State of Oklahoma
County Highway System
Design Guidelines
Manual

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OCCEDB

OKLAHOMA Transportation

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Developed Jointly by

Oklahoma Department of Transportation

and the

Oklahoma Cooperative Circuit Engineering Districts Board

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PREFACE

The Oklahoma Department of Transportation, ODOT, and the Association of County Commissioners of Oklahoma, ACCO, pursuant to State Statute Title 69 § 689 first developed the County Roads Design Guidelines Manual in 1991. The intent here is to update methodologies and information for future use in the design on the County Highway System. The Design Subcommittee made recommendations and forwarded those recommendations on for comments to the Oklahoma Department of Transportation, Circuit Engineering Districts, Federal Highway Administration, and the Oklahoma Association of County Engineers.

Counties and Engineers use this manual as guidance on projects that exist on the County Highway System. These projects may be classified as:

(Examples of work activities included)

1. New Construction - new alignment
2. Reconstruction - major changes to horizontal/vertical alignment, pavement structure
3. Resurfacing, Restoration, Rehabilitation (3R) – overlays, minor pavement width and/or alignment changes.

If existing or future traffic counts surpass 2,500 Average Daily Traffic then the engineer shall refer to the appropriate ODOT and/or AASHTO guidelines.

The “Green Book” table references are taken from AASHTO’s “A Policy on Geometric Design of Highways and Streets 2018”, 7th Edition. The “Low Volume” table references are taken from AASHTO’s “Guidelines for Geometric Design of Very Low-Volume Local Roads, 2019”.

Herein are minimum acceptable design criteria that the designer should make every effort to surpass while considering social, economic and environmental impacts.

The presentation of new design values in this text does not imply that the existing county roads are unsafe, nor does it mandate the initiation of improvement projects. For 3R projects existing design values/geometrics may be retained. Specific site investigations and accident history analysis often indicate that the existing design features are performing in satisfactory manner. The cost of full reconstruction for these facilities will often not be justified.

These guidelines do not include information on ADA compliance or storm water management. The Engineer and Owner should ensure that current state and federal laws are observed. Use of sound engineering judgment prevails over manual guidelines. The guidelines’ purpose is to provide a safe, cost-effective road system.

The subcommittee has made every effort to balance safety, costs and engineering judgment in the development of these guidelines.

Design Subcommittee:

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CHAPTER 1

PLAN DEVELOPMENT

A. GENERAL INFORMATION

In order that all submitted plans be compatible and consistent with ACCO and ODOT policies the plans should be developed using ODOT guidelines.

1. The web link workplace and Seed files for roadway can be obtained from ODOT's website at https://www.odot.org/roadway/cadd_support/

2. ODOT Standard Drawings can be found at http://www.odot.org/cnstrctengr.htm on ODOT's web page. Traffic Pay Item Notes can be found with the Traffic Standard Drawings.

Please note that on Pay Item Sheets, the pay item descriptions must exactly match the pay items listed on ODOT's master Pay Item list, http://www.okladot.state.ok.us/contracts/itemlist.htm

Index of Sheets

The following is a typical order of sheets. Dependent on the project, more or less sheets may be required.

1. Title Sheet
2. Typical
   a. Roadway Typical
   b. Guardrail Widening Typical
   c. Drive Typical
3. Summary of Pay Quantities & Notes (Roadway)
4. Summary of Pay Quantities & Notes (Bridge)
5. Summary of Pay Quantities & Notes (Traffic)
6. Roadway and Traffic Summaries Use Every Time (If Applicable)
   a. Erosion Control
   b. Surfacing
   c. Earthwork
   d. Drives
   e. Drainage Structures
   f. Fence
   g. Guardrail
   h. Ditch Treatment
   i. Pavement Markings
   j. Mailbox
   k. Removals
   l. Permanent Signs
7. Drainage Area Map
8. SWMP, Storm Water Management Plan
9. Survey Data Sheets / Alignment Data Sheets
10. Roadway Detail Sheets
    a. Roadway Details Sheet
       i. Superelevation Detail
       ii. Rounding Detail
       iii. Curb & Gutter Detail
       iv. Mailbox Turnout Detail
       v. Interface Detail (Asphalt Only)
    b. Intersection Detail
    c. Demolition Plan
11. Plan & Profile Sheets
12. Traffic Detail Sheets
    a. Signing & Striping
    b. Sequence of Construction
    c. Temporary Traffic Control and Detour sheets
13. Erosion Control
14. General Plan & Elevation
15. Substructure Layout
    a. Staking Diagram
16. Foundation Boring Logs
17. Details of Abutment
    a. Abutment Details
    b. Bearing Assembly
18. Details of Piers
    a. Special Design
19. Details of Superstructure
    a. Special Design
20. Details of Approach Slabs
21. Cross Sections

CHAPTER 2

SURVEY

NOTE: The Specifications, and all forms noted in this document can be downloaded from the ODOT Website at: www.okladot.state.ok.us/survey/.

This survey shall meet the requirements described in OKLAHOMA ADMINISTRATIVE CODE, 245:15, Subchapter 13 (Minimum Standards for Land Surveying) and Subchapter 21, which includes the complete text of **Oklahoma Statute Title 65:3 – 119** (Corner Perpetuation and Filing Act) as adopted by the Oklahoma State Board of Licensure For Professional Engineers and Land Surveyors, (latest effective version at the time of survey).

These Specifications are written for projects utilizing the United States Survey Foot as the unit of measurement.

For each specific project, additional requirements and/or amendments to these specifications maybe provided by the Oklahoma Department of Transportation and shall be covered by **Survey Special Provisions** written at the time of contract negotiation and/or during the survey scope definition.

I. GENERAL

A. The scope and coverage of the field survey to be accomplished are as necessary to prepare Functional, Right of Way, and Construction Plans.

B. All field surveys, computer files, and other documents shall be complete in every respect, and the information shall be set forth in a professional manner.

C. Any discrepancy between newly acquired and existing survey data must be brought to the attention of ODOT for resolution, including plans, section corners, previous surveys, horizontal or vertical control, or other items.

D. Any issues regarding adherence to the Specifications, or the Survey Special Provisions must be brought to the attention of ODOT for resolution.

II. CONTROL

A. GENERAL

1. ACCURACY, There are two distinct accuracies for Horizontal and Vertical Control:
   a. Network Accuracy: Accuracy that is relative to the National Geodetic Survey (NGS) Continuously Operating Reference Stations (CORS).
   b. Local Accuracy: Accuracy that is relative to the specific project itself.

Both accuracies will be expressed as Circular Root Mean Square Error (RMSE) at 2

Sigma (95%Confidence). These accuracy definitions are currently used by the National Geodetic Survey, and are better suited to modern three dimensional survey control networks than the older, Linear Accuracy definitions (1st Order, 2nd Order, etc.).

B. HORIZONTAL CONTROL
   1. The survey is to be placed on the current NGS Oklahoma State Plane Coordinate System, NAD83(2011) or the latest iteration, unless prior approvalis granted by ODOT to use a different horizontal datum.

   2. Primary Control will be derived from a fully constrained, Three DimensionalStatic GPS Network Adjustment, utilizing a minimum of three NGS CORS and any published hard monuments within 5 miles of the project. To ensure the highest accuracy, the Network will be fully constrained vertically; by inclusion of at least 4 acceptable benchmarks (The CORS in the Network Adjustment are acceptable as benchmarks). These may be Published NGS or USGS Monuments, or may be taken from previously completed ODOT Projects, as approved (in advance) by ODOT.

   3. Double OPUS Solutions (different days, different times of day) will also be obtained, and will serve as a general confirmation of the integrity of the adjustment results. OPUS Solutions may be used for project control in someinstances, with prior approval by ODOT.

   4. The Horizontal Control shall meet or exceed the following accuracy criteria:
      a. NETWORK ACCURACY: 0.10 FOOT
      b. LOCAL ACCURACY : 0.05 FOOT

C. VERTICAL CONTROL
   1. NETWORK VERTICAL CONTROL:
      a. Vertical Control Datum will be NAVD 88, derived from the vertical component of the three dimensional GPS Control Network, previouslydescribed.
   2. LOCAL VERTICAL CONTROL:
      a. Direct Differential Leveling will be used to establish local benchmark elevations along the project. As a minimum, this will consist of the mean of two distinct runs, or level loop. The unadjusted vertical differences between intermediate benchmarks, for each Level Run, areto be shown in the Check Levels and Benchmark List. The Adjusted Elevations for each benchmark will be derived by distributing the error between Source Benchmarks, equitably along the entire length of the Level Loop, with each intermediate benchmark receiving a proportional share of the error. Adjusted Elevations will be the sourcefor all Digital Terrain Modeling, and Topography.

b. In towns, benchmarks shall be set not greater than one block (or 300 feet) apart, and in rural sections benchmarks shall be set approximately700 feet apart, where practical. A benchmark will be set on each crossdrain structure. A permanent benchmark will be set on, or outside the anticipated Right of Way, approximately each quarter mile, where practical.

c. Examples of acceptable benchmarks include the following: X cut in concrete. 80d or larger nails or railroad spikes in trees or utility poles,survey monument set in concrete.

3. The Vertical Control shall meet or exceed the following accuracy criteria:
   a. NETWORK ACCURACY (FROM GPS OR LEVELING): 0.10FOOT
   b. LOCAL ACCURACY (CONFIRMED BY LEVELING): 0.02 FOOT

4. The following Survey Control Data notation is contained in the ODOT, Survey Division MicroStation® Design File Standard, as part of the first Survey Data Sheet. This notation must appear on the Survey Data Sheets andon the title sheets of Functional, Right of Way, and Construction plans:

SURVEY CONTROL DATA

1. HORIZONTAL CONTROL:
   A. Horizontal control for this survey is the NGS Oklahoma State Plane CoordinateSystem, NAD83 (CORS), (**North or South** Zone).*

   B. ESTIMATED NETWORK ACCURACY – North**:** **0.07** Ft. East **0.07** Ft. Ellipsoid:
   0.10 Ft.

   C. LOCAL ACCURACY (CONFIRMED BY RTK OR TRAVERSE) – North: **0.07** Ft., East **0.07** Ft., Ellipsoid**:** **0.10** Ft. (Note these values are the maximum allowableRoot Mean Square Error (RMSE) at the 95% Confidence Level. Actual values will vary by project).
2. BEARINGS:
   The bearings shown herein or hereon are grid bearings derived from the NGS Oklahoma State Plane Coordinate System and are not Astronomical. The angle of variance betweenGrid North (GN) and the astronomical True North (TN) is depicted diagrammatically.

3. VERTICAL CONTROL:
   A. Level datum is NGS, NAVD 88 (specify GEOID model used for this project to deriveorthometric heights)

B. ESTIMATED NETWORK ACCURACY:
GPS Network Adjustment -or-OPUS Projects -or- GPS Double OPUS Solution -or-Direct Differential Leveling, Double Loop: **0.10** Ft.

C. LOCAL ACCURACY: Direct Differential Leveling (through the length of theproject): **0.02** Ft.

Note: These values are the maximum allowable Root Mean Square Error (RMSE) at the95% Confidence Level. Actual values will vary by project.

* Project specific. Show only that which applies.

<u>“Assumed” or “Arbitrary” level datum is not acceptable.</u>

III. CENTERLINE/ALIGNMENT

A. The alignment shall be made on the section lines if feasible. If the alignment is not ona section line, complete and accurate ties are to be shown at all crossings of major land lines (angle and distance from Centerline to corners).

B. Survey centerline stationing shall run from South to North and from West to East,where practical.

C. Stations are established at even 100 foot increments from a designated Point of Beginning. Stationing for Points on Tangent (POT’s), Points of Intersection (PI’s),Points of Curvature (PC’s), Points on Sub-Tangent (POST’s), and other controllingpoints on the alignment shall be defined.

D. All Centerline curves shall be computed on the arc definition based on the length ofthe radius.

E. Complete curve data is to be shown for all horizontal curves (P.I. Station w/X & Y coordinates, Delta, Degree, Tangent, Length, Radius and External). All major curvepoints (P.C., P.I. and P.T.) are to be set and referenced.

F. The intersection points of the Centerline of Survey with all Section Lines, Quarter Section Lines, Subdivision Lines and Centerline of Streets shall have points set on them and referenced. In addition to the Reference Point information, these points of intersection shall have the following shown; stationing, coordinates, and distanceseach direction to the land corners.

G. If existing centerline stationing exists then all P.O.T.’s, P.I.’s, P.C.’s, P.T.’s, and P.O.S.T.’s or any other principal control pointshall be iron pins, approved monuments or well defined crosses cut in concrete and shall be referenced to permanent points. In no instance will wooden stakes be accepted. The distance between Centerline control points shall be approximately 1,000 to 1,500 feet, where practical.

H. Reference points shall be set and described so as to make them as easily recoverable as possible. All reference points for survey monuments shall be of a permanent nature, such as a #4 rebar/iron pin, “x” on concrete walk, approved monument, R.R. spike in a tree or any accessible permanent object with a precise measuring point. A minimum of three reference points shall be set on each point referenced and arrangedso that, at least two of the reference points shall fall on a true line passing through thepoint being referenced, either by both reference points being on the same side or on both sides, with the angle from the line or lines to be as great as practical (near perpendicular to one another, for maximum strength of figure). The first reference point shall be set a minimum of 50 feet from the Centerline of Survey. Subsequent points shall be no more than 100 feet apart. If possible, at least two reference points should be set beyond the anticipated Right of Way Lines so they will not be disturbedor destroyed by construction. All points and reference points set in cultivated fields shall be buried a minimum of 12” deep. Bearings and distances shall be shown between all reference points and the points they are referencing.

IV. TOPOGRAPHY

A. In urban or platted areas all topography shall be obtained for approximately 100 feet.In rural areas all topography within 150 feet shall be obtained. In addition, any othertopography that might affect the acquisition of Right of Way or the preparation of theplans shall be obtained. Typical examples are homes or businesses that are located beyond the normal distance that topography is obtained. If there is an existing driveway, used to access to such structures, then the buildings must be located and identified in the survey.

B. Topography to be located/identified includes, but is not limited to; existing paving, roads, trails, bridges/drainage structures, utility lines, buildings, driveways, gates/fieldentrances (show width of gates), mail boxes, gas pumps, storage tanks (both above and below ground), and any other manmade cultural or topographic feature that mightaffect proper design and/or impact Right of Way acquisition.

C. If any topographic features are discovered during the course of the survey, that are suspected to be of historical, archaeological, or cultural significance, such as Native American Graves, or other evidence of occupation by prehistoric peoples, notificationmust be sent immediately to ODOT’s Environmental Programs Division, so they can investigate the site in question. **At no time** will such sites be depicted on the sheets. In the Historical Letter and Written Report, they should be described as**“Potential Cultural Resource Sites”** with **no specific information** given, as to the exact location or nature of the sites.

D. Areas such as private dumps, underground fuel storage tanks, etc. should be identifiedon the Survey Data Sheets as **“Potential Environment**

Contamination". Specific details of these sites are to be included in the Historical Letter and Written Report.

V. DIGITAL TERRAIN MODELING

A. Digital Terrain Model (DTM) data shall be taken to a minimum of 150 feet right andleft of the centerline of survey or to a minimum of 50 feet beyond the proposed new right-of-way lines, whichever is greater.

B. For Roadway-Size Drainage Structures (culverts less than 20 feet in length), a separate flowline profile (3 dimensional breakline depicting horizontal and verticallocation) of the stream shall be obtained for a distance of 500 feet upstream and downstream.

C. For Bridge-Sized Structures with floors (Double 10 foot culverts or larger) flowlineprofiles will be obtained for a distance of 500 feet upstream and downstream.

D. For Bridge-Sized Structures without floors, flowline profiles will be obtained for adistance of 500 feet upstream and downstream.

E. Intervals between individual readings will be a maximum of 25 feet for the first 150feet, then 50 feet beyond, with care being taken to obtain readings at significant horizontal breaks or vertical "head-cuts" in the flowline.

F. From a minimum of 100 feet before, to 100 feet after bridge locations (structures 20feet or longer), DTM and Topographic Data will be extended to a minimum of 500 feet right and left of centerline of survey.

G. For all bridge structures, the banks and toes shall be located for a distance of 500 feet upstream and downstream.

H. In Urban Areas, at Street Intersections, breaklines shall be obtained at the Centerlineof Streets, edges of paving, and ditch flowlines 100 feet. Additionally, if curbs are present, breaklines will be obtained on tops of curbs, and in gutters lines 150 feet.

VI. UTILITIES

A. All public and privately owned utility lines and facilities, both overhead and underground, shall be located to a minimum of 150 feet right and left, or to the limitsof the topography and DTM. This information will include the location, size, type material, and ownership with name, address, and telephone number of owner. Allutilities will be shown at zero elevation, with the exception of the following:

B. Elevations shall be shown on low-wires of overhead utilities crossing Centerline of Survey. A graphic depiction of the swag of the low-wire shall be shown only on hightension lines.

C. Elevations shall be shown on storm sewers and sanitary sewers. This will includemanholes, lamp holes that fall within the limits of the topography and DTM.

D. On crossings, inlets and outfalls shall be located, with elevations, right and left ofcenterline, to the first manhole beyond the limits of the topography and DTM.

E. The source of utilities information shall be denoted in the Survey Data Sheets, whether located by the owning company, or by a contracted locating company, or byother means.

VII. LAND SURVEYS

A. All work pertaining to Land Survey points that are calculated, monumented, or otherwise used in the survey will be performed under the responsible charge anddirect supervision of a Professional Land Surveyor (PLS) licensed in the State ofOklahoma.

B. The PLS shall file Oklahoma Certified Corner Records for all Public Lands SurveySystem Corners used to complete the survey.

C. Land Corners are to be established, referenced and filed in both directions of the surveyed bridge (Section Corners and 1/4 Section Corners). If the Centerline of Survey is not on a section or 1/4 section line, the points of intersection of the Centerline of Survey and the section and 1/4 section lines that it crosses are to be set and referenced and ties shown in the submitted notes. All Section Corners and Quarter Section Corners monumented or found in place shall be referenced by a minimum of three Reference Points, as required by the Corner Perpetuation and Filing Act. A detailed diagram, depicting the Corner Monuments and their associated Reference Points will be shown on the Survey Data Sheets. The size and type of monument will be described in detail. A brief narrative, describing the history and pedigree of each corner, as well as justification for using a particular corner location will also be shown. The same is to apply to Original GLO/BLM/USGS Survey Meander Lines and Corners and all Original Government Survey Subdivision Lines and Lot Lines.

D. All non-original corners shall be set in accordance with the Bureau of LandManagement's "Manual of Surveying Instructions" (Revised: 2009).

E. All Original Townsites and platted Subdivision Lots and Blocks within or adjacent tothe Existing Right of Way limits shall be depicted.

F. POT's, POC's, PI's or POST's, shall be calculated for the centerline of all streetsintersecting the Survey Centerline (not monumented).

VIII. DRAINAGE

High water elevations shall be taken for all bridge structures and other major streams.Extreme care shall be taken in obtaining this information The location shall be shownwhere the reading was taken, (Bridge Seat, visible drift, or other spot delineated by witnesses), date on which the High Water Event occurred and the source of information. If the information is provided by a local resident, the name and address of the witness shall be shown.

IX. PROPERTY OWNERSHIPS AND RIGHT OF WAY

A. In instances of non-typical circumstances related to properties or right of way, any documents pertaining to boundary disputes, court cases, unrecorded plats, or otherRecord Evidence will be submitted with the survey.

B. Recorded deeds and easements shall be used in determining Existing Right of Way. Existing Plans shall also be utilized as a supplemental source of information. Any conflicts between the two data sources should be discussed with ODOT prior to completion of the project, with the goal of finding an equitable solution, agreeable toall parties.

X. RAILROADS

At all railroad crossings complete surveys shall be made on the railroads using the Railroad Alignment and Railroad Station Numbers for a distance not less than 500 feet on each side of Centerline of Survey. DTM Data shall extend to a minimum of 50 feet beyond the Railroad Right of Way Lines. A three dimensional breakline of the top of each rail shall be obtained at intervals not to exceed 100 feet, to a minimumdistance of 1,000 feet each side of Centerline of Survey.

1. When a Railroad is parallel to the Survey Centerline, within the limit of theDTM, or as specified in the Survey Special Provisions, elevations shall be obtained on the top of each rail at approximately 500 foot intervals.
2. The location, size and flowline profiles of all railroad structures shall beobtained;
3. A typical section (side view) shall be obtained on all railroad bridges
4. Railroad structures shall be described and tied to the Centerline of Survey.

CHAPTER 3

BASIC DESIGN CONTROLS

A. FUNCTIONAL CLASSIFICATION

The County Highway System in Oklahoma should be functionally classified as to its use and relative importance to the transportation needs of the county. This concept impacts project selection as well as project design.

B. TRAFFIC VOLUME

The design traffic volume will be based upon the road's functional classification. All projects, not including 3R projects, on the Major and Minor Collector System will base design upon a 20-year traffic volume projection. A minimum 2% per year growth rate may be used unless other traffic factors are known. Local Roads, and 3R projects on Major and Minor collectors, may base design on the current average of a continuous seven-day traffic count to achieve an average daily traffic, ADT, count regardless of the improvement. For all bridge replacement projects use future projected traffic volume.

C. TERRAIN

The topography of the land traversed has an influence on the alignment of roads and streets. Topography does affect horizontal alignment, but it is more evident in the effect on vertical alignment. To characterize variations, engineers generally separate topography into three classifications according to terrain:

- Level terrain is that condition where highway sight distances, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expense.

- Rolling terrain is that condition where the natural slopes consistently rise above and fall below the road or street grade and where occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment.

- Mountainous terrain is that condition where longitudinal and transverse changes in the elevation of the ground with respect to the road or street are abrupt and where benching and side hill excavation are frequently required to obtain acceptable horizontal and vertical alignment.

Terrain classifications pertain to the general character of a specific route corridor. Routes in valleys or passes of mountainous areas that have all the characteristics of roads or streets traversing level or rolling terrain should be classified as level or rolling.

In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars, and mountainous terrain aggravates the situation, resulting in some trucks operating at crawl speeds.

D. MINIMUM DESIGN SPEED

Geometric design features should be consistent with a design speed selected as appropriate for terrain conditions. Low design speeds are generally applicable to roads with winding alignment in rolling or mountainous terrain or where environmental conditions dictate. Higher design speeds are generally applicable to roads in level terrain or where other environmental conditions are favorable.

The design speed for a project should represent the operating speed that is expected on the completed project. Design speed is a function of the terrain on which the project is constructed and the type of surfacing to be constructed. Design speed is defined as the speed selected to control the geometric features of the project taken including features such as horizontal curvature and superelevation, stopping sight distance, passing sight distance and maximum grades. It is the speed that can be safely maintained through the project when traffic and weather conditions are so favorable that geometrics of the highway govern. On county roads there may be an occasional geometric feature (usually a horizontal curve) where conditions warrant a lower design speed. These exceptions should be communicated to the driver by a warning sign with a speed advisory plate indicating that a reduction to a certain speed is needed.

The following table gives the minimum design speed for various terrain conditions, type of surface and current or projected ADT.

Table 3-1. Design Speeds

Type of Terrain	**Design Speed (mph) for Specified Design Volume (veh/day)**				
	Under 50	**50 to 250**	**250 to 400**	**400 to 2000**	**2000 and over**
Level	30	30	40	50	50
Rolling	20	30	30	40	40
Mountainous	20	20	20	30	30

(Table 5-1, “Green Book”)

The designer should strive for a higher design speed for specific features of the road where they can be obtained at nominal cost. The County may post a speed limit different than the design speed if the completed road conditions warrant a change in the speed limit would be reasonable and safe. (OK ST. Title 47 § 11-803) Refer to the current edition of the Manual on Uniform Traffic Control Devices, which indicates the proper process to decide on a speed limit.

E. HYDROLOGY (CROSS DRAINS)

All aspects of design pertaining to drainage shall be based as a minimum on a 5-year storm event (Q5). 10-year minimum on collector; local roads 5-10 years. No overtopping of the roadway or shoulder (based on a 5-year storm event) will be allowed in design considerations. This criterion shall only relate to those structures less than 20’ in length, measured along the roadway centerline, not categorized as bridge structures. See Chapter 10 for details of drainage design requirements.

CHAPTER 4

HORIZONTAL ALIGNMENT

A. GENERAL INFORMATION

All geometric elements should, as far as economically practical, be designed to operate at a speed likely to be observed under normal conditions. Typically county road projects are designed with regular horizontal curves. Compound curves should be avoided as they are not aesthetically pleasing and mislead the driver's expectations of how sharp the turn is.

This chapter consolidates many of the often-used tables, or parts of tables from AASHTO's "Green Book". Further discussions on side friction, passing sight distances, stopping sight distances, compound curves, & spiral curves can be found there.

B. ALIGNMENT

Alignment between control points should be designed to as high a standard as possible consistent with the environmental impacts, topography, terrain, design traffic volume, the amount of reasonably obtainable right-of-way, and the amount and cost of earthwork involved. Sudden changes between curves of widely different radii or between sharp curves should be avoided. The design should include passing opportunities if at all feasible.

The locations of cross street intersections should be considered when determining the alignment. See Chapter 7, At-Grade intersections for more discussion.

C. ROADWAY CROWN

Pavement or surfacing crown should be adequate to provide proper drainage. Normally, cross slopes should be as shown below in Table 4-1.

Table 4-1. Cross Slopes

Surface type	**Range in cross slope rate for a single lane (%)**
Paved	1.5 - 2
Unpaved	2 - 6

(Table 4-1, "Green Book")

D. SUPERELEVATION

Superelevation is the rate of roadway cross slope expressed in percent (%). For rural roads with bituminous-type surfaces, superelevation should not be more than 10%, and an emax of 8% is typical in Oklahoma, where snow and ice are factors. Superelevation shall not exceed 6% on bridges and the preferred rate for constructability is 2% (See Chapter 12).

Depending on the maximum superelevation value, the minimum radii to be used for different design speeds are shown in Table 4-2. These minimum radii should be the exception rather than the rule. The purpose of the table given here is to assist the designer to come up with an acceptable alignment for the chosen design speed.

Table 4-2. Minimum Radii
Normal Crown assumed to be 2%

emax	Design speed (mph)	Min R without super (ft)	With Superelevation		
			Min R ADT<250 (ft)	Min R ADT 250 to 400 (ft)	Min R ADT>400 (ft)
8%	20	1640	40	40	76
	25	2370	75	75	134
	30	3240	75	135	214
	35	4260	135	215	314
	40	5410	215	315	444
	45	6710	315	445	587
	50	8150	465	585	758
	55	9720	585	760	960
10%	20	1680	35	35	72
	25	2420	70	70	126
	30	3320	70	125	200
	35	4350	125	200	292
	40	5520	200	290	410
	45	6830	290	410	540
	50	8280	410	540	694
	55	9890	540	695	877

(Tables 3-10 & 3-11, “Green Book”)
(Tables 4-4 & 4-5, “Low Volume”)

After the alignment is determined, the designer can refer to table 4-3 for the appropriate superelevation rates. Typically, narrow paved shoulders will rotate with the travelled way. For shoulders wider than 4 feet, the shoulder breakover should not exceed 0.07 ft/ft. AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads, 2019, advises that for low volume roads, the superelevation tables from the “Green Book” should be used utilizing reduced design speeds. Table 4-3 combines Green Book tables 3-10b and 3-17b and gives the revised design speed headings from exhibits 5 & 6 in AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads, 2019. The values from the green book have been truncated in table 4.3 at the minimum radii given in the Guidelines for Very Low Volume Roads.

Superelevation runoff is the length of highway needed to accomplish the change in cross slope from a section with zero cross slope (adverse crown removed) to a fully superelevated section. These values are also in Table 4-3. The tangent runout length is the length to remove the adverse crown and can be found by entering the table at the typical section slope (usually 2.0). Spirals are not typically used in Oklahoma, particularly on county roads. Adjustments in design runoff lengths may be necessary for smooth riding, surface drainage, and good appearance.

Table 4-3. Min Radii for Design Superelevation Rates & Runoffs at Design ADT & Speeds

L = Runoff length based on a 12’ lane.
R values are for emax = 8%
If R in table < actual R, move down to next line

	DESIGN SPEED (mph)																			
ADT <250 veh/day	20		25		30		35		40		45		50		55		60			
ADT from 250 to 400 veh/day	20		25		30				35		40		45		50		55		60	
ADT > 400 veh/day	15		20		20		25		30		35		40		45		50		55	
e(%)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)	L(ft)	min R(ft)
NC		932		1640		1640		2370		3240		4260		5410		6710		8150		9720
2.0	31	676	32	1190	32	1190	34	1720	36	2370	39	3120	41	3970	44	4930	48	5990	51	7150
2.2	34	605	36	1070	36	1070	38	1550	40	2130	43	2800	46	3570	49	4440	53	5400	56	6450
2.4	37	546	39	959	39	959	41	1400	44	1930	46	2540	50	3240	53	4030	58	4910	61	5870
2.6	40	496	42	872	42	872	45	1280	47	1760	50	2320	54	2960	58	3690	62	4490	66	5370
2.8	43	453	45	796	45	796	48	1170	51	1610	54	2130	58	2720	62	3390	67	4130	71	4950
3.0	46	415	49	730	49	730	51	1070	55	1480	58	1960	62	2510	67	3130	72	3820	77	4580
3.2	49	382	52	672	52	672	55	985	58	1370	62	1820	66	2330	71	2900	77	3550	82	4250
3.4	52	352	55	620	55	620	58	911	62	1270	66	1680	70	2170	76	2700	82	3300	87	3970
3.6	55	324	58	572	58	572	62	845	65	1180	70	1570	74	2020	80	2520	86	3090	92	3710
3.8	58	300	62	530	62	530	65	784	69	1100	74	1470	79	1890	84	2360	91	2890	97	3480
4.0	62	277	65	490	65	490	69	729	73	1030	77	1370	83	1770	89	2220	96	2720	102	3270
4.2	65	255	68	453	68	453	72	678	76	955	81	1280	87	1660	93	2080	101	2560	107	2080
4.4	68	235	71	418	71	418	75	630	80	893	85	1200	91	1560	98	1960	106	2410	112	2910
4.6	71	215	75	384	75	384	79	585	84	834	89	1130	95	1470	102	1850	110	2280	117	2750
4.8	74	193	78	349	78	349	82	542	87	779	93	1060	99	1390	107	1750	115	2160	123	2610
5.0	77	172	81	314	81	314	86	499	91	727	97	991	103	1310	111	1650	120	2040	128	2470
5.2	80	154	84	284	84	284	89	457	95	676	101	929	108	1230	116	1560	125	1930	133	2350
5.4	83	139	88	258	88	258	93	420	98	627	105	870	112	1160	120	1480	130	1830	138	2230
5.6	86	126	91	236	91	236	96	387	102	582	108	813	116	1090	124	1390	134	1740	143	2120
5.8	89	115	94	216	94	216	99	358	105	542	112	761	120	1030	129	1320	139	1650	148	2010
6.0	92	105	97	199	97	199	103	332	109	506	116	713	124	965	133	1250	144	1560	153	1920
6.2	95	97	101	184	101	184	106	308	113	472	120	669	128	909	138	1180	149	1480	158	1820
6.4	98	89	104	170	104	170	110	287	116	442	124	628	132	857	142	1110	154	1400	163	1730
6.6	102	82	107	157	107	157	113	267	120	413	128	590	137	808	147	1050	158	1330	169	1650
6.8	105	76	110	146	110	146	117	248	124	386	132	553	141	761	151	990	163	1260	174	1560
7.0	108	70	114	135	114	135	120	321	127	360	135	518	145	716	156	933	168	1190	179	1480
7.2	111	64	117	125	117	125	123	214	131	336	139	485	149	672	160	878	173	1120	184	1400
7.4	114	60	120	115	120	115	127	198	135	312	143	451	153	628	164	822	178	1060	189	1320
7.6			123	105	123	105	130	182	138	287	147	417	157	583	169	765	182	980	194	1230
7.8							134	170	142	261	151	380	161	533	173	701	187	901	199	1140

(Tables 3-10b & 3-17b, “Green Book”; Exhibits 5 & 6, “Low Volume”)

CHAPTER 5
VERTICAL ALIGNMENT

A. GENERAL INFORMATION

A driver's ability to see ahead is needed for safe and efficient operation of a vehicle. While frequent areas with passing sight distances are desirable, it is not always practical to provide them on the county system. The designer should use good engineering judgment to exceed minimum distances while considering earthwork, cross streets, drainage, and aesthetics. This chapter consolidates many of the often-used tables, or parts of tables from AASHTO's "Green Book". Further discussions on passing sight distances, stopping sight distances, K values for trucks, & truck-climbing lanes can be found there.

B. GRADE

The maximum design grades to be used on county road projects shall be according to the chart below.

Table 5-1. Grades

Terrain	Design Speeds (mph)								
	20	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Level	7	7	7	7	7	7	6	6	5
Rolling	10	10	9	9	8	8	7	7	6
Mountainous	12	11	10	10	10	10	9	9	8

(Table 6-2 for Rural Collectors, "Green Book")
(Note: "Local Roads" may use "Green Book" Table 5-2)

The maximum design grade should be used infrequently rather than as a value to be used in most cases. At the other extreme, for short grades less than 500ft, the maximum gradient may be 2% steeper.

C. VERTICAL CURVES

Adequate passing sight distance is desirable; however, the control factor for vertical curves shall be adequate stopping sight distance. Criteria for stopping sight distance for crest vertical curves shall be height of eye 3.5 feet and height of object 2.0 feet. For sag vertical curves a headlight sight distance longer than the stopping sight distance is required. The K values below were calculated using the calculated stopping sight distance from the "Green Book", Table 3-1 and the crest formula on pg 3-166 and the sag formula on pg. 3-173, which are based on passenger cars. The Low Volume K numbers for crest curves come from AASHTO's "Low Volume", Exhibit 12. This publication recommends using the "Green Book" for sag curves.

If designing for a road with a high percentage of trucks or recreational vehicles, this table should not be used.

Table 5-2. Minimum Stopping Sight Distance

Design Speed (mph)	**Stopping Sight Distance (ft)**	**K Value CREST ADT<250**	**K Value CREST ADT 250-400**	**K Value CREST ADT>400**	**K Value SAG All ADT**
20	111.9	3.8	4.2	6.1	16.5
25	151.9	6.1	7.2	11.1	25.5
30	196.7	8.4	12.6	18.5	36.4
35	246.2	13.4	19.5	29.0	49.0
40	300.6	21.4	29.0	43.1	63.4
45	359.8	31.3	41.7	60.1	78.1
50	423.8	44.5	56.8	83.7	95.7
55	492.4	61.7	76.0	113.5	114.9
60	566	82.7	102.4	150.6	135.7

(Tables 3-35 + 3-37, equations on pg 3-171 & 3-178, “AASHTO Green Book”) (Table 4-9, “Low Volume”)

The K value is a coefficient by which the algebraic difference in grade may be multiplied to determine the length in feet of the vertical curve, which will provide the minimum sight distance. Curve lengths are usually rounded up and the minimums should be avoided if possible. A maximum K of 167 for both crest and sag curves is generally sufficient for curbed sections to allow for proper drainage.

The locations of cross street intersections should be considered when determining the vertical alignment. See Chapter 7, At-Grade Intersections, for more discussion. The sight distances available at the intersection can best be viewed graphically in the plan profile section.

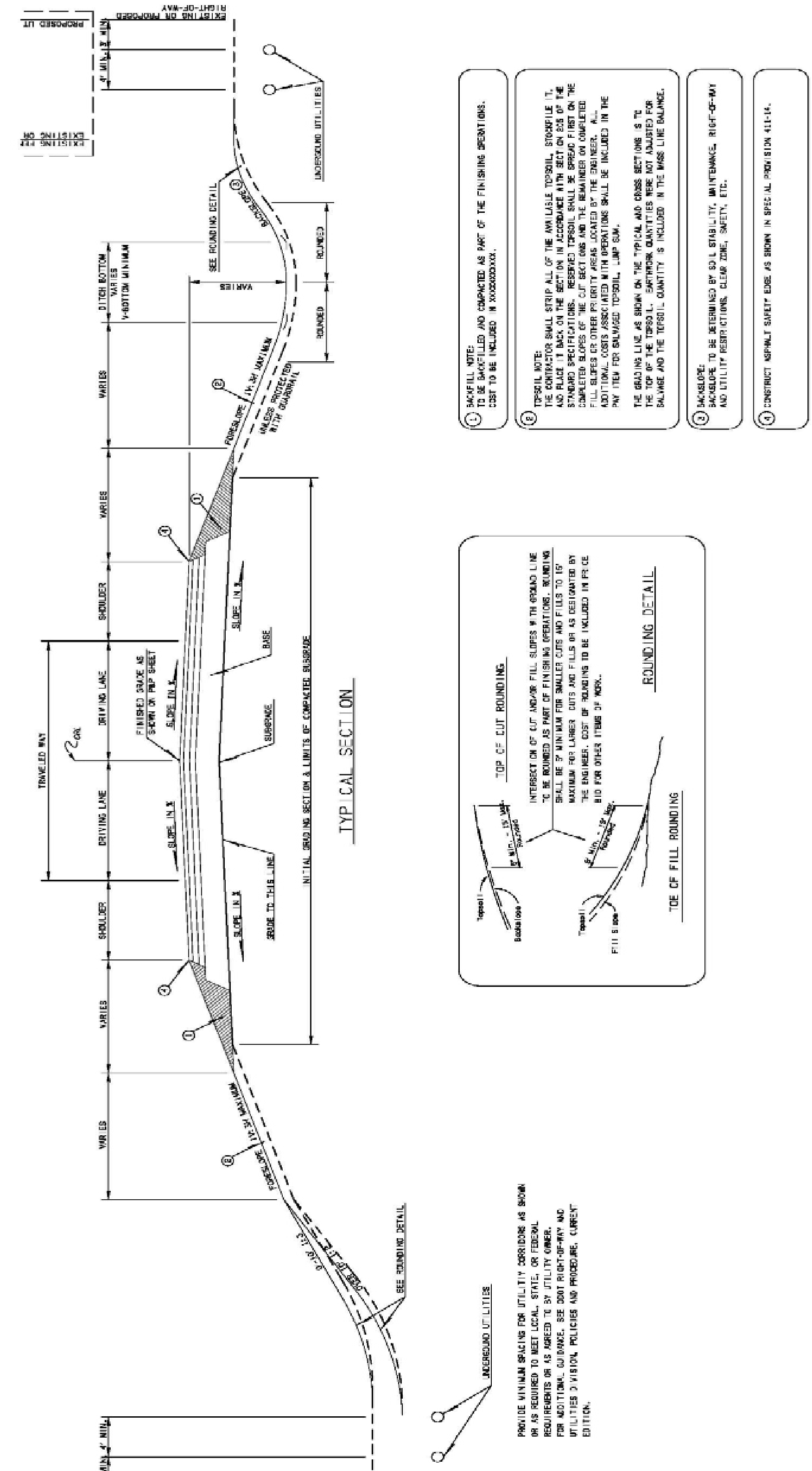
TYPICAL SECTION
TRAVELED WAY
VARIES
SHOULDER
DRIVING LANE
DITCH BOTTOM VARIES V-BOTTOM MINIMUM
FINISHED GRADE AS SHOWN ON P&P SHEET
SLOPE IN %
GRADE TO THIS LINE
SUBGRADE
BASE
INITIAL GRADING SECTION & LIMITS OF COMPACTED SUBGRADE
FORESLOPE 1V: 3H MAXIMUM
UNLESS PROTECTED WITH GUARDRAIL
BACKSLOPE
ROUNDED
SEE ROUNDING DETAIL
UNDERGROUND UTILITIES
EXISTING OR PROPOSED RIGHT-OF-WAY
PROPOSED UT
3' MIN. 4' MIN.
PROVIDE MINIMUM SPACING FOR UTILITY CORRIDORS AS SHOWN OR AS REQUIRED TO MEET LOCAL, STATE, OR FEDERAL REQUIREMENTS OR AS AGREED TO BY UTILITY OWNER. FOR ADDITIONAL GUIDANCE, SEE ODOT RIGHT-OF-WAY AND UTILITIES DIVISION, POLICIES AND PROCEDURE, CURRENT EDITION.
TOP OF CUT ROUNDING
TOE OF FILL ROUNDING
ROUNDING DETAIL
Topsoil
Backslope
Fill Slope
INTERSECTION OF CUT AND/OR FILL SLOPES WITH GROUND LINE TO BE ROUNDED AS PART OF FINISHING OPERATIONS. ROUNDING SHALL BE 5' MINIMUM FOR SMALLER CUTS AND FILLS TO 15' MAXIMUM FOR LARGER CUTS AND FILLS OR AS DESIGNATED BY THE ENGINEER. COST OF ROUNDING TO BE INCLUDED IN PRICE BID FOR OTHER ITEMS OF WORK.
(1) BACKFILL NOTE: TO BE BACKFILLED AND COMPACTED AS PART OF THE FINISHING OPERATIONS. COST TO BE INCLUDED IN XXXXXXXXXX.
(2) TOPSOIL NOTE: THE CONTRACTOR SHALL STRIP ALL OF THE AVAILABLE TOPSOIL, STOCKPILE IT, AND PLACE IT BACK ON THE SECTION IN ACCORDANCE WITH SECTION 205 OF THE STANDARD SPECIFICATIONS. RESERVED TOPSOIL SHALL BE SPREAD FIRST ON THE COMPLETED SLOPES OF THE CUT SECTIONS AND THE REMAINDER ON COMPLETED FILL SLOPES OR OTHER PRIORITY AREAS LOCATED BY THE ENGINEER. ALL ADDITIONAL COSTS ASSOCIATED WITH OPERATIONS SHALL BE INCLUDED IN THE PAY ITEM FOR SALVAGED TOPSOIL, LUMP SUM.
THE GRADING LINE AS SHOWN ON THE TYPICAL AND CROSS SECTIONS IS TO THE TOP OF THE TOPSOIL. EARTHWORK QUANTITIES WERE NOT ADJUSTED FOR SALVAGE AND THE TOPSOIL QUANTITY IS INCLUDED IN THE MASS LINE BALANCE.
(3) BACKSLOPE: BACKSLOPE TO BE DETERMINED BY SOIL STABILITY, MAINTENANCE, RIGHT-OF-WAY AND UTILITY RESTRICTIONS, CLEAR ZONE, SAFETY, ETC.
(4) CONSTRUCT ASPHALT SAFETY EDGE AS SHOWN IN SPECIAL PROVISION 411-14.

FIGURE 5-1

CHAPTER 6

CROSS-SECTION ELEMENTS

A. ROADWAY WIDTH

The minimum roadway width is the sum of the traveled way and shoulder width given in the table below. Shoulder width is measured from the edge of traveled way to the point of intersection of shoulder slope and foreslope. In mountainous terrain or sections with heavy earthwork, the graded width of shoulder in cuts may be decreased by up to 2 feet, but in no case should the roadway width be less than 20 feet.

Table 6-1. Traveled Way Width (ft) for Design Volumes and Speed

Design Speed (mph)	ADT Less than 250	ADT 250 - 399	ADT 400 - 2000	ADT 2000 - 2500
Width of Traveled Way				
<30	18	18	20	22
35	18	18	20	22
40	18	20	20	22
45	20	20	22	22
50	20	20	22	22
55	20	20	22	24
Width (ft) of Shoulder (Each Side)				
All Speeds	2	2	3	6*

(Page 5-7 Geometric Design of Highways and Streets)
*At least 2ft of the shoulder shall be paved.

B. SHOULDERS

Recommend shoulders be constructed of gravel as a minimum.

C. SIDESLOPES

Slopes should be as flat as feasible. Recoverable foreslopes increase safety by providing maneuver area in emergencies, are more stable than steep slopes, aid in the establishment of plant growth and simplify maintenance work. Vehicles that leave the traveled way can often be kept under control if slopes and drainage ditches are recoverable. Such recovery areas should be provided where terrain and right-of-way controls permit.

Combinations of rate and height of slope should provide for vehicle recovery. Where controlling conditions (such as high fills, right-of-way restrictions, or the presence of rocks, watercourses, or other hazards) make this impractical, an analysis shall be performed to determine the proper method of treatment. See Roadside Safety, Chapter 8 and AASHTO Roadside Design Guide for additional discussions of this analysis.

Cut sections should be designed with adequate ditches to promote proper drainage. The foreslope within the clear zone shall not be steeper than 1V:3H unless protected by guardrail. Shoulders shall be widened to accommodate guardrail to provide a uniform width of traveled way and outside shoulders. The backslope shall not exceed the maximum required for stability, maintenance, right-of-way and utility restrictions, clear zone, and safety.

The Special Provision 411-14(a-b)09, Asphalt Safety Edge, should be included as it will apply to most county projects where the paved shoulder is 4 feet or less.

D. DITCHES

As a minimum, ditches shall have a cross-sectional area adequate to handle a 5-year flood (Q5). The elevation of the bottom of the ditch shall be a minimum of 1.0 ft. below the subgrade at the edge of shoulder. The minimum desirable grade for drainage ditches should be 0.5% in order to avoid sedimentation. However, ditch grades may be designed as flat as 0.4% as the minimum slope for grassed channels and 0.2% for concrete lined channels to meet site conditions. The maximum grade should be based on a tolerable velocity for vegetation and shear on soil types. See Drainage Design, Chapter 10 for additional discussions. Ditch slopes greater than 3% (or velocities greater than 8 ft/sec) should consider erosion control techniques such as paved ditch liner, riprap lined ditches, ditch checks, wider ditch bottoms, etc. Rounded or flat bottom ditches are preferred. V-ditches may be used in areas with limited right-of-way. Interceptor ditches should be used in areas of steep backslopes and hillsides.

CHAPTER 7

AT-GRADE INTERSECTIONS

A. SIGHT DISTANCE

Intersections should be carefully situated to avoid steep profile grades and to ensure adequate approach sight distance. Intersections are not well situated on short-crest vertical curves, just beyond a short-crest vertical curve, or on a sharp horizontal curve. When there is no practical alternate to such a location, the approach sight distance on each leg should be checked carefully. Where necessary, backslopes should be flattened and horizontal or vertical curves lengthened to provide additional sight distance. Sight distance should be sufficient to permit a vehicle on the minor leg of the intersection to cross the traveled way without requiring the approaching through traffic to slow down. The suggested corner sight distance for each design speed would be as given in the table below.

Table 7-1. Intersection Sight Distance

Design Speed (mph)	**Stopped Passenger Car Turning Left Design Distance (ft)**
20	225
25	280
30	335
35	390
40	445
45	500
50	555
55	610
60	665
65	720

(Table 9-7, "Green Book")

Note: Intersection sight distance shown is for a stopped passenger car to turn left onto a two-lane highway with no median and grades 3 percent or less. For other conditions, the time gap must be adjusted and required sight distance recalculated.

Where practical, it is desirable to increase the Corner Intersection Sight Distance especially where higher volumes of trucks are present.

Table 7-2. Truck Intersection Sight Distance

Design Speed (mph)	Corner Intersection Sight Distance (feet)	
	Single Unit Truck	**Combination Truck**
20	280	340
25	350	425
30	420	510
35	490	595
40	560	680
45	630	765
50	700	850
55	770	930
60	840	1015
65	910	1100

(Equation 9-1, pg. 9-45, “Green Book”)

For additional information for the calculation of corner intersection sight distance, see Chapter 9 of the AASHTO “Policy on Geometric Design of Highways and Streets”. If the recommended Corner Intersection Sight Distances cannot be met, the intersection should be changed to a full stop controlled intersection with the introduction of proper traffic control devices.

B. TURNING RADIUS

Intersections should be designed with a pavement corner radius that is adequate for anticipated truck traffic to minimize trucks crossing over into adjacent lane. See the Chapter 9 of the AASHTO “Policy on Geometric Design of Highways and Streets” for turning paths.

Intersection legs that operate under stop control preferably should be 90°. The intersection legs should not be less than 75°, but may allow 60° when ADT<400 and the intersection site has no negative accident history due to turning movements.

Minimum Edge Radius of 25 feet shall be used.

CHAPTER 8

ROADSIDE SAFETY

A. CLEAR ZONE WIDTH

Clear Zone is the distance from the edge of the driving lane to an obstacle. The probability of vehicle departure from the driving lane increases as traffic volumes rise. The minimum clear zone width of 2’ is required on all projects. Refer to the current version of AASHTO’s Roadside Design Guide for further details.

Table 8-1. Clear Zone Requirements

Design ADT	Width (ft)
0 – 400	2
401 – 2500	7 - 10

(Pg. 4-35, “Low Volume 2019 second edition)

As an alternative to using the table values above, the designer may use two methods to reduce the clear zone widths. With the first method, a designer may use a cost-effectiveness analysis that assesses the appropriate roadside design. A NCHRP program, Roadside Safety Analysis (RSAP), is one analysis that compares alternate safety treatments and provides guidance in selecting a design. In the second method the designer may submit a design exception that is recorded by the Oklahoma Department of Transportation see chapter 15.

B. GUARDRAIL END TREATMENTS

For all projects under 400 design ADT, the designer may use a guardrail anchor unit, a turn down end treatment Type A, on the leading edge of guardrail (designer to provide detail sheet). Remember to include a delineator as shown on the standard at the end.

Over 400 design ADT shall require on the leading edge of guardrail, a crash tested end treatment, NCHRP 350 or MASH, (Refer to current ODOT Traffic Safety Standard).

CHAPTER 9

GEOMETRIC DESIGN CRITERIA

A. GENERAL INFORMATION

The notes below shall apply to the table found on the following page. This table serves as a useful quick reference guide for minimum new design values on new and reconstruction projects. The engineer should make every effort to exceed these minimums where project attributes, such as costs, are not greatly affected. On 3R projects existing design values/geometrics may be used after investigating safety improvements through traffic counts and accident studies. (see Chapter 16).

(1) **Design Year.** Recommended that on Major / Minor collector system a 20-year projection be used.

(2) **Design Speed.** The design speed should equal or exceed the anticipated posted or regulatory speed limit after construction.

(3) **Shoulder Width.** All shoulder widths refer to the constant slope between the edge of the travel lane and the point of intersection of the shoulder slope and the side slope. (See Chapter 5).

(4) **Right-of-Way Width.** The minimum Right-of-Way width will be the sum of the travel lane width, the necessary width for fill and cut slopes, and width needed for parallel utility. (unless utility easement option is used)

(5) **Clear Zone.** See Chapter 8.

(6) **Back Slopes.** Back slopes should be flat as possible and it is recommended no steeper than 1(V):3(H) for maintenance activities, but may be as steep as 1(V):1/4(H) in rock cuts.

(7) **Minimum Radius for ADT>400 / Superelevation Rate.** The values provided in the table are based on a emax=.08, which will apply in most cases. See Chapter 4 for lower ADT**.**

(8) **Vertical Curvature (K-Values).** Values in the table are minimums for ADT > 400. See Chapter 5.

(9) **Structural Capacity**. Title 69 Sec. 662, "County Built" project must be a min. H-23 tons operating rating. See Chapter 12 for projects not county built.

(10) **Bridge Width.** Title 69 Sec. 662, "County Built" project must be a min. 24' wide.

Table 9-1. Minimum Geometric Design Criteria

Design Element			Manual Section	ADT 0-250	ADT 251-400	ADT 401-1500	ADT 1501-2000	ADT 2001-2500
Design Year			Ch. 3	Current (1)				
Design Speed mph (2)		Level	Ch. 3	30	40	50	50	50
		Rolling	Ch. 3	30	30	40	40	40
		Mountainous	Ch. 3	20	20	30	30	30
Surface Type				Gravel		Paved		
Lane Width			Ch. 6	9	10	11	11	12
Shoulder		Type						
		Width (3)	Table 6-1	2	2	3	3	6*
Cross Slope		Paved	Table 4-1	1.5%-2%				
		Gravel		2%-6%				
Right of Way Width				See Part (4)				
Clear Zone				See Part (5)				
Side Slopes	Cut	Foreslope	Ch. 6	Min. 1V:3H				
		Backslope	Ch. 6	Recommended Min. 1V:3H (6)				
	Fill		Ch. 6	Min. 1V:3H				
Design Speed (mph)				30	35	40	45	50
Min. Stopping Sight Distance (ft)			Table 5-2	196.7	246.2	300.6	369.8	423.8
Min. Radius (ft) (7)			Table 4-2	214	314	444	587	758
Min. Superelevation (7)				See Table 4-3				
Vertical Curvature K-Value (8)		Crest	Table 5-2	18.5	29	43.1	60.1	83.7
		Sag	Table 5-2	36.4	49	63.4	78.1	95.7
Maximum Grade		Level	Table5-1	7	7	7	7	6
		Rolling	Table 5-1	9	9	8	8	7
		Mountainous	Table 5-1	10	10	10	10	9
Minimum Grade				Desirable 0.5%; Minimum 0.0%				
New and Reconstructed Bridges		ADT		0-250	251-400	401-1500	1501-2500	
		Structural Capacity	Ch. 12	HL-93 (9)				
		Width	Ch. 12	County Bridge Standards (10)				
Existing Bridges to Remain in Place		Structural Capacity	Ch. 12	H-25	H-25	H-25	H-25	
		Width	Ch. 12	20	22	24	26	

*At least 2ft of the shoulder shall be paved.

CHAPTER 10

DRAINAGE DESIGN

A. STORM FREQUENCY

All drainage for county road projects shall be computed using no less than the 5-year rainfall frequency curves unless the area served dictates the use of a greater return frequency. Drainage structures shall be designed in accordance with the table below.

Roadway Classification	Exceedance Probability (%)	Return Period (Year)
Major Collector System or AADT > 2000 VPD	4%	25
Minor Collector System or AADT 400 < 2000 VPD	10%	10
Local Road System	20%-10%	5-10

B. DESIGN METHODOLOGY

General guidelines for Q calculation methods:

1. USGS Method for 1 square mile < drainage area < 2,500 square miles; see "Techniques for Estimating Peak-Streamflow Frequency for Unregulated Streams and Streams Regulated by Small Floodwater Retarding Structures in Oklahoma" by U.S. Geological Survey and Water-Resources Investigations Report 97-4202. Calculation aids are available at: http://water.usgs.gov/osw/streamstats/oklahoma.html

   SCS Method for 200 acres < drainage area < 640 acres; see "NEH-Part 630-Hydrology" for SCS Method. (NEH = National Engineering Handbook and Part 630 is the hydrology section. Link to NEH manual: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=STELPRDB1043063

2. Rational Method for drainage area < 200 acres; see ODOT Roadway Design Manual Chapter 15, Drainage latest edition for "Rational Method."

Further guidance for the Rational Method is included below:

The Rational Method may be used to compute the design flows for all structures less than those classified as Bridge Structures, i.e. 20 feet or more in span. This method is given in the formula:

$$Q = C * I * A$$

where:

Q = total flow in cfs

C = runoff coefficient, see Table 10-5.

I = intensity in inches /hour. See Tables 10-3 and 10-4.

A = area of the drainage basin in acres and is less than 200 acres.

The runoff coefficient, C, is a factor used to modify the amount of runoff from an area under consideration because of surface conditions which change the drainage characteristics. This coefficient, C, is a factor which decreases the total runoff from 100%. Table 10-5 is included with a range of values for the most anticipated conditions.

The Time of Concentration is determined and from that the intensity, I, is calculated. The Time of Concentration is the time required for water to flow from the most remote part of the watershed to the drainage structure and is broken into two parts: time for overland flow and time for channel flow. Formula for Time of Concentration is:

$Tc = To + Tf$

where:

Tc = total time of concentration

To = time of flow overland to the channel

Tf = time of flow through the channel to the drainage structure

The Time of Concentration of overland flow, To, can be computed by:

$To = k\,(Lo^{0.37}) / (So^{0.20})$

where:

To = Time of Concentration in minutes

Lo = Length of the overland flow in feet

So = slope in feet / feet

k = a coefficient dependent on ground cover, see Table 10-1.

Table 10-1

Ground Cover Material	K
Concrete/asphalt	0.372
Commercial development	0.445
Residential development	0.511
Rocky, bare soil	0.604
Cultivated soil	0.775
Woodlands, thin grass	0.942
Average pasture	1.040
Tall grasses	1.130

Time of Concentration for channel flow, Tf, can be computed by:

$Tf = k' (Lf^{0.77}) / (Sf^{0.385})$

where:

Tf = Time of Concentration in minutes
Lf = channel length in feet
Sf = channel slope in feet / feet
k' = a coefficient dependent on type of channel, see Table 10-2.

Table 10-2

Channel condition	K'
Straight, clean stream	0.00592
Average stream, few obstructions	0.00835
Meandering stream w/pools	0.01020
V-ditch	0.01252

With the time of concentration calculate the intensity from:

$I = a / (Tc + b)^{c}$

where:

values of a, b, and c are found in Table 10-4 for each zone in the state of Oklahoma and the different zones are found in Table 10-3 on the next page.

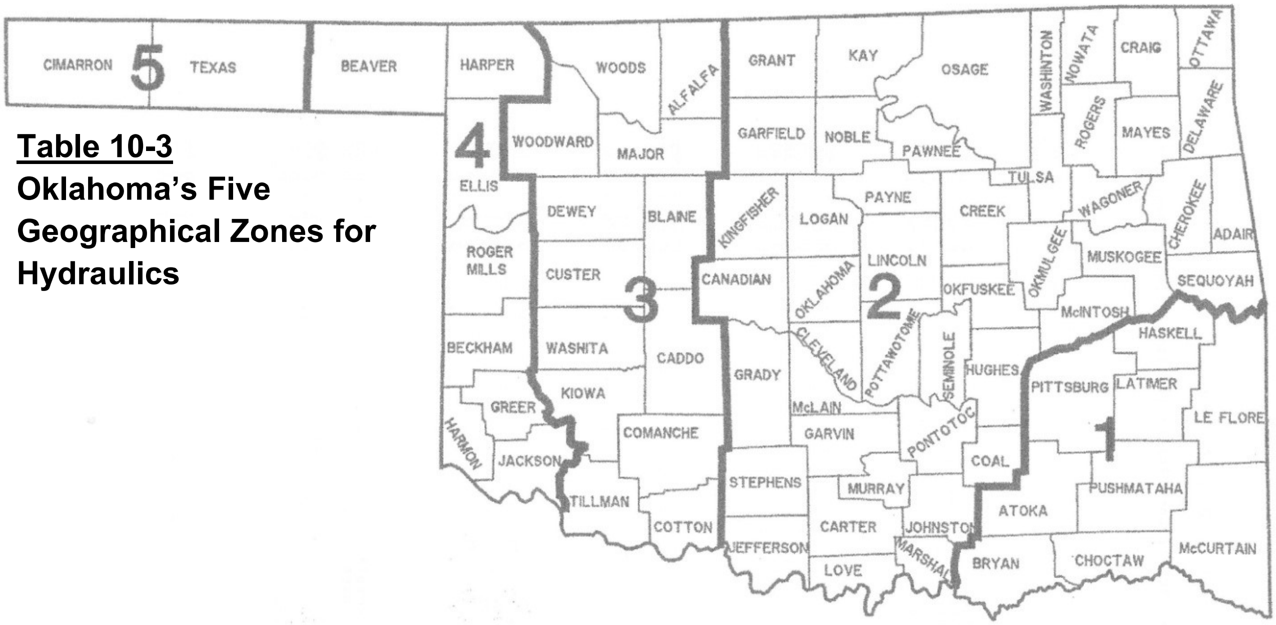

Table 10-3
Oklahoma's Five Geographical Zones for Hydraulics

	TABLE 10-4: RAINFALL FREQUENCY					
	2 Year	**5 Year**	**10 Year**	**25 Year**	**50 Year**	**100 Year**
ZONE 1	a = 52.00	69	79	91	100	112
	b = 10.50	15				
	c = 0.782	0.7825				
ZONE 2	a = 56.43	72	82	95	108	120
	b = 11.50	15				
	c = 0.810	0.8000				
ZONE 3	a = 40.85	73	84	97	110	120
	b = 7.00	15				
	c = 0.772	0.8100				
ZONE 4	a = 41.30	75	88	103	117	129
	b = 7.50	15				
	c = 0.790	0.8350				
ZONE 5	a = 53.38	84	97	114	127	142
	b = 10.50	15				
	c = 0.865	0.8820				

Table 10-5
Estimated Values of Runoff Coefficient, C, for Rational Formula

LAND USE	VALUES OF C
Business:	
Downtown areas	0.70-0.95
Neighborhood Areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.25-0.40
Apartment dwelling areas	0.50-0.70
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets:	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.85
Lawns:	
Sandy soil, flat – 2%	0.05-0.10
Sandy soil, average 2%-7%	0.10-0.15
Sandy soil, steep 7%	0.15-0.35
Heavy soil, flat – 2%	0.13-0.17
Heavy soil, average 2%-7%	0.18-0.22
Heavy soil, steep 7%	0.25-0.35
Agricultural land:	
Bare, packed soil, smooth	0.30-0.60
Bare, packed soil, rough	0.20-0.50
Cultivated rows:	
Heavy soil, no crop	0.30-0.60
Heavy soil with crop	0.20-0.50
Sandy soil, no crop	0.20-0.40
Sandy soil with crop	0.10-0.25
Pasture:	
Heavy soil	0.15-0.45
Sandy soil	0.05-0.25
Woodlands	0.05-0.25

C. OPEN CHANNEL FLOW

Highway ditches and drainage channels shall be designed using the Mannings formula:

$Q = (1.49/n)\ (A)(R^{2/3})(S^{1/2})$

where:

- Q = discharge in cubic feet per second, cfs
- A = area of the channel section in square feet
- n = roughness coefficient, see Table 10-6.
- R = hydraulic radius in feet, R = Area / wetted perimeter
- S = slope of channel in feet per feet, ft/ft

This formula should also be used to compute flow through culverts behaving as open channels. The maximum desirable velocity should not exceed 8 ft/sec in any open channel under optimum conditions and velocities less than 3 ft/sec should be avoided to prevent the settling of solids suspended in storm water effluent.

D. CULVERT DESIGN

Drainage culverts for cross drains may be designed using the Manning's Equation for open channel flow. When the engineer warrants a more detailed analysis the culvert shall be designed according to methods as set forth in the FHWA's HY-8 or the ODOT Roadway Design Manual, Hydraulics Section. The HY-8 Culvert Analysis and Design Program may be downloaded at:

https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/

Side drains shall not be less than 18 inches in equivalent diameter and cross drains shall not be less than 24 inches in equivalent diameter. As with the channels and ditches, the culverts shall be sized to provide optimum flow rates for soil conditions.

No corregated metal pipes shall be used under roadways.

TABLE 10-6

ROUGHNESS COEFFICIENTS FOR USE IN MANNING EQUATION (1) (4)

I. Closed Conduits (2)	
A. Concrete Pipe	0.011-0.013
B. Corrugate metal pipe or pipe arch	
1. 2 2/3" x 1/2" corrugation (riveted pipe) **(3)**	
a. Plain or fully coated	0.024
b. Paved invert (25% and 50% paved)	
(1) Flow full depth	0.021-0.018
(2) Flow 0.8 depth	0.021-0.016
(3) Flow 0.5 depth	0.027
2. 2" x 1" corrugation	0.027
3. 6" x 2" corrugation (field bolted)	0.032
C. plastic	0.009
1. PE smooth walls	0.009-0.015
2. PE with corrugated walls	0.018-0.025
3. PVC smooth walls	0.009-0.011
D. Vitrified clay pipe	0.012-0.104
E. Cast-iron pipe, uncoated	0.013
F. Steel pipe	0.009-0.011
G. Brick	0.014-0.017
H. Monolithic Concrete	
1. Wood forms, rough	0.015-0.017
2. Wood forms, smooth	0.012-0.014
3. Steel forms	0.012-0.013
I. Cemented ruble masonry walls	
1. Concrete floor and top	0.017-0.022
2. Natural floor	0.019-0.025
J. Laminated treated wood	0.015-0.017
K. Vitrified clay liner plates	0.015
II. Lined Open Channels (2)	
A. Concrete, with surfaces indicated:	
1. Formed, no finish	0.013-0.017
2. Trowel finish	0.012-0.014
3. Float finish	0.013-0.015
4. Float finish, some gravel on bottom	0.016-0.017
5. Gunite, good section	0.016-0.019
6. Gunite, wavy section	0.018-0.022
B. Concrete bottom float finished sided as indicated:	
1. Dressed stone in mortar	0.015-0.017
2. Random stone in mortar	0.020-0.025
3. Cement rubble masonry	0.020-0.025
4. Cement ruble masonry, plastered	0.016-0.020
5. Dry rubble (riprap)	0.020-0.030

C. Gravel bottom, sides as indicate:	
1. Formed concrete	0.107-0.020
2. Random stone in mortar	0.020-0.023
3. Dry rubble (riprap)	0.023-0.033
D. Brick	0.014-0.017
E. Asphalt	
1. Smooth	0.013
2. Rough	0.016
F. Wood, planed, clean	0.011-0.013
G. Concrete lined excavated rock:	
1. Good section	0.017-0.020
2. Irregular section	0.022-0.027
III. Unlined Open Channels (2)	
A. Earth uniform section	
1. Clean, recently completed	0.016-0.018
2. Clean, after weathering	0.018-0.020
3. With short grass, few weeds	0.022-0.027
4. In gravely soil, uniform section, clean	0.022-0.025
B. Earth, fairly uniform section,	
1. No vegetation	0.022-0.025
2. Grass, some weeds	0.025-0.030
3. Dense weeds or aquatic plants in deep channels	0.030-0.035
4. Sides, clean, gravel bottom	0.025-0.030
5. Sides, clean, cobble bottom	0.030-0.040
C. Dragline excavated or dredged,	
1. No vegetation	0.028-0.033
2. Light brush on banks	0.035-0.050
D. Rock,	
1. Based on design section	0.035
2. Based on actual mean section,	
a. Smooth and uniform	0.035-0.040
b. Jagged and irregular	0.040-0.045
E. Channels not maintained, weeds and brush uncut,	
1. Dense weeds, high as flow depth	0.080-0.012
2. Clean bottom, brush on sides	0.050-0.080
3. Clean bottom brush on sides, highest stage of flow	0.070-0.011
4. Dense brush, high stage	0.100-0.140
IV. Street and Expressway Gutters:	
A. Concrete gutter, trowel finish	0.012
B. Asphalt pavement,	
1. Smooth texture	0.013
2. Rough texture	0.016
C. Concrete gutter with asphalt pavement,	
1. Smooth	0.013
2. Rough	0.015
D. Concrete pavement,	
1. Float finish	0.014
2. Broom finish	0.016
E. For gutters with small slope, where sediment may accumulate, increase all above values of n by	0.002

V. Highway Channels and Swales With Maintained Vegetation (values show are for velocities of 2 and 6 f.p.s.),	
A. Depth of flow up to 0.7 feet	
1. Bermuda grass, Kentucky bluegrass, buffalo grass,	
a. Mowed to 2 inches	0.070-0.045
b. Length 4 to 6 inches	0.090-0.050
2. Good stand, any grass,	
a. Length about 12 inches	0.180-0.090
b. Length about 24 inches	0.300-0.150
3. Fair stand, any grass,	
a. Length about 12 inches	0.140-0.080
b. Length about 24 inches	0.250-0.130
B. Depth of flow 0.7-1.5 feet	
1. Bermuda grass, Kentucky bluegrass, buffalo grass,	
a. Mowed to 2 inches	0.050-0.350
b. Length 4 to 6 inches	0.060-0.040
2. Good stand, any grass,	
a. Length about 12 inches	0.120-0.070
b. Length about 24 inches	0.200-0.100
3. Fair stand, any grass,	
a. Length about 12 inches	0.100-0.060
b. Length about 24 inches	0.170-0.090
VI. Natural Stream Channels, (3)	
A. Minor streams (surface width at flood stage less than 100 feet)	
1. Fairly regular section,	
a. Some grass and weeds, little or no brush	0.030-.035
b. Dense growth of weeds, depth of flow materially greater than weed height	0.035-.050
c. Some weeds, light brush on banks	0.040-0.050
d. Some weeds, heavy brush on banks	0.050-0.070
e. Some weeds, dense willows on banks	0.060-0.080
f. For trees within channel, with branches submerged at high stage, increase all above values by	0.010-0.100
2. Irregular section, with pools, slight channel meander, increase values in 1. a-e about	0.010-0.020
3. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage,	
a. bottom of gravel, cobbles and few boulders	0.040-0.050
b. Bottom of cobbles, with large boulders	0.050-.0070
B. Flood plains (adjacent to natural streams,	
1. Pasture, no brush,	
a. Short grass	0.030-0.035
b. High grass	0.035-0.050
2. Cultivated areas,	
a. No crop	0.030-0.040
b. Mature row crops	0.035-0.045
c. Mature field crops	0.040-0.050
3. Heavy weeds, scattered brush	0.050-0.070
4. Light brush and trees	
a. Winter	0.050-0.060

b. Summer	0.100-0.160
5. Medium to dense brush,	
a. Winter	0.070-0.110
b. Summer	0.100-0.160
6. Dense willows, summer, not bent over by current	0.150-0.200
7. Cleared land with tree stumps, 100-150 per acre,	
a. No sprouts	0.040-0.050
b. With heavy growth of sprouts	0.060-0.080
8. Heavy stand of timber, a few down trees, little undergrowth,	
a. Flood depth below branches	0.100-0.120
b. Flood depth reaches branches	0.120-0.160
C. Major streams (surface width at flood stage more than 100 feet), Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of n may be somewhat reduced. Follow recommendation of note 7 if possible. The value of n for larger streams of most regular sections, with no boulders of brush, may be in the range of from	0.028-0.033

Table 10-6 Footnotes:

(1) Estimates are by Bureau of Public Roads (FHWA) unless otherwise noted and are for straight alignment. A small increase in value of n may be made for channel alignment other than straight.

(2) Ranges for section I through III are for good to fair construction. For poor quality construction use larger values of n.

(3) The tentative values of n cited are principally derived from measurements made on fairly short but straight reaches of natural streams. Where slopes calculated from flood elevations along a considerable length of channel, involving meanders and bends, are to be used in velocity calculations by the Manning formula, the value of n must be increased to provide for the additional loss of energy caused by beds. The increase may be in the range of perhaps 3% to 15%.

(4) The presence of foliage on trees and brush under flood stage will materially increase the value of n. Therefore, roughness coefficients for vegetation in leaf will be larger than for bare branches. For trees in channels or on banks, and for brush on banks where submergence of branches increases with depth of flow, n will increase with rising stage.

CHAPTER 11

PAVEMENT DESIGN

A. GENERAL INFORMATION

Typical projects for county roads can be broken down into three major catagories. The first type of project would be bridge replacement projects with short approach roadway sections. The second type of project would be longer roadway paving projects. These longer roadway projects may include one or more bridge structure(s) but the roadway design effort is a large part of the design effort. The third type of project would be mainly structural overlays. The first two project types will have surfacing designed with preferred programs such as WinPass or PaveExpress. If other design methods are used they shall be based on the latest AASHTO pavement design methods. Overlay project designs should use the latest AASHTO design method.

Pavement design, collection of data, data summary and calculations may be completed by a geotechnical firm hired as a subcontractor by the Design Engineer.

Designers may need to consult the Geotechnical Investigation, Chapter 13, for futher consideration.

B. DESIGN CONSIDERATIONS

- A current or projected ADT count and percentage and type of truck loadings will be necessary for any design. (Note oil field traffic, agriculture, industrial, mining and aggregate production)

- Soil Types and properties obtained from one or more of the following
  - Bridge Borings
  - Roadway Borings
  - Oklahoma Soil Classification Charts

- Length of Project
  - Bridge with short approaches
  - Large roadway projects
  - Overlay only

- Design Life
  - The design traffic volume will be based upon the road's functional classification. All projects, not including 3R projects, on the Major and Minor

Collector System will base design upon a 20-year traffic volume projection. A minimum 2% per year growth rate may be used unless other traffic factors are known. Local Roads, and 3R projects on Major and Minor collectors, may base design on the current average of a continuous seven-day traffic count to achieve an average daily traffic, ADT, count regardless of the improvement.

- Work Type
  - New Construction - new alignment.
  - Reconstruction* - major changes to horizontal/vertical alignment, pavement structure.
  - 3R Resurfacing, Restoration, Rehabilitation (3R) – overlays, minor pavement width and/or alignment changes.

  * For reconstruction projects, alternate methods that incorperate existing pavement structure may be considered that will enhance pavement structure while providing an efficient design.

C. COMPUTATIONAL METHODS FOR PAVEMENT THICKNESS

- WinPass
- PaveExpress
- If other design methods are used they shall be based on the latest AASHTO pavement design methods.

CHAPTER 12

BRIDGE DESIGN

A. GENERAL INFORMATION

County bridge design must consider the ultimate use of the bridge given its location. Most county bridges should be able to remain in service for 50 to 75 years with minor maintenance and repair. These structures carry people, school buses, agricultural products, ranching products, oil field equipment and other uses, and should be designed conservatively. The designer should be aware of extreme events that could occur and take reasonable cost-effective measures so the structures would suffer little or no damage.

If the new structure meets the definition of a bridge length structure according to Title 23 Code of Federal Regulations 650 Subpart C the State of Oklahoma Department of Transportation Bridge Division will need to be notified.

6. BRIDGE WIDTHS

Bridge width consideration should take into account the approach roadway width, agricultural equipment use, special truck use, and the functional classification. Future ADTs should be used for bridge and approach roadway designs.

7. HYDRAULICS

A hydraulic report should be written and submitted to the bridge owner and the reviewing agency. The 100-year frequency event shall never overtop the bridge deck or approach slabs and preferably fall below the low chord. Minimum design Qs for passing flows without roadway overtopping for different road classifications:

Roadway Classification	Exceedance Probability (%)	Return Period (Year)
Major Collector System or AADT > 2000 VPD	4%	25
Minor Collector System or AADT 400 < 2000 VPD	10%	10
Local Road System	20%-10%	5-10

If the approach roadway has a fuse plug the design Q will be the Q when flow goes over the fuse plug.

Q calculation methods

1. USGS Method for 1 square mile < drainage area < 2,500 square miles; see "Methods for Estimating the Magnitude and frequency of Peak Streamflows for Unregulated Streams in Oklahoma Developed by Using Streamflow Data Through 2017" by U.S. Geological Survey in cooperation with the ODOT. Methods for Estimating the Magnitude and Frequency of Peak Streamflows for Unregulated Streams in Oklahoma Developed by Using Streamflow Data Through 2017 (usgs.gov)
   Calculation aids are available at:
   http://water.usgs.gov/osw/streamstats/oklahoma.html

2. SCS Method for 200 acres < drainage area < 640 acres; see "NEH-Part 630-Hydrology" for SCS Method. (NEH = National Engineering Handbook and Part 630 is the hydrology section. Link to NEH manual: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=STELPRDB1043063

3. Rational Method for drainage area < 200 acres; see ODOT Roadway Design Manual Chapter 15, Drainage latest edition for "Rational Method."

Fuse plugs

Fuse plugs should be incorporated in approach roadway when possible. If a fuse plug cannot be constructed, the design Q will be the minimum Q that passes under the bridge with freeboard.

Freeboard

Freeboard is the distance between the water surface at the design Q measured to the lowest point on the bottom chord of the girder or ceiling of a reinforced concrete box. Freeboard shall be a minimum of 1 foot or as required by the local floodplains management policies.

Velocities

1. Flows under a span bridge should not exceed 8 ft/sec over proposed channel bottom for 50-year computed velocity or not exceed 25% change comparing existing to proposed structure.
2. The flow rate past the concrete floor of the apron area shall not exceed 8 ft/sec for 50-year computed velocity or less than 25% change over existing and proposed structure.
3. All RCBs shall be constructed with concrete aprons and minimum 4ft curtain wall.

Backwater

1. In a FEMA Designated floodplain Zone A backwater should not exceed 1-foot elevation rise over the natural flow elevation r as required by local floodplain management policies.
2. In a floodway FEMA Designated floodplain Zone AE backwater should have zero rise over what was modeled when mapped.

8. HORIZONTAL ALIGNMENT

Curves

Curves on bridges should be avoided if at all possible. Do not construct a curve at each end of a bridge with the bridge being on a tangent. Use good engineering judgment for bridge alignment and sight distance.

Superelevation

The bridge and roadway should be designed such that the horizontal and vertical alignment smoothly transitions vehicles from roadway to the bridge and back to the roadway adjusting tangents, curves, and superelevation as needed.

Superelevation on bridges is not recommended; however, if necessary, then the superelevation should be held constant for the full length of the bridge. Preference for constructability is that superelevation across a bridge should not exceed 2%; the maximum allowed is 6%. Use sound engineering judgment when constructing superelevation on bridges.

9. VERTICAL ALIGNMENT

Roadway traffic velocities for sag and crest curves shall govern vertical alignment. Longitudinal slopes on the bridge shall remain constant. Crest curves are not recommended; however, if necessary, shall be sufficiently flat for the driver to see the end of the bridge from the beginning of the bridge.

Haunches

a. Bridges should have no more than 4” haunch between deck and beam.
b. Haunches should be calculated to allow for dead load deflections.
c. For all haunch depths, shear studs or interface shear reinforcing should extend, from the top flange, a minimum of 2” above the bottom mat of bridge deck reinforcing.

Alignments that force the beams to be constructed on a grade steeper than 1% shall have beveled anchor plates whose bevel angle is the same as the beam slope and the anchor plate thickness at the center line of the bearing shall be 1½”. The maximum preferred beam slope is 6%.

10. BRIDGE SKEWS

Reinforced Concrete Boxes, RCB

Both skewed and non-skewed RCBs may be rotated at any angle as needed to align with the creek channel but clear zone requirements must still be met.

Span Bridges

County span bridges typically have 0-degree skew or 30-degree skew but can be any skew up to 45-degrees. Bridges should not exceed a 45-degree skew.

Use good engineering judgment when requiring a skewed bridge.

11. ROADSIDE SAFETY

Guardrail end units that attach to the bridge barrier rail shall meet guidelines in Chapter 8. Use reflector units at bridge rail ends. If deviations from these guidelines are necessary, use good engineering judgment when designing end units for bridge barrier railing.

12. LOADS

The minimum design load shall meet the AASHTO Load and Resistance Factor Design, LRFD version adopted by ODOT. The design load rating is for the HL93 loading, inventory & operating. The legal load rating is for the Type 3, 3S2, EV, & SHV for locally owned structures. The Type 3 must have a rating of 25 tons or greater (Type 3 is analogous to the H20 but has a higher gross weight).

For locally funded “County Built” projects the minimum design standards require a minimum 25-ton operating load rating.

Heavier design loads may be required by site conditions such as nearby industry with heavy haul trucks such as agriculture, logging and mining. Use sound engineering judgment to justify designing for a lesser load.

13. FOUNDATIONS

Design bridge foundations with bearing resistance, friction resistance, or a combination of the two in accordance with AASHTO LRFD design and ODOT accepted methods. Place bridge foundations in/on rock or determined foundation material. Existing streambed and potential scour depth are to be considered in the design of the foundations. Deep foundations that are not socketed into rock are to extend a minimum of twelve (12) feet below the streambed and four (4) diameters below scour. Drilled shafts are to be designed a minimum of two (2) diameters into rock unless geotechnical investigations and design show otherwise. Piles shall be driven a minimum of fifteen (15) feet. If 15 feet is not able to be provided or other geotechnical consideration require, pilot holes are to be used.

Typical foundation types to consider are:

1. Drilled shafts
2. Pile bents
3. Spread footings
4. Pile footings
5. Geosynthetic Reinforced Soils (GRS)

Soundings

Soundings should be made at each foundation structure. If soundings were not taken at each pier and the top of rock differs by more than 10 feet between adjacent soundings, then additional soundings shall be taken such that soundings are taken at each pier and both abutments. A qualified geotechnical company familiar with the geology of the area should determine the nominal resistance and resistance factors for the proposed type of foundation.

See Geotechnical Investigations, Chapter 14 for additional information.

CHAPTER 13

SPECIFICATIONS FOR THE GEOTECHNICAL INVESTIGATION FOR ROADWAY DESIGN

A. GENERAL INFORMATION

These specifications provide the procedures for obtaining the geotechnical information, for county road design and construction. These specifications include the general guidelines for conducting geotechnical investigations and are governed by the "Geotechnical Engineering Circular No. 5 - Evaluation of Soil and Rock Properties", FHWA-IF-02-034, April 2002, the most current AASHTO and ASTM test procedures, and AASHTO R-10.

Geotechnical information is obtained through subsurface investigations, field tests, and the corresponding laboratory tests conducted on samples obtained in the field. The Geotechnical Engineer provides direction and oversight of these operations with day-to-day coordination through the project geotechnical specialist.

A Geotechnical Engineer is a registered professional engineer with geotechnical expertise. A geotechnical specialist is a civil engineer, geologist, engineering geologist, or a trained, experienced, qualified individual that has been certified by the ODOT Materials Division or other approved designated authority.

The Geotechnical Engineer is required to submit a boring, sampling, and testing plan to the Design Engineer for approval prior to beginning the subsurface exploration in order to resolve all matters with regard to sampling, testing and analysis of data.

In conducting geotechnical investigations, the Geotechnical Engineer is responsible for and will be compensated for the following items of work:

- Securing right-of-way
- Filing and obtaining U.S. Army Corps of Engineers Wetland Permits.
- Locating and marking utility crossings, with OKIE, where borings, test pits, or trenches are required in the geotechnical investigation.
- Planning and arranging for traffic control when required in conducting the geotechnical investigation. Traffic control is to be subcontracted outside of ODOT and is required to meet the most current Manual on Uniform Traffic Control Device Specifications during the geotechnical investigation.
- Provide the required location of all test borings and pavement core locations conducted in the preliminary soil surveys, detailed soil investigations and geological investigations. The survey shall be referenced to plan station and offset from the centerline of survey, construction reference line (CRL) or base line given on the

project plans. If the project is a new alignment that is beyond the reasonable reach by a measuring tape of 100 ft. from a reference line, then a supplemental survey contract may be approved.

- Dozer services required for access to test boring locations.
- Borehole closing when applicable.

B. SCOPE

The geotechnical investigation shall consist of performing all or parts of the following surveys and investigations required by the Design Engineer.

Preliminary Soil Surveys

1. **Pedological and Geological Survey:** A Pedological and Geological Survey is required for new alignments, new construction requiring a raising of the grade on and above existing alignments. A Pedological Soils Survey is reliant on knowledge of the soil series mapping units and the corresponding taxonomic classification system established by the Natural Resources Conservation Service (NRCS). More detailed information about Pedological Soil Surveys and the NRCS Soil Classification System are provided in Appendix 1 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm. The general procedures for conducting the Pedological activities are presented below in option A and option B as directed. This includes the procedures for sampling and testing.

Option A

a. The pedological survey requires plotting the Center Reference Line (CRL) or the Centerline (CL) for the proposed highway alignment on the appropriate U.S. Department of Agriculture Soil Conservation (SCS) county soil survey report map sheet(s). The map units are delineated on aerial photographs that comprise the aforementioned sheets. They are usually scaled at 1:20,000 and occasionally 1:24,000; either is acceptable. The plotting procedure is also used to establish the length of each soil series map unit (soil phase) as the alignment crosses the map unit delineation. These lengths or distances are to be summed and provided in the report. The CRL and CL locations are taken from the project plans. In the case of soil series complexes, as map units, e.g. Niotaze-Darnell, each series is to be located and treated separately. The type and degree of assistance, as well as the names of the NRCS, or other soils scientist(s) personnel rendering assistance, shall be documented and referenced in detail.

b. Take adequate sample quantities at the site of each soil series to ensure proper testing of each soil horizon as well the composite bulk sample(s). Pits are acceptable and may be a preferred method. These are to be made along the CRL or CL or referenced to them. If the map unit repeats within the alignment, it need not be resampled, if the series is confirmed by boring to be the same.

c. A composite bulk sample is defined as a mixture of the total depths (thicknesses) of each of the B and C horizons. For example, if a soil series description lists the B horizons as Bt1, Bt2, Btk, Bt3, and B/C, these together will constitute one composite "B" bulk sample. Subsequently, the C/B and C horizons will constitute a second bulk sample "C", for soil series that contain those particular horizons. In the event that the map unit does not have a B horizon but has an A/C horizon instead, the composite bulk sample shall be taken of the total depth of horizons listed below the A horizon e.g. the A/C or B/C horizon. It is important that the bulk sample be a well blended mixture of soils that are representative of all the respective horizons in the composite sample. In most cases, soil map unit revisions and recorrelations have probably been made to at least a few of the map units encountered along the CRL. This new information is available at the local NRCS field offices, usually located in the county seat or the NRCS State Soil Scientist in Stillwater OK. The NRCS Web Soil Survey is also a good source for county soils maps and information, http://websoilsurvey.nrcs.usda.gov/app/. Copies of all official soils series descriptions, including the new recorrelated series are required for inclusion in the Pedological report.

d. Use the soil map unit with its associated current official soil series description and classification as a guide for sampling and other engineering interpretations. For example, the official description of Kirkland clay loam, 0 – 1% slope; Fine mixed, superactive, thermic Udertic Paleustoll, 6/99, is to be used as a guide for sampling. The Fine mixed, superactive, thermic, Udertic Paleustaoll is the soil series taxonomic description. It consists of the order, suborder, great group, subgroup modifier, particle size, mineralogy, and soil temperature. In this description the typical thickness of the A horizon is 8 inches, the Btl horizon is typically 8 to 19 inches thick, the 2Bt3 is 75 to 82 inches thick, etc. In the map unit of interest, the depths and thickness of the subhorizons may vary from that of the description given in the county soil survey report and/or in the official soil series description. However, they must be within the "Range in Characteristics," as described in the official soil series description (OSD). A Soil Taxonomy Statement is required for each soil series consisting of a written interpretation of each taxonomy description sub-part for a total of seven parts. Guidelines for preparing the Soil

Taxonomy Statement are included in Appendix 1 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm.

e. There may be inclusions of a contrasting or similar soil series within the map unit being sampled. They may be listed and described in the "Competing Series" or the "Geographically Associated Soils" paragraphs in the official soil series descriptions. Select the best-fit soil series description from this list, if possible, for the inclusion in the report.

f. Laboratory tests required for all representative subhorizon samples for each soil series are as follows:

   1. Plastic Limit, AASHTO T90
   2. Liquid Limit, AASHTO T89
   3. Gradation required for complete soil classification, AASHTO T88
   4. pH, AASHTO T289
   5. Electrical Resistivity, AASHTO T288
   6. Soluble Sulfates, for projects in ODOT Field Divisions 4, 5, 6, & 7, OHD L-49

g. Laboratory tests required for the bulk composite sample for the B and C horizons of each soil series are as follows:

   1. Plastic Limit, AASHTO T90
   2. Liquid Limit, AASHTO T89
   3. Gradation required for complete soil classification, AASHTO T88
   4. Moisture-Density, AASHTO T99 – (include a minimum of 5 points)
   5. Resilient Modulus, AASHTO T307
   6. Soluble Sulfates, for projects in ODOT Field Divisions 4, 5, 6, & 7, OHD L-49

h. The geologic portion of this survey shall consist of the inclusion of a representative sample of the R horizon. A geologic statement describing the R horizon in geological terminology shall be included in the report. If the R horizon is shale it shall be sampled and subjected to the soil laboratory tests listed under paragraph "f" above. The terminology for describing the R horizon material shall be taken from the "Standard Guide for the Description of Surface and Subsurface Geological Rock Formations of Oklahoma" found in Appendix 3 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm.

i. The quantities of soil required for the tests are provided in AASHTO R-13.

j. Personnel requirements. The person performing the pedological soil survey and providing the report shall hold a Bachelor of Science (BS) degree in Soil Science or Civil Engineering. The person may hold a BS in a natural science (i.e. geology or forestry) provided the natural science has a minimum of 30 credit hours of natural sciences with 15 of those hours in soil science. Alternatively, a resume of pertinent education and experience shall be submitted to the Geotechnical Engineer of the Oklahoma Department of Transportation for review and approval.

Option B

The CRL or centerline of the proposed project is to be plotted on the soil survey map as in Option A. The soil series are to be organized by the Soil Taxonomy Order. The most predominant soil series (largest lineal extent) for each Order in the project extent is to be sampled and tested as required in Option A.

2. **Shoulder Soil Survey:** A Shoulder Soil Survey is required for the widening of existing pavement at grade. This survey shall apply to the adding of shoulders, and widening existing roadways. The general procedure for conducting the shoulder soil survey is as follows:

    a. The sampling location shall be within the station extents of the widening section using the average width of the improvement and a sampling interval of 1000 feet. Sample locations shall apply to all widening extents as detailed in the project plans, i.e., outside pavement shoulder.

    b. The sampling depth shall be 36 inches consisting of the top 6 inches and the bottom 30 inches provided that there is a reasonable consistency and similarity of material. If different material is encountered in the bottom 30 inches, subdivide the layers and include a sample from each layer.

    c. Report the extent(s) of similar soil classifications within the station extents of the project.

    d. Record the depth of groundwater or perched water zones measured from the top of ground elevation at the end of drilling.

    e. A composite bulk sample(s) of the full sampling depth representative of the whole project extent or of each different soil extent as identified in item 2c.

f. Laboratory tests required of all sample interval depths and/or soil layers are as follows:
    1. Plastic Limit, AASHTO T90
    2. Liquid Limit, AASHTO T89
    3. Gradation required for complete soil classification, AASHTO T88
    4. Moisture-density, AASHTO T99
    5. Resilient modulus, AASHTO T307
    6. Soluble Sulfates, for projects in ODOT Field Divisions 4,5,6, &7, OHD L-49

g. Guidelines for quantities of soil samples are given in AASHTO R13

3. **In Place Soil Survey:** The In Place Soil Survey may be used to evaluate the subgrade of existing pavement sections, which are to be reconstructed with no change in grade or alignment. The general procedure for conducting the In Place Soil Survey is the same as for the Shoulder Soil Survey with the following exceptions:

    a. The sampling interval for grading projects is 1000 ft. or wherever there is a visual change in soil types. Sampling locations for existing pavement sections will most likely be project specific such as at a bridge approaches and underpasses.

    b. The sampling depth shall be 36 inches unless otherwise noted. Sample and test the different soil types encountered in the boring and record the extent(s) of similar soil classifications within the station extents of the project.

4. **Pavement and Subgrade Soil Survey:** A Pavement and Subgrade Soil Survey is required when the properties of an existing pavement structure and the underlying subgrade soils are needed for evaluation of the pavement load capacity and for an overlay design. At the discretion of the engineer the Falling Weight Deflectometer (FWD) may be required for evaluating the pavement structure (surface, base, and subbase). The general procedure for conducting pavement deflection tests shall meet all requirements of the ASTM D4694 and D4695 with the following additional requirements:

    a. FWD tests are to be conducted in the outside wheel path in a staggered pattern at a spacing of 250 feet along the highway centerline. Additional requirements for the FWD analysis are as follows:
        1. The FWD is to be operated during a time frame of April through November or when the ambient temperature has been a minimum of

45 degrees for 3 successive days prior to and during the testing operations.

2. The air and pavement temperatures are to be recorded by the FWD equipment for each test location and according to ASTM D4695, Subsection 7.1.5.
3. At each FWD test location, the test procedure shall be according to ASTM D4694, Subsection 9. Load and deflection sensors are to be in current calibration at the time of testing, as required by ASTM D4694, Subsection 8. Deflection testing shall include 2 seating drops and 4 recording drops per test location. Local and County roads will be tested with a 7,500 lb. load.

b. Back calculation analysis of the pavement section shall be made using the most current edition of the Modulus program. For asphalt pavement sections, provide the back-calculated resilient modulus of the subgrade and the elastic modulus of the composite pavement structure. For concrete pavement sections, provide the modulus of subgrade reaction, the pavement section thickness, and the pavement condition as determined according to the survey described in item 5d. A copy of the FWD report shall be submitted, in Microsoft Excel Format, electronically to the Design Engineer.

c. A minimum of five pavement cores per mile (more if there is an obvious change in pavement structure) shall be taken to document the thicknesses, types, and condition of the payment layers. Take the cores at FWD test locations. Provide a digital, color photograph of each core with scale. Record the layer thicknesses and the degree of stripping or deterioration of asphalt pavement cores. Record honeycomb, deterioration cracking (D-Cracking), and separations in concrete pavements. Examples of the required core logs are provided in Appendix 5 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm. Cores shall be taken in the middle of the slab in PCC Pavements. Ground Penetrating Radar may be used to reduce the number of cores taken to accurately determine the pavement section profile.

d. Pavement surface condition shall be described according to the distress patterns as detailed in the FHWA publication No. FHWA-RD-03-031 “Distress Identification Manual for the Long Term Pavement Performance Program”.

e. For plain jointed, rigid pavements, joint efficiency shall be tested in each direction, in the right wheel path of the right lane, every 600 feet (180m) at the transverse contraction joint. A core shall be cut through the joint at the test site and the core condition reported.

f. The pavement subgrade shall be sampled to a depth of 36 inches below existing pavement. Dynamic Cone Penetration tests, DCPT, may be requested to further evaluate the strength and consistency of the subgrade.

g. Report the extent(s) of similar subgrade soils within the station extents of the project.

h. Record the depth of groundwater or perched water zones measured from the top of ground elevation at the end of drilling.

i. Laboratory tests required of granular bases, subbases, and subgrade soils are as follows:
   1. Plastic Limit, AASHTO T90
   2. Liquid Limit, AASHTO T89
   3. Gradation required for complete soil classification, AASHTO T88

j. Guidelines for quantities of soil samples are given in AASHTO R13.

5. **Borrow Pit Investigation:** A borrow pit investigation is required where selective subgrade topping is requested. The specifications for selective subgrade topping are provided in the most current issue of the ODOT Standard Specifications for Highway Construction, Section 202.02 B.

   a. The size of the borrow pit shall be based on plan estimates of borrow quantities needed.

   b. A borrow pit location within a 30-mile haul distance of the project is acceptable.

   c. As a minimum requirement, a boring shall be drilled at each geometric corner and two near the center. A minimum depth of ten feet per boring shall be analyzed for select material.

   d. Record the depth of groundwater or perched water zones measured from the top of the ground elevation at the end of drilling.

   e. If the borrow source is rock, investigate the rippability by use of seismic velocity. Refer to the seismic velocity charts found in the Appendix 3 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm to estimate the rippability of rock.

f. If the borrow sources can be select graded in a cut section of the proposed project site, the above items c. through e. all apply.

g. If a borrow source is unavailable, then a pavement layer requiring borrow may be substituted with an equivalent layer of chemically stabilized soil or a soil-aggregate blend.

h. Soils that are to be placed within the top 2 ft. of the grading section shall be tested for soluble sulfates according to OHD L-49.

i. Laboratory tests required of borrow pit soil samples are as follows:
   1. Plastic Limit, AASHTO T90
   2. Liquid Limit, AASHTO T89
   3. Gradation required for complete soil classification, AASHTO T88
   4. Soluble Sulfates, for projects in ODOT Field Divisions 4,5,6, &7, OHD L-49

6. **Resilient Modulus Tests:** Resilient modulus testing is required for the pavement design of all State and Federal Aid highway projects. This test is conducted, according to the requirements of AASHTO T-307, on composite bulk samples obtained in Pedological, Shoulder, and In Place Soil Surveys. A qualified technician having a minimum of 2 years continuous experience in resilient modulus testing shall conduct resilient Modulus testing for ODOT.

   ODOT requires two resilient modulus tests for each composite sample:
   - One test at 95 % of maximum dry density, optimum moisture content
   - One test at 95 % of maximum dry density, 2 % wet of optimum moisture content.

7. **Laboratory Tests:** All laboratory tests required for the Preliminary Soil Surveys shall be performed by technicians certified by the Highway Construction Materials Certification Board in a laboratory qualified by the ODOT Materials Division.

C. DETAILED SOIL INVESTIGATION

If needed, a detailed Soil Investigation is required for analyzing the geotechnical problems related to roadway designs. These geotechnical problems include embankment and foundation soil settlement and stability, cut and natural slope stability, problem soils related to roadway subgrades and embankments, roadway structures, and construction recommendations. A detailed soil investigation of these problems is required in conjunction with the Pedological and Geological Survey. The interpretation and judgment of the pedological and geological site conditions is the responsibility of the Geotechnical Engineer.

1. **Embankment and Foundation Soil Settlement and Stability (Embankments Between 0-10 feet Above Natural Ground Line):** Estimates of embankment and underlying foundation soil settlement, slope stability and design slopes are required. Assuming reasonable parameters for anticipated embankment makes these estimates and foundation soils based on the soil series types occurring within the project extent. These estimates are required for embankments crossing each soil series encountered along the project alignment. Use NAVFAC D 7.01 to determine estimates of reasonable soil parameters for anticipated embankment and foundation soils as described by the pedological soil units.

2. **Embankment and Foundation Soil Settlement and Stability (Embankments Greater Than 10 Feet Above Natural Ground Line):** Estimates of embankment and underlying foundation soil settlement and stability may be required by the Design Engineer. Borings are to be typically spaced every 200 feet (erratic conditions) to 500 feet (uniform conditions), with at least one boring made in each Pedological soil unit. The primary borings are to be Standard Penetration Test (SPT) borings. These borings, which are for obtaining soil samples and information, should be supplemented with in situ field tests such as the Cone Penetration Test (CPT) or the Flat Plate Dilatometer Test (DMT) to obtain additional information for determining the soil and rock subsurface conditions as follows:

    a. Stratigraphy

        1) Physical description and extent of each stratum
        2) Thickness and elevation of top and bottom of each stratum

    b. For cohesive soils (each stratum)

        1) Natural moisture contents
        2) Atterberg limits
        3) Presence of organic materials
        4) Evidence of desiccation or previous soil disturbance, shearing or slickensides
        5) Swelling characteristics
        6) Shear strength
        7) Compressibility – **NOTE:** The Standard Penetration Test is not to be used for shear strength or compressibility analysis in cohesive soils. Shear

strength and compressibility can be determined by laboratory consolidation tests conducted on undisturbed soil samples or by in situ field tests such as the Cone Penetration Test (CPT) or the Flat Plate Dilatometer Test (DMT).

c. For granular soils (each stratum)

   1) In-situ density (average and range) typically determined from Standard Penetration Tests (SPT) or Cone Penetration Tests (CPT)

   2) Grain-size distribution (gradation)

   3) Presence of organic materials

d. Ground water (for each aquifer if more than one is present)

   1) Piezometric surface over the site area, existing, past, and probable range in future (observation at several times.)

   2) Perched water table

e. Bedrock

   1) Depth and elevation over the entire site

   2) Type of rock (Lithology)

   3) Extent and character of weathering

   4) Joints, including distribution, spacing, whether open or closed, and joint filing.

   5) Faults

   6) Solution features in limestone or other soluble rocks

   7) Core recovery and soundness (RQD)

f. Engineering Analysis. The minimum guidelines required for engineering analysis, based upon soil classification, are given in Table 1 of Appendix 2 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm. Additional guidelines should be noted for the following conditions:

   1) When soft ground is encountered (SPT ‘N’ Resistance < 4), conduct in situ tests and/or undisturbed sample exploration in each soil series mapping unit. Conduct continuous in situ tests and/or undisturbed sampling throughout the foundation soils until firm material (SPT ‘N’ Resistance > 30) or rock is encountered.

   2) When medium stiff to very stiff (5 < SPT ‘N’ resistance < 30) is encountered, follow the minimum sampling and testing criteria in Table 2 of Appendix 2 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm.

3) If rock is encountered within a depth equal to twice the embankment height, conduct continuous rock coring as detailed in Table 2 of Appendix 2 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm.

4) Groundwater investigations shall be made according to Table 2 of Appendix 2 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm.

5) For bridge embankment headers, conduct a detailed study of the embankment and foundation soils within 200 feet back and 200 feet forward of each bridge abutment.

3. **Cut and Natural Slope Stability:** Cut slopes greater than 30 feet below the natural ground line in soil shall be analyzed for both end of construction and long germ slope stability conditions. If slope materials are overconsolidated (OCR > 2) then the residual shear strength shall be used in the long-term slope stability analysis. Soils coming from cuts that will be placed within the top 2 ft. of the grading section shall be checked for soluble sulfates according to OHD L-49.

4. **Problem Soils Related to Roadway Subgrades and Embankments:** Additional field exploration, laboratory testing and analysis are required to determine the long-term performance and/or suitability of the following soil and rock that may be incorporated into the roadway subgrade and embankment or found in the foundation soils below the roadway embankment:

    a. Organic soils
    b. Normally consolidated clays
    c. Expansive clays and shales
    d. Dispersive soils
    e. Collapsible soils
    f. Degradable shales
    g. Caliche
    h. Mine spoils (all types) and caves
    i. River or stream meander loops and cutoffs and ox-bow lakes
    j. Karst features (e.g., gypsum, limestone)

    These soils and conditions are coordinated with the Pedological and Geological Survey and Borrow Pit Investigation. The interpretation and judgment of these soil conditions is the responsibility of the Geotechnical Engineer.

5. **Roadway Structures:** Check the bearing capacity, settlement and stability of roadway structures (i.e. retaining walls) according to the most current AASHTO Standard Specifications for Highway Bridges.

6. **Construction Recommendations:** The Geotechnical Engineer may recommend chemically stabilized bases, subbases and subgrades as directed by the Design Engineer or in lieu of select borrow requirements of the most current edition of the Oklahoma Department of Transportation (ODOT) Standard Specifications for Highway Construction. These recommendations are limited to lime, fly ash, CKD, and Portland cement and the method of evaluation shall follow ASTM D4609, OHD L-50 and OHD L-51.

D. GEOLOGICAL INVESTIGATION

A Geological Field Investigation may be required for any or all of the following:
1. rock cuts of 10 feet or greater
2. shallow rock mapped within a proposed cut section
3. rock mechanics analysis
4. geological hazards
5. rock fills

A geological field investigation may consist of the following elements:
1. borings
2. slope stability analysis
3. rippability ratings
4. evaluation of geological hazards
5. shear strength of rock fills
6. evaluation of excavated rock for use as a source of aggregate
7. Geological statements.

The Geological Investigation is in conjunction with the Pedological and Geological Survey. Dimensions are to be in English or metric units, whichever is compatible with the Plans. Any interpretations and judgments made of the site geologic conditions are the responsibility of the Geotechnical Engineer. The investigation may include the following:

1. **Borings:** Space borings through cut sections within the project extent every 100 feet in the longitudinal centerline (CL or CRL) direction. Provide a minimum of two borings along a straight line perpendicular to the centerline or planned slope face to establish a geological cross-section of the cut. Two of these borings shall be continuously cored to characterize the soil and/or rock properties. The depths of all borings are to extend a minimum of 10 feet below the deepest plan grade. Record the location of perched or permanent water tables for a minimum of 24 hours.

2. **Seismograph Surveys:** Seismograph Surveys of cut sections may be required. The equipment must be capable of determining rock properties throughout the

entire depth of the cut, plus 10 feet below plan grade. Depths to each rock layer must be accurate to the nearest foot.

3. **Rock Stability Analysis:** Rock stability analysis is required when the dip of the geological formation exceeds 20 degrees into the slope face. Ensure the analysis meets all the requirements of the kinematic slope stability program, RockPack III (or equivalent), using the stereographic projection procedure. This analysis is necessary to determine the slope stability of closely spaced (2 ft. or less) rock joints (fractures) and/or tilted (dipping greater than 10 degrees) rock strata of the cut slope. These measurements will allow development of the local structural geology, in three dimensions, required for making this analysis. The data that is required for this analysis is the dip, and dip direction of both the rock strata and of the joints (fractures) in the rock. The equipment necessary to obtain the dip, and joint orientation data is a Clar and/or Brunton compass. This device gives magnetic headings and dip angles. Trenching or oriented cores may be necessary in order to expose enough rock strata to make the measurements. The shear strength of the jointed rock shall be based on the requirements of the Hoek-Brown (1988) criteria. If the observations identify joints (fractures) in which shear failures may occur, or fractures that contain soil infilling; then, the shear strength of the infilling or fractures is required to be taken into account in the overall slope stability analysis. In argillaceous massive shales (non-laminar), slope stability analysis shall be based on the use of a soil mechanics approach.

4. **Rippability:** Determine rippability by a refraction seismograph. The seismograph must be capable of providing valid, useable signals for calculating the depth to bedrock to nearest foot. It must be capable of sensing rock layers to the depth of the proposed cut. Calculations of rock rippability shall be made from the resulting sound wave velocities. The rock rippability rating of each layer shall be reported as rippable, marginal, or non-rippable.

5. **Geologic Hazards:** Identify any geologic hazards (e.g. sinkholes, landslides, and others). These are to be precisely located and dimensioned to the nearest foot. Record all occurrences in the final report. GPS coordinates may be used in addition to Public Land Survey legal descriptions. Locations must be referenced to the CL or CRL by plan station and offset.

6. **Rock Fill Embankments:** Determine the shear strength values of rock fill embankments. Using the results of the triaxial shear tests will generate the model. Conduct the testing on 1-in. size aggregates from the specified rock fill aggregate source.

7. **Geologic Site Assessment:** Provide a geologic site assessment of the rock type and layering conditions in the cuts along the CL or CRL. This report will be based on available geologic maps, bulletins etc., along with a field, on-site investigation. The assessment will pertain to the geologic conditions and character of the rock strata as provided in the above geologic information sources.

8. **Equipment:** List the equipment used to make the observations (e.g. borings, seismograph surveys, rippability, and stability analysis) in the report. Provide the make, model, and manufacturer.

Descriptive Terminology and Rock Classification: The descriptive terminology and rock classification shall be based upon the "Standard Guide for the Description of Surface and Subsurface Geological Rock Formations of Oklahoma" as presented in Appendix 3 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm. The finished boring log shall be a compilation of all classification and description from laboratory tests and field logging.

E. GEOTECHNICAL EXPLORATION, IN SITU TEST PROCEDURE

1. The most current issue of the following ASTM Standards for in situ testing will govern and shall be used.
   a. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils – ASTM D1586
   b. Electronic Friction Cone and Piezocone Penetration Testing of Soils – ASTM D5778
   c. Mechanical Cone Penetration Test – ASTM D3441
   d. Flat Plate Dilatometer Test – ASTM D 6635
   e. Pressuremeter Test – ASTM D 4719
   f. Vane Shear Test – ASTM D 2573
   g. Dynamic Cone Penetrometer Test – ASTM D 6951

2. The most current issue of the following ASTM and AASHTO Standards for sampling will govern and shall be used.
   a. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils – ASTM D1586
   b. Practice for Thin-Walled Tube Geotechnical Sampling of Soils – ASTM D1587
   c. Practice for Rock Core Drilling and Sampling of Rock for Site Investigation – ASTM D2113
   d. Practice for Preserving and Transporting Soil Samples – ASTM D4220
   e. Collection and Preservation of Water Samples – AASHTO R24

f. Standard Test Method for Determining Subsurface Liquid Levels in Borehole or Monitoring Well (Observation Well) – ASTM D4750

3. **Bore Hole Completion and Site Restoration:** All borings should be properly closed at the end of the field exploration for safety considerations and to prevent cross contamination of soil strata and groundwater. The general procedures for borehole completion and site restoration are as follows:
   a. Responsibility The driller is responsible for properly plugging the borehole.
   b. Timetable Ensure borings are plugged within 10 days of completion of drilling or groundwater observations to prevent contamination of groundwater.
   c. Backfill Consider the following:
      1. For Pedological, shoulder, and in-place borings, backfill and compact the borehole with borehole cuttings.
      2. In pavements, backfill the boreholes with cuttings. Compact, by tamping, the cuttings to a depth of 6 in. below the bottom of the pavement. Fill the remainder of the boring with either quick setting concrete or asphalt patch depending upon the pavement type.
      3. For embankment and cut section borings, follow the procedures outlined in **AASHTO R-22**.
   d. Property Cleanup As practical, the site should be returned to its original conditions. For sensitive locations, take before and after photographs to address possible complaints from the landowner.

4. **Field Logging:** Field logs shall be based upon the descriptive terminology and classification of rock detailed in the "Standard Guide for The Description of Surface and Subsurface Geological Rock Formations of Oklahoma" as presented in Appendix 3 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm.

5. **Method of Drilling:** An appropriate method of rotary drilling shall be used for the foundation and geologic conditions encountered. These are described in the AASHTO Manual on Subsurface Investigations, 1988. There is no restriction on the type of drill equipment other than it shall be capable of performing all of the field sampling and testing as outlined in the above referenced manual. Samples may be taken from the flight augers unless water table conditions are encountered. The practice of auger refusal is **not** an acceptable technique for defining the top of bedrock. The top of bedrock shall be established by sampler refusal as outlined in **ASTM D 1586 - Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils.** For borings over water in lakes or rivers, drilling

operations shall be performed on a barge supported by spud rods firmly anchored at each corner.

6. **Geologic Statement:** A general geologic review and assessment(s) shall be provided as a statement in the Geologic Investigation. It will include cross section(s) and provide drawings, showing the orientation of the rock masses or layered rock formations at each cut section investigated. The drawings will provide station designations along the centerline of survey or CRL and offset distances left and/or right. The geologic summary will be provided based on all available geologic information. Examples of such sources are as follows:
    a. Oklahoma Geological Survey
    b. Oklahoma Water Resources Board
    c. U.S. Geological Survey
    d. Tulsa Geological Society, and others

F. LABORATORY TESTS

All laboratory testing shall be performed by technicians certified by the Highway Construction Materials Certification Board in a laboratory qualified by the ODOT Materials Division.

1. Where appropriate, soils and rock samples are to be tested and results reported according to the most current AASHTO/ASTM Standards for the following tests:
    a. Soils Classification, Gradation and Plasticity Index – AASHTO T88 , T89, and T90
    b. Moisture Content, AASHTO T265
    c. Specific Gravity, AASHTO T100
    d. Chunk Density, AASHTO T233
    e. Hydrometer, AASHTO T88
    f. Double Hydrometer, ASTM D4221
    g. Pinhole Test, ASTM D4647
    h. pH, AASHTO T289
    i. Moisture-Density Test
        1) Standard, AASHTO T99
        2) Modified, AASHTO T180
    j. Electrical Resistivity, AASHTO T288
    k. Slake Durability, ASTM D4644
    l. Unconfined Compression Test, AASHTO T208
    m. Point Load Test, ASTM D5731
    n. One-Dimensional Consolidation Test, AASHTO T216
    o. Drained Direct Shear Test, AASHTO T236

p. Triaxial Sheer Test
    1) Unconsolidated Undrained, ASTM D2850
    2) Consolidated Undrained, ASTM D4767
q. Residual shear strength, ASTM D6467
r. One Dimensional Swell or Settlement Potential of Cohesive Soils, ASTM D456

2. Classification and description of soils and compaction shales follow the practice as outlined in ASTM D2487 and D2488. For classification purposes, define, test, and report for the following particle size distribution.

    3 in. (75 mm)
    ¾ in. (19 mm)
    No. 4 (4.75 mm)
    No. 10 (2.00 mm)
    No. 40 (425µm)
    No. 200 (75µm)

3. A pocket penetrometer or any other “pocket” measurement device shall **not** be used to determine rock or soil properties for the purposes of this investigation.

G. FINAL WRITTEN REPORT

The final report shall be written by a Geotechnical Engineer with a broad experience and background in engineering for the type of roadway work identified in the project. All pertinent information to be included in the final report is detailed in Appendix 4 – Guidelines For Preparing Geotechnical Reports at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm. Appendix 5 at http://www.okladot.state.ok.us/roadway/Rdy-pavement.htm provides the Standard Forms For Reporting Geotechnical Information.

CHAPTER 14
SPECIFICATIONS FOR THE GEOTECHNICAL INVESTIGATION OF BRIDGES AND RELATED STRUCTURES

GENERAL: The general procedure for the execution of investigation for bridge and related structures' foundations shall be governed by the AASHTO Manual on Subsurface Investigations, 1988, and Geotechnical Engineering Circular No. 5, FHWA NHI-16-072, April 2017. Unless otherwise noted herein by the following exceptions or amplifications, said investigations shall subscribe to, as a minimum requirement, the general guidelines given in Chapters 1.0 through 10.0 and Appendices A through H of the AASHTO Manual on Subsurface Investigations and Geotechnical Engineering Circular No. 5.

The Consultant is required to furnish the Department with the proper data on the engineering properties and analysis and design requirements as specified in and according to the most current AASHTO LRFD Design Specifications including interims. These AASHTO specifications are minimum requirements, and the Consultant may exceed them. The Consultant is responsible for providing the Department with sufficient information as necessary to verify foundation adequacy.

In making geotechnical investigations, the Consultant is responsible for damages that occur to property as a result of those investigations. The Consultant is required to submit verification that ~~he has~~ permission of the property owner for access to the site has been granted, and that OKIE confirmation numbers have been obtained for all underground and overhead utilities to the Department for approval prior to beginning the subsurface exploration. A pre-work conference is required to resolve all matters with regard to sampling, testing, and analysis of data. The Department's geotechnical policies and procedures represent the state of practice and will govern. All references to AASHTO and ASTM standards and test procedures refer to the most recent version of the standard or test procedure, unless otherwise noted. The Consultant will follow the proposed boring plan provided with the Task Order and comply with the conditions of the 404 permit and USFWS Consultation as applicable.

ENVIRONMENTAL REQUIREMENTS: On most projects, the Geotechnical Task Orders will be issued after the environmental studies are complete for federally funded projects or after the environmental checklist is complete for non-federally funded projects. The Geotechnical Consultant will submit the proposed sampling and drilling plan which will show any clearing outside the maintained right-of-way and pads or haul roads constructed in waters to Local Government projects 404 permit reviewer. The proposed sampling and drilling plan will be on an aerial map showing the proposed access path locations, boring points and any areas proposed for bulldozer work clearly shown at an appropriate scale (1"=400 FT or larger is preferred). In addition, the Geotechnical consultant will provide shape files georeferenced in State Plane North or South in feet or KMZ files indicating proposed locations of such. The review of the proposed plan will be completed within 30 days of submittal of complete information. If the project is located in a US Army Corps of Engineers (USACE) property, additional 60 days will be required for coordination with the USACE office. If there are no impacts to species or jurisdictional waters or wetlands, work can start immediately after the review.

If impacts to waters and wetlands are identified, the Geotechnical Consultant will work with the Designer and Local Government projects 404 permit reviewer to minimize the impact and include the impacts due to geotechnical work. The appropriate 404 permit from US Army Corps of Engineers (USACE) required for the geotechnical investigation will be obtained by Local Government projects 404 permit reviewer and the geotechnical consultant shall comply with the permit conditions and adhere to the proposed sampling and drilling plan.

If impacts to any threatened and endangered species are identified, the Designer will work with the Geotechnical Consultant and Local Government projects 404 permit reviewer to minimize the impact and include the impacts due to geotechnical work in the information provided for US Fish and Wildlife Services (USFWS) Consultation for the project. Additional information from the Geotechnical Consultant regarding the type of work and equipment used may be required. The USFWS consultation and any survey will be completed by ODOT's Environmental Programs Division at the Request from Local Government Division Project Manager and the Geotechnical Consultant shall comply with the conditions of the consultation and adhere to the proposed sampling and drilling plan. If the project is located in a Critical Habitat for any threatened and endangered species, formal consultation with USFWS will be required through Environmental Programs Division for federally funded projects and USACE for non-federally funded projects and this process could take 6 months or more.

The Geotechnical Consultant shall notify County or City prior to performing any field work. The Geotechnical Consultant shall obtain permission from property owners prior to doing any field work in properties outside of the County or City Right-of-Way. The Geotechnical Consultant shall be responsible for restoring the property to the original conditions prior to field work. These include but not restricted to repairing fences, filling up holes, etc.

If the Geotechnical Consultant encounters or exposes any abnormal condition indicating the presence of a hazardous material or toxic waste, the Consultant shall immediately suspend the work in the area and guidance from Environmental Division through the Local Government Project Manager. The Consultant may continue the work in unaffected areas of the project, unless otherwise directed by Environmental Program Division. Abnormal conditions include, but are not limited to, the presence of the following:

1. Barrels, drums, tanks, or other chemical containers;
2. Noxious odors emanating from the soil or water table;
3. Excessively hot earth or smoke indicating a possible chemical reaction;
4. Stained or oily soil or groundwater; or
5. Any other condition that indicates a hazardous material or toxic waste.

The Consultant shall treat these conditions with extreme caution and shall not attempt work without appropriately trained, qualified, and equipped personnel.

If disposing of soil or rock cuttings containing suspected to contain hazardous material or toxic waste, the Consultant shall comply with all applicable local, State, and federal rules and regulations. The disposal work may be performed by the Consultant under a supplemental agreement to the Contract or by the County or City.

Whenever encountering human remains, the remains of prehistoric dwelling sites, or prehistoric or historic age artifacts during construction operations on a previously reviewed and coordinated off-site facility, immediately cease the operation and notify the Local Government Project Manager, who will contact the ODOT Cultural Resources Program. ODOT Cultural Resources Program will coordinate with the appropriate State, Federal, or Tribal authorities for the disposition of any artifacts or materials excavated from the off-site facility.

EXCEPTIONS TO AND AMPLIFICATIONS OF BORING PLAN: At least one boring will be made at each pier element and two borings at each pile bent and abutment. Additional requirements are noted below in item numbers one through eighteen (1-18).

1. **Square or Rectangular Footings and Raft Foundations:** For large square or rectangular footings and raft foundations, least dimension 20 feet (6.10m), more than one boring will be required at such foundations as directed by the Department. All of these borings shall be sampled as indicated in items 4 and 5.

2. **Spread Footings and Deep Foundations:** Where substructure units will be supported on spread footings, the minimum depth of the subsurface exploration shall extend below the anticipated bearing level a minimum of two footing widths for isolated, individual footings where $L \leq 2B$, and four footing widths for footings where $L \geq 5B$. For intermediate footing lengths, the minimum depth of exploration may be estimated by linear interpolation as a function of L between depths of 2B and 5B below the bearing level. Greater depths may be required where warranted by local conditions.

Where substructure units will be supported on deep foundations, the depth of the subsurface exploration shall extend a minimum of 30 feet (9.14m) below the top of the rock. Where pile or drilled shafts will be used, the subsurface exploration shall extend at least two times the maximum pile group dimension below the anticipated tip elevation, unless the foundations will be end bearing on or in rock. For piles bearing on rock, exclusive of shale, a minimum of 20 feet (6.10m) of rock core shall be obtained at each exploration location to ensure the exploration has not been terminated on a boulder. Borings shall extend to a minimum depth of 120 feet (36.58m) if rock or shale is not encountered.

3. **Additional Borings:** Additional borings at each pier location will be necessary in nonuniform conditions, such as erosive rock formation, in both the longitudinal and transverse direction to the bridge centerline. A differential depth of 5 feet (1.52m) or more in any boring in profile shall constitute a condition that will require additional borings. Seismic survey can be substituted in lieu of borings to verify depth differentials. Should the average RQD from all core runs for any one boring be less than 45 percent, then an additional boring under the requirements of 5a will be required, and an explanation will be required as to why this has occurred. Also, if the RQD is less than 20 percent in any one core run, then an additional 10 feet (3.05m) of coring will be required. The RQD is to be based on 5 foot (1.52m) core runs only.

4. **Sampling Interval:** The maximum sampling interval throughout the boring depth is 5.0 feet (1.52m) in homogeneous strata. In nonhomogeneous strata, the sampling interval is less than 2.5 feet (0.76m) with testing and sampling at changes in strata. The standard penetration test split-barrel sampler will be used in all cases except when soft clays or
silts are encountered, in which case thin-wall tube samples may be substituted.

5. **Weathered Rock or Shale:** When weathered rock or shale is encountered, the Standard Penetration Test (SPT) shall be made at the top of the weathered rock or shale and continued until refusal is met in accordance with current ASTM D 1586 Section 7.1. Thereafter, one of the following is required:

    a. Continuous core barrel sampling according to current ASTM D 2113 (minimum size NWG and NQ3WL) to a total depth of 30 feet (9.14m) and shall be restricted to locations shown on the enclosed map or as directed. All core logs shall include the information as required by ASTM D5878.
    b. Pressuremeter tests immediately following the refusal of the standard penetration test and at 5 foot (1.52m) intervals thereafter to a total depth of 30 feet (9.14m).
    c. Dynamic Cone Penetrometer Test described in Item 12 and under Field Tests shall be made at the top of the weathered rock or shale following the refusal of the Standard Penetration Test and at 5 foot (1.52m) intervals, or as directed

in Item 12. The use of the Dynamic Cone Penetrometer Test described in Item 3 under Field Tests shall be restricted in use to locations shown on enclosed map or as directed. Note the Dynamic Cone Penetrometer Test is a Department Bridge Division test.

6. **Recommended Load Carrying Capacity:** When directed by the Department, the Consultant shall recommend the load carrying capacity for the rock or shale, including end bearing and side shear (skin resistance) and other foundation analysis as required by procedures outlined in the most current AASHTO LFRD Standard Specifications for Highway Bridges including Interims. When directed by the Department to recommend load capacity for LFRD projects identified on the enclosed map or as directed, analysis will require the use of the unconfined compressive test and/or point load test on rock core specimens. Where applicable the Pressuremeter test, ASTM D 4719, may be used in shale to estimate end bearing and side shear. Rock Mass Modulus may be estimated based on methods using the rock mass rating (RMR) or the RQD. The use of other insitu tests (i.e., borehole dilatometer and the borehole jack, ASTM D 4971) may also be acceptable. Typically, settlements or deformations within a rock foundation will be controlled by the deformation modulus corresponding to the overall rock mass and will not be controlled by the deformation modulus of intact rock. The deformation modulus of intact rock serves only as the upper bound of the rock mass modulus. The Hoek-Brown Strength criteria for fractured rock shall be used in the estimation of end bearing and side for spread footings and drilled shafts in fractured rock.

7. **Structures Less Than 250 Feet (76.20m) in Length:** In the alluvium and bedrock, at least one pier and both abutment borings are required to be sampled as indicated in Items 4 and 5, logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488. At all other borings, the bedrock is to be sampled as indicated in Item 5, logged, and described according to current ASTM D2487 and D2488. If required, the recommended load carrying capacity as described in Item 6 shall be based on the composite data from all boring locations.

8. **Structures Between 250 and 600 Feet (76.20m and 182.87m) in Length:** In the alluvium and bedrock, at least two pier and both abutment borings are required to be sampled as indicated in Items 4 and 5, logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488. At all other borings, the bedrock is to be sampled as indicated in Item 5 and logged and described according to current ASTM D2487 and D2488. **Structures Greater Than 600 Feet (182.87m) in Length:** In the alluvium and bedrock, at least three pier and both abutment borings are required to be sampled as indicated in Items 4 and 5, logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488. At all other borings, the bedrock is to be sampled as indicated in Item 5 and logged and described according to current ASTM D2487 and D2488. In addition to Item 13 requirements, for depths to top of rock greater than 60 feet (18.29m), at least one boring shall be sampled

continuously by the Standard Penetration Test (SPT) and logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488 and/or Cone Penetration Test (CPT, CPTU) according to the current ASTM 5778 for the full depth of the boring. For structures in excess of 1500 feet (457.18m), borings may be spaced at 100 foot (30.48m) intervals in a staggered pattern.

9. **Borings in Bodies of Water:** For borings in bodies of water (i.e., lakes, rivers and streams), all underlying soil material shall be sampled continuously by SPT, according to current ASTM D1586 procedure, until weathered rock or shale is encountered, and thereafter sampling shall be according to Items 5a, 5b, and 5c requirements. In the case of when soft clays or silts are encountered above weathered rock or shale, thin-walled tube samples may be substituted.

10. **Parallel Structures:** For new parallel structures or widening of an existing structure and addition of a new parallel structure, treat as separate bridges requiring borings for each bridge respectively.

11. **Dynamic Cone Penetrometer Test:** If the Dynamic Cone Penetrometer test is used to determine the load carrying capacity as required in Item 6, then a minimum of seven (7) consecutive cone tests having a penetration resistances of two consecutive 50 blows per 6 inch (152.4mm) increment are required at a maximum of 5 foot (1.52m) intervals, and shall continue to the bottom of the boring. Following the first Dynamic Cone Penetrometer test, do not discontinue Dynamic Cone Penetrometer testing at 5-ft (1.52m) intervals through the remainder of the boring, even if a test results in less than 50 blows per 6 inch (152.4mm) increment.

12. **Rock Depths Greater Than 60 Feet (18.29m):** For depths to top of rock greater than sixty (60) feet (18.29m) in cohesive and/or granular materials, an estimate of point and skin resistance for friction piles or drilled shafts by static analysis of the various layers shall be made by the SPT and/or CPT methods for the full depth of the boring. This requirement shall be in addition to Item 5 requirements when the rock depth is greater than 60 feet (18.29m).

13. **Scour Depth:** For scour depth estimates, the mean D50 (mean diameter of the bed material) in granular alluvium is required. Gradation samples shall be tested in the laboratory by appropriate test procedure and described by ASTM D2487 on all samples taken according to the 5 foot (1.52m) intervals in Item 4 in granular alluvium. The depth of weathered rock or shale described in Item 5 is required. In rock or shale sampled by continuous core barrel, fracture spacing shall be plotted per foot of depth for all core runs. The following criteria are required at pier locations.

    a. One boring for structures less than 250 feet (76.20m) in length.

b. Two borings for structures between 250 and 600 feet (76.20m and 182.87m) in length.
c. Three borings for structures greater than 600 feet (182.87m) in length.

14. **Water Table and Water Sampling:** The water table shall be measured at the end of drilling and at 24 hours in all boreholes as specified in the most current ASTM D4750. The Consultant will confirm and monitor the presence of artesian water. For structures located in Divisions 5 and 6 or at locations where available sources of geological and/or geotechnical literature and data indicate the presence of salts, or when stream surface, soil surface, or surface vegetation indicate the presence of salts, water samples shall be taken from surface pools and from at least two boreholes at 10-foot (3.05m) intervals. For county bridge structures water samples shall be taken from surface pools and from at least one boring at a depth of 10 feet (3.05m) below the water table. Also, water samples are required as indicated above when available literature and/or data suggest the presence of gypsum, or when boring logs indicate the presence of gypsum interbedded within the soil or rock.

15. **Bridge Approach Embankment Settlement and Slope Stability:** For embankment heights that are greater than 15 feet (4.57m), settlement and slope stability predictions shall be made according to the requirements of the Specifications for Geotechnical Investigations for Roadway Design. Settlement predictions by in situ tests (CPTU and DMT) are allowed and preferred.

16. **Retaining Walls:** Geotechnical investigation as set forth in this specification will be required for all retaining wall footings and wall pressures. In the rigid gravity, semigravity, non-gravity cantilevered, mechanically stabilized earth (MSE), prefabricated modular and anchored retaining walls, spacing of borings for retaining walls will be at intervals of 100 to 200 feet (30 to 60m) along the back face of the wall. Additional requirements are specified in Chapter 11 of the AASHTO LRFD Design Specifications including interims. For walls where settlement is evaluated, settlement predictions by in-situ tests (CPTU and DMT) are allowed and preferred.

    In the case of anchored walls, borings must be drilled along the centerline of, in front of, and behind the proposed wall according to the following requirements:.

    a. Wall borings (borings performed along the actual wall centerline) are required at 100 ft to 200 ft spacing, and should extend at least to a depth H below the planned bottom of the excavation, where H is the height of the wall at that location.
    b. Borings drilled behind the wall are required at a distance of 1.0 - 1.5Hbehind the back face of the wall and at critical section centerline at a 150 foot (45.72m) spacing. Back borings should extend to a depth 2H below final grades. If the ground behind the wall slopes up, borings should be drilled within a distance of 1.5H to 2H from the wall. These borings should be deep enough to allow assessing potentially larger sliding masses occurring up the slope.

c. Borings drilled in front of the wall should be spaced up to 200 ft along the alignment, be located between 0.75H to H in front of the wall, and be advanced to at least to a depth H below the planned bottom of the excavation.
d. Where soft to very soft fine-grained soils exist within the terminal boring depths outlined herein, the depth should be increased at least by H for borings along and behind the wall, and by 0.5H for borings in front of the wall.
e. All borings within a 200 foot (60.96m) spacing of critical section centerline will be sampled as specified in Item 4.
f. Carefully record water level and caving of borings.
g. Soil tests for anchor environment shall include electrical resistivity, pH, and sulfate(s) tested in a minimum of two back borings at 5 foot (1.52m) intervals.

Geotechnical evaluations for retaining walls including external stability (sliding, overturning, bearing capacity), global stability, and settlement shall be performed according to AASHTO LRFD Bridge Design Specifications and addressed in the geotechnical report. Internal stability of MSE walls is addressed by the Contractor responsible for wall construction. Stability analyses for MSE Walls should also address compound stability wherein failure planes intersect the reinforced fill and exit below the toe of the wall.

17. **Integral Abutments:** For embankment heights that are greater than 15 feet (4.57 m) settlement and lateral squeeze predictions of the foundation soil shall be made according to the requirements of the Specifications for Geotechnical Investigations for Roadway Design.

FIELD RECONNAISSANCE AND TOLERANCE:

1. Observe and report the following site conditions in reference to the geotechnical investigation of the structure:

   a. Surface soil types.
   b. Gullies, excavations, slopes or stream banks.
   c. Surface and subsurface water.
   d. Topography and vegetation.
   e. Location of existing structures.
   f. Unusual drilling conditions.
   g. Underground and overhead utilities.
   h. Permission of property owners.
   i. Stream debris.

2. Deviations from the boring location plan are allowed, due to inaccessible conditions, when approved by the Department.

3. Vertical control of all borings shall be plus or minus (±) 0.10 foot (0.03m), as documented by survey notes. Elevations shall be taken with an engineer's level (i.e.,

Wye Level or higher equivalent). If the project is a new alignment that is beyond reasonable reach by a distance measuring tape of 100 feet (30.48 m) from a reference line, then request a survey contract item.

4. The tolerance in hole location shall be plus or minus (±) 1.0 foot (0.3m), by taping or chaining.

METHOD OF DRILLING: An appropriate method of rotary drilling shall be used for the foundation and geologic conditions encountered as specified in the AASHTO Manual on Subsurface Investigations, 1988. Drilling with continuous flight augers is prohibited. There are no other restrictions on the type of drill equipment, other than that it shall be capable of performing all of the field sampling and testing outlined in the AASHTO Manual on Subsurface Investigations, 1988. The practice of auger refusal using a solid core or hollow-stem auger is not an acceptable technique for identifying top of rock. For borings over water in lakes or rivers, drilling operations shall be performed on a barge supported by spud rods at all barge corners which are anchored firmly into underlying geology.

SAMPLING: The most current issue of the following ASTM and AASHTO Standards will govern and shall be used:

1. ASTM D1586, Method for Standard Penetration Test and Split Barrel Sampling of Soils.
2. ASTM D1587, Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes.
3. ASTM D2113, Practice for Rock Core Drilling and Sampling of Rock for Site Exploration.
4. ASTM D4220, Practice for Preserving and Transporting Soil Samples.
5. AASHTO T264, Collection and Preservation of Water Samples.
6. ASTM D4750, Standard Test Method for Determining Subsurface Liquid Levels in Borehole or Monitoring Well (Observation Well).

FIELD TESTS: The most current issue of the following ASTM Standards will govern and shall be used:

1. Standard Penetration Test (SPT) - ASTM D1586. Partial increments of the Standard Penetration Test should be measured to the nearest 1/16 of an inch (1.59mm). All SPT field N-values are to be corrected to a 60 percent efficiency.
2. Cone Penetration Test (CPT, CPTU) - ASTM D 5778. For the CPTU a u piezocone tip is required.
3. Flat Dilatometer Test (DMT) - ASTM D6635
4. Pressuremeter (PMT) - ASTM D 4719

5. Borehole Jack Test - ASTM D 4971
6. Dynamic Cone Penetrometer Test - This test is adopted by the Department's Bridge Division and described generally in subsection B.4.2 of the AASHTO Manual on Subsurface Investigations, 1988. The Dynamic Cone Penetrometer test used by the Department Bridge Division is known as the Texas Cone Penetrometer Test. Deviations from the AASHTO Manual on Subsurface investigations, 1988, are as follows: 10 blows to seat the cone and the penetration in inches per 50 blows for the first and second 50 blows; if 6 inches (152.4m) of penetration is obtained before 50 blows, then the number of blows per 6 inches (152.4m) shall be recorded for a total of 12 inches (304.8mm).. Hammers furnishing equivalent energy to a 170-pound (77.11kg) hammer with a 24 inch (609.6mm) drop will be acceptable. The dynamic cone penetrations should be reported to the nearest 1/16 of an inch (1.59 mm).

7. Field Permeability Tests - ASTM D6391

LABORATORY TESTS: Engineering judgment should be used in developing the laboratory testing program. The intent of the laboratory testing program is to provide information necessary to properly characterize the site. It is not necessary to perform all soil classification tests on all samples, for example. In developing the program, consideration should be given to the visually/manually observed soil classification types throughout the subsurface and the relative benefits of performing a specific laboratory soil classification test.

Laboratory testing shall be performed by technicians certified by the Highway Construction Materials Certification Board in a laboratory qualified by the Department Materials Division. For all samples taken, the following shall apply:

1. Soil and rock samples are to be tested in the laboratory and results reported according to the most current ASTM Standards for the following tests: a. Soil Classification (Gradation and Plasticity Index).
    b. Moisture Content.
    c. Specific Gravity.
    d. Density (AASHTO procedure only).
    e. Hydrometer, Double Hydrometer Pinhole Test.
    f. Slake Durability.
    g. Unconfined Compression Test: to the extent that sample quality allows, tests are to be conducted at intervals small enough to provide a valid average of the type of rock under consideration as required by ASTM D7012.
    h. Point Load Test.
    i. One-Dimensional Consolidation Test.
    j. Drained Direct Shear Test.
    k. Triaxial Shear Test.
        1) Unconsolidated Undrained.
        2) Consolidated Undrained-Pore Pressure Measurement.

l. Percent Swell and Swell Pressure Test.
m. Soluble Sulfate (OHD L-49).

2. Water samples are to be taken at a minimum of 10 feet (3.05m) intervals with a positive sealing sampler in at least two bore holes. Water levels shall be allowed to reach an equilibrium condition before sampling. Borings advanced by mud (bentonite slurry) rotary drilling technique shall be bailed before water sampling, and groundwater levels should be allowed to reach an equilibrium condition. Where needed, casing must be installed. Samples are to be analyzed for:
   a. CL ion (ppm) by AASHTO T260 (Alternate Method Number 1 - Potentiometric Titration).
   b. SO ion (ppm) by AASHTO T105, ASTM C114.
   c. pH by ASTM G51.

3. Classification and description of soils and compaction shale shall follow ASTM D 2487 and D2488. For clarification purposes, define and test for the following particle size distribution:

   3 in. (75mm)

   3/4 in. (19mm)

   No. 4 (4.75mm)

   No. 10 (2.00mm)

   No. 40 (425μm)

   No. 200 (75μm)

4. A pocket penetrometer or any other "pocket" measurement shall **not** be used to determine rock or soil properties.

5. Soil tests required for anchored retaining wall anchor environments are:
   a. Electrical resistivity, ASTM G57, AASHTO T289 Sample Preparation
   b. pH, ASTM D4972.
   c. Sulfate, ASTM D516.

FIELD LOGGING: Descriptive terminology and classification of rock shall be based on the requirements of subsection E.6 in the AASHTO Manual on Subsurface Investigations, 1988 as well as the Department's local practice. The finished boring log shall be a compilation of all classification and description from laboratory tests and field logging.

GEOLOGIC STATEMENT: A general review and assessment of specific site geology shall be reported based on all available soil surveys and geologic publications and maps for the location. All sources shall be documented.

MINIMUM PLUGGING REQUIREMENTS FOR GEOTECHNICAL BORINGS: The general procedure for the plugging of Geotechnical Borings shall be governed by the current Oklahoma Water Resources Board specifications “Plugging Requirements for Geotechnical Borings”. Unless otherwise noted herein by the following exceptions or amplifications, said procedures shall subscribe to, as a minimum requirement, the general guidelines given in 785:35-11-1 and 11-2 of the Oklahoma Water Resource Board’s Regulations.

Exceptions and Amplifications to the above are as follows:

1. Responsibility for proper plugging lies with the Consultant.
2. Borings shall be plugged to prevent pollution of groundwater within ten (10) days of completion of drilling.
3. A multi-purpose completion report shall be submitted to the Oklahoma Water Resources Board within thirty (30) days of completion and plugging of each geotechnical boring and to the Department in the Final Written Report.
4. Guidelines for borehole plugging, grouting procedures, grout mixes, etc., are explicitly detailed in the Oklahoma Water Resources Board’s Specifications.

FINAL WRITTEN REPORT: In addition to the graphical and tabular data, a written report shall also be made. It shall contain all required data, and when requested, an interpretation and analysis of the data along with definite engineering recommendations for design based upon the various factors. The geotechnical report shall be thorough in reporting all backup data and calculations documenting analyses and recommendations in accompanying appendices to the report. The materials and conditions which may be encountered during construction shall also be discussed. The Geotechnical Engineer responsible for the report preparation should have a broad enough background in engineering to have some knowledge of the type of structures which normally would be used in a certain location, including their foundation requirements and limitations. Geotechnical problems that may impact design performance and construction based on the findings of the geotechnical report shall be reported and recommendations made. The recommendations should be brief, concise and, where possible, definite. Reasons for recommendations and their supporting data should be included. The units in the analyses and final report shall be consistent with plan requirements and directives. The final report will require GINT computer generated boring logs. The final report shall be submitted electronically in pdf format. Foundation boring log plan sheet(s) shall be submitted electronically in both a .dgn and .pdf format that is transferrable to the Bridge Division Design plan sheets in accordance with formats provided with Task Orders. A physical hard copy of the report is not required unless specifically requested with the Task Order. The written report should include the following specific items:

1. **Pile Support**
    a. Method of support: Friction or end bearing, in rock or soil or both.
    b. Suitable pile type or types: Reasons for choice and/or exclusion of types.
    c. Pile tip elevations:
        1) Estimated - Average values, with range of variation if desirable.
        2) Specified - Explain reasons, such as driving through fill, negative skin friction, scour, underlying soft layers, piles and uneconomically long, etc.
    d. Allowable pile loading: Specify method of analysis.
    e. Settlement considerations: Requirements of structure vs. soil conditions. Specify method of analysis.
    f. Cut-off elevations: Water table, etc.
    g. Test piles required: Location for maximum utility.
    h. Load tests required and use of dynamic pile driving formula.
    i. Effects on adjacent construction.
    j. Corrosion effects of various soils and waters, and possibility of galvanic reaction.
    k. Scour depth knowledge.
    l. P-Y curve analysis, when specified on Task Orders.

2. **Drilled Shaft Support**
    a. Method of support: Friction or end bearing, in rock or soil or both.
    b. Suitable drilled shaft size: Reasons for choice and/or exclusion of sizes.
    c. Drilled shaft base elevations.
    d. When coring and unconfined compression testing are the methods of testing, provide the appropriate friction or bearing values in accordance with AASHTO LRFD. Include a description of rock joints; open or closed, intact or tightly jointed, joint condition, joint orientation and a description of any material that may be filling joints and seams.
    e. Settlement considerations: Requirements of structure vs. soil conditions. Specify method of analysis.
    f. Cut-off elevations: Water table, etc.
    g. Drilled shafts required: Locations for maximum utility.
    h. Corrosion effects of various soils and waters.
    i. Scour depth knowledge.
    j. When bedrock is not found, P-Y curve analysis.

3. **Footing Foundation Support**

    a. Elevation of footing.
    b. Allowable soil pressure - for bearing and for settlement; considering soil, adjacent foundations, water table, etc.
    c. Material on which footing is to be placed.
    d. Scour depth.

4. **Construction Considerations**

    a. Water table: Fluctuations, control in excavations, pumping, tremie seals, etc.
    b. Adjacent structures: Protection against damage from excavation, pile driving, drainage, etc.
    c. Pile driving: Difficulties or unusual conditions which may be encountered.
    d. Excavation: Control of earth slopes including shoring, sheeting, bracing, and special procedures, variation in, type of material encountered, etc.
    e. AASHTO LRFD Seismic Soil Site Classification.

Additional Information: The Consultant shall provide the following to the Department, all of which should be included in the report:

1. Name of the Professional Engineer, Engineer-in-Training and/or Geologist at the site preparing any field boring logs and interpreting the geologic profile.
2. Name of the driller. Logging by driller in lieu of an Engineer and/or Geologist will not be allowed.
3. Type of equipment used.
4. Method (or combination) of drilling used.
5. Size of drive hammer and free fall used on sampler in dynamic tests.
6. Type and size of core barrels.
7. Description of sampler(s). Diameter of any casing used.
8. A report shall specify current ASTM / AASHTO specification numbers.
9. Deviation from sampling and field testing equipment requirements as specified by current ASTM and/or AASHTO Standards.

ACCEPTANCE: The Department, upon review of the final report and foundation boring log plan sheet(s), shall exercise final authority as to whether the Consultant has provided sufficient information or if additional data or borings are required. The Department further reserves the right to review all phases of the geotechnical report including all field and laboratory data, computations, and analysis.

CHAPTER 15
DESIGN EXCEPTIONS

Engineers have studied design factors that relate to roadway conditions, safety, vehicles and drivers through many years of practice and research. These factors may change overtime as new research is conducted due to changing variables such as vehicle technology. This manual contains the minimum design guidelines that a designer should follow based on these nationally recognized studies. Safety will always be a designer's main focus.

County road and bridge improvements are challenged by, limits on available construction dollars (County Improvements for Roads and Bridges, CIRB, is capped at 120 million dollars per year), existing narrow R/W width (State Constitution has set 37 counties with 33' or less R/W width), mountainous terrain, nearly 83,000 miles of road and over 13,600 bridges. With all that being said, there are circumstances, conditions that may allow a designer to use alternate values based upon engineering judgment. These exceptions should not be considered the norm and not strictly based off of project cost alone.

A designer has to balance safety with project cost. Situations such as low traffic volumes, mitigation measures, limited accidents, and 3R (Resurfacing, Restoration, Rehabilitation) projects are possible decision factors. A critical concern is the accident report. On lower volume roads it may require a longer period of an accident report study and checking with the local sheriffs' department to gather issues related to the current road design.

Project funding sources should not dictate the process of approving a design exception. There are no county roads on the National Highway System, NHS, and the Oklahoma Department of Transportation has entered into a *Stewardship and Oversight Agreement on Project Assumption and Program Oversight* to act on FHWA's behalf. Per the FHWA Memorandum dated May 5, 2016 from Acting Director, Office of Program Administration, Robert B. Mooney, states that on "Non-NHS roadway and State design criteria not met on Federal-aid projects: State Transportation Authority is the approving authority for design deviations in accordance with State laws, regulations, directives and safety standards. States can determine their own level of documentation depending on State laws and risk management practices."

Process

The ideal time to bring up potential exceptions is during the project scoping. At this time the designer/engineer has not invested much time and money in the project. Commissioners may bring up their concerns and the engineer may have potential exceptions in mind. A different designer may be selected under contract for the project and may require a second scoping meeting to discuss possible alternatives. Design exceptions introduced after the Plan-in-Hand meeting may impact the design engineering cost and/or delay the project. They are discouraged after this point in the process.

The designer will be responsible for completing, attaching supporting documentation, acquiring signatures, and providing copies to all parties of the signed design exception request form including supporting documentation.

All design exceptions shall be received by ODOT Local Government Division.

Resources

Federal Highway Administration. July 2007. "Mitigation Strategies for Design Exceptions", FHWA-SA-07-011.

DESIGN EXCEPTION

To: Local Public Agency Official

From: ______________________ / Consultant Firm / Circuit Engineering District

Subject: Design Exception for Project Number: ______________________

J/P #: ____________ System: ____________ Route: ____________

County: ____________ Field Division: ______________________

Project Location: ______________________

____

Function classification (Check one from each column)

Rural: ______ Arterial: ______
Urban: ______ Collector: ______
Local Road: ______

Major exceptions to County Road Design Guidelines:

______ Design Speed
______ Shoulder Width
______ Structural Capacity
______ Vertical Alignment
______ Stopping Sight Distance
______ Superelevation
______ Lateral Offset
______ Lane Width
______ Bridge Width
______ Horizontal Alignment
______ Grades
______ Cross Slopes
______ Vertical Clearance

Cost to build to full standard: ______________________

Cost to build with design exception: ______________________

Mitigation measures: ______________________

____

______________________ Attached: ______ In Report: ______

Return to ODOT by: ______________________

Concurrence: Recommended

____
Local Public Agency Official

____
Design Engineer

____

____
Local Public Agency Official

____
Local Public Agency Official

Comments: ______________________

____

Attachments:

Bridge Data: ______ Accident History: ______
Location Map: ______ Traffic Data: ______
Special Conditions (traffic generators): ______

Other: ______________________

____

____

Chapter 16
Resurfacing, Restoration, and Rehabilitation
3R

Overview:
Resurfacing, restoration and rehabilitation (3R) projects focus primarily on the preservation, extending of the service life of existing facilities and providing safety enhancements. Work may include: resurfacing, pavement structural and joint repair, lane and shoulder widening, bridge repair, cross drain replacement, removal or protection of roadside obstacles, and improving bridges to meet current standards for structural loading and to accommodate the approach roadway width. Projects may have limited improvements to existing horizontal and vertical alignments. Usually, crash history will dictate when to address safety considerations. Generally, projects where more than 25% of the roadway needs full depth patching should be considered for reconstruction.

Design notes:
This chapter provides design flexibility on certain qualified sites that meet conditions which will still provide or improve the safety elements of the location. An accident report by the Oklahoma Highway Patrol and/or Sheriff's Office will be critical in determining appropriate safety improvements if required. Resulting side slope, drainage, and clear zone requirements shall be considered when determining 3R eligibility.

Surface:
Whether or not a hard surface may qualify for a 3R project is dependent on its existing condition. For an asphalt surface, the designer will refer to the latest version of PASER MANUAL – Asphalt, Pavement Surface evaluation and Rating from The Transportation Information Center, University of Wisconsin-Madison. This surface rating system describes the conditions of the existing roadway surface using a scale of 1 to 10, failed to excellent. Using this methodology, no roadway selected for 3R purposes should fall below a rating of 4. Preconstruction timeframes, greatly reduced, still may cause the road to deteriorate to a rating of 3. This may cause adjustments to construction quantities. This overall methodology for condition assessment can be applied to a concrete surface using the PASER Manual for concrete.

Pavement Design:
- Pavement Design will be based upon current ADT, restoring the facility to a 20 year lifespan.
- 3R projects shall consist of a minimum treatment depth of 3".
- The number of geotechnical borings may be reduced under 3R in comparison to what is called out in Chapter 13 based on engineering judgement for the existing facility.

Alignment:
Usually, 3R projects will not involve changes vertical or horizontal alignments. There could be instances in a localized area where, due to crash history or existing curvature is not consistent within the overall project alignment, that adjustments maybe included in the 3R

project. The design speed chosen on the project will dictate the conditions required unless a design exception is approved.

Table 16-1: Minimum 3R Design Guideline

Design Element	**Current ADT**		
	0 - 400	401 - 1500	1501 - 2500
Design Speed	45 mph	45 mph	45 mph
Shoulder Width	1 ft	1 ft	2 ft*
Lane Width	10 ft	11 ft	11 ft
Clear Zone	2 ft	2 ft	2 ft
Bridge width to remain in place	20 ft	24 ft	24 ft
Bridge structural capacity (Operating rating)	H-23	H-23	H-45

*Shoulder width must be paved.

References:

Transportation Information Center PASER Manual downloads, https://interpro.wisc.edu/tic/resources/publications-available-for-download/