method to determine flow for the areas around lot 176 on Echota Lane, lot 98 on Sequoyah Drive, and lot 20 on Tahlequah Lane. The runoff coefficient was determined using the TDOT Drainage Manual (TDOT 2021). The surface type was specified as a rural forested area, meaning that the runoff coefficient ranges from 0.1-0.3. Given the mountainous topography of the site, the higher end of this range was used to set the runoff coefficient at 0.25. The intensity was determined using the IDF curve for Johnson City and the calculated time of concentration, as outlined in the TDOT Drainage Manual (TDOT 2021). The time of concentration was calculated using the NRCS Runoff Method. The time of concentration path was determined as the longest path within the drainage area that stormwater would travel. The first 100 feet of the time of concentration line was assumed to be sheet flow over a wooded surface, and the remaining length was assumed to be shallow concentrated flow over a wooded surface. Each of the three sites were determined to have a time of concentration of approximately 20 minutes. The Johnson City IDF (Intensity-Duration-Frequency) curve returns an intensity of 3.4 inches per hour for a 20-minute time of concentration during a 10-year storm event. The final values needed for the Rational Method were the drainage areas for each of the identified areas. The drainage areas were delineated using the existing contours and the locations of the existing stormwater pipes and ditches. The flow rates were calculated for each of the sites and used to determine the effectiveness of the existing stormwater pipes. The analysis of the existing stormwater pipes was completed using the Federal Highway Administration's Hydraulic Toolbox (Federal Highway Administration N.D.). The analyzed pipes were determined as the pipes downstream of where the pooling occurred. For lot 76 on Echota Lane, the pipe was determined to be a 12" corrugated metal pipe with a slope of 0.5%. Manning's roughness coefficient for a corrugated metal pipe is 0.024. This information, along with the calculated flow was put into Hydraulic Toolbox to calculate the depth of water in the pipe. The same process was used for the locations on Sequoyah Drive and Tahlequah Lane. The resulting flow depths are shown in **Figure 7** as the line running across the pipe. In each of the three cases, the existing pipes were determined to be adequate to handle the maximum amount of discharge for a 10-year storm event. Therefore, the stormwater pipes are not causing the pooling. The most likely cause of the pooling is the ditch not being able to move stormwater downstream to the outlet pipe.

Figure 7: Flow Depths



Echota Lane Lot 176 Sequoyah Drive Lot 98 Tahlequah Lane Lot 20

The flow depths produced by the Hydraulic Toolbox show that the existing stormwater pipes are capable of handling the 10-year storm events. Because these three locations were determined to be the worst-case scenarios throughout the entire community, it is safe to assume that the other existing stormwater pipes are capable of handling flow volumes produced by a 10-year storm event. As a result of the pipe analysis, the ditches were determined to be the main factor causing the pooling.

The mountainous terrain and steep roadway slopes within the community led to the roadside ditches being lined with rip-rap. In cases where the slopes are steep, the rip-rap serves as a mechanism to slow the water flowing through the ditch. The Manning's roughness coefficient of a rip-rap lined ditch is significantly higher than that of a grass-bottom ditch. In cases where the slopes are mild, specifically in the three identified problem areas, the roughness of the existing ditch is too high to allow water to flow to the outlet pipe. To solve this problem, a new ditch cross-section was generated that features a smoother channel bottom and a consistent longitudinal slope. The channel bottom was determined to be uniform earth channel with short grass which corresponds to a roughness coefficient of 0.027, as opposed to 0.033 for a rip-rap lined ditch of the same dimensions. The decrease in roughness of the channel lining increased the flow capacity of the ditch. The consistent slope of 0.002 ft/ft ensures that gravity flow allows stormwater to reach the outlet pipe. This solution can be applied in other areas throughout the community where pooling becomes an issue.

A long term maintenance plan was developed to keep the stormwater infrastructure operating at sufficient levels and mitigate damages caused by improper stormwater management. The maintenance plan was generated following the guidelines outlined in the Long Term Maintenance Plan Template for the City of Murfreesboro, TN (MWSD Engineering 2015). The purpose of the plan is to prevent pipe blockages, similar to the ones shown in **Figure 8**, from limiting the performance of the stormwater infrastructure. Quarterly inspections are to be conducted on the stormwater pipes and ditches within the community. Additional inspections can be conducted as needed during the fall season when leaves are more likely to interfere with the stormwater pipes and ditches. Services to be performed during these inspections include litter removal, erosion repair, debris removal, and sediment removal. These services shall only be performed in areas where necessary.

Figure 8: Existing Pipe Blockages

Construction Design

Construction services were conducted to determine the bill of quantities, scheduling, and cost estimates for the proposed multi-year plan to improve the existing roadway of Chelaque Estates. The multi-year plan offers fix solutions for each inventory item noted in the roadway assessment. The bill of quantities was constructed using Microsoft Excel to determine the materials and services required for each fix option (Hendrickson 1989). A construction schedule was created using Microsoft Project and was informed by the work breakdown structure (WBS) (Hendrickson 1989). A cost estimate for each fix option was constructed through Microsoft Excel by using the unit costs for bill of quantities approach (Hendrickson 1989).

The framework for the multi-year plan to improve the roadway of Chelaque Estates were constructed using 2019 Chelaque Estates Road Repair Statement of Work. The plan includes a priority list with recommended solutions grouped by street names (examples of which are shown in **Table 6** and **Table 7**), along with their respective estimated costs and schedule duration. The mechanically stable earth and soldier pile retaining wall designs were recommended for areas with shoulder loss due to hill instability. Erosion controls were recommended for area experiencing minor failure of hill instability. The drainage ditch design was recommended for areas experiencing substantial water pooling over multiple days. A long-term maintenance plan was recommended for areas where drainage pipes require removal of debris and sediments. Safety improvements were recommended for areas with concerns of road visibility, high speed, and lane departures. Future safety improvements in some areas will require design work for safety rail.

Table 6: Work Required for Keetoowah Drive and Minor Roads

Fix Number	Flag	Work Required	Group
Keetoowah Dr			
1	D	Repave section; Downhill erosion control	FC/HS
2	E	Extend drain ditch; erosion control; repave section	FC
3	F	Repave section	HS/FC
4	U	Gaurdrail	S-GR
5	C	Repave section	FC
6	B	Repave section	FC/HS
7	Y	Retaining wall	S-RW
Wilderness Dr			
1	G	Repave section	FC
2	W	grade, topsoil, and seed uphill; clean ditch	SW/HS
Nowata Ct			
1	V	Repave Section	FC

Table 7: Work Required for Chelaque Way and Minor Roads

Fix Number	Flag	Work Required	Group
Chelaque Way			
1	N	large area of repavement	FC
2	R	expand ditch; clean ditch	SW
3	A	medium to large area of repavement	FC
4	K	repave shoulder	FC
5	M	large area of repavement	FC
6	T	additional safety sign	SW
7	Q	grade downhill, slope, and seed hill; repave section	HS/FC
8	P	repave area; extend drain ditch	HS/FC
Muskogee Dr			
1	S	Guard rail	SW
Lakeview Dr			
1	I	grade uphill slope and seed	HS
Sequoyah Dr			
1	O	Extend Ditch	SW
Kahiti Ct			
1	L	large area of repavement; retaining wall	FC/HS
2	X	retaining wall	RW
Channel Point Dr			
1	H	mitigate water into ditch	SW
2	J	retaining wall	RW

The bill of quantities was created using Microsoft Excel to determine the materials required for the different repair options proposed, as shown in Appendix E. Roadway material quantities (tons) were determined using the input parameters defined under pavement designs for minimum thickness (inches) of each layer, their respective densities (pounds per cubic foot), and the area of the roadway section (square foot). Retaining wall quantities were measured using the input parameters for the area of the wall (square foot), area of the concrete footing (square foot), and the number of steel beam and timber required. Stormwater improvements were measured using the input area (square foot) of the proposed ditch design for seeding and erosion control matting. Safety improvements were determined based on the number of additional signage and signposts recommended by Knoxx Engineering. Other safety improvements for the roadway (rumble grooves in centerline and raised line striping) were measured in linear foot.

A duration schedule was planned for each fix option using Microsoft Project. A list of activities per repair solutions are shown in the WBS found in Appendix E. The schedule is informed by the activity list to determine the time durations for general construction, drainage, roadway, structure, and safety improvements. The durations for each activity were based on best judgement.

The cost estimations were calculated using a unit price database from Tennessee Department of Transportation (TDOT) 2022 bid prices, which are separated into four regions based on county. The TDOT 2022 bid prices are based on contractor bids which include taxes, markups, and labor for the specified cost items listed in the Microsoft Excel spreadsheet found in Appendix E. The project site is in Hawkins County, which is region 1. Other costs estimate for materials not listed in TDOT 2022 bid prices were found using RSMeans price database.

Conclusion

In conclusion, the Knoxx Engineering team was tasked with performing a roadway assessment of the twelve miles of roadways within Chelaque Estates and providing a multi-year repair plan for the homeowner's association. A prioritized inventory of the twenty-five worst damage locations was developed to inform the necessary design work. The existing soils were analyzed in order to develop two unique solutions, MSE and soldier pile wall options, to stabilize unsafe slopes. Traffic calming devices, including signage and physical roadway modifications, and a site-specific pavement design were recommended in order to improve the safety and resilience of the roadways. The effectiveness of the existing stormwater infrastructure was determined via a stormwater analysis, and solutions to enhance ditch drainage were recommended. Each of the repair types were priced and scheduled to produce the multi-year repair plan.

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Appendix A: Roadway Assessment

APPENDIX A01 – ROADWAY ASSESSMENT FLOWCHART

Chelaque Community Forum Survey

This survey's purpose is to collect data on the conditions of the roadways in Chelaque Estates. We would like feedback from the community in order to help us prioritize roadway repairs and understand any safety concerns you may have. The survey will be live until the end of the day on April 22nd. You are able to return and change your answers at any time before that date if you would like.

We are a group of seniors enrolled in Senior Design at the University of Tennessee Knoxville. We have been assigned a project in your community, the goal of which is to create a 3-5 year roadway maintenance and repair plan. The project will be completed at the end of the year.

* Required

1. Do you currently reside in Chelaque Estates? *

Mark only one oval.

- Yes, I am a homeowner / I live in Chelaque Estates.
- No, I am a lot owner / I do not live in Chelaque Estates.

2. What street do you live on? *

Mark only one oval.

- Catoosa Drive
- Channel Point Drive
- Chelaque Way
- Echota Lane
- Kahiti Court
- Keetoowah Drive
- Lakeview Drive
- Mountain View Drive
- Muskogee Drive
- Nowata Court
- Sequoyah Drive
- Setico Court
- Tahlequah Lane
- Taskigi Court
- Toqua Lane
- Waterview Lane
- Wilderness Drive
- No Response
- Other: ____________________

3. What roads do you regularly drive or walk on within the community? *

Check all that apply.

- [ ] Catoosa Drive
- [ ] Channel Point Drive
- [ ] Chelaque Way
- [ ] Echota Lane
- [ ] Kahiti Court
- [ ] Keetoowah Drive
- [ ] Lakeview Drive
- [ ] Mountain View Drive
- [ ] Muskogee Drive
- [ ] Nowata Court
- [ ] Sequoyah Drive
- [ ] Setico Court
- [ ] Tahlequah Lane
- [ ] Taskigi Court
- [ ] Toqua Lane
- [ ] Waterview Lane
- [ ] Wilderness Drive
- [ ] Other: ____________________

4. What area(s) depicted on the map do you believe most urgently require intervention or repair? Are there any areas not depicted on the map that you would like to bring attention to? Please include any supporting information, if available. Examples of problems include damage to the road and areas where water may flood or wash over the road. *

5. Please submit any photos you may have of areas of roadway damage

6. Are there any areas on the roadways that feel unsafe to you as a pedestrian or driver? If so, please explain the location and nature of the safety concern. Some examples of safety concerns are a place where you have had a near-miss crash or a place where you can't see very well around a corner.

7. Have you had any experiences in which you felt unsafe due to your speed while approaching a turn or due to the speed of another driver? If so, where?

8. What other concerns do you have regarding the roadways in Chelaque Estates? Please remember that our team is equipped to handle issues related to the fields of transportation, water, construction, and geotechnical (soil) engineering.

9. What result do you want from the roadway assessment?

ROAD INVENTORY LIST OF DAMAGES							
Pont	Location	Description of Damages	Specific Observations	Road Failure	Difficulty	Road Safety	Location
A	Chel. Way between TP 58-60 near Lot 2 (-83.2015607, 36.3321075) **[28.]**	Fatigue cracking from water erosion and road dipping from excessive load	Road Dips, Rutting, indicating signs of fatigue cracking	3	3	2	4
B	Keetoowah near Lot 13/14 (-83.2021055, 36.3309169) **[27.]**	Undercutting on downhill side of road, road fractures perpendicular to road direction	Small fracture on pavement, pavement shears onto the downhill side of roadway	3	2	2	4
C	Keetoowah stretch under TVA powerlines (-83.2028086, 36.3284465) **[26.]**	Previous landslides and erosion, causing fatigue cracking, potential retaining wall addition	Fracture splits across pavement over previous patched repair, shoulder starts to shear onto the hill	2	3	3	3
D	Keetoowah near Lot 21-23 (-83.2032478, 36.3272585)	Undercutting on downhill side of road, fatigue cracking that has been unsuccessfully repaired. . The uphill side of road has hillside shearing	Shoulder pavement shears onto hill, fatigue cracking, early signs of hill instability	4	4	3	2
E	Keetoowah near Lot 39/40 (-83.2041216, 36.3259009) **[19.]**	Extensive fatigue cracking across entire road width	Large area on both sides of fatigue cracking, signs of water "soaking" in pavement, previous patch repairs are failing	4	3	3	1
F	Keetoowah near Lot 52/53 (-83.2002934, 36.3260238) **[16.]**	Hillside shearing downhill, causing fatigue cracking. Possible retaining wall location	Road Dips, Rutting, indicating signs of fatigue cracking	4	3	3	1
G	Wilderness Dr at bend near Lot 40 (-83.2036901, 36.3250184) **[18.]**	Fatigue cracking and fracture at downhill side of road	previous repair work; signs of failure, shoulders are deteriorating, sharp curve, and hill shears	4	3	3	1
H	Intersection of Channel Point and Muskogee (-83.1916023, 36.325462) **[10.]**	Excess water flowing across intersection, could design better drain system	Good condition rip rap, but excess water is mitigating across the road	2	2	1	3
I	Lake View Dr near Lot 87-89 (-83.1934879, 36.325891) **[12.]**	Steep dropoff from road, potential for hill shearing, needs retaining wall	Debris onto road from shearing uphill	3	2	3	2
J	Channel Point near Lot 77 (TP 8) (-83.1938024, 36.3255517) **[11.]**	Needs retaining wall, potential for landslide. Road had also been repaired for erosion previously	hill shearing on downhill slope, shoulder is in fair conditions	2	1	2	3
K	Chel. Way near Lot 116-118 (-83.1867952, 36.3254885) **[8.]**	Excessive weight has caused road dipping and fatigue cracking	early signs of rutting, shoulder are being to be mossy	3	2	1	4
L	Kahiti Ct near Lot 122 (-83.1891971, 36.3229193) **[9.]**	Severe undercutting and cracking along downhill side of road. Needs repaving and potential retaining wall	Severe downhill shearing, fractured pavements, shoulders are beginning to shear off. Large area of road deterioration	4	3	3	1
M	Chel. Way near Lot 101 (-83.1847269, 36.3217983) **[7.]**	Road had been repaired in patches but experiencing fatigue cracks	previous repair work; large area of fatigue cracking	3	2	2	2
N	Chel. Way near Lot 65 (-83.1843893, 36.3195792) **[5.]**	Ongoing construction has caused fatigue and fracture cracking. *Worst spot near Howells' house	heavy construction trucks; large area of rutting/ FC; signs of water seeping into pavement	4	3	3	3
O	Sequoyah near Lot 82/83 (-83.18685, 36.32164) **[R19]**	Excess runoff covering roadway during rainfall. Need drainage design	signs of fatigue cracking	3	2	2	2
P	Chel. Way E near Lot 43/44 (-83.1822612, 36.3199376) **[4.]**	Undercutting and fatigue cracking issues. Needs repaving	uphill shearing, shoulders deteriorating, FC along shoulder; ditch can be improved	2	2	1	2
Q	Tahlequah Ln near Lot 26 (-83.1801486, 36.317415) **[2.]**	Undercutting and slight fatigue cracking along downhill side of road	shoulder deteriorating along downside of hill	3	2	1	2
R	Chel. Way near Lot 25 (-83.1804413, 36.3178507) **[3.]**	Standing water forming during rainfall, need a design for drainage	water pools, ditch needs to be expanded and regularly cleaned out	4	3	3	2
S	Muskogee from Lot 147-150	Residents suggested guardrails installed for safety	Safety concerns - guard rails	1	3	4	4
T	Intersection of Muskogee and Chel. Way	Residents suggested mirrors, yielding signs, or any other way to improve safety for this intersection	Safety Concerns - steep slope at intersection	2	1	3	4
U	Curve on Keetoowah near intersection of Keetoowah and Nowata	Residents suggested guardrails due to sharp turn and low visibility	Safety concerns - sharp turn	2	3	3	4
V	Nowata Ct near Lot 6/7 (-83.20543, 36.33014) **[R22]**	Extensive fatigue and fracture cracking across roadway	signs of fatigue cracking	3	3	2	3
W	Wilderness Dr near Lot 43 (-83.2066829, 36.3220122) **[31.]**	Severe undercutting, rain washes debris from drainage ditch into roadway	hill shearing from uphill, debris from hills causing drains to clog and excess debris washing onto pavement	4	3	3	1
X	Kahiti Ct	Retaining wall addition for slope stability	safety concerns- retaining wall to stabilize hill shearing	1	2	4	1
Y	Keetoowah Dr	Retaining wall addition for slope stability	safety concerns- hill shearing	1	2	4	2

Symbol	Description
[##]	Reference # on Google MyMaps

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Chelaque Way				
		FC, Rutting, Long	TP 59-60/L2	A
		FC	L116-118	K
		FC	L101	M
		FC	L65	N
		UC/ FC	L43/44	P
		UC/FC	L26	Q
		SW	L25	R

Symbol	Description
L#	Lot #
TP#	Telephone Pole #
FC	Fatigue Cracking
UC	Undercutting
SW	Standing Water
HS	Hill Shearing
RW	Retaining Wall
S	Safety
+	Intersection

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Channel Point				
		SW I w/ Muskogee		H
		RW	L77/TP8	J

Distance - road start	Total SqFt	Other Safety Recommendation	Location	Point
		S- GR Muskogee	L147-150	S
		SW	L167	T
		S- GR iw/ Keetoowah & Nowata	+	U

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Keetowah Dr				
		UC	L13/14	B
		FC	TVA	C
		UC/ FC/ /HS	L21/23	D
		FC	L39/40	E
		HS/ FC	L52/53	F
		RW		Y

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Lakeview Dr				
		HS	L87-89	I

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Wilderness Dr				
		FC	L40	G
		UC/ SW	L43	W

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Kahiti Ct				
		UC/ FC/ ~RW	L122	L
		RW		X

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Sequoyah				
		SW	L82/83	O

Distance - road start	Total SqFt	Notes	Lot #/ TP #	Point
Nowata Ct				
		FC	L6/7	V

Rank per Category			
Road Failure	**Difficulty**	**Road Safety**	**Location**
3	3	2	4
3	2	2	4
2	3	3	3
4	4	3	2
4	3	3	1
4	3	3	1
4	3	3	1
2	2	1	3
3	2	3	2
2	1	2	3
3	2	1	4
4	3	3	1
3	2	2	2
4	3	3	3
3	2	2	2
2	2	1	2
3	2	1	2
4	3	3	2
1	3	4	4
2	1	3	4
2	3	3	4
3	3	2	3
4	3	3	1
1	2	4	1
1	2	4	2

Score per Category			
Road Failure	**Difficulty**	**Road Safety**	**Location**
75	75	50	100
75	50	50	100
50	75	75	75
100	100	75	50
100	75	75	25
100	75	75	25
100	75	75	25
50	50	25	75
75	50	75	50
50	25	50	75
75	50	25	100
100	75	75	25
75	50	50	50
100	75	75	75
75	50	50	50
50	50	25	50
75	50	25	50
100	75	75	50
25	75	100	100
50	25	75	100
50	75	75	100
75	75	50	75
100	75	75	25
25	50	100	25
25	50	100	50

Each Category Ranked from 1 to 4. Detailed for specfic numbering criteria are listed in Appendix A titled, "level of severity"

Final Score	
Points	**Score**
A	73
B	65
C	68
D	86
E	75
F	75
G	75
H	48
I	64
J	46
K	59
L	75
M	58
N	83
O	58
P	44
Q	51
R	79
S	70
T	56
U	71
V	69
W	75
X	51
Y	55

Final Rank List	
Points	**Score**
D	86
N	83
R	79
E	75
F	75
G	75
L	75
W	75
A	73
U	71
S	70
V	69
C	68
B	65
I	64
K	59
M	58
O	58
T	56
Y	55
Q	51
X	51
H	48
J	46
P	44

Weight Distribution	
Weight	Category
30%	Failure
30%	Difficulty of Repair
25%	Safety
15%	Location

Road Failure by Type (30%)

Undercutting

1. Signs of shoulder deteriorating
2. Shoulder is damaged
3. Shoulder completely deteriorated
4. Shoulder completely deteriorated and starting to shear downhill

Fatigue Cracking

1. Signs of Cracking
2. Minor Cracking occurred
3. Cracking is poorly damaged
4. Cracking is poorly damaged in large sections

Standing Water

1. Drainage/ Clog
2. Water Pools after 1 to 2 days
3. Water Pools after multiple days (3+)
4. Signs of Water Seeping into pavement

Hill Shearing

1. Early signs of hill shearing
2. Hill begins to shear from uphill (causing road debris)
3. Hill begins to shear downhill (Loss of shoulder)
4. Hill shears downhill with steep slope

Safety

1. Speed Concern
2. Minor Road debris
3. Visibility; Sharp Turns; Steep Slopes
4. Drivability; driving off shoulder; possible damages to vehicles

Difficulty of Repair by Type (30%)

Undercutting

Use other categories below to determine the best course of action for repair.

Fatigue Cracking

1. Small section of overlay
2. Large section of overlay
3. Small section of pavement
4. Large section of pavement

Standing Water

1. Clean out with regular maintenance required
2. Grade Slope
3. Grade Slope and Erosion Control Matting
4. Excavate Ditch, Grade Slope, and Erosion Control Matting

Hill Shearing

1. Grade Slope and Spread Topsoil
2. Seeding with Erosion control blanket
3. Retaining Wall Structure (MSE)
4. Retaining Wall Structure (Soldier Pile)

Safety

1. Additional signage required
2. Rumble Strip on shoulders required
3. Structure Required (Guardrails)

Location (15%)

1. Side Road w/ less than 20% affected
2. Side Road w/ more than 20% affected
3. Main Road w/ less than 40% affected
4. Main Road w/ more than 40% affected

Safety (25%)

1. Little to no concerns
2. Medium concerns
3. High concerns

Rainfall Date: 4/18/2022 Rainfall Amount: 1.4"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	60	No	No	No
Keetoowah	52	50	No	No	No
Keetoowah	51	60	Yes	No	No
Echota	176	25	Yes	Yes	Yes
Echota	176	75	Yes	Yes	Yes
Sequoyah	98, 99	100	Yes	Yes	Yes
Sequoyah	98	10	Yes	Yes	Yes
Sequoyah	96	10	Yes	Yes	No
Sequoyah	97	125	Yes	No	No
Sequoyah	94	15	No	No	No
Chelaque Way	53	100	No	No	No
Tahlequah	20	25	Yes	Yes	No
Chelaque Way East	59	30	No	No	No

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

S	10
Ia	2
P	1.4

Ia>P

Rainfall Date: 5/1/2022 Rainfall Amount: .25"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	-	No	No	-
Keetoowah	52	-	No	No	-
Keetoowah	51	-	No	No	-
Echota	176	-	Yes	No	-
Echota	176	-	Yes	No	-
Sequoyah	98, 99	-	No	No	-
Sequoyah	98	-	No	No	-
Sequoyah	96	-	No	No	-
Sequoyah	97	-	No	No	-
Sequoyah	94	-	No	No	-
Chelaque Way	53	-	No	No	-
Tahlequah	20	-	Yes	No	-
Chelaque Way East	59	-	No	No	-

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

S	10
Ia	2
P	0.25

Ia>P

Rainfall Date: 5/23/2022 Rainfall Amount: .9"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	60	No	No	-
Keetoowah	52	50	No	No	-
Keetoowah	51	60	No	No	-
Echota	176	25	Yes	No	-
Echota	176	75	Yes	No	-
Sequoyah	98, 99	100	No	No	-
Sequoyah	98	10	No	No	-
Sequoyah	96	10	No	No	-
Sequoyah	97	125	No	No	-
Sequoyah	94	15	No	No	-
Chelaque Way	53	100	No	No	-
Tahlequah	20	25	Yes	No	-
Chelaque Way East	59	30	No	No	-

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

S	10
Ia	2
P	0.9

Ia>P

Rainfall Date: 7/7/2022 Rainfall Amount: 1.01"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	-	No	No	-
Keetoowah	52	-	No	No	-
Keetoowah	51	-	No	No	-
Echota	176	-	No	No	-
Echota	176	-	No	No	-
Sequoyah	98, 99	-	No	No	-
Sequoyah	98	-	No	No	-
Sequoyah	96	-	No	No	-
Sequoyah	97	-	No	No	-
Sequoyah	94	-	No	No	-
Chelaque Way	53	-	No	No	-
Tahlequah	20	-	No	No	-
Chelaque Way East	59	-	No	No	-

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

S	10
Ia	2

P	1.01	Ia>P

Rainfall Date: 7/8/2022 Rainfall Amount: 0.28"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	-	No	No	-
Keetoowah	52	-	No	No	-
Keetoowah	51	-	No	No	-
Echota	176	-	No	No	-
Echota	176	-	No	No	-
Sequoyah	98, 99	-	No	No	-
Sequoyah	98	-	No	No	-
Sequoyah	96	-	No	No	-
Sequoyah	97	-	No	No	-
Sequoyah	94	-	No	No	-
Chelaque Way	53	-	No	No	-
Tahlequah	20	-	No	No	-
Chelaque Way East	59	-	No	No	-

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

S	10	
Ia	2	
P	0.28	Ia>P

Rainfall Date: 7/9/2022 Rainfall Amount: 0.14"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	-	No	No	-
Keetoowah	52	-	No	No	-
Keetoowah	51	-	No	No	-
Echota	176	-	No	No	-
Echota	176	-	No	No	-
Sequoyah	98, 99	-	No	No	-
Sequoyah	98	-	No	No	-
Sequoyah	96	-	No	No	-
Sequoyah	97	-	No	No	-
Sequoyah	94	-	No	No	-
Chelaque Way	53	-	No	No	-
Tahlequah	20	-	No	No	-
Chelaque Way East	59	-	No	No	-

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

S	10
Ia	2
P	0.14

Ia>P

Rainfall Date: 7/10/2022 Rainfall Amount: 0.26"

Road	Lot #	Initial Pooling Length (ft)	Water Remaining Day 2	Day 3	Day 4
Chelaque Way	160	-	No	No	-
Keetoowah	52	-	No	No	-
Keetoowah	51	-	No	No	-
Echota	176	-	No	No	-
Echota	176	-	No	No	-
Sequoyah	98, 99	-	No	No	-
Sequoyah	98	-	No	No	-
Sequoyah	96	-	No	No	-
Sequoyah	97	-	No	No	-
Sequoyah	94	-	No	No	-
Chelaque Way	53	-	No	No	-
Tahlequah	20	-	No	No	-
Chelaque Way East	59	-	No	No	-

Runoff Calculations

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

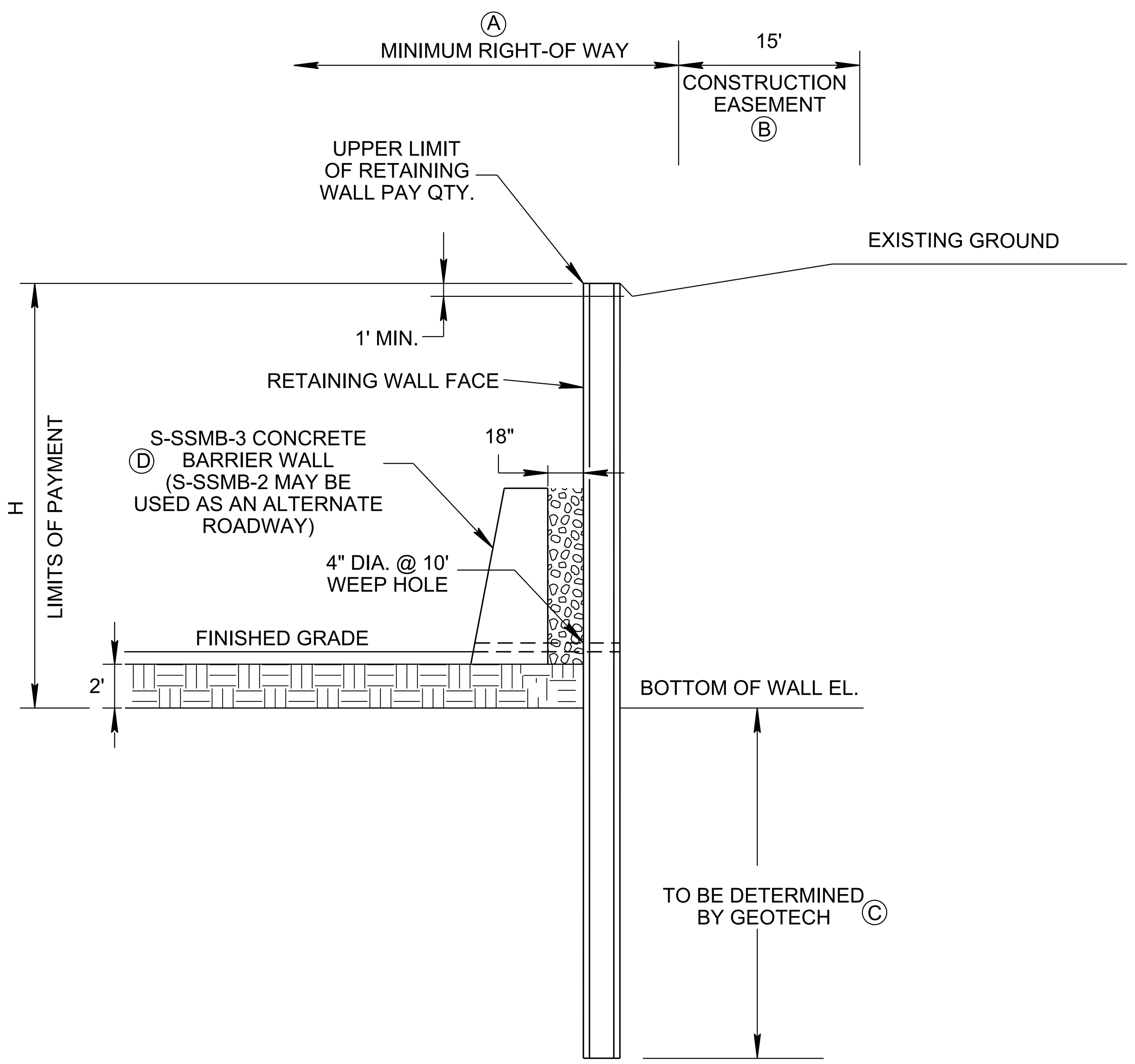
Q: runoff (in)
P: rainfall (in)
Ia: Initial abstractions
S: Maximum retention

Ia= 0.2*S
S= (1000/CN)-10
CN= 50

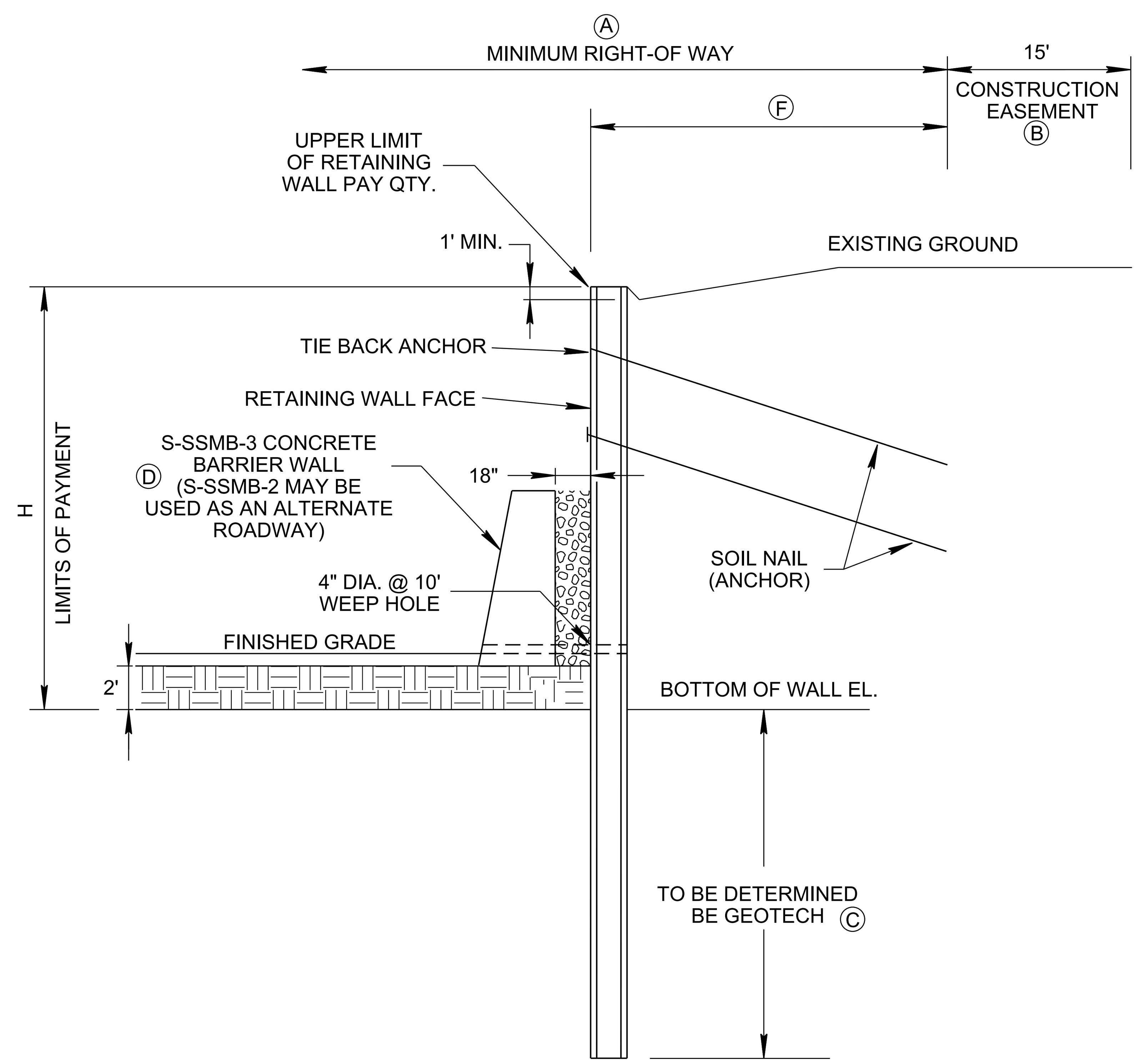
S	10
Ia	2
P	0.26

Ia>P

Appendix B: Geotechnical Design



SOLDIER PILE WALL TYPICAL SECTION IN CUT
(NOT APPLICABLE FOR FILL SECTION)



SOIL ANCHORED WALL TYPICAL SECTION IN CUT
(NOT APPLICABLE FOR FILL SECTION)

WALL TYPES

- STEEL PILES WITH WOOD LAGGING
- STEEL PILES WITH CONCRETE LAGGING
- CONCRETE WITH WOOD LAGGING
- CONCRETE WITH CONCRETE LAGGING

GENERAL NOTES

THE PURPOSE OF THIS DRAWING IS TO BE A GUIDE AND TO ILLUSTRATE TO THE ROADWAY DESIGNER THE RIGHT-OF-WAY, SAFETY AND DRAINAGE REQUIREMENTS ASSOCIATED WITH RETAINING WALLS. THIS IS NOT A STRUCTURAL DESIGN DRAWING.

(A) THE ENTIRE WALL MUST BE BUILT WITHIN THE RIGHT-OF-WAY, INCLUDING SOIL ANCHORS AND/OR ROCK ANCHORS, IF USED.

(B) A MINIMUM OF 15' CONSTRUCTION EASEMENT REQUIRED BEHIND WALL AND ANCHORS, IF USED.

(C) DESIGNER TO CALCULATE S.F. OF WALL BASED ON TOP OF PILE DOWN TO 2' BELOW FINISHED GRADE. DISTANCE NEEDED BELOW FINISHED GRADE TO BE DETERMINED BY GEOTECH. COSTS FOR LENGTH BELOW 2' TO BE INCLUDED IN PRICE BID FOR RETAINING WALL.

(D) IF WALL IS WITHIN CLEAR ZONE OF ROADWAY, PLACE CONCRETE BARRIER WALL PER (S-SSMB-3).

(E) BEGINNING AND END OF WALLS SHOULD BE PLACED OUTSIDE THE CLEAR ZONE. IF THIS OPTION IS NOT FEASIBLE, USE A TL-3 END TERMINAL OR CRASH CUSHION, ATTACHED TO CONCRETE BARRIER WALL. DO NOT ATTACH IT TO THE WALL ITSELF.

(F) AS THE LENGTH OF THE SOIL ANCHOR CAN VARY DRAMATICALLY, DEPENDING ON EXISTING SOIL CONDITIONS, THE GEOTECH ENGINEER SHALL DETERMINE AND SUPPLY THE REQUIRED LENGTH TO THE DESIGNER, IF THIS TYPE OF WALL IS TO BE USED.

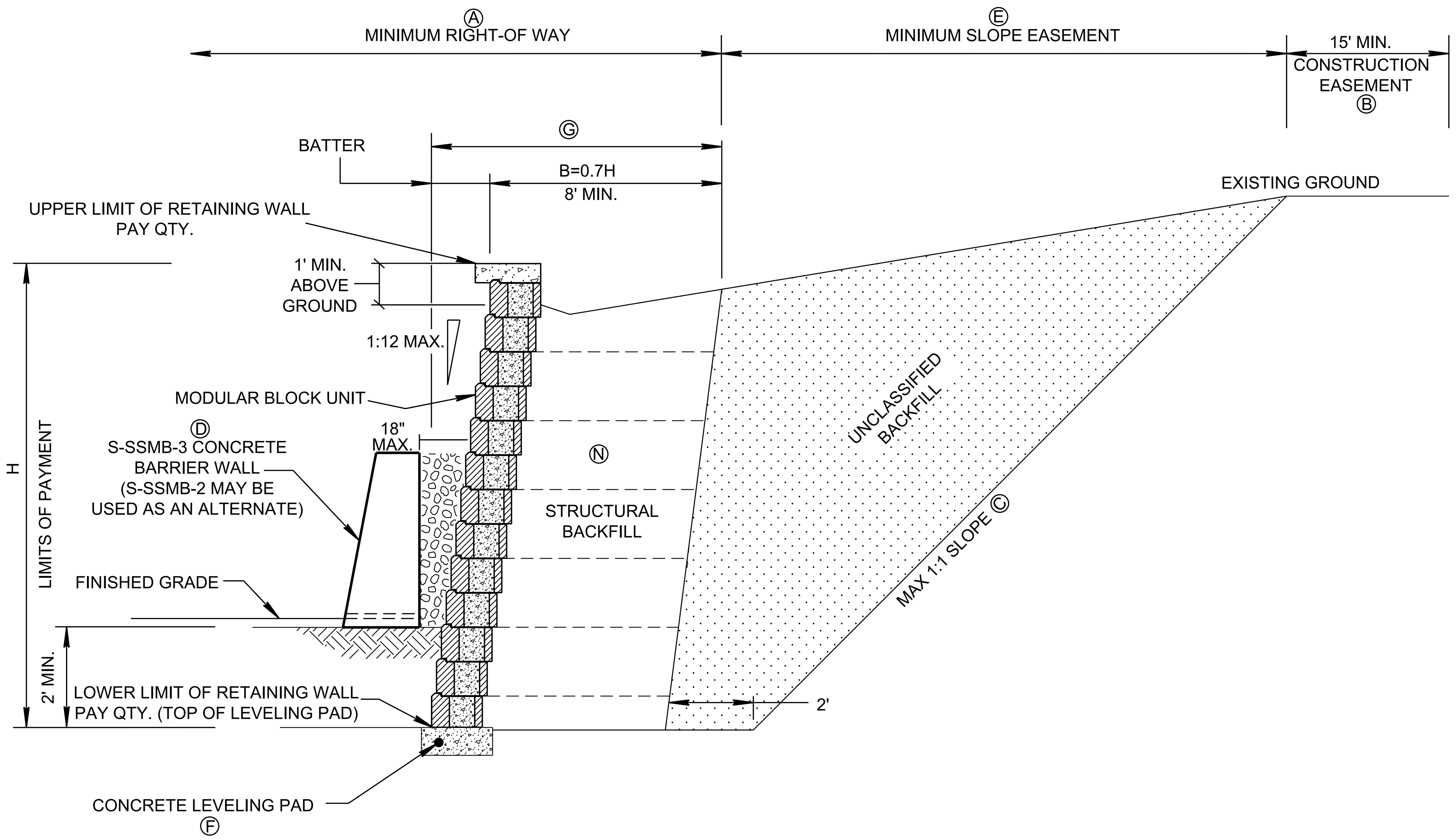
STATE OF TENNESSEE
STANDARD DRAWING
DEPARTMENT OF TRANSPORTATION

ROADWAY FEATURES AT SOLDIER PILE AND SOIL ANCHORED RETAINING WALLS

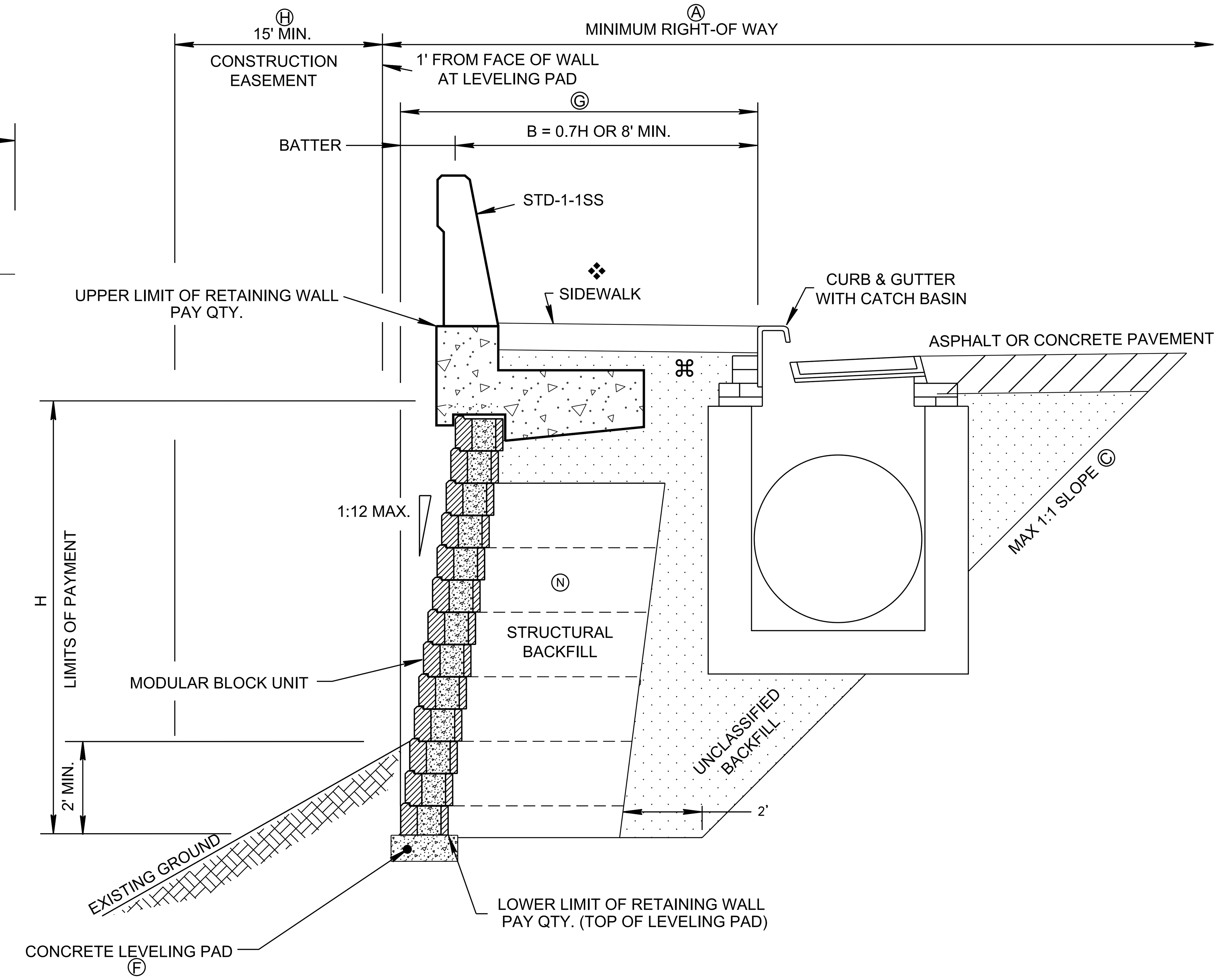
08-15-2015 | W-SP-1

NOT TO SCALE

LLP



MECHANICALLY STABILIZED EARTH (MSE) WALL MODULAR BLOCK TYPICAL SECTION IN CUT (NOT RECOMMENDED IN CUT SECTIONS)

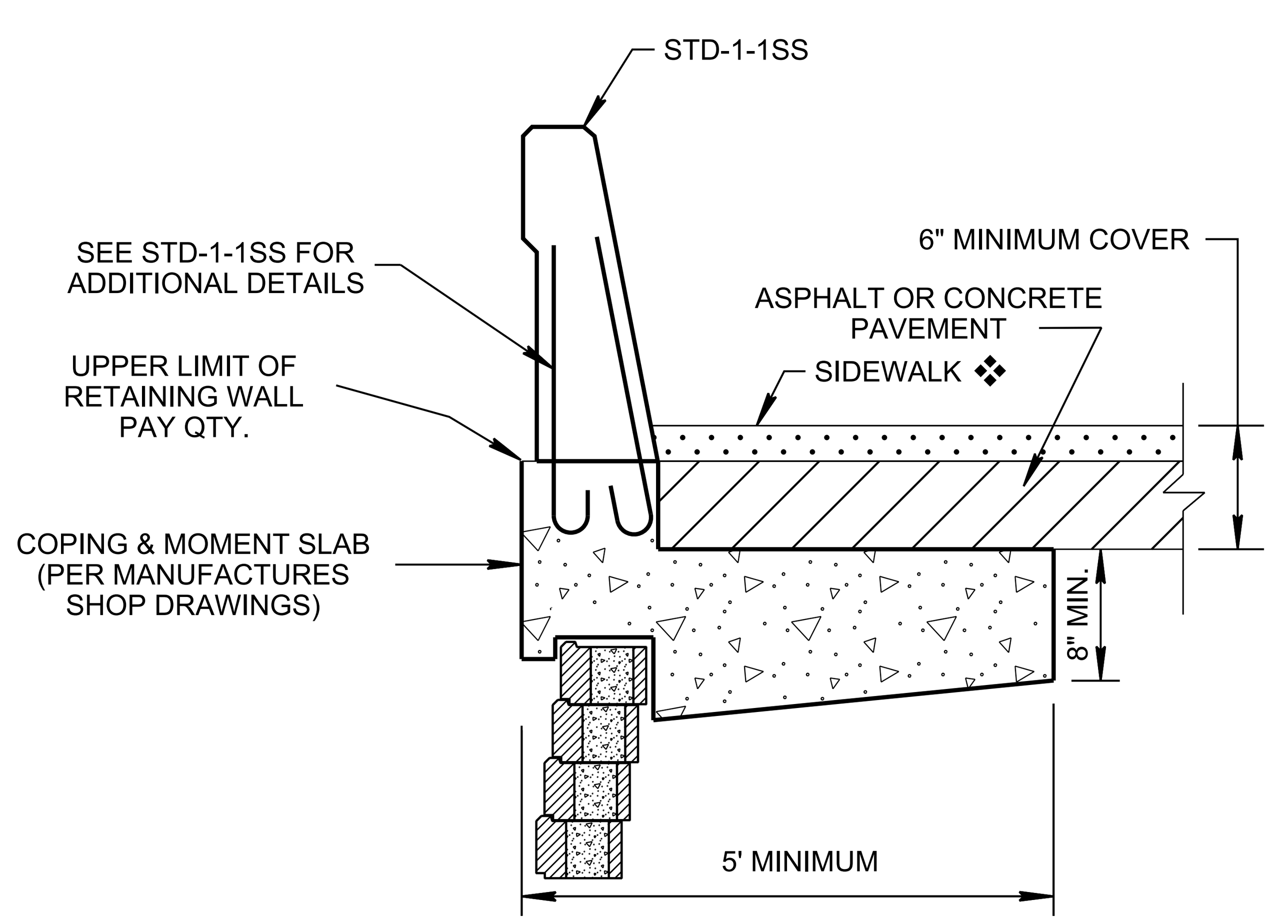


MECHANICALLY STABILIZED EARTH (MSE) WALL MODULAR BLOCK TYPICAL SECTION IN FILL

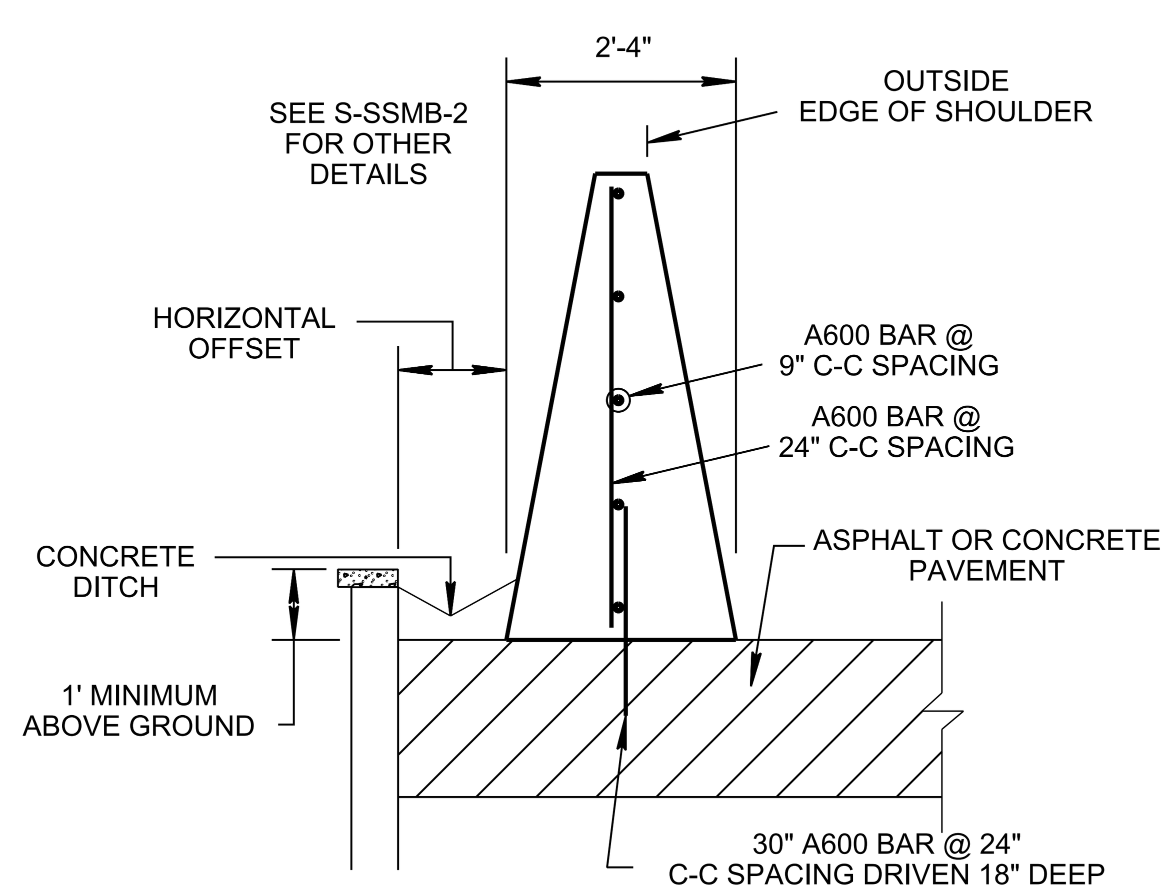
LEGEND

❖ WALL TYPE MAY ALSO BE USED WHEN ROAD SECTION HAS A SHOULDER, INSTEAD OF CURB, GUTTER, AND SIDEWALK.

⌘ WHEN LIGHT POLES ARE PROPOSED, WALL DESIGNER TO BE AWARE THAT THE FOUNDATION FOR THE POLES WILL LIKELY BE A MINIMUM OF 15' DEEP.



CONCRETE BARRIER ATTACHMENT DETAIL TO BE PROVIDED BY MANUFACTURER



ALTERNATE ATTACHMENT DETAIL FOR 51" SINGLE SLOPE CONCRETE BARRIER

GENERAL NOTES

THE PURPOSE OF THIS DRAWING IS TO BE A GUIDE AND TO ILLUSTRATE TO THE ROADWAY DESIGNER THE RIGHT-OF-WAY, SAFETY AND DRAINAGE REQUIREMENTS ASSOCIATED WITH RETAINING WALLS. THIS IS NOT A STRUCTURAL DESIGN DRAWING.

Ⓐ THE ENTIRE WALL MUST BE BUILT WITHIN THE RIGHT-OF-WAY, PLUS 1' IN FRONT OF WALL PANELS (AT LEVELING PAD) WHEN IN A FILL.

Ⓑ A MINIMUM OF 15' CONSTRUCTION EASEMENT REQUIRED BEHIND SLOPE TIE IN.

Ⓒ ACTUAL UNDERCUT DEPTH AND BACKFILL SLOPE TO BE DETERMINED BY THE GEOTECHNICAL ENGINEER.

Ⓓ IF WALL IS WITHIN CLEAR ZONE OF ROADWAY, OR MEETS ANY OF THE CRITERIA SPECIFIED IN SP 624, PLACE CONCRETE BARRIER WALL IN FRONT OF WALL. COST TO BE INCLUDED IN S.F. COST OF THE WALL.

Ⓔ BACKFILL AREA TO BE PURCHASED AS SLOPE EASEMENT UNTIL TIED IN WITH EXISTING GROUND LINE, UNLESS GEOTECHNICAL ENGINEER DEEMS SELECT BACKFILL A NECESSITY. IN WHICH CASE THE BACKFILL AREA SHALL BE PURCHASED AS RIGHT-OF-WAY.

Ⓕ COST OF LEVELING PAD, WILL BE PAID FOR IN THE COST OF THE RETAINING WALL.

Ⓖ MEASURED AT TOP OF WALL, INCLUDES "B" (0.7 x WALL HEIGHT) AND BATTER (1:12 MAX.). MINIMUM 8' PLUS BATTER.

Ⓗ AREA OUTSIDE OF WALL TO BE GRADED TO DRAIN AWAY FROM WALL. ALL GRADING TO BE INCLUDED IN CONSTRUCTION EASEMENT.

Ⓘ ALL COSTS ASSOCIATED WITH MOMENT SLAB TO BE INCLUDED IN THE COST OF THE RETAINING WALL.

Ⓙ BEGINNING AND END OF WALLS SHOULD BE PLACED OUTSIDE THE CLEAR ZONE. IF THIS OPTION IS NOT FEASIBLE, USE A TL-3 END TERMINAL OR CRASH CUSHION.

Ⓚ IF DRAINAGE STRUCTURES ARE PRESENT WITHIN STRUCTURAL BACKFILL AREA, THE WALL MANUFACTURER SHALL DETERMINE THE EXTENT OF THIS INSTALLATION AND DESIGN THE WALL ACCORDINGLY.

Ⓛ DEFER TO QPL. ONLY APPROVED WALL TYPES MAY BE USED.

Ⓜ COST OF CONCRETE BARRIER SHALL BE PAID SEPARATELY.

Ⓝ WALL DESIGNER TO BE AWARE OF ANY FEATURES THAT MAY INTERFERE WITH STRUCTURAL BACKFILL. ITEMS COULD INCLUDE, BUT ARE NOT LIMITED TO; DRAINAGE STRUCTURES, LIGHT POLES (FOUNDATIONS ARE TYPICALLY AT LEAST 15' DEEP), UTILITIES, ETC.

STATE OF TENNESSEE
STANDARD DRAWING
DEPARTMENT OF TRANSPORTATION

ROADWAY FEATURES FOR MSE MODULAR BLOCK FACING RETAINING WALL

08-15-2015 | W-MSE-2

NOT TO SCALE

LLP

PURPOSE

For our Senior Design Project, our student team will be designing for repairs within the Chelaque Estates Community. The design will require knowledge of the underlying soil and its bearing capacity. To determine the Soil's Bearing Capacity, the team will need to collect soil samples from multiple locations throughout the community. These samples will then be brought back to our Civil Engineering Lab to conduct tests to classify the type of soil. The classification of the soil samples is then compared to the US Soil map to confirm accurate data. The Bearing Capacity is then given based on the soil classification.

TEAM MEMBERS

Ashley Hightower – Transportation Lead

Braden Boyd – Geotechnical Lead

EQUIPMENT

Hand Auger – device used as a corkscrew to extract soil samples

Measurement Wheel – used to determine exact location of samples

Ziplock Bags – doubled bags to transport soil samples

DETERMINING LOCATIONS TO COLLECT SAMPLES

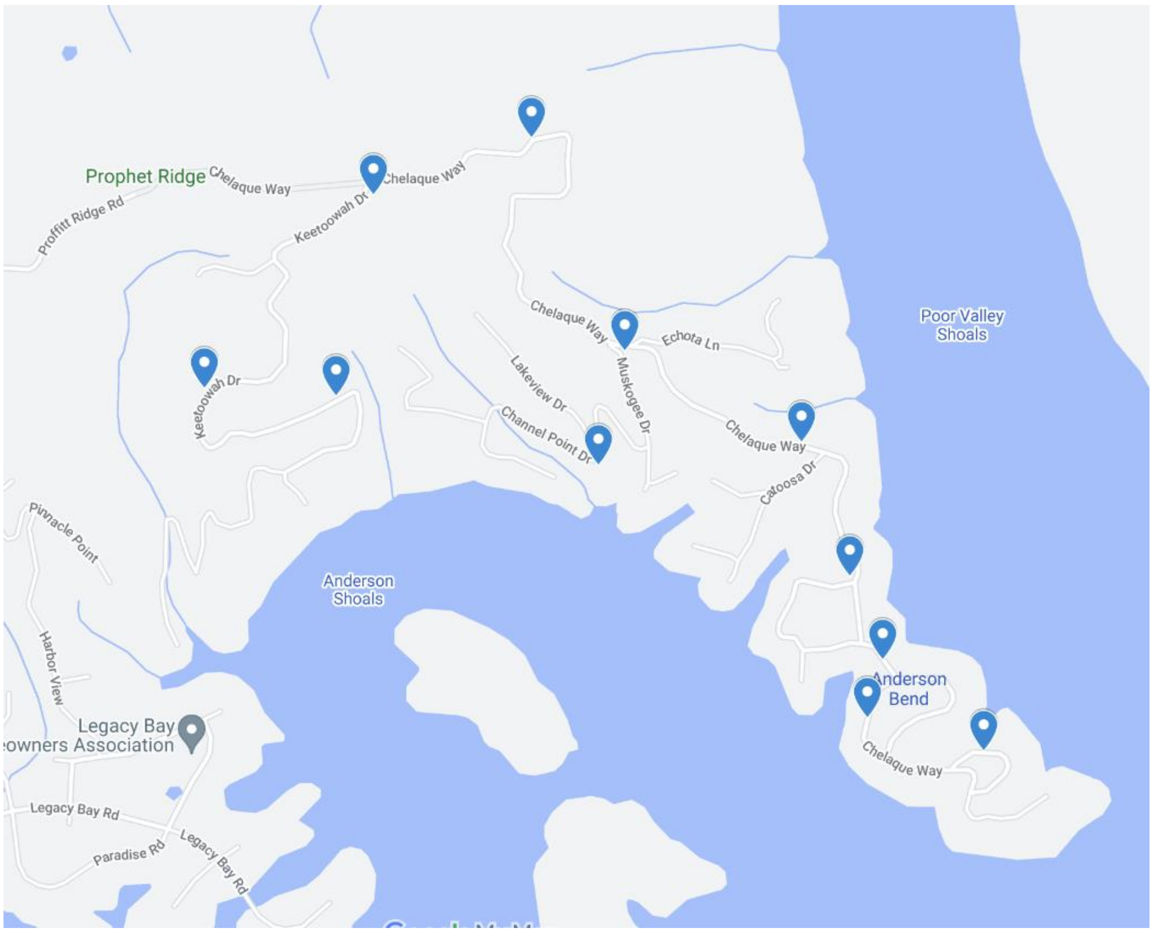
We would ideally collect at least two samples of each of the different types of soils of the community given by the US Soils Map. We would also like to collect samples near 5 feet off the roadway, to avoid digging into someone's property, and to not dig into the compacted base of the roadway. The team will collect samples from both Chelaque Way and the side roads, to get a representation of both. The Homeowner's Association Presidents suggested sampling from empty lots or within common areas of the community.

CALLING 811

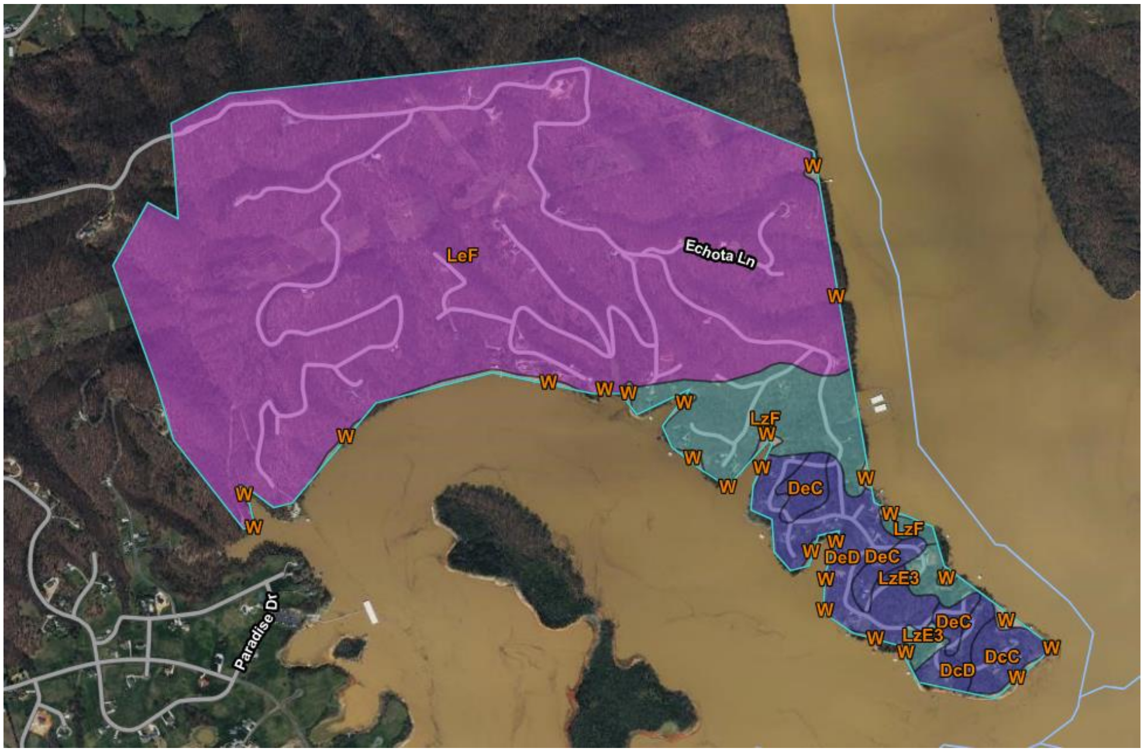
After determining locations for sampling, the team will need to let 811 (Call before you dig) know to mark underground utilities. This is a preventative measure to ensure that the team does not collect samples from areas with underlying utilities. This should occur at least 3 days before planning to collect samples.

OPTIONAL LOCATIONS FOR SAMPLING

1. Chelaque Way at light pole near construction lot
2. Chelaque Way at Construction Lot (near Howell's)
3. Tahlequah Court empty lot, near light pole 6
4. Pavilion Area, intersection of Chelaque and Sequoyah
5. Chelaque Way near double light pole
6. Intersection of Chelaque and Muskogee
7. Intersection of Channel Point and Lakeview
8. Chelaque Way at light pole 70
9. Intersection of Chelaque and Keetoowah
10. Keetoowah at light pole 18
11. Keetoowah at light pole 27



Locations throughout Chelaque Estates for Proposed Sampling Locations



Chelaque Estates Soils Data

PROPOSED LOCATIONS FOR SAMPLING

1. **Keetoowah Drive at light pole 18**

We decided to sample here as one of the locations within the A rated soil areas of the Soils Map. This location was determined to be at lots 25 and 26 on Keetoowah, with both being empty lots. This location will also be representative of the potential repairs along Keetoowah Drive.

2. **Intersection of Chelaque Way and Keetoowah Drive**

This will be our other sampling location within the A rated soil areas of the Soils Map. This location will be representative of nearby soils along the initial stretch of Chelaque Way. This location is not directly within a lot, and the nearby lots are not currently occupied.

3. **Chelaque Pavilion at the intersection of Chelaque Way and Sequoyah Drive**

This location will be representative of the C rated soil areas of the Soils Map. This is a common area of the community, and therefore not immediately on an occupied lot.

4. **Marina**

This will be our other sampling location within the C rated soil area of the Soils Map. This is also a common area of the community and will be representative of soil characteristics for nearby repair locations.

5. **Chelaque Way at Construction Lot (near Howells')**

This location is representative of the B rated soil areas of the Soils Map. This location is on a lot currently undergoing construction, as well as being one of the worst road conditions in the neighborhood, needing repair.

6. **Tahlequah Lane near light pole 6**

This will be our other location representative of B rated soil areas. This location is near potential repair locations, near lots 25 and 26 on Tahlequah Lane, which are both housing residents.

Knoxx Engineering Soil Sampling

John D. Tickle Building

863 Neyland Drive

Knoxville, TN 37916

Knoxx Engineering is a team of students from the Civil Engineering Department at the University of Tennessee, Knoxville. Knoxx Engineering is currently working on their Senior Design Project, in coordination with Chelaque Estates of Mooresburg, TN. As part of the team's work, the team will be conducting tests on soil samples to be collected within the community. Locations were thoughtfully planned and provided to 811 ("Call Before You Dig") to mark underground utilities. The soil samples will be collected using a hand auger and the remaining hole will be backfilled by team members at the sampling locations.

It is your understanding that the Knoxx Engineering Team will collect a soil sample using a hand auger and backfill the soil after collecting the sample.

Resident Printed Name ____

Resident Signature ____

Copy of (1 of 6) Receipts from Tennessee 811

TN811 POSITIVE RESPONSE NOTIFICATION

TICKET NUMBER:	222583399	OLD TICKET NUM:	
Message Type:	Normal	For Code:	B01
Hours Notice:	72	Seq Num:	0
Prepared By:	HarmonyO.7156	Taken Date:	09/15/22 14:14

Excavator Information

Excavator:	SENIOR DESIGN PROJECT - UNIV. OF TENNESSEE, K	Excavator Phone:	(423) 579-3730
Address:	4302 HARBOR DRIVE	Caller:	BRADEN BOYD
City, St, Zip:	KINGSPORT, TN 37664	Caller Phone:	(423) 579-3730
Contact Fax:		Contact:	BRADEN BOYD
Contact Email:	bboyd16@vols.utk.edu	Contact Phone:	(423) 579-3730
Call Back:			

Work Information

State:	TN	Work To Begin:	09/20/22 AT 14:15
County:	HAWKINS	Update Date:	09/30/22 AT 00:00
Place:	MOORESBURG	Expire Date:	10/05/22 AT 00:00
Address:	161 CHELAQUE WAY		
Intersection:	KEETOOWAH DR		
Latitude:	36.331602	Longitude:	-83.201474
Secondary Lat:	36.332328	Secondary Long:	-83.200112
Work Type:	SOIL TEST BORINGS	Explosives: No	WhitePaint: No
Done For:	SENIOR DESIGN PROJECT UTK	Directional Boring:	No
Extent:		Add'l Addr In Remarks:	No

Location Information (DIRECTION)

Location Information (REMARKS)

MARK SW CORNER OF INTER... COLLECTING SOIL SAMPLES BY BORING WITH A HAND AUGER. THE PASSCODE FOR THE GATE ON PROFFIT RIDGE RD/CHELAQUE WAY IS 952. PLEASE CALL JODY HOWELLS AT (423)300-9707 WHEN ARRIVING AT CHELAQUE ESTATES...

GRIDS: [141D] [141E]

Utilities Notified:

Code	Name	Manually Added
B01	ATT/D-(270) 791-2182 - B01	False
HEC	Holston Electric Cooperative - HEC	False

Chelaque Estates Boring Plan

Purpose:

Knoxx Engineering is to perform soil field sampling at multiple locations within Chelaque Estates. Samples from each location will be tested in the lab in order to determine the soil's bearing capacity, which will inform the pavement design and maximum allowable load.

Liability:

This action has been approved by the clients at Chelaque Estates, Dave Margozzi and Jody and Dave Howells, and the department head, Dr. Chris Cox.

Location:

Several locations within Chelaque Estates, located at 599 Proffitt Ridge Rd, Mooresburg, TN 37811. See attached map for exact locations.

Date:

TBD

Crew Members:

Driller – Larry Roberts

Laborer – Ashley Hightower

Laborer – Braden Boyd

Safety:

While onsite, crew members will follow standards outlined by OSHA and the NDA Drilling Safety Guide. All required PPE will be worn while necessary, including hard hats, gloves, long pants, closed-toed shoes, protective eyewear, and ear protection. Risks associated with boring include pinch points, crushing, loud noise, sharp edges, overhead objects, heavy lifting, tripping, and moving machinery.

Boring Plan:

Report: …

Additional Work: ...

Liquid Limit Determination - Sample 1					Plastic Limit Determination - Sample 1	
Determination No.	1	2	3	4	Tare No.	L17ϕ
Tare No.	C8	C11	D9	L2ϕ1	Mass of Wet Soil + Tare (g)	12.47
Mass of Wet Soil + Tare (g)	30.46	25.78	25.86	20.9	Mass of Dry Soil + Tare (g)	11.91
Mass of Dry Soil + Tare (g)	27.11	23.58	23.66	18.7	Mass of Water (g)	0.56
Mass of Water (g)	3.35	2.2	2.2	2.2	Mass of Tare (g)	9.33
Mass of Tare (g)	15.2	15.5	15.46	9.47	Water Content (PL) =	21.7054264
Mass of Dry Soil (g)	11.91	8.08	8.2	9.23		
Water Content (%)	28.1276238	27.2277228	26.8292683	23.8353196		
No. of Blows	18	8	10	33		
Liquid Limit Determination - Sample 2					Plastic Limit Determination - Sample 2	
Determination No.	1	2	3	4	Tare No.	D7
Tare No.	L206	29	B3	L171	Mass of Wet Soil + Tare (g)	20.1
Mass of Wet Soil + Tare (g)	18.03	21.37	26.6	22.47	Mass of Dry Soil + Tare (g)	19.19
Mass of Dry Soil + Tare (g)	15.74	18.76	23.84	19.32	Mass of Water (g)	0.91
Mass of Water (g)	2.29	2.61	2.76	3.15	Mass of Tare (g)	15.34
Mass of Tare (g)	9.34	11.18	15.41	9.32	Water Content (PL) =	23.6363636
Mass of Dry Soil (g)	6.4	7.58	8.43	10		
Water Content (%)	35.78125	34.4327177	32.7402135	31.5		
No. of Blows	10	16	21	35		
Liquid Limit Determination - Sample 3					Plastic Limit Determination - Sample 3	
Determination No.	1	2	3		Tare No.	L178
Tare No.	182	L181	45		Mass of Wet Soil + Tare (g)	14.72
Mass of Wet Soil + Tare (g)	18.22	19.62	25.99		Mass of Dry Soil + Tare (g)	13.64
Mass of Dry Soil + Tare (g)	15.91	17.12	22.36		Mass of Water (g)	1.08
Mass of Water (g)	2.31	2.5	3.63		Mass of Tare (g)	9.4
Mass of Tare (g)	9.4	9.39	11.2		Water Content (PL) =	25.4716981
Mass of Dry Soil (g)	6.51	7.73	11.16			
Water Content (%)	35.483871	32.3415265	32.5268817			
No. of Blows	9	21	26			
Liquid Limit Determination - Sample 4					Plastic Limit Determination - Sample 4	
Determination No.	1	2	3		Tare No.	D13

Tare No.	A12	L190	L172		Mass of Wet Soil + Tare (g)	21.25
Mass of Wet Soil + Tare (g)	26.6	16.42	16.08		Mass of Dry Soil + Tare (g)	20.35
Mass of Dry Soil + Tare (g)	23.68	14.68	14.39		Mass of Water (g)	0.9
Mass of Water (g)	2.92	1.74	1.69		Mass of Tare (g)	16.99
Mass of Tare (g)	15.8	9.45	9.36		Water Content (PL) =	26.7857143
Mass of Dry Soil (g)	7.88	5.23	5.03			
Water Content (%)	37.0558376	33.2695985	33.5984095			
No. of Blows	9	29	21			
Liquid Limit Determination - Sample 5					Plastic Limit Determination - Sample 5	
Determination No.	1	2	3		Tare No.	32
Tare No.	L180	C5	39		Mass of Wet Soil + Tare (g)	15.6
Mass of Wet Soil + Tare (g)	21.73	27.3	22.4		Mass of Dry Soil + Tare (g)	14.48
Mass of Dry Soil + Tare (g)	17.74	23.63	19.38		Mass of Water (g)	1.12
Mass of Water (g)	3.99	3.67	3.02		Mass of Tare (g)	11.02
Mass of Tare (g)	9.24	15.59	11.69		Water Content (PL) =	32.3699422
Mass of Dry Soil (g)	8.5	8.04	7.69			
Water Content (%)	46.9411765	45.6467662	39.2717815			
No. of Blows	4	12	28			
Liquid Limit Determination - Sample 6					Plastic Limit Determination - Sample 6	
Determination No.	1	2	3		Tare No.	L188
Tare No.	A5	43	H6		Mass of Wet Soil + Tare (g)	13.18
Mass of Wet Soil + Tare (g)	22.53	20.17	18.79		Mass of Dry Soil + Tare (g)	12.47
Mass of Dry Soil + Tare (g)	20.91	18.25	16.89		Mass of Water (g)	0.71
Mass of Water (g)	1.62	1.92	1.9		Mass of Tare (g)	9.4
Mass of Tare (g)	15.61	11.25	9.34		Water Content (PL) =	23.1270358
Mass of Dry Soil (g)	5.3	7	7.55			
Water Content (%)	30.5660377	27.4285714	25.1655629			
No. of Blows	4	13	31			

THE UNIVERSITY OF TENNESSEE

Department of Civil and Environmental Engineering

Project Name:	Boring No:	Sample No: SAMPLE 1	Depth:
Team Members:			Date:
Mass of Original Sample (W_o): 100.02	Mass of 200 Wash residue ($W_{residue}$): 14.46	Mass of W_{200} (W_0-$W_{residue}$): 85.56	

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000	136.59	136.59	0	0	0	100%
40	0.425	115.35	121.85	6.5	6.5	6.4987	94%
60	0.250	107.06	108.05	0.99	7.49	7.488502	93%
100	0.150	105.89	107.24	1.35	8.84	8.838232	91%
200	0.075	747.65	753.07	5.42	14.26	14.25715	86%
pan	0.000	473.43	473.63	0.2	14.46	14.45711	86%

Hydrometer No: 152H	Concentration of Dispersing Agent (X_d): 40 g/L	Volume of Stock Solution (V_d): 125 mL
Dispersing Agent Correction (Cd = 0.001$X_d V_d$) 5 g/L	Meniscus Correction (cm) 0.5 g/L	
Specific Gravity (G_s): 2.7	% passing No. 4 Sieve= 100	W_{200}/W_0 0.8554

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm³)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer (Nm)
	0.5	20	0.998	40	0.23	35.73	9.7	0.01345	0.059241	35.37%	30%
	1	20	0.998	40	0.23	35.73	9.7	0.01345	0.04189	35.37%	30%
	2	20	0.998	40	0.23	35.73	9.7	0.01345	0.029621	35.37%	30%
	4	20	0.998	40	0.23	35.73	9.7	0.01345	0.020945	35.37%	30%
	8	20	0.998	41	0.23	36.73	9.6	0.01345	0.014734	36.36%	31%
	15	20	0.998	41	0.23	36.73	9.6	0.01345	0.01076	36.36%	31%
	30	20	0.998	40	0.23	35.73	9.7	0.01345	0.007648	35.37%	30%
	60	20	0.998	37	0.23	32.73	10.2	0.01345	0.005546	32.40%	28%
	90	20	0.998	34	0.23	29.73	10.7	0.01345	0.004638	29.43%	25%
	1440	20	0.998	23	0.23	18.73	12.5	0.01345	0.001253	18.54%	16%

[1] $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm³) at temperature T.

[2] $R_{corr} = R + m - C_d + C_m$

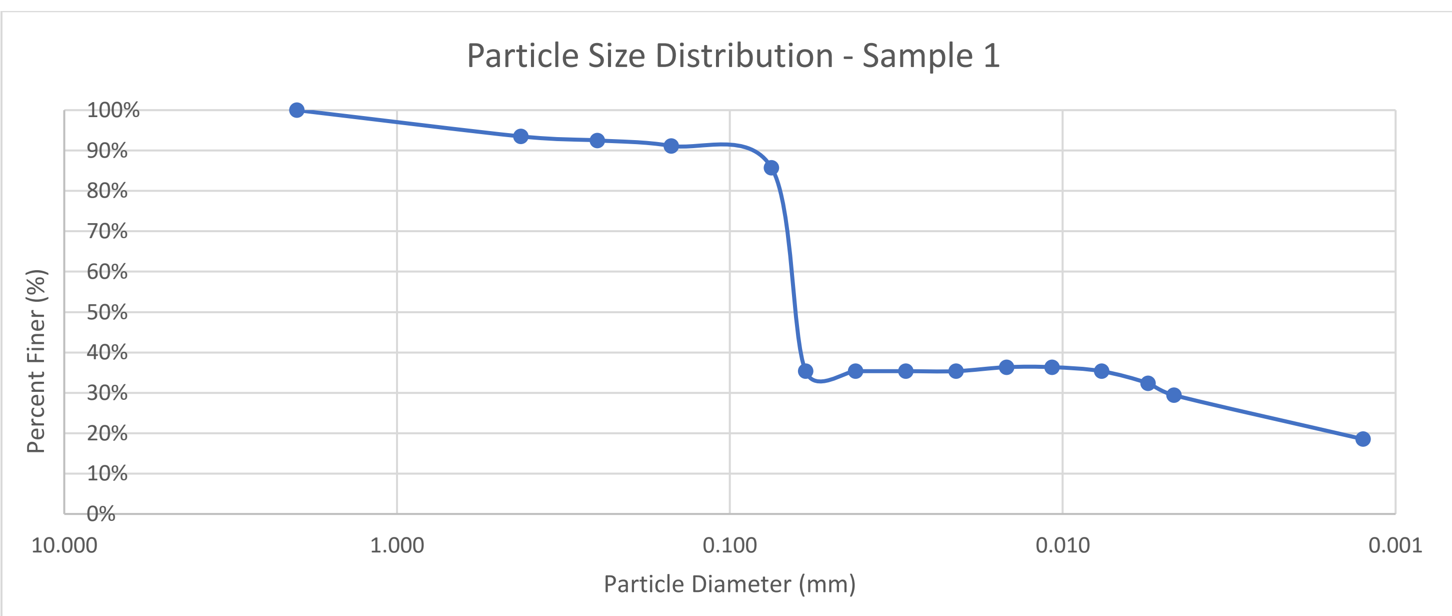
[3] L obtained from Table 2 of ASTM D422

[4] K obtained from Table 3 of ASTM D422

[5] $D = K\,(L/t)^{1/2}$ where t is elapsed time

[6] $P = (R_{corr}\, a/W_o)$ where a obtained from Table 1 of ASTM D422

[7] Refer to ASTM D422, Section 16 (based on W_{200}/W_O)



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Department of Civil and Environmental Engineering

Project Name:	Boring No:	Sample No: SAMPLE 2	Depth:
Team Members:			Date:
Mass of Original Sample (W_o): 100	Mass of 200 Wash residue ($W_{residue}$): 9.88	Mass of W_{200} ($W_0 - W_{residue}$): 90.12	

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000	136.59	136.59	0	0	0	100%
40	0.425	115.35	119.83	4.48	4.48	4.48	96%
60	0.250	107.06	108.03	0.97	5.45	5.45	95%
100	0.150	105.89	106.96	1.07	6.52	6.52	93%
200	0.075	747.62	750.89	3.27	9.79	9.79	90%
pan	0.000	473.43	473.52	0.09	9.88	9.88	90%

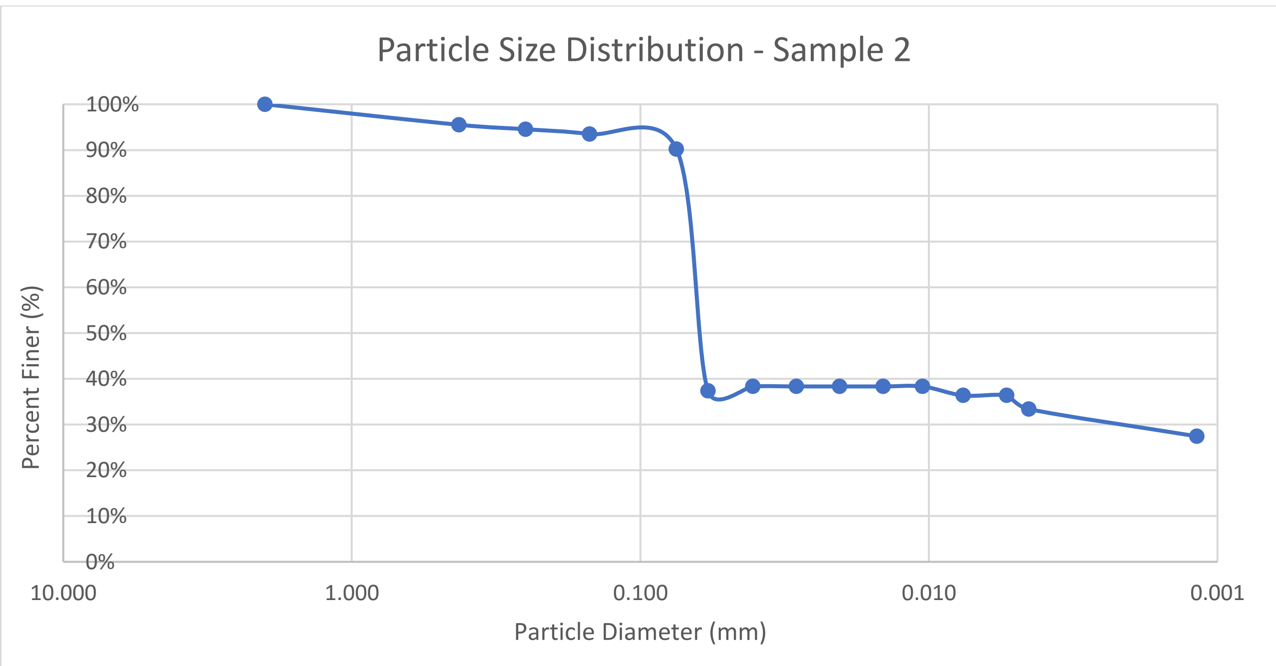
Hydrometer No: 152H	Concentration of Dispersing Agent (X_d): 40 g/L	Volume of Stock Solution (V_d): 125 mL	
Dispersing Agent Correction (Cd = $0.001X_dV_d$) 5 g/L	Meniscus Correction (cm) 0.5 g/L		
Specific Gravity (G_s): 2.7	% passing No. 4	Sieve= 100	W_{200}/W_0 0.9012

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm³)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer (Nm)
	0.5	20	0.998	42	0.23	37.73	9.4	0.01345	0.058318	37.35%	34%
	1	20	0.998	43	0.23	38.73	9.2	0.01345	0.040796	38.34%	35%
	2	20	0.998	43	0.23	38.73	9.2	0.01345	0.028847	38.34%	35%
	4	20	0.998	43	0.23	38.73	9.2	0.01345	0.020398	38.34%	35%
	8	20	0.998	43	0.23	38.73	9.2	0.01345	0.014424	38.34%	35%
	15	20	0.998	43	0.23	38.73	9.2	0.01345	0.010533	38.34%	35%
	30	20	0.998	41	0.23	36.73	9.6	0.01345	0.007608	36.36%	33%
	60	20	0.998	41	0.23	36.73	9.6	0.01345	0.00538	36.36%	33%
	90	20	0.998	38	0.23	33.73	10.1	0.01345	0.004506	33.39%	30%
	1440	20	0.998	32	0.23	27.73	11.1	0.01345	0.001181	27.45%	25%

1 $m = 1000[0.99823 - \rho_w - 0.000025(T - 20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm³) at temperature T.

2 $R_{corr} = R + m - C_d + C_m$
3 L obtained from Table 2 of ASTM D422
4 K obtained from Table 3 of ASTM D422
5 $D = K(L/t)^{1/2}$ where t is elapsed time
6 $P = (R_{corr}\, a/W_0)$ where a obtained from Table 1 of ASTM D422
7 Refer to ASTM D422, Section 16 (based on W_{200}/W_0)



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Department of Civil and Environmental Engineering

Project Name: Boring No: Sample No: SAMPLE 3 Depth:

Team Members: Date:

Mass of Original Sample (W_o): 100.02 Mass of 200 Wash residue ($W_{residue}$): 10.38 Mass of W_{200} ($W_o - W_{residue}$): 89.64

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000	136.59	136.59	0	0	0	100%
40	0.425	115.35	124.52	9.17	9.17	9.168166	91%
60	0.250	107.06	107.68	0.62	9.79	9.788042	90%
100	0.150	105.89	106.18	0.29	10.08	10.07798	90%
200	0.075	747.62	747.92	0.3	10.38	10.37792	90%
pan	0.000	473.43	473.43	0	10.38	10.37792	90%

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = 0.001$X_d V_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

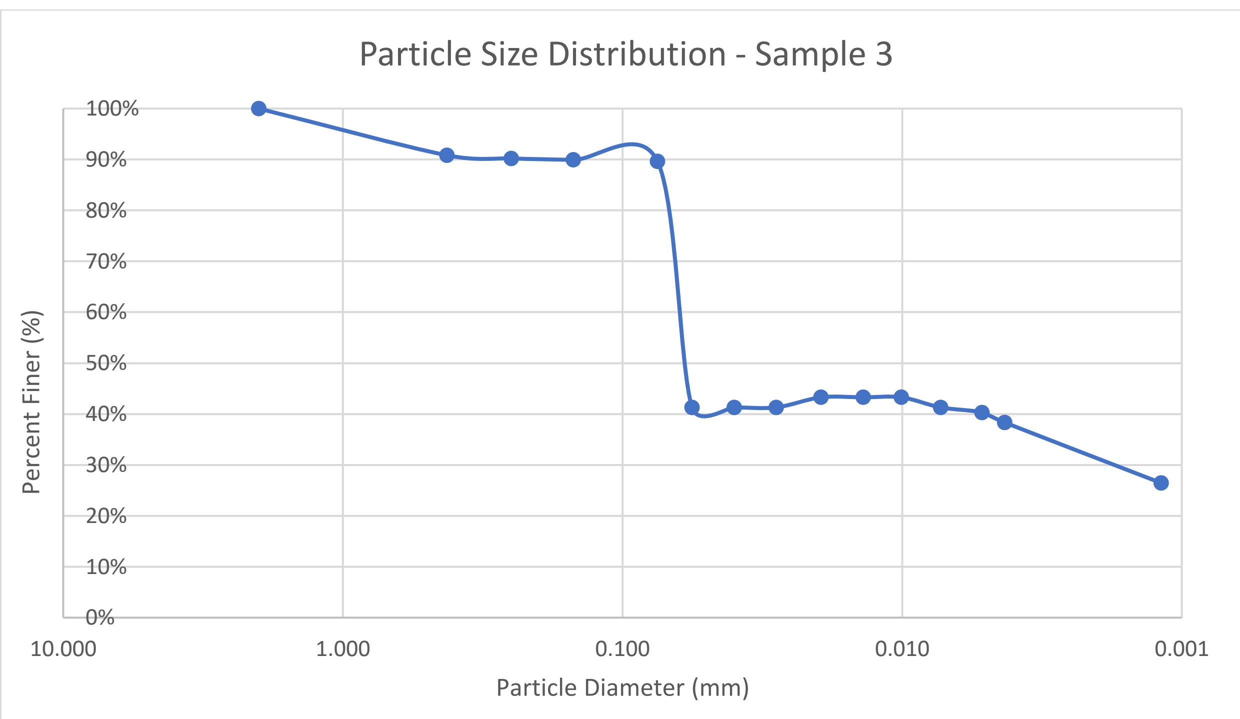
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_o 0.8962

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm³)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer (Nm)
	0.5	20	0.998	46	0.23	41.73	8.8	0.01345	0.056426	41.30%	37%
	1	20	0.998	46	0.23	41.73	8.8	0.01345	0.039899	41.30%	37%
	2	20	0.998	46	0.23	41.73	8.8	0.01345	0.028213	41.30%	37%
	4	20	0.998	48	0.23	43.73	8.4	0.01345	0.019491	43.28%	39%
	8	20	0.998	48	0.23	43.73	8.4	0.01345	0.013782	43.28%	39%
	15	20	0.998	48	0.23	43.73	8.4	0.01345	0.010065	43.28%	39%
	30	20	0.998	46	0.23	41.73	8.8	0.01345	0.007285	41.30%	37%
	60	20	0.998	45	0.23	40.73	8.9	0.01345	0.00518	40.31%	36%
	90	20	0.998	43	0.23	38.73	9.2	0.01345	0.0043	38.34%	34%
	1440	20	0.998	31	0.23	26.73	11.2	0.01345	0.001186	26.46%	24%

1 $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm³) at temperature T.

2 $R_{corr} = R + m - C_d + C_m$
3 L obtained from Table 2 of ASTM D422
4 K obtained from Table 3 of ASTM D422
5 $D = K\,(L/t)^{1/2}$ where t is elapsed time
6 $P = (R_{corr}\,a/W_o)$ where a obtained from Table 1 of ASTM D422
7 Refer to ASTM D422, Section 16 (based on W_{200}/W_o)



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Department of Civil and Environmental Engineering

Project Name: Boring No: Sample No: SAMPLE 4 Depth:

Team Members: Date:

Mass of Original Sample (W, 100.02 Mass of 200 Wash residue ($W_{residue}$: 26.71 Mass of W_{200} (W_0-$W_{residue}$): 73.31

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000	136.59	136.59	0	0	0	100%
40	0.425	115.35	119.68	4.33	4.33	4.329134	96%
60	0.250	107.06	121.25	14.19	18.52	18.5163	81%
100	0.150	105.89	111.49	5.6	24.12	24.11518	76%
200	0.075	747.62	750.19	2.57	26.69	26.68466	73%
pan	0.000	473.43	473.45	0.02	26.71	26.70466	73%

Hydrometer No: 152H Concentration of Dispersing Agent (X_d): 40 g/L Volume of Stock Solution (V_d): 125 mL

Dispersing Agent Correction (Cd = 0.001$X_d V_d$) 5 g/L Meniscus Correction (cm) 0.5 g/L

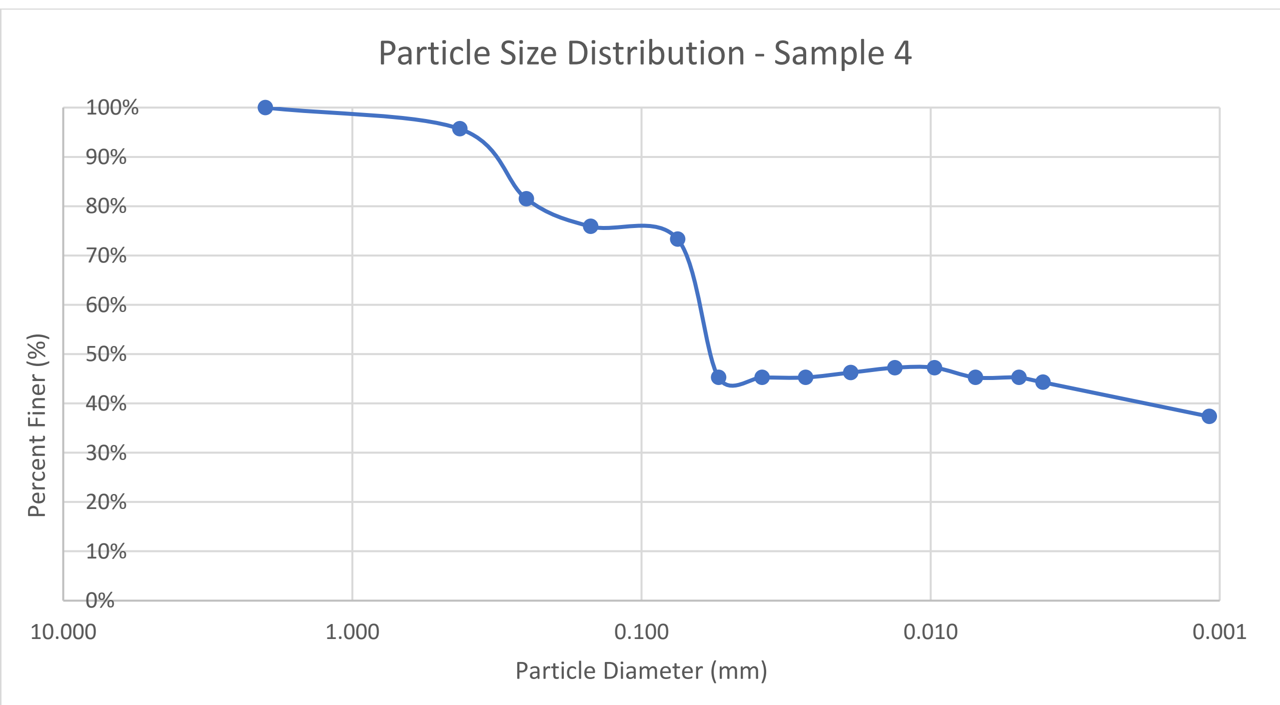
Specific Gravity (G_s): 2.7 % passing No. 4 Sieve= 100 W_{200}/W_0 0.733

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm³)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer (Nm)
	0.5	20	0.998	50	0.23	45.73	8.1	0.01345	0.054135	45.26%	33%
	1	20	0.998	50	0.23	45.73	8.1	0.01345	0.038279	45.26%	33%
	2	20	0.998	50	0.23	45.73	8.1	0.01345	0.027068	45.26%	33%
	4	20	0.998	51	0.23	46.73	7.9	0.01345	0.018902	46.25%	34%
	8	20	0.998	52	0.23	47.73	7.8	0.01345	0.013281	47.24%	35%
	15	20	0.998	52	0.23	47.73	7.8	0.01345	0.009699	47.24%	35%
	30	20	0.998	50	0.23	45.73	8.1	0.01345	0.006989	45.26%	33%
	60	20	0.998	50	0.23	45.73	8.1	0.01345	0.004942	45.26%	33%
	90	20	0.998	49	0.23	44.73	8.3	0.01345	0.004085	44.27%	32%
	1440	20	0.998	42	0.23	37.73	9.4	0.01345	0.001087	37.35%	27%

[1] m = 1000[0.99823 − ρ_w − 0.000025 (T − 20)], where T is water temperature (°C) and ρ_w is water unit mass (g/cm³) at temperature T.

[2] $R_{corr} = R + m - C_d + C_m$
[3] L obtained from Table 2 of ASTM D422
[4] K obtained from Table 3 of ASTM D422
[5] $D = K (L/t)^{1/2}$ where t is elapsed time
[6] $P = (R_{corr}\, a/W_0)$ where a obtained from Table 1 of ASTM D422
[7] Refer to ASTM D422, Section 16 (based on W_{200}/W_0)



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Department of Civil and Environmental Engineering

Project Name:	Boring No:	Sample No: SAMPLE 5	Depth:
Team Members:			Date:
Mass of Original Sample (W_0): 100.02	Mass of 200 Wash residue ($W_{residue}$): 8.3	Mass of W_{200} (W_0-$W_{residue}$): 91.72	

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000	136.59	136.59	0	0	0	100%
40	0.425	115.35	120	4.65	4.65	4.64907	95%
60	0.250	107.06	108.96	1.9	6.55	6.54869	93%
100	0.150	105.89	106.99	1.1	7.65	7.64847	92%
200	0.075	747.62	748.27	0.65	8.3	8.29834	92%
pan	0.000	473.43	473.43	0	8.3	8.29834	92%

Hydrometer No: 152H	Concentration of Dispersing Agent (X_d): 40 g/L	Volume of Stock Solution (V_d): 125 mL	
Dispersing Agent Correction (Cd = 0.001$X_d V_d$) 5 g/L	Meniscus Correction (cm) 0.5 g/L		
Specific Gravity (G_s): 2.7	% passing No. 4	Sieve= 100	W_{200}/W_0 0.917

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_w (g/cm³)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer (Nm)
	0.5	20	0.998	51	0.23	46.73	7.9	0.01345	0.053463	46.25%	42%
	1	20	0.998	51	0.23	46.73	7.9	0.01345	0.037804	46.25%	42%
	2	20	0.998	51	0.23	46.73	7.9	0.01345	0.026731	46.25%	42%
	4	20	0.998	51	0.23	46.73	7.9	0.01345	0.018902	46.25%	42%
	8	20	0.998	51	0.23	46.73	7.9	0.01345	0.013366	46.25%	42%
	15	20	0.998	50	0.23	45.73	8.1	0.01345	0.009884	45.26%	42%
	30	20	0.998	49	0.23	44.73	8.3	0.01345	0.007075	44.27%	41%
	60	20	0.998	47	0.23	42.73	8.6	0.01345	0.005092	42.29%	39%
	90	20	0.998	46	0.23	41.73	8.8	0.01345	0.004206	41.30%	38%
	1440	20	0.998	38	0.23	33.73	10.1	0.01345	0.001126	33.39%	31%

[1] m = 1000[0.99823 − ρ_w − 0.000025 (T − 20)], where T is water temperature (°C) and ρ_w is water unit mass (g/cm³) at temperature T.

[2] $R_{corr} = R + m - C_d + C_m$

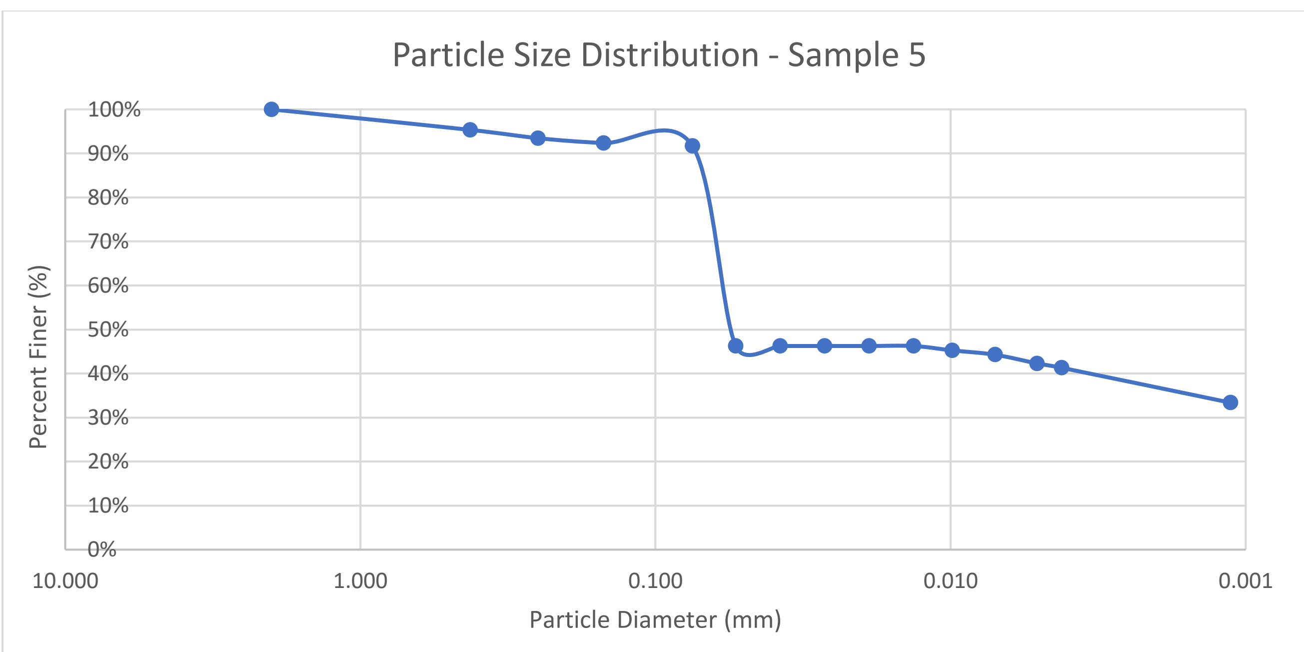
[3] L obtained from Table 2 of ASTM D422

[4] K obtained from Table 3 of ASTM D422

[5] $D = K (L/t)^{1/2}$ where t is elapsed time

[6] P = (R_{corr} a/W_0) where a obtained from Table 1 of ASTM D422

[7] Refer to ASTM D422, Section 16 (based on W_{200}/W_0)



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Project Name:		Boring No:		Sample No: SAMPLE 2		Depth:	
Team Members:						Date:	
Mass of Original Sample (W_o	100	Mass of 200 Wash residue ($W_{residue}$:	24.55	Mass of W_{200} (W_0-$W_{residue}$):		75.45	

Mechanical Analysis

Sieve #	Opening (mm)	Sieve Mass (g)	Sieve + Soil Mass (g)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative Percent Retained (%)	Cumulative Percent Passing (%)
10	2.000	136.59	136.59	0	0	0	100%
40	0.425	115.35	130	14.65	14.65	14.65	85%
60	0.250	107.06	112.32	5.26	19.91	19.91	80%
100	0.150	105.89	108.24	2.35	22.26	22.26	78%
200	0.075	747.62	749.84	2.22	24.48	24.48	76%
pan	0.000	473.43	473.5	0.07	24.55	24.55	75%

Hydrometer No:	152H	Concentration of Dispersing Agent (X_d):	40 g/L	Volume of Stock Solution (V_d):	125 mL		
Dispersing Agent Correction (Cd = 0.001$X_d V_d$)	5 g/L	Meniscus Correction (cm)	0.5 g/L				
Specific Gravity (G_s):	2.7	% passing No.	4	Sieve=	100	W_{200}/W_0	0.7545

Hydrometer Analysis

Time	Elapsed Time (min)	Temp (°C)	Unit mass, ρ_u (g/cm³)	Hydrometer Reading, R (g/L)	Temp Correction m	Corrected Reading, R_{corr}	Effective Depth, L (cm)	Constant, K	Particle Diamter, D (mm)	Particle Percent Finer	Total Percent Finer (Nm)
	0.5	20	0.998	41	0.23	36.73	9.6	0.01345	0.058935	36.36%	27%
	1	20	0.998	41	0.23	36.73	9.6	0.01345	0.041673	36.36%	27%
	2	20	0.998	41	0.23	36.73	9.6	0.01345	0.029467	36.36%	27%
	4	20	0.998	42	0.23	37.73	9.4	0.01345	0.020618	37.35%	28%
	8	20	0.998	42	0.23	37.73	9.4	0.01345	0.014579	37.35%	28%
	15	20	0.998	41	0.23	36.73	9.6	0.01345	0.01076	36.36%	27%
	30	20	0.998	37	0.23	32.73	10.2	0.01345	0.007843	32.40%	24%
	60	20	0.998	35	0.23	30.73	10.6	0.01345	0.005653	30.42%	23%
	90	20	0.998	31	0.23	26.73	11.2	0.01345	0.004745	26.46%	20%
	1440	20	0.998	20	0.23	15.73	13	0.01345	0.001278	15.57%	12%

1 $m = 1000[0.99823 - \rho_w - 0.000025\,(T - 20)]$, where T is water temperature (°C) and ρ_w is water unit mass (g/cm³) at temperature T.

2 $R_{corr} = R + m - C_d + C_m$

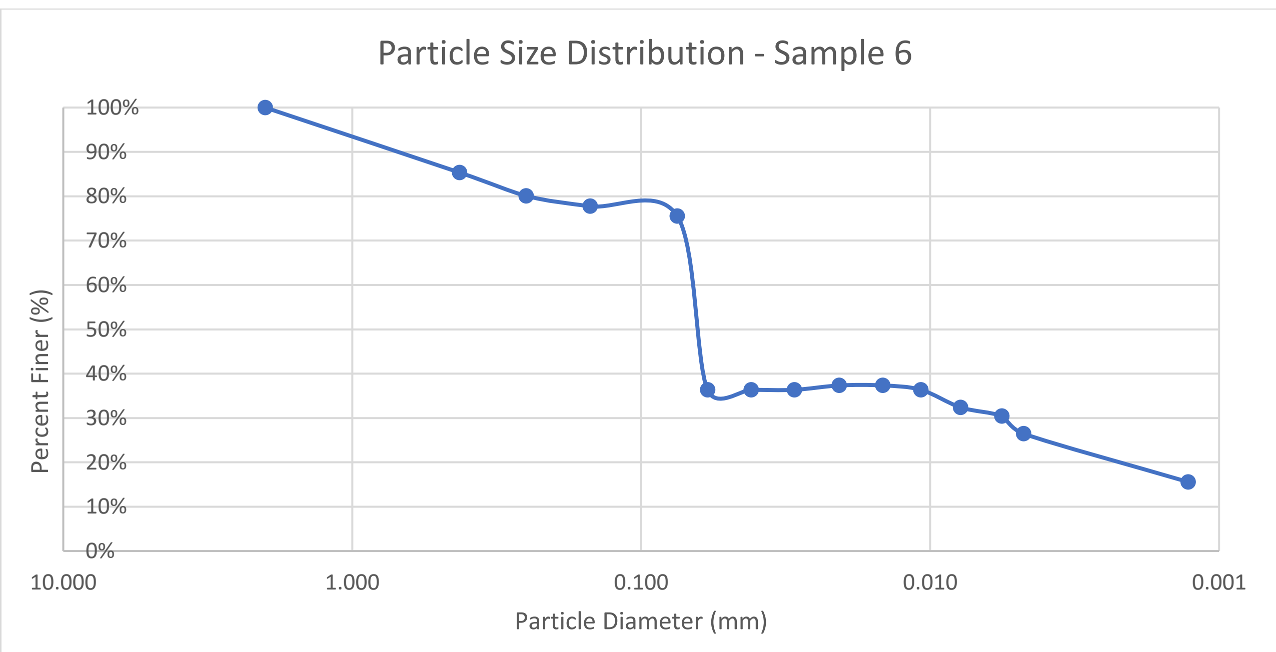
3 L obtained from Table 2 of ASTM D422

4 K obtained from Table 3 of ASTM D422

5 $D = K\,(L/t)^{1/2}$ where t is elapsed time

6 $P = (R_{corr}\,a/W_0)$ where a obtained from Table 1 of ASTM D422

7 Refer to ASTM D422, Section 16 (based on W_{200}/W_0)



Unified Soil Classification System (USCS) - (ASTM D2487)

D 2487

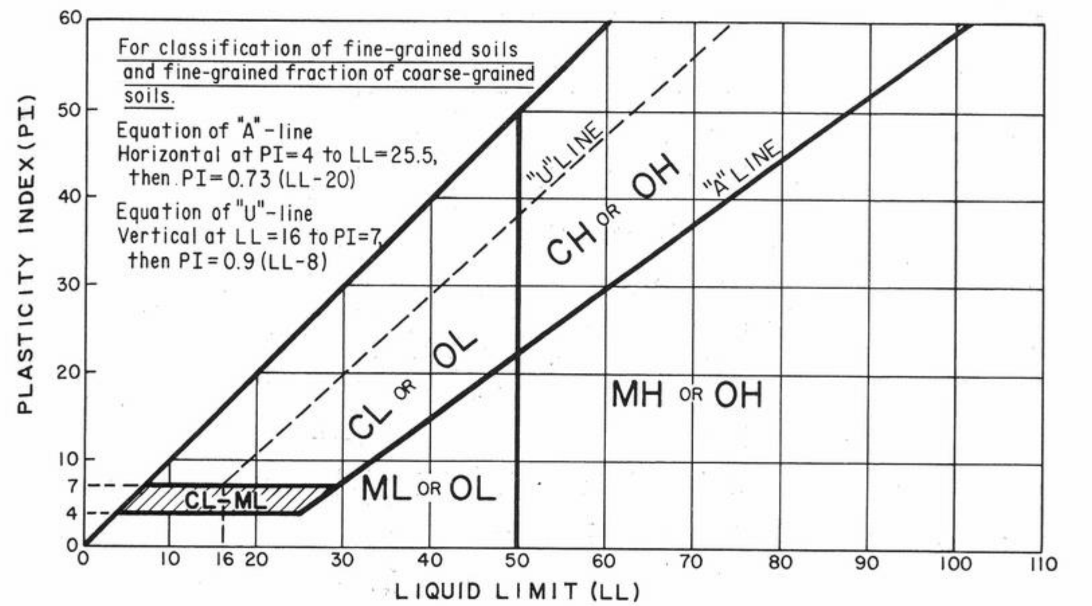
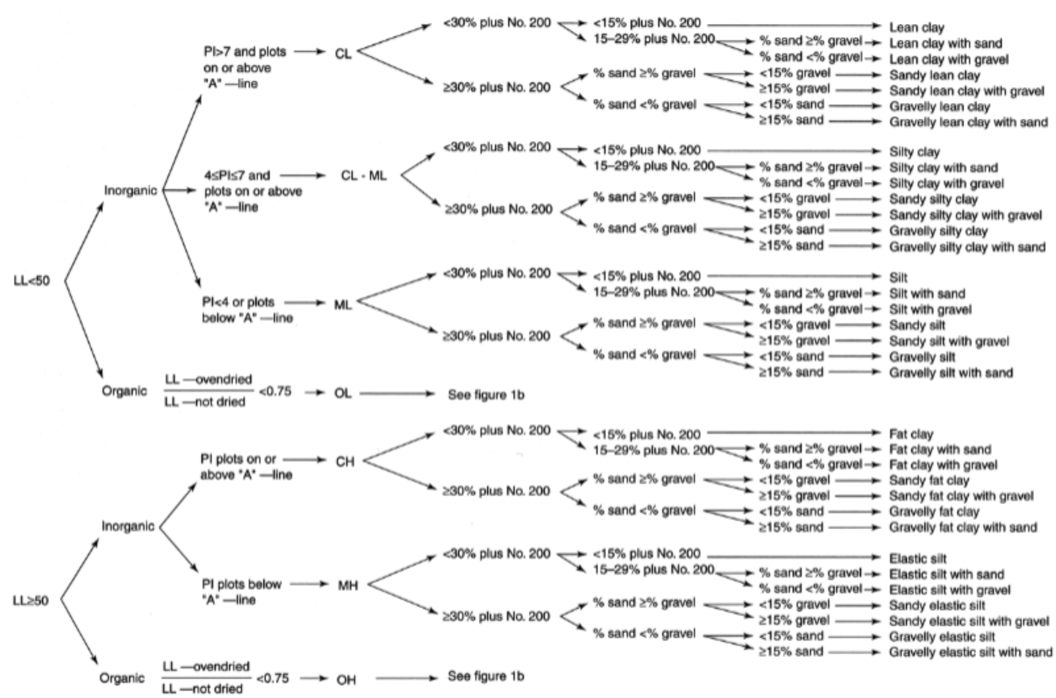


FIG. 3 Plasticity Chart

Figure 6-4 Flow Chart for Classifying Fine-Grained Soil (50% or More Passes No. 200 Sieve)



	Liquid Limit	Plastic Limit	Plasticity Index	Classification
Sample 1	26	21.7	4.3	Silt
Sample 2	32.5	23.6	8.9	Silt
Sample 3	32.5	25.5	7	Silt
Sample 4	33.5	26.8	6.7	Silt with Sand
Sample 5	41	32.4	8.6	Silt
Sample 6	26	23.1	2.9	Silt with Sand

Section 4

MSE Wall Design Example

This design (Figure 9-12) presents the basic calculations for the analysis of stability of an MSE wall.The detailed calculations for internal stability of the MSE mass with regard to reinforcement stresses and required length for pullout are not addressed here. For current information in this area, see the *AASHTO Standard Specification for Highway Bridges.*

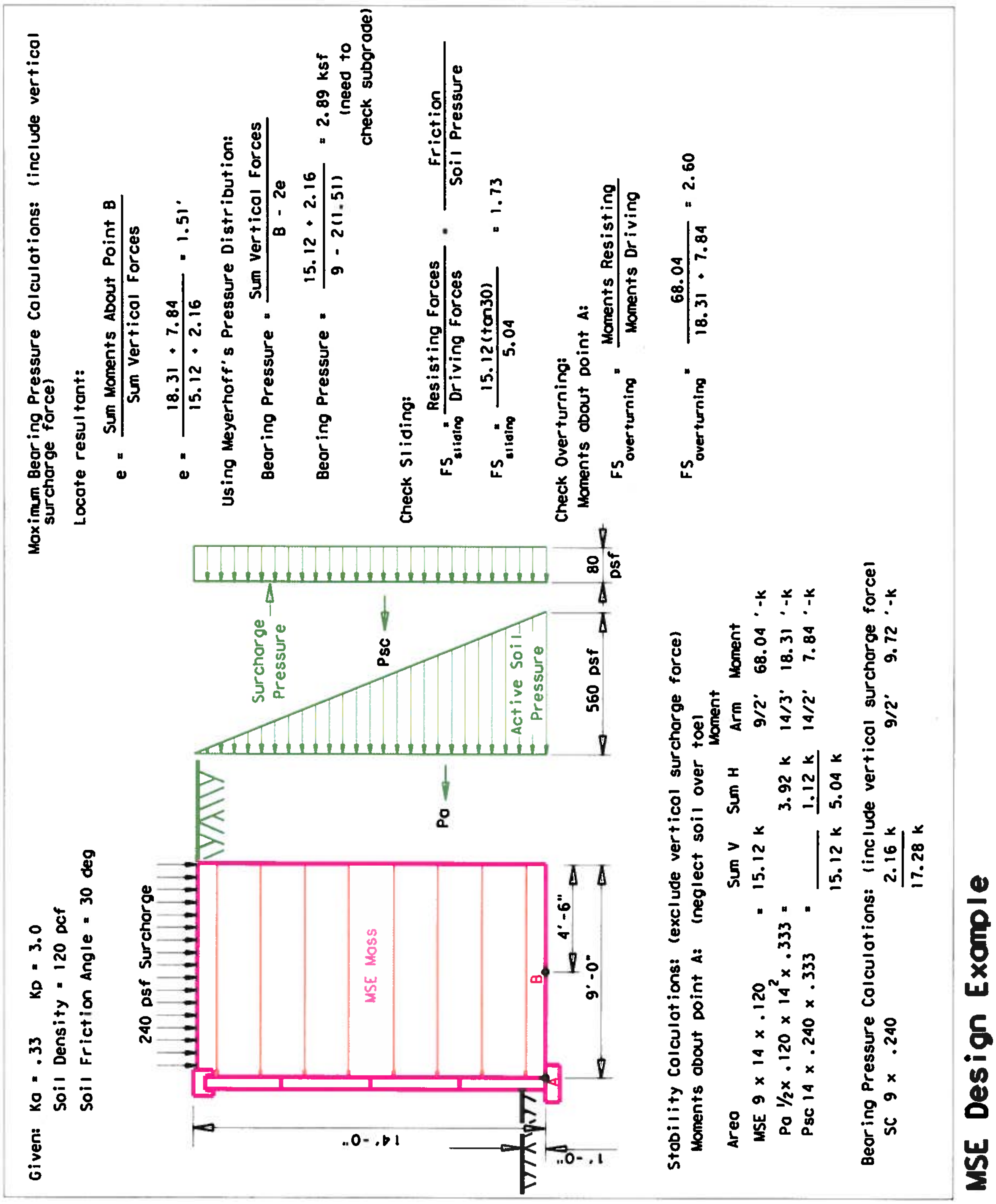
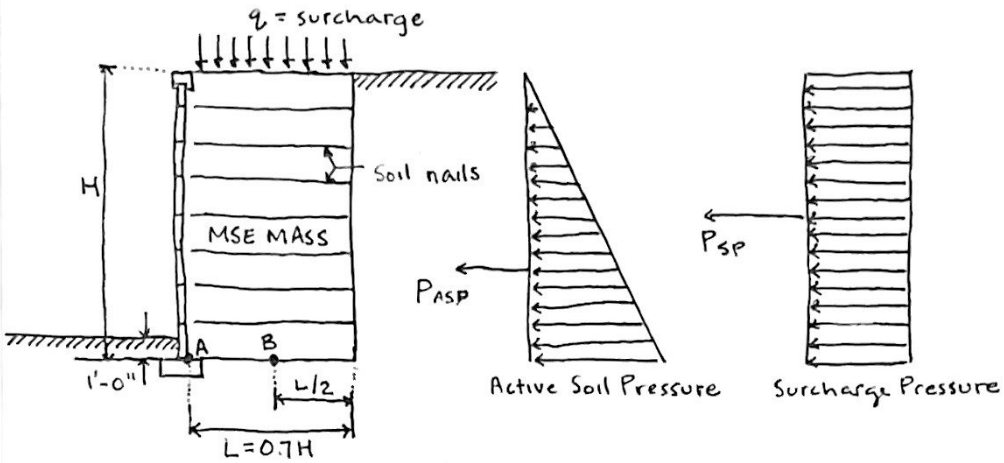


Figure 9-12. MSE wall design example.

MSE WALL DESIGN



Silty Sand Soil used for backfill

Unit Weight = 146.5 pcf

Friction Angle = 35°

RANKINE THEORY

$$K_a = \tan^2\left(45 - \tfrac{1}{2}\phi'\right)$$

$$= \tan^2\left(45 - \tfrac{1}{2}(35)\right) = 0.271$$

$$K_p = 1/K_a = 3.69$$

STABILITY CALCULATIONS (excluding vertical surcharge)

	Area	Arm	Moment (k-ft)	from A
MSE MASS	$H(0.7H)(0.1465) = 0.1026H^2$	$0.35H$	$0.0359H^3$	↻
P_{ASP}	$0.5(0.271)(0.1465)H^2 = 0.0199H^2$	$H/3$	$0.0066H^3$	↺
P_{SP}	$0.271Hq = 0.271Hq$	$H/2$	$0.1355qH^2$	↺

$\Sigma M < 0$ (ccw Positive)

$$\Sigma M = 0.0066H^3 + 0.1355qH^2 - 0.0359H^3 < 0$$

$$0.1355qH^2 < 0.0293H^3$$

$$q < 0.216H \quad (\text{ksf}) \Rightarrow q < 216H \ (\text{psf})$$

MAX BEARING PRESSURE CALCULATIONS (including vertical surcharge force)

Locate Resultant: $e = \dfrac{\Sigma \text{ Moments about B}}{\Sigma \text{ Vertical Forces}}$

$$e = \frac{0.0066H^3 + 0.1355qH^2}{0.7Hq + 0.1026H^2} = \frac{0.0066H^3 + 0.1355(0.216H)H^2}{0.7H(0.216H) + 0.1026H^2}$$

$$e = 0.141H$$

Meyerhoff's Pressure Distribution:

$$\text{Bearing Pressure} = \frac{\Sigma \text{ Vertical Forces}}{L - 2e} = \frac{0.7H(0.216H) + 0.1026H^2}{0.7H - 2(0.141H)}$$

$$= 0.607H \ (\text{ksf}) \Rightarrow 607H \text{ psf}$$

CHECK SLIDING

$$FS_{sliding} = \frac{\text{Friction}}{\text{Soil Pressure}} = \frac{0.1026H^2(\tan(35))}{0.0199H^2 + 0.271H(0.216H)} = 0.9 \quad \therefore \text{UNSAFE}$$

CHECK OVERTURNING (moment about A)

$$FS_{overturning} = \frac{\text{Mom. Resisting}}{\text{Mom. Driving}} = \frac{0.0359H^3}{0.0066H^3 + 0.1355H^2(0.216H)} = 1.0 \quad \therefore \text{UNSAFE}$$

MSE WALL WITHOUT SURCHARGE

STABILITY CALCULATIONS

	Area	Arm	Moment (k-ft)	from A
MSE MASS	$H(0.7H)(0.1465) = 0.1026H^2$	$0.35H$	$0.0359H^3$	↷
PASP	$0.5(0.271)(0.1465)H^2 = 0.0199H^2$	$H/3$	$0.0066H^3$	↶

MAX BEARING PRESSURE CALCULATIONS

Locate Resultant $$e = \frac{0.0066H^3}{0.1026H^2}$$

$$e = 0.064H$$

Meyerhoff's Pressure Distribution

Bearing Pressure $$= \frac{0.1026H^2}{0.7H - 2(0.064H)}$$

$$= 0.180\ H\ \text{ksf} \Rightarrow 180\ H\ \text{psf}$$

CHECK SLIDING

$$FS_{sliding} = \frac{0.1026H^2(\tan 35°)}{0.0199H^2} = 3.61 \quad \therefore \text{Safe}$$

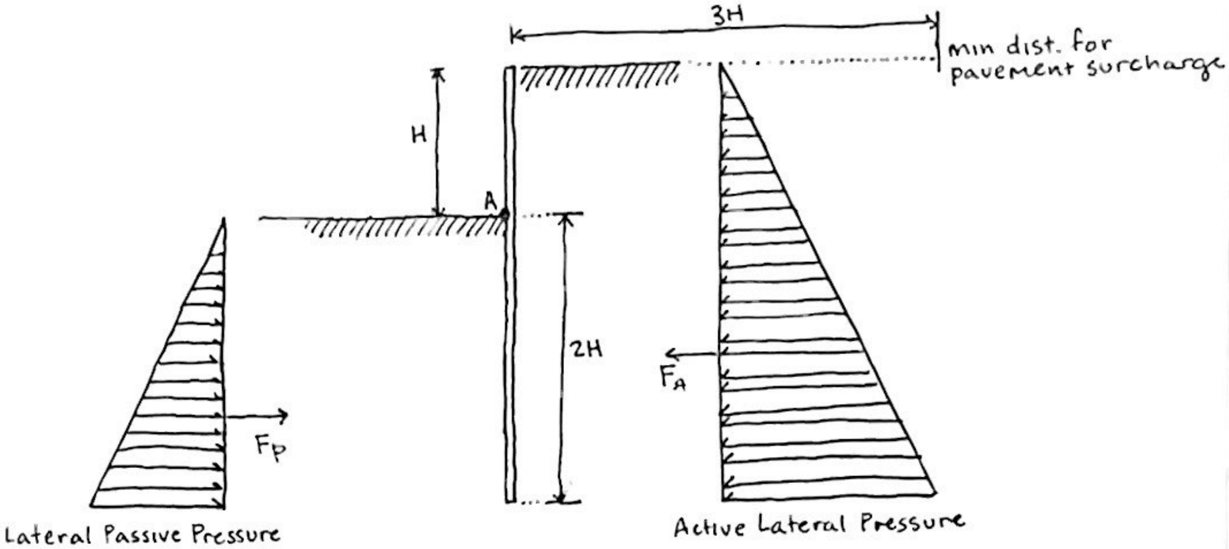
CHECK OVERTURNING

$$FS_{overturn} = \frac{0.0359H^3}{0.0066H^3} = 5.44 \quad \therefore \text{Safe}$$

★ Design will not have surcharge (pavement) with H (wall height) length from top of wall

SOLDIER PILE DESIGN

* Any surcharge (pavement) will be at a minimum of 3H from top of wall



SILTY SAND BACK/FRONT FILL

Unit Weight = 146.5 pcf
Friction Angle = 35°

RANKINE THEORY

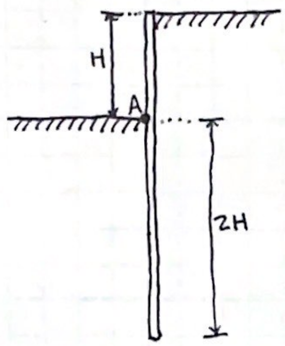
$K_a = \tan^2(45 - \frac{1}{2}\phi') = \tan^2(45 - \frac{1}{2}(35))$

$K_a = 0.271$

RESULTANT LATERAL FORCES

	Force	Arm (from A)	Moment
← Active	$0.271(3H)(146.5) = 119.1H$	H	$119.1H^2$ ↻
→ Passive	$0.271(2H)(146.5) = 79.4H$	$4H/3$	$105.9H^2$ ↺

* Wall will be stable with no surcharge because clockwise moment is greater than the clockwise moment



Active Earth Pressure at A
= Max Load experienced by Lagging

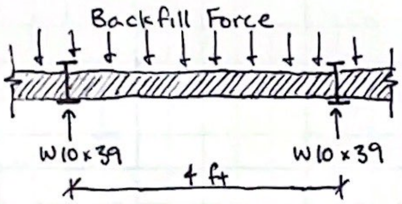
Rankine Theory

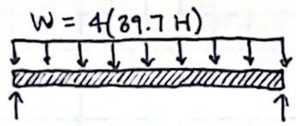
$K_a = \tan^2(45 - \frac{1}{2}\phi')$

$K_a = 0.271$

Silty Sand: $\phi' = 35°$
146.5 pcf

Resultant Force at A:
$= 0.271(H)(146.5) = 39.7H$ psf





6"×6"×4' Timber can carry max w = 1040 lb/ft

$(1040 \text{ lb/ft}) = (4 \text{ ft})(39.7H \text{ lb/ft}^2)$

max H = 6.55 ft

∴ Walls under 5.5', use stacked 6"×6"×4' spans for lagging. Can increase to 8"×8"×4'

Appendix C: Transportation Design

REV. 06-28-19: ADDED GENERAL NOTE NO. (10). REVISED DESIGN NOTE NO. (F).

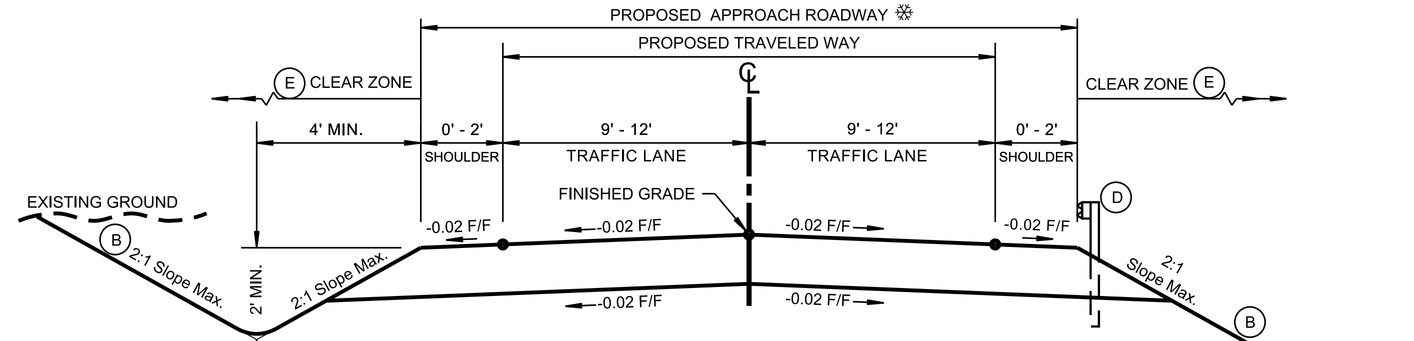
TABLE I MINIMUM DESIGN SPEEDS FOR LOW-VOLUME ROADS

TYPE OF TERRAIN	DESIGN SPEED (MPH) FOR SPECIFIED DESIGN ADT (VEH/DAY)			
	UNDER 50	50 TO 250	250 TO 400	400 TO 2,000
LEVEL	30	30	40	50
ROLLING	20 (J)	30	30	40
MOUNTAINOUS	20 (J)	20 (J)	20 (J)	30

TABLE II
DESIGN STANDARDS FOR LOW-VOLUME LOCAL ROADS AND STREETS (ADT ≤ 400)

		DESIGN SPEED (MPH) (J)	15	20	25	30	35	40
PROPOSED APPROACH ROADWAY (FEET)		RURAL LOCAL ROADS	18	18	18	18	18	18
		RECREATIONAL AND SCENIC ROADS	18	18	18	18	18	20
		INDUSTRIAL/COMMERCIAL ACCESS	20	20	22	24	24	24
		URBAN LOCAL ROADS LOW DEVELOPMENT DENSITY (2.0 OR LESS DWELLINGS/ACRE)	20	20	20	20	20	20
		URBAN LOCAL ROADS MEDIUM DEVELOPMENT DENSITY (2.1 TO 6 DWELLINGS/ACRE)	28	28	28	28	28	28
MINIMUM HORIZONTAL CURVE RADIUS (FEET) BY SUPERELEVATION RATE	ALL CLASSIFICATIONS (G)	NC -2%	50	107	198	333	510	762
		0%	47	99	181	300	454	667
		RC 2%	44	92	167	273	408	593
		3%	43	89	160	261	389	561
		4%	42	86	154	250	371	533
		5%	41	83	149	240	355	508
		6%	39	81	144	231	340	485
		7%	38	78	139	222	327	464
		8%	38	76	134	214	314	444
MINIMUM STOPPING SIGHT DISTANCE (FEET)		ADT 0 TO 100 (VEH/DAY)	65	90	115	135	170	215
		ADT 101 TO 400 (VEH/DAY)	65	95	125	165	205	250
MINIMUM " K " VALUES	CREST VERTICAL CURVE	ADT 0 TO 100 (VEH/DAY)	2	4	7	9	14	22
		ADT 101 TO 400 (VEH/DAY)	2	5	8	13	20	29
		SAG VERTICAL CURVE	10	17	26	37	49	64
MAXIMUM GRADE (%)	TYPE OF TERRAIN	LEVEL	9	8	7	7	7	7
		ROLLING	12	11	11	10	10	9
		MOUNTAINOUS	17	16	15	14	13	12

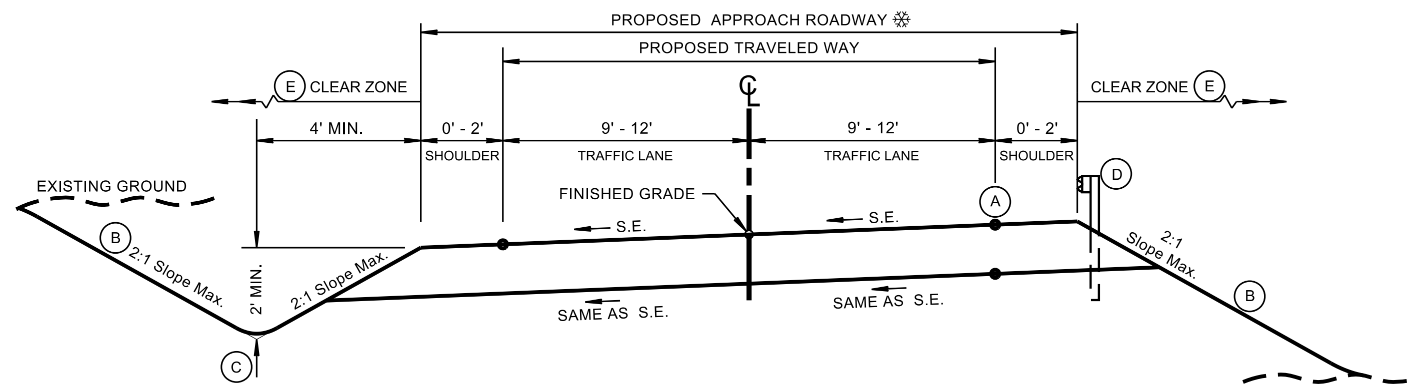
FOR SUPERELEVATION SEE STANDARD DRAWINGS RD11-SE SERIES (G)



TANGENT SECTION

LEGEND

❊ SEE TABLE II FOR WIDTHS



SUPERELEVATED SECTION (G)

BRIDGE DESIGN - MINIMUM CLEAR WIDTHS AND DESIGN LOADINGS (K) (L)

DESIGN ADT (VEH/DAY)	MINIMUM CLEAR (A) WIDTH (FEET) (I)	DESIGN LOADING (STRUCTURAL CAPACITY) FOR NEW AND RECONSTRUCTED BRIDGES	(F) DESIGN LOADING (STRUCTURAL CAPACITY) FOR EXISTING BRIDGES TO REMAIN IN PLACE (H)
0 TO 100	18	HL-93	H-15
101 TO 400	20	HL-93	H-15

DESIGN NOTES

(A) THE SLOPE OF THE SHOULDER AND THE ROADWAY PAVEMENT SHALL BE THE SAME IN ALL SITUATIONS.

(B) MAXIMUM 2(H):1(V) OR AS RECOMMENDED BY THE GEOTECHNICAL OFFICE. WHEN A 2(H):1(V) SLOPE IS USED, AND THE FILL HEIGHT EXCEEDS SIX FT., GUARDRAIL SHOULD BE CONSIDERED. WHERE RIGHT-OF-WAY IS NOT AN ISSUE, STANDARD DRAWING RD11-S-11 (CASE II) SLOPES MAY BE USED.

(C) SEE STANDARD DRAWING RD11-S-11A FOR ROUNDING OF ROADSIDE DITCH SLOPES.

(D) SEE STANDARD DRAWING S-PL-6 FOR TYPICAL GUARDRAIL PLACEMENT.

(E) SITE-SPECIFIC CONDITIONS AND ENGINEERING JUDGMENT OF THE DESIGNER SHOULD BE THE TWO PRIMARY DETERMINANTS OF THE APPROPRIATE CLEAR ZONE WIDTH FOR LOW-VOLUME LOCAL ROADS. AT LOCATIONS WHERE A CLEAR ZONE OF 6 FEET OR MORE IN WIDTH CAN BE PROVIDED AT LOW COST AND WITH MINIMUM SOCIAL/ENVIRONMENTAL IMPACT, SUCH CLEAR ZONE SHOULD BE CONSIDERED. WHERE PROVISION OF A CLEAR ZONE IS NOT PRACTICAL, NONE IS REQUIRED.

(F) FOR BRIDGE PROJECTS WHERE THE TOTAL APPROACH ROADWAY WIDTH (TRAVELED WAY PLUS SHOULDERS) IS SURFACED, THAT SURFACE WIDTH SHOULD BE CARRIED ACROSS THE STRUCTURE. THE WIDTH OF THE BRIDGE CANNOT BE LESS THAN THE PROPOSED ROADWAY WIDTH SELECTED FROM TABLE II. THE TOTAL APPROACH ROADWAY WIDTH CANNOT BE LESS THAN THE EXISTING ROADWAY WIDTH, AS DETERMINED ABOVE. HOWEVER, ON UNSURFACED RURAL ROADS, WITHOUT DEFINED TRAVELED WAY OR DEFINED SHOULDERS, THE WIDTH DETERMINED FROM TABLE 2 WILL SUFFICE.

(G) FOR THE DESIGN OF SUPERELEVATION TRANSITIONS, USE THE SUPERELEVATION DESIGN SPEED LISTED DIRECTLY ABOVE THE SELECTED MINIMUM HORIZONTAL CURVE RADIUS. FOR EXISTING ROADS WHERE SUPERELEVATION IS NOT PRESENT AND NO SITE-SPECIFIC SAFETY PROBLEM IS KNOWN, SUPERELEVATION MAY NOT BE NECESSARY. REMOVAL OF NORMAL CROWN BY SUPERELEVATING THE ENTIRE ROADWAY AT THE NORMAL CROSS SLOPE MAY BE USED UNLESS SUPERELEVATION IS NEEDED AS DETERMINED BY THE DESIGNER. THE DESIGNER SHOULD ASSESS THE PROJECT SITE AND USE ENGINEERING JUDGEMENT WHEN MAKING THIS DETERMINATION. FOR UNPAVED ROADS, REMOVAL OF NORMAL CROWN BY SUPERELEVATING THE ENTIRE ROADWAY AT THE NORMAL CROSS SLOPE MAY BE USED OR SUPERELEVATION MAY BE ELIMINATED.

(H) THESE STRUCTURES SHOULD BE ANALYZED INDIVIDUALLY, TAKING INTO CONSIDERATION THE CLEAR WIDTH PROVIDED, TRAFFIC VOLUMES, REMAINING LIFE OF THE STRUCTURE, PEDESTRIAN VOLUMES, SNOW STORAGE, DESIGN SPEED, ACCIDENT RECORD, AND OTHER PERTINENT FACTORS.

(I) CURB-TO-CURB OR BETWEEN RAILS, WHICHEVER IS THE LESSER.

(J) DESIGN SPEED SHOULD BE SELECTED BASED ON ACTUAL OR ANTICIPATED OPERATING SPEED AND CONDITIONS ON THE ROAD BEING DESIGNED.

(K) DESIGN LOADING: ALL NEW AND REHABILITATED BRIDGES SHALL BE DESIGNED FOR HL-93 LOADING.

(L) FOR NEW CONSTRUCTION OR RECONSTRUCTION PROJECTS: THE MINIMUM CLEAR WIDTH FOR NEW BRIDGES SHALL BE EQUAL TO THE FULL WIDTH OF THE APPROACH ROADWAY (CURB-TO-CURB OR FULL SHOULDER WIDTH AS APPLICABLE). WIDTH SHOULD BE AVAILABLE FOR FARM EQUIPMENT USE AS REQUIRED.

GENERAL NOTES

(1) THIS STANDARD DRAWING IS INTENDED TO BE USED FOR THE DESIGN OF LOW-VOLUME ROADWAYS CLASSIFIED AS LOCAL ROADS. FOR ADDITIONAL GUIDANCE NOT COVERED ON THIS SHEET, REFERENCE SHOULD BE MADE TO AASHTO "GUIDELINES FOR GEOMETRIC DESIGN OF LOW-VOLUME ROADS," (2019).

(2) PROJECTS WITH DESIGN SPEEDS GREATER THAN 40 MPH SHALL USE STANDARD DRAWING RD11-TS-1A.

(3) FOR INTERSECTION SIGHT DISTANCE, SEE SECTION 4.6 OF THE AASHTO "GUIDELINES FOR GEOMETRIC DESIGN OF LOW-VOLUME ROADS," (2019). FOR HIGHER ADT'S REFER TO THE RD11-SD-SERIES STANDARD DRAWINGS FOR ADDITIONAL GUIDANCE.

(4) IF NO ABOVE GROUND UTILITIES ARE INVOLVED, MINIMUM RIGHT-OF-WAY SHOULD BE THE TRAVELED WAY PLUS CLEAR ZONE.

(5) IF ABOVE GROUND UTILITIES ARE INVOLVED, MINIMUM RIGHT-OF-WAY SHOULD BE SUFFICIENT TO ACCOMMODATE THE UTILITIES OUTSIDE THE CLEAR ZONE.

(6) DESIGNER SHOULD CONSIDER ANY KNOWN SITE-SPECIFIC SAFETY PROBLEMS AND TYPICAL DAILY USE OF THE ROADWAY WHEN DETERMINING ROADWAY GEOMETRICS ON A CASE-BY-CASE BASIS. SITE-SPECIFIC SAFETY PROBLEMS MAY BE INDICATED BY CRASH DATA, SKID MARKS, ROADSIDE DAMAGE, SPEED DATA, OR CONCERNS RAISED BY LOCAL OFFICIALS, POLICE, OR LOCAL RESIDENTS.

(7) FOR EXISTING ROADS, CROSS-SECTION WIDTHS NEED NOT BE MODIFIED, EXCEPT IN THOSE CASES WHERE THERE IS KNOWN EVIDENCE OF A SITE-SPECIFIC SAFETY PROBLEM AS LONG AS THE MINIMUM CRITERIA, AS SHOWN IN TABLE I, IS MET.

(8) FOR THIS STANDARD THE FOLLOWING ARE THE POSSIBLE ROADWAY USES:

a. RURAL LOCAL ROADS SERVE A DUAL FUNCTION OF PROVIDING ACCESS TO ABUTTING PROPERTIES AS WELL AS PROVIDING THROUGH OR CONNECTING SERVICE BETWEEN OTHER LOCAL ROADS.
b. RECREATIONAL AND SCENIC ROADS SERVE SPECIALIZED LAND USES, INCLUDING PARKS, TOURIST ATTRACTIONS, AND RECREATION FACILITIES, SUCH AS CAMPSITES OR BOAT-LAUNCH RAMPS. WHEN AVAILABLE, PEAK-SEASON ADT SHOULD BE USED FOR DESIGN.
c. INDUSTRIAL OR COMMERCIAL ACCESS ROADS SERVE DEVELOPMENTS THAT MAY GENERATE A SIGNIFICANT PROPORTION OF TRUCK OR OTHER HEAVY VEHICLE TRAFFIC.
d. URBAN LOCAL ROADWAYS SERVE A DUAL FUNCTION OF PROVIDING ACCESS TO ABUTTING PROPERTIES AS WELL AS PROVIDING THROUGH OR CONNECTING SERVICE BETWEEN OTHER LOCAL ROADS.

(9) ROADWAY SURFACE TYPE SHOULD MATCH EXISTING SURFACE OR SHALL BE DETERMINED BY LOCAL GUIDELINES. WHEN EXISTING SURFACE IS ASPHALT, SEE DESIGN GUIDELINES FOR PAVEMENT DESIGN GUIDANCE.

(10) THE MINIMUM DESIRED SHOULDER WIDTH IS 2' FOR EACH SIDE OF ALL PROPOSED ROADWAYS.

▪ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED

STATE OF TENNESSEE
STANDARD DRAWING
DEPARTMENT OF TRANSPORTATION

DESIGN STANDARDS FOR LOW-VOLUME ROADS

01-01-2019 RD11-TS-1

NOT TO SCALE

LLP

REV. 2-5-16: UPDATE GENERAL NOTE ⑥.

GENERAL NOTES

Ⓐ THIS STANDARD DRAWING IS INTENDED TO BE USED FOR THE DESIGN OF LOW-VOLUME (CURRENT ADT (<= 400) ROADWAYS CLASSIFIED AS LOCAL ROADS. FOR ADDITIONAL GUIDANCE NOT COVERED ON THIS SHEET, REFERENCE SHOULD BE MADE TO AASHTO "GUIDELINES FOR GEOMETRIC DESIGN OF VERY LOW-VOLUME LOCAL ROADS (ADT (<= 400)," 2001.

Ⓑ PROJECT WITH DESIGN SPEEDS GREATER THAN 40 MPH SHALL USE STANDARD DRAWING RD01-TS-1.

Ⓒ FOR INTERSECTION SIGHT DISTANCE, SEE PAGES 40 TO 47 OF THE AASHTO "GUIDELINES FOR GEOMETRIC DESIGN OF VERY LOW-VOLUME LOCAL ROADS (ADT (<= 400)," 2001.

Ⓓ IF NO ABOVE GROUND UTILITIES ARE INVOLVED, MINIMUM RIGHT-OF-WAY SHOULD BE TRAVELWAY PLUS CLEAR ZONE.

Ⓔ IF ABOVE GROUND UTILITIES ARE INVOLVED, MINIMUM RIGHT-OF-WAY SHOULD BE SUFFICIENT TO ACCOMMODATE THE UTILITIES OUTSIDE THE CLEAR ZONE.

Ⓕ DESIGNER SHOULD CONSIDER ANY KNOWN SITE-SPECIFIC SAFETY PROBLEMS AND TYPICAL DAILY USE OF THE ROADWAY WHEN DETERMINING ROADWAY GEOMETRICS ON A CASE-BY-CASE BASIS. SITE-SPECIFIC SAFETY PROBLEMS MAY BE INDICATED BY CRASH DATA, SKID MARKS, ROADSIDE DAMAGE, SPEED DATA, OR CONCERNS RAISED BY LOCAL OFFICIALS POLICE OR LOCAL RESIDENTS.

Ⓖ FOR EXISTING ROADS, CROSS-SECTION WIDTHS NEED NOT BE MODIFIED, EXCEPT IN THOSE CASES WHERE THERE IS KNOWN EVIDENCE OF A SITE-SPECIFIC SAFETY PROBLEM AS LONG AS THE MINIMUM CRITERIA, AS SHOWN IN THE TABLE BELOW, IS MET.

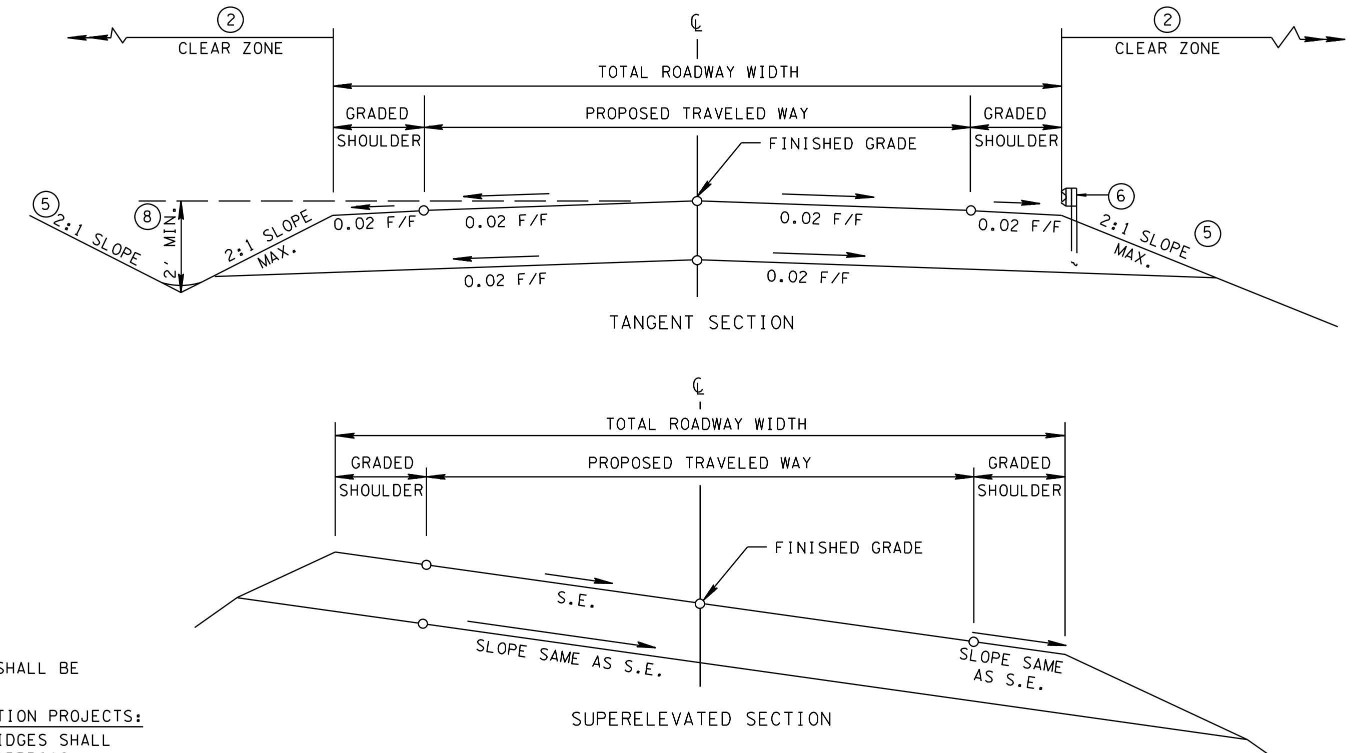
Ⓗ FOR THIS STANDARD THE FOLLOWING ARE THE POSSIBLE ROADWAY USES:

A. RURAL LOCAL ROADS SERVE A DUAL FUNCTION OF PROVIDING ACCESS TO ABUTTING PROPERTIES AS WELL AS PROVIDING THROUGH OR CONNECTING SERVICE BETWEEN OTHER LOCAL ROADS.
B. RECREATIONAL AND SCENIC ROADS SERVE SPECIALIZED LAND USES, INCLUDING PARKS, TOURIST ATTRACTIONS, AND RECREATION FACILITIES, SUCH AS CAMPSITE OR BOAT-LAUNCH RAMPS. WHEN AVAILABLE, PEAK-SEASON ADT SHOULD BE USED FOR DESIGN.
C. INDUSTRIAL OR COMMERCIAL ACCESS ROADS SERVE DEVELOPMENTS THAT MAY GENERATE A SIGNIFICANT PROPORTION OF TRUCK OR OTHER HEAVY VEHICLE TRAFFIC.
D. URBAN LOCAL ROADWAYS SERVE A DUAL FUNCTION OF PROVIDING ACCESS TO ABUTTING PROPERTIES AS WELL AS PROVIDING THROUGH OR CONNECTING SERVICE BETWEEN OTHER LOCAL ROADS.

Ⓘ ROADWAY SURFACE TYPE SHOULD MATCH EXISTING SURFACE OR SHALL BE DETERMINED BY LOCAL GUIDELINES. WHEN EXISTING SURFACE IS ASPHALT, SEE DESIGN GUIDELINES FOR PAVEMENT DESIGN GUIDANCE.

DESIGN LOADING:
ALL NEW AND REHABILITATED BRIDGES SHALL BE DESIGNED FOR HL-93 LOADING.

FOR NEW CONSTRUCTION OR RECONSTRUCTION PROJECTS:
THE MINIMUM CLEAR WIDTH FOR NEW BRIDGES SHALL BE EQUAL TO THE FULL WIDTH OF THE APPROACH ROADWAY (CURB-TO-CURB OR FULL SHOULDER WIDTH AS APPLICABLE).



TYPICAL CROSS-SECTIONS

TABLE 1

DESIGN STANDARDS FOR LOW-VOLUME LOCAL ROADS AND STREETS (ADT≤400)

			15	20	25	30	35	40
	DESIGN SPEED (MPH) ⑨		15	20	25	30	35	40
MINIMUM TOTAL ROADWAY WIDTH BY USE (FEET)	RURAL LOCAL ROADS		18	18	18	18	18	18
	RECREATIONAL AND SCENIC ROADS		18	18	18	18	18	20
	INDUSTRIAL/COMMERCIAL ACCESS		20	20	21	23	23	23
	URBAN LOCAL ROADS LOW DEVELOPMENT DENSITY (2.0 OR LESS DWELLINGS/ACRE)		20	20	20	20	20	20
	URBAN LOCAL ROADS MEDIUM DEVELOPMENT DENSITY (2.1 TO 6 DWELLINGS/ACRE)		28	28	28	28	28	28
MINIMUM HORIZONTAL CURVE RADIUS (FEET) BY SUPER ELEVATION RATE	ALL CLASSIFICATIONS ③	NC -2%	50	107	198	333	510	762
		0%	47	99	181	300	454	667
		RC 2%	44	92	167	273	408	593
		3%	43	89	160	261	389	561
		4%	42	86	154	250	371	533
		5%	41	83	149	240	355	508
		6%	39	81	144	231	340	485
		7%	38	78	139	222	327	464
		8%	38	76	134	214	314	444
MINIMUM STOPPING SIGHT DISTANCE (FEET)	ADT 0 TO 100 (VEH/DAY)		65	90	115	135	170	215
	ADT 101 TO 400 (VEH/DAY)		65	95	125	165	205	250
MINIMUM " K " VALUES	CREST VERTICAL CURVE	ADT 0 TO 100 (VEH/DAY)	2	4	7	9	14	22
		ADT 101 TO 400 (VEH/DAY)	2	5	8	13	20	29
	SAG VERTICAL CURVE		10	17	26	37	49	64
MAXIMUM GRADE (%)	TYPE OF TERRAIN	LEVEL	9	8	7	7	7	7
		ROLLING	12	11	11	10	10	9
		MOUNTAINOUS	17	16	15	14	13	12
SUPERELEVATION			SEE STANDARD DRAWING RD01-SE-2 AND RD01-SE-3 ③					

TABLE 2

MINIMUM CLEAR WIDTHS AND DESIGN LOADINGS FOR NEW AND RECONSTRUCTED BRIDGES

DESIGN ADT (VEH/DAY)	DESIGN LOADING (STRUCTURAL CAPACITY)	MINIMUM CLEAR WIDTH (FEET) ①
0 TO 100	HL-93	18
101 TO 400	HL-93	20

TABLE 3

MINIMUM CLEAR WIDTHS AND DESIGN LOADINGS ① FOR EXISTING BRIDGES TO REMAIN IN PLACE ④

DESIGN ADT (VEH/DAY)	DESIGN LOADING (STRUCTURAL CAPACITY)	MINIMUM CLEAR WIDTH (FEET) ⑦
0 TO 100	H-15	18
101 TO 400	H-15	20

FOOTNOTES

① FOR BRIDGE PROJECTS WHERE THE TOTAL APPROACH ROADWAY WIDTH (TRAVELED WAY PLUS SHOULDERS) IS SURFACED, THAT SURFACE WIDTH SHOULD BE CARRIED ACROSS THE STRUCTURE. THE WIDTH OF THE BRIDGE CANNOT BE LESS THAN THE PROPOSED ROADWAY WIDTH SELECTED FROM TABLE 1. THE TOTAL APPROACH ROADWAY WIDTH CANNOT BE LESS THAN THE EXISTING ROADWAY WIDTH, AS DETERMINED ABOVE, HOWEVER, ON UN SURFACED RURAL ROADS, WITHOUT DEFINED TRAVELED WAY OR DEFINED SHOULDERS, THE WIDTH DETERMINED FROM TABLE 1 WILL SUFFICE.

② SITE-SPECIFIC CONDITIONS AND ENGINEERING JUDGMENT OF THE DESIGNER SHOULD BE THE TWO PRIMARY DETERMINANTS OF THE APPROPRIATE CLEAR ZONE WIDTH FOR LOW-VOLUME LOCAL ROADS. AT LOCATIONS WHERE A CLEAR ZONE OF 6 FEET OR MORE IN WIDTH CAN BE PROVIDED AT LOW COST AND WITH MINIMUM SOCIAL/ENVIRONMENTAL IMPACT, SUCH CLEAR ZONE SHOULD BE CONSIDERED. WHERE PROVISION OF A CLEAR ZONE IS NOT PRACTICAL, NONE IS REQUIRED.

③ FOR THE DESIGN OF SUPER ELEVATION TRANSITIONS, USE THE SUPER ELEVATION DESIGN SPEED LISTED DIRECTLY ABOVE THE SELECTED MINIMUM HORIZONTAL CURVE RADIUS. FOR EXISTING ROADS WHERE SUPER ELEVATION IS NOT PRESENT AND NO SITE-SPECIFIC SAFETY PROBLEM IS KNOWN, SUPER ELEVATION MAY NOT BE NECESSARY. REMOVAL OF NORMAL CROWN BY SUPER ELEVATING THE ENTIRE ROADWAY AT THE NORMAL CROSS SLOPE MAY BE USED UNLESS SUPER ELEVATION IS NEEDED AS DETERMINED BY THE DESIGNER. THE DESIGNER SHOULD ASSESS THE PROJECT SITE AND USE ENGINEERING JUDGEMENT WHEN MAKING THIS DETERMINATION. FOR UNPAVED ROADS, REMOVAL OF NORMAL CROWN BY SUPER ELEVATING THE ENTIRE ROADWAY AT THE NORMAL CROSS SLOPE MAY BE USED OR SUPER ELEVATION MAY BE ELIMINATED.

④ THESE STRUCTURES SHOULD BE ANALYZED INDIVIDUALLY, TAKING INTO CONSIDERATION THE CLEAR WIDTH PROVIDED, TRAFFIC VOLUMES, REMAINING LIFE OF THE STRUCTURE, PEDESTRIAN VOLUMES, SNOW STORAGE, DESIGN SPEED, ACCIDENT RECORD, AND OTHER PERTINENT FACTORS.

⑤ MAXIMUM 2(H):1(V) OR AS RECOMMENDED BY THE GEOTECHNICAL OFFICE. WHEN A 2(H):1(V) SLOPE IS USED, AND THE FILL HEIGHT EXCEEDS SIX FEET, GUARDRAIL SHOULD BE CONSIDERED. WHERE RIGHT-OF-WAY IS NOT AN ISSUE, STANDARD DRAWING RD01-S-11 (CASE II) SLOPES MAY BE USED.

⑥ SEE GUARDRAIL STANDARD DRAWINGS (S-GR31, S-GRS, S-GRC-SERIES) FOR GUARDRAIL PLACEMENT. FOR LOW-VOLUME LOCAL ROAD BRIDGE REPLACEMENT PROJECTS, USE MINIMUM GUARDRAIL SHOWN ON STANDARD DRAWING S-PL-6. FOR ALL OTHER PROJECT REFERENCE SHOULD BE MADE TO THE AASHTO "ROADSIDE DESIGN GUIDE", 2011.

⑦ CURB-TO-CURB OR BETWEEN RAILS, WHICHEVER IS THE LESSER.

⑧ MINIMUM DITCH OR SWALE SHALL BE 2 FEET DEEP WITH 2(H):1(V) SIDE SLOPES. THIS V-DITCH OR SWALE SHALL BE USED UNLESS CONDITIONS NECESSITATE OTHERWISE (SUCH AS DISCHARGE IN DITCH OR UNDERMINING OF ROADWAY SURFACE).

⑨ DESIGN SPEED SHOULD BE SELECTED BASED ON ACTUAL OR ANTICIPATED OPERATING SPEED AND CONDITIONS ON THE ROAD BEING DESIGNED.

MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

DESIGN STANDARDS FOR LOW-VOLUME LOCAL ROADS (ADT ≤ 400)

3-15-07 RD01-TS-1A

Chelaque Co

Send

Questions Responses 24 Settings

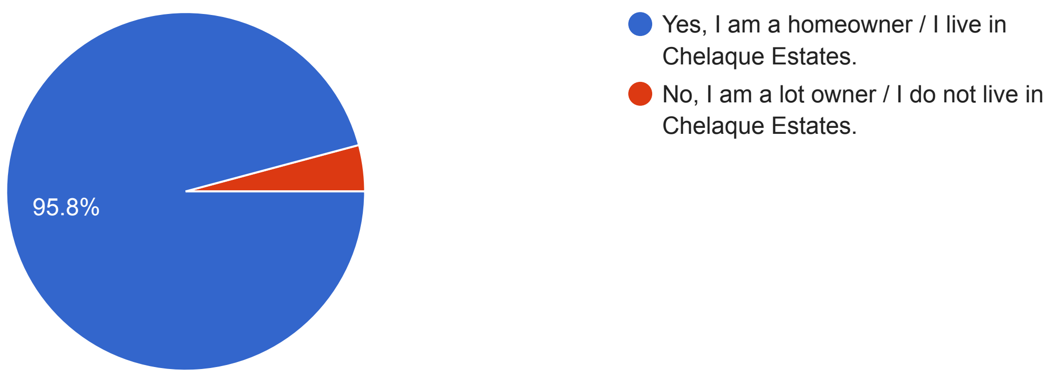
24 responses

Accepting responses

Summary Question Individual

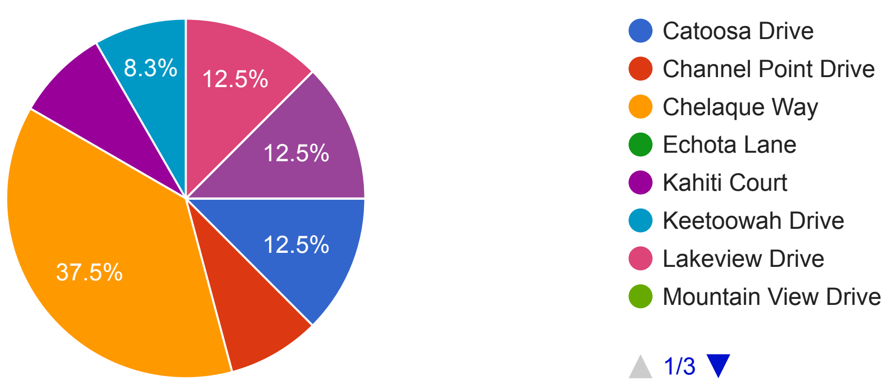
Do you currently reside in Chelaque Estates?

24 responses



What street is your lot/house on?

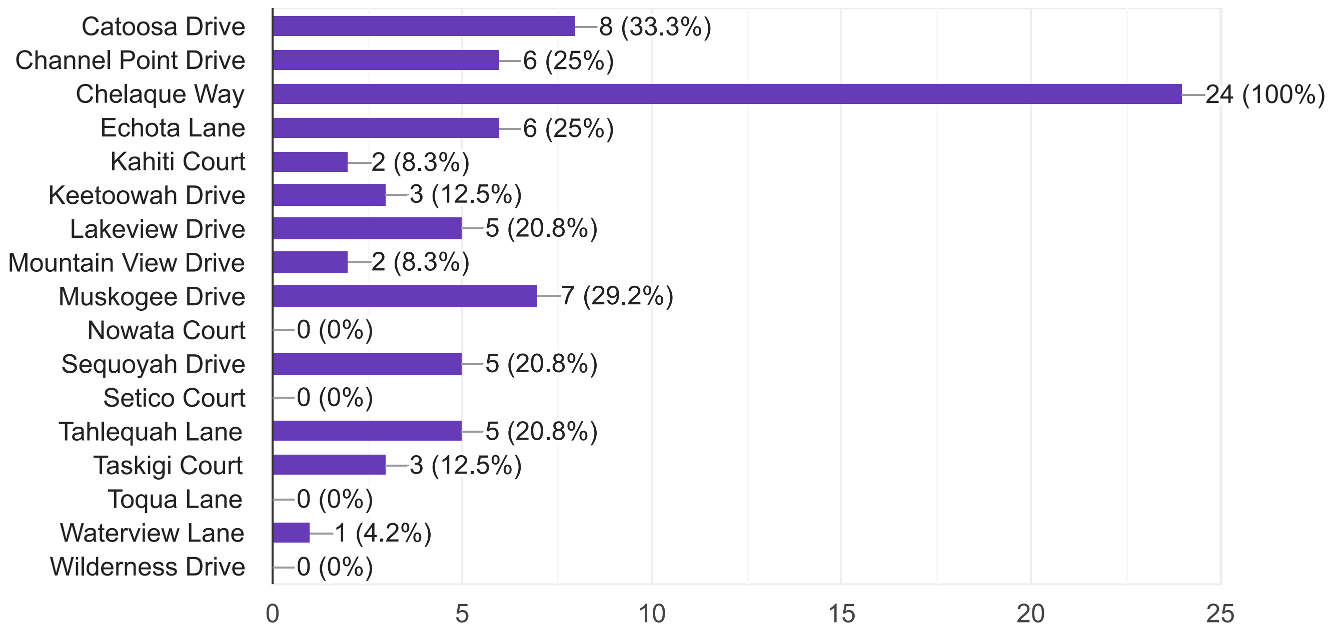
24 responses



What roads do you regularly drive or walk on within the community?

Copy

24 responses



What area(s) depicted on the map do you believe most urgently require intervention or repair? Are there any areas not depicted on the map that you would like to bring attention to? Please include any supporting information, if available. Some examples of problems include safety issues, damage to the road, and areas where water may flood or wash over the road. You also have the option to take pictures of the area and upload them in a following question, or send them to Jody Howells. You can describe the location of the area by the nearest street address, by GPS coordinates, or by the lot number.

24 responses

Lot 66/ road is so crumbled, one either hits the underneath of their car, or drives off the road to the left.

Chelaque Way; across from Lot 255 on Chelaque Way, curves without guard rails on Chelaque Way, leaving Chelaque before reaching Gate House.

Area #5 on your map is the main area for repair. Also, #6

Keetoowah has several areas

As I travel mostly Chelaque Way, my concern areas are on Chelaque way where it approaches the T on Sequoyah Drive. Area is on the right side of road before stop sign. Has been repaired and is in need of repair again. And of course, the section of road across from Ron Johnson's house, where new construction is. My concern about that site is why did it get so damaged? I understand construction vehicles on the road, but this damage seems unusually bad.

I rate the following points as high. 27,29,19,15,31,9

Any area on a curve should have a guard rail.

Please submit any photos of areas of roadway damage or safety issues that have not been described on the map, if available. If you're not able to submit the pictures here, please send them to Jody Howells at jchowells@hotmail.com

View folder

0 responses

No responses yet for this question.

Are there any areas on the roadways that feel unsafe to you as a pedestrian or driver? If so, please explain the location and nature of the safety concern. Some examples of safety concerns are a place where you have had a near-miss crash or a place where you can't see very well around a corner.

19 responses

None

Lot 110/ Trucks don’t stay in their lane.

Winter snow and ice on Chelaque Way when entering Chelaque just pass the trailer storage across from Weavers house, original owners Lot. 255. Caution when approaching when temperatures are below freezing.

The areas of safety concerns are on the blind corners of our one way roads, particularly Sequoyah Dr. and Chelaque Way near #5 on your map. If everyone is traveling the correct way, it isn't a real concern. The problem arises when someone drives the wrong way on these roads, which happens too often. Lately, it has been a way for some to avoid a bad road section, so they choose to go the wrong way. Since we live on Sequoyah, we've had many near misses on Sequoyah Dr., walking and driving, while coming around a blind corner to unexpectedly meet head-on with someone who is traveling the wrong way. Often, they are construction trucks or delivery trucks. Another area that is difficult is the upper end of Muscogee Dr. as it connects with Chelaque Way. It's difficult to see traffic from almost any direction at that intersection from Muscogee Dr. There are plants there that may need to be removed.

I have not run into any specific issues. Night driving the area might be different.

Have you had any experiences in which you felt unsafe due to your speed while approaching a turn or due to the speed of another driver? If so, where?

19 responses

No

Lot 110/ blind hill for drivers going too fast with pedestrians present.
Lot 146 thru Lot 145: trucks & cars fly around the turns, going in other lane.

Speed of other drivers and Commercial trucks seems to have increased in the past few years.

Again, some drivers drive way too fast on blind corners. I'm not sure what other measures we can take on our one-way roads other than the signage we already have. We've had mirrors installed in some two way roadways, but I'm not sure they are helpful or would be useful on our one-way roads at blind corners.

no

Most residents are aware of our roads and maintain safe speeds. Sometimes there are issues with construction workers and trucks mainly on Chelaque way coming down through the switch backs.

Same as above. Usually die to speed and trajectory of large construction vehicles.

What other concerns do you have regarding the roadways in Chelaque Estates? Please remember that our team is equipped to handle issues related to the fields of transportation, water, construction, and geotechnical (soil) engineering.

21 responses

Lot 90 & 91: road was repaired last year, already crumbling.

My concern is erosion. Too many times in the past the HOA has hired inexperienced and unlicensed contractors that have caused more damage than they've fixed. Often, they cut down large, healthy trees next to the roads without regard to the root systems under the roads that eventually decay from being killed and collapse the road. Also, the drainage along our roadways and some of the fixes have been highly ineffective or the fix was worse than the original problem.

Stabilize the deterioration

Though not well versed on the subject, my concern would be other areas where drainage may still be an issue. Seems drainage is a main concern in our road issues.

We have weight limits for trucks but we don't know where the weights came from or if they are correct for our roads. Would you have any suggestions for truck weight limits?

Main road is too rough in places.

What result do you want from the roadway assessment?

23 responses

Hoping our roads are as safe as possible for our community & those visiting.

Suggestions to stay ahead of repairs on roads in Chelaque.

I would like to see solid explanations of the issues we have with clearly designed ideas for addressing them. Well written explanations with diagrams and/or photos would help in long term planning.

Long term assessment and prioritize needed repairs.

Because of our limited financial resources, I would like to see, firstly, that the areas of current concern are addressed and professionally prioritized. Secondly, an assessment of where the professionals feel we could have future issues. I feel if these issues can be identified before any actual damage appears, and the problem corrected early, perhaps we would save some money.

Priority list for repairs. Suggestions to prevent further road damage. Proper road repair guidelines.

I believe the roads are being adequately maintained. I do think we should add protective railings in some areas and install a few "stop" or "yield" signs.

Reviewer #	Timestamp	Do you currently reside in Chelaque Estates?	What street is your lot/house on?	What roads do you regularly drive or walk on within the community?	What area(s) depicted on the map do you believe most urgently require intervention or repair? Are there any areas not depicted on the map that you would like to bring attention to? Please include any supporting information, if available. Some examples of problems include safety issues, damage to the road, and areas where water may flood or wash over the road. You also have the option to take pictures of the area and upload them in a following question, or send them to Jody Howells. You can describe the location of the area by the nearest street address, by GPS coordinates, or by the lot number.	Please submit any photos of areas of roadway damage or safety issues that have not been described on the map, if available. If you're not able to submit the pictures here, please send them to Jody Howells at jchowells@hotmail.com	Are there any areas on the roadways that feel unsafe to you as a pedestrian or driver? If so, please explain the location and nature of the safety concern. Some examples of safety concerns are a place where you have had a near-miss crash or a place where you can't see very well around a corner.	Have you had any experiences in which you felt unsafe due to your speed while approaching a turn or due to the speed of another driver? If so, where?	What other concerns do you have regarding the roadways in Chelaque Estates? Please remember that our team is equipped to handle issues related to the fields of transportation, water, construction, and geotechnical (soil) engineering.	What result do you want from the roadway assessment?
1	4/1/2022 17:51:13	Yes, I am a homeowner / I live in Chelaque Estates.	Sequoyah Drive	Catoosa Drive, Chelaque Way, Echota Lane, Lakeview Drive, Muskogee Drive, Sequoyah Drive, Tahlequah Lane, Taskigi Court	Not on the map, on Chelaque Way, in front of the pavilion, the area has cracking (alligatoring) and should be added. I would assume this heavily traveled area may have some issues with drainage going under the road.		On Chelaque Way, coming into the neighborhood and just before the intersection with Keetowah. Recently "repaired", this area is very uneven for the speed some people travel at that point. The jar of hitting that area and the undulation caused is alerting for many that are unaware of it.		I feel reflectors on the guardrails would be helpful during times of dense fog and nighttime travel.	First, thanks so much for your attention to this. Dr. J has been great to work with and I hope this project is a great educational experience for you and us. This examination of our roads and plan is a well needed step for our neighborhood. While this is great, the neighborhood has faltered in the implementation of such projects in the past because of a lack of experienced road engineering oversight to make sure the job is done correctly. As much as we need what you have stated, we also need a choice of several road engineers/contractors that can oversee that the project is done correctly. If this project is solely done by those living in the neighborhood, than we will again spend money on a project that will only have to be redone at an additional cost.
2	4/1/2022 18:04:23	Yes, I am a homeowner / I live in Chelaque Estates.	Channel Point Drive	Channel Point Drive, Chelaque Way, Muskogee Drive	It would be nice if the main road, which everyone uses, was resurfaced after drainage and shoulder issues were mitigated.		The big trees in front of the house that supports the buffalo bills force all traffic to the middle of the road. The mailbox at the green house makes me want to tend towards the median. The road in front of the new build is pretty bumpy but I think they are fixing that.	Yes Most of the blind curves on the main road.	Longevity. Roads are expensive and we need what we have to last as long as possible.	I have no preferred outcome.
3	4/1/2022 18:04:50	Yes, I am a homeowner / I live in Chelaque Estates.	Sequoyah Drive	Catoosa Drive, Channel Point Drive, Chelaque Way, Echota Lane, Lakeview Drive, Muskogee Drive, Sequoyah Drive, Taskigi Court	Area #5 on your map is the main area for repair. Also, #6		The areas of safety concerns are on the blind corners of our one way roads, particularly Sequoyah Dr. and Chelaque Way near #5 on your map. If everyone is traveling the correct way, it isn't a real concern. The problem arises when someone drives the wrong way on these roads, which happens too often. Lately, it has been a way for some to avoid a bad road section, so they choose to go the wrong way. Since we live on Sequoyah, we've had many near misses on Sequoyah Dr., walking and driving, while coming around a blind corner to unexpectedly meet head-on with someone who is traveling the wrong way. Often, they are construction trucks or delivery trucks. Another area that is difficult is the upper end of Muscogee Dr. as it connects with Chelaque Way. It's difficult to see traffic from almost any direction at that intersection from Muscogee Dr. There are plants there that may need to be removed.	Again, some drivers drive way too fast on blind corners. I'm not sure what other measures we can take on our one-way roads other than the signage we already have. We've had mirrors installed in some two way roadways, but I'm not sure they are helpful or would be useful on our one-way roads at blind corners.	My concern is erosion. Too many times in the past the HOA has hired inexperienced and unlicensed contractors that have caused more damage than they've fixed. Often, they cut down large, healthy trees next to the roads without regard to the root systems under the roads that eventually decay from being killed and collapse the road. Also, the drainage along our roadways and some of the fixes have been highly ineffective or the fix was worse than the original problem.	I would like to see solid explanations of the issues we have with clearly designed ideas for addressing them. Well written explanations with diagrams and/or photos would help in long term planning.
4	4/1/2022 18:35:30	Yes, I am a homeowner / I live in Chelaque Estates.	Catoosa Drive	Catoosa Drive, Chelaque Way	Chelaque Way; across from Lot 255 on Chelaque Way, curves without guard rails on Chelaque Way, leaving Chelaque before reaching Gate House.		Winter snow and ice on Chelaque Way when entering Chelaque just pass the trailer storage across from Weavers house, original owners Lot. 255. Caution when approaching when temperatures are below freezing.	Speed of other drivers and Commercial trucks seems to have increased in the past few years.		Suggestions to stay ahead of repairs on roads in Chelaque.
5	4/1/2022 23:47:51	Yes, I am a homeowner / I live in Chelaque Estates.	Keetoowah Drive	Chelaque Way, Keetoowah Drive	Near my home at 1151 Keetoowah Drive there are several potholes, eroding shoulders and uneven patches.		Proffitt Ridge Road, the county road that provides access to ,Chelaque, is more dangerous than any road in the community.	One must drive slowly and cautiously on all roads in Chelaque as there are many twists and turns in the roads.	The poor foundations of the roads make them subjects to erosion, weak shoulders and poor surfaces.	Please create a prioritized schedule for repairs and maintenance based on science and engineering principles, not "squeaky wheels" created by homeowners. Some of the secondary streets connected to Chelaque Way need to be analyzed for safety and structural concerns. Your assistance is much appreciated.
6	4/3/2022 10:26:31	Yes, I am a homeowner / I live in Chelaque Estates.	Catoosa Drive	Catoosa Drive, Chelaque Way	8		No	No	None	A plan for correction based on priority and cost
7	4/3/2022 15:44:13	Yes, I am a homeowner / I live in Chelaque Estates.	Lakeview Drive	Channel Point Drive, Chelaque Way, Echota Lane, Lakeview Drive, Mountain View Drive, Muskogee Drive	I rate the following points as high. 27,29,19,15,31,9			Most residents are aware of our roads and maintain safe speeds. Sometimes there are issues with construction workers and trucks mainly on Chelaque way coming down through the switch backs.	We have weight limits for trucks but we don't know where the weights came from or if they are correct for our roads. Would you have any suggestions for truck weight limits?	Priority list for repairs. Suggestions to prevent further road damage. Proper road repair guidelines.
8	4/3/2022 18:24:06	No, I am a lot owner / I do not live in Chelaque Estates.	Keetoowah Drive	Chelaque Way, Echota Lane, Keetoowah Drive, Waterview Lane	Keetoowah has several areas		I have not run into any specific issues. Night driving the area might be different.	no	Stabilize the deterioration	Long term assessment and prioritize needed repairs.
9	4/5/2022 17:24:52	Yes, I am a homeowner / I live in Chelaque Estates.	Channel Point Drive	Channel Point Drive, Chelaque Way, Muskogee Drive	Any area on a curve should have a guard rail.					I believe the roads are being adequately maintained. I do think we should add protective railings in some areas and install a few "stop" or "yield" signs.
10	4/8/2022 11:57:21	Yes, I am a homeowner / I live in Chelaque Estates.	Chelaque Way	Chelaque Way, Echota Lane, Sequoyah Drive, Tahlequah Lane	I am concerned that the latest tree cutting will cause erosion problems on some of the steeper slopes and safety issues on at least one curve. The area that I'm most concerned about is just below the Susan and Gary Siemsen residence on Chelaque Way (where lots 147 & 148 meet.) Driving in here late at night, especially in the rain, makes this corner hazardous because the trees are no longer there to give a visual and there's nothing to stop a sliding vehicle going downhill or around the corner. There is little shoulder in the event that an oncoming vehicle cuts the corner. The road is now totally exposed to the elements with no protection from snow or freezing rain. A guardrail with reflectors would really help.		Yes, per a prior question, just down from the Susan and Gary Siemsen residence on Chelaque Way. I have marked it on the map with an explanation.	Mostly on the three top curves on Chelaque Way between the Ison and England residences. (Marked on map.)	Questions--pros-cons for both please: 1) What is the effect of a tree canopy on our roads? 2) What is the effect of direct sun on our roads?	I am a big fan of planning for the future. We need to have a comprehensive plan for dealing with our roads, with a qualified committee and a solid roadmap to our future. This report will be a huge help. Thank you all for your hard work and help.
11	4/8/2022 19:53:04	Yes, I am a homeowner / I liv	Catoosa Drive	Catoosa Drive, Chelaque Way	Main road needs new pavement.			No	Main road is too rough in places.	Pave main road.
12	4/11/2022 9:47:21	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way, Echota Lane	Reflective markers on some curves on Chelaque Way for fog reasons and night time driving should be installed		On curves coming down the mountain on Chelaque Way. I live on Chelaque and vehicles greatly exceed the speed limit	Yes, top of the mountain approaching the downhill portion of Chelaque	Some crumbling edges of roadways	Fog and night time reflectors. Speed control, accountability by residents or speed bumps
13	4/12/2022 1:36:57	Yes, I am a homeowner / I liv	Lakeview Drive	Channel Point Drive, Chelaque Way, Lakeview D	1. Road repair on Chelaque way near Keetowah intersection. Patch is raised higher than road su		Lower portions of Keetowah are in bad shape. Large construction vehicles cross the center line in many of the tight curves in the neighborhood. Steep grade and near powerlines on Chelaque way.	Same as above. Usually die to speed and trajectory of large construction vehicles.	Road wear and tear due to very heavy construction vehicles constantly entering and exiting the neighborhood.	Better overall roads for the community

14	4/12/2022 9:10:22	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way, Tahlequah Lane	Team UT, since I was part of the initial road review, the current map represents the areas of my c		The upper half of Chelaque Way (from the gate down the hill for approximately 1 mile) has several hairpin turns which walkers and drivers need to be alert.	No.	Our roads are and should be considered by the Community as a critical asset to Chelaque Estates. Not only the upkeep and maintenance are important for safe travel but home values to be maintained or enhanced. Treating the source of road issues and the root cause will be paramount for in how the CHOA spends it's time and money on these critical road needs.	The outcomes I believe will serve the Community the most are two-fold. One, identification and data supported conformation of the main root cause and effect of "agents" that attack our roads. Second, is a template/roadmap of how to plan the time wise repairs necessary to keep on roads safe and sound. This template/roadmap can be the basis for how the community invests in a 3-5 year repair cycle and the cost range associated with plan execution. This will be critical in my estimation on setting community fiscal expectations and take the whack-a-mole approach out of the equation. Thank you for your work on this project!
15	4/12/2022 14:41:26	Yes, I am a homeowner / I liv	Kahiti Court	Catoosa Drive, Chelaque Way, Kahiti Court, Kee	The situation at Point 3!!!					Thanks for coming out and for asking our opinion.
16	4/14/2022 18:59:45	Yes, I am a homeowner / I liv	Lakeview Drive	Channel Point Drive, Chelaque Way, Lakeview D	I did not see any mention of some roadway damage on Lakeview at the intersection with Channel		Point or the depression on Muskogee Dr right after coming off Chelaque Way		My main worry is water damaging roadways	
17	4/16/2022 20:51:03	Yes, I am a homeowner / I liv	Kahiti Court	Catoosa Drive, Chelaque Way, Kahiti Court	I have been told most areas with back fill used to construct roads are the areas failing first. Also		Many residents, visitors, and contractors do not drive within the lane. Many contractors are in hurry and drive too fast. Safety concerns driving Chelaque is an increasing issue as more homes are build and more heavily used. Only one way into community and out of community.	Steep grade on Chelaque down the mountain. Steep grade on Muskogee hard to see if car is coming if you need to turn right while heading up Muskogee. Most sharp curves where a large vehicle or someone driving too fast will come over in my lane.	Concern on construction of roads, if all water problems have been corrected, update rules our community should enforce with contractors. Also major concern how they handle snow and ice. Need to be more proactive with salt, preps and removal.	Long term planning of costs to maintain road, general summary of current road conditions with potential problems for major future repairs projection. A long term plan where road repair and improvement is sustainable. Use our budget optimally.
18	4/19/2022 15:16:27	Yes, I am a homeowner / I liv	Chelaque Way	Catoosa Drive, Chelaque Way, Sequoyah Drive,	Lot 66/ road is so crumbled, one either hits the underneath of their car, or drives off the road to the left.		**Lot 110/ Trucks don't stay in their lane.**	**Lot 110/ blind hill for drivers going too fast with pedestrians present.** **Lot 146 thru Lot 145: trucks & cars fly around the turns, going in other lane.**	**Lot 90 & 91: road was repaired last year, already crumbling.**	Hoping our roads are as safe as possible for our community & those visiting.
19	4/19/2022 15:49:07	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way, Tahlequah Lane	Water erosion of roads needs to be addressed in several areas - Sequoyah (near lot 82 & 83), Tahlequah have several areas where ditches are not deep enough to keep water from going under the road; and large runoffs at top of Chelaque Way and areas of Keetoowah.		Where Muskogee joins Chelaque Way can be dangerous. Some drivers have a hard time stopping on the hill intersecting with Chelaque Way and the visibility to traffic coming up Chelaque is not that good.	Not really	**Some dips in Chelaque that have been repaired are starting to dip again. The repair made on Chelaque Way around P1L90, within the last couple of years, is already starting to dip again. Don't believe we should be making these road repairs without proper surveys of ground and believe resurfacing to help strengthen the roads is going to be necessary in the near future.**	Road repair plan that addresses drainage issues, wear issues and resurfacing that board can and will follow.
20	4/19/2022 17:11:59	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way	Point 4 and 5		Because of recent tree removal there need to be more guardrails		East chelaque way near new build	A plan to fix the roads and a plan to maintain them into the future
21	4/19/2022 18:02:02	Yes, I am a homeowner / I liv	Sequoyah Drive	Chelaque Way, Sequoyah Drive, Taskigi Court	As I travel mostly Chelaque Way, my concern areas are on Chelaque way where it approaches the T on Sequoyah Drive. Area is on the right side of road before stop sign. Has been repaired and is in need of repair again. And of course, the section of road across from Ron Johnson's house, where new construction is. My concern about that site is why did it get so damaged? I understand construction vehicles on the road, but this damage seems unusually bad.		None	No	Though not well versed on the subject, my concern would be other areas where drainage may still be an issue. Seems drainage is a main concern in our road issues.	Because of our limited financial resources, I would like to see, firstly, that the areas of current concern are addressed and professionally prioritized. Secondly, an assessment of where the professionals feel we could have future issues. I feel if these issues can be identified before any actual damage appears, and the problem corrected early, perhaps we would save some money.
22	4/19/2022 18:33:47	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way	Since I live near gate, I see only a little road on regular basis		All roads need painted yellow and white lines and I also believe rumble grooves in the center to alert drivers they are crossing center.	I was actually hit head-on while riding my motorcycle a few years back 1/8 mile inside our gate by a contractor who was distracted. Totalled my bike and caused me surgery and rehab. I believe rumble grooves in the center of all our roads would have prevented that as it would have alerted him before he took my complete lane. Also at our address at 171 Chelaque Way, we have had to dive for ditch several times while doing clean up due to people driving 50+mph out of Chelaque.	They are too narrow IMHO in many places but we are probably stuck with what the original contractor stuck us with.	Safer roads. Roads that will last another 30+years
23	4/21/2022 18:28:10	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way	i have no input most travel in and out on Chelaque Way.		no input	only have issues on some turns if cars or large trucks are approaching. I just slow down and allow the traffic to clear the turn. Some guard rails are so close to the road makes you need more turn room to stay away from the guard rail.	Concerned about one way in and only one way out.	Suggestions on how to improve and maintain the roads with something we can do yearly to protect our roads.
24	4/26/2022 14:08:29	Yes, I am a homeowner / I liv	Chelaque Way	Chelaque Way	Not qualified to rank.		None	None	**Possible loss of roadway due to easement erosion on bend 100 yds down hill from 184 Chelaque Way.**	Useable report which will guide Chelaque Board members to spent assessment $'s wisely.

Manual on Uniform Traffic Control Devices (MUTCD)

2009 Edition Chapter 2C. Warning Signs And Object Markers

Section 2C.01 Function of Warning Signs

Support:
01 Warning signs call attention to unexpected conditions on or adjacent to a highway, street, or private roads open to public travel and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations.

Section 2C.02 Application of Warning Signs

Standard:
01 **The use of warning signs shall be based on an engineering study or on engineering judgment.**

Guidance:
02 *The use of warning signs should be kept to a minimum as the unnecessary use of warning signs tends to breed disrespect for all signs. In situations where the condition or activity is seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist.*

Option:
03 Consistent with the provisions of Chapter 2L, changeable message signs may be used to display a warning message.

04 Consistent with the provisions of Chapter 4L, a Warning Beacon may be used in combination with a standard warning sign.

Support:
05 The categories of warning signs are shown in Table 2C-1.

Table 2C-1. Categories of Warning Signs and Plaques

Category	Group	Section	Signs or Plaques	Sign Designations
Roadway Related	Changes in Horizontal Alignment	2C.07	Turn, Curve, Reverse Turn, Reverse Curve, Winding Road, Hairpin Curve, 270-Degree Curve	W1-1,2,3,4,5,11,15
		2C.08	Advisory Speed	W13-1P
		2C.09	Chevron Alignment	W1-8
		2C.10	Combination Horizontal Alignment/Advisory Speed	W1-1a,2a
		2C.11	Combination Horizontal Alignment/Intersection	W1-10,10a,10b,10c,10d
		2C.12	Large Arrow (one direction)	W1-6
		2C.13	Truck Rollover	W1-13
		2C.14	Advisory Exit or Ramp Speed	W13-2,3
		2C.15	Combination Horizontal Alignment/Advisory Exit or Ramp Speed	W13-6,7

06 Warning signs provided in this Manual cover most of the conditions that are likely to be encountered. Additional warning signs for low-volume roads (as defined in Section 5A.01), temporary traffic control zones, school areas, grade crossings, and bicycle facilities are discussed in Parts 5 through 10, respectively.

07 Section 1A.09 contains information regarding the assistance that is available to jurisdictions that do not have engineers on their staffs who are trained and/or experienced in traffic control devices.

Section 2C.03 Design of Warning Signs

Standard:

01 **Except as provided in Paragraph 2 or unless specifically designated otherwise, all warning signs shall be diamond-shaped (square with one diagonal vertical) with a black legend and border on a yellow background. Warning signs shall be designed in accordance with the sizes, shapes, colors, and legends contained in the "Standard Highway Signs and Markings" book (see Section 1A.11).**

Option:

02 A warning sign that is larger than the size shown in the Oversized column in Table 2C-2 for that particular sign may be diamond-shaped or may be rectangular or square in shape.

Table 2C-2. Warning Sign and Plaque Sizes

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
Horizontal Alignment	W1-1,2,3,4,5	2C.07	30 x 30*	36 x 36	36 x 36	36 x 36	—	48 x 48
Combination Horizontal Alignment/Advisory Speed	W1-1a,2a	2C.10	36 x 36	36 x 36	48 x 48	48 x 48	—	48 x 48
One-Direction Large Arrow	W1-6	2C.12	48 x 24	48 x 24	60 x 30	60 x 30	—	60 x 30
Two-Direction Large Arrow	W1-7	2C.47	48 x 24	48 x 24	—	—	—	60 x 30
Chevron Alignment	W1-8	2C.09	18 x 24	18 x 24	30 x 36	36 x 48	—	24 x 30
Combination Horizontal Alignment/Intersection	W1-10,10a, 10b,10c,10d,10e	2C.11	36 x 36	36 x 36	36 x 36	48 x 48	—	—
Hairpin Curve	W1-11	2C.07	30 x 30	30 x 30	36 x 36	48 x 48	—	48 x 48
Truck Rollover	W1-13	2C.13	36 x 36	36 x 36	36 x 36	48 x 48	—	36 x 36
270-degree Loop	W1-15	2C.07	30 x 30	30 x 30	36 x 36	48 x 48	—	48 x 48
Intersection Warning	W2-1,2,3,4,5,6,7,8	2C.46	30 x 30	30 x 30	36 x 36	—	24 x 24	48 x 48
Advanced Traffic Control	W3-1,2,3	2C.36	30 x 30	30 x 30	48 x 48	48 x 48	30 x 30	—
Be Prepared to Stop	W3-4	2C.36	36 x 36	36 x 36	48 x 48	48 x 48	30 x 30	—
Reduced Speed Limit Ahead	W3-5	2C.38	36 x 36	36 x 36	48 x 48	48 x 48	—	—
XX MPH Speed Zone Ahead	W3-5a	2C.38	36 x 36	36 x 36	48 x 48	48 x 48	—	—
Draw Bridge	W3-6	2C.39	36 x 36	36 x 36	48 x 48	—	—	60 x 60
Ramp Meter Ahead	W3-7	2C.37	36 x 36	36 x 36	—	—	—	—

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
No Shoulder	W8-23	2C.31	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Shoulder Ends	W8-25	2C.31	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Left (Right) Lane Ends	W9-1	2C.42	36 x 36	36 x 36	36 x 36	48 x 48	30 x 30*	48 x 48
Lane Ends Merge Left (Right)	W9-2	2C.42	36 x 36	36 x 36	36 x 36	48 x 48	30 x 30*	48 x 48
Right (Left) Lane Exit Only Ahead	W9-7	2C.43	132 x 72	132 x 72	132 x 72	132 x 72	—	—
Bicycle	W11-1	2C.49	30 x 30	30 x 30	36 x 36	—	24 x 24*	48 x 48
Pedestrian	W11-2	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Large Animals	W11-3,4,16,17, 18,19,20,21,22	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Farm Vehicle	W11-5,5a	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Snowmobile	W11-6	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Equestrian	W11-7	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Emergency Vehicle	W11-8	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Handicapped	W11-9	2C.50	30 x 30*	36 x 36	36 x 36	—	—	48 x 48
Truck	W11-10	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Golf Cart	W11-11	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Emergency Signal Ahead (plaque)	W11-12P	2C.49	36 x 30	36 x 30	36 x 30	—	—	—
Horse-Drawn Vehicle	W11-14	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Bicycle / Pedestrian	W11-15	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Trail Crossing	W11-15a	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Trail X-ing (plaque)	W11-15P	2C.49	24 x 18	24 x 18	30 x 24	—	—	36 x 30
Double Arrow	W12-1	2C.25	30 x 30*	36 x 36	36 x 36	—	—	—
Low Clearance (with arrows)	W12-2	2C.27	36 x 36	36 x 36	48 x 48	48 x 48	30 x 30*	—
Low Clearance	W12-2a	2C.27	78 x 24	78 x 24	—	—	—	—
Advisory Speed (plaque)	W13-1P	2C.08	18 x 18	18 x 18	24 x 24	30 x 30	—	30 x 30
Advisory Exit or Ramp Speed	W13-2,3	2C.14	24 x 30	24 x 30	36 x 48	36 x 48	—	48 x 60

Size of Warning Sign	Size of Supplemental Plaque			
	Rectangular			Square
	1 Line	2 Lines	Arrow	
24 x 24	24 x 12	24 x 18	24 x 12	18 x 18
30 x 30				
	1 Line	2 Lines	Arrow	
36 x 36	30 x18	30 x 24	30 x 18	24 x 24
48 x 48				

Notes:

1. Larger supplemental plaques may be used when appropriate
2. Dimensions in inches are shown as width x height

Option:

05 If a diamond-shaped warning sign is placed on the left-hand side of a multi-lane roadway to supplement the installation of the same warning sign on the right-hand side of the roadway, the minimum size identified in the Single Lane column in Table 2C-2 may be used.

06 Signs and plaques larger than those shown in Tables 2C-2 and 2C-3 may be used (see Section 2A.11).

Guidance:

07 *The minimum size for all diamond-shaped warning signs facing traffic on exit and entrance ramps should be the size identified in Table 2C-2 for the mainline roadway classification (Expressway or Freeway). If a minimum size is not provided in the Freeway Column, the Expressway size should be used. If a minimum size is not provided in the Freeway or the Expressway Column, the Oversized size should be used.*

Section 2C.05 Placement of Warning Signs

Support:

01 For information on placement of warning signs, see Sections 2A.16 to 2A.21.

02 The time needed for detection, recognition, decision, and reaction is called the Perception-Response Time (PRT). Table 2C-4 is provided as an aid for determining warning sign location. The distances shown in Table 2C-4 can be adjusted for roadway features, other signing, and to improve visibility.

Table 2C-4. Guidelines for Advance Placement of Warning Signs

Posted or 85th-Percentile Speed	Advance Placement Distance[1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0[3]	10[4]	20[4]	30[4]	40[4]	50[4]	60[4]	70[4]
20 mph	225 ft	100 ft[6]	N/A[5]	—	—	—	—	—	—
25 mph	325 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
30 mph	460 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
35 mph	565 ft	100 ft[6]	N/A[5]	N/A[5]	N/A[5]	—	—	—	—
40 mph	670 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—	—
45 mph	775 ft	175 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—
50 mph	885 ft	250 ft	200 ft	175 ft	125 ft	100 ft[6]	—	—	—
55 mph	990 ft	325 ft	275 ft	225 ft	200 ft	125 ft	N/A[5]	—	—

Posted or 85th-Percentile Speed	Advance Placement Distance[1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0[3]	10[4]	20[4]	30[4]	40[4]	50[4]	60[4]	70[4]
60 mph	1,100 ft	400 ft	350 ft	325 ft	275 ft	200 ft	100 ft[6]	—	—
65 mph	1,200 ft	475 ft	450 ft	400 ft	350 ft	275 ft	200 ft	100 ft[6]	—
70 mph	1,250 ft	550 ft	525 ft	500 ft	450 ft	375 ft	275 ft	150 ft	—
75 mph	1,350 ft	650 ft	625 ft	600 ft	550 ft	475 ft	375 ft	250 ft	100 ft[6]

1. The distances are adjusted for a sign legibility distance of 180 feet for Condition A. The distances for Condition B have been adjusted for a sign legibility distance of 250 feet, which is appropriate for an alignment warning symbol sign. For Conditions A and B, warning signs with less than 6-inch legend or more than four words, a minimum of 100 feet should be added to the advance placement distance to provide adequate legibility of the warning sign.
2. Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are determined by providing the driver a PRT of 14.0 to 14.5 seconds for vehicle maneuvers (2005 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E) minus the legibility distance of 180 feet for the appropriate sign.
3. Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2005 AASHTO Policy, Exhibit 3-1, Stopping Sight Distance, providing a PRT of 2.5 seconds, a deceleration rate of 11.2 feet/second2, minus the sign legibility distance of 180 feet.
4. Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distance is determined by providing a 2.5 second PRT, a vehicle deceleration rate of 10 feet/second^2, minus the sign legibility distance of 250 feet.
5. No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing. An alignment warning sign may be placed anywhere from the point of curvature up to 100 feet in advance of the curve. However, the alignment warning sign should be installed in advance of the curve and at least 100 feet from any other signs.
6. The minimum advance placement distance is listed as 100 feet to provide adequate spacing between signs.

∴ Sign at 100 ft before turn

Guidance:

03 *Warning signs should be placed so that they provide an adequate PRT. The distances contained in Table 2C-4 are for guidance purposes and should be applied with engineering judgment. Warning signs should not be placed too far in advance of the condition, such that drivers might tend to forget the warning because of other driving distractions, especially in urban areas.*

04 *Minimum spacing between warning signs with different messages should be based on the estimated PRT for driver comprehension of and reaction to the second sign.*

05 *The effectiveness of the placement of warning signs should be periodically evaluated under both day and night conditions.*

Option:

06 Warning signs that advise road users about conditions that are not related to a specific location, such as Deer Crossing or SOFT SHOULDER, may be installed in an appropriate location, based on engineering judgment, since they are not covered in Table 2C-4.

Section 2C.06 Horizontal Alignment Warning Signs

Support:

01 A variety of horizontal alignment warning signs (see Figure 2C-1), pavement markings (see Chapter 3B), and delineation (see Chapter 3F) can be used to advise motorists of a change in the roadway alignment. Uniform application of these traffic control devices with respect to the amount of change in the roadway alignment conveys a consistent message establishing driver expectancy and promoting effective roadway operations. The design and application of horizontal alignment warning signs to meet those requirements are addressed in Sections 2C.06 through 2C.15.

Figure 2C-1 Horizontal Alignment Signs and Plaques

Standard:

02 **In advance of horizontal curves on freeways, on expressways, and on roadways with more than 1,000 AADT that are functionally classified as arterials or collectors, horizontal alignment warning signs shall be used in accordance with Table 2C-5 based on the speed differential between the roadway's posted or statutory speed limit or 85th-percentile speed, whichever is higher, or the prevailing speed on the approach to the curve, and the horizontal curve's advisory speed.**

results in excessive signage, not recommended

Table 2C-5. Horizontal Alignment Sign Selection

Type of Horizontal Alignment Sign	Difference Between Speed Limit and Advisory Speed				
	5 mph	**10 mph**	**15 mph**	**20 mph**	**25 mph or more**
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W1-10) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

Note: Required means that the sign and/or plaque shall be used, recommended means that the sign and/or plaque should be used, and optional means that the sign and/or plaque may be used.

See Section 2C.06 for roadways with less than 1,000 AADT.

∴ prioritize chevrons for visibility... driver already knows to go slow / change in alignment has already occurred before most turns

Option:

03 Horizontal Alignment Warning signs may also be used on other roadways or on arterial and collector roadways with less than 1,000 AADT based on engineering judgment.

Section 2C.07 Horizontal Alignment Signs (W1-1 through W1-5, W1-11, W1-15)

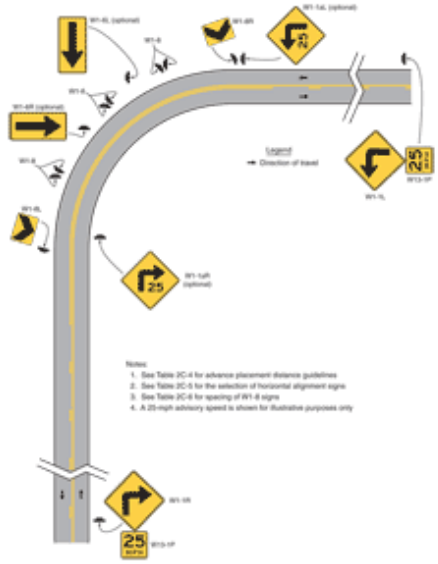
Standard:

01 **If Table 2C-5 indicates that a horizontal alignment sign (see Figure 2C-1) is required, recommended, or allowed, the sign installed in advance of the curve shall be a Curve (W1-2) sign unless a different sign is recommended or allowed by the provisions of this Section.**

02 **A Turn (W1-1) sign shall be used instead of a Curve sign in advance of curves that have advisory speeds of 30 mph or less (see Figure 2C-2).**

Figure 2C-2 Example of Warning Signs for a Turn

Figure 2C-2. Example of Warning Signs for a Turn



Guidance:

03 *Where there are two changes in roadway alignment in opposite directions that are separated by a tangent distance of less than 600 feet, the Reverse Turn (W1-3) sign should be used instead of multiple Turn (W1-1) signs and the Reverse Curve (W1-4) sign should be used instead of multiple Curve (W1-2) signs.*

Option:

04 A Winding Road (W1-5) sign may be used instead of multiple Turn (W1-1) or Curve (W1-2) signs where there are three or more changes in roadway alignment each separated by a tangent distance of less than 600 feet.

05 A NEXT XX MILES (W7-3aP) supplemental distance plaque (see Section 2C.55) may be installed below the Winding Road sign where continuous roadway curves exist for a specific distance.

06 If the curve has a change in horizontal alignment of 135 degrees or more, the Hairpin Curve (W1-11) sign may be used instead of a Curve or Turn sign.

07 If the curve has a change of direction of approximately 270 degrees, such as on a cloverleaf interchange ramp, the 270-degree Loop (W1-15) sign may be used instead of a Curve or Turn sign.

Guidance:

08 *When the Hairpin Curve sign or the 270-degree Loop sign is installed, either a One-Direction Large Arrow (W1-6) sign or Chevron Alignment (W1-8) signs should be installed on the outside of the turn or curve.*

Section 2C.08 Advisory Speed Plaque (W13-1P)

Option:

01 The Advisory Speed (W13-1P) plaque (see Figure 2C-1) may be used to supplement any warning sign to indicate the advisory speed for a condition.

Standard:

02 **The use of the Advisory Speed plaque for horizontal curves shall be in accordance with the information shown in Table 2C-5. The Advisory Speed plaque shall also be used where an engineering study indicates a need to advise road users of the advisory speed for other roadway conditions.**

03 **If used, the Advisory Speed plaque shall carry the message XX MPH. The speed displayed shall be a multiple of 5 mph.**

04 **Except in emergencies or when the condition is temporary, an Advisory Speed plaque shall not be installed until the advisory speed has been determined by an engineering study.**

05 **The Advisory Speed plaque shall only be used to supplement a warning sign and shall not be installed as a separate sign installation.**

06 **The advisory speed shall be determined by an engineering study that follows established engineering practices.**

Support:
07 Among the established engineering practices that are appropriate for the determination of the recommended advisory speed for a horizontal curve are the following:

A. An accelerometer that provides a direct determination of side friction factors
B. A design speed equation
C. A traditional ball-bank indicator using the following criteria:
   1. 16 degrees of ball-bank for speeds of 20 mph or less
   2. 14 degrees of ball-bank for speeds of 25 to 30 mph
   3. 12 degrees of ball-bank for speeds of 35 mph and higher

08 The 16, 14, and 12 degrees of ball-bank criteria are comparable to the current AASHTO horizontal curve design guidance. Research has shown that drivers often exceed existing posted advisory curve speeds by 7 to 10 mph.

Guidance:
09 *The advisory speed should be determined based on free-flowing traffic conditions.*

10 *Because changes in conditions, such as roadway geometrics, surface characteristics, or sight distance, might affect the advisory speed, each location should be evaluated periodically or when conditions change.*

Section 2C.09 Chevron Alignment Sign (W1-8)

Standard:
01 **The use of the Chevron Alignment (W1-8) sign (see Figures 2C-1 and 2C-2) to provide additional emphasis and guidance for a change in horizontal alignment shall be in accordance with the information shown in Table 2C-5.**

Option:
02 When used, Chevron Alignment signs may be used instead of or in addition to standard delineators.

Standard:
03 **The Chevron Alignment sign shall be a vertical rectangle. No border shall be used on the Chevron Alignment sign.**

04 **If used, Chevron Alignment signs shall be installed on the outside of a turn or curve, in line with and at approximately a right angle to approaching traffic. Chevron Alignment signs shall be installed at a minimum height of 4 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the traveled way.**

Guidance:
05 *The approximate spacing of Chevron Alignment signs on the turn or curve measured from the point of curvature (PC) should be as shown in Table 2C-6.*

Table 2C-6. Typical Spacing of Chevron Alignment Signs on Horizontal Curves

Advisory Speed	Curve Radius	Sign Spacing
15 mph or less	Less than 200 feet	40 feet
20 to 30 mph	200 to 400 feet	80 feet
35 to 45 mph	401 to 700 feet	120 feet
50 to 60 mph	701 to 1,250 feet	160 feet
More than 60 mph	More than 1,250 feet	200 feet

Note: The relationship between the curve radius and the advisory speed shown in this table should not be used to determine the advisory speed.

06 *If used, Chevron Alignment signs should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.*

Standard:
07 **Chevron Alignment signs shall not be placed on the far side of a T-intersection facing traffic on the stem approach to warn drivers that a through movement is not physically possible, as this is the function of a Two-Direction (or One-Direction) Large Arrow sign.**

08 **Chevron Alignment signs shall not be used to mark obstructions within or adjacent to the roadway, including the beginning of guardrails or barriers, as this is the function of an object marker (see Section 2C.63).**

Section 2C.10 Combination Horizontal Alignment/Advisory Speed Signs (W1-1a, W1-2a)

Option:
01 The Turn (W1-1) sign or the Curve (W1-2) sign may be combined with the Advisory Speed (W13-1P) plaque (see Section 2C.08) to create a combination Turn/Advisory Speed (W1-1a) sign or combination Curve/Advisory Speed (W1-2a) sign (see Figure 2C-1).

02 The combination Horizontal Alignment/Advisory Speed sign may be used to supplement the advance Horizontal Alignment warning sign and Advisory Speed plaque based upon an engineering study.

Standard:
03 **If used, the combination Horizontal Alignment/Advisory Speed sign shall not be used alone and shall not be used as a substitute for a Horizontal Alignment warning sign and Advisory Speed plaque at the advance warning location. The combination Horizontal Alignment/Advisory Speed sign shall only be used as a supplement to the advance Horizontal Alignment warning sign. If used, the combination Horizontal Alignment/Advisory Speed sign shall be installed at the beginning of the turn or curve.**

Guidance:
04 *The advisory speed displayed on the combination Horizontal Alignment/Advisory Speed sign should be based on the advisory speed for the horizontal curve using recommended engineering practices (see Section 2C.08).*

Section 2C.11 Combination Horizontal Alignment/Intersection Signs (W1-10 Series)

Option:
01 The Turn (W1-1) sign or the Curve (W1-2) sign may be combined with the Cross Road (W2-1) sign or the Side Road (W2-2 or W2-3) sign to create a combination Horizontal Alignment/Intersection (W1-10 series) sign (see Figure 2C-1) that depicts the condition where an intersection occurs within or immediately adjacent to a turn or curve.

Guidance:
02 *Elements of the combination Horizontal Alignment/Intersection sign related to horizontal alignment should comply with the provisions of Section 2C.07, and elements related to intersection configuration should comply with the provisions of Section 2C.46. The symbol design should approximate the configuration of the intersecting roadway(s). No more than one Cross Road or two Side Road symbols should be displayed on any one combination Horizontal Alignment/Intersection sign.*

Standard:
03 **The use of the combination Horizontal Alignment/Intersection sign shall be in accordance with the appropriate Turn or Curve sign information shown in Table 2C-5.**

Section 2C.12 One-Direction Large Arrow Sign (W1-6)

Option:
01 A One-Direction Large Arrow (W1-6) sign (see Figure 2C-1) may be used either as a supplement or alternative to Chevron Alignment signs in order to delineate a change in horizontal alignment (see Figure 2C-2).

Section 2A.18 Mounting Height

Standard:
01 **The provisions of this Section shall apply unless specifically stated otherwise for a particular sign or object marker elsewhere in this Manual.**

Support:
02 The mounting height requirements for object markers are provided in Chapter 2C.

03 In addition to the provisions of this Section, information affecting the minimum mounting height of signs as a function of crash performance can be found in AASHTO's "Roadside Design Guide" (see Section 1A.11).

Standard:
04 **The minimum height, measured vertically from the bottom of the sign to the elevation of the near edge of the pavement, of signs installed at the side of the road in rural areas shall be 5 feet (see Figure 2A-2).**

05 **The minimum height, measured vertically from the bottom of the sign to the top of the curb, or in the absence of curb, measured vertically from the bottom of the sign to the elevation of the near edge of the traveled way, of signs installed at the side of the road in business, commercial, or residential areas where parking or pedestrian movements are likely to occur, or where the view of the sign might be obstructed, shall be 7 feet (see Figure 2A-2).**

Option:
06 The height to the bottom of a secondary sign mounted below another sign may be 1 foot less than the height specified in Paragraphs 4 and 5.

Standard:
07 **The minimum height, measured vertically from the bottom of the sign to the sidewalk, of signs installed above sidewalks shall be 7 feet.**

08 **If the bottom of a secondary sign that is mounted below another sign is mounted lower than 7 feet above a pedestrian sidewalk or pathway (see Section 6D.02), the secondary sign shall not project more than 4 inches into the pedestrian facility.**

Option:
09 Signs that are placed 30 feet or more from the edge of the traveled way may be installed with a minimum height of 5 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the pavement.

Standard:
10 **Directional signs on freeways and expressways shall be installed with a minimum height of 7 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the pavement. All route signs, warning signs, and regulatory signs on freeways and expressways shall be installed with a minimum height of 7 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the pavement. If a secondary sign is mounted below another sign on a freeway or expressway, the major sign shall be installed with a minimum height of 8 feet and the secondary sign shall be installed with a minimum height of 5 feet, measured vertically from the bottom of the sign to the elevation of the near edge of the pavement.**

11 **Where large signs having an area exceeding 50 square feet are installed on multiple breakaway posts, the clearance from the ground to the bottom of the sign shall be at least 7 feet.**

Option:
12 A route sign assembly consisting of a route sign and auxiliary signs (see Section 2D.31) may be treated as a single sign for the purposes of this Section.

13 The mounting height may be adjusted when supports are located near the edge of the right-of-way on a steep backslope in order to avoid the sometimes less desirable alternative of placing the sign closer to the roadway.

Standard:
14 **Overhead signs shall provide a vertical clearance of not less than 17 feet to the sign, light fixture, or sign bridge over the entire width of the pavement and shoulders except where the structure on which the overhead signs are to be mounted or other structures along the roadway near the sign structure have a lesser vertical clearance.**

Option:
15 If the vertical clearance of other structures along the roadway near the sign structure is less than 16 feet, the vertical clearance to an overhead sign structure or support may be as low as 1 foot higher than the vertical clearance of the other structures in order to improve the visibility of the overhead signs.

16 In special cases it may be necessary to reduce the clearance to overhead signs because of substandard dimensions in tunnels and other major structures such as double-deck bridges.

Support:
17 Figure 2A-2 illustrates some examples of the mounting height requirements contained in this Section.

Section 2A.19 Lateral Offset

Standard:
01 **For overhead sign supports, the minimum lateral offset from the edge of the shoulder (or if no shoulder exists, from the edge of the pavement) to the near edge of overhead sign supports (cantilever or sign bridges) shall be 6 feet. Overhead sign supports shall have a barrier or crash cushion to shield them if they are within the clear zone.**

02 **Post-mounted sign and object marker supports shall be crashworthy (breakaway, yielding, or shielded with a longitudinal barrier or crash cushion) if within the clear zone.**

Guidance:
03 *For post-mounted signs, the minimum lateral offset should be 12 feet from the edge of the traveled way. If a shoulder wider than 6 feet exists, the minimum lateral offset for post-mounted signs should be 6 feet from the edge of the shoulder.*

Support:
04 The minimum lateral offset requirements for object markers are provided in Chapter 2C.

05 The minimum lateral offset is intended to keep trucks and cars that use the shoulders from striking the signs or supports.

Guidance:
06 *All supports should be located as far as practical from the edge of the shoulder. Advantage should be taken to place signs behind existing roadside barriers, on over-crossing structures, or other locations that minimize the exposure of the traffic to sign supports.*

Option:
07 Where permitted, signs may be placed on existing supports used for other purposes, such as highway traffic signal supports, highway lighting supports, and utility poles.

Standard:
08 **If signs are placed on existing supports, they shall meet other placement criteria contained in this Manual.**

Option:
09 Lesser lateral offsets may be used on connecting roadways or ramps at interchanges, but not less than 6 feet from the edge of the traveled way.

10 On conventional roads in areas where it is impractical to locate a sign with the lateral offset prescribed by this Section, a lateral offset of at least 2 feet may be used.

11 A lateral offset of at least 1 foot from the face of the curb may be used in business, commercial or residential areas where sidewalk width is limited or where existing poles are

CHAPTER 4
LOW-VOLUME ROAD DESIGN

Pavement structural design for low-volume roads is divided into three categories:

(1) flexible pavements,
(2) rigid pavements, and
(3) aggregate-surfaced roads

This chapter covers the design of low-volume roads for these three surface types using procedures based on design charts (nomographs) and design catalogs These two procedures are covered in Sections 4 1 and 4 2, respectively For surface treatment or chip seal pavement structures, the procedures for flexible pavements may be used

Because the primary basis for all rational pavement performance prediction methods is cumulative heavy axle load applications, it is necessary in this Guide to use the 18-kip equivalent single axle load (ESAL) design approach for low-volume roads, regardless of how low the traffic level is or what the distribution is between automobiles and trucks

Since many city streets and county roads that fall under the low-volume category may still carry significant levels of truck traffic, the maximum number of 18-kip ESAL applications considered for flexible and rigid pavement design is 700,000 to 1 million The practical minimum traffic level that can be considered for any flexible or rigid pavement during a given performance period is about 50,000 18-kip ESAL applications For the aggregate-surfaced (gravel) roads used for many county and forest roads, the maximum traffic level considered is 100,000 18-kip ESAL applications, while the practical minimum level (during a single performance period) is 10,000

4.1 DESIGN CHART PROCEDURES

4.1.1 Flexible and Rigid Pavements

The low-volume road design chart procedures for flexible and rigid pavements are basically the same as those for highway pavement design The low-volume road procedure basically relies on the set of design requirements (developed in Chapter 2) as well as the basic step-by-step procedures described in Chapter 3 The primary difference in the design for low-volume roads is the level of reliability that may be used Because of their relative low usage and the associated low level of risk, the level of reliability recommended for low-volume road design is 50 percent The user may, however, design for higher levels of 60 to 80 percent, depending on the actual projected level of traffic and the feasibility of rehabilitation, importance of corridor, etc

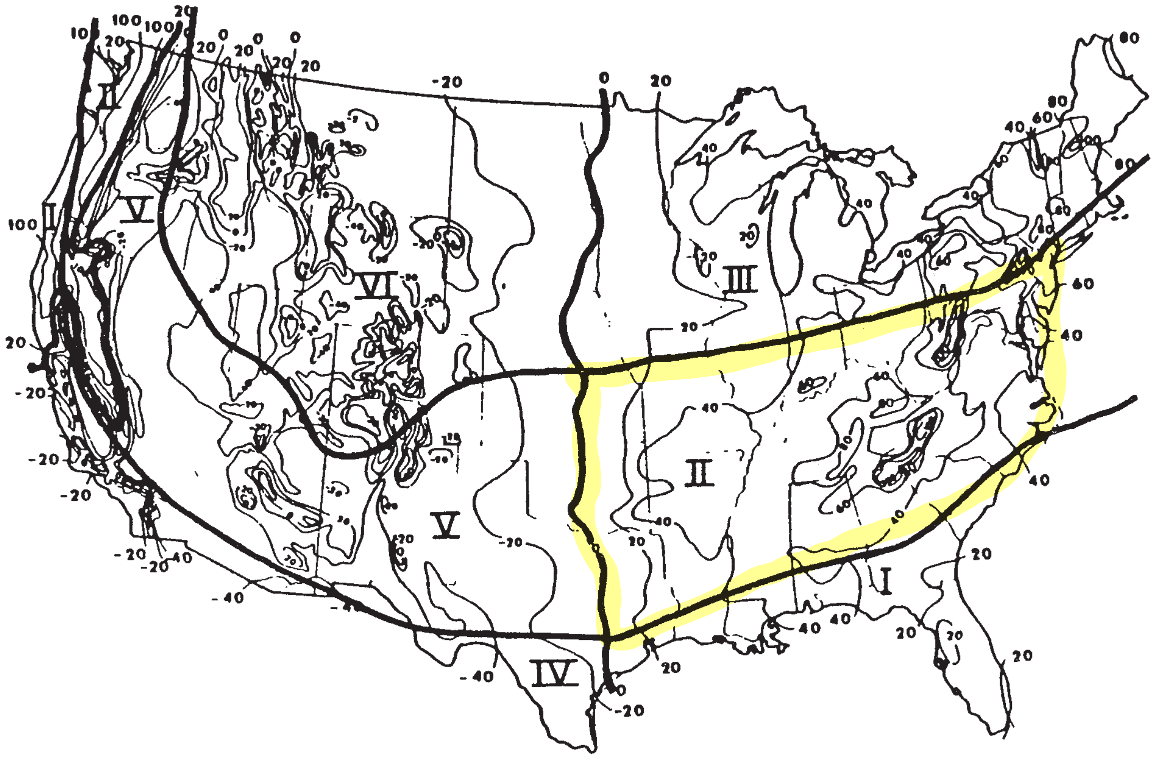
If, in estimating an effective resilient modulus of the roadbed material (M_R) or an effective modulus of subgrade reaction (k), it is not possible to determine the lengths of the seasons or even the seasonal roadbed soil resilient moduli, the following suggestions should be considered

Season Lengths. Figure 4 1 provides a map showing six different climatic regions of the United States and the environmental characteristics associated with each Based on these regional characteristics, Table 4 1 may be used to define the season lengths needed for determining the effective roadbed soil resilient modulus (Section 2 3 1) for flexible pavement design or the effective modulus of subgrade reaction (Section 3 2 1) for rigid pavement design

Seasonal Roadbed Soil Resilient Moduli. Table 4 2 provides roadbed soil resilient modulus values that may be used for low-volume road design if the user can classify the general quality of the roadbed material as a foundation for the pavement structure If the suggested values in this table are combined with the suggested season lengths identified in the previous section, effective roadbed soil resilient modulus values (for flexible pavement design only) can be generated for each of the six U S climatic regions These M_R values are presented in Table 4 3

4.1.2 Aggregate-Surfaced Roads

The basis for treating the effects of seasonal moisture changes on roadbed soil resilient modulus, M_R, is



REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze - thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze - thaw cycling
VI	Dry, hard freeze, spring thaw

Figure 4.1. The Six Climatic Regions in the United States (*12*)

Table 4.1. Suggested Seasons Length (Months) for the Six U.S. Climatic Regions

U.S. Climatic Region	Season (Roadbed Soil Moisture Condition)			
	Winter (Roadbed Frozen)	Spring-Thaw (Roadbed Saturated)	Spring/Fall (Roadbed Wet)	Summer (Roadbed Dry)
I	0 0*	0 0	7 5	4 5
II	1 0	0 5	7 0	3 5
III	2 5	1 5	4 0	4 0
IV	0 0	0 0	4 0	8 0
V	1 0	0 5	3 0	7 5
VI	3 0	1 5	3 0	4 5

*Number of months for the season

"1.0" "0.5" "7.0" "3.5" etc

Table 4.2. Suggested Seasonal Roadbed Soil Resilient Moduli, M_R (psi), as a Function of the Relative Quality of the Roadbed Material

Relative Quality of Roadbed Soil	Season (Roadbed Soil Moisture Condition)			
	Winter (Roadbed Frozen)	Spring-Thaw (Roadbed Saturated)	Spring/Fall (Roadbed Wet)	Summer (Roadbed Dry)
Very good	20,000*	2,500	8,000	20,000
Good	20,000	2,000	6,000	10,000
Fair	20,000	2,000	4,500	6,500
Poor	20,000	1,500	3,300	4,900
Very poor	20,000	1,500	2,500	4,000

*Values shown are Resilient Modulus in psi

Table 4.3. Effective Roadbed Soil Resilient Modulus Values, M_R (psi), That May be Used in the Design of Flexible Pavements for Low-Volume Roads. Suggested values depend on the U.S. climatic region and the relative quality of the roadbed soil.

U.S. Climatic Region	Relative Quality of Roadbed Soil				
	Very Poor	Poor	Fair	Good	Very Good
I	2,800*	3,700	5,000	6,800	9,500
II	2,700	3,400	4,500	5,500	7,300
III	2,700	3,000	4,000	4,400	5,700
IV	3,200	4,100	5,600	7,900	11,700
V	3,100	3,700	5,000	6,000	8,200
VI	2,800	3,100	4,100	4,500	5,700

*Effective Resilient Modulus in psi

∴ use M_R = 5,500 psi

ing in this graph for a total damage equal to 1 0 Figure 4 4 provides an example in which the design is controlled by the serviceability criteria: $\overline{D}_{BS}$ is equal to 10 inches

Step 9. The base layer thickness determined in the last step should be used for design if the effects of aggregate loss are negligible If, however, aggregate loss is significant, then the design thickness is determined using the following equation:

$$D_{BS} = \overline{D}_{BS} + (0\ 5 \times GL)$$

where

GL = total estimated aggregate (gravel) loss (in inches) over the performance period

If, for example, the total estimated gravel loss was 2 inches and the average base thickness required was 10 inches, the design thickness of the aggregate base layer would be

$$D_{BS} = 10 + (0\ 5 \times 2) = 11 \text{ inches}$$

Step 10. The final step of the design chart procedure for aggregate-surfaced roads is to convert a portion of the aggregate base layer thickness to an equivalent thickness of subbase material This is accomplished with the aid of Figure 4 5 Select the final base thickness desired, $^{D}BS_f$ (6 inches is used in the example) Draw a line to the estimated modulus of the subbase material, E_{SB} (15,000 psi is used in the example) Go across and through the scale corresponding to the reduction in base thickness, $^{D}BS_i - {}^{D}BS_f$ (11 minus 6 equal to 5 inches is used in the example) Then, for the known modulus of the base material, E_{BS} (30,000 psi in the example), determine the required subbase thickness, D_{SB} (8 inches)

4.2 DESIGN CATALOG

The purpose of this Section is to provide the user with a means for identifying reasonable pavement structural designs suitable for low-volume roads The catalog of designs presented here covers aggregate-surfaced roads as well as both flexible and rigid pavements It is important to note, however, that although the structural designs presented represent precise solutions using the design procedure described in the previous section, they are based on a unique set of assumptions relative to design requirements and environmental conditions The following specific assumptions apply to all three types of structural designs considered:

(1) All designs are based on the structural requirement for one performance period, regardless of the time interval The range of traffic levels for the flexible and rigid pavement designs is between 50,000 and 1,000,000 18-kip ESAL applications The allowable range of relative traffic for aggregate-surfaced road design is between 10,000 and 100,000 18-kip ESAL applications

(2) All designs presented are based on either a 50- or 75-percent level of reliability

(3) The designs are for environmental conditions corresponding to all six of the U S climatic regions (See map in Figure 4 1)

(4) The designs are for five qualitative levels of roadbed soil strength or support capability: Very Good, Good, Fair, Poor, and Very Poor Table 4 2 indicates the levels of roadbed soil resilient modulus that were used for each soil classification Table 4 1 indicates the actual lengths of the seasons used to quantify the effects of each of the six climatic regions on pavement performance

(5) The terminal serviceability for the flexible and rigid pavement designs is 1 5 and the overall design serviceability loss used for aggregate-surfaced roads is 3 0 (Thus, if the initial serviceability of an aggregate-surfaced road was 3 5, the corresponding terminal serviceability inherent in the design solution is 0 5)

4.2.1 Flexible Pavement Design Catalog

Tables 4 6 and 4 7 present a catalog of flexible pavement SN values (structural numbers) that may be used for the design of low-volume roads when the more detailed design approach is not possible Table 4 6 is based on the 50-percent reliability level and Table 4 7 is based on a 75-percent level The range of SN values shown for each condition is based on a specific range of 18-kip ESAL applications at each traffic level

High	700,000 to 1,000,000
Medium	400,000 to 600,000
Low	50,000 to 300,000

Table 4.6. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for the Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality—Inherent Reliability: 50 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2 3–2 5*	2 5–2 7	2 8–3 0	2 1–2 3	2 4–2 6	2 8–3 0
	Medium	2 1–2 3	2 3–2 5	2 5–2 7	1 9–2 1	2 2–2 4	2 5–2 7
	Low	1 5–2 0	1 7–2 2	1 9–2 4	1 4–1 8	1 6–2 1	1 9–2 4
Good	High	2 6–2 8	2 8–3 0	3 0–3 2	2 5–2 7	2 7–2 9	3 0–3 2
	Medium	2 4–2 6	2 6–2 8	2 8–3 0	2 2–2 4	2 5–2 7	2 7–2 9
	Low	1 7–2 3	1 9–2 4	2 0–2 7	1 6–2 1	1 8–2 4	2 0–2 6
Fair	High	2 9–3 1	3 0–3 2	3 1–3 3	2 8–3 0	2 9–3 1	3 1–3 3
	Medium	2 6–2 8	2 8–3 0	2 9–3 1	2 5–2 7	2 6–2 8	2 8–3 0
	Low	2 0–2 6	2 0–2 6	2 1–2 8	1 9–2 4	1 9–2 5	2 1–2 7
Poor	High	3 2–3 4	3 3–3 5	3 4–3 6	3 1–3 3	3 2–3 4	3 4–3 6
	Medium	3 0–3 2	3 0–3 2	3 1–3 4	2 8–3 0	2 9–3 2	3 1–3 3
	Low	2 2–2 8	2 2–2 9	2 3–3 0	2 1–2 7	2 2–2 8	2 3–3 0
Very poor	High	3 5–3 7	3 5–3 7	3 5–3 7	3 3–3 5	3 4–3 6	3 5–3 7
	Medium	3 2–3 4	3 3–3 5	3 3–3 5	3 1–3 3	3 1–3 3	3 2–3 4
	Low	2 4–3 1	2 4–3 1	2 4–3 1	2 3–3 0	2 3–3 0	2 4–3 1

*Recommended range of structural number (SN)

Table 4.7. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality— Inherent Reliability: 75 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2 6–2 7*	2 8–2 9	3 0–3 2	2 4–2 5	2 7–2 8	3 0–3 2
	Medium	2 3–2 5	2 5–2 7	2 7–3 0	2 1–2 3	2 4–2 6	2 7–3 0
	Low	1 6–2 1	1 8–2 3	2 0–2 6	1 5–2 0	1 7–2 2	2 0–2 6
Good	High	2 9–3 0	3 0–3 2	3 3–3 4	2 7–2 8	3 0–3 1	3 3–3 4
	Medium	2 6–2 8	2 7–3 0	3 0–3 2	2 4–2 6	2 6–2 9	2 9–3 2
	Low	1 9–2 4	2 0–2 6	2 2–2 8	1 8–2 3	2 0–2 5	2 2–2 8
Fair	High	3 2–3 3	3 3–3 4	3 4–3 5	3 0–3 2	3 2–3 3	3 4–3 5
	Medium	2 8–3 1	2 9–3 2	2 7–3 3	2 7–3 0	2 8–3 1	3 0–3 3
	Low	2 1–2 7	2 2–2 8	2 3–2 9	2 0–2 6	2 1–2 7	2 3–2 9
Poor	High	3 5–3 6	3 6–3.7	3 7–3 9	3 4–3 5	3 5–3 6	3 7–3 8
	Medium	3 1–3 4	3.2–3 5	3 4–3 6	3 0–3 3	3 1–3 4	3 3–3 6
	Low	2 4–3 0	2 4–3 0	2 5–3 2	2 3–2 8	2 3–2 9	2 5–3 2
Very poor	High	3 8–3 9	3 8–4 0	3 8–4 0	3 6–3 8	3 7–3 8	3 8–4 0
	Medium	3 4–3 7	3 5–3 8	3 5–3 7	3 3–3 6	3 3–3 6	3 4–3 7
	Low	2 6–3 2	2 5–3 3	2 6–3 3	2 5–3 1	2 5–3 1	2 6–3 3

*Recommended range of structural number (SN)

∴ 50% reliability ⇒ 2.8 – 3.0

75% reliability ⇒ 3.0 – 3.2

Once a design structural number is selected, it is up to the user to identify an appropriate combination of flexible pavement layer thicknesses which will provide the desired load-carrying capacity This may be accomplished using the criteria for layer coefficients (a_i-values) presented in Section 2 3 5 and the general equation for structural number

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

where

a_1, a_2, a_3 = layer coefficient for surface, base, and subbase course materials, respectively, and

D_1, D_2, D_3 = thickness (in inches) of surface, base, and subbase course, respectively

4.2.2 Rigid Pavement Design Catalog

Tables 4 8a, 4 8b, 4 9a, and 4 9b present the catalog of portland cement pavement slab thicknesses that may be used for the design of low-volume roads when the more detailed design approach is not possible Tables 4 8a and 4 8b are based on a 50-percent reliability level, without granular subbase and with granular subbase, respectively Tables 4 9a and 4 9b are based on a 75-percent level, without granular subbase and with granular subbase, respectively The assumptions inherent in these design catalogs are as follows:

(1) Slab thickness design recommendations apply to all six U S climatic regions
(2) If the option to use a subbase is chosen, it consists of 4 to 6 inches of high quality granular material
(3) Mean PCC modulus of rupture (S'_c) is 600 or 700 psi
(4) Mean PCC elastic modulus (E_c) is 5,000,000 psi
(5) Drainage (moisture) conditions are fair (C_d = 1 0)
(6) The 18-kip ESAL traffic levels are

High	700,000 to 1,000,000
Medium	400,000 to 600,000
Low	50,000 to 300,000

(7) The levels of roadbed soil quality and corresponding ranges of effective modulus of subgrade reaction (k-value) are

Very Good	Greater than 550 pci
Good	400 to 550 pci
Fair	250 to 350 pci
Poor	150 to 250 pci
Very Poor	Less than 150 pci

4.2.3 Aggregate-Surfaced Road Design Catalog

Table 4 10 presents a catalog of aggregate base layer thicknesses that may be used for the design of low-volume roads when the more detailed design approach is not possible The thicknesses shown are based on specific ranges of 18-kip ESAL applications at traffic levels

High	60,000 to 100,000
Medium	30,000 to 60,000
Low	10,000 to 30,000

One other assumption inherent in these base thickness recommendations is that the effective resilient modulus of the aggregate base material is 30,000 psi, regardless of the quality of the roadbed soil This value should be used as input to the nomograph in Figure 4 5 to convert a portion of the aggregate base thickness to an equivalent thickness of subbase material with an intermediate modulus value between the base and roadbed soil

REFERENCES FOR PART II

1 "Flexible Pavement Designer's Manual—Part I," Texas State Department of Highways and Public Transportation, Highway Division, 1972

2 "Design Manual for Controlled Access Highways," Texas Highway Department, January 1960

3 Van Til, C J , McCullough, B F , Vallerga, B A , and Hicks, R G , "Evaluation of AASHO Interim Guides for Design of Pavement Structures," NCHRP Report 128, 1972

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Roadway Design Division

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- Distress Data – used to pick project per pavement management Region staff
- Distress Data available for use by pavement designers in concert with historical data

3.3 Design Life

The analysis period for design of pavement structure will depend on the type of project. The analysis periods will conform to the following:

Table 3-1: Pavement Structure Analysis Periods

	Design Life
New Construction	20 Years
Major Reconstruction	20 Years
Asphalt Rehabilitation – Interstates & Freeways	8 Years Minimum
Asphalt Rehabilitation – Other Routes	12 Years Minimum
PCC Rehabilitation (CPR)	15 Years or Greater

3.4 Life Cycle Cost Analysis

A life cycle cost analysis (LCCA) will be performed on Interstates and Major Primary Routes for new and reconstructed roadways. The cost for all routine activities of pavement maintenance will be used in the LCCA, and will be based on the most current actual expenditure information available from the Maintenance Division. A detailed discussion of procedures and practices for LCCA is presented in Chapter 7. The following sections provide a brief summary of cost elements to be included with the LCCA.

A LCCA will not be required if:

- The new roadway is adjacent to an existing roadway and the pavement type needs match the existing, or
- The existing pavement is in sound condition and the cost to restore it to an acceptable level of service is minor compared to the cost of a new pavement structure or major rehabilitation.

In either of the above cases, a decision will likely be made based on engineering judgment rather than an engineering and economic analysis of alternative actions.

For the basis of LCCA, it is assumed that the asphalt or the concrete pavements will have a residual value equal to an aggregate base course for reconstruction. It is assumed that at the end of the analysis period, each alternate will be equal and no monetary value will be given for LCCA.

- Calculate Life Cycle Cost Analysis (LCCA) for Pavement Alternates – The pavement designer will calculate life cycle cost analyses for the pavement alternates. Chapter 7 of this document describes in greater detail the process used to complete the LCCA.

4.2.3 Pavement Design Approval

The pavement designer will submit the pavement design and life cycle cost analysis to the Assistant Chief Engineer of Design for approval. Once the pavement design has been approved, the pavement designer will forward the approved design to the roadway design engineer who initiated the request. A copy of the pavement design will be kept on file.

4.3 Flexible Pavement Design

4.3.1 Design Input Parameters

The parameters listed in the following paragraph have been for use in calculating the required SN of flexible pavements. These parameters are input into a generic software that uses the *1993 AASHTO Guide for Design of Pavement Structures* to obtain a required SN. Two options for the generic software to be used are WinPAS and PaveXpress.

Pavement reliability is defined as the probability that a pavement section will perform satisfactorily over the design period; typical values used in the design process are 95% for Interstates and Principal Arterials to 90% for local streets and roads.

Overall standard deviation is a measure of the overall confidence the designer may have in the design inputs; TDOT utilizes 0.45 for new flexible pavement design. The range of S_O values provided in Part II (section 2.1.3 of the *1993 AASHTO Guide for Design of Pavement Structures*) are 0.40 – 0.50.

When using various softwares based on the 1993 AASHTO Guide, default values may be provided that are typically associated with the recommended values in the guide. For example, the 1993 AASHTO Guide states that the overall standard deviation for the case where the variance of projected future traffic *is* considered is 0.49 for flexible pavements; the value of 0.44 is used when the variance of projected future traffic is *not* considered.

Subgrade resilient modulus must also be calculated for the roadbed soil materials, this values is typically determined by some sort of index test if not measured directly, a reasonable estimate of resilient modulus (Mr (psi) is to use the relationship of Mr = 1,500 x CBR (California Bearing Ratio). The Pavement Service Ability Index (PSI) is also used in AASHTO 1993 pavement design, this index provides a relative measure of the condition of the roadway structure. The design process utilizes a drop of serviceability over the design life as an measure of performance, a typical change in PSI of 1.7 for most designs, this is determined from an initial serviceability of 4.2 and an final terminal serviceability of 2.5.

The final parameter utilized in the design process is a measure of the traffic over the design life. The concept of Equivalent Single Axle Loads (ESAL) is normally used, and this represents the accumulation of a number of standard axles over the pavement structure. Average annual daily traffic

(AADT), average daily load (ADL), and equivalent single axle loads (ESALs) typically are provided by the Strategic Transportation Investments Division.

4.3.2 Determining Pavement Thicknesses

Each component of the pavement structure is assigned structural credit. This structural credit is calculated using "a" layer coefficients. The "a" coefficient for each layer is multiplied by the layer thickness to establish the structural credit for that layer. The structural credit of each component is then combined to yield an actual SN. Table 4-2 identifies the TDOT established "a" layer coefficients. The "a" layer coefficients have been validated by research efforts from the University of Tennessee[1,2].

Table 4-2: "a" Layer Coefficients

Layer	"a" Layer Coefficient
Surface, Grading D	0.40
Surface, Grading E	0.40
Surface, Grading OGFC	0.30
Leveling, Grading C	0.40
Leveling, Grading C-S	0.40
Leveling, Grading C-W	0.40
Binder, Grading B-Mod-2	0.40
Binder, Grading B-Mod	0.40
Binder, Grading B	0.40
Black Base, Grading A	0.40
Black Base, Grading A-S	0.30
Black Base, Grading A-CRL	0.30
Mineral Aggregate Base Grading D	0.10/0.14*
Cement Treated Base	0.23
Lime Fly-Ash Base	0.28
Subgrade Treatment – Lime	0.08
Subgrade Treatment – Cement	0.15

* 0.14 will be used for limestone base in Regions 1 – 4. If limestone is not specified in Region 4, west of the Tennessee River, then 0.10 will be used.

Each pavement material type shown in Table 4-2 has specific gradations and maximum aggregate sizes that influence the ability to compact each layer to the required densities to provide adequate pavement performance. In order to achieve appropriate layer densities during construction, the following table illustrates the minimum and maximum asphalt layer thicknesses associated with each material type.

[1] Huang, Baoshan; Drumm, Eric; Laboratory Evaluation of Layer Structural Coefficients for HMA Pavements, *Volume 1 – Hot Mix Asphalt,* Knoxville: The University of Tennessee, March 2008

[2] Huang, Baoshan; Drumm, Eric; Laboratory Evaluation of Layer Structural Coefficients for HMA Pavements, *Volume 2 – Layer Coefficient and Index Properties of Base Materials,* Knoxville: The University of Tennessee, June 2005 – May 2007

Table 4-3: Asphalt Layer Thickness

ASPHALT LAYER THICKNESS				
TYPE AND GRADING	MAXIMUM NOMINAL AGG. SIZE	MAXIMUM AGGREGATE SIZE	MINIMUM LAYER THICKNESS	MAXIMUM LAYER THICKNESS
Black Base, Grading "A"	2"	2"	3"	4"
Black Base, Grading "A-S"	2"	2"	3"	4"
Black Base, Grading "A-CRL"	2"	2"	3"	4"
Binder, Grading "B"	1-1/2"	2"	3"	4"
Binder, Grading "B-Mod"	1'	1"	1-1/2"	2"
Binder, Grading "B-Mod2"	1-1/8"	1-1/8"	2"	2-3/4"
Surface, Grading "D"	1/2"	5/8"	1-1/8"	1-1/2"
Surface, Grading "E"	1/2"	5/8"	1-1/8"	1-1/2"

* Maximum nominal size is the first screen retaining any material as long as % passing first screen retaining material is 90% to 99%. Otherwise, maximum nominal size is same as maximum size.
** Maximum size is last screen through which 100% of material should pass.

4.3.3 Surface Courses

4.3.3.1 Surface, Grading D

This item is typically used on TDOT projects, unless an open-graded friction course (OGFC) is used. OGFCs have typically only been used in experimental applications. A 1.25-inch layer is the minimum thickness for OGFC, with a maximum layer thickness of 1.5 inches. Typically, a 1.25-inch layer is used for mainline surface course.

4.3.3.2 Surface, Grading E

This item is typically used for shoulder applications. A 1.25-inch layer is the minimum thickness, with a maximum layer thickness of 1.5 inches. Typically, a 1.5-inch layer is used for a shoulder surface course greater than 4 ft wide.

4.3.3.3 Surface, Grading OGFC

Open Graded Friction Courses (OGFC) were at one time used only as an experimental pavement surface application for locations with high wet-weather skidding crash histories or locations with high potential for hydroplaning. More recently, OGFCs have been gaining popularity, especially as mixture design issues contributing to severe raveling and degradation of the surface have been resolved. OGFCs have been shown to reduce tracking spray and backspray and now are being considered more frequently for high-speed applications such as interstates and other high-speed routes.

4.3.4 Leveling Courses

4.3.4.1 Leveling, Grading C

This item is typically used as a pure leveling course. Its main application is generally at the regional level. A 1.25-inch layer is the minimum thickness, with a maximum layer thickness of 1.5 inches.

4.3.4.2 Leveling, Grading C-S

This item is typically used as a surface leveling course prior to the use of an open-graded friction course.

4.3.4.3 Leveling, Grading C-W

This item is typically used as a wearing course. Its main application is generally at the regional level, and it is usually used on low-volume roads. A 1.25-inch layer is the minimum thickness, with a maximum layer thickness of 1.5 inches.

4.3.5 Binder Courses

4.3.5.1 Binder, Grading B-Mod-2

A 2-inch layer is the minimum thickness, with a maximum thickness of 2.75 inches.

4.3.5.2 Binder, Grading B-Mod

This item is generally used at the regional level. A 1.5-inch layer is the minimum thickness, with a maximum layer thickness of 2 inches.

4.3.5.3 Binder, Grading B

This item is generally used at the regional level. A 3-inch layer is the minimum thickness, with a maximum layer thickness of 4 inches.

4.3.6 Black Base Courses

4.3.6.1 Black Base, Grading A

This item is always used on TDOT projects. A 3-inch layer is the minimum thickness, with a maximum layer thickness of 4 inches.

4.3.6.2 Black Base, Grading A-S

This item serves as a drainage layer. It is typically used on 4-lane divided highways. Underdrains are used in conjunction with an A-S mix. If an A-S mix is used, it is followed by Black Base, Grading A > Binder, Grading B-Mod-2 > and Surface, Grading D. A 3-inch layer is the minimum thickness, with a maximum layer thickness of 4 inches.

4.3.6.3 Black Base, Grading A-CRL

This item serves as an asphalt-crack relief layer (A-CRL). It is a modification of the A-S mix and is used in crack and seat projects. Underdrains are used in conjunction with an A-CRL mix. A 3-inch layer is the minimum thickness, with a maximum layer thickness of 4 inches.

4.3.7 Aggregate Base

4.3.7.1 Mineral Aggregate Base Grading D

This item serves as the unbound aggregate layer. On most new construction projects, development of pavement designs begin with a minimum 10 inch aggregate layer for use with asphalt pavement designs. The thicknesses of the asphalt layers are then proportioned accordingly.

The starting thickness for some small projects and other unique situations such as interchange ramps may be less than 10 inches for this unbound aggregate layer, depending on site-specific considerations.

The mineral aggregate base layer has a minimum thickness of 4".

The pavement designer will either daylight the layer or specify to use underdrains. This will be based on project-specific conditions.

4.3.7.2 Treated Permeable Base

Treated base layers also may be used either to provide stability or drainability of the pavement structure. The minimum thicknesses for these layers typically is 4 to 6 inches.

The pavement designer will call for a 4" treated permeable base under concrete pavements. This item will serve as a drainage layer. Underdrains are used in conjunction with a treated permeable base.

Per Standard Specification Section 313, the contractor may elect to use either a cement treated or an asphalt treated permeable base.

4.3.7.3 Lime Fly-Ash Base

This item is used when alternate bases are bid. It consists of stabilizing the mineral aggregate with hydrated lime and fly ash. The pavement designer will consider the type of subgrade as well as any special requests from the region are taken when bidding lime fly-ash base.

4.3.8 Subgrade Treatment

Subgrades with low CBR values are generally treated with cement or other approved processes. A project level geotechnical report will recommend which material is appropriate for the soil encountered within the project limits.

4.3.9 Selecting Pavement Mixes

TDOT uses PG 64-22, PG 70-22, PG 76-22, and PG 82-22 performance grade asphalt binders. Figure 4-2 identifies when each binder grade is used.

Binder	Application
PG 64-22	• Routes where AADT < 10,000
PG 70-22	• Routes where AADT ≥ 10,000 (except as noted) • Specified NHI Routes (SR 5, SR 15, SR 22, SR 43)
PG 76-22	• All Interstates and Freeways
PG 82-22	• High Pavement Stress Locations • Selected Urban Interstate Projects with Extremely High Volumes • Very high volume areas with high % trucks • Intersections with large traffic volumes and/or high truck traffic

Figure 4-2: Selection of Performance Grade Asphalt Binder

4.4 Rigid Pavement Design

4.4.1 Input Parameters

The parameters listed in the following paragraphs are for use in calculating the required thickness of rigid pavements and required SN when asphalt shoulders are used. These parameters are input into a generic software that uses the *1993 AASHTO Guide for Design of Pavement Structures* to obtain a required SN.

Pavement reliability is defined as the probability that a pavement section will perform satisfactorily over the design period; typical values used in the design process are 95% for Interstates and Principal Arterials to 90% for local streets and roads.

Overall standard deviation is a measure of the overall confidence the designer may have in the design inputs; TDOT utilizes 0.35 for new rigid pavement design. The range of S_O values provided in Part II (section 2.1.3 of the *1993 AASHTO Guide for Design of Pavement Structures*) are 0.30 – 0.40.

When using various softwares based on the 1993 AASHTO Guide, default values may be provided that are typically associated with the recommended values in the guide. For example, the 1993 AASHTO Guide states that the overall standard deviation for the case where the variance of projected future traffic *is* considered is 0.39 for rigid pavements; the value of 0.34 is used when the variance of projected future traffic is *not* considered.

Subgrade resilient modulus must also be calculated for the roadbed soil materials, this values is typically determined by some sort of index test if not measured directly, a reasonable estimate of resilient modulus Mr (psi) is to use the relationship of Mr = 1,500 x CBR (California Bearing Ratio). The Pavement Service Ability Index (PSI) is also used in AASHTO 1993 pavement design, this index provides a relative measure of the condition of the roadway structure. The design process utilizes a drop of serviceability over the design life as an measure of performance, a typical change in PSI of 2.0 for most designs, this is determined from an initial serviceability of 4.5 and an final terminal serviceability of 2.5.

pg II-69

min is 50,000 18-kip ESAL

recommended level of reliability is 50%

may design for 60-80%

- feasibility of rehab, importance of corridor, etc

flexible Section 2.3.1 ↰ ↱ rigid Section 3.2.1

find M_R & k

effective resilient mod. of roadbed matl & effective mod. subgrade rxn

need length of seasons

↳ table 4.1

if can classify general quality of roadbed matl

↳ table 4.2 for resilience mods

— this & table 4.1 for flexible only

↳ this is what we want

(rigid has no base)

we are in zone II wet, freeze-thaw cycling

Table 4.1. Suggested Seasons Length (Months) for the Six U.S. Climatic Regions

U.S. Climatic Region	Season (Roadbed Soil Moisture Condition)			
	Winter (Roadbed Frozen)	Spring-Thaw (Roadbed Saturated)	Spring/Fall (Roadbed Wet)	Summer (Roadbed Dry)
I	0 0*	0 0	7 5	4 5
II	1 0	0 5	7 0	3 5
III	2 5	1 5	4 0	4 0
IV	0 0	0 0	4 0	8 0
V	1 0	0 5	3 0	7 5
VI	3 0	1 5	3 0	4 5

*Number of months for the season

Table 4.2. Suggested Seasonal Roadbed Soil Resilient Moduli, M_R (psi), as a Function of the Relative Quality of the Roadbed Material

Relative Quality of Roadbed Soil	Season (Roadbed Soil Moisture Condition)			
	Winter (Roadbed Frozen)	Spring-Thaw (Roadbed Saturated)	Spring/Fall (Roadbed Wet)	Summer (Roadbed Dry)
Very good	20,000*	2,500	8,000	20,000
Good	20,000	2,000	6,000	10,000
Fair	20,000	2,000	4,500	6,500
Poor	20,000	1,500	3,300	4,900
Very poor	20,000	1,500	2,500	4,000

*Values shown are Resilient Modulus in psi

good based on Dr. Baoshan Huang's advice & soil quality in eastern TN

Table 4.3. Effective Roadbed Soil Resilient Modulus Values, M_R (psi), That May be Used in the Design of Flexible Pavements for Low-Volume Roads. Suggested values depend on the U.S. climatic region and the relative quality of the roadbed soil.

U.S. Climatic Region	Relative Quality of Roadbed Soil				
	Very Poor	Poor	Fair	Good	Very Good
I	2,800*	3,700	5,000	6,800	9,500
II	2,700	3,400	4,500	5,500	7,300
III	2,700	3,000	4,000	4,400	5,700
IV	3,200	4,100	5,600	7,900	11,700
V	3,100	3,700	5,000	6,000	8,200
VI	2,800	3,100	4,100	4,500	5,700

*Effective Resilient Modulus in psi

M_R = 5500 psi for subgrade

II-77 for assumptions

1) between 50,000 to 1,000,000 18-kip ESAL

2) designs based on 50 or 75 % reliability

→ we will use 95% - TDOT standard

3) ✓

4) ✓

5) terminal serviceability is 1.5

4.2.1

table 4.6 for 50% reliability

table 4.7 for 75%

high 18 kip ESAL range (1,000,000 ESAL)

20-year road lifespan

$SN = a_1 D_1 + a_2 D_2 + a_3 D_3$

a values in 2.3.5 (pg II-17)

Table 4.6. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for the Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality—Inherent Reliability: 50 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2 3–2 5*	2 5–2 7	2 8–3 0	2 1–2 3	2 4–2 6	2 8–3 0
	Medium	2 1–2 3	2 3–2 5	2 5–2 7	1 9–2 1	2 2–2 4	2 5–2 7
	Low	1 5–2 0	1 7–2 2	1 9–2 4	1 4–1 8	1 6–2 1	1 9–2 4
Good	High	2 6–2 8	2 8–3 0	3 0–3 2	2 5–2 7	2 7–2 9	3 0–3 2
	Medium	2 4–2 6	2 6–2 8	2 8–3 0	2 2–2 4	2 5–2 7	2 7–2 9
	Low	1 7–2 3	1 9–2 4	2 0–2 7	1 6–2 1	1 8–2 4	2 0–2 6
Fair	High	2 9–3 1	3 0–3 2	3 1–3 3	2 8–3 0	2 9–3 1	3 1–3 3
	Medium	2 6–2 8	2 8–3 0	2 9–3 1	2 5–2 7	2 6–2 8	2 8–3 0
	Low	2 0–2 6	2 0–2 6	2 1–2 8	1 9–2 4	1 9–2 5	2 1–2 7
Poor	High	3 2–3 4	3 3–3 5	3 4–3 6	3 1–3 3	3 2–3 4	3 4–3 6
	Medium	3 0–3 2	3 0–3 2	3 1–3 4	2 8–3 0	2 9–3 2	3 1–3 3
	Low	2 2–2 8	2 2–2 9	2 3–3 0	2 1–2 7	2 2–2 8	2 3–3 0
Very poor	High	3 5–3 7	3 5–3 7	3 5–3 7	3 3–3 5	3 4–3 6	3 5–3 7
	Medium	3 2–3 4	3 3–3 5	3 3–3 5	3 1–3 3	3 1–3 3	3 2–3 4
	Low	2 4–3 1	2 4–3 1	2 4–3 1	2 3–3 0	2 3–3 0	2 4–3 1

*Recommended range of structural number (SN)

Table 4.7. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality— Inherent Reliability: 75 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2 6–2 7*	2 8–2 9	3 0–3 2	2 4–2 5	2 7–2 8	3 0–3 2
	Medium	2 3–2 5	2 5–2 7	2 7–3 0	2 1–2 3	2 4–2 6	2 7–3 0
	Low	1 6–2 1	1 8–2 3	2 0–2 6	1 5–2 0	1 7–2 2	2 0–2 6
Good	High	2 9–3 0	3 0–3 2	3 3–3 4	2 7–2 8	3 0–3 1	3 3–3 4
	Medium	2 6–2 8	2 7–3 0	3 0–3 2	2 4–2 6	2 6–2 9	2 9–3 2
	Low	1 9–2 4	2 0–2 6	2 2–2 8	1 8–2 3	2 0–2 5	2 2–2 8
Fair	High	3 2–3 3	3 3–3 4	3 4–3 5	3 0–3 2	3 2–3 3	3 4–3 5
	Medium	2 8–3 1	2 9–3 2	2 7–3 3	2 7–3 0	2 8–3 1	3 0–3 3
	Low	2 1–2 7	2 2–2 8	2 3–2 9	2 0–2 6	2 1–2 7	2 3–2 9
Poor	High	3 5–3 6	3 6–3.7	3 7–3 9	3 4–3 5	3 5–3 6	3 7–3 8
	Medium	3 1–3 4	3.2–3 5	3 4–3 6	3 0–3 3	3 1–3 4	3 3–3 6
	Low	2 4–3 0	2 4–3 0	2 5–3 2	2 3–2 8	2 3–2 9	2 5–3 2
Very poor	High	3 8–3 9	3 8–4 0	3 8–4 0	3 6–3 8	3 7–3 8	3 8–4 0
	Medium	3 4–3 7	3 5–3 8	3 5–3 7	3 3–3 6	3 3–3 6	3 4–3 7
	Low	2 6–3 2	2 5–3 3	2 6–3 3	2 5–3 1	2 5–3 1	2 6–3 3

*Recommended range of structural number (SN) pavement design manual

select PG 64-22 (pg 13)

↳ performance grade asphalt binder

pg 8 the "a" values are based off AASHTO's guide

TDOT uses 90% reliability for local roads

resilient modulus must be calc. for roadbed soil materials

↳ measure directly or find California Bearing Ratio (CBR)

final parameter is ESAL (accumulation of # axles over pavement structure)

4.3.2 Determining Pavement Thicknesses

Each component of the pavement structure is assigned structural credit. This structural credit is calculated using "a" layer coefficients. The "a" coefficient for each layer is multiplied by the layer thickness to establish the structural credit for that layer. The structural credit of each component is then combined to yield an actual SN. Table 4-2 identifies the TDOT established "a" layer coefficients. The "a" layer coefficients have been validated by research efforts from the University of Tennessee[1,2].

will use AASHTO guide for SN #

90% reliability

Table 4-2: "a" Layer Coefficients

Layer	"a" Layer Coefficient
→ Surface, Grading D	0.40 — 1.25" – 1.5"
Surface, Grading E	0.40
Surface, Grading OGFC	0.30
Leveling, Grading C	0.40
Leveling, Grading C-S	0.40
Leveling, Grading C-W	0.40
→ Binder, Grading B-Mod-2	0.40 — 2" – 2.75"
Binder, Grading B-Mod	0.40
Binder, Grading B	0.40
Black Base, Grading A	0.40
Black Base, Grading A-S	0.30
Black Base, Grading A-CRL	0.30
→ Mineral Aggregate Base Grading D	0.10/0.14* — min 10" or 4"
Cement Treated Base	0.23
Lime Fly-Ash Base	0.28
Subgrade Treatment – Lime	0.08
Subgrade Treatment – Cement	0.15

* 0.14 will be used for limestone base in Regions 1 – 4. If limestone is not specified in Region 4, west of the Tennessee River, then 0.10 will be used.

Each pavement material type shown in Table 4-2 has specific gradations and maximum aggregate sizes that influence the ability to compact each layer to the required densities to provide adequate pavement performance. In order to achieve appropriate layer densities during construction, the following table illustrates the minimum and maximum asphalt layer thicknesses associated with each material type.

[1] Huang, Baoshan; Drumm, Eric; Laboratory Evaluation of Layer Structural Coefficients for HMA Pavements, *Volume 1 – Hot Mix Asphalt*, Knoxville: The University of Tennessee, March 2008

[2] Huang, Baoshan; Drumm, Eric; Laboratory Evaluation of Layer Structural Coefficients for HMA Pavements, *Volume 2 – Layer Coefficient and Index Properties of Base Materials*, Knoxville: The University of Tennessee, June 2005 – May 2007

75% reliability SN is 3.0 - 3.2

50% reliability SN is 2.8 - 3.0

so 90% reliability SN is ~3.2 - 3.4

want $SN > 3.2$

check design of Chelaque way:

$D_1 + D_2 = 3\text{in}$ $a_1 = 0.40$, $a_2 = 0.40$

$D_3 = 4\text{ in} + 12\text{ in}$ $a_3 = 0.12$

$SN = 0.4(3\text{in}) + 0.12(16\text{ in})$

$SN = 3.12$

∴ $3.12 < 3.2$, design of Chelaque way is less reliable

D_1	D_2	D_3
2,	4,	10

start with max: 1.5, 2.75, 10

$SN = 0.4(1.5\text{in}) + 0.4(2.75\text{ in}) + 0.12(10\text{ in})$

$SN = 2.9$, too thin

find min D_3: $3.2 = 0.4(1.5\text{in} + 2.75\text{in}) + 0.12\, D_3$

$D_3 \geq 12.5\text{in}$

∴ subbase @ 95% compaction

minimum thicknesses:

surface grading D @ 1.5in

binder BM-2 @ 2.75in

aggregate base @ 12.5in

TDOT std. dwg RD11TS1

CURRENT\In Progress\10-100.00 Roadway Design Standards IP\100.03 RD11 Typical Sections and Design Criteria

TABLE I MINIMUM DESIGN SPEEDS FOR LOW-VOLUME ROADS

TYPE OF TERRAIN	DESIGN SPEED (MPH) FOR SPECIFIED DESIGN ADT (VEH/DAY)			
	UNDER 50	50 TO 250	250 TO 400	400 TO 2,000
LEVEL	30	30	40	50
ROLLING	20 (J)	30	30	40
MOUNTAINOUS	20 (J)	20 (J)	20 (J)	30

TABLE II
DESIGN STANDARDS FOR LOW-VOLUME LOCAL ROADS AND STREETS (ADT ≤ 400)

			DESIGN SPEED (MPH) (J) 15	20	25	30	35	40
PROPOSED APPROACH ROADWAY (FEET)	RURAL LOCAL ROADS		18	18	18	18	18	18
	RECREATIONAL AND SCENIC ROADS		18	18	18	18	18	20
	INDUSTRIAL/COMMERCIAL ACCESS		20	20	22	24	24	24
	URBAN LOCAL ROADS LOW DEVELOPMENT DENSITY (2.0 OR LESS DWELLINGS/ACRE)		20	20	20	20	20	20
	URBAN LOCAL ROADS MEDIUM DEVELOPMENT DENSITY (2.1 TO 6 DWELLINGS/ACRE)		28	28	28	28	28	28
MINIMUM HORIZONTAL CURVE RADIUS (FEET) BY SUPERELEVATION RATE	ALL CLASSIFICATIONS (G)	NC -2%	50	107	198	333	510	762
		0%	47	99	181	300	454	667
		RC 2%	44	92	167	273	408	593
		3%	43	89	160	261	389	561
		4%	42	86	154	250	371	533
		5%	41	83	149	240	355	508
		6%	39	81	144	231	340	485
		7%	38	78	139	222	327	464
		8%	38	76	134	214	314	444
MINIMUM STOPPING SIGHT DISTANCE (FEET)	ADT 0 TO 100 (VEH/DAY)		65	90	115	135	170	215
	ADT 101 TO 400 (VEH/DAY)		65	95	125	165	205	250
MINIMUM "K" VALUES	CREST VERTICAL CURVE	ADT 0 TO 100 (VEH/DAY)	2	4	7	9	14	22
		ADT 101 TO 400 (VEH/DAY)	2	5	8	13	20	29
	SAG VERTICAL CURVE		10	17	26	37	49	64
MAXIMUM GRADE (%)	TYPE OF TERRAIN	LEVEL	9	8	7	7	7	7
		ROLLING	12	11	11	10	10	9
		MOUNTAINOUS	17	16	15	14	13	12

FOR SUPERELEVATION SEE STANDARD DRAWINGS RD11-SE SERIES (G)

choose speed limit for curve radius ≤ min curve radius

10 mph for ≤ 38 ft

15 mph for ≤ 76 ft & > 38 ft

20 mph for ≤ 134 ft & > 76 ft

→ not included in design solution to avoid too many signs

RE: MUTCD Section 2C

Standard:

02 **In advance of horizontal curves on freeways, on expressways, and on roadways with more than 1,000 AADT that are functionally classified as arterials or collectors, horizontal alignment warning signs shall be used in accordance with Table 2C-5 based on the speed differential between the roadway's posted or statutory speed limit or 85th-percentile speed, whichever is higher, or the prevailing speed on the approach to the curve, and the horizontal curve's advisory speed.**

Table 2C-5. Horizontal Alignment Sign Selection

Type of Horizontal Alignment Sign	Difference Between Speed Limit and Advisory Speed				
	5 mph	10 mph	15 mph	20 mph	25 mph or more
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W1-10) (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required	Required	Required
Chevrons (W1-8) and/or One Direction Large Arrow (W1-6)	Optional	Recommended	Required	Required	Required
Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp	Optional	Optional	Recommended	Required	Required

Note: Required means that the sign and/or plaque shall be used, recommended means that the sign and/or plaque should be used, and optional means that the sign and/or plaque may be used.
See Section 2C.06 for roadways with less than 1,000 AADT.

Option:

03 Horizontal Alignment Warning signs may also be used on other roadways or on arterial and collector roadways with less than 1,000 AADT based on engineering judgment.

Table 2C-6. Typical Spacing of Chevron Alignment Signs on Horizontal Curves

Advisory Speed	Curve Radius	Sign Spacing
15 mph or less	Less than 200 feet	40 feet
20 to 30 mph	200 to 400 feet	80 feet
35 to 45 mph	401 to 700 feet	120 feet
50 to 60 mph	701 to 1,250 feet	160 feet
More than 60 mph	More than 1,250 feet	200 feet

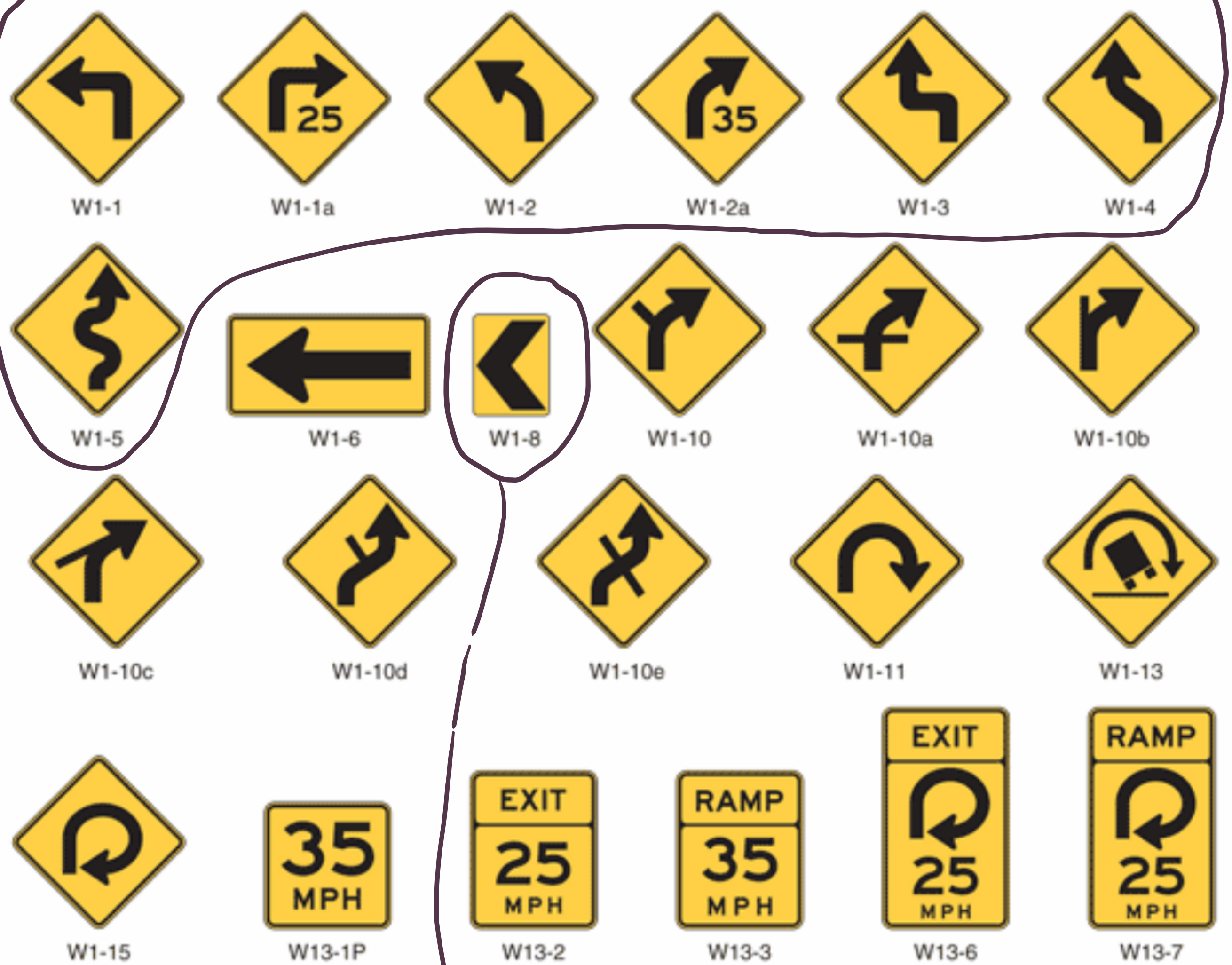
Table 2C-4. Guidelines for Advance Placement of Warning Signs

Posted or 85th-Percentile Speed	Advance Placement Distance[1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0[3]	10[4]	20[4]	30[4]	40[4]	50[4]	60[4]	70[4]
20 mph	225 ft	100 ft[6]	N/A[5]	—	—	—	—	—	—
25 mph	325 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
30 mph	460 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
35 mph	565 ft	100 ft[6]	N/A[5]	N/A[5]	N/A[5]	—	—	—	—
40 mph	670 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—	—
45 mph	775 ft	175 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—
50 mph	885 ft	250 ft	200 ft	175 ft	125 ft	100 ft[6]	—	—	—
55 mph	990 ft	325 ft	275 ft	225 ft	200 ft	125 ft	N/A[5]	—	—
60 mph	1,100 ft	400 ft	350 ft	325 ft	275 ft	200 ft	100 ft[6]	—	—
65 mph	1,200 ft	475 ft	450 ft	400 ft	350 ft	275 ft	200 ft	100 ft[6]	—
70 mph	1,250 ft	550 ft	525 ft	500 ft	450 ft	375 ft	275 ft	150 ft	—
75 mph	1,350 ft	650 ft	625 ft	600 ft	550 ft	475 ft	375 ft	250 ft	100 ft[6]

1. The distances are adjusted for a sign legibility distance of 180 feet for Condition A. The distances for Condition B have been adjusted for a sign legibility distance of 250 feet, which is appropriate for an alignment warning symbol sign. For Conditions A and B, warning signs with less than 6-inch legend or more than four words, a minimum of 100 feet should be added to the advance placement distance to provide adequate legibility of the warning sign.
2. Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are determined by providing the driver a PRT of 14.0 to 14.5 seconds for vehicle maneuvers (2005 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E) minus the legibility distance of 180 feet for the appropriate sign.
3. Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2005 AASHTO Policy, Exhibit 3-1, Stopping Sight Distance, providing a PRT of 2.5 seconds, a deceleration rate of 11.2 feet/second2, minus the sign legibility distance of 180 feet.
4. Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distance is determined by providing a 2.5 second PRT, a vehicle deceleration rate of 10 feet/second^2, minus the sign legibility distance of 250 feet.
5. No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing. An alignment warning sign may be placed anywhere from the point of curvature up to 100 feet in advance of the curve. However, the alignment warning sign should be installed in advance of the curve and at least 100 feet from any other signs.
6. The minimum advance placement distance is listed as 100 feet to provide adequate spacing between signs.

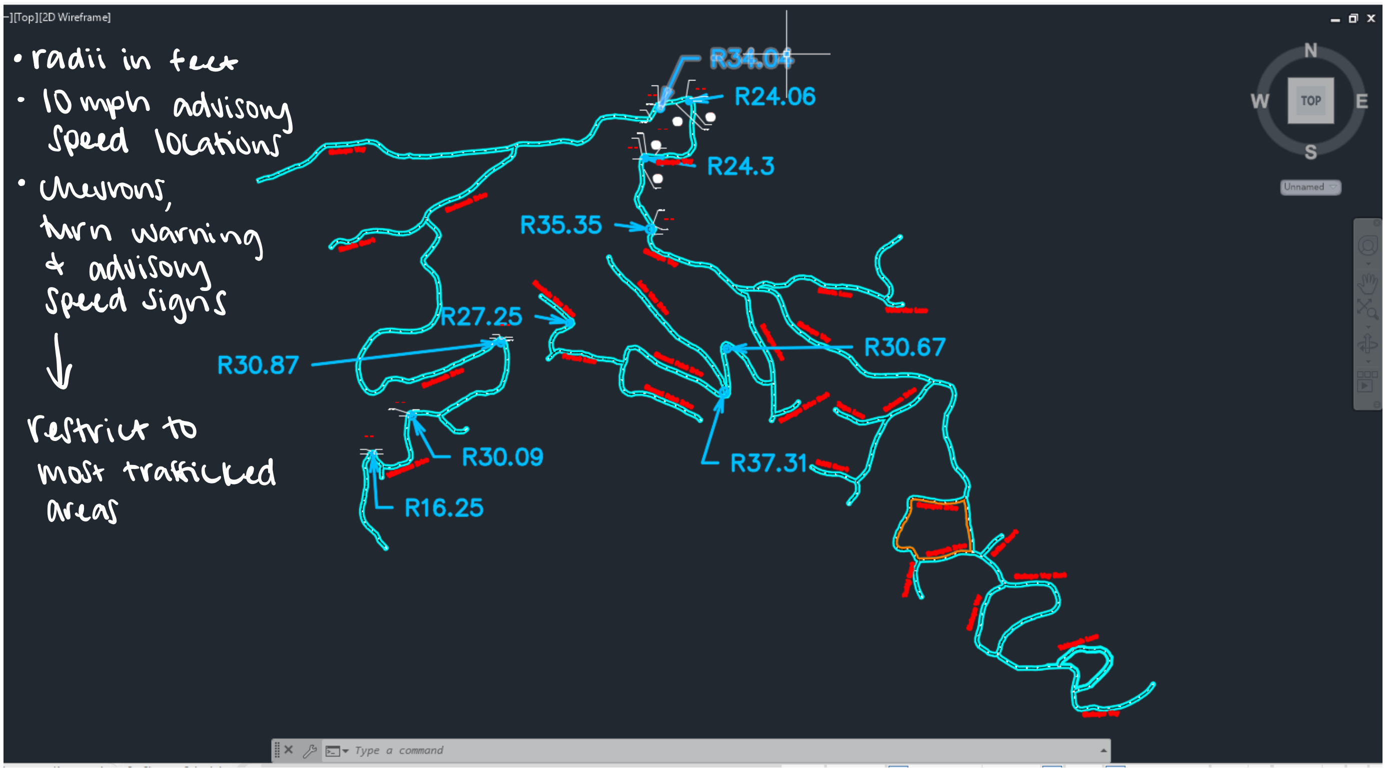
30 x 30 in MUTCD table 2C-2

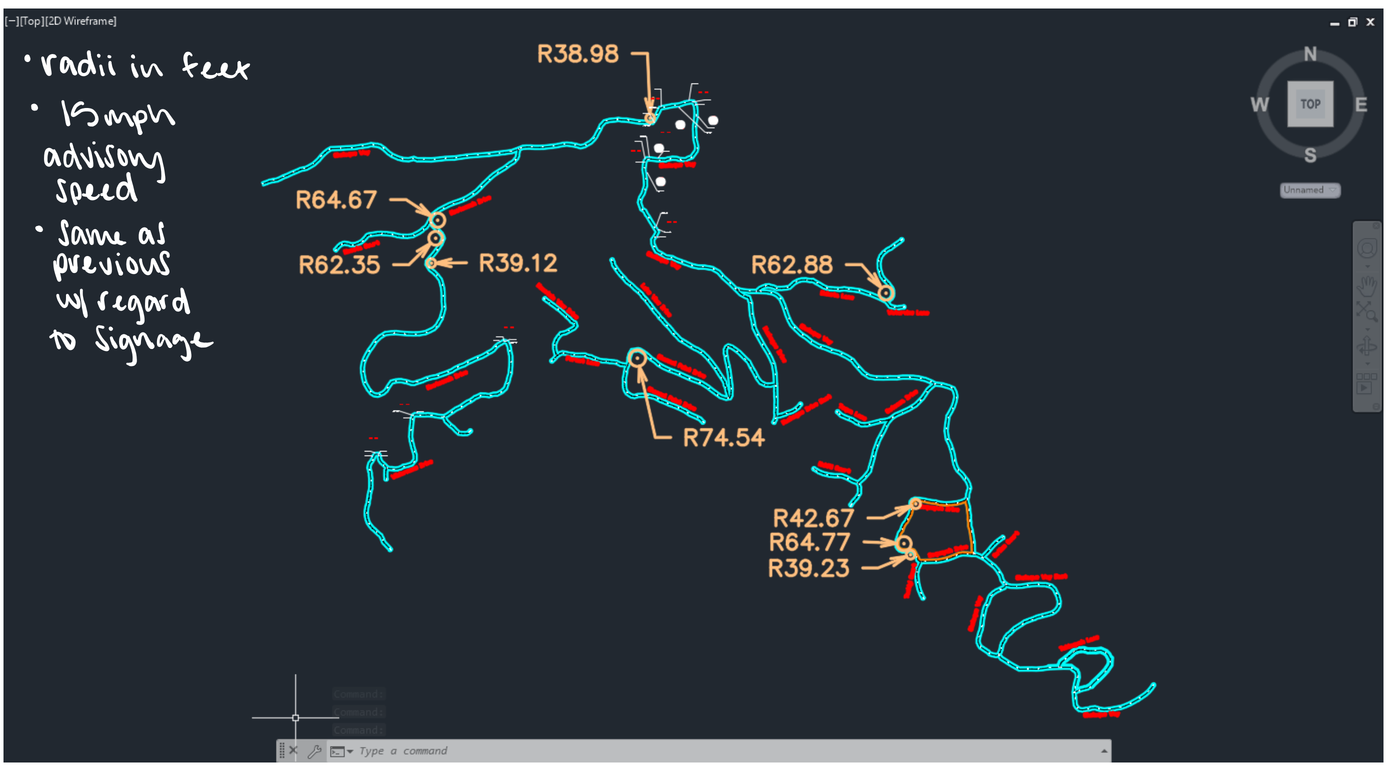
Figure 2C-1. Horizontal Alignment Signs and Plaques

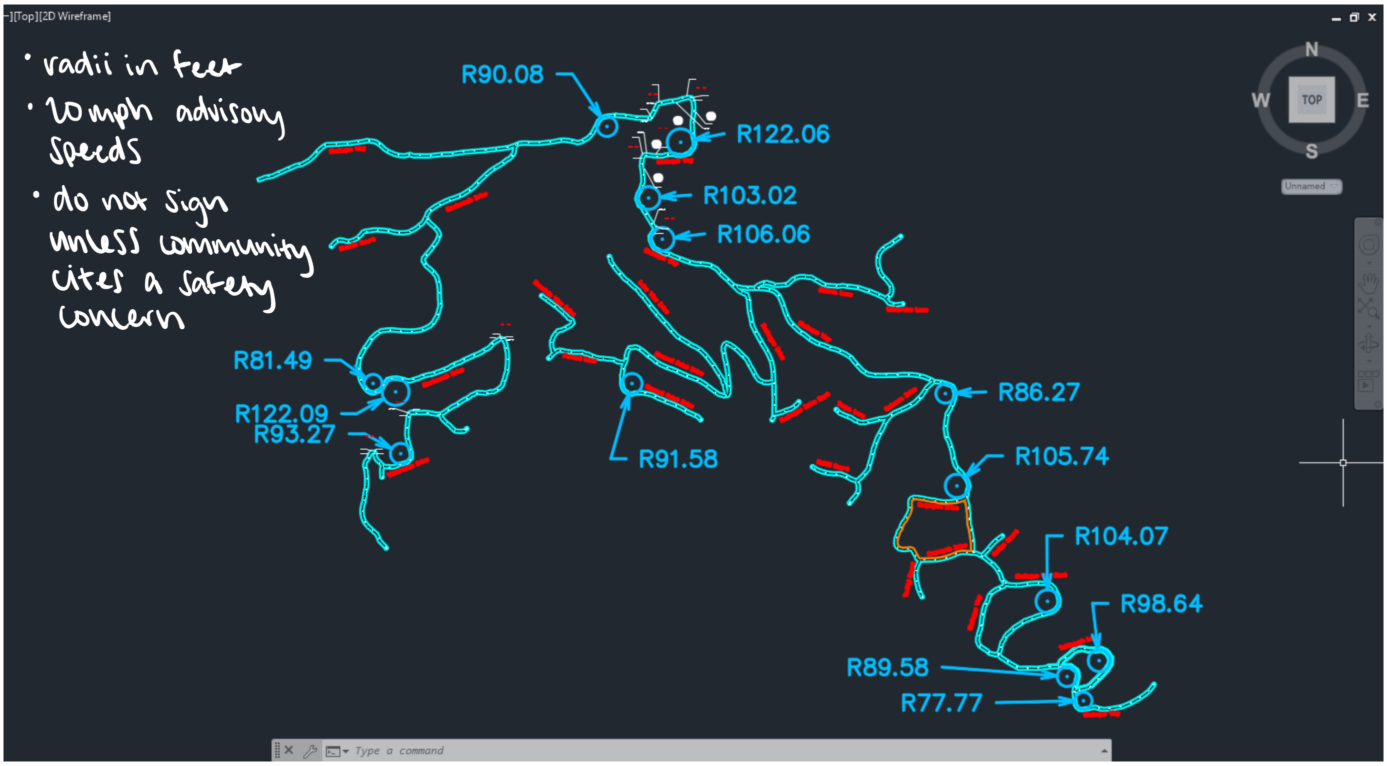


Note: Turn arrows and reverse turn arrows may be substituted for the curve arrows and reverse curve arrows on the W1-10 series signs where appropriate.

18x24 MUTCD table 2C-2

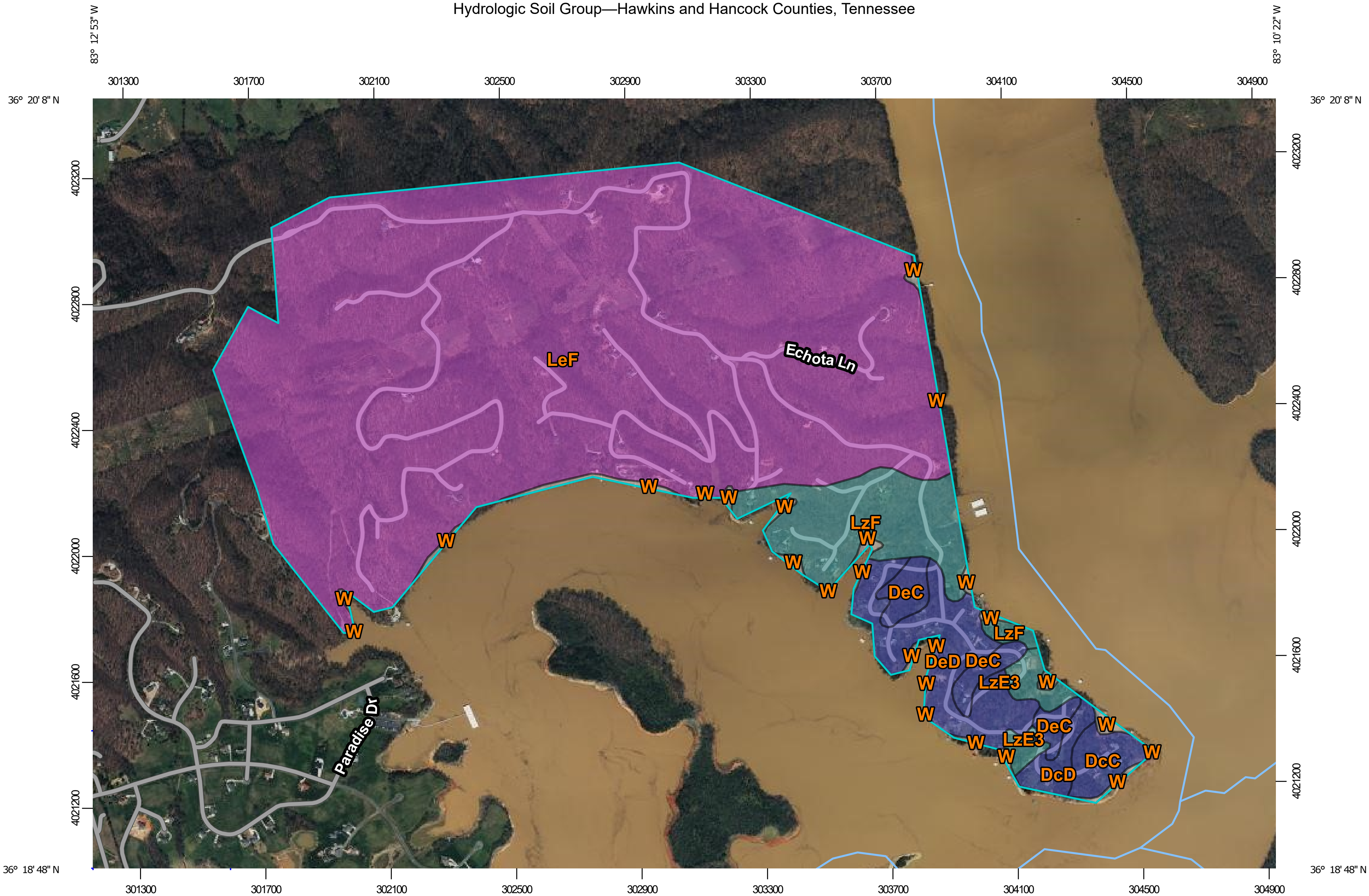

-][Top][2D Wireframe]
• radii in feet
• 10 mph advisory speed locations
• chevrons, turn warning & advisory speed signs
↓
restrict to most trafficked areas
R34.04
R24.06
R24.3
R35.35
R27.25
R30.87
R30.67
R30.09
R37.31
R16.25
N
W
TOP
E
S
Unnamed
Type a command


[−][Top][2D Wireframe]
• radii in feet
• 15mph advisory speed
• same as previous w/ regard to signage
R38.98
R64.67
R62.35
R39.12
R62.88
R74.54
R42.67
R64.77
R39.23
N
W
TOP
E
S
Unnamed
Type a command

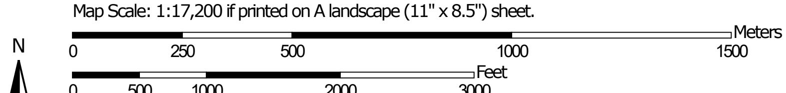


][Top][2D Wireframe]
• radii in feet
• 20 mph advisory speeds
• do not sign unless community cites a safety concern
R90.08
R122.06
R103.02
R106.06
R81.49
R122.09
R93.27
R91.58
R86.27
R105.74
R104.07
R98.64
R89.58
R77.77
N
W
TOP
E
S
Unnamed
Type a command

Appendix D: Water Resources Design



Map Scale: 1:17,200 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Soil Rating Lines

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Soil Rating Points

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Hawkins and Hancock Counties, Tennessee
Survey Area Data: Version 16, Sep 10, 2021

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 21, 2021—Sep 24, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
DcC	Decatur silt loam, 5 to 12 percent slopes	B	9.4	1.4%
DcD	Decatur silt loam, 12 to 20 percent slopes	B	6.8	1.0%
DeC	Dewey silt loam, 6 to 15 percent slopes	B	14.2	2.1%
DeD	Dewey silt loam, 15 to 25 percent slopes	B	34.9	5.2%
LeF	Lehew channery loam, 25 to 60 percent slopes	A	545.9	80.8%
LzE3	Litz shaly silt loam, 20 to 35 percent slopes, severely eroded (sil)	C	8.2	1.2%
LzF	Litz shaly silt loam, 35 to 60 percent slopes (sil)	C	45.3	6.7%
W	Water		10.5	1.6%
Totals for Area of Interest			**675.3**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Hydrologic Soil Calculations for Chelaque Estates - Based on TDOT Hydrology Manual Chapter 4

Cover Type:	woods	Grade	**A**	**B**	**C**	**D**
		CN	45	66	77	83

	Abbreviation	Soil Name	Rating	Acres	Percentage	CN	Acres*CN
	LeF	Lehew channery loam	A	545.9	0.82127275	45	24565.5
	DcC	Decatur silt loam	B	9.4	0.01414172	66	620.4
	DcD	Decatur silt loam	B	6.8	0.01023018	66	448.8
	DeC	Dewey silt loam	B	14.2	0.02136302	66	937.2
	DeD	Dewey silt loam	B	34.9	0.05250489	66	2303.4
	LzE3	Litz shaly silt loam	C	8.2	0.01233639	77	631.4
	LzF	Litz shaly silt loam	C	45.3	0.06815105	77	3488.1
SUM				664.7	1		32994.8

AVG CN: **50** (SUM of Acres*CN)/(SUM of Acres)

% A	% B	% C
82.12728	9.823981	8.04874379

Survey of Existing Stormwater Pipes

highlighted pipes selected for further analysis

From Lat	From Long	To Lat	To Long	Length (ft)	Material	Size (in)	notes
36.33231	83.20686	36.33219	83.20674	40	cmp	18	Materials: cmp - Corrugated metal pipe, hdpe - high density polyethylene (plastic)
36.33222	83.20118	36.33218	83.20117	38	cmp	18	
36.33201	83.20025	36.33196	83.20019	40	cmp	15	2'x2' area drain to headwall, pipe half full of dirt
36.33036	83.20304	36.33023	83.20308	41	cmp	24	
36.2277	83.20288			6	cmp	12	2'x2' area drain that empties to edge of road
under slovin driveway, lot 23 - completely filled with debris					cmp	18	completely filled with debris
36.32647	83.20205	36.32638	83.20196	34	cmp	12	
36.32597	83.20059	36.3258	83.20048	48	cmp	36	
36.32559	83.20148	36.32545	83.20151	30	cmp	12	completely covered entrance
36.32508	83.20258	36.32509	83.20255	30	cmp	12	
36.32502	83.20277	36.32482	83.20287	70	cmp	15	
36.32503	83.20386	36.32494	83.20377	40	cmp	36	
36.32303	83.20254	36.32296	83.20546	30	cmp	12	
36.32235	83.20542	36.32227	83.20569	38	cmp	12	
36.33308	83.19632	36.33301	83.1963	34	cmp	15	
36.33073	83.19593	36.33071	83.19581	40	cmp	15	
36.32924	83.19492	36.32913	83.19481	38	hdpe	12	from headwall to 2'x2' area drain
36.32913	83.19481	36.32908	83.19468	50	hdpe	12	from 2'x2' area drain, exits at end of retaining wall
36.32907	83.19445	36.32898	83.1943	55	cmp	18	
36.32892	83.19345	36.32882	83.19341	40	cmp	15	
36.32821	83.19196	36.32812	83.19188	40	cmp	18	
36.32846	83.18996	36.32838	83.18997	26	cmp	12	
36.32826	83.18889	36.32813	83.18889	42	cmp	12	

36.32794	83.18769	36.32785	83.1877	33	cmp	12	
36.32475	83.19128	36.32467	83.19129	40	cmp	12	come out 5' from each other
36.32473	83.19121	36.32467	83.19129	35	cmp	12	
36.3256	83.19158	36.32551	83.19164	35	hdpe	12	from is a headwall
36.32543	83.19291	36.32544	83.19285	30	cmp	15	buried exit
36.32565	83.19317	36.32565	83.19307	30	cmp	12	from and to metal headwall
36.32528	83.1931	36.32519	83.19313	45	cmp	24	
36.32663	83.19877	36.32655	83.19872	30	cmp	12	buried exit
36.32622	83.19652	36.3263	83.19639	40	cmp	24	
36.32547	83.19648	36.32542	83.19653	30	cmp	12	
36.31749	83.18028	36.31738	83.1802	25	cmp	15	2'x2' area drain, 25' 12" cmp coming in on both sides parallel with ditch
36.3179	83.18084	36.31795	83.18086	33	cmp	15	25' 12" cmp coming in on both sides parallel with ditch
36.31794	83.18398	36.31789	83.18386	40	cmp	15	from completely covered, to half full of dirt
36.31871	83.18329	36.31867	83.18323	28	cmp	15	
36.31899	83.18246	36.31892	83.18244	25	cmp	15	
36.31977	83.18367	36.31987	83.18374	40	cmp	15	
36.32065	83.18459	36.32071	83.18453	20	cmp	2	20' long 2" wide under drain connected to pipe on end
36.32075	83.18483	36.32068	83.18473	37	cmp	15	
36.3222	83.18496	36.32226	83.18487	40	cmp	15	2'x2' area drain with two 25' 12" cmp connecting to ditch
36.32062	83.18654	36.32052	83.18647	40	cmp	15	
XXXXXX	XXXXXX	XXXXXX	XXXXXX	XX	XXX	XX	pipe west of Brasington lot 71, one end completely buried in Bourne lot 91 yard
36.32162	83.18703	36.32166	83.18711	28	cmp	12	
36.32461	83.18538	36.32461	83.18554	40	cmp	15	
36.3249	83.18659	36.32494	83.18672	30	cmp	15	
36.32446	83.18837	36.32437	83.18838	30	cmp	12	

36.32415	83.18769	36.32418	83.18783	33	cmp	15	
36.32307	83.1893	36.32298	83.1893	40	cmp	12	
36.32283	83.18876	36.32276	83.18877	30	cmp	12	2'x2' area drain w/ 6' 12" coming from Kahiti & 13' 12" coming from Catoosa
36.32257	83.18855	36.32256	83.18861	35	cmp	12	
36.32622	83.18874	36.32614	83.18879	30	cmp	15	

4.04.1 RATIONAL METHOD

The Rational method is recommended for estimating the design storm runoff for drainage areas less than 100 acres. The Rational Method is the preferred method to be used when all of the required data is available. The Rational Method for computing *peak* storm runoff is expressed as Equation 4-1:

$$Q = CiA \qquad (4\text{-}1)$$

Where: Q = peak rate of runoff, (ft^3/s)
C = weighted runoff coefficient representing a ratio of runoff to rainfall, (unitless)
i = average rainfall intensity for a duration equal to the time of concentration, for a selected return period, (in/hr)
A = drainage area tributary to the point under design, (acres)

Although the formula is not dimensionally correct (ft^3/s vs. ac*in/hr), the conversion coefficient of 1.008 is ignored as being insignificant. For further technical information and details, refer to the 1965 and 2001 (metric) publications *Hydraulic Design Series 4 (HDS-4)* by the FHWA. The results obtained using the Rational Method to estimate peak discharge is very sensitive to the parameters selected for use in the equation. Under some conditions, peak runoff occurs before all of the drainage area contributes runoff to the point of analysis. The likelihood of error in the runoff estimate increases as the size and complexity of the drainage area increases. This likelihood of error is why the limit is set at 100 acres for applying the Rational Method by TDOT. The designer should use sound engineering judgment when estimating peak runoff values using the Rational Method.

4.04.1.1. RUNOFF COEFFICIENT

The runoff coefficient represents the ratio of the rate of runoff to the rate of rainfall at an average intensity (i) when all the drainage area is contributing. The runoff coefficient is tabulated as a function of land use conditions; however, the coefficient is also a function of slope, rainfall intensity, infiltration, and other abstractions. The amount of water reaching the drainage structure is reduced by evaporation, transpiration, infiltration, and ponding. Two methods are commonly used for calculating the runoff coefficient. The first is to utilize known soil properties, infiltration rates, and land slopes. This method requires information from the Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), and/or other agencies for pervious and impervious surface soil conditions. The second method for calculating the runoff coefficient is to utilize tables developed for various types of surface conditions and land use. Typical runoff coefficients to be used on TDOT projects are shown in Table 4-2.

Complex watersheds with several different types of land use will require that a weighted runoff coefficient be computed. The weighted runoff coefficient is computed by multiplying the runoff coefficient for each land use type by the respective area for each land use; summing these values, and then dividing the sum by the total area. An example of how to compute a weighted runoff coefficient is provided in the chapter Appendix. It should be noted that the Rational Method produces better results when the land use within the watershed being studied is fairly consistent over the entire area.

Surface Type and Condition[1,2]	Runoff Coefficient (C)
Rural Areas	
Concrete or sheet asphalt pavement	0.8 - 0.9
Asphalt macadam pavement	0.6 - 0.8
Gravel roadways or shoulders	0.4 - 0.6
Bare earth	0.2 - 0.9
Steep grassed areas (2H:1V)	0.5 - 0.7
Turf meadows	0.1 - 0.4
Forested areas	0.1 - 0.3
Cultivated fields	0.2 - 0.4
C=0.25 selected to account for steep terrain combined with forested area	
Urban Areas	
Flat residential, with about 30 percent of area impervious	0.40
Flat residential, with about 60 percent of area impervious	0.55
Moderately steep residential, with about 50 percent of area impervious	0.65
Moderately steep developed area, with about 70 percent of area impervious	0.80
Flat commercial/industrial, with about 90 percent of area impervious	0.80

[1]For flat slopes and/or permeable soil, use the lower values. For steep slopes and/or impermeable soil, use the higher values.
[2]For areas where there is a shallow bedrock surface, use the higher values.

Table 4-2
Runoff Coefficients (C) for Use in the Rational Method
Reference: USDOT, FHWA, HDS-4 (2001)

4.04.1.2 INTENSITY

Rainfall intensity (I) is the average rainfall rate (in/hr) for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design, and the time of concentration calculated for the drainage area, the rainfall intensity can be determined from Rainfall Intensity Duration Frequency (IDF) Curves. To view the IDF curves and the rainfall intensity data, navigate to the following link and follow the IDF Curve Guide:

https://hdsc.nws.noaa.gov/hdsc/pfds/

Drainage Areas and Time of Concentration Line

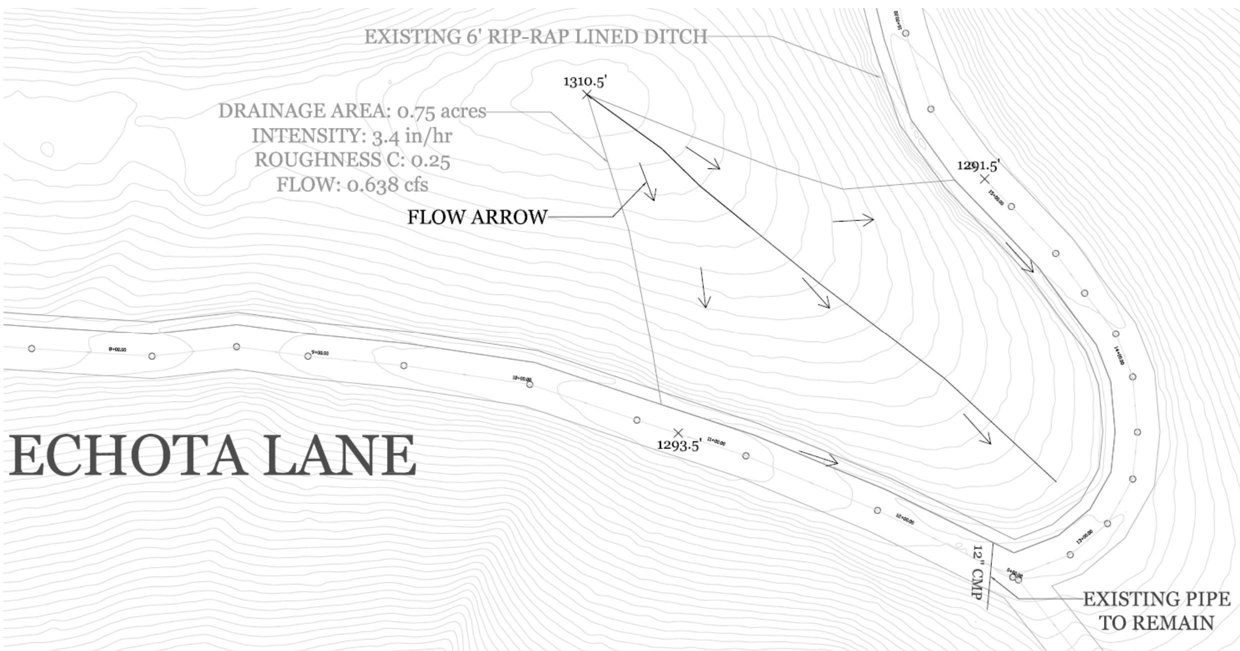
Method for delineating drainage areas:

- start at local highpoint for the area upstream of the pipe being analyzed
- create drainage area by moving perpendicular down the slope towards the ditch and capturing all of the locations that drain to the outlet pipe

Method for time of concentration line (marked as the dark line in the following images):

- start at highpoint
- generate the longest route that rainfall can take to reach the outlet pipe through the drainage area
- assume the first 100’ are sheet flow and the rest is shallow concentrated flow

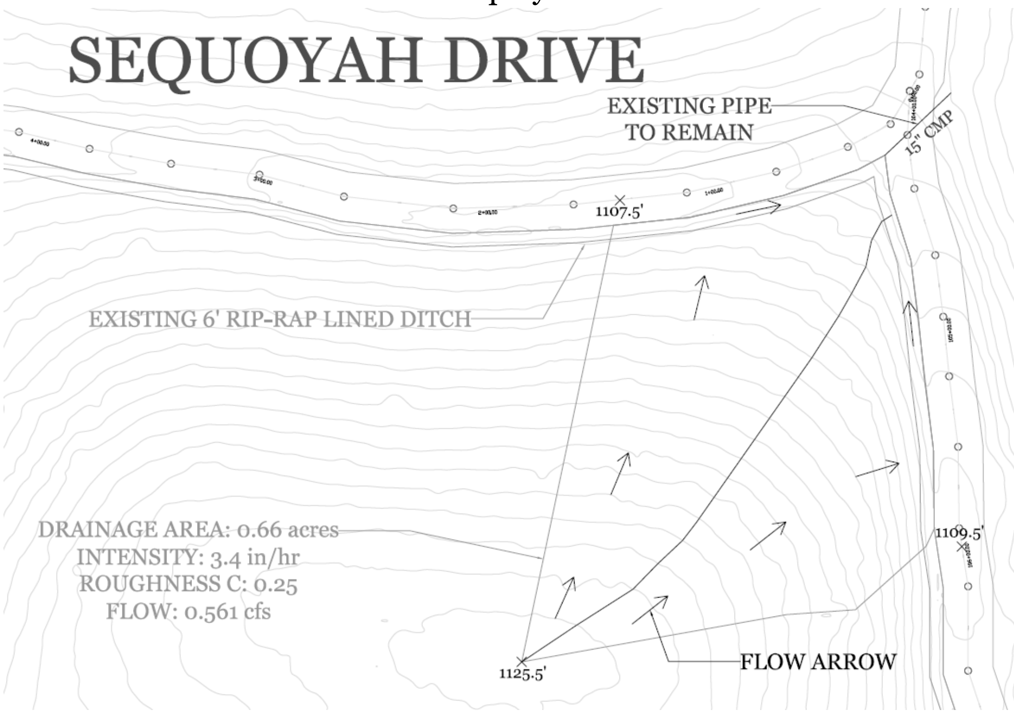
Echota



Drainage Area: 0.75 Acres

Time of Concentration Line: 100’ sheet flow, 200’ shallow concentrated flow

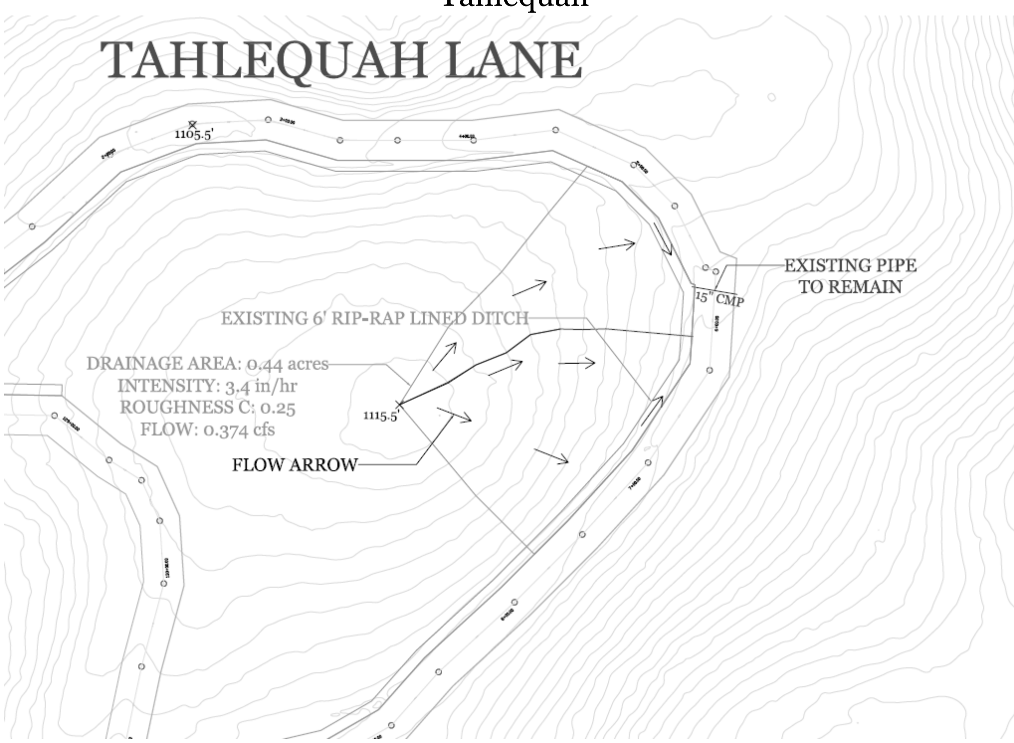
Sequoyah



Drainage Area: 0.66 Acres

Time of Concentration Line: 100' sheet flow, 162' shallow concentrated flow

Tahlequah



Drainage Area: 0.44 Acres

Time of Concentration Line: 100' sheet flow, 71' shallow concentrated flow

Time of Concentration NRCS Runoff Method

Sheet Flow $$T = \frac{0.007 \times (n \times L)^{0.8}}{P2^{0.5} \times s^{0.4}}$$

Shallow Concentrated Flow $$T = \frac{L}{3600 \times V}$$

	Sheet Flow						Shallow Concentrated Flow						
Location	Surface	Manning's n	Flow Length (ft)	2-yr, 24-hr Rainfall Depth (in)	Slope (ft/ft)	Sheet Flow Tc (hr)	Surface	Shallow Flow Velocity Factor	Flow Length (ft)	Slope (ft/ft)	Average Velocity (ft/s)	Shallow Concentrated Flow Tc (hr)	Total Tc (minutes)
Echota	Woods	0.45	100	2.8	0.04	0.319	Woodlands	5.032	200	0.063	1.258	0.044	21.8
Sequoyah	Woods	0.45	100	2.8	0.045	0.304	Woodlands	5.032	162	0.093	1.531	0.029	20.0
Tahlequah	Woods	0.45	100	2.8	0.045	0.304	Woodlands	5.032	71	0.099	1.580	0.012	19.0

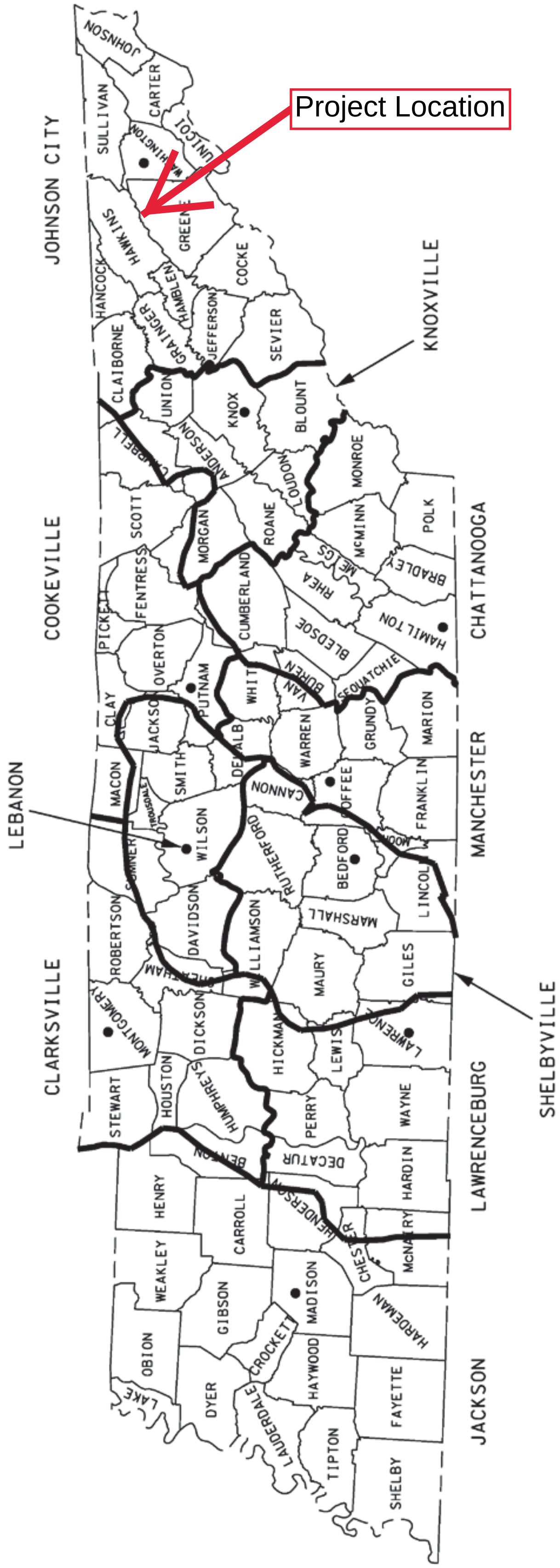


Figure 4A-1
IDF Zone Location Map

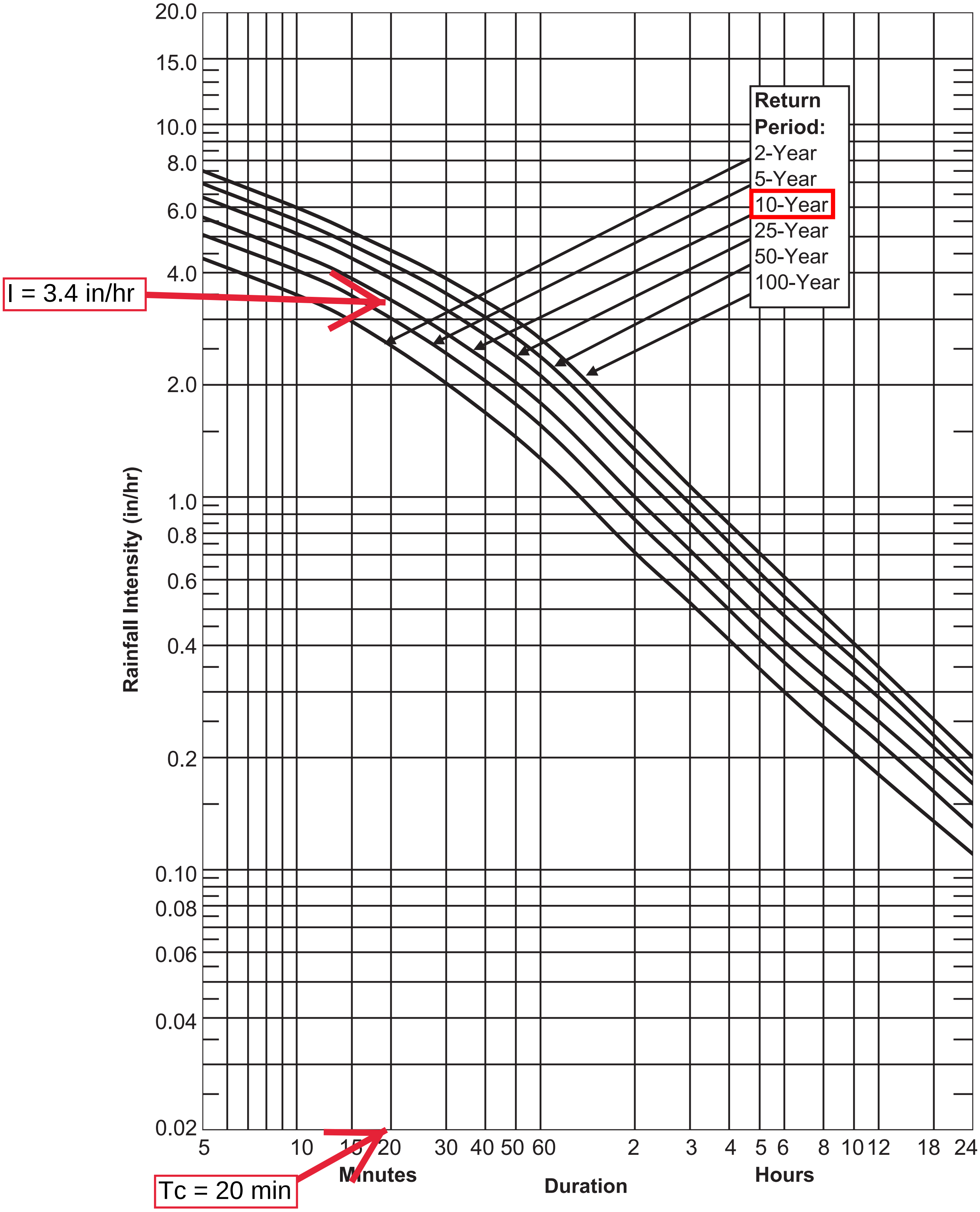


Figure 4A-6
Johnson City IDF Curve
NOTE: T_c = 5 minutes is a minimum value to use in all cases
Reference: National Weather Service, NOAA Atlas 14, Volume 2 (2004)

Rational Method $Q = CiA$

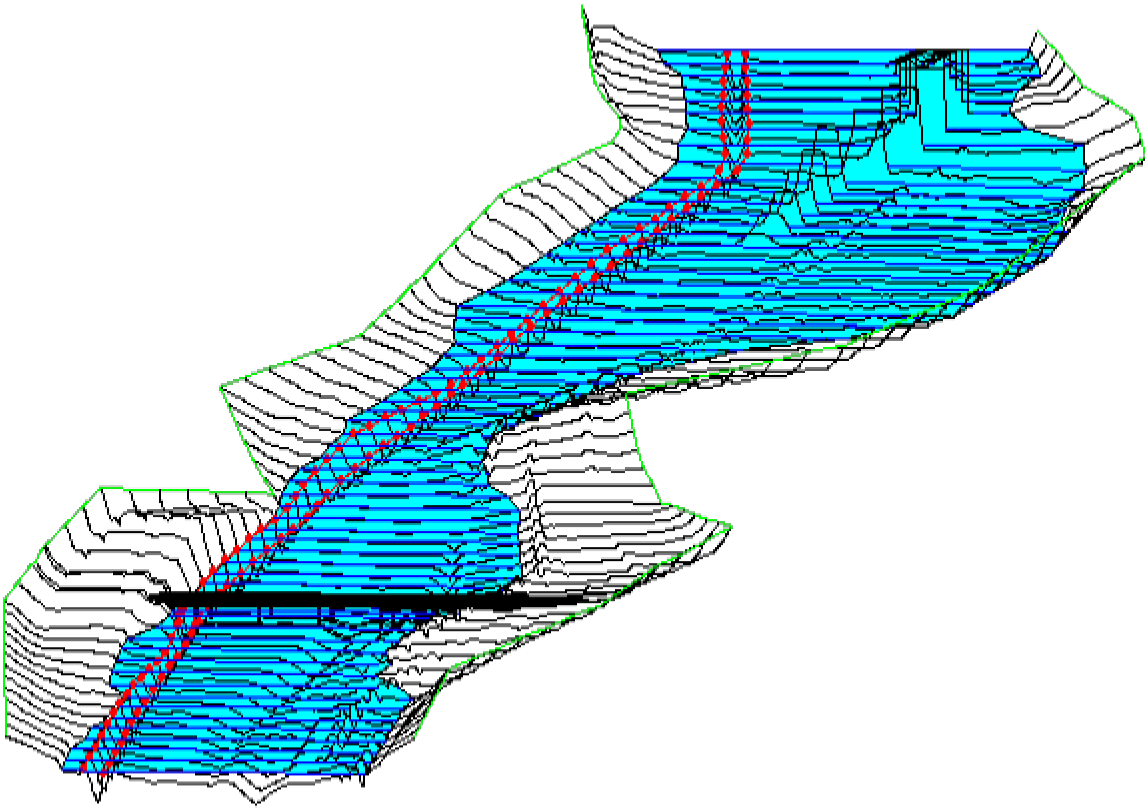
	C	i	A	Q	
Echota	0.25	3.4	0.75	0.6375	cfs
Sequoyah	0.25	3.4	0.66	0.561	cfs
Tahlequah	0.25	3.4	0.44	0.374	cfs

C	Runoff Coefficient
i	Rainfall Intensity (in/hr)
A	Area (Acres)
Q	Flow Rate

US Army Corps of Engineers®
Hydrologic Engineering Center

HEC-RAS

River Analysis System



Manning's Roughness Coefficient

Version 6.2

Exported - October 2022

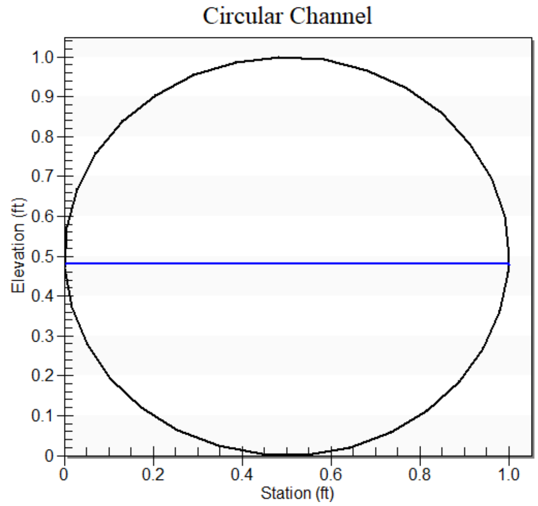
The Manning's roughness coefficients must be entered for each culvert type. HECRAS uses Manning's equation to compute friction losses in the culvert barrel, as described in the section entitled "Culvert Hydraulics" of this chapter. Suggested values for Manning's n values are listed in Table 6-1 and Table 6-2, and in many hydraulics reference books. Roughness coefficients should be adjusted according to individual judgment of the culvert condition.

Table 6-1 Manning's "n" for Closed Conduits Flowing Partly Full

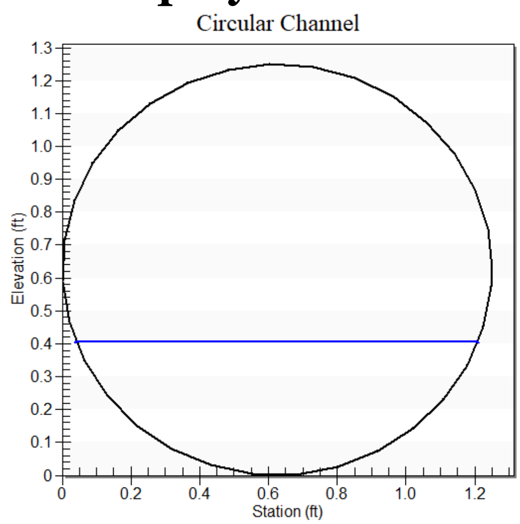
Type of Channel and Description	Minimum	Normal	Maximum
Brass, smooth:	0.009	0.010	0.013
Steel:			
Lockbar and welded	0.010	0.012	0.014
Riveted and spiral	0.013	0.016	0.017
Cast Iron:			
Coated	0.010	0.013	0.014
Uncoated	0.011	0.014	0.016
Wrought Iron:			
Black	0.012	0.014	0.015
Galvanized	0.013	0.016	0.017
Corrugated Metal:			
Subdrain	0.017	0.019	0.021
Storm Drain	0.021	0.024	0.030
Lucite:	0.008	0.009	0.010
Glass:	0.009	0.010	0.013
Cement:			
Neat, surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
Concrete:			
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and	0.011	0.013	0.014
some debris	0.011	0.012	0.014
Finished	0.013	0.015	0.017
Sewer with manholes, inlet, etc., straight	0.012	0.013	0.014
Unfinished, steel form	0.012	0.014	0.016
Unfinished, smooth wood form	0.015	0.017	0.020
Unfinished, rough wood form			
Wood:			
Stave	0.010	0.012	0.014
Laminated, treated	0.015	0.017	0.020

Flow Depths Determined in FHWA Hydraulic Toolbox

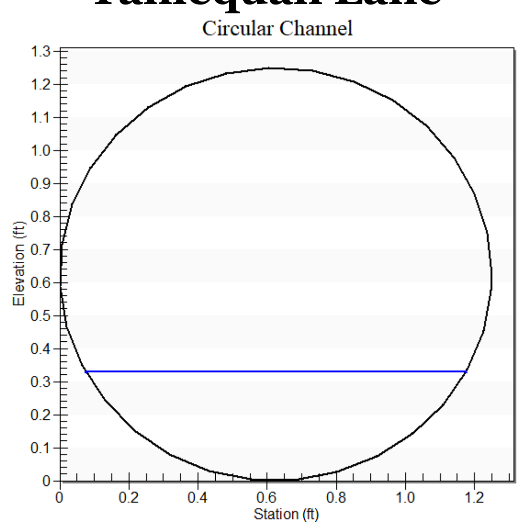
Echota Lane



Sequoyah Drive



Tahlequah Lane



Result: All pipes adequately sized

Show

Manning's n Values

Reference tables for Manning's n values for Channels, Closed Conduits Flowing Partially Full, and Corrugated Metal Pipes.

Manning's n for Channels (Chow, 1959).

Type of Channel and Description	**Minimum**	**Normal**	**Maximum**
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. dense willows, summer, straight	0.110	0.150	0.200
2. cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. heavy stand of timber, a few down trees, little	0.080	0.100	0.120

undergrowth, flood stage below branches			
5. same as 4. with flood stage reaching branches	0.100	0.120	0.160
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.020
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.030
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth winding and sluggish			
1. no vegetation	0.023	0.025	0.030
2. grass, some weeds	0.025	0.030	0.033
3. dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. earth bottom and rubble sides	0.028	0.030	0.035
5. stony bottom and weedy banks	0.025	0.035	0.040
6. cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. no vegetation	0.025	0.028	0.033
2. light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. smooth and uniform	0.025	0.035	0.040
2. jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.050	0.080	0.120
2. clean bottom, brush on sides	0.040	0.050	0.080
3. same as above, highest stage of flow	0.045	0.070	0.110
4. dense brush, high stage	0.080	0.100	0.140
5. Lined or Constructed Channels			
a. Cement			
1. neat surface	0.010	0.011	0.013
2. mortar	0.011	0.013	0.015
b. Wood			
1. planed, untreated	0.010	0.012	0.014
2. planed, creosoted	0.011	0.012	0.015
3. unplaned	0.011	0.013	0.015
4. plank with battens	0.012	0.015	0.018
5. lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.020
4. unfinished	0.014	0.017	0.020
5. gunite, good section	0.016	0.019	0.023
6. gunite, wavy section	0.018	0.022	0.025
7. on good excavated rock	0.017	0.020	

Proposed Manning's n value for ditches

8. on irregular excavated rock	0.022	0.027	
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.020
2. random stone in mortar	0.017	0.020	0.024
3. cement rubble masonry, plastered	0.016	0.020	0.024
4. cement rubble masonry	0.020	0.025	0.030
5. dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.020	0.025
2. random stone mortar	0.020	0.023	0.026
3. dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. glazed	0.011	0.013	0.015
2. in cement mortar	0.012	0.015	0.018
g. Masonry			
1. cemented rubble	0.017	0.025	0.030
2. dry rubble	0.023	0.032	0.035
h. Dressed ashlar/stone paving	0.013	0.015	0.017
i. Asphalt			
1. smooth	0.013	0.013	
2. rough	0.016	0.016	
j. Vegetal lining	0.030		0.500

Current Manning's n value for ditches

Manning's n for Closed Conduits Flowing Partly Full (Chow, 1959).

Type of Conduit and Description	Minimum	Normal	Maximum
1. Brass, smooth:	0.009	0.010	0.013
2. Steel:			
Lockbar and welded	0.010	0.012	0.014
Riveted and spiral	0.013	0.016	0.017
3. Cast Iron:			
Coated	0.010	0.013	0.014
Uncoated	0.011	0.014	0.016
4. Wrought Iron:			
Black	0.012	0.014	0.015
Galvanized	0.013	0.016	0.017
5. Corrugated Metal:			
Subdrain	0.017	0.019	0.021
Stormdrain	0.021	0.024	0.030
6. Cement:			
Neat Surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
7. Concrete:			
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016

Unfinished, rough wood form	0.015	0.017	0.020
8. Wood:			
Stave	0.010	0.012	0.014
Laminated, treated	0.015	0.017	0.020
9. Clay:			
Common drainage tile	0.011	0.013	0.017
Vitrified sewer	0.011	0.014	0.017
Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
Vitrified Subdrain with open joint	0.014	0.016	0.018
10. Brickwork:			
Glazed	0.011	0.013	0.015
Lined with cement mortar	0.012	0.015	0.017
Sanitary sewers coated with sewage slime with bends and connections	0.012	0.013	0.016
Paved invert, sewer, smooth bottom	0.016	0.019	0.020
Rubble masonry, cemented	0.018	0.025	0.030

Manning's n for Corrugated Metal Pipe (AISI, 1980).

Type of Pipe, Diameter and Corrugation Dimension	n
1. Annular 2.67 x 1/2 inch (all diameters)	0.024
2. Helical 1.50 x 1/4 inch	
8" diameter	0.012
10" diameter	0.014
3. Helical 2.67 x 1/2 inch	
12" diameter	0.011
18" diameter	0.014
24" diameter	0.016
36" diameter	0.019
48" diameter	0.020
60" diameter	0.021
4. Annular 3x1 inch (all diameters)	0.027
5. Helical 3x1 inch	
48" diameter	0.023
54" diameter	0.023
60" diameter	0.024
66" diameter	0.025
72" diameter	0.026
78" diameter and larger	0.027
6. Corrugations 6x2 inches	
60" diameter	0.033
72" diameter	0.032
120" diameter	0.030
180" diameter	0.028

FishXing Version 3.0 Beta, 2006

Appendix E: Construction Design

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
104-03.71	ADDITIONAL WORK	S.F.	2	$1.60	$12,560.00	7850.00
			STATE	$1.60	$12,560.00	7850.00
105-01	CONSTRUCTION STAKES, LINES AND GRADES	LS	1	$75,847.17	$379,235.87	5.00
			2	$54,627.46	$655,529.53	12.00
			3	$294,098.12	$3,088,030.25	10.50
			4	$445,602.55	$3,119,217.87	7.00
			STATE	$209,913.44	$7,242,013.52	34.50
108-03	CPM PROJECT SCHEDULE	LS	1	$73,027.50	$73,027.50	1.00
			3	$78,374.00	$156,748.00	2.00
			4	$133,812.34	$401,437.03	3.00
			STATE	$105,202.09	$631,212.53	6.00
109-04.20	FORCE ACCOUNT	DOLL	3	$1.00	$25,000.00	25000.00
			STATE	$1.00	$25,000.00	25000.00
109-10.01	TRAINEE	HOUR	1	$0.80	$7,792.00	9740.00
			3	$0.80	$6,736.00	8420.00
			4	$0.80	$13,184.00	16480.00
			STATE	$0.80	$27,712.00	34640.00
201-01	CLEARING AND GRUBBING	LS	1	$637,728.25	$3,826,369.51	6.00
			2	$157,671.36	$788,356.80	5.00
			3	$164,322.38	$1,314,579.00	8.00
			4	$171,397.37	$1,199,781.61	7.00
			STATE	$274,195.65	$7,129,086.92	26.00
201-05.31	VEGETATION REMOVAL	LS	1	$19,381.68	$19,381.68	1.00
			STATE	$19,381.68	$19,381.68	1.00
201-07.01	REMOVAL AND DISPOSAL OF BRUSH & TREES	LS	2	$11,082.32	$44,329.27	4.00
			STATE	$11,082.32	$44,329.27	4.00
202-01	REMOVAL OF STRUCTURES AND OBSTRUCTIONS	LS	1	$43,255.03	$43,255.03	1.00
			3	$34,120.00	$136,480.00	4.00
			4	$162,111.76	$648,447.02	4.00
			STATE	$92,020.23	$828,182.05	9.00
202-01.02	REMOVAL OF ASBESTOS	LS	2	$13,772.76	$13,772.76	1.00
			3	$11,879.17	$35,637.50	3.00
			4	$84,676.82	$254,030.47	3.00
			STATE	$43,348.68	$303,440.73	7.00
202-01.03	REMOVAL OF TRASH AND DEBRIS	LS	1	$19,381.68	$19,381.68	1.00
			STATE	$19,381.68	$19,381.68	1.00
202-01.05	REMOVAL OF ASBESTOS	LS	4	$126,259.51	$126,259.51	1.00
			STATE	$126,259.51	$126,259.51	1.00
202-01.13	REMOVAL OF PIPE	L.F.	2	$27.70	$3,102.60	112.00
			3	$31.00	$620.00	20.00
			4	$22.00	$594.00	27.00
			STATE	$27.15	$4,316.60	159.00
202-01.14	REMOVAL OF PIPE	L.F.	2	$34.25	$6,678.53	195.00
			STATE	$34.25	$6,678.53	195.00
202-01.15	REMOVAL OF PIPE	L.F.	2	$24.51	$710.79	29.00
			STATE	$24.51	$710.79	29.00
202-01.50	REMOVAL OF STRUCTURES AND OBSTRUCTIONS	EACH	2	$2,150.00	$15,050.00	7.00
			STATE	$2,150.00	$15,050.00	7.00
202-02.01	REMOVAL OF PIPE	L.F.	2	$43.00	$774.00	18.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			3	$30.00	$1,260.00	42.00
			4	$73.44	$7,050.00	96.00
			STATE	$58.23	$9,084.00	156.00
202-02.02	REMOVAL OF PIPE	L.F.	3	$30.00	$1,230.00	41.00
			4	$18.76	$1,501.00	80.00
			STATE	$22.57	$2,731.00	121.00
202-02.03	REMOVAL OF PIPE	L.F.	3	$30.00	$4,620.00	154.00
			4	$22.00	$2,112.00	96.00
			STATE	$26.93	$6,732.00	250.00
202-02.04	REMOVAL OF PIPE	L.F.	4	$22.00	$2,332.00	106.00
			STATE	$22.00	$2,332.00	106.00
202-02.20	REMOVAL OF PIPE	L.F.	2	$28.00	$6,580.00	235.00
			STATE	$28.00	$6,580.00	235.00
202-02.21	REMOVAL OF PIPE	L.F.	2	$28.00	$7,056.00	252.00
			3	$20.00	$22,880.00	1144.00
			4	$18.00	$3,924.00	218.00
			STATE	$20.98	$33,860.00	1614.00
202-02.22	REMOVAL OF PIPE	L.F.	2	$28.00	$12,068.00	431.00
			3	$20.00	$12,940.00	647.00
			4	$18.00	$3,978.00	221.00
			STATE	$22.31	$28,986.00	1299.00
202-02.23	REMOVAL OF PIPE	L.F.	2	$28.00	$5,796.00	207.00
			3	$25.00	$8,825.00	353.00
			STATE	$26.11	$14,621.00	560.00
202-02.24	REMOVAL OF PIPE	L.F.	3	$30.00	$6,420.00	214.00
			STATE	$30.00	$6,420.00	214.00
202-03	REMOVAL OF RIGID PVMT, SIDEWALK, ETC.	S.Y.	1	$115.40	$8,655.00	75.00
			3	$19.64	$28,462.50	1449.00
			4	$15.58	$114,954.40	7378.00
			STATE	$17.08	$152,071.90	8902.00
202-03.01	REMOVAL OF ASPHALT PAVEMENT	S.Y.	1	$12.00	$3,636.00	303.00
			3	$22.34	$1,289,521.60	57730.00
			4	$35.95	$549,593.10	15288.00
			STATE	$25.13	$1,842,750.70	73321.00
202-04.01	REMOVAL OF STRUCTURES	LS	1	$86,317.52	$258,952.56	3.00
			2	$84,370.22	$674,961.72	8.00
			3	$147,247.14	$736,235.72	5.00
			4	$70,268.14	$140,536.27	2.00
			STATE	$100,593.68	$1,810,686.27	18.00
202-04.02	REMOVAL OF STRUCTURES	LS	3	$130,000.00	$260,000.00	2.00
			4	$32,834.55	$65,669.09	2.00
			STATE	$81,417.27	$325,669.09	4.00
202-04.03	REMOVAL OF STRUCTURES	LS	3	$35,000.00	$35,000.00	1.00
			4	$229,426.07	$458,852.13	2.00
			STATE	$164,617.38	$493,852.13	3.00
202-04.04	REMOVAL OF STRUCTURES	LS	4	$216,406.83	$432,813.65	2.00
			STATE	$216,406.83	$432,813.65	2.00
202-04.50	REMOVAL OF STRUCTURES	LS	2	$13,030.09	$13,030.09	1.00
			STATE	$13,030.09	$13,030.09	1.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			STATE	$10.52	$27,975.00	2660.00
202-08.25	REMOVAL OF MEDIAN BARRIER	LS	2	$16,000.00	$16,000.00	1.00
			STATE	$16,000.00	$16,000.00	1.00
202-08.28	REMOVAL OF MEDIAN BARRIER	L.F.	2	$24.25	$8,730.00	360.00
			3	$25.00	$30,000.00	1200.00
			4	$26.43	$145,904.94	5521.00
			STATE	$26.07	$184,634.94	7081.00
203-01	ROAD & DRAINAGE EXCAVATION (UNCLIFIED)	C.Y.	1	$7.44	$4,526,244.60	608664.00
			2	$30.32	$2,167,975.78	71508.00
			3	$15.11	$13,677,487.60	905440.00
			4	$7.59	$4,415,018.43	581802.21
			STATE	$11.44	$24,786,726.41	2167414.21
203-01.06	ROAD & DRAINAGE EXCAVATION (UNCLASS)	LS	2	$25,856.08	$25,856.08	1.00
			STATE	$25,856.08	$25,856.08	1.00
203-01.11	PRESPLITTING OF ROCK EXCAVATION	S.Y.	3	$66.00	$75,966.00	1151.00
			STATE	$66.00	$75,966.00	1151.00
203-01.13	ROAD & DRAINAGE EXC (STREAM MITIGATION)	C.Y.	1	$53.09	$75,547.07	1423.00
			3	$20.00	$12,280.00	614.00
			STATE	$43.12	$87,827.07	2037.00
203-01.60	ROAD & DRAINAGE EXCAVATION	C.Y.	3	$165.00	$615,450.00	3730.00
			STATE	$165.00	$615,450.00	3730.00
203-01.61	ROAD & DRAINAGE EXCAVATION	C.Y.	3	$30.00	$310,380.00	10346.00
			STATE	$30.00	$310,380.00	10346.00
203-01.79	EXCAVATION/BACKFILL	C.Y.	3	$60.00	$21,900.00	365.00
			STATE	$60.00	$21,900.00	365.00
203-02.01	BORROW EXCAVATION (GRADED SOLID ROCK)	TON	1	$18.47	$1,145,998.26	62056.00
			3	$23.10	$10,495,932.20	454407.00
			STATE	$22.54	$11,641,930.46	516463.00
203-02.02	BORROW EXCAVATION (GRADED SOLID ROCK)	C.Y.	2	$46.44	$1,060,072.13	22828.00
			STATE	$46.44	$1,060,072.13	22828.00
203-02.05	BORROW EXCAVATION	C.Y.	2	$62.50	$13,812.50	221.00
			STATE	$62.50	$13,812.50	221.00
203-03	BORROW EXCAVATION (UNCLASSIFIED)	C.Y.	2	$34.83	$116,477.83	3344.00
			3	$16.65	$5,324,630.55	319811.00
			4	$4.82	$2,304,661.84	478311.63
			STATE	$9.66	$7,745,770.22	801466.63
203-03.01	BORROW EXCAVATION (SELECT MATERIAL)	C.Y.	4	$28.00	$2,072.00	74.00
			STATE	$28.00	$2,072.00	74.00
203-03.10	SELECT GRANULAR MATERIAL	TON	4	$20.80	$445,881.47	21435.56
			STATE	$20.80	$445,881.47	21435.56
203-04	PLACING AND SPREADING TOPSOIL	C.Y.	1	$2.55	$101,566.50	39830.00
			2	$21.40	$89,458.25	4181.00
			3	$11.91	$617,291.85	51821.82
			4	$5.27	$263,039.21	49890.40
			STATE	$7.35	$1,071,355.81	145723.21
203-05	UNDERCUTTING	C.Y.	2	$8.72	$2,267.20	260.00
			3	$25.48	$2,033,850.00	79810.00
			4	$7.97	$300,006.25	37641.00
			STATE	$19.85	$2,336,123.45	117711.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
203-06	WATER	M.G.	1	$11.56	$23,466.80	2030.00
			2	$20.63	$13,992.00	678.30
			3	$41.37	$2,064,232.00	49896.00
			4	$19.40	$157,190.35	8101.56
			STATE	$37.21	$2,258,881.15	60705.86
203-07	FURNISHING & SPREADING TOPSOIL	C.Y.	1	$38.00	$15,428.00	406.00
			2	$11.76	$12,287.38	1045.00
			3	$28.89	$50,785.50	1758.00
			4	$17.50	$507.50	29.00
			STATE	$24.40	$79,008.38	3238.00
203-08	CHANNEL EXCAVATION (UNCLASSIFIED)	C.Y.	1	$17.44	$24,799.68	1422.00
			2	$12.46	$6,915.30	555.00
			STATE	$16.04	$31,714.98	1977.00
203-10	EMBANKMENT (COMPACTED IN PLACE)	C.Y.	3	$7.00	$248,129.00	35447.00
			4	$15.00	$1,729,860.00	115324.00
			STATE	$13.12	$1,977,989.00	150771.00
203-10.05	SETTLEMENT PLATE / MONITORING DEVICE	EACH	4	$8,500.00	$17,000.00	2.00
			STATE	$8,500.00	$17,000.00	2.00
203-10.15	WASTE MATERIAL	C.Y.	4	$25.00	$356,250.00	14250.00
			STATE	$25.00	$356,250.00	14250.00
203-11	SCALING AND TRIMMING	S.Y.	1	$52.50	$551,722.50	10509.00
			STATE	$52.50	$551,722.50	10509.00
203-15.03	COMPACTED CLAY	C.Y.	3	$100.00	$5,200.00	52.00
			STATE	$100.00	$5,200.00	52.00
203-20.01	CHANNEL SUBSTRATE	C.Y.	1	$214.61	$22,319.44	104.00
			2	$26.68	$5,922.96	222.00
			3	$200.00	$2,800.00	14.00
			STATE	$91.30	$31,042.40	340.00
203-30.01	ROADWAY APPROACHES	LS	1	$33,445.00	$33,445.00	1.00
			2	$125,000.00	$125,000.00	1.00
			STATE	$79,222.50	$158,445.00	2.00
203-40.02	ROCK ANCHORS	L.F.	2	$117.00	$230,490.00	1970.00
			STATE	$117.00	$230,490.00	1970.00
203-40.17	ROCK DOWEL	L.F.	1	$159.20	$59,700.00	375.00
			STATE	$159.20	$59,700.00	375.00
203-50	CONSTRUCTION OF HAUL ROAD	LS	2	$169,134.81	$338,269.61	2.00
			3	$162,750.00	$325,500.00	2.00
			4	$198,000.00	$198,000.00	1.00
			STATE	$172,353.92	$861,769.61	5.00
203-50.01	CONSTRUCTION OF HAUL ROAD	LS	3	$125,000.00	$125,000.00	1.00
			STATE	$125,000.00	$125,000.00	1.00
204-02.01	DRY EXCAVATION (BRIDGES)	C.Y.	1	$29.97	$22,268.00	743.00
			2	$43.65	$48,534.00	1112.00
			3	$78.56	$47,998.00	611.00
			4	$24.42	$206,733.40	8466.00
			STATE	$29.78	$325,533.40	10932.00
204-02.10	DRILLED CAISSON - EARTH	L.F.	3	$81.00	$27,945.00	345.00
			4	$103.99	$326,943.00	3144.00
			STATE	$101.72	$354,888.00	3489.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			STATE	$61.40	$228,395.54	3720.00
209-65.14	TEMPORARY STREAM DIVERSION	LS	4	$1,000.00	$1,000.00	1.00
			STATE	$1,000.00	$1,000.00	1.00
303-01	MINERAL AGGREGATE, TY A BASE, GRADING D	TON	1	$30.98	$5,717,684.64	184567.00
			2	$39.78	$2,399,282.60	60308.20
			3	$31.46	$7,397,333.38	235124.72
			4	$35.96	$3,870,504.41	107644.89
			STATE	$32.99	$19,384,805.03	587644.81
303-01.01	GRANULAR BACKFILL (ROADWAY)	TON	1	$38.15	$342,968.50	8990.00
			2	$37.95	$40,640.11	1071.00
			3	$26.74	$27,164.00	1016.00
			4	$48.61	$929,245.61	19115.34
			STATE	$44.38	$1,340,018.22	30192.34
303-01.02	GRANULAR BACKFILL (BRIDGES)	TON	1	$45.72	$97,655.26	2136.00
			2	$48.48	$14,009.60	289.00
			3	$62.18	$16,230.00	261.00
			4	$112.26	$21,329.52	190.00
			STATE	$51.89	$149,224.38	2876.00
303-01.03	GRANULAR BACKFILL (RETAINING WALLS)	TON	2	$47.00	$302,022.00	6426.00
			4	$33.35	$45,956.30	1378.00
			STATE	$44.59	$347,978.30	7804.00
303-01.09	MINERAL AGGR,TY A BS,GRADING D LIMESTONE	TON	4	$34.00	$1,074,162.00	31593.00
			STATE	$34.00	$1,074,162.00	31593.00
303-02	MINERAL AGGR,TY B BASE, GR	TON	4	$41.07	$1,963,426.03	47812.05
			STATE	$41.07	$1,963,426.03	47812.05
303-10.01	MINERAL AGGREGATE (SIZE 57)	TON	1	$41.27	$786,094.19	19047.00
			2	$44.48	$227,182.08	5108.00
			3	$37.34	$1,522,531.00	40775.50
			4	$47.75	$593,477.03	12430.00
			STATE	$40.45	$3,129,284.30	77360.50
303-10.03	MINERAL AGGREGATE (SIZE 68)	TON	4	$57.00	$239.40	4.20
			STATE	$57.00	$239.40	4.20
303-10.04	MINERAL AGGREGATE	TON	2	$46.00	$56,028.00	1218.00
			STATE	$46.00	$56,028.00	1218.00
303-20.02	RIVER GRAVEL	TON	3	$90.00	$136,800.00	1520.00
			STATE	$90.00	$136,800.00	1520.00
304-01.04	PROCESSING (RECLAIMED BASE MATERIAL)	S.Y.	4	$5.29	$472,428.46	89255.00
			STATE	$5.29	$472,428.46	89255.00
304-01.08	PORTLAND CEMENT (FULL DEPTH RECLAMATION)	TON	4	$294.41	$933,585.00	3171.00
			STATE	$294.41	$933,585.00	3171.00
307-01.01	ASP. CONC. MIX(PG64-22) (BPMB-HM) GR. A	TON	1	$272.11	$15,238.16	56.00
			2	$98.66	$845,239.00	8567.50
			3	$117.42	$96,620.50	822.85
			4	$153.60	$1,477,756.00	9621.00
			STATE	$127.70	$2,434,853.66	19067.35
307-01.07	ASPHALT CONC MIX(PG64-22)(BPMB-HM)GR B-M	TON	3	$85.00	$25,500.00	300.00
			STATE	$85.00	$25,500.00	300.00
307-01.08	ASPHALT CONC MX(PG64-22)(BPMB-HM)GR B-M2	TON	1	$148.19	$482,789.70	3258.00
			2	$107.33	$1,390,586.62	12956.50

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			STATE	$608.61	$196,908.20	323.54
411-12.04	SCORING RUMBLE STRIPE (NON-CONT. 4IN)	L.M.	1	$446.30	$19,682.00	44.10
			2	$443.13	$62,082.42	140.10
			3	$551.90	$35,641.50	64.58
			4	$826.50	$88,661.99	107.27
			STATE	$578.75	$206,067.91	356.05
411-12.05	SCORING FOR CENTERLINE RUMBLE (4IN WIDTH	L.M.	1	$631.00	$5,994.50	9.50
			STATE	$631.00	$5,994.50	9.50
414-03.01	EMULSIFIED ASPHALT FOR MICRO-SURFACING	TON	1	$1,291.35	$450,681.15	349.00
			2	$967.25	$2,211,135.79	2286.00
			3	$1,081.64	$214,921.87	198.70
			4	$985.45	$1,126,369.35	1143.00
			STATE	$1,006.64	$4,003,108.16	3976.70
414-03.02	AGGREGATE FOR MICRO SURFACING	TON	1	$155.15	$451,641.65	2911.00
			2	$116.44	$2,213,681.98	19012.00
			3	$131.64	$215,231.40	1635.00
			4	$119.09	$1,126,394.25	9458.00
			STATE	$121.36	$4,006,949.28	33016.00
414-03.03	MICRO SURFACING	S.Y.	2	$2.87	$707,399.13	246437.00
			STATE	$2.87	$707,399.13	246437.00
414-04.03	ASPHALT EMULSION (SCRUB SEAL)	TON	2	$1,950.00	$251,550.00	129.00
			3	$1,895.00	$274,775.00	145.00
			4	$190.00	$19,000.00	100.00
			STATE	$1,458.09	$545,325.00	374.00
414-04.04	MINERAL AGGREGATE(SCRUB SEAL)	TON	2	$80.00	$85,280.00	1066.00
			3	$76.00	$91,580.00	1205.00
			4	$86.00	$71,380.00	830.00
			STATE	$80.05	$248,240.00	3101.00
415-01.01	COLD PLANING BITUMINOUS PAVEMENT	TON	1	$24.20	$4,039,593.89	166937.00
			2	$28.44	$5,746,799.67	202071.00
			3	$29.77	$13,032,261.27	437705.00
			4	$34.82	$4,098,514.65	117695.00
			STATE	$29.12	$26,917,169.48	924408.00
415-01.02	COLD PLANING BITUMINOUS PAVEMENT	S.Y.	1	$7.23	$423,553.97	58563.00
			2	$6.21	$555,665.44	89518.00
			3	$5.75	$182,812.99	31766.00
			4	$5.24	$441,174.99	84218.00
			STATE	$6.07	$1,603,207.39	264065.00
501-01.03	PORTLAND CEM CONCRETE PVMT (PLAIN) 10"	S.Y.	3	$130.00	$3,772,860.00	29022.00
			4	$179.51	$3,270,672.20	18220.00
			STATE	$149.09	$7,043,532.20	47242.00
501-01.04	PORTLAND CEM CONCRETE PVMT (PLAIN) 11"	S.Y.	4	$161.39	$4,422,570.17	27403.00
			STATE	$161.39	$4,422,570.17	27403.00
501-01.16	PORTLAND CEM CNC PVMT (PL) 13"FAST TRACK	S.Y.	2	$379.00	$3,274,181.00	8639.00
			STATE	$379.00	$3,274,181.00	8639.00
501-01.42	PARTIAL DEPTH PCC PAVEMENT REPAIR	S.Y.	3	$400.00	$100,000.00	250.00
			STATE	$400.00	$100,000.00	250.00
501-03.10	CONCRETE SHOULDER RUMBLE STRIPS	L.F.	2	$3.50	$15,925.00	4550.00
			4	$15.71	$7,148.05	455.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			3	$8.93	$187,889.64	21046.46
			4	$9.24	$96,510.21	10445.00
			STATE	$9.11	$311,168.10	34149.46
604-04.02	APPLIED TEXTURE FINISH (EX STRUCTURES)	S.Y.	1	$11.87	$48,920.60	4123.00
			2	$13.05	$47,153.82	3612.00
			4	$11.08	$170,260.80	15371.00
			STATE	$11.53	$266,335.22	23106.00
604-04.03	BRIDGE END DRAINS(2'X8')	EACH	4	$3,731.94	$3,731.94	1.00
			STATE	$3,731.94	$3,731.94	1.00
604-04.05	BRIDGE END DRAINS	EACH	4	$3,000.00	$3,000.00	1.00
			STATE	$3,000.00	$3,000.00	1.00
604-04.41	THREE STAR STATE EMBLEM	EACH	1	$1,200.00	$4,800.00	4.00
			3	$1,500.00	$18,000.00	12.00
			4	$4,452.71	$115,770.40	26.00
			STATE	$3,299.30	$138,570.40	42.00
604-05.31	BRIDGE DECK GROOVING (MECHANICAL)	S.Y.	1	$8.65	$27,871.32	3223.00
			2	$13.00	$26,780.00	2060.00
			3	$6.00	$59,396.95	9906.00
			4	$3.08	$128,119.36	41604.00
			STATE	$4.26	$242,167.63	56793.00
604-07.01	RETAINING WALL	S.F.	2	$48.00	$242,304.00	5048.00
			3	$74.97	$1,048,188.00	13982.00
			4	$86.20	$1,199,008.50	13910.00
			STATE	$75.58	$2,489,500.50	32940.00
604-07.02	RETAINING WALL	S.F.	3	$90.72	$550,860.00	6072.00
			4	$59.27	$922,097.71	15557.98
			STATE	$68.10	$1,472,957.71	21629.98
604-07.03	RETAINING WALL	S.F.	2	$284.00	$30,956.00	109.00
			3	$88.50	$1,461,172.50	16510.00
			4	$115.87	$2,123,396.70	18326.00
			STATE	$103.46	$3,615,525.20	34945.00
604-07.04	RETAINING WALL	S.F.	3	$120.00	$607,320.00	5061.00
			4	$96.76	$1,216,919.99	12577.00
			STATE	$103.43	$1,824,239.99	17638.00
604-07.05	RETAINING WALL	S.F.	4	$136.57	$353,716.30	2590.00
			STATE	$136.57	$353,716.30	2590.00
604-07.06	RETAINING WALL	S.F.	4	$137.83	$1,250,945.08	9076.00
			STATE	$137.83	$1,250,945.08	9076.00
604-07.07	RETAINING WALL	S.F.	4	$54.30	$136,455.90	2513.00
			STATE	$54.30	$136,455.90	2513.00
604-07.08	RETAINING WALL	S.F.	4	$99.29	$135,928.01	1369.00
			STATE	$99.29	$135,928.01	1369.00
604-07.09	RETAINING WALL	S.F.	4	$94.90	$324,368.20	3418.00
			STATE	$94.90	$324,368.20	3418.00
604-07.10	RETAINING WALL	S.F.	4	$134.02	$278,895.62	2081.00
			STATE	$134.02	$278,895.62	2081.00
604-07.11	RETAINING WALL	S.F.	4	$96.76	$101,694.76	1051.00
			STATE	$96.76	$101,694.76	1051.00
604-07.12	RETAINING WALL	S.F.	4	$70.37	$90,847.67	1291.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			STATE	$427.81	$505,675.00	1182.00
702-01	CONCRETE CURB	C.Y.	2	$1,274.00	$36,946.00	29.00
			3	$515.64	$423,340.00	821.00
			4	$1,523.00	$112,702.26	74.00
			STATE	$620.12	$572,988.26	924.00
702-01.01	EXTRUDED SLOPING CURB	L.F.	3	$29.27	$25,640.00	876.00
			4	$35.00	$19,845.00	567.00
			STATE	$31.52	$45,485.00	1443.00
702-02	CONCRETE GUTTER	C.Y.	4	$667.63	$22,375.62	33.52
			STATE	$667.63	$22,375.62	33.52
702-03	CONCRETE COMBINED CURB & GUTTER	C.Y.	1	$992.86	$27,800.00	28.00
			2	$565.63	$416,416.75	736.20
			3	$408.39	$993,607.00	2433.00
			4	$628.00	$374,916.00	597.00
			STATE	$477.77	$1,812,739.75	3794.20
703-01	PORTLAND CEMENT CONCRETE DITCH PAVING	C.Y.	2	$580.00	$34,800.00	60.00
			3	$1,100.00	$4,400.00	4.00
			4	$800.00	$30,400.00	38.00
			STATE	$682.35	$69,600.00	102.00
703-02	CEM CONCRETE DITCH PAVING (REINFORCED)	C.Y.	4	$1,273.57	$75,140.63	59.00
			STATE	$1,273.57	$75,140.63	59.00
705-01.01	GUARDRAIL AT BRIDGE ENDS	L.F.	1	$68.00	$25,500.00	375.00
			2	$85.00	$22,950.00	270.00
			3	$79.50	$27,825.00	350.00
			4	$107.97	$27,814.00	257.60
			STATE	$83.10	$104,089.00	1252.60
705-01.02	GUARDRAIL AT BRIDGE PIERS	L.F.	1	$30.00	$1,200.00	40.00
			2	$35.00	$630.00	18.00
			3	$50.00	$1,750.00	35.00
			4	$85.00	$1,700.00	20.00
			STATE	$46.73	$5,280.00	113.00
705-01.04	METAL BEAM GUARD FENCE	L.F.	1	$58.00	$10,440.00	180.00
			2	$80.64	$28,344.88	351.50
			3	$79.50	$7,950.00	100.00
			4	$87.44	$18,100.86	207.00
			STATE	$77.32	$64,835.74	838.50
705-01.13	ROCK DRILLING FOR GUARDRAIL POST	EACH	3	$85.25	$53,025.50	622.00
			STATE	$85.25	$53,025.50	622.00
705-01.50	SHOP CURVED GUARDRAIL AT BR ENDS	L.F.	1	$30.00	$1,050.00	35.00
			STATE	$30.00	$1,050.00	35.00
705-02.01	SINGLE GUARDRAIL, WITH RUB-RAIL (TYPE 2)	L.F.	1	$18.25	$3,650.00	200.00
			2	$35.00	$875.00	25.00
			3	$39.15	$5,139.06	131.25
			4	$36.00	$4,500.00	125.00
			STATE	$29.43	$14,164.06	481.25
705-02.02	SINGLE GUARDRAIL (TYPE 2)	L.F.	1	$24.78	$655,191.25	26435.00
			2	$33.45	$1,003,500.00	30000.00
			3	$30.00	$900,000.00	30000.00
			4	$35.00	$210,000.00	6000.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			4	$23.77	$17,018.25	716.00
			STATE	$23.35	$27,830.61	1192.00
712-06	SIGNS (CONSTRUCTION)	S.F.	1	$8.89	$402,172.97	45242.00
			2	$8.70	$497,637.10	57191.50
			3	$8.59	$812,621.34	94641.83
			4	$8.18	$542,771.45	66337.06
			STATE	$8.56	$2,255,202.86	263412.40
712-06.16	SIGNS (CNSTR)(REDUCED SPEED WARNING)	EACH	1	$585.33	$8,780.00	15.00
			3	$679.39	$25,817.00	38.00
			4	$1,424.58	$17,094.92	12.00
			STATE	$795.26	$51,691.92	65.00
712-06.20	OVERHEAD SIGN COVERING	S.F.	4	$30.00	$15,000.00	500.00
			STATE	$30.00	$15,000.00	500.00
712-07.02	TEMPORARY BARRICADES (TYPE II)	L.F.	2	$23.56	$777.48	33.00
			4	$13.97	$1,341.00	96.00
			STATE	$16.42	$2,118.48	129.00
712-07.03	TEMPORARY BARRICADES (TYPE III)	L.F.	1	$21.56	$15,935.14	739.00
			2	$15.63	$9,219.14	590.00
			3	$19.81	$18,324.72	925.00
			4	$18.05	$52,695.68	2920.00
			STATE	$18.59	$96,174.68	5174.00
712-08.03	ARROW BOARD (TYPE C)	EACH	1	$1,166.75	$64,171.14	55.00
			2	$1,290.48	$150,985.64	117.00
			3	$1,278.02	$323,340.20	253.00
			4	$1,363.20	$140,409.20	103.00
			STATE	$1,285.81	$678,906.18	528.00
712-08.08	SPEED FEEDBACK SIGN ASSEMBLY	EACH	1	$5,833.33	$35,000.00	6.00
			2	$5,004.85	$30,029.10	6.00
			3	$3,680.94	$66,257.00	18.00
			4	$5,805.82	$29,029.08	5.00
			STATE	$4,580.43	$160,315.18	35.00
712-08.09	DIGITAL SPEED LIMIT SIGN ASSMBLY	EACH	1	$6,445.14	$225,580.00	35.00
			2	$5,360.48	$128,651.62	24.00
			3	$4,335.11	$359,814.00	83.00
			4	$3,700.00	$37,000.00	10.00
			STATE	$4,941.09	$751,045.62	152.00
712-08.10	MOBILE MESSAGE SIGN UNIT W/ATTENUATOR	HOUR	2	$114.46	$139,640.00	1220.00
			3	$103.82	$680,000.00	6550.00
			4	$120.00	$150,000.00	1250.00
			STATE	$107.50	$969,640.00	9020.00
712-08.12	QUEUE PROTECTION TRUCK	DAY	1	$1,571.43	$220,000.00	140.00
			3	$1,477.29	$3,250,040.00	2200.00
			4	$1,172.18	$1,734,832.00	1480.00
			STATE	$1,362.53	$5,204,872.00	3820.00
712-08.13	QUEUE PROTECTION TRUCK (EMRGNCY CLL OUT)	DAY	4	$1,537.07	$46,112.10	30.00
			STATE	$1,537.07	$46,112.10	30.00
712-08.14	PORTABLE QUEUE WARNING SYSTEM	DAY	1	$750.00	$390,000.00	520.00
			2	$2,216.40	$110,820.00	50.00
			3	$4,400.00	$70,400.00	16.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
713-17.50	SIGN MOUNTED ON BRIDGE PARAPET	EACH	4	$713.64	$13,559.16	19.00
			STATE	$713.64	$13,559.16	19.00
713-17.60	SIGN MOUNTED ON CONC MEDIAN B.R	EACH	4	$713.64	$9,277.32	13.00
			STATE	$713.64	$9,277.32	13.00
713-20.30	SIGN ADJUSTMENTS	EACH	1	$350.00	$1,750.00	5.00
			2	$325.00	$650.00	2.00
			3	$520.00	$27,040.00	52.00
			4	$300.00	$15,000.00	50.00
			STATE	$407.71	$44,440.00	109.00
713-20.40	GRAFFITI REMOVAL	S.F.	1	$3.15	$1,575.00	500.00
			2	$3.15	$1,575.00	500.00
			3	$3.15	$1,575.00	500.00
			4	$3.50	$875.00	250.00
			STATE	$3.20	$5,600.00	1750.00
713-30.08	BARRIER MOUNTED PERF/KNOCKOUT SIGN SUPP.	LB.	4	$4.25	$318.75	75.00
			STATE	$4.25	$318.75	75.00
713-30.09	BARRIER MOUNTED SIGN SUPPORT	EACH	1	$825.00	$6,600.00	8.00
			2	$825.00	$1,650.00	2.00
			3	$1,146.43	$8,025.00	7.00
			4	$430.85	$5,601.00	13.00
			STATE	$729.20	$21,876.00	30.00
713-30.10	BARRIER MOUNTED SIGN SUPPORT (PERF)	EACH	1	$425.00	$2,125.00	5.00
			2	$425.00	$850.00	2.00
			3	$425.00	$425.00	1.00
			4	$425.00	$425.00	1.00
			STATE	$425.00	$3,825.00	9.00
714-01.01	STRUCTURAL LIGHTING	LS	3	$260,000.00	$260,000.00	1.00
			4	$32,447.72	$64,895.44	2.00
			STATE	$108,298.48	$324,895.44	3.00
714-01.02	STRUCTURAL LIGHTING	LS	4	$54,895.44	$54,895.44	1.00
			STATE	$54,895.44	$54,895.44	1.00
714-01.20	STRUCTURAL LIGHTING	LS	3	$42,000.00	$42,000.00	1.00
			STATE	$42,000.00	$42,000.00	1.00
714-02.01	ENCASED CONDUIT (2" PVC, SCHEDULE 80)	L.F.	3	$87.00	$295,800.00	3400.00
			STATE	$87.00	$295,800.00	3400.00
714-02.02	ENCASED CONDUIT (2" PVC, SCHEDULE 40)	L.F.	4	$8.20	$37,884.00	4620.00
			STATE	$8.20	$37,884.00	4620.00
714-03	JACKED OR BORED CONDUIT	L.F.	3	$170.00	$76,500.00	450.00
			4	$24.49	$9,060.00	370.00
			STATE	$104.34	$85,560.00	820.00
714-03.01	DIRECT BRL CONDUIT (2"PVC, SCHEDULE 40)	L.F.	3	$42.80	$1,267,436.40	29613.00
			4	$15.58	$236,327.97	15168.00
			STATE	$33.58	$1,503,764.37	44781.00
714-04.01	CONDUIT (STRUCTURES - 1" RGS)	L.F.	4	$15.51	$31,190.61	2011.00
			STATE	$15.51	$31,190.61	2011.00
714-04.03	CONDUIT	L.F.	4	$191.80	$5,754.00	30.00
			STATE	$191.80	$5,754.00	30.00
714-05.02	PULL BOXES (TYPE A)	EACH	4	$713.02	$1,426.04	2.00
			STATE	$713.02	$1,426.04	2.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
716-50.01	ROADWAY CLEANING FOR PAVEMENT MARKING	L.M.	1	$50.00	$1,100.00	22.00
			2	$117.50	$2,350.00	20.00
			3	$100.00	$2,600.00	26.00
			4	$255.81	$11,000.00	43.00
			STATE	$153.60	$17,050.00	111.00
717-01	MOBILIZATION	LS	*	$500.00	$500.00	1.00
			1	$143,801.01	$6,039,642.42	42.00
			2	$90,709.66	$5,896,127.79	65.00
			3	$192,656.71	$13,004,327.77	67.50
			4	$275,179.61	$12,933,441.84	47.00
			STATE	$170,220.40	$37,874,039.82	222.50
717-01.03	MOBILIZATION (PER CALL-OUT)	EACH	1	$2,500.00	$25,000.00	10.00
			2	$2,500.00	$20,000.00	8.00
			3	$4,250.00	$63,750.00	15.00
			4	$2,200.00	$35,200.00	16.00
			STATE	$2,937.76	$143,950.00	49.00
717-01.04	MOBILIZATION	EACH	*	$500.00	$5,000.00	10.00
			1	$648.90	$44,125.00	68.00
			2	$1,267.86	$35,500.00	28.00
			3	$1,254.72	$66,500.00	53.00
			4	$1,892.31	$123,000.00	65.00
			STATE	$1,223.77	$274,125.00	224.00
718-01.01	NOISE BARRIER	S.F.	3	$74.00	$1,358,492.00	18358.00
			4	$68.45	$2,003,556.39	29271.00
			STATE	$70.59	$3,362,048.39	47629.00
718-01.02	NOISE BARRIER	S.F.	4	$61.85	$2,205,509.15	35659.00
			STATE	$61.85	$2,205,509.15	35659.00
719-01	SWEEPING	L.M.	3	$45.15	$1,023,099.00	22660.00
			STATE	$45.15	$1,023,099.00	22660.00
719-01.02	ROADWAY SWEEPING	L.M.	4	$69.77	$129,004.73	1849.00
			STATE	$69.77	$129,004.73	1849.00
719-01.11	SWEEPING	L.M.	4	$69.77	$1,068,039.16	15308.00
			STATE	$69.77	$1,068,039.16	15308.00
719-01.21	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.22	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.23	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.24	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.25	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.26	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.27	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00
719-01.28	STRUCTURE AND SITE CLEANING	LS	3	$300.00	$300.00	1.00
			STATE	$300.00	$300.00	1.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			3	$1,941.33	$23,296.00	12.00
			STATE	$1,836.00	$29,376.00	16.00
730-26.14	PEDESTRIAN PUSHBUTTON ADJUSTMENT	EACH	4	$1,260.00	$2,520.00	2.00
			STATE	$1,260.00	$2,520.00	2.00
730-35.01	RF DATA SYSTEM	EACH	4	$6,038.50	$6,038.50	1.00
			STATE	$6,038.50	$6,038.50	1.00
730-35.06	BATTERY BACK-UP AND POWER CONDITIONER	EACH	2	$8,200.00	$8,200.00	1.00
			3	$49,000.00	$147,000.00	3.00
			4	$17,511.65	$17,511.65	1.00
			STATE	$34,542.33	$172,711.65	5.00
730-40	TEMPORARY TRAFFIC SIGNAL SYSTEM	EACH	1	$49,338.48	$197,353.91	4.00
			2	$9,780.00	$9,780.00	1.00
			3	$75,528.00	$377,640.00	5.00
			4	$25,000.00	$50,000.00	2.00
			STATE	$52,897.83	$634,773.91	12.00
730-40.02	TEMPORARY TRAFFIC SIGNAL SYSTEM	LS	2	$36,982.94	$147,931.74	4.00
			4	$43,477.19	$43,477.19	1.00
			STATE	$38,281.79	$191,408.93	5.00
730-50.10	SOLAR POWERED FLASHING ASSEMBLY	EACH	4	$8,350.00	$66,800.00	8.00
			STATE	$8,350.00	$66,800.00	8.00
730-50.20	RECT RAPID FLASHING BEACON ASSM(SOLAR P)	EACH	4	$12,378.92	$74,273.52	6.00
			STATE	$12,378.92	$74,273.52	6.00
730-99.01	TRAINING	LS	4	$54,895.44	$54,895.44	1.00
			STATE	$54,895.44	$54,895.44	1.00
740-06.01	GEOMEMBRANE	S.Y.	2	$15.13	$21,872.18	1446.00
			STATE	$15.13	$21,872.18	1446.00
740-07.03	GEOGRID REINFORCEMENT TYPE 1	S.Y.	4	$5.50	$22,764.50	4139.00
			STATE	$5.50	$22,764.50	4139.00
740-07.04	GEOGRID REINFORCEMENT TYPE 2	S.Y.	1	$4.20	$10,130.40	2412.00
			2	$6.37	$54,789.50	8599.00
			3	$2.56	$35,541.00	13905.00
			4	$5.36	$102,913.50	19185.00
			STATE	$4.61	$203,374.40	44101.00
740-10.03	GEOTEXTILE (TYPE III)(EROSION CONTROL)	S.Y.	1	$4.08	$70,455.05	17274.00
			2	$3.84	$19,306.51	5024.00
			3	$2.14	$51,003.90	23820.00
			4	$2.89	$181,347.94	62796.05
			STATE	$2.96	$322,113.40	108914.05
740-10.04	GEOTEXTILE (TYPE IV) (STABILIZATION)	S.Y.	1	$4.46	$6,509.87	1461.00
			2	$3.39	$32,890.45	9699.00
			3	$1.04	$196,038.84	188372.00
			4	$2.05	$105,938.69	51788.97
			STATE	$1.36	$341,377.85	251320.97
740-11.01	TEMPORARY SEDIMENT TUBE 8IN	L.F.	3	$6.79	$28,450.00	4190.00
			4	$4.39	$22,538.26	5134.00
			STATE	$5.47	$50,988.26	9324.00
740-11.02	TEMPORARY SEDIMENT TUBE 12IN	L.F.	1	$3.57	$82,263.51	23043.00
			3	$5.44	$79,693.80	14659.00
			4	$2.57	$162,006.16	62941.00

Item Number	Description	Unit of Measure	Region	Average Unit Price	Total Cost	Total Quantity
			STATE	$3.66	$40,353.98	11020.83
805-01.02	TURF REINFORCEMENT MAT (CLASS II)	S.Y.	1	$5.88	$1,528.80	260.00
			2	$94.50	$3,024.00	32.00
			3	$13.60	$3,889.05	286.00
			4	$11.00	$110.00	10.00
			STATE	$14.54	$8,551.85	588.00
805-12.01	EROSION CONTROL BLANKET (TYPE I)	S.Y.	1	$1.02	$26,810.10	26370.00
			2	$1.15	$8,291.05	7229.00
			STATE	$1.04	$35,101.15	33599.00
805-12.02	EROSION CONTROL BLANKET (TYPE II)	S.Y.	1	$0.95	$166,273.75	175025.00
			2	$1.36	$4,201.28	3098.00
			3	$1.00	$46,913.00	46802.00
			4	$2.50	$1,250.00	500.00
			STATE	$0.97	$218,638.03	225425.00
805-12.03	EROSION CONTROL BLANKET (TYPE III)	S.Y.	1	$1.37	$43,226.24	31552.00
			3	$3.50	$339.50	97.00
			STATE	$1.38	$43,565.74	31649.00
805-12.08	700 GRAM COIR FIBER EROSION BLANKET	S.Y.	1	$3.78	$2,929.50	775.00
			3	$7.00	$5,145.00	735.00
			4	$11.00	$5,500.00	500.00
			STATE	$6.75	$13,574.50	2010.00
806-02.03	PROJECT MOWING	CYCL	1	$1,500.00	$22,500.00	15.00
			2	$3,000.00	$18,000.00	6.00
			3	$4,450.00	$35,600.00	8.00
			4	$8,863.64	$97,500.00	11.00
			STATE	$4,340.00	$173,600.00	40.00
806-02.12	MOWING, WEEDEATING & LITTER PICKUP(URBN)	CYCL	4	$11,199.24	$134,390.88	12.00
			STATE	$11,199.24	$134,390.88	12.00
908-21.01	BEARINGS	EACH	4	$16,147.58	$96,885.48	6.00
			STATE	$16,147.58	$96,885.48	6.00
908-21.02	BEARINGS	EACH	4	$16,147.58	$96,885.48	6.00
			STATE	$16,147.58	$96,885.48	6.00
908-21.03	BEARINGS	EACH	4	$16,147.58	$96,885.48	6.00
			STATE	$16,147.58	$96,885.48	6.00
908-21.04	BEARINGS	EACH	4	$16,147.58	$96,885.48	6.00
			STATE	$16,147.58	$96,885.48	6.00
930-08.28	LOADING TEST (GROUTED ANCHOR)	EACH	2	$8,330.00	$33,320.00	4.00
			STATE	$8,330.00	$33,320.00	4.00
930-08.29	PROOF LOADING TEST (GROUTED ANCHOR)	EACH	2	$1,330.00	$47,880.00	36.00
			STATE	$1,330.00	$47,880.00	36.00
930-08.30	EXTENDED CREEP LOADING TEST (GRTD ANCHR)	EACH	2	$16,700.00	$33,400.00	2.00
			STATE	$16,700.00	$33,400.00	2.00

ITEM NUMBER	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT PRICE 2022	COST ESTIMATED		UNIT PRICE STATE	UNIT PRICE 2021
A	**PAVEMENT RECONSTRUCTION**							
203-01	ROAD & DRAINAGE EXCAVATION (UNCLIFIED)	C.Y.		$ 7.44				
203-01.05	EXCAVATION/ BACKFILL	C.Y.		$ 60.00				
203-02.01	BORROW EXCAVATION (SOLID ROCK)	TON		$ 18.47				
203-04	PLACING AND SPREADING TOPSOIL	C.Y.		$ 2.55				
203-07	FURNISHING AND SPREADING TOPSOIL	C.Y.		$ 38.00				
202-03.01	REMOVAL OF ASPHALT PAVEMENT	S.Y.		$ 12.00				
402-01	BITUMINOUS MATERIAL FOR PRIME COAT (PC)	TON		$ 75.86				
403-01	BITUMINOUS MATERIAL FOR TACK COAT (TC)	TON		$ 750.19				
303-01	MINERAL AGGREGATE, TYPE A BASE, GRADING D	TON	21	$ 30.98	$ 639	PER 100FT		
303-01.01	GRANULAR BACKFILL (ROADWAY)	TON		$ 38.15				
303-10.01	MINERAL AGGREGATE (SIZE 57)	TON	115	$ 41.27	$ 4,729	PER 100FT		
307-01.08	ASPHALT CONCRETE MIX (PG64-22)(BPMB-HM) GR B-M2	TON	32	$ 148.19	$ 4,670	PER 100FT		
501.03.10	CONCRETE SHOULDER RUMBLE STRIPS	L.F.		$ 4.61				
B	**SLOPE STABILIZATION**							
604-07.01	RETAININGWALL	S.F.		$ 75.58			$ 75.58	
303-01.03	GRANULAR BACKFILL (RETAINING WALLS)	TON		$ 44.59			$ 44.59	
801-01	SEEDING (WITH MULCH)	S.Y.		$ 37.80				
805-12.01	EROSION CONTROL BLANKET (TYPE I)	S.Y.		$ 1.02				
805-12.02	EROSION CONTROL BLANKET (TYPE II)	S.Y.		$ 0.95				
C	**DRAINAGE**							
604-02.30	CONCRETE CULVERT ENCASEMENT	L.F.		$ 1,515.35				
607-50.06	PRECAST CONCRETE BOX CULVERT (12' X 8')	L.F.		$ 3,660.00				
607-03.02	18" CONCRETE PIPE (III)	L.F.		$ 77.41				
607-05.02	24" CONCRETE PIPE (III)	L.F.		$ 104.05				
607-06.02	30" CONCRETE PIPE (CLASS)	L.F.		$ 179.45				
740-10.01	GEOTEXTILE (TYPE I)(SUBSURFACE DRAINAGE)	S.Y.						
740-10.03	GEOTEXTILE (TYPE III)(EROSION CONTROL)	S.Y.		$ 4.08				
740-10.04	GEOTEXTILE (TYPE IV)(STABILIZATION)	S.Y.		$ 4.46				
D	**CONSTRUCTION AND EQUIPMENTS**							
717-01.04	EQUIPMENT MOBILIZATION	EACH		$ 648.90				
105-01	CONSTRUCTION STAKES, LINES AND GRADES	L.S.		$ 75,847.17				
712-06	SIGNS (CONSTRUCTION)	S.F.		$ 8.89				
712-06.16	SIGNS (CONSTRUCTION)(REDUCED SPEED WARNING)	EACH		$ 585.33				
712-07.03	TEMPORARY BARRICADES (TYPE III)	L.F.		$ 21.56				
E	**SAFETY UPGRADES**							
713-20.30	SIGN ADJUSTMENTS	EACH		$ 350.00				
705-02.02	SINGLE GUARDRAIL (TYPE 2)	L.F.		$ 24.78				
706-10.81	GUARDRAIL REFLECTORS	EACH		$ 4.75				
712-04.08	RAISED RUMBLE STRIP	L.F.		$ 15.80			$ 15.80	

ITEM NUMBER	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	
A	ROADWAY REPAIRS			PER STATION
303-01	MINERAL AGGREGATE, TYPE A BASE, GRADING D	TON	21	PER 100 FT
303-10.01	MINERAL AGGREGATE (SIZE 57)	TON	115	PER 100 FT
307-01.08	ASPHALT CONCRETE MIX (PG64-22)(BPMB-HM) GR B-M2	TON	32	PER 100 FT
202-03.01	REMOVAL OF ASPHALT PAVEMENT	S.Y.	244	PER 100 FT
	REMOVAL OF BASE STONE	C.Y.	81	PER 100 FT
	CENTERLINE STRIPING	L.F	100	PER 100 FT
B	GEOTECHNICAL IMPROVEMENTS			
	MSE RETAINING WALL	S.F.	1056	
	MSE RETAINING WALL CONCRETE FOOTING	C.F.	352	
	W10X39 STEEL BEAM (12' LENGTH) PER 4' SPAN	E.A.	2	
	6"x6"x4' TIMBER LAGGING (4' SP WALL) PER 4' SPAN	E.A.	8	
303-01.03	GRANULAR BACKFILL (RETAINING WALLS)	TON		
801-01	SEEDING (with mulch)	S.Y.		
805-12.01	EROSION CONTROL BLANKET (TYPE I)	S.Y.		
805-12.02	EROSION CONTROL BLANKET (TYPE II)	S.Y.		
805-12.03	EROSION CONTROL BLANKET (TYPE III)	S.Y.		
C	STORMWATER IMPROVEMENTS			
	DITCH GRADING	L.F.		
	12" CMP	L.F.		
	15" CMP	L.F.		
E	SAFETY IMPROVEMENTS			
	GAURDRAILS	L.F.		
	GUARD RAILS ENDCAP IMPACT ABSORBER	E.A.		
	U-CHANNEL POST	E.A.	28	
	TURN WARNING SIGN (LEFT), W1-1, 30"X30"	E.A.	2	
	TURN WARNING SIGN (RIGHT), W1-1, 30"X30"	E.A.	2	
	CHEVRON SIGN, W1-8, 18"X24"	E.A.	48	
	ADVISORY SPEED SIGN 10MPH, W13-1P, 18"X18"	E.A.	4	

INPUT PARAMETERS		
WIDTH OF ROADWAY	ft	22
LENGTH OF ROADWAY	ft	100
THICKNESS OF BASE LAYER	IN	12.5
THICKNESS OF BINDER LAYER	IN	2.75
THICKNESS OF SURFACE LAYER	IN	1.5
DENSITY OF BASE STONE	PCF	100
DENSITY OF ASPHALT BASE	PCF	125
DENSITY OF SURFACE MIX	PCF	150
OUTPUT		
AREA	S.F.	2200
BASE STONE	TON	115
ASPHALT BASE	TON	32
SURFACE MIX	TON	21

Pricing Table per Fix Number on Keetoowah Drive Major and Minor Roads

Keetoowah Dr

Fix Number	Flag	Work Required	Notes	Group	Cost
1	D	fix Shoulder, downhill erosion control, overlay	fix Shoulder, downhill erosion control, overlay	FC/HS	
2	E	extend drain ditch, erosion control, repave	Road dipping/ rutting/ fatigue cracking	FC	
3	F	Repave area	Road dipping/ rutting/ fatigue cracking	HS/FC	
4	U	Gaurdrail	sharp turn, low visibility	S-GR	
5	C	overlay or repave	fatigue cracking, pavement split	FC	
6	B	Overlay or Repave, *add curb?	undercutting	FC/HS	
7	Y	Retaining wall	slope stability	S-RW	

Wilderness Dr

Fix Number	Flag	Work Required	Notes	Group	Cost
1	G	Repave area	shoulders deteriorating, sharp curve, and fatigue cracking	FC	
2	W	grade, topsoil, and seed uphill; clean ditch	debris from uphill; clogged ditch; excess debris onto roadway	SW/HS	

Nowata Ct

Fix Number	Flag	Work Required	Notes	Group	Cost
1	V	repave area	fatigue cracking	FC	

Pricing Table per Fix Number on Chelaque Way and Minor Roads

Chelaque Way

Fix Number	Flag	Work Required	Notes	Group	Cost
1	N	large area of repavement	heavy construction, water seeping into pavement causing further damage	FC	
2	R	expand ditch, regularly maintained	water pooling	SW	
3	A	medium to large area of repavement	rutting and fatigue cracking	FC	
4	K	overlay shoulder	starting to rut, shoulder needs to be redone	FC	
5	M	large area of repavement	large area of fatigue cracking	FC	
6	T	additional safety sign	steep slope	SW	
7	Q	grade/ seed hill and overlay shoulders	shoulder deteriorating along downside of hill	HS/FC	
8	P	repave area and expand drain ditch	uphill shearing, fatigue cracking	HS/FC	

Muskogee Dr

Fix Number	Flag	Work Required	Notes	Group	Cost
1	S	install guard rail	safety concerns	S-GR	

Lakeview Dr

Fix Number	Flag	Work Required	Notes	Group	Cost
1	I	grade uphill slope and seed	debris washes onto road	HS	

Sequoyah

Fix Number	Flag	Work Required	Notes	Group	Cost
1	O	mitigate water	early signs of fatigue cracking from water	SW	

Kahiti Ct

Fix Number	Flag	Work Required	Notes	Group	Cost
1	L	large area of repavement, retaining wall	severe downhill shearing, fractured pavements, loss of shoulder	FC/HS	
2	X	retaining wall	safety concerns	RW	

Channel Point

Fix Number	Flag	Work Required	Notes	Group	Cost
1	H	mitigate water into ditch	good condition rip rap; water continues to mitigate accross road	SW	
2	J	retaining wall to stabilize slope	safety concern from downhill slope	RW	

Repair Order		Year 1		Year 2		Year 3		Year 4		Year 5	
Road	**Repair/ Flag #**	**6 Month**	**12 Month**	**18 Month**	**24 Month**	**30 Month**	**36 Month**	**42 Month**	**48 Month**	**54 Month**	**60 Month**
Keetowah Dr.	D, E, F	X									
	B, C		X								
	Y							X			
	U									X	
Wilderness Dr	G			X							
	W			X							
Nowata Ct	V				X						
Chelaque Way	A, T			X							
	R, M, K				X						
	P, Q					X					
	N					X					
Muskogee Dr.	S									X	
Lakeview Dr	I						X				
Sequoyah	O						X				
Kahiti Ct	X							X			
	L										
Channel Point	H						X				
	J							X			

Project Activity for Pavement

1. Clear Debris
2. Remove Asphalt/ Base Stone
3. Excavate
4. Backfill to Dirt Grade and Compact
5. Fill Material to Base Stone Grade and Compact
6. Fill Material to Binder Grade and Compact
7. Pave Asphalt

Project Activity for Retaining Wall (Reference Drawing)

1. Material Selection
2. Clear Trees and Debris
3. Excavate Trench
    a. Backfill
4. Footing
    a. Reinforcement
    b. Concrete
5. Concrete Wall

Project Activity for Drainage

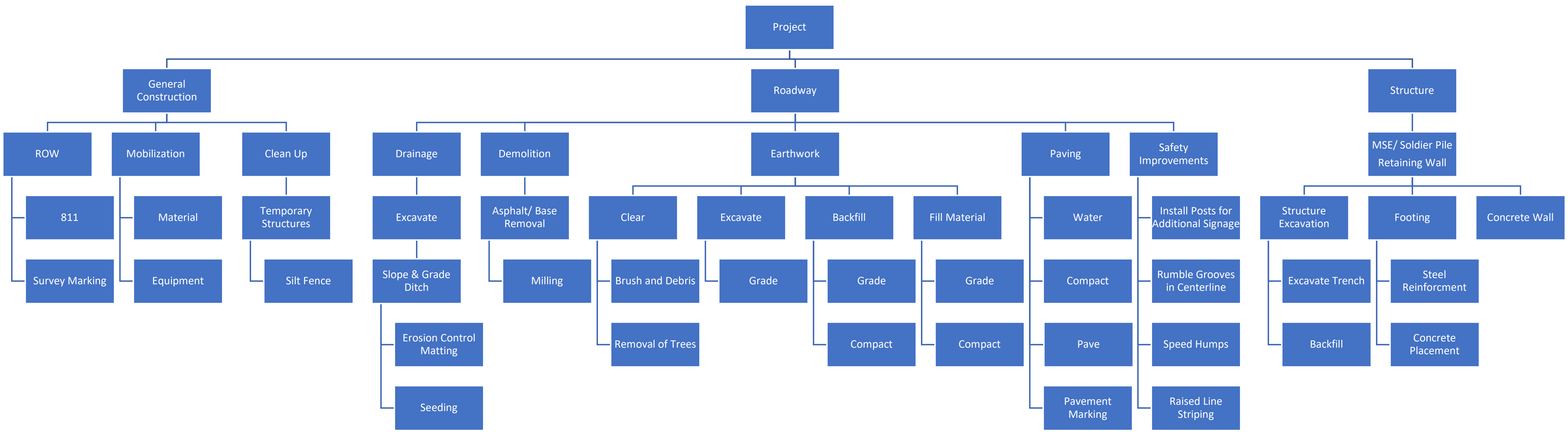
1. Temporary Silt Fence
2. Excavate Coarse Aggregate (Rip Raps)
3. Excavate Trench for Ditch
4. Grade Slope of Ditch
    a. Erosion Control Matting
    b. Seeding
5. Implement Maintenance Plan

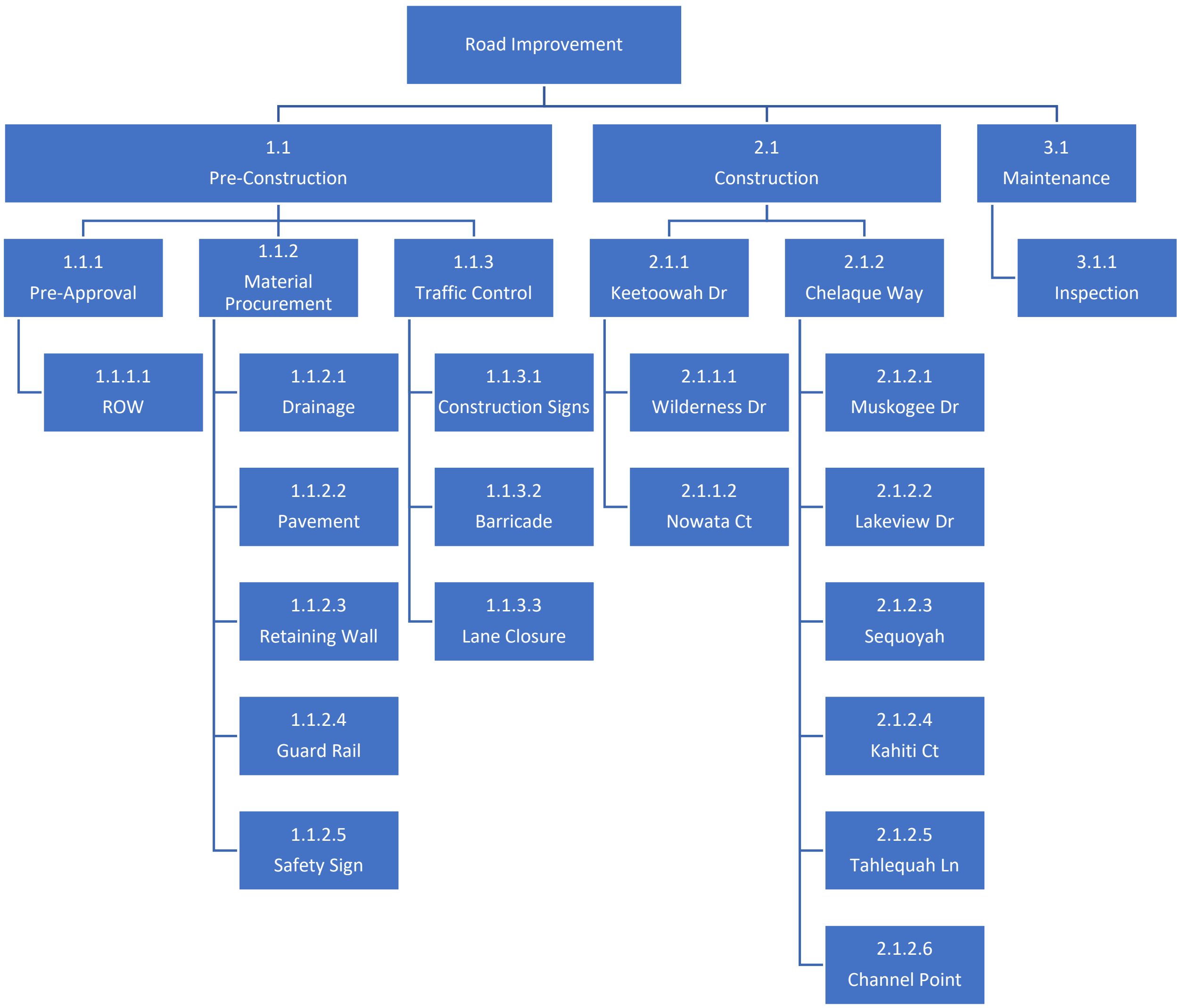
Project Activity for Erosion Control

1. Slope Hill
    a. Spread Topsoil
    b. Seeding with Deep Root Vegetation
2. Erosion Control Blanket

Project Activity for Safety Improvement (Additional Signage)

1. Acquire Materials (Reflective Signs)
2. Install Signposts
3. Install Signs


Project
General Construction
Roadway
Structure
ROW
Mobilization
Clean Up
Drainage
Demolition
Earthwork
Paving
Safety Improvements
MSE/ Soldier Pile Retaining Wall
811
Survey Marking
Material
Equipment
Temporary Structures
Silt Fence
Excavate
Slope & Grade Ditch
Erosion Control Matting
Seeding
Asphalt/ Base Removal
Milling
Clear
Brush and Debris
Removal of Trees
Excavate
Grade
Backfill
Grade
Compact
Fill Material
Grade
Compact
Water
Compact
Pave
Pavement Marking
Install Posts for Additional Signage
Rumble Grooves in Centerline
Speed Humps
Raised Line Striping
Structure Excavation
Excavate Trench
Backfill
Footing
Steel Reinforcment
Concrete Placement
Concrete Wall


Road Improvement
1.1
Pre-Construction
2.1
Construction
3.1
Maintenance
1.1.1
Pre-Approval
1.1.2
Material Procurement
1.1.3
Traffic Control
2.1.1
Keetoowah Dr
2.1.2
Chelaque Way
3.1.1
Inspection
1.1.1.1
ROW
1.1.2.1
Drainage
1.1.2.2
Pavement
1.1.2.3
Retaining Wall
1.1.2.4
Guard Rail
1.1.2.5
Safety Sign
1.1.3.1
Construction Signs
1.1.3.2
Barricade
1.1.3.3
Lane Closure
2.1.1.1
Wilderness Dr
2.1.1.2
Nowata Ct
2.1.2.1
Muskogee Dr
2.1.2.2
Lakeview Dr
2.1.2.3
Sequoyah
2.1.2.4
Kahiti Ct
2.1.2.5
Tahlequah Ln
2.1.2.6
Channel Point

gantter™

Project Name **Project 2**

		Name	Duration	Start	Finish	Predecessors	Resources	Custom 1	Custom 2	Custom 3	Custom 4	Custom 5
1		**Pavement**	**17days**	**12/01/2022**	**12/23/2022**							
2		Clear Debris	3days	12/01/2022	12/05/2022							
3		remove asphalt/base stone	3days	12/06/2022	12/08/2022	2						
4		Excavate	2days	12/09/2022	12/12/2022	3						
5		Backfill to Dirt grade	2days	12/13/2022	12/14/2022	4						
6		Compact dirt	2days	12/13/2022	12/14/2022	4						
7		Fill material to base stone	2days	12/13/2022	12/14/2022	4						
8		Compact material	2days	12/13/2022	12/14/2022	4						
9		fill material to binder grade	2days	12/13/2022	12/14/2022	4						
10		Compact material	2days	12/13/2022	12/14/2022	4						
11		Pave Asphalt	7days	12/15/2022	12/23/2022	10						
12		**Retaining Wall**	**24days**	**12/01/2022**	**01/03/2023**							
13		Material selection	1day	12/26/2022	12/26/2022	1						
14		Clear trees and debris	1day	12/27/2022	12/27/2022	13						
15		excavate trench	1day	12/27/2022	12/27/2022	13						
16		Backfill trench	1day	12/27/2022	12/27/2022	13						
17		Footing foundation	3days	12/27/2022	12/29/2022	13						
18		reinforcement	1day	12/30/2022	12/30/2022	17						
19		concrete	1day	01/02/2023	01/02/2023	18						
20		Temporary silt fence	2days	12/01/2022	12/02/2022							
21		Masonry wall	1day	01/03/2023	01/03/2023	19						
22		**Drainage**	**2days**	**12/06/2022**	**12/07/2022**							
23		excavate tranch for ditch	1day	12/06/2022	12/06/2022	20,36						
24		**Grade slope of ditch**	**1day**	**12/07/2022**	**12/07/2022**	**23**						
25		erosion control matting	1day	12/07/2022	12/07/2022	23						
26		seeding	1day	12/07/2022	12/07/2022	23						
27		**Erosion Control**	**2days**	**12/08/2022**	**12/09/2022**							
28		**slope hill**	**1day**	**12/08/2022**	**12/08/2022**							
29		spread topsoil	1day	12/08/2022	12/08/2022	26						
30		seeding with deep root	1day	12/08/2022	12/08/2022	26						
31		erosion control blanket	1day	12/09/2022	12/09/2022	30						
32		**Safety Improvements**	**17days**	**12/05/2022**	**12/27/2022**							
33		acquire reflective signs	11days	12/12/2022	12/26/2022	31						
34		install signposts	1day	12/27/2022	12/27/2022	33						
35		attach signs	1day	12/27/2022	12/27/2022	33						
36		excavate rip raps	1day	12/05/2022	12/05/2022	20